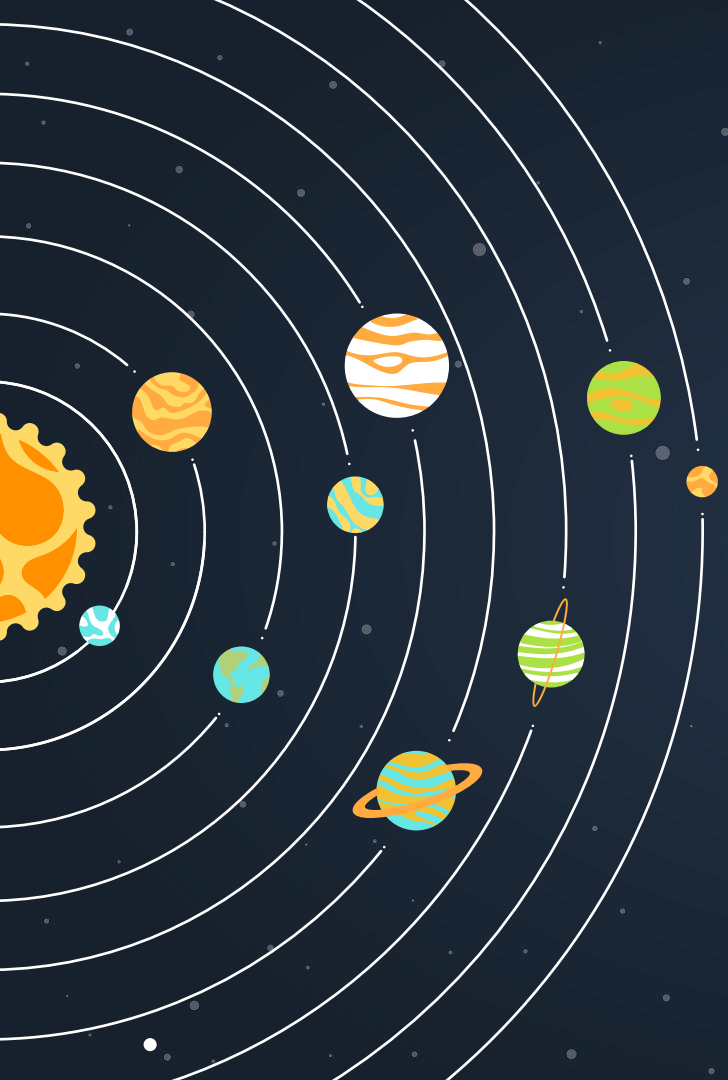
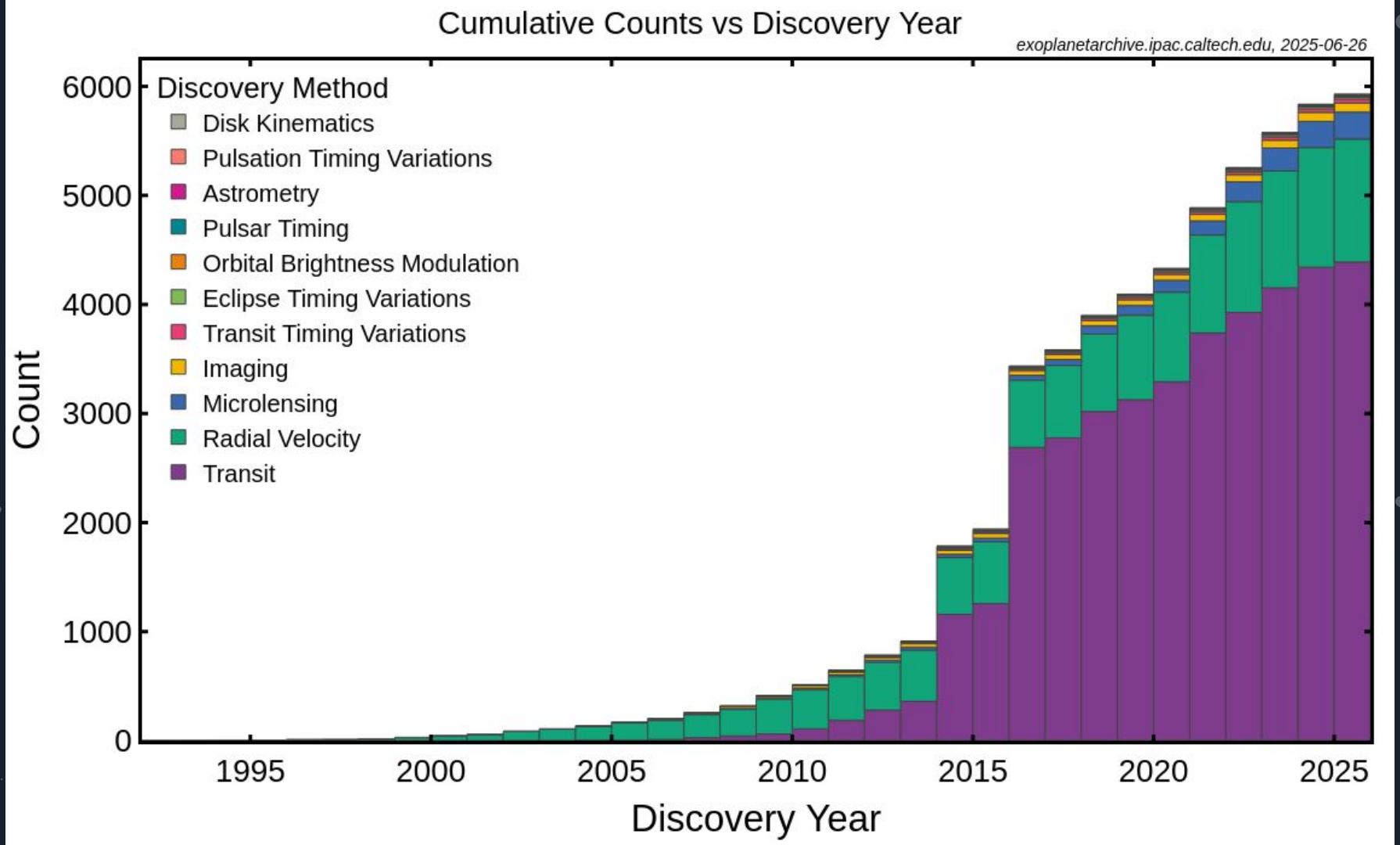
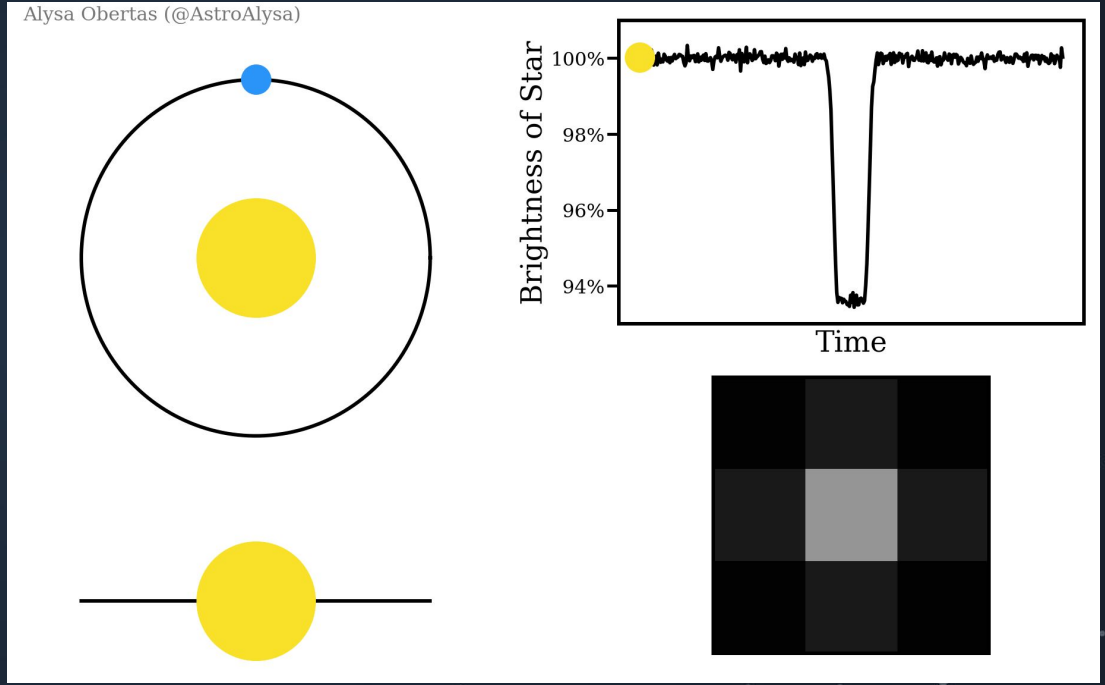


EXOPLANET DETECTION METHODS


Cumulative Counts vs Discovery Year
exoplanetarchive.ipac.caltech.edu, 2025-06-26
Discovery Method
Disk Kinematics
Pulsation Timing Variations
Astrometry
Pulsar Timing
Orbital Brightness Modulation
Eclipse Timing Variations
Transit Timing Variations
Imaging
Microlensing
Radial Velocity
Transit
Count
0
1000
2000
3000
4000
5000
6000
1995
2000
2005
2010
2015
2020
2025
Discovery Year

METHOD I: THE TRANSIT METHOD

- We can see planets **transit** their stars
- This makes the stars appear fainter for a time!
- We can see this by looking at **light curves** -- time-resolved photometry measurements

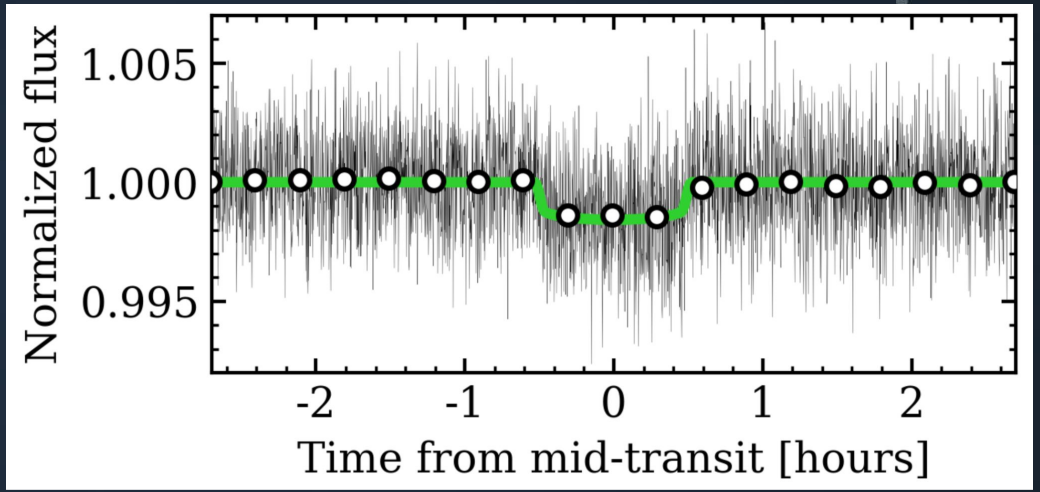


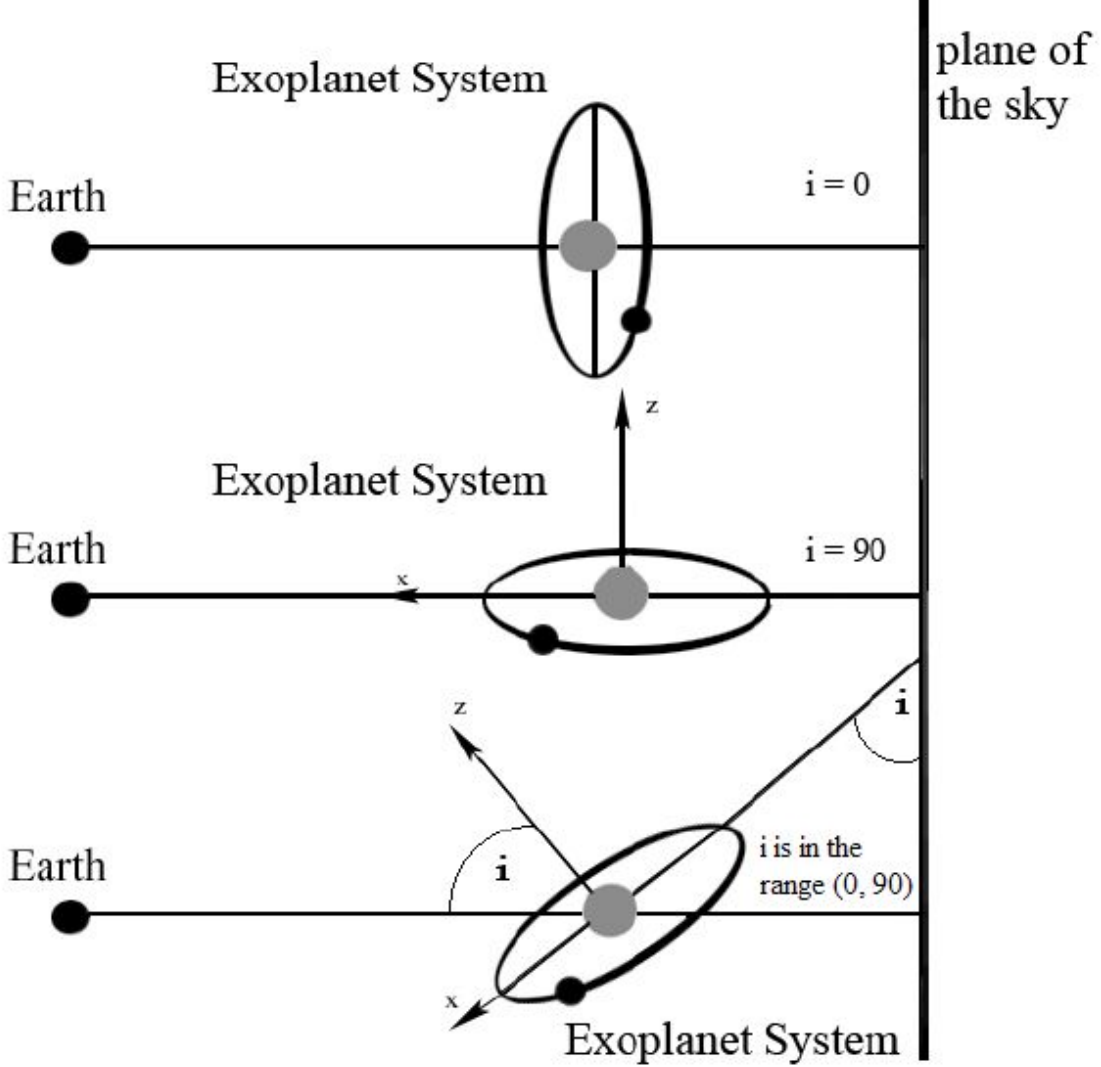
METHOD I: THE TRANSIT METHOD

- **Transit depth:**

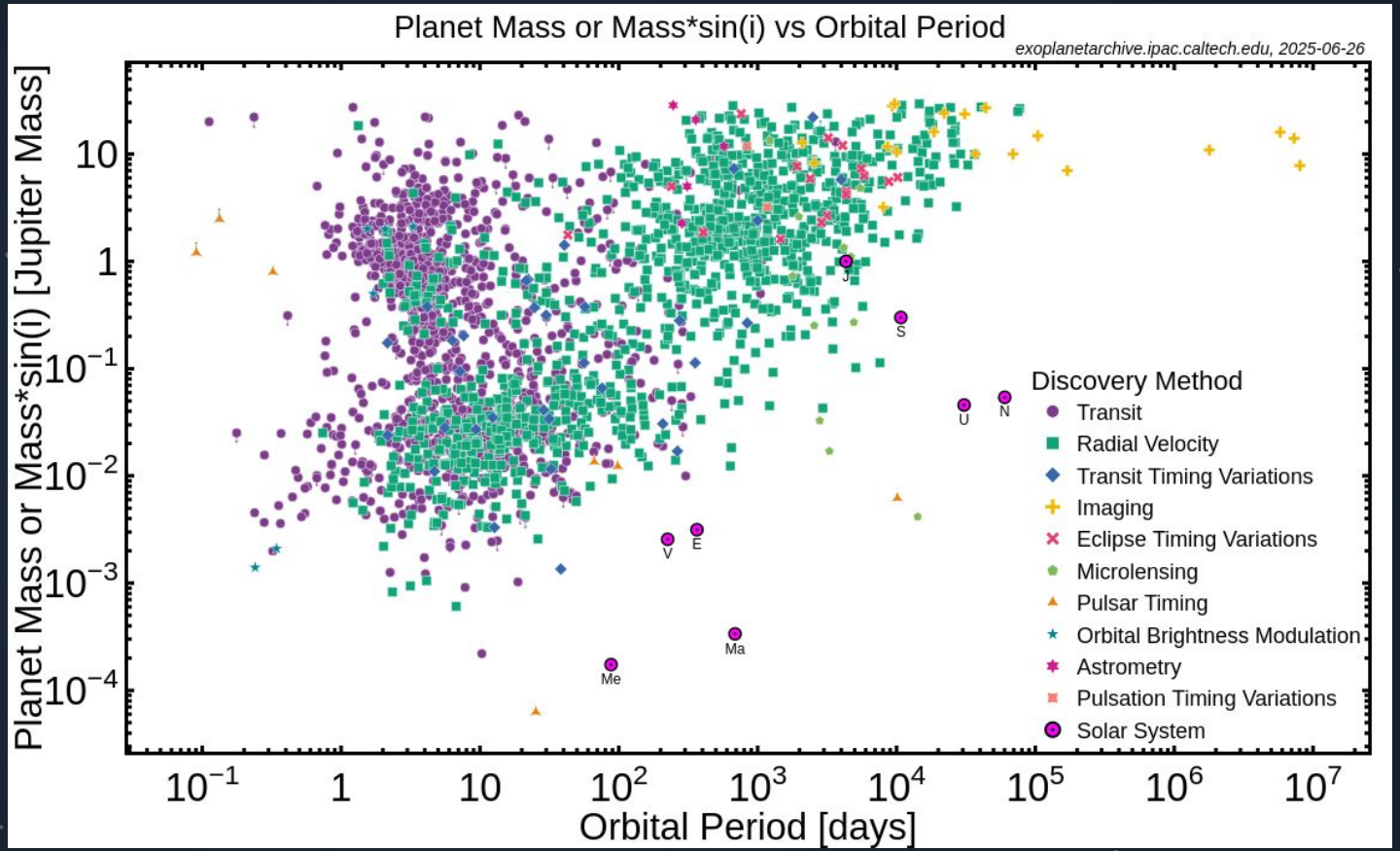
$$Z = (R_p/R_*)^2$$

- ~1% for Jupiter-sized planets, ~0.01% for Earth-sized planets!
- Can measure planet's period, inclination, and radius




plane of the sky
Exoplanet System
Earth
i = 0
z
Exoplanet System
Earth
i = 90
x
z
i
Earth
i
i is in the range (0, 90)
x
Exoplanet System

$P_{tr} \sim R_*/a$


Planet Mass or Mass*sin(i) vs Orbital Period
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Planet Mass or Mass*sin(i) [Jupiter Mass]
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Pulsation Timing Variations
Solar System
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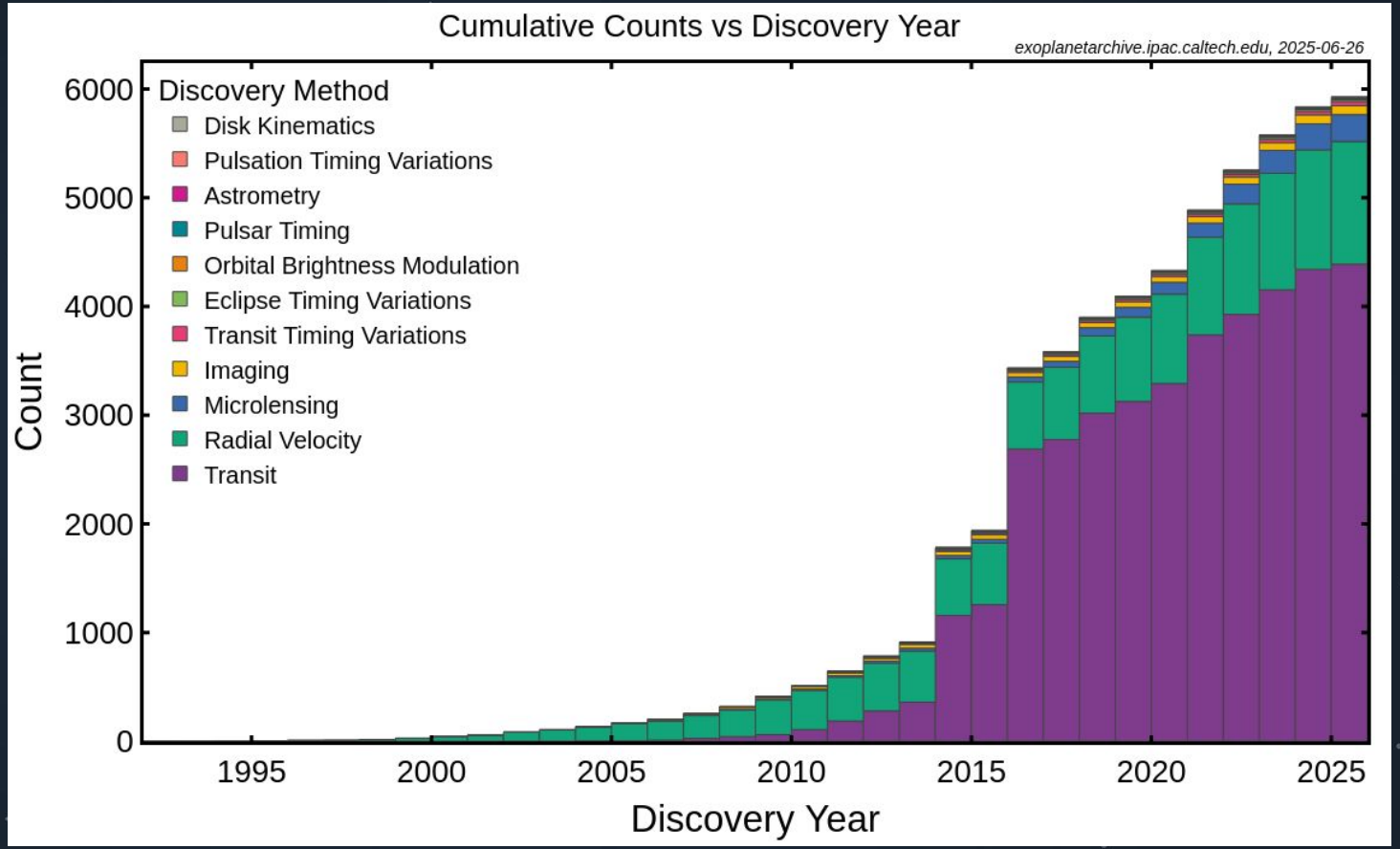
Me

Kepler (and K2) and TESS caused those two jumps!

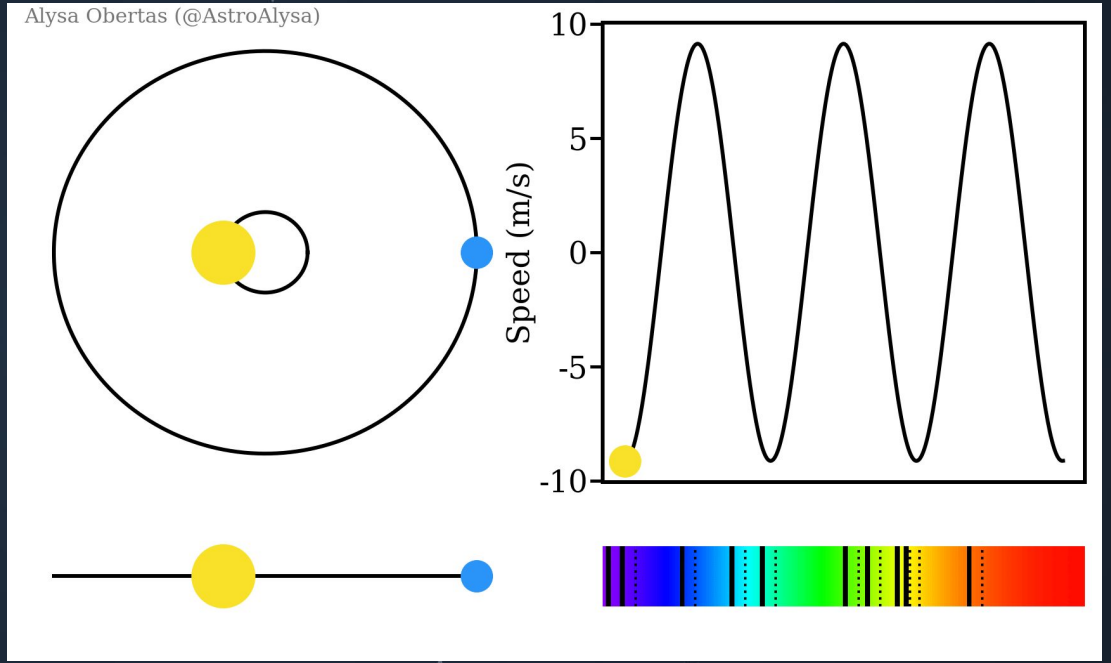


METHOD 2: RADIAL VELOCITIES

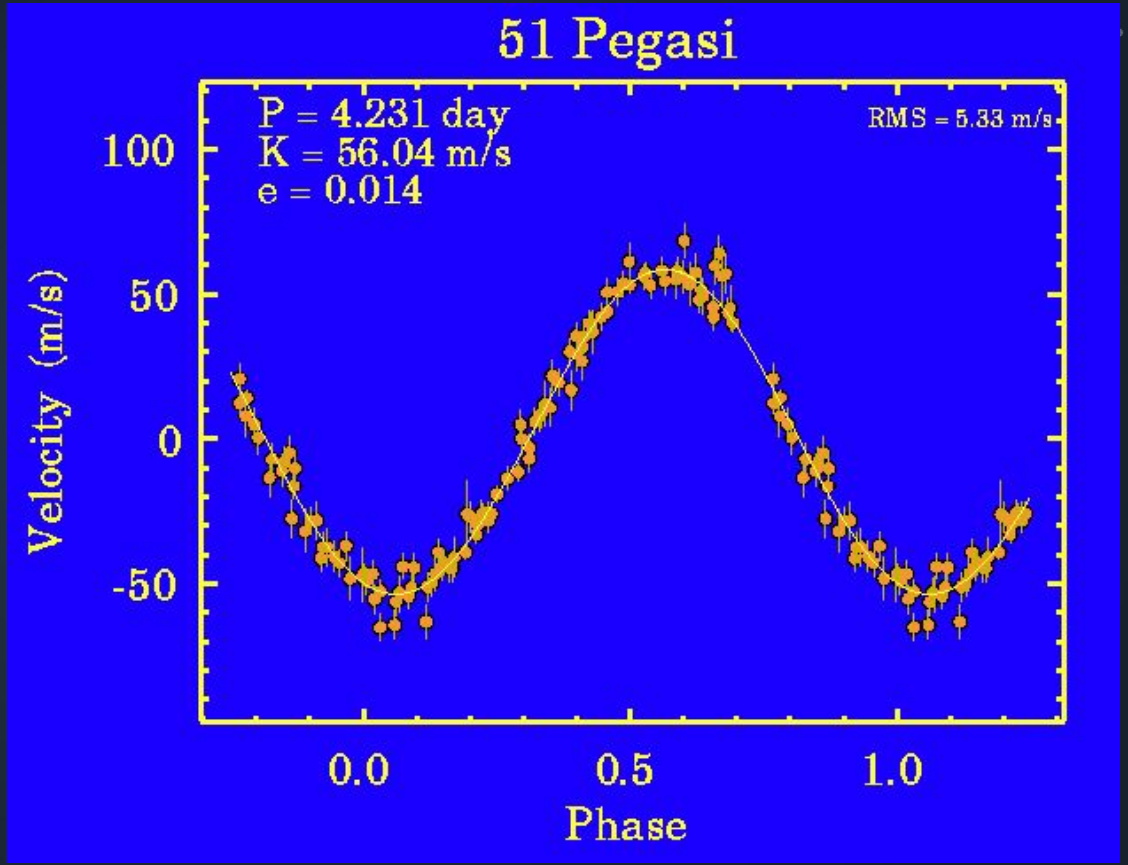
- Time-resolved spectroscopy to measure a planet's **Doppler shift**

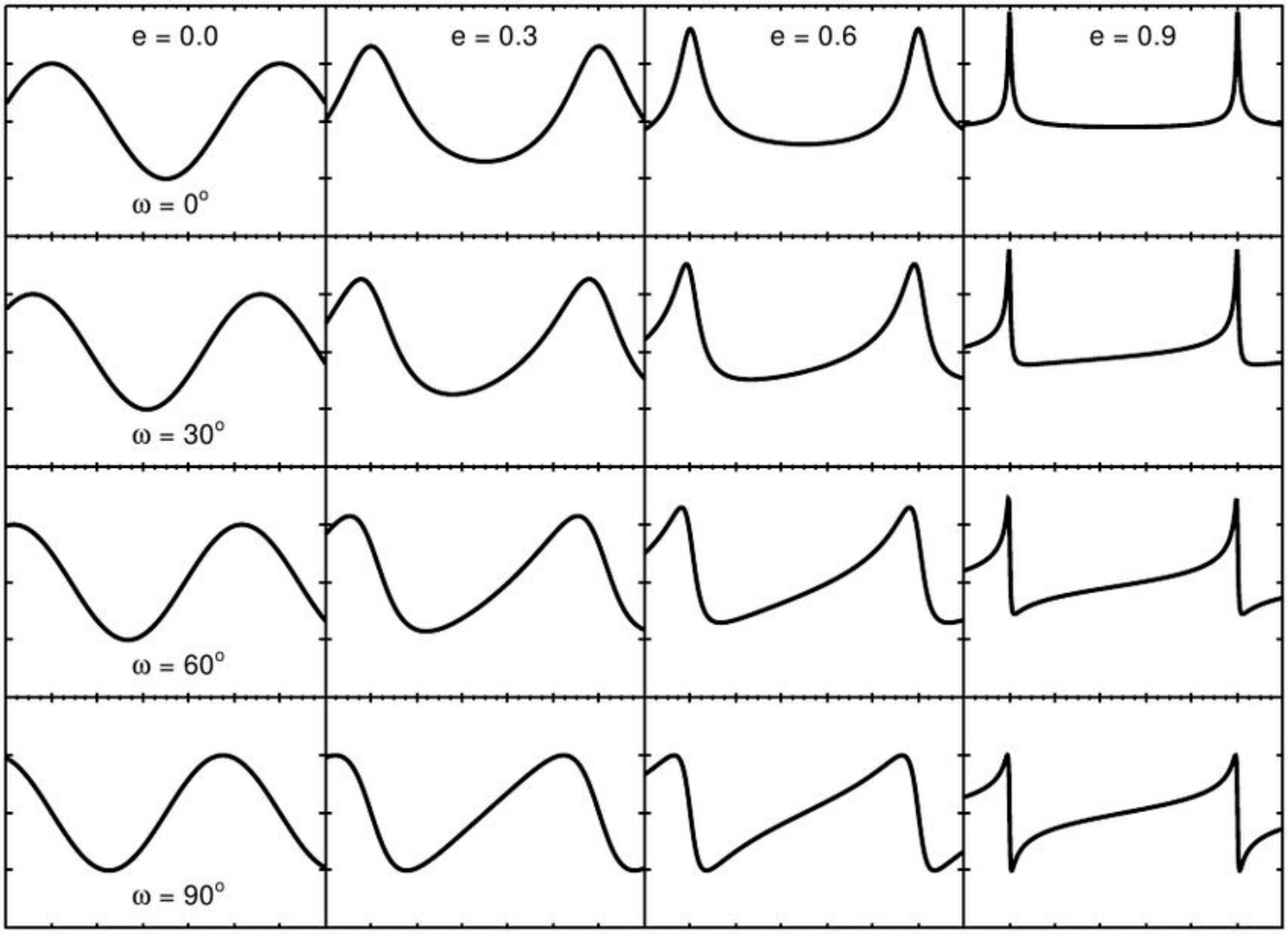
$$\lambda' = \lambda * \frac{\sqrt{1 + v/c}}{\sqrt{1 - v/c}}$$

- Can measure planet's period, eccentricity, and ***minimum* mass**

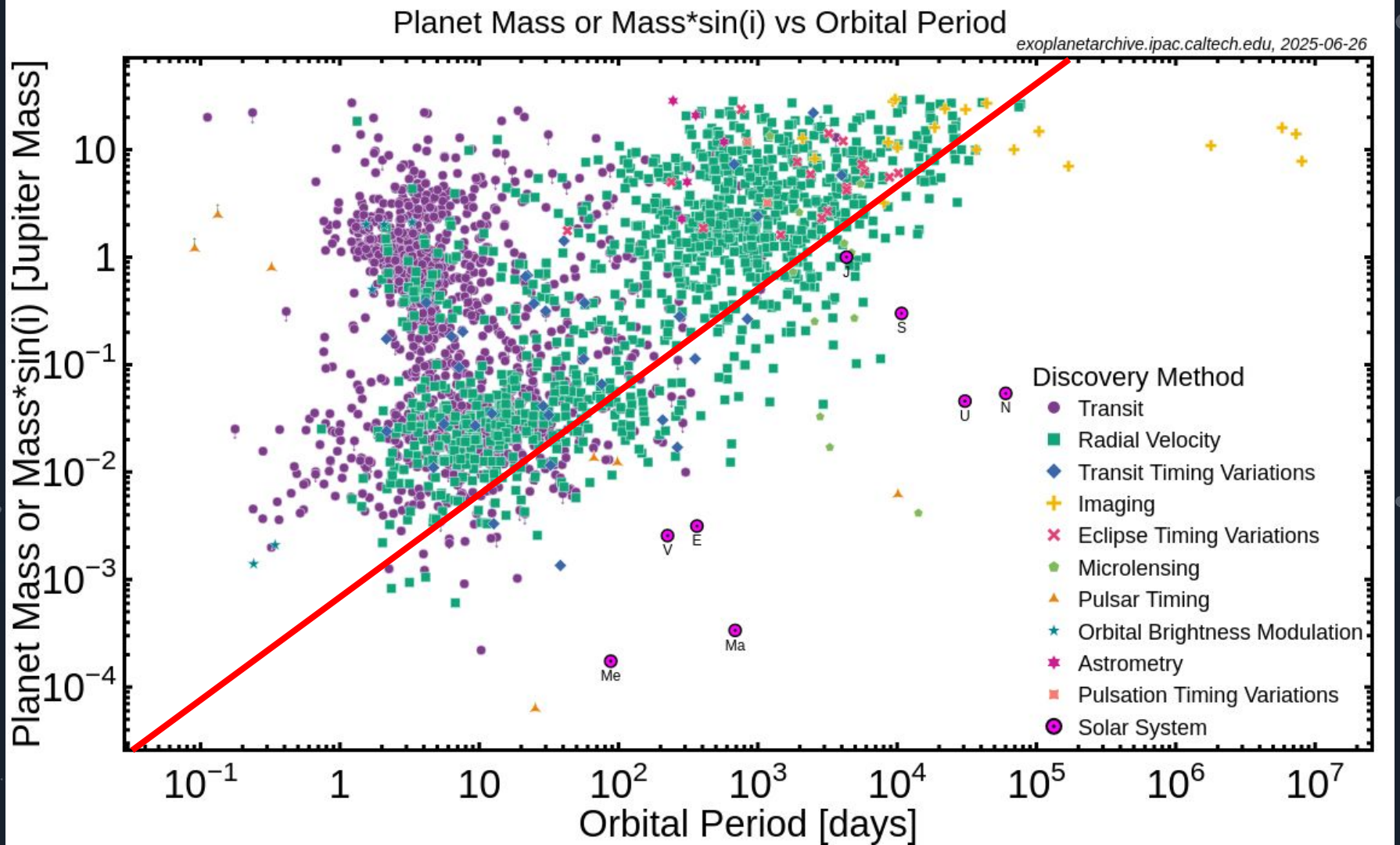


- Best instruments in the world (HARPS, NIRPS, MAROON-X, ESPRESSO, etc.) can reach precision of 1 m/s or lower!
- Instruments being built right now will reach precision of 10 cm/s




e = 0.0
e = 0.3
e = 0.6
e = 0.9
ω = 0°
ω = 30°
ω = 60°
ω = 90°

$$K = M_p \sin i \left(\frac{2\pi G}{P M_\star^2} \right)^{1/3}$$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Solar System
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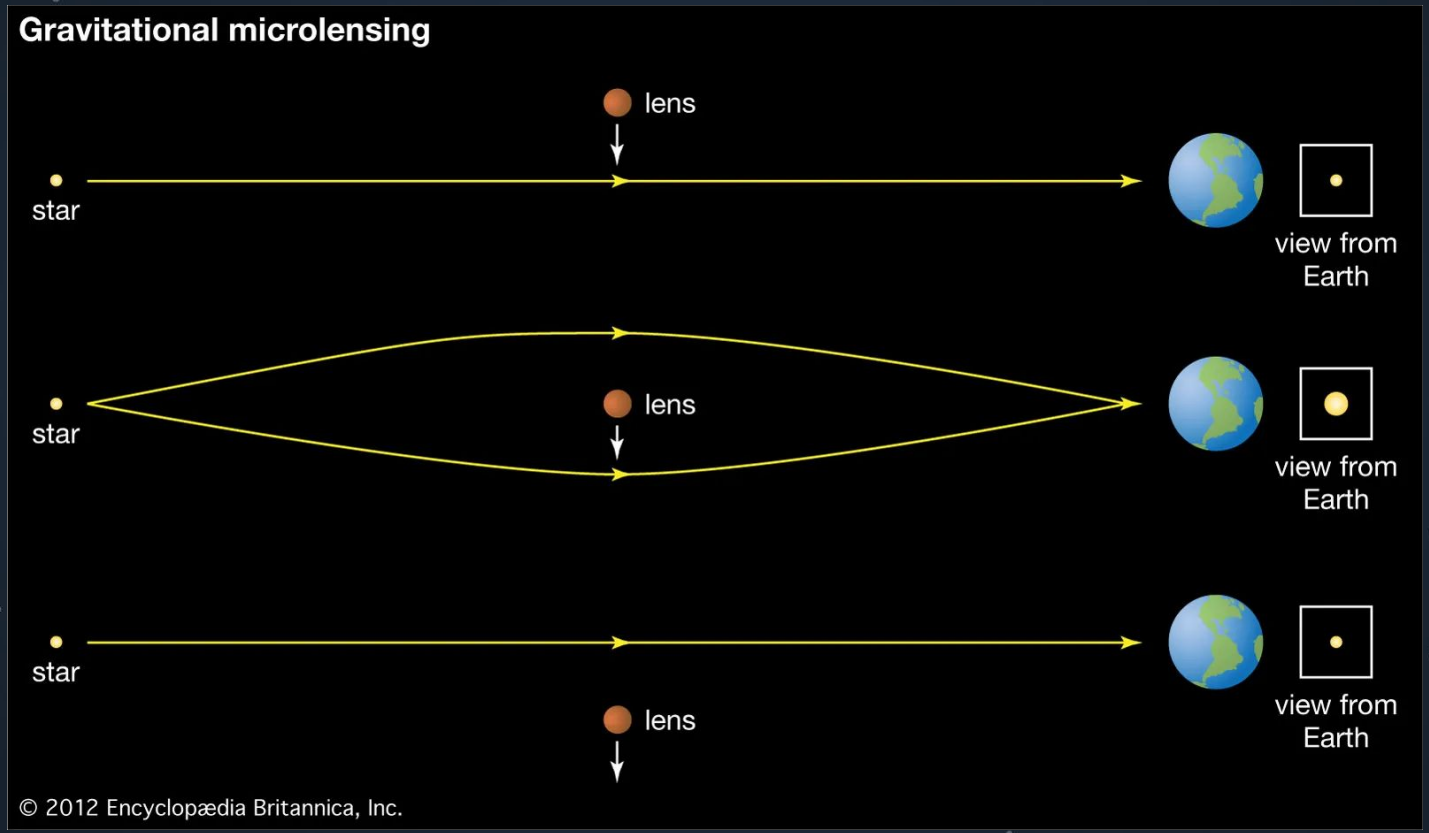
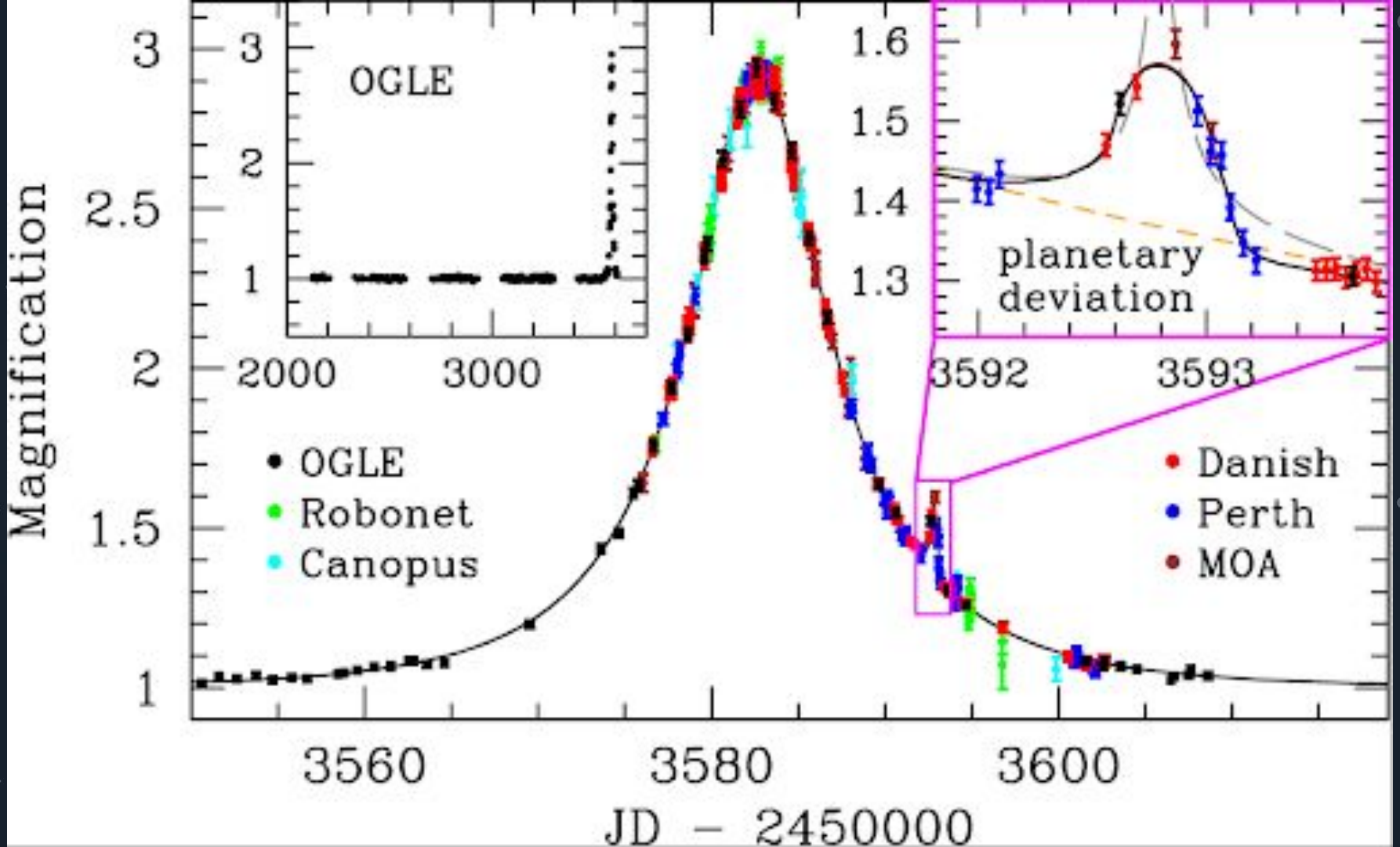
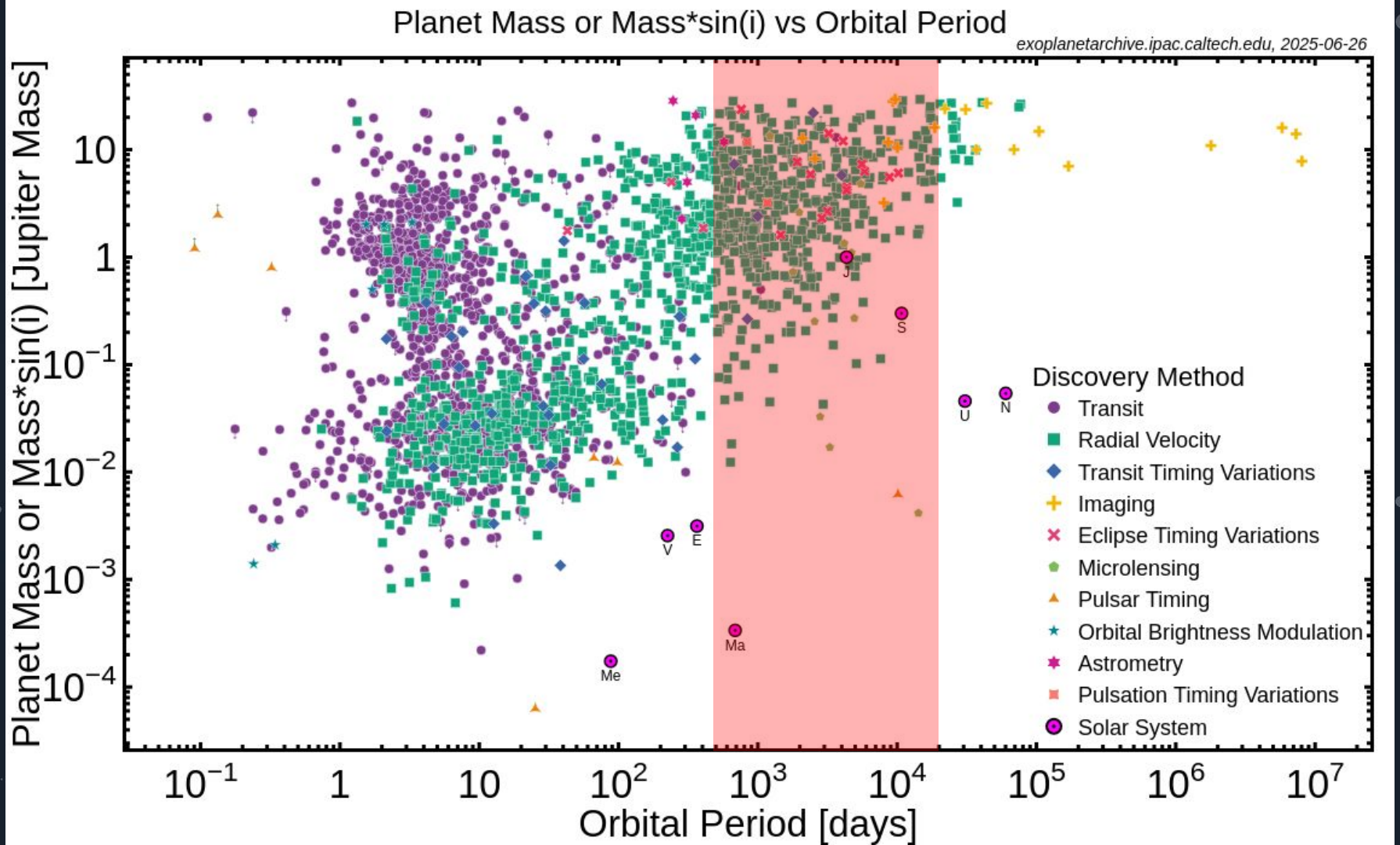
OTHER METHODS

METHOD 3: MICROLENSING




Magnification
JD − 2450000
OGLE
planetary deviation
OGLE
Robonet
Canopus
Danish
Perth
MOA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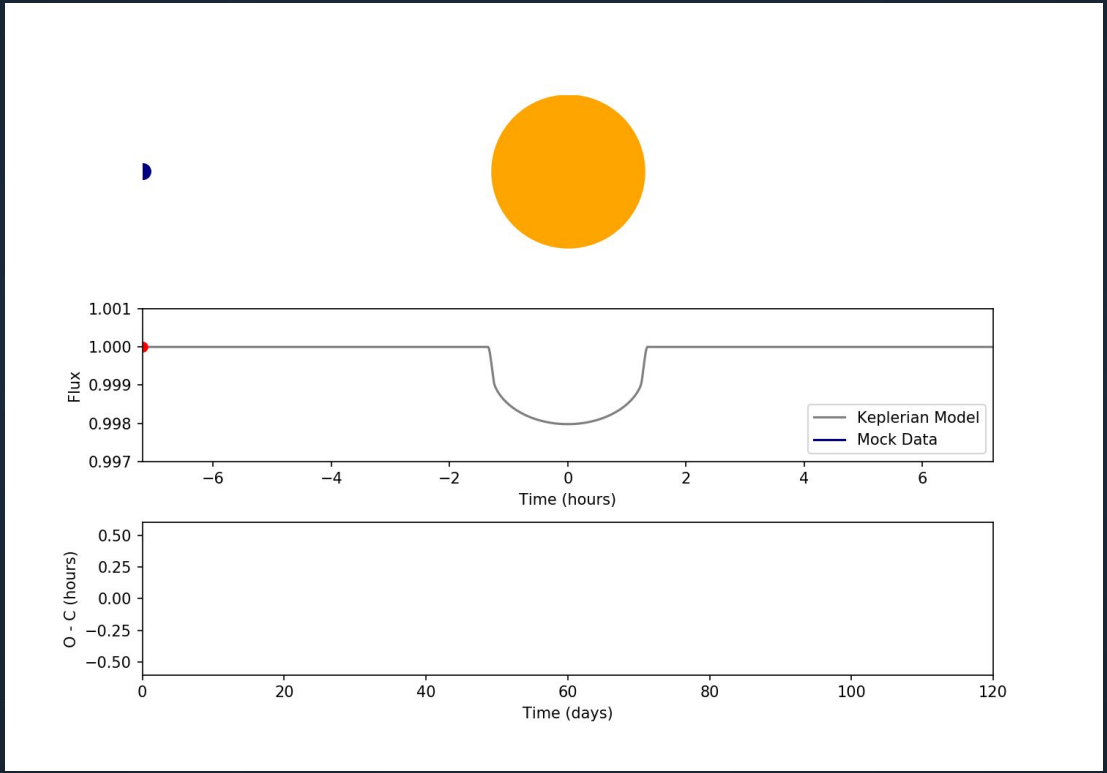
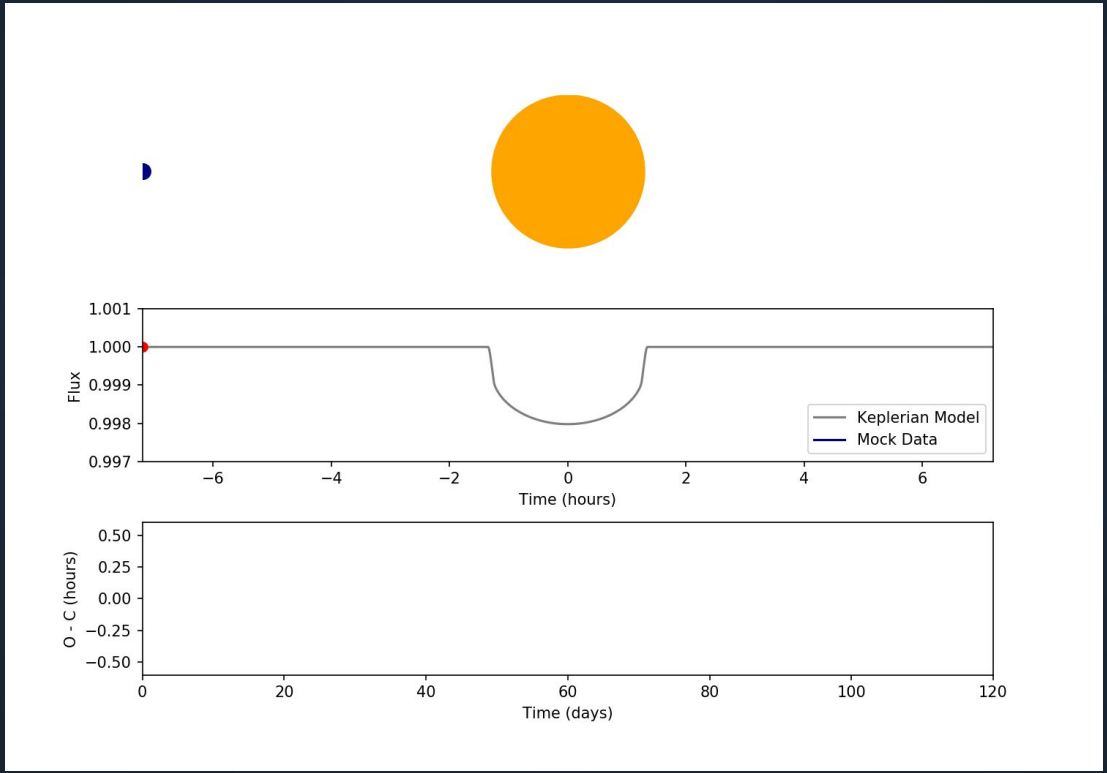
METHOD 4: TRANSIT TIMING VARIATIONS



Animations: Juliette Becker

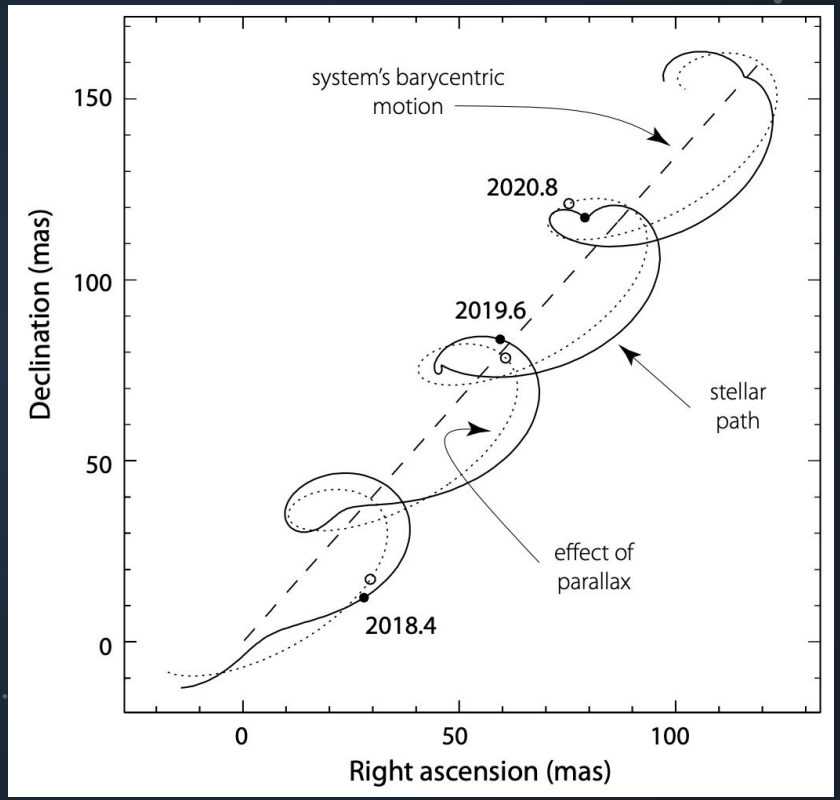
METHOD 4: TRANSIT TIMING VARIATIONS

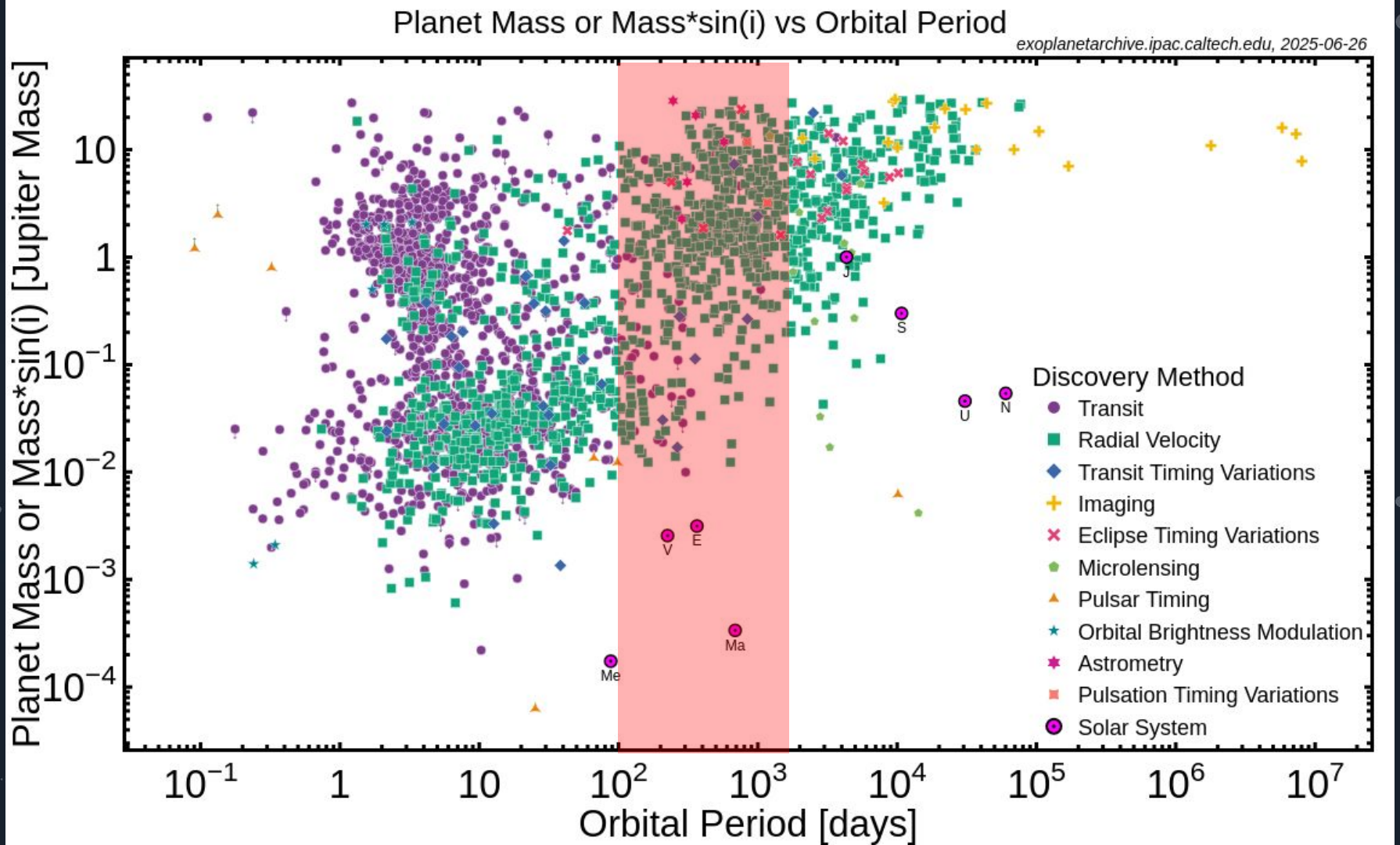


Animations: Juliette Becker

METHOD 5: ASTROMETRY

- Observe change in location of star due to planet motion
- REALLY hard to do, because stars barely move! Especially relative to motion of Earth around Sun or star's proper motion
- Final data from *Gaia* coming next year, should increase number of planets detected this way from 5 to ~many thousands
- Can tell period, eccentricity, minimum mass

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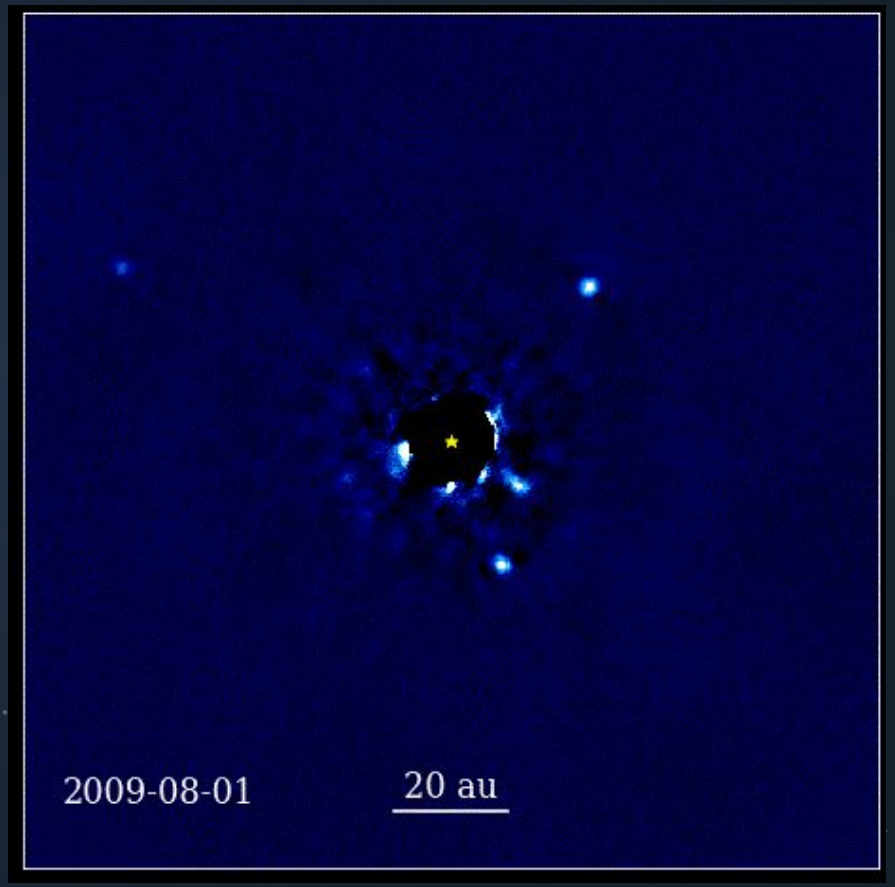
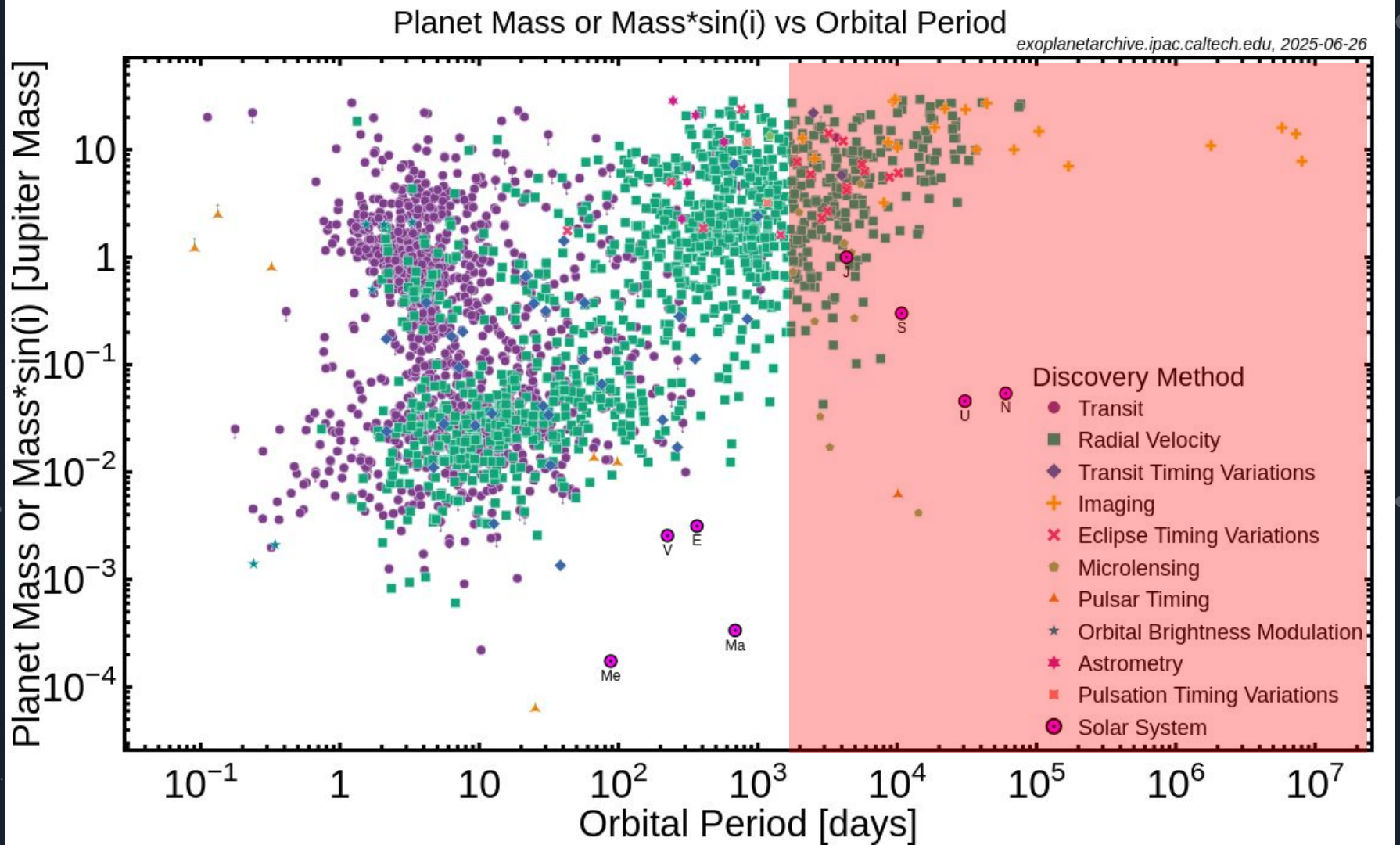
METHOD 6: DIRECT IMAGING

- See planets directly with big telescopes!
- Block out star with a **coronagraph**
- Only works on *big*, young planets really far away!
- Can tell planet period, eccentricity, rough idea of planet mass/size from brightness

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10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-1}
1
10
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
Orbital Period [days]
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