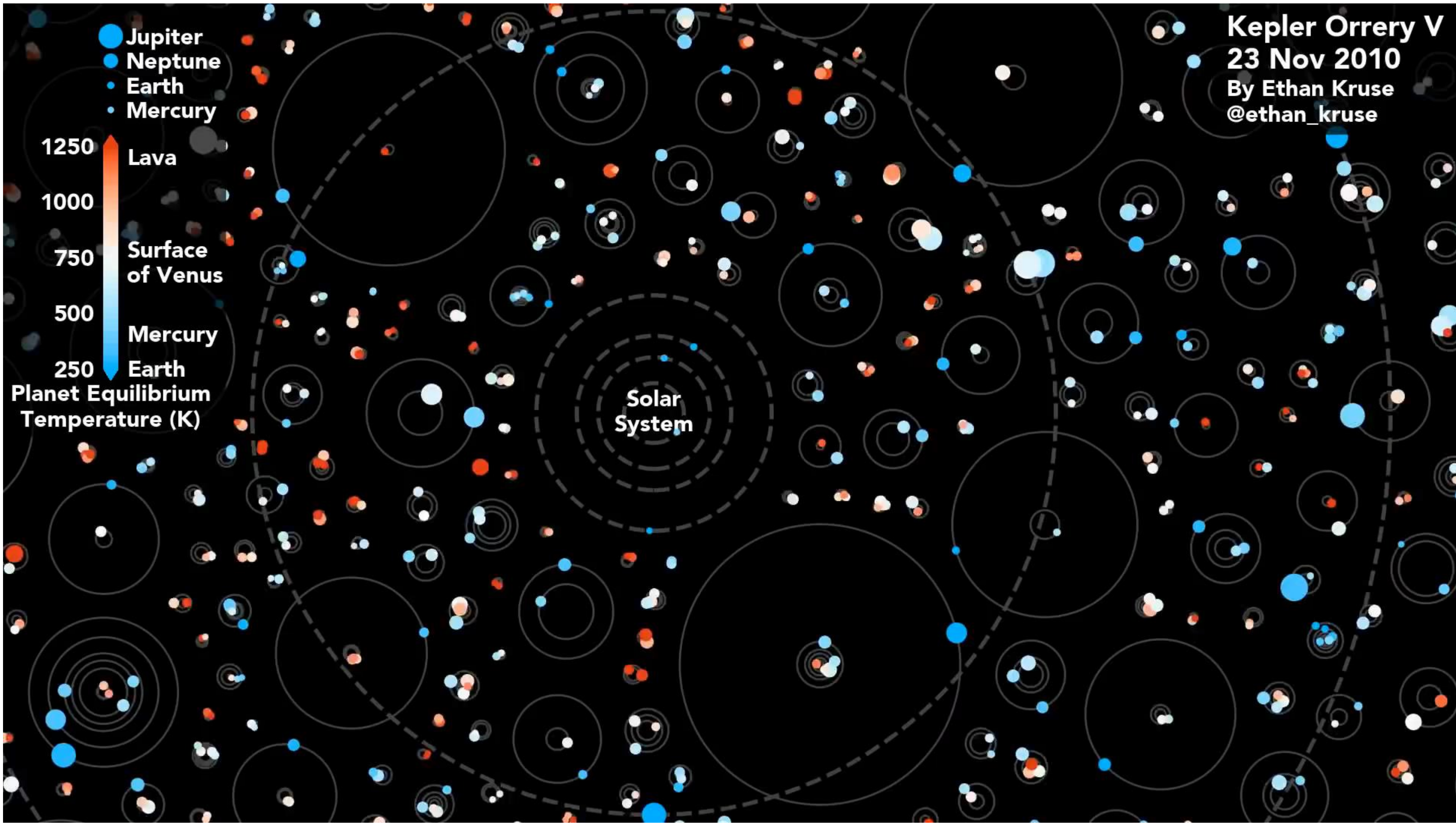
Kepler Orrery V

726 exoplanet “systems” (Oct 2018)



Notice PLEASE

- **Please pick up your papers**
  - **There is great value in our comments and your followup!**
  - **Improvement comes via PRACTICE**
  - **Earn your: “Recovery Points” and “TBD grades”**

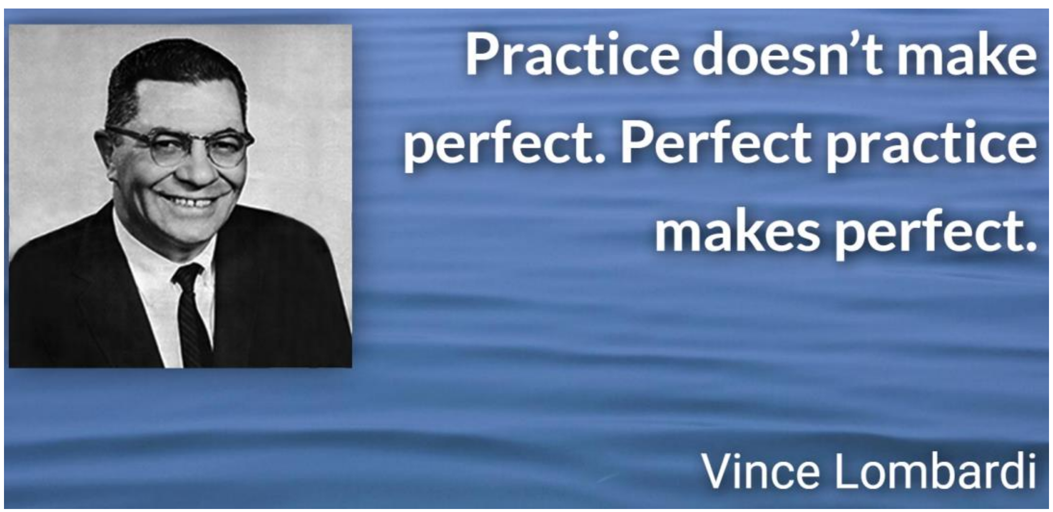
- **Course grades are posted**

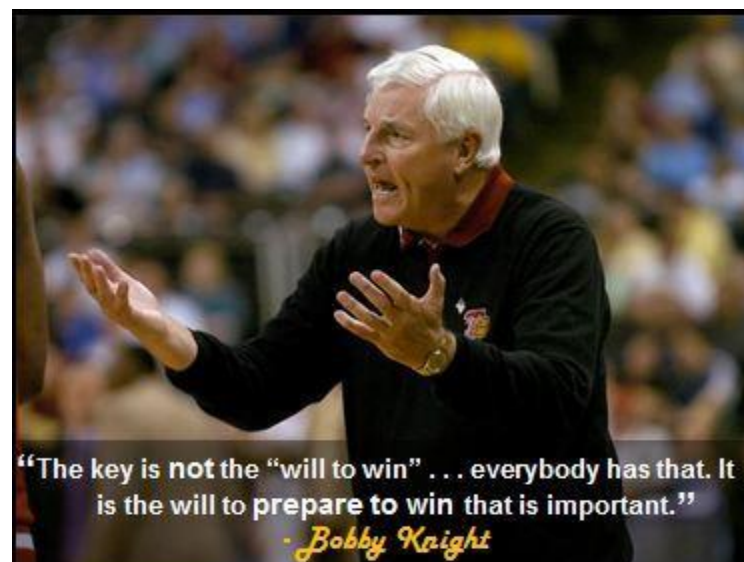
- **Next TIMESTEP meeting (March 4; PAS 218)**
  - ***Resume Building and Interview Preparation***

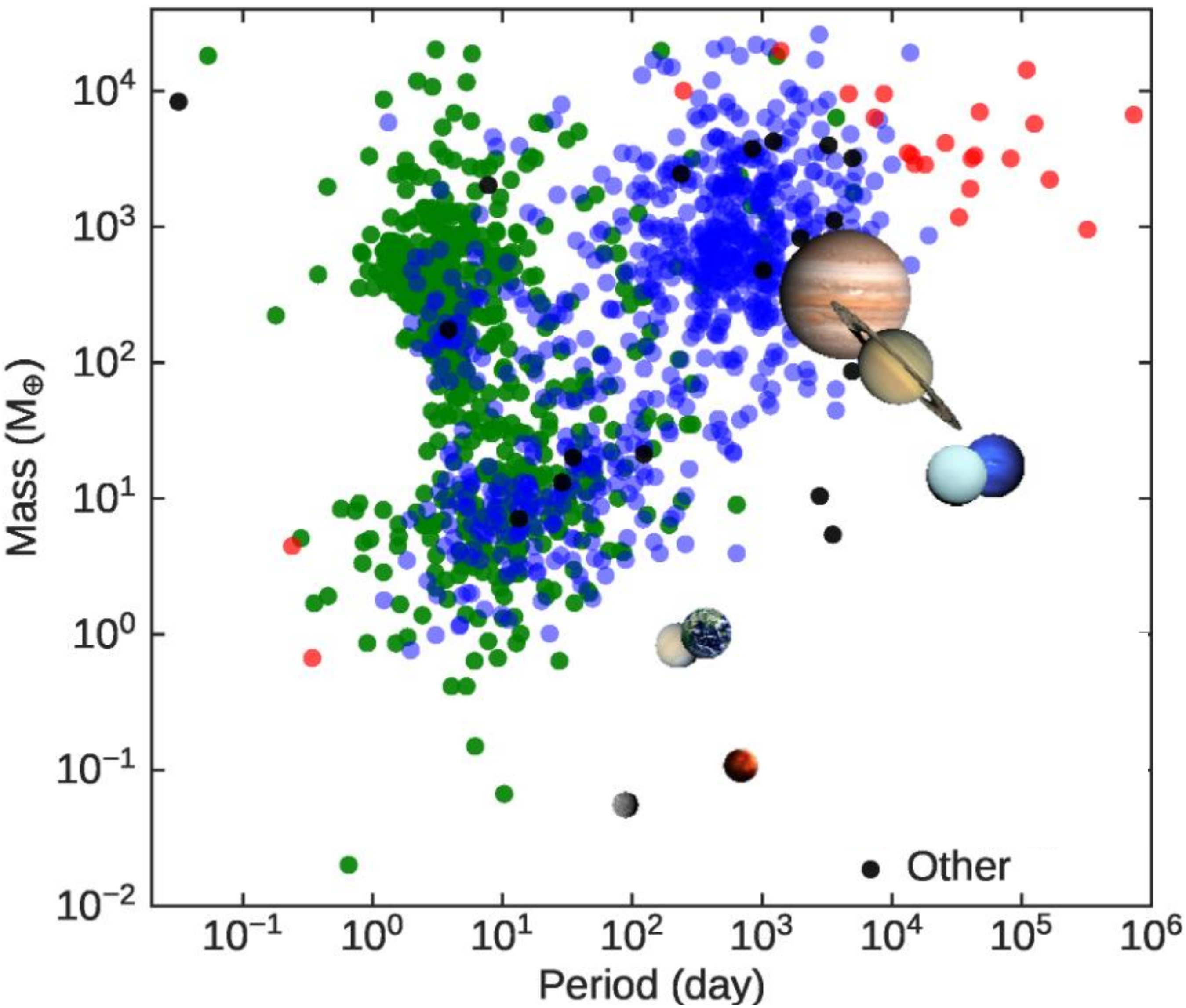
- **Exam #1 (March 4)**
  - **Prepare by removing “TBD grades” and working on “Recovery Points”**
  - **Practice at ATOMM and office hours**

Pick up your Papers

contemplate, repeat, and discuss with us







Known exoplanets

Which techniques are represented by the different colors?

Work together!

NGTS-10b: the shortest period hot Jupiter yet discovered FREE

James McCormac ✉, Edward Gillen, James A G Jackman, David J A Brown, Daniel Bayliss, Peter J Wheatley, David R Anderson, David J Armstrong, François Bouchy, Joshua T Briegal ... Show more

Author Notes

Monthly Notices of the Royal Astronomical Society, Volume 493, Issue 1, March 2020, Pages 126–140, https://doi.org/10.1093/mnras/staa115

Published: 20 February 2020 **Article history** ▾

In last week's science news!

ABSTRACT

We report the discovery of a new ultrashort period (USP) transiting hot Jupiter from the Next Generation Transit Survey (NGTS). NGTS-10b has a mass and radius of $2.162^{+0.092}_{-0.107}\,M_J$ and $1.205^{+0.117}_{-0.083}\,R_J$ and orbits its host star with a period of 0.7668944 ± 0.0000003 d, making it the shortest period hot Jupiter yet discovered. The host is a 10.4 ± 2.5 Gyr old K5V star (T_{eff} = 4400 ± 100 K) of Solar metallicity ([Fe/H] = -0.02 ± 0.12 dex) showing moderate signs of stellar activity. NGTS-10b joins a short list of USP Jupiters that are prime candidates for the study of star–planet tidal interactions. NGTS-10b orbits its host at just 1.46 ± 0.18 Roche radii, and we calculate a median remaining inspiral time of 38 Myr and a potentially measurable orbital period decay of 7 s over the coming decade, assuming a stellar tidal quality factor $Q'_s = 2 \times 10^7$.

Can you make a scale drawing?

$$a = 4.5\ R_{star}$$

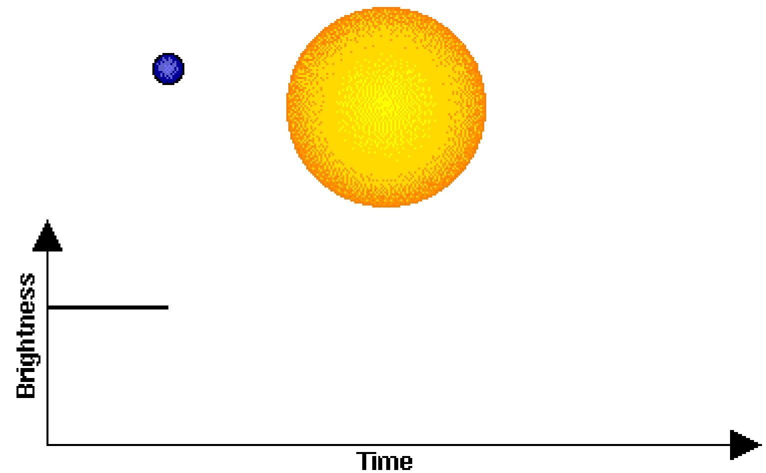
https://arxiv.org/archive/astro-ph

Indirect Method #3

eclipses ("transits")

probabilities: 0.5% (Earth-like); 10% (Jupiter-like)

A planet can cross in front of a star diminish some of the star's light.



How does the drop in flux scale with diameter of the planet?

What percentage signal drop do you expect?

Sun-Jupiter= ?

Sun-Earth = ?

Work together!

Our Textbook's Statement (p. 300)

What does it mean exactly?

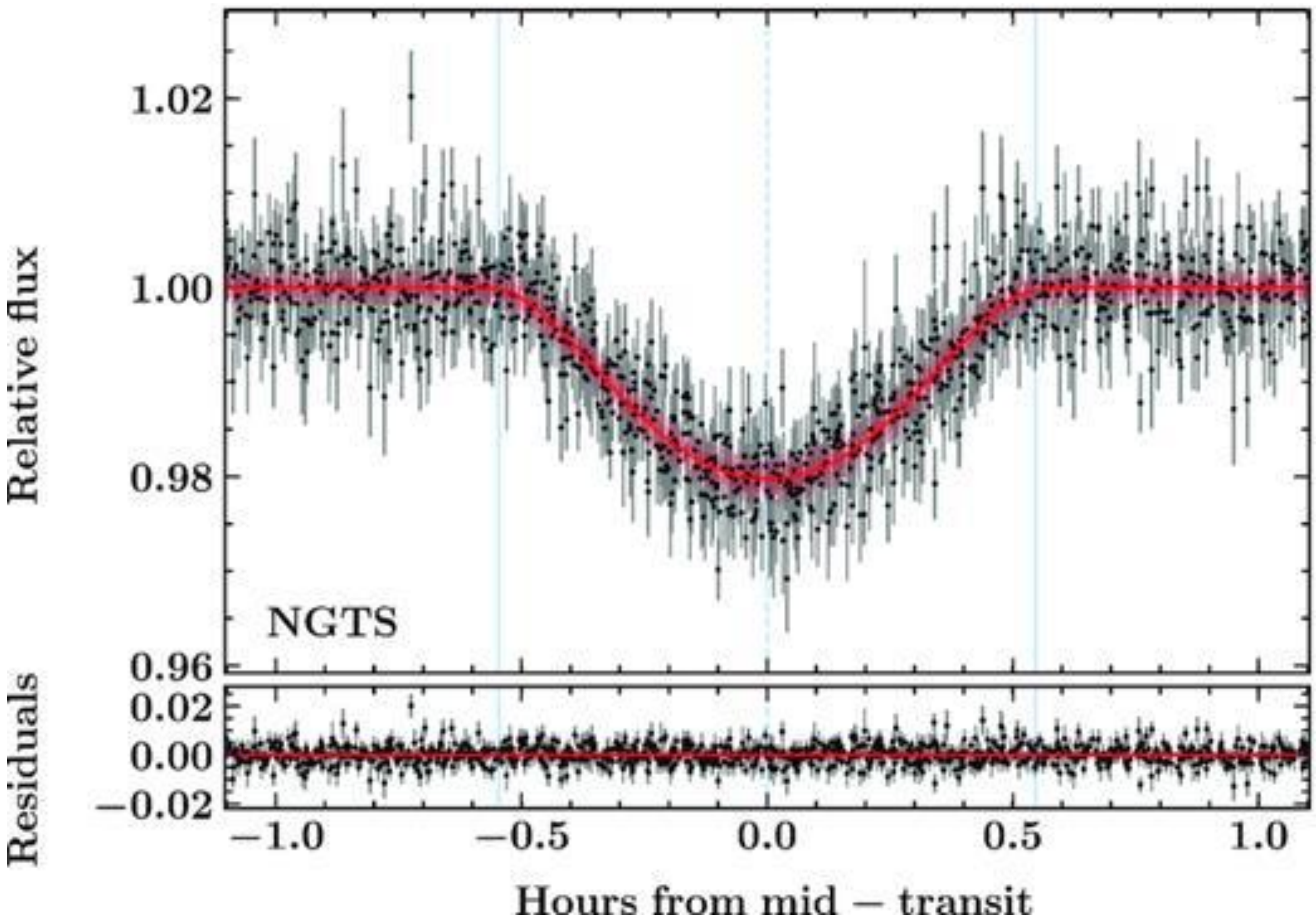
"If the cross-section of the planet is πR_B^2 and the cross-section of the star is πR_A^2, then when the planet lies directly between the star and an observer, the star's measured flux F drops by a fractional amount …"

Can you illustrate that amount in a "lightcurve"?

$\delta F/F = [\pi R_B^2 \; / \; \pi R_B^2\,] = (R_B \;/\; R_B)^2$ (Eqn 12.22)

Work together!

Lightcurve of NGTS-10b



Solution

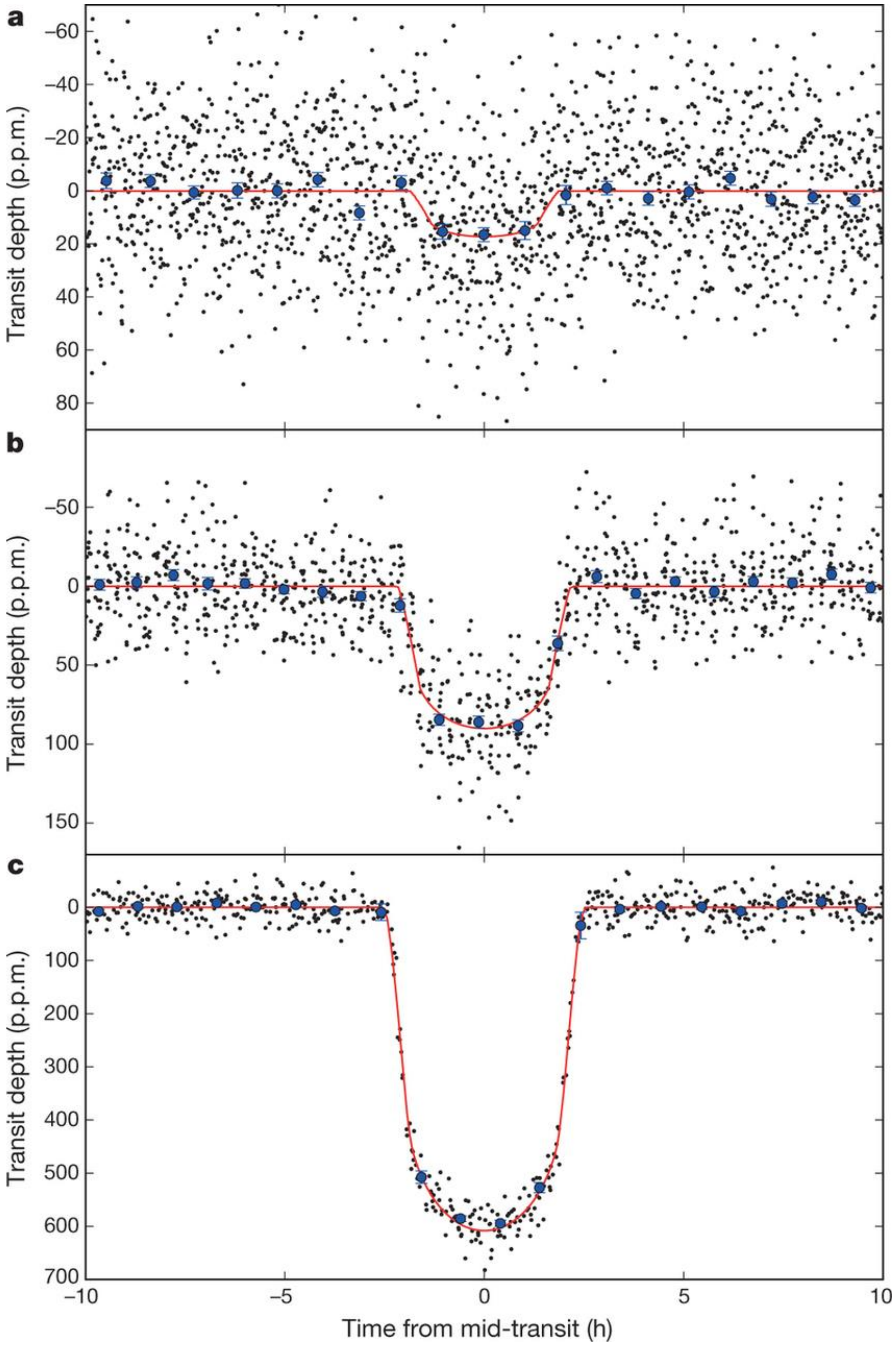
- We want: $(F - \delta F) / F$

- Fractional change in area
  - (AREA – area) / AREA
  - $(\pi R^2 - \pi r^2) / \pi R^2$
  - $1 - (r/R)^2$

How many parts per million reduction in flux?

- $R_{Jup} \sim 0.1\ R_{Sun}$
  - So, Jupiter would reduce the Sun's light by 1%.

- $R_{Earth} \sim 0.01\ R_{Sun}$
  - So, Earth would diminish Sun's light by ~0.01 %.



Kepler 37 b,c,d planets

R_{Earth} =

0.35

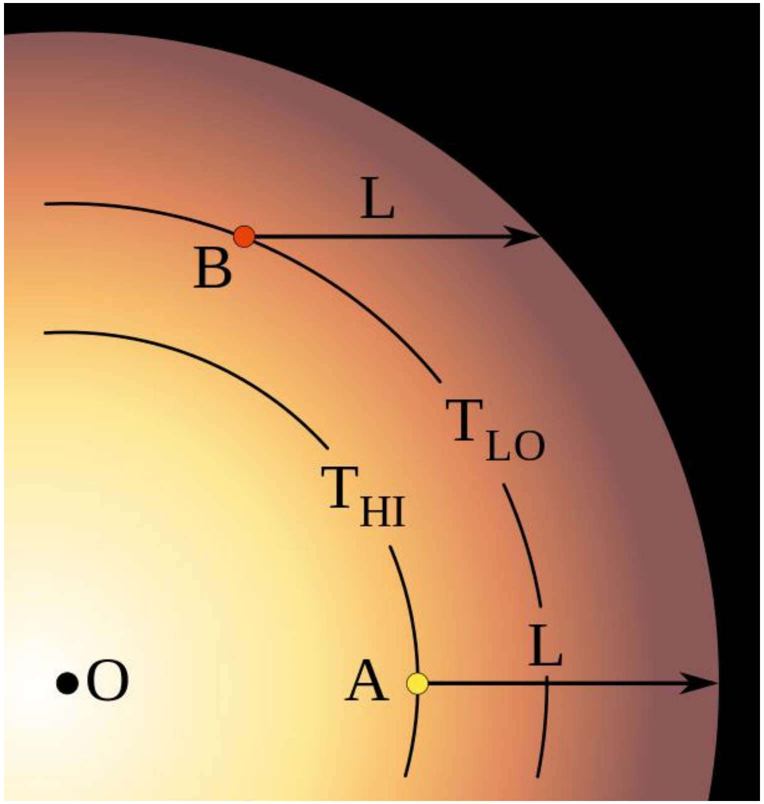
0.74

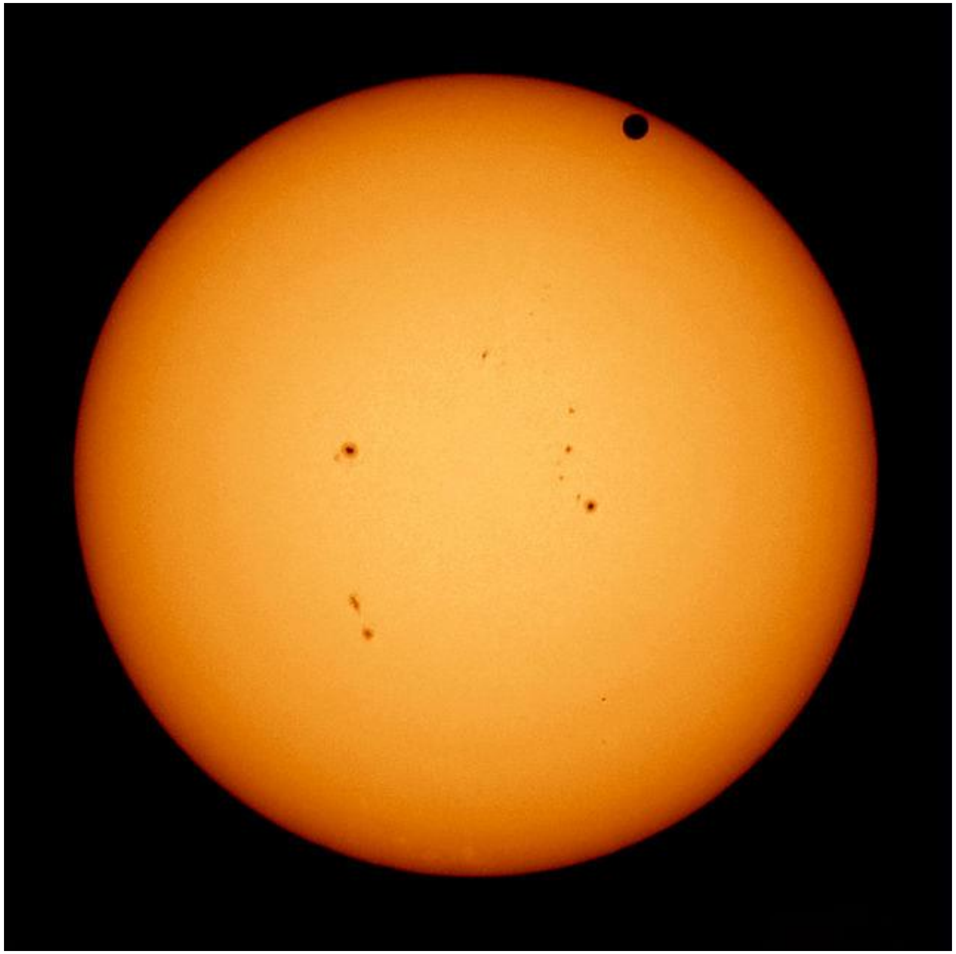
2

More than Meets the Eye

limb darkening and star spots

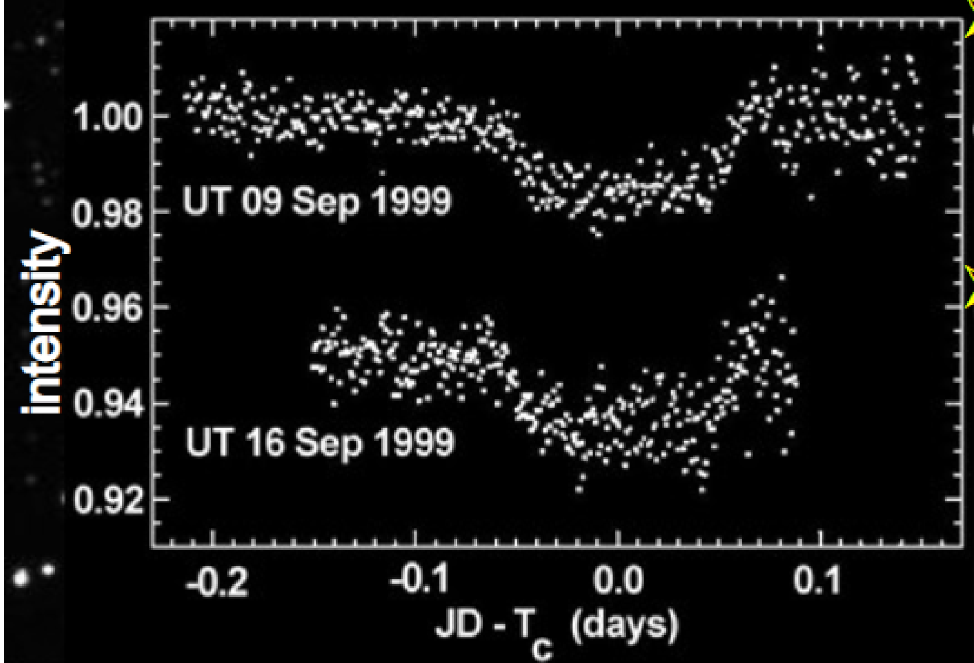
How overcome the effects of intermittent star spots?





The Planet Around Star HD 209458

Charbonneau *et al.* 2000

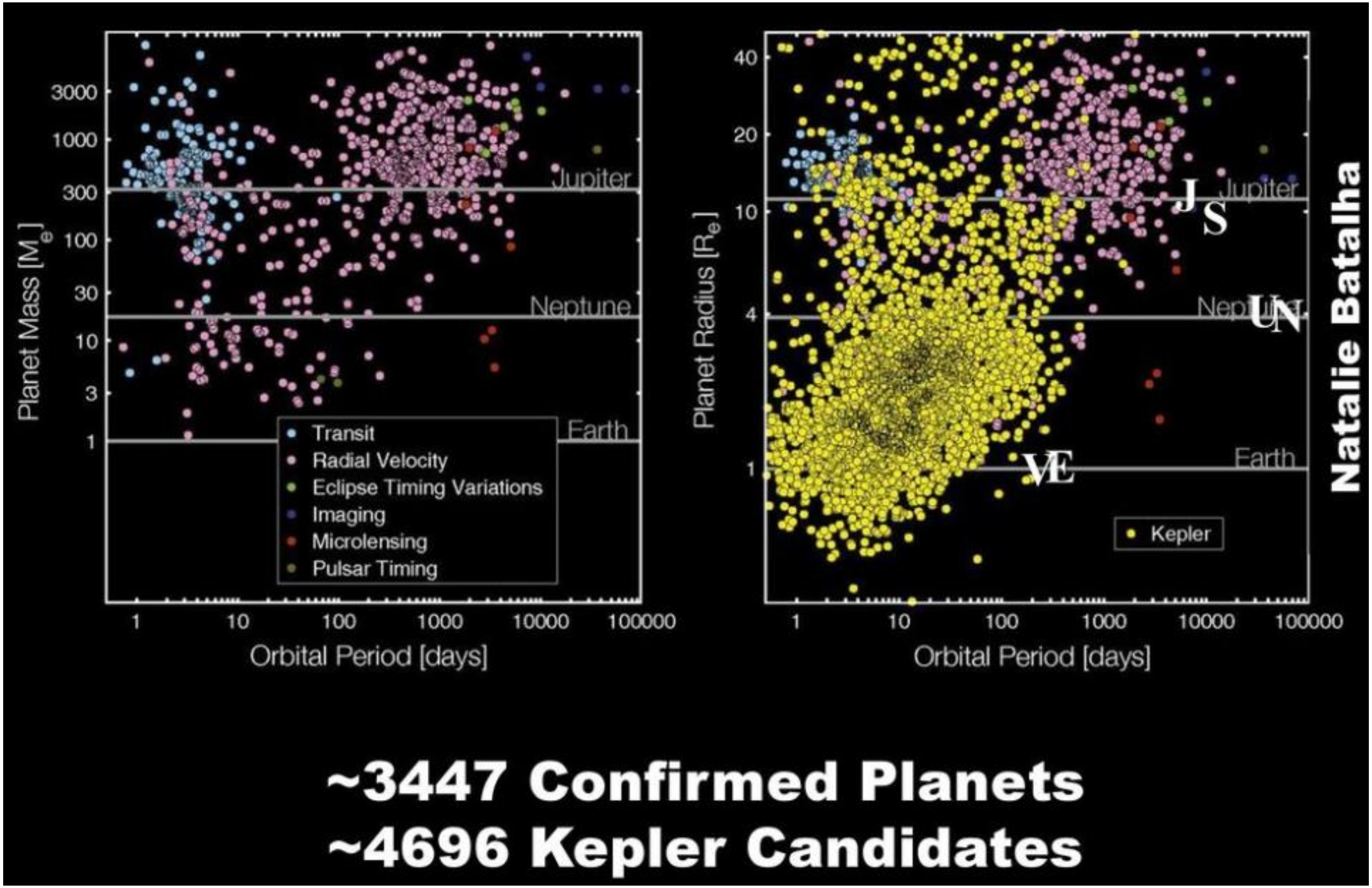


- The planet around HD209458 was discovered by the radial velocity signal.
- After discovery, a transit was observed ⇒ this gives a good measure of the *inclination*. From M sin *i*, we can then derive M.

Definitely a gas giant planet like Jupiter!

- $M_P = 0.69 \pm 0.05\ M_{JUP}$
- $R_P = 1.40 \pm 0.17\ R_{JUP}$
- density = $\rho = 0.31 \pm 0.07\ g/cm^3$

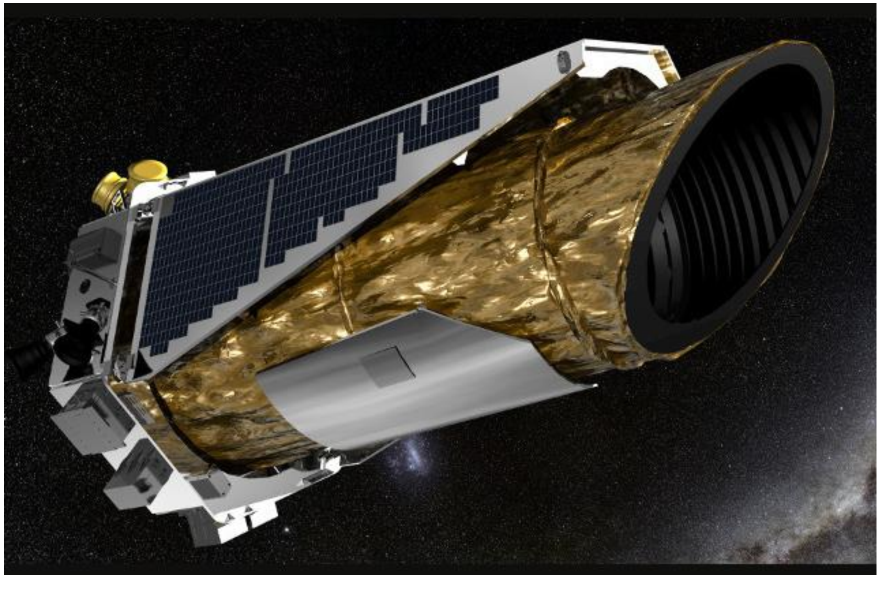
Mass Measurement Requires Multiple Techniques



Kepler Mission (2009-2018)

observed 150,000 stars towards a "fixed-field" in Cygnus

The objective was a combined differential photometric precision (CDPP) of 20 parts per million (PPM) on a magnitude 12 star for a 6.5-hour integration.



TESS Mission (2018 ->)

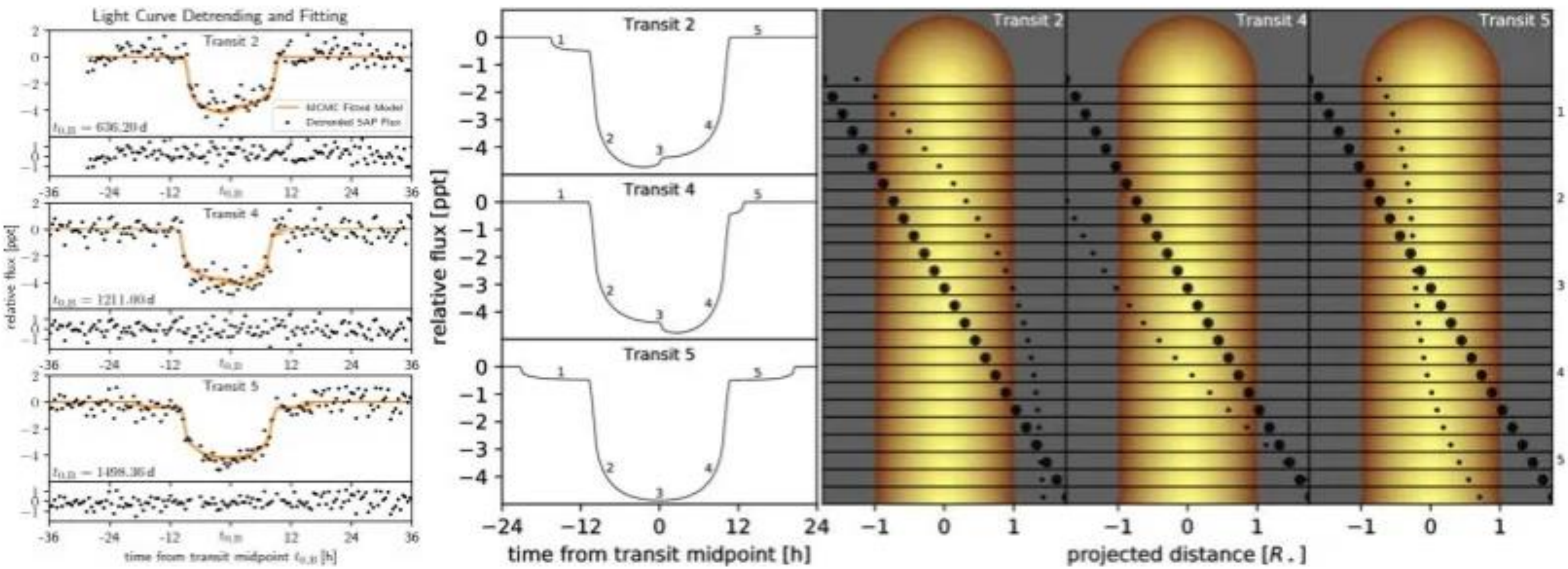
Transiting Exoplanet Survey Satellite

surveying 85% of the sky vs. Kepler 0.25%

- **TESS's two-year all-sky survey will focus on nearby G, K, and M-type stars with apparent magnitude brighter than magnitude 12.**

- **Approximately 500,000 stars will be studied, including the 1,000 closest red dwarfs across the whole sky, an area 400 times larger than that covered by the *Kepler* mission.**

Kepler-1625 b
plus … the first detected exomoon?



Nine of the ~4000 known exoplanets could currently detect Earth via transit

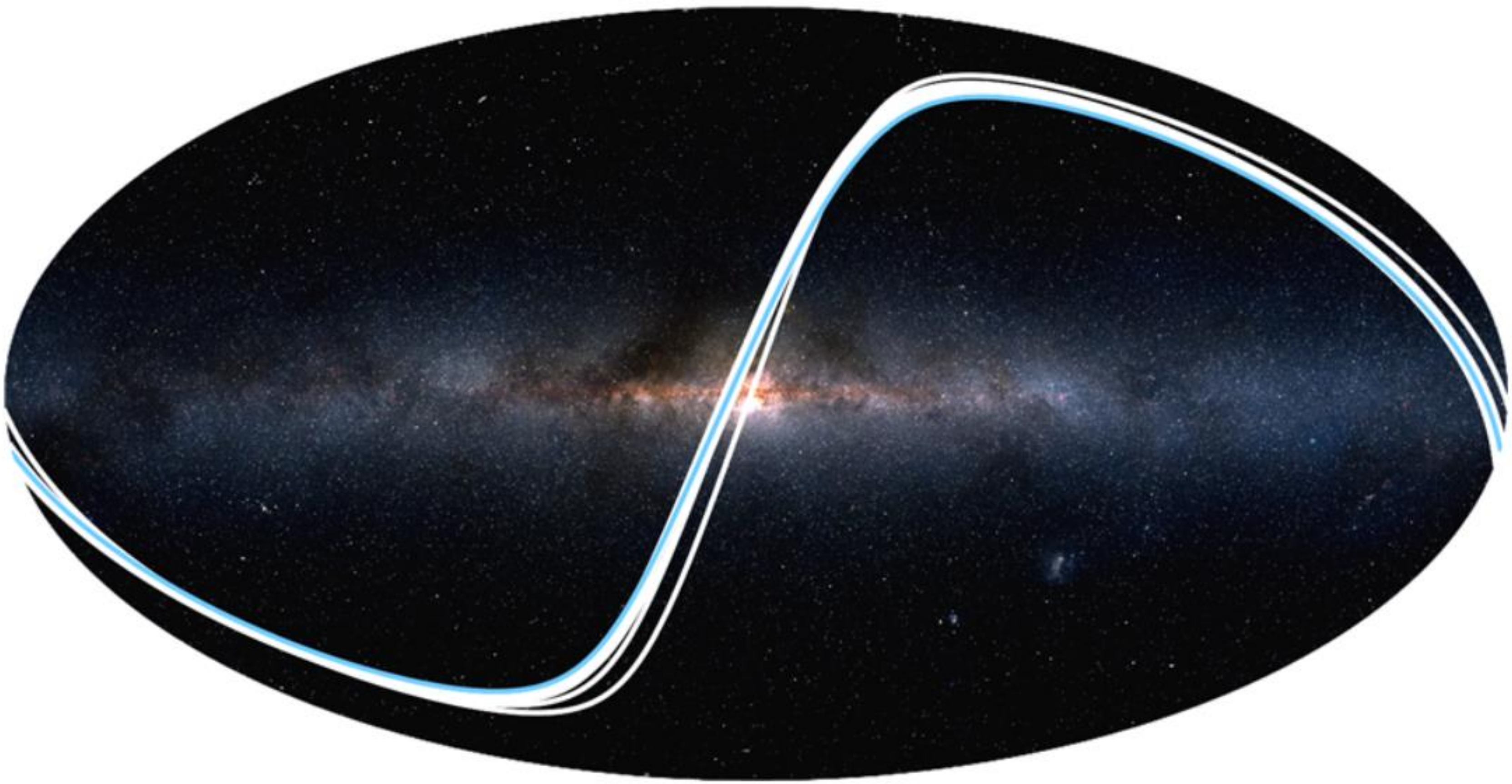
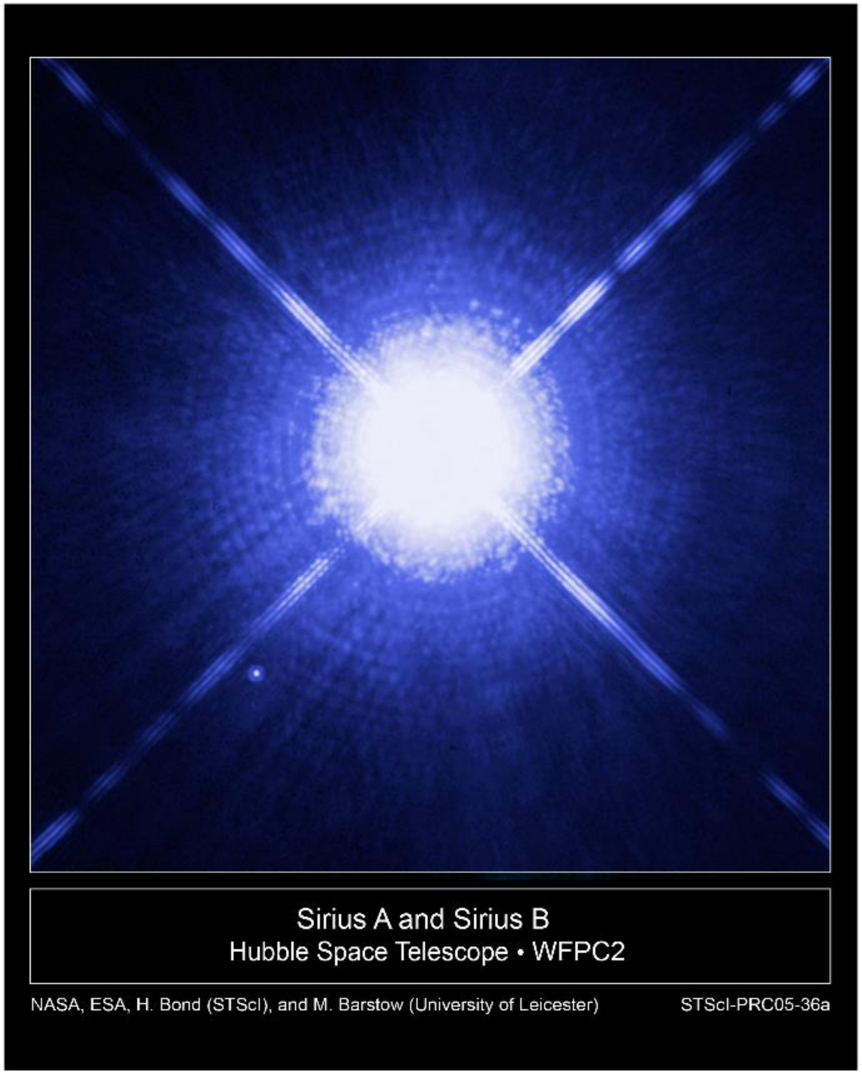


Image showing where transits of our solar system planets can be observed. Each line represents where one of the planets could be seen to transit, with the blue line representing Earth; an observer located here could detect us. 2MASS / A. Mellinger / R. Wells

Direct Imaging of Exoplanets



Why would an alien be challenged to "see" Jupiter from a distance of 10 pc?

You should be able to calculate the relative brightness of Jupiter and Sun.

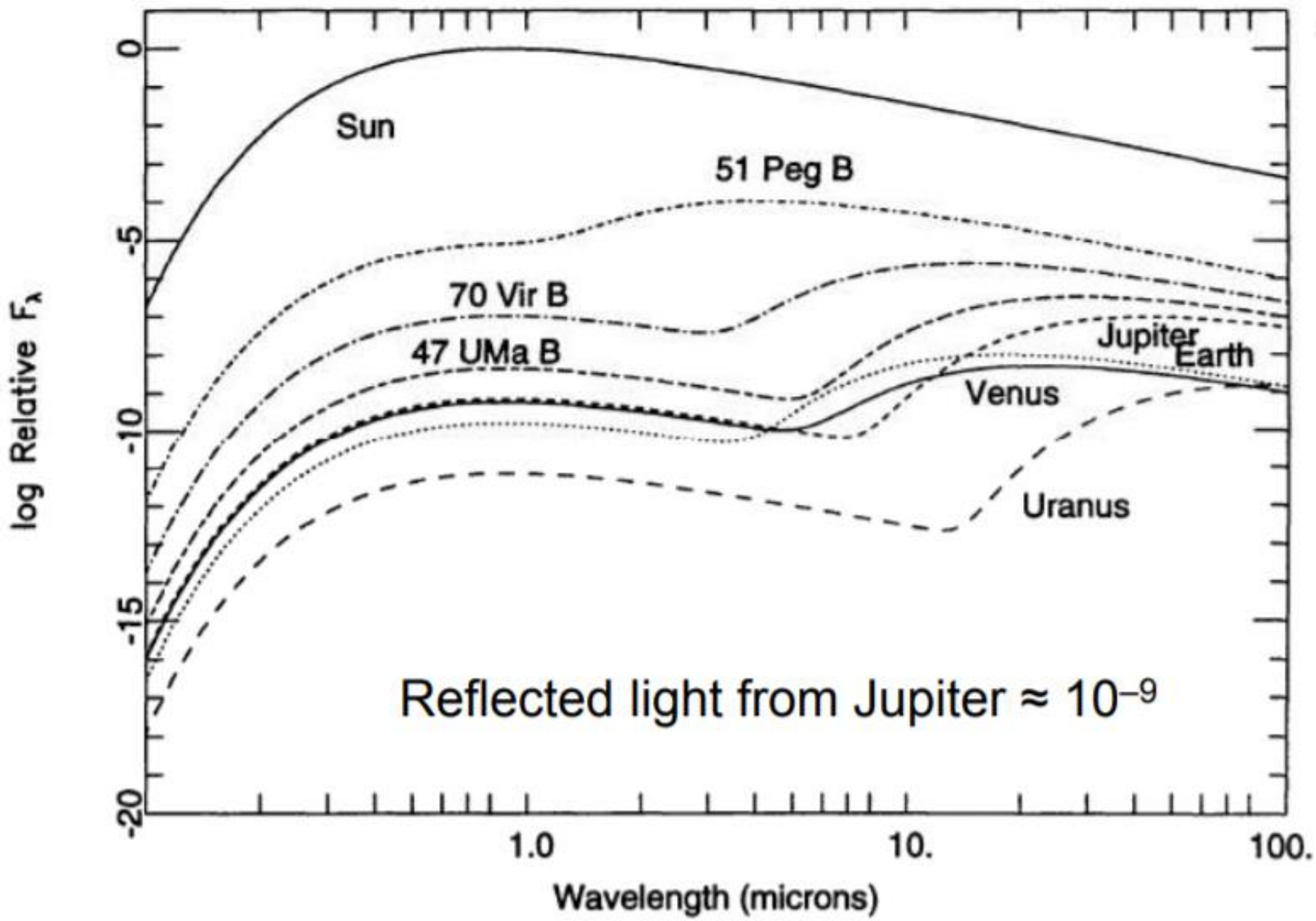
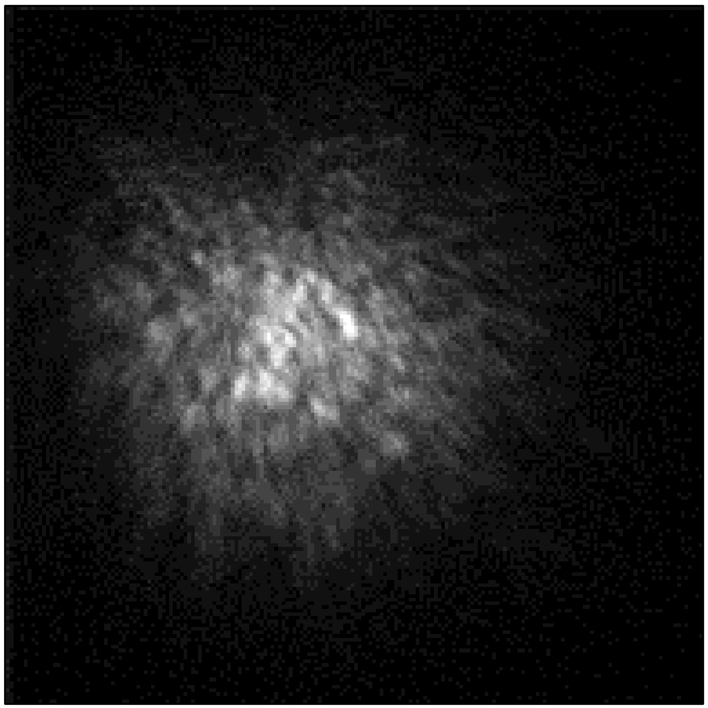


Figure 1. Relative fluxes of the Sun, Venus, Earth, Jupiter, Uranus, and the companion objects to 51 Pegasi, 70 Virginis, and 47 Ursae Majoris from 0.10 μm to 100 μm.

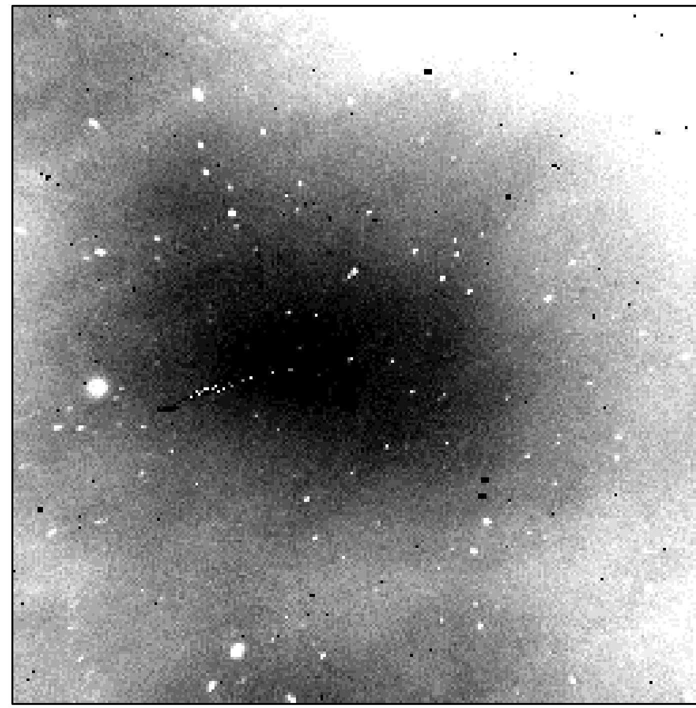
Earth's Atmosphere Hurts !

It absorbs, blurs, and even emits its own light.



Turbulence blurs & twinkles starlight.

"seeing"

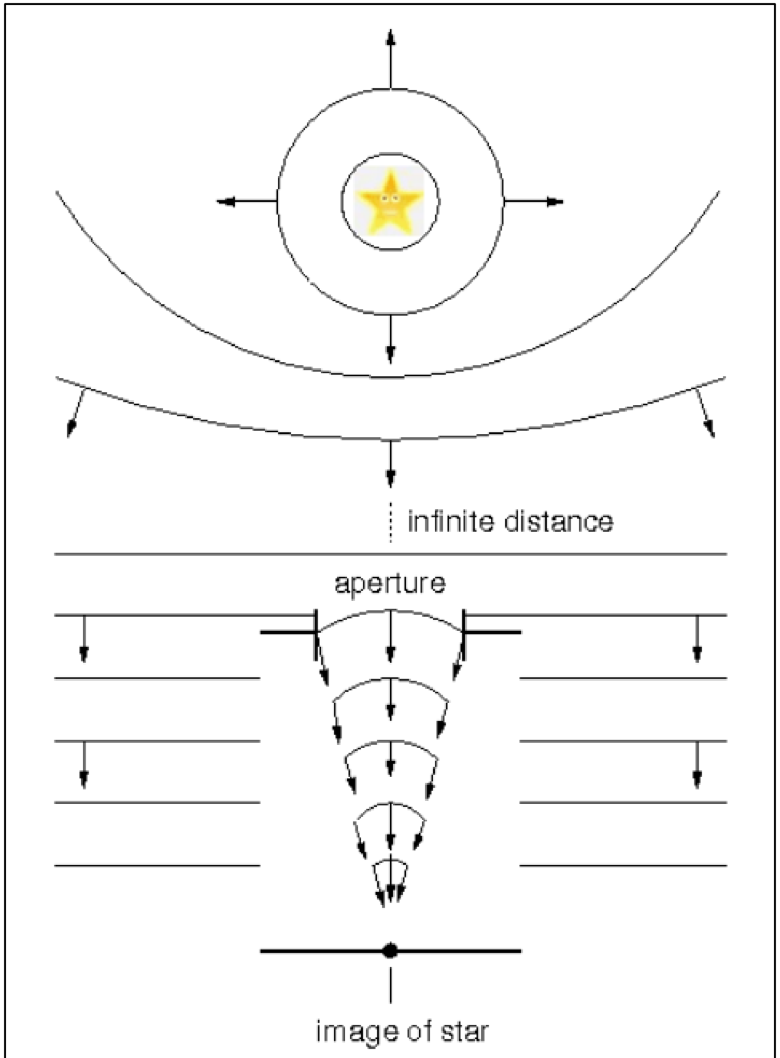


An infrared look through the atmosphere on a clear night

Ch
se
An
fre

Direct Imaging

What is a "perfect" image?



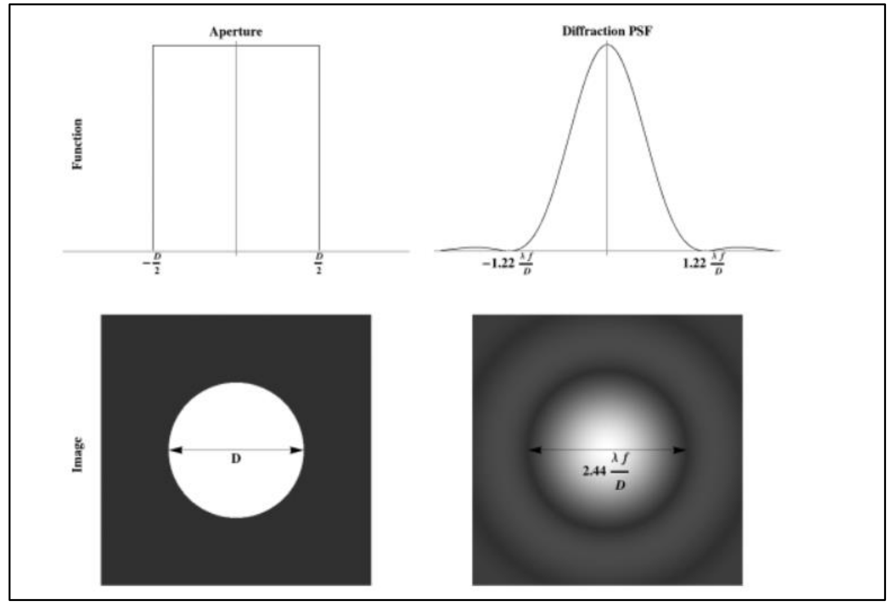
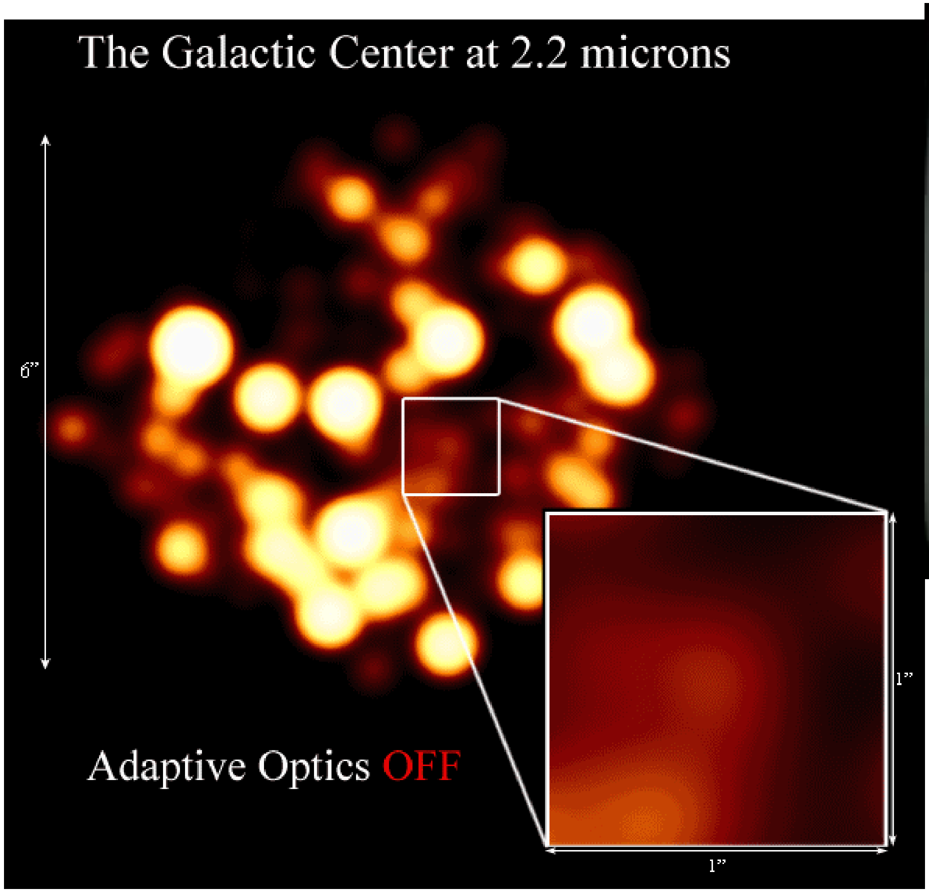
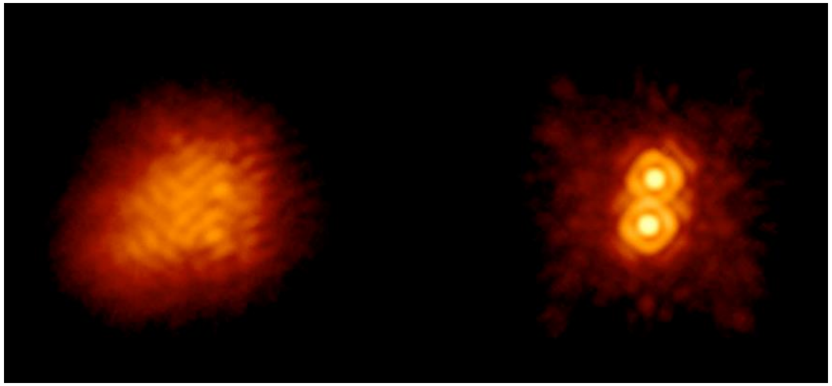


Image diameter α 2.44 λ / D

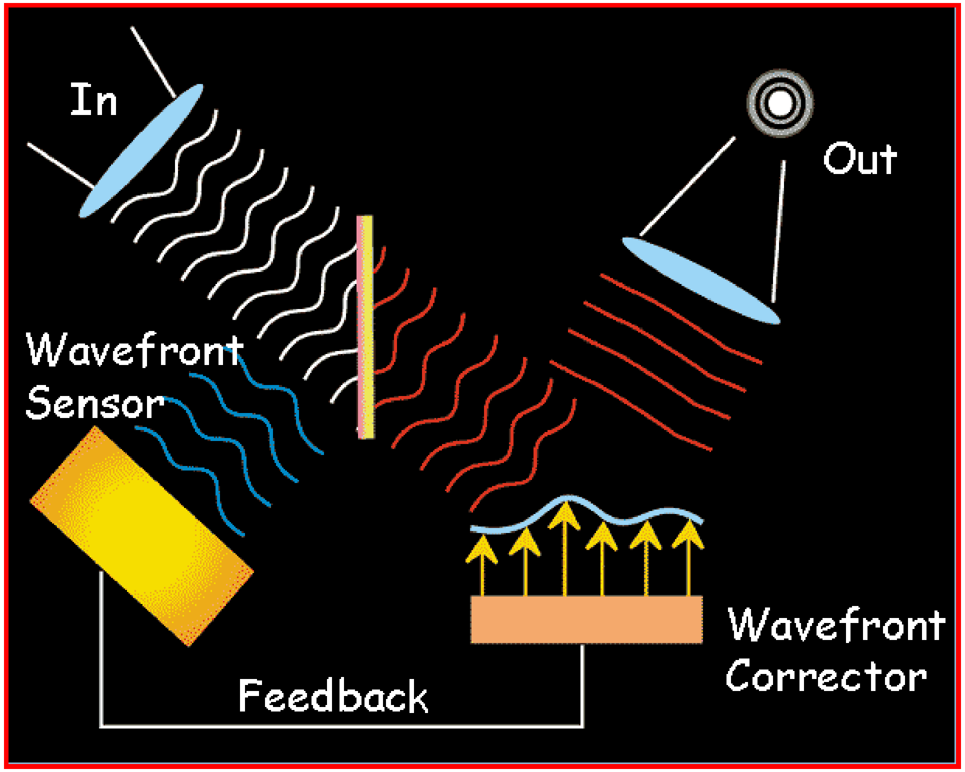
(what units?)

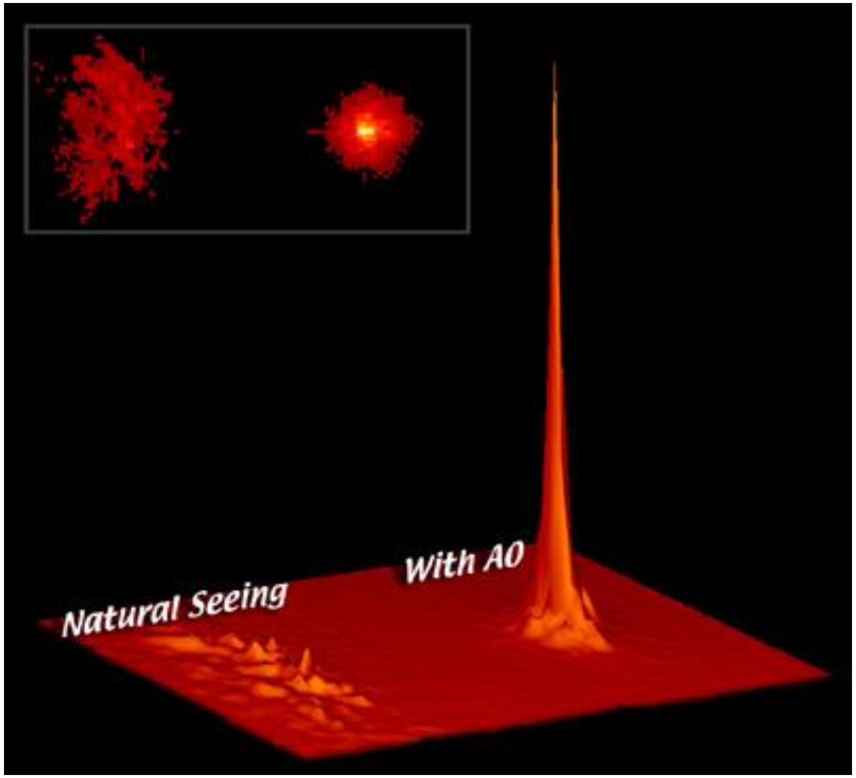
Adaptive Optics
"removing" atmospheric blurring



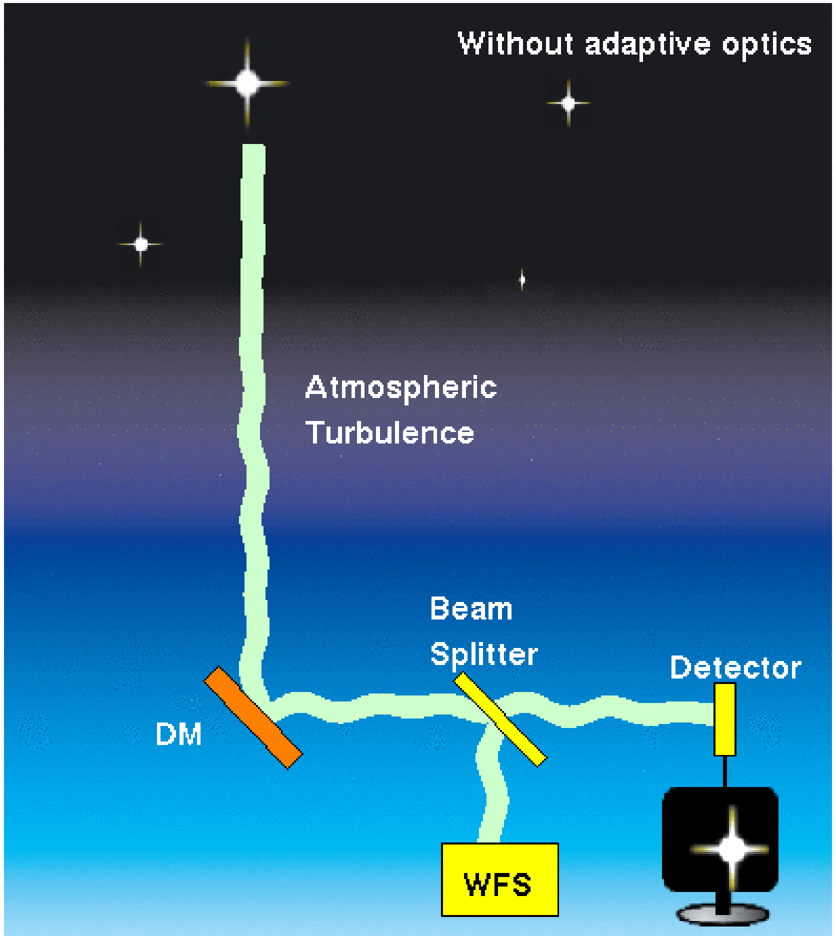


Adaptive Optics

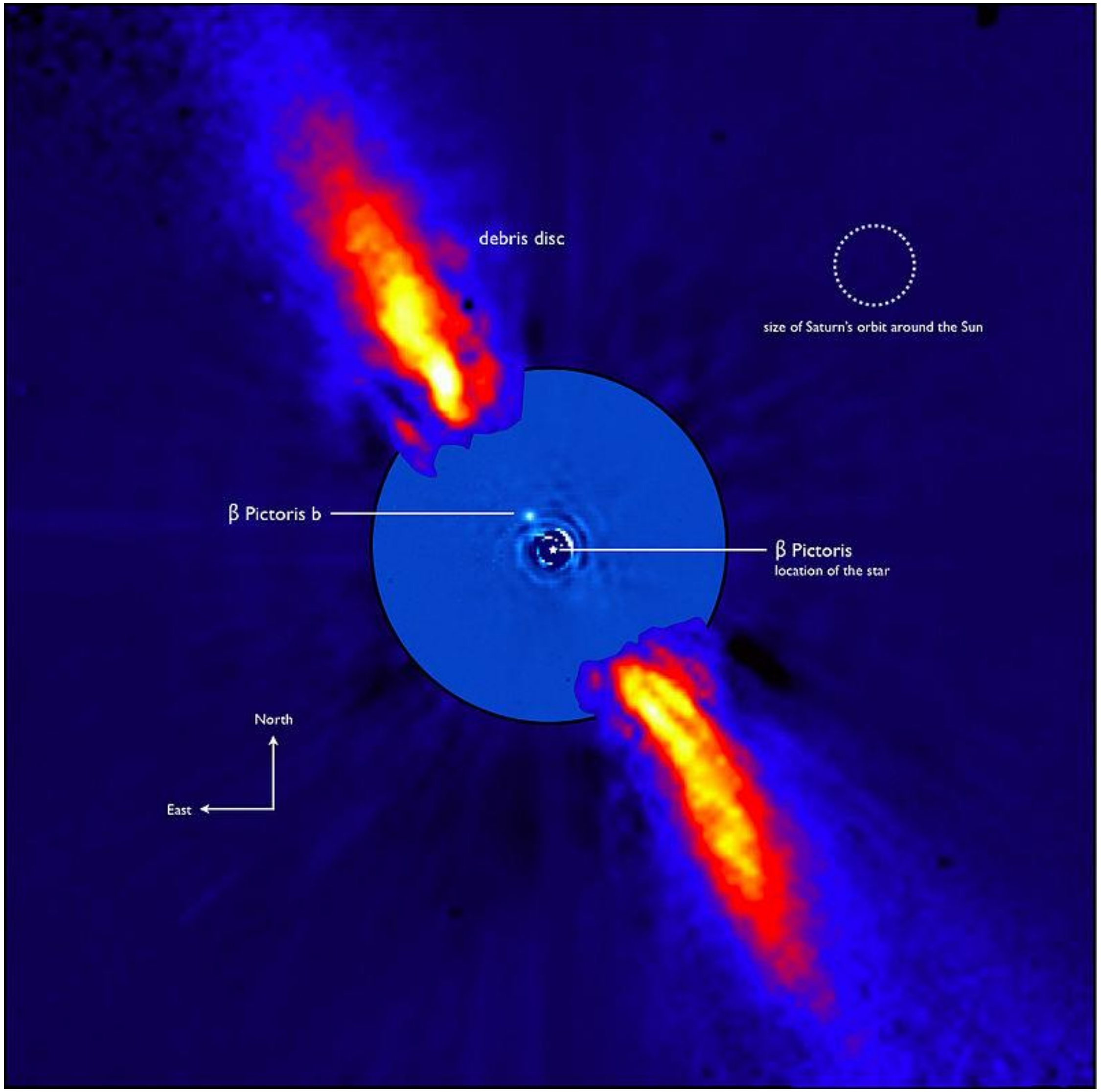




AO in Action


Without adaptive optics
Atmospheric
Turbulence
Beam
Splitter
Detector
DM
WFS

β Pic b


debris disc
size of Saturn's orbit around the Sun
β Pictoris b
β Pictoris
location of the star
North
East