Detecting Other Worlds with a Backyard Telescope!

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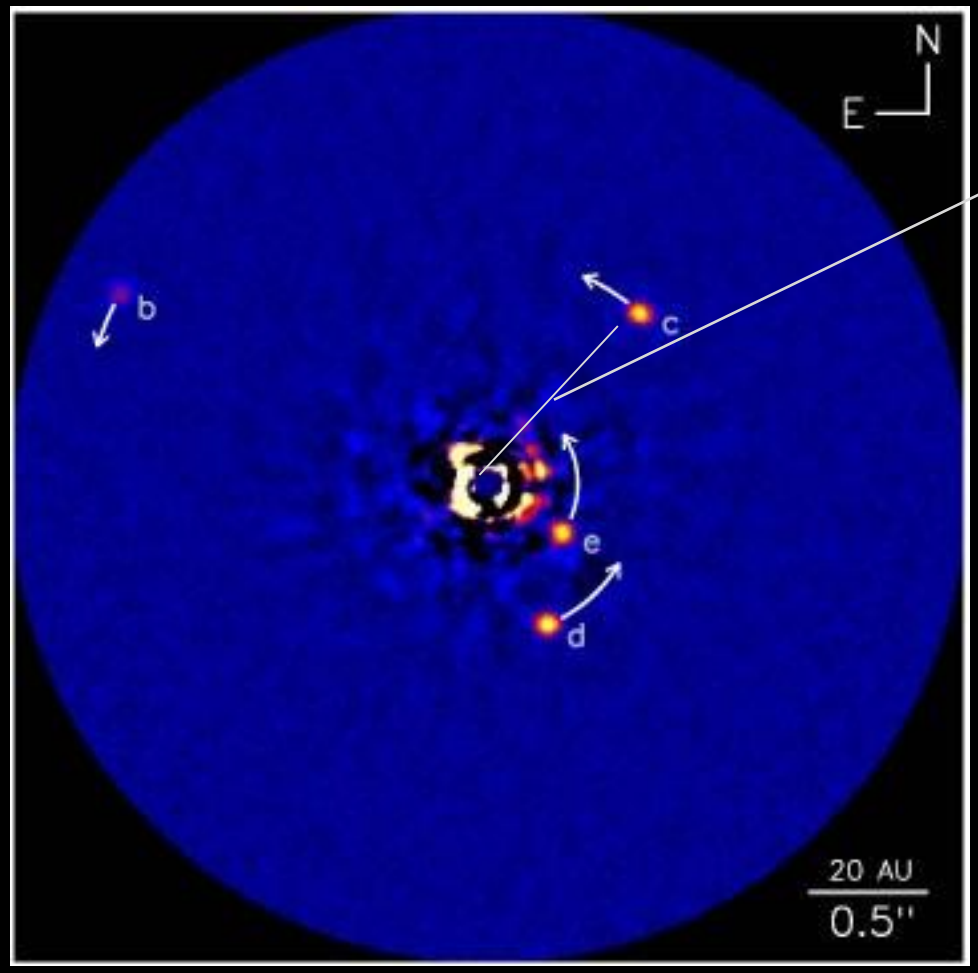
The Night Sky

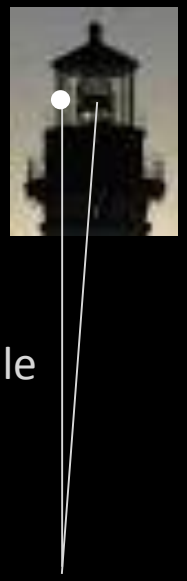
Q: Which stars have one or more planets (exoplanets) around them?

A: Most of them!

HR 8799

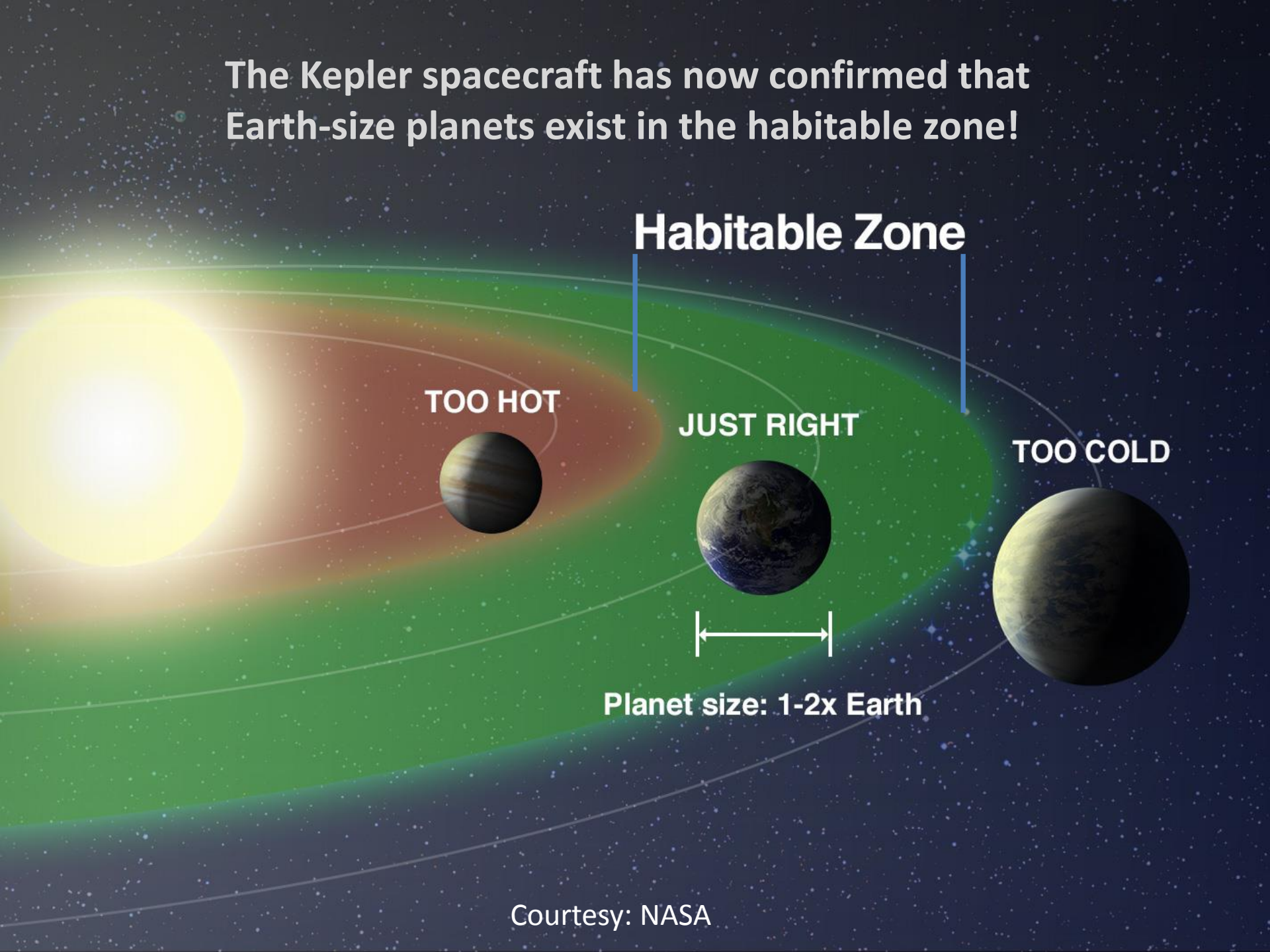


Equivalent to seeing the reflected light of a baseball that is ¼” from a lighthouse
1 mile away:



Courtesy: Keck Observatory

The Kepler spacecraft has now confirmed that Earth-size planets exist in the habitable zone!



Courtesy: NASA

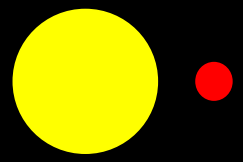
What is Driving Us?

- How do planets form?
- How was our solar system formed?

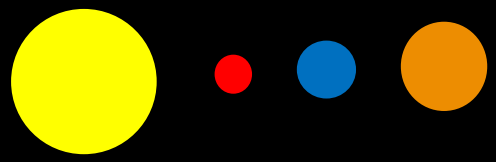
The ultimate goal:
detect signs of any kind of life from
a planet in the habitable zone

The Strange World of “Other Worlds”

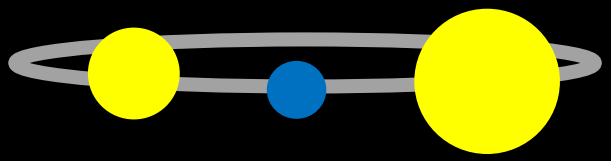
- Most exoplanets we have discovered are close-in, large planets: “Hot Jupiters”



- Some stars have multiple planets

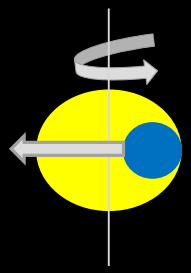


- Some planets orbit multiple stars

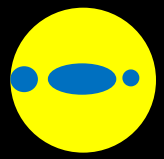


- Some “planets” are free-floating

- Some planets’ orbits are opposite from their star’s rotation



- Some planetesimals are disintegrating around their host star



By the Numbers

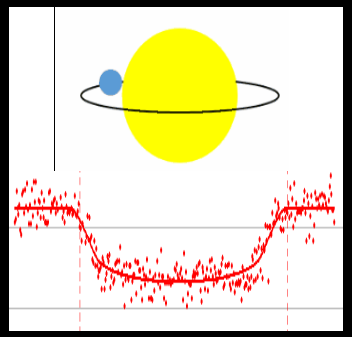
- 3,388 confirmed exoplanets
- 2,416 unconfirmed candidates
- 297 candidates in the habitable zone

The Challenge

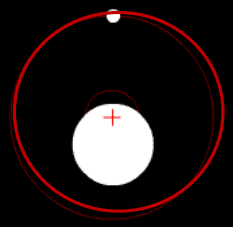
- How to detect a planet from its host star
- Similar to detecting the light reflecting off a baseball next to a lighthouse!

Exoplanet Detection Methods

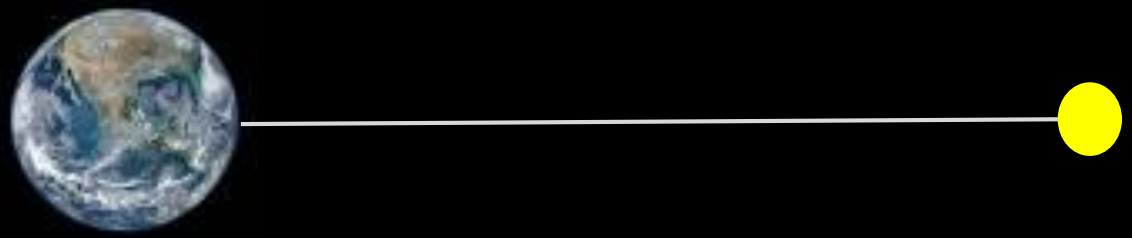
- Transit Method:
  - the dominant method used by amateur astronomers



- Radial Velocity Method



- Microlensing



- Direct Imaging

Exoplanet Detection Methods

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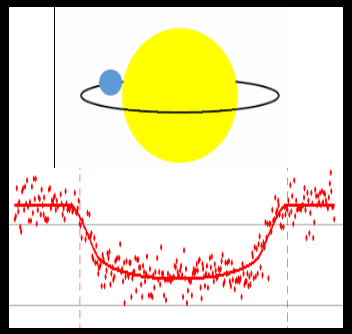

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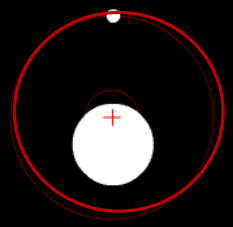
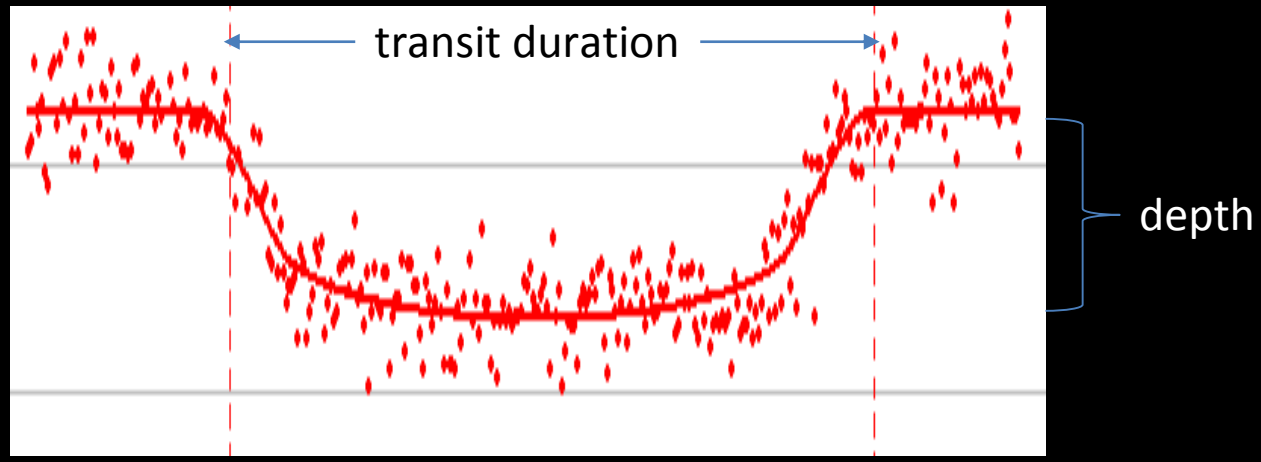


- Microlensing

- Direct Imaging

The Light Curve



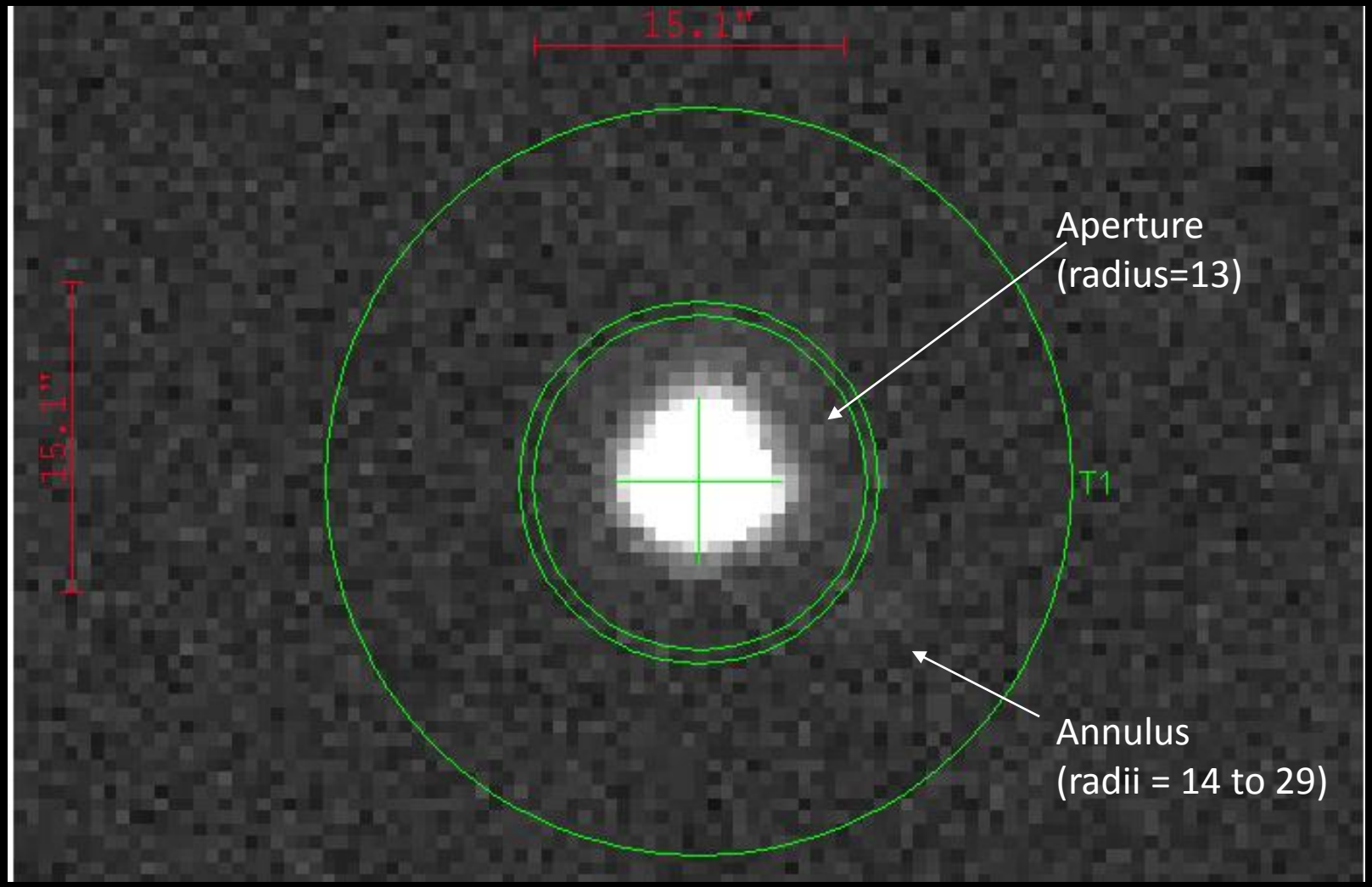
We can learn a lot just from the light curve!

- How big the planet is
- How far it is from its host star
- How inclined is its orbit from our line-of-sight
- Whether it is truly a planet or another star

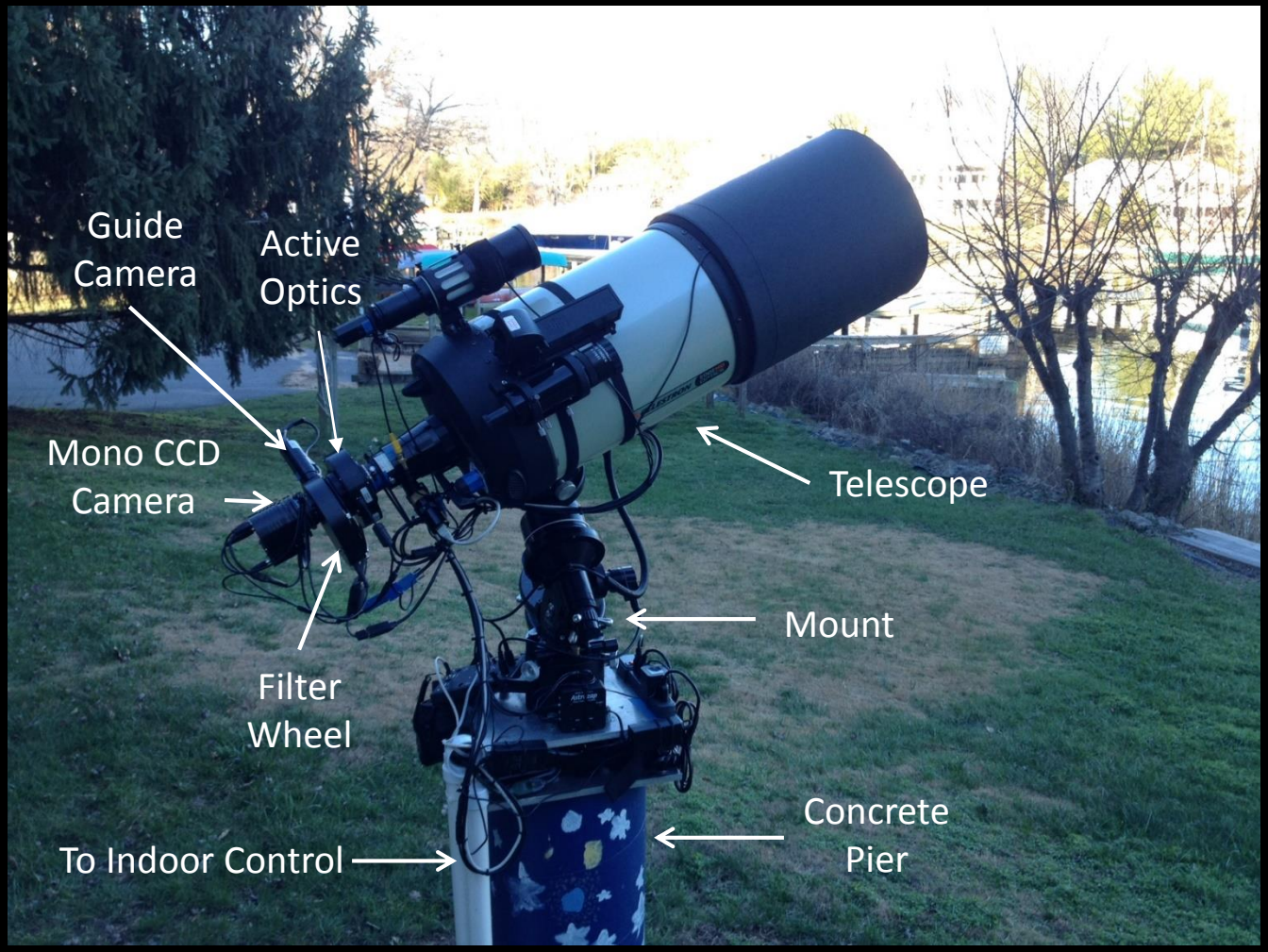
How do Amateur Astronomers Create Light Curves?

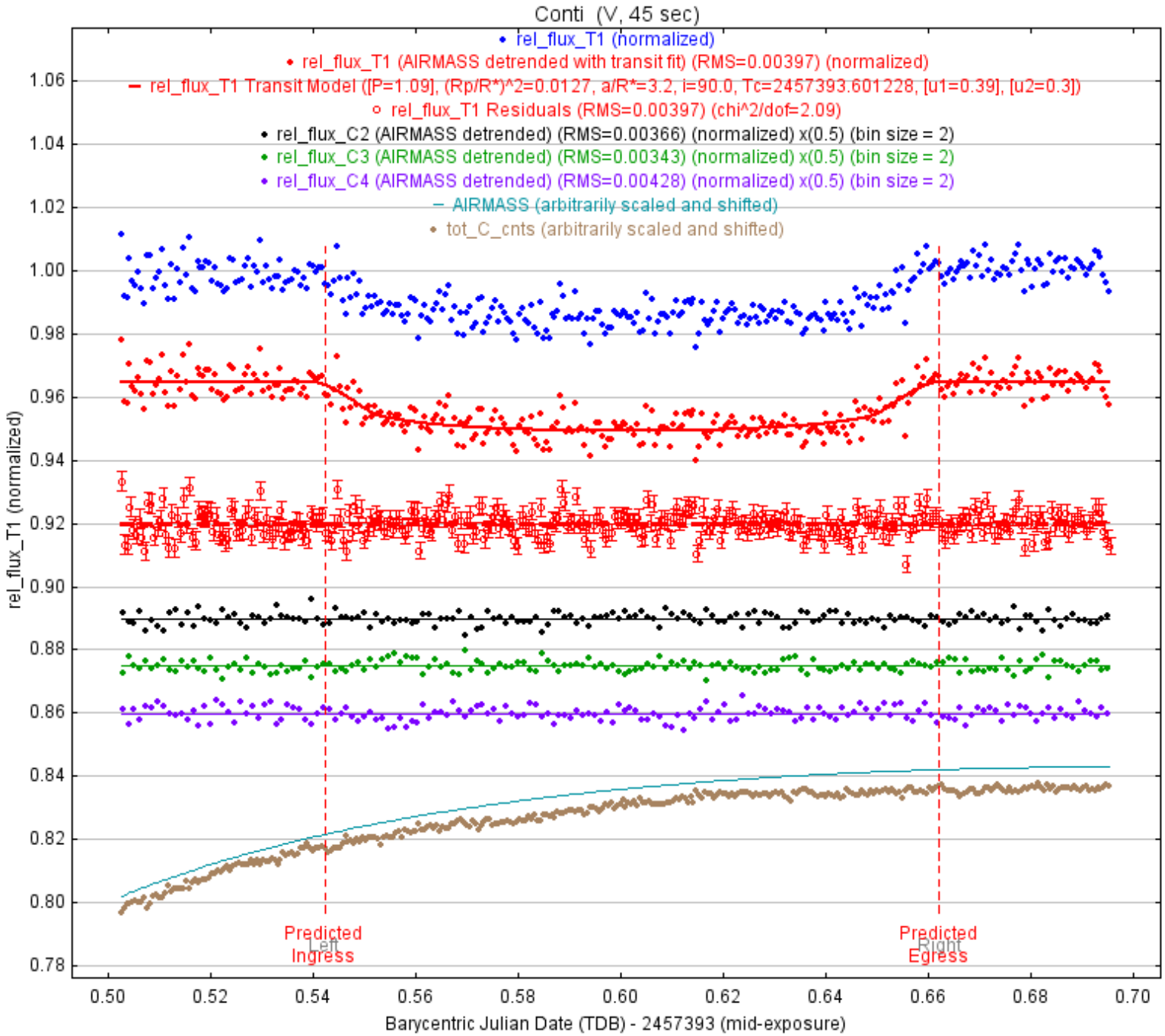
- Compare the relative change in light between the host star and multiple comparison stars
- Use same equipment as for deep sky imaging

The Key Tools of Differential Photometry: the Aperture and Annulus

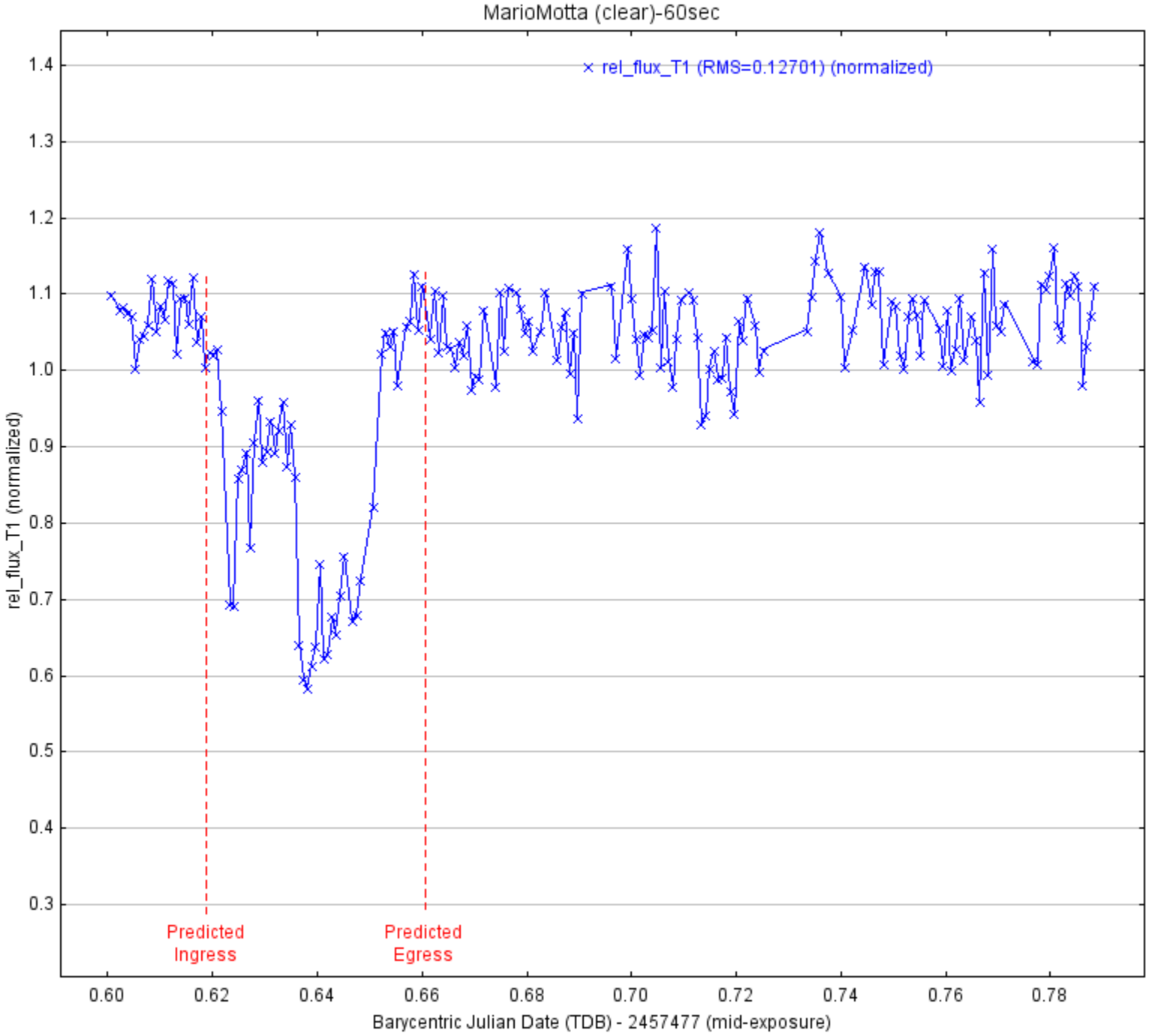


Typical Setup
Location: Suburban Annapolis, MD

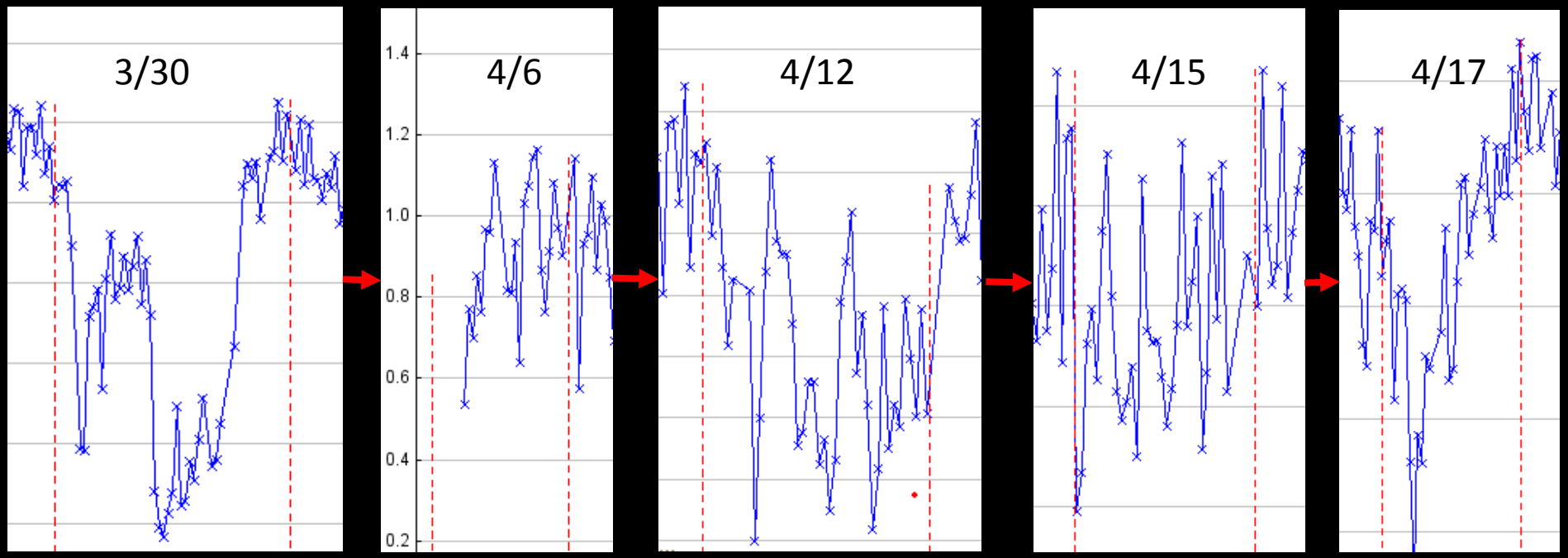



WASP-12b on UT2016-01-06
Conti (V, 45 sec)
rel_flux_T1 (normalized)
rel_flux_T1 (AIRMASS detrended with transit fit) (RMS=0.00397) (normalized)
rel_flux_T1 Transit Model ([P=1.09], (Rp/R*)^2=0.0127, a/R*=3.2, i=90.0, Tc=2457393.601228, [u1=0.39], [u2=0.3])
rel_flux_T1 Residuals (RMS=0.00397) (chi^2/dof=2.09)
rel_flux_C2 (AIRMASS detrended) (RMS=0.00366) (normalized) x(0.5) (bin size = 2)
rel_flux_C3 (AIRMASS detrended) (RMS=0.00343) (normalized) x(0.5) (bin size = 2)
rel_flux_C4 (AIRMASS detrended) (RMS=0.00428) (normalized) x(0.5) (bin size = 2)
AIRMASS (arbitrarily scaled and shifted)
tot_C_cnts (arbitrarily scaled and shifted)
rel_flux_T1 (normalized)
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
Predicted Left Ingress
Predicted Right Egress
0.50
0.52
0.54
0.56
0.58
0.60
0.62
0.64
0.66
0.68
0.70
Barycentric Julian Date (TDB) - 2457393 (mid-exposure)

A Disintegrating Planetesimal: WD1145 UT2016-03-30



WD-1145+017 Observations



Courtesy of Mario Motta

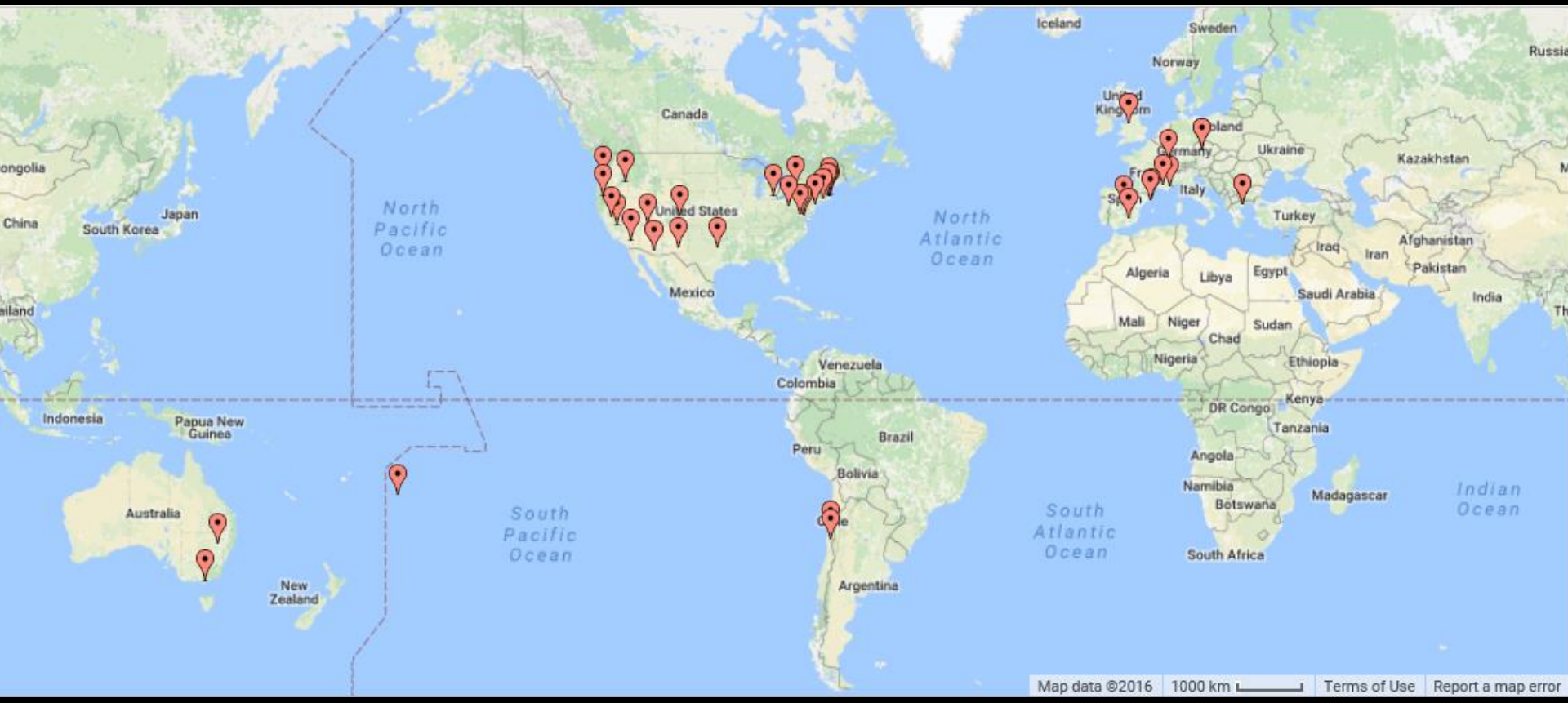
Exoplanet Observing vs. Deep Sky Imaging

- Exoplanet Observing is more demanding in many respects
- In many cases it is more forgiving
- And, it has its own unique rewards!

Amateur Astronomy Contributions To-Date

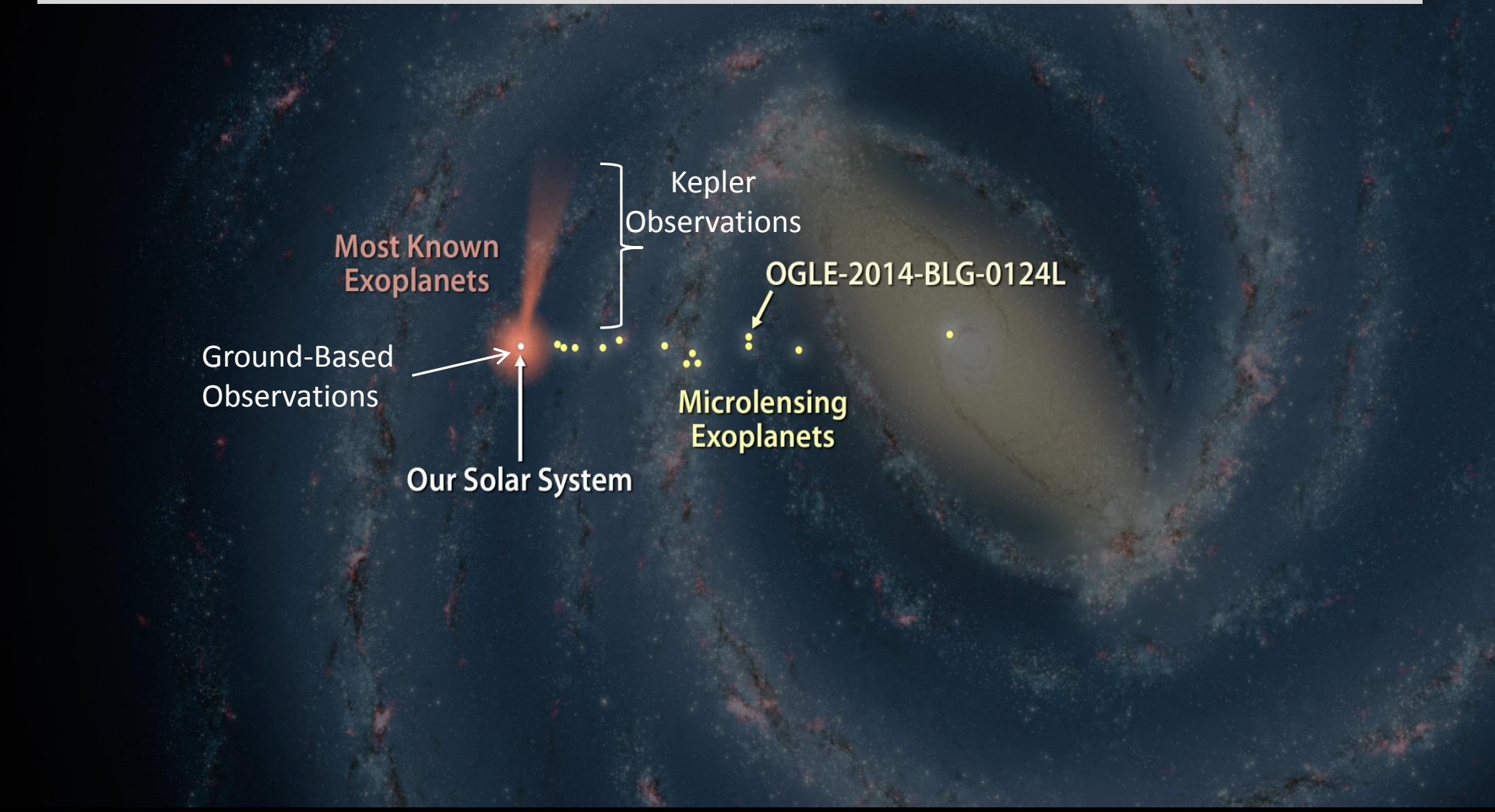
- Confirm new exoplanets – the KELT program
- Refine information about known exoplanets – the Hubble collaboration
- Help determine Transit Timing Variations – the ETD project
- Conduct private surveys

World-Wide Network of Observers

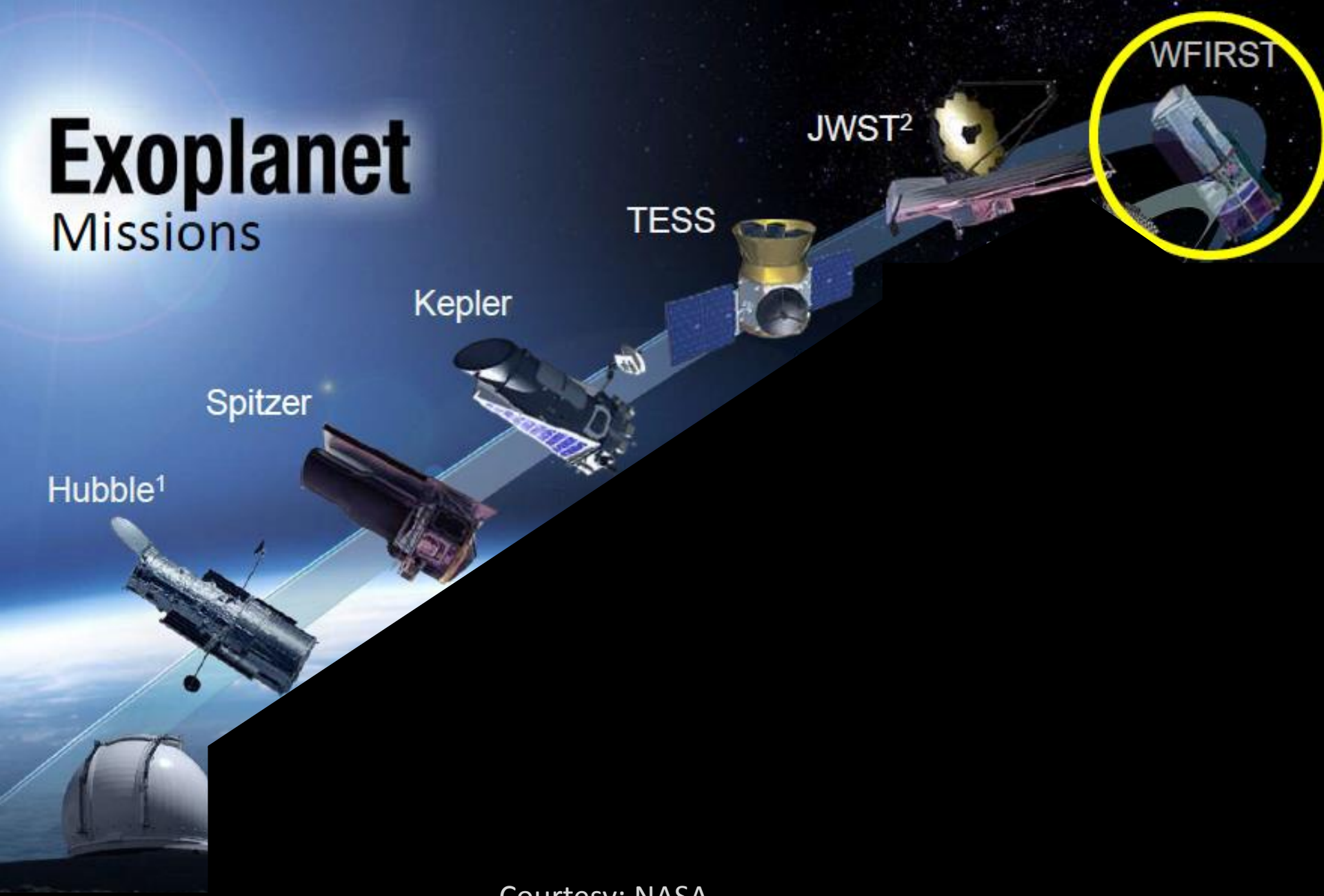


The Future

Until now, we are mostly looking in our immediate neighborhood!

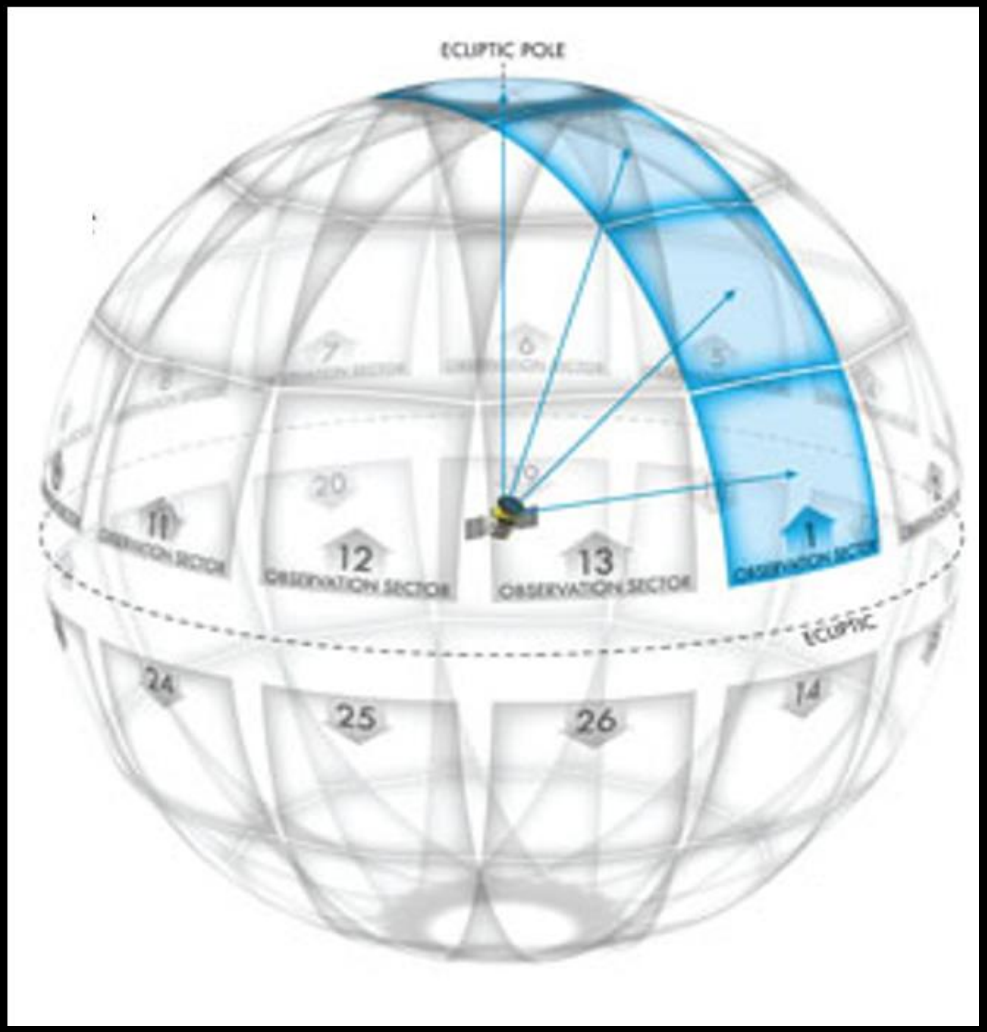


Courtesy NASA/JPL-Caltech

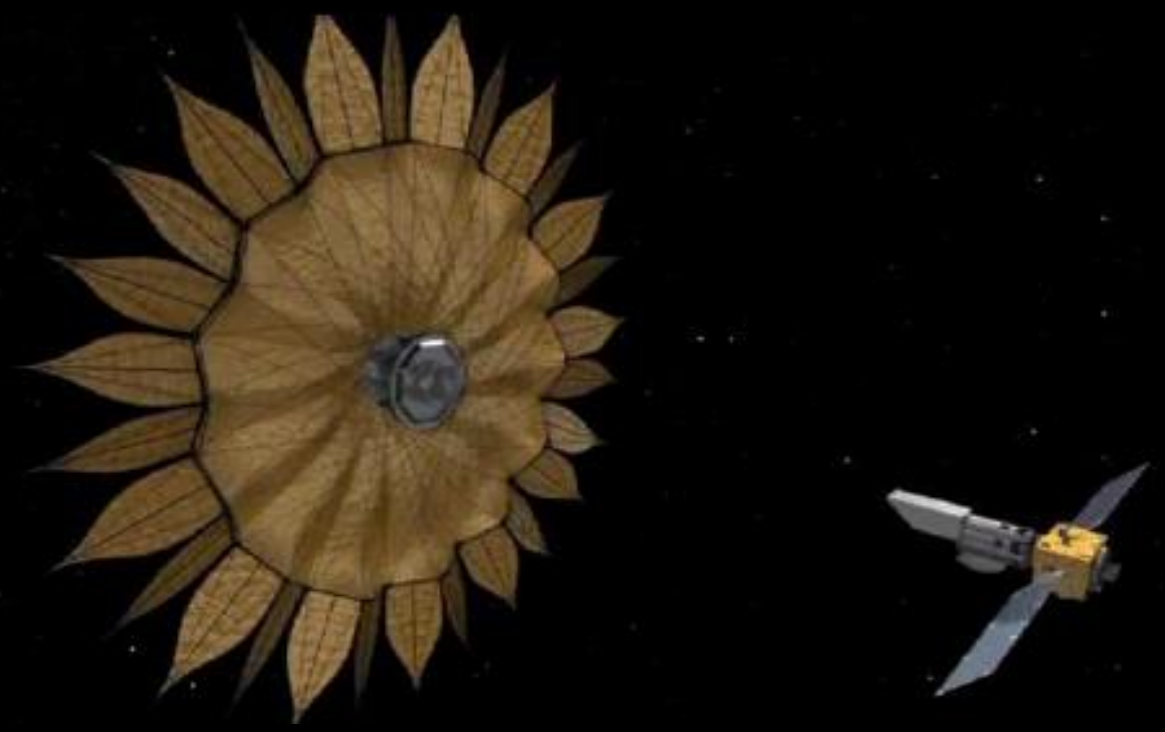


Courtesy: NASA

TESS Survey

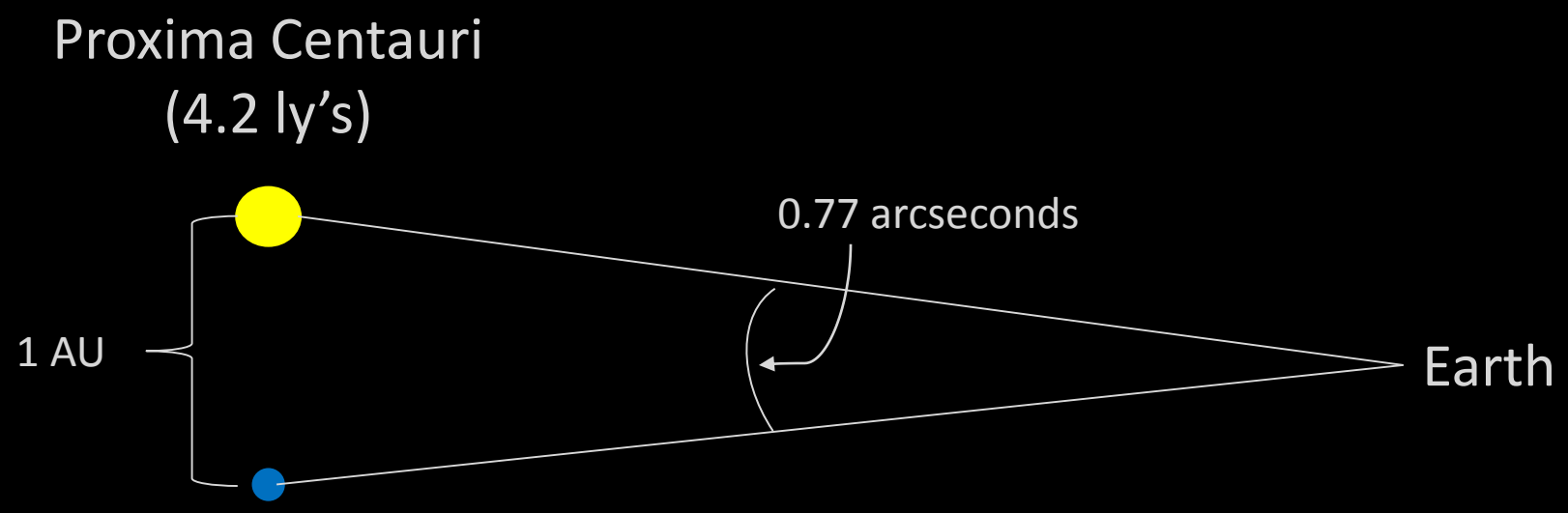

ECLIPTIC POLE
11
OBSERVATION SECTOR
20
12
OBSERVATION SECTOR
13
OBSERVATION SECTOR
1
ECLIPTIC
24
25
26
14

Starshade Technology

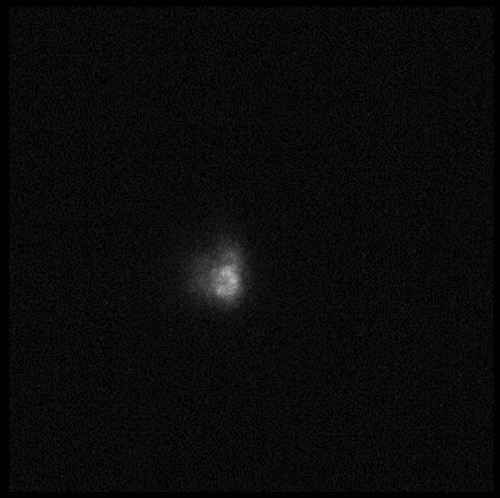


Courtesy: NASA

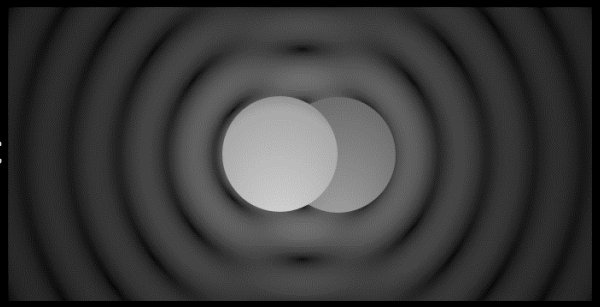
Will Amateur Astronomers be able to directly detect exoplanets?



Challenges



- <u>Seeing</u> limitations:
  atmospheric turbulence makes it difficult to differentiate both sources
  - (typical amateur astronomer seeing: 2-3 arcseconds)



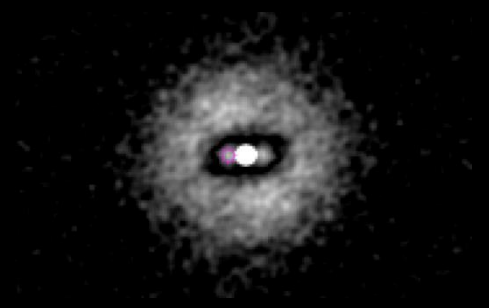
By Spencer Bliven - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=31456019

- <u>Diffraction</u> limitations:
  the wave nature of light produces an Airy disc pattern for both point sources
  - (Rayleigh criterion for a 14” aperture: 0.46 arcseconds)

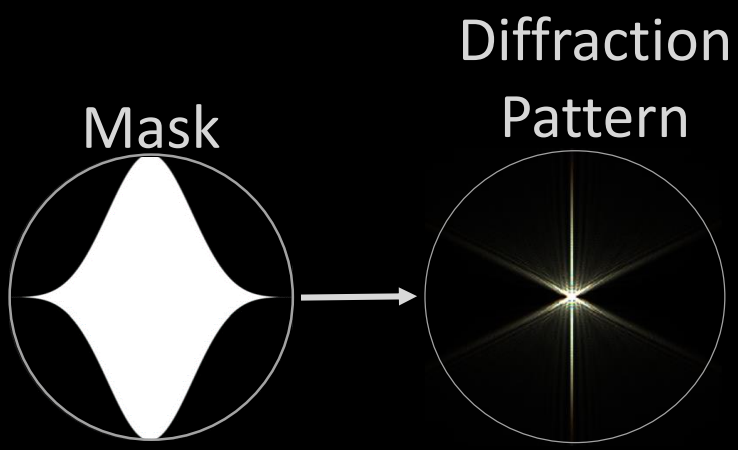
- <u>Differential magnitude</u> limitations:
  the extreme differences in magnitude between both objects makes it difficult to collect photons for the reflected light from the planet

Possible Solutions

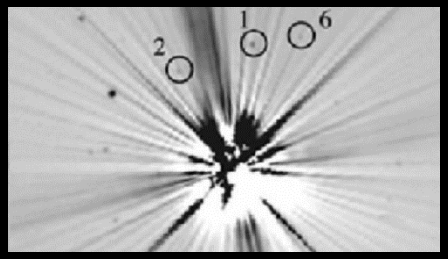
- Seeing limitations:
  speckle interferometry



- Diffraction limitations:
  shaped aperture masks



- Differential magnitude limitations:
  charge injection devices



Summary

- Amateur astronomers are able to conduct exoplanet transit observations with amazing accuracy
- Their contribution to exoplanet research continues to be of value to professional astronomers
- The need for such observations in the near future will continue to grow
- Amateur astronomers' contribution to exoplanet research beyond just the transit method is promising

Links

- www.aavso.org/exoplanet-section
- www.astrodennis.com
  - “A Practical Guide to Exoplanet Observing”

Will stars ever seem the same again?