Gautham Narayan

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RESEARCH INTERESTS

- Observational Cosmology and Cosmography
- Time-domain Astrophysics, particularly Transient Phenomena
- Wide-field Ultraviolet, Optical and Infrared Surveys
- Multi-messenger Astrophysics & Rapid Follow-up Studies
- Statistics, Data Science and Machine Learning

PROFESSIONAL APPOINTMENTS

Current: Lasker Data Science Fellow, Space Telescope Science Institute
June 2017–present

Previous: Postdoctoral Fellow, National Optical Astronomy Observatory
Jul 2013–Jun 2017[1]

EDUCATION

Harvard University

Ph.D. Physics, May 2013
Thesis: "Light Curves of Type Ia Supernovae and Cosmological Constraints from the ESSENCE Survey"
Adviser: Prof. Christopher W. Stubbs
A.M. Physics, May 2007

Illinois Wesleyan University

B.S. (Hons) Physics, Summa Cum Laude, May 2005
Thesis: "Photometry of Outer-belt Objects"
Adviser: Prof. Linda M. French

AWARDS AND GRANTS

- 2nd ever recipient of the Barry M. Lasker Data Science Fellowship, STScI, 2017–present
- Co-I on several *Hubble Space Telescope* programs with grants totaling over USD 1M, 2012–present
- Co-I, grant for developing ANTARES broker, Heising-Simons Foundation, USD 567,000, 2018
- STScI Director's Discretionary Funding for student research, USD 2500, 2017–present
- LSST Cadence Hackathon, USD 1400, 2018
- Best-in-Show, Art of Planetary Science, Lunar and Planetary Laboratory, U. Arizona, 2015
- Purcell Fellowship, Harvard University, 2005
- Research Honors, Summa Cum Laude, Member of $\Phi B K$, $\Phi K \Phi$, IWU, 2005

RESEARCH HISTORY AND SELECTED PUBLICATIONS

I work at the intersection of cosmology, astrophysics, and data science. Below are brief descriptions of my work on key topics, together with a related publication (full list of publications is at end).

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[1] Formally employed by The University of Arizona CS Dept. from Dec 2014–Apr 2016, but located at NOAO

Machine Learning for Time-Domain Discovery

- Lead developer of machine-learning algorithms for time-series classification on state-of-the-art alert broker system: ANTARES
- Key focus on anomaly detection to identify rare and unusual transients
- Two accepted, three in prep. publications
- Presently testing ANTARES on Zwicky Transient Facility (ZTF) alerts as test bed for Large Synoptic Survey Telescope (LSST)
- Lead of validation team for Photometric LSST Astronomical Time-Series Classification Challenge (PLAsTiCC) — public challenge with $30,000 in prizes for novel algorithms
- Evolving research area — will become effort to build generative models of the entire time-domain sky for statistical studies

Narayan et al., '18, "Machine-learning-based Brokers for Real-time Classification of the LSST Alert Stream", ApJS Special Issue "Data: Insights and Challenges in a Time of Abundance"

Understanding the Physics of Rare and Unusual Transients

- Leading analysis of progenitor constraints from *Kepler* SN 2018agk, and ultra-rapid transient AT 2018dzv with my student D. Muthukrishna
- Led or made major contributions to several projects studying unusual SN, including SN 2018oh, SN 2009ku, SN 2008ha, as well as open-source tools to model such events
- Combining work on machine learning with interest in rare & unusual transients by developing novel methods for anomaly detection, incorporating gravitational wave, neutrino and high-energy gamma ray signals into alert-brokers.

Narayan et al., '11, "Displaying the Heterogeneity of the SN 2002cx-like Subclass of Type Ia Supernovae with Observations of the Pan-STARRS-1 Discovered SN 2009ku", ApJL

Cosmology and the Nature of Dark Energy

- Led analysis using ESSENCE and literature SNIa to derive cosmological constraints on dark energy equation of state w; co-authored analysis on PS1 SNIa Foundation photometric SNIa, RAISIN NIR SNIa
- Co-developed BayeSN with K. Mandel — probabilistic model to infer distance moduli, light curve, and dust properties from UV+Optical+NIR data of low-z SNIa; currently evolving into model for SNIa SED inference at cosmological distances for *WFIRST*, future surveys
- Leading analysis apply BayeSN-SED to combined Foundation, Pan-STARRS & literature samples — will be the largest dataset of confirmed cosmological SNIa

Narayan et al., '16, "Light Curves of 213 Type Ia Supernovae from the ESSENCE Survey", ApJS

Operations, Calibration & Optimization of Wide-field Surveys

- Implementing active learning for *TESS* and LSST — targeted observations of least-understood sources to refine machine learning models, and improve survey performance iteratively
- Lead analysis to use *Hubble* imaging and large-aperture spectroscopy to establish faint spectrophotometric standards for LSST and future surveys
- Extensive involvement in transient pipeline development & validation for Pan-STARRS, survey simulations for Foundation, YSE, and analysis of cadence for LSST Wide-Fast-Deep Survey

Narayan et al., '18, "Sub-percent Photometry: Faint DA White Dwarf Spectrophotometric Standards for Astrophysical Observatories", ApJS, submitted

PROFESSIONAL AFFILIATIONS

I am an active member of several groups and projects, completed and on-going:

The LSST Dark Energy Science Collaboration (DESC)	The PLAsTiCC Team
The LSST Transient & Variable Stars Collaboration (TVS)	The ANTARES Project
The *Kepler* Extra Galactic Survey (KEGS)	The DA White Dwarf Calibration Team
The Foundation Survey	The Young Supernova Experiment (YSE)
The Pan-STARRS PS1 Science Collaboration	The ESSENCE Collaboration
The Mosaic z-band Legacy Survey (MzLS)	The RAISIN Survey

Member of the American Astronomical Society (2007–present)

OBSERVING EXPERIENCE

I am an observational cosmologist with extensive experience with different facilities:

- Co-I on several major *HST* programs with *WFC3*, *ACS* and *STIS* including:
  GO-12967 (18 orbits), 12999 (8 orbits), 13046 (100 orbits), 13711 (60 orbits), 14216 (100 orbits), 14244 (8 orbits) and 15113 (54 orbits)
- MMT Observatory: 15 nights of Blue Channel spectroscopy on site, 2 nights of remote observing
- Magellan Observatory: 7 nights LDSS3 imaging and long-slit spectroscopy
    1 night of IMACS long-slit spectroscopy
- Gemini Observatory: Analysis of GMOS spectroscopy from ∼5 nights of queue observing
- Kitt Peak National Observatory: several nights of imaging on the 4 m with MOSAIC 1.1 & 3
- Cerro-Tololo Inter-American Observatory: 5 nights of imaging on the 0.9 m with Tek2K
    Analysis of 197 nights of MOSAIC-II imaging for ESSENCE/SuperMacho
- WIYN Observatory: 3 nights of imaging on the WIYN 3.5 m with ODI
- F. L. Whipple Observatory: several nights of long-slit spectroscopy on the 1.5 m with FAST
    and imaging on the 1.2 m with Keplercam, both on-site and remote
- Las Cumbres Observatory: Analysis of 120 hours of 1 m SINISTRO imaging

I've helped design, implement, schedule and optimize numerous surveys. Together with Armin Rest and Mark Huber, I adapted the SMSN `photpipe` pipeline to work on numerous other projects. To date, it has processed ∼4 PB of images, including the entirety of the PS1 Medium Deep Survey, and discovered several thousand transient and variable sources. My experience as an observer has also benefited from instructing several undergraduates, graduate students and postdocs.

SOFTWARE PROFICIENCIES

- Developer on several packages available at <http://github.com/gnarayan>
- Core research strength: inference with bespoke probabilistic and machine learning models
- Extensive experience developing image processing pipelines for ground and space telescopes
- Fluent in Python, C++, IDL and Perl
- Comfortable with C, R, Java, Fortran 95, and IRAF
- Familiarity with Scheme, ML, Haskell, PhP, Ruby and Julia
- Well-versed with several database architectures, provenance, redundancy, and version control
- Proficient with SLURM, HTCondor, PBS, LSF and SGE distributed computing environments
- Some familiarity with Amazon Web Services, Kubernetes and Docker, XSEDE, and Hadoop

MENTORING AND TEACHING

Daniel Muthukrishna (U. Cambridge), Co-Adviser, 2017–present

- Presently in 2nd year of Ph.D with K. Mandel at Cambridge
- Research with Narayan on deep learning for transient classification (RAPID)
- Publication in progress: Muthukrishna, Narayan & Mandel, 2018, in prep.
- Muthukrishna is key member of LSST PLAsTiCC validation team
- Working with Narayan, Rest and KEGS team on AT 2018dzv

Linoy Kotler (American University), REU Adviser, 2018–present

- Research on wavelet-based classification of Foundation photometric SNIa sample
- Currently preparing for GRE and will likely continue work in Spring for senior capstone project
- Will be co-author on upcoming Foundation cosmology analysis: Jones et al., 2019, in prep.

Tayeb Zaidi (Macalester College), Honors Thesis Adviser, 2016–7

- Began working with Narayan on ANTARES as summer REU student at NOAO in 2015
- Continued work on time-series classification for Senior Honors (earned April 2017)
- Published Narayan, Zaidi, Soraisam et al., 2018, adapted for LSST PLAsTiCC
- Now applying his experience with ML techniques in graduate work at Bryn Mawr College, PA

Marcus Lee (TOCC/UA), REU Adviser & Mentor 2014–5

- First indigenous (Tohono O'odham) student to complete REU program at NOAO
- Evaluated different techniques for period estimation of variable stars
- REU program was introduction to astronomy, statistics and programming
- Transferred to U. Arizona from Tohono O'odham Community College in Fall after REU

Daniel Alcantara (Bard College), Research Collaborator, 2016–present

- Intern with R. Street at Las Cumbres Observatory working on microlensing detection
- Worked with Narayan to dramatically improve performance of prototype classifier
- Algorithm being used with MARS broker to find microlensing candidates with ZTF
- Submission of Alcantara, Bachelet, Narayan and Street, 2018 imminent

I've authored papers with grad students from the U. Arizona Computer Science Dept. on ANTARES, particularly Zhe Wang and Shuo Yang, connecting their research with astrophysics.

Instructor for:	ZTF Summer School, Pasadena, Aug. 2018 LSST Data Science Fellowship Program, Session 5, Baltimore, Jan. 2018 LSST Data Science Fellowship Program, Session 3, Tucson, Apr. 2017 NOAO Teen Astronomy Cafe, "How Stars Die", Tucson, Nov. 2017 NOAO Big Data Workshop for Tucson High School Students, Tucson, Jan. 2017 Python Workshop for NOAO/NSO REU Students, Tucson, Summer 2014 & 2015

I will be a Kavli Visitor at the University of Cambridge in Spring 2019. I've additionally served as a Teaching Assistant at Harvard, as Teaching Assistant, Lab Assistant and Tutor at Illinois Wesleyan, and as guest lecturer for Astro 102 (Instructors: C. Salyk and K. Garmany) at the Tohono O'odham Community College.

INVITED COLLOQUIA/SEMINARS/CONFERENCES, 2015–PRESENT

Kavli Visitor, University of Cambridge, Institute of Astronomy, Scheduled, Spring 2019
University of Minnesota, Dept. of Physics and Astronomy Colloquium, Nov. 2018
LSST Cadence Hackathon, New York, NY, Sep. 2018
Machine Learning for Science and Engineering, Pittsburgh, Jun. 2018
NSF Workshop on Multi Messenger Astrophysics, College Park, May 2018
LSST Photometric Classification Challenge "PLAsTiCC" Sprint Week - New York, NY, May. 2018
Python in Astronomy - New York, NY, Apr. 2018
New Advances in NIR type Ia Supernova Science - Pittsburgh, PA, Apr. 2018
LSST PLAsTiCC Workshop - New York, NY, Jul. 2017
Supernovae: The LSST Revolution - Evanston, IL, Jun. 2017
Building the Infrastructure for Time-Domain Alert Science in the LSST Era - Tucson, AZ, May 2017
Hot Wiring the Transient Universe V - Philadelphia, PA, Oct. 2016
Photometric Classification of Supernovae workshop - Chicago, IL, Apr. 2016
LSST Joint Technical Meeting - Santa Cruz, CA, Feb 2016
Hot Wiring the Transient Universe IV - Santa Barbara, CA, May 2015
Illinois Wesleyan University Natural Science Colloquium - Bloomington, IL, Apr. 2015
Tools for Astronomical Big Data - Tucson, AZ, March 2015

SERVICE & PUBLIC OUTREACH WORK

Chair, Enabling Multi Messenger Astrophysics in the Big Data Era, Apr. 25–26, 2019
SOC, Deep Learning for Multimessenger Astrophysics: Real-time Discovery at Scale, Oct. 2018
LOC, Building the Infrastructure for Time-Domain Alert Science in the LSST Era, May 2017
Organizer, Astronomy on Tap - Tucson/Space Drafts, 2015-2017
Organizer, NOAO FLASH Talk Series, 2015–2017
Organizer, NOAO Coffee Hour Series, 2014–5
Reviewer for the AAS Journals, ongoing
Speaker, Space Telescope Public Lecture Series, Chasing Supernovae with Kepler, Sep. 2018
Guest, Three Body Problems Podcast, Bringing Data Science Into Astronomy, Sept. 2018
Scientist, TED-Ed Original Videos (Pt. 1) (Pt. 2)
Speaker, 365 Days of Astronomy Podcast (Pt. 1) (Pt. 2)
Speaker, Youth for Astronomy and Engineering, Nov. 2018
Speaker, NerdNite Baltimore, Mar. 2018
Panelist, Tucson Comic Con and TUSCon, Nov. 2015 and 2016
     "Robots in Space" and "The Physics of Space Battles"
Speaker, Astronomy on Tap - Tucson with the Tucson Symphony Orchestra, Oct. 2016
     "A Trip through Gustav Holst's Planets"
Speaker, Astronomy on Tap - Tucson, Jan. 2015
     "If You Only Knew The Power of The Dark Side"
Speaker, Green Valley Astronomy Club, Sahuarita, AZ, May 2016
Volunteer, Science Night, Elvira Elementary School, Tucson, AZ, Mar. 2015 and Mar. 2017
Volunteer, Astronomy Night, Arizona Sonoran Desert Museum, Jul. 2015
Volunteer, Kitt Peak National Observatory Open Night for the Tohono O'odham Nation, May 2015
Volunteer, Tucson Festival of Books, Mar. 2015

I've led public stargazing at the Museum of Science in Boston (2011–2), the Table Mountain star party, WA (2006) and throughout my time as an undergraduate at Illinois Wesleyan's Mark Evans Observatory (2001–5).

REFERENCES

Prof. Christopher Stubbs   Dept. of Physics, Harvard University
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LIST OF PUBLICATIONS

h-index: 27, 2909 citations.   (Mendeley/Scopus/Google Scholar)
Publications are listed with 1st author or major contributor first.

Primary Publications

[1] **Machine-learning-based Brokers for Real-time Classification of the LSST Alert Stream**. G. Narayan, T. Zaidi, M. D. Soraisam, Z. Wang, M. Lochner, T. Matheson, A. Saha, S. Yang, Z. Zhao, J. Kececioglu, C. Scheidegger, R. T. Snodgrass, T. Axelrod, T. Jenness, R. S. Maier, S. T. Ridgway, R. L. Seaman, E. M. Evans, N. Singh, C. Taylor, J. Toeniskoetter, E. Welch, S. Zhu, and ANTARES Collaboration. *Astrophys. J. Suppl. Ser.*, May 2018. 236:9.

[2] **Light Curves of 213 Type Ia Supernovae from the ESSENCE Survey**. G. Narayan, A. Rest, B. E. Tucker, R. J. Foley, W. M. Wood-Vasey, P. Challis, C. Stubbs, R. P. Kirshner, C. Aguilera, A. C. Becker, S. Blondin, A. Clocchiatti, R. Covarrubias, G. Damke, T. M. Davis, A. V. Filippenko, M. Ganeshalingam, A. Garg, P. M. Garnavich, M. Hicken, S. W. Jha, K. Krisciunas, B. Leibundgut, W. Li, T. Matheson, G. Miknaitis, G. Pignata, J. L. Prieto, A. G. Riess, B. P. Schmidt, J. M. Silverman, R. C. Smith, J. Sollerman, J. Spyromilio, N. B. Suntzeff, J. L. Tonry, and A. Zenteno. *Astrophys. J. Suppl. Ser.*, May 2016. 224:3.

[3] **Toward a Network of Faint DA White Dwarfs as High-precision Spectrophotometric Standards**. G. Narayan, T. Axelrod, J. B. Holberg, T. Matheson, A. Saha, E. Olszewski, J. Claver, C. W. Stubbs, R. C. Bohlin, S. Deustua, and A. Rest. *Astrophys. J.*, May 2016. 822:67.

[4] **Displaying the Heterogeneity of the SN 2002cx-like Subclass of Type Ia Supernovae with Observations of the Pan-STARRS-1 Discovered SN 2009ku**. G. Narayan, R. J. Foley, E. Berger, M. T. Botticella, R. Chornock, M. E. Huber, A. Rest, D. Scolnic, S. Smartt, S. Valenti, A. M. Soderberg, W. S. Burgett, K. C. Chambers, H. A. Flewelling, G. Gates, T. Grav, N. Kaiser, R. P. Kirshner, E. A. Magnier, J. S. Morgan, P. A. Price, A. G. Riess, C. W. Stubbs, W. E. Sweeney, J. L. Tonry, R. J. Wainscoat, C. Waters, and W. M. Wood-Vasey. *Astrophys. J. Lett.*, Apr. 2011. 731:L11.

[5] **Type Ia Supernova Light Curve Inference: Hierarchical Models in the Optical and Near-infrared**. K. S. Mandel, G. Narayan, and R. P. Kirshner. *Astrophys. J.*, Apr. 2011. 731:120.

[6] **SN 2006bt: A Perplexing, Troublesome, and Possibly Misleading Type Ia Supernova**. R. J. Foley, G. Narayan, P. J. Challis, A. V. Filippenko, R. P. Kirshner, J. M. Silverman, and T. N. Steele. *Astrophys. J.*, Jan. 2010. 708:pp. 1748–1759.

[7] **Survey requirements for accurate and precise photometric redshifts for Type Ia supernovae**. Y. Wang, G. Narayan, and M. Wood-Vasey. *Mon. Not. R. Astron. Soc.*, Nov. 2007. 382:pp. 377–381.

[8] **The Complete Light-curve Sample of Spectroscopically Confirmed SNe Ia from Pan-STARRS1 and Cosmological Constraints from the Combined Pantheon Sample**. D. M. Scolnic, D. O. Jones, A. Rest, Y. C. Pan, R. Chornock, R. J. Foley, M. E. Huber, R. Kessler, G. Narayan, A. G. Riess, S. Rodney, E. Berger, D. J. Brout, P. J. Challis, M. Drout, D. Finkbeiner, R. Lunnan, R. P. Kirshner, N. E. Sanders, E. Schlafly, S. Smartt, C. W. Stubbs, J. Tonry, W. M. Wood-Vasey, M. Foley, J. Hand, E. Johnson, W. S. Burgett, K. C. Chambers, P. W. Draper, K. W. Hodapp, N. Kaiser, R. P. Kudritzki, E. A. Magnier, N. Metcalfe, F. Bresolin, E. Gall, R. Kotak, M. McCrum, and K. W. Smith. *Astrophys. J.*, Jun. 2018. 859:101.

[9] **Cosmological Constraints from Measurements of Type Ia Supernovae Discovered during the First 1.5 yr of the Pan-STARRS1 Survey**. A. Rest, D. Scolnic, R. J. Foley, M. E. Huber, R. Chornock, G. Narayan, J. L. Tonry, E. Berger, A. M. Soderberg, C. W. Stubbs, A. Riess, R. P. Kirshner, S. J. Smartt, E. Schlafly, S. Rodney, M. T. Botticella, D. Brout, P. Challis, I. Czekala, M. Drout, M. J. Hudson, R. Kotak, C. Leibler, R. Lunnan, G. H. Marion, M. McCrum, D. Milisavljevic, A. Pastorello, N. E. Sanders, K. Smith, E. Stafford, D. Thilker, S. Valenti, W. M. Wood-Vasey, Z. Zheng, W. S. Burgett, K. C. Chambers, L. Denneau, P. W. Draper, H. Flewelling, K. W. Hodapp, N. Kaiser, R.-P. Kudritzki, E. A. Magnier, N. Metcalfe, P. A. Price, W. Sweeney, R. Wainscoat, and C. Waters. *Astrophys. J.*, Nov. 2014. 795:44.

[10] **Systematic Uncertainties Associated with the Cosmological Analysis of the First Pan-STARRS1 Type Ia Supernova Sample**. D. Scolnic, A. Rest, A. Riess, M. E. Huber, R. J. Foley, D. Brout, R. Chornock, G. Narayan, J. L. Tonry, E. Berger, A. M. Soderberg, C. W. Stubbs, R. P. Kirshner, S. Rodney, S. J. Smartt, E. Schlafly, M. T. Botticella, P. Challis, I. Czekala, M. Drout, M. J. Hudson, R. Kotak, C. Leibler, R. Lunnan, G. H. Marion, M. McCrum, D. Milisavljevic, A. Pastorello, N. E. Sanders, K. Smith, E. Stafford, D. Thilker, S. Valenti, W. M. Wood-Vasey, Z. Zheng, W. S. Burgett, K. C. Chambers, L. Denneau, P. W. Draper, H. Flewelling, K. W. Hodapp, N. Kaiser, R.-P. Kudritzki, E. A. Magnier, N. Metcalfe, P. A. Price, W. Sweeney, R. Wainscoat, and C. Waters. *Astrophys. J.*, Nov. 2014. 795:45.

[11] **Seeing Double: ASASSN-18bt Exhibits a double-power-law Rise in the Early-Time {\em K2} Light Curve**. B. J. Shappee, T. W.-s. Holoien, M. R. Drout, K. Auchettl, M. D. Stritzinger, C. S. Kochanek, K. Z. Stanek, E. Shaya, G. Narayan, J. S. Brown, S. Bose, D. Bersier, J. Brimacombe, P. Chen, S. Dong, S. Holmbo, B. Katz, J. A. Munnoz, R. L. Mutel, R. S. Post, J. L. Prieto, J. Shields, D. Tallon, T. A. Thompson, P. J. Vallely, S. Villanueva, Jr., L. Denneau, H. Flewelling, A. N. Heinze, K. W. Smith, B. Stalder, J. L. Tonry, H. Weiland, T. Barclay, G. Barentsen, A. M. Cody, J. Dotson, F. Foerster, P. Garnavich, M. Gully-santiago, C. Hedges, S. Howell, D. Kasen, S. Margheim, R. Mushotzky, A. Rest, B. E. Tucker, A. Villar, A. Zenteno, G. Beerman, R. Bjella, G. Castillo, J. Coughlin, B. Elsaesser, S. Flynn, R. Gangopadhyay, K. Griest, M. Hanley, J. Kampmeier, R. Kloetzel, L. Kohnert, C. Labonde, R. Larsen, K. A. Larson, K. M. Mccalmont-everton, C. Mcginn, L. Migliorini, J. Moffatt, M. Muszynski, V. Nystrom, D. Osborne, M. Packard, C. A. Peterson,

M. Redick, L. H. Reedy, S. E. Ross, B. Spencer, K. Steward, J. E. Van Cleve, J. V. D. M. Cardoso, T. Weschler, A. Wheaton, J. Bulger, T. B. Lowe, E. A. Magnier, A. S. B. Schultz, C. Z. Waters, M. Willman, E. Baron, Z. Chen, J. M. Derkacy, F. Huang, L. Li, W. Li, X. Li, L. Rui, H. Sai, L. Wang, L. Wang, X. Wang, D. Xiang, J. Zhang, J. Zhang, K. Zhang, T. Zhang, X. Zhang, X. Zhao, P. J. Brown, J. J. Hermes, J. Nordin, S. Points, G. M. Strampelli, and A. Zenteno. *ArXiv e-prints*, Jul. 2018.

[12] **GALEX and Pan-STARRS1 Discovery of SN IIP 2010aq: The First Few Days After Shock Breakout in a Red Supergiant Star**.   S. Gezari, A. Rest, M. E. Huber, **G. Narayan**, K. Forster, J. D. Neill, D. C. Martin, S. Valenti, S. J. Smartt, R. Chornock, E. Berger, A. M. Soderberg, S. Mattila, E. Kankare, W. S. Burgett, K. C. Chambers, T. Dombeck, T. Grav, J. N. Heasley, K. W. Hodapp, R. Jedicke, N. Kaiser, R. Kudritzki, G. Luppino, R. H. Lupton, E. A. Magnier, D. G. Monet, J. S. Morgan, P. M. Onaka, P. A. Price, P. H. Rhoads, W. A. Siegmund, C. W. Stubbs, J. L. Tonry, R. J. Wainscoat, M. F. Waterson, and C. G. Wynn-Williams. *Astrophys. J. Lett.*, Sep. 2010. 720:pp. L77–L81.

Publications Under Review or In Preparation

[13] **Sub-percent Photometry: Faint DA White Dwarf Spectrophotometric Standards for Astrophysical Observatories**. **G. Narayan**, T. Matheson, A. Saha, A. Calamida, T. Axelrod, J. Claver, K. Mandel, R. C. Bohlin, S. Deustua, E. Olszewski, J. B. Holberg, A. Rest, C. Shannahan, A. Vaz, A. Zenteno, G. Strampelli, I. Hubeny, C. W. Stubbs, S. Points, E. Sabbi, and J. Mackenty. *Astrophys. J. Suppl. Ser., submitted*, Nov. 2018.

[14] **Photometry and Spectroscopy of Faint Candidate Spectrophotometric DA White Dwarfs**. A. Calamida, T. Matheson, A. Saha, E. Olszewski, **G. Narayan**, J. Claver, J. Holberg, T. Axelrod, C. Shananhan, C. W. Stubbs, R. Bohlin, S. Deustua, I. Hubeny, J. Mackenty, S. Points, A. Rest, and E. Sabbi. *Astrophys. J. Suppl. Ser., submitted*, Nov. 2018.

[15] **RAPID: Real-time Automated Photometric Identification using Deep-learning**. D. Muthukrishna, **G. Narayan**, and K. Mandel. *PASP, Special Edition, in preparation*, 2018.

Unrefereed Publications

[16] **Multi-Messenger Astrophysics: Harnessing the Data Revolution**.   G. Allen, W. Anderson, E. Blaufuss, J. S. Bloom, P. Brady, S. Burke-Spolaor, S. B. Cenko, A. Connolly, P. Couvares, D. Fox, A. Gal-Yam, S. Gezari, A. Goodman, D. Grant, P. Groot, J. Guillochon, C. Hanna, D. W. Hogg, K. Holley-Bockelmann, D. A. Howell, D. Kaplan, E. Katsavounidis, M. Kowalski, L. Lehner, D. Muthukrishna, **G. Narayan**, J. E. G. Peek, A. Saha, P. Shawhan, and I. Taboada. *ArXiv e-prints*, Jul. 2018.

[17] **The Photometric LSST Astronomical Time-series Classification Challenge (PLAsTiCC): Data set**. The PLAsTiCC team, T. Allam, Jr., A. Bahmanyar, R. Biswas, M. Dai, L. Galbany, R. Hložek, E. E. O. Ishida, S. W. Jha, D. O. Jones, R. Kessler, M. Lochner, A. A. Mahabal, A. I. Malz, K. S. Mandel, J. R. Martínez-Galarza, J. D. McEwen, D. Muthukrishna, **G. Narayan**, H. Peiris, C. M. Peters, K. Ponder, C. N. Setzer, The LSST Dark Energy Science Collaboration, T. LSST Transients, and Variable Stars Science Collaboration. *ArXiv e-prints*, Sep. 2018.

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