# 第七届全国统计物理与复杂系统学术会议

# 会议手册

## 主办单位

中国科学院理论物理研究所

## 承办单位

云南大学

## 协办单位

昆明理工大学

2023 年 07 月 26 - 07 月 28 日

中国昆明

# 目 录

# 会议背景

## 会议简介

为加强国内外统计物理与复杂系统研究领域学者之间的学术交流，经中国物理学会和凝聚态物理与统计物理分会批准，由中国科学院理论物理研究所主办，云南大学承办，昆明理工大学协办，第七届全国统计物理与复杂系统学术会议将于 2023 年 7 月 26 日至 7 月 28 在云南省昆明市举行。会议主要以邀请报告、口头报告及墙报展示的形式，交流国内外统计物理与复杂系统领域的最新进展，同时讨论中国统计物理与复杂系统研究的现状与发展趋势。热烈欢迎国内外从事统计物理与复杂系统及相关领域研究的专家学者及研究生踊跃参加！

## 会议主题

本次大会将主要针对统计物理与复杂系统的以下领域进行交流：

1. 平衡与非平衡统计物理基础理论；
2. 统计物理学数值计算与模拟方法；
3. 量子物理前沿相关的统计物理；
4. 无序与玻璃系统；
5. 软物质系统；
6. 非线性科学与复杂网络；
7. 生命与生态系统；
8. 机器学习、智能与认知。

为提高国内统计物理与复杂系统方向的研究生及青年教师的创新能力和学术水平、培养统计物理和复杂系统研究方向的青年骨干，统计物理与复杂系统学术会议委员会决定在会后开展为期十四天左右的暑期班（机器学习与统计物理讲习班），详见网站 https://conferences.koushare.com/spcsc2023/custom/584。

## 会议委员会

**学术委员会：**（按姓氏拼音顺序）

主　席：欧阳钟灿　（中科院理论物理所）
副主席：陈晓松　（北京师范大学）
　　汤雷翰　（香港浸会大学）
　　赵　鸿　（厦门大学）
　　郑　波　（云南大学）
委　员：艾保全　（华南师范大学）
　　敖　平　（四川大学）
　　陈绍英　（内蒙古呼伦贝尔学院）
　　陈　勇　（北京航空航天大学）

邓友金　（中国科学技术大学）
董高高　（江苏大学）
狄增如　（北京师范大学）
方海平　（华东理工大学）
韩一龙　（香港科技大学）
黄　亮　（兰州大学）
黄吉平　（复旦大学）
蒋建华　（苏州大学）
姜泽辉　（哈尔滨工业大学）
邝　华　（广西师范大学）
孔祥木　（曲阜师范大学）
李　炜　（华中师范大学）
刘艳辉　（贵州大学）
刘宗华　（华东师范大学）
柳　飞　（北京航空航天大学）
吕琳媛　（电子科技大学）
欧阳钢　（湖南师范大学）
屈世显　（陕西师范大学）
全海涛　（北京大学）
申传胜　（安庆师范大学)
施夏清　（苏州大学)
谭志杰　（武汉大学）
涂育松　（扬州大学）
涂展春　（北京师范大学）
王　健　（扬州大学）
王建辉　（南昌大学）
王旭明　（宁夏大学）
汪　劲　（国科温州研究院）
吴晨旭　（厦门大学）
邢向军　（上海交通大学）
许爱国　（北京应用物理与数学研究所）
徐莉梅　（北京大学）
严　钢　（同济大学）
杨晓荣　（西藏大学）
叶方富　（中科院物理研究所）
玉素甫-艾比布拉（新疆大学）
曾春华　（昆明理工大学）
张力发　（南京师范大学）
张　潘　（中国科学院理论物理研究所）
张胜利　（西安交通大学）
郑志刚　（华侨大学）
钟　凡　（中山大学）
周昌松　（香港浸会大学）
周海军　（中科院理论物理所）

周　涛　（电子科技大学）
周　昕　（中国科学院大学）

## 会议举办单位

**主办单位：**中国科学院理论物理研究所
**承办单位：**云南大学
**协办单位：**昆明理工大学

**会议工作委员会：**

组　长：　郑波，周海军
副组长：　陈晓松，胡世谦，曾春华
秘书长：　杨帆
组　员：　段溪宁，胡皓，年磊磊，熊龙，王登科，徐留芳，徐欣，严钢，张潘

## 致 谢

感谢中国科学院理论物理研究所、云南大学物理与天文学院、 昆明理工大学理学院。

# 参会须知

## 会议报到

**报到时间：**2023年7月25日

报到地点：会议住宿的2家指定宾馆（银园酒店、丽水云泉酒店）（注：25日没报到的代表可于 26 日在在云南大学呈贡校区学生会堂 （主会场)报到；学生在报到时需提供学生证或其他有效证明。）

## 会议住宿

银园酒店（地址：昆明市呈贡区春融东路与毓秀路交叉口西北角）

丽水云泉酒店（地址：昆明市呈贡区聚贤街768号）

## 会议联系人

王登科

电话：15096616881

杨帆

电话：15987166838

段溪宁

电话：13577702829

Email：physics@ynu.edu.cn

# 会议交通

## 机场直通车（附呈贡大学城机场直通车二维码）

A、长水机场——酒店

发车时段：07:59/08:59/09:59/10:59/11:59/12:59/13:59/14:59/15:59/16:59/17:59/18:59/19:59/21:00

B、酒店——长水机场

发车时段：07:00/08:00/09:00/10:00/11:00/12:00/ 13:00/14:00/15:00/16:00/17:00/18:00/19:00/20:00

温馨提醒：（1）需提前购票：直通车公司会提前一天关停无人订票的车次，请确认好出行时间后尽量提前订票。当某车次只有一人订票时，可能会提前或延后半小时发车。（2）上下车地点：呈贡大学城范围内无固定上下车地点，任一学校或小区门口都可以接送，机场班线的具体上下车地点请在下单支付前备注好。长水机场上下车地点固定为三层出发外侧车道。

长水国际机场——丽水云泉大酒店

公共交通路线

路线一：地铁6号线（【菊华站】换乘）→地铁4号线（【斗南站】换乘）→地铁1号线（至【联大街站】E出口）→公交226路（至【聚贤街师范大学站】下），步行0.57公里，全程耗时约1小时35分钟。

路线二：地铁6号线（【菊华站】换乘）→地铁4号线（至【吴家营站】A

出口）→公交216路（至【聚贤街理工大学站】下），步行0.55公里，全程耗时约1小时38分钟。

路线三：空港快线昆明南站专线（至【昆明南站】）→公交K38路（至【联大街师大北门站】下），步行1.2公里，全程耗时约1小时40分钟。

驾车（出租车、网约车）：途径机场高速/石龙路，距离32.9公里，耗时约46分钟（打车约85元）；途径机场高速/东绕城高速，距离43.1公里，全程耗时约46分钟（打车约110元）。

昆明南站（高铁站）——丽水云泉大酒店

公共交通路线：乘坐K38（【昆明南站西广场站】上车，聚贤街【景明南路站】下车），全程耗时约5分钟。

驾车（出租车、网约车）：途径聚贤街，距离3.0公里，全程耗时约7分钟（打车约8元）；途径联大街/景明南路，距离3.8公里，全程耗时约10分钟（打车约10元）。

步行：途径聚贤街，距离2.4公里，全程耗时约37分钟。

昆明火车站——丽水云泉大酒店

公共交通路线

路线一：地铁1号线（至【联大街站】E出口）→公交226路（至【聚贤街站师范大学】下），全程耗时约1小时8分钟。

路线二：地铁1号线（至【市级行政中心清风站】B口出）→公交216路（【昆明南站】上，聚贤街【景明南路站】下），全程耗时约1小时12分钟。

驾车（出租车、网约车）：途经汕昆高速/昆磨高速，距离29.3公里，耗时约37分钟（打车约80元）；途径彩云北路/彩云中路，距离28.2公里，全程耗时55分钟（打车约70元）。

长水国际机场——银园酒店

公共交通路线

路线一：地铁6号线（【菊华站】换乘）→地铁4号线（【斗南站】换乘）→地铁1号线（至【谊康南路】C出口）→公交DZ38路（至【中庄谊康南路】下），步行100米，全程耗时1小时28分钟。

路线二：空港快线昆明南站专线（至【昆明南站】）→地铁4号线（至【联大

街】换乘）→地铁1号线（至【谊康南路】C出口）→公交DZ38路（至【中庄谊康南路】下），步行100米，全程耗时1小时51分钟。

驾车（出租车、网约车）：途径机场高速/东绕城高速，距离43.1公里，耗时约43分钟（打车约110元）。途径机场高速/石龙路，距离33.6公里，全程耗时约48分钟（打车约85元）。

昆明南站（高铁站）——银园酒店

公共交通路线：地铁4号线（至【联大街】换乘）→地铁1号线（至【谊康南路】C出口），步行1.1公里。

驾车（出租车、网约车）：途经联大街/春融东路或祥园街/景明南路，距离5.4公里，全程耗时约14分钟（打车约15元）。

昆明火车站——银园酒店

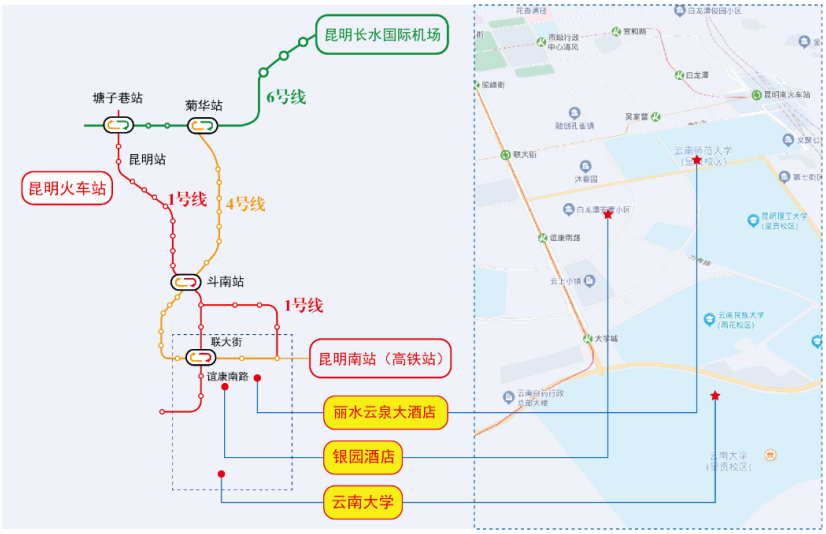
公共交通路线：

路线一：地铁1号线（至【谊康南路】C出口），步行1.1公里。全程耗时55分钟。

路线二：公交C85路（【春融街站】上，【景明南路理工大学站】下），步行1公里。全程耗时1小时46分钟。

驾车（出租车、网约车）：途经汕昆高速/昆磨高速，距离 28.3 公里，全程耗时约 39 分钟（打车约 75 元）；途径彩云北路/彩云中路，距离 27.3 公里，全程耗时 50 分钟（打车约 70 元）。

## 交通线路图



## 会议期间交通

酒店距离云南大学呈贡校区主会场约 20 分钟车程，大会安排有交通大巴负责住宿酒店至云南大学呈贡校区主会场之间的通勤。请您提前 5 分钟候车、准点上车。

丽水云泉大酒店-云南大学会场

发车地点：丽水云泉大酒店大厅外

发车时间：26 日上午 7:30，27、28 日上午 8:00

昆明银园酒店-云南大学会场

发车地点：银园酒店大厅门口

发车时间：26 日上午 7:30，27、28 日上午 8:00

注：每日下午会议结束后，将安排通勤车辆从云南大学会场至酒店进行晚餐，请您在会议结束后在会场外根据指引候车。

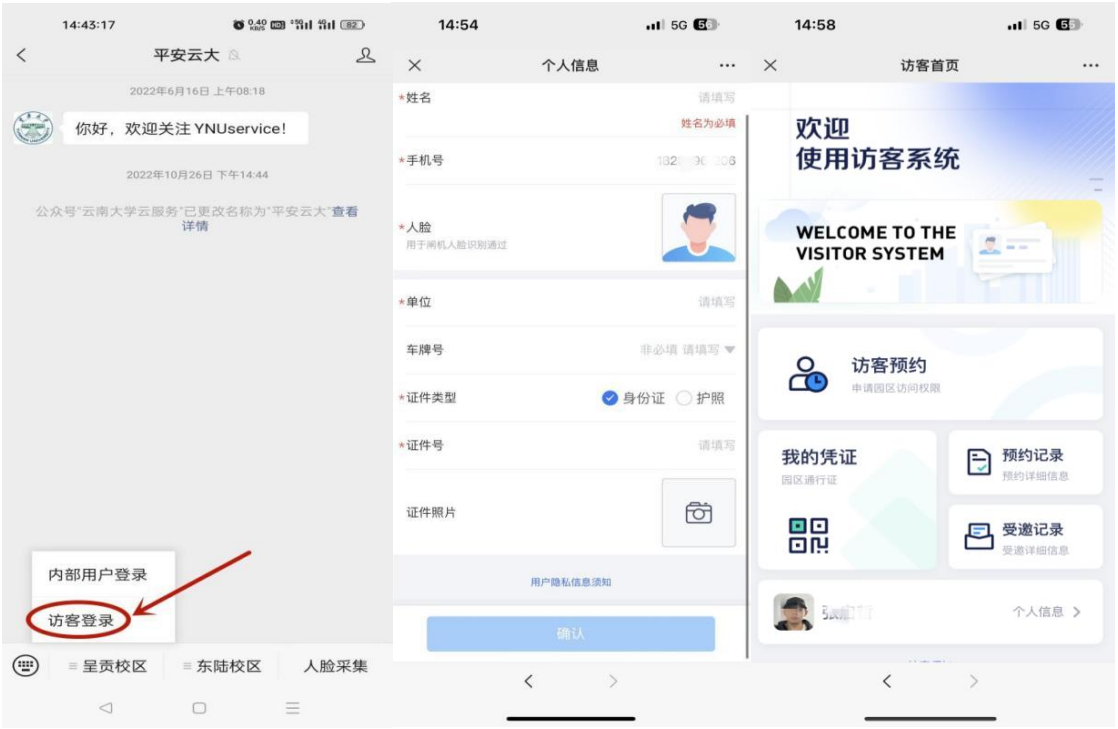
车辆安排负责人：王登科 15096616881

注意：除通勤车之外，其他车辆无法入校。

**温馨提示：**

云南大学目前处于半封闭状态，除通勤车之外，其他车辆无法入校。会务组将提前联系参会人员收齐个人身份信息集中办理入校，参会期间统一乘坐大巴进出校园。如参会人员自行入校，请提前关注“平安云大”微信公众号注册、预约呈贡校区入校流程。注册完成后，预约流程如下：

1. 关注公众号“平安云大”，选择呈贡校区-访客登录进行注册；
2. 注册完成后，进入访问预约。点击访问类型，类型选择游客，访问部门选择公安处，被访人号码，呈贡校区被访人号码填写 65960110。
3. 填写完成提交成功后，平安云大公众号主页面会推送一条访问单通过通知提示预约成功。
4. 注意事项:游客公众号预约进校需提前 15 分钟进行，时间为 9:00-17:00，预约成功后可通过刷身份证或人脸进入校园，进校后必须遵守学校安全管理规定。



# 会场地图

# 会议议程

## 会议总体议程

| 日期 | 时间 | 事项 | 地点 |
|---|---|---|---|
| 07 月 25 日 | 13:00 - 22:00 | 现场报道 | 入住宾馆 |
| | 17:30 - 19:30 | 晚餐 | 丽水云泉 银园酒店 |
| 07 月 26 日 | 08:00 - 12:00 | 现场报道 | 学生会堂 |
| | 08:00 - 08:30 | 开幕式 | 学生会堂 |
| | 08:30 - 12:00 | 大会报告 | 学生会堂 |
| | 10:00 - 10:30 | 全体合影 | 学生会堂 |
| | 12:00 - 14:00 | 午餐 | 馀味堂一楼 |
| | 14:00 - 18:00 | 分会报告 | 文汇楼各分会教室 |
| | 18:30 - 20:00 | 晚餐 | 酒店自助餐 |
| 07 月 27 日 | 08:30 - 12:00 | 大会报告 | 学生会堂 |
| | 12:00 - 13:00 | 午餐 | 馀味堂一楼 |
| | 13:00 - 14:40 | 墙报展示 | 学生会堂 |
| | 14:40 - 18:00 | 分会报告 | 文汇楼各分会教室 |
| | 18:30 - 20:00 | 晚宴 | 丽水云泉桌餐 |
| 07 月 28 日 | 08:30 - 12:00 | 分会报告 | 文汇楼各分会教室 |
| | 12:00 - 14:00 | 午餐 | 馀味堂一楼 |
| | 14:00 - 17:00 | 大会报告 | 学生会堂 |
| | 17:00 - 17:30 | 闭幕式 | 学生会堂 |
| | 18:00 - 19:30 | 晚餐 | 馀味堂三楼 |

## 开幕式（26 日上午）

| 主会场<br>地点：学生会堂 | |
|---|---|
| 主持人：郑波（云南大学） | |
| 08:00-08:30 | 云南大学领导<br>中国科学院理论物理研究所领导<br>欧阳钟灿院士 |

## 大会报告（26 日上午）

| 主会场（26 日）<br>地点：学生会堂 | | | | |
|---|---|---|---|---|
| 第一单元 ，7 月 26 日，星期三，08:30-10:00<br>主持人：欧阳钟灿 | | | | |
| D01 | 08:30-09:00 | 李保文 | 南方科技大学 | 低维微纳米尺度声子热传导：来自芯片散热的非平衡态统计物理问题 |
| D02 | 09:00-09:30 | 张林峰 | 深势科技公司 | AI-Assisted Enhanced Sampling: What Remains Hard |
| D03 | 09:30-10:00 | 方海平 | 华东理工大学 | 吸附在碳基表面的离子：从统计物理到颠覆性计算 |
| | 10:00-10:30 | 照相与茶歇 | | |
| 第二单元，7 月 26 日，星期三，10:30-12:00<br>主持人：汤雷翰 | | | | |
| D04 | 10:30-11:00 | Hidetoshi Nishimori | 东京工业大学（日本） | Quantum annealing and its application to quantum simulation |
| D05 | 11:00-11:30 | 邢建华 | 匹兹堡大学（美国） | Dynamics of cell state transitions emerges as a new frontier of studying complex systems |
| D06 | 11:30-12:00 | 胡延庆 | 南方科技大学 | 人类的群体行为与复杂网络上的传播动力学 |

## 分会报告（26 日下午）

| 分会场 I：平衡与非平衡统计物理基础理论（26 日）<br>地点：文汇楼 2202 | | | | |
|---|---|---|---|---|
| 第一单元 ，7 月 26 日，星期三，14:00-16:00<br>主持人：邢向军 | | | | |
| I01 | 14:00-14:25 | 董辉 | 中国工程物理研究院研究生院 | 有限时间热力学 |
| I02 | 14:25-14:50 | 李新征 | 北京大学 | 复相图与超临界区域 |
| I03 | 14:50-15:07 | 郭伟 | 昆明学院 | Weak ergodicity breaking and anomalous diffusion in collective motion of active particles under spatiotemporal disorder |
| I04 | 15:07-15:24 | 刘剑 | 北京工商大学 | Anomalous diffusive behaviors of the intermittent stochastic process |
| I05 | 15:24-15:41 | 侯吉旋 | 东南大学 | Theoretical model for the Mpemba effect through the canonical first-order phase transition (含有一级相变的姆潘巴效应的理论模型) |
| I06 | 15:41-15:58 | 全海涛 | 北京大学 | Achieving the maximum power of a Brownian heat engine |
| | 16:00-16:20 | | 茶歇 | |
| 第二单元，7 月 26 日，星期三，16:20-18:10<br>主持人：黄吉平 | | | | |
| I07 | 16:20-16:45 | 李鹰 | 浙江大学 | Non-reciprocity in macroscopic heat transfer |
| I08 | 16:45-17:10 | 年磊磊 | 云南大学 | 单分子电子输运中的量子态调控 |
| I09 | 17:10-17:27 | 符维成 | 天水师范学院 | Instability dynamics of nonlinear normal modes in one-dimensional lattices |

| | | | | |
|---|---|---|---|---|
| I10 | 17:27-17:44 | 徐宝明 | 德州学院 | Quantum fluctuation theorem for initial near-equilibrium system |
| I11 | 17:44-18:01 | 熊大兴 | 闽江学院 | Subdiffusive energy transport and antipersistent correlations due to the scattering of phonons and discrete breathers |
| **分会场 II：统计物理学数值计算与模拟方法（26 日）** | | | | |
| **地点：文汇楼 2201** | | | | |
| **第一单元 ，7 月 26 日，星期三，14:00-16:00** | | | | |
| **主持人：邓友金** | | | | |
| II01 | 14:00-14:25 | 陈庆虎 | 浙江大学物理学院 | The topological excitation and transport of the vortex-antivortex pairs in a magnetically nanostructured superconductors |
| II02 | 14:25-14:50 | 谢志远 | 中国人民大学 | 张量重正化群在经典统计模型中的新发展 |
| II03 | 14:50-15:07 | 周迪 | 北京理工大学 | 广义强非线性拓扑能带理论 |
| II04 | 15:07-15:24 | 刘玉海 | 北京邮电大学 | Thermodynamic and dynamical signatures of a quantum spin Hall insulator to superconductor transition |
| II05 | 15:24-15:41 | 张凡 | 北京师范大学 | Phase Transitions of Models of XY Spins with Generic Direction Dependent Interactions |
| II06 | 15:41-15:58 | 胡坤 | 北京师范大学物理学系 | Wetting transition in the transverse-field spin- 1/2 XY model with boundary fields |
| | 16:00-16:20 | | | 茶歇 |
| **第二单元，7 月 26 日，星期三，16:20-18:10** | | | | |
| **主持人：樊京芳** | | | | |
| II07 | 16:20-16:45 | 樊京芳 | 北京师范大学 | Universal gap scaling in percolation |

| | | | | |
|---|---|---|---|---|
| II08 | 16:45-17:02 | 王振 | 中国科学院理论物理研究所 | 一维强非线性晶格的热化 |
| II09 | 17:02-17:19 | 张忠卫 | 同济大学 | 包含声子相干性的热传导理论及其应用 |
| II10 | 17:19-17:36 | 谢柏松 | 北京师范大学 | 量子动理学方法研究粒子对产生 |
| II11 | 17:36-17:53 | 周能吉 | 杭州师范大学 | 自旋玻色耦合系统中基态量子相变数值研究 |
| **分会场 III：量子物理前沿相关的统计物理（26 日）<br>地点：文汇楼 2303** | | | | |
| **第一单元 ，7 月 26 日，星期三，14:00-16:06<br>主持人：任捷** | | | | |
| III01 | 14:00-14:25 | 应磊 | 浙江大学 | The origin of Hilbert quantum scars |
| III02 | 14:25-14:50 | 蔡子 | 上海交通大学 | Prethermal time-crystalline spin ice and monopole confinement in a driven magnet |
| III03 | 14:50-15:15 | 李有泉 | 浙江大学 | Manipulation of Skyrmions and the Promising Applications |
| III04 | 15:15-15:32 | 马晨 | 中国科学院理论物理研究所 | Non-maximal chaos in some Sachdev-Ye-Kitaev-like models |
| III05 | 15:32-15:49 | 徐玉良 | 鲁东大学 | Dynamics of quantum correlation on XXZ chain with Dzyaloshinskii-Molriya interaction |
| III06 | 15:49-16:06 | 苏山河 | 厦门大学 | Measurement-based quantum thermal machines |
| | 16:06-16:25 | | 茶歇 | |
| **第二单元，7 月 26 日，星期三，16:25-18:15<br>主持人：柳飞** | | | | |
| III07 | 16:25-16:50 | 窦文杰 | 西湖大学 | Quantum thermodynamics in the strong coupling regimes |

| | | | | |
|---|---|---|---|---|
| III08 | 16:50-17:15 | 吕京涛 | 华中科技大学 | Coupled power and heat transport in nonlinear waveguide arrays |
| III09 | 17:15-17:40 | 陈金灿 | 厦门大学 | An innovative insight into one century-old physics theorem |
| III10 | 17:40-17:57 | 陆金成 | 苏州科技大学 | Multitask quantum thermal machines and cooperative effects |
| III11 | 17:57-18:16 | 王晨 | 浙江师范大学 | Quantum thermal transport based on circuit quantum electrodynamics systems |
| **分会场 IV：无序与玻璃系统（26 日）<br>地点：文汇楼 2216** | | | | |
| **第一单元 ，7 月 26 日，星期三，14:00-16:00<br>主持人：张洁** | | | | |
| IV01 | 14:00-14:25 | 王宇杰 | 上海交通大学 | 待定 |
| IV02 | 14:25-14:50 | 武振伟 | 北京师范大学 | 无序体系拓扑结构与物性关联 |
| IV03 | 14:50-15:07 | Chris HC. Nguyen | 香港科技大学 | Air arrival network: Characteristcs and optimal sequencing optimization |
| IV04 | 15:07-15:24 | 李明 | 合肥工业大学 | Explosive Percolation Obeys Standard Finite-Size Scaling in an Event-based Ensemble |
| IV05 | 15:24-15:41 | 刘易文 | 华东师范大学 | 双层网络上消息传播-意见形成的耦合动力学研究 |
| IV06 | 15:41-15:58 | 崔丽杰 | 中山大学 | 财富分配的影响因素研究：基于动理学交易模型 |
| | 16:00-16:20 | | | 茶歇 |
| **第二单元，7 月 26 日，星期三，16:20-18:10<br>主持人：王宇杰** | | | | |
| IV07 | 16:20-16:45 | 张洁 | 上海交通大学 | The yielding of granular matter is marginally stable and critical |
| IV08 | 16:45-17:10 | 张格 | 香港城市大学 | 无序固体形变机制研究 |

| | | | | |
|---|---|---|---|---|
| IV09 | 17:10-17:35 | 童华 | 中国科学技术大学 | Emerging exotic compositional order on approaching low-temperature equilibrium glasses |
| IV10 | 17:35-17:52 | 张会军 | 西安交通大学 | 基于衍射实验的幂律研究玻璃态的微观结构 |
| IV11 | 17:52-18:09 | 韩一龙 | 香港科技大学 | 用胶体研究玻璃态的表面与内部熔化 |
| **分会场 V：软物质系统（26 日）<br>地点：文汇楼 2301** | | | | |
| **第一单元 ，7 月 26 日，星期三，14:00-16:00<br>主持人：吴晨旭** | | | | |
| V01 | 14:00-14:25 | 杨明成 | 中国科学院物理研究所 | Odd response-induced phase separation of active spinners |
| V02 | 14:25-14:50 | 张何朋 | 上海交大 | Collective phenomena of chiral swimming microorganisms |
| V03 | 14:50-15:07 | 罗孟波 | 浙江大学 | 纳米颗粒拥挤环境中高分子链亚扩散的模拟研究 |
| V04 | 15:07-15:24 | 万端端 | 武汉大学 | Effects of orientational and positional randomness of particles on photonic band gap |
| V05 | 15:24-15:41 | 孙运祥 | 宁波大学 | 功能性纤维 Suckerin 自组装过程中的“微相分离”现象和 pH-响应分子机理 |
| V06 | 15:41-15:58 | 黄栋 | 苏州大学 | 如何区分尘埃等离子体的强弱耦合？ |
| | 16:00-16:20 | | 茶歇 | |
| **第二单元，7 月 26 日，星期三，16:20-18:00<br>主持人：罗孟波** | | | | |
| V07 | 16:20-16:45 | 吴晨旭 | 厦门大学 | Wrapping dynamics and critical conditions for active nonspherical nanoparticle uptake |
| V08 | 16:45-17:10 | 叶方富 | 国科温州研究院/中国科学院 | 活性物质与细胞动力学 |

| | | | | |
|---|---|---|---|---|
| | | | 物理研究所 | |
| V09 | 17:10-17:27 | 丁泓铭 | 苏州大学 | 纳米-生物界面作用的物理机制及调控策略研究 |
| V10 | 17:27-17:44 | 陈梦瑶 | 南方科技大学 | Realizing the multifunctional metamaterial for fluid flow in a porous medium |
| V11 | 17:44-18:01 | 徐留芳 | 吉林大学 | 几个统计模型相变类型的计算模拟研究 |
| **分会场 VI：非线性科学与复杂网络（26 日）** | | | | |
| **地点：文汇楼 2316** | | | | |
| **第一单元 ，7 月 26 日，星期三，14:00-16:00** | | | | |
| **主持人：纪鹏** | | | | |
| VI01 | 14:00-14:25 | 艾保全 | 华南师范大学 | 手性活性混合粒子的自发分离 |
| VI02 | 14:25-14:50 | 兰岳恒 | 北京邮电大学 | Koopman 分析在非线性动力学中的应用 |
| VI03 | 14:50-15:07 | 顾长贵 | 上海理工大学 | Frequency-amplitude correlation inducing first-order phase transition in coupled oscillators |
| VI04 | 15:07-15:24 | 邹勇 | 华东师范大学 | 相同步与耦合方向的识别 |
| VI05 | 15:24-15:41 | 史贵元 | 北京师范大学 | 复杂网络非线性动力学临界点的普适上下界 |
| VI06 | 15:41-15:58 | 樊华伟 | 西安邮电大学 | Eigenvector-based analysis of cluster synchronization in general complex networks of coupled chaotic oscillators |
| | 16:00-16:20 | | 茶歇 | |
| **第二单元，7 月 26 日，星期三，16:20-18:10** | | | | |
| **主持人：兰岳恒** | | | | |
| VI07 | 16:20-16:45 | 黄子罡 | 西安交通大学 | How do neuromodulators promote cognitive flexibility |
| VI08 | 16:45-17:10 | 纪鹏 | 复旦大学 | 网络上的信号传播 |

| | | | | |
|---|---|---|---|---|
| VI09 | 17:10-17:35 | 邹为 | 华南师范大学 | Solvable dynamics of coupled high-dimensional generalized limit-cycle oscillators |
| VI10 | 17:35-17:52 | 周杰 | 华东师范大学 | The structure of uni-directional chain for the synchronization of networked chaotic systems |
| VI11 | 17:52-18:17 | 胡岗 | 北京师范大学 | 寻找网络的暗节点和暗结构 |
| **分会场 VII：生命与生态系统（26 日）<br>地点：文汇楼 2311** | | | | |
| **第一单元 ，7 月 26 日，星期三，14:00-16:00<br>主持人：汪劲** | | | | |
| VII01 | 14:00-14:25 | 汤雷翰 | 香港浸会大学 | Agent-based model of COVID-19 transmission for location-specific risk assessment and control |
| VII02 | 14:25-14:50 | 汪劲 | Stony Brook University | 分子生物学和系统生物学的物理机制 |
| VII03 | 14:50-15:07 | 梁师翎 | 洛桑联邦理工学院 | Universal thermodynamic bounds on symmetry breaking in living systems |
| VII04 | 15:07-15:24 | 徐丽 | 中科院长春应化研究所 | 非平衡态生态系统的稳定性研究 |
| VII05 | 15:24-15:41 | 蔡蔚然 | 苏州大学 | 生命的群舞：互利网络形成的自适应机制与其动力学特性 |
| VII06 | 15:41-15:58 | 康举 | 中山大学物理学院 | Intraspecific predator interference promotes biodiversity in ecosystems |
| | 16:00-16:20 | | | 茶歇 |
| **第二单元，7 月 26 日，星期三，16:20-18:01<br>主持人：张胜利** | | | | |
| VII07 | 16:20-16:45 | 刘锋 | 南京大学 | 转录爆发的调控和约束机制 |

| | | | | |
|---|---|---|---|---|
| VII08 | 16:45-17:10 | 张胜利 | 西安交通大学 | Studies on the Dynamic Structures of Several Key Proteins |
| VII09 | 17:10-17:27 | 刘艳辉 | 贵州大学 | Quantification of macromolecule crowding at single molecule level |
| VII10 | 17:27-17:44 | 徐新鹏 | 广东以色列理工学院 | Persistent random walk: a phenomenological paradigm for cell migration on solid substrates |
| VII11 | 17:44-18:01 | 曹远胜 | 清华大学 | The physical basis for the diversity of eukaryotic cell migration |
| **分会场 VIII：机器学习、智能与认知（26 日）** | | | | |
| **地点：文汇楼 2302** | | | | |
| **第一单元 ，7 月 26 日，星期三，14:00-16:00** | | | | |
| **主持人：赵鸿** | | | | |
| VIII01 | 14:00-14:25 | 黄海平 | 中山大学 | 关于记忆 |
| VIII02 | 14:25-14:50 | 黄旭辉 | 中国航天科工智能科技研究院 | 类脑脉冲神经网络学习与识别 |
| VIII03 | 14:50-15:07 | 郑文 | 太原理工大学 | The Classification and Structural Characteristics of Amorphous Materials Based on Interpretable Deep Learning |
| VIII04 | 15:07-15:24 | 黄子涵 | 湖南大学 | 基于深度学习的反常扩散表征方法 |
| VIII05 | 15:24-15:41 | 黎勃 | 哈尔滨工业大学（深圳） | 两类决策问题的统计物理研究 |
| VIII06 | 15:41-15:58 | 张万舟 | 太原理工大学 | Snake net with a neural network for detecting multiple phases in the phase diagram |
| | 16:00-16:20 | | 茶歇 | |
| **第二单元，7 月 26 日，星期三，16:20-18:10** | | | | |
| **主持人：狄增如** | | | | |

| | | | | |
|---|---|---|---|---|
| VIII07 | 16:20-16:45 | 刘金国 | 香港科技大学（广州） | 基于张量网络的贝叶斯推断理论 |
| VIII08 | 16:45-17:10 | 汤迎 | 北京师范大学珠海校区 | Learning nonequilibrium statistical mechanics and dynamical phase transitions |
| VIII09 | 17:10-17:27 | 唐宾泽 | 北京大学 | Machine learning aided interfacial atomic structure identification from AFM images |
| VIII10 | 17:27-17:44 | 郑国忠 | 陕西师范大学 | The evolution of trust and trustworthiness based on Q-learning |
| VIII11 | 17:44-18:01 | 宋天舒 | 中国矿业大学 | Numerically stable neural network for simulating Kardar-Paris-Zhang growth in the presence of uncorrelated and correlated noises |
| VIII12 | 18:01-18:18 | 罗俊藤 | 华东师范大学 | 基于贝叶斯推断定量评估干预政策对 COVID-19 感染和恢复的影响 |

## 大会报告（27 日上午）

| 主会场（27 日） | | | | |
|---|---|---|---|---|
| 第三单元 ，7 月 27 日，星期四，08:30-10:00<br>主持人：胡岗 | | | | |
| D07 | 08:30-09:00 | 张嘉漪 | 复旦大学 | 视觉信息编解码和视觉修复 |
| D08 | 09:00-09:30 | 弭元元 | 重庆大学 | A Brain-inspired Computational Model for Spatio-temporal Sequence Recognition |
| D09 | 09:30-10:00 | 刘宗华 | 华东师范大学 | 基于真实脑网络结构的大脑功能机制研究 |
| | 10:00-10:30 | | | 茶歇 |
| 第四单元，7 月 27 日，星期四，10:30-12:00<br>主持人：陈晓松 | | | | |
| D10 | 10:30-11:00 | 邓友金 | 中国科学技术大学 | The Ising model in high dimensions |
| D11 | 11:00-11:30 | 黄亮 | 兰州大学 | 量子疤痕概念及进展 |
| D12 | 11:30-12:00 | 许爱国 | 北京应用物理与计算数学研究所 | 复杂流动“介尺度”动理学建模研究 |

## 墙报展示（27 日中午）

| 地点：学生会堂（27 日） |
|---|
| 时间：13:00 －14:40 |
| 注：墙报尺寸为 90cm(宽)*120cm(高) |

## 分会报告（27 日下午）

### 分会场 Ⅰ：平衡与非平衡统计物理基础理论（27 日）

地点：文汇楼 2202

第三单元 ，7 月 27 日，星期四，14:40-16:21

主持人：田矗舜

| | | | | |
|---|---|---|---|---|
| I12 | 14:40-15:05 | 田矗舜 | 中国科学院理论物理研究所 | 全同粒子纠缠动力学的热化之路 |
| I13 | 15:05-15:30 | 吴建达 | 上海交通大学李政道研究所 | String magnetic states: A possible way toward a unified understanding on 1D and 2D quantum magnetic systems |
| I14 | 15:30-15:47 | 陈杰 | 同济大学 | Phonon Transport in Low-Dimensional Materials |
| I15 | 15:47-16:04 | 李云云 | 同济大学 | Autonomous Ratcheting by Stochastic resetting |
| I16 | 16:04-16:21 | 刘伟 | 西安科技大学 | Ising 模型，Baxter-Wu 模型和 Majority-Vote 模型的临界点前兆行为及高阶相变 |
| | 16:21-16:40 | | 茶歇 | |

第四单元，7 月 27 日，星期四，16:40-18:00

主持人：全海涛

| | | | | |
|---|---|---|---|---|
| I17 | 16:40-17:05 | 闫磊磊 | 郑州大学 | 基于超冷离子量子系统的量子信息热力学实验研究 |
| I18 | 17:05-17:30 | 阴帅 | 中山大学 | 非朗道相变的非平衡动力学 |
| I19 | 17:30-17:47 | 陈含爽 | 安徽大学 | 球对称受限系统中布朗运动的随机重置转变 |
| I20 | 17:47-18:01 | 丁成祥 | 安徽工业大学 | Dynamical relaxation behaviors of a critical quench |

### 分会场 Ⅱ：统计物理学数值计算与模拟方法（27 日）

地点：文汇楼 2201

第三单元 ，7 月 27 日，星期四，14:40-16:21

主持人：周昕

| | | | | |
|---|---|---|---|---|
| II12 | 14:40-15:05 | 林海青 | 浙江大学 | Excitations, Entanglement, and Quantum Phase Transitions |
| II13 | 15:05-15:30 | 高毅勤 | 北京大学 | 人工智能技术应用于分子计算 |
| II14 | 15:30-15:47 | 周昕 | 中国科学院大学 | Ice Nucleation on Nanosize Substrates |
| II15 | 15:47-16:04 | 张志森 | 厦门大学 | HTR: a High-Speed Cage Structure Recognition Algorithm |
| II16 | 16:04-16:21 | 乔崇智 | 北京师范大学 | 基于定标粒子理论的 2 维流体状态方程构建 |
| | 16:21-16:40 | | | 茶歇 |

**第四单元，7 月 27 日，星期四，16:40-18:00**

**主持人：许爱国**

| | | | | |
|---|---|---|---|---|
| II17 | 16:40-17:05 | 熊龙 | 云南大学 | 斯格明子的非平衡态动力学行为 |
| II18 | 17:05-17:30 | 林传栋 | 中山大学 | 高速可压缩化学反应流的离散玻尔兹曼模拟研究 |
| II19 | 17:30-17:47 | 贾英琦 | 北京应用物理与计算数学研究所 | 变加速度单模 Rayleigh-Taylor 不稳定性的非平衡动理学研究 |
| II20 | 17:47-18:01 | 陈杰 | 北京应用物理与计算数学研究所 | 基于离散 Boltzmann 方法的 Rayleigh-Taylor 不稳定性动理学研究：界面张力、粘性和热传导的影响 |

## 分会场 III：量子物理前沿相关的统计物理（27 日）

**地点：文汇楼 2303**

**第三单元 ，7 月 27 日，星期四，14:40-16:21**

**主持人：蒋建华**

| | | | | |
|---|---|---|---|---|
| III12 | 14:40-15:05 | 邢向军 | 上海交通大学 | 受非保守力驱动的朗之万系统的热力学和随机热力学 |
| III13 | 15:05-15:30 | 任捷 | 同济大学 | 声波和声子有自旋吗？-高阶微商场论的老树新芽 |

| | | | | |
|---|---|---|---|---|
| III14 | 15:30-15:47 | 张哲东 | 香港城市大学 | Quantum Theory for Exciton-Polariton Condensations |
| III15 | 15:47-16:04 | 艾清 | 北京师范大学 | Criticality-Based Avian Navigation and Quantum Metrology |
| III16 | 16:04-16:21 | 刘全城 | 巴伊兰大学 | 多体系统中分数量子化的回归时间 |
| | 16:21-16:40 | | | 茶歇 |
| 第四单元，7 月 27 日，星期四，16:40-18:00<br>主持人：王建辉 | | | | |
| III17 | 16:40-17:05 | 杨志成 | 北京大学 | Using models with static quantum many-body scars to generate time-crystalline behavior under periodic driving |
| III18 | 17:05-17:30 | 彭新华 | 中国科学技术大学 | Quantum sensing of complex quantum many-body physics |
| III19 | 17:30-17:55 | 王建辉 | 南昌大学 | Thermodynamics and fluctuations in finite-time quantum heat engines under reservoir squeezing |
| III20 | 17:55-18:12 | 赵文垒 | 江西理工大学 | Superexponential behaviors of out-of-time ordered correlators, Loschmidt echo and energy diffusion in non-Hermitian Floquet systems |
| 分会场 Ⅳ：无序与玻璃系统（27 日）<br>地点：文汇楼 2216 | | | | |
| 第三单元 ，7 月 27 日，星期四，14:40-16:21<br>主持人：孙刚 | | | | |
| Ⅳ12 | 14:40-15:05 | 石锐 | 浙江大学 | Mechanism of hierarchical ion solvation in water |
| Ⅳ13 | 15:05-15:30 | 李艳伟 | 北京理工大学 | 局域塑性响应与过冷动力学的关联 |
| IV14 | 15:30-15:47 | 李欣阳 | 中科院理论物理所 | Thermodynamic crossovers in supercritical fluids |
| IV15 | 15:47-16:04 | 张齐 | 江苏科技大学 | 局域约束下的相变与系综不 |

| | | | | |
|---|---|---|---|---|
| | | | | 等价性 |
| IV16 | 16:04-16:21 | 蔡超然 | 西北大学 | SIS 模型与 UAU-SIS 模型的传播阈值的简单关系 |
| | 16:21-16:40 | | | 茶歇 |
| 第四单元，7 月 27 日，星期四，16:40-18:00<br>主持人：石锐 | | | | |
| IV17 | 16:40-17:05 | 孙刚 | 北京师范大学 | Amorphous Solidification of a Supercooled Liquid in the Limit of Rapid Cooling |
| IV18 | 17:05-17:30 | 杨志豪 | 香港科技大学 | Complete Realization of Energy Landscape and Non-equilibrium Trapping Dynamics in Spin Glass and Optimization Problem |
| IV19 | 17:30-17:47 | 李福祥 | 湖南大学 | Kibble-Zurek behavior in disordered topological systems |
| IV20 | 17:47-18:04 | 周健文 | 中科院理论物理所 | Hierarchical cycle-tree packing model for K-core attack problem |
| 分会场 V：软物质系统（27 日）<br>地点：文汇楼 2301 | | | | |
| 第三单元 ，7 月 27 日，星期四，14:40-16:21<br>主持人：张何朋 | | | | |
| V12 | 14:40-15:05 | 徐莉梅 | 北京大学物理学院 | Order behind disorder in non-equilibrium phase transitions |
| V13 | 15:05-15:30 | 徐磊 | 香港中文大学 | Experimentally Revealing the Three-Component Structure of Water |
| V14 | 15:30-15:47 | 汤启云 | 东南大学 | Evaporation Induced Liquid Expansion and Bubble Formation in Binary Mixtures |
| V15 | 15:47-16:04 | 张传彪 | 菏泽学院 | 物质表面的纳米结构与性质对水结冰机制的影响 |
| V16 | 16:04-16:21 | 杨成 | 绵阳师范学院 | 液态水中的第三种微观结构 |
| | 16:21-16:40 | | | 茶歇 |

| | | | | |
|---|---|---|---|---|
| 第四单元，7 月 27 日，星期四，16:40-18:00<br>主持人：徐莉梅 | | | | |
| V17 | 16:40-17:05 | 孙兆茹 | 上海科技大学 | 基于机器学习的水溶液研究 |
| V18 | 17:05-17:30 | 陈亮 | 宁波大学 | 复杂碳基表面离子吸附的调控及应用 |
| V19 | 17:30-17:47 | 王春雷 | 上海大学 | 界面水的有序行为对界面性质影响 |
| V20 | 17:47-18:01 | 赵亮 | 扬州大学 | 基于界面氧长程迁移的动态共价界面的大面积动态特性 |
| **分会场 VI：非线性科学与复杂网络（27 日）**<br>地点：文汇楼 2316 | | | | |
| 第三单元 ，7 月 27 日，星期四，14:40-16:21<br>主持人：刘宗华 | | | | |
| VI12 | 14:40-15:05 | Konstantinos Efstathiou | 昆山杜克大学 | Collective Dynamics of Coupled Second-Order Oscillators |
| VI13 | 15:05-15:30 | 罗玉辉 | 昭通学院 | 非线性混沌系统中随机重置诱导反常输运 |
| VI14 | 15:30-15:47 | 郑志刚 | 华侨大学 | Enhanced explosive synchronization in coupled oscillators with higher-order interactions |
| VI15 | 15:47-16:04 | 袁五届 | 淮北师范大学 | 突触强度变化引起神经动力学转变 |
| VI16 | 16:04-16:21 | 陈理 | 陕西师范大学 | 公平演化动力学及其钉扎调控 |
| | 16:21-16:40 | | | 茶歇 |
| 第四单元，7 月 27 日，星期四，16:40-18:00<br>主持人：郑志刚 | | | | |
| VI17 | 16:40-17:05 | 唐明 | 华东师范大学 | 复杂网络上的非马尔可夫传播动力学及其应用研究 |

| | | | | |
|---|---|---|---|---|
| VI18 | 17:05-17:30 | 张海峰 | 安徽大学 | 动力学数据驱动的高阶网络结构重构 |
| VI19 | 17:30-17:47 | 徐克生 | 江苏大学 | Noise-induced coexisting firing patterns in hybrid-synaptic interacting networks |
| VI20 | 17:47-18:01 | 黄晓东 | 华南理工大学 | 心肌早搏的基本动力学机制 |
| **分会场 Ⅶ：生命与生态系统（27 日）** | | | | |
| **地点：文汇楼 2311** | | | | |
| **第三单元 ，7 月 27 日，星期四，14:40-16:21** | | | | |
| **主持人： 王维康** | | | | |
| VII12 | 14:40-15:05 | 傅雄飞 | 中国科学院深圳先进技术研究院 | Pattern diversity emerges from a simple gene network. |
| VII13 | 15:05-15:30 | 王寿文 | 西湖大学 | Learning cell dynamics from single-cell genomic data |
| VII14 | 15:30-15:47 | 林杰 | 北京大学 | Fingering instability accelerates population growth of a growing cell collective |
| VII15 | 15:47-16:04 | 王维康 | 中科院理论物理所 | Quantification of cell phenotype transition manifold with information geometry |
| VII16 | 16:04-16:21 | 白阳 | 中国科学院深圳先进技术研究院 | Cross-regulation between proteome reallocation and metabolic flux redistribution governs bacterial transition kinetics during nutrient shifts. |
| | 16:21-16:40 | | | 茶歇 |
| **第四单元，7 月 27 日，星期四，16:40-18:00** | | | | |
| **主持人：谭志杰** | | | | |
| VII17 | 16:40-17:05 | 谭志杰 | 武汉大学 | 基于物理的 RNA 三维结构预测与评估 |
| VII18 | 17:05-17:30 | 唐乾元 | 香港浸会大学 | 蛋白质进化中的统计规律：基于 AlphaFold 数据库的研究 |

| | | | | |
|---|---|---|---|---|
| VII19 | 17:30-17:47 | 谈荣日 | 江西科技师范大学 | 朊蛋白错误折叠及分子聚集机制的分子动力学研究 |
| VII20 | 17:47-18:04 | 曹学正 | 厦门大学 | Dynamic Crosslinking of Chromatins Managed Nucleolus Ripening in Nucleus |
| **分会场 Ⅷ：机器学习、智能与认知（27 日）** | | | | |
| **地点：文汇楼 2302** | | | | |
| **第三单元 ，7 月 27 日，星期四，14:40-16:21** | | | | |
| **主持人：李炜** | | | | |
| Ⅷ13 | 14:40-15:05 | 俞连春 | 兰州大学 | Understanding the basic design principles of human brains from the perspective of complex systems |
| Ⅷ14 | 15:05-15:30 | 王琦 | 国防科技大学理学院 | A Simple Yet Effective Strategy to Robustify the Meta Learning Paradigm |
| Ⅷ15 | 15:30-15:47 | 黄振业 | 中国科学院理论物理研究所 | Energy–Information Trade-off Induces Continuous and Discontinuous Phase Transitions in Lateral Predictive Coding |
| Ⅷ16 | 15:47-16:04 | 黄刚 | 中国科学院理论物理研究所 | Liquid-to-glass transitions in supervised learning with deep neural networks |
| Ⅷ17 | 16:04-16:21 | 李炜 | 华中师范大学 | Transfer learning of phase transitions in percolation and directed percolation |
| | 16:21-16:40 | | | 茶歇 |
| **第四单元，7 月 27 日，星期四，16:40-18:00** | | | | |
| **主持人：俞连春** | | | | |
| Ⅷ18 | 16:40-17:05 | 许志钦 | 上海交通大学 | 深度学习的简单偏好 |
| Ⅷ19 | 17:05-17:30 | 敖平 | 四川大学 | 待定 |
| Ⅷ20 | 17:30-17:47 | 马锐 | 厦门大学 | Learning physical properties of membrane during endocytosis with PINN |

| | | | | |
|---|---|---|---|---|
| Ⅷ21 | 17:47-18:04 | 张文俊 | 安徽中医药大学 | The characteristics of cycle-nodes-ratio and its application to network classification |

## 分会报告（28 日上午）

| 分会场 I：平衡与非平衡统计物理基础理论（28 日）<br>地点：文汇楼 2202 | | | | |
|---|---|---|---|---|
| 第五单元，7 月 28 日，星期五，08:30-10:00<br>主持人：钟凡 | | | | |
| I21 | 08:30-08:55 | 郭文安 | 北京师范大学 | Exotic surface critical behaviors in two-dimensional quantum magnets |
| I22 | 08:55-09:12 | 王宜森 | 兰州大学 | Thermalization Frustration and Control of Intermodal Energy Flow in Graphene Nanoresonators |
| I23 | 09:12-09:29 | 王鹏 | 宁夏大学 | Nonequilibrium transport characteristics of substances in a rough potential field |
| I24 | 09:29-09:46 | 钟凡 | 中山大学 | Critical Phenomena with Memory |
| I25 | 09:46-10:03 | 于小泉 | 中物院研究生院 | A Non-Unitary Conformal Field Theory Approach to Two-Dimensional Turbulence |
| | 10:03-10:30 | | 茶歇 | |
| 第六单元，7 月 28 日，星期五，10:30-12:00<br>主持人：郭文安 | | | | |
| I26 | 10:30-10:55 | 张勇 | 厦门大学 | 近可积非线性晶格的能量均分 |
| I27 | 10:55-11:12 | 王健 | 扬州大学 | 长程关联的 FPUT-β 模型中趋向能均分的动力学过渡行为研究 |
| I28 | 11:12-11:29 | 贺达海 | 厦门大学 | 一维晶格热传导的调控：完美绝热与声子透明输运 |
| I29 | 11:29-11:46 | 杨哩娜 | 北京理工大学 | Enhancing interfacial thermal conductance of amorphous interface by optimized interfacial mass distribution |
| I30 | 11:46-12:03 | 刘卯鑫 | 北京师范大学 | Quantum Phase Transition and Eigen Microstate Condensation in the Quantum |

| | | | | |
|---|---|---|---|---|
| | | | | Rabi Model |
| **分会场 II：统计物理学数值计算与模拟方法（28 日）**<br>**地点：文汇楼 2201** | | | | |
| **第五单元，7 月 28 日，星期五，08:30-10:00**<br>**主持人：范之杰** | | | | |
| II21 | 08:30-08:55 | 范之杰 | 中国科学技术大学 | Clock Quantum Monte Carlo Method for Long-range Interacting Systems |
| II22 | 08:55-09:12 | 万彪 | 国科温州研究院 | Revealing diffusion and binding free energy landscape of transcription factor protein around DNA for sequence detection and genetic regulation |
| II23 | 09:12-09:29 | 戴立强 | 国科温州研究院 | Revealing atomic-scale molecular diffusion of transcription factors along DNA |
| II24 | 09:29-09:46 | 吴凯 | 中国科学院大学温州研究院 | Widely Regulate Ice Nucleation via Small Interaction Perturbations |
| II25 | 09:46-10:03 | 邓霖 | 兰州大学 | Energy localization and equipartition in graphene lattice |
| | 10:03-10:30 | | 茶歇 | |
| **第六单元，7 月 28 日，星期五，10:30-12:00**<br>**主持人：熊龙** | | | | |
| II26 | 10:30-10:55 | 胡皓 | 安徽大学 | 各向异性系统中的普适临界逾渗行为 |
| II27 | 10:55-11:12 | 高志斌 | 西安交通大学 | The role of high-order anharmonicity and off-diagonal terms in thermal conductivity: a case study of multi-phase CsPbBr3 |
| II28 | 11:12-11:29 | 余荫铠 | 中山大学 | 相互作用狄拉克费米子的非平衡量子临界性 |

| 分会场 III：量子物理前沿相关的统计物理（28 日） | | | | |
|---|---|---|---|---|
| 地点：文汇楼 2303 | | | | |
| 第五单元，7 月 28 日，星期五，08:30-10:00<br>主持人：张力发 | | | | |
| III21 | 08:30-08:55 | 刘俊杰 | 上海大学 | Quantum fluctuation and thermodynamics of quantum thermal machines |
| III22 | 08:55-09:12 | 于长水 | 大连理工大学 | Quantum self-contained thermodynamical devices |
| III23 | 09:12-09:29 | 柳飞 | 北京航空航天大学 | 量子跳跃轨迹的半马氏过程 |
| III24 | 09:29-09:46 | 张堃 | 西北大学 | Quantum fluctuation theorem of dissipative information |
| III25 | 09:46-10:03 | 徐国华 | 浙江大学 | Quantum Dynamics of Continuous Time Crystals |
| | 10:03-10:30 | 茶歇 | | |
| 第六单元，7 月 28 日，星期五，10:30-12:00<br>主持人：熊持 | | | | |
| III26 | 10:30-10:55 | Gentaro Watanabe | 浙江大学 | Quantum performance of microscopic heat engines under outcoupling |
| III27 | 10:55-11:20 | 龚明 | 中国科学技术大学 | 无序模型的 Anderson 局域化和迁移率边：从单体物理到多体物理 |
| III28 | 11:20-11:37 | 熊持 | 闽江学院 | 超流体中的量子涡旋和湍流 |
| III29 | 11:37-11:54 | 徐洪亚 | 兰州大学 | Klein 微腔中的波混沌与局域化 |
| III30 | 11:54-12:11 | 王成震 | Wesleyan University | Asymmetric Transport in Nonlinear Complex Wave Systems |
| 分会场 IV：无序与玻璃系统（28 日） | | | | |
| 地点：文汇楼 2216 | | | | |
| 第五单元，7 月 28 日，星期五，08:30-10:00<br>主持人：赵金华 | | | | |

| | | | | |
|---|---|---|---|---|
| IV21 | 08:30-08:55 | 曾红丽 | 南京邮电大学 | 利用耦合分析方法推理种群演化适应度 |
| IV22 | 08:55-09:12 | 毛俊雯 | 湖州师范学院 | An integrated modeling approach to characterizing substrate inhibition of microbial growth |
| IV23 | 09:12-09:29 | 刘德明 | 兰州大学 | 细胞间竞争增长与环境耦合反馈动力学 |
| IV24 | 09:29-09:46 | 王嘉慧 | 中北大学 | A new variable-boostable 3D chaotic system with hidden and coexisting attractors: Dynamical analysis, periodic orbit coding, circuit simulation, and synchronization |
| IV25 | 09:46-10:03 | 常鑫 | 西北大学 | Combined effect of simplicial complexes and interlayer interaction: An example of information-epidemic dynamics on multiplex networks |
| | 10:03-10:30 | | 茶歇 | |
| **第六单元，7 月 28 日，星期五，10:30-12:00<br>主持人：曾红丽** | | | | |
| IV26 | 10:30-10:55 | 玉素甫·艾比布拉 | 新疆大学 | Minimum Backbone of Complex Networks |
| IV27 | 10:55-11:20 | 赵金华 | 华南师范大学 | A percolation-based analytical approach to combinatorial optimization problems on graphs |
| IV28 | 11:20-11:37 | 韩礼雷 | 华东师范大学 | 时变网络上的非马尔可夫动力学 |
| IV29 | 11:37-11:54 | 刘思博 | 香港浸会大学 | Financial Systems, Production Networks, and the Environment |
| **分会场 V：软物质系统（28 日）** | | | | |

| | | | | |
|---|---|---|---|---|
| 地点：文汇楼 2301 | | | | |
| 第五单元，7 月 28 日，星期五，08:30-10:00<br>主持人：徐磊 | | | | |
| V21 | 08:30-08:55 | 徐宁 | 中国科学技术大学 | Instabilities of disordered solids under load |
| V22 | 08:55-09:12 | 张天辉 | 苏州大学 | Dynamics of Quincke particles with Tunable Memory |
| V23 | 09:12-09:29 | 巫浩 | 国科温州研究院 | Vestigial Osmotic Pressure |
| V24 | 09:29-09:46 | 沈翔瀛 | 南方科技大学 | Achieving adjustable elasticity with non-affine to affine transition |
| V25 | 09:46-10:03 | 郝少倩 | 浙江师范大学 | Directional Movement of Nano Substances on Asymmetric Surfaces |
| | 10:03-10:30 | | 茶歇 | |
| 第六单元，7 月 28 日，星期五，10:30-12:00<br>主持人：徐宁 | | | | |
| V26 | 10:30-10:55 | 谭鹏 | 复旦大学 | 玻璃转变和结晶过程的动力学关联 |
| V27 | 10:55-11:12 | 雷群利 | 南京大学 | Self-Assembled Transformable Maxwell Crystals |
| V28 | 11:12-11:29 | 王庭 | 云南大学 | Non-equilibrium thermodynamics of chiral active Brownian particles: from pressure to sedimentation |
| V29 | 11:29-11:46 | 周雨欣 | 同济大学 | 限制环境中活性物质的群体感知和模式形成 |
| V30 | 11:46-12:03 | 施夏清 | 苏州大学 | 取向有序活性物质的敏感性 |
| **分会场 VI：非线性科学与复杂网络（28 日）**<br>**地点：文汇楼 2316** | | | | |

| | | | | |
|---|---|---|---|---|
| 第五单元，7 月 28 日，星期五，08:30-10:00<br>主持人：占萌 | | | | |
| VI21 | 08:30-08:55 | 张宏 | 浙江大学 | Topological charge-density-vector method of identifying filaments of scroll waves |
| VI22 | 08:55-09:12 | 张朝阳 | 宁波大学 | Kramers Rate Theory of Pacemaker Dynamics in Noisy Excitable Media |
| VI23 | 09:12-09:29 | 姚成贵 | 嘉兴学院 | A minimal physiologically based model of the ultradian NREM-REM cycle |
| VI24 | 09:29-09:46 | 张希昀 | 暨南大学 | A spatial vaccination strategy to reduce the risk of vaccine-resistant variants |
| VI25 | 09:46-10:03 | 董家奇 | 兰州大学 | 最优化马尔科夫随机搜索与覆盖时间的软下界 |
| | 10:03-10:30 | | 茶歇 | |
| 第六单元，7 月 28 日，星期五，10:30-12:00<br>主持人：张宏 | | | | |
| VI26 | 10:30-10:55 | 占萌 | 华中科技大学 | 新能源电力系统同步稳定多尺度建模与分析 |
| VI27 | 10:55-11:20 | 杨会杰 | 上海理工大学 | Synchronization of Chaotic Systems from the Perspective of Machine Learning |
| VI28 | 11:20-11:37 | 王圣军 | 陕西师范大学 | Power-law statistics of synchronous transition in inhibitory neuronal networks |
| VI29 | 11:37-11:54 | 熊科诏 | 西安科技大学 | 复杂网络上的局域化热输运现象 |
| VI30 | 11:54-12:11 | 张永文 | 昆明理工大学 | 空气污染事件的复杂性和普适性研究 |
| **分会场 VII：生命与生态系统（28 日）**<br>地点：文汇楼 2311 | | | | |
| 第五单元，7 月 28 日，星期五，08:30-10:00<br>主持人：黄胜友 | | | | |

| | | | | |
|---|---|---|---|---|
| VII21 | 08:30-08:55 | 李文飞 | 南京大学 | 蛋白分子功能动力学：能量面阻挫与别构调控 |
| VII22 | 08:55-09:20 | 黄胜友 | 华中科技大学 | 基于统计势迭代方法的生物分子相互作用能量计算 |
| VII23 | 09:20-09:37 | 楚夏昆 | 香港科技大学（广州） | Quantifying chromosome structural dynamical pathways during cell fate decision making processes |
| VII24 | 09:37-09:54 | 彭云辉 | 华中师范大学 | Deciphering the principles of nucleosome dynamics and interactions through integrative computational approaches |
| VII25 | 09:54-10:11 | 赵蕴杰 | 华中师范大学 | AI-based scoring function to evaluate native-like RNA-protein complexes |
| | 10:11-10:30 | | 茶歇 | |
| **第六单元，7 月 28 日，星期五，10:30-12:00<br>主持人：涂育松** | | | | |
| VII26 | 10:30-10:55 | 严钢 | 同济大学 | 数据驱动的复杂系统动力学推理及应用 |
| VII27 | 10:55-11:20 | 涂育松 | 扬州大学 | G-四链体 DNA 与双悬臂类配体小分子特异性作用的动力学过程 |
| VII28 | 11:20-11:37 | 刘振兴 | 北京师范大学 | Cooperativity and Folding Kinetics in a Multidomain Protein with Interwoven Chain Topology |
| VII29 | 11:37-11:54 | 张庆 | 中科院北京基因组所 | A dynamic kissing model for enhancer-promoter communication on the surface of transcriptional condensate |
| VII30 | 11:54-12:11 | 李典杰 | 北京大学 | ATP hydrolysis kinetics and thermodynamics as determinants of calcium oscillation in pancreatic β cells |
| **分会场 VIII：机器学习、智能与认知（28 日）** | | | | |

| 地点：文汇楼 2302 | | | | |
|---|---|---|---|---|
| 第五单元，7 月 28 日，星期五，08:30-10:00<br>主持人：张潘 | | | | |
| VIII22 | 08:30-08:55 | 王新刚 | 陕西师范大学 | Inferring Attracting Basins of Power System with Machine Learning |
| VIII23 | 08:55-09:12 | 朱月英 | 武汉纺织大学 | The critical behavior of Hegselmann–Krause opinion model with smart agents |
| VIII24 | 09:12-09:29 | 马智钦 | 昆明理工大学 | Early warning signals of tipping points in scomplex systems: deep learning via surrogate data |
| VIII25 | 09:29-09:46 | 崔鹏碧 | 北京师范大学珠海校区 | Network localization strength regulates innovation diffusion with macro-level social influence |
| VIII26 | 09:46-10:03 | 刘聪 | 兰州大学 | Resonance-like collective behavior induced by the diversity of system components |
| | 10:03-10:30 | | 茶歇 | |
| 第六单元，7 月 28 日，星期五，10:30-12:00<br>主持人：王新刚 | | | | |
| VIII27 | 10:30-10:55 | 陈育涵 | 北京师范大学 | Mechanism of spatial-temporal heterogeity of multiple regions during different brain states |
| VIII28 | 10:55-11:12 | 王艳成 | 北京航空航天大学中法航空学院 | Fractionalized conductivity and emergent self-duality near topological phase transitions |
| VIII29 | 11:12-11:29 | 王骏 | 华东理工大学 | 宏观传热中的双稳态与逻辑运算 |
| VIII30 | 11:29-11:46 | 李耿 | 北京师范大学系统科学学院 | A shortcut to finite-time memory erasure |
| VIII31 | 11:46-12:03 | 马登科 | 南京师范大学 | 一维超晶格体系中声子局域化引起的温度震荡 |

## 大会报告（28 日下午）

| 主会场（28 日）<br>地点：学生会堂 | | | | |
|---|---|---|---|---|
| 第五单元，7 月 28 日，星期五，14:00-15:30<br>主持人：赵鸿 | | | | |
| D13 | 14:00-14:30 | 张潘 | 中国科学院理论物理研究所 | 基于自回归神经网络的统计力学计算方法及应用 |
| D14 | 14:30-15:00 | 左光宏 | 国科温州研究院 | CVTree&CLTree：基于全基因组的微生物进化与分类方法 |
| D15 | 15:00-15:30 | 王炜 | 南京大学 | 生物分子模拟----进展与挑战 |
| | 15:30-16:00 | 茶歇与讨论 | | |
| 第六单元，7 月 28 日，星期五，16:00-17:00<br>主持人：方海平 | | | | |
| D16 | 16:00-16:30 | Federico Ricci-Tersenghi | 罗马大学（意大利） | Statistical physics of random constraint satisfaction problems |
| D17 | 16:30-17:00 | 陈晓松 | 北京师范大学 | 复杂系统的涌现与相变：本征微观态凝聚及其重整化群理论 |

## 闭幕式（28 日下午）

| 主会场<br>地点：学生会堂 | |
|---|---|
| 主持人：周海军 | |
| 17:00-17:30 | 优秀墙报&口头报告颁奖<br>下届会议组委会委员致辞<br>欧阳钟灿院士致辞<br>会议工作委员会主任 周海军致辞 |

# 墙报展示目录

## 地点：学生会堂

| 主题 | 编号 | 作者 | 单位 | 题目 |
|---|---|---|---|---|
| 平衡与非平衡统计物理基础理论（19人） | Z1 | 杨家豪 | 上海交通大学 | Confinement of many-body Bethe strings |
| | Z2 | 曾植 | 中山大学 | Driven Critical dynamics in Gross-Neveu-Yukawa Universality Class |
| | Z3 | 王骁 | 李政道研究所 *Collective topological active particles: Non-ergodic superdiffusion and ageing in complex environments* | E8 dynamics in a perturbed quantum critical Ising chain and its experimental realization in Antiferromagnet BaCo2V2O8 |
| | Z4 | 刘德华 | 南昌大学 | Enhancement of quantum heat engine under Bose-Einstein Condensation by adiabatically change of phase-space density |
| | Z5 | 杨哩娜 | 北京理工大学 | Enhancing interfacial thermal conductance of amorphous interface by optimized interfacial mass distribution |
| | Z6 | 吴雨心 | 北京大学 | Heat statistics in the relaxation process of the Edwards-Wilkinson elastic manifold |
| | Z7 | 黎智轩 | 中山大学 | Imaginary-Time Quantum Relaxation Critical Dynamics with Semi-Ordered Initial States |
| | Z8 | 张文超 | 陕西师范大学 | Investigation on the phase properties of QCD at finite temperature with the Tsallis statistics |

| | | | | |
|---|---|---|---|---|
| | Z9 | 罗荣祥 | 福州大学 | Negative differential thermal resistance of fluids induced by heat baths |
| | Z10 | 余荫铠 | 中山大学 | Nonequilibrium quantum criticality of interacting Dirac fermions |
| | Z11 | 王尧 | 中国科学技术大学 | On the lower bound of the Heisenberg uncertainty product in the Boltzmann states |
| | Z12 | 裴继辉 | 北京大学 | On the validity of Margenau-Hill quasiprobability of quantum work |
| | Z13 | 袁结红 | 南昌大学 | Quantum Brayton refrigeration and heat engine cycle with finite-size Bose-Einstein condensate |
| | Z14 | 李清慧 | 鲁东大学 | Spatial distribution of thermal energy and specific heat in a coupled spring system |
| | Z15 | 黄晨龙 | 厦门大学 | Tightest universal finite-time Landauer bound |
| | Z16 | 韩文辉 | 兰州大学 | 颗粒气体中布朗马达随机热力学定律的实验研究 |
| | Z17 | 张强 | 广西大学 | 一维长程弱界面 FPU 模型热输运特性的研究 |
| | Z18 | 常志超 | 中国矿业大学 | Large deviation approach for kinetic roughening in the Kardar-Parisi-Zhang growth with long-range temporal and spatial correlations |
| | Z19 | 施宏达 | 昆明学院 | Collective topological active particles: Non-ergodic superdiffusion and ageing in complex environments |
| 统计物理学数值计算与模拟方法（11 人） | Z20 | 俞崔前 | 同济大学 | Characteristics of distinct thermal transport behaviors in single-layer and multilayer graphene |
| | Z21 | 万飞 | 南开大学 | Detecting gradient magnetic field aided by correlated random walk |
| | Z22 | 鲁爽 | 同济大学 | Enhancement of the lattice thermal conductivity of two-dimensional functionalized |

| | | | | |
|---|---|---|---|---|
| | | | | MXenes by inversion symmetry breaking |
| | Z23 | 方胜 | 中国科学技术大学 | Geometric Upper Critical Dimensions of the Ising Model |
| | Z24 | 张凡 | 北京师范大学 | Models of XY Spins with Generic Direction Dependent Interactions |
| | Z25 | 方胜 | 中国科学技术大学 | Monte Carlo study of duality and the Berezinskii-Kosterlitz-Thouless phase transitions of the two-dimensional ***q***-state clock model in flow representations |
| | Z26 | 王锦程 | 西安科技大学 | Phase transitions and critical phenomena of Blume-caple model in complex networks |
| | Z27 | 吴永欣 | 中国矿业大学 | Scaling behavior and avalanche dynamics of a class of generalized long-range elastic-string models |
| | Z28 | 余航 | 兰州大学 | Thermal rectifiers based on one dimensional van der Waals heterostructures |
| | Z29 | 胡坤 | 北京师范大学物理学系 | Wetting transition in the transverse-field spin-1/2 XY model with boundary fields |
| | Z30 | 岑炳玲 | 广西大学 | 基于跟驰模型的异质交通流稳定性分析 |
| 量子物理前沿相关的统计物理（22 人） | Z31 | 高云静 | 上海交通大学 | A Proposal for Detecting Superfluidity in Neutron stars |
| | Z32 | 侯迪莎 | 北京师范大学 | Effective model for superconductivity in magic-angle graphene |
| | Z33 | 杨昂 | 浙江大学物理学院 | Emergent Superdiffusive-Ballistic-Superdiffusive Transition at Infinite Temperature in a Long-Range XXZ Model |
| | Z34 | 胡丽贞 | 北京师范大学 | Entanglement in frustrated Heisenberg ladder with alternating interactions |
| | Z35 | 张盼盼 | 北京师范大学 | Entanglements, return probabilities and critical behaviors in XXZ spin chain |

| | | | |
|---|---|---|---|
| Z36 | 张晓东 | 兰州大学 | Experimental test of the Rosenzweig-Porter model for the transition from Poisson to Gaussian unitary ensemble statistics |
| Z37 | 陈谦谦 | 卡弗里理论科学研究所 | Inverting quantum many-body scars & non-Hermitian weak ergodicity breaking |
| Z38 | 王有林 | 厦门大学 | Optimal control of finite-time measurement-driven machines |
| Z39 | 陈镜伊 | 厦门大学 | Optimal figure of merit of low-dissipation quantum refrigerators |
| Z40 | 夏世豪 | 厦门大学 | Performance improvement of a fractional quantum Stirling heat engine |
| Z41 | 李玥 | 鲁东大学 | Quantum entanglement and quantum phase transitions in non-Hermitian XY spin systems |
| Z42 | 王俊霖 | 浙江大学 | Quantum many-body states of matter and entangled photon generation in synthetic dimensions |
| Z43 | 肖洋 | 南昌大学 | Quantum Otto engine with quantum correlations |
| Z44 | 陈嘉文 | 中国工程物理研究院 | Statistical mechanics of vortices on a sphere |
| Z45 | 黄泓博 | 中国工程物理研究院研究生院 | 等温捷径的量子比特信息擦除 [Qubit Reset with Shortcut-to-Isothermal Scheme] |
| Z46 | 吴文欣 | 兰州大学 | 非线性狄拉克系统中的波包动力学研究 |
| Z47 | 张瑞杰 | 兰州大学 | 光子晶体仿真实现圆形 spin-1 三带模型 Klein 边界势阱反常边界态 |
| Z48 | 马振渤 | 兰州大学 | 三分量粒子弹球的能谱统计研究 |
| Z49 | 刘小楠 | 兰州大学 | 伪可积隔板弹球系统中液体表面波的实验研究 |
| Z50 | 单永杰 | 兰州大学 | 相对论性量子系统中的回旋镖效应研究 |

| | | | | |
|---|---|---|---|---|
| | Z51 | 彭晓珍 | 兰州大学 | 一维 Ray-splitting 狄拉克弹球系统中的周期轨理论 |
| | Z52 | 冯赵然 | 同济大学 | 离散时间晶体的流形学习物态分类 |
| 无序与玻璃系统（5人） | Z53 | 余镇浩 | 浙江大学 | A Unified Description of Water's Structure, Anomalies, and Criticality by a Hierarchical Two-State Model |
| | Z54 | 马金楼 | 浙江大学 | Abundant many-body states in Jaynes-Cummings-Hubbard arrays |
| | Z55 | 樊欣祎 | 中科院理论物理研究所 | Backdoor to the Hidden Ground State Planted Vertex Cover Example |
| | Z56 | 石弯弯 | 南京师范大学 | Effects of infinite-range interaction on the localization properties of one-dimensional disordered harmonic chains |
| | Z57 | 李德彰 | 华南理工大学 | Exact solutions of the residual entropy of two-dimensional ice models |
| 软物质系统（9人） | Z58 | 齐航凯 | 浙江大学 | Effect of Grafting Density on the Adsorption of End-Grafted Polymer Chains |
| | Z59 | 高达 | 厦门大学 | Emergent morphologies of curvature-controlled active surfaces |
| | Z60 | 王美婷 | 厦门大学 | Membrane buckling and the determination of Gaussian curvature modulus |
| | Z61 | 林榕梅 | 广西师范大学 | Molecular Insights into the Self-Assembly of a Full-Length hIAPP Trimer: β-Protofibril Formed by β-Hairpin Lateral or Longitudinal Association |
| | Z62 | 朱睿健 | 中科院理论物理研究所 | Thermal Stabilities of Two-Dimensional Ball-Stick Polygons: A Critical Edge Number |
| | Z63 | 沈一凡 | 浙江大学 | 活性高分子链的扩散以及在纳米颗粒上临界吸附的模拟研究 |
| | Z64 | 杨金荣 | 华东师范大学 | 水系电池的锌离子快速脱水 |

| | | | | |
|---|---|---|---|---|
| | Z65 | 郭盼 | 上海大学 | 羧基修饰的表面上水分子功能性的理论研究 |
| | Z66 | 王宇倩 | 同济大学 | 圆形行走机器人的布朗运动 |
| 非线性科学与复杂网络（12人） | Z67 | 刘聪 | 兰州大学 | Coupling diversity-induced partial collapse in coupled tipping systems |
| | Z68 | 王任飞 | 华东师范大学 | Impact of agent-based intervention strategies on the COVID -19 pandemic in large-scale dynamic contact networks |
| | Z69 | 彭文艳 | 浙江大学 | Spreading dynamics of capital flow transfer in complex financial networks |
| | Z70 | 陈嘉琦 | 上海理工大学 | Unraveling the Impact of Non-pharmaceutical interventions on SARS-CoV-2Mutation Dynamics |
| | Z71 | 陈钰书 | 西南石油大学 | 城市多层通勤网络中通勤感染对流行病传播的影响 |
| | Z72 | 段正路 | 江西师范大学 | 反馈诱导的声学相干共振增强 |
| | Z73 | 刘畅 | 兰州大学 | 含自适应动力学的二维连续渗流 |
| | Z74 | 罗浩杰 | 南宁 | 具有局域多体相互作用的 2-DKuramoto 模型上的螺旋波 |
| | Z75 | 葛伦 | 华东师范大学 | 社会面-封控区耦合系统中的COVID-19非马尔可夫传播过程 |
| | Z76 | 曾浪 | 华东师范大学 | 时变网络中个体活跃-吸引潜能关联性对于传播动力学的影响 |
| | Z77 | 刘易文 | 华东师范大学 | 双层网络上消息传播-意见形成的耦合动力学研究 |
| | Z78 | 杨大海 | 陕西师范大学 | 自突触延迟对单个神经元发放准确性的作用 |
| 生命与生态系统（7人） | Z79 | 李典杰 | 北京大学 | ATP 水解自由能决定胰岛 β 细胞中的钙振荡行为 |
| | Z80 | 黄淼 | 中国科学院理论物理研究所 | Information Geometry on Cell Manifolds |
| | Z81 | 彭璐 | 北京师范大学珠海校区 | Theoretical perspective on synthetic man-made life: learning from the origin of life |

| | | | | |
|---|---|---|---|---|
| | Z82 | 施博文 | 北京大学 | 生物网络能源底物分离现象研究 |
| | Z83 | 施博文 | 北京大学 | 生物网络中交叉信号研究 |
| | Z84 | 张荣鑫 | 陕西师范大学 | 用等势线曲率法定位心脏中螺旋波的相位变化点 |
| | Z85 | 张易 | 中国科学院深圳先进技术研究院 | Navigated range expansion promotes migratory culling |
| 机器学习（4人） | Z86 | 俞崔前 | 同济大学 | Enhancing thermal transport in multilayer structures: A molecular dynamics study on Lennard-Jones solids |
| | Z87 | 魏施展 | 山东大学 | High-Performance Neuromorphic Computing Based on Ferroelectric Synapses with Excellent Conductance Linearity and Symmetry |
| | Z88 | 林志伟 | 厦门大学 | Inferring membrane properties during clathrin-mediated endocytosis using machine learning |
| | Z89 | 陈江芷 | 同济大学 | Unsupervised Classification of Braid Group and Knot Topology in Non-Hermitian Systems |

# 报告摘要集

## 主会场

大会报告 D01
报告人：李保文
单位：南方科技大学
题目：低维微纳米尺度声子热传导：来自芯片散热的非平衡态统计物理问题
摘要：

大会报告 D02
报告人：张林峰
单位：深势科技公司
题目：AI-Assisted Enhanced Sampling: What Remains Hard
摘要：Artificial Intelligence (AI) has revolutionized enhanced sampling in computational chemistry and biophysics, enabling the exploration of intricate energy landscapes and the computation of free energy profiles. In this talk, we will delve into the state-of-the-art AI-assisted enhanced sampling techniques, highlighting their strengths and limitations while addressing the ongoing challenges faced by researchers in this field. We will point out some essential difficulties and discuss potential solutions in light of the progress made with generative pre-trained models.

大会报告 D03
报告人：方海平
单位：华东理工大学
题目：吸附在碳基表面的离子：从统计物理到颠覆性计算
摘要：碳不仅仅是人体主要元素，也是自然界各种材料中最重要的元素之一。生物体和自然界的大量碳一芳香环结构（以碳原子为主体的环状结构，例如苯环）存在、例如大量芳香环氨基酸、DNA 和 RNA、木质素等。近几十年，石墨烯、碳纳米管、富勒烯等富含芳香环的结构被发现。一般来说，这些结构中的碳以只有极小的极化电荷，与水分子和离子之间仅存在较弱的 van de Waals 作用。在化学上，很早就理解到芳香环上有 π 电子，但直到上世纪八十年代，人们发现富含 π 电子的芳香环与离子之间有强的非共价键作用（离子-π 作用）。由于离子与水之间存在水合作用，这样的竞争导致水溶液中的单个离子的离子-π 作用被大幅度减弱，从而一直被低估甚至被忽视。如果从统计物理观点，芳香环上的过程是“水合离子吸附– 脱附– 另一个水合离子吸附– 脱附…”的动态过程，结果与浓度相关，这样大量离子的参与会极大的提高离子-π 作用的重要性。我们在这个报告中，将介绍离子吸附在芳香环表面，通过考虑大量离子的效应，用碳纳米管、石墨烯膜用于低浓度盐水分离[1,2]，在热扰动帮助下，在稍高等非饱和溶液的石墨和石墨烯表面形成氯化二钠（$Na_2Cl$, 钠氯元素比 2:1）[3] 和（CaCl，钙氯元素比 1:1）[4]等具有室温铁磁性的的二维晶体，和由钙、镁等非过渡金属诱导的生物磁性[5]。我们还将介绍由此获得的远超目前国际上水流量的实用化海水淡化膜和设计并制造便携式单兵海水淡化器（专利[CN213537355U]）[该保温杯大小的淡化器可以为落海者提供五天淡水维持生命]，和仅仅含钙、镁和生物材料的

人体友好的核磁共振显影剂（不含传统铁磁材料）。
参考文献：
[1] Jian Liu, et al., **Phys. Rev. Lett**. , 2015, 115(16),164502.
[2] Liang Chen, Gwt al., **Nature**, 2017,550(7676) ,380.
[3] Guosheng Shi, et al., **Nat. Chem.**, 2018, 10(7), 776.
[4] Lei Zhang, et al.,, **Natl. Sci. Rev.** 8, nwaa274 (2021),
[5] Haijun Yang, et al., **arXiv:2010.07774 (2020)**

大会报告 D04
报告人：Hidetoshi Nishimori
单位：东京工业大学（日本）
题目：Quantum annealing and its application to quantum simulation
摘要：Quantum annealing is a quantum-mechanical algorithm to find the ground state of the Ising model with general interactions [1]. Since many real-world optimization problems can be mapped to the ground-state search of the Ising model, quantum annealing has been studied very actively both in academia and in the industry [2, 3], in particular stimulated by its hardware realization by D-Wave systems [4]. In the present talk, I first overview the concept and significance of quantum annealing and then proceed to the description of several recent developments in the understanding of non-equilibrium dynamics of the transverse-field Ising model by quantum simulations on the quantum hardware [5, 6].
[1] T. Kadowaki and H. Nishimori, Phys. Rev. E58, 5355 (1998)
[2] P. Hauke et al, Rep. Prog. Phys. 83, 05401 (2020)
[3] O. Ezratty, arXiv:2305.09518
[4] M.W. Johnson et al, Nature 473, 194 (2011)
[5] A. D. King et al, Nature Phys. 18, 1324 (2022)
[6] A. D. King et al, Nature 617, 61 (2023)

大会报告 D05
报告人：邢建华
单位：匹兹堡大学（美国）
题目：Dynamics of cell state transitions emerges as a new frontier of studying complex systems
摘要：It has long been a perplexing question in the field of life sciences: How can a single cell develop into a complex organism comprised of various types of cells? The ability to reprogram terminally differentiated cells into pluripotent stem cells or other cell types has opened up new avenues for regenerative medicine. These advancements in biomedical research have also given rise to a nascent field focused on studying cell state transitions within the framework of dynamical systems. This field naturally extends the study of state transitions in physics and chemistry (Hanggi et al., Rev Mod Phys, 62:251, 1990) to complex cellular systems that exist out of thermodynamic equilibrium. Such systems exhibit a large number of highly interconnected degrees of freedom and operate across broad timescales.
The recent explosion of single-cell data presents both challenges and unprecedented

opportunities for physicists to analyze the data and uncover underlying mechanistic principles. In this presentation, I aim to provide an introduction to this exciting and rapidly evolving field, with a particular focus on the research conducted in my laboratory.

大会报告 D06
报告人：胡延庆
单位：南方科技大学
题目：人类的群体行为与复杂网络上的传播动力学
摘要：

大会报告 D07
报告人：张嘉漪
单位：复旦大学
题目：视觉信息编解码和视觉修复
摘要：Despite the importance of timing in our daily lives, our understanding of how the human brain mediates sec- ond-scale time perception is limited. Here, we combined intracranial stereoelectroencephalography (SEEG) recordings in epileptic patients and circuit dissection in mice to show that visual cortex (VC) encodes timing information. We first asked human participants to perform an interval-timing task and found VC to be a key timing brain area. We then conducted optogenetic experiments in mice and showed that VC plays an impor- tant role in the interval-timing behavior. We further found that VC neurons fired in a time-keeping sequential manner and exhibited increased excitability in a timed manner. Finally, we used a computational model to illustrate a self-correcting learning process that generates interval-timed activities with scalar-timing prop- erty. Our work reveals how localized oscillations in VC occurring in the seconds to deca-seconds range relate timing information from the external world to guide behavior.

大会报告 D08
报告人：弭元元
单位：重庆大学
题目：A Brain-inspired Computational Model for Spatio-temporal Sequence Recognition
摘要：Temporal sequence processing is fundamental in brain cognitive functions. Experimental data has indicated that the representations of ordinal information and contents of temporal sequences are disentangled in the brain, but the neural mechanism underlying this disentanglement remains largely unclear. Here, we investigate how recurrent neural circuits learn to represent the abstract order structure of temporal sequences, and how the disentangled representation of order structure facilitates the processing of temporal sequences. We show that with an appropriate training protocol, a recurrent neural circuit can learn tree-structured attractor dynamics to encode the corresponding tree-structured orders of temporal sequences. This abstract temporal order template can then be bound with different contents, allowing for flexible and

robust temporal sequence processing.
We hope that this study gives us insights into the mechanism of representing the ordinal information of temporal sequences in the brain, and helps us to develop brain-inspired temporal sequence processing algorithms.

大会报告 D09
报告人：刘宗华
单位：华东师范大学
题目：基于真实脑网络结构的大脑功能机制研究
摘要：The human brain is the most complicated and fascinated system and executes various important brain functions, but its underlying mechanism is a long-standing problem. In recent years, based on the progress of complex network science, much attention has been paid to this problem and many important results have been achieved, thus it is the time to make a summary to help further studies. For this purpose, we here make a brief but comprehensive review on those results from the aspect of brain networks, i.e., from the angle of synchronization and complex network. First, we briefly discuss the main features of human brain and its cognitive functions
through synchronization. Then, we discuss how to construct both the anatomical and functional brain networks, including the pathological brain networks such as epilepsy and Alzheimer’s diseases. Next, we discuss the approaches of studying brain networks. After that, we discuss the current progress of understanding the mechanisms of brain functions, including the aspects of chimera state, remote synchronization, explosive synchronization, intelligence quotient, and remote propagation. Finally, we make a brief discussion on the envision of future study.

大会报告 D10
报告人：邓友金
单位：中国科学技术大学
题目：The Ising model in high dimensions
摘要：Critical phenomena of the high-dimensional Ising model ($d>d_c=4$) have been proved to be trivial—i.e., governed by the Gaussian fixed point (GFP) in the renormalization group. Nevertheless, we show that the high-d Ising model can display rich critical phenomena, particularly from the perspective of percolation. First, the finite-size scaling behavior is simultaneously governed by the GFP and the complete-graph (CG) asymptotic (corresponding to the Landau mean-field theory). Second, the Ising model in the random-cluster representation, regarded as a correlated percolation model, exhibits simultaneously two upper critical dimensions at $d_c=4$ and $d_p=6$. The interplay of the GFP and the CG asymptotic can lead to extremely rich scaling properties, some of which are dependent of boundary conditions. Our work establishes a systematic understanding of the critical phenomena for the Ising model in high dimensions.

大会报告 D11
报告人：黄亮

单位：兰州大学
题目：量子疤痕概念及进展
摘要：遍历通常被认为是统计物理的一个基础性假设。而对量子系统，遍历则意味着初始状态信息的完全丢失，导致系统退相干，破坏其量子资源属性。量子疤痕是抑制量子遍历的一种现象，将量子波动和经典周期轨道有机的联系了起来。对其机制和条件的理解有助于提出调控量子遍历及退相干的新方案。报告将介绍量子疤痕的概念及图像，讨论不同领域对量子疤痕现象的研究和应用，并汇报我们在相对论性量子系统中发现的疤痕态现象及规律的研究进展。

大会报告 D12
报告人：许爱国
单位：北京应用物理与计算数学研究所
题目：复杂流动“介尺度”动理学建模研究
摘要：由于介质的非均匀性和环境的多样性，冲击与爆轰引发的往往是典型的多尺度非平衡复杂流动。这类系统内部往往含有不同尺度的空间结构和动理学模式。这些中间尺度的结构和模式的存在显著影响着系统的热力学性质与物理功能。其中的大尺度、缓变行为一般可以使用 Navier-Stokes（NS）方程组很好的描述。但在一些低压稀疏区域流动行为描述、冲击波或爆轰波内部结构描述、快变流动或反应引发的非平衡行为描述等方面，NS 方程组在物理功能方面表现出不足。同时，对于我们所关心的流动行为，微观分子动力学（Molecular Dynamics, MD）模拟往往又由于适用的（时空）尺度受限而无能为力。这些“介尺度”行为的建模与机理研究是当前“介科学”研究的核心内容。

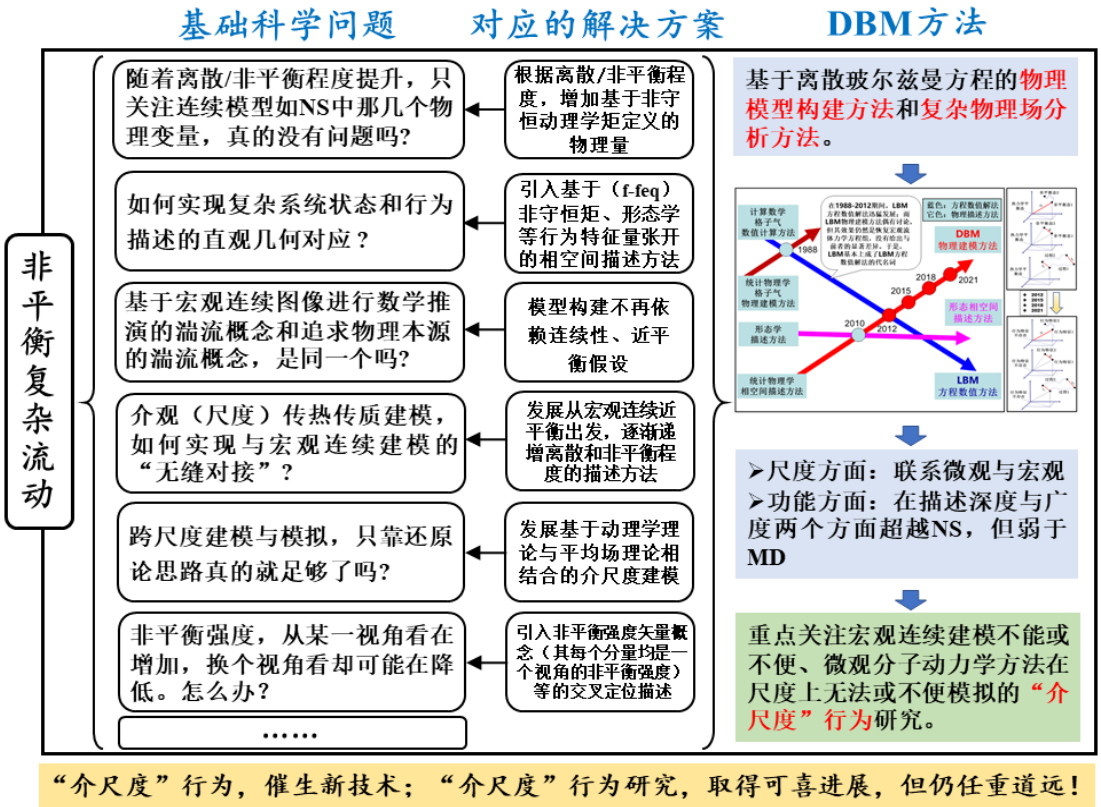



图 1：催生 DBM 建模与分析方法的基础科学问题与对应解决思路

非平衡复杂流动研究，已取得巨大进展，但仍然面临一些基础科学问题带来

的挑战，如图 1 所示。本报告从物理学角度思考各种不同尺度、不同粗粒化程度物理建模之间的区别与互补（如图 2 所示），介绍我们课题组近年来在 DBM(Discrete Boltzmann Modeling/Model/Method) “介尺度”建模与模拟方面的研究进展。离散玻尔兹曼方法，就是针对上述几个基础科学问题，基于离散玻尔兹曼方程发展的物理模型构建方法和复杂物理场分析方法。它是统计物理学粗粒化描述方法、非平衡行为描述方法、相空间描述方法在离散玻尔兹曼方程框架下的具体应用和进一步发展。DBM，由 LBM 中物理建模一支（有所舍弃有所添加）发展而来。它针对的是数值实验研究中“如何描述”和“如何分析”两大问题（给出对离散格式的最必要物理约束，不给出具体离散格式），不再基于传统流体建模的连续性假设和近平衡近似，不再使用标准 LBM 的“格子气”图像，增添基于相空间的非平衡状态与效应的检测、呈现、描述与分析方案，随着时间引入更多的信息提取技术和复杂物理场分析技术。

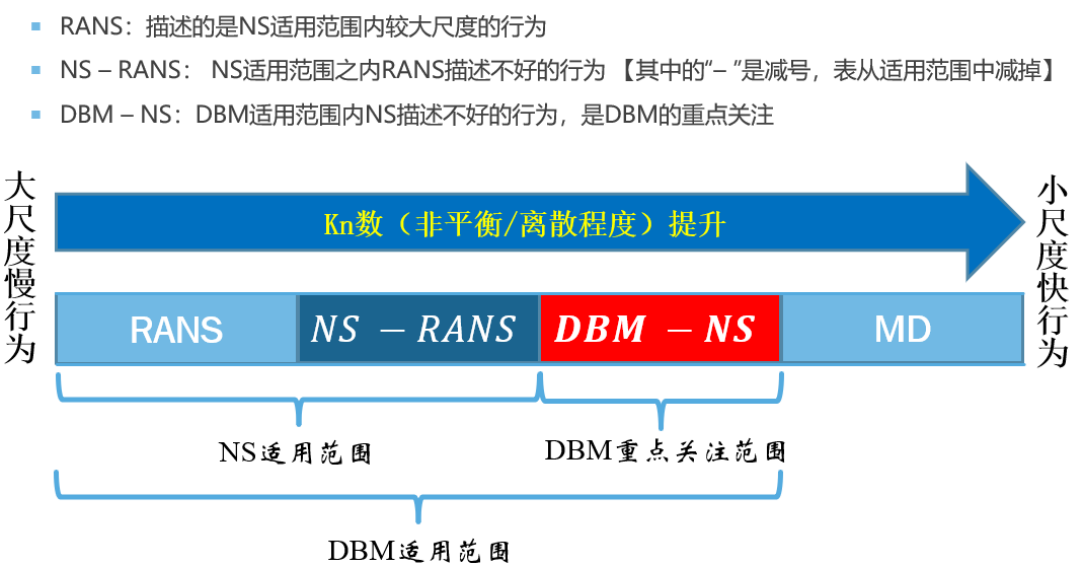



图 2：几种不同尺度的物理建模适用范围示意图

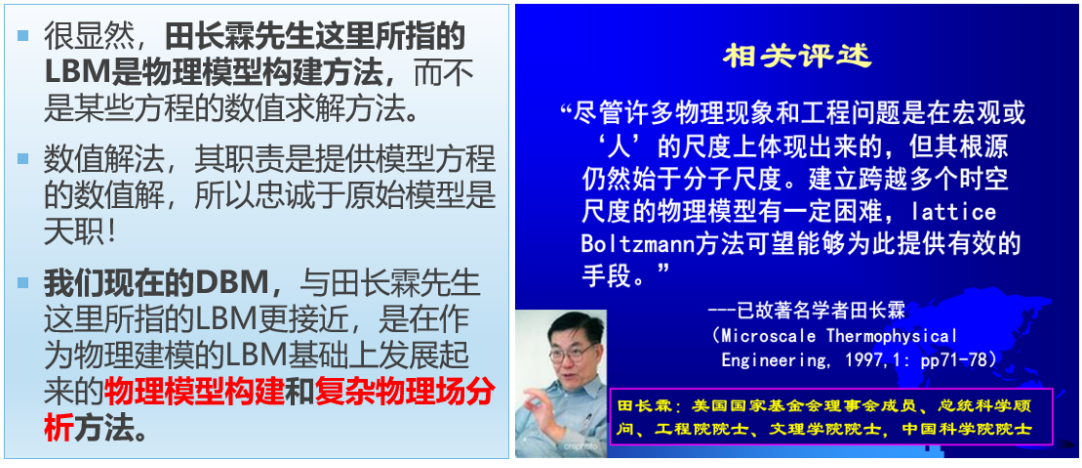



图 3：LBM 物理建模方法、LBM 方程数值解法与 DBM

从数学建模角度来看，DBM 建模与传统流体建模的典型差异就是使用离散 Boltzmann 方程取代原来的 Navier-Stokes(NS)方程。但从物理建模角度来看，这一取代是有“增益”的：一个 DBM 相当于一个连续流体模型外加一个相关热力学非平衡（Thermodynamic Non-Equilibrium, TNE）行为的粗粒化模型；该连续流体

模型可以是也可以超越 NS。DBM 内含一系列（传统流体建模不具有的）非平衡状态描述方法、非平衡信息提取技术；在不同程度非平衡行为、离散效应描述方面，具有一定程度的跨尺度自适应性。

随着离散程度、非平衡程度提升，使用更多的物理量来描述系统状态和行为，是 DBM 区别于传统流体建模和其它动理学方法的典型特征。从动理学宏观建模视角，是获得更准确本构关系的要求（如图 4 所示）；从动理学理论视角，是获得更准确分布函数的要求。视角不同，殊途同归。DBM，是理论模型构建与复杂物理场分析方法，不是某些方程的数值求解方法。

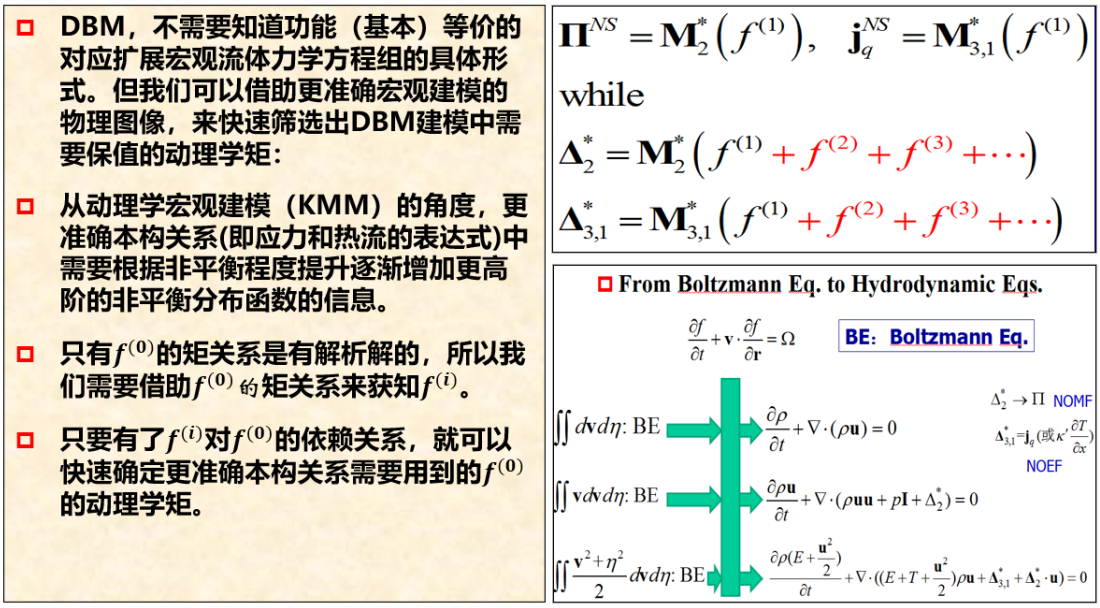



图 4：从更准确本构关系需求出发考虑 DBM 构建思路

鉴于我们面对的的状况是：工程应用采用的(多)是宏观连续建模，但也发现一些不满意，因而我们首先考虑的是：介尺度建模如何与宏观连续建模“无缝对接”？所以，DBM 的出发点是：“介尺度”范围中靠近宏观的一侧。由于发展的阶段性，目前 DBM 考虑的主要情形尚属于 Chapman-Enskog 多尺度分析理论有效的情形。需要指出的是，DBM 中的玻尔兹曼方程是根据具体情形结合平均场理论修正后的玻尔兹曼方程。

通过 DBM，可以方便地研究复杂流动过程中引起熵增的主要机制及其相对重要性【Zhang, et al. CNF2016】。DBM 所提供的热力学非平衡行为特征除了可用于目标区域真实分布函数主要特征的恢复【Lin, et al. PRE2014; Zhang, et al. FoP2018】，TNE 行为还可用于不同界面的物理甄别和界面追踪技术设计【Lai, et al. PRE2016】；TNE 强度 D 极大值点可以作为划分相分离 SD(Spinodal Decomposition)和 DG(Domain Growth)两个阶段的第一物理判据【Gan, et al. Soft Matter 2015】；由 TNE 特征量熵增率极大值点可以作为划分相分离 SD 和 DG 两个阶段的第二物理判据【Zhang, et al. Soft Matter 2019】；通过考察某些 TNE 强度，可以实现同时观测物质混合和能量混合【Zhang, et al. CPC2019】；TNE 效应之一 NOEF 强度线性增长阶段的终点可以作为 RTKHI 共存系统中 KHI 主导到 RTI 主导的物理判据【Chen et al. PoF 2020】；TNE 效应帮助理解系统离散度(由 Kn 数描述)对动理学行为的影响【Ye, et al. Entropy 2020】；在液滴碰撞动力学研究中，TNE 行为特征可以作为区分碰撞类型和不同阶段的物理判据【Zhang, et al. FoP 2020】；在气泡融合动理学研究中，平均应力各分量的特征均表现出阶段

性。气泡内$\bar{\Delta}^{*}_{2xx}$可用来标定气泡融合特征、划分气泡的融合阶段【Sun, et al. PRE 2022】;（二维情形）界面长度 L 也是 TNE 行为表征视角之一，L 指数增长阶段对应气泡加速阶段；dL/dt 第一个极大值点和 NOMF 引发的熵产率变化率的第一个极大值点，均可作为 RTI 气泡速度进入渐进阶段的物理判据【Chen, et al. PRE2022】; 等等。图 5-8 给出几个 DBM 具体应用实例。

相对于宏观行为，“介尺度”行为描述需要更多的物理量。“介尺度”行为典型特征为：离散效应显著、热力学非平衡效应显著。DBM 的“介观”特性为：（1）在尺度方面：联系微观与宏观；（2）在功能方面：在描述深度与广度两个方面超越 NS，但弱于 MD。“介尺度”行为，催生新技术；“介尺度”行为研究，取得可喜进展，但仍任重道远！

大会报告 D13
报告人：张潘
单位：中国科学院理论物理研究所
题目：基于自回归神经网络的统计力学计算方法及应用
摘要：在这个报告中，张潘将介绍他与合作者提出的统计力学计算框架 VAN (variational autoregressive networks)。这个框架借助自回归神经网络来构建具有高表述能力的变分概率分布，并通过强化学习的方法来学习参数，可以同时计算系统的自由能上界，测量系统的能量，熵及各种热力学量，并无偏地对变分分布进行直接采样。然后张潘将介绍此方法在平衡态统计物理，特别是自旋玻璃理论中的应用，并介绍如何将此方法推广到非平衡统计物理中，用于求解化学主方程。最后张潘将介绍 VAN 方法在量子纠错码(quantum error correction)中的应用。

大会报告 D14
报告人： 左光宏
单位： 国科温州研究院
题目： CVTree&CLTree：基于全基因组的微生物进化与分类方法
摘要：CVTree 是郝柏林院士提出的物种亲缘关系与分类研究方法。它基于全基因组且无需序列比对，能高效准确的处理大量物种的进化与亲缘关系。当前，该方法可通过网络服务器 WebCVTree3 (http://cvtree.online) 进行访问。它实现了进化树与分类系统的自动比对与交互显示。最新版的 WebCVTree4（http://cvtree.online/v4/）也在全网进行测试中。通过使用 CVTree，我们在基于一万多的基因数据的基础上，我们系统研究了十个科与一个目的下级分类单元的亲缘关系，并将其与基于 16S rRNA 亲缘关系树(基于“All Species Living Tree”项目的亲缘关系，并基于 LVTreeViewer (http://cvtree.online/lvtree/) 的研究结果进行一一比对。我们发现，虽然当前分类系统越来越多的依赖基于 16S rRNA 序列分析的结果，但是基于全基因组的 CVTree 方法的结果与分类系统更加一致，特别是在种的级别上。这说明 CVTree 方法，合理利用了全基因组序列中物种信息，避免了基于 16S rRNA 序列联配方法，由于信息量有限而导致的种级别的分辨能力不足的缺陷。进一步的，为了提高 CVTree 的应用场景，我们还进一步整理了 CVTree 的流程，形成了基于 K 串统计进行分类与进化研究的并行的程序框架，并加入了一些新的算法（http://github.com/ghzuo/cvtree）。为了更加快捷的比较亲缘关系与分类系统，我们还开发了 CLTree 程序（http://github.com/ghzuo/collapse），实现自动比对，并基于 Shannon 熵的原理量化了两者之间的差异。我们相信，随

着基因组测序越来越便捷，微生物的亲缘关系与分类系统的研究将需要越来越多的参考全基因组的研究结果，而 CVTree 方法将是一件研究微生物进化与分类的有力的研究工具。

大会报告 D15
报告人：王炜
单位：南京大学
题目：生物分子模拟----进展与挑战
摘要：

大会报告 D16
报告人：Federico Ricci-Tersenghi
单位：罗马大学（意大利）
题目：Statistical physics of random constraint satisfaction problems
摘要：In this talk, I will first review some important results which have been obtained in the study of random constraint satisfaction problems, thanks to the ideas and techniques borrowed from the statistical physics of disordered systems. I will try to make evident the key role played by spin glass states and the glassy dynamics in determining the hardness to solve the constraint satisfaction problem. In the last part of the talk, I will discuss some open problems and possible promising approaches to solving them.

大会报告 D17
报告人：陈晓松
单位：北京师范大学
题目：复杂系统的涌现与相变：本征微观态凝聚及其重整化群理论
摘要：当前，人类迫切需要研究大量个体组成的复杂系统，涉及物理系统、生命系统、气候系统、社会系统等，以应对和处理当前遇到的各类科学及社会挑战。其中，对复杂系统涌现及相变行为的研究尤为重要与迫切。由于复杂系统一般不处于平衡态，其能量函数、序参量一般未知，传统相变临界现象理论不再适用于这些复杂系统。当今，随着计算模拟及实验观测技术的发展，我们可获得复杂系统所有个体状态随时间的演化，由此可定义系统微观态的系综。我们可将系综中的微观态可分解成相互独立本征微观态的线性叠加，叠加系数的平方表示该本征微观态在系综中的概率，有限大小的概率预示着对应本征微观态的凝聚，以及系统发生了涌现及相变，从而建立了复杂系统的本征微观态理论。进一步，我们还建立了本征微观态的重整化群理论。本征微观态理论及其重整化群理论已被成功应用于物理系统、群体运动、细胞系统、气候系统、流体系统和大脑系统等。最后，对复杂系统研究的未来发展进行了展望。

## 分会场 I：平衡与非平衡统计物理基础理论

邀请报告 I01
报告人：董辉
单位：中国工程物理研究院研究生院

题目：有限时间热力学
摘要：近些年统计热力学研究出现了新的发展趋势，一方面所研究的物理系统尺寸变小，体系的热涨落和量子涨落成为描述系统性质的重要方面，产生了如小系统非平衡统计物理或者纳米热力学等新兴学科方向；另一方面所研究的物理系统的动力学过程时间尺度变短，体系偏离平衡态，催生出了有限时间热力学等研究方向。本报告将介绍近些年有限时间热力学基础理论的发展及其在能源物理中的应用。

邀请报告 I02
报告人： 李新征
单位： 北京大学
题目： 复相图与超临界区域
摘要：超临界区域经常被描述为状态空间中一个均一的、不存在相变的区域，但超临界物质在不同状态下展示的不同行为规律，表明它们实际上具备不同的物理特质。这里，我们利用李-杨理论，给出了一个描述超临界区域物性解析性质变化的数学语言。以 T-P 相图为例，传统的李-杨理论把其中的一个物理量 T 或 P 从实数扩展为复数，通过李-杨零点在热力学极限下是否可以无限靠近实轴来理解相变【1-2】。超临界区域物性的解析变化，因为不是相变，是不能被这个语言描述的。我们将复空间中李-杨零点类比为电荷，进而将自由能类比为一个由此分布决定的电势场。由此，我们发现无论在临界点以上或以下，物理量在真实物理空间（两个实轴形成的平面，如 T-P 相图）中的解析性质均可以由这个复空间中的场来描述。这个结论可以被两个体系（范德华模型体系与水体系）中的解析结果与数值结果佐证。超临界区域内，这两个系统的等温压缩系数 kT（或等压膨胀系数 Cp）这种响应函数的峰值的轨迹，与相应的复 T（或复 P）-空间中的最接近真实物理空间的零点在真实物理空间的投影的轨迹几乎重合。这些结果显示超临界区域的物性变化有一种潜在的相变特质。同时，这个扩展也使李-杨理论用一个完全统一的方式来描述相变区域与超临界区域成为可能【3】。参考文献：
【1】C. N. Yang and T. D. Lee, Phys. Rev. 87, 404 (1952). 【2】T. D. Lee and C. N. Yang, Phys. Rev. 87, 410 (1952). 【3】X. Y. Ouyang, Q. J. Ye, and X. Z. Li, arXiv:2303.16784

口头报告 I03
报告人： 郭伟
单位： 昆明学院
题目： Weak ergodicity breaking and anomalous diffusion in collective motion of active particles under spatiotemporal disorder
摘要：The effects of spatiotemporal disorder, i.e., both the noise and quenched disorder, on the dynamics of active particles in two dimensions are investigated. We demonstrate that within the tailored parameter regime, the non-ergodic superdiffusion and nonergodic subdiffusion occur in the system, identifified by the observable quantities (the mean squared displacement and ergodicity-breaking parameter) averaged over both the noise and realizations of quenched disorder. Their origins are attributed to the competition effects between the neighbor alignment and spatiotemporal disorder on the collective motion of active particles. These results may be helpful for further

understanding the onequilibrium transport process of active particles, as well as for detection of the transport of self-propelled particles in complex and crowded environments.

口头报告 I04
报告人： 刘剑
单位： 北京工商大学
题目： Anomalous diffusive behaviors of the intermittent stochastic process
摘要：The intermittent stochastic phenomenon is observed in various systems and is increasingly attracting attention, such that there is a need for a theoretical model of the process. We present a prototypal two-state random walk model of a renewal process alternating between the continuous-time random walk state and Lévy walk state. The diffusive behavior is analyzed and discussed by calculating the mean squared displacement analytically and numerically. The results reveal that the intermittent stochastic process shows very different properties from the single-state process.

口头报告 I05
报告人： 侯吉旋
单位： 东南大学
题目： Theoretical model for the Mpemba effect through the canonical first-order phase transition (含有一级相变的姆潘巴效应的理论模型)
摘要：姆潘巴效应是指在相同条件下原本高温物体降温比低温物体更快的反直觉现象。本次演讲中我们将报告一个产生含有正则一级相变的姆潘巴效应的理论模型。该模型指出原本温度较低的物体在发生一级相变时会被长时间地囚禁在亚稳态，而原本温度较高的物体则不需要经过亚稳态即可发生一级相变，因而导致了姆潘巴效应。作为一个例子，我们将利用蒙特卡洛模拟演示 Blume-Emery-Griffiths(BEG)模型的降温过程。对拥有不同初始温度的 BEG 系统进行降温并经历一级相变，计算机模拟将清楚地展示出姆潘巴效应发生的演化路径。本模型可能会对理解水的姆潘巴效应有一定帮助。

口头报告 I06
报告人： 全海涛
单位： 北京大学
题目： Achieving the maximum power of a Brownian heat engine
摘要：The pursuit of achieving high power in micro-engines has gained increasing interests in recent years. We consider a heat engine with a single Brownian particle as the working substance and optimize control protocols of heat-engine cycles in general damped situation. We obtain results of the maximum power (EMP) for an arbitrary friction coefficient, ranging from the overdamped regime to the underdamped limit. It is demonstrated that our approach recovers previous results about EMP in both the overdamped regime and the underdamped limit regime. In addition, by interpolating results from both the overdamped and underdamped limit, we derive an upper bound on the maximum power of Brownian heat engines $P_{\mathrm{bound}}\approx\sqrt{\lambda_{H}}T_{H}(1-\sqrt{T_{L}/T_{H}})(1-

\sqrt{(1+T_{L}/T_{H})/2})/2$, where $T_{L}$ and $T_{H}$ are temperatures of two heat baths, and $\lambda_{H}$ is the maximum stiffness of the cycle. Our results bring valuable insights for designing high-performance Brownian heat engines in experimental setups.

邀请报告 I07
报告人： 李鹰
单位： 浙江大学
题目： Non-reciprocity in macroscopic heat transfer
摘要：Non-reciprocity is a key mechanism for realizing important thermal functional devices such as thermal diodes. However, compared with other fields, the concept and theory of non-reciprocal heat transfer dominated by thermal diffusion at the macro scale remain unclear. Here, we establish a thermal scattering theory to properly define and analyze the degree of non-reciprocity in heat transfer. Based on the theory, we proposed a three-port thermal circulator based on moving medium, and studied its transmission properties under both oscillational and constant temperature excitations. The external bias of thermal convection splits the wave vector of the thermal signal, thus producing thermal non-reciprocity with non-trivial dependence on field frequency and convection velocity. A proof-of-concept experiment is implemented, which agrees well with both the theoretical and simulation results. Being the first to experimentally realize macroscopic thermal non-reciprocity resorting to the external bias method, this work clarifies the long-standing doubts about this subject and provides a powerful theoretical tool for the analysis of thermal scattering-related problems.

邀请报告 I08
报告人： 年磊磊
单位： 云南大学
题目： 单分子电子输运中的量子态调控
摘要：1974 年 Aviram 和 Ratner 从理论上提出了分子二极管的概念，之后分子电子学应运而生，并获得了广泛关注。电子在单分子结中的输运是分子电子学关注的核心，为研究非平衡量子输运与统计提供了重要平台。我们聚焦单分子量子输运中电子与声子和光子的耦合，旨在揭示声子和光子的统计属性，以及光子辅助的电子输运。发现声子可以被电流激发至非热态，而非热态的声子不能用单一的有效温度描述，需引入热态熵和冯诺依曼熵联合表征，进而可以提取出有用功。利用量子干涉效应实现了电致单光子发射和量子关联，分子相干性的存在可以诱导光子压缩。在光子辅助的电子输运过程中，可以利用单电子输运探测光子的一级和二级量子相变，同时可以利用量子相变增强光电转换的效率。

口头报告 I09
报告人： 符维成
单位： 天水师范学院
题目： Instability dynamics of nonlinear normal modes in one-dimensional lattices
摘要：Nonlinear normal modes (NNMs) are periodic orbits which play an important role in many-body Hamiltonian systems with nonlinear interactions. These orbits can

lead to a long-time metastable state, which have been one of the core concerns in statistical mechanics [1,2]. Our research show that in different models, the instability threshold and stability time of NNMs as the function of system size and perturbation strength obey the same law [3]. In this talk, I will report recent related results. It is found that these NNMs have extremely rich dynamic behaviors. For example, period doubling bifurcation, tangent bifurcation and Hope bifurcation can be observed in the same NNM under different system sizes, which will lead to extremely rich dynamic properties of the system. It is found that the instability threshold of NNM exhibits some beautiful structures as the system size changes. Finally, the effect of instability dynamics on the thermalization properties of a system will be briefly discussed.

口头报告 I10
报告人： 徐宝明
单位： 德州学院
题目： Quantum fluctuation theorem for initial near-equilibrium system
摘要：Quantum fluctuation theorem (FT) commonly requires the system initially prepared in an equilibrium state. Whether there exists universal exact quantum FT for initial states beyond equilibrium needs further discussions. In the present paper, we initialize the system in a near-equilibrium state, and derive the corresponding modified Jarzynski equality by using perturbation theory. The correction is nontrivial since it directly leads to the principle of maximum work or the second law of thermodynamics for near-equilibrium system, and also offers a much tighter bound of work. Two prototypical near-equilibrium systems driven by a temperature gradient and an external field, are taken into account, to confirm the validity and the generality of our theoretical results. Finally, a fundamental connection between quantum critical phenomenon and near-equilibrium state at really high temperature is revealed.

口头报告 I11
报告人： 熊大兴
单位： 闽江学院
题目： Subdiffusive energy transport and antipersistent correlations due to the scattering of phonons and discrete breathers
摘要：While there are many physical processes showing subdiffusion and some useful particle models for understanding the underlying mechanisms have been established, a systematic study of subdiffusive energy transport is still lacking. Here we present convincing evidence that, in the range of system size investigated, the energy subdiffusion can take place in a Hamiltonian lattice system with both harmonic nearest-neighbor and anharmonic long-range interactions. In particular, we show that the interaction range dependence of antipersistent energy-current correlations are relevant to this special type of energy subdiffusion. The underlying mechanisms are related to the various scattering processes of phonons and discrete breathers. Our results shed light on understanding the extremely slow energy transport.

邀请报告 I12

报告人： 田矗舜
单位： 中国科学院理论物理研究所
题目： 全同粒子纠缠动力学的热化之路
摘要：通过对约束在混沌腔中的无相互作用全同费米子体系建立了纯态演化过程中纠缠动力学的解析理论，严格给出了一个既不需要系综，也不需要相互作用便能发生热化的方案。

邀请报告 I13
报告人： 吴建达
单位： 上海交通大学李政道研究所
题目： String magnetic states: A possible way toward a unified understanding on 1D and 2D quantum magnetic systems
摘要：Based on the algebraic Bethe ansatz formalism, we study spin dynamics in the anti-ferromagnetic spin-1/2 XXZ chain with the Ising anisotropy via the form-factor formulae. Various excitations at different energy scales are identified crucial to the dynamic spin structure factors under the guidance of sum rules. At small magnetic polarization, gapless excitations of psinons and antipsinons corresponding to length-1 string (trivial string), dominate the low energy spin dynamics. In contrast, spin dynamics at intermediate and high energies is characterized by the length two- and three-string states. The dynamic spectra of the identified dominant excitations evolve with clear energy separations when tuning the magnetic field, conveying a simple and straightforward way to clearly identify the novel string excitations as well as its dispersions in proper condensed matter systems [1]. Our predictions have been experimentally confirmed on the quasi-one-dimensional material SrCo2V2O8 [2, 3] and BaCo2V2O8 [4]. The concrete progress on string magnetic states further motivates us to develop truncated string state space approach (TS3A) following a simple observation of fast decay of spectra weight in the spin dynamic structure factor with increasing string length [5]. The TS3A then successfully provides a string-state-based unified picture for the spin dynamics observed in different magnetic phase in the material of YbAlO3 whose effective model becomes non-integrable in the magnetic ordering phases [6]. The TS3A we constructed paves down a possible way toward a unified understanding on 1D and 2D quantum magnetic system [5]. [1] W. Yang, J. Wu, S. Xu, Z. Wang, and C. Wu, Phys. Rev. B 100, 184406 (2019). [2] Z. Wang, J. Wu, W. Yang, A. K. Bera, D. Kamenskyi, S. Xu, A. T. M. N. Islam, B. Lake, C. Wu, and A. Loidl, Nature, 554, 219 (2018). [3] A. K. Bera, J. Wu, W. Yang, Z. Wang, R. Bewley, M. Boehm, M. Bartkowiak, O. Prokhnenko, B. Klemke, A. T. M. N. Islam, J. M. Law, Bella Lake, Nature Phys. 16, 625 (2020). [4] Z. Wang, M. Schmidt, A. Loidl, J. Wu, H. Zou, W. Yang, C. Dong, Y. Kohama, K. Kindo, D. I. Gorbunov, S. Niesen, O. Breunig, J. Engelmayer, T. Lorenz, Phys. Rev. Lett. 123, 067202 (2019). [5] J. Yang and J. Wu, to submit (2023). [6] J. Yang, T. Xie, S. E. Nikitin, J. Wu, and A. A. Podlesnyak, Accepted by Phys. Rev. B Letter (2023).

口头报告 I14
报告人： 陈杰

单位： 同济大学
题目： Phonon Transport in Low-Dimensional Material
摘要：Nanoscale heat conduction has attracted substantial recent interests due to both the technological importance of thermal management in nanoelectronic devices and the scientific merits of novel transport physics. In this talk, I will present the recent theoretical advances in my group on the phonon transport in low-dimensional materials from the following three aspects. First, I shall discuss the novel phonon transport mechanisms, including the phonon hydrodynamics, the coherent phonon transport in periodic nanostructures, and a generalized decay law for thermal phonons. The impact of phonon coherence on thermal transport will be revealed, and a few examples will be discussed as the applications of the theories. Then, I will discuss the interfacial heat transfer mechanisms in 2D heterogeneous systems, including solid/solid interface under inter-layer rotation and solid/liquid interface with surface modifications. In particular, I will demonstrate the power of atomic level simulations in probing the novel interfacial phenomena different from the bulk case. Finally, I will briefly mention the advantages of atomic simulations combined with machine learning techniques for studying heat conduction in realistic materials, such as the multiple-target predictions, high-order anharmonicity, and structure optimization.

口头报告 I15
报告人： 李云云
单位： 同济大学
题目： Autonomous Ratcheting by Stochastic resetting
摘要：We proposed a generalization of the stochastic resetting mechanism for a Brownian particle diffusing in a 1D periodic potential: randomly in time, the particle gets reset to the bottom of the potential well it was in. Numerical simulation shows that in mirror asymmetric potentials, stochastic resetting rectifies its motion with maximum drift speed for an optimal average resetting time. As a result, an unbiased Brownian tracer diffusing on an asymmetric substrate can rectify its motion by an adaptive stop-and-go strategy. Our proposed ratchet mechanism can model directed autonomous motion of molecular motors and micro-organisms.

口头报告 I16
报告人： 刘伟
单位： 西安科技大学
题目： Ising 模型，Baxter-Wu 模型 和 Majority-Vote 模型的临界点前兆行为及高阶相变
摘要：本文详细分析了二维有限尺寸晶格中 Ising 和 Baxter-Wu 模型的平衡态伪相变，讨论了高阶相变作为一阶和二阶相变前兆行为的可能性，进一步，研究了不同网络结构和噪声产生机制下 Majority-Vote 模型的非平衡相变临界点的前兆行为。对于平衡态相变，我们用 Wang-Landau 抽样来获得状系统态密度。利用微正则熵的最不敏感拐点分析，得到了模型中一阶、二阶和三阶伪相变。Ising 模型的二阶相变和 Baxter-Wu 模型的一阶相变的微正则分析结果与传统的正则分析结果一致。此外，在两个模型中都发现了三阶相变，暗示了高阶相变的普遍性。

对于 Majority-Vote 模型的非平衡相变，讨论了方形格子和随机规则网络及其作为投票层和噪声层的组合。发现当投票层结构趋于局域结构时，投票层和噪声层的耦合会导致临界现象的消失，并找到了临界点消失的大致位置。同时发现三阶依赖相变只有在系统存在临界行为时才会出现，表明三阶依赖相变可以作为临界相变的前兆。

邀请报告 I17
报告人： 闫磊磊
单位： 郑州大学
题目： 基于超冷离子量子系统的量子信息热力学实验研究
摘要：随着量子信息和微观热力学的迅速发展，在量子 Jarzynski 方程、不确定性、量子信息擦除等量子力学的不同领域，开始涌现出既包含量子性质又展现热力学特征的新型量子信息热力学理论。超冷离子系统作为研究量子物理的一个优秀实验系统，拥有良好的量子控制技术、耗散通道构建方案、振动模式耦合、电子态调控等量子调控技术与性质，可以被设计成一个高度可控的量子信息热力学研究实验平台，模拟非平衡量子信息热力学过程。在该报告中，我将汇报下基于超冷离子系统，在量子信息热力学理论的实验模拟与证实方面的一些研究进展，如量子兰道尔原理、耗散时间不确定关系等。

邀请报告 I18
报告人： 阴帅
单位： 中山大学
题目： 非朗道相变的非平衡动力学
摘要：Deconfined quantum criticality (DQC) arises from fractionalization of quasi-particles and leads to fascinating behaviors beyond the Landau-Ginzburg-Wilson (LGW) description of phase transitions. The unusual aspects of DQC in equilibrium also suggest exotic phenomena out of equilibrium, which are still largely unexplored. Here we study manifestations of DQC when driving (quantum annealing) a two-dimensional quantum magnet through a critical point separating antiferromagnetic and spontaneously dimerized ground states. Numerical simulations show that the celebrated Kibble-Zurek scaling (KZS) mechanism is inadequate for describing the annealing process. To explain our results, we introduce the concept of dual asymmetric KZS, where a deconfinement time enters in addition to the conventional relaxation time and the scaling also depends on the direction in which the system is driven through the critical point according to a duality principle connecting the topological defects in the two phases. These defects -- spinons in the dimerized phase and space-time hedgehogs in the antiferromagnetic phase -- require a much longer time scale for equilibration than the amplitude of the order parameter. Beyond the new insights into DQC, our scaling approach provides a new window into out-of-equilibrium criticality with multiple length and time scales.

口头报告 I19
报告人： 陈含爽
单位： 安徽大学

题目： 球对称受限系统中布朗运动的随机重置转变
摘要：近年来，重置随机过程受到了非平衡统计物理领域的广泛关注[1-3]。随机重置一个优点是其优化平均首达时间的功能。一个有趣的问题是：什么条件下重启具有这个功能，这对重置在随机搜索的应用至关重要。研究表明，随着模型参数的变化，重启可以实现角色的转变，即所谓的“重置转变”[4-5]。我们解析给出任意维球对称受限系统中随机重启布朗运动平均吸收时间随重置速率和初始位置的关系。当初始位置距球心距离大于一个临界值时，存在一个最优的重置速率可以使得平均吸收时间最小；否则，平均吸收时间随重置速率单调增加。我们表明该临界距离只与维度有关[6]。
[1] M. R. Evans and S. N. Majumdar, Phys. Rev. Lett. 106, 160601 (2011).
[2] M. R. Evans and S. N. Majumdar, J. Phys. A: Math. Theor. 44, 435001 (2011).
[3] M. R. Evans, S. N. Majumdar, and G. Schehr, J. Phys. A: Math. Theor. 53, 193001 (2020).
[4] S. Reuveni, Phys. Rev. Lett. 116, 170601 (2016).
[5] A. Pal and S. Reuveni, Phys. Rev. Lett. 118, 030603 (2017).
[6] H.S. Chen and F. Huang, Phys. Rev. E. 105, 034109 (2022)

口头报告 I20
报告人： 丁成祥
单位： 安徽工业大学
题目： Dynamical relaxation behaviors of a critical quench
摘要：We study the universal dynamical relaxation behaviors of a quantum XY chain following a quench, paying special attention to the case that the prequenched Hamiltonian, or the postquenched Hamiltonian, or both of them are at critical points of equilibrium quantum phase transitions. In such “critical quench”, we find very interesting real-time dynamical scaling behaviors and the crossover phenomena between them. For a quench from a noncritical point to a critical point, we find that, compared to the noncritical quench, the universal power-law scaling behavior does not change; however, there may be a crossover between the exponential decaying behavior and the power-law scaling. For a quench from a critical point to a noncritical point, the power-law scaling behaviors $t^{-3/2}$ and $t^{-3/4}$ in the noncritical quenches may be changed to $t^{-1}$ and $t^{-1/2}$, respectively. If the prequenched Hamiltonian is set to be a point that is close to but not exactly at a critical point, we find interesting crossover phenomena between different power-law scaling behaviors. We also study the quench from the vicinity of a multicritical point, we find crossover behaviors that are induced by a different mechanism, and new crossover exponent is found. All the results are related to the gap-closing properties of the energy spectrum of the critical points.

邀请报告 I21
报告人： 郭文安
单位： 北京师范大学
题目： Exotic surface critical behaviors in two-dimensional quantum magnets
摘要：At a bulk critical point, the divergence of correlation length makes the influence of boundaries more pronounced; therefore, the surface may show rich and novel critical

behaviors. The subject of surface criticality has attracted numerous previous investigations and obtained renewed attention when quantum phase transitions are involved. In this talk, I will present our recent works on exotic surface critical behaviors.

口头报告 I22
报告人： 王宜森
单位： 兰州大学
题目： Thermalization Frustration and Control of Intermodal Energy Flow in Graphene Nanoresonators
摘要：As the essential cause of the intrinsic dissipation that limits the quality of graphene nanoresonators, intermodal energy transfer is also a key issue in thermalization dynamics. Typically systems with larger initial energy demand shorter time to be thermalized. However, we find quantitatively that instead of becoming shorter, the equipartition time of the graphene nanoresonator can increase abruptly by one order of magnitude. This thermalization frustration emerges due to the partition of the normal modes based on the hierarchical symmetry, and a sensitive on-off switching of the energy flow channels between symmetry classes controlled by Mathieu instabilities. A strain-based strategy to control this phenomenon and consequently the intermodal energy transfer is proposed. The results uncover the decisive roles of symmetry in the thermalization at the nanoscale, and may also shed lights for improving the performance of graphene nanoresonators.

口头报告 I23
报告人： 王鹏
单位： 宁夏大学
题目： Nonequilibrium transport characteristics ofsubstancesin a rough potential field
摘要：A Langevin equation is proposed to describe the transport of overdamped Brownian particles in a periodic rough potential and driven by an unbiased periodic force. The equation can be transformed into the Fokker–Planck equation by using the Kramers–Moyal expansions. The time-dependent solution of Fokker–Planck equation demonstrates different modes of the probability flow. These modes include creeping in a single direction, direction reversal and oscillating in both directions in the coordinate space. By varying the roughness and noise intensity, the flow can transform between the modes. The correlation between the noise and space indicates that the noise can maintain the oscillation of the modes and prolong the transient time to the steady state at which the flow tends to be zero.

口头报告 I24
报告人： 钟凡
单位： 中山大学
题目： Critical Phenomena with Memory
摘要：Memory is a ubiquitous characteristic of complex systems and critical phenomena are one of the most intriguing phenomena in nature. Here, we propose an Ising model with a prior formed memory and develop a corresponding theory of critical

phenomena with such a memory for complex systems and discovered a series of surprising novel results. We show that a naive theory of a usual Hamiltonian with a direct inclusion of a power-law decaying long-range temporal interaction parameterized by a decaying exponent θ violates radically a hyperscaling law for all spatial dimensions d even at and below the upper critical dimension dc. This entails indispensable consideration of the Hamiltonian for dynamics, rather than the usual practice of just focusing on the corresponding dynamic Lagrangian alone. A dimensional constant dt is demanded to rectify a hyperscaling law, to produce correct unique mean-field critical exponents via an effective spatial dimension originating from temporal dimension, and to transform the time and change the dynamic critical exponent. For d < dc, we develop a renormalization-group theory by employing the momentum-shell technique to the leading nontrivial order explicitly and to higher orders formally in ε = dc –d but to zero order in 1- θ and find that more scaling laws besides the hyperscaling law are broken due to the breaking of the fluctuation-dissipation theorem. Moreover, because dynamics and statics are intimately interwoven, even the static critical exponents involve contributions from the dynamics and hence do not restore the short-range exponents even for θ = 1 and the crossover between the short-range and long-range fixed points is discontinuous contrary to the case of long-range spatial interaction. In addition, a new scaling law relating the dynamic critical exponent with the static ones emerges, indicating that the dynamic critical exponent is not independent. However, once dt is displaced by a series of ε and 1- θ such that most values of the critical exponents are changed, all scaling laws are saved again, even though the fluctuation-dissipation theorem keeps violating. For d > dc, we develop an effective-dimension theory by carefully discriminating the corrections of both temporal and spatial dimensions and find three different regions. For d ≥ dc0 = 4, the upper critical dimension of the usual short-range theory, the usual Landau mean-field theory with fluctuations confined to the effective-dimension equal to dc0, correctly describe the critical phenomena with memory, while for dc < d ≤ 4, there exist new universality classes whose critical exponents depend only on the space dimension but not at all on θ. All these results show that the dimensional constant dt is the fundamental ingredient of the theories for critical phenomena with memory. However, its value continuously varies with the space dimension and vanishes exactly at d = 4, reflecting the variation of the amount of the temporal dimension that is transferred to the spatial one with the strength of fluctuations. Moreover, special finite-size scaling ubiquitously appears except for d = dc0.

口头报告 I25
报告人： 于小泉
单位： 中物院研究生院
题目： A Non-Unitary Conformal Field Theory Approach to Two-Dimensional Turbulence
摘要：At a bulk critical point, the divergence of correlation length makes the influence of boundaries more pronounced; therefore, the surface may show rich and novel critical behaviors. The subject of surface criticality has attracted numerous previous investigations and obtained renewed attention when quantum phase transitions are

involved. In this talk, I will present our recent works on exotic surface critical behaviors.

邀请报告 I26
报告人： 张勇
单位： 厦门大学
题目： 近可积非线性晶格的能量均分
摘要：能量均分定理是统计物理最基本的假设。1955 年，世界上第一台计算机问世不久，Fermi 和 Pasta，Ulam，Tsingou （FPUT）四位科学家就用它来验证一维非线性链能否达到均分状态。结果出乎意料，系统没有演化到均分状态，而是周而复始回到初始非平衡态，这就是著名的 FPUT 问题。60 多年过去了，无论是理论研究还是数值模拟都没给出热化过程的清晰规律和统一图像。FPUT 问题依然是非线性动力学和统计物理的挑战。本报告将介绍我们课题组在这一问题上最近的研究进展。我们统一定义了不同非线性相互作用模型的微扰强度，将非线性链看成 Toda 可积模型的微扰。我们发现尽管不同非线性模型热化途径有所不同，但在热力学极限下，它们都遵循普适热化律，即均分时间与微扰强度成平方反比。

口头报告 I27
报告人： 王健
单位： 扬州大学
题目： 长程关联的 FPUT-β 模型中趋向能均分的动力学过渡行为研究
摘要：能量均分定理是统计物理的核心和基础，该定理假设存在任意小的非线性的系统能量，随着系统的演化，最终会在不同傅里叶模式上实现均分。系统实现能量均分化的过程也称为系统热化。自从费米等人最初在非线性的 FPUT 系统中发现不同傅立叶模间能量回溯现象，有关能量均分和热化的问题的得到了大量关注和研究。长程相互作用力的系统在自然界并不少见，近年来引起了很多学者的关注和研究。我们研究了含有非线性长程关联的 Fermi-Pasta-Ulam-Tsingou(FPUT)-β 模型体系中不同傅里叶模式上的能量分布随弛豫时间的演化过程。该 FPUT-β 模型假设粒子之间长程非线性相互作用能量随着粒子间格点距离做 δ 幂律衰减。通过加速后的大规模的数值模拟，在系统达到稳态后，我们发现随着衰减幂律 δ 的增加，能量在不同傅里叶模式分布在 δ=1 附近出现显著的动力学过渡行为：在衰减指数 δ<1 时，这时体系呈现出典型的长程体系特征，由于体系缺乏遍历性，因而能量在傅里叶空间模式上出现了显著的局域化，能量主要局域短波模式上，并且能量的分布接近于线性体系的声子色散关系。在衰减指数 δ>1 时，随着衰减指数 δ 的增加，系统的长程关联减弱，傅里叶空间模式能量的分布逐渐趋向于均匀分布，接近于最近邻的能均分结果。通过模式能量的频谱分析，我们发现由于长程关联衰减指数 δ 的增加，增强的近邻相互作用带来高频模式能量与其他模式能量的频谱交叠，进而促进了不同模式能量的交换使得能量在不同模式上达到均分，表明模式能量功率谱的不同频率重叠是造成这种动态过渡的原因。在含有长程非线性作用的体系中能量在不同傅里叶模式上分布如何，以及向近邻相互作用体系的能均分过渡，对于理解体一般体系的普遍热化规律，深化经典统计物理对长程体系动力学的基础认识具有重要意义和价值。 参考文献:
J. Wang and A.-C. Li, "Dynamic crossover towards energy equipartition in the Fermi-Pasta-Ulam-Tsingou β model with long-range interactions", Phys. Rev. E 106, 014135

(2022).

口头报告 I28
报告人： 贺达海
单位： 厦门大学
题目： 一维晶格热传导的调控：完美绝热与声子透明输运
摘要：近年来，热超构材料的研究引起了人们的广泛兴趣。在介观尺度下调控热超构材料的热传导性质具有重要的理论和应用价值。在本报告中我将介绍在一维简谐晶格中实现完美绝热的理论探索。基于朗之万格林函数理论，我们提出了一维简谐晶格实现完美绝热的两个等价理论条件。在此基础上我们设计了一类完美绝热的晶格模型，实现全频率域声子的局域化。进一步地，我们还发现该完美绝热超晶格系统表现出完全平能带的色散关系及超局域化等新奇物理性质。此外，我们提出了利用梯度下降法找到与目标传输系数对应的晶格构型的一般方法，在一定程度上解决了热传导的逆问题，实现了在任意有限频段内的声子准透明输运。我们的研究给出了一维简谐晶格实现完美绝热的理论和调控声子传输系数的方法，为实验上寻找及设计超低或超高热导率材料提供理论指导。

口头报告 I29
报告人： 杨哩娜
单位： 北京理工大学
题目： Enhancing interfacial thermal conductance of amorphous interface by optimized interfacial mass distribution
摘要：Interfacial thermal resistance arises challenges for the thermal management as the modern semiconductors are miniatured to nanoscale. Previous studies found that graded mass distribution in interface can maximumly enhance the interfacial thermal conductance of crystalline interface, however, whether this strategy is effective for amorphous interface is less explored. In this work, graded mass distribution in the amorphous interface between crystalline Si and crystalline Ge is optimized to increase the interfacial thermal conductance by the extended atomistic Green's function method. The results show that atomic mass of 26 amu for one type of atomic mass, and 24 amu and 31 amu for two types of atomic mass in the amorphous interface, can maximumly increase the interfacial thermal conductance. Therefore, the strategy of graded mass distribution is still effective when only considering the atoms in the amorphous interface. In addition, applying the value of the smaller atomic mass of the two sides to the amorphous interface can largely enhance the interface thermal conductance, which is only 0.9% smaller than the maximum value. Further analyses show that atomic mass of 26 amu can increase the phonon modal transmission at high frequency (> 4 THz), and the phonon spectral transmissions are almost the same at low frequency (<2 THz) for different distributions of atomic mass in the amorphous interface in this work. The findings of this work are expected to provide references for optimizing the interfacial thermal conductance of amorphous interfaces for semiconductor devices.

口头报告 I30
报告人： 刘卯鑫

单位： 北京师范大学
题目： Quantum Phase Transition and Eigen Microstate Condensation in the Quantum
摘要：We introduce an eigen microstate approach (EMA) in the quantum system to describe the quantum phase transition without knowing the order parameter. Phases of a quantum system is determined by the so-called eigen microstates and their corresponding eigen values, which statisfy scaling relation in the critical regime. The quantum Rabi model (QRM) is taken as an example to demonstate the EMA. Using both analytical and numerical calculations, we obtain the critial point, critical exponents and scaling functions of the superradiant phase transition in the QRM. It suggests that a new phase emergency can be interpreted as a consensation of a specific eigen microstate. We expect in further studies the EMA will be applied to more complex quantum phase transition problems in which order parameters can not be easily defined.

## 分会场 II：统计物理学数值计算与模拟方法

邀请报告 II01
报告人： 陈庆虎
单位： 浙江大学物理学院
题目： The topological excitation and transport of the vortex-antivortex pairs in a magnetically nanostructured superconductors
摘要：The nonreciprocal charge transport, exhibiting dependence on the polarity of the applied current, such as the diode effect and the rectification effect, is of great importance for both theoretical research and device applications in low-power electronics engineering. To achieve the nonreciprocal transport property in superconductors generally requires to break both the spatial inversion symmetry and the time-reversal symmetry, and therefore touches on the very fundamental issues in superconductivity. Of particular interest is the superconducting diode effect, which exhibits dissipationless superconducting transport for just one direction of the applied current, being the base element of the emergent superconducting electronics and has received extensive attention in recent years as a consequence. We studied the vortex dynamics coupled with associated heat dissipation by numerically solving the time-dependent Ginzburg-Landau equations and the heat transfer equation. The nonreciprocal transport properties in a superconductor/nanoscale-magnetic-dot hybrid structure are studied. Our vortex dynamics simulations reveal that the topological excitations of the vortex-antivortex pairs and their motion are responsible for the observed superconducting diode effect without applied magnetic fields, showcasing the relevance of the field-free diode effect in both fundamental research and potential applications. Refs: Field-Free Superconducting Diode in a Magnetically Nanostructured Superconductor, Ji Jiang, M. V. Milousevic, Yong-Lei Wang, Zhi-Li Xiao, F. M. Peeters, and Qing-Hu Chen*, Phys. Rev. Appl. 18, 034064 (2022)

邀请报告 II02
报告人： 谢志远
单位： 中国人民大学

题目： 张量重正化群在经典统计模型中的新发展
摘要：经典统计模型中的相变和临界现象是张量重正化群的一个重要研究对象，在过去的 20 年里取得了一系列进展。在本报告中，我将介绍最近我们课题组在这个方向上的两个方法性工作。第一个是变分的角转移矩阵重正化群，它是目前求解二维张量网络模型最为精确的计算方法之一，并为研究三维张量网络模型提供了新思路。第二个是适用于高维统计模型的虚时演化方法，它提供了一套求解二维转移矩阵本征态的实用方法，是虚时演化原理在三维统计模型中的第一次成功尝试。

口头报告 II03
报告人： 周迪
单位： 北京理工大学
题目： 广义强非线性拓扑能带理论
摘要：近年来，拓扑理论已在经典系统里得到了广泛研究，比如声学，光学，力学和生物动力学平台。这些创新应用主要局限于线性拓扑能带理论。然而，尽管“物质拓扑相”已在量子和经典系统中得到了广泛研究，但在广义非线性动力学中仍缺乏普遍认知。我们在一维广义强非线性薛定谔方程中首次引入非线性贝里相位，并严格证明其量子化条件。我们把“体边对应关系”推广到非线性领域，产生由振幅控制的、自由切换的非线性拓扑相。我们发现非线性拓扑模在空间上衰减至不动点，表现出反常行为。本工作证明了非线性拓扑不变量广泛存在于自然界，为研究非线性拓扑动力学提供了扎实的理论基础。

口头报告 II04
报告人： 刘玉海
单位： 北京邮电大学
题目： Thermodynamic and dynamical signatures of a quantum spin Hall insulator to superconductor transition
摘要：The thermodynamic and dynamical properties of a model of Dirac fermions with a deconfined quantum critical point (DQCP) separating an interaction-generated quantum spin Hall insulator from an s-wave superconductor [Liu et al., Nat. Commun. 10, 2658 (2019)] are studied using quantum Monte Carlo simulations. Inside the deconfined quantum critical region bound by the single-particle gap, spinons and spinless charge-2e skyrmions emerge. Since the model conserves total spin and charge, and has a single length scale, these excitations lead to a characteristic linear temperature dependence of the uniform spin and charge susceptibilities. At the DQCP, the order parameter dynamic structure factors show remarkable similarities that support emergent Lorentz symmetry. Above a critical temperature, superconductivity is destroyed by the proliferation of spin-1/2 vortices.

口头报告 II05
报告人： 张凡
单位： 北京师范大学
题目： Phase Transitions of Models of XY Spins with Generic Direction Dependent Interactions

摘要：We study thermal phase transitions of models of XY spins with generic direction dependent interactions, which preserve as symmetries only a combination of lattice and spin rotations in both two and three dimensions. Our models may be thought of as generalizations of the well studied classical versions of the compass models. Using both renormalization group calculations and Monte Carlo simulations we present a theory for the continuous transitions found in our models. Apart from their applications to magnets with spin-orbit coupling we argue that such models are effective theories of the thermal and quantum melting of valence bond solid order in quantum magnets.

口头报告 II06
报告人： 胡坤
单位： 北京师范大学物理学系
题目： Wetting transition in the transverse-field spin- 1/2 XY model with boundary fields
摘要：The wetting transition in the transverse-field spin-1/2 XY model with opposite boundary fields hLx hRx < 0 is studied analytically and numerically. We find that the phase diagram is complex and that the wetting transition is of three types: first, second, and fourth order. The energy gap is obtained analytically, and the magnetization profile, correlation functions, and wetting layer thickness are obtained numerically. For |hLx|, |hRx| < hw, a first-order phase transition occurs at hLx = -hRx , where hw is the continuous wetting transition point. For |hRx| larger than hw, the continuous wetting transition occurs at hLx = hw, and vice versa. For g = 1-γ2, the wetting transition is second order, and commensurate and incommensurate phases occur for g < 1-γ2 and g > 1-γ2, respectively. For g = 1-γ2, the wetting transition is fourth order. For this fourth-order phase transition, the third derivative of the surface magnetization oscillates and diverges near the transition point. The correlation length exponent is ν = 2, and the dynamic exponent is z = 2. Thus, this fourth-order transition belongs to a new universality class.

邀请报告 II07
报告人： 樊京芳
单位： 北京师范大学
题目： Universal gap scaling in percolation
摘要：Universality is a principle that fundamentally underlies many critical phenomena, ranging from epidemic spreading to the emergence or breakdown of global connectivity in networks. Percolation, the transition to global connectedness on gradual addition of links, may exhibit substantial gaps in the size of the largest connected network component. We uncover that the largest gap statistics is governed by extreme-value theory. This allows us to unify continuous and discontinuous percolation by virtue of universal critical scaling functions, obtained from normal and extreme-value statistics. Specifically, we show that the universal scaling function of the size of the largest gap is given by the extreme-value Gumbel distribution. This links extreme-value statistics to universality and criticality in percolation.

口头报告 II08
报告人： 王振
单位： 中国科学院理论物理研究所
题目： 一维强非线性晶格的热化
摘要：已有的研究表明预热化是弱相互作用系统的典型特征：系统在弱相互作用下首先很快演化至准稳态，然后在更长的时间尺度上转变到热力学平衡态。并且热化时间与相互作用强的平方成反比。对于具有强非线性扰动的系统，我们发现它们在统计上等价于一个弱相互作用系统。以一维非线性晶格系统为例，我们发现部分相互作用不参与振动模式（或波）之间的能量交换，我们将其称之为平庸相互作用。这些平庸相互作用一方面会增强线性色散，另一方面等效地削弱了非线性相互作用，从而得到一个弱相互作用的重正化波系统。基于等效系统，我们得到一个修正的 Zakharov 方程。此方程预测的热化时间仍然与相互作用强度的平方成反比，只不过此时是重正化后的相互作用强度。从这个意义上讲，在强非线性或高温下，热化时间的平方反比律仍然适用于此类系统。最后，数值模拟验证了我们的理论预测。

口头报告 II09
报告人： 张忠卫
单位： 同济大学
题目： 包含声子相干性的热传导理论及其应用
摘要：理解和量化热声子相干性是物理学中的一个基本问题。经典理论也无法描述声子相干性及其对热输运的影响。近期，我们在考虑相干效应的情况下从理论上发展了声子衰减的普适定律。然后，提出了一种能同时考虑传统的声子气体模型和热声子的波动性质的热传导模型。我们的理论和模拟发现在不同的温度范围内会出现两种不同类型的相干性，即声子本征的相干性和相互的相干性。另外，基于声子相干理论的研究还表明非晶体中局部非传播模式之间的强相位相关性（在非晶系统中通常称为扩散子）会触发热传导，表现出了依赖于相干性的热传导形式。我们的工作为理解和量化热声子的相干性建立了一个基本框架，这会对固体热输运性质的预测产生普遍影响。

口头报告 II10
报告人： 谢柏松
单位： 北京师范大学
题目： 量子动理学方法研究粒子对产生
摘要：目前激光强度已经达到 1023W/cm2，随着欧洲 ELI 和上海极端光站 SEL 设施的完成，未来激光强度会更高，距离真空产生正负电子对的施温格极限临界强度 1029W/cm2 又接近了很多。本报告将介绍在强场下正负粒子对产生研究中的动理学方法，包括量子弗拉索夫方程（QVE）和狄拉克-海森堡-魏格纳分布函数（DHW）等，我们将给出这两个半经典动理学方法的量子物理与统计物理特性以及相关的动量谱干涉性与螺旋特性等，对近期北师大强场物理研究组用该方法得到的一些有趣结果进行分析与讨论，并对该研究方向与统计物理的关系等做简短评述与展望。

口头报告 II11

报告人： 周能吉
单位： 杭州师范大学
题目： 自旋玻色耦合系统中基态量子相变数值研究
摘要：自旋玻色耦合系统中发生的各种量子相变现象，由此获得准确的临界特性，包括相变点和各种临界指数值，以及自旋体系和玻色子体系的基态临界行为。

邀请报告 II12
报告人： 林海青
单位： 浙江大学
题目：Excitations, Entanglement, and Quantum Phase Transitions
摘要：

邀请报告 II13
报告人： 高毅勤
单位： 北京大学
题目： 人工智能技术应用于分子计算
摘要：

口头报告 II14
报告人： 周昕
单位： 中国科学院大学
题目： Ice Nucleation on Nanosize Substrates
摘要：The microscopic mechanism of water freezing, especially about character of the formed critical ice nucleus, remains elusive. Water freezing mostly occurs on the contacted surfaces of water with various substrates (or impurities). Simulations and theories (the classical nucleation theory) as well as experiments showed that the ice nucleation had an abrupt transition while the size of substrates is comparable to that of critical ice nucleus. It provides a general way to probe experimentally the size and its temperature dependence of the small (a few nanometer) and transient (lifetime in nanoseconds) critical nucleus in the water-ice (and another 1st order) phase transition. In addition, it also provides a good method in simulations for detecting properties of the coexistent phases (e.g., ice and water) under the supercooling condition, which is crucial for understanding the microscopic pathway of phase transitions.

口头报告 II15
报告人： 张志森
单位： 厦门大学
题目： HTR: a High-Speed Cage Structure Recognition Algorithm
摘要：Clathrate hydrates have diverse and significant applications, including but not limited to future energy resources, gas storage and transport, gas separation, water desalination, and refrigeration. However, studying the nucleation, growth, dissociation, and micro/nanoscale properties of clathrate hydrates, which are crucial for these applications, is challenging through experiments but accessible through molecular simulations. Nevertheless, extracting useful insights necessitates the identification of

cage structures. In this work, we present a highly efficient and accurate hierarchical topology ring (HTR) algorithm for recognizing cage structures. The HTR algorithm can identify complete cages of all types and is particularly optimized for large-scale systems comprising millions of water molecules. Furthermore, it enables the unique identification of topological isomers of cages and n × guest@cage configurations. Additionally, we validate the utility of HTR for identifying cages in clathrate hydrates under mechanical loads until failure.

口头报告 II16
报告人： 乔崇智
单位： 北京师范大学
题目： 基于定标粒子理论的 2 维流体状态方程构建
摘要：定标粒子理论（Scaled Particle Theory, SPT）[1]的成功可归功于其物理思想，即在考虑向流体中插入粒子所需做的功时，将其分解为体积功和表面贡献这两部分。基于此，该理论框架可以同时描述流体的均相热力学性质与界面热力学性质， SPT 理论被地广泛于生物、材料、化工等多个领域。在 SPT 理论中表面贡献主要包括平面表面张力贡献以及由于弯曲界面曲率所造成的两个曲率贡献项贡献。近年来，除两个曲率贡献外的高阶曲率项（也称为 non-Hadwiger 项）的存在也被证实[2]。与三维硬球流体相同，在二维硬盘流体中高阶曲率项的存在也被模拟验证[3]。同时在处理二维硬盘流体时，SPT 理论的精度也不及一些基于模拟数据构建的半经验状态方程，如 Solana 方程。那么是否可以通过引入高阶曲率项的方法来提高二维 SPT 理论的精度？近期我们通过引入一个高阶曲率项的方法发展了硬球流体的增强定标粒子理论（Augmented Scaled Particle Theory, ASPT）[4]。本工作中，我们将 ASPT 理论拓展到二维硬盘流体，结果表明我们的二维 ASPT 可以更准确的计算二维流体的均相及表面热力学性质，并首次自洽地给出了高阶曲率项的一个解析表达式[5]。
参考文献:

[1] H. Reiss, H.L. Frisch, J.L. Lebowitz, Statistical Mechanics of Rigid Spheres, J. Chem. Phys., 1959, 31 (2), 369 – 380.
[2] H. Hansen-Goos, Communication: Non-Hadwiger Terms in Morphological Thermodynamics of Fluids, J. Chem. Phys., 2014, 141 (17), 171101.
[3] S.C. Martin, H. Hansen-Goos, B.B. Laird, Surface Free Energy of a Hard-Disk Fluid at Curved Hard Walls: Theory and Simulation, J. Phys. Chem. B, 2020, 124 (36), 7938 – 7947.
[4] C. Qiao, S. Zhao, H. Liu, W. Dong, Augmented Scaled Particle Theory, J. Phys. Chem. B, 2020, 124 (7), 1207 – 1217.
[5] C. Qiao, S. Zhao, W. Dong, Augmented scaled particle theory for a hard disk fluid, J. Mol. Liq., 2022, 367, 120507.

邀请报告 II17
报告人： 熊龙
单位： 云南大学
题目： 斯格明子的非平衡态动力学行为

摘要：本次报告简要介绍我们研究组最近在斯格明子非平衡态动力学的研究工作。磁性材料中的斯格明子是近年来发现的一种非平庸拓扑自旋结构，其自旋的特殊缠绕方式诱导出丰富的相结构和非平衡态动力学行为。发展和应用 Monte Carlo 方法和 Landau-Lifshitz-Gilbert 方程，并结合非稳态短时动力学模拟方法，可以克服临界慢化困难。我们研究了电流驱动下铁磁、反铁磁材料中斯格明子的动力学行为，探测到斯格明子钉扎相变和热蠕动行为，以及正常和反常霍尔运动等，并且和 Thiele 理论方法结果一致。进一步，我们给出了自旋转移矩及自选耦合矩耦合的 Rashba 效应的斯格明子新奇相变行为，基于临界行为设计了逻辑器件。

邀请报告 II18
报告人： 林传栋
单位： 中山大学
题目： 高速可压缩化学反应流的离散玻尔兹曼模拟研究
摘要：高速可压缩化学反应流体在许多重要的领域中都有广泛的应用，包括航空航天、能源动力、环境保护、国防建设等领域。近十年发展起来的离散玻尔兹曼方法（Discrete Boltzmann method, DBM）在冲击波、流体不稳定性、化学反应流等诸多复杂流体系统的应用方面取得显著进展，为一些极端条件下物理化学问题的研究提供了新的研究思路和方法。DBM 模型基于非平衡统计物理学的基本方程——玻尔兹曼方程发展起来的理论模型构建方法和复杂物理场分析方法，使用离散速度，给出对离散格式的最必要物理约束，但不拘泥于具体离散格式；可以用于深入分析非平衡、不稳定、可压缩化学反应流的演化过程。本研究报告介绍了高速可压缩化学反应流 DBM 的建模思路和模拟分析结果，并重点讨论了不稳定爆轰波在演化过程中的流体力学和热力学非平衡效应。研究发现，在爆轰波波振面周围与波后区域的偏离特征有很大不同。在不稳定爆轰的演化过程中，化学反应项的动理学矩的表现出三种不同类型的周期振荡。经过快速傅里叶变换，展示了这些振荡过程主要由一些不同频率的信号组成，并且这些频率具有明显的倍数关系。该研究工作的开展有助于进一步推动计算流体力学、非平衡统计物理学、化学反应动力学等交叉学科的应用发展。

口头报告 II19
报告人： 贾英琦
单位： 北京应用物理与计算数学研究所
题目： 变加速度单模 Rayleigh-Taylor 不稳定性的非平衡动理学研究
摘要：Rayleigh-Taylor 不稳定性（RTI）广泛存在于自然界和工程领域，对 RTI 演化过程中物理机理的研究具有重要的理论意义和工程应用价值。目前常加速度下的 RTI 问题已经开展了大量研究并获得了相对成熟的物理认识，但是在惯性约束聚变（ICF）等情形引发的 RTI 的加速度却是变化的，而目前针对变加速度下的 RTI 研究相对较少，物理认识不足。 与常加速度下的 RTI 类似，系统内部会出现大量中间尺度（介尺度）的空间结构和模式，这些结构和模式的存在与演化影响着系统的性能和物理功能。这些介尺度结构和模式的研究对基于连续和近平衡假设的宏观流体建模构成挑战。近年来快速发展起来的离散 Boltzmann 方法（DBM）提供了一套较为完备的复杂物理场建模和分析方法，可以通过热动非平衡效应、熵产生率和形态学分析等研究流体系统中的非平衡动理学效应[1]。因此本研究使用 DBM 研究变加速度下的 RTI 动理学。 本研究中，变加速度是指

加速度在特定时间经历两次方向反转的情形[2]。本文首先分析了单个算例的结果，通过对比先前文献中的结果，验证程序和计算结果；除宏观特征量以外，还利用 DBM 提供的新视角（ Δ_2^*、Δ_3,1^*、Δ_3^* 等特征量）研究了系统的非平衡状态、程度与效应。然后在此基础上，分别改变加速度大小和两次加速度反转时刻，模拟了 RTI 演化过程。研究表明，加速度大小和加速度反转时刻对 RTI 演化过程具有重要影响，比如界面位置、尖钉气泡的位置和发展趋势、局部和全局非平衡特征的演化等。这对深入理解 RTI 演化机制和流体动理学行为具有重要意义。研究方法和思路，可推广应用于其它非平衡复杂流动研究。

口头报告 II20
报告人： 陈杰
单位： 北京应用物理与计算数学研究所
题目： 基于离散 Boltzmann 方法的 Rayleigh-Taylor 不稳定性动理学研究：界面张力、粘性和热传导的影响
摘要：利用考虑分子间作用力的离散玻尔兹曼方法研究了可压缩流动的二维 Rayleigh-Taylor(RT)不稳定性。考察了界面张力、粘性和热传导的影响。研究发现，界面张力对扰动振幅、气泡速度以及两种熵产生率的影响都表现出阶段性。界面张力在气泡加速阶段抑制 RT 不稳定性的发展；而在气泡渐进速度阶段，界面张力对 RT 不稳定性的发展表现出先促进后抑制的作用。粘性和热传导对 RT 不稳定性的发展表现出抑制作用。粘性对与热流相关的熵产生率在早期阶段表现出抑制作用，在后期表现出先促进后抑制的作用。热传导对与热流相关的熵产生率在早期阶段表现出促进作用，在后期表现出先促进后抑制的作用。鉴于形态特征量界面长度 L（三维情形为面积 S）与系统的非平衡程度和轻重流体混合程度均密切相关，我们研究了界面长度的演化特征与潜在的物理功能。发现，在气泡加速阶段，形态学界面长度呈指数增长。界面长度变化率的第一个极大值点，可以做为 RT 不稳定性发展进入气泡渐进速度阶段的一个判据。与粘性应力相关的熵产生率的变化率的第一个极大值点也可以做为 RT 不稳定性发展进入气泡渐进速度阶段的判据。

邀请报告 II21
报告人： 范之杰
单位： 中国科学技术大学
题目： Clock Quantum Monte Carlo Method for Long-range Interacting Systems
摘要：

口头报告 II22
报告人： 万彪
单位： 国科温州研究院
题目： Revealing diffusion and binding free energy landscape of transcription factor protein around DNA for sequence detection and genetic regulation
摘要：How transcription factor (TF) proteins locate the target sites on the genome is essential to genetic regulation. It has been demonstrated that the TF proteins alternates between 3D searching in the bulk and 1D sliding along DNA for efficiently locating the specific DNA sequences. But the dynamics of the spontaneous association/dissociation

and diffusion of the TF proteins remain puzzling. Here we designed a simplified spherical protein model with stochastic simulations for describing the globular TF domain protein. By modeling TF protein-DNA potential profiles based on protein-DNA electrostatic and HB interactions, the TF protein diffusion and dissociation time scales are properly accounted. We noticed that the rotational degrees of the spherical protein impact differently on the dynamics of diffusion and association/dissociation. Compared with dissociation, the protein undergoes restrained oriental changes during diffusion along DNA, which gives rise to a difference between the diffusion and binding free energy landscapes. Notably, the simulations also suggested that protein dissociation from specific target site proceeds dominantly via diffusion to neighboring sites, hence protein dissociation kinetics likely reflect DNA sequence impacts from both core binding site and flanking sites, which provides insight into the measurements of dissociation kinetics and the relative protein-DNA binding affinity to the central DNA binding site.

口头报告 II23
报告人： 戴立强
单位： 国科温州研究院
题目： Revealing atomic-scale molecular diffusion of transcription factors along DNA
摘要：Transcription factor (TF) target search on genome is highly essential for gene expression and regulation. High-resolution determination of TF diffusion along DNA remains technically challenging. Here, we constructed a TF model system using the plant WRKY domain protein in complex with DNA from crystallography and demonstrated microsecond diffusion dynamics of WRKY on DNA by employing all-atom molecular-dynamics (MD) simulations. Notably, we found that WRKY preferentially binds to one strand of DNA with significant energetic bias compared with the other, or nonpreferred strand. The preferential DNA-strand binding becomes most prominent in the static process, from nonspecific to specific DNA binding, but less distinct during diffusive movements of the domain protein on the DNA. Remarkably, without employing acceleration forces or bias, we captured a complete one-base-pair stepping cycle of the protein tracking along major groove of DNA with a homogeneous poly-adenosine sequence, as individual hydrogen bonds break and reform at the protein–DNA binding interface. Further DNA-groove tracking motions of the protein forward or backward, with occasional sliding as well as strand crossing to minor groove of DNA, were also captured. The processive diffusion of WRKY along DNA has been further sampled via coarse-grained MD simulations. The study thus provides structural dynamics details on diffusion of a small TF domain protein, suggests how the protein approaches a specific recognition site on DNA, and supports further high-precision experimental detection. The stochastic movements revealed in the TF diffusion also provide general clues about how other protein walkers step and slide along DNA.

口头报告 II24
报告人： 吴凯
单位： 中国科学院大学温州研究院

题目： Widely Regulate Ice Nucleation via Small Interaction Perturbations

摘要：Heterogeneous ice nucleation on material surfaces has been found to correlate to numerous features of surfaces and/or interfacial waters, but the understanding remains elusive after a long-termly pursuit. It needs to provide approaches to describe generally the diverse nucleation efficacy of various surfaces in physics. Data-driven estimators were recently developed to predict the nucleation temperature of many surfaces without giving a clear physical picture. Here we present a theoretical approach to formulating the nucleation free energy barrier on various surfaces from interaction functions of surfaces to water molecules as well as the density difference of interfacial water from ice. The change of nucleation barrier under small interaction perturbations is correlated to the collective perturbation energy change of all water molecules in forming critical ice nuclei, whose value can vary in an extensive range depending on details of interaction perturbation functions. We verify the expectation via molecular dynamics simulations and show that nucleation temperature is linearly shifted by the amplitude (whose amplitudes are restricted below the thermodynamic fluctuation level) of surfaces' interaction perturbations up to a few tens of Kelvins. Thus, surfaces with slightly different interactions with water molecules possibly have obviously different efficacy in facilitating nucleation, indicating many challenges in predicting their nucleation ability. This work provides quantitative insights into understanding heterogeneous ice nucleation, and it is helpful in predicting of nucleation efficacy of various surfaces.

口头报告 II25

报告人： 邓霖

单位： 兰州大学

题目： Energy localization and equipartition in graphene lattice

摘要：The equipartition theorem lies in the foundation of statistical physics, which has attracted much attentions since the pioneering numerical experiments by Fermi, Pasta, Ulam, and Tsingou (FPUT) [1]. Most of the works focus on two key issues: 1) the route to thermalization; 2) the timescale for the energy equipartition. In this work, we focus on the thermalization dynamics of graphene lattice with periodic boundary condition. When only one mode is initially excited with small energy, the existence of □-breathers, firstly proposed by S. Flach et al.[2], is confirmed in the flexural modes of graphene, which is the exact time-periodic solutions exponentially localized in the normal mode space. The stability of □-breather can be determined by Floquet theory. Furthermore, based on the wave-turbulence theory [3], we predicted a square-inverse relation between the equilibration timescale □□□ and the specific energy □ of the system, which are corroborated with extensively numerical simulations [Fig. 1]. These results cast profound understandings to the thermalization dynamics at the nanoscale.

邀请报告 II26

报告人： 胡皓

单位： 安徽大学

题目： 各向异性系统中的普适临界逾渗行为

摘要：各向异性系统广泛存在，但人们对这类系统的普适临界行为的理解远不如对各向同性系统的。我们结合逾渗理论和蒙特卡洛模拟[1,2]，研究了二维晶格上处于平衡态的补丁粒子系统中的逾渗相变。当粒子上的补丁大小增加或者系统的温度降低时，由补丁连接形成的粒子集团变大，在逾渗阈值处开始出现横贯系统的临界集团。对于三角晶格上的单补丁粒子（也叫 Janus 粒子）系统，在低温时出现的取向有序的条纹相中，临界逾渗集团在沿着条纹方向比垂直于条纹方向延伸得更长，因而集团是各向异性的。我们发现[2]，经过一个合适的尺度变换后，可以用标准各向同性逾渗理解上述系统中的各向异性临界逾渗行为。我们还将尺度变换的方法应用于理解其它各向异性系统中的逾渗，例如晶格上取向对齐的硬棒粒子系统和具有各向异性相互作用的 q 态 Potts 模型（经 Kasteleyn-Fortuin 变换后 q≠1 的 Potts 模型对应于有关联的逾渗）。其中对于各向异性 Potts 模型，需要一个剪切变换来建立与各向同性模型的联系。

参考文献：

[1] Q. Wang, Z. He, J. Wang, H. Hu*, Phys. Rev. E 105, 034118 (2022).
[2] H. Hu*, R. M. Ziff, Y. Deng, Phys. Rev. Lett. 129, 034118 (2022).

口头报告 II27

报告人： 高志斌
单位： 西安交通大学

题目： The role of high-order anharmonicity and off-diagonal terms in thermal conductivity: a case study of multi-phase CsPbBr3

摘要： In this talk, we show the effects of three- and four-phonon scatterings, perturbative anharmonic phonon renormalization, and off-diagonal terms of coherent phonons on thermal conductivity exemplified by the study of the $CsPbBr_3$ phase change perovskite. We cover a temperature range that spans its full structural spectrum using state-of-the-art implementations and first-principles simulations. In particular, we display that the interactions among acoustic phonons and optical phonons lead to an opposite trend of phonon frequency shifts for the high-lying optical phonons in orthorhombic and cubic $CsPbBr_3$ as a function of temperature. Our identified thermal transport mechanism in halide perovskites stresses wave-like tunneling of coherent phonons in ultralow and glass-like thermal conductivity.

Keywords: Thermal conductivity, Anharmonic lattice dynamics, four-phonon, off-diagonal terms

References：

[1] T. Lanigan-Atkins, X. He, M. J. Krogstad, D. M. Pa- jerowski, D. L. Abernathy, G. N. M. N. Xu, Z. Xu, D.-Y. Chung, M. G. Kanatzidis, S. Rosenkranz, R. Osborn, and O. Delaire, *Nat. Mater.* **20,** 977 (2021).
[2] W. Lee, H. Li, A. B. Wong, D. Zhang, M. Lai, Y. Yu, Q. Kong, E. Lin, J. J. Urban, J. C. Grossman, and P. Yang, *Proc. Natl Acad. Sci. USA* **114,** 8693 (2017).
[3] M. Simoncelli, N. Marzari, and F. Mauri, *Nat. Phys.* **15,** 809 (2019).

口头报告 II28

报告人： 余荫铠
单位： 中山大学

题目： 相互作用狄拉克费米子的非平衡量子临界性
摘要：狄拉克费米子是凝聚态系统中常见的低能激发准粒子，往往在各种相变临界现象中扮演重要角色。相互作用的狄拉克费米子的量子临界性质由 Gross-Neveu 普适类描述，该普适类的非平衡临界性质并未被前人涉足。在这项工作中，我们使用行列式量子蒙特卡罗模拟狄拉克费米子系统的虚时演化，求解其在临界点的弛豫动力学，首次确定了手征海森堡普适类初始滑移指数 θ＝-0.84(4)。这一工作开辟了新的研究领域：费米子非平衡临界性质的数值研究。我们还讨论了非平衡费米子蒙卡缓解符号问题的可能性。

## 分会场 III：量子物理前沿相关的统计物理

邀请报告 III01
报告人：应磊
单位：浙江大学
题目：The origin of Hilbert quantum scars
摘要：Violations of the eigenstate thermalization hypothesis are rare in strongly correlated quantum systems but are crucial due to their potential applications in quantum information. Among these, the quantum many-body scar state is a recently discovered example of weak ergodic breaking that offers a new way to mitigate quantum decoherence caused by quantum thermalization. However, traditional many-body scar states are mostly based on the constraint model, which is difficult to be realized in many experimental platforms. Thus, could similar phenomena be found in more quantum many-body systems? To answer this question, we propose a new class of scar states based on the Bose-Hubbard model for arbitrary dimensions. From the perspective of the Hilbert space, this state is in a subspace weakly coupled with the thermalized region. At the same time, this novel state has been observed in the superconducting quantum processor. Furthermore, we introduce its origin and potential applications based on aspects of the quantum-classical correspondence and multipartite entanglement, respectively.

邀请报告 III02
报告人：蔡子
单位：上海交通大学
题目：Prethermal time-crystalline spin ice and monopole confinement in a driven magnet
摘要：Studies on systems far from equilibrium open up new avenues for investigating exotic phases of matter. A driven-dissipative frustrated spin system is examined in this talk, and we suggest an out-of-equilibrium non-magnetic phase where the spins do not order but adhere to the ice rule in space and establish a long-range crystalline order in time. In contrast to the conventional spin ice, the dynamics of monopoles is confined due to the nonequilibrium feature of our model. Possible experimental realizations of our model has been discussed.

邀请报告 III03
报告人：李有泉
单位：浙江大学
题目：Manipulation of Skyrmions and the Promising Applications
摘要：There has been spectacular progress in the study on multiferroics, which is expected to make a realistic step toward an electrical control of magnetism or four state memories. We propose a tilted Heisenberg model of which the continuum limit is a gauge Landau-Lifshitz equation that provides a unified description for various exotic spin orders appeared. For certain gauge potential, we solved the magnetic skyrmion phase and also predicted the emergence of meron phase [1]. We also propose a mechanism to pin skyrmions in chiral magnet [2], and find that the position-dependent electric field can induce the Hall motion of the skyrmion [3]. Furthermore, we study spin-orbital driven ferroelectricity [4]; spin-orbital coupling and charge effect in Mott insulators showing that the tilted Heisenberg model can be derived from the Hubbard model in the presence of spin-orbital coupling as the large U limit [5]. The idea of tilted Heisenberg model has been extended to the SU(3) case by experts working on high-energy physics recently [6]. Moreover, we show that in the stationary regime the chirality of the domain wall can be efficiently reversed when the electric field is applied along the direction of the magnetic field. These characteristics suggest that the multiferroic domain wall may provide a new prospective means to design faster and low-power-consumption domain wall devices [7,8]. These results are expected to motivate experimentalists to prepare new type of multiferroics material or design new spintronics device [9-11].
参考文献：
[1] Y. Q. Li, Y. H. Liu, and Y. Zhou, General spin order theory via gauge Landau-Lifshitz equation, Phys. Rev. B. 84, (2011) 205123;
[2] Y. H. Liu and Y. Q. Li, A mechanism to pin skyrmions in chiral magnets, J. Phys.: Condens. Matter 25 (2013) 076005;
[3] H. Liu, Y. Q. Li, and J. H. Han, Skyrmion dynamics in multiferroic insulators, Phys. Rev. B 87 (2013) 100402 (R);
[4] S. Zhu and Y. Q. Li, Spin-orbital driven ferroelectricity, J. Phys.: Condens. Matter 26 (2014) 395901;
[5] S. Zhu，Y. Q. Li, and C. D. Batista, Spin-orbit coupling and electronic charge effects in Mott insulators, Phys. Rev. B 90 (19), (2014) 195107;
[6] Y. Akagi, et al., Isolated skyrmions in the CP nonlinear sigma model with DM type interaction, Phys. Rev. D 103 (2021) 065008;
[7] H. B. Chen, Y. H. Liu and Y. Q. Li, Electric field control of multiferroic domain wall motion, J. Appl. Phys. 115 (2014) 133913;
[8] H. B. Chen and Y. Q. Li, Electric-field control of elective spin excitations in Neel-type skyrmions, Appl. Phys. Express 12 (2019) 093003;
[9] Y. H. Liu and Y. Q. Li, Dynamics of magnetic skyrmions, Chin. Phys. B 24 (2015) 017506;
[10] R. Wiesendanger, Nanoscale magnetic skyrmions in metallic films and multilayers: a new twist for spintronics, Nature Review Materials, 1 (2016) 1

[11] C. Reichhardt and C. J. O. Reichhardt, Statics and dynamics of skyrmions interacting with pining: a review, arXiv:2102.10464v1. (2021).

口头报告 III04
报告人：马晨
单位：中国科学院理论物理研究所
题目：Non-maximal chaos in some Sachdev-Ye-Kitaev-like models
摘要：We study the chaos exponent of some variants of the Sachdev-Ye-Kitaev (SYK) model, namely, the N = 1 supersymmetry (SUSY)-SYK model and its sibling, the (N|M)-SYK model which is not supersymmetric, for arbitrary interaction strength. We find that for large q the chaos exponent of these variants, as well as the SYK and the N = 2 SUSY-SYK model, all follow a single-parameter scaling law. By quantitative arguments we further make a conjecture, i.e. that the found scaling law might hold for general one-dimensional (1D) SYK-like models with large q. This points out a universal route from maximal chaos towards completely regular or integrable motion in the SYK model and its 1D variants.

口头报告 III05
报告人：徐玉良
单位：鲁东大学
题目：Dynamics of quantum correlation on XXZ chain with Dzyaloshinskii-Molriya interaction
摘要：The non-equilibrium dynamics of quantum correlation on XXZ chain with Dzyaloshinskii-Molriya interaction is investigated by using and quantum renormalization group method. After importing the quantum quench, i.e., the sudden introduction of DM interaction, the entanglement and quantum correlation between the non-nearest-neighbor spin(or spin block) are calculated. It is found that there are some similar properties in the entanglement and quantum correlation: they periodically fluctuates with time under certain DM action. The effect of DM has an important influence on the dynamic characteristic of entanglement and quantum correlation, i.e., the time of the quantum correlation evolution reaching the first maximum value. When the system size becomes large and especially the thermodynamic limit is approaching, the characteristic time has a mutation behavior at the quantum critical point, and its first derivative also exhibits strange behavior and finite-size scaling behavior. It is found that the scaling behavior of the time-evolution characteristic of the entanglement is similar to that of entanglement in the equilibrium state. After a certain quench time, the quantum correlation and entanglement show the concussion increase with the increase of the DM interaction. When the system becomes large, the concussion change of quantum correlation also can reflect that the quantum phase transition from quantum antiferromagnetic N é el phase to spin liquid one occurs.

口头报告 III06
报告人：苏山河
单位：厦门大学

题目：Measurement-based quantum thermal machines
摘要：A modified Otto engine and a measurement-feedback cooler are introduced, where invasive measurement provides the fuel to drive thermodynamic cycles. For the engine, a standard process of thermalization is replaced by the projective measurement operation. The performance of the quantum engine is improved by suitably controlling the angles of the measurement basis. For the cooler, the measurement-feedback information moves heat from the cold to hot bath without any work input and even make the maximum coefficient of performance larger than the Carnot limit. A generalized Clausius inequality including the information demonstrates that this seemingly paradoxical result does not violate the laws of thermodynamics.

邀请报告 III07
报告人：窦文杰
单位：西湖大学
题目：Quantum thermodynamics in the strong coupling regimes
摘要：A system interacting with its surroundings exchanges energy in various forms, such as through the flow of heat or particles. These transport processes contain valuable information about both the system and surroundings. At the quantum scale, describing such non-equilibrium processes is relevant to understanding, for example, how charges flow through a semiconductor quantum dot or through a molecular junction. But how do quantum phenomena govern energy transport processes, and how can the resulting effects be harnessed to develop novel quantum technologies? Answering these questions theoretically is a very difficult task, particularly for a system that is strongly coupled to its surroundings. We present an approach based on a density matrix expansion to study thermodynamic properties of a quantum system strongly coupled to two or more baths. For slow external driving of the system, we identify the adiabatic and nonadiabatic contributions to thermodynamic quantities, and we show how the first and second laws of thermodynamics are manifested in the strong coupling regime. Particularly, we show that the entropy production is positive up to second order in the driving speed. When electron-electron interactions are included, we see exotic Kondo resonances as well as Coulomb blackade appearing in thermodynamic quantities.

邀请报告 III08
报告人：吕京涛
单位：华中科技大学
题目：Coupled power and heat transport in nonlinear waveguide arrays
摘要：In isolated nonlinear optical waveguide arrays with bounded energy spectrum, simultaneous conservation of energy and power of the optical modes enables study of coupled thermal and particle transport in the negative temperature regime[1-2]. Here, based on exact numerical simulation and rationale from Landauer formalism, we predict generic violation of the Wiedemann-Franz law in such systems. This is rooted in the spectral decoupling of thermal and power current of optical modes, and their different temperature dependence. Our work extends the study of coupled thermal and particle transport into unprecedented regimes, not reachable in natural condensed

matter and atomic gas systems[3]. 1. F. O. Wu, A. U. Hassan, and D. N. Christodoulides, Thermodynamic theory of highly multimoded nonlinear optical systems, Nat. Photonics 13, 776 (2019). 2.Z Xiong, F. O. Wu, J.-T. Lü, Z. Ruan, D. N. Christodoulides, Y. Chen, K-space thermodynamic funneling of light via heat exchange, Phys. Rev. A 105, 033529 (2022). 3.M. Lian, Y.-J. Chen, Y. Geng, Y. Chen, J.-T. Lü, Violation of the Wiedemann-Franz law in coupled thermal and power transport of optical waveguide arrays, in preparation.

参考文献：
[1]. F. O. Wu, A. U. Hassan, and D. N. Christodoulides, Thermodynamic theory of highly multimoded nonlinear optical systems, Nat. Photonics 13, 776 (2019).
[2]. Z Xiong, F. O. Wu, J.-T. Lü, Z. Ruan, D. N. Christodoulides, Y. Chen, K-space thermodynamic funneling of light via heat exchange, Phys. Rev. A 105, 033529 (2022).
[3].M. Lian, Y.-J. Chen, Y. Geng, Y. Chen, J.-T. Lü, Violation of the Wiedemann-Franz law in coupled thermal and power transport of optical waveguide arrays, in preparation.

邀请报告 III09
报告人：陈金灿
单位：厦门大学
题目：An innovative insight into one century-old physics theorem
摘要：The Nernst theorem and vanishing heat capacity at absolute zero temperature are two consequences of quantum statistic physics, which are independent of each other. It is proved through thermodynamic theory that the two consequences are mutually deducible and equivalent to each other. Moreover, some innovative insights related to the Nernst theorem are proposed.

口头报告 III10
报告人：陆金成
单位：苏州科技大学
题目：Multitask quantum thermal machines and cooperative effects
摘要：Including the phonon-assisted inelastic process in thermoelectric devices makes it possible to enhance the performance of nonequilibrium work extraction. In this work, we demonstrate that inelastic phonon-thermoelectric devices have a fertile functionality diagram, where particle current and phononic heat currents are coupled and fueled by the chemical potential difference. Such devices can simultaneously perform multiple tasks, e.g., heat engines, refrigerators, and heat pumps. Guided by the entropy production, we mainly study the efficiencies and coefficients of performance of multitask quantum thermal machines, where the roles of the inelastic scattering process and multiple biases in multiterminal setups are emphasized. Specifically, in a three-terminal double-quantum-dot setup with a tunable gate, we show that it efficiently performs two useful tasks due to the phonon-assisted inelastic process. For the four-terminal four-quantum-dot thermoelectric setup, we find that additional thermodynamic affinity furnishes the system with both enriched functionality and enhanced efficiency. Our work provides insights into optimizing phonon-thermoelectric devices.

口头报告 III11
报告人：王晨
单位：浙江师范大学
题目：Quantum thermal transport based on circuit quantum electrodynamics systems
摘要：Quantum thermal transport has attracted increasing attention in hybrid quantum systems, e.g., circuit quantum electrodynamics platforms[1-3]. It becomes an interdisciplinary field, including quantum transport, quantum thermodynamics, and quantum optics. Here we focus on thermal transport based on circuit quantum electrodynamics (cQED) systems, which serves as one representative kind of hybrid quantum systems[4,5]. Functional thermal device effects and distinct microscopic transport pictures are exhibited[4-6], which are tightly related with cycle transition processes[7]. [1]A. Ronzani, B. Karimi, J. Senior, Y. C. Chang, J. T. Peltonen, C. D. Chen, and J. P. Pekola, Tunable photonic heat transport in a quantum heat valve, Nat. Phys. 14, 991 (2018). [2]J. Senior, A. Gubaydullin, B. Karimi, J. T. Peltonen, J. Ankerhold, and J. P. Pekola, Heat rectifification via a superconducting artifificial atom, Comm. Phys. 3, 40 (2020). [3]J. P. Pekola and B. Karimi, Colloquium: Quantum heat transport in condensed matter systems, Rev. Mod. Phys. 93, 041001 (2021). [4]WC, H. Chen, and J. Q. Liao, Nonequilibrium thermal transport and photon squeezing in a quadratic qubit-resonator system, Phys. Rev. A 104, 033701 (2021). [5]Z. H. Chen, H. X. Che, Z. K. Chen, WC, and J. Ren, Tuning nonequilibrium heat current and two-photon statistics via composite qubit-resonator interaction, Phys. Re. Research 4, 013152 (2022). [6] Z. H. Chen, F. Y. Wang, H. Chen, J. C. Lu, and WC, Chin. Phys. Lett. 40, 050501 (2023). [7] L. Q. Wang, Z. Wang, WC, and J. Ren, Cycle flux ranking of network analysis in quantum thermal devices, Phys. Rev. Lett. 128, 067701 (2022).
参考文献：
[1] A. Ronzani, B. Karimi, J. Senior, Y. C. Chang, J. T. Peltonen, C. D. Chen, and J. P. Pekola, Tunable photonic heat transport in a quantum heat valve, Nat. Phys. 14, 991 (2018).
[2] J. Senior, A. Gubaydullin, B. Karimi, J. T. Peltonen, J. Ankerhold, and J. P. Pekola, Heat rectifification via a superconducting artifificial atom, Comm. Phys. 3, 40 (2020).
[3] J. P. Pekola and B. Karimi, Colloquium: Quantum heat transport in condensed matter systems, Rev. Mod. Phys. 93, 041001 (2021).
[4] WC, H. Chen, and J. Q. Liao, Nonequilibrium thermal transport and photon squeezing in a quadratic qubit-resonator system, Phys. Rev. A 104, 033701 (2021).
[5] Z. H. Chen, H. X. Che, Z. K. Chen, WC, and J. Ren, Tuning nonequilibrium heat current and two-photon statistics via composite qubit-resonator interaction, Phys. Re. Research 4, 013152 (2022).
[6] Z. H. Chen, F. Y. Wang, H. Chen, J. C. Lu, and WC, Chin. Phys. Lett. 40, 050501 (2023).
[7] L. Q. Wang, Z. Wang, WC, and J. Ren, Cycle flux ranking of network analysis in quantum thermal devices, Phys. Rev. Lett. 128, 067701 (2022).

邀请报告III12
报告人：邢向军

单位：上海交通大学
题目：受非保守力驱动的朗之万系统的热力学和随机热力 学
摘要：We construct a unified theory of thermodynamics and stochastic thermodynamics for classical nonequilibrium systems driven by non-conservative forces, using the recently developed covariant Ito-Langevin theory. The thermodynamic forces are split into a conservative part and a non-conservative part. Thermodynamic functions are defined using the reference conservative system. Work and heat are partitioned into excess parts and house-keeping parts, which are due to, respectively, conservative forces and non-conservative forces. Excess entropy production (EP) and house-keeping EP are analogously defined. The splitting of thermodynamic forces is subjected to an arbitrariness resembling a gauge symmetry, with each gauge defining a reference conservative Langevin system. In the special Gibbs gauge, the nonequilibrium steady state (NESS) is characterized by Gibbs canonical distribution, the excess heat agrees with that defined by Hatano and Sasa, and the excess EP agrees with that of Glansdorff and Prigogine, i.e., it is the time rate of the second-order variation of system entropy near the NESS. Adopting the Gibbs gauge, and focusing on the excess parts of thermodynamic quantities, a complete analogy between thermodynamics of non-conservative systems and that of conservative systems is established. One important consequence of this analogy is that both the free energy and excess EP are minimized at NESS. Our theory therefore constitutes a statistical foundation both for the steady-state thermodynamics theory due to Sasa and Tasaki and for the stability theory of NESS due to Glansdorff and Prigogine. These results are valid even if the system is far from equilibrium. By studying detailed fluctuation theorem, we find striking differences between systems with symmetric kinetic matrices and those with asymmetric kinetic matrices. For systems with asymmetric kinetic matrices, the total EP is the sum of house-keeping EP, excess EP, and pumped entropy. Entropy pumping is an exchange of entropy between the system and environment without necessarily involving dissipation. In the presence of entropy pumping, the system may behave as either a demon or an antidemon. Fluctuation theorems and work relations are derived both for total work and for excess work. For systems with symmetric kinetic matrices, there is no entropy pumping, yet in the Gibbs gauge, the excess work and house-keeping work each satisfies a separate fluctuation theorem. We illustrate our theory using many concrete examples.

邀请报告III13
报告人：任捷
单位：同济大学
题目：声波和声子有自旋吗？-高阶微商场论的老树新芽
摘要：声波和声子有自旋吗？在这个报告里，我将跟大家分享我们近期在声波自旋和声子自旋方面的一些初步探索。我们从场论和 Noether 定理出发，展示如何从张宗燧先生的高阶微商场论，涌现出标量场的自旋角动量，从而揭示纵声学波的自旋和声子自旋起源场的极化的旋转。具体的，我将介绍声波和声子自旋的理论提出，实验验证，及潜在应用，包括弹性波自旋和声表面波的自旋轨道耦合，声波自旋的观测及其自旋动量锁定，超表面波导里声波自旋及其应用，对称性选

择的声近场辐射与双面神现象，拓扑声子晶体的边界态声子自旋与局域依赖的手性耦合等等。期待未来弹性声波自旋与光学和磁性的结合，或者声子自旋与光子、磁子自旋的结合，将为量子器件的多模态多自由度调控带来更多新的可能性。

口头报告III14
报告人：张哲东
单位：香港城市大学
题目：Quantum Theory for Exciton Polariton Condensations
摘要：The coherent effects at nanoscale are of great significance for studying the out-of-equilibrium properties of matter. Recent advance in experiments is calling for the generalization and deeper understanding of quantum fluctuations beyond thermal equilibrium. These led to heightened interest and demand for an extensive theoretical study of quantum thermodynamics far from equilibrium, which is just a beginning of the field. In this talk I will give an overview of the quantum thermodynamics of the nonequilibrium Bose condensations at mesoscopic scale, and their cooperative phenomena [1,2,3]. These may bring us new knowledge about the nonequilibrium phase of matter. I will present the quantum statistical theory for the exciton-polariton condensation and phonon condensation, both of which highlight the Fröhlich’s mechanism [1,2]. A nonlinear equation of motion was developed for the condensates in the basis of reduced density matrix. The results predict a nonequilibrium phase transition through the variation of particle statitics, and therefore elaborate the off-diagonal long-range order (ODLRO) as an order parameter in the nonequilibrium regime [2]. Our work provides a universal description for the nonequilibrium Bose condensations ranging from microwave to optical regimes.

口头报告III15
报告人：艾清
单位：北京师范大学
题目：Criticality-Based Avian Navigation and Quantum Metrology
摘要：It has been long since we knew that many animals can utilize the weak geomagnetic field for navigation. In the framework of radical-pair hypothesis, we theoretically propose avian navigation assisted by quantum criticality. We show that quantum criticality can not only be used for bionic devices, but also be utilized in avian retina to improve the magnetoreception. Here, in the avian navigation, the radical pair play the role as measuring apparatus for the weak geomagnetic field. We further investigate the effects of different noises on the criticality-based quantum metrology. We show that the scheme is robust against single-photon loss by analytical solutions, while it may fail in the presence of two-photon loss. Finally, we suggest that our theoretical proposals can be experimentally verified by quantum simulations.

口头报告III16
报告人：刘全城
单位：巴伊兰大学
题目：多体系统中分数量子化的回归时间

摘要：Recurrence in the dynamics of physical systems is an important phenomenon that has many far-reaching consequences. In classical physics, Poincare's recurrence theorem states that a complex system will return to its initial state within a finite time when left alone. This theorem has been extended to the quantum case and has been observed experimentally. In this work, we investigate quantum recurrence for a quantum system that interacts with periodic measurements. Specifically, we consider interacting spin systems where the measurements are performed on one spin. We ask the question: if the monitored spin is initially prepared in the upstate (for example), how long will it take to measure the spin for the first time in the upstate again? We show that the mean recurrence time is fractionally quantized and characterized by the number of dark states, which are eigenstates of the spin system where the monitored spin and the surrounding bath are not entangled. The mean recurrence time is invariant when changing the sampling rate, and this invariance is topologically protected by the quantized winding number.

邀请报告III17
报告人：杨志成
单位：北京大学
题目：Using models with static quantum many-body scars to generate time-crystalline behavior under periodic driving
摘要：We propose a scheme that generates period-doubled responses via periodically driving certain Hamiltonians hosting quantum many-body scars, akin to recent experimental observations in driven Rydberg atom arrays. Our construction takes advantage of an su(2) spectrum generating algebra associated with the static quantum-scarred Hamiltonian, which enacts a pi-rotation within the scar subspace after one period of time evolution with appropriately chosen driving parameters. This yields period-doubled (subharmonic) responses in local observables for any choice of initial state residing in the scar subspace. The quasienergy spectrum features atypical pi-paired eigenstates embedded in an otherwise fully thermal spectrum. The protocol requires neither a large driving frequency nor a large driving amplitude, and is thus distinct from the prethermalization physics in previous investigations of the driven PXP model. We demonstrate our scheme using several spin-1/2 and spin-1 quantum scarred models possessing an exact su(2) spectrum generating algebra, as well as a symmetry-deformed PXP model, where the su(2) algebra is only approximate. Our results extend the class of models hosting quantum many-body scars that can be leveraged to yield time-crystalline behaviors under periodic driving.

邀请报告III18
报告人：彭新华
单位：中国科学技术大学
题目：Quantum sensing of complex quantum many-body physics
摘要：Quantum many-body physics, a core issue in the forefront of condensed matter physics, plays a highly crucial role in the fields of quantum control and quantum information. Owing to the advances in quantum information technology, the full

quantumness of sensors and targets can be harnessed to enable novel measurement schemes that have no classical counterparts. Via a probe spin, we realize the first experimental detection of Lee-Yang zeros in a thermodynamic many-body system. The direct detection of Lee-Yang zeros is intrinsically difficult because they would occur only at complex values of physical parameters, which are generally regarded as unphysical. Recently, by employing quantum sensors, we propose and implement a novel platform-universal protocol via quantum channel design for selectively detecting arbitrary-high-order correlations in quantum many-body systems, which is missing in conventional approaches such as nonlinear optics, transport measurement, magnetic resonance spectroscopy. This new method will provide a new toolbox for quantum many-body characterization, quantum noise study, quantum control, the non-equilibrium quantum many-body physics and so on.

邀请报告III19
报告人：王建辉
单位：南昌大学
题目：Thermodynamics and fluctuations in finite-time quantum heat engines under reservoir squeezing
摘要：Quantum heat engines have access to nano-scale open systems in which quantum effects manifest themselves, such as coherence, correlation and squeezing, etc. We investigate the thermodynamics and fluctuations of a finite-time quantum Otto engine alternatively driven by a hot squeezed and a cold thermal reservoir. We show that reservoir squeezing significantly enhances the performance by increasing the thermodynamic efficiency and the power, and enables higher stability by decreasing the relative power fluctuations and speeding up the convergence of quantum efficiency to its most probable value. We also demonstrate the counterintuitive result that, owing to purely quantum origin, the efficiency in finite time can be larger than the Otto limit which is reached only the reversible case.

口头报告III20
报告人：赵文垒
单位：江西理工大学
题目：Superexponential behaviors of out-of-time ordered correlators, Loschmidt echo and energy diffusion in nonHermitian Floquet systems
摘要：In this talk, I will discuss our recent investigations on the superfast dynamics in a kind of non-Hermitian Floquet systems. These systems combine the periodically-modulated nonlinear interaction and non-Hermiticity, which can be realized in optical setups incorporating the gain-or-loss and Kerr medium. Interestingly, we find that the periodically delta modulation on nonlinear interaction leads to the double exponential growth of mean energy, which arises from the feedback of non-Hermiticity-induced exponential growth in the quantum state's amplitude due to the delta-kicking modulation of nonlinearity. We have theoretically established the equivalence between a particular class of Out-of-time ordered correlators and the fidelity of two quantum states. This fidelity is directly proportional to the Loschmidt echo, and we have revealed

the double exponential behavior of these quantities during time evolution. Our findings demonstrate the occurrence of superexponential instability in wave chaos, which represents a novel characteristic in non-Hermitian chaotic systems.

邀请报告 III21
报告人：刘俊杰
单位：上海大学
题目：Quantum fluctuation and thermodynamics of quantum thermal machines
摘要：研究量子热机的热力学及其热力学量的涨落行为，有助于优化量子热机的效能。在这个报告中，我将围绕两个问题简要介绍我们在这方面所做的努力：一是热力学不确定性关系在量子热机中的适用性问题以及量子相干性的影响； 二是系统环境耦合较强时如何完整地描述量子热机的热力学。我们通过结合解析和具体热机模型计算，发现了热力学不确定性在量子热机中不总是被满足，同时量子相干性会增大量子涨落。我们也发展了适用于强耦合区间的量子热力学理论，揭示了系统环境强耦合对量子热机效能的具体影响。

口头报告 III22
报告人：于长水
单位：大连理工大学
题目：Quantum self-contained thermodynamical devices
摘要：Abstract: Quantum thermodynamics is an interdisciplinary discipline of classical thermodynamics and quantum mechanics, which not only studies the validity of classical thermodynamic laws at the microscopic level, but also provides a platform for designing quantum thermodynamic devices with special functions according to quantum mechanical properties and studying the quantum characteristics of quantum thermodynamic systems. Here we mainly begin with self-contained quantum refrigerators and the working principle of quantum refrigerators, and introduce the exploitation and utilization of strong internal coupling of quantum systems in the design of various quantum thermodynamical devices.

口头报告 III23
报告人：柳飞
单位：北京航空航天大学
题目：量子跳跃轨迹的半马氏过程
摘要：我们明确构建了量子跳跃轨迹的半马氏随机过程。该理论的一个应用场景是量子计数统计学。相较于文献中广泛使用的倾斜量子主方程，我们的理论有三个独特优势。首先，理论是经典概率论的结果，经典的等待时间分布函数“封装”了物理系统的量子属性。其次，，我们的理论能研究更一般的统计量：它们可以依赖于相邻的两次塌缩波函数。最后，半马过程的构建使得我们能够运用连续时间克隆算法模拟量子开系统的大偏差函数，具体的例子是随机重启的量子开系统的大偏差性质。

口头报告 III24
报告人：张堃

单位：西北大学
题目：Quantum fluctuation theorem of dissipative information
摘要：Information spreads in time evolution. For example, correlations dissipate when the correlated system locally couples to a third party, such as the environment. This simple but important fact is known as the quantum data-processing inequality. Here we theoretically reveal the quantum fluctuation theorem behind the quantum informational inequality. When the two-point measurement scheme is applied, the fluctuation theorem of dissipative information captures the dynamics of classical information [PRX Quantum3, 030315 (2022)]. The fluctuation theorem quantitatively predicts the statistics of such process. To fully capture the quantum nature, we have extended the fluctuation theorem established to the quasiprobability regime [arXiv: 2201.00385]. We also experimentally applied an interference-based method to measure the amplitudes composing the quasiprobability and verify our established fluctuation theorem on the IBM quantum computers.

口头报告 III25
报告人：徐国华
单位：浙江大学
题目：Quantum Dynamics of Continuous Time Crystals
摘要：Continuous time crystals (CTCs) are found as a novel phase characterized by the perpetual oscillations under the coupling between environments and the system. In this work, we show that the perpetual oscillations in the CTCs are induced by the competition between the quantum coherence in the system and the dissipation to the environment. Such quantum feature of the CTCs is demonstrated by the boundary time crystal (BTC) as an example, which preserves the quantum coherence for any initial state in the thermodynamic limit. We also find that the CTCs can be exactly described by an effective non-Hermitian Hamiltonian (NHH), which shows the PT symmetry breaking. Furthermore, the two limits, $N \to \infty$ and $t \to \infty$, are non-commutable in the time crystal phase, which indicates that the continuous time-translational symmetry is spontaneously broken. Finally, we establish a general phenomenological theory of the CTCs as a counterpart of the Landau's theory for equilibrium systems.

邀请报告 III26
报告人：Gentaro Watanabe
单位：浙江大学
题目：Quantum performance of microscopic heat engines under outcoupling
摘要：

邀请报告 III27
报告人：龚明
单位：中国科学技术大学
题目：无序模型的 Anderson 局域化和迁移率边:从单体物理到多体物理

摘要：最近有大量的理论研究关注多体模型的 Anderson 局域化，即 MBL。但是，MBL 和单粒子 AL 之间的关系，到目前是不清楚的。尽管在理论上预言了迁移率边的存在，实验上并没有观察到它们。在这个报告中，我们提出一类模型来回答这个问题。首先，我们讨论扩展态和局域态的耦合，我们发现如果局域态是通过非共度势产生的，那么在交叠态附近会产生临界态（critical state)。然后，我们将这个结果推广到高维无序模型，我们发现在 2d 和 3d 模型中，交叠态可以产生扩展态，但是非交叠区域的性质不变化，从而产生迁移率边。最后我们从随机矩阵的角度研究了这个问题，并发现一类新的随机矩阵，它们可以支持迁移率边，即交叠区域和非交叠区域有完全不同的性质 --- 进一步我们发现这些性质对非厄米矩阵也是成立的。我们的研究提供了一个新的视角来理解迁移率边的性质。

口头报告 III28
报告人：熊持
单位：闽江学院
题目：超流体中的量子涡旋和湍流
摘要：Superfluids (e. g. liquid helium-II and Bose-Einstein condensates in cold atoms) are important in both theoretical studies and practical applications. Researches on quantum vorticity and quantum turbulence are not only crucial in understanding the properties of superfluids, but also shed light on the development of turbulence models of classic fluids. We will present an emergent gauge theory formulation to describe vorticity and turbulence in quantum fluids. Based on the nonlinear Klein-Gordon equation, we first consider a general relativistic quantum fluid and construct an emergent gauge theory for quantum vortices, then compare the results with direct numerical computations and simulations, as well as other methods such as the vortex filament approach. We work in both two- and three-dimensional fluid systems. Studies on the statistical properties of quantum vortices also lead to a better understanding about the physical laws of their tangled state -- quantum turbulence.

口头报告 III29
报告人：徐洪亚
单位：兰州大学
题目：Klein 微腔中的波混沌与局域化
摘要：量子混沌中的局域化现象，如疤痕、混沌散射共振、动力学局域化等，抑制遍历性。Klein 隧穿是相对论性量子力学在诞生之初预言的奇特现象：满足 Dirac 方程的粒子能以非指数衰减的异常大几率穿透任意高且宽的势垒。直观上，Klein 隧穿破坏波的局域化。然而，基于混沌 Klein 微腔体系，我们发现显著的 Klein 混沌散射共振及相应的局域模式。

口头报告 III30
报告人：王成震
单位：Wesleyan University
题目：Asymmetric Transport in Nonlinear Complex Wave Systems
摘要：Nonlinearity-induced asymmetric transport (AT) can be utilized for on-chip implementation of nonreciprocal devices that do not require odd-vector biasing. This

scheme, however, is subject to a fundamental bound dictating the maximum transmittance-asymmetry is inversely proportional to the asymmetry intensity range (AIR) over which AT occurs. Contrary to the conventional wisdom, we show that the implementation of losses can lead to an increase of the AIR without deteriorating the AT. We develop a general theory that provides a new upper bound for AT in nonlinear complex quantum graphs and highlights the importance of losses and their structural complexity. Also, we give the statistical description of transmittance asymmetry via random matrix theory. Our predictions are confirmed numerically and experimentally using a microwave complex network of coaxial cables.

## 分会场 IV：无序与玻璃系统

邀请报告 IV01
报告人：王宇杰
单位：
题目：
摘要：

邀请报告 IV02
报告人：武振伟
单位：北京师范大学
题目：无序体系拓扑结构与物性关联
摘要：液体与玻璃在人们日常生产生活中无处不在，人类对玻璃材料的使用有超过 5000 年的历史，但玻璃态及玻璃转变的本质仍是目前复杂物理系统、凝聚态、和材料科学等众多科学领域所面临的最深刻、最有趣、也是最困难的问题之一。随着对无序系统物性研究的加深，人们逐渐意识到非晶态物质中原子中程结构对系统性质的重要影响，建立超越短程序的结构动力学关系对于理解液体和玻璃的本质以及玻璃转变过程有着至关重要的作用。非晶态作为自然界中最广泛存在一种物质形态，其与晶体材料结构上最大的不同在于不具备相对单一的结构基元。因此在液体与玻璃态物质研究中，如何理解和描述其内部大量结构基元间的相互连接和组合方式一直是领域内的一个关键科学问题，这恰好属于拓扑学的研究范畴：理解抽象实体之间的基本邻接关系。当下无序非平衡体系结构的研究表征中，使用最为普遍的结构序参量大多基于基本组成单元最近邻几何特征给出，由于对种类繁多的短程结构的拓扑不变性认识不清，人们在刻画无序体系的结构动力学关系时，往往只能给出定性层面的研究结果，难以建立具有良好一一对应性的定量型结构物性关系，极大地阻碍了人们对液体及玻璃等典型无序复杂物理系统的认识和理解，从而也无法对相关领域新材料的开发提供十分有力的理论支撑。本次报告将简要介绍拓扑思想在无序体系原子结构及结构物性关系研究中的应用背景和主要结果，并就目前的一些开放性问题与大家分享讨论。

口头报告 IV03
报告人：Chris HC.Nguyen
单位：香港科技大学

题目：Air arrival network: Characteristcs and optimal sequencing optimization
摘要：Air transportation networks come with unique operational constraints that require careful management. This study investigates the characteristics of the arrival network in air transportation and their impact on transit time, with a focus on influx density, holding time, and wake separation. The study's results emphasize the need for a well-designed optimization algorithm to alleviate congestion and enhance the efficiency of the arrival network. To this end, the study proposes an extension of an existing optimization algorithm for dynamical route coordination that incorporates a message-passing approach. The algorithm is specifically tailored for the air traffic context and considers the unique operational constraints of the arrival network. One of its key features is that it balances the trade-off between optimizing transit time and minimizing unfairness in aircraft sequencing. Additionally, the algorithm's linear complexity makes it apposite for real-time settings. Overall, this study provides valuable insights into the development of optimization algorithms for air traffic management and offers a promising solution to reduce congestion in arrival traffic flow.

口头报告 IV04
报告人：李明
单位：合肥工业大学
题目：Explosive Percolation Obeys Standard Finite-Size Scaling in an Event-based Ensemble
摘要：Explosive percolation in the Achlioptas process, which has attracted much research attention, is known to exhibit a rich variety of critical phenomena that are anomalous from the perspective of continuous phase transitions. Hereby, we show that, in an event-based ensemble, the critical behaviors in explosive percolation are rather clean and obey the standard finite-size scaling theory, except for the large fluctuation of pseudo-critical points. In the fluctuation window, multiple fractal structures emerge and the values can be derived from a crossover scaling theory. Further, their mixing effects account well for the previously observed anomalous phenomena. Making use of the clean scaling in the event-based ensemble, we determine with a high precision the critical points and exponents for a number of bond-insertion rules, and clarify ambiguities about their universalities. Our findings hold true for any spatial dimensions.

口头报告 IV05
报告人：刘易文
单位：华东师范大学
题目：双层网络上消息传播-意见形成的耦合动力学研究
摘要：多层网络被广泛地应用于研究多个具有相互作用的动态过程的演化特性。人群的意见形成是一个复杂的过程而且受到其他因素的影响，例如社交媒体上的消息传播。然而，这两种动力学的演化时间尺度具有较大的差异。近年来的研究表明，两种动力学的相对时间尺度对于二者的耦合演化具有重要的影响。基于此，我们在双层网络上构建了一个具有不同演化时间尺度的耦合传播模型—阈值噪声投票者-SIR 耦合传播模型，来描述消息传播和意见形成的相互作用。基于平均场理论的理论分析和蒙特卡洛模拟结果都表明意见的形成取决于相关消息的传

播以及初始时刻持该意见的个体比例，这暗示了双稳态与磁滞现象的存在。此外，在有限尺寸系统中，我们的模型表现出引人注目的“相翻转”现象，即持某一意见的个体比例随时间在高密度状态和低密度状态之间来回切换。我们的结果阐明了社交媒体上的消息传播对群体意见共识的重要影响，以及在社交网络传播资源有限的情况下少数的异见者比例对于群体意见翻转的必要性，这对于舆情管控与辟除谣言有着深刻的启示。

口头报告 IV06
报告人：韩礼雷
单位：华东师范大学
题目：时变网络上的非马尔可夫动力学
摘要：许多实证研究表明，与人类活动相关的接触的发生是具有重尾事件间时间分布的非马尔可夫过程。 此外，越来越多的经验证据表明感染率和恢复率具有时间依赖性。 然而，我们缺乏一个综合框架来分析和理解时变网络上的非马尔可夫接触和传播过程。 在本文中，我们提出了一种一般形式来研究非马尔可夫时变网络上的非马尔可夫动力学。 我们发现，在某些条件下，时变网络上的非马尔可夫动力学等价于静态网络上的马尔可夫动力学。 有趣的是，这个结果独立于底层网络拓扑。

邀请报告 IV07
报告人：张洁
单位：上海交通大学
题目：The yielding of granular matter is marginally stable and critical
摘要：The mechanical yield of dense granular materials is a captivating rheological phenomenon. Beyond this point, stress no longer increases with strain at a significant deformation level. Understanding the behavior of mechanical responses associated with yielding is a fundamental objective in granular physics and related fields such as glassy physics, material sciences, geophysics, and active matter biophysics. However, despite nearly half a century of theoretical efforts, the nature of yielding in amorphous solids remains largely elusive compared to its crystalline counterpart. In this study, we conducted experimental investigations on the mechanical responses of two-dimensional bidisperse jammed disks under volume-invariant pure shear, with a specific focus on the yielding behavior. Our findings reveal that the microscopic mechanical and geometrical characteristics of configurations under shear can be described by two critical exponents: one for weak-force distribution and another for small-gap distribution, originally proposed for the isotropic jamming transition. We observe that the yielding transition satisfies the condition of marginal mechanical stability, as indicated by a scaling relationship between these two exponents. Furthermore, following yielding, a state of global instability emerges. The criticality of yielding is evidenced by a significant peak in susceptibility, which quantifies the fluctuation of a glass overlap order parameter. Additionally, we identify a distinct transition preceding yielding, which corresponds to the onset of structural anisotropy. These findings shed light on the complex nature of yielding in amorphous solids and contribute to our understanding of granular physics and related disciplines.

邀请报告 IV08
报告人：张格
单位：香港城市大学
题目：无序固体形变机制研究
摘要：无序固体是由任何空间尺度的颗粒无序堆积所组成的固体，例如玻璃、塑料、纳米粒子镀膜和混凝土等。在外力作用下，有些无序固体塑性好，有些差。微观来说，颗粒在形变过程中会发生重排。在塑性差的固体中，重排的颗粒形成剪切带；然而在塑性好的固体中，重排的颗粒形成不规则的形状。 为了解释这一区别，以前的科学家提出了弹塑性模型，但是该模型只在定性上和粒子模拟吻合。我们运用机器学习改进原模型，提出了结构弹塑性模型。新模型的结果在定量上和粒子模拟基本吻合。

邀请报告 IV09
报告人：童华
单位：中国科学技术大学
题目：Emerging exotic compositional order on approaching low-temperature equilibrium glasses
摘要：The ultimate fate of a glass former upon cooling has been a fundamental problem in condensed matter physics and materials science since Kauzmann. Recently, this problem has been challenged by a model with an extraordinary glass-forming ability effectively free from crystallization and phase separation, two well-known fates of most glass formers, combined with a particle-size swap method. Thus, this system is expected to approach the ideal glass state if it exists. However, we discover exotic compositional order as the coexistence of space-spanning network-like structures formed by small-large particle connections and patches formed by medium-size particles at low temperatures. Therefore, the glass transition is accompanied unexpectedly by exotic compositional ordering inaccessible through ordinary structural or thermodynamic characterizations. Such exotic compositional ordering is found to have an unusual impact on structural relaxation dynamics. Our study thus raises fundamental questions concerning the role of unconventional structural ordering in understanding glass transition.

口头报告 IV10
报告人：张会军
单位：西安交通大学
题目：基于衍射实验的幂律研究玻璃态的微观结构
摘要：压缩 d 维晶体显然满足幂律 $1/\phi \propto V \propto a^d \propto 1/q_1^d$，$\phi$是密度或体积分数，V 是平均原子体积，a 是晶格常数，$q_1$ 是结构因子的第一个峰的位置。近年来的衍射实验发现此幂律在玻璃中仍然成立，只是幂指数从三维的 d = 3 变成约 2.5（小于），其机制尚有争议。近年来，二维材料得到了广泛的关注，但是二维玻璃体系是否存在类似的非整数幂律至今还没有报道。我们用计算机模拟压缩硬球和具有台阶势的软球组成的二维晶体模型，观察多多晶-非晶态转变【1】，证实了不同组分的非晶态都符合幂律（图 1），并且发现 d 反比于可压缩部分的体积分

数【2】。我们认为在压缩过程中，局部不均匀形变导致非整数幂律。另外，我们调节二元金属玻璃和硬球玻璃的组分，同样观察到分数幂律，且幂指数与原子直径比成指数关系变化【3】。这些发现对于我们理解无序玻璃体系及其形变有很大的帮助。

参考文献：

[1] Huijun Zhang and Yilong Han, Compression-induced polycrystal-glass transition in binary crystals，Physical Review X, 8, 041023 (2018).

[2] Huijun Zhang, Kaiyao Qiao, and Yilong Han, Fractional power-law in two-dimensional binary glasses under compression. Nature Communications 11, 462 (2020).

[3] Huijun Zhang, Chengjie Luo, Zhongyu Zheng, and Yilong Han, Effects of size ratio on particle packing in binary glasses. Acta Materialia 464 246, 118700 (2023).

口头报告 IV11

报告人：韩一龙

单位：香港科技大学

题目：用胶体研究玻璃态的表面与内部熔化

摘要：玻璃态熔化是通常研究的液体到玻璃态转变的反过程，但并不简单可逆，需分别研究。玻璃态熔化缺乏单粒子尺度的实验；超稳定玻璃是一个研究热点，但在胶体中尚未实现；“玻璃能否像晶体一样预熔化？”，此问题没有被提出；我们用胶体实验回答了以上三个挑战[1] ，具有吸引势的胶体小球气相沉积形成具有自由表面的二维胶体玻璃，其稳定系数落在超稳玻璃范围。缓慢变温来减弱吸引势造成与超稳玻璃类似的表面熔化，表面对结构与动力学参量的影响具有不同的穿透深度，从而划分出两个表面层 ，两层的厚度都在逼近熔点时呈幂函数增长，可达上百层粒子，类似晶体预熔化行为。与慢变温造成预熔化不同，快速变温则造成熔化。我们对比了玻璃与晶体表面预熔化和熔化的相似与不同，及动力学机理[1]。另外，对胶体玻璃内部熔化的初步研究发现与模拟研究类似的液体成核行为，并用机器学习预言了熔化发生位置，支持了最近高分子玻璃熔化的发现。

参考文献：

[1] Qi Zhang, Wei Li, Kaiyao Qiao, Yilong Han, Surface premelting and melting of colloidal glasses, Sci. Adv. 9, eadf1101 (2023)

邀请报告Ⅳ12

报告人：石锐

单位：浙江大学

题目：Mechanism of hierarchical ion solvation in water

摘要：Ions exhibit highly ion-specific complex behaviors when solvated in water, which remains a mystery despite the fundamental importance of ion solvation in nature, science, and technology. The difficulty mainly comes from the characterization of water structure under the impact of ions. Here we explain these ion-specific properties by the ion-induced hierarchical dipolar, translational, and bond-orientational orderings of ion hydration shell under the competition between ion-water electrostatic interactions and inter-water hydrogen bonding. We first characterize this competition by a new length lambda_HB, explaining the ion-specific effects on solution dynamics. Then, by continuously tuning ion size and charge, we find that the bond-orientational order of

the ion hydration shell highly develops for specific ion size and charge combinations. This ordering drastically stabilizes the hydration shell; its degree changes the water residence time around ions by 11 orders of magnitude for main-group ions. Based on these results, we develop a theoretical model, incorporating the ion-specific effects on solvation and water structure, which explains the concentration and temperature dependences of solution dynamics in a unified manner. These findings are fundamental to ionic processes in the aqueous solutions, paving the way toward a microscopic theory of ionic solutions.

邀请报告Ⅳ13
报告人：李艳伟
单位：北京理工大学
题目：局域塑性响应与过冷动力学的关联
摘要：液体降温过程中，可能会在低于结晶温度时不结晶，形成过冷液体，进一步降温，过冷液体会经历玻璃化转变形成非晶固体。液体-非晶固体转变过程中，体系黏度飙升，而其静态结构却变化不大，保持长程无序的状态，这与液体-晶体转变截然不同。此外，在非晶液-固转变过程中，体系的动力学会越来越慢，动力学关联函数呈现两步松弛，并伴随体系不同区域粒子运动快慢不同等复杂而有趣的现象。玻璃体系动力学与静态性质是否存在关联一直是玻璃化转变研究中的核心问题之一？围绕这一问题，我们从塑性的视角建立了与动力学的联系。具体为，对粒子施加一瞬时的力，观察粒子不能回弹的位移大小，这一不可逆位移反映了粒子局域的塑性响应。基于此，我们定义了塑性关联长度，并发现塑性长度在理想玻璃化转变点外推为 0，且与松弛时间之间存在指数依赖关系。另外，我们的结果表明塑性长度与动力学在弛豫时间尺度有明显的关联，而弹性性质，如描述粒子振动强度的 Debye-Waller 因子，或其简谐近似下的均方位移，或低频振动模的参与分数仅在较短时间与动力学有关联。

口头报告Ⅳ14
报告人：李欣阳
单位：中科院理论物理所
题目：Thermodynamic crossovers in supercritical fluids
摘要：Can liquid-like and gas-like states be distinguished beyond the critical point, where the liquidgas phase transition no longer exists and conventionally only a single supercritical fluid phase is defined? Recent experiments and simulations report strong evidence of dynamical crossovers above the critical temperature and pressure. Despite using diffffferent criteria, existing theoretical explanations generally consider a single crossover line separating liquid-like and gas-like states in the supercritical fluid phase. We argue that such a single-line scenario is inconsistent with the supercritical behavior of the Ising model, which has two crossover lines due to its symmetry, violating the universality principle of critical phenomena. To reconcile the inconsistency, we defifine two thermodynamic crossover lines in supercritical flfluids as boundaries of liquid-like, indistinguishable and gas-like states. Near the critical point, the two crossover lines follow critical scalings with exponents of the Ising universality class, supported by calculations of theoretical models and analyses of experimental data from the standard

database. The upper line agrees with crossovers independently estimated from the inelastic X-ray scattering data of supercritical argon, and from the small-angle neutron scattering data of supercritical carbon dioxide. The lower line is verifified by the equation of states for the compressibility factor. This work provides a fundamental framework for understanding supercritical physics in general phase transitions.

口头报告Ⅳ15
报告人：张齐
单位：江苏科技大学
题目：局域约束下的相变与系综不等价性
摘要：传统统计物理认为统计系综不等价性是发生在系统相变边界上由非叠加性引起的特殊现象。然而在以复杂网络与随机矩阵等局域约束系统中，统计系综不等价却被发现存在于局域约束系统的整个相空间中，且并不依赖于相变的产生，而是由约束数量随系统规模增长而增加的局域约束所导致。因此对局域约束系统的系综不等价性的研究迫切需要回答的问题是，在局域约束系统的相边界上，统计系综不等价性的存在是由那种机制主导的。近期我们通过构建了具有 Core-Periphery 结构的加权网络，将网络的边权重凝聚到少数几个核心节点的边上，从而在加权网络中形成了特殊的“玻色-爱因斯坦凝聚”，实现了在局域约束系统中产生相变这一现象。通过研究加权网络正则系综的边权重的统计涨落与系综之间的相对熵密度在加权网络的玻色爱因斯坦凝聚附近的变化情况，我们发现在局域约束存在的情况下，当系统温度大于临界温度时，传统的系综等价判据即对应约束值的统计涨落趋于零，并不能够保证局域约束系统在热力学极限状态下的系综等价性，局域约束系统中的随系统规模增长而增加的局域约束仍然会导致系综不等价性的存在。当系统温度小于临界温度大于零时，统计涨落判据和相对熵判据均表明系综不等价性的存在。只有在温度等于零时，系统中的约束数量不再随系统规模增长而增长时，系综不等价的产生才由相变主导，但是此时的系统已经不在满足局域约束的条件。因此局域约束很可能是比相变更强的能够导致系综不等价的机制，但是我们仍然需要更具体的工作来验证这个结果。

口头报告Ⅳ16
报告人：蔡超然
单位：西北大学
题目：SIS 模型与 UAU-SIS 模型的传播阈值的简单关系
摘要：复杂网络上传播模型的传播阈值是网络流行病学最关心的问题之一。本文给出了双层网络上信息-疾病耦合动力学模型的传播阈值解析表达式。本文提出的传播阈值公式揭示了单层网络 SIS 模型与多路复用网络 UAU-SIS 模型的传播阈值的关系，这意味着单层网络的理论结论可用于提高复用网络的阈值精度。

邀请报告Ⅳ17
报告人：孙刚
单位：北京师范大学
题目：Amorphous Solidification of a Supercooled Liquidin the Limit of Rapid Cooling
摘要：We monitor the transformation of a liquid into an amorphous solid in simulations of a glass forming liquid by measuring the variation of a structural order parameter with

either changing temperature or potential energy to establish the influence of the cooling rate on amorphous solidification. We show that the latter representation, unlike the former, exhibits no significant dependence on cooling rate. This independence extends to the limit of instantaneous quenches which we find can accurately reproduce the solidification observed during slow cooling. We conclude that amorphous solidification is an expression of the topography of the energy landscape and present the relevant topographic measures.

邀请报告Ⅳ18
报告人：杨志豪
单位：香港科技大学
题目：Complete Realization of Energy Landscape and Non equilibrium Trapping Dynamics in Spin Glass and Optimization Problem
摘要：Energy landscapes are high-dimensional surfaces representing the dependence of system energy on variable configurations, which determine crucially the system's emergent behavior but are difficult to be analyzed due to their high-dimensional nature. In this article, we introduce an approach to reveal the complete energy landscapes of small spin glasses and Boolean satisfiability problems, which also unravels their non-equilibrium dynamics at an arbitrary temperature for an arbitrarily long time. In contrary to our common belief, our results show that it can be less likely to identify the ground states when temperature decreases, due to trapping in individual local minima, which ceases at different time, leading to multiple abrupt jumps with time in the ground-state probability. Simulations agree well with theoretical predictions on these remarkable phenomena. Finally, for large systems, we introduce a variant approach to extract partially the energy landscapes and observe both analytically and in simulations similar phenomena. This work introduces new methodology to unravel the non-equilibrium dynamics of glassy systems, and provides us with a clear, complete and new physical picture on their long-time behaviors inaccessible by modern numerics.

口头报告Ⅳ19
报告人：李福祥
单位：湖南大学
题目：Kibble-Zurek behavior in disordered topological systems
摘要：The discovery of nonlocal order parameters in real space provides a feasible scheme for studying dynamical critical behavior in topological systems. We study the critical phenomena in the one-dimensional Su-Schrieffer-Heeger model by investigating the inhomogeneities in the local winding number in real space. By slowly quenching the system across the topological phase transition during a finite time interval, we find that the length scale defined through the local winding number satisfies the Kibble-Zurek mechanism. In contrast to the density of excitation, the scaling of this length scale is in full analog to the behavior of traditional continuous phase transitions with local order parameter and spontaneous symmetry breaking. These results extend our understanding to the Kibble-Zurek mechanism and topological phase transition in nonequilibrium.

口头报告Ⅳ20
报告人：周健文
单位：中科院理论物理所
题目：Hierarchical cycle-tree packing model for K-core attack problem
摘要：The K-core of a graph is the unique maximum subgraph within which each vertex connects to at least K other vertices. The K-core optimal attack problem asks to construct a minimum-sized set of vertices whose removal results in the complete collapse of the K-core. In this paper, we construct a hierarchical cycle-tree packing model which converts a long-range correlated K-core pruning process into static patterns and analyze this model through the replica-symmetric (RS) cavity method of statistical physics. The cycle-tree guided attack (CTGA) message-passing algorithm exhibits superior performance on random regular and Erdős－Rényi graphs. It provides new upper bounds on the minimal cardinality of the K-core attack set. The model of this work may be extended to construct optimal initial conditions for other irreversible dynamical processes.

邀请报告 IV21
报告人：曾红丽
单位：南京邮电大学
题目：利用耦合分析方法推理种群演化适应度
摘要：结合统计物理中的逆伊辛模型和种群演化过程中基因型分布随时间的变化，我们研究了种群演化的适应度重构问题。Kimura-Neher-Shraiman 等人发现，在准连锁平衡（QLE）条件下，适应度函数中的上位性贡献与种群状态分布参量（可利用直接耦合分析方法，从数据中学习得到）之间，存在特定的比例关系，称为 KNS 理论 1。大量的数值模拟实验验证了该结论的正确性和有效性。另外，在推导种群状态累积量的过程中，通过高斯闭合操作的引入，发现利用群体状态量上位性贡献可以直接求解上位性，且其推理结果与 KNS 理论相当 2-3。基于此，我们在新冠病毒基因序列的基础上，高效推理了不同基因位点之间的上位性 4。同时，新冠肺炎在全球范围内的持续流行，基因序列数量大幅增加。为此，我们首次在暂态 QLE 假设下，讨论了新冠病毒上位性的时间演化规律 5。对病原体适应性，尤其是上位性贡献的深入理解，是研究病原体致病机理的基础，同时为研发相关药物、制定临床综合诊疗方法提供了重要理论支撑。

口头报告 IV22
报告人：毛俊雯
单位：湖州师范学院
题目： An integrated modeling approach to characterizing substrate inhibition of microbial growth
摘要：Substrate inhibition of bacterial growth that the growth rate first increases with substrate concentration and then decreases is observed when nutrients supply exceeds the critical concentration. The deviation from the Monod growth is previously described by curve fitting of the empirical models to the experimental data. Here, we propose a minimal two-pathway model by incorporating negative regulation of

molecular processes into bacterial growth pathway. Using this integrated model, we find that the conditions of substrate inhibition can be captured by the initial physiological state and concentration of the inoculum cells. Furthermore, the model predicts that the duration of lag phase in microbial growth is significantly prolonged by the enhanced substrate supply, which has been reported in published experimental data. These results indicate that microorganisms might adopt completely different growth strategies regarding the adaptation and growth in response to nutrient-rich and nutrient-poor environments. Finally, we clarify different mechanisms between substrate inhibition and product inhibition through a more complex model involving product inhibition, for example, lactic acid produced by bacterial fermentation can inhibit bacterial growth. Remarkably, the model predictions of substrate concentrated-dependent growth rates reproduce the experimental observations of available growth data of Lactobacillus strains, regarding L. bulgaricus, L. casei, and L. plantarum. Our modeling approach provides new insights into understanding a novel connection between bacterial growth and substrate supply, facilitating efficient substrate utilization and biodegradation in industry bioreactors.

口头报告 IV23
报告人：刘德明
单位：兰州大学
题目：细胞间竞争增长与环境耦合反馈动力学
摘要：微环境的稳态是保持细胞正常增殖、分化、代谢和功能活动的重要条件。近期一些生物学研究表明，衰老和癌症会改变细胞微环境组分并打破微环境稳态。为了探究多细胞生物体如何应对衰老和癌症的“双重束缚”，我们将微环境反馈机制引入到多细胞生物的细胞竞争增长动力学中，其中各类细胞的占比决定微环境的状态，微环境的状态又反过来调节细胞的竞争能力。结果表明，微环境反馈可以有效地延长生物体寿命，但由于肿瘤微环境的出现，生物体不可避免的丧失功能细胞导致死亡。在研究肿瘤微环境出现的快慢所导致的寿命缩短时，我们发现癌细胞占比相对于衰老细胞占比对微环境的反馈速率可以作为衡量对肿瘤微环境治疗效果的参数，理论上的结果也与真实数据中接近。此外，在研究癌细胞的竞争能力对寿命的影响时，我们发现存在最优的竞争能力值使得生物体存活最久，这是没有微环境反馈时无法出现的现象。微环境反馈还可以导致生物体出现有趣的 Parrondo 悖论现象：当癌细胞的竞争能力在过高和过低的值之间切换时，多细胞生物体能够比每一种情况下单独活得更久。这些结果可能为针对肿瘤微环境的靶向治疗提供一些线索。

口头报告 IV24
报告人：王嘉慧
单位：中北大学
题目：A new variable-boostable 3D chaotic system with hidden and coexisting attractors: Dynamical analysis,periodic orbit coding, circuit simulation,and synchronization
摘要：The study of hidden attractors plays a very important role in the engineering applications of nonlinear dynamical systems. In this paper, a new three-dimensional

(3D) chaotic system is proposed in which hidden attractors and self-excited attractors appear as the parameters change. Meanwhile, asymmetric coexisting attractors are also found as a result of the system symmetry. The complex dynamical behaviors of the proposed system were investigated using various tools, including time-series diagrams, Poincare first return maps, bifurcation diagrams, and basins of attraction. Moreover, the unstable periodic orbits within a topological length of 3 in the hidden chaotic attractor were calculated systematically by the variational method, which required six letters to establish suitable symbolic dynamics. Furthermore, the practicality of the hidden attractor chaotic system was verified by circuit simulations. Finally, offset boosting control and adaptive synchronization were used to investigate the utility of the proposed chaotic system in engineering applications.

口头报告 IV25
报告人：常鑫
单位：西北大学
题目：Combined effect of simplicial complexes and interlayer interaction: An example of information-epidemic dynamics on multiplex networks
摘要：In this paper, we investigate the effect of self-awareness (interlayer interaction) for information-epidemic dynamics with simplicial complexes both near and away from the epidemic threshold. It is shown that, contrary to previous views, self-awareness plays a key role near the epidemic threshold. In small homogeneous networks, multiple susceptibility peaks can emerge in the susceptibility of the epidemic layer under the combined effect of simplicial complexes and self-awareness, even two types of multiple susceptibility peaks with completely opposite mechanisms. This means that one needs to be very careful when obtaining epidemic thresholds based on susceptibility. Moreover, the self-awareness can regulate the presence or absence of bistable phenomena both in epidemic prevalence and epidemic threshold. We also found that the time series of disease may be nonmonotonic, with a peak, and that self-awareness is one of the factors controlling the relative height between maximum and steady state. In addition, we modify heterogeneous mean-field theory and partial effective degree theory to accommodate the introduction of simplicial complexes in dynamics. We believe that our study has implications for other dynamics concerning higher-order and interlayer interactions.

邀请报告 IV26
报告人：玉素甫·艾比布拉
单位：新疆大学
题目：Minimum Backbone of Complex Networks
摘要：Connected minimal dominating set (CMDS) has been proposed as virtual backbone or spine of wireless ad hoc networks. mathematical and heuristic algorithm have been proposed in the literature for CMDS. In this paper, we have successfully transformed global interactions into local interactions and proposed a statistical physics model to calculate the size of the CMDS for the Regular random graph and ER random graph. We develop Belief Propagation Decimation (BPD) algorithm to construct CMDS

and predicted the ground state energy using the theory of replica symmetry. We compared the results of BPD and greedy algorithm. The results of BPD are much better than those of greedy algorithm, but when the connectivity is relatively large, the results of BPD seriously deviate from the predicted value of RS (but still better than greedy algorithm), because when the connectivity is relatively large, the belief propagation equation (BP) no longer converges near zero entropy, which leads to the CMDS constructed by BPD being greater than the predicted value of RS. We will use the first-order replica symmetry breaking theory to study the solution space of CMDS and discuss the convergence of the BP equation.

邀请报告 IV27
报告人：赵金华
单位：华南师范大学
题目：A percolation-based analytical approach to combinatorial optimization problems on graphs
摘要：Combinatorial optimization problems on graphs are a typical class of hard computational tasks, which is a common topic spanning the analysis of algorithms, the computational complexity, and the statistical physics. It is usually believed that analytical frameworks are quite limited on graphical combinatorial optimizations, and existing methods focus on developing fast approximate algorithms for them. Here we show that, for the specific matching and cover problems on graphs, based on the greedy leaf removal (GLR) procedure in different versions as a local method, we can develop a core percolation theory underlying the GLR procedure on random graphs, and finally reach an analytical framework for their energy densities of ground states. We show our analytical frameworks for matching and cover problems on undirected, directed, and bipartite graphs. Our percolation-based analytical frameworks directly work at zero temperature, and provide an alternate yet a more intuitive perspective to ground states of optimization problems.

口头报告 IV28
报告人：崔丽杰
单位：中山大学
题目：财富分配的影响因素研究：基于动理学交易模型
摘要：作为人类社会的核心问题，财富分配和贫富差距一直是世界各国所重点关注的热点和难点研究课题。目前，如何准确模拟和预测在复杂社会条件下的财富分配问题，这是非常具有挑战性的开放性问题。作为一种经济物理学方法，动理学交易模型能够为财富分配的模拟研究提供有效的手段[1-4]。动理学模型具有简单方便、准确可靠、易于并行等诸多优势，并已在财富分配等复杂经济系统得到成功应用。针对复杂条件下的财富分配问题，我们构建了能够模拟随机经济交易过程的动理学模型，并考虑了储蓄倾向、经济增长和马太效应对交易过程的影响机制。基于该动理学模型，我们模拟研究了不同储蓄倾向、经济增长和马太效应情况下的财富分配情况。为了定量描述和分析财富分布的规律特征，我们引入了五个衡量指标，即熵、重合度、偏离度、基尼系数和 Kolkata 指数。研究发现：熵与重合度的变化趋势相似，而与偏离度的变化趋势相反；基尼系数和 Kolkata

指数随着储蓄倾向的增加而下降，随着马太效应的增加而上升；储蓄倾向的提升有助于降低财富差距，而经济利润和马太效应加剧了财富不平等。本工作的开展将有助于有效推进动理学方法在复杂系统的应用研究，进一步完善相关经济问题的理论框架，为相关政策的制定提供理论依据。

口头报告 IV29
报告人：刘思博
单位：香港浸会大学
题目：Financial Systems, Production Networks, and the Environment
摘要：This paper presents empirical evidence on the complex interactions between financial systems and pollution dynamics across the world. Drawing on a combination of theoretical frameworks and empirical data, we present three key findings. Firstly, we demonstrate that increasing shareholder awareness towards environmental issues can lead to a statistically significant reduction in pollution levels within a given country. Secondly, we find that firms facing greater shareholder pressures tend to strategically outsource their pollution activities to countries with less stringent environmental regulations, leading to a significant increase in pollution levels in those countries. Lastly, our research suggests that financial market incentives alone do not lead to an overall reduction in emissions; instead, they often result in the relocation of emissions through product networks to other countries, creating negative environmental externalities. Our study highlights the need for a comprehensive approach that considers the environmental impact of financial activities. Our findings have important implications for policymakers, investors, and firms, and contribute to the ongoing conversation about sustainability and the role of financial systems in promoting environmentally responsible practices. Overall, our empirical evidence provides new insights into the complex interplay between financial systems and pollution dynamics, and contributes to the growing body of literature on the environmental impact of economic activities.

## 分会场 V：软物质系统

邀请报告 V01
报告人： 杨明成
单位： 中国科学院物理研究所
题目： Odd response-induced phase separation of active spinners
摘要： Due to the breaking of time-reversal and parity symmetries and the presence of non-conservative microscopic interactions, active spinner fluids and solids, respectively, exhibit nondissipative odd viscosity and nonstorage odd elasticity, engendering phenomena unattainable in traditional passive or active systems. In this talk, we report the effects of odd viscosity and elasticity on phase behaviors of active spinner systems. We find the spinner fluid under a simple shear experiences an anisotropic equilibrium-like gas-liquid phase separation driven by the odd-viscosity stress, showing both binodal and spinodal decompositions and critical point. In the formed dense liquid phase, the odd elasticity instantly takes over the odd viscosity to condense the liquid into a solid phase. The unusual phase behavior essentially arises

from the competition between thermal fluctuations and the odd response-induced effective attraction. Our findings demonstrate that the cooperation of odd viscosity and elasticity can lead to exotic phase behavior, revealing their fundamental roles in phase transition.

邀请报告 V02
报告人： 张何朋
单位： 上海交大
题目： Collective phenomena of chiral swimming microorganisms
摘要：Swimming microorganisms can develop collective phenomena with extended spatiotemporal coherence through interactions between individual cells. In this talk, I will discuss two recent studies on this subject. First, we carried out experiments with marine algae (Effrenium voratum), which swim in circles at the air-liquid interface, and discovered that effective hydrodynamic repulsion between cells in the far field suppresses density fluctuations and generates disordered hyperuniform states under a wide range of density conditions. The second study focused on bacteria (Paenibacillus vortex) colonies growing on agar plates. In this system, while active turbulence without manifest chirality takes place in the bulk, cells self-organize into a wide, clockwise (viewed from the air side) flow all along the typically tortuous centimeter-scale external boundary. We traced the origin of these robust edge flows back to a weak chiral symmetry breaking mechanism at the individual level. Experimental results in both studies were quantitatively reproduced in simple particle models with hydrodynamic and excluded-volume interactions.

口头报告 V03
报告人： 罗孟波
单位： 浙江大学
题目： 纳米颗粒拥挤环境中高分子链亚扩散的模拟研究
摘要：高分子的亚扩散是复杂环境的动力学表现，亚扩散反映了高分子与环境的复杂相互作用，理解高分子亚扩散的特征和机制具有重要科学意义。拥挤环境中的高分子，如高分子纳米复合材料中的高分子和细胞内部的生物大分子，不仅扩散变慢，而且扩散过程通常表现为亚扩散，即质心的均方位移随时间非线性增长 $<\Delta r^2(t)> \sim t^{\alpha}$ 且 $\alpha < 1$。我们通过计算机模拟研究了高分子在纳米颗粒拥挤环境中亚扩散，发现高分子的吸附、纳米颗粒的无序分布是引起高分子亚扩散的原因。高分子具有复杂的构象，在扩散的同时其构象也发生变化，这导致高分子在纳米颗粒上的吸附时间（或纳米颗粒间移动的等待时间τ）趋于无穷，从而引起高分子的亚扩散，这与连续时间随机行走(CTRW)的理论模型相似。当纳米颗粒的位置无序度ξ较高时，高分子可同时吸附到多个纳米颗粒上，导致高分子的等待时间τ变长而出现亚扩散的运动特征，很好地符合 CTRW 的理论模型。
参考文献
[1] C. Y. Li, C. J. Qian, Q. H. Yang and M. B. Luo, J. Chem. Phys., 2014, 140, 104902.
[2] C. Y. Li, M. B. Luo, J. H. Huang and H. Li, Phys. Chem. Chem. Phys., 2015, 17, 31877–31886.

[3] X. W. Huang, Y. Peng, J. H. Huang and M. B. Luo, Phys. Chem. Chem. Phys., 2017, 19, 29975–29983.
[4] D. A. Tsehay and M. B. Luo, Phys. Chem. Chem. Phys., 2018, 20, 9582–9590.
[5] Q. H. Yang, H. K. Qi, X. Yang and M. B. Luo, Soft Matter, 2021, 17, 1000–1007.
[6] D. Y. Hua, R. A. A. Khan and M. B. Luo, Macromolecules 2022, 55, 10468–10478.

口头报告 V04
报告人： 万端端
单位： 武汉大学
题目： Effects of orientational and positional randomness of particles on photonic band gap
摘要：Using computer simulations, we explore how thermal noise-induced randomness in a self-assembled photonic crystal affects its photonic band gaps (PBGs). We consider a two-dimensional photonic crystal composed of a self-assembled array of parallel dielectric hard rods of infinite length with circular or square cross section. We find that PBGs can exist over a large range of intermediate packing densities and the largest band gap does not always appear at the highest packing density studied. Remarkably, for rods with square cross section at intermediate packing densities, the transverse magnetic (TM) band gap of the self-assembled (i.e., thermal) system can be larger than that of identical rods arranged in a perfect square lattice. By considering hollow rods, we find the band gap of transverse electric (TE) modes can be substantially increased while that of TM modes show no obvious improvement over solid rods. We further investigate how PBGs are influenced solely by positional or orientational randomness of particles. Our study suggests that particle shape and internal structure can be used to engineer the PBG of a self-assembled system despite the positional and orientational randomness arising from thermal noise.

口头报告 V05
报告人： 孙运祥
单位： 宁波大学
题目： 功能性纤维 Suckerin 自组装过程中的“微相分离”现象和 pH-响应分子机理
摘要：蛋白质通过自由单体的聚集形成高度有序的交叉β纤维结构。这一过程因与阿尔茨海默病等淀粉样退行性疾病的密切关联而为人所知，但同时也作为一些蛋白质维持正常细胞和组织生理功能的一种功能形式而备受广泛关注。蛋白质多肽自组装纳米材料具有生物相容性、结构可控性和低免疫原性等优点，这为其在生物医学和生物纳米技术领域的广泛应用提供了重要保障。因此，揭示其自组装分子机理和内在的物理化学性质对未来蛋白质自组装纳米材料的设计和应用至关重要。在本次报告中，我以类嵌段共聚物的多肽——鱿鱼环齿功能性纤维 Suckerin 为例，探讨了其自组装过程中的“微相分离现象”、“热滞效应”和 pH 响应机制。

口头报告 V06
报告人： 黄栋

单位： 苏州大学
题目： 如何区分尘埃等离子体的强弱耦合？
摘要：尘埃等离子体，也称复杂等离子体，指由自由电子、离子、中性气体原子和带电尘埃颗粒组成的复杂系统。实验条件下，大量带电尘埃颗粒可自组织形成二维固体或液体，由于其颗粒运动合适的时空尺度，可通过顶视高速相机精确记录每个颗粒的运动轨迹，由此实现单颗粒动理学层面的完全测量。耦合参数是指系统颗粒间平均势能和平均动能之比。过去的研究人为地将耦合参数等于 1 定义为强弱耦合分界线，但这样的定义并没有明确的物理图像。我们通过对二维尘埃等离子体液体动力学行为的研究，发现当系统瞬时横波声速等于颗粒平均速率（20 倍熔点）时，此时系统的黏度正好处于最小值。这一结果揭示了黏度随耦合参数的变化的转变机制来自于系统的动力学机制转变。进一步研究发现，在典型液体区，系统黏度起源于单个颗粒失去或得到“最近邻”颗粒的微观动力学过程。基于该结果，我们提出可以将系统 20 倍熔点作为新的强弱耦合分界线。此外，通过计算机模拟系统地研究了不同参数条件下的二维和三维尘埃等离子体的动力学行为。通过计算系统的热容、扩散系数、黏度系数、热导系数等一系列物理量，发现它们随系统相对耦合参数的变化均满足标度律。更有意义的是，这些物理量均在系统二十倍熔点处发生显著转变，该转变点正好符合超临界流体中的 Frenkel 线。基于以上结果，我们认为，将系统 20 倍熔点定义为新的强弱耦合分界线具有明确的物理意义。

邀请报告 V07
报告人： 吴晨旭
单位： 厦门大学
题目：Wrapping dynamics and critical conditions for active nonspherical nanoparticle uptake
摘要：The cellular uptake of self-propelled nonspherical nanoparticles(NPs) or viruses by cell membrane is crucial in many biological processes with its universal dynamics, however, remaining to be elucidated. In this study, using Onsager variational principle, we obtain a general wrapping equation for nonspherical self-propelled nanoparticles. Two analytical critical conditions are theoretically found, indicating a continuous full uptake for prolate particles and a snapthrough full uptake for oblate particles. They precisely capture the full uptake critical boundaries in the phase diagrams numerically constructed in terms of active force, aspect ratio, adhesion energy density, and membrane tension. It is found that enhancing activity (active force), reducing effective dynamic viscosity, increasing adhesion energy density, and decreasing membrane tension, can significantly improve the wrapping efficiency of the self-propelled nonspherical nanoparticles. These results give a panoramic view of the uptake dynamics of active nonspherical nanoparticles, and may offer novel instructions for designing an effective active NP-based vehicle for controlled drug delivery.

邀请报告 V08
报告人： 叶方富
单位： 国科温州研究院/中国科学院物理研究所
题目： 活性物质与细胞动力学

摘要：活性物质是由自驱动的个体通过相互作用形成的非平衡多体系统。从物理角度看，细胞也是一种活性物质。细胞的运动或迁移，尤其是细胞群体的协同迁移，不仅调控胚胎发育、伤口愈合等生理过程，也在肿瘤侵袭转移过程中扮演重要的角色。细胞的迁移不仅受其所处的生化微环境影响，也同样受控于其所处的物理微环境，例如细胞外基质的几何特性以及力学特性等因素；单细胞本身的运动能力、细胞形状、细胞间黏附力也同样对细胞群体的协同迁移起重要作用。本报告将从活性物质理论出发，介绍报告人近期关于细胞迁移动力学研究的一些结果，聚焦三个问题：1)如何构建合理的粗粒化(物理模型去描述细胞群体动力学？2)细胞间如何通过胞外基质传输力学信号？3)胞外基质上的细胞迁移具有什么样的动力学特性？

口头报告 V09
报告人： 丁泓铭
单位： 苏州大学
题目： 纳米-生物界面作用的物理机制及调控策略研究
摘要：近年来，随着纳米技术的迅猛发展，纳米粒子在生物医学领域得到了广泛的应用。纳米粒子的引入也产生了各种各样的纳米-生物界面，例如纳米粒子与生物膜的界面，纳米粒子与蛋白质的界面，纳米尺度下生物大分子之间的界面等。深入理解纳米-生物界面相互作用，不仅能加深对一些基本生命问题的认识，同时也对设计新型纳米粒子并在实际应用有着重要的指导意义。近几年来，我们通过运用多尺度分子模拟方法，并与实验课题组保持密切合作，对上述问题展开了系统地研究。在纳米粒子与细胞膜界面作用方面，我们主要研究了纳米粒子表面修饰配体的物理化学性质对其内吞行为的影响，特别是发现之前忽视的配体嫁接到纳米粒子方式也会显著影响内吞效率和内吞途径；在纳米材料与血浆蛋白界面作用方面，我们主要揭示了纳米粒子表面蛋白冠形成的内在机制，特别是如何利用物理化学手段调控纳米材料表面蛋白冠的组成，从而精确控制纳米粒子的生物学行为。期望相关研究能够加深纳米粒子在生命过程中与各类界面的相互作用机制，并推进人工纳米粒子在材料化学、纳米医学等领域的广泛应用。

口头报告 V10
报告人： 陈梦瑶
单位： 南方科技大学
题目： Realizing the multifunctional metamaterial for fluid flow in a porous medium
摘要：Metamaterials are artificial materials that can achieve unusual properties through unique structures. In particular, their “invisibility” property has attracted enormous attention due to its little or negligible disturbance to the background field that avoids detection. This invisibility feature is not only useful for the optical field, but it is also important for any field manipulation that requires minimum disturbance to the background, such as the flow field manipulation inside the human body. There are several conventional invisible metamaterial designs: a cloak can isolate the influence between the internal and external fields, a concentrator can concentrate the external field to form an intensified internal field, and a rotator can rotate the internal field by a specific angle with respect to the external field. However, a multifunctional invisible device that can continuously tune across all these functions has never been realized due

to its challenging requirements on material properties. Inside a porous medium flow, however, we overcome these challenges and realize such a multifunctional metamaterial. Our hydrodynamic device can manipulate both the magnitude and the direction of the internal flow and, at the same time, make negligible disturbance to the external flow. Thus, we integrate the functions of the cloak, concentrator, and rotator within one single hydrodynamic metamaterial, and such metamaterials may find potential applications in biomedical areas such as tissue engineering and drug release.

口头报告 V11
报告人： 徐留芳
单位： 吉林大学
题目： 几个统计模型相变类型的计算模拟研究
摘要：统计物理与复杂系统领域的同步现象、涌现现象层出不穷。人们发展出了多类模型研究，并借助于计算机模拟手段研究这类问题。在统计物理经典模型里研究相变还是比较清楚的，但如果想将这些研究结果推广到诸如活性物质或非平衡稳态系统中，如何通过计算模拟手段描述其相变的分类与本质，一直是一个重要的问题。我们尝试基于 Vecsek 模型通过计算其关联长度与系统尺度等几个关键参数的关系，刻画其发生相变时的分类与本质，并尝试将此方法推广到不同的模型中，为利用统计物理方法研究复杂系统问题提供一种有效尝试。

邀请报告 V12
报告人： 徐莉梅
单位： 北京大学物理学院
题目： Order behind disorder in non-equilibrium phase transitions
摘要： Disordered systems exhibit unique properties that distinguish them from conventional physical systems. These include a lack of overall structural order and symmetry, non-equilibrium behavior in thermodynamics. As a result, traditional physical theories, such as those based on crystal-based solid-state physics, equilibrium statistical physics and phase transitions are inadequate to describe disordered systems. To address these challenges, it is essential to develop new approaches to characterize and understand the properties of disordered systems by uncovering hidden order behind the disorder, particularly those that may not be immediately evident due to the absence of long-range order. In this talk, I will discuss our recent progress on equilibrium and non-equilibrium phase transition, and its connection between the structure, thermodynamics, and dynamics of disordered systems. This is important for understanding the behavior of disordered systems, and is critical for establishing a universal theoretical framework for disordered systems.

邀请报告 V13
报告人： 徐磊
单位： 香港中文大学
题目： Experimentally Revealing the Three-Component Structure of Water
摘要：Combining principal component analysis (PCA) of X-ray spectra with MD simulations, we experimentally reveal the existence of three basic components in water.

These components exhibit distinct structures, densities, and temperature dependencies. Among the three, the two major components correspond to the low-density liquid (LDL) and the high-density liquid (HDL) predicted by the two-component model, and the third component exhibits a unique 5-hydrogen-bond configuration with ultra-high local density. As the temperature increases, the LDL component decreases and the HDL component increases, while the third component varies non-monotonically with a peak around 20 °C to 30 °C. The 3D structure of the third component is further illustrated as the uniform distribution of five hydrogen-bonded neighbors on a spherical surface. Our study reveals experimental evidence for water's possible three-component structure, which provides a fundamental basis for understanding water's special properties and anomalies [1].

[1] Zhipeng Jin, Jiangtao Zhao, Gang Chen, Guo Chen, Zhenlin Luo, and Lei Xu, Soft Matter 18, no. 39, 7486–96, 2022.

口头报告 V14

报告人： 汤启云
单位： 东南大学

题目： Evaporation Induced Liquid Expansion and Bubble Formation in Binary Mixtures

摘要：Recently, binary solvents have been employed to tailor the structure and thermodynamics of soft materials. Here we observe an anomalous liquid expansion after quenching the coexistence binary mixtures in the vapor phase to low pressures by using numerical calculations [1]. This evaporation-induced expansion can be attributed to the pressure imbalance near the liquid-vapor interface, which originates from the interplay between the complex thermodynamics of binary mixtures both in the vapor and liquid phases, as well as their dynamical asymmetries. In addition, careful modulation of the pressure quench in the vapor phase can result in spinodal bubble formation inside liquid phase. The findings indicate that the thermodynamics-kinetics interplay could foster our fundamental understanding of the evaporation process and promote its practical applications.

REFERENCES

[1] Q. Tang, M. Müller, Phys. Rev. Lett., 126, 028003 (2021).

口头报告 V15

报告人： 张传彪
单位： 菏泽学院

题目： 物质表面的纳米结构与性质对水结冰机制的影响

摘要：自然界中的结冰过程通常都是异相成核，物质表面的多种微观性质都会影响表面水的结冰机制。我们使用分子动力学模拟研究了亲疏水位点混杂排列的表面的水结冰过程，和受限空间导致的水结冰过程。通过研究亲疏水位点混杂排列的表面的水结冰过程，我们发现表面水的类冰预排列结构和这种预排列结构的尺寸对表面的成核能力有重要影响。当表面上存在一个大于临界核尺寸的，且足够光滑的局部区域时，该区域内的表面水会出现类冰预排列结构，这种预排列有利于降低成核自由能垒，从而有利于结冰。亲疏水位点的混杂排列会使表层水的预

排列结构消失，从而难以促进结冰。因此表面的整体平均性质并不能很好的指示表面的结冰能力，而临界核尺寸内的性质更能决定整个表面的结冰能力。通过研究受限空间导致的水结冰过程，我们发现当受限空间尺寸足够大，且受限距离恰好能容纳整数层冰时，受限空间内部的水会出现类冰预排列结构，从而容易促进结冰。受限空间内部水的结冰温度随着受限距离增加而波动式降低。我们也研究了冰从受限空间内部生长到外部的过程，发现受限空间外部水的结冰温度随受限距离的增大而减小。此外，我们也发现，不同于体相冰，二维受限冰的锯齿面（主棱面）比扶手椅面（次棱面）更容易促进结冰。这些结果可以使我们能更好的理解进而控制水的结冰过程。

口头报告 V16
报告人： 杨成
单位： 绵阳师范学院
题目： 液态水中的第三种微观结构
摘要：水是地球上最常见的液体，具有很多的反常性质。常温常压下的液态水是由高密度液体和低密度液体混合而成。我们通过全原子的分子动力学模拟发现，在液态水中水分子的微观结构除了已知的高密度结构和低密度结构之外,还存在一种含量较低的新的微观结构——超高密度的五氢键结构。这种新的结构分散在液态水中，会吸引高密度水分子，排斥低密度水分子。并且处在新结构水分子周围的高密度水分子会变得更加稳定。这一新的微观结构的发现使得液态水在空间结构和动力学上都变得更加的不均匀。

邀请报告 V17
报告人： 孙兆茹
单位： 上海科技大学
题目： 基于机器学习的水溶液研究
摘要：由于在能源、环境、生物等领域的重要应用，电解质溶液计算是统计计算物理的一大难题，其中不同浓度下离子对水中氢键影响的长短程效应，不同离子之间的特异性和协同性等问题是当前的研究热点之一。我们运用机器学习和第一性原理计算相结合的方法，对水溶液进行大规模的第一性原理精度的分子动力学模拟。在此基础上，我们研究了 MgX2 溶液中离子的特异性效应，并进一步研究了溶液中碳酸的解离反应。

邀请报告 V18
报告人： 陈亮
单位： 宁波大学
题目： 复杂碳基表面离子吸附的调控及应用
摘要： 碳基表面的离子吸附、脱附行为及其平衡，对碳基表面在离子筛分、浓缩、结晶过程在环境水处理、新功能晶体材料等领域应用极为重要。通过调节离子和碳基表面芳香环、及其离子与芳香环周围含氧基团等作用，在低离子浓度溶液实现高效离子筛分，其中对二价离子保持高截留率的同时，连续刷新高水通量记录；在中等离子浓度(未饱和)获得 Na2Cl、NaCl2 等阴阳离子配比和传统理解不同的晶体；通过碳基表面电势调控，实现了这些晶体高产量制备，进一步发现

这些晶体具有压电、金属性、磁性等优异物理特性；发展出放射性核素超高通量筛分、超高灵敏应力传感等原创颠覆性技术。

口头报告 V19
报告人： 王春雷
单位： 上海大学
题目： 界面水的有序行为对界面性质影响
摘要：本报告将首先简要介绍分子尺度上的水，并介绍分子尺度的水有序或无序结构如何影响表面性质，如润湿、摩擦、介电常数和冰成核。特别是，我预测了在室温下“不会完全润湿水的有序水”，这可以解决该领域的长期问题。一些工作在 TiO2 表面、滑石、羟基化 Al2O3、羟基化 SiO2 和一些金属表面上发现了类似的现象。

口头报告 V20
报告人： 赵亮
单位： 扬州大学
题目： 基于界面氧长程迁移的动态共价界面的大面积动态特性
摘要：动态材料与传统材料不同，它们能够自适应地调整自身结构，以对外界环境、物理/化学刺激作出动态响应。传统动态共价材料只能通过化学键的局部交换或成键实现材料的动态变化，无法实现化学组分沿界面的长程迁移。我们提出大面积动态共价界面的概念，通过界面上共价化学键的可逆断开或重连带来化学组分沿界面的长程迁移，实现大面积的动态共价特性。具体地，基于第一性原理的计算，以二维碳材料界面为载体，从石墨烯[1]、到具有曲率的碳纳米管[2]，再到多元碳环混合的联苯烯[3]，利用界面含氧官能团的碳氧键断裂/形成及质子迁移的可逆反应，实现含氧官能团的长程迁移，并探索出界面曲率[2]、金属衬底支撑[4]、界面形态设计[3]等调控大面积动态共价特性的方法，并应用于界面的水裂解反应[5]。这些研究暗示着二维材料大面积动态共价界面及动态特性的普适性，同时又展现出和界面自身结构相关的新特性，也为其在分子识别、界面催化等领域的应用提供理论支撑。
参考文献:
[1] Y. Tu*, L. Zhao et al., Water-Mediated Spontaneously Dynamic Oxygen Migration on Graphene Oxide with Structural Adaptivity for Biomolecule Adsorption, Chin. Phys. Lett., 37, 066803 (2020).
[2] G. Zhu, ..., L. Zhao*, Y. Tu*, Unexpected Spontaneous Dynamic Oxygen Migration on Carbon Nanotubes., Nanoscale, 13, 15231 (2021).
[3] B. Situ, …, L. Zhao*, Y. Tu*, Locally Spontaneous Dynamic Oxygen Migration on Biphenylene: a DFT study, Phys. Chem. Chem. Phys., Published Online. (2023).
[4] Z. Yan, ..., L. Zhao*, Y. Tu*, Remarkably Enhanced Dynamic Oxygen Migration on Graphene Oxide Supported by Copper Substrate, Nanoscale Horiz., 7, 1082 (2022).
[5] Z. Huang, ..., L. Zhao*, Y. Tu*, Unexpectedly Spontaneous Water Dissociation on Graphene Oxide Supported by Copper Substrate, J. Colloid Interf. Sci., 642, 112 (2023).

邀请报告 V21

报告人： 徐宁
单位： 中国科学技术大学
题目： Instabilities of disordered solids under load
摘要：Under quasistatic shear or compression, a disordered solid undergoes plastic deformations caused by mechanical instabilities. A widely accepted mechanism of the plasticity is the fold instability, which predicts a power-law vanishing of the lowest frequency of normal modes of vibration on approaching the instability. Assuming that disordered solids are close to instabilities, we predict that the lowest frequencies associated with fold instabilities contribute a density of vibrational states D(ω) □ ω^3 with ω being the frequency. This is also verified by our direct calculations of the density of vibrational states for disordered solids unstable to some deformations. We further find that, in addition to the fold instability, there exists another type of instability for systems with a non-vanishing second derivative of the interaction potential. Compared with the fold instability, this instability exhibits more discontinuous features, so we name it as discontinuous instability. We find that this instability is caused by the breaking of a stabilizing bond. Here we define the stabilizing bond as the bond whose removal will cause an unstable normal mode of vibration. We evidence that the stabilizing bonds generally exist in disordered solids, which may be new local indicators of mechanical failures of disordered solids.

口头报告 V22
报告人： 张天辉
单位： 苏州大学
题目： Dynamics of Quincke particles with Tunable Memory
摘要：Memory of active particles has profound effect on their collective behaviors. Quincke particles propelled by a square wave electric field (SWE) exhibit memory of velocity because of inertia and polarization. As the relaxation times of inertia and polarization become comparable with the half period of the square wave, Quincke particles exhibit frequency-dependent memory of velocity and propulsion. The memory of Quincke particles can be tuned and enhanced by amplitude and frequency of SWE. Most importantly, because of the dipolar interaction between particles with highly aligned velocity and in-plane dipoles, the memory of Quincke particles is enhanced in dense clusters. The dynamic clusters exhibit frequency-dependent collective behavior. In addition, the activity, in terms of speed, of Quincke particles is frequency-dependent as well. At high frequencies, where the activity of Quincke particles is highly reduced, dense active crystals form in which shock waves are excited and propagate with a persistent direction determined by memory.

口头报告 V23
报告人： 巫浩
单位： 国科温州研究院
题目： Vestigial Osmotic Pressure
摘要：Recent experiments have indicated that at least a part of the osmotic pressure across the giant unilamellar vesicle (GUV) membrane was balanced by the rapid

formation of the monodisperse daughter vesicles inside the GUVs through an endocytosis-like process. Therefore, we investigated a possible osmotic role played by these daughter vesicles for the maintenance of osmotic regulation in the GUVs and, by extension, in living cells. We highlighted a mechanism whereby the daughter vesicles acted as osmotically active solutes (osmoticants), contributing an extra vestigial osmotic pressure component across the membrane of the parent vesicle, and we showed that the consequences were consistent with experimental observations. Our results highlight the significance of osmotic regulation in cellular processes, such as fission/fusion, endocytosis, and exocytosis.

口头报告 V24
报告人： 沈翔瀛
单位： 南方科技大学
题目： Achieving adjustable elasticity with non-affine to affine transition
摘要：For various engineering and industrial applications it is desirable to realize mechanical systems with broadly adjustable elasticity to respond flexibly to the external environment. Here we discover a topology-correlated transition between affine and non-affine regimes in elasticity in both two- and three-dimensional packing-derived networks. Based on this transition, we numerically design and experimentally realize multifunctional systems with adjustable elasticity. Within one system, we achieve solid-like affine response, liquid-like non-affine response and a continuous tunability in between. Moreover, the system also exhibits a broadly tunable Poisson's ratio from positive to negative values, which is of practical interest for energy absorption and for fracture-resistant materials. Our study reveals a fundamental connection between elasticity and network topology, and demonstrates its practical potential for designing mechanical systems and metamaterials.

口头报告 V25
报告人： 郝少倩
单位： 浙江师范大学
题目： Directional Movement of Nano Substances on Asymmetric Surfaces
摘要：操控固体界面上物质的定向运动在化学、生物学、医学等领域有着重要的意义。近年来，研究人员提出了许多有效的方法来驱动物质的运动，即利用外界能量实现物质定向传输的主动型方法和利用界面性质或结构梯度来驱动物质运动的被动型方法。然而，目前的大多数研究只能实现物质的单向短程驱动，如何实现对纳米物质运动方向的操控和连续运动仍然是一个挑战。我们利用全原子分子动力学模拟方法，研究了非对称楔形表面上纳米液滴/颗粒的自发运动，并对其运动的物理机理进行了分析。首先，我们发现通过调节液滴的初始位置和润湿状态可实现液滴在楔形表面运动方向的调控，突破了液滴在楔形界面上只能单向运动的限制，建立了液滴运动的理论模型与模拟结果很好地吻合。其次，我们构建了石墨烯/六方氮化硼平面异质结实现了液滴的定向驱动，为界面调控液滴提供了新的方法，拓展了平面二维异质结的应用范围。最后，我们构建了非对称楔形轨道为纳米颗粒的连续运动提供了新的方法。这些结果为界面操控物质的定向运输提供了新的思路，有望对进一步设计基于纳米物质的自驱动界面提供指导。

邀请报告 V26
报告人： 谭鹏
单位： 复旦大学
题目： 玻璃转变和结晶过程的动力学关联
摘要：玻璃转变和结晶分别形成处于玻璃态的非晶固体和晶体。学界目前对玻璃相变和玻璃态的本质仍存在较大争议。不可否认的是，大部分实际体系中的玻璃转变和结晶过程在动力学方面存在密切关联，并且这个动力学过程是非各态历经和慢弛豫的复杂非平衡过程。我们将详细介绍我们在这一领域的研究中取得的一些进展，如结晶过程中的非经典形核路径、玻璃态结晶原理和玻璃态中多层级的弛豫的极限形式。最后，我们将讨论如何对这类非平衡过程在有限时间尺度内进行调控。

口头报告 V27
报告人： 雷群利
单位： 南京大学
题目： Self-Assembled Transformable Maxwell Crystals
摘要：Under thermodynamic equilibrium, colloidal particles in the disordered fluid state can self-assemble into ordered structures driven by either entropy or enthalpy. In this work, by using Monte Carlo simulation, we study the self-assembly of perfectly aligned rod particles with lateral flat cutting. We find that with the help of surface attractions particles with different cutting degree can self-assemble into different crystal phases characterized by different bond coordination z that varies from 3 to 6. Importantly, we identify a transformable Maxwell structure with redundant bonds (z=5). We find that this structure can support either bulk or edge floppy models depending on its Poisson's ratio that can be tuned from positive to negative by a uniform soft twist. This self-assembled transformable Maxwell structure may act as mechanical meta-materials with potential application in micro-mechanical engineering.

口头报告 V28
报告人： 王庭
单位： 云南大学
题目： Non-equilibrium thermodynamics of chiral active Brownian particles: from pressure to sedimentation
摘要：The equation of state (EOS) of active particles is a central issue in the thermal dynamics of active matter. While pressure is not a state function for non-chiral active particles with external torque[1], it is unclear whether the EOS exists and how the pressure behaves for active particles with intrinsic rotation (charity). By simulation and analytical calculation, we find the EOS exists for the mechanical pressure of ideal disk chiral active Brownian particles (CABPs). The pressure is independent of wall-particle interaction strength. Furthermore, we find that the pressure behaviors ranges from convectional flows to the thermal diffusion, and is strongly influenced by the system size and chirality, as indicated by the intrinsic convectional and diffusive length scales. Furthermore, we put the CABPs under gravity (sedimentation). We find the validity of

the equilibrium-like exponential decay of the density profile depends on the critical length scale of diffusion, while the failure of it essentially originates from the rich polarization field of the CABPs. Surprisingly, we also find the pressure on the bottom boundary is independent of charity. These findings deepen our understanding of the thermal dynamical behaviors of chiral active particle systems.

口头报告 V29
报告人： 周雨欣
单位： 同济大学
题目： 活性粒子的视觉感知集体行为
摘要：活性物质在不同尺度范围内能够展现出从随机结构到复杂结构的自组织行为。在生物系统中，从细菌菌落、细胞到动物，低密度下聚集和协同运动是一种普遍存在的现象。这往往需要个体组分之间的通信行为，而通信则需通过复杂的内部信号通路来实现。与生物系统相比，人工合成活性粒子的运动性可以通过磁场、电场、光、声波、化学物质等进行外部调节。关于活性粒子集体动力学的理论分析和数值模拟研究是十分广泛的。Vicsek 模型通过改变种群密度或邻近个体间的相互作用强度展现了各种时空模式。此外，人们还通过 Run-tumble 粒子模型和活性布朗粒子模型研究了活性物质系统的相分离现象。然而，目前研究主要通过分析粒子所受作用力探究其集体动力学行为，关于活性物质个体之间信息交流与其协同行为之间的关系鲜见报道。因此我们以朗之万方程为模型，将生物系统中广泛存在的信息交流方式引入活性粒子模型，研究在圆形环境中通过视觉感知进行信息交流改变自推进速度的活性粒子的集体动力学行为。通过改变感知范围参数、自推进持续长度以及噪声强度能够形成六角晶格、团簇以及混合相。结果表明该模型在非常低的填充率下，由于几何边界和视觉感知的联合影响活性粒子能够形成稳定紧密排列的团簇。

口头报告 V30
报告人： 施夏清
单位： 苏州大学
题目： 取向有序活性物质的敏感性
摘要： 在此报告中我将介绍二维干性取向有序活性物质的长程有序对于种群和基底空间淬火随机扰动的敏感性。种群扰动采用内在个体手性分布的形式。我们使用粒子模型和从中导出的流体动力学理论的组合，表明在有限系统中，所有有序相都能够抵抗有限数量的这种手性扰动。但是在热力学极限条件下，均匀活性极化序和向列序对任意手性淬火无序的扰动都不稳定。对于空间淬火随机扰动，我们发现在随机耦合过程中，极性有序相仍然具有长程有序性，但在各态历经和自平均效应与无扰动情况有本质不同。对于随机散射情况，极化序随着系统大小变化而变化，具有强烈的非自平均性，样品与样品的涨落占主导地位，这使我们阐明有序的热力学渐近状态非常困难。这些研究表明淬火随机扰动对活性物质系统的影响可以在热力学极限下改变系统的相态本质，定向有序活性物质对这种扰动非常脆弱。

## 分会场 VI：非线性科学与复杂网络

邀请报告 VI01
报告人：艾保全
单位： 华南师范大学
题目： 手性活性混合粒子的自发分离
摘要：我们利用数值模拟的方法研究手性活性混合粒子（顺时针转动粒子和逆时针转动粒子）自发分离的行为。结果表明，在运动引起的相分离（MIPS）过程中，手性混合粒子能够自发分离。MIPS 中隐藏的速度对齐使不同类型的粒子聚集在不同的团簇中，从而实现分离。在此过程中，噪声并不总是阻碍对粒子的分离，有时它能促进混合物的分离。由于该过程中隐藏的速度对齐不是全局的，因此，分离行为依赖系统尺寸的大小。此外，我们还发现 MIPS 引起的混合物分离与通过显式速度对齐作用引起的分离机制不相同。 这些发现对于理解手性混合物的分离机制，并可应用于活性混合物分离实验中。

邀请报告 VI02
报告人： 兰岳恒
单位： 北京邮电大学
题目： Koopman 分析在非线性动力学中的应用
摘要：怎样从时序数据获取非线性系统的动力学特征？怎样确定系统的重要结构和运动模式？怎样建立表达系统特征的简化模型？这些都是复杂系统研究的基本问题，需要有一套系统的分析方法。Koopman 算符理论直接从可观测量出发，考察定义在状态空间中相关函数的演化，从而将一个非线性问题转化为无穷维函数空间中的线性问题。所以，我们只需要选择合适的函数空间，就可以用一个高维的线性问题来近似原有的非线性问题，并保持相关的低频时空特征不变。目前这一理论被用于各种模型和数据的分析，产生了一批有重要意义的结果。我们将从 Koopman 算符的定义出发，讲述其基本性质和谱特征的数值计算方法，以及在几个典型非线性系统中的应用。

口头报告 VI03
报告人： 顾长贵
单位： 上海理工大学
题目： Frequency-amplitude correlation inducing first-order phase transition in coupled oscillators
摘要：The first-order phase transitions in coupled oscillators have been widely studied because of their discontinuity and irreversibility. In previous research, the designed coupling mechanisms between each pair of oscillators can cause the first-order phase transitions occur stably. In the present study, we propose a new mechanism which requires the existence of an inversely proportional relationship between the natural frequencies and the intrinsic amplitudes in the homogeneously coupled oscillators. Based on two classical oscillator models, i.e., the Poincar´e model and the Stuart–Landau model, the emergence of explosive oscillation death is independent of the frequency distributions. Our findings indicate that the first-order phase transitions can be induced by the frequency-amplitude correlation for the first time. Therefore, it provides a novel perspective to understand explosive phenomena in coupled oscillators.

口头报告 VI04
报告人： 邹勇
单位： 华东师范大学
题目： 相同步与耦合方向的识别
摘要：相位相干性分析最初是在 20 多年前引入的，用于理解两个弱耦合混沌系统之间的相互作用。近年来，它在气候科学中得到了广泛的应用，例如，确定 ENSO 和印度季风之间的相位一致性，以及南美季风系统和罗斯比波之间的相位相干性。然而，据我们所知，在这些已有的事件同步分析中，锁相平台长度没有得到充分考虑，而是将整个平台视为一个单独的事件。相位同步的平台包含着有助于定量表征不同位置之间的同步水平。此外，我们通过锁相平台的共发生率和前兆率，提出了所有锁相平台和极端干旱事件的广义事件同步分析。我们将巴西东北部周围海洋和降水之间的遥相关作为一个实例进行研究。最后，以脑电 EEG 数据为例，研究睁眼与闭眼两种状态下直接和间接连接的区别。

口头报告 VI05
报告人： 史贵元
单位： 北京师范大学
题目： 复杂网络非线性动力学临界点的普适上下界
摘要：从全球气候剧烈变化、生态系统大规模灭绝，到疾病大流行、信息爆炸式传播、金融市场系统性风险等，复杂系统在越过某个临界点时——由量变引发质变——可能会发生剧烈和不可逆的变化。预测复杂系统的临界点，是许多领域共同关心的研究前沿。然而，理论求解非线性复杂系统临界点的精确值极其困难，现有理论研究往往基于平均场等近似手段。而三体运动、蝴蝶效应等众所周知的例子告诉我们，在非线性系统中，任何近似都会使得最终的误差难以估计。本文中我们用构造、放缩等方法求解临界点严格的上下界，从理论上避免了高估或低估系统性风险的可能性。该工作证明了非线性动力系统的所有临界点都落在网络的最大 k 核与最大特征值之间。最后，论文以基因转录调控网络、生态网络、疾病传播等模型为例，对方法展开了验证和讨论。（注：报告主要基于已发表的期刊论文 https://doi.org/10.1103/PhysRevLett.130.097401）

口头报告 VI06
报告人： 樊华伟
单位： 西安邮电大学
题目： Eigenvector-based analysis of cluster synchronization in general complex networks of coupled chaotic oscillators
摘要：Whereas topological symmetries have been recognized as crucially important to the exploration of synchronization patterns in complex networks of coupled dynamical oscillators, the identification of the symmetries in large-size complex networks remains as a challenge. Additionally, even though the topological symmetries of a complex network are known, it is still not clear how the system dynamics is transited among different synchronization patterns with respect to the coupling strength of the oscillators. We propose here the framework of eigenvector-based analysis to identify the synchronization patterns in the general complex networks and, incorporating the conventional method of eigenvalue analysis, investigate the emergence and transition

of the cluster synchronization states. We are able to argue and demonstrate that, without a prior knowledge of the network symmetries, the method is able to predict not only all the cluster synchronization states observable in the network, but also the critical couplings where the states become stable and the sequence of these states in the process of synchronization transition. The efficacy and generality of the proposed method are verified by different network models of coupled chaotic oscillators, including artificial networks of perfect symmetries and empirical networks of non-perfect symmetries. The new framework paves a way to the investigation of synchronization patterns in large-size, general complex networks.

邀请报告 VI07
报告人： 黄子罡
单位： 西安交通大学
题目： How do neuromodulators promote cognitive flexibility
摘要：Neuromodulator system is essential for maintaining the normal cognitive function of biological brain, which can promote its flexibility to cope with complex environment and draw on advantages and avoid disadvantages. Modeling the dynamics of neuromodulator systems will help to understand their working mechanisms, effectively support clinical research on neural dysfunction, as well as novel brain-like intelligence research based on spiking neural networks. This talk introduces our recent works of dynamic modeling from mechanism to function of neuromodulator systems, such as dopamine, norepinephrine, and acetylcholine systems. And summarizes the important role of neuromodulator systems in realization of perception, cognition, memory, decision making and other functions, including the dopamine modulation of prime-recency balance in decision making, acetylcholine modulation of speed-precision balance in perception, norepinephrine modulation of attention and SNR optimization. The potential application of the dynamic model of neuromodulator systems in the field of brain-like intelligence is also briefly discussed.

邀请报告 VI08
报告人： 纪鹏
单位： 复旦大学
题目： 网络上的信号传播
摘要：具有时空特性的信号传播是复杂系统研究的基础问题之一，但是其与底层拓扑结构间的关系尚不明确。围绕这一问题，我们通过构建通用理论框架，将复杂网络局域拓扑特征与信号的时空传播动力学联系起来，解析提取出了网络模体在预测信号局域和全局响应中的作用。尤其是，以局域拓扑和全局链路为切入点，定性分析了网络局域模体与信号传递模式间的关联，定量了全局链路中模体空间分布对信号传递的叠加效应。研究结果为大脑中的神经传递模式预测提供了可靠理论依据，并为绘制全脑神经联接图谱反演提供了新方法。

邀请报告 VI09
报告人： 邹为
单位： 华南师范大学

题目： Solvable dynamics of coupled high-dimensional generalized limit-cycle oscillators

摘要：We introduce a new model consisting of globally coupled high-dimensional generalized limit-cycle oscillators, which explicitly incorporates the role of amplitude dynamics of individual units in the collective dynamics. In the limit of weak coupling, our model reduces to theD-dimensionalKuramoto phase model, akin to a similar classic construction of the well-known Kuramoto phase model from weakly coupled two dimensional limit-cycle oscillators. For the practically important case of D=3, the incoherence of the model is rigorously proved to be stable for negative coupling ($K < 0$) but unstable for positive coupling ($K > 0$); the locked states are shown to exist if $K > 0$; in particular, the onset of amplitude death is theoretically predicted. For $D \geq 2$, the discrete and continuous spectra for both locked states and amplitude death are governed by two general formulas. Our proposed D-dimensional model is physically more reasonable, because it is no longer constrained by fixed amplitude dynamics, which puts the recent studies of theD-dimensionalKuramoto phase model on a stronger footing by providing a more general framework forD-dimensional limit-cycle oscillators.

口头报告 VI10

报告人： 张永文

单位： 昆明理工大学

题目： 空气污染事件的复杂性和普适性研究

摘要： 由于人类工业化，污染物的排放，近年来我们要遭受空气污染事件的危害。空气污染事件表现出一些时空复杂性的特征。在空间上，我们发现空气污染物的关联函数存在幂律衰减行为，长达上千公里,冬季尤其显著（Zhang et al, EPL, 2018）；并且，我们通过对中国中东部和美国东西部的空气污染研究还发现了行星 Rossby 波（位于中高纬度地区的长尺度大气波列，波长为 5000～7000 公里）对地表空气污染物的生成有很重要的作用（Zhang et al, Geophys. Res. Lett, 2019）。在时间上，我们发现空气污染事件具有长期记忆行为（Yu et al, Front. Phys., 2022; Sci. Total Environ, 2023 ）；污染事件的等待时间分布服从一个统一标度法则，标度函数可以被广义的 Gamma 函数很好地拟合。

邀请报告 VI11

报告人： 胡岗

单位： 北京师范大学

题目： 寻找网络的暗节点和暗结构

摘要：从网络数据揭示网络结构（网络重构）是网络科学的重要问题。实际网络重构的一个重要困难是数据缺失，一些网络节点不能测量（暗节点），从网络部分可测节点（明节点）数据确定网络暗节点和相关暗结构成为网络科学的一个重要挑战。报告讨论如何充分挖掘明节点数据中的信息，并综合这些信息，提出暗节点最小子结构（motifs）概念，并利用这些 motifs 把网络的暗世界明化。

邀请报告 VI12

报告人： Konstantinos Efstathiou

单位： 昆山杜克大学
题目： Collective Dynamics of Coupled Second-Order Oscillators
摘要：Second-order oscillator networks generalize the famous Kuramoto model to take into account the effect of oscillator inertias and they present a much wider variety of dynamical behaviors. First, we discuss the self-consistent method that described the stationary states of such systems and we analyze the effect of inertia. However, such systems may also attain states that are not stationary. In these non-stationary states the order parameter, characterizing the degree of synchrony among oscillators, changes in time in an almost periodic manner. We demonstrate non-stationary states through numerical simulations and we associate their appearance to the formation of secondary synchronized clusters besides the main synchronized cluster. Then we discuss the role of inertia and of the frequency distribution of individual oscillators in the formation of secondary synchronized clusters using a combination of dynamical systems theory and simplified dynamical models. Finally, we extend the discussion for both the self-consistent method and the oscillatory states to the case of second-order Sakaguchi-Kuramoto oscillators. Based on joint work with Jian Gao (Beijing University of Posts and Telecommunications).

邀请报告 VI13
报告人： 罗玉辉
单位： 昭通学院
题目： 非线性混沌系统中随机重置诱导反常输运
摘要：非线性混沌系统中主要通过吸引域来表征系统状态对初始条件的敏感依赖，而分岔图则特征系统状态对系统参数的敏感依赖。在多种吸引域共存的系统中，随机重置对系统的粒子输运有何影响仍有待阐明。本报告基于具有随机重置和粗糙势的混沌系统中研究运动粒子的反常输运，并重点研究了随机重置、粗糙度和非平衡噪声如何影响粒子的输运，并揭示随机重置诱导非线性混沌系统中反常输运的物理机制：从动力学的角度来看，粒子被随机重置到一个新的吸引域，该吸引域可能不同于最初的吸引域。从能量景观的角度来看，粒子被随机重置到新能量状态的能量景观，该新能量状态可能不同于初始能量状态。这种重置可以导致无输运和有限净迁移之间或负迁移和正迁移之间的转变。粗糙度和噪声也会导致类似的转变。基于这种机制，粒子输运可以通过这些参数来调控，如随机重置、粗糙度和噪声的共同作用可以增强系统的稳定性、负迁移，以及类共振激活。通过方差（如均方速度等）和相关函数（如速度自相关函数、位置-速度相关函数等）来分析这些结果。这些结果在生物、物理、化学、甚至社会系统中有潜在应用。

口头报告 VI14
报告人： 郑志刚
单位： 华侨大学
题目： Enhanced explosive synchronization in coupled oscillators with higher-order interactions
摘要：Explosive synchronization underlying many realistic dynamic processes has attracted great attention in the various fields. We generalize the Kuramoto model with

heterogeneous coupling incorporating the higher-order interactions encoded with the simplicial complexes. It is shown that the introduced nonlinear couplings can significantly enhance the emergence of explosive synchronization in addition to the pairwise interactions. In particular, we uncover that the critical thresholds manifesting the onset or vanishing of the abrupt synchronization are enlarged as the fraction of the higher-order interactions increases. As a consequence, the backward critical order parameter characterizing the desynchronization transition and the width of hysteresis supporting the bistability are remarkably improved. More importantly, we provide an analytical treatment for untangling the stability properties of the equilibrium states at different levels, which allows us to understand the bifurcation mechanism and locate the associated critical points. This study is a step forward in highlighting the importance of higher-order interactions among dynamical units, which might provide control strategies for the induced abrupt emergent phenomena in networked system.

口头报告 VI15
报告人： 袁五届
单位： 淮北师范大学
题目： 突触强度变化引起神经动力学转变
摘要：实验发现，清醒时突触强度增强并伴随着神经元的非同步强直性（Tonic）发放，睡眠时突触强度减弱并伴有神经元的阵发性（Burst）发放，这种阵发性发放表现出同步的阵发性从而产生睡眠的慢波活动。进一步实验表明：突触强度增强对应着神经元从 Tonic 到 Burst 的发放转变，突触强度减弱对应着神经元从 Burst 到 Tonic 的发放转变。目前，针对这种突触强度的变化与神经动力学转变间的因果关系和网络动力学机制还不清楚。我们采用 Hindmarsh-Rose 神经元网络耦合模型研究发现，突触强度的变化可以引起相应神经动力学的转变，这种转变的动力学机制是耦合的突触电流所表现的振荡特性。特别地，在同质网络中不同的神经元基本上同时发生动力学转变，并且发生这种转变的临界突触强度与网络的平均度呈现出指数为-1 的幂律关系；在异质网络中，不同连接度的神经元所发生的这种转变是分层次的，对于连接度越大的神经元，其临界突触强度越小；当突触强度持续增大时，神经元的动力学在经过多层次、多时间尺度的同步动力学转变后最终达到完全同步（一种“病态”同步），这一结果表明了睡眠的重要性和必要性。另外，我们也研究了一种清醒和睡眠周期内一种交替变化的突触可塑性机制，这种可塑性机制可以自发地实现突触强度变化引起神经动力学转变的网络动力学。

口头报告 VI16
报告人： 陈理
单位： 陕西师范大学
题目： 公平演化动力学及其钉扎调控
摘要：效率与公平是社会发展必须兼顾的两个准则，与效率密切相关的合作行为之前已经研究了很多了，而从科学角度我们对公平演化机制尚不清楚，主流理论结果和行为实验结果存在矛盾。部分原因是以往理论的模型太过囿于理性经济人假设，假设个体是完全理性与自私的，但现实世界中并非总是如此，基于不同动机他们也常有善举。在此背景下，基于最后通牒博弈，我们放宽了理论假设，探

索人群中偶发的公平行为是如何影响人群整体的公平演化，我们揭示了小概率自发公平行为足以激发整体人群到完全公平水平，呈现典型一级相变过程。平均场理论分析表明公平演化呈现典型的双稳态结构，偶发公平行为能有效地驱动人群跳到高公平解。这一发现暗示着如果想提升社会的公平水平，可以通过钉扎少数人来实现。

References:
[1] Probabilistic fair behaviors spark its boost in the Ultimatum Game: the strength of good Samaritans. Guozhong Zheng, Jiqiang Zhang, Rizhou Liang, Lin Ma, and Li Chen, Journal of Physics: Complexity. 3, 035004 (2022).
[2] Pinning control of social fairness in the Ultimatum game, Guozhong Zheng, Jiqiang Zhang, Zhenwei Ding, Lin Ma, and Li Chen, Journal of Statistical Mechanics: Theory and Experiment, 2023, 043404 (2023).

邀请报告 VI17
报告人： 唐明
单位： 华东师范大学
题目： 复杂网络上的非马尔可夫传播动力学及其应用研究
摘要：具有时序特征的非马尔可夫传播动力学是当前网络传播领域的研究热点之一。目前相关研究面临着三个具有挑战性的问题：第一，缺乏一个普适的理论框架来分析和理解非马氏传播的时间演化过程。第二，非马氏传播在一定条件下是否可以等价为相应的马氏传播动力学？第三，非马尔可夫特性将如何影响网络中的动力学行为？针对这一非马氏传播过程，我们分别发展了一套平均场理论和点对近似理论,并关注了以上几个问题,获得了一些初步的结果。此外,我们也将非马尔可夫传播模型应用于真实流行病传播的预测与防控研究,取得了较好的效果。

邀请报告 VI18
报告人： 张海峰
单位： 安徽大学
题目： 动力学数据驱动的高阶网络结构重构
摘要：许多真实的复杂系统不仅仅具有二元关系的交互作用还存在多体之间的高阶交互作用，传统的复杂网络模型已不足以刻画这种复杂、多样的交互作用，因而对高阶网络模型的研究得到了广泛关注。现有的研究多是在高阶网络结构已知的基础上研究其上的动力学或者进行结构挖掘，然而在很多时候网络的结构是未知的，而节点上的动力学数据可能更容易获取，那么如何从节点的动力学数据重构出高阶网络结构具有重要的科学意义。本报告将介绍本课题组在这个方向的一些探讨，具体包括如何利用统计推断的方法从不同的动力学驱动的数据中重构出两类典型的高阶网络——单纯复形结构及一致超图结构。

口头报告 VI19
报告人： 徐克生
单位： 江苏大学
题目： Noise-induced coexisting firing patterns in hybrid-synaptic interacting networks

摘要：Variability in synaptic conductance has been evidenced by neuroscientists, but the precise mechanisms whereby it contributes to coexisting firing activities are subtle and remain elusive. We present an excitatory–inhibitory balanced neural network of nodes with hybrid synaptic coupling to investigate the dynamic role of synaptic noise intensity and excitatory weight in the appearance of coexisting firing patterns. This neural network can produce two forms of coexisting firing patterns: time-varying and parameter-dependent multistability under different combinations of synaptic noise intensity and excitatory weight. Synaptic noise intensity and excitatory weight are significant but different in producing two forms of coexisting firing states. Synaptic noise is beneficial for the emergence of various firing patterns and their firing transitions, and excitatory weight can change the synaptic noise intensity range of coexisting firing states. Our results shed light on the emergence of multistability in neuronal networks with hybrid interactions and peak synaptic variability.

口头报告 VI20
报告人：黄晓东
单位： 华南理工大学
题目： 心肌早搏的基本动力学机制
摘要：心律失常是导致心脏猝死的主要原因，而早搏是诱发心律失常的一种重要行为。我们之前的数值模拟研究表明非均匀的心肌组织中由于存在较大的空间复极梯度而导致动力学失稳，进而产生早搏[1-3]。但目前对其中分岔机制的认识仍不清楚。本报告介绍我们最近在这方面的工作进展[4]。我们采用一维非均匀可激发介质模型模拟非均匀心肌组织，通过数值模拟和线性稳定性分析的方法对其中的自激发行为进行研究，发现这一简单的模型具有复杂的时空性质，其可揭示早搏的三种分岔机制：超临界霍普夫分岔，双吸引子，亚临界霍普夫分岔。这些复杂的行为依赖于空间不均匀性的梯度以及恢复时间。这一简单模型的结果揭示了早搏发生的本质而普遍的规律，可为理解及控制相关心律失常提供新的认识。

邀请报告 VI21
报告人： 张宏
单位： 浙江大学
题目： Topological charge-density-vector method of identifying filaments of scroll waves
摘要：Scroll waves have been found in a variety of three-dimensional excitable media, including physical, chemical, and biological origins. Scroll waves in cardiac tissue are of particular significance as they underlie ventricular fibrillation that can cause sudden death. The behavior of a scroll wave is characterized by a line of phase singularity at its organizing center, known as a filament. A thorough investigation into the filament dynamics is the key to further explore the general theory of scroll waves in excitable media and the mechanisms of ventricular fibrillation. In this paper, we propose a method to identify filaments of scroll waves in excitable media. From the definition of the topological charge of filaments, we obtain the discrete expression of the topological charge density vector, which is useful in calculating the topological charge vectors at each grid in the space directly. The set of starting points of these topological charge

vectors represents a set of phase singularities, thereby forming a line of phase singularity, that is, a filament of a scroll wave.

口头报告 VI22
报告人： 张朝阳
单位： 宁波大学
题目： Kramers Rate Theory of Pacemaker Dynamics in Noisy Excitable Media
摘要：Rhythmic activities, which are usually driven by pacemakers, are common in biological systems. In noisy excitable media, pacemakers are self-organized firing clusters, but the underlying dynamics remains to be elucidated. Here we develop a Kramers rate theory of coupled cells to describe the firing properties of pacemakers and their dependence on coupling strength and system size and dimension. The theory captures accurately the simulation results of tissue models with stochastic Hodgkin-Huxley equations except when transitions from pacemakers to spiral waves occur under weak coupling.

口头报告 VI23
报告人： 姚成贵
单位： 嘉兴学院
题目： A minimal physiologically based model of the ultradian NREM-REM cycle
摘要：The study of sleep dynamics has attracted the attention of researchers due to their significance in maintaining normal development, stabilising various metabolic functions, and improving the body's immunity. We construct a sleep model with '3 flip-flops' to reproduce sleep's circadian and ultradian rhythms. Switch between wakefulness (Wake), rapid eye movement (REM) and non-rapid eye movement (NREM) sleep. We find that there exist two kinds of node-saddle bifurcation by applying the linear stability analysis for the new model with net drives, one controls the transition between wakefulness and sleep, and another regulates the cycle of NREM sleep and REM sleep. Further, we use the theory of potential landscapes to uncover the physical mechanism of the transition of brain state. The topography of the underlying landscape characterises the capability of changing from one form of the brain to another. We investigate how barrier height is influenced by net drive. When the net drive increases, the size and other states decrease. The corresponding transition of the brain state is quantitatively measured by changing the height of barriers.Finally, normal sleep with 24 hours of circadian rhythm and 1.5 hours of ultradian rhythm, which agrees with physiological data, is reduplicated under circadian, ultradian drive, and homeostatic processes with appropriate parameters.

口头报告 VI24
报告人： 张希昀
单位： 暨南大学
题目： A spatial vaccination strategy to reduce the risk of vaccine-resistant variants
摘要：The COVID-19 pandemic demonstrated that the process of global vaccination against a novel virus can be a prolonged one. Social distancing measures, that are

initially adopted to control the pandemic, are gradually relaxed as vaccination progresses and population immunity increases. The result is a prolonged period of high disease prevalence combined with a fitness advantage for vaccine-resistant variants, which together lead to a considerably increased probability for vaccine escape. A spatial vaccination strategy is proposed that has the potential to dramatically reduce this risk. Rather than dispersing the vaccination effort evenly throughout a country, distinct geographic regions of the country are sequentially vaccinated, quickly bringing each to effective herd immunity. Regions with high vaccination rates will then have low infection rates and vice versa. Since people primarily interact within their own region, spatial vaccination reduces the number of encounters between infected individuals (the source of mutations) and vaccinated individuals (who facilitate the spread of vaccine-resistant strains). Thus, spatial vaccination may help mitigate the global risk of vaccine-resistant variants.

口头报告 VI25
报告人： 董家奇
单位： 兰州大学
题目： 最优化马尔科夫随机搜索与覆盖时间的软下界
摘要：在面对具有复杂结构的大系统时，受限于有限的记忆容量，基于随机行走模型的搜索算法常常是我们获取系统内信息的主要手段。随机搜索的效率通过随机行走的平均覆盖时间，即访问系统中全部节点的平均时间，进行衡量。平均覆盖时间更小的随机行走模型不仅是生物演化的潜在方向，其对于工程技术中的搜索、局部路由器等算法设计也具有非常重要的意义。 在本次报告中，我们以异质系统中的普适覆盖时间分布理论为基础，提出了一种估计马尔科夫随机搜索算法覆盖时间下界的理论方案。该理论指出，最优随机搜索的重标度覆盖时间的最概然值不会小于 N lnN，而平均覆盖时间的下界则会略大于 N lnN。当随机搜索只能通过在邻居间跳转实现时，受限于具体的网络结构，“最优”随机搜索的平均覆盖时间常常无法达到理论下界，此时，随机搜索的优化方向是尽可能是减小首通时间的涨落，而非减小全局平均首通时间。我们以理论优化指标为基础，通过引入了“等效停留时间”，提出了“软”覆盖时间下界的概念，并以 ER 随机图和无标度网络为例，展示了两类网络结构中随机搜索的“软”覆盖时间下界。我们的工作为定量评价随机搜索算法，理解复杂系统中的演化方向提供了基础理论。

邀请报告 VI26
报告人： 占萌
单位： 华中科技大学
题目： 新能源电力系统同步稳定多尺度建模与分析
摘要：电力系统是非常重要的基础设施，被誉为现代文明的基石，同时又是已知的最为复杂的人造系统。当前电力系统正经历着第二次伟大历史变革，即以电力电子为主导的多样化装备（如风机、光伏、直流等）正逐步大规模替换传统电力设备（如同步发电机）。相应地，国内外已经出现了多次机理不明的电网振荡事故，尤其在新能源注入率较高的弱电网条件下。事故并没有得到很好解决，当前人们也仍缺乏对于新一代电力系统的基础认识。报告将从以传统同步发电机为主导的传统电力系统稳定问题出发，提炼新一代电力系统动态稳定问题与框架，介

绍报告人研究小组的一些研究进展及成果，以此激发统计物理与复杂系统方向的研究人员的广泛兴趣。

邀请报告 VI27
报告人： 杨会杰
单位： 上海理工大学
题目： Synchronization of Chaotic Systems from the Perspective of Machine Learning
摘要：Machine learning models, such as the reservoir computing, the long-short-term memory, and the deep-belief neural networks have made great success in shor-term prediction for chaotic systems. But whether these trained machine learning models have really captured the characteristics of the learned systems is a basic scientific question to be answered. In this investigation we try to answer it by means of the synchronizations between the trained reservoir computing models and the corresponding chaotic systems. Interesting findings include: (1) The topological characteristics of a trajectory generated by a trained reservoir computing neural network, such as the correlation-dimension, the multi-scale entropy, and the memory effect, are very close with that for the real one. (2) The reservoir computing models successfully trained with the trajectories of hyper-chaotic subsystems or spatiotemporally chaotic systems can synchronize robustly with the learned real systems. (3) A drive-response scheme of reservoir computers coupled by a nonlinear controller is proposed to realize lag synchronization, providing a new data-driven route to achieve lag synchronization. (4) The reservoir computing model, long short-term memory network and deep belief network can reproduce successfully the statistical properties of correlation dimension and recurrence time for chaotic systems. And by sharing a common signal, the pairwise, cascading and ring-coupled synchronization between machine learning models are realized. Hence, the models are equivalent in characterizing and modeling chaotic systems. In a nut-shell, the machine learning model can not only predict chaotic systems in the short term, but also capture the long-term characteristics of the learned system. Robust synchronizations among the trained neural network models and the real chaotic systems can be realized. These evidences show that the well-trained machine learning models have captured the characteristics of complex chaotic systems.

口头报告 VI28
报告人： 王圣军
单位： 陕西师范大学
题目： Power-law statistics of synchronous transition in inhibitory neuronal networks
摘要：We investigate the relationship between the synchronous transition and the power law behavior in spiking networks which are composed of inhibitory neurons and balanced by dc current. In the region of the synchronous transition, the avalanche size and duration distribution obey a power law distribution. We demonstrate the robustness of the power law for event sizes at different parameters and multiple time scales. Importantly, the exponent of the event size and duration distribution can satisfy the critical scaling relation. By changing the network structure parameters in the parameter region of transition, quasi-criticality is observed, that is, critical exponents depart away

from the criticality while still hold approximately to a dynamical scaling relation. The results suggest that power law statistics can emerge in networks composed of inhibitory neurons when the networks are balanced by external driving signal.

口头报告 VI29
报告人： 熊科诏
单位： 西安科技大学
题目： 复杂网络上的局域化热输运现象
摘要： 复杂网络普遍存在于自然和人造系统，近年来网络科学吸引了极大的关注，但很少有人关注其对热传导的影响。目前对热传导的研究主要集中在一维（1d）和二维（2d）晶格等规则系统上，然而诸如纳米颗粒网络以及纳米纤维网络等现实系统不是规则的，而是异质结构的，它们的热传导性质在很大程度上仍是未知的。基于纳米网络的飞速发展以及它们在工程和技术上的重要性，了解热在这些真实的纳米网络上是如何传导的以及网络结构对热传导的影响已经显得非常必要。本次报告将从模型建立，数值模拟和理论分析三个方面简要介绍复杂网络的结构变化对网络热传导的影响，以及相关的局域化热输运现象。

口头报告 VI30
报告人：周杰
单位： 华东师范大学
题目： The structure of uni-directional chain for the synchronization of networked chaotic systems
摘要：In this paper, we introduce the structure of uni-directional chain (UDC) as a benchmark to probe the synchronizability of networked chaotic system. By studying the relation between the length of UDC and its synchronizability, we identify a region of coupling strength, referred to as strong controllable region (SCR), where a UDC with arbitrary length could realize synchronization that is robust to non-local disturbance. More importantly, it is found that there exists a kind of chaotic oscillators where the region of negative master stability function (MSF) overlaps with the SCR. As MSF implements local stability analysis to provide the necessary condition for the appearance of synchronization, while SCR permits stable synchronization corresponding to non-local disturbance pertinent to sufficient condition, the role of MSF for such kind of oscillator may be equivalent to provide sufficient condition of network synchronization. Besides, we propose methods for the control of network synchronization based on the characteristic of UDC. For networks with fixed structure, by obtaining a minimal spanning tree, each node chooses one of its neighbors and follows its dynamics with uniform coupling strength to realize synchronization. For growing networks, by establishing directed connection from newly added nodes to existing nodes. An interacting structure which is similar to the combination of a group of UDCs is formed and the system is guaranteed to be controlled within the SCR.

## 分会场 VII：生命与生态系统

邀请报告 VII01

报告人：汤雷翰
单位：香港浸会大学
题目：Agent-based model of COVID-19 transmission for location-specific risk assessment and control
摘要：Since the emergence of the Omicron variant in November 2021, control measures that were highly effective against previous SARS-CoV-2 strains have been shown to be insufficient to stop the virus, leading to sweeping outbreaks or lockdowns. Furthermore, mass qPCR test has been practiced in many places as an ultimate means of source control. Local authorities adjust the frequency of testing according to the overall scale of the outbreak. Public venues such as shopping malls, airports, etc., allow entry only when negative test result within a certain period is presented. So how effective are these measures? To answer this question, we consider an agent-based model of disease transmission which can be adapted to a great variety of community transmission patterns. From the statistics of individual's visit trajectories, a location-based network model for transmission risk propagation can be established. Under a given daily routine of individuals in the community, the model is able to predict the epidemic growth rate  in terms of the characteristics of disease progression within an infected individual, and of the propagation matrix linking a list of locations. Furthermore, a risk index can be assigned to each location that corresponds to its significance as a transmission node. The effectiveness of testing and quarantine measures in reducing  can be evaluated quantitatively without going into the details of the visit pattern. On the other hand, transmission hotspots and amplifying mechanisms can be identified through a detailed study of the risk propagation matrix. We illustrate these concepts and results via simplified scenarios which nevertheless could aid the design of more efficient epidemic control measures, particularly when combined with human mobility data and practices.

邀请报告 VII02
报告人：汪劲
单位：Stony Brook University
题目：分子生物学和系统生物学的物理机制
摘要：The rapid data accumulations in biology have motivated the development and refinement of concepts and tools to dissect the physical mechanisms underlying living systems. Notably, landscape and flux theory has proven useful in this endeavor. Together with the concepts and tools developed in other areas of physics, significant progress has been made in unraveling the principles underlying molecular and systems biology. Here recent advances in nonequilibrium landscape and flux theory are reviewed and their application to biological systems is surveyed. Many of these results are expected to be important cornerstones as the field continues to build our understanding of life.

口头报告 VII03
报告人：梁师翎
单位：洛桑联邦理工学院
题目：Universal thermodynamic bounds on symmetry breaking in living systems

摘要：Living systems are maintained out-of-equilibrium by external driving forces, thus continuously dissipating energy. Non-equilibrium steady states are characterized by emergent selection phenomena that break equilibrium symmetries dictated solely by energetic properties. In our recent work [1], we use the matrix-tree theorem to derive universal thermodynamic bounds on these symmetry-breaking features in biochemical systems. The presented bounds are independent of the kinetics and hold for both closed and open reaction networks, whether they are uni-molecular or catalytic. Our results can also be extended to the Master Equations in the chemical space. Using our framework, we recover the thermodynamic constraints in kinetic proofreading. Finally, we show that the contrast of reaction-diffusion patterns can be bounded only by the non-equilibrium driving force. The generality of these results paves the way to understanding the potentialities and limitations of non-equilibrium conditions in shaping steady-state properties of biochemical systems.

口头报告 VII04
报告人：徐丽
单位：中科院长春应化研究所
题目：非平衡态生态系统的稳定性研究
摘要：复杂系统可以表现出稳定状态之间的转换。我们采用非平衡统计力学中的势与流的能量地貌理论作为量化生态系统全局稳定性的一般框架。我们探索了一个经典的浅水湖泊模型，该模型显示了图 1A 中确定性相图与营养水平的关系。系统有两种稳定状态，是一个典型的鞍节分叉。图 1B 显示了随着养分增加的系统的能量地貌的变化。我们可以将平均通量解释为非平衡驱动力，将熵产生速率解释为非平衡热力学损耗。此外，非平衡互相关函数的时间不可逆性可以被视为关键跃迁的预警信号。我们的预警预测基于随机非线性系统的势与流的能量地貌方法。该方法是通用的，可用于探索许多其他复杂生态系统的稳定性。本文中的早期预警信号可以潜在地预测关键转变。而且它们比传统的既定方法更早。

口头报告 VII05
报告人：蔡蔚然
单位：苏州大学
题目：生命的群舞：互利网络形成的自适应机制与其动力学特性
摘要：互利网络是一种通过物质或服务的交换达成的合作形式，在生态乃至社会-经济系统中都扮演着关键角色。在多地域和多种群的经验观察中早已发现这类网络普遍表现出高度关联的嵌套化和模块化模式，然而其形成的机理却尚未阐明。受种群适存度最大化原则驱动，我们提出一种基于栖位的自适应优化机制使这两种结构可同时自然产生，并在数据比对中得到验证。由此机制，我们澄清了互利网络在多个时间尺度上的关键动态属性，包括互利作用对网络稳定性的双向作用以及对环境变化的记忆效应。最重要的是我们发现在进化时间尺度上，这两种特征结构之所以能在种群入侵和消亡的压力下仍得以保持，是与这种自适应性密不可分的。

口头报告 VII06
报告人：康举

单位：中山大学物理学院
题目：Intraspecific predator interference promotes biodiversity in ecosystems
摘要：Explaining biodiversity is a fundamental issue in ecology. A long-standing puzzle lies in the paradox of the plankton: many species of plankton feeding on a limited type of resources coexist, apparently flouting competitive exclusion principle (CEP), which holds that the number of predator (consumer) species cannot exceed that of the resources at steady state. Here we present a mechanistic model, and show that the intraspecific interference among the consumers enables strikingly a plethora of consumer species to coexist at constant population densities with only one or a handful of resource species. The facilitated biodiversity is resistant to stochasticity, either with stochastic simulation algorithm or individual-based modeling. Our model naturally explains the classical experiments that invalidate CEP, quantitatively illustrates the universal S shape pattern of the rank-abundance curves across a wide range of ecological communities, and can be broadly used to resolve the mystery of biodiversity in many natural ecosystems.

邀请报告 VII07
报告人：刘锋
单位：南京大学
题目：转录爆发的调控和约束机制
摘要：Gene transcription often occurs in discrete bursts, and it can be difficult to deduce the underlying regulatory mechanisms for transcriptional bursting with limited experimental data. Here, we categorize numerous gene states and identify six essential transcriptional events, each comprising a series of state transitions; transcriptional bursting is characterized as a sequence of four events, capable of being organized in various configurations, in addition to the beginning and ending events. Associating the transcriptional kinetics with the mean durations and recurrence probabilities of the events enables us to unravel how transcriptional bursting is modulated by various regulators including transcription factors. Through analytical derivation and numerical simulation, this study reveals key state transitions contributing to transcriptional sensitivity and specificity, typical characteristics of burst profiles, global constraints on transcription noise, major regulatory modes in individual genes and across the genome, and requirements for fast gene induction upon stimulation. Our results suggest that transcriptional patterns are essentially controlled by a shared set of transcriptional events operating under specific promoter architectures and regulatory modes, the number of which is actually limited.

邀请报告 VII08
报告人：张胜利
单位：西安交通大学
题目：Studies on the Dynamic Structures of Several Key Proteins
摘要：In this talk, we give a report on our recently studies on the dynamic structures of several key proteins. Lymphokine-activated killer T-cell-originated protein kinase (TOPK) is a potential target for cancer therapy. We proposed the N-terminal premodel

(NTPM) of the TOPK monomer via homology modeling and molecular dynamic simulations and analyzed the conformational dynamics by Markov state model analysis. The electronegative insert (ENI) motif of the NTPM can be opened with a small probability under wild type, regulated by the so-called "N-C" interaction zone consisting of the N-terminal head, the coil between $\beta$3-strand and $\alpha$C-helix, and the ENI motif. Glutamate substitution at threonine residue 9 or tyrosine residue 74 promotes the closed-open transition, revealing the details of phosphorylation. From the X-ray experimental data, we identified the inactive and active states of p38$\alpha$ using principal component analysis. To understand the auto-activation process and the internal driving mechanism, a computational paradigm that couples the targeted molecular dynamics simulations, the String Method, and the umbrella sampling strategy were employed to generate the conformational landscape of p38$\alpha$. Auto-activation of p38$\alpha$ is regulated by pY323 through destabilization of the hydrophobic core structure and aided by R173, which explain the conformational transition of p38$\alpha$ induced by Y323 phosphorylation. Additionally, with the binding of TAB1, the conformational changes of p38$\alpha$ auto-activation were characterized by the movement of the activation loop (A-loop) away from the $\alpha$G helix toward the $\alpha$F, $\alpha$E helixes and L16-loop. The conformational changes, including the A-loop alpha-structure breaking and the stronger hydrogen bond network formation, are accompanied by the extension of the A-loop and more intramolecular interactions in p38$\alpha$. TAB1 correlates with other regions of p38$\alpha$ that are distal from the TAB1-binding site, including the A-loop, $\alpha$C helix, and L16-loop, which regulates the intramolecular correlation of p38$\alpha$. And, the phosphorylation further enhances the correlations between the A-loop and the other regions of p38$\alpha$. The correlation results imply the regulation process of p38$\alpha$ conformational transformations.

口头报告 VII09
报告人：刘艳辉
单位：贵州大学
题目： Quantification of macromolecule crowding at single molecule level
摘要：Macromolecule crowding has a prominent impact on a series of biochemical processes in the cell. It is also expected to promote macromolecular complexation induced by excluded volume effects, which is conflicting with the recent advances in the thermodynamic interaction between inert, synthetic polymers, and nucleic acids. Along this line, a novel method combining high-resolution magnetic tweezers and extended crowder-oxDNA model was applied to resolve these discrepancies by systematically studying the kinetics and thermodynamics of the folding/unfolding transition for an individual DNA hairpin in a crowded environment. More specifically, from the magnetic tweezersbased experiments, the linear dependence of critical force of DNA hairpin on the PEG concentration was demonstrated, which is consistent with the results based on the crowder-oxDNA model in which the Lennard-Jones potential was adopted to express the interaction between the crowders and DNA hairpin. These consistencies highlight that the excluded volume effects are mainly responsible for the interaction between PEG and DNA hairpin, which is different from the interaction between dextran and DNA hairpin. In the meantime, the dependence of the folding rate

on the molecule weight of PEG, which was diffffferent from FRET-based results, was fifirst identifified. The proposed method opens a path to detect the interaction between an inert, and synthetic molecule, and the DNA hairpin, which is important to accurately mimic the cytosolic environments using mixtures of different inert molecules.

口头报告 VII10
报告人：徐新鹏
单位：广东以色列理工学院
题目：Persistent random walk: a phenomenological paradigm for cell migration on solid substrates
摘要：Cell physics; Cell migration; Persistent random walk; cell-matrix interactions
Abstract: Cell migration is essential to many biological processes such as embryonic morphogenesis, wound healing, and cancer progression. The main challenge in the study of cell motility is to understand how cells respond to external stimuli such as chemical, geometrical, and physical signals. The response frequently involves movement toward or away from an external stimulus, and such a response is called a taxis. Many different types of taxis are known, including chemotaxis, haptotaxis, curvotaxis, and durotaxis, etc. Such cellular taxis are characterized, in most biological literature, simply as positive or negative, depending on whether it is toward or away from the external stimulus. However, another important feature in the tactic movement of living cells – the non-negligible active random fluctuations – has not been accounted properly. In this talk, I adopt a simple way to account for such active fluctuations, without resolving the underlying complex molecular mechanisms, by introducing stochastic forces into the equations of motion of individual cells. Such phenomenological description of the random motion of living cells has a long history dating back to Przibram (1913) and Furth (1920), who introduced the notion of persistent random walk (PRW) to the description of random swimming of living microorganisms. However, the PRW model has not been applied to the migration of crawling animal cells until Gail and Boone (1970) for fibroblasts on flat, homogeneous solid substrates. Later on, the PRW model has been found to work also well for many (although not all) cell types such as blood neutrophil leucocytes (Allan and Wilkinson, 1978), microvessel endothelial cells (Stokes et al, 1991), and lung epithelial cells (Wright et al, 2008). I propose that the PRW model and the related self-propelled particle models provide a phenomenological paradigm for the quantification of cellular taxis, in which the fluctuations or randomness is taken into account by persistent random motion and the taxis is included into some “potentials” derived from phenomenological cell models. Based on this simple idea, I will present our theoretical models for some typical cellular taxis such as haptotaxis on substrates with fibronectin gradients, curvotaxis on stiff cylinders, and durotaxis on substrates with stiffness gradients. [1]. Xiaoyu Yu#, Haiqin Wang#, Fangfu Ye, Qihui Fan*, Xiaochen Wang*, and Xinpeng Xu*, Biphasic curvature-dependence of cell migration inside microcylinders: persistent randomness versus directionality, bioRxiv:2022.522287 (Doi: 10.1101/2022.12.30.522287), Submitted.

口头报告 VII11
报告人：曹远胜
单位：清华大学
题目：The physical basis for the diversity of eukaryotic cell migration
摘要：Cell migration is a vital process in wound healing, immune response and cancer metastasis. One of the major challenges in understanding the eukaryotic cell migration is the huge diversity of migration modes, despite the conserved machinery. Here we develop a simple physical model that combines signaling dynamics and cell morphology, and show that distinct cell migration modes emerge from the mechanochemical coupling. Moreover, our investigation reveals that the observed patterns of traction forces in different Dictyostelium cell types can be attributed to non-specific frictional interactions between cells and their substrate. Our model provides a simple but comprehensive framework to understand the diverse phenotype of cell migration.

邀请报告 VII12
报告人：傅雄飞
单位：中国科学院深圳先进技术研究院
题目：Pattern diversity emerges from a simple gene network
摘要：Bacterial colony development involves cell growth and collective motion, resulting in a spatiotemporal community with environmental heterogeneity and stochastic cell positioning. Recent research has shown that Escherichia coli, with a simple synthetic circuit known as the mutually repressing switch, exhibits growth-rate dependent bistability mediated by cellular metabolic conditions. In this study, we report on an autonomously patterned system that emerged from a simple cell-fate-decision network with the power of deterministic bifurcation and stochastic gene expression fluctuation. The deterministic bifurcation introduces a ring-shaped zone at the level of the whole colony, which can be programmed by a set of parameters. The stochastic gene expression induces segregation strips at the moving front, which are strongly affected by the population heterogeneity of the early establishment stage of the bacterial colony. Taken together, our results show that a simple network that responds to environmental cues can create diverse patterns via environmental heterogeneity and intrinsic gene expression fluctuation.

邀请报告 VII13
报告人：王寿文
单位：西湖大学
题目：Learning cell dynamics from single-cell genomic data
摘要：A goal of single cell genome-wide profiling is to reconstruct dynamic transitions during cell differentiation, disease onset, and drug response. Single cell assays have recently been integrated with lineage tracing, a set of methods that identify cells of common ancestry to establish bona fide dynamic relationships between cell states. These integrated methods have revealed unappreciated cell dynamics, but their analysis faces recurrent challenges arising from noisy, dispersed lineage data. Here, we develop

coherent, sparse optimization (CoSpar) as a robust computational approach to infer cell dynamics from single-cell transcriptomics integrated with lineage tracing. Built on assumptions of coherence and sparsity of transition maps, CoSpar is robust to severe down-sampling and dispersion of lineage data, which enables simpler experimental designs and requires less calibration. In datasets representing hematopoiesis, reprogramming, and directed differentiation, CoSpar identifies early fate biases not previously detected, predicting transcription factors and receptors implicated in fate choice. Documentation and detailed examples for common experimental designs are available at https://cospar.readthedocs.io/. I will also briefly touch on our recent progress in developing a new lineage tracing mouse model with extremely large barcode capacity and possibility to computationally decode cellular lineages from single-cell genomic measurements.

口头报告 VII14
报告人：林杰
单位：北京大学
题目：Fingering instability accelerates population growth of a growing cell collective
摘要：During the growth of a cell collective, such as the development of microbial colonies, the local cell growth increases the local pressure, which in turn suppresses cell growth. How this pressure-growth coupling affects the growth of a cell collective remains unclear. Here, we answer this question using a continuum model of cell collective. We find that a fast-growing leading front and a slow-growing interior of the cell collective emerge due to the pressure-dependent growth rate. The leading front can exhibit fingering instability and we confirm the predicted instability criteria numerically with the leading front explicitly simulated. Intriguingly, we find that fingering instability is not only a consequence of local cell growth but also enhances the entire population's growth rate as positive feedback. Our work unveils the fitness advantage of fingering formation quantitatively and suggests that the ability to form protrusion can be evolutionarily selected.

口头报告 VII15
报告人：王维康
单位：中科院理论物理所
题目：Quantification of cell phenotype transition manifold with information geometry
摘要：Cell phenotype transition (CPT) is widely happened in many biological processes like development and precise control of CPT is critical in these processes. Recent advancements in single-cell sequencing techniques have revealed that cell transition dynamics in development are confined to low-dimensional manifolds. However, there is currently no available method for quantifying the manifolds from experimental data. Current methods, such as manifold learning, can only preserve the topology information and only be used for visualization. In this work, we present a novel method to quantify the cell phenotype transition manifold using information geometry. We transform single cells' high-dimensional expression vectors into probability distributions with Gaussian embedding. The Fisher-Rao metric is then defined naturally

in this embedding space. And with the defined metric, we calculated the Ollivier-Ricci curvature of each single cell. Our analyzes revealed that cells with low curvature are related to critical transition. To further analyze the invariant characteristics of the manifold in CPT, we calculated the information velocity of each single cell based on RNA velocity, which also contains the information of critical points. We applied this method to different single-cell RNA sequencing datasets. Comparing with traditional methods, our approach focuses on analyzing the invariant characteristics of the manifold in CPT. And the results illustrated that it can be a general approach for quantifying the CPT manifold.

口头报告 VII16
报告人：白阳
单位：中国科学院深圳先进技术研究院
题 目 ： Cross-regulation between proteome reallocation and metabolic flux redistribution governs bacterial transition kinetics during nutrient shifts.
摘要：Bacteria need to adjust their metabolism and protein synthesis simultaneously to adapt to changing nutrient conditions. It's still a grand challenge to predict how cells coordinate such adaptation due to the cross-regulation between the metabolic fluxes and the protein synthesis. Here we developed a dynamic Constrained Allocation Flux Balance Analysis method, which integrates flux-controlled proteome allocation and protein limited flux balance analysis. This framework can predict the redistribution dynamics of metabolic fluxes without requiring detailed enzyme parameters. We reveal that during nutrient up-shifts, the calculated metabolic fluxes change in agreement with experimental measurements of enzyme protein dynamics. During nutrient down-shifts, we uncover a switch of metabolic bottleneck from carbon uptake proteins to metabolic enzymes, which disrupts the coordination between metabolic flux and their enzyme abundance. Our method provides a quantitative framework to investigate cellular metabolism under varying environments and reveals insights into bacterial adaptation strategies.

邀请报告 VII17
报告人：谭志杰
单位：武汉大学
题目：基于物理的 RNA 三维结构预测与评估
摘要：RNA 是非常重要的生物大分子，除了储存传递基因信息外，RNA 还具有基因调控和催化等重要的生物功能，RNA 的重要功能与其结构及结构稳定性紧密相关。因而，发展理论和计算模型预测 RNA 三维结构及其稳定性有助于对 RNA 生物功能的深入理解及其相关应用，RNA 三维结构预测往往包含三维结构集的预测和对三维结构集的评估两个方面。 近来，我们分别发展了基于物理和基于片段组装的粗粒化模型预测 RNA 三维结构集，并发展了粗粒化统计势对 RNA 三维结构集进行评估，具体包括：1，发展了基于物理的结构预测模型，此模型通过结合实验碱基堆积热力学参数引入温度效应并通过结合离子凝聚理论和紧束缚离子模型引入离子效应，此模型可以对 RNA 假结、吻环复合体等的三维结构及稳定性进行较好预测；2，发展了基于二级结构和片段结构集的 RNA 三维结

构组装模型 FebRNA，此模型可以基于二级结构对不同类型 RNA 的三维结构进行高效预测；3，发展了基于序列分离度的粗粒化统计势 cgRNASP，针对 RNA 三维结构预测竞赛产生的实际测试集--Puzzles 结构集，此粗粒化统计势的性能优于现有其它全原子统计势和打分函数，且计算速度为现有全原子统计势和打分函数的近百倍。FebRNA 和 cgRNASP 已分别制备为软件包供下载使用：https://github.com/Tan-group/FebRNA ； https://github.com/Tan-group/cgRNASP 。
*Emails: yltan@wtu.edu.cn; zjtan@whu.edu.cn.

邀请报告 VII18
报告人：唐乾元
单位：香港浸会大学
题目：蛋白质进化中的统计规律：基于 AlphaFold 数据库的研究
摘要：统计物理方法与 AI 预测数据的结合为探索生命复杂系统的普适规律提供了全新的强大工具。以蛋白质进化问题为例，传统的蛋白质进化研究往往关注同一个家族的蛋白质序列或者结构（微观视角），而随着 AlphaFold 预测的海量蛋白质结构的出现，研究者可以把视角扩展到大量蛋白质的集合，甚至是直接对比不同物种体内的全部蛋白质，从中挖掘统计趋势（宏观视角）。本次报告将介绍我们基于 AlphaFold 数据库进行研究的一些最新进展，包括基于预测结构的研究和基于预测误差的研究。在基于 AlphaFold 预测结构的研究中（Tang et al, Mol Biol Evol, 39(10), msac197, 2022），我们通过对比 40 多种模式生物体内相似链长的蛋白质，发现了蛋白质分子进化中的统计规律：随着物种复杂度的提高，生物体内的蛋白质在进化中呈现出特定的统计趋势，蛋白质序列将趋向于出现更显著的亲疏水片段分隔，蛋白质结构将趋向于更高的柔性和模块化程度，蛋白质的功能专一性也不断提高。在基于 AlphaFold 结构预测误差的研究中，我们从预测误差中构建了氨基酸相互作用矩阵，并用微扰分析方法建立起了 AlphaFold 结构预测误差与蛋白质动力学的突变稳定性之间的关系。这些基于 AlphaFold 的统计研究在分子进化和物种进化之间建立了联系，有助于我们理解生物复杂性的演化。

口头报告 VII19
报告人：谈荣日
单位：江西科技师范大学
题目：朊蛋白错误折叠及分子聚集机制的分子动力学研究
摘要：朊病毒疾病是人类和各种脊椎动物的致命神经退行性疾病，可在相同或不同物种的个体之间传播。朊病毒疾病发病机制中的关键是细胞型朊病毒蛋白(PrPC)的构象转化为错误折叠形式的朊病毒蛋白(PrPSc)。为了解残基定点突变诱导朊病毒蛋白聚集的机理，我们采用分子动力学模拟方法对野生型和 V180I、H187R、Double 三种不同的突变体在水溶液环境中进行了 500ns 的动力学模拟。结果表明，三种突变位点对朊蛋白(PrP)的动力学性质有不同的影响。V180I 变体的螺旋 2 上 N 端残基周围的高波动性导致螺旋 2 上的氢键减少，β 折叠区域内氢键数量的增加促进了 β 折叠的生成。同时，H187R 和 Double 中部分盐桥的缺失导致朊病毒蛋白的亚结构域出现分离现象，这加速了 PrPC 向 PrPSc 的转变。另外，为了阐明乙醇对人类朊病毒蛋白结构稳定性的影响，我们采取分子动力学模拟方法分析人类朊蛋白在不同乙醇环境下的构象变化和动力学特征。计算结果表明，在高温环境中二级结构的 β 折叠更容易发生延伸现象，α 螺旋结构也更容

易被破坏。当温度在 500K 时，发现乙醇会破坏蛋白之间的疏水相互作用并使内部氢键保持稳定，从而保护蛋白质的二级结构。

口头报告 VII20
报告人：曹学正
单位：厦门大学
题目：Dynamic Crosslinking of Chromatins Managed Nucleolus Ripening in Nucleus
摘要：The network structure of chromatins packing within the nucleus of eukaryotic cells evolves with time due to the involved dynamic effects like non-equilibrium biological processes and reposition of genes in response to environmental cues etc., which plays a critical role in governing the nucleolus ripening and thereby related biological functions of cells. Through performing systematic numerical simulations to investigate the ripening process of nucleoli in dynamically crosslinked chromatin networks, it is demonstrated that the nucleolus ripening completes in the way of either direct fusion or the well-known Ostwald ripening depending on whether the structural relaxation of chromatin chains can or can not catch up with the size growth of nucleolus droplets. Moreover, we construct a phase diagram to summarize the nucleolus ripening at varied densities and lifetimes of dynamic crosslinks, providing potentially universal predictions for understanding how dynamic crosslinking of chromatins manage the nucleolus ripening in nucleus.

邀请报告 VII21
报告人：李文飞
单位：南京大学
题目：蛋白分子功能动力学：能量面阻挫与别构调控
摘要：随着近年来蛋白质静态结构预测问题的重大突破，蛋白分子的动力学研究越来越受到人们的关注。作为蛋白分子机器的典型代表，酶分子被广泛用于研究蛋白分子的功能动力学机制。自然界的酶由于进化通常具备了惊人的工作效率。酶分子采取怎样的物理策略来实现催化循环中多个物理化学步骤的精巧耦合与协同运作，从而克服催化循环中的限速步骤、实现高效率催化是一个尚未完全理解的基本生物物理问题。在最近的系列工作中，我们以腺苷酸激酶 AdK 为例，尝试建立理论模型，并基于分子模拟、能量统计以及序列进化分析等方法，探讨酶分子实现高效率催化所采取的物理策略，揭示出酶分子多尺度能量阻挫特征、别构性质、以及酶催化动力学之间的关联。在此基础上，进一步探讨了基于定向进化设计、力学调控、拥挤环境等方法来提高酶催化速率的可能方案。
参考文献：
[1] Zhang YY et al., Frustration and the Kinetic Repartitioning Mechanism of Substrate Inhibition in Enzyme Catalysis, J. Phys. Chem. B 2022, 126 (36) 6792 - 6801
[2] Lu JJ et al., Role of Repeated Conformational Transitions in Substrate Binding of Adenylate Kinase, J. Phys. Chem. B, 2022, 126 (41), 8188-8201
[3] Li WF et al., Overcoming the Bottleneck of the Enzymatic Cycle by Steric Frustration. Phys. Rev. Lett. 2019, 122, 238102.
[4] Song RH et al., Principles Governing Catalytic Activity of Self-Assembled Short Peptides, J. Am. Chem. Soc. 2019, 141, 223− 231.

[5] Li WF et al，Frustration, Specific Sequence Dependence, and Nonlinearity in Large-amplitude Fluctuations of Allosteric Proteins. PNAS, 2011, 108,3504－3509.

邀请报告 VII22
报告人：黄胜友
单位：华中科技大学
题目：基于统计势迭代方法的生物分子相互作用能量计算
摘要：生命是一个复杂的非平衡系统，生物大分子蛋白质和核酸（包括 DNA 和 RNA）是其中两类最重要的生命物质单元，也是生命活动的执行者。生命不是单个分子的特征，而是分子间相互作用的系统。生命体中的几乎所有功能和活动都依赖于生物大分子如蛋白质和核酸及其相互作用来完成。因此，确定生物大分子间的相互作用及其复合物结构，对于理解生命活动的分子机制和揭示疾病的发生发展机理，从而通过对其调控来治疗疾病和开发药物，提高人民的健康水平有着重要的理论意义和社会价值。其中一类重要生物大分子相互作用计算方法是基于玻尔兹曼统计原理的统计势能量函数模型，由于其具有普适性和计算速度综合优势，因此在生物大分子相互作用和结构预测中获得了广泛应用，但其多年来面临一个“参考态”无法准确计算难题，亟待解决。针对这一问题，我们提出了一套基于物理统计力学原理的结构-能量关系的迭代模型，将模型运用到多种生物分子相互作用统计势能量函数推导中，克服了多年来基于知识的统计势能量函数中“参考态”不可计算的难题，突破了传统基于统计势生物分子相互作用能量函数的精度极限。

口头报告 VII23
报告人：楚夏昆
单位：香港科技大学（广州）
题目：Quantifying chromosome structural dynamical pathways during cell fate decision making processes
摘要：Cell fate decision making process, essential for cell and tissue development, is determined by the underlying gene regulatory networks. As the scaffold for gene expression, chromosomes fold into different 3D structures in the cell nucleus for different types of cells. When cell switches its fate, the chromosome reorganizes its structure to underpin the desired gene expression function. In light of the intimate structure-function relationship, the dynamical picture of chromosome structural reorganization during cell fate decision making is key to the understanding of the process. However, this is very challenging to acquire. The current challenges are mainly from the lack of simultaneous determination of chromosome structure and dynamics (experimental challenges) and the lack of a physical description of the underlying dynamics (theoretical and computational challenges). Here, we developed a data-driven model that integrates the experimental Hi-C data into a coarse-grained polymer model and built the 3D chromosome structural ensembles at different states of the cells [1-5]. We then devised a nonequilibrium landscape-switching simulation approach to study the changes of the chromosome structural ensembles during the cell-state transition. We quantified the chromosome structural reorganization pathways in cell fate decision making transition among the stem cell and the terminally differentiated cells. The

quantified pathways provided useful insights into the cellular-level processes at the microscopic molecular level. The results, which show extensive good agreements with experiments, demonstrate that our computational framework is promising to study chromosome structure dynamics in complex cellular processes.

口头报告 VII24
报告人：彭云辉
单位：华中师范大学
题目：Deciphering the principles of nucleosome dynamics and interactions through integrative computational approaches
摘要：Nucleosome comprises ~147 bp of DNA wrapped around a histone octamer and is a central point in coordinating various signaling pathways in epigenetic regulation. The molecular recognition of nucleosomes by chromatin factors frequently occurs through the interactions with the nucleosomal and linker DNA, histone tails, histone globular domains, and by recognizing their specific covalent modifications. Elucidating the physicochemical properties of these interactions is essential for our understanding of the principles of chromatin organization and regulation. In our recent work, we have integrated molecular dynamics simulations, protein interaction network analysis, electrostatic calculation, and bioinformatics approaches to decipher the physicochemical properties of nucleosome dynamics and interactions and the effects of epigenetic modifications and histone cancer mutations on them. Through several hundred microseconds of all-atom molecular dynamics simulations, we have generated extensive atomistic conformational ensembles of full nucleosomes and characterized the kinetic and thermodynamic properties of histone tails, histone octamer, and nucleosomal DNA. We show that histone modifications and mutations affect tail dynamics and tail-DNA interactions, altering tail residence time on DNA molecules to modulate nucleosome recognition by binding partners. Our results also reveal that DNA methylation induces pronounced changes in geometry for both linker and nucleosomal DNA, modulating nucleosome dynamics and preventing spontaneous DNA unwrapping for the methylated nucleosome. Finally, we have compiled a dataset of more than 8000 histone cancer mutations and predicted the potential 'oncohistone' mutations. We have mapped the cancer mutations onto our previously constructed histone-interaction networks and our electrostatic analysis and binding free energy calculations have revealed their potential effects on disrupting nucleosome interactions with various chromatin factors. Our studies should provide novel insight to understand the principles of nucleosome dynamics and interactions and corresponding regulatory mechanisms related to epigenetic modifications and histone cancer mutations.

口头报告 VII25
报告人：赵蕴杰
单位：华中师范大学
题目：AI-based scoring function to evaluate native-like RNA-protein complexes
摘要：RNA-protein complexes underlie numerous cellular processes, including basic translation and gene regulation. The high-resolution structure determination of the

RNA-protein complexes is essential for elucidating their functions. Therefore, computational methods capable of identifying the native-like RNA-protein structures are needed. To address this challenge, we thus develop DRPScore, a deep-learning-based approach to identify the native-like RNA-protein structures. DRPScore is tested on representative sets of RNA-protein complexes of various degrees of binding-induced conformation change ranging from fully rigid docking (bound-bound) to fully flexible docking (unbound-unbound). Out of the top 20 predictions, DRPScore selects native-like structures with a success rate of 91.67% on the testing set of bound RNA-protein complexes and 56.14% on the unbound complexes. DRPScore consistently outperforms the existing methods with a roughly 10.53-15.79% improvement, even for the most difficult unbound cases. Furthermore, DRPScore significantly improves the accuracy of the native interface interaction predictions. DRPScore should be broadly useful for modeling and designing RNA-protein complexes.

邀请报告 VII26
报告人：严钢
单位：同济大学
题目：数据驱动的复杂系统动力学推理及应用
摘要：真实复杂系统包含许多相互作用的个体，其隐含的动力学形式往往也比较复杂。随着近些年微观实验手段和数字化技术的快速发展，学界和业界积累了大量实际观测数据（包括个体交互的网络结构以及个体的活动序列）。如何从这些观测数据中推理实际复杂系统的动力学成为一个迫切需要解决的问题，也是理解系统功能和进行调控的重要前提。本报告将重点讲述数据驱动的复杂系统随机微分方程的推理方法，以及在传染病扩散、自然集群运动、阿兹海默症病毒蛋白传播以及复杂工程系统中的应用进展。

邀请报告 VII27
报告人：涂育松
单位：扬州大学
题目：G-四链体 DNA 与双悬臂类配体小分子特异性作用的动力学过程
摘要：G-四链体是一种非经典的核酸二级结构，对包括癌症在内的各种药理和生物过程具有重要意义，其配体小分子的筛选是关键和重要一环。当前，配体小分子如何与 G-四链体 DNA 的作用机制尚不清楚，特别是他们相互作用的动力学过程鲜有研究。我们报告 G-四链体 DNA 与双悬臂类配体小分子特异性作用的动力学过程。这个双悬臂类配体小分子具有两个能够灵活翻转的类似鸟嘌呤碱基大小的芳香环，通过类似悬臂的作用利用 π-π 堆积作用自由抓取 DNA 碱基，对 G-四链体折叠过程中各个亚稳态之间的转变起到重要的桥接作用，显著地降低了 G-四链体折叠亚稳态之间的转变势垒，从而大大加速了折叠动力学过程。同时，合作者的单分子拉伸实验证实了，G-四链体结构形成的时间在加入双臂型配体小分子后缩短了几十倍。我们报告的 G-四链体 DNA 与双悬臂类配体小分子特异性作用的动力学过程，为 G-四链体 DNA 的结构形成和稳定性以及相应配体小分子筛选，提供了关键的理论理解。

口头报告 VII28

报告人：刘振兴
单位：北京师范大学
题目：Cooperativity and Folding Kinetics in a Multidomain Protein with Interwoven Chain Topology
摘要：Although a large percentage of eukaryotic proteomes consist of proteins with multiple domains, not much is known about their assembly mechanism, especially those with intricate native state architectures. Some have a complex topology in which the structural elements along the sequence are interwoven in such a manner that the domains cannot be separated by cutting at any location along the sequence. Such proteins are multiply connected multidomain proteins (MMPs) with the three-domain (NMP, LID, and CORE) phosphotransferase enzyme adenylate kinase (ADK) being an example. We devised a coarse-grained model to simulate ADK folding initiated by changing either the temperature or guanidinium chloride (GdmCl) concentration. The simulations reproduce the experimentally measured melting temperatures (associated with two equilibrium transitions), FRET efficiency as a function of GdmCl concentration, and the folding times quantitatively. Although the NMP domain orders independently, cooperative interactions between the LID and the CORE domains are required for complete assembly of the enzyme. Kinetic simulations show that, on the collapse time scale, multiple interconnected metastable states are populated, attesting to the folding heterogeneity. The network of kinetically connected states reveals that the CORE domain folds only after the NMP and LID domains, reflecting the interwoven nature of the chain topology.

口头报告 VII29
报告人：张庆
单位：中科院北京基因组所
题目：A dynamic kissing model for enhancer-promoter communication on the surface of transcriptional condensate
摘要：Enhancer-promoter (E-P) communication is key to gene transcription regulation in eukaryotes. The formation of transcriptional condensates, which might be caused by liquid-liquid phase separation, has been considered as an important mechanism for E-P contacts. However, the detailed kinetic mechanism of how the condensates mediate E-P contacts, and how such contacts may regulate gene transcription remain unclear. Thus, we proposed a polymer physics-based E-P communication model. By comparing multiple model settings, we found that one scenario matches experimental data most when E-P contacts were constrained to the spherical surface of condensates. Based on this observation, we proposed a model of gene expression regulation with E-P dynamically kissing on the surface of transcriptional condensates. Last, we demonstrated that a seeming contradiction of gene expression bursting observed in the single-molecular tracking data can be well explained by this model. In summary, we proposed a coarse-grained yet effective model of E-P dynamic kissing, which will facilitate a more comprehensive understanding of enhancer-mediated gene regulation.

口头报告 VII30

报告人：李典杰
单位：北京大学
题目：ATP hydrolysis kinetics and thermodynamics as determinants of calcium oscillation in pancreatic β cells
摘要：Cellular ATP plays an important role in the calcium oscillation signal transduction pathway of pancreatic β cells. It triggers oscillation by binding the ATP-sensitive K+ channels (KATP), and maintains the oscillation by providing ATP hydrolysis free energy for the normal function of ion pumps on the plasma membrane. To reveal how cellular ATP level and ATP hydrolysis free energy affect calcium oscillation, we first constructed a simplified kinetic model of KATP and calcium pumps, then analyzed their thermodynamic characteristics. Bifurcation of calcium oscillation is determined by both cellular ATP concentration and ATP hydrolysis free energy such that an insufficient ATP energy supply would result in dysfunctional calcium oscillation. Second, to investigate the glucose sensing in β cells, we developed a glycolysis-calcium model that considers the dynamics of ATP and free energy levels. The model simulated three calcium patterns in wild type cells and impaired calcium response of KATP mutant cells, allowing the use of the ATP-free energy phase plane to explore the underlying mechanism. Our results reveal the thermodynamics of calcium oscillation and provide a framework for understanding the thermodynamics of other ion transport systems.

## 分会场 VIII：机器学习、智能与认知

邀请报告 VIII01
报告人：黄海平
单位：中山大学
题目：关于记忆
摘要：本报告将简介关于记忆的广义物理模型。在该模型中，我们发现突触可塑性的时间尺度将影响记忆形成的热力学相图，相图的稳定性与突触连接矩阵的渐进谱相关，数学上推广了著名的 Marcenko-Pastur 律；并且，考虑双向不对称突触结构，动力学序列提取将变成可能，并且数学上导致一类新型的非厄米矩阵渐近谱。

邀请报告 VIII02
报告人：黄旭辉
单位：中国航天科工智能科技研究院
题目：类脑脉冲神经网络学习与识别
摘要：

口头报告 VIII03
报告人：郑文
单位：太原理工大学
题目：The Classification and Structural Characteristics of Amorphous Materials Based on Interpretable Deep Learning

摘要：Defining the structure characteristics of amorphous materials is one of the fundamental problems that need to be solved urgently in complex materials because of their complex structure and long-range disorder. In this study, we develop an interpretable deep learning model capable of accurately classifying amorphous configurations and characterizing their structural properties. The results demonstrate that the multi-dimensional hybrid convolutional neural network can classify the 2D liquids and amorphous solids of molecular dynamics simulation. The classification process does not make a priori assumptions on the amorphous particle environment, and the accuracy is 92.75%, which is better than other convolutional neural networks. Moreover, our model utilizes the gradient-weighted activation-like mapping method, which generates activation-like heat maps that can precisely identify important structures in the amorphous configuration maps. We obtain an order parameter from the heatmap and conduct finite scale analysis of this parameter. Our findings demonstrate that the order parameter effectively captures the amorphous phase transition process across various systems. These results hold significant scientific implications for the study of amorphous structural characteristics via deep learning.

口头报告 VIII04
报告人：黄子涵
单位：湖南大学
题目：基于深度学习的反常扩散表征方法
摘要：Anomalous diffusion, a complex phenomenon that deviates from the normal diffusion landscape, has been observed in various physical, chemical, and biological systems. The characterization of anomalous diffusion trajectories is a crucial but challenging task, with three main subtasks of interest: the determination of the anomalous diffusion coefficient/exponent, the identification of the underlying diffusion model, and the semantic segmentation of complex anomalous diffusion processes. However, traditional statistical methods often require long trajectories and are sensitive to the selection of fitting range, leading to potential inaccuracies and inconsistencies in the characterization of anomalous diffusion dynamics. Given these challenges, we have sought solutions in the realm of deep learning, which offers a promising avenue for delivering robust and precise characterizations of anomalous diffusion. In our previous works, we developed two deep learning models, WADNet and U-AnDi, to address the aforementioned tasks in the analysis of anomalous diffusion trajectories. Here, WADNet is designed to tackle the first two subtasks, with corresponding workflow shown in Figure 1. It infers the anomalous diffusion exponent of a single short trajectory, overcoming the limitations of traditional statistics-based methods. Furthermore, WADNet can also classify the diffusion model of trajectories, a task that poses significant challenges for classical methods. WADNet demonstrates excellent performance and stability in these tasks, showing a particular strength in handling noisy trajectory data. On the other hand, the U-AnDi model (Figure 2) focuses on the third subtask, i.e., the semantic segmentation of anomalous diffusion. Utilizing deep convolutional networks, U-AnDi excels in identifying transient changes of diffusion states from raw trajectory data. In particular, when tested on real-world anomalous

diffusion data, U-AnDi produced segmentation results that were highly consistent with experimental observations. In summary, our work underscores the potential of deep learning in advancing our understanding and characterization of anomalous diffusion dynamics. The models we have developed, WADNet and U-AnDi, provide robust and accurate solutions to the intricate challenges in this field. Their successful application to real-world data further highlights the practical significance of deep learning methodologies in the study of anomalous diffusion. Future research will continue to refine these models and explore their potential in providing even more accurate and comprehensive characterizations of anomalous diffusion.

口头报告 VIII05
报告人：黎勃
单位：哈尔滨工业大学（深圳）
题目：两类决策问题的统计物理研究
摘要：本报告将应用统计物理的方法探讨两类决策问题的算法设计与分析。在第一类问题中，我们关注交通输运网络的拥堵管理。其中决策者需要调整输运网络的参数（如路费）以减缓拥堵，并同时考虑网络使用者对参数调整的响应； 我们把该问题建模为图上的双层优化问题，并设计了相应的消息传递算法以高效地求解该问题。 在第二类问题中，我们关注面对不确定性环境下的决策问题。以经典的多臂老虎机模型及相应的上置信界(upper confidence bound，UCB)算法为例，我们采用了路径积分方法与大偏差理论框架分析该体系，解析地刻画了决策者损失的相对概率分布，以及对决策者造成重大损失的典型事件及路径。

口头报告 VIII06
报告人：张万舟
单位：太原理工大学
题目：Snake net with a neural network for detecting multiple phases in the phase diagram
摘要：Unsupervised machine learning applied to the study of phase transitions is an ongoing and interesting research direction. The active contour model, also called the snake model, was initially proposed for target contour extraction in two-dimensional images. In order to obtain a physical phase diagram, the snake model with an artificial neural network is applied in an unsupervised learning way by the authors of [Phys. Rev. Lett. 120, 176401 (2018)]. It guesses the phase boundary as an initial snake and then drives the snake to convergence with forces estimated by the artificial neural network. In this work we extend this unsupervised learning method with one contour to a snake net with multiple contours for the purpose of obtaining several phase boundaries in a phase diagram. For the classical Blume-Capel model, the phase diagram containing three and four phases is obtained. Moreover, a balloon force is introduced, which helps the snake to leave a wrong initial position and thus may allow for greater freedom in the initialization of the snake. Our method is helpful in determining the phase diagram with multiple phases using just snapshots of configurations from cold atoms or other experiments without knowledge of the phases.

邀请报告 VIII07
报告人：刘金国
单位：香港科技大学（广州）
题目：基于张量网络的贝叶斯推断理论
摘要：这个报告将物理学中的张量网络语言，对机器学习领域中的贝叶斯推断任务用更加简洁的数学语言诠释，并提出新的更加高效的推断算法。贝叶斯推断是机器学习中的重要的数学模型，其内容包括在观察到一组事件变量结果后，计算该事件出现的概率，推断其它事件的发生概率以及最可能出现的其它事件变量的取值。新提出的框架利用了张量收缩的最新的进展，包括大型张量网络收缩顺序的优化，自动微分以及范型张量网络技术，将会在理论简洁性和性能方面超越传统算法。

邀请报告 VIII08
报告人：汤迎
单位：北京师范大学珠海校区
题目：Learning nonequilibrium statistical mechanics and dynamical phase transitions
摘要：Nonequilibrium statistical mechanics inherit challenges of the equilibrium, including accurately describing the joint distribution of a large number of configurations, and also poses new challenges as the distribution evolves over time. Characterizing dynamical phase transitions as an emergent behavior further requires tracking nonequilibrium systems under a control parameter. While a number of methods have been proposed, such as tensor networks for one-dimensional lattices, we lack a method for arbitrary time beyond the steady state and for higher dimensions. Here, we develop a general computational framework to study time evolution of nonequilibrium systems in statistical mechanics by leveraging variational autoregressive networks, which offers an efficient computation on the dynamical partition function, a central quantity for discovering the phase transition. We apply the approach to prototype models of nonequilibrium statistical mechanics, including the kinetically constrained models of structural glasses up to three dimensions. The approach uncovers the active-inactive phase transition of spin flips, the dynamical phase diagram, as well as new scaling relations. Our study paves the way for machine learning dynamical phase transitions in nonequilibrium systems.

口头报告 VIII09
报告人：唐宾泽
单位：北京大学
题目：Machine learning aided interfacial atomic structure identification from AFM images
摘要：Relevant to broad applied fields and natural processes, interfacial ionic hydrates has been widely studied by ultrahigh-resolution atomic force microscopy (AFM). However, the complex relationship between AFM signal and the investigated system makes it difficult to determine the atomic structure of such complex system from AFM images alone. Using machine learning, we achieved precise identification of the atomic structures of interfacial water/ionic hydrates based on AFM images, including the

position of each atom and the orientation of water molecules. Furthermore, it was found that structure prediction of ionic hydrates can be achieved cost-effectively by transfer learning using neural network (NN) trained with easily available interfacial water data. Thus, this work provides an efficient and economical methodology which not only opens up avenues to determine atomic structures of more complex systems from AFM images, but may also help to interpret other science-wide studies involving sophisticated experimental results.

口头报告 VIII10
报告人：郑国忠
单位：陕西师范大学
题目：The evolution of trust and trustworthiness based on Q-learning
摘要：Behavioral experiments have shown that trust is universal among human beings, contradicting the predictions from orthodox Economics. Most previous studies fail to address the mechanism behind this, they primarily adopt the framework of imitation learning, where individuals update their strategies through imitating the behavior of others who have high payoffs. Here, we resort to a different paradigm by introspection, where individuals' decision-making is based on themselves' past experiences and expectations for the future. Specifically, with Q-learning algorithm, we show that trust and trustworthiness naturally arise when individuals focus on both historical experience and foresight. However, the maintenance of trust requires a relatively stable environment, if too many misunderstandings happen, trust can break down, and the level of investment trust increases significantly with the increase of the multiplier for reciprocal trusting behavior. These findings hold for either two-person scenario or a population setup. Our results suggest that we may need a paradigm shift from the traditional imitation learning to reinforcement learning in understanding the emergence of trust and trustworthiness in our society.

口头报告 VIII11
报告人：宋天舒
单位：中国矿业大学
题目：Numerically stable neural network for simulating Kardar-Paris-Zhang growth in the presence of uncorrelated and correlated noises
摘要：Numerical simulations are important tools for exploring the dynamic scaling properties of the nonlinear Kadar-Paris-Zhang (KPZ) equation. Yet the inherent nonlinearity frequently causes numerical divergence within the strong-coupling regime using conventional simulation methods. To sustain the numerical stability, previous works either utilized discrete growth models belonging to the KPZ universality class or modify the original nonlinear term by the designed specified operators. However, recent studies revealed that these strategies could cause abnormal results. Motivated by the above-mentioned facts, we propose a convolutional neural network-based method to simulate the KPZ equation driven by uncorrelated and correlated noises, aiming for overcoming the challenge of numerical divergence, and obtaining reliable scaling exponents. We first train the neural network to represent the determinant terms of the

KPZ equation in a data-driven manner. Then, we perform simulations for the KPZ equation with various types of temporally and spatially correlated noises. The experimental results demonstrate that our neural network could estimate effectively the scaling exponents eliminating numerical divergence.

口头报告 VIII12
报告人：罗俊藤
单位：华东师范大学
题目：基于贝叶斯推断定量评估干预政策对 COVID-19 感染和恢复的影响
摘要：为了应对 2019 年冠状病毒病 (COVID-19) 大流行，全球 197 个国家采取了各种防控政策，也产生了不同的抑制效果。许多学者对非药物干预政策和疫苗对 COVID-19 的抑制作用进行了建模分析。然而，之前的研究集中在定量评估干预政策与 COVID-19 再生数的影响。我们考虑了各种干预政策对 COVID-19 感染和恢复的影响，提出了一种基于真实数据通过贝叶斯推断定量评估各种政策对 COVID-19 感染和恢复的影响的方法。通过对有效再生数和恢复率的拟合，定量评估各种干预政策对 COVID-19 感染和恢复的影响。结果显示，干预政策可以同时降低 COVID-19 的感染率，提高 COVID-19 的恢复率。更值得注意的是，干预政策对感染率的影响会大于对恢复率的影响。

邀请报告 VIII13
报告人：俞连春
单位：兰州大学
题目：Understanding the basic design principles of human brains from the perspective of complex systems
摘要：Our brain evolved under the constraints of space, energy supply, while adhering to the universal principles governing natural complex systems. Understanding the principles of brain design would not only help us better understand how our brains work, but it would also help us develop more energy efficient artificial intelligence and precision treatments for brain diseases. In this talk, I will present our serious works on this topic to demonstrate that the physical principles such as stochastic resonance, criticality, and heterogeneity are capable of promoting our brains' capacity in a variety of ways—from energy efficient information processing in neurons and neuronal networks to flexible balance between functional segregation and integration at large scale brain networks to the cognitive capacity such as fluid intelligence. I will also discuss the possible applications of these principles in future brain medicines.

邀请报告 VIII14
报告人：王琦
单位：国防科技大学理学院
题目：A Simple Yet Effective Strategy to Robustify the Meta Learning Paradigm
摘要：Meta learning is a promising paradigm to enable skill transfer across tasks. Most previous methods employ the empirical risk minimization principle in optimization. However, the resulting worst fast adaptation to a subset of tasks can be catastrophic in risk-sensitive scenarios. To robustify fast adaptation, this paper optimizes meta learning

pipelines from a distributionally robust perspective and meta trains models with the measure of expected tail risk. We take the two-stage strategy as heuristics to solve the robust meta learning problem, controlling the worst fast adaptation cases at a certain probabilistic level. Experimental results show that our simple method can improve the robustness of meta learning to task distribution, alleviate the heavy tail effect in risk, and reduce the conditional expectation of the worst fast adaptation risk.

口头报告 VIII15
报告人：黄振业
单位：中国科学院理论物理研究所
题目：Energy–Information Trade-off Induces Continuous and Discontinuous Phase Transitions in Lateral Predictive Coding
摘要：Lateral predictive coding is a recurrent neural network which creates energy-efficient internal representations by exploiting statistical regularity in external sensory inputs. Here we investigate the trade-off between energy minimization and information robustness in a linear model of lateral predictive coding. We observe phase transitions in the synaptic weight matrix at several critical trade-off temperatures, especially a continuous transition which breaks permutation symmetry and builds cyclic dominance, and a discontinuous transition with the associated sudden emergence of tight competition between excitatory and inhibitory interactions. Self-organized hierarchical structures also form in the network at low temperatures. Our results indicate the structural complexity of lateral predictive coding networks.

口头报告 VIII16
报告人：黄刚
单位：中国科学院理论物理研究所
题目：Liquid-to-glass transitions in supervised learning with deep neural networks
摘要：While deep learning has been successful in a large variety of applications, its mechanism remains elusive. Under common over-parametrized settings, the loss landscape of deep neural networks is characterized by a connected level set, which, from the perspective of statistical physics, is analogous to the energy landscape of liquids. However, this scenario is at odds with the good generalization ability of deep learning, which is typically expected in solid-like systems. We resolve the paradox by revealing the coexistence of liquid and glass phases in deep neural networks, via metropolis dynamic simulations on the benchmark MNIST and random datasets. The network parameters decorrelate rapidly in central hidden network layers, while slow relaxations with aging effects are displayed in the layers near boundaries due to the constraints imposed by inputs and outputs. The boundary-mediated liquid-to-glass transitions are summarized in a phase diagram, which agrees qualitatively with a previous theoretical prediction based on mean-field thermodynamic calculations using random inputs and outputs[1]. Our simulations show that the impact of data structure on dynamics is observable in the glassy phase, but not in the liquid phase. In the latter, statistical physics treatments that rely on random structureless ensembles could be directly relevant to the learning of real-world data.

口头报告 VIII17
报告人：李炜
单位：华中师范大学
题目：Transfer learning of phase transitions in percolation and directed percolation
摘要：The latest advances of statistical physics have shown remarkable performance of machine learning in identifying phase transitions. In this paper, we apply domain adversarial neural network (DANN) based on transfer learning to studying nonequilibrium and equilibrium phase transition models, which are percolation model and directed percolation (DP) model, respectively. With the DANN, only a small fraction of input configurations (two-dimensional images) needs to be labeled, which is automatically chosen, to capture the critical point. To learn the DP model, the method is refined by an iterative procedure in determining the critical point, which is a prerequisite for the data collapse in calculating the critical exponent ν⊥. We then apply the DANN to a two-dimensional site percolation with configurations filtered to include only the largest cluster which may contain the information related to the order parameter. The DANN learning of both models yields reliable results which are comparable to the ones from Monte Carlo simulations. Our study also shows that the DANN can achieve quite high accuracy at much lower cost, compared to the supervised learning.

邀请报告 VIII18
报告人：许志钦
单位：上海交通大学
题目：深度学习的简单偏好
摘要：

邀请报告 VIII19
报告人：王磊
单位：中国科学院物理研究所
题目：A deep variational free energy approach to dense hydrogen
摘要：

口头报告 VIII20
报告人：马锐
单位：厦门大学
题目：Learning physical properties of membrane during endocytosis with PINN
摘要：Endocytosis is a fundamental cellular process in eukaryotic cells that facilitates the transport of molecules into the cell. Extensive biochemical information regarding the protein dynamics involved in endocytosis has been obtained through fluorescence microscopy, and electron tomography has provided geometric information about membrane shapes. However, accurately measuring biophysical information such as osmotic pressure and membrane tension remains challenging due to the small dimensions of endocytic invaginations. In this talk, I will present a novel approach that

combines Machine Learning with the Helfrich model of the membrane and a dataset of membrane shapes extracted from electron tomography to infer biophysical information about endocytosis. Our results demonstrate that Machine Learning can identify solutions that both match the experimental profile and satisfy the membrane shape equations. Additionally, we reveal that during the early stage of endocytosis, the inferred membrane tension is negative, indicating the presence of strong compressive forces at the boundary of the endocytic invagination. This method presents a generic framework for extracting membrane information from super-resolution imaging.

口头报告 VIII21
报告人：张文俊
单位：安徽中医药大学
题目：The characteristics of cycle-nodes-ratio and its application to network classification
摘要：Cycles, which can be found in many different kinds of networks, make the problems more intractable, especially when dealing with dynamical processes on networks. On the contrary, tree networks in which no cycle exits, are simplifications and usually allow for analyticity. There lacks a quantity, however, to tell the ratio of cycles which determines the extent of network being close to tree networks. Therefore, we introduce the term Cycle Nodes Radio (CNR) to describe the ratio of number of nodes belonging to cycles to the number of total nodes, and provide an algorithm to calculate CNR. CNR is studied in both network models and real networks. The CNR remains unchanged in different sized Erd ″os–Rényi (ER) networks with the same average degree, and increases with the average degree, which yields a critical turning point. The approximate analytical solutions of CNR in ER networks are given, which fits the simulations well. Furthermore, the difference between CNR and two-core radio (TCR) is analyzed. The critical phenomenon is explored by analysing the giant component of networks. We compare the CNR in network models and real networks, and find the latter is generally smaller. Combining the coarse-graining method can distinguish the CNR structure of networks with high average degree. The CNR is also applied to four different kinds of transportation networks and fungal networks, which give rise to different zones of effect. It is interesting to see that CNR is very useful in network recognition of machine learning.

邀请报告 VIII22
报告人：王新刚
单位：陕西师范大学
题目：Inferring Attracting Basins of Power System with Machine Learning
摘要：Power systems dominated by renewable energy encounter frequently large, random disturbances, and a critical challenge faced in power-system management is how to anticipate accurately whether the perturbed systems will return to the functional state after the transient or collapse. Whereas model-based studies show that the key to addressing the challenge lies in the attracting basins of the functional and dysfunctional states in the phase space, the finding of the attracting basins for realistic power systems

remains a challenge, as accurate models describing the system dynamics are generally unavailable. Here we propose a new machine learning technique, namely balanced reservoir computing, to infer the attracting basins of a typical power system based on measured data. Specifically, trained by the time series of a handful of perturbation events, we demonstrate that the trained machine can predict accurately whether the system will return to the functional state in response to a large, random perturbation, thereby reconstructing the attracting basin of the functional state. The working mechanism of the new machine is analyzed, and it is revealed that the success of the new machine is attributed to the good balance between the echo and fading properties of the reservoir network; the effect of noisy signals on the prediction performance is also investigated, and a stochastic-resonance-like phenomenon is observed. Finally, we demonstrate that the new technique can be also utilized to infer the attracting basins of coexisting attractors in typical chaotic systems.

口头报告 VIII23
报告人：朱月英
单位：武汉纺织大学
题目：The critical behavior of Hegselmann－Krause opinion model with smart agents
摘要：The Hegselmann－Krause (HK) model allows one to characterize the continuous change of agent opinions with the bounded confidence threshold ε. To consider the heterogeneity of agents in characteristics, we study the HK model on homogeneous and heterogeneous networks by introducing a kind of smart agent. Different from the averaging rule in opinion update of HK model, smart agents will consider, in updating their opinions, the environmental influence following the fact that the agent behavior is often coupled with environmental changes. The environment is characterized by a parameter that represents the biased resource allocation between different cliques. We focus on the critical behavior of the underlying system. A phase transition point separating a complete consensus from the coexistence of different opinions is identified, which occurs at a critical value ε_c for the bounded confidence threshold. We state analytically that ε_c can take only one of two possible values, depending on the behavior of the average degree ka of a social graph, when agents are homogeneous in characteristics. Results also suggest that the phase transition point weakly depends on the network structure but is strongly correlated with the fraction of smart agents and the environmental parameter. We finally establish the finite size scaling law that stresses the role that the system size has in the underlying opinion dynamics. Meanwhile, introducing smart agents does not change the functional dependence between the time to reach a complete consensus and the system size. However, it can drive a complete consensus to be reached faster, for homogeneous networks that are far from the mean field limit.

口头报告 VIII24
报告人：马智钦
单位：昆明理工大学

题目：Early warning signals of tipping points in scomplex systems: deep learning via surrogate data

摘要：Both theory and observation suggest that many complex systems can have tipping points where a sudden shift to a contrasting dynamical regime is possible. Recently, deep learning algorithms have been applied to predict bifurcation types with better outcomes. However, the results show that the theoretical models are significantly more accurate than the empirical systems since the algorithm does not fully exploit the information in the data of the study system but instead learns from a universe of possible models. Here, we use historical data from real systems to generate a dataset with similar statistical properties to the original data through surrogate data. We also develop a deep learning algorithm classifier that provides early warning signals of transitions in future time series by exploiting information about the dynamic characteristics of pre-critical transitions and non-critical transitions. Using surrogate data with machine learning algorithms has been shown to be effective in predicting early warning signals for complex systems.

口头报告 VIII25

报告人：崔鹏碧

单位：北京师范大学珠海校区

题目：Network localization strength regulates innovation diffusion with macro-level social influence

摘要：Innovation diffusion in the networked population is an essential process that drives the progress of human society. Despite the recent advances in network science, a fundamental understanding of network properties that regulate such processes is still lacking. Focusing on an innovation diffusion model with pairwise transmission and macro-level social influence, i.e., more adopters in the networked population lead to a higher adoption tendency among the remaining individuals, we observe discontinuous phase transitions when the influence is sufficiently strong. Through extensive analyses of a large corpus of empirical networks, we show that the tricritical point depends on the network localization strength, which our newly proposed metric can effectively quantify. The metric reveals the deep connection between the critical and tricritical points and further indicates a trade-off: networks that allow less attractive products to prevail tend to yield slower diffusion and lower market penetration and verse versa. Guided by this trade-off, we demonstrate how marketers can rewire the networks to modulate product diffusion according to their needs. Finally,we conclude that the core-periphery structure, being sensitive to the change of the three structure quantities, essentially determines localization strength, and further regulates the phase transition.

口头报告 VIII26

报告人：刘聪

单位：兰州大学

题目：Resonance-like collective behavior induced by the diversity of system components

摘要：Diversity is omnipresent in natural and synthetic extended systems, the

phenomenon of diversity-induced resonance (DIR), wherein a moderate degree of the diversity can provoke an optimal collective response, provides researchers a brand-new strategy to amplify and utilize the weak stimulation. As yet the relevant advances focus mostly on the three ideal situations, where (I) the distribution of diversity is only Gaussian distribution, (II) the interactions among components are only pairwise, and (III) the interactions among elements are uncorrelated with the physical proximity of agents. On the basis of our recent works, we show that: (I) this DIR can be extended to arbitrary distribution of the diversity. (II) Such DIR can be induced by the heterogeneous high-order couplings. (III) A system speed resonance can be viewed by the motion of agents in systems of mobile oscillators.

邀请报告 VIII27
报告人： 陈育涵
单位： 北京师范大学
题目： Mechanism of spatial-temporal heterogeity of multiple regions during different brain states
摘要：The brain, through its complex, multi-levelled structure, comprised of numerous neurons and brain regions, achieves an internal “division of labor” and coordination that facilitates the performance of a wide range of diverse cognitive functions. During different brain states, such as anesthesia state, the performance of advanced functions is significantly disrupted, compared to the awake state. Understanding the mechanism underlying the disruption or implementation of brain functions during different brain states, however, is very challenging for such a multi-scale, structurally complex brain system. To address this issue, we propose a design principle for brain structure that balances energy economy and functional integration/cooperation, considering the brain’s remarkably low energy consumption despite its complex cognitive functions. We identify four balance rules of structural design at four levels of the brain. Under these rules, the brain structure exhibits spatial heterogenous patterns at various levels. Furthermore, we found different spatio-temporal features during anesthesia and awake states, including the spatial pattern of the power spectrum, the spatial pattern and temporal fluctuation for various eigen micro-states. We built a bottom-up large-scale non-equilibrium field model based on the neuronal activity model. Then we revealed the anatomical structural difference derived the heterogeneity of the firing rate of neural activity in the various brain regions. Together, these findings suggest that the structural heterogenous pattern may contribute to the heterogeneity of brain regional activity during different brain states.

口头报告 VIII28
报告人： 王艳成
单位： 北京航空航天大学中法航空学院
题目： Fractionalized conductivity and emergent self-duality near topological phase transitions
摘要： The experimental discovery of the fractional Hall conductivity in two-dimensional electro gases revealed new types of quantum particles, called anyons,

which are beyond bosons and fermions as they possess fractionalized exchange statistics. These anyons are usually studied deep inside an insulating topological phase. It is natural to ask whether such fractionalization can be detected more broadly, say near a phase transition from a conventional to a topological phase. To answer this question, we study a strongly correlated quantum phase transition between a topological state, called a Z2 quantum spin liquid, and a conventional superfluid using large-scale quantum Monte Carlo simulations. Our results show that the universal conductivity at the quantum critical point becomes a simple fraction of its value at the conventional insulator-to-superfluid transition. Moreover, a dynamically self-dual optical conductivity emerges at low temperatures above the transition point, indicating the presence of the elusive vison particles. Our study opens the door for the experimental detection of anyons in a broader regime, and has ramifications in the study of quantum materials, programmable quantum simulators, and ultra-cold atomic gases. In the latter case, we discuss the feasibility of measurements in optical lattices using current techniques.

口头报告 VIII29
报告人： 王骏
单位： 华东理工大学
题目： 宏观传热中的双稳态与逻辑运算
摘要：双稳现象是自然界中一种基本的和普遍存在的非线性现象。利用其进行信息的存储、计算等高阶应用，依赖于人工结构中双稳态的构建和调制。近 20 年来，声子学的提出和蓬勃发展，提供了实现热逻辑器件的底层原理和具体方法。然而，声子学关注的是微观层面的传热；在宏观层面以傅里叶定律为基础的热传导体系中，如何实现双稳态乃至逻辑运算，依然是现代热力学和传热学领域的一大挑战。本报告中，我将展示我们近期提出的宏观传热中双稳态的设计，我们从理论、模拟和实验三个维度验证了该设计的可行性和可靠性。然后，我将基于该宏观热双稳态模型，给出若干以宏观热流为工质的逻辑器件的实例。最后，我将展望未来在宏观传热中实现信息加工和存储的路径和趋势。

口头报告 VIII30
报告人： 李耿
单位： 北京师范大学系统科学学院
题目： A shortcut to finite-time memory erasure
摘要：In order to achieve fast computation, it is crucial to reset the memory to a desired state within a limited time. However, the inherent delay in the system's response often prevents reaching the desired state once the control process is completed. To address this challenge, we propose a shortcut strategy that incorporates an auxiliary control to guide the system towards an equilibrium state that corresponds to the intended control, thus enabling accurate memory reset. Through the application of thermodynamic geometry, we derive an optimal shortcut protocol for erasure processes that minimizes energy cost. This research aims to provide insights into the design of finite-time erasure while reducing energy costs, thereby alleviating the burden of heat dissipation.

口头报告 VIII31
报告人： 马登科
单位： 南京师范大学
题目： 一维超晶格体系中声子局域化引起的温度震荡
摘要：低维体系中的声子和热输运，往往会存在一些新奇的现象。比如一维和二维体系中热导率的尺寸效应等。我们在一维原子链超晶格体系中，通过非平衡分子动力学模拟和理论推导，发现高温热源到低温热源间的温度分布，存在震荡现象。温度震荡的幅度在线性体系最强，随着非线性相互作用的引入，逐渐减弱，最后过渡到正常的温度递减规律。而随着 on-site 相互作用的引入，温度震荡现象迅速消失。通过功率谱和晶格动力学分析，我们发现震荡温度的来源是，高频声子在超晶格轻原子处产生局域化，在线性和弱非线性情况下，很难被热化。