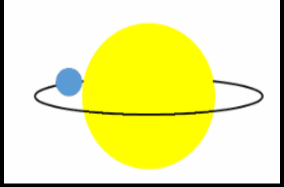


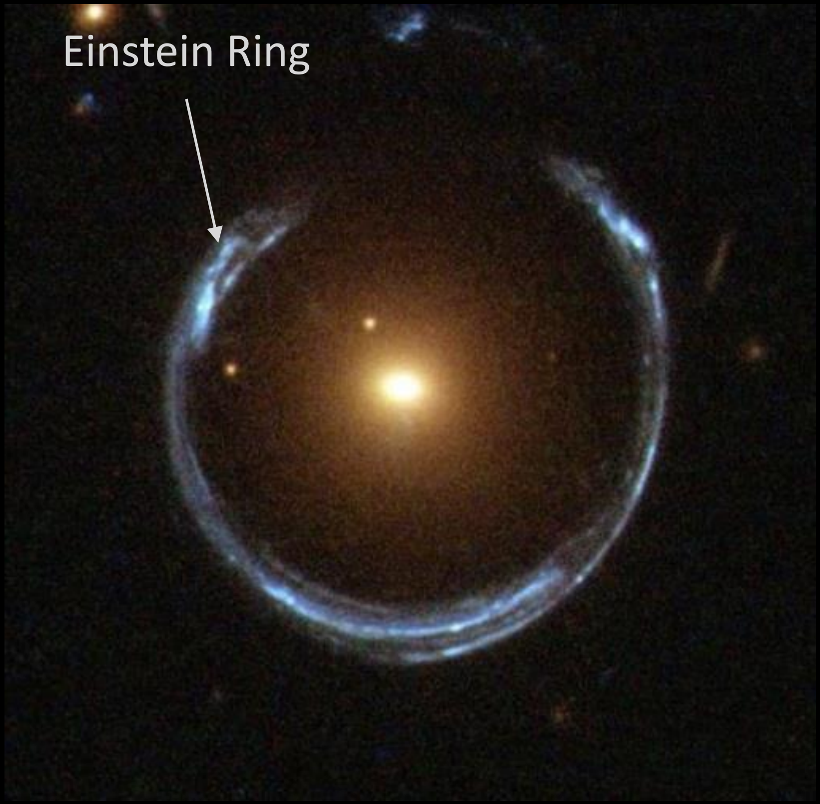
Exoplanet Detection via Microlensing

Dennis M. Conti
Chair, AAVSO Exoplanet Section
www.astrodennis.com

Background

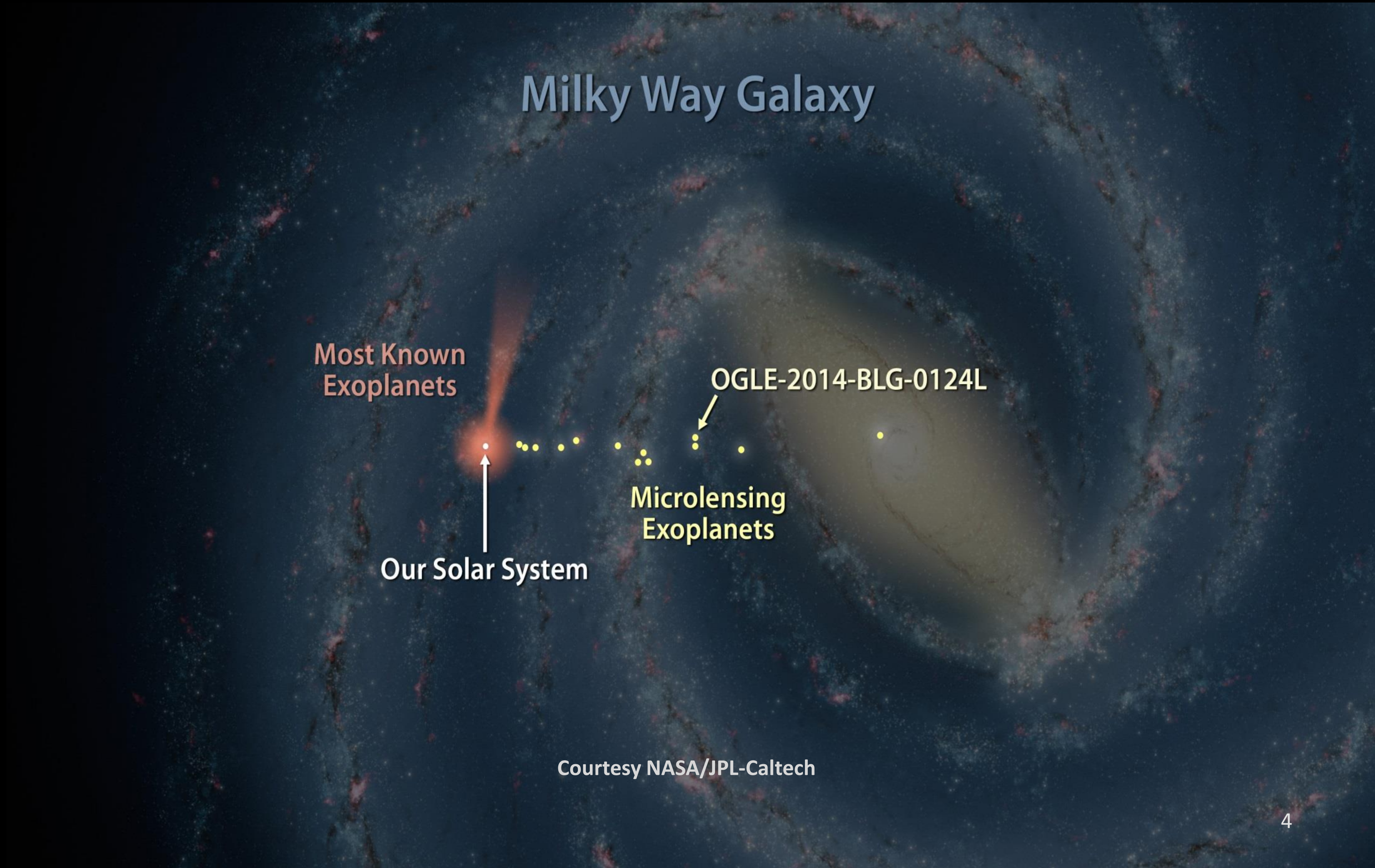
- According to Einstein's General Theory of Relativity, an object with mass will warp spacetime
  - thus light passing near that object will get diverted and create one or more additional "images"
- Microlensing: gravitational lensing by foreground object(s) that "lens" a background or "source" star
- Typically, the observation is toward the center of the Milky Way
- The changes in the light curve of the source star are used to characterize the intervening object(s)
- One of several methods used to detect exoplanets, especially Earth-size
- Amateur astronomers can and have helped conduct microlensing observations

Gravitational Lensing on a Cosmological Scale



Courtesy: ESA, Hubble, NASA

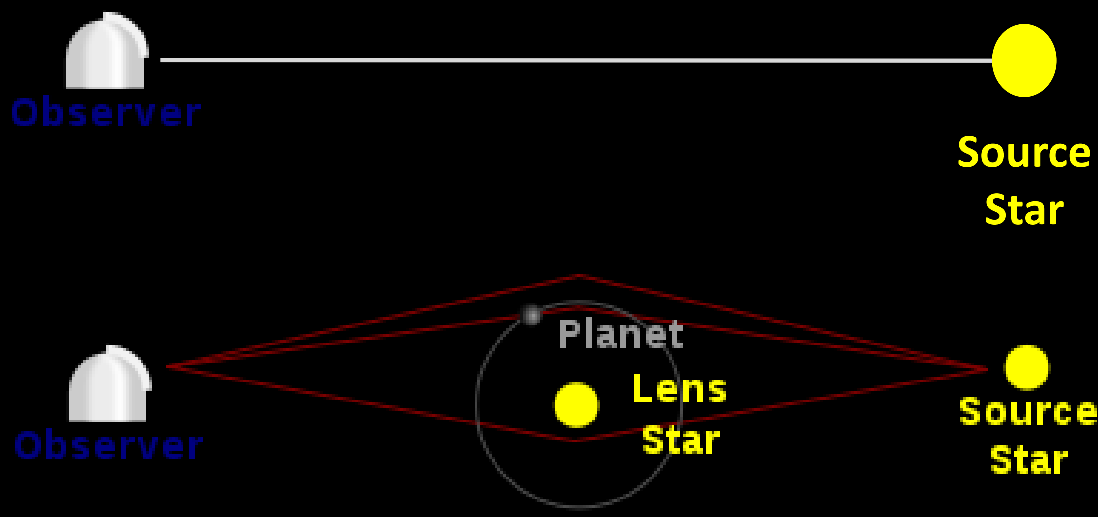
Microlensing:
Gravitational Lensing on a More "Local" Scale



Baade's Window:
a clearing of dust near the Galactic center – an ideal location for microlensing observations

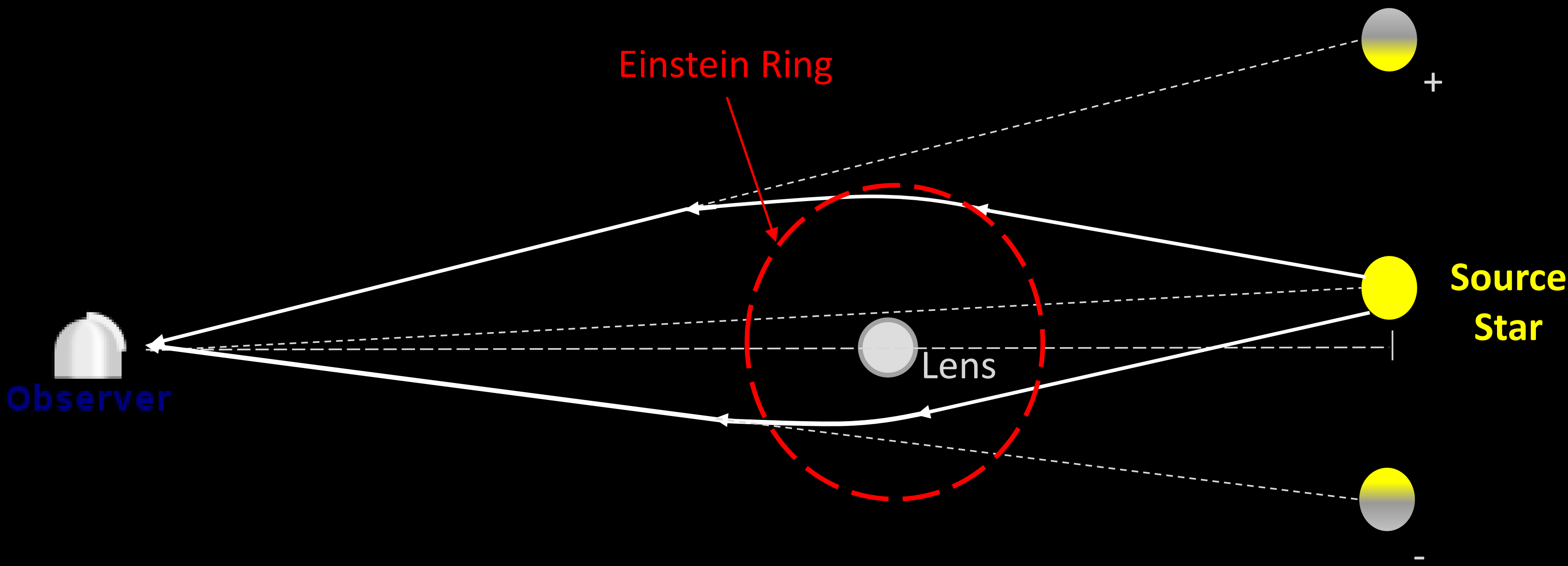
Courtesy: Sky and Telescope

Microlensing



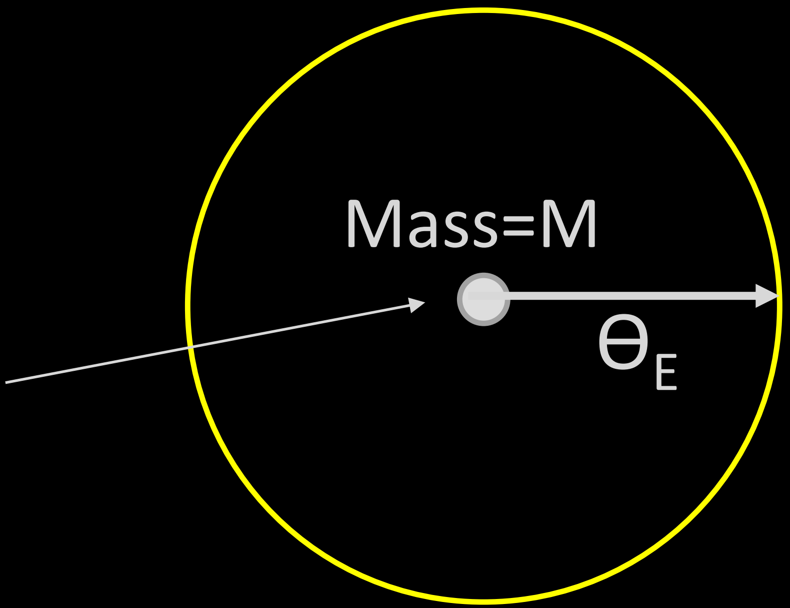
Due to our inability to resolve the multiple "images" created, we see an apparent change in the light curve of the Source Star.

Microlensing Geometry



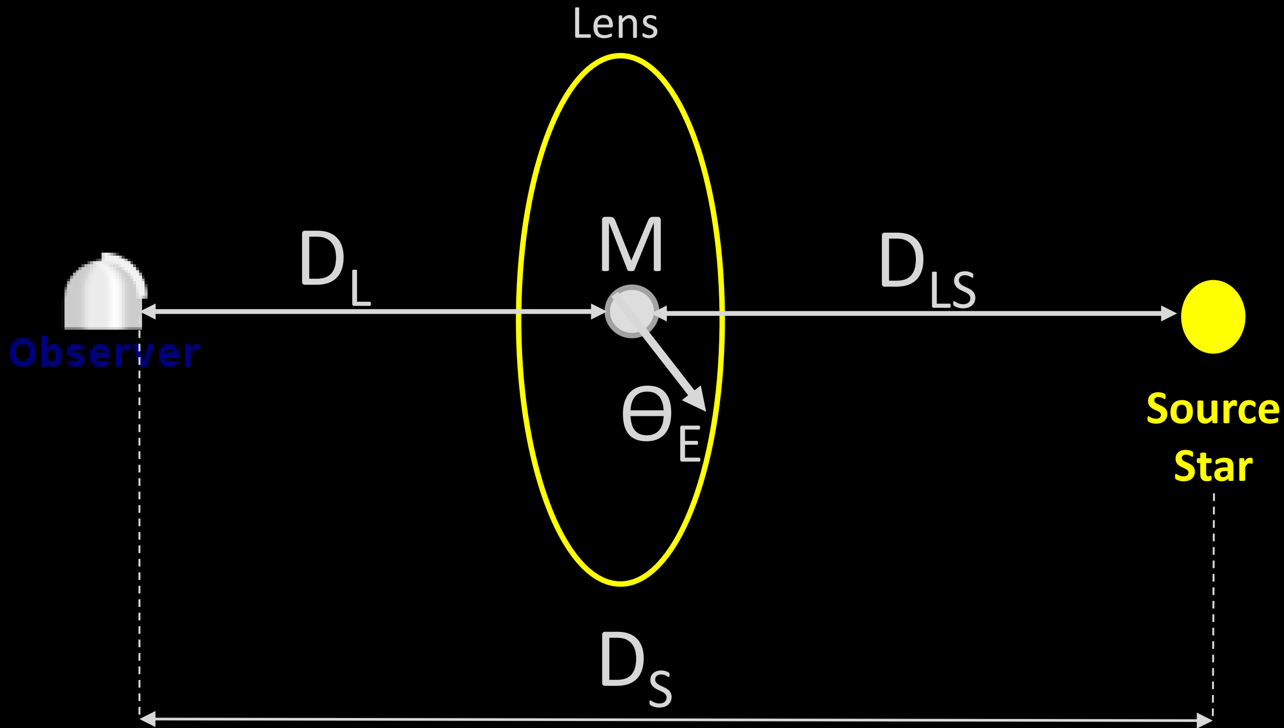
The Einstein Ring

A single-point lens



Θ_E = Einstein Radius

The Einstein Radius



$$\Theta_E = \left(\frac{4GM}{c^2} * \frac{D_{LS}}{D_L D_S} \right)^{1/2}$$

Size of the Einstein Radius

$$\Theta_E = \left[\frac{4GM}{c^2} * \frac{D_{LS}}{D_L D_S} \right]^{1/2}$$

Θ_E increases when:

- the mass of the lens increases
- the distance between the Lens and the Source Star increases
- the distance between the Observer and the Lens or Source Star decreases

Example

- Let: M = mass of our Sun

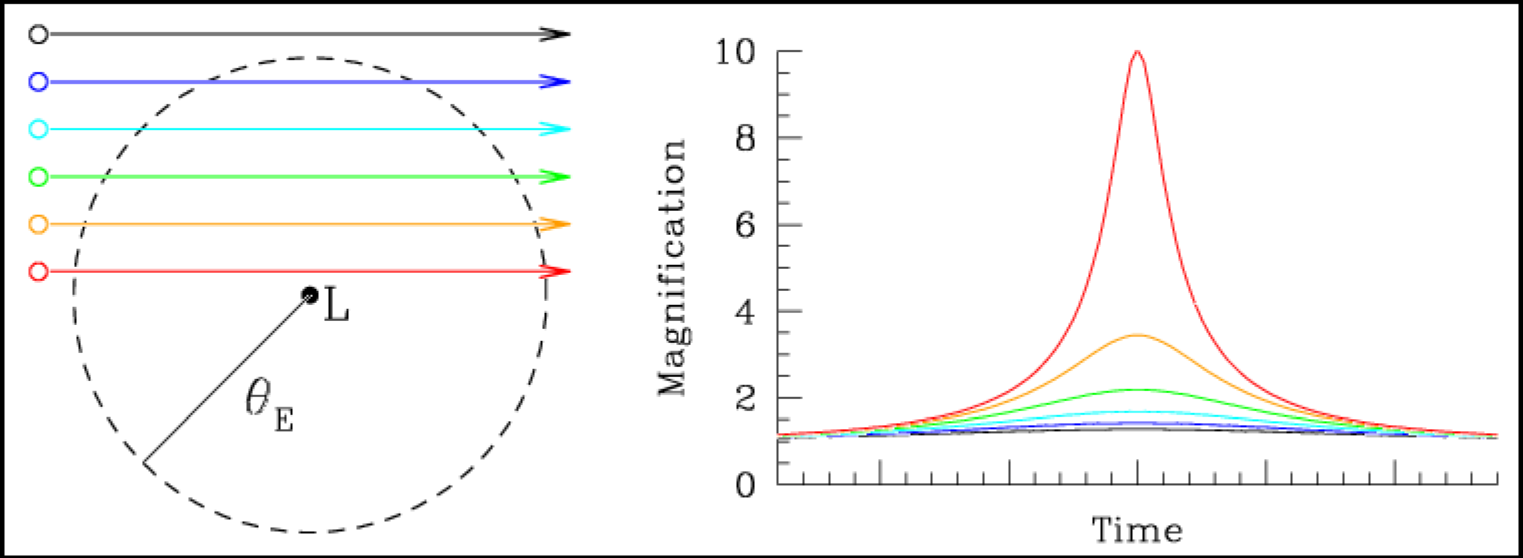
  D_S = distance to Galactic center = 8,000 parsecs
  = 26,080 light years

  D_L = ½*D_S (namely, the lens is half-way between Earth and the Galactic center)

- Then, Θ_E = 1 miliarcsecond
  Too small for our telescopes to resolve so images are merged as one!

Magnification of the Source Star

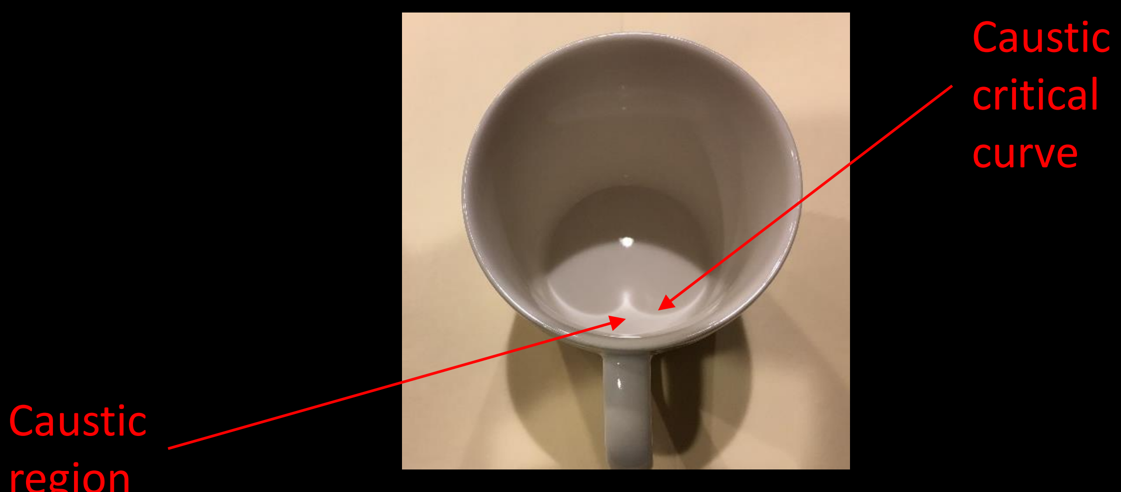
- A function of how close the trajectory of the Source Star comes to the center of the lens



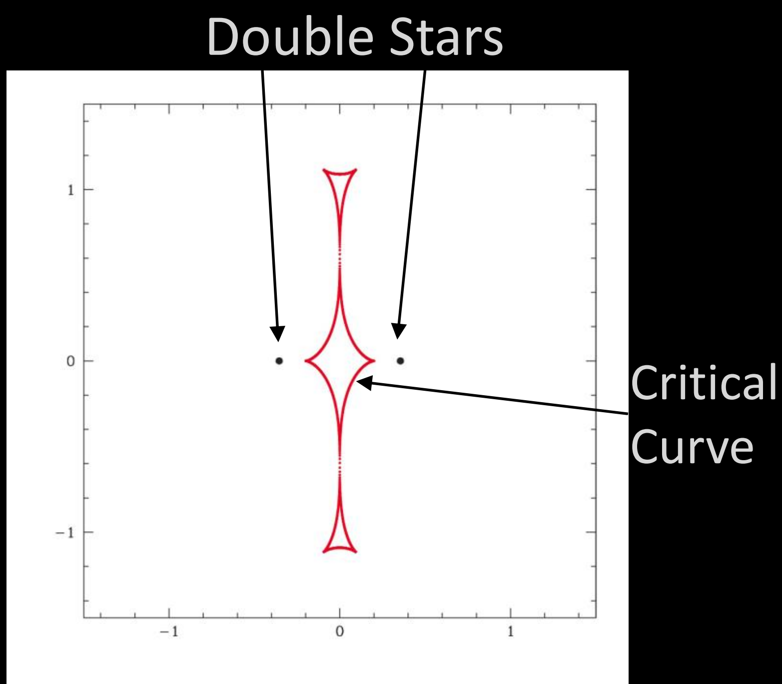
Courtesy: Prof. Penny D. Sackett

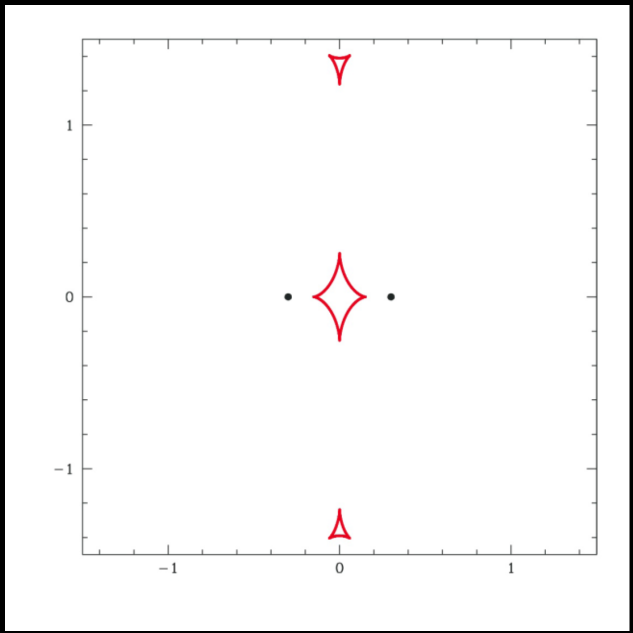
What happens if there is a second mass in the Einstein ring?

- The second mass could be another star that is part of a double star system, or it could be a planet
- In either case, one or more "caustic" regions are formed within the Einstein radius bounded by "critical curves"
- An example of a caustic in everyday life is the reflection of light off the inside surface of a cup



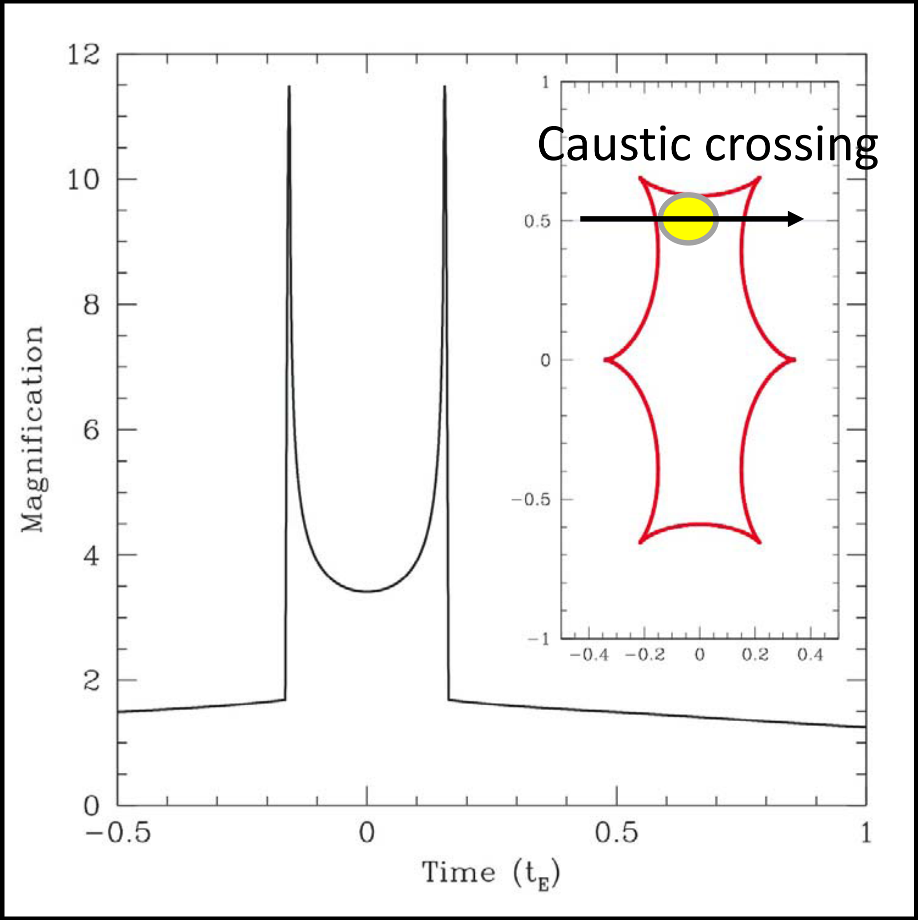
Examples of Microlensing Caustics





Courtesy: Scott Gaudi

What happens to the Source Star's light curve when it crosses a caustic?

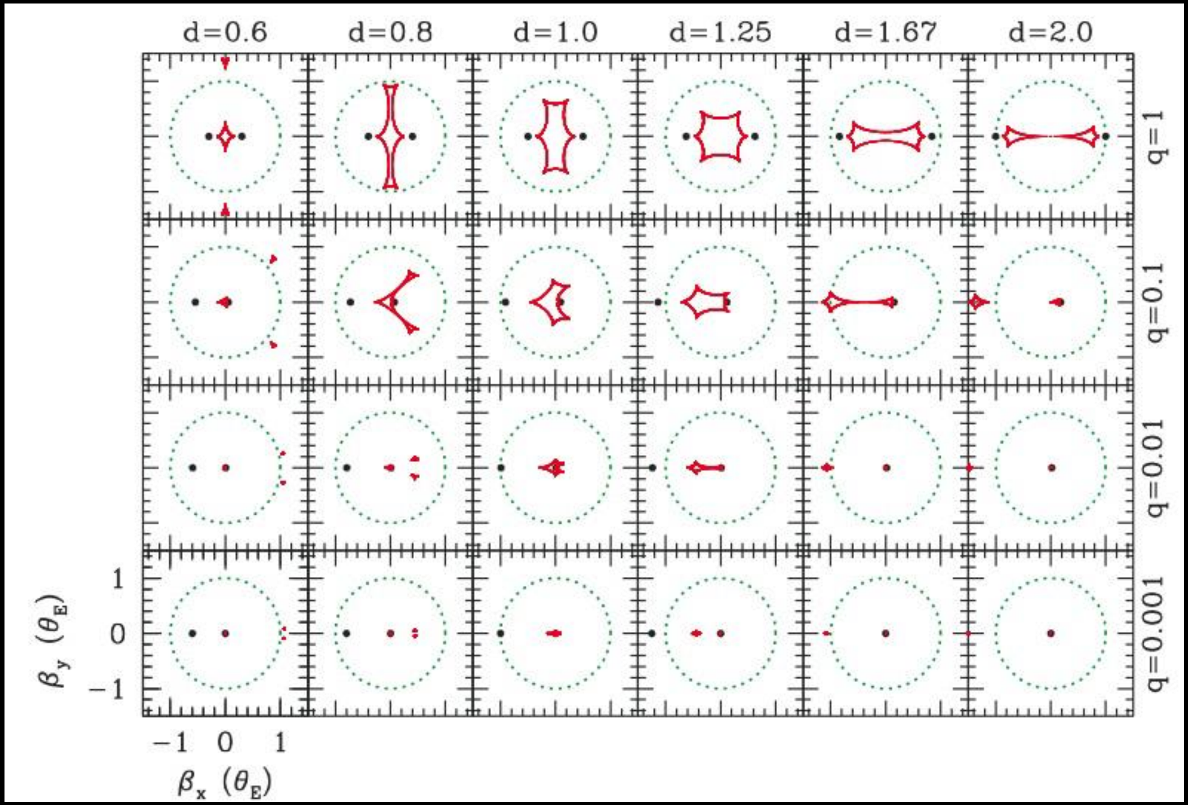


Courtesy: Scott Gaudi

Size and Shape of Caustics

- A function of:
  - the distance between the two lens objects (d)
  - the ratio of mass of the two lens objects (q)

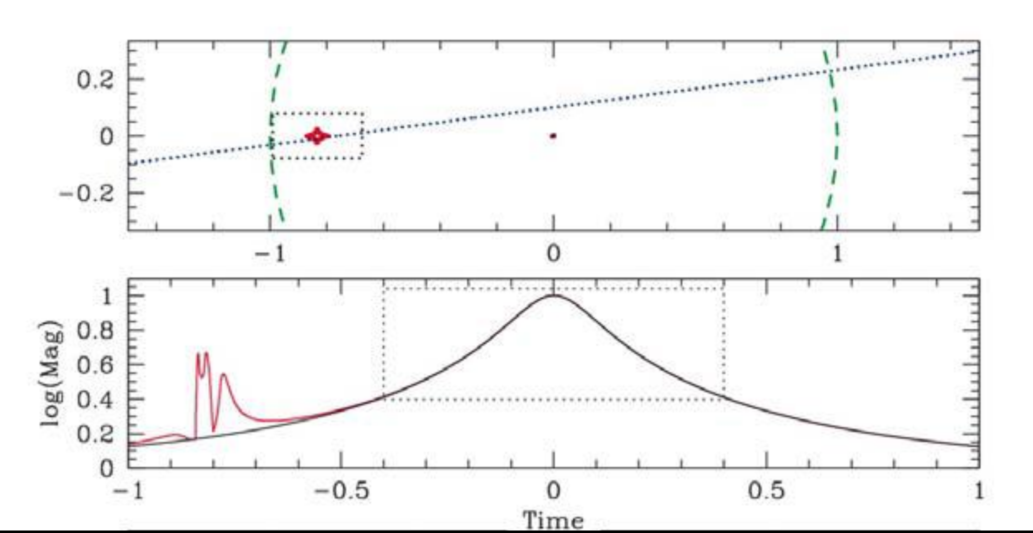
Distance →



Mass Ratio ↓

Courtesy: Scott Gaudi

What does crossing a planetary caustic look like?



Courtesy: Scott Gaudi

- Time to cross a <u>planetary caustic</u> is on the order of hours
- Time to cross a <u>double star caustic</u> is on the order of days
- Time to completely cross the <u>Einstein ring</u> could be on the order of weeks

What can we learn from the light curve of a planetary caustic crossing?

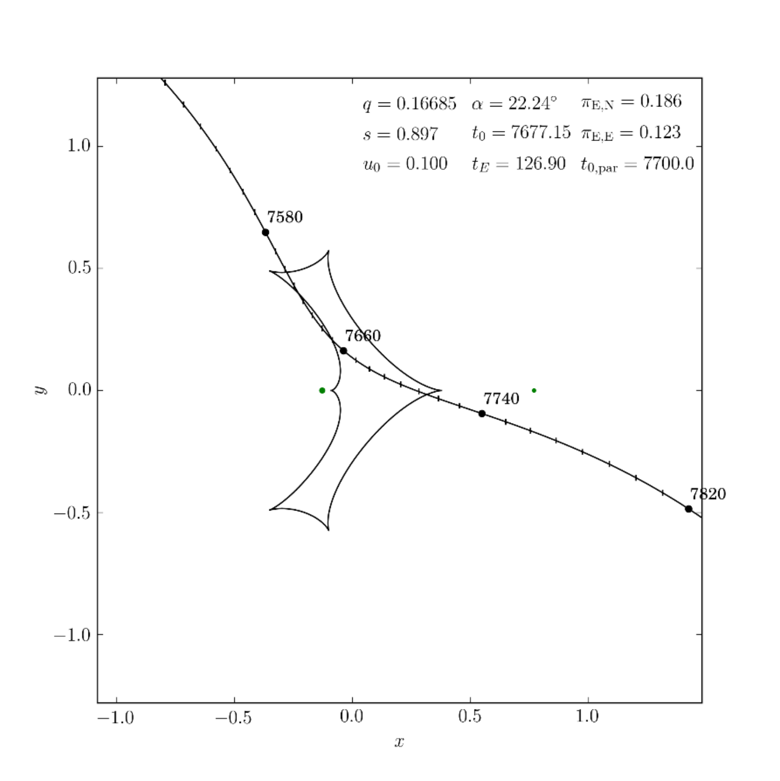
- The ratio of mass of the planet to the mass of the primary lens star

- Constraints on the distance between the planet and the primary lens star

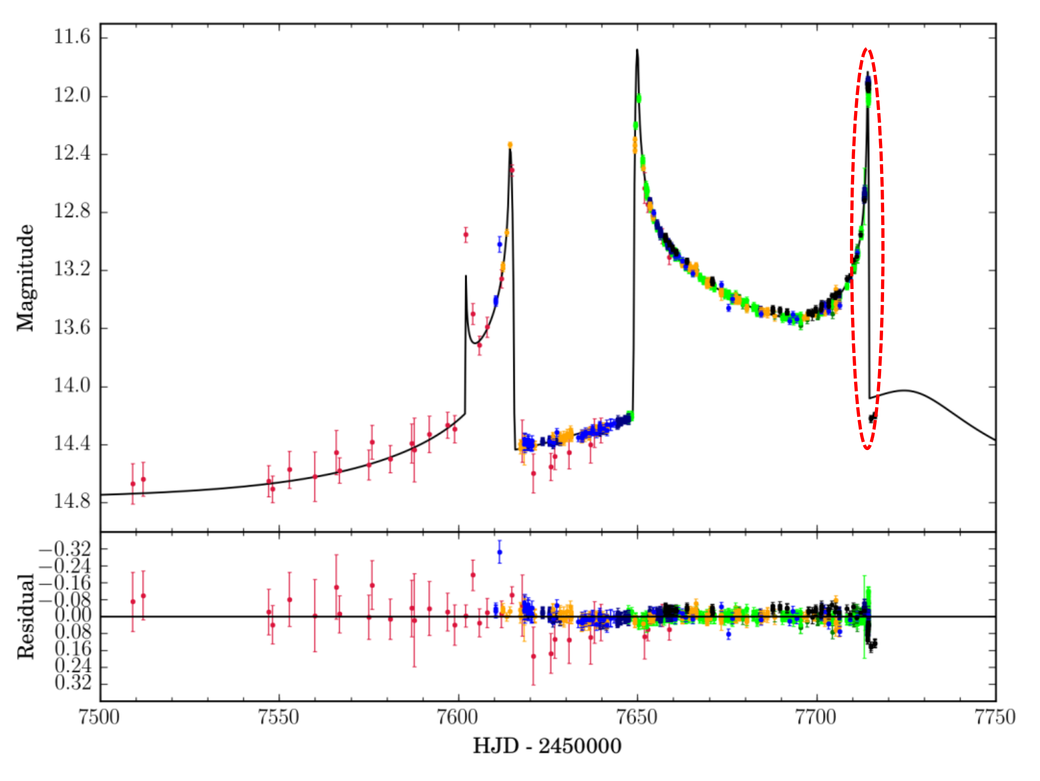
Gaia 16aye:
A Recent Microlensing Event of a Double Star System

Crossing the Caustic

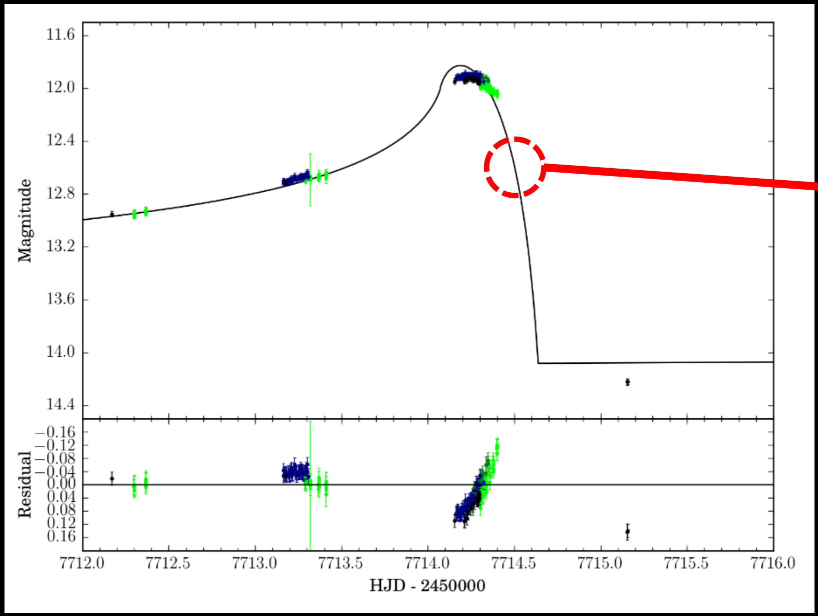
Trajectory of Source Star



Resulting Light Curve



Last Caustic Crossing: Expanded View

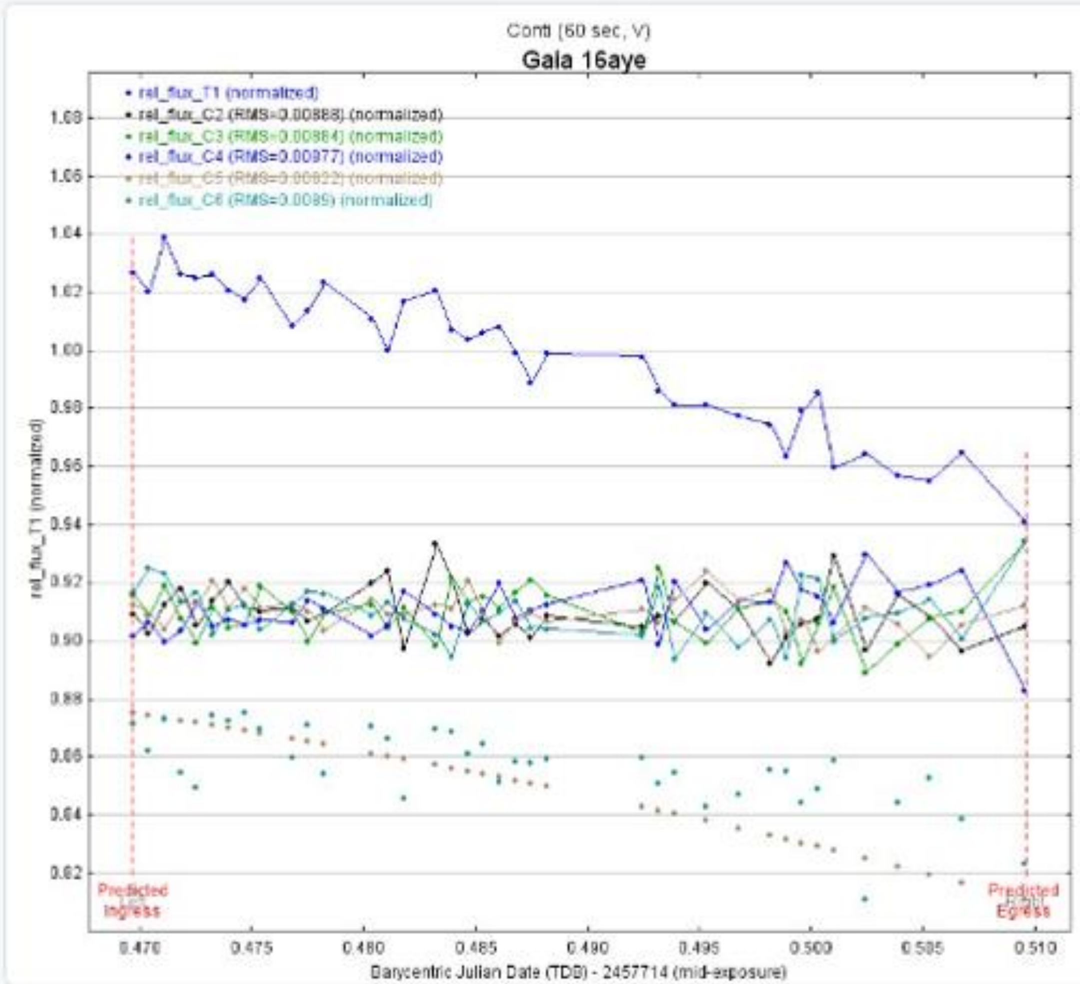


Dennis Conti's Observation

Tweet to International Community

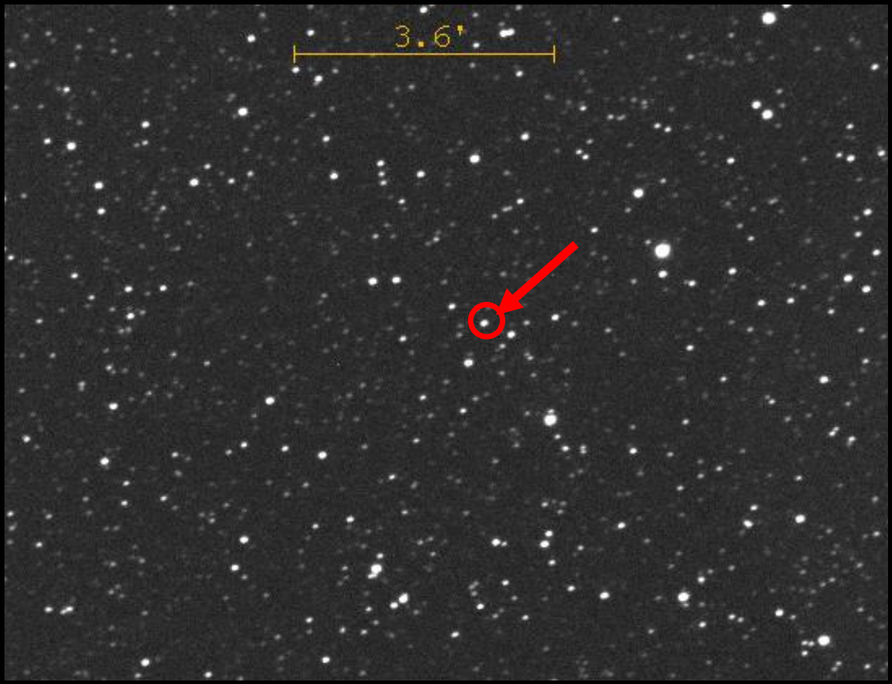
Matthew Penny @emptypenny · 3h

Last night Dennis Conti saw **#Gaia16aye** fall by at least 0.08 mag in 1 hour between HJD 7714.47 and 7714.51 (Nov 21 23:15 UT-Nov 22 00:15).



A One Day Difference!

November 21, 2016



November 22, 2016

Amateur Astronomer Participation in Microlensing Events

- Advantages:
  - can act on short notice
  - world-wide coverage provides good temporal and geographic coverage
  - multiple, simultaneous observations can reduce uncertainties

- Participation opportunities:
  - The OGLE (Optical Gravitational Lensing Experiment) project: it provides microlensing alerts
  - Ohio State's MicroFUN (Microlensing Followup) project: it is supporting a Spitzer microlensing program through 2018 (email: ufun-homebase@astonomy.ohio-state.edu)

Summary

- Astronomers can determine certain characteristics of a planetary or double star system based on the light curve produced by a microlensing event
- Amateur astronomers are ideally suited to conduct follow-up microlensing events