



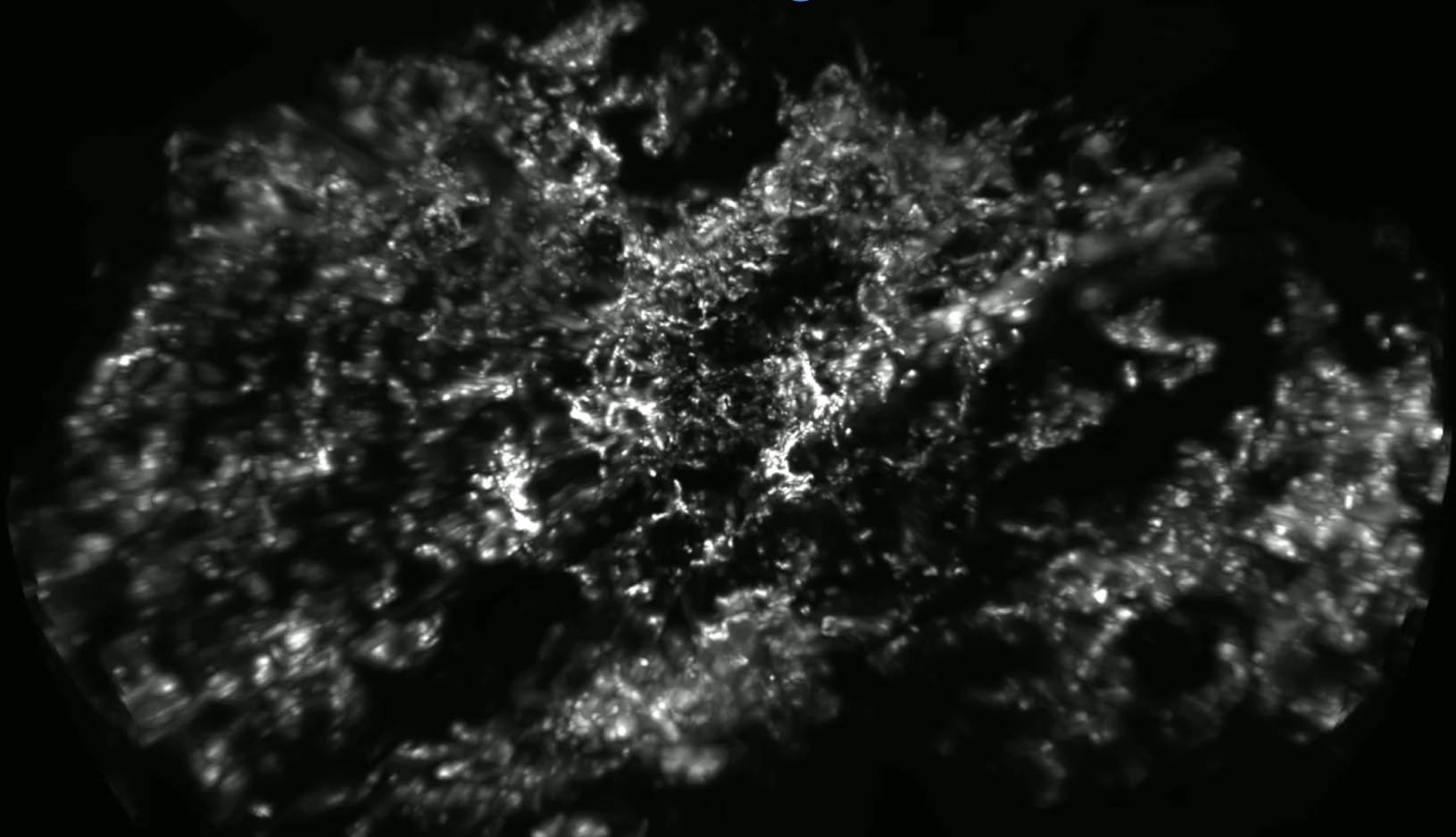
The Highest Angular Resolution 3D Dust Map

Andrew Saydjari

Hubble Fellow @ Princeton

NHFP Symposium
September 17th, 2024

How White is get here?



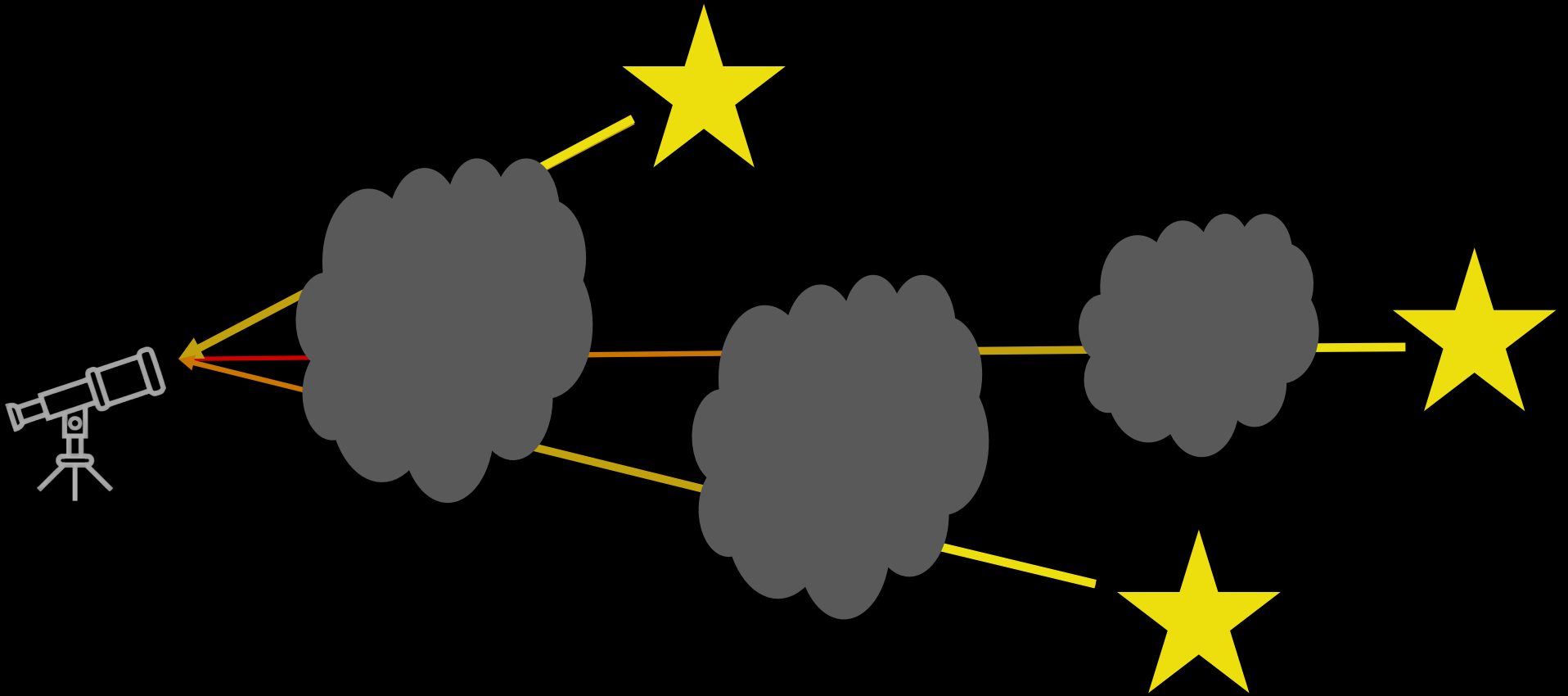


Bayestar19 (Green+2019)

~ 1/3rd of disk is missing!

VC: Greg Green

3D Dust Mapping Scheme: Star Reddenings

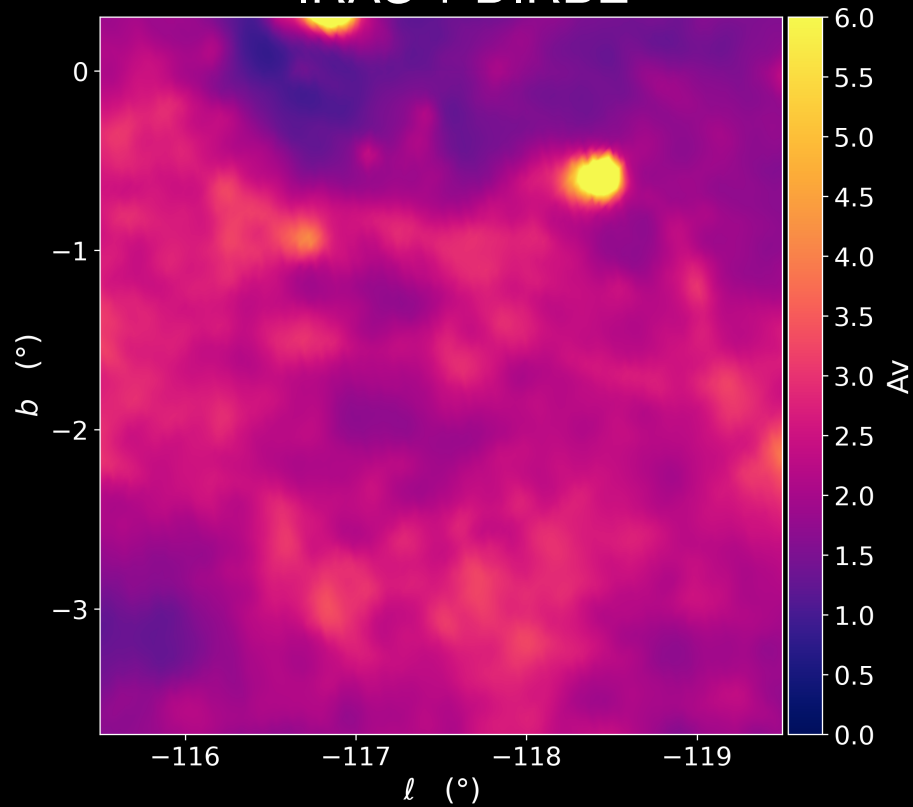


[Not to scale]

Comparing Dust Maps

Emission

IRAS + DIRBE



Wavelength: $100 \mu\text{m}$

Citation: Schlegel+1998

Coverage: 100%

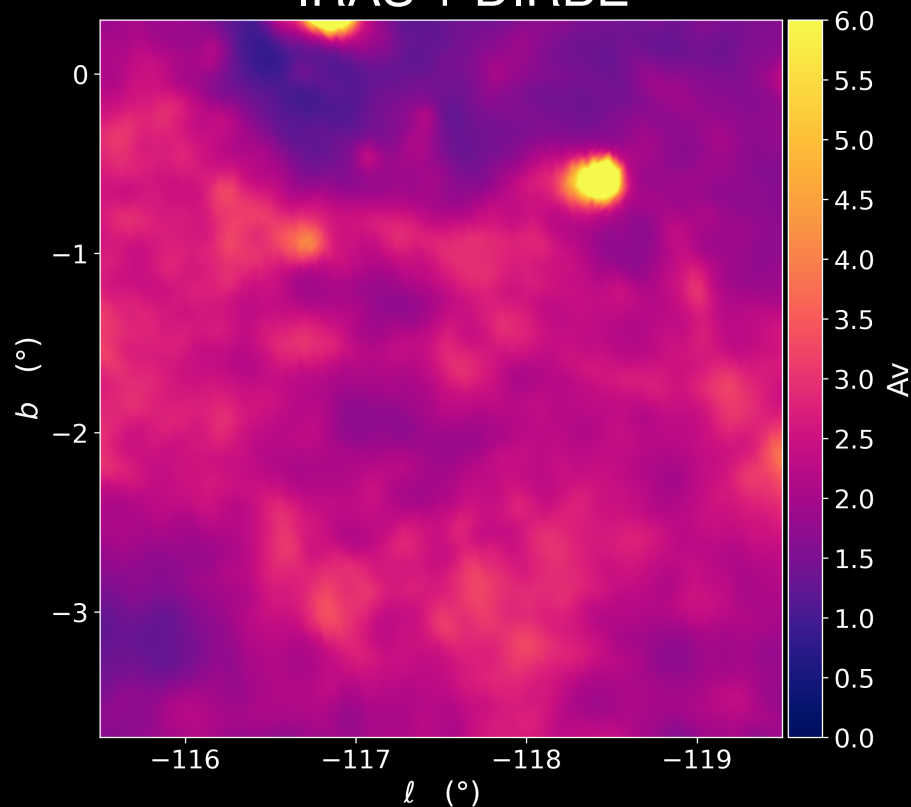
PSF FWHM: $6.1'$

Max Distance: --

Comparing Dust Maps

Emission

IRAS + DIRBE

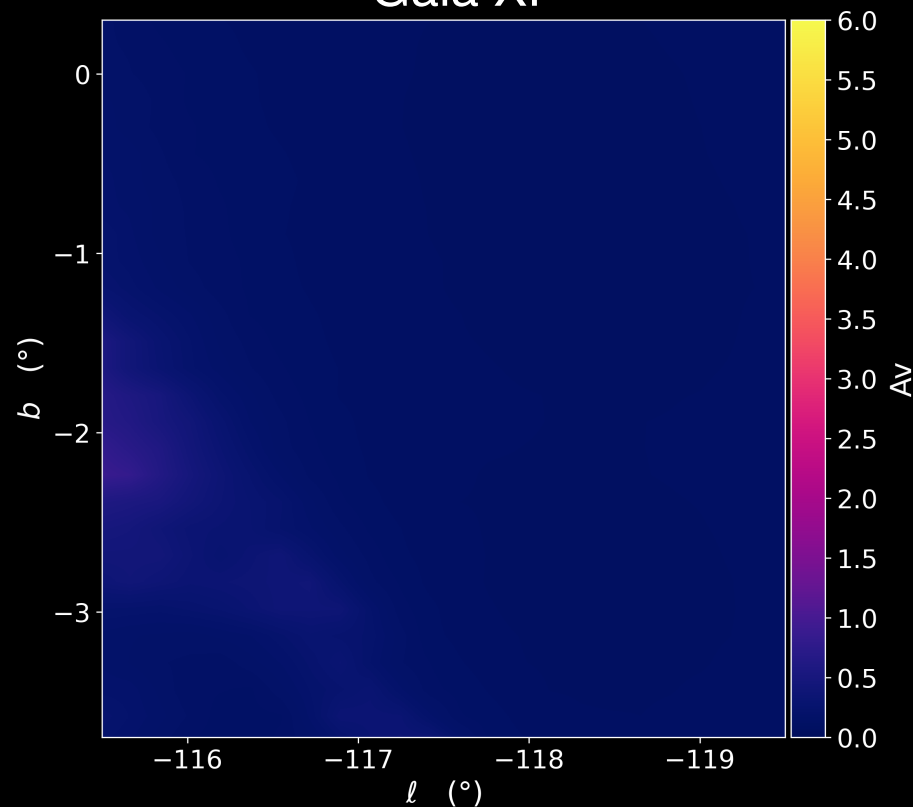


Wavelength: $100 \mu\text{m}$
Citation: Schlegel+1998

Coverage: 100%
PSF FWHM: $6.1'$
Max Distance: --

Gaia XP

Extinction



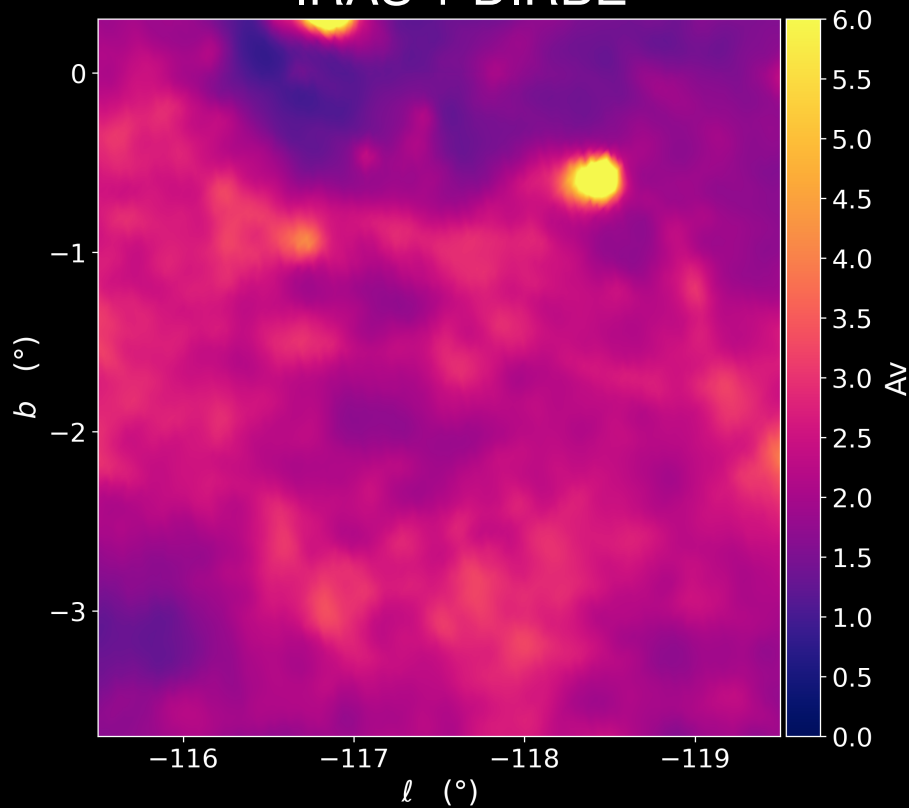
Wavelength: Optical
Citation: Edenhofer+2023
[incl. [Saydjari](#)]

Coverage: 100%
PSF FWHM: ($\sim 14'$)
Max Distance: 1.2 kpc

Comparing Dust Maps

Emission

IRAS + DIRBE

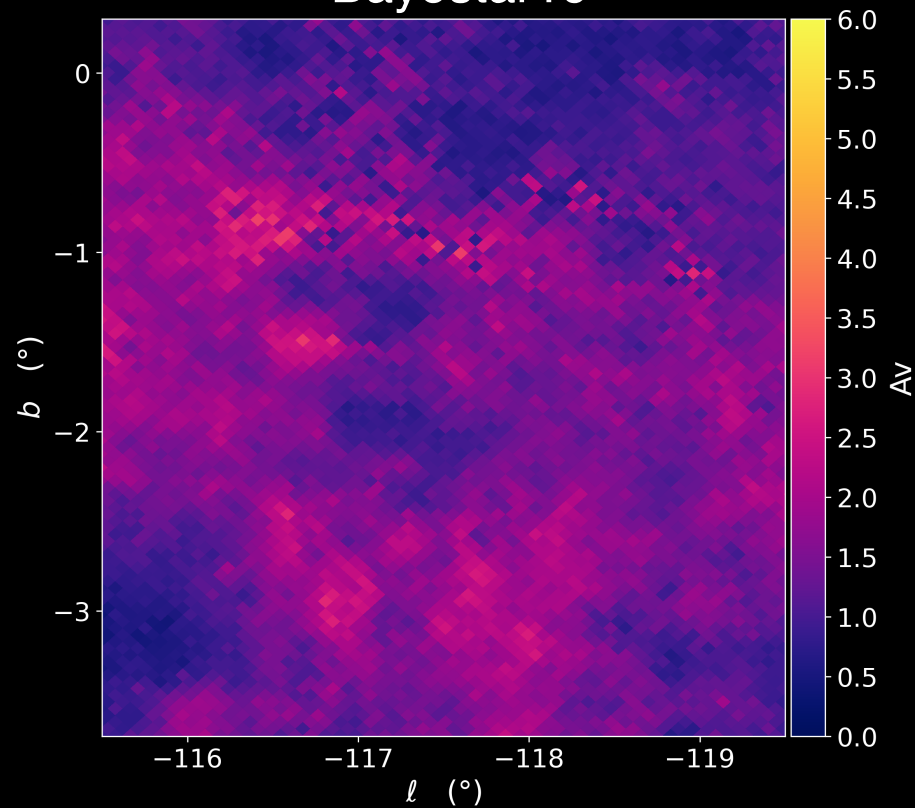


Wavelength: $100 \mu\text{m}$
Citation: Schlegel+1998

Coverage: 100%
PSF FWHM: $6.1'$
Max Distance: --

Bayestar19

Extinction



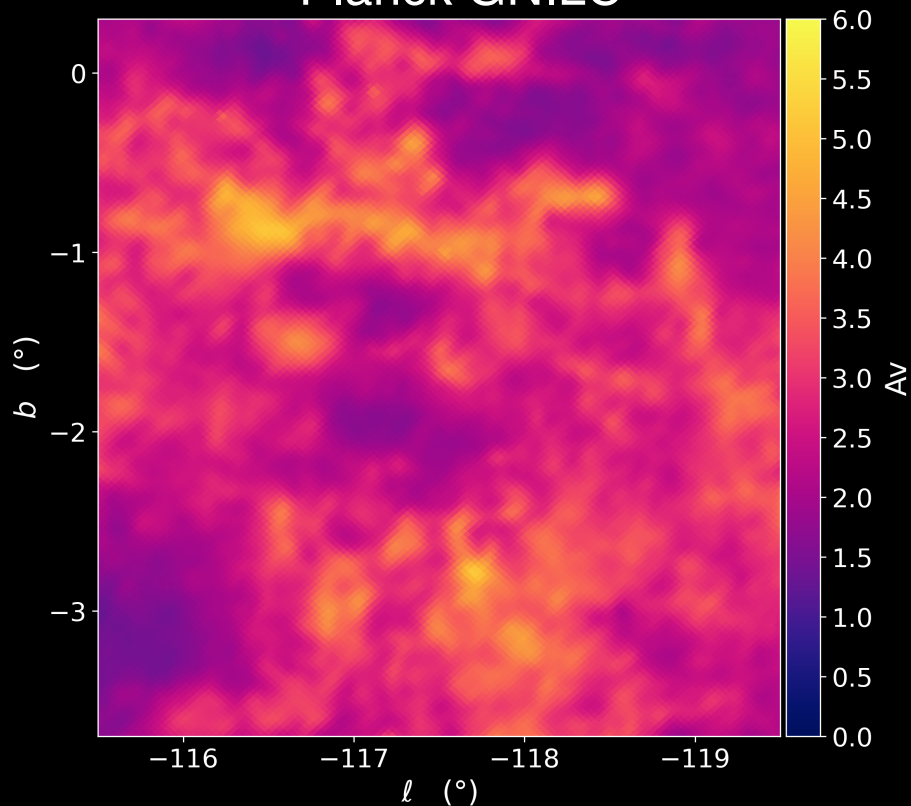
Wavelength: Optical-NIR
Citation: Green+2019

Coverage: 75%
PSF FWHM: ($\sim 3'.4$)
Max Distance: ~ 6 kpc

Comparing Dust Maps

Emission

Planck GNILC



Wavelength: $850 \mu\text{m}$ (353 GHz)

Citation: Planck Collab+2016

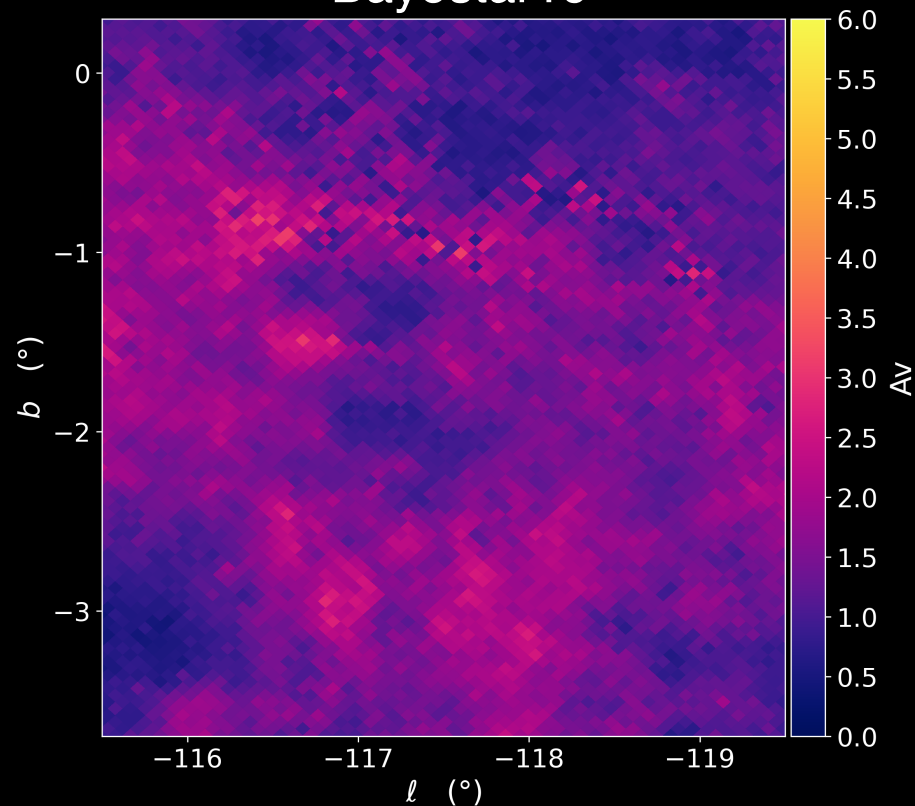
Coverage: 100%

PSF FWHM: $\sim 5'$

Max Distance: --

Bayestar19

Extinction



Wavelength: Optical-NIR

Citation: Green+2019

Coverage: 75%

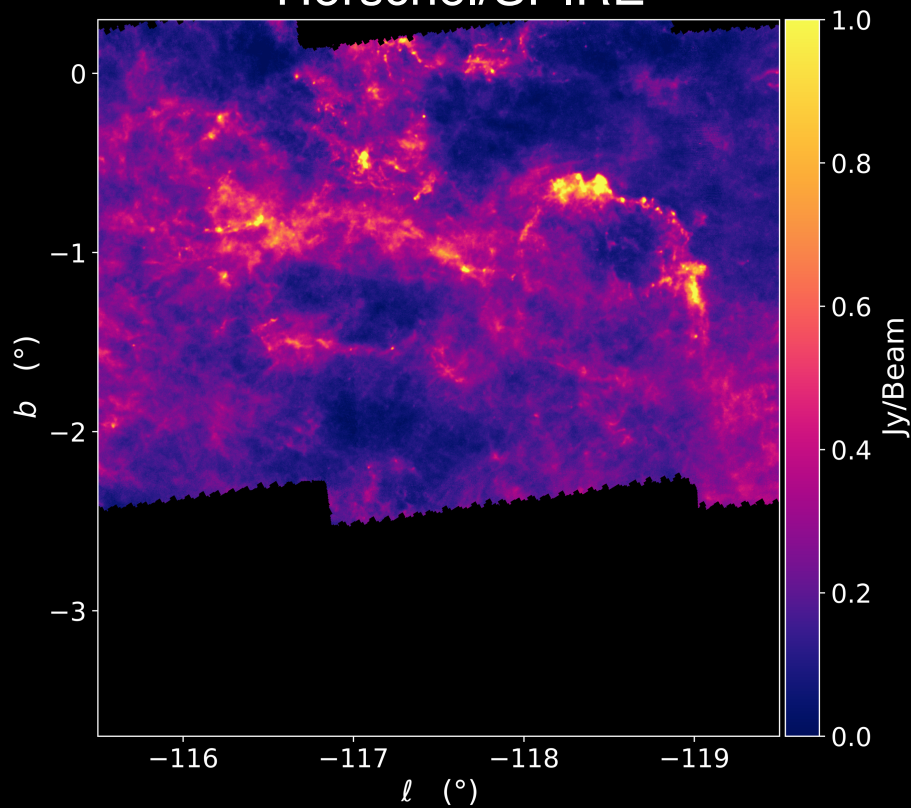
PSF FWHM: ($\sim 3'.4$)

Max Distance: ~ 6 kpc

Comparing Dust Maps

Emission

Herschel/SPIRE

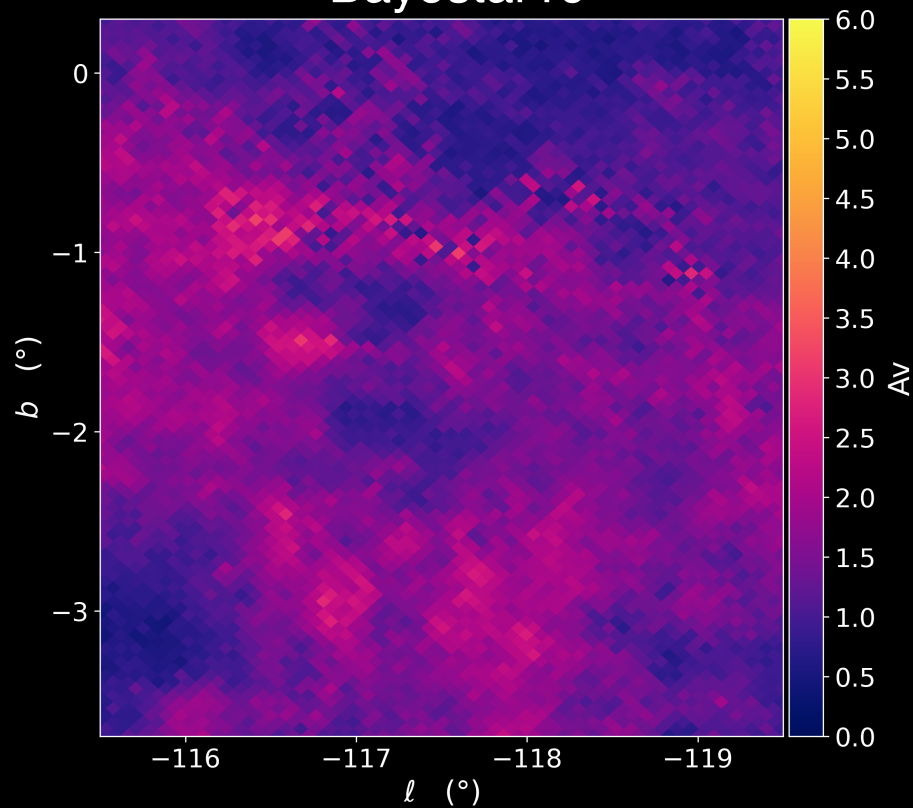


Wavelength: $500 \mu\text{m}$
Citation: Griffin+2010

Coverage: $\sim 2\%$
PSF FWHM: $36.6''$
Max Distance: --

Bayestar19

Extinction



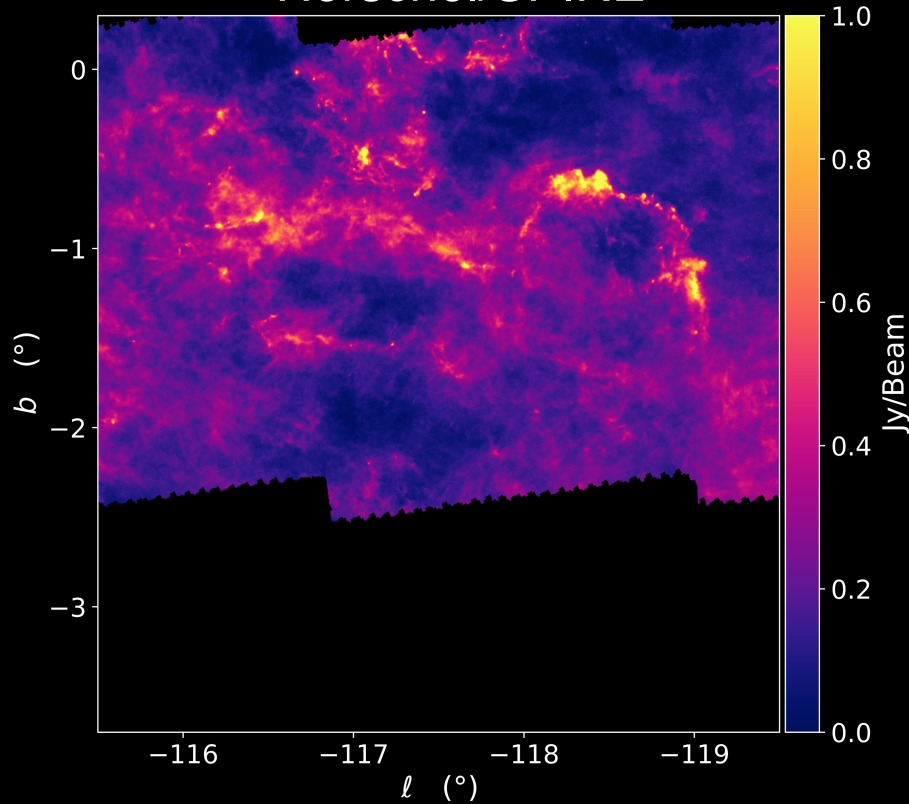
Wavelength: Optical-NIR
Citation: Green+2019

Coverage: 75%
PSF FWHM: ($\sim 3'.4$)
Max Distance: ~ 6 kpc

Comparing Dust Maps

Emission

Herschel/SPIRE

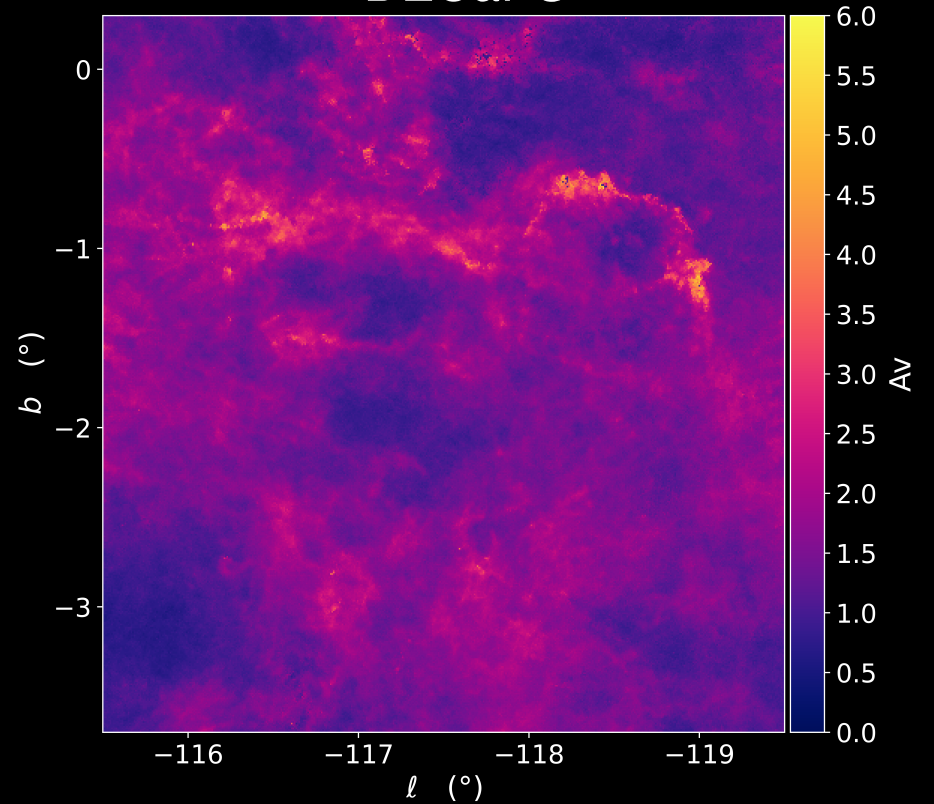


Wavelength: $500 \mu\text{m}$
Citation: Griffin+2010

Coverage: $\sim 2\%$
PSF FWHM: $36.6''$
Max Distance: --

DECaPS

Extinction



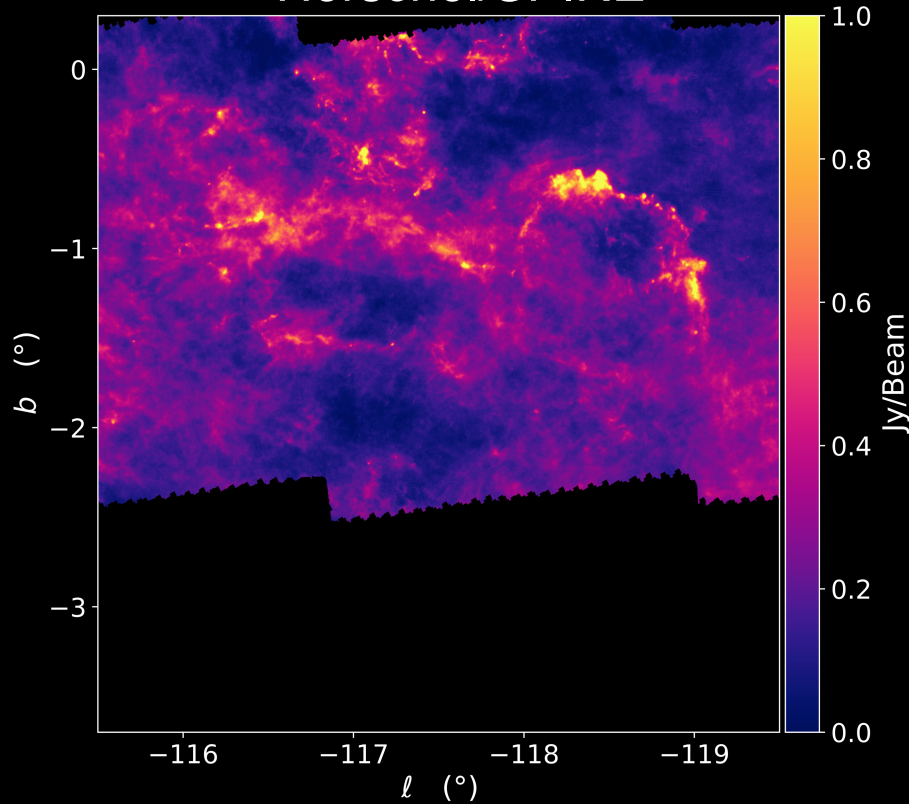
Wavelength: Optical-NIR-IR
Citation: Zucker/Saydjari/Speagle+2024

Coverage: 6.5%
PSF FWHM: $1'.07$
Max Distance: ~ 10 kpc

But wait, DECaPS is 3D!

Emission

Herschel/SPIRE

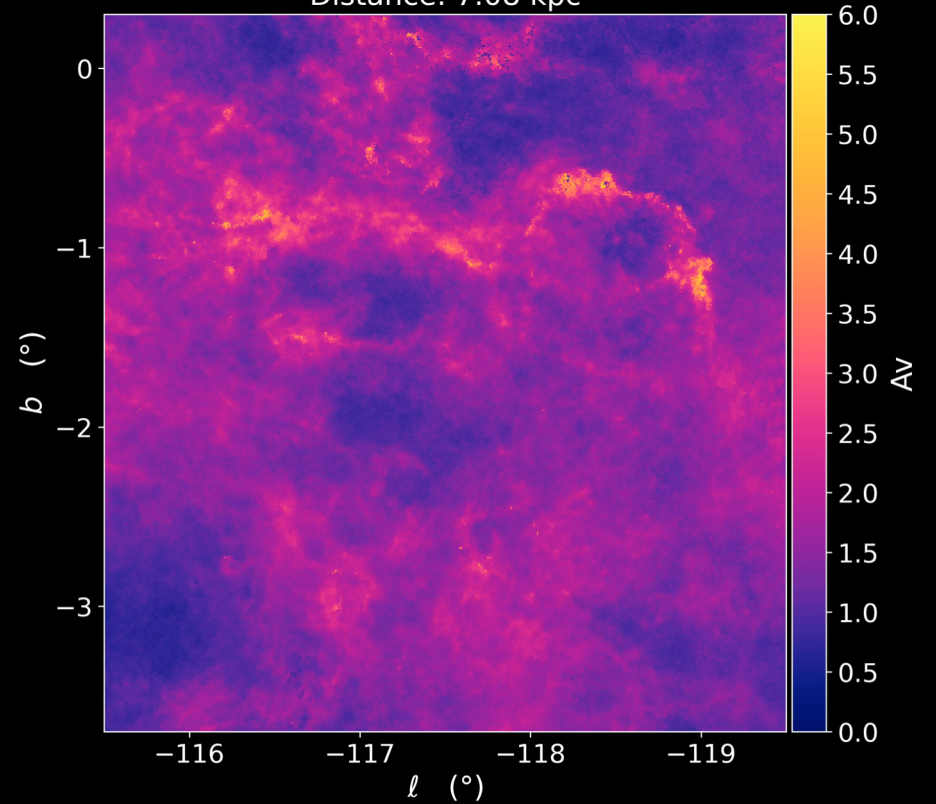


Wavelength: $500 \mu\text{m}$
Citation: Griffin+2010

Coverage: $\sim 2\%$
PSF FWHM: $36.6''$
Max Distance: --

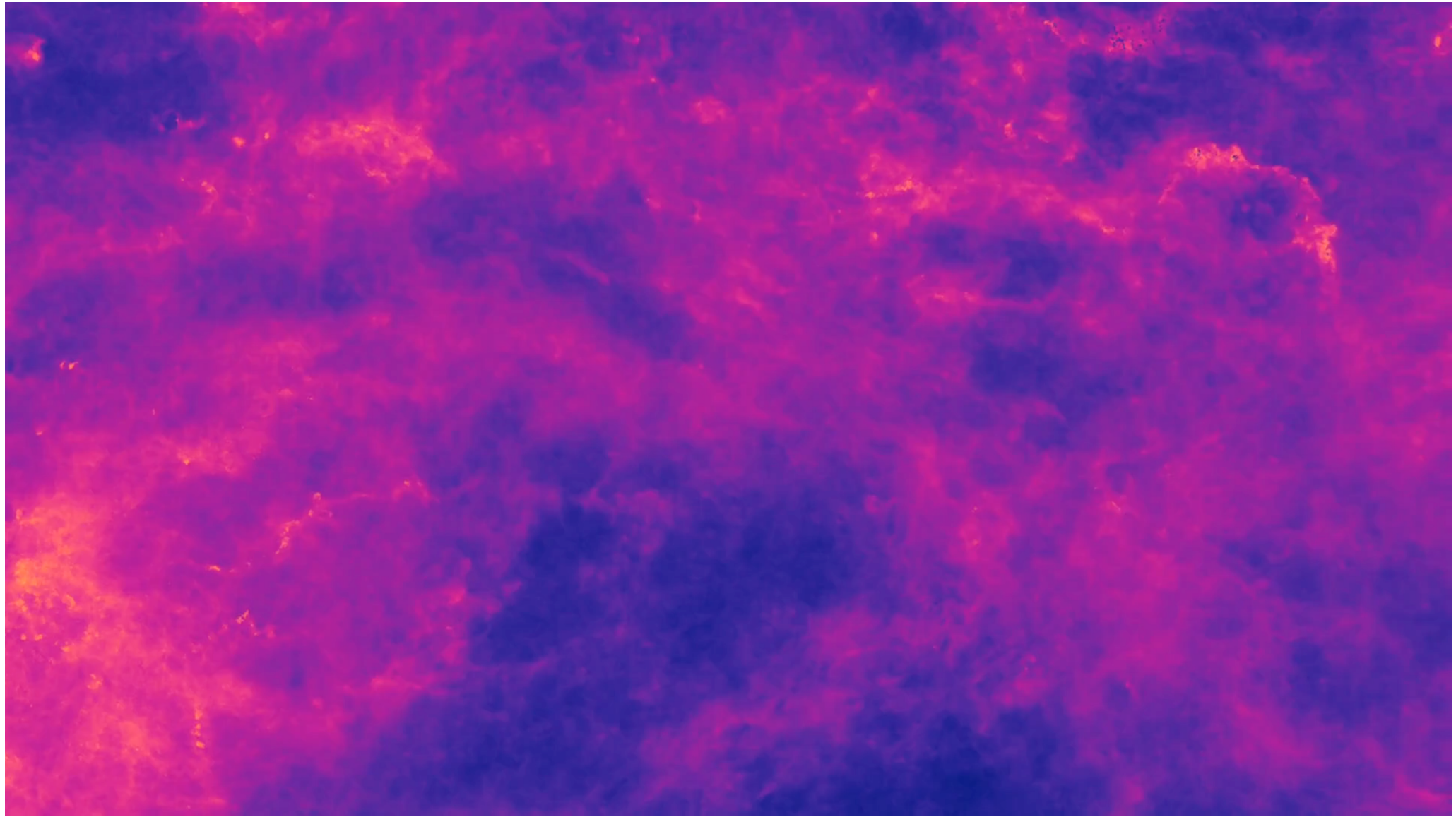
Distance: 7.08 kpc

Extinction

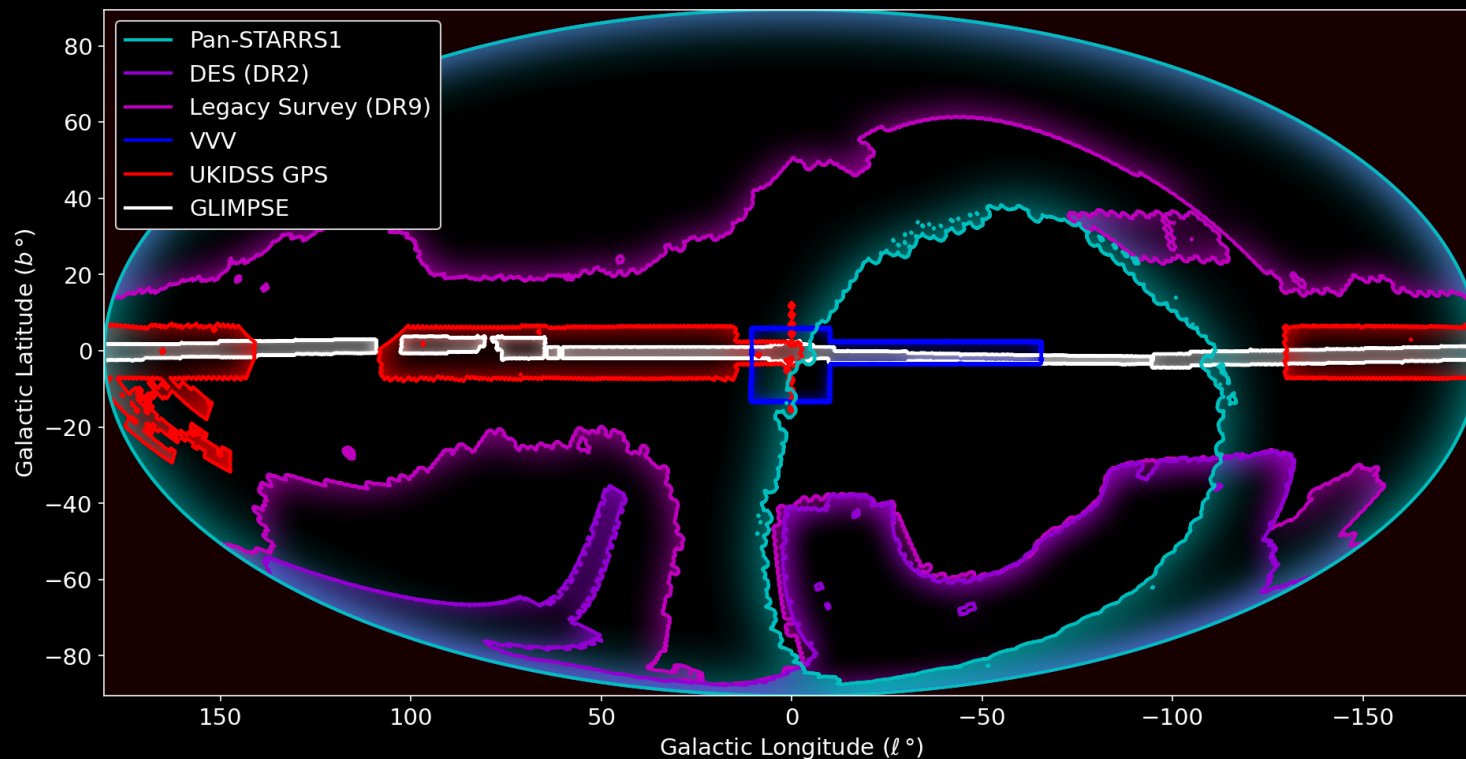


Wavelength: Optical-NIR-IR
Citation: Zucker/Saydjari/Speagle+2024

Coverage: 6.5%
PSF FWHM: $1'.07$
Max Distance: ~ 10 kpc



What is DECaPS2?



Optical-NIR Survey of Galactic Plane

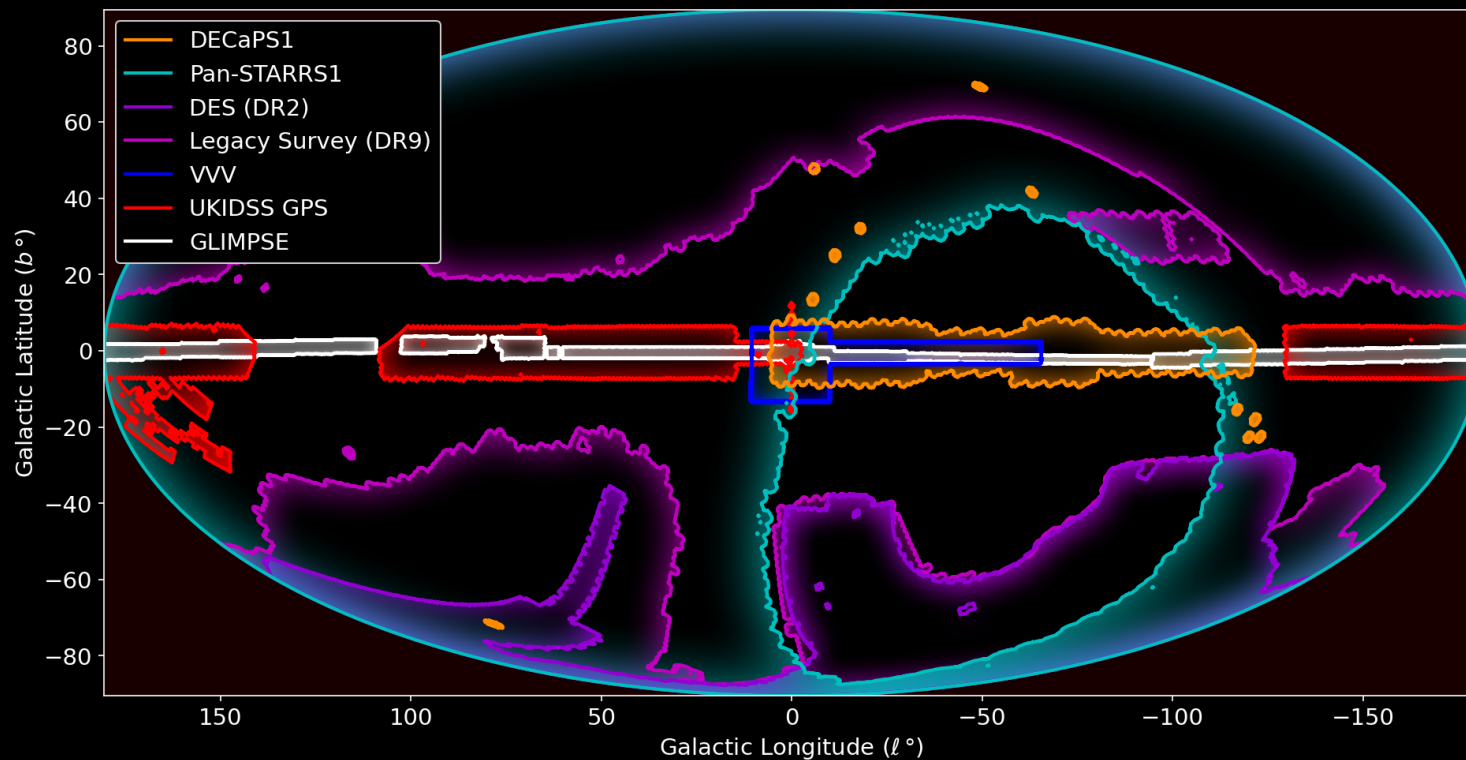
5 photometric bands (grizY)

6.5% sky (2700 deg²)

using **DECam**

Photometric depth (23.5, 22.6, 22.1, 21.6, 20.8 AB mag)

What is DECaPS2?



Optical-NIR Survey of Galactic Plane

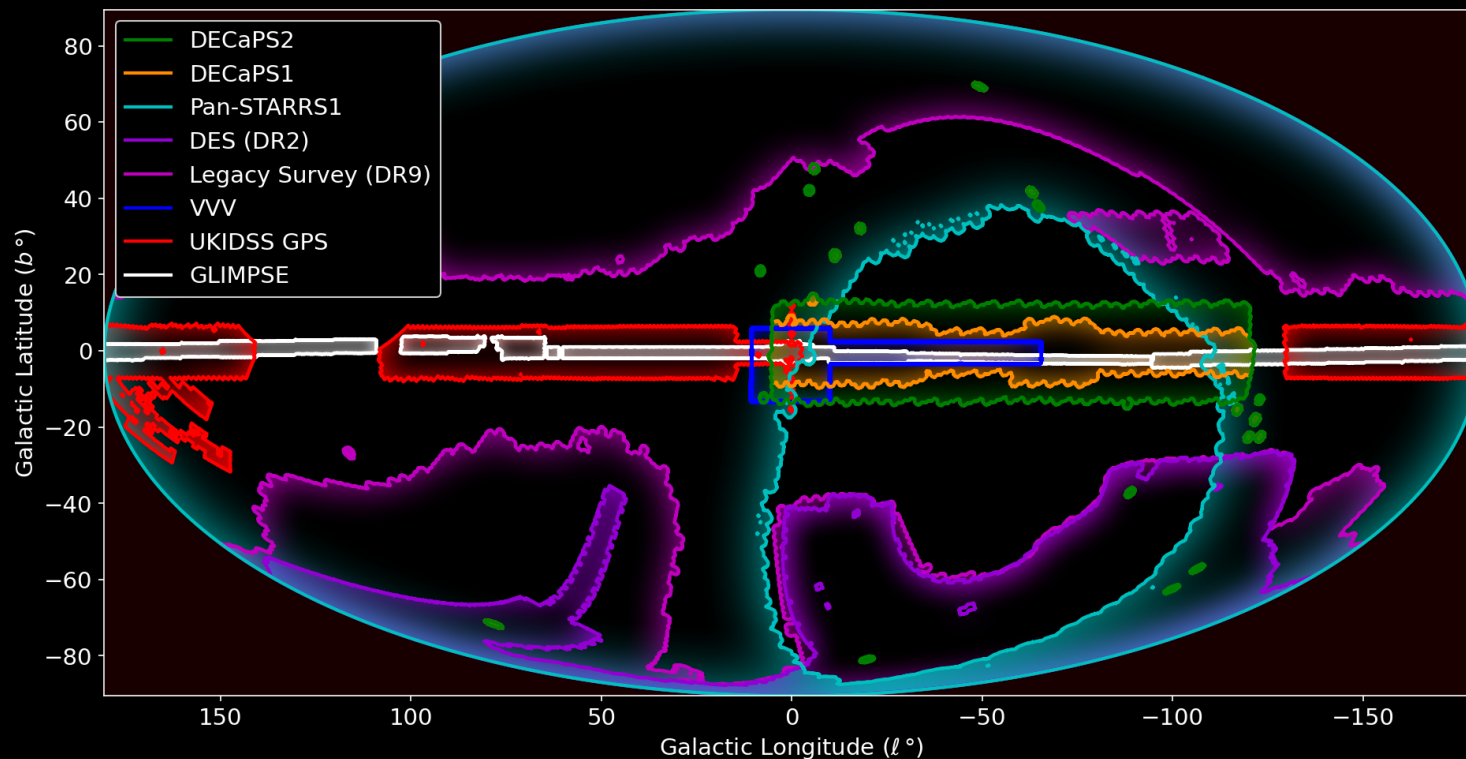
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Optical-NIR Survey of Galactic Plane

5 photometric bands (grizY)

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using **DECam**

Photometric depth (23.5, 22.6, 22.1, 21.6, 20.8 AB mag)

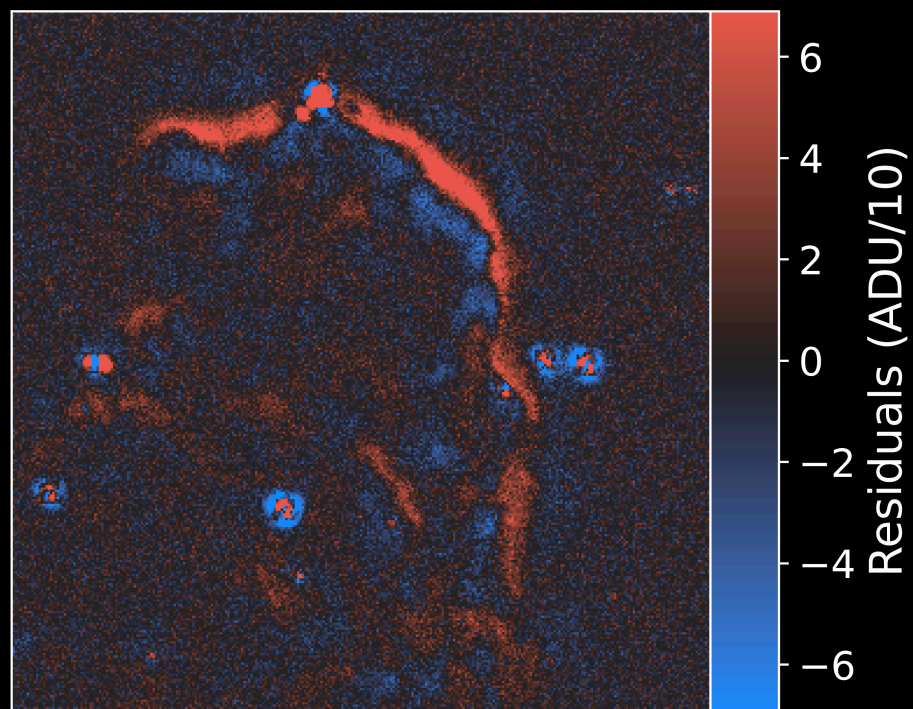
How do we separate the background?

Focus on r-band image of HII Region (CED 116)

Zoom-Out Image (zrg=RGB)



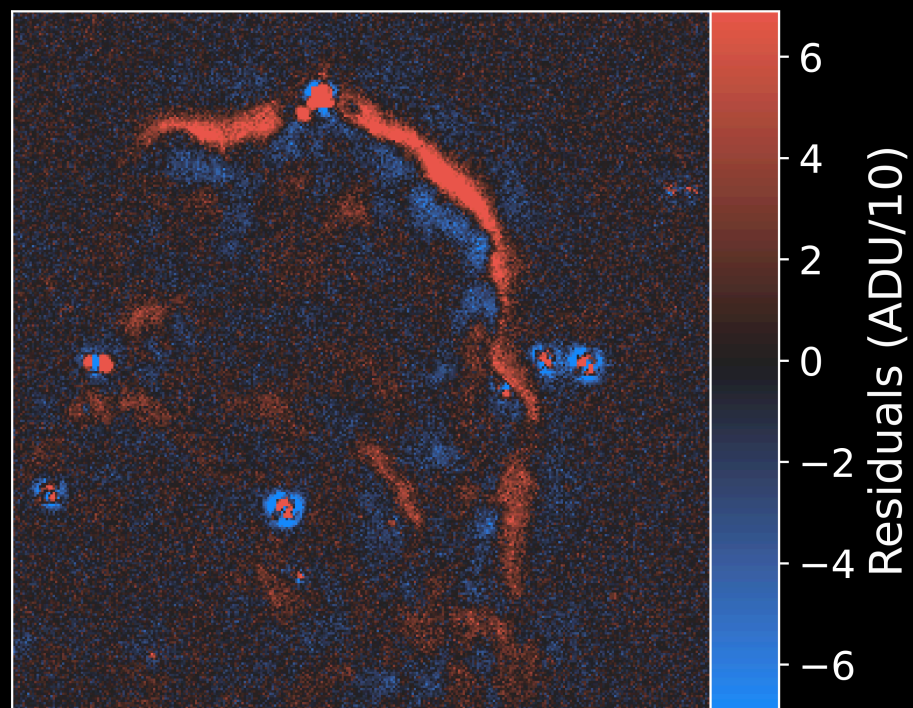
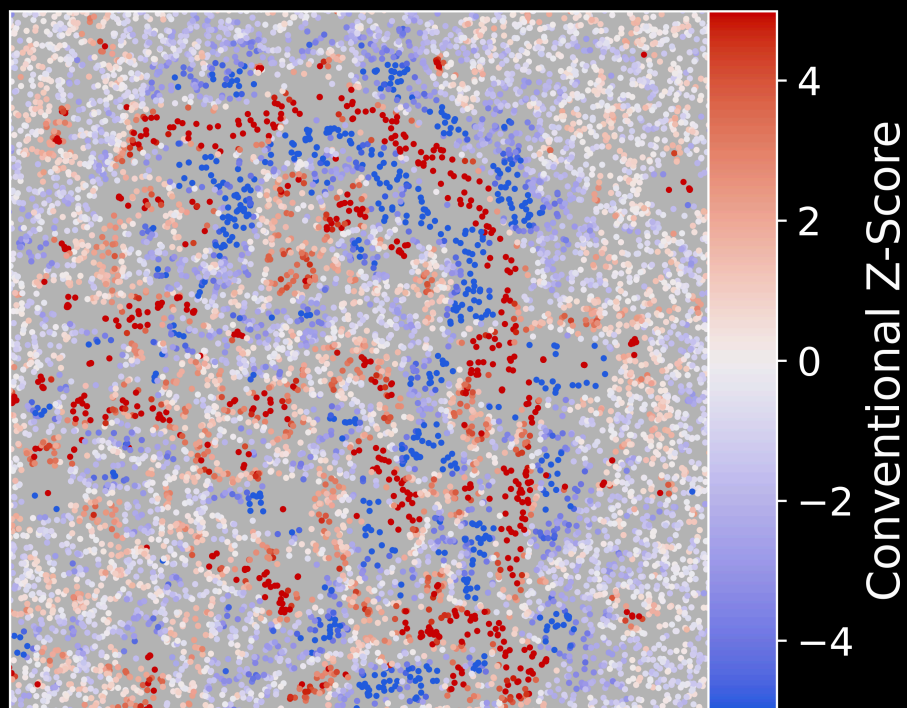
Moving
Median
Background



Most photometric pipelines use locally smooth backgrounds on scales \gg PSF

What is the impact of background mismodeling?

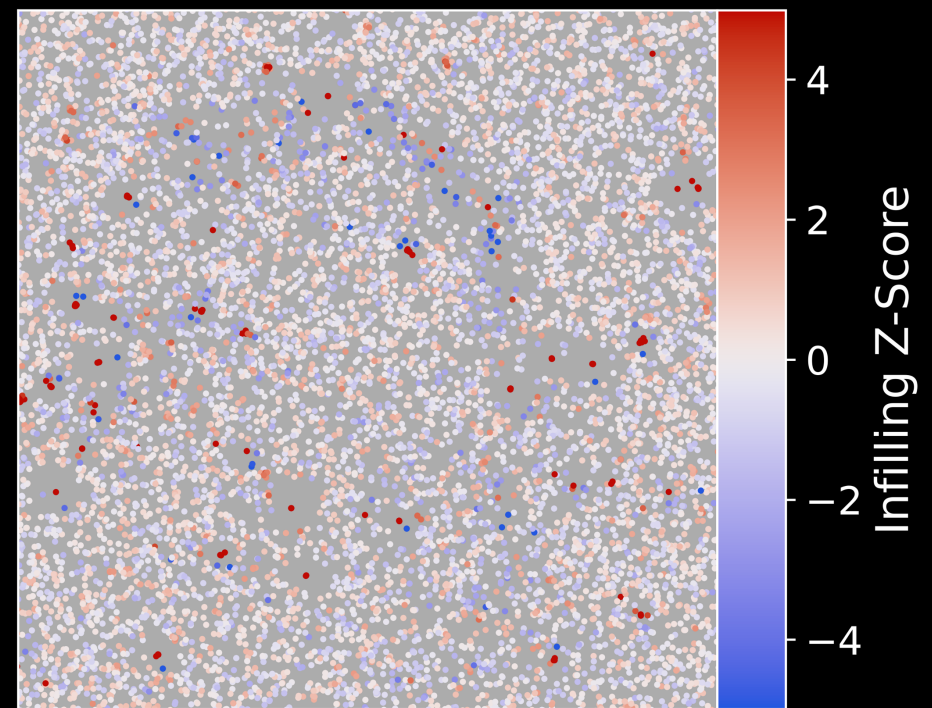
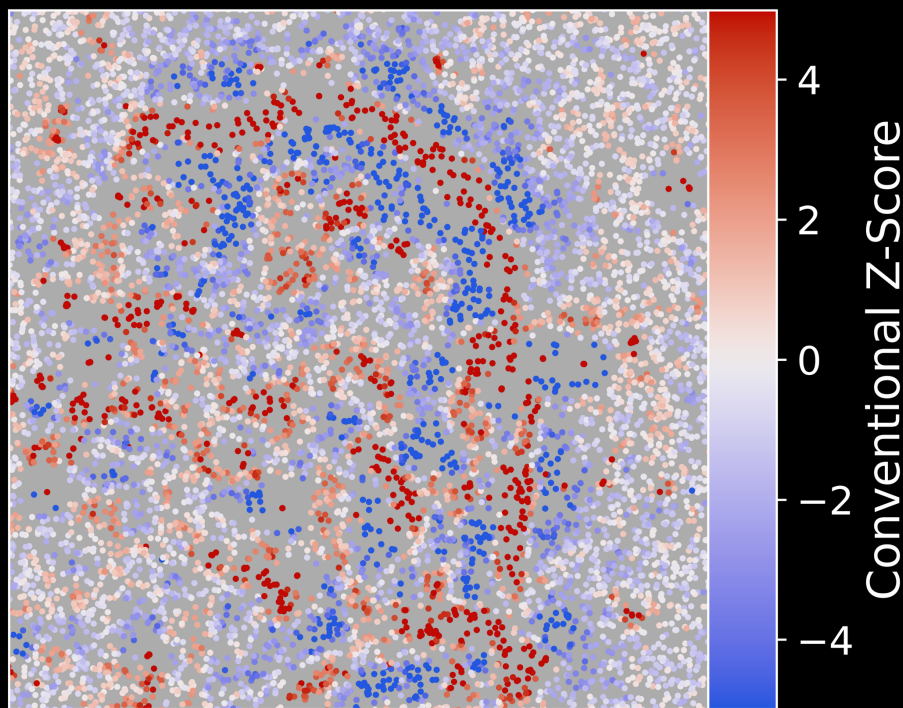
Spatially-correlated bias in flux and flux uncertainty poisons downstream analysis



“Conventional” photometric solution from `crowdsourcing`

Correcting Flux and Flux Uncertainties

Significantly reduces correlation between photometry and filament structure



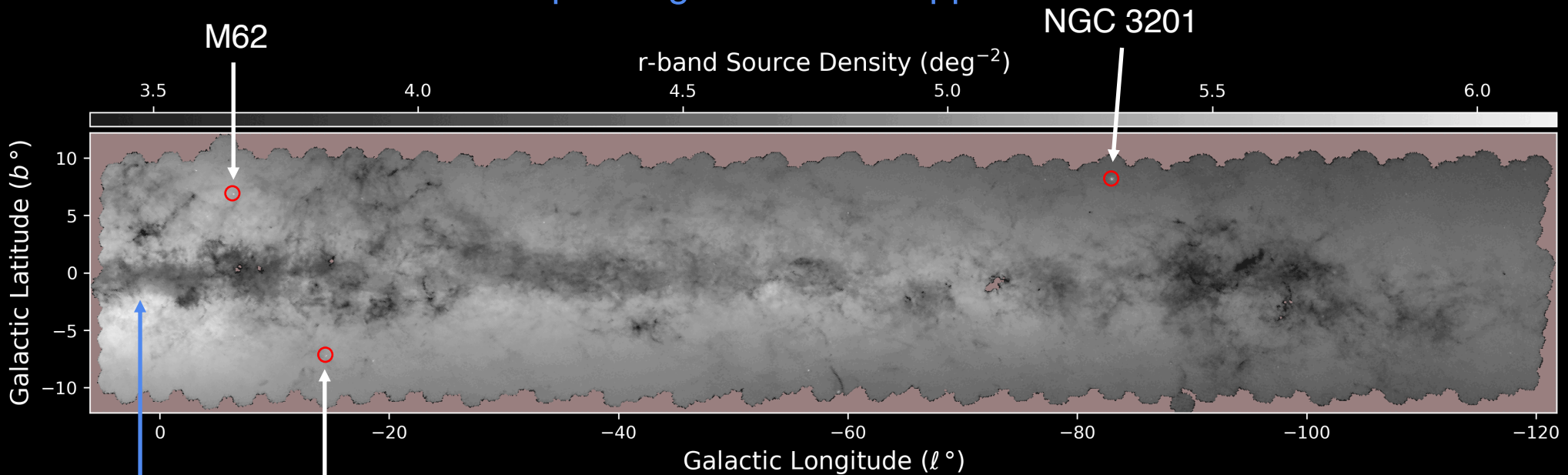
Correction by background interpolation



CloudCovErr.jl

How many sources in the catalog?

No pointing boundaries apparent!



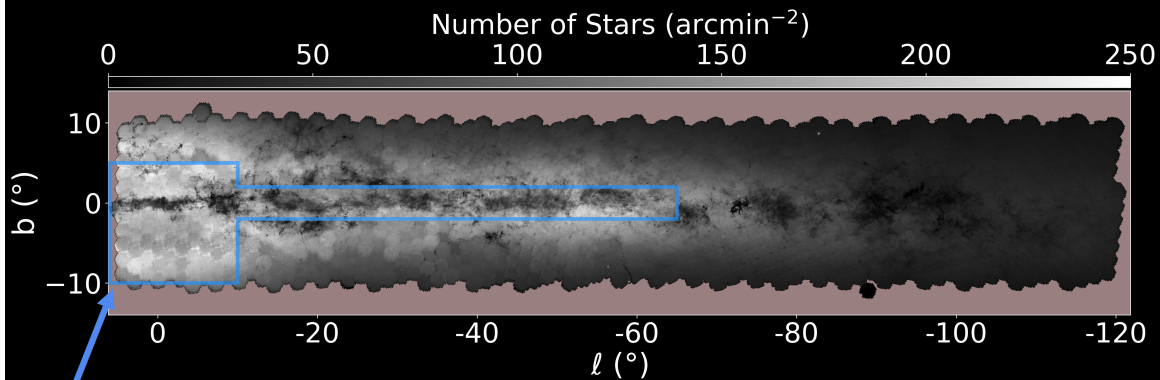
NIR reaches further into Galactic Disk

(One of the) Largest Photometric Catalogues (# objects)
3.32 Billion Sources
34 Billion Detections

Where are our stars?

Xmatch: DECaPS2 + VVV + 2MASS + unWISE + Gaia ϖ

Require 4 Bands

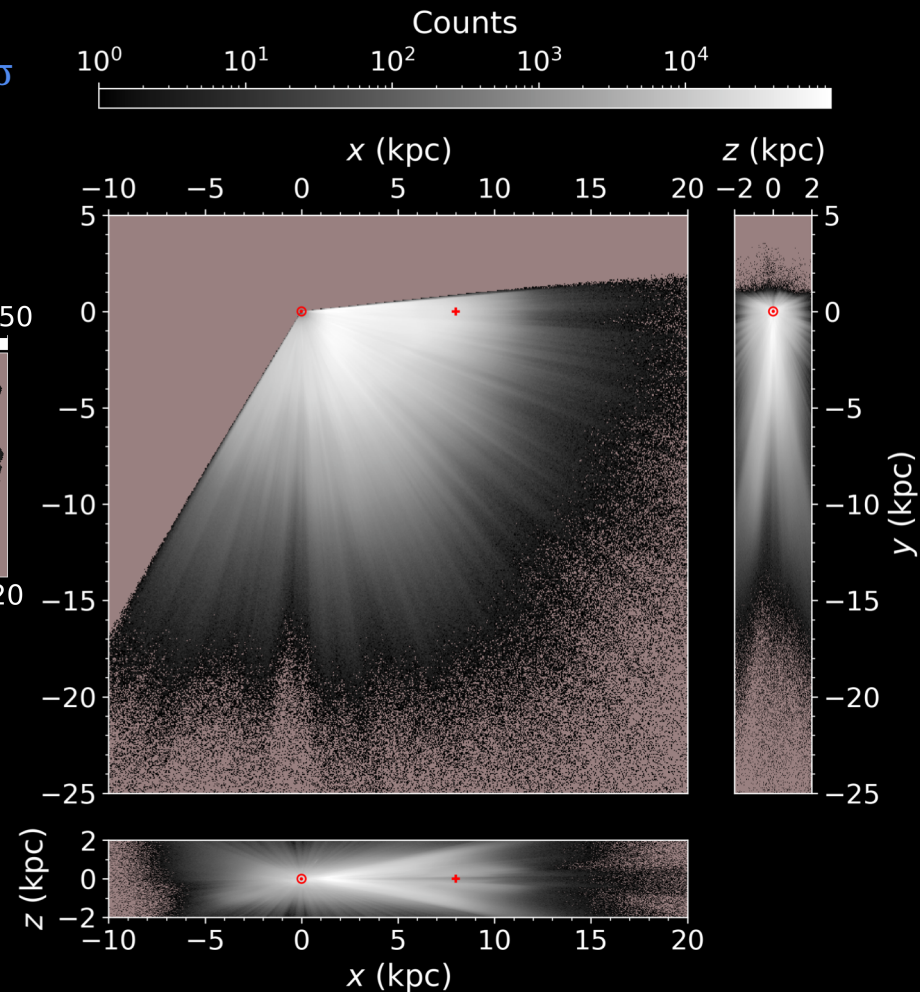


VVV Boundary

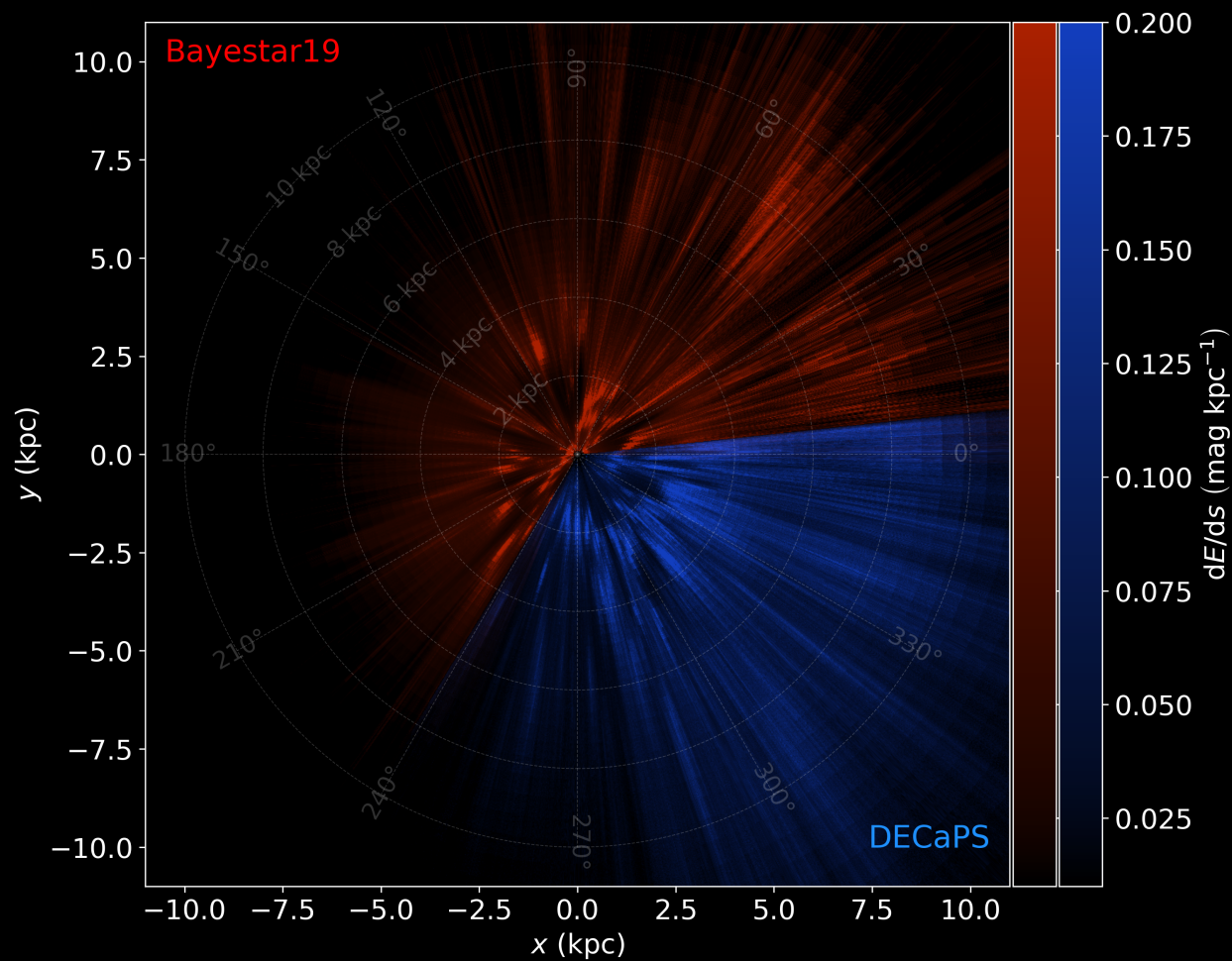
Forward model by “brute force” sampling
of MISTv1.2 models



Speagle & Zucker+2024 [incl. [Saydjari](#)]

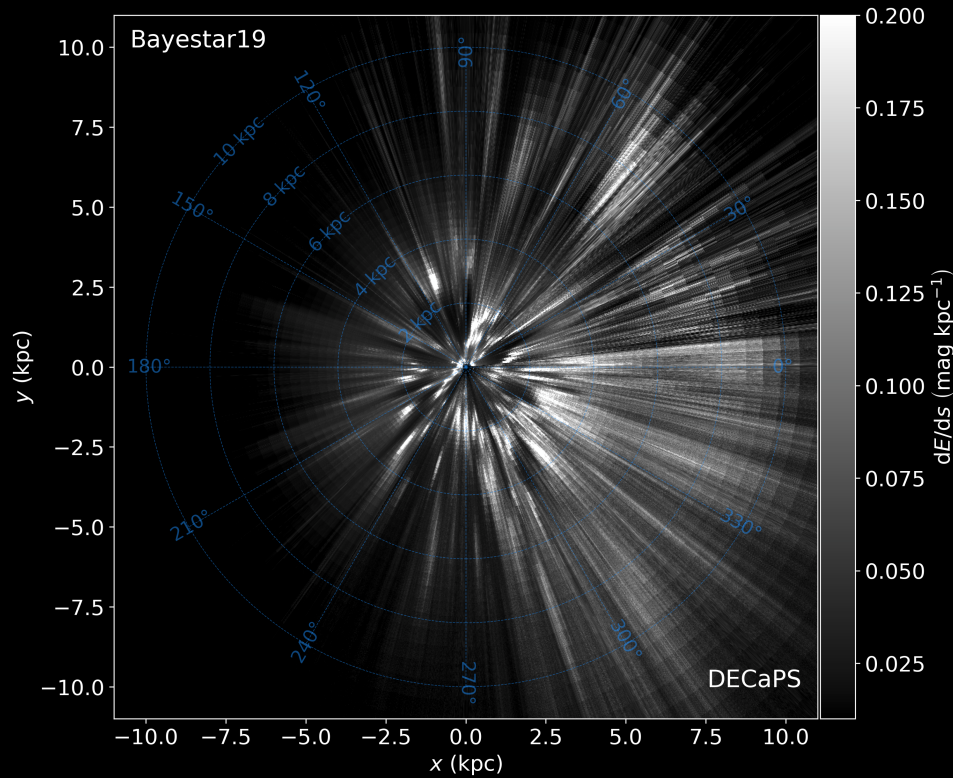


A complete view of 3D dust to 10 kpc



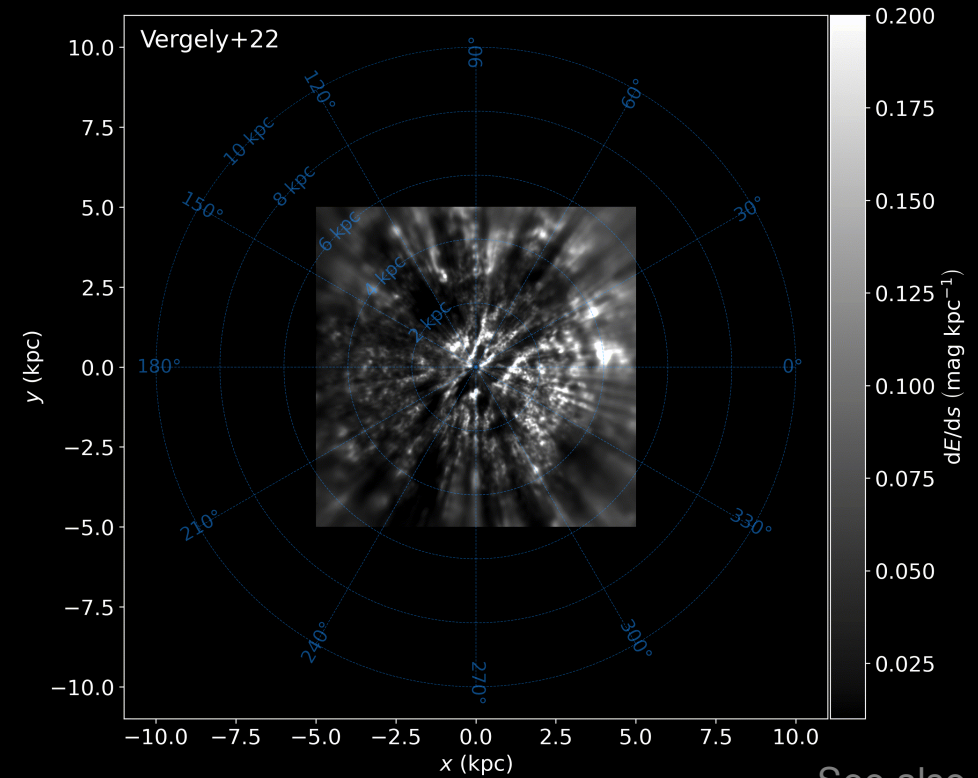
Top Down Comparison

DECaPS2/PS1 + VVV + 2MASS + WISE + Gaia ϖ



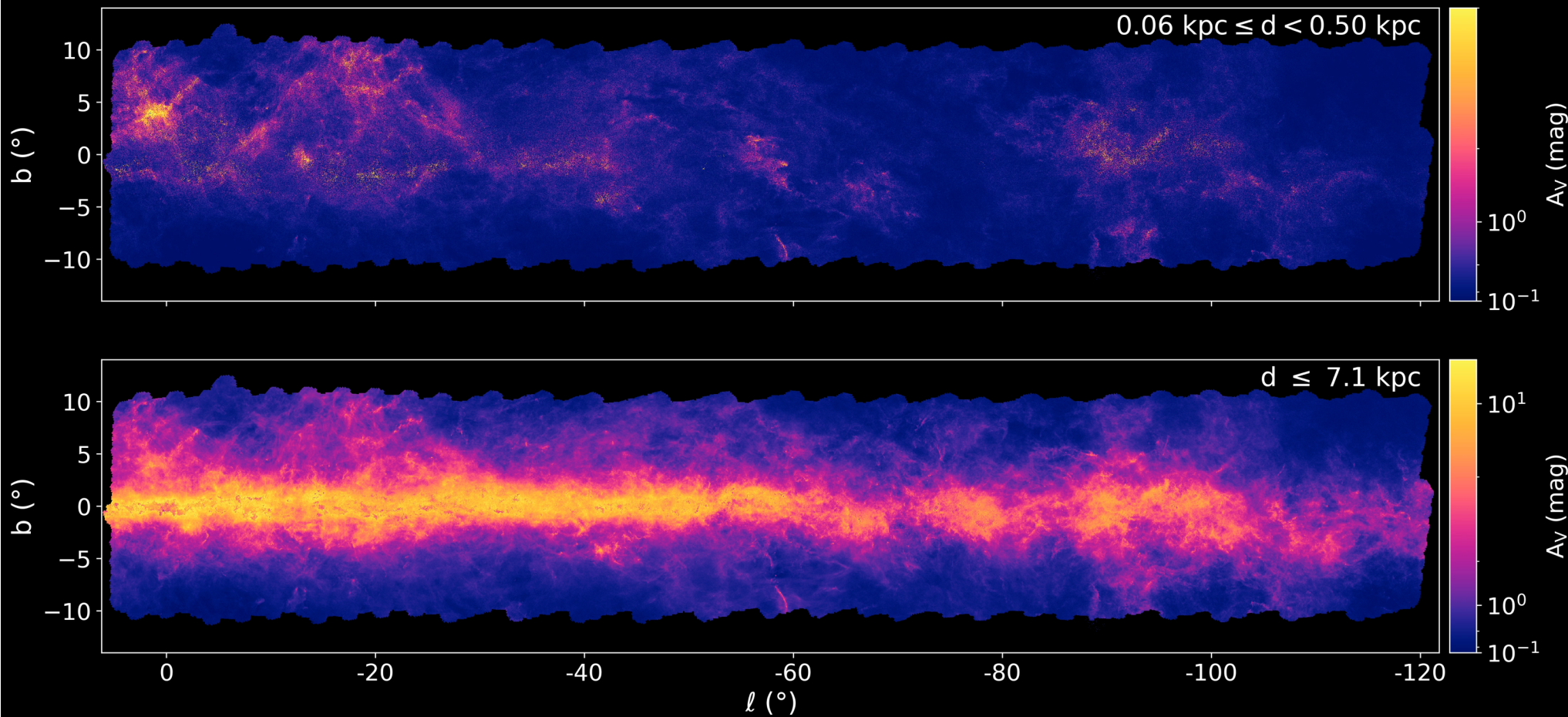
Green+2019
Zucker, Saydjari, & Speagle+2024

Gaia + 2MASS + (APOGEE+GALAH+LAMOST+RAVE)

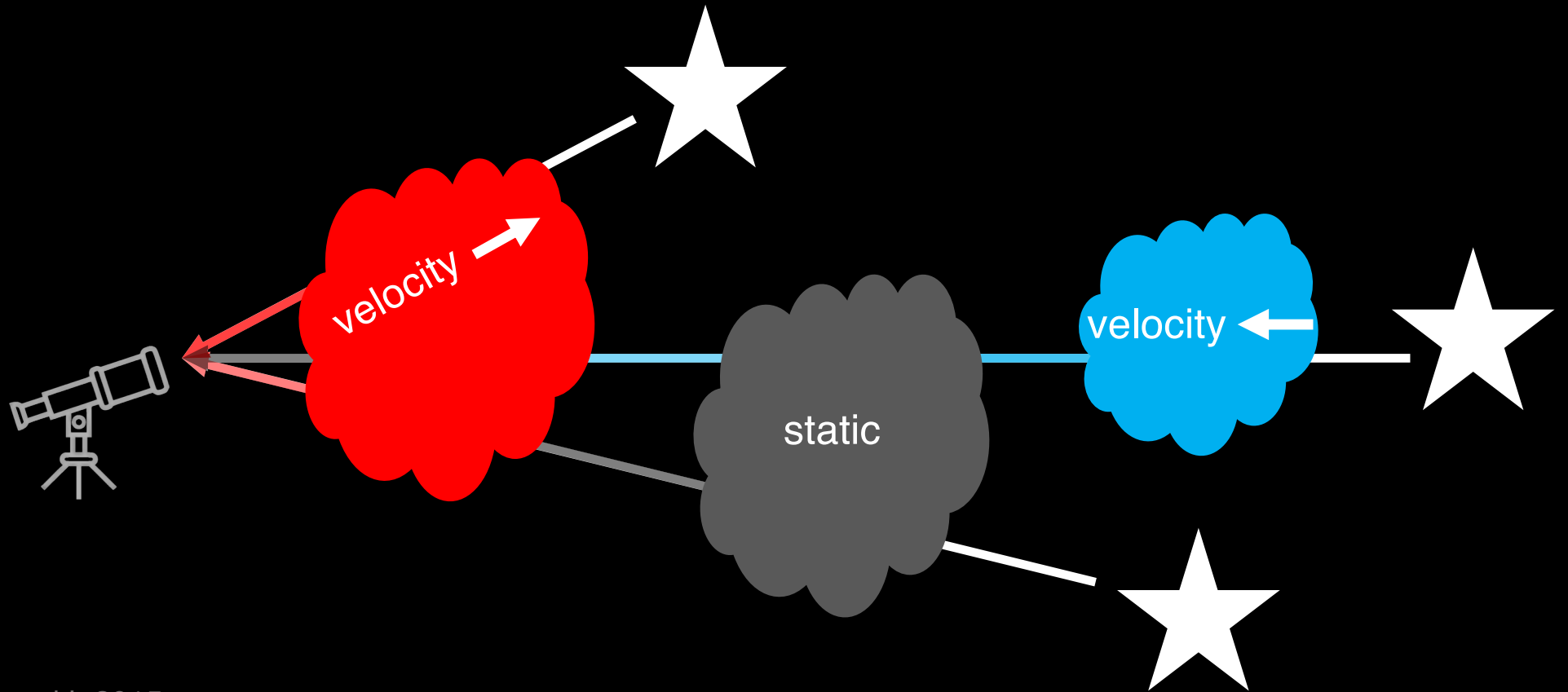


See also
Vergely+2022 [3/5 kpc] Edenhofer+2023 [1.25 kpc]
Dharmawardena+2024 [2.8 kpc]

Plane of Sky Slices



What's next? DIB kinematics!



Zasowski+2015

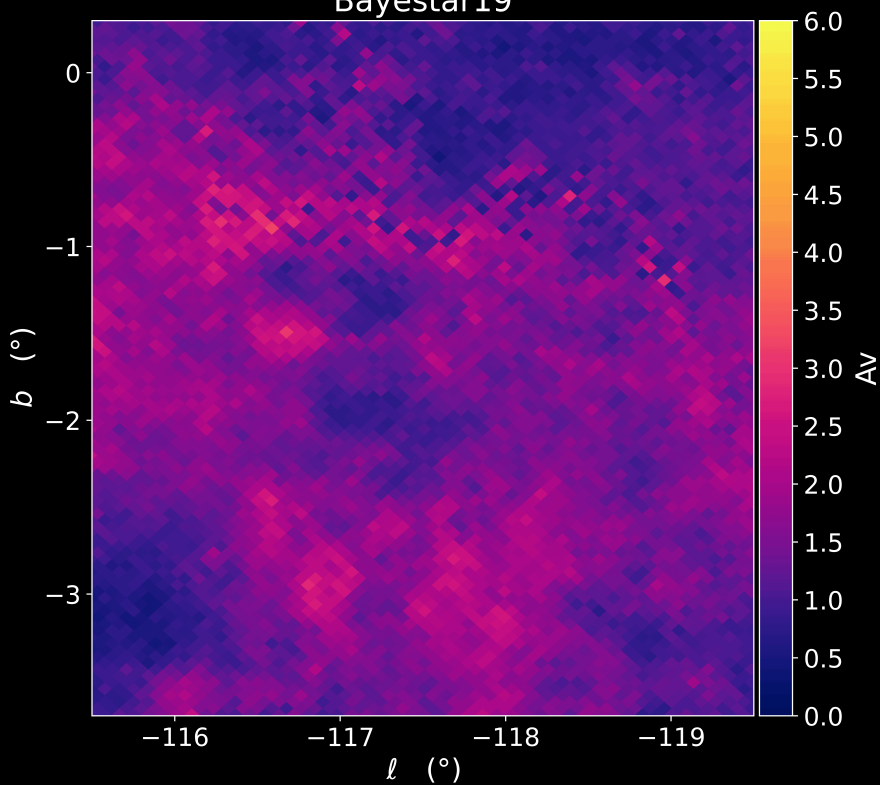
Tchernyshyov, Peek, & Zasowski 2018

[Not to scale]

Complexity of Interstellar Dust

Spatial

Bayestar19



6.1 Billion Voxels



Aaron Meisner

Dustin Lang

Ioana Zelko

Tansu Daylan

Albert Lee

David Schlegel

Frank Valdes

The DECam Plane Survey Team



Catherine Zucker

Josh Speagle

Doug Finkbeiner

Eddie Schlafly

Greg Green

DECaPS2 Dust Map Team

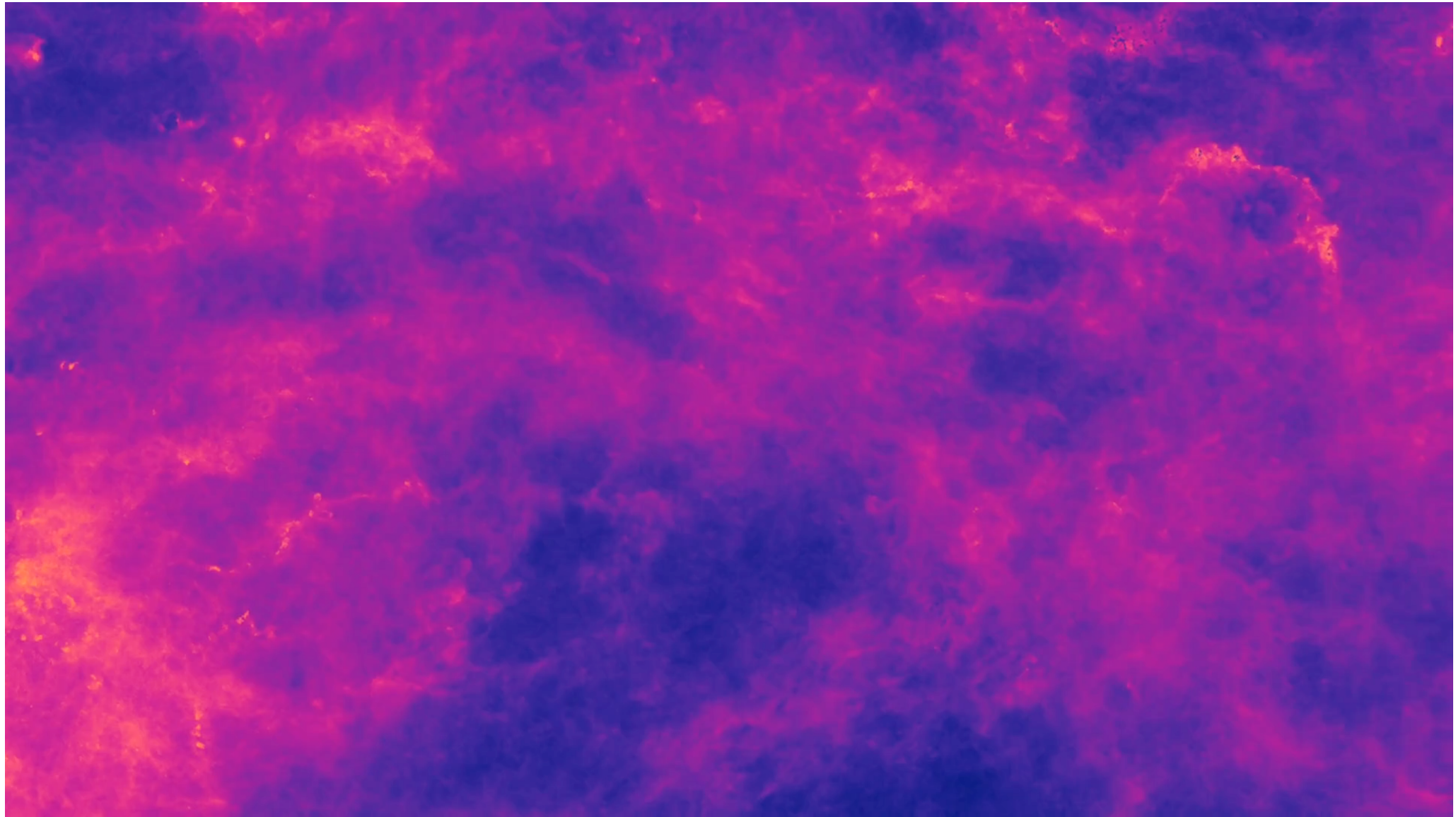


Gordian Edenhofer

Bob Benjamin

Alyssa Goodman

Josh Peek



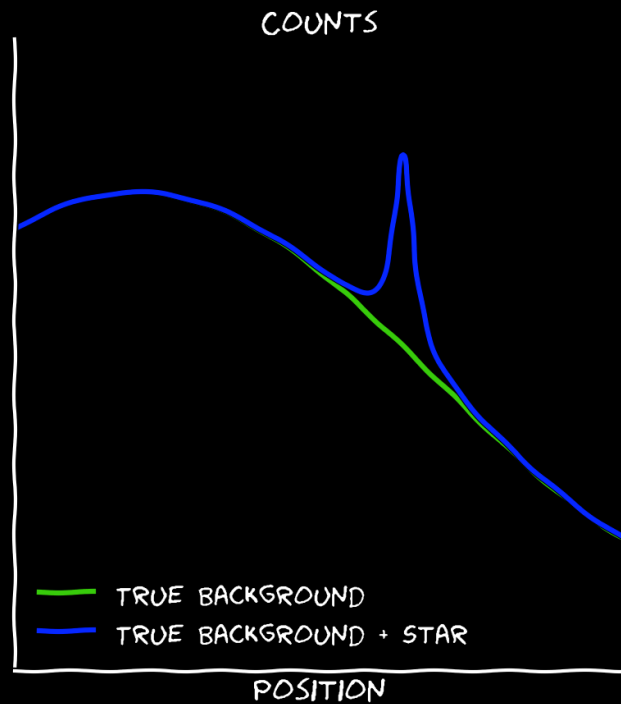


Back Up Slides

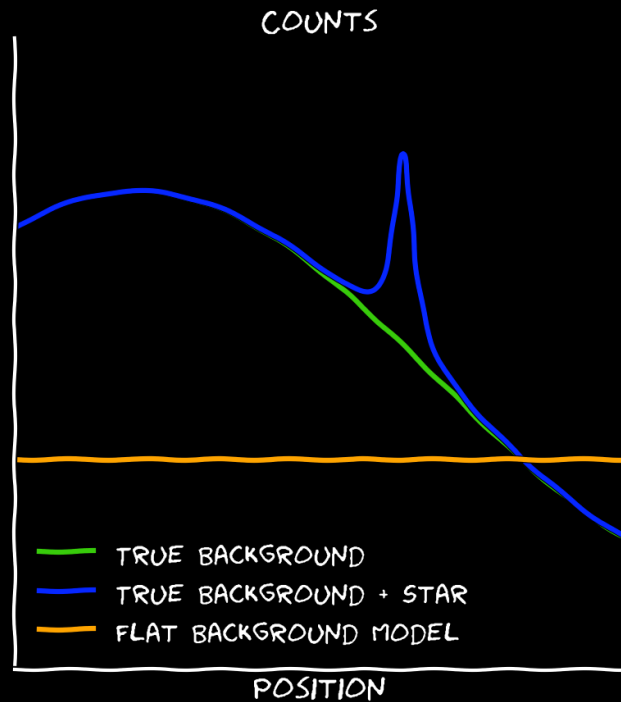
DECam: CCD S8

Lobster Nebula (NGC 6357)

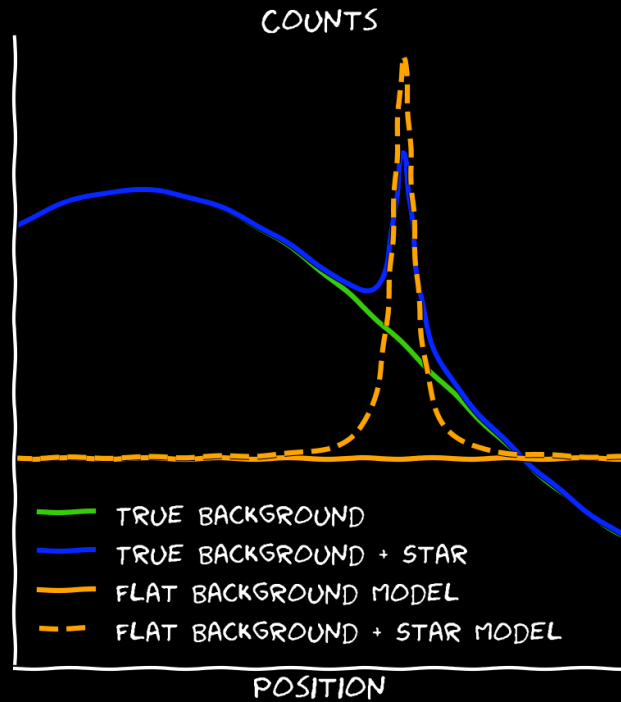
How can we fix the photometric catalogue?



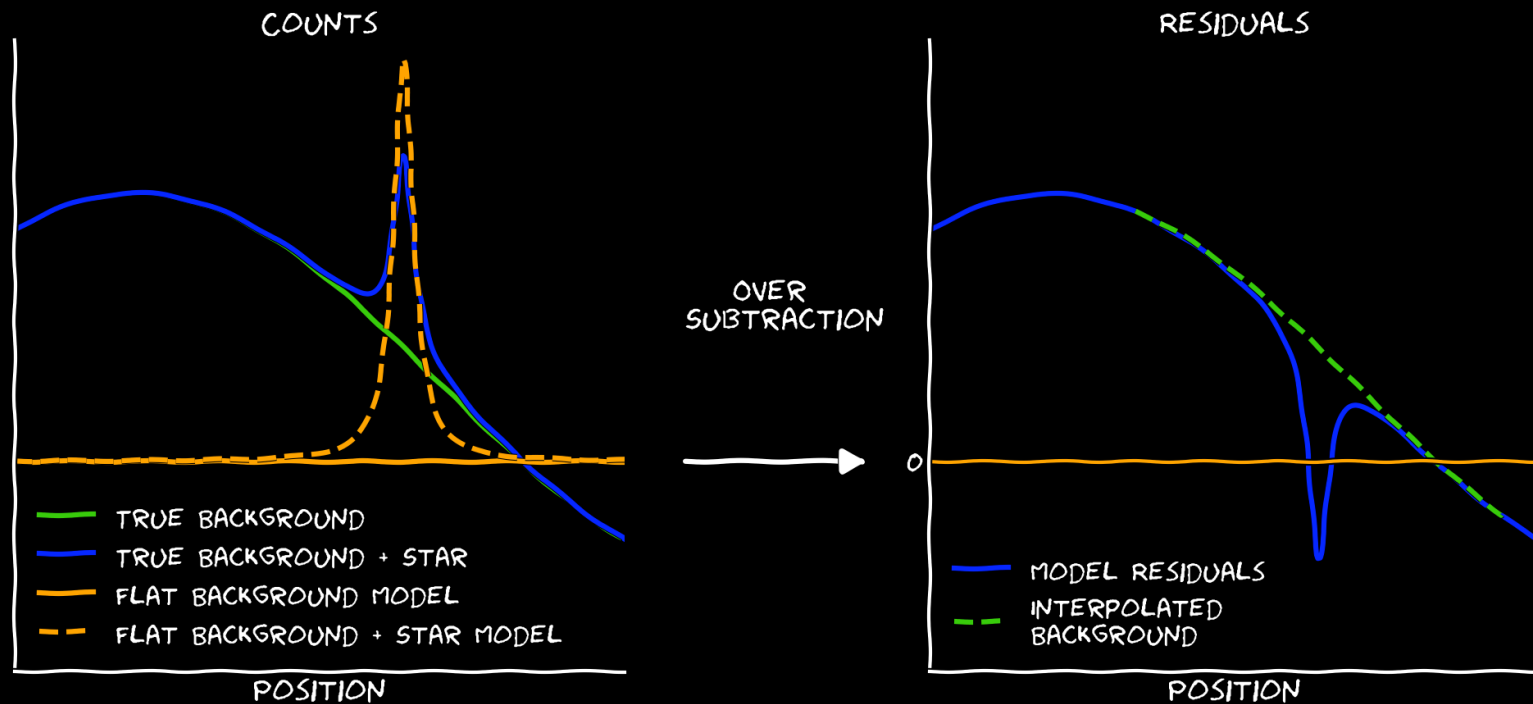
How can we fix the photometric catalogue?



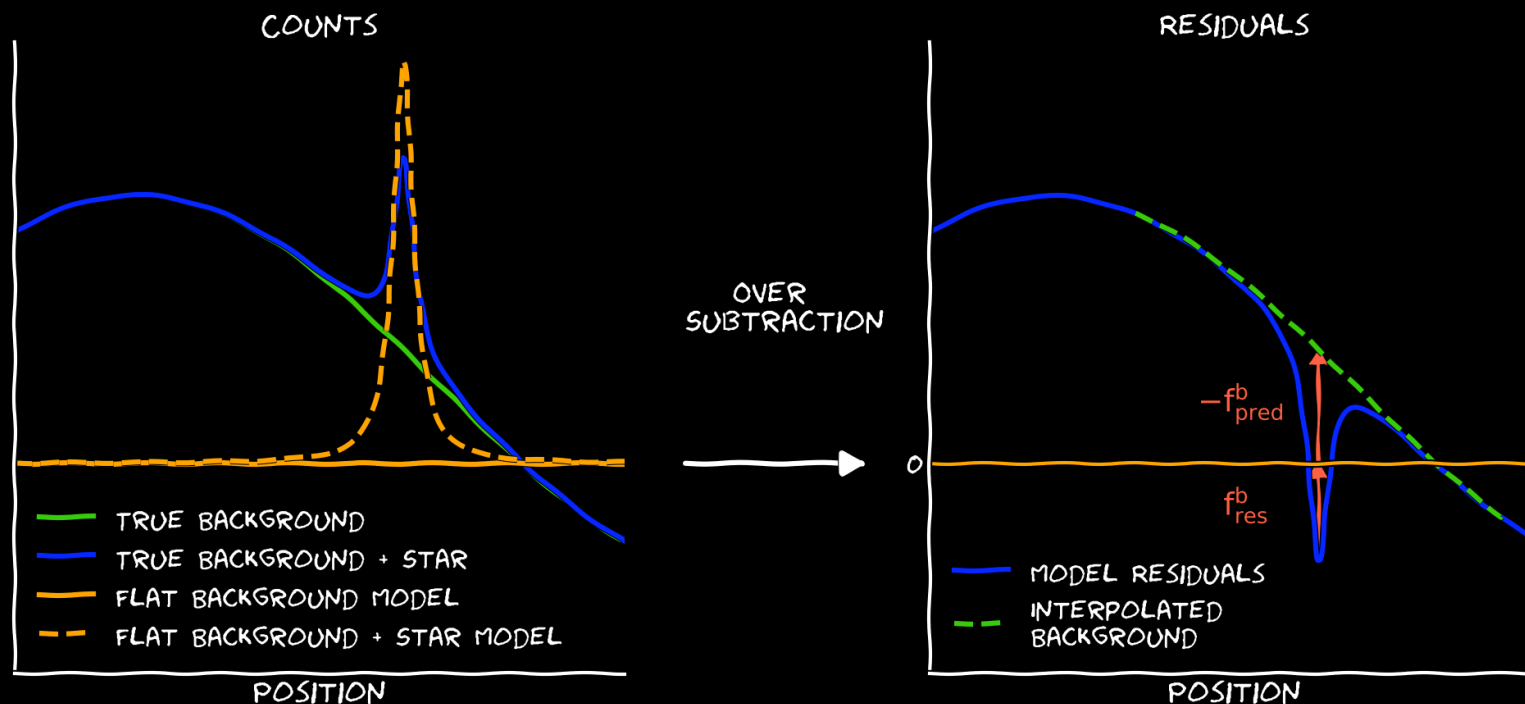
How can we fix the photometric catalogue?



How can we fix the photometric catalogue?



How can we fix the photometric catalogue?



All you need is the...

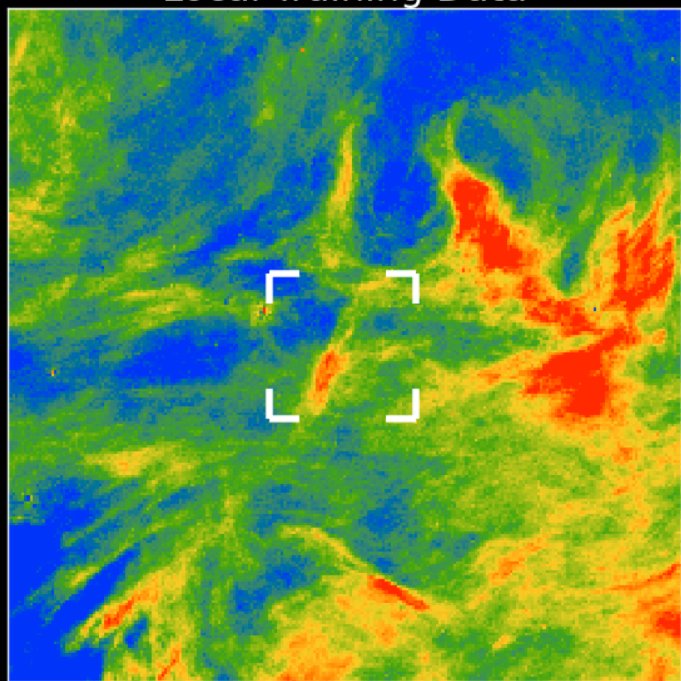
PSF Full Covariance
 Residuals Mean Interpolated Background

$$f^b = \frac{p \hat{C}^{-1} r}{p \hat{C}^{-1} p} + \frac{p \hat{C}^{-1} \mu}{p \hat{C}^{-1} p} = f_{res}^b - f_{pred}^b$$

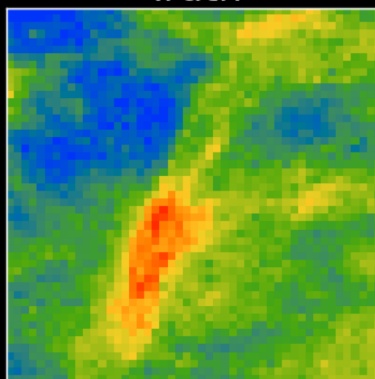


A WISE Example: Pipe Nebula

Local Training Data



Truth



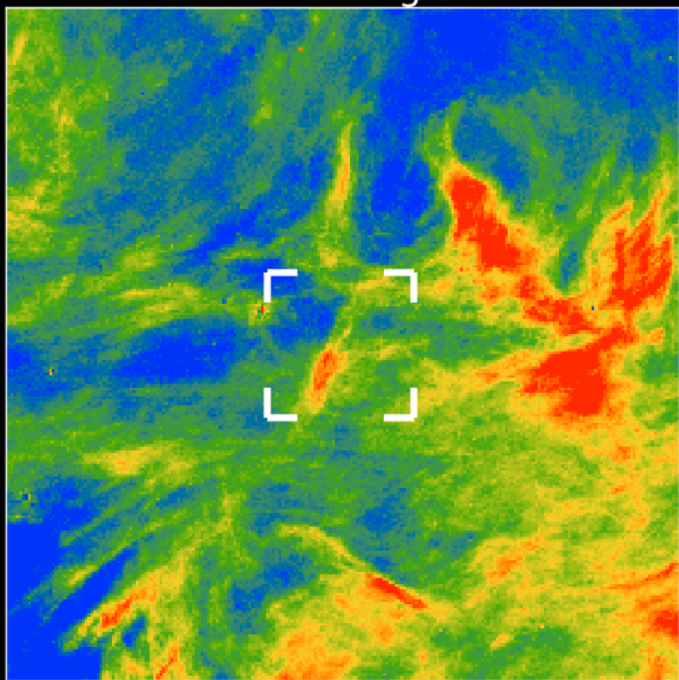
36 42 48 54 60 66 72 78
Mjy/sr

Train covariance matrix on local translations of subimage window



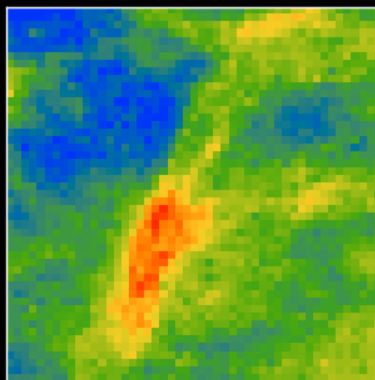
A WISE Example: Pipe Nebula

Local Training Data

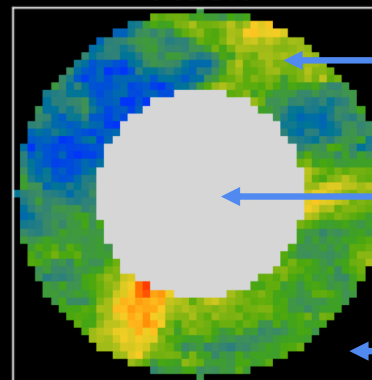


36 42 48 54 60 66 72 78
MJy/sr

Truth



Mask



use these pixels

to predict these pixels

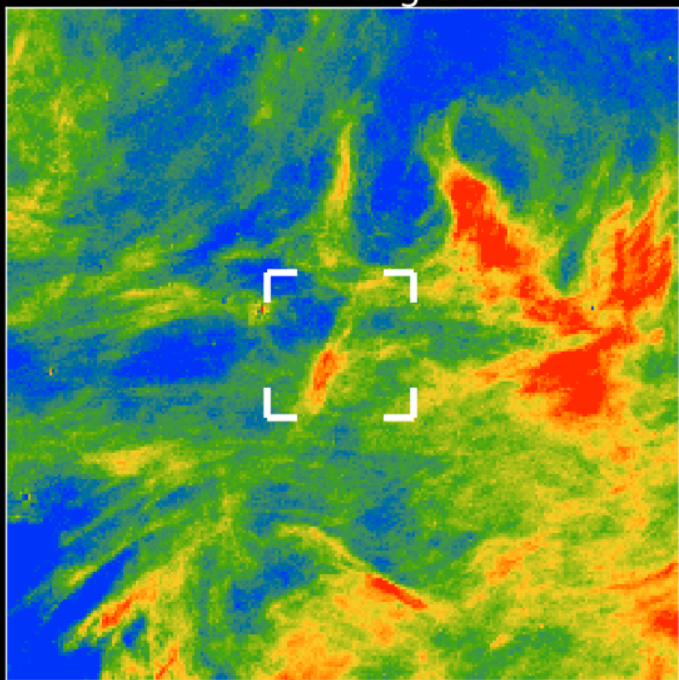
ignore these pixels

Make a guess for masked region conditional on the local background



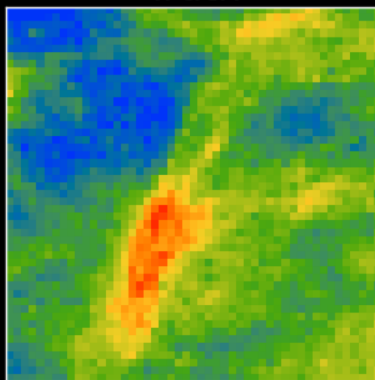
A WISE Example: Pipe Nebula

Local Training Data

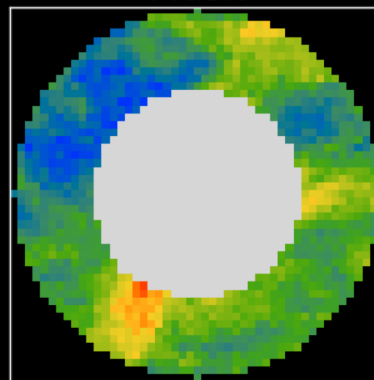


36 42 48 54 60 66 72 78
MJy/sr

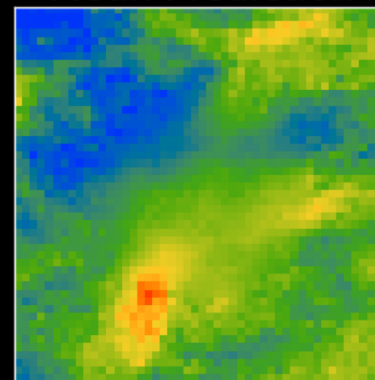
Truth



Mask



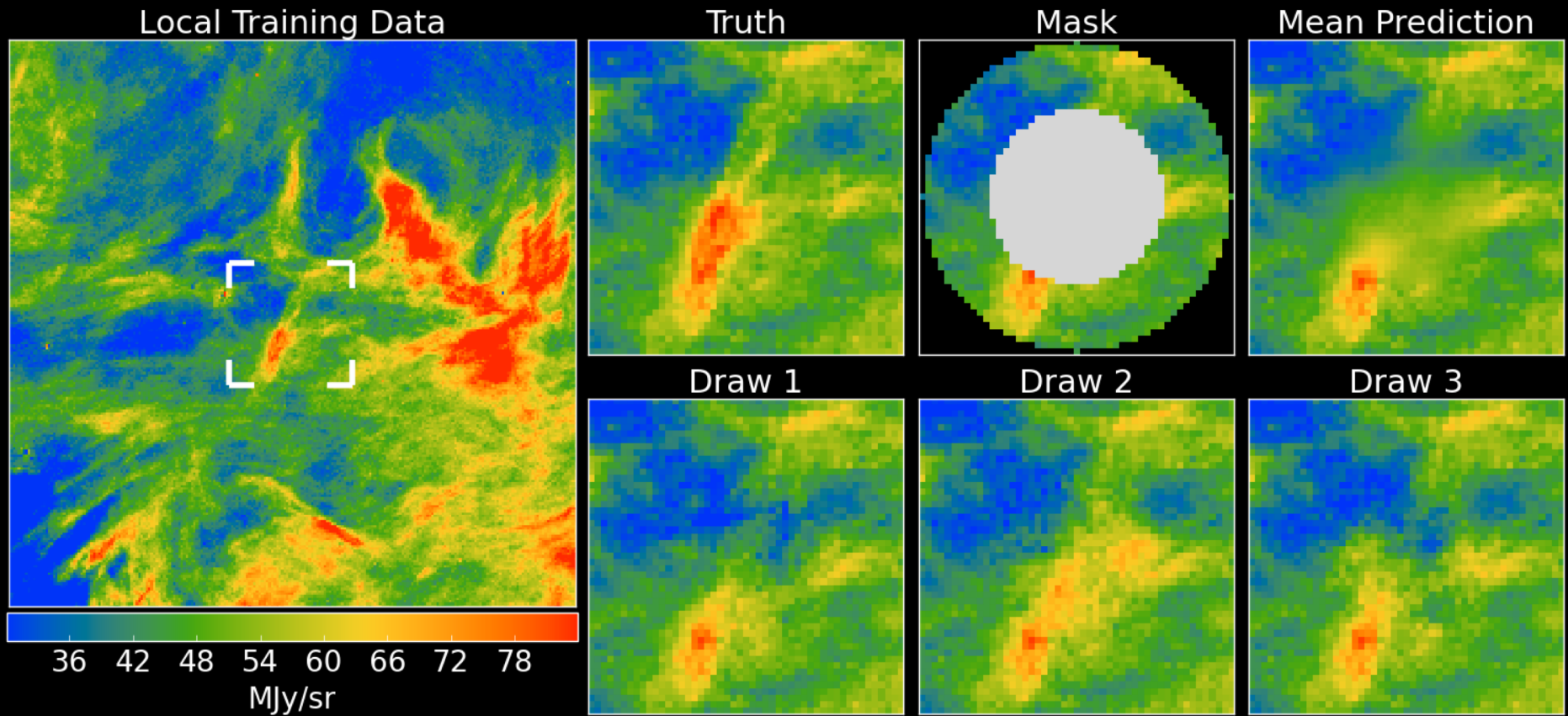
Mean Prediction



Reasonable guess given information we have



A WISE Example: Pipe Nebula

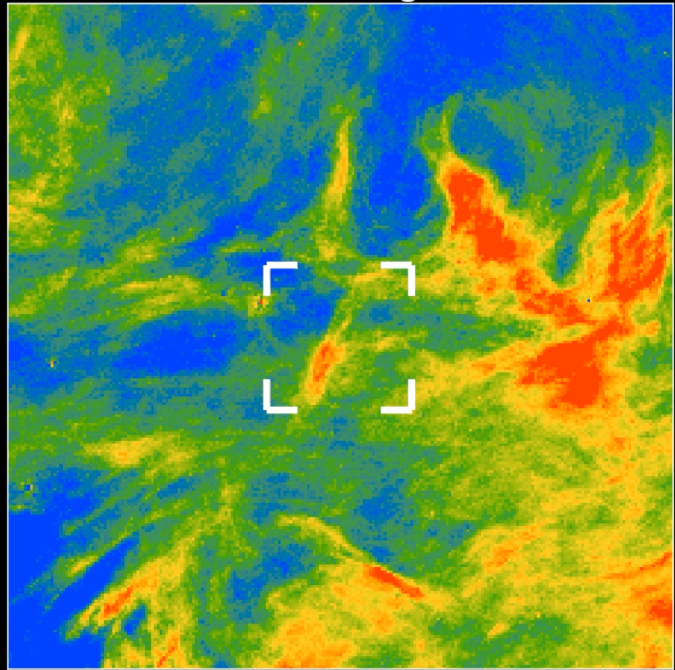


Further, the conditional covariance of the infill gives statistical draws

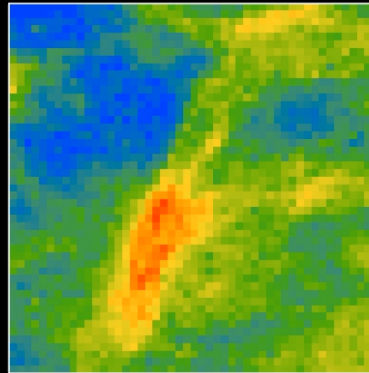


Robust to star-mask size

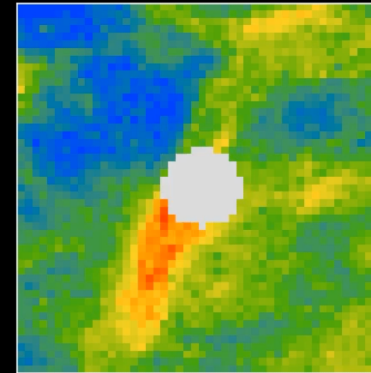
Local Training Data



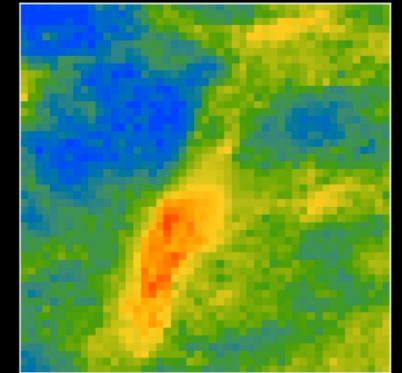
Truth



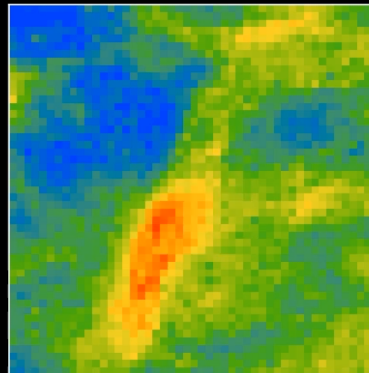
Mask



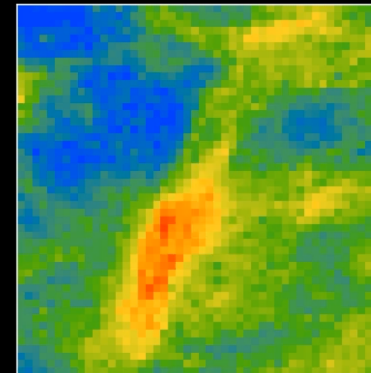
Mean Prediction



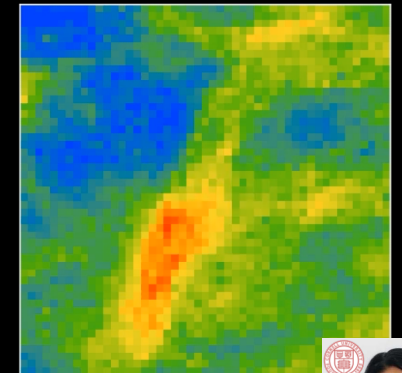
Draw 1



Draw 2



Draw 3



40 50 60 70 80
Mjy/sr

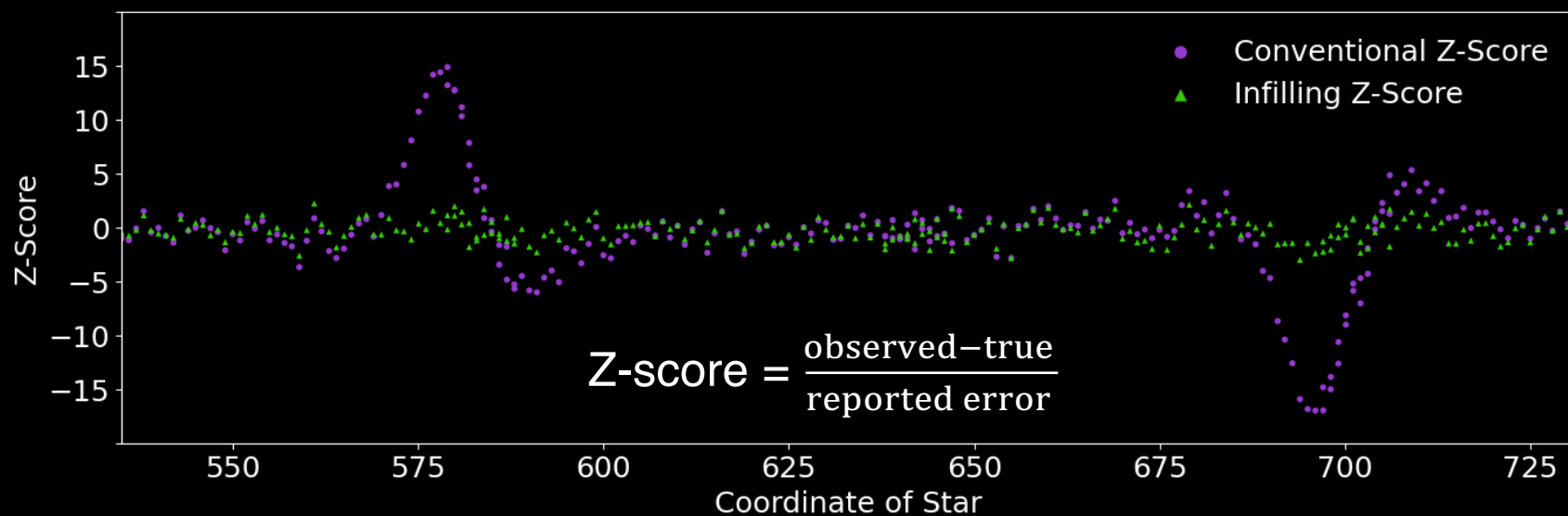
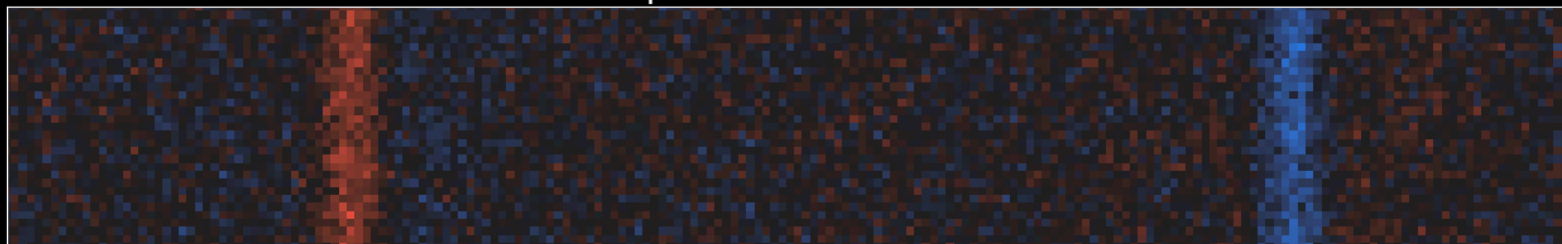
Even better feature interpolation with smaller mask

Higher-Order
Statistical Consistency

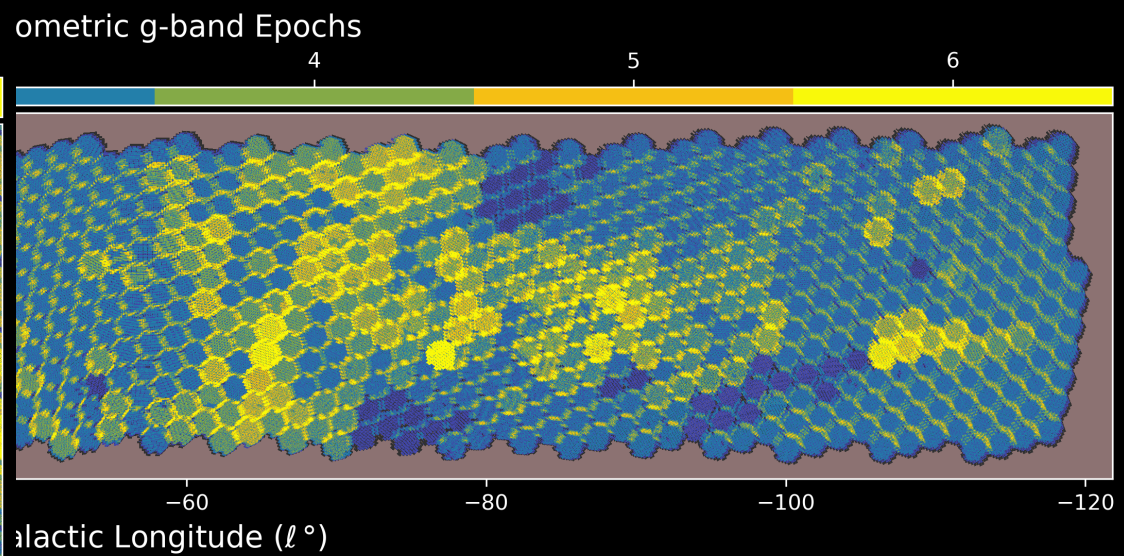
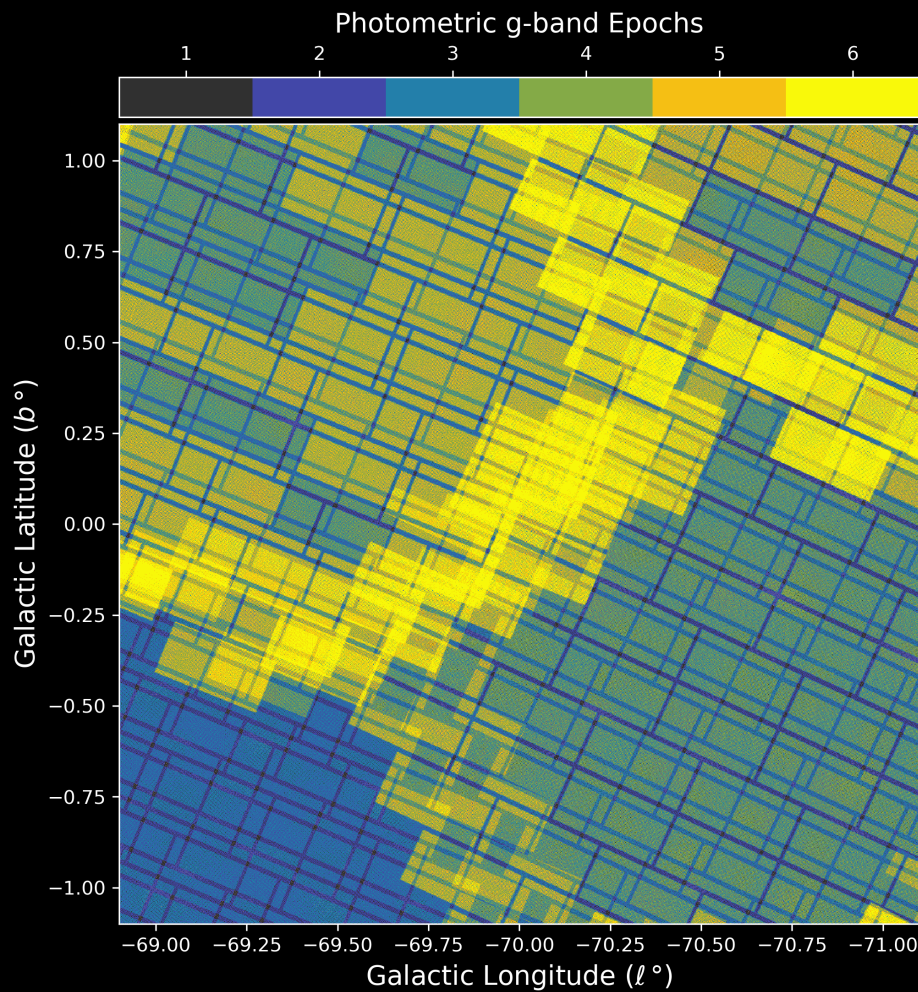


Does infilling improve photometry?

Sample 2D Residual Field



How many visits?

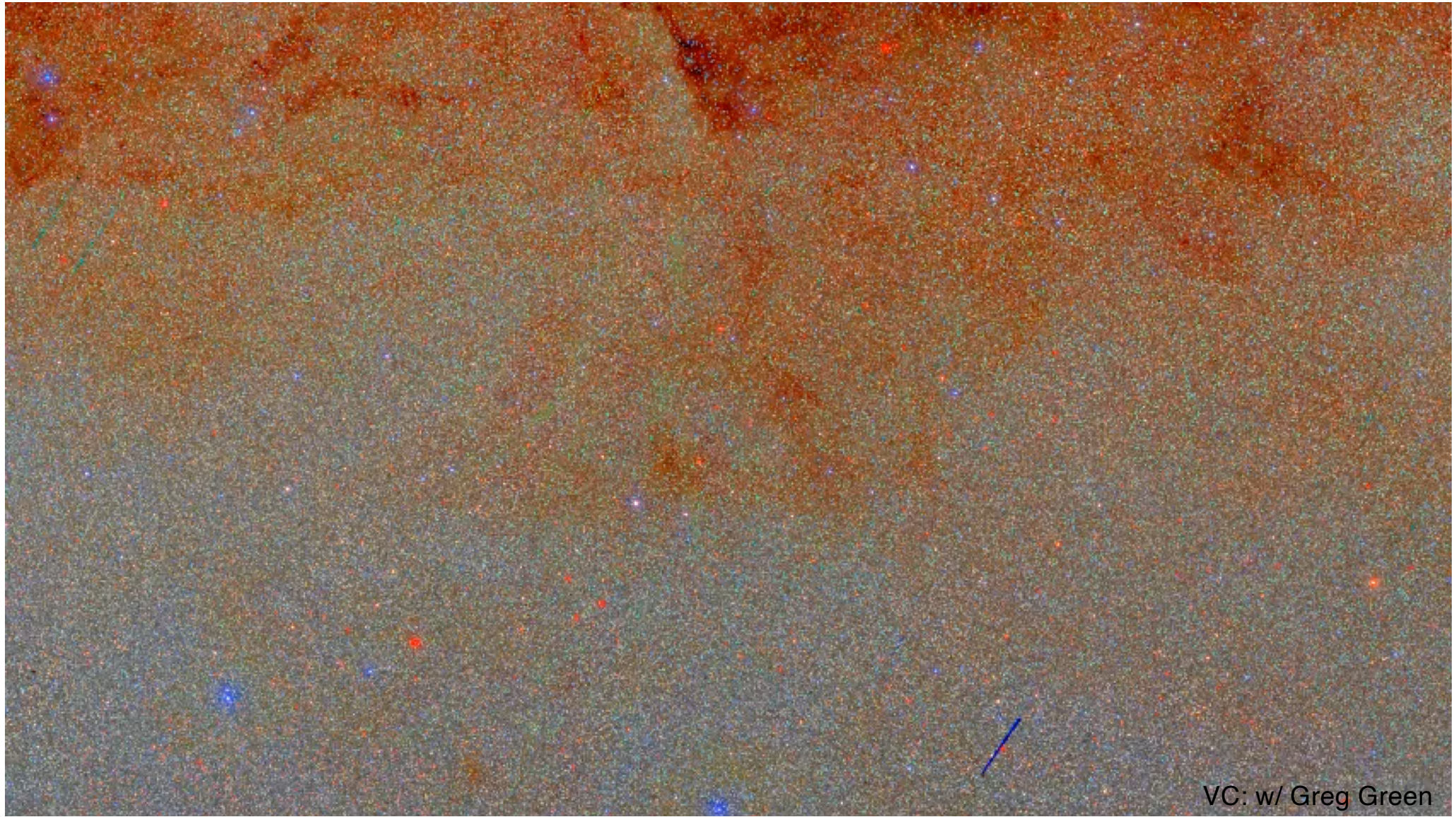


- Average 3 visits/band
- 1" average seeing
- < 10 mmag photometric calibration
- 100 mas astrometry (20 mas post-Gaia)

Gaia
Selection Fxn

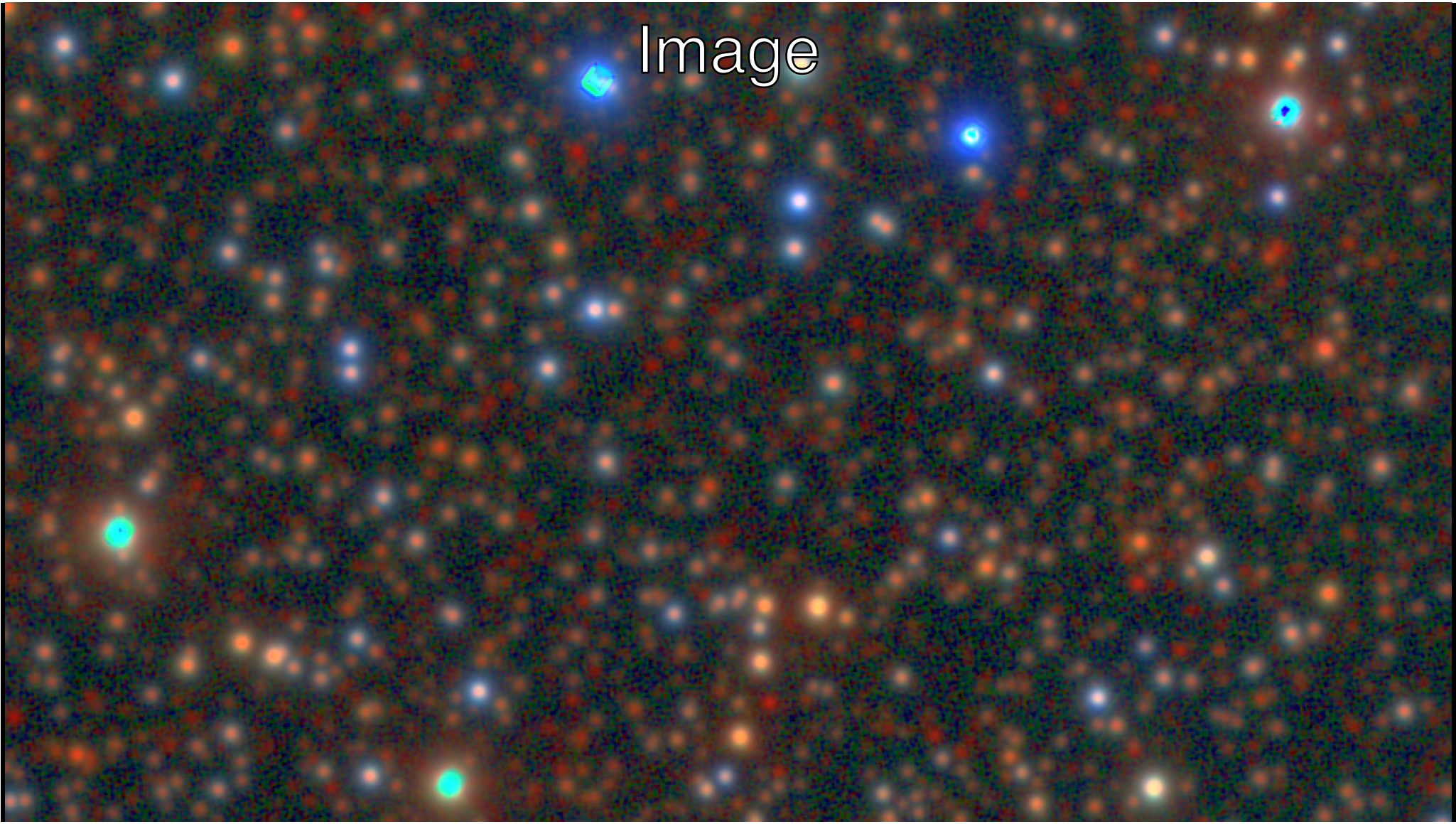
Cantat-Gaudin et al. [incl. Saydjari] (2023)



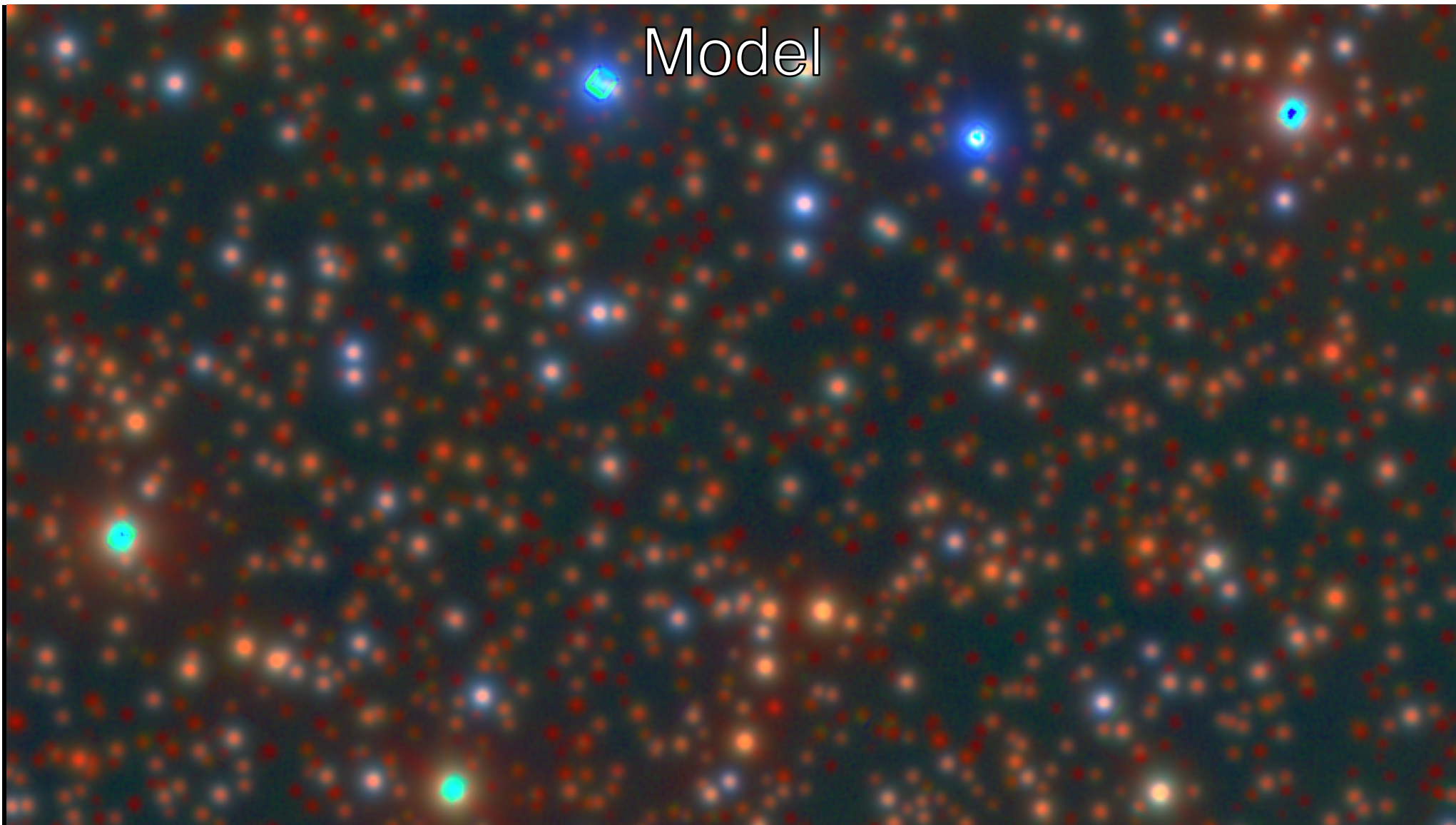


VC: w/ Greg Green

Image



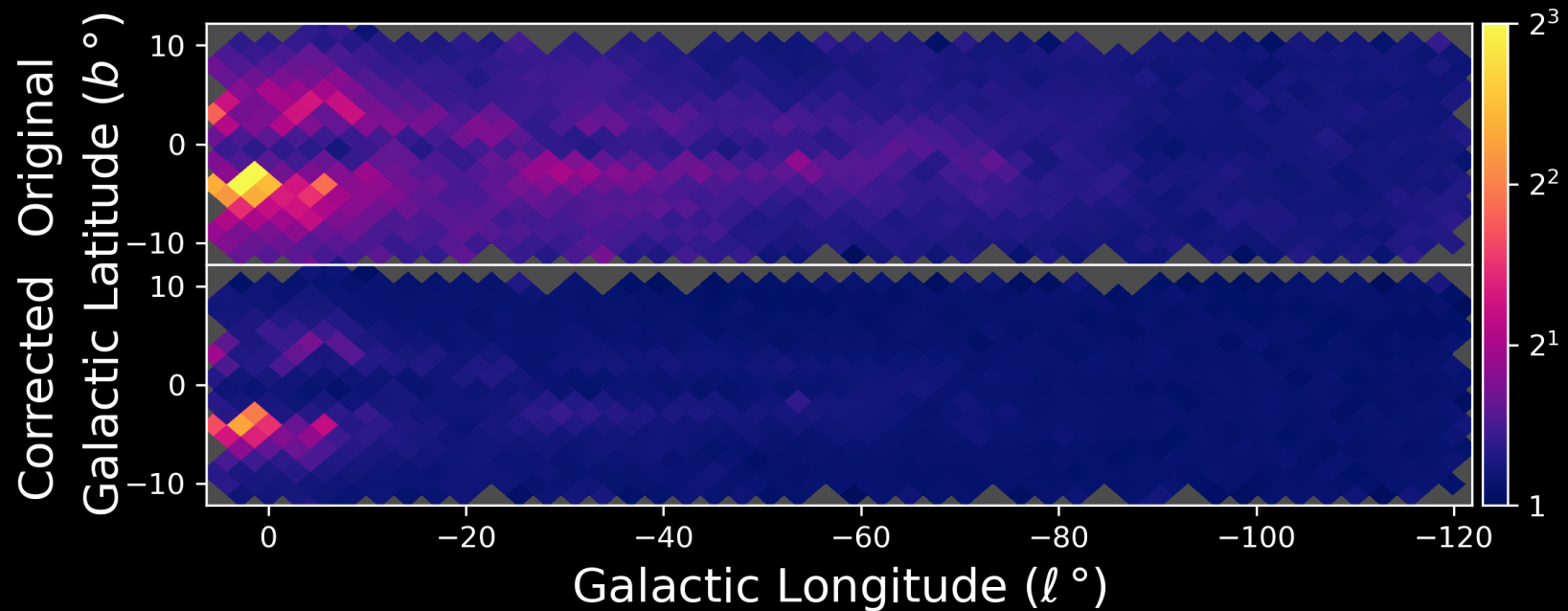
Model



Are the new error bars right?

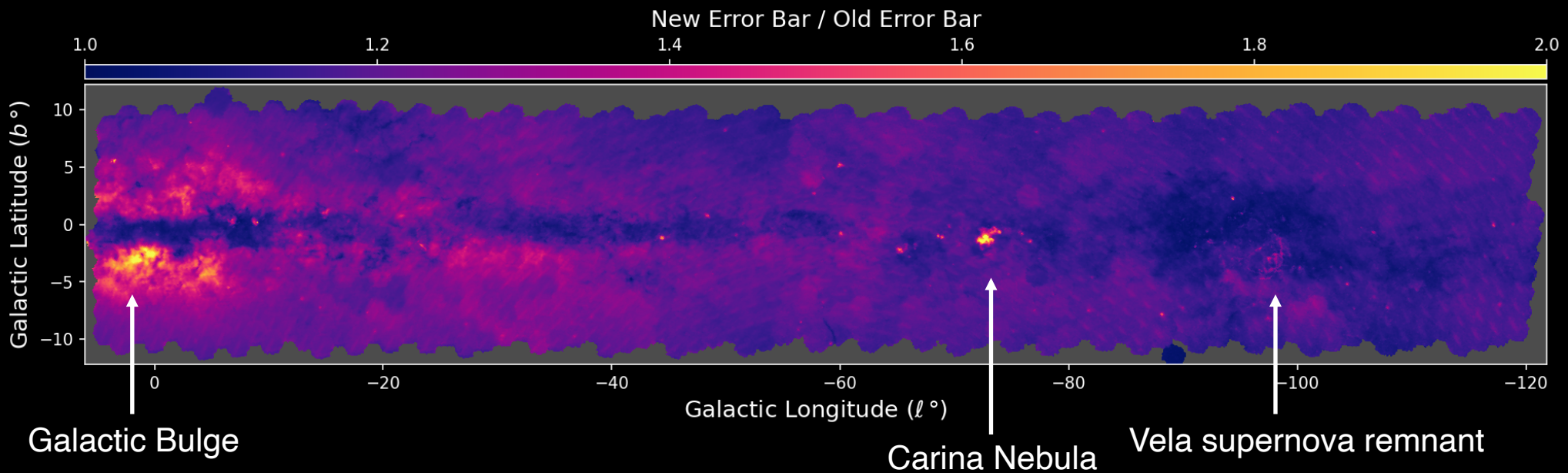
Use injection tests to check if the distribution of photometric errors are normal

Multiplicative Underestimation of Error (z-band)



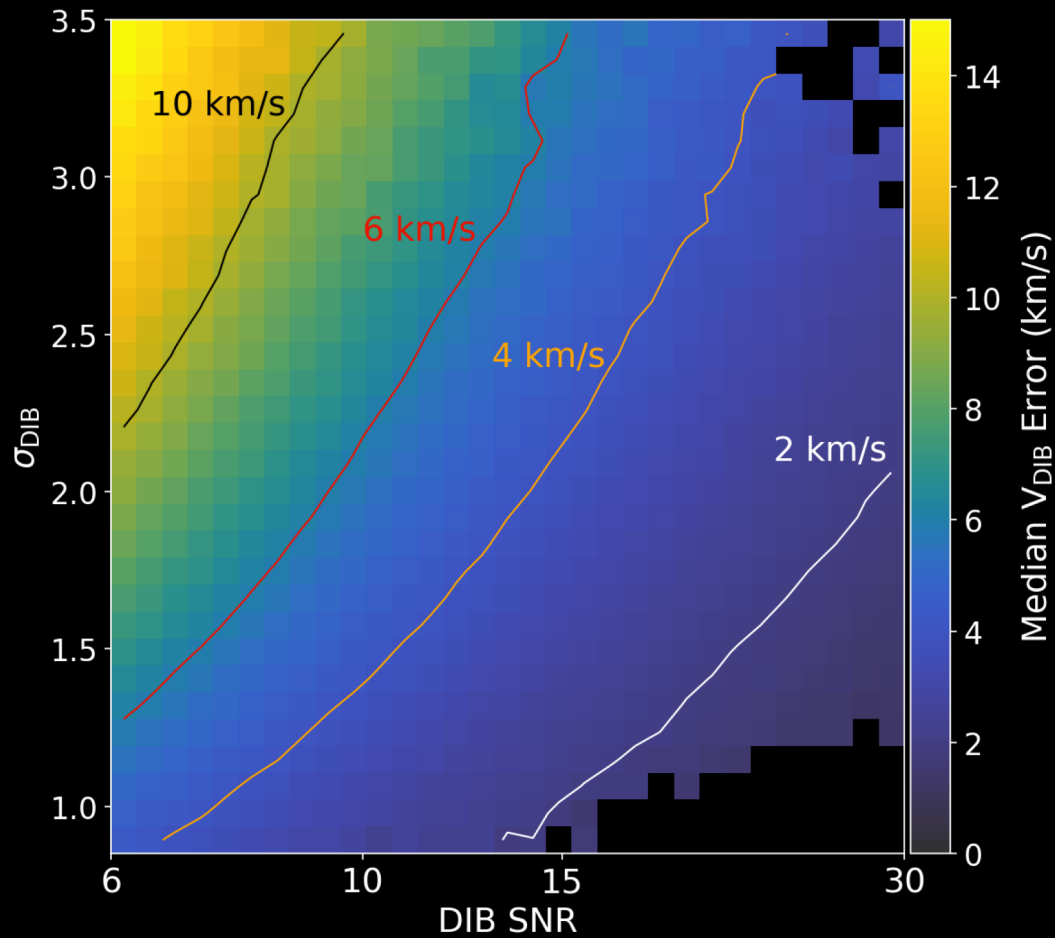
How much did the error bars change?

A view of where we were overconfident before!



Afterburner for ANY pipeline outputting PSF and residuals

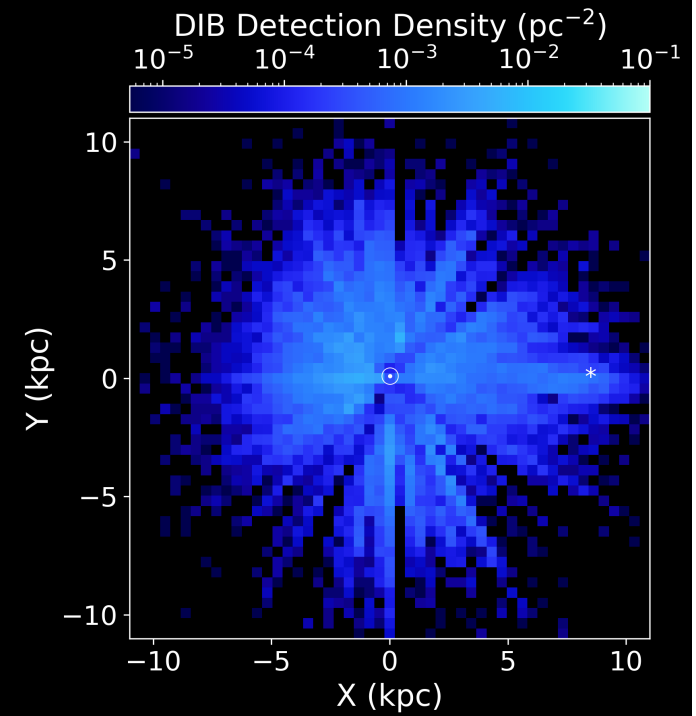
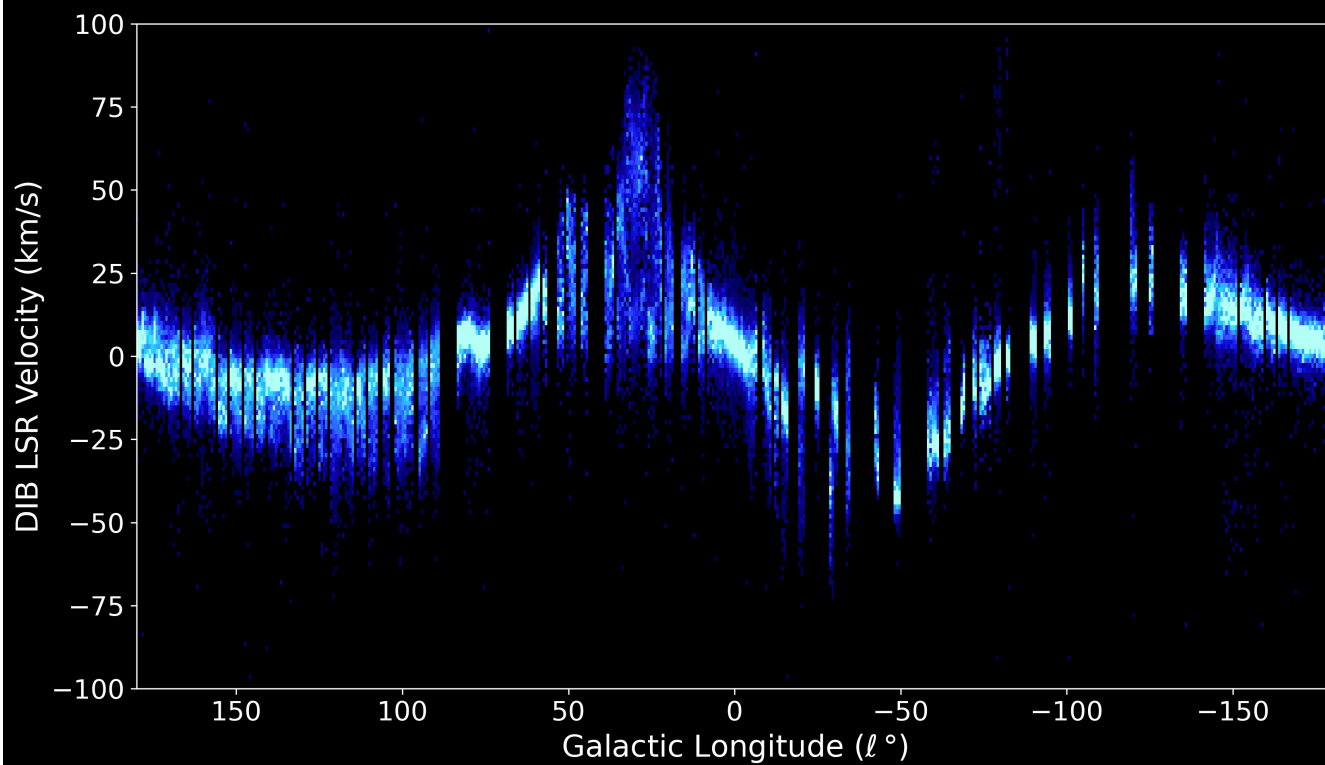
DIB Kinematic Precision



Comparison:
 ^{12}CO Composite Survey
~ 1.3 km/s Precision

Dame et al. (2001)

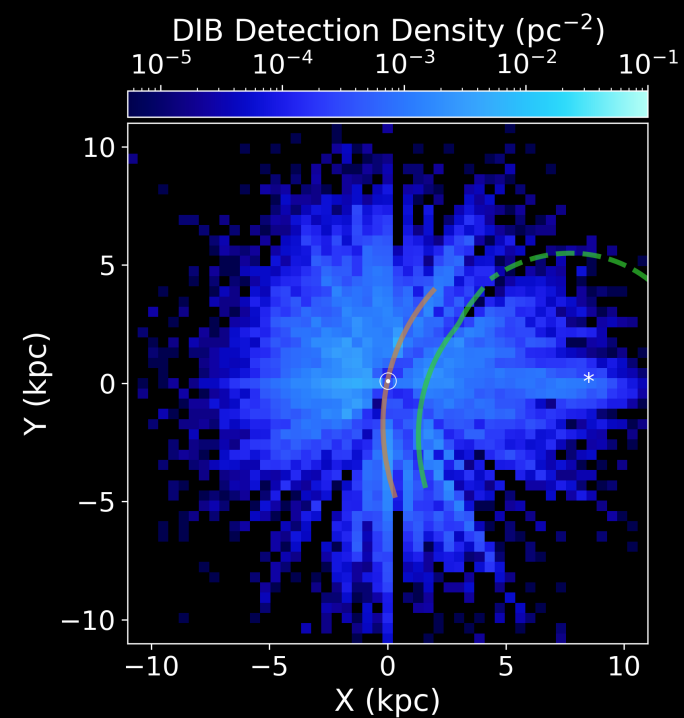
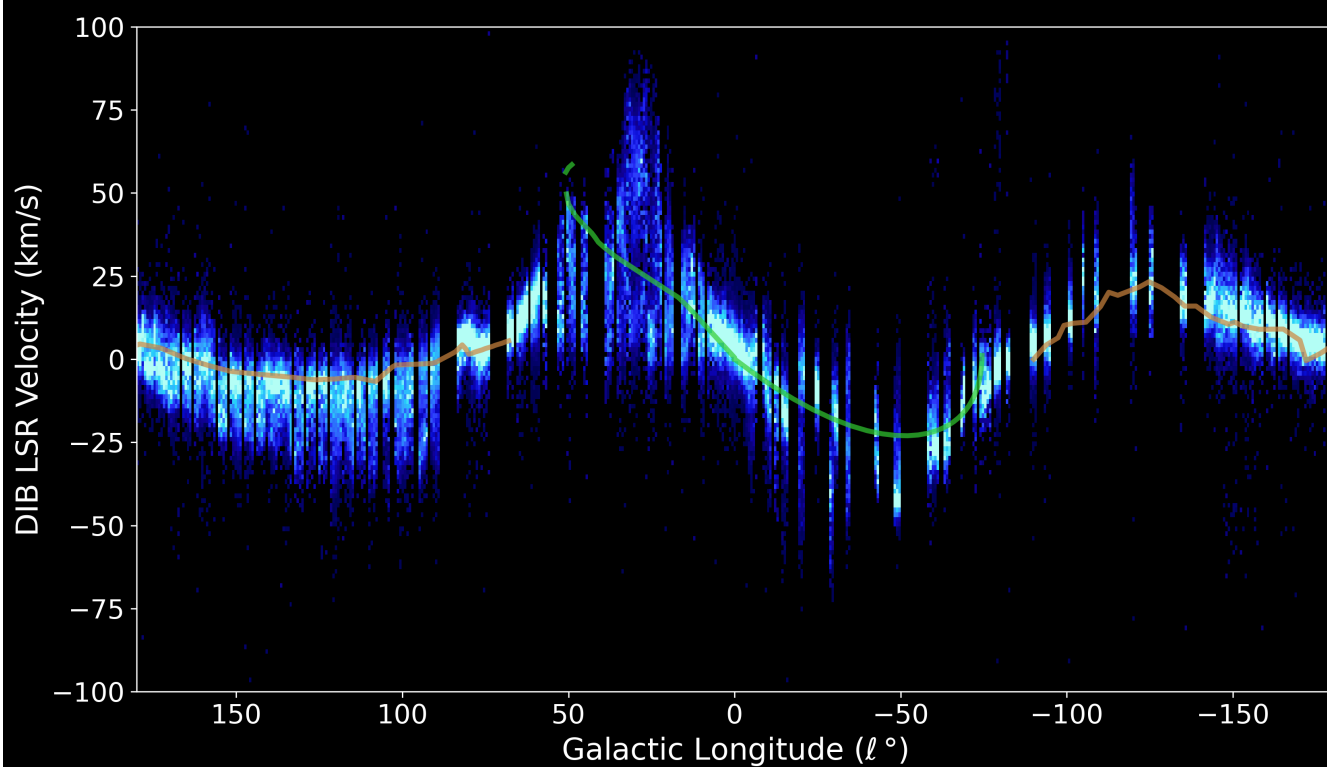
Detecting Spiral Arms in DIBs



Detecting Spiral Arms in DIBs

Sagittarius-Carina

Local

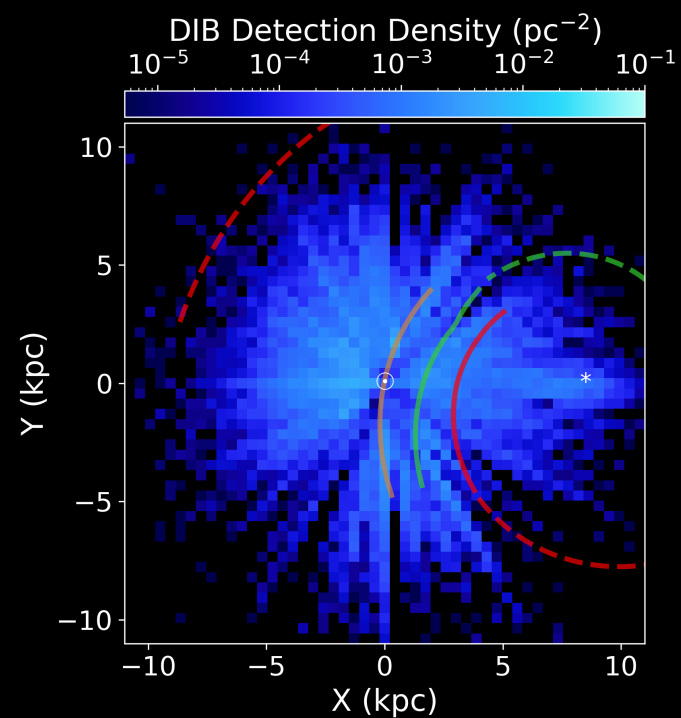
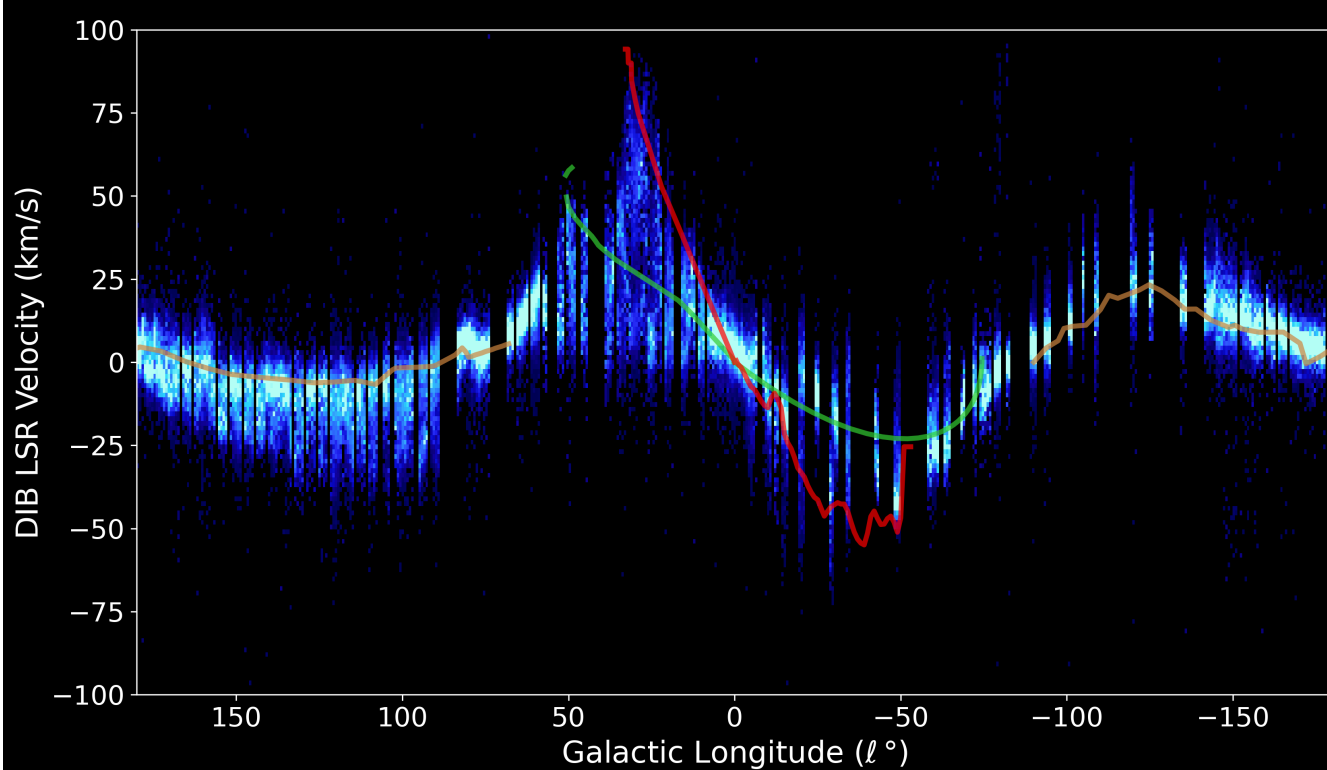


Detecting Spiral Arms in DIBs

Scutum-Centarus

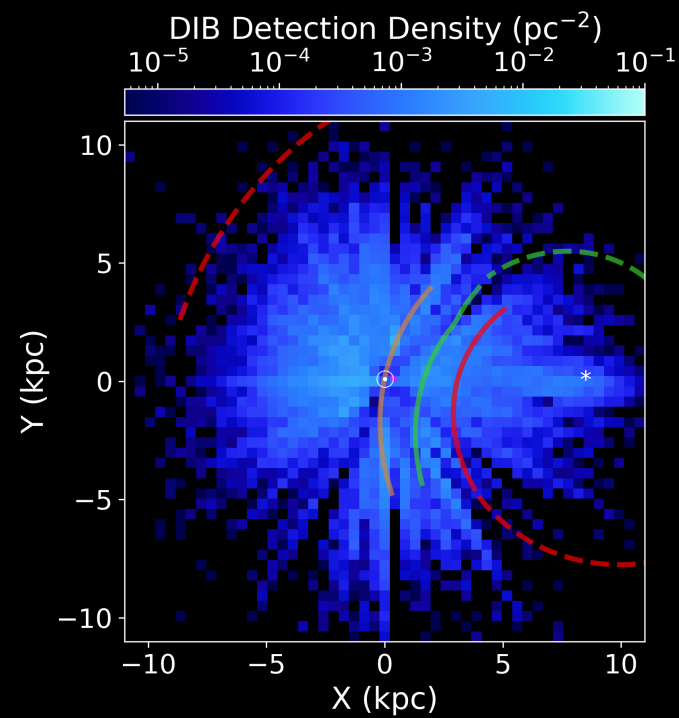
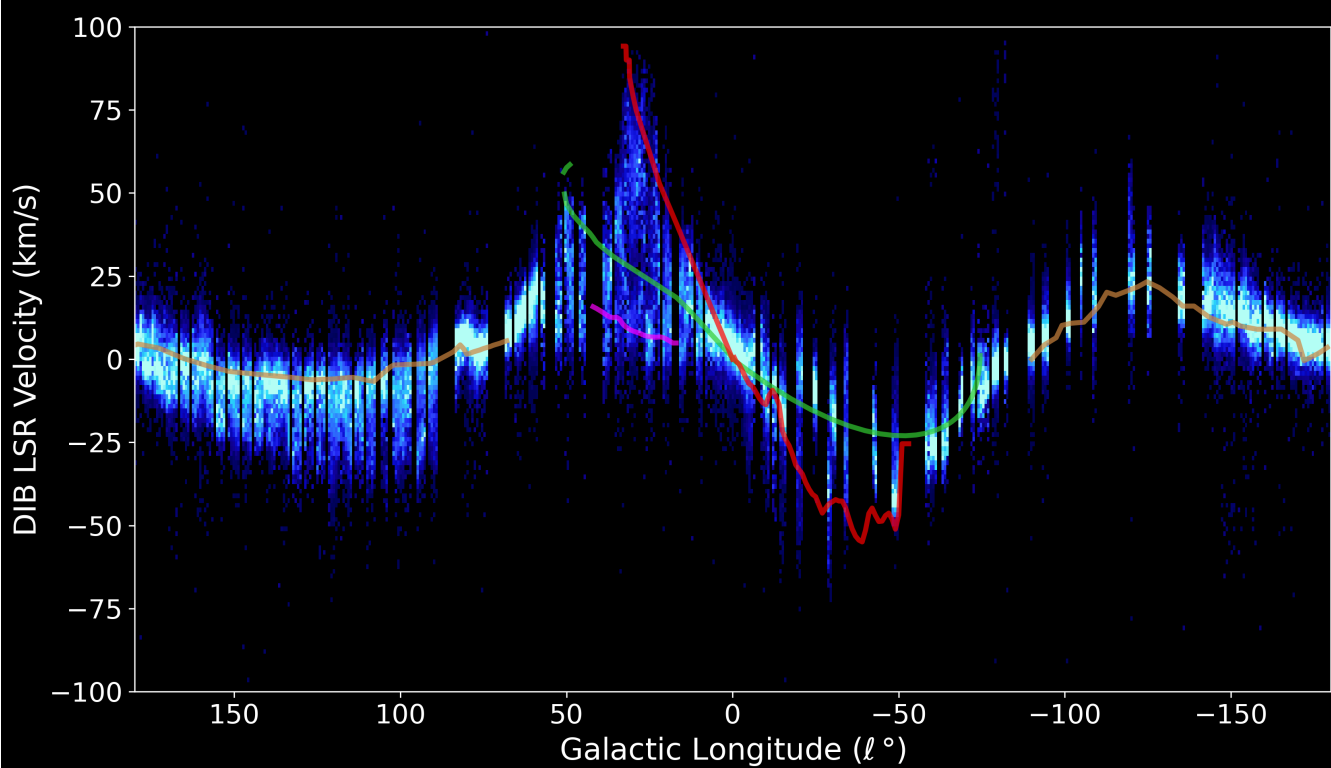
Sagittarius-Carina

Local



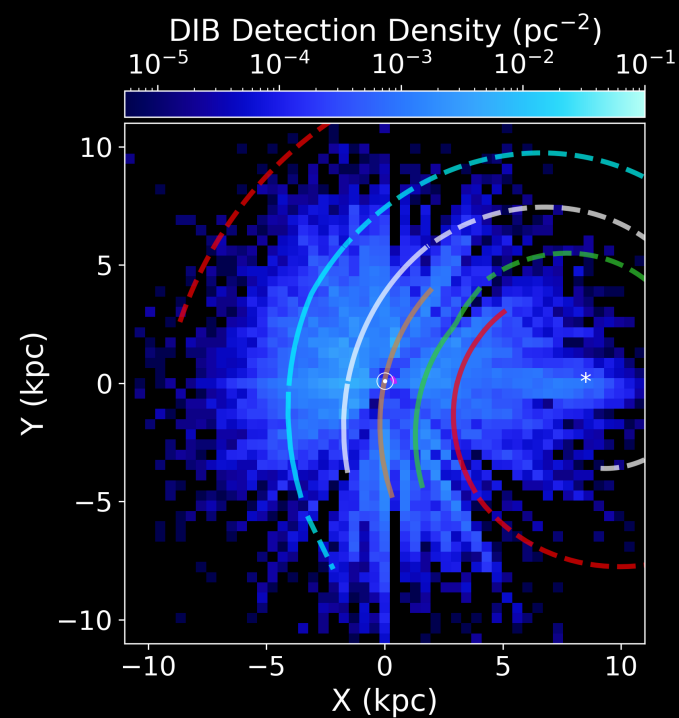
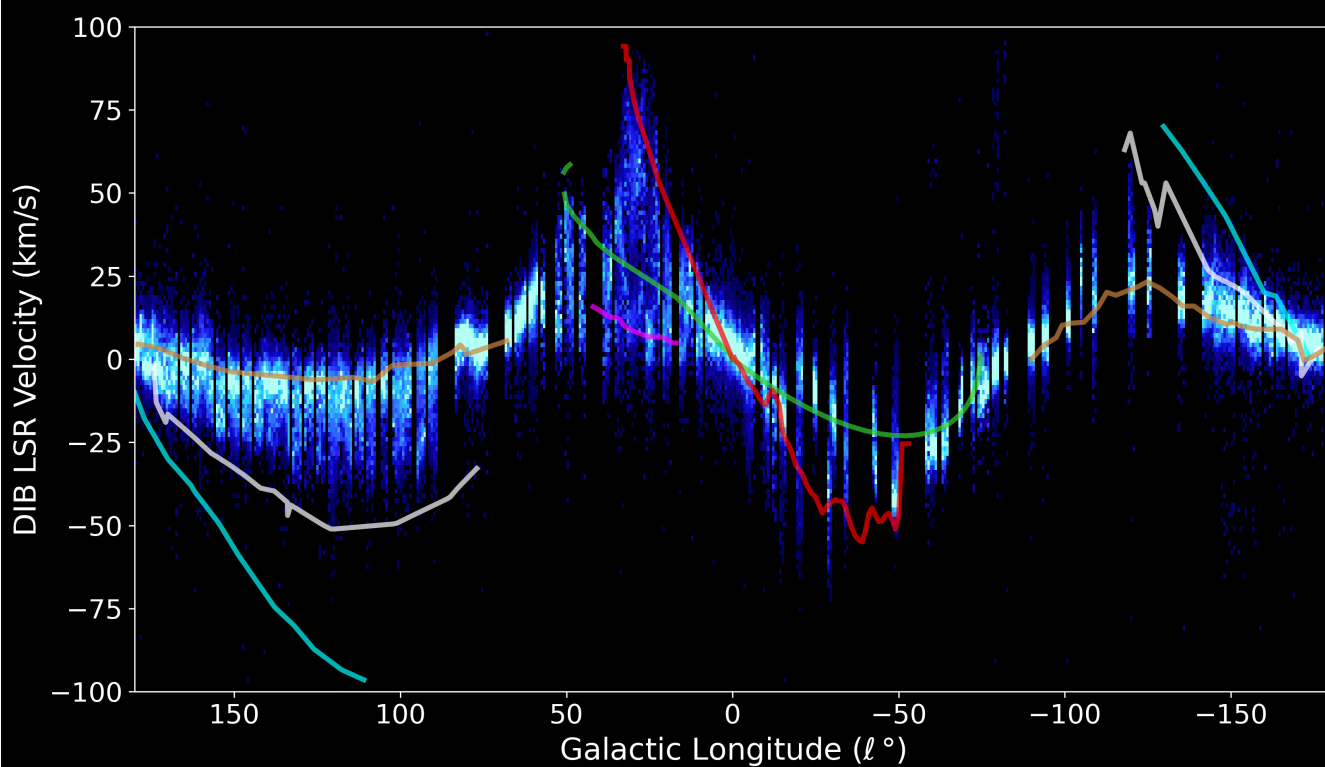
Detecting Spiral Arms in DIBs

Scutum-Centarus Sagittarius-Carina Aquila Rift Local



Detecting Spiral Arms in DIBs

Scutum-Centarus Sagittarius-Carina Aquila Rift Local Perseus Outer



Detecting Spiral Arms in DIBs

Correspondence between DIB kinematic substructures and CO

