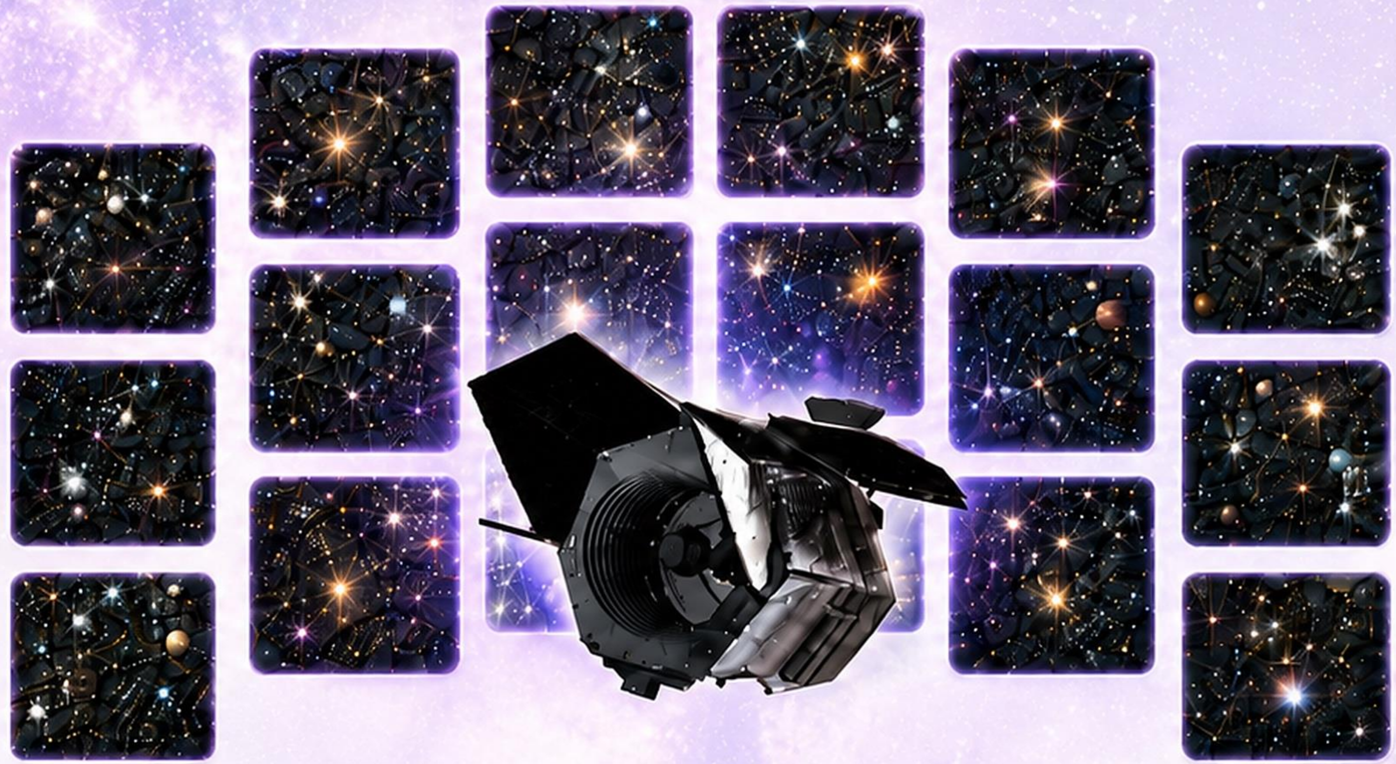


Roman

Microlensing Yield

Farzaneh Zohrabi

Sagan Summer Workshop 2026

LSU

ROMAN GALACTIC EXOPLANET SURVEY
Project Infrastructure Team

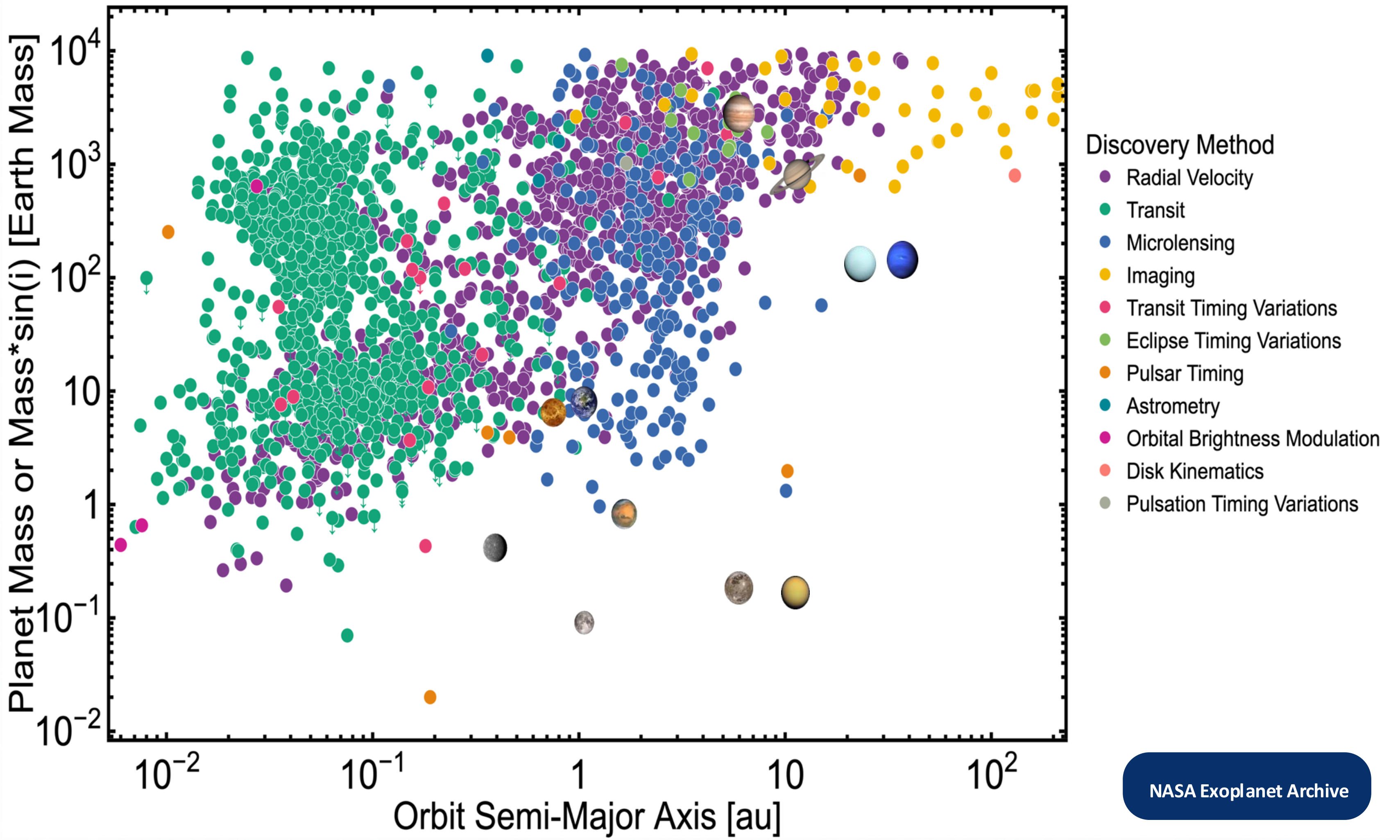
The Demographic Problem

Hot Jupiters: <~1%
e.g., Cumming+1999, Udry+2003, Gould+2006

Super Earths, Mini Neptunes, & Scorched Rocks: ~30-50%
e.g., Howard+2012, Fressin+2013, ...

Gas giants: ~10-30%
e.g., Cumming+2008 Gould+2010, Suzuki+2016

Wide-orbit giants: <1%
e.g., Bowler+2015, Nielsen et al. 2019



NASA Exoplanet Archive

Roman’s Role in the Census

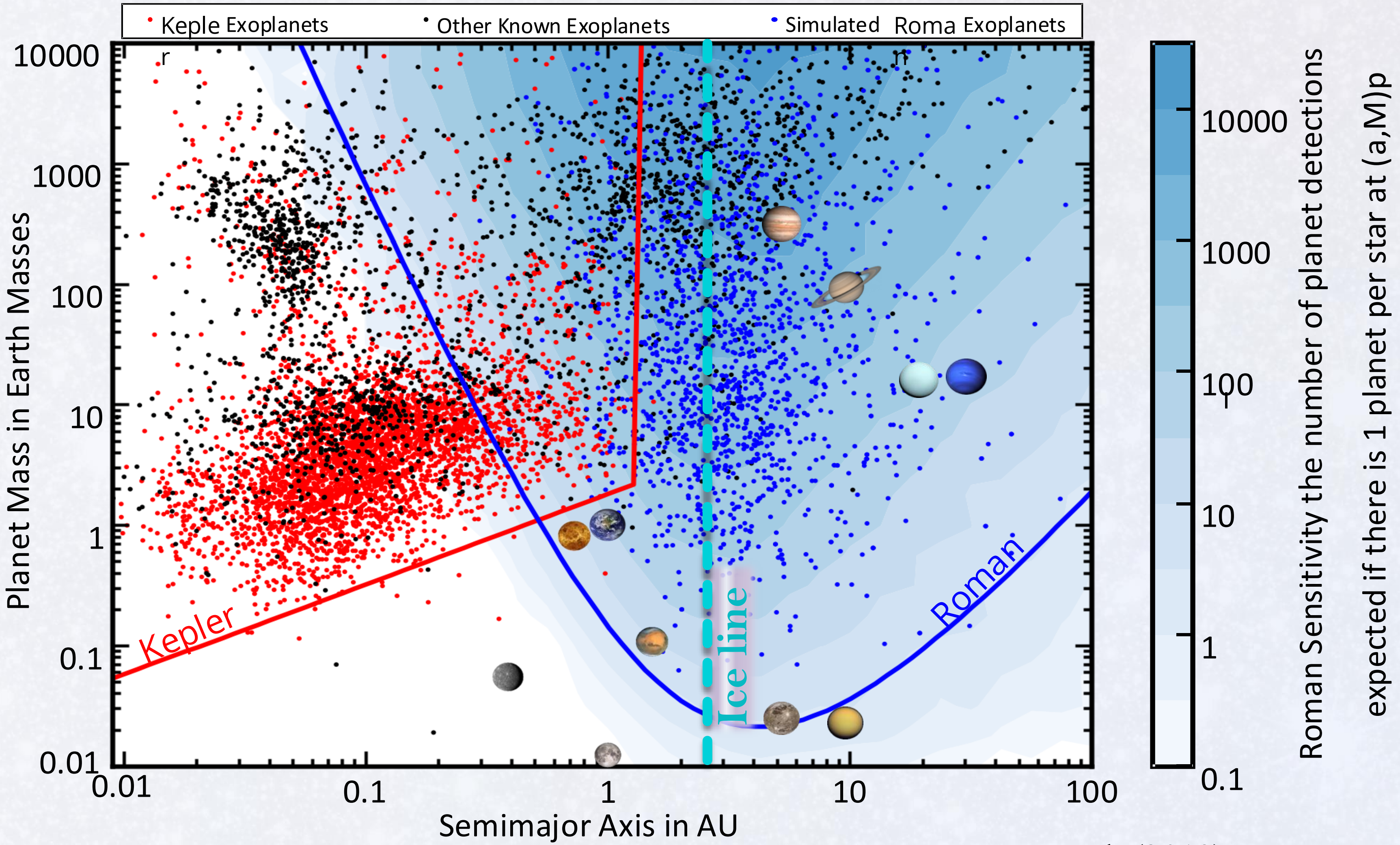
Roman extends exoplanet demographics to cold planets near and beyond the snow line.

1 **Known census**

Large samples, but strongest leverage close to host stars.

2 **Roman window**

Microlensing probes cold planets and fills up the demographic gap.



Penny et al. (2019)

What do we mean by “yield”?

Yield is the expected number of detected planets under a specified set of assumptions.
It is a forecast — not a universal constant.

1 Roman sensitivity
What the survey
can detect

×

2 Planet occurrence
What nature
actually provides

→

3 Roman yield
What Roman is
expected to detect

Galactic Model | Field Layout | Cadence & Exposure | Color Combination | Detection Criteria | Planetary Mass Function

A yield number is incomplete unless the survey design and planet occurrence model are stated.

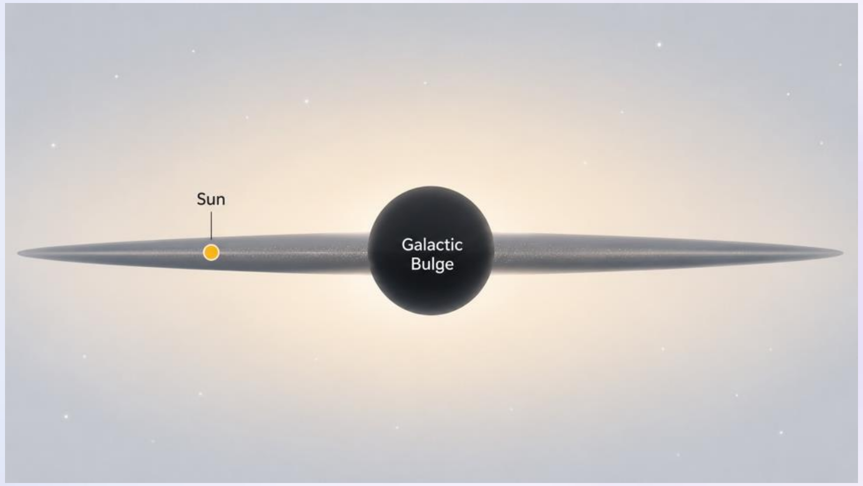
gulls Simulator

gulls → Galactic Model → Observing Scenarios → Injects a Planet → Lightncurve Generator → Detection Criteria → Fisher Matrix Analysis

- Penny et al., 2013
- Penny et al., 2014
- Penny et al., 2019

Galactic Model

The Galaxy defines which microlensing events Roman can sample, and how often they occur.



Source list + Lens list per tile

- Stellar densities
- Distances and velocities
- Luminosity function
- Extinction
- Roman magnitudes

SynthPop star catalogs

Open-source, modular Galactic population synthesis model

gulls imports separate star catalogs as:

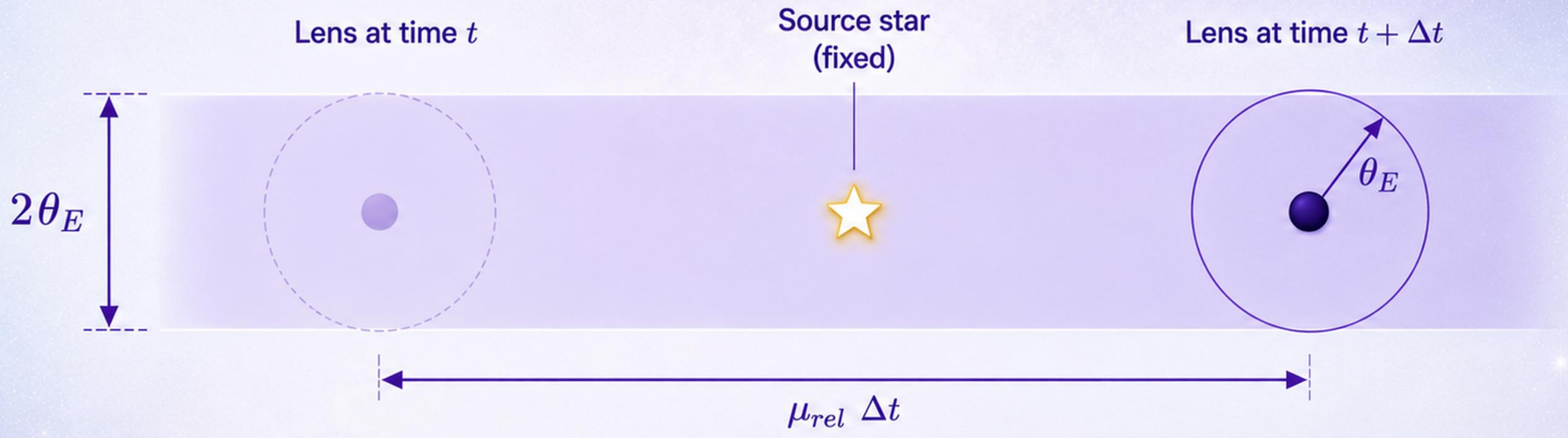
Lens list
Source list
Background Stars lists

Yield changes if the Galactic model changes.

Reference: Klüter & Huston et al. 2025, AJ, 169, 317 — SYNTHPOP

Geometric Microlensing Event-Rate Weight

Top-down view on the plane of the sky



Angular area swept per unit time by the lensing cross-section

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Galactic Model Assumptions in the Yield Calculation

$$W_i = \boxed{\Omega_{tile}\ \Gamma_{deg^2}}\ N_p \frac{w_i}{\sum_j w_{raw,j}}$$

Absolute event-rate normalization from the Galactic model

What it means

- Ω_{tile} : solid angle of the simulated sky tile
- Γ_{deg^2} : microlensing event rate per square degree per year
- Together: expected microlensing event rate in that tile

What it depends on

- source and lens densities
- bulge/disk structure
- extinction and luminosity function
- kinematics

Yield normalization is model-dependent and will improve as Roman, Rubin, and Euclid refine the Galactic model.

gulls Simulator

gulls → Galactic Model → Observing Scenarios → Injects a Planet → Lightncurve Generator → Detection Criteria → Fisher Matrix Analysis

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- Penny et al., 2014
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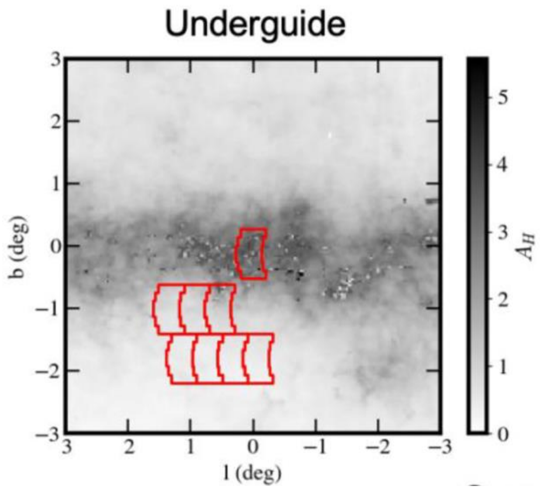
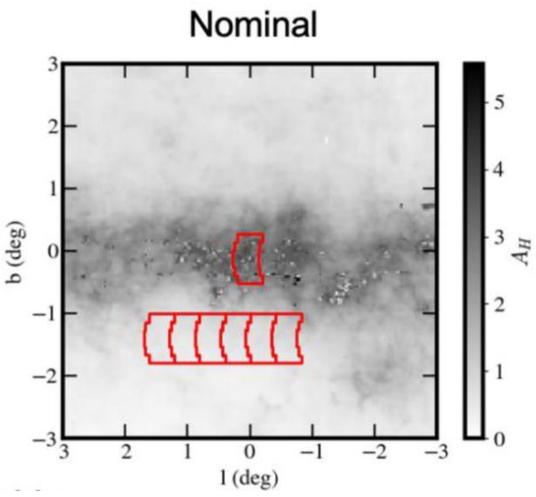
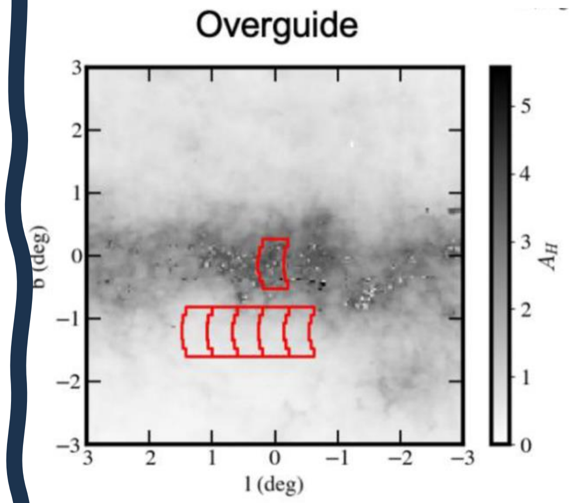
Core Community Survey Definition Committee Recommendations



63 days/season
12.6 min cadence
58s exposures
Low cadence GC
380 days total



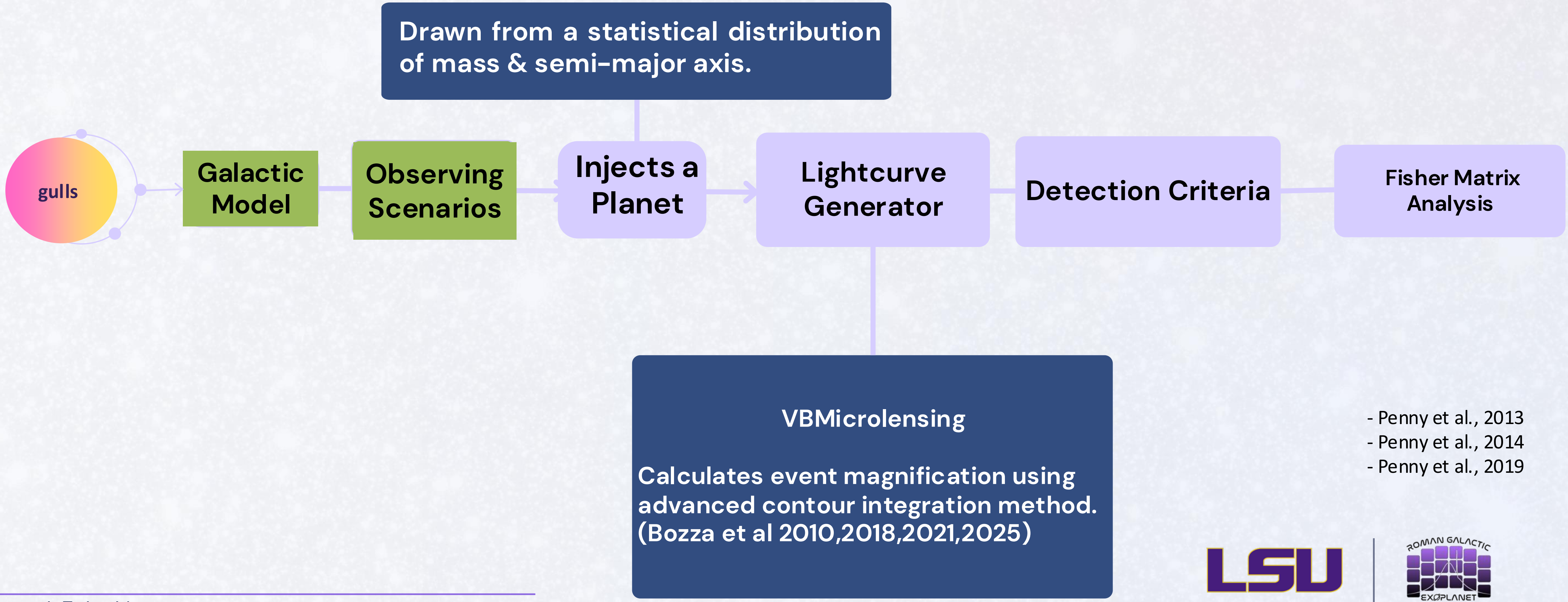
68.5 days/season
14.8 min cadence
73s exposures
High cadence GC
420 days total



70.5 days/season
12.1 min cadence
66s exposures
High cadence GC
440 days total

Christiansen & Huber et al. (2024)

gulls Simulator



- Penny et al., 2013
- Penny et al., 2014
- Penny et al., 2019

Detection Criteria: When Does a Simulated Planet Count?

A simulated planetary light curve contributes to the bound-planet yield only if it passes the adopted detection test.

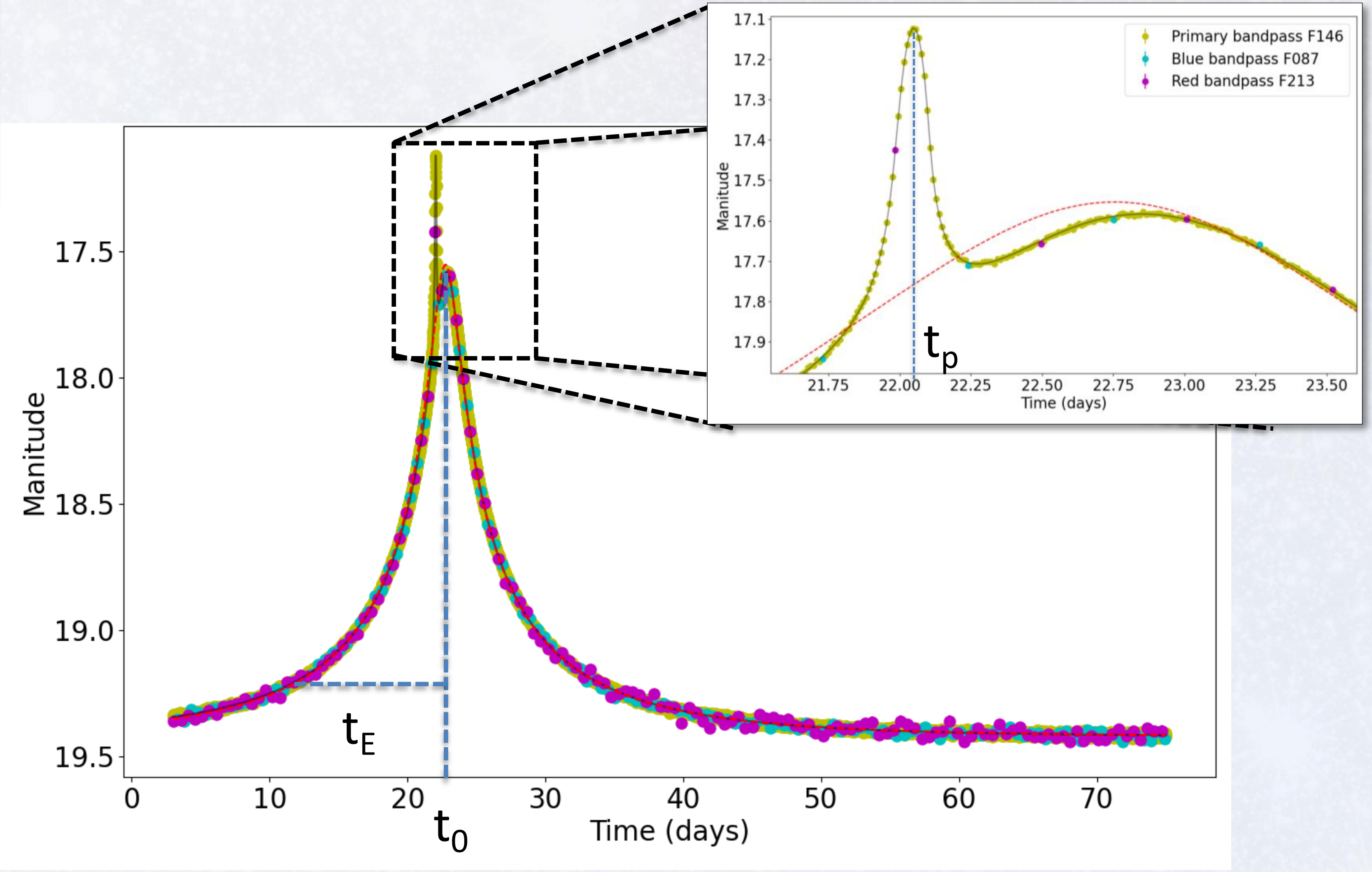
$$\Delta\chi^2 = \chi^2\_single - \chi^2\_planet > 160$$

The planetary model must improve the fit by more than the adopted threshold.

$$q = \frac{M_p}{M_L}$$

$$\Downarrow$$

$$q \approx \left(\frac{t_p}{t_E}\right)^2$$



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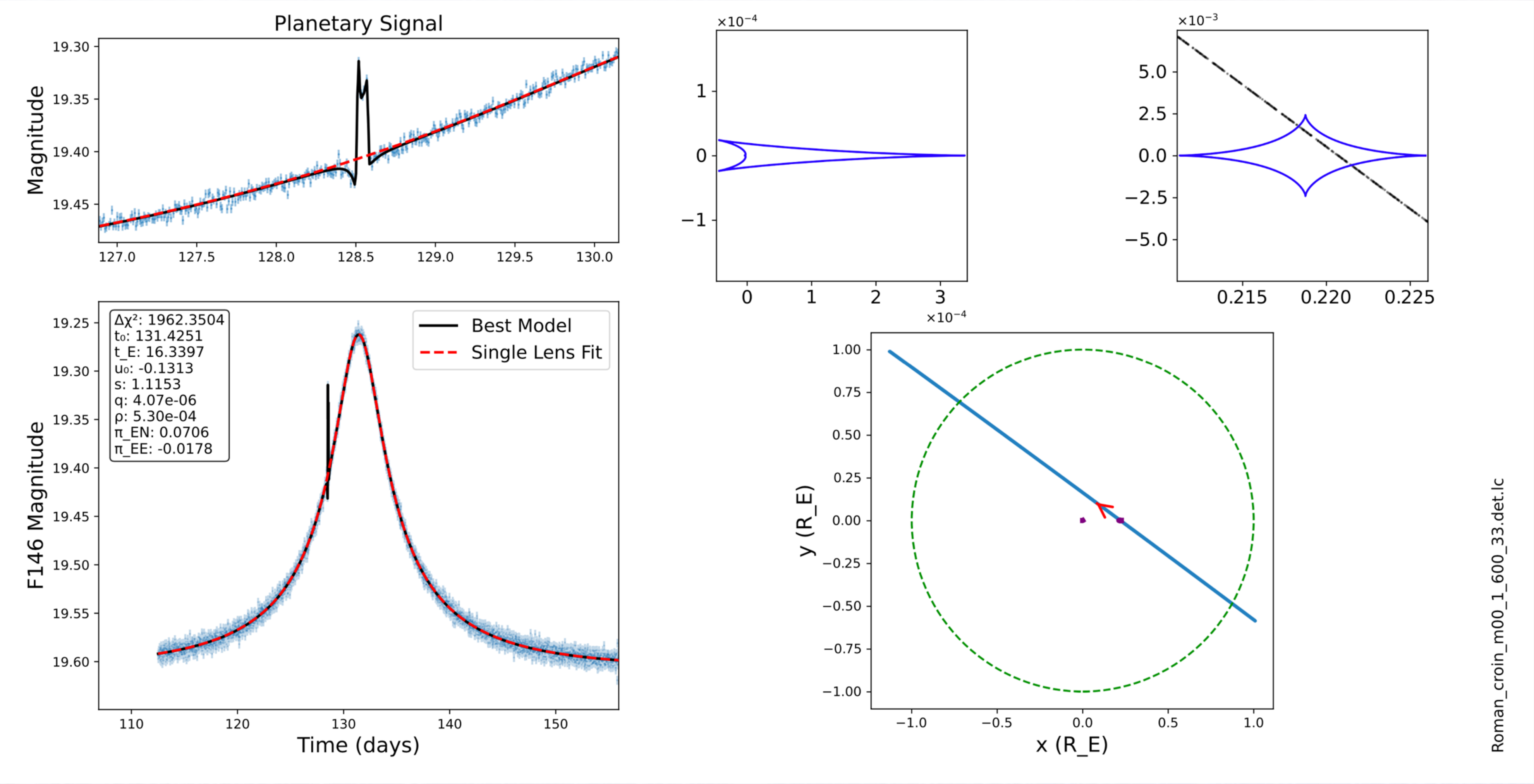
gulls Simulator – Visualization



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Galactic Model | **Field Layout** | **Cadence & Exposure** | **Color Combination** | **Detection Criteria** | **Planetary Mass Function**

A yield number is incomplete unless the survey design and planet occurrence model are stated.

Planetary Mass Functions in the Yield Calculation

- **The number of planets that exist per star.**

- **N_p** sets the total number of planets per star over the adopted parameter range.

- Different occurrence models **re-weight the same simulated detections** differently.

Study	Sample	Where the sample came from	Parameterized as
Cassan et al. (2012)	3 planets	OGLE alerts + PLANET follow-up (2002–2007)	$f(M_p, a)$
Suzuki et al. (2016)	23 planets	MOA-II survey alerts (2007–2012)	$f(q, s)$
Zang et al. (2025)	63 planets	KMTNet microlensing survey	$f(q)$, ~flat in log s

$$q = \frac{M_{planet}}{M_{lens}}$$

s = projected separation in Einstein-radius units

Planetary Mass Functions

Cassan et al. 2012

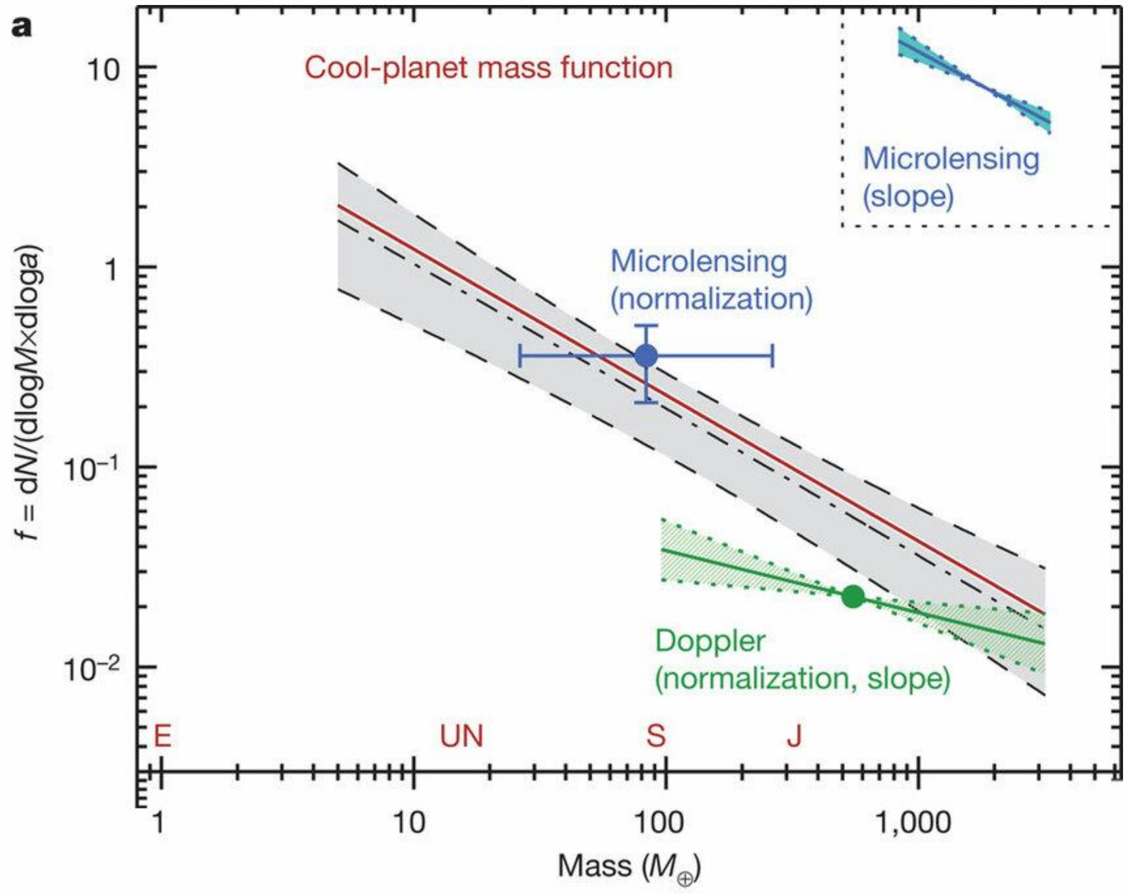
•Physical mass and semimajor axis

•Small microlensing sample

•Directly constrained only to approximately 5 Earth Mass

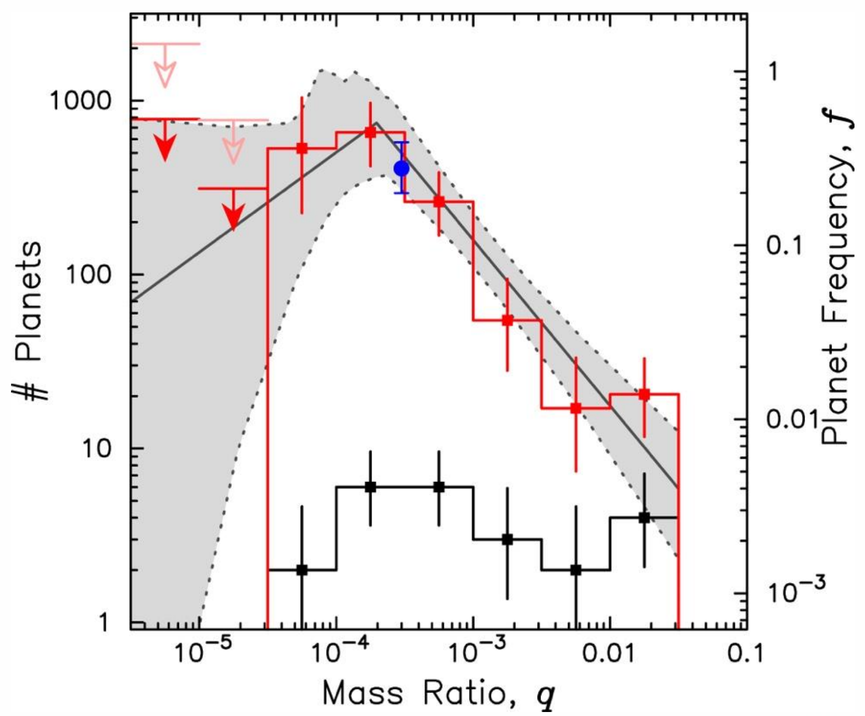
•Roman forecasts extrapolate below this range

Cassan et al 2012

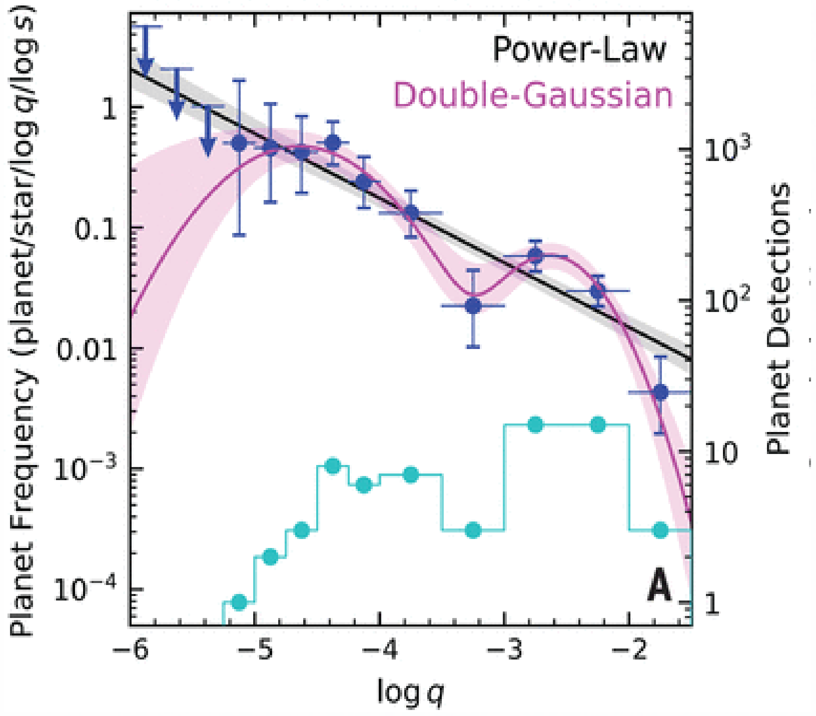


Planetary Mass Functions

Suzuki et al 2016

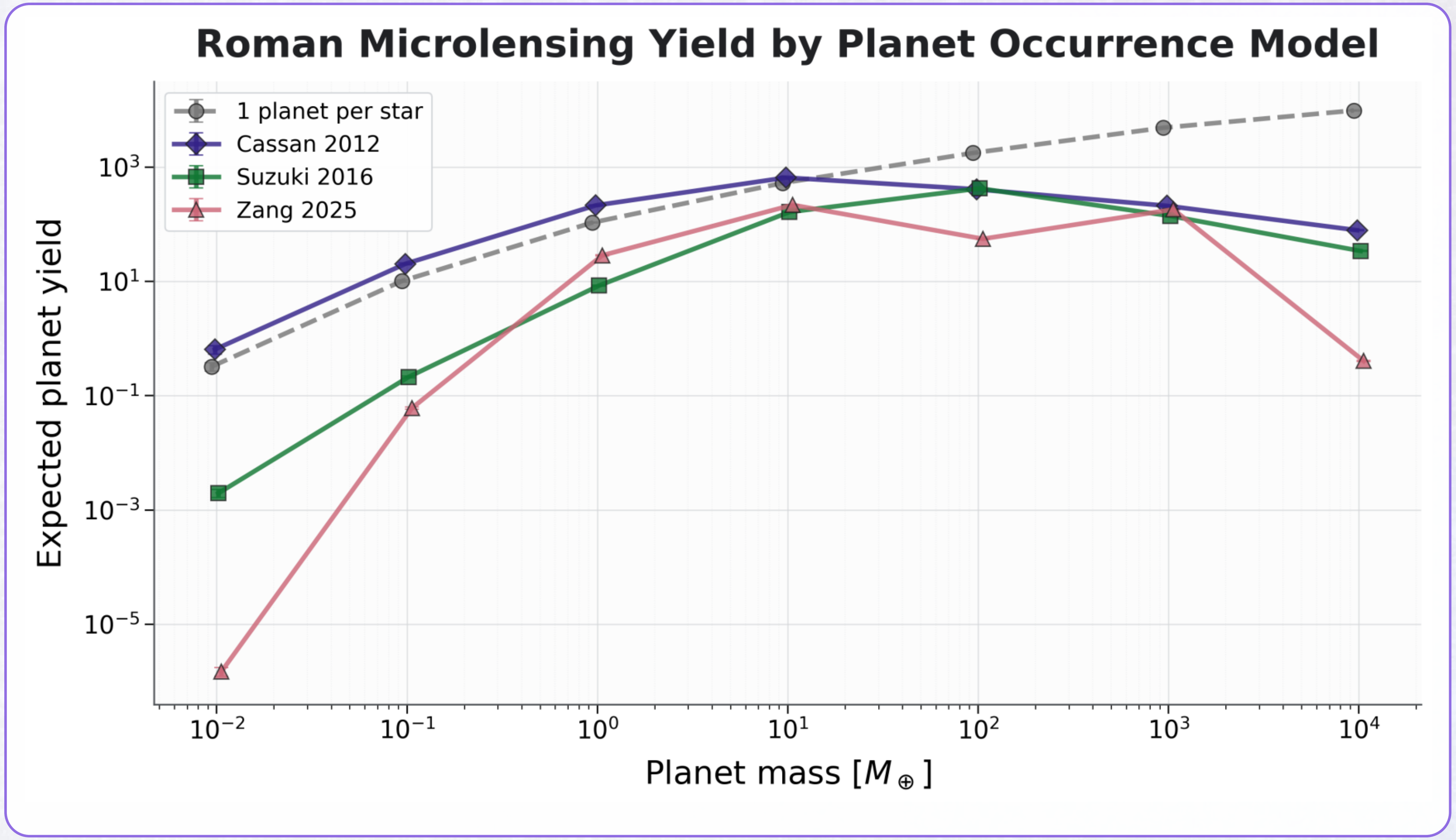


Zang et al 2025



At sub-Earth masses, different yield predictions mostly reflect uncertainty in planet occurrence—not disagreement about Roman's sensitivity.

How Does Planetary Occurrence Assumptions Effect the Roman Yield?



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How Does Planetary Occurrence Assumptions Effect the Roman Yield?

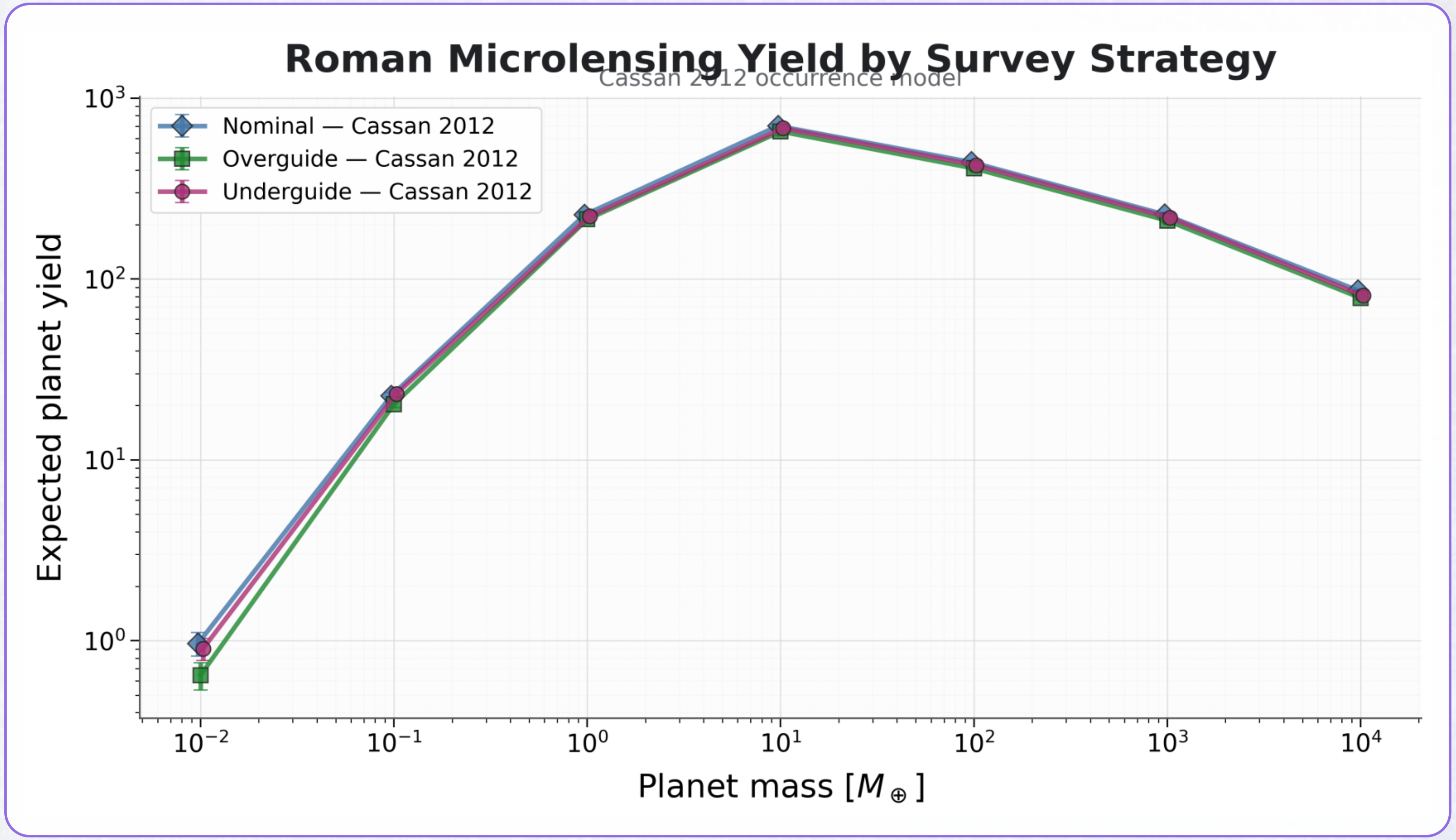
Roman Microlensing Yield by Planet Occurrence Model

Overguide strategy · expected detections rounded to whole planets

Planet Mass [$M_\oplus$]	Cassan 2012	Suzuki 2016	Zang 2025
0.01	1	0	0
0.1	20	0	0
1	214	8	29
10	655	164	218
100	409	424	56
1,000	210	140	182
10,000	79	34	0
Total	**1,588**	**770**	**484**

Yields are rounded to the nearest whole planet. Uncertainties are omitted for presentation clarity.

How Does Survey Strategy Effect the Roman Yield?



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Conclusions & Outlook

1. **Bound-planet yield is a conditional forecast**

   It combines the Galactic event rate, Roman survey design, detection criteria, and the assumed planet occurrence model.

2. **Complementary missions sharpen the forecast**

   Gaia, Rubin, Euclid, ground-based microlensing, and Roman improve occurrence rates and Galactic models.

3. **Characterization turns planet detections into a physical understanding of planetary systems**

4. **Every Roman yield is a discovery**

   More planets, fewer planets, or an unexpected mass distribution will reshape planet demographics, formation, and evolution.

Roman will transform exoplanet science not by matching our predictions, but by replacing assumptions with measurements.


Thank You