WFIRST-AFTA: What Can We Learn by Detecting Thousands of Cold Exoplanets via Microlensing?

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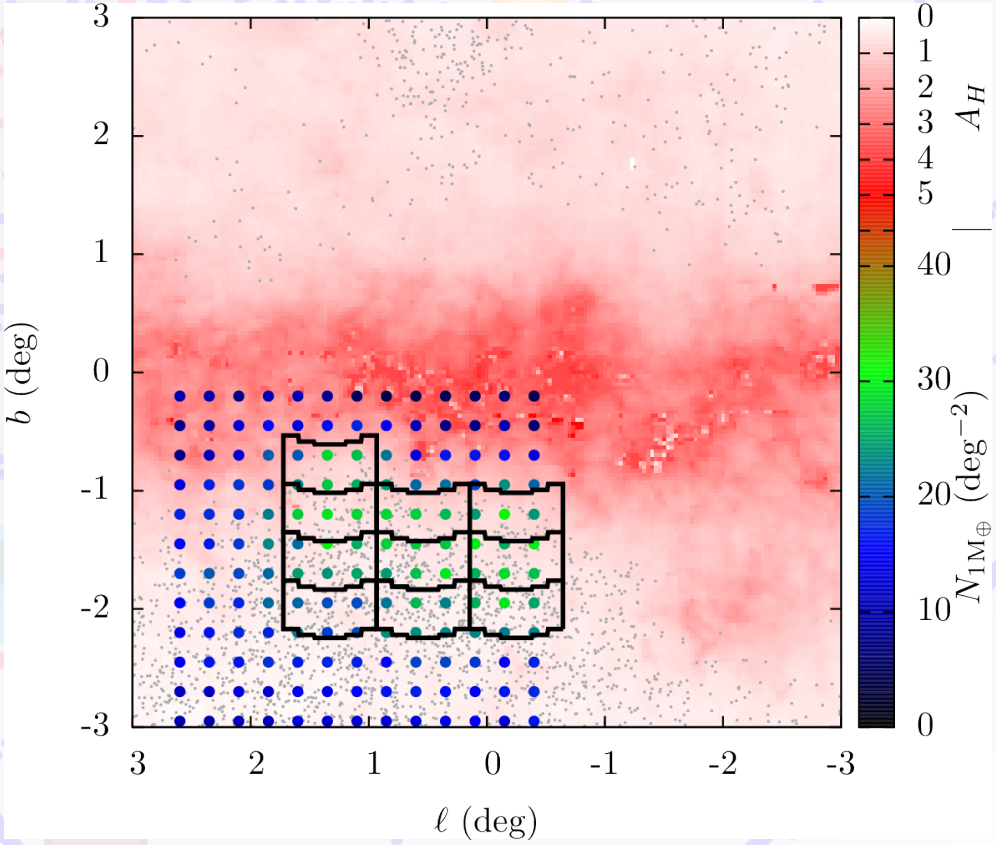
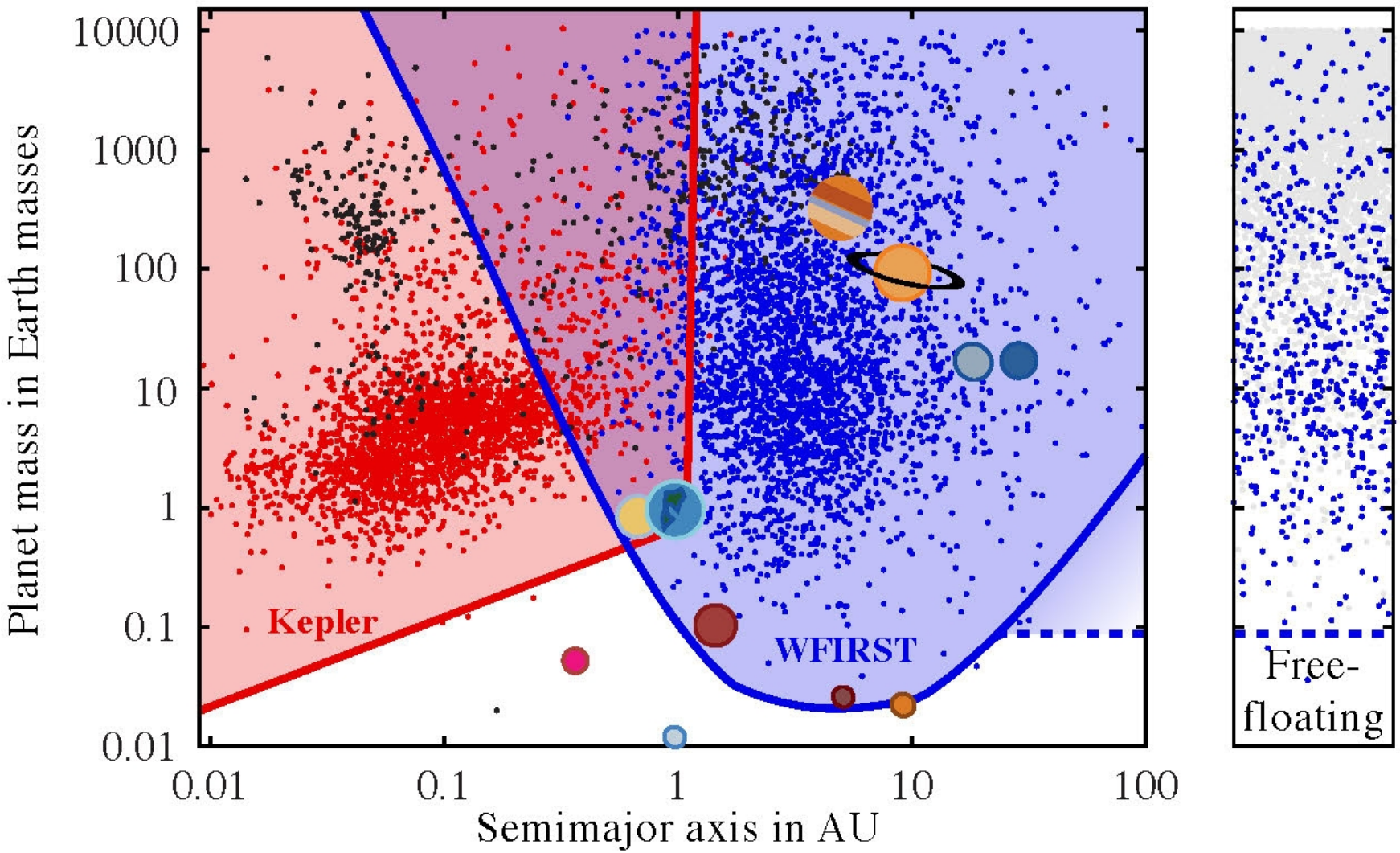
Contributions from Scott Gaudi, Andrew Mann & especially Sean Raymond

Baseline AFTA survey

- 432 days split across 6 72-day seasons
- 10 fields, total 2.8 deg^2
- 15 minute cadence in wide 1-2um bandpass
- Less frequent color measurements

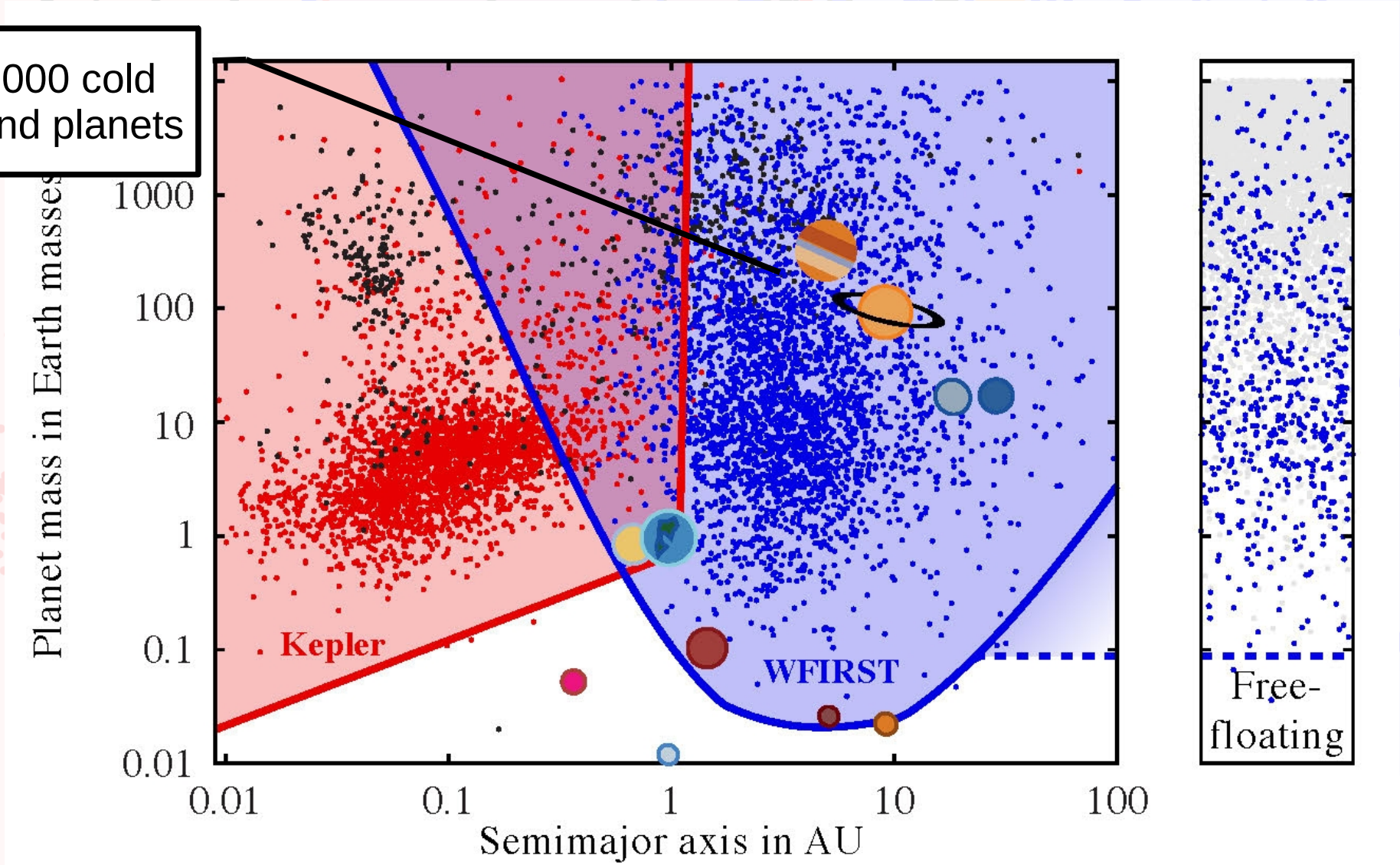


The WFIRST microlensing survey



The WFIRST microlensing survey: What do we learn?

~3000 cold bound planets



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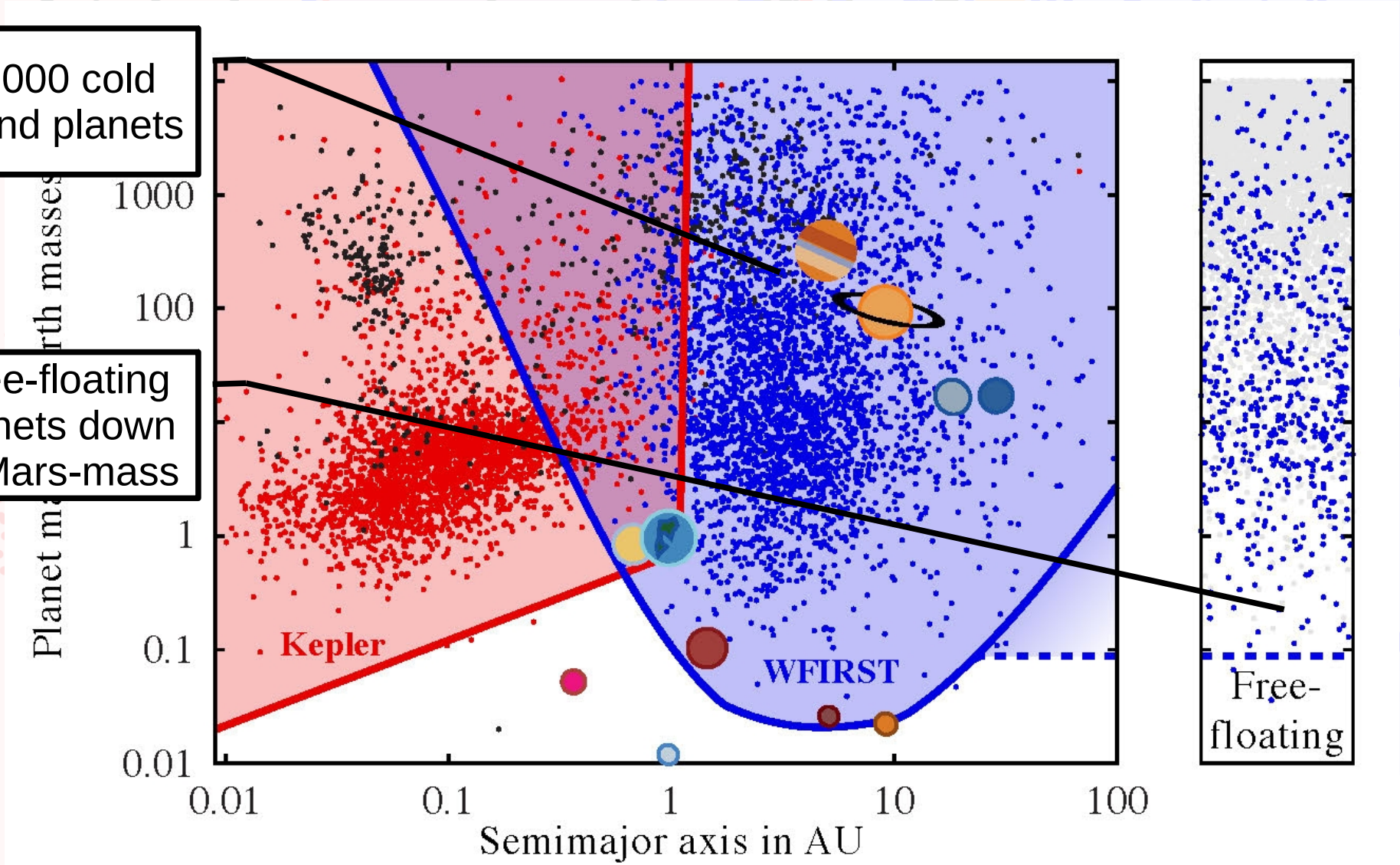
Free-floating planets down to Mars-mass



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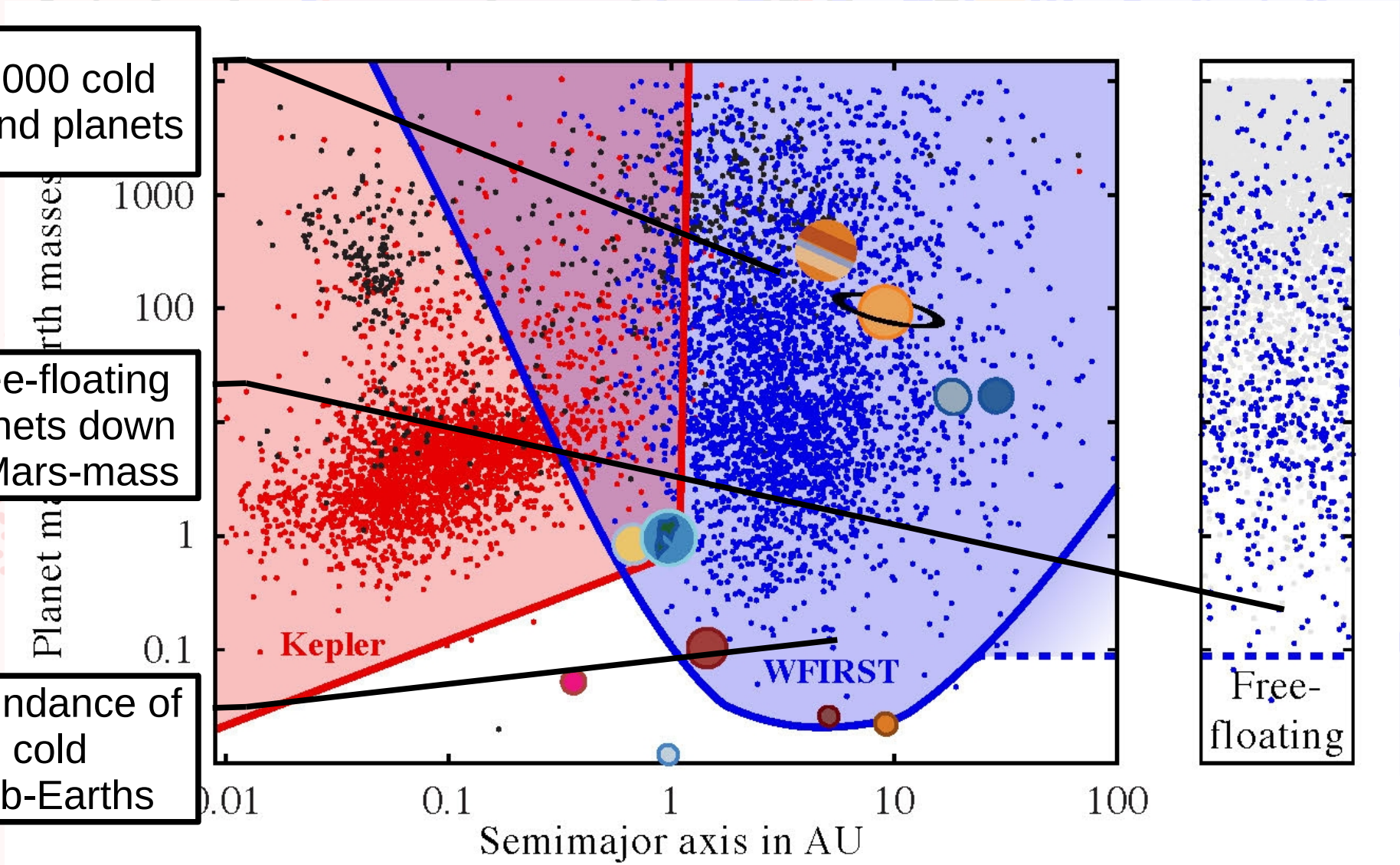
Abundance of cold sub-Earths



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Mass + distance of most

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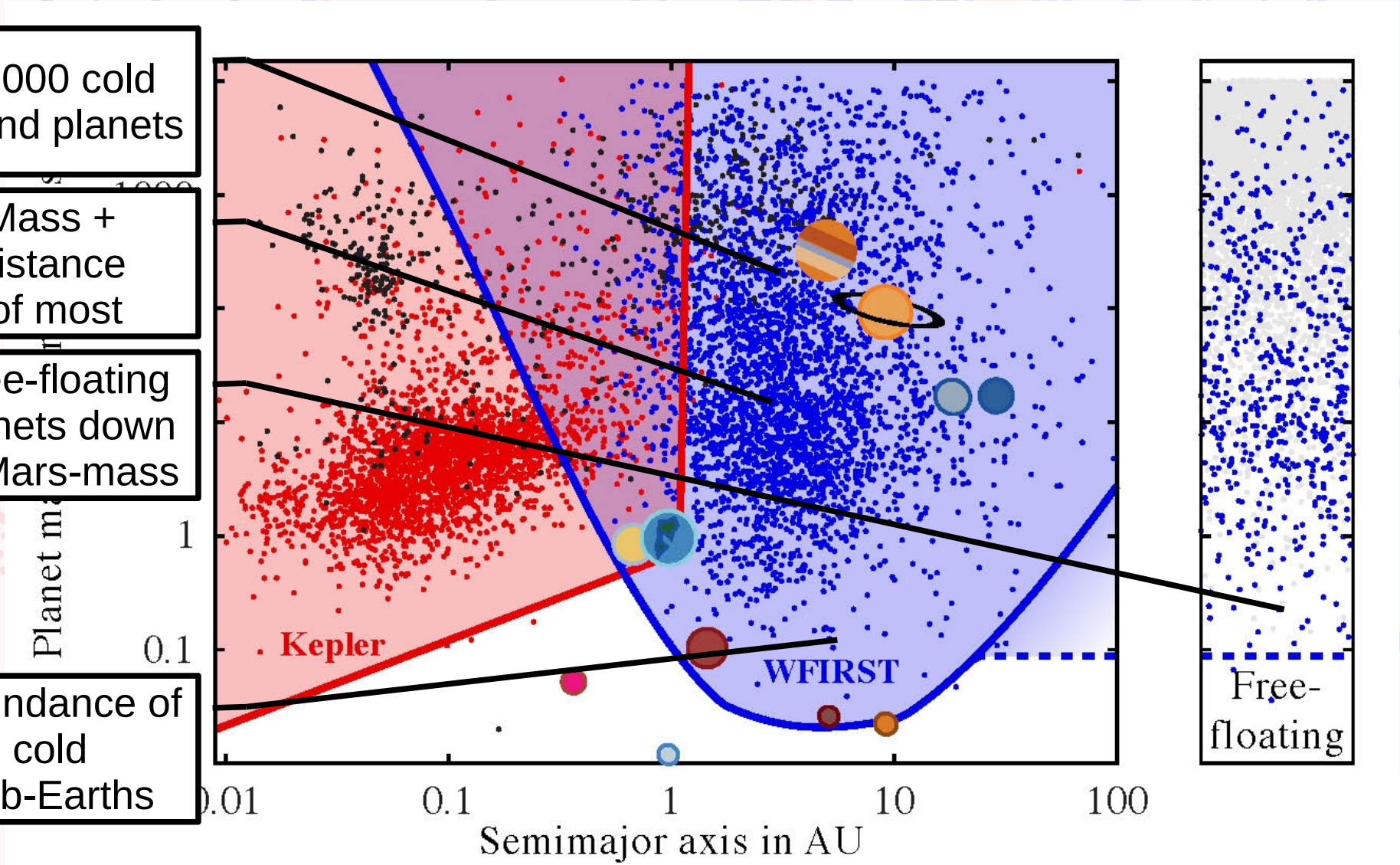

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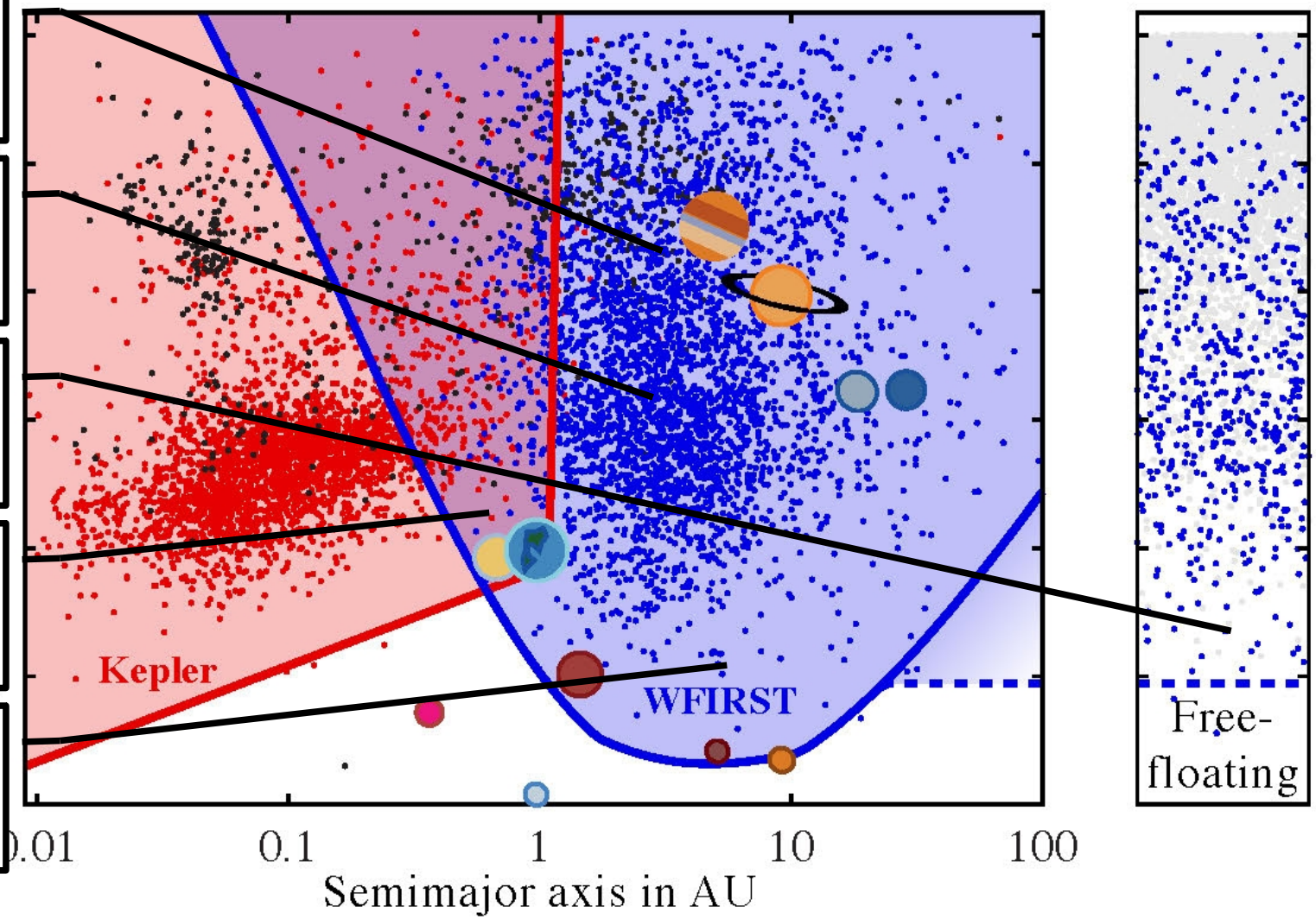
Outer HZ + Kepler overlap

Abundance of cold sub-Earths



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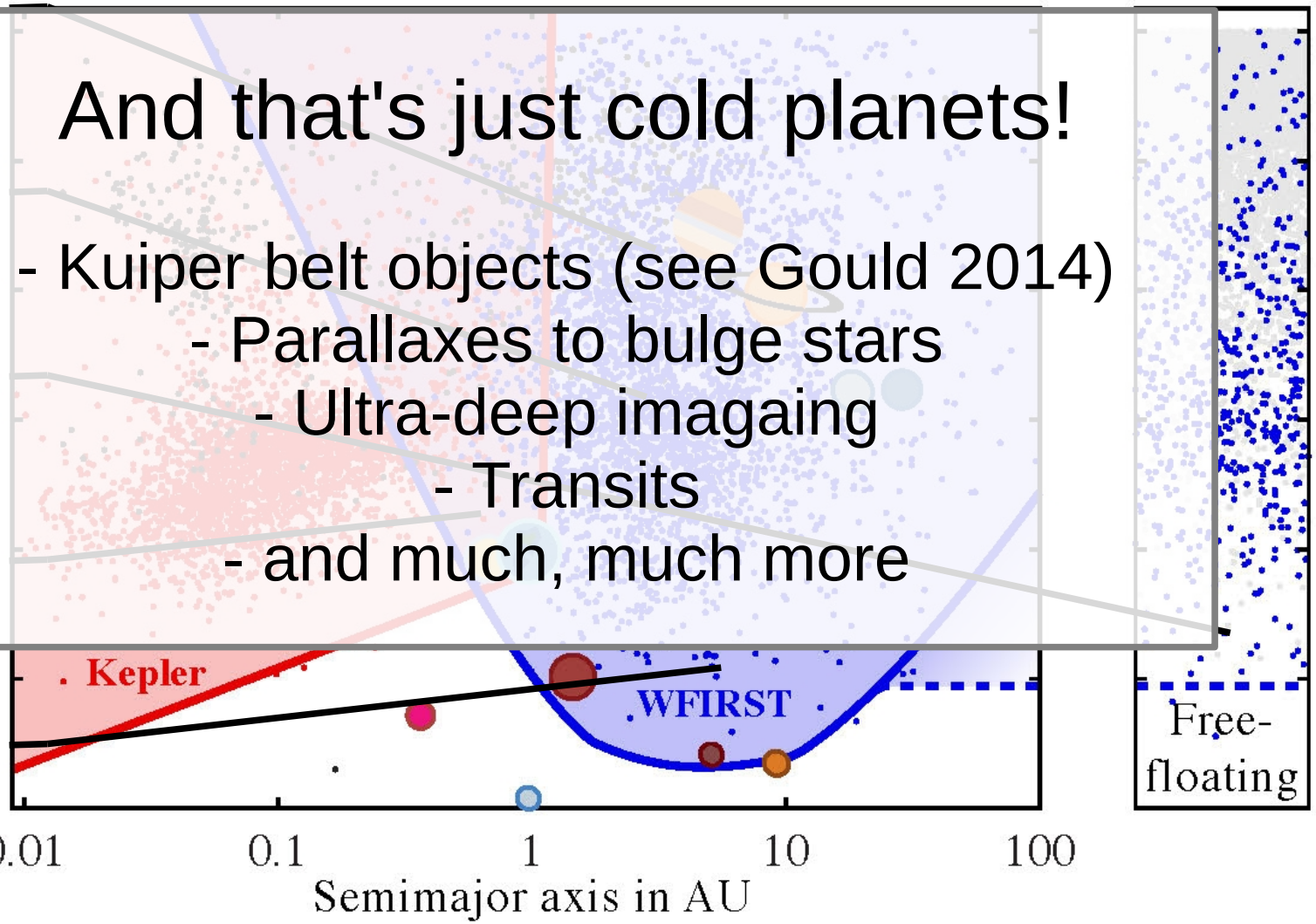
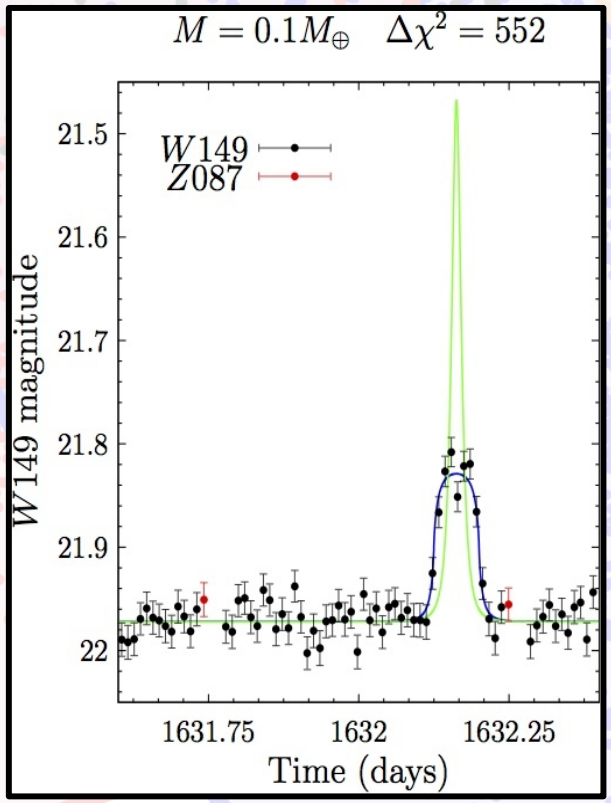


And that's just cold planets!

- Kuiper belt objects (see Gould 2014)
- Parallaxes to bulge stars
- Ultra-deep imagaing
- Transits
- and much, much more

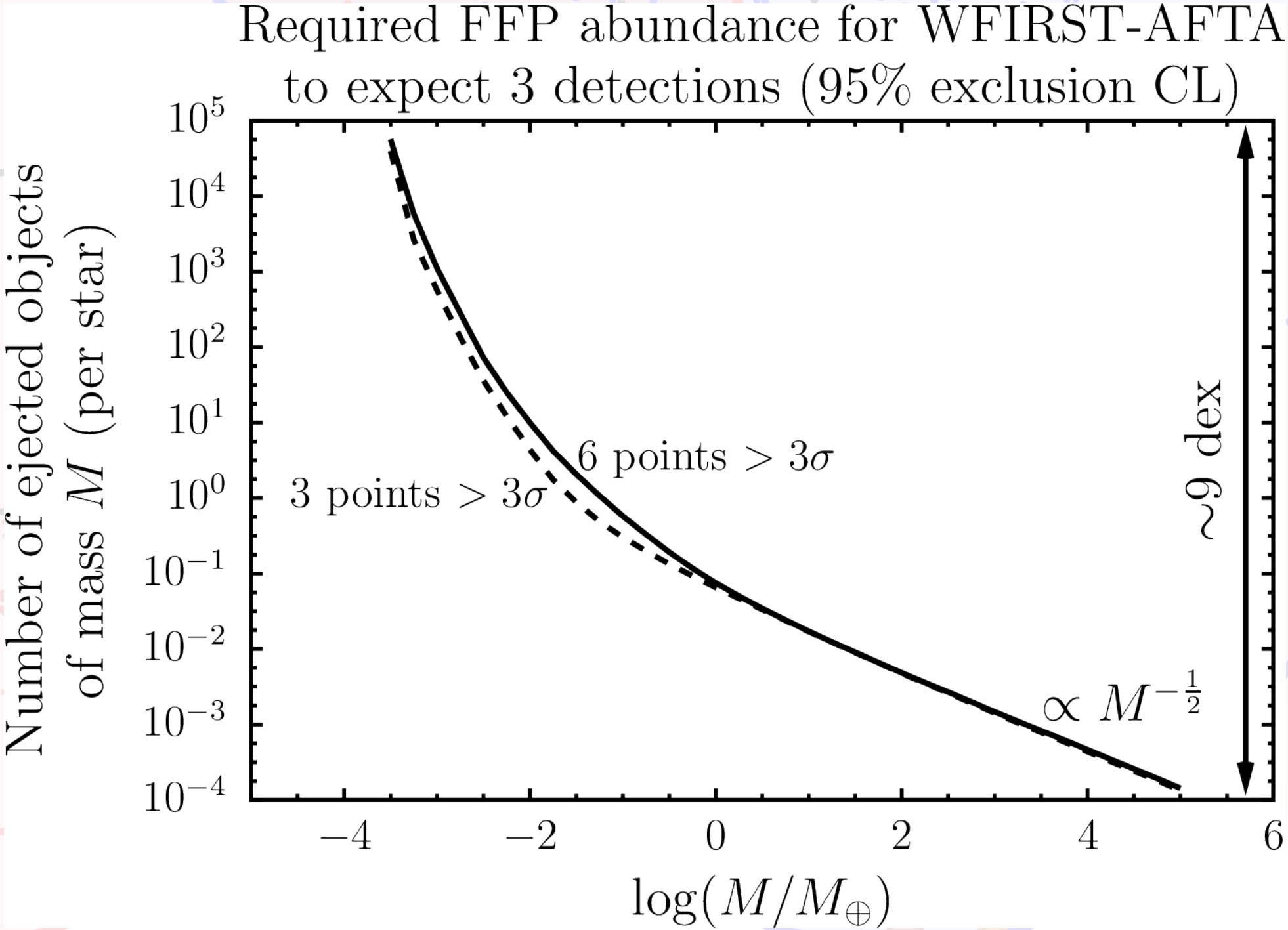
Free-floating planets

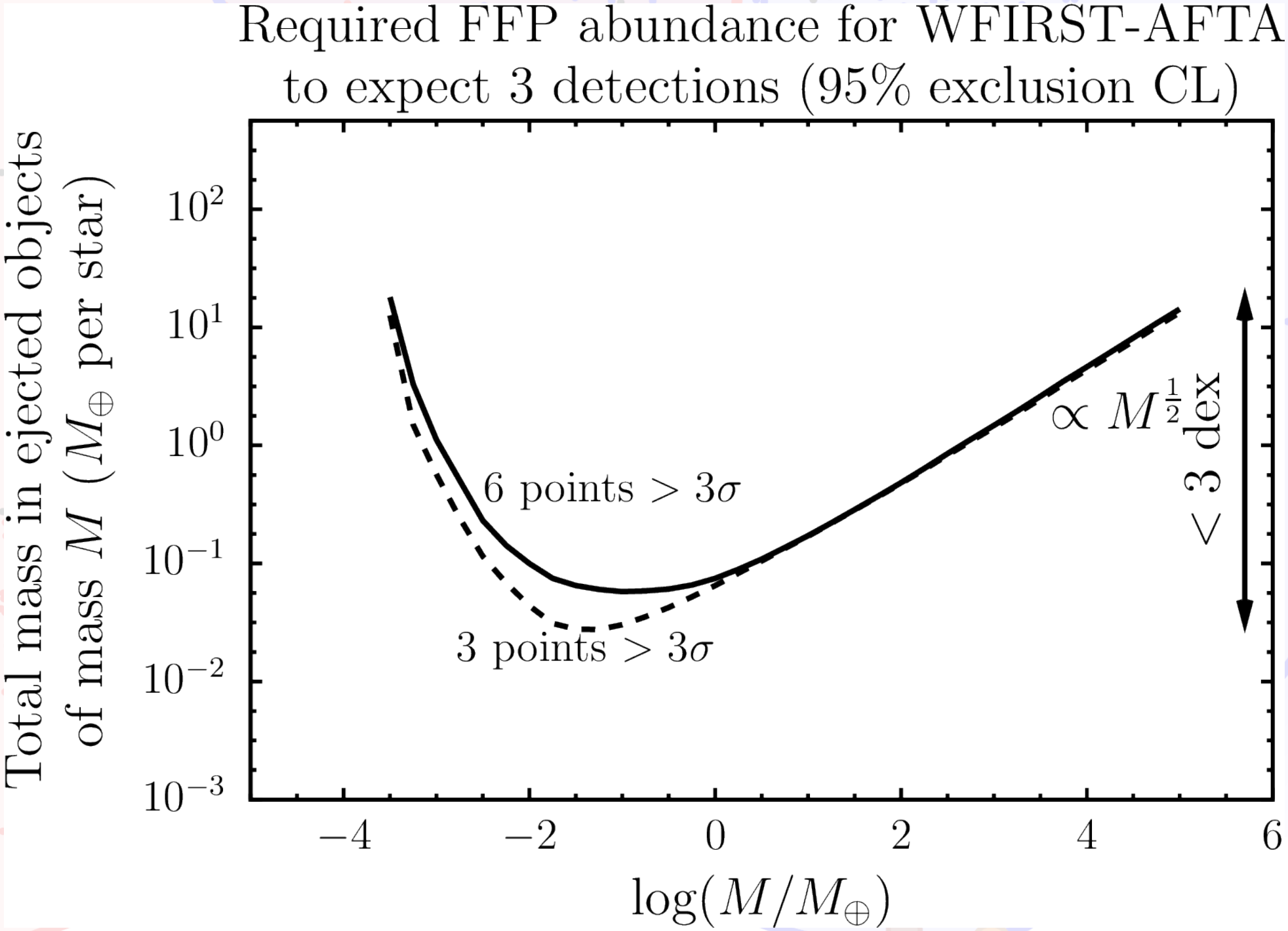


Free floating Mars
(~23 sigma)

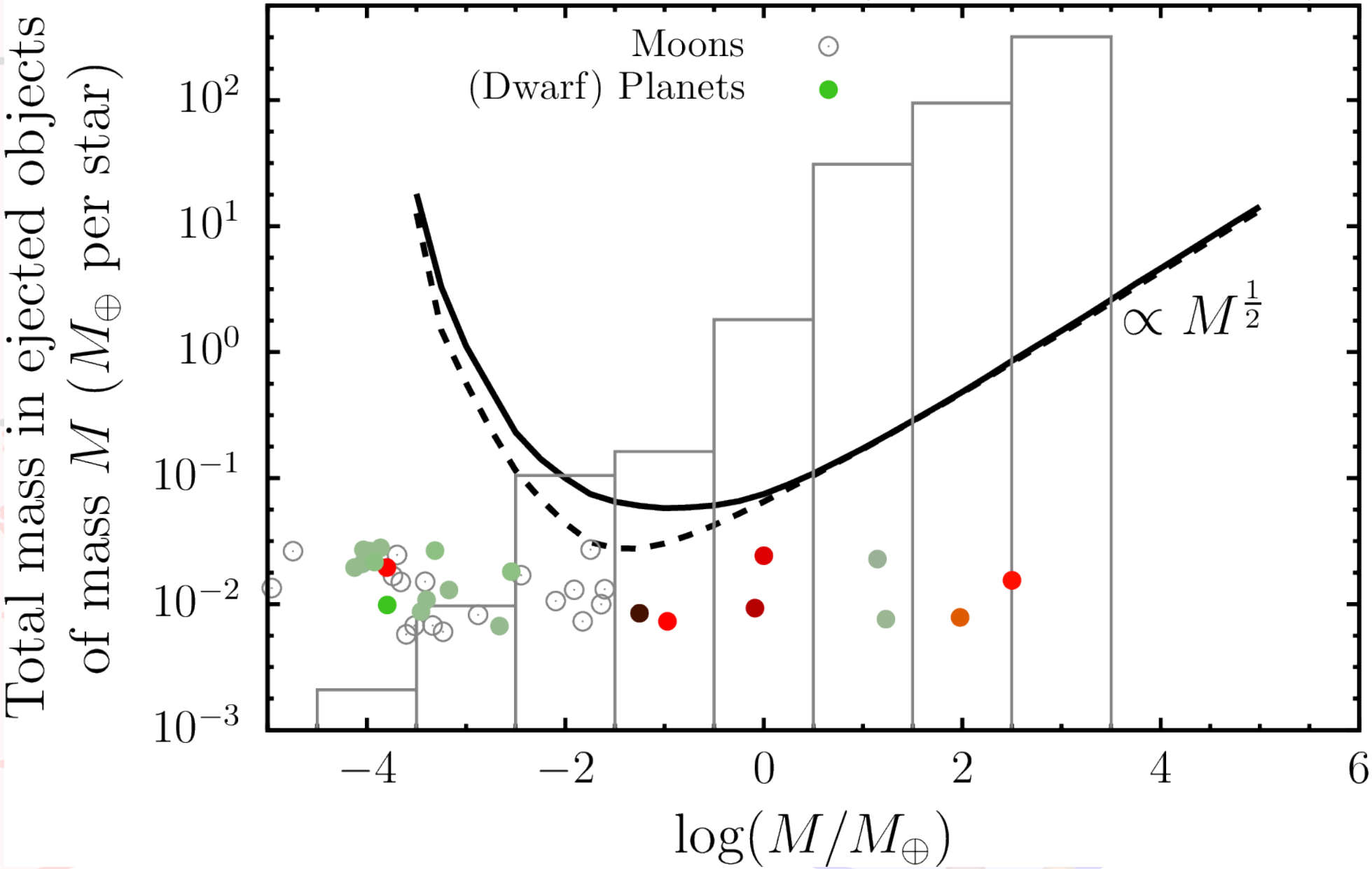
- Free-floating planets may be more common than stars in the Galaxy.
- WFIRST-AFTA can detect free-floating planets down the mass of Mars.
- Expect to detect hundreds of free-floating planets.
- Sensitive to moons of free-floating planets.

From AFTA SDT interim report

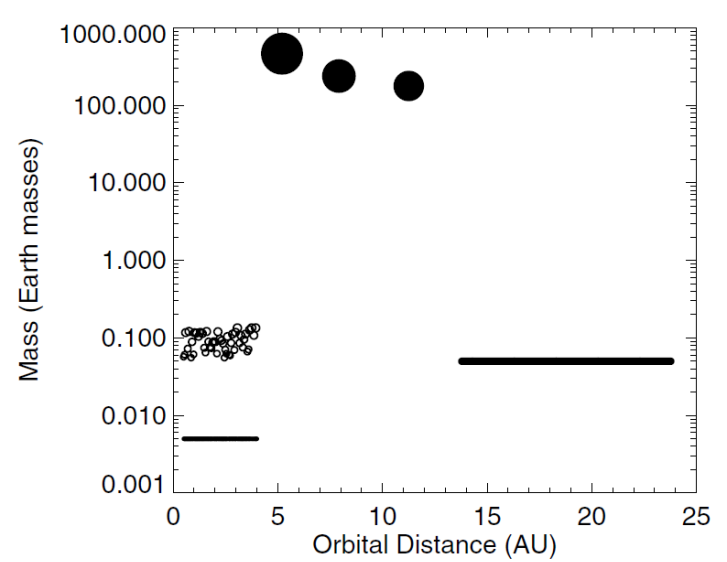

Required FFP abundance for WFIRST-AFTA
to expect 3 detections (95% exclusion CL)
Number of ejected objects
of mass M (per star)
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
6 points > 3σ
3 points > 3σ
$\sim$9 dex
$\propto M^{-\frac{1}{2}}$
−4
−2
0
2
4
6
$\log(M/M_\oplus)$

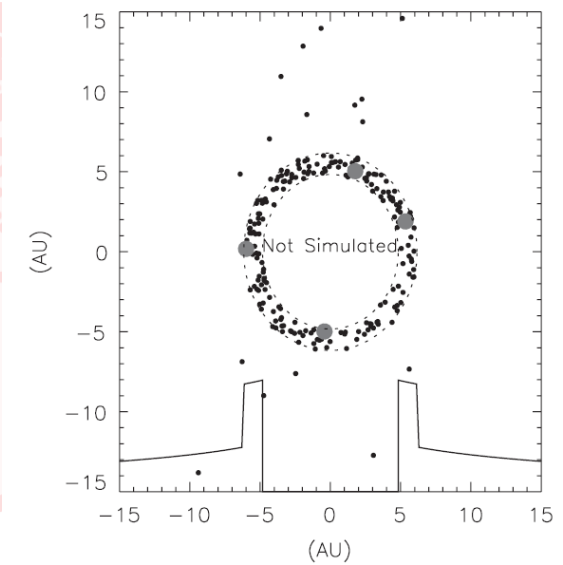

Required FFP abundance for WFIRST-AFTA
to expect 3 detections (95% exclusion CL)
Total mass in ejected objects
of mass M ($M_\oplus$ per star)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
6 points $> 3\sigma$
3 points $> 3\sigma$
$\propto M^{\frac{1}{2}}$
< 3 dex
-4
-2
0
2
4
6
$\log(M/M_\oplus)$

Required FFP abundance for WFIRST-AFTA to expect 3 detections (95% exclusion CL)



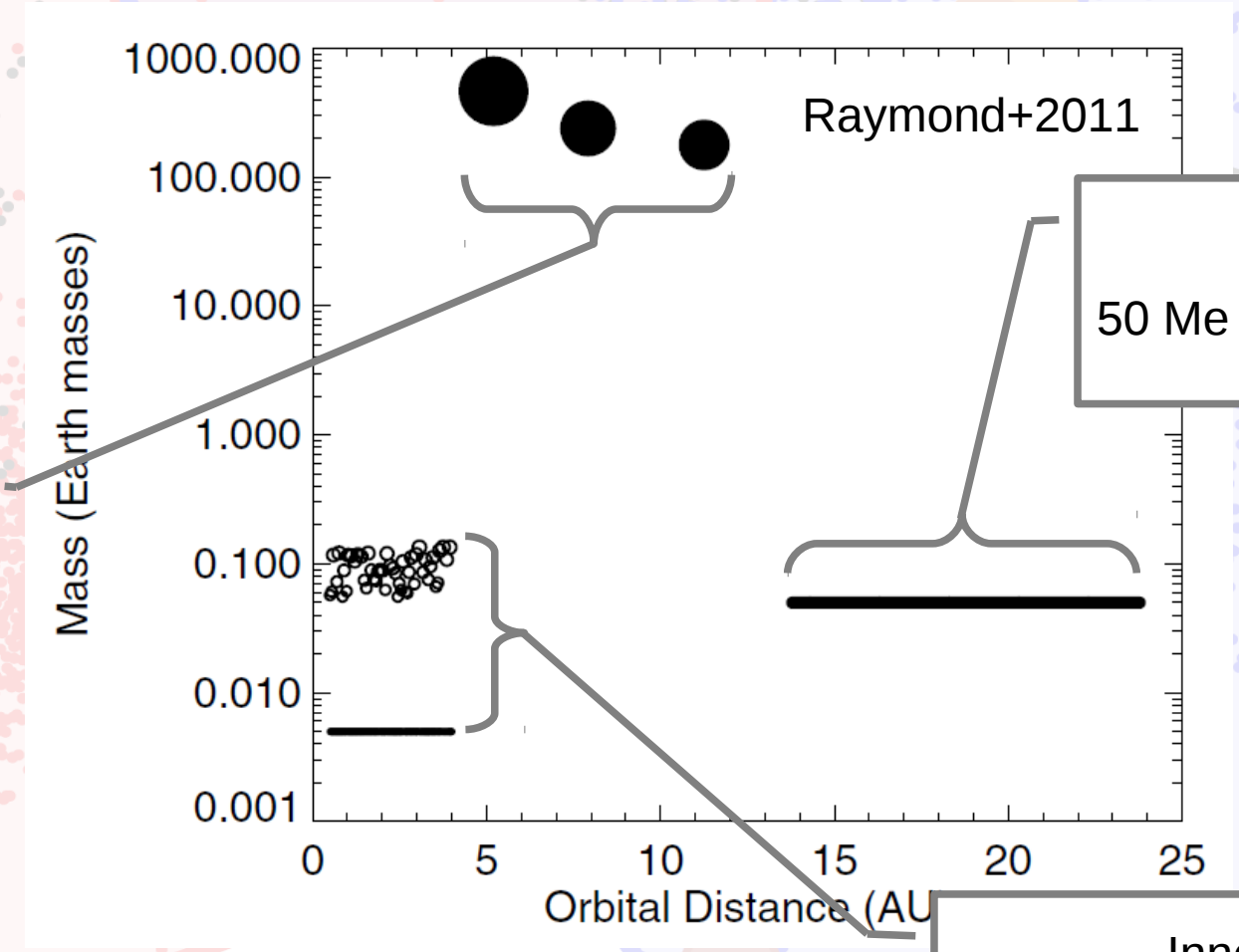
Simulations of Ejected Oligarchs





- Simulations of planet formation in the oligarchic growth phase can predict the number of low-mass FFPs
- Two examples:
  - Planetesimals + oligarchs with giant planets (Raymond et al. 2011, 2012)
  - Planetesimals + oligarchs without giant planets (Mann et al. 2010)
- Many other sims can make similar predictions

Starting conditions

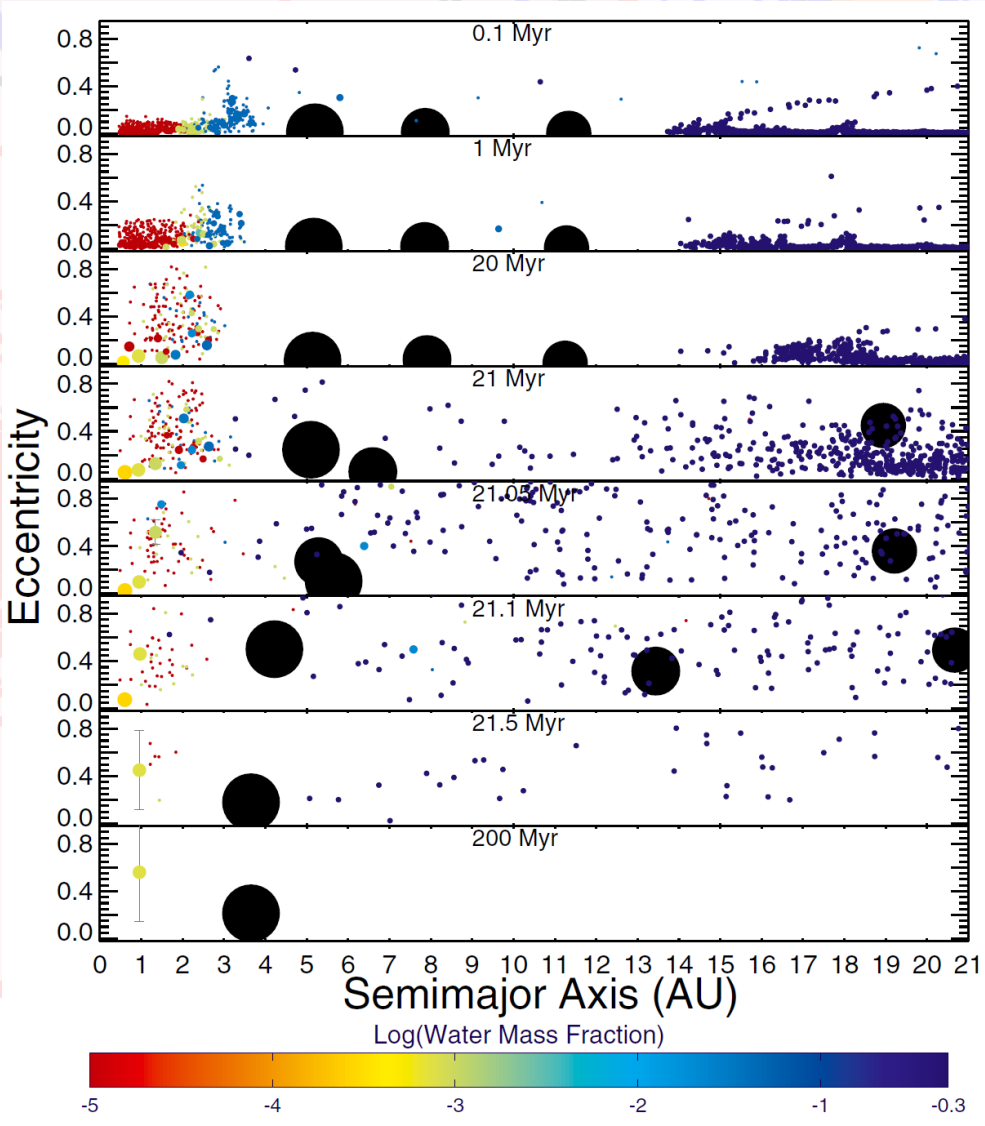


3 Giant planets:
>90% unstable
<10% stable

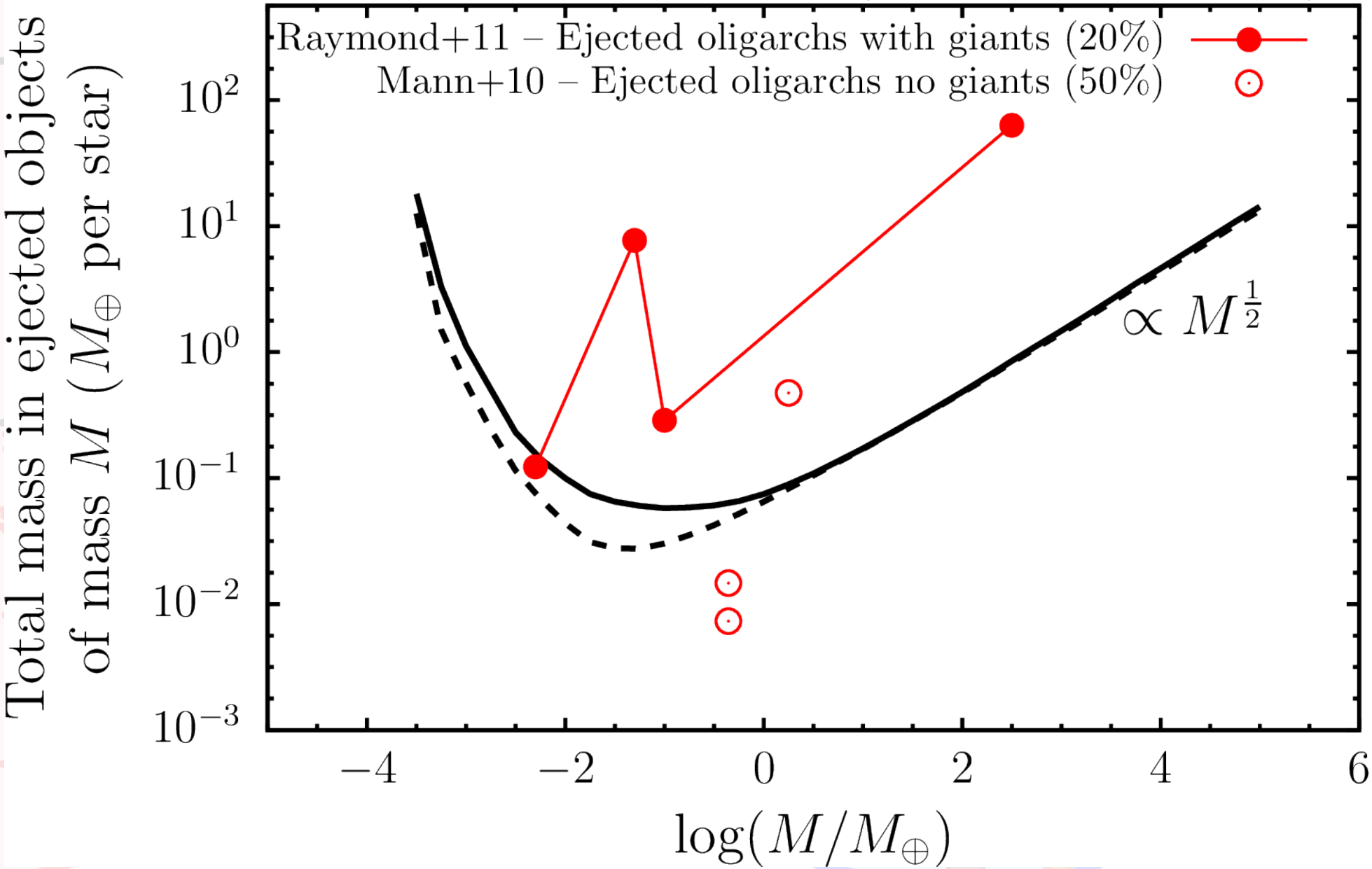
Outer disk:
50 Me of 0.05 Me objects

Inner disk:
2.5 Me of 0.005 Me objects
2.5 Me of ~0.1 Me Embryos

Dynamics and Growth



Required FFP abundance for WFIRST-AFTA to expect 3 detections (95% exclusion CL)



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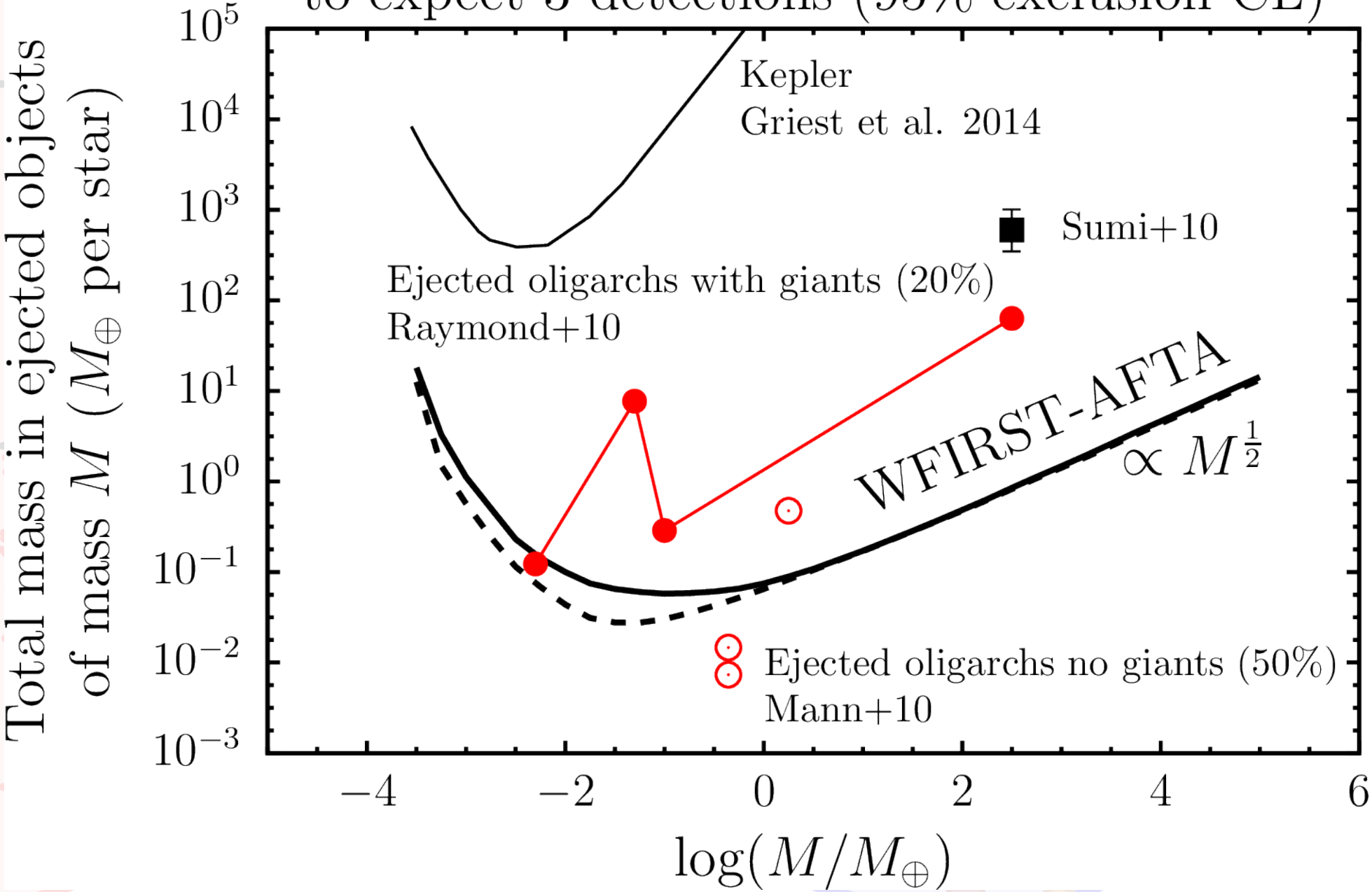

Conclusions

Bound

- WFIRST-AFTA will do for cold planets what Kepler has done for hot planets
- Will measure abundance of cold bound planets down to mass of solar system moons
- Will measure masses of most of its bound planets

Free-floating

- WFIRST-AFTA will find hundreds of FFPs
- Sensitive to planetesimals pushed beyond ~10 AU or ejected
- Will measure “total loosely- or un-bound mass in objects of mass M per star” for Plutos to Jupiters if it is above 1 Mearth/star