# The Stars, Milky Way, and Local Volume (SMWLV) Collaboration


**Tom J. Wilson**
University of Exeter

*On behalf of the SMWLV Collaboration*


SMWLV

University of Exeter

LSST
LSST:UK Consortium

Photos courtesy of Carlos Corco, flickr.com/ccorco

# SMWLV -  Quick Summary

https://rubin-smwlv.github.io/

Co-chairs: Kristen Dage, Peregrine McGehee, Tom J. Wilson

**Organization**
- Science Working Groups (SWG)
- SWG goals

**Collaborative Overlaps:**
- Synergies with other Science Collaborations, particularly: TVS, DESC, Galaxies
- Shared connections via Task Forces

**Communication:**
- Monthly collaboration-wide telecon
- Monthly meetings for active science working groups
- Email, slack, LSST community forum

**Activity:**
- Multiple SWGs organizing virtual workshops
- Work on roadmaps
- Ongoing preparation
- Research facilitated by in-kind contribs.

**Membership:**
- Who are members? **anyone interested in SMWLV science with LSST**
- Should you become a member? **yes**
- How to become a member? **short application on SMWLV website**

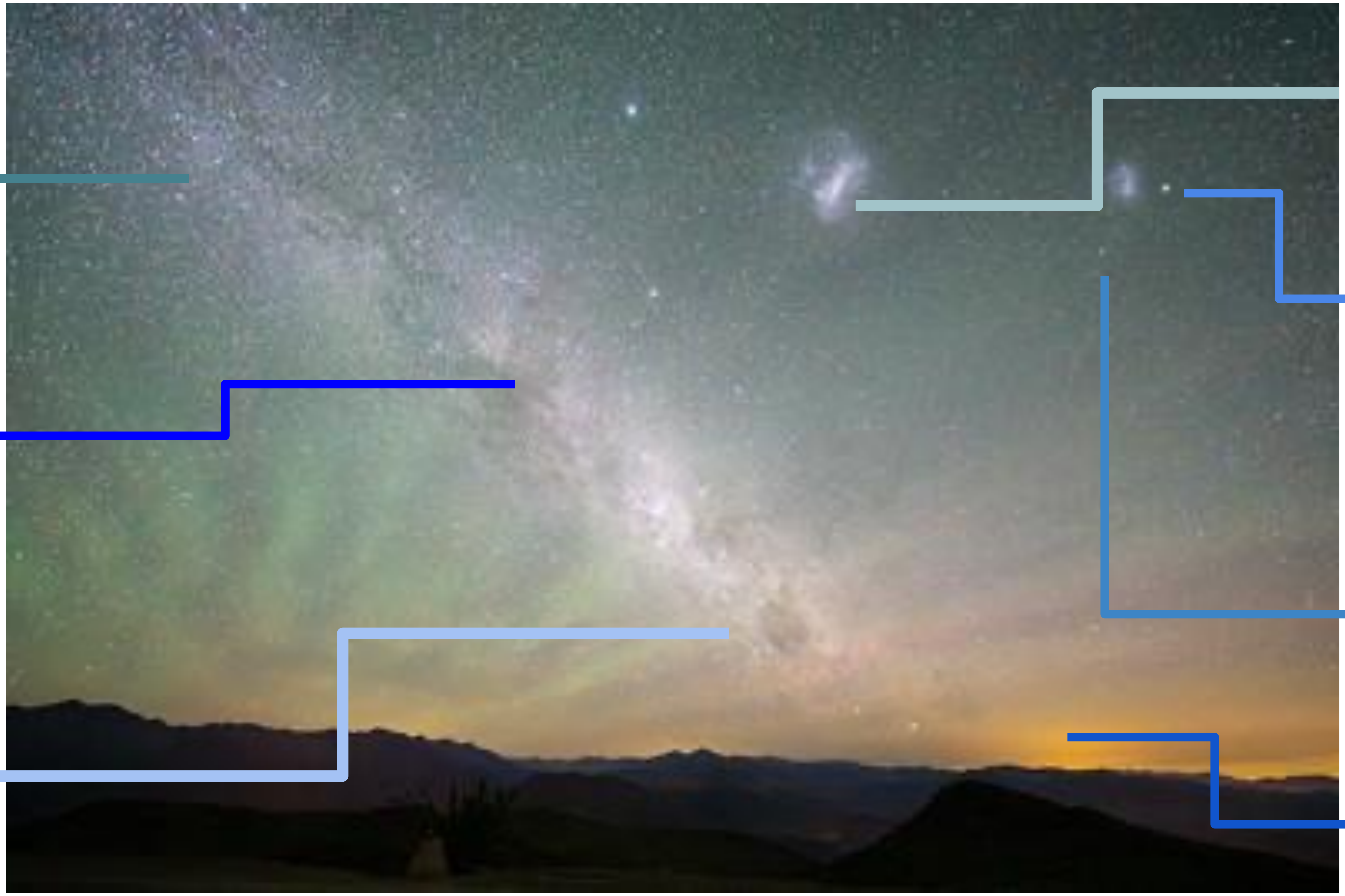
*Membership application QR code*

# Collaboration Structure and Overview

## Science Working Groups:

# Collaboration Structure and Overview

**Science Working Groups:**



# Collaboration Structure and Overview

**Science Working Groups:**

*Chair: John Gizis*

## Solar Neighborhood

The Solar Neighborhood Working Group will enable the discovery and study of very-low-mass stars, brown dwarfs, and white dwarfs within 200 parsecs of the Sun.

# Collaboration Structure and Overview

**Science Working Groups:**

*Chairs: Ana Chies Santos, Kristen Dage, Ana Ennis*

## Star Clusters

The Star Clusters Working Group will enable the systematic study and characterization of both resolved star clusters, as well as unresolved (extragalactic star clusters) out to distances of tens of megaparsecs.

# Collaboration Structure and Overview

## Science Working Groups:

*Chairs: Alexey Bobrick, Bolivia Cuevas Otahola, Angeles Perez Villegas*

*Joint with the Transient and Variable Stars Science Collaboration*

### Variable Stars

Thanks to the long baseline of Rubin, the survey will reveal stars transient on a number of time scales

# Collaboration Structure and Overview

**Science Working Groups:**

## Galactic Bulge

LSST will provide a unique map of the kinematic properties and metallicity distribution of the bulge.

*Chairs: Will Clarkson, Victor Debattista*

# Collaboration Structure and Overview

**Science Working Groups:**

## Galactic Structure and ISM

LSST will help us understand better the structure of the Milky Way and mapping interstellar dust distribution

*Chair: Peregrine McGehee*

# Collaboration Structure and Overview

**Science Working Groups:**

*Chairs:*
*Knut Olsen, Jennifer Sobeck*

## Magellanic Clouds

LSST will study stars with a complexity of differing ages and metallicities in the Magellanic Clouds, as well as eclipsing binaries.

# Collaboration Structure and Overview

**Science Working Groups:**

## Near Field Cosmology

LSST can uncover detailed chemical abundances of stars in the Milky Way to infer the properties of the very first stars

*Chairs: Massimo Dall'Ora, Haifeng Wang*

# Synergies with other Science Collaborations

- Solar Neighborhood

  Chair: John Gizis
- Variable Stars

  Co-chairs: Alexey Bobrick, Bolivia Cuevas Otahola,
  Angeles Perez-Villegas

  Joint with TVS
- Star Clusters

  Co-chairs: Ana Chies Santos, Kristen Dage,
  Ana Ennis
- Galactic Bulge

  Co-chairs: Will Clarkson, Victor Debattista
- Magellanic Clouds

  Co-chairs: Knut Olsen, Jennifer Sobeck
- Galactic Structure & ISM

  Chair: Peregrine McGehee
- Near Field Cosmology

  Chair: Massimo Dall'Ora, Haifeng Wang

→

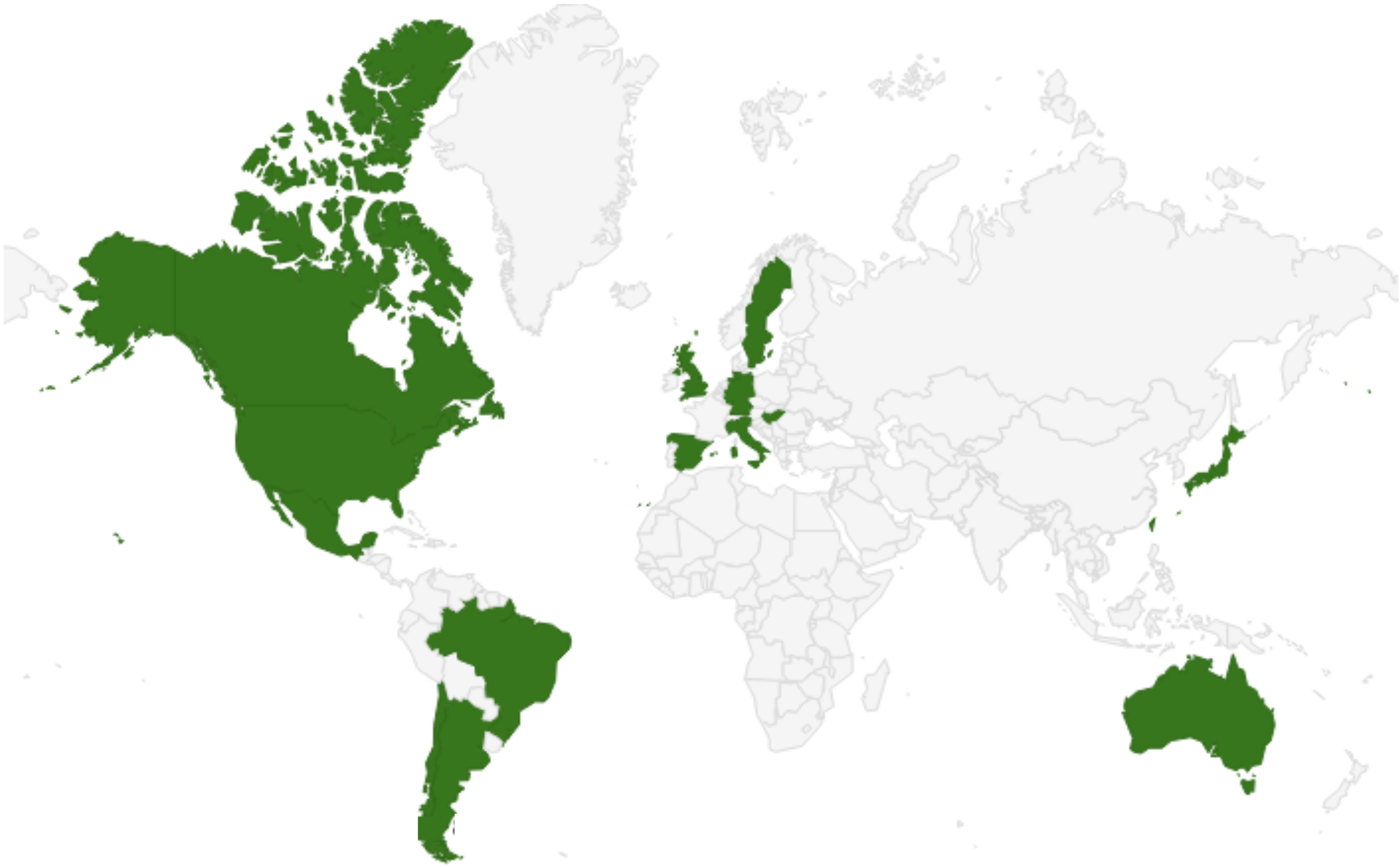
Connections with **Task Forces**:

- **DESC**: Dark Matter
- **Galaxies**: Low Surface Brightness
- **TVS**: Crowded Stellar Fields
- **Galaxies**: Spectroscopic Globular Cluster Studies

- Community discussion of Milky Way science and survey cadence

# Membership and Data Rights Policy

- SMWLV places no restrictions on members’ institutional status, career stage, or LSST data rights access status.
- SMWLV welcomes all individuals who can make a contribution to furthering SMWLV science.



Roughly 200 members, ~15 countries and 5 continents represented

# Membership and Data Rights Policy

First Name *

Last Name *

Affiliation *

Email Address *

Please enter your preferred email address here.

Website

If you have a website that you would like to share with the SMWLV science collaboration, please enter that here.

Working Group *

- Select -

Your interests

If you wish, please describe your Milky Way science related interests in a few sentences.

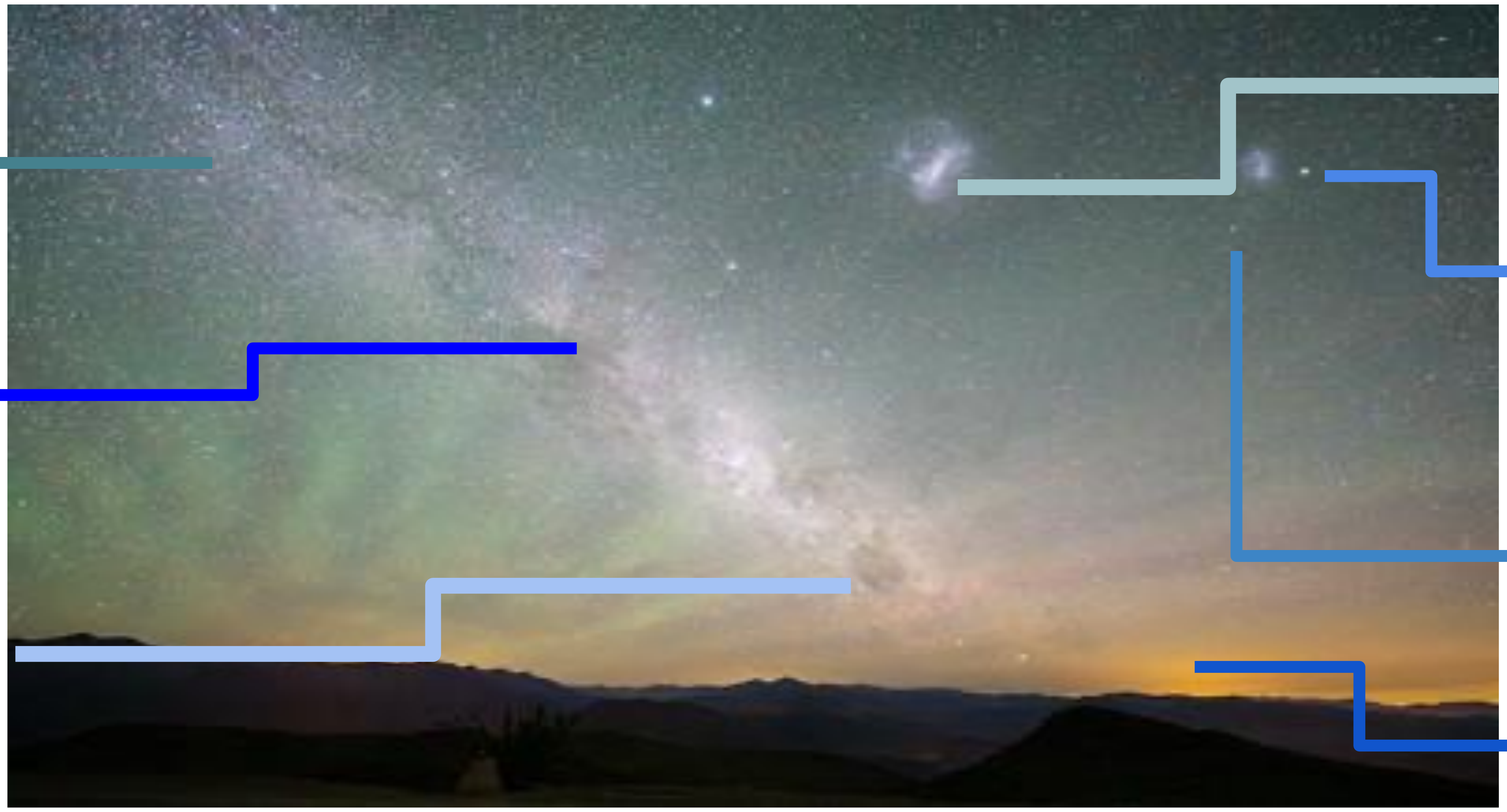
Submit

https://rubin-smwlv.github.io/membership.html

# Synthesis & Takeaways

*Membership application QR code*

- We very gladly welcome new members! Join us!!
- Lots of activity and interest, good international participation from early career researchers.
- Able to make lots of cross connections between SWGs and other SCs despite covering quite a broad range of topics.



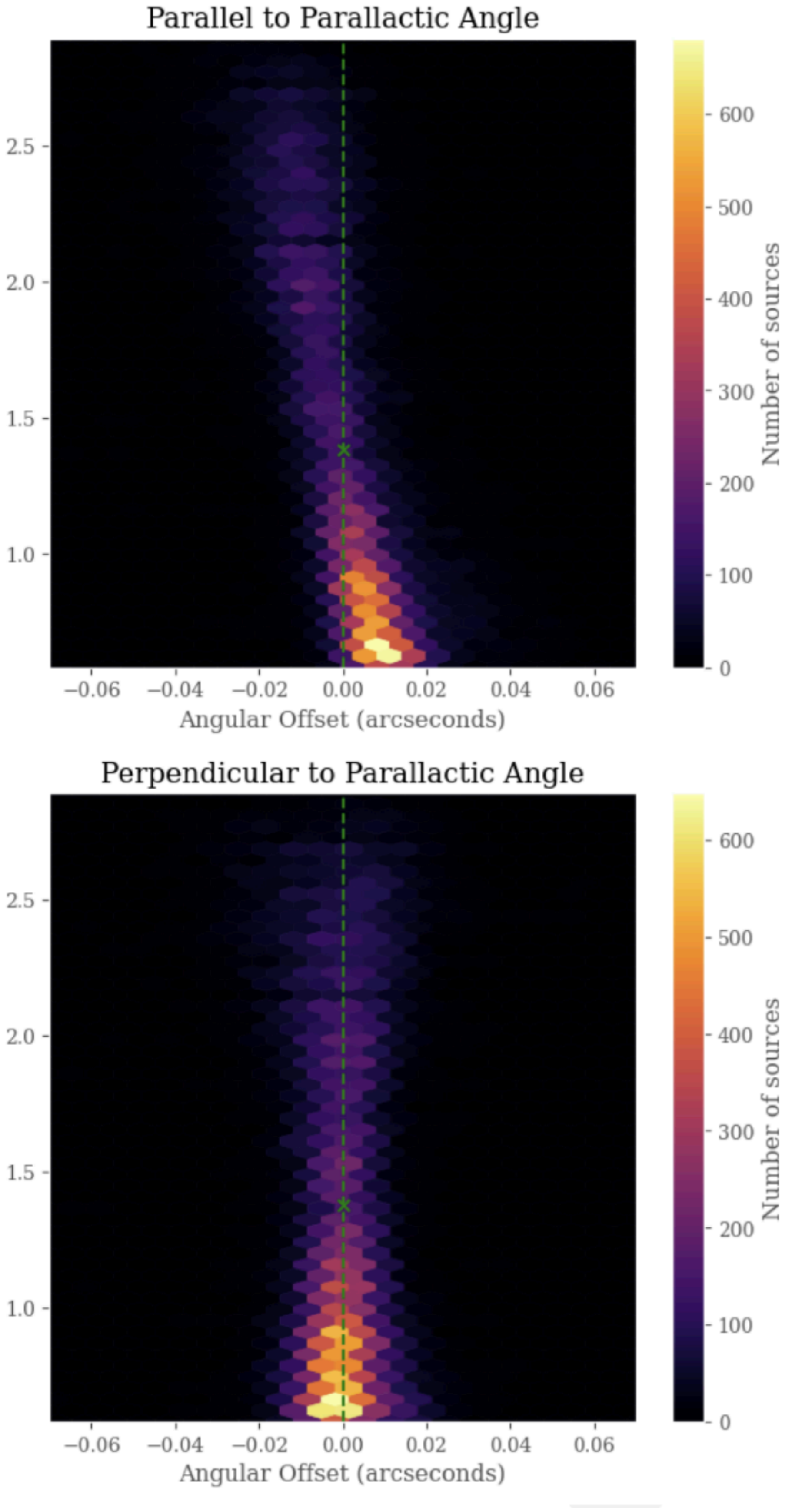
# Key Science Drivers of Software Development in SMWLV?

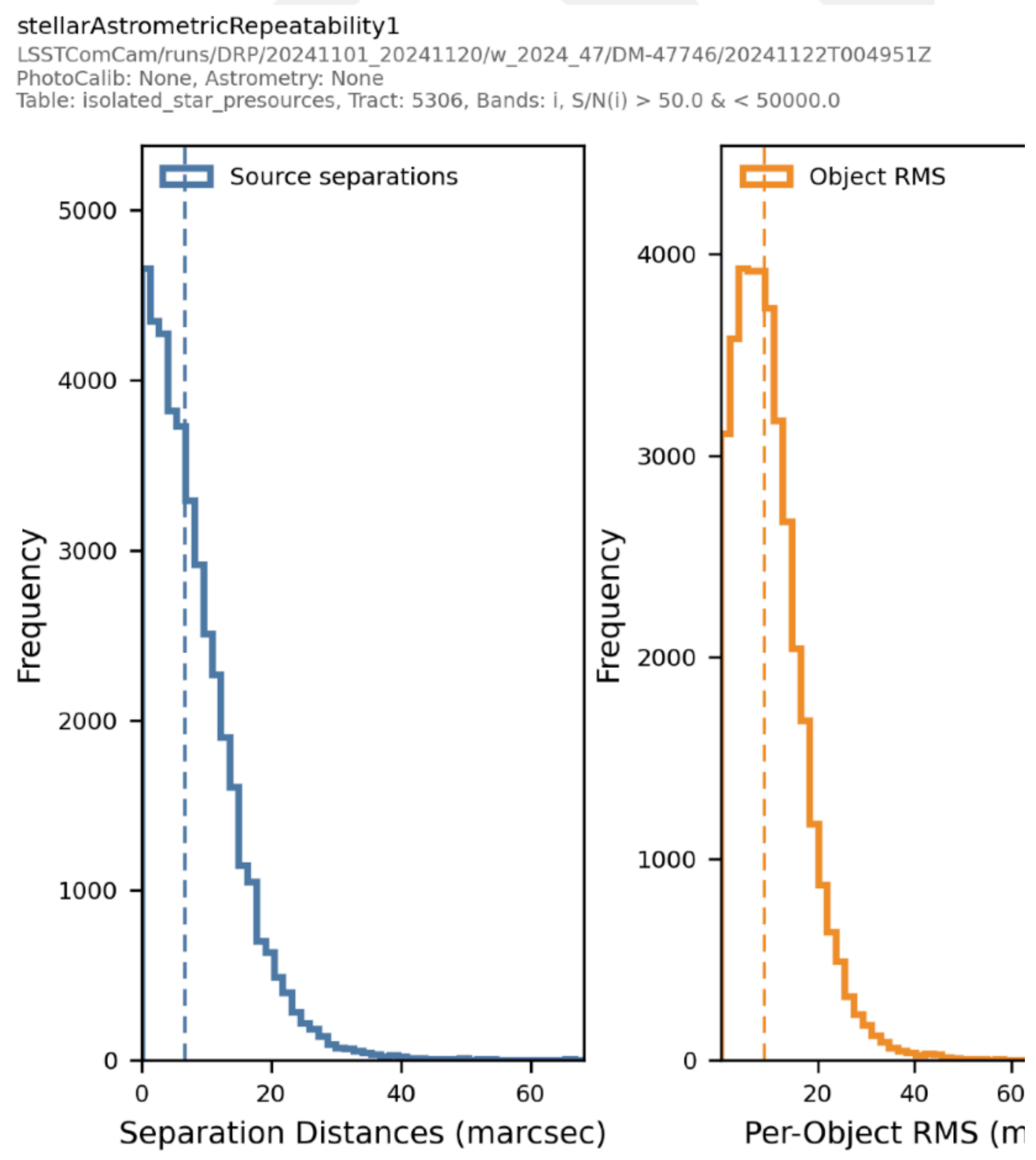
- Stellar classification
- Dust extinction
- Crowded-field photometry
- Astrometry in the Galactic plane

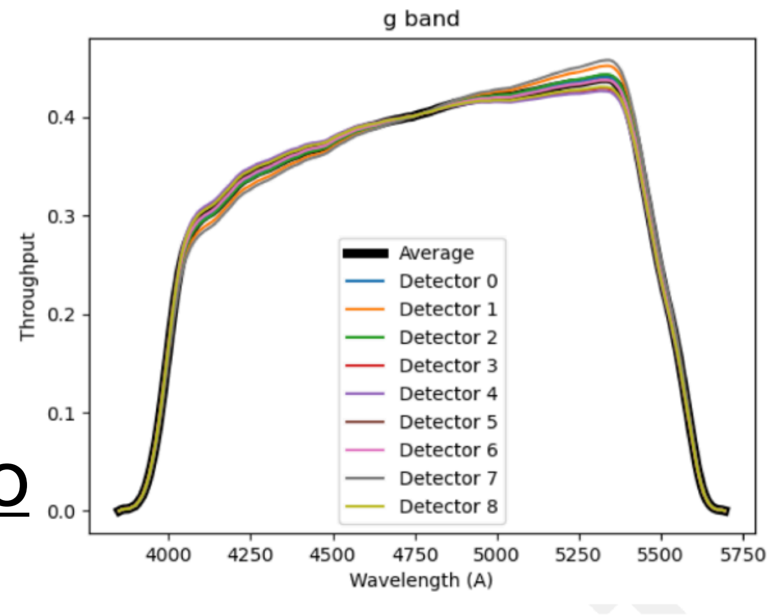
- Understanding the LSST Science Pipeline itself
- Understanding the Rubin Observatory itself, and the L*S*ST

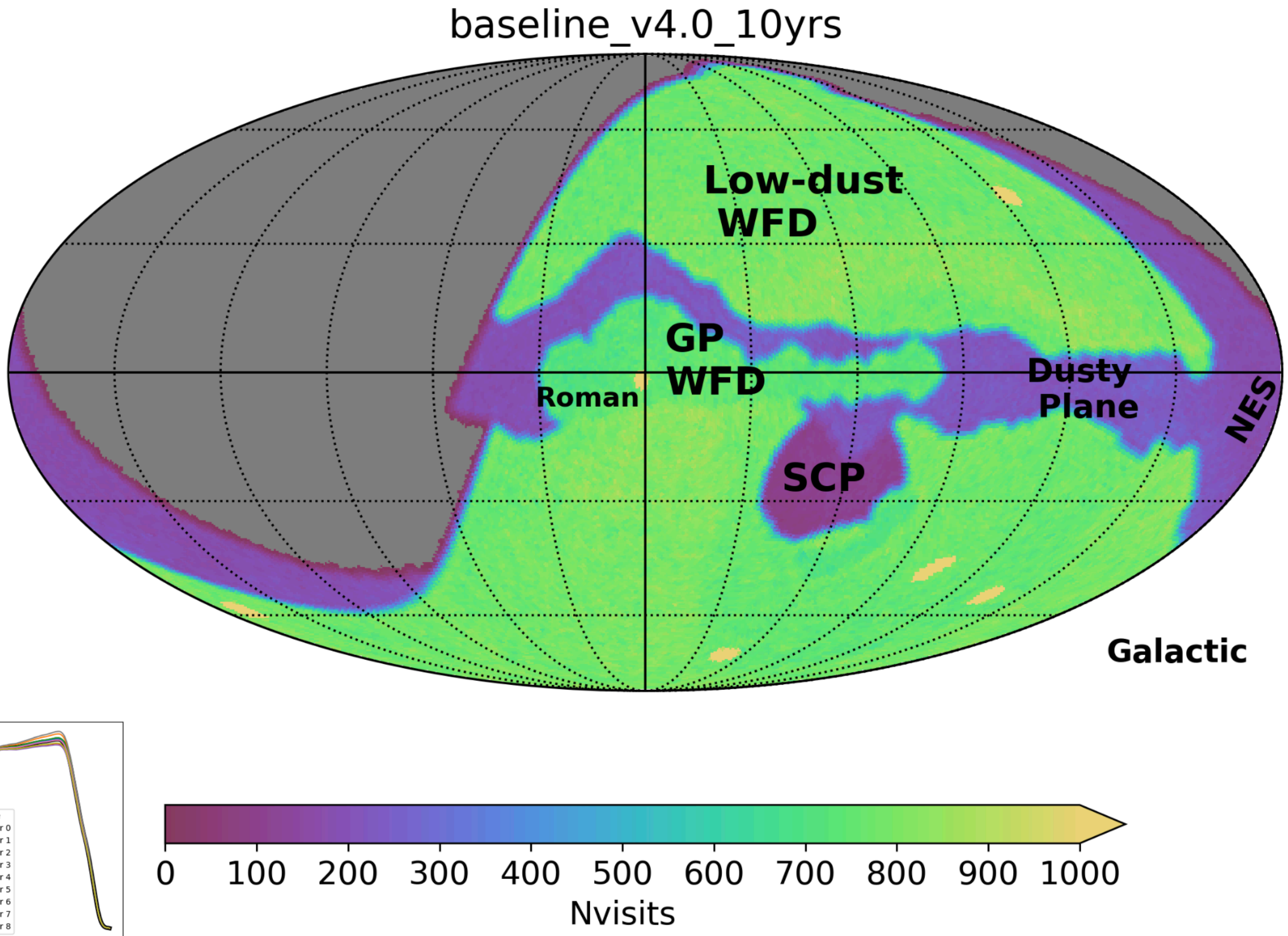
# Understanding the Rubin Observatory and the LSST

| Band | Number of Visits | Mean PSF FWHM *arcsec* | STD. DEV. PSF FWHM *arcsec* |
|---|---|---|---|
| All | 775 | 1.12 | 0.23 |
| u | 28 | 1.49 | 0.08 |
| | | 1.07 | 0.14 |
| | | 1.18 | 0.22 |
| | | 1.09 | 0.24 |



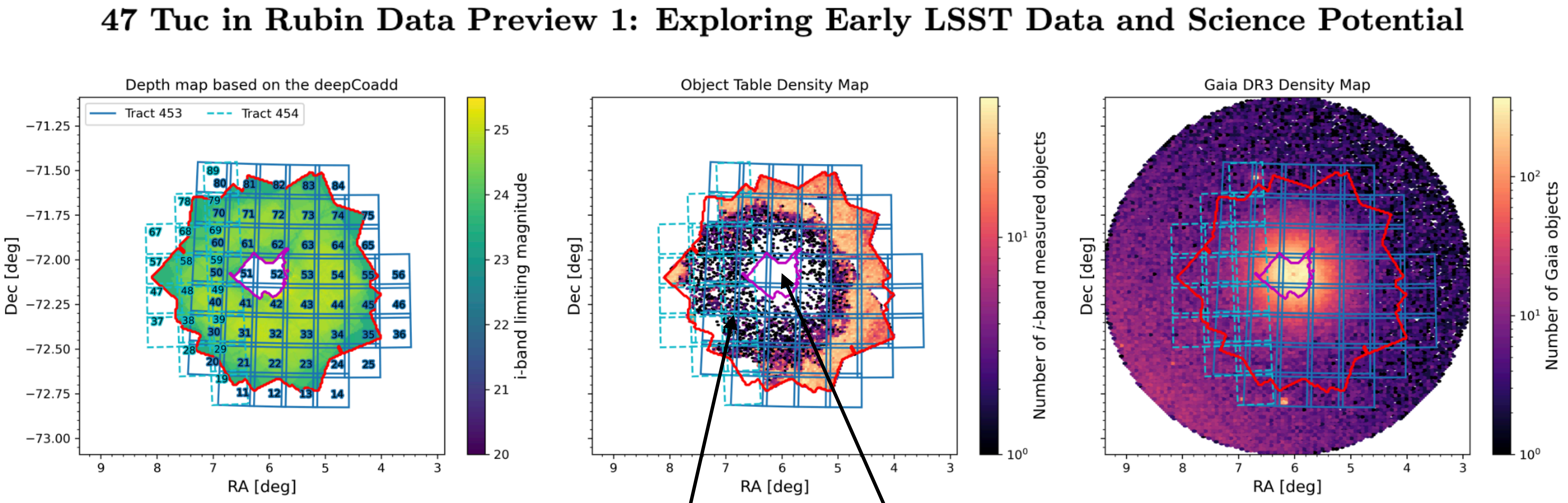




SITCOMTN-149, https://sitcomtn-149.lsst.io

PSTN-056, https://pstn-056.lsst.io

# Understanding (the Weaknesses of) the LSST Pipeline



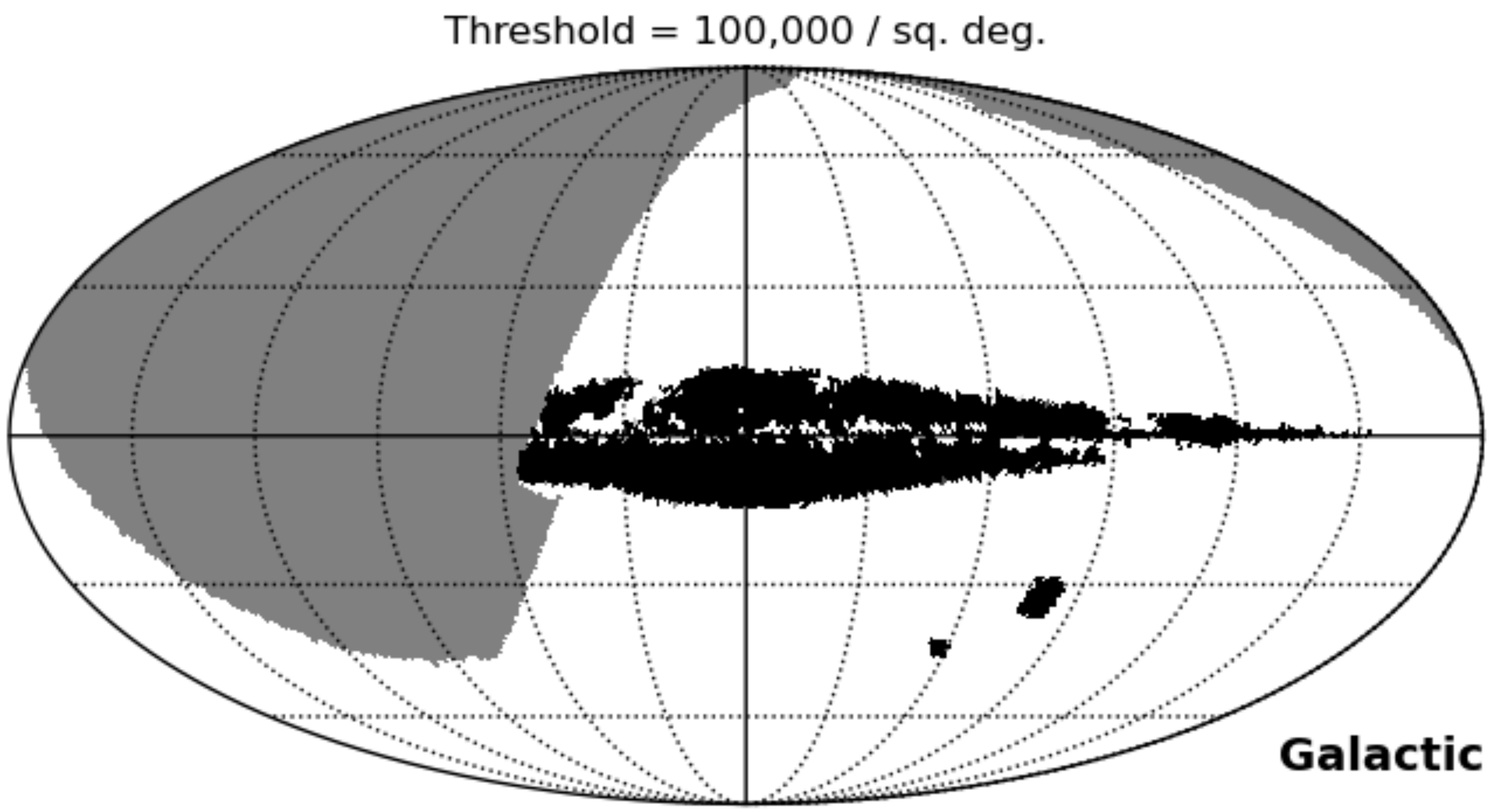

**Saturation — can we profile-fit the wings of saturated objects?**

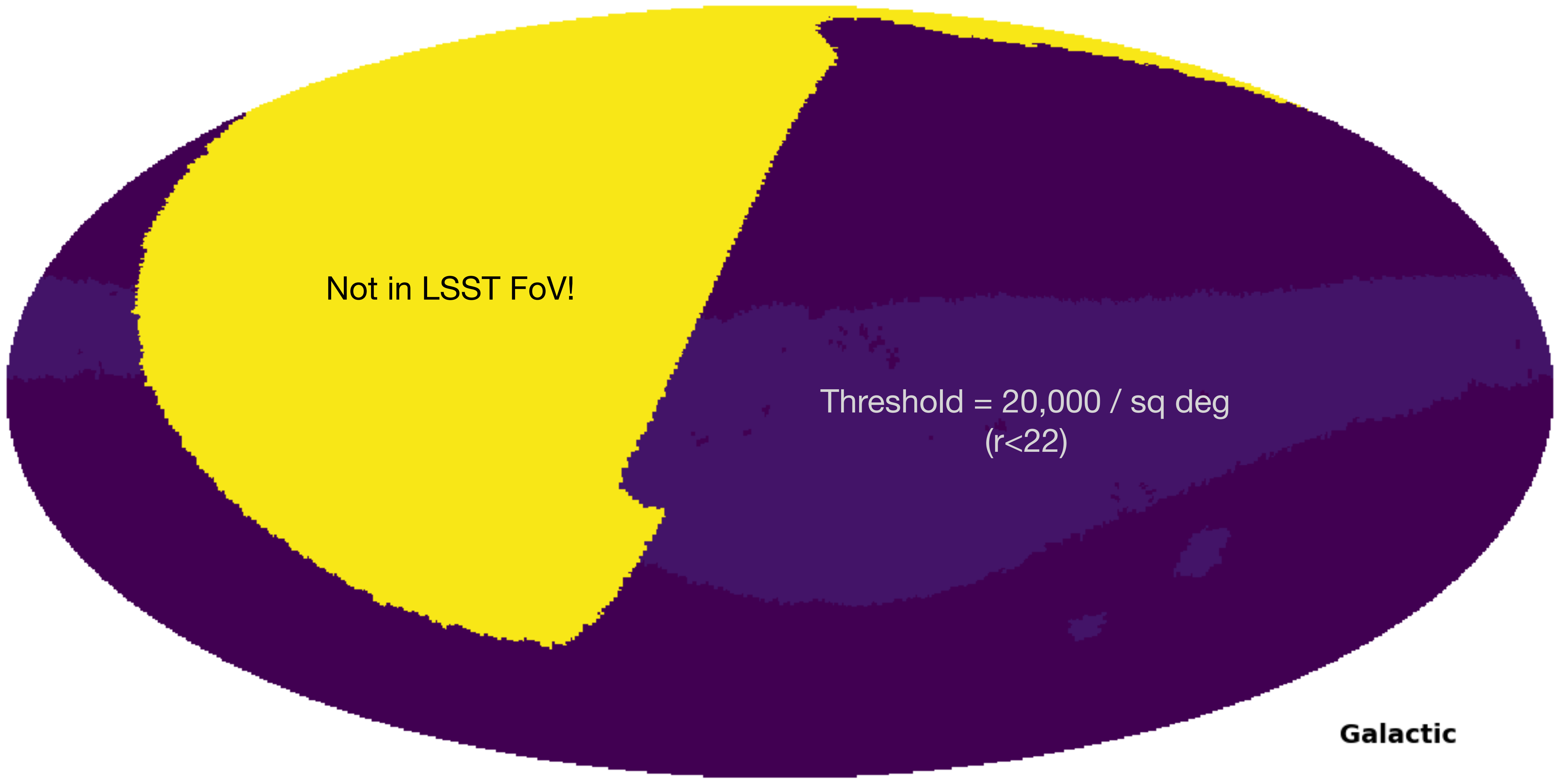
**Artificially low counts — why are we failing to detect these objects?**

Chio et al. (2025), https://arxiv.org/abs/2507.01343

# Understanding (the Weaknesses of) the LSST Pipeline

**“Fallback” pipeline for Prompt Processing? At what density? Just PP?**



# What Can We Learn From Star Clusters?

Star clusters are groups of bound stars that provide valuable infromation of the host galaxies

It is possible to characterize their structure by extracting the profiles of their integrated light (fitting isophotes), called Surface Brightness Profiles (SBPs)

nProFit is a valuable tool to extract the SBPs, and obtain the sizes, masses, densities and concentration of samples of clusters in a given image by fitting King and Wilson models

nProFit is a modular code developed in Fortran and Python and is publicly available [https://github.com/umbramortem](https://github.com/umbramortem)

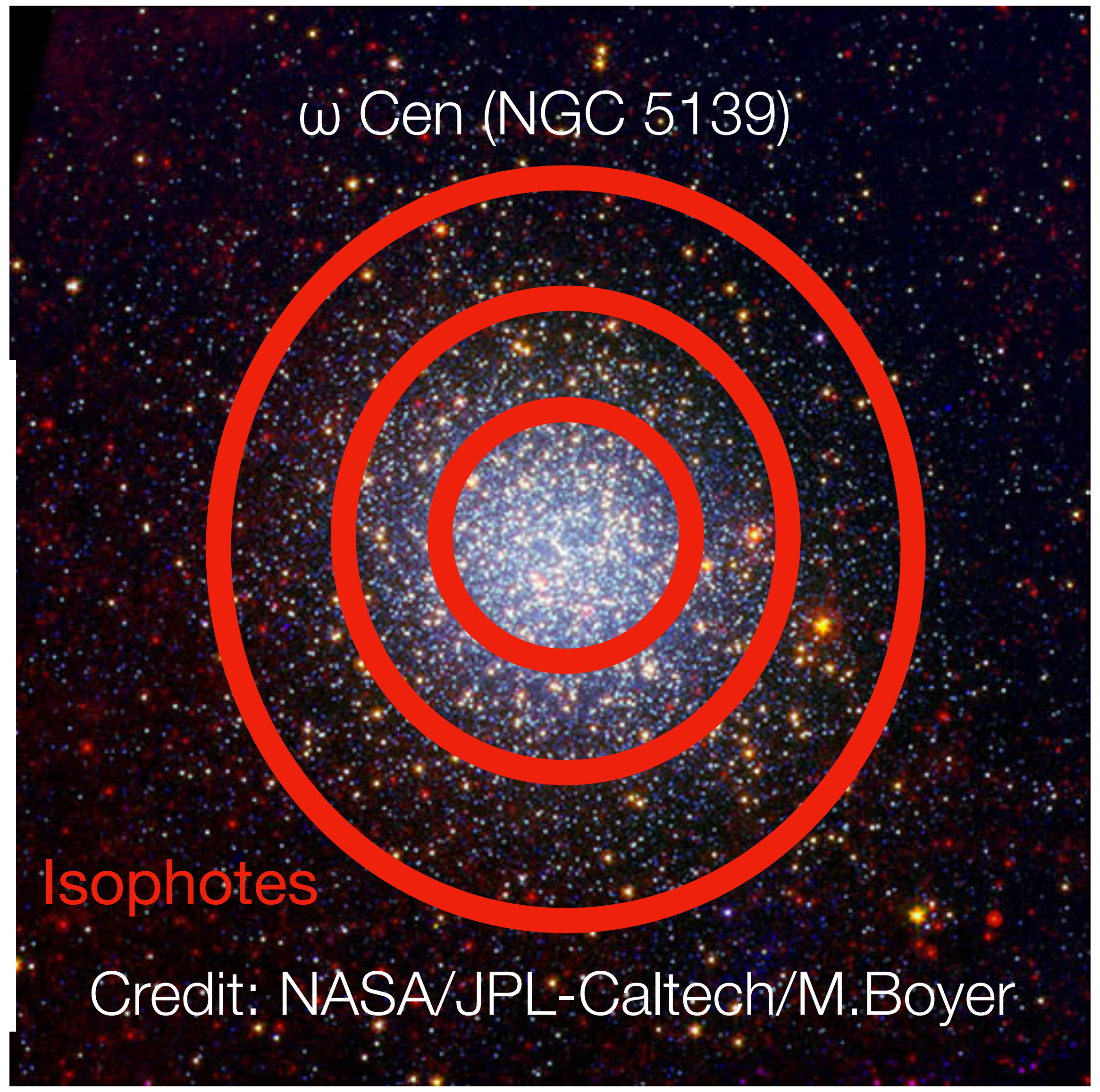
King:
$$f(\varepsilon) \propto \begin{cases} \exp(\varepsilon/\sigma_0^2) - 1, & \varepsilon > 0, \\ 0, & \varepsilon \le 0, \end{cases}$$

Wilson:
$$f(\varepsilon) \propto \begin{cases} \exp(\varepsilon/\sigma_0^2) - 1 + \frac{\varepsilon}{\sigma_0^2}, & \varepsilon > 0, \\ 0, & \varepsilon \le 0, \end{cases}$$

$$\sigma_0^2 \equiv \frac{4\pi G \rho_0 r_0^2}{9}$$

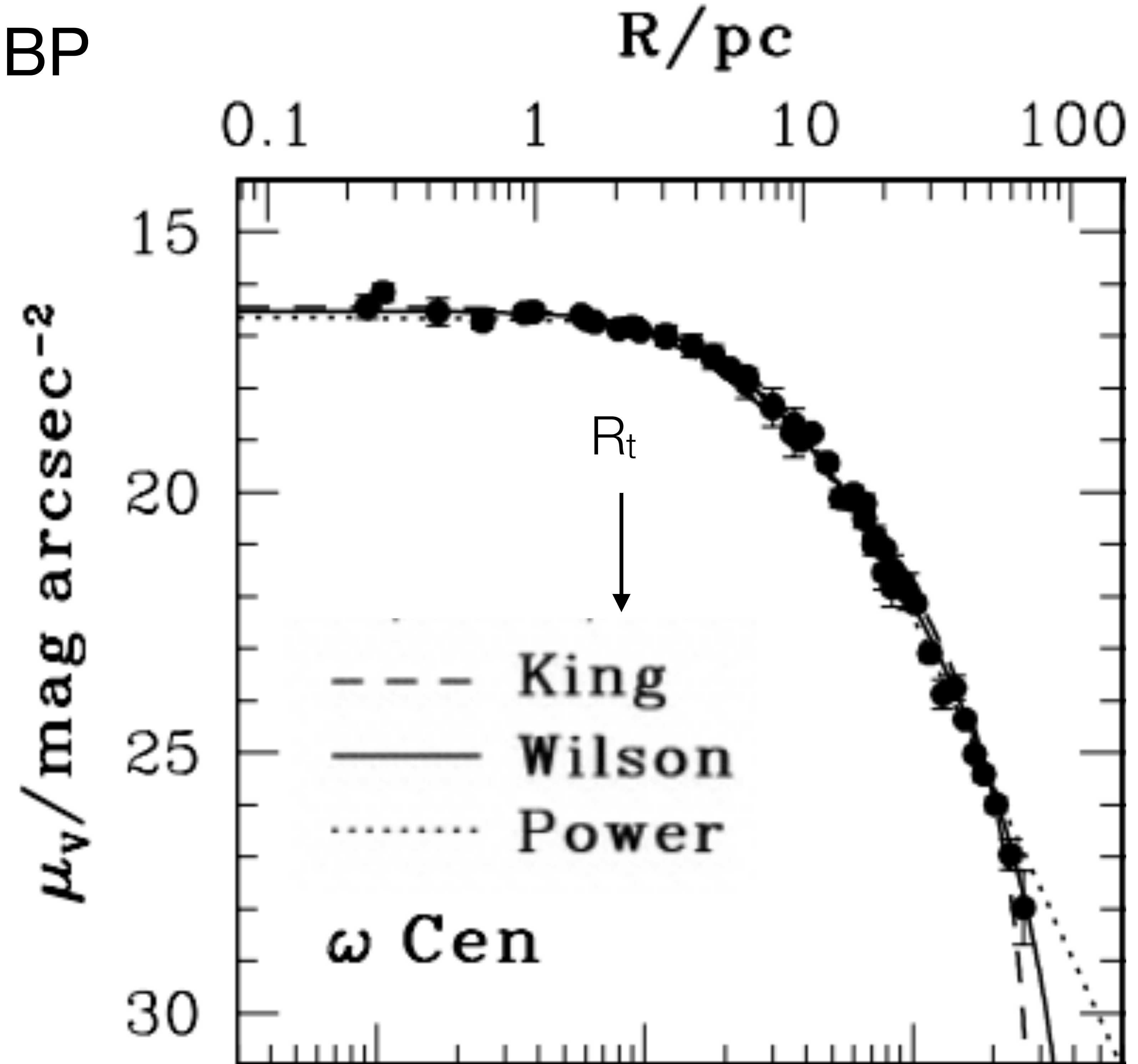
King (1962)

Star Cluster




SBP

McLaughln & Van der Marrel 2005

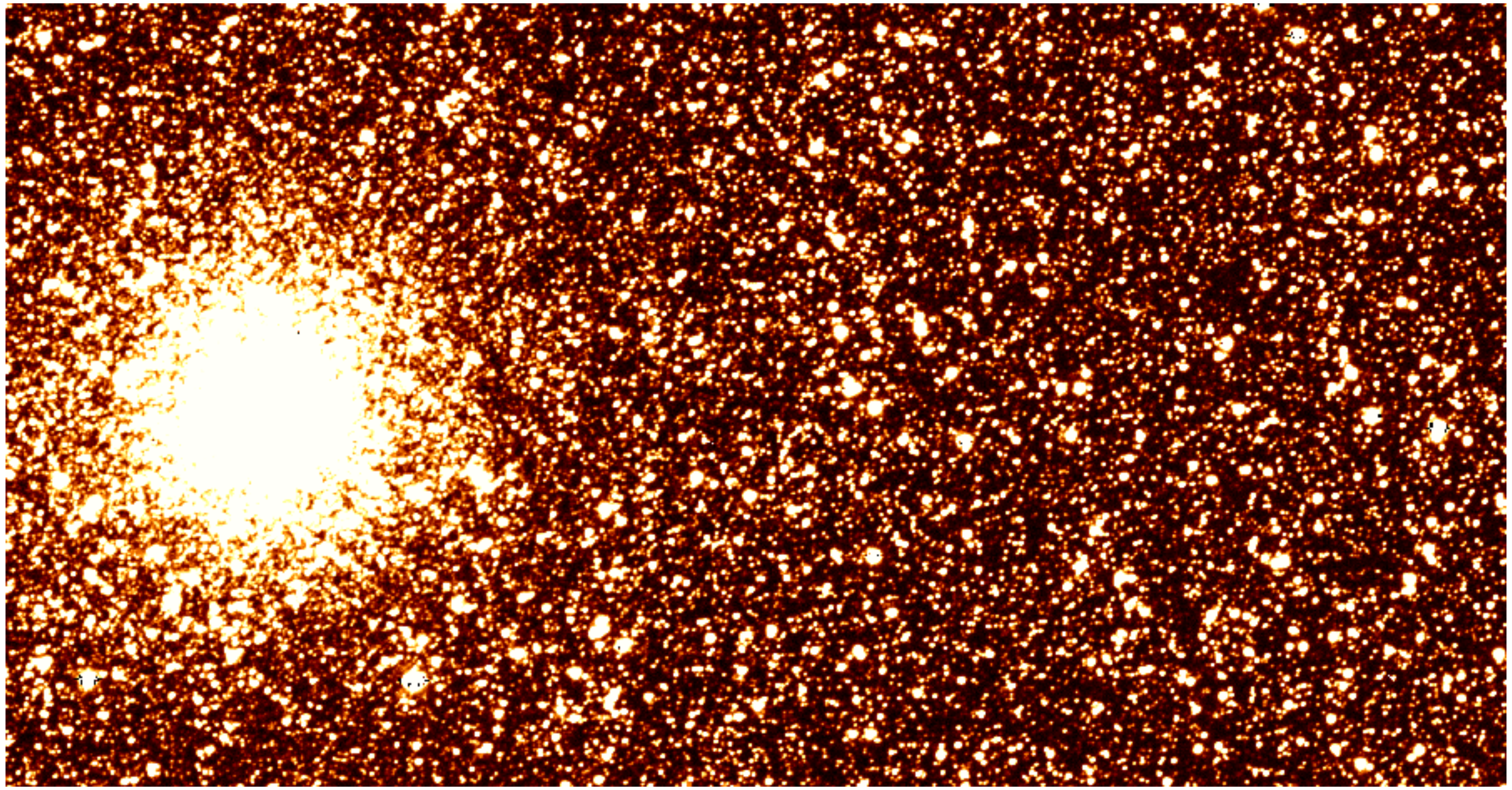



**MEX-UNA-S4**

# Precision photometry and variability tools in crowded fields

Authors/contributors: Massimo Dall'Ora, Mahtab Gholami, Alonso Luna
Contact: massimo.dallora@inaf.it

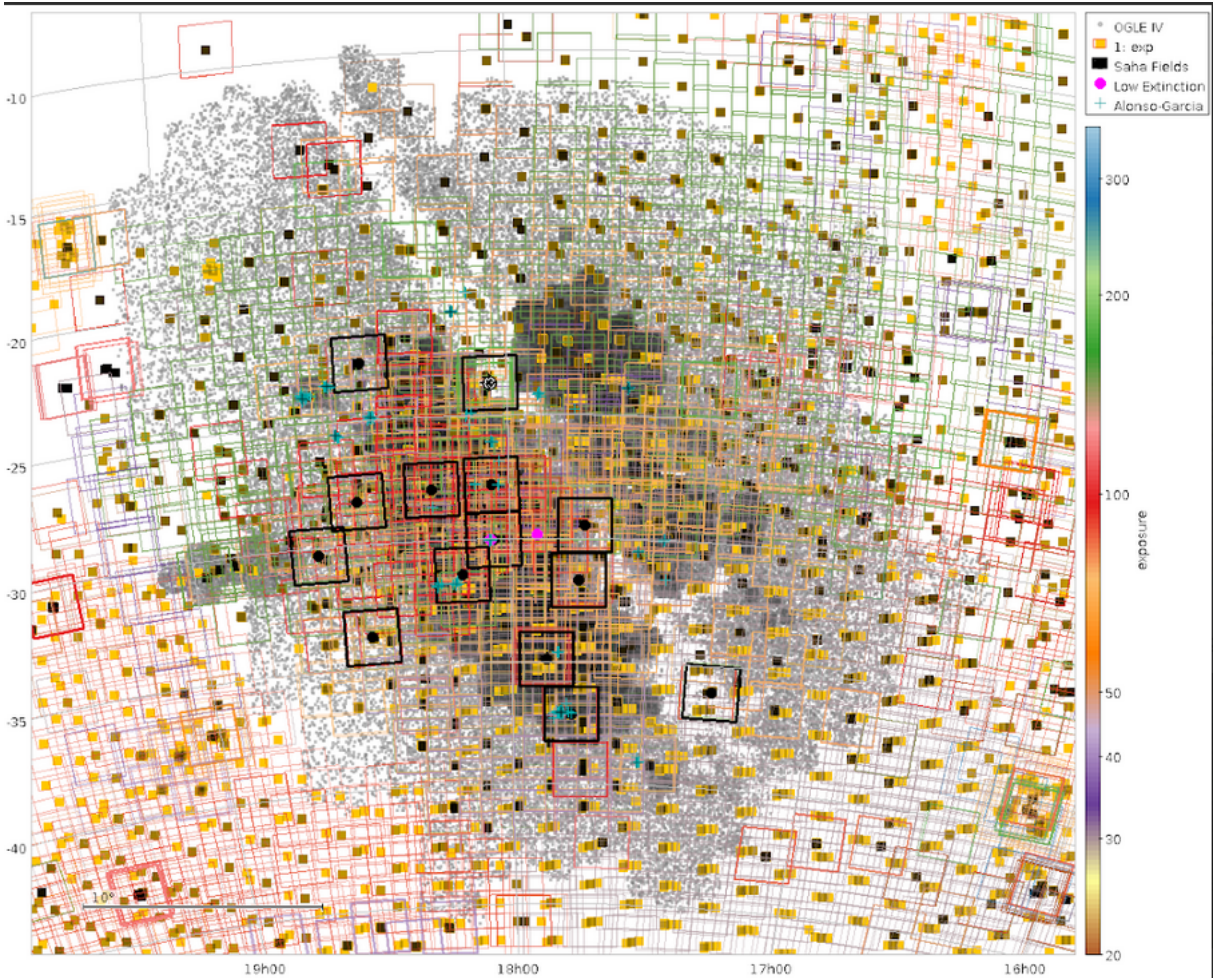
- Motivations: to provide a suite of tools to achieve accurate PSF photometry in crowded fields, and periodic variables detection and characterization
- Directable in-kind contribution
- Bash-driven fully automatic pipeline to get Daophot/Allstar PSF photometry in crowded fields
- Python module to extract candidate periodic variables from the produced photometry, based on the Generalized Lomb-Scargle (GLS) algorithm
- Python module to measure the candidate variables mean magnitude and amplitude, with automatic outlier detection and rejection and evaluation of the errors



**ITA-INA-S10**

# A test dataset

- Excellent DECam data of the Galactic bulge are available at the Noirlab Archive
- The dataset includes the six “Saha’s Fields”, discussed in Saha et al. 2019
- The scientific goal is a reddening and metallicity map, based on RR Lyrae stars
- Other fields have been added, bringing the Saha’s fields to 14



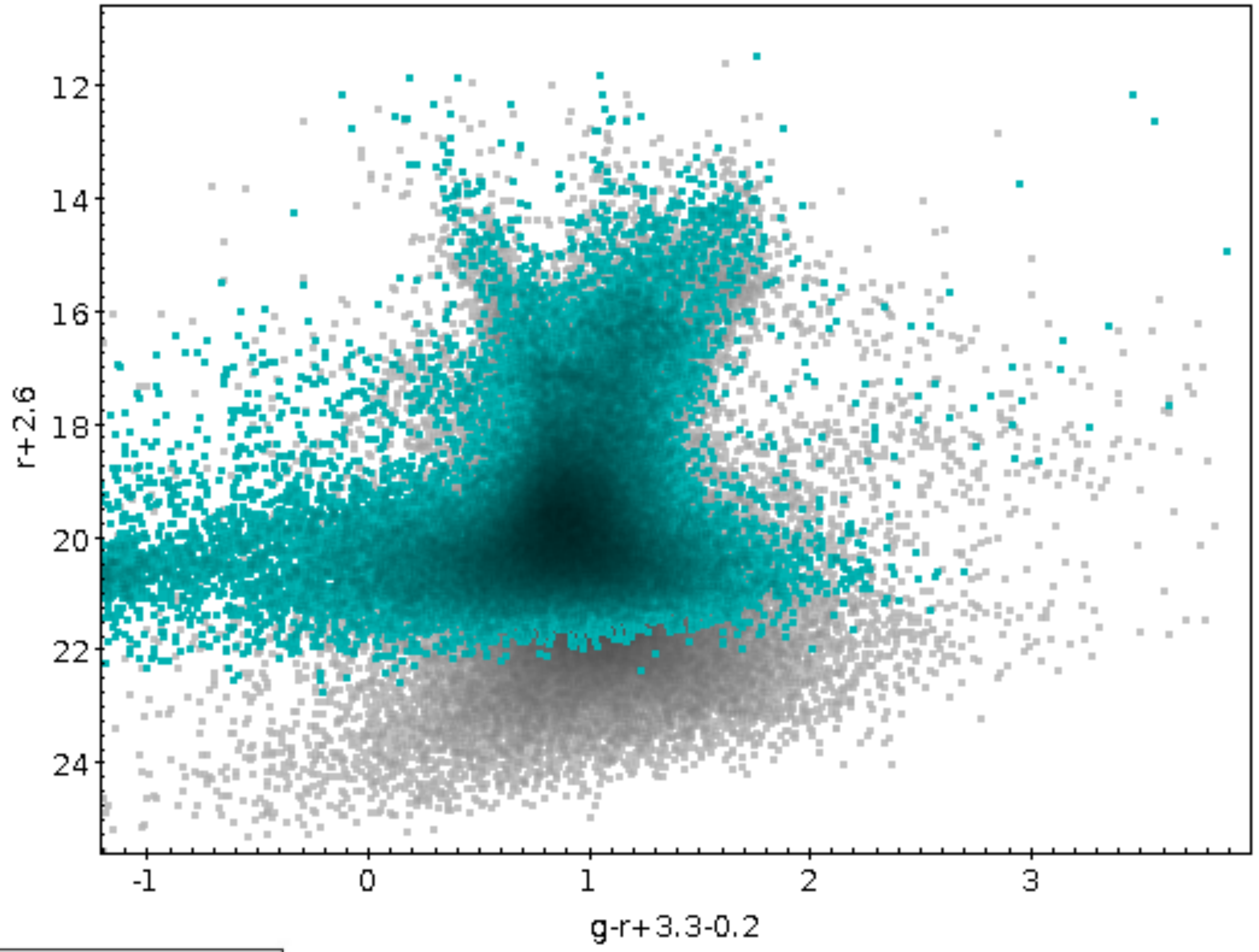

**ITA-INA-S10**

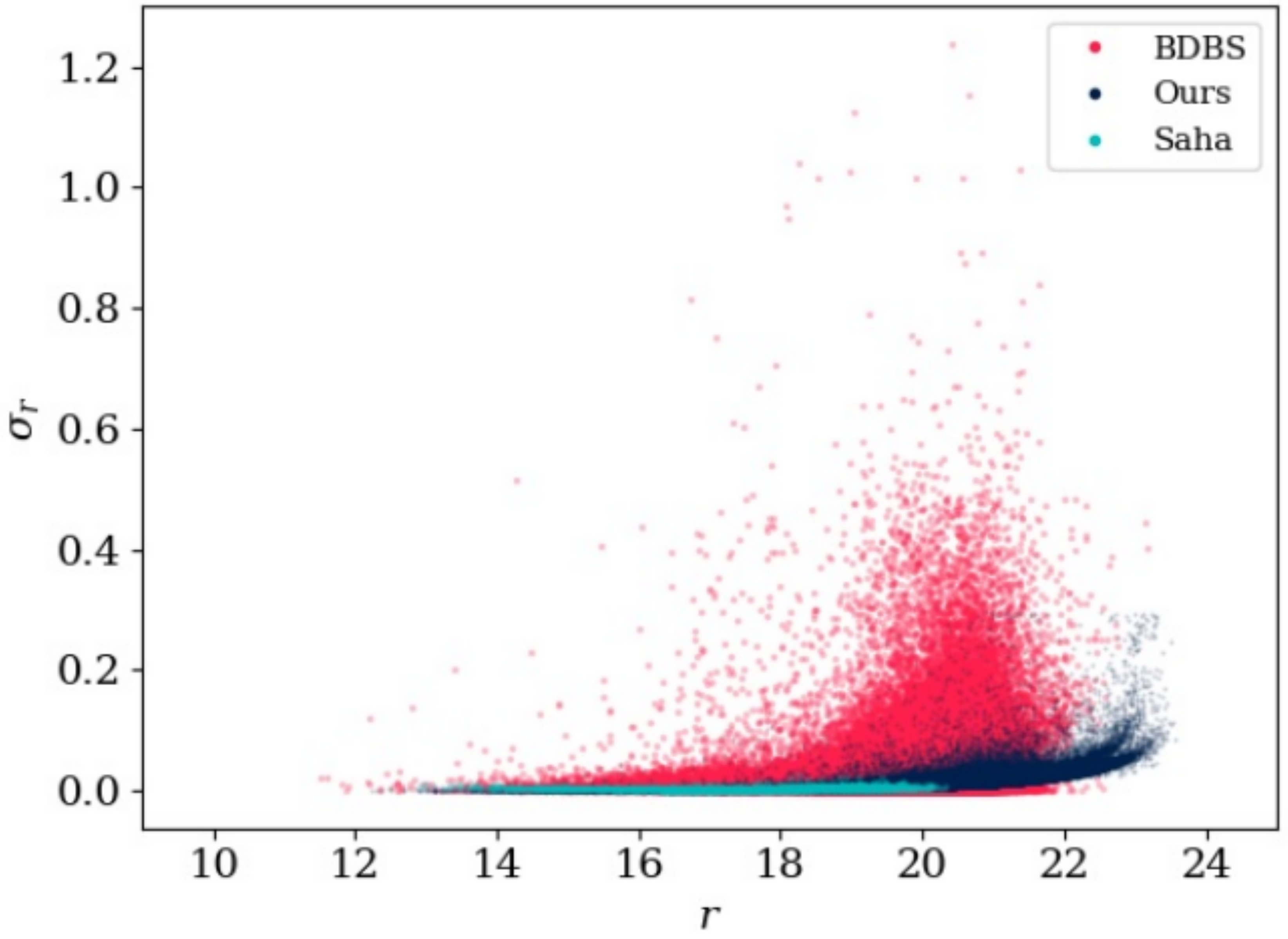
# Automatic PSF photometry pipeline

- Bash scripts to drive a fully automatic (no human intervention) reduction of the DECam data, based on Daophot IV / Allstar
- Makes use of SExtractor and custom Fortran routines, to remove the outliers from the PSF stars list
- Allframe run available with a little manual intervention to align the catalogs and generate the input star list
- Can be adapted to other instruments
- In-kind contribution: **preliminary** release available [Here]
- **Contact** the authors for assistance and hints

**ITA-INA-S10**

- CMD in the area around NGC 6569. Grey points are the photometry provided by the data reduced with the pipeline. Cyan points are the BDBS photometry.
- Note that the expected Rubin-LSST single-visit photometric limit is around 24




Run of the photometric error in BDBS, Saha, and the present pipeline

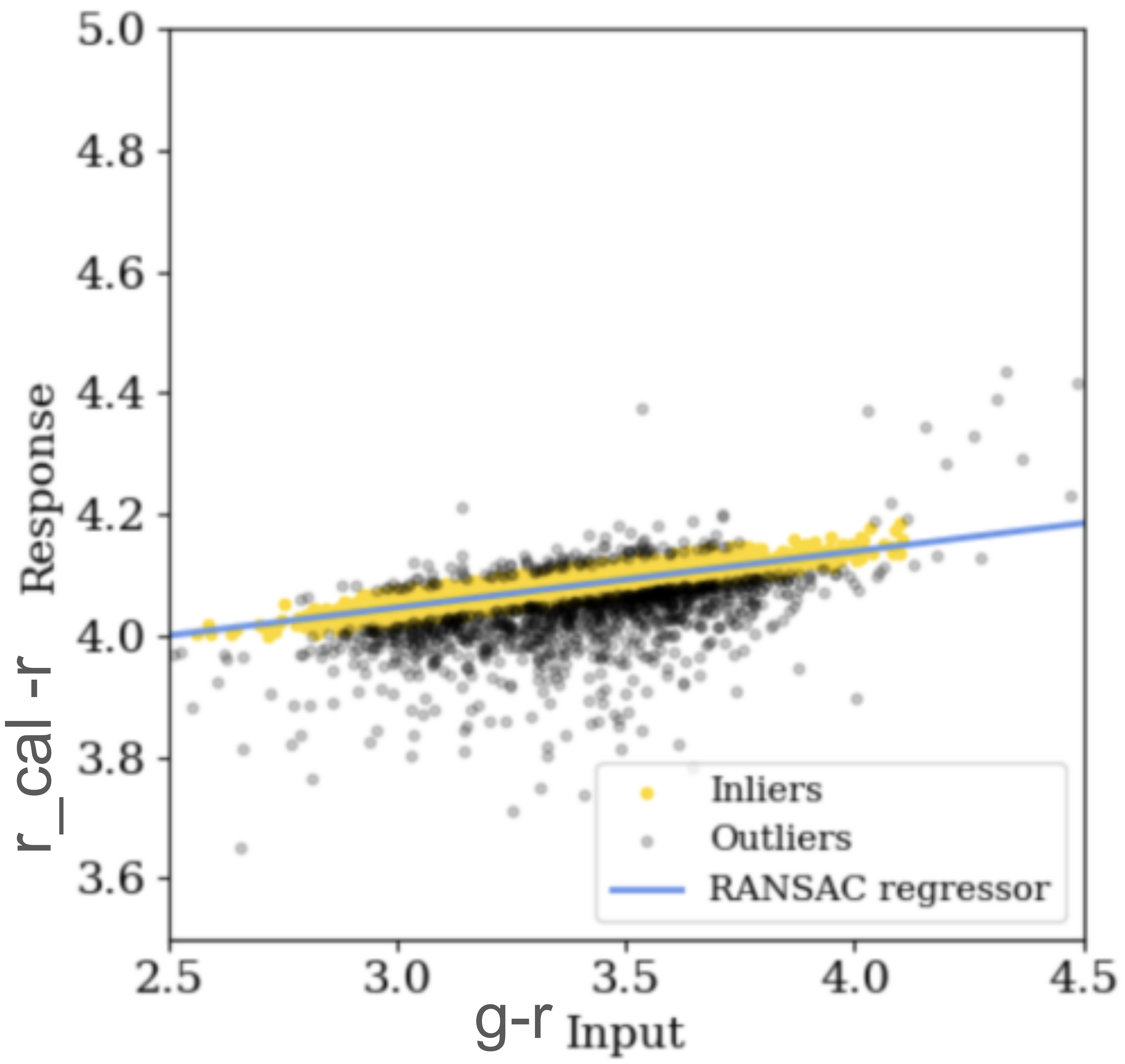
# Automatic photometric calibration

Python code to calibrate instrumental magnitudes into SDSS photometric system

The calibration is based on local standards, that can be provided by the Gaia DR3 synthetic photometry

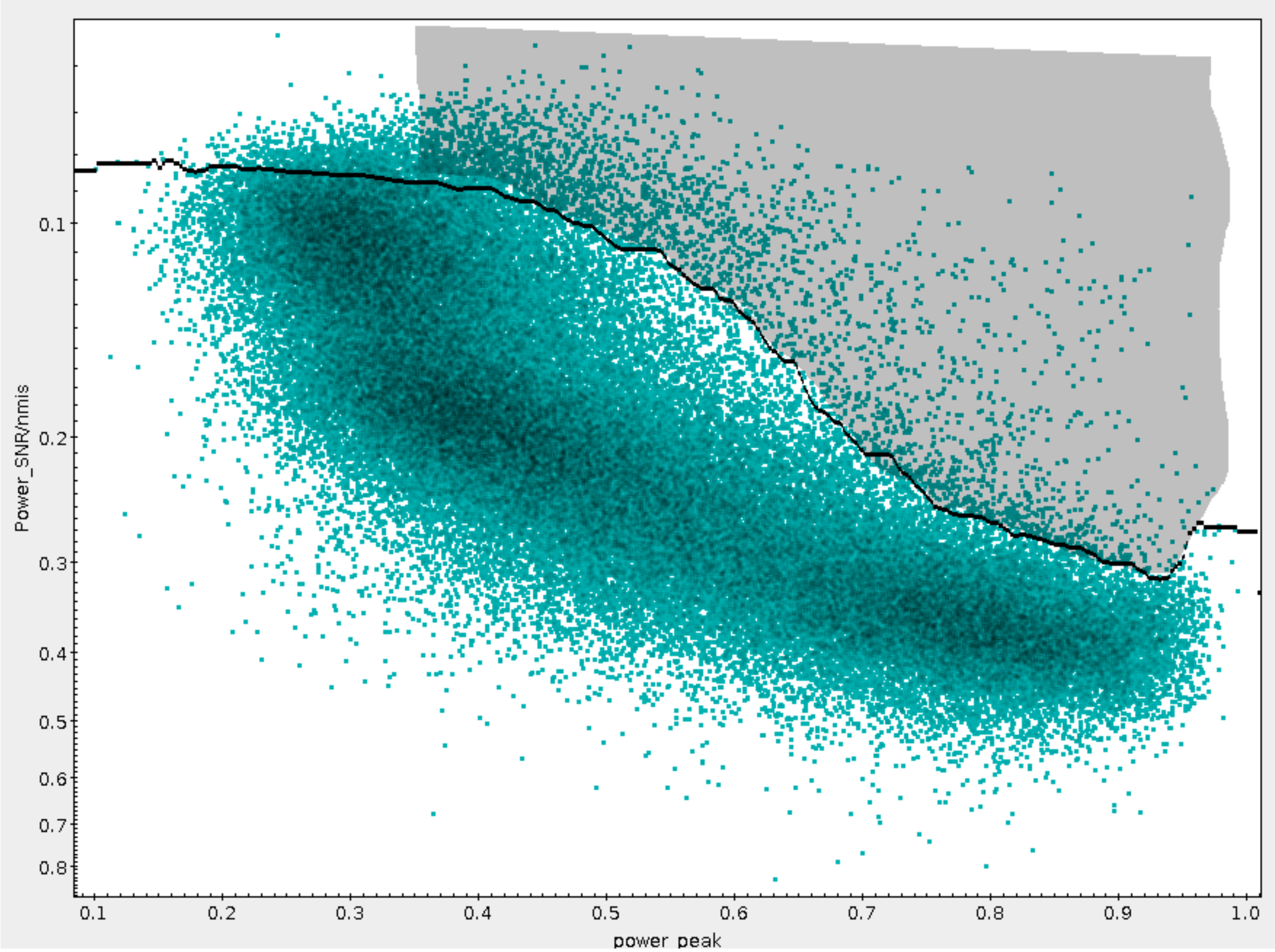
The code is based on the RANSAC algorithm, to automatically discard the outliers

The typical accuracy (rms) is 0.02-0.03 mag



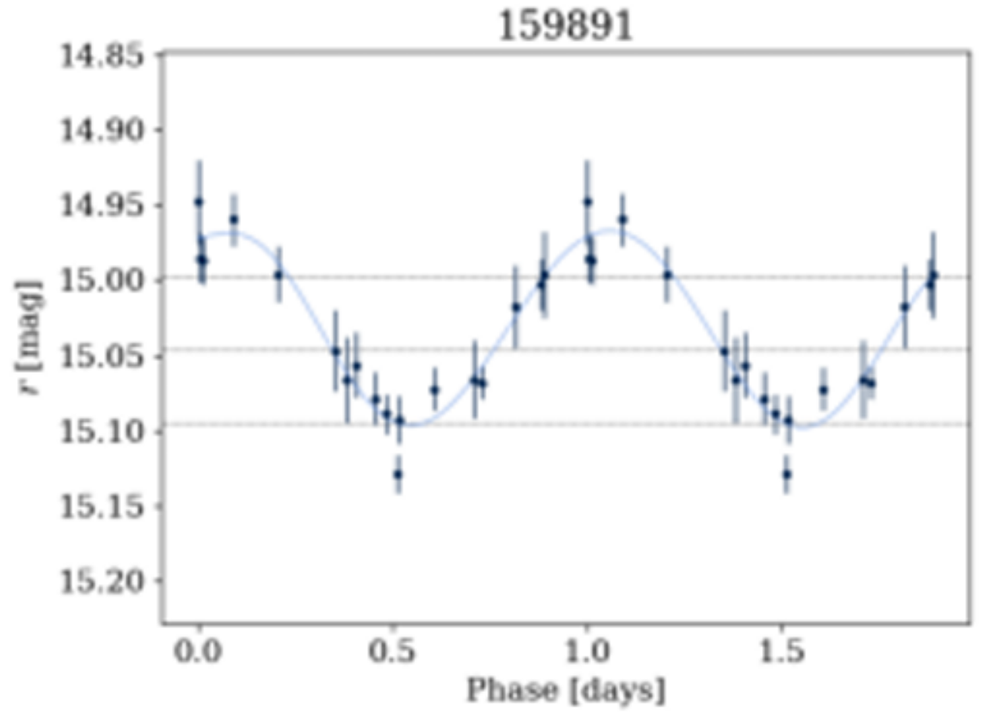

**ITA-INA-S10**

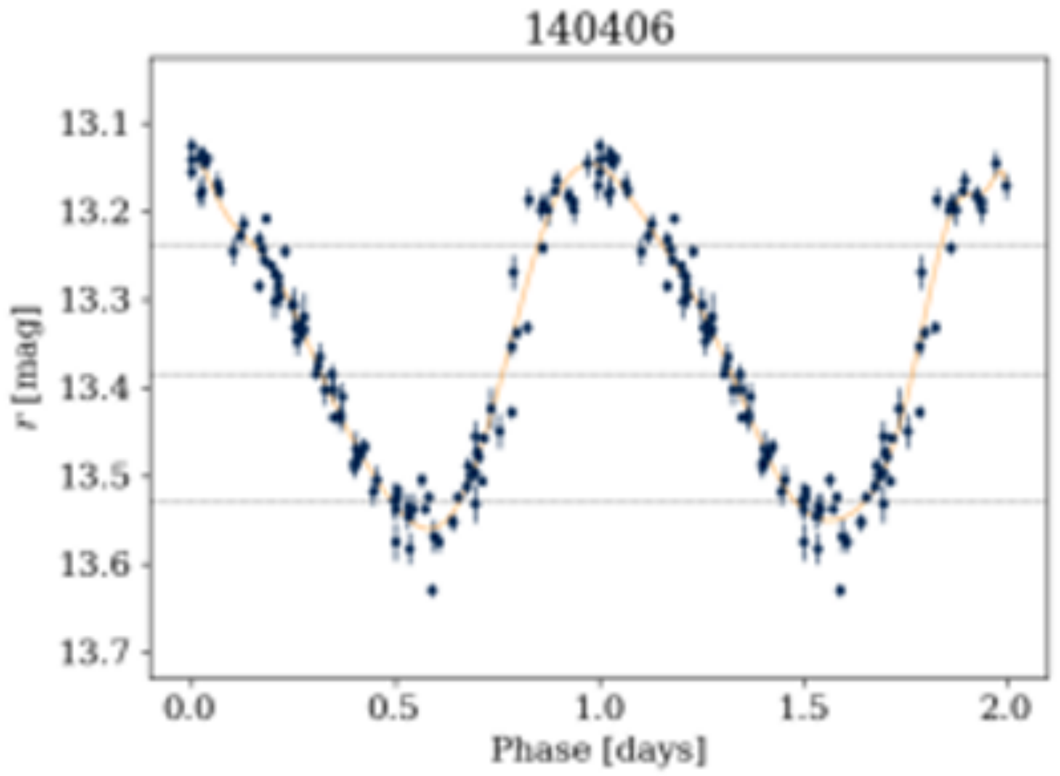
# Variability search and characterization

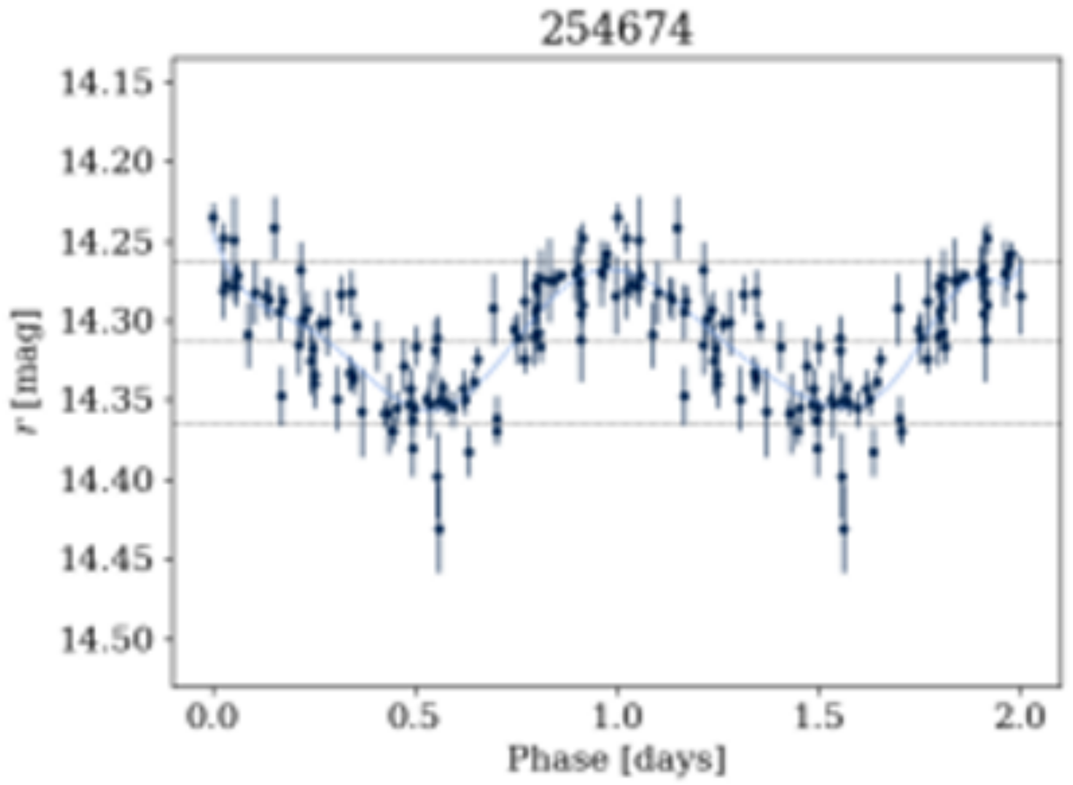



Candidates selection from the Generalized Lomb-Scargle analysis. Here is plotted the GLS power peak, vs. the power S/N ratio. Black line is the 95th quantile of the distribution.
In this plane, stars above this limit (shaded area), are the strongest candidates.

Python code available on request



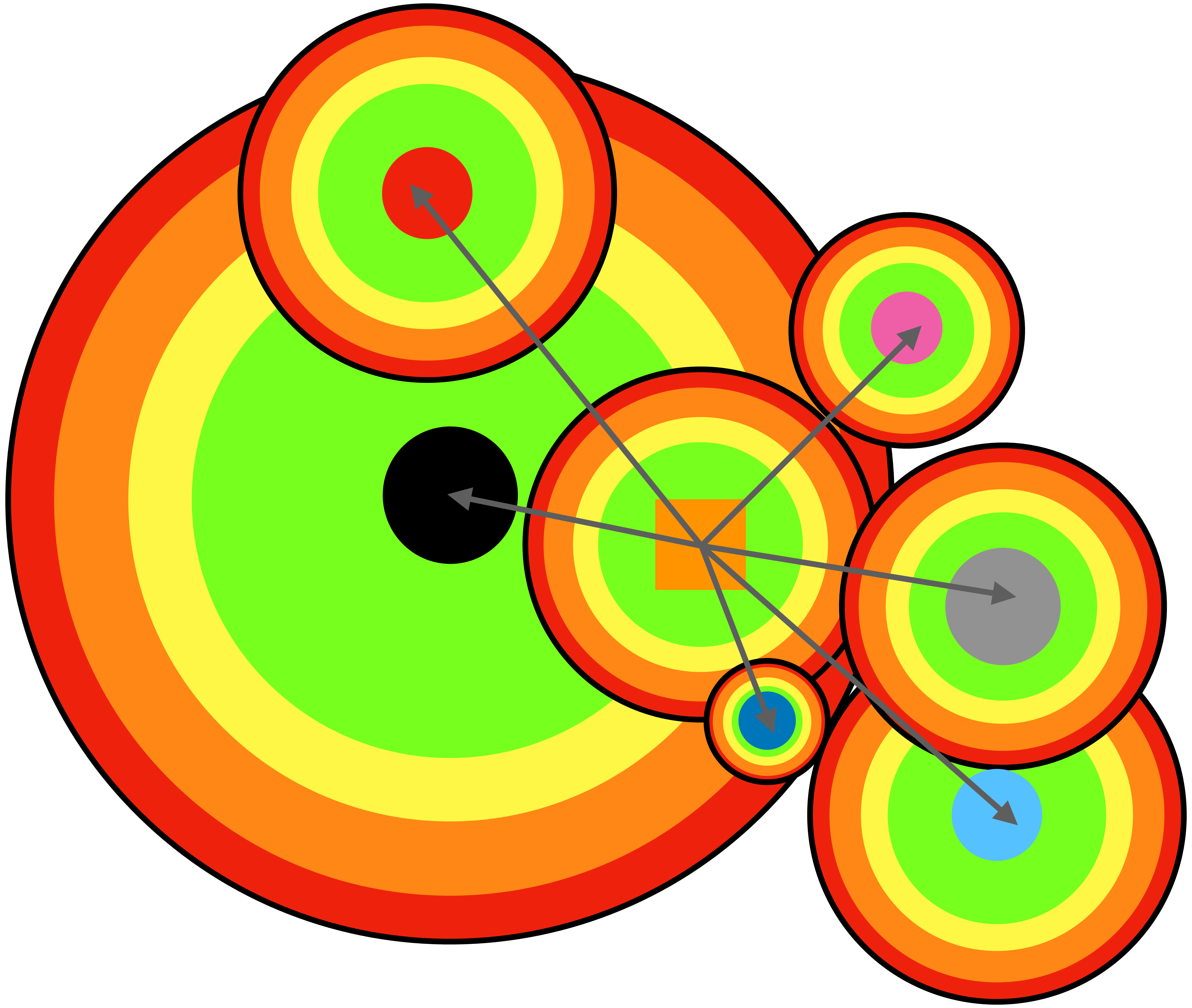

Examples of light curve fitting with automatic outliers rejection (with the RANSAC algorithm)
Lines show the mean magnitude and the 3-sigma interval

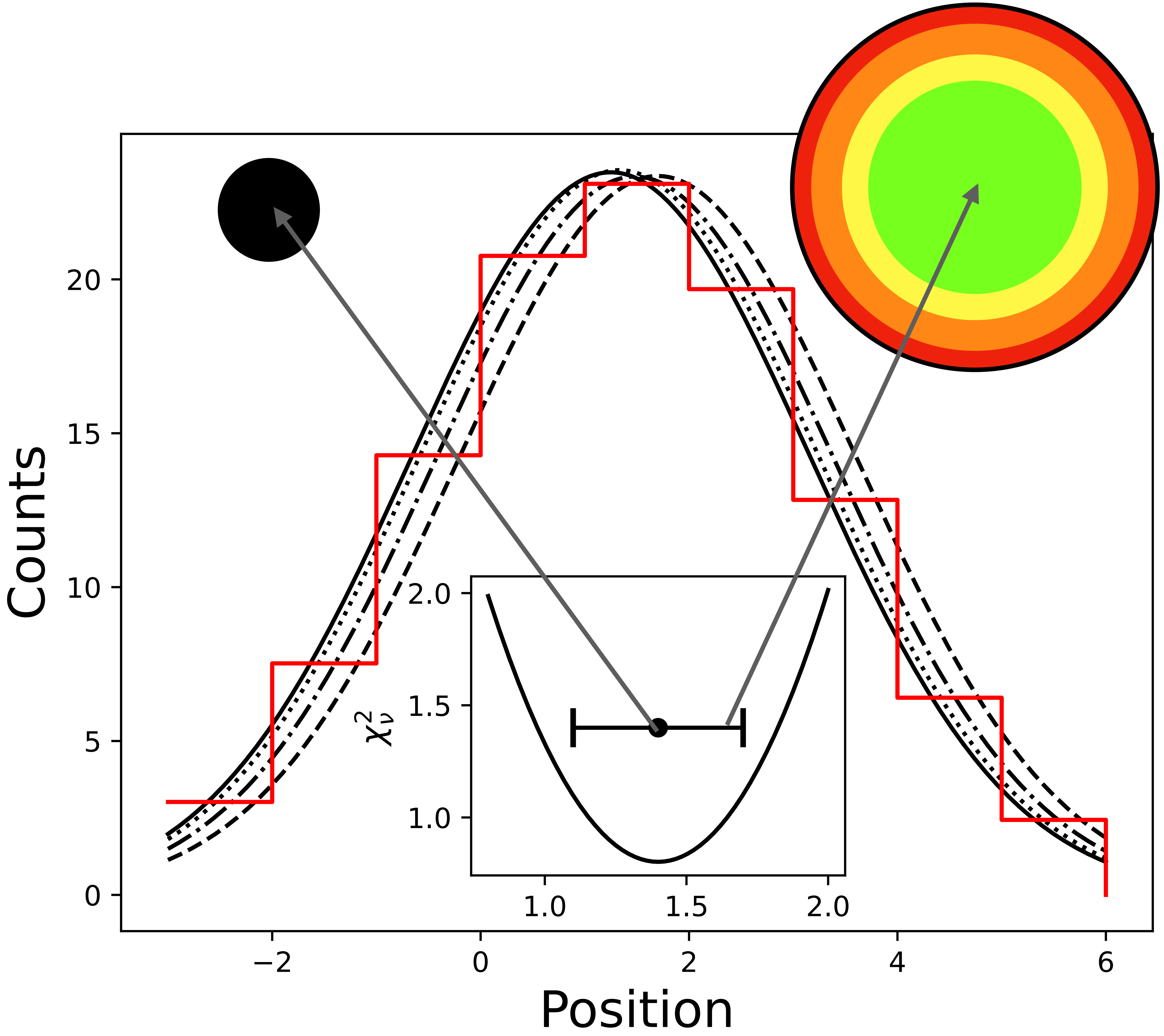
The code computes the mean magnitude and amplitude, and the associated errors

Python code available on request

**ITA-INA-S10**

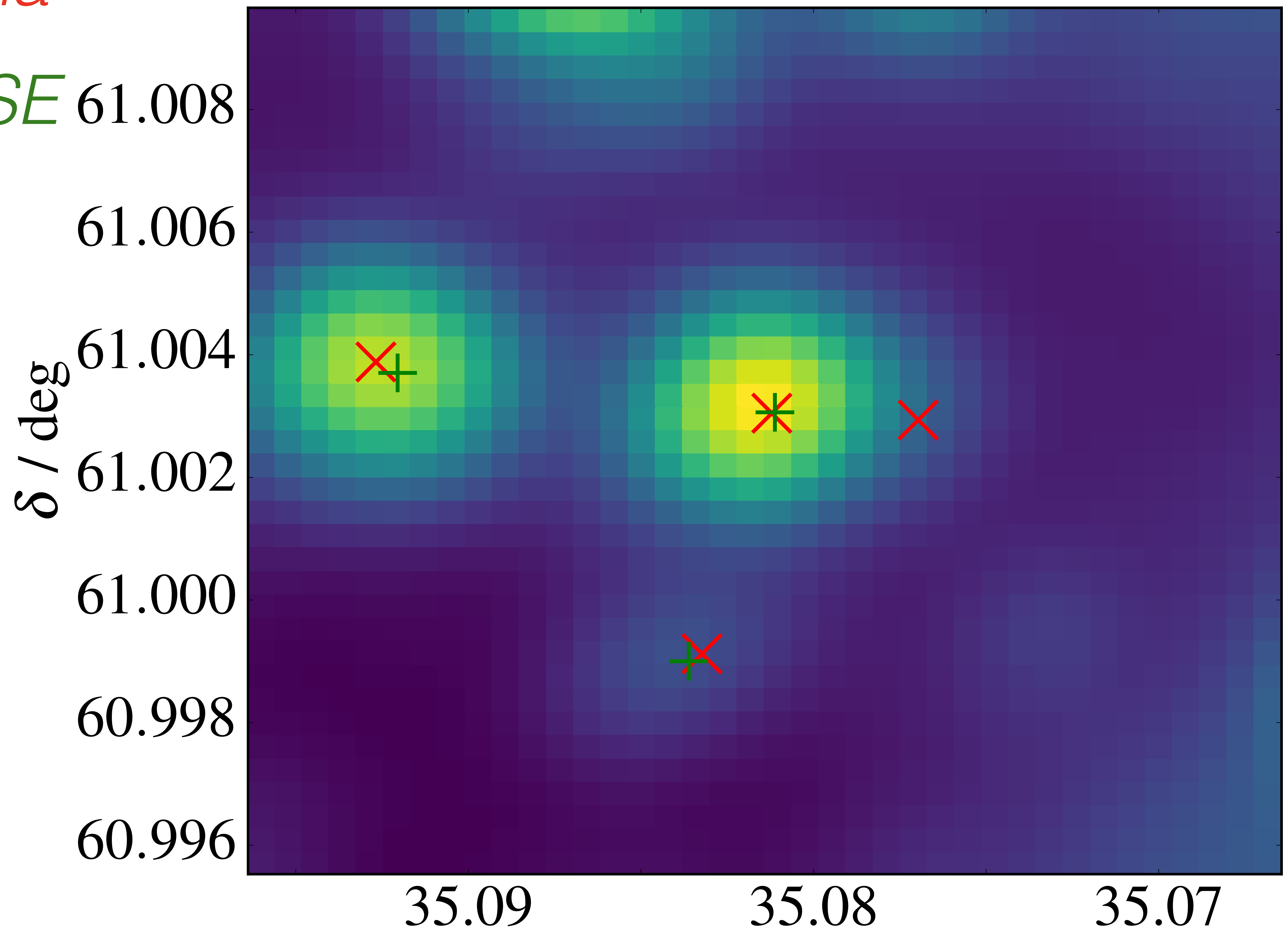
# Astrometry in the Galactic Plane

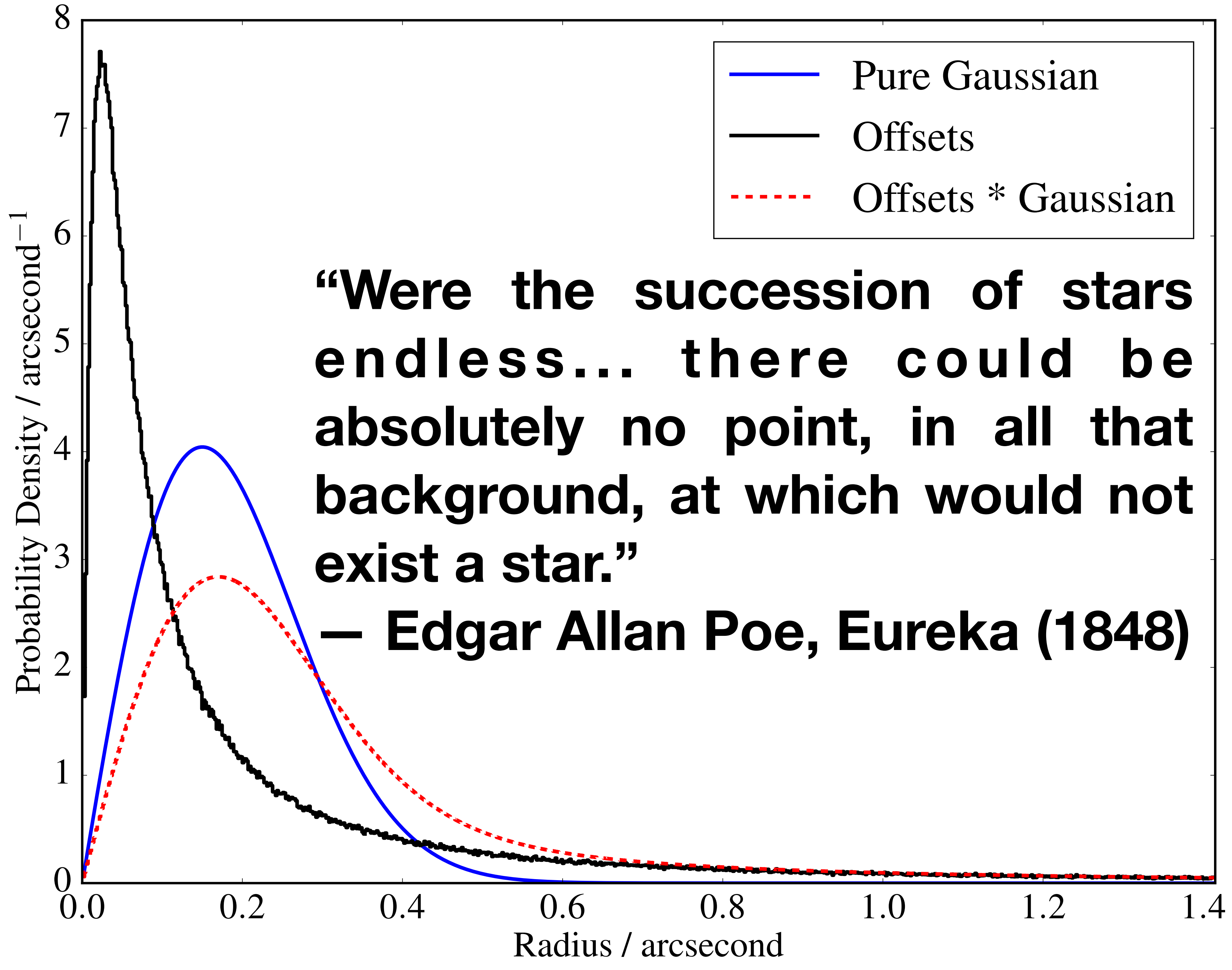




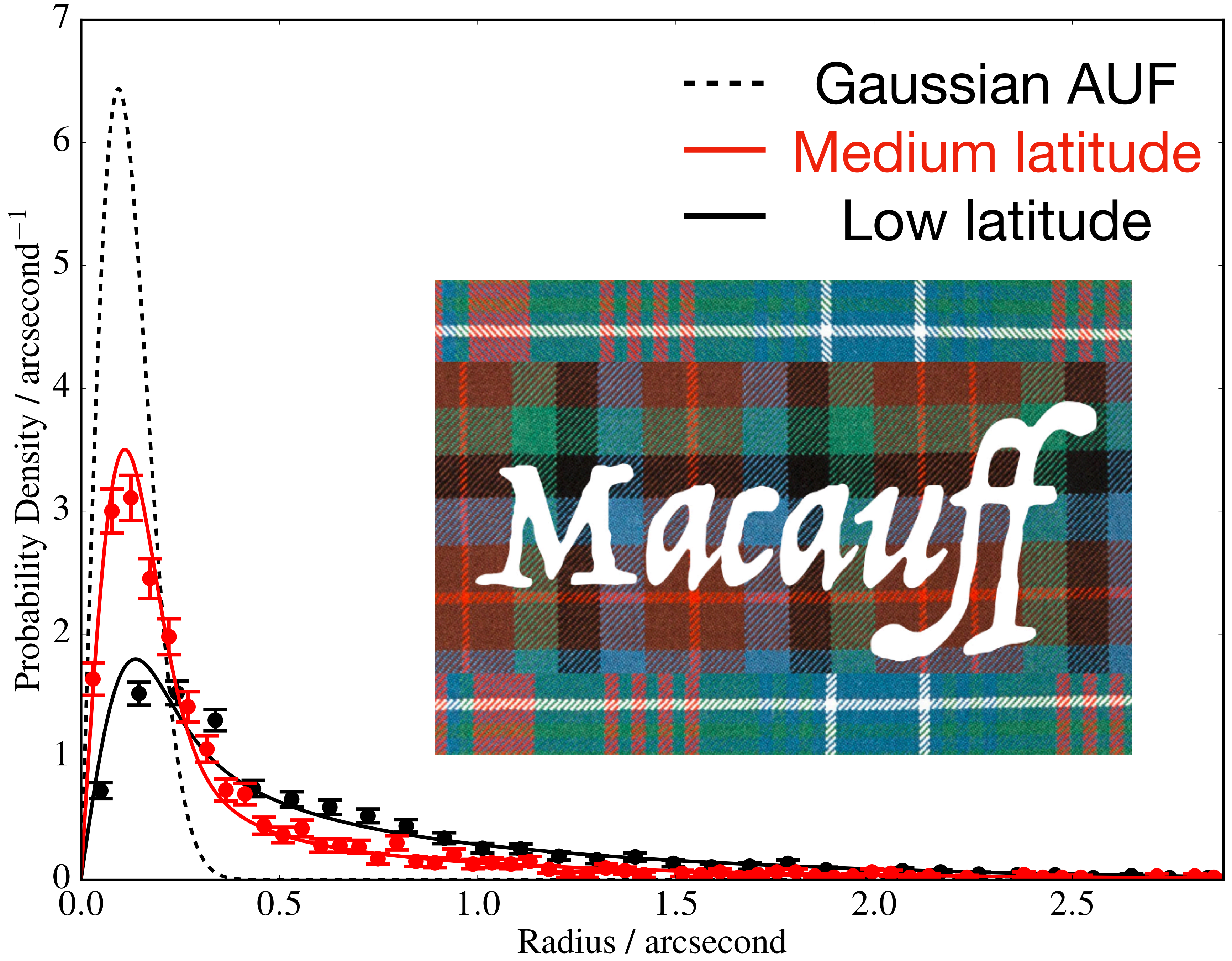

**UKD-UKD-S9**

# Astrometry in the Galactic Plane



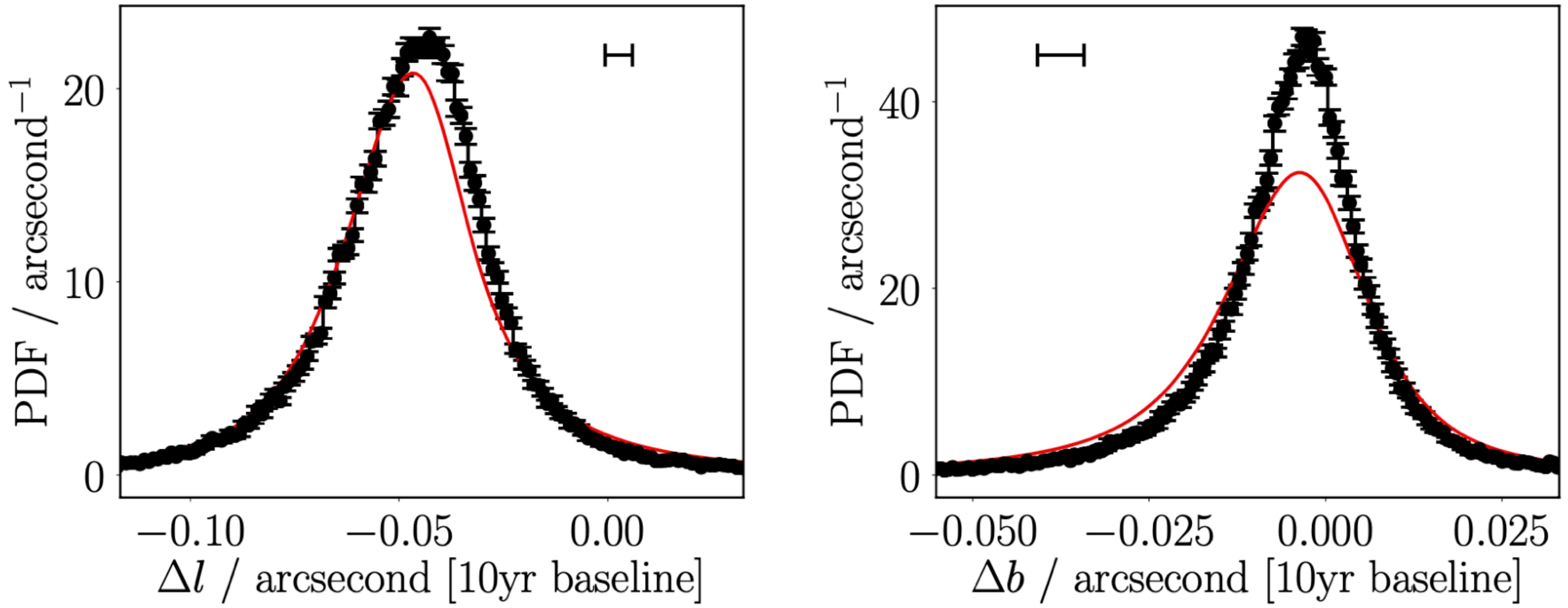

**"Were the succession of stars endless... there could be absolutely no point, in all that background, at which would not exist a star."**
**— Edgar Allan Poe, Eureka (1848)**



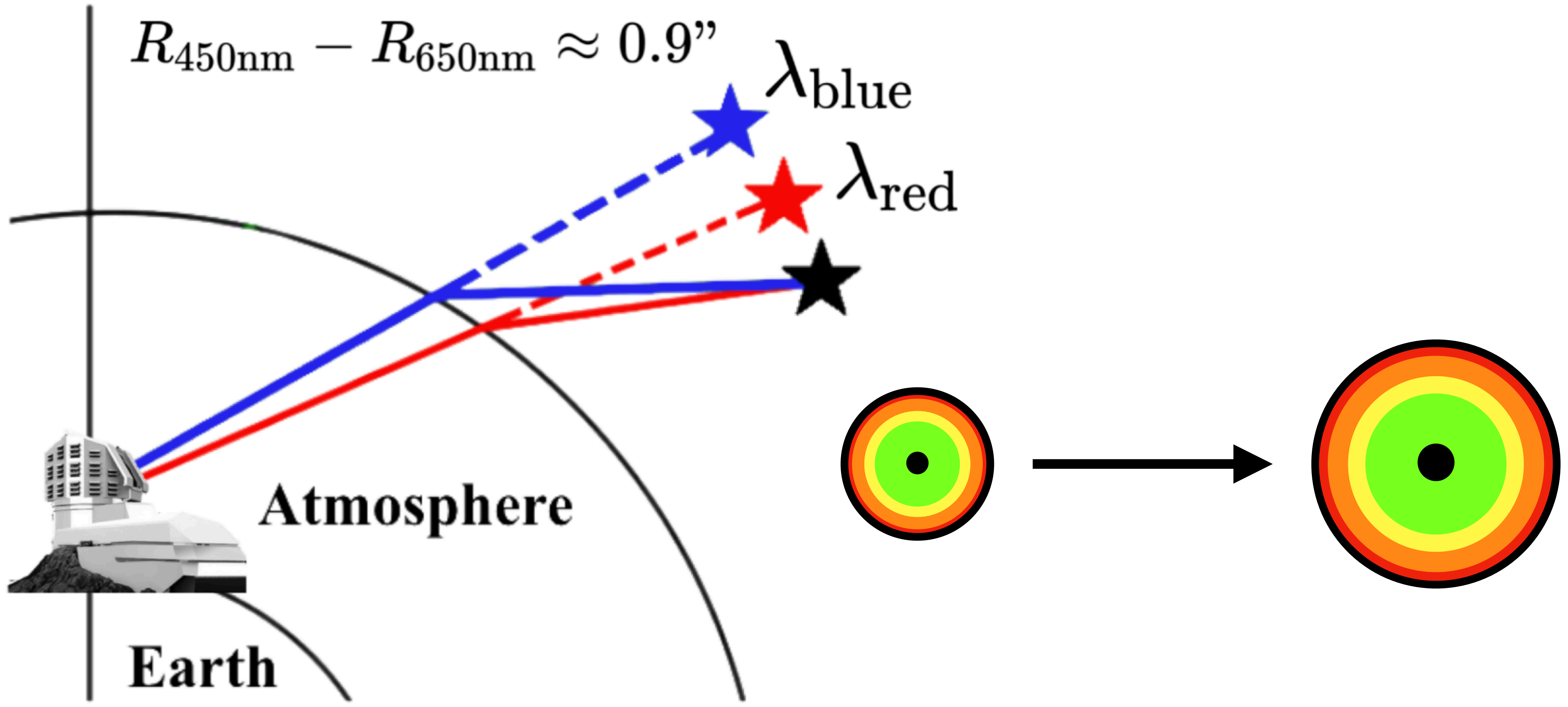

Wilson & Naylor (2017, 2018a,b)
*WISE* - Wright et al. (2010)
*Gaia* DR2 - Gaia Collaboration, Brown A. G. A., et al. (2018)

**UKD-UKD-S9**

# Astrometry in the Galactic Plane

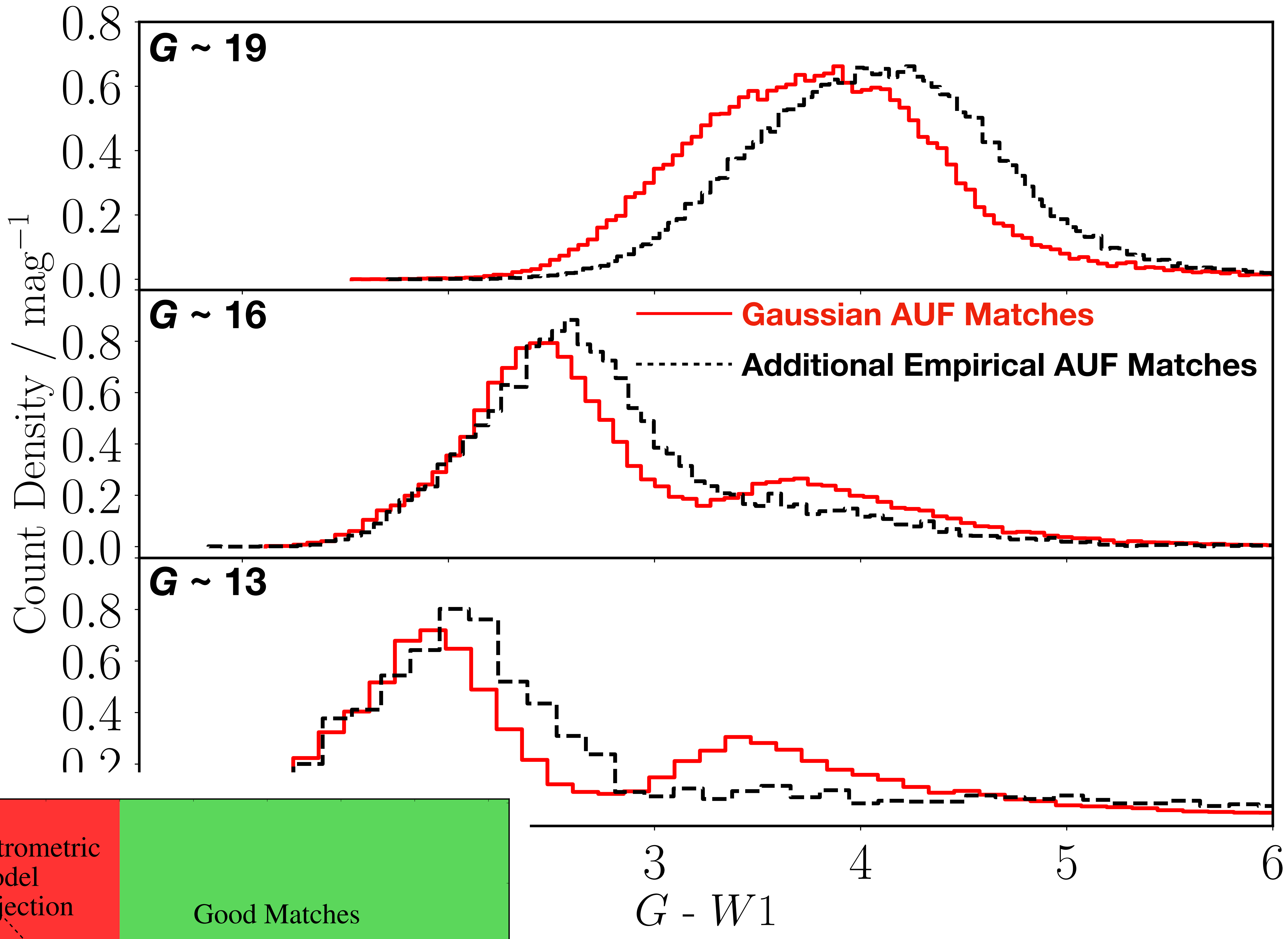


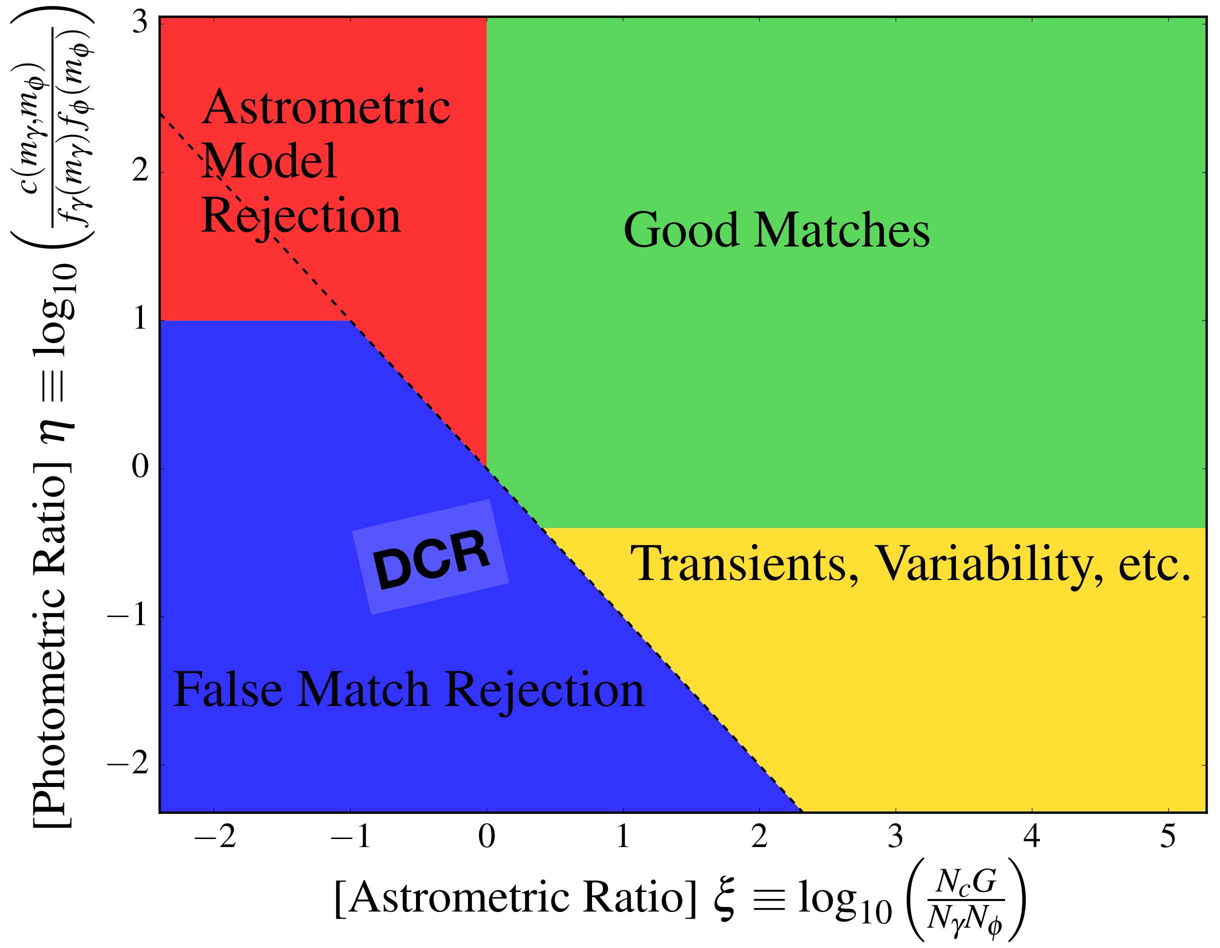

Wilson (2023, RASTI, 2, 1)
*Gaia* eDR3 - Gaia Collaboration et al. (2021)




Lee et al. (2024)

**UKD-UKD-S9**

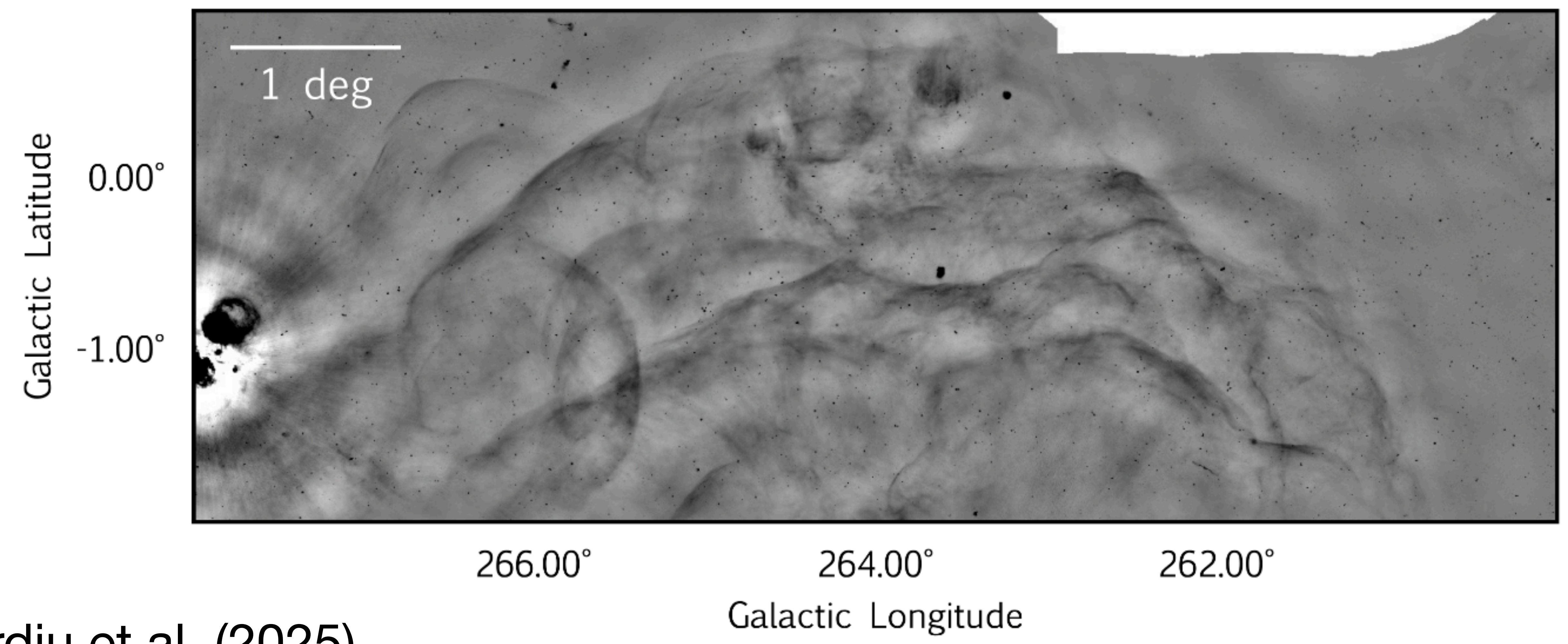


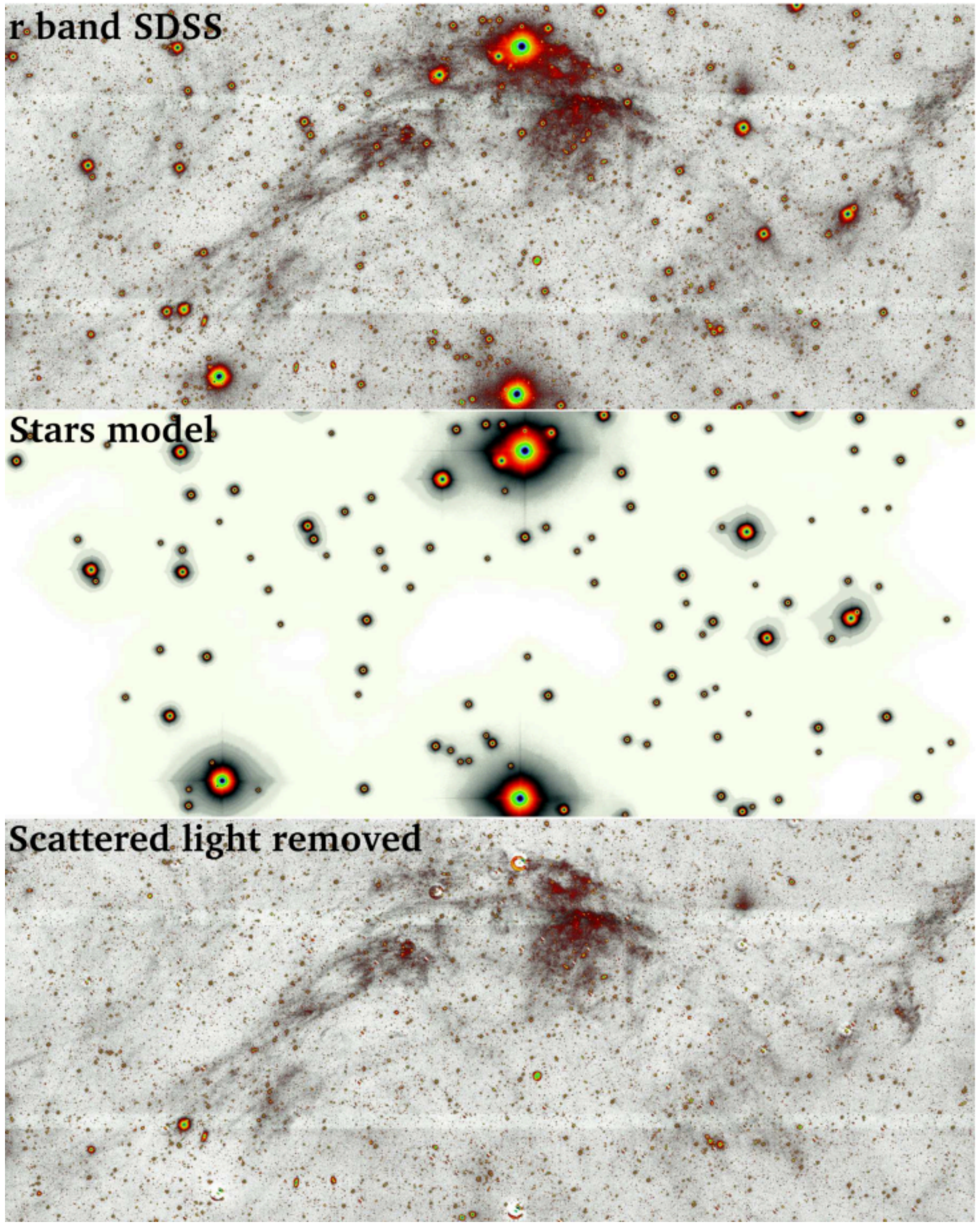

Wilson & Naylor (2018b)

# The Dusty Interstellar Medium

**With its 10-square-degree field of view, Rubin will get excellent views of the large-scale Galactic ISM.**
**But how do you accurately extract fluxes/magnitudes for these structures with stars and galaxies overlaid?**




Bordiu et al. (2025)

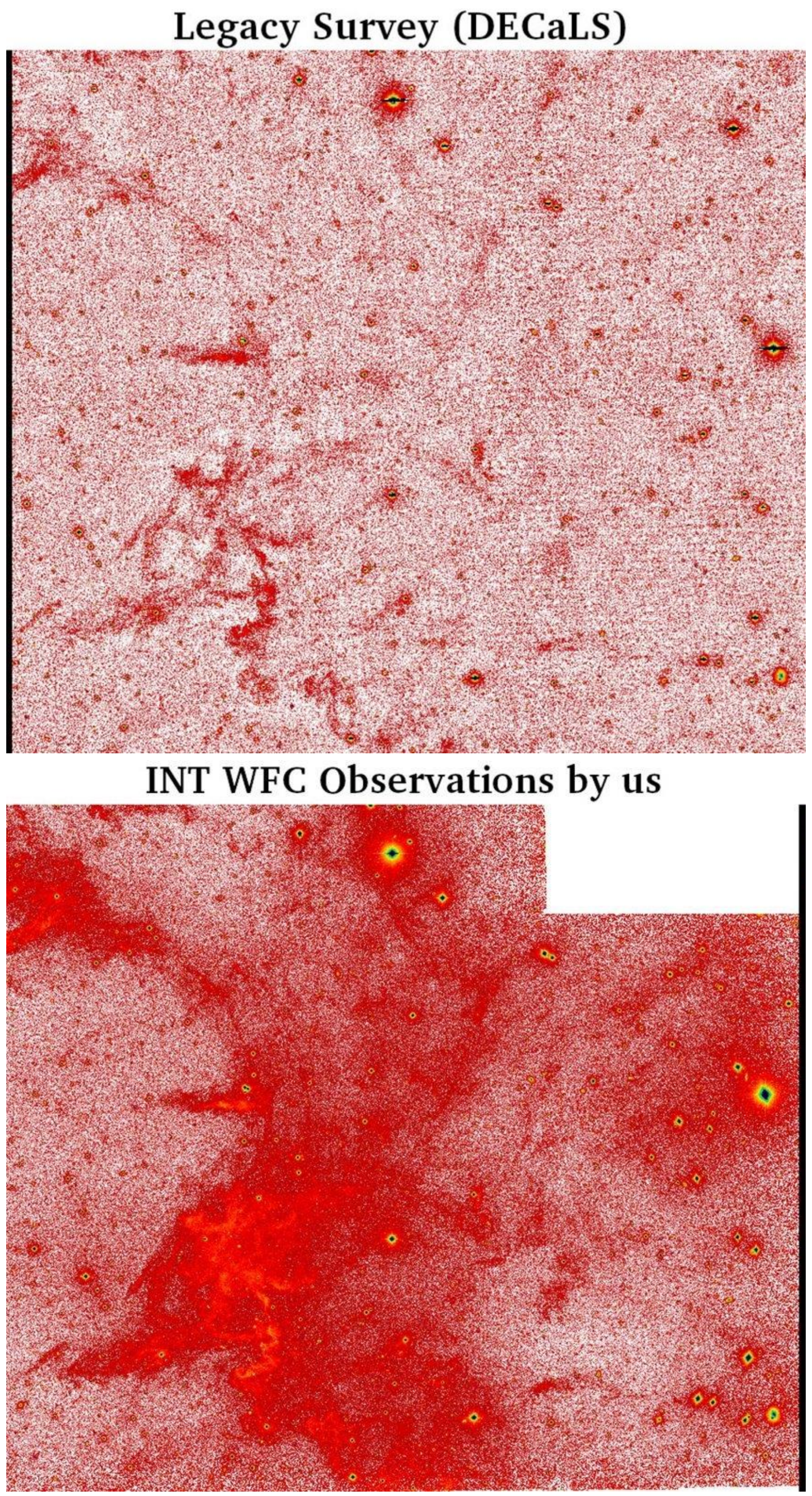



Román, Trujillo & Montes (2020)

**ITA-INA-S5**

# LSB: Night-sky subtraction

- "Background": anything unwanted in images
- Background-subtraction: mask flux to keep, model and subtract the rest
  - Goal is to reach noise limit w/o structure (e.g. residual sky gradients)
- **Top-right:** image processed assuming ISM emission ("cirrus") is background
- **Bottom-right:** same field processed using low-surface-brightness optimised pipeline
- Producing images like the bottom right for LSST is the LSB Working Group's goal




Courtesy: Javier Román

Aaron Watkins (University of Hertfordshire)

**UKD-UKD-S6**

# LSB: Software Efforts

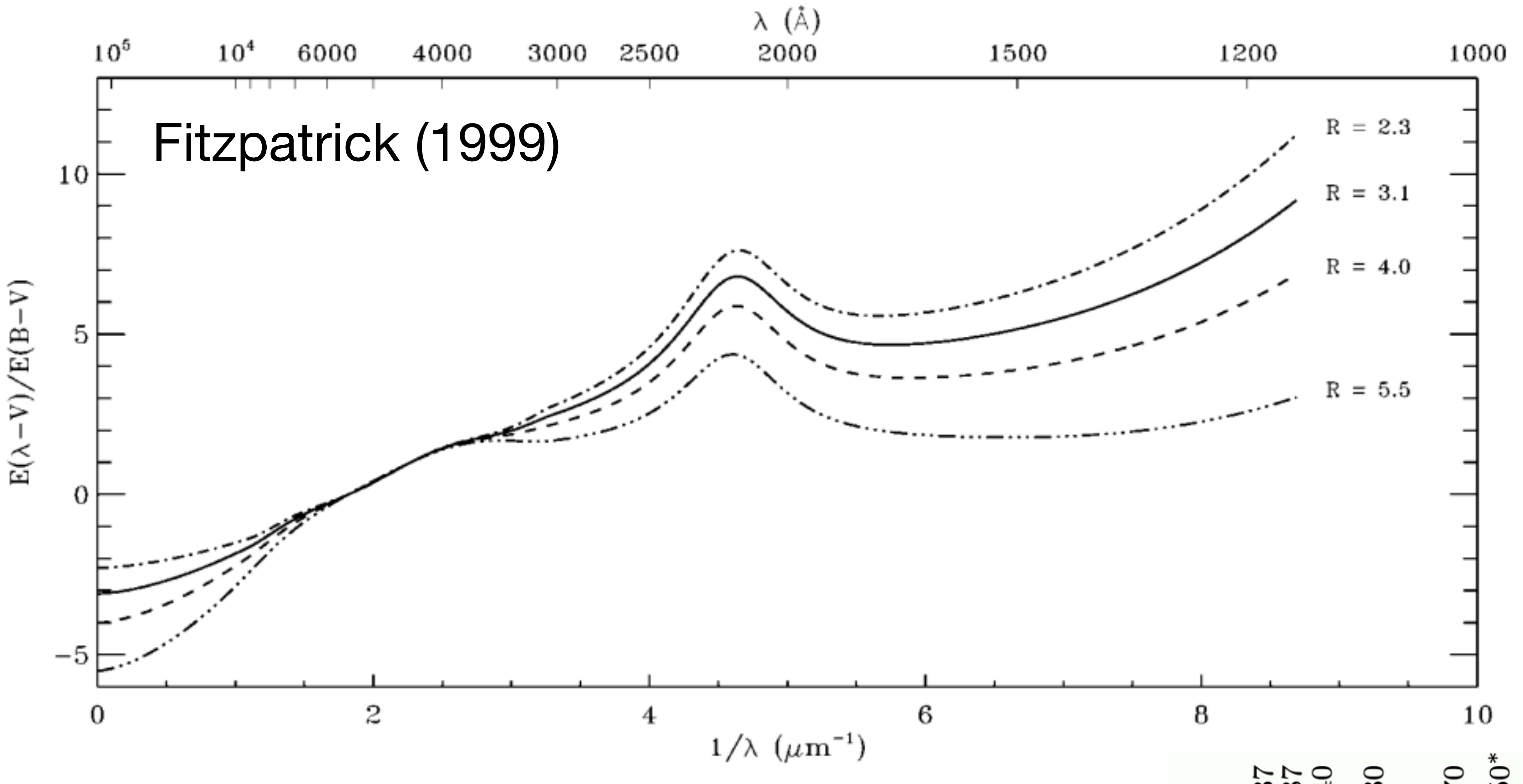
- Working with skyCorrection.py
  - https://github.com/lsst/pipe_tasks/blob/main/python/lsst/pipe/tasks/skyCorrection.py
- Three basic steps:
  - Bin whole focal plane image
  - Fit model to the binned image
  - Subtract model from image at native resolution
- LSB compliance: heavy masking + low-order model
  - Extended sources excluded from model
  - Crowded fields act like extended sources, so similar problem

Rubin first-look images: produced using an LSB-compliant pipeline

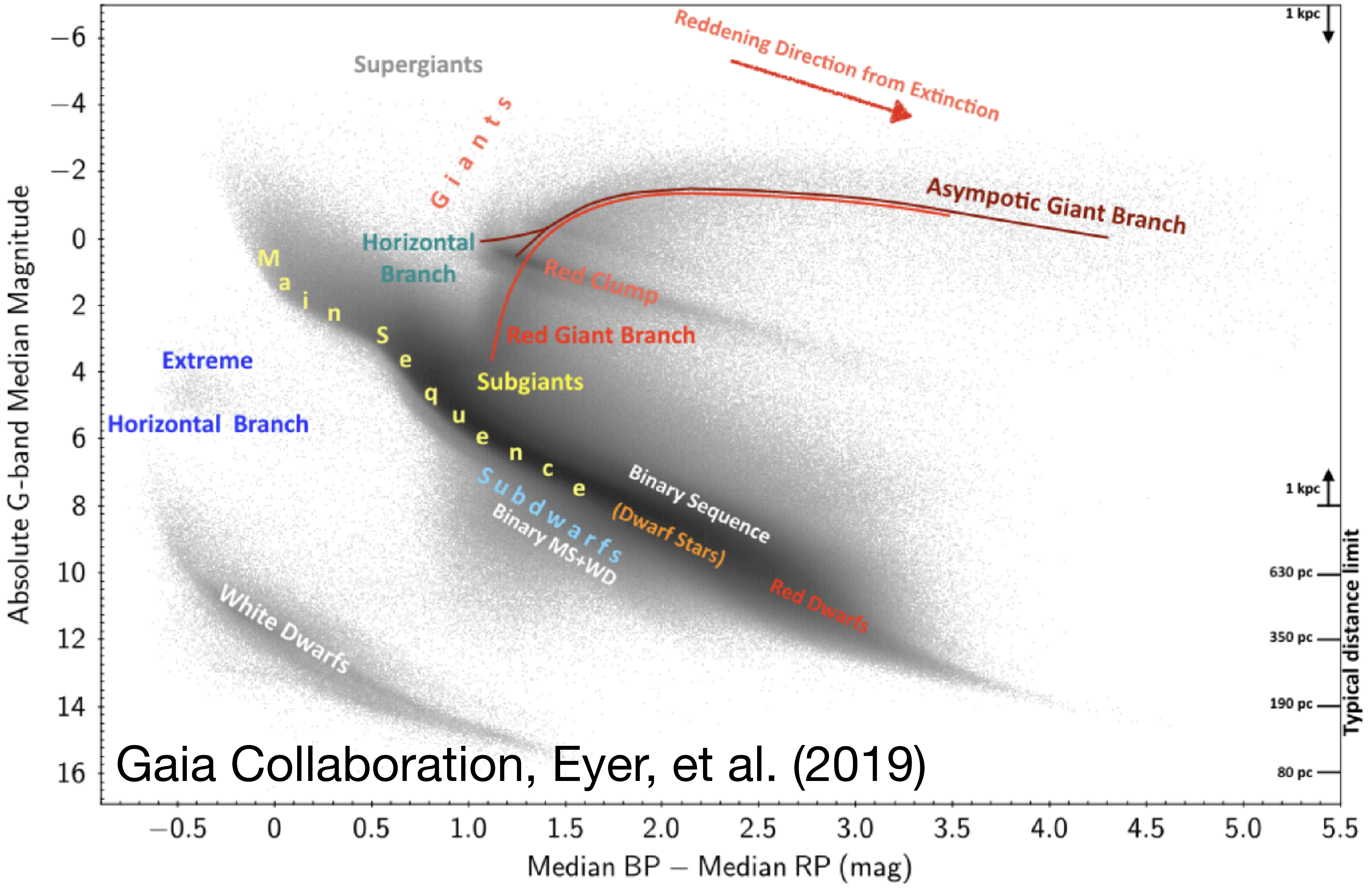
Aaron Watkins (University of Hertfordshire)

**UKD-UKD-S6**

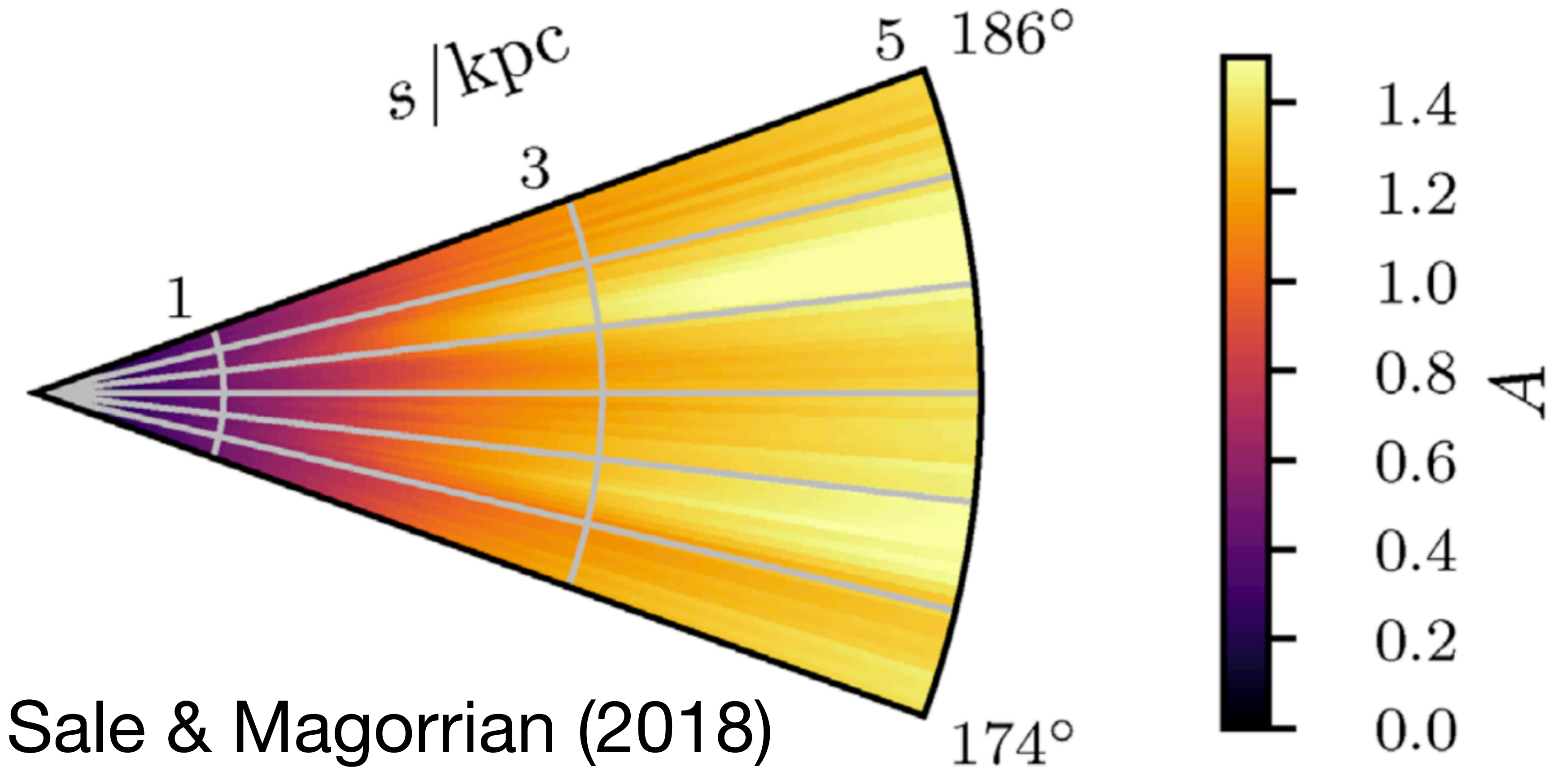
# Dust and Extinction Curves



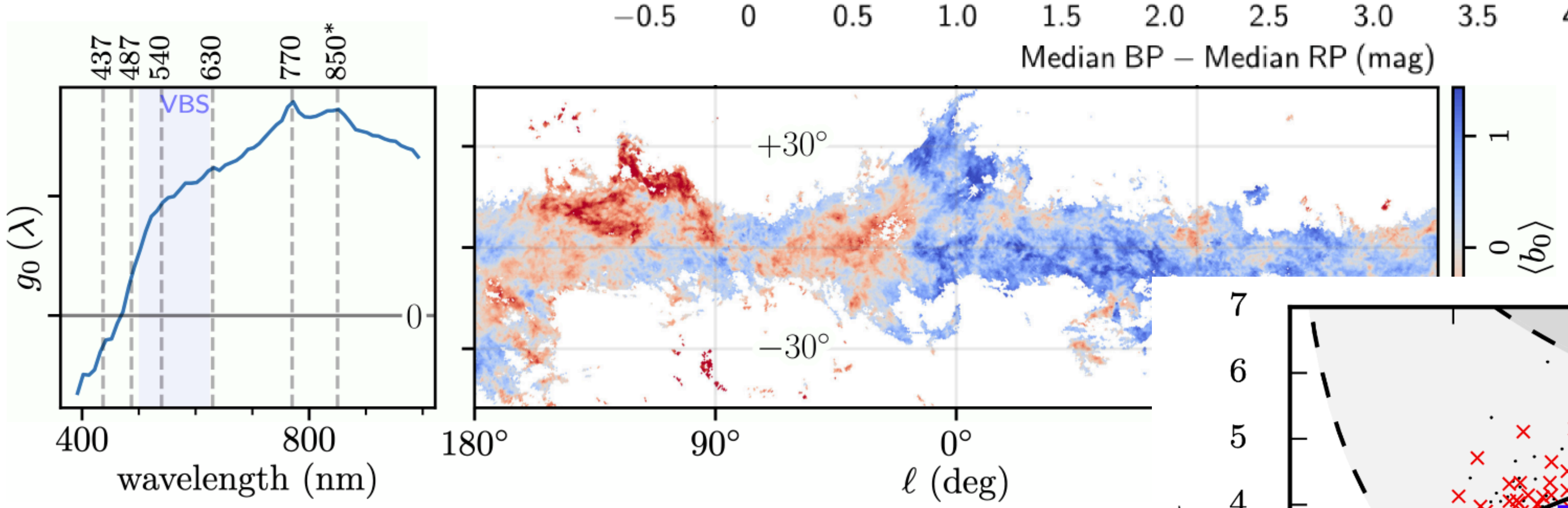

Fitzpatrick (1999)



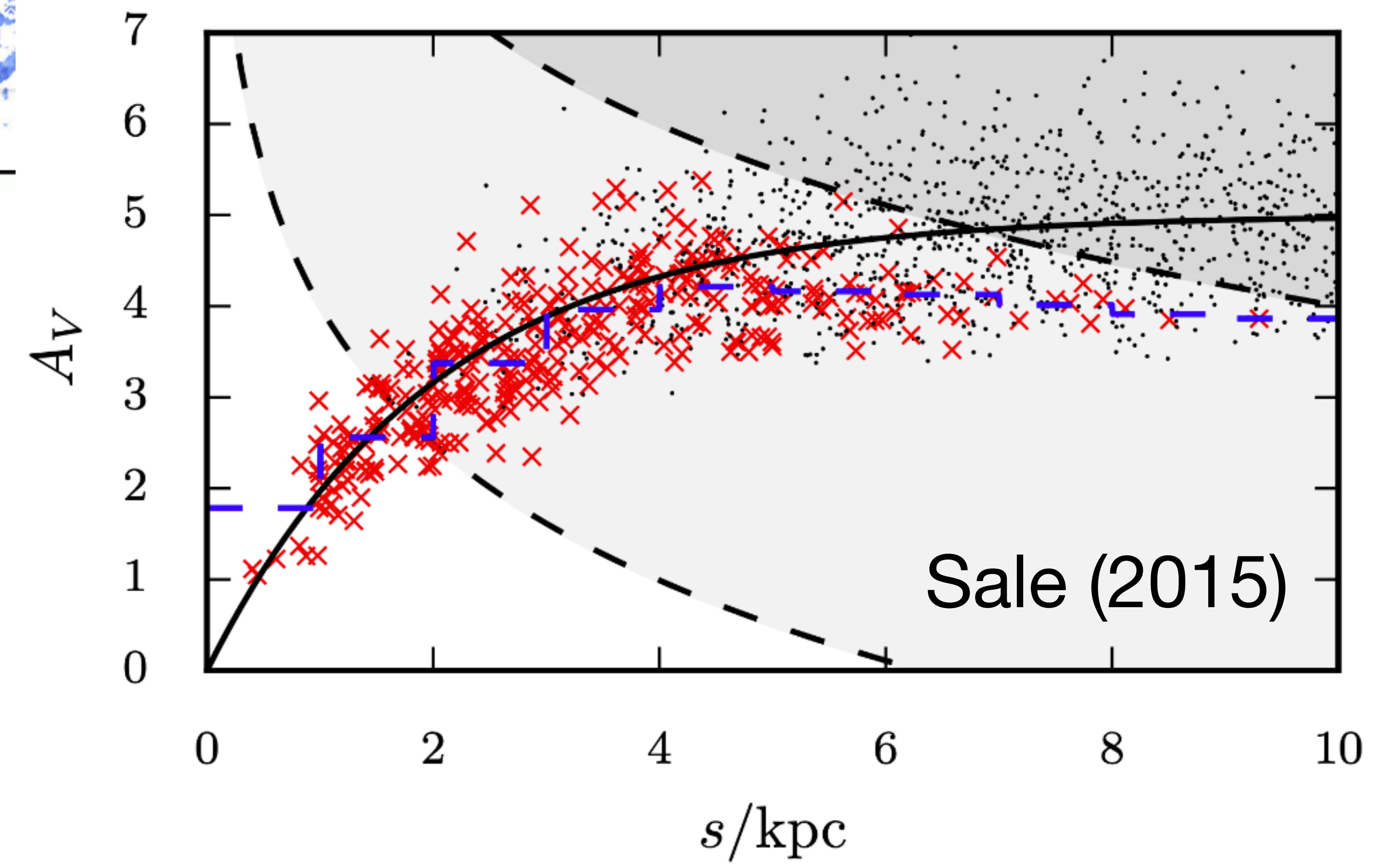

Gaia Collaboration, Eyer, et al. (2019)




Sale & Magorrian (2018)




Green, Zhang & Zhang (2025)




Sale (2015)

**???-???-???**

# Synthesis & Takeaways

*Membership application QR code*

- We very gladly welcome new members! Join us!!
- Lots of activity and interest, good international participation from early career researchers.
- Able to make lots of cross connections between SWGs and other SCs despite covering quite a broad range of topics.
- Many science questions that require software-based solutions to be answered.