Prospects for measuring $\eta_\oplus$ from WFIRST

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with

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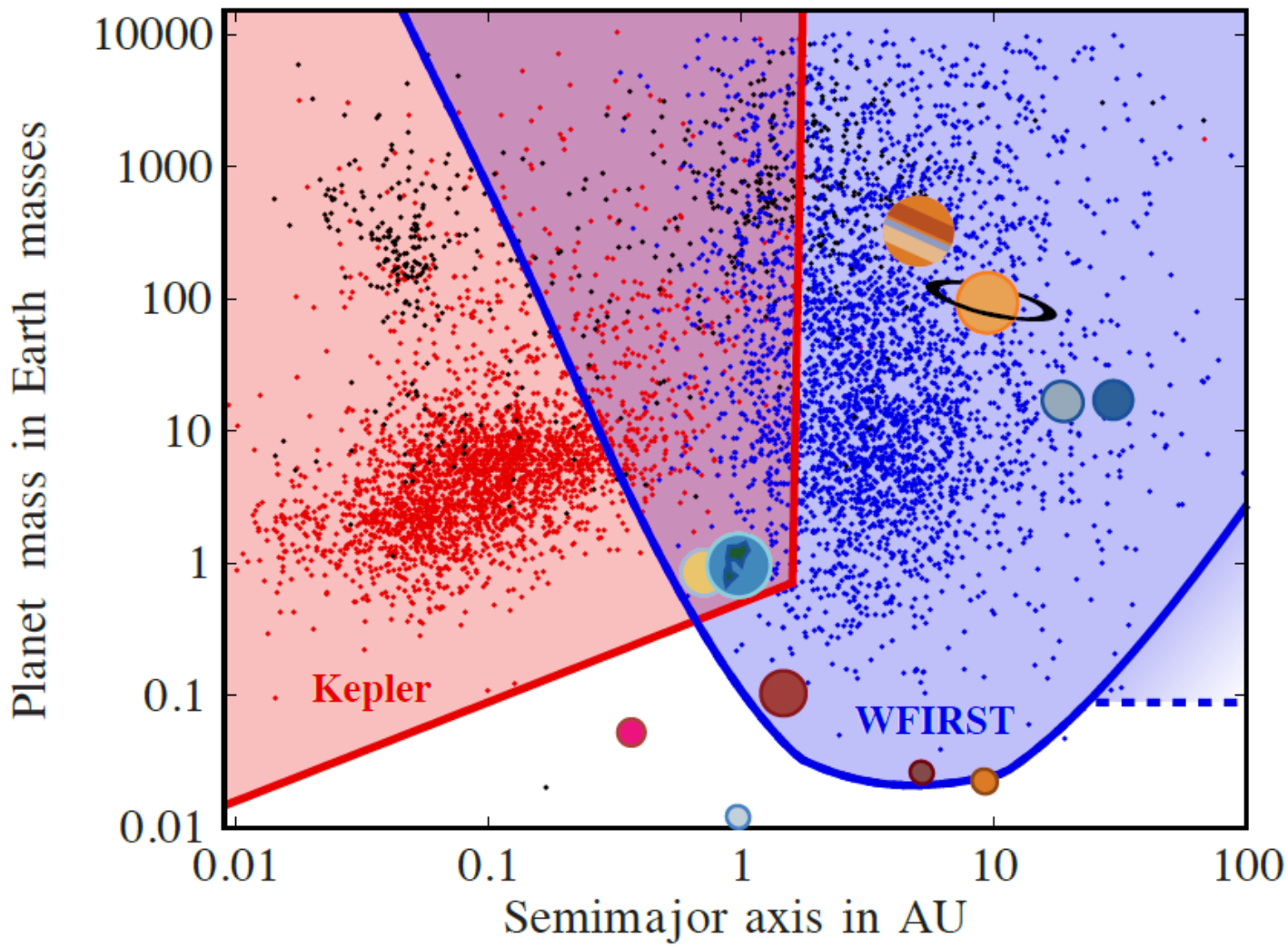
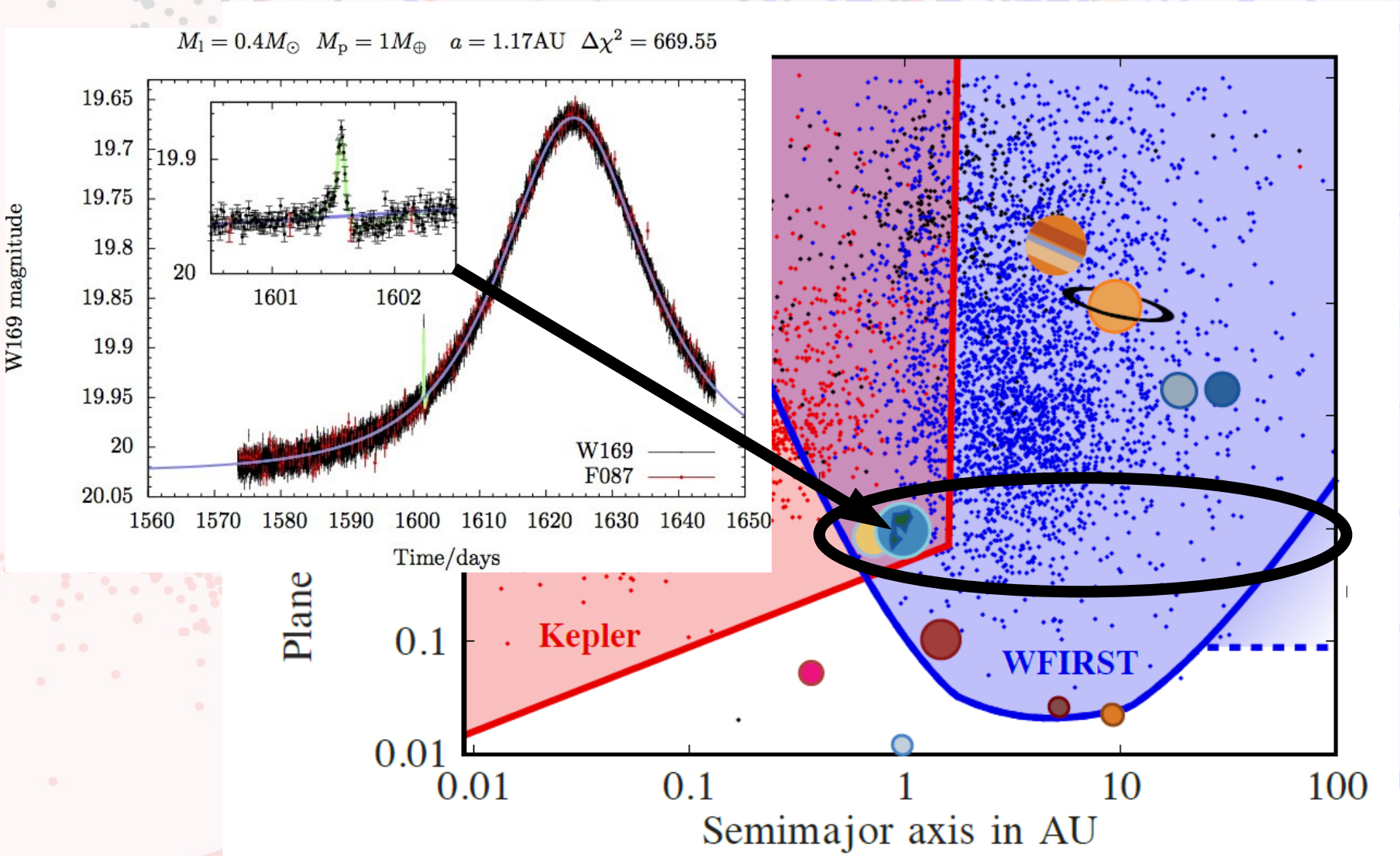
- AFTA-WFIRST in the Habitable Zone
- How the AFTA-WFIRST yields were estimated
- What is it we actually want to measure?

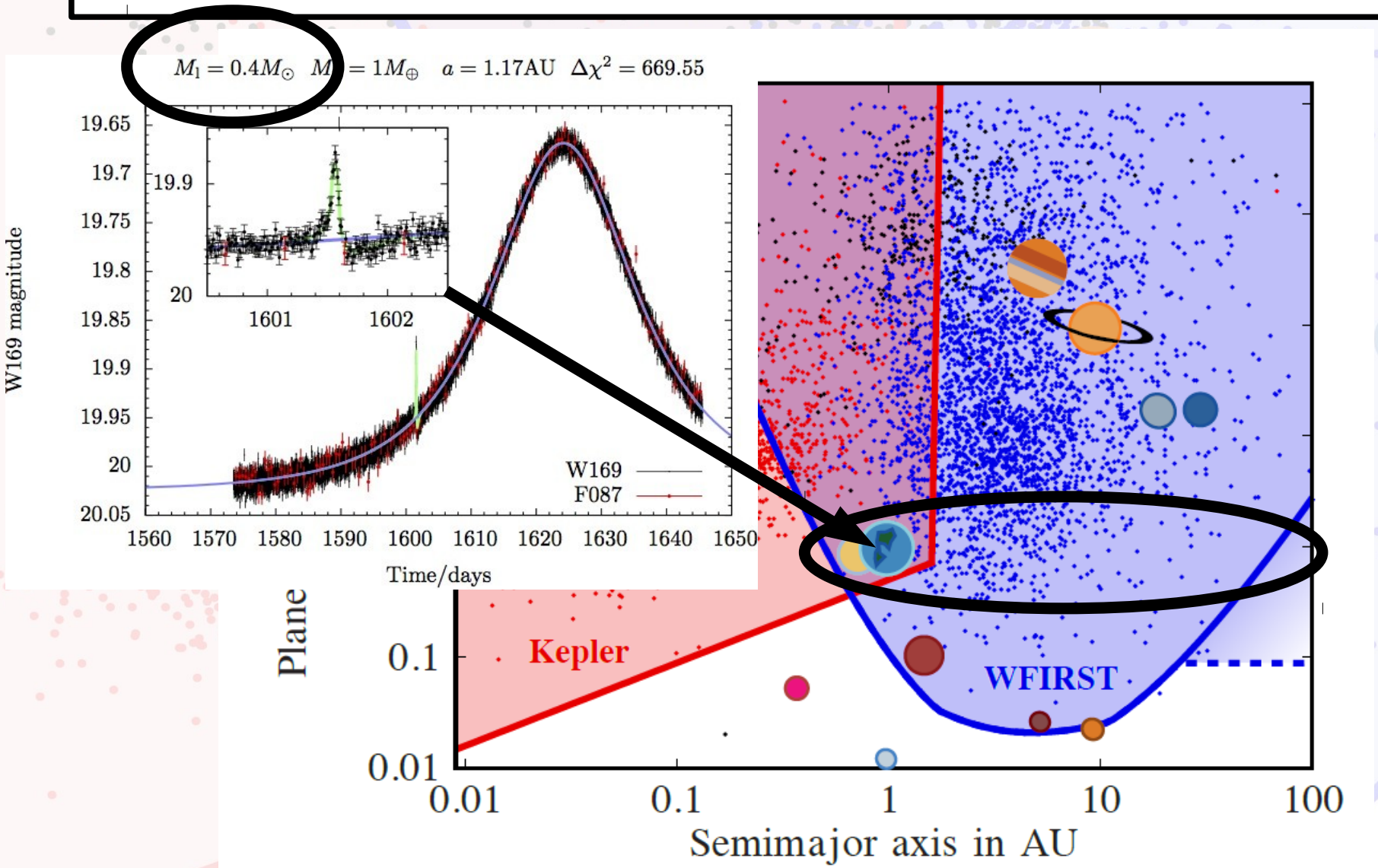
The WFIRST microlensing survey



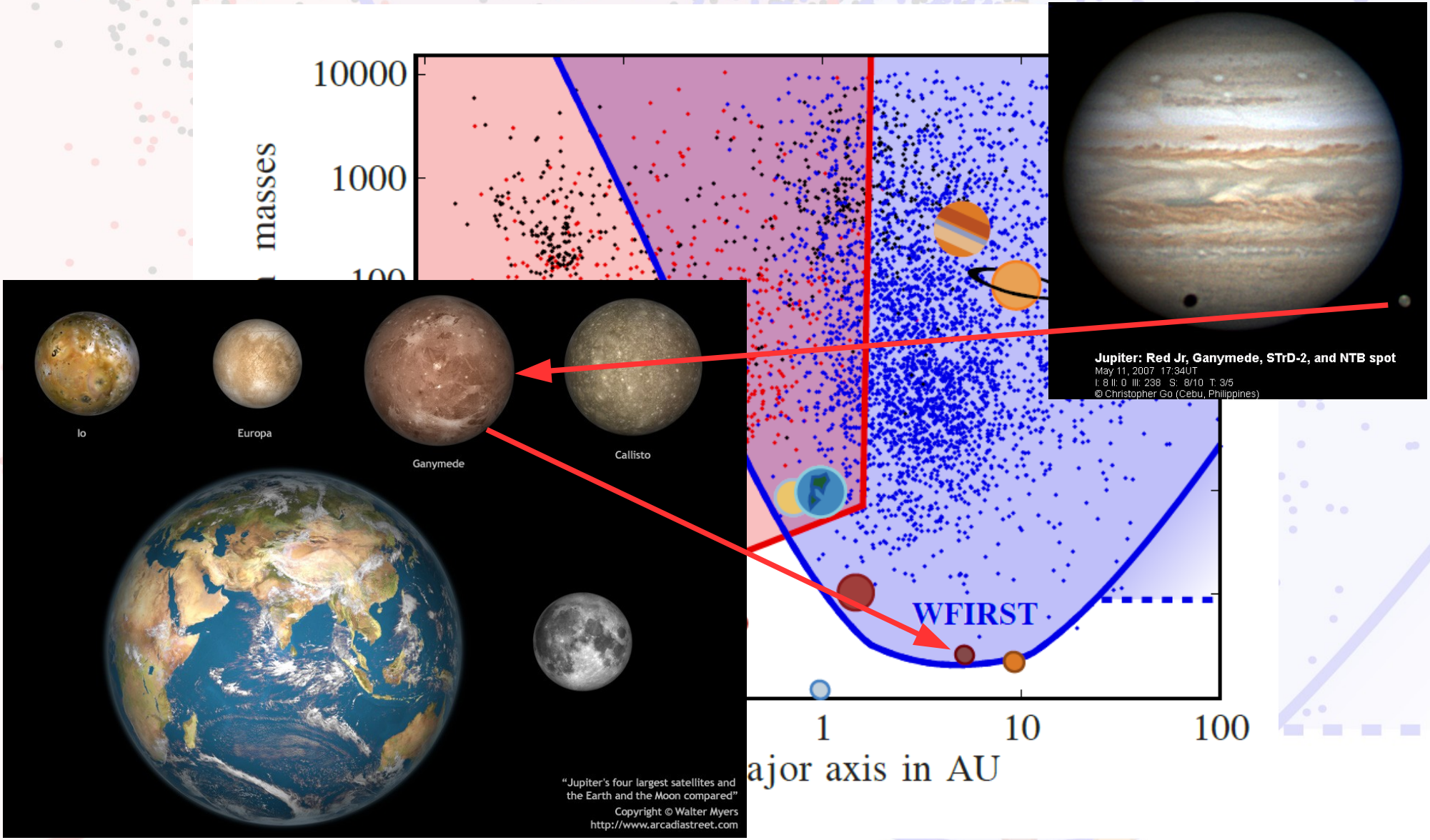
Earth-mass planets from 1AU out



Earth-mass planets from 1AU out



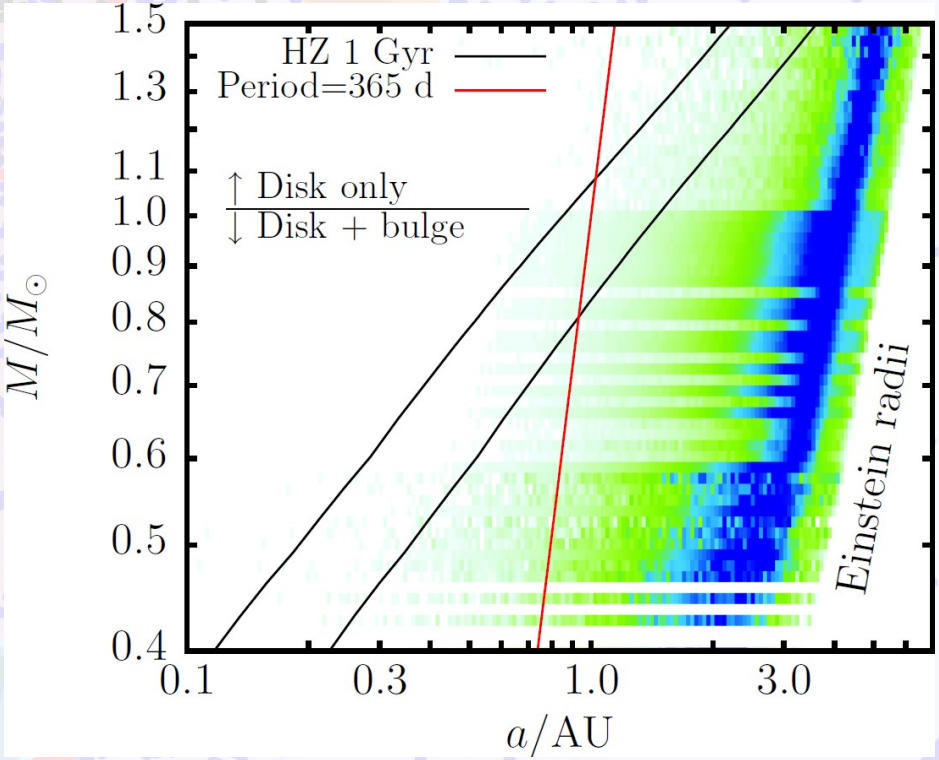
Really low-mass planets



So what about the Habitable Zone?

- Transits most sensitive to HZ of low-mass hosts
- Microlensing most sensitive to HZ of high-mass hosts

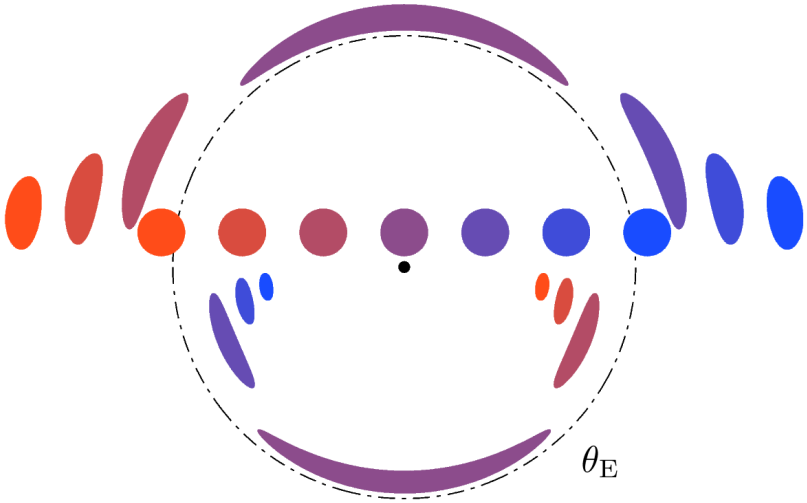
  -but how sensitive?

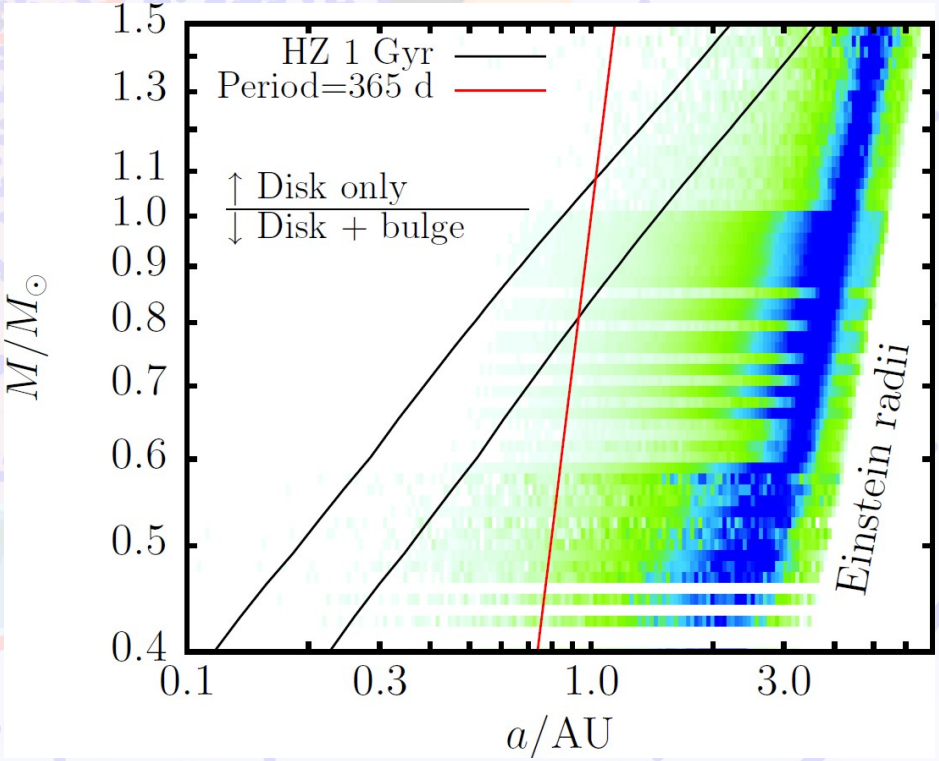


$$\frac{a_{\rm HZ}}{r_{\rm E}} \simeq 0.3 \begin{cases} M^{1.5} & M \lesssim 1 M_\odot \\ M^{1.75} & M \gtrsim 1 M_\odot \end{cases}$$

So what about the Habitable Zone?

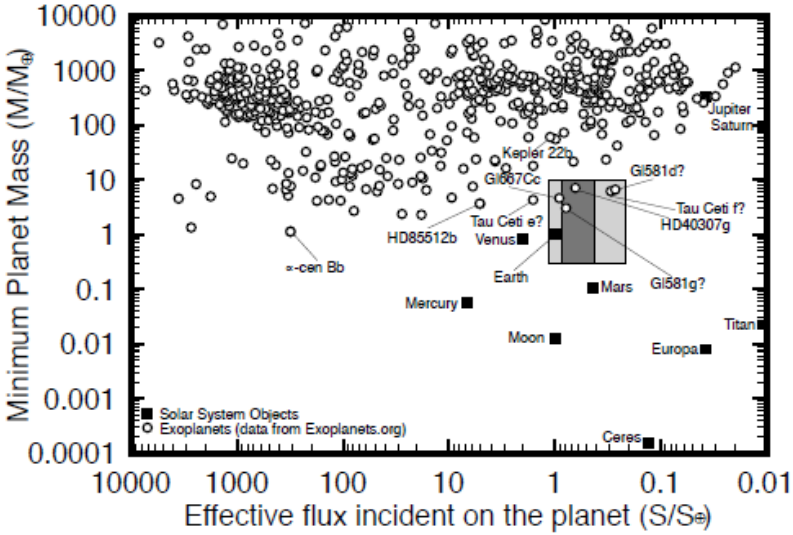
- Microlensing is works best for planets near the Einstein ring
- Detectable when they perturb an image





AFTA in the Habitable Zone

- Using the recent Kopparapu et al HZ definition

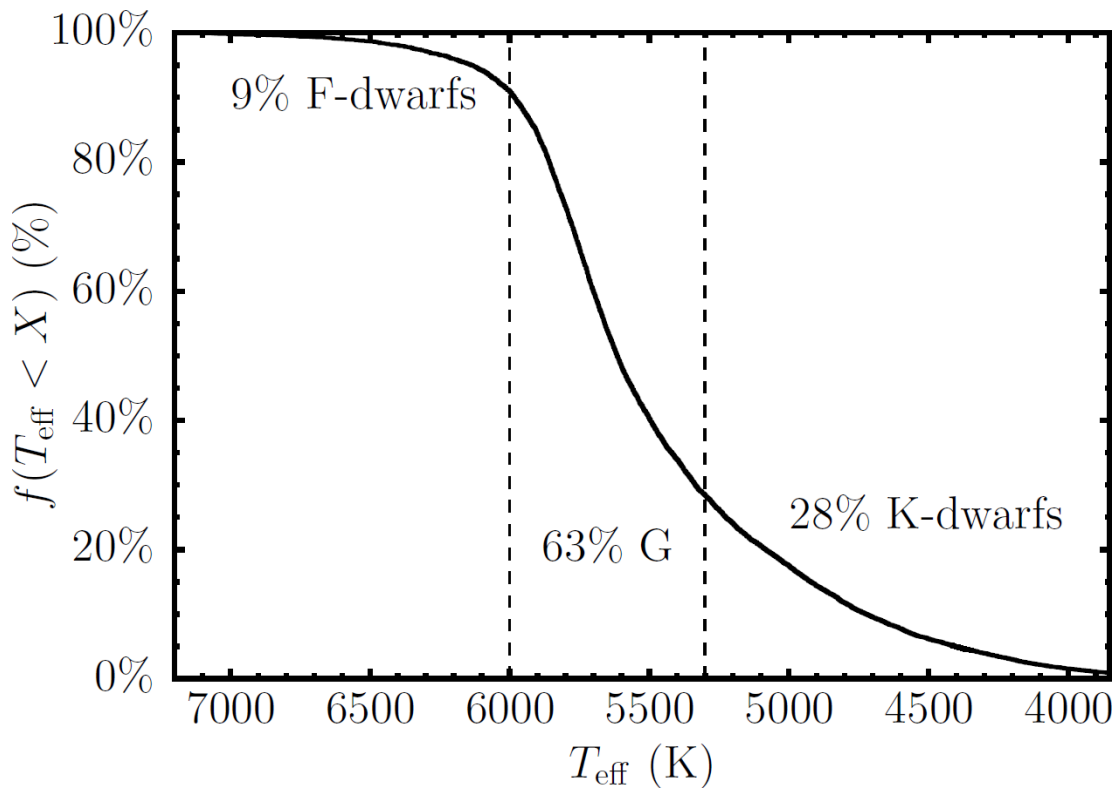


- Take the WFIRST simulations and throw out everything but FGK dwarfs (no hope for M)
- Put an Earth mass planet in the HZ of each star

AFTA in the Habitable Zone

For FGK dwarf lenses, 1 HZ Earth per star:

~1 detection



But wait...

1) There is substantial uncertainty in that estimate

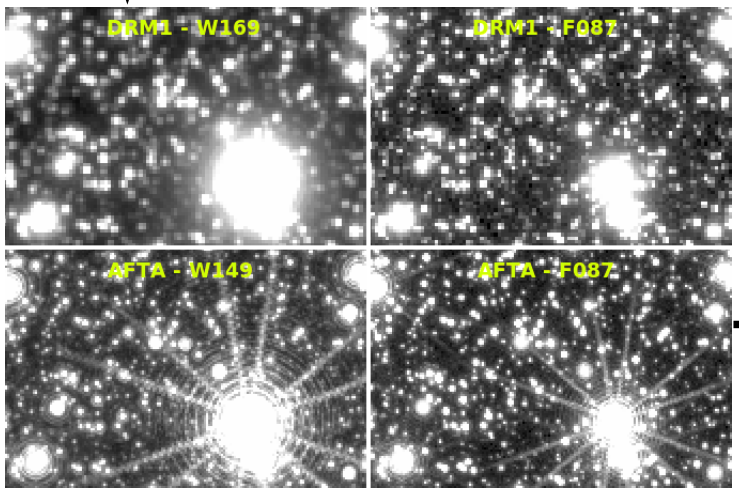
- Microlensing event rates uncertain
- On the edge of a sensitivity cliff – v. dependent on eventual performance of the detector etc.
- Dave Bennett would tell you a different number

2) Are currently habitable bulge planets what we are interested in?

3) There is substantial sensitivity nearby – we can extrapolate (and interpolate with Kepler)

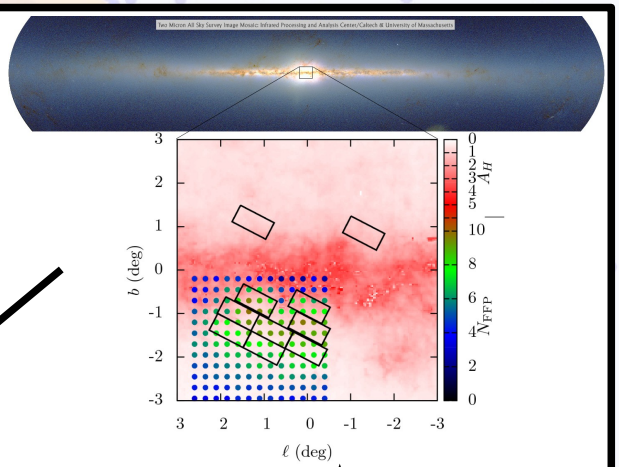
Estimating the number of detections

Draw source, lens,
Generate images



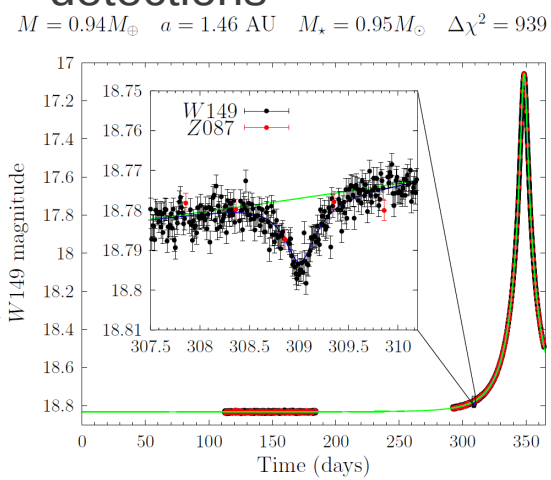
Normalize to
event rates

Number of
detections

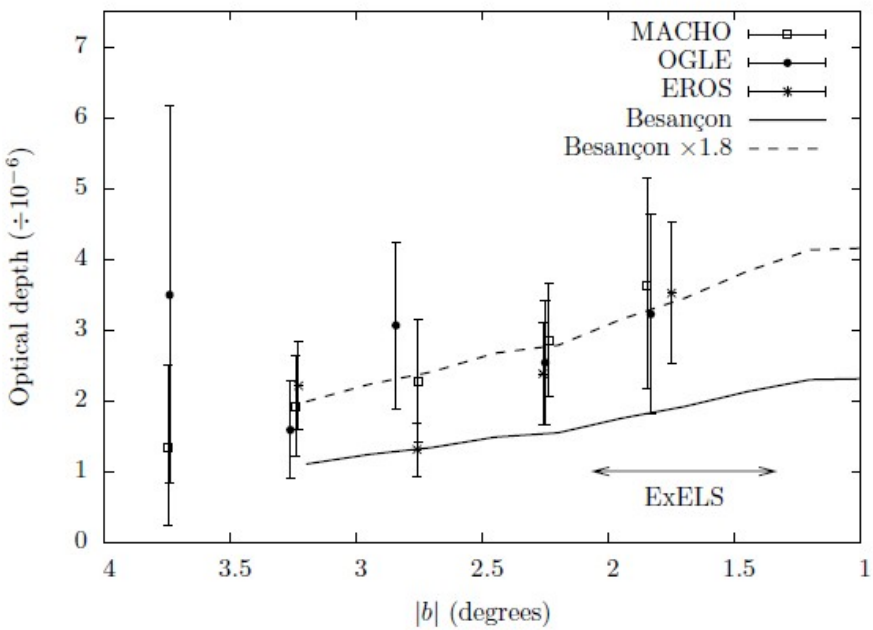


Count up
detections

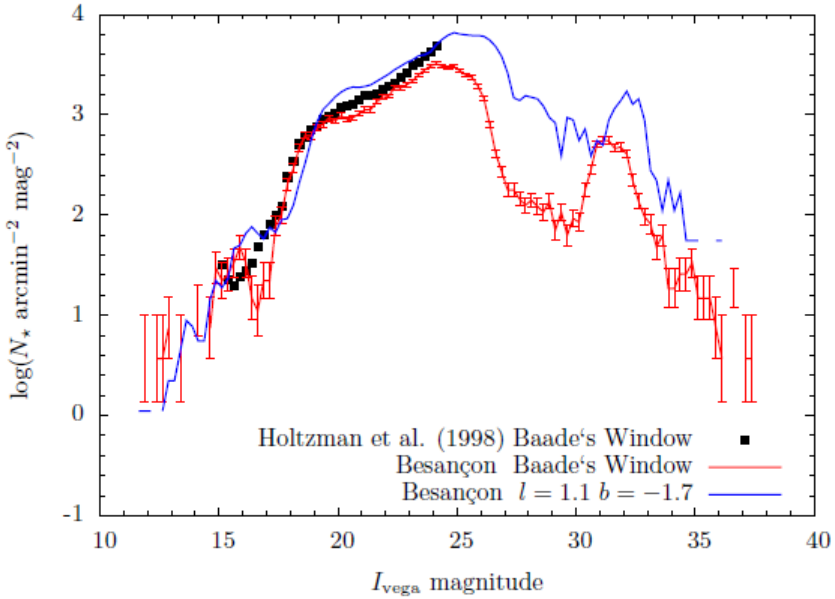
Generate lightcurves,
Do photometry



Things that could go wrong. I



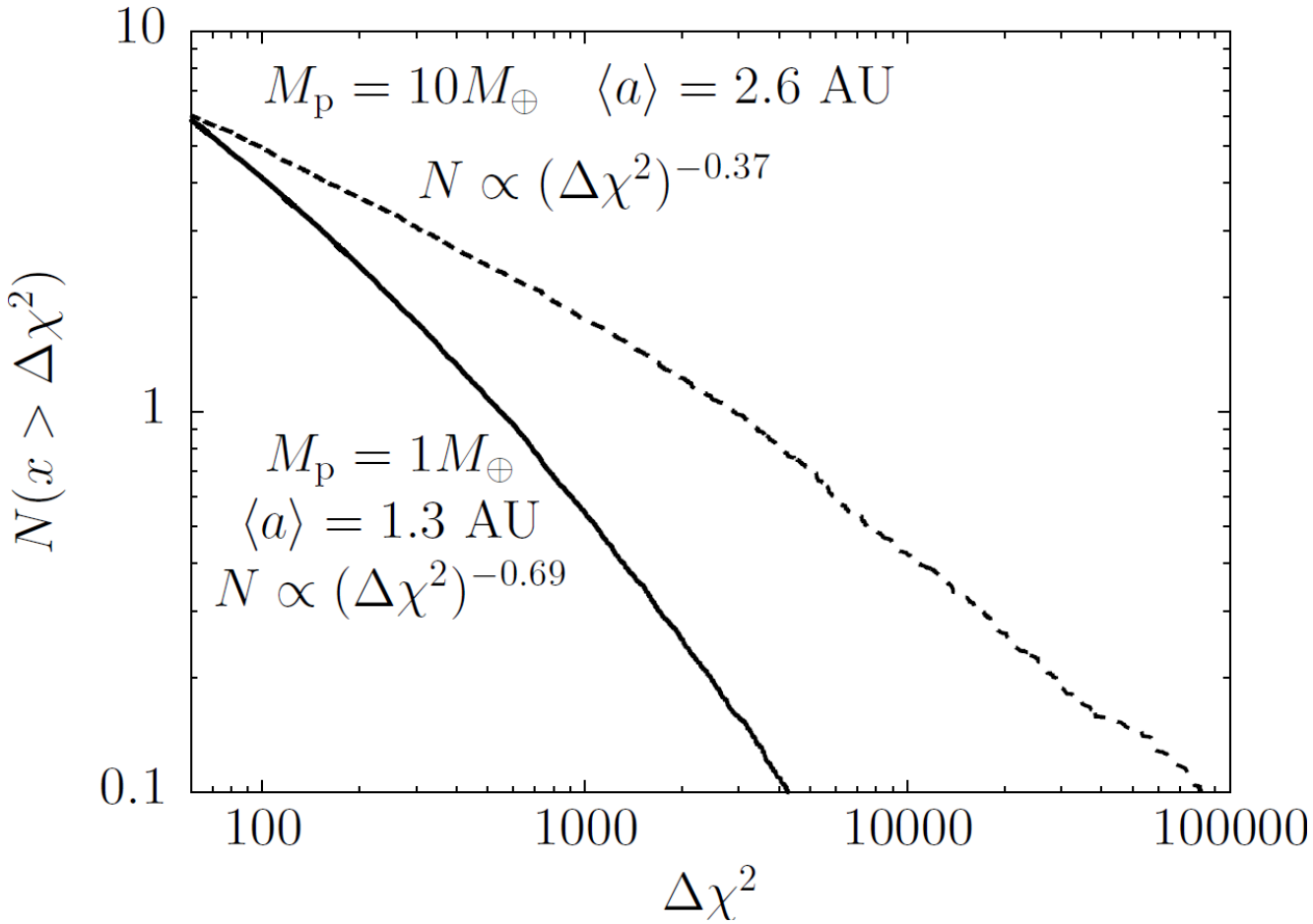
Optical depth and source counts are underpredicted by the Galactic model



Crude x2.33 correction applied, but could be wrong for FGK lenses

Things that could go wrong. II

Sensitivity cliff

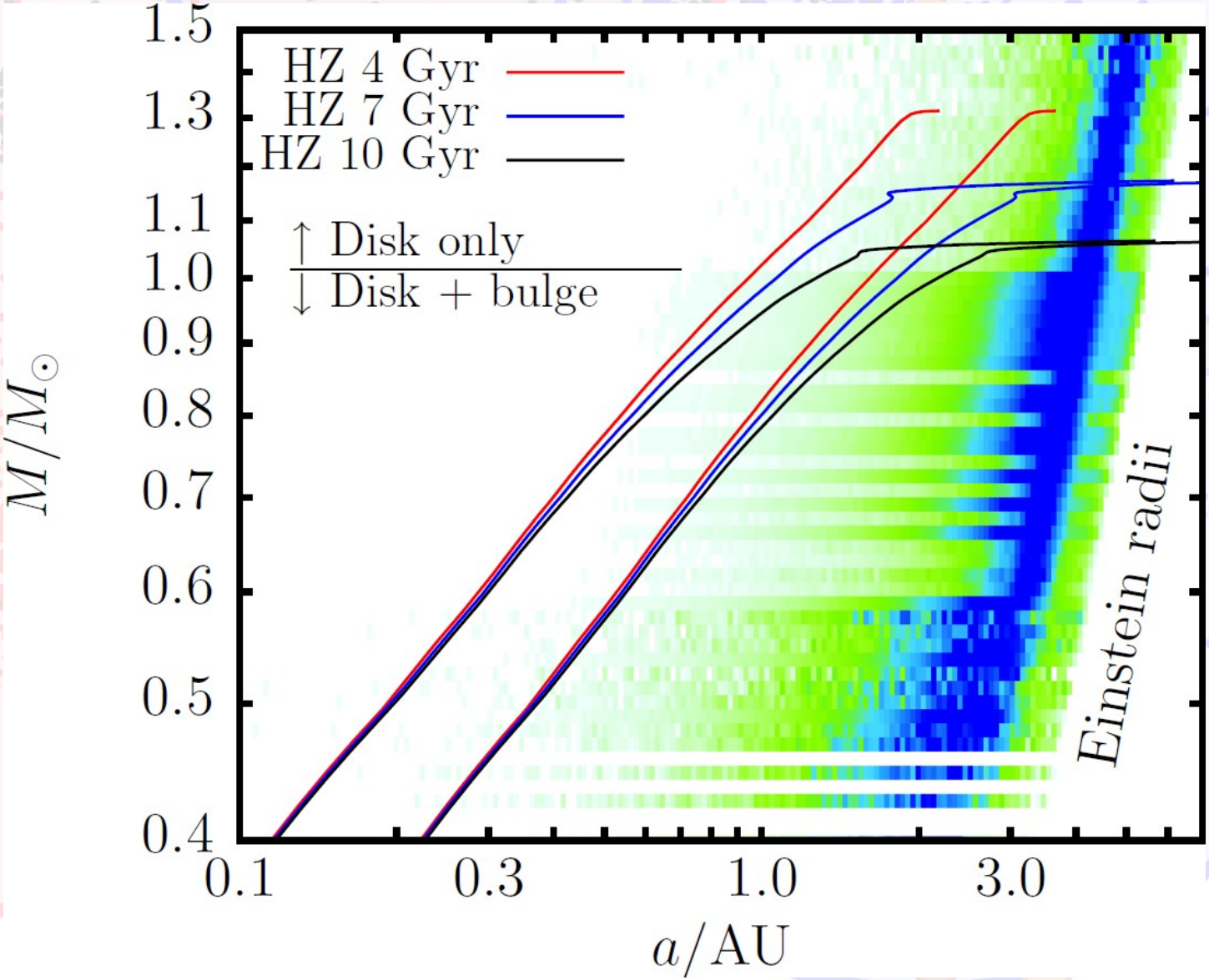


#whatshouldwecall$\eta_{\oplus}$

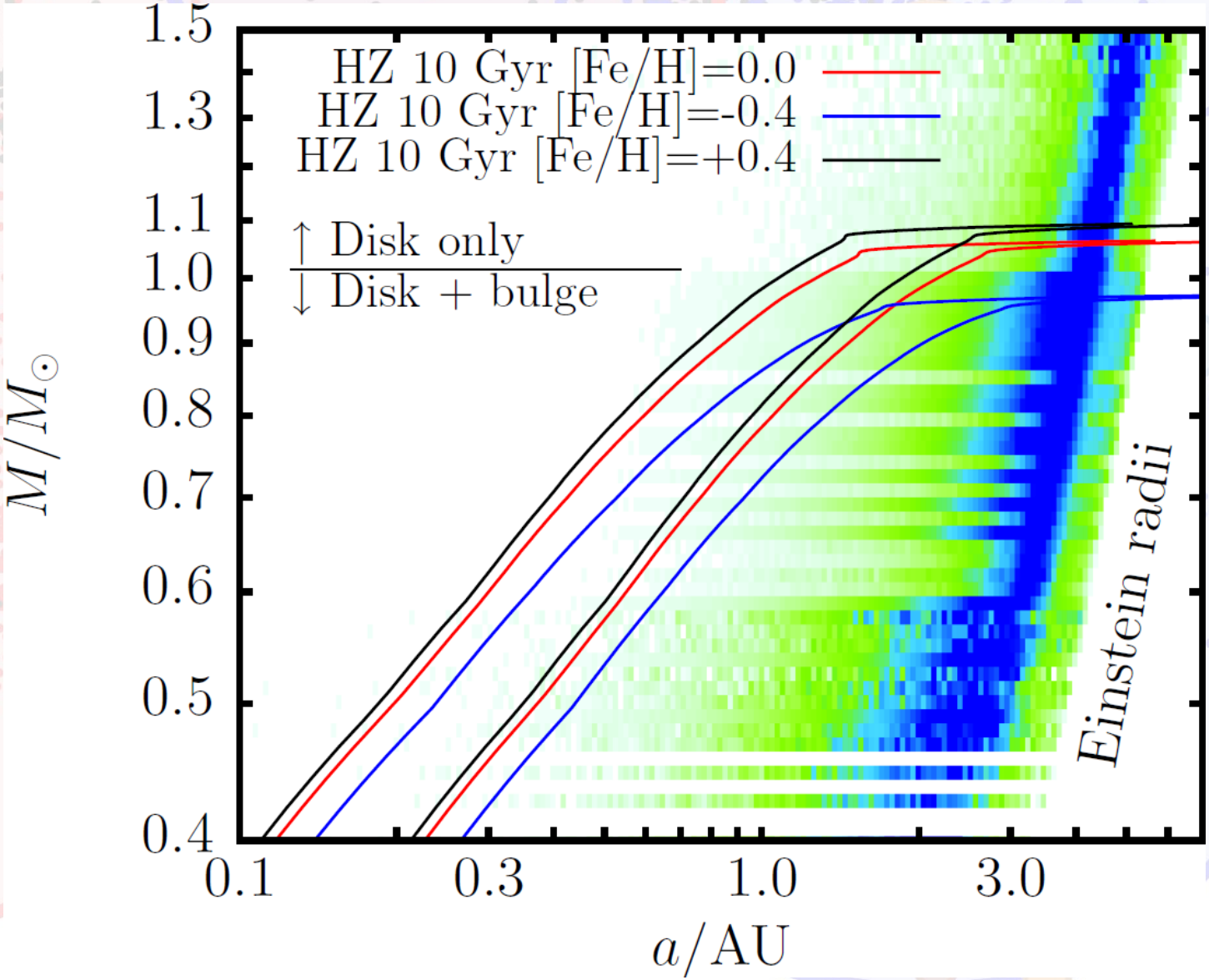
What is the question we want to answer?

- ~~Does ε ??? have a habitable planet?~~
- How many habitable planets are there currently in the Galaxy?
- What is the fraction of nearby stars with habitable planets?

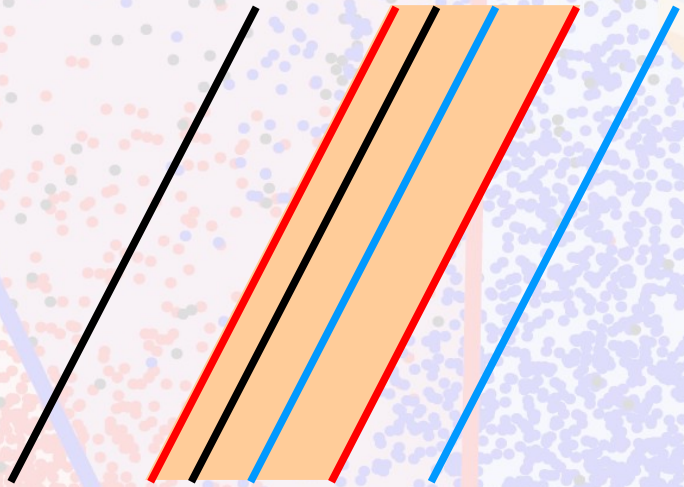
Habitable Zone as f(Age)



Habitable Zone as f([Fe/H])



Spying on the Neighbors



AFTA-WFIRST yields if 1 planet per star in shifted HZ around FGK dwarfs			
Mass/HZ	**HZ x 1.0** **0.99–1.68 AU**	**HZ x 1.5** **1.49–2.52 AU**	**HZ x 2.0** **1.98–3.36 AU**
10.0 Mearth	8.2	25.0	52.9
3.2 Mearth	3.2	11.1	23.9
1.0 Mearth	1.1	4.5	9.9

1.0 dex

0.3 dex

Kepler and AFTA-WFIRST

- Kepler will measure radii but not masses for HZ planets around M & K dwarfs
- AFTA will measure masses but not radii for near-HZ planets around K & G dwarfs

Conclusions

- Detecting HZ planets with AFTA will be difficult
- AFTA *will* detect planets just outside the HZ and measure abundance power laws that can be extrapolated inwards
- Combining these with Kepler results extrapolated outwards should give a robust estimate of $\eta_{\oplus}$
- Conclusions will strongly depend on AFTA's actual performance and other uncertainties