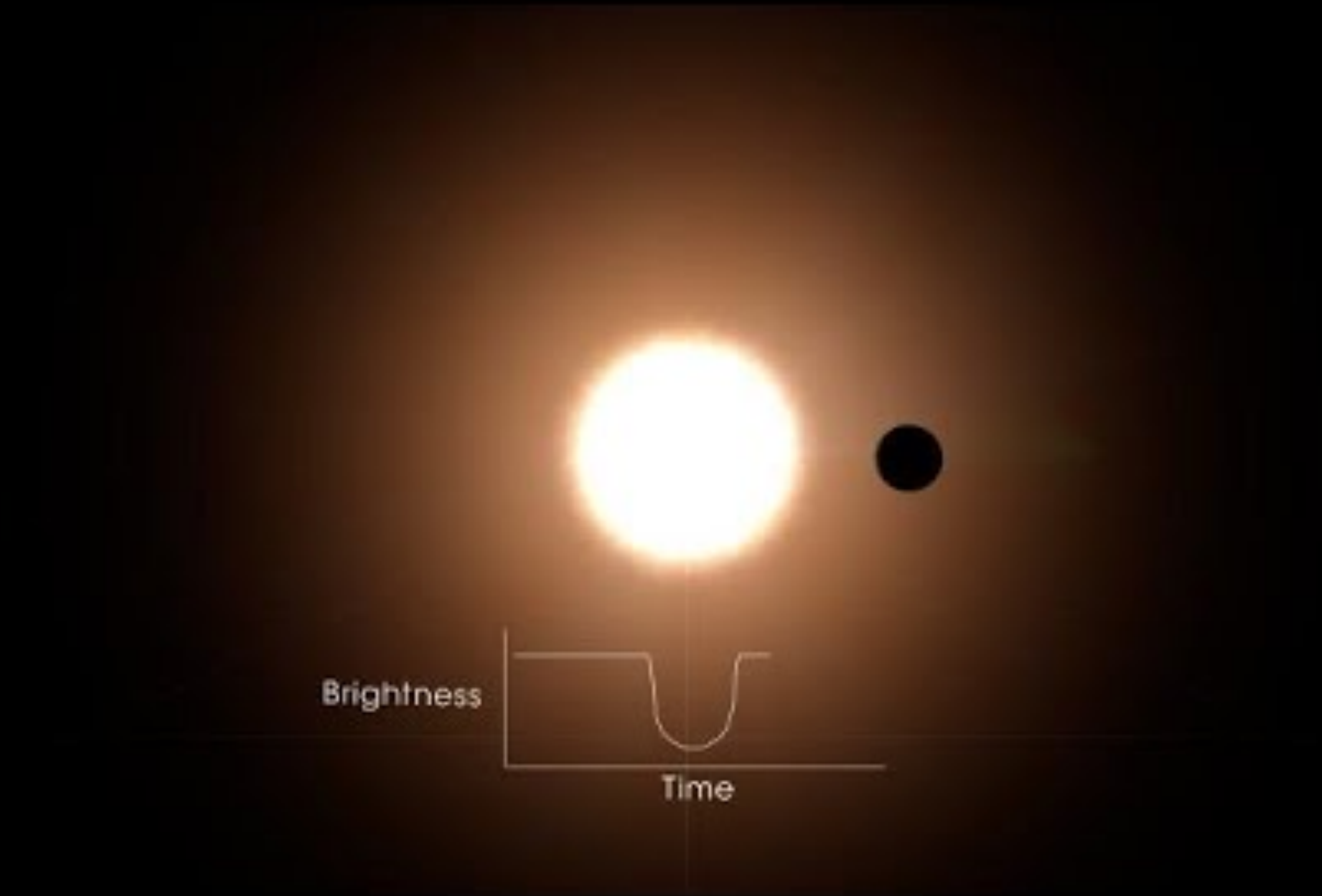
ASTR 405
Planetary Systems
Transit

Fall 2025

Prof. Jiayin Dong

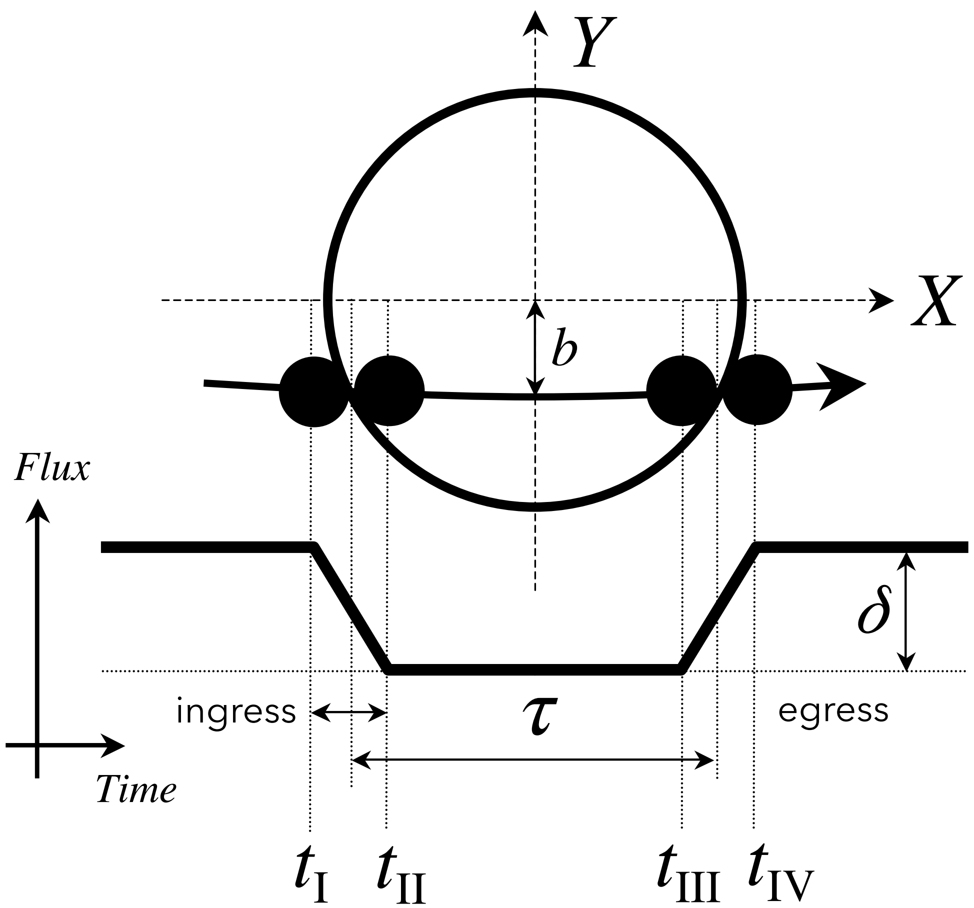
Module I: Exoplanet Detection Methods

- 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



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

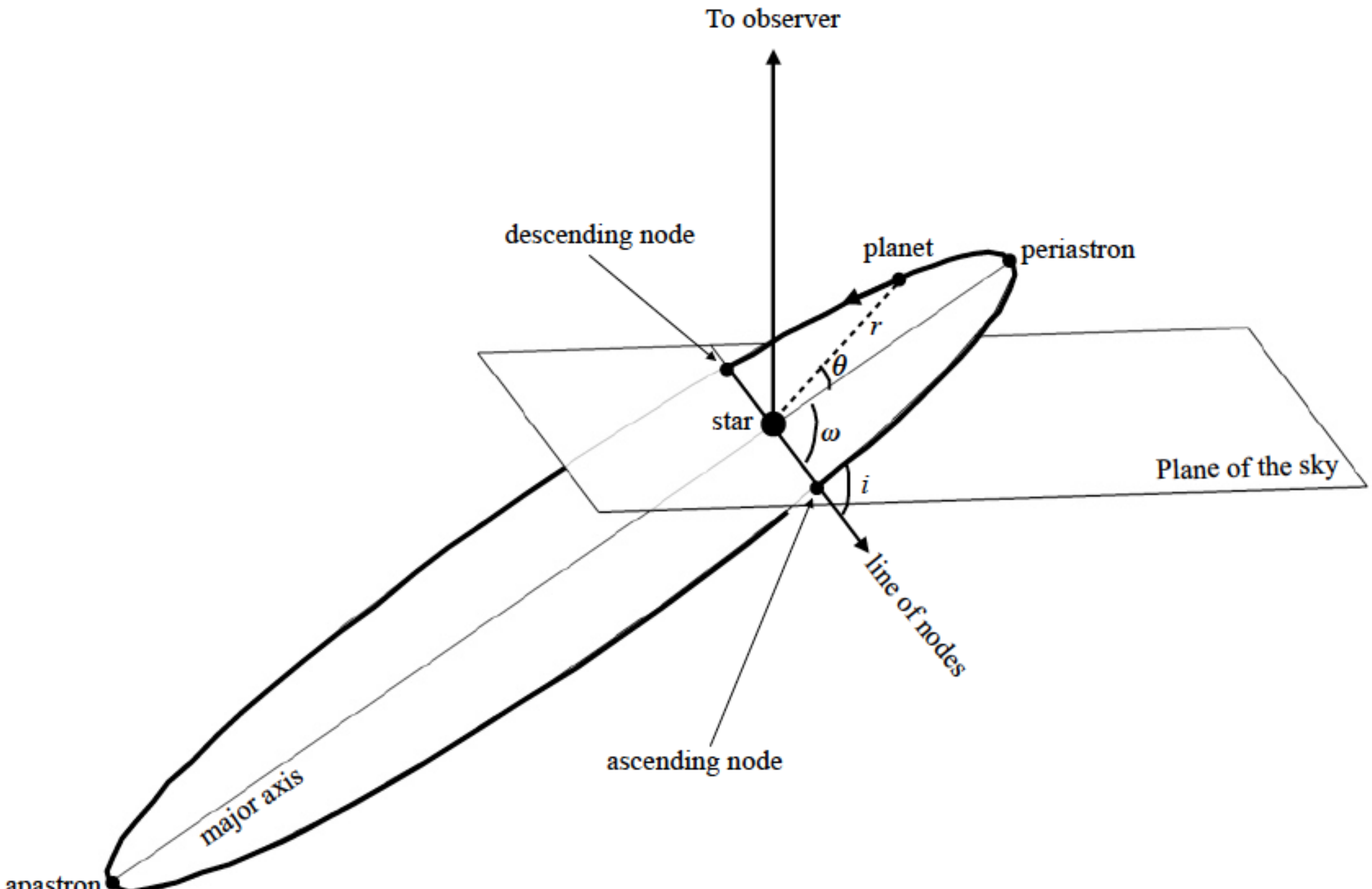
$$b = a\cos i/R_\star$$

- Transit duration

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

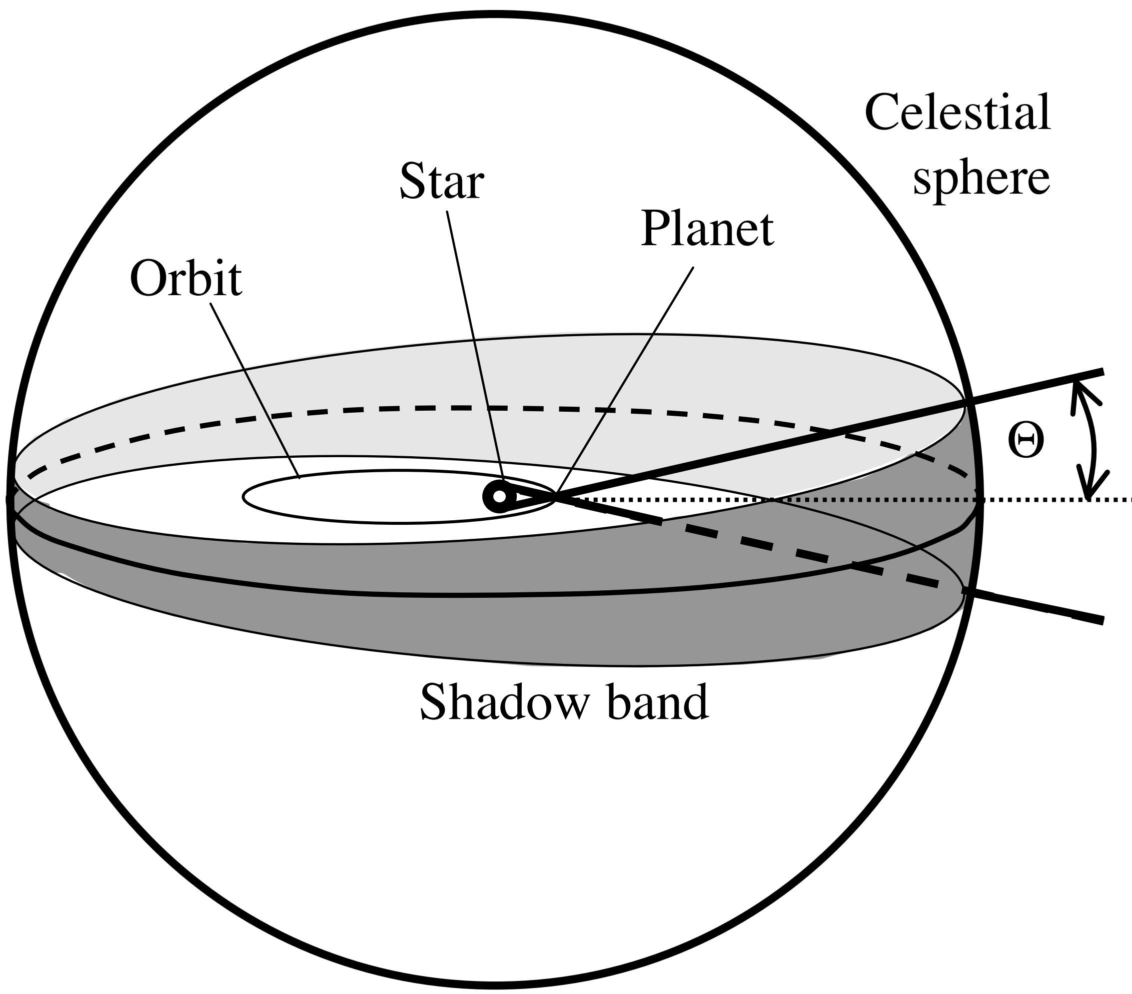
- Ingress ($t_\mathrm{I} \rightarrow t_\mathrm{II}$)
- Egress ($t_\mathrm{III} \rightarrow t_\mathrm{IV}$)

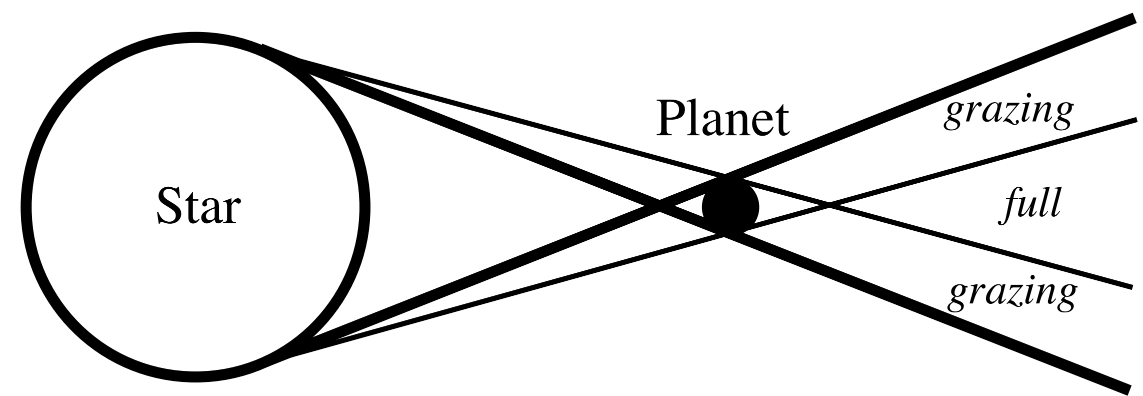
Geometry of a 3D Orbit



Transit Probability

Winn 09



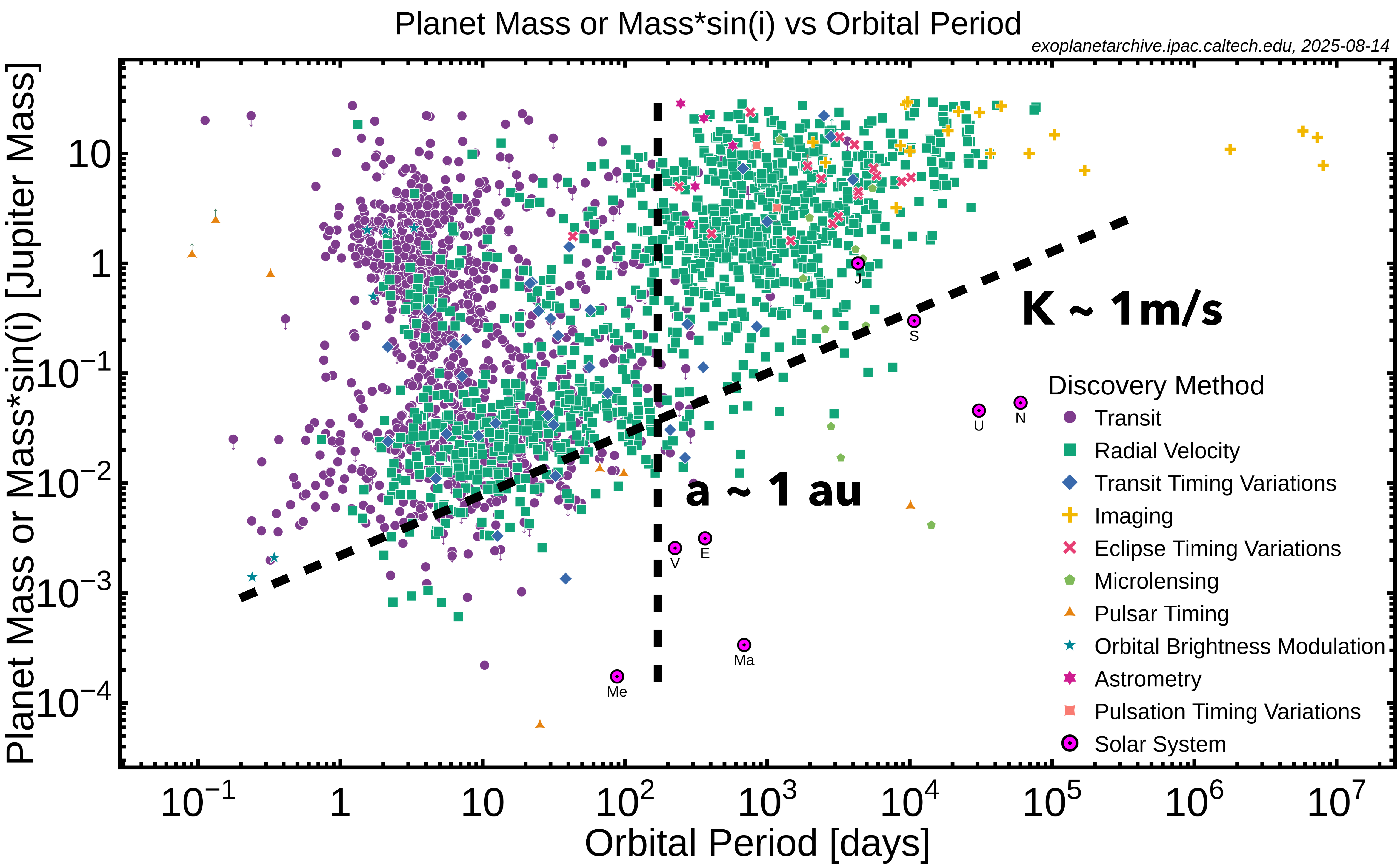


$$P_{\text{transit}} \sim \frac{\text{Solid angle of the shadow band}}{\text{Solid angle of the sphere}} \sim \frac{R_\star}{a}$$

In-Class Activity

Calculating Transit Depth and Probability

Exoplanet Mass–Period Distribution



Transit Missions

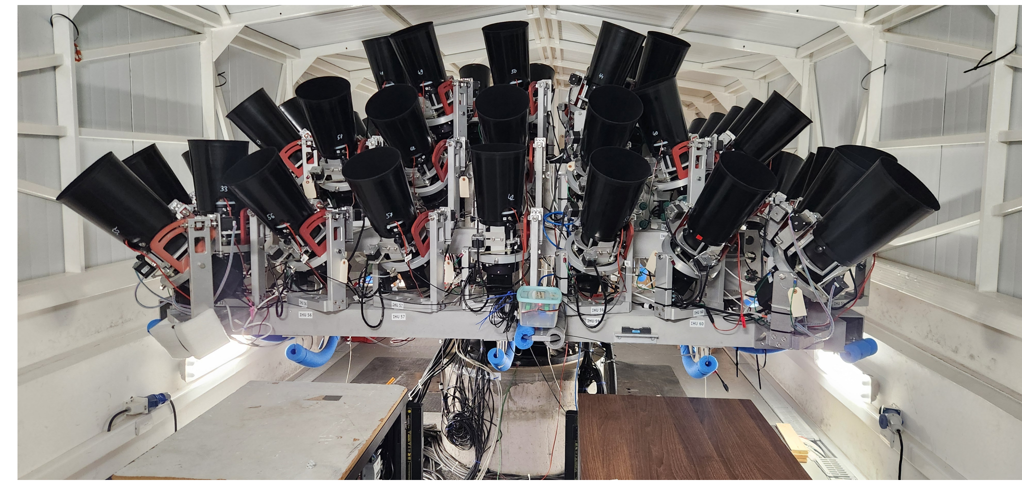
Ground-based

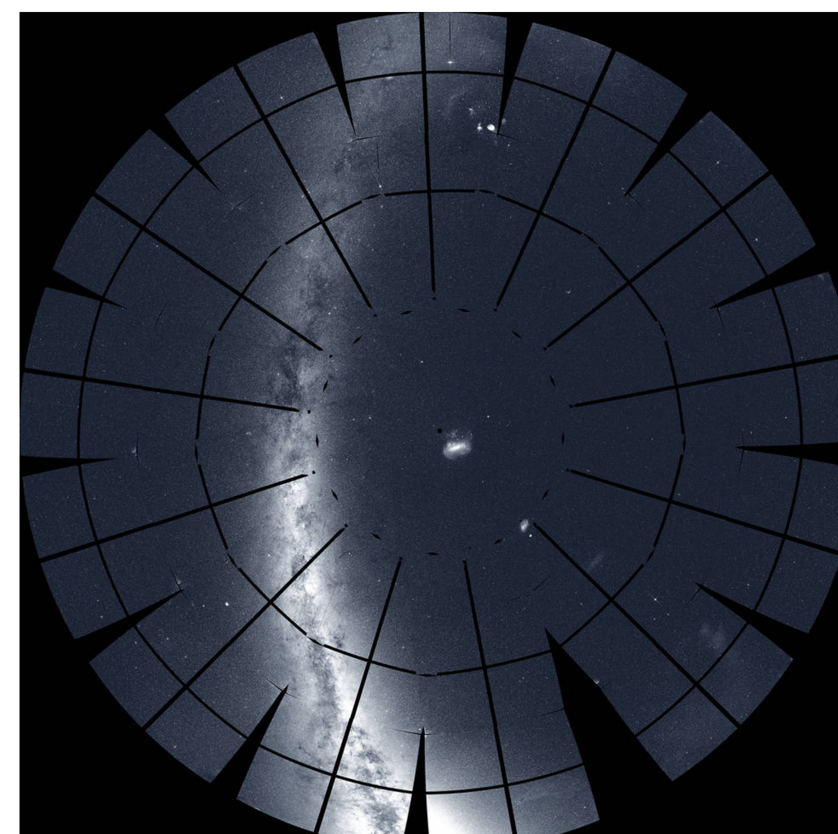
- Early Efforts: HD 209458b (first transit exoplanet)
- Ongoing surveys: **SPECULOOS** (targeting M dwarfs, team previously discovered TRAPPIST 1), **HAT-PI** (just commissioned, ultra-wide field of view)

Space-based

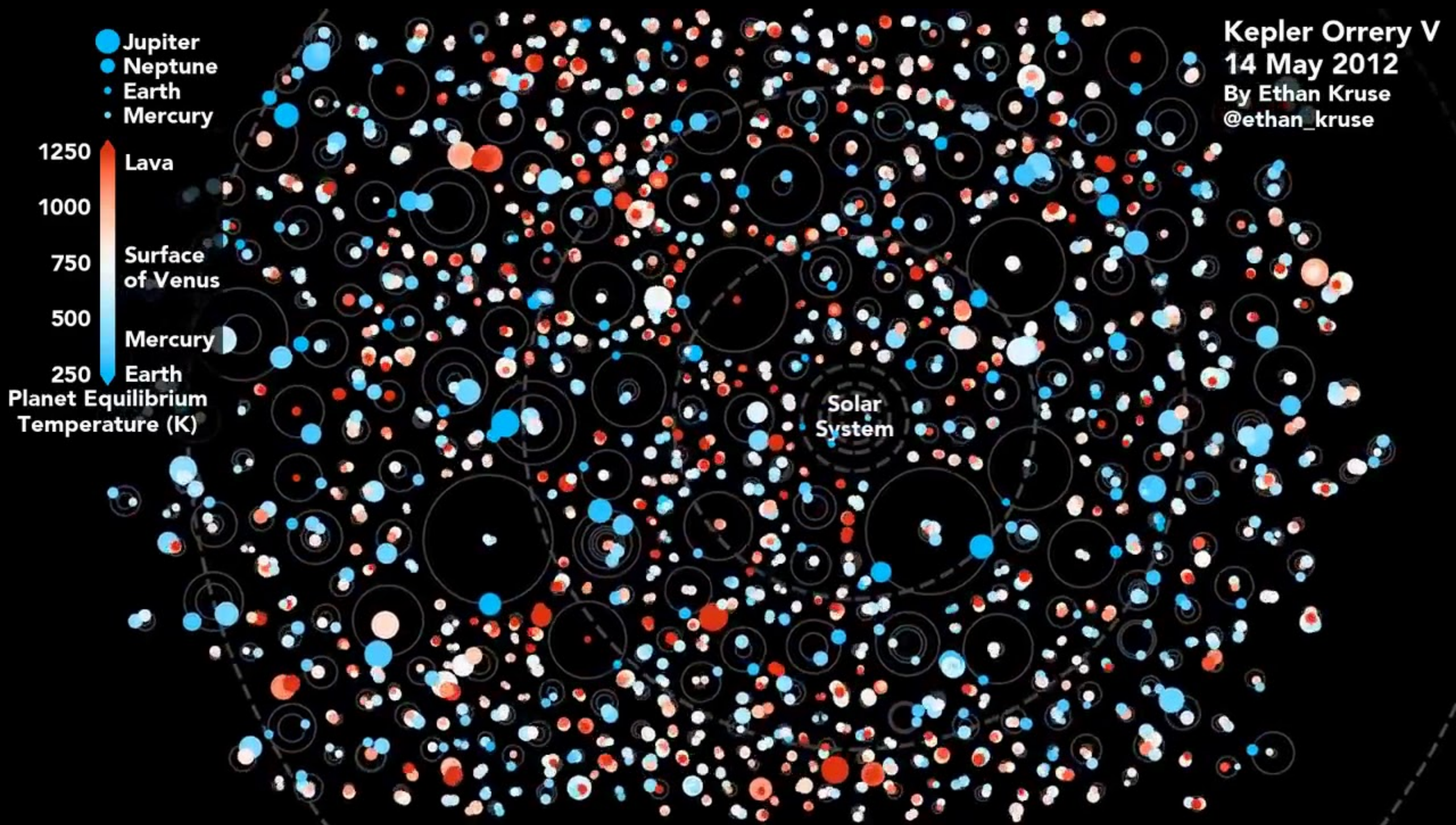
- **CoRoT** (2006–2013): first space transit observatory
- **Kepler & K2** (2009–2018): most transformative exoplanet transit mission
- **TESS** (2018–present): first all-sky survey
- **CHEOPS** (2020–present)

Optical array of HAT-PI





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

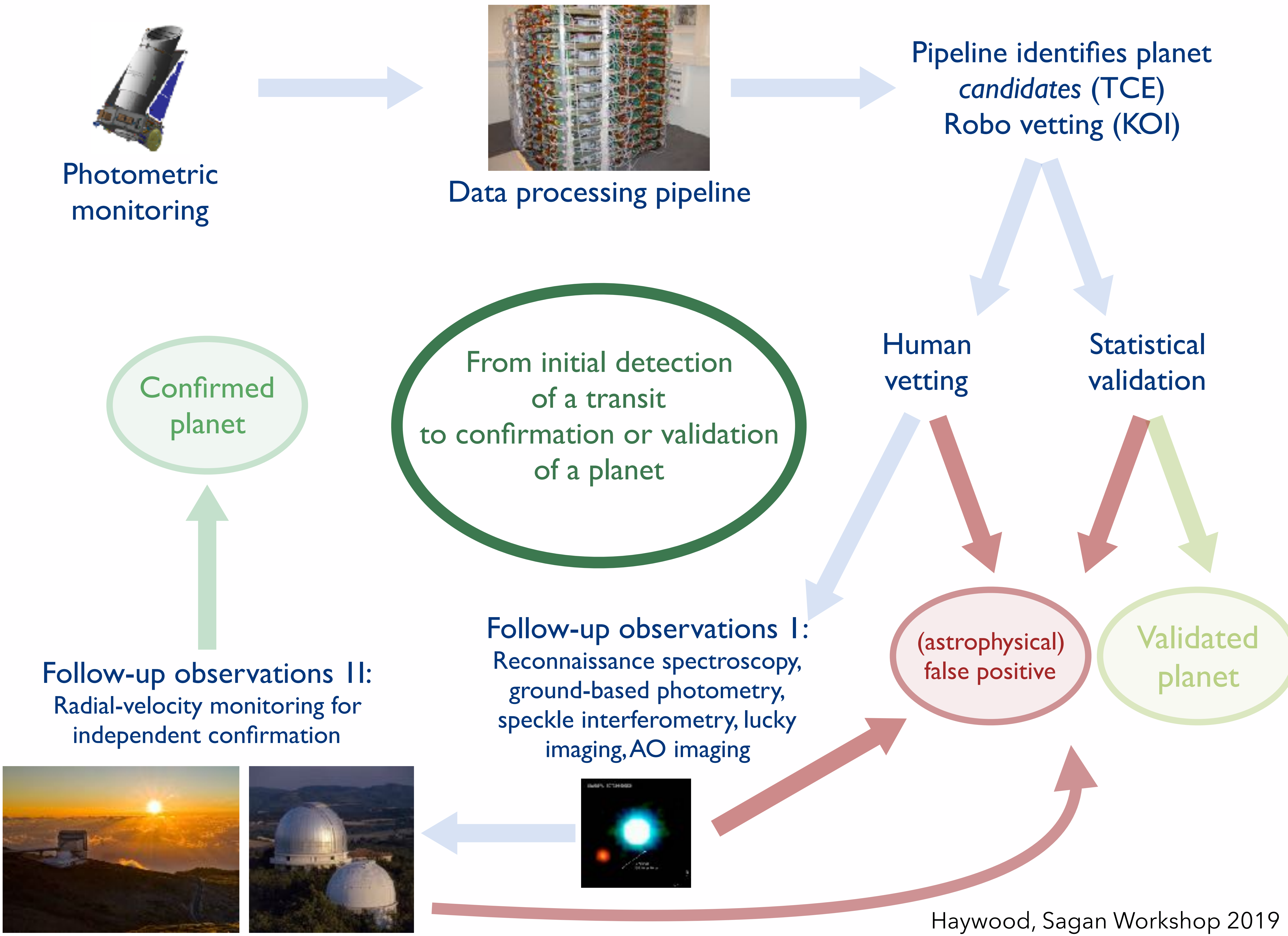


https://www.youtube.com/watch?v=5I_FOEh47RY

In-Class Activity

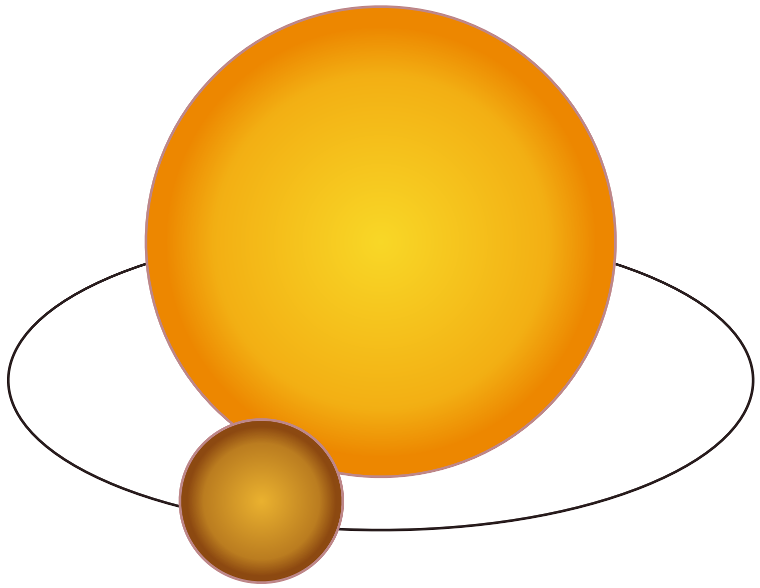
Drawing Transits

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

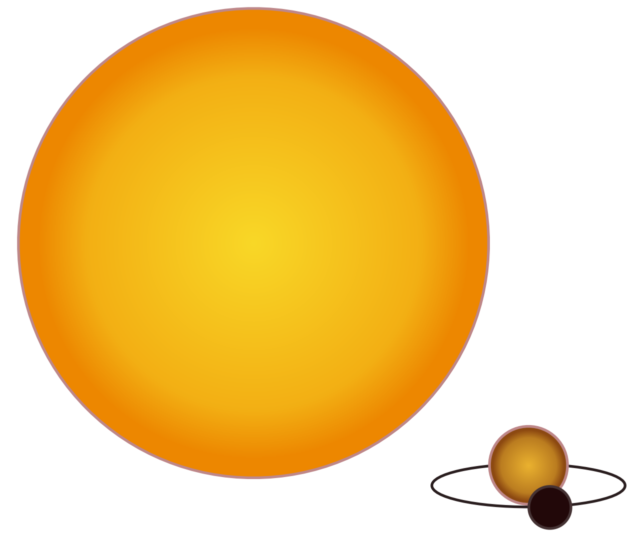


Haywood, Sagan Workshop 2019

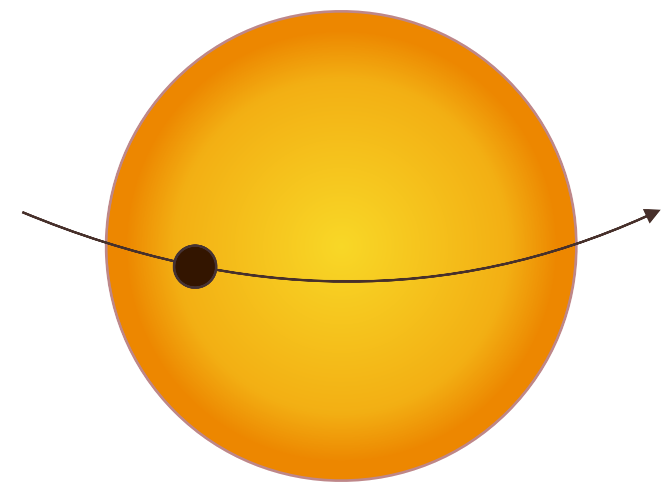
Astrophysical scenarios that create transits (astrophysical false positives)



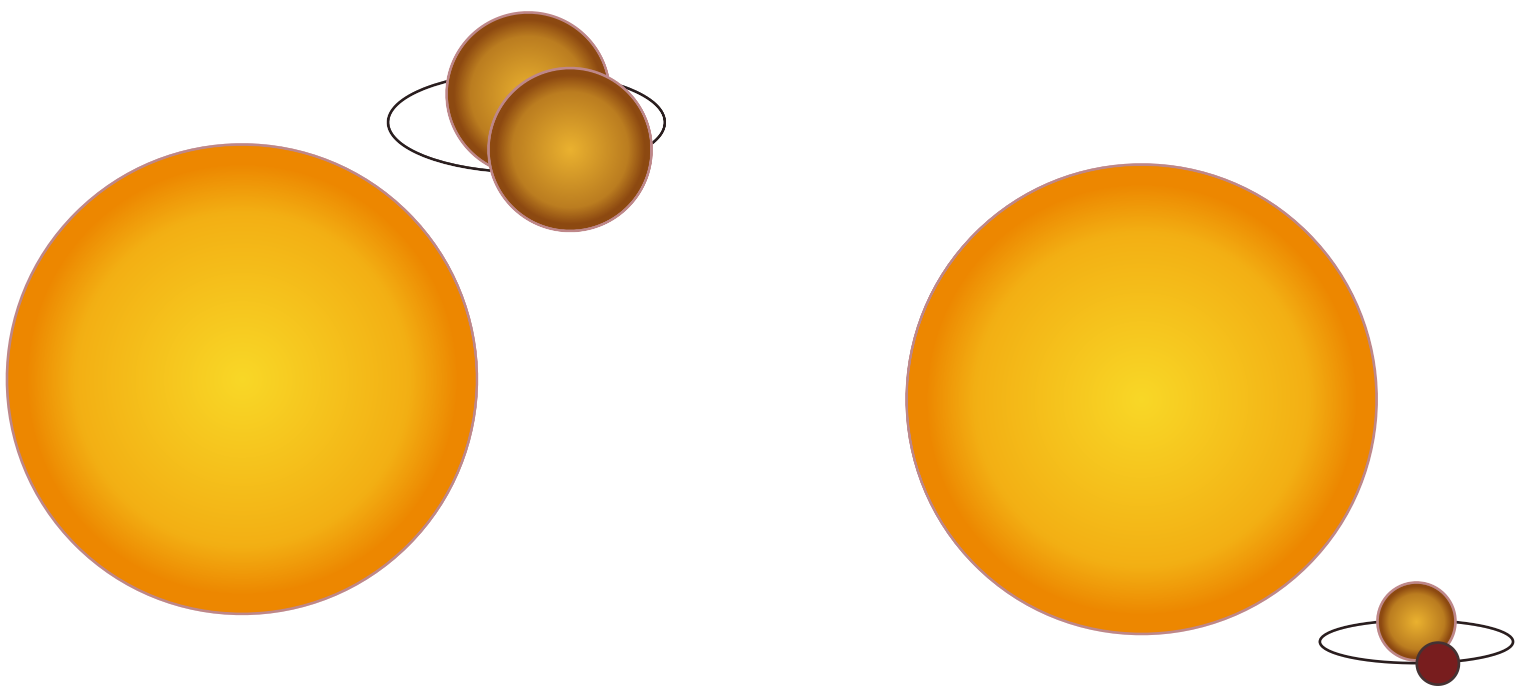
Grazing stellar binaries



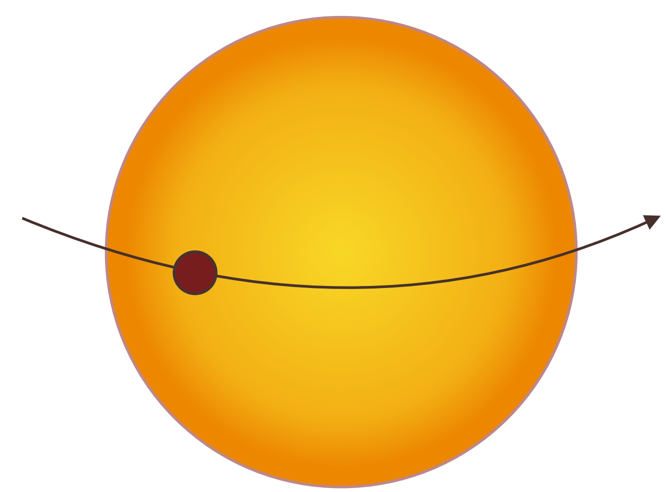
Background transiting planet



Transiting planets



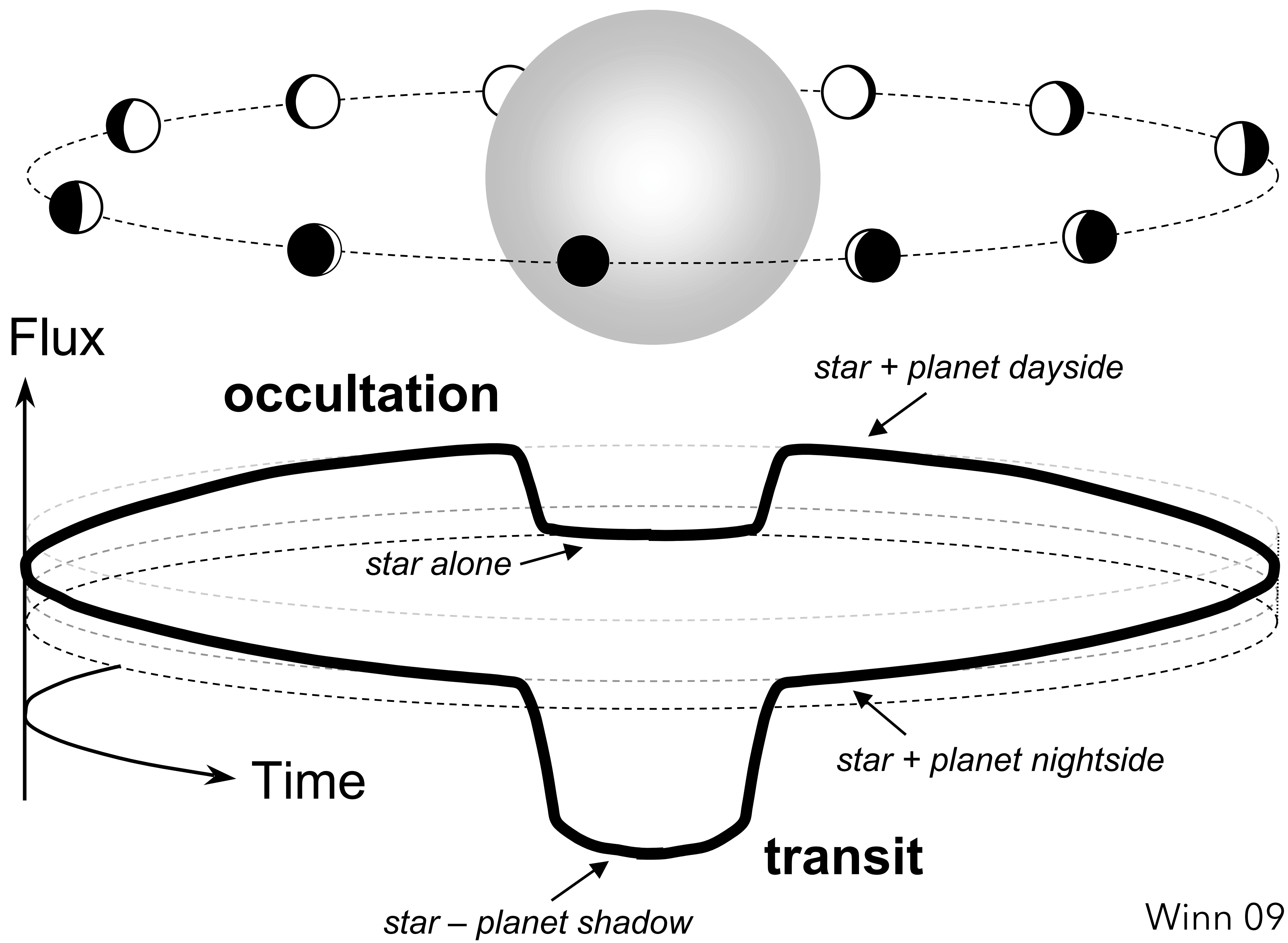
Blended stellar binaries
(background eclipsing binaries)



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