Lei Lei

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Research Keywords:
Observational Cosmology; Gravitational Strong Lensing; Dark Matter; Dark Energy; JWST/Chandra; GRB/kilonova

Education

PhD | *Astrophysics* | **Supervisors: Yi-Zhong Fan** — Sep 2021 – Jun 2026
University of Science and Technology of China (USTC) — Hefei, China

BS | *Astronomy* — Sep 2017 – Jun 2021
Yunnan University (YNU), Outstanding Graduate (Top 10 Example) — Kunming, China

Project Experience

1. Einstein Probe (EP), Space X-Ray Misson — Nov 2022 – present
Purple Mountain Observatory (PMO), Chinese Academy of Science — Nanjing, China

- EP STP Associate Member

2. Wide Field Survey Telescope (WFST), 2.5 meter — Sep 2021 – Sep 2022
USTC & PMO — Hefei & Nanjing, China

- Led the study on the limiting magnitudes of the telescope
- A member of the high-energy neutrino follow-up observations team

3. Multi-channel Photometric Survey Telescope (Mephisto), 1.6 meter — Sep 2019 – Sep 2021
YNU — Kunming, China

- Led the study on the sky survey strategy & variable stars classification

Languages

English: fluent
Chinese: native

Academic Skills

Programming Languages: Python, Matlab, Bash
Instruments: JWST, Keck, Chandra, eROSITA, Swift/XRT, insight-HXMT, EP, WFST, DESI, LAMOST, Fermi-LAT, ZTF
Observations: statistical analysis, X-ray/optical/Gamma-ray spectral fitting, imaging processing

Funding

National Scholarship — 2025
Ministry of Education, China — ∼30000 ¥

National Scholarship — 2022
Ministry of Education, China — ∼20000 ¥

President's Award of the Nanjing Branch of the Chinese Academy of Sciences — 2025
Nanjing Branch of the Chinese Academy of Sciences — ∼1200 ¥

Cyrus Tang Fundation USTC Scholarship of WFST Researches — 2022
USTC — ∼2000 ¥

1st Academic Scholarship (annually) — 2021–2026
USTC — ∼20000 ¥/yr

National College Student Innovation Training Program — 2019-2021
YNU — ∼15000 ¥

RESEARCH EXPERIENCE

Research Conclusion:

Dark matter has self-interactions and no significant electromagnetic coupling, and rarely forms dark stars; Dark energy does not originate from black holes and has no significant electromagnetic coupling.

1. **Strong Lensing Non-parametric Reconstruction of Low-mass Subhalo** (As the corresponding and 1st author, published in ApJL, 2025)

   Discovered a flat dark matter core in a high-z strong lens, akin to nearby dwarf galaxies—marking its first clear observation at such distances. The observed subhalo structure likely favors self-interacting (SIDM) or wave dark matter over traditional cold dark matter, with SIDM being the more probable explanation.

2. **WIMP Dark Matter Annihilation Powered Very Massive Dark Stars in JWST High redshift Galaxies** (As the 1st author, published in ApJ, 2025)

   JWST has observed high z massive galaxies with a high SFE that challenged the current theory of galaxy star formation. Massive Dark Stars powered by WIMPs may explain this phenomenon. We found that massive Dark Stars suggested by the JWST data are in strong tension with existing MACHO constraints. In contrast, Pop III stars remain a plausible and unruled-out explanation, making them the more likely origin.

3. **Are black holes the source of dark energy?** (As the 1st author, published in SCIENCE CHINA Physics, Mechanics & Astronomy(SCPMA), **journal highlight**, 2024)

   The idea of whether non-singularity black holes could generate dark energy is intriguing. The high-quality spectra provided by JWST have enabled the study of quasars at higher redshifts. Our study shows that the latest JWST observations can strongly rule out cosmological coupling of SMBHs as an origin for dark energy.

4. **SMBHs evolution in quiescent hosts: Remnants of Little Red Dots (LRDs), Not Dark Energy Sources** (As the 1st author, under review in PRL, 2025, arXiv:2506.19589)

   We have assembled a sample of SMBHs at $z \sim 2-7$ hosted in quiescent elliptical galaxies, which allowed us to definitively rule out—with high confidence ($> 8\sigma$)—the mass evolution expected if SMBHs were the source of dark energy. Moreover, our findings show that the evolution of LRDs can naturally account for the apparent mass growth of $z \sim 2$ SMBHs, previously attributed to cosmological coupling.

5. **Does the JWST high-z galaxy hint at a static universe without dark matter and dark energy?** (As the 1st author, under review in MNRAS, 2025, arXiv:2508.04277)

   The JWST high z galaxies have very small apparent diameters, which in previous studies has been considered evidence of a cosmology with covariant physical constants and tired light (CCC+TL). However, we ruled out this model with $H(z)$ data at approximately an $\sim 8\sigma$ level. We think that the small diameters of the galaxies is caused by galaxy physics rather than the cosmological model.

6. **The sensitivity and survey strategy of Mephisto and WFST** (As the 1st author, two papers published in RAA, 2021&2023, one is the **journal highlight**.)

   I have been deeply involved in the preliminary research of these two optical survey telescopes. I led the calculation of the survey limits of the WFST. I also took charge of optimizing the survey strategy for the Mephisto telescope, and I developed code for classification using machine learning, which has now been adopted by Mephisto's W survey.

7. **JWST observations constrain the dark energy-electromagnetic coupling** (As corresponding author, published in RAA, **journal highlight**, 2025)

This is the work of a master's student I co-advised. We analyzed high-resolution spectra of high-z galaxies from JWST and obtained constraints on the fine-structure constant $\frac{\Delta\alpha}{\alpha}(z)$. We found that these constraints provide the strongest limits so far on the dark energy-electromagnetic coupling strength, four orders of magnitude higher than previous limits from the CMB.

8. **Searching for Axionlike Particles with X-Ray Observations of α Cen star** (As the 2nd author, published in PRL, 2025, I led the analysis of observational data)

   Instruments like Chandra and eROSITA are too sensitive to observe the Sun, so we propose observing nearby stars to search for axion-like particles produced by stars. We found a potential signal of about $\sim 4\sigma$, but it needs to be verified with future observations. We provided the strongest limits on stellar axion-photon couplings, which are $\mathcal{O}(100)$ to $\mathcal{O}(10000)$ stronger than previous limits from sources like GW170817.

9. **Co-author of Other Studies about Cosmology and GRB/kilonova** (published in ApJL, SCPMA, ApJ, JCAP)

   We also studied the effects of cosmic string loops and PBHs on JWST galaxies. I also participated the kilonova searches and γ-ray/X-ray emissions from superluminous supernovae.

SUPERVISION

Co-advise 2 Master Students 2023–2026
Studying Cosmology with JWST/DESI, the advised work was invited by an international conference.

Co-advised 1 Bachelor Student 2023–2024
The thesis about JWST dark star I advised won the YNU Outstanding Graduation Thesis Award.

PRESENTATIONS

Invited ROB colloquium, Royal Observatory of Belgium, Belgium Jun 2024
Can Dark Stars account for the star formation efficiency excess at very high redshifts? Oral

2025 Annual Meeting of the Chinese Astronomical Society, China Nov 2025
Subhalo in Strong Lensing: Dark Matter Self-interacting and wave Oral

2025 Strong Lensing Annual Meeting, China Oct 2025
Subhalo in Strong Lensing shows Dark Matter Self-interacting or wave properties Oral

Invited Talk, Axion Dark Matter: Theory and Observation, China May 2025
Subhalo in Strong Lensing: Dark Matter Self-interacting and wave Oral

Invited Seminar, Shanghai Jiaotong University, China Mar 2021
A survey of the 3.5 keV Oral

MIT Technology Review 10 Breakthrough Technologies 2025 Meeting, China Jan 2025
Unveiling the Dark Sector via Sky Survey: Outlook of LSST Science Oral

2024 Purple Mountain Dark Matter Meeting, China Oct 2024
Unveiling the Properties of Dark Matter and Dark Energy via JWST high z Observations Oral

Invited Talk, 2024 Annual Meeting of the Jiangsu Physical Society, China May 2024
Quantum uncertainty at the galaxy scale: wave-like Dark Matter, Outstanding Report Award Oral

2024 Annual Meeting of the Jiangsu Astronomical Society, China Jul 2024
Subhalo Density Distribution and the Properties of Dark Matter Oral

2023 Annual Meeting of the Jiangsu Physical Society, China May 2023
Next generation survey: AGN and physics/cosmology, Outstanding Report Award Oral

2023 Annual Meeting of the Jiangsu Astronomical Society, China Jun 2023
Are black holes the source of dark energy? Oral

2023 UFITS Junior Cosmology Symposium Agenda, China Aug 2023
Are black holes the source of dark energy? Oral

2023 Purple Mountain Dark Matter Meeting, China Dec 2023
WIMP Dark Matter Annihilation Powered Very Massive Dark Stars in JWST High Redshift Galaxies Oral

1st "Nova" Astronomy and Space Science Meeting of USTC, China May 2023
Exploring Dark Sector & Origin of Life with JWST: Series Progress Oral

Honors and Awards

Jiangsu Astronomical Society Jul 2025–Present
Membership

Outstanding Student 2023
University of Chinese Academy of Sciences, Nanjing

Outstanding Invited Report Award 2024
2024 Annual Meeting of the Jiangsu Astronomical Society

Outstanding Report Award 2023
2023 Annual Meeting of the Jiangsu Astronomical Society

Merit Student 2023
PMO

Top 1 Academic Three Minutes of University of Chinese Academy of Sciences 2023
University of Chinese Academy of Sciences, Nanjing

Outstanding Graduate 2021
YNU

Top 10 YNU Example, Included as a training case in the YNU self-evaluation report 2023
YNU

Publications

Paper Summary: 10 papers as 1st/corresponding author; 6 paper as 2nd author.
Note: The label "*" indicates the corresponding author.

1. **Lei Lei***, et al. A Dense Dark Matter Core of the Subhalo in the Strong Lensing System JVAS B1938+666. ApJL, 2025, 991(1): L27.
2. **Lei Lei**, et al. Black holes as the source of dark energy: A stringent test with high-redshift JWST AGNs. SCIENCE CHINA Physics, Mechanics & Astronomy (SCPMA), 2024, 67(2): 229811, SCPMA News Highlights.
3. **Lei Lei**, et al. Can Dark Stars account for the star formation efficiency excess at very high redshifts?. ApJ. 2025, 980(2): 249.
4. **Lei Lei**, et al. Limiting Magnitudes of the Wide Field Survey Telescope (WFST). RAA, 2023, 23(3): 035013, RAA Highlights.
5. **Lei Lei** et al., Identifications of RR Lyrae Stars and Quasars from the Simulated Data of Mephisto-W Survey. RAA, 2022, 22(2): 025004.
6. **Lei Lei**, et al. On the Exposure Time of the Mephisto-W Survey. Astronomical Research and Technology, 2021, 18(1): 115-121.
7. **Lei Lei**, et al. Black Holes in the Red-sequence Elliptical Galaxies at Redshifts $\sim 0.7 - 2.5$: Not Dark Energy Source but Remanants of Little Red Dots. submitted to PRL, arXiv:2506.19589.

8. **Lei Lei**, et al. Stringent constraint on the CCC+TL cosmology with H(z) Measurements. submitted to MNRAS, arXiv:2508.04277.

9. Ze-Fan Wang, **Lei Lei***, et al. JWST observations constrain the time evolution of fine structure constants and dark energy-electromagnetic coupling. RAA, 2024, 24(12): 125012, RAA Highlights.

10. Ze-Fan Wang*, **Lei Lei***, et al. New H(z) measurement at Redshift = 0.12 with DESI Data Release 1. arXiv:2601.07345.

11. Yu-Xuan Chen, **Lei Lei**, et al. Searching for Axionlike Particles with X-Ray Observations of Alpha Centauri. PRL, 2025, 134: 241001.

12. Yi-Ying Wang, **Lei Lei**, et al. Modeling the JWST High-redshift Galaxies with a General Formation Scenario and the Consistency with the ΛCDM Model. ApJL, 2023, 954: L48.

13. Zi-Wei Wang, **Lei Lei**, et al. The nanohertz stochastic gravitational wave background from cosmic string loops and the abundant high redshift massive galaxies. SCPMA, 2023, 66: 120403.

14. Guan-Wen Yuan, **Lei Lei**, et al. Rapidly growing primordial black holes as seeds of the massive high-redshift JWST Galaxies. SCPMA, 2024, 67: 109512.

15. Yi-Ying Wang, **Lei Lei**, et al. Digging into the Ultraviolet Luminosity Functions of Galaxies at High Redshifts: Galaxies Evolution, Reionization, and Cosmological Parameters. ApJ, 2024, 975(2): 285.

16. Yi-Ying Wang, **Lei Lei**, et al. Lensing amplitude anomaly and varying electron mass alleviate the Hubble and S_8 tensions. JCAP,2026,01:009.

17. Shu Niu, Qiang Yuan, Shui-Nai Zhang, **Lei Lei**, et al. Detection of extended X-ray emission surrounding PSR B0656+14 with eROSITA. ApJ accepted, arXiv:2501.17046.

18. Hao Zhou, Zhi-Ping Jin*, Stefano Covino, **Lei Lei**, et al. GRB 080503: A Very Early Blue Kilonova and an Adjacent Nonthermal Radiation Component. ApJ, 2023, 943(2): 104.

19. Runduo Liang, Zhengyan Liu, **Lei Lei**, et al. Kilonova-Targeting Lightcurve Classification for Wide Field Survey Telescope. Universe, 2024, 10(1): 10.

20. Zhen-Bo Su, Zhen-Yi Cai, Jun-Xian Wang, ... , **Lei Lei**, et al. Could the Interband Lag of Active Galactic Nucleus Vary Randomly?. ApJ, 2024, 976(2): 155.

21. Jin-Tai Wu, Si-Yi Jiang, **Lei Lei**, et al. Mapping the Radial Velocities and Line Intensity Ratios of Diffuse Ionized Medium in the Orion Molecular Cloud Complex. Acta Astronomica Sinica, 2020, 61(6): 68.

22. Jin-Tai Wu, Jin-Da Li, Si-Yi Jiang, **Lei Lei**, et al. The difference method forsolving the reaction-diffusion equation —Planetary cooling model as an example. College Physics, 2020, 39(3): 72-77.