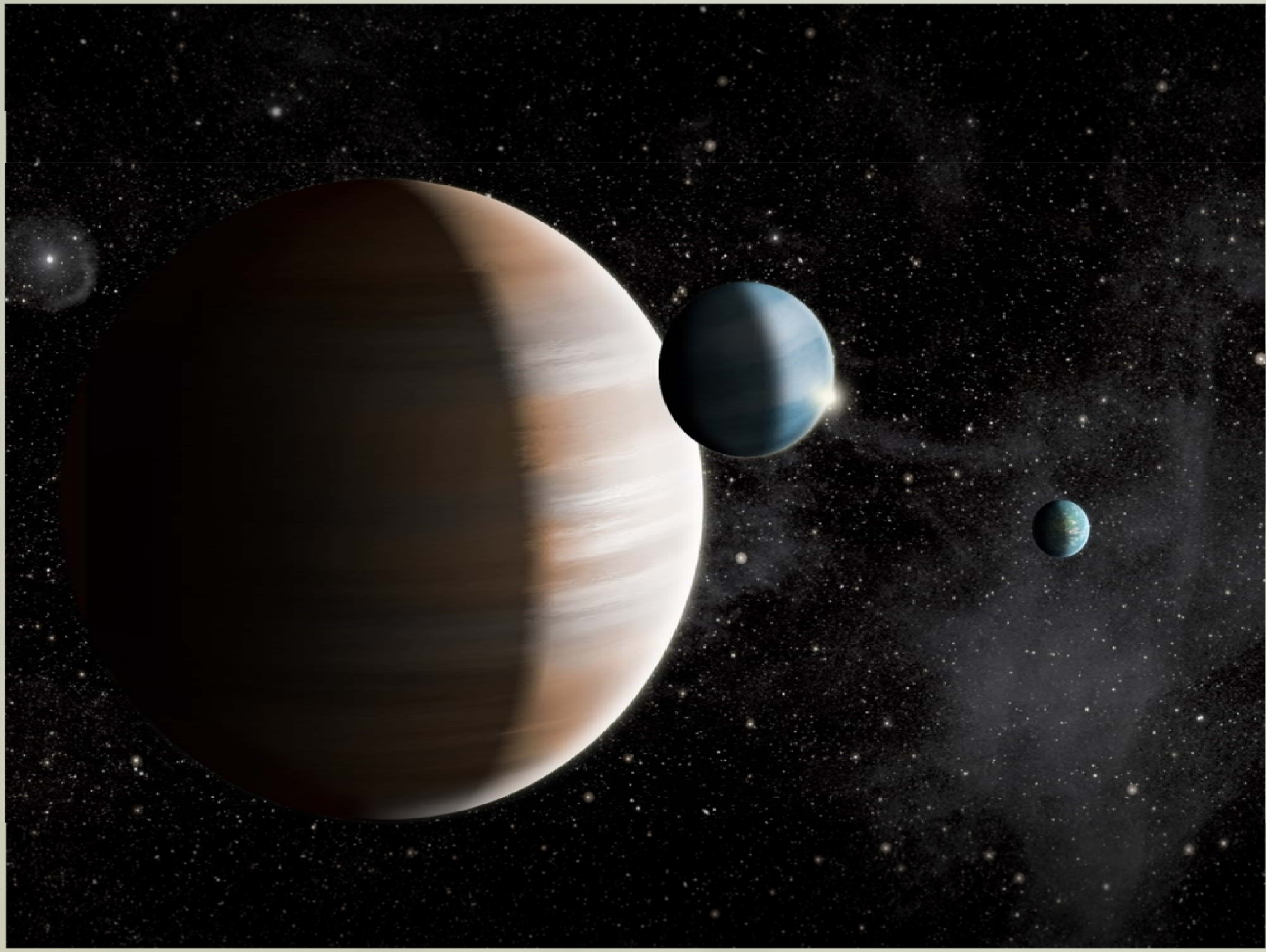
Three Regimes of Exoplanets Inferred From Host Star Metallicities



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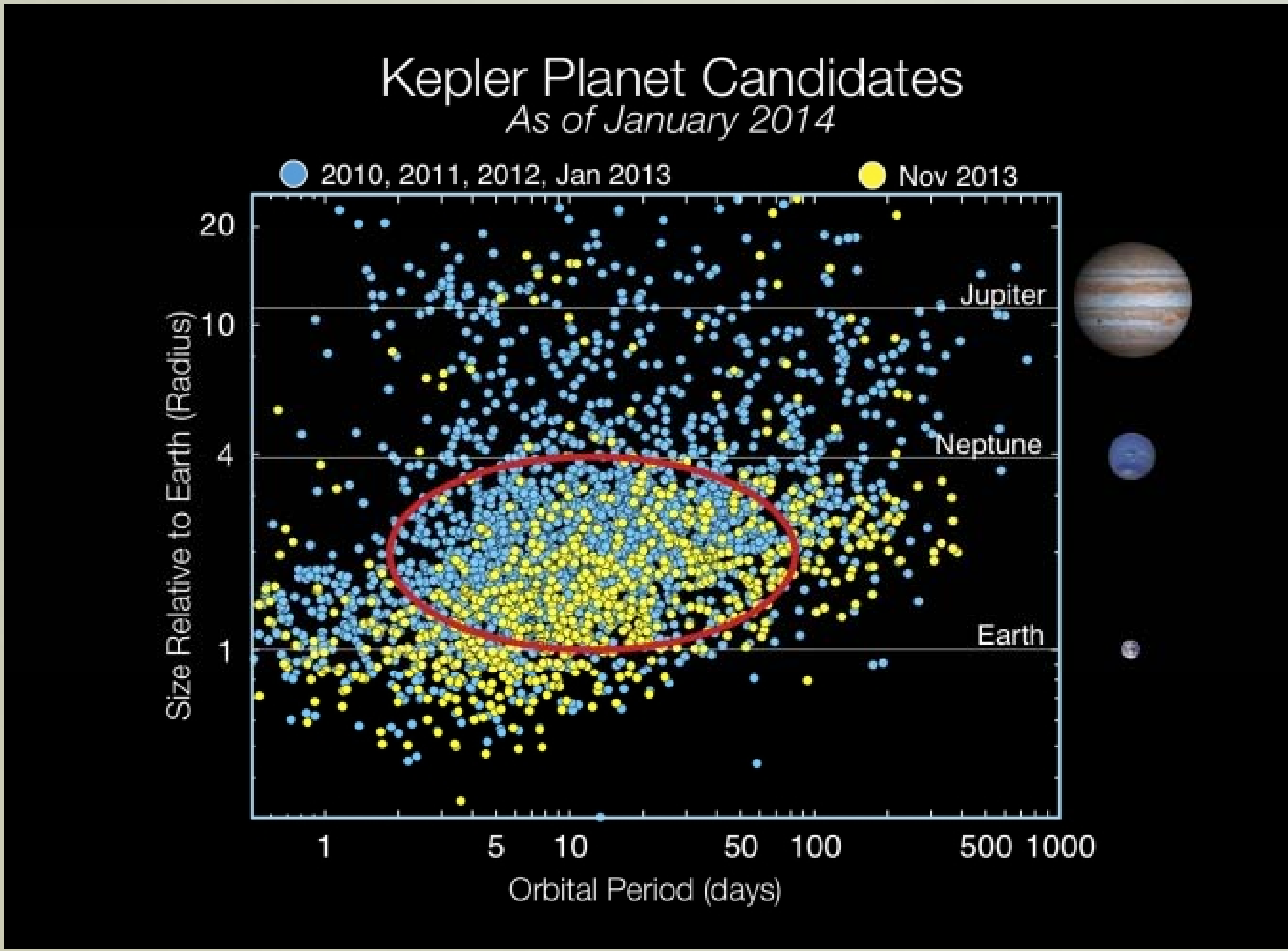
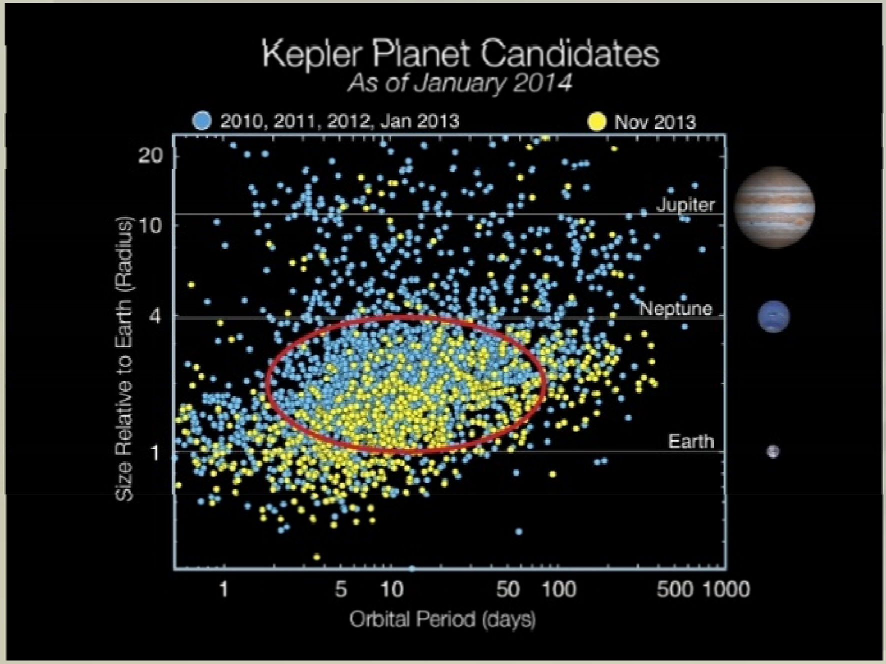
And Martin Bizzarro, David Latham and Dimitar Sasselov

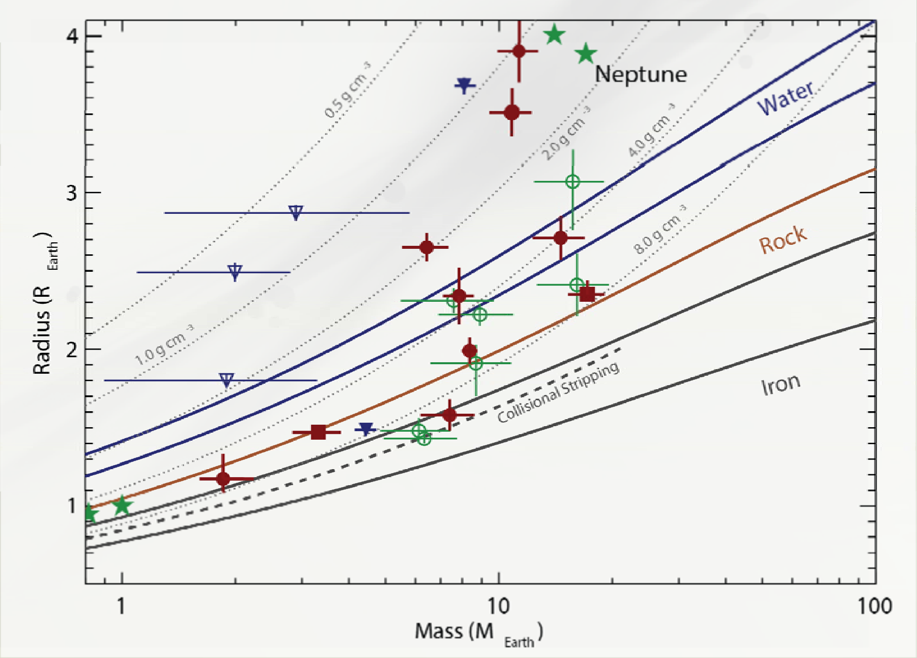
Majority of Kepler's Planets: $R_P \sim 1\text{-}4\ R_\oplus$



PLANETS WITH SIZES 1 - 4 $R_{\oplus}$

What is the composition of these very common planets
with no Solar System analogues?





Dumusque el al. 2014

The Planet-Metallicity Correlation

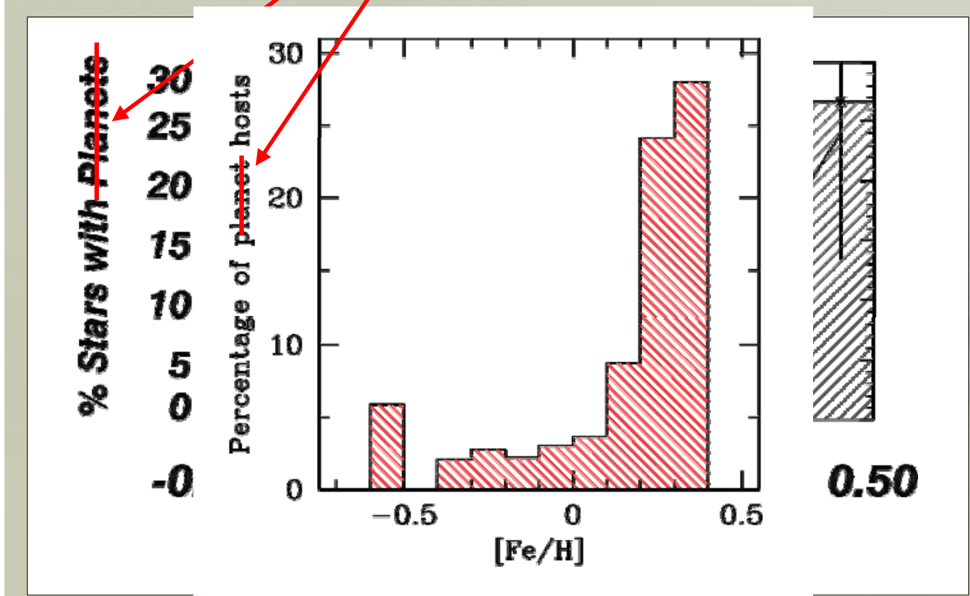
- Metal-rich stars tend to host hot Jupiter exoplanets
- Small planets form at a wide range of metallicities

close-in hot Jupiter planets

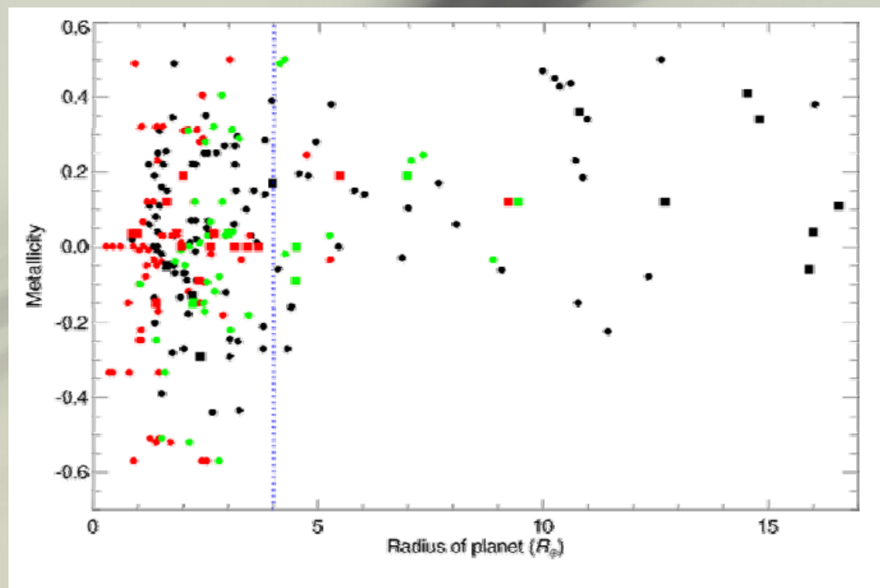
close-in hot Jupiter planets

Santos et al. 2004

Fischer & Valenti 2005

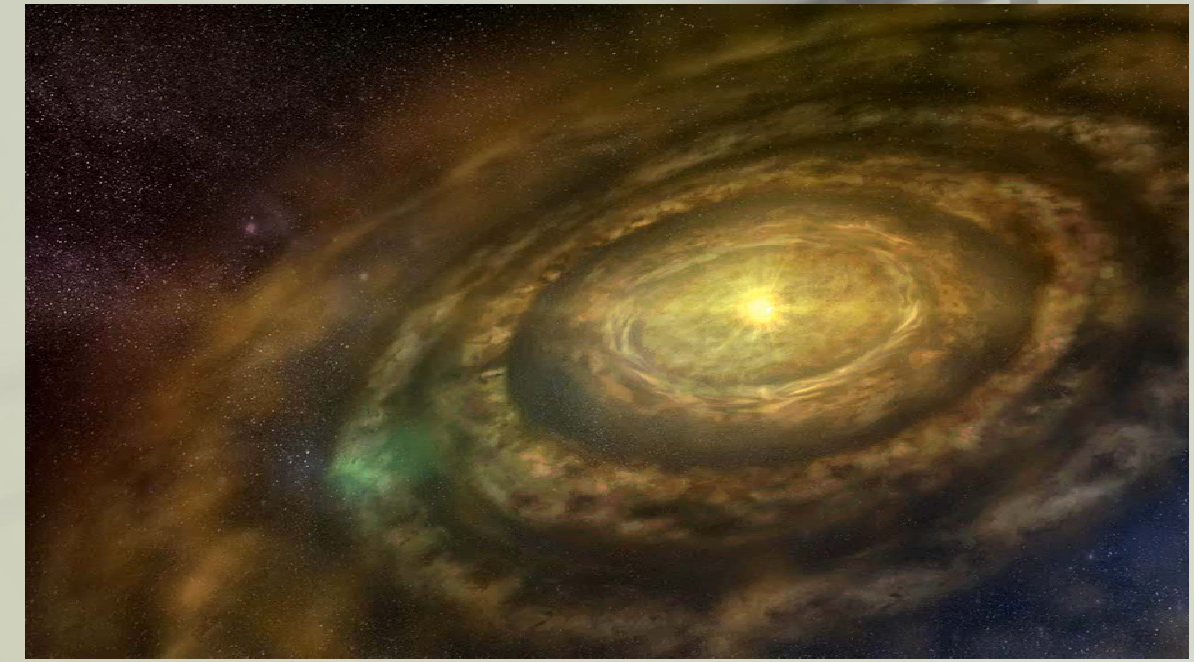


Buchhave el al. 2012, Nature



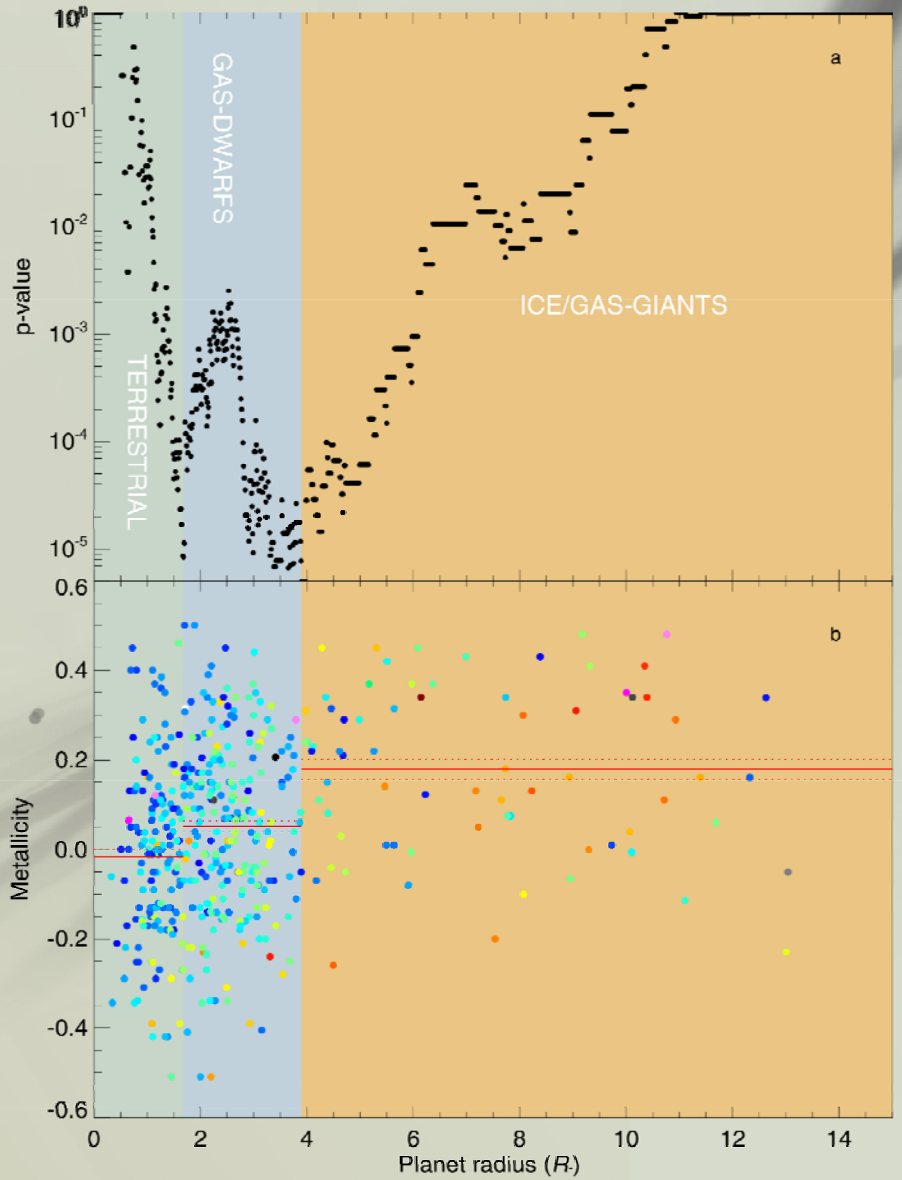
Kepler Host Star Metallicities

- Metallicities
  - 600 Kepler exoplanets candidates
  - 405 unique host stars
  - Over 2000 high-resolution spectra from four different instruments
- The metallicity of the host stars reflects the metallicity of the initial protoplanetary disc
- Homogeneously derived metallicities using SPC
- Many small exoplanets



Three Regimes of Exoplanets Inferred From Host Star Metallicities

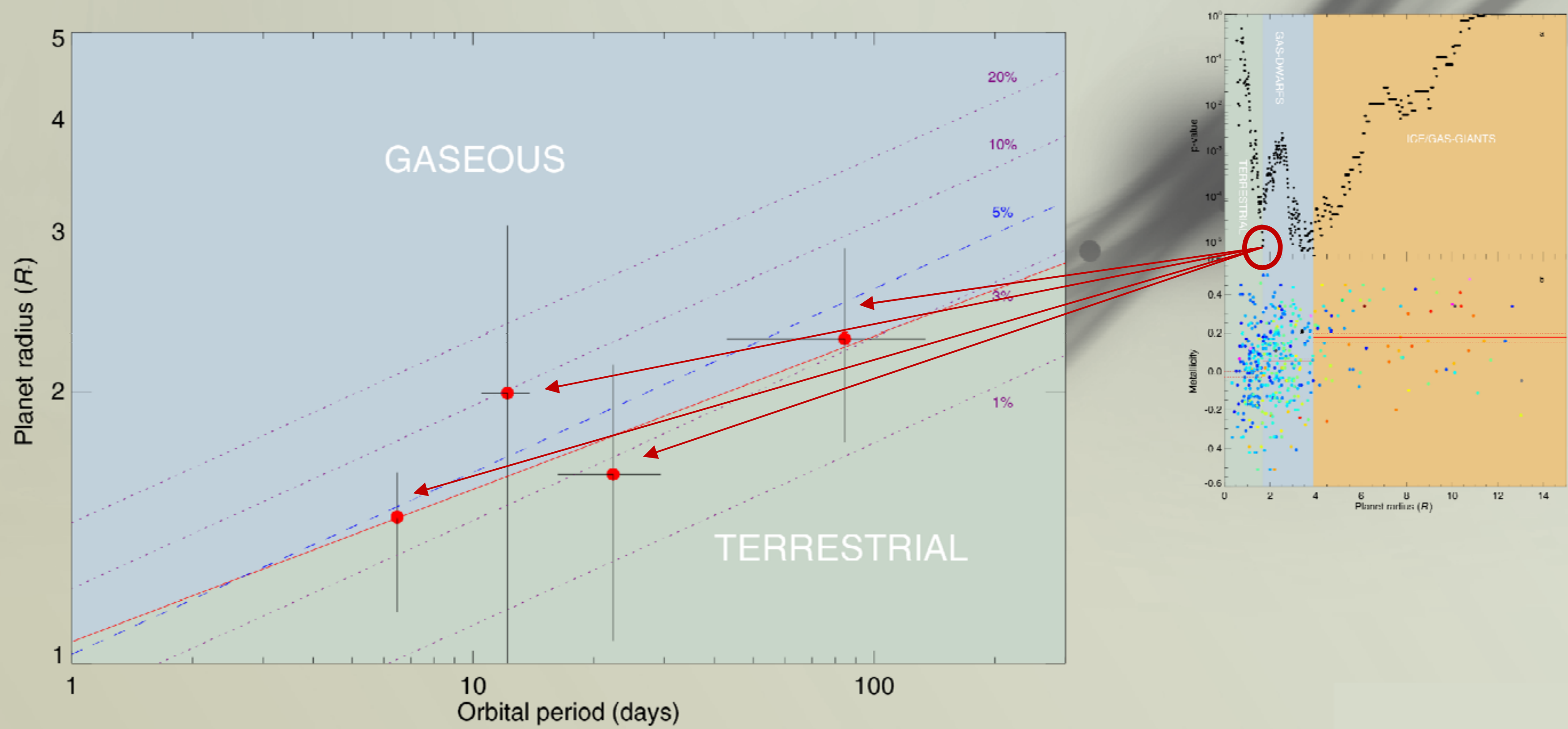
- Two features in K-S test diagram
  - $R_P = 1.7\ R_\oplus$ (4.5σ)
  - $R_P = 3.9\ R_\oplus$ (4.6σ)
- Monte Carlo simulation
  - $R_P = 1.55^{+0.88}_{-0.04} R_\oplus$ $(4.2^{+0.5}_{-0.4}\sigma)$
  - $R_P = 3.52^{+0.74}_{-0.28} R_\oplus$ $(4.7^{+0.6}_{-0.4}\sigma)$
- Interpretation:
  - Three regimes of exoplanets inferred from host star metallicities
    - Ice/gas-giants
    - Gas-dwarfs
    - Terrestrial planets
- Removing highly irradiated planets increased the significance of feature at 1.7 $R_\oplus$ from 3.5σ to 4.5σ
- Transition from rocky to gaseous planets
  - *Metallicity sweet spot for terrestrial planet formation*



Rocky to gaseous transition radius dependence on period

$M_{cr} \approx 2.6\, M_{\oplus} \left(\frac{\eta}{0.3}\right)^{1/2} \left(\frac{P_{orb}}{1\ \text{day}}\right)^{5/12}$, where $\eta = M_{atm}/M_{cr}$ (Rafikov 2006)

(High accretion luminosity core case – out to ~ 0.3 AU)



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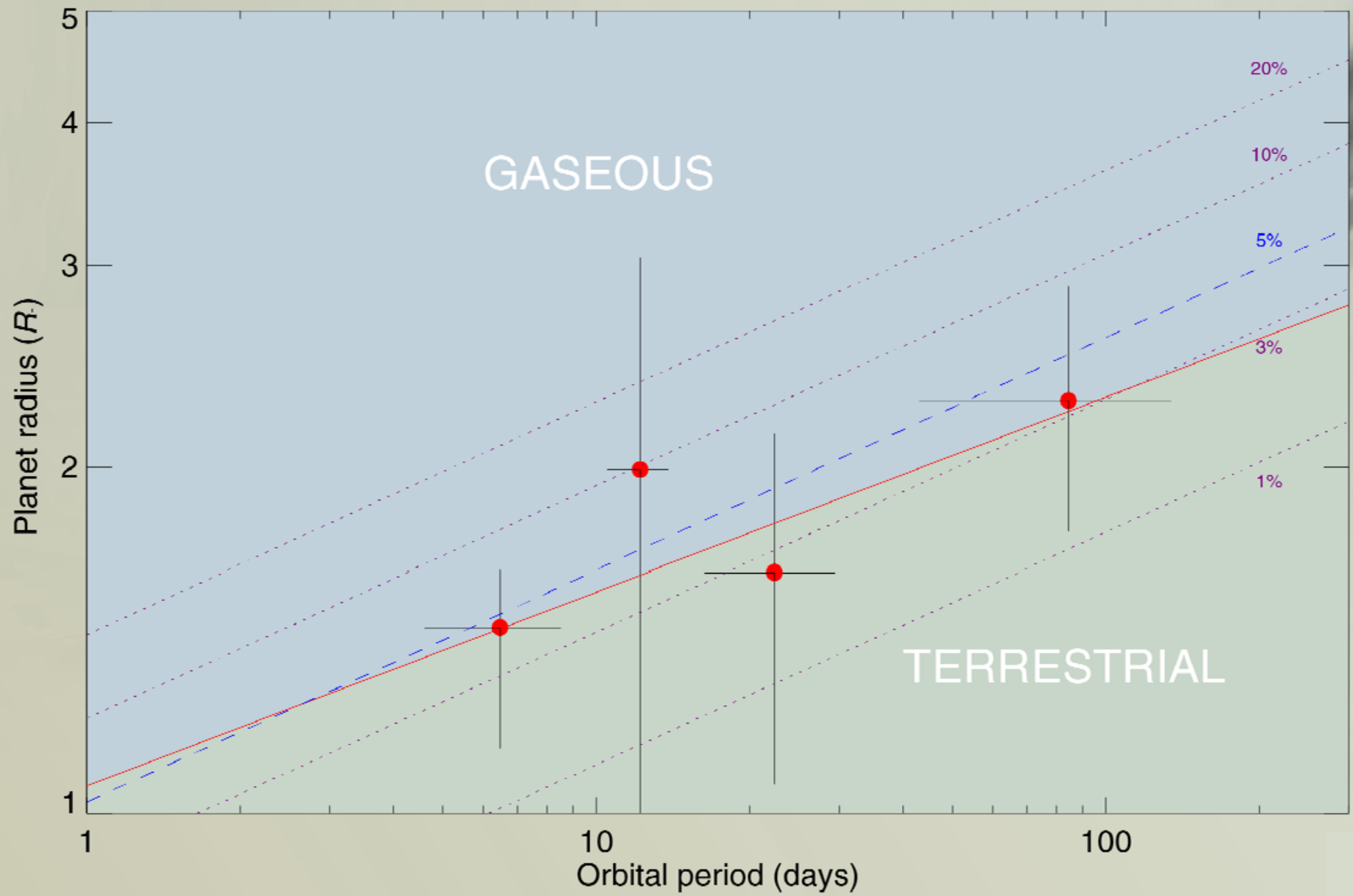


NEXT STEPS:
MASSES OF LONGER PERIOD SUPER-EARTHS

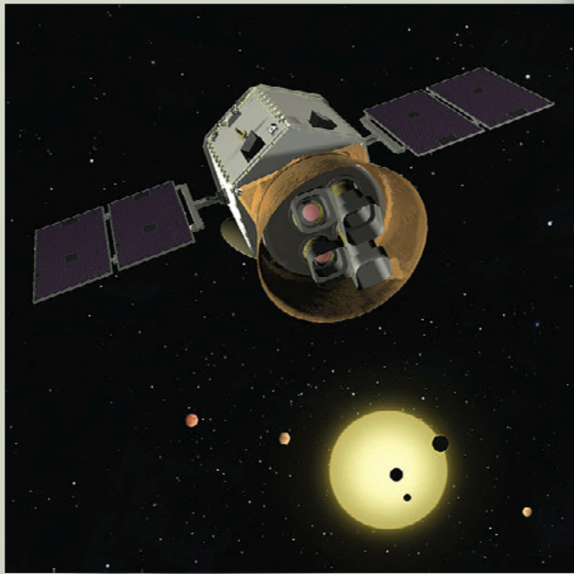
Program on HARPS-N to measure masses of longer period super-Earths

- 79 hours of extra HARPS-N time
- Time added to the GTO program (guaranteed time) to ensure proper time coverage of a few candidates
- Observed about 40 hours this season so far (80 observations)
- Masses of two larger planets emerging
  - Rp ~ 2 Re
  - Mp ~ similar to Kepler-10c in composition
- Only a very limited number of candidates from Kepler remain after all constrains are met

NEXT STEPS

TESS - Transiting Exoplanet Survey Satellite (NASA)

- Will find small transiting exoplanets orbiting bright stars across the full sky, some of which could be longer period (launch 2017)

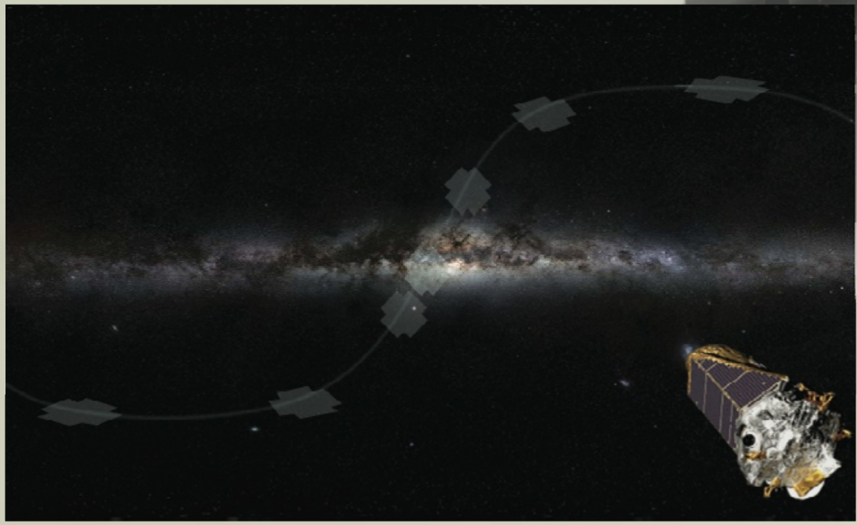


K2

- K2 (Kepler) will also discover small exoplanets orbiting bright host stars, but limited in the ability to find longer period planets

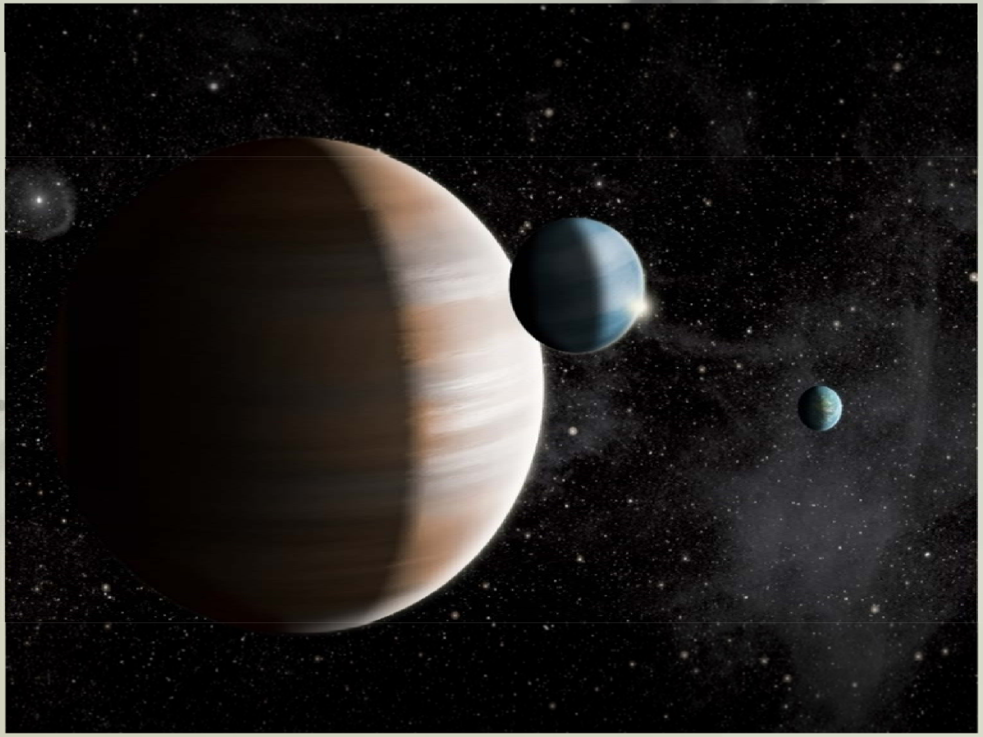
PLATO (ESA)

- Longer period planets orbiting bright stars (launch 2024)



CONCLUSIONS

- Three regimes of exoplanets inferred from host star metallicities
- Transition from rocky to gaseous planets inferred from host star metallicity
- Observational prediction that large and massive (heavy) rocky planets exist at longer orbital periods



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