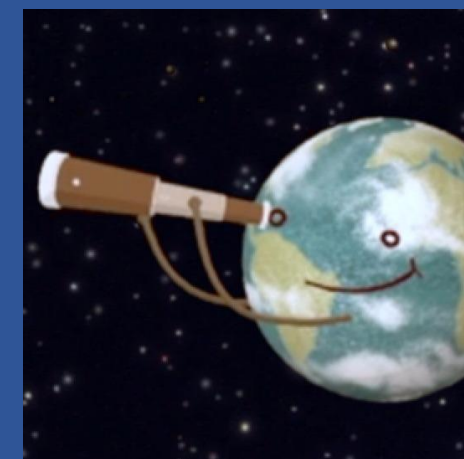




Finding Jupiters in a Haystack via Citizen Science

Sarah Casewell

STFC Ernest Rutherford Fellow and Lecturer
slc25@Leicester.ac.uk



Exoplanets!

First exoplanet announced in 1995: 51 Peg b

Found via RV measurements

It was the size of Jupiter

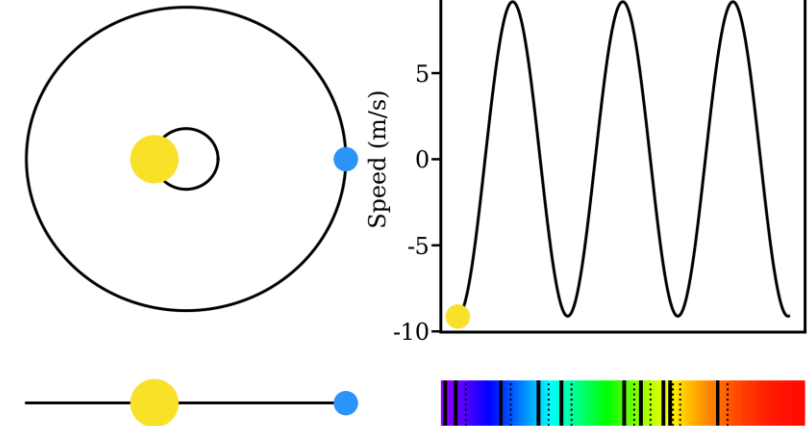
It has a mass of half that of Jupiter

It has an orbit of ~4 days

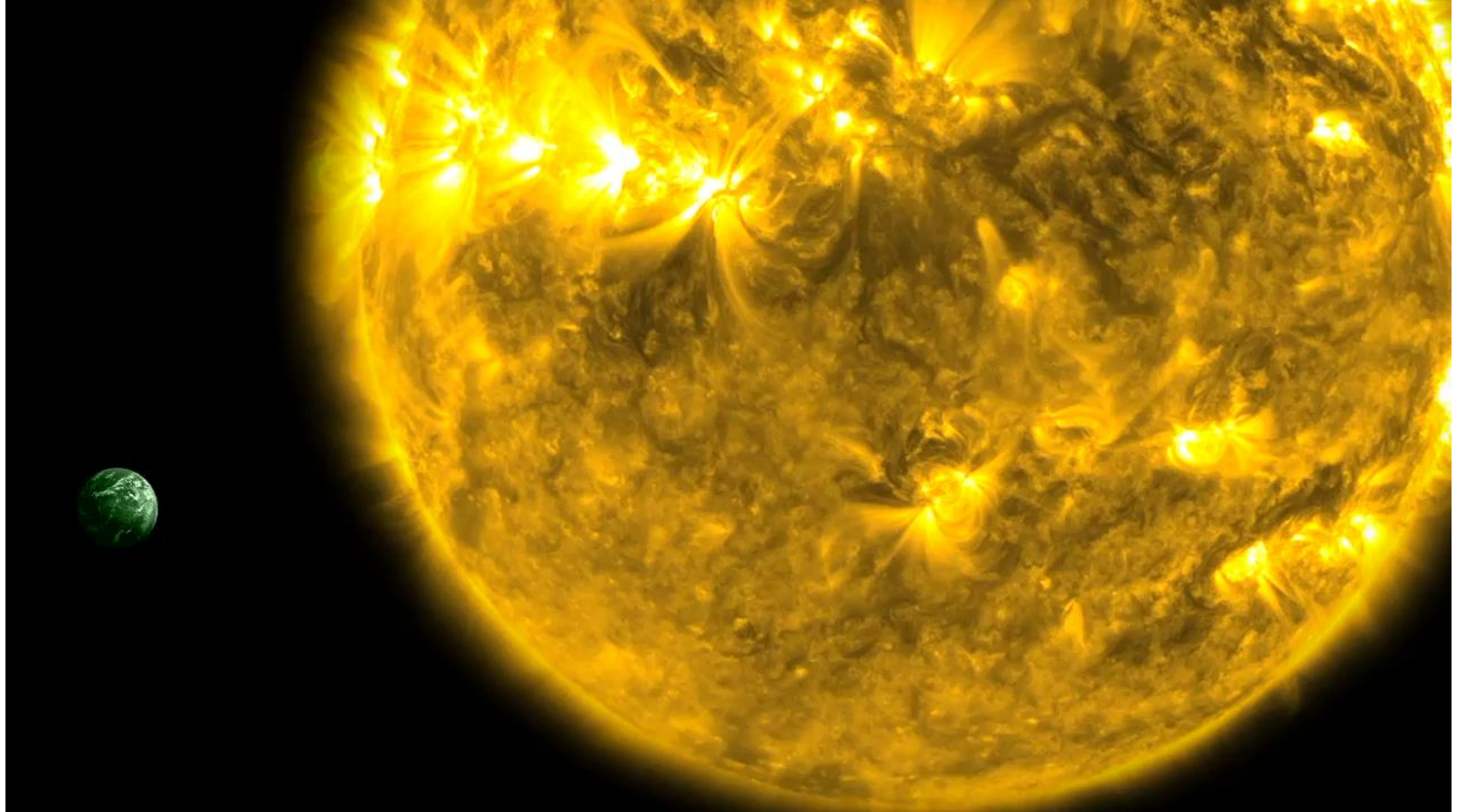
Over 5,500 known now ~4000 found via transit method



Alysa Obertas (@AstroAlysa)

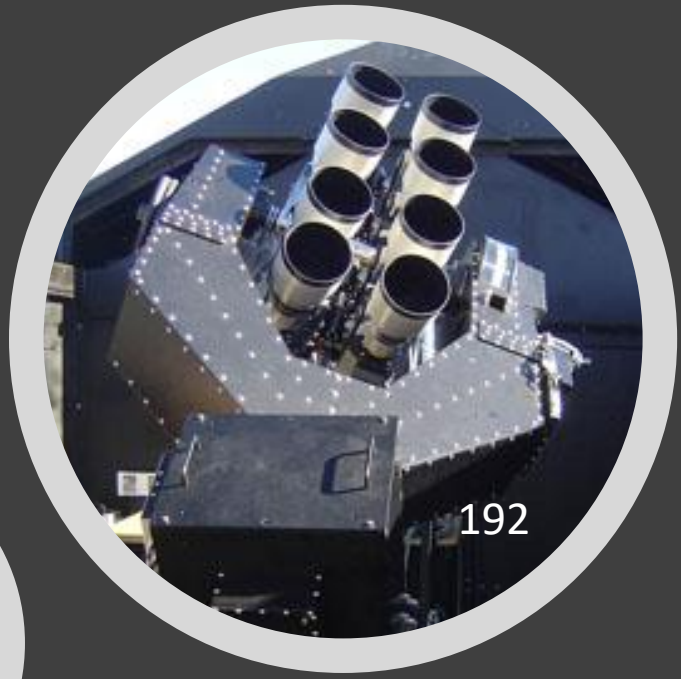


Transits





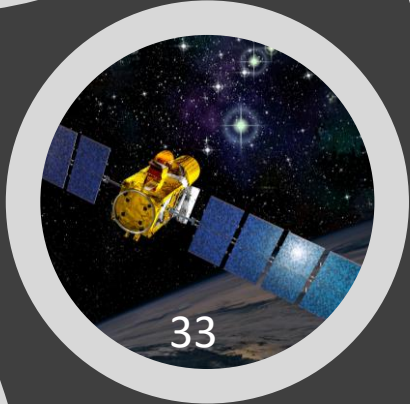
30



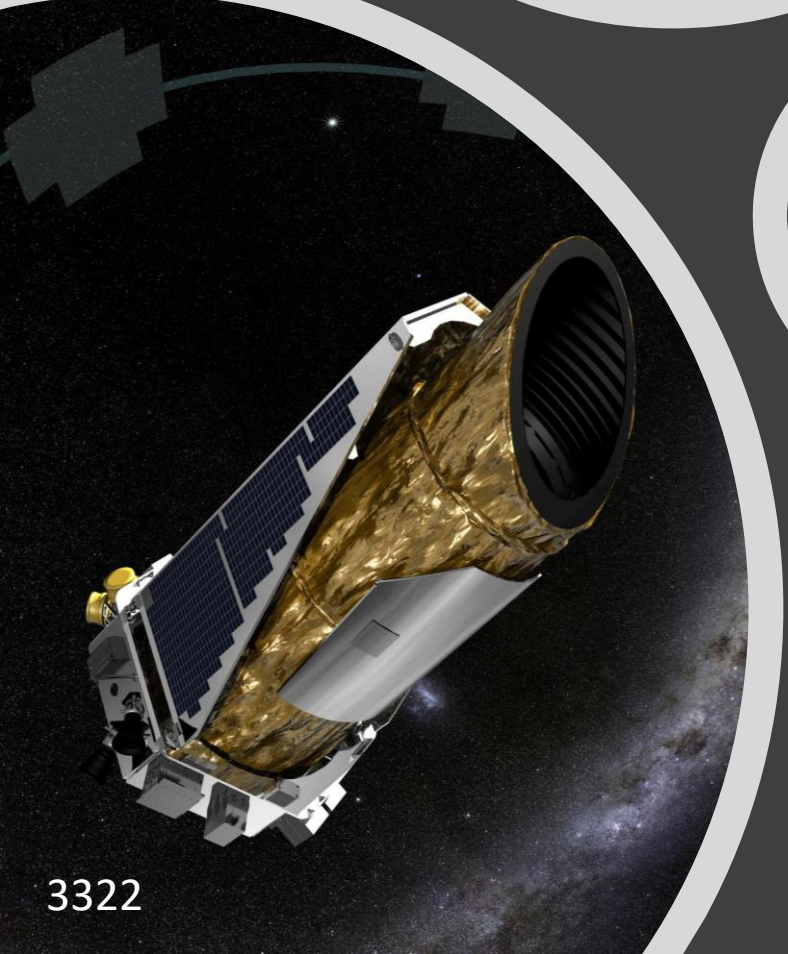
192



442



33



3322

Transit factories!

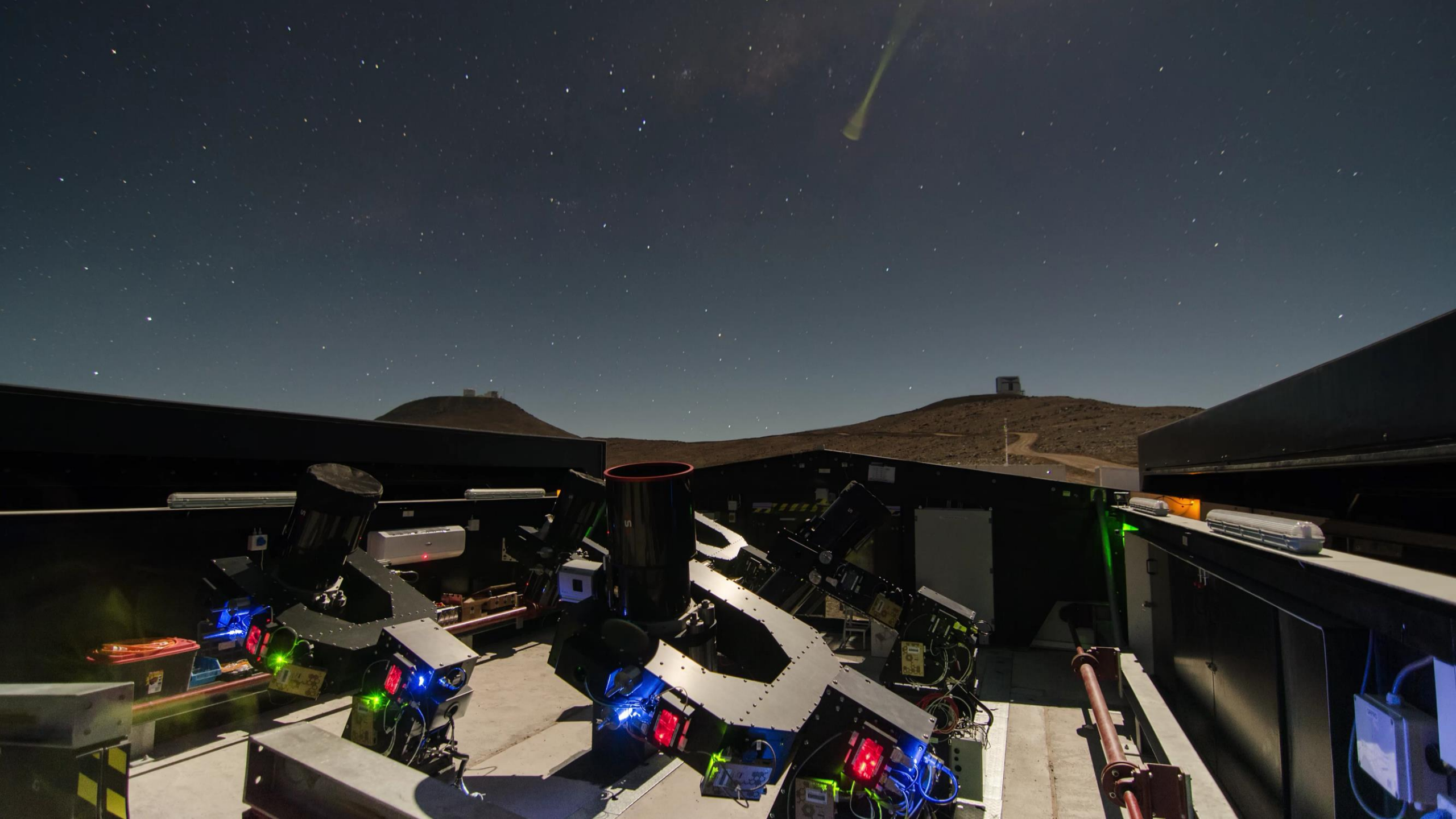


2026 launch



Next Generation Transit Survey

- 12 20cm telescopes
- Located at Paranal in the Atacama desert, Chile
- Observe in the optical with similar precision to TESS
- Looking for Neptune sized planets around cool stars
- Found over 30 planets so far, and contributed to ~40 others
- Over 100 publications: eclipsing binaries, BDs, flares, clusters, dippers
- Consortium: Geneva, Leicester, Warwick, Cambridge, Belfast, DLR Berlin
- Contact Peter Wheatley P.J.Wheatley@warwick.ac.uk

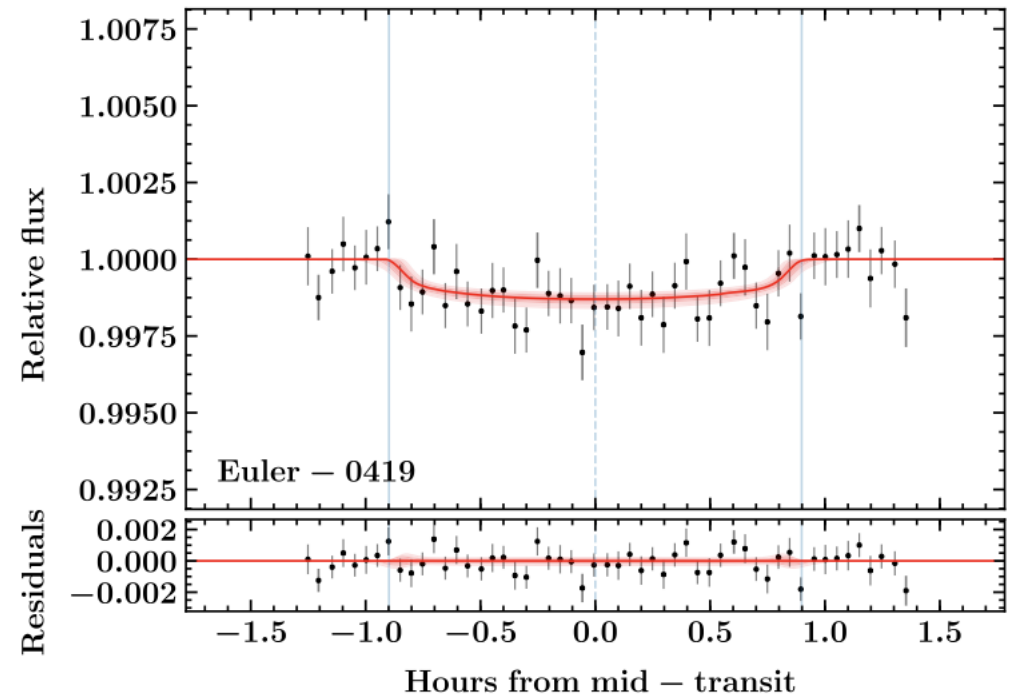
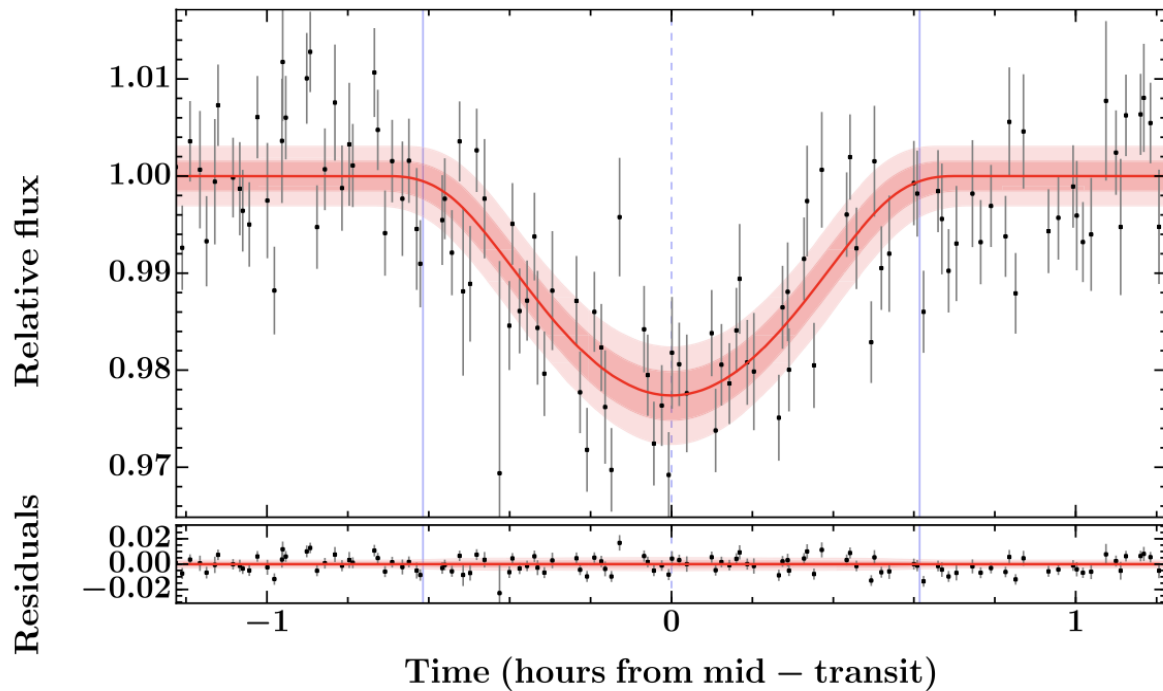
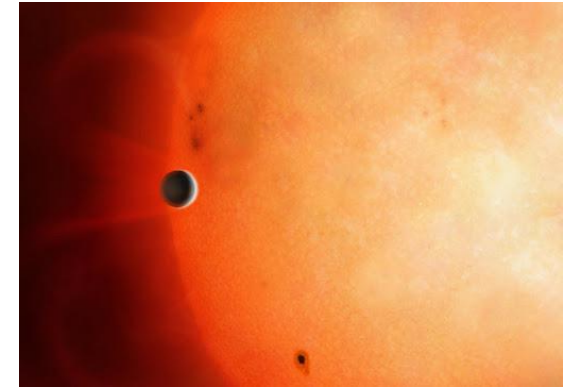


Next Generation Transit Survey



NGTS-1b
M dwarf star
Half mass and size of sun
Orbit is 2.3 days
0.8 Jupiter masses
1.33 Jupiter radii

NGTS-4b
K dwarf star
3/4 size of sun
Orbit is 1.33 days
0.06 Jupiter masses
20 Earth masses



Finding planets by hand.....

Sp Type	T _{eff} [K]	M1 [M _☉]	R1 [R _☉]	ρ1 [ρ _☉]	lumclass	V	T	J	V-K	J-H	μ _{ra} [mas]	μ _{dec} [mas]	D11 V
M0V / K5III	-	-	-	-	-	15.52	-	12.70	3.59	0.64	-29.8±9.6	-44.7±9.6	0.001

[LC & periodogram](#)
[Nearby objects](#)
[SED fitting](#)
[Phase fold](#)
[Fitting](#)
[Centroid fitting](#)
[TESS Info](#)
[Uploaded files](#)
[Download NGTS data](#)

Field: NG0532-3633 Camera: 809 Campaign: 2016,2016S,2016S2,2016S3 Tag: CYCLE1706

Date range: 20160807 08:35:46--20170429 00:09:47 N_{img}: 207538

α: 05:30:51.4 δ: -36:37:51.71

α: 82.7142738678 δ: -36.6310319339

I_{NGTS}: 14.24

Other detections

[NG0532-3633.1.021676](#)

[\(NG0532-3633.809.2016S.TEST18\)](#)

[NG0532-3633.3.020001](#)

[\(NG0532-](#)

[3633.809.2016,2016S,2016S2,2016S3.CYCLE1706\)](#)

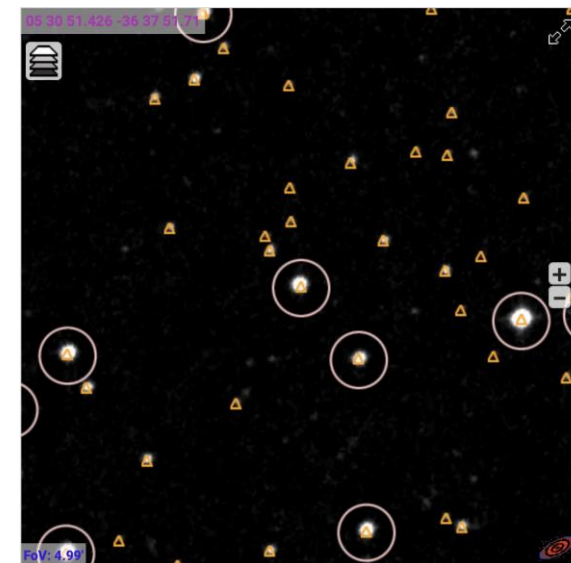
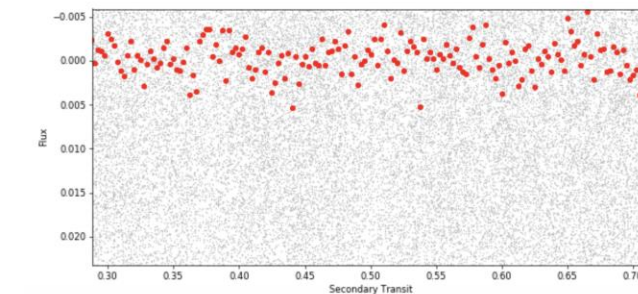
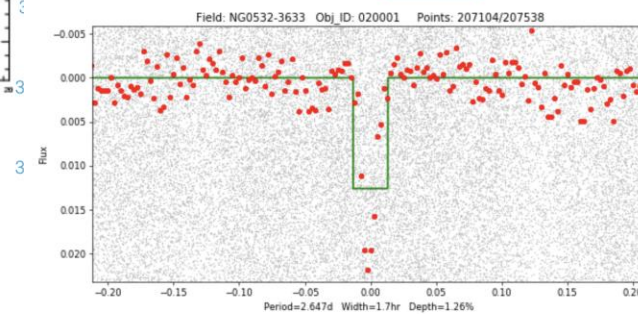
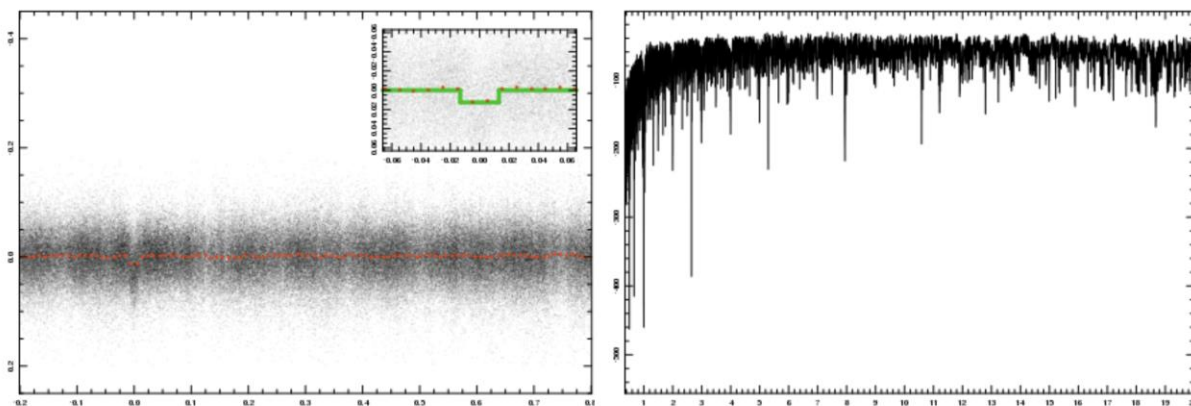
[NG0532-3633.4.021651](#)

[\(NG0532-](#)

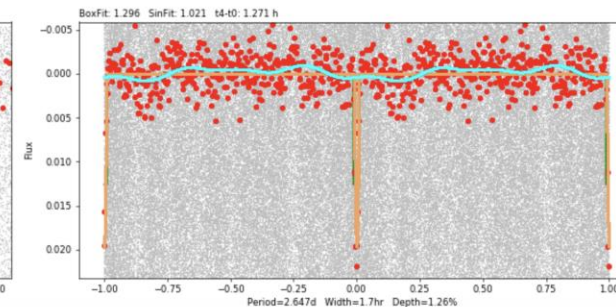
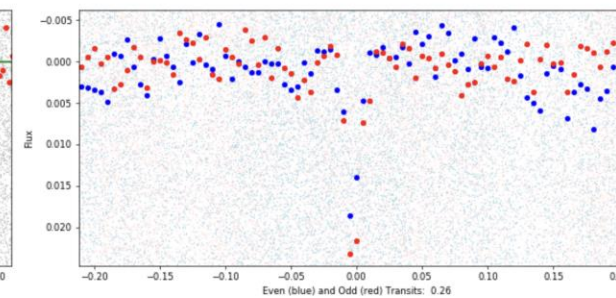
[3633.809.2016,2016S,2016S2,2016S3.CYCLE1807_DC](#)

[NG0532-3633.4.021651](#)

[\(NG0532-](#)



Odd even transits



OPIS pages:

- Periodograms
- Zoom of eclipse
- Lightcuves
- Phase folded on candidate periods
- Centroiding

Planet Hunters NGTS

Discover hidden worlds with the
Next-Generation Transit Survey

[Learn more](#)



Launched 19 Oct 2021

ZOONIVERSE

Citizen Science

I have always wanted to do scientific research but earning a living was always the top priority. With citizen science I can contribute to scientific research without neglecting my career

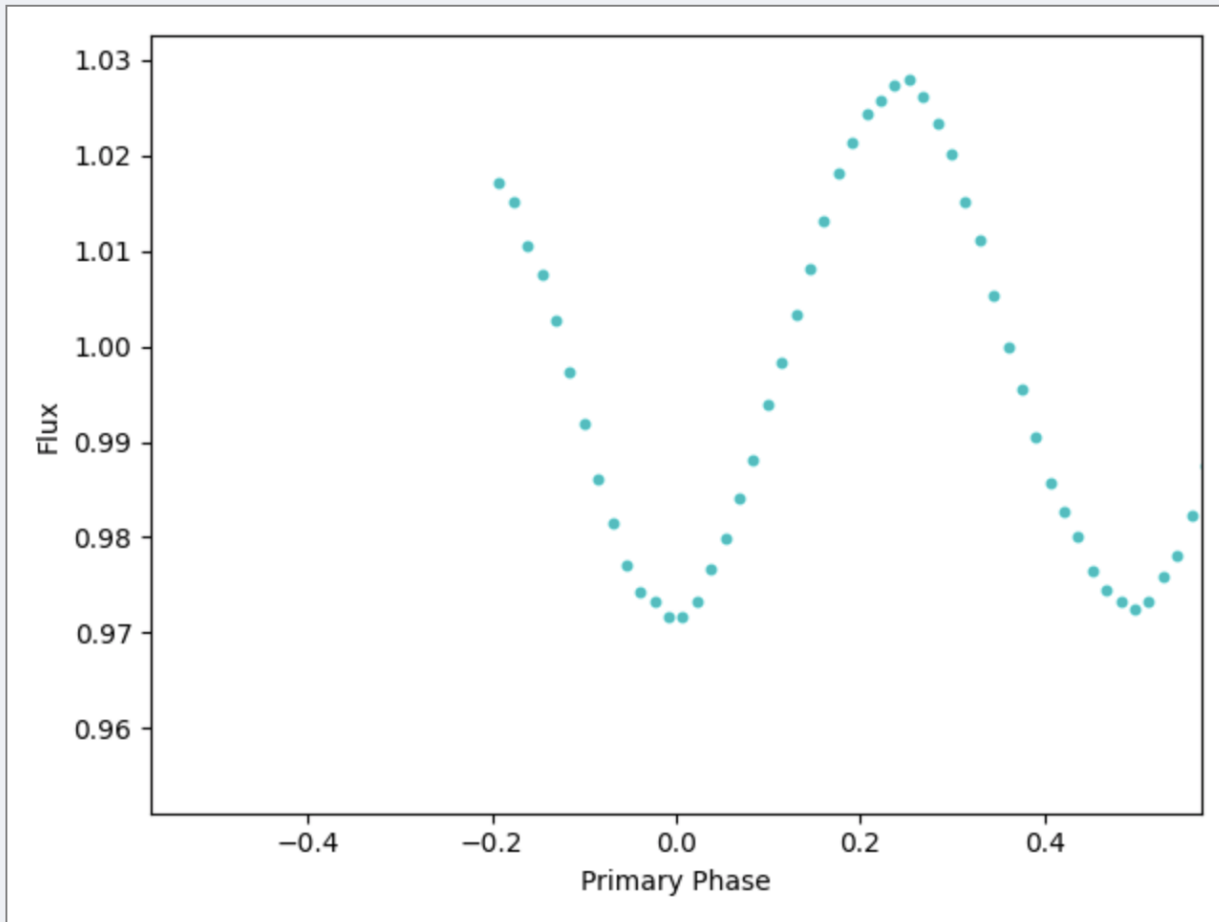
Citizen science is perfect for me because I can do something meaningful and something I'm passionate about. I can do it however I feel. I can work 15 min/month or 20 hrs/ day depending on my mood.
Citizen science allows me to be vulnerable and at the same time it encourages me to learn.


To satisfy my scientific curiosity!
Citizen science gives me the opportunity to be involved in science without having to put other parts of my life on hold.

I'd always had an interest in space, so I decided to give some space-related projects a try. I went in with low expectations, just wanting to help out in some small way. Since then, I have discovered or co-discovered planets around distant stars, supernovae, galaxies lighting up dust clouds in vibrant colours, and over 100 substellar objects called Brown Dwarfs; all from the comfort of my own home. There's a certain allure to being the first human to see an object in space.

ZOONIVERSE

Workflow



 You should sign in!

TASK

TUTORIAL

Exoplanet Transit Search

Look at folded light curve. What do you see?

(Select all that apply)

A U-shaped or box-shaped dip in the middle

A V-shaped dip in the middle

No significant dip in the middle

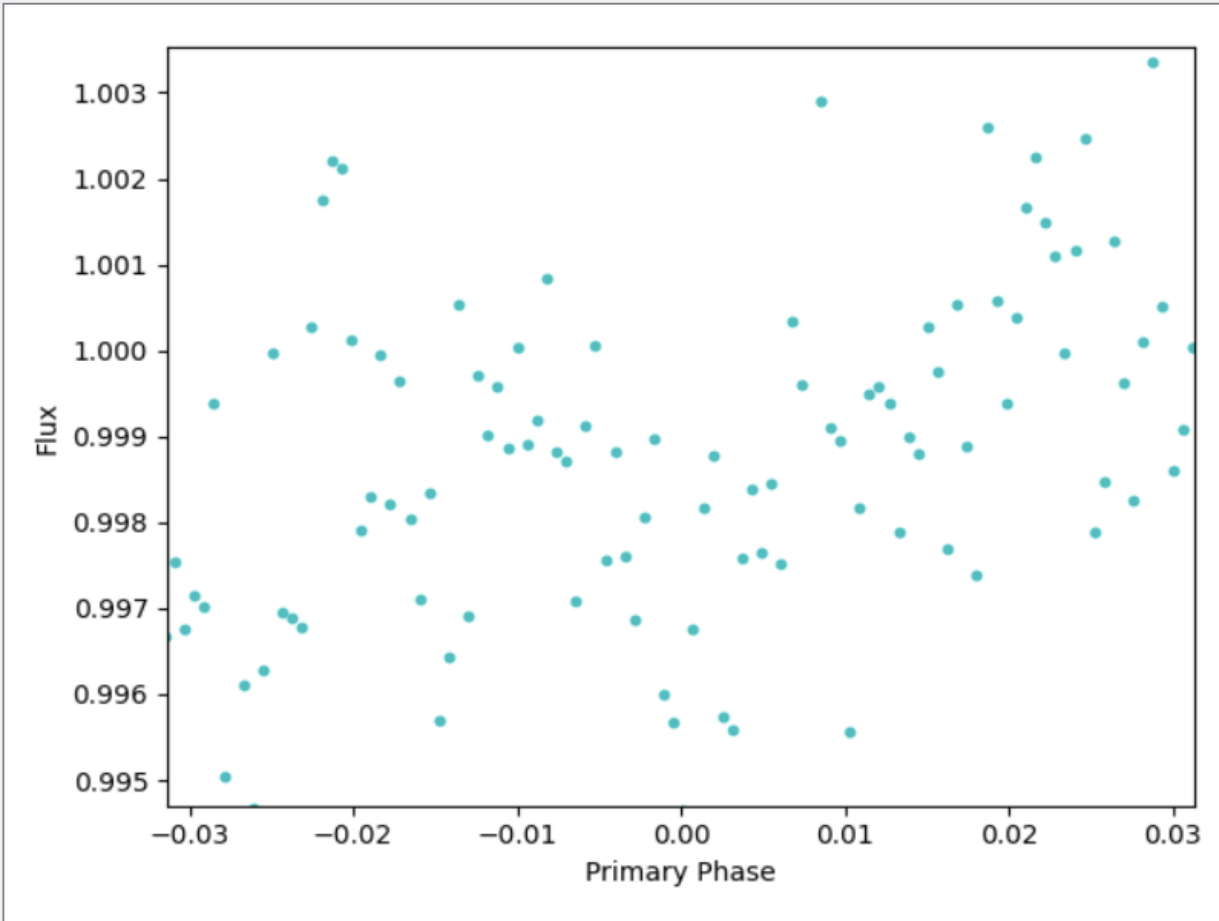
Stellar variability


A large data gap near the middle

NEED SOME HELP WITH THIS TASK?

Done & Talk

Done



 You should sign in!

TASK

TUTORIAL

Exoplanet Transit Search

Look at folded light curve. What do you see?

(Select all that apply)

A U-shaped or box-shaped dip in the middle

A V-shaped dip in the middle

No significant dip in the middle

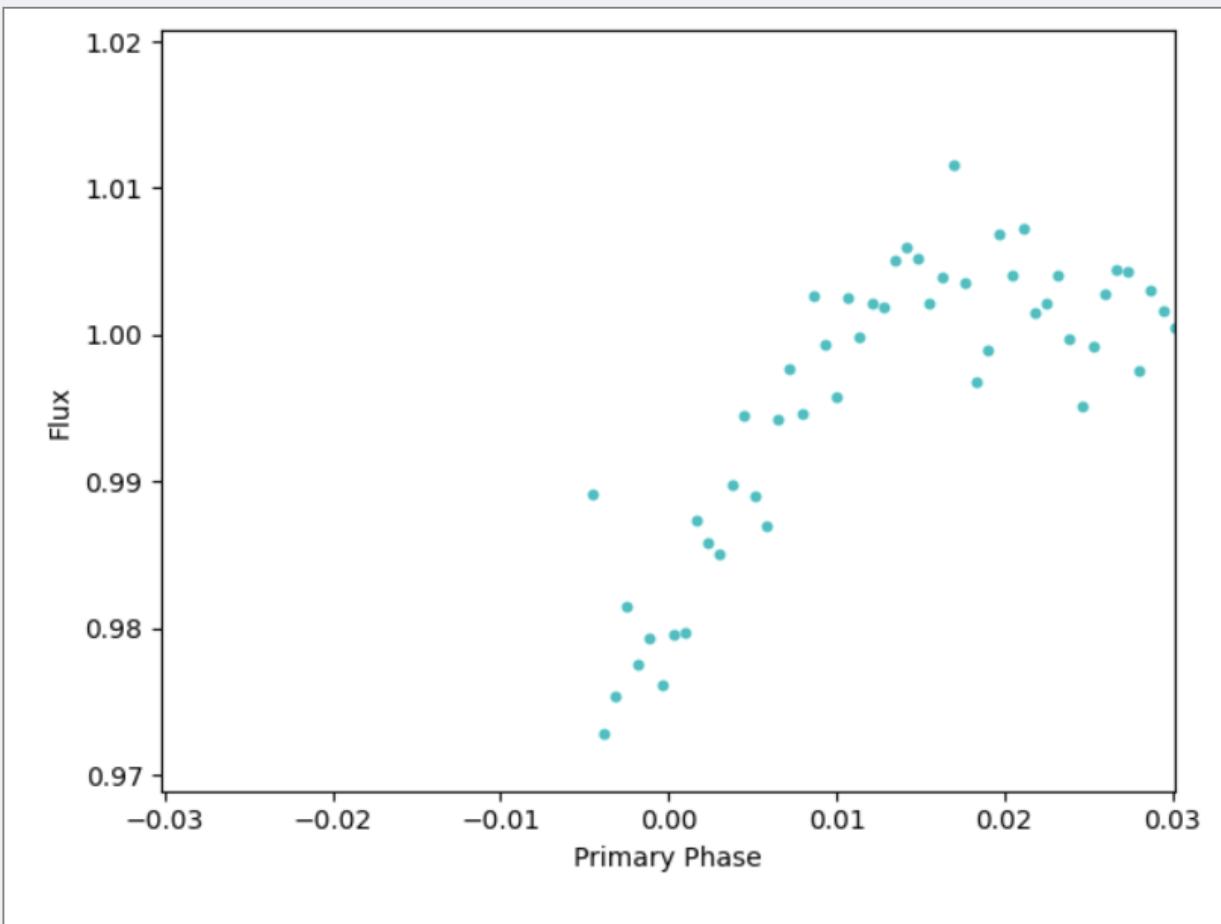
Stellar variability


A large data gap near the middle

NEED SOME HELP WITH THIS TASK?

Done & Talk

Done



 You should sign in!

TASK

TUTORIAL

Exoplanet Transit Search

Look at folded light curve. What do you see?

(Select all that apply)

A U-shaped or box-shaped dip in the middle

A V-shaped dip in the middle

No significant dip in the middle

Stellar variability

A large data gap near the middle

NEED SOME HELP WITH THIS TASK?

Done & Talk

Done

Workflow

Exoplanet Transit Search



Exoplanet Transit Search
Look at folded light curve. What do you see?
(Select all that apply)

- A U-shaped or box-shaped dip in the middle
- A V-shaped dip in the middle
- No significant dip in the middle
- Stellar variability
- A large data gap near the middle

NEED SOME HELP WITH THIS TASK?

Secondary Eclipse Check
Look at the middle of the folded light curve. What do you see? There is: (Choose the best category that applies)

- A secondary eclipse
- No secondary eclipse
- A large data gap

NEED SOME HELP WITH THIS TASK?

Secondary Eclipse Check

Odd Even Transit Check
Compare the odd (green points) and even (magenta points) transits. Do the transits have similar depths?

- Yes
- No

NEED SOME HELP WITH THIS TASK?

Odd Even Transit Check

Workflow

Exoplanet Transit Search

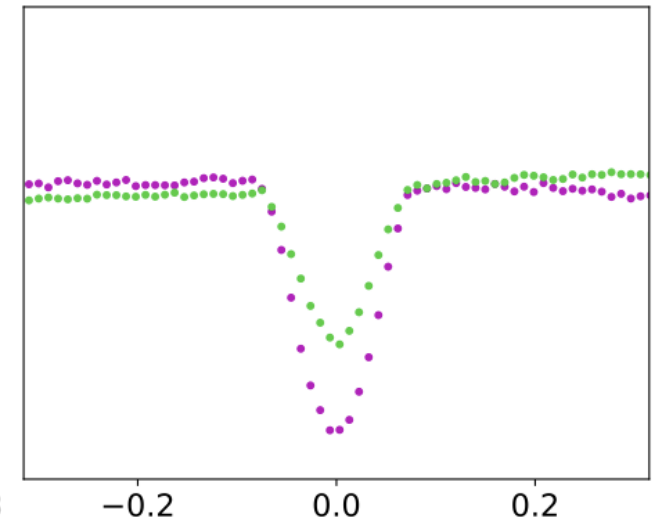
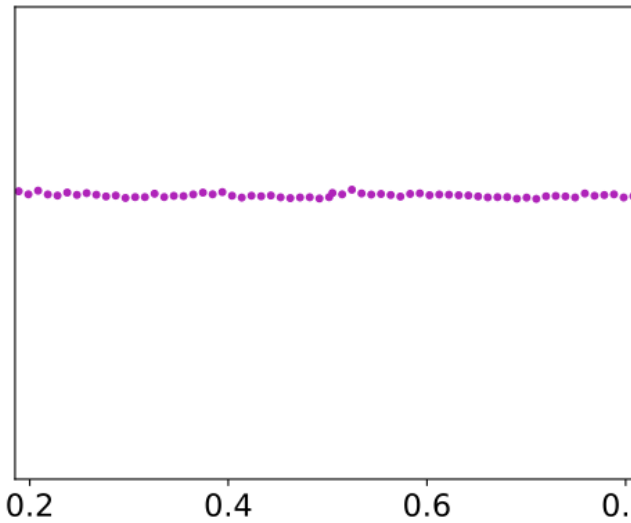
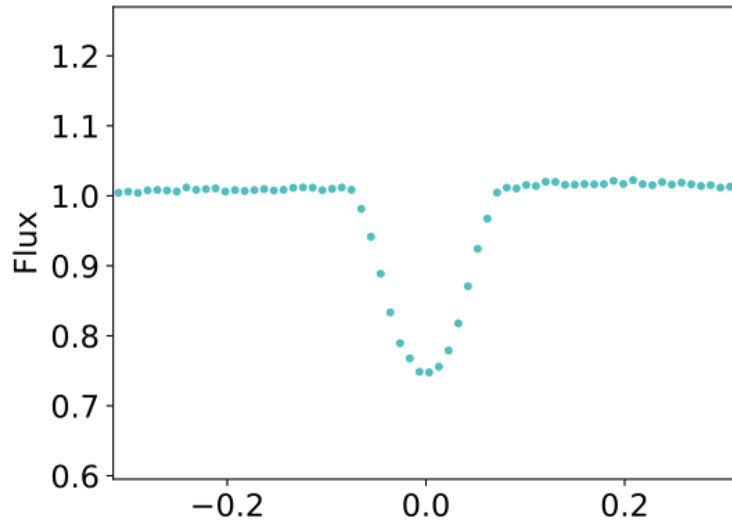


Primary Phase

Secondary Phase

Primary Phase

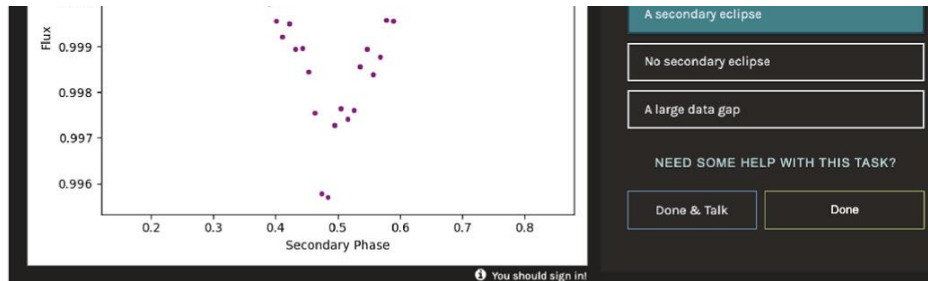
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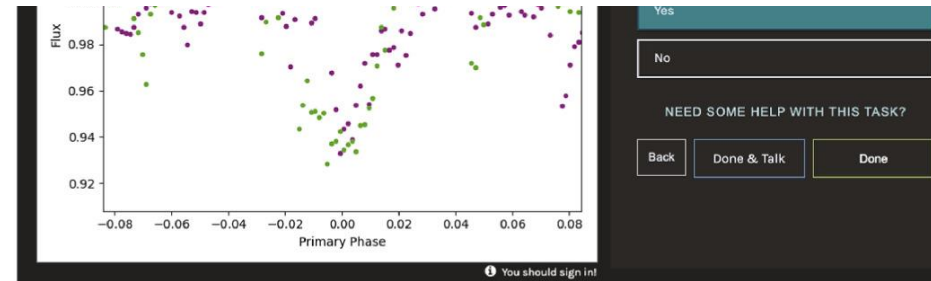
Primary Phase

Secondary Phase

Primary Phase



Secondary Eclipse Check



Odd Even Transit Check

Oct-18-2021

Launch Date

14,518

Registered Volunteers

5,713

Classifications Yesterday

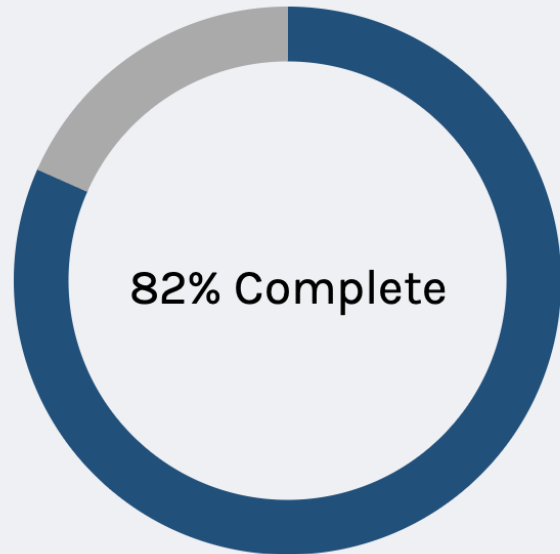
Live Workflows

Exoplanet Transit Search

Retirement limit: 20

Images retired: 199,566 / 244,234

ETC* 109 days



Odd Even Transit Check

Retirement limit: 15

Images retired: 26,584 / 26,584

ETC* 0 days

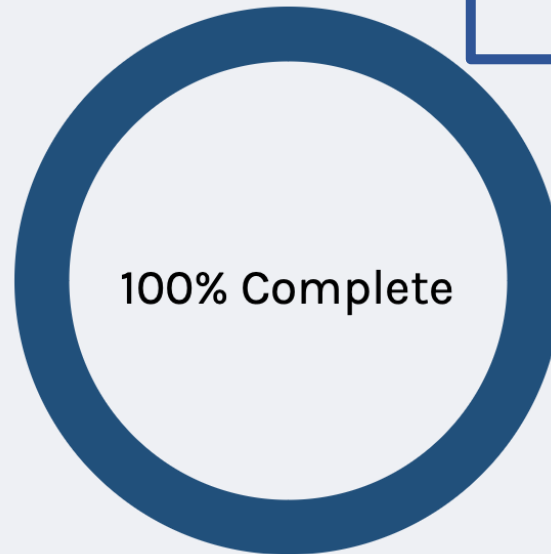


Secondary Eclipse Check

Retirement limit: 15

Images retired: 26,584 / 26,584

ETC* 0 days



2,626,380 classifications
87.9% classifications by 8559 people
85,000 stars
Median per user 40
Mean per user 268
74% success for known planets

*Estimated time to completion is based on the classification rate for the past 14 days and may be incorrect due to the way we currently report the data, or unavailable for some workflows.

What did we find?

105,534 to 5 candidates!

All hot Jupiters

Periods 1.7 -9.9 days

Variety of host stars

M dwarf ($0.33 M_{\text{sun}}$) – lowest mass M dwarf to host a giant planet if confirmed

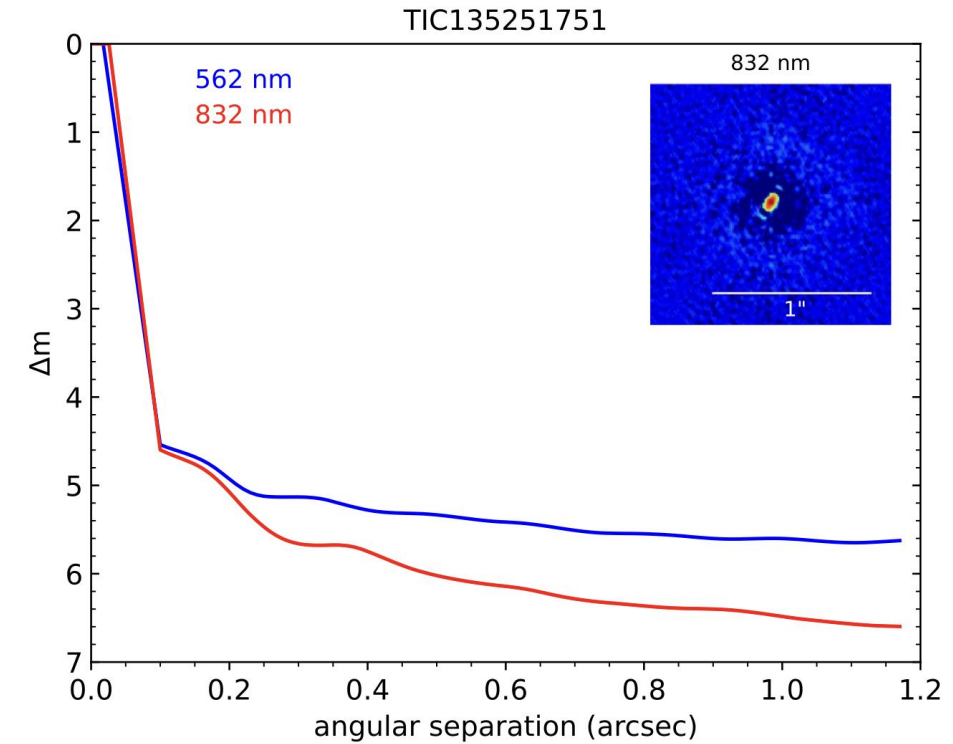
F1+F4 binary + Hot Jupiter ($\sim 3 M_{\text{Jup}}$)– S-type system?

K/M dwarf+ $9 M_{\text{Jup}}$ (max mass)

K dwarf + Hot Jupiter

G dwarf+ Hot Jupiter

O'Brien et al., 2024

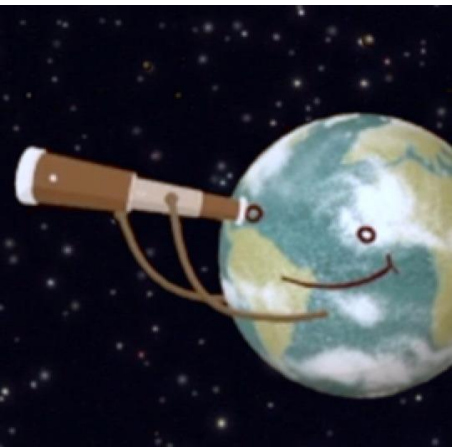


Search the realm beyond Neptune
for new brown dwarfs and planets.

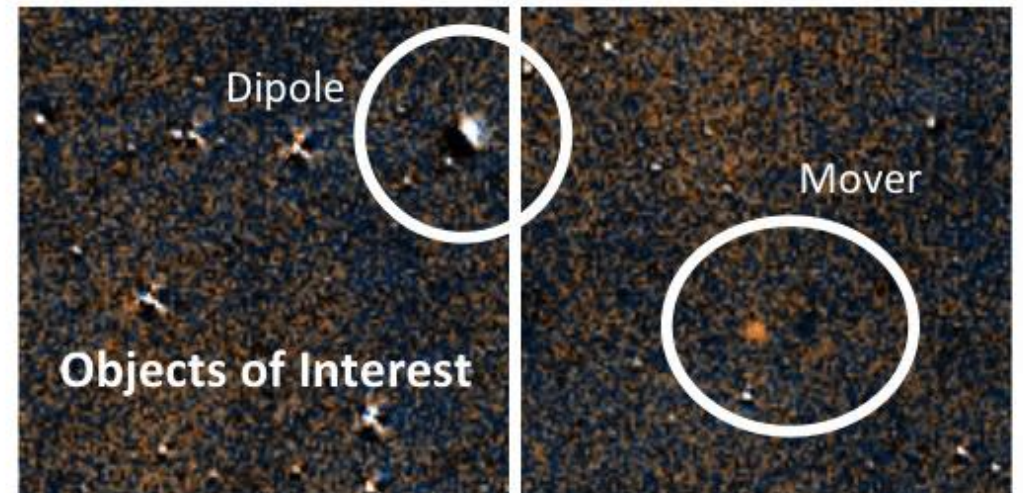
Learn more

Get started

Backyard Worlds



- Very different workflow
- Identify moving objects
- Blinking images
- Very active community
- Citizen scientists leading science!



Discovery of the Remarkably Red L/T Transition Object VHS J183135.58-551355.9

THOMAS P. BICKLE¹, ADAM C. SCHNEIDER², JONATHAN GAGNÉ^{3,4}, JACQUELINE K. FAHERTY⁵,
AUSTIN ROTHERMICH⁵, JOHANNA M. VOS^{6,5}, GENARO SUÁREZ⁵, J. DAVY KIRKPATRICK⁷, AARON M. MEISNER⁸,
MARC J. KUCHNER⁹, ADAM J. BURGASSER¹⁰, FEDERICO MAROCCO⁷, SARAH L. CASEWELL¹¹, DAN CASELDEN⁵,
DANIELLA C. BARDALEZ GAGLIUFFI¹² AND THE BACKYARD WORLDS: PLANET 9 COLLABORATION

¹School of Physical Sciences, The Open University, Milton Keynes, MK7 6AA, UK

²United States Naval Observatory, Flagstaff Station, 10391 West Naval Observatory Rd., Flagstaff, AZ 86005

³Planétarium Rio Tinto Alcan, Espace pour la Vie, 4801 av. Pierre-de Coubertin, Montréal, Qc

⁴Institute for Research on Exoplanets, Université de Montréal, Département de Physique, C.P. 6128 S.

⁵Department of Astrophysics, American Museum of Natural History, C

⁶School of Physics, Trinity College Dublin, The U.

⁷IPAC, Mail Code 100-22, Caltech, 1200 E. Califor.

⁸NSF's National Optical-Infrared Astronomy Research Laborato

⁹Exoplanets and Stellar Astrophysics Laboratory, NASA Goddard Space Fligh

¹⁰Department of Astronomy & Astrophysics, University of Calif.

¹¹School of Physics and Astronomy, University of Lei

¹²Department of Physics & Astronomy, Amherst College, 25 L

THE ASTROPHYSICAL JOURNAL, 923:48 (15pp), 2021 December 10
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A Wide Planetary Mass Companion Discovered through the Citizen Science Project Backyard Worlds: Planet 9

Jacqueline K. Faherty¹, Jonathan Gagné^{2,3}, Mark Popinchalk^{1,4,5}, Johanna M. Vos¹, Adam J. Burgasser⁶,
Schümann⁷, Adam C. Schneider^{8,9}, J. Davy Kirkpatrick¹⁰, Aaron M. Meisner¹¹, Marc J. Kuchner¹²,
Gagliuffi¹, Federico Marocco¹⁰, Dan Caselden¹³, Eileen C. Gonzales^{14,19}, Austin Rothermich¹,
Debes¹⁶, Christian Aganze⁶, Andrew Ayala¹, Chih-Chun Hsu^{6,20}, William J. Cooper^{17,18},
Roman Gerasimov⁶, and Christopher A. Theissen^{6,20}
Backyard Worlds: Planet 9 Collaboration

The Enigmatic Brown Dwarf WISEA J153429.75-104303.3 (a.k.a. “The Accident”)

J. Davy Kirkpatrick¹, Federico Marocco¹, Dan Caselden², Aaron M. Meisner³, Jacqueline K. Faherty⁴,
Adam C. Schneider^{5,6}, Marc J. Kuchner⁷, S. L. Casewell⁸, Christopher R. Gelino¹, Michael C. Cushing⁹,
Peter R. Eisenhardt¹, Edward L. Wright¹¹, and Steven D. Schurr¹

¹IPAC, Mail Code 100-22, Caltech, 1200 E. California Boulevard, Pasadena, CA 91125, USA; davy@ipac.caltech.edu

²Gigamon Applied Threat Research, 619 Western Avenue, Suite 200, Seattle, WA 98104, USA

³NSF's National Optical-Infrared Astronomy Research Laboratory, 950 N. Cherry Avenue, Tucson, AZ 85719, USA

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⁵US Naval Observatory, Flagstaff Station, P.O. Box 1149, Flagstaff, AZ 86002, USA

⁶Department of Physics and Astronomy, George Mason University, MS3F3, 4400 University Drive, Fairfax, VA 22030, USA

⁷NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, Code 667, Greenbelt, MD 20771, USA

THE ASTRONOMICAL JOURNAL, 163:116 (11pp), 2022 March

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OPEN ACCESS

Discovery of 16 New Members of the Solar Neighborhood Using Proper Motions from CatWISE2020

Tarun Kota¹, J. Davy Kirkpatrick², Dan Caselden³, Federico Marocco², Adam C. Schneider^{4,5}, Jonathan Gagné^{6,7},
Jacqueline K. Faherty³, Aaron M. Meisner⁸, Marc J. Kuchner⁹, Sarah Casewell¹⁰, Kanishk Kacholia¹¹,
Tom Bickle^{12,13}, Paul Beaulieu¹², Guillaume Colin¹², Leslie K. Hamlet¹², Jörg Schümann¹², and Christopher Tanner¹²

<https://doi.org/10.3847/1538-3881/ac4713>



RESEARCH NOTES OF THE AAS

ACCESS DJ220838.73+454434.04: a White Dwarf Companion in the AR Lacertae System

Thomas P. Bickle¹, Peter A. Jalowiczor², Sarah L. Casewell³, Jacqueline K. Faherty⁴,
Rocio Kiman⁵, Adam C. Schneider^{6,7}, J. Davy Kirkpatrick⁸, Aaron M. Meisner⁹,
Marc J. Kuchner¹⁰, Dan Caselden⁴
Published June 2022 · © 2022. The Author(s). Published by the American Astronomical Society.
[Research Notes of the AAS, Volume 6, Number 6](#)
Citation: Thomas P. Bickle et al 2022 Res. Notes AAS 6 127
DOI: 10.3847/2515-5172/ac780a

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⁵Department of Astrophysics, American Museum of Natural History, Central Park West, New York, NY

⁶School of Physics, Trinity College Dublin, The University of Dublin, Dublin 2, Ireland

⁷IPAC, Mail Code 100-22, Caltech, 1200 E. California Ave., Pasadena, CA 91125, USA

⁸NSF's National Optical-Infrared Astronomy Research Laboratory, Flagstaff, AZ 86005, USA

⁹Exoplanets and Stellar Astrophysics Laboratory, Bhatnagar Road, Sector 13, Chandigarh, India

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THE ASTROPHYSICAL JOURNAL, 923:48 (15pp), 2021 December 10
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34 papers (23 refereed+11 Research notes)
Over 400 published BDs
Publications led by grad students -- 2
Publications led by undergrads -- 9
Publications led by high school students -- 2
Publications led by citizen scientists -- 7

The Enigmatic Brown Dwarf

J. Davy Kirkpatrick¹, Federico Marocco², Adam C. Schneider^{5,6}, Marc J. Kuchner⁹, Peter R. Eisenhauer³

¹IPAC, Mail Code 100-22, Caltech, Pasadena, CA 91125, USA

²Gigamon Applied Technologies, Inc., 10000 E. Harvard Ave., Denver, CO 80231, USA

³NSF's National Optical-Infrared Astronomy Research Laboratory, Flagstaff, AZ 86005, USA

⁴Department of Astrophysics, American Museum of Natural History, Central Park West, New York, NY 10024, USA

⁵US Naval Observatory, 3450 Massachusetts Ave., Washington, DC 20391, USA

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<https://doi.org/10.3847/1538-4357/ac2499>



Secondary Mass Companion Discovered through the Citizen Science Project
Backyard Worlds: Planet 9

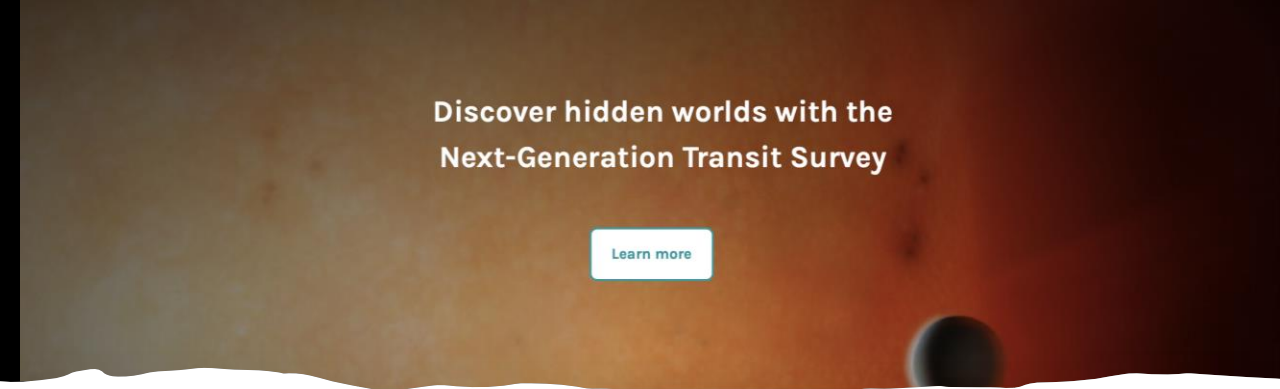
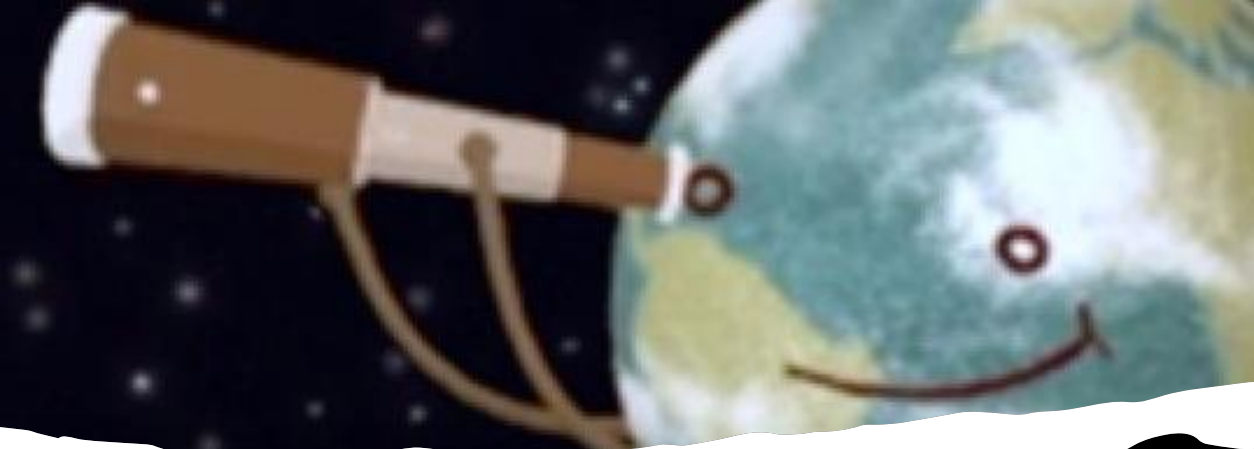
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Collaboration

NOTES OF THE AAS

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Published June 2022. © 2022. The Author(s). Published by the American Astronomical Society.
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Citation Thomas P. Bickle et al 2022 Res. Notes AAS 6 127
DOI 10.3847/2515-5172/ac780a

<https://doi.org/10.3847/1538-3881/ac4713>





Any questions???

ZOO NIVERSE



NGTS: Next-generation transit survey

How to get involved?



Contact Peter Wheatley
P.J.Wheatley@warwick.ac.uk



- Twelve telescopes at ESO Paranal
 - Optimized for exoplanet transits
 - Same precision as TESS
- Science
 - Long-period transiting planets
 - Young planets
 - Photometric support for VLT, JWST etc
 - Anything else you are interested in!
(brown dwarfs, binaries, white dwarfs, stellar flares, supernovae...)