SPHEREx: Mission Status and Cosmology with the All-Sky Galaxy Survey

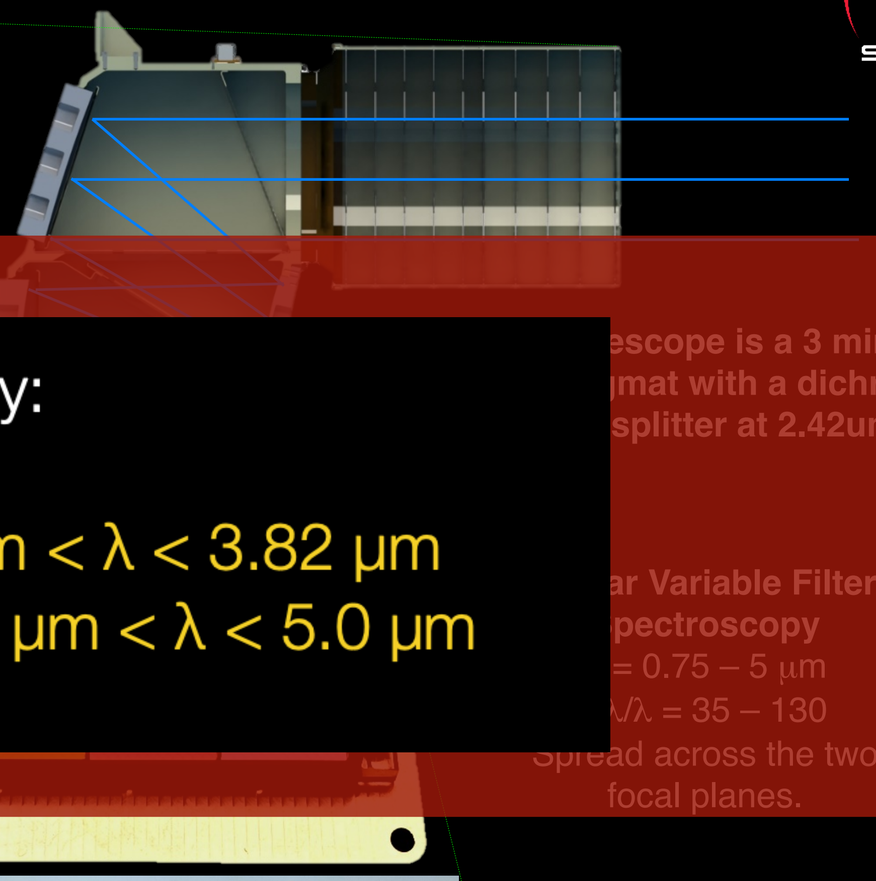
Richard Feder (UCB/LBNL)

on behalf of the SPHEREx team

https://spherex.caltech.edu

CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

What is SPHEREx?

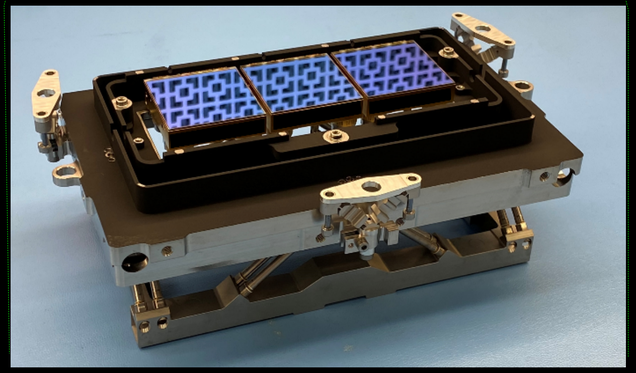


For <u>every</u> 6.2” pixel over the entire sky:

- ➡ R=35-41 spectra spanning 0.75 μm < λ < 3.82 μm
- ➡ R=110-130 spectra spanning 3.82 μm < λ < 5.0 μm

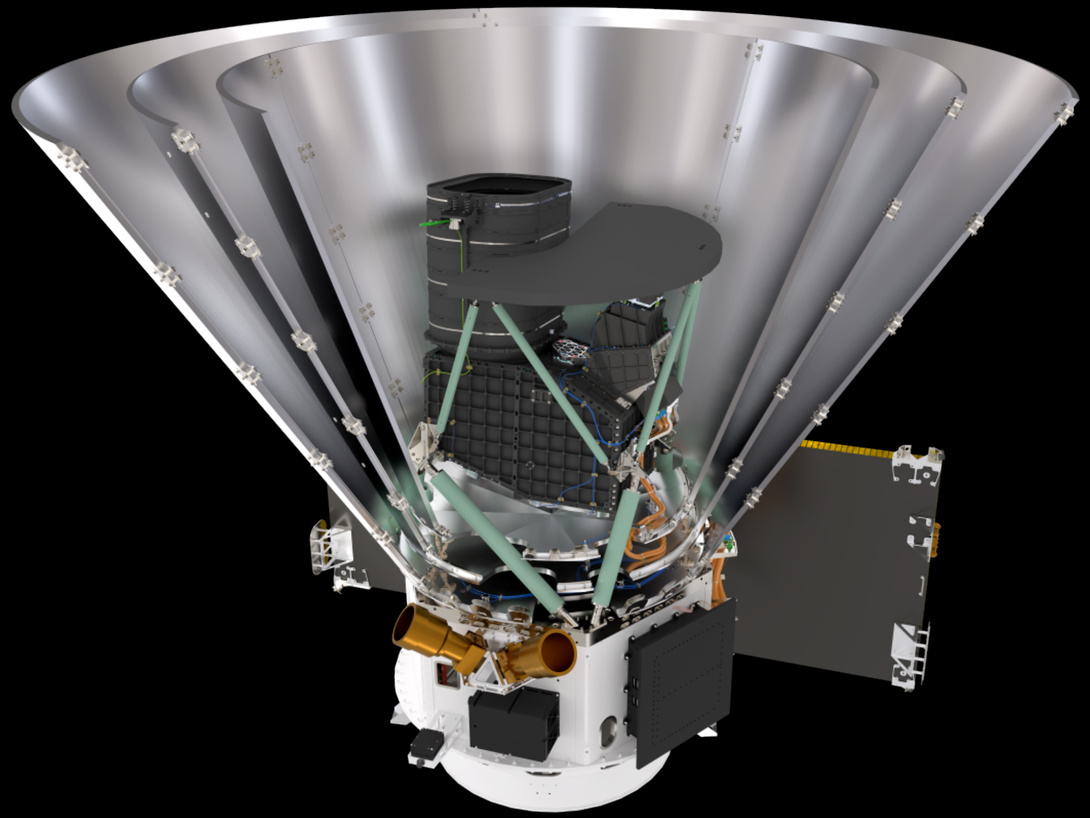
escope is a 3 mirror
mat with a dichroic
splitter at 2.42um.

ar Variable Filter
pectroscopy
= 0.75 – 5 μm
λ/λ = 35 – 130
Spread across the two
focal planes.



Mosaics of 2x3 H2RG arrays located directly behind the LVFs generate the spectral images.

SPHEREx Science Themes



Optimized for three scientific goals:

How Did the Universe Begin?

-3D galaxy survey probes inflation through measurements of primordial non-Gaussianity

How Did Galaxies Begin?

-Charting cosmic light production in the NIR through intensity mapping

What are the Conditions for Life Outside the Solar System?

–Survey of Milky Way interstellar ices through absorption line spectroscopy

A PERFECT LAUNCH… AFTER EIGHT DELAYS

March 11th, 8:10pm

T-0

SpaceX

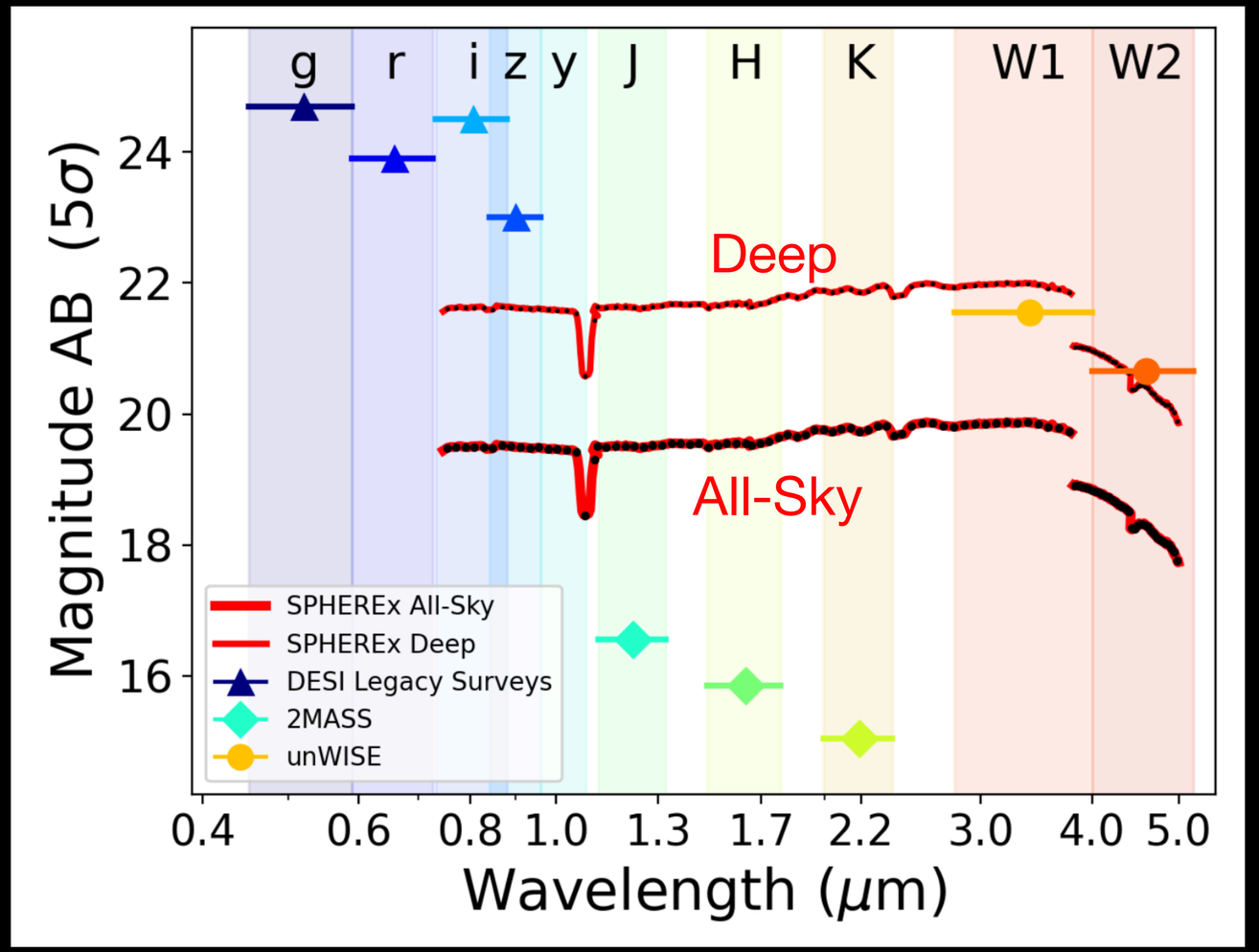
Photo: Pao-Yu Wang

T+40 min.

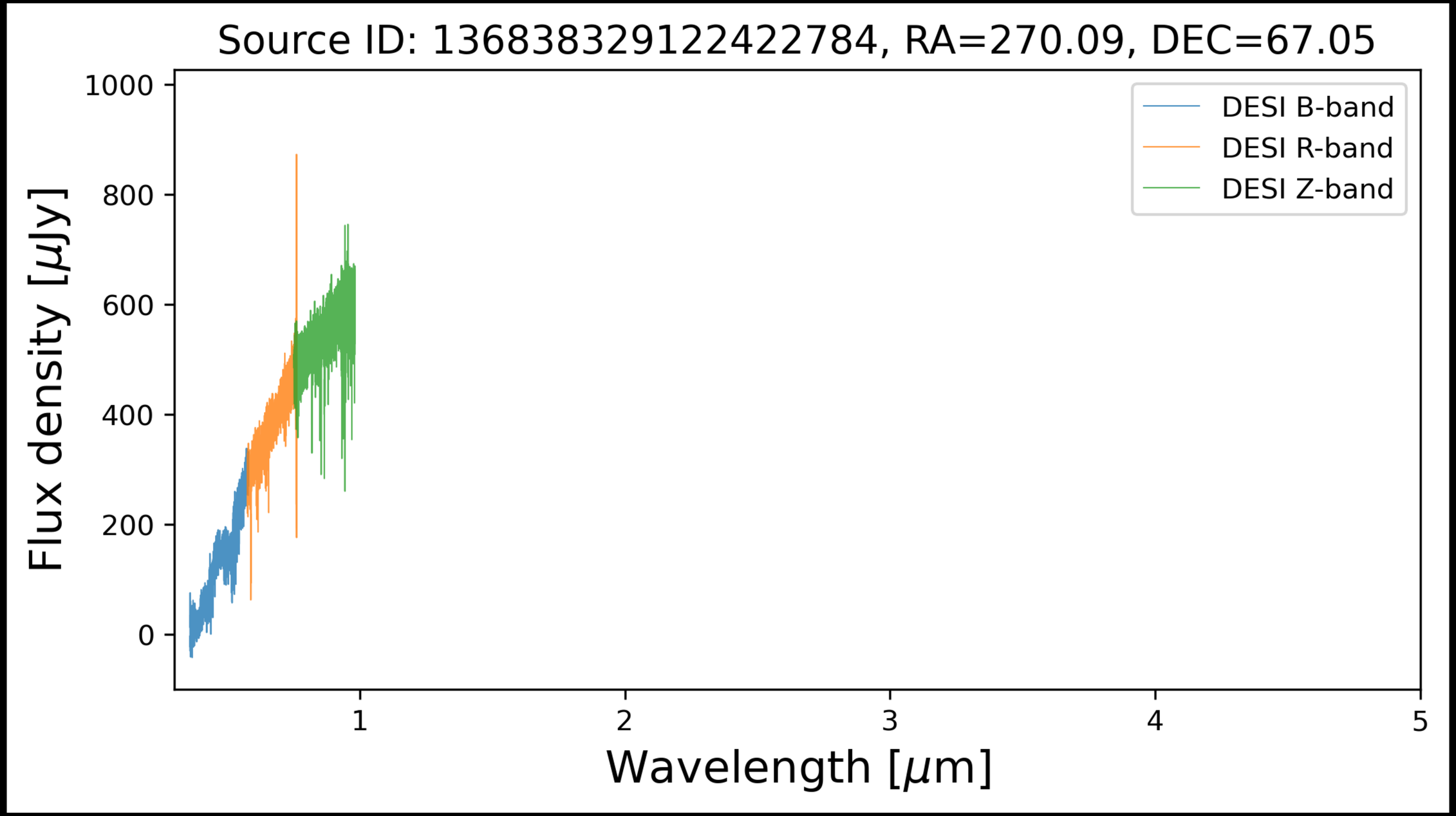
SpaceX

Spectral coverage and point source flux sensitivity

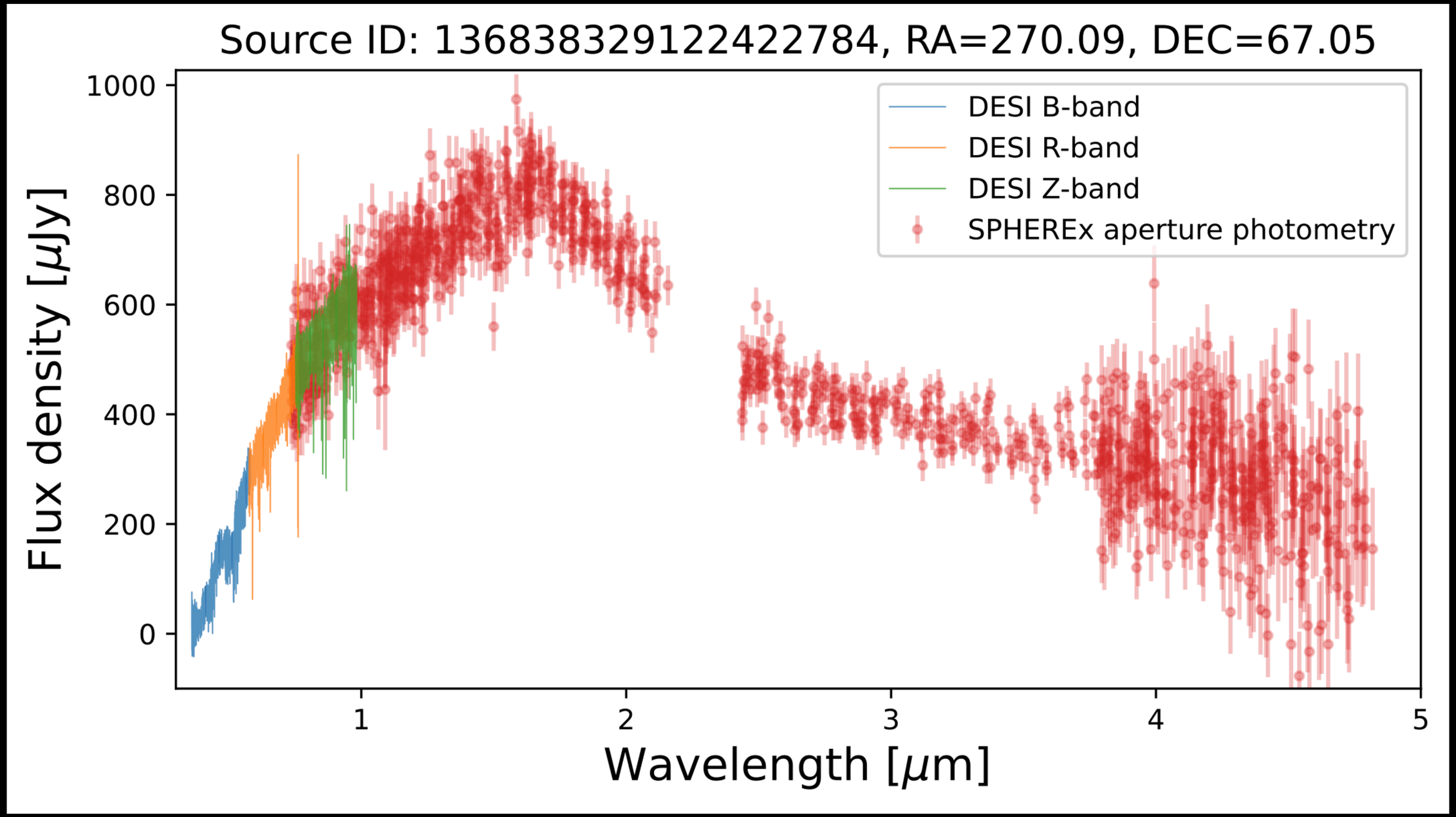
- Sensitivity estimates derived from flight data
- Overlap at short wavelengths with I-band, z-band
- At long wavelengths, channel co-added depths approach that of unWISE
- Deep fields have ~50x more coverage



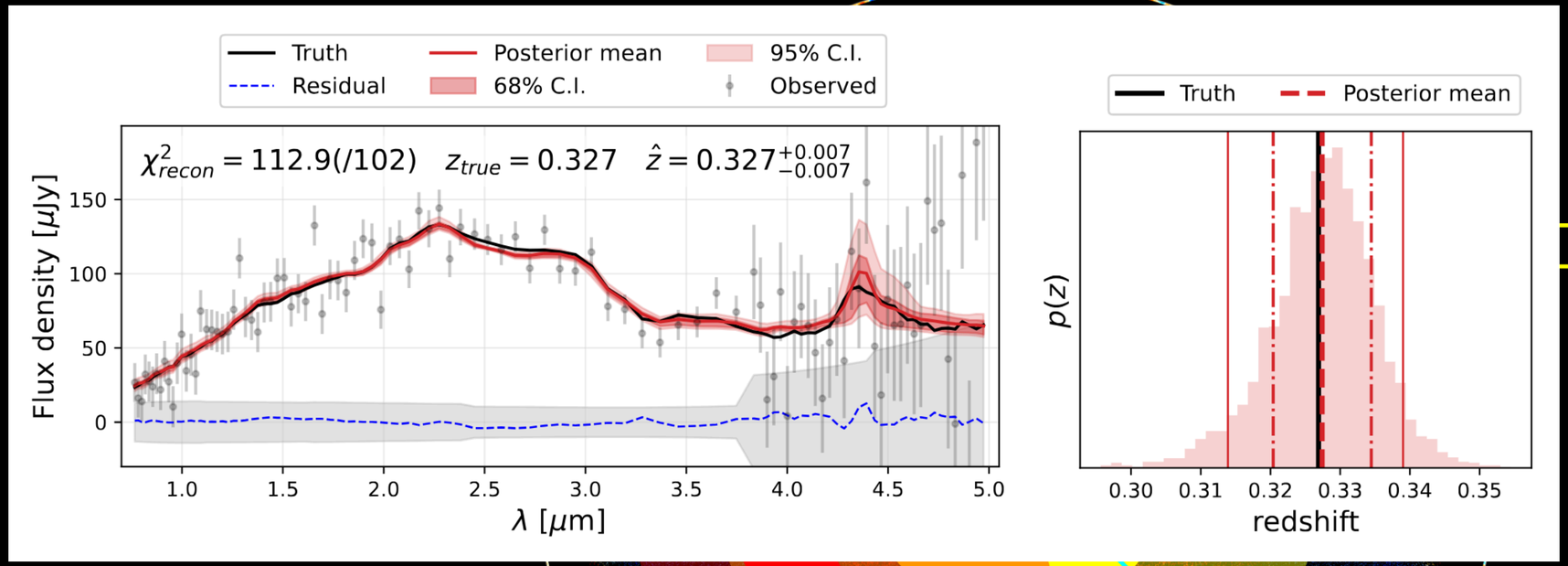
Bock+25 (in prep.)


Source ID: 13683832912242278 4, RA=270.09, DEC=67.05
DESI B-band
DESI R-band
DESI Z-band
Flux density [μJy]
1000
800
600
400
200
0
1
2
3
4
5
Wavelength [μm]

(Real *SPHEREx* data!!!)



SPHEREx Redshift Survey



SPHEREx

All-sky spectroscopic survey
Science targets inflation

Over 30000 sq. deg.:
19M; < 0.3%
50M; < 1%
445M; < 10%
800M; < 20%

(Feder+2024)

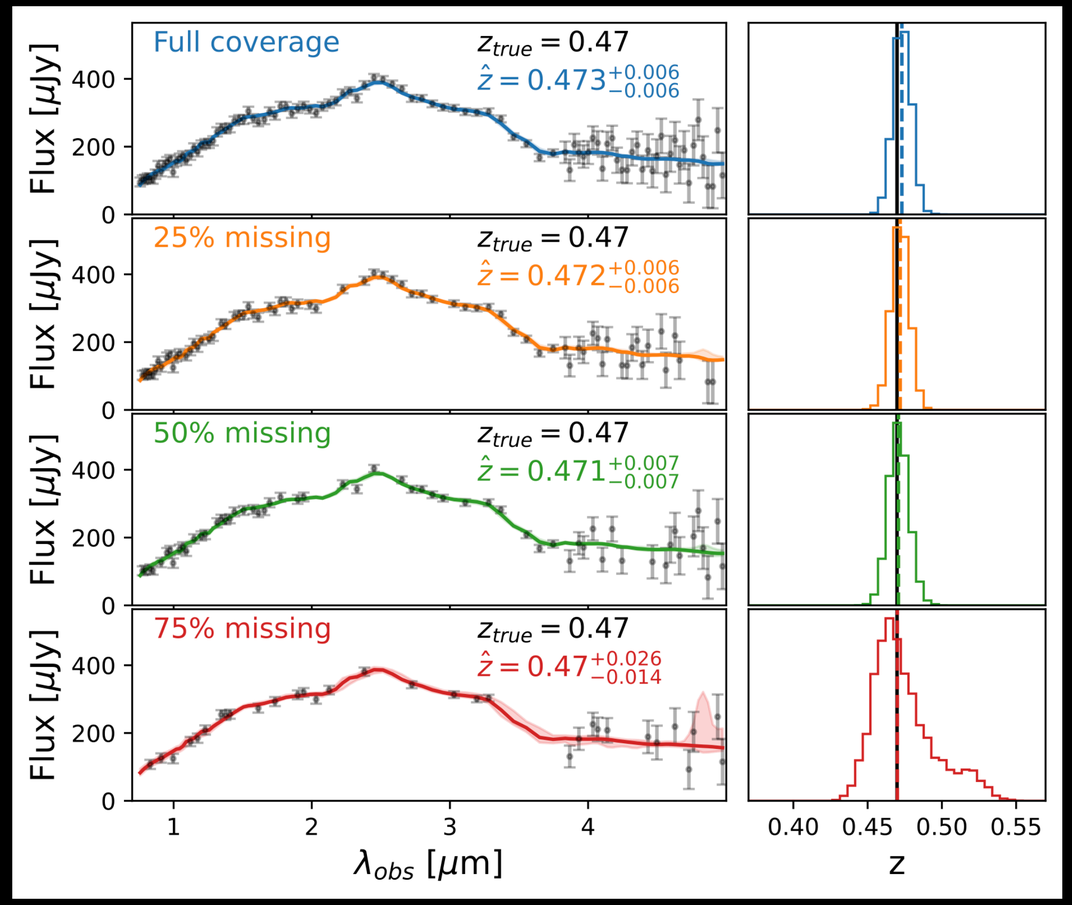
*Emission lines help (Hα+[NII], Pa-α, [OIII]+Hβ) but not used in official redshift forecasts

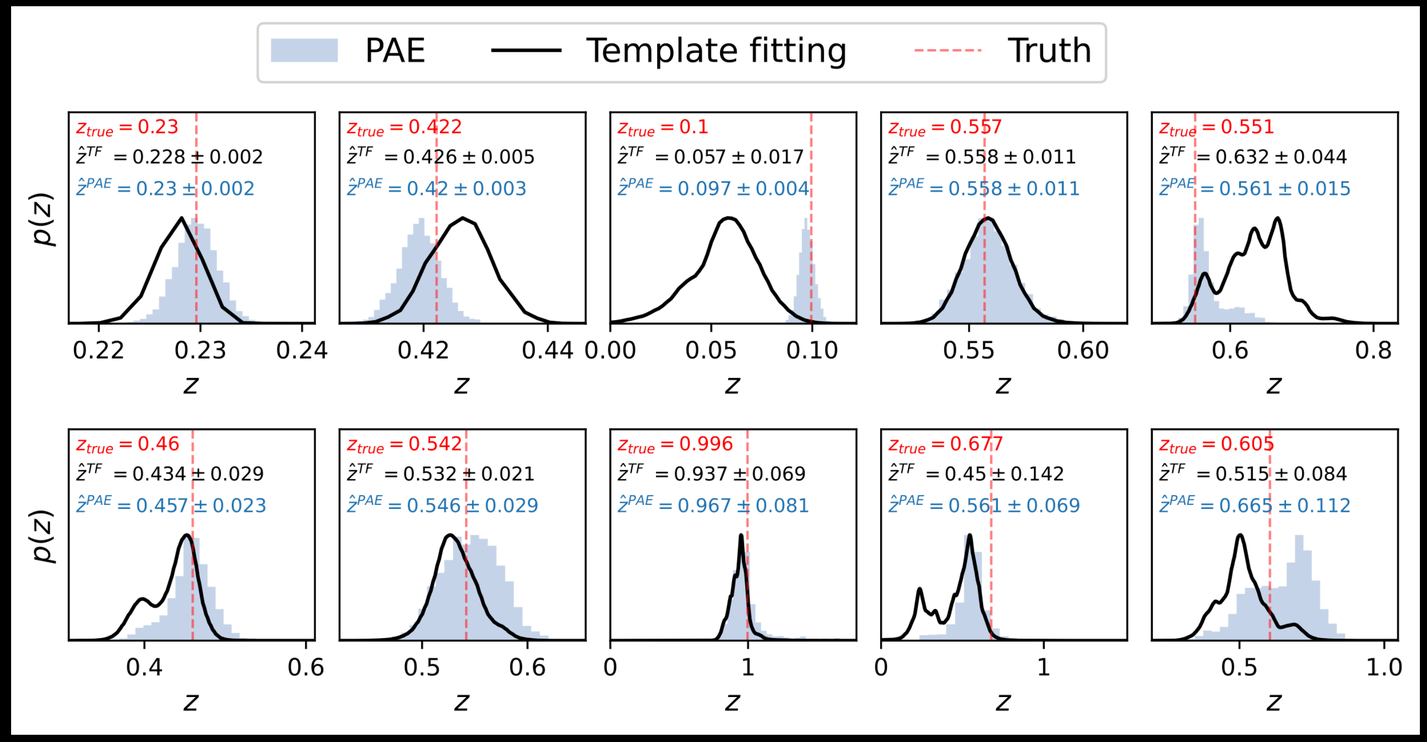
Euclid

BAO and lensing survey
Science targets dark energy
15,000 sq. deg. area
30M spec-zs
2B photo-zs

Picture credit: Ménard & Shtarkman, SDSS

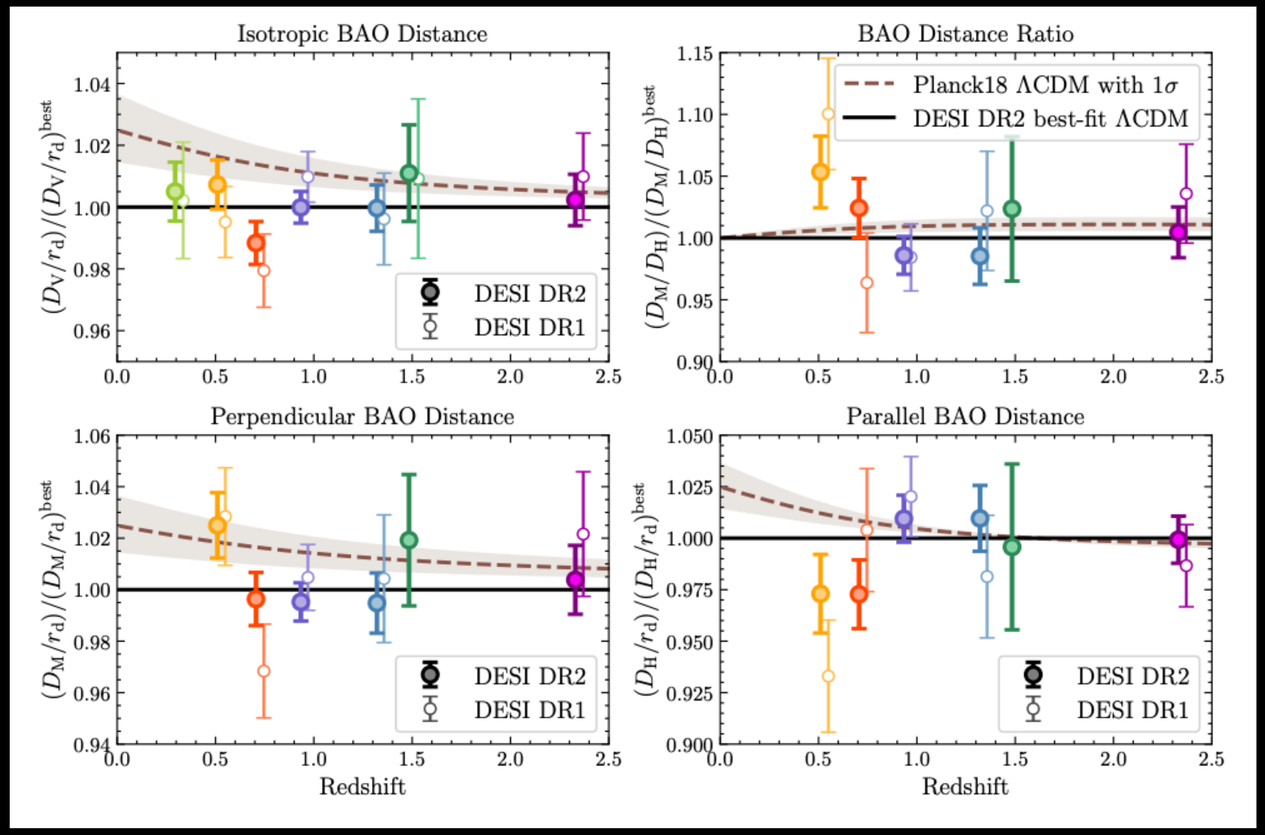
Improved Redshift Estimation with Probabilistic Autoencoders

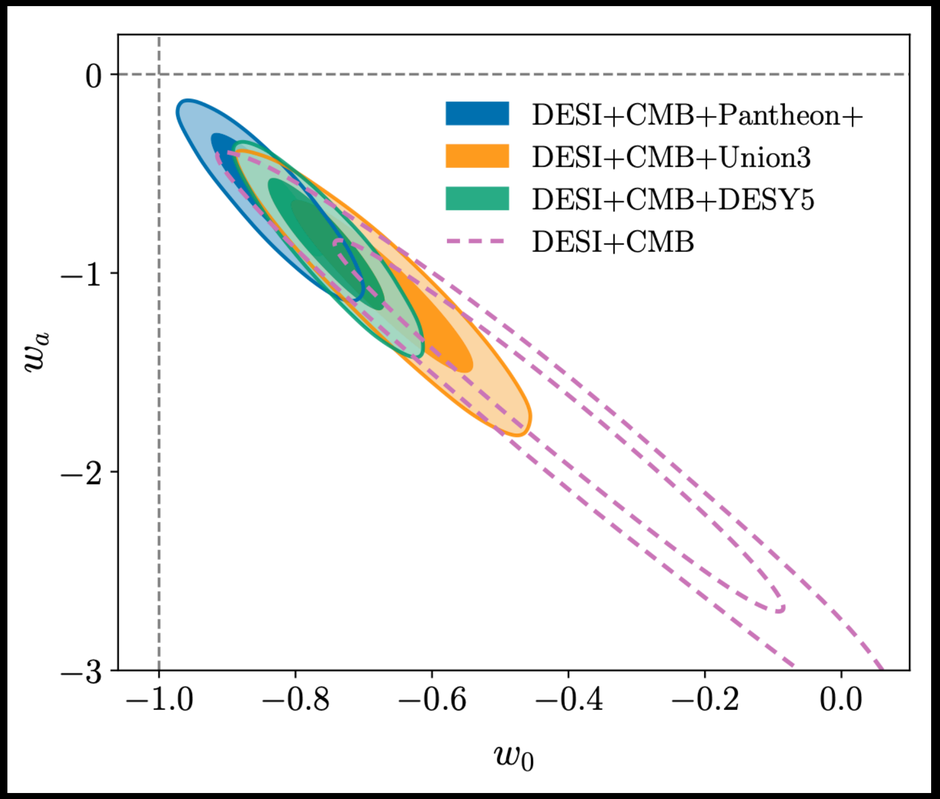




Feder, Seljak, Parker 25c (in prep.)

BAO Measurements in the DESI era

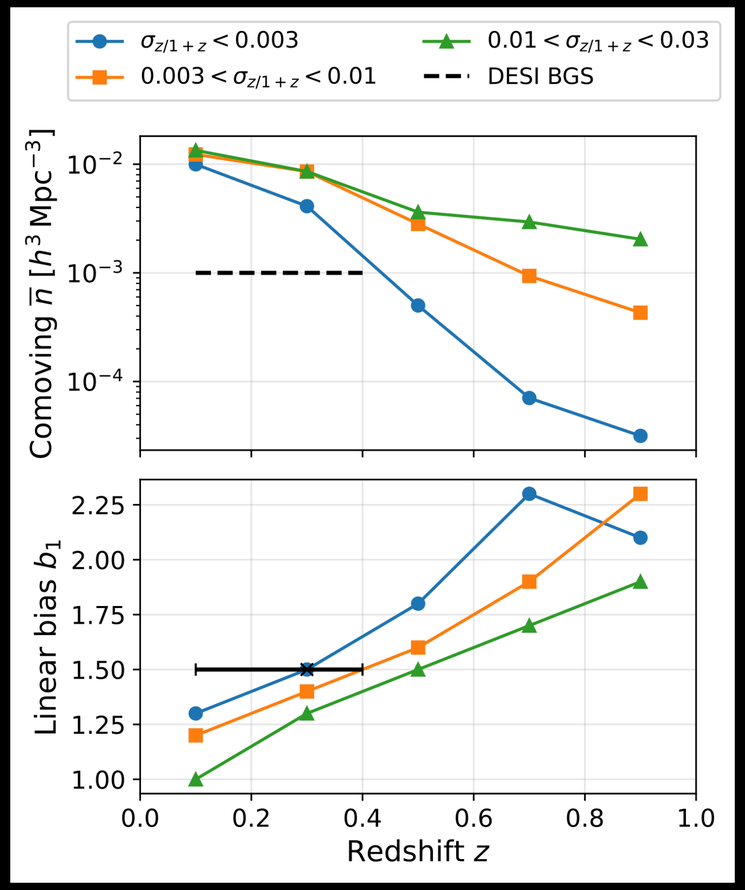


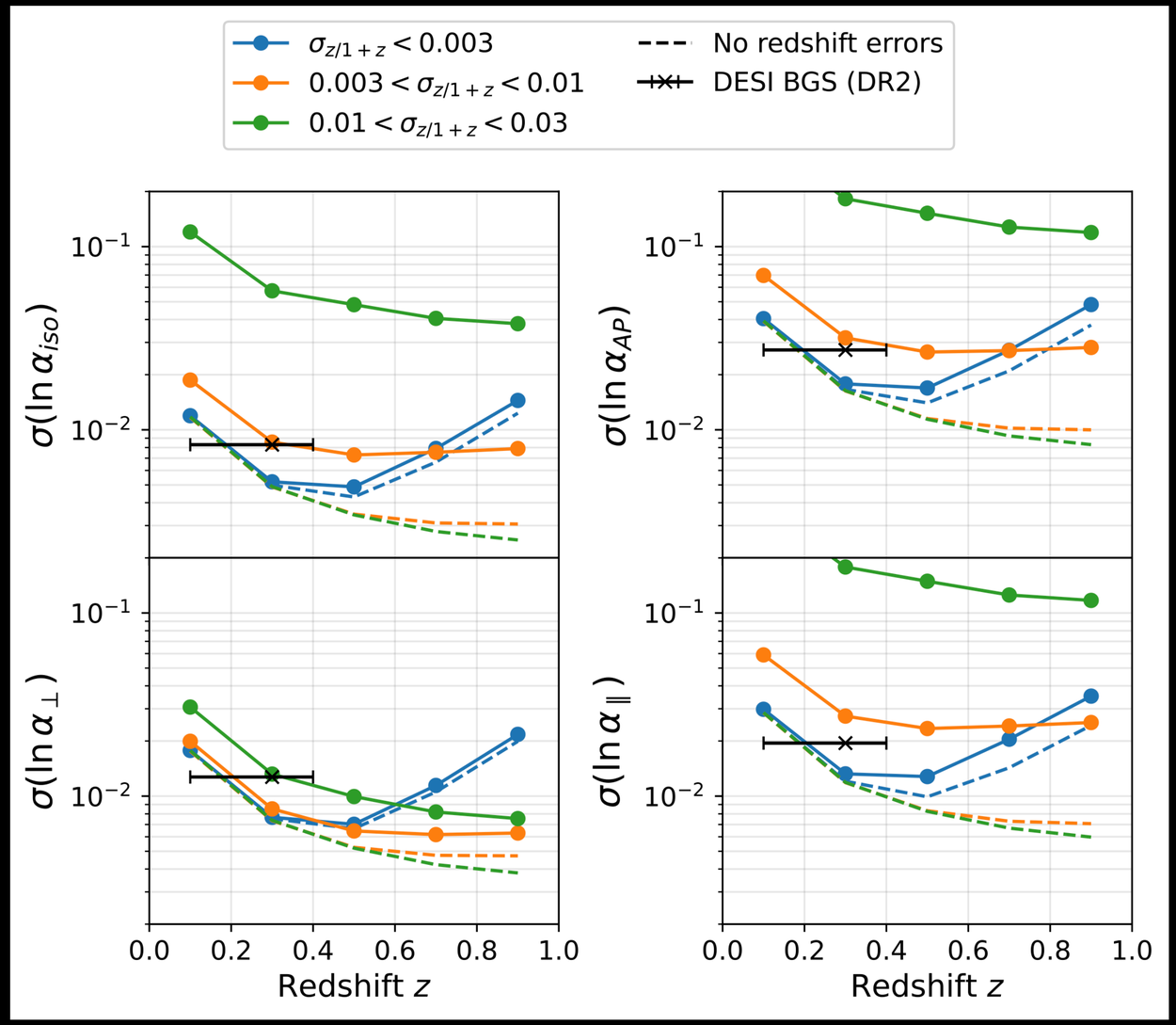


DESI DR2 results II

BAO Measurements in the DESI era

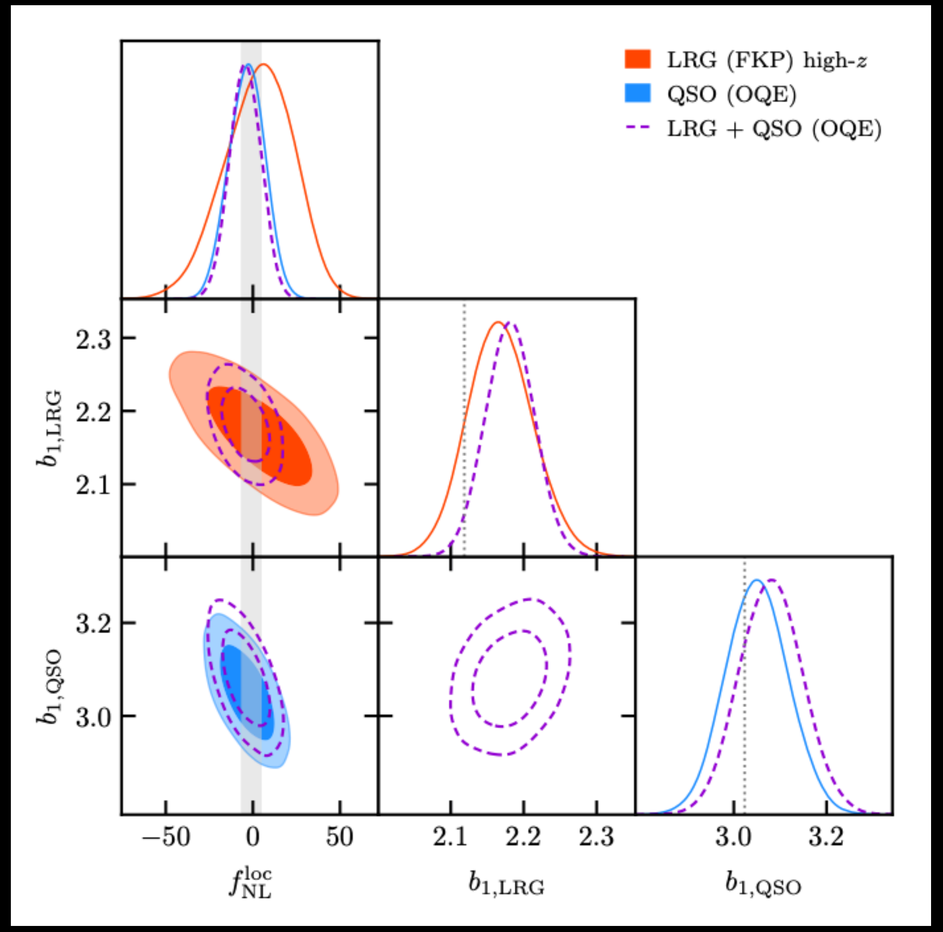
SPHEREx can fill in a unique gap for BAO measurements at low redshift





Probing Inflation with *SPHEREx*

- *SPHEREx* has sensitivity to drastically improve constraints on local PNG
  - Current forecasts: $\sigma(f_{NL}^{loc}) = 0.8$ (PS only)
- SFB proving useful for modeling wide-angle/GR effects, systematics discovery/mitigation, etc.
  - HG+OD 21 (*SuperFab*), HG+24 (SFB on eBOSS EZmocks), RW+24 (SFB->PSM), RW+25a/b, SB+25 (BOSS reanalysis, in prep.)
- An optimized galaxy MT analysis could yield further improvements, but more work is needed to understand interaction with systematics, selection function

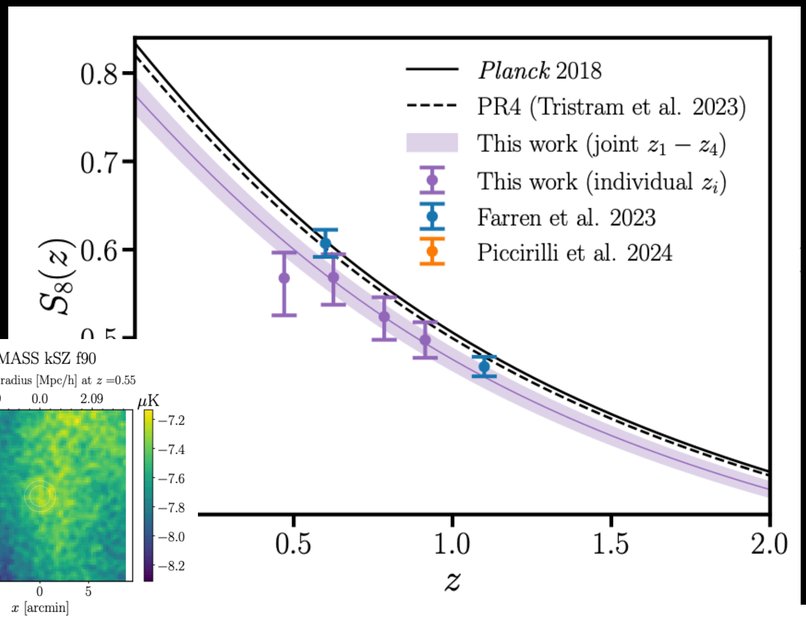


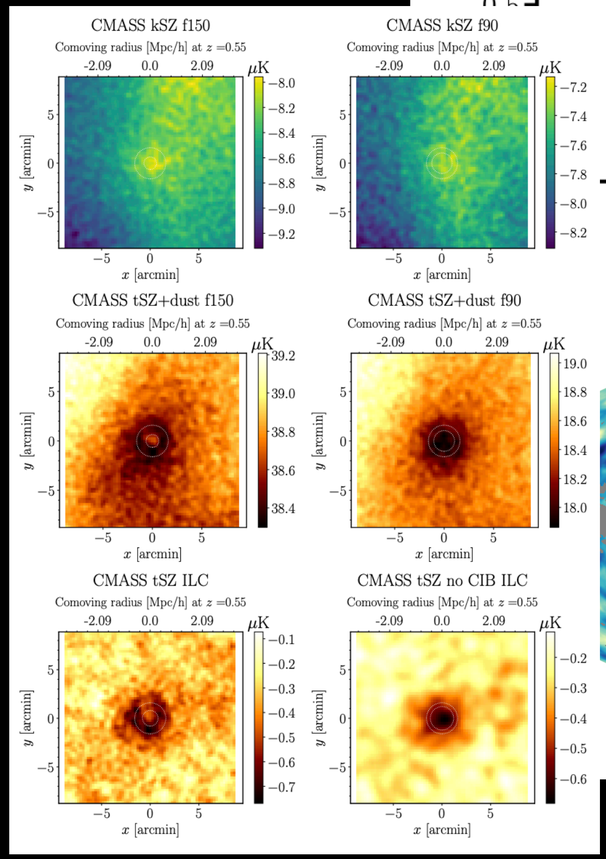
DESI 2024 (Chaussidon+2024)

Cross-correlation science

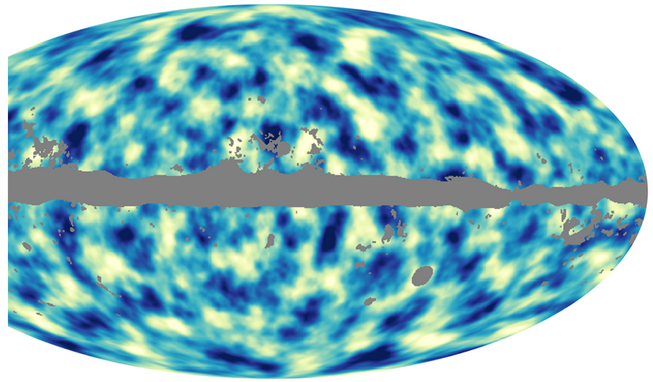
- CMB secondary anisotropies (lensing, kSZ, tSZ)

Sailer+24





Schaan+21

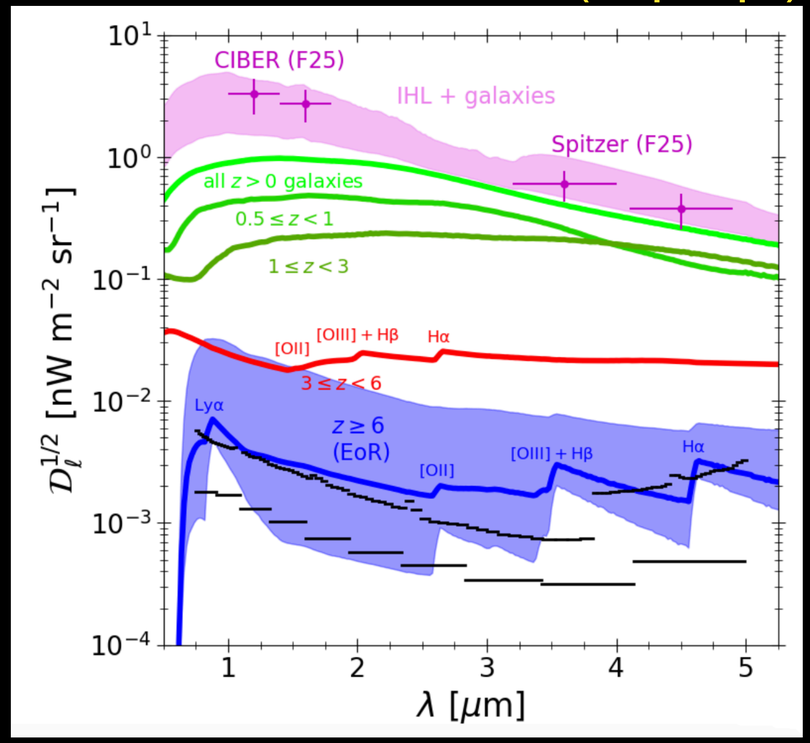


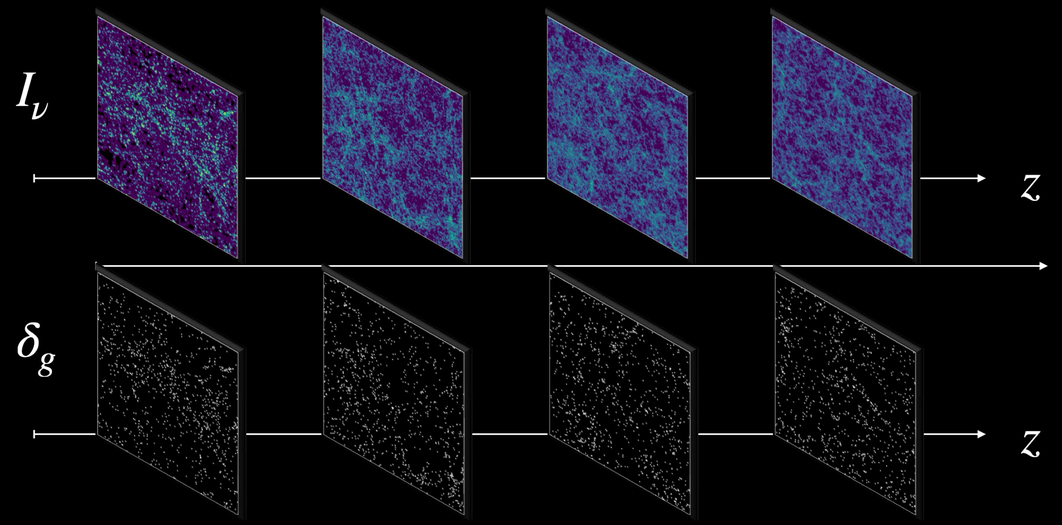
Planck

Cross-correlation science

- CMB secondary anisotropies (lensing, kSZ, tSZ)
- NIR extragalactic background light (EBL) redshift tomography
  - bI x dI/dz from angular scales dominated by linear clustering
  - 1h clustering vs. redshift —> evolution of non-linear structure formation

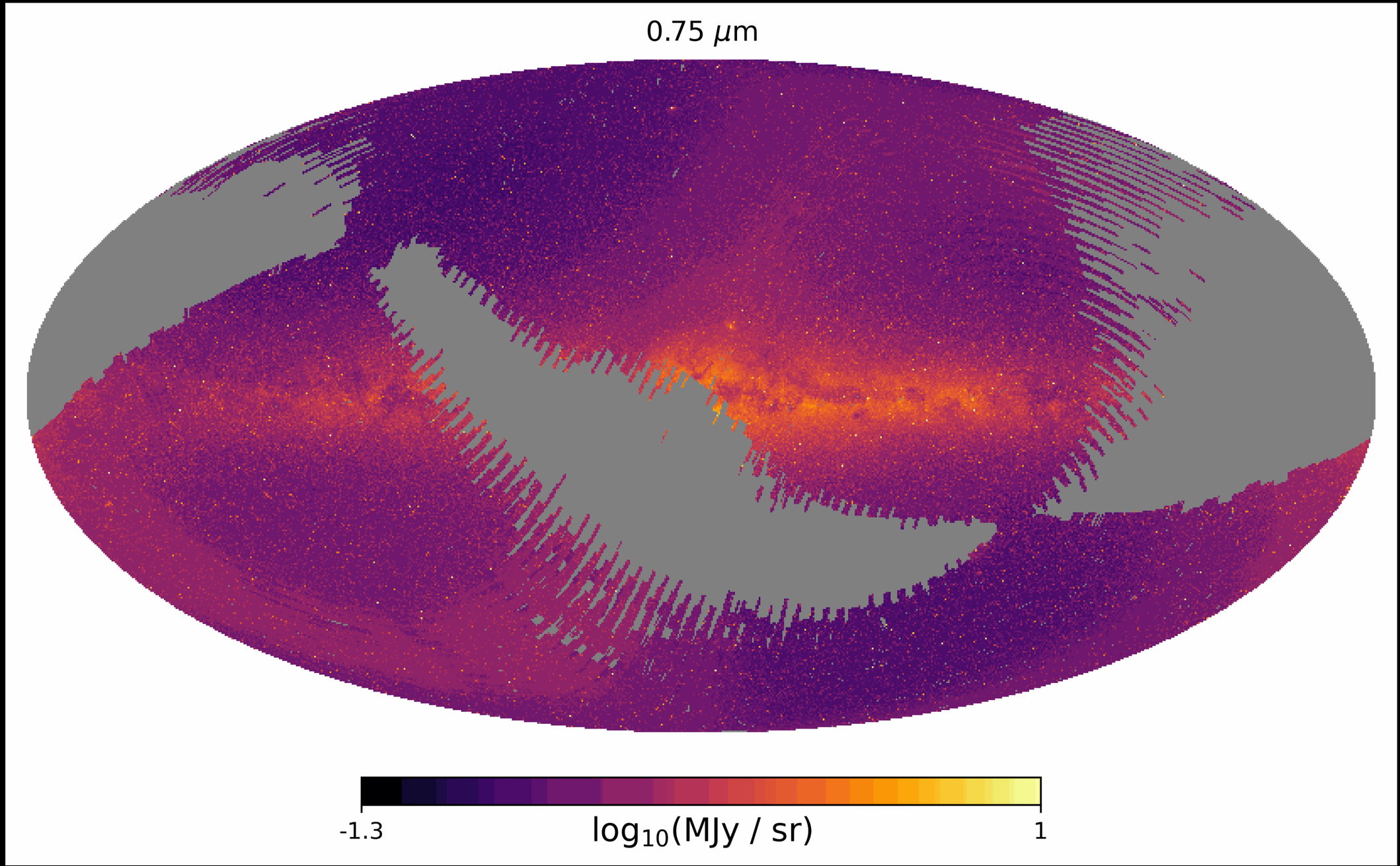
Bock+25 (in prep.)





Coverage as of September 23

Credit: Ari Cukierman, Giulia Murgia




Thanks for Listening!

BACKUP SLIDES

Public products

Product	Schedule	Notes
Quick Release Calibrated Spectral Images	Within two months of acquisition	Updated weekly at IRSA
Calibration Products	As needed	Calibrations used with quick release calibrated images
Reprocessed Calibrated Spectral Images	Year 1 and Year 2 data releases	Cumulative re-processing of spectral image data
All-sky Data Cubes	Year 1 and Year 2 data releases	
High Reliability Source Catalog	8 months after end of survey 3	
Deep Field Mosaics	May 2028	Galaxy Formation science theme
Stellar Type/Ice Column Density Catalog	May 2028	Interstellar Ices science theme
Redshift Catalog	May 2028	Cosmic Inflation science theme
Legacy Catalogs: Stellar/Brown Dwarfs, Galaxy Clusters, Solar System	May 2028	Science Team Legacy Catalogs

Table 4. Availability of SPHEREx Science Data Products. Note that Year 1 observations end in May 2026, and Year 2 observations end in May 2027.

Tool	Availability	Description
Spectrophotometry	August 2025	Measure spectra at user-supplied positions, using the same PSF photometry method as the Level 3 pipeline
Spectral Image Cutout	October 2025	Select sections of spectra images based on user criteria (spatial area, band, time)
Source Discovery	October 2025	Identify significant signal in user-supplied spatial region (with user constraints), without priors on the position
Custom Mosaic	February 2026	Create single-wavelength images from spectral images using user supplied criteria, including synthetic bands
Spectral Cube Cutout	November 2026	Extract subsets from the All-sky Spectral Cube, returning FITS cubes with a HEALPix projection, and optionally interpolate for synthetic bands

Table 5. Availability of SPHEREx-specific analysis and visualization tools at IRSA

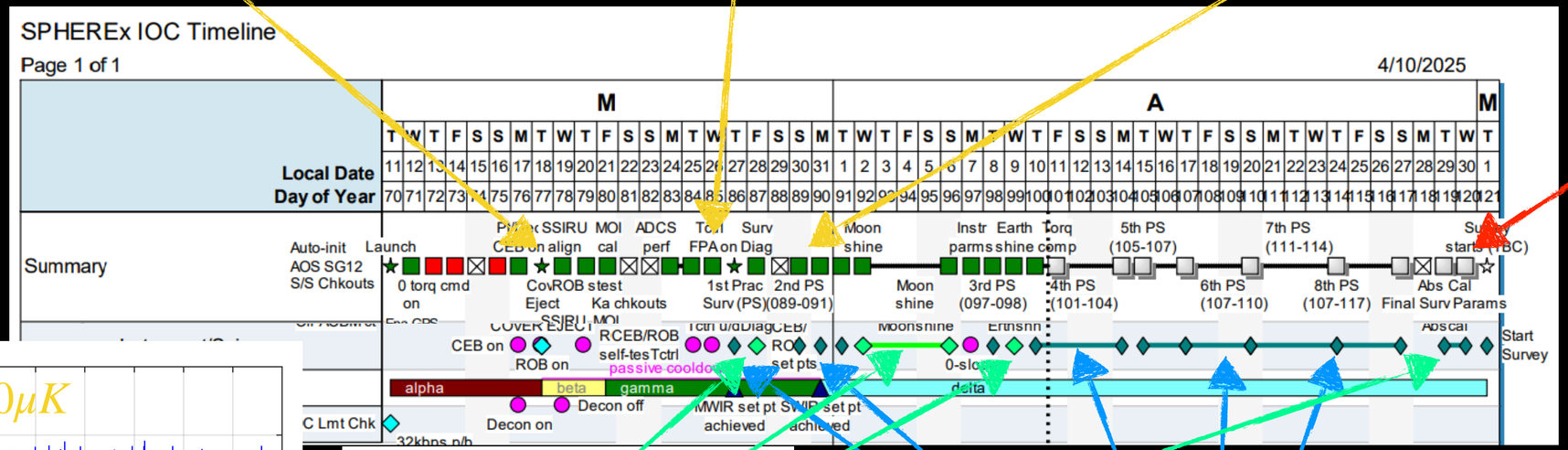
In-Orbit Checkout

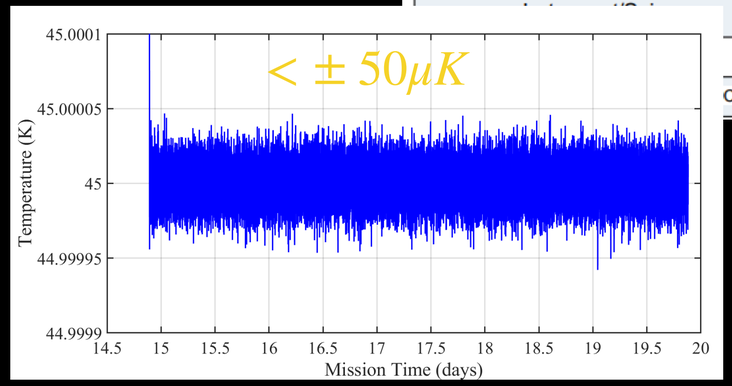
3/18: Cover Eject

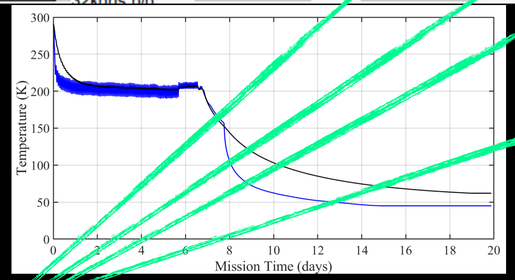
3/26: Detectors turned on

3/30: Focal Plane Temperature at Target: 62K/45K

Start of Science Survey







Systematics Experiments

Practice Surveys with multiple configurations

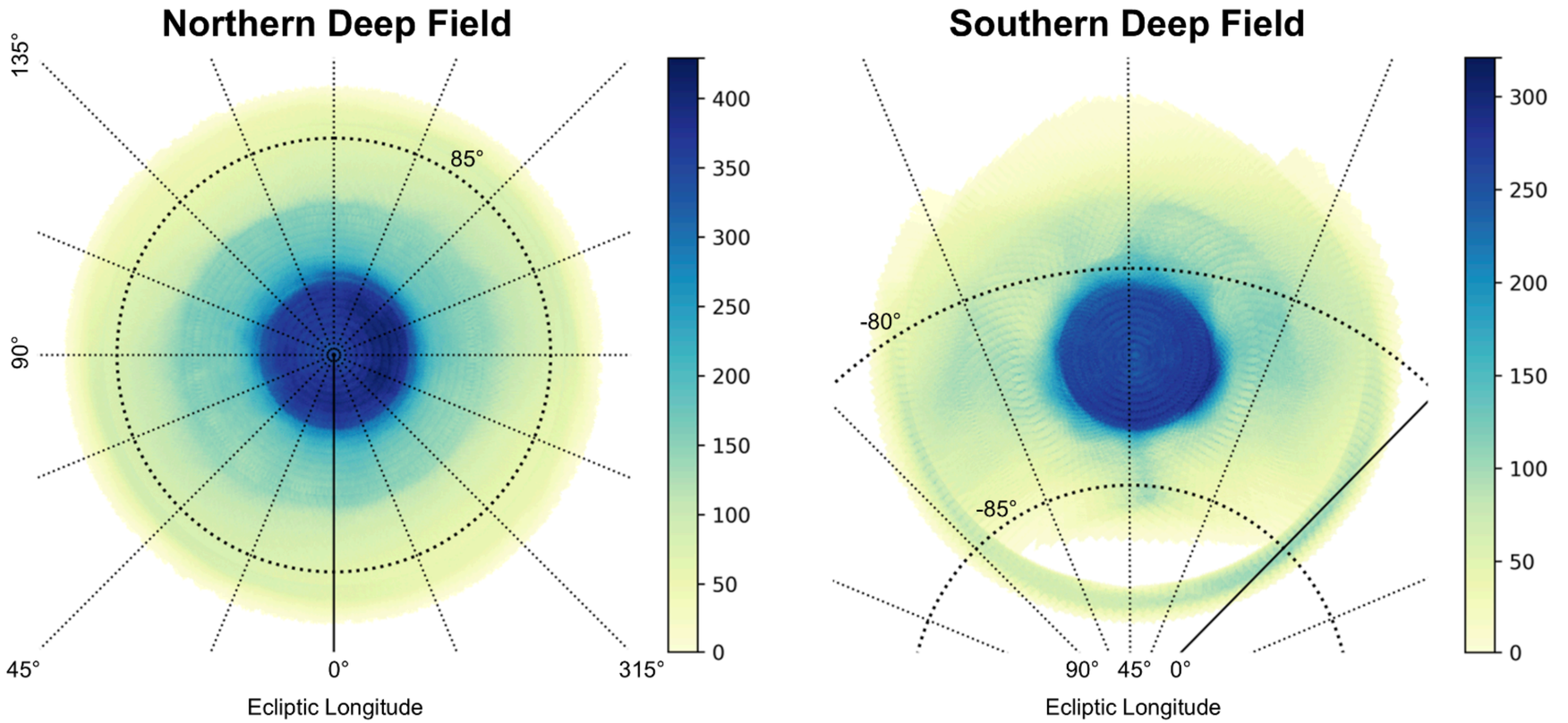


Figure 9. Coverage of the SPHEREx deep fields, shown as the minimum number of hits in each $6\farcs2$ sky pixel over all 102 spectral channels after 2 years of planned observations. The northern field is centered on the north ecliptic pole, while the southern field is displaced from the south ecliptic pole is centered at ecliptic latitude $-82°$ and ecliptic longitude $-44°.8$ to avoid the Magellanic clouds. We overlay ecliptic coordinates for reference.

Redshifts from low-resolution spectroscopy

(Feder+2023b)

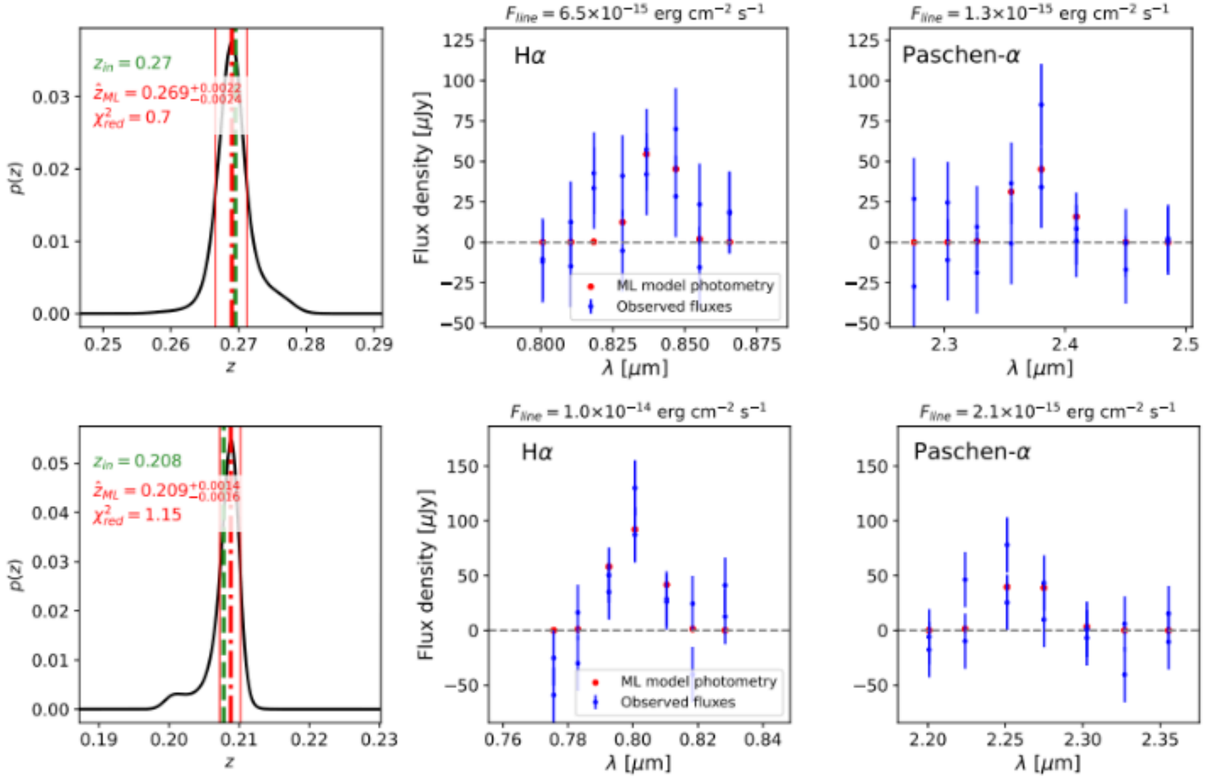
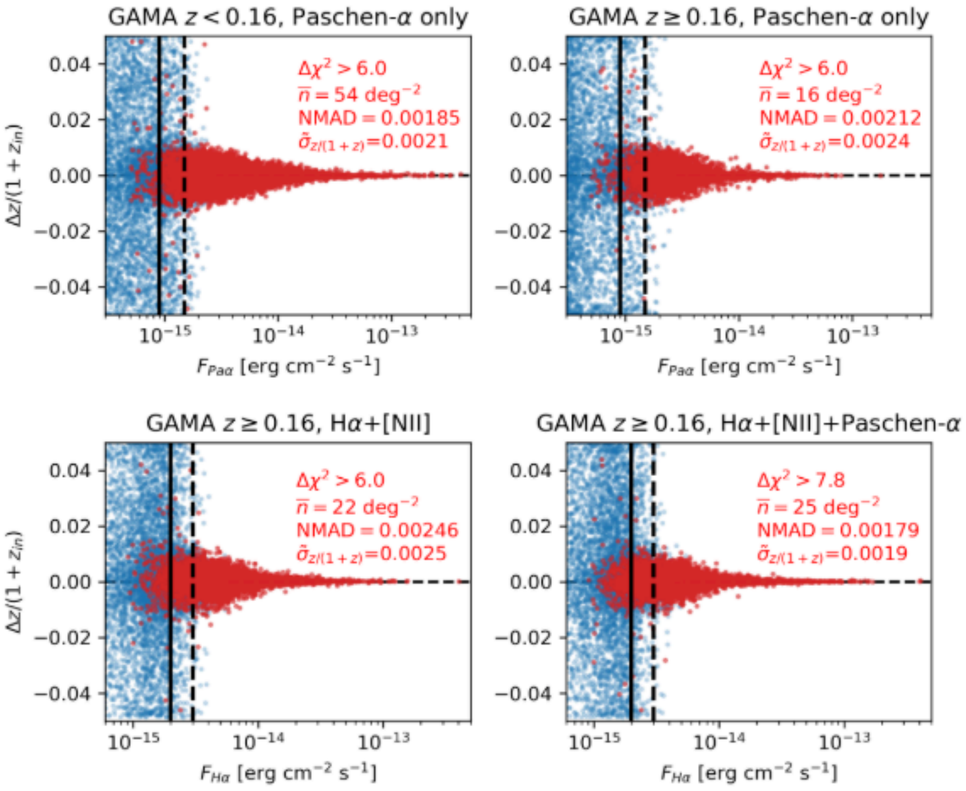


Figure 26. Line fits and redshift PDFs for simulated SPHEREx measurements of three isolated, low-redshift galaxies. The left column shows the derived line redshift PDFs – the green and red dashed lines indicate the input and recovered redshifts for each case, while the solid red lines bound the 68% credible interval of each PDF. The middle and right columns show the synthetic fluxes (blue) and best-fit model photometry (red) for measurements near Hα and Paschen-α, respectively.



Redshift recovery tests on “bright galaxy sample”, full sky depth

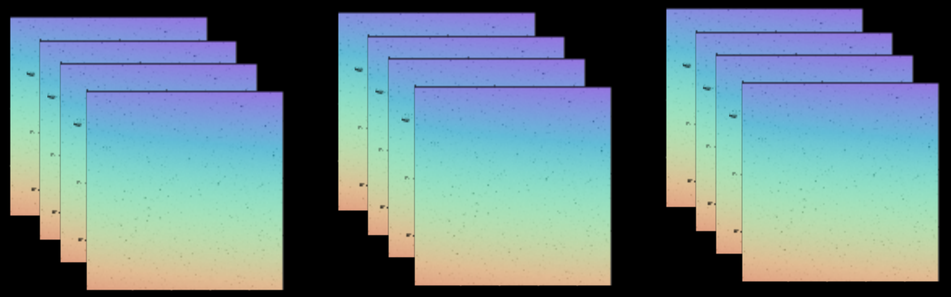
SPHEREx will provide an all-sky spectral archive

Delivered to the NASA/IPAC Infrared Science Archive (IRSA)

→ Enables a wide range of community science with well-calibrated data products

Calibrated Spectral Image Data

- Available in archive within 2 months
- Reprocessed images released after Year 1 and Year 2

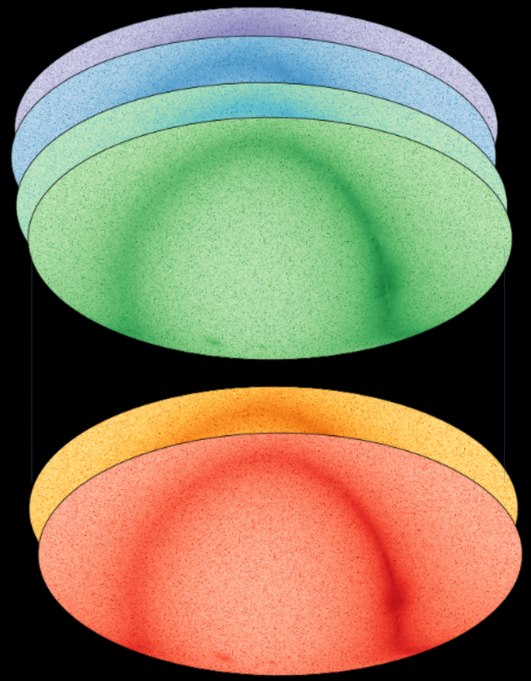


Archive functionality

- User-driven Spectrophotometry
- Custom Mosaics
- LVF Image Cutout
- General search, retrieval and visualization

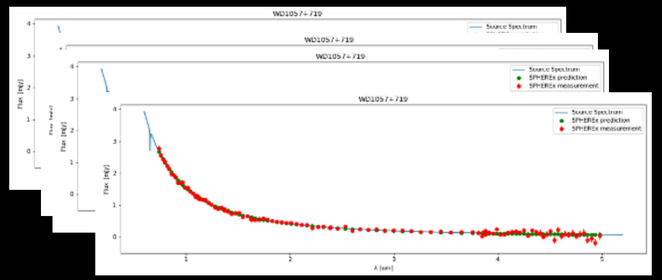
102 All-sky Data Cubes

- Released after Year 1 and 2



High Reliability Source Catalog

- Photometry in 102 spectral channels
- Sources selected from input catalog



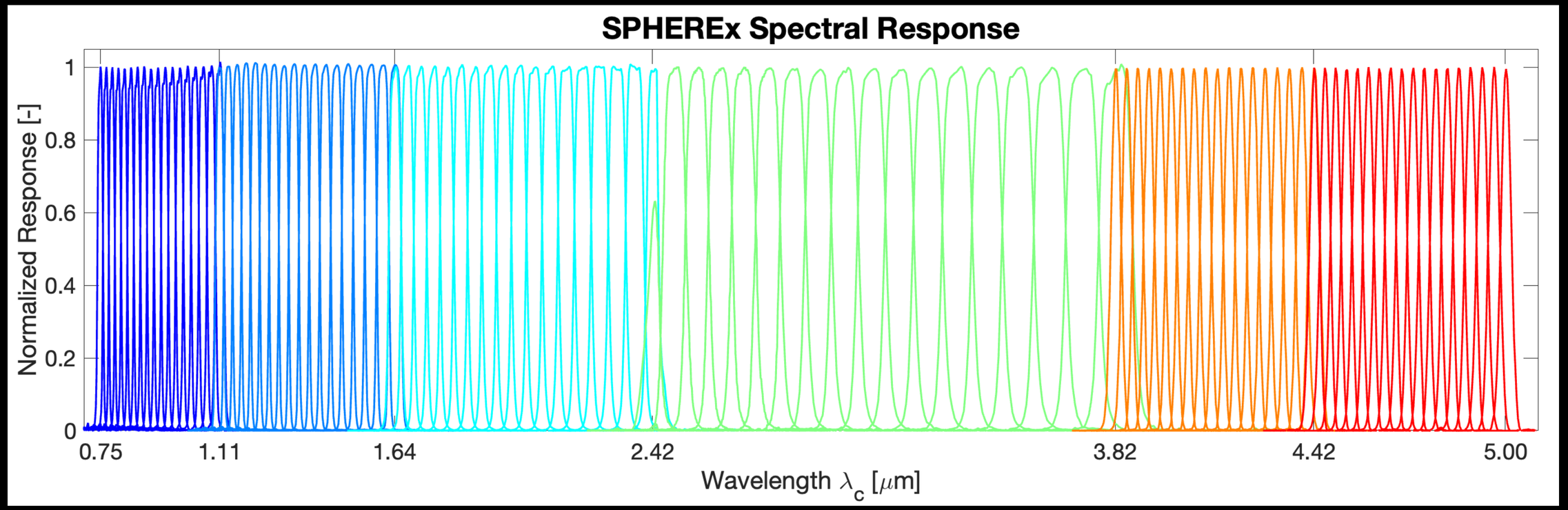
Legacy Data Products

- Released at end of mission
- Legacy Deep Field Mosaics
- Legacy Galaxy Catalog
- Legacy Stellar Type/Ice Column Density Catalog

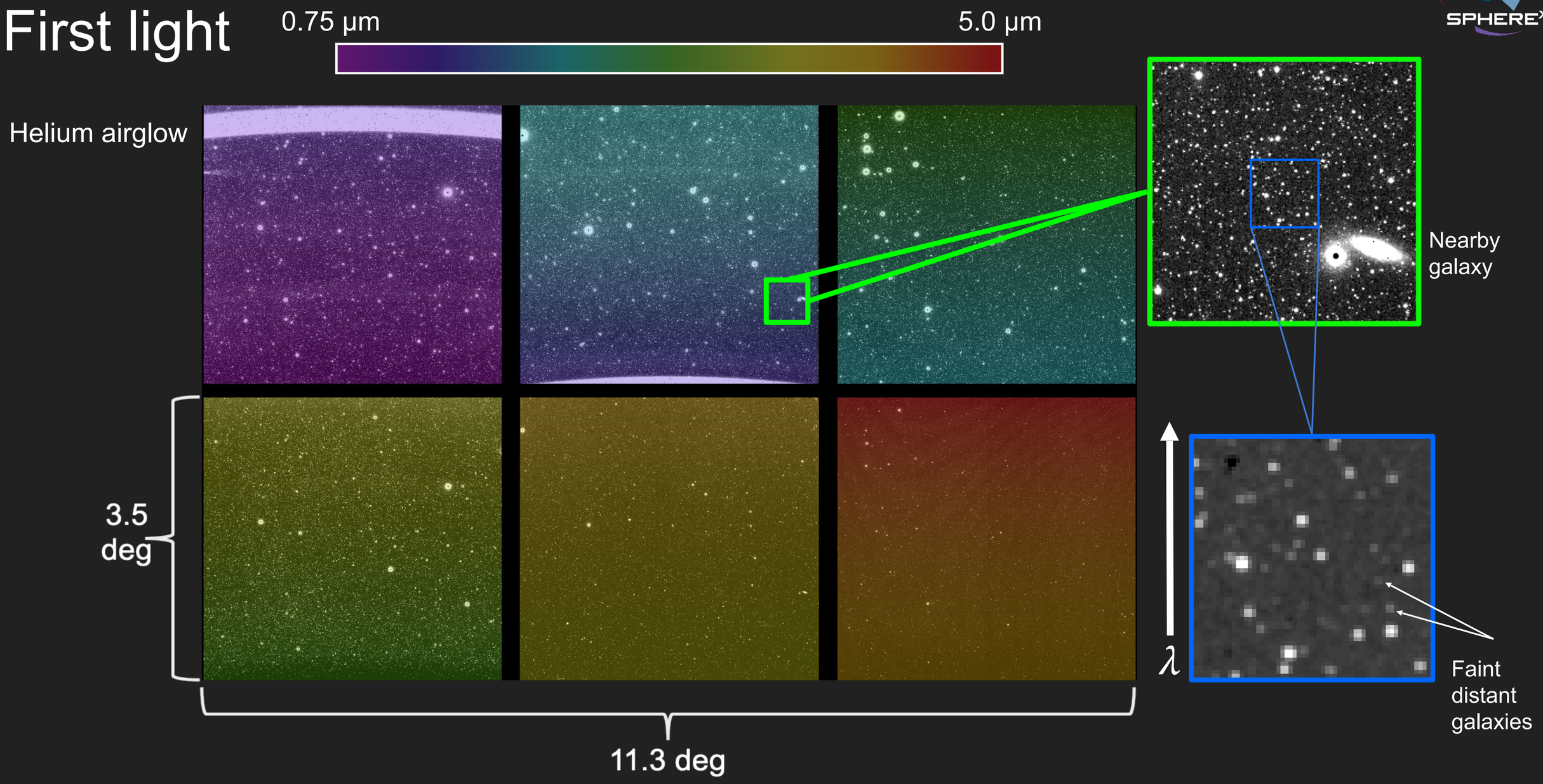
Spectral Response

R=35-40

R=110-130

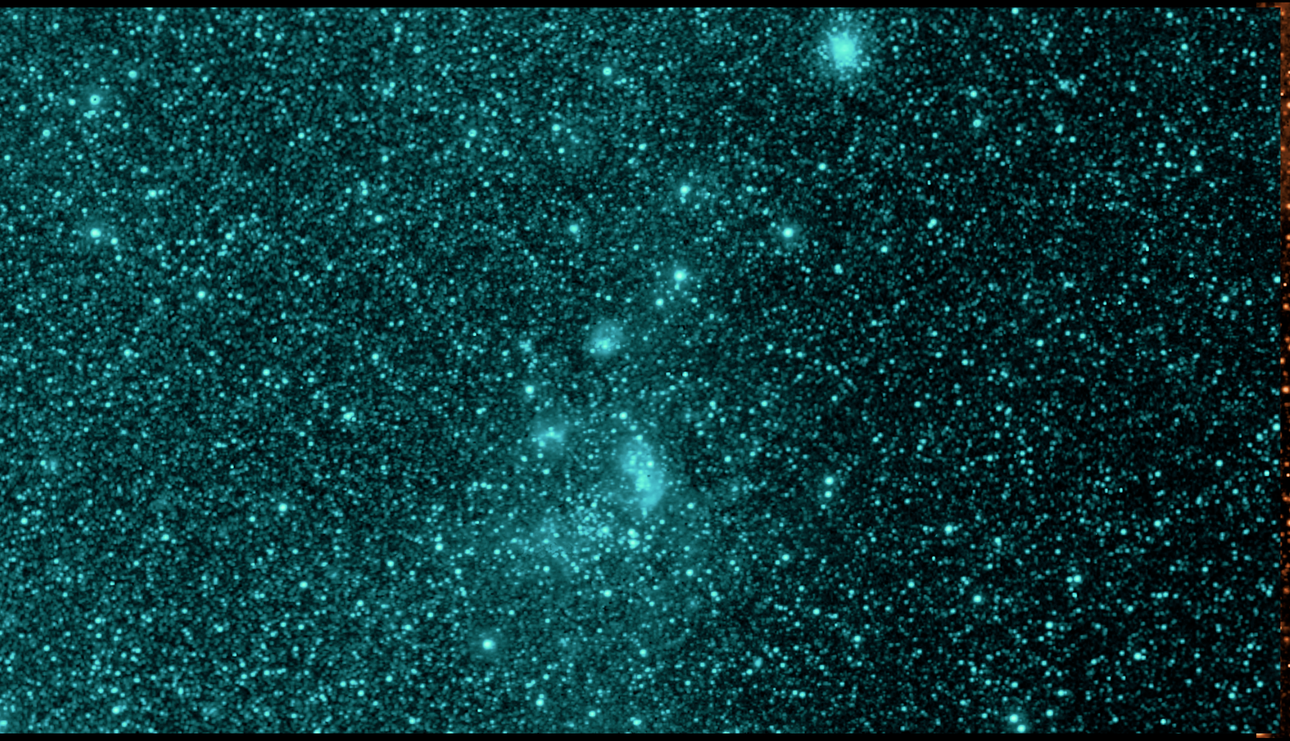


First light

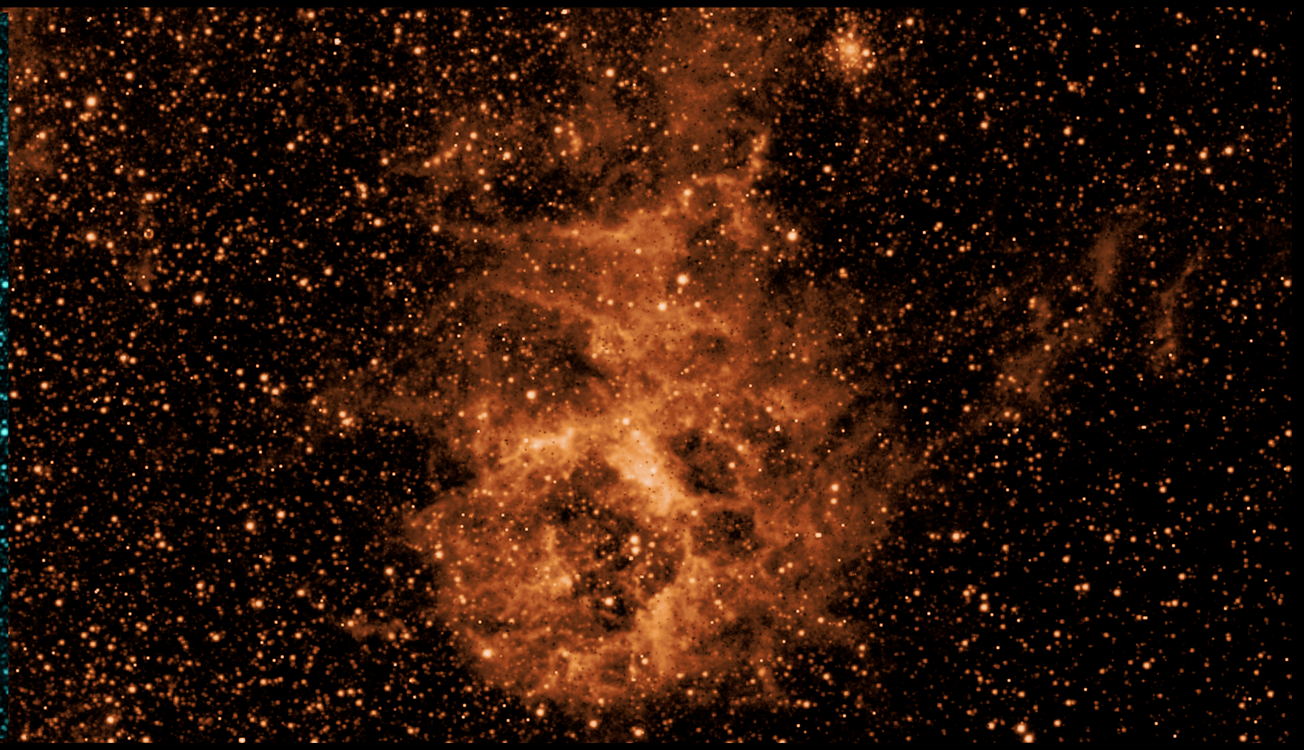

0.75 μm
5.0 μm
Helium airglow
Nearby galaxy
3.5 deg
11.3 deg
λ
Faint distant galaxies

Early observations of NGC 1760 (LMC)

0.98 μm



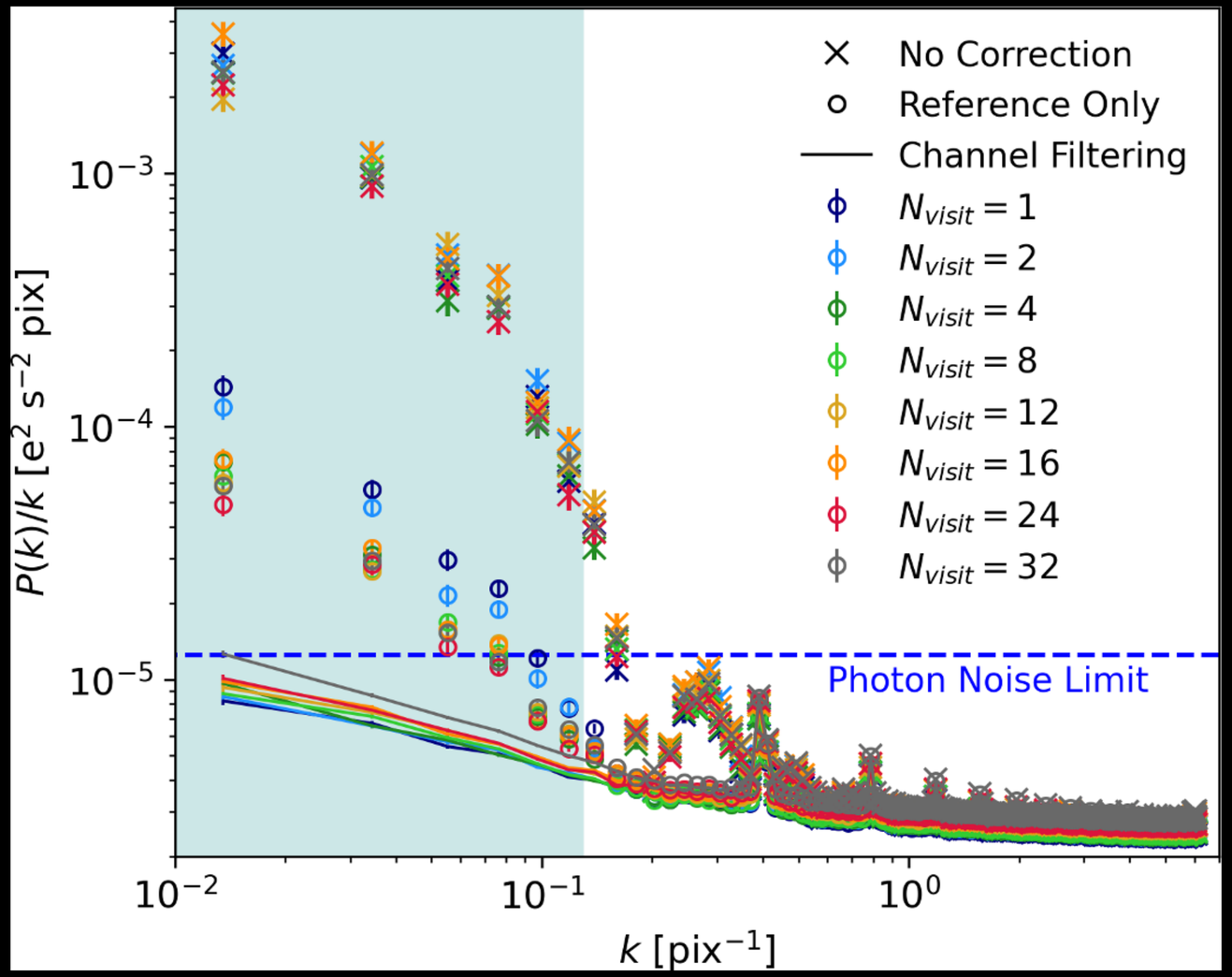
3.29 μm



https://spherex.caltech.edu/images

Diffuse structure from PAHs
(polycyclic aromatic hydrocarbons)

Row Chopping, Channel Filtering to reduce noise



Individual exposure integration time fixed by survey length (2 surveys a year

More reference readings = longer single frame interval

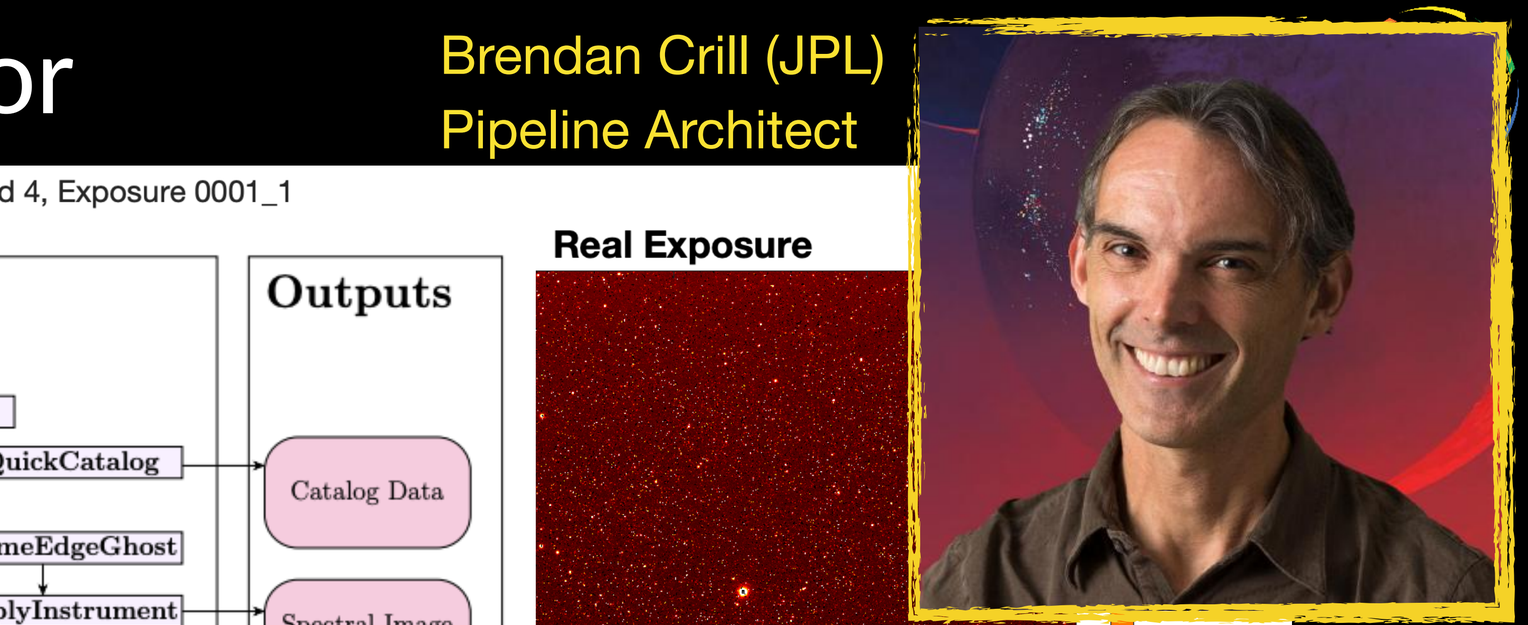
➔ fewer samplings per exposure

➔higher per pixel noise

➔higher noise at all frequencies!

SPHEREx Sky Simulator

Brendan Crill (JPL)
Pipeline Architect



Band 4, Exposure 0001_1

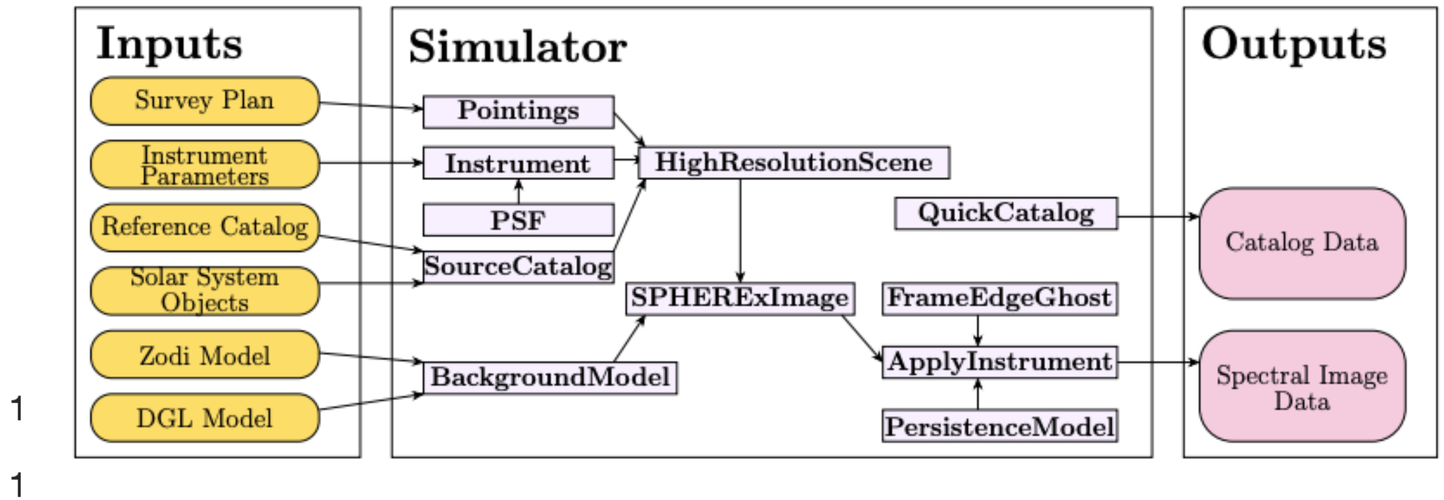
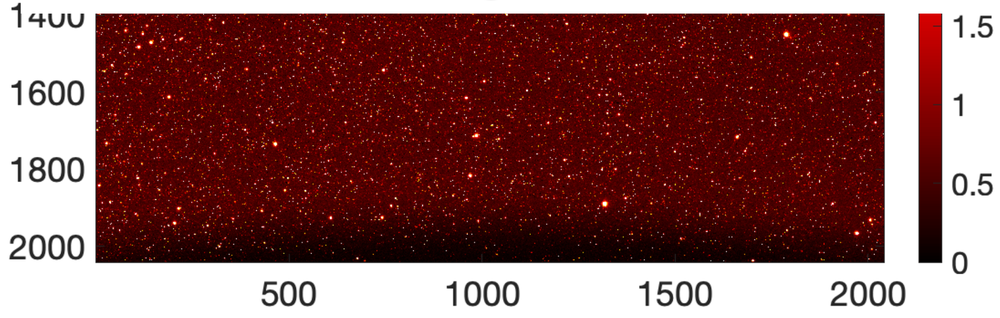


Figure 1. SPHEREx Simulator architecture.



Real Exposure

Search...
Help | Adv

Xiv:2505.24856

Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 30 May 2025]

The SPHEREx Sky Simulator: Science Data Modeling for the First All-Sky Near-Infrared Spectral Survey

Brendan P. Crill, Yoonsoo P. Bach, Sean A. Bryan, Jean Choppin de Janvry, Ari J. Cukierman, C. Darren Dowell, Spencer W. Everett, Candice Fazar, Tatiana Goldina, Zhaoyu Huai, Howard Hui, Woong-Seob Jeong, Jae Hwan Kang, Phillip M. Korngut, Jae Joon Lee, Daniel C. Masters, Chi H. Nguyen, Jeonghyun Pyo, Teresa Symons, Yujin Yang, Michael Zemcov, Rachel Akeson, Matthew L. N. Ashby, James J. Bock, Tzu-Ching Chang, Yun-Ting Cheng, Yi-Kuan Chang, Asantha Cooray, Olivier Doré, Andreas L. Faisst, Richard M. Feder, Michael W. Werner

Pre-launch single visit sensitivity vs. ecliptic latitude

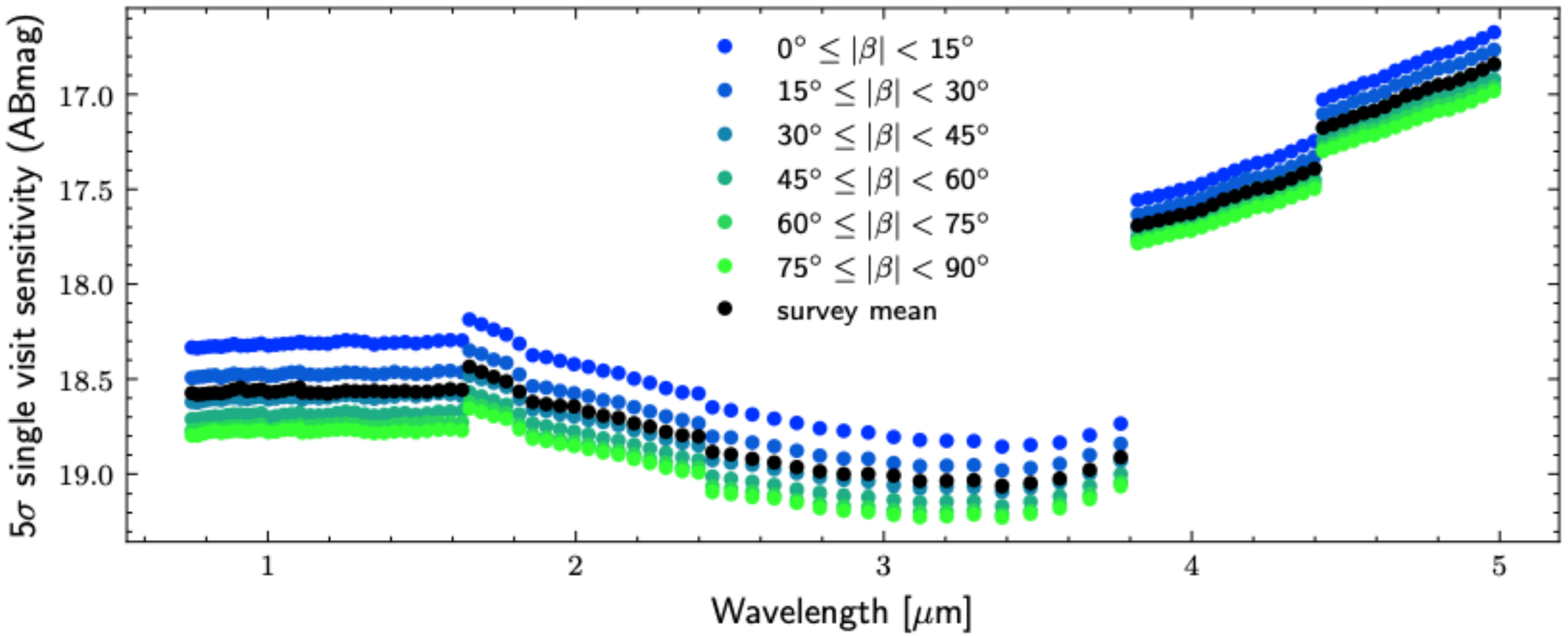


Figure 17. SPHEREx 5σ point source sensitivity in a single visit (with the pre-launch integration time 112.5 s) vs. wavelength as estimated by the Simulator; colors represent bins of ecliptic latitude β.

Crill+2025