Roman-Subaru/HSC concurrent observations for rogue planets mass measurement

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Subaru Instrument: **HSC**

Number of nights (hours): **minimum 20 nights (200hrs) , nominal 30 nights (300hrs)**

Condition of nights (moon phase, airmass, seeing): **any dark and gray nights are acceptable**

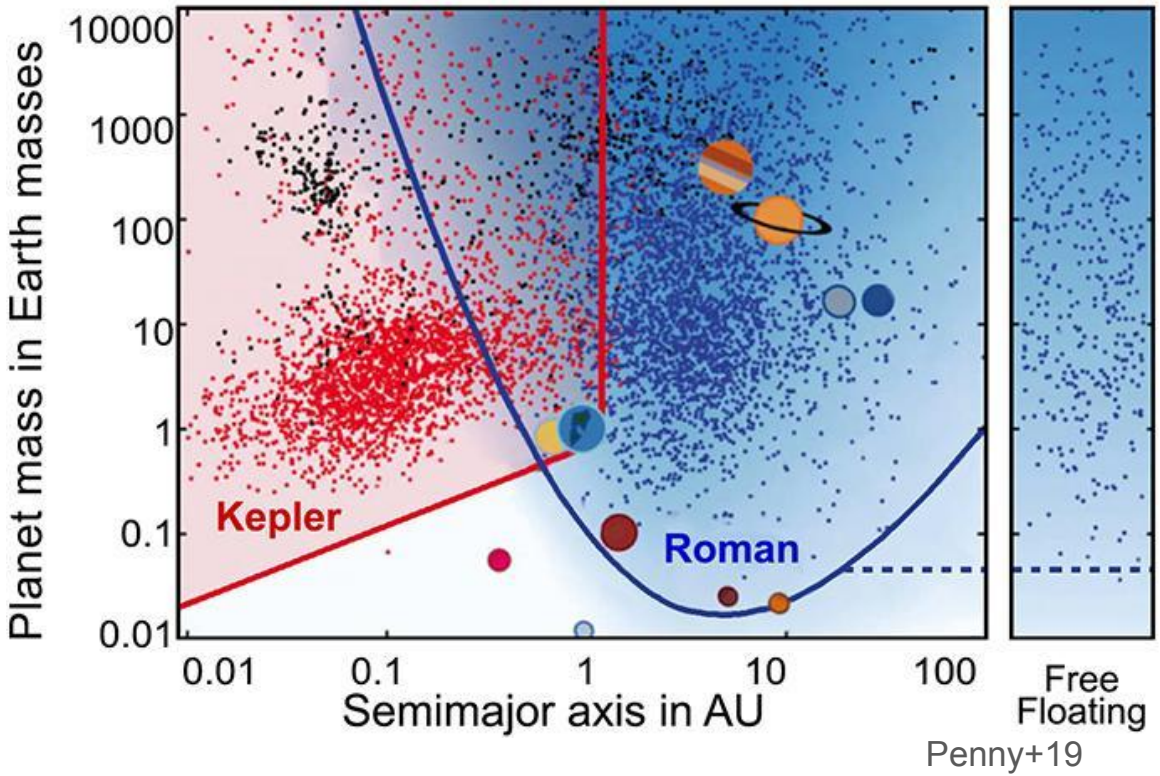
Time critical (year, season, date, time): **GBTDS season, e.g., around Feb 15 - Apr 25 and Aug 18 - Oct 28**

Relevant CCS/ other Roman program: **Roman Galactic Bulge Time Domain Survey (GBTDS)**

Category: **exoplanet, stellar physics, solar system**

Key words: **gravitational microlensing, exoplanets**

Large room to improve Roman planets mass measurement



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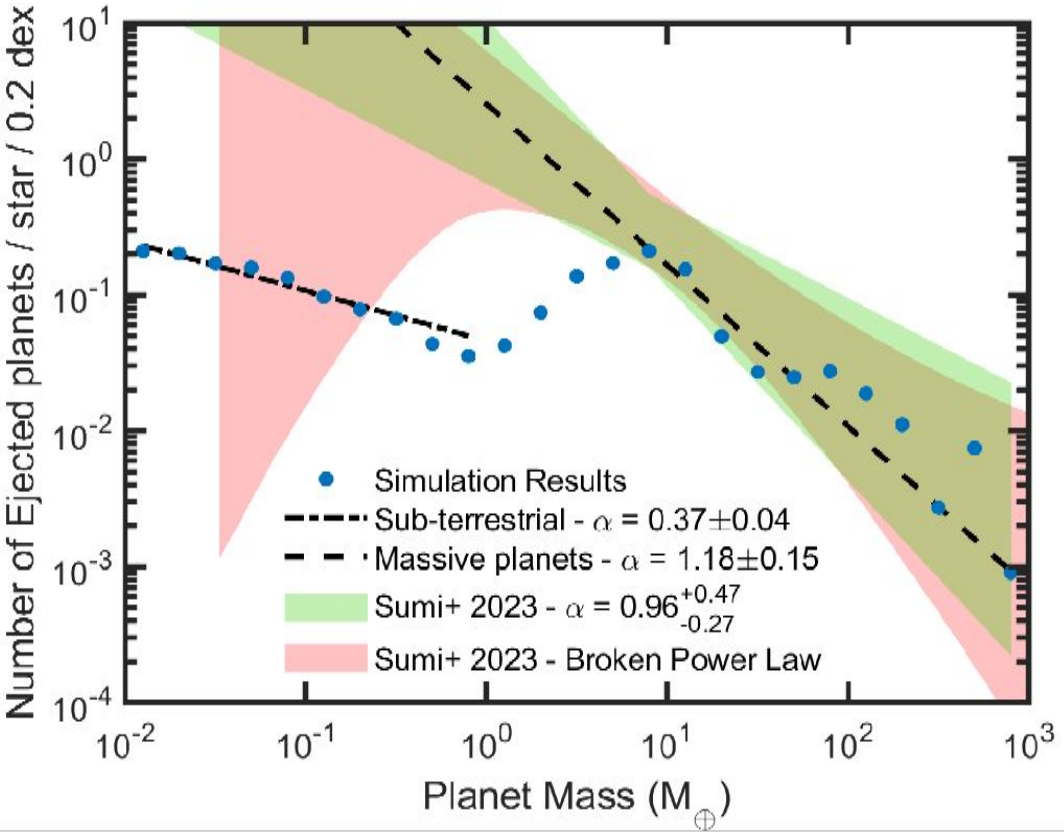
- GBTDS shall detect 1400 cold bound planets and **200-1000 FFPs (Free Floating Planets)**
- The masses of 40% of the detected bound planets shall be measured with 20% uncertainty or better.
- FFPs frequency shall be measured, but **the mass of each FFP will be never measured by the Roman data alone**.

Precise and acuurate mass measurements on large sample are essential to understand the planet formation.

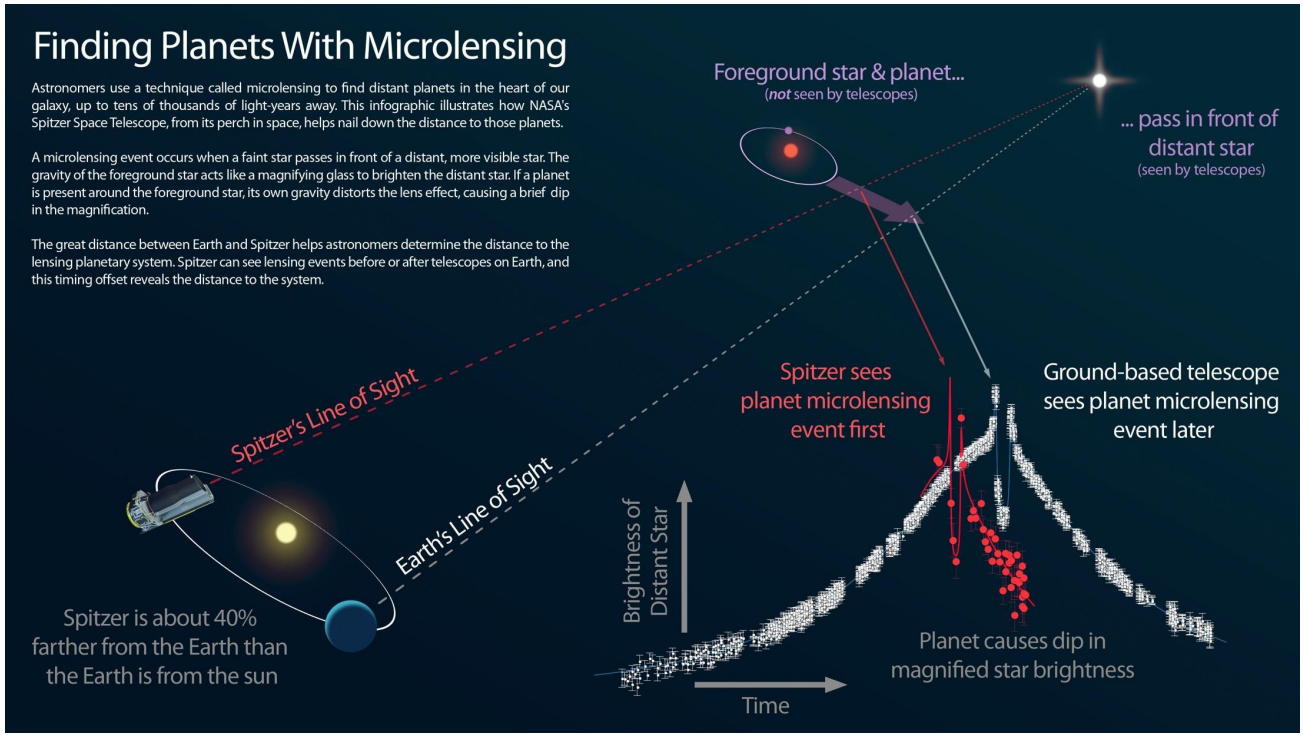
FFP mass-function: Theory vs Observations



Coleman & DeRocco 24

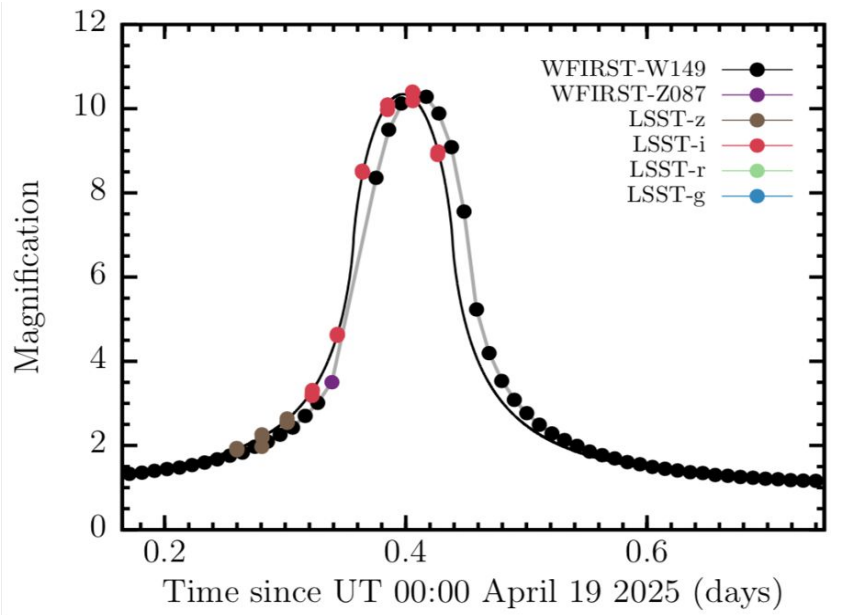
- Planets ejected from binary systems (circumbinary planets) are major contribution to the FFPs
- For > 10 M_{Earth}, the model is consistent with the data, whereas Earth mass FFP or smaller ones are predicted less.
- Note: the current FFP mass-function is derived w/ the Galactic model. The mass of each FFP is not measured.

Microlensing parallax by the concurrent observations



Altough the above is for the Spitzer-Earth (1AU separation) program, idea is same for Roman-Earth (0.01 AU separation). With the small separation, we can resolve the lightcurve differences in short events, leading to the parallax measurement. With the angular Einstein radius measurement from Roman, we can derive the lens mass without any model.

Microlensing parallax by the concurrent observations



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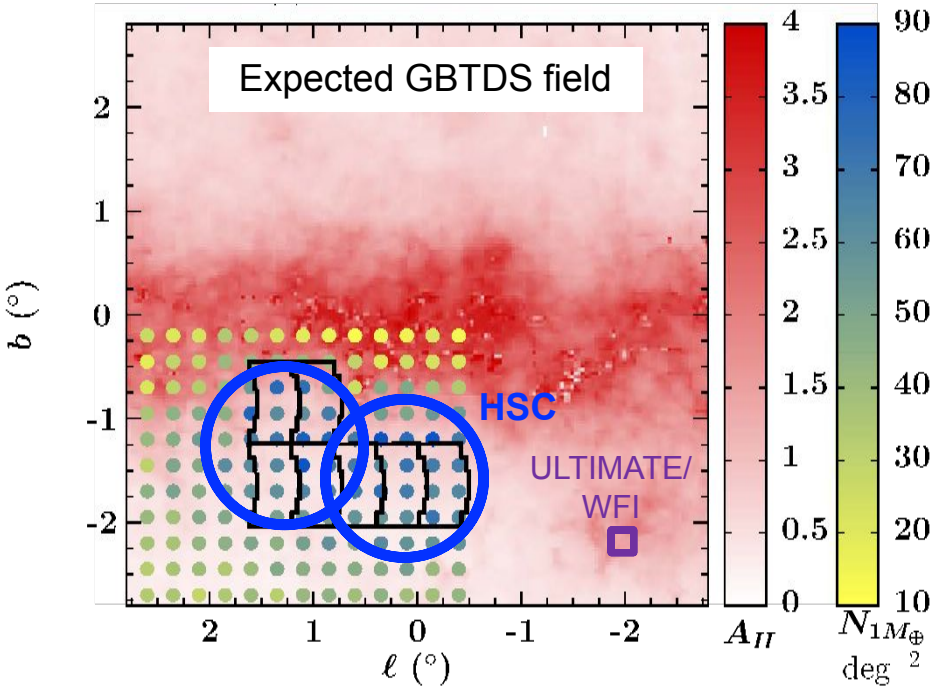
- Roman-HSC concurrent observation is the only way to measure the masses of FFPs.
- **With 20 nights of HSC, ~10 FFPs will be observed (based on Penny+2019, Sumi+23 and assumption of 50% detection efficiency for HSC compared to Roman).**
- **HSC data will also help to reduce false positives.**

Why HSC observations are needed?



HSC and ULTIMATE/WFI FOV are overploted on the Roman GBTDS. Colored dots show the Roman's detection rate of "bound" 1 Earth mass planets.

- GBTDS area: FOV x 7 fields
- That is compared to HSC and ULTIMATE/WFI FOV in the plot.
- HSC can cover the whole GBTDS field with just 2 foot prints.
- Since the FFP lensing events are short time(< a few hours), high cadence observations over the large area are needed.

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Summary

- ✔ The mass measurement of microlensing (bound and unbound) planets from GBTDS can be improved by the concurrent observations with Subaru/HSC.
- ✔ FFPs mass measurement is necessary to understand the planet formation
  - Planet ejection can be constrained (only) by the FFP mass function.
- ✔ FFPs mass measurement is possible only by the Roman-Subaru/HSC concurrent observations.
- ✔ 20 nights (35 nights) of HSC observations will detect 10 (17) FFPs.

Significance of the Synergy: Only HSC-Roman concurrent observations can measure the mass function of FFPs, which will be directly compared to the theoretical model, leading to understand the planet formation process.