The Roman GBTDS in a Galactic Context

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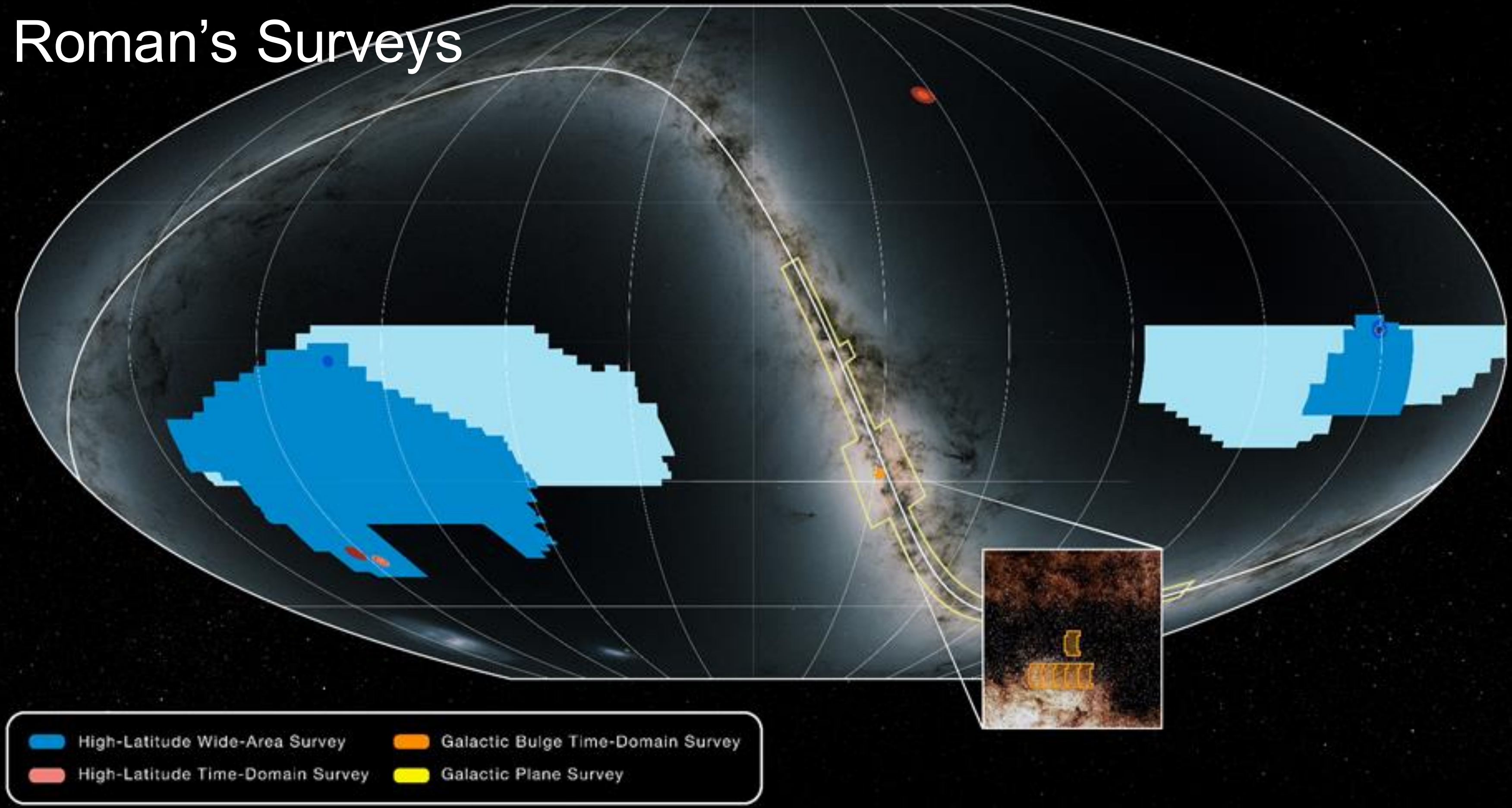
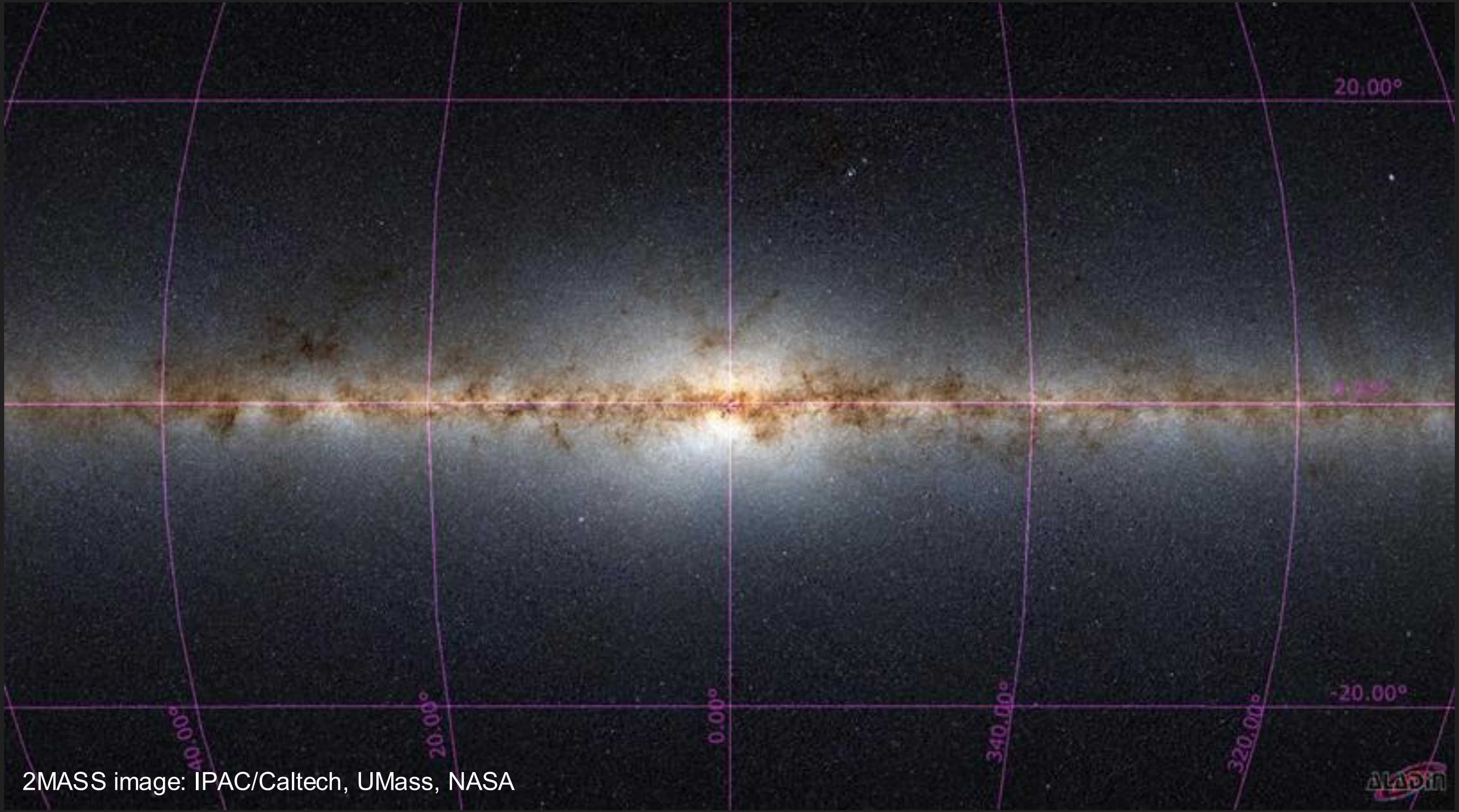
Roman’s Surveys



Source: RDox

The Galactic Bulge Time Domain Survey Fields



2MASS image: IPAC/Caltech, UMass, NASA

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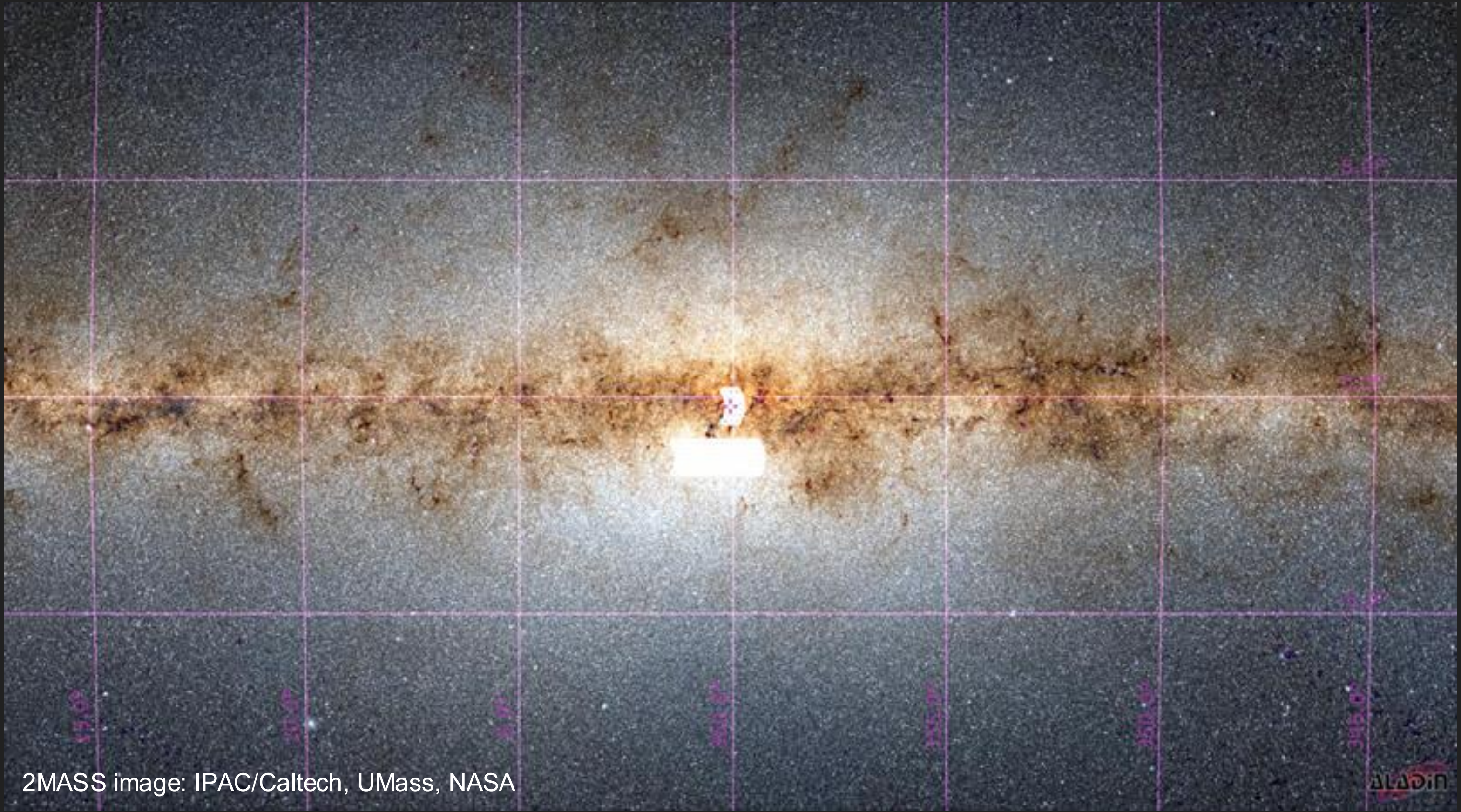

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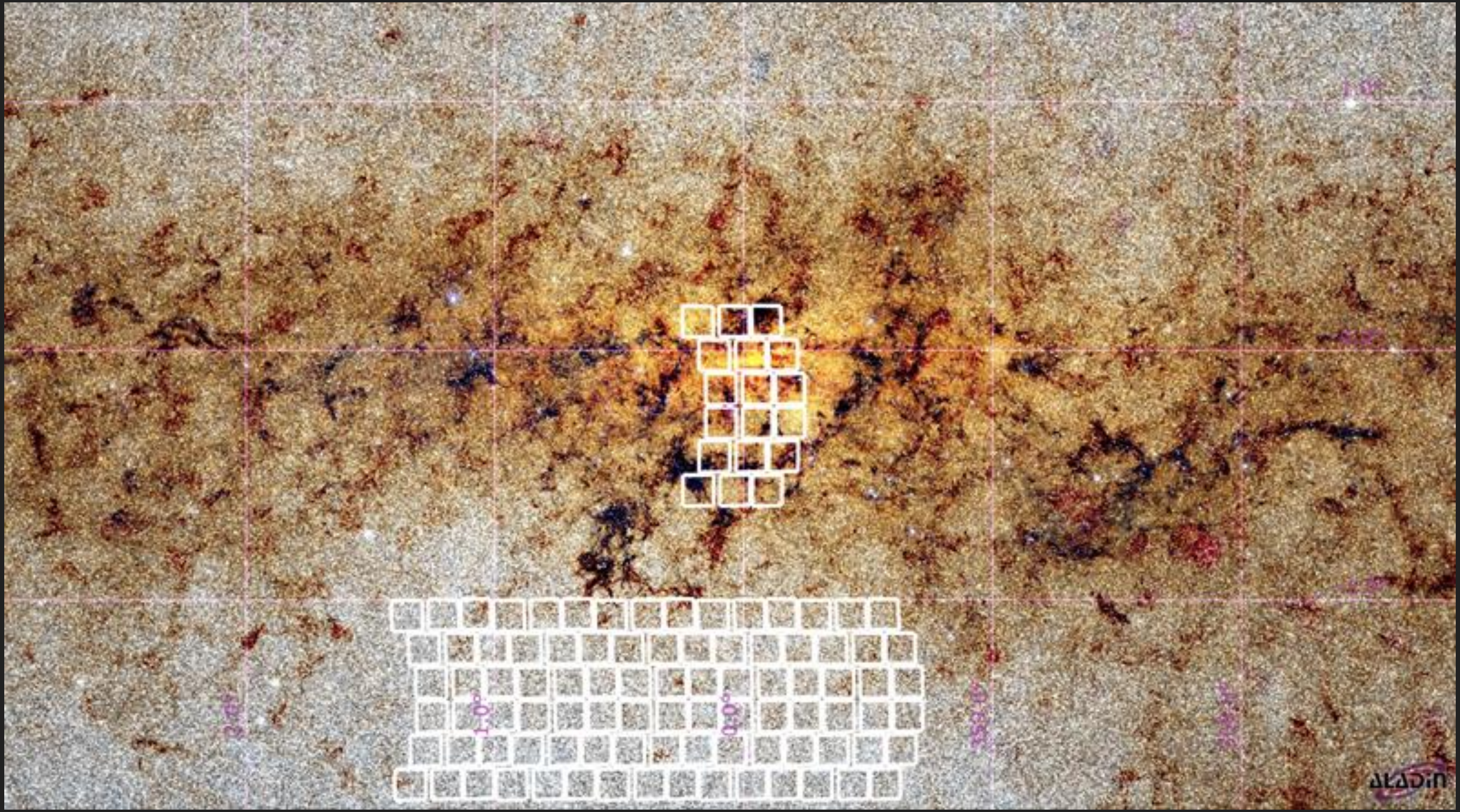

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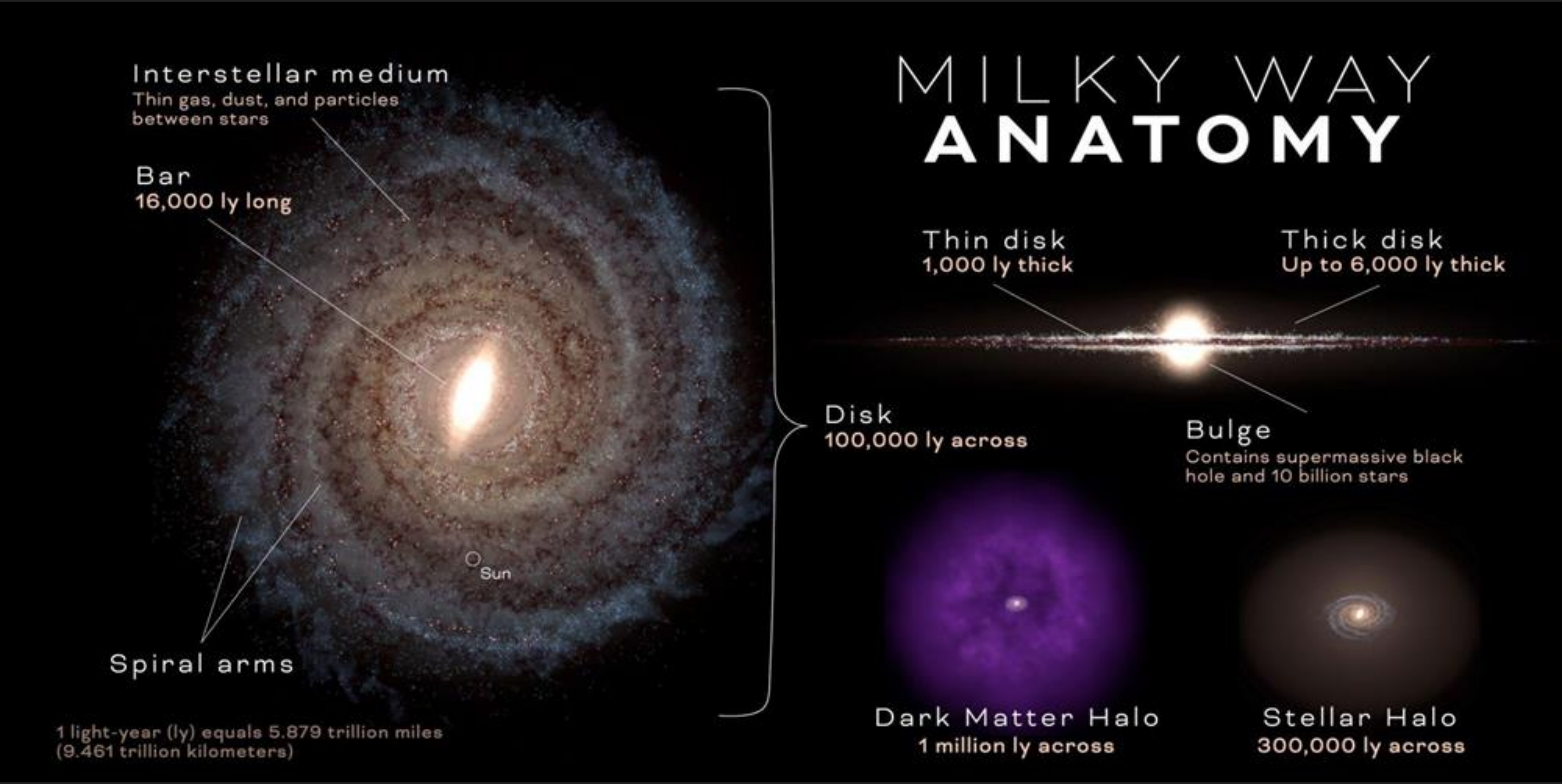
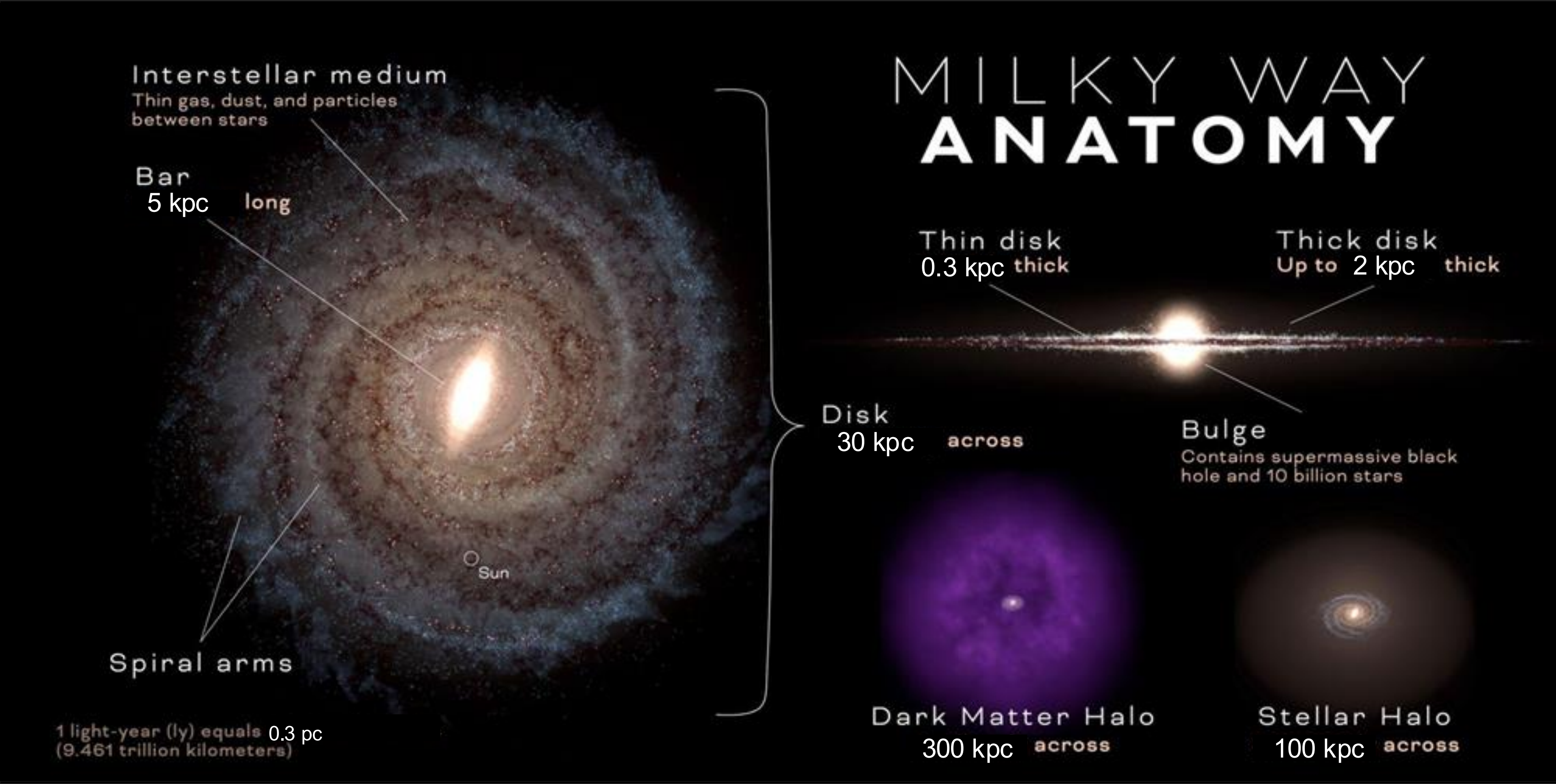


Credit: NASA Goddard Space Flight Center, Scott Wiessinger, Adriana Manrique Gutierrez, Ashley Balzer



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Why might exoplanets be different across these populations?

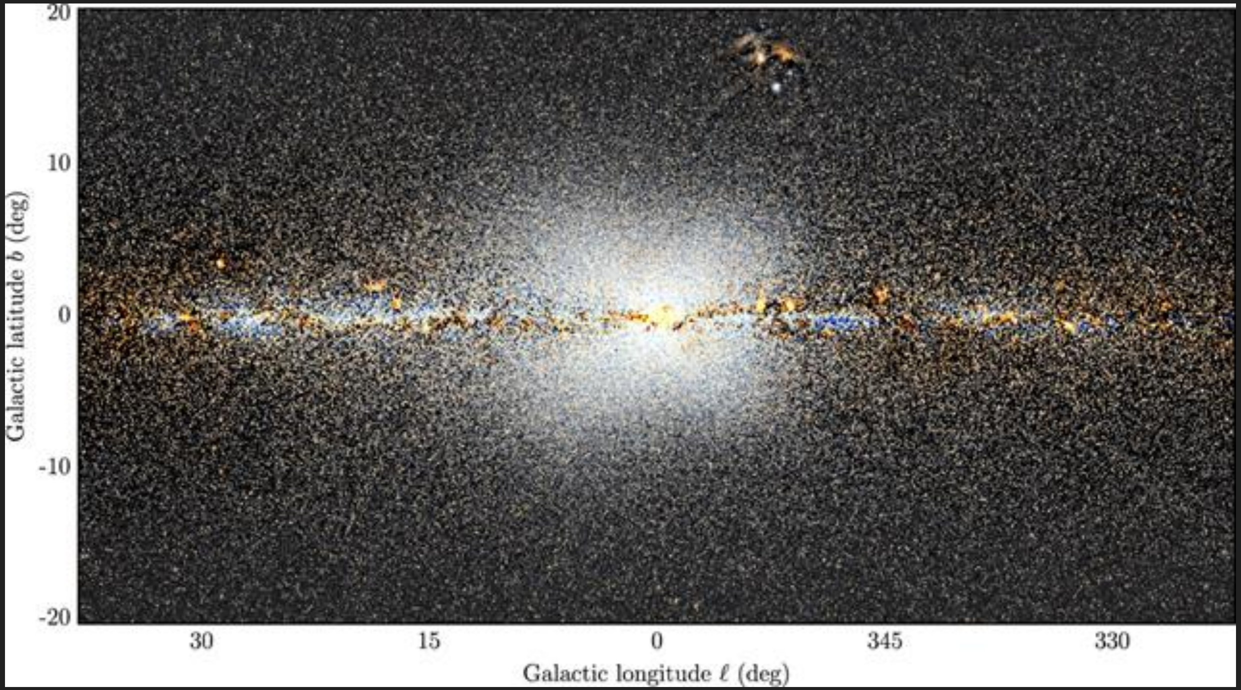
Different stellar populations / Galactic regions have different:

- ages
- metallicities (e.g. [Fe/H])
- alpha-abundances (e.g. O, Ne, Mg, Si, S, Ar, Ca, and Ti)
- density of surrounding stars
- stellar mass and multiplicity

which all may impact planet formation and evolution

The Galactic Bulge

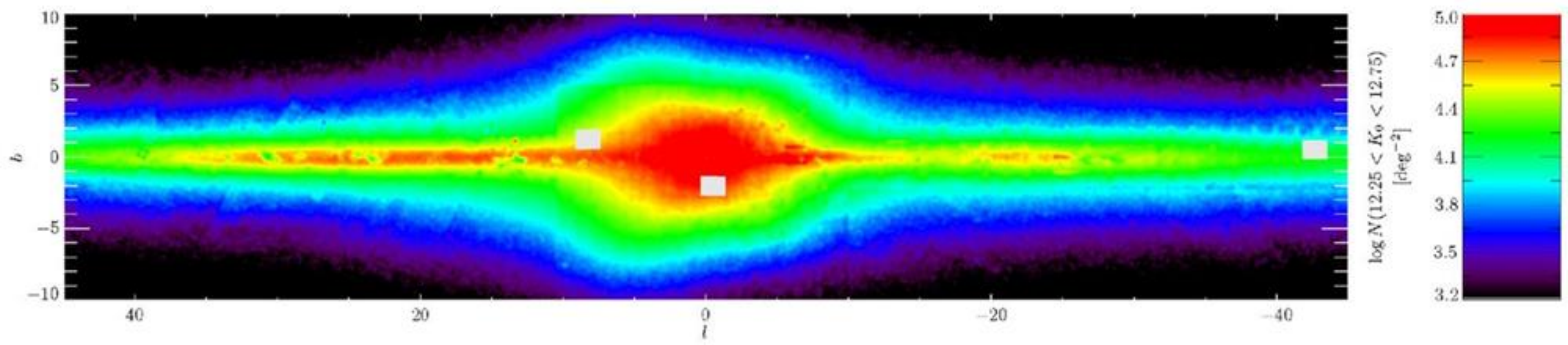
The central bar is dominated by a boxy/peanut-shaped structure, angled 20-30º from our line of sight



WISE image of the Milky Way at 3.4, 4.6 microns; Ness & Lang (2016)

The Galactic Bulge

- The central bar is dominated by a boxy/peanut-shaped structure, angled 20-30^o from our line of sight
- Additional proposed substructures include a long bar reaching beyond the bulge region, and a smaller inner nuclear bar



Extinction-corrected Ks star counts; Wegg, Gerhard, & Portail (2015)

The Galactic Bulge

Substructures

- A boxy/peanut-shaped structure
- Long and nuclear bar substructures
- A possible spheroidal component
- A difficult-to-disentangle inner disk
- A recently proposed “knot” of stars in the inner 1.5 kpc on radial orbits

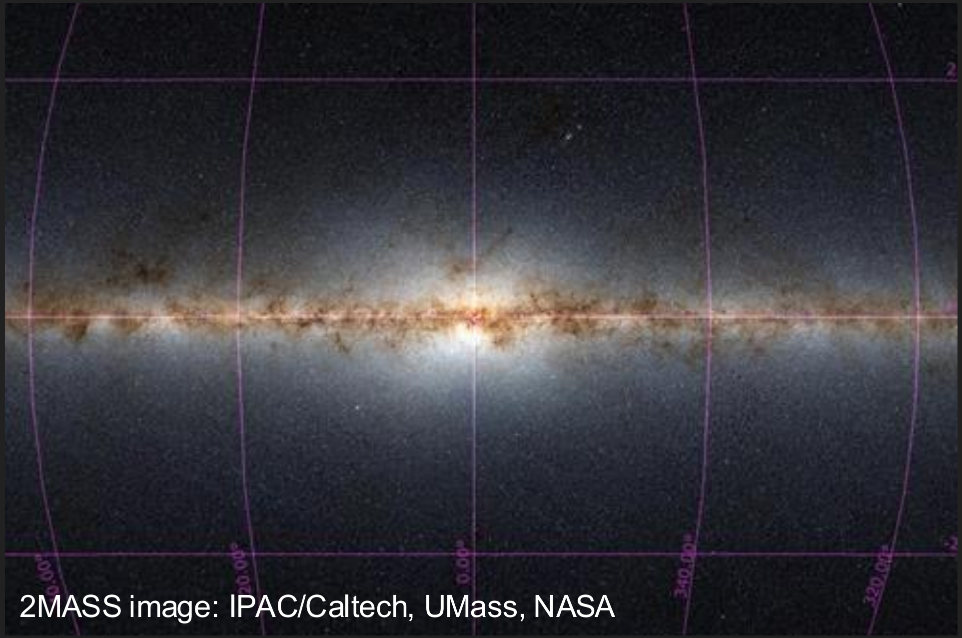
The bar rotates cylindrically around the GC, and stars also stream along it.

Stellar contents

- ~2 x 10^{10} Msun
- Primarily old stars ~10 Gyr, with some evidence of younger stars
- Mostly metal-rich stars [Fe/H]~0.3, which are alpha-element poor
- Also somewhat less metal-rich stars [Fe/H]~-0.3, which are alpha-enhanced

The Disk

- Stars of many ages and active star formation
- Lots of gas and dust
- Spiral arms
- Significant uncertainty about interior structures where bulge and other nuclear populations intersect
- Kinematically, we see a rotation curve with position-dependent velocity dispersions
- ~5 x 10^{10} Msun



2MASS image: IPAC/Caltech, UMass, NASA

The Disk

Thin Disk:

- Continuous star formation since ~10 Gyr ago
- Lost of young stars, dust, and gas
- Metal-rich, around Solar, with age and radial gradients

Thick Disk:

- Chemically distinct
- Older age and larger scale heights
- Metal-poor
- >10 Gyr

The Disk

The outer regions are warped and flaring beyond the Sun’s orbit

ESA/Gaia/DPAC, S. Payne-Wardenaar, E. Poggio et al. (2025)

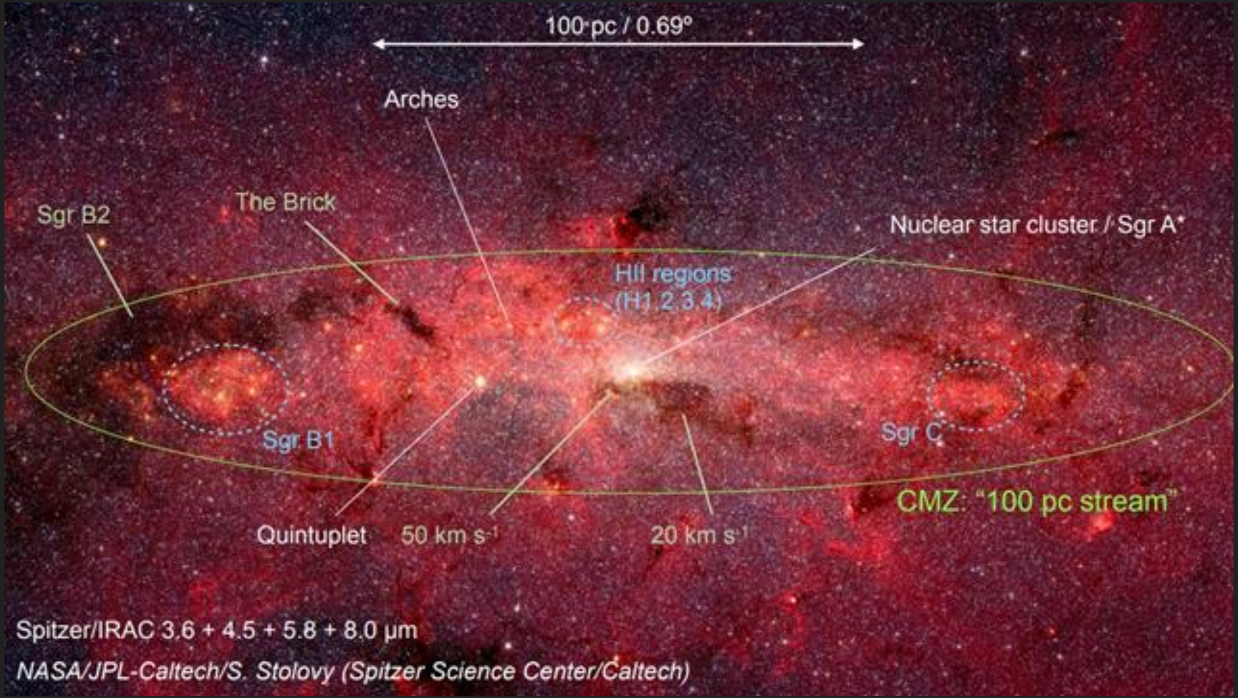
The Stellar Halo

- ~1% of the Milky Way's stellar mass
- Almost negligible when viewing the Galactic bulge, but not zero!
- Extended spheroidal population of old (mostly >10 Gyr), extremely metal-poor stars
- High-velocity stars, often with random motion
- Many substructures/streams from accreted dwarf galaxies

James Josephides \ S5 Collaboration

The Nuclear Stellar Disk & Cluster (NSD & NSC)

Additional populations exist in the innermost parts of the Galaxy



The Nuclear Stellar Disk & Cluster (NSD & NSC)

Nuclear Stellar Disk

- ~10^8 Msun
- Dense, inner ~200 pc
- More metal-rich than the bulge, with a smaller set of metal-poor stars
- Most stars >8 Gyr old, with a smaller younger population

Nuclear Star Cluster

- ~2 x 10^7 Msun
- Incredibly dense, inner ~5 pc
- More metal-rich than the NSD
- Most stars >10 Gyr old, with a smaller younger population

Are exoplanets different across these populations?

- Microlensing: no definitive evidence of Galactocentric radius dependence so far, with large uncertainties (e.g. Nunota et al, 2024)
- Transits: metallicity-dependence confirmed, but limited Galactic reach

Roman will help answer this question by:

- High-precision microlensing detections, including mass/distance info (e.g. from color-dependent centroid shift of image elongation) for many
- Detecting transiting planets through the line of sight into and past the bulge

Predicting Galactic Distributions for Roman's Microlensing Events

Galactic Model Simulations

We need to accurately simulate all of these populations to optimize and interpret microlensing surveys.

Population synthesis Galactic models:

- I develop and use SynthPop
- Other tools include genstars, the Besancon model, Galaxia, TRILEGAL, and more
- We can plug these into microlensing simulators (like GULLS and PopSyCLE) to mimic a real microlensing survey

Galactic Model Ingredients

For each population:

- Stellar mass density distribution
- Kinematics
- Age
- Metallicity
- Initial mass function

For the Galaxy overall:

- Dust map
- Extinction law
- Isochrones (stellar evolution model)
- Initial-final mass relation

Running SynthPop

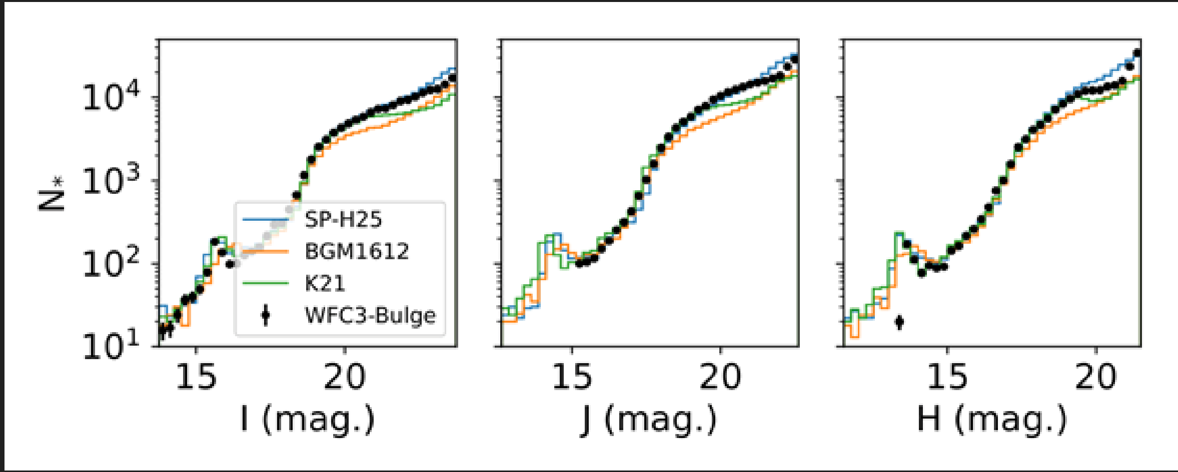
Inputs:

- Configuration (re: items on the previous slide)
- Field coordinates & size
- Magnitude limit (if any)

Output

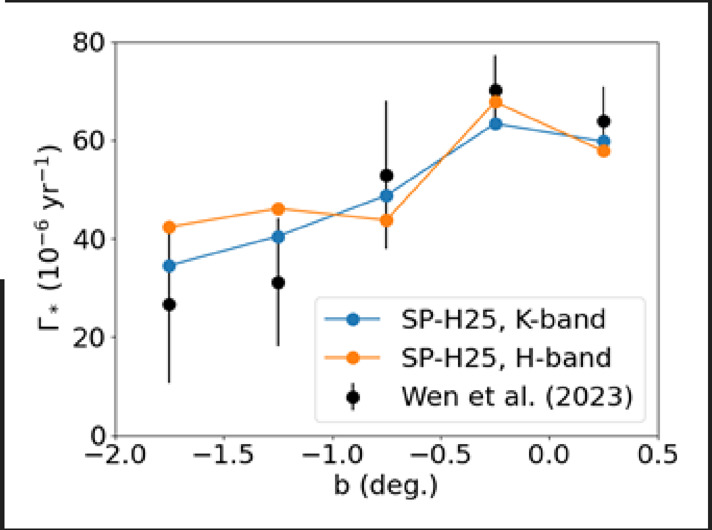
- A catalog of stars with intrinsic and observable properties

Comparing Models to Observation



WFC3 Bulge Treasury Program (Brown et al. 2009, 2010) luminosity functions against SynthPop (SP-H25), the Besancon Model (version 1612), and genstars (Koshimoto et al, 2021)

Raw UKIRT event rates against SynthPop simulations



Huston et al. (2026)

Microlensing Simulation Approaches

PopSyCLE method: Simulate a large area and propagate stellar motions across the sky to search for close crossings

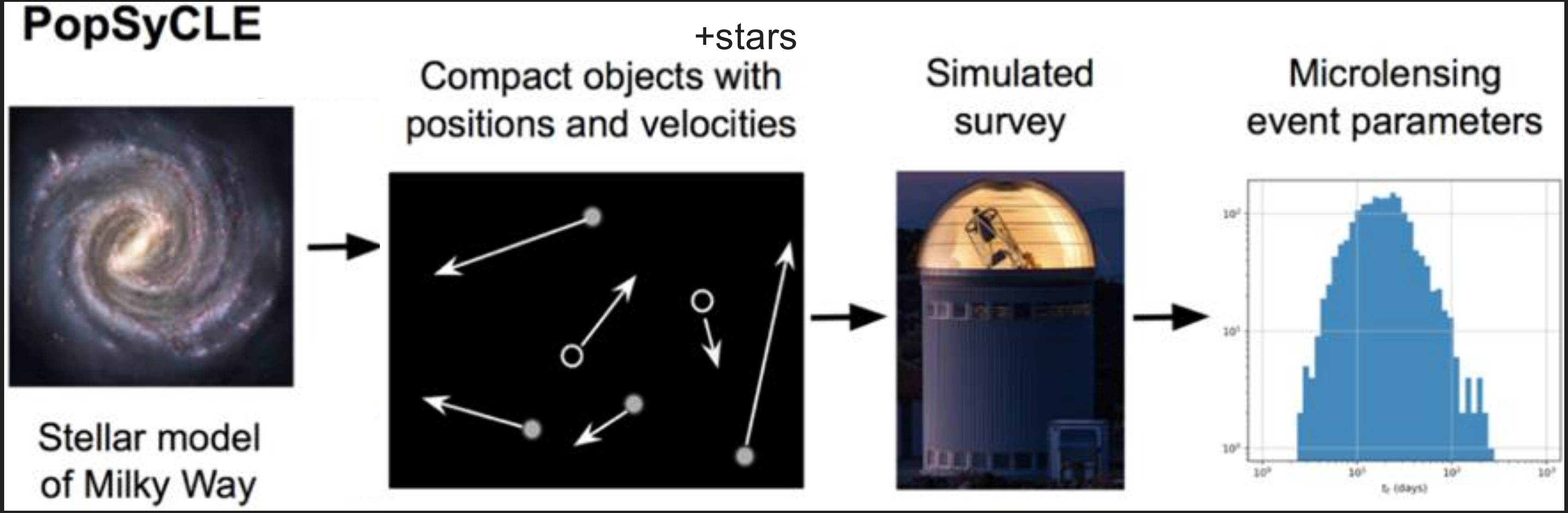


Diagram adapted from Lam et al. (2020)

Microlensing Simulation Approaches

Randomly drawn stars from catalogs

- Underlying rates for PSPL events can be calculated from a lens catalog and a source catalog:

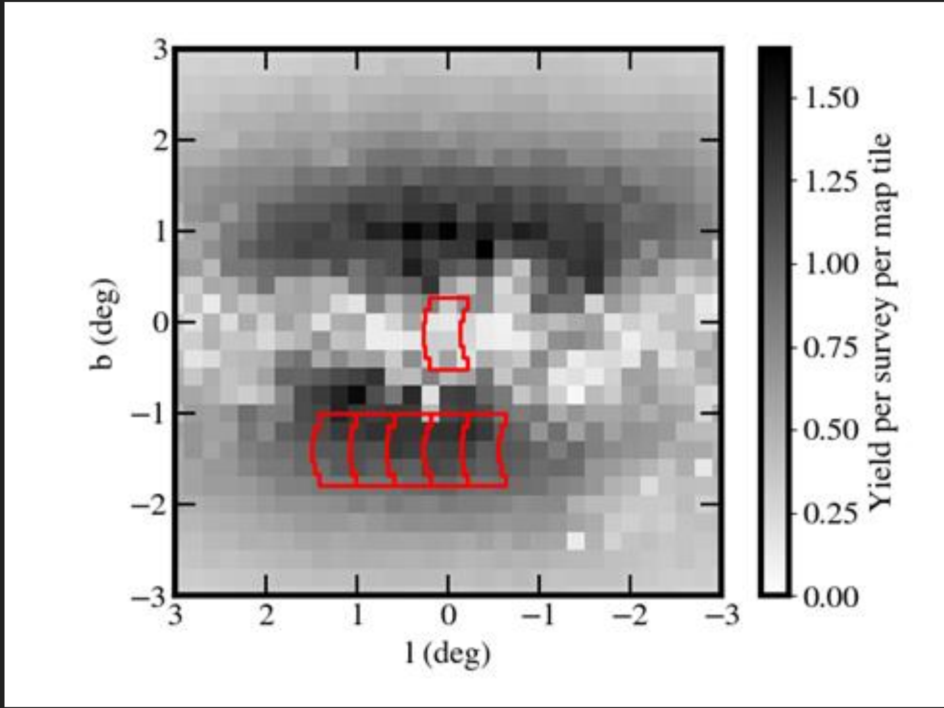
$$\Gamma = \frac{1}{\Omega_s \Omega_l} \sum^{n_s} \sum^{n_l}_{D_l < D_s} 2\mu_{\mathrm{rel}}\theta_{\mathrm{E}}$$

- Use GULLS to incorporate planets + detectability for a given survey

Survey optimization

We produced a simulated star catalog for the GTBDS fields with SynthPop.

We used the GULLS microlensing simulator to predict the Galactic distributions of Roman microlensing events.



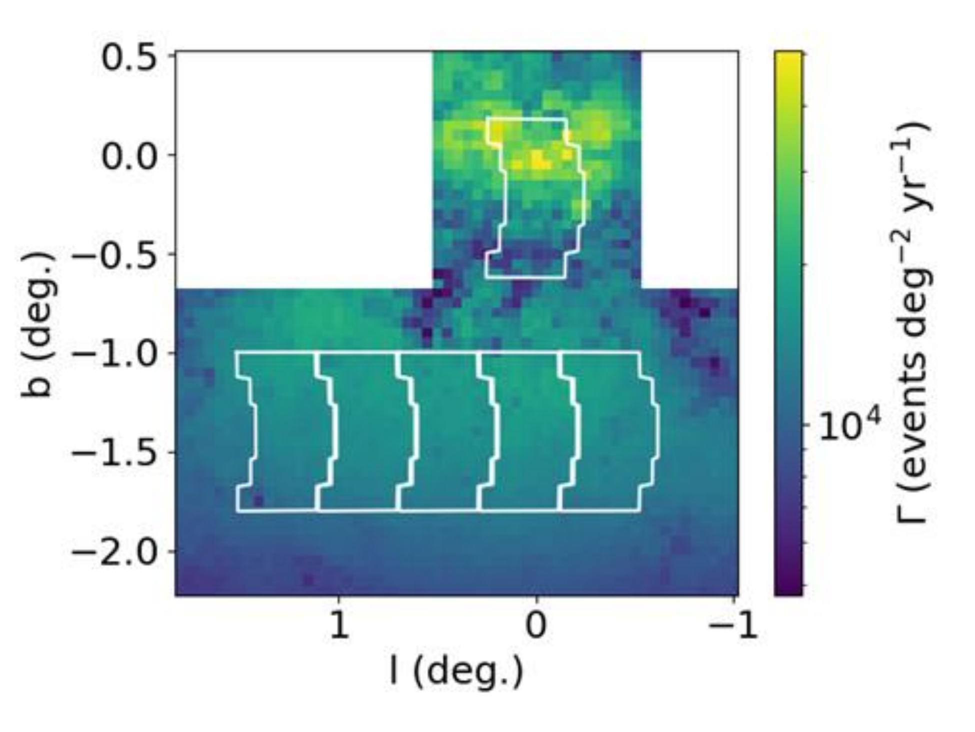
*Note GC field rates were underestimated in this simulation due to extinction handling

GBTDS CCS Report
M. Penny's gbtds_optimizer

Updated (stellar) Microlensing Event Rates in the GBTDS

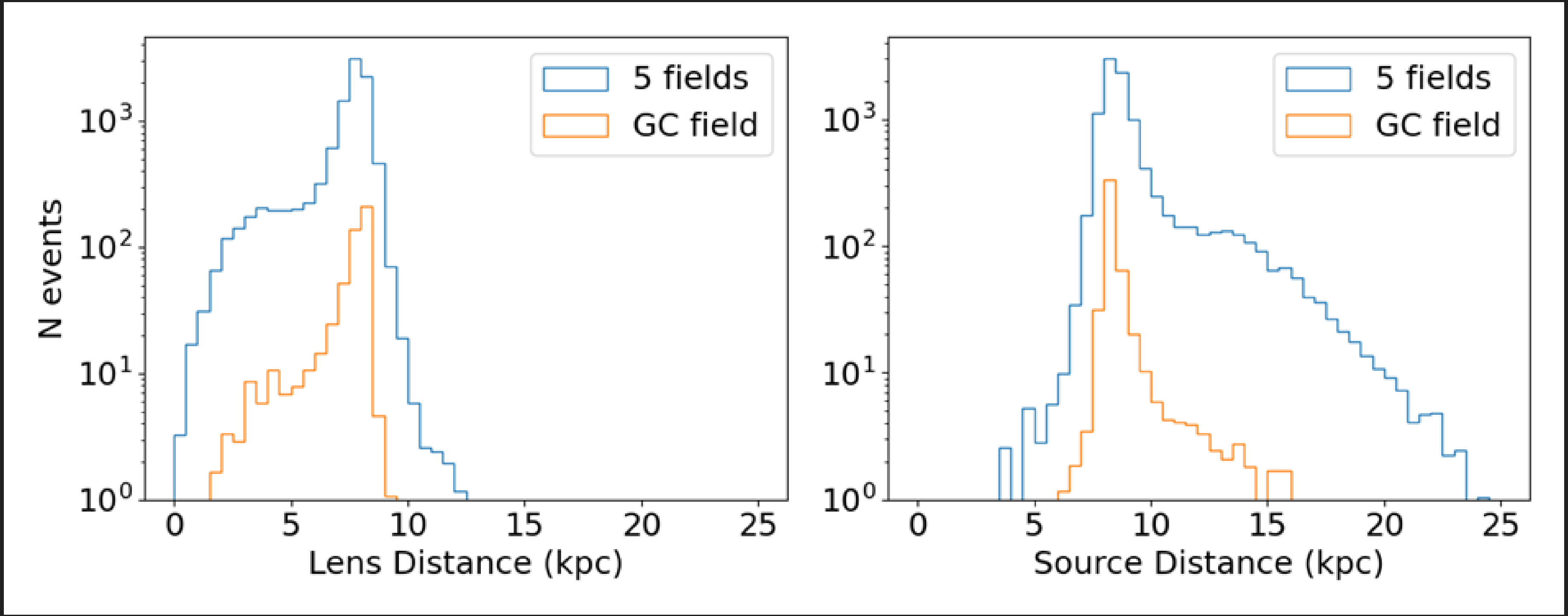
~12,000 total stellar microlensing events detectable in the F146 light curves

Much higher rates toward the GC than previous simulations that excluded the NSD and overestimated extinction



Underlying event rate (Huston et al, in prep.)

Lens and Source Distances



Huston et al. (in prep.)

*Note GC field rates were underestimated in this simulation due to the extinction law approximation

Lens and Source Galactic Populations

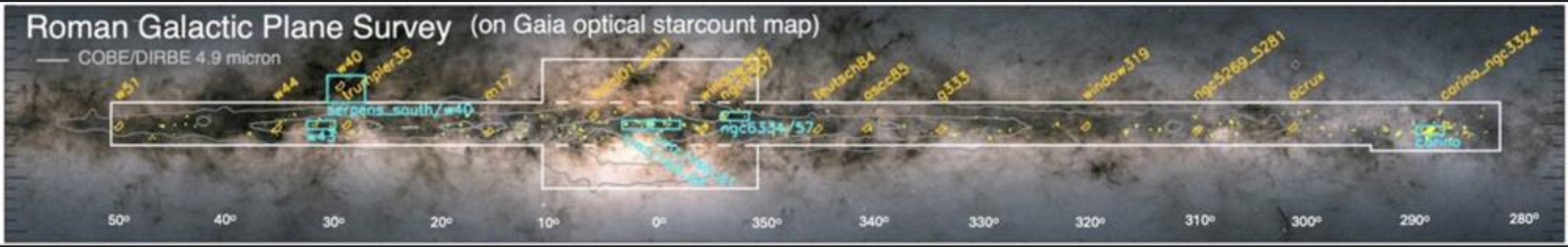
	Lower Bulge		Galactic Center	
Population	lens	source	lens	source
bulge	79.7%	79.5%	50.7%	46.4%
halo	0.1%	0.1%	0.1%	0.0%
nuclear stellar disk	0.3%	0.3%	32.4%	42.2%
thick disk	1.1%	1.6%	0.6%	0.2%
thin disk	18.9%	18.5%	16.2%	11.1%

Huston et al. (in prep.)

*Note GC field rates were underestimated in this simulation due to the extinction law approximation

Roman will also further improve our understanding of the Milky Way's structure.

- Observational constraints on IR microlensing statistics are extremely limited pre-Roman
- The Galactic Plane survey will also examine much of the bulge and plane at unprecedented depth



GPSDC Report

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Summary

- The Milky Way is comprised of several populations with very different chemistries and dynamics.
- Roman will examine the planetary populations across Galactic environments in unprecedented detail.
- Roman will also provide valuable new insight on the Milky Way’s stellar structures and populations.
- I look forward to having my models proven wrong and making them better!