

Exopag Talk
AAS 2020

Exoplanet Demographics of Wide Orbit Planets : Microlensing

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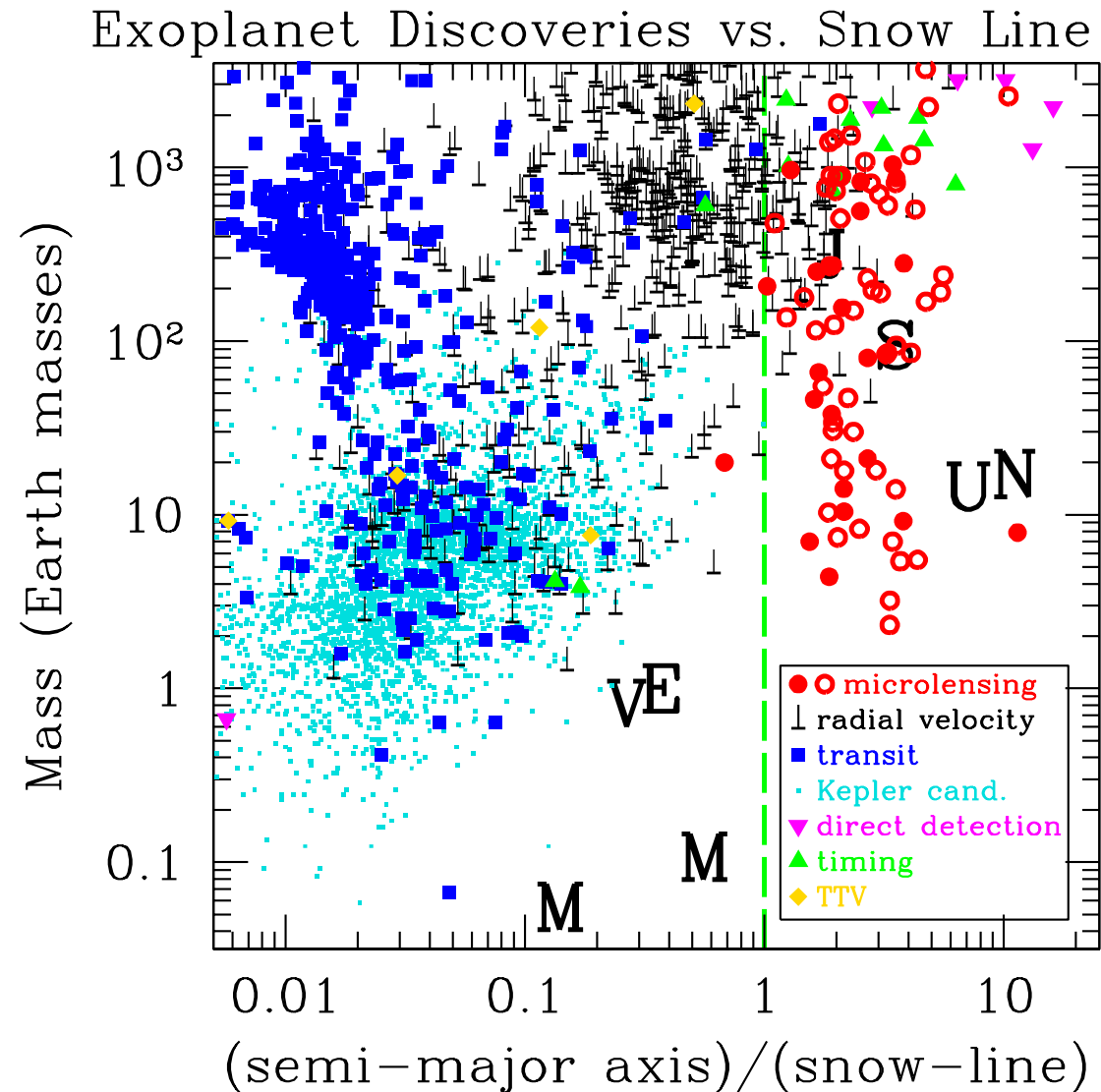
University of Maryland College Park

NASA Goddard Space Flight Center

Jan 03, 2020

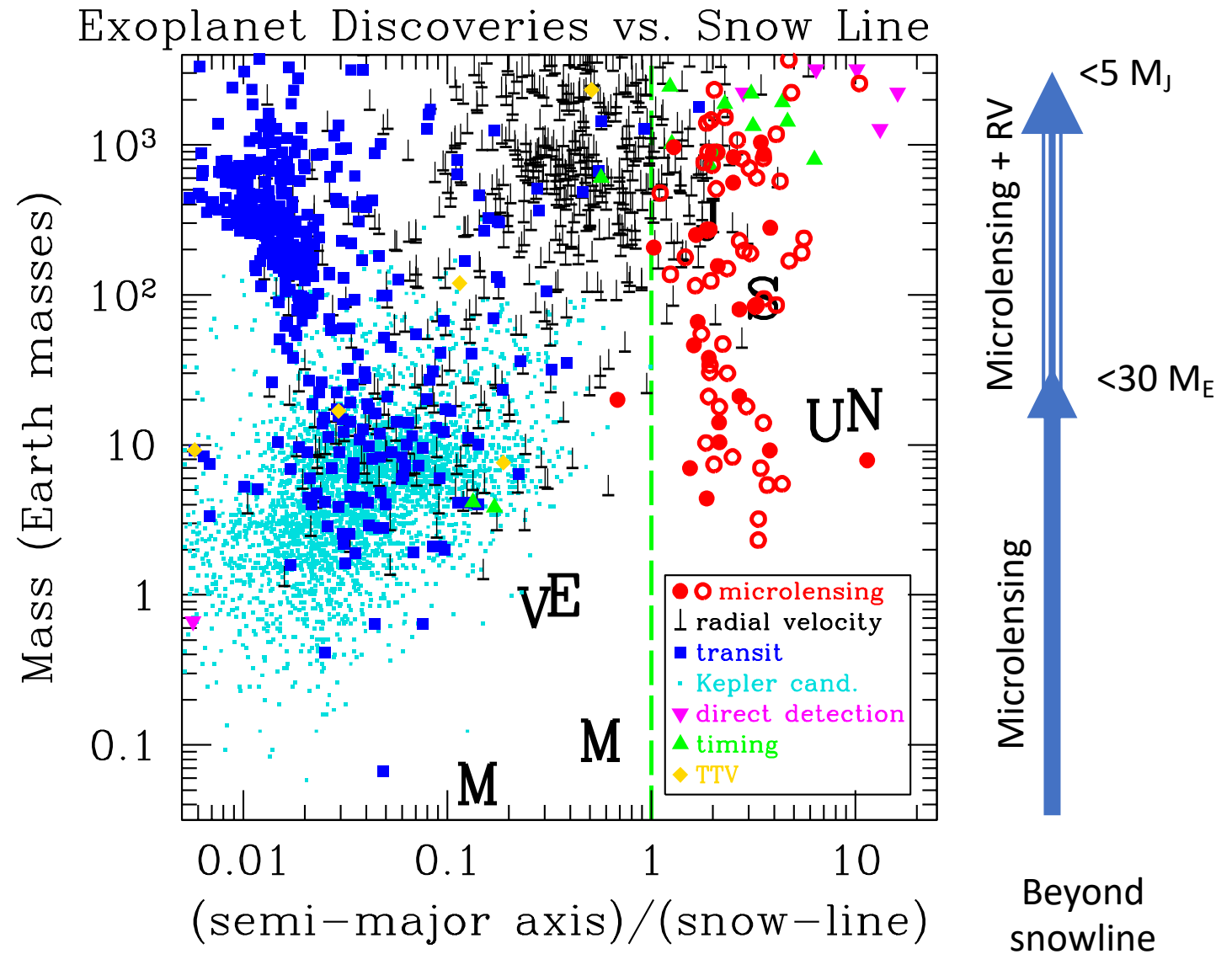
To determine wide orbit planet formation

- Step 1 : detect planets
- Step 2: statistical study of the observations to guide to the theory



To determine wide orbit planet formation

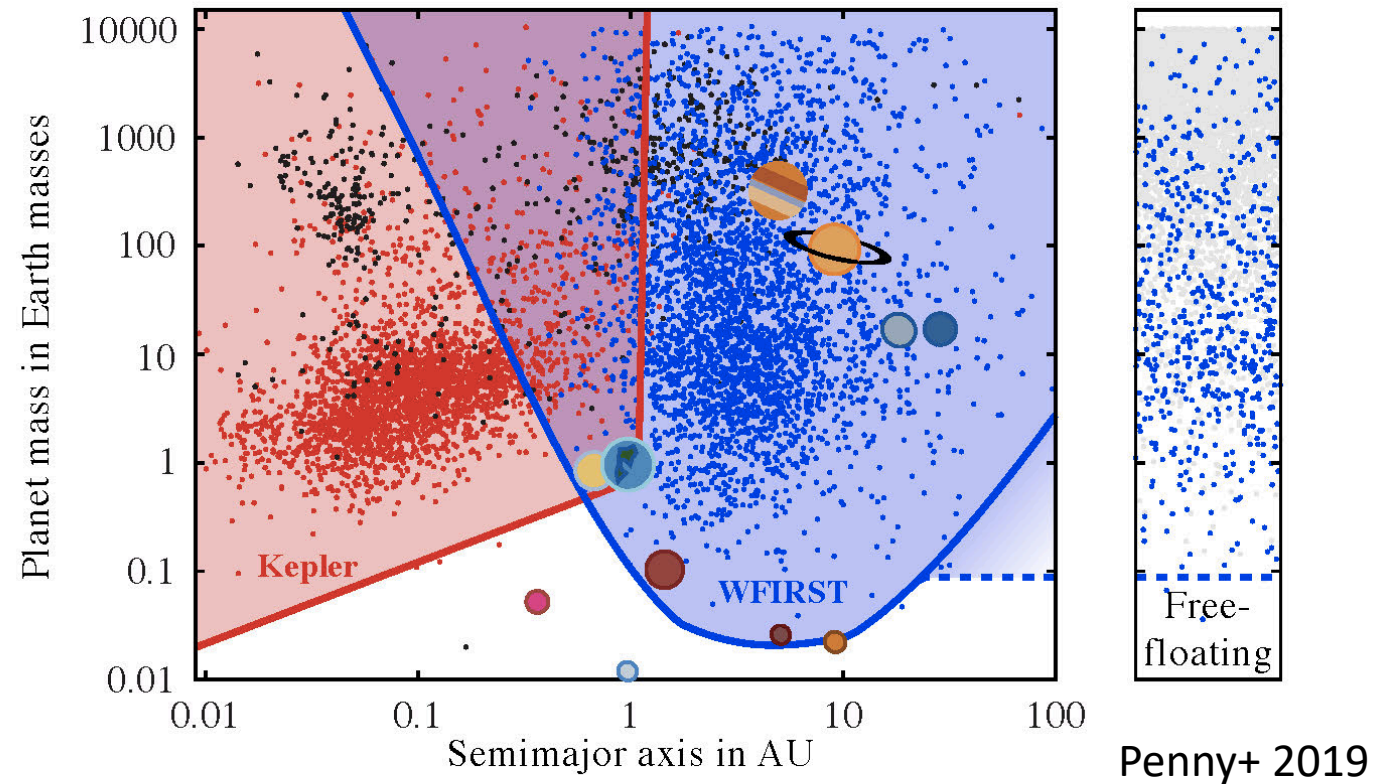
- These planets are considered to form beyond snowline
- They consist of both low mass and high mass planets
- Microlensing only method to detect low mass wide orbit planets



To determine wide orbit planet formation

- Can detect low-mass planets at low stellar lensing magnification which allows detection of planets further from the Einstein radius (wider range of separations, including the HZ).
- Detect host stars separating from sources to determine masses

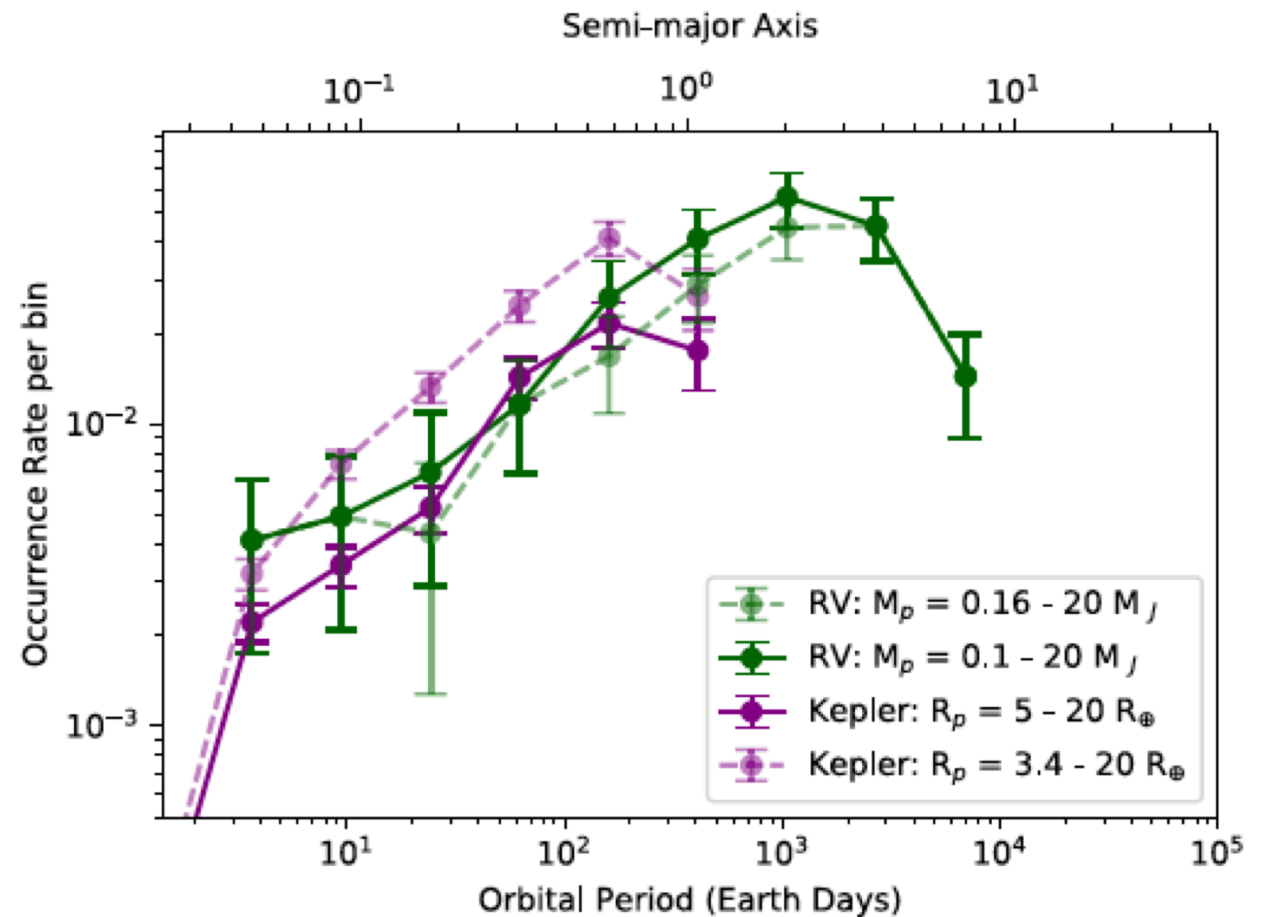
Space based microlensing survey with WFIRST



WFIRST (on track for Oct 2025 launch) will find >1000 such planets

RV statistics on wide orbit planets

- Most planets around 1AU separation
- Sensitive to very wide range of orbital separations
- This sample lacks host mass dependence
- The lowest planet mass is $\sim 30 M_E$ where RV sensitivity is low in wide orbit

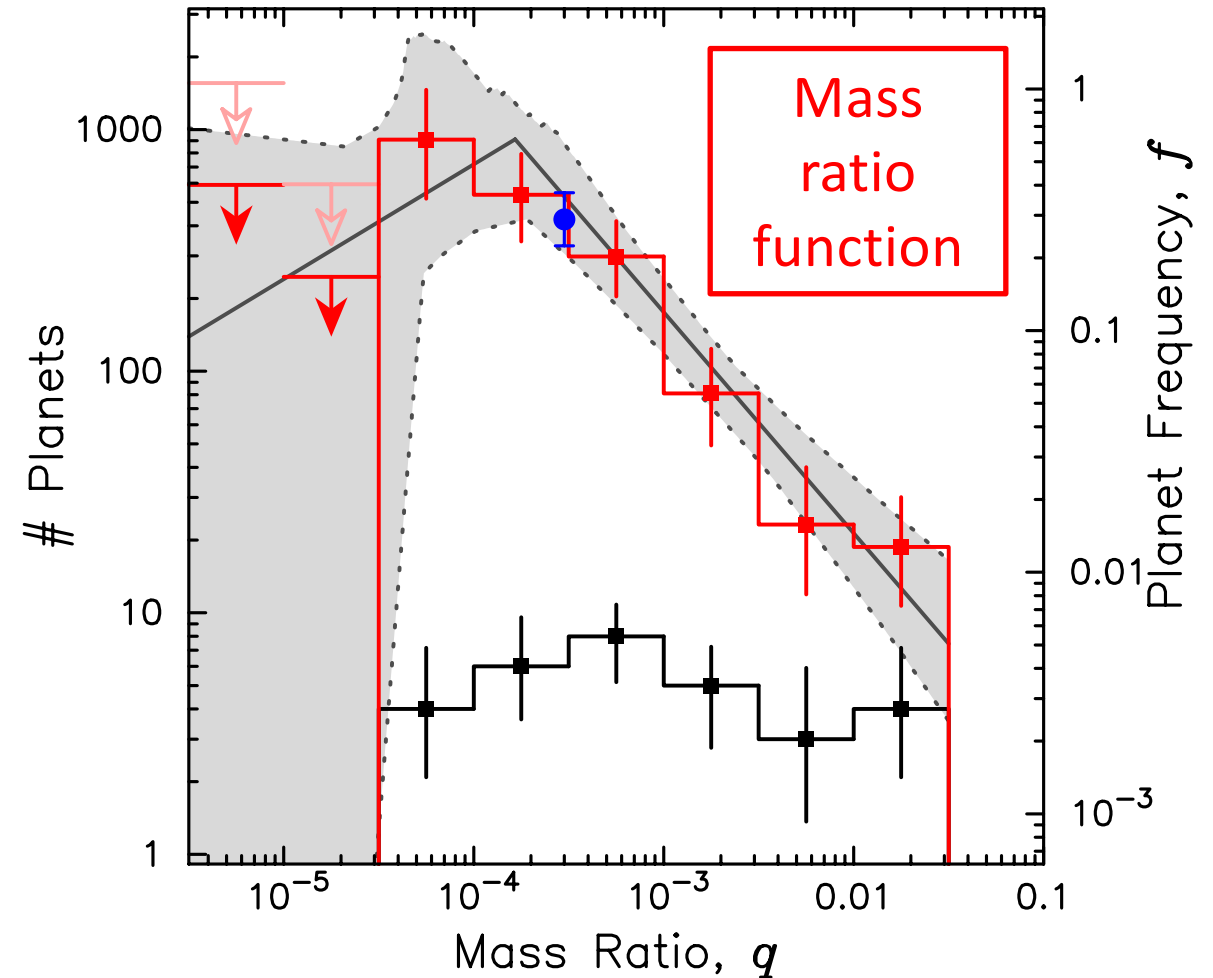
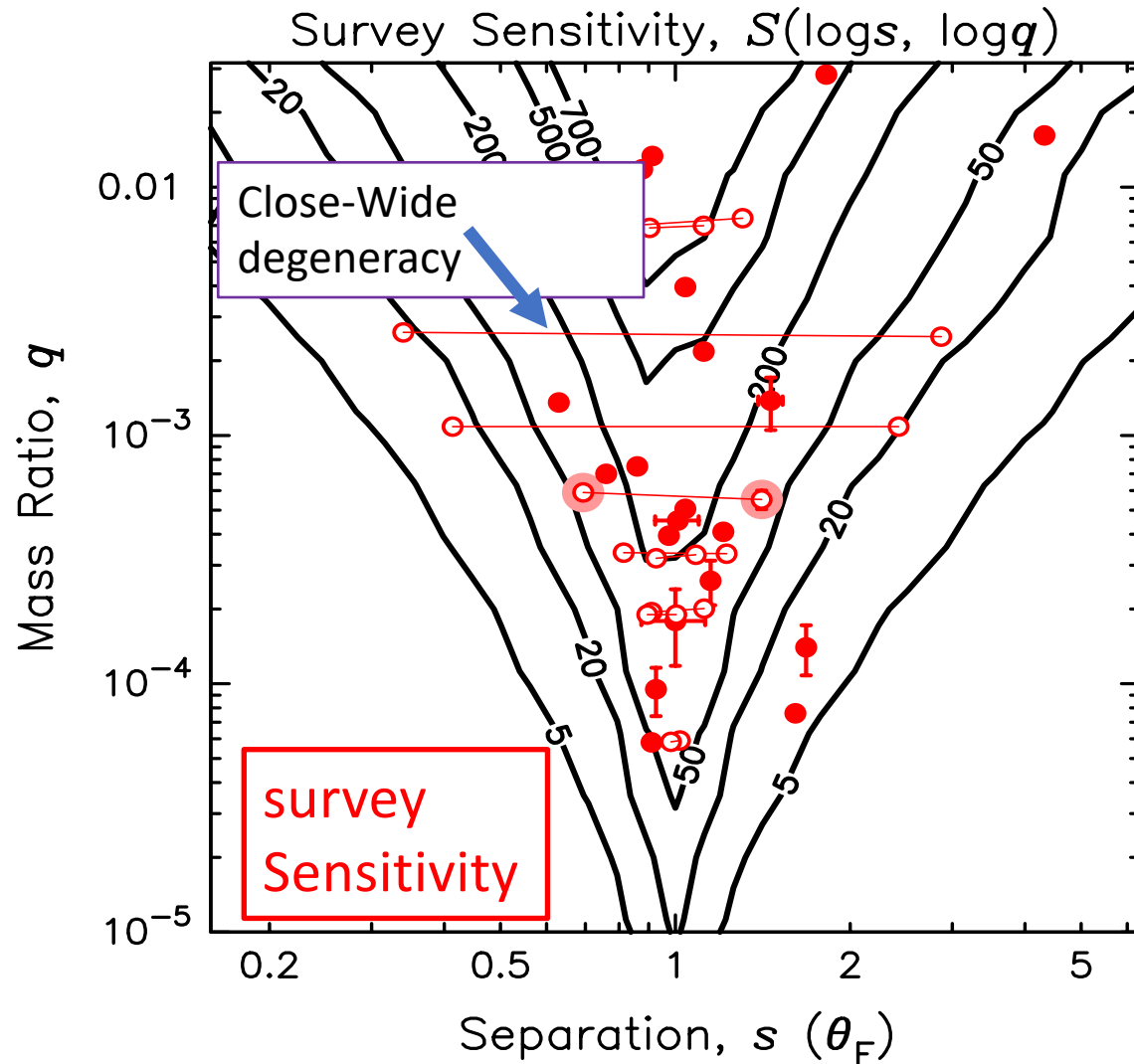


Fernandes+ 2019

Microlensing statistics with mass ratio function

Microlensing planet detection light curves mostly yield mass ratios

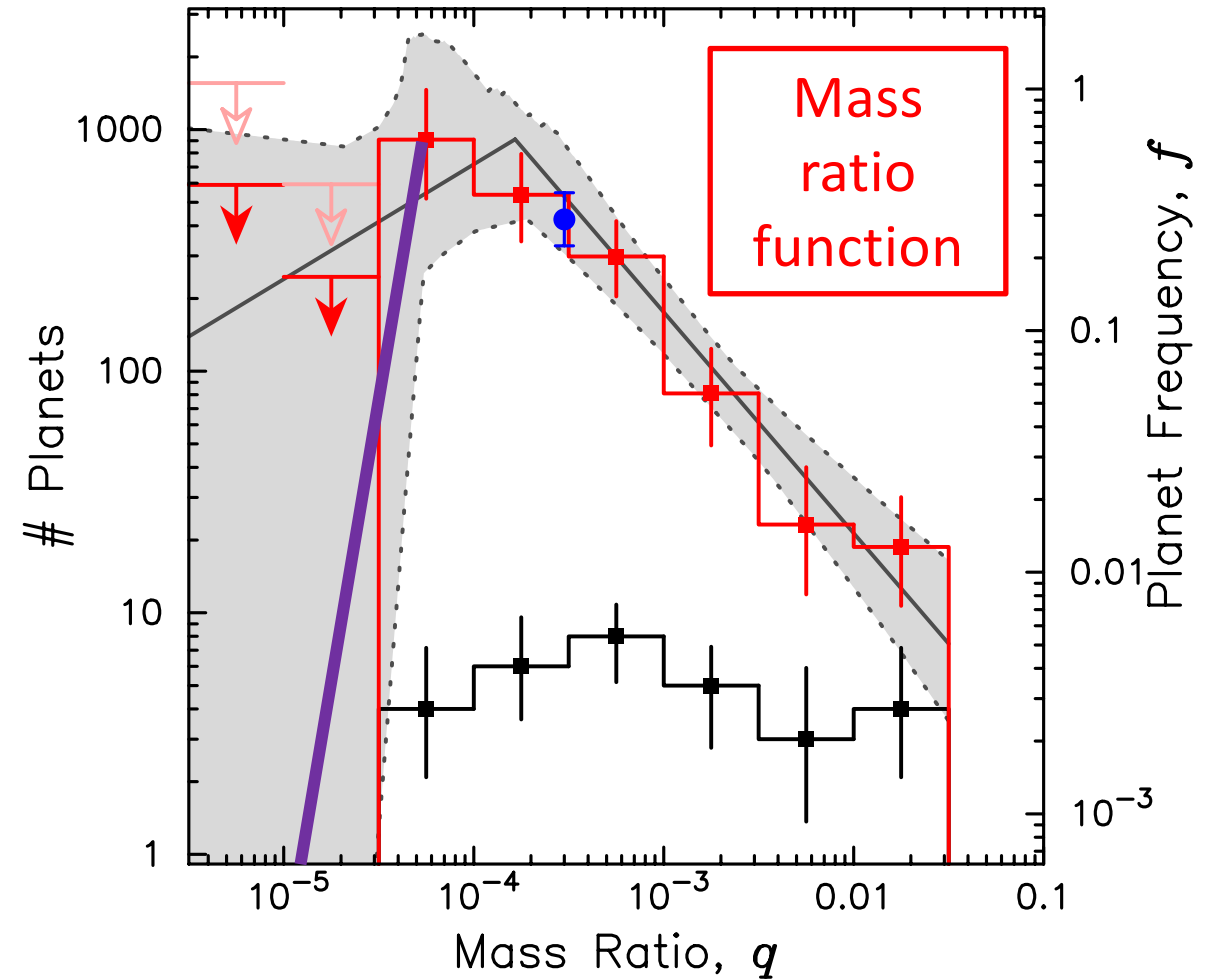
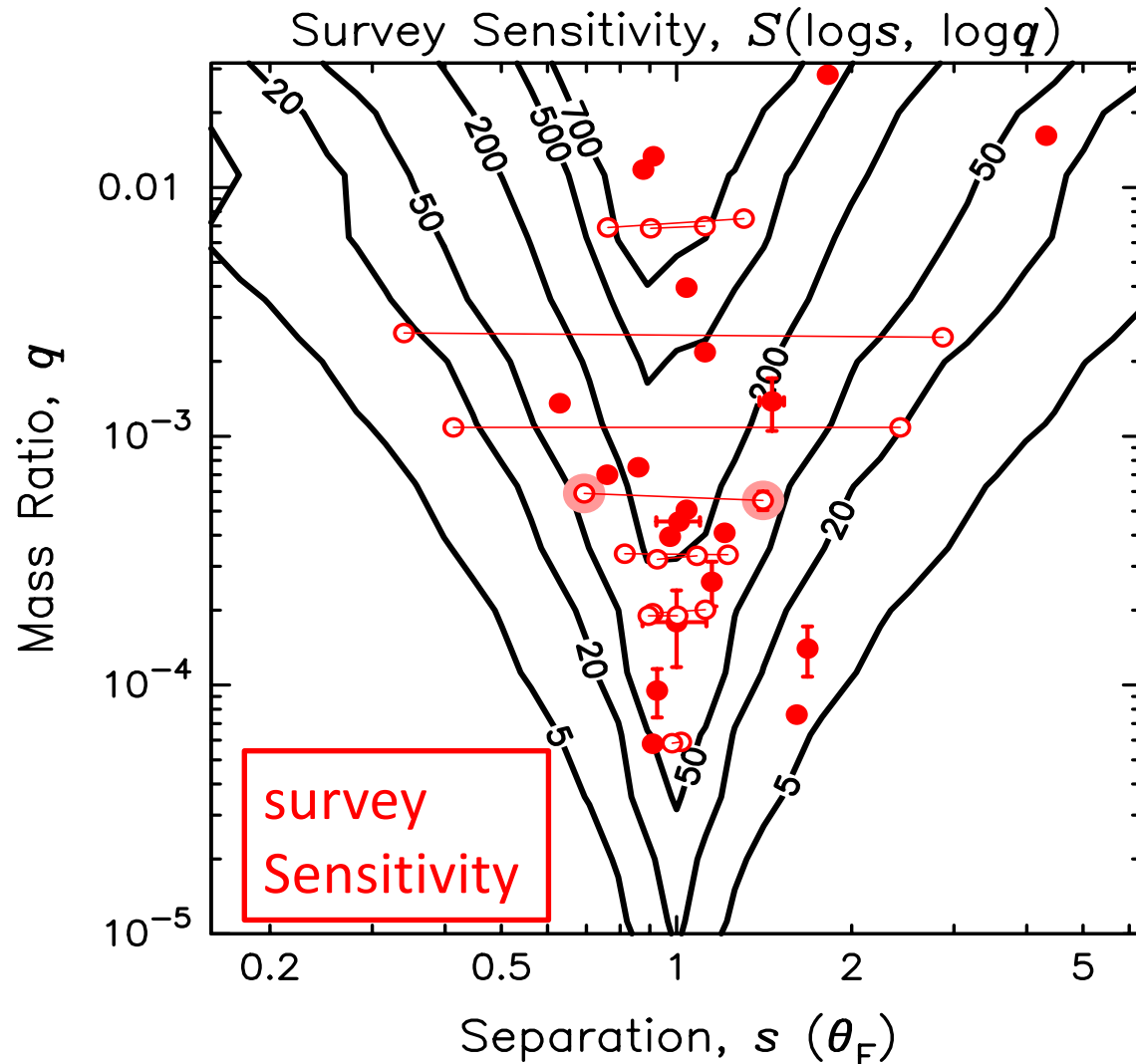
Suzuki+ 2016



Microlensing statistics with mass ratio function

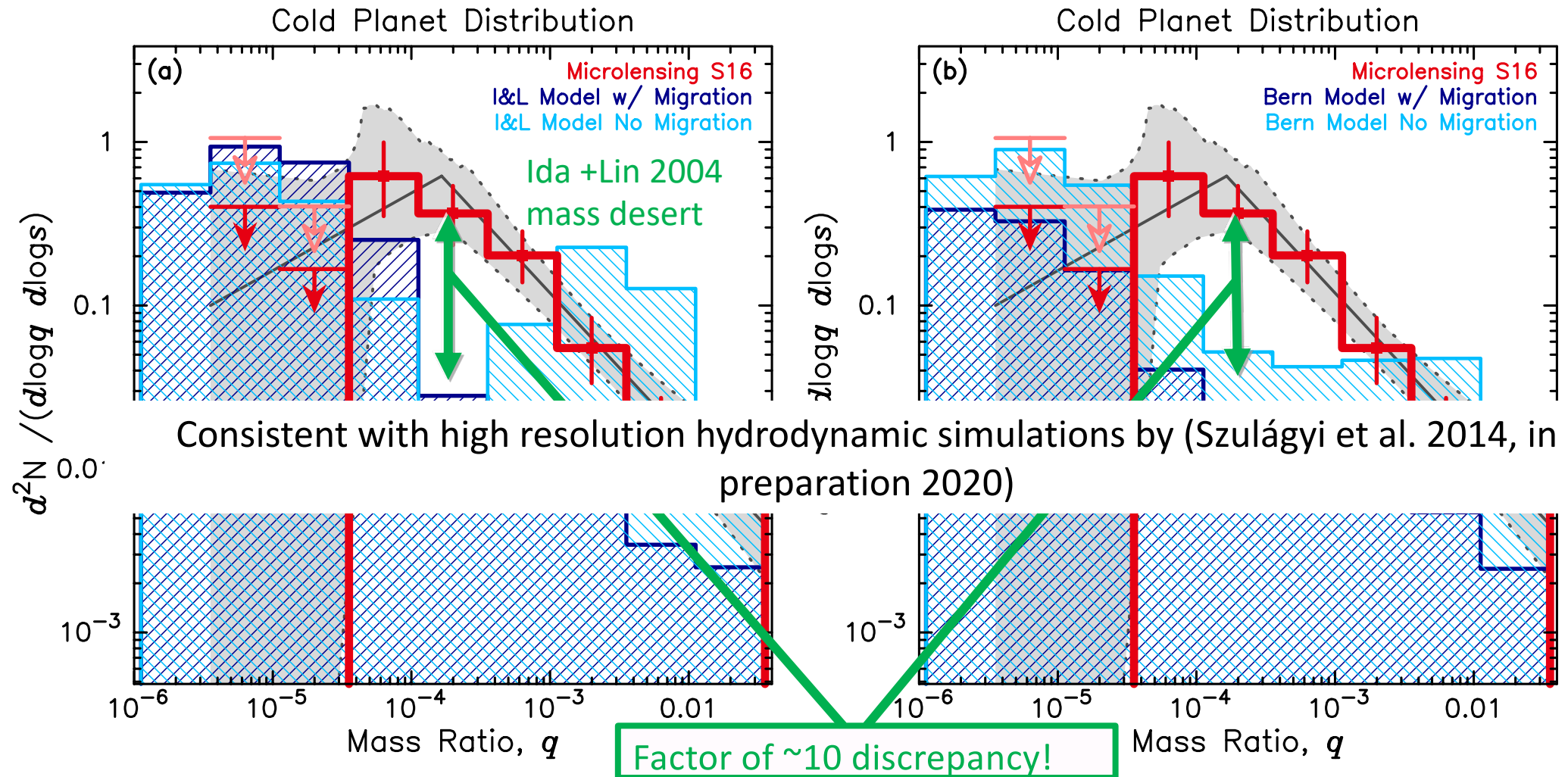
Microlensing planet detection light curves mostly yield mass ratios

Suzuki+ 2016



Jung+ 2019

Microlensing Mass Ratio Function Shows no Sign of Runaway Gas Accretion

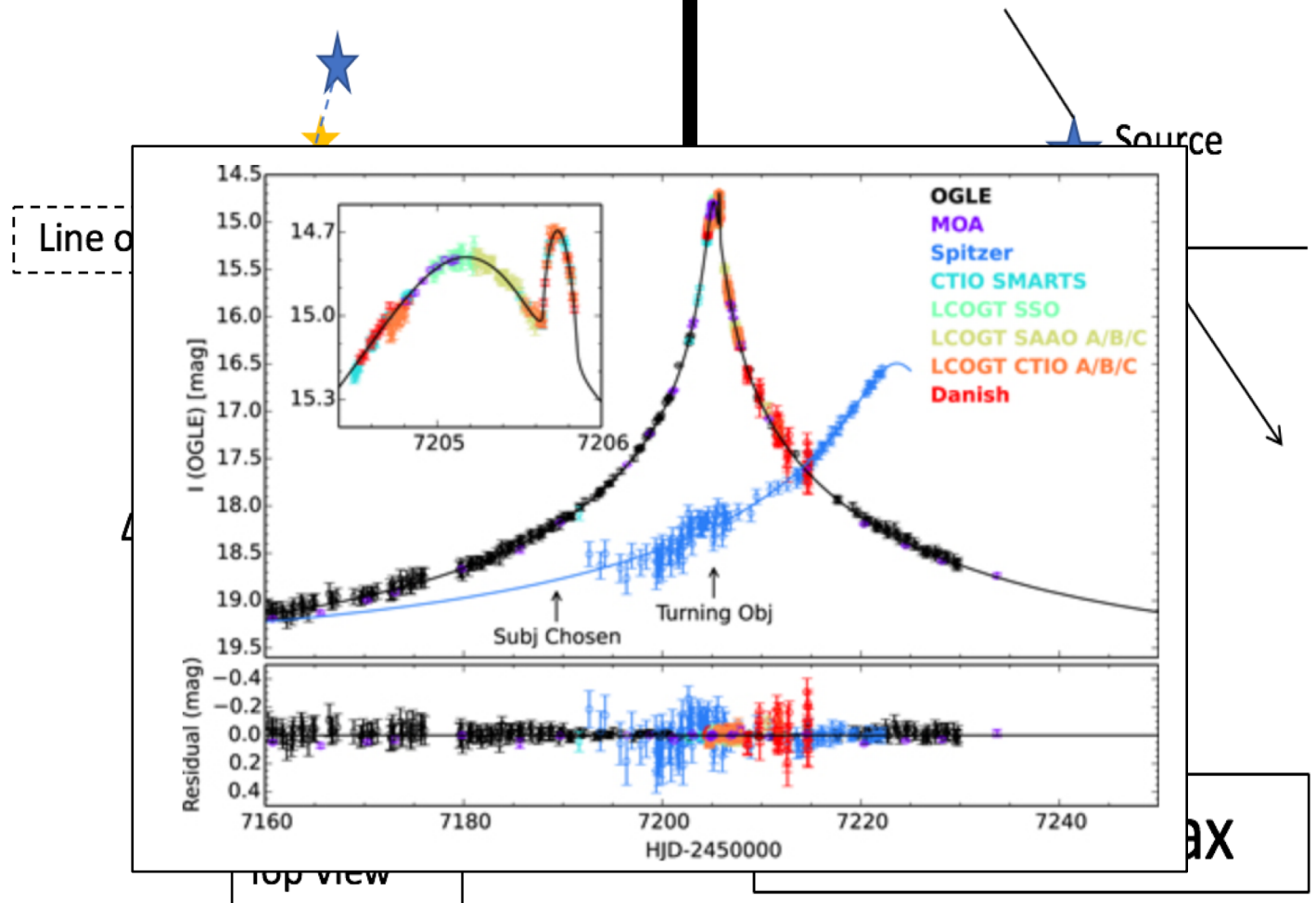


Mass ratio $\rightarrow$ Mass Measurements

Orbital Microlensing Parallax and Satellite Parallax both are detected during light curve magnification.

WFIRST will determine some masses from orbital parallax.

Orbital Microlensing Parallax

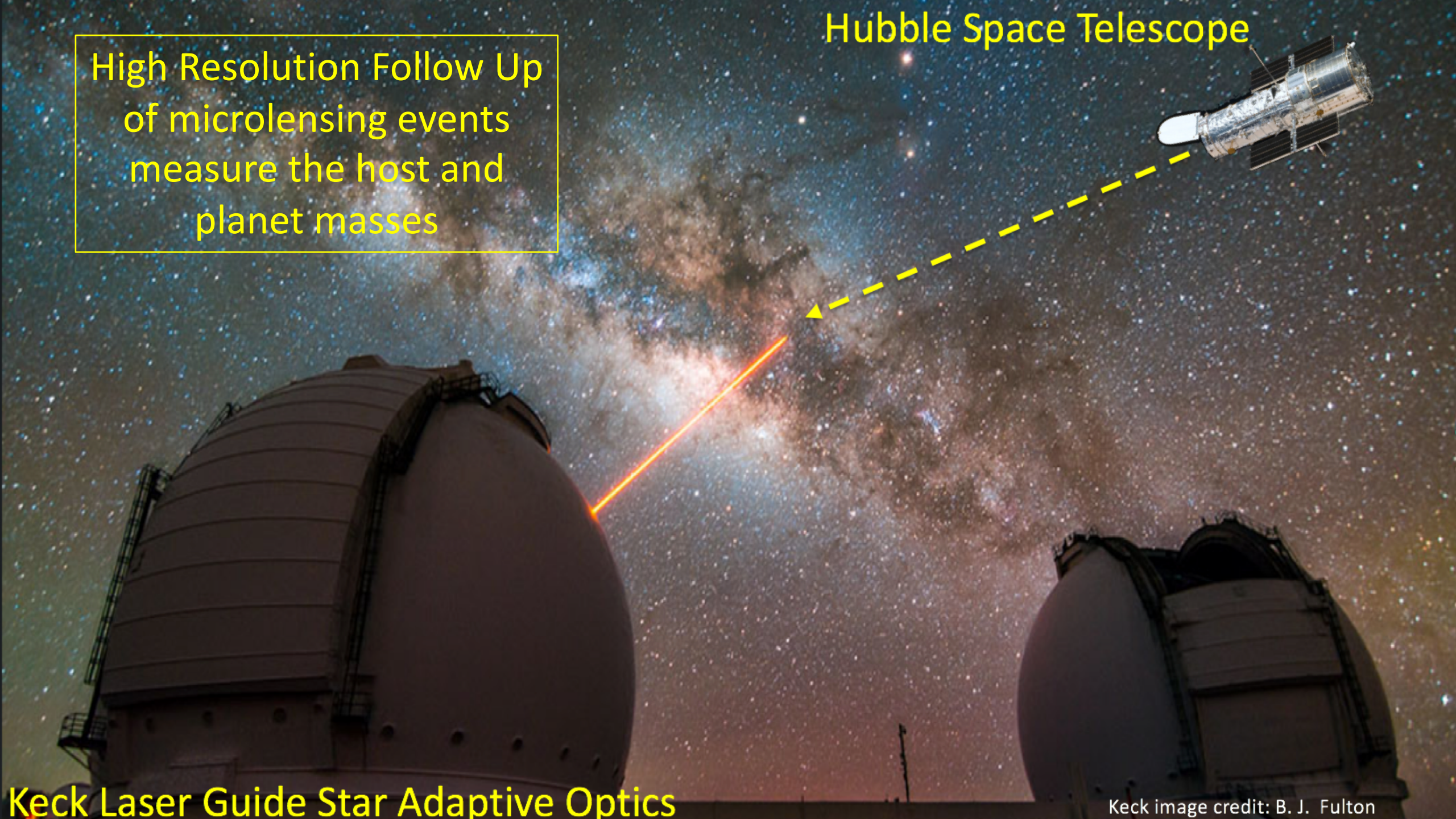


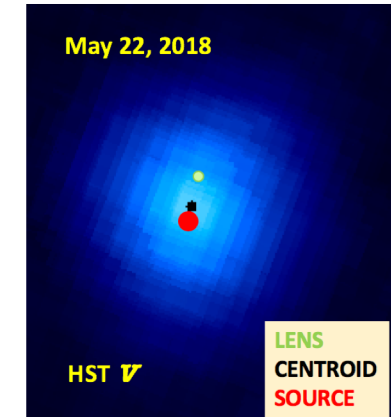
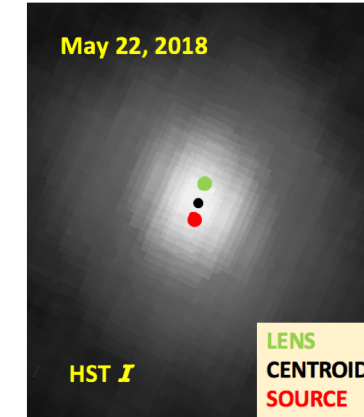
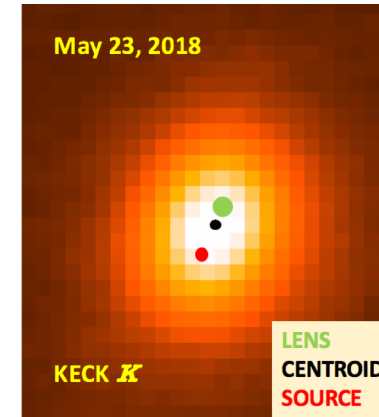
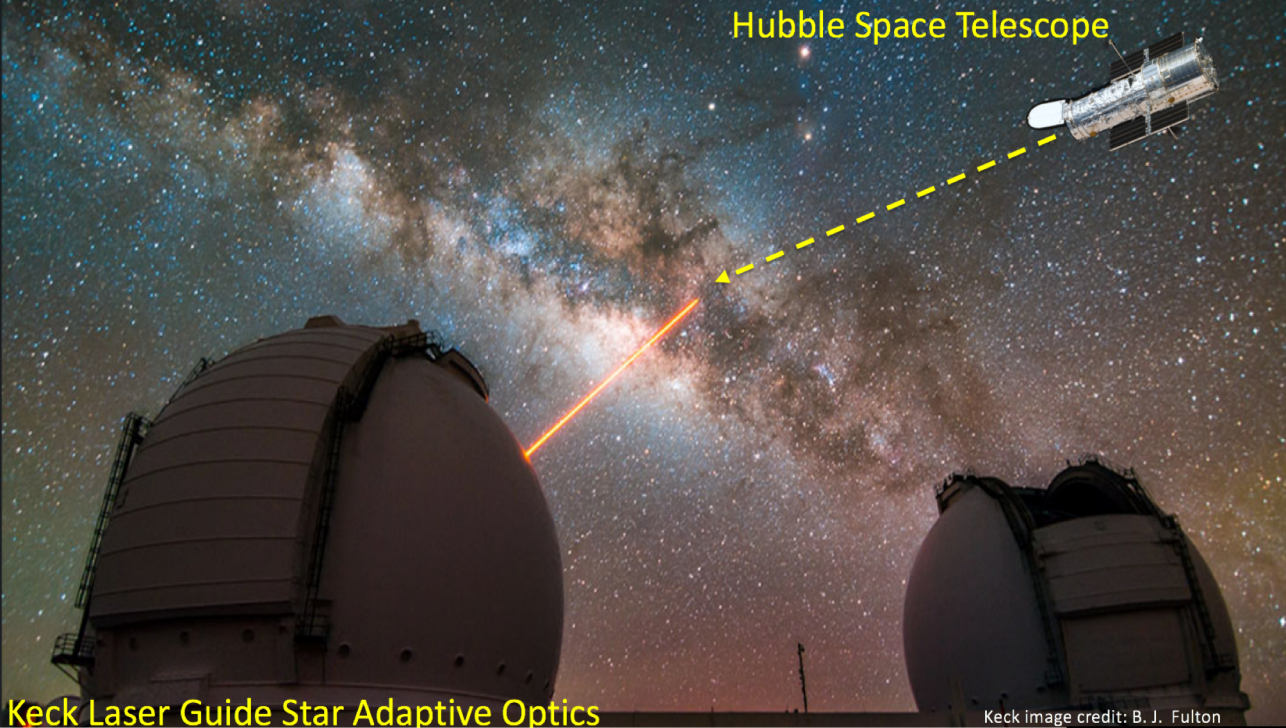
Hubble Space Telescope

High Resolution Follow Up
of microlensing events
measure the host and
planet masses

Keck Laser Guide Star Adaptive Optics

Keck image credit: B. J. Fulton





Bhattacharya+ 2018

Sep ~ 34 mas

- High resolution lens detection will be the primary method of mass measurement of WFIRST microlensing survey. WFIRST on own survey will be able to measure most masses of $>50\%$ events.
- Not all mass measurements will be possible – upper limits on binary companions (Bhattacharya+ 2017)

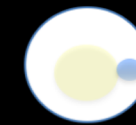
Light from source is still bent due to gravity

→ During the event

Few months after

→ 5-6 years later

A decade later

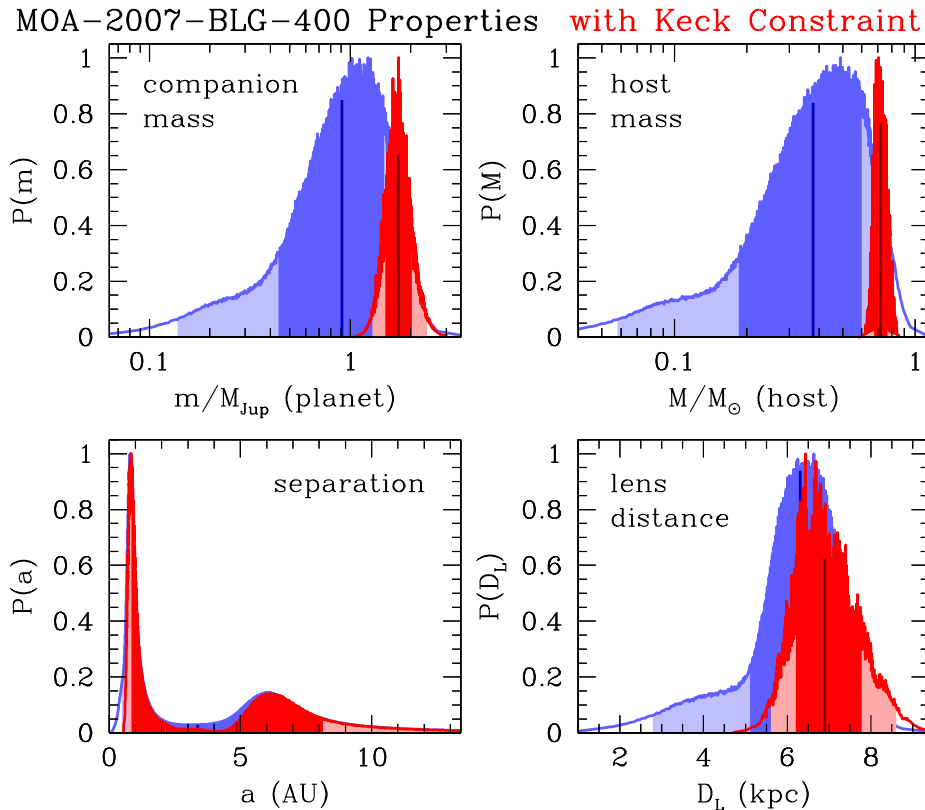


Source
Lens Host Star
Planet

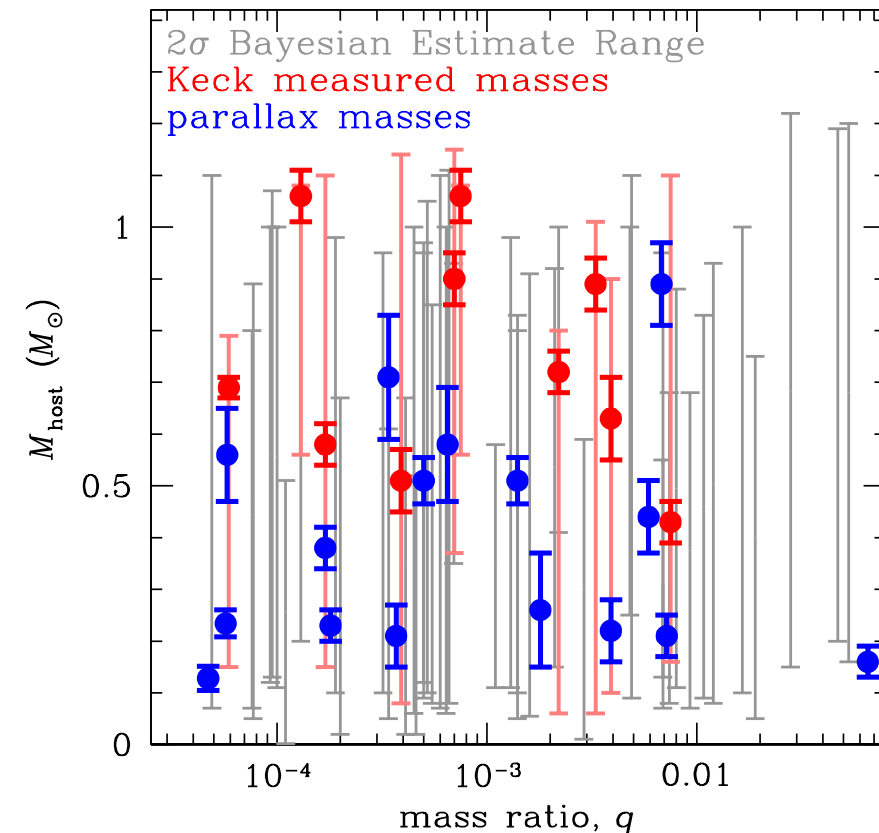
Time increasing

Current Mass measurements and their comparisons to mass estimates

Bhattacharya+ 2020



Planet-Star Mass Ratios vs. Host Masses



- Mass measurements are more precise than mass estimates from galactic model
- It is difficult to detect planetary signals in low magnification events from ground, however WFIRST will be able to detect and measure mass of lot of them.
- Kepler/ RV $\rightarrow$ WFIRST/Microlensing

Wide Orbit Planet Demographics

To determine wide
orbit planet formation

Parameters

Challenges

Solution

Radial Velocity

Host mass, Planet mass $\times$
 $\sin i$, orbital separation

Inclination not known
unless transit detections

Microlensing

Mass ratio and Host
mass (Primarily
measured)
Planet mass and 2-D
planet-host separation

3-D orbital separation
not known

Clanton + Gaudi 2014, 2016

How to consider inclinations in statistical studies
or mass upper/ lower limits -- topic for
discussion?

Radial Velocity

Detection Efficiency of all stars in the sample

To combine separation/ mass vs host mass

To properly evaluate and compare to theory, detection sensitivities of each host star is needed

To expand on current and past occurrence rates with future missions

Change of observing strategy based on interesting events would introduce selection bias. This can be corrected as long as the changes are recorded.

Bennett+ 2019 NAS WP

Database of detection efficiency ?

Microlensing

Detection efficiency for all events in the sample

Mass ratio as a function of host masses and orbital separations

Mass of planets as a function of host masses and orbital separations

Reason: it is not certain if mass ratio is a more fundamental property than mass