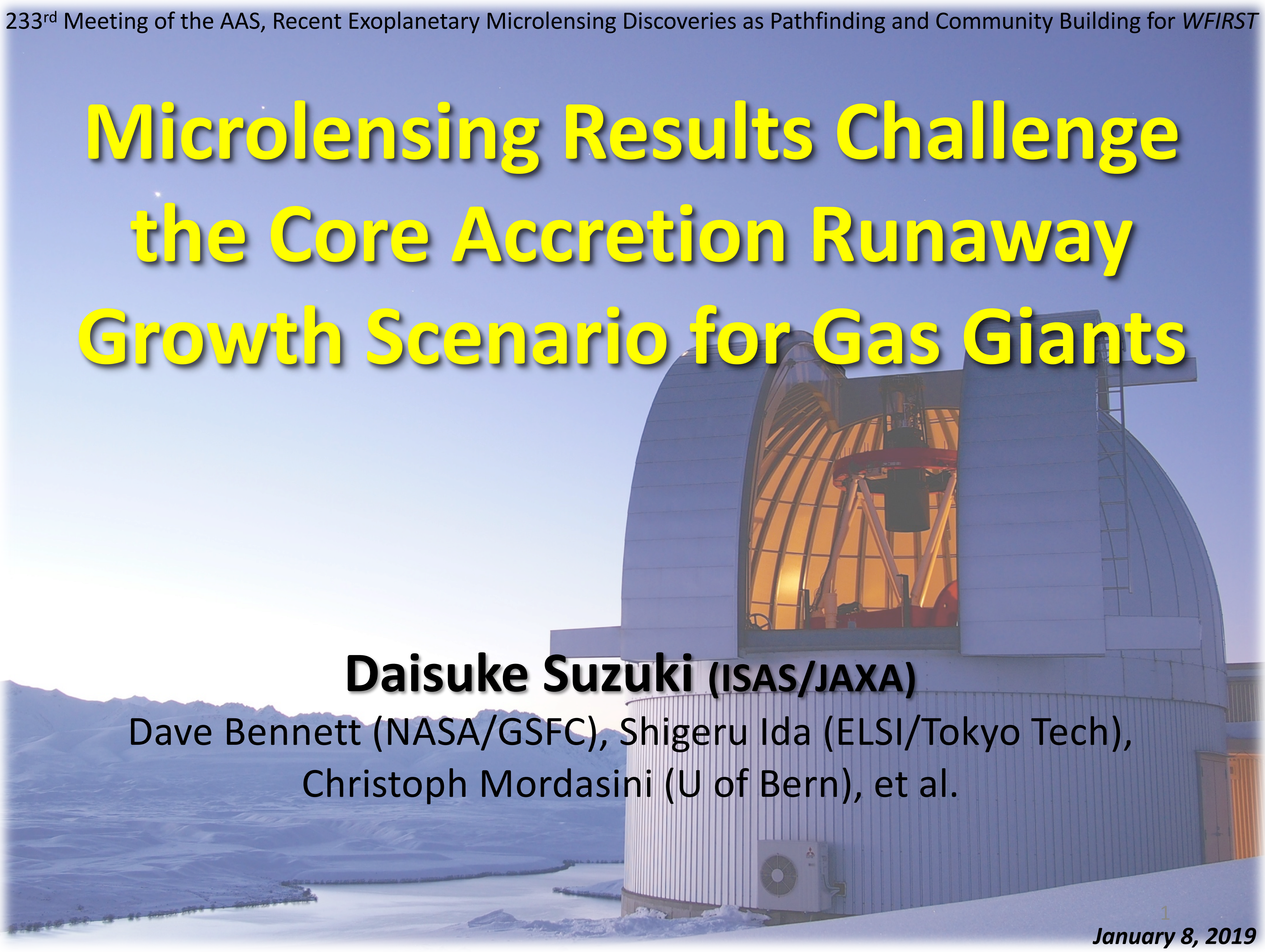
233rd Meeting of the AAS, Recent Exoplanetary Microlensing Discoveries as Pathfinding and Community Building for *WFIRST*



Microlensing Results Challenge the Core Accretion Runaway Growth Scenario for Gas Giants

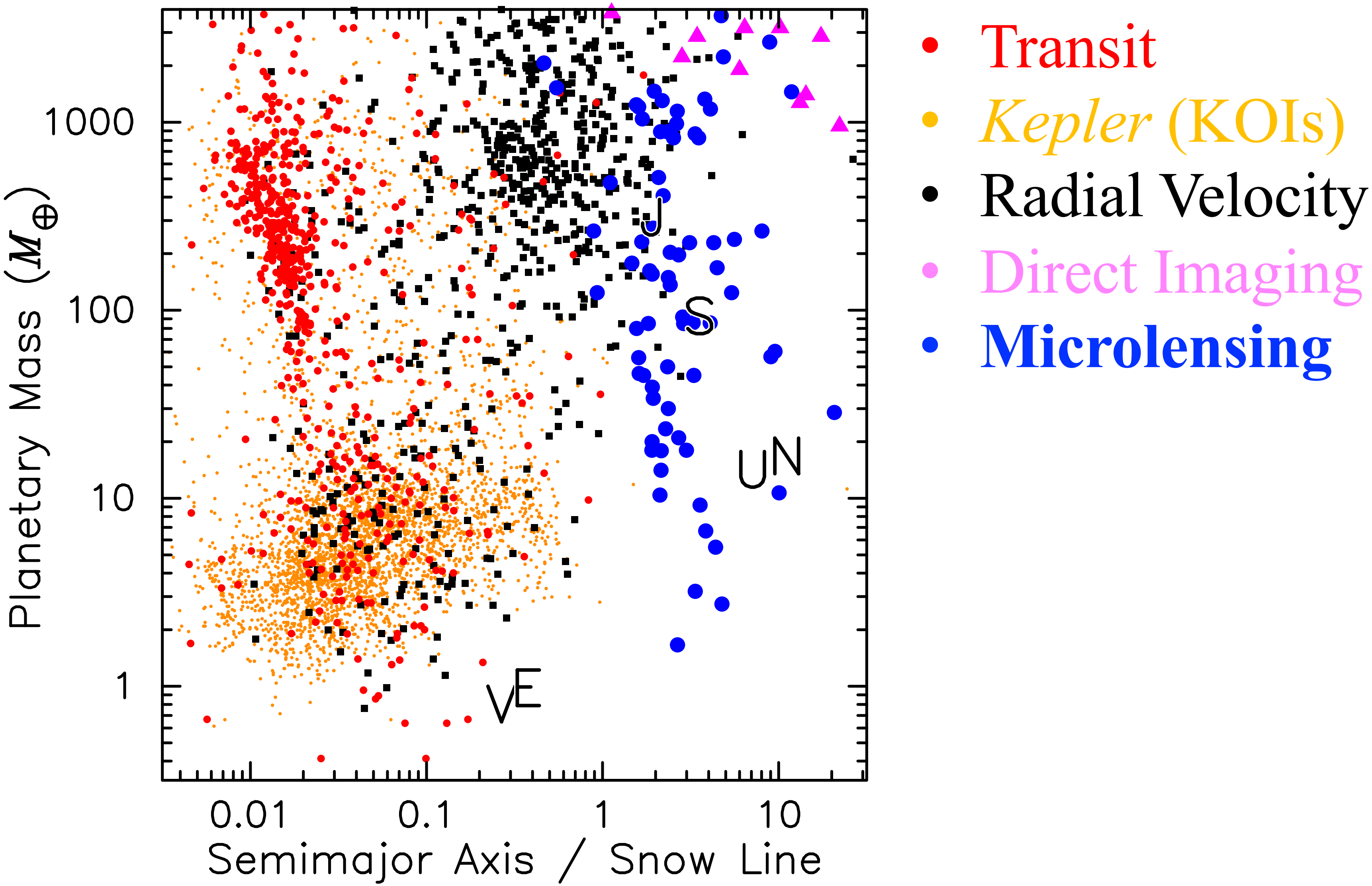
Daisuke Suzuki **(ISAS/JAXA)**

Dave Bennett (NASA/GSFC), Shigeru Ida (ELSI/Tokyo Tech),

Christoph Mordasini (U of Bern), et al.

January 8, 2019

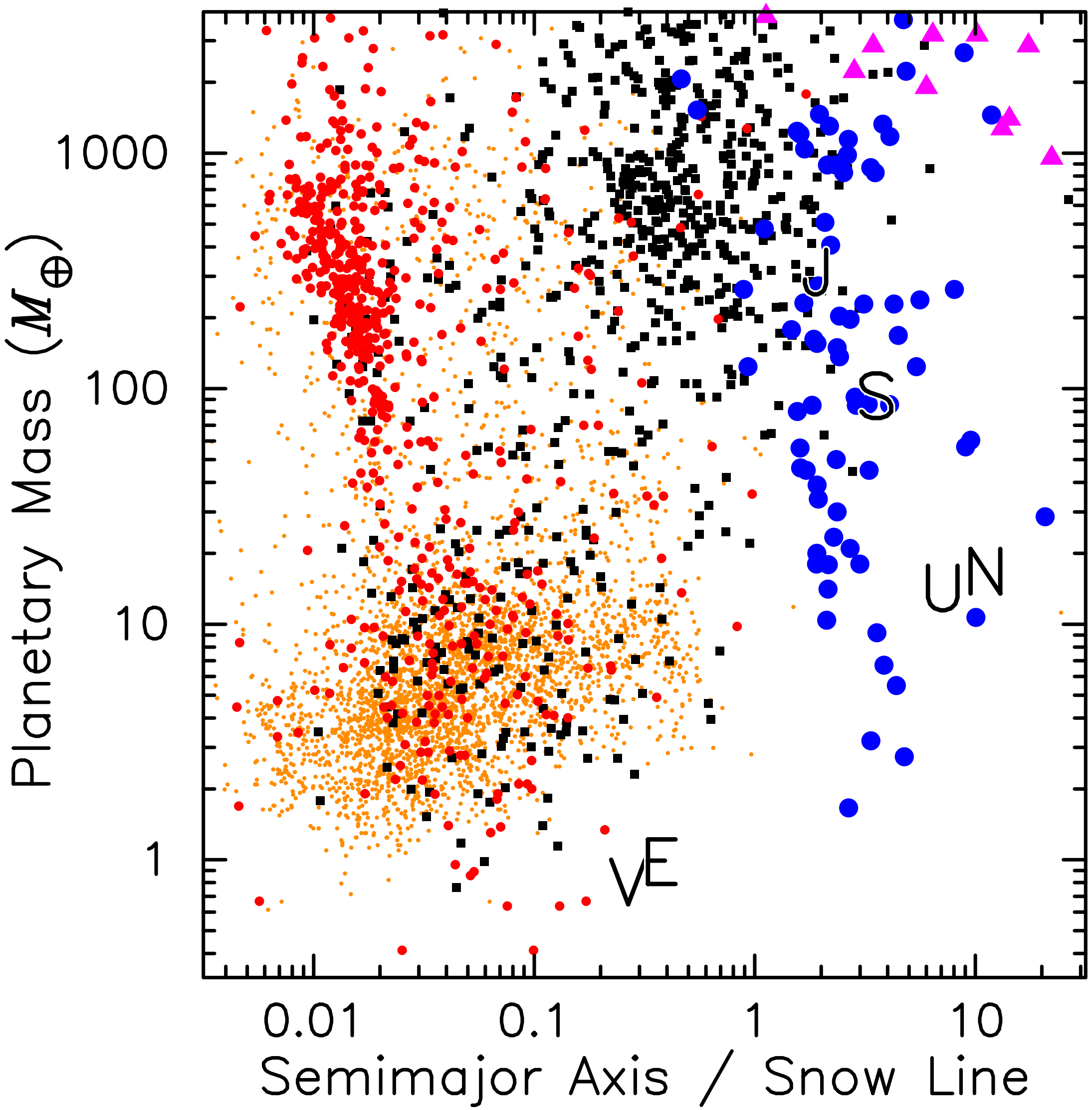
Planet Distribution



(NASA Exoplanet Archive, exoplanet.eu)

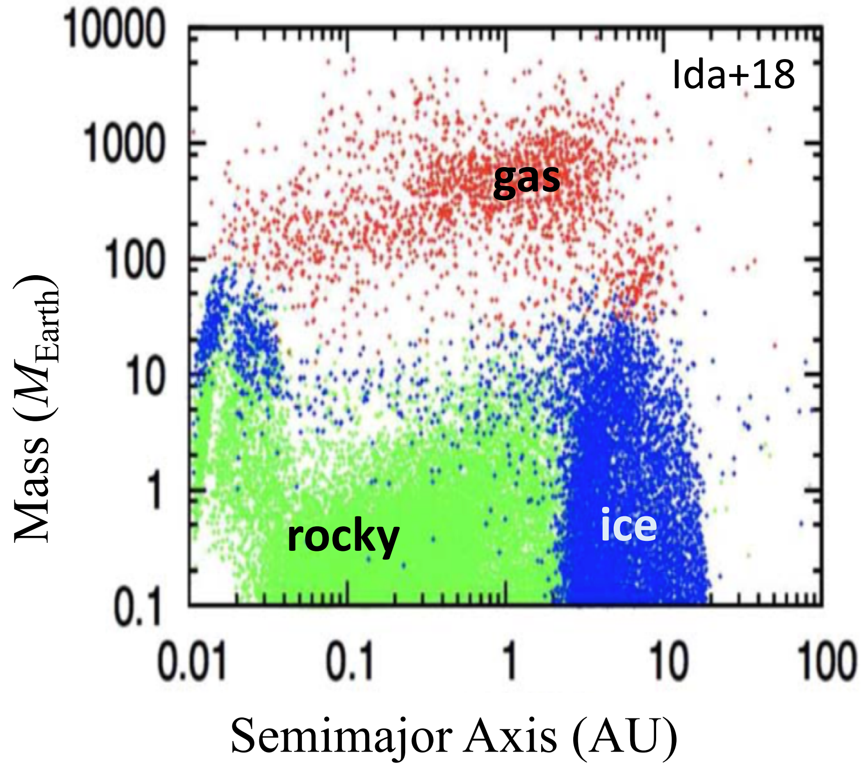
Snow line: $a_{snow} = 2.7\ (M/M_{Sun})$ AU

Planet Distribution

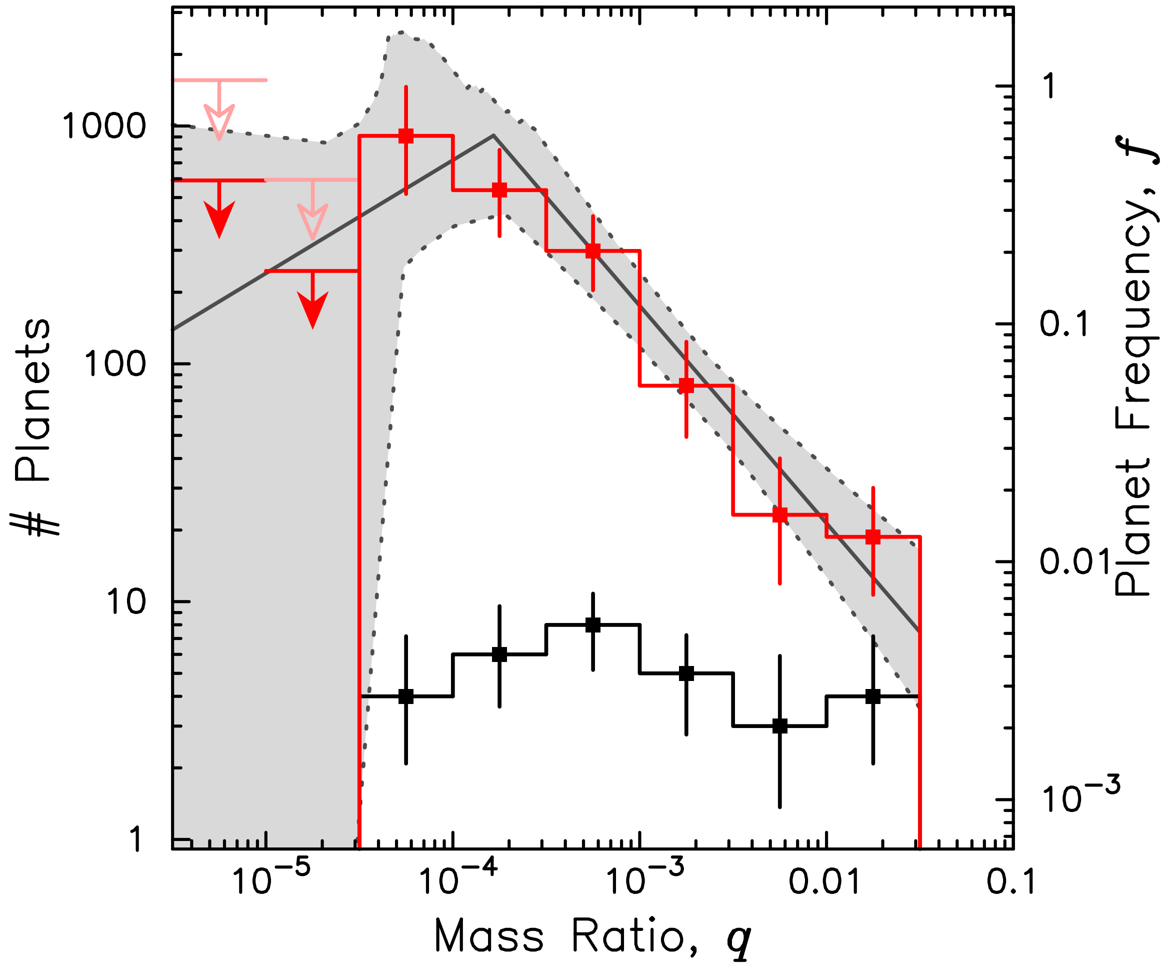


(NASA Exoplanet Archive, exoplanet.eu)

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



Microlensing Planet Distribution

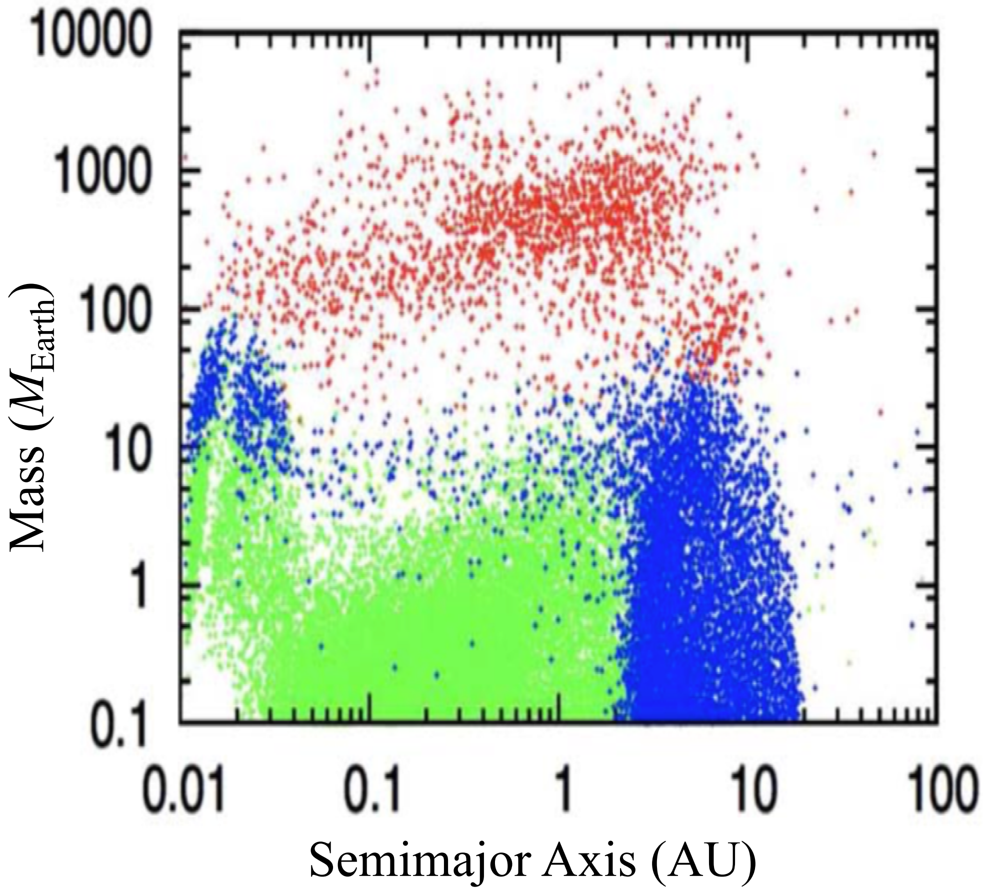


(Suzuki+16: S16)

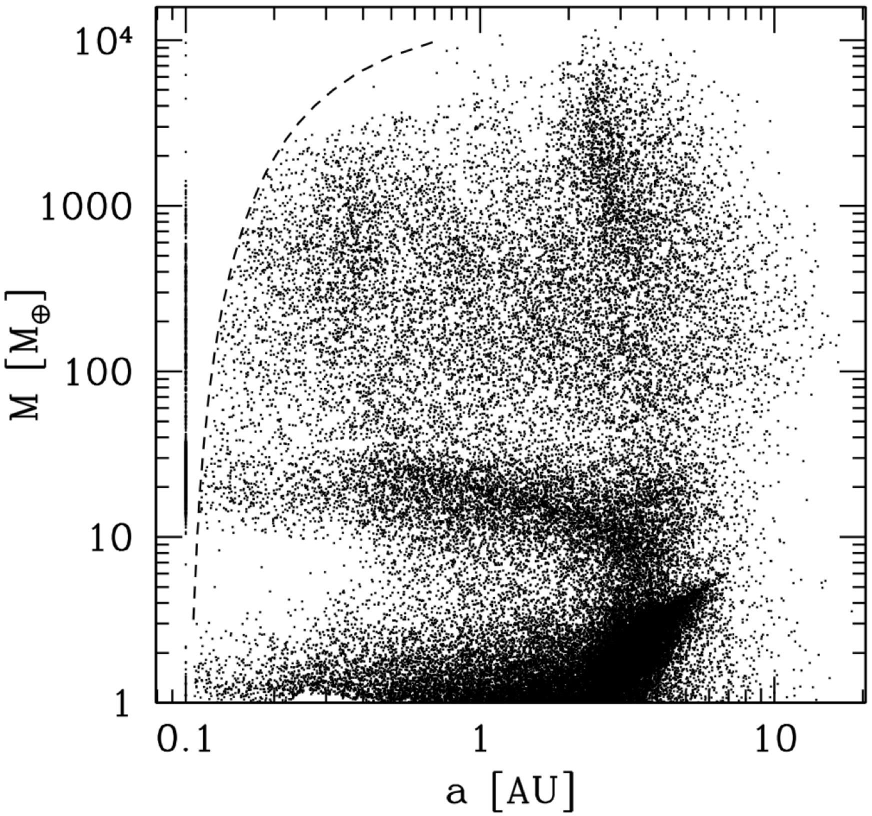
30 planets detected in 6yr MOA survey,
4yr µFUN survey (Gould+10) and 6yr PLANET survey (Cassan+12)

Population Synthesis

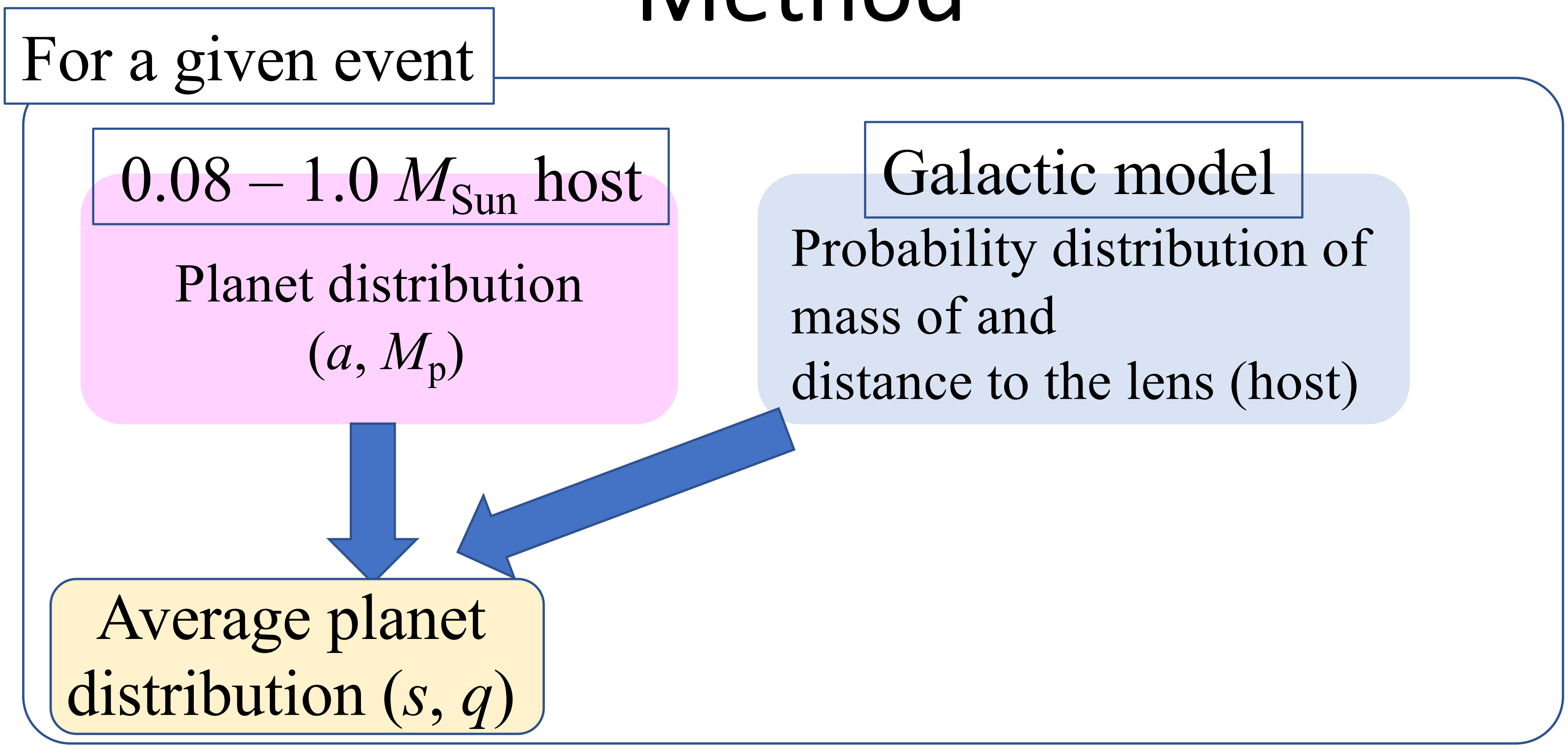
Ida & Lin Model
(e.g., Ida & Lin 04, Ida+18)



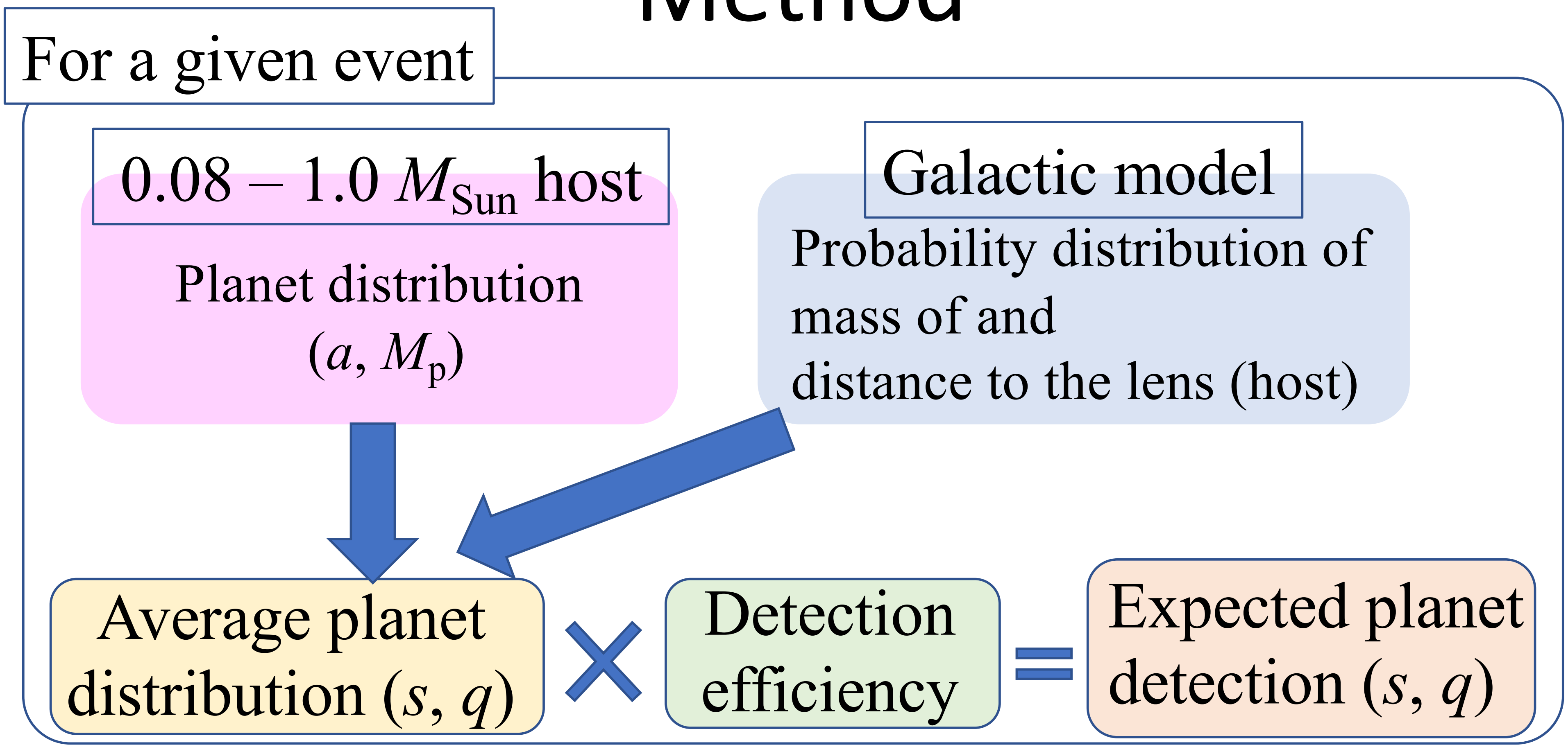
Bern Model
(e.g., Mordasini et al. 09)



Method


For a given event
0.08 – 1.0 M_{Sun} host
Planet distribution
(a, M_{p})
Galactic model
Probability distribution of mass of and distance to the lens (host)
Average planet distribution (s, q)

Method


For a given event
0.08 – 1.0 M_{Sun} host
Planet distribution
(a, M_{p})
Galactic model
Probability distribution of
mass of and
distance to the lens (host)
Average planet
distribution (s, q)
×
Detection
efficiency
=
Expected planet
detection (s, q)

Method

For a given event

0.08 – 1.0 M_{Sun} host

Planet distribution
(a, M_p)

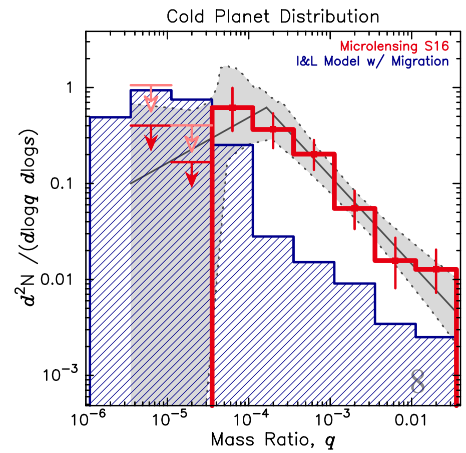
Galactic model

Probability distribution of
mass of and
distance to the lens (host)

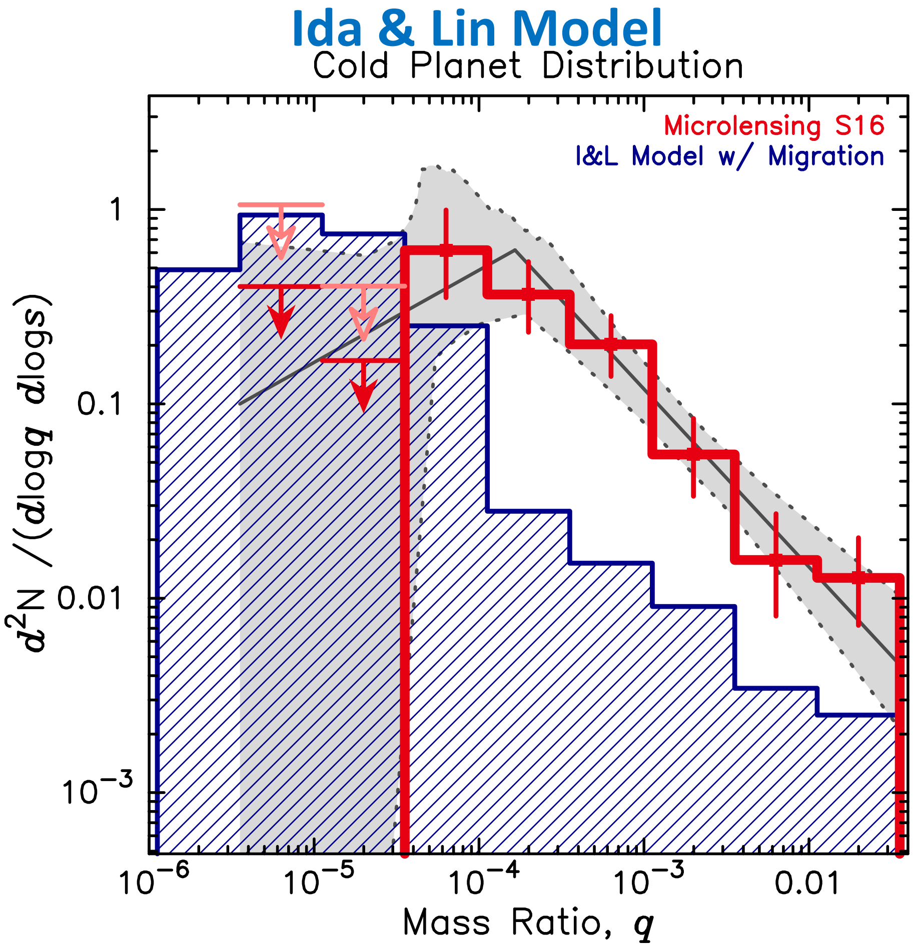
Average planet distribution (s, q) × Detection efficiency = Expected planet detection (s, q)

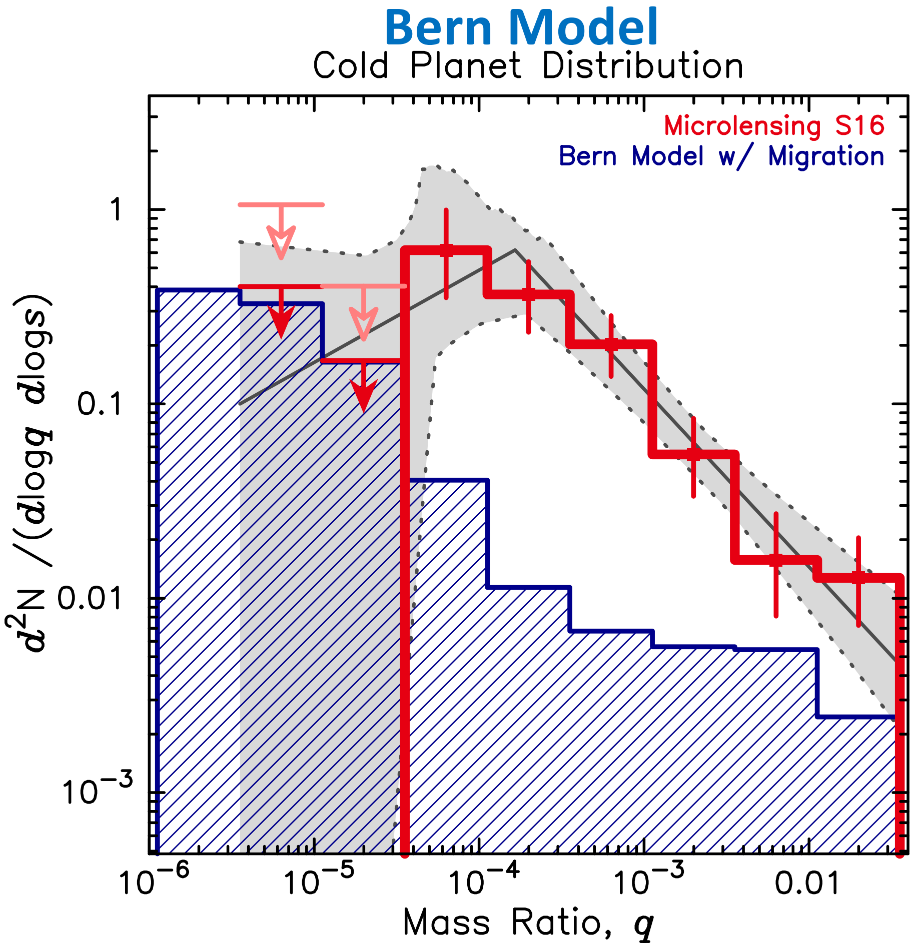
Sum of each of 1640 events yields the expected # of planet detections in S16

Detection efficiency correction



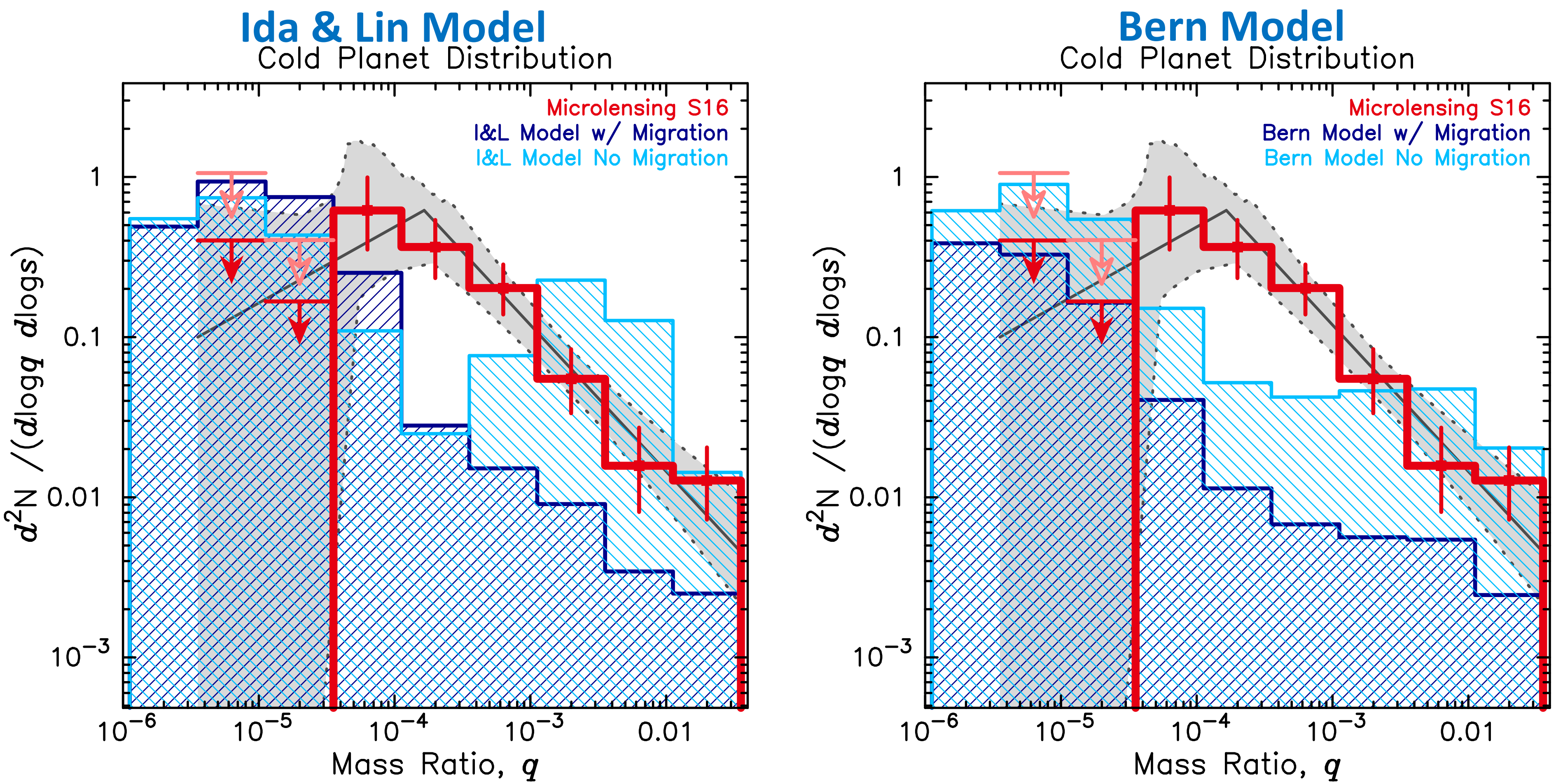
Default Pop. Synthesis vs. *q*-function





IL and Bern models expect consistently smaller number of cold planets

w/ and w/o Planet Migration

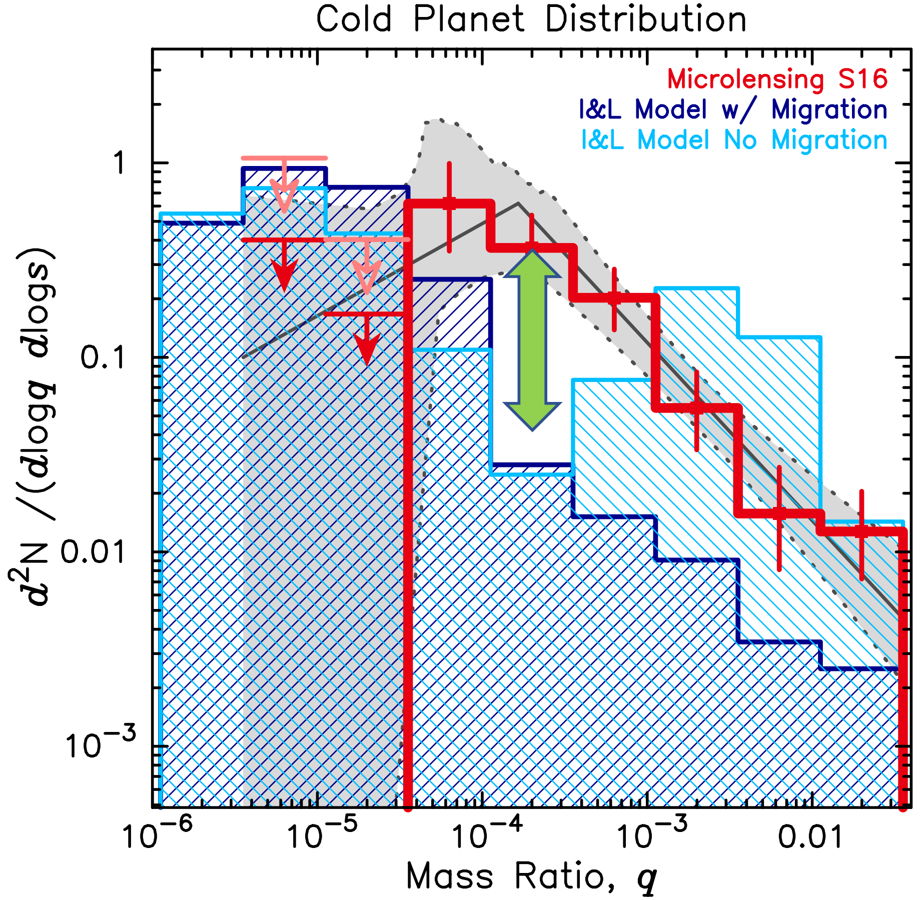


~factor 10 difference at $1\times10^{-4} < q < 4\times10^{-4}$;

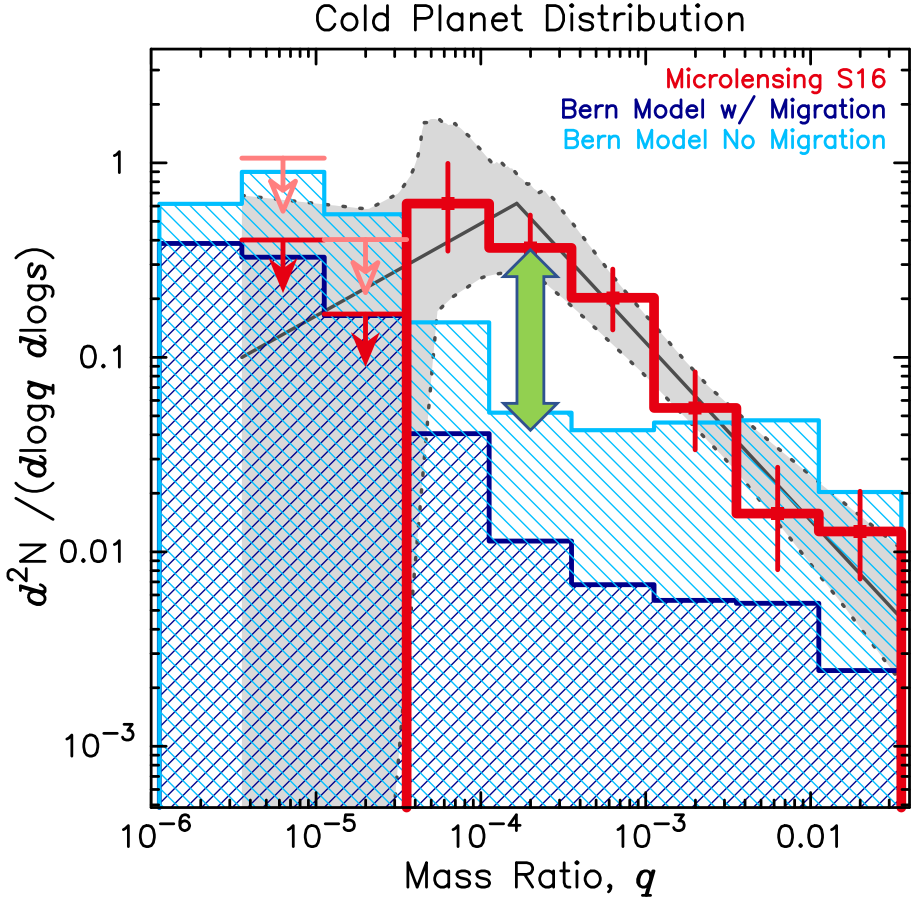
20-80 M_{Earth} for median 0.6 M_{Sun} host

w/ and w/o Planet Migration

Ida & Lin Model

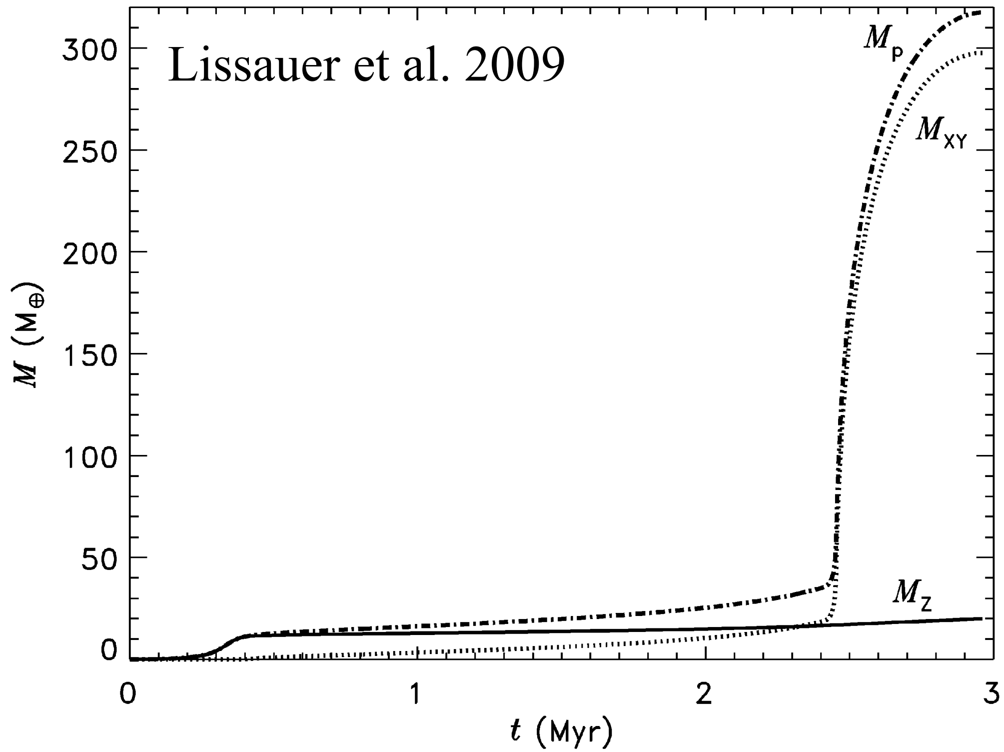


Bern Model



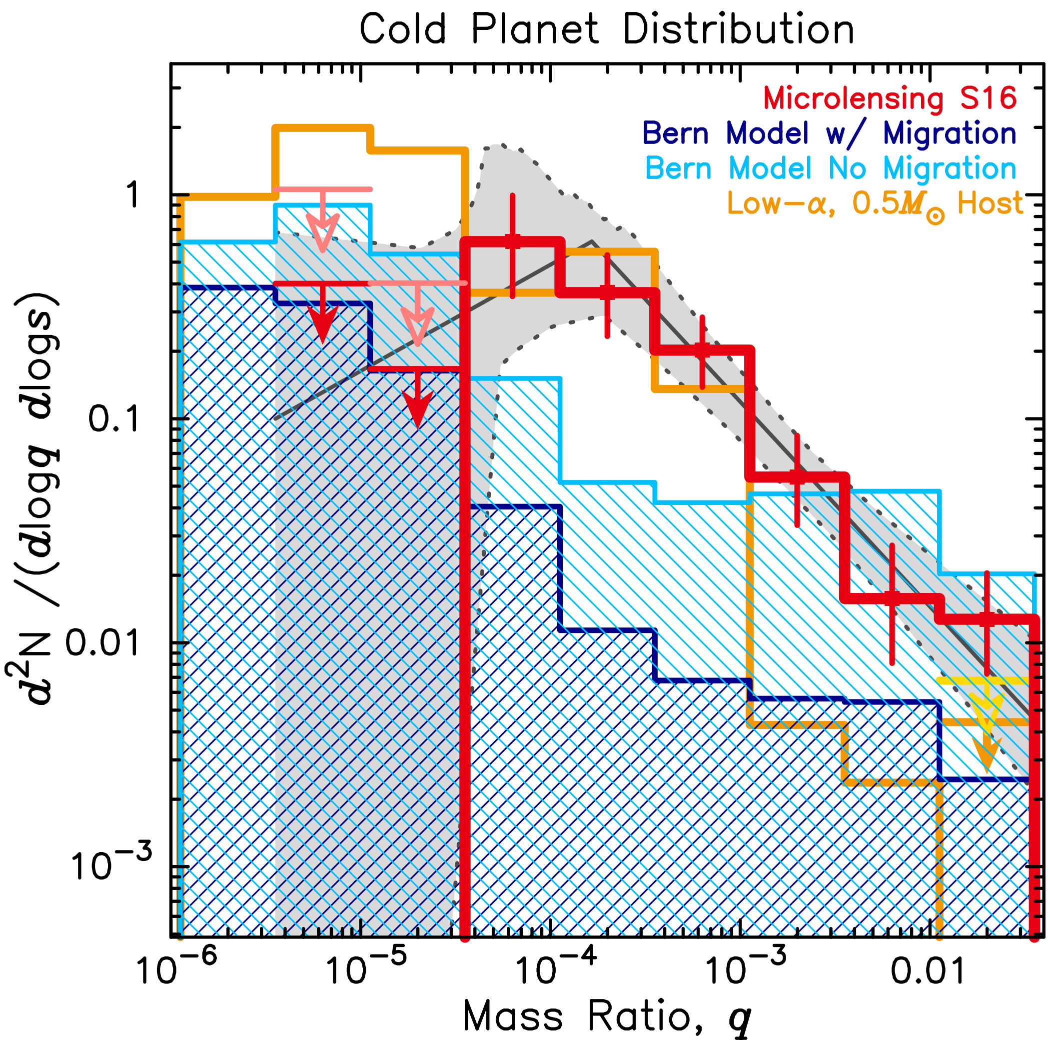
~factor 10 difference at $1\times10^{-4} < q < 4\times10^{-4}$;
20-80 M_{Earth} for median 0.6 M_{Sun} host

Runaway gas accretion



- Core accretion holds that rock-ice cores of $M_Z \sim 10$ M_{Earth} form beyond the snow line
- Cores begin to slowly accrete H & He gas (M_{XY})
- When $M_{XY} \sim M_Z$, exponential "runaway" growth begins

Low α-viscosity Bern Model

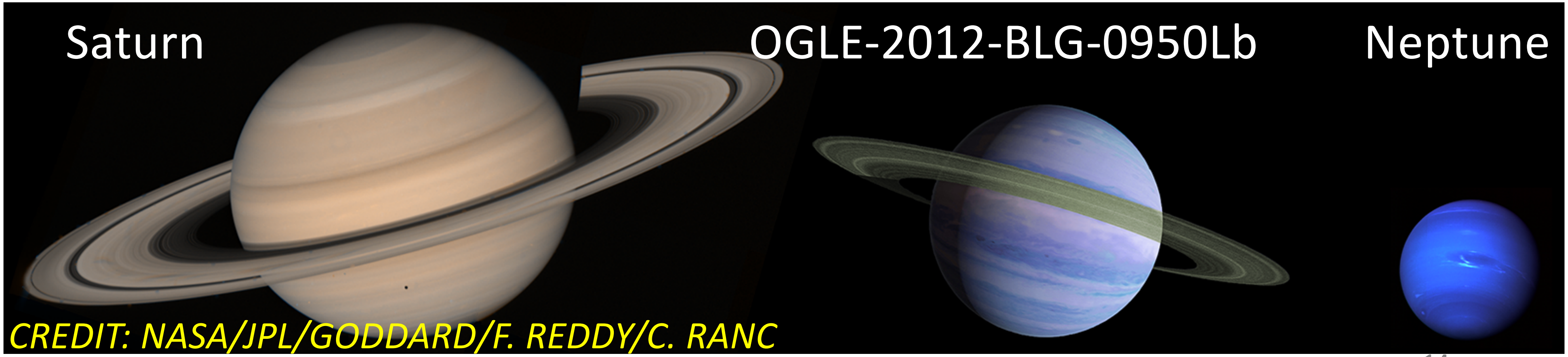


The low α-viscosity model is NOT consistent with the data at q~10^{-5} and 10^{-2} for Bern model.

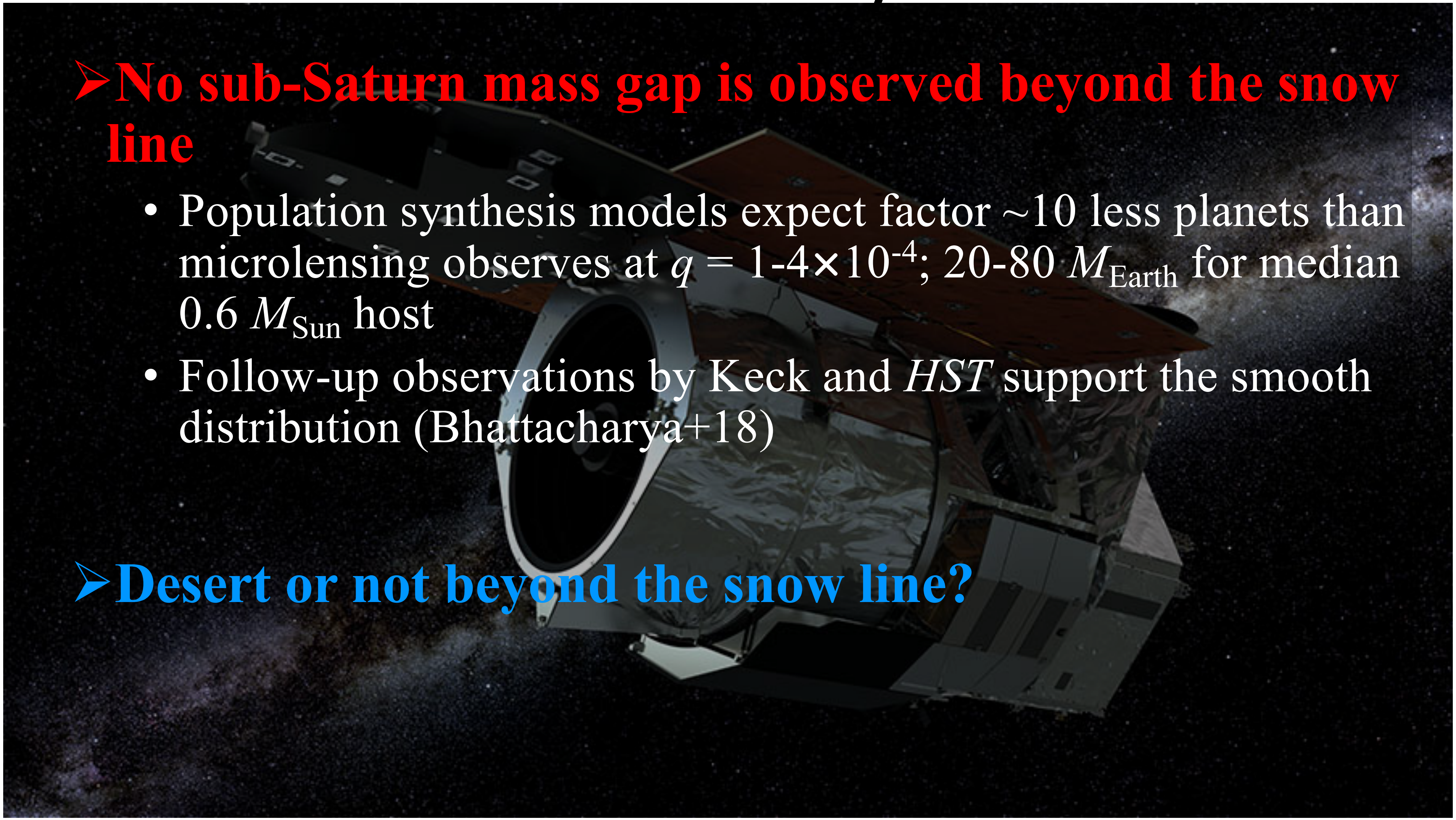
Measured cold-planet masses in the middle of the expected desert

- ➢The desert (20-80 $M_{\rm Earth}$) could be smoothed out by a range of host masses
- ➢One of S16 sample, OGLE-2012-BLG-0950Lb has a mass of **39 ± 8 $M_{\rm Earth}$** around a 0.6 $M_{\rm Sun}$ host (Bhattacharya+18)
  - ❑See Aparna's poster #247.09

- ➢Another case from μlensing (Beaulieu+16) and two from RV sample (Mayor+11)



Summary



- **No sub-Saturn mass gap is observed beyond the snow line**
  - Population synthesis models expect factor ~10 less planets than microlensing observes at $q = 1\text{-}4\times10^{-4}$; 20-80 M_{Earth} for median 0.6 M_{Sun} host
  - Follow-up observations by Keck and *HST* support the smooth distribution (Bhattacharya+18)

- **Desert or not beyond the snow line?**

See Suzuki et al. 2018 ApJL (arXiv:1812.11785)

Conclusion

- No sub-Saturn mass gap is observed beyond the snow line
- Desert or not beyond the snow line?
- WFIRST will do the ultimate microlensing survey and mass measurement for most cases

See Suzuki et al. 2018 ApJL (arXiv:1812.11785)