Completing the Census of Exoplanets with WFIRST.

AAS 227
WFIRST Special Session
January 5, 2016

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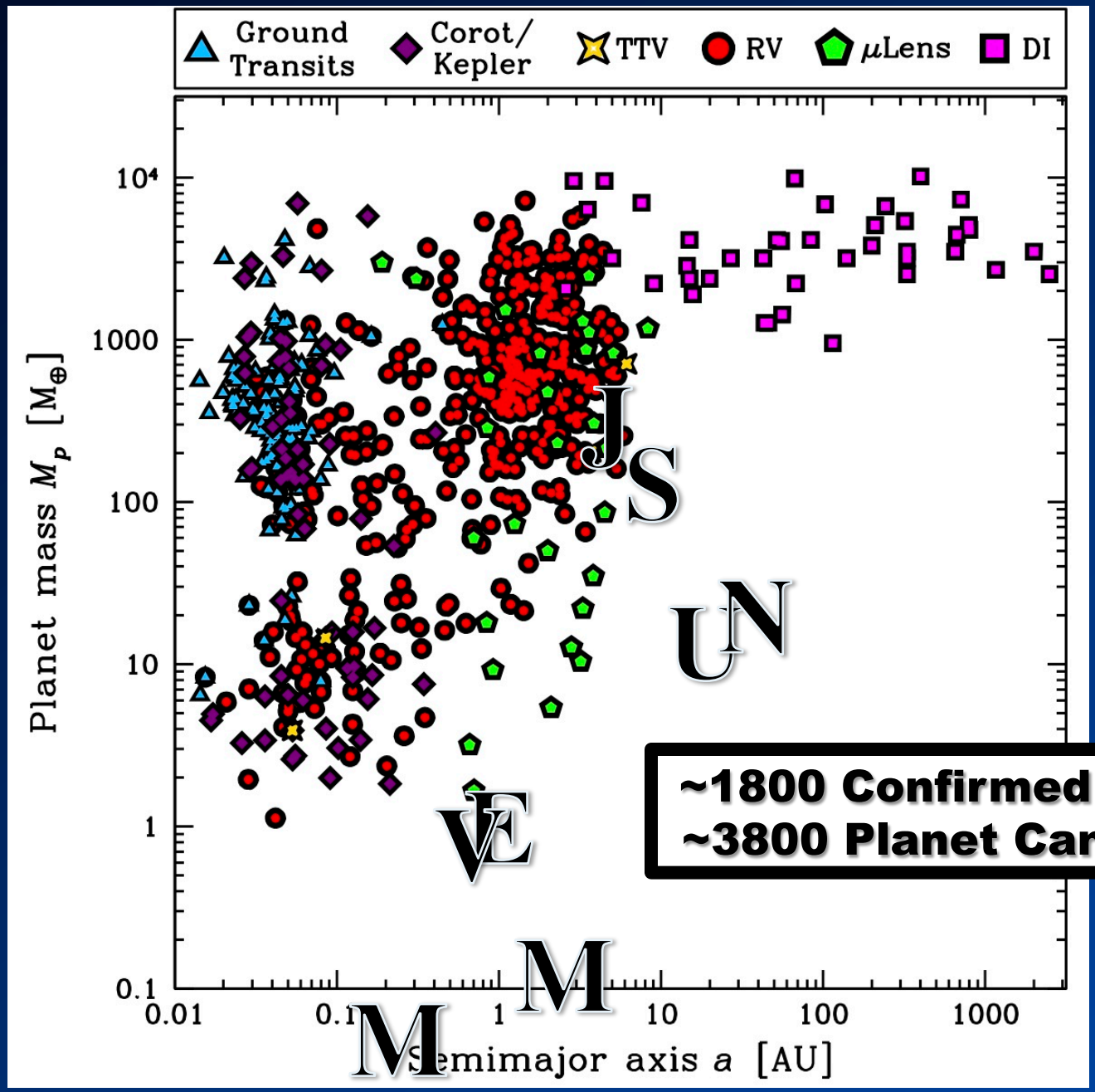
(with the WFIRST SDTs and on behalf of the WFIRST Microlensing SIT)

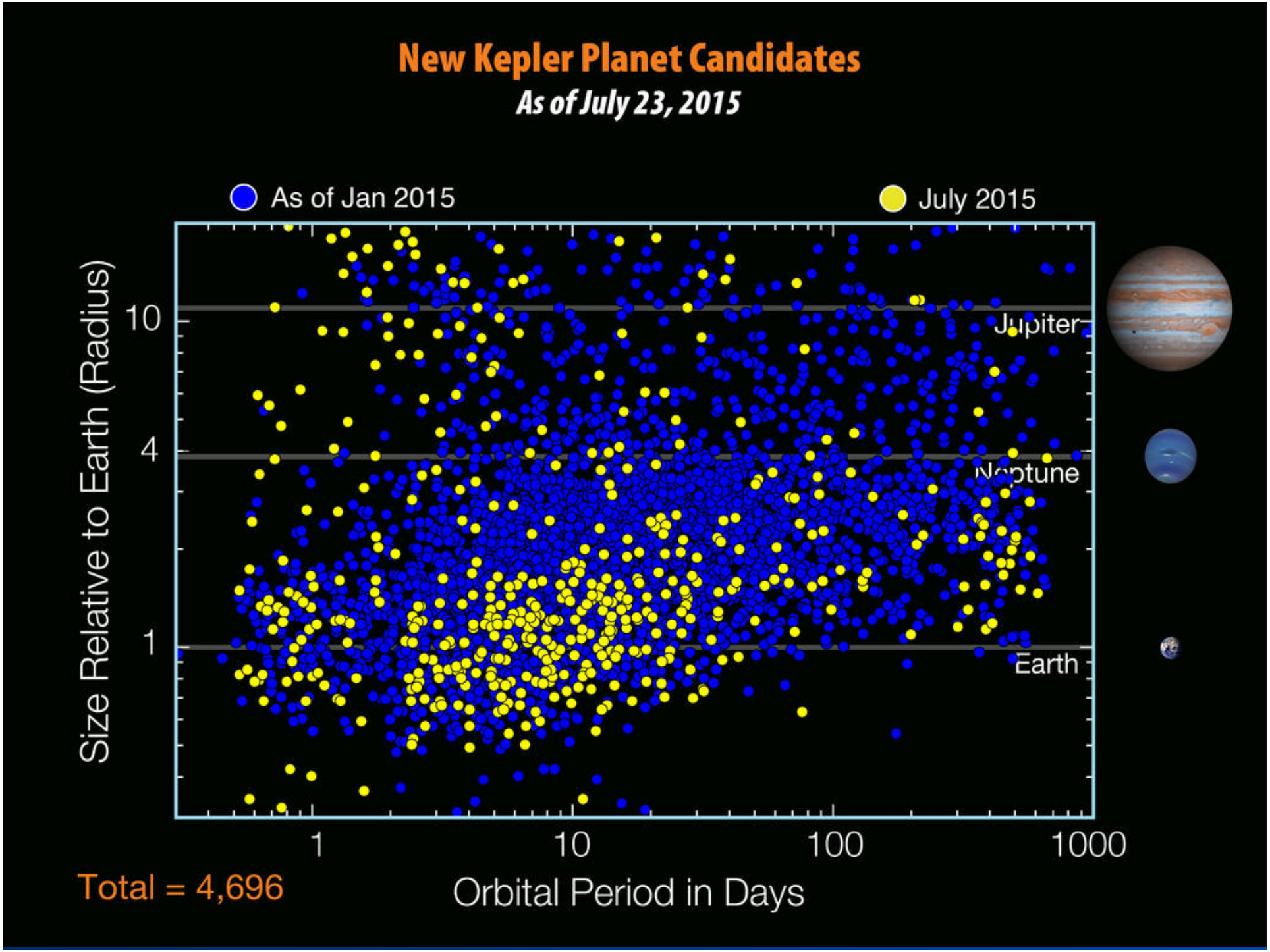
Planet Formation.

Must understand the physical processes by which micron-sized grains in protoplanetary disks grow by $10^{\sim 13-14}$ in size and $10^{\sim 38-41}$ in mass.

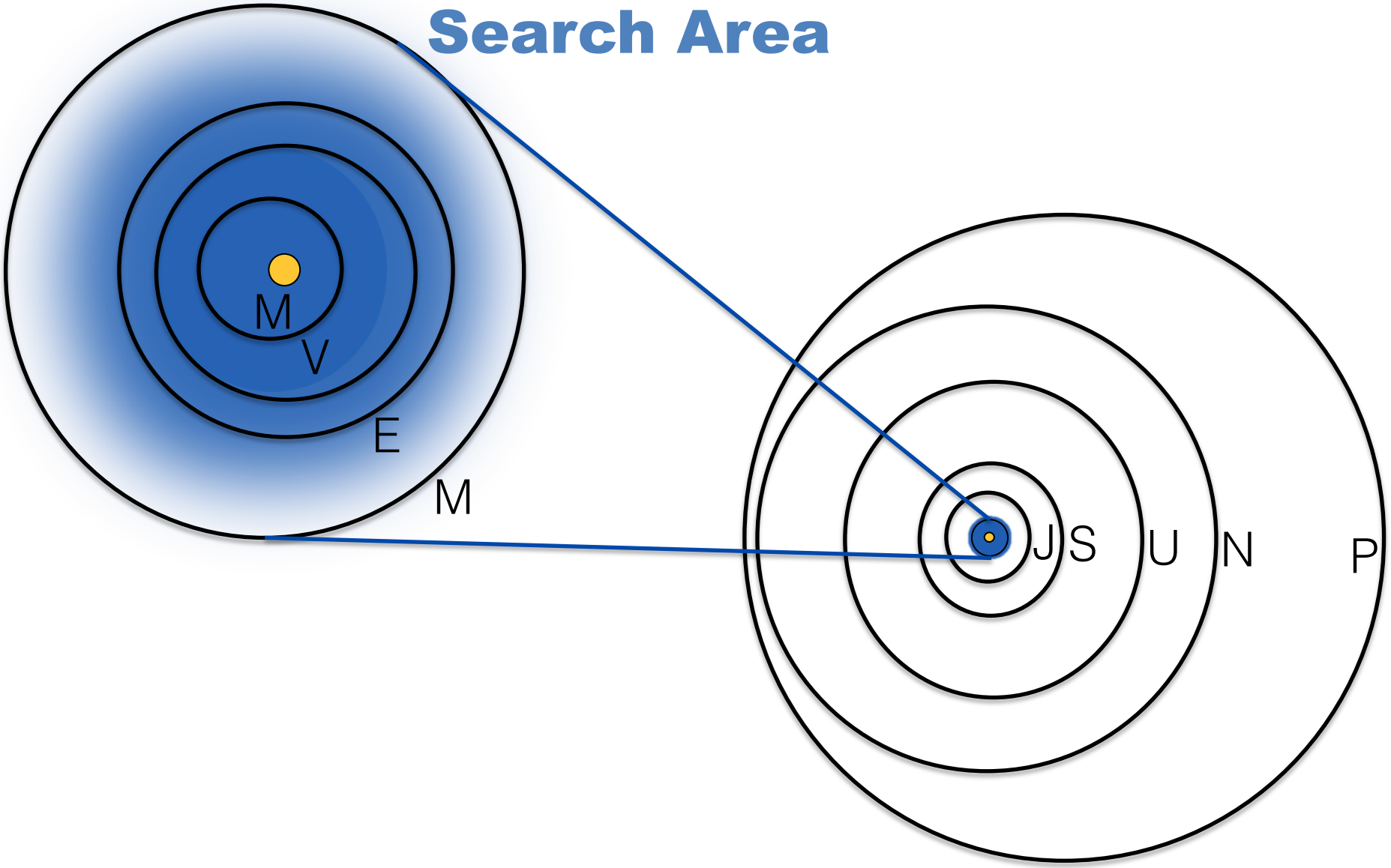
Hard!

A Complete Exoplanet Census.


Ground Transits
Corot/ Kepler
TTV
RV
μLens
DI
Planet mass M_p [$M_\oplus$]
Semimajor axis a [AU]
0.01
0.1
1
10
100
1000
0.1
1
10
100
1000
10⁴
J
S
U
N
V
E
M
M
~1800 Confirmed Planets
~3800 Planet Candidates


New Kepler Planet Candidates
As of July 23, 2015
As of Jan 2015
July 2015
Size Relative to Earth (Radius)
10
4
1
Jupiter
Neptune
Earth
1
10
100
1000
Orbital Period in Days
Total = 4,696

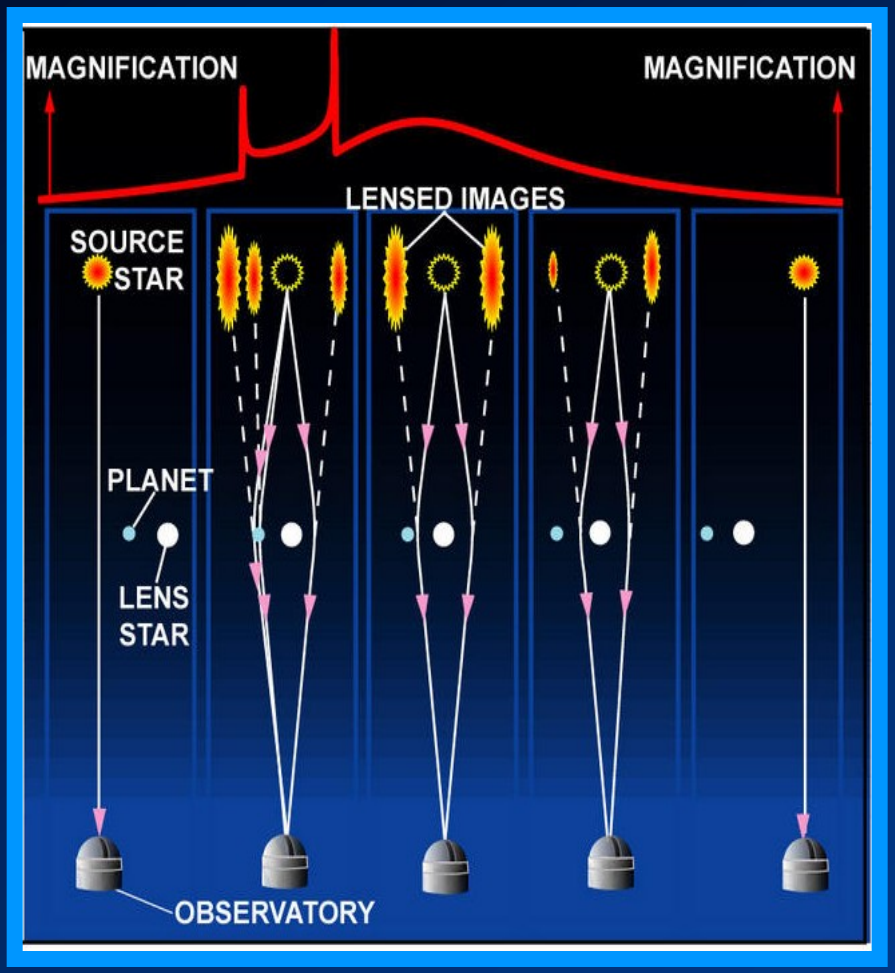
Kepler's Search Area

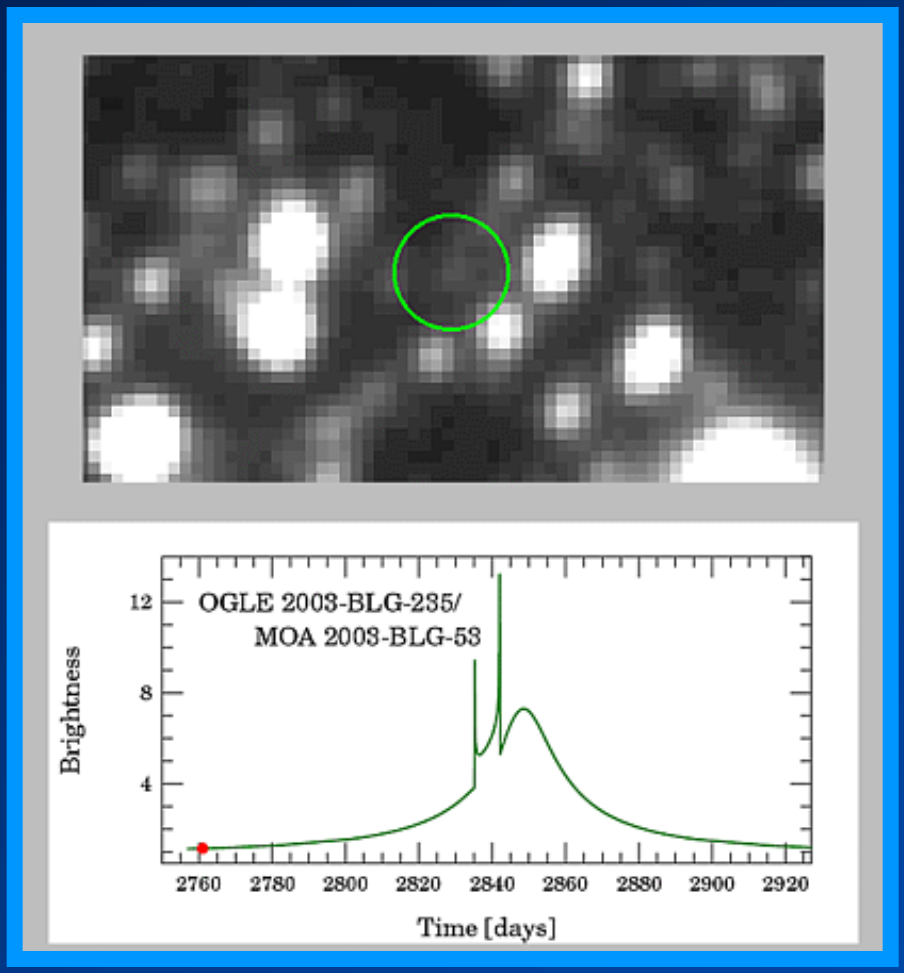


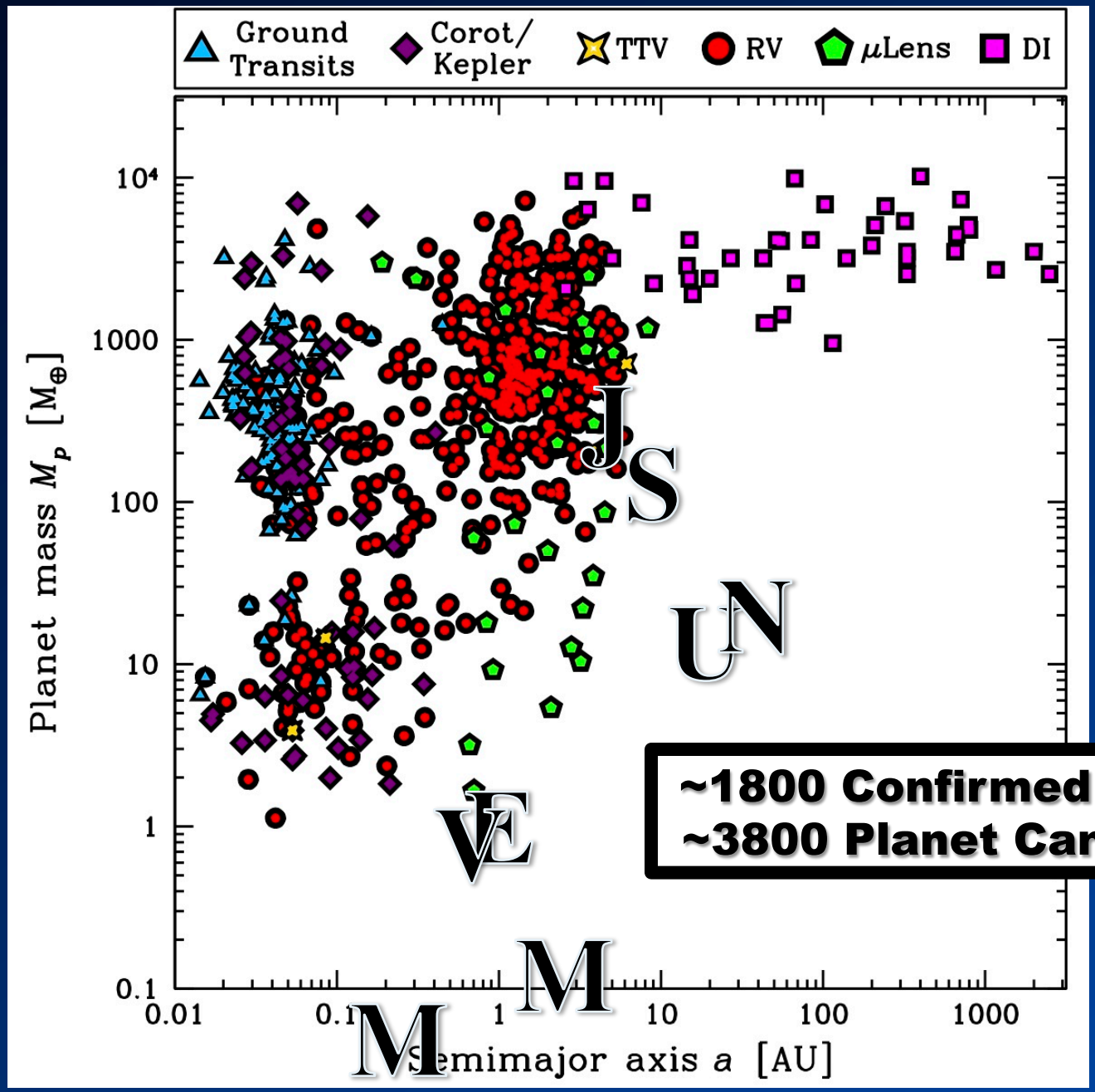
Why complete the census?

- A complete census is likely needed to understand planet formation and evolution.
  - Most giant planets likely formed beyond the snow line.
  - Place our solar system in context.
  - Water for habitable planets likely delivered from beyond the snow line.
- Mother nature is more imaginative that we are.

Microlensing.



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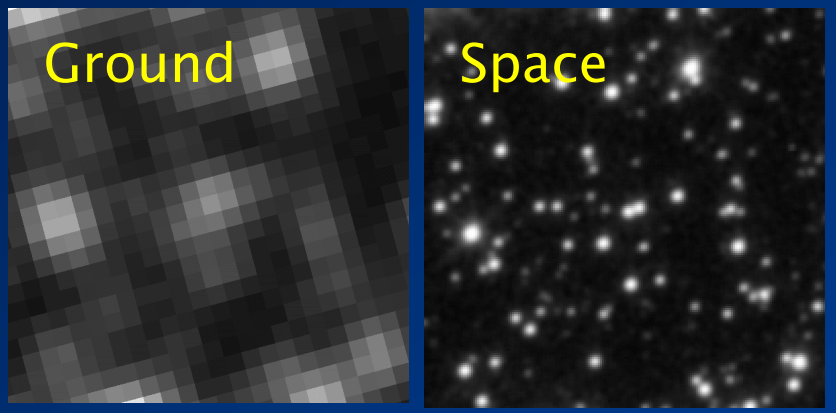
Earth Mass and Below?

- Monitor hundreds of millions of bulge stars continuously on a time scale of ~10 minutes.
  - Event rate ~10^{-5}/year/star.
  - Detection probability ~0.1–1%.
  - Shortest features are ~30 minutes.
- Relative photometry of a few %.
  - Deviations are few – 10%.
- Resolve main sequence source stars for smallest planets.
- Masses: resolve background stars for primary mass determinations.

Ground vs. Space.

- Infrared.
  - More extincted fields.
  - Smaller sources.
- Resolution.
  - Low-magnification events.
  - Isolate light from the lens star.
- Visibility.
  - Complete coverage.
- Smaller systematics.
  - Better characterization.
  - Robust quantification of sensitivities.



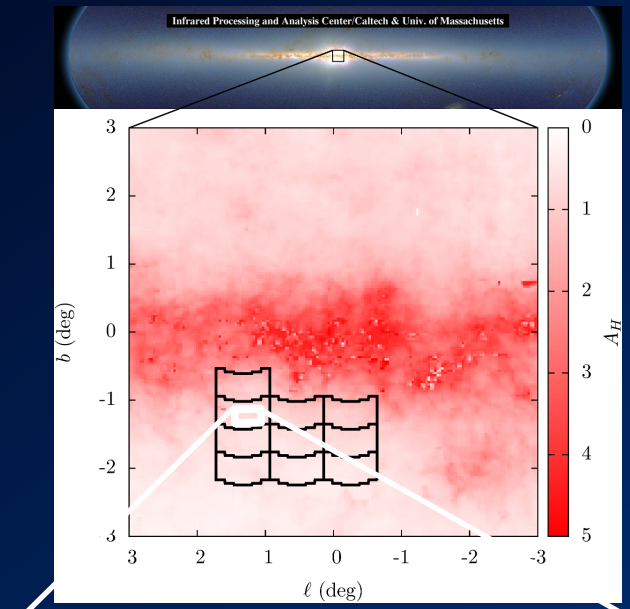
The field of microlensing event MACHO 96-BLG-5 (Bennett & Rhie 2002)

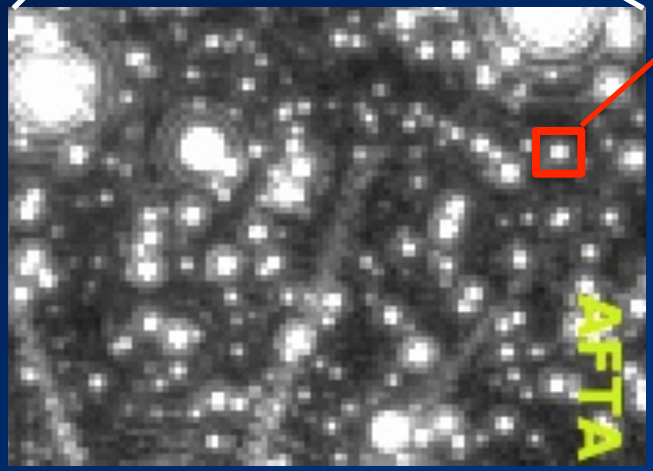
Science enabled from space: sub-Earth mass planets, habitable zone planets, free-floating Earth-mass planets, mass measurements.

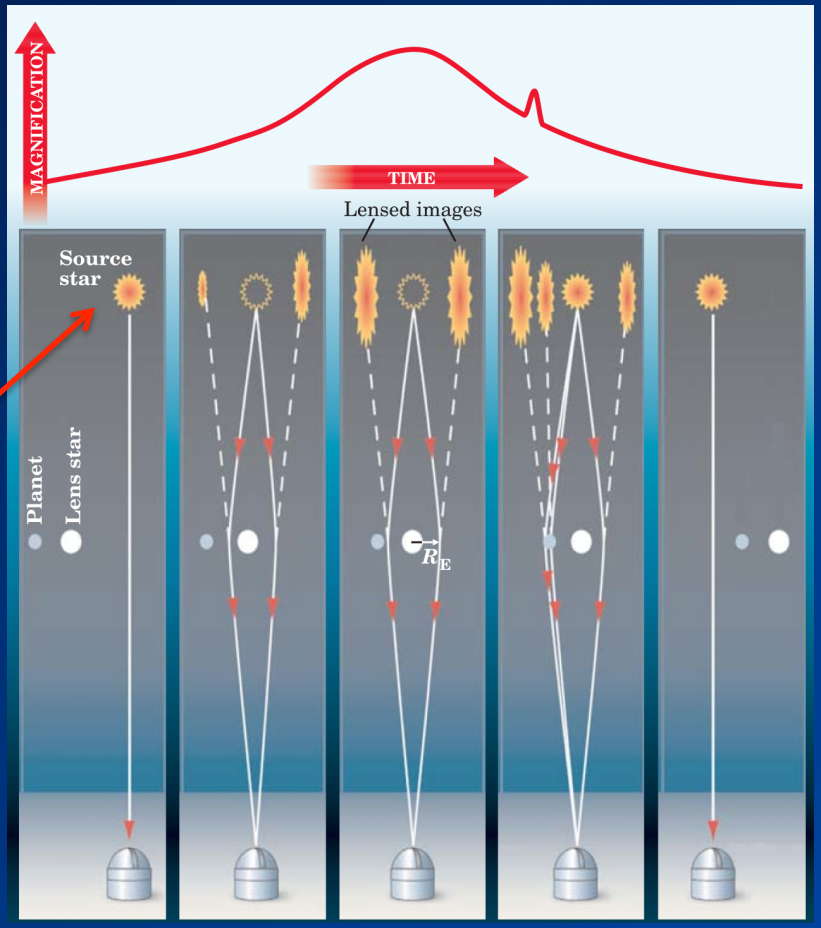
WFIRST.

Microlensing Simulations.

(Matthew Penny)







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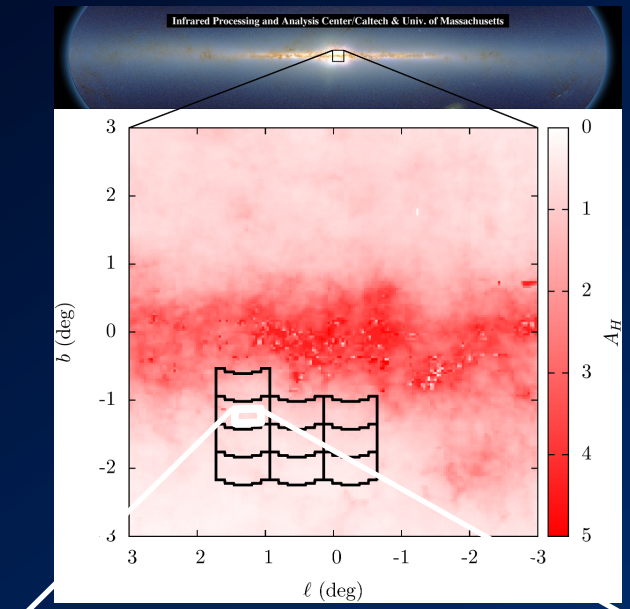
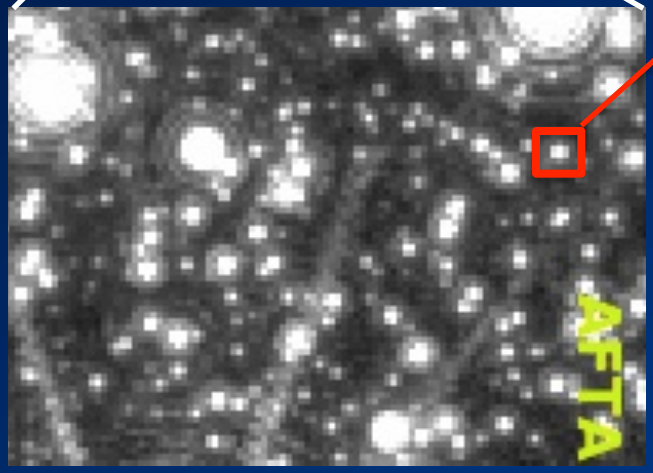
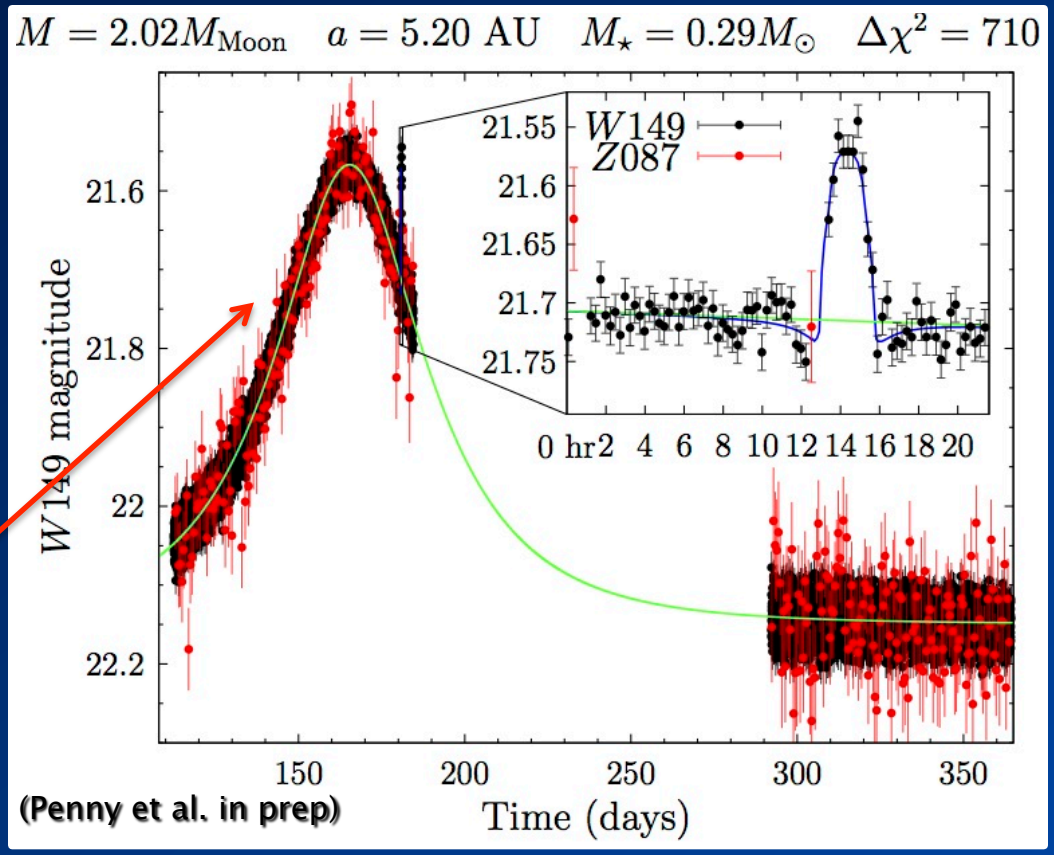
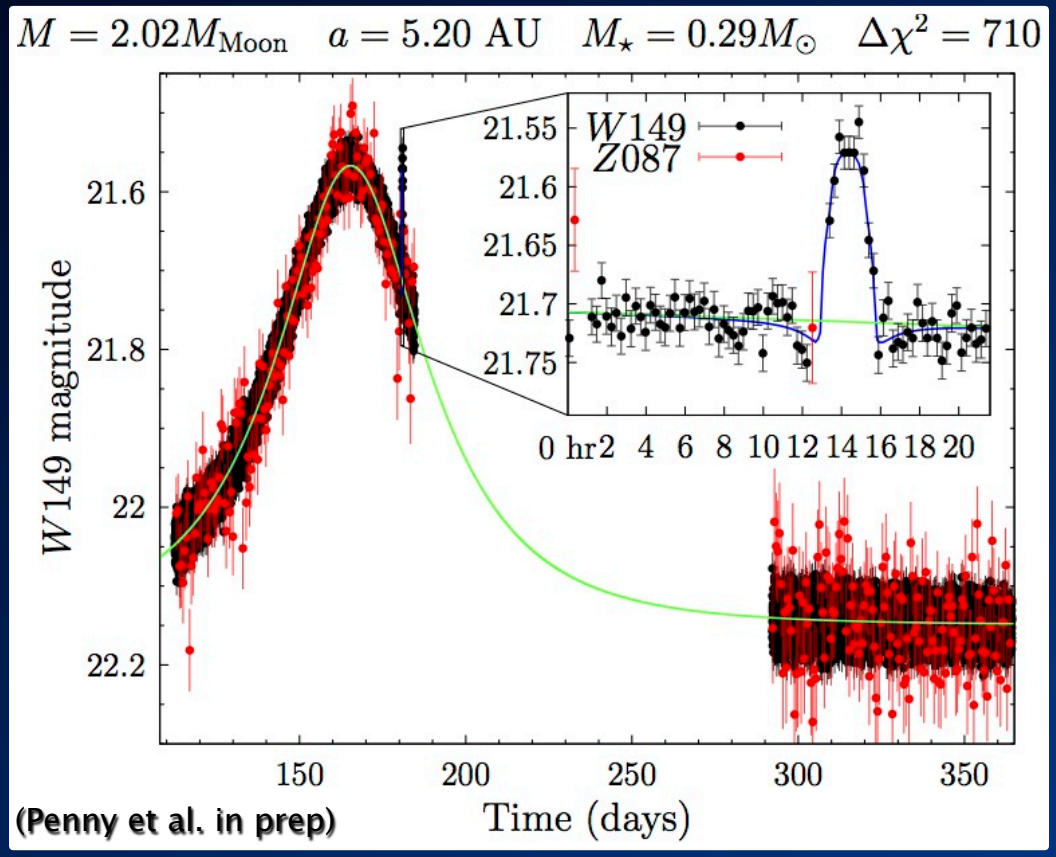


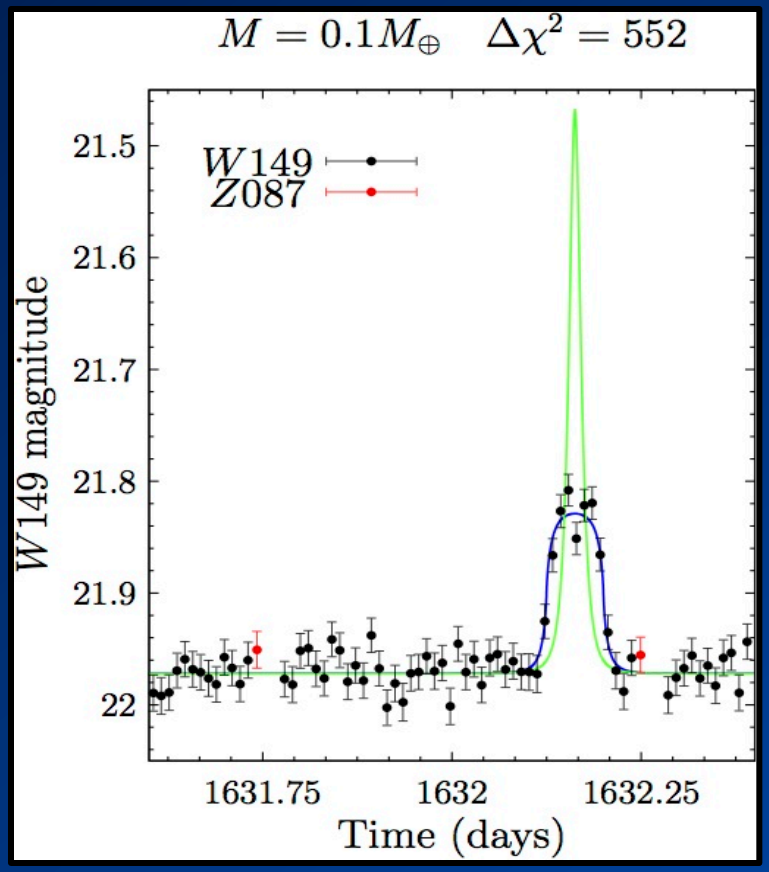




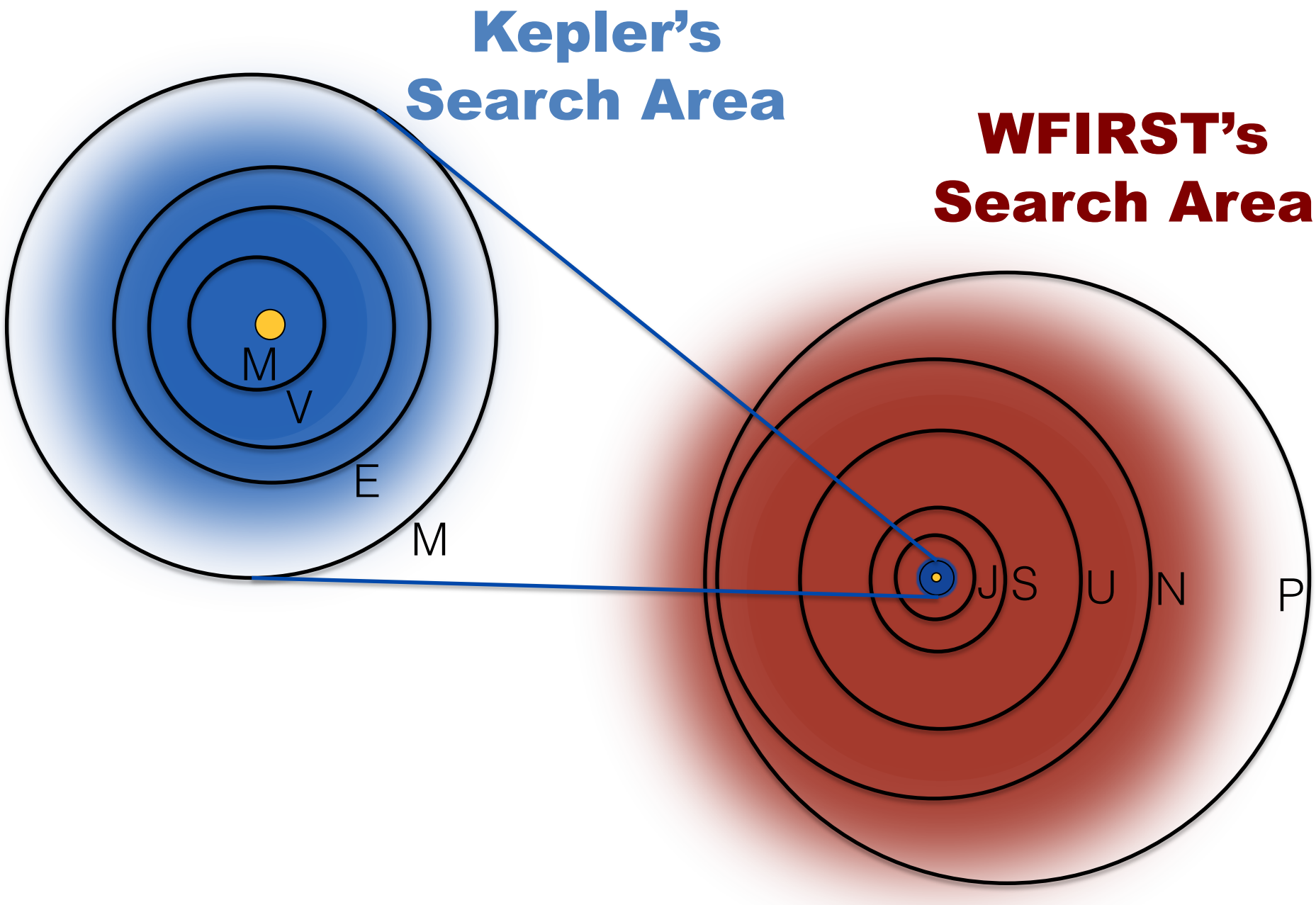
(Penny et al. in prep)



2 × Mass of the Moon @ 5.2 AU (~27 sigma)



Free floating Mars (~23 sigma)


Kepler's
Search Area
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M
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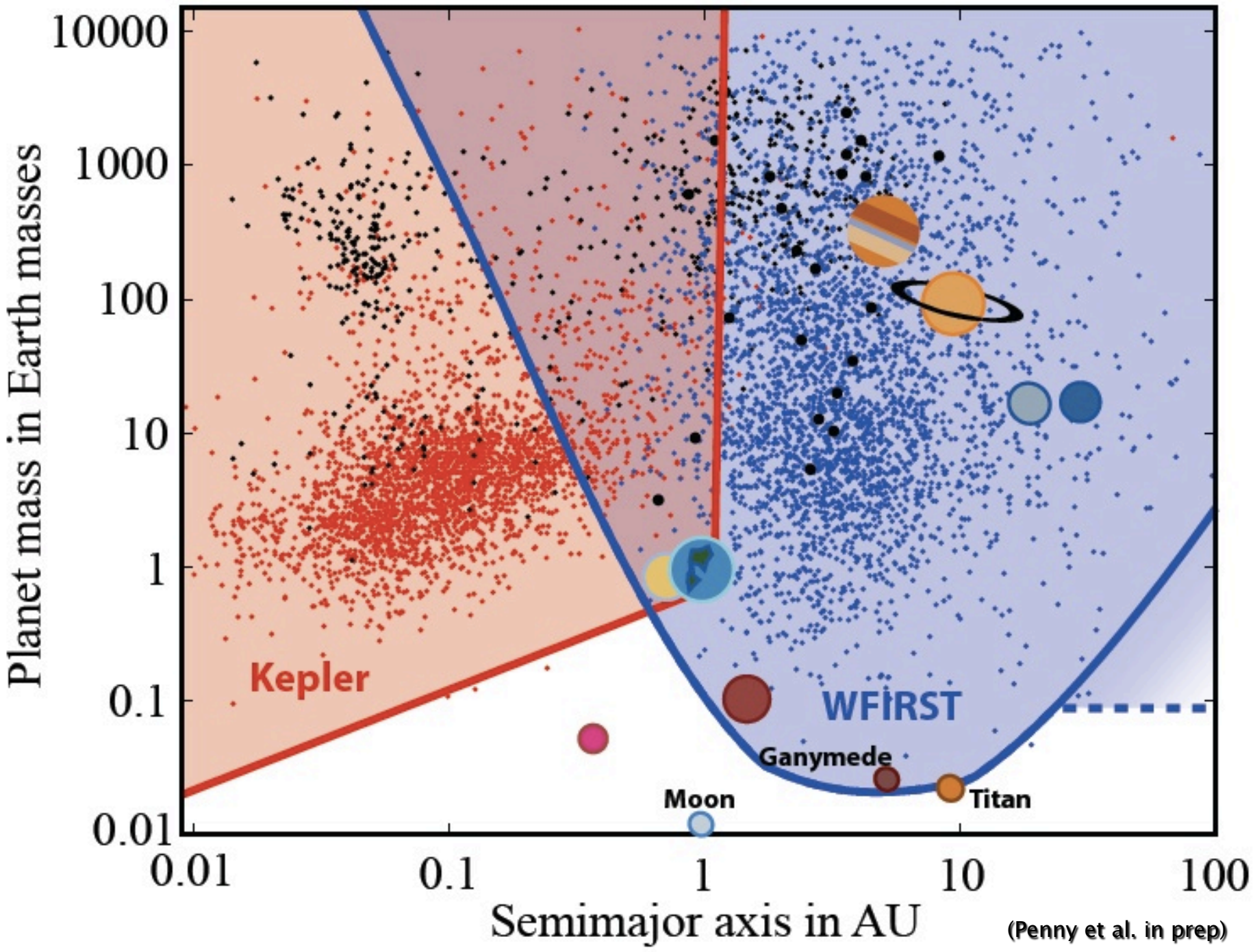
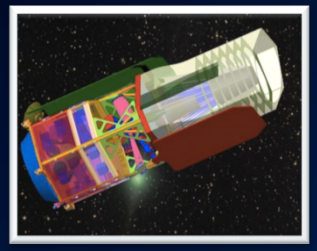
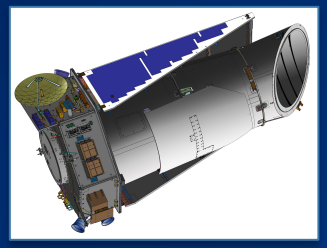

10000
1000
100
10
1
0.1
0.01
Planet mass in Earth masses
0.01
0.1
1
10
100
Semimajor axis in AU
Kepler
WFIRST
Ganymede
Moon
Titan
(Penny et al. in prep)

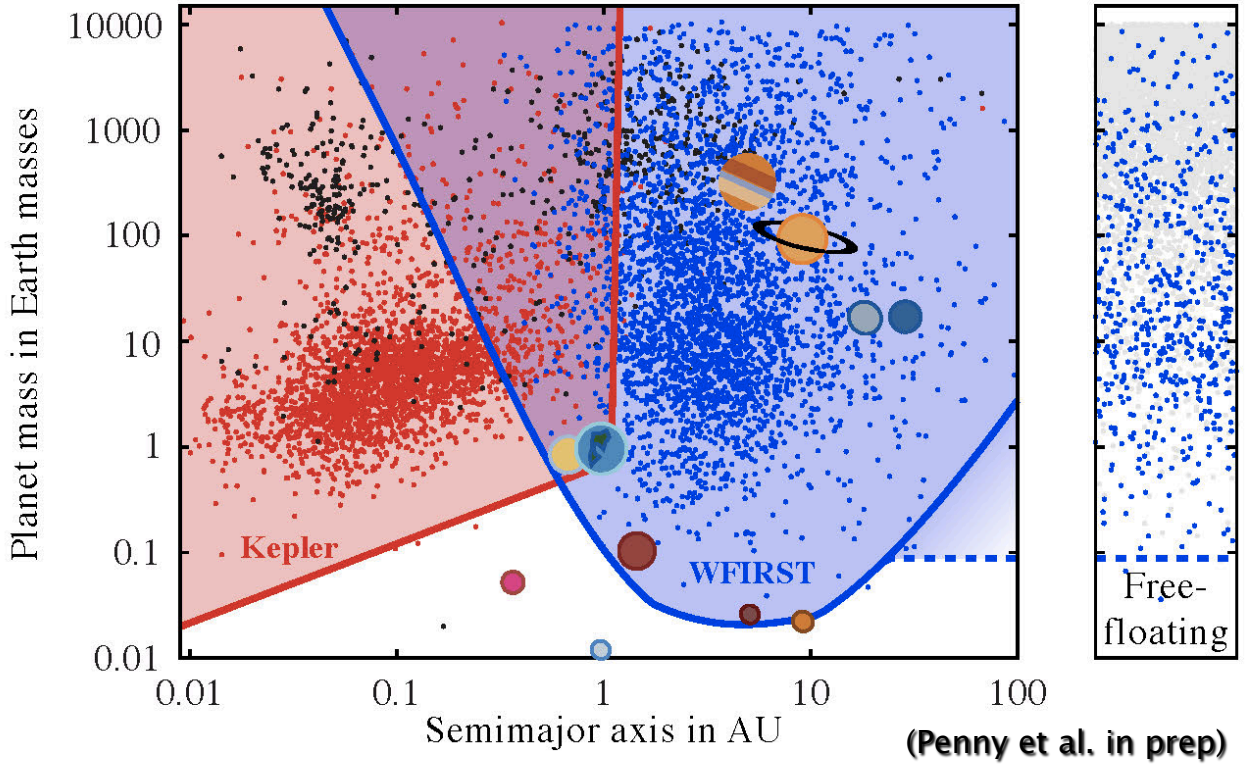
Completing the Exoplanet Census.



Together, Kepler and WFIRST complete the statistical census of planetary systems in the Galaxy.



- ~2600 detections.
- Some sensitivity to "outer" habitable zone planets.
- Sensitive to analogs of all the solar systems planets except Mercury.
- Hundreds of free-floating planets.
- Characterize the majority of host systems.
- Galactic distribution of planets.
- Sensitive to lunar-mass satellites.



To Do.

- Lots!
  - Improve our understanding of microlensing event rates:
    - Refine Galactic models.
    - Near-IR microlensing survey.
    - Near-IR luminosity function.
    - Measure the Galactic distribution of planets (Spitzer, K2).
  - Optimize the survey strategy:
    - Field location, number, and cadence.
    - Optimize number and choice of filters.
  - Determine the precision of the measured event parameters:
  - Determine hardware, software, and calibration requirements.
  - Identify and carry out needed precursor observations.
  - Develop data reduction and analysis tools.
- WFIRST Microlensing Science Investigation Team (PI S. Gaudi, Deputy PI D. Bennett)
- Help!