Completing Exoplanet Census with Nancy Grace Roman Space Telescope

Aparna Bhattacharya
NASA Goddard Space Flight Center
University of Maryland College Park

Roman Galactic Exoplanet Survey

- 6 seasons – each of 72 days (expected)
- 6 seasons spread over 5 years including first 2 and last 2 bulge seasons
  - 3 early seasons, 3 late seasons
- 7 galactic bulge fields every 15 min
- Filters:
  - Wide band W149 (Each field once every 15 minutes) ~ 40000 images of each field
  - F184 or K band every 12 hours ~ 800 images of each field
  - Z087 or R062 (Red) every 12 hours ~ 800 images of each field

Look for Scott Gaudi talk tomorrow for how and why these specifications were selected.

Roman Galactic Exoplanet Survey

The exoplanets are wide orbit planets of different masses (Super Jupiter to Mars Mass) at beyond the snowline around G, K, M type stars.

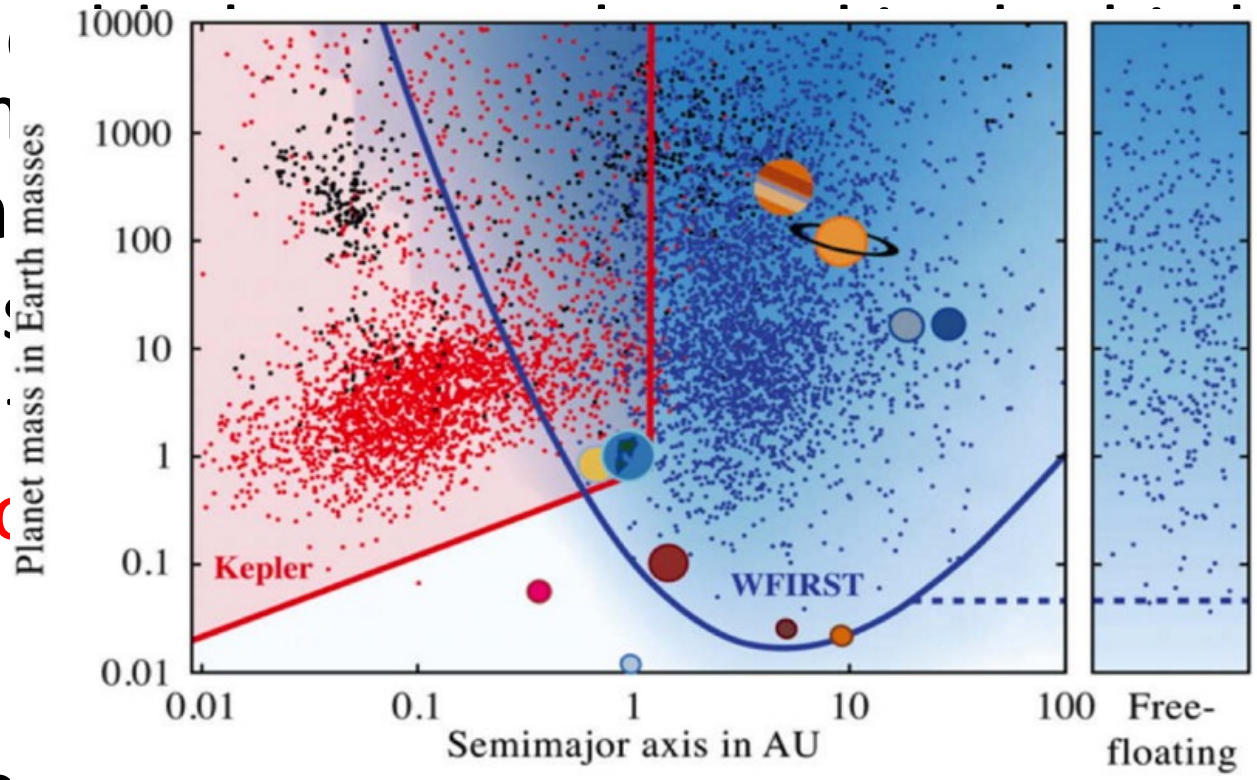
Predictions
1400+ exoplanets with mass as small as Mars mass (Penny+ 2019) and about 700+ mass measurements

Time Domain data will:

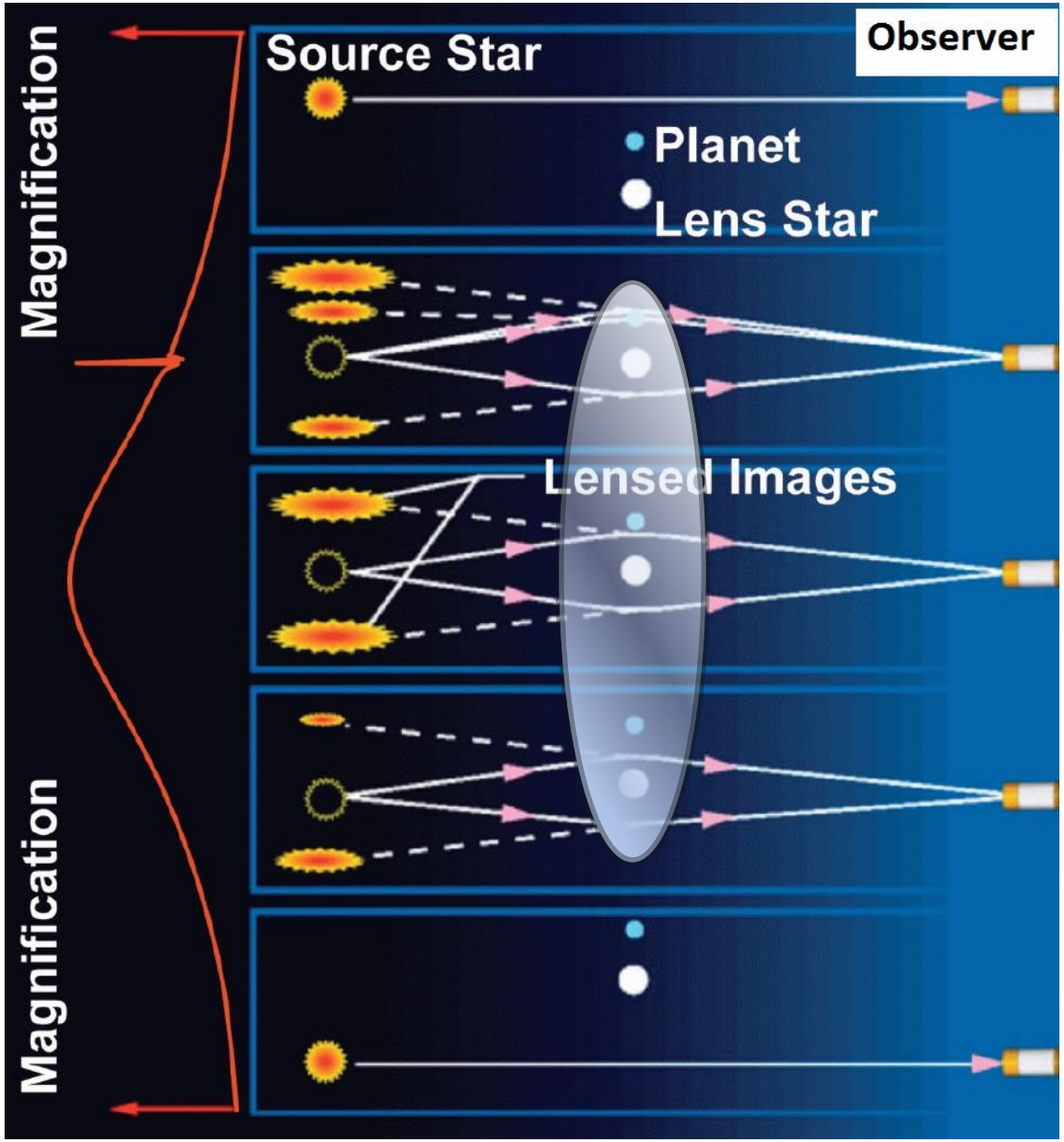
1. Detect the exoplanets
2. Measure the mass of the exoplanets.

The importance of cold low mass exoplanets

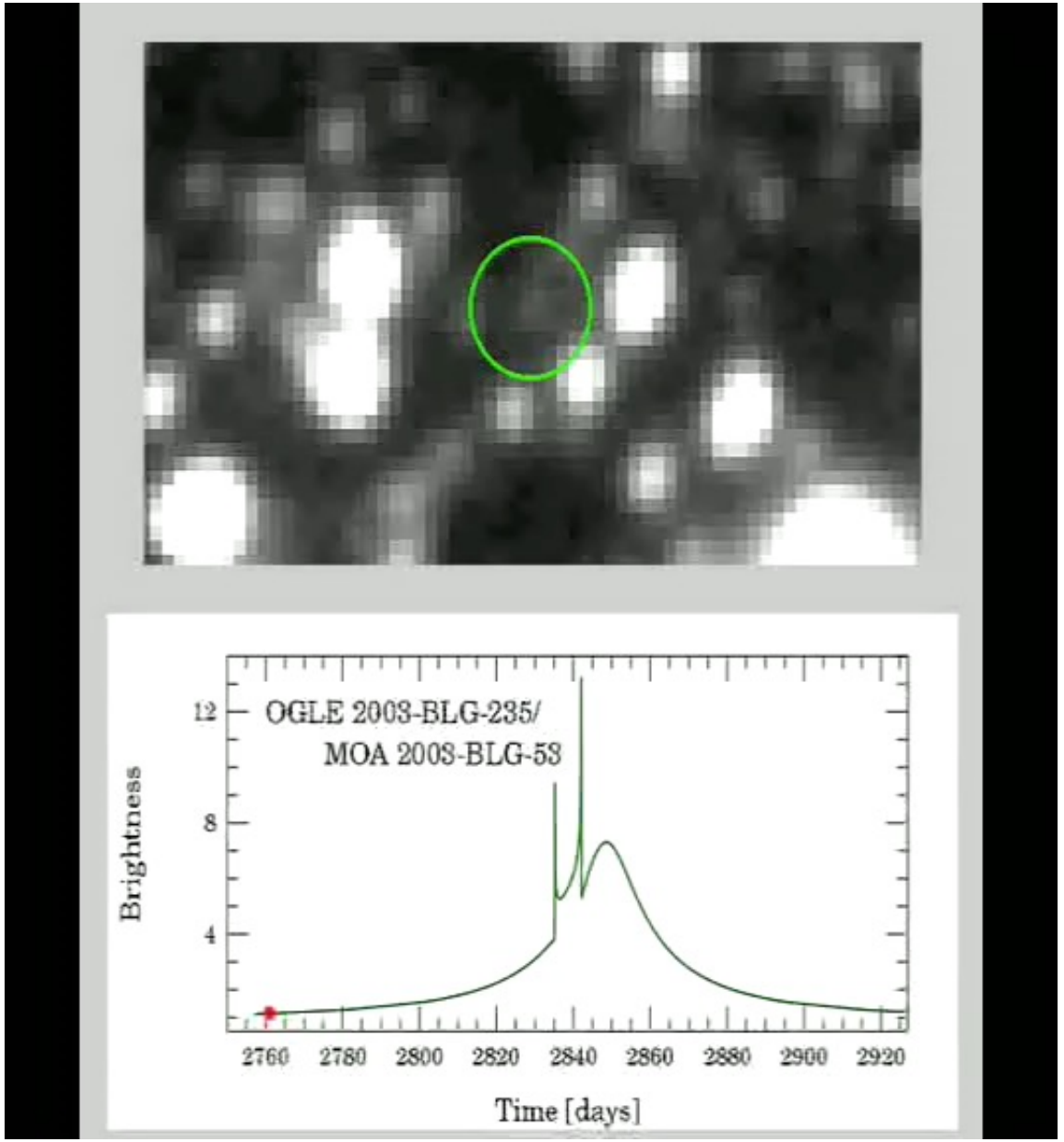
- Wide orbit … place of planet form…
- How comm…
- Where doe…
- Do planets … us?
- What kind … ly earth like planets?



Action: Detect the exoplanets, build a statistics of exoplanet mass, their host star masses, their separations and their distances.



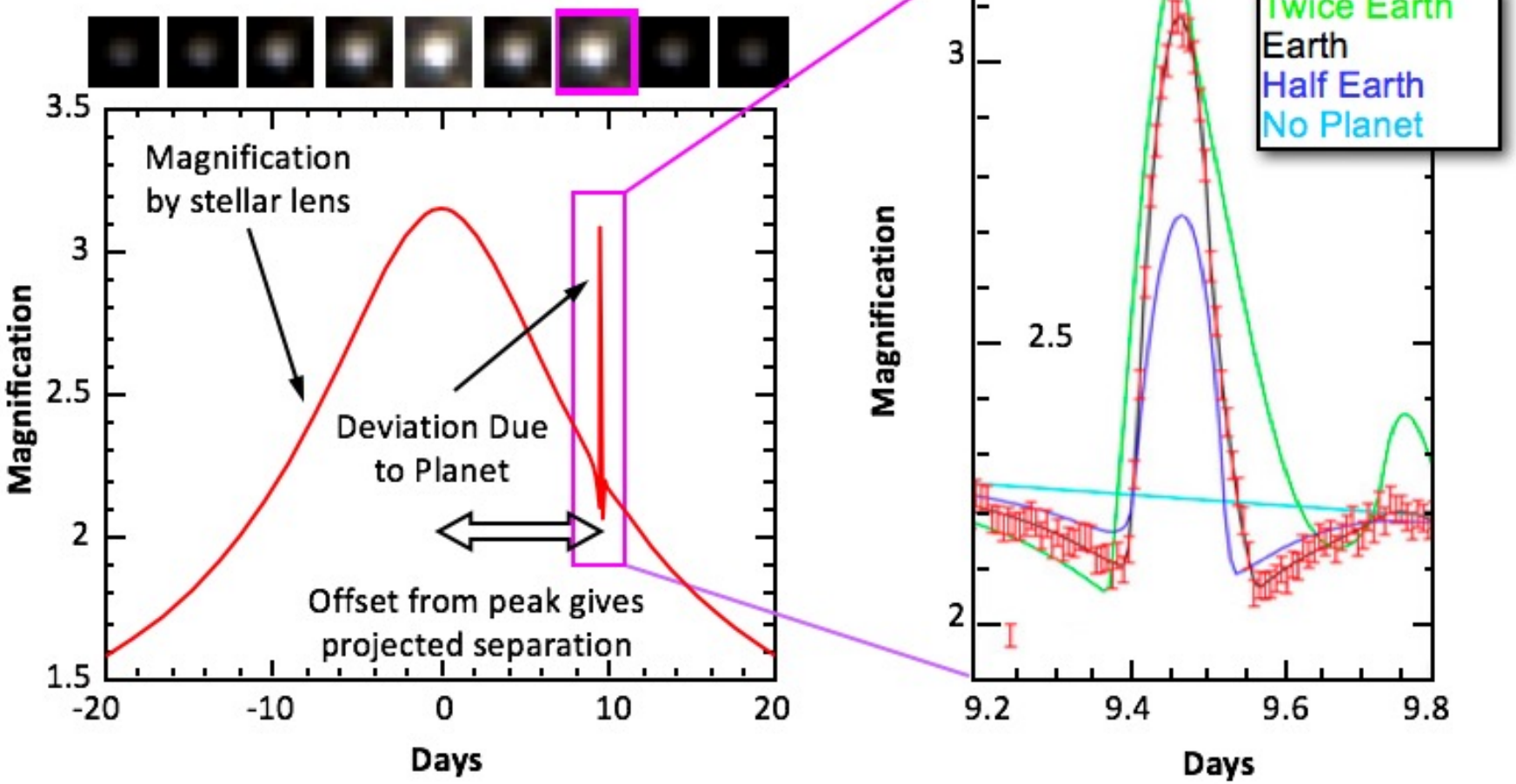
Since chances are small, we look at dense galactic field, but the signals are strong.



Most Light Curves give mass ratios of planet-host stars

Microlensing Exoplanet Detection

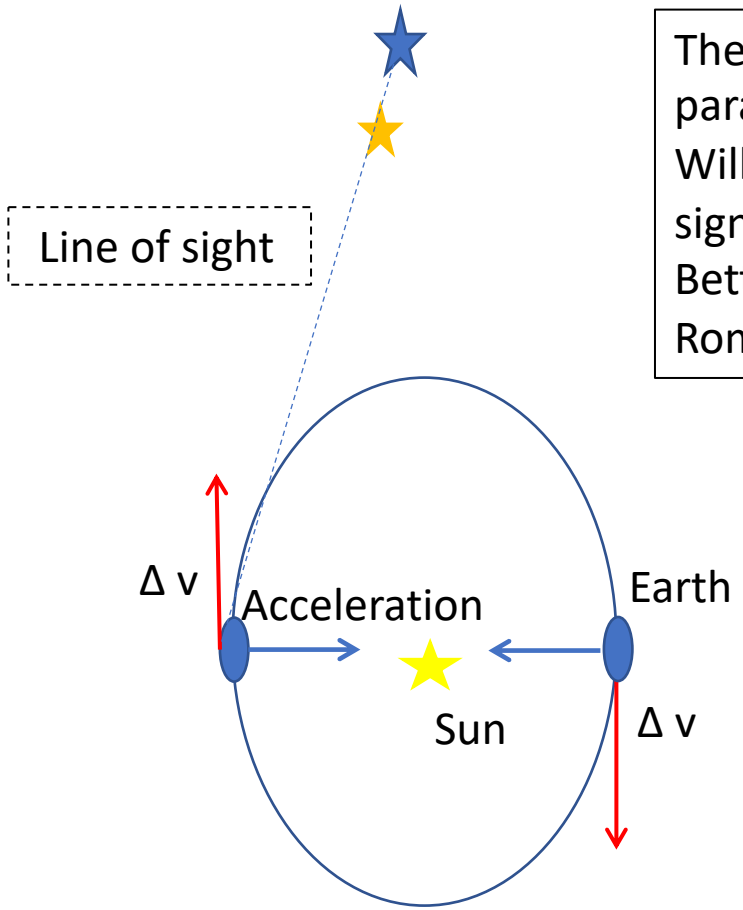
Light Curve



Muraki et al 2011, ApJ 741, 22

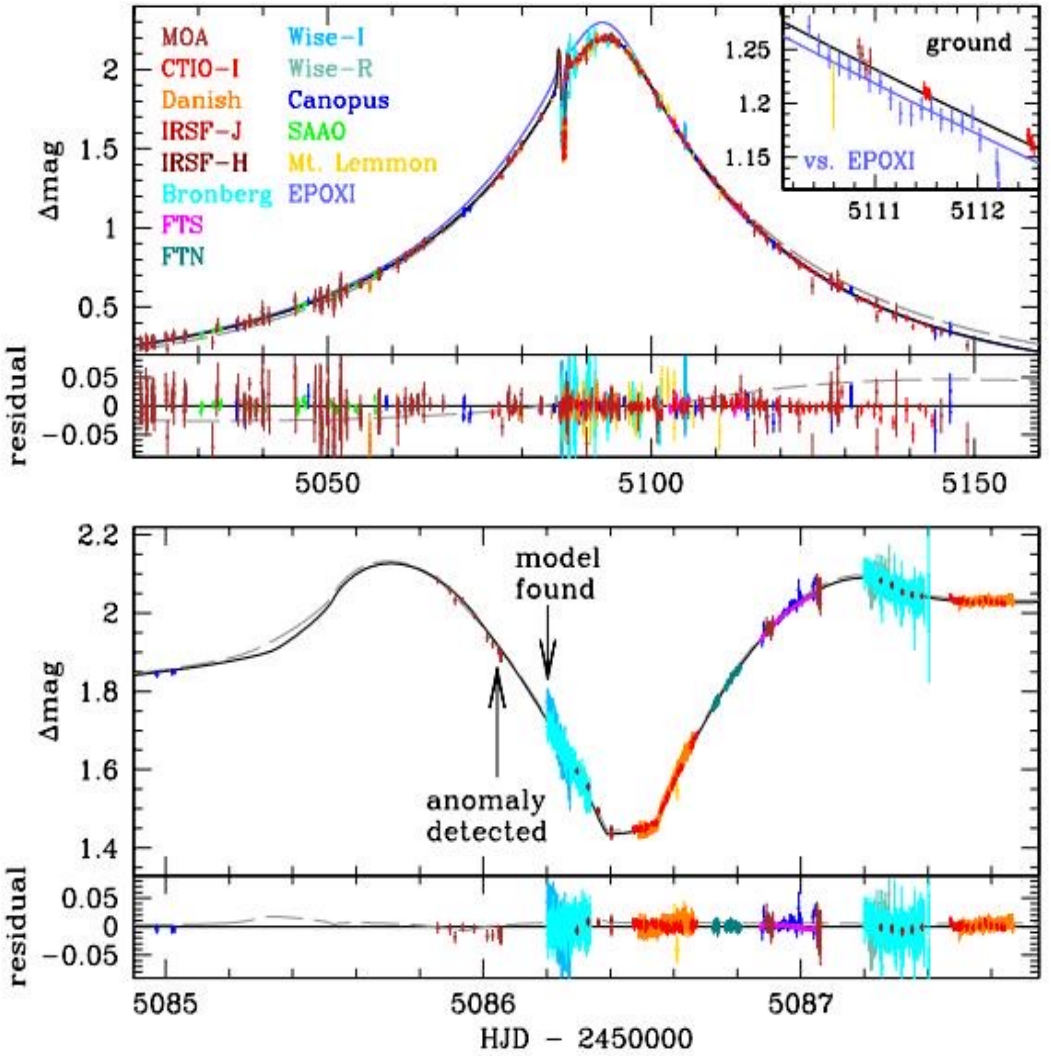
Mass measurement only from the light curve

Orbital Microlensing Parallax



Top View

The planet and parallax detection Will improve significantly due to Better photometry of Roman.



Sebastiano Calchi Novati talk today
For more on photometry analysis

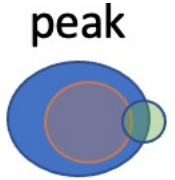
$M_H = 0.56 \pm 0.09\ M_\odot$

$M_P = 10.4 \pm 1.7\ M_\oplus$

$a_\perp = 3.2^{+1.9}_{-0.5}$ AU

Mass Measurement with Lens Detection

We need mass measurements of planet and its host stars and their separation to answer which stars are likely to host which type of planets.

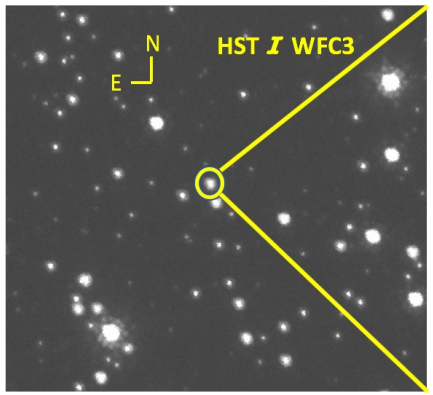


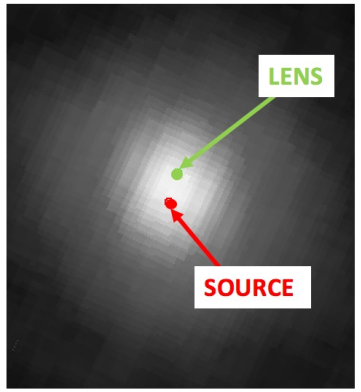
The light curve planet detection gives planet-host mass ratio, we need high resolution follow up observations with Keck and Hubble for mass measurements (as precursor). Roman will observe multi epoch data in high resolution to measure mass.

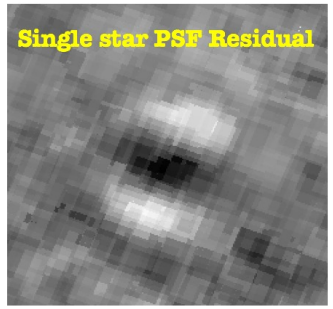
~4.5 Years Later

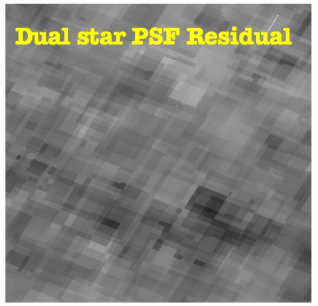
~ 10-30 mas separation

Mass Measurement by Lens Detection

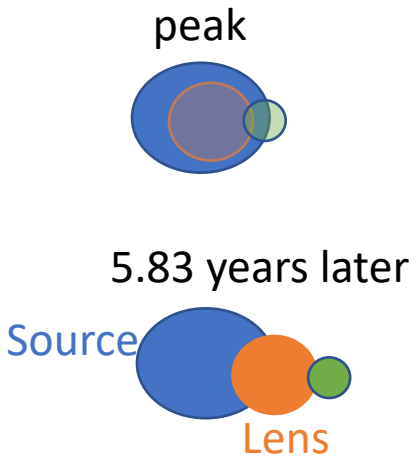








Follow-up taken with HST 5.83 years after the peak of the event on May 22, 2018



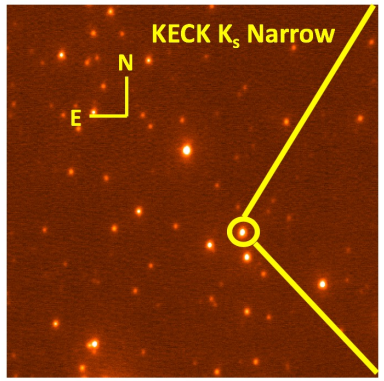
Separation = 34 mas

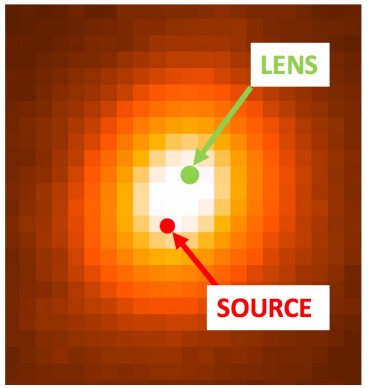
$M_H = 0.6 \pm 0.04\ M_{Sun}$

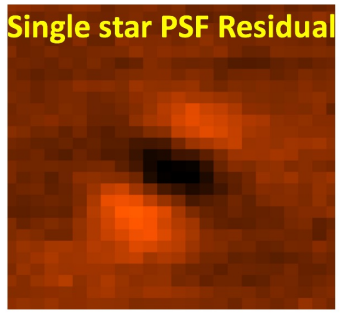
$M_P = 39 \pm 8\ M_E$

$D_L = 2.1 \pm 0.23$ kpc

Bhattacharya+ 2018

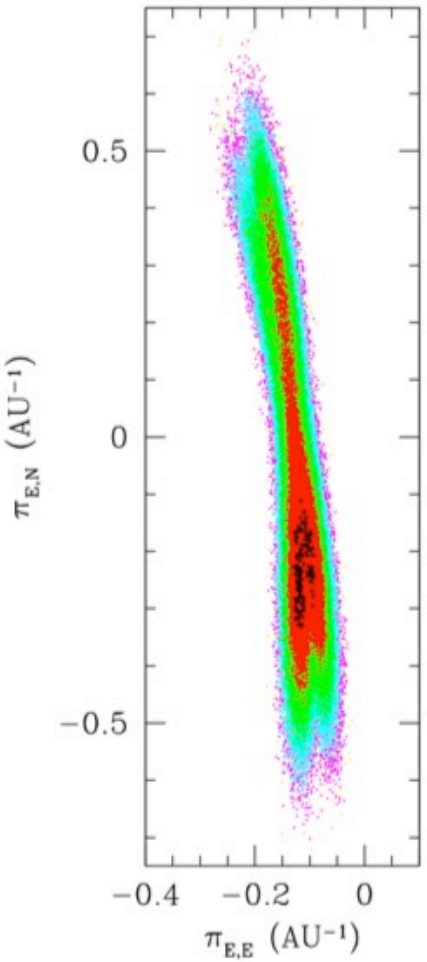




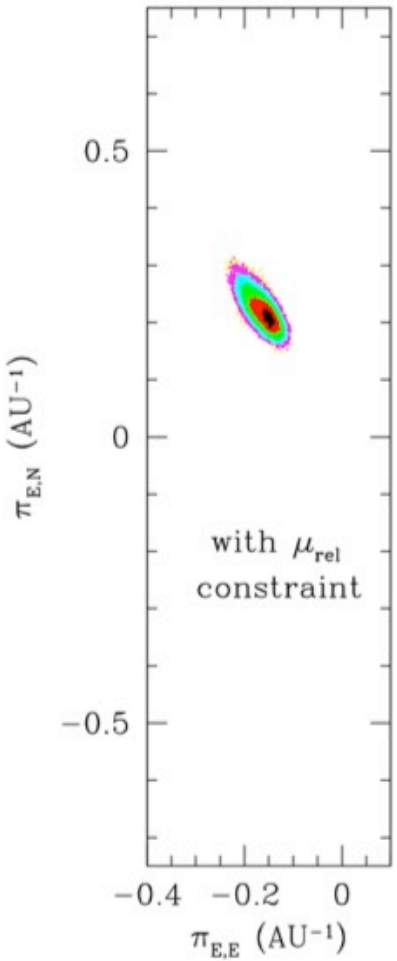


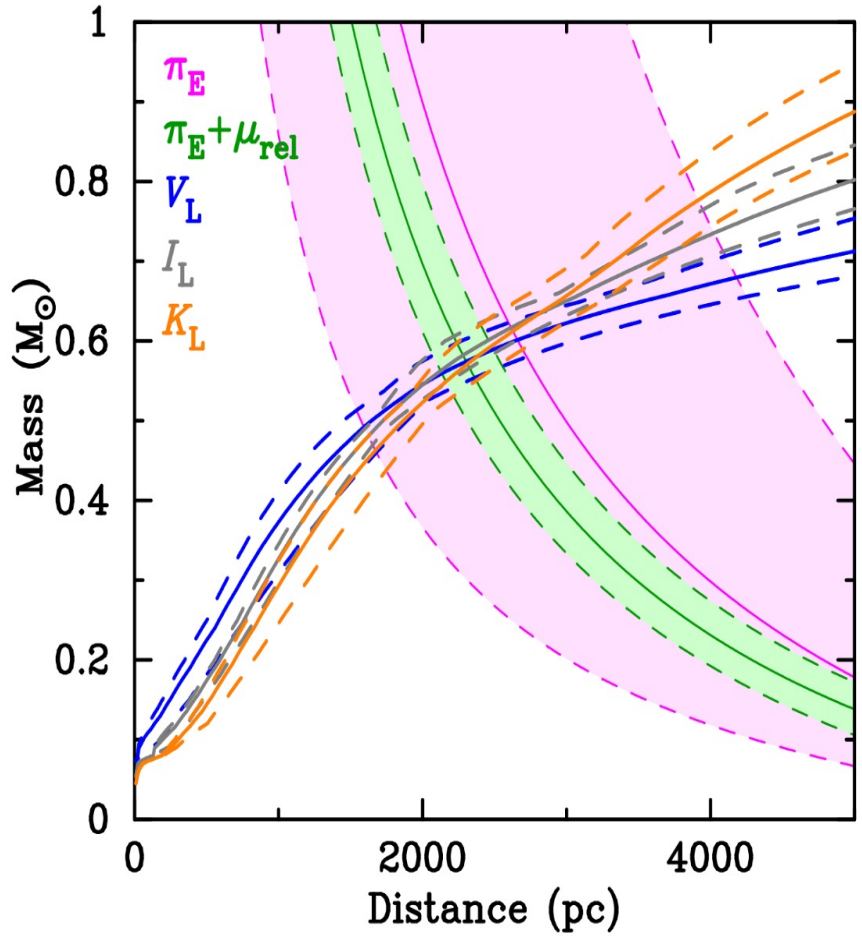
Follow-up taken with Keck AO on May 23, 2018

From Light Curve



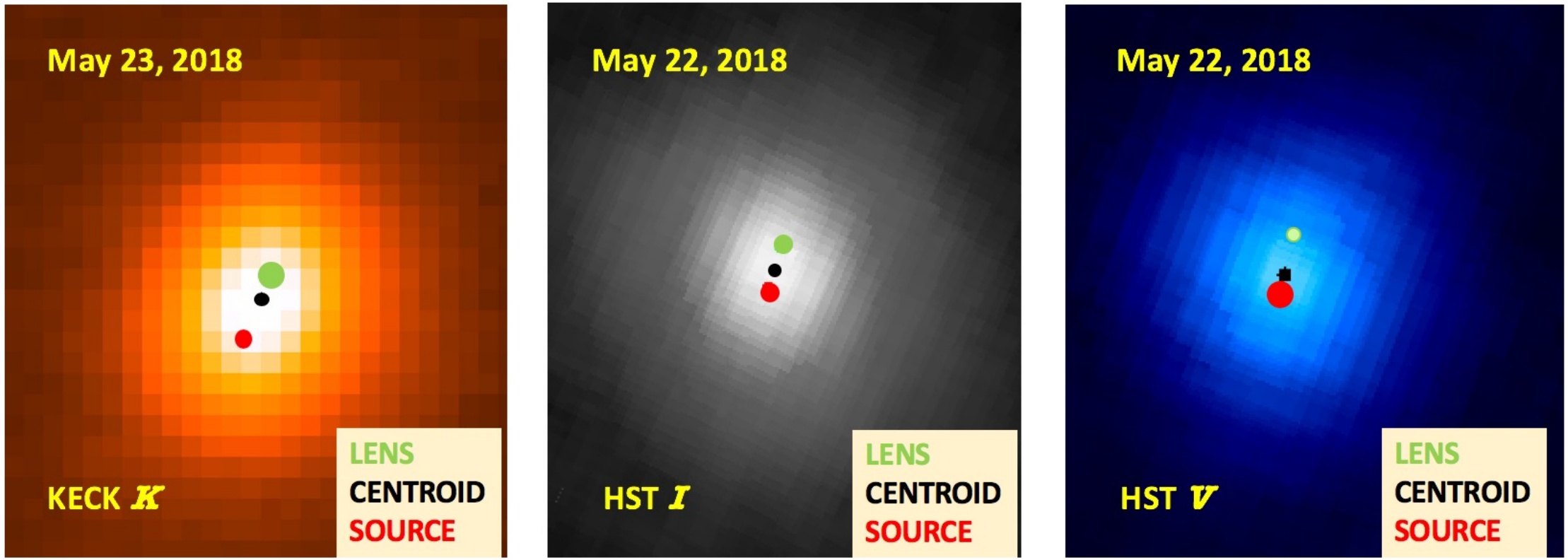
From High - Res





Roman will have both (data will be time domain+ images high resolution) +
Also observations will be taken in 2 different epochs

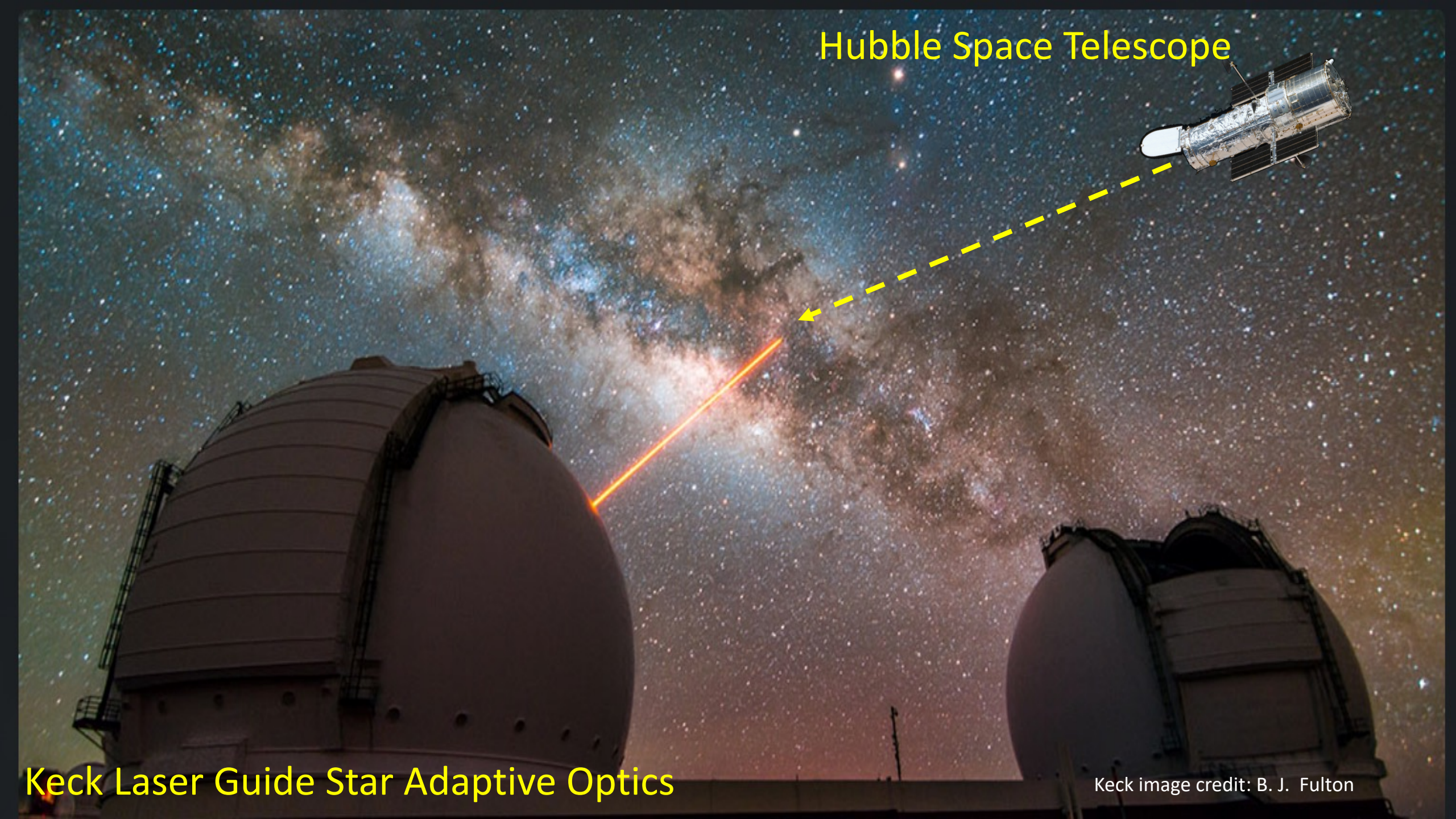
V vs K Color Dependent Centroid Shift



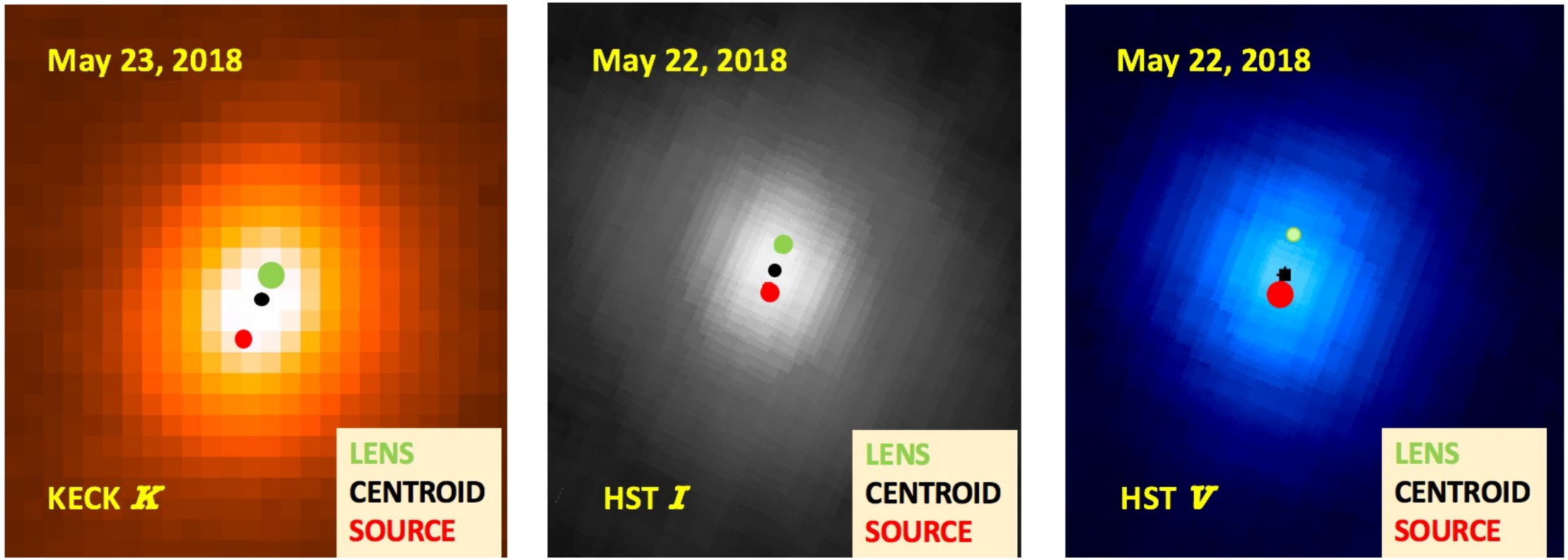
With color dependent centroid shift the lens can be detected in smaller separations 10-30 mas

Simultaneous Observations with Hubble and Keck

In Roman this will be done between different bands.


Hubble Space Telescope
Keck Laser Guide Star Adaptive Optics
Keck image credit: B. J. Fulton

V vs K Color Dependent Centroid Shift



With color dependent centroid shift the lens can be detected in smaller separations 10-30 mas

Simultaneous Observations with Hubble and Keck

In Roman this will be done between different bands.

Confirming centroid shift and Measured Masses

OGLE-2003-BLG-235

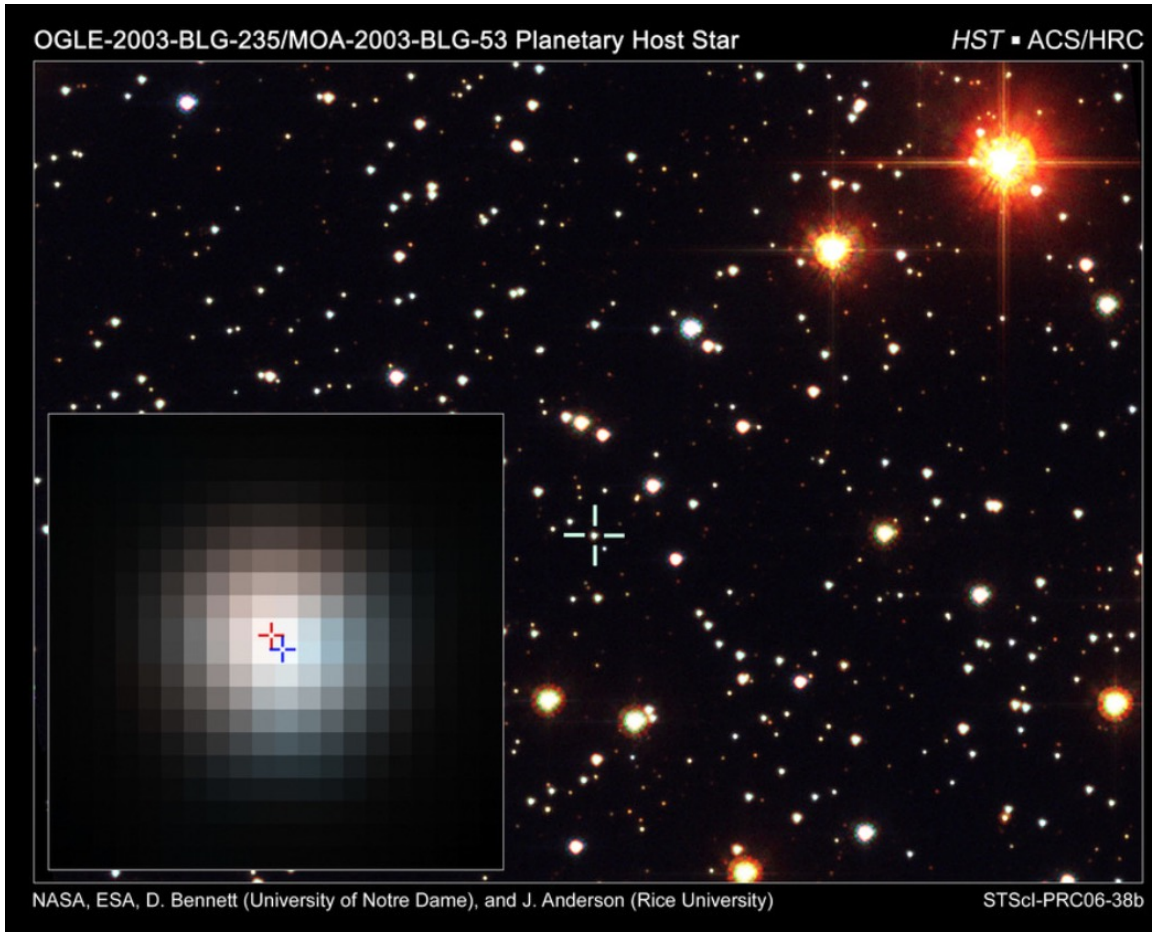
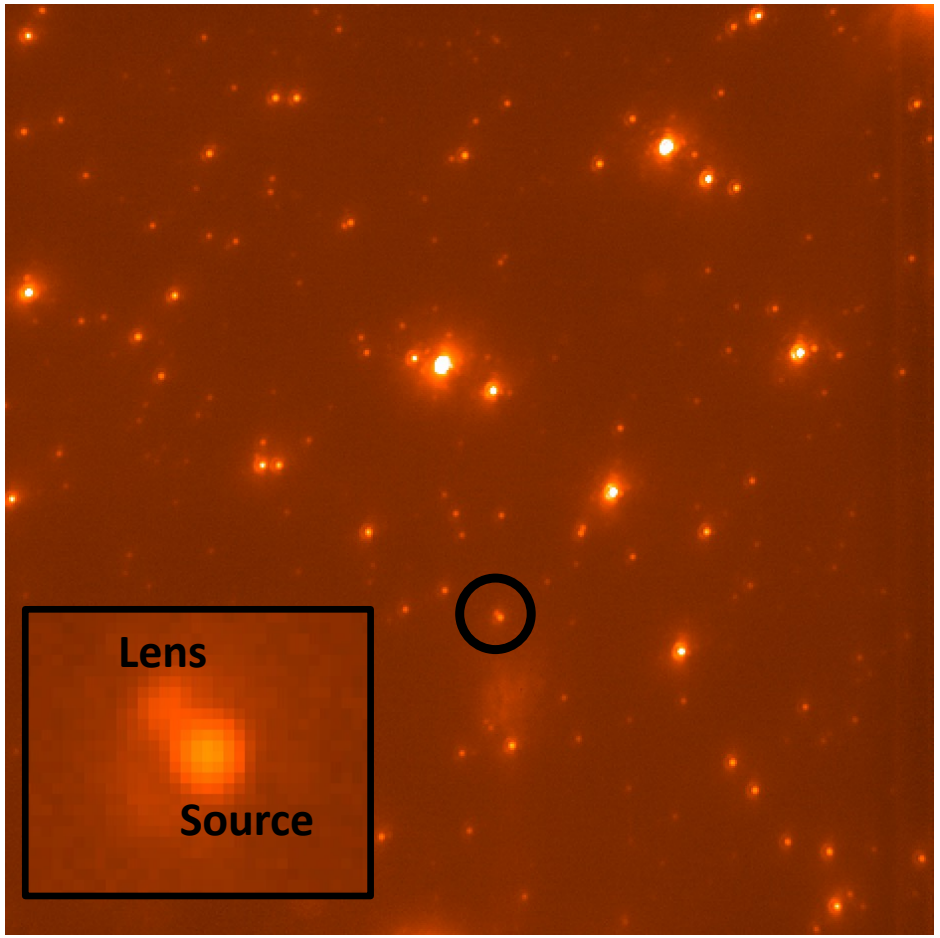


Image by HST ACS in 2005 Bennett+ 2006



Keck NIRC2 Narrow camera image in 2018
Bhattacharya+ 2022

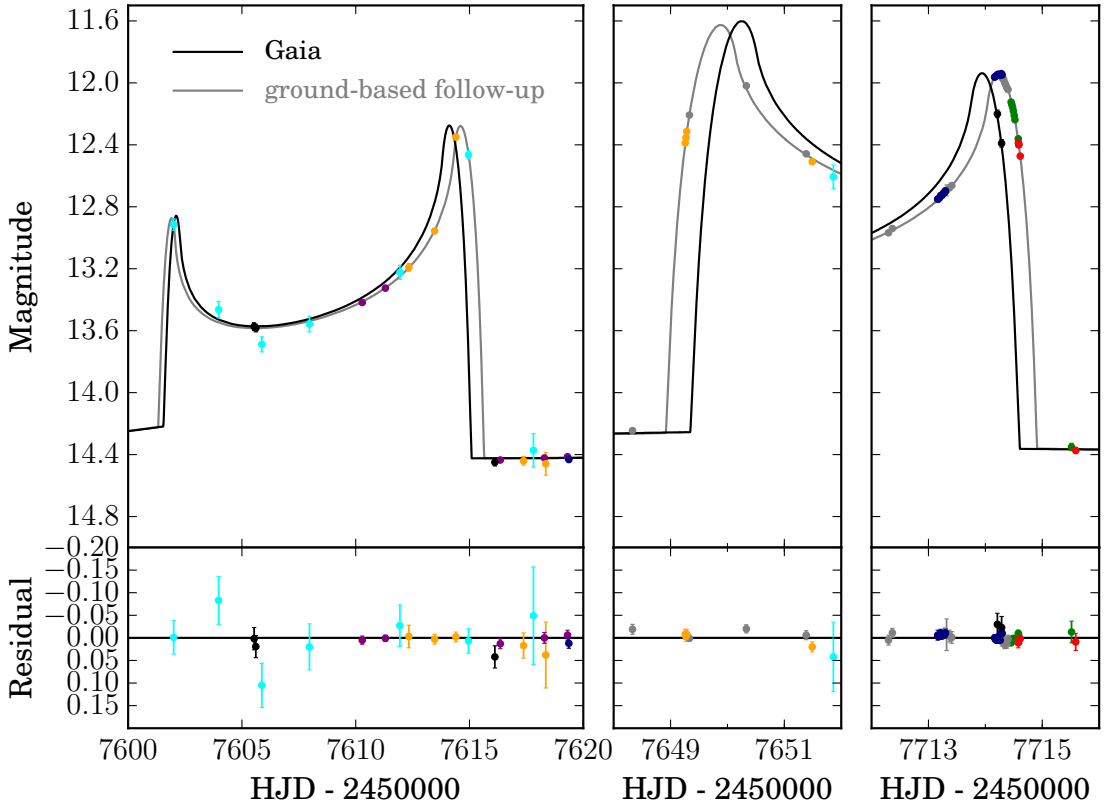
Highlights

We can detect free floating planets using this method since we do not need to depend on the light from the host.

- See Samson Johnson talk tomorrow.

We can get mass measurements even for free floating planets using the parallax/ finite source method using LSST- PRIME – ROMAN

- The only method in which we can get mass measurements of free floating planets.



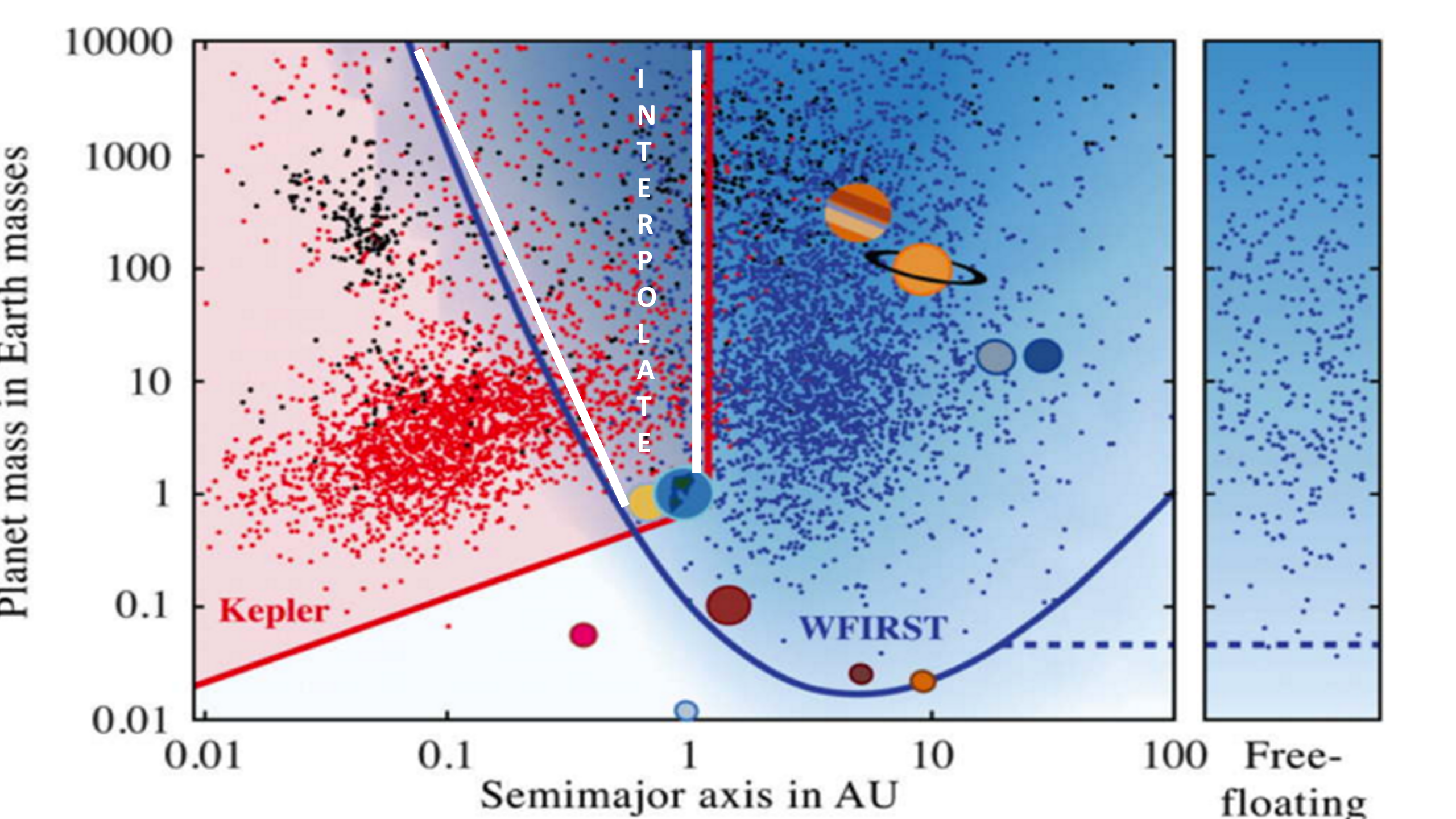
Wyrzykowski+ 2020

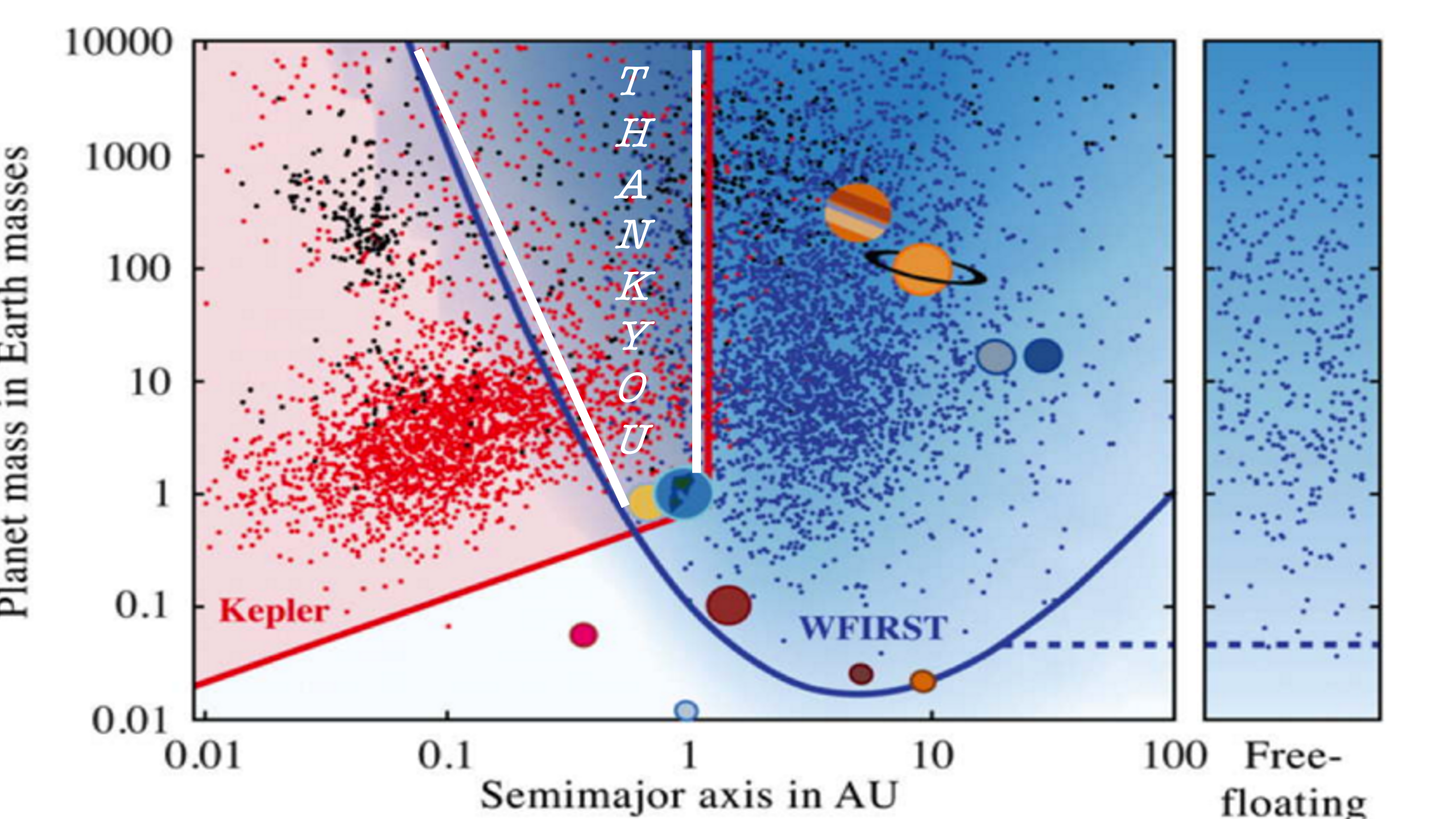
With 1400+ cold low mass exoplanets and 700+ mass measurements around G,K,M stars

- Wide orbit cold planets are located in the birthplace of planet formation –just beyond the snowline
- How common is our solar system?
- Where does the water on earth come from?
- Do planets form in the same way even far from us?
- What kind of stars host earth like planets?

(500+ planets in 10ME and 180 planets in 1 ME (Penny 2019))

- The only way to get mass measurements of free-floating planets


10000
1000
100
10
1
0.1
0.01
Planet mass in Earth masses
0.01
0.1
1
10
100
Free-floating
Semimajor axis in AU
INTERPOLATE
Kepler
WFIRST


10000
1000
100
10
1
0.1
0.01
Planet mass in Earth masses
0.01
0.1
1
10
100
Free-floating
Semimajor axis in AU
THANKYOU
Kepler
WFIRST