

# Charlotte Ward

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Department of Astrophysical Sciences, Princeton University  
Peyton Hall · 4 Ivy Lane · Princeton, NJ 08544

<https://charlotteaward.github.io>  
[charlotte.ward@princeton.edu](mailto:charlotte.ward@princeton.edu)

## Education

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Ph.D., Astronomy, University of Maryland at College Park	2022
Thesis: <i>Tracing the formation and merger-driven growth of massive black holes with the Zwicky Transient Facility</i>	
M.Sc., Astronomy, University of Maryland at College Park	2019
B.Sc. (Adv) (Hons), Physics & Mathematics, University of Sydney	2016
Thesis: <i>Machine learning techniques for discovery of Fast Radio Bursts with the Parkes Radio Telescope</i>	

## Professional Employment and Internships

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Assistant Professor, The Pennsylvania State University	Starting 2025
Postdoctoral Research Associate, Princeton University	2022 – 2025
HEP Center for Computational Excellence Graduate Summer Internship, Lawrence Berkeley National Laboratory	2019
School of Physics Laboratory Tutor, University of Sydney	2017
Summer Scholar, Centre for Astronomy and Space Science, CSIRO	2015, 2016
Nanjing Research Exchange Visiting Scholar, Nanjing University	2015
Faculty of Science Information Officer, University of Sydney	2014 – 2015
Undergraduate research student, Quantum Control Laboratory, University of Sydney	2015
Undergraduate research student, Institute of Medical Physics, University of Sydney	2014

## Research interests

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Multi-wavelength analysis of astrophysical transients; dwarf galaxy AGN; changing-state AGN; tidal disruption events; quasi periodic eruptions; SMBH binaries; optical studies of pulsars; multi-resolution image modeling techniques for joint-survey analysis; large-scale pipelines for wide-field time-domain surveys.

## Observing Proposals and Grants

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<b>PI:</b> <i>Joint modeling of imaging data from LSST and complementary surveys to maximize early transient science</i> (LSST Discovery Alliance Small Grant Proposal, \$8K awarded)	2024
<b>PI:</b> <i>Understanding young radio jets in changing-look AGN with ATCA</i> (ATCA)	2024
<b>PI:</b> <i>Investigating newly launched radio jets in changing-state AGN</i> (ASKAP Variable And Slow Transients (VAST) radio survey)	2024
<b>PI:</b> <i>Newly born radio jets in galaxy nuclei: Determining rates and mechanisms for the appearance of bright radio emission in previously radio-quiet AGN.</i> (ASKAP VAST)	2024
<b>PI:</b> <i>Understanding episodic SMBH accretion triggering with changing-look AGN</i>	

(Magellan, Princeton allocation)	2023
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<b>PI:</b> <i>Investigating 10 Candidates for Gravitational Wave Recoil from an SMBH merger</i> (Keck, NASA allocation, \$15K grant awarded)	2023
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<b>PI:</b> <i>Confirming the presence of AGN for the variability-selected IMBH candidates from ZTF and WISE</i> (Magellan, Princeton allocation)	2023
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## Honors, Awards and Press Coverage

<i>Equity Prize for Outreach</i> , Department of Astrophysical Sciences, Princeton U.	2024
<i>Martin and Beate Block Winter Award</i> , Aspen Center for Physics	2023
<i>ZTF IMBH paper featured in Astrobites article</i>	2023
<i>ZTF Recoiling AGN paper featured in New Scientist</i>	2021
<i>Graduate Student Summer Research Fellowship</i> , University of Maryland at College Park	2020
<i>Graduate School Dean's Fellowship for Astronomy</i> , University of Maryland at College Park	2017
<i>Physics Foundation Scholarship No III</i> , University of Sydney	2016
<i>School of Physics Honours Scholarship</i> , University of Sydney	2016
<i>Faculty of Science Merit Scholarship</i> , University of Sydney	2013-2015
<i>School of Physics Smith Prize in Experimental Physics</i> , University of Sydney	2013

## Selected Colloquia, Seminars and Conference Talks

<i>Invited Talk</i> , HEACOSS-2024 conference	2024
<i>Invited Talk</i> , SIFA Morning Tea, University of Sydney School of Physics	2024
<i>Invited Seminar</i> , Naval Research Laboratory Remote Sensing Division	2024
<i>Contributed Talk</i> , Rubin Community Workshop	2024
<i>Contributed Talk</i> , Tidal Disruption Events and Nuclear Transients conference	2024
<i>Invited Colloquium</i> , The Pennsylvania State University, Department of Astronomy	2023
<i>Contributed Talk</i> , IMBHs: The Dawn of a Revolutionary Era conference	2023
<i>Invited Seminar</i> , ASKAP Variable And Slow Transients (VAST) team meeting	2023
<i>Contributed Talk</i> , Aspen Winter Conference: eXtreme Black Holes	2023
<i>Invited Colloquium</i> , Lawrence Berkeley National Laboratory, Computer Sciences Division	2022
<i>Invited Seminar</i> , Stanford KIPAC Tea Talk	2022
<i>Invited Colloquium</i> , Lawrence Berkeley National Laboratory, Physics Division	2022
<i>Invited Colloquium</i> , Australia Telescope National Facility, CSIRO	2022
<i>Invited Seminar</i> , Nanograv Meeting	2022
<i>Contributed Talk</i> , IMBHs: New Science from Stellar Evolution to Cosmology conference	2022
<i>Contributed Talk</i> , Aspen Winter Conference: Dynamical Formation of GW Sources	2022
<i>Invited Seminar</i> , Johns Hopkins University AGN Journal Club	2021
<i>Invited Seminar</i> , NASA Goddard AGN Seminar Series	2021
<i>Contributed Talks</i> , ZTF Team Meetings in Stockholm, Tel Aviv, and Pasadena	2018-2019

## EDI and Public Outreach

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New Jersey State Museum & Planetarium ‘Science Under the Stars’ speaker	2024
<i>Peyton Observatory Public Observing: volunteer/ lead observer/co-coordinator</i> , Princeton U.	2022 - 2024
<i>EDI seminar series coordinator</i> , Princeton University	2023 - 2024
<i>Astronomy on Tap Trenton Chapter: co-coordinator/speaker</i> , Princeton University	2023 - 2024
<i>Postdoc - Grad Student Mentoring Program mentor</i> , Princeton University	2023 - 2024
<i>Co-lead of GRAD-MAP (Graduate Resources Advancing Diversity in Maryland Astronomy and Physics) program</i> , University of Maryland	2020-2021
<i>Astronomy outreach volunteer</i> , University of Maryland. Selected events: GRAD-MAP Open House (speaker, coordinator)	2019-2021
GRAD-MAP visits to Prince George’s Community College, Howard University, Montgomery CC and Howard CC (speaker, coordinator)	2019-2021
Anne Arundel County Public Library’s STEM day (volunteer)	2019
UMD observatory Open House (volunteer)	2018
<i>Pulse@Parkes High School Outreach Program volunteer</i> , CSIRO	2014-2015

## Professional Service and Leadership

<i>Invited Speaker</i> , VLASS Epoch 4 Review Panel	2024
<i>Discussion Panelist</i> , Hubble Space Telescope Cycle 32 Review	2024
<i>Astrocoffee (arXiv journal club) host</i> , Princeton University	2023 - ongoing
<i>Referee for MNRAS, ApJ</i>	2022 - ongoing
VLASS Survey Science working group	2024 - ongoing
<i>CanTAC Gemini external proposal referee</i>	2022
<i>Co-coordinator of the Department of Astronomy Journal Club</i> , University of Maryland	2019-2021

## Teaching and Research Mentoring

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<i>Undergraduate Summer Research Program Advisor</i> , Princeton University	2023, 2024
<i>Undergraduate Junior Thesis Advisor</i> , Princeton University	2023, 2024
<i>Undergraduate Senior Thesis Advisor</i> , Princeton University	2024
<i>Masters Thesis Co-advisor (engineering)</i> , Princeton University	2023
<i>Undergraduate Summer Research Program Co-Advisor</i> , Space Telescope Science Institute	2023
<i>GROWTH time-domain astronomy school tutor</i> , San Diego State University	2020
<i>Research advisor, GRAD-MAP Winter Workshop</i> , University of Maryland	2019
<i>Teaching Assistant</i> , ‘Special Problems in Astronomy: Big Data’, University of Maryland	2018
<i>Research Co-advisor, GRAD-MAP Winter Workshop</i> , University of Maryland	2018
<i>GRAD-MAP Python Bootcamp developer</i> , University of Maryland	2018
<i>3rd year computational physics lab tutor</i> , University of Sydney	2017
<i>2nd year experimental physics lab tutor</i> , University of Sydney	2017

## Selected Peer-Reviewed and Submitted Publications

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**36 total, 22 with significant contributions**, h-index=21, 3097 total citations.

\*: graduate student <sup>†</sup>: undergraduate student

**Ward, C.**, Melchior, P., Sampson, M.\* et al. ‘Disentangling transients and their host galaxies with Scarlet2: A framework to forward model multi-epoch imaging’, submitted to *Astronomy and Computing*, 2024, arXiv: 2409.15427.

**Ward, C.**, Gezari, S., Nugent, P et al. ‘Panic at the ISCO: time-varying double-peaked broad lines from evolving accretion disks are common amongst optically variable AGN’, **2024**, *The Astrophysical Journal*, 961, 172.

**Ward, C.**, Gezari, S., Nugent, P et al. ‘Variability-selected intermediate mass black hole candidates in dwarf galaxies from ZTF and WISE’, **2022**, *The Astrophysical Journal*, 936, 104.

**Ward, C.**, Gezari, S., Frederick, S. et al. ‘AGNs on the Move: A Search for Off-nuclear AGNs from Recoiling Supermassive Black Holes and Ongoing Galaxy Mergers with the Zwicky Transient Facility’, **2021**, *The Astrophysical Journal*, 913, 102.

Sampson, M.\*, Melchior, P., **Ward, C.**, Birmingham, S.<sup>†</sup> ‘Score matching diffusion models as data-driven priors for improved multi-band source separation’, **2024**, *Astronomy and Computing*, Volume 49, id.100875, doi:10.1016/j.ascom.2024.100875.

Uppal, A.<sup>†</sup>, **Ward C.**, et al. ‘Astrometric Jitter as a Detection Diagnostic for Recoiling and Slingshot Supermassive Black Hole Candidates’, in press *ApJ*, **2024**, arXiv: 2405.11026.

Ridley, E.\*, Nicholl, M., **Ward, C.** et al. ‘AT2017bcc: time-varying double-peaked emission lines following the sudden ignition of a dormant galactic nucleus’, **2024**, *MNRAS*, 531, 1905.

Burke, C., Liu, Y.<sup>†</sup>, **Ward, C.** et al. ‘Dwarf AGNs from Variability for the Origins of Seeds (DAVOS): Properties of Variability-Selected AGNs in the COSMOS Field and Expectations for Rubin Observatory’, **2024**, *ApJ*, 971, 140.

Onoue, M. et al., (author 7 of 35), ‘A Post-Starburst Pathway to Forming Massive Galaxies and Their Black Holes at  $z > 6$ ’, submitted to *Nature Astronomy*, **2024**, arXiv: 2409.07113.

Nyland, K. et al. (including **Ward, C.**) ‘VLASS Epoch 4 Science Case’ white paper, **2024**, <https://science.nrao.edu/vlass/library/white-papers>.

Liang, Y.\*, Melchior, P., et al. (author 7 of 7) ‘Outlier Detection in the DESI Bright Galaxy Survey’, **2023**, *ApJL*, 956, L6.

Liang, Y.\*, Melchior, P. et al. (author 5 of 5), ‘Autoencoding Galaxy Spectra II: Redshift Invariance and Outlier Detection’, **2023**, *ApJ*, 166, 75.

Hammerstein, E.\*, Gezari, S. et al. (author 7 of 9), ‘Integral Field Spectroscopy of 13 Tidal Disruption Event Hosts from the ZTF Survey’, **2023**, *ApJ*, 957, 86.

Arcodia, R. et al (author 17 of 19), ‘O Corona, where art thou? eROSITA’s view of UV-optical-IR variability-selected massive black holes in low-mass galaxies’, **2023**, A&A, 681, A97.

Brightman, M., **Ward, C.** et al. ‘A Luminous X-Ray Transient in SDSS J143359.16+400636.0: A Likely Tidal Disruption Event’, **2021**, The Astrophysical Journal, 909, 102.

Hammerstein, E.\* , Gezari, S., van Velzen, S. et al. (author of 6 of 20) ‘Tidal Disruption Event Hosts Are Green and Centrally Concentrated: Signatures of a Post-merger System’, Erica Hammerstein et al. **2021**, ApJL, 908, L20.

van Velzen, S., Hammerstein, E.\* , Gezari, S., et al. (author 6 of 44) ‘Seventeen Tidal Disruption Events from the First Half of ZTF Survey Observations: Entering a New Era of Population Studies’, **2021**, ApJ, 908, 4.

Frederick, S. et al. (author 8 of 20), ‘A Family Tree of Optical Transients from Narrow-Line Seyfert 1 Galaxies’, **2021**, ApJ, 920, 56.

Stein, R. et al. (including Ward, C.), ‘A tidal disruption event coincident with a high-energy neutrino’, **2021**, Nature Astronomy, 5, 510.

Coppejans, D. L. et al. (author 22 of 38), ‘A Mildly Relativistic Outflow from the Energetic, Fast-rising Blue Optical Transient CSS161010 in a Dwarf Galaxy’, **2020**, ApJL 895, L23.

Andreoni, I. et al. (author 16 of 52), ‘GROWTH on S190814bv: Deep Synoptic Limits on the Optical/Near-infrared Counterpart to a Neutron Star-Black Hole Merger’, **2020**, ApJ, 890, 131.

van Velzen, S. et al. (author 15 of 41), ‘The First Tidal Disruption Flare in ZTF: From Photometric Selection to Multi-wavelength Characterization’, **2019**, ApJ, 172, 198.

Mahabal, A. et al. (author 15 of 50), ‘Machine Learning for the Zwicky Transient Facility’, **2019**, PASP, 131, 997.

Frederick, S. J. et al. (author 15 of 20), ‘A New Class of Changing-look LINERs’, **2019**, The Astrophysical Journal, 883, 31.

Hung, T. et al. (author 15 of 28), ‘Discovery of Highly Blueshifted Broad Balmer and Metastable Helium Absorption Lines in a Tidal Disruption Event’, ApJ, **2019**, 879, 119.

Duev, D. et al. (author 11 of 11), Real-bogus classification for the Zwicky Transient Facility using deep learning’, **2019**, MNRAS, 489, 3582.

van Roestel, J. et al. (author 10 of 12), ‘Simultaneous Observations of the Northern TESS Sectors by the Zwicky Transient Facility’, **2019**, RNAAS, 3, 9, 136.

Perley, D. et al. (author 63 of 65), ‘The fast, luminous ultraviolet transient AT2018cow: extreme supernova, or disruption of a star by an intermediate-mass black hole?’, **2019**, The Monthly Notices of the Royal Astronomical Society, 484, 1.

Dobie, D. . et al. (author 28 of 30), ‘An ASKAP Search for a Radio Counterpart to the First High-significance Neutron Star—Black Hole Merger LIGO/Virgo S190814bv’, **2019**, The Astrophysical Journal, 887, 13.

Nordin, J. et al. (including Ward, C.), ‘Transient processing and analysis using AMPEL: alert management, photometry, and evaluation of light curves’, **2019**, A&A, 631, 147.

Kerr, M. et al. (author 3 of 6), ‘Extreme Scattering Events Towards Two Young Pulsars’, **2018**, MNRAS, 474, 4.

Hobbs, G. et al. (author 9 of 78), ‘A pilot ASKAP survey of radio transient events in the region around the intermittent pulsar PSR J1107- 5907’, **2016**, MNRAS, 456, 4.

Lynch, C. et al. (author 6 of 6), ‘Radio detections of southern ultracool dwarfs’, **2016**, The Monthly Notices of the Royal Astronomical Society, 457, 2.

## Papers in preparation

**Ward, C.**, Kerr, M., et al. ‘Optical detections and upper limits for isolated and binary radio pulsars in the PanSTARRS, HSC-wide and Legacy Surveys’, in prep.

**Ward, C.**, et al. ‘Double-peaked emitters in hard X-ray-selected AGN populations’, in prep.

Birmingham, S.<sup>†</sup>, **Ward, C.** et al. ‘The onset of optical variability and launching of young radio jets in changing-state AGN’, in prep.

## Skills

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*Software:* Key astronomy and computing software such as jax, Github, Docker, Swarp, Scamp, SExtractor, Psfex, Aplot, astropy, ds9, Hotpants, iraf, LaTeX, scikit-learn.

*Observing and data reduction:* Obtaining and reducing optical imaging, spectrograph and IFU observations.

*Time-domain astronomy tools:* Source investigation and follow-up with the Transient Name Server, Vizier, NED, the HEASARC Data Archive, the GROWTH Marshal, SkyPortal and alert brokers such as AMPEL.

*Transient alert filtering:* Developing filters for transient alerts from large optical surveys and implementing machine learning classifiers for transient discovery.

*Optical image modeling:* Forward modeling optical images for source characterization and photometry.

*High performance computing:* Developing software for computationally intensive analysis and processing of large data sets on supercomputing clusters, including on GPUs. Use of cluster resource management and checkpointing software. Use of HPSS archives for data storage.

*Database management:* SQL query construction. Use of postgresSQL for database management.