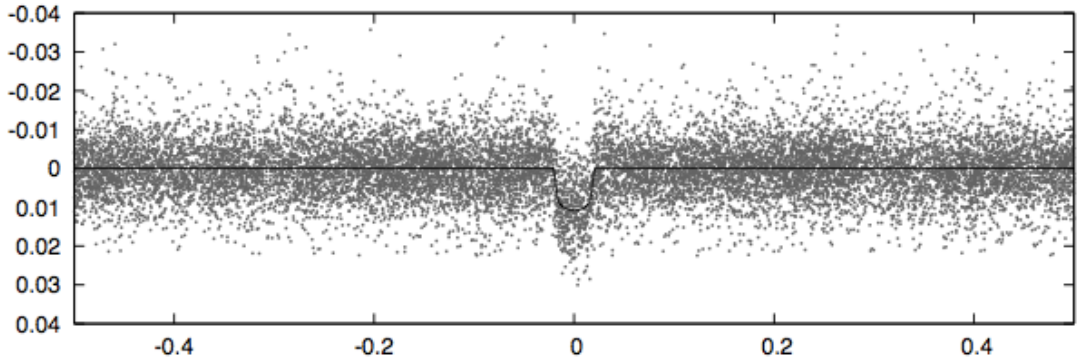
The Future of Ground-Based Transit Surveys



Exoplanetary Science, Rencontres du Vietnam

Quy Nhon, 20-26 April, 2014

Daniel Bayliss

Mt Stromlo Observatory, RSAA

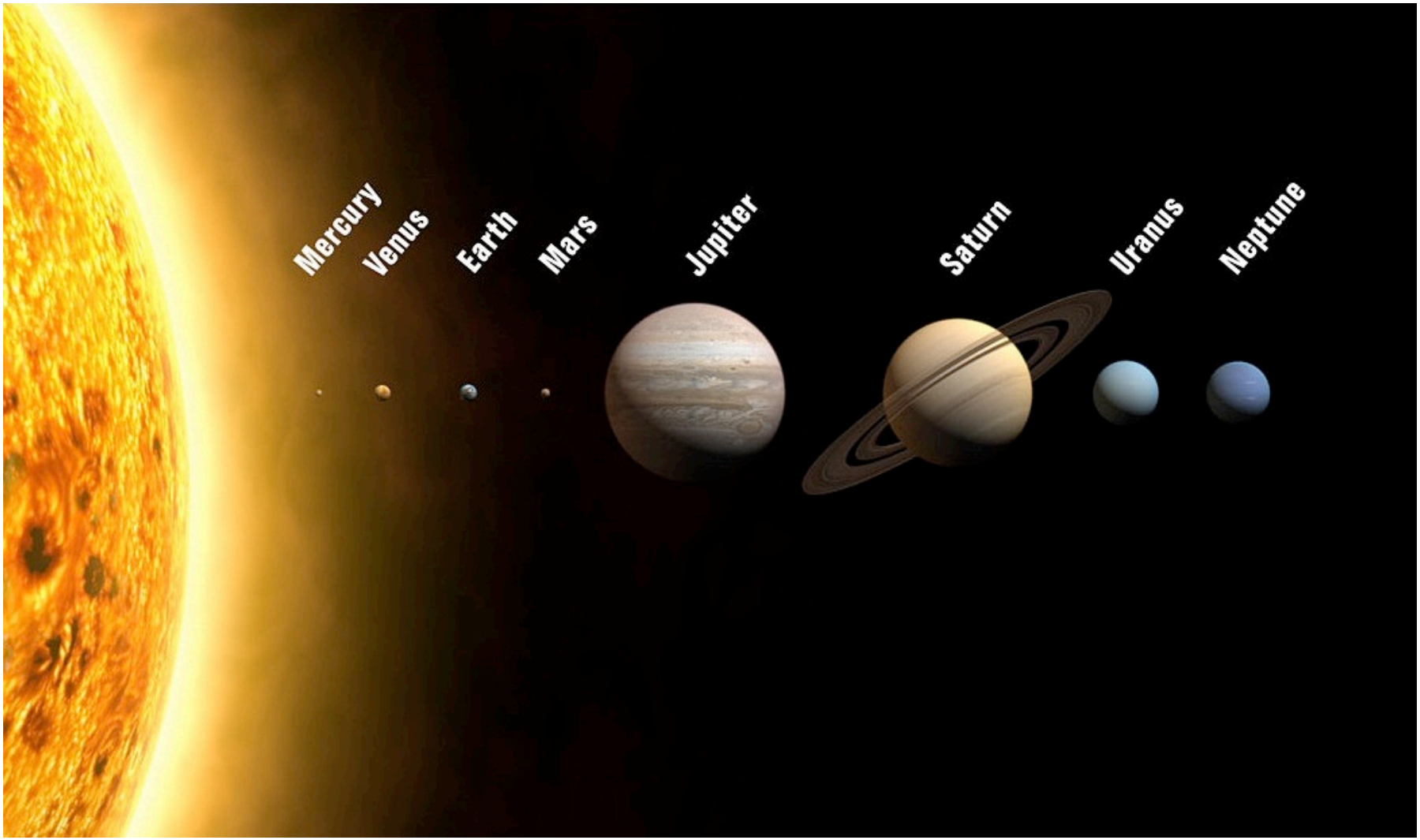
Australian National University

Overview

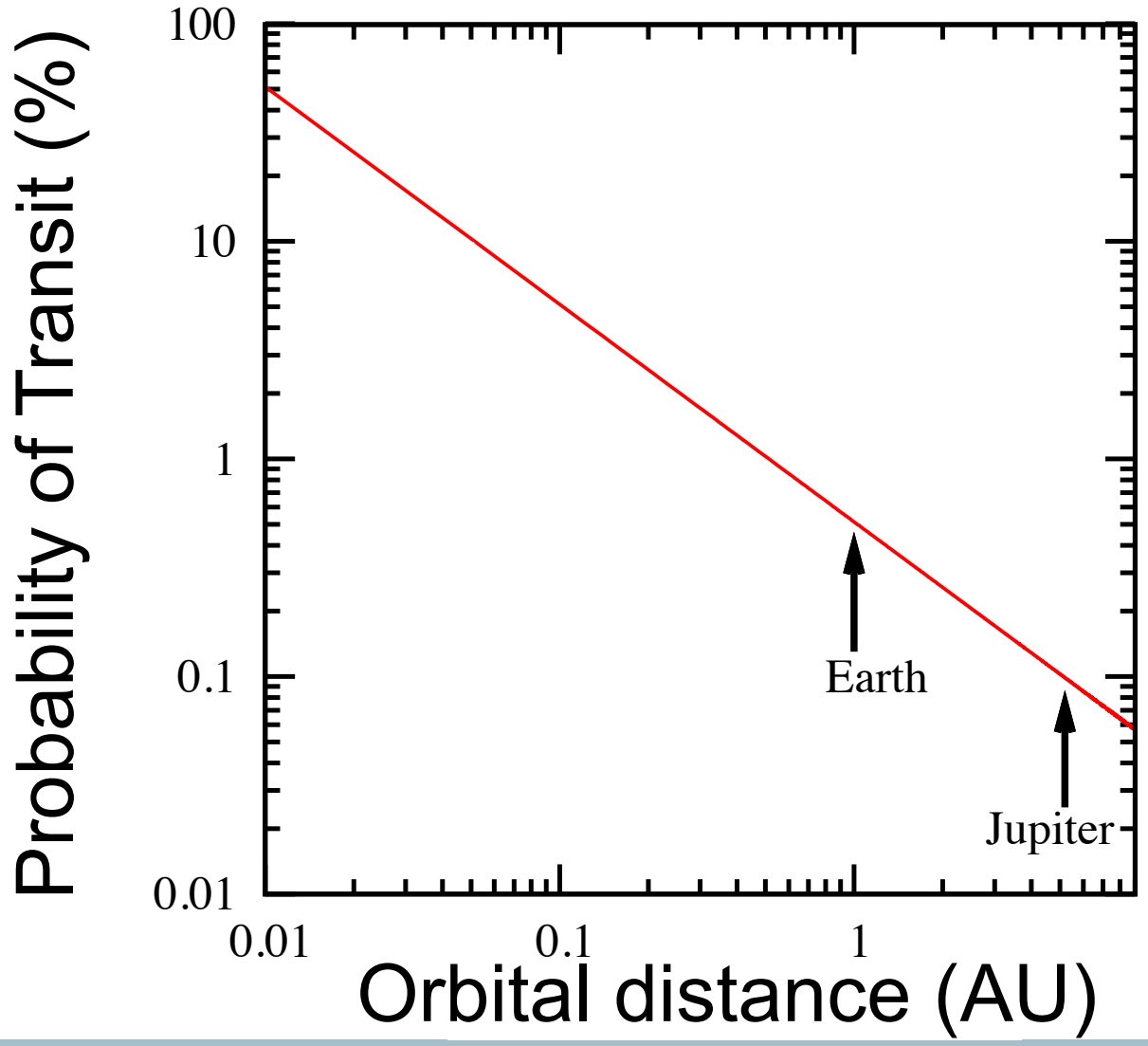
1. Past - Beginning the Journey.
2. Present - Hot Jupiters Galore.
3. Future - The Space Race.

1. Past - Beginning the Journey

Moving Beyond the Solar System



Solar System - Long Odds



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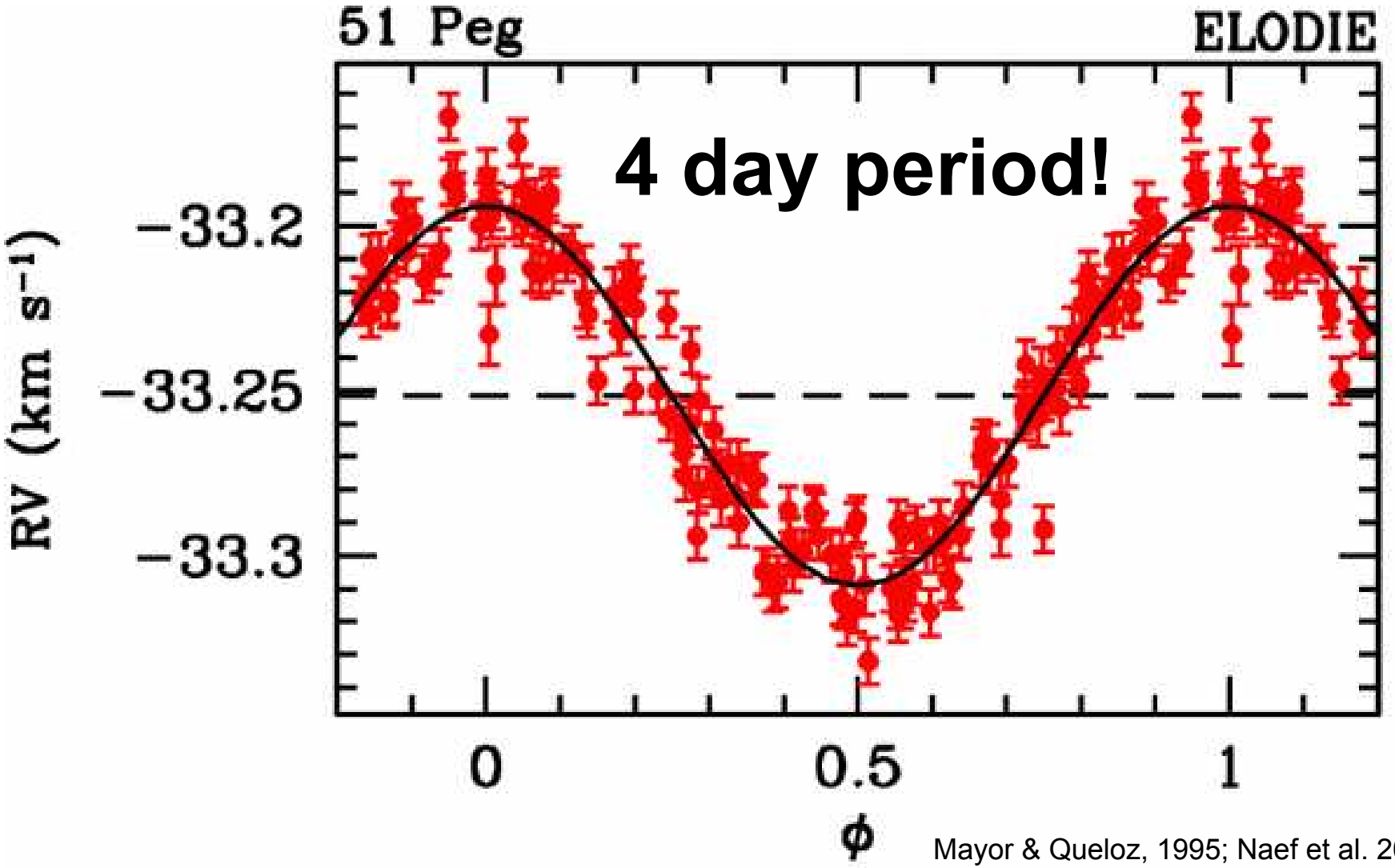
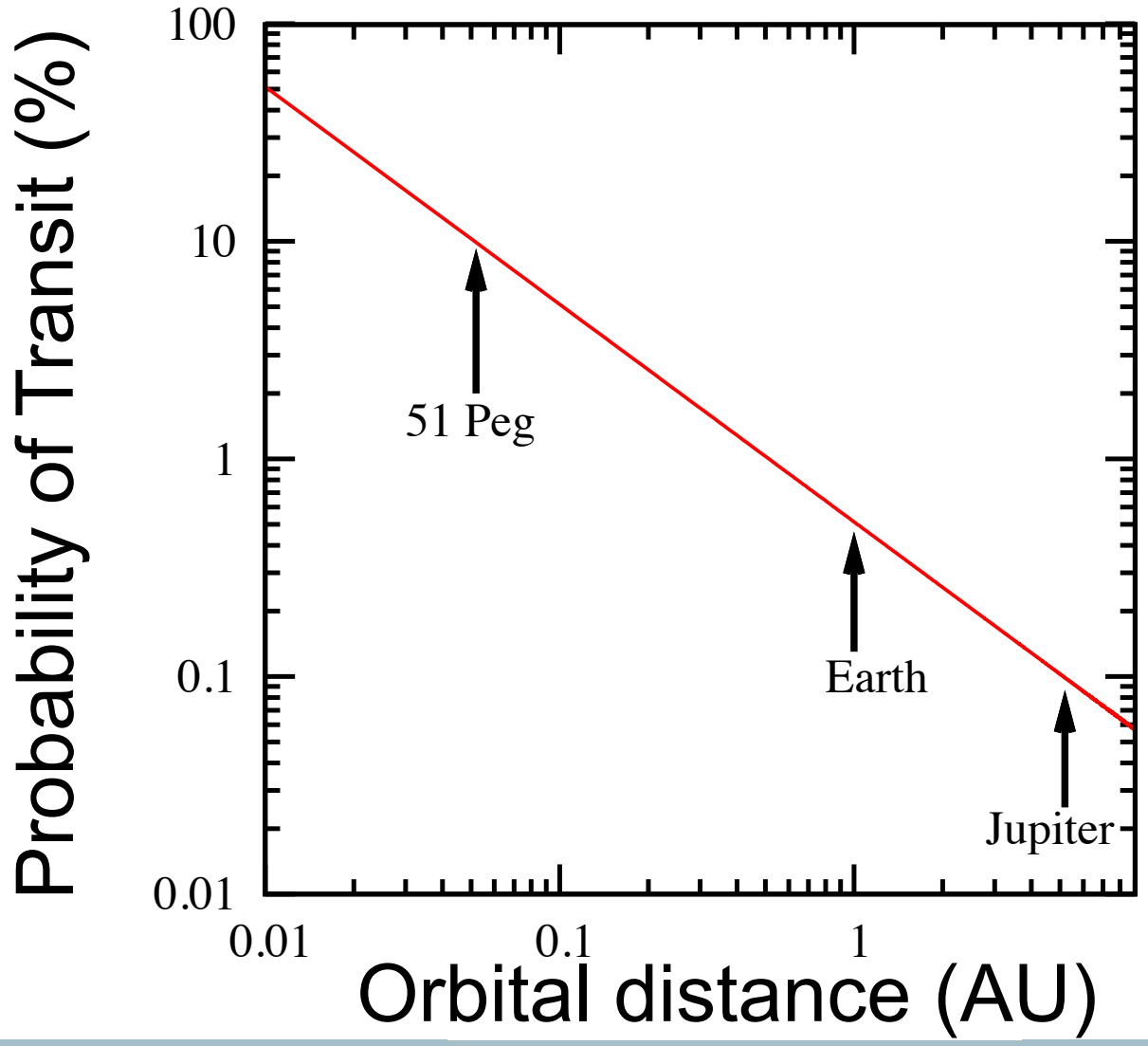
- "*the detection of terrestrial-sized planets would require ... a spaceborne platform to avoid the effects of variations in sky transparency and scintillation*"
- *"Because the probability is so small ...the search program must be designed to continuously monitor hundreds or thousands of stars"*
- *"Based on the stated assumptions, a detection rate of one planet per year of observation appears possible."*

1995: Hot planets discovered

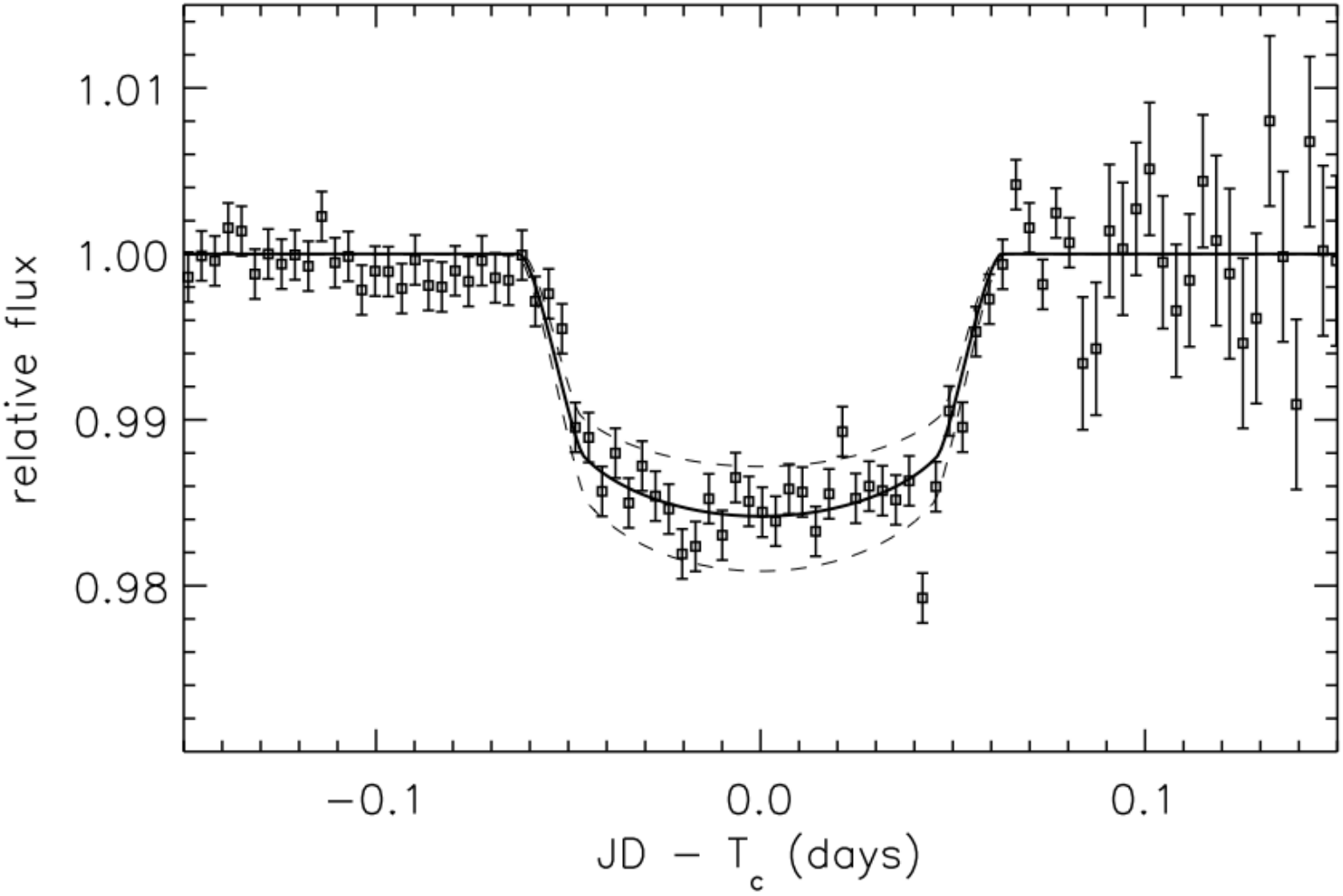


Mayor & Queloz, 1995; Naef et al. 2004

Increasing the Odds



HD209458b - a transiting exoplanet



Charbonneau et al., 2000

Status and Prospects of Planetary Transit Searches: Hot Jupiters Galore

Keith Horne *(kdh1@st-and.ac.uk)*

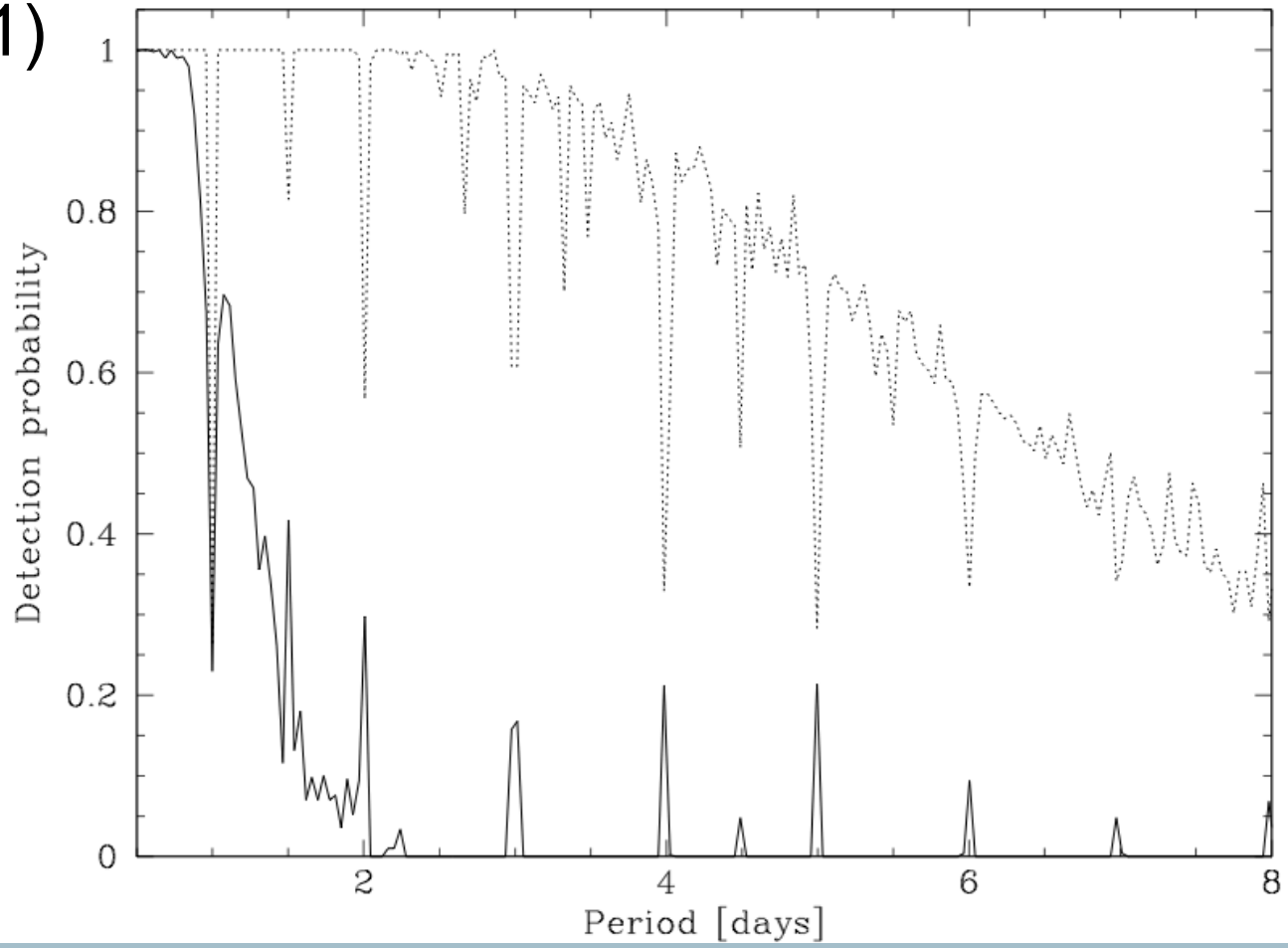
Physics & Astronomy, St.Andrews University, KY16 9SS, Scotland, UK

Abstract. The first transiting extrasolar planet, orbiting HD 209458, was a Doppler wobble planet before its transits were discovered with a 10 cm CCD camera. Wide-angle CCD cameras, by monitoring in parallel the light curves of tens of thousands of stars, should find hot Jupiter transits much faster than the Doppler wobble method. The discovery rate could easily rise by a factor 10. The sky holds perhaps 1000 hot Jupiters transiting stars brighter than $V = 13$. These are bright enough for follow-up radial velocity studies to measure planet masses to go along with the radii from the transit light curves. I derive scaling laws for the discovery potential of ground-based transit searches, and use these to assess over two dozen planetary transit surveys currently underway. The main challenge lies in calibrating small systematic errors that limit the accuracy of CCD photometry at milli-magnitude levels. Promising transit candidates have been reported by several groups, and many more are sure to follow.

Horne, 2003

Some hold-ups

- Red noise (see Pont, Shay & Queloz, MNRAS, 2006, 373, 231)



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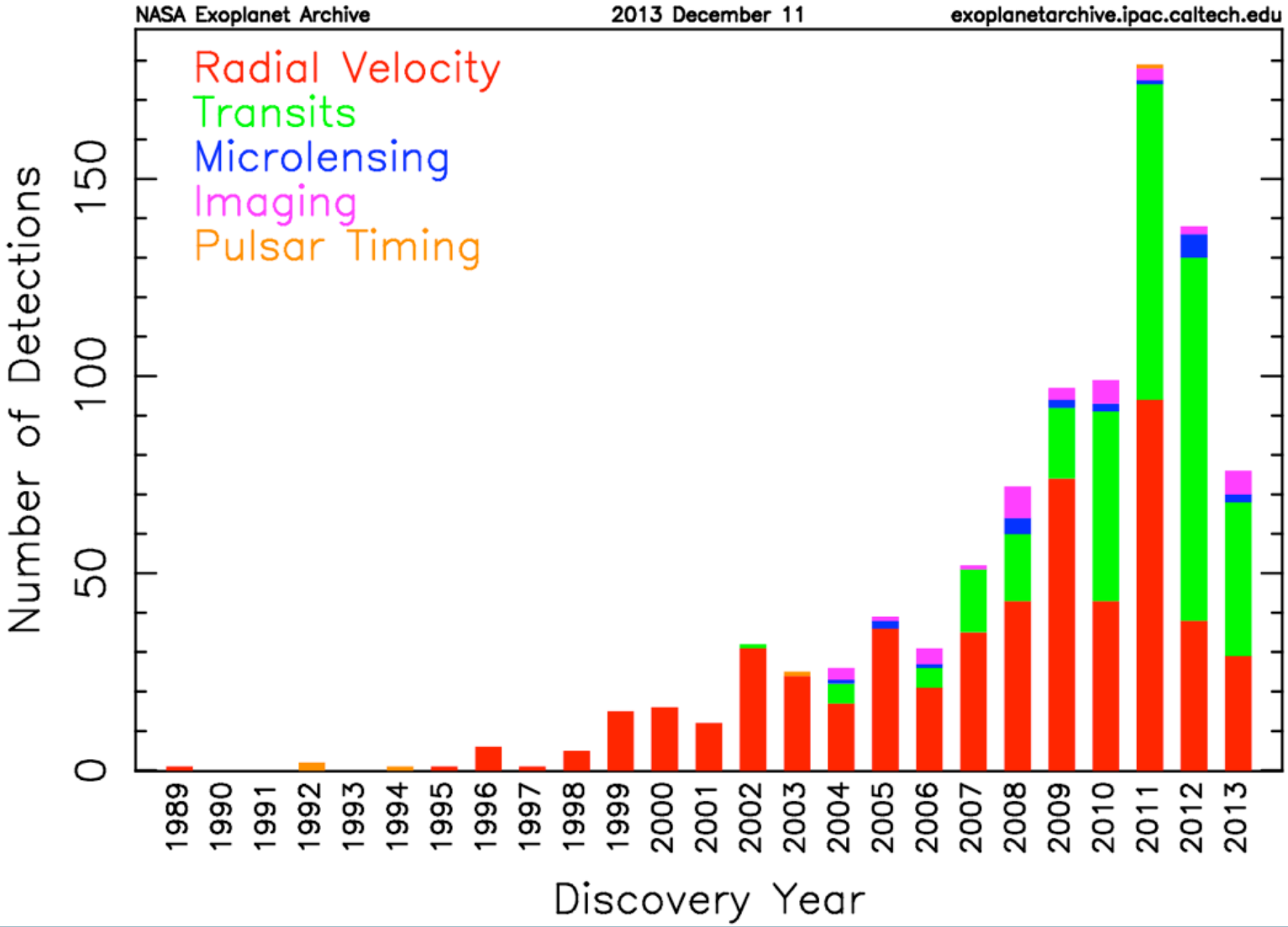
- Canonical “1% of stars have hot Jupiters” was wrong, leading to lower than expected yields.
- Frequency appears to be a factor of 3 lower from ground-based (Bayliss & Sackett, 2011) and space-based transit surveys (Howard et al., 2012).
- Discrepancy probably due to a less “clean” sample (particularly binaries), and lower mean [Fe/H] of targets.

2. Present - Hot Jupiters Galore

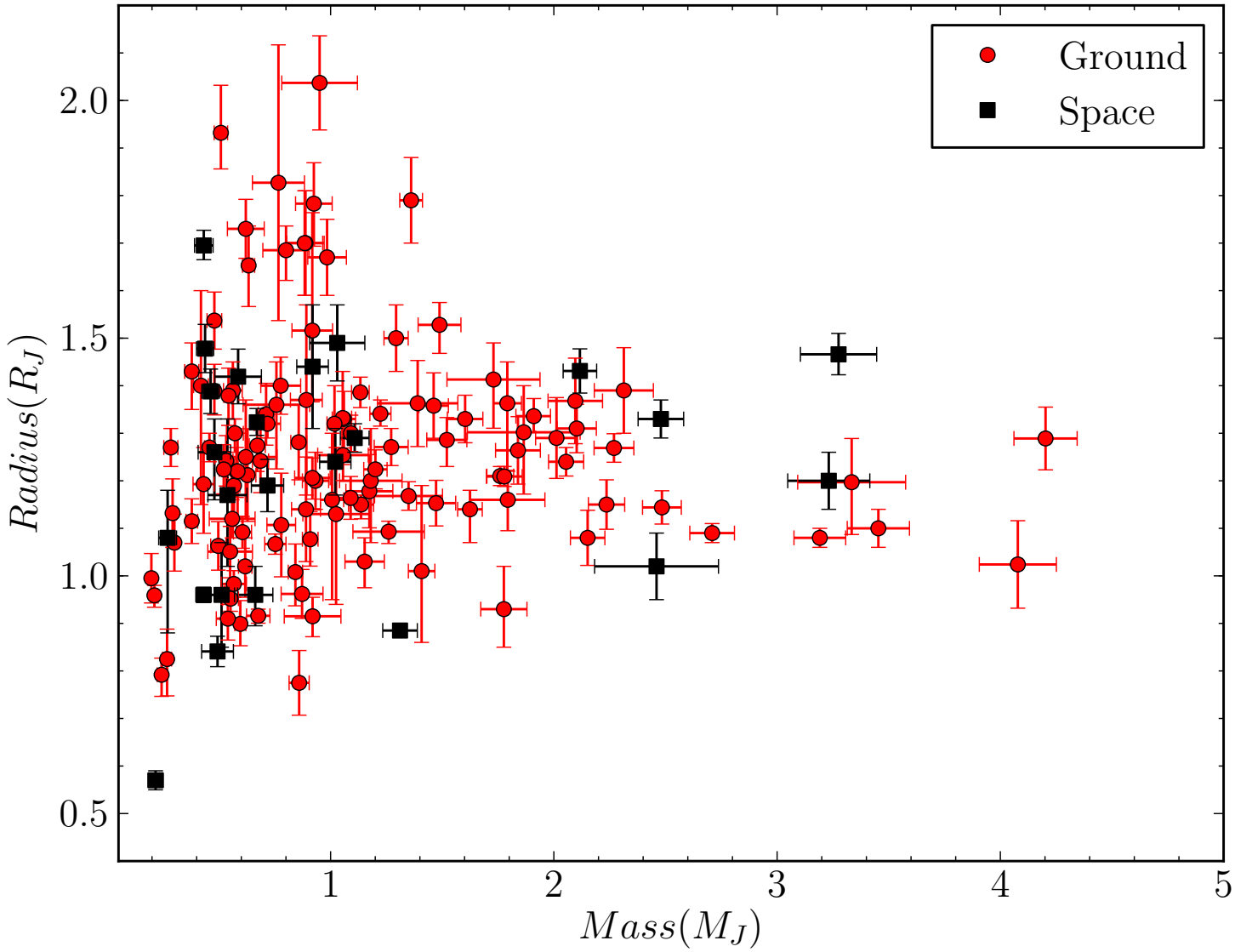
Transits now dominating discoveries.



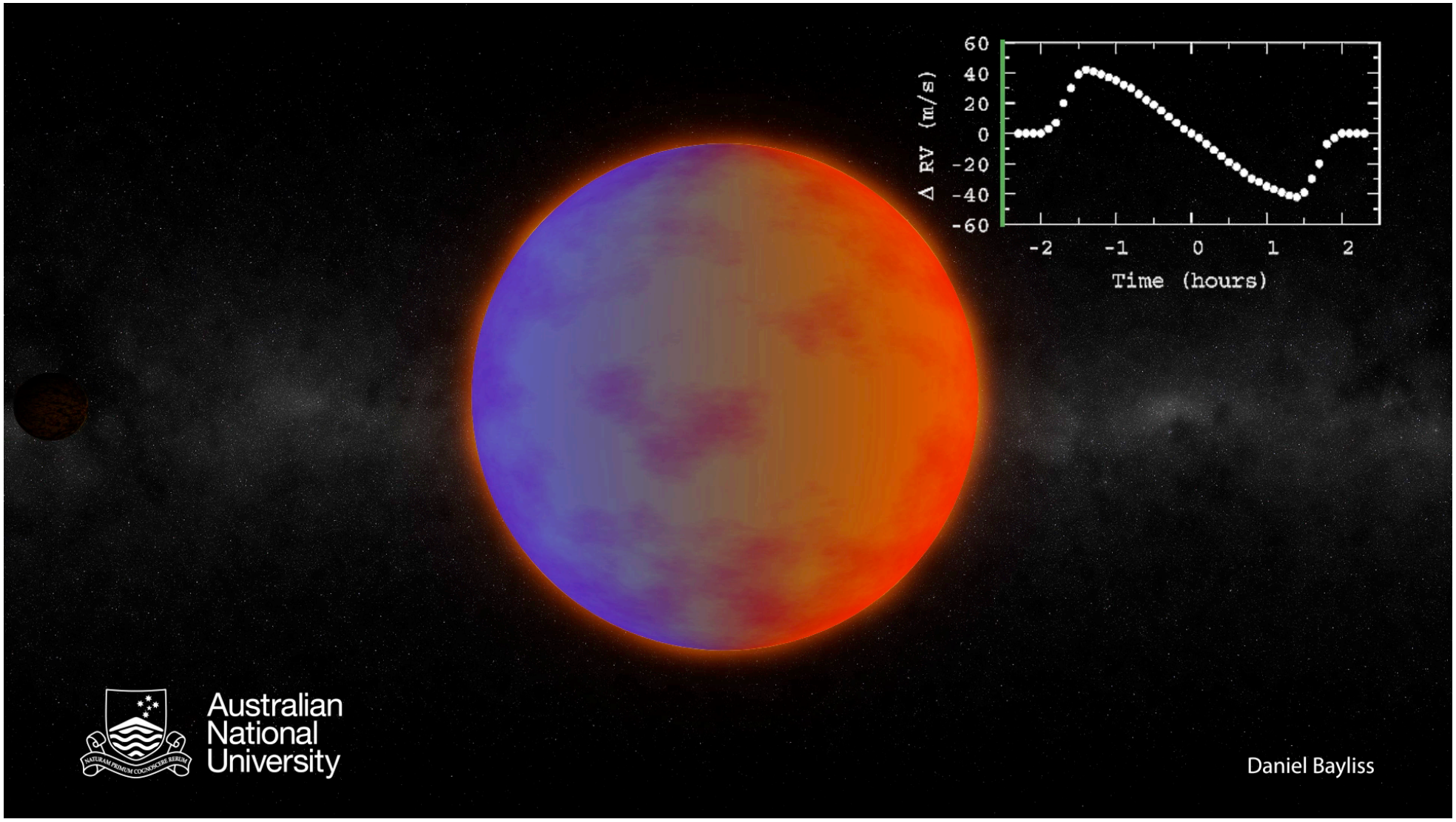
Counting Hot Jupiters

- Data from exoplanet.org:
  - $M_P > 0.1 M_J$
  - Period < 10days
  - Uncertainty < 0.3 M_J & R_J
- 145 hot Jupiters

Highlight 1 - Densities



Highlight 2 - Spin Orbit Alignment



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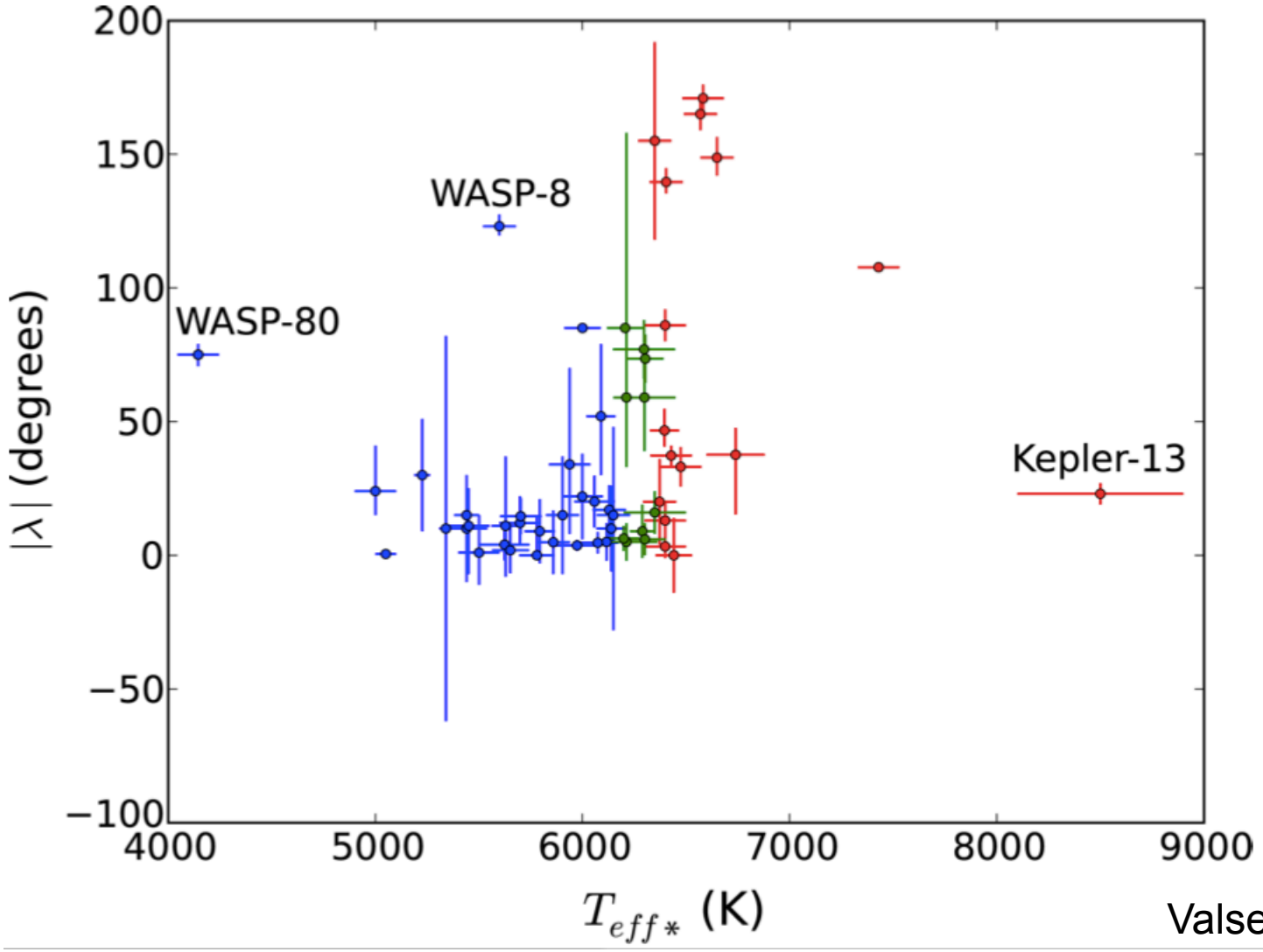
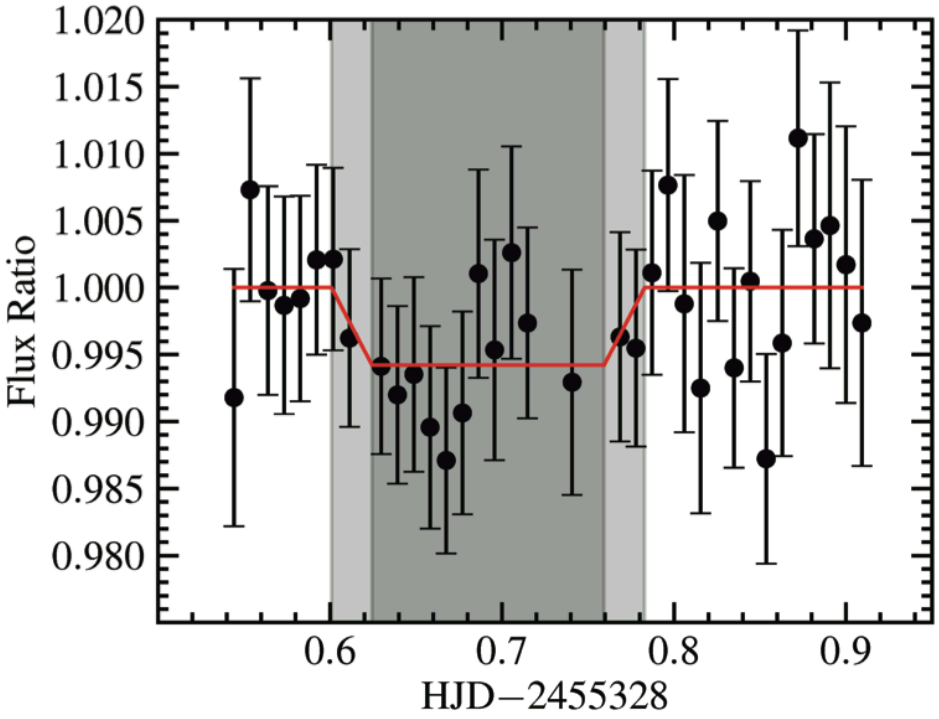
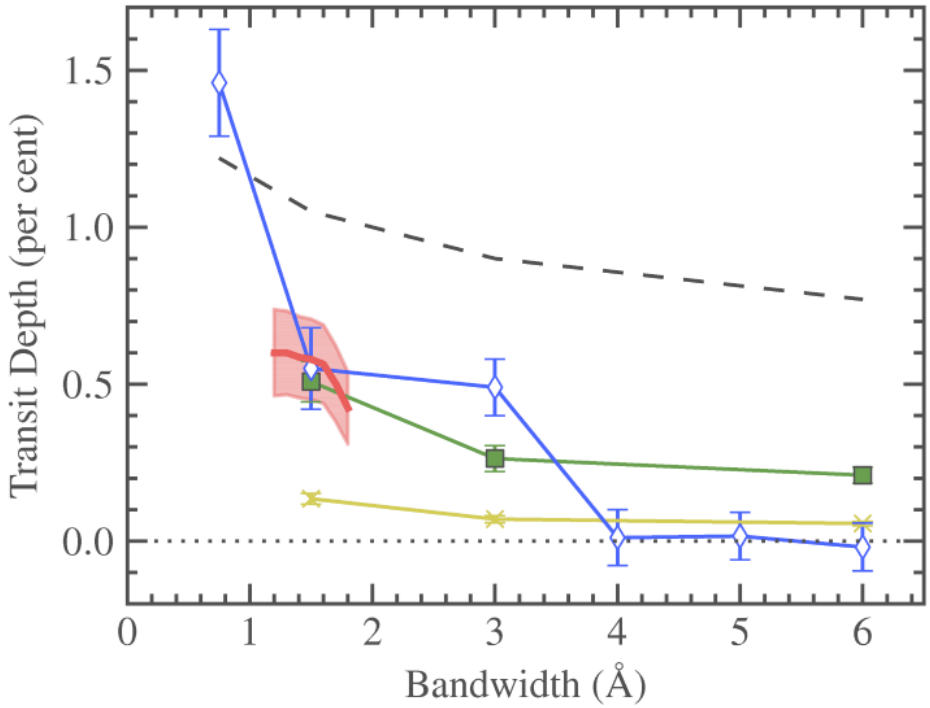


Valsecchi & Rasio 2014

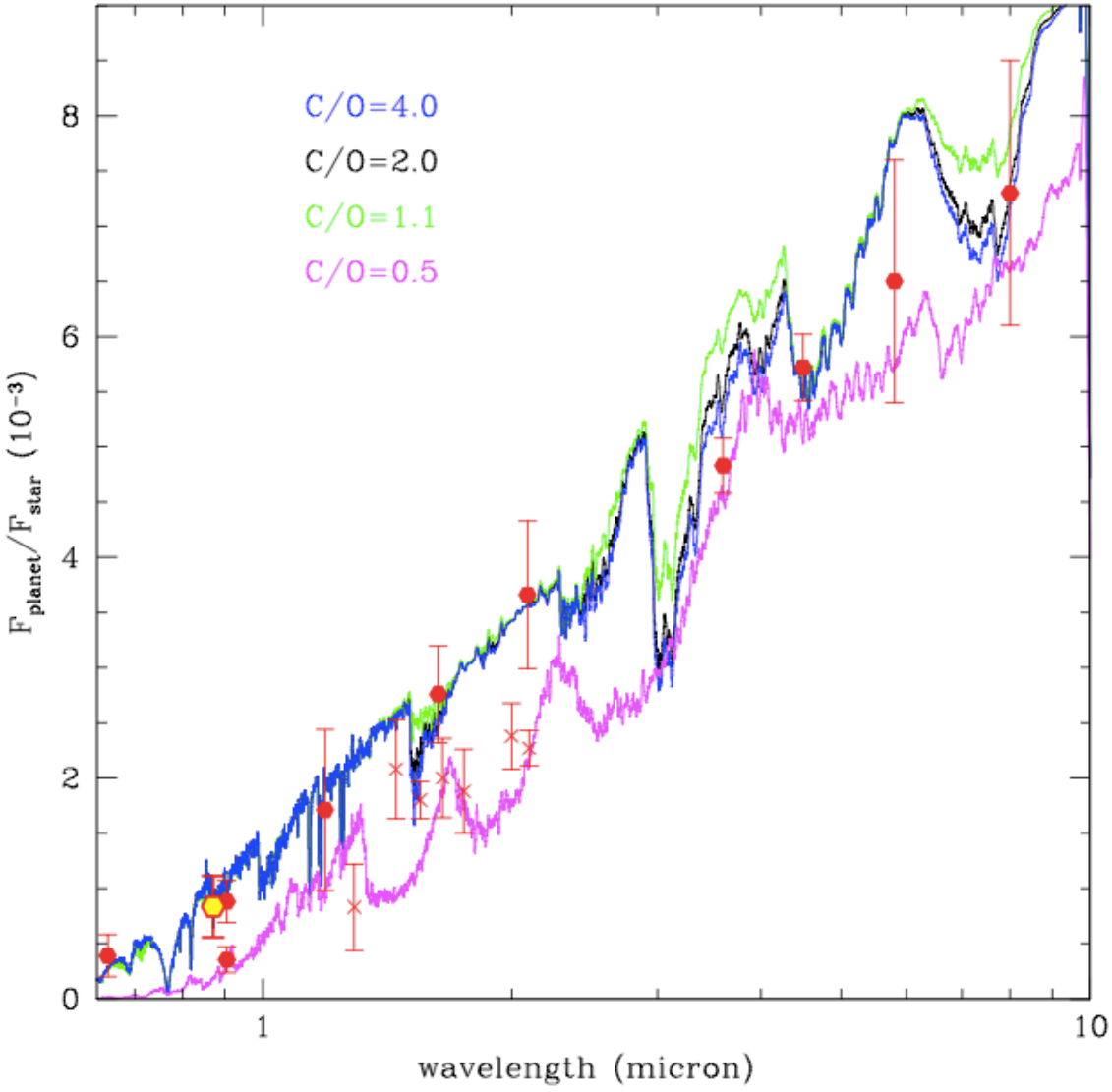
Highlight 3 - Transmission Spectroscopy





WASP-17b - Na detection (Snellan et al., 2008, Wood et al., 2011, Zhou & Bayliss 2012).

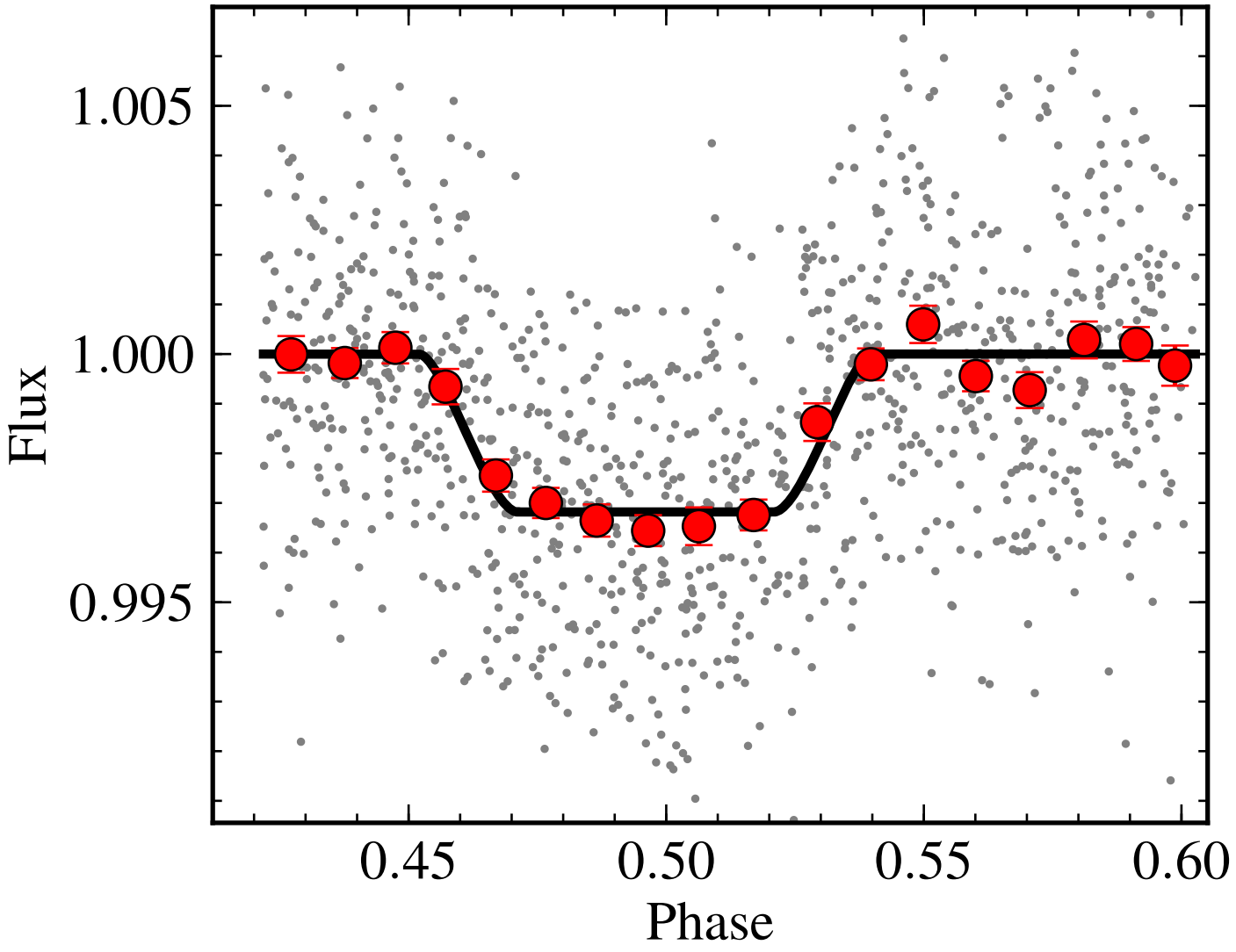
Highlight 4 - Emission Spectroscopy



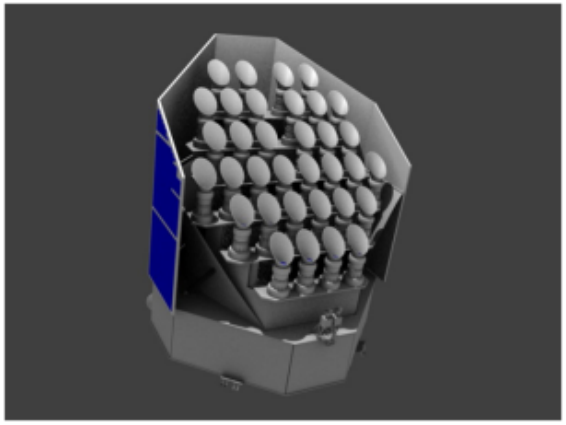
WASP-19b

Zhou et al., 2013

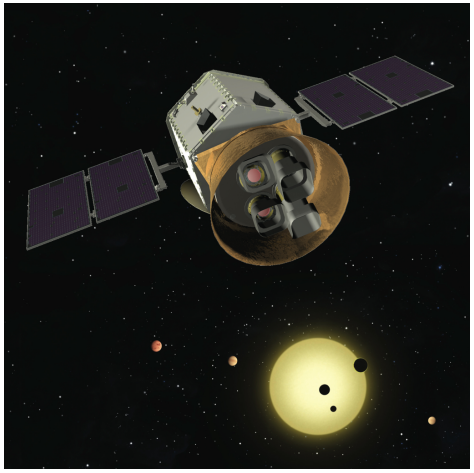
NIR Ground based photometry

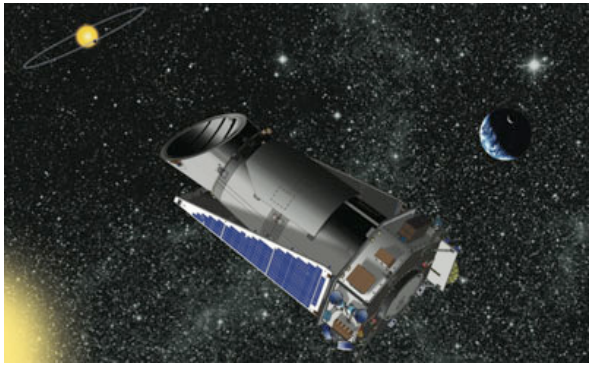


IRIS2/AAT
WASP-19b, Ks band
in prep.



3. Future - The Space Race

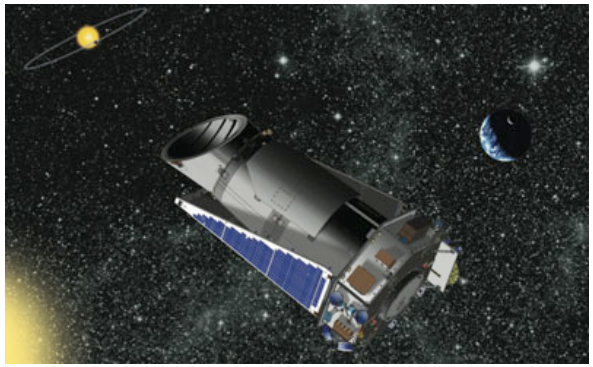




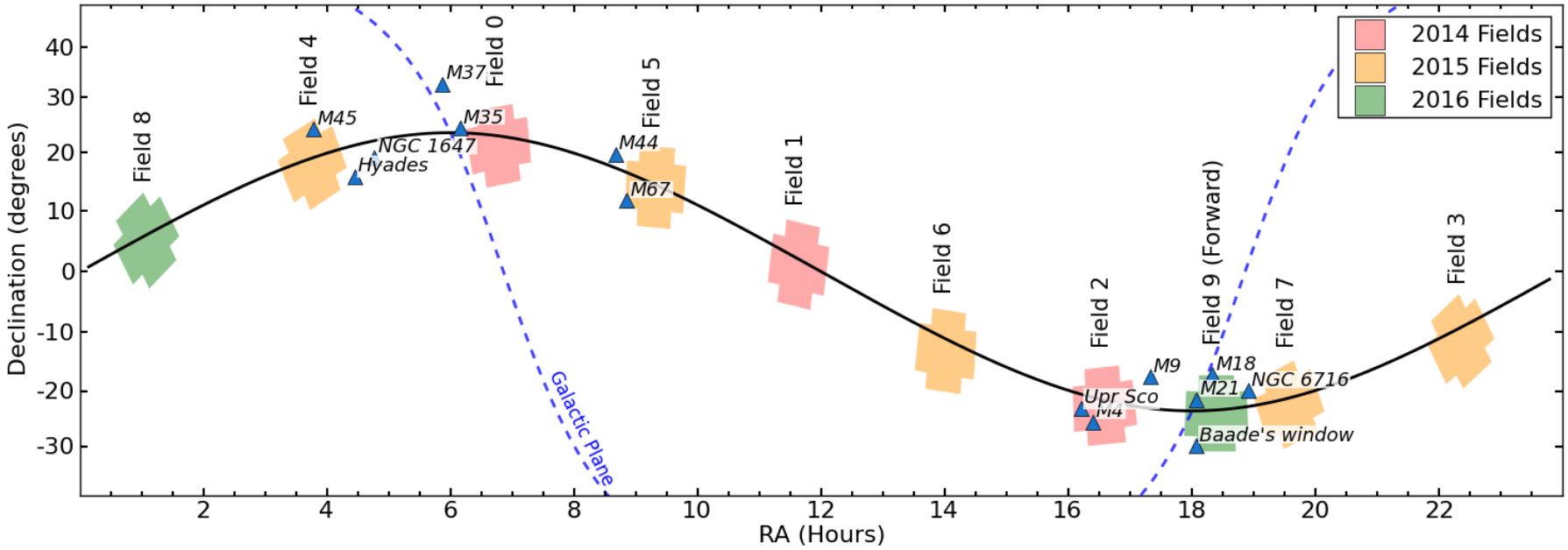
Space Missions

- The landscape is changing rapidly with planned space-based missions that mimic current ground-based surveys: bright-stars, wide-field and short period.
- Most important surveys (in chronological order):
  - Kepler K2
  - TESS
  - PLATO

Kepler K2



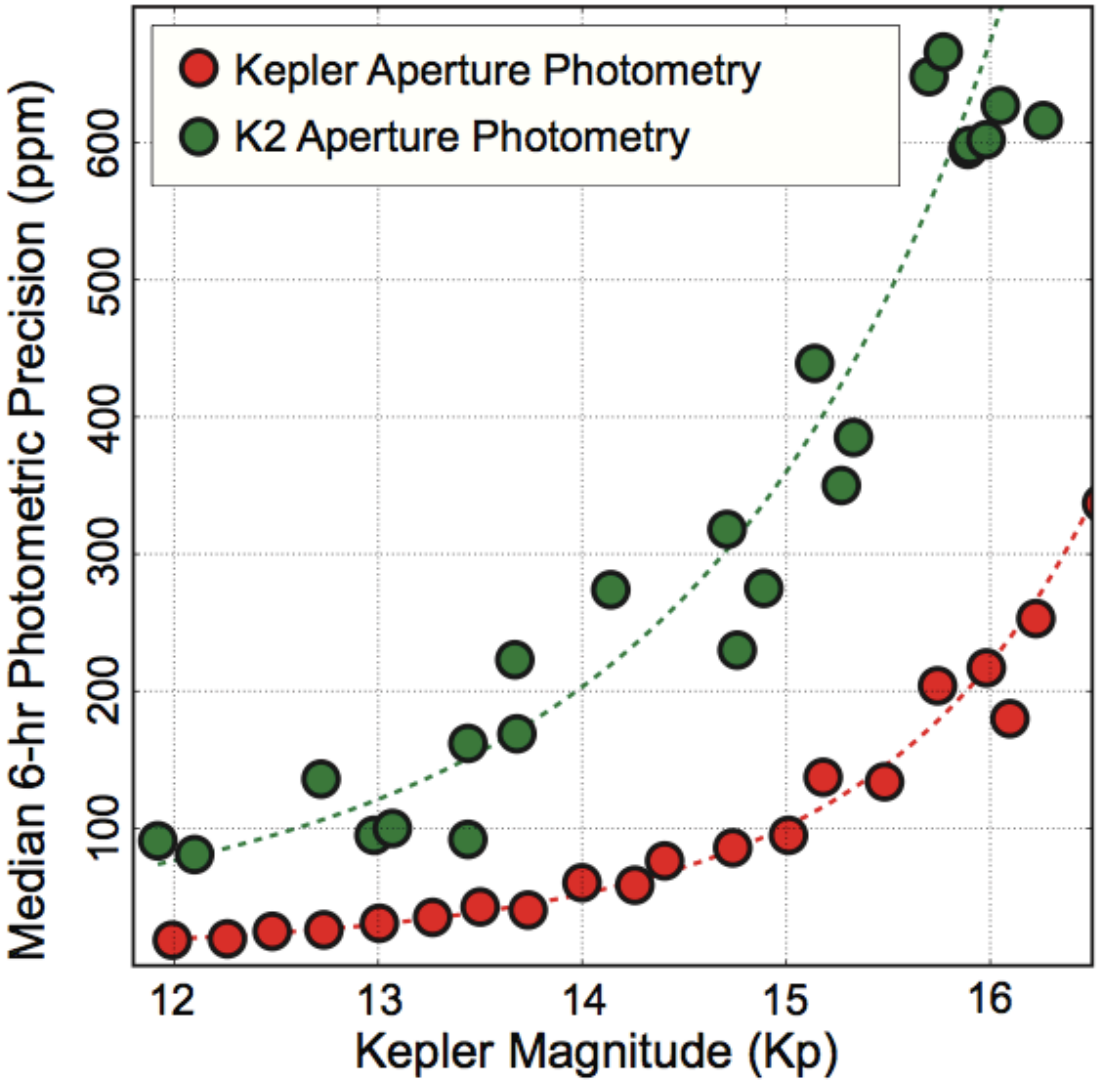
- On two reaction wheels, Kepler is limited to pointing near the ecliptic plane.
- Will point for ~80 days per field.
- FOV slightly narrower (8.5x8.5 degs)



Kepler K2

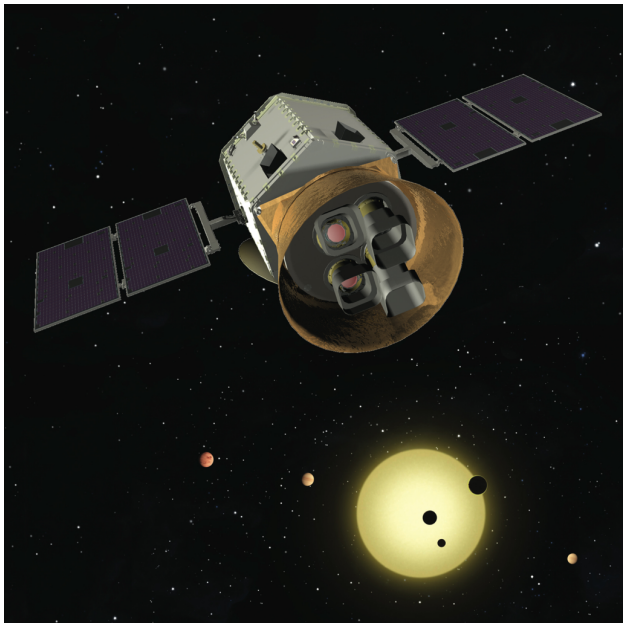
- More fuel burnt - Lifetime is therefore 2-3 years.
- Between 5,000 and 20,000 targets at 30mins. Due to new orbit, << primary mission.
- Community targets + open data policy.

K2 Precision

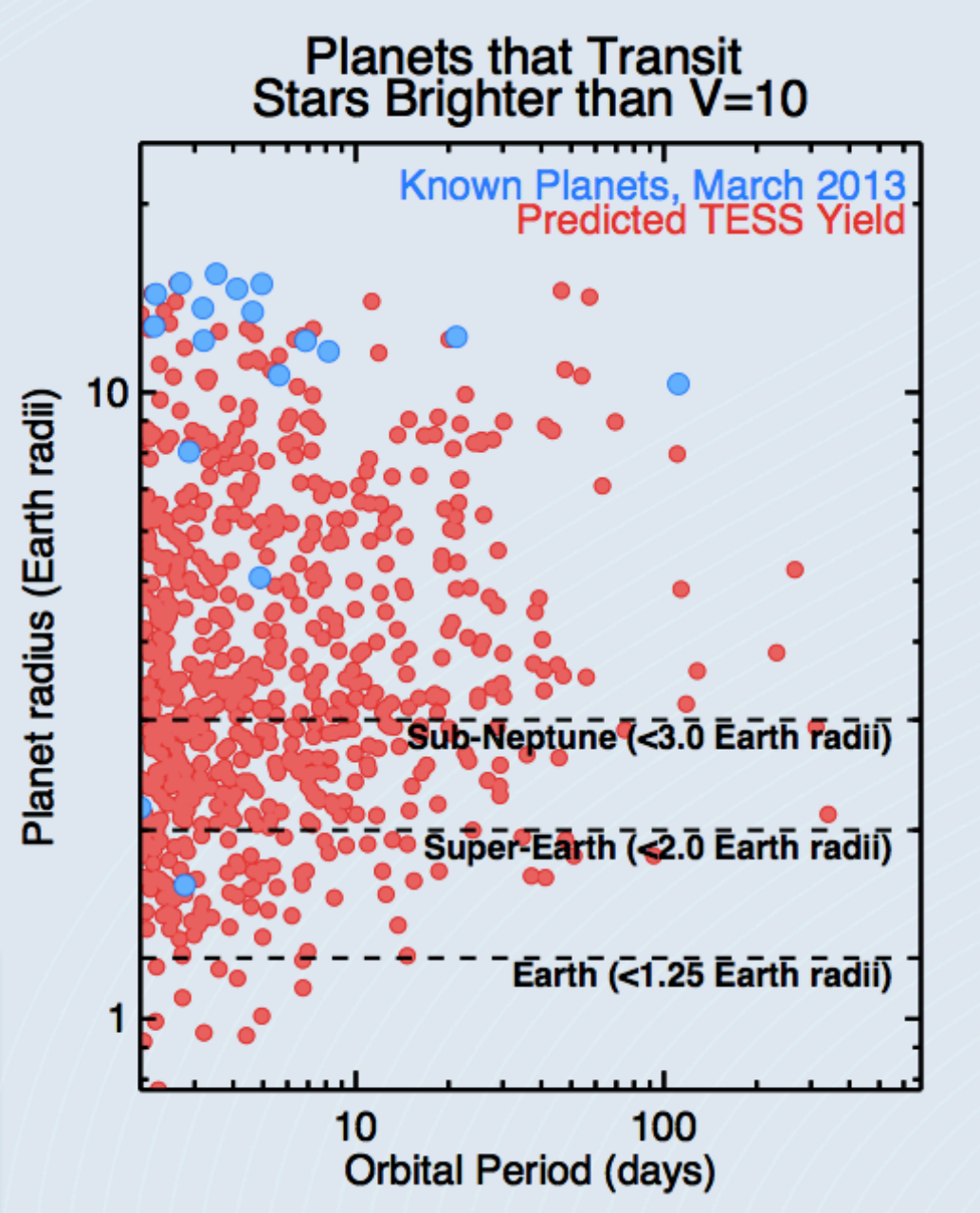


Howell et al., 2014

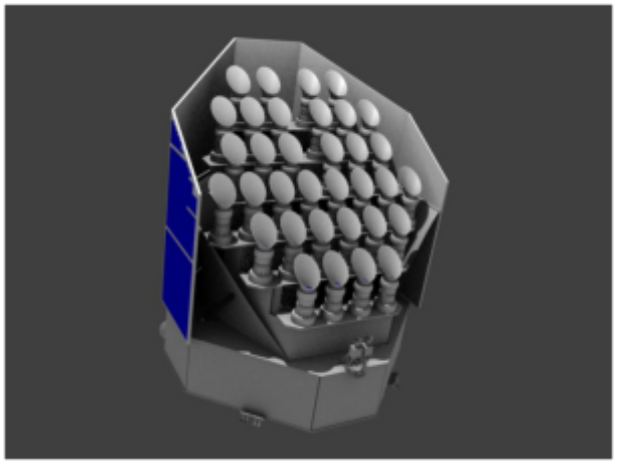
TESS



- Scheduled for 2017
- 2 year, all-sky survey
- $4 < I_{mag} < 12$
- 1 month per field
- Two long-duration fields at ecliptic poles
- 500,000 target stars in two years


Planets that Transit
Stars Brighter than V=10
Known Planets, March 2013
Predicted TESS Yield
Planet radius (Earth radii)
10
1
Sub-Neptune (<3.0 Earth radii)
Super-Earth (<2.0 Earth radii)
Earth (<1.25 Earth radii)
10
100
Orbital Period (days)

PLATO

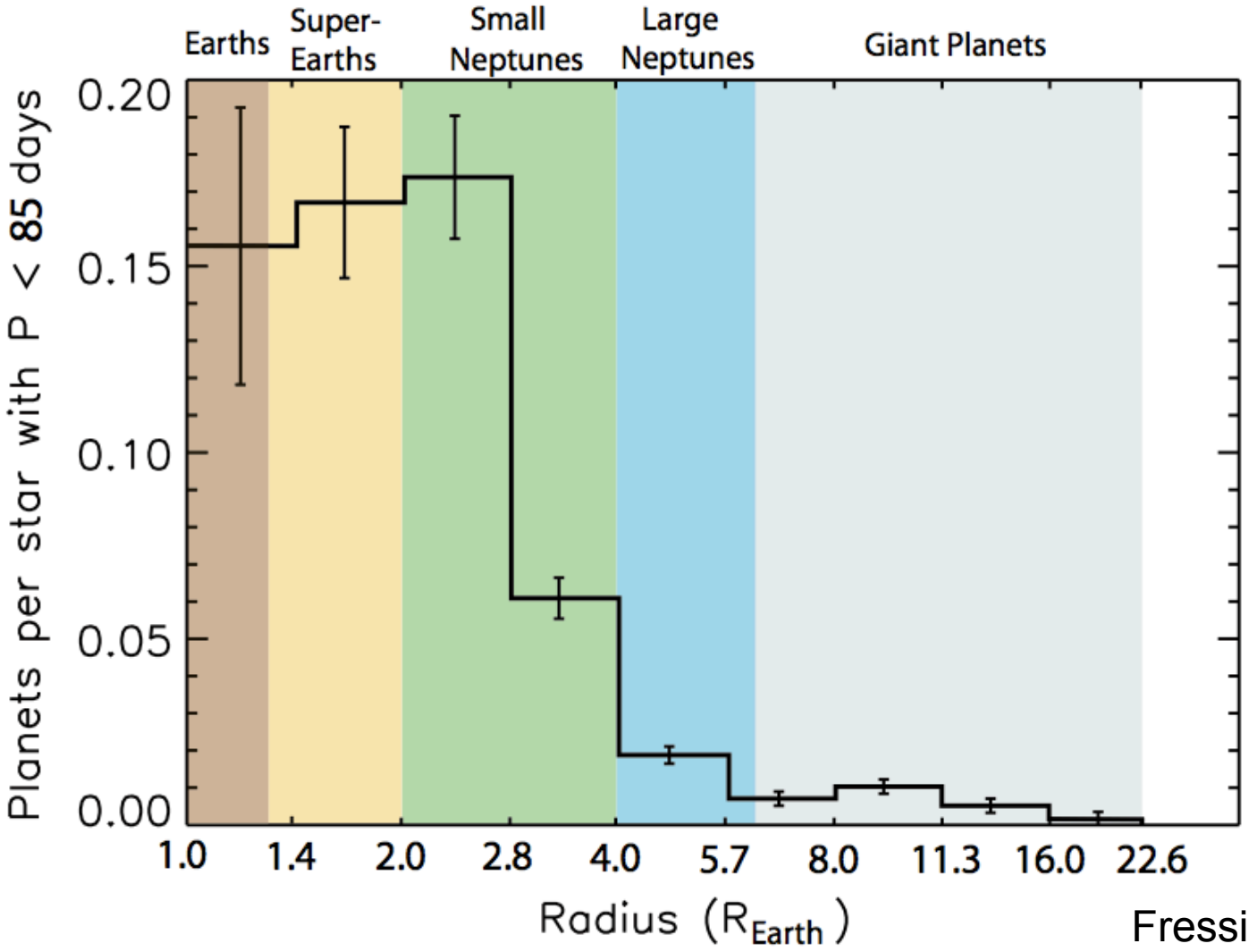


- Scheduled for 2024
- 6 year mission at L2
- Two long-term target fields lasting 2–3 years each
- A step-and-stare phase where a large number of different fields are observed for up to 5 months per field.
- 50% of sky covered in the 6 years.

Ground-based surveys

- Is there still a case for ground-based transit surveys if these space missions are successful?
- PERHAPS - but parameter space needs to be selected with great care.
- We are now in a better position to robustly determine yields in advance.

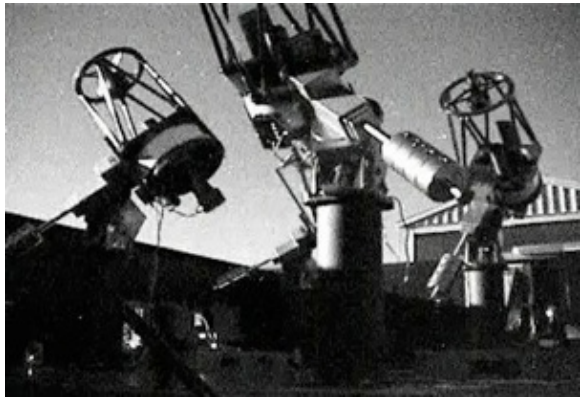
Frequency of Exoplanets



Fressin et al., 2013

Low Mass Hosts

- TESS and PLATO are small aperture telescopes, which limits them to bright targets.
- Low mass stars are intrinsically faint, therefore ground-based surveys could focus on low mass stars fainter than TESS/PLATO will probe.
- MEarth is one such project.



Specialised Searches

- Searches in particular environments (e.g. clusters).
- Searches around particular hosts (e.g. white dwarfs, EcBs).
- Frequencies (therefore yields) less certain in some of these cases.

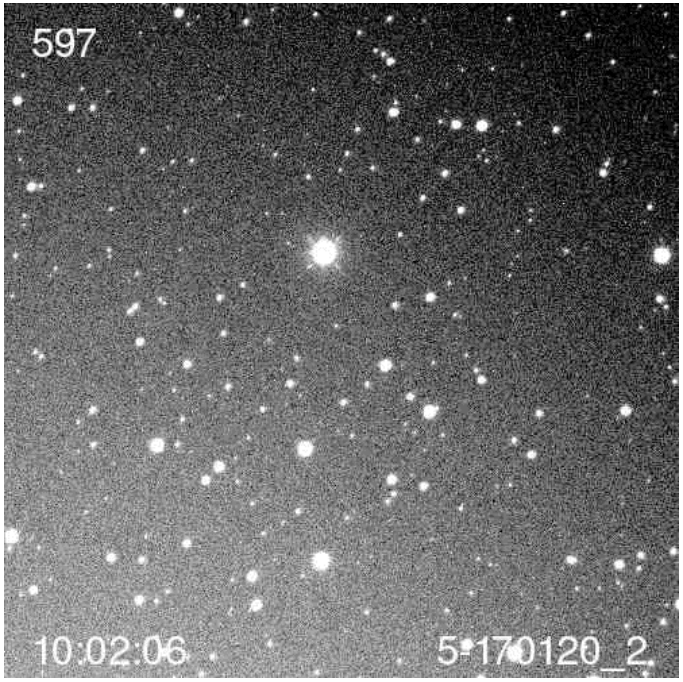
Long Period Planets

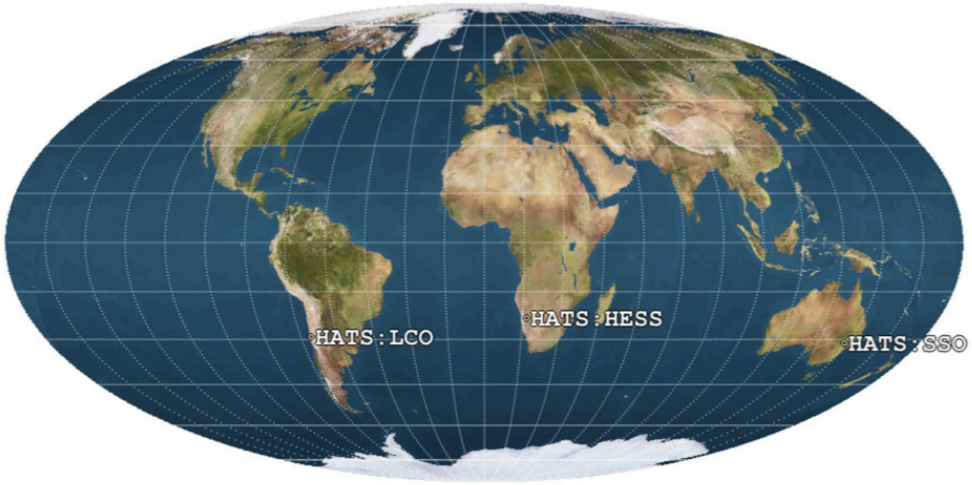
- TESS is all-sky, but will only stay on most fields for 27d.
- There is an opportunity for ground-based surveys to stay on fields for much longer. Antarctica provides an opportunity for such a project (Ji-Lin Zhou's talk). Global networks such as HATSouth (Bakos et al., 2013) provide another opportunity.

Small Radii Planets

- TESS is scheduled for launch in 2017. It will survey northern hemisphere first.
- This window of time gives projects such as HATSouth and NGTS time to discover smaller radius transiting planets before TESS (Marion Neveu's NGTS talk).

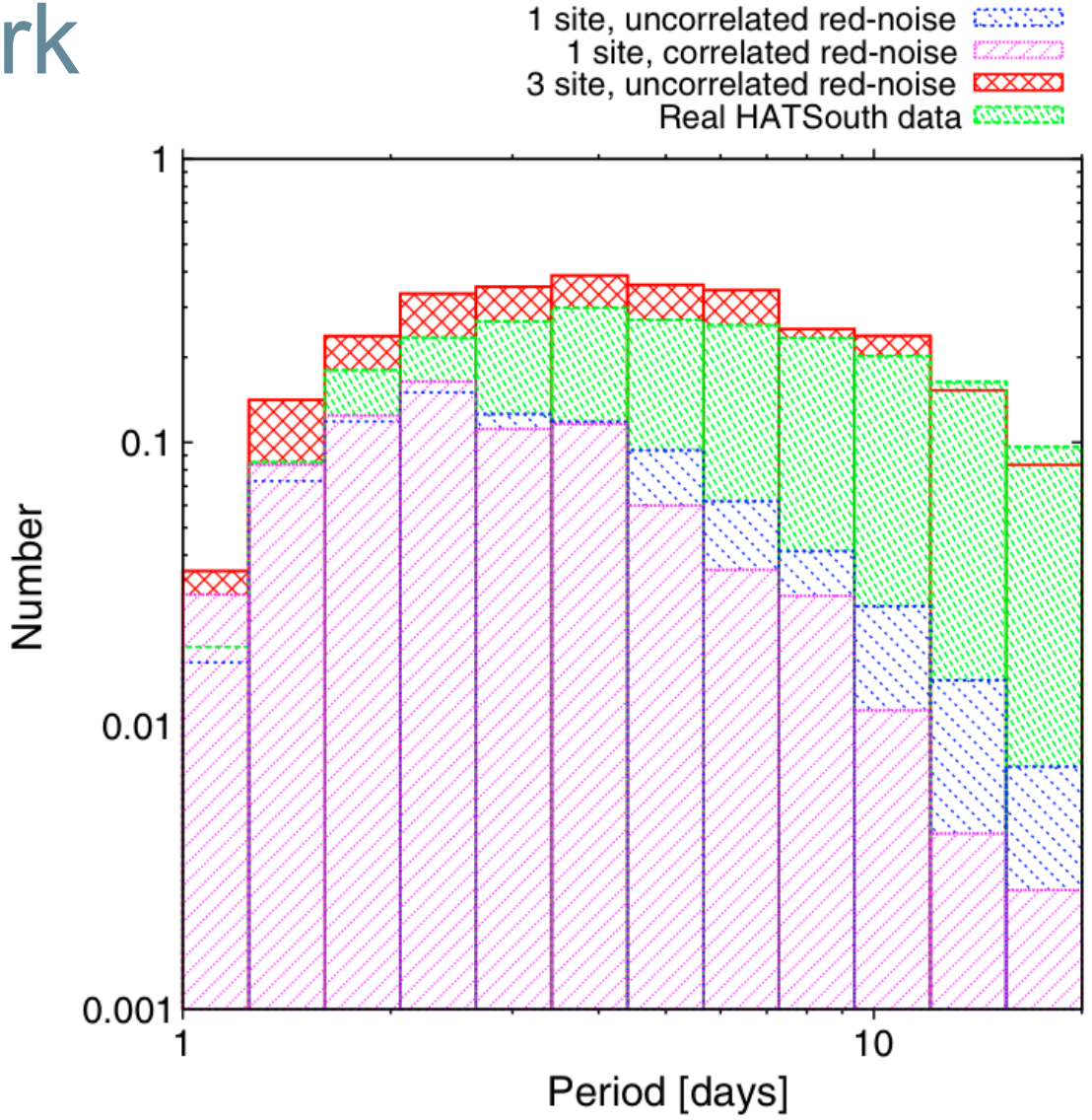
HATSouth Survey





HATSouth Network

- 11<V<15
- 700+ candidates
- 5 published planets
- Higher fraction of m-dwarfs hosts
- Higher fraction of hot Saturns/ Neptunes.



Bakos et al., 2013

Hazards of the Ground

Jan 2013 Bushfire at SSO

Conclusions

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- This will continue for next 4-5 years, pushing to longer periods and lower radii.
- K2, TESS and PLATO will force ground-based surveys to find a specialised niche to remain relevant.
- There will be a huge demand for high precision RV follow-up... HARPS-East or HARPS-West?!