# **Benjamin James (BJ) Fulton**

NASA Exoplanet Science Institute / IPAC-Caltech Research Scientist / NN-EXPLORE Project Scientist (408) 528-4858

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### **Research Interests**

I strive to understand Earth's context in the galaxy through the detection, characterization, and demography of exoplanets. I push the radial velocity detection method to the limit through advanced analysis techniques, observational strategies, and hardware optimization.

### **Education**

- 2017 Doctor of Philosophy in Astronomy from the Institute for Astronomy at the University of Hawaii, Manoa
- 2014 Master of Science in Astronomy from the Institute for Astronomy at the University of Hawaii, Manoa
- 2009 Bachelor of Science in Physics with a Minor in Astronomy and Planetary Science from the University of California, Santa Barbara

# **Professional Appointments**

NASA Exoplanet Science Research Scientist / April 2018 - present Institute / Caltech / JPL **NN-EXPLORE Project Scientist** California Institute of Texaco Postdoctoral Fellow August 2017 - April 2018 Technology Institute for Astronomy, **National Science Foundation Graduate** August 2014 - August 2017 **Research Fellow** University of Hawaii Institute for Astronomy, **Graduate Research Assistant** August 2012 - August 2014 University of Hawaii Las Cumbres Observatory, Research Associate (Astronomy) March 2009 - August 2012 Goleta, CA

# **Publication statistics**

- 9 first author & major contributions in 4 second author refereed publications
- 132 total refereed publications
- Contributions to 4 Nature publications
- 4538 citations (519 citations to first-author papers)
- h-index = 35

## **Research Experience**

- Discovered a gap in the radius distribution of small planets found by *Kepler*. This has significant implications for our understanding of the formation and evolution of planets smaller than Neptune (Fulton et al. 2017)
- Served as project scientist for the <u>NN-EXPLORE program</u>, primarily overseeing the development of the pipeline and archive for the <u>NEID spectrograph</u>
- Developed an open source software package for the analysis of radial velocity time-series data written in object-oriented Python (radvel.readthedocs.io)
- Wrote software that allows the Automated Planet Finder (APF) telescope at Lick Observatory to operate autonomously.
   APF has been collecting high-precision radial velocities every night for the past 7 years.
- Development of the "Jump" target management database and web application used by the California Planet Search team, which honed my skills in Django, Javascript, CSS, Haml, and Docker (jump.caltech.edu)
- Developed a new technique to extract radial velocities from low signal-to-noise spectra which enabled the discovery of the Jupiter-size transiting exoplanet KELT-8b (<u>Fulton et al. 2015b</u>)
- Published <u>Fulton et al. 2015a</u>, and <u>Fulton et al. 2016</u> announcing the discovery of 5 new low-mass planets orbing four nearby stars. These discoveries were made possible, in large part, by the APF facility.
- Worked extensively with collaborators at the Space Telescope Science Institute on a project to revolutionize the way that
  radial velocities are calculated from gas absorption cell spectroscopy
- Published a paper (Fulton et al., 2013) for which I modeled the Rossiter-McLaughlin (R-M) effect to measure the stellar obliquity of HAT-P-17. I ported/adapted an existing Differential Evolution Markov Chain Monte Carlo code from IDL to Python, and wrote the model calculation code from scratch to take advantage of a new semi-analytical model of the R-M effect.
- Developed an automated planet detection algorithm to search for the signatures of planets in heterogeneous radial velocity datasets and characterize pipeline detection efficiency using injection-recovery tests (<u>Howard & Fulton 2016</u>)

### **Academic Awards**

- 2018 Robert J. Trumpler award from the Astronomical Society of the Pacific for a PhD thesis considered particularly important to astronomy
- 2017 Texaco prize postdoctoral fellowship at Caltech
- 2016 ARCS Foundation Honolulu Scholar of the Year
- 2016 Columbia ARCS Award in Astronomy
- 2015 Student Excellence in Research Award at the University of Hawaii at Manoa
- 2014 National Science Foundation Graduate Research Fellowship
- 2009 Physics Research Honors award upon graduation from UC Santa Barbara

### **Student Mentoring**

### Cayla Dedrick, Caltech Undergraduate (2018-present)

Cayla adapted and improved upon my algorithm for automated detection of planets in radial velocity data and used it to discover two planets straddling the habitable zone of a nearby star (Dedrick et al., in prep.)

### Lee Rosenthal, Caltech PhD Candidate (2018-present)

Lee expanded on the automated planet detection code developed by Cayla Dedrick and turned it into a publicly available open-source Python package. He used this to discover ~25 new planets in Keck/HIRES radial velocity data as part of a large program to measure the demographic properties of long-period gas giant planets. I'm currently serving as co-advisor with Andrew Howard. (Rosenthal et al., Fulton et al., and code release in prep.)

# Ilya Sherstyuk, Caltech Undergraduate (Summer 2019)

Ilya developed an algorithm to analyze stellar activity indicators to distinguish between planets and stellar rotation signatures in radial velocity datasets

### Teaching Experience

- 2015 Designed curriculum and instructed "Introduction to Astronomy" summer course at the University of Hawaii at Manoa
- 2015 Designed and lead a "Python for Astronomers" seminar at the University of Hawaii
- 2012-2015 Lectured and advised students during the annual HiSTAR program for K-12 students in Hawaii

### **Invited Talks**

- 2019 Colloquium speaker at Stanford, CA
- 2018 Colloquium speaker at Lowell Observatory in Flagstaff, Arizona
- 2018 Center for Space and Habitability Colloquium speaker at Universität, Bern, Switzerland
- 2018 Planetary Science / IPLEX seminar speaker at the University of California, Los Angeles
- 2017 Panelist on occurrence rate panel at the ExoPAG16 meeting
- 2017 FLASH seminar speaker at the University of California at Santa Cruz
- 2016 Seminar speaker at the Center for Habitable Worlds at Penn State University
- 2013 Public talk at a conference of The American Congress of Obstetricians and Gynecologists

### **Conferences and Meetings**

- 2019 Contributed talk at the Extreme Solar Systems conference in Reykjavik, Iceland
- 2019 Contributed talk at the Extreme Precision Radial Velocity Conference in Grindelwald, Switzerland
- 2019 Contributed talk at the Kepler and K2 Science Meeting in Pasadena, California
- 2019 Attended the Telluric Hackathon in New York City, New York
- 2018 Contributed talk at the Keck Science Meeting in Pasadena, California
- 2018 Contributed talk at the ExSoCal 2018 conference in Pasadena, California
- 2018 Contributed talk at the Exoplanets II conference in Cambridge, UK
- 2017 Co-Chair of "observing strategy" session at the Extremely Precise Radial Velocities III conference at Penn State
- 2017 Poster at the Extremely Precise Radial Velocities III conference at Penn State
- 2017 Contributed talk at the Kepler & K2 SciCon IV

- 2017 Contributed talk at the 2017 Aspen Winter Conference: Formation and Dynamical Evolution of Exoplanets
- 2016 Poster at the Exoplanets I conference in Davos, Switzerland
- 2015 Poster at the Extreme Solar Systems III conference in Waikaloa, HI
- 2015 Poster at the Sagan Workshop in Pasadena, CA
- 2015 Poster at the Extreme Precision Radial Velocity workshop in New Haven, CT
- 2014 Poster at the Toward Other Earths II conference in Porto, Portugal
- 2014 Poster at the Sagan Workshop in Pasadena, CA
- 2014 Poster at the Exoplanetary Science conference in Quy Nhon, Vietnam
- 2013 Poster at the Kepler Science Conference II in Mountain View, CA
- 2013 Poster at the American Astronomical Society Winter Meeting in Long Beach, CA

# **Observing Experience**

- ~100 full or partial nights using the HIRES instrument on the Keck I telescope located on Maunakea
- ~800 nights on the Automated Planet Finder Telescope at Lick Observatory (mostly robotic running on my software)
- Approximately 20 nights using the OPTIC imager on the University of Hawaii 2.2 m telescope located on Maunakea
- Approximately 7 nights on the Nickel 1.0 m at Lick Observatory
- Approximately 180 nights on the Sedgwick telescope of the Las Cumbres Observatory network (mostly robotic running on my software)

### **Hobbies and Interests**

- Auto racing
  - 2018 SCCA San Diego Match Tour STU class win
  - 2016-2018 SCCA regional STU class champion
- Digital photography, including astrophotography
   (Astronomy Picture of the Day, 08/26/2011 <a href="http://apod.nasa.gov/apod/ap110826.html">http://apod.nasa.gov/apod/ap110826.html</a>)

### **Publication List**

### First Author

- Fulton, B.J. et al. (2018); The California Kepler Survey VII. Precise Planet Radii Leveraging Gaia DR2 Reveal the Stellar Mass Dependence of the Planet Radius Gap, AJ, 156, 264, (2018AJ....156...264F)
- Fulton, B.J. et al. (2018); RadVel: The Radial Velocity Modeling Toolkit, PASP, 130, 986, (2018PASP..130d4504E)
- Fulton, B.J. et al. (2017); The California-Kepler Survey. III. A Gap in the Radius Distribution of Small Planets, AJ, 154, 109 (2017AJ....154...109F)
- Fulton, B.J. et al. (2016); Three Temperate Neptunes Orbiting Nearby Stars, ApJ, 830, 46 (2015ApJ...830...1F)
- Fulton, B.J. et al. (2015b); KELT-8b: A Highly Inflated Transiting Hot Jupiter and a New Technique for Extracting Highprecision Radial Velocities from Noisy Spectra, ApJ, 810, 30 (2015ApJ...810...30F)
- Fulton, B.J. et al. (2015a); Three Planets Orbing HD 7924, ApJ, 805, 175 (2015ApJ...805..175F)
- Fulton, B.J. et al. (2014); A Search for Planetary Eclipses of White Dwarfs in the Pan-STARRS1 Medium-deep Fields, ApJ, 796, 114 (2014ApJ...796..114F)
- Fulton, B. J. et al. (2013); The Stellar Obliquity and the Long-period planet in the HAT-P-17 Exoplanetary System, ApJ, 772, 80 (2013ApJ...772...80F)
- Fulton, B. J. et al (2011); Long-term Transit Timing Monitoring and Refined Light Curve Parameters of HAT-P-13b, 2011, AJ, 142, 84 (2011AJ...142...84F)

#### Significant Contributions

- Howard, A. W., and Fulton, B. J. (2016); Limits on Planetary Companions from Doppler Surveys of Nearby Stars, PASP, 128, 969, (2016PASP..128k4401H). - Performed all analysis, produced all plots, and wrote most of the methods section
- Street, R. A., Fulton, B. J. et al (2015); Extended Baseline Photometry of Rapidly Changing Weather Patterns on the Brown Dwarf Binary Luhman-16, ApJ, 812, 161, (2015ApJ...812..161S) – Extracted the photometry in an initial reduction (the photometry was eventually superseded in the referee process)
- Knutson, H., Fulton, B. J. et al (2014); Friends of Hot Jupiters. I. A Radial Velocity Search for Massive, Long-period Companions to Close-in Gas Giant Planets, ApJ, 785, 126, (2014ApJ...785..126K) – Performed all radial velocity analysis, and wrote some of the methods section
- Sinukoff, E.; Fulton, B. J.; Scuderi, L.; Gaidos, E. (2013); Below One Earth The Detection, Formation, and Properties of Subterrestrial Worlds, Space Science Reviews, 10.1007 (http://dx.doi.org/10.1007/s11214-013-0019-1) – Performed analysis and wrote text for one of the major sections of the paper involving Kepler photometry

### High Impact Journals

- Benneke et al. (2019); A sub-Neptune exoplanet with a low-metallicity methane-depleted atmosphere and Mie-scattering clouds, Nature Astronomy, Volume 3, Issue 813B (2019NatAs...3..813B)
- Gaudi et al. (2017); A giant planet undergoing extreme-ultraviolet irradiation by its hot massive-star host, Nature, Volume 546, Issue 7659 (2017Natur.546..514G)
- Howard et al. (2013); A rocky composition for an Earth-sized exoplanet, Nature, Volume 503, Issue 7476 (2013Natur.503..381H)
   Nugent et al. (2011); Supernova SN 2011fe from an exploding carbon-oxygen white dwarf star, Nature, Volume 480, Issue 7377 (2011Natur.480..344N)

#### Other Publications

- Gaidos et al. (2019); Planetesimals around stars with TESS (PAST) I. Transient dimming of a binary solar analogue at the end of the planet accretion era, MNRAS, 488, 4465 (2019MNRAS.488.4465G)
- Zhou et al. (2019); Two New HATNet Hot Jupiters around A Stars and the First Glimpse at the Occurrence Rate of Hot Jupiters from TESS, AJ, 158, 141Z (2019AJ....158..141Z)
- Hey et al. (2019); Six new rapidly oscillating Ap stars in the Kepler long-cadence data using super-Nyquist asteroseismology, MNRAS, 488, 18H (2019MNRAS, 488, ...18H)
- Vanderburg et al. (2019); TESS Spots a Compact System of Super-Earths around the Naked-eye Star HR858, ApJ, 881L, 19V (2019AJ...158...79D)
- David et al. (2019); A Warm Jupiter-sized Planet Transiting the Pre-main-sequence Star V1298 Tau, AJ, 158, 79D (2019AJ....158...79D)
- Johns et al. (2019); KELT-23Ab: A Hot Jupiter Transiting a Near-solar Twin Close to the TESS and JWST Continuous Viewing Zones, AJ, 158, 78J (2019AJ....158...78J)
- Yahalomi et al. (2019); The Mass of the White Dwarf Companion in the Self-lensing Binary KOI-3278: Einstein versus Newton, ApJ, 880, 33Y (2019ApJ...880...33Y)
- Hirsch et al. (2019); Discovery of a White Dwarf Companion to HD 159062, ApJ, 878, 50H (2019ApJ...878...50H)
- Huber et al. (2019); A Hot Saturn Orbiting an Oscillating Late Subgiant Discovered by TESS, AJ, 157, 245H (2019AJ...157..245H)
- Mills et al. (2019); The California-Kepler Survey. VIII. Eccentricities of Kepler Planets and Tentative Evidence of a Highmetallicity Preference for Small Eccentric Planets, AJ, 157, 198M (2019AJ....157..198M)
- Berardo et al. (2019); Revisiting the HIP 41378 System with K2 and Spitzer, AJ, 157, 185B (2019AJ...157..185B)
- Dragomir et al. (2019); TESS Delivers Its First Earth-sized Planet and a Warm Sub-Neptune, AJ, 875, 7D (2019ApJ...875L...7D)
- Mills et al. (2019); Long-period Giant Companions to Three Compact, Multiplanet Systems, AJ, 157, 145M (2019AJ....157..145M)
- Kosiarek et al. (2019); K2-291b: A Rocky Super-Earth in a 2.2 day Orbit, AJ, 157, 116K (2019AJ....157...116K)
- Livingston et al. (2019); Spitzer Transit Follow-up of Planet Candidates from the K2 Mission, AJ, 157, 102L (2019AJ....157..102L)
- Kosiarek et al. (2019); Bright Opportunities for Atmospheric Characterization of Small Planets: Masses and Radii of K2-3b, c, and d and GJ3470 b from Radial Velocity Measurements and Spitzer Transits, AJ, 157, 97K (2019AJ...157...97K)
- Bryan et al. (2019); An Excess of Jupiter Analogs in Super-Earth Systems, AJ, 157, 52B (2019AJ....157...52B)
- Wang et al. (2019); HD 202772A: A Transiting Hot Jupiter around a Bright, Midly Evolved Star in a Visual Binary Discovered by TESS, AJ, 157, 51W (2019AJ....157...51W)
- Labadie-Bartz et al. (2019); KELT-22Ab: A Massive, Short-Period Hot Jupiter Transiting a Near-solar Twin, ApJS, 240, 13L (2019ApJS...240...13L)
- Mawet et al. (2019); Deep Exploration of Eps Eridani with Keck Ms-band Vortex Coronagraphy and Radial Velocities: Mass and Orbital Parameters of the Giant Exoplanet, AJ, 157, 33M (2019AJ....157...33M)
- David et al. (2018); Discover of a Transiting Adolescent Sub-Neptune Exoplanet with K2, AJ, 156, 302D (2018AJ...156.302D)
- Livingston et al. (2018); Sixty Validated Planets from K2 Campaigns 5–8, AJ, 156, 277L (2018AJ...156..277L)
- Weiss et al. (2018); The California-Kepler Survey. VI. Kepler Multis and Singles Have Similar Planet and Stellar Properties Indicating a Common Origin, AJ, 156, 254W (2018AJ...156.254W)
- Crossfield et al. (2018); A TESS Dress Rehearsal: Planetary Candidates and Variables from K2 Campaign 17, ApJS, 239, 5C (2018ApJS..239...5C)
- Peterson et al. (2018); A 2 R<sub>⊕</sub> Planet Orbiting the Bright Nearby K Dwarf Wolf 503, AJ, 156, 188P (2018AJ....156..188P)
- Van Eylen et al. (2018); An asteroseismic view of the radius valley: stripped cores, not born rocky, MNRAS, 479, 4786V (2018MNRAS, 479, 4786V)
- Brady et al. (2018); Kepler-1656b: A Dense Sub-Saturn with an Extreme Eccentricity, AJ, 156, 147B (2018AJ...156.147B)

- Liang et al. (2018); Two Warm, Low-density Sub-Jovian Planets Orbiting Bright Stars in K2 Campaigns 13 and 14, AJ, 156, 127 (2018AJ....156..127Y)
- Petigura et al. (2018); Dynamics and Formation of the Near-resonant K2-24 System: Insights from Transit-timing Variations and Radial Velocities, AJ, 156, 89 (2018AJ....156...89P)
- Dressing et al. (2018); Characterizing K2 Candidate Planetary Systems Orbiting Low-mass Stars. III. A High Mass and Low Envelope Fraction for the Warm Neptune K2-55b, AJ, 156, 70 (2018AJ....156...70D)
- Liang et al. (2018); Planetary Candidates from K2 Campaign 16, AJ, 156, 22 (2018AJ...156...22Y)
- Yee et al. (2018); HAT-P-11: Discovery of a Second Planet and a Clue to Understanding Exoplanet Obliquities, AJ, 155, 255 (2018AJ...155..255Y)
- Curtis et al. (2018); K2-231 b: A Sub-Neptune Exoplanet Transiting a Solar Twin in Ruprecht 147, AJ, 155, 173C (2018AJ....155..173C)
- Bowler et al. (2018); Orbit and Dynamical Mass of the Late-T Dwarf GL 758 B, AJ, 155, 159B (2018AJ....155..159B)
- Hartman et al. (2018); HAT-TR-318-007: A Double-lined M Dwarf Binary with Total Secondary Eclipses Discovered by HATNet and Observed by K2, AJ, 155, 114H (2018AJ....155...114H)
- Johnson et al. (2018); KELT-21b: A Hot Jupiter Transiting the Rapidly Rotating Metal-poor Late-A Primary of a Likely Hierarchical Triple System, AJ, 155, 100J (2018AJ....155..100J)
- Petigura et al. (2018); The California-Kepler Survey. IV. Metal-rich Stars Host a Greater Diversity of Planets, AJ, 155, 89P (2018AJ...155...89P)
- Henning et al. (2018); HATS-50b through HATS-53b: Four Transiting Hot Jupiters Orbiting G-type Stars Discovered by the HATSouth Survey, AJ, 155, 79H (2018AJ....155...79H)
- Weiss et al. (2018); The California-Kepler Survey. V. Peas in a Pod: Planets in a Kepler Multi-planet System Are Similar in Size and Regularly Spaced, AJ, 155, 48W (2018AJ....155...48W)
- Petigura et al. (2018); Planet Candidates from K2 Campaigns 5–8 and Follow-up Optical Spectroscopy, AJ, 155, 21P (2018AJ....155...21P)
- Ciardi et al. (2018); K2-136: A Binary System in the Hyades Cluster Hosting a Neptune-sized Planet, AJ, 155, 10C (2018AJ...155...10C)
- Grunblatt et al. (2017); Seeing Double with K2: Testing Re-inflation with Two Remarkably Similar Planets around Red Giant Branch Stars, AJ, 154, 254 (2017AJ....154...254G)
- Dressing et al. (2017); Characterizing K2 Candidate Planetary Systems Orbiting Low-mass Stars. II. Planetary Systems Observed During Campaigns 1–7, AJ, 154, 207 (2017AJ....154..207D)
- Lund et al. (2017); KELT-20b: A Giant Planet with a Period of P ~ 3.5 days Transiting the V ~ 7.6 Early A Star HD 185603, AJ, 154, 194 (2017AJ....154..194L)
- Shporer et al. (2017); K2-114b and K2-115b: Two Transiting Warm Jupiters, AJ, 154, 188 (2017AJ...154..188S)
- Shporer et al. (2017); Three Statistically Validated K2 Transiting Warm Jupiter Exoplanets Confirmed as Low-mass Stars, ApJ, 847, 18 (2017ApJ...847L...18S)
- Christiansen et al. (2017); Three's Company: An Additional Non-transiting Super-Earth in the Bright HD 3167 System, and Masses for All Three, AJ, 154, 122 (2017AJ....154..122C)
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- Sinukoff, E., et al. (2017); K2-66b and K2-106b: Two Extremely Hot Sub-Neptune-size Planets with High Densities, AJ, 153, 271 (2017AJ...153..271S)
- Weiss, L., et al. (2017); New Insights on Planet Formation in WASP-47 from a Simultaneous Analysis of Radial Velocities and Transit Timing Variations, AJ, 153, 265 (2017AJ....153..265W)
- McLeod, K., et al. (2017); KELT-18b: Puffy Planet, Hot Host, Probably Perturbed, AJ, 153, 263 (2017AJ....153..263M).
- Crossfield, I., et al. (2017); Two Small Transiting Planets and a Possible Third Body Orbiting HD 106315, AJ, 153, 255 (2017AJ...153..255C)
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- Zheng, W., et al. (2017); Discovery and Follow-up Observations of the Young Type la Supernova 2016coj, ApJ, 841, 64Z (2017ApJ...841...64Z)
- Pepper, J., et al. (2017); KELT-11b: A Highly Inflated Sub-Saturn Exoplanet Transiting the V = 8 Subgiant HD 93396, AJ, 153, 215 (2017AJ...153..215P)
- Zhou, G., et al. (2017); HAT-P-67b: An Extremely Low Density Saturn Transiting an F-subgiant Confirmed via Doppler Tomography, AJ, 153, 211 (2017AJ....153...211Z)
- Stevens, D., et al. (2017); KELT-12b: A P~5 day, Highly Inflated Hot Jupiter Transiting a Mildly Evolved Hot Star, AJ, 153, 178 (2017AJ....153..178S)
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- Oberst, T., et al. (2017); KELT-16b: A Highly Irradiated, Ultra-short Period Hot Jupiter Nearing Tidal Disruption, AJ, 153, 97 (2017AJ...153...970)
- De Wit, J., et al. (2017); Planet-induced Stellar Pulsations in HAT-P-2's Eccentric System, ApJ, 836, 17 (2017ApJ...836L..17D)
- David, T., et al. (2017); A Transient Transit Signature Associated with the Young Star RIK-210, ApJ, 835, 168 (2017ApJ...835...168D)
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- Rappaport, S., et al. (2017); EPIC 220204960: A Quadruple Star System Containing Two Strongly Interacting Eclipsing Binaries, MNRAS (2017MNRAS.tmp..145R)
- Bayliss, D., et al. (2017); EPIC 201702477b: A Transiting Brown Dwarf from K2 in a 41 day Orbit, AJ, 153, 15 (2017AJ....153...15B)
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- Kirk, B. et al. (2016); Kepler Eclipsing Binary Stars. VII. The Catalog of Eclipsing Binaries Found in the Entire Kepler Data Set, AJ, 151, 68 (2016AJ....151...68K)
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- Hartman, J. D. et al. (2015); HAT-P-50b, HAT-P-51b, HAT-P-52b, and HAT-P-53b: Three Transiting Hot Jupiters and a Transiting Hot Saturn From the HATNet Survey, AJ, 150, 168 (2015AJ....150..168H)
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- Bakos, G. A. et al. (2015); HATS-7b: A Hot Super Neptune Transiting a Quiet K Dwarf Star, ApJ, 813, 111 (2015ApJ...813...111B)
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