Observations vers le bulbe galactique : défis, promesses et opportunités

pour l'étude de la démographie des planètes à partir de 2027

Clément Ranc (IAP / Sorbonne Université)

Roman Galactic Exoplanet Survey Project Infrastructure Team (RGES PIT)

Arthur Vigan (LAM)

Roman CGI

The Roman Galactic Exoplanet Survey

Wide-Field Instrument (WFI)

- 0.5-2.3 µm bandpass
- 0.281 sq. deg. FoV
- 18 H4RG detectors (288 Mpixels)
- 7 filtres, prisme et prisme pour spectroscopie

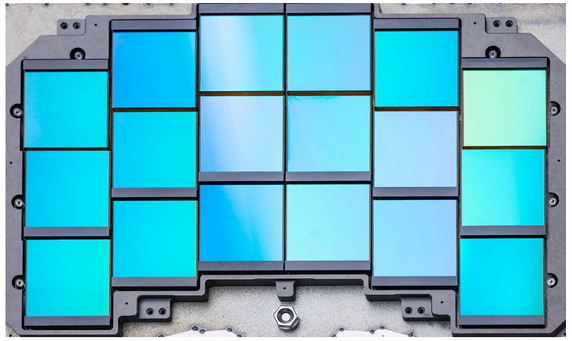
Coronograph Instrument (CGI)

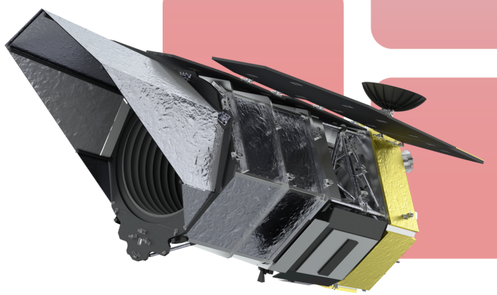
- Imagerie haut contraste dans le visible
- Spectrographe et polarimètre
- 3 types de masques pour le coronographe
- Démonstrateur technologique pendant 2 mois

5 Core Community Surveys liés au WFI

- High-latitude Imagining Survey
- High-latitude Spectroscopy Survey
- SNe Survey
- **Galactic Bulge Time Domain Survey**
- Galactic Plane Survey

Properties	Roman
Eff. Aperture	2.28m
FOV	0.281 deg^2
Wavelengths	~0.5-2 µm (WFI)
FWHM@1µm	0.10”
Pixel Size	0.11”
Launch/ Lifetime	2026/5 years
Orbit	L2





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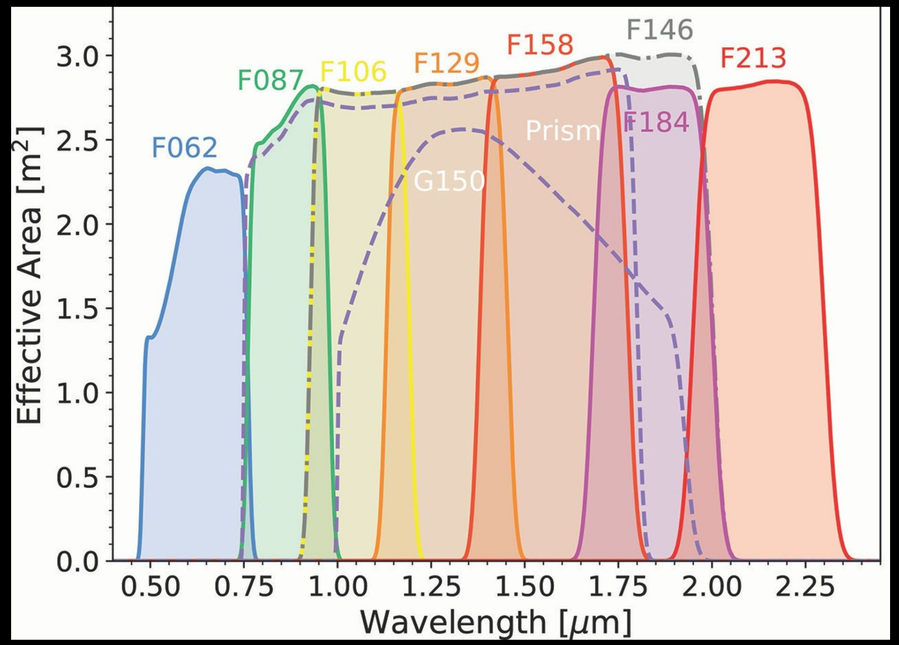
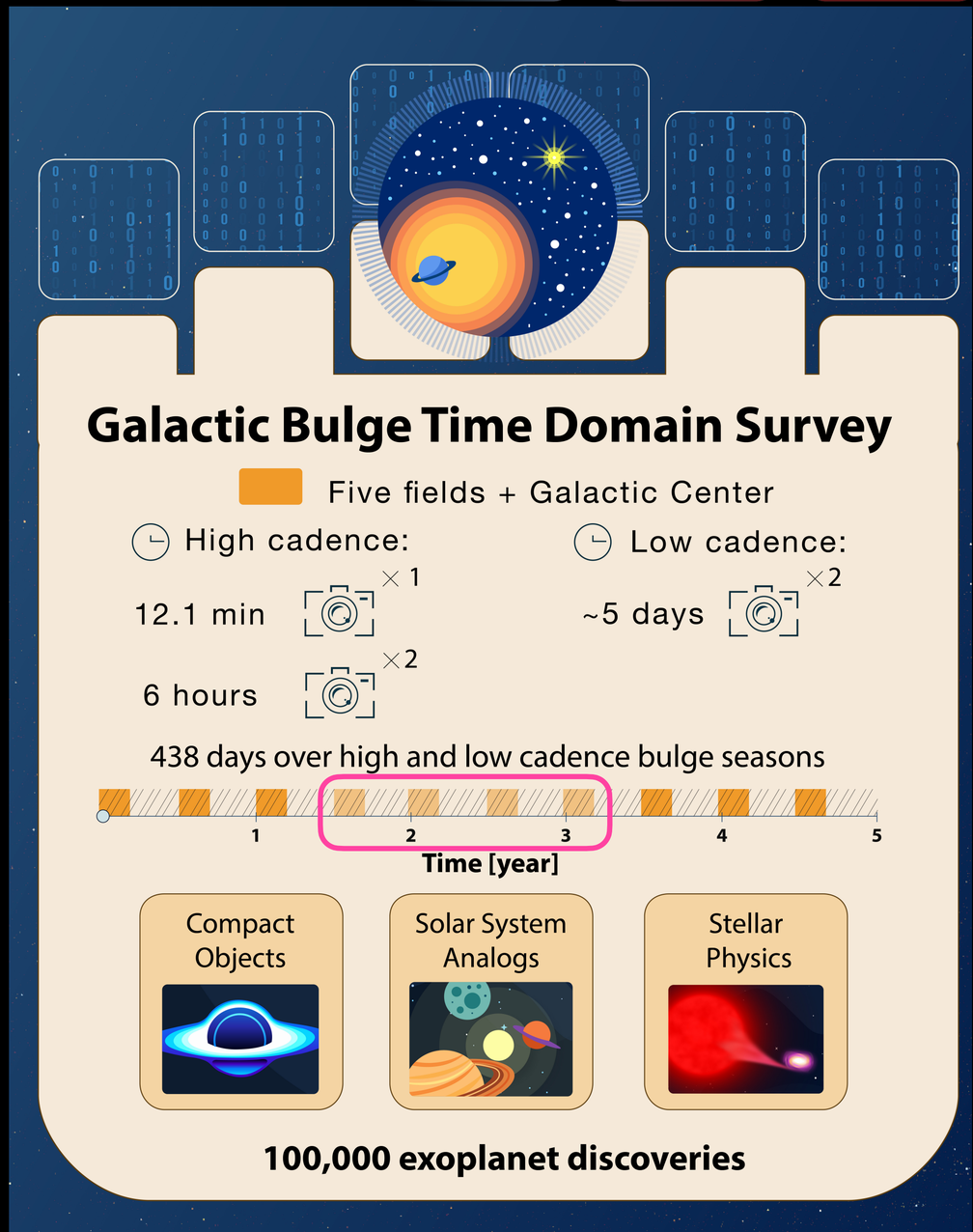
PIT : Sustained funding for teams to work in partnership with the science centers to develop infrastructure needed to enable the community to pursue Roman's ambitious science goals in cosmology and exoplanet demographics.

Parameters for the Roman Galactic Bulge Time Domain Survey (RGBTDS)

- 5 fields toward the Galactic bulge
  + 1 field on the Galactic center
- Survey area: ~1.5 deg^2
- 6 x 72-day over 5 yrs at high cadence
- Observing cadence in different filters:
  - Wide band W146 (0.93-2 um): 12 min^{-1}, 67s exposures (50,000+ images), 1 photon/s at 27.6 mag
    OR W146 + F213 (K) every ~5 days
  - Observations in F087 (Z) and F213 (K): ~3 hours^{-1}



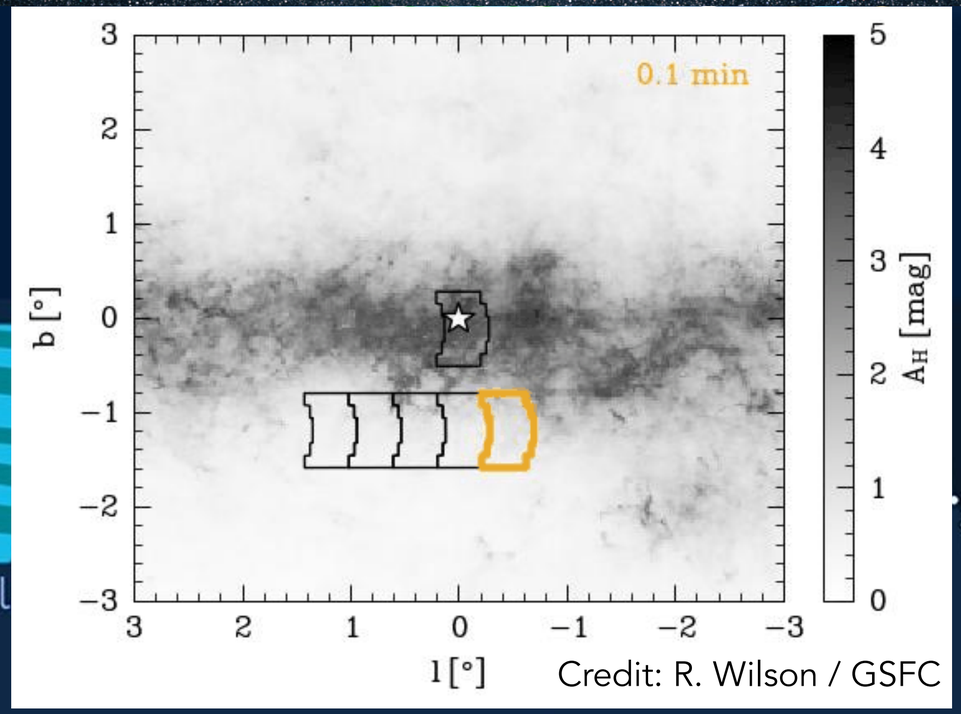


GALACTIC BULGE
TIME-DOMAIN SURVEY

The area of

8.5

full moons



Credit: R. Wilson / GSFC

APRIL

438 days, primarily in six sets of 72 days each

Full survey area imaged every 12 minutes

1.7 square degrees

Mission of the Roman Galactic Exoplanet Survey PIT

- Mass function of exoplanets with masses in the range 1 M_E < m < 30 M_J and orbital semi-major axes ≥ 1 AU to better than 15% per decade in mass.
- Frequency of bound exoplanets with masses in the range 0.1 M_E < m < 0.3 M_E to better than 25%.
- Determining masses of, and distances to, host stars of 40% of the detected planets with a precision of 20% or better.
- Frequency of free floating planetary-mass objects in the Galaxy from Mars to 10 M_J. If there is 1 M_E free-floating planet per star, measure this frequency to better than 25%.
- Estimating the frequency of planets orbiting FGK stars with mass ratio and estimated projected semimajor axis within 20% of the Earth-Sun system) […].

- US-based : 45
- EU: 9 (France 3, Italy 2, Poland 2, UK 1, Germany 1)
- Japan: 5
- New Zealand: 3
- China, Australia, India: 1

+ Many more not in the PIT yet

High resolution images, planet mass measurement method…

Jean-Philippe Beaulieu
IAP

Follow up,
high resolution,
planet detection and characterization…

C. Ranc, IAP

Simulations, event modeling,
MSOS pipeline until 2025…

Étienne Bachelet
CPJ UMLP Besançon

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Mission of the RGES PIT

- Improve the microlensing event rate and yield calculations by improving the input Galactic models, incorporating new measurements of the near-infrared event rate obtained by the PRIME survey
- Develop and test the prototype photometry and astrometry pipeline, event detection pipeline, lightcurve modeling pipeline, and detection efficiency (or completeness) pipeline, with the goal of making these publicly-available and user-friendly
- Develop the occurrence rate formalism and methodology.

RGES PIT Leadership

Role	People (Institution)
Principal	B. Scott Gaudi (OSU)
Science PI	David P. Bennett (UMD/GSFC)
Project Manager	Christopher Brandon (OSU)
Education & Outreach Programs	Keivan Stassun (Vanderbilt)

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- WG #1: Leadership and Project Management
- WG #2: Education, Outreach, and Community
- WG #3: Event Modeling
- WG #4: Lens Flux Analysis
- WG #5: Event and Anomaly Detection
- WG #6: Variable Stars
- WG #7: Survey Simulations and Pipeline Validation
- WG #8: Contemporaneous and Precursor Observations
- WG #9: Data Challenges, Outreach, and Citizen Science
- WG #10: Microlensing Mini-Courses
- WG #11: Free Floating Planets
- WG #12: Efficiency and Occurrence Rate Analysis
- WG #13: Astrometry
- WG #14: Global Pipeline

How? Usir

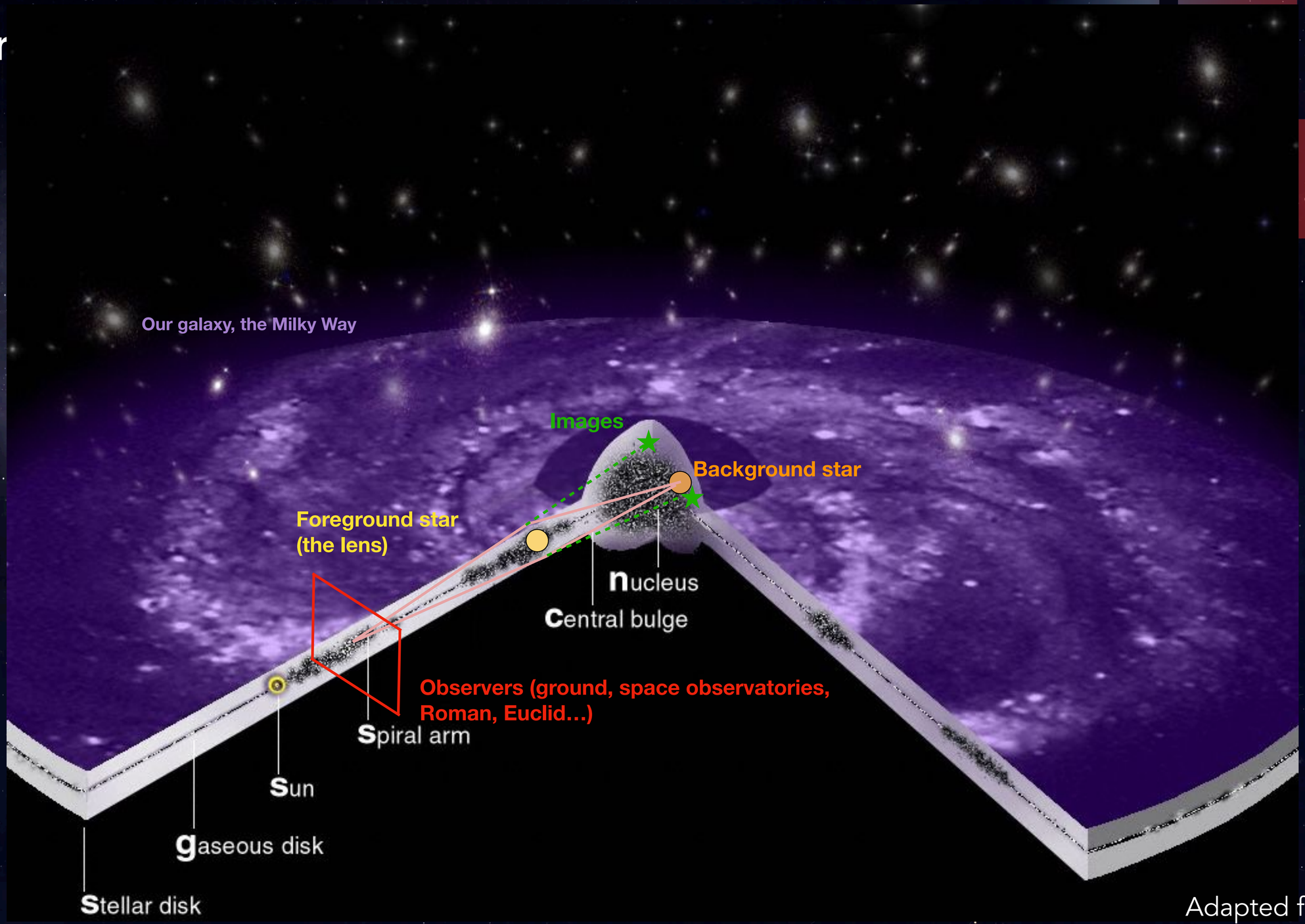

Image: NASA

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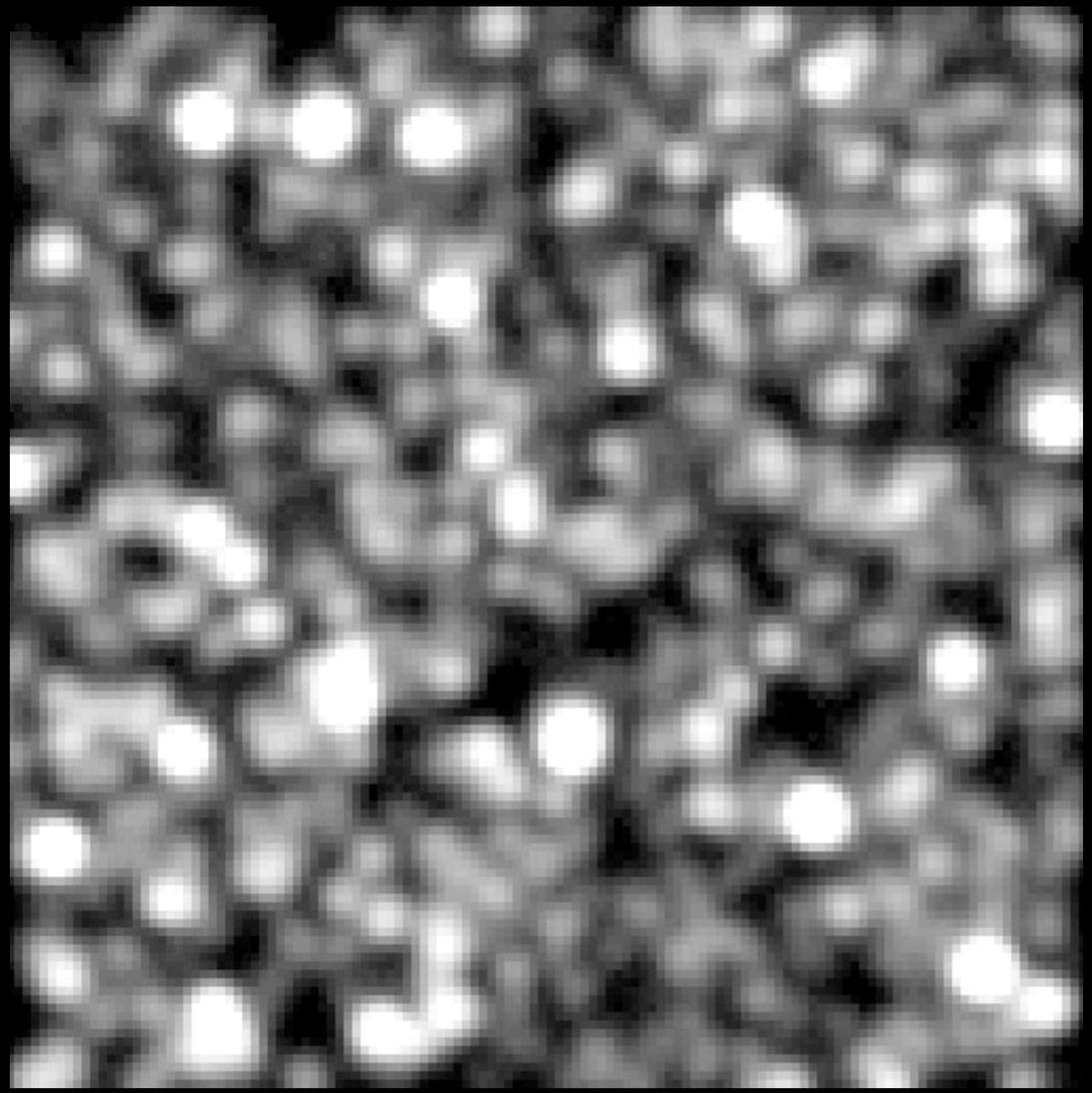
Adapted from ESA

Detection of microlensing events towards the Galactic bulge



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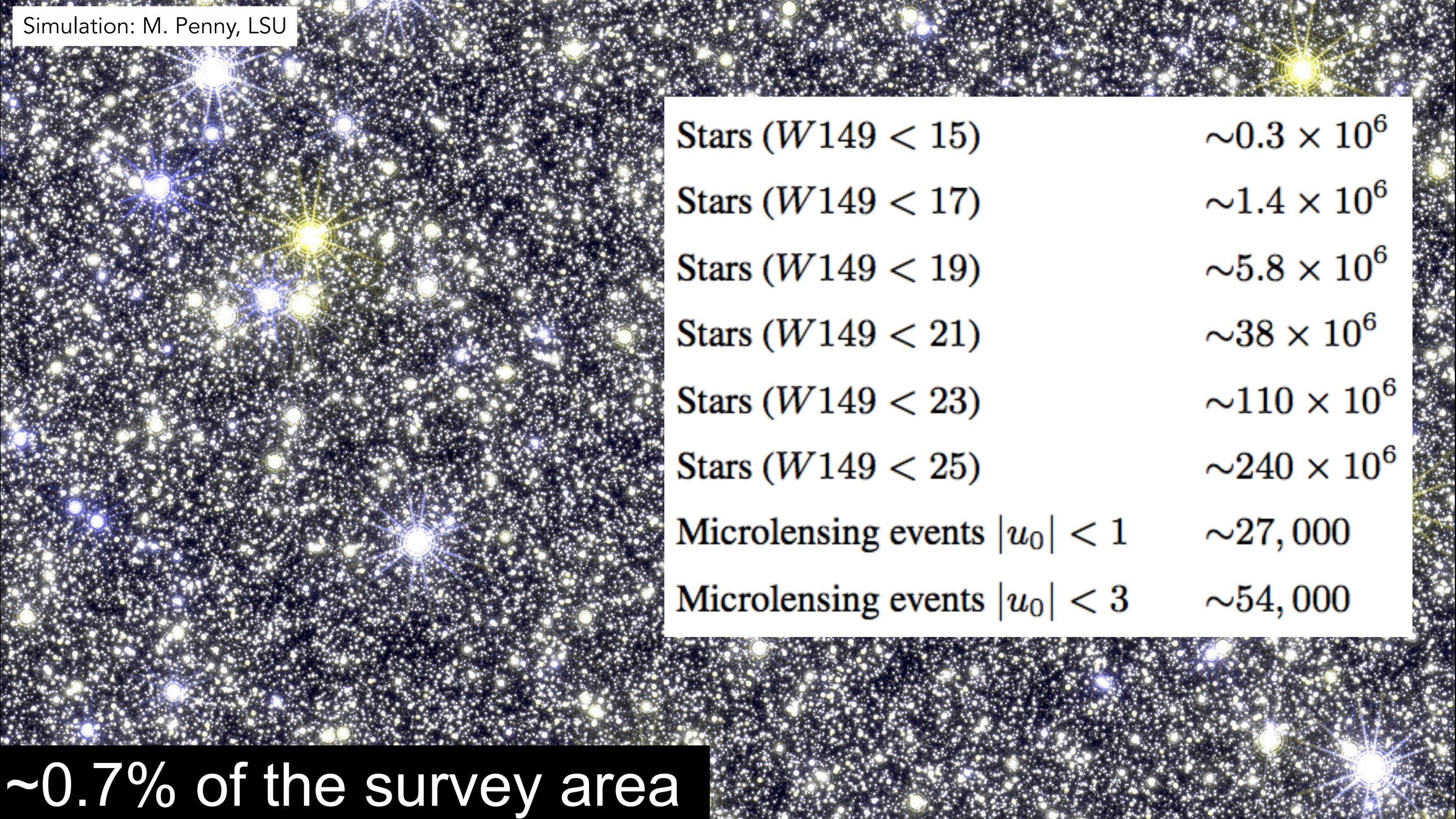
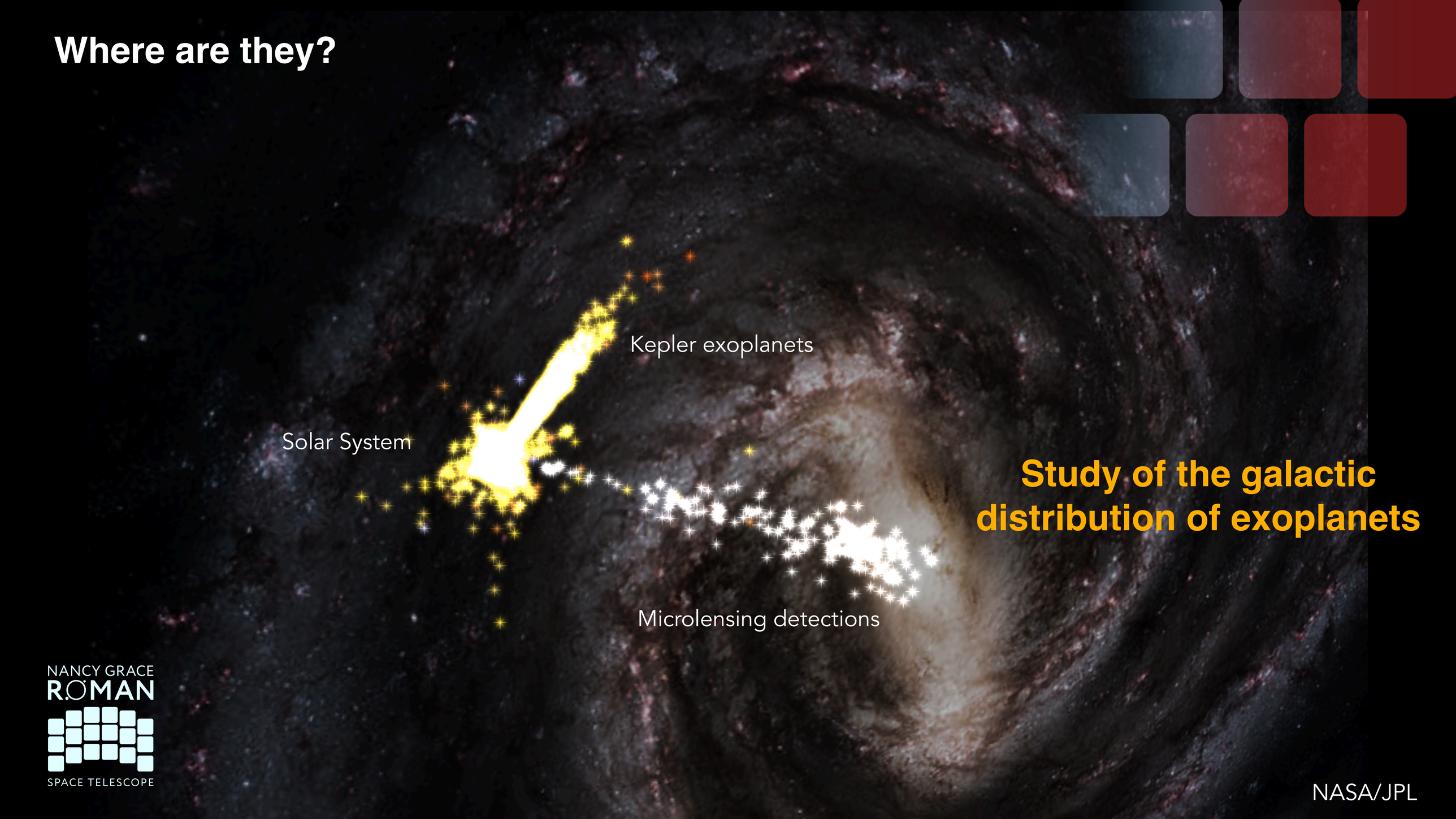


Stars ($W149 < 15$)	$\sim 0.3 \times 10^6$
Stars ($W149 < 17$)	$\sim 1.4 \times 10^6$
Stars ($W149 < 19$)	$\sim 5.8 \times 10^6$
Stars ($W149 < 21$)	$\sim 38 \times 10^6$
Stars ($W149 < 23$)	$\sim 110 \times 10^6$
Stars ($W149 < 25$)	$\sim 240 \times 10^6$
Microlensing events $\lvert u_0 \rvert < 1$	$\sim 27,000$
Microlensing events $\lvert u_0 \rvert < 3$	$\sim 54,000$

~0.7% of the survey area

Where are they?



Study of the galactic distribution of exoplanets

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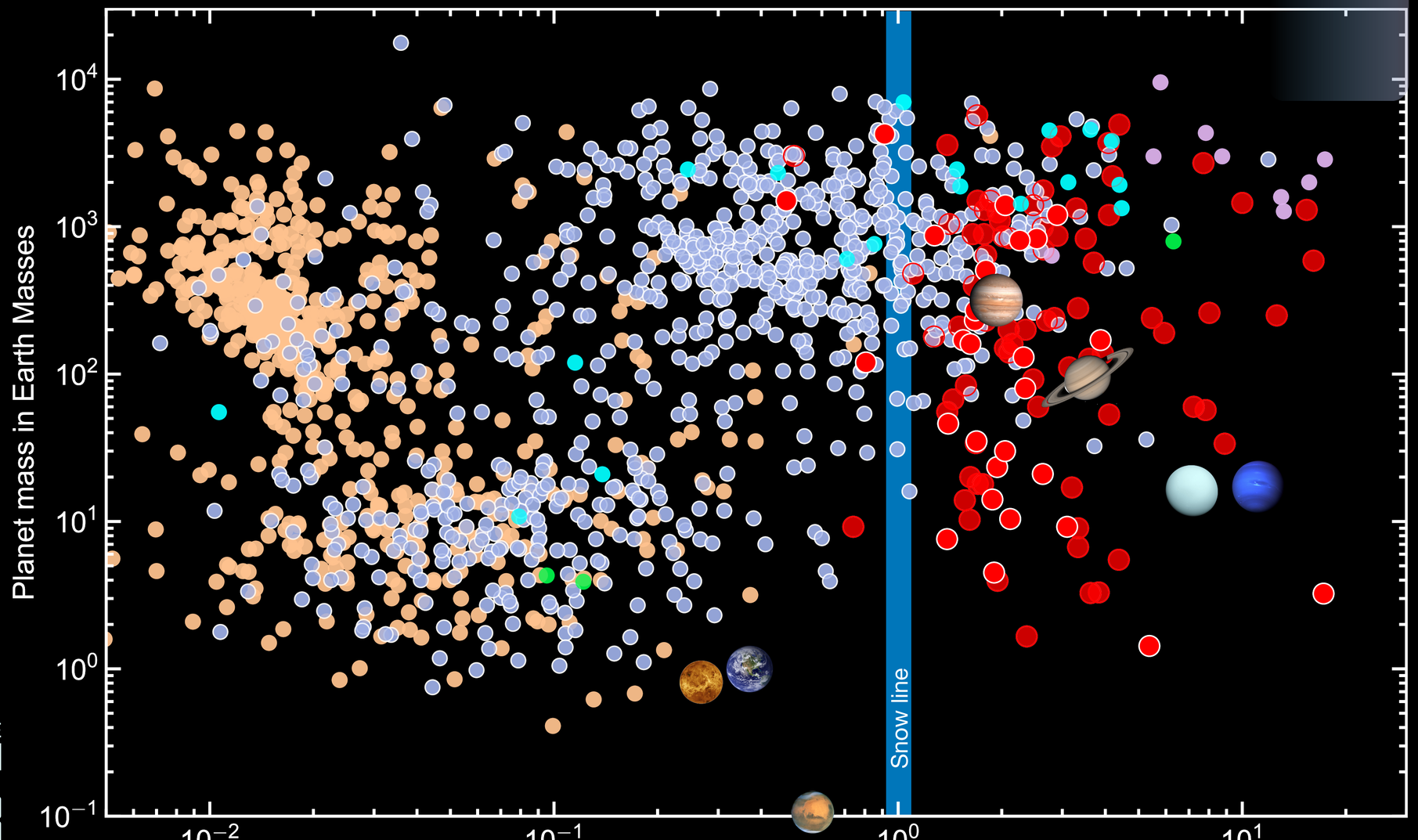
NASA/JPL

Where are they?



Mass measurement

Mass estimate

RV
Transits
Microlensing
Imaging
TTV
Pulsar

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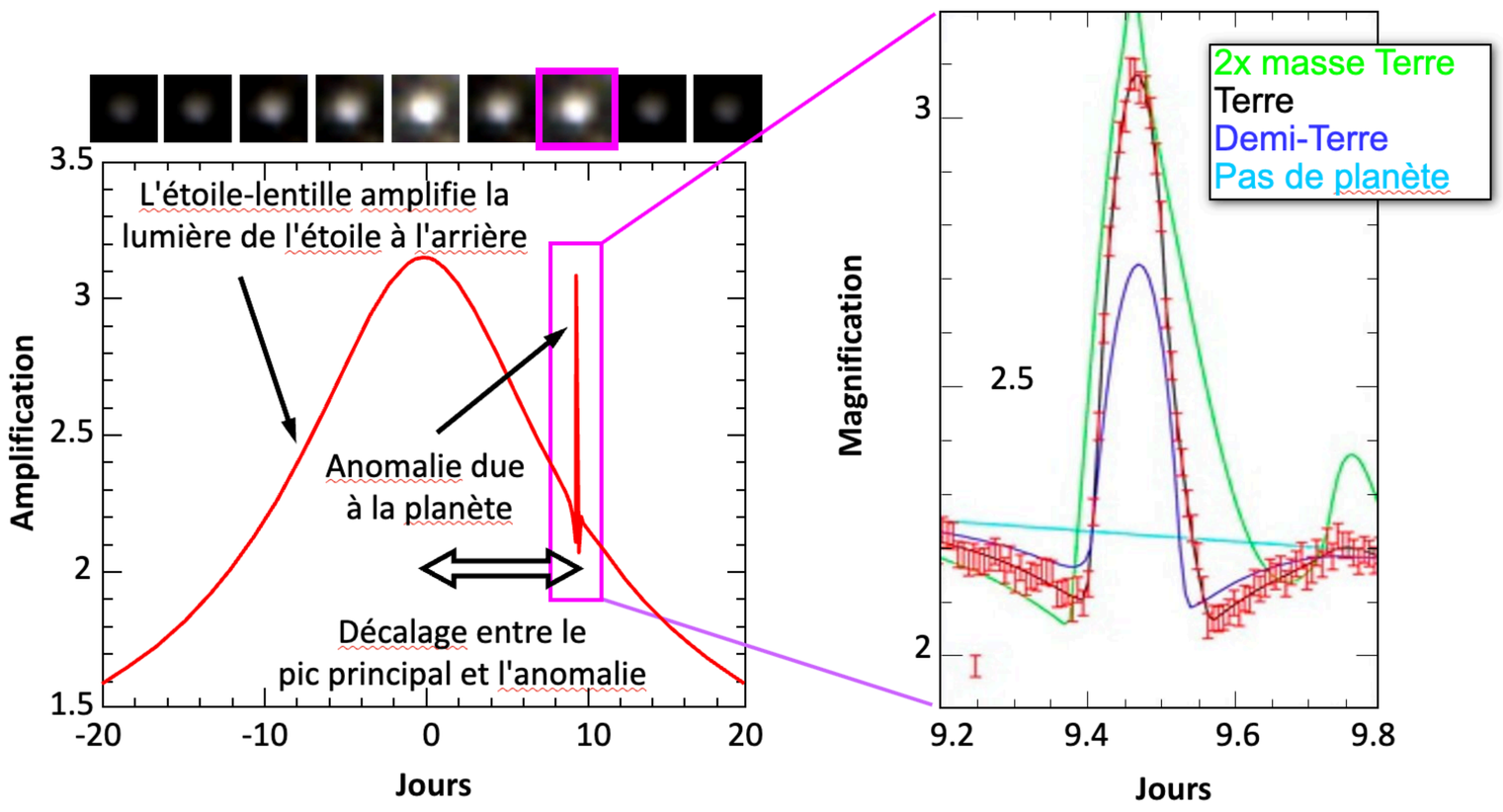
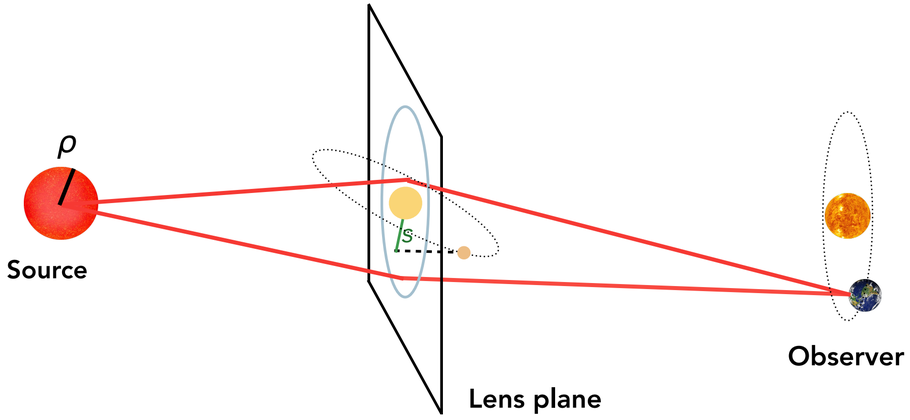
Detections with high S/N ratio





What we always measure:

- The timescale t_E
- Planet-to-host mass ratio: $q = \frac{\text{Mass of}}{\text{Mass of}}$
- Host star-planet separation

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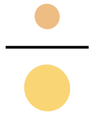
Mass measurements using high resolution from space

3 unknown

- Host star mass
- Exoplanet mass
- Distance to exoplanetary system

Measured from microlensing light curve:

- Mass ratio: $\frac{\text{Exoplanet mass}}{\text{Host star mass}}$ = 

High resolution images in order to detect the lens **alone**:

- Lens brightness = host star brightness $\propto \frac{f(M)}{D_L^2}$
  - Host star mass = f (distance)

- Lens-source relative motion
  - Lens total mass $\propto \mu_{\text{rel}}^2 \left(\frac{1}{D_L} - \frac{1}{D_S} \right)^{-1}$ = 

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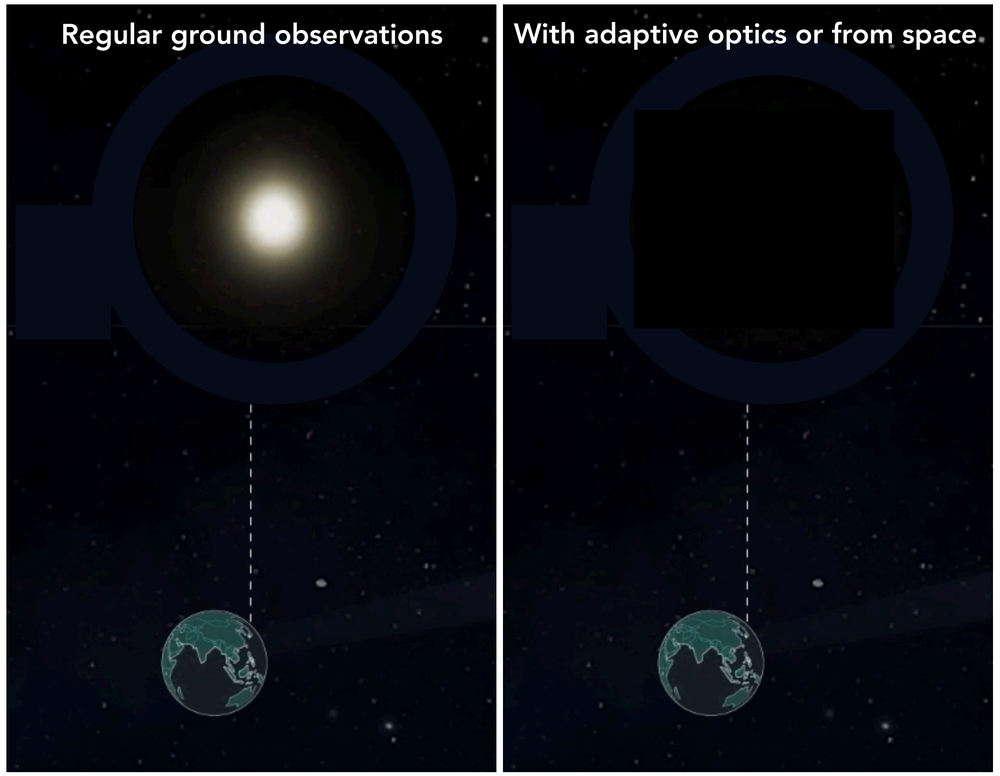
Simulated observation toward the microlensing target

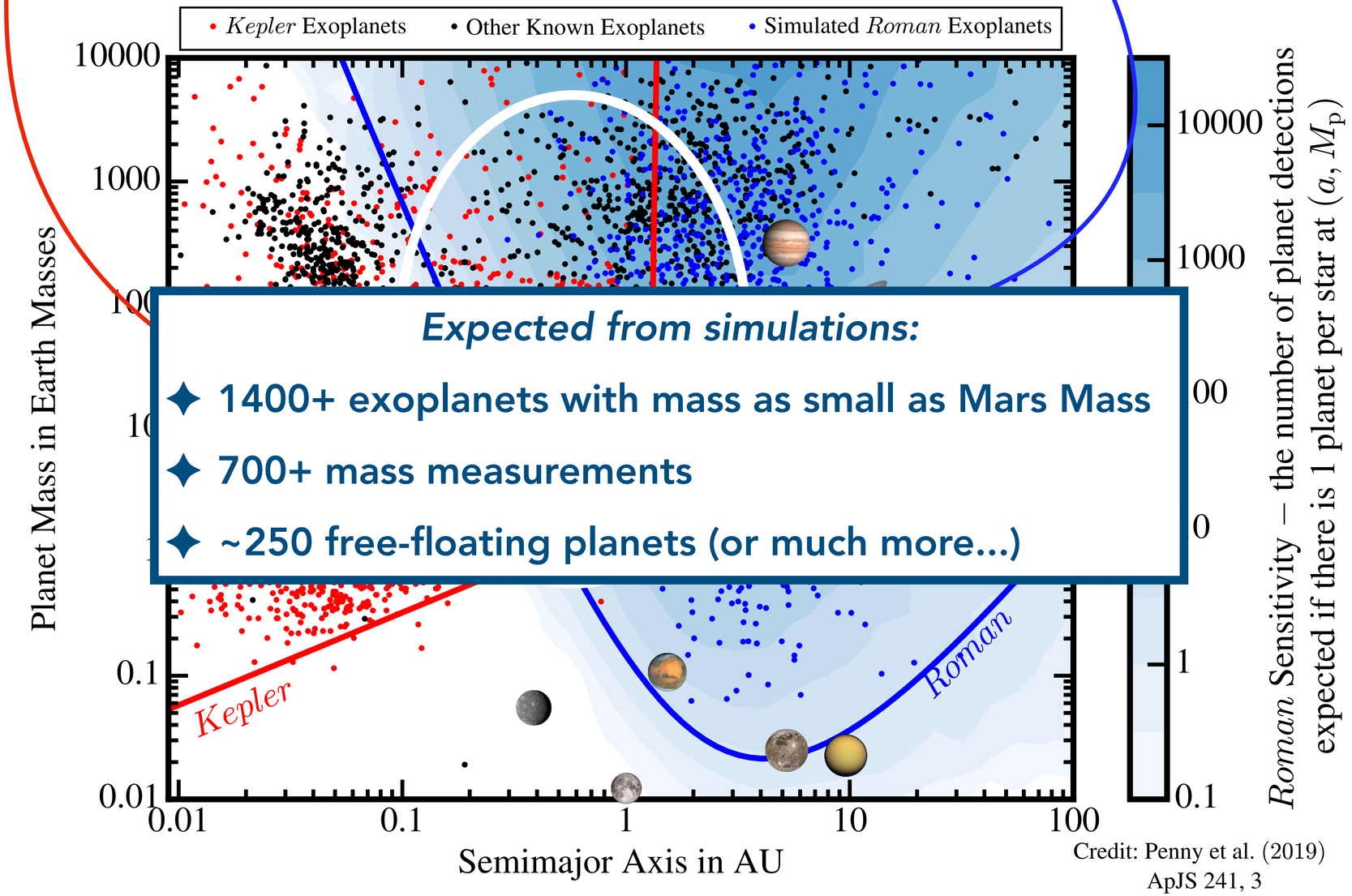


Video adapted from NASA's Goddard Space Flight Center/CI Lab

Roman expected yields from microlensing

NASA Kepler Exoplanets

Roman **Microlensing** Exoplanets

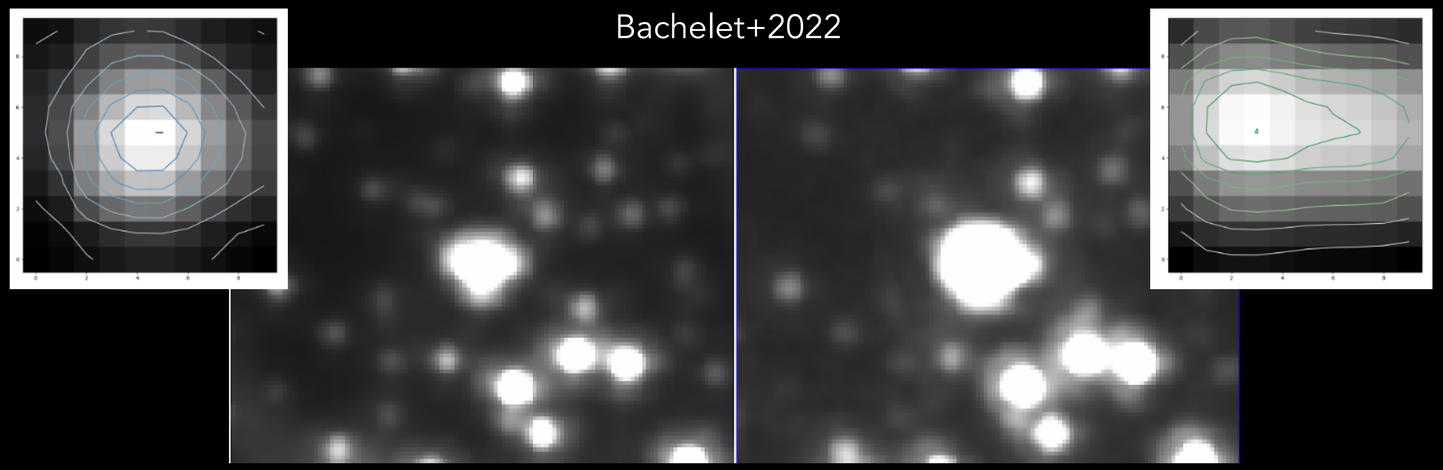


Expected from simulations:

- **1400+ exoplanets with mass as small as Mars Mass**
- **700+ mass measurements**
- **~250 free-floating planets (or much more…)**

Credit: Penny et al. (2019)
ApJS 241, 3

Synergy with ESA Euclid: increase mass-measurement number and precision



Roman W149 at t=0

Euclid VIS at t=-1800 days

E. Bachelet
CPJ Besançon

Natalia Rektsini
Postdoc IAP

Manon Gilles
Doctorante IAP

Himanshu Verma
Postdoc LSU

- Mini-survey of 2x the Roman fields in March 2025
- Processing by the Euclid Exoplanet Working Group and the VIS Team, coordinated at IAP. Responsible for ESA iQ2: N. Rektsini & C. Ranc
- Public data release: June 2026

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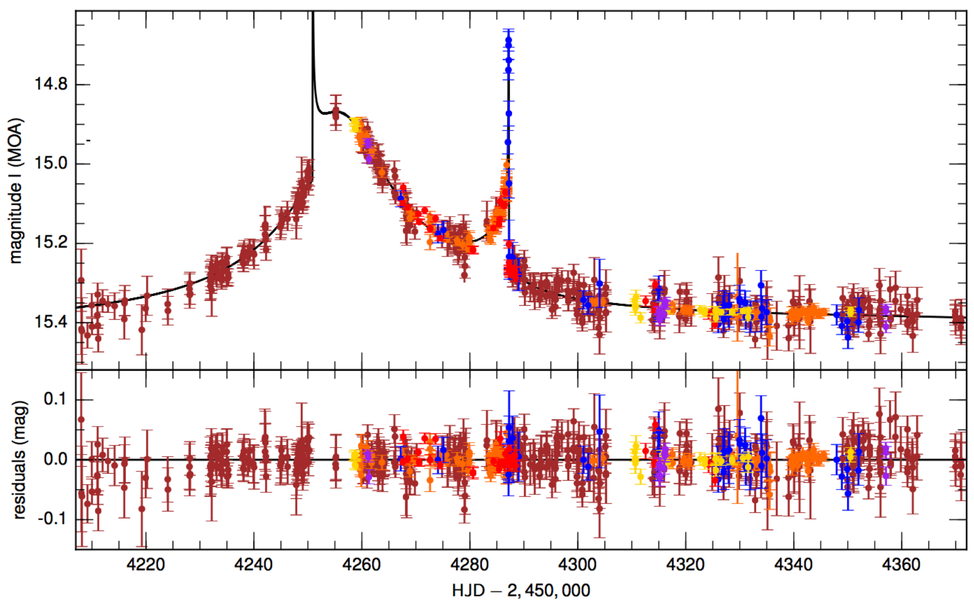
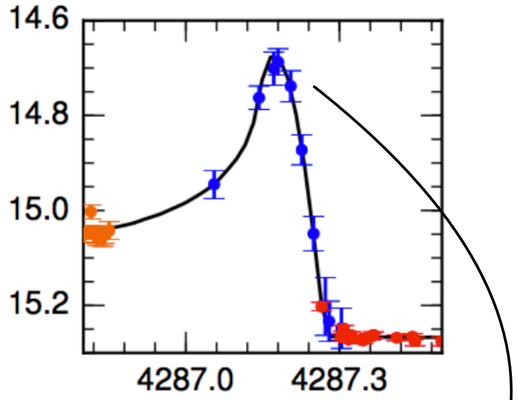
- Perspectives: proposal Q3/Q4 submitted yesterday for simultaneous observations Roman + Euclid to measure the mass of free-floating planetary mass objects, using parallax (already successful with Gaia, Spitzer).

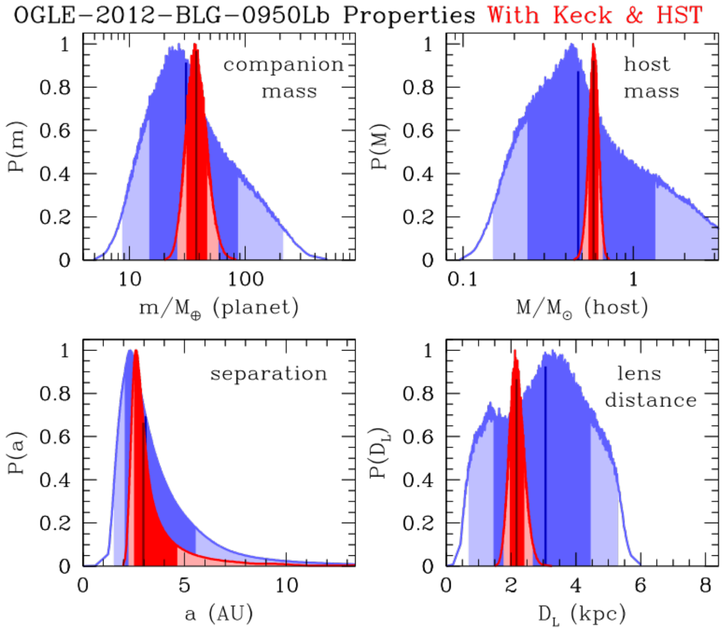
A few examples...

MOA-2007-BLG-197

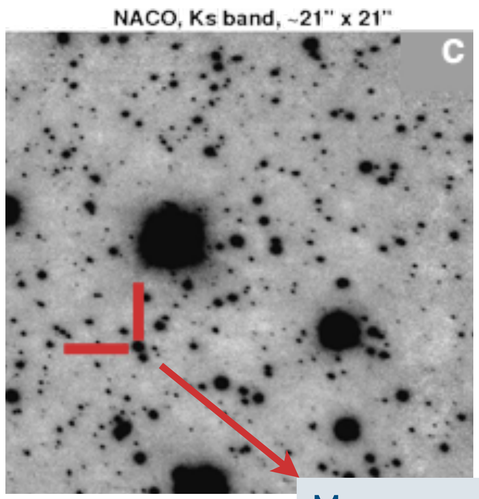




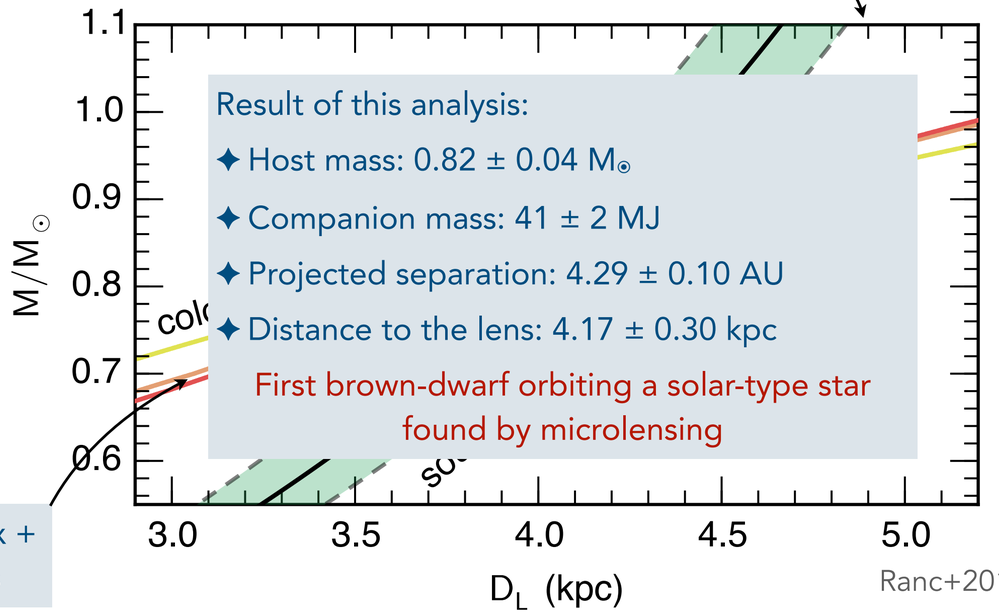
Constraint from
light curve model parameters



E.g., Bhattacharya+2018, and many more...



Measurement of the lens flux +
source flux in 3 passbands

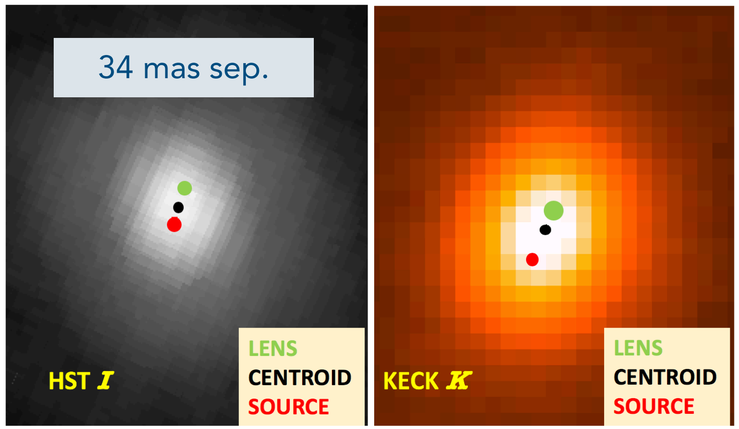


Result of this analysis:

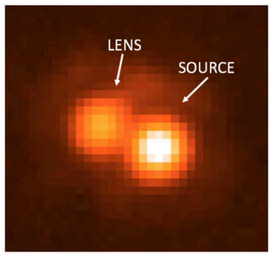
- ✦ Host mass: 0.82 ± 0.04 $M_\odot$
- ✦ Companion mass: 41 ± 2 MJ
- ✦ Projected separation: 4.29 ± 0.10 AU
- ✦ Distance to the lens: 4.17 ± 0.30 kpc

First brown-dwarf orbiting a solar-type star
found by microlensing

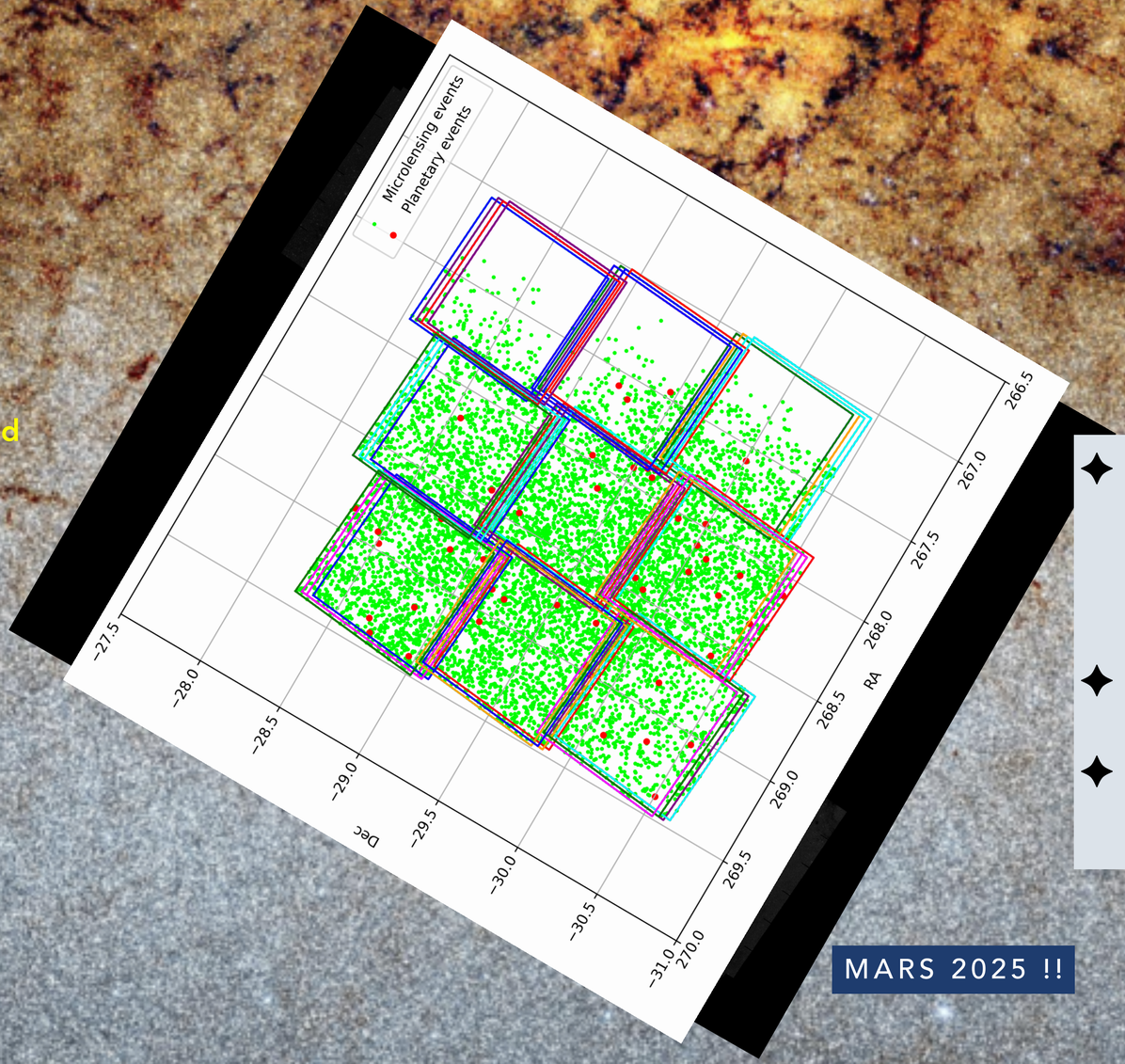
Ranc+2015

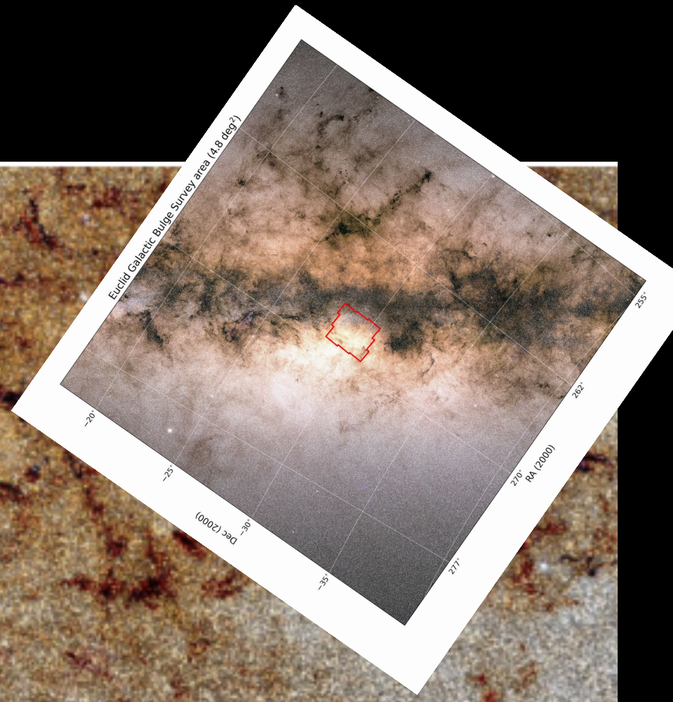


And resolved...



A lot of science beyond Roman already enabled





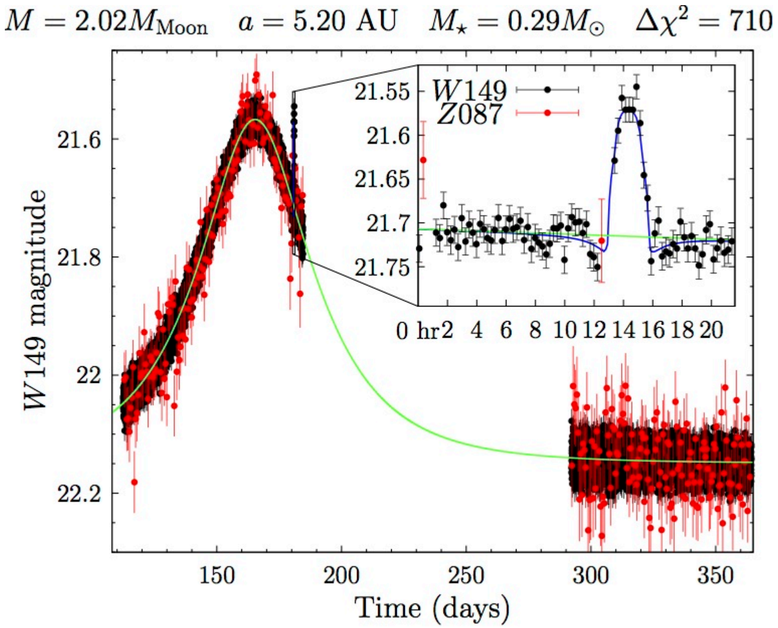
Euclid

- High resolution images for 8000 historical events, and hundreds of exoplanets
- Extinction maps
- Star densities and soon the dynamics

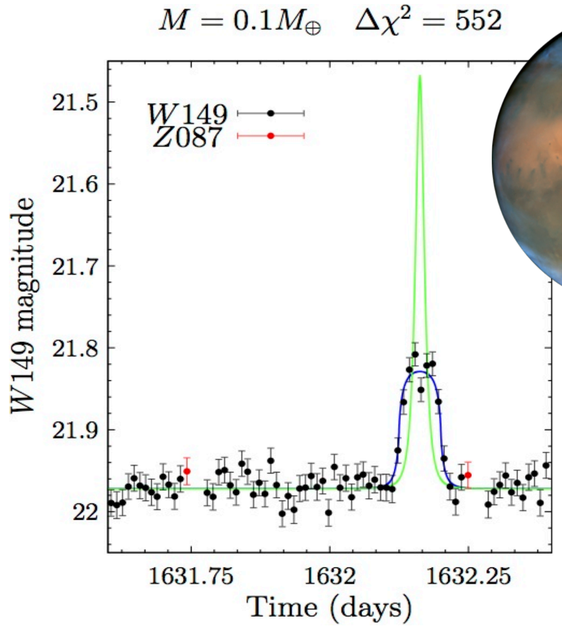
MARS 2025 !!

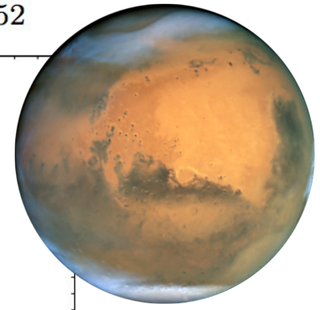
Bozza+, sub.
Beaulieu+, in prep
Kerins+, in prep
Rektsini+, in prep
Gilles+, in prep
Ranc+, in prep

Expectations on free-floating planets using microlensing



Penny+2019





... but it could also be a flare

See, e.g., Kunimoto et al. 2025

Mass	Mass Function			
($M_\oplus$)	One-Per-Star	Log-Uniform	N/star/dex	N_{det}
0.01	1.22	0.349	1335	466
0.1	17.9	5.13	146	751
1	88.3	25.2	16	404
10	349	83.0	1.8	146
100	1250	298	0.2	57
1000	4100	976	0.02	21
10000	13300	3170	0.002	7
Total	3750	897		1852

Johnson+2020
Scott Gaudi

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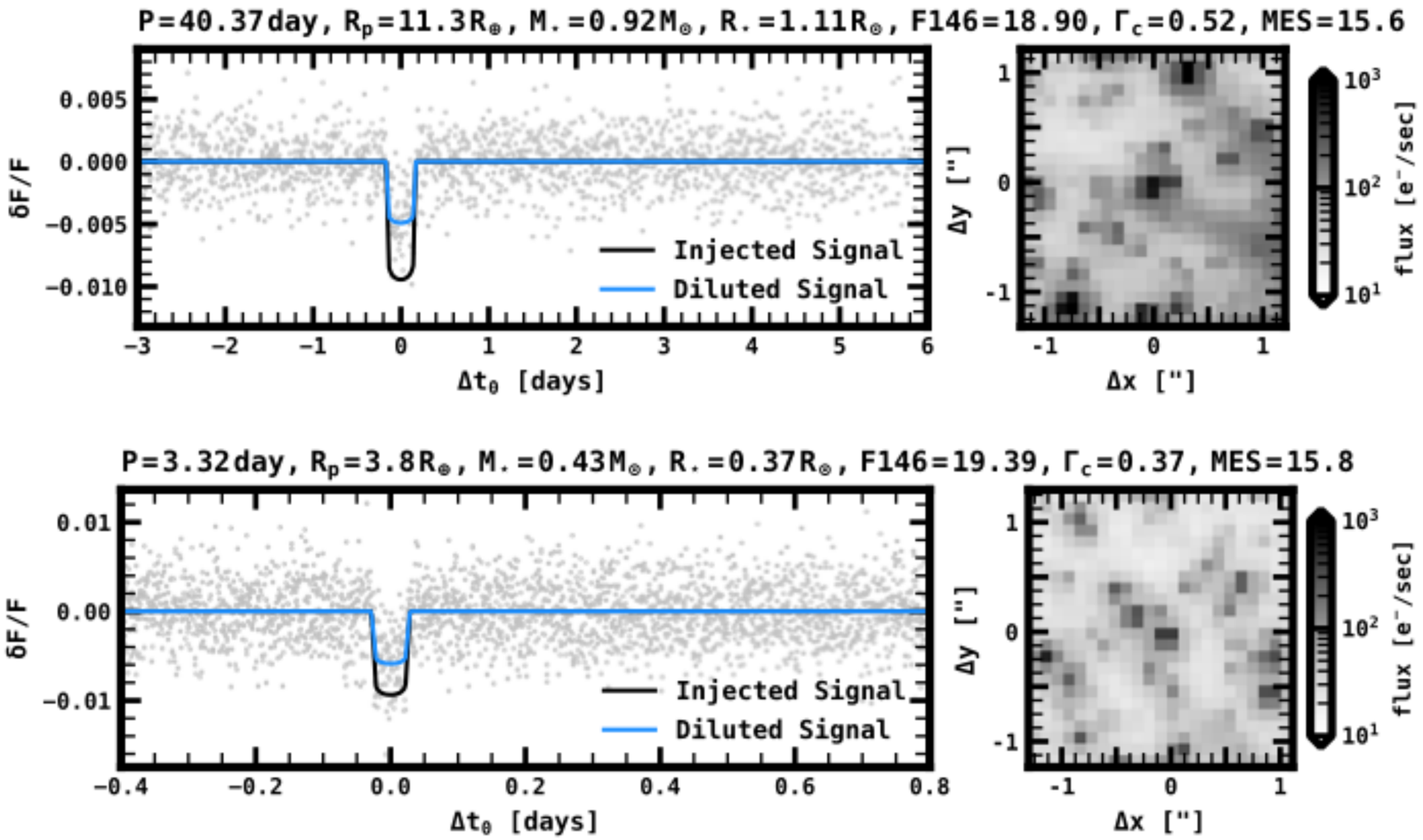
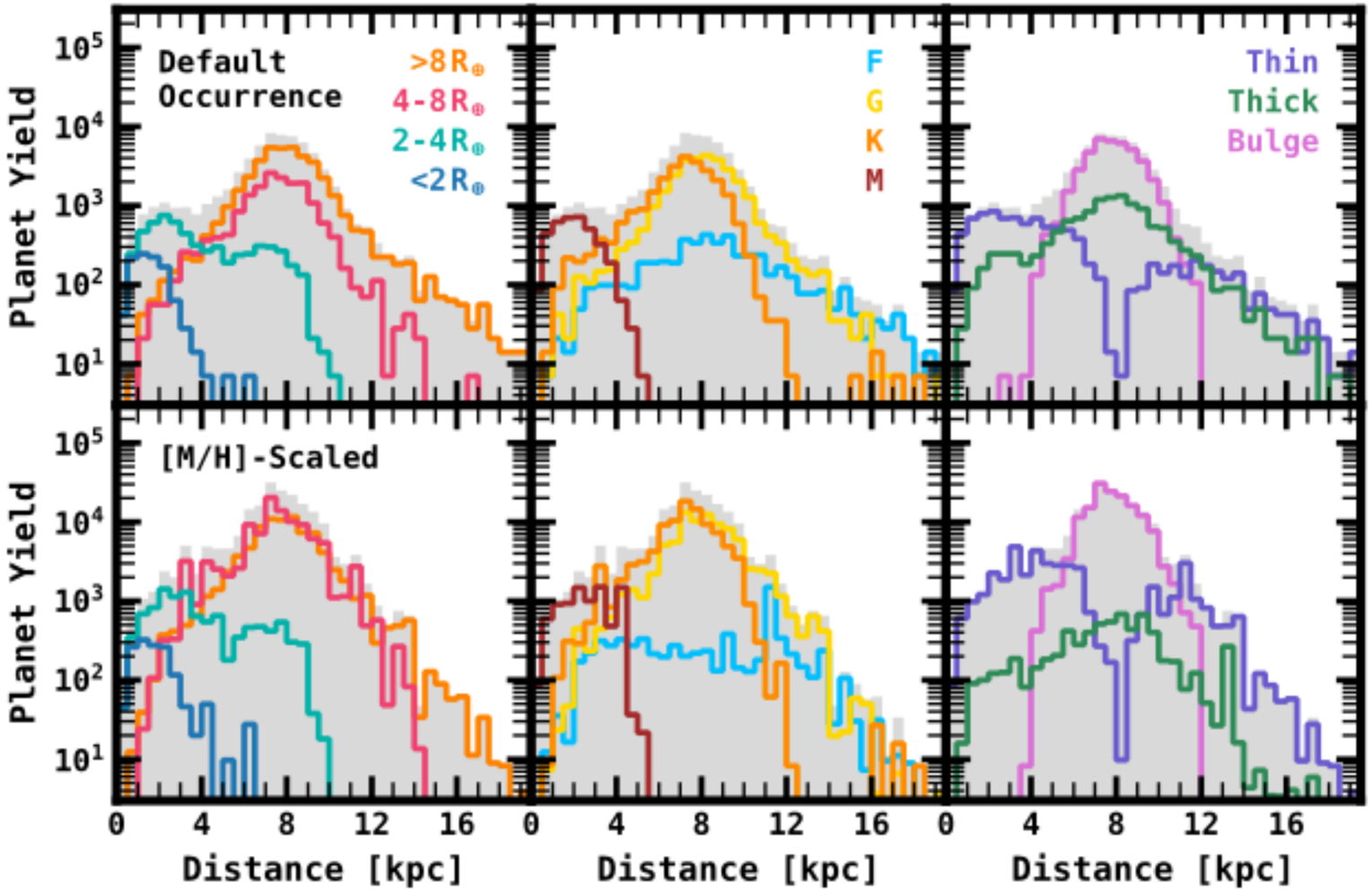
Roman as an exoplanet transit survey



- Detection of > 100,000 transits!
- BUT... how to estimate false positives?

Wilson+2023

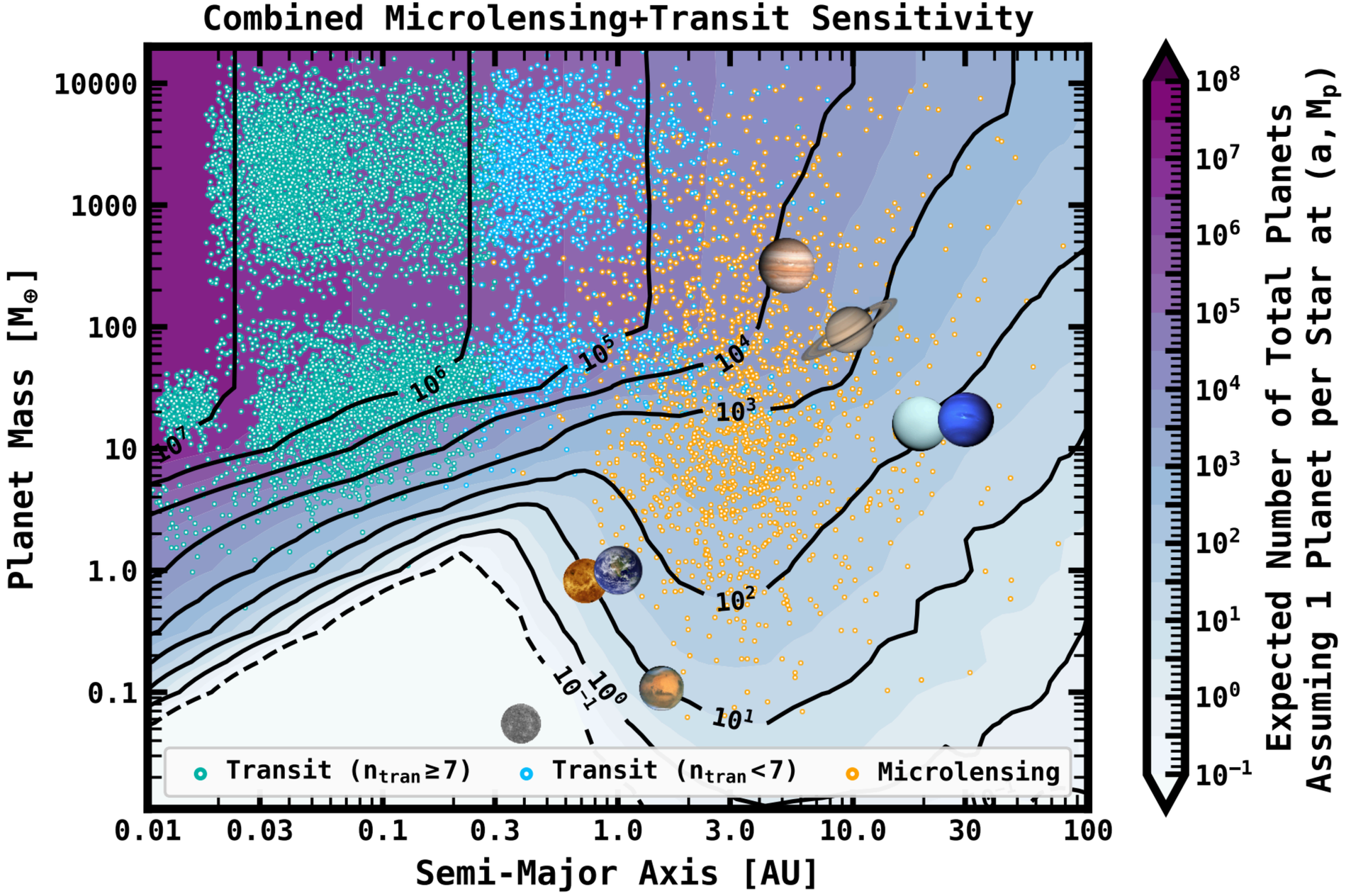
Probing the (galactic) exoplanet population around different hosts type



- Detection of > 100,000 transits!
- BUT... how to estimate false positives?

Wilson+2023

Updated yield of the RGES: a new demographics of planets coming soon



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Summary

- The Roman Galactic Bulge Time Domain Survey will detect **thousands of cold exoplanets via microlensing, including hundreds or thousands of free-floating planets**.
- The Roman Galactic Bulge Time Domain Survey will detect **10^5 of hot, warm, and cool exoplanets via transits**
- Roman will enable a **large statical census of planets** in a large range of semi-major axes for planet mass > 2x Earth in different stellar populations of the Milky Way
- Combined constraints from bound and free-floating planets will provide a powerful constraint on planets formation theories.
- First season starts in **February 2027 (expected)**
- **All data will be non-proprietary and publicly available via the Mikulski Archives for Space Telescopes (MAST) at STScI.**

- Color information is key for transits and microlensing (synergy with CFHT, VISTA).
- Any follow up from the ground or space will help during the gaps.
- Keep an eye on the **Roman Galactic Plane Survey in the General Astrophysics Survey**!

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