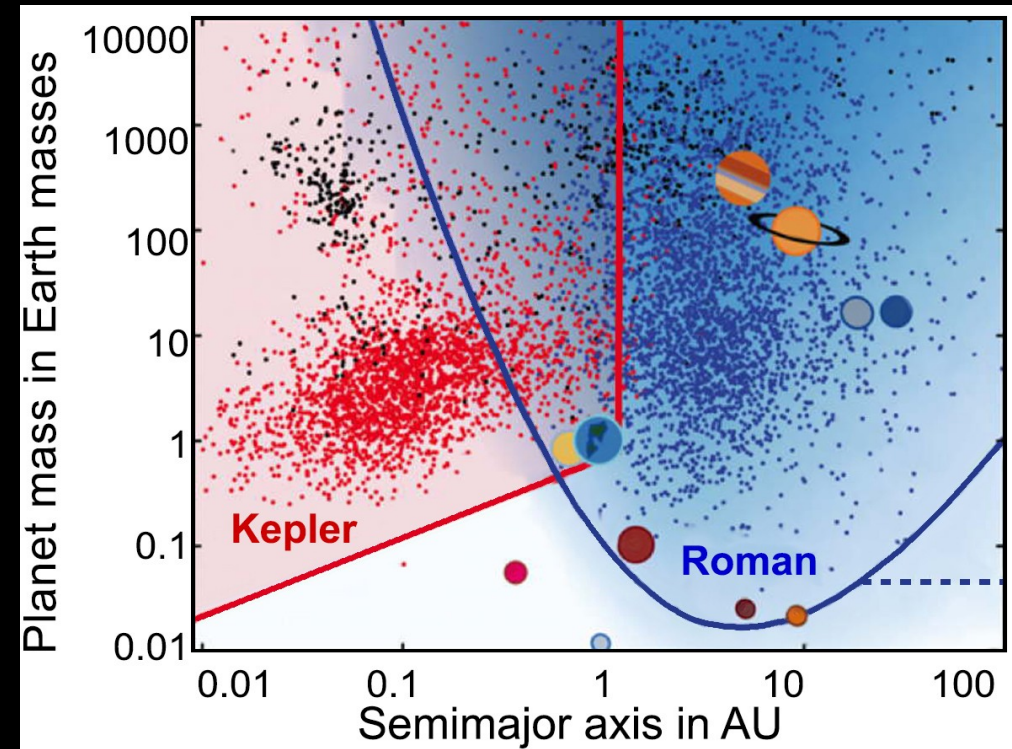


Synergies between Roman and other surveys: the case of microlensing

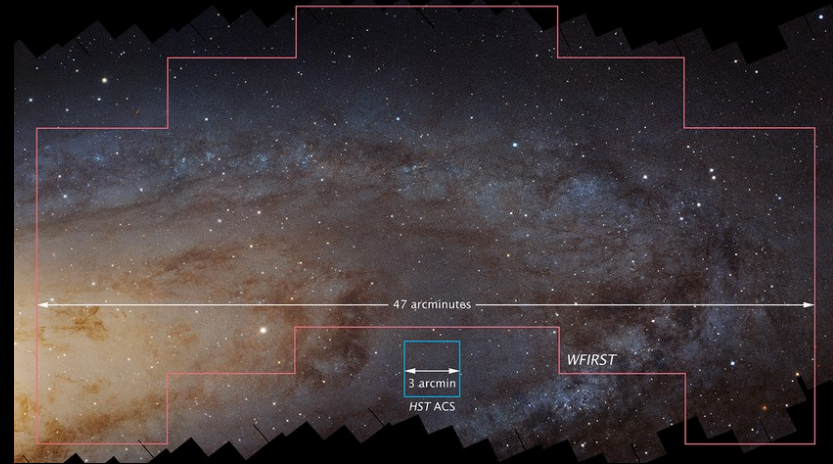
Etienne Bachelet



Roman microlensing survey



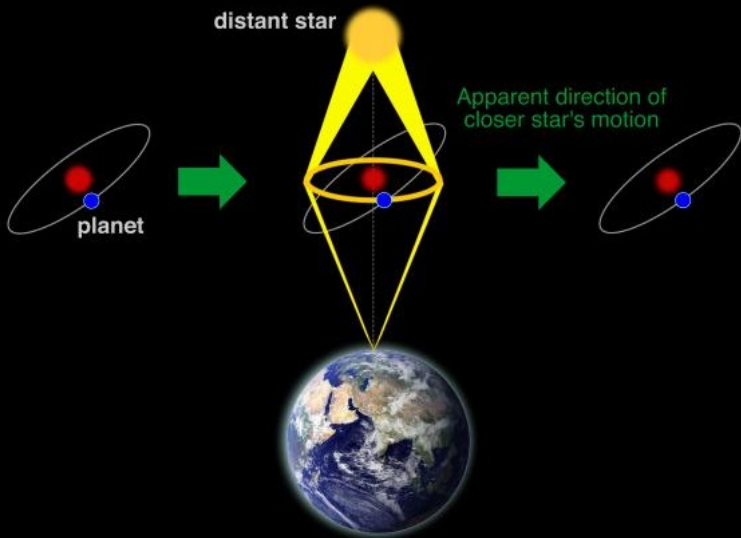
Penny et al. 2019, ApJS



- 5 yrs of ~70 d survey of the Bulge
- > 1400 cold planets
- sensitive to all host types
- hundreds of free-floating planets

Microlensing in a nutshell

If there is a planet orbiting the closer star, and it happens to align with the Einstein ring, its mass will enhance the lens effect and increase the magnification for a short time

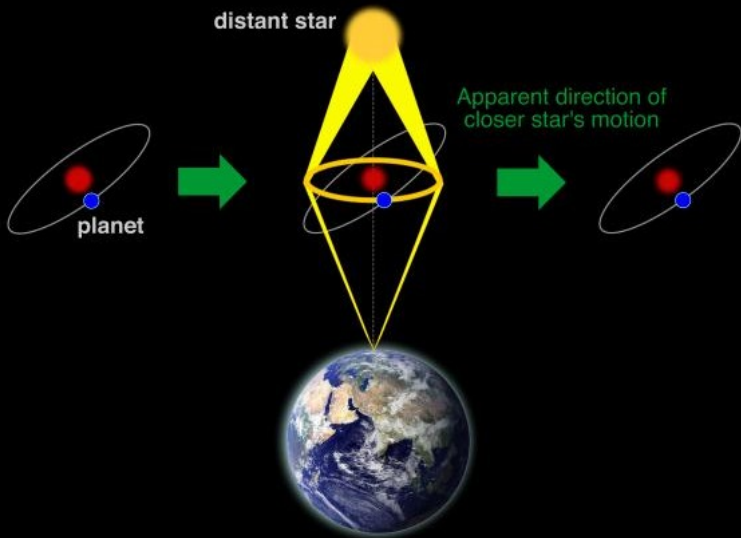


The planet causes a small blip on the graph

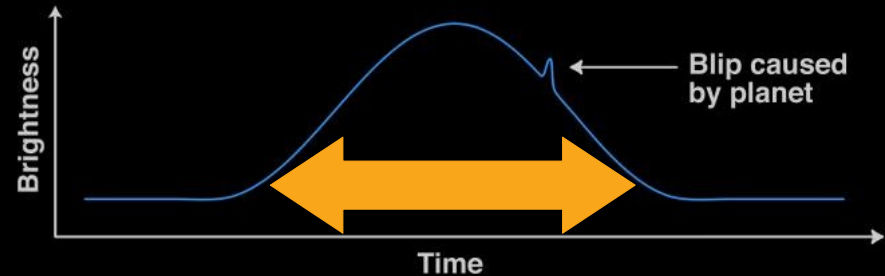


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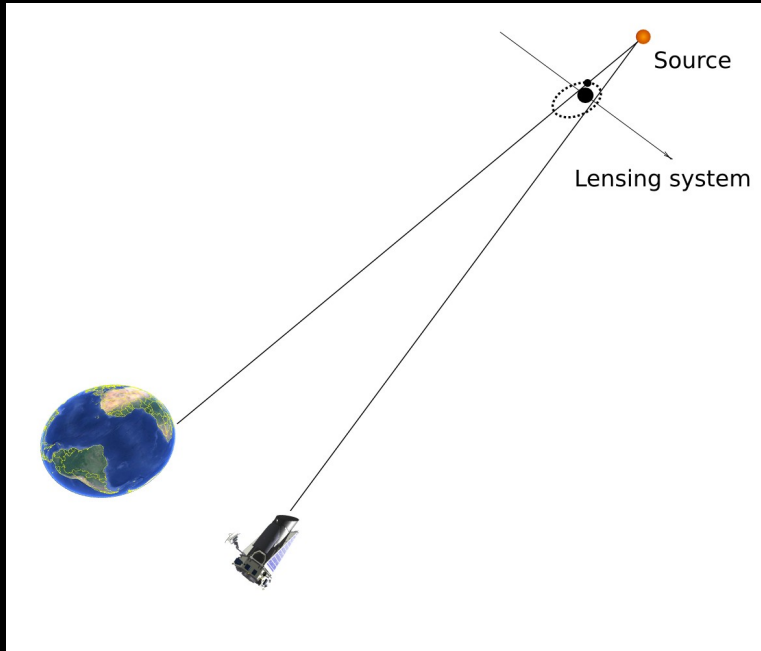


$$2t_E \propto M_I^{0.5}$$

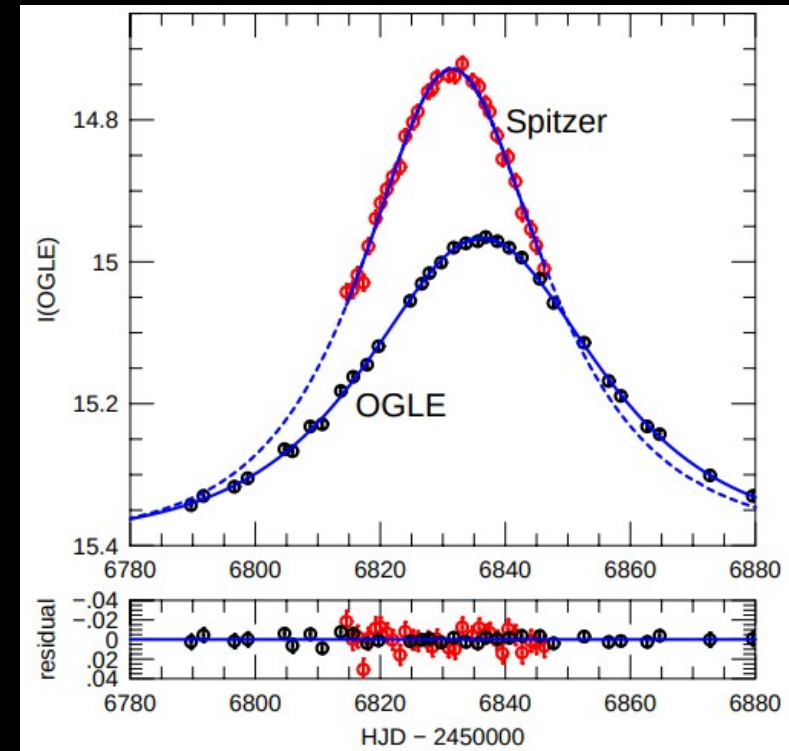


Microlensing challenge: the mass and distance degeneracy

- microlensing parallax



Spitzer-Earth Microlensing Parallax
Yee et al. 2015. ApJ



Microlensing challenge: the mass and distance degeneracy

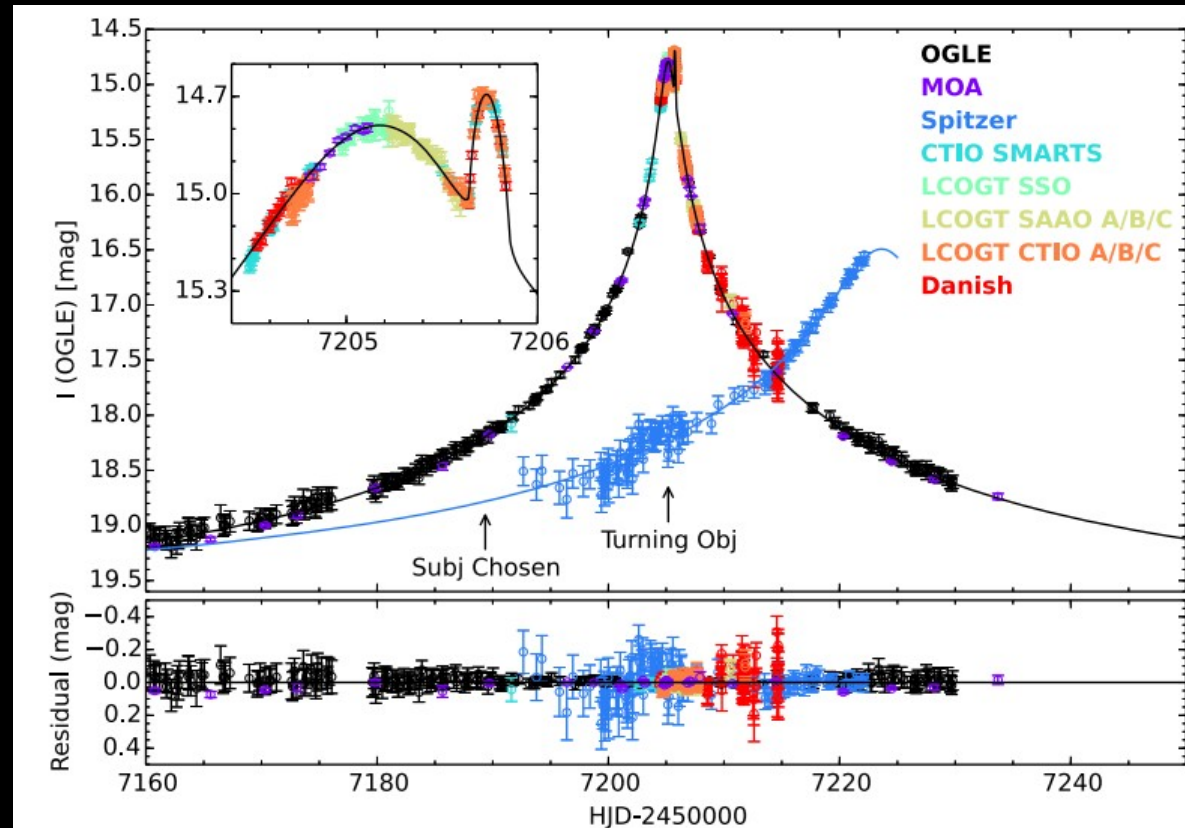
- microlensing parallax + finite source effects

Spitzer-Earth Microlensing Parallax
Street et al. 2016, ApJ

But see also

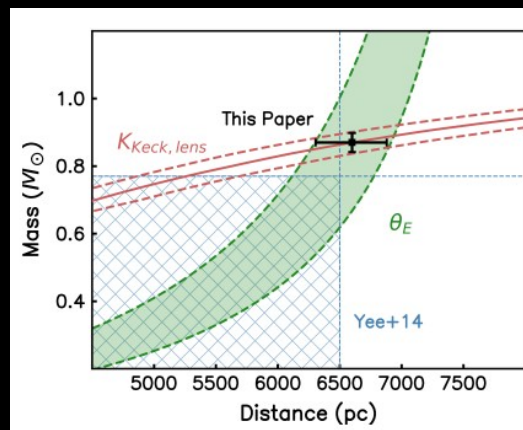
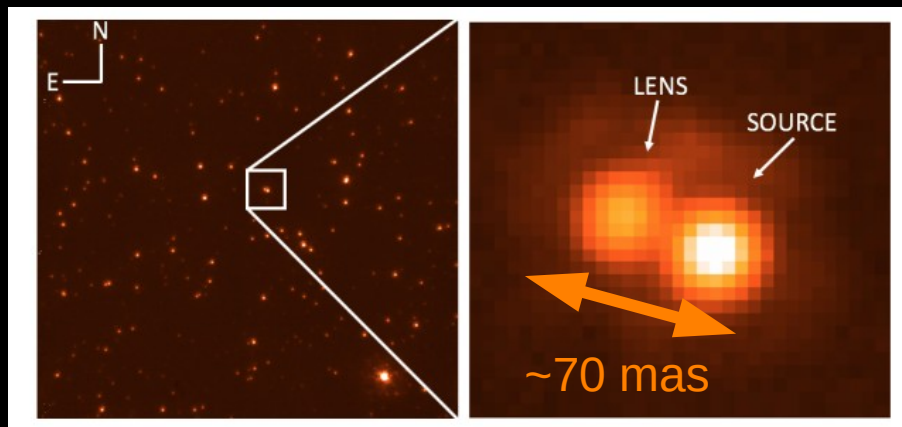
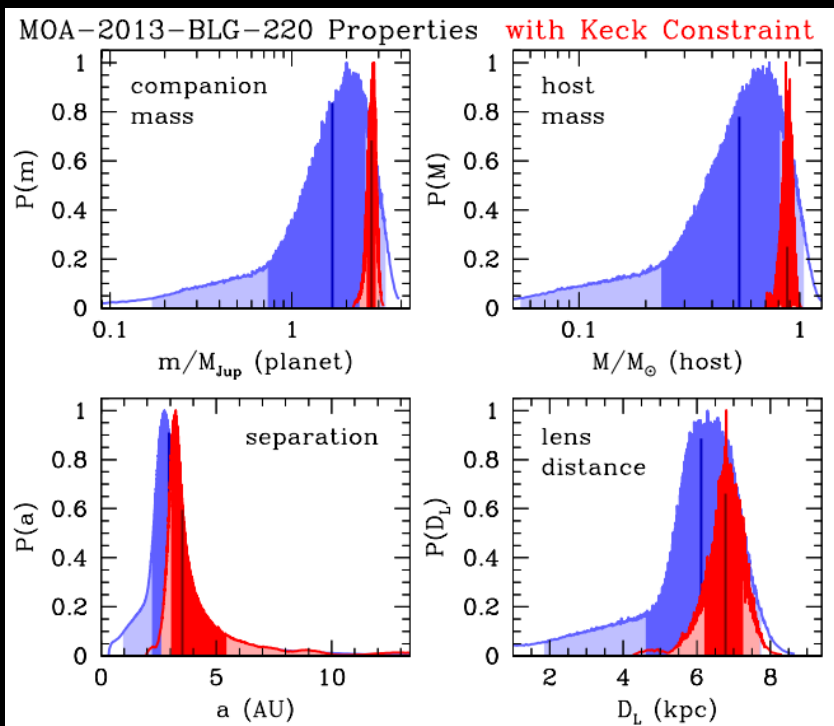
Zang et al. 2020, ApJ
Yuki et al. 2020, AJ
Gould et al. 2020, JKAS
Ryu et al. 2018, ApJ
Jung et al. 2019, AJ
Calchi Novati et al. 2019, AJ
Shvartzval et al. 2019, AJ
Chung et al. 2019, ApJ
Shin et al. 2018, ApJ

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Microlensing challenge: the mass and distance degeneracy

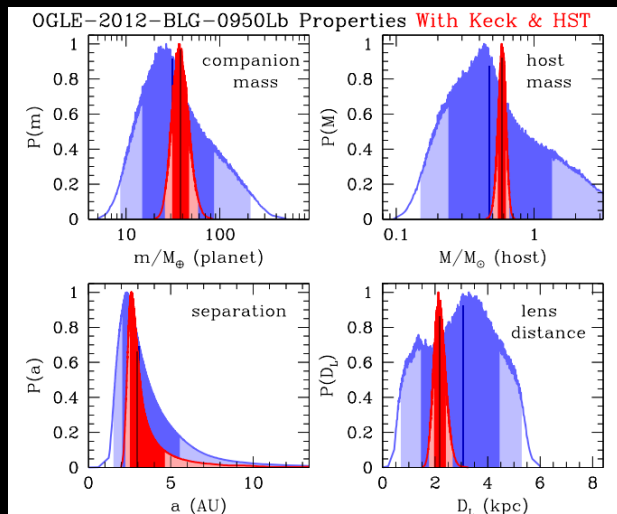
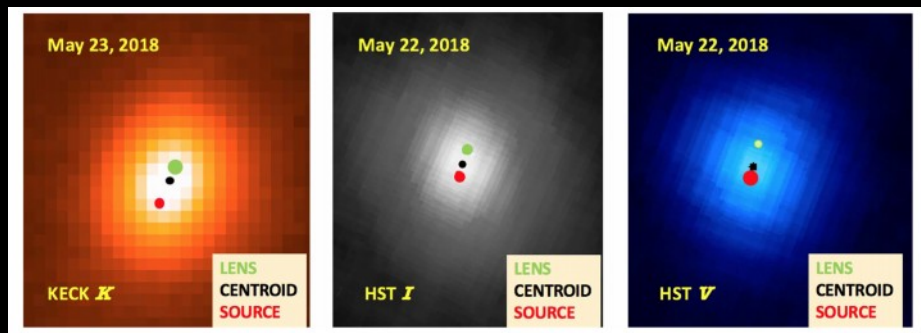
- lens flux and relative proper motion (prior/posterior high resolution imaging)



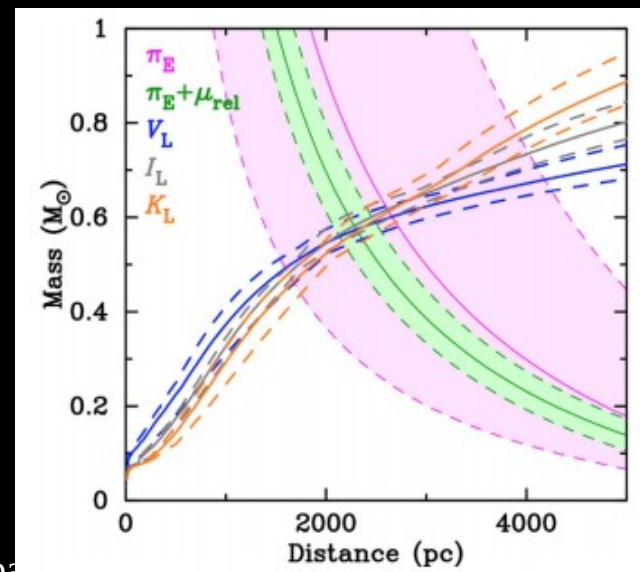
Vandorou et al. 2020, AJ

Microlensing challenge: the mass and distance degeneracy

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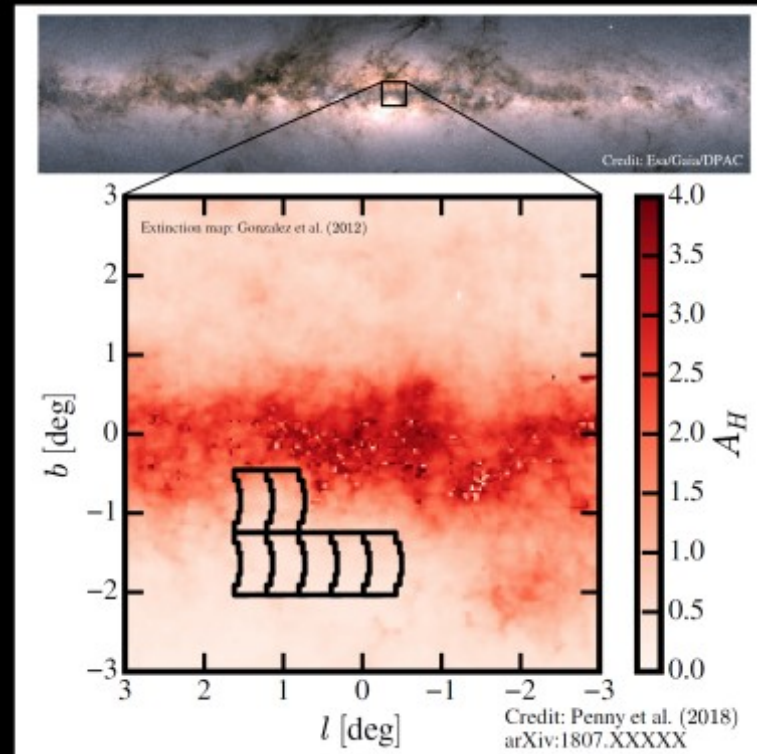
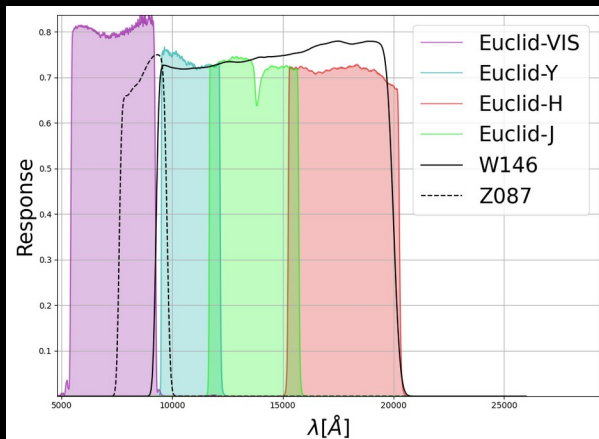


Bhattacharya et al. 2018, AJ

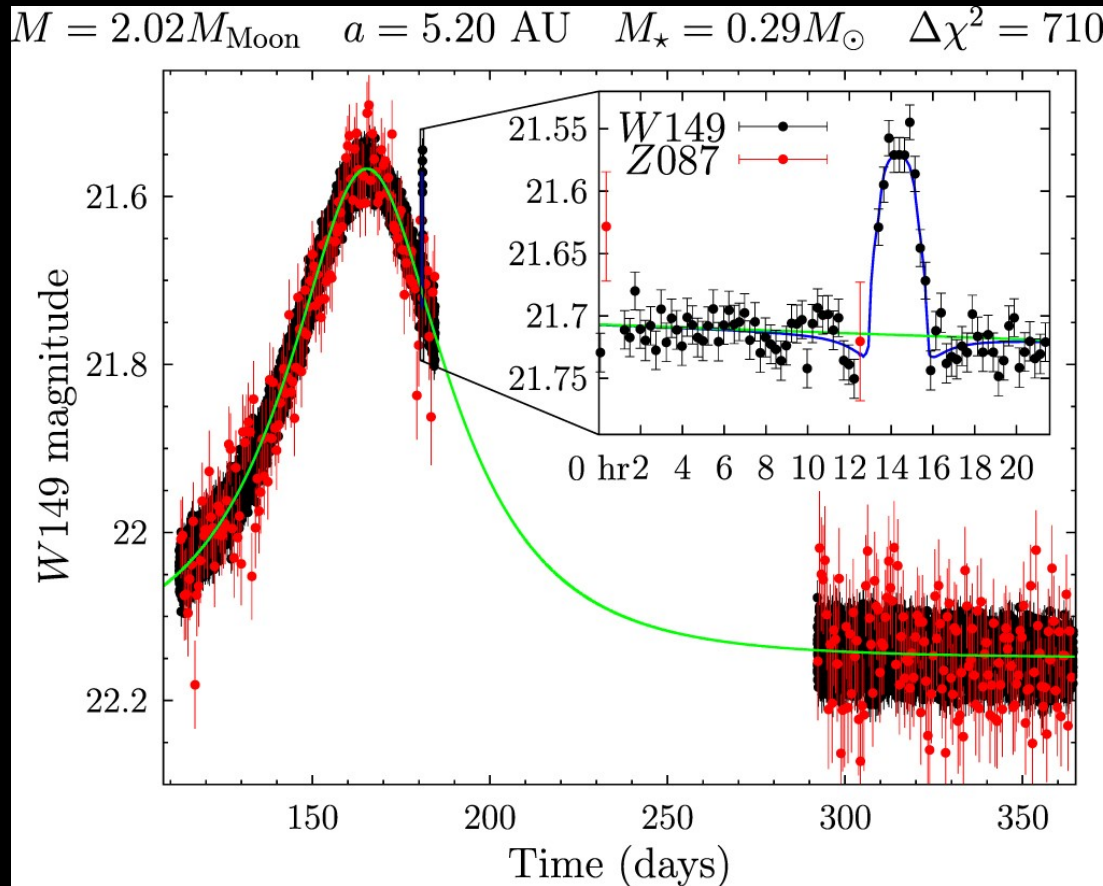


Roman microlensing survey

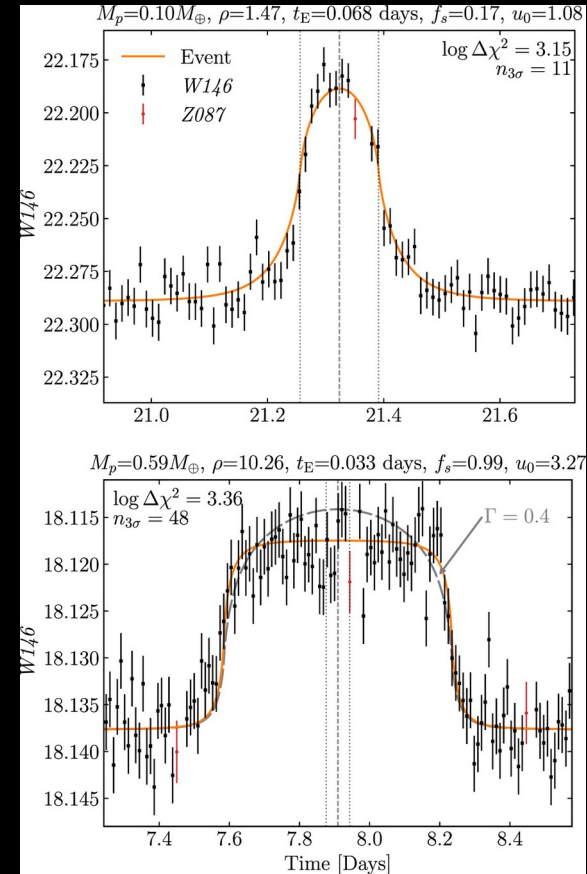
- 7 fields for a total of ~ 2 deg²
- Wide W146 filter (ZP W146 ~ 27.6 mag AB)
- 15 minute cadence
- Observations every at least 12 hours in at least one other filter (e.g., Z087, F184), 900 total obs
- 6 x 72 day seasons.
- $\sim 41,000$ exposures in W146
- ~ 432 total days spread over 5-year



Roman microlensing survey



Penny et al. 2019. APJS

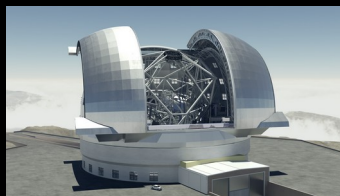


Samson et al. 2020. AJ

Roman microlensing survey

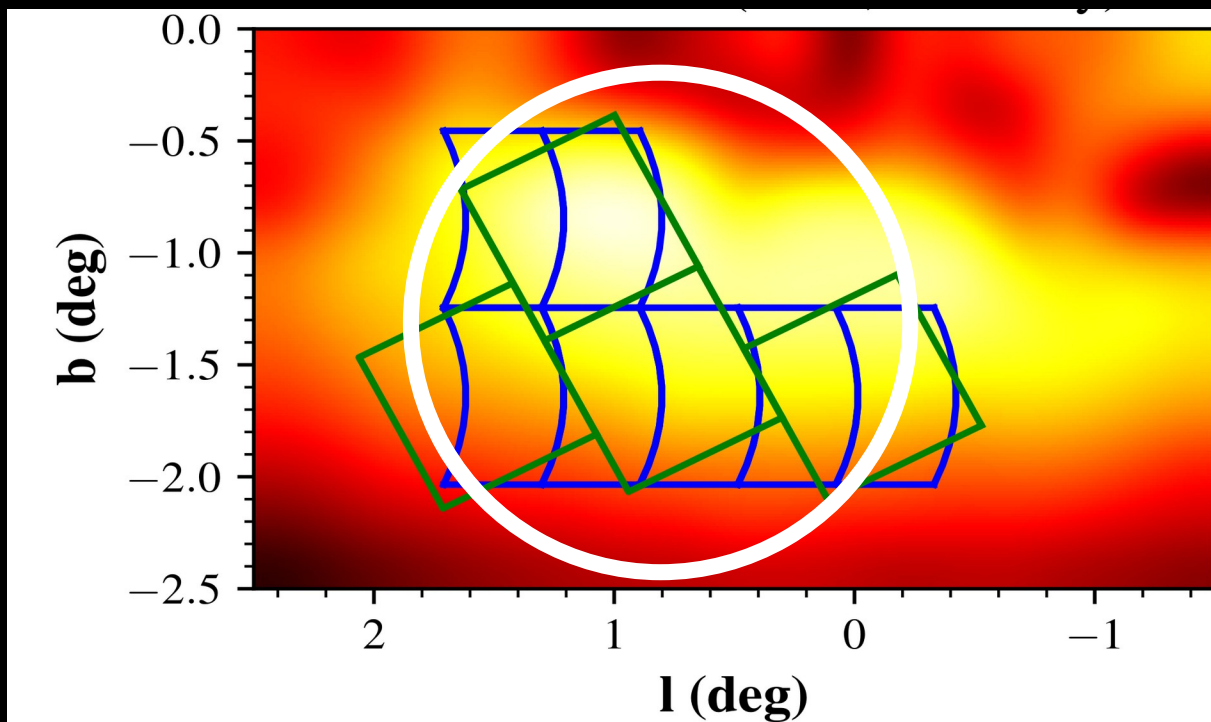
- Microlensing (*Penny et al. 2019, APJS; Samson et al. 2020, AJ*)
 - 30,000 + events
 - 1400 + planets with $M_p > 0.1 M_E$, ~ 200 with $M_p < 3 M_E$
 - 300 + FFP
 - Binaries, stellar remnants, mass function...
- “Auxiliary” science
 - Transiting planets ($\sim 10^5$ planets, *Montet et al. 2017, PASP*)
 - Asteroseismology of Bulge giants (*Gould et al. 2015, JKAS*)
 - Extremely KBO searches (*Gould et al. 2014, JKAS*)
 - More...
- All data \sim immediately public

Potential synergies



AND MANY MORE!

Gigantic FOV



ROMAN

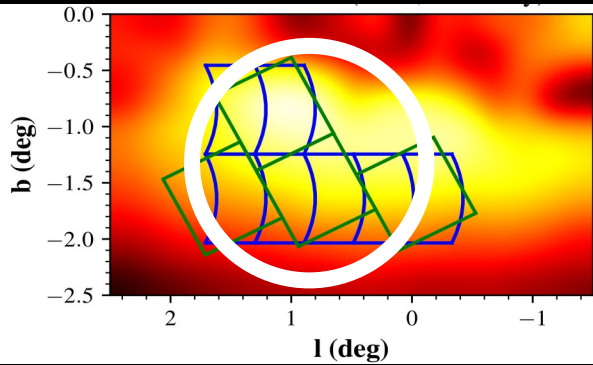
EUCLID

RUBIN

Bachelet et al. A&A submitted

Roman-Euclid-LSST synergies

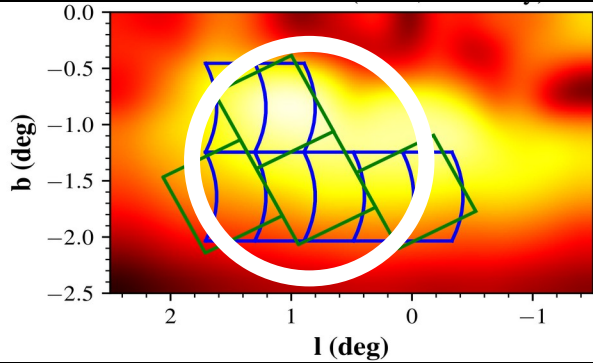
	ROMAN	Euclid	Rubin
λ	[0.6,2] μm	[0.6,2] μm	u,g,r,i,z
FOV	0.3 deg^2	$\sim 0.53 \text{ deg}^2$	$\sim 3.5 \text{ deg}^2$
Pixel Scale	0.11 mas/pix	0.1,0.3 mas/pix	0.2 mas/pix
Limit mag	$\sim 27 \text{ mag}$	$\sim 25 \text{ mag}$	$\sim 27 \text{ mag}$
Location	L2	L2	Cerro Pachón
First light	~ 2027	~ 2023	~ 2023



ROMAN EUCLID RUBIN

Roman-Euclid-LSST synergies

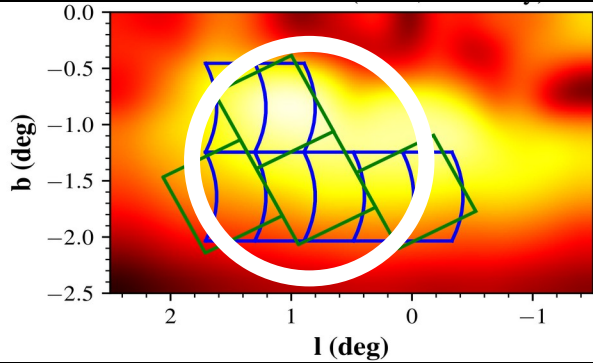
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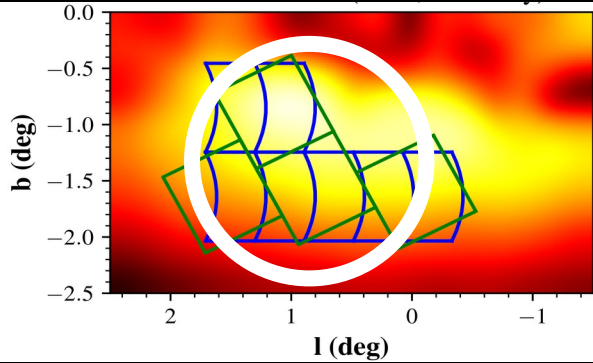
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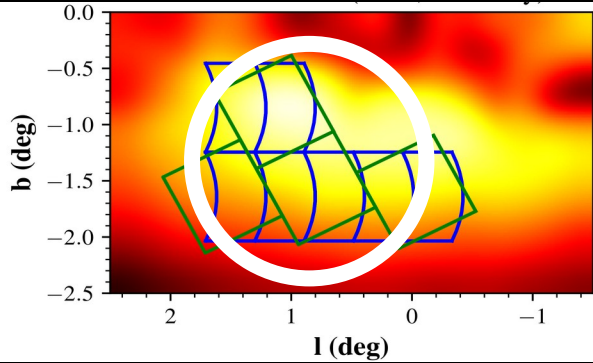
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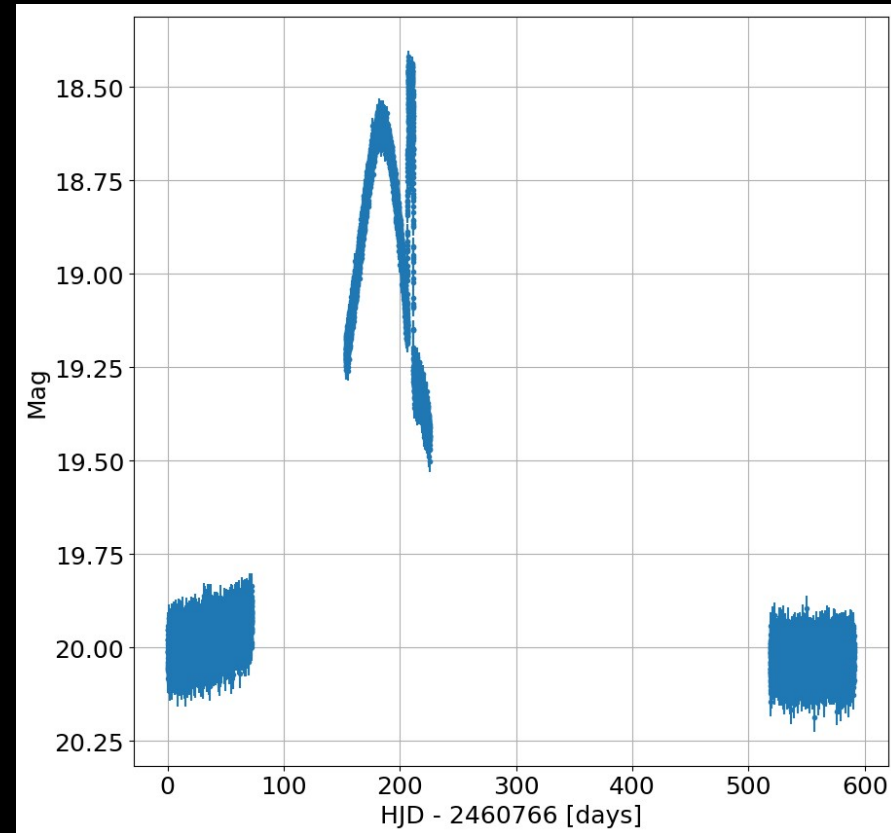


ROMAN EUCLID RUBIN

Time complementarity

Enhancing Science in the Galactic Plane through Coordinated Rubin, Roman and Euclid Observing Strategies. *Street et al.*

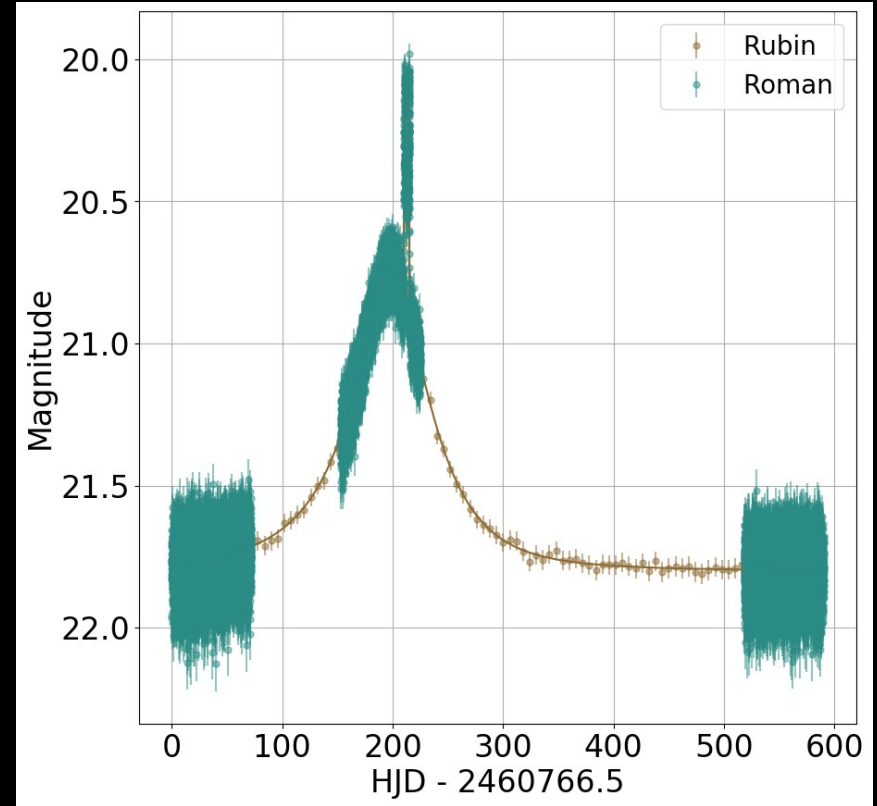
Unique Science from a Coordinated LSST-WFIRST Survey of the Galactic Bulge. *Street et al. 2018*



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Euclid-Roman Joint Survey

1. Early Euclid survey of Roman fields

Bachelet et al. A&A under review

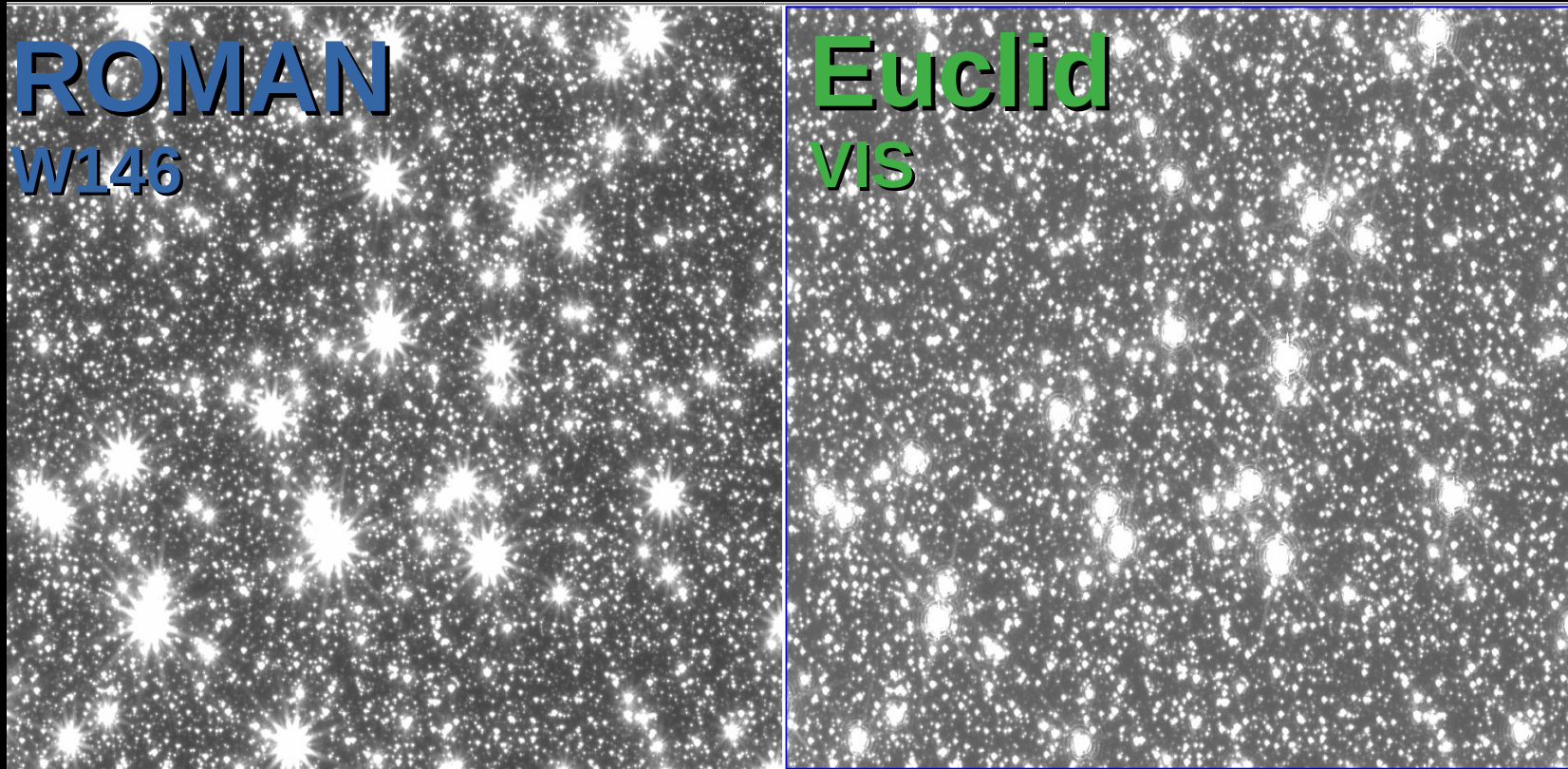
Measurement of proper motions and flux of the sources and lenses

~ 4 pointing of Roman fields x 16 dithering images x 300 s VIS = ~7 h

Euclid-Roman Joint Survey

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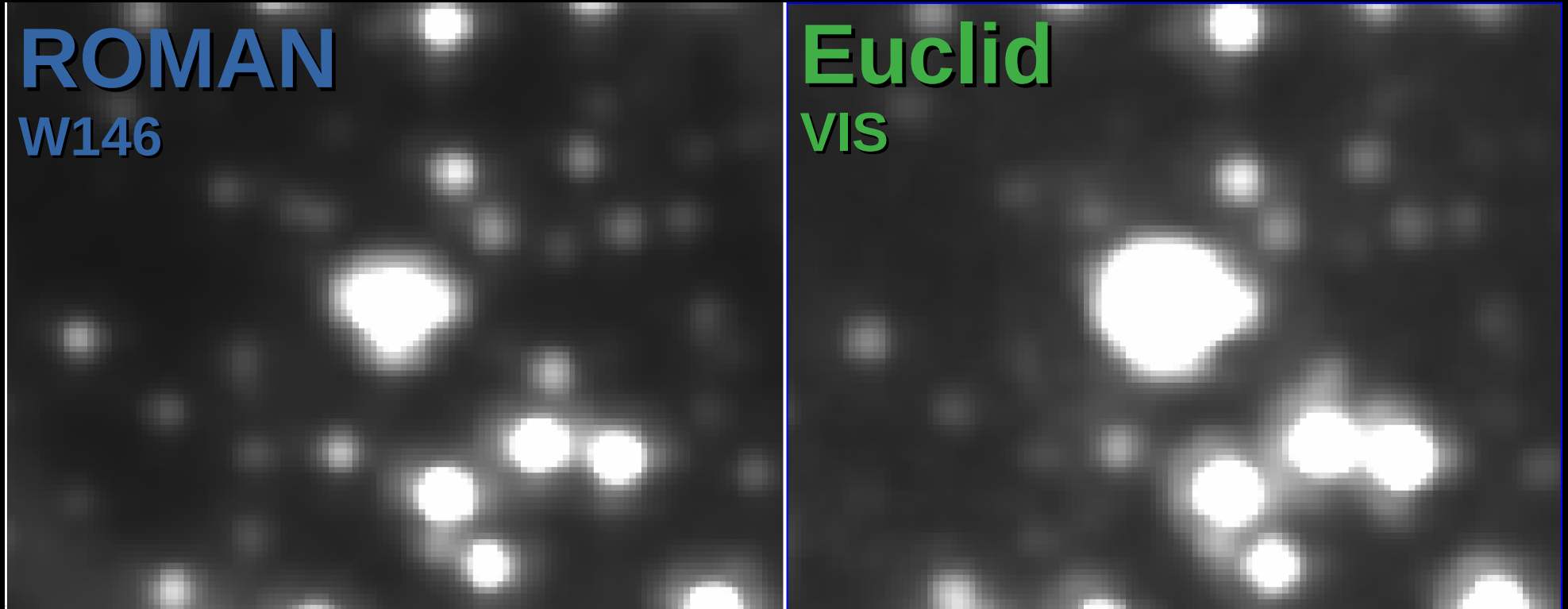
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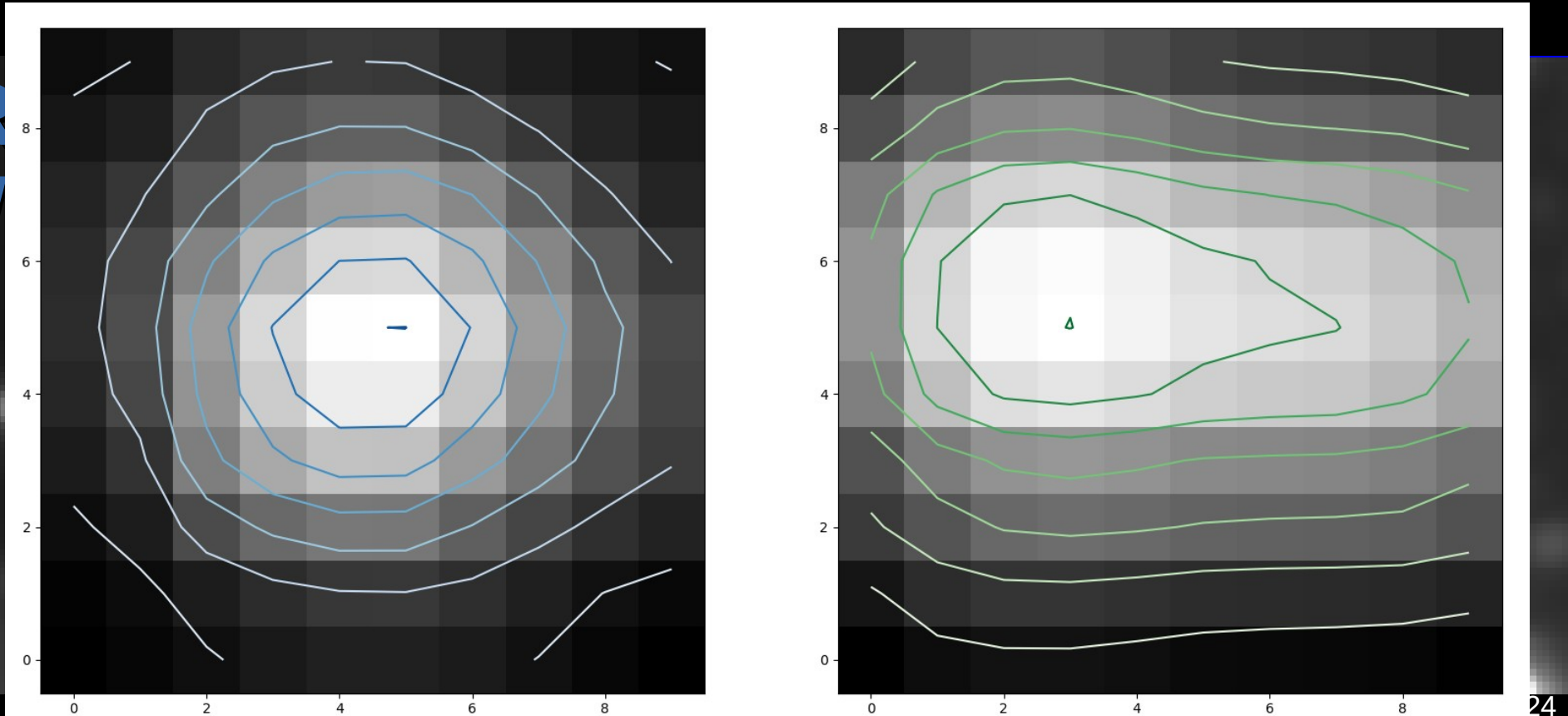
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Euclid-Roman Joint Survey

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Bachelet et al. A&A under review



Euclid-Roman Joint Survey

1. Early Euclid survey of Roman fields

Bachelet et al. A&A under review

- Constraints from high-resolution for **30,000 events** :
 - source/lens proper motion (>30% of events better than 1mas/yr)
 - source and lens fluxes (>40% of events better than 0.1 mag)
- **Mass and distance measurement** for a large fraction of events **after year 1 of Roman**.

Euclid-Roman Joint Survey

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Bachelet et al. A&A under review

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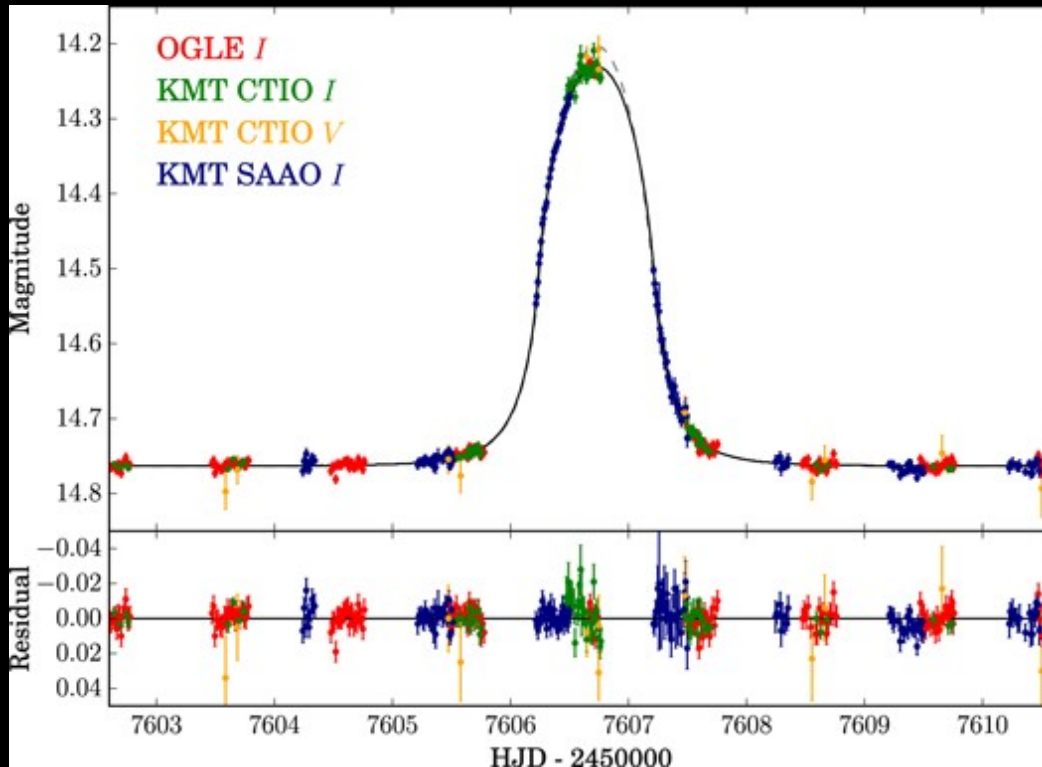
2. Simultaneous Euclid/Roman survey during mission extension

Measure the parallax down to the FFP regime

~ 30 d windows, 30 min cadence, 300 s VIS

Euclid-Roman Joint Survey

2. Simultaneous Euclid/Roman survey during mission extension



Jupiter-mass in the Disk

OR

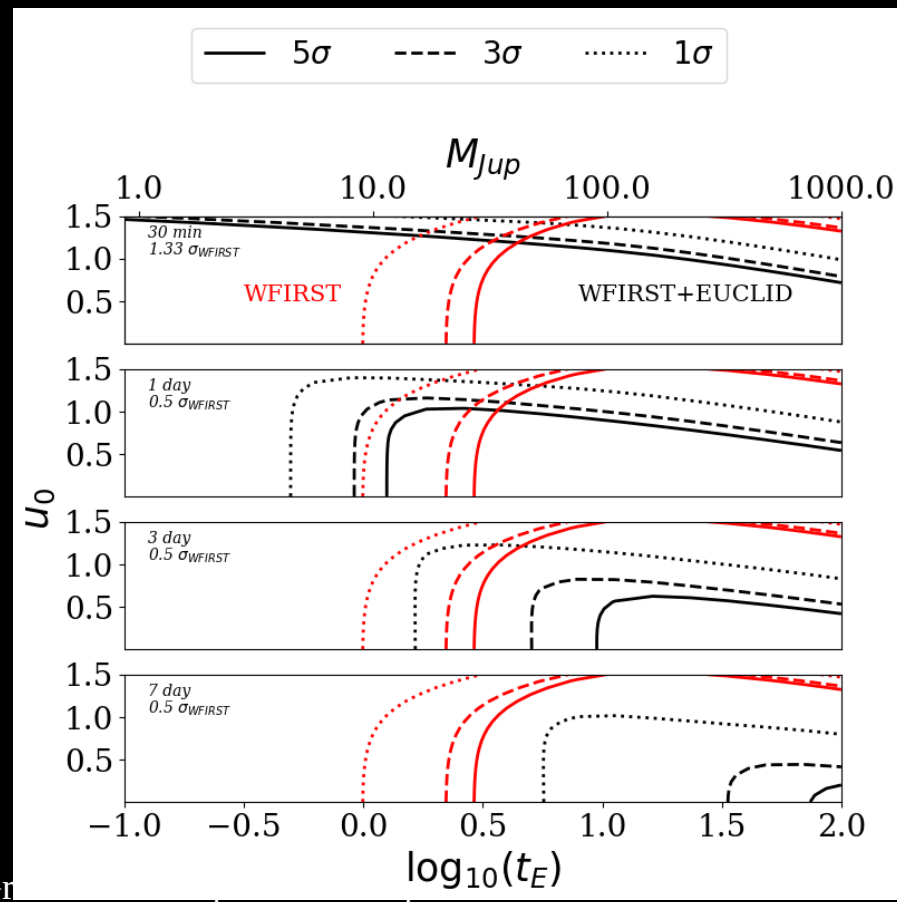
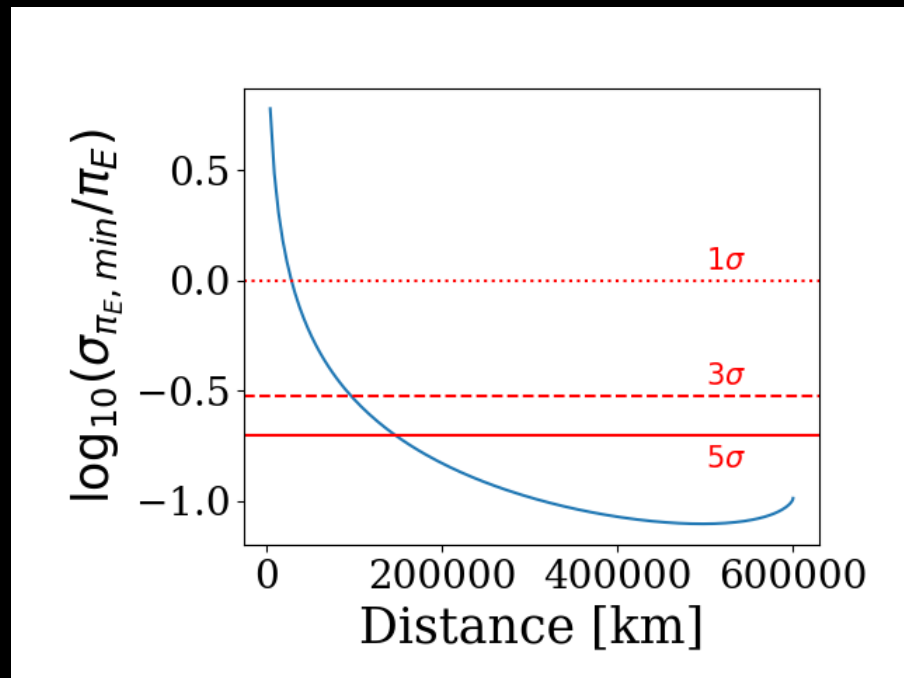
Saturn-mass in the Bulge

Mróz, P. et al, AJ, 2018

Euclid-Roman Joint Survey

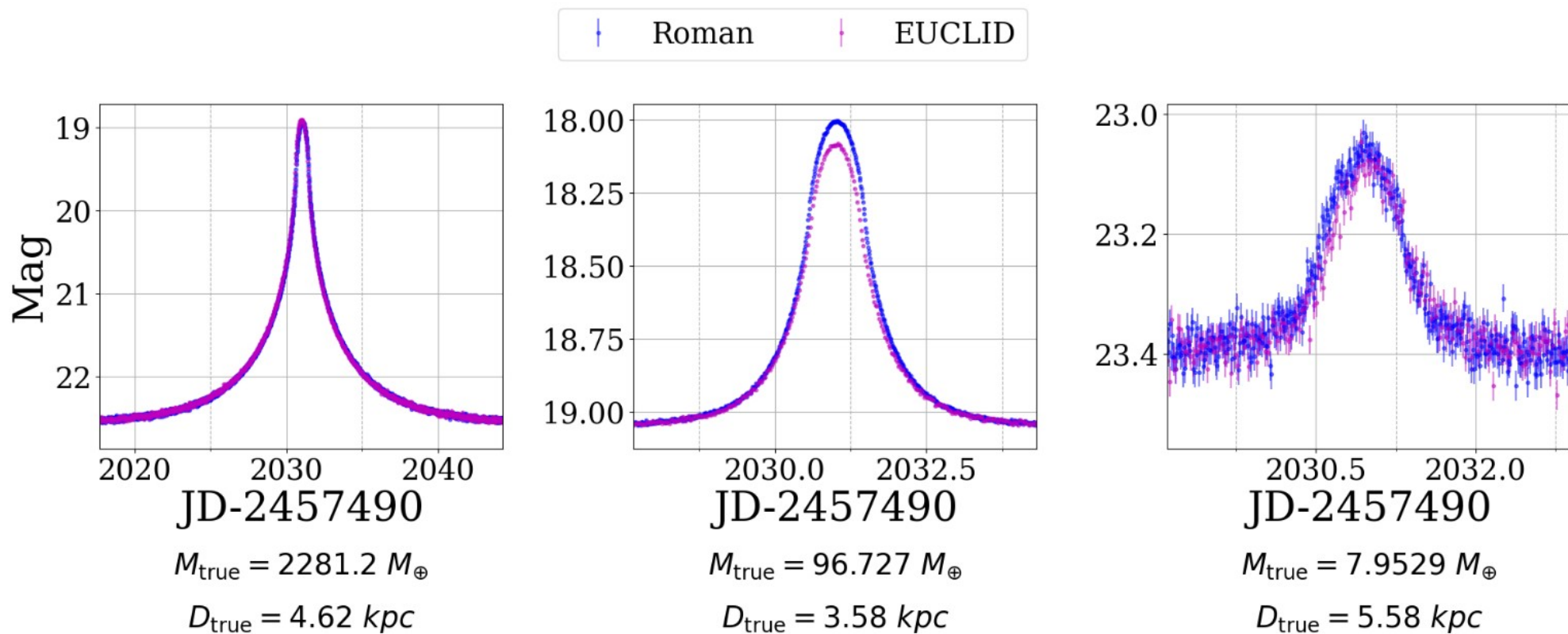
2. Simultaneous Euclid/Roman survey during mission extension

Bachelet and Penny, APJL, 2019



Euclid-Roman Joint Survey

2. Simultaneous Euclid/Roman survey during mission extension



Euclid-Roman Joint Survey

2. Simultaneous Euclid/Roman survey during mission extension

- We simulated $\sim 10^{11}$ unique lens/source pairs with 2 different FFP populations and both with Euclid VIS and H
- Apply several criterion for detection of :
 - the event (S/N)
 - the parallax π_E at 5σ
 - finite source effect

Euclid-Roman Joint Survey

2. Simultaneous Euclid/Roman survey during mission extension

δ Jupiter-mass, 2 FFP per MS

FFP Model	Filter Combination	S/N only	S/N + Parallax	S/N + Finite Source	All Constraints
Sum (2011)	W146 + VIS	490	450	18	18
	W146 + NISP (<i>H</i>)	490	450	19	19
Mróz (2019)	W146 + VIS	130	110	28	28
	W146 + NISP (<i>H</i>)	130	110	31	31

δ Earth-mass, 10 FFP per MS

Euclid-Roman Joint Survey

2. Simultaneous Euclid/Roman survey during mission extension

FFP Model	Filter Combination	S/N only	S/N + Parallax	S/N + Finite Source	All Constraints
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Unique opportunity to measure :

- ~85 % of FFP will have measurement of parallax at 5σ

Euclid-Roman Joint Survey

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- ~85 % of FFP will have measurement of parallax at 5σ
- mass, distance and kinematics for 20-30 FFP/year

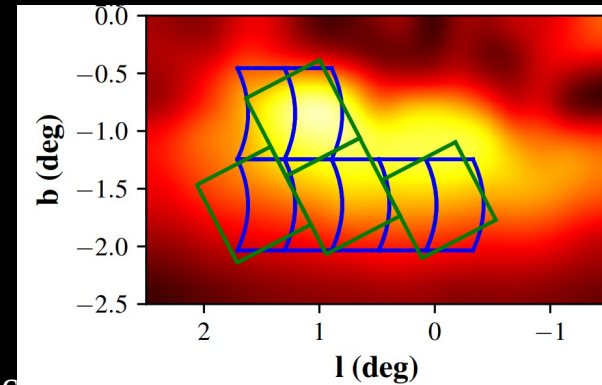
Euclid-Roman Joint Survey: **the masses and distances!**

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1. Early Euclid survey of Roman fields

Bachelet et al. A&A under review

- 4 pointing x 16 dithering images x 300s in VIS ~ 7 hours
- **Unique constraints on masses and distances of 30,000 events (and 1400 planets), including a large fraction of events after year 1 of Roman.**



Euclid-Roman Joint Survey: **the masses and distances!**

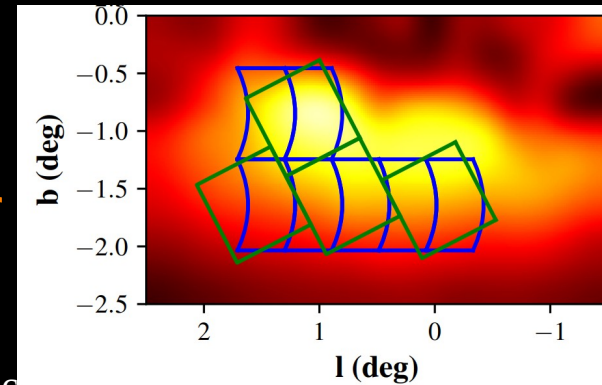
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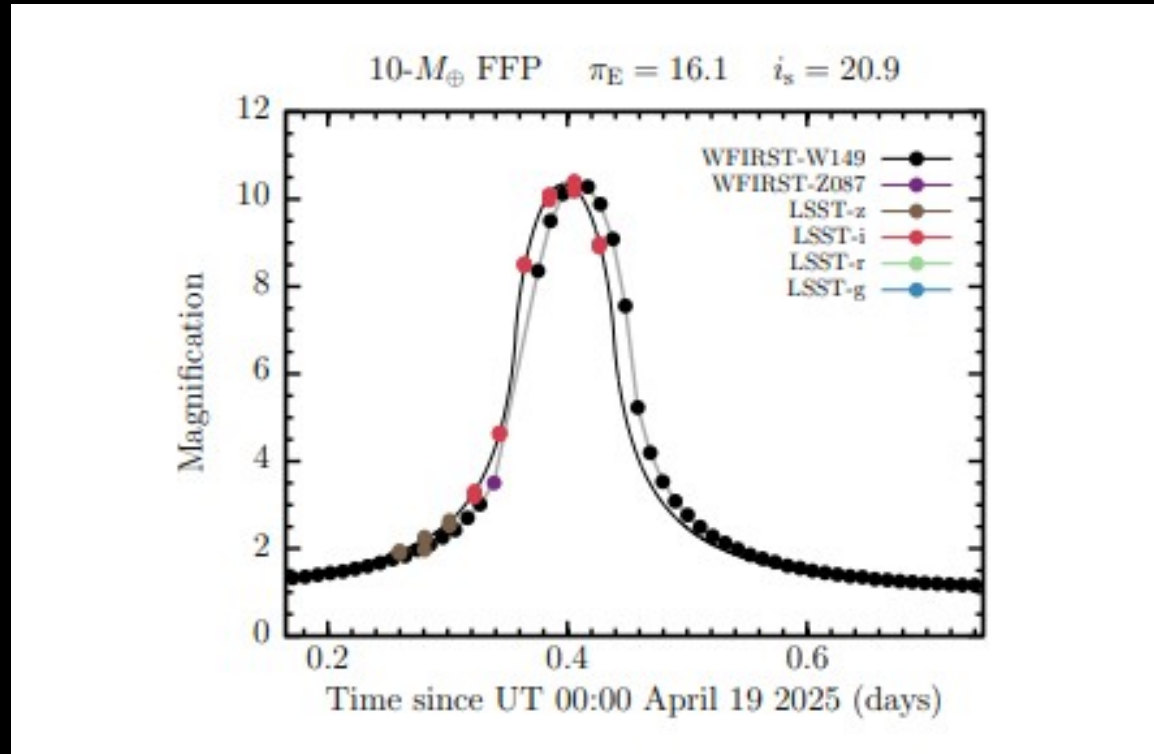
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2. Simultaneous Euclid/Roman survey during mission extension

- ~30 d joint survey of the Roman fields
- **Parallax detection at 5σ down to the FFP regime**
- **Mass, distance and kinematics for 20-30 FFP/year**



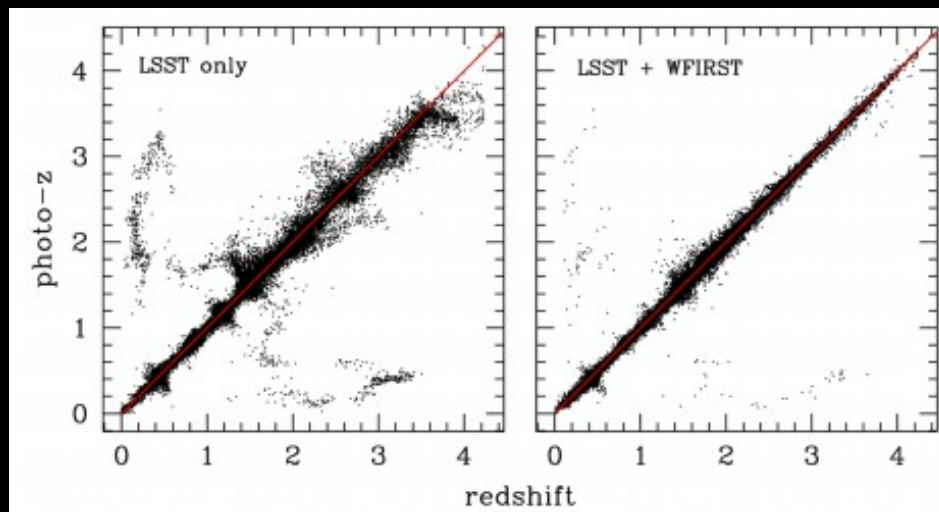
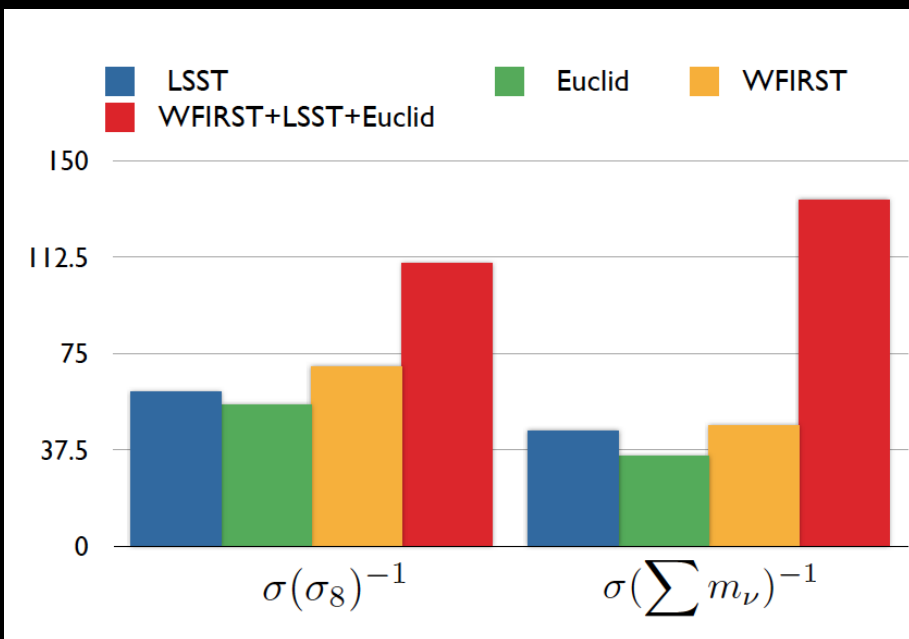
Roman-Rubin parallax of FFP



LSST Science Collaborations. 2017. arXiv:1708.04058

From microlensing to all sciences...

Jain, B. et al. 2015. arXiv1501.07897v2



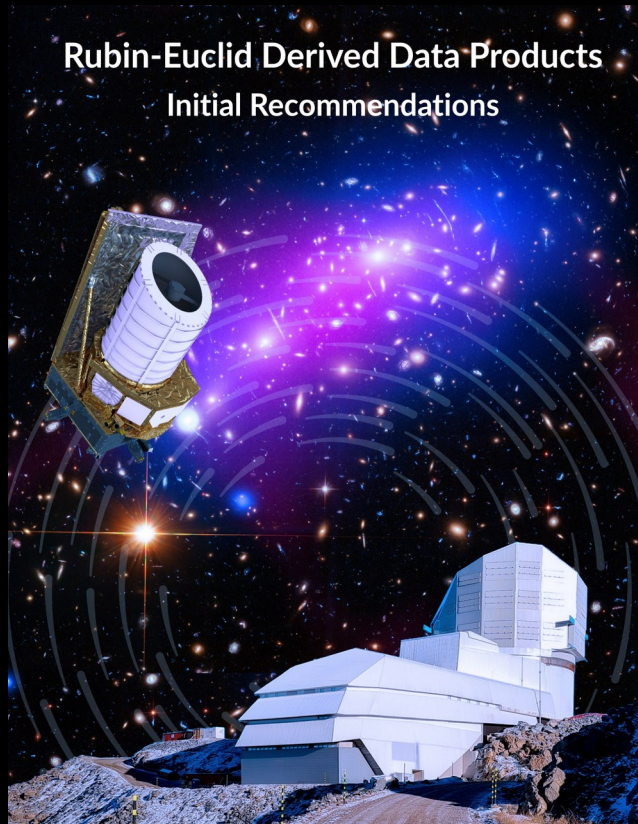
See Also:

Rhodes, J. et al. 2017. ApJS.233.21R

Chary, R. R. et al. 2019. BAAS.51.202

Capak, P. et al. 2019. arXiv:1904.10439

From microlensing to all sciences...



Guy, L. et al. 2022 [arXiv:2201.03862](https://arxiv.org/abs/2201.03862)

Extra-Galactic science:

- Dark energy
- Local Group and Large Structure
- Stellar Streams

....

Galactic science:

- Exoplanets/FFP
- Variables stars (RR Lyraes, Cepheids ...)
- Young Stellar Objects
- Solar System

....

Definition of Derived Data Products