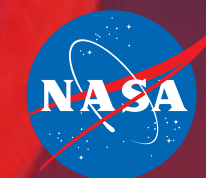


Dr. Rob Zellem (he/him)

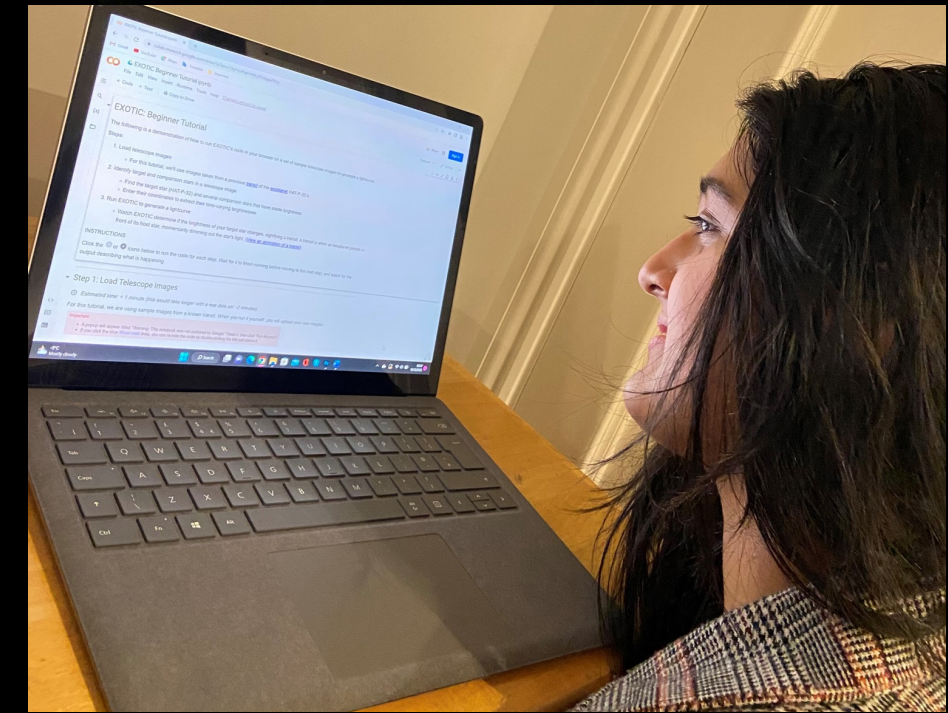
EXOPLANET WATCH

Inviting Citizen Scientists to
Observe Transiting Exoplanets



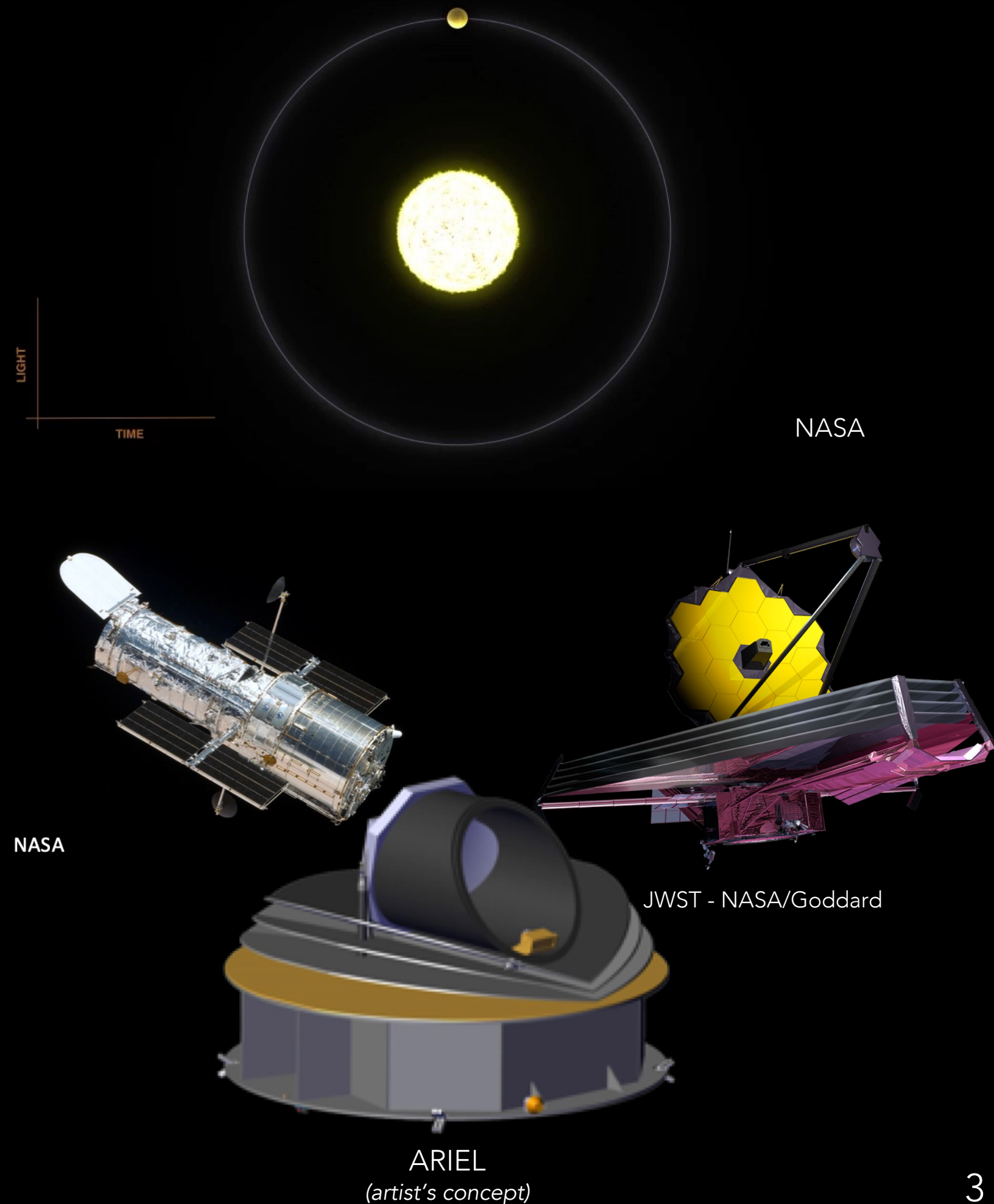
OVERVIEW

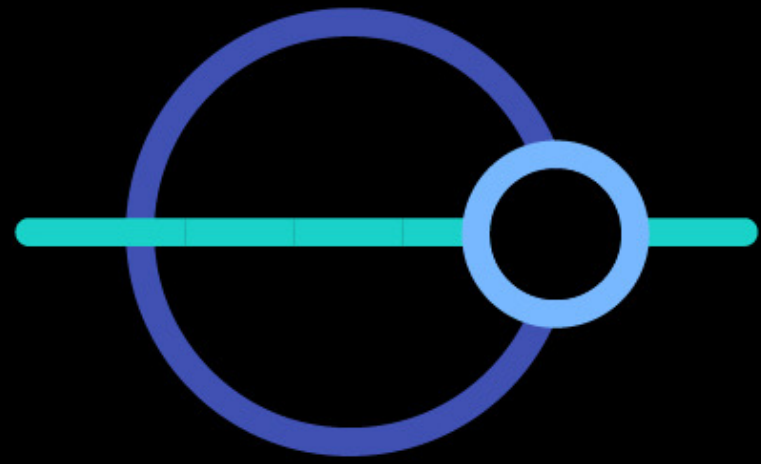
- Announcing the general audience launch of Exoplanet Watch: a citizen science project to monitor transiting exoplanets
 - Limited launch with amateur and professional astronomers since 2021
- Anyone and everyone can participate!
 - Learn how exoplanet science is really done!



TRANSITS

- Measures the change in brightness as the planet passes in front of or behind its host star
- Also allow us to study a planet's atmosphere
 - Exoplanet Watch refines transit times
 - You can help!

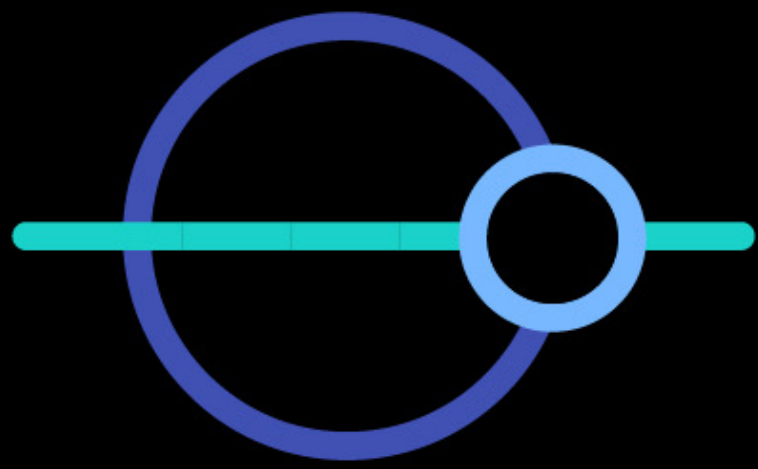




EXOPLANET WATCH

CITIZEN SCIENTISTS MONITORING
TRANSITING EXOPLANETS

- Citizen science project to routinely observe transiting exoplanets to keep their transit times precise
 - You will help enable NASA science!



EXOPLANET WATCH

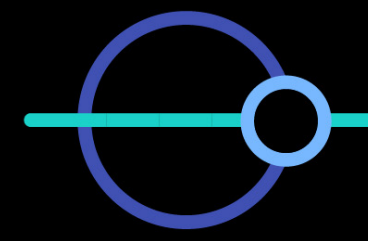
- Collaborative effort to complement existing surveys
- Data is immediately public
- Target requests by professional astronomers
- Observers are listed as co-authors
- Part of NASA's Universe of Learning



GOALS

- **Education goals:** to engage and teach the public about exoplanets and enable them to do science
- **Science goals:** to ensure efficient use of large telescopes; discover and confirm new exoplanets; monitor stellar variability

USER EXPERIENCE



EXOPLANET WATCH

What to Observe

No matter where you are on Earth, it's likely that at least a few transiting exoplanets will be visible tonight. You can look up upcoming transits so that you know when and where to look for them. Transits can last anywhere from an hour to five or six hours, and some are even longer. When observing an exoplanet transit, it's important to capture the star's baseline brightness before the exoplanet starts passing in front of it, then capture the transit as well as an hour or two after the transit ends, so that the baseline brightness of the star can be measured again.

Name	Date	Mag	Duration	Start Time	End Time	Max Depth	Notes
Kepler-90b	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system
Kepler-90c	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system
Kepler-90d	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system
Kepler-90e	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system
Kepler-90f	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system
Kepler-90g	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system
Kepler-90h	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system
Kepler-90i	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system
Kepler-90j	2019-09-01	12.7	1.2	01:00	02:00	0.12	Kepler-90 system

radio button at the top of the form.

- Select an observatory near your location or choose "manual coordinate entry" at the end of the list.
- Under "Date window" select the "base date" that you would like to begin scheduling and fill in the appropriate number of days before and/or after this base date. In addition, you can optionally include constraints on the target's elevation during the transit if your horizon has limited visibility.
- Once you hit the "Submit" button, the service might take a few seconds to minutes to load, depending on the number of days you have requested.
- On the page that does open, you can sort the planets according to their "Exoplanet Watch rank" where a low number (e.g., 1) is higher priority than a larger number (e.g., 1000). You can also filter your targets based upon the host star's "Magnitude (V, 'mag') and the expected transit depth ("Depth, 'mm") in units of parts per thousand (ppm). You can sort the list by the date, by the name of the exoplanet, or by the Exoplanet Watch rank, as well as by the magnitude of the star.



Observe



AstrolmageJ

Analyze

Upload

Publish

AAVSO
American Association of Variable Star Observers

Home | Submit | Search | Documentation

Exoplanet Database: Submit Observation

Upload Here

Select Site *

none

Select Equipment Package *

none

Report form: *

Choose File (No files selected)

Images: *

Choose Files (No files selected)

Submit

I accept the GDPR (see below)

* This field is required
- Cannot find your site and/or equipment? Add it here: Site & Equipment
- You must check the GDPR box to confirm that you understand that the personal information contained in the Site and/or Equipment selection is part of the data shared with others when they download your data.

How to Participate

Get Involved | How to Observe | How to Analyze Your Data | How to Submit Your Data | Request an Exoplanet Observation

Request an Exoplanet Observation

Exoplanet Watch partners with the MicroObservatory's DIY Planet Search to obtain robotic telescope observations of transiting exoplanets for Exoplanet Watch participants who do not have their own telescope. MicroObservatory is generously sharing ten years of archived transiting exoplanet observations with us so that you can participate in Exoplanet Watch.

Submit your email address below to check out a night's observation of an exoplanet transit taken by a robotic telescope. Once you have this data, use EXOTIC, our data reduction software, to produce a lightcurve using this data that you can then submit to the AAVSO, the American Association of Variable Star Observers. (If you haven't used EXOTIC before, try the tutorial to learn how to use it first.) Use the Standard version of EXOTIC to process the data we give you, so you can create your own light curve of a transiting exoplanet.

Once submitted, your data will be shared with the professional astronomers who study exoplanets and your light curve will be included on Exoplanet Watch's Results webpage. If your observations or light curves are used in a scientific paper, your name will be listed as a co-author on the paper, and you will get credit for participating in scientific research!

When you check out data, the observation is yours for two weeks, so you have two weeks to process the data and upload the resulting light curve to the AAVSO. You will be the only person to receive this data set during this time. At the end of this period, we will email you to let you know your data has been reclaimed so that it can be reassigned to someone else who can use it if you haven't processed it by then. You can make data requests every two weeks if you want to make another light curve.

The exoplanet you will be studying is randomly selected for you, so you can't request data of a specific exoplanet.

As with any astronomical observation, some nights are clear and some nights are cloudy. We can't guarantee that the data set you get will be from a clear night. If you get a cloudy data set, you can try to process it anyway and see if it works. If the sky is completely clouded over, come back in two weeks and request another data set. Hopefully it will be from a clearer night.

Email

Yes, Sign me up for monthly email updates from Exoplanet Watch, including nightly target identifications, software updates, and other news.

I'm not a robot

Submit

Harvard/CfA

Request Data

Publications of the Astronomical Society of the Pacific, 132:054-011 (22pp), 2020 May
https://doi.org/10.1088/1538-3873/ab70c7

Utilizing Small Telescopes Operated by Citizen Scientists for Transiting Exoplanet Follow-up

Robert T. Zellem¹, Kyle A. Pearson^{1,2}, Ethan Blaser^{1,3}, Martin Fowler⁴, David R. Ciardi⁵, Anya Biferno⁶, Bob Massey⁶, Franck Marchis⁶, Robert Baer⁷, Conley Ball⁸, Mike Chasin^{9,10}, Mike Conley¹¹, Scott Dixon^{12,13}, Elizabeth Flecker¹⁴, Sanyela Hernandez¹⁵, Saiy Nair¹⁶, Quinn Perain¹⁷, Frank Sienkiewicz¹⁸, Kalle Toek¹⁹, Vivek Vijayakumar²⁰, Mark R. Swain²¹, Gad M. Roudier²², Geoffrey Bryden²³, Dennis M. CoRoT²⁴, Doreen H. Hill²⁵, Carl W. Hergele²⁶, Mary Drossart²⁷, Stephen R. Kane²⁸, Michael Fitzgerald²⁹, Pat Boyce³⁰, Laura Petroska³¹, Wilfred Ge³², Lynn Cominsky³³, Rachel Zimmerman-Brachman³⁴, Denise Smith³⁵, Michelle J. Creech-Eakman³⁶, John Engelle³⁷, Alexandra Burradell³⁸, Diana Dragomir^{39,40,41}, Nemanja Jovanovic⁴², Brandon Lawton⁴³, Emmanuel Arbouche⁴⁴, Marc Kuchner⁴⁵, and Armand Michard⁴⁶

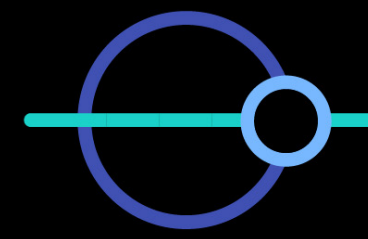
¹Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA; rzellem@jpl.nasa.gov
²Lunar and Planetary Laboratory, University of Arizona, 927N E University Blvd, Tucson, AZ 85721, USA
³University of Virginia, Charlottesville, VA 22904, USA
⁴Citizen Scientist, Los Rios College, Orchard Road, South Wrentham, Wiltshire SO21 1EX, UK
⁵NASA Exoplanet Science Institute, California Institute of Technology, MC 314-6, 1200 E California Blvd, Pasadena, CA 91125, USA
⁶American Association of Variable Star Observers, 49 Bay State Rd, Cambridge, MA 02138, USA
⁷SETI Institute, 1515 Bernardo Ave, Suite 200, Mountain View, CA 94035, USA
⁸Univ. Lille, 19 rue Vauquelin, F-59000 Lille, France
⁹Southern Illinois University Carbondale, MC 4011, 1245 Lincoln Dr, Carbondale, IL 62901, USA
¹⁰Citizen CATE, Equipment, USA
¹¹Laguna Blanca School, 4125 Paloma Dr, Santa Barbara, CA 93110, USA
¹²Boyce Research Institutes and Education Foundation, USA
¹³San Diego Astronomy Association, USA
¹⁴Towson University, 800 York Rd, Towson, MD 21286, USA
¹⁵Stanford Online High School, 415 Broadway Academy Hall, Floor 2, 8853, Redwood City, CA 94063, USA
¹⁶The Center for Astrophysics, Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA
¹⁷Department of Earth and Planetary Sciences, University of California, Riverside, CA 92521, USA
¹⁸Edith Cowan University, 270 Joondalup Drive, Joondalup, WA 6027, Australia
¹⁹Southern State University, 1801 East Coast Ave, Robert Park, CA 94928, USA
²⁰Macquarie University, Sydney, New South Wales 2109, Australia
²¹Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
²²Department of Physics, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801, USA
²³Raytheon Intelligence, Information, and Services, 300 N Lake Ave, Suite 1120, Pasadena, CA 91101, USA
²⁴The University of New Mexico, Albuquerque, NM 87131, USA
²⁵Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA 02139, USA
²⁶Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, USA
²⁷California Institute of Technology, 1200 East California Boulevard, Pasadena, CA 91125, USA
²⁸NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 20771, USA
²⁹Received 2019 September 26, accepted 2020 March 11, published 2020 April 8

Abstract

Due to the efforts by numerous ground-based surveys and NASA's Kepler and Transiting Exoplanet Survey Satellite (TESS), there will be hundreds, if not thousands, of transiting exoplanets ideal for atmospheric characterization via spectroscopy with large platforms such as James Webb Space Telescope and ARIEL. However their next predicted mid-transit time could become so increasingly uncertain over time that significant overhead would be required to ensure the detection of the entire transit. As a result, follow-up observations to characterize these exoplanetary atmospheres would require less-efficient use of an observer's time—which is an issue for large platforms where minimizing observing overheads is a necessity. Here we demonstrate the power of citizen scientists operating smaller observatories (<1 m) to keep ephemerides "fresh," defined here as when the 1 σ uncertainty in the mid-transit time is less than half the transit duration. We advocate for the creation of a community-wide effort to perform ephemeris maintenance on transiting exoplanets by citizen scientists. Such observations can be conducted with even a 6 inch telescope, which has the potential to save up to ~10,000 days for a 1000-planet survey. Based on a preliminary analysis of 14 transits from a single 6 inch MicroObservatory telescope, we empirically estimate the ability of small telescopes to benefit the community. Observations with a

³⁰ NASA Hubble Fellow.

USER EXPERIENCE



EXOPLANET WATCH

What to Observe

No matter where you are on Earth, it's likely that at least a few transiting exoplanets will be visible tonight. You can look up upcoming transits so that you know when and where to look for them. Transits can last anywhere from an hour to five or six hours, and some are even longer. When observing an exoplanet transit, it's important to capture the star's baseline brightness before the exoplanet starts passing in front of it, then capture the transit as well as an hour or two after the transit ends, so that the baseline brightness of the star can be measured again.

Planet Name	Host Star	Distance (ly)	Transit Depth (%)
Kepler-90c	Kepler-90	1050	0.84
Kepler-11f	Kepler-11	1050	0.84
Kepler-16b	Kepler-16	1024	0.84
Kepler-17b	Kepler-17	1050	0.84
Kepler-18b	Kepler-18	1252	0.84
Kepler-20b	Kepler-20	1014	0.84
Kepler-22b	Kepler-22	1249	0.84
Kepler-37b	Kepler-37	1050	0.84
Kepler-41b	Kepler-41	1050	0.84
Kepler-42b	Kepler-42	1050	0.84
Kepler-43b	Kepler-43	1050	0.84
Kepler-44b	Kepler-44	1050	0.84
Kepler-45b	Kepler-45	1050	0.84
Kepler-46b	Kepler-46	1050	0.84
Kepler-47b	Kepler-47	1050	0.84
Kepler-48b	Kepler-48	1050	0.84
Kepler-49b	Kepler-49	1050	0.84
Kepler-50b	Kepler-50	1050	0.84
Kepler-51b	Kepler-51	1050	0.84
Kepler-52b	Kepler-52	1050	0.84
Kepler-53b	Kepler-53	1050	0.84
Kepler-54b	Kepler-54	1050	0.84
Kepler-55b	Kepler-55	1050	0.84
Kepler-56b	Kepler-56	1050	0.84
Kepler-57b	Kepler-57	1050	0.84
Kepler-58b	Kepler-58	1050	0.84
Kepler-59b	Kepler-59	1050	0.84
Kepler-60b	Kepler-60	1050	0.84
Kepler-61b	Kepler-61	1050	0.84
Kepler-62b	Kepler-62	1050	0.84
Kepler-63b	Kepler-63	1050	0.84
Kepler-64b	Kepler-64	1050	0.84
Kepler-65b	Kepler-65	1050	0.84
Kepler-66b	Kepler-66	1050	0.84
Kepler-67b	Kepler-67	1050	0.84
Kepler-68b	Kepler-68	1050	0.84
Kepler-69b	Kepler-69	1050	0.84
Kepler-70b	Kepler-70	1050	0.84
Kepler-71b	Kepler-71	1050	0.84
Kepler-72b	Kepler-72	1050	0.84
Kepler-73b	Kepler-73	1050	0.84
Kepler-74b	Kepler-74	1050	0.84
Kepler-75b	Kepler-75	1050	0.84
Kepler-76b	Kepler-76	1050	0.84
Kepler-77b	Kepler-77	1050	0.84
Kepler-78b	Kepler-78	1050	0.84
Kepler-79b	Kepler-79	1050	0.84
Kepler-80b	Kepler-80	1050	0.84
Kepler-81b	Kepler-81	1050	0.84
Kepler-82b	Kepler-82	1050	0.84
Kepler-83b	Kepler-83	1050	0.84
Kepler-84b	Kepler-84	1050	0.84
Kepler-85b	Kepler-85	1050	0.84
Kepler-86b	Kepler-86	1050	0.84
Kepler-87b	Kepler-87	1050	0.84
Kepler-88b	Kepler-88	1050	0.84
Kepler-89b	Kepler-89	1050	0.84
Kepler-90b	Kepler-90	1050	0.84



Observe



AAVSO
American Association of Variable Star Observers

Exoplanet Database: Submit Observation

Upload Here

Select Site *

Select Equipment Package *

Report form: *

Choose File: No files selected

Image(s): *

Choose File: No files selected

Submit

I accept the OEPH (see below)

I cannot find your site and/or equipment? Add it here: Site & Equipment

Your must check the OEPH box to confirm that you understand that the personal information contained in the Site and/or Equipment selection is part of the data shared with others when they download your data.

Utilizing Small Telescopes Operated by Citizen Scientists for Transiting Exoplanet Follow-up

Robert T. Zellem¹, Kyle A. Pearson^{2,3}, Ethan Blaser^{1,2,3}, Martin Fowler⁴, David R. Ciardi⁵, Anya Biferno⁶, Bob Massey⁶, Franck Marchis⁶, Robert Baer^{7,8}, Conley Ball⁹, Mike Chasin^{10,11}, Mike Conley¹², Scott Dixon^{13,14}, Elizabeth Flecker¹⁵, Sanyela Hernandez¹⁶, Stacy Nair¹⁷, Quinn Perian¹⁸, Frank Sienkiewicz¹⁹, Kaitie Toal²⁰, Virek Vijayakumar²¹, Mark R. Swain²², Gad M. Rosler²³, Geoffrey Bryden²⁴, Dennis M. CoRoT²⁵, Doreen H. Hill²⁶, Carl W. Hergenrother²⁷, Mary Doussard²⁸, Stephen R. Kane²⁹, Michael Fitzgerald³⁰, Pat Boyce³¹, Laura Petricola³², Wilfred Ge³³, Lynn Cominsky³⁴, Rachel Zimmerman-Brachman³⁵, Denise Smith³⁶, Michelle J. Creech-Eakman³⁷, John Engelke³⁸, Alexandra Burnald³⁹, Diana Dragomir^{40,41,42}, Nemanja Jovanovic⁴³, Brandon Lawton⁴⁴, Emmanuel Arbouch⁴⁵, Marc Kuchner⁴⁶, and Armand Mouchak⁴⁷

¹Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA; ²radem@jpl.nasa.gov
³Lunar and Planetary Laboratory, University of Arizona, 629 E. University Blvd, Tucson, AZ 85721, USA
⁴University of Virginia, Charlottesville, VA 22904, USA
⁵Citizen Scientist, Leuven, Belgium
⁶Citizen Scientist, Leuven, Belgium
⁷Citizen Scientist, Leuven, Belgium
⁸Citizen Scientist, Leuven, Belgium
⁹Citizen Scientist, Leuven, Belgium
¹⁰Citizen Scientist, Leuven, Belgium
¹¹Citizen Scientist, Leuven, Belgium
¹²Citizen Scientist, Leuven, Belgium
¹³Citizen Scientist, Leuven, Belgium
¹⁴Citizen Scientist, Leuven, Belgium
¹⁵Citizen Scientist, Leuven, Belgium
¹⁶Citizen Scientist, Leuven, Belgium
¹⁷Citizen Scientist, Leuven, Belgium
¹⁸Citizen Scientist, Leuven, Belgium
¹⁹Citizen Scientist, Leuven, Belgium
²⁰Citizen Scientist, Leuven, Belgium
²¹Citizen Scientist, Leuven, Belgium
²²Citizen Scientist, Leuven, Belgium
²³Citizen Scientist, Leuven, Belgium
²⁴Citizen Scientist, Leuven, Belgium
²⁵Citizen Scientist, Leuven, Belgium
²⁶Citizen Scientist, Leuven, Belgium
²⁷Citizen Scientist, Leuven, Belgium
²⁸Citizen Scientist, Leuven, Belgium
²⁹Citizen Scientist, Leuven, Belgium
³⁰Citizen Scientist, Leuven, Belgium
³¹Citizen Scientist, Leuven, Belgium
³²Citizen Scientist, Leuven, Belgium
³³Citizen Scientist, Leuven, Belgium
³⁴Citizen Scientist, Leuven, Belgium
³⁵Citizen Scientist, Leuven, Belgium
³⁶Citizen Scientist, Leuven, Belgium
³⁷Citizen Scientist, Leuven, Belgium
³⁸Citizen Scientist, Leuven, Belgium
³⁹Citizen Scientist, Leuven, Belgium
⁴⁰Citizen Scientist, Leuven, Belgium
⁴¹Citizen Scientist, Leuven, Belgium
⁴²Citizen Scientist, Leuven, Belgium
⁴³Citizen Scientist, Leuven, Belgium
⁴⁴Citizen Scientist, Leuven, Belgium
⁴⁵Citizen Scientist, Leuven, Belgium
⁴⁶Citizen Scientist, Leuven, Belgium
⁴⁷Citizen Scientist, Leuven, Belgium

Abstract

Due to the efforts by numerous ground-based surveys and NASA's Kepler and Transiting Exoplanet Survey Satellite (TESS), there will be hundreds, if not thousands, of transiting exoplanets ideal for atmospheric characterization via spectroscopy with large platforms such as James Webb Space Telescope and ARIEL. However their next predicted mid-transit time could become so increasingly uncertain over time that significant overhead would be required to ensure the detection of the entire transit. As a result, follow-up observations to characterize these exoplanets would require low-efficient use of an observer's time—which is an issue for large platforms where minimizing observing overheads is a necessity. Here we demonstrate the power of citizen scientists operating smaller observatories (<1 m) to keep ephemerides "fresh," defined here as when the 1 σ uncertainty in the mid-transit time is less than half the transit duration. We advocate for the creation of a community-wide effort to perform ephemeris maintenance on transiting exoplanets by citizen scientists. Such observations can be conducted with even a 6-inch telescope, which has the potential to save up to ~10,000 days for a 1000-planet survey. Based on a preliminary analysis of 14 transits from a single 6-inch MicroObservatory telescope, we empirically estimate the ability of small telescopes to benefit the community. Observations with a

⁴⁸ NASA Hubble Fellow.

Plan

AstrolmageJ

Analyze

Upload

Publish

How to Participate

Get Involved | How to Observe | How to Analyze Your Data | How to Submit Your Data | Request an Exoplanet Observation

Request an Exoplanet Observation

Exoplanet Watch partners with the MicroObservatory's DIY Planet Search to obtain robotic telescope observations of transiting exoplanets for Exoplanet Watch participants who do not have their own telescope. MicroObservatory is generously sharing ten years of archived transiting exoplanet observations with us so that you can participate in Exoplanet Watch.

Submit your email address below to check out a night's observation of an exoplanet transit target by a robotic telescope. Once you have this data, use EXOTIC, our data reduction software, to produce a lightcurve using this data that you can then submit to the AAVSO, the American Association of Variable Star Observers. (If you haven't used EXOTIC before, try the tutorial to learn how to use it first.) Use the Standard version of EXOTIC to process the data we give you, so you can create your own light curve of a transiting exoplanet.

Once submitted, your data will be shared with the professional astronomers who study exoplanets and your light curve will be included on Exoplanet Watch's Results webpage. If your observations or light curves are used in a scientific paper, your name will be listed as a co-author on the paper, and you will get credit for participating in scientific research!

When you check out data, the observation is yours for two weeks, so you have two weeks to process the data and upload the resulting light curve to the AAVSO. You will be the only person to receive this data set during this time. At the end of this period, we will email you to let you know your data has been reclaimed so that it can be reassigned to someone else who can use it if you haven't processed it by then. You can make data requests every two weeks if you want to make another light curve.

The exoplanet you will be studying is randomly selected for you, so you can't request data of a specific exoplanet.

As with any astronomical observation, some nights are clear and some nights are cloudy. We can't guarantee that the data set you get will be from a clear night. If you get a cloudy data set, you can try to process it anyway and see if it works. If the sky is completely clouded over, come back in two weeks and request another data set. Hopefully it will be from a clearer night.

Email

Yes, Sign me up for monthly email updates from Exoplanet Watch, including nightly target identifications, software updates, and other news.

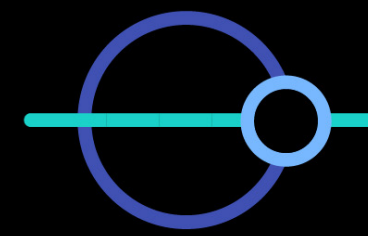
I'm not a robot

Submit



Request Data

USER EXPERIENCE



EXOPLANET WATCH

What to Observe

No matter where you are on Earth, it's likely that at least a few transiting exoplanets will be visible tonight. You can look up upcoming transits so that you know when and where to look for them. Transits can last anywhere from an hour to five or six hours, and some are even longer. When observing an exoplanet transit, it's important to capture the star's baseline brightness before the exoplanet starts passing in front of it, then capture the transit as well as an hour or two after the transit ends, so that the baseline brightness of the star can be measured again.

Name	RA	Dec	RA (h:m:s)	Dec (d:m:s)	RA (h:m:s)	Dec (d:m:s)	RA (h:m:s)	Dec (d:m:s)	RA (h:m:s)	Dec (d:m:s)
Kepler-90c	19h 08m 47s	+35d 12m 56s	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56
Kepler-90d	19h 08m 47s	+35d 12m 56s	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56
Kepler-90e	19h 08m 47s	+35d 12m 56s	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56
Kepler-90f	19h 08m 47s	+35d 12m 56s	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56
Kepler-90g	19h 08m 47s	+35d 12m 56s	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56
Kepler-90h	19h 08m 47s	+35d 12m 56s	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56
Kepler-90i	19h 08m 47s	+35d 12m 56s	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56
Kepler-90j	19h 08m 47s	+35d 12m 56s	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56	19:14:47	+35:21:56



Observe



AAVSO
American Association of Variable Star Observers

Exoplanet Database: Submit Observation

Upload Here

Select Site *

Select Equipment Package *

Report form: *

Submit

Utilizing Small Telescopes Operated by Citizen Scientists for Transiting Exoplanet Follow-up

Robert T. Zellem¹, Kyle A. Pearson^{2,3}, Ethan Blaser^{3,4}, Martin Fowler⁵, David R. Ciardi⁶, Anya Biferno⁷, Bob Massey⁸, Franck Marchis⁹, Robert Baer¹⁰, Conley Ball¹¹, Mike Chasin^{12,13}, Mike Conley¹⁴, Scott Dixon^{15,16}, Elizabeth Flecker¹⁷, Sanyela Hernandez¹⁸, Saiy Nair¹⁹, Quinn Perian²⁰, Frank Sienkiewicz²¹, Kalle Toek²², Virek Vijayakumar²³, Mark R. Swain²⁴, Gad M. Roudier²⁵, Geoffrey Bryden²⁶, Dennis M. Coon²⁷, Doreen H. Hill²⁸, Carl W. Hergenrother²⁹, Mary Drossard³⁰, Stephen R. Kane³¹, Michael Fitzgerald³², Pat Boyce³³, Laura Petricola³⁴, Wilfred Ge³⁵, Lynn Cominsky³⁶, Rachel Zimmerman-Brachman³⁷, Denise Smith³⁸, Michelle J. Creech-Eakman³⁹, John Engelke⁴⁰, Alexandra Burnald^{41,42}, Diana Dragomir^{43,44}, Nemanja Jovanovic⁴⁵, Brandon Lawton⁴⁶, Emmanuel Abouch⁴⁷, Marc Kuchner⁴⁸, and Armand Michard⁴⁹

Plan

How to Participate

Request an Exoplanet Observation

Exoplanet Watch partners with the MicroObservatory's DIY Planet Search to obtain robotic telescope observations of transiting exoplanets for Exoplanet Watch participants who do not have their own telescope. MicroObservatory is generously sharing ten years of archived transiting exoplanet observations with us so that you can participate in Exoplanet Watch.

Submit your email address below to check out a night's observation of an exoplanet transit target by a robotic telescope. Once you have this data, use EXOTIC, our data reduction software, to produce a lightcurve using this data that you can then submit to the AAVSO, the American Association of Variable Star Observers. (If you haven't used EXOTIC before, try the tutorial to learn how to use it first.) Use the Standard version of EXOTIC to process the data we give you, so you can create your own light curve of a transiting exoplanet.

Once submitted, your data will be shared with the professional astronomers who study exoplanets and your light curve will be included on Exoplanet Watch's Results webpage. If your observations or light curves are used in a scientific paper, your name will be listed as a co-author on the paper, and you will get credit for participating in scientific research!

When you check out data, the observation is yours for two weeks, so you have two weeks to process the data and upload the resulting light curve to the AAVSO. You will be the only person to receive this data set during this time. At the end of this period, we will email you to let you know your data has been reclaimed so that it can be reassigned to someone else who can use it if you haven't processed it by then. You can make data requests every two weeks if you want to make another light curve.

The exoplanet you will be studying is randomly selected for you, so you can't request data of a specific exoplanet.

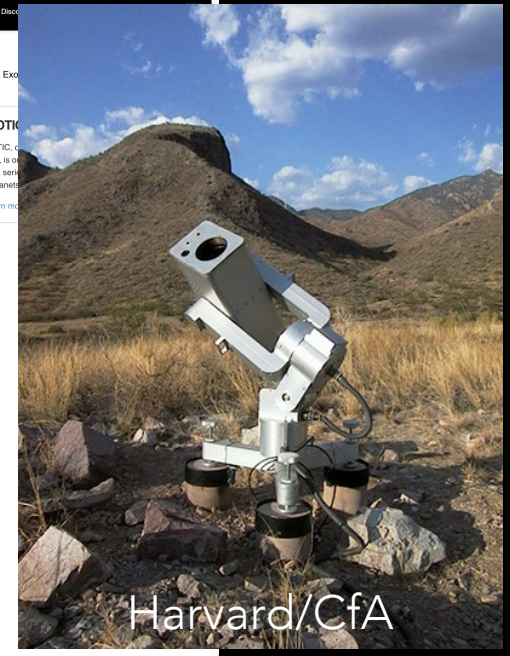
As with any astronomical observation, some nights are clear and some nights are cloudy. We can't guarantee that the data set you will be from a clear night. If you get a cloudy data set, you can try to process it anyway and see if it works. If the sky is completely clouded over, come back in two weeks and request another data set. Hopefully it will be from a clearer night.

Email

Yes, Sign me up for monthly email updates from Exoplanet Watch, including nightly target identifications, software updates, and other news.

I'm not a robot

SUBMIT



Request Data

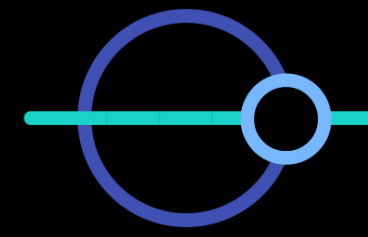
AstrolmageJ

Analyze

Upload

Publish

USER EXPERIENCE



EXOPLANET WATCH

What to Observe

No matter where you are on Earth, it's likely that at least a few transiting exoplanets will be visible tonight. You can look up upcoming transits so that you know when and where to look for them. Transits can last anywhere from an hour to five or six hours, and some are even longer. When observing an exoplanet transit, it's important to capture the star's baseline brightness before the exoplanet starts passing in front of it, then capture the transit as well as an hour or two after the transit ends, so that the baseline brightness of the star can be measured again.

Name	Date	Duration	Depth
Kepler-90b	2016-09-09	1.2	0.01
Kepler-90c	2016-09-09	1.2	0.01
Kepler-90d	2016-09-09	1.2	0.01
Kepler-90e	2016-09-09	1.2	0.01
Kepler-90f	2016-09-09	1.2	0.01
Kepler-90g	2016-09-09	1.2	0.01
Kepler-90h	2016-09-09	1.2	0.01
Kepler-90i	2016-09-09	1.2	0.01
Kepler-90j	2016-09-09	1.2	0.01

1. You can prioritize the Exoplanet Watch targets by selecting the "Exoplanet Watch targets" radio button at the top of the form.
2. Select an observatory near your location or choose "manual coordinate entry" at the end of the list.
3. Under "Date window" select the "base date" that you would like to begin scheduling and fill in the appropriate number of days before and/or after this base date. In addition, you can optionally include constraints on the target's elevation during the transit if your horizon has limited visibility.
4. Once you hit the "Submit" button, the service might take a few seconds to minutes to load, depending on the number of days you have requested.
5. On the page that does open, you can sort the planets according to their "Exoplanet Watch rank" where a low number (e.g., 1) is higher priority than a larger number (e.g., 1000). You can also filter your targets based upon the host star's "Magnitude (V, mag)" and the expected transit depth ("Depth, mm" in units of parts per thousand ppt). You can sort the list by the date, by the name of the exoplanet, or by the Exoplanet Watch rank, as well as by the magnitude of the star.



Observe



AAVSO
American Association of Variable Star Observers

Exoplanet Database: Submit Observation

Upload Here

Select Site *

Select Equipment Package *

Report form: *

Image(s): *

Submit

Utilizing Small Telescopes Operated by Citizen Scientists for Transiting Exoplanet Follow-up

Robert T. Zellem¹, Kyle A. Pearson^{2,3}, Ethan Blaser^{1,4}, Martin Fowler⁵, David R. Ciardi⁶, Anya Biferno⁷, Bob Massey⁸, Franck Marchis⁹, Robert Baer¹⁰, Conley Ball¹¹, Mike Chasin^{12,13}, Mike Conley¹⁴, Scott Dixon^{15,16}, Elizabeth Flecker¹⁷, Sanyela Hernandez¹⁸, Saiy Nair¹⁹, Quinn Perian²⁰, Frank Sienkiewicz²¹, Kalle Toal²², Virek Vijayakumar²³, Mark R. Swain²⁴, Gad M. Roudier²⁵, Geoffrey Bryden²⁶, Dennis M. CoRoT²⁷, Doreen H. Hill²⁸, Carl W. Hergele²⁹, Mary Drossart³⁰, Stephen R. Kane³¹, Michael Fitzgerald³², Pat Boyce³³, Laura Petricola³⁴, Wilfred Ge³⁵, Lynn Cominsky³⁶, Rachel Zimmerman-Brachman³⁷, Denise Smith³⁸, Michelle J. Creech-Eakman³⁹, John Engelke⁴⁰, Alexandra Burnald⁴¹, Diana Dragomir^{42,43}, Nemanja Jovanovic⁴⁴, Brandon Lawton⁴⁵, Emmanuel Abouch⁴⁶, Marc Kuchner⁴⁷, and Armand Michard⁴⁸

Abstract

Due to the efforts by numerous ground-based surveys and NASA's Kepler and Transiting Exoplanet Survey Satellite (TESS), there will be hundreds, if not thousands, of transiting exoplanets ideal for atmospheric characterization via spectroscopy with large platforms such as James Webb Space Telescope and ARIEL. However their next predicted mid-transit time could become so increasingly uncertain over time that significant overhead would be required to ensure the detection of the entire transit. As a result, follow-up observations to characterize these exoplanetary atmospheres would require less-efficient use of an observer's time—which is an issue for large platforms where minimizing observing overheads is a necessity. Here we demonstrate the power of citizen scientists operating smaller observatories (<1 m) to keep ephemerides "fresh," defined here as when the 1 σ uncertainty in the mid-transit time is less than half the transit duration. We advocate for the creation of a community-wide effort to perform ephemeris maintenance on transiting exoplanets by citizen scientists. Such observations can be conducted with even a 6-inch telescope, which has the potential to save up to ~10,000 days for a 1000-planet survey. Based on a preliminary analysis of 14 transits from a single 6-inch MicroObservatory telescope, we empirically estimate the ability of small telescopes to benefit the community. Observations with a

Plan

AstrolmageJ

Analyze

Upload

Publish

How to Participate

Request an Exoplanet Observation

Exoplanet Watch partners with the MicroObservatory's DIY Planet Search to obtain robotic telescope observations of transiting exoplanets for Exoplanet Watch participants who do not have their own telescope. MicroObservatory is generously sharing ten years of archived transiting exoplanet observations with us so that you can participate in Exoplanet Watch.

Submit your email address below to check out a night's observation of an exoplanet transit taken by a robotic telescope. Once you have this data, use EXOTIC, our data reduction software, to produce a lightcurve using this data that you can then submit to the AAVSO, the American Association of Variable Star Observers. (If you haven't used EXOTIC before, try the tutorial to learn how to use it first.) Use the Standard version of EXOTIC to process the data we give you, so you can create your own light curve of a transiting exoplanet.

Once submitted, your data will be shared with the professional astronomers who study exoplanets and your light curve will be included on Exoplanet Watch's Results webpage. If your observations or light curves are used in a scientific paper, your name will be listed as a co-author on the paper, and you will get credit for participating in scientific research!

When you check out data, the observation is yours for two weeks, so you have two weeks to process the data and upload the resulting light curve to the AAVSO. You will be the only person to receive this data set during this time. At the end of this period, we will email you to let you know your data has been reclaimed so that it can be reassigned to someone else who can use it if you haven't processed it by then. You can make data requests every two weeks if you want to make another light curve.

The exoplanet you will be studying is randomly selected for you, so you can't request data of a specific exoplanet.

As with any astronomical observation, some nights are clear and some nights are cloudy. We can't guarantee that the data set you get will be from a clear night. If you get a cloudy data set, you can try to process it anyway and see if it works. If the sky is completely clouded over, come back in two weeks and request another data set. Hopefully it will be from a clearer night.

Email

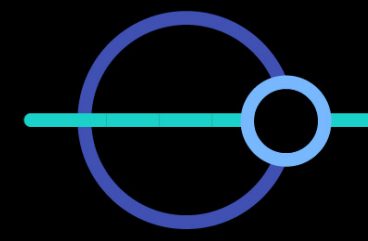
Yes, Sign me up for monthly email updates from Exoplanet Watch, including nightly target identifications, software updates, and other news.

Submit



Request Data

USER EXPERIENCE



EXOPLANET WATCH

What to Observe

No matter where you are on Earth, it's likely that at least a few transiting exoplanets will be visible tonight. You can look up upcoming transits so that you know when and where to look for them. Transits can last anywhere from an hour to five or six hours, and some are even longer. When observing an exoplanet transit, it's important to capture the star's baseline brightness before the exoplanet starts passing in front of it, then capture the transit as well as an hour or two after the transit ends, so that the baseline brightness of the star can be measured again.

Star Name	Planet Name	RA (J2000)	Dec (J2000)	RA (MJD)	Dec (MJD)	RA (MJD)	Dec (MJD)	RA (MJD)	Dec (MJD)
51 Pegasi b	51 Pegasi b	22h 06m 00s	+52° 06' 35"	58548.000	58548.000	58548.000	58548.000	58548.000	58548.000
51 Pegasi b	51 Pegasi b	22h 06m 00s	+52° 06' 35"	58548.000	58548.000	58548.000	58548.000	58548.000	58548.000

Embedded below is the **Transit Finder**, a helpful tool for planning your own observations of any transiting exoplanet.

- You can prioritize the Exoplanet Watch targets by selecting the "Exoplanet Watch targets" radio button at the top of the form.
- Select an observatory near your location or choose "manual coordinate entry" at the end of the list.
- Under "Date window" select the "base date" that you would like to begin scheduling and fill in the appropriate number of days before and/or after this base date. In addition, you can optionally include constraints on the target's elevation during the transit if your horizon has limited visibility.
- Once you hit the "Submit" button, the service might take a few seconds to minutes to load, depending on the number of days you have requested.
- On the page that does open, you can sort the planets according to their "Exoplanet Watch rank" where a low number (e.g., 1) is higher priority than a larger number (e.g., 1000). You can also filter your targets based upon the host star's "Magnitude (V, mag)" and the expected transit depth ("Depth, mm" in units of parts per thousand ppt). You can sort the list by the date, by the name of the exoplanet, or by the Exoplanet Watch rank, as well as by the magnitude of the star.



Observe

Plan



AAVSO
American Association of Variable Star Observers

Exoplanet Database: Submit Observation

Upload Here

Select Site *

Select Equipment Package *

Report form: *

Choose File: No files selected

Image(s): *

Choose File(s): No files selected

Submit

I accept the CEPPH (see below)

* This field is required
* Cannot find your site and/or equipment? Add it here: Site & Equipment
* You must check the CEPPH box to confirm that you understand that the personal information contained in the Site and/or Equipment selection is part of the data shared with others when they download your data.

AstrolmageJ

Analyze

Upload

Publish

How to Participate

Request an Exoplanet Observation

Exoplanet Watch partners with the MicroObservatory's DIV Planet Search to obtain robotic telescope observations of transiting exoplanets for Exoplanet Watch participants who do not have their own telescope. MicroObservatory is generously sharing ten years of archived transiting exoplanet observations with us so that you can participate in Exoplanet Watch.

Submit your email address below to check out a night's observation of an exoplanet transit target by a robotic telescope. Once you have this data, use EXOTIC, our data reduction software, to produce a lightcurve using this data that you can then submit to the AAVSO, the American Association of Variable Star Observers. (If you haven't used EXOTIC before, try the tutorial to learn how to use it first.) Use the Standard version of EXOTIC to process the data we give you, so you can create your own light curve of a transiting exoplanet.

Once submitted, your data will be shared with the professional astronomers who study exoplanets and your light curve will be included on Exoplanet Watch's Results webpage. If your observations or light curves are used in a scientific paper, your name will be listed as a co-author on the paper, and you will get credit for participating in scientific research!

When you check out data, the observation is yours for two weeks, so you have two weeks to process the data and upload the resulting light curve to the AAVSO. You will be the only person to receive this data set during this time. At the end of this period, we will email you to let you know your data has been reclaimed so that it can be reassigned to someone else who can use it if you haven't processed it by then. You can make data requests every two weeks if you want to make another light curve.

The exoplanet you will be studying is randomly selected for you, so you can't request data of a specific exoplanet.

As with any astronomical observation, some nights are clear and some nights are cloudy. We can't guarantee that the data set you get will be from a clear night. If you get a cloudy data set, you can try to process it anyway and see if it works. If the sky is completely clouded over, come back in two weeks and request another data set. Hopefully it will be from a clearer night.

Email

Yes, Sign me up for monthly email updates from Exoplanet Watch, including nightly target identifications, software updates, and other news.

I'm not a robot

Submit



Request Data

Publications of the Astronomical Society of the Pacific, 132:054401 (22pp), 2020 May
<https://doi.org/10.1088/1538-3873/ab70c7>

Utilizing Small Telescopes Operated by Citizen Scientists for Transiting Exoplanet Follow-up

Robert T. Zellem¹, Kyle A. Pearson^{1,2}, Ethan Blaser^{1,3}, Martin Fowler⁴, David R. Ciardi⁵, Anya Biferno⁶, Bob Massey⁶, Franck Marchis⁶, Robert Baer⁷, Conley Ball⁸, Mike Chasin^{1,11}, Mike Conley¹², Scott Dixon^{1,13}, Elizabeth Flekher¹⁴, Sanyela Hernandez¹⁵, Saiy Nair¹⁶, Quinn Perian¹⁷, Frank Sienkiewicz¹⁸, Kalle Toek¹⁹, Virek Vijayakumar²⁰, Mark R. Swain²¹, Gad M. Roudier²², Geoffrey Bryden²³, Dennis M. Cozz²⁴, Dokters H. Hill²⁵, Carl W. Hergeimother²⁶, Mary Dussault²⁷, Stephen R. Kane²⁸, Michael Fitzgerald²⁹, Pat Boyce³⁰, Laura Petricola³¹, Wilfred Ge³², Lynn Cominsky³³, Rachel Zimmerman-Brachman³⁴, Denise Smith³⁵, Michelle J. Creech-Eakman³⁶, John Engelage³⁷, Alexandra Burradell³⁸, Diana Dragomir^{39,40,41}, Nemanja Jovanovic⁴², Brandon Lawton⁴³, Emmanuel Arbouch⁴⁴, Marc Kuchner⁴⁵, and Armand Mouchak⁴⁶

¹Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA; rzellem@jpl.nasa.gov
²Lunar and Planetary Laboratory, University of Arizona, 1629 E University Blvd, Tucson, AZ 85724, USA
³University of Virginia, Charlottesville, VA 22904, USA
⁴Citizen Scientist, Los Rios, Orchard Road, South Weymouth, Wiltshire SO21 1EX, UK
⁵NASA Exoplanet Science Institute, California Institute of Technology, MC 118-6, 1200 E California Blvd, Pasadena, CA 91125, USA
⁶American Association of Variable Star Observers, 49 Bay State Rd, Cambridge, MA 02138, USA
⁷SETI Institute, 150 Bernardo Ave, Suite 200, Mountain View, CA 94035, USA
⁸Univ. Lille, 19 rue Vauquelin, F-59000 Lille, France
⁹Southern Illinois University Carbondale, MC 4011, 1245 Lincoln Dr, Carbondale, IL 62901, USA
¹⁰Citizen, CAVE Equipment, USA
¹¹Laguna Blanca School, 4125 Palma Dr, Santa Barbara, CA 93110, USA
¹²Boyce Research Initiatives and Education Foundation, USA
¹³San Diego Astronomy Association, USA
¹⁴Towson University, 800 York Rd, Towson, MD 21286, USA
¹⁵Stanford Online High School, 415 Broadway Academy Hall, Floor 2, 883, Redwood City, CA 94063, USA
¹⁶The Center for Astrophysics, Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA
¹⁷Department of Earth and Planetary Sciences, University of California, Riverside, CA 92521, USA
¹⁸Edith Cowan University, 270 Joondalup Drive, Joondalup, WA 6027, Australia
¹⁹Southern State University, 1801 East Coast Ave, Roblet Park, CA 94928, USA
²⁰Macquarie University, Sydney, New South Wales 2109, Australia
²¹Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
²²Department of Physics, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801, USA
²³Raytheon Intelligence, Information, and Services, 300 N Lake Ave, Suite 1120, Pasadena, CA 91101, USA
²⁴The University of New Mexico, Albuquerque, NM 87131, USA
²⁵Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA 02139, USA
²⁶Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, USA
²⁷California Institute of Technology, 1200 East California Boulevard, Pasadena, CA 91125, USA
²⁸NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 20771, USA
²⁹Received 2019 September 26, accepted 2020 March 11, published 2020 April 8

Abstract

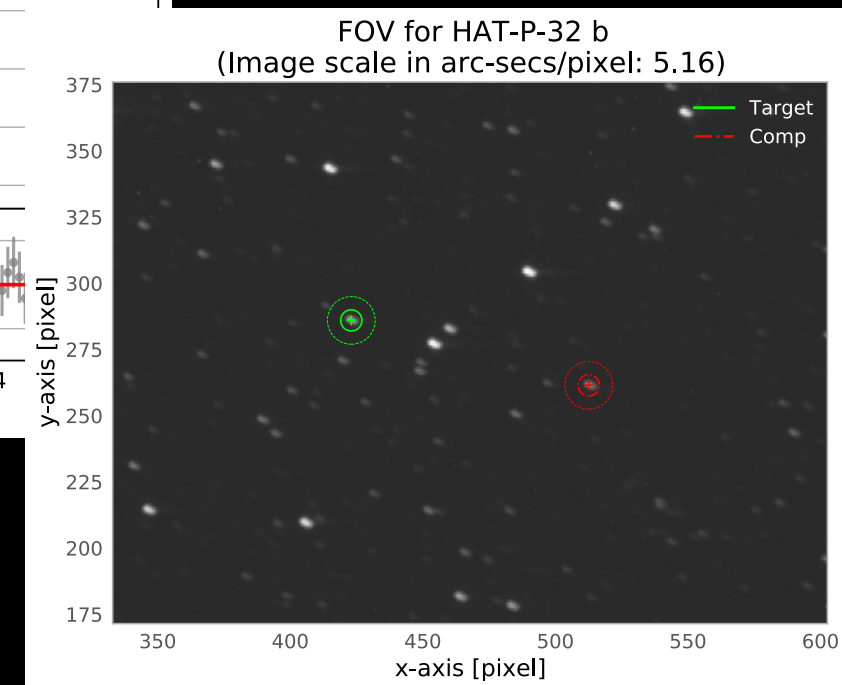
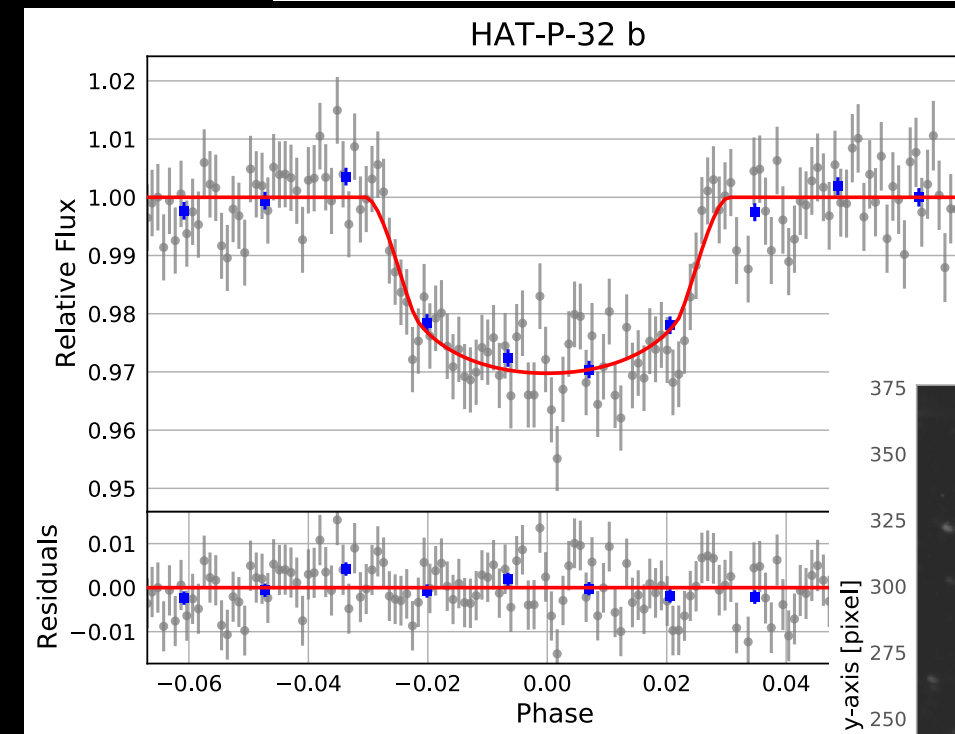
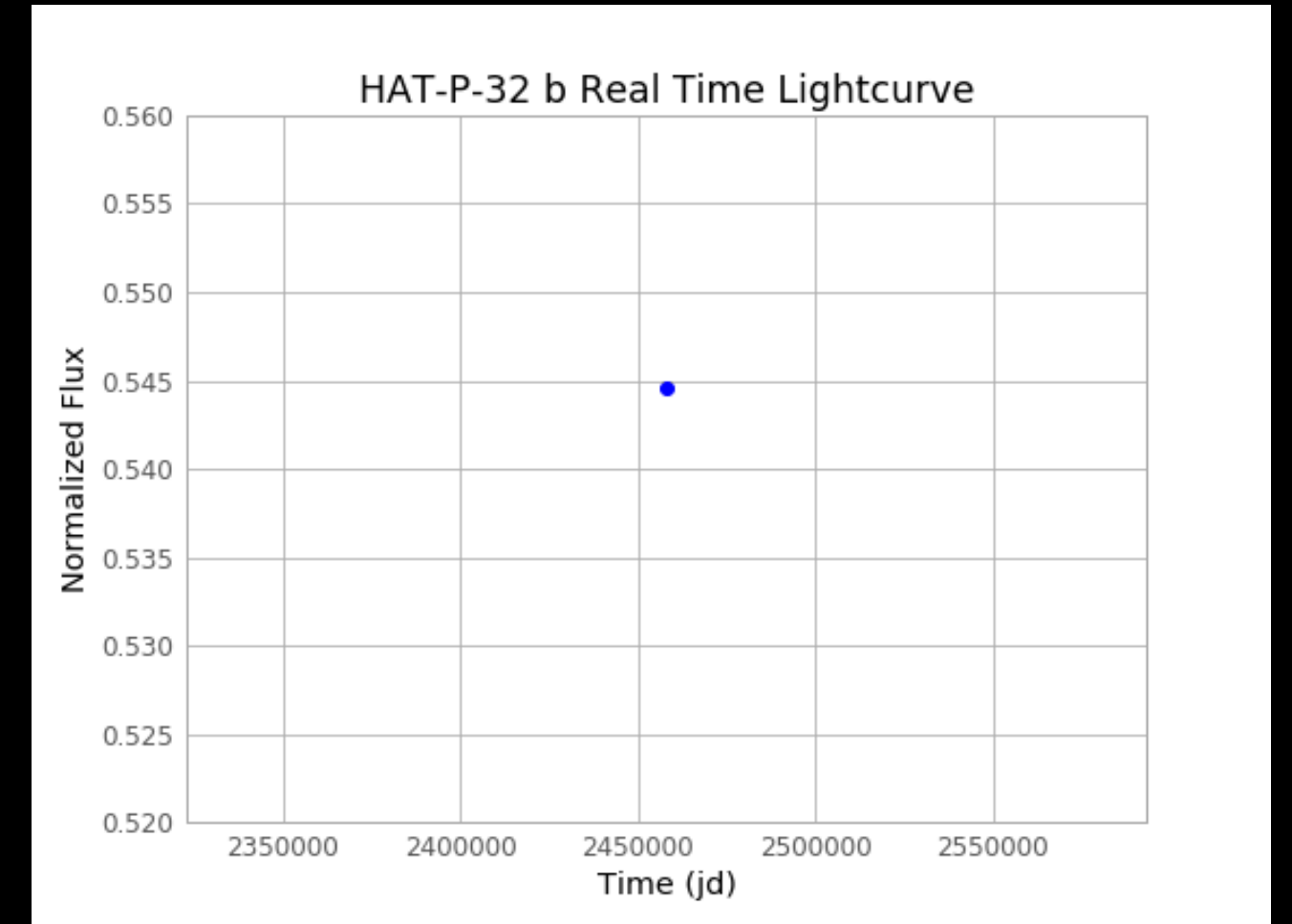
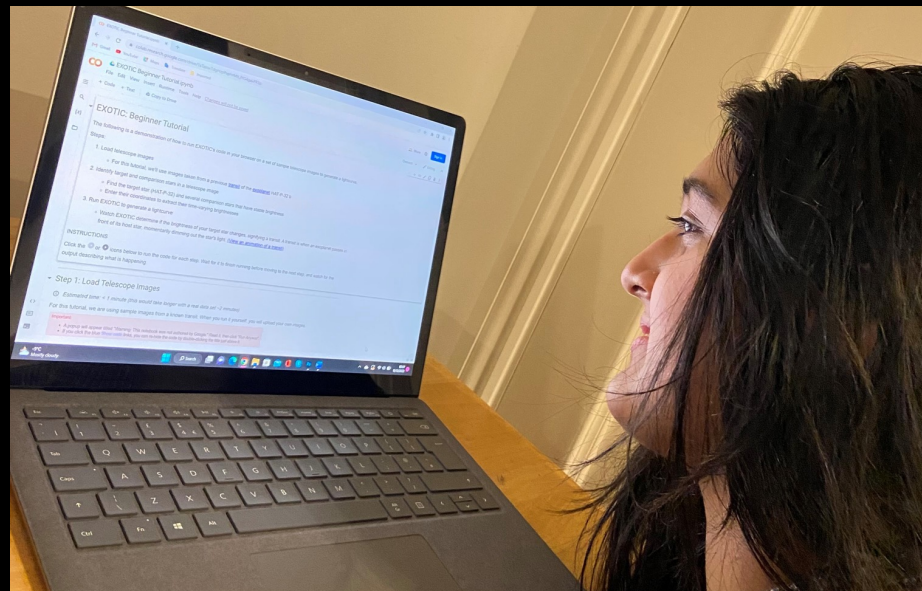
Due to the efforts by numerous ground-based surveys and NASA's Kepler and Transiting Exoplanet Survey Satellite (TESS), there will be hundreds, if not thousands, of transiting exoplanets ideal for atmospheric characterization via spectroscopy with large platforms such as James Webb Space Telescope and ARIEL. However their next predicted mid-transit time could become so increasingly uncertain over time that significant overhead would be required to ensure the detection of the entire transit. As a result, follow-up observations to characterize these exoplanetary atmospheres would require less-efficient use of an observatory's time—which is an issue for large platforms where minimizing observing overheads is a necessity. Here we demonstrate the power of citizen scientists operating smaller observatories (<1 m) to keep ephemerides "fresh," defined here as when the 1 σ uncertainty in the mid-transit time is less than half the transit duration. We advocate for the creation of a community-wide effort to perform ephemeris maintenance on transiting exoplanets by citizen scientists. Such observations can be conducted with even a 6 inch telescope, which has the potential to save up to ~10,000 days for a 1000-planet survey. Based on a preliminary analysis of 14 transits from a single 6 inch MicroObservatory telescope, we empirically estimate the ability of small telescopes to benefit the community. Observations with a

³⁹ NASA Hubble Fellow.

1

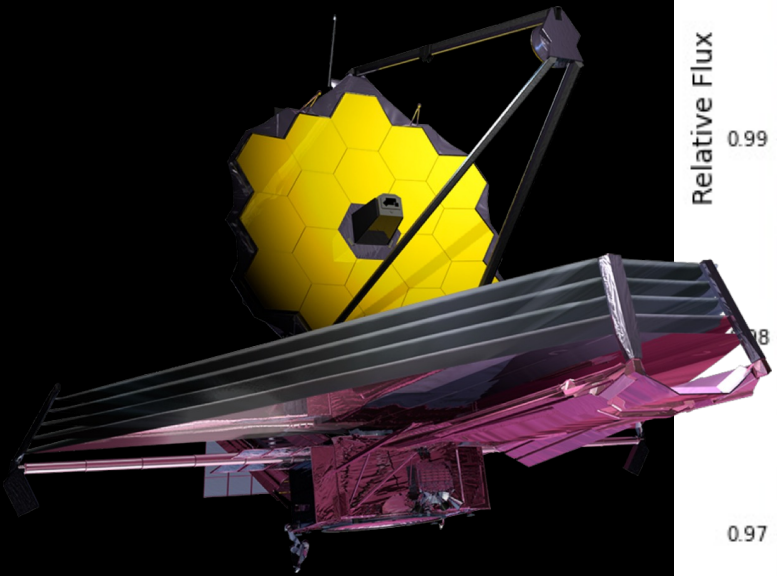
EXOTIC

- EXOplanet Transit Interpretation Code
- Real astronomy analysis tool
- Teach you how science is done
- Have step-by-step tutorials on how to use

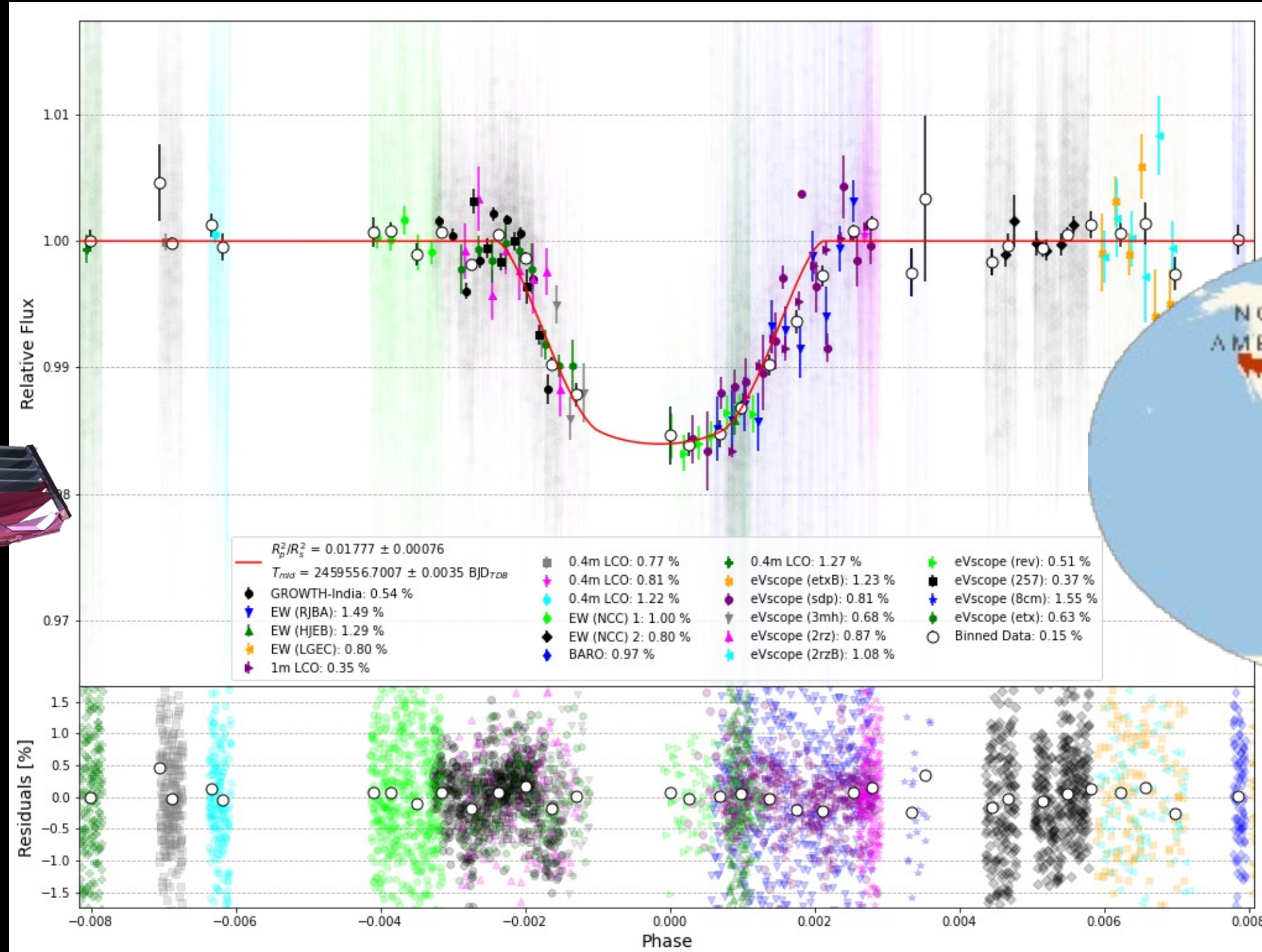


Zellem et al. 2020

DEC 2021 OBSERVING CAMPAIGN

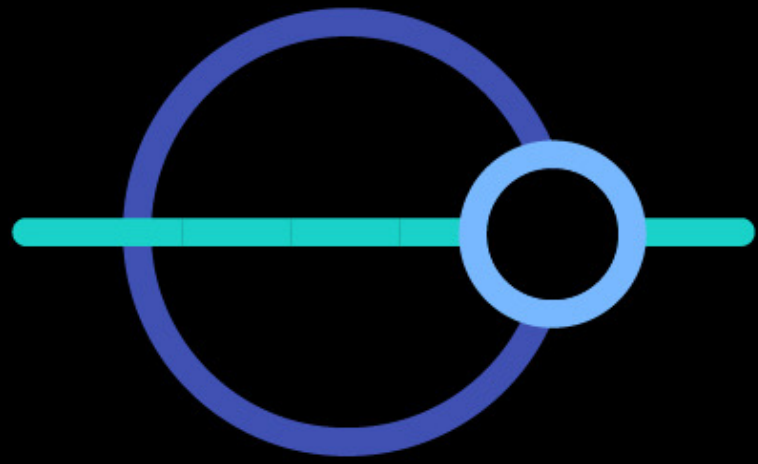


JWST - NASA/Goddard



24 facilities; $\leq 0.7\text{-m}$ (30-in)

Pearson et al. (2022)



EXOPLANET WATCH

Get started here:
[exoplanets.nasa.gov/exoplanet-
watch](https://exoplanets.nasa.gov/exoplanet-watch)



Exoplanet Watch
Workshop
Jan 18, 2023, 4 PM EST

