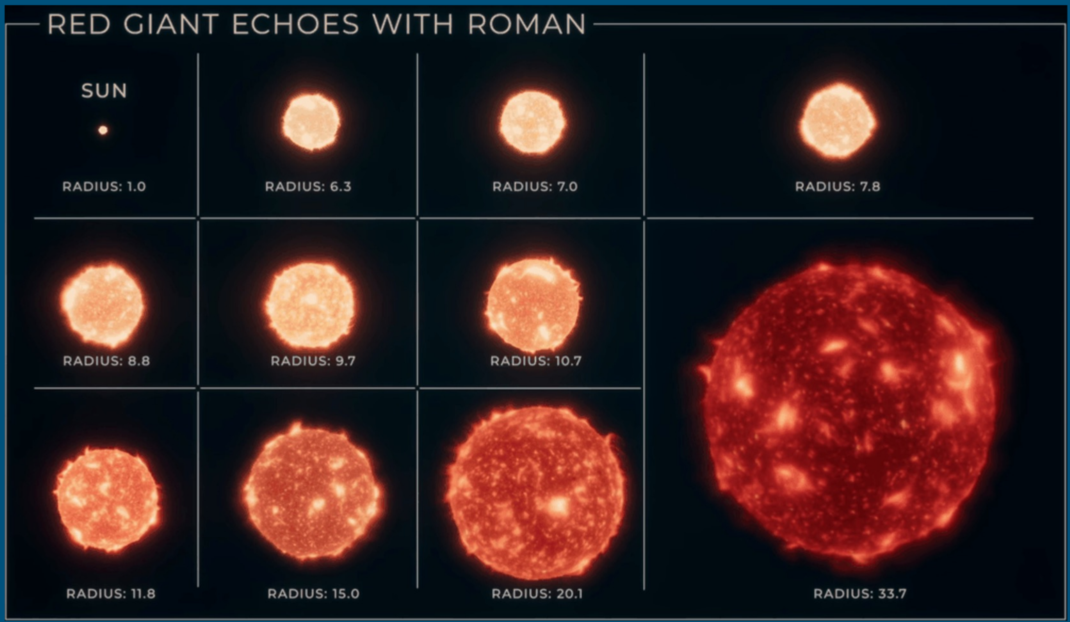
# Asteroseismology of Red Giants with the Roman GBTDS

Trevor Weiss & The Roman Asteroseismology Wide Field Science Team

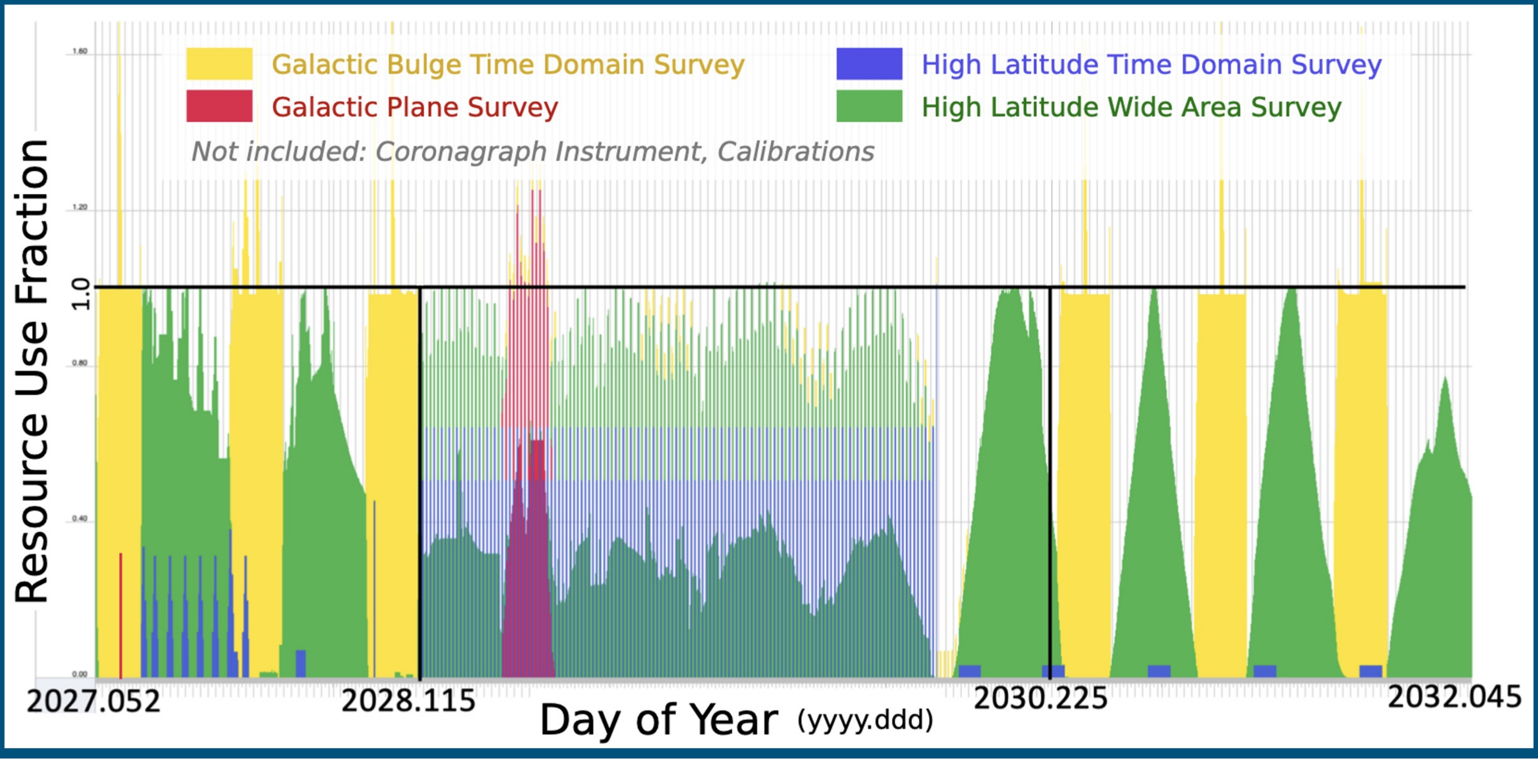



STScI Press Release — *NASA's Roman Could Bring New Waves of Information on Galaxy's Stars* — November 20th, 2025

Roman/iPAC Meeting — *Shifting Landscapes in Astrophysics: New Frontiers to Explore with Roman* — July 13th, 2026

# Nancy Grace Roman Space Telescope

- Galactic Bulge Time Domain Survey (GBTDS)
  - Six campaigns at 12.1 min cadence; four campaigns at ~ 3 day cadence
  - ~0.11 arcsec pixels
  - Photometric and spectroscopic observations for stellar characterization of temperatures and metallicities



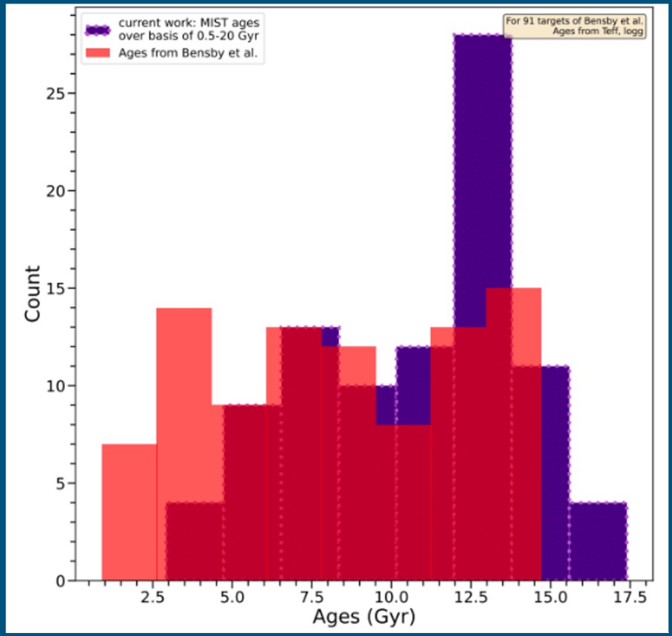

ROTAC 2025

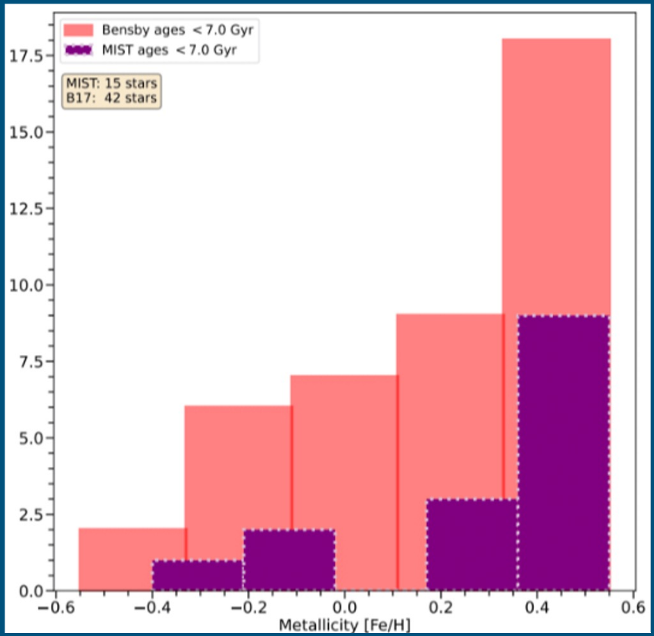
# Galactic Bulge

- Bulge stellar ages remain debated:
  - Evidence of a younger stellar population (Bensby et al. 2013, Valle et al. 2015)
  - Case for an older population (Lian et al. 2020, Joyce et al. 2023)

- Roman's infrared capabilities and high resolution will enable more detailed observations of the bulge

Joyce+ 2023



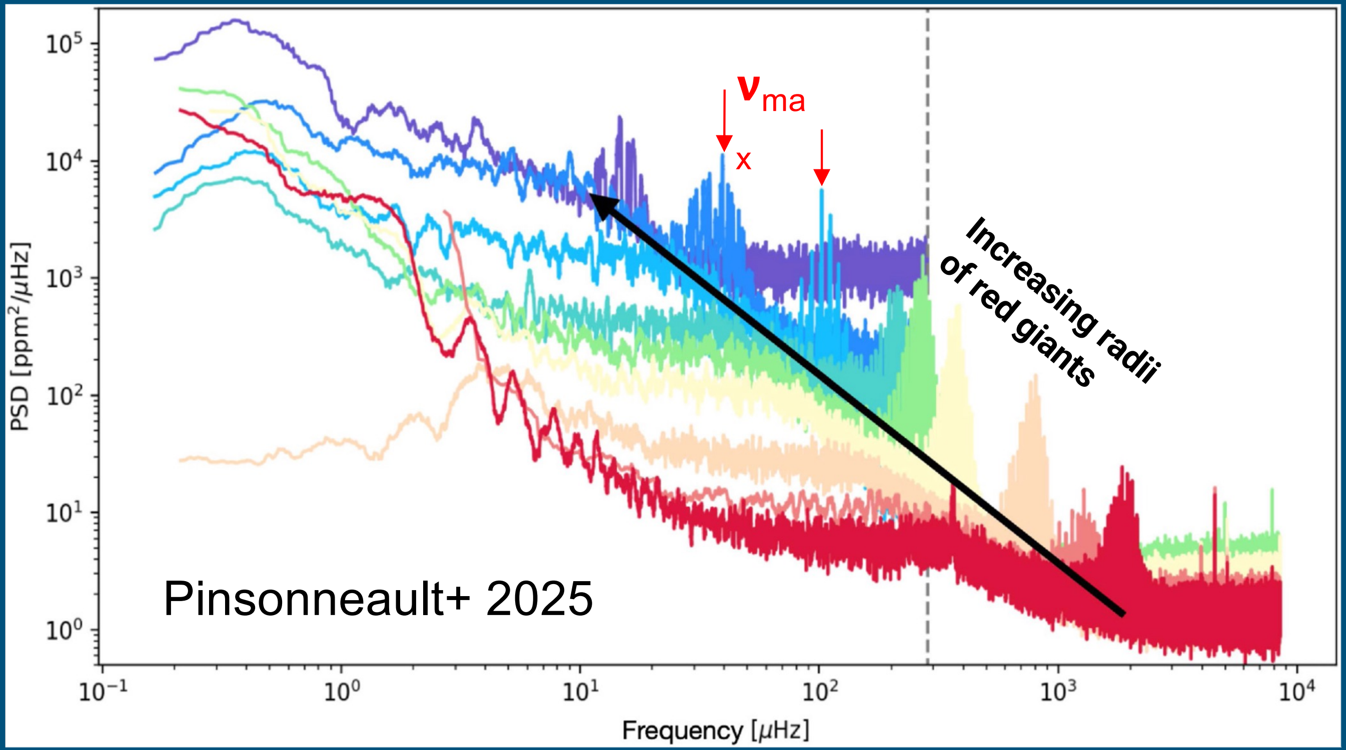




## How do we measure stellar ages at the bulge?

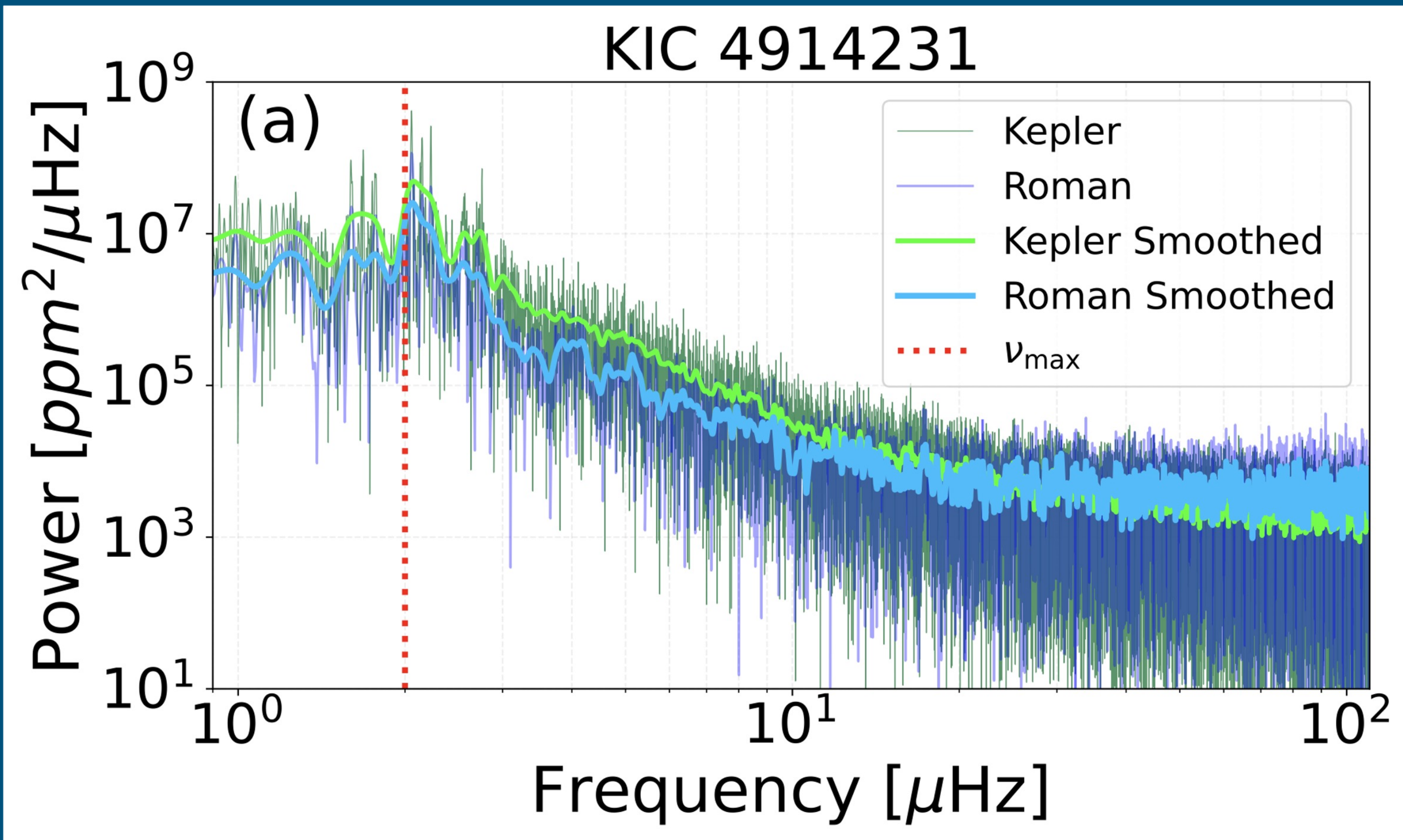
# Asteroseismology

- Study of solar-like oscillations generated by near-surface convective motions.

- Accurate and precise mass, radii, and ages for stellar populations (Miglio+ 2013, Pinsonneault+ 2018) can be derived with $\boldsymbol{\nu}_{max}$ & $\Delta\boldsymbol{\nu}$ from asteroseismology (e.g. Kjeldsen & Bedding 1995; Stello+ 2008)



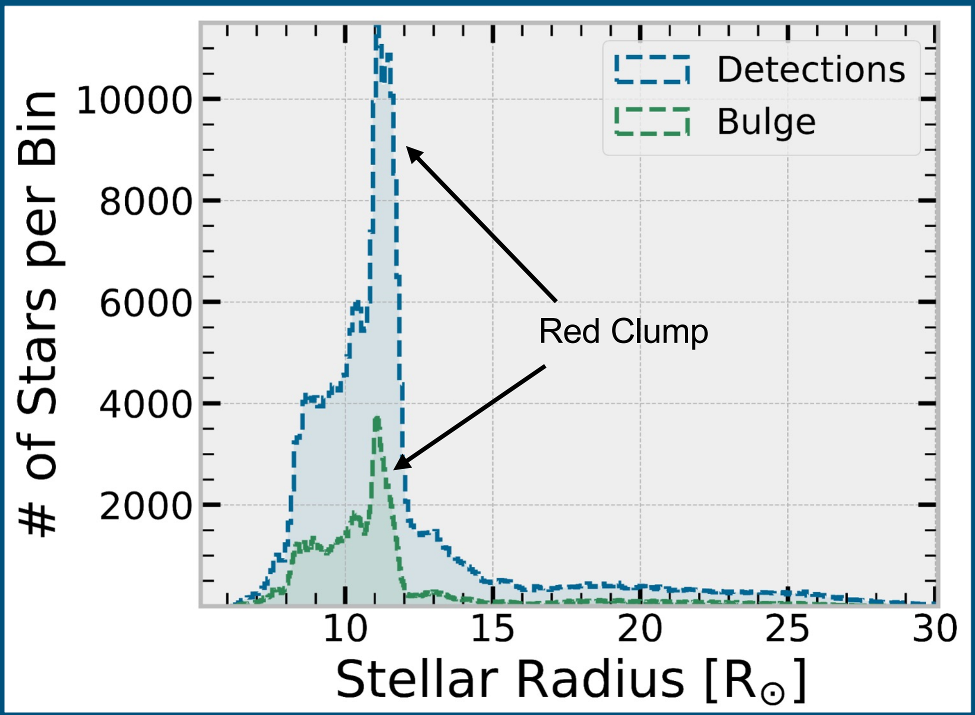

$$\frac{M}{M_\odot} = \left(f_{\nu_{\rm max}}\frac{\nu_{\rm max}}{\nu_{\rm max,\odot}}\right)^3 \left(f_{\Delta\nu}\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-4} \left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{3/2}$$

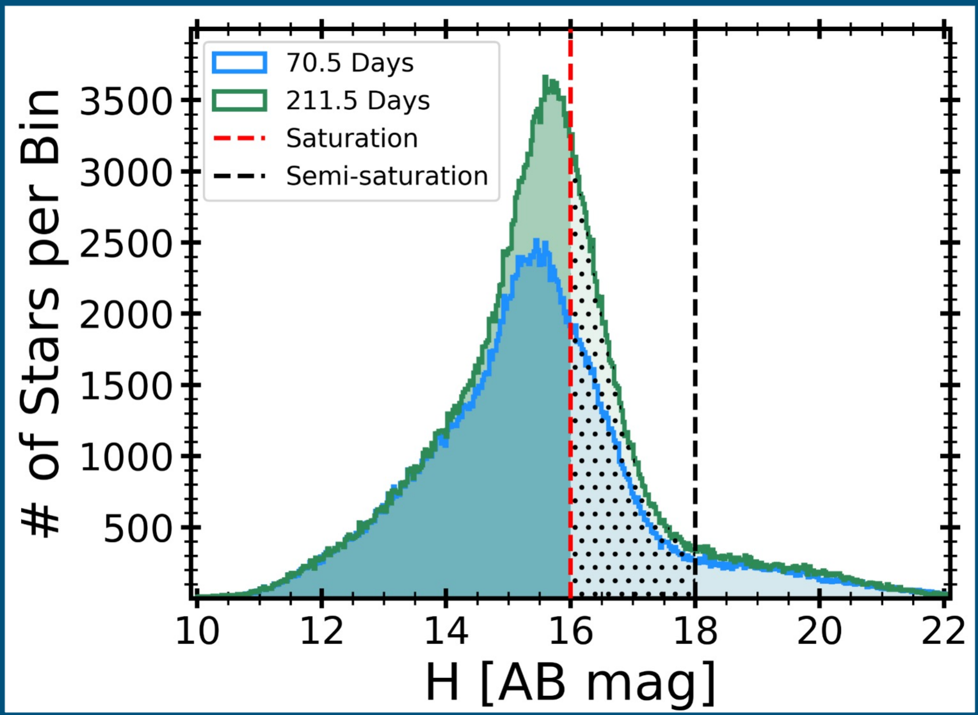



Noah Downing
(Yale
University)

Further details about modeling in Weiss+ 2025

# Asteroseismic Yields



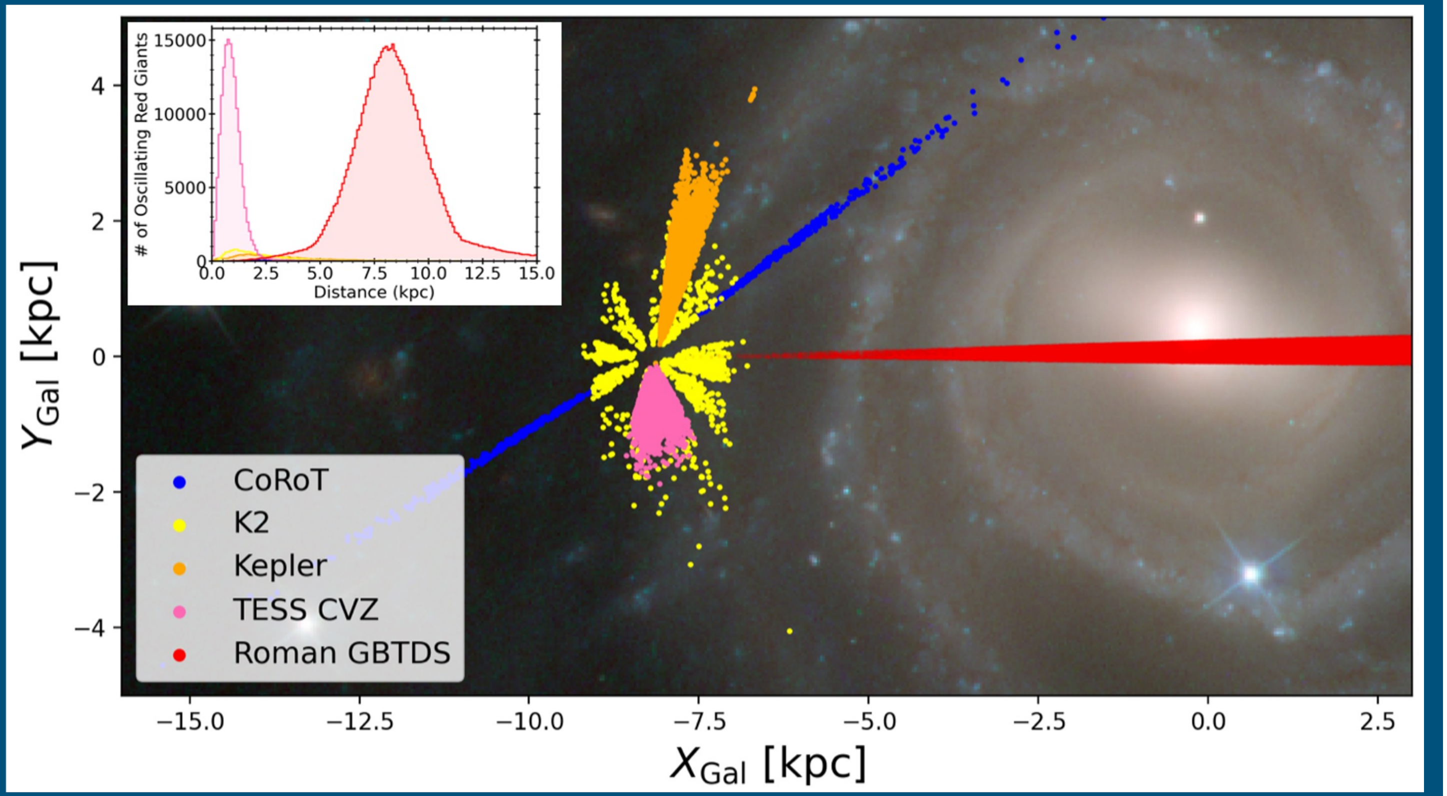




- With Roman, estimated **~300,000** asteroseismic red giants and red clump stars; **~200,000** in the bulge (Weiss+ 2025)
- **~ 50%** of total detections will be identified in first 70 days of observations

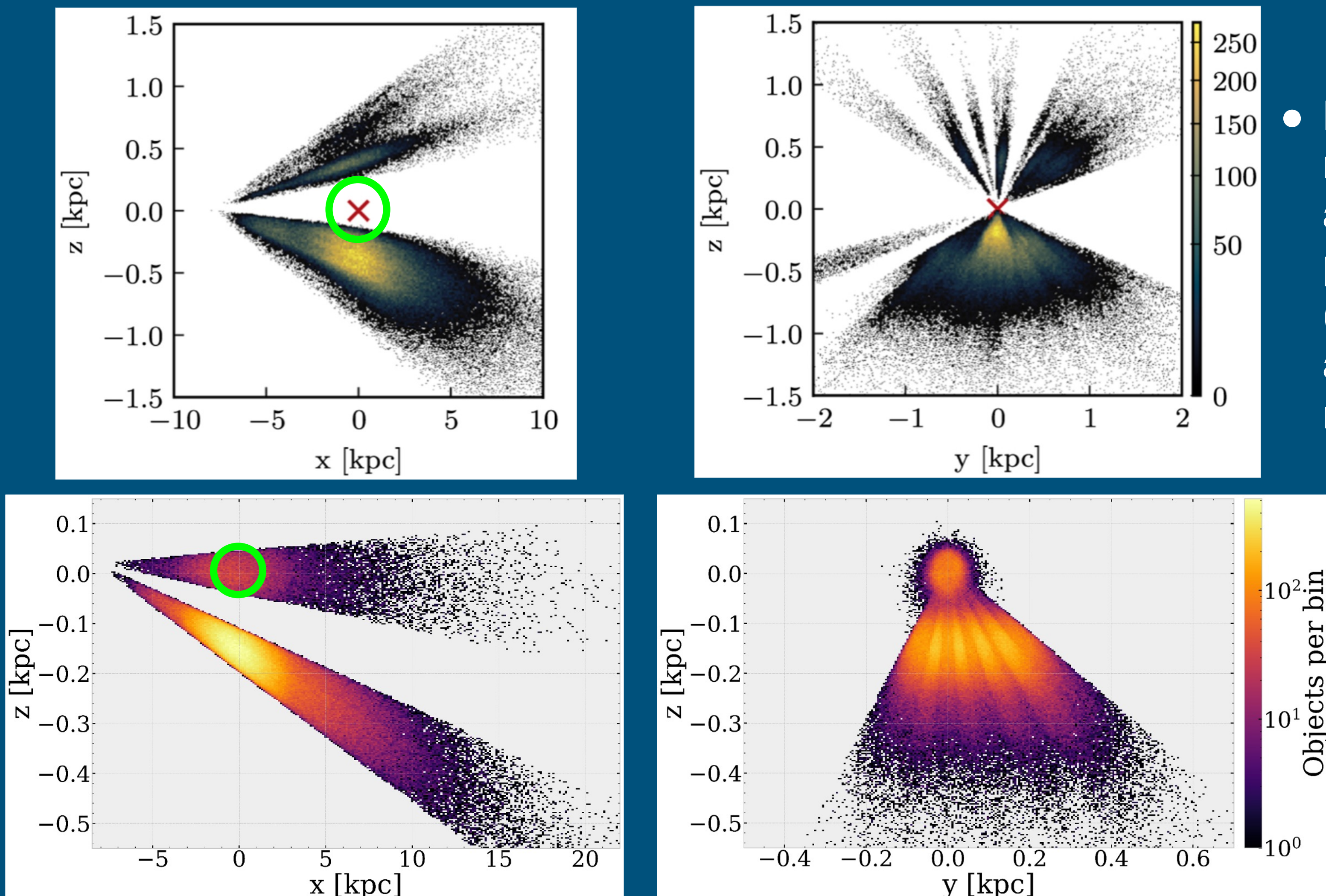
# Distances

- Asteroseismology has been used in missions like *Kepler/K2* (~16,000 detected), *CoRoT* (~500 detected), and *TESS* (~160,000 detected), but none have studied the galactic bulge.

- Provide data on stellar populations in the bulge, e.g. stellar ages and information on exoplanets through host stars.



# Distances




Hey+ 2023

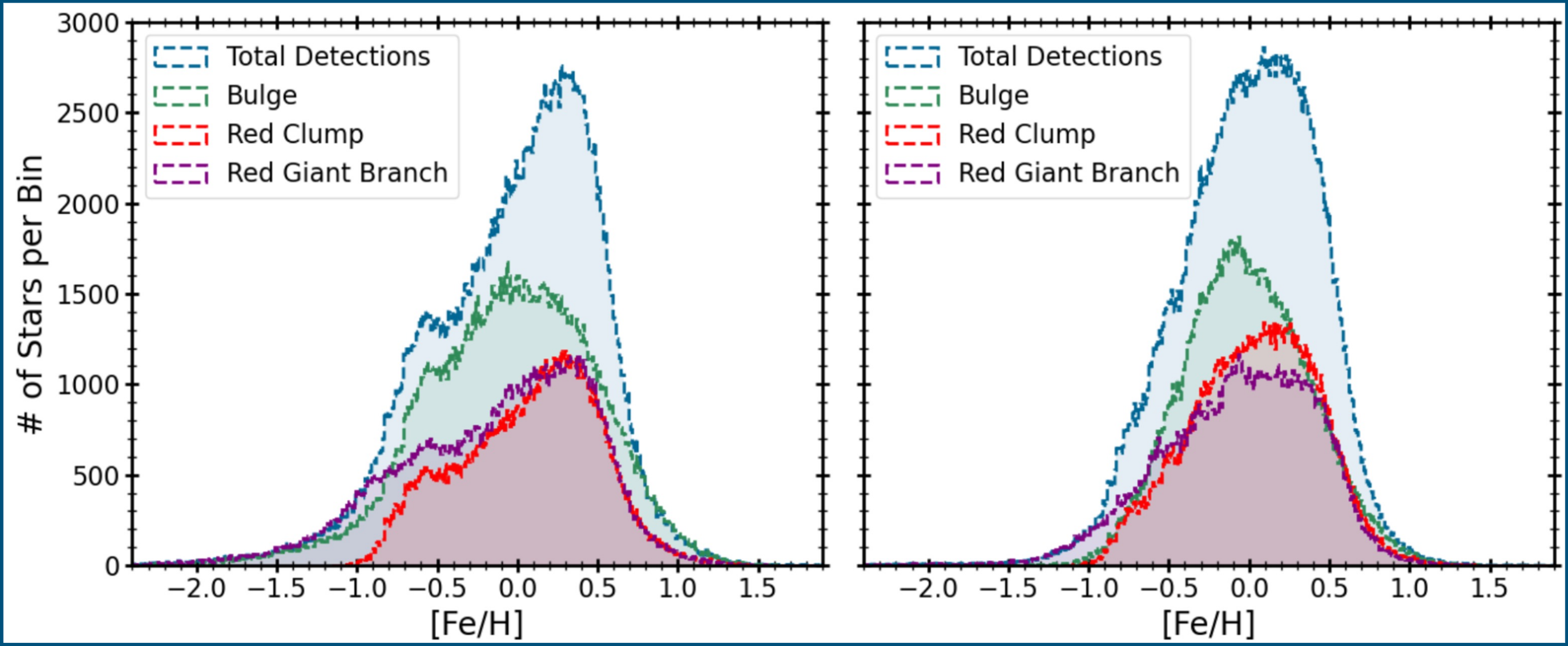
- Roman will measure global asteroseismic parameters (mass, age) that are difficult to measure using ground-based data, which will be key for models of bulge and bar (Shen & Li 2015; Portail+ 2017)

# Age/Metallicity Relation

Weiss+ 2025

AMR @ Bulge

Without AMR @ Bulge




- Adopting age-metallicity at the bulge from Joyce+ 2023 yields ~10% less, while differences between Marshall and Schlegel extinction maps are marginal

## Stellar Ages

- 30% of the sample will have $\boldsymbol{\nu}_{max}$ and $\Delta\boldsymbol{\nu}$ measurements
  - **<u>~25%</u>** age uncertainties

- The remaining 70% can use measured parallax ($\varpi$) (Gould+ 2015, Gaia+ 2023) with the Stefan-Boltzmann law :

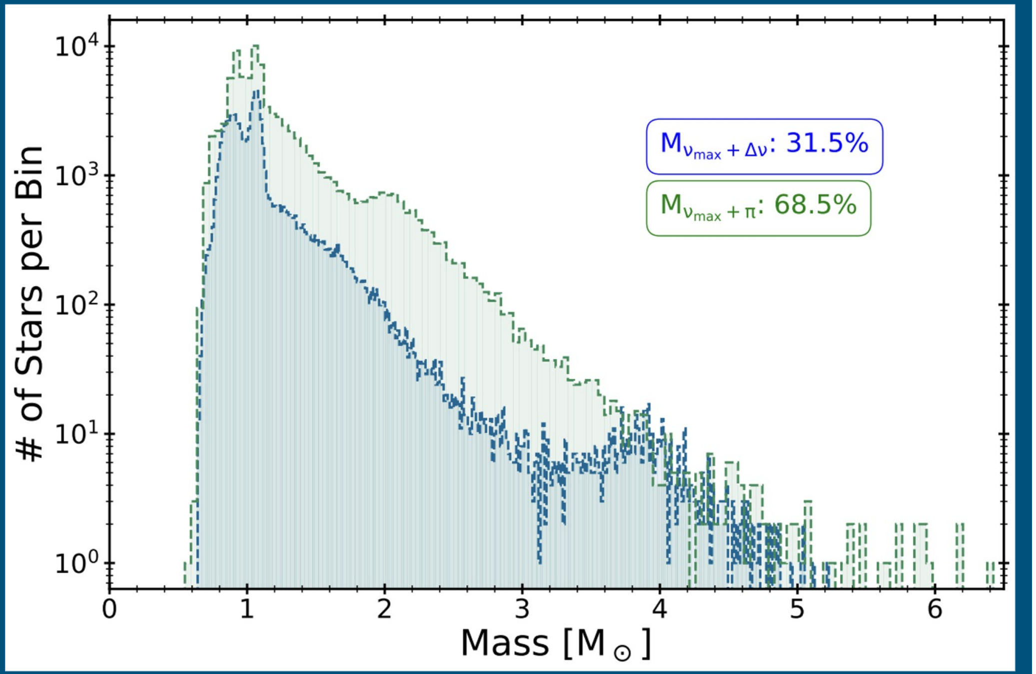
$$\frac{L}{L_\odot} = \left(\frac{R}{R_\odot}\right)^2 \left(\frac{T}{T_\odot}\right)^4$$

- We can solve for radius, and use $\boldsymbol{\nu}_{max}$ to get mass:

$$\frac{M}{M_\odot} = \left(f_{\nu_{\max}} \frac{\nu_{\max}}{\nu_{\max,\odot}}\right) \left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{1/2} \left(\frac{R}{R_\odot}\right)^2$$

- **<u>~15%</u>** age uncertainties with $\boldsymbol{\nu}_{max}$ and $\varpi$

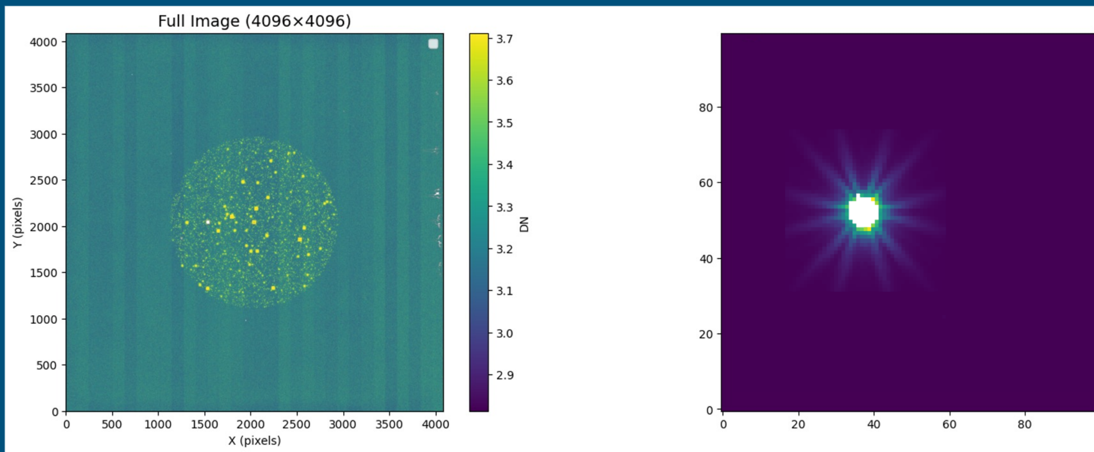
## All objects with $\boldsymbol{\nu}_{max}$ will have $\varpi$, which is more precise at measuring stellar ages.

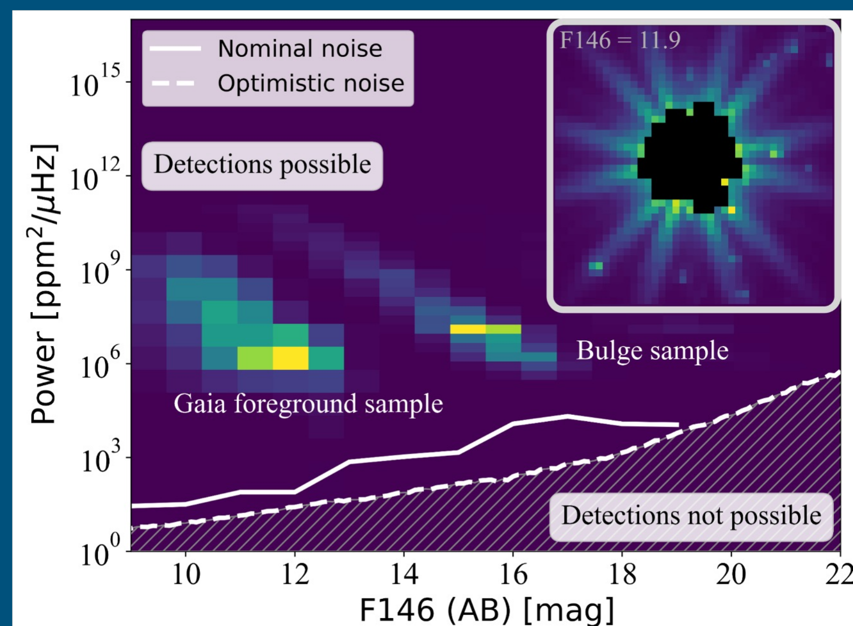



Weiss+ 2025

# Saturation Pipeline

- Differential photometry is possible using either a PSF-agnostic weighted photometry method (halophot; White+ 2017; Pope+ 2019) or aperture photometry (Wilson+ 2023)
- Simulations indicate a noise floor that enables asteroseismology in the bulge

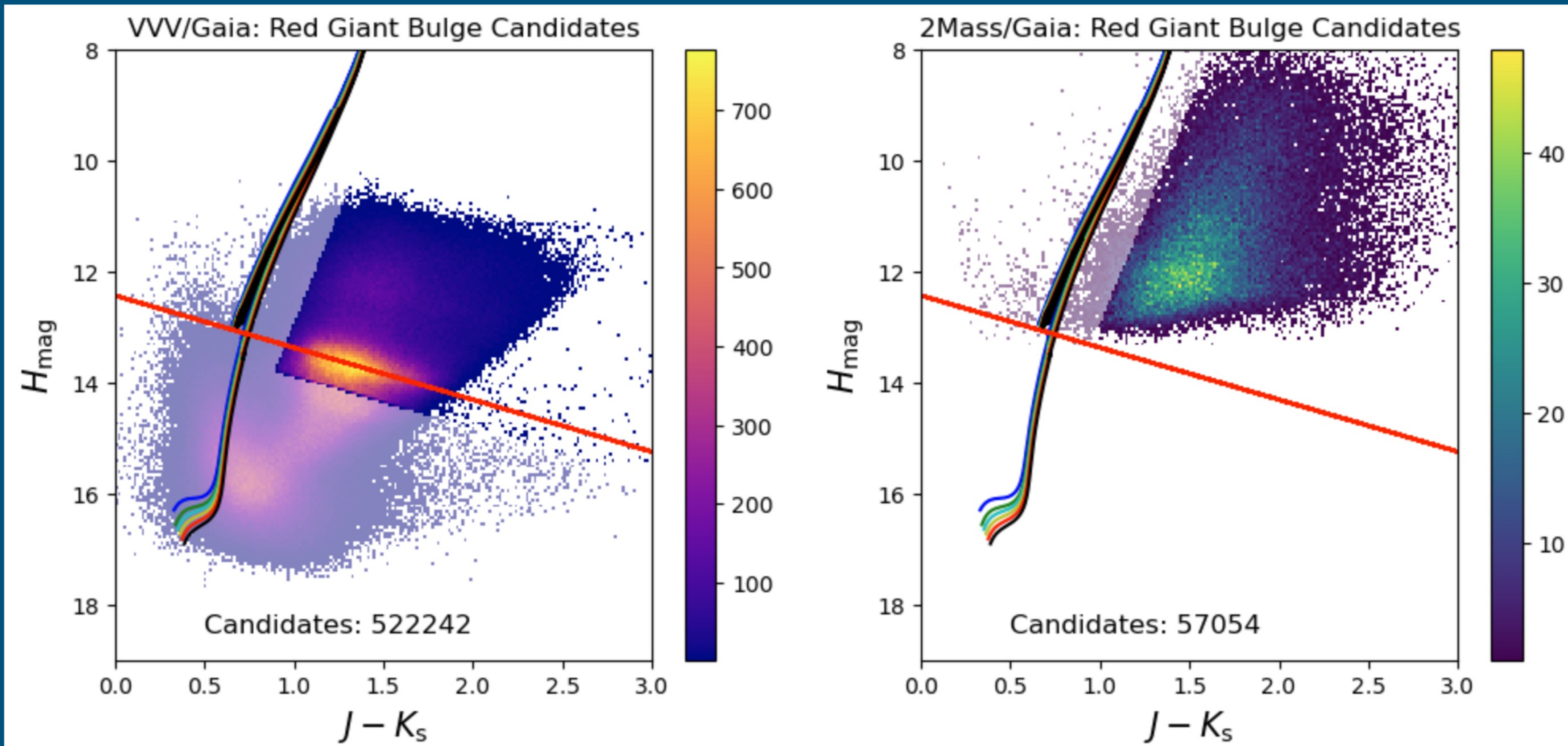



See Lauryn James' Poster: "*A Saturated Photometry Approach for Asteroseismology in the Galactic Bulge Time Domain Survey*"

# Real Target List

Work by Adam Ballas, Madeline Howell & Marc Pinsonneault (OSU)



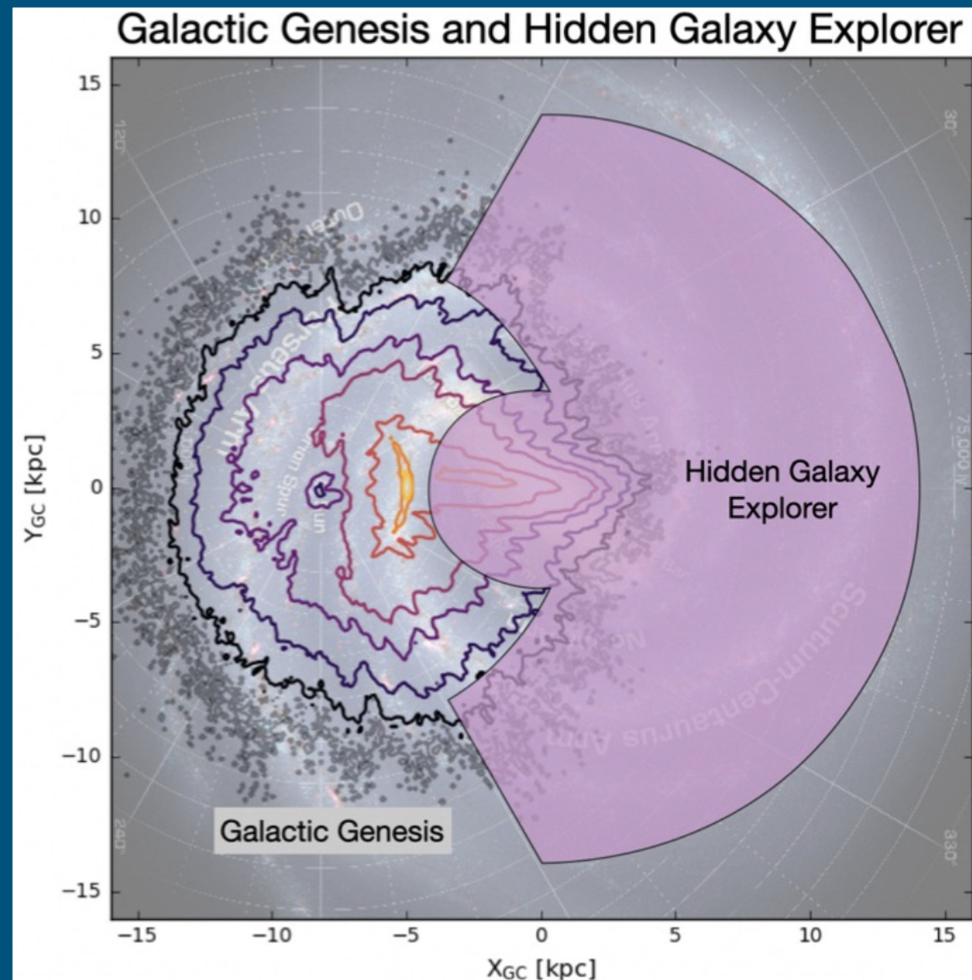

- Significant number of candidates are RC stars, which will serve as a calibration sample

## Key Takeaways

- Conservative estimates in adopted noise models and detection probabilities result in over **300,000** detections, with roughly **200,000** of them members of the bulge.
- Simulations of saturated differential photometry indicate a noise floor amenable to asteroseismology
- First time probing stellar giants at the galactic center, contributing to existing bulge and bar models.
- Age precision of 15% with $\boldsymbol{\nu}_{max}$ and $\varpi$.
  - Selection function disfavors the youngest and oldest stars in the bulge.
- From VVV and 2MASS x Gaia, identified ~500,000 bulge red giant seismic candidates in GBTDS.
  - Currently deriving Teffs for the candidate sample to enable seismic mass and age estimates for first data release.

## Future Work


HIDDEN GALAXY EXPLORER
APO
LCO
HGE
UNVEILING THE HIDDEN MILKY WAY


Galactic Genesis and Hidden Galaxy Explorer
Hidden Galaxy Explorer
Galactic Genesis
$Y_{GC}$ [kpc]
$X_{GC}$ [kpc]
15
10
5
0
−5
−10
−15

# Acknowledgements and Citations

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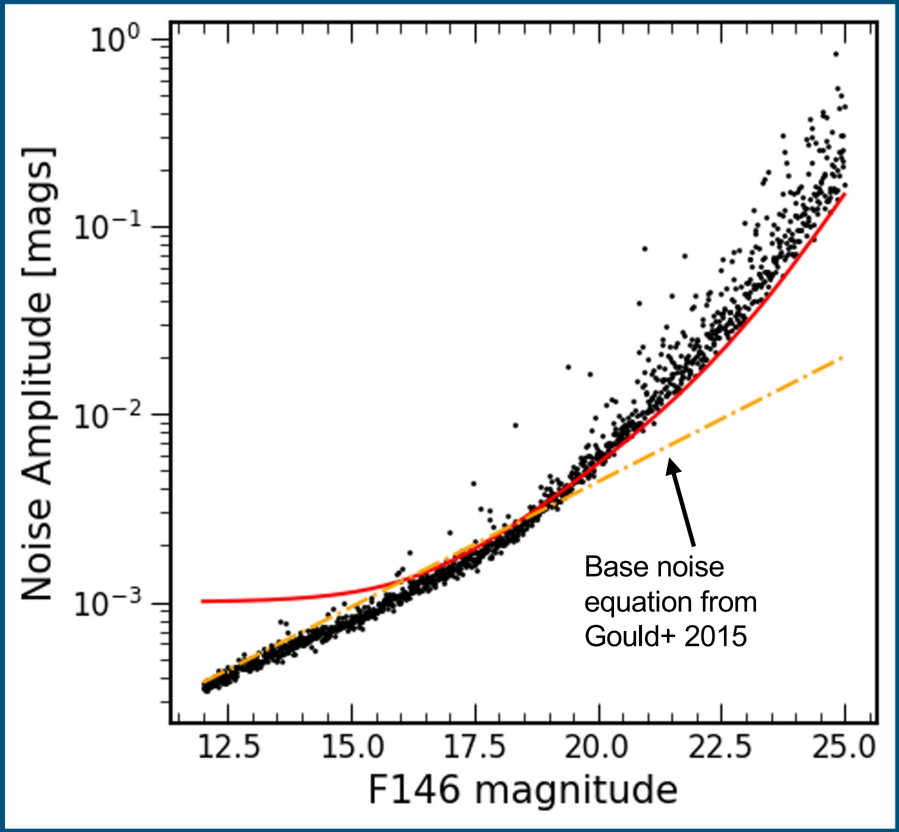
Weiss et al. 2025

# Supplemental Slides

- Kepler light curves modified to mimic Roman:
  - Adjusting amplitude to match Roman's near-IR observations
  - Reducing baseline to 6x70 days
  - Injecting noise following projected Roman performance (conservative estimate in red *[Penny+ 2019]* and optimistic estimate in black *[Wilson+ 2023]*)
  - Varying cadence to be either 7.5 or 15 minutes (12.1 minutes after ROTAC 2025)



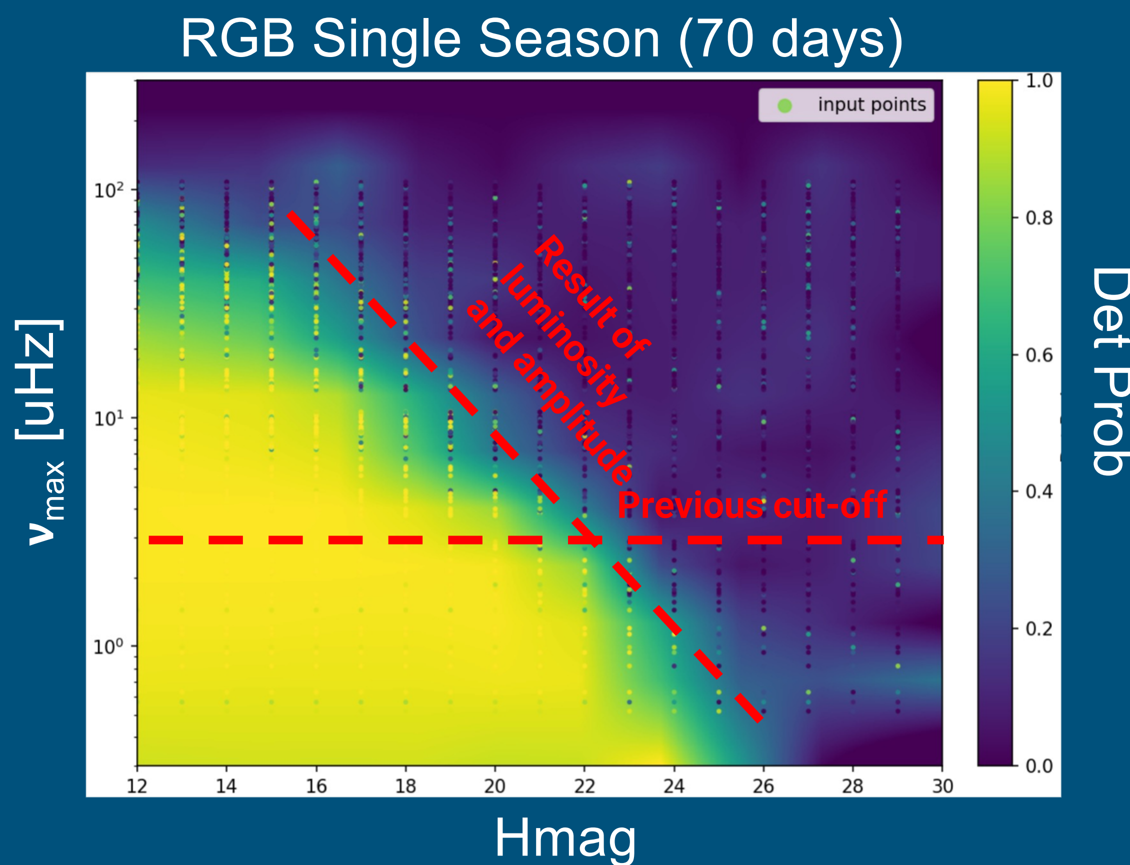

Weiss+ 2025

# Supplemental Slides

- Determined detection probabilities through two methods:
  - SNR approach – statistical criterion (Chaplin+ 2011, Lund & Chaplin 2026)
  - Convolutional Neural Network – empirical approach mimicking “by eye” detections (Hon+ 2018)

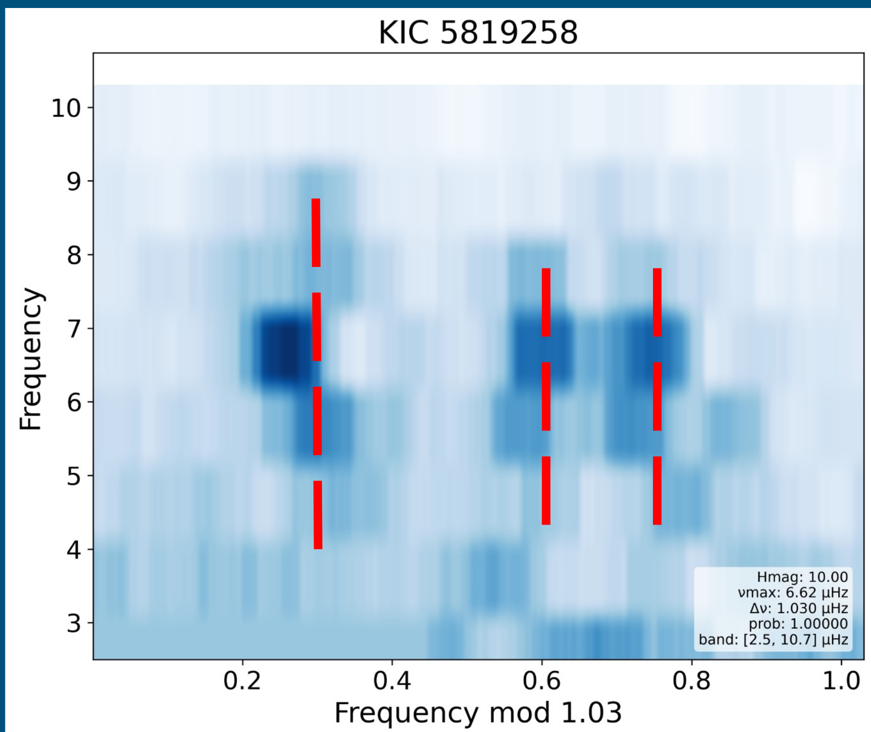
- Objects harder to detect at:
  - Higher frequencies
  - Fainter magnitudes

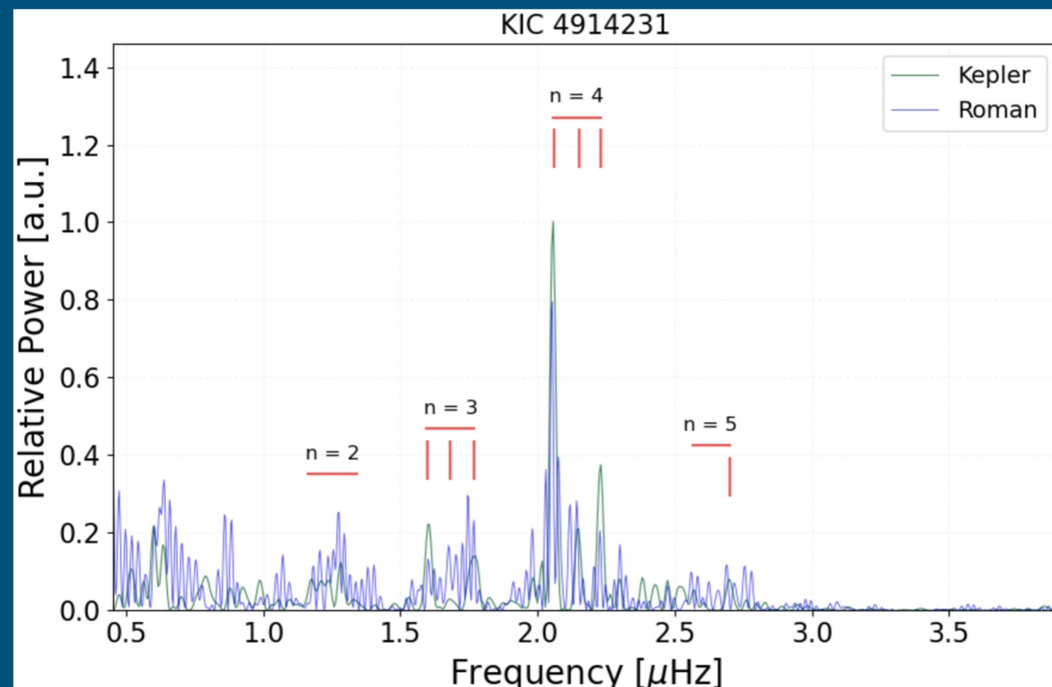
- Luminous giant detections modeled from Yu+ 2020 catalog



# Supplemental Slides

- Given a $\boldsymbol{\nu}_{max}$ detection, results ran through SYD pipeline (Huber+ 2009) and automated vetting (Reyes+ 2022) to identify $\Delta\boldsymbol{\nu}$ detections (Claudia Reyes, ANU & Dennis Stello, UNSW)



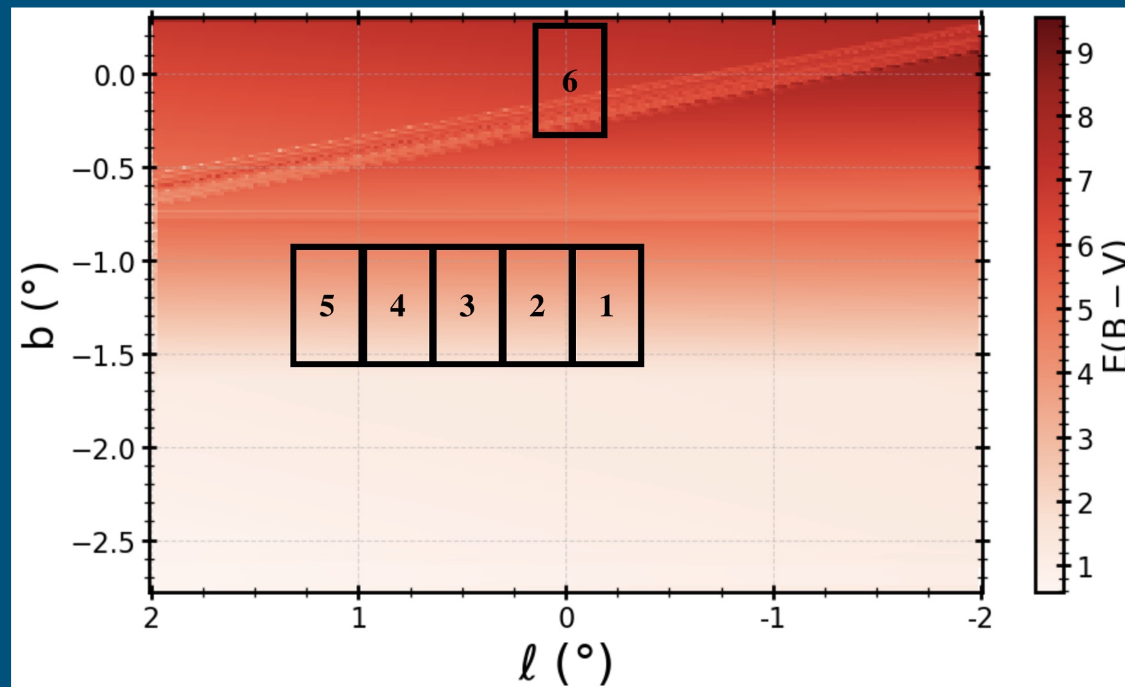

Modes identified from Stello+ 2014

# Supplemental Slides

- Stellar populations based on *Galaxia* models (Sharma+ 2011).
  - Uses the Besançon galaxy model (Robin+ 2003).
  - Assumes a bar-shaped bulge (Blitz+ 1993).

- Extinction added to the *Galaxia* photometry according to both Marshall+ 2006 and Schlegel+ 1998 extinction maps.

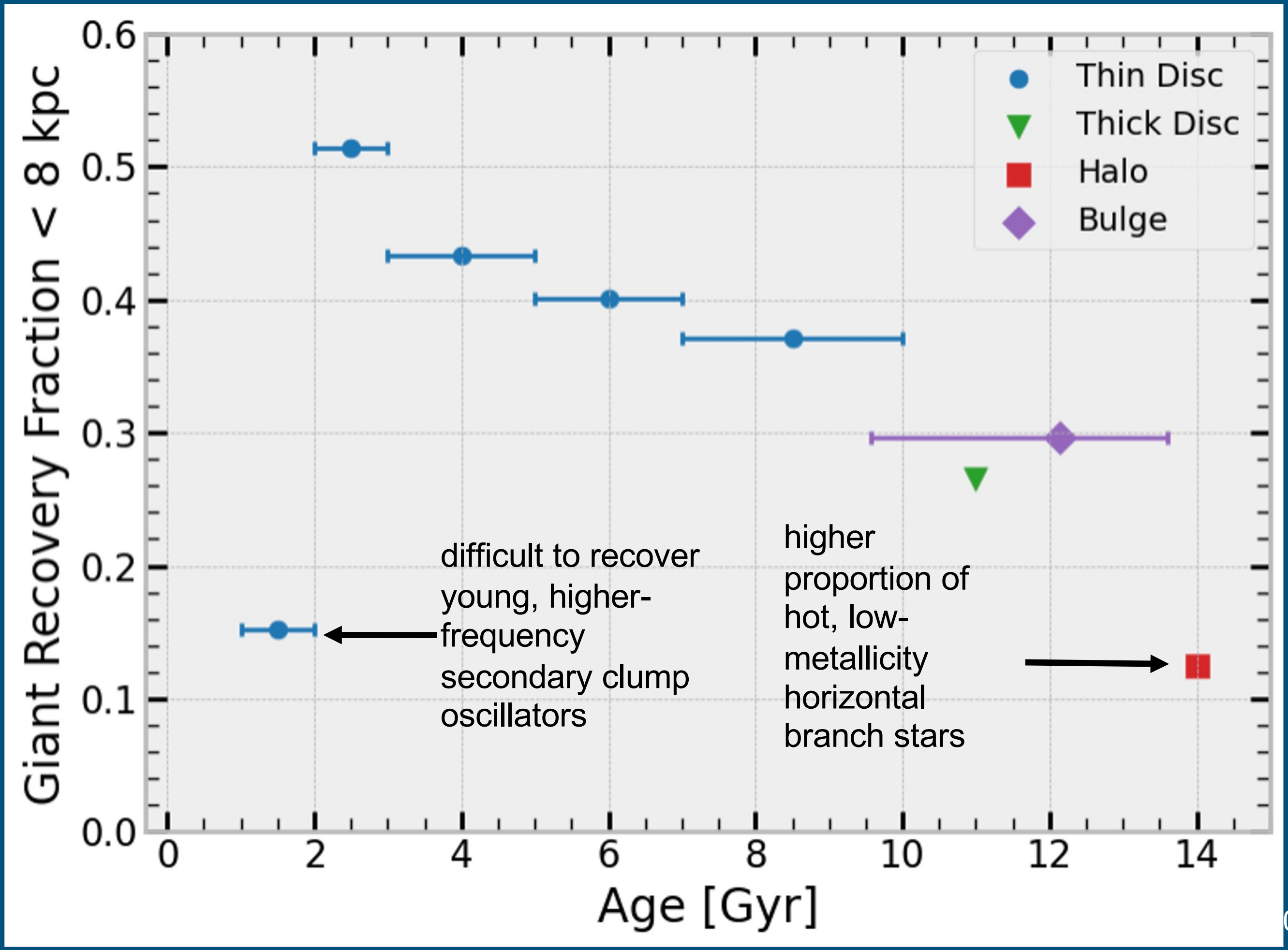
- *Galaxia* assumes a single age for the galactic bulge, so an age-metallicity relationship from Joyce+ 2023 was introduced.




Weiss+ 2025

## Supplemental Slides

- *Galaxia* simulates objects in different regions of the Milky Way, and varies the ages of the thin disc
- With Roman, corrections to the selection functions will be needed to account for poor recovery of both younger and older stellar objects



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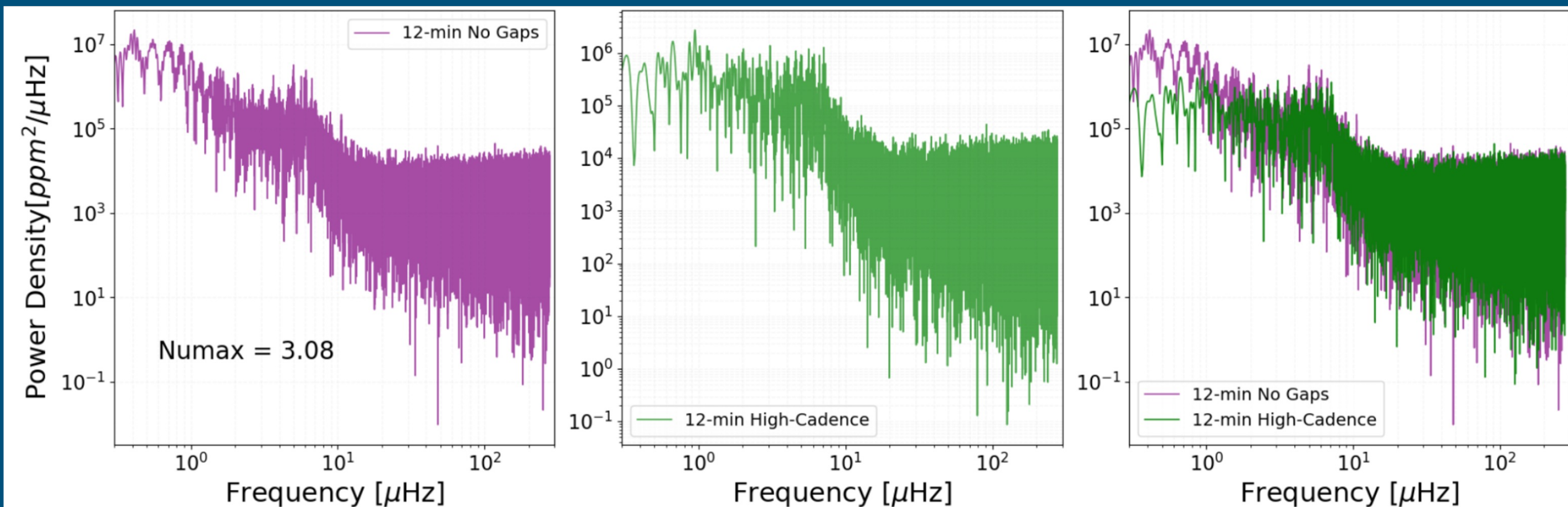

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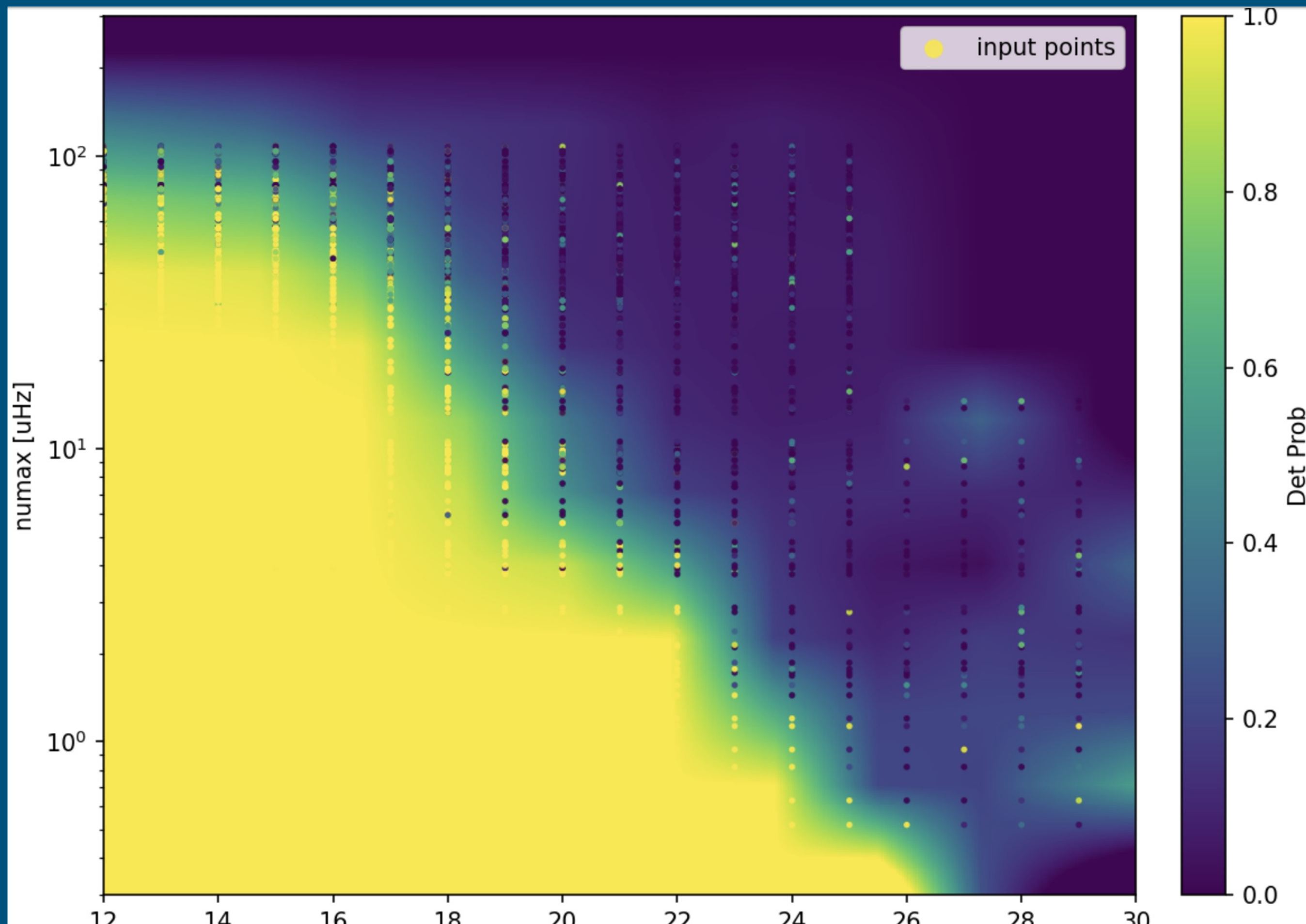

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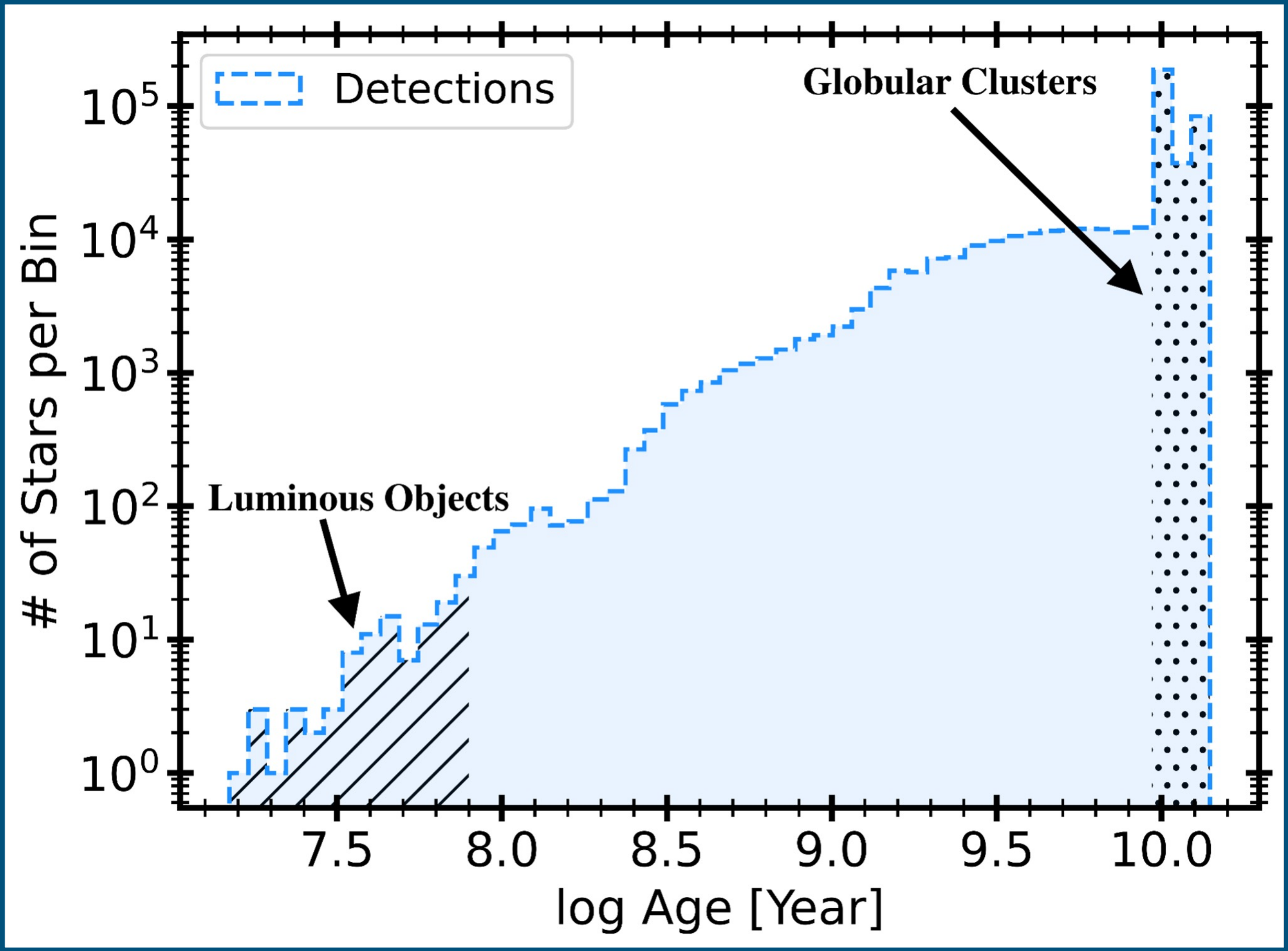

## Supplemental Slides

Weiss+ 2025