

# Exoplanets



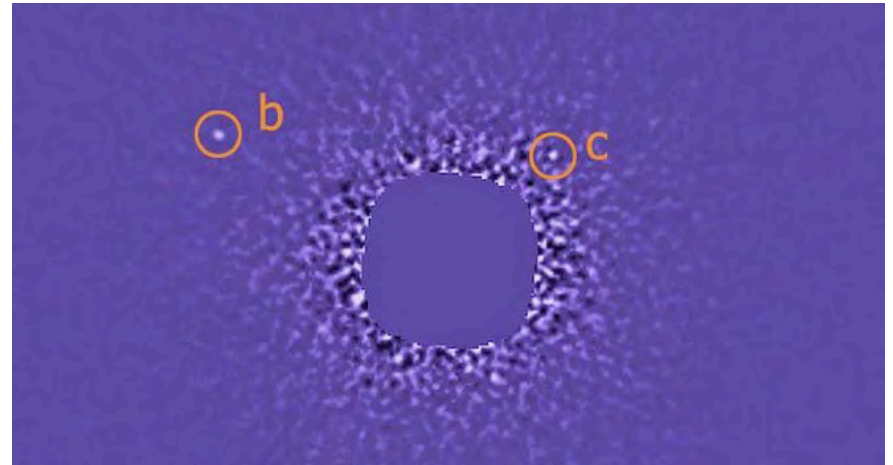
Daniel Bayliss

Mt Stromlo Observatory

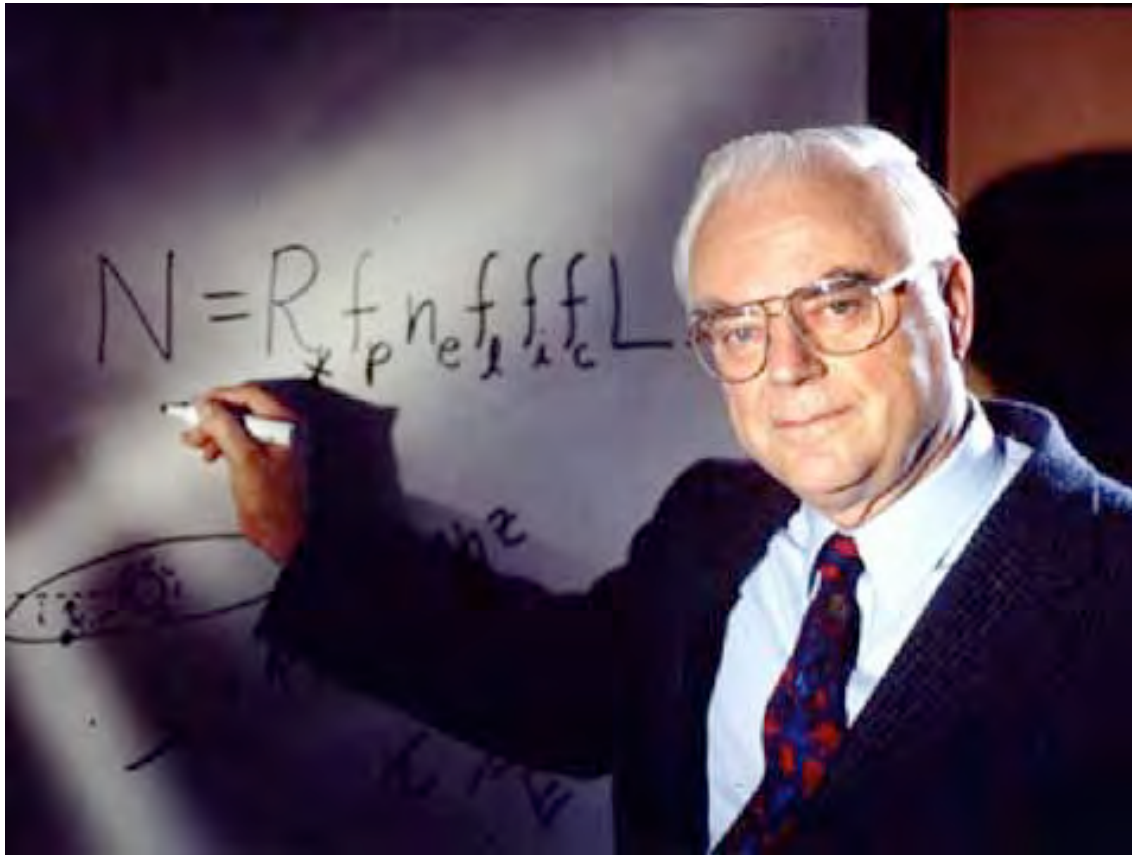
RSAA, ANU

# Planets 101

- What is a planet?
- What is an exoplanet?



# How many exoplanets are there out there?



Frank Drake with his famous equation -  $f_p$  is fraction of stars with planets

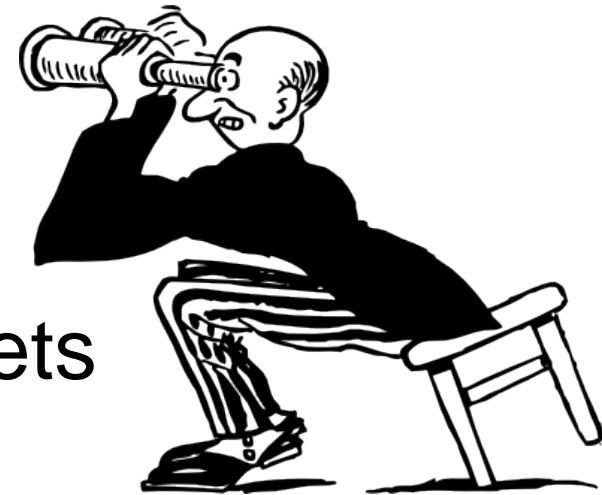
# Picture of Earth



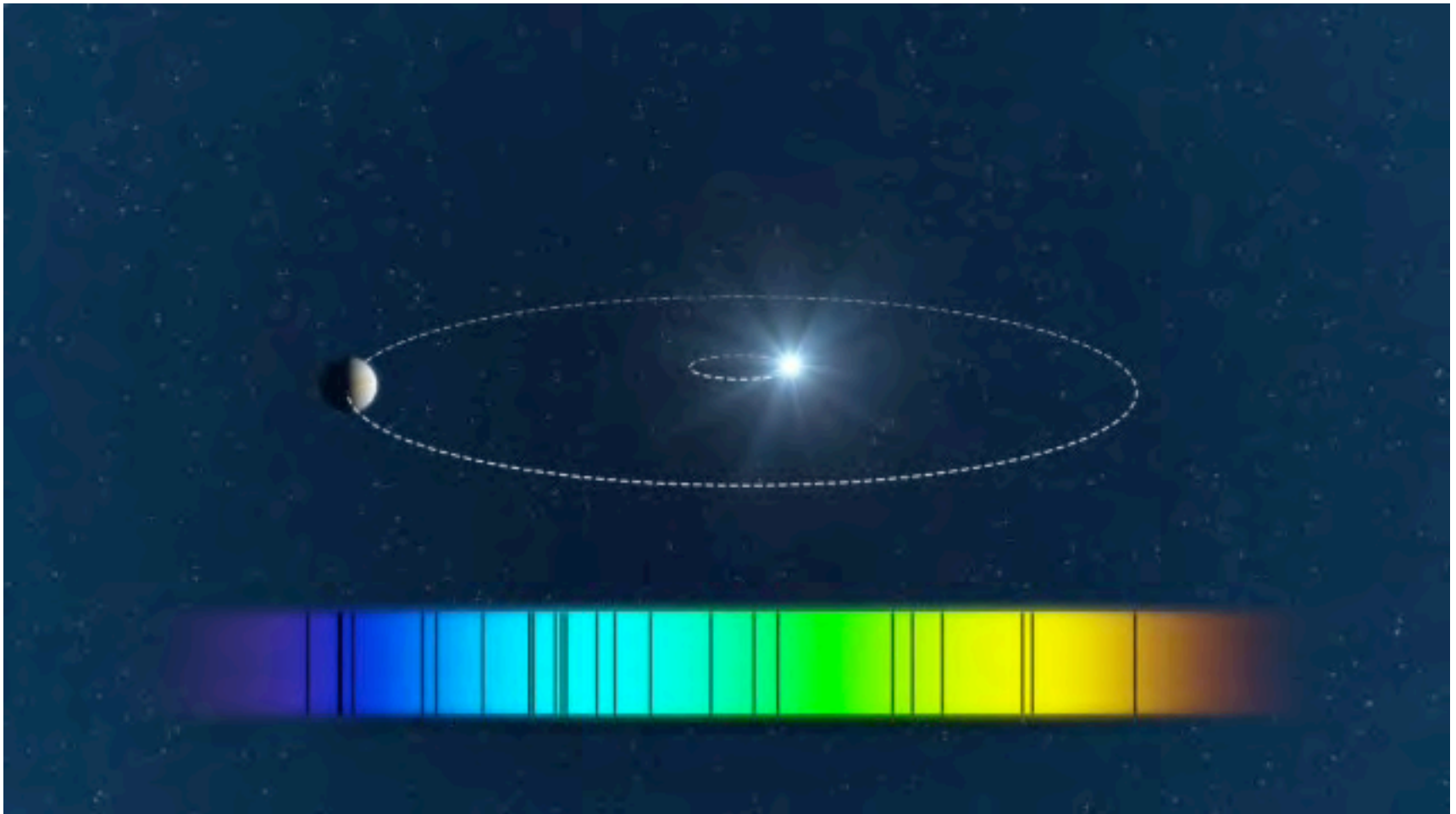
Cassini spacecraft images Earth from over 1 billion km away!

# Planets are hard to see!

- Closest star is 40,000 times further away than than the Cassini image!
- To make matters worse, planets are very close to bright stars.
- As a result astronomers need to use clever techniques to detect and study exoplanets.



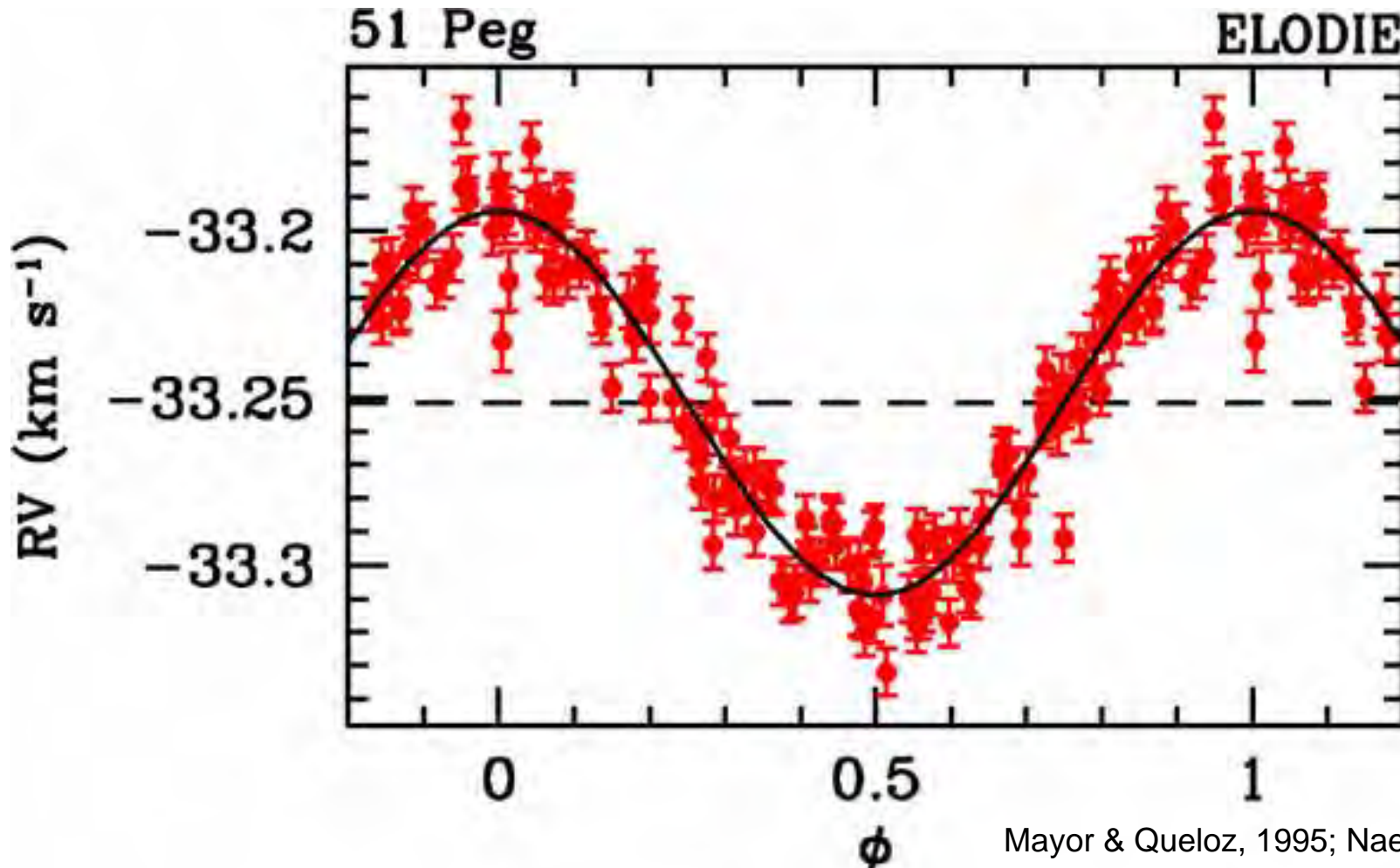
# Technique No. 1 - Radial Velocity



ESO/L. Calçada



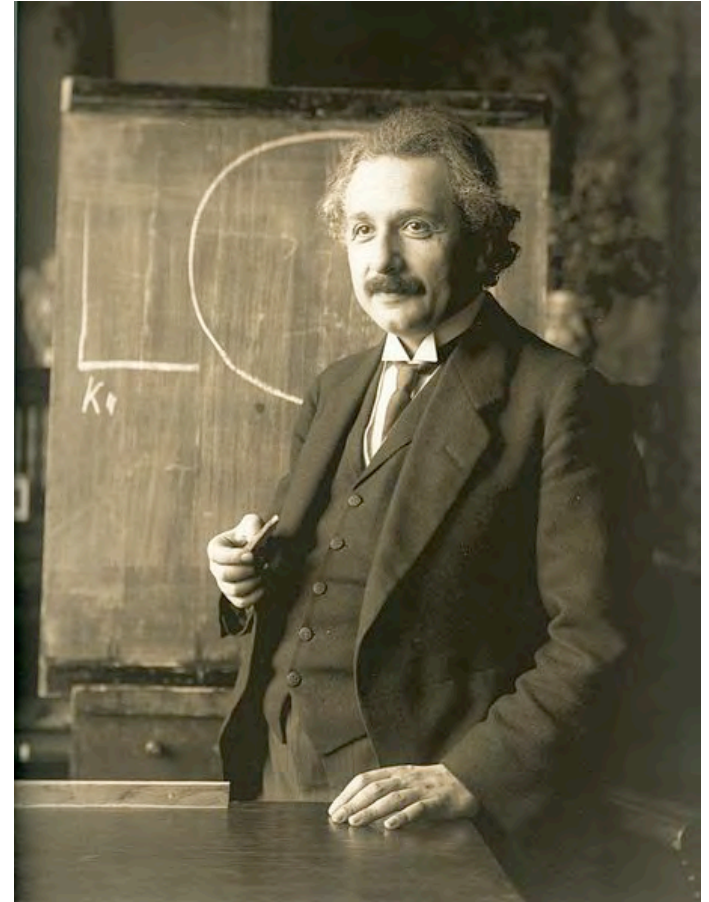
# Wobbling star = orbiting planet!



Mayor & Queloz, 1995; Naef et al. 2004

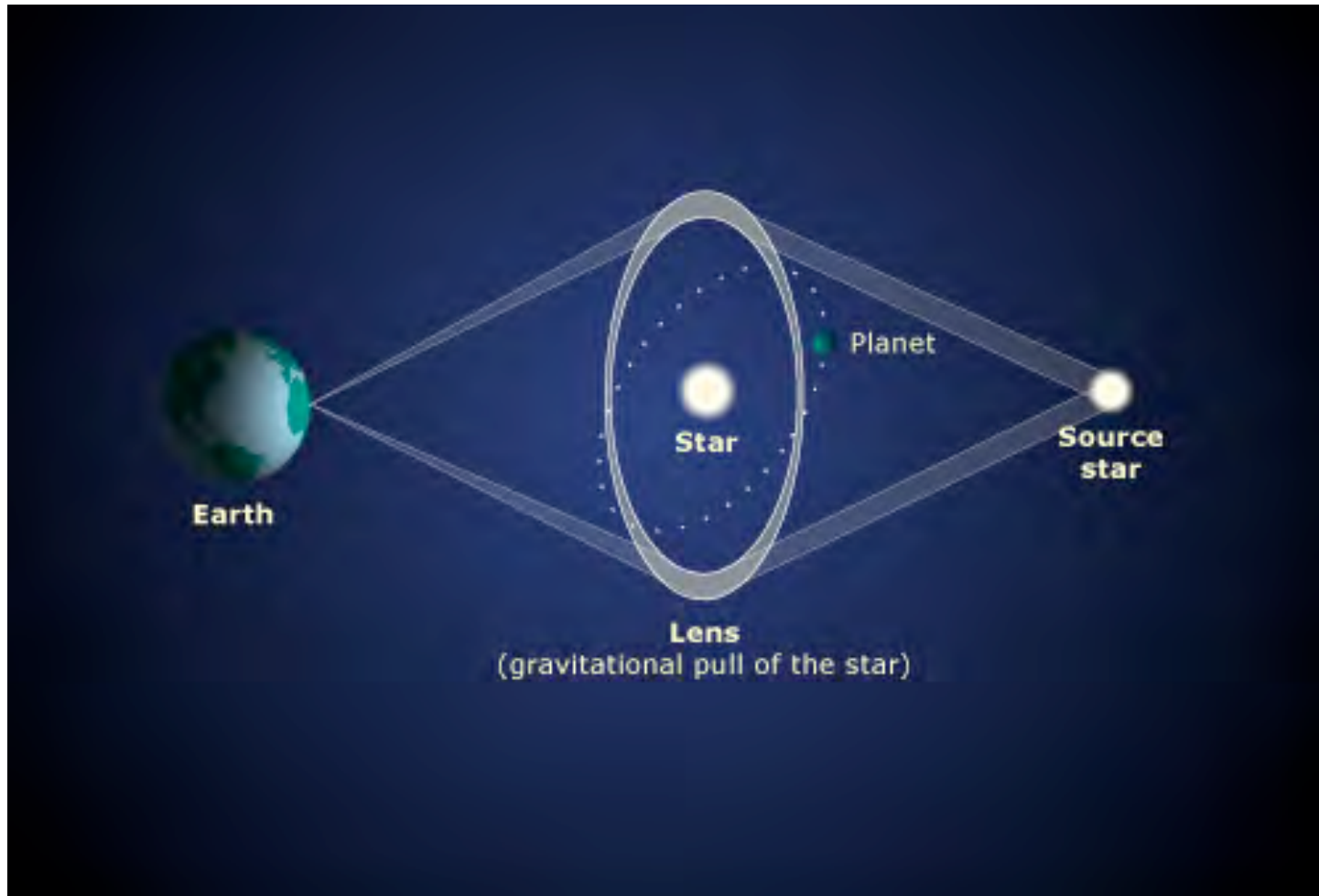
## Technique No. 2 - Microlensing

- In 1924 Einstein worked out that light from distant stars could be bent by the gravity of a foreground star!





# Microlensing



# Microlensing



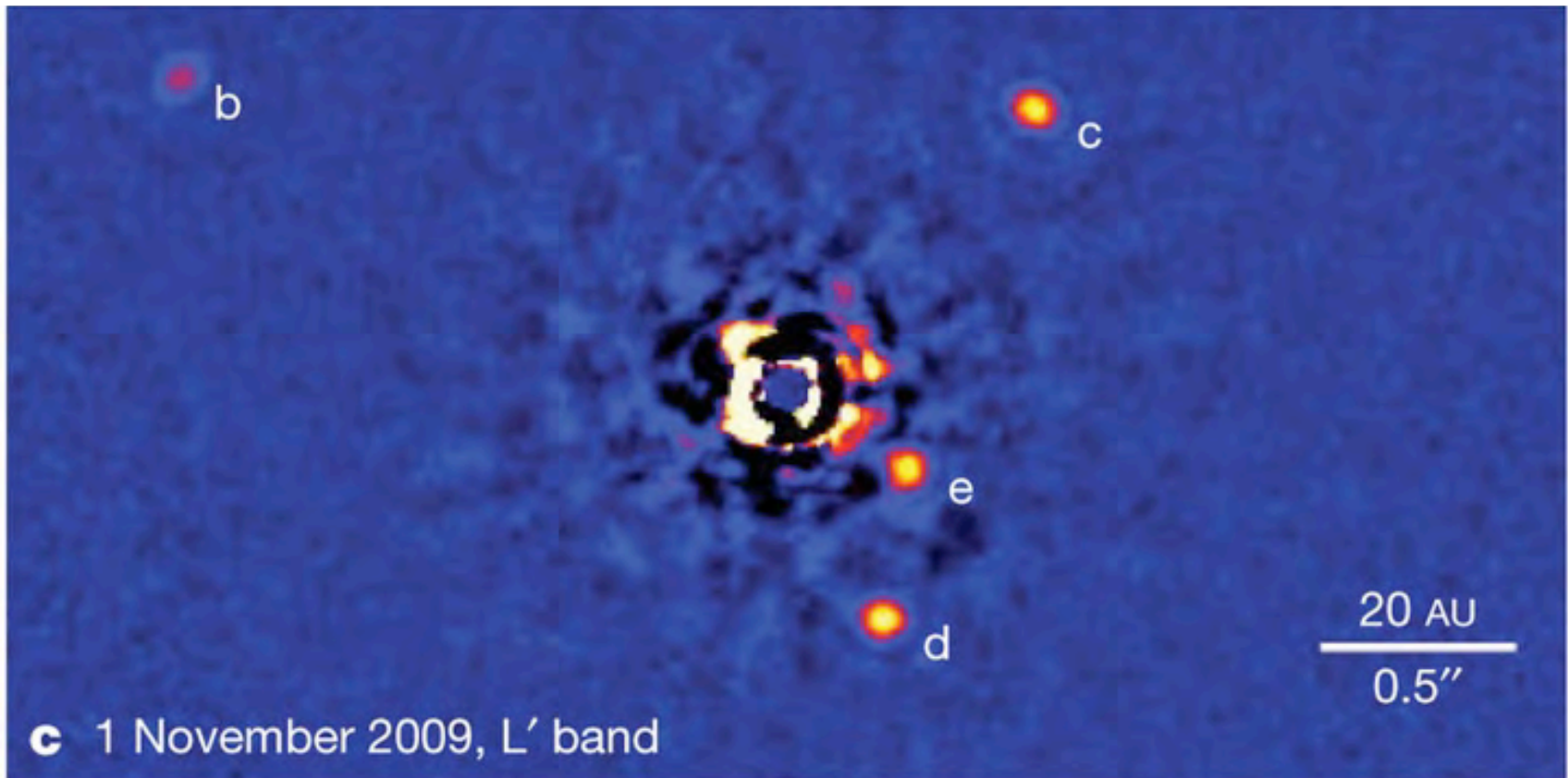
Animation: JPL

## Technique No. 3 - Direct Imaging

- Hard to take an image of an exoplanet
- They appear very close to the star they orbit - which appears very bright!



# Technique No. 3 - Direct Imaging





# Technique No. 4 - Transiting Exoplanets

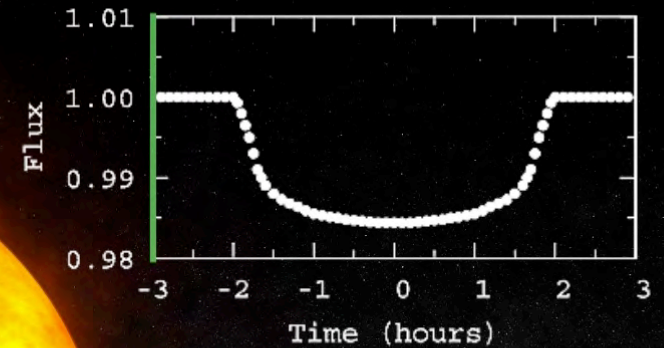
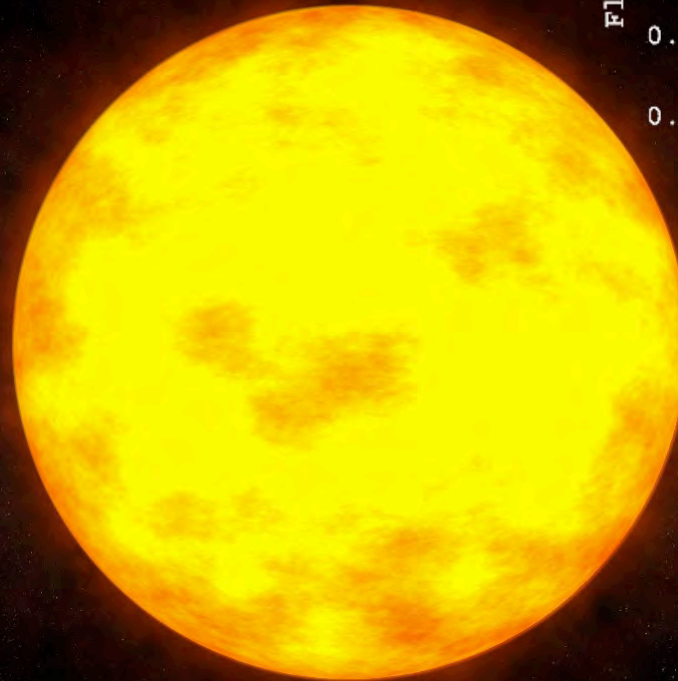
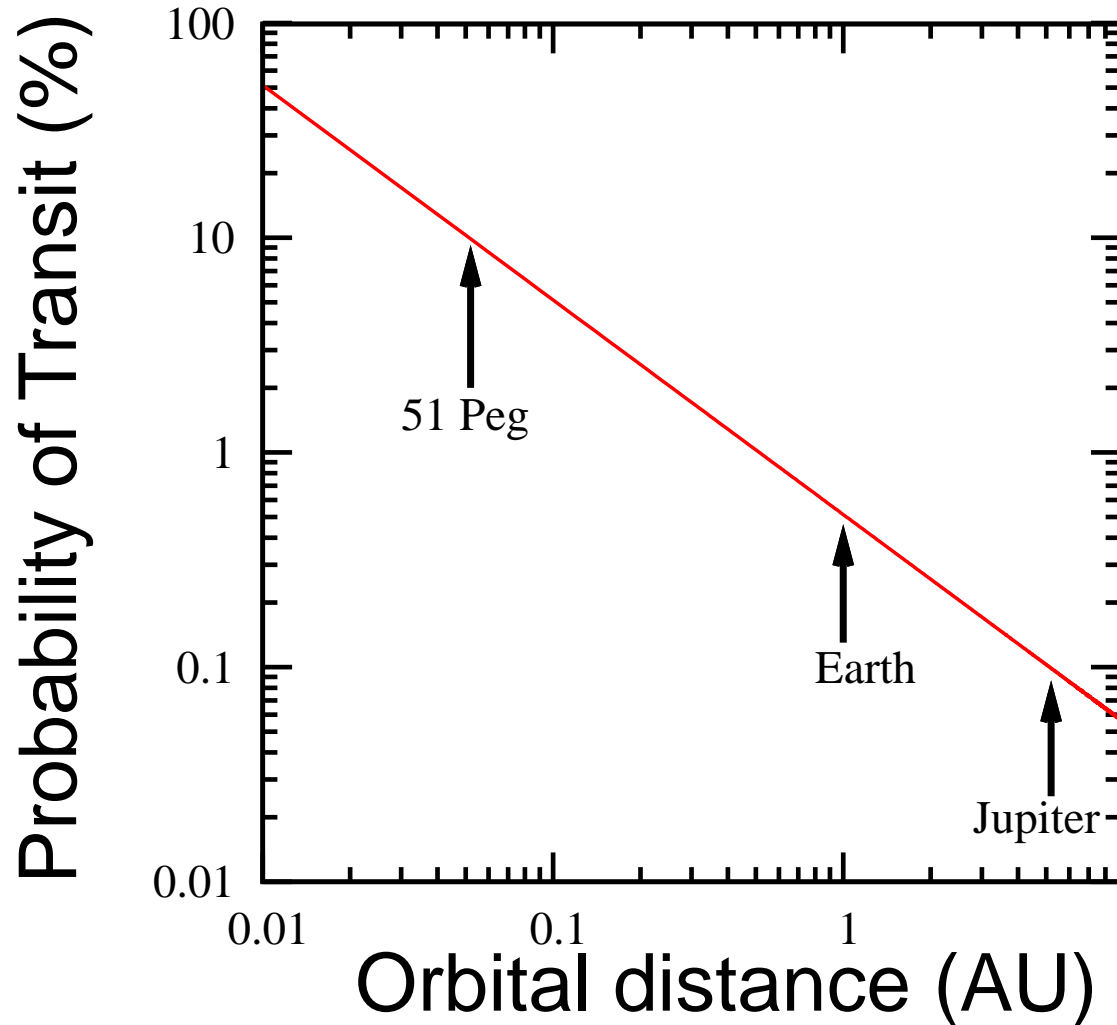




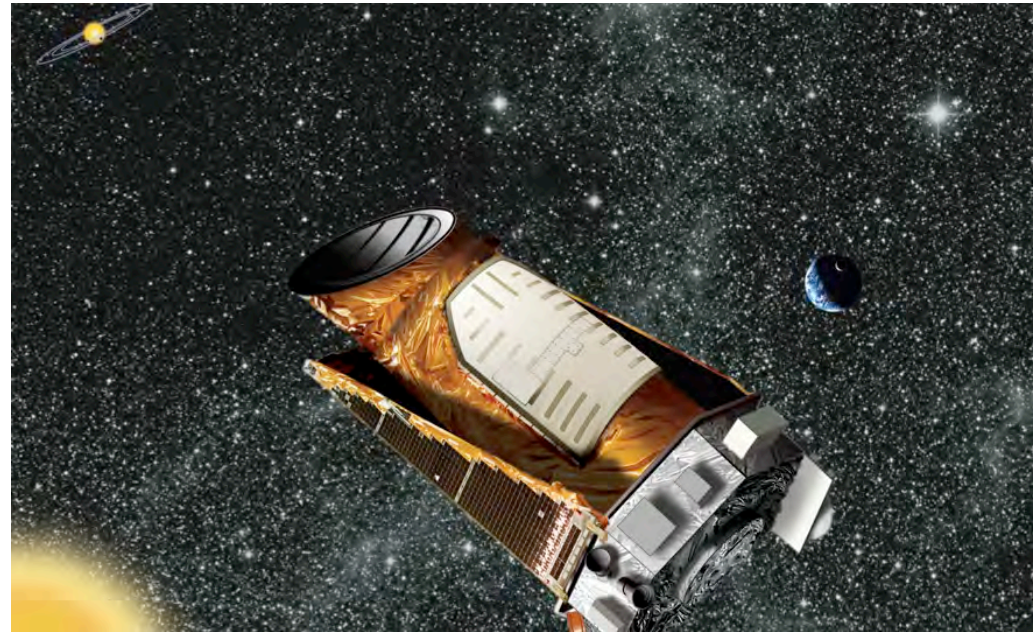
Image: N. Nikalov, MSO, 6 June 2012



# Transits require special alignment

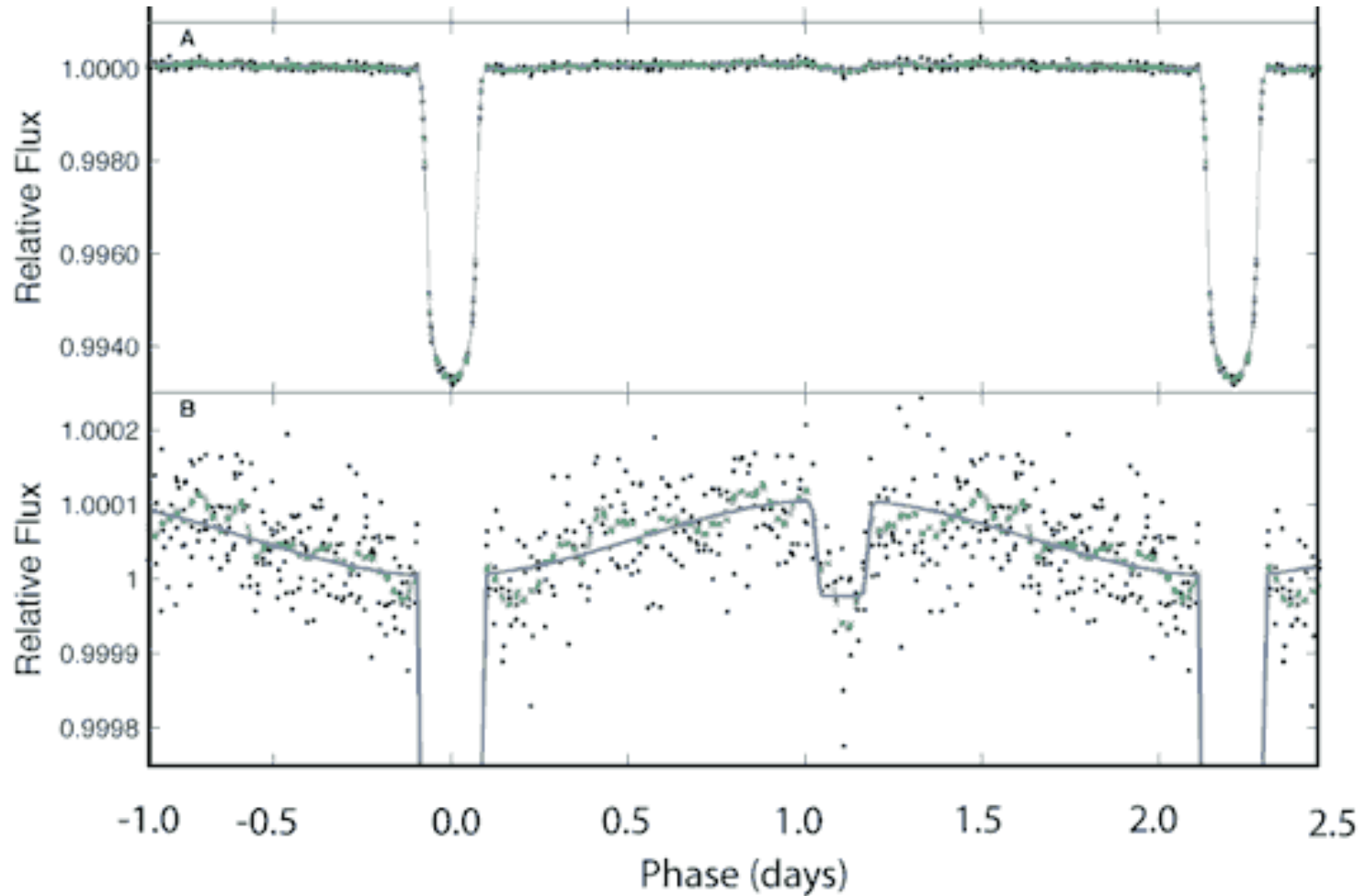


# Kepler Mission



Images:NASA

# Exoplanet “HAT-P-7” from Kepler



# Kepler - Planet frequency

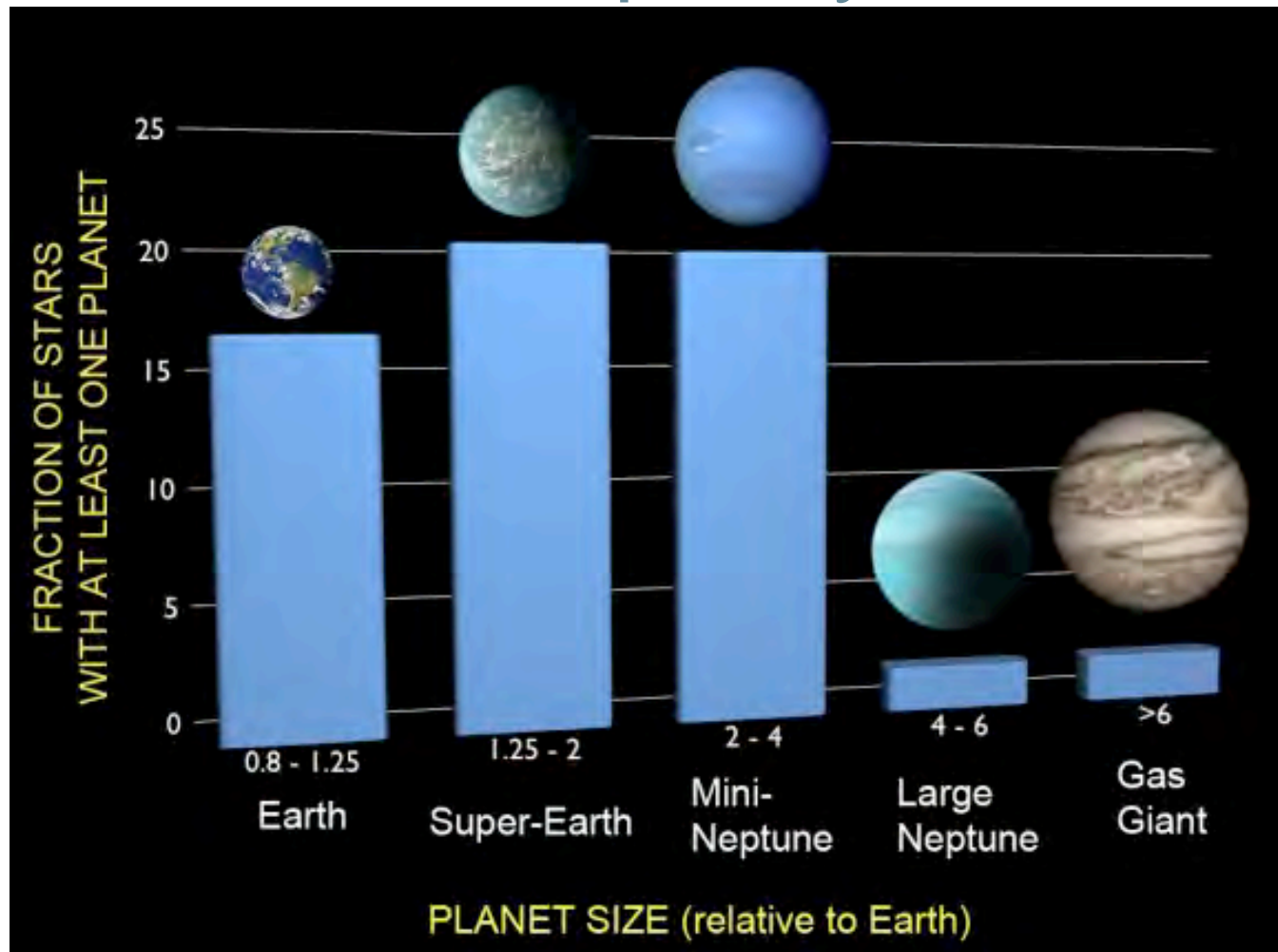


Image:NASA



# Australian Exoplanet hunting - HATSouth

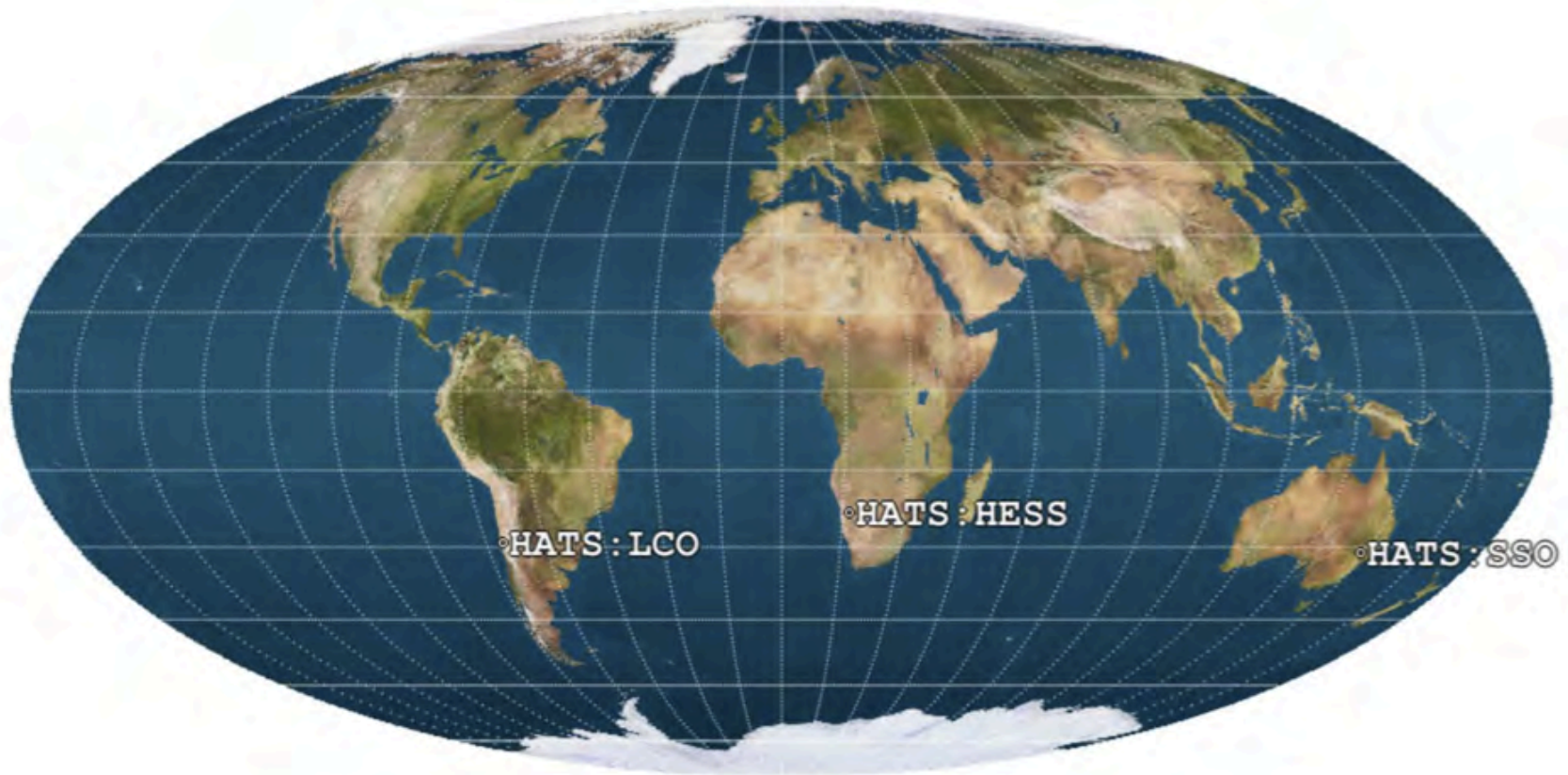


# Siding Spring Observatory





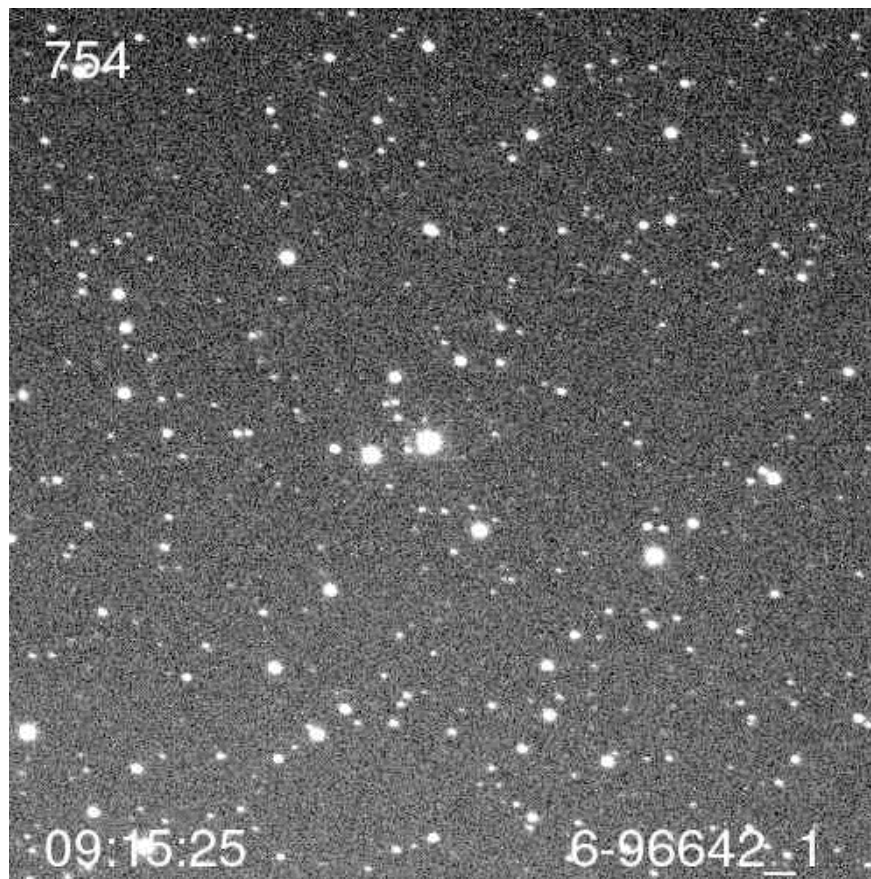
# HATSouth Network of Telescopes



# A day in the life of HATSouth telescopes ...



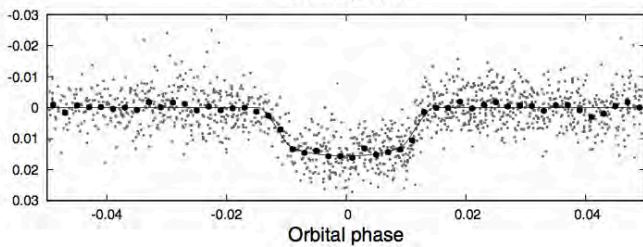
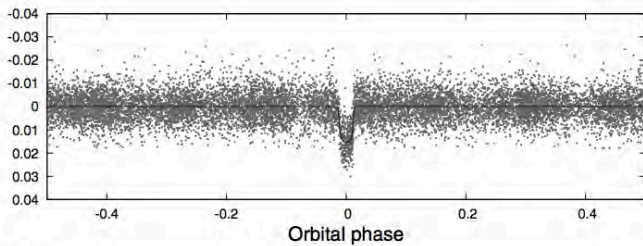
# “Videoing” the sky



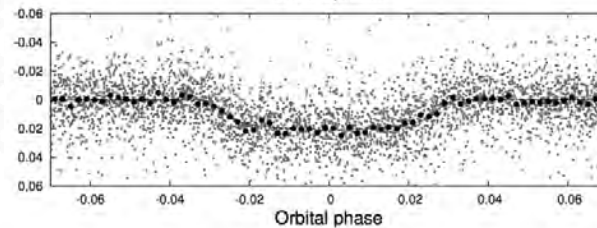
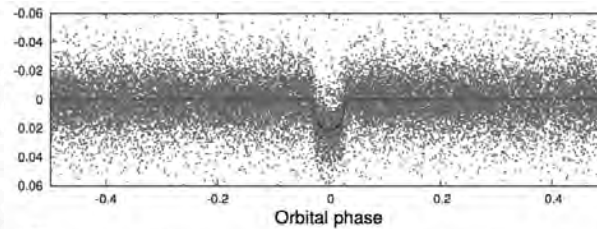
0.2% of the HATSouth field



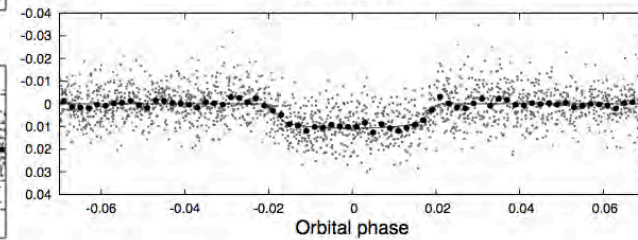
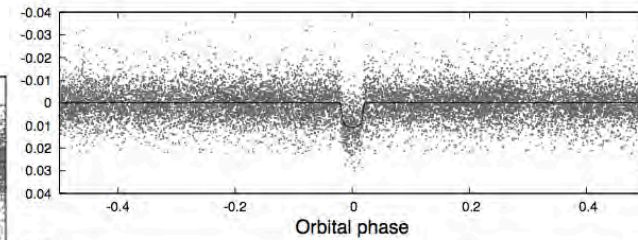
# Exoplanets found so far: HATS-1b, HATS-2b & HATS-3b



Penev et al., 2013



Mohler-Fischer et al., 2013



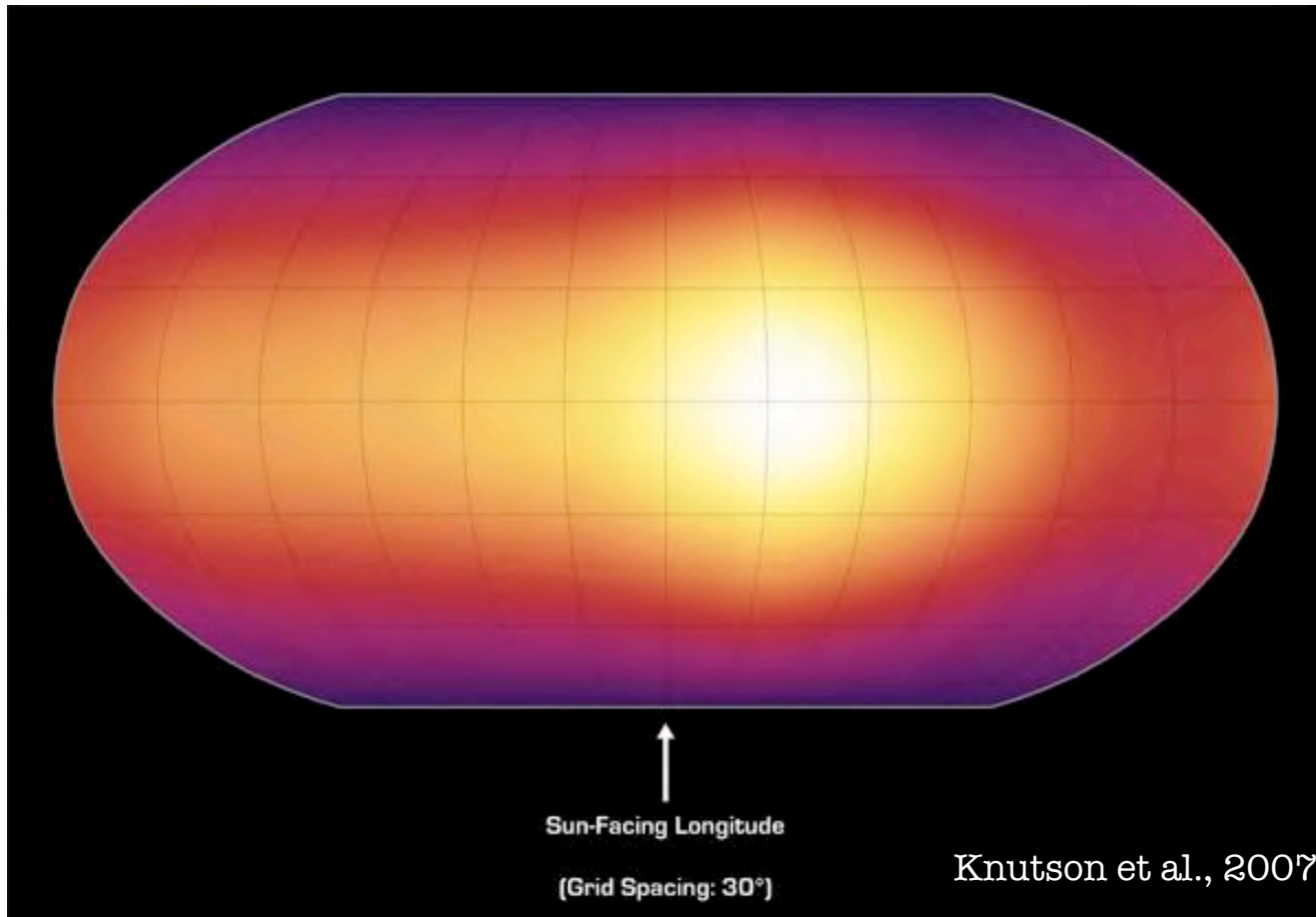
Bayliss et al., 2013

# Studying Planets

- Now we have discovered planets we want to study them:
  - What are their orbits?
  - How hot are they?
  - What are they made of?



# Hot and very windy!

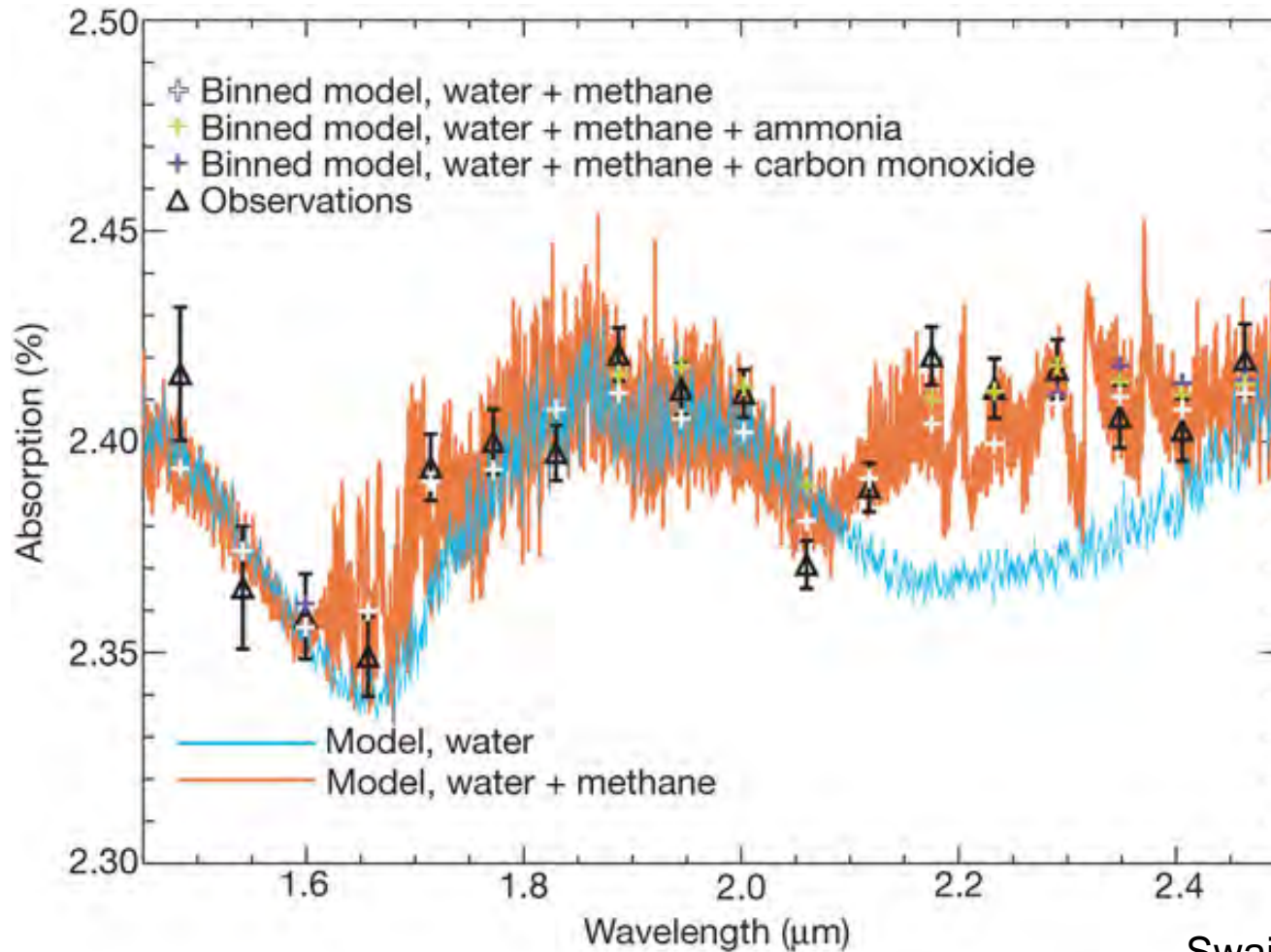


Temperatures of around 2000C!

Wind speed of 10,000 km/h

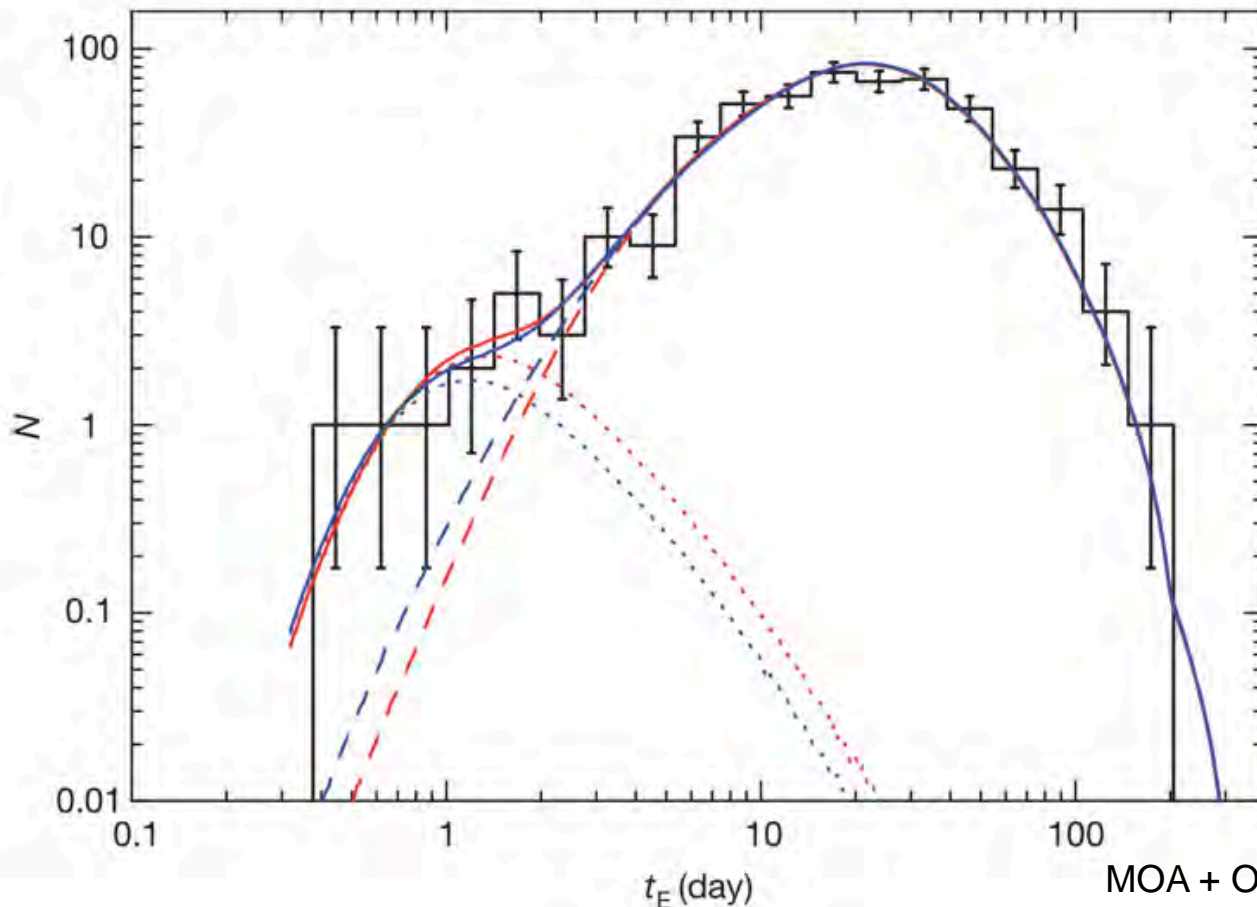


# Exoplanet's have water!



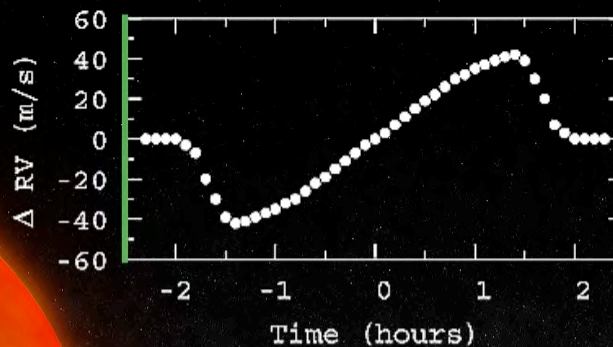
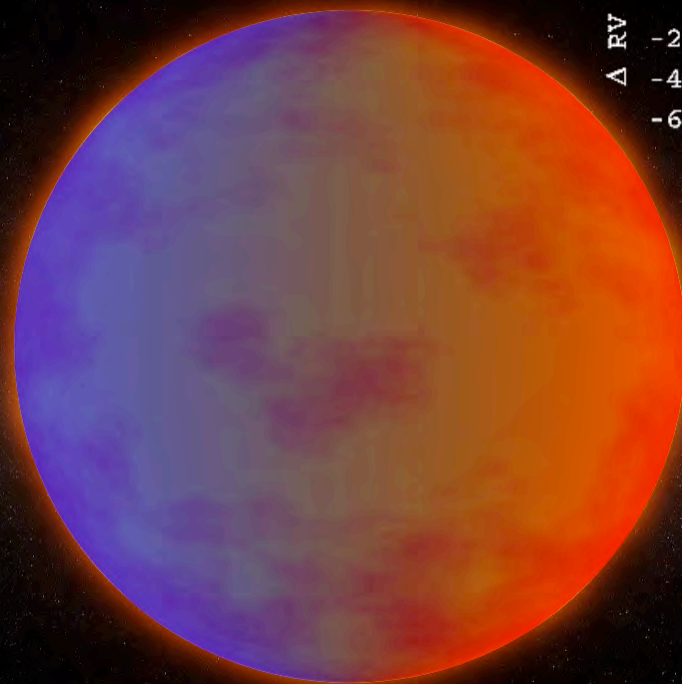
Swain et al., 2008

Many exoplanets are free floating (i.e. do not orbit a star).



MOA + OGLE teams, 2011

# Some orbit backwards!



## Summary (to date...)

- Planets are **abundant** and **diverse**
- Using transits, microlensing, and radial velocity surveys we know now that planets are abundant in our Galaxy
- Transiting planet discoveries are showing a wide diversity in the physical properties of planets.
- We still have not found another Earth yet, but we are getting closer!





Questions?

