

# ASTR 405

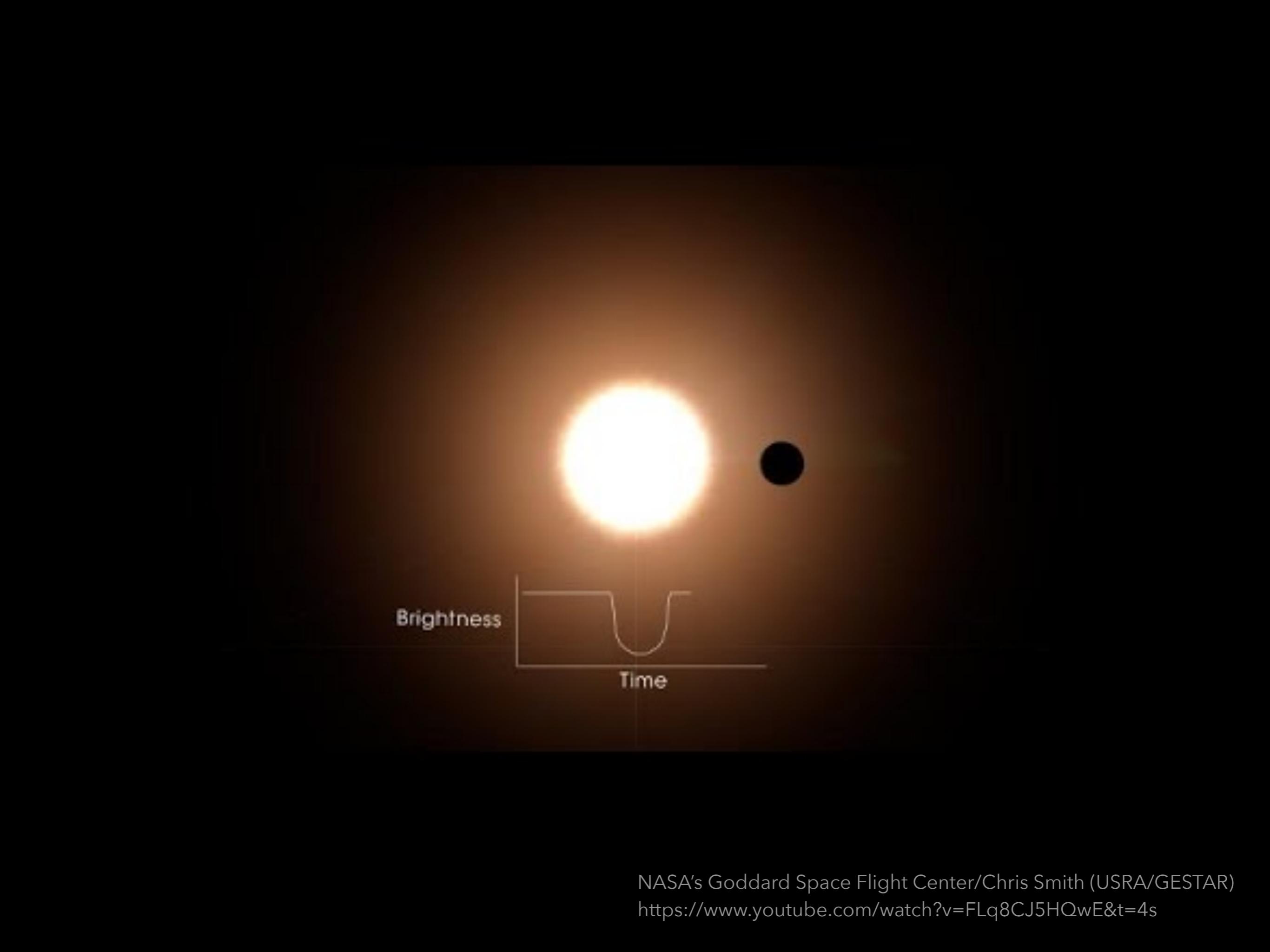
# Planetary Systems

## Transit

Fall 2025  
Prof. Jiayin Dong

# Module I: Exoplanet Detection Methods

- Radial Velocity: detecting exoplanets by measuring Doppler shifts from a star's radial reflex motion along our line of sight
- Astrometry: detecting exoplanets by measuring tiny changes in a star's sky position from its tangential reflex motion
- Transit: detecting exoplanets by observing **the dimming of a star's light** when a planet passes in front of it
- Microlensing
- Direct Imaging

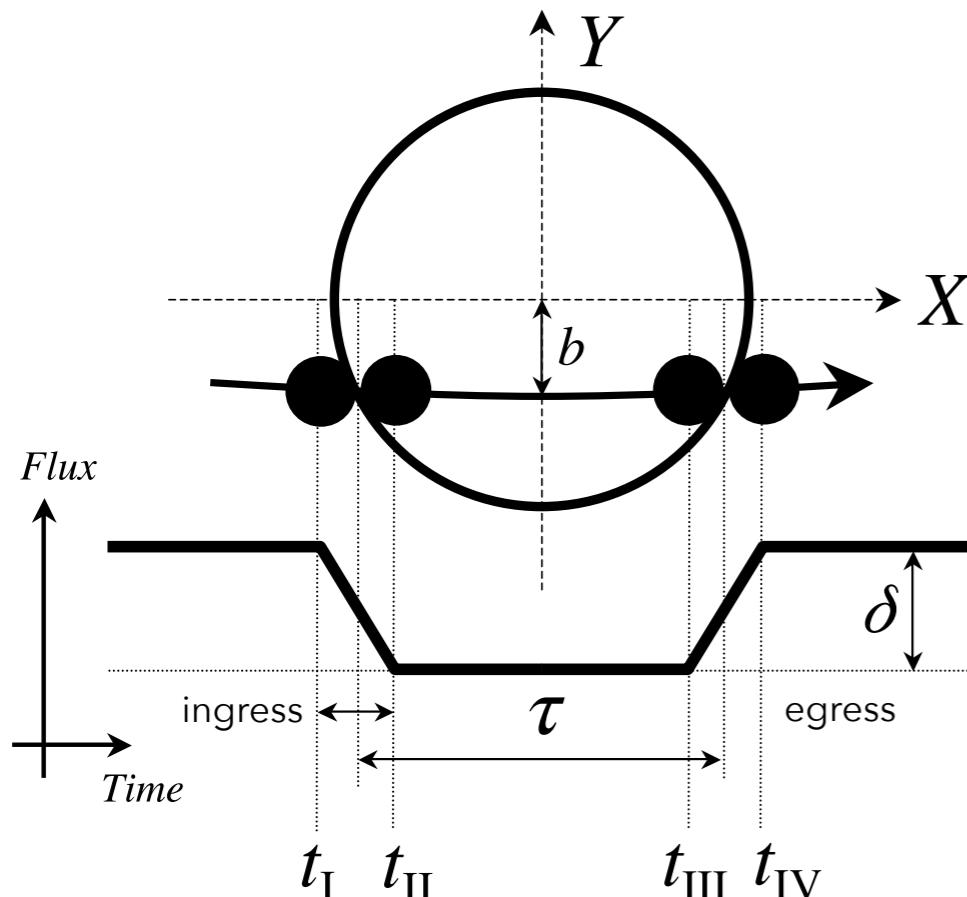


A diagram illustrating a transit event, likely a solar eclipse. At the top, a large, bright yellow-orange circle represents the Sun, and a smaller black circle to its right represents a celestial body like Earth or the Moon. Below this, a graph shows 'Brightness' on the vertical axis and 'Time' on the horizontal axis. The graph displays a sharp drop in brightness (the 'eclipse') starting from the left edge of the black circle, reaching a minimum at the center, and returning to baseline as it exits on the right. A small white segment is visible on the far left of the graph.

Time

NASA's Goddard Space Flight Center/Chris Smith (USRA/GESTAR)  
<https://www.youtube.com/watch?v=FLq8CJ5HQwE&t=4s>

# Transit Depth, Duration, and Impact Parameter



Adapted from Winn 09

- Transit depth

$$\delta = (R_p/R_\star)^2$$

- Impact parameter

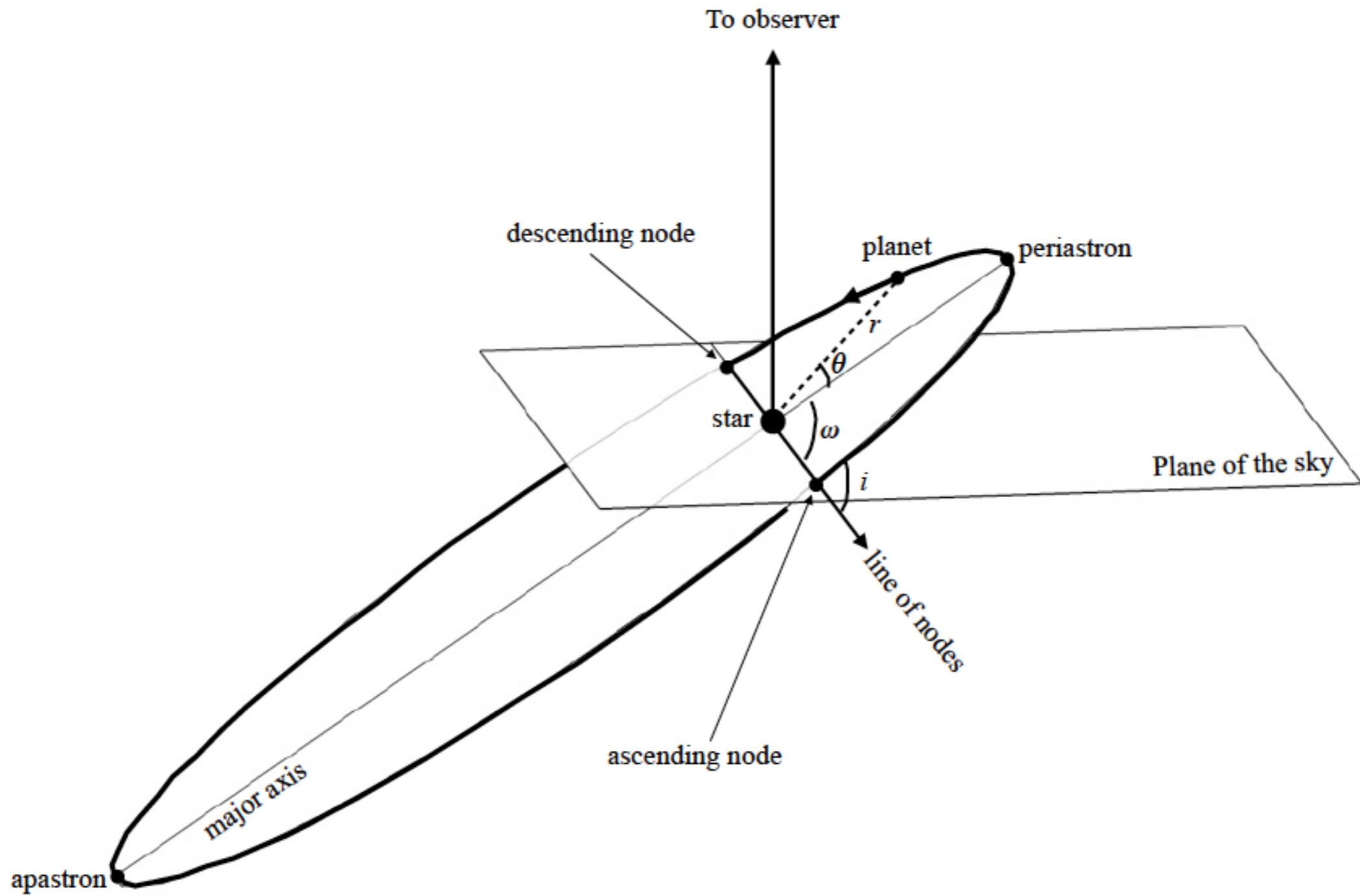
$$b = a \cos i / R_\star$$

- Transit duration

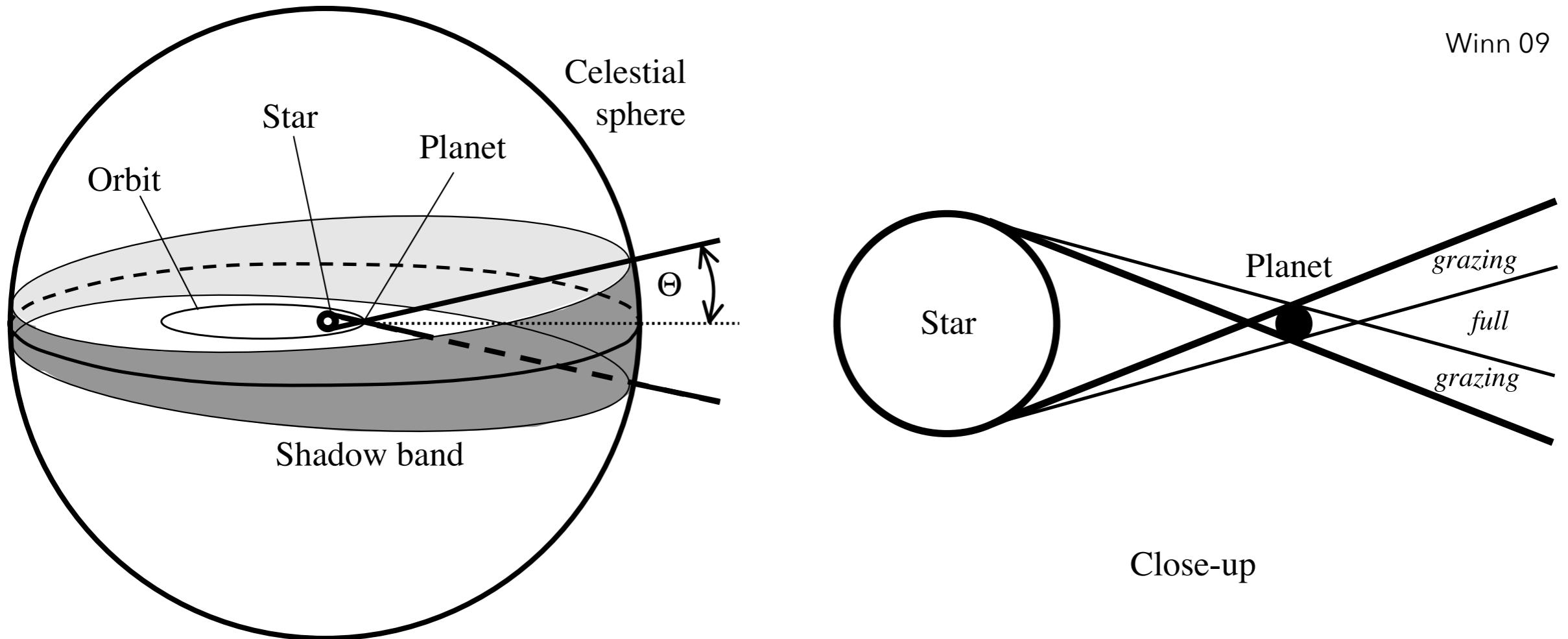
$$\tau \approx \frac{2R_\star}{v_p} \approx 13 \text{ hr} \left( \frac{M_\star}{M_\odot} \right)^{-1/2} \left( \frac{a}{1 \text{ au}} \right)^{1/2} \left( \frac{R_\star}{R_\odot} \right)$$

- Ingress ( $t_I \rightarrow t_{II}$ )
- Egress ( $t_{III} \rightarrow t_{IV}$ )

# Geometry of a 3D Orbit



# Transit Probability



$$P_{\text{transit}} \sim \frac{\text{Solid angle of the shadow band}}{\text{Solid angle of the sphere}} \sim \frac{R_\star}{a}$$

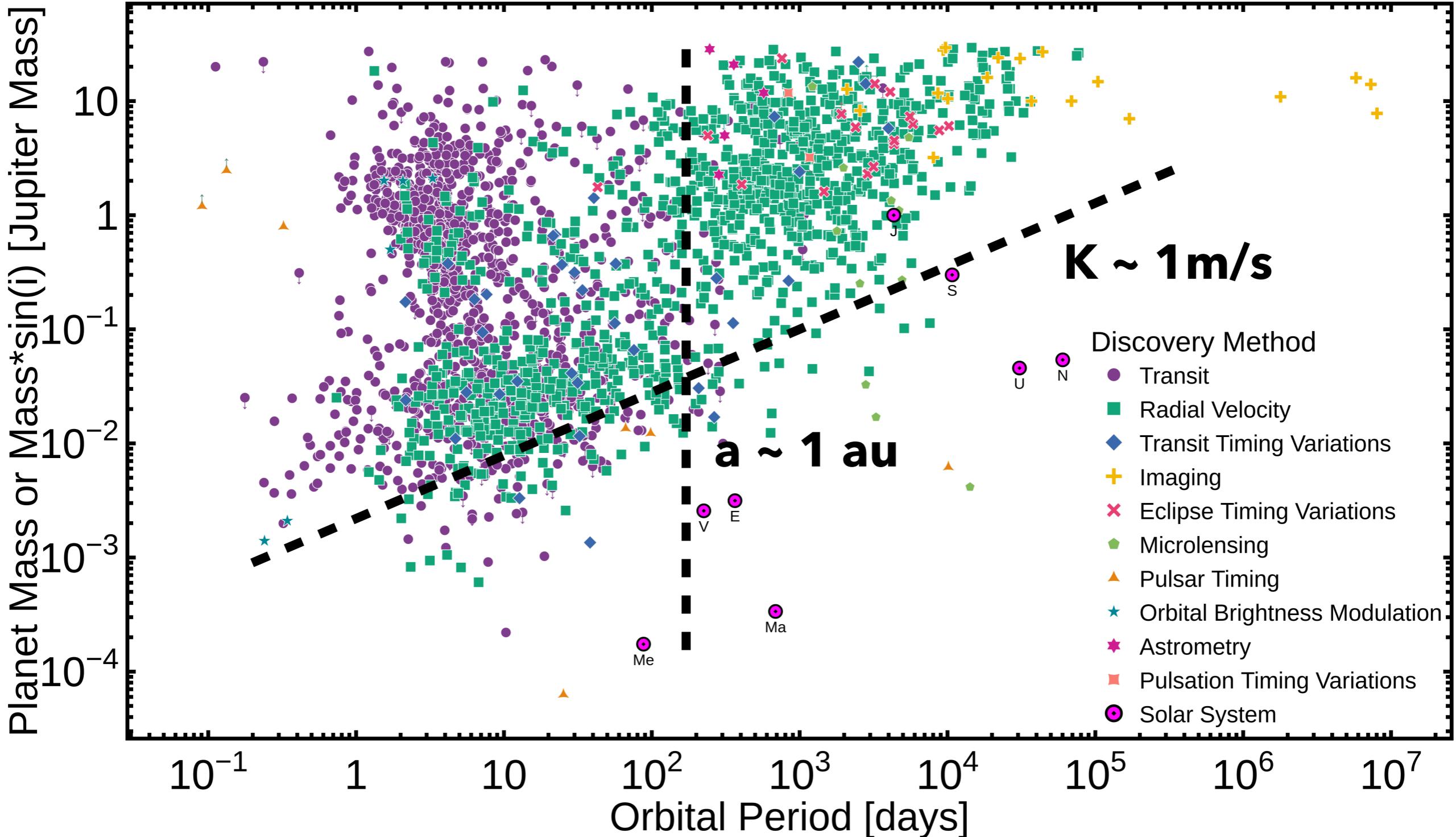
## **In-Class Activity**

Calculating Transit Depth and Probability

# Exoplanet Mass–Period Distribution

Planet Mass or Mass $\cdot\sin(i)$  vs Orbital Period

exoplanetarchive.ipac.caltech.edu, 2025-08-14



# Transit Missions

## Ground-based

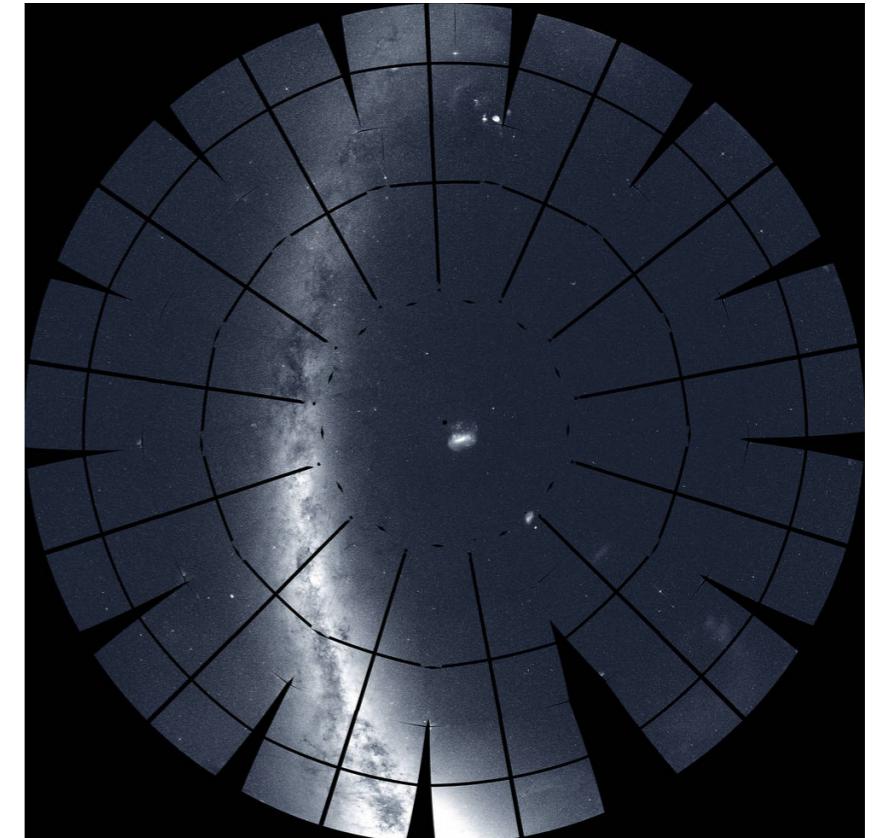
- Early Efforts: HD 209458b (first transit exoplanet)
- Ongoing surveys: **SPECULOOS** (targeting M dwarfs, team previously discovered TRAPPIST 1), **HAT-PI** (just commissioned, ultra-wide field of view)



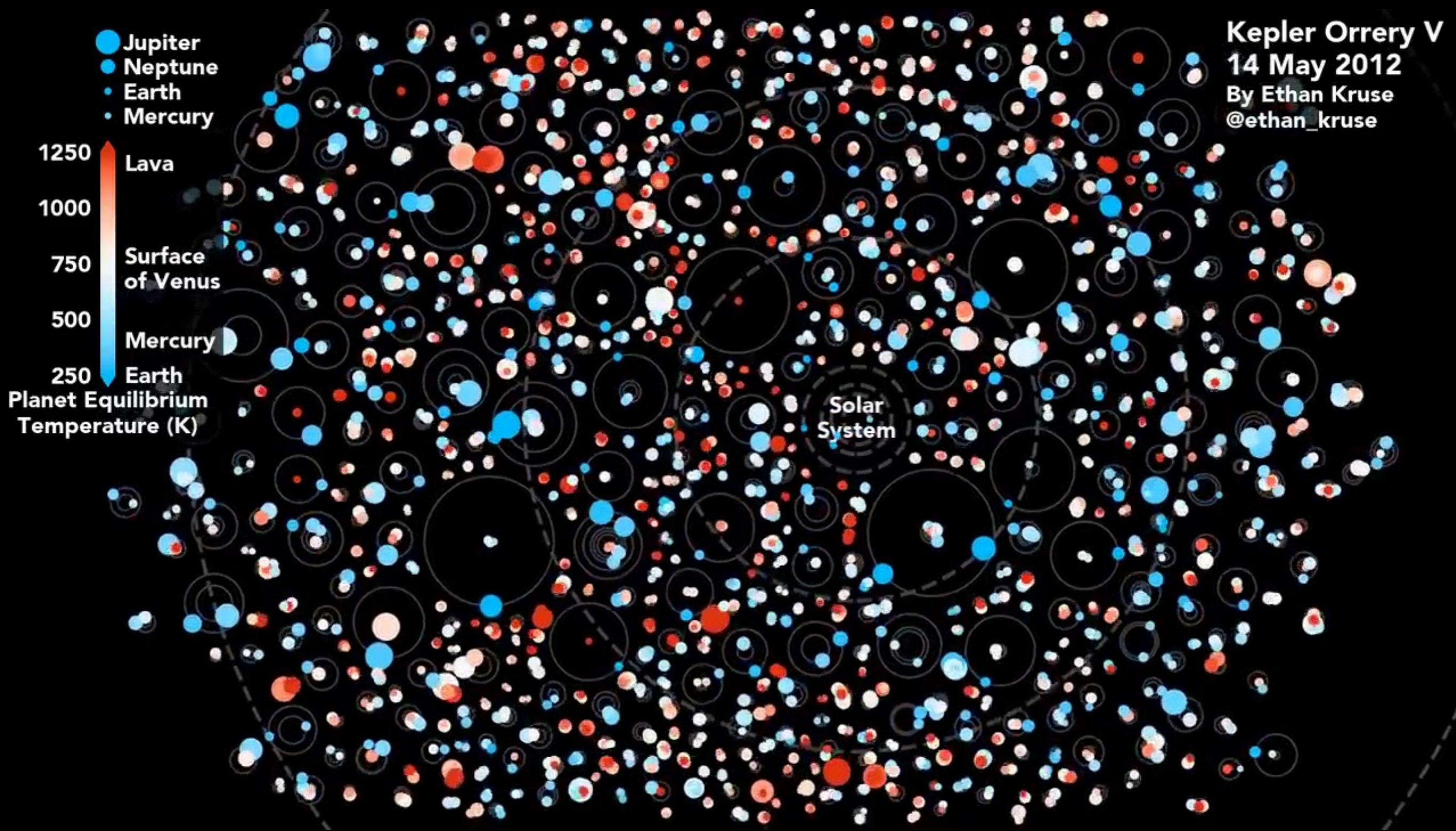
Optical array of HAT-PI

## Space-based

- **CoRoT** (2006–2013): first space transit observatory
- **Kepler & K2** (2009–2018): most transformative exoplanet transit mission
- **TESS** (2018–present): first all-sky survey
- **CHEOPS** (2020–present)



Mosaic of the southern sky taken by NASA's TESS.  
(Image credit: NASA/MIT/TESS/Ethan Kruse/USRA)

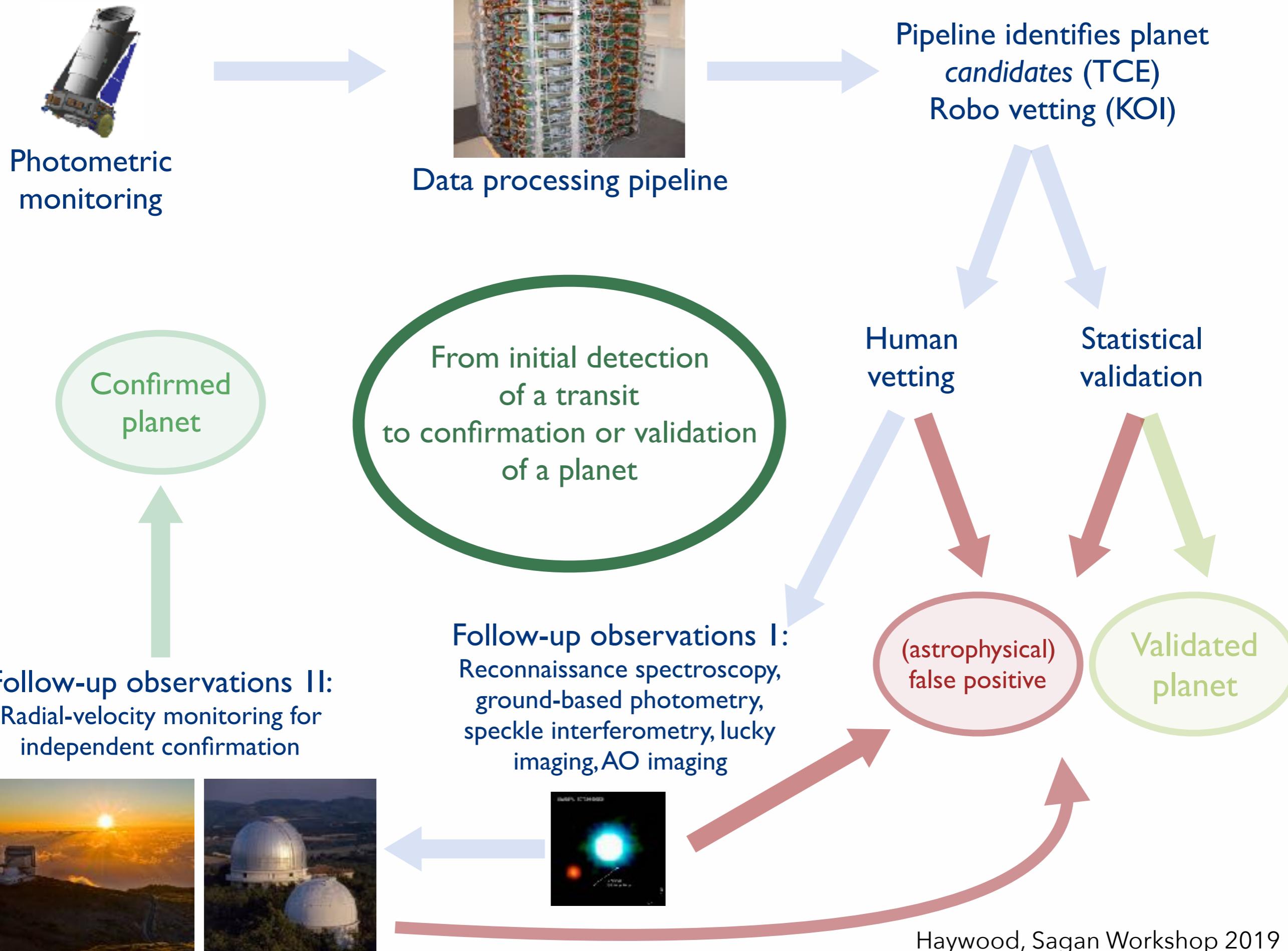


[https://www.youtube.com/watch?v=5I\\_FOEh47RY](https://www.youtube.com/watch?v=5I_FOEh47RY)

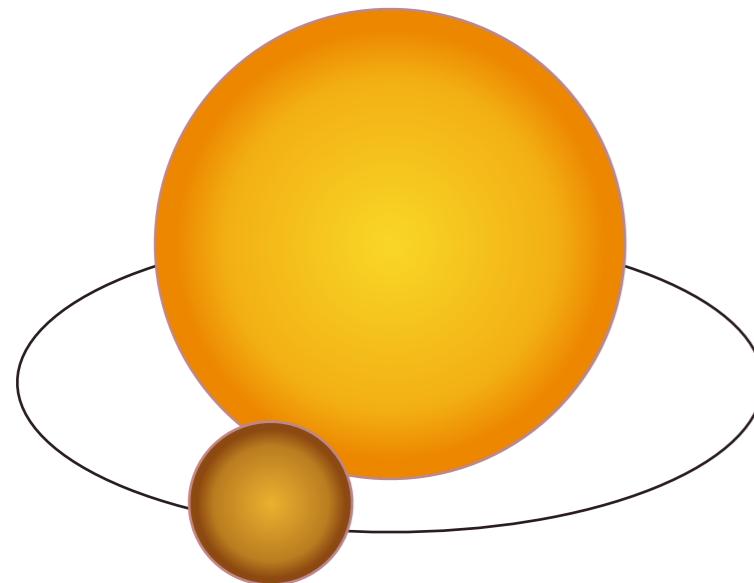
# **In-Class Activity**

## Drawing Transits

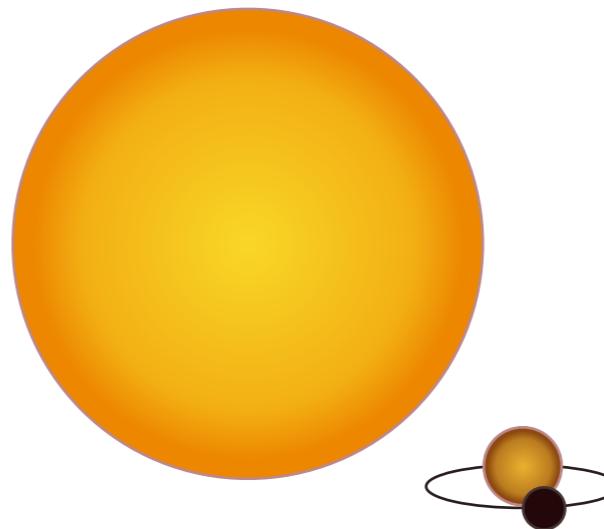
**From initial detection  
of a transit  
to confirmation or validation  
of a planet**



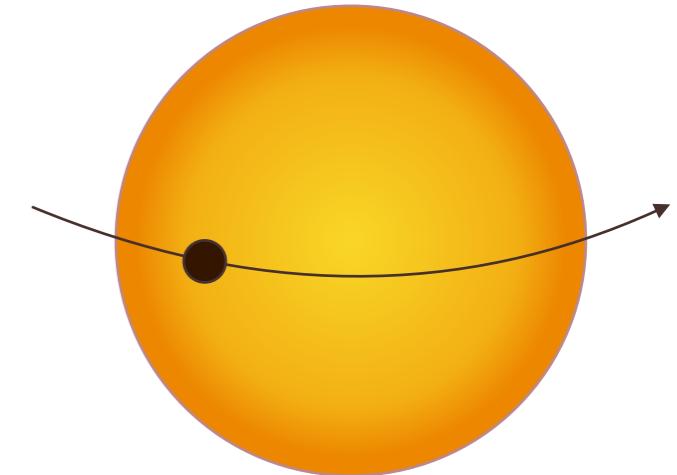
# Astrophysical scenarios that create transits (astrophysical false positives)



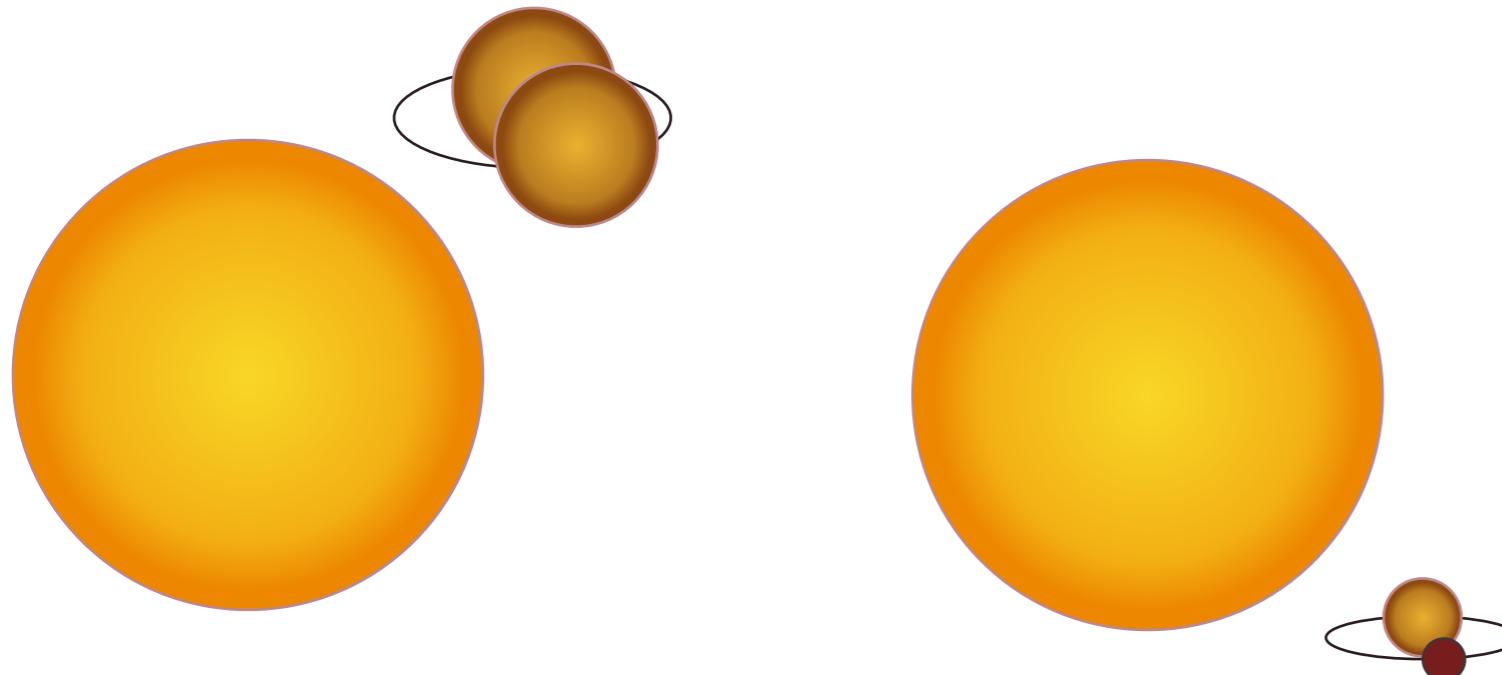
Grazing stellar binaries



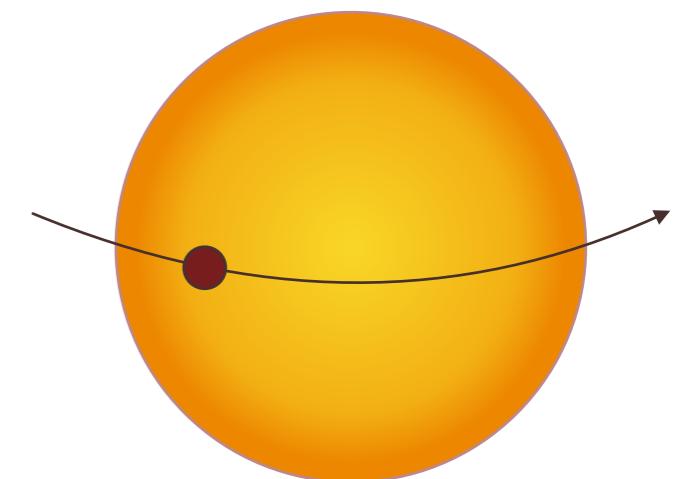
Background transiting planet



Transiting planets



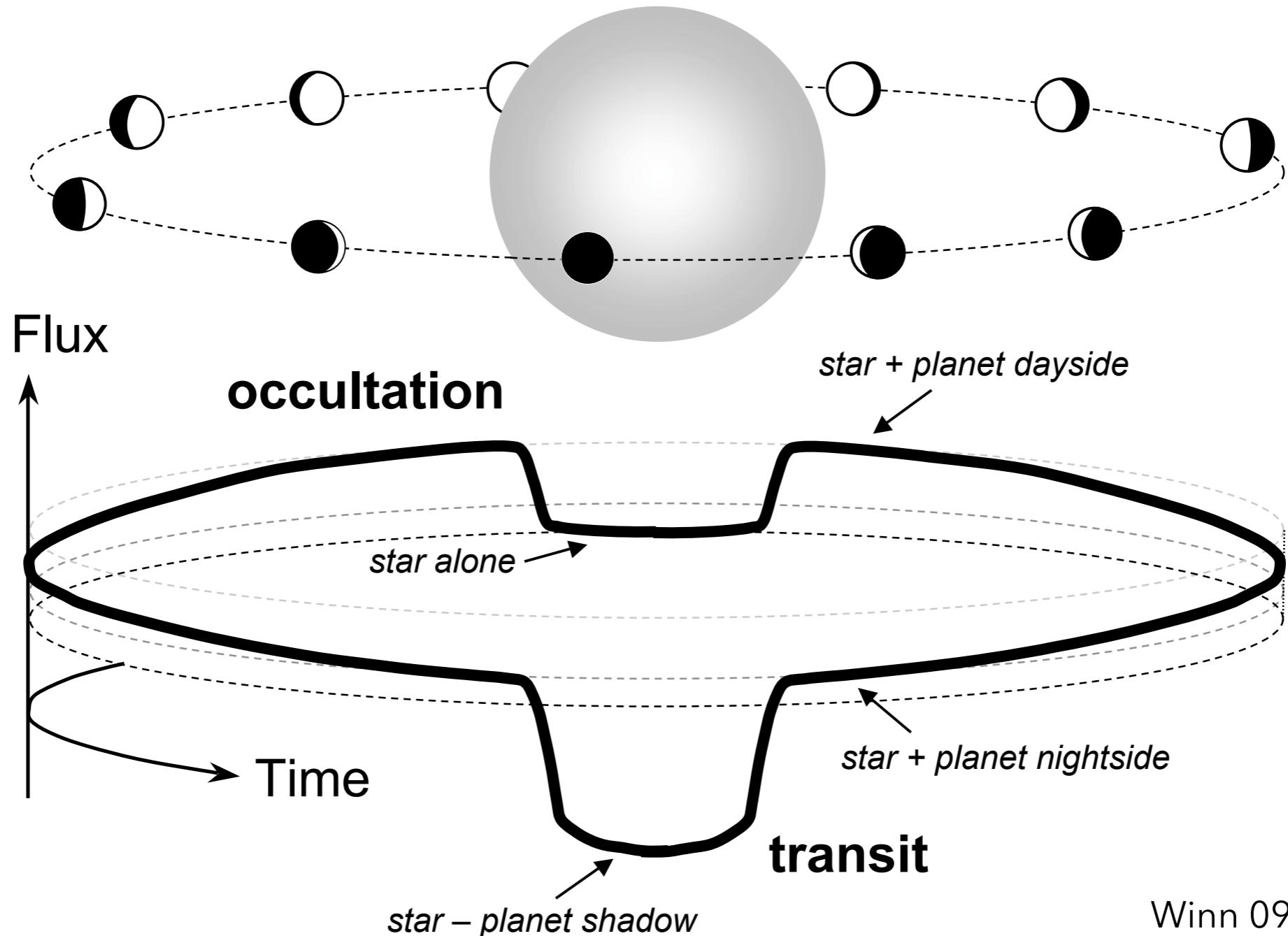
Blended stellar binaries  
(background eclipsing binaries)



Transiting red/brown dwarfs

Morton et al. 2011, 2012; Santerne et al., 2012, 2013; Latham et al. 2009;  
Collier Cameron et al. 2007; Pont et al. 2005 and others

# A Complete Picture of Eclipses



Winn 09