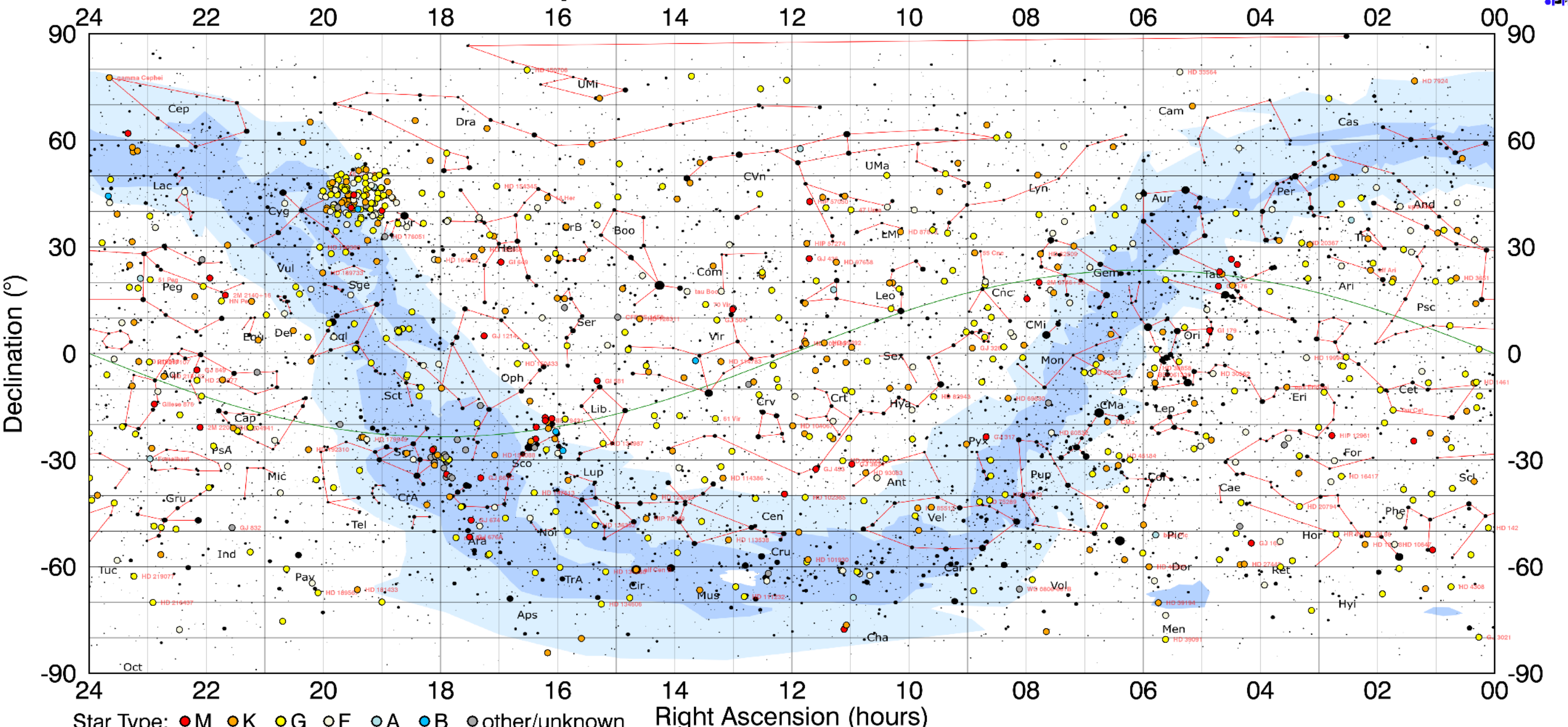
Discover Exoplanets

Practical assignment

Exoplanets have long been speculated to exist

- 1987 First predictions
- 1990's large object revolving round a pulsar
- …
- Exoplanet.eu (>1000 planets listed)

Location of All the Stars with Exoplanets



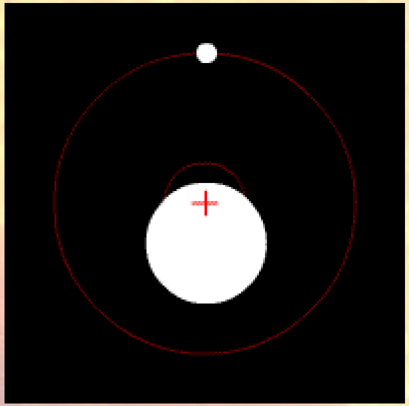
Credit: PHL @ UPR Arecibo, Jim Cornmell phl.upr.edu, Sep 2013

Why are exoplanets so hard to find?

- Planets are much smaller than stars
- No light source, reflection only (albedo)
- Overexposed by starlight

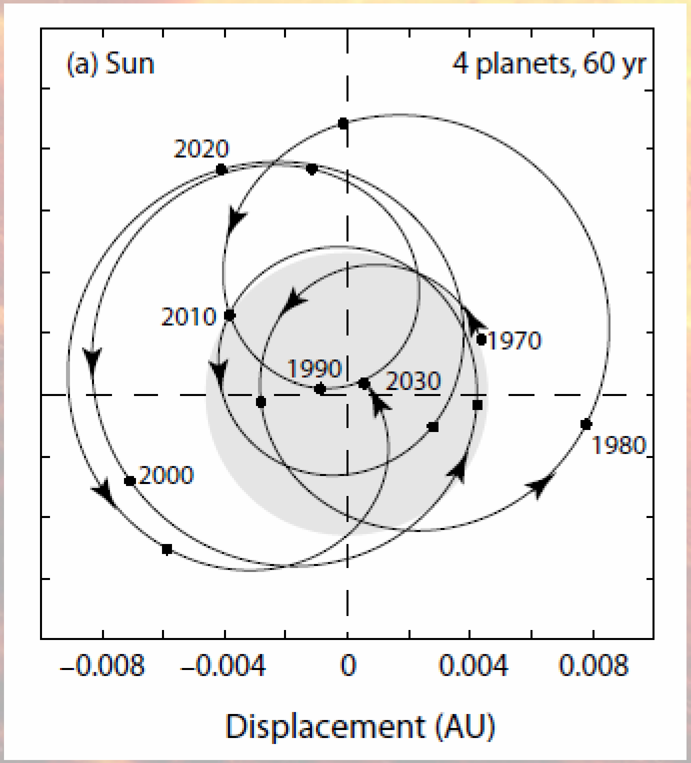
Mechanics

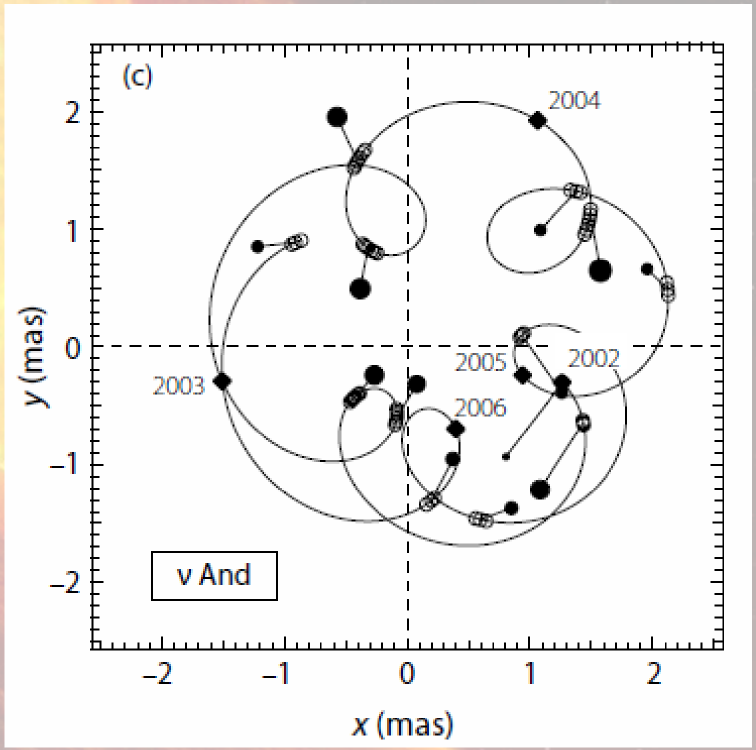
Star and planet evolve around the same barycenter



Detection Methods

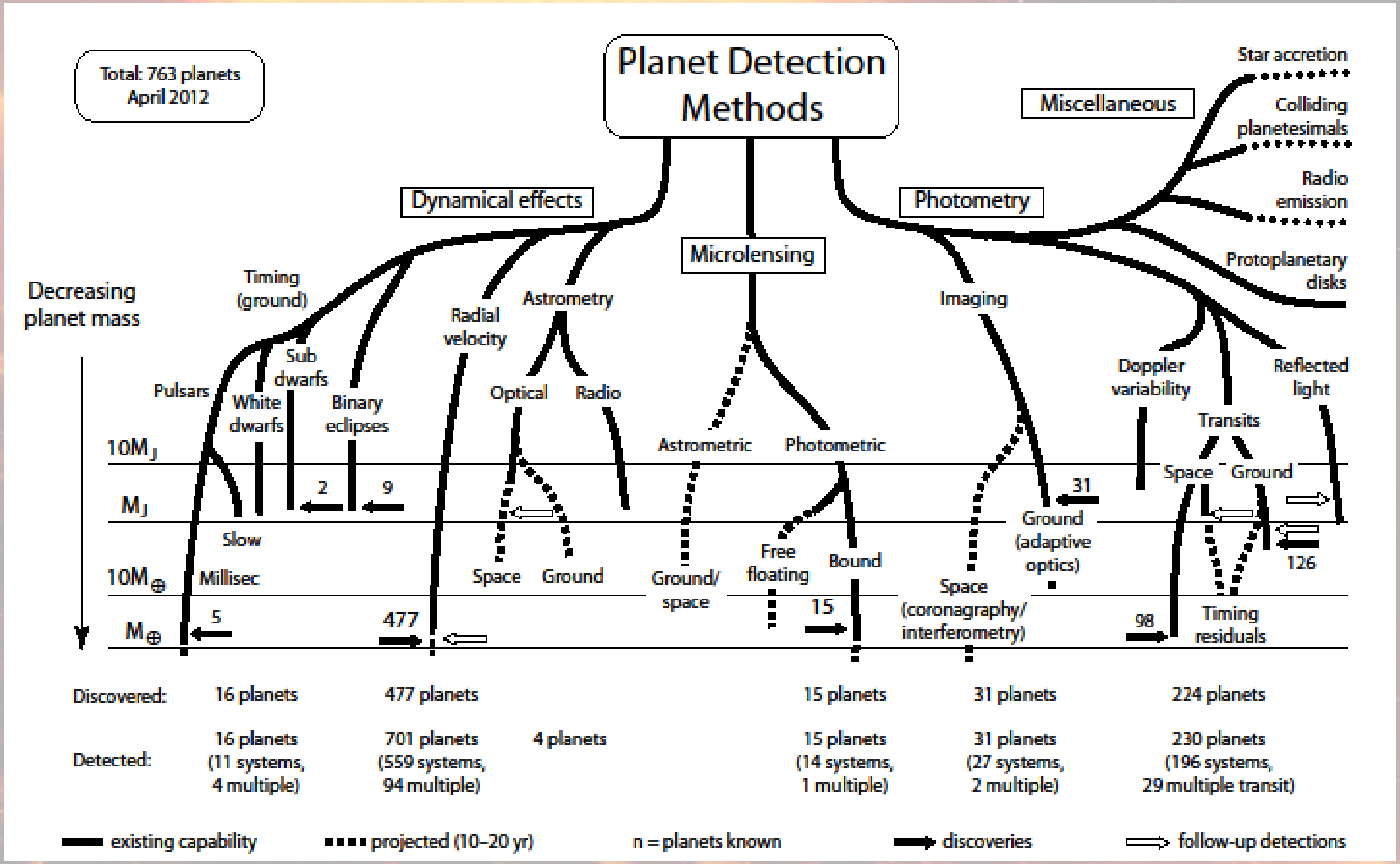
Astrometry, direct observation of star





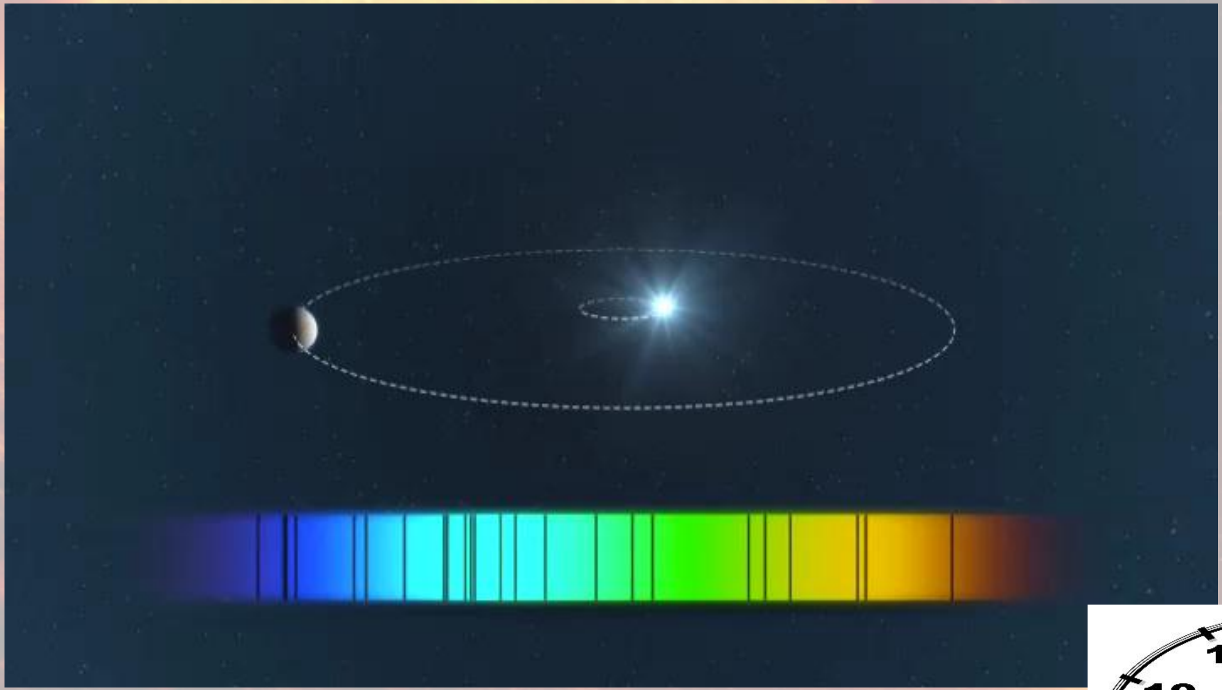
Detection Methods

Overview

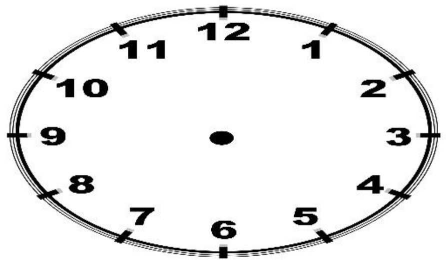


Detection Methods

- Radial velocity

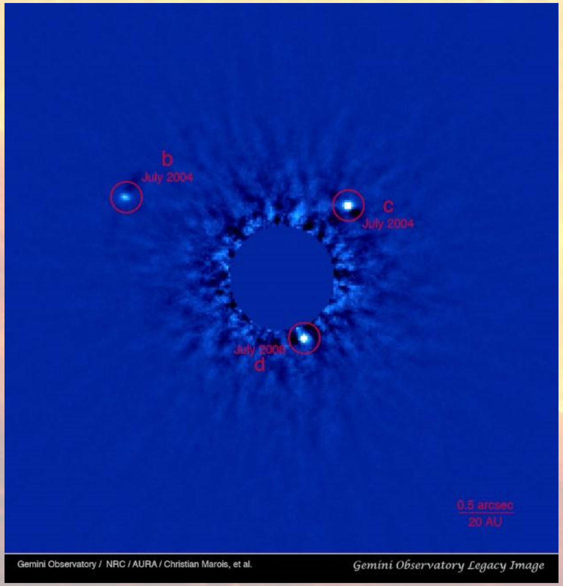


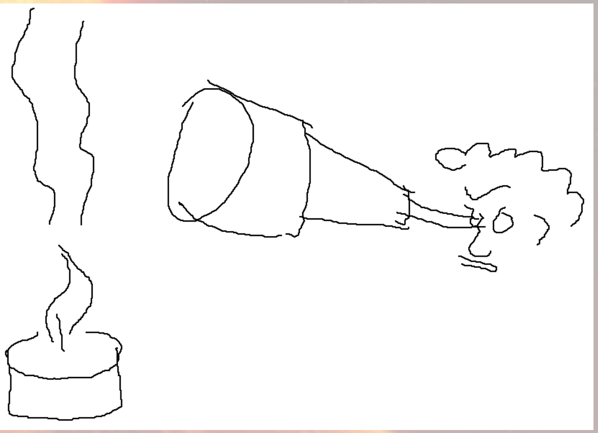
Where is the observer?



Detection Methods

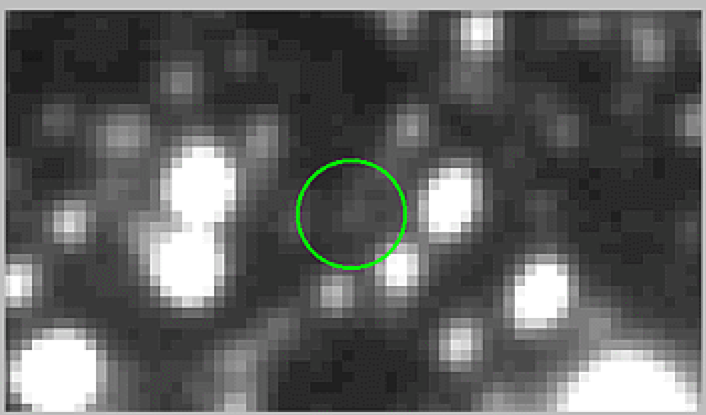
- Direct imaging

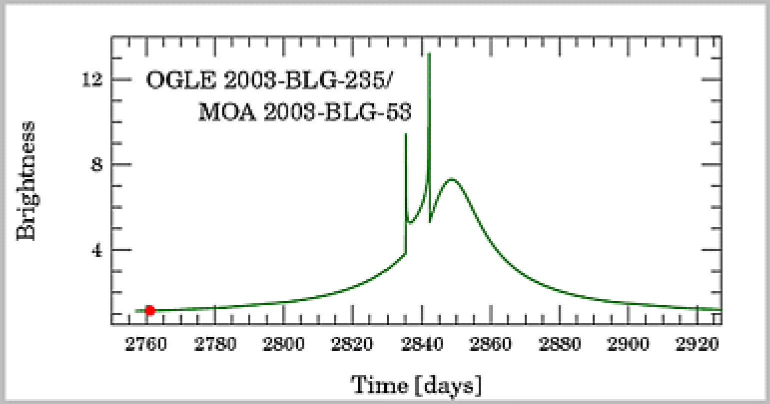


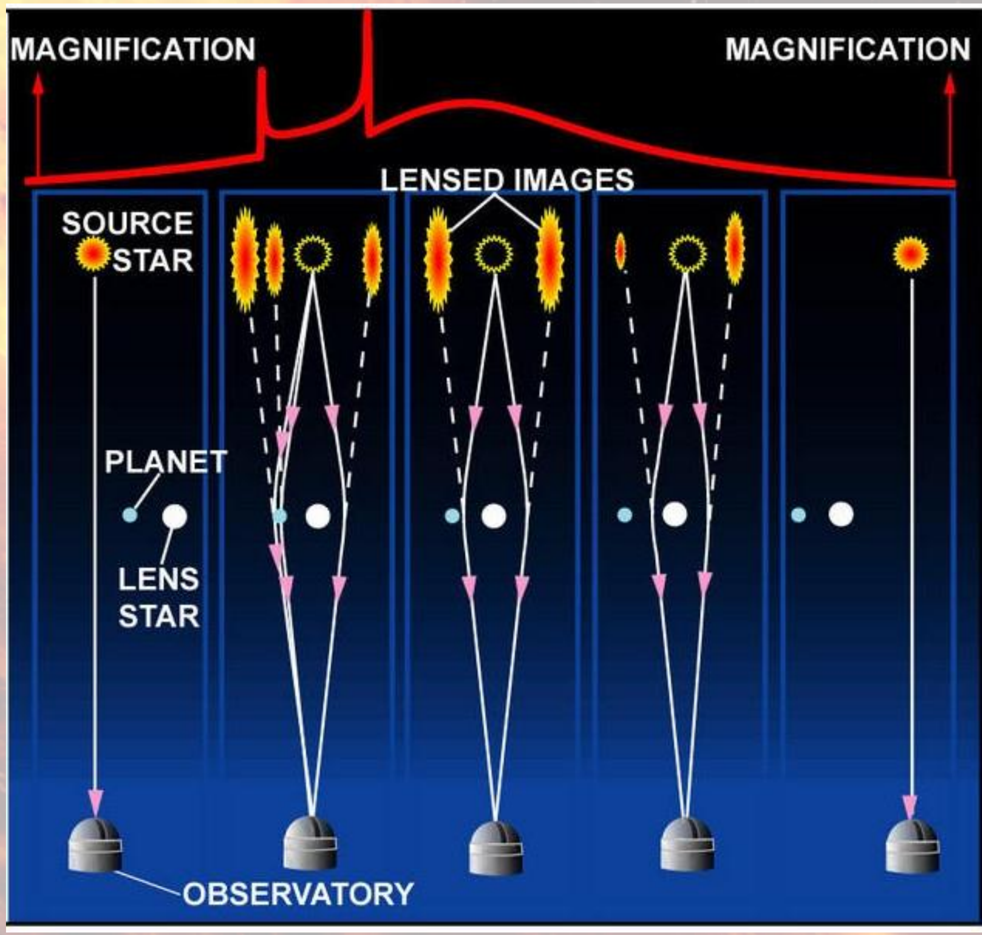


Detection Methods

- Microlensing (Einstein's general relativity)

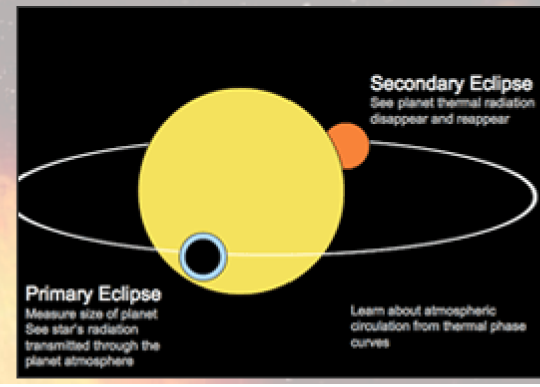


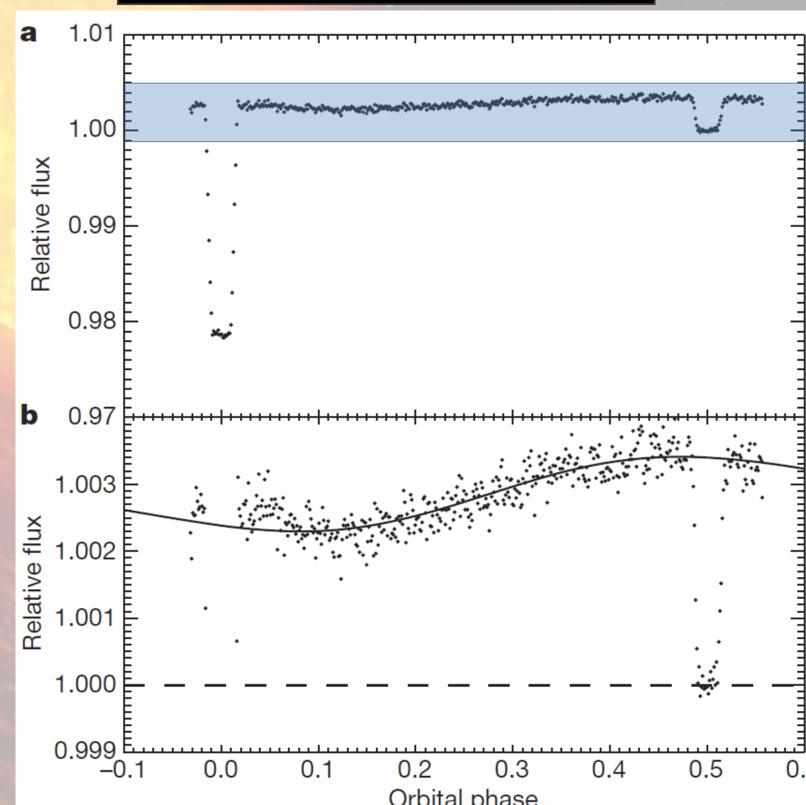




Detection Methods

- transit or occlusion





The assignment

Question:

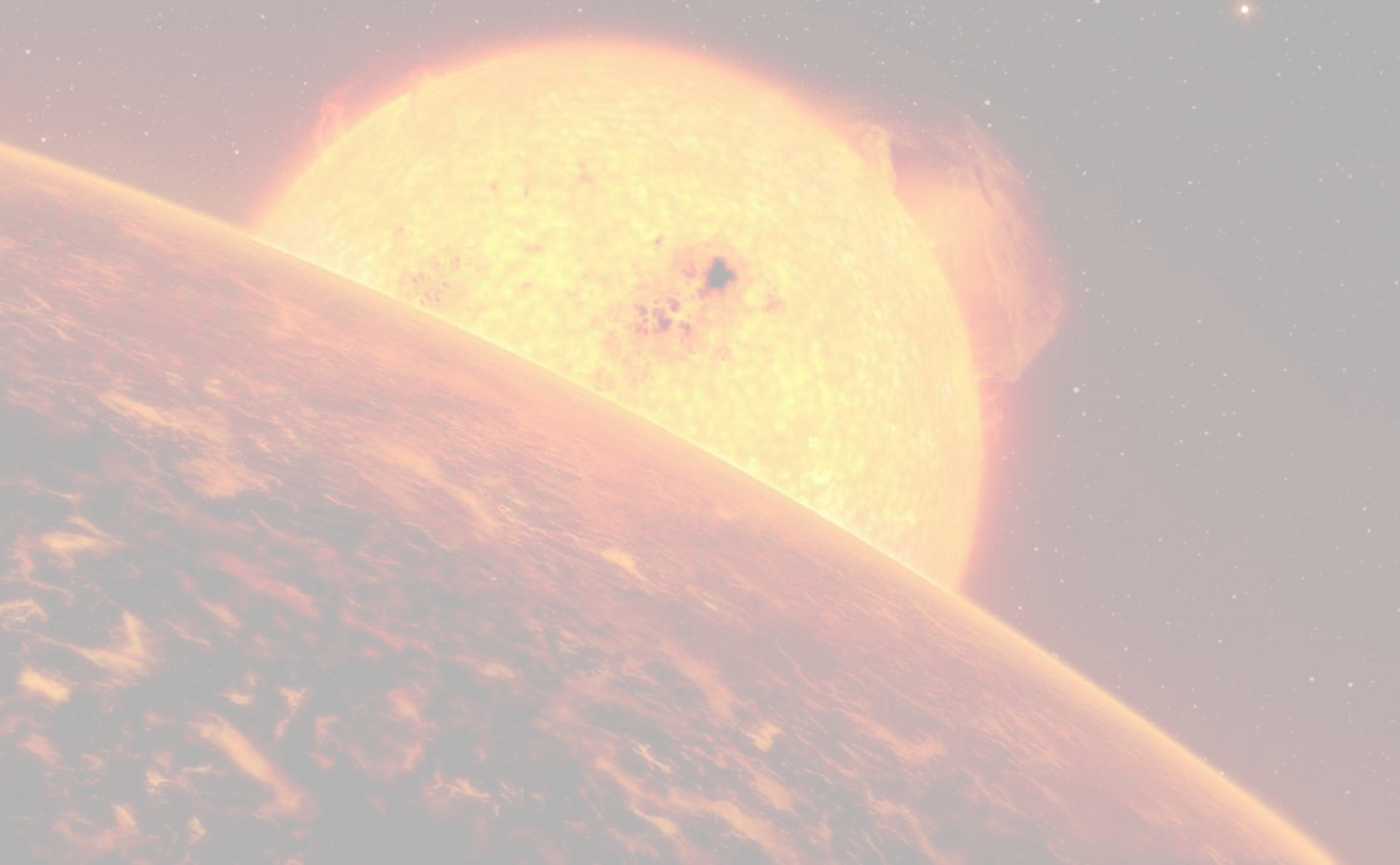
What is the relation between the diameter of a planet and the star’s intensity dip during a transient passage.
Obviously: the larger the planet, the deeper the dip. Find a mathematical relation.
Write that relation in a linear form.

Measurements:

- Take four planets of different sizes. Measure their diameters with calipers (This is something astronomers can’t do).
- Measure the deflections (at least three readings each) and plot the data.
- Manipulate your data so you can plot it in a linear graph (Excel). This is your calibration graph (nice if you put in error bars).
- Take a fifth planet and derive its diameter from its transient and your calibration curve. This is the astronomers way!
- Check with your calipers, and compare with your transient measurement.

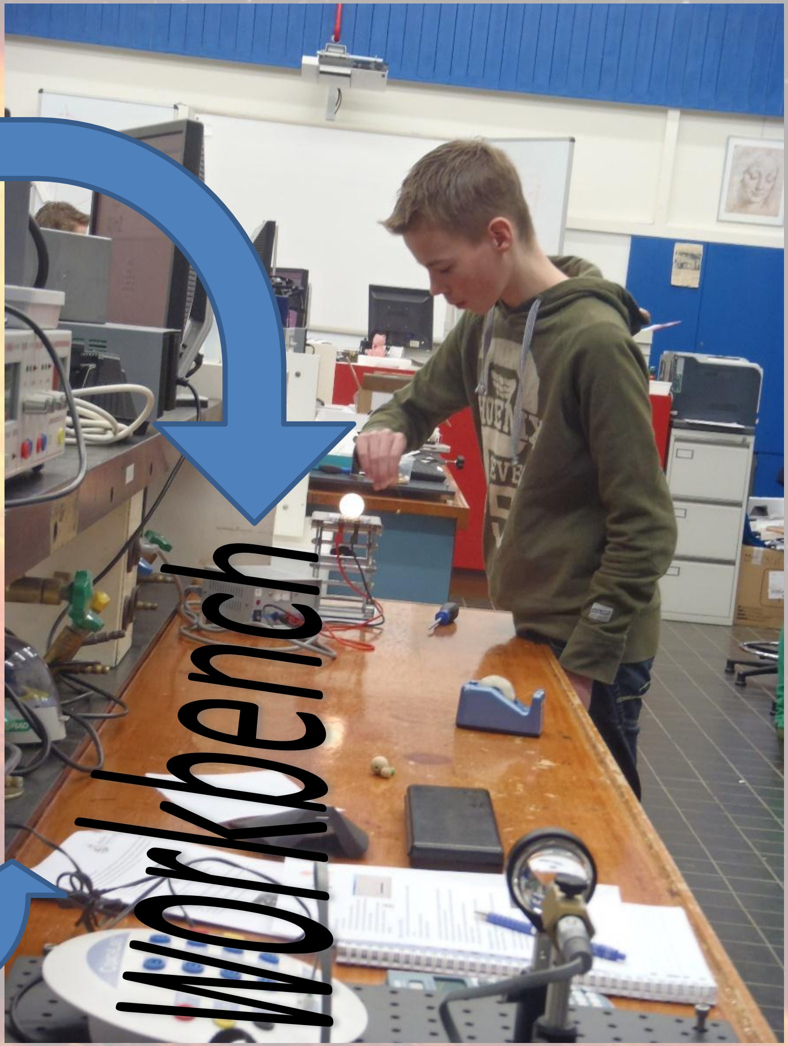
- Astronomers know the size stars. Our star has diameter of 40 mm (official match ball)

First: Set up your system

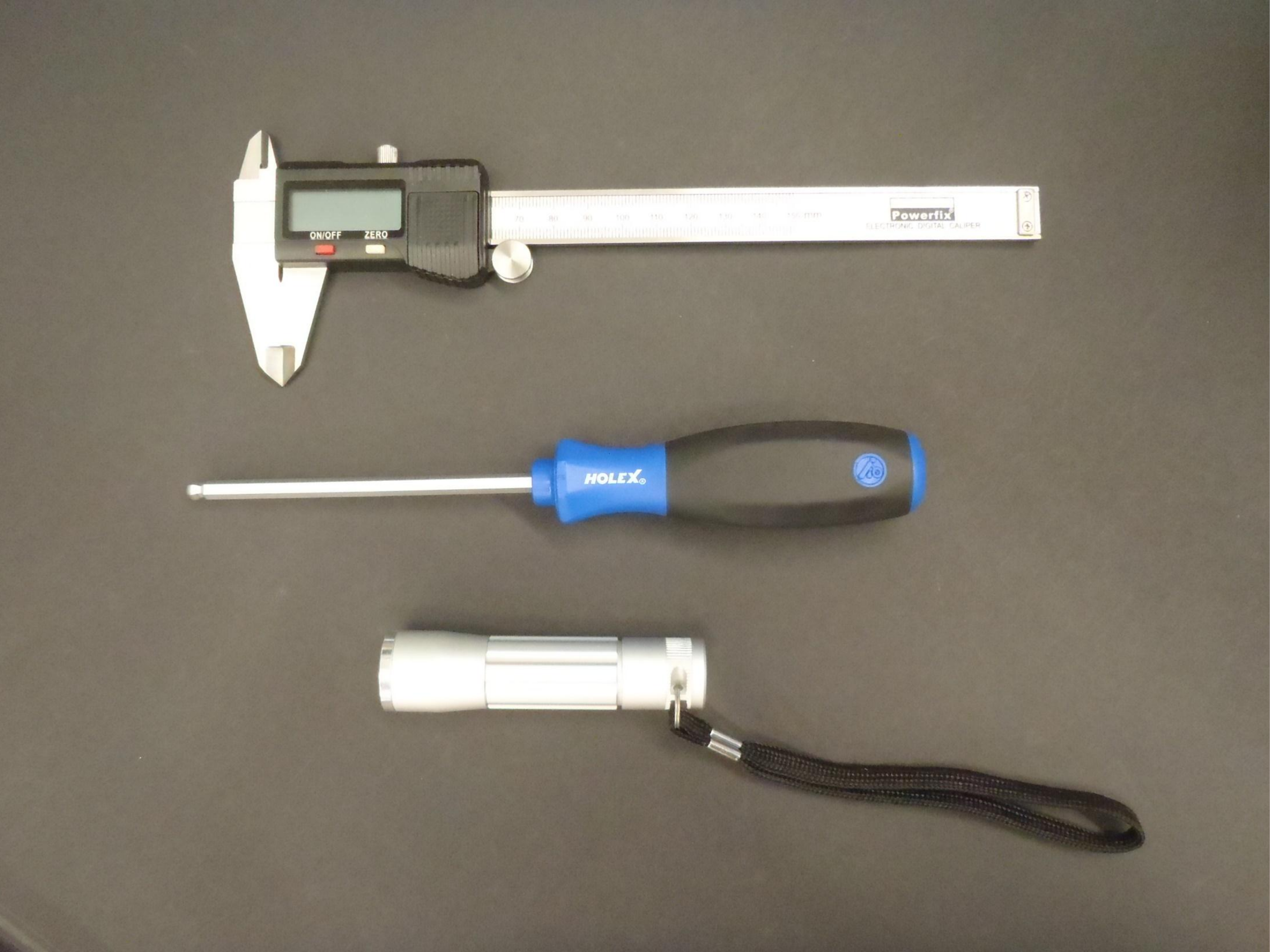


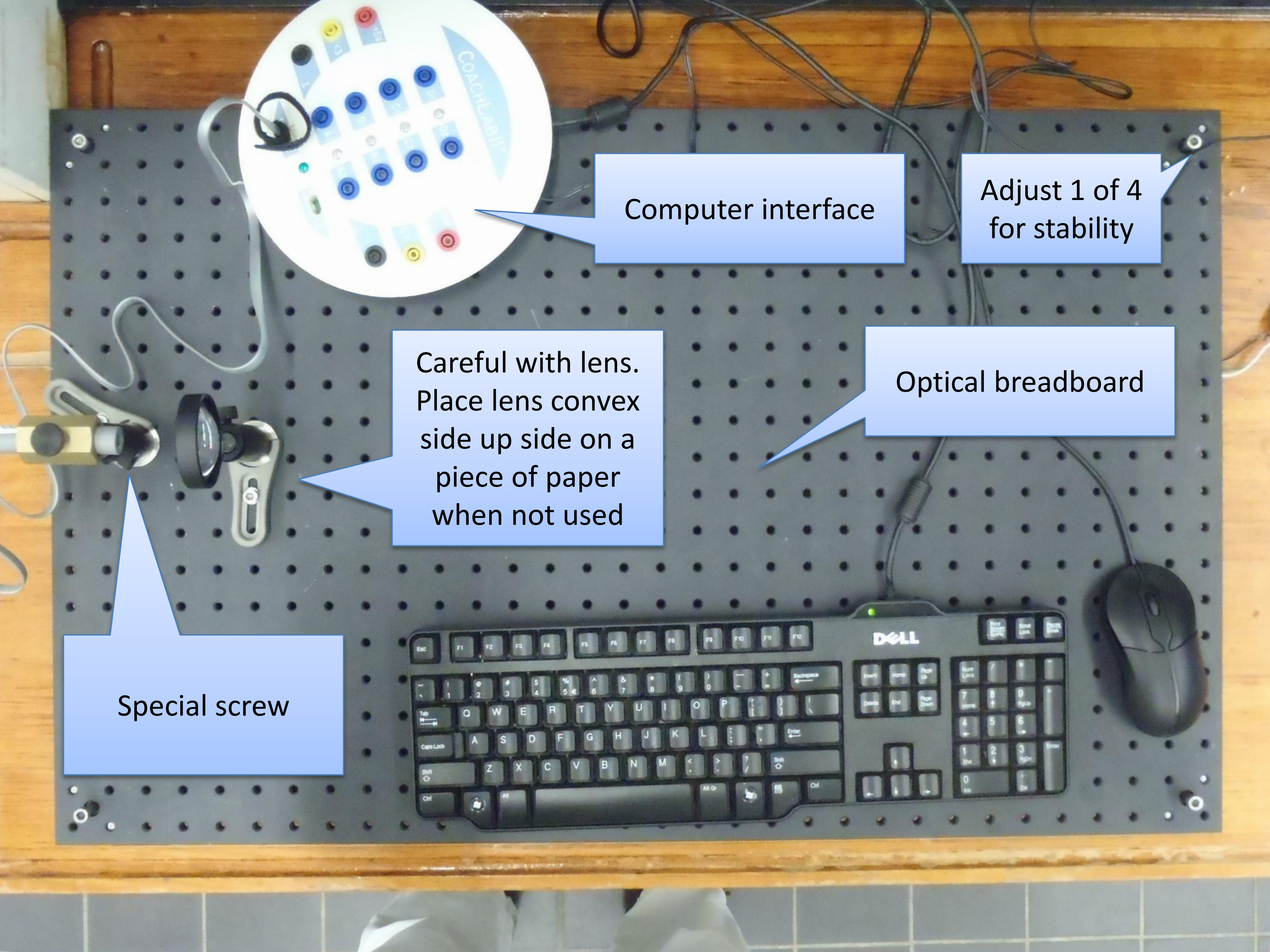
Build planetary system on this end

Make this distance as large as possible

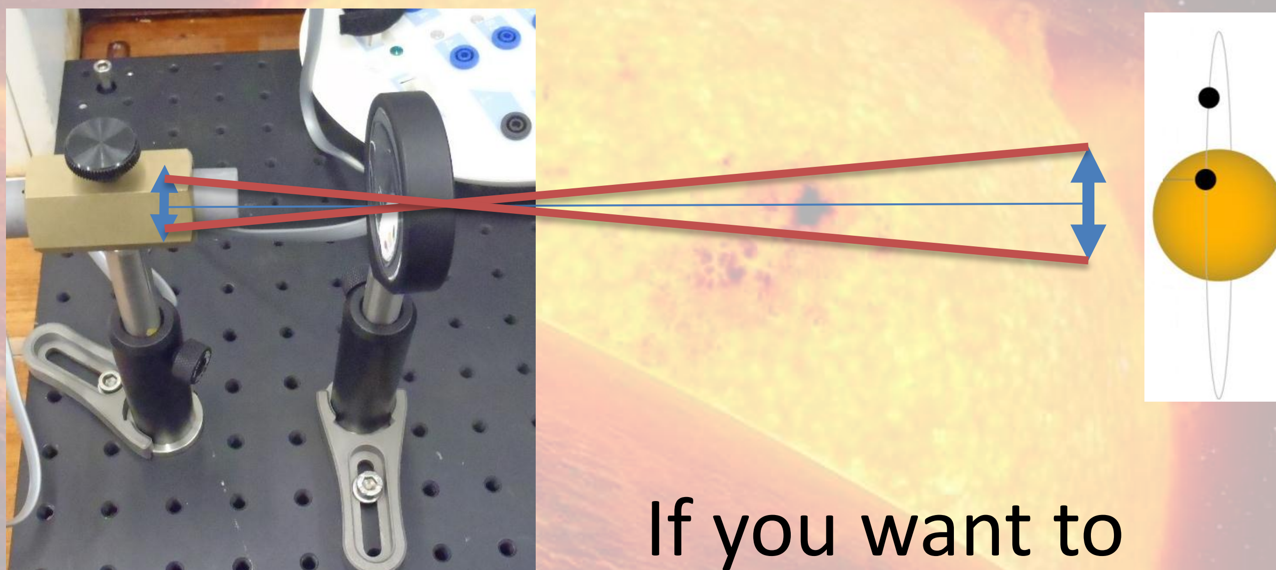


Build telescope system on this end (where the computer is)


ON/OFF
ZERO
Powerfix
ELECTRONIC DIGITAL CALIPER
HOLEX

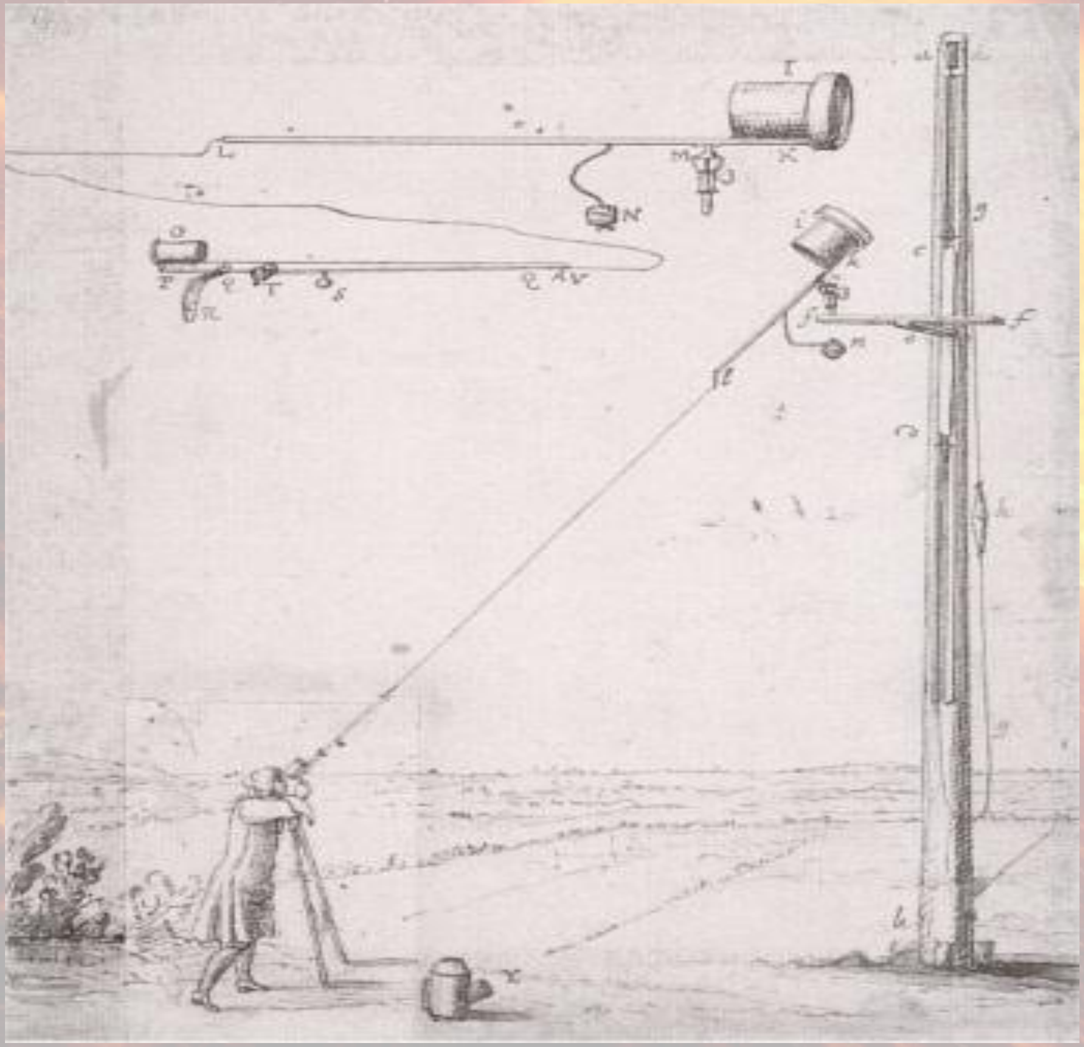

Computer interface
Adjust 1 of 4 for stability
Careful with lens. Place lens convex side up side on a piece of paper when not used
Optical breadboard
Special screw
DELL

The sensor is very small …

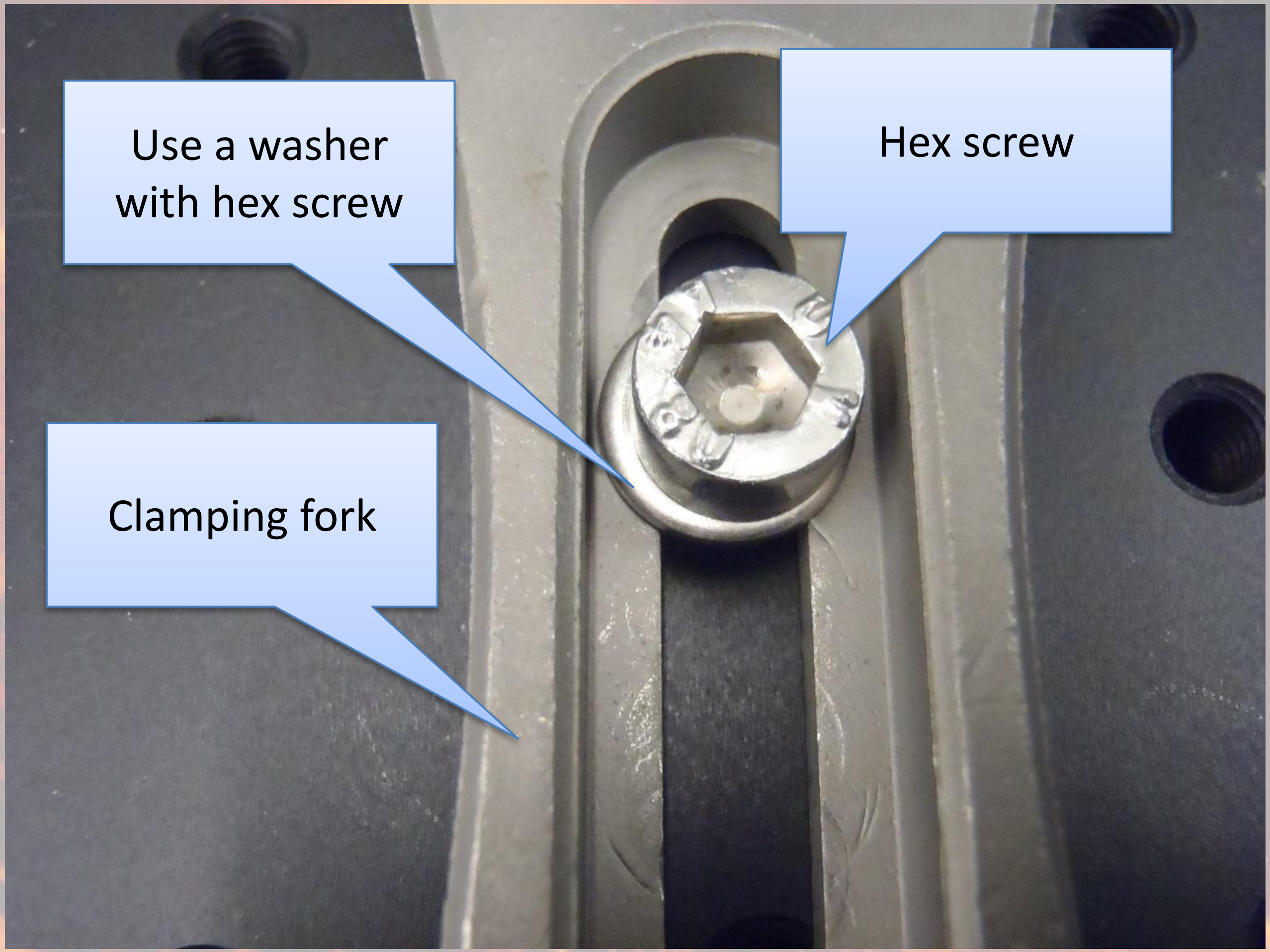


If you want to image the star and its planet …

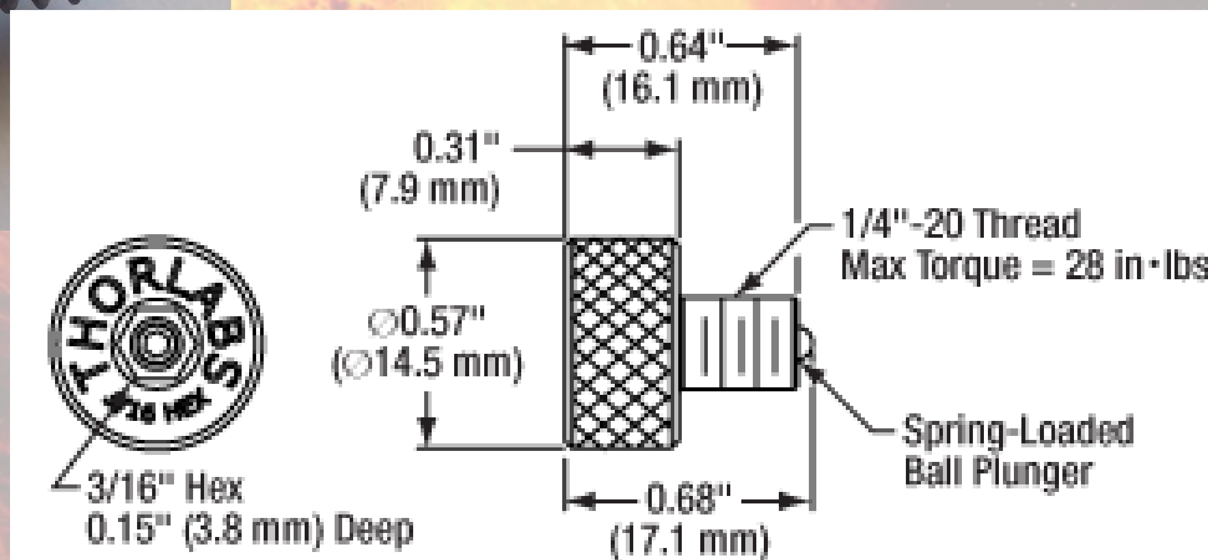
Tubeless telescope (Christaan Huygens)



- When is a tube not needed?

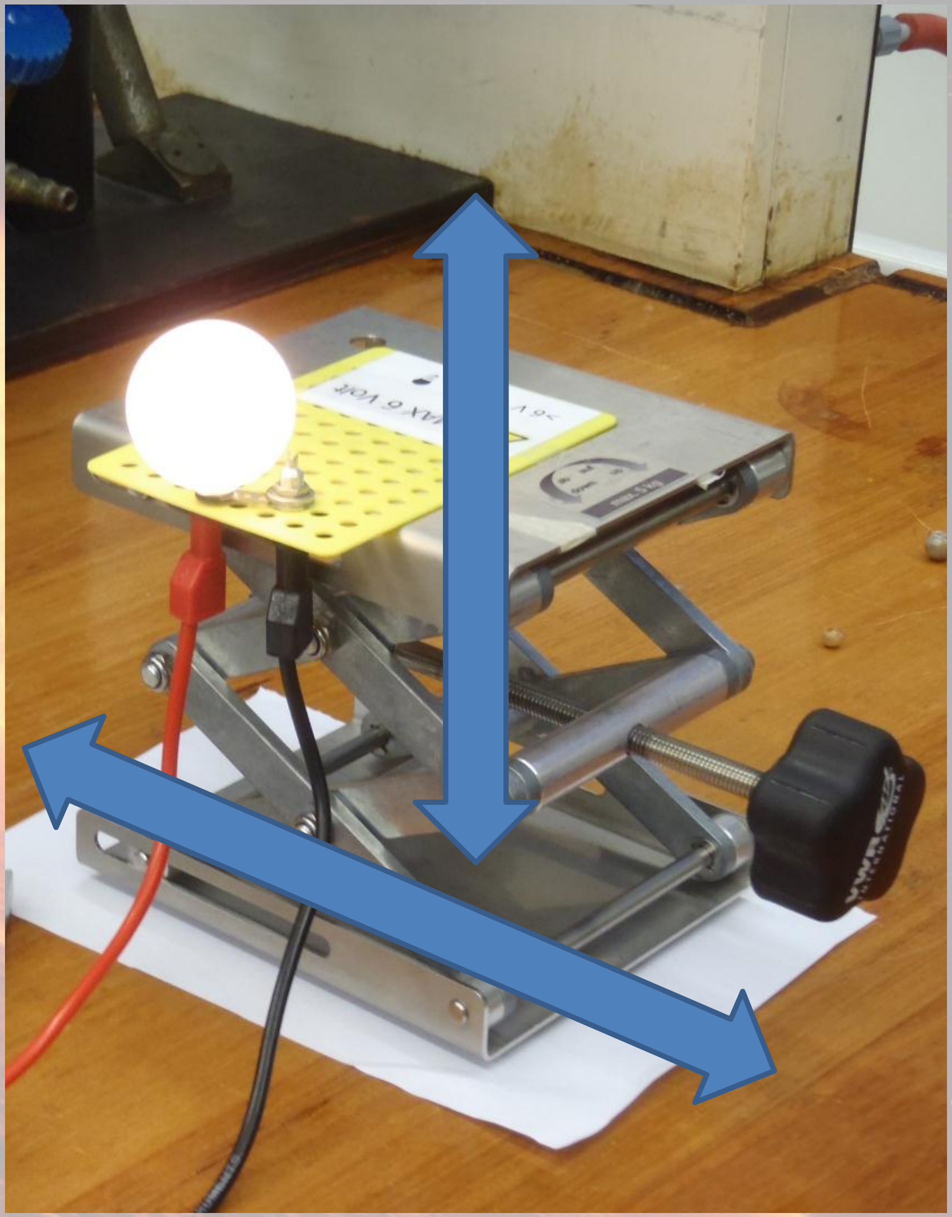

Use a washer with hex screw
Hex screw
Clamping fork


ON/OFF
ZERO
Powerfix
ELECTRONIC DIGITAL


0.64"
(16.1 mm)
0.31"
(7.9 mm)
1/4"-20 Thread
Max Torque = 28 in·lbs
THORLABS
⌀0.57"
(⌀14.5 mm)
Spring-Loaded
Ball Plunger
3/16" Hex
0.15" (3.8 mm) Deep
0.68"
(17.1 mm)

Labjack knob
Z-axis positioning

Labjack on paper sheet
Y-axis positioning



IPCOACH settings

- Load activity Discover Exoplanets
- Sample time 100 sec
- Sample freq 1000 Hz

Assignment:

- Derive a relation between the change in light intensity during a passage and the size of the planets.
- Make a linear calibration curve using four planets with known diameters (calipers).
- Use the aclibration curve to predict the diameter of a fifth planet from your light signal.
- Check your result using calipers.
- Discuss the uncertainties (systematic errors) and make suggestions to improve the setup.

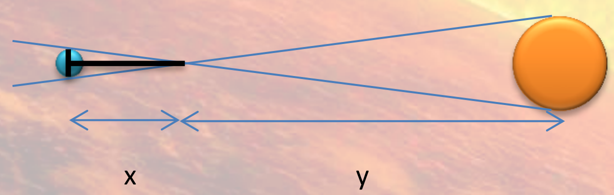
Drake's equation

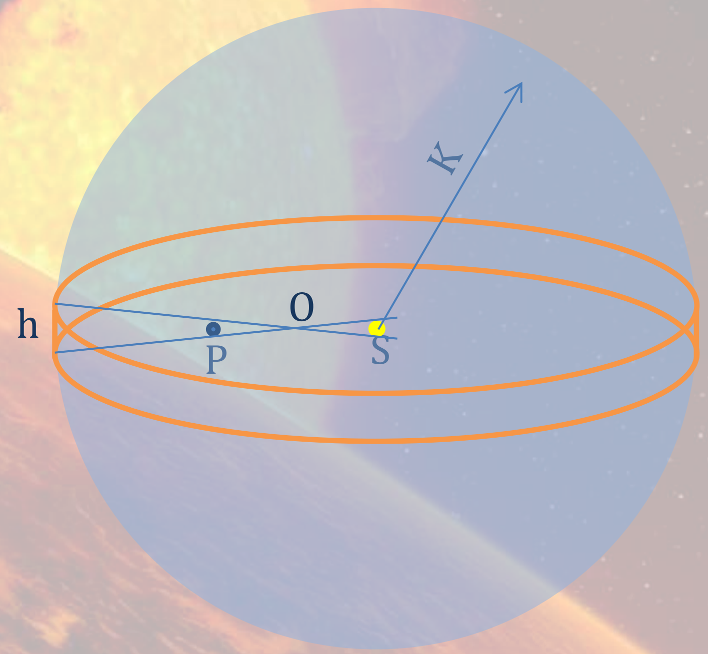
- $N = R^* \bullet f_p \bullet n_e \bullet f_l \bullet f_i \bullet f_c \bullet L$
- R^* = the average rate of star formation in our galaxy
- f_p = the fraction of those stars that have planets
- n_e = the average number of planets that can potentially support life per star that has planets
- f_l = the fraction of planets that could support life that actually develop life at some point
- f_i = the fraction of planets with life that actually go on to develop intelligent life (civilizations)
- f_c = the fraction of civilizations that develop a technology that releases detectable signs of their existence into space
- L = the length of time for which such civilizations release detectable signals into space

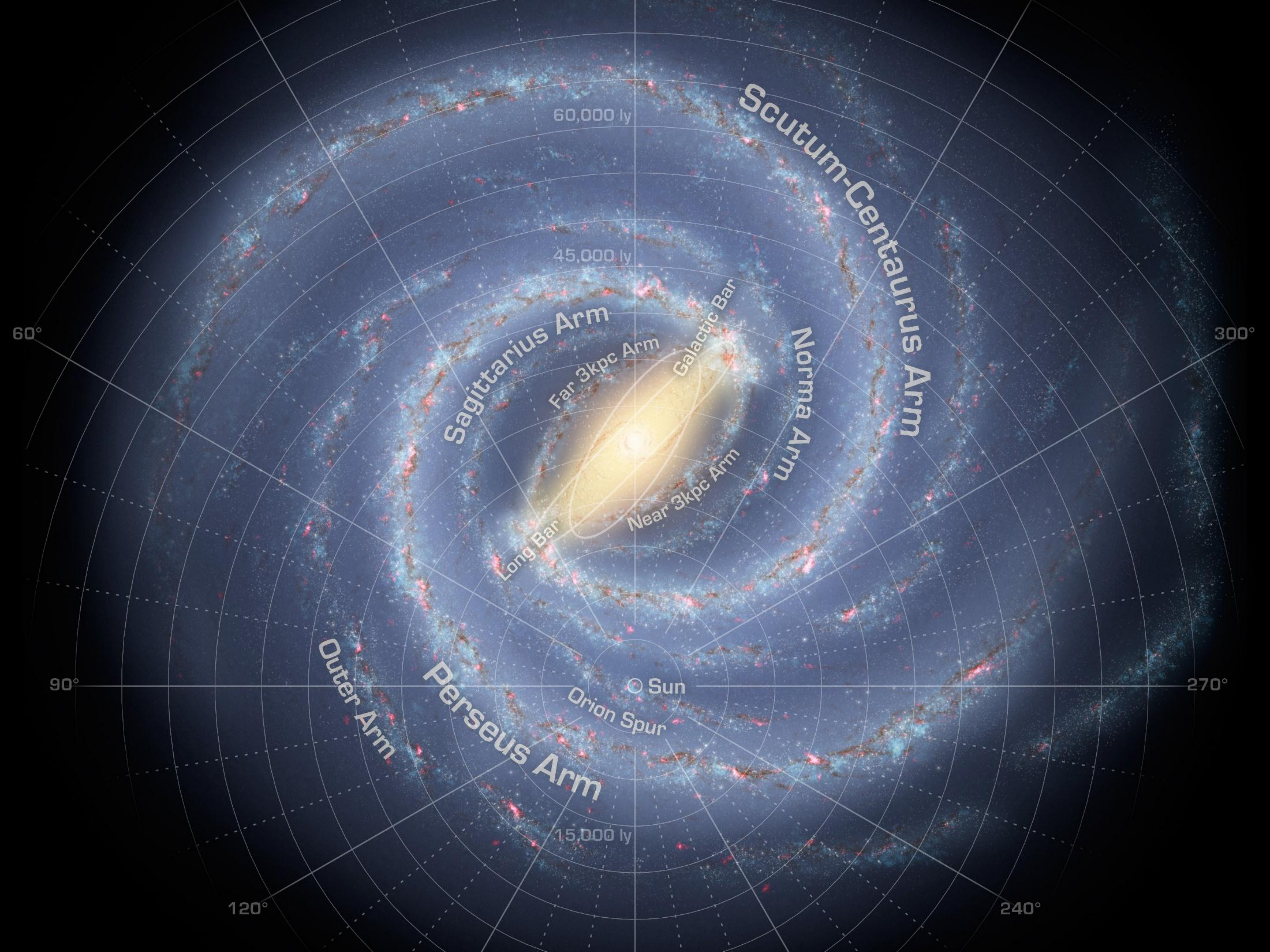
What is the chance we find aliens (or aliens find us) with the transient method

Diameters: earth/sun = 1/100

Distance sun/earth = 1/100 sun diameters







Scutum-Centaurus Arm
60,000 ly
45,000 ly
Galactic Bar
Sagittarius Arm
Far 3kpc Arm
Norma Arm
Near 3kpc Arm
Long Bar
60°
300°
90°
270°
Sun
Orion Spur
Outer Arm
Perseus Arm
15,000 ly
120°
240°