Brief Introduction to Roman and Microlensing

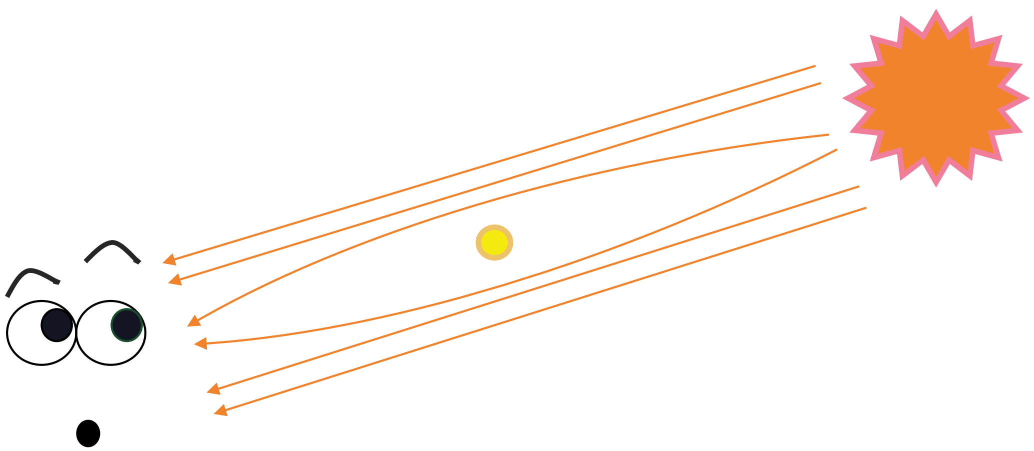
Roman Galactic Bulge Time Domain Survey Data Challenge
AAS 247

What is a microlensing event?

When a foreground stellar object passes between us and a more distant background star, its gravity will bend and magnify the light from the more distant star.

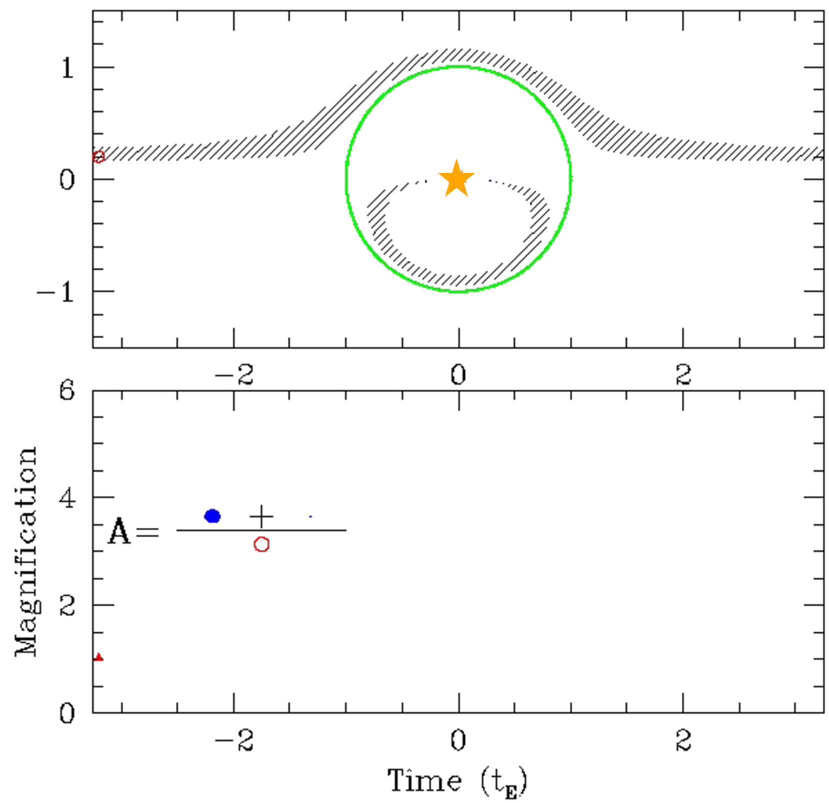
The foreground stellar object is called the 'lens'

and the background star is called the 'source'.



Single lens scenario

- Source star
- Source images
- Einstein ring
- Lens star

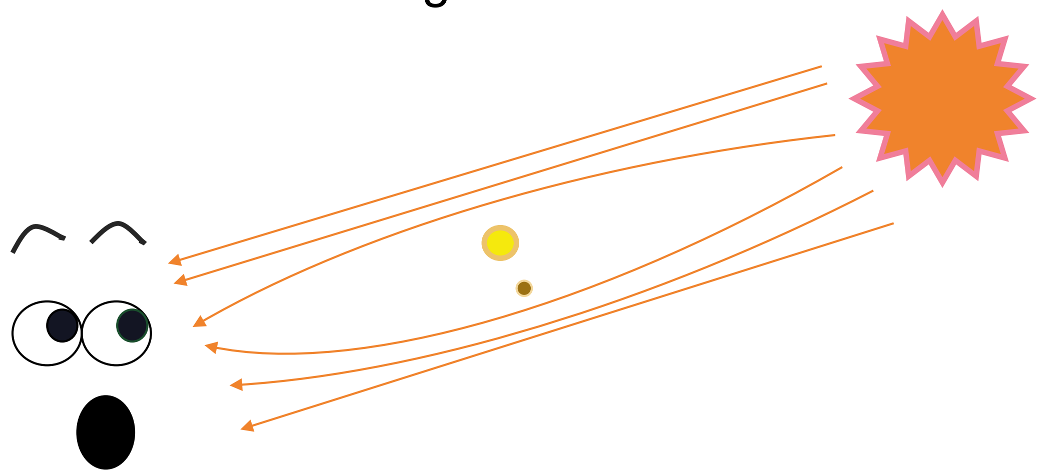


As the source star moves behind a single lens, its light is deflected and images of the source change as function of time.

We can see this change on a light curve.

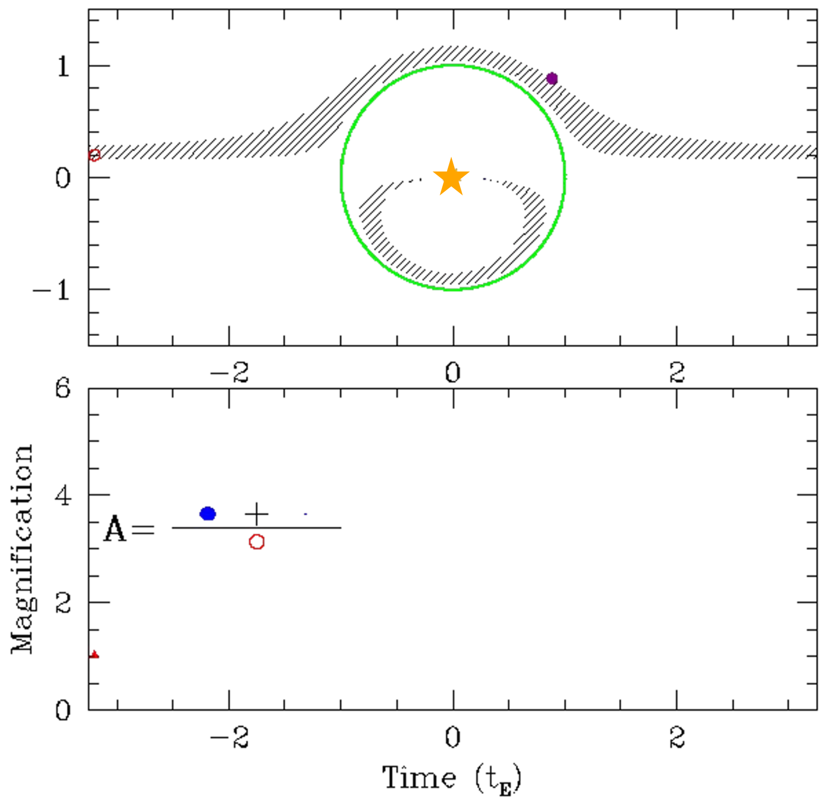
Binary lens scenario

When the lens is made up of two bodies, like a star and a planet, the second body will further deflect the source’s light.



Binary lens scenario

- Source star
- Source images
- Einstein ring
- Lens star
- Lens companion



When the lens has a companion, the companion will further deflect the light from the source.

The presence of a companion will create anomalous features on the light curve, such as spikes or dips.

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Single lens parameters

t_E	Einstein crossing time (days)
t_0	Time of peak magnification (days)
t_*	Source crossing time (days)
u	Impact parameter (dimensionless)
ρ	Angular source size (θ_S) normalized by angular Einstein ring radius (θ_E) (dimensionless)
F_S, F_B	Source and blend flux

Binary lens parameters

Single lens parameters

+

q	Mass-ratio (dimensionless)
s	The projected separation of the two lens masses, normalized by θ_E

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For a full list of light curve model parameters see:
https://www.microlensing-source.org/glossary/

Don’t forget, higher order effects could be present too

- Finite source effects
- Lens orbital motion
- Microlensing Parallax
- Xallarap
- Magnification of a second source

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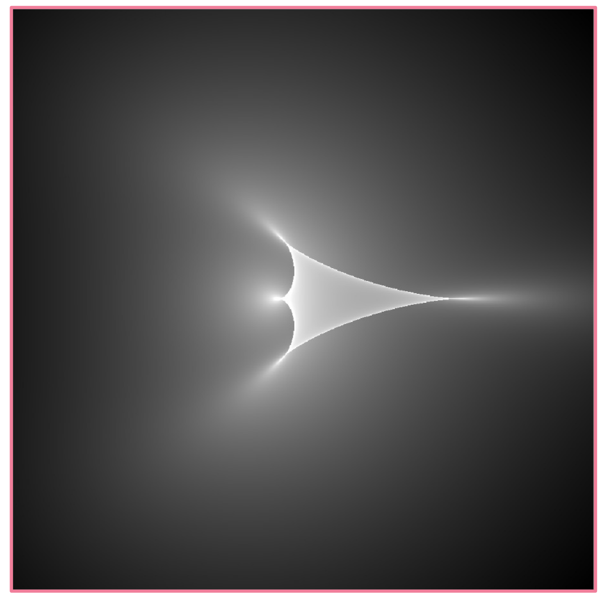
What are caustics and how are they related to light curves?

If you've seen this pattern in a pool, then you've seen **caustics**.

In the case of a pool, water is refracting light causing the rays to converge – and thus increasing their intensity.



In the case of **microlensing**, instead of water, **gravity** is bending light and creating areas of high magnification.

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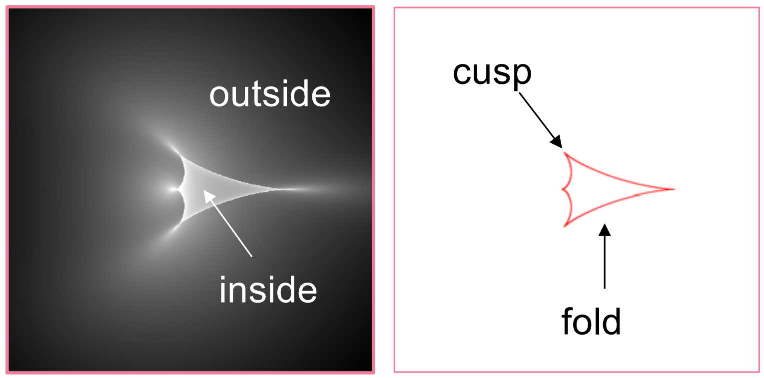
Caustics are closed curves with an ‘outside’ and an ‘inside’. The points are called **cusps**, and the curve segments are called **folds**.



When light from the source passes near or across a caustic, this will form a **spike or anomaly** on the light curve

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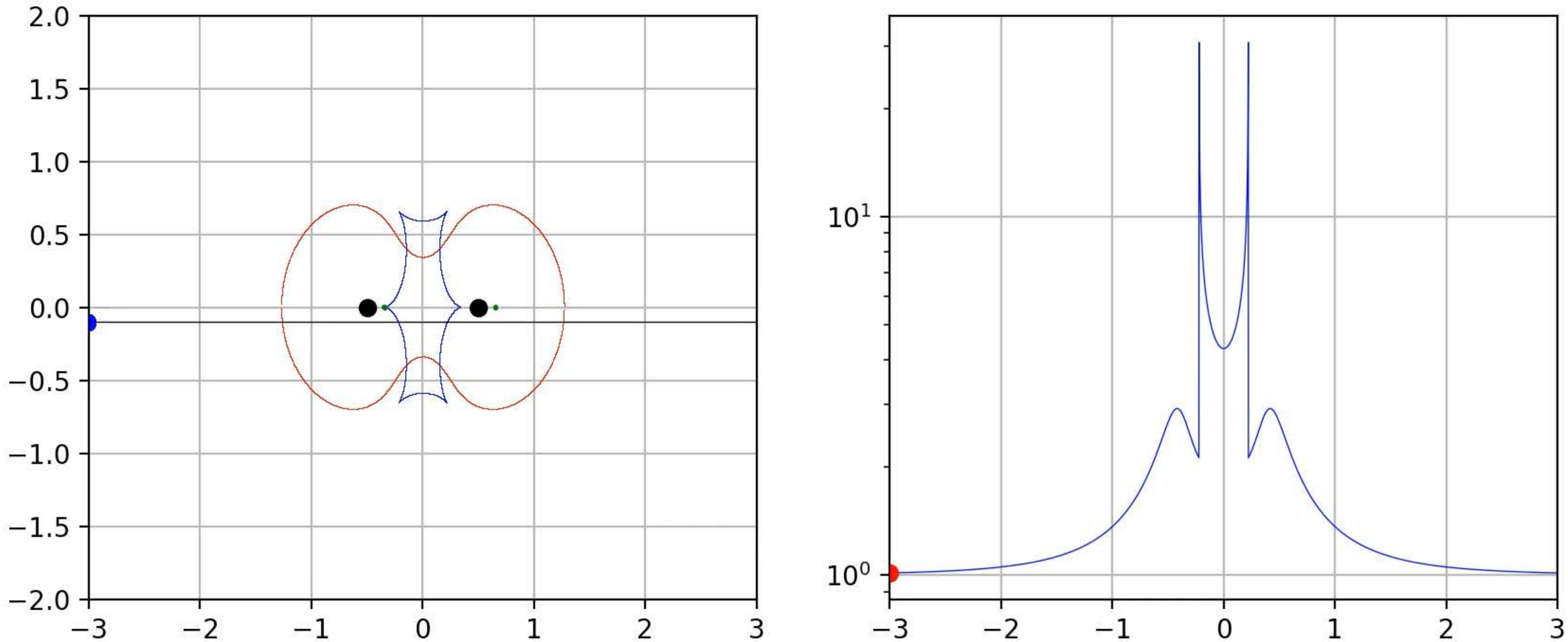

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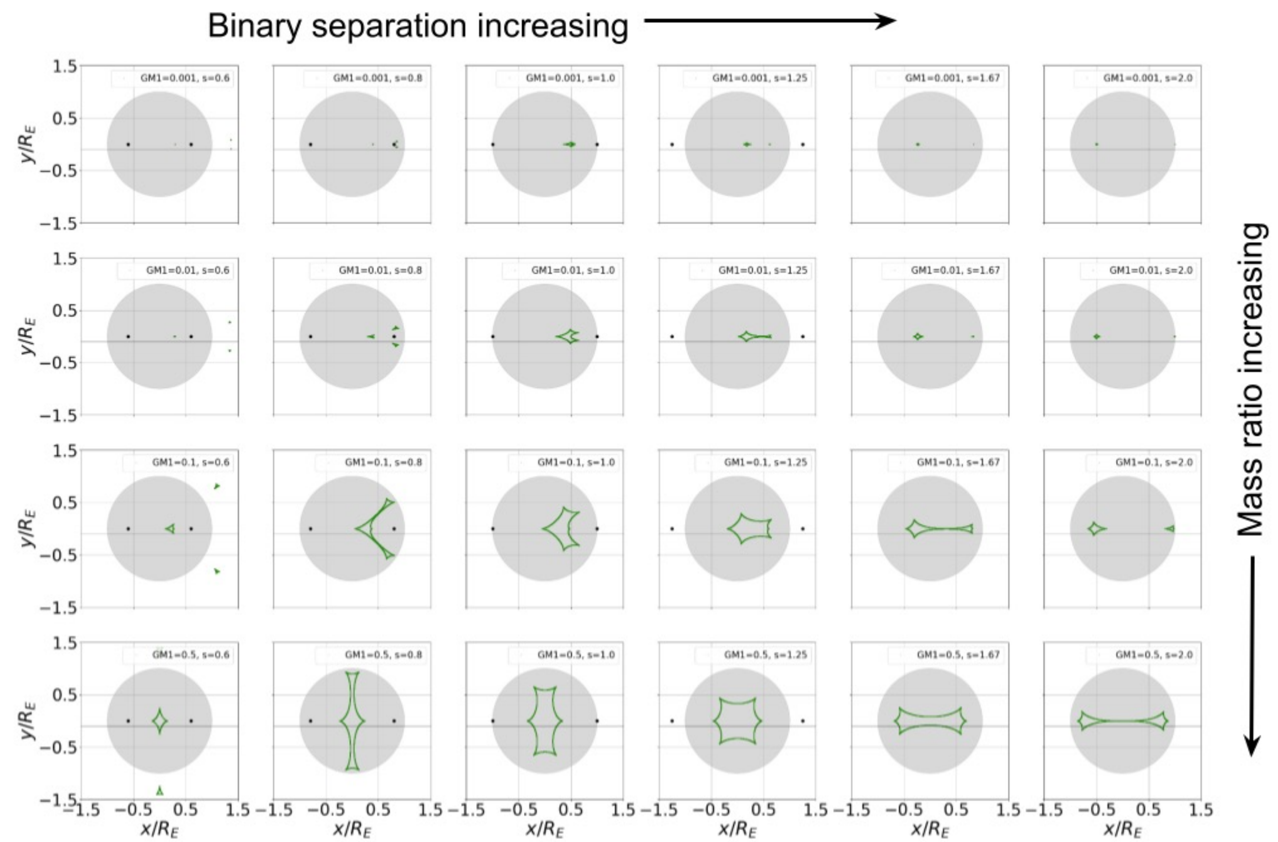
Number of caustics, their shapes, sizes, and locations depend on *q* and *s*



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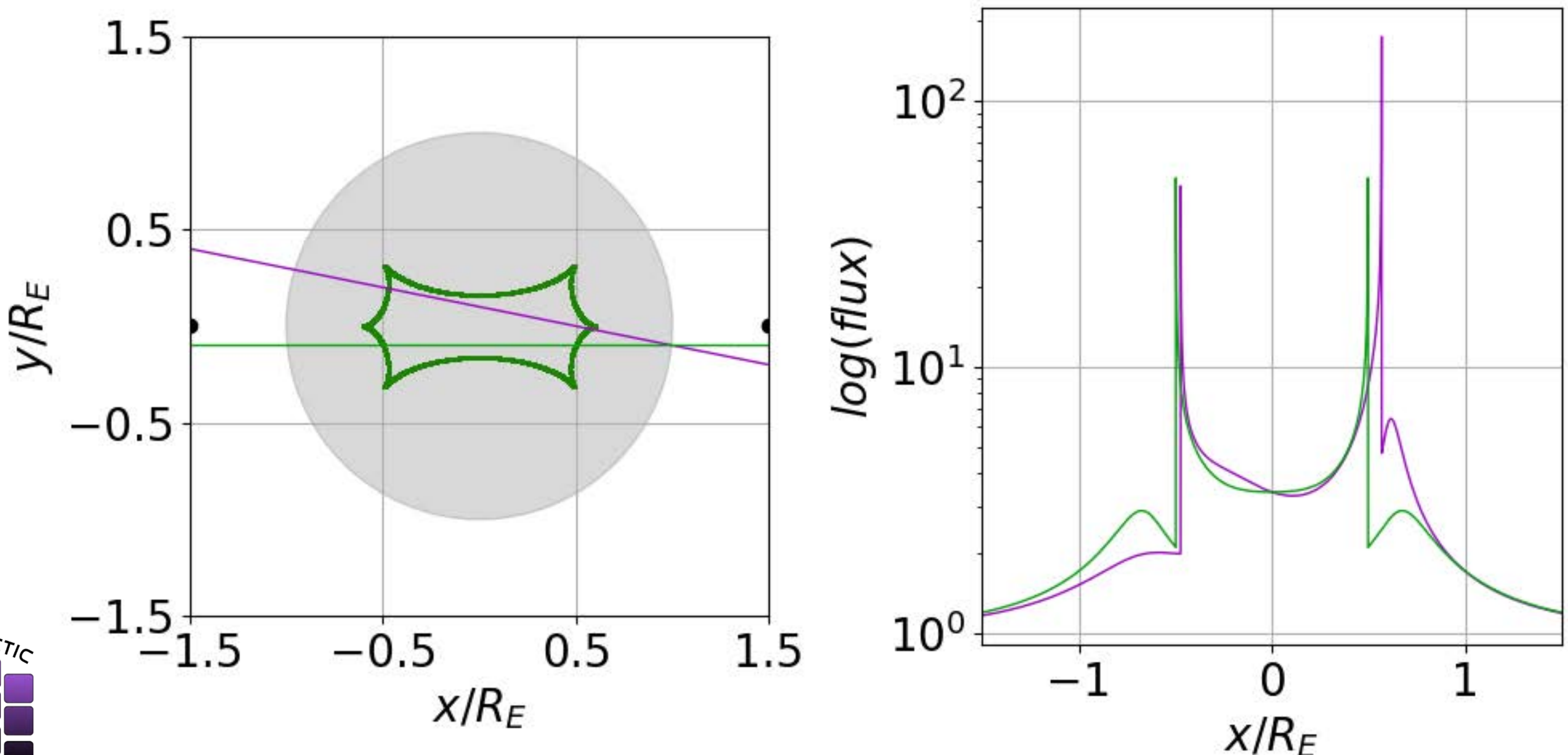
Light curve depends on the source trajectory

The source can take any trajectory, relative to the lens geometry, so the light dcurve for the same binary lens can look quite different depending on the angle of incidence.



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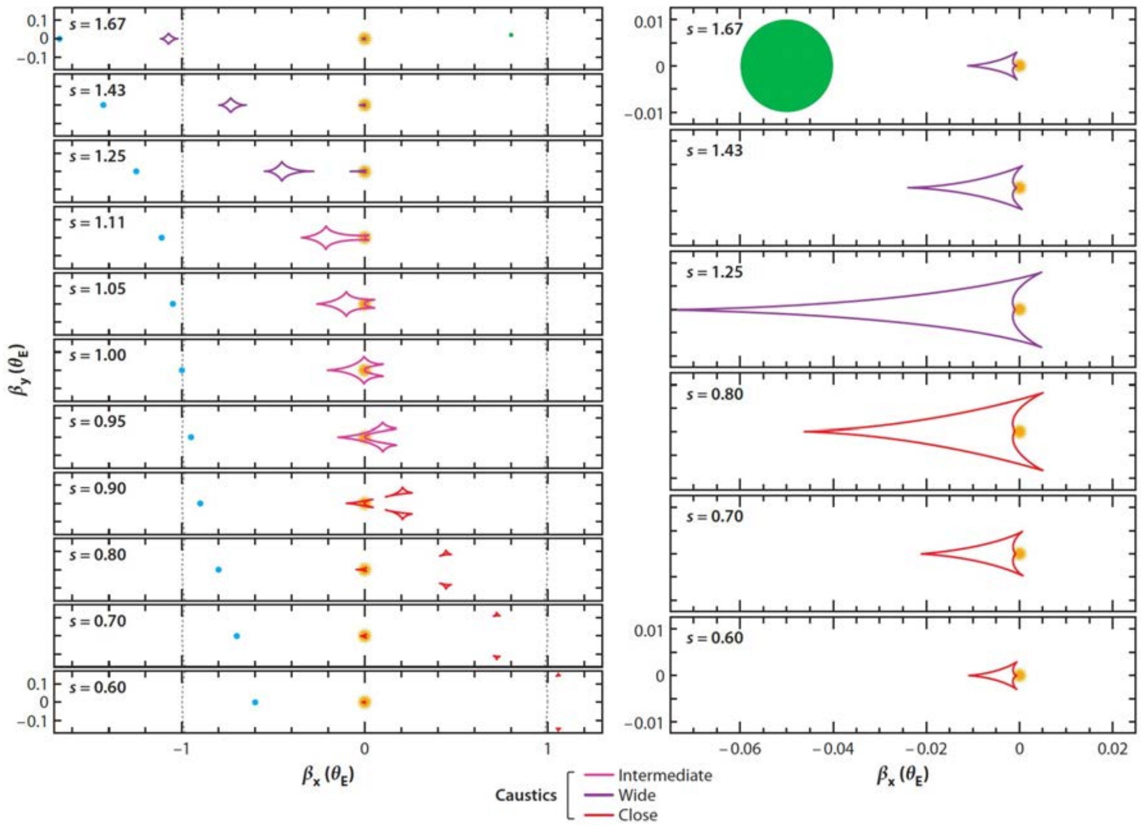
Planetary caustics ($q \ll 1$)

If s $\not\approx 1$,there are two types of caustics if :

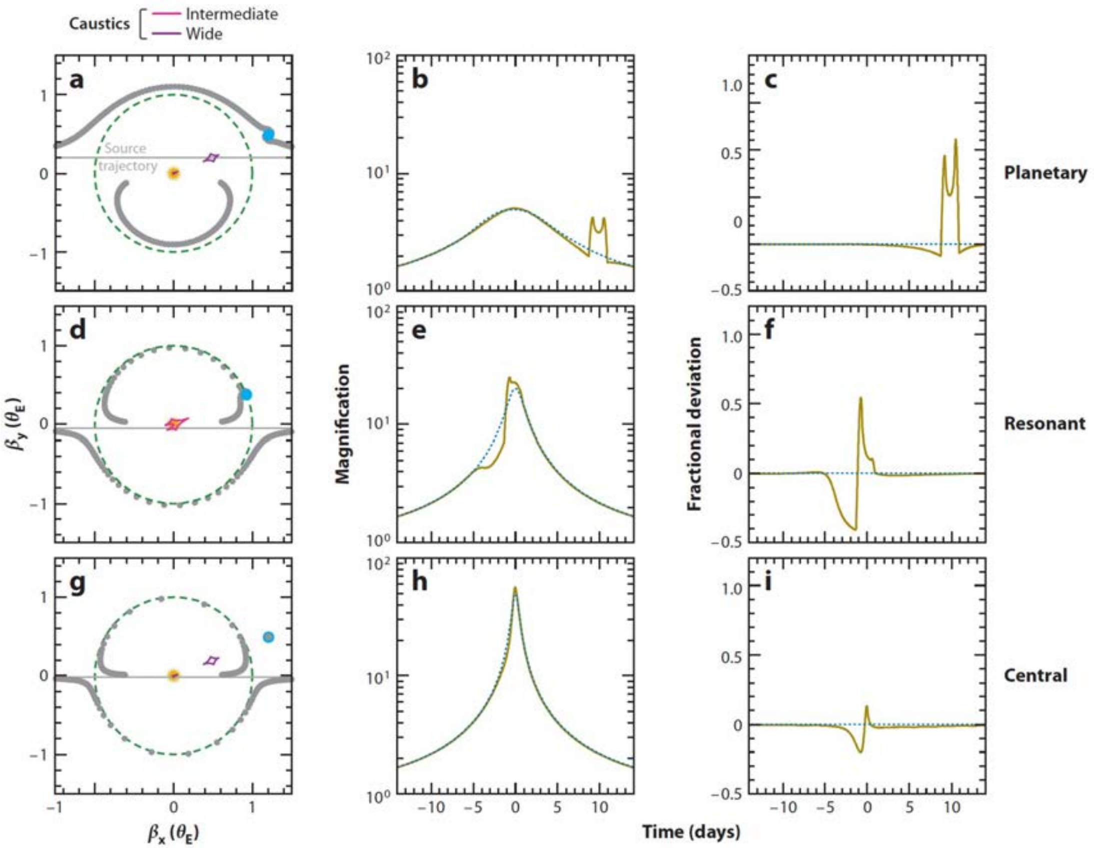
- ‘planetary’ caustic(s) associated with the planet (one caustic if s>1; two caustics if s<1)
- small ’central’ caustic located near the primary

If s ~ 1, one large but weak ‘resonant’ caustic located near the primary



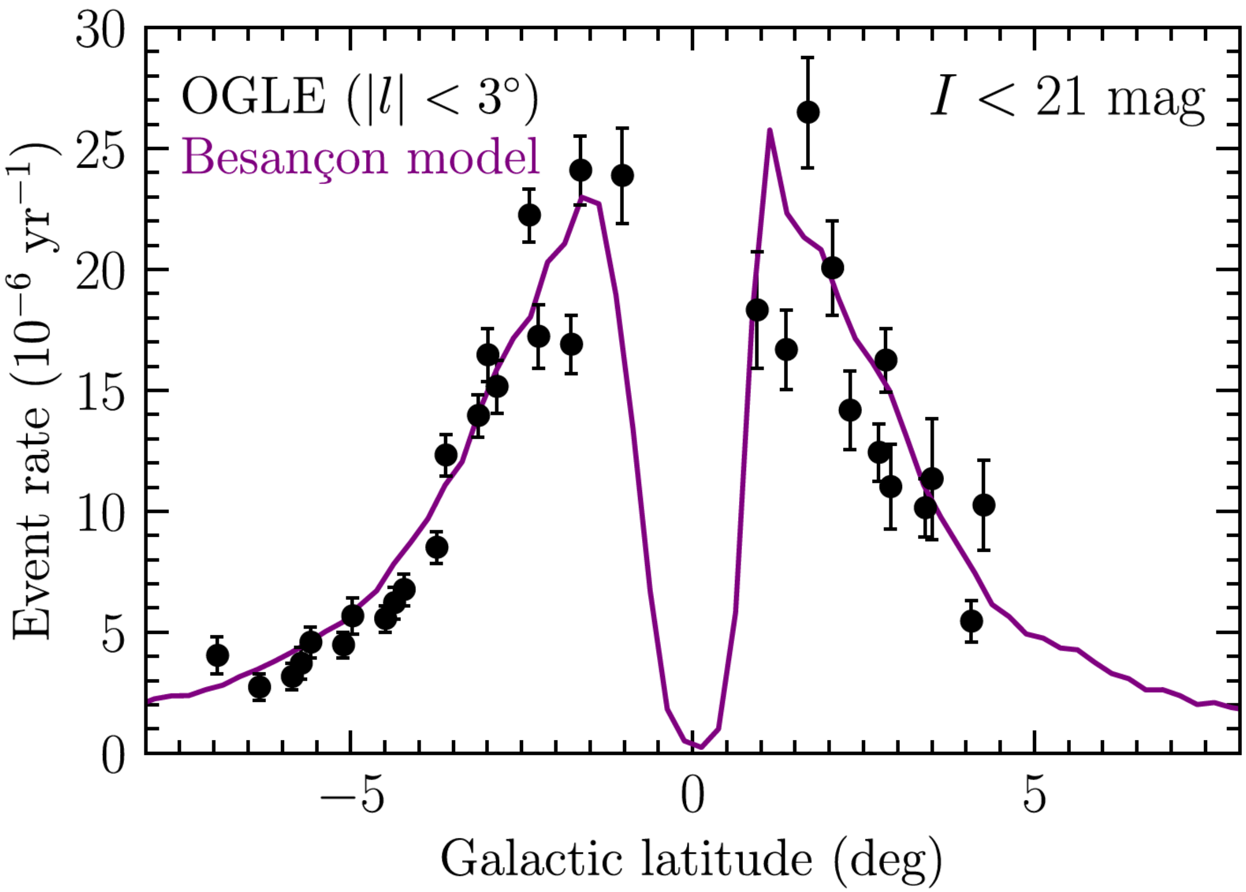
Three types of perturbations due to planets

Central caustic perturbation in high-magnification events
Planetary caustic perturbation (generally in the wings of low-magnification events)
Resonant caustic perturbation (generally weak but longer perturbations)



Microlensing is rare

The event rate is ~10^{-5}per star per year



Need to monitor millions of stars with a cadence of ~10 minutes

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Summary of Roman Space Telescope Properties

Properties	Roman
Eff. Aperture	2.28m
FOV	0.281 deg^2
Wavelengths	~0.5-2 μm (WFI)
FWHM@1μm	0.10”
Pixel Size	0.11”
Launch/ Lifetime	Late 2026/Early 2027
Lifetime	5 + 5 years
Orbit	L2

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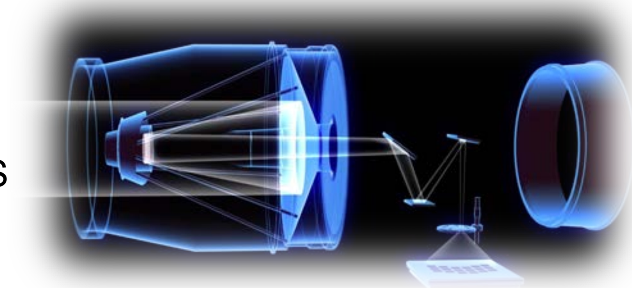
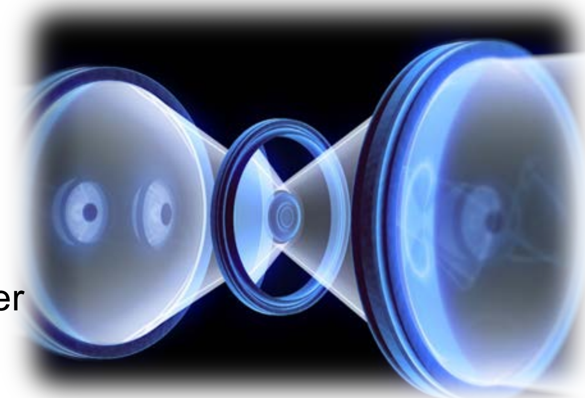
Wide-Field Instrument (WFI)

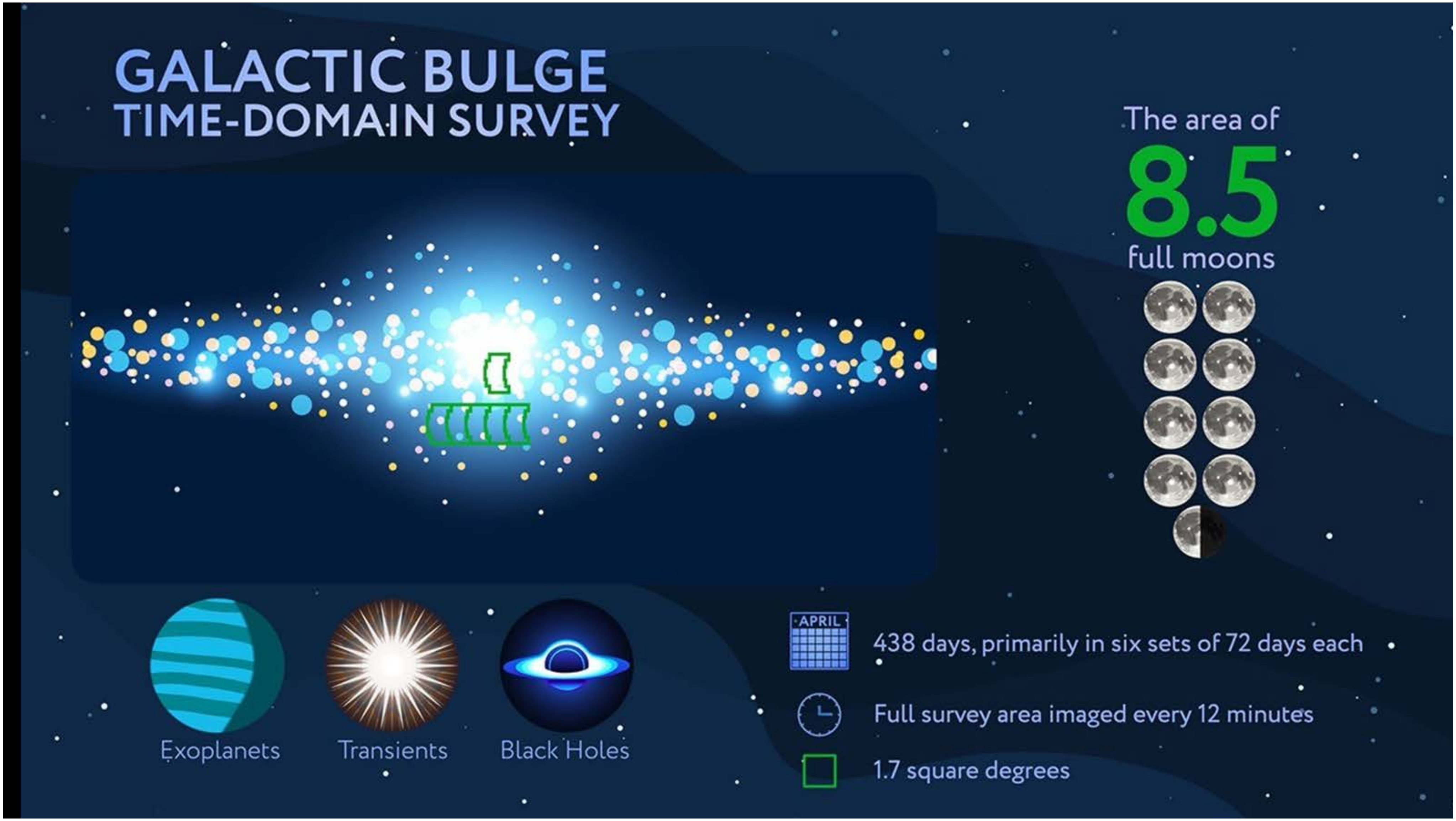
- ~0.5–2.0 micron bandpass
- 0.281 sq. deg. FoV (~100x HST ACS FoV)
- 18 H4RG detectors (288 Mpixels)
- 7 filter imaging, grism and prism spectroscopy



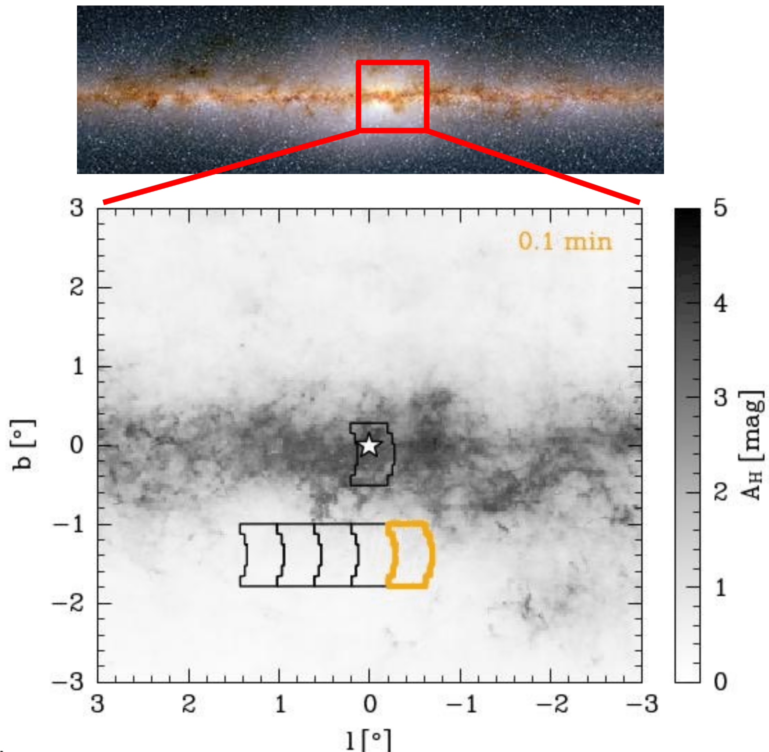
Coronagraph Instrument (CGI)

- Visible (545-865nm) high-contrast imager
- Polarimeter and spectrograph
- 3 types of coronagraph masks




GALACTIC BULGE
TIME-DOMAIN SURVEY
The area of
8.5
full moons
APRIL
438 days, primarily in six sets of 72 days each
Full survey area imaged every 12 minutes
1.7 square degrees
Exoplanets
Transients
Black Holes

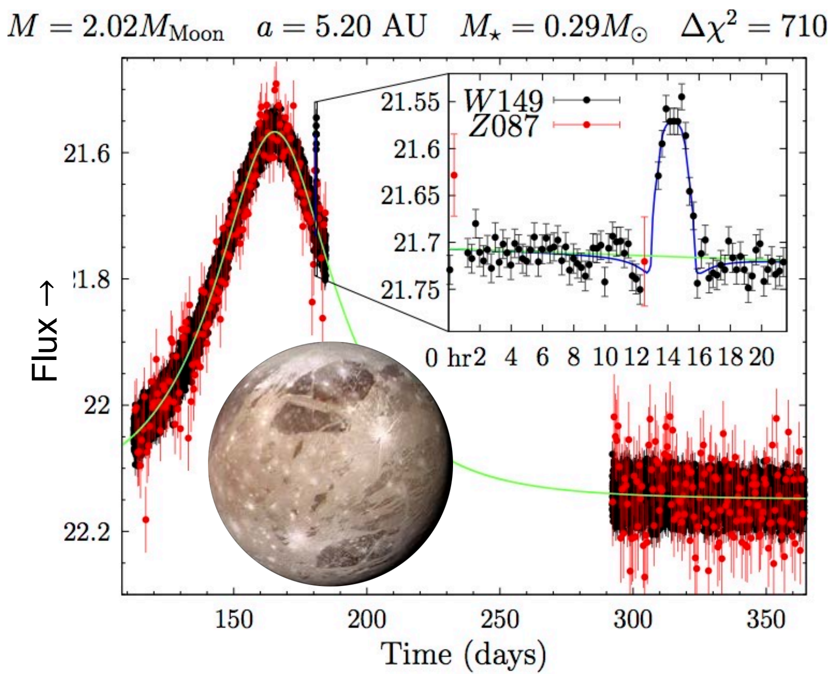
Parameters for the Roman Galactic Bulge Time Domain Survey (RGBTDS)



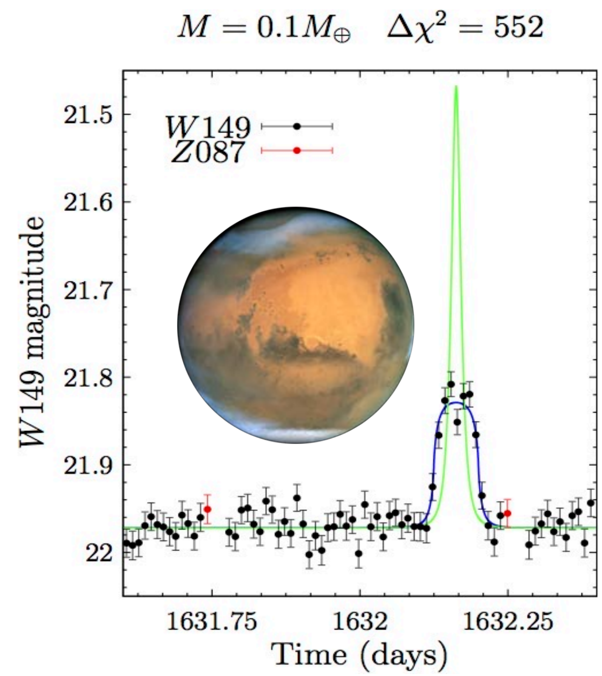
Credit: R. Wilson (GSFC)

- 5 fields for a total of ~1.5 deg^2
- + GC field
- Wide F146AB (0.93-2 μm) filter*.
- ~12-minute cadence, ~67s exposures
- Observations every ~3 hours in secondary filters (F087,F213),
- 6 x 72-day seasons (98% efficiency).
- ~50,340 exposures in W149AB.
- ~438 total days spread over 5-year mission.

Simulated Microlensing Planet Detections



2 × Mass of the Moon @ 5.2 AU
(~ 27 sigma)



Free floating Mars
(~23 sigma)

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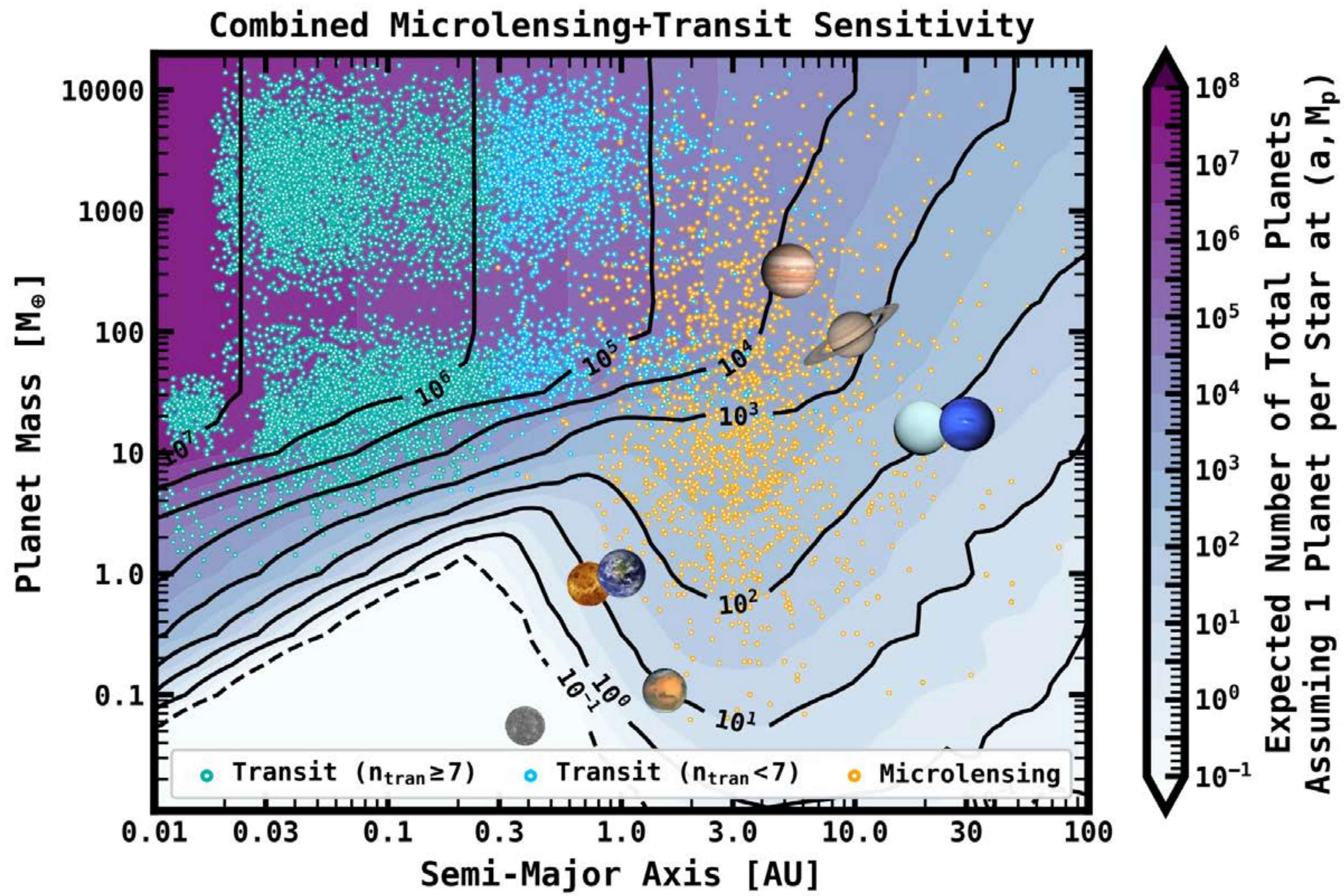

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