

Planet formation theory

Daisuke Suzuki (ISAS/JAXA)

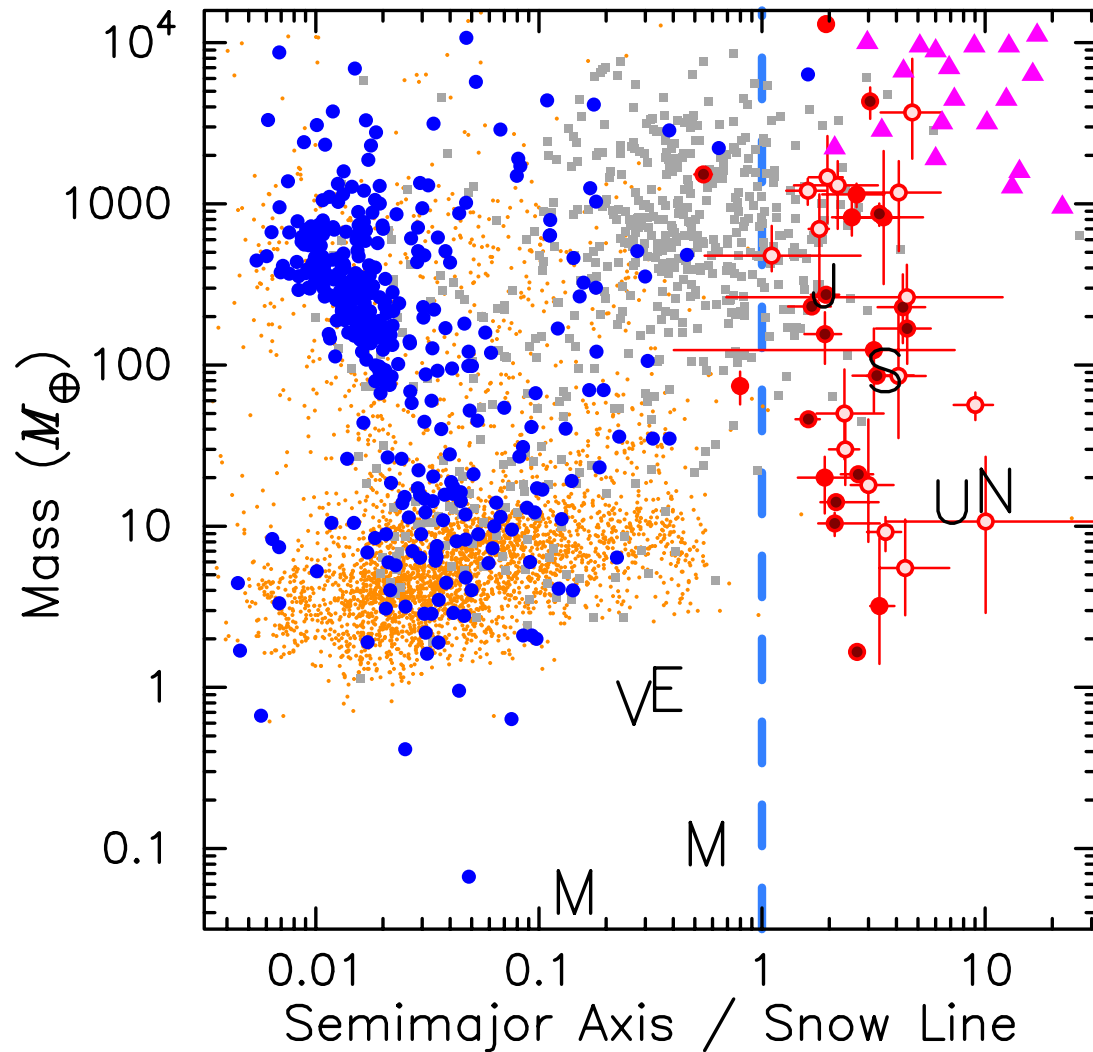
David Bennett (NASA/GSFC), Shigeru Ida (ELSI/Tokyo Tech),
Christoph Mordasini, Yann Alibert (U Bern), Doug Lin (UCSC)

Planet Mass Ratio Distribution: Microlensing VS Population Synthesis

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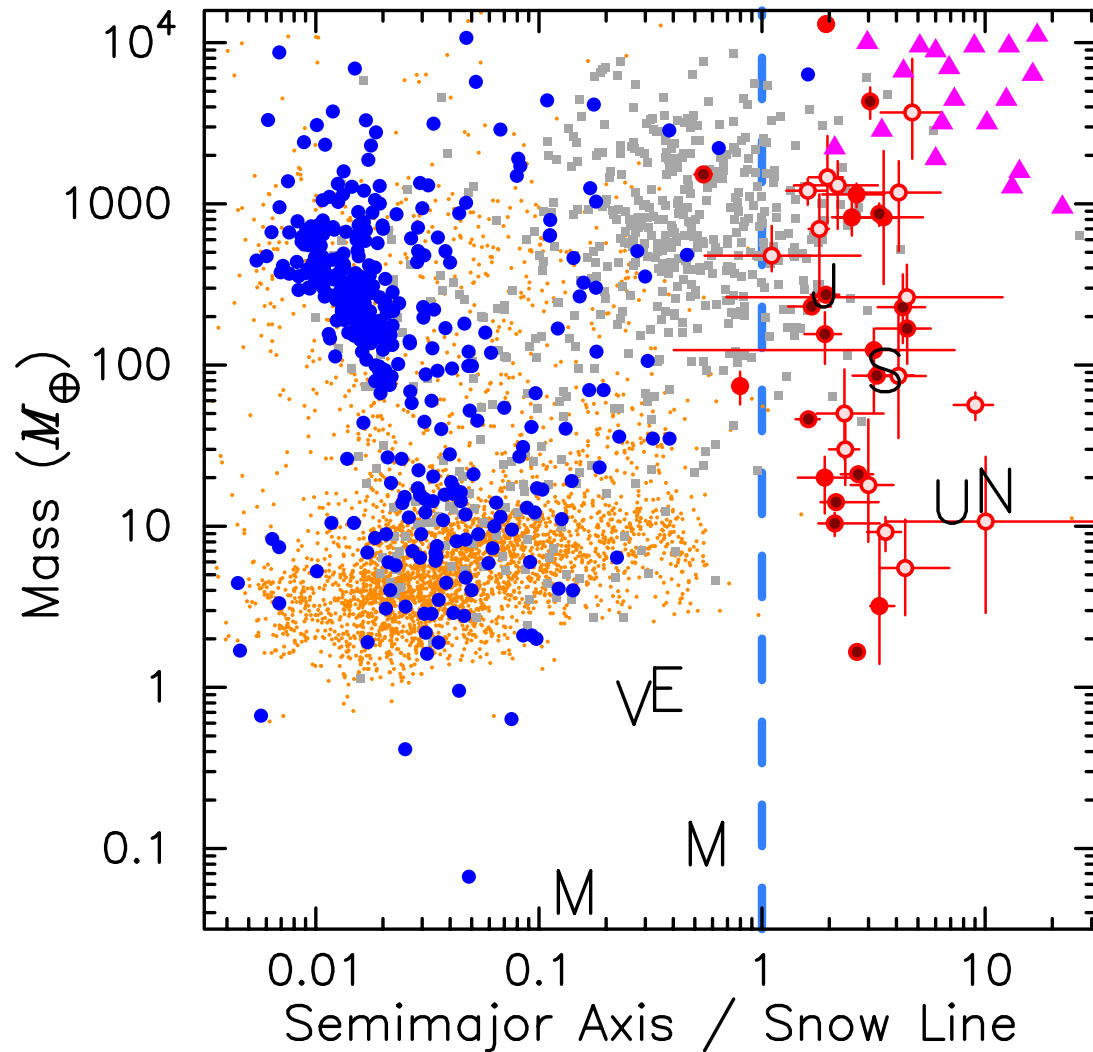
Planet distribution



Snowline: $a_{\text{snow}} = 2.7 (M/M_{\text{Sun}}) \text{ AU}$

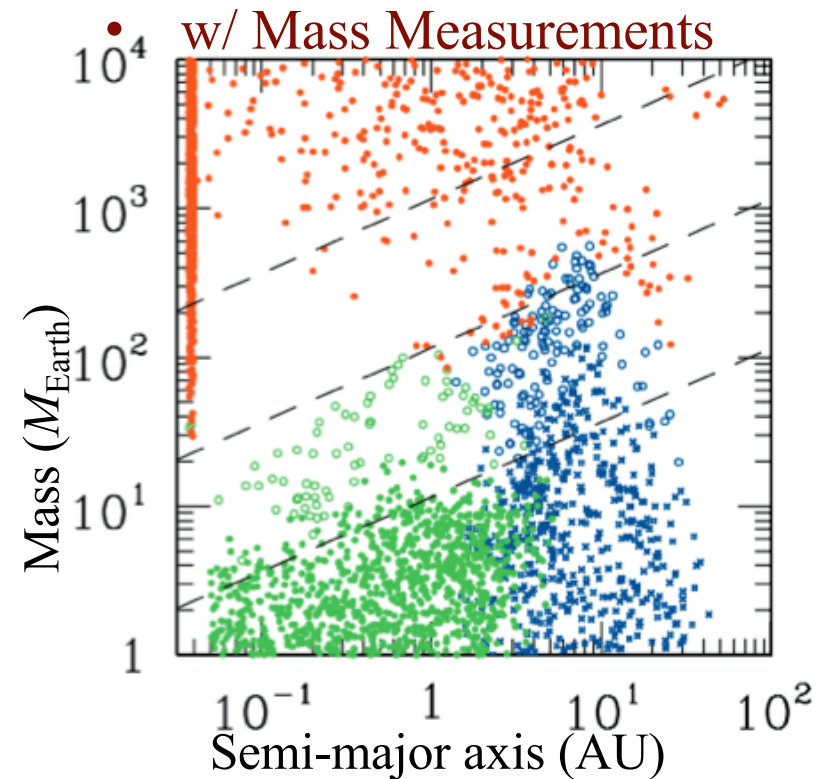
- Transit
- Kepler (KOIs)
- Radial Velocity
- Direct Imaging
- Microlensing
 - w/ Mass Measurements

Planet distribution

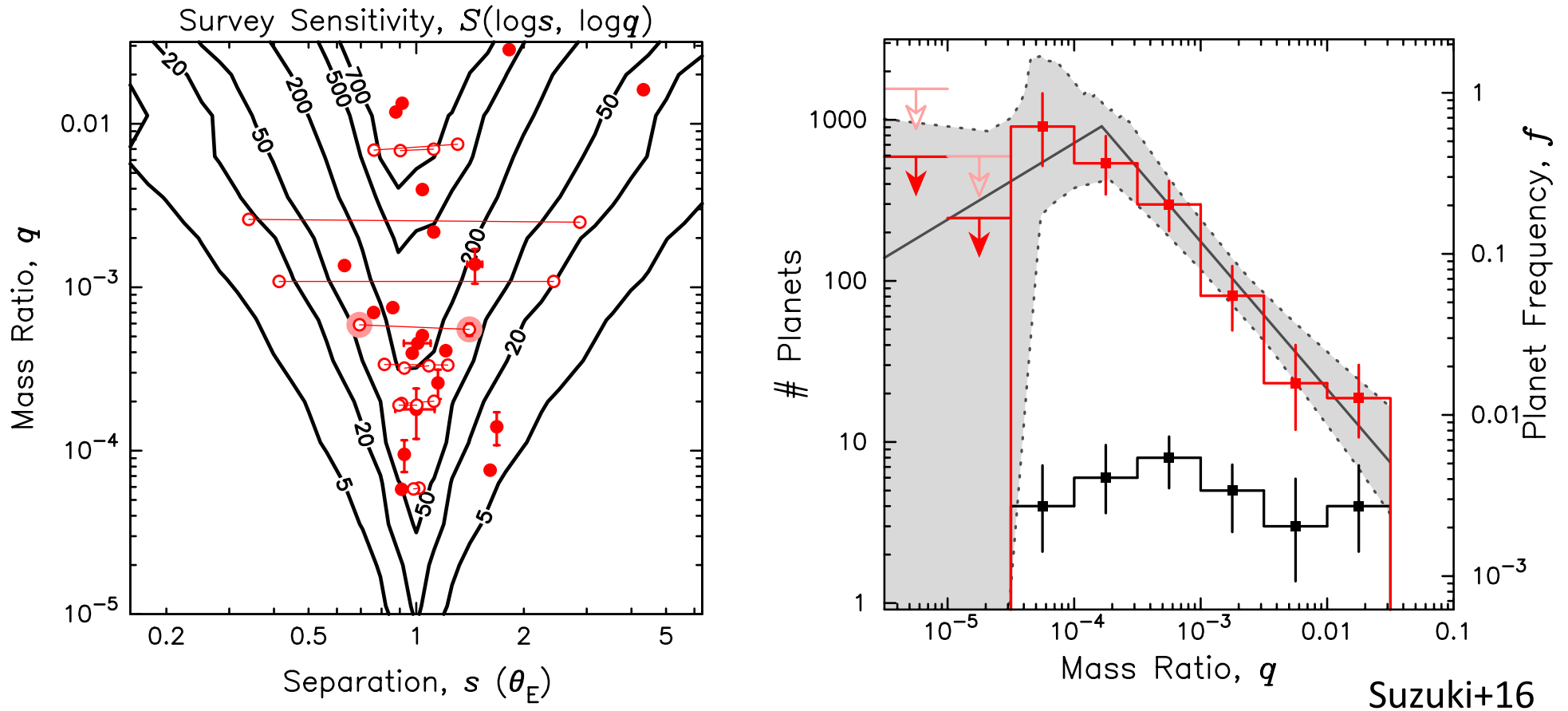


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- Transit
- Kepler (KOIs)
- Radial Velocity
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- Microlensing



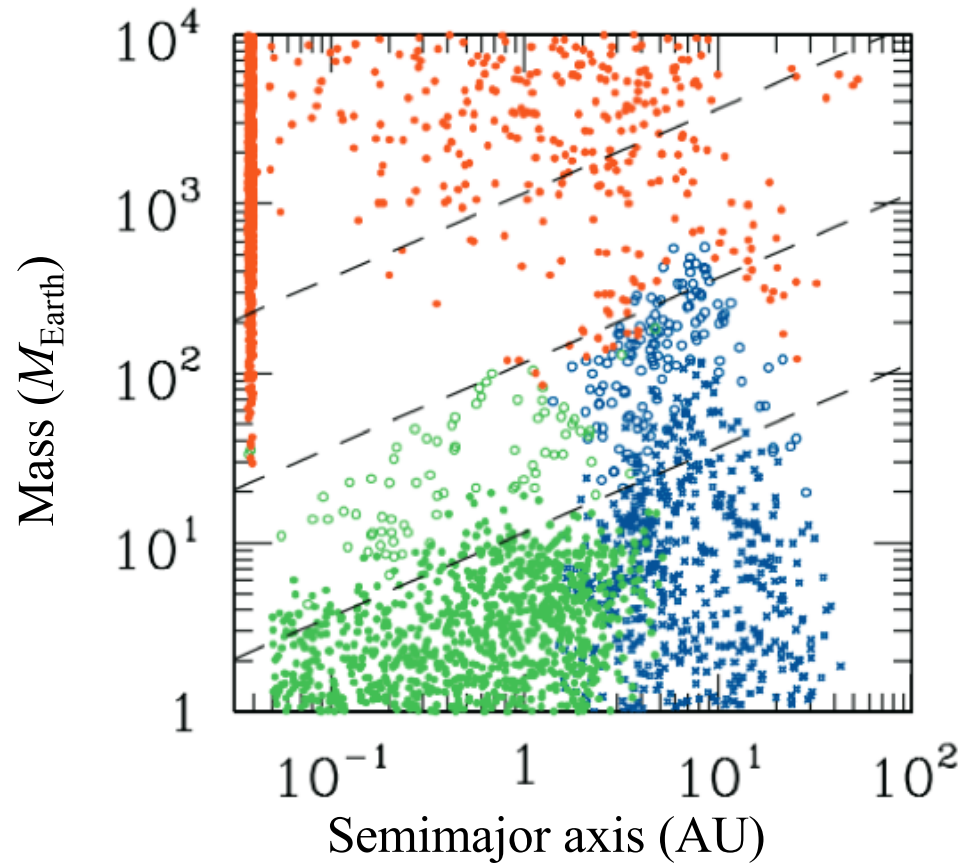
Microlensing planet distribution



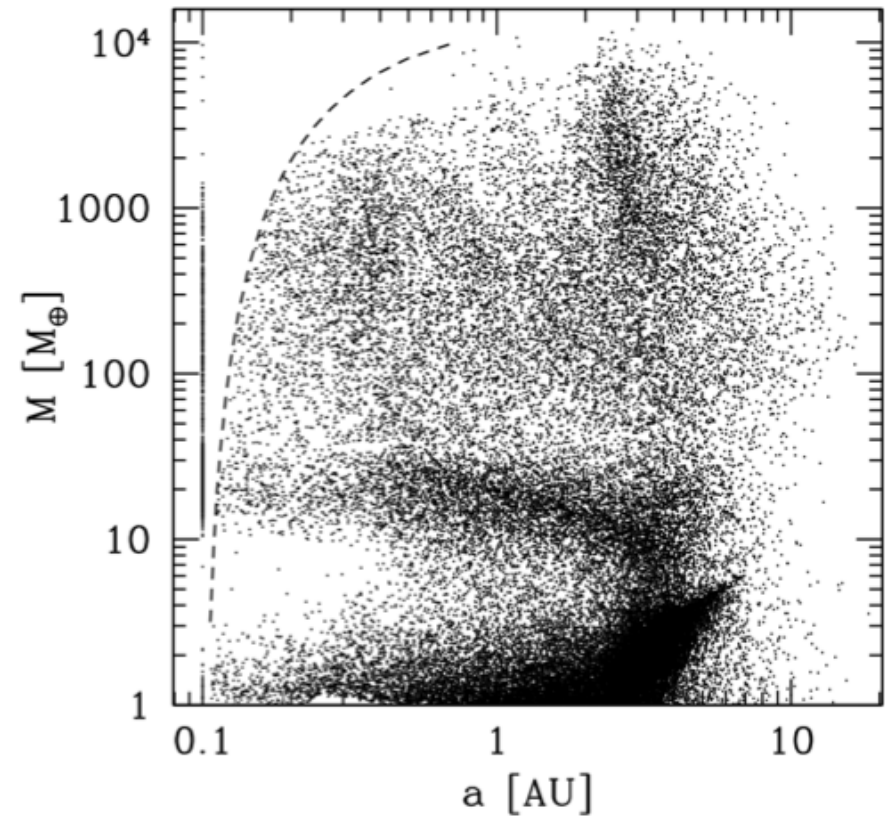
30 planets detected in 6yr MOA survey,
4yr μ FUN survey (Gould+10) and 6yr PLANET survey (Cassan+12)

Population Synthesis

Ida & Lin Model
(e.g., Ida & Lin 2004)



Bern Model
(e.g., Mordasini et al. 2009)



Method

Population synthesis (by S.Ida, C.Mordasini)

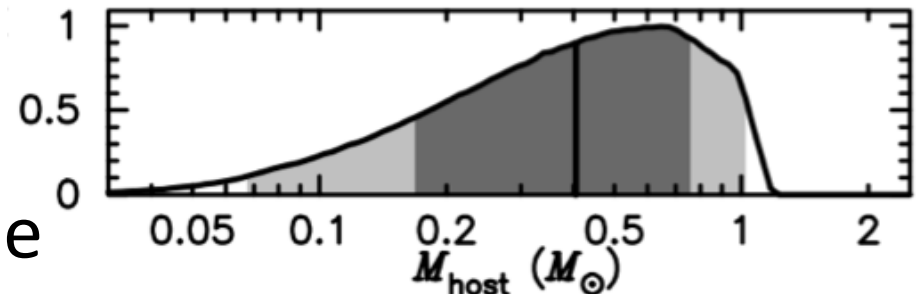
- Host star mass
 - $\log M = \{-1.30, -1.15, \dots, -0.25, -0.10\}$ for Ida & Lin Model
 - $\log M = \{-0.90, -0.60, -0.30, 0.00\}$ for Bern Model
- a few ~ 10 thousand systems in each host mass

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Randomly collect the simulated planetary systems to get average planetary distribution on s - q plane



Comparison1:

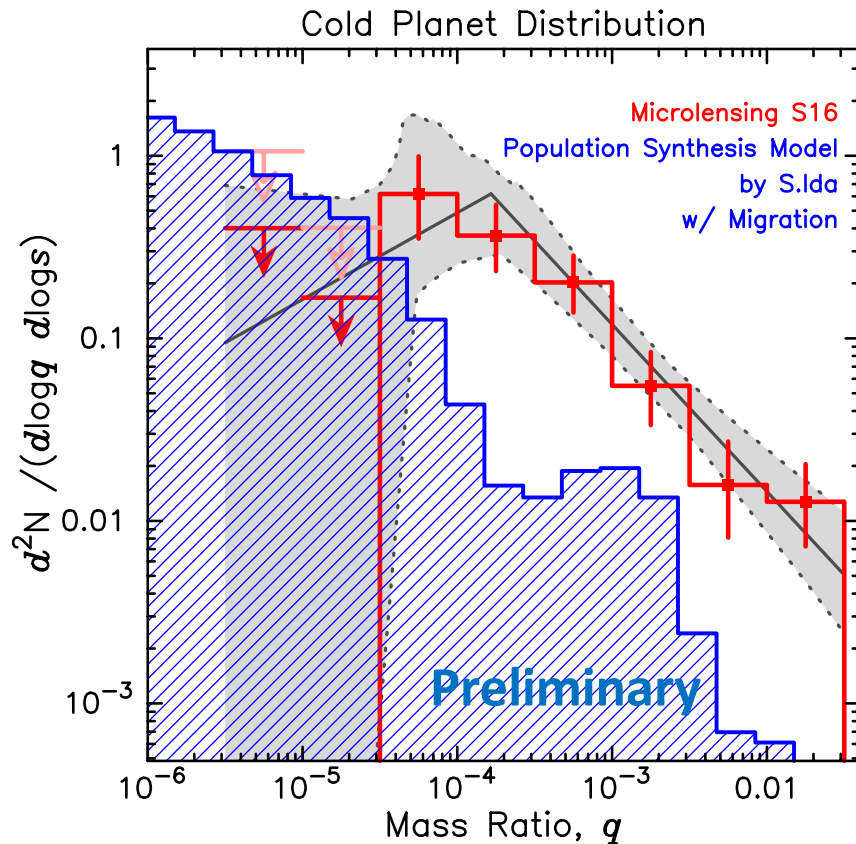
Simulated planet distribution vs. Mass Ratio function

Comparison2:

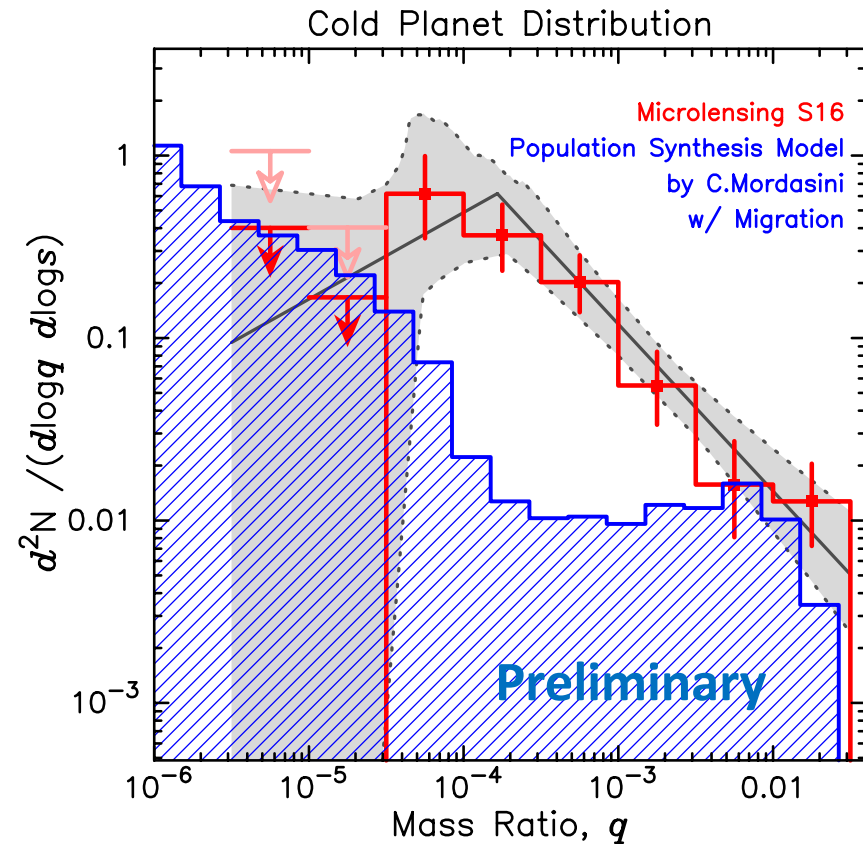
Expected planet distribution vs. Observed planet distribution

Comp1: Pop. synthesis vs. q -function

Ida & Lin Model



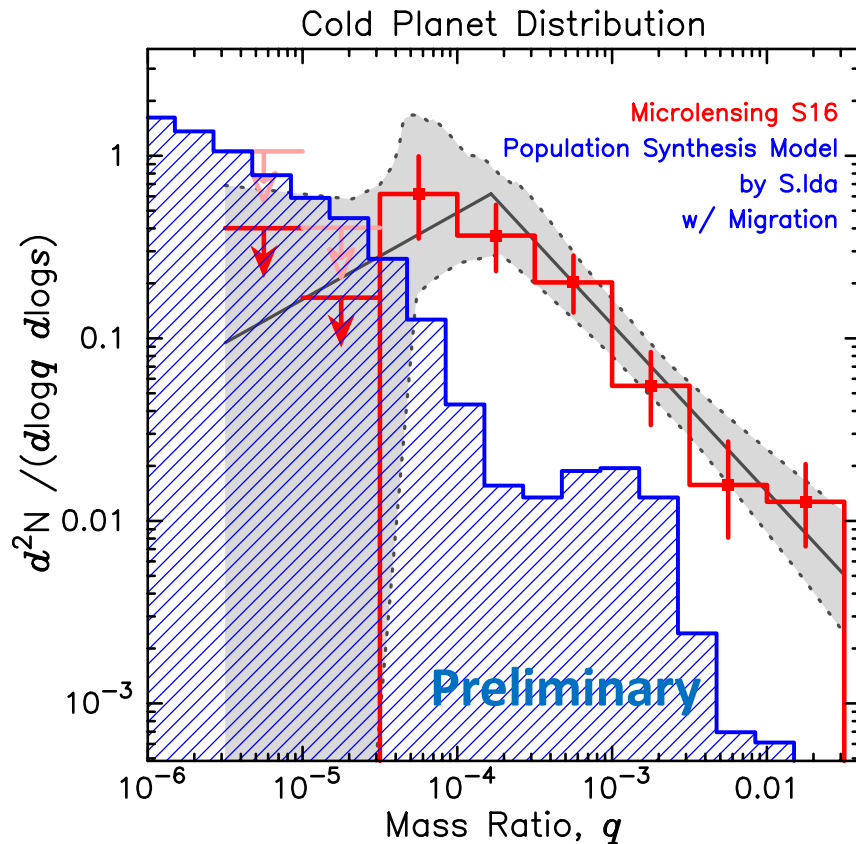
Bern Model



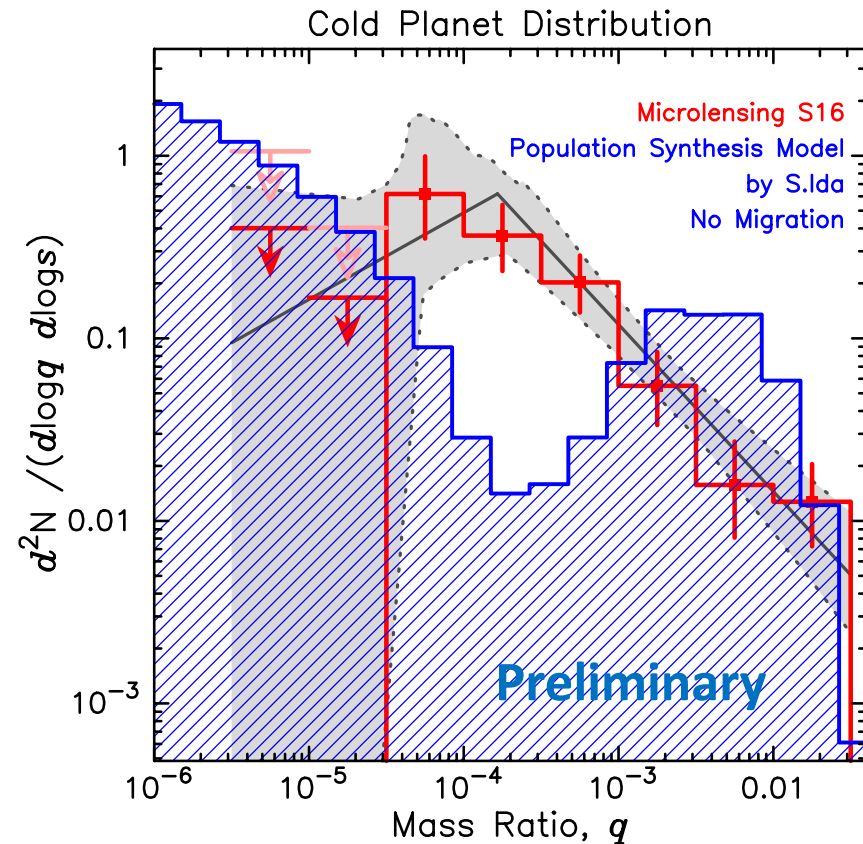
~factor 25 difference at $q \sim 3 \times 10^{-4}$,
i.e, around $50 M_{\text{Earth}}$

Comp1: w/ and w/o planet migration

Ida & Lin Model



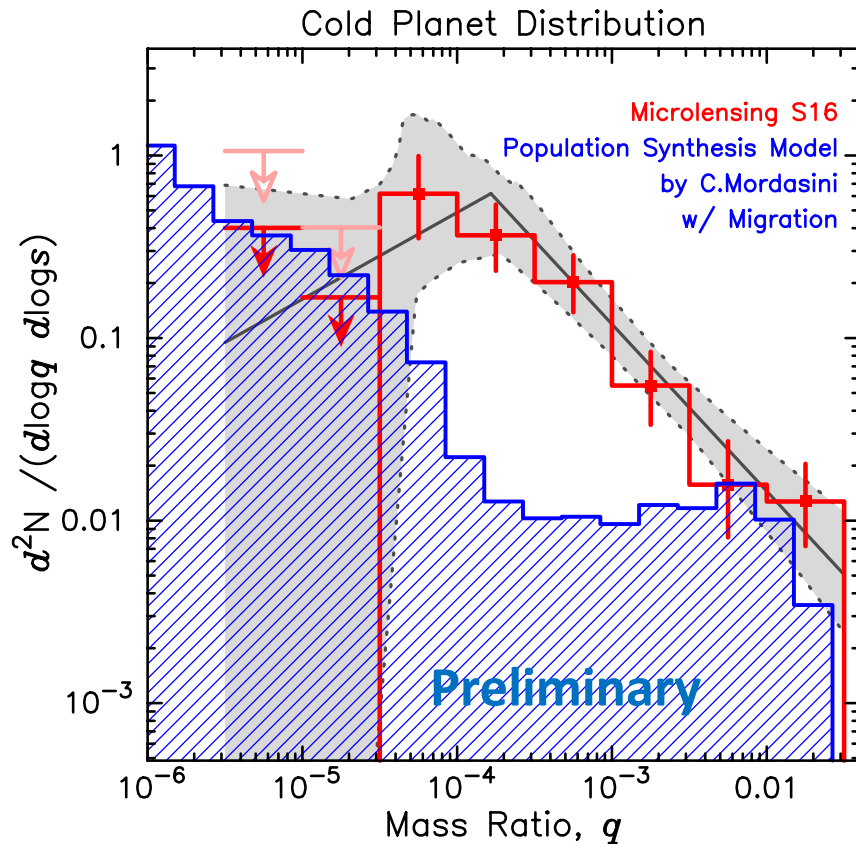
Ida & Lin Model No Migration



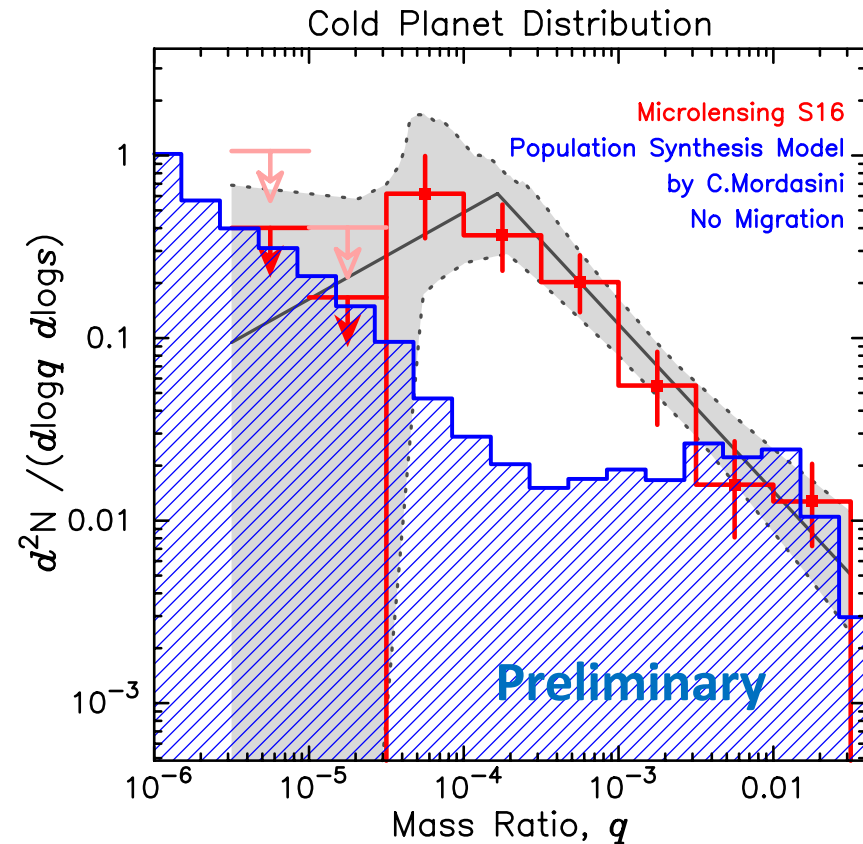
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Bern Model



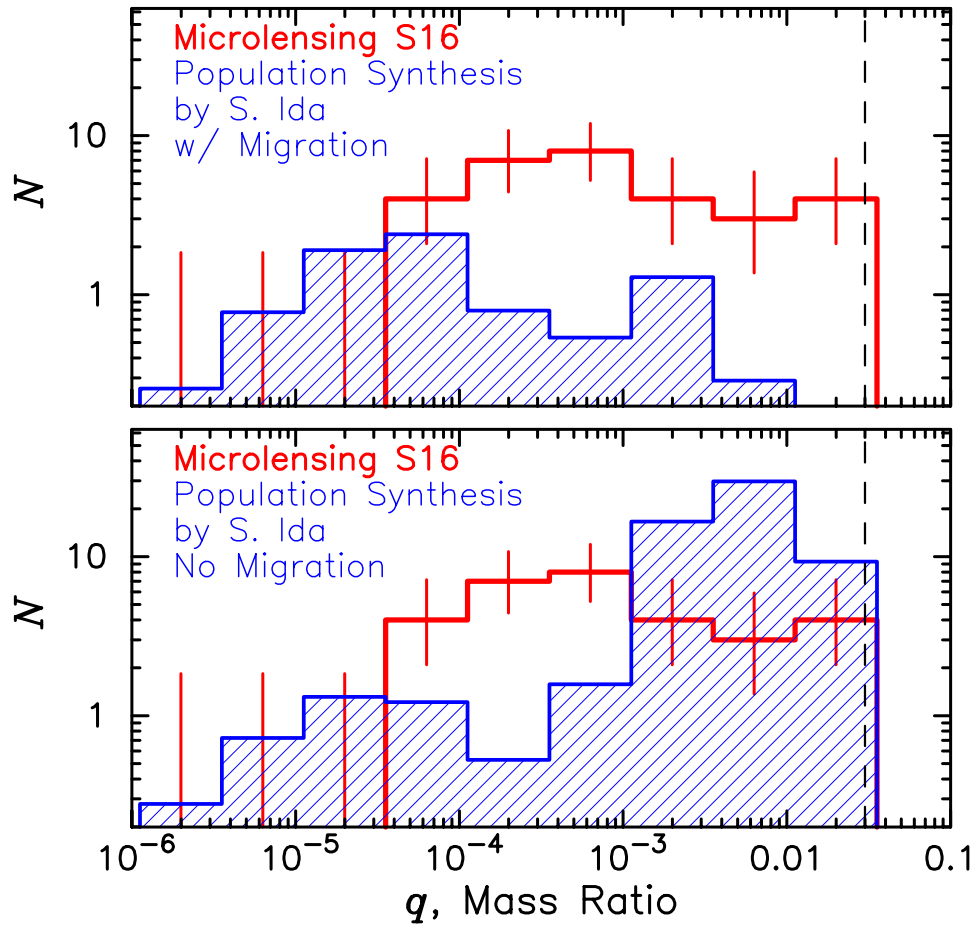
Bern Model No Migration



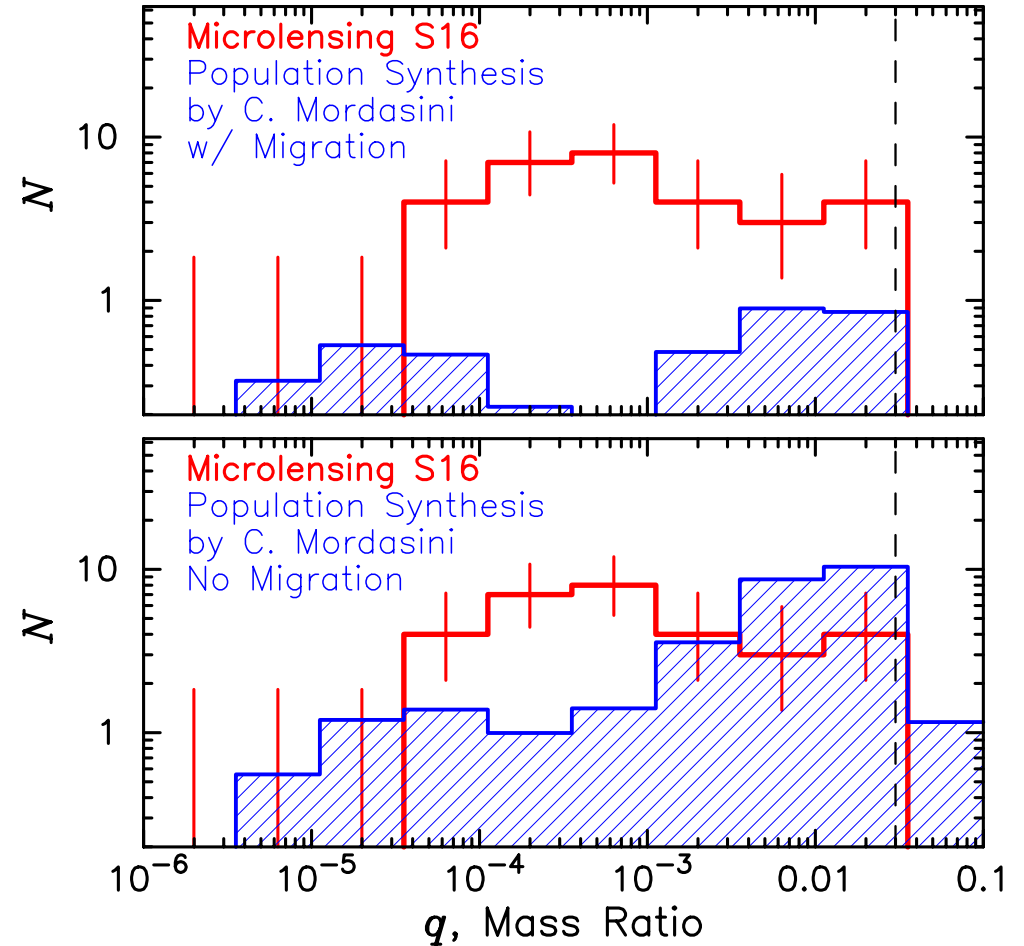
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Comp2: expected vs. observed (Preliminary)

Ida & Lin Model



Bern Model



Comp2 is better for the simple comparison with the Poisson probability.

Conclusion

- **No sub-Saturn mass gap is observed beyond the snow line**
- \sim factor 25 difference in planet frequency between the observations and population synthesis model around $50 M_{\text{Earth}}$
- Changing migration fraction does NOT explain the discrepancy
- Need new theories for the cold planet formation?
- Definitely we need more microlensing planets with mass measurements to estimate the cold planet mass function rather than mass ratio