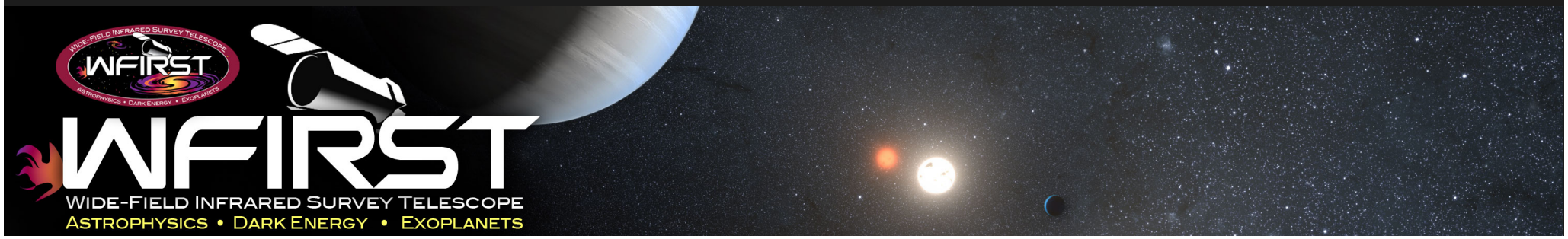
The WFIRST Exoplanet Microlensing Survey:
Core Science Goals and Predicted Yields

Scott Gaudi
(on behalf of Matthew Penny)
Ohio State University

and the *WFIRST* Microlensing SIT



The *WFIRST* Microlensing SIT*

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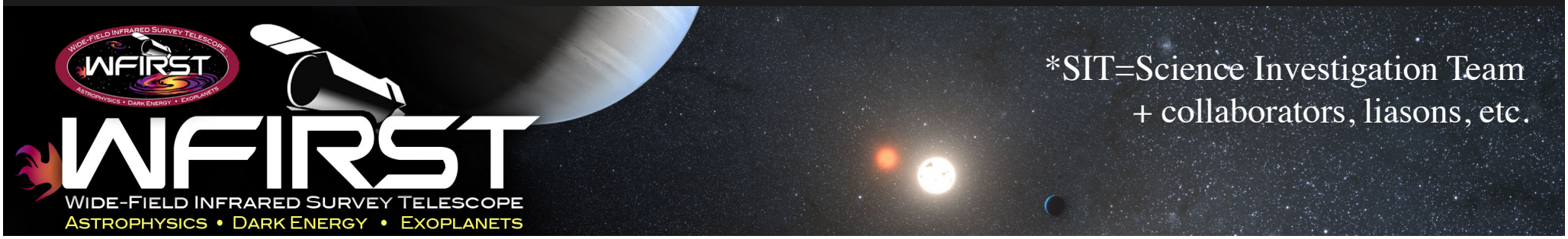
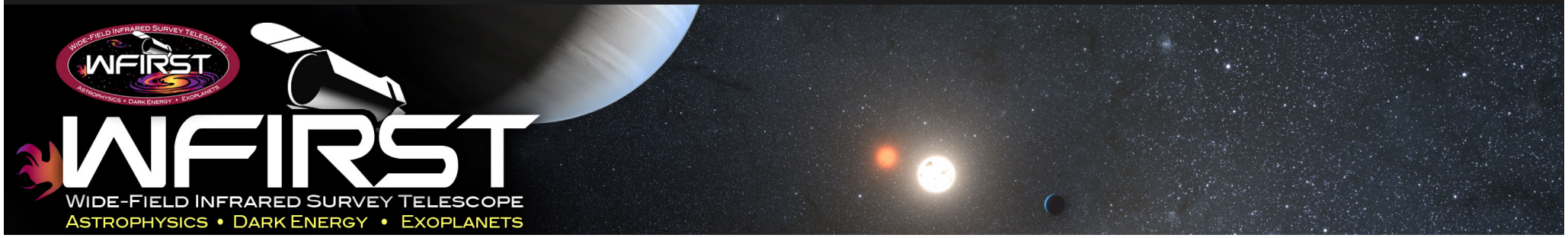


*SIT=Science Investigation Team
+ collaborators, liasons, etc.

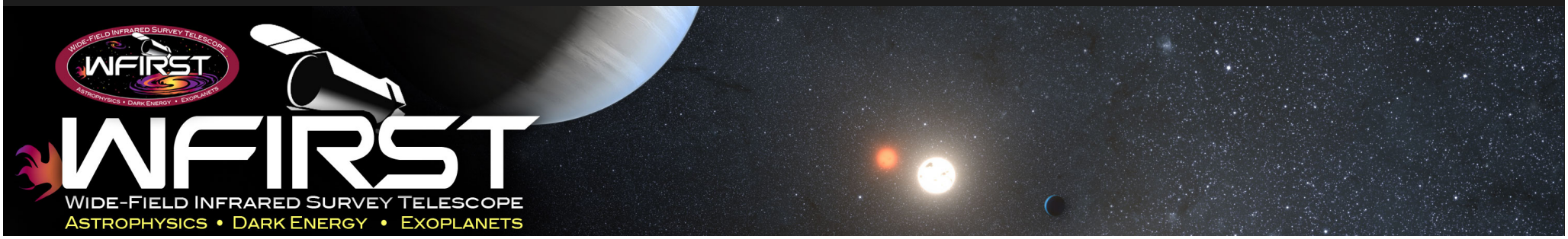
Goals of the *WFIRST* Microlensing Survey

WFIRST will conduct a statistical census of exoplanetary systems in the Galaxy from the outer habitable zone to free-floating planets, including analogs to all of the planets in our Solar System with masses greater than Mars, by monitoring stars toward the Galactic bulge using the microlensing technique

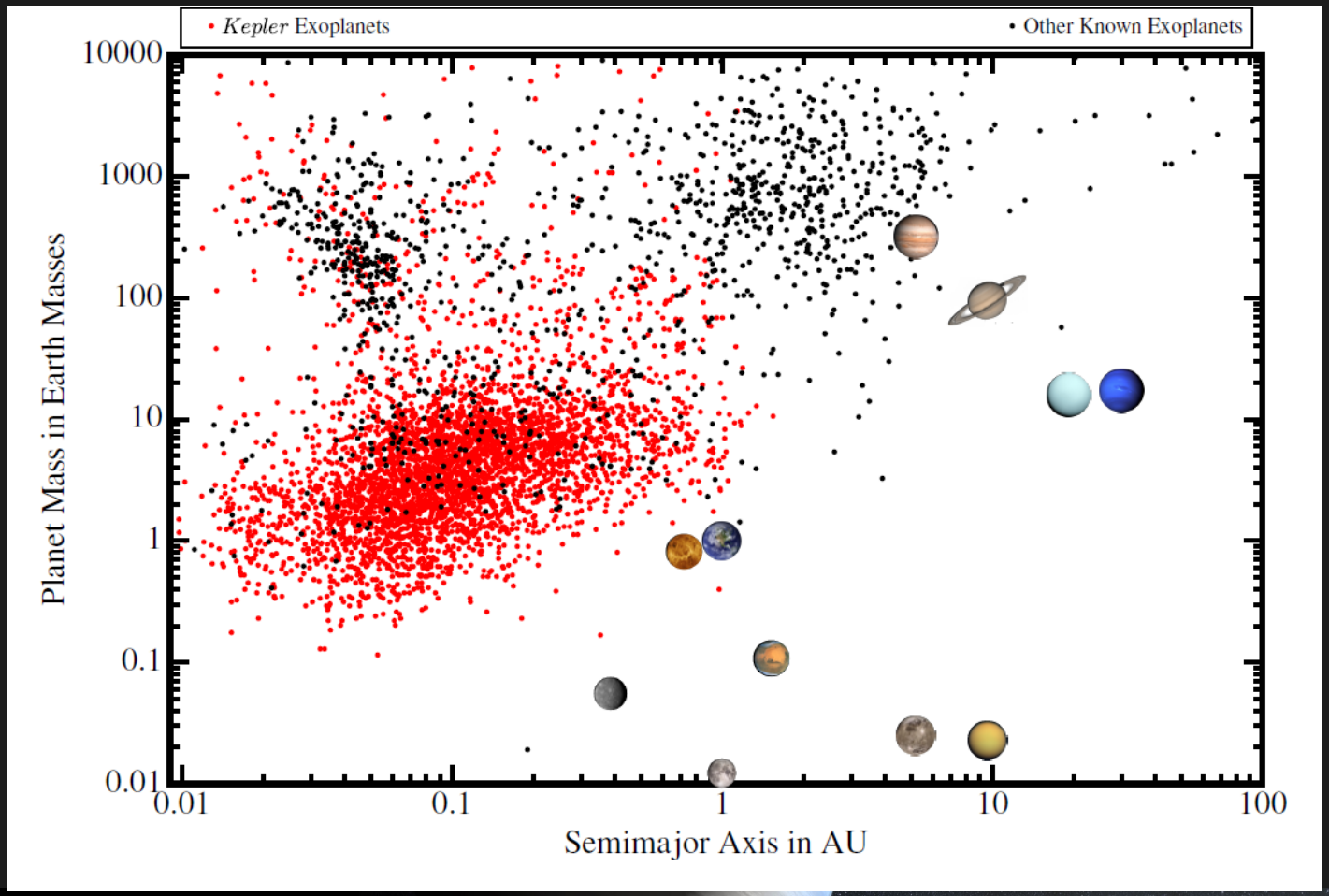


Why Microlensing? Why *WFIRST*?

- Exoplanets are the end state of planet formation & evolution.
- Exoplanet demographics provide a boundary condition to constrain the complex physics of the formation and evolution of planetary systems.
- A full understanding of planet formation requires demographics at all orbital separations, and over a wide range of masses.
- Planet demographics feed into questions of the prevalence and origin of life in the universe.



Why Microlensing? Why *WFIRST*?



Planet formation efficiency likely peaks near the ice line, at ~1.5-4 AU. In core accretion theory, planetesimals pass through multiple stages of growth, with pauses & runaways, which should imprint on the mass function of planets.

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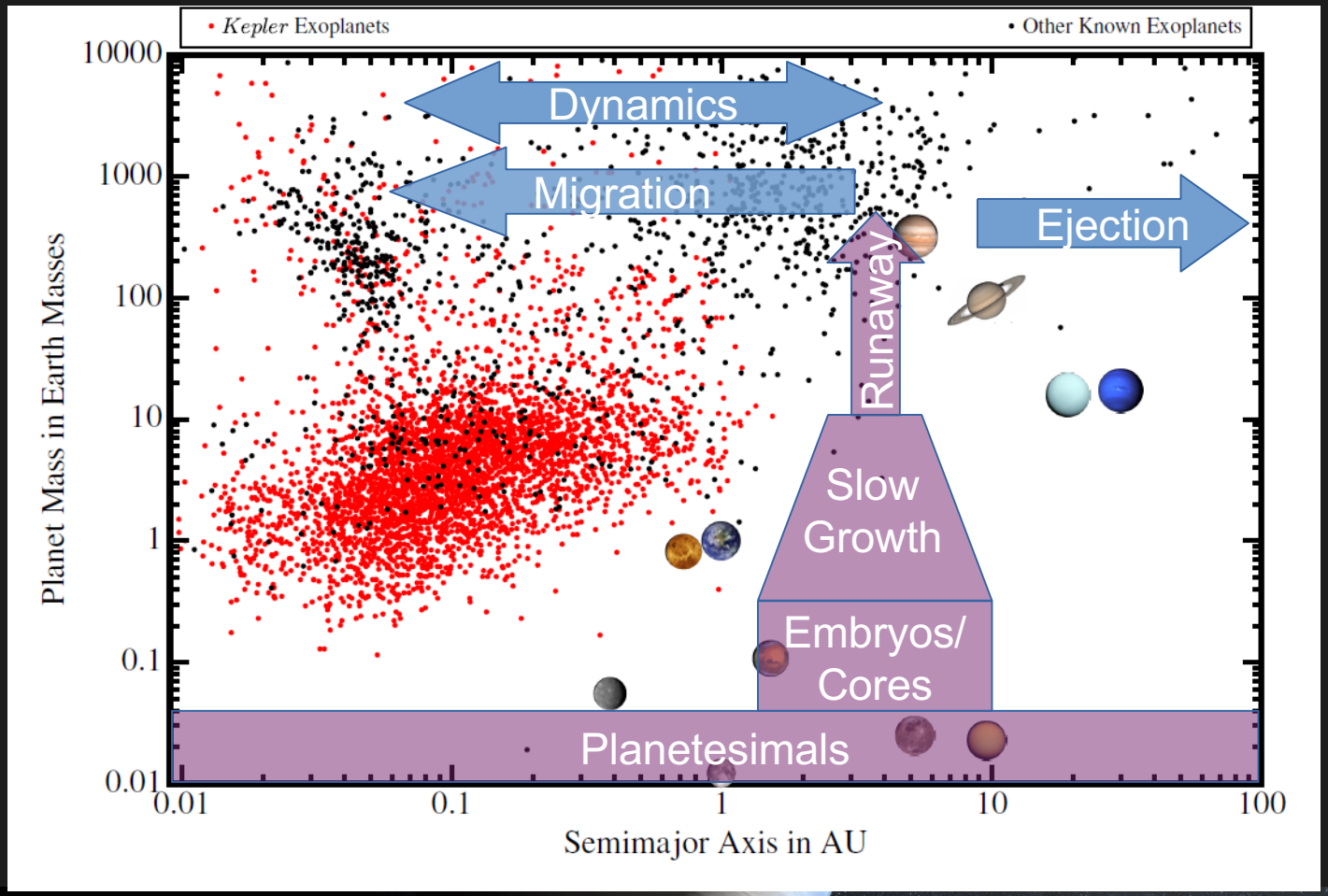
Why Microlensing? Why *WFIRST*?



Critical core mass for runaway gas accretion: ~10 M_{Earth}

Isolation mass of planetary embryos: ~0.1 M_{Earth}

Migration & dynamics can reshape planetary systems

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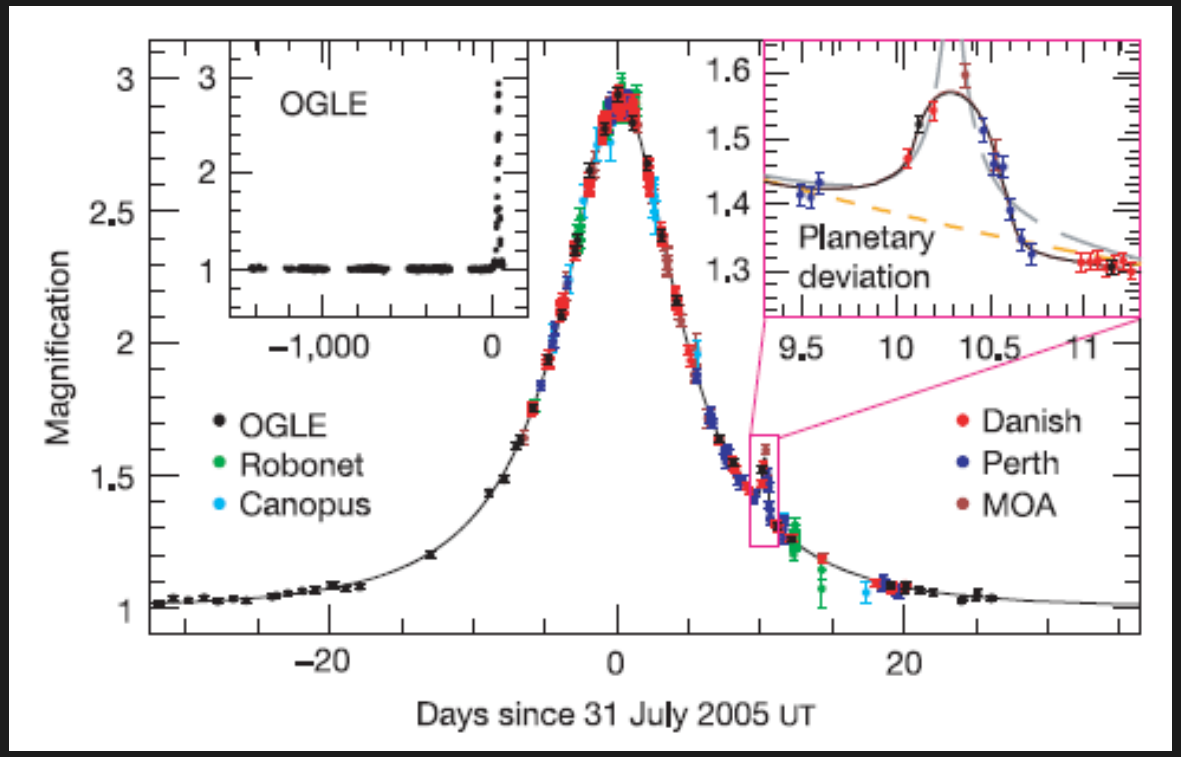
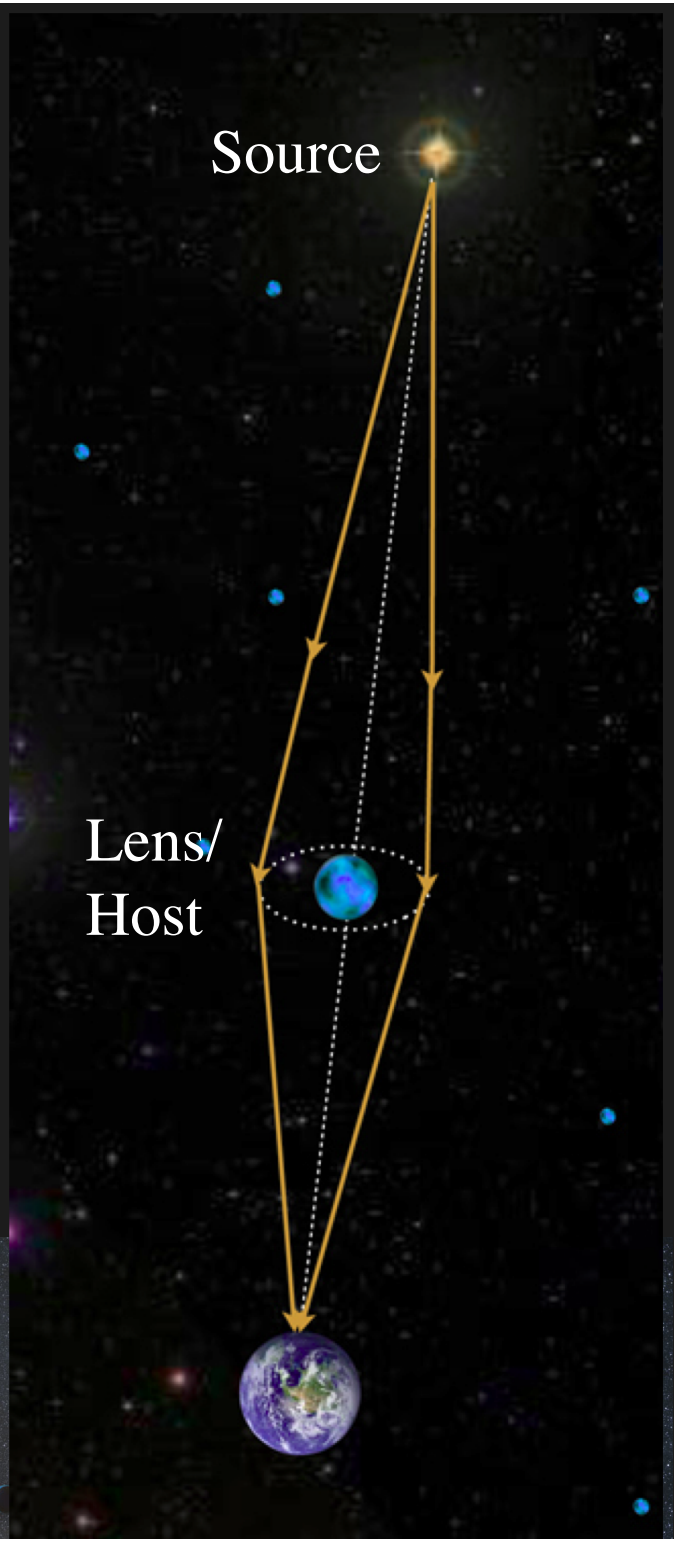
What is Microlensing?



Measure: Mass ratio, q, and projected separation, s, in units of the Einstein radius



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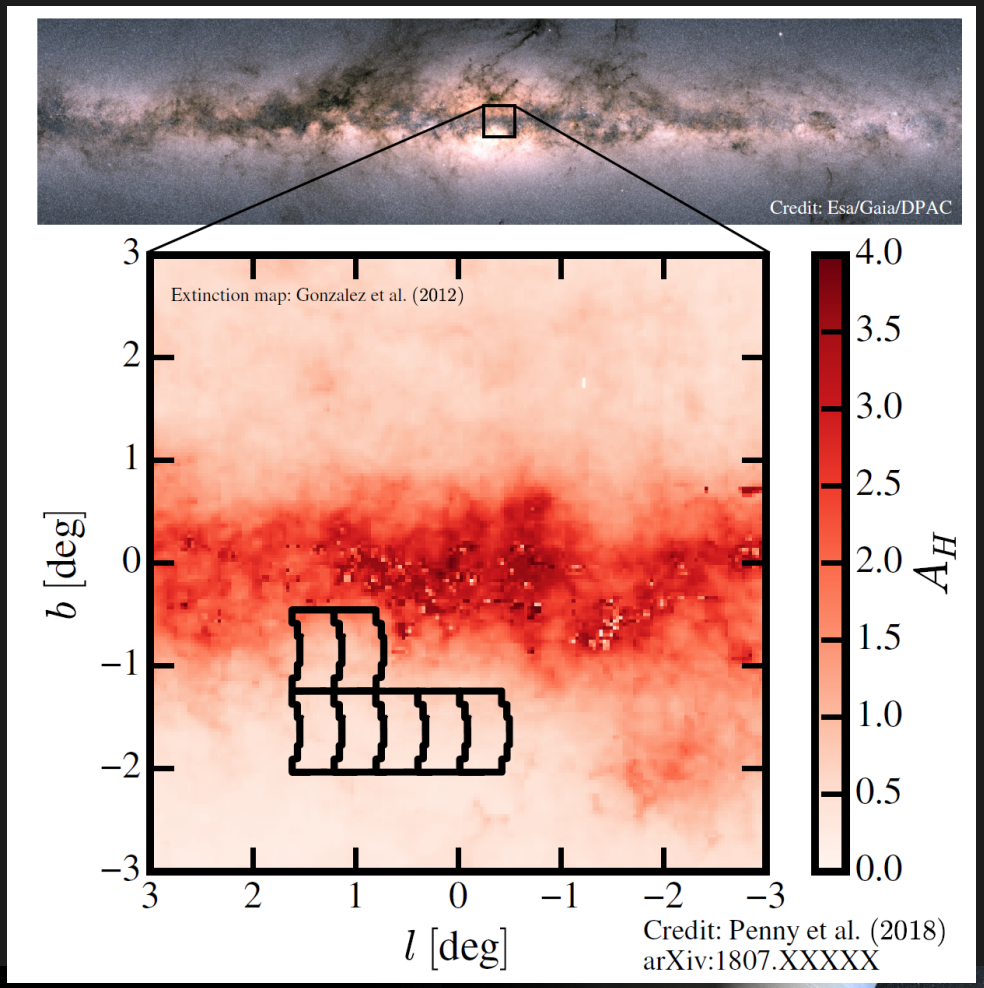
WFIRST's Microlensing Survey



- ~2 deg^2 (7 fields)
- 6 x 72 day seasons
- 15 min cadence
- 4.5 yr baseline
- 1-2 μm bandpass
- ~100 million stars
- ~20,000 microlensing events

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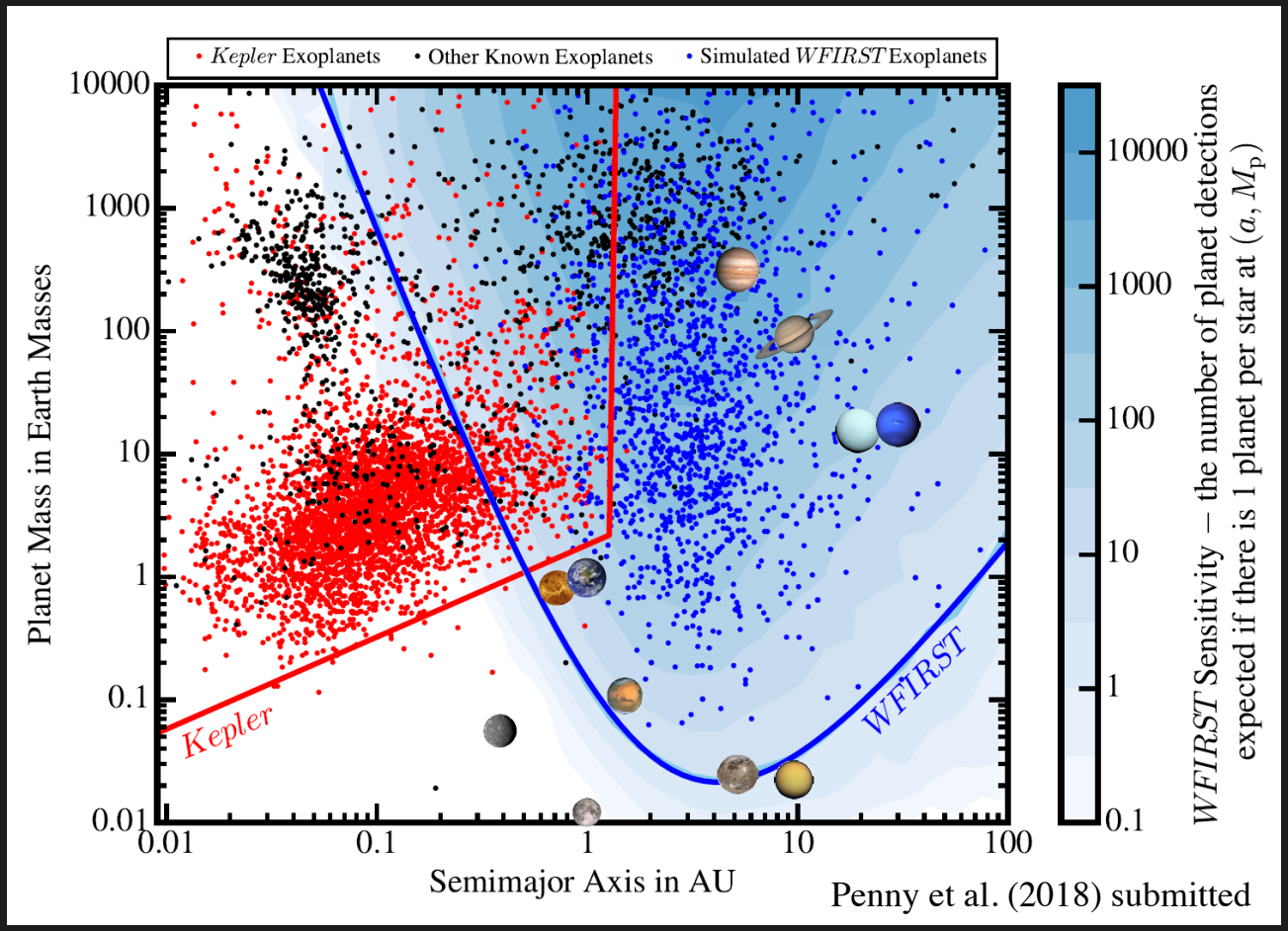
What will *WFIRST* Find?



Sensitivity over a wide range of masses and orbits:

$Mass/M_{Earth}$	Planets
1000	220
100	410
10	550
1	180
0.1	20

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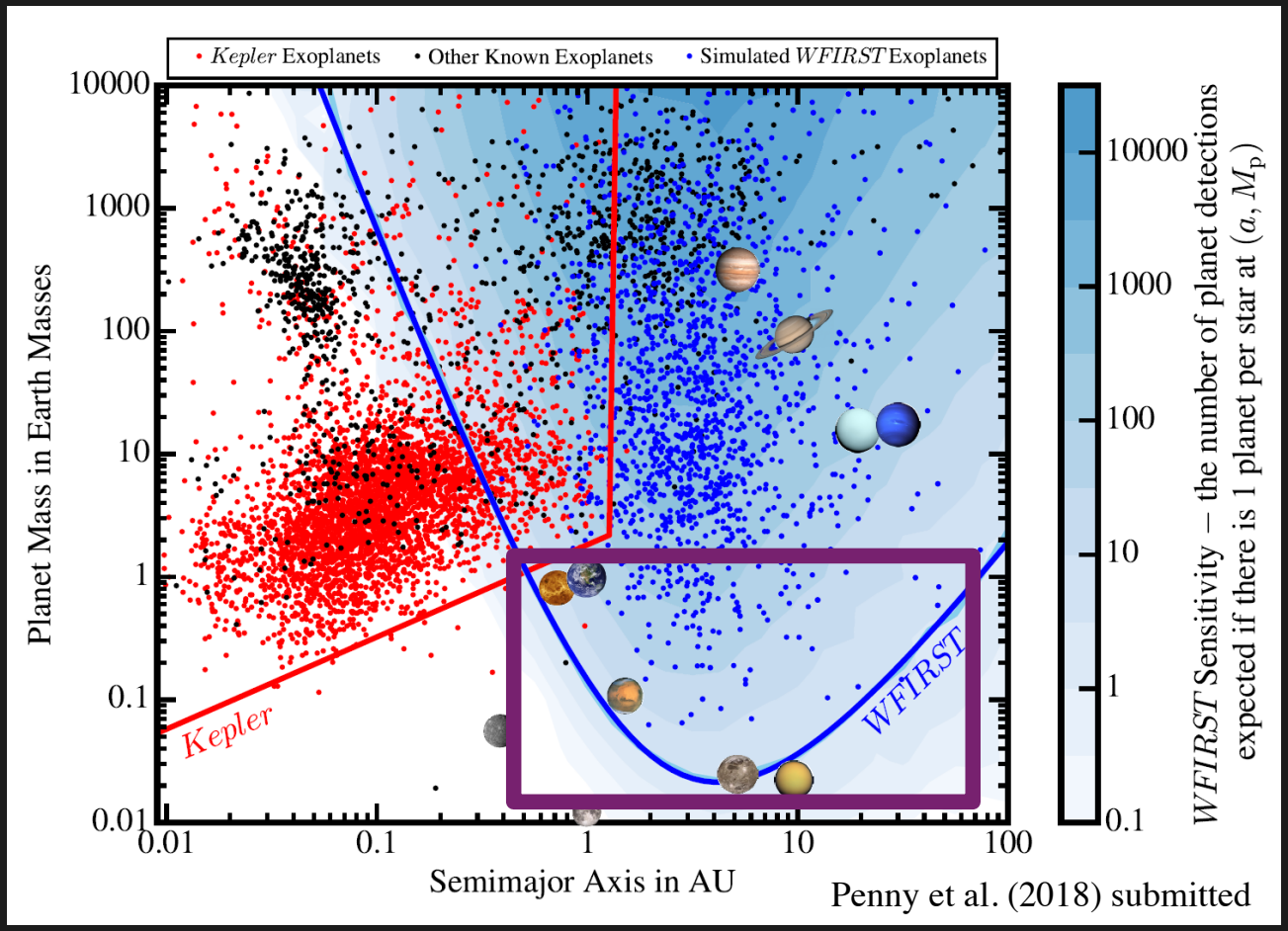
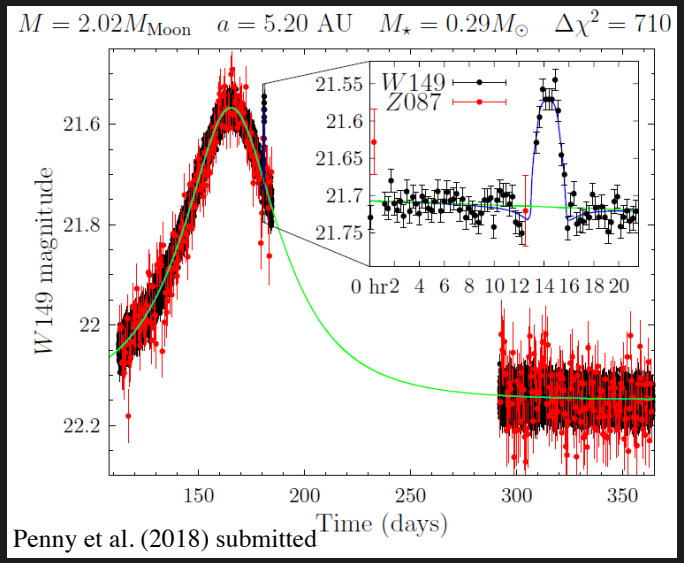
What will *WFIRST* Find?



Low-mass planets



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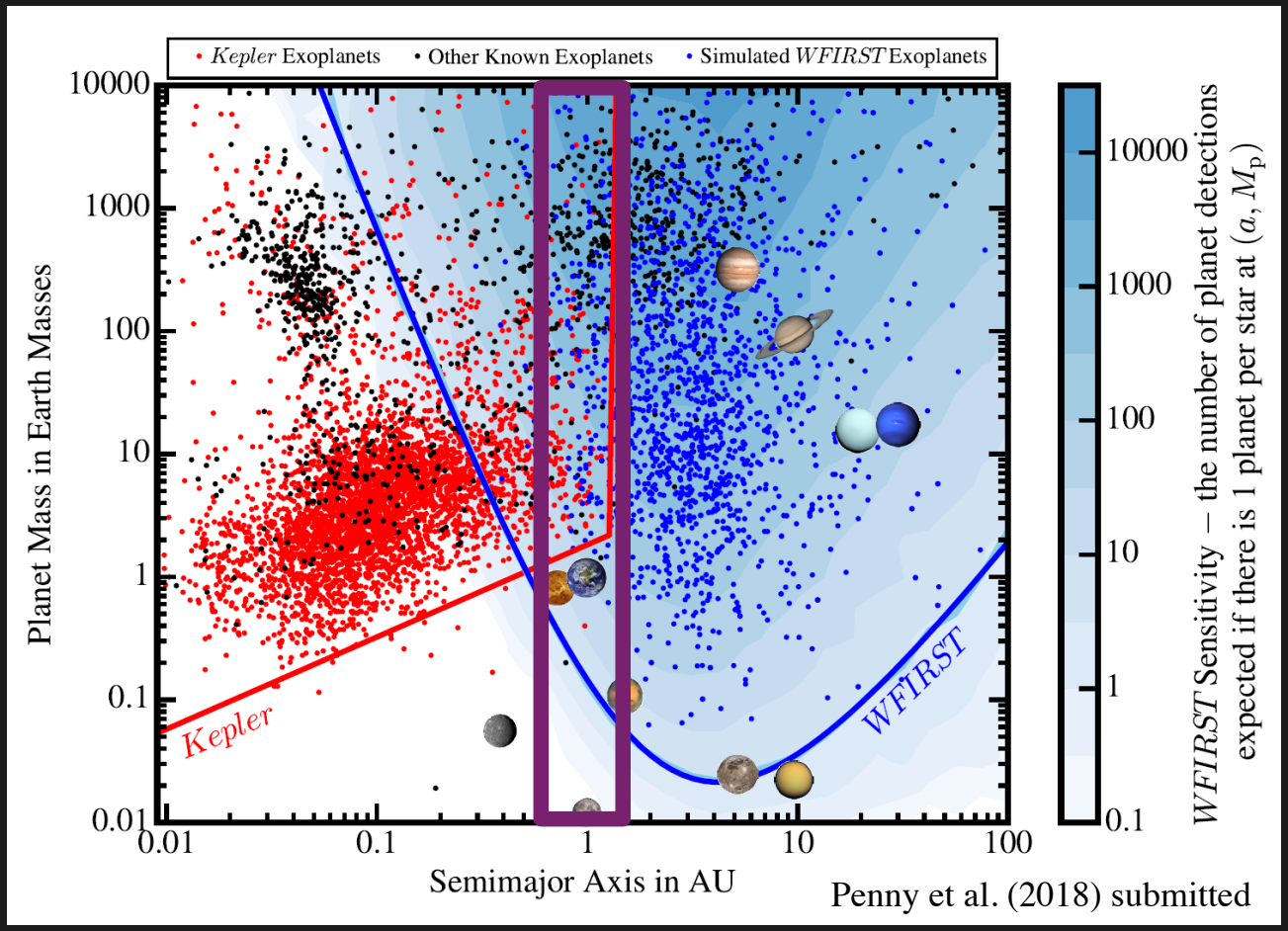

Sensitivity in, & just outside the habitable zone

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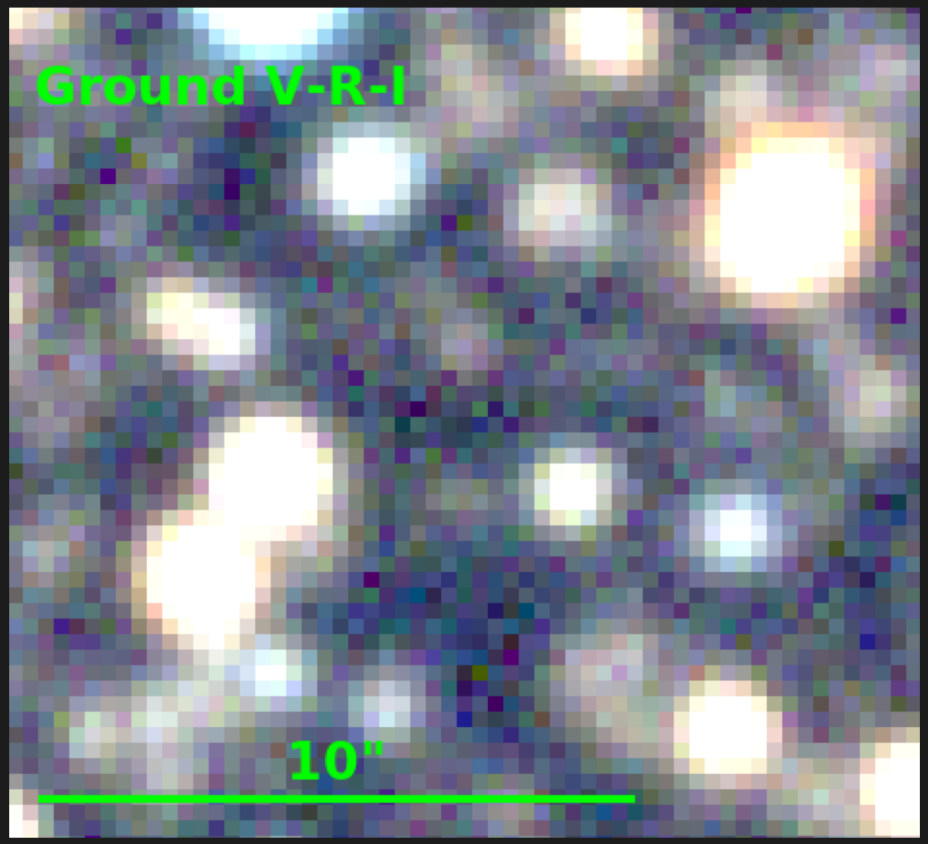
Masses not Mass Ratios



Penny et al. (2018) submitted

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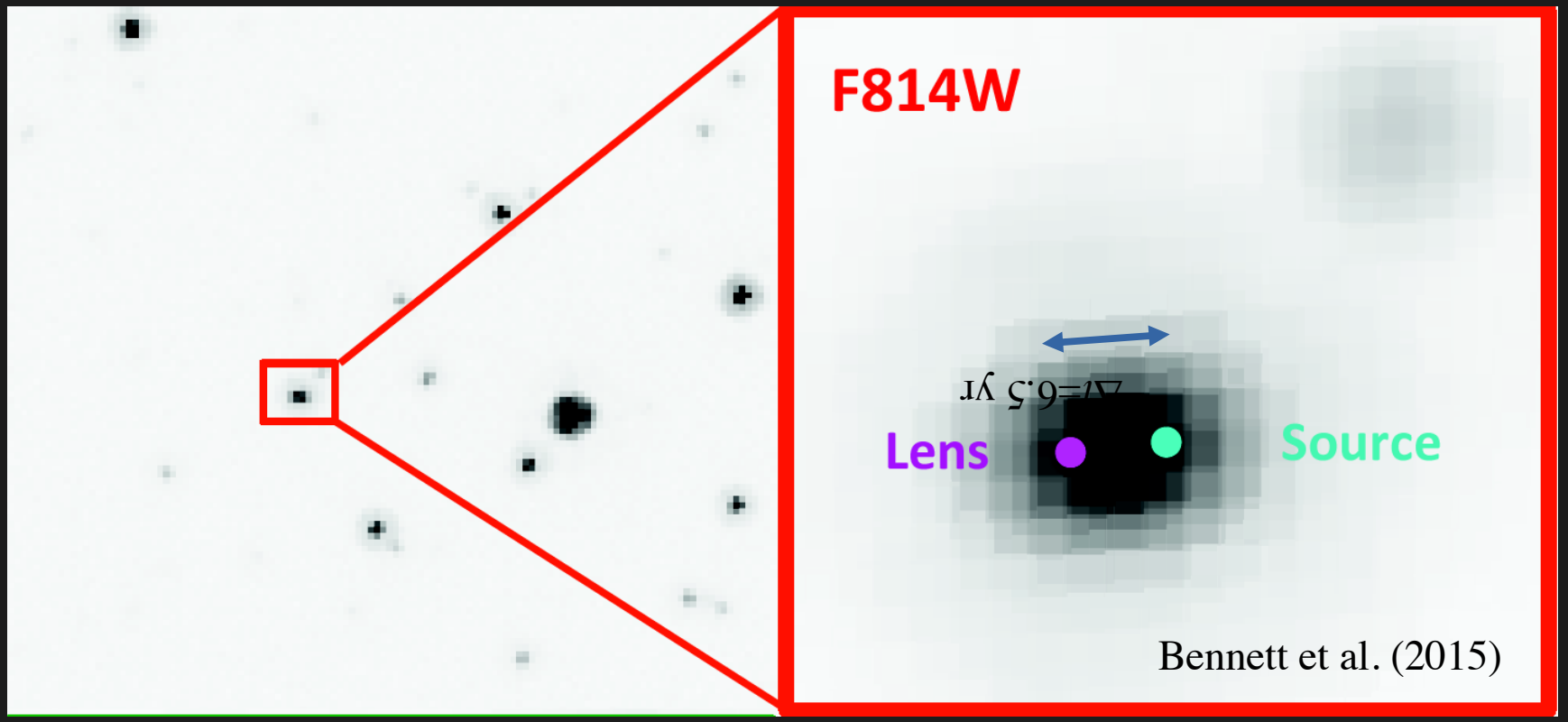
Masses not Mass Ratios



Measure: lens color & magnitude
+ angular Einstein radius
→ mass and distance of lens and planet

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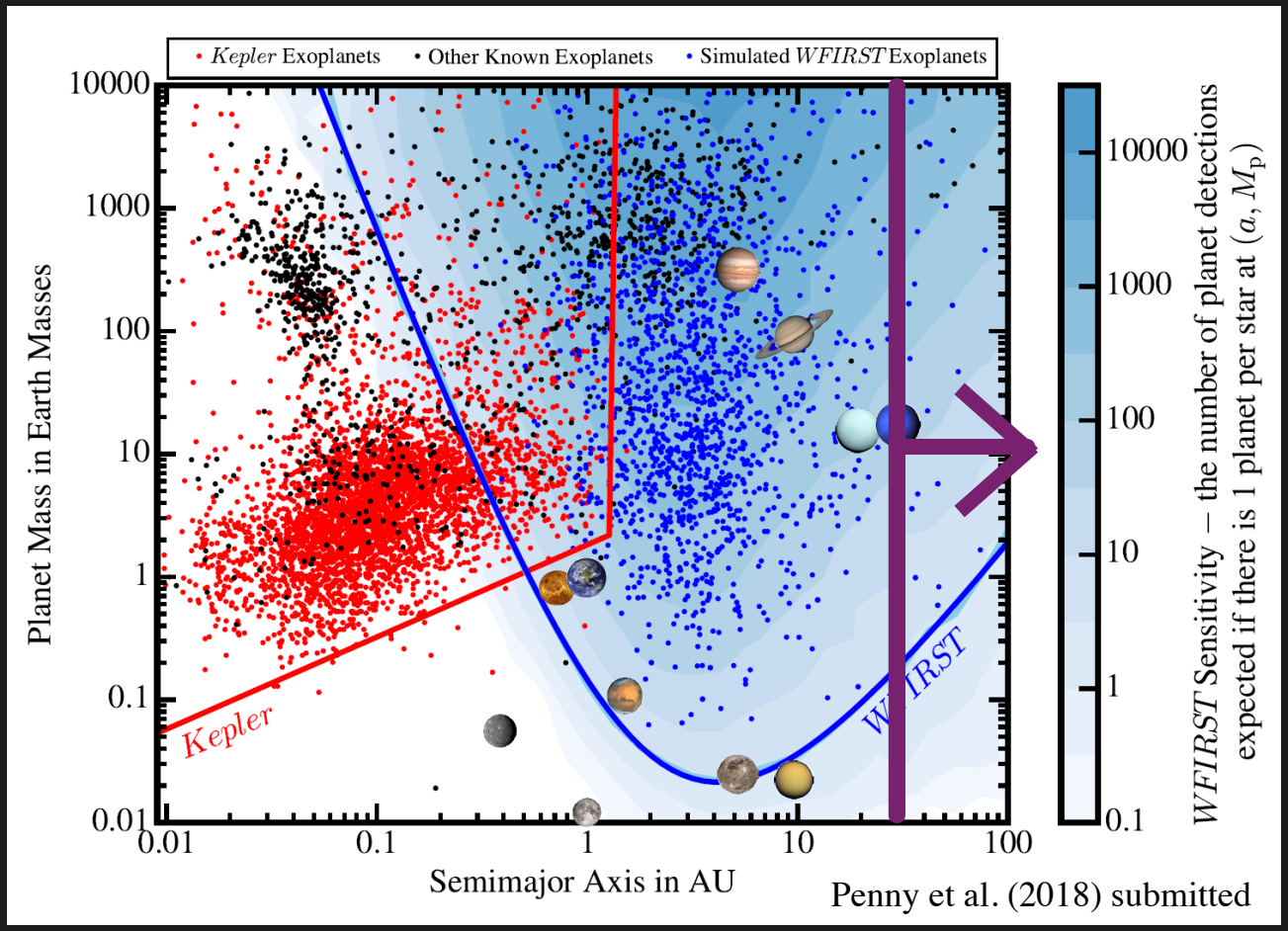
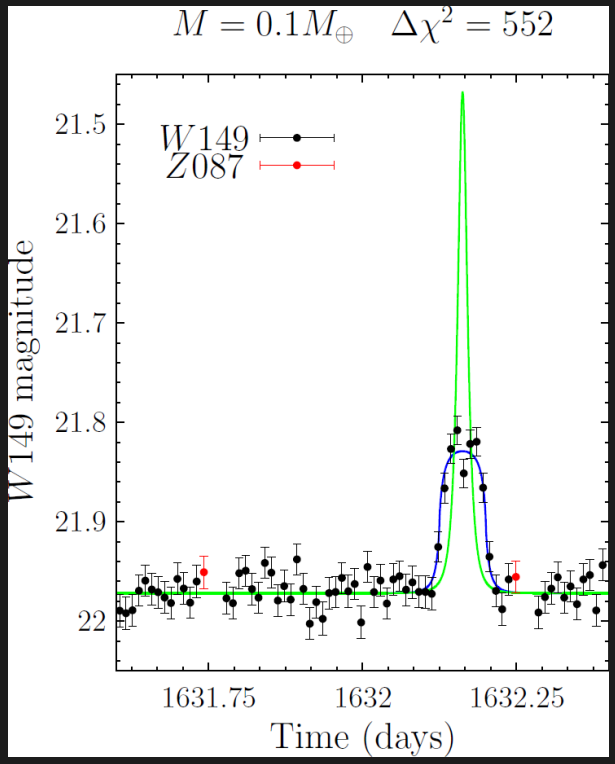
What will *WFIRST* Find?



Free-Floating Planets



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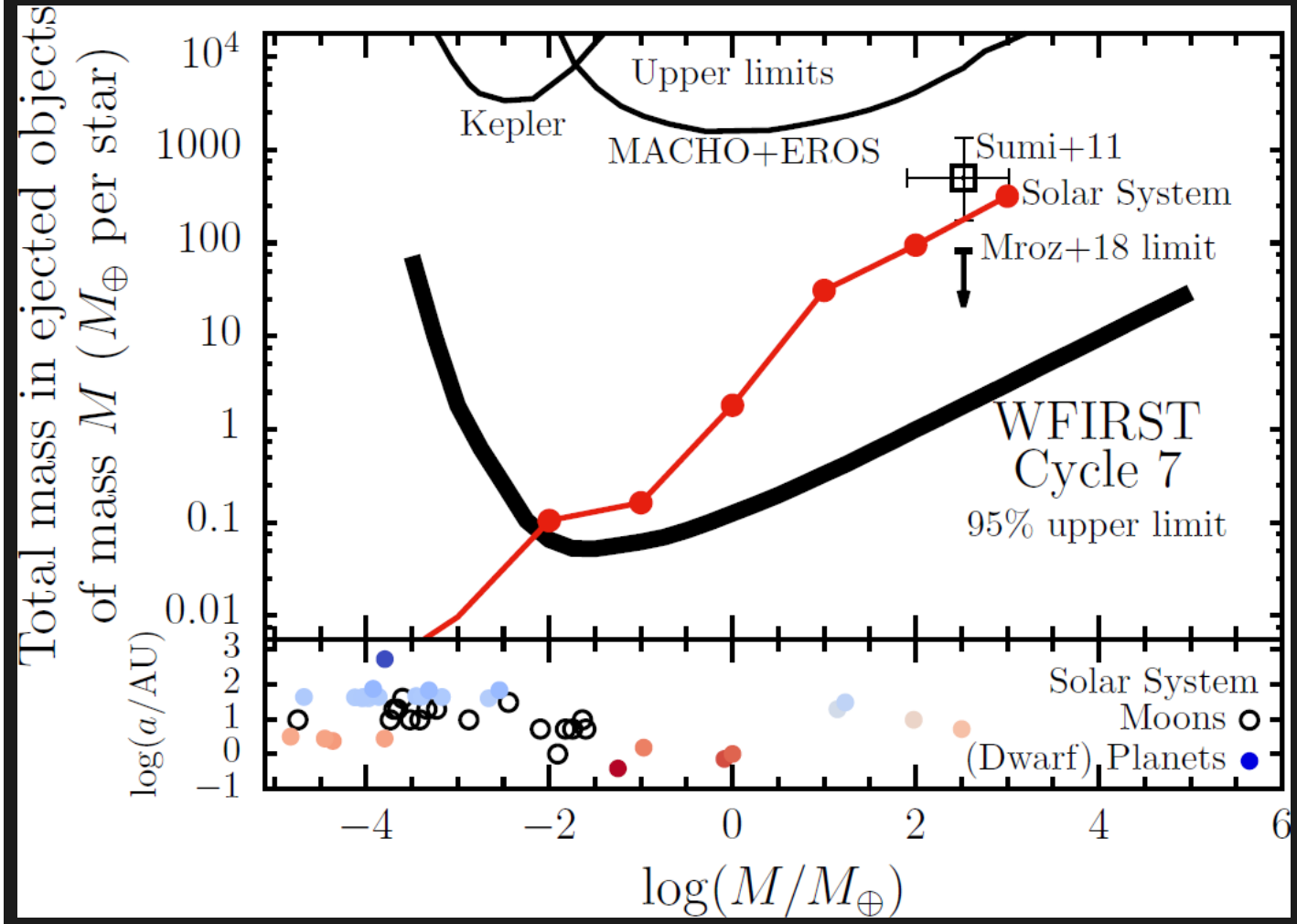

- Wide-orbit & free floating planets
- Wide sensitivity to measure mass budget in range down to 0.1-1 Earth-masses per star.
- Note: update is work in progress by Samson Johnson (OSU grad student)

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Additional Science with the *WFIRST* Microlensing Survey

- Additional microlensing: mass function, binaries, black holes & stellar remnants, astrometric microlensing
- Transiting planets: ~$10^{4\text{-}5}$ hot and warm Jupiters & Neptunes (Montet+2017)
- Asteroseismology of bulge giants (Gould+2014b)
- Geometric parallaxes for giants out to the bulge?
- Extremely deep KBO searches (Gould+2014a)
- Many more possibilities…
- All data ~immediately public

Area	$1.96\ \mathrm{deg}^2$
Baseline	4.5 years
Seasons	6×72 days
$W149$ Exposures	$\sim 41,000$ per field
$W149$ Cadence	15 minutes
$W149$ Saturation	~ 14.8
Phot. Precision	0.01 mag @ $W149 \sim 21.15$
$Z087$ Exposures	~ 860 per field
$Z087$ Saturation	~ 13.9
$Z087$ Cadence	$\lesssim 12$ hours
Stars ($W149 < 15$)	$\sim 0.3 \times 10^6$
Stars ($W149 < 17$)	$\sim 1.4 \times 10^6$
Stars ($W149 < 19$)	$\sim 5.8 \times 10^6$
Stars ($W149 < 21$)	$\sim 38 \times 10^6$
Stars ($W149 < 23$)	$\sim 110 \times 10^6$
Stars ($W149 < 25$)	$\sim 240 \times 10^6$

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What's Next?

- 23rd International Microlensing Conference and Hack Week
  - 28-30 January, 2019 / Center for Computational Astrophysics / New York City
  - https://microlensing.science/23/
- Second data challenge – topic to be determined - input welcome.
- Continued development of the WFIRST survey parameters.
- We will work to continue to build the microlensing community.
- **We need you!** We need your expertise, your new ideas, specifically with regards to:
  - Theory: why is understanding the demographics of outer planetary systems important?
  - Data analysis: How do we go from raw images to the high-level data that provides all of the information we can extract about planetary populations?
  - Fitting of microlensing events: How do we cope with degeneracies, multi-planet systems, the 'unknown unknowns'?