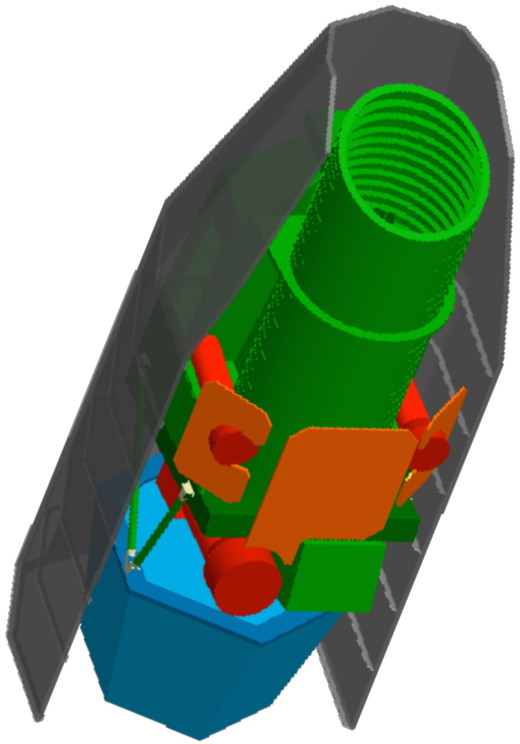
Implications of Kepler Results for the WFIRST Exoplanet Program



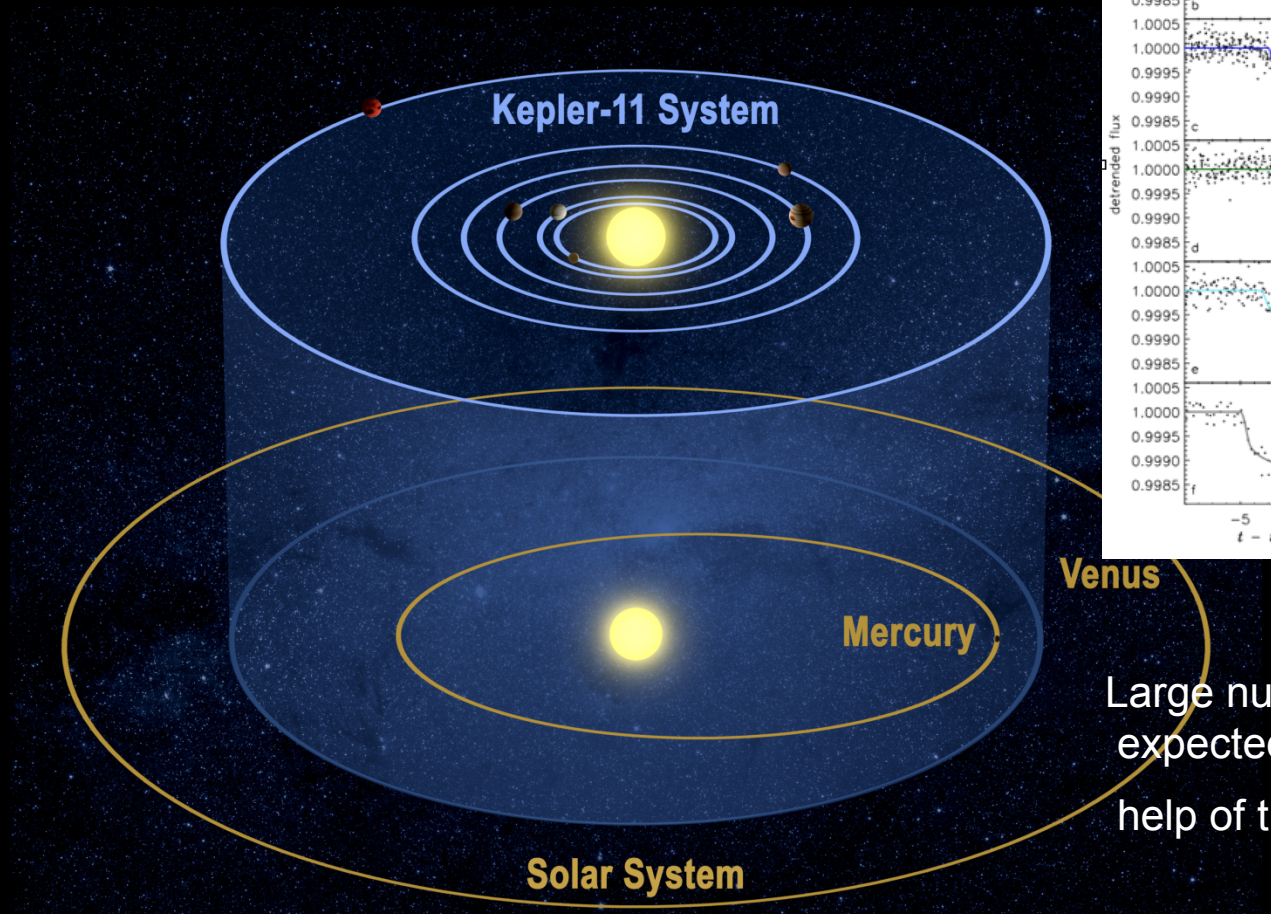
David Bennett
University of
Notre Dame

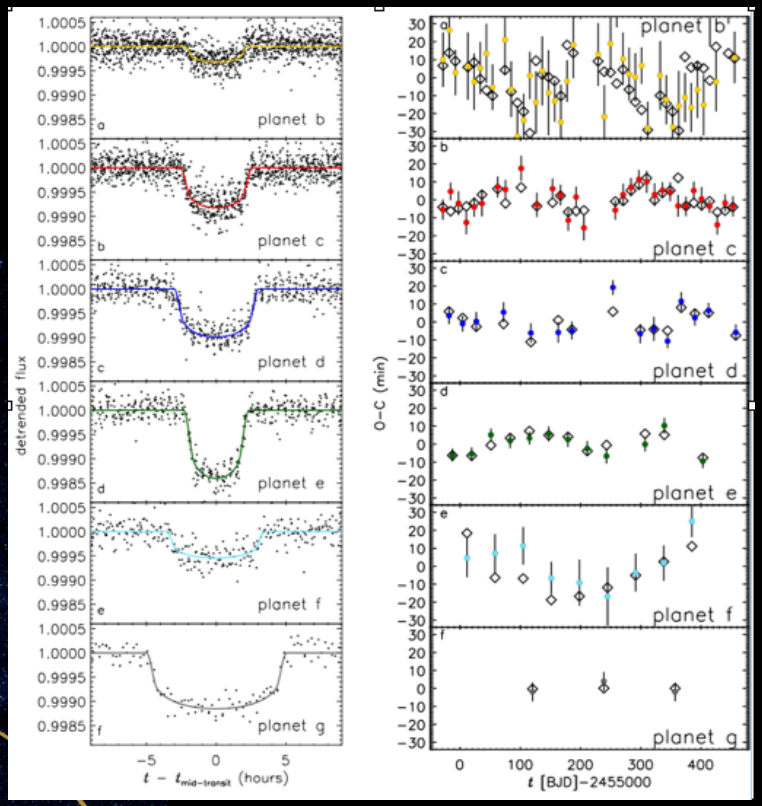
with slides from
Bill Borucki and
Dimitar Sasselov

Unique Science from Space-based Survey

- ***Exoplanet Survey Question #1: How do planetary systems form and evolve?***
  - complementary to Kepler
  - Exoplanet sensitivity down to sub-Earth masses at 0.5 AU - ∞
  - down to 0.1 Earth-masses over most of this range
  - free-floating planets down to 0.1 Earth-masses
    - free-floating planet mass distribution is important for understanding planet formation.
- ***Exoplanet Survey Question #2: How common are potentially habitable worlds?***
  - $\eta_{\oplus}$ = fraction of planetary systems with an earth-like planet in the habitable zone
  - But what is earth-like?
  - Kepler results imply: $\eta_{\oplus\text{-mass}}$ is not the same as $\eta_{\oplus\text{-radius}}$
  - We need to answer question #1 to understand habitability
    - many planet formation details may have implications for habitability

6 Transiting Planets in the Kepler-11 System



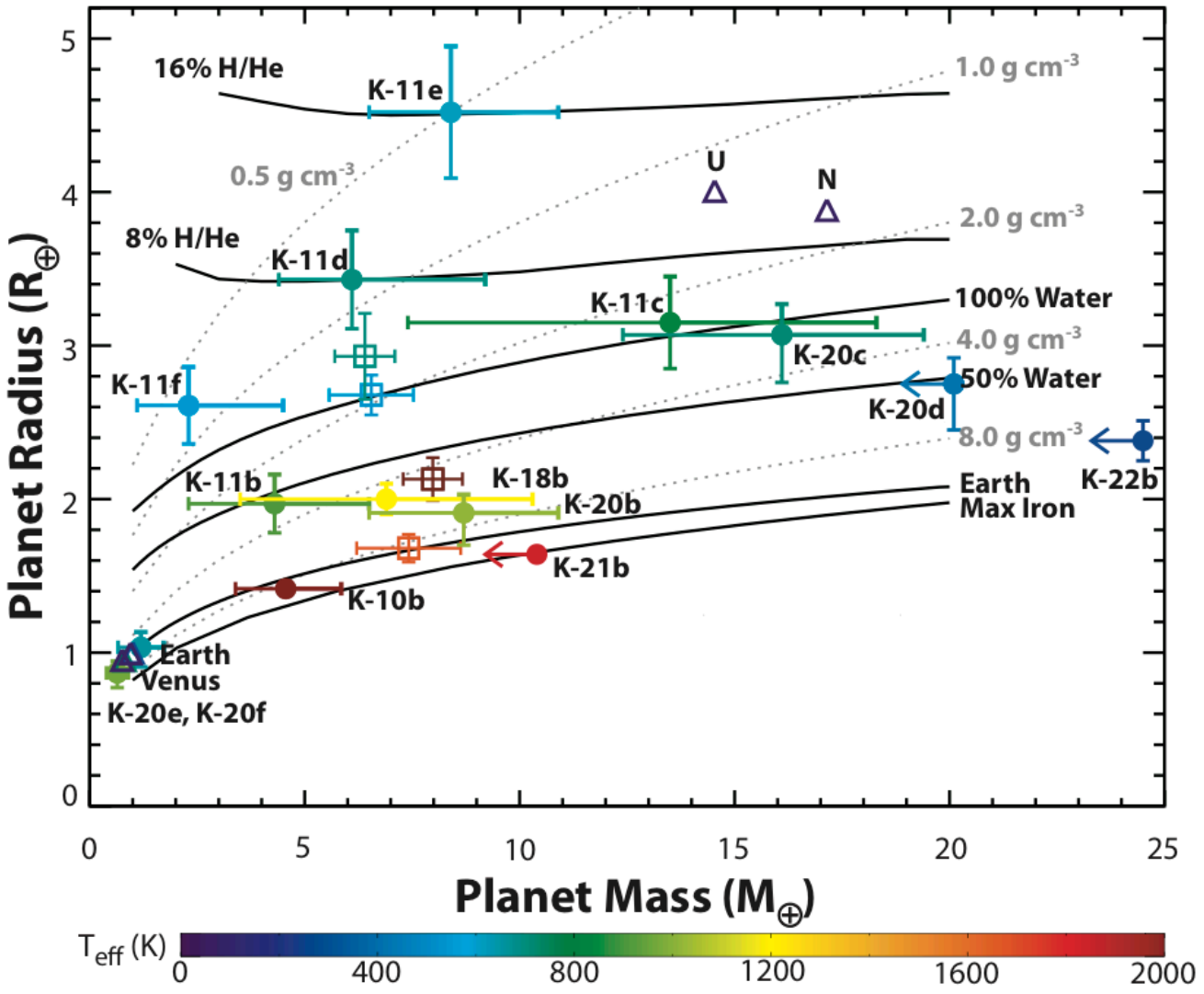


Large numbers of exoplanets are expected to be validated with the help of transit timing variations.

KEPLER IS EXPLORING THE PHASE SPACE BETWEEN EARTH AND NEPTUNE

Kepler
A Search for Earth-size Planets

low-mass planets in short period orbits can have low densities



Borucki

The Minimum Mass Solar Nebula

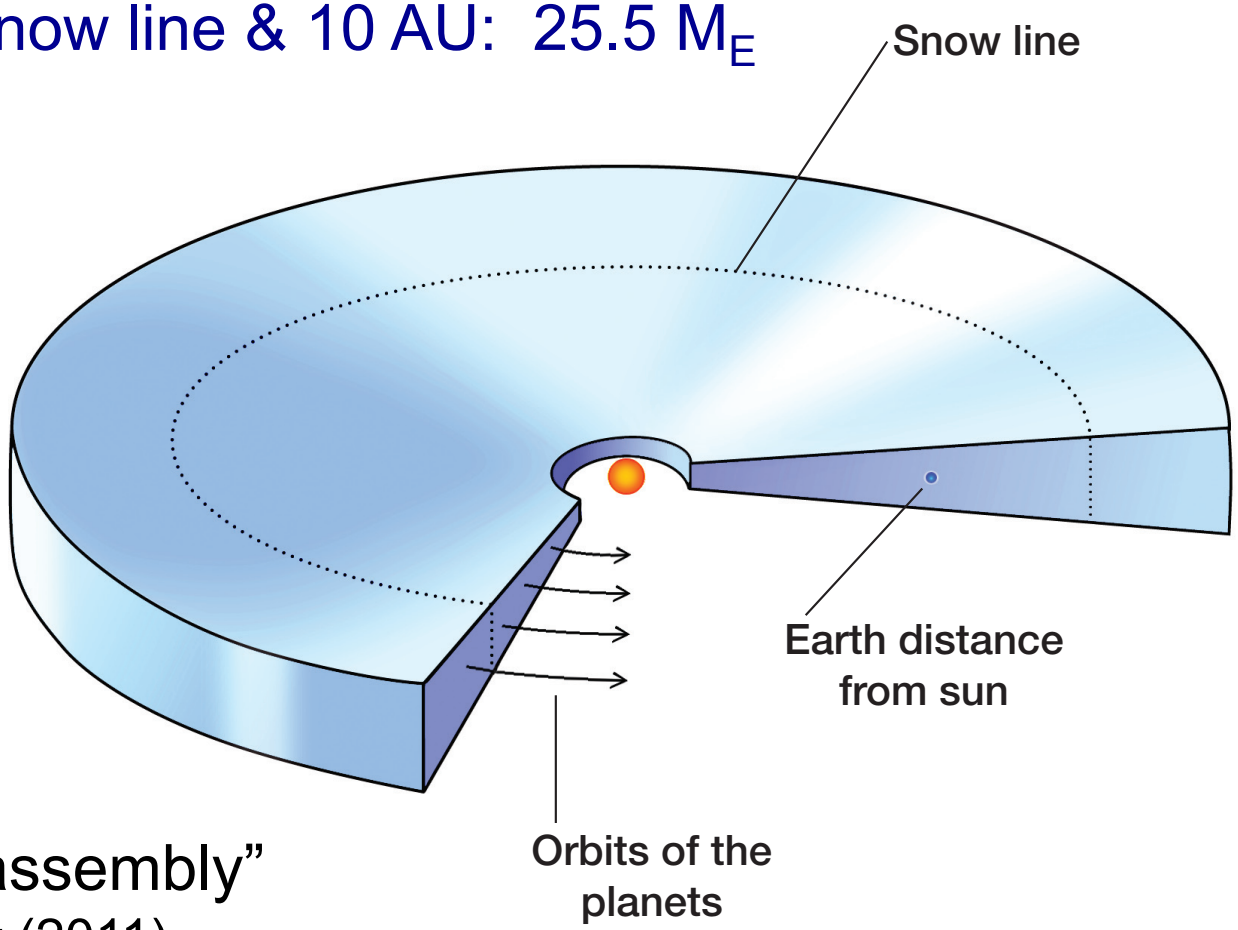
A la Hayashi (1981): integrated mass of solids at:

(1)Inside of 1 AU: 3.3 M_E

(2)Between 1 AU & Snow line: 5.7 M_E

(3)Between Snow line & 10 AU: 25.5 M_E

Kepler finds small planets with lots of volatiles at ~0.25 AU, so what are planets like between 1 AU and the snow line, where volatiles were thought to be more common?



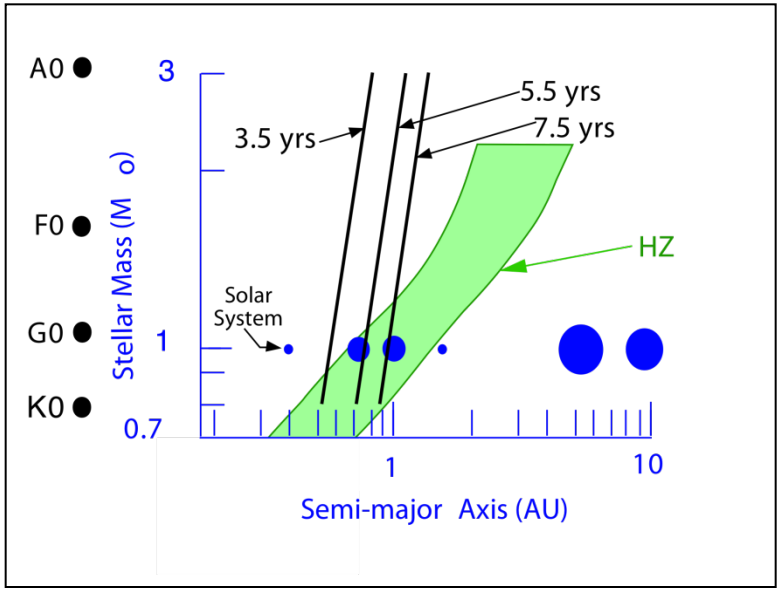
…or

"migration then assembly"

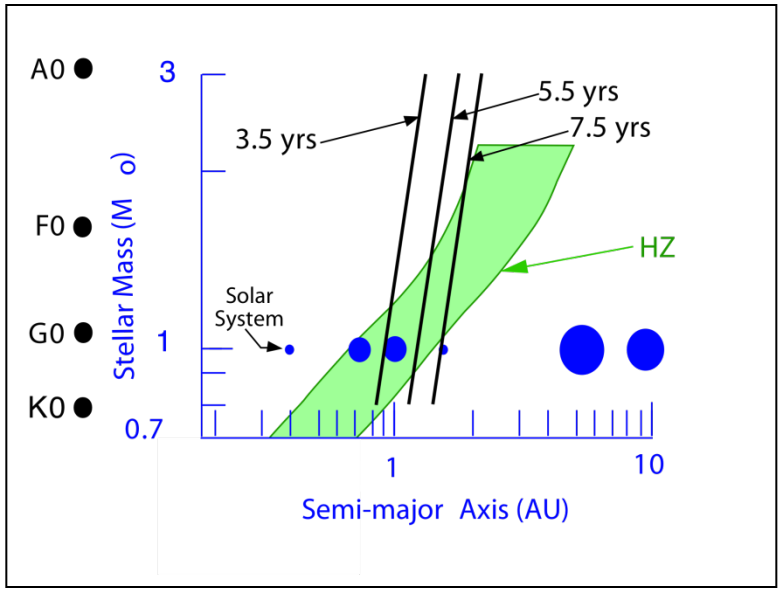
Hansen & Murray (2011)

COVERAGE OF HZ FOR 1.0 AND 1.4 EARTH-RADIUS PLANETS

Kepler
A Search for Earth-size Planets



Search coverage for 1.0 Earth-radius planets when 8 transits are observed.



Search coverage for 1.4 Earth-radius planets when 4 transits are observed

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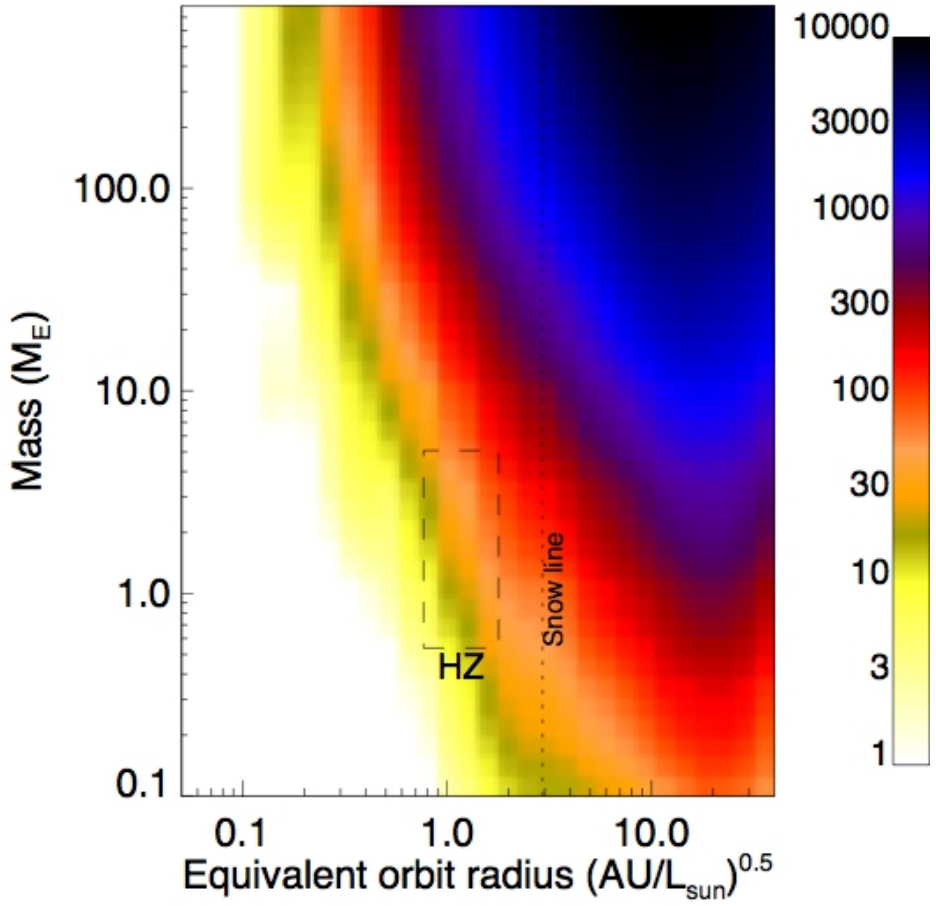
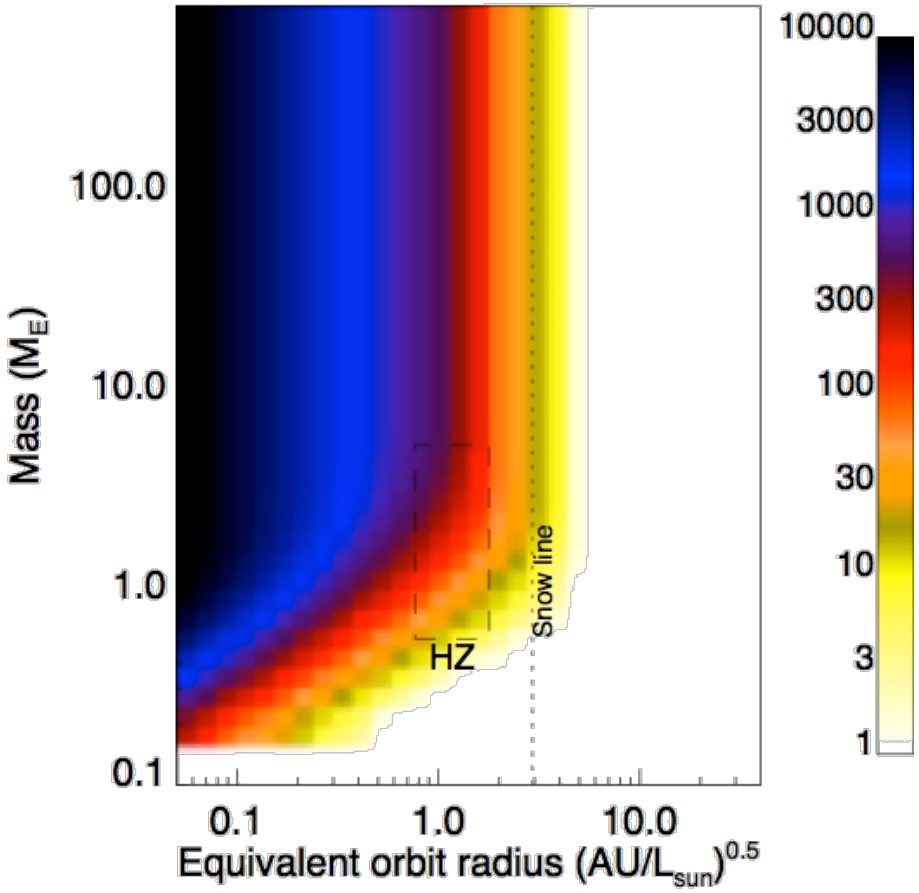
WFIRST vs. Kepler

WFIRST – w/ extended mission



Kepler ~12 yr mission

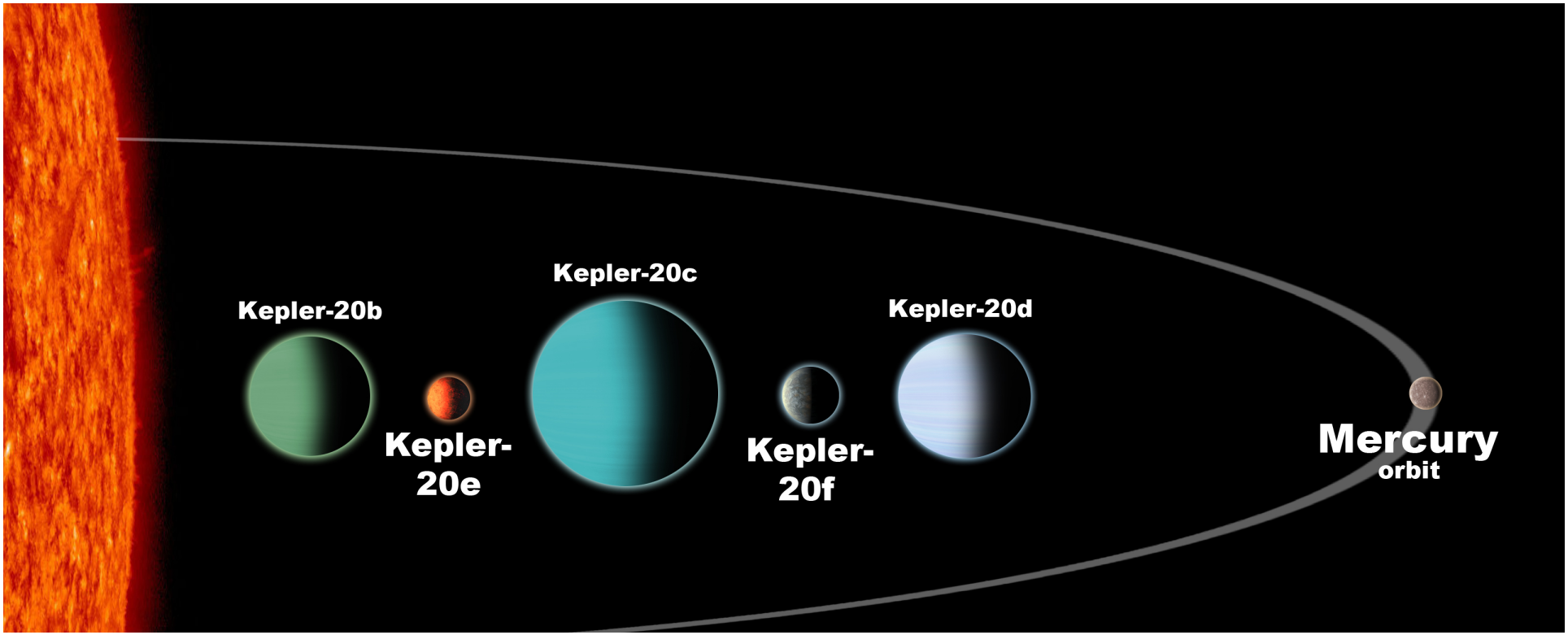


Figures from B. MacIntosh of the ExoPlanet Task Force

Exoplanet Community Evolution

- Huge growth in the past 10 years
- TPF effort is a much smaller fraction of the community
- Much more interest in smaller, quicker projects
  - Kepler
  - TESS (Transiting Exoplanet Sky Survey) – all-sky
  - FINESSE, ECHO – transiting planet spectra
- Concern that TPF may still seem to be unaffordable in 2020
- Probe-class Direct Detection Mission
  - Possible interest in a star shade for WFIRST
    - Sensitive to super-earths and exozodi
    - Small increase in WFIRST requirements – wave-front sensor & IFU
    - Relatively small loss in observing time
    - Star shade is a separate mission
    - Stronger political support

The Kepler-20 System



M_P	$8.7M_E$	$\sim 0.5M_E$	$16.1M_E$	$\sim 1.0M_E$	< 20	M_E
$\langle\rho\rangle$	6.5+/-2	> 5	2.9+/-1	> 2.2	< 4	g cm^{-3}

The Solar System