Anowar J. Shajib

Contact Information

Department of Astronomy and Astrophysics
The University of Chicago
5640 South Ellis Avenue
Chicago, IL 60637

Phone: (213) 271-7056
E-mail: ajshajib@uchicago.edu
Web: https://ajshajib.github.io

Research Interests

Observational cosmology, galaxy evolution, strong gravitational lensing, statistical methods, and machine learning

Professional Positions

NHFP Einstein Fellow, Department of Astronomy and Astrophysics, The University of Chicago, September 2021 – present.
KICP Fellow, Kavli Institute of Cosmological Physics, September 2021 – present.
Postdoctoral Scholar, Department of Astronomy and Astrophysics, The University of Chicago, November 2020 – August 2021.

Education

University of California, Los Angeles, USA

Ph.D., Astronomy & Astrophysics, September 2020.

- Dissertation title: "The Hubble constant and The ΛCDM cosmology: A Magnified View using Strong Lensing"
- Advisor: Prof. Tommaso Treu

M.S., Astronomy, June 2016

- Advisor: Prof. Edward L. Wright

The University of Tokyo, Japan

B.S., Physics, March 2014

Awards, Fellowships, and Honors

NASA Hubble Fellowship Program, Einstein Fellowship, 2021
Rodger Doxsey Travel Prize for dissertation talk, 235$^{\text{th}}$ American Astronomical Society Meeting, Hawaii, USA, 2020

Dissertation Year Fellowship from UCLA Graduate Division, 2019-2020

Graduate Student Travel Stipend, Munich Institute for Astro- and Particle Physics, 2018

Graduate Division Fellowship, UCLA, 2014-2015

Full-tuition Undergraduate Scholarship from Government of Japan, Ministry of Education, Culture, Sports, Science, and Technology, 2009-2014

Publication statistics

36 total published/submitted papers. 11 first-author, 2 second-author, and 23 other co-authored papers. **First author citations**: 336, **total citations:** 2,536, h-index: 21 (11/12/2022, ADS).

Invited conference talks

1. IAUS 381: Strong gravitational lensing in the era of big data. Italy, June 2023.
2. Workshop on Bridging Gaps between Dynamical Probes of Galaxies, Lorentz Center, Netherlands, April 2022.
3. Dark Energy Survey meeting plenary talk, May 2020.

Colloquia and Seminar Talks (* invited)

1. *Colloquium, Dept. of Astronomy, Boston University, March 2023.
2. *Colloquium, Dept. of Physics & Astronomy, Johns Hopkins University, February 2023.
3. *Astrophysics Symposium, Physics Department, Yale University, USA, January 2022.
4. *Astronomy Colloquium, Indiana University, Bloomington, USA, January 2022.
5. Virtual Astronomy Software Talk (VAST), virtual, December 2022.
6. *Astronomy Lunch Seminar (virtual), Kavli IPMU, University of Tokyo, Japan, November 2022.
7. *KICC Cosmology Group Seminar, Cambridge University, UK, March 2022.
8. *Physics Web-colloquium Series, Pabna University of Science and Technology, Bangladesh, July 2021.
9. *Argonne National Lab–UChicago Joint Cosmology Meeting, USA, May 2021.
10. *Open seminar by Dvorkin Group, Harvard University, USA, April 2021.
11. Survey Science Group Meeting, University of Chicago, USA, October 2020.
12. *Colloquium (remote), Institute of Cosmology and Gravitation, University of Portsmouth, UK, April 2020.
13. FLASH Friday talk, University of California, Santa Cruz, California, USA, December 2019.
14. Science talk, Infrared Processing and Analysis Center, California Institute of Technology, USA, November 2019.
15. Astrophysics Seminar, Jet Propulsion Laboratory, California, USA, November 2019.
16. Cosmology seminar, Berkeley Center For Cosmological Physics, University of California, Berkeley, USA, November 2019.
17. *Cosmology seminar, Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, USA, November 2019.
18. Journal club seminar, Center for Astrophysics and Space Sciences, University of California, San Diego, USA, November 2019.
19. Astrophysics seminar, University of California, Irvine, USA, October 2019.
20. Thursday lunch seminar, Princeton University, USA, October 2019.
21. Galaxy lunch talk, Yale University, USA, October 2019.
22. Galaxies and Cosmology Seminar, Center for Astrophysics, Harvard & Smithsonian, USA, October 2019.
23. Galaxy journal club, Space Telescope Science Institute, USA, October 2019.
24. Particle Astrophysics Seminar, Fermilab, USA, October 2019.
25. Lunch talk, Carnegie Observatories, Pasadena, USA, September 2019.
26. Astronomy seminar. University of California, Riverside, USA, May 2019.
27. *MPA Lensing Group Seminar, Munich, Germany, June 2018.

Contributed Talks

1. 241st American Astronomical Society Meeting, USA, January 2023.
2. NHFP Fellows' Symposium. STScI, Baltimore, USA, September 2022.
3. Boom! workshop on Explosive Transients with LSST. The University of Illinois at Urbana-Champaign, USA, July 2022.
4. NHFP Fellows' Symposium, remote, October 2021.
5. Spatially Resolved Spectroscopy with Extremely Large Telescopes, University of Oxford, UK, September 2021.
6. 237th American Astronomical Society Meeting, USA, January 2021.
7. Dissertation talk, 235th American Astronomical Society Meeting, Hawaii, USA, January 2020.
8. Dark Energy Survey meeting, University of Sussex, UK, November 2019.
9. Non-Standard Cosmology Probes, Aspen Center of Physics workshop, Colorado, USA, August 2019.
10. Tensions between the Early and the Late Universe. Kavli Institute for Theoretical Physics, University of California, Santa Barbara, USA, July 2019.
11. Keck Science Meeting. Caltech, USA, September 2018.
12. Extragalactic distance scale in the *GAIA* era, Munich Institute for Astro- and Particle Physics workshop. Germany, June 2018.
13. Shedding Light on the Dark Universe with Extremely Large Telescopes. UCLA, USA, April 2018.
14. Strong Lensing by Galaxies and Clusters. Aosta, Italy, June 2017.

Media Coverage

1. Siegel, E., "Astronomically Rare 'Double Lens' Yields Best Single System Measurement Of Cosmic Expansion", Forbes, 2019.

Poster presentation

1. Cosmic Controversies. Kavli Institute for Cosmological Physics, University of Chicago, USA, October 2019.
2. Tensions between the Early and the Late Universe. Kavli Institute for Theoretical Physics, University of California, Santa Barbara, USA, August 2019.

Approved Grants (PI)

1. *Hubble Space Telescope* AR-16149 (2020). PI: Shajib. Systematics in H_0 from lensing: a comprehensive study of internal structure in elliptical galaxies. **Grant: ∼$100K**.

Approved Computing Proposals (Co-PI)

1. UChicago Midway2 Research Allocation, 1,000,000 CPU hours. PI: Frieman. First semester, 2022–23.
2. UChicago Midway2 Research Allocation, 371,800 CPU hours. PI: Frieman. Second semester, 2021–22.
3. UChicago Midway2 Research Allocation, 352,00 CPU hours. PI: Frieman. First semester, 2021–22.
4. XSEDE Startup Allocation, 200,000 CPU hours (TG-AST190038, 2019). PI: Treu. Highly-detailed strong-gravitational lens modeling to measure the Hubble constant.

Approved Observing Proposals (CoI)

1. *Hubble Space Telescope* GO-17130 (2022). A 4% determination of the Hubble constant from gravitational time delays with maximally flexible lens mass profile. **Grant: ∼$40K**.
2. Very Large Telescope, MUSE, P110 (2022). PI: Zanella. From cosmology to star-forming regions: two compelling cases for MUSE narrow-field mode.
3. *James Webb Space Telescope* GO-1794 (Cycle 1, 2021). PI: Suyu. 100% gain in precision and accuracy of H0 measurement from JWST stellar kinematics of a lens galaxy.
4. Very Large Telescope, MUSE, P108 (2021). PI: Zanella. From cosmology to star-forming regions: two compelling cases for MUSE narrow-field mode.
5. *Hubble Space Telescope* GO-16773 (2021). PI: Glazebrook. A SNAPshot Legacy Survey of Bright Gravitational Lenses. **Grant: ∼$120K**.
6. *Hubble Space Telescope* GO-15652 (2018). PI: Treu. H_0, the stellar initial mass function, and other dark matters from a large sample of quadruply imaged quasars.
7. 2-m Himalayan Chandra Telescope (2018). PI: Courbin. Photometric monitoring of the quadruply lensed quasar PSOJ0147+4630.
8. Very Large Telescope, MUSE NFM Science Verification (2018, 103A). PI: Zanella. From cosmology to star-forming regions: two compelling cases for MUSE NFM.
9. Keck U053(2017A), U032(2017B), U011(2018A), U011(2018B), U029(2019A), U065(2019B), U021(2021A), U030(2022B). PI: Treu. Dark energy with gravitational time-delay: OSIRIS spectroscopy of lensing galaxies.
10. Gemini proposals GS-2022B-Q-230, 2023A. PI: E. Buckley-Geer.

Workshops

1. International Space Science Institute (ISSI) workshop on Strong Lensing, Switzerland, July 2022 **(invited)**.
2. Bridging Gaps between Dynamical Probes of Galaxies, Lorentz Center, Netherlands, April 2022 **(invited)**.
3. Non-Standard Cosmology Probes, Aspen Center of Physics, Colorado, USA, August–September 2019.
4. TMT Early Career Initiative Workshop, Los Angeles, December 2018.
5. Extragalactic distance scale in the *GAIA* era, MIAPP, Germany, June–July 2018.
6. Mary Lea & C. Donald Shane Observational Astronomy Workshop, UCO/Lick Observatory, October 2014.

Observing Experience

OSIRIS, Keck I, 16.5 nights,
NIRC2, Keck II, 3 nights,
MOSFIRE, Keck I, 3 nights,
Shane telescope PFcam and Nickel telescope imager, Lick Observatory, 1 night.

Data Analysis Experience

Hubble Space Telescope (WFC3), W. M. Keck Observatory (OSIRIS, NIRC2), Very Large Telescope (MUSE), *Wide-field Infrared Survey Explorer*, *Wilkinson Microwave Anisotropy Probe*, *Planck*, Sloan Digital Sky Survey.

Scientific Software Development

- Lead developer of lens-modeling automator DOLPHIN.
- Co-developer and maintainer for the lens-modeling software LENSTRONOMY, an affiliated package of ASTROPY.

Computer Skills

Programming Languages: Python, C, C++, PHP, SQL, JavaScript
Astronomy Software: SourceExtractor, DS9
Other Software/Framework: TensorFlow, Flask

Collaboration Membership

- Rubin Observatory LSST's Dark Energy Science Consortium (DESC), **co-convener (from April 2023)** of Strong-Lensing Topical Team (SLTT)
- STRong-lensing Insights into Dark Energy Survey (STRIDES), an external collaboration of the Dark Energy Survey (DES), **Co-PI**
- Time-delay Cosmography (TDCOSMO), **co-chair** of environment analysis subgroup
- H_0 Lenses in COSMOGRAIL's Wellspring (H0LiCOW)
- Rubin Observatory LSST's Strong Lensing Science Consortium (SLSC)
- LensWatch

Professional Service

- SOC member, NHFP symposium, 2022.
- Subject-matter expert reviewer in a NASA peer review, 2022.
- Future Leader participant, AURA annual meeting, 2021.
- Referee for MNRAS (Monthly Notices of the Royal Astronomical Society) and ApJ (The Astrophysical Journal, American Astronomical Society)
- Graduate admission committee member (2019), Division of Astronomy, UCLA

Mentoring

- **Eden Molina:** UCLA undergraduate student, completed a project to model doubly-imaged lensed quasars from NIRC2 imaging data. Mentored Fall 2018–Winter 2020. Coauthored and published a paper (Shajib, Molina, et al., 2021).
- **Vedant Sahu:** UCLA undergraduate student, working on a project to apply machine learning techniques in modeling quadruply-lensed quasars. Mentored Summer 2019–Spring 2021.
- **Chin Yi Tan:** UChicago graduate student, working on a project to build an automated pipeline for modeling galaxy–galaxy lenses. Mentored since Winter 2021. Supported through a HST grant as myself being the PI.
- **Hannah Skobe:** UChicago post-baccalaureate scholar, working on a project to upscale lower-resolution astronomical images using machine learning. Mentored since Spring 2021. Supported through a HST grant.
- **Abigail Lee:** UChicago graduate student, worked on measuring the Hubble constant from a time-delay strong lensing system. Mentored Summer 2021–Summer 2022.
- **Aidan Cloonan:** UChicago undergraduate student, working on a project to compare structural properties of strong lensing galaxies and the parent population of elliptical galaxies. Mentored since Summer 2021.
- **Pierre Boccard:** EPFL Masters student on an exchange program to UChicago, working on a project to measure the dark energy parameter w using a compound lens system. Mentored since Winter 2023.

Teaching

University of Chicago, USA

Guest Lecturer

- Astro 298 - Undergraduate Research Seminar (Spring 2022)

University of California, Los Angeles, USA

Guest Lecturer

- Physics 127 - General Relativity (Spring 2015)
- Astro 81 - Astronomy I: Stars and Nebulae (Winter 2016)

Teaching Assistant

- Astronomy 3 - Nature of Universe (Fall 2014)
- Physics 1C - Electrodynamics, Optics and Special Relativity (Winter 2015)
- Physics 127 - General Relativity (Spring 2015)
- Physics 6C - Physics for Life Sciences Majors: Light, Fluids, Thermodynamics, Modern Physics (Fall 2015)
- Astronomy 81 - Astrophysics I: Stars and Nebulae (Winter 2016)
- Astronomy 140 - Stellar Systems and Cosmology (Spring 2016)
- Physics 12 - Physics of Sustainable Energy (Winter 2017)

Outreach

Coordinator of **Lifelong Learning Outreach program**, KICP, 2022–23.
Speaker at **Lifelong Learning Talk series**, multiple talks at the Chicago Public Library and senior centers, 2022.
Cal-Bridge program, hosted a workshop at UCLA for California State University undergraduates on Graduate admission preparation, March 2019.
Lecturer at Astronomy Live! Summer workshop for high school students, 2018.
Astronomy Live!, visited K-12 schools to perform various demos as part of the UCLA Astronomy outreach program.
Exploring Your Universe, performed various demos in UCLA's annual science festival, 2014-17.
Star show presenter, UCLA Planetarium, 2014-2016.
Public talk, UCLA Planetarium, 2014.

Publications

First-author publications

† Mentee

1. **Shajib, A. J.**, et al. TDCOSMO. XIII. Improved Hubble constant measurement from lensing time delays using spatially resolved stellar kinematics of the lens galaxy. arXiv:2301.02656, 2023. Accepted by A&A.
2. **Shajib, A. J.**, et al. Strong Lensing by Galaxies. Invited review article for ISSI workshop on strong lensing, to be submitted to Space Science Reviews. arXiv:2210.10790, 2022.
3. **Shajib, A. J.**, et al. LensingETC: a tool to optimize multi-filter imaging campaigns of galaxy-scale strong lensing systems. ApJ, 938, 141, 2022.
4. **Shajib, A. J.**, et al. TDCOSMO. IX. Systematic comparison between lens modelling software programs: time delay prediction for WGD 2038−4008. A&A, 667, A123, 2022.
5. **Shajib, A. J.**, et al. Dark matter haloes of massive elliptical galaxies at z $\sim$ 0.2 are well described by the Navarro–Frenk–White profile. MNRAS, 503, 2, 2380-2405, 2021.
6. **Shajib, A. J.**, Molina, E.†, et al. High-resolution imaging follow-up of doubly imaged quasars. MNRAS, 503, 2, 1557-1567, 2021.
7. **Shajib, A. J.**, et al. STRIDES: A 3.9 per cent measurement of the Hubble constant from the strong lens system DES J0408–5354. MNRAS, 494, 6072–6102, 2020.
8. **Shajib, A. J.** Unified lensing and kinematic analysis for *any* elliptical mass profile. MNRAS, 488, 1387–1400, 2019.
9. **Shajib, A. J.**, et al. Is every strong lens model unhappy in its own way? Uniform modelling of a sample of 13 quadruply+ imaged quasars. MNRAS, 483, 5649–5671, 2019.
10. **Shajib, A. J.**, Treu, T., and Agnello, A. Improving time-delay cosmography with spatially resolved kinematics. MNRAS, 473, 210–226, 2018.
11. **Shajib, A. J.** and Wright, E. L. Measurement of the integrated Sachs-Wolfe effect using the AllWISE data release. ApJ, 827:116 (9pp), 2016.

Second-author publications

1. Birrer, S., **Shajib, A. J.**, et al. lenstronomy II: A gravitational lensing software ecosystem. Journal of Open Source Software, 6(62), 3283, 2021.
2. Birrer, S., **Shajib, A. J.**, et al. TDCOSMO IV: Hierarchical time-delay cosmography – joint inference of the Hubble constant and galaxy density profiles. A&A 643, A165, 2020.

Other co-authored publications

1. Sonnenfeld, A., et al. Strong lensing selection effects. arXiv:2301.13230, 2023.
2. Pierel, J. D. R., et al. LensWatch: I. Resolved HST Observations and Constraints on the Strongly-Lensed Type Ia Supernova 2022qmx ("SN Zwicky"). arXiv:2211.03772, 2022.
3. Zaborowski, E., et al. Identification of Galaxy-Galaxy Strong Lens Candidates in the DECam Local Volume Exploration Survey Using Machine Learning. arXiv:2210.10802, 2022.
4. Birrer, S., Millon, M., Sluse, D., **Shajib, A.,** et al. Time-Delay Cosmography: Measuring the Hubble Constant and other cosmological parameters with strong gravitational lensing. arXiv:2210.10833, 2022.
5. Mozumdar, P., et al. TDCOSMO. XII. New lensing galaxy redshift and velocity dispersion measurements from Keck spectroscopy of eight lensed quasar systems. arXiv:2209.14320, 2022.
6. Ertl, S., et al. TDCOSMO XI. Automated Modeling of 9 Strongly Lensed Quasars and Comparison Between Lens Modeling Software. arXiv:2209.03094, 2022.
7. Lemon, C., et al. Gravitationally lensed quasars in Gaia – IV. 150 new lenses, quasar pairs, and projected quasars. arXiv:2206.07714, 2022.

8. Schmidt, T., Treu, T., Birrer, S., **Shajib, A. J.**, et al. STRIDES: Automated uniform models for 30 quadruply imaged quasars. arXiv:2206.04696, 2022.
9. Morgan, R., et al. DeepZipper II: Searching for Lensed Supernovae in Dark Energy Survey Data with Deep Learning. arXiv:2204.05924, 2022.
10. Akhazhanov, A., et al. Finding quadruply imaged quasars with machine learning. I. Methods. MNRAS, 513, 2, 2407-2421, 2022.
11. Birrer, S., Dhawan. S., and **Shajib, A. J.** The Hubble constant from strongly lensed supernovae with standardizable magnifications. ApJ, 924, 1, 2, 2022.
12. Ding, X., et al. Time Delay Lens Modelling Challenge. MNRAS, 503, 1096-1123, 2021.
13. Buckley-Geer, E. J., et al. STRIDES: Spectroscopic and photometric characterization of the environment and effects of mass along the line of sight to the gravitational lenses DES J0408−5354 and WGD 2038−4008. MNRAS, 498, 3, 3241-3274, 2020.
14. Lemon, C., et al. The STRong lensing Insights into the Dark Energy Survey (STRIDES) 2017/2018 follow-up campaign: Discovery of 10 lensed quasars and 10 quasar pairs. MNRAS, 494, 3, 3491-3511, 2020.
15. Millon, M., et al. TDCOSMO - I. An exploration of systematic uncertainties in the inference of H_0 from time-delay cosmography. A&A, 639, A101, July 2020.
16. Wong, C. K., et al. H0LiCOW – XIII. A 2.4 per cent measurement of H_0 from lensed quasars: 5.3σ tension between early- and late-Universe probes. In press (MNRAS), MNRAS, 498, 1, 1420-1439, 2020.
17. Chen, G. C.-F., et al. A SHARP view of H0LiCOW: H_0 from three time-delay gravitational lens systems with adaptive optics imaging. MNRAS, 490, 1743–1773, 2019.
18. Taubenberger, S., et al. The Hubble Constant determined through an inverse distance ladder including quasar time delays and Type Ia supernovae. A&A, 628, L7, 2019.
19. Rusu, C. E., et al. H0LiCOW XII. Lens mass model of WFI2033-4723 and blind measurement of its time-delay distance and H_0. MNRAS, 498, 1, 2020, 1420-1439, 2020.
20. Sluse, D., et al. H0LiCOW X: Spectroscopic/imaging survey and galaxy-group identification around the strong gravitational lens system WFI2033-4723. MNRAS, 490, 613–633, 2019.
21. Birrer, S., et al. H0LiCOW - IX. Cosmographic analysis of the doubly imaged quasar SDSS 1206+4332 and a new measurement of the Hubble constant. MNRAS, 484, 4726–4753, 2019.
22. Chen, G. C.-F., et al. Constraining the microlensing effect on time delays with new time-delay prediction model in H_0 measurements. MNRAS, 481, 1115–1125, 2018.
23. Williams, P. R., et al. Discovery of three strongly lensed quasars in the Sloan Digital Sky Survey. MNRAS: Letters, 477, L70–L74, 2018.

Non-refereed papers

1. Di Valentino, E., et al. Snowmass2021 - Letter of interest cosmology intertwined IV: The age of the universe and its curvature. Astroparticle Physics, Volume 131, 102607, 2021.
2. Di Valentino, E., et al. Snowmass2021 - Letter of interest cosmology intertwined III: $f\sigma_8$ and S_8. Astroparticle Physics, Volume 131, 102604, 2021.
3. Di Valentino, E., et al. Snowmass2021 - Letter of interest cosmology intertwined II: The Hubble constant tension. Astroparticle Physics, Volume 131, 102605, 2021.
4. Di Valentino, E., et al. Snowmass2021 - Letter of interest cosmology intertwined I: Perspectives for the next decade Astroparticle Physics, Volume 131, 102606, 2021.
5. Beaton, R. L., et al. Measuring the Hubble Constant Near and Far in the Era of ELT's. BAAS 51(3) 456, 2019.

6. Ding, X., Treu, T., **Shajib, A. J.**, et al. Time Delay Lens Modelling Challenge: I. Experimental Design. arXiv:1801.01506, 2018.