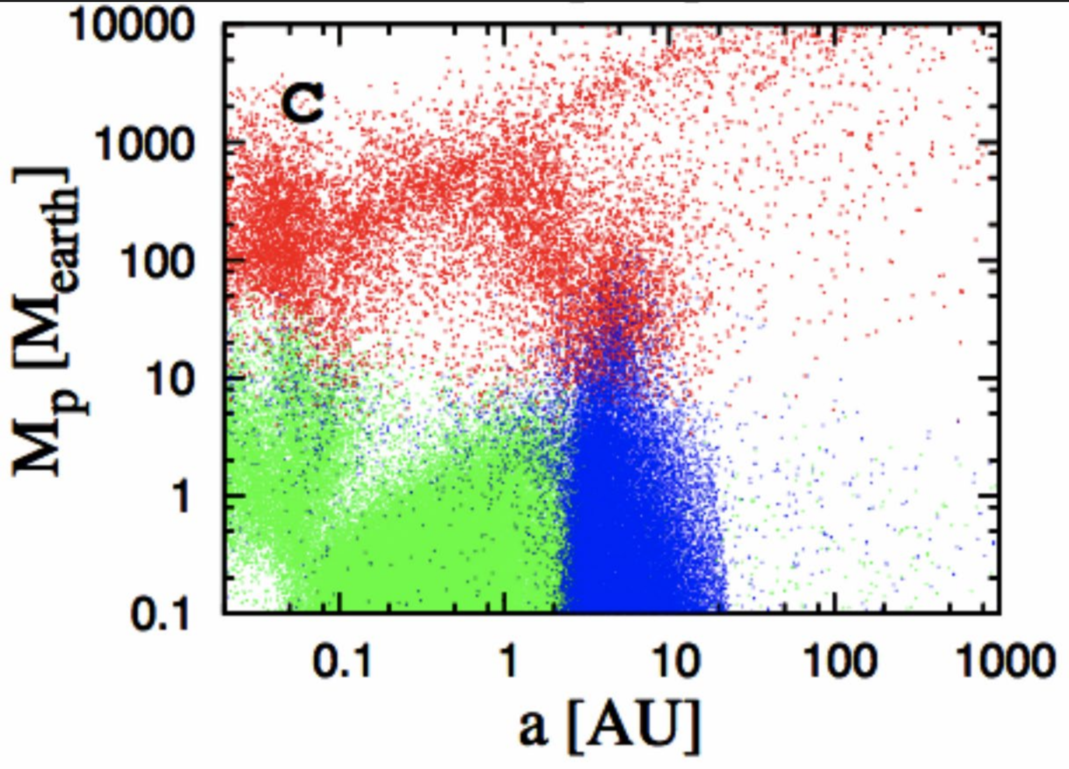
Science in the Galactic Bulge with

The Nancy Grace Roman Space Telescope

Rachel Street, Las Cumbres Observatory

Image credits: NASA

Exoplanet demographics are a critical test of planet formation theory

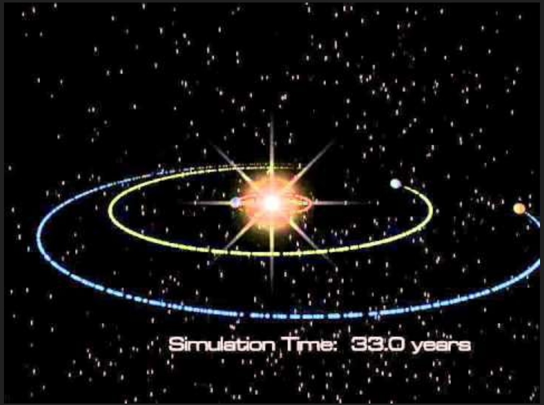


Planetary populations predicted from core accretion

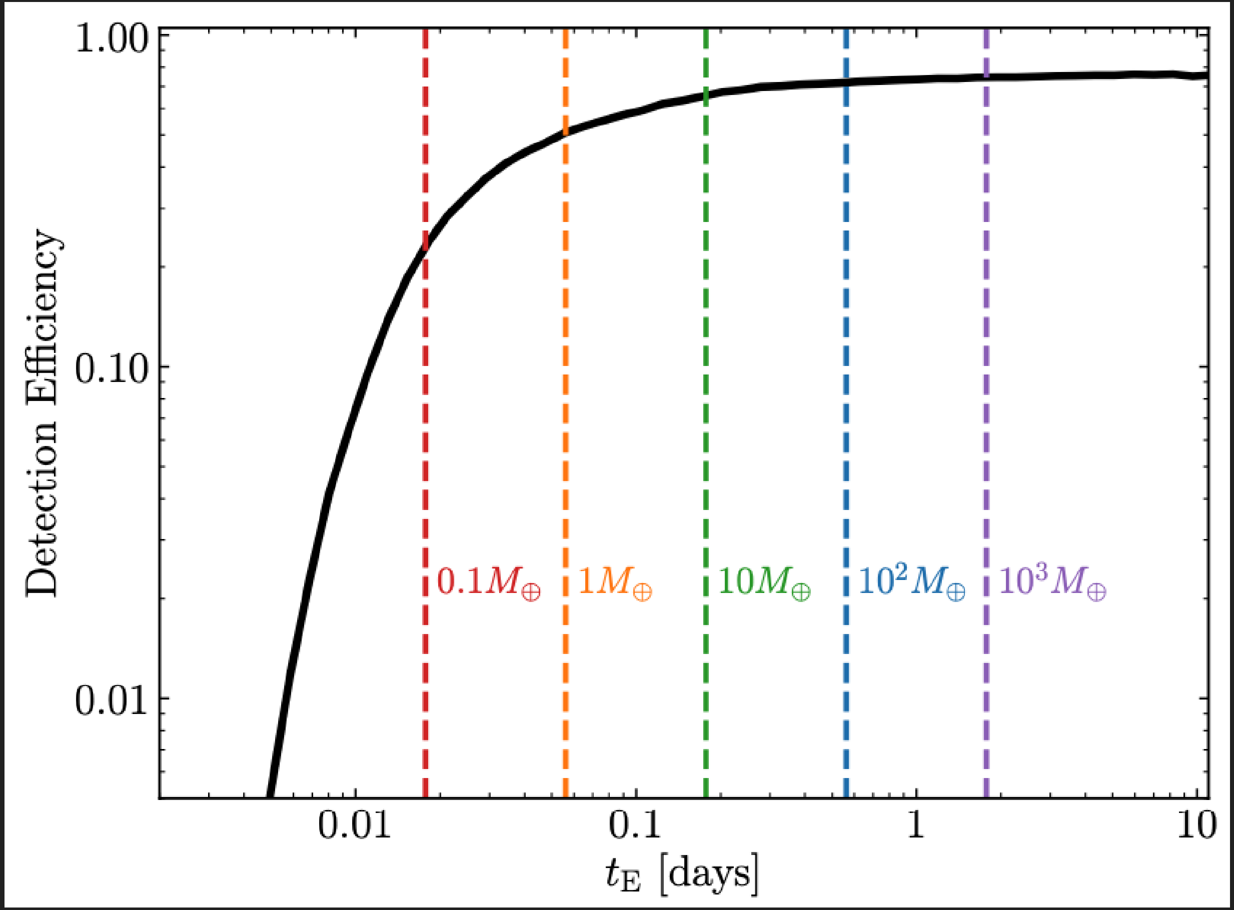
Rocky
Icy
Gas giants

Ida et al 2013

Free-floating planet population tests theories of formation and orbital evolution

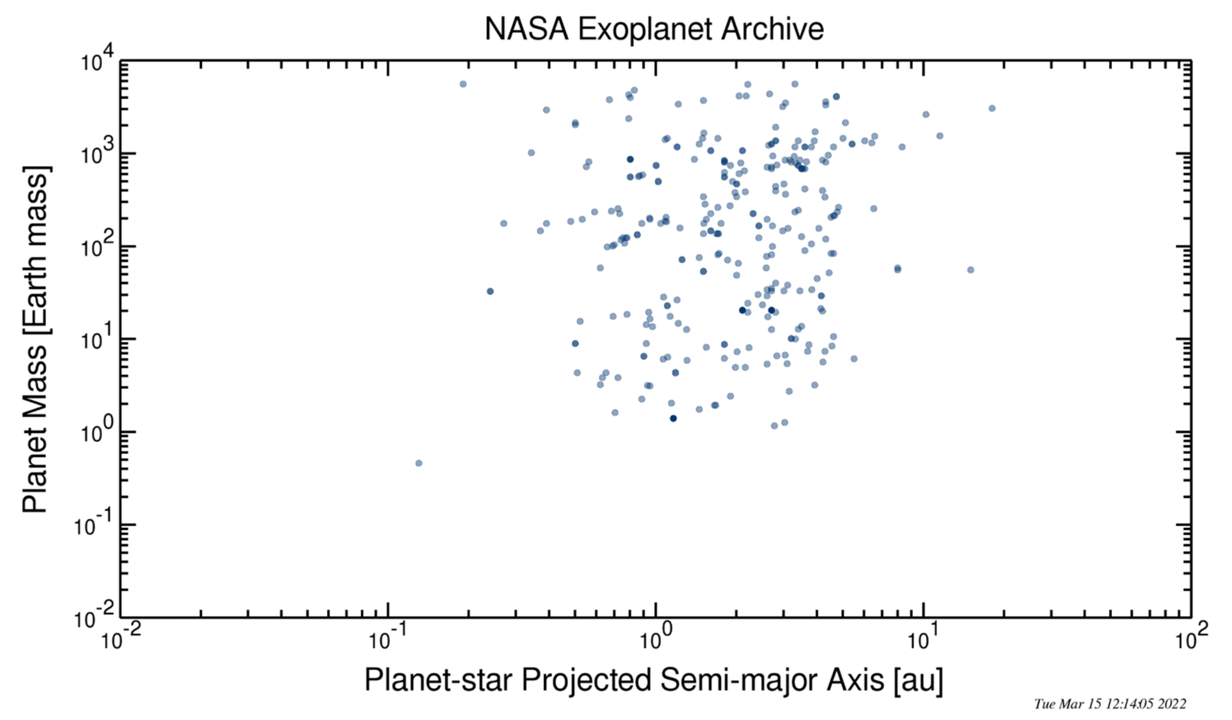


Trent Schindler, NSF Northwestern



Roman detection efficiency for FFPs - Johnson et al. 2020

Significance of Roman's Galactic Bulge Survey



Current sample of microlensing events

Ground-based surveys + follow-up teams

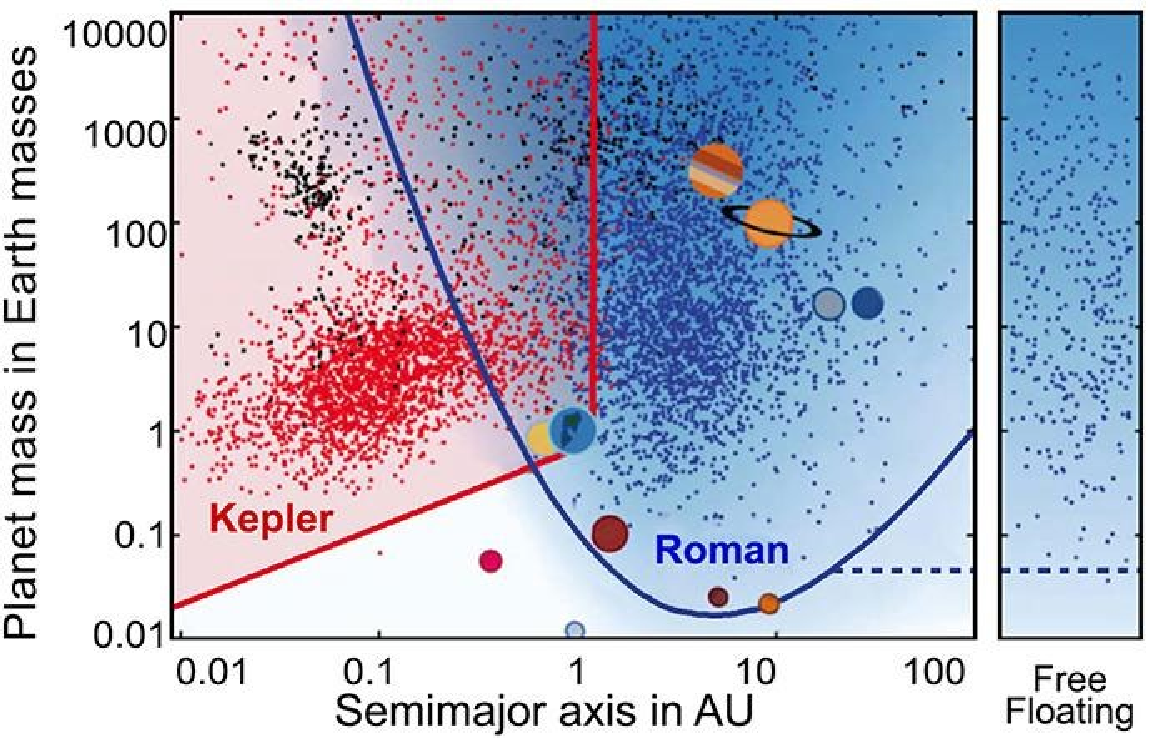
30 years

358 planets

~5 candidate FFPs

OGLE, MOA, KMTNet, EROS, MACHO
MicroFUN, MiNSTEp, PLANET, RoboNet & more

Significance of Roman's Galactic Bulge Survey



Penny et al. 2018

5yr mission

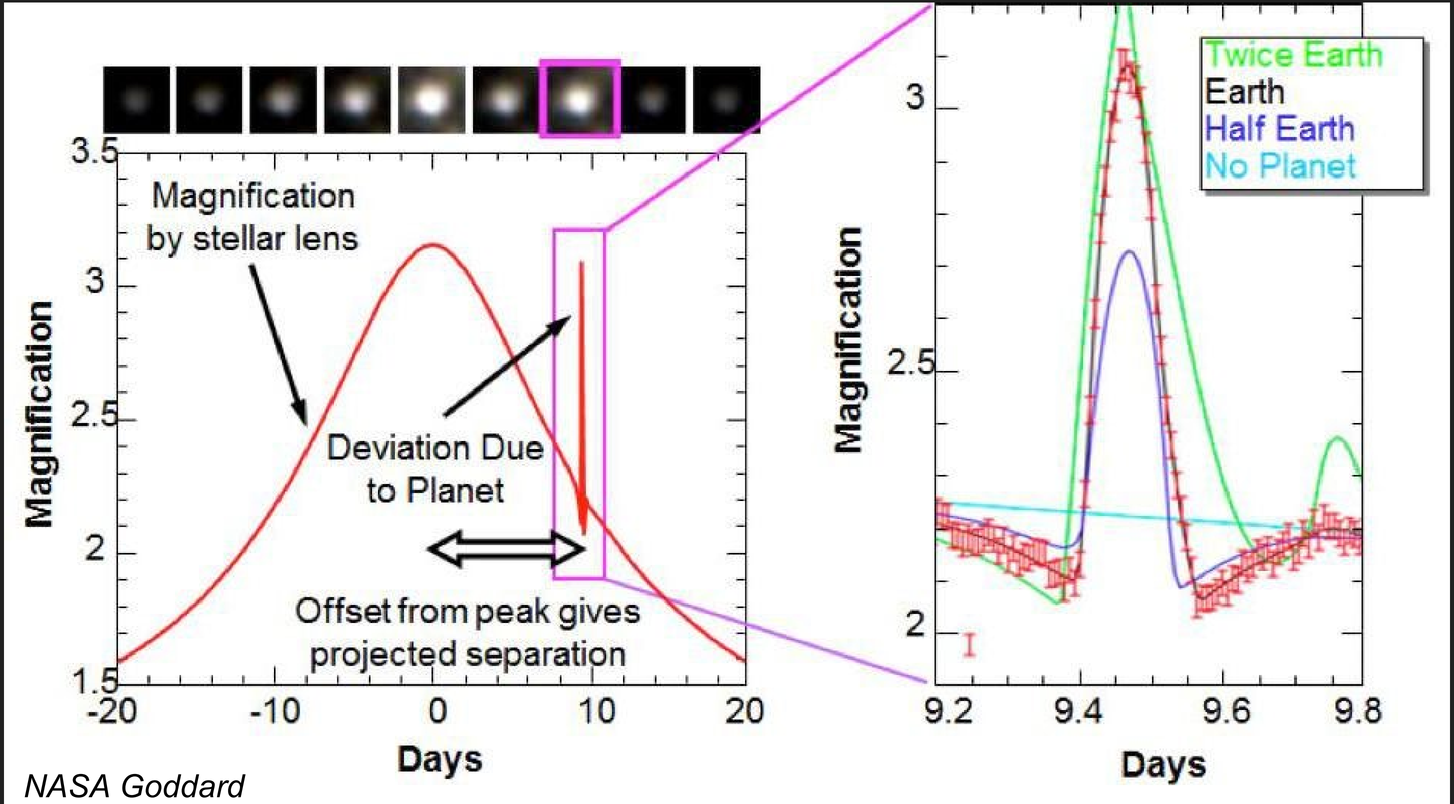
~1400 bound exoplanets
Penny et al 2018

~250 free-floating planets
Johnson et al. 2020

Masses ≥ 0.1 MEarth

Sample will reveal clustering in parameter space

Space-based survey is vital

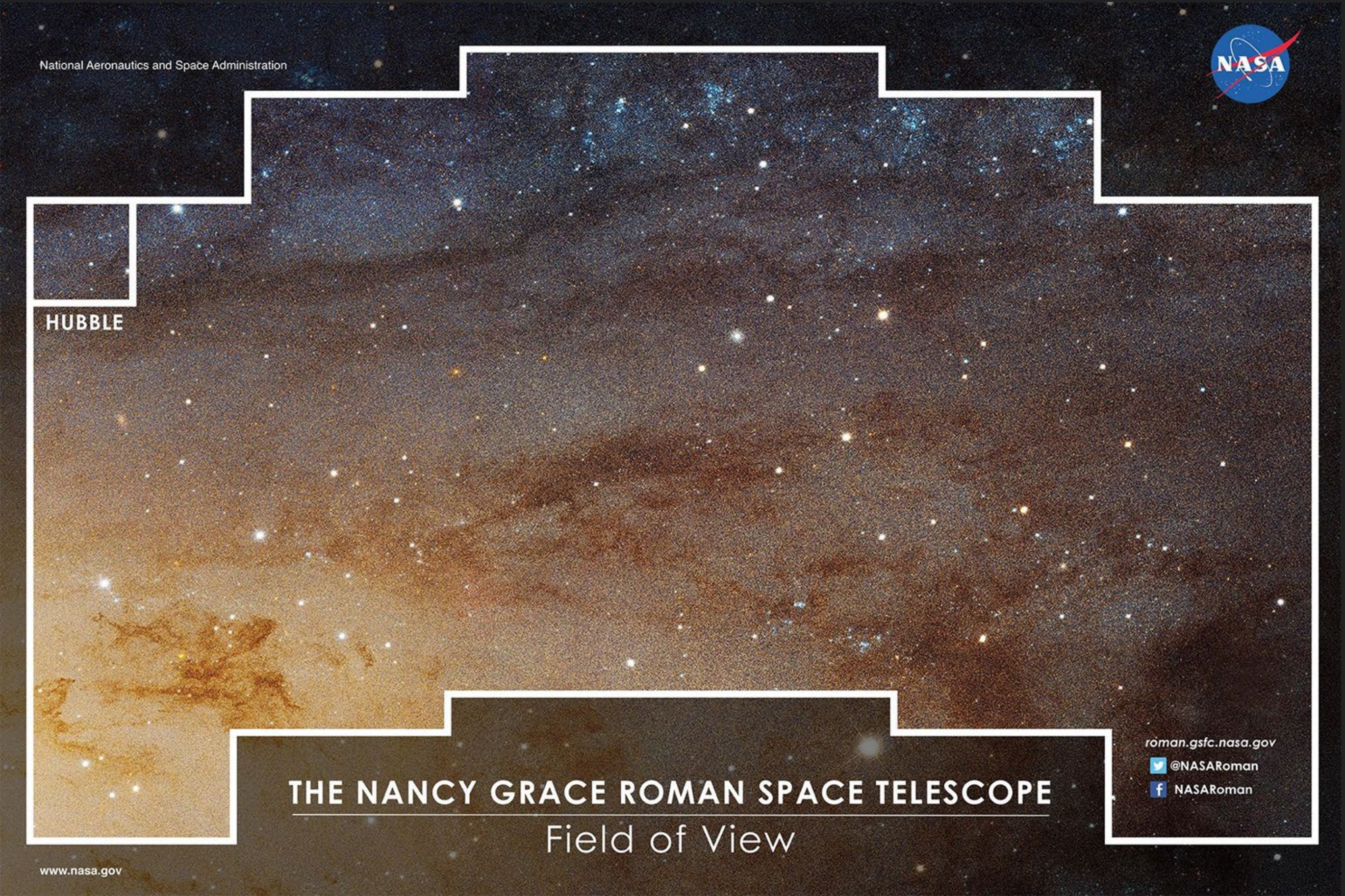


Photometric precision

High cadence

Continuous monitoring

Roman/WFI is ideal for microlensing science



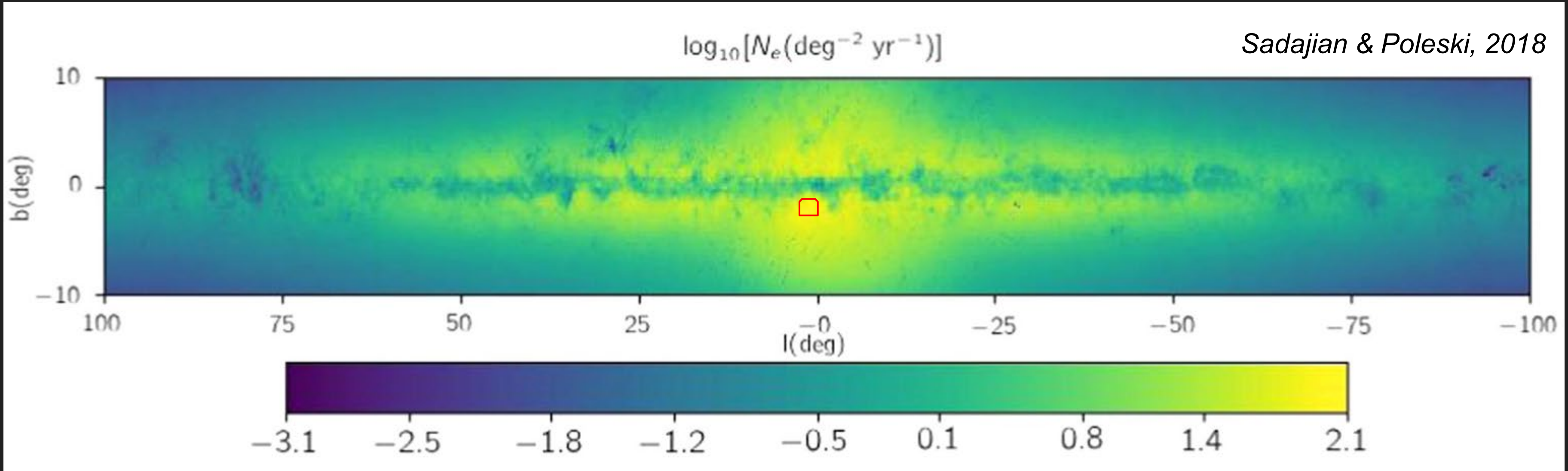
Microlensing event rate ≤ 3.1×10^{-6} yr^{-1} deg^{-2}
Highest in the Galactic Bulge
Mroz et al 2020

Requires:
Large field of view
Telescope aperture
<1 arcsec pixel scale
NIR passbands

Could community-based proposals achieve the same science?

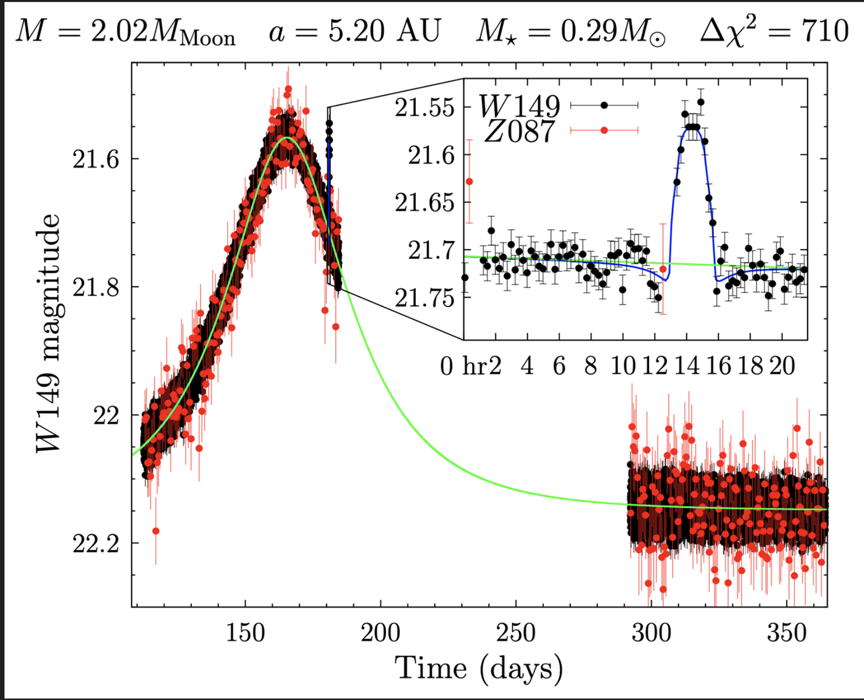
Very limited flexibility in the survey design

Microlensing events are *heavily* concentrated in Galactic Bulge region



Bulge survey cadence determined by event parameters

Transient events with timescales ranging from <1 day to 100+day
Planetary anomalies have durations of hours-days



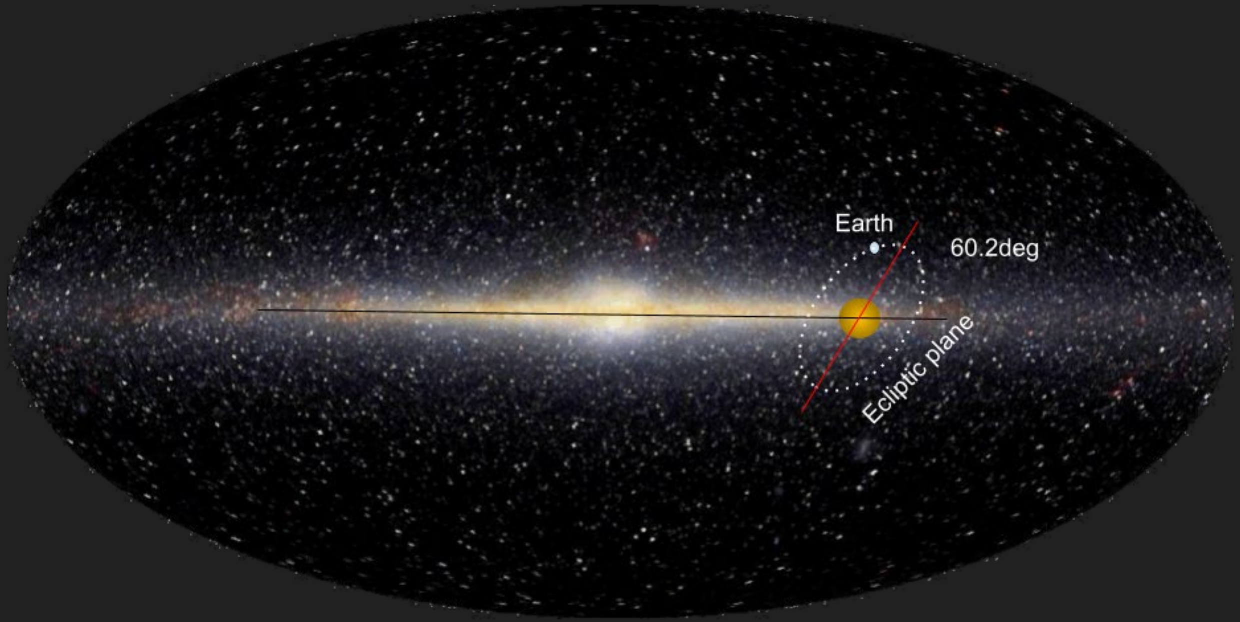
Cadence has to be << 1hr
Continuous monitoring essential

Penny et al 2018
Simulated Roman lightcurve of microlens with anomaly due to 0.025 M_{Earth} planet

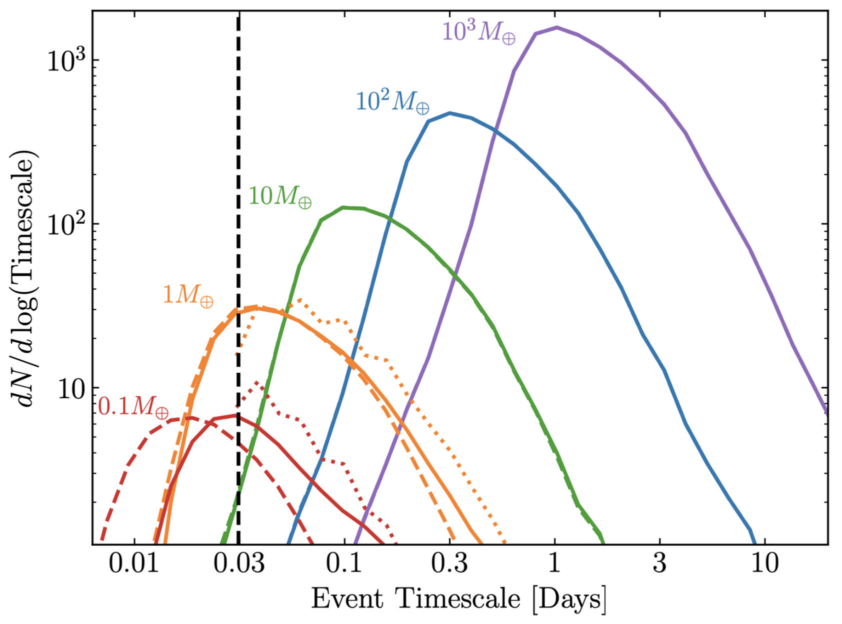
Scientific Yield Increases with Bulge Survey Duration

Number of events detected scales linearly with survey duration

Roman survey seasons limited by Bulge window of visibility



Scientific Yield Increases Dramatically with Number of Seasons



Event timescales for distribution of low-mass lenses expected from Roman [Johnson et al.2020]

Single season:

Detect some FFPs, stellar events up to ~70d

Multiple seasons:

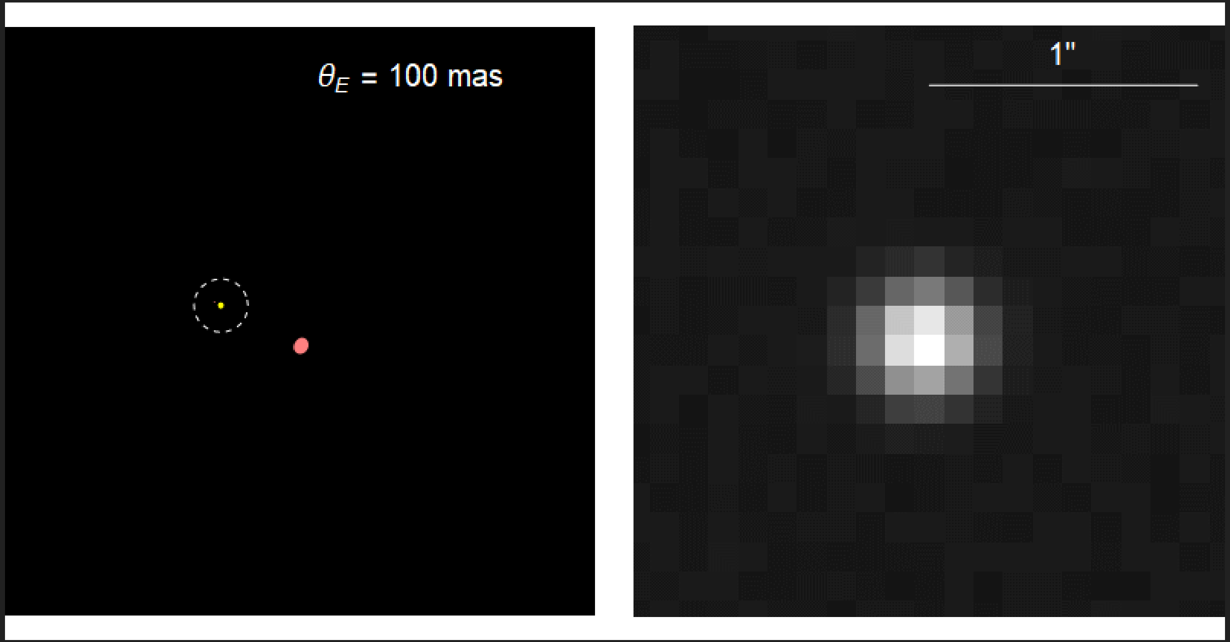
Sensitive to broader range of lens masses, distances and dynamics

Essential baseline data

Scientific Yield Increases Dramatically with Number of Seasons

Multiple seasons:

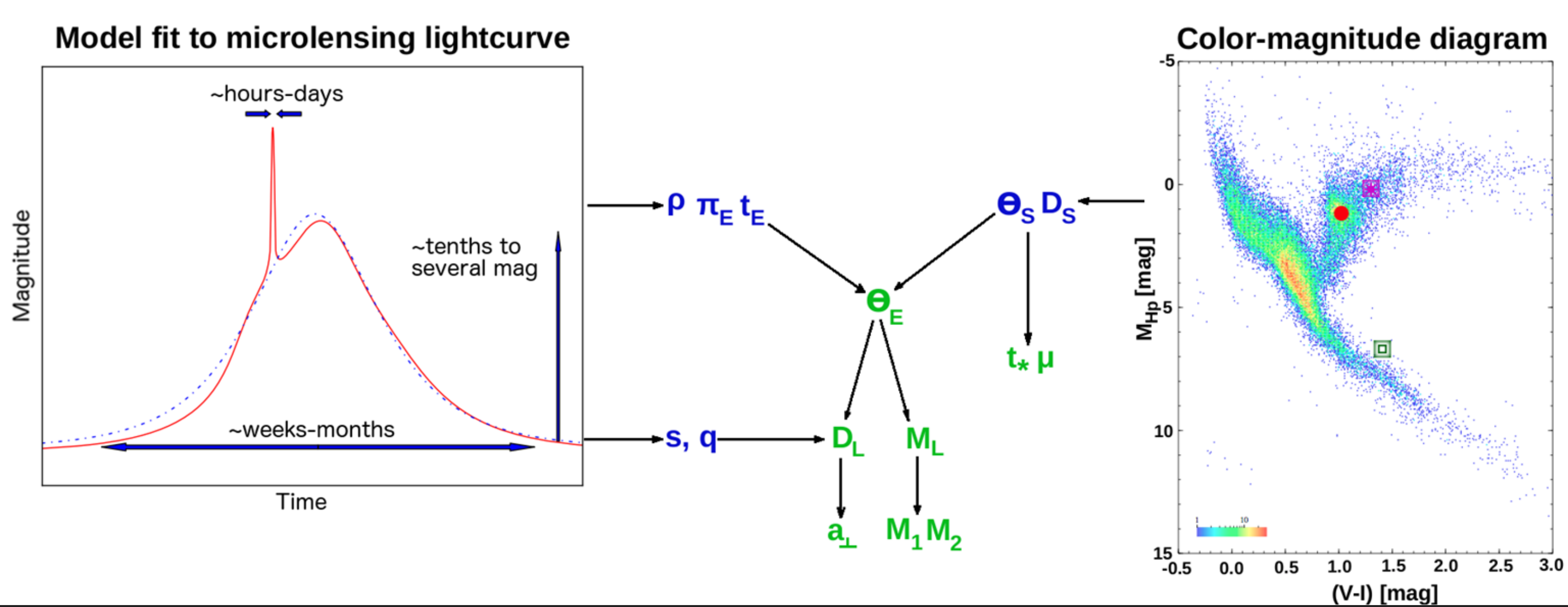
Constrain (much longer) astrometric microlensing signature,
Also detection of flux from some lenses



Simulation of microlensing event with an (exaggerated) Θ_E =100mas, showing Roman PSF. Credit:Valerio Bozza

Multi-band photometry necessary for source characterization

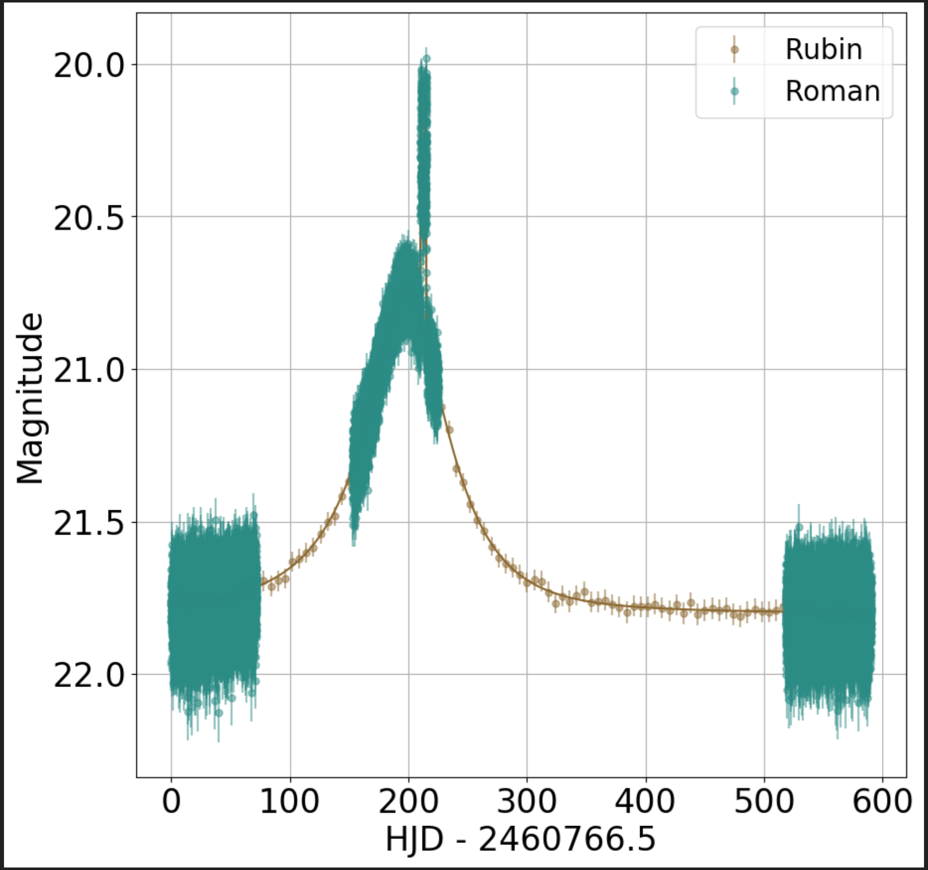
Timeseries photometry in two filters provides an independent estimate of the source star angular radius, necessary to constrain the mass of the lens



Could community-based proposals achieve the same science?

- Any community-based proposal would necessarily arrive at virtually the same survey design
- Community proposals would make it harder to argue for consistent long blocks of time and a consistent strategy
- Essentially this would duplicate the work of the first Microlensing SIT
- Existing Bulge survey design supported by community

Coordination with Rubin Observatory



Highly complementary cadence and wavelength

Rubin can fill Roman's inter-season gaps

- Detect short events that would be missed
- Constrain long event parameters
- Detect anomalies that would be missed

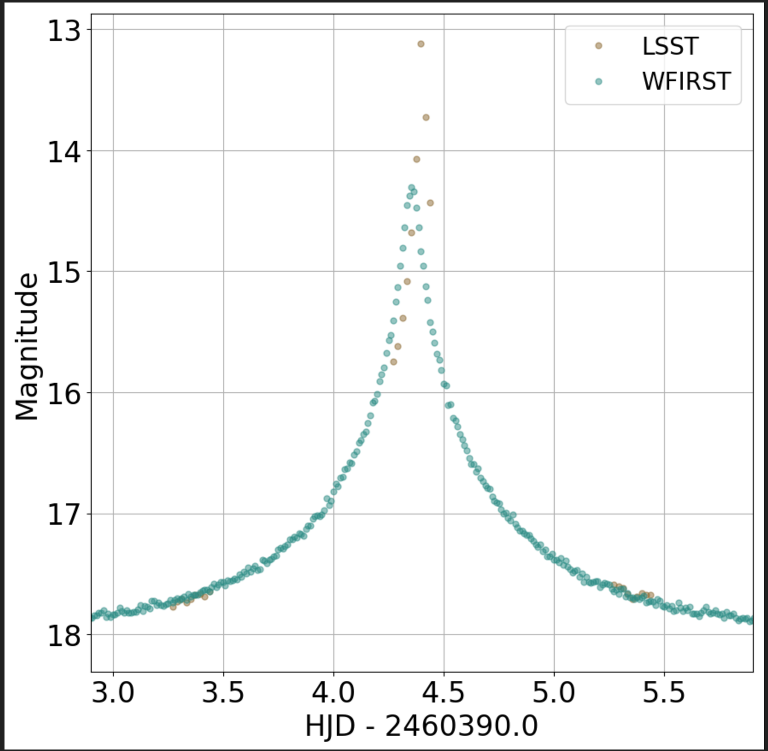
See Street et al. 2018

Coordination with Rubin Observatory

Highly complementary cadence and wavelength

Rubin can constrain parallax to Free-Floating Planet events discovered by Rubin

Contemporaneous observations from both observatories are possible for limited periods of the seasons



See Street et al. 2018

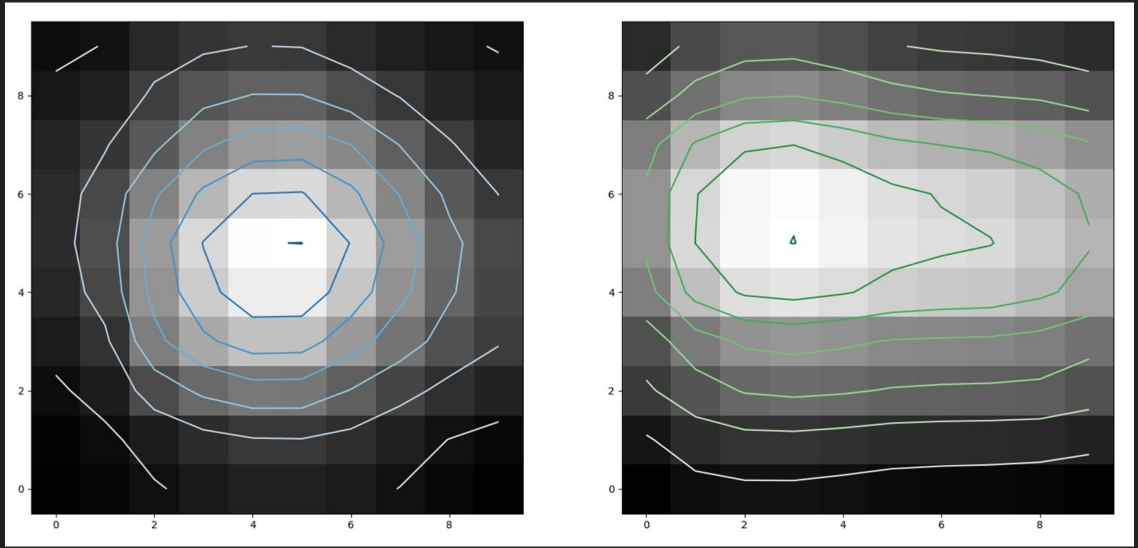
Coordination with the Euclid Mission

Small investment of Euclid time can place strong constraints on thousands of Roman events
~7hr precursor survey of Roman field by Euclid

- Relative proper motion of ~30% of Roman events
- Lens magnitudes of ~42% of Roman events

Complementary bandpasses and early observations will detect lens flux, providing constraints on lens mass

Roman PSF during event | Euclid PSF prior to event



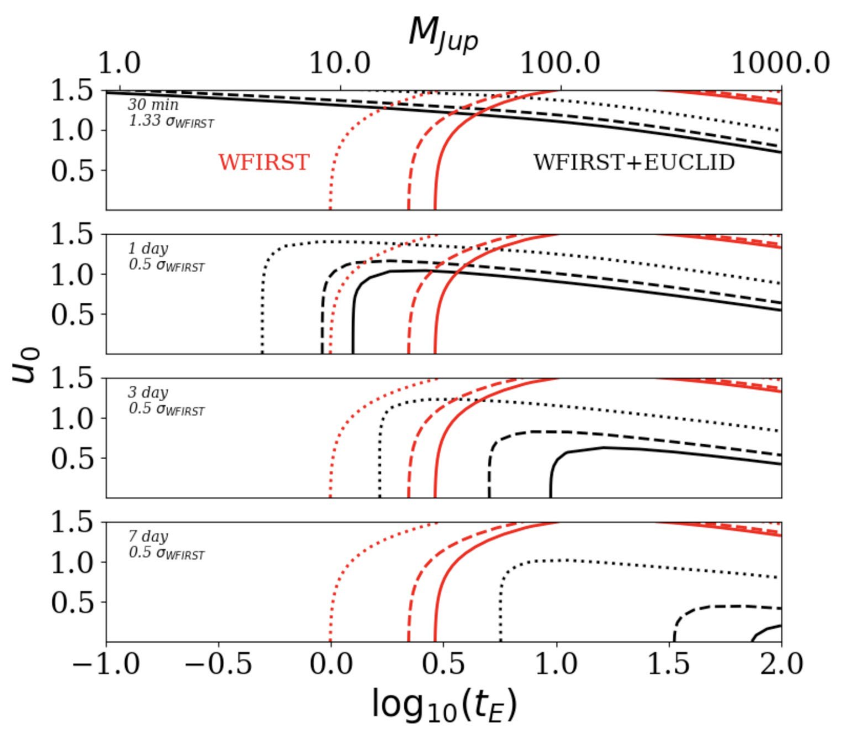
Simulated Roman and Euclid images - Bachelet et al. 2022

Coordination with the Euclid Mission

Simultaneous observations by both missions can constrain parallax of Free-Floating Planet events

Joint survey would detect ~130 FFP events in 1st year of Roman

Bulge survey proposed as an Euclid ancillary science program



Bachelet et al. 2019

Strong community interest in Galactic Bulge Science

7 out of 46 Rubin survey strategy white papers advocated for surveys of Galactic Plane including the Bulge

Time-domain science benefits from Roman cadence/wavelengths

Wide range of science

- 3D Bulge structure
- Bulge stellar populations
- Bulge structure formation/evolution
- Transiting planets
- Transiting white dwarfs
- Stellar variability
- Pre-main sequence stars & Young stellar objects
- Cataclysmic variables
- X-ray binary outbursts/variability
- Novae/supernovae
- New dwarf galaxies
- Ultracool brown dwarf variability

Lund et al. 2018, Prisinzano et al. 2018, Gonzalez et al. 2018, Street et al. 2018a & b, Strader et al. 2018, Bono et al. 2018

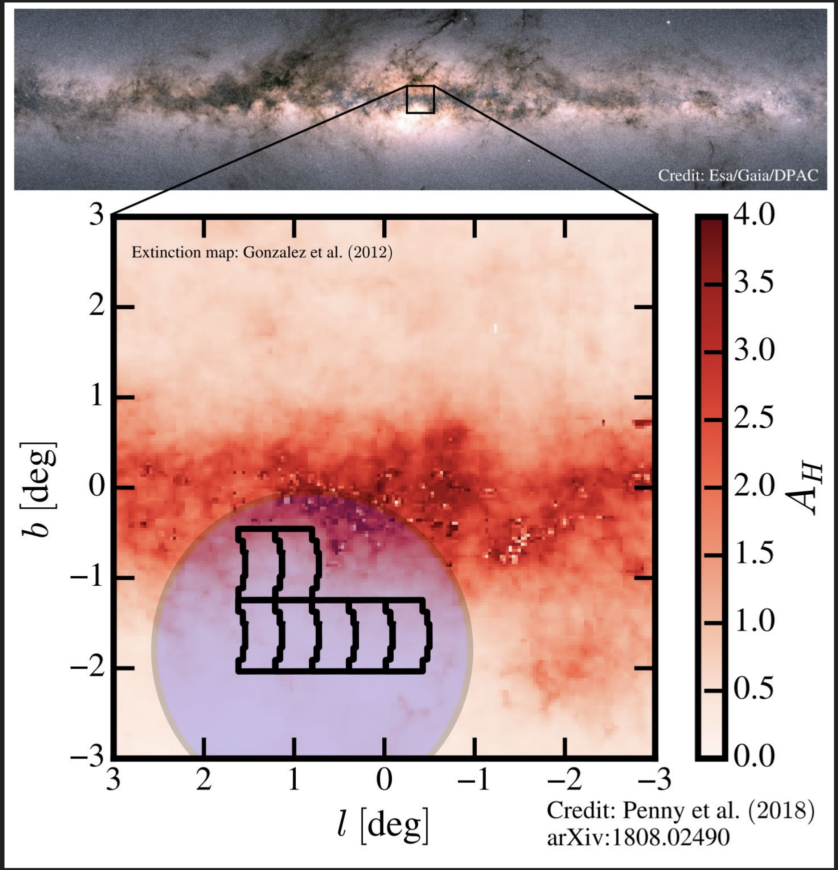
Summary

Roman Galactic Bulge survey strategy is well designed for microlensing science

Community-endorsed survey strategies

- Roman MicroSIT
- Rubin survey strategy task forces

Unique opportunity to maximize the combined science return of three groundbreaking survey facilities



Overlap of Roman (black outline) and Rubin (blue circle) survey footprints in the Bulge [Penny et al 2018]