Astrophysics and cosmology with SPHEREx

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on behalf of the SPHEREx collaboration

SPHEREx (see, e.g., Doré+ 2014,2016)

AAS 243, New Orleans, LA

SPHEREx

An all-sky spectral survey
Launch: early 2025

most relevant to PhysCos

Extragalactic background light (EBL), intensity mapping

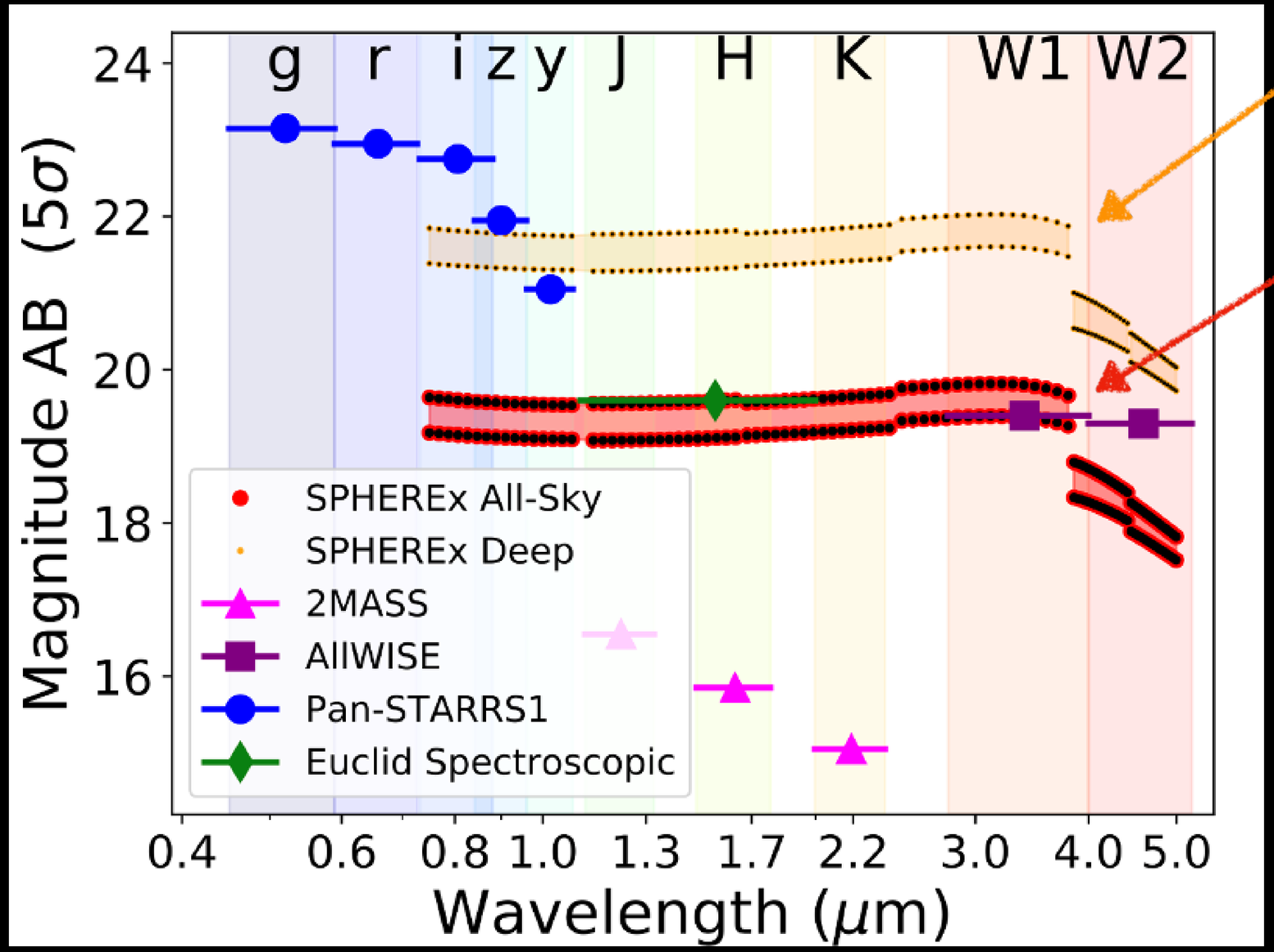
Large-scale structure, f_{NL} via power spectrum and bispectrum

Detect and quantify CO and H_2O ice in the Milky Way's ISM

Legacy archive: R~35-130 spectrum from 0.75-5 microns in every 6'' pixel of the sky. Depth m_{AB} ~19.5 (all-sky), ~22 (in two ~100 deg^2 deep fields).

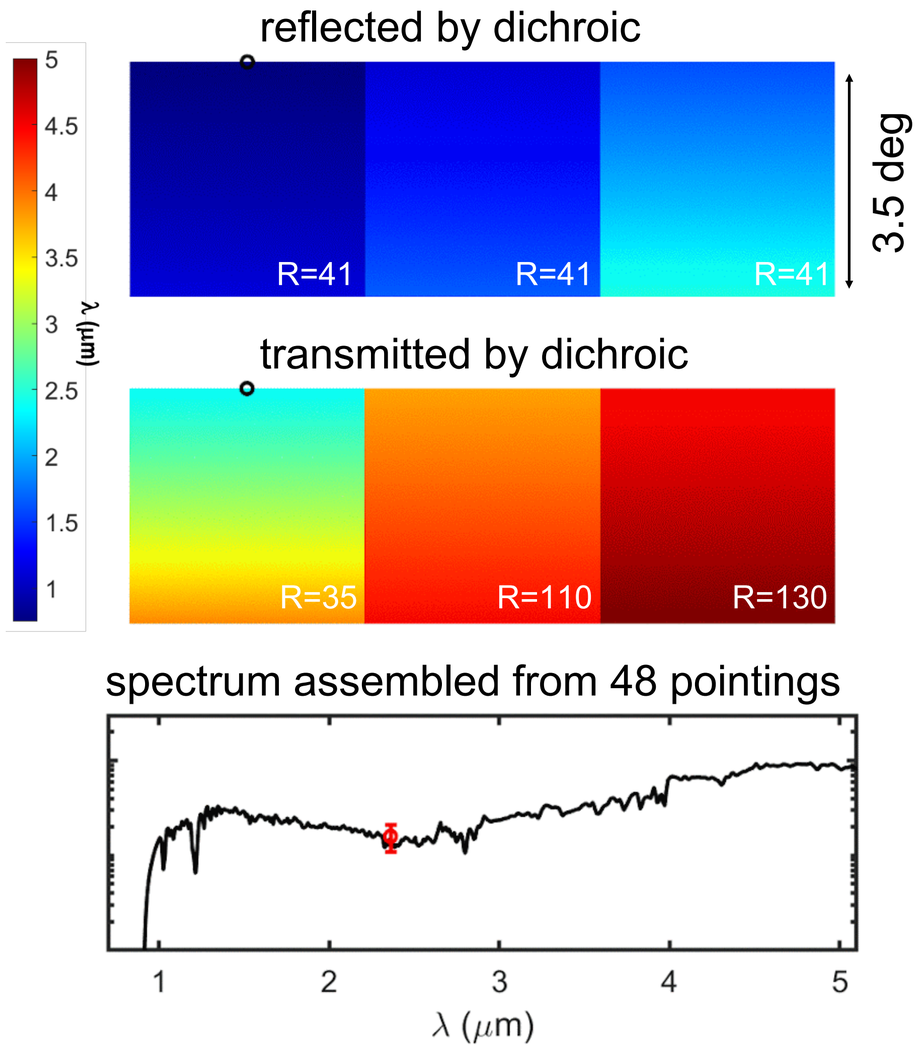
SPHEREx (see, e.g., Doré+ 2014,2016)

SPHEREx in context

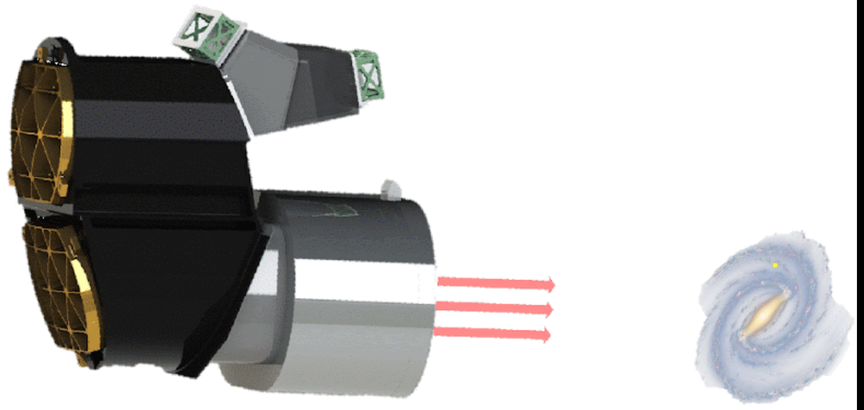


- In deep fields (100 deg^2 each), we achieve depths of m_{AB} ~ 22.
- All-sky survey ~2.5 mags shallower, comparable in depth to WISE from ~3-5 microns, Euclid from ~1-2 microns.
- However, we sample band with 102 spectral channels instead of a few broad photometric filters.

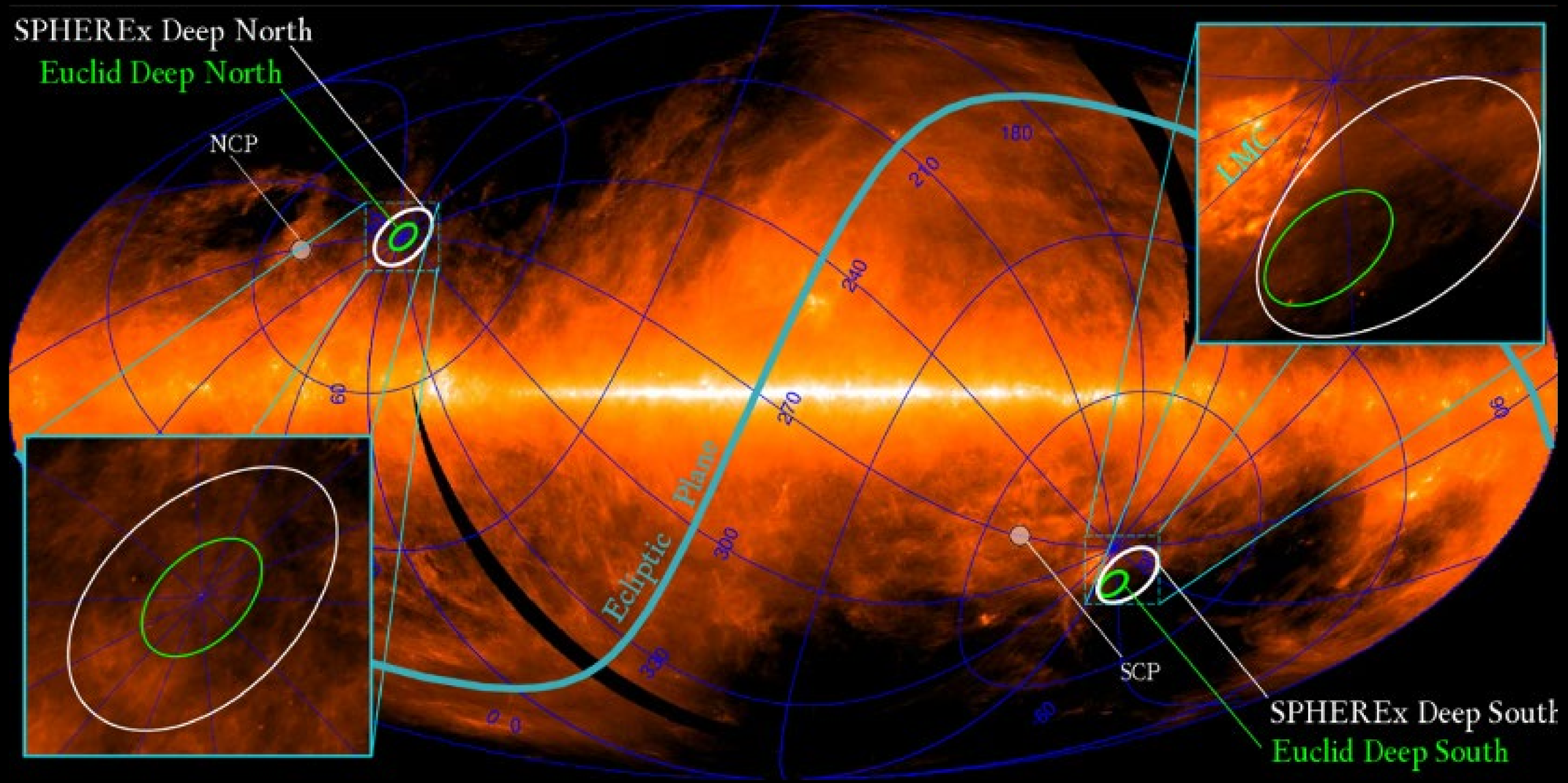
Efficient spectrophotometry with Linear Variable Filters



Full spectral range covered for a single source after several scans



Naturally results in deep fields at ecliptic poles



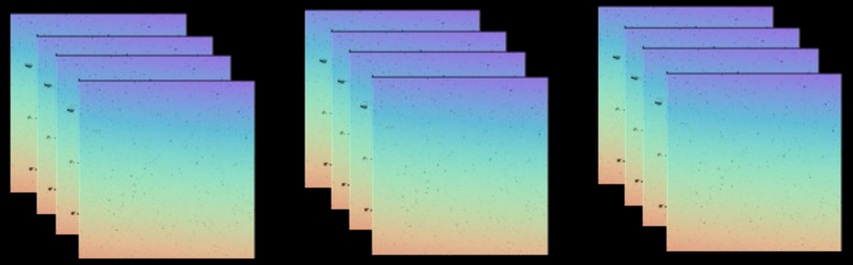
SPHEREx data products

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 2.

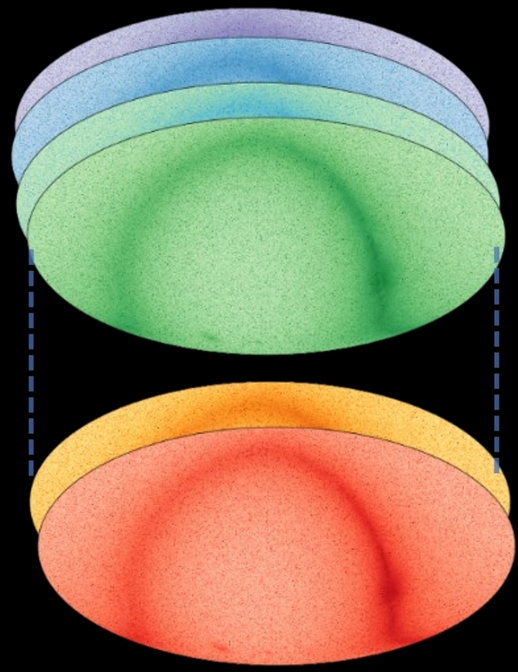


Archive functionality

- User-driven spectrophotometry
- Custom mosaics
- LVF image cutouts
- General search, retrieval, visualization

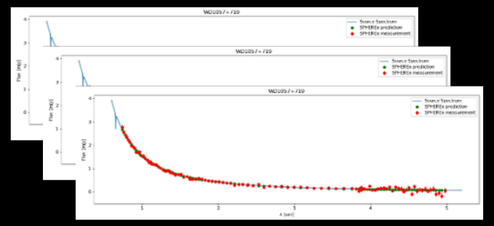
102 all-sky data cubes

- Released after year 1 and 2



High-reliability catalog

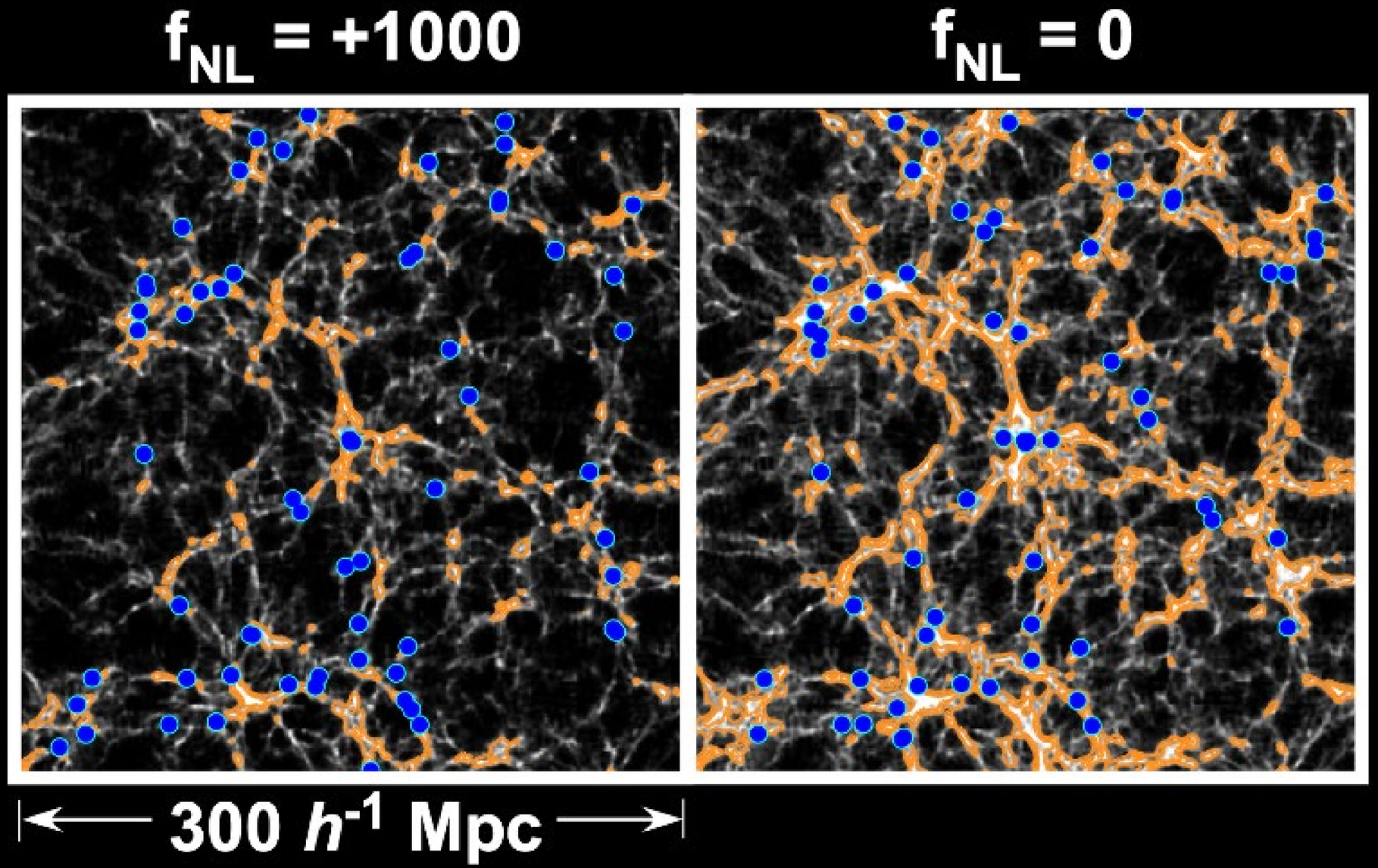
- Photometry in 102 channels
- Sources selected from input



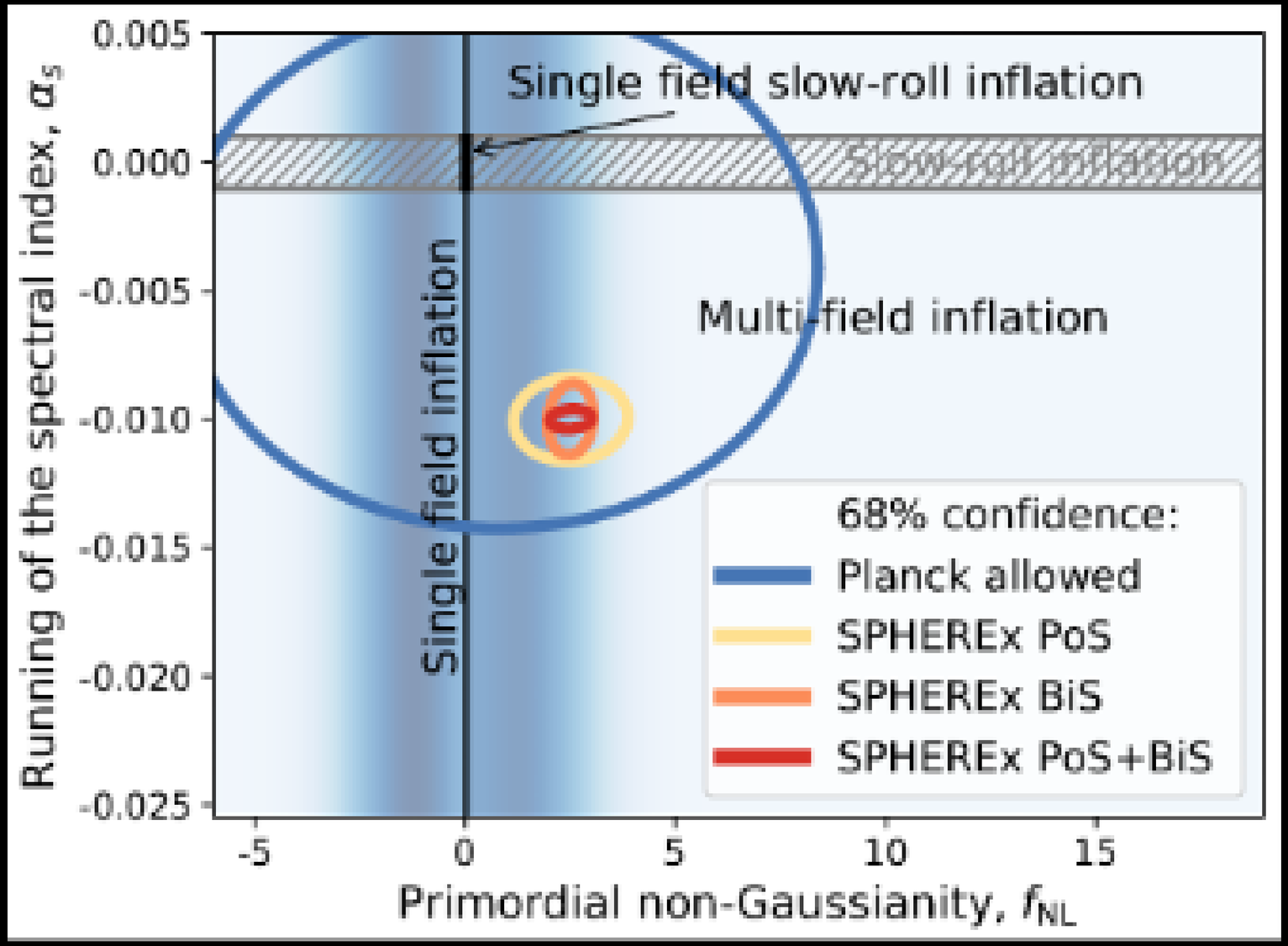
Legacy data products

- Released at end of mission
- Deep field mosaics
- Galaxy catalog
- Stellar type / ice column density catalog

The science: inflation and large-scale structure



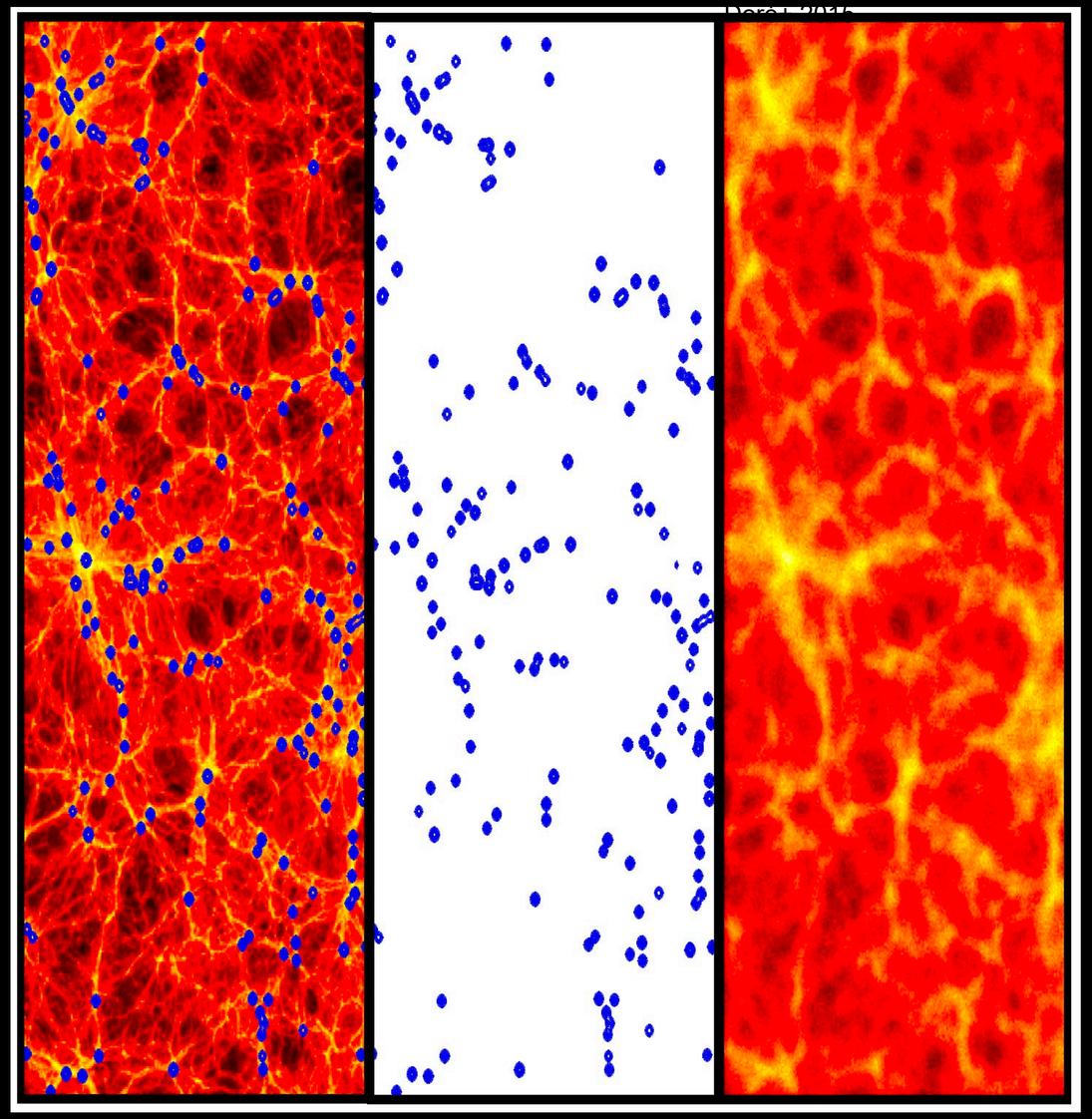
The science: inflation and large-scale structure



Did Multiple Fields Drive Inflation?

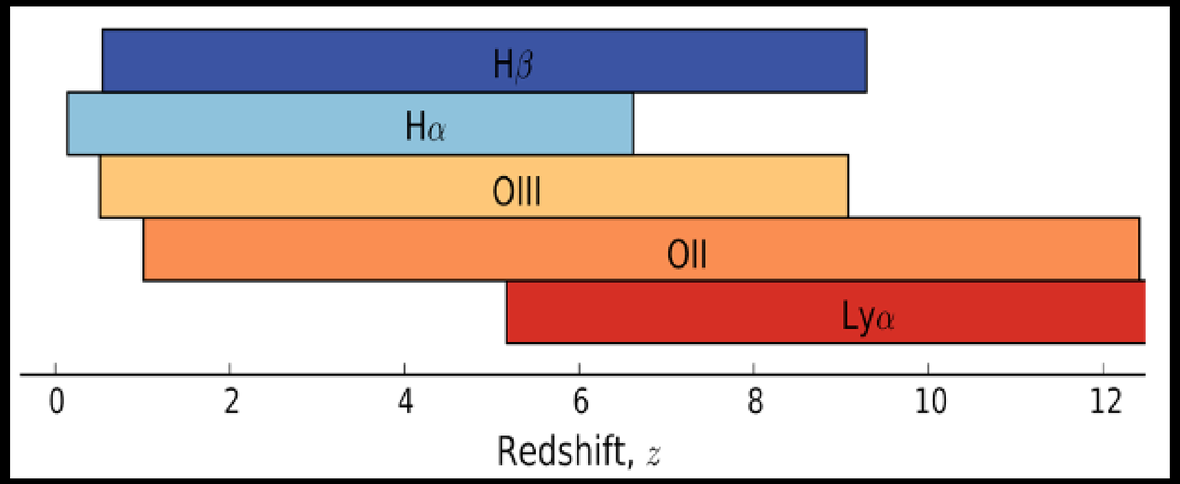
- Single-field models predict $f_{NL} < 0.01$
- Multi-field models predict $f_{NL} > 1$
- Non-inflationary models (Steinhardt *et al.*) predict $f_{NL} \sim 1$

The science: galaxy formation and the EBL

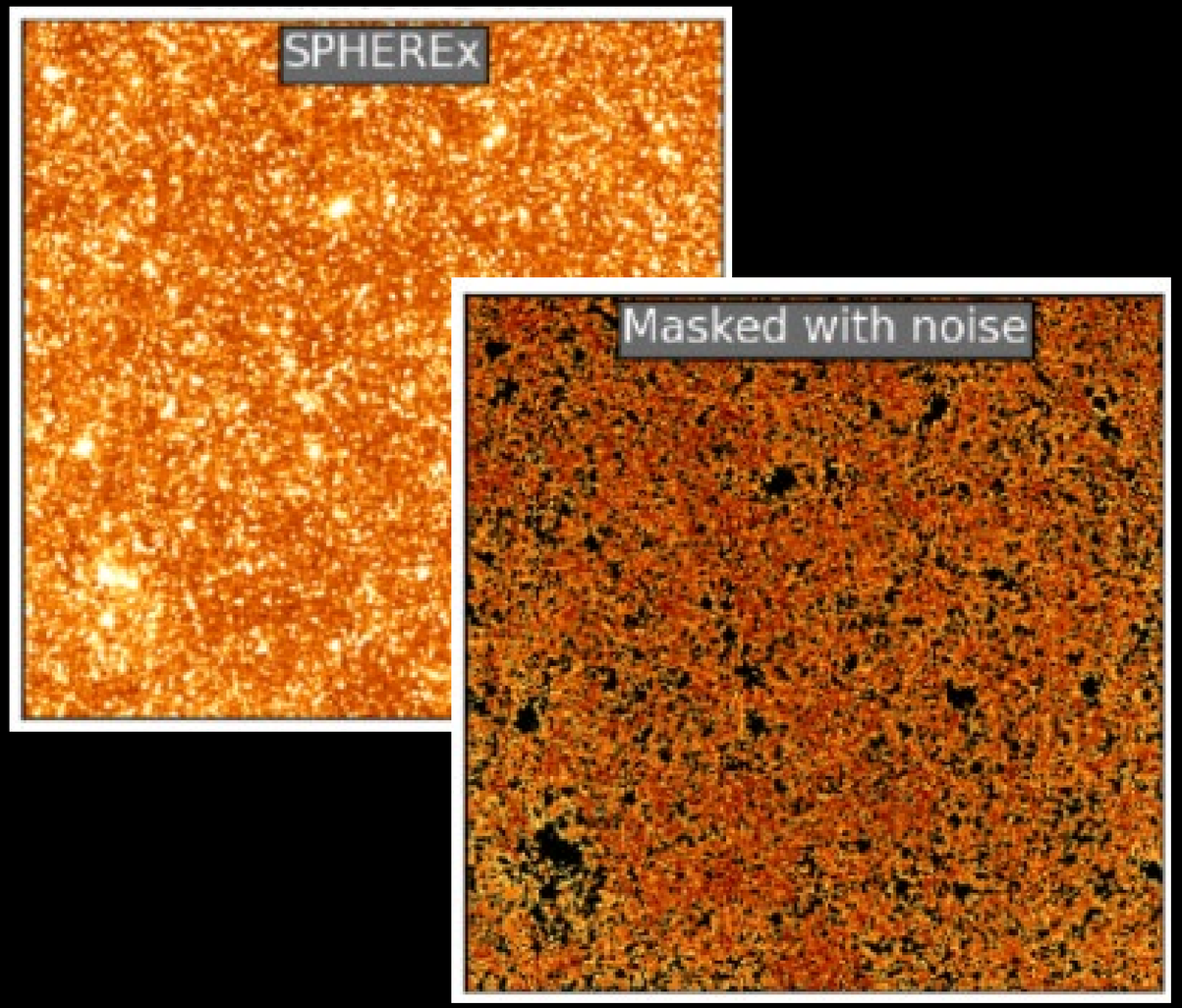


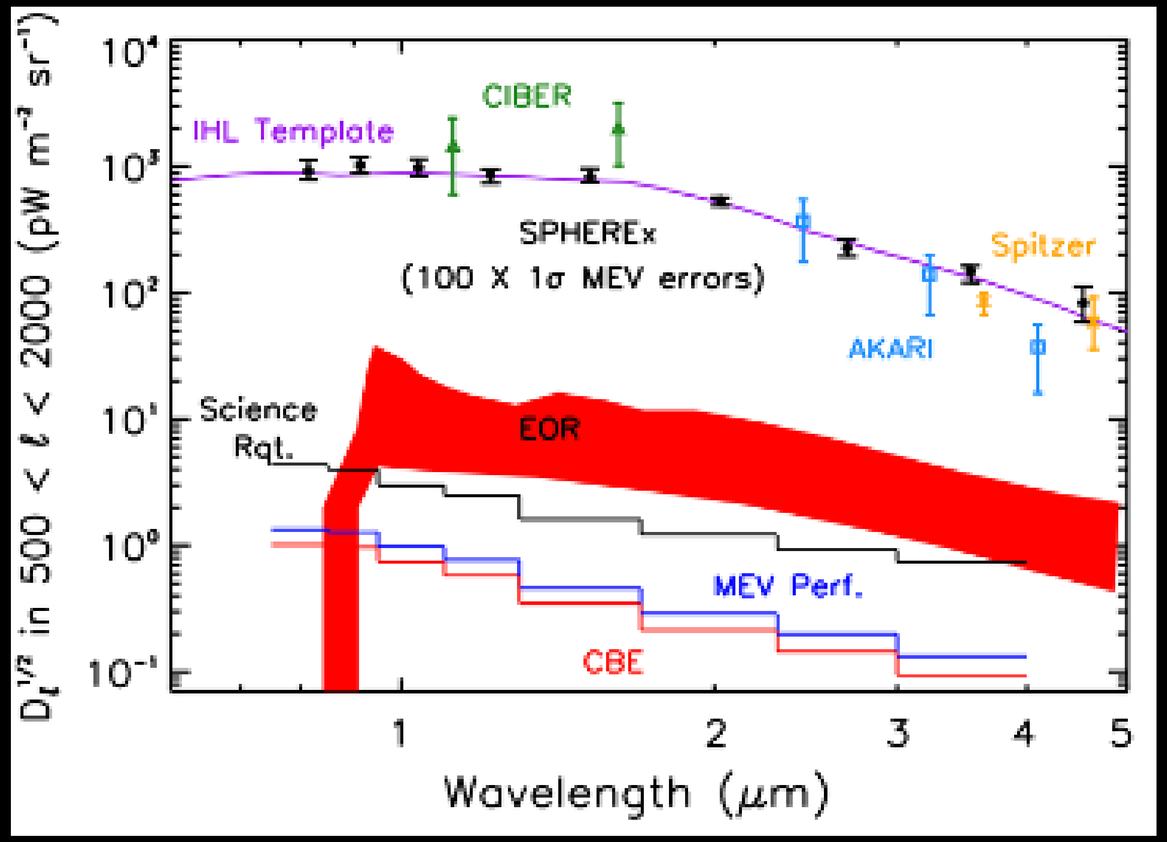
Bright galaxies that we directly detect are just the tip of the iceberg. Maps of diffuse emission will constrain the entire galaxy population statistically.

SPHEREx captures strong optical/near-UV/near-IR emission lines over a broad redshift range.



The science: galaxy formation and the EBL

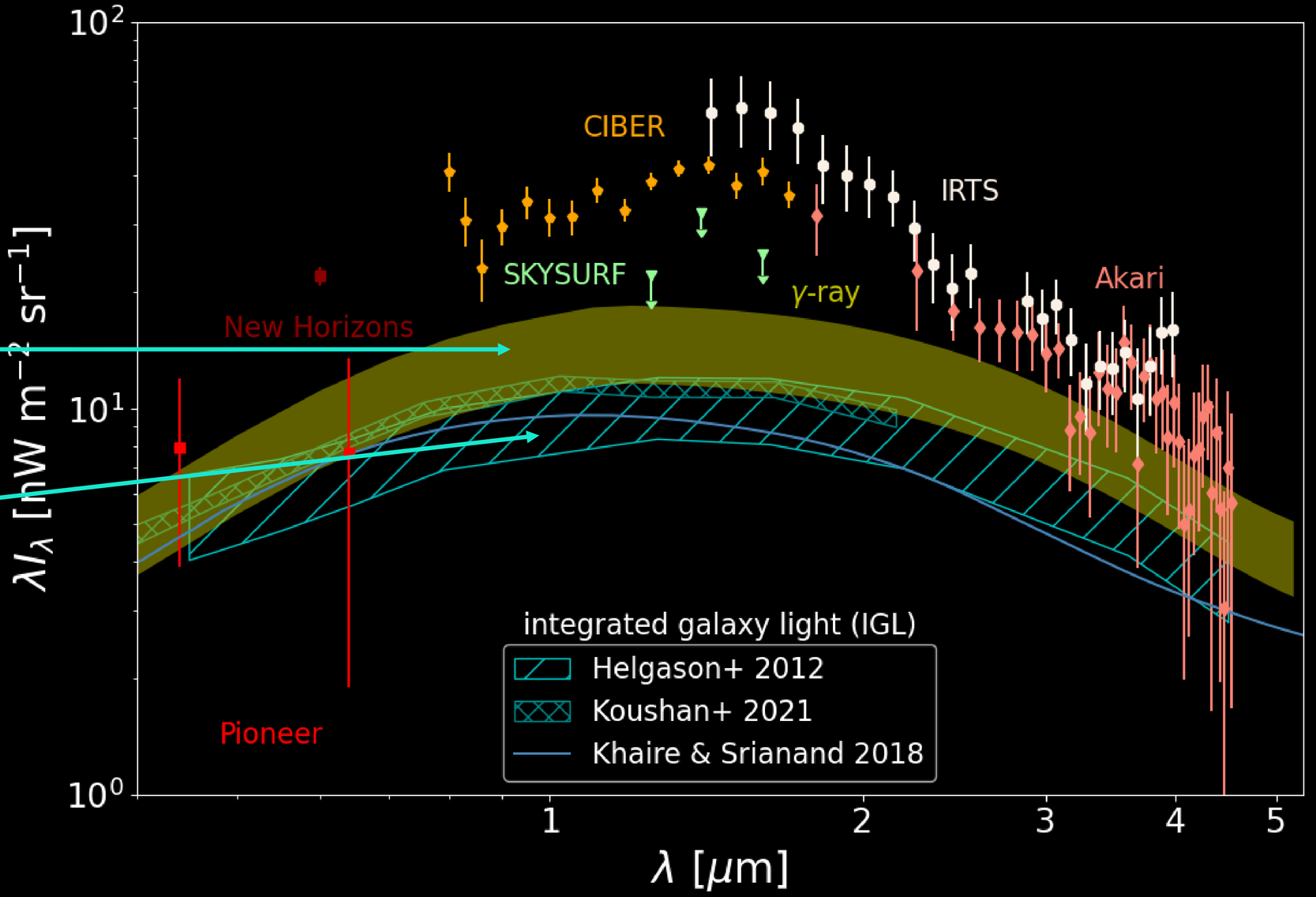




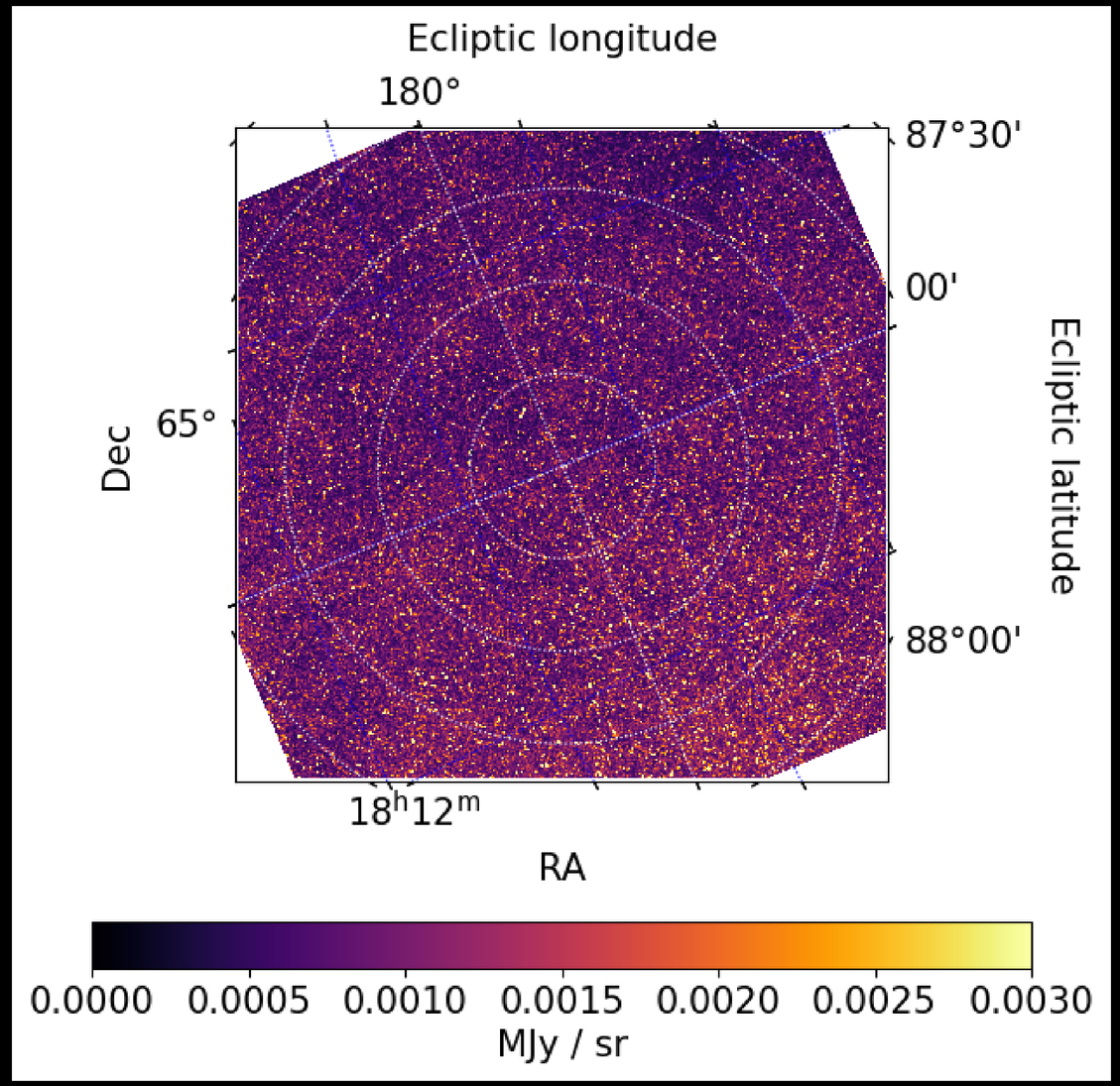
Here: 'anisotropy color,' i.e., power spectrum at given scale vs. wavelength.

Additional science: exotic physics with the EBL?

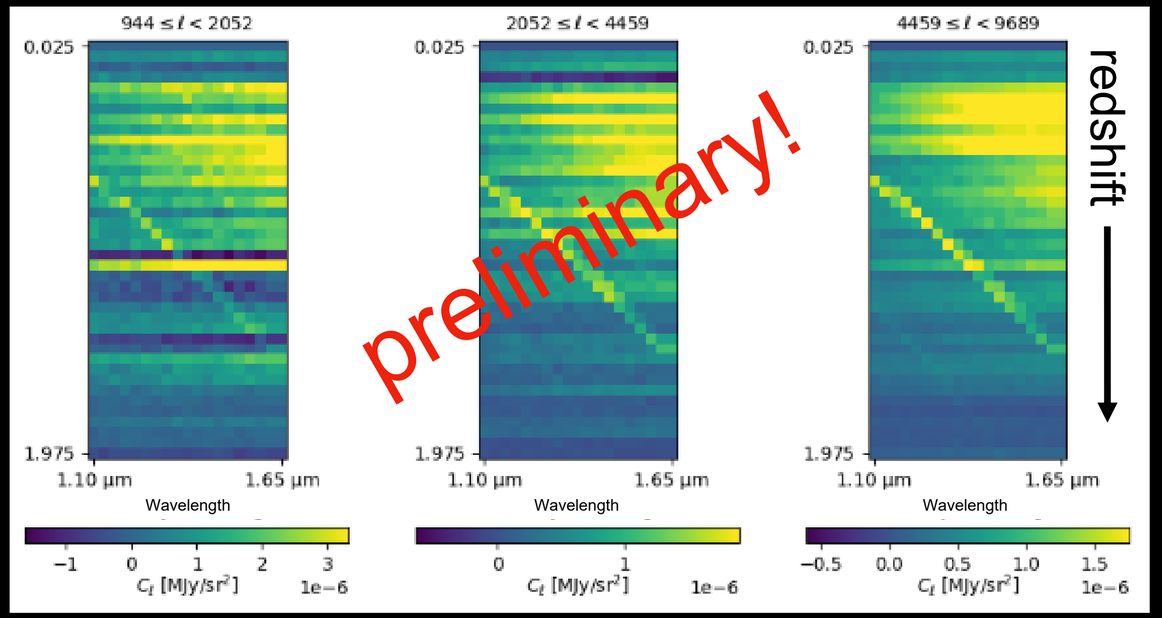
- Gamma rays from blazars pair produce off the EBL, resulting in non-zero opacity. Constraints on that opacity then constrain EBL.
- In mild tension with expected EBL from galaxies.
- Can use to constrain models of DM that produce photons (see, e.g., Bernal+ 2208.13794).



Ongoing modeling efforts, pipeline development



- End-to-end simulations in progress!
  - Includes real survey plan, assembly of mosaics from individual exposures (left), LVF response, Zodiacal light, galactic emission, EBL, self-consistent mock galaxy catalogs.
  - Working on galaxy/EBL cross-correlation pipeline (below). Visible ‘streak’ is Hα.



Conclusions and next steps

- SPHEREx will provide a rich dataset with which to constrain fundamental cosmology and galaxy formation physics.
- Legacy archive will enable yet more possibilities, many surely we haven’t thought of yet!
- TVAC tests nearing completion at Caltech, then off to Ball. Pipeline maturing in parallel.
- On track for early 2025 launch. Stay tuned!

SPHEREx (see, e.g., Doré+ 2014,2016)

Questions?

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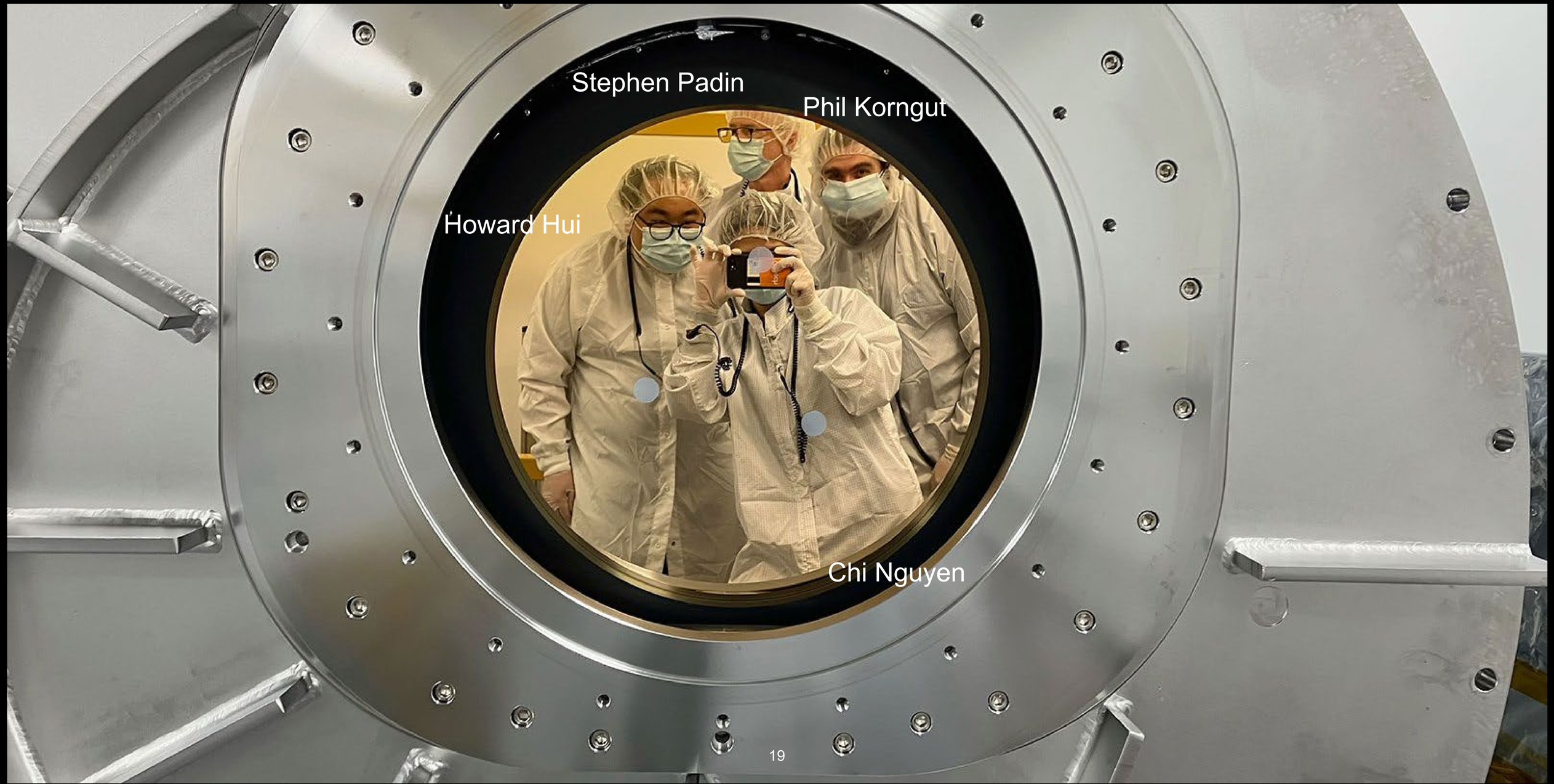
Learn more this week:

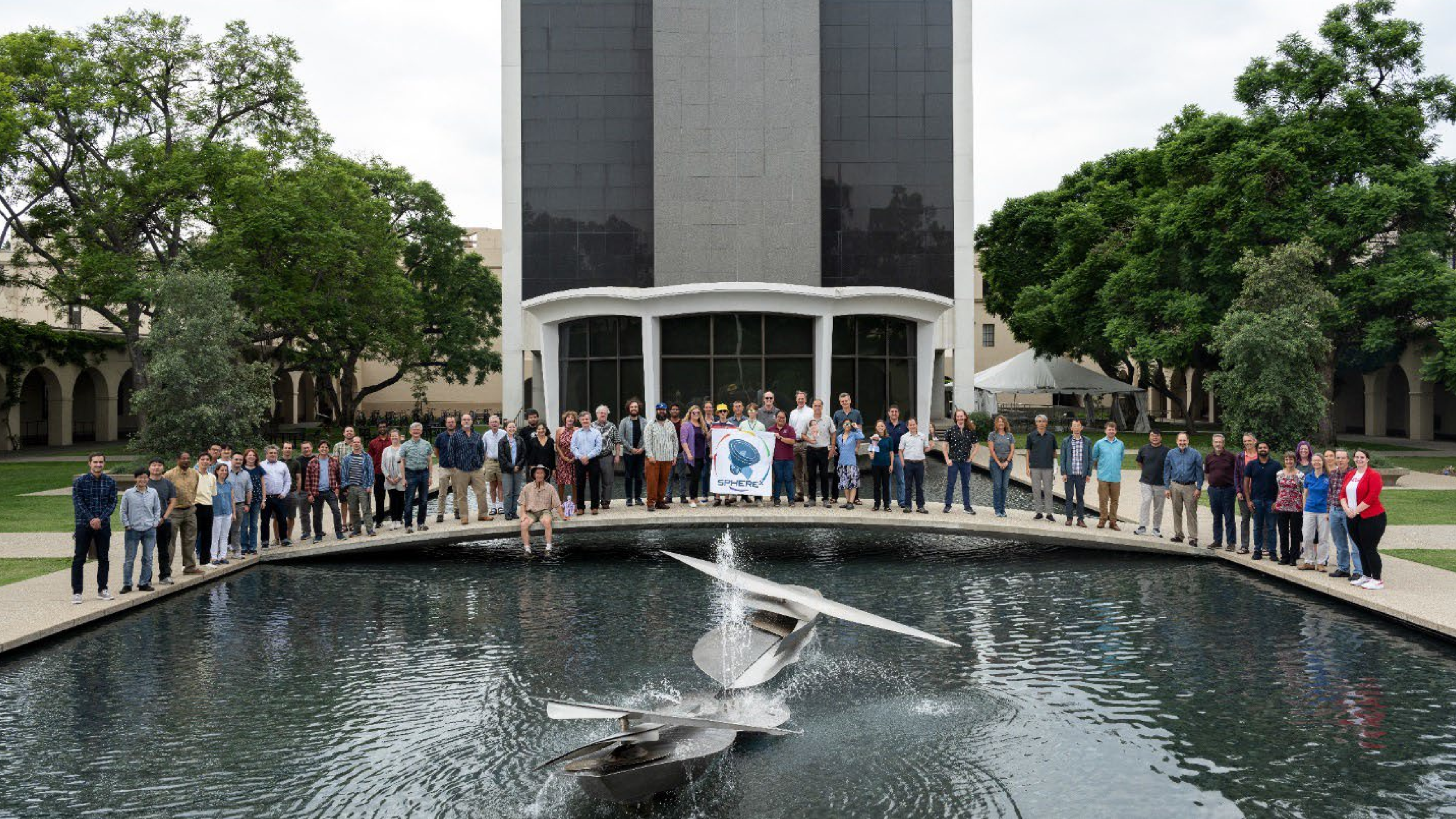
- Tues @ 12:30: talk by Chi Nguyen (overview at hyperwall)
- Tues @ 2pm: talk by me (EBL modeling, session 251)
- Tues @ 5:30: poster by Abby Williams (flat fielding, session 258)
- Wed @ 3:40: plenary by PI Jamie Bock (probes of early Universe)
- Wed @ 5:30: poster from Chi (detector performance, session 360)

SPHEREx (see, e.g., Doré+ 2014,2016)

backup

Current status: spectral calibration at Caltech




SPHEREx

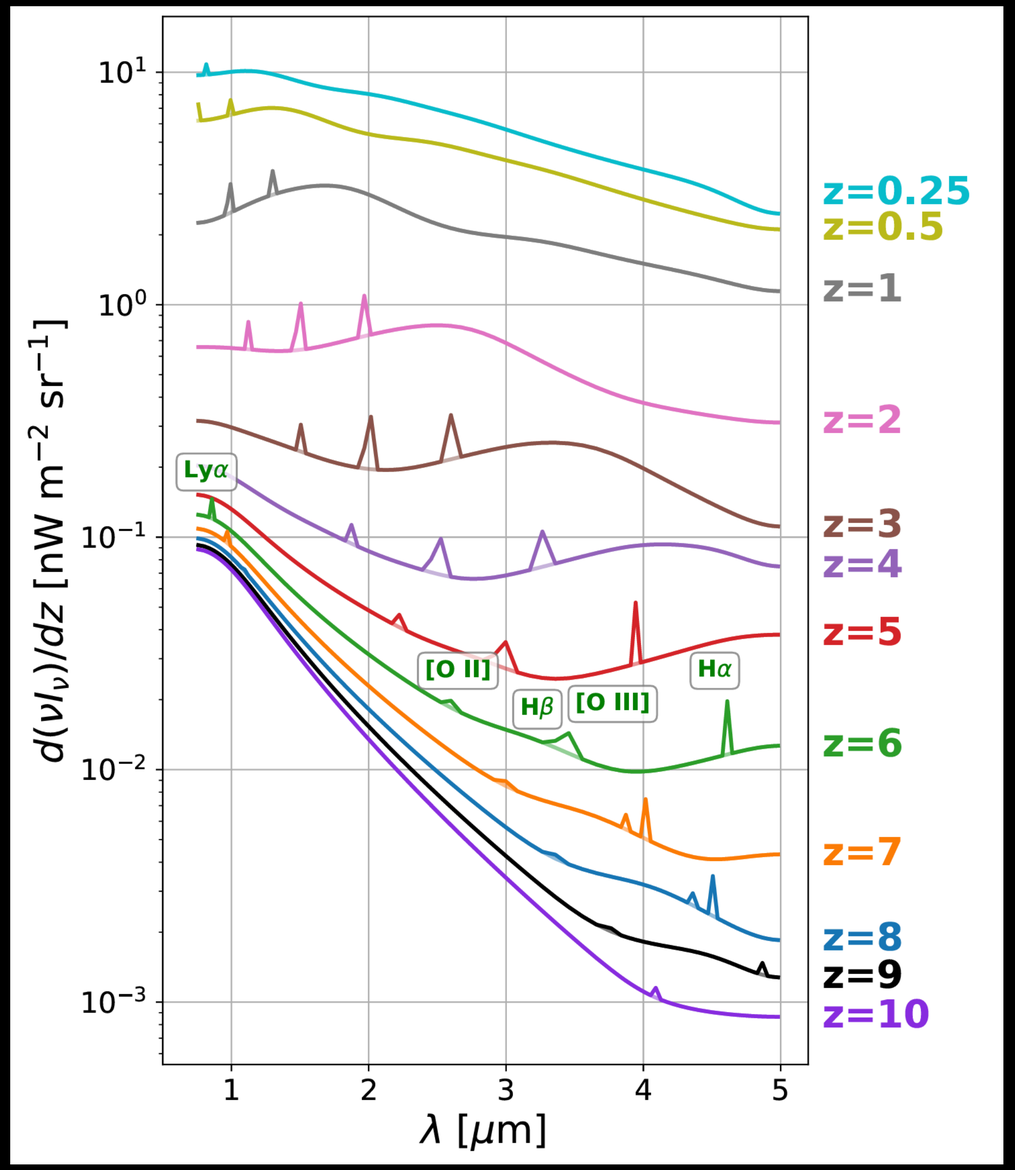
The science: galaxy formation and the EBL

Expecting whopping cross-correlation detections across range of redshifts. Promising cross-correlation partners include Rubin, Euclid, Roman, DESI, CMB experiments.

Cross correlations reveal characteristic SED of tracer population.

For example, cross-correlation with Euclid sample reveals 2-5 micron portion of SED, not covered by Euclid itself.

Can potentially constrain bias of sources with additional modeling.

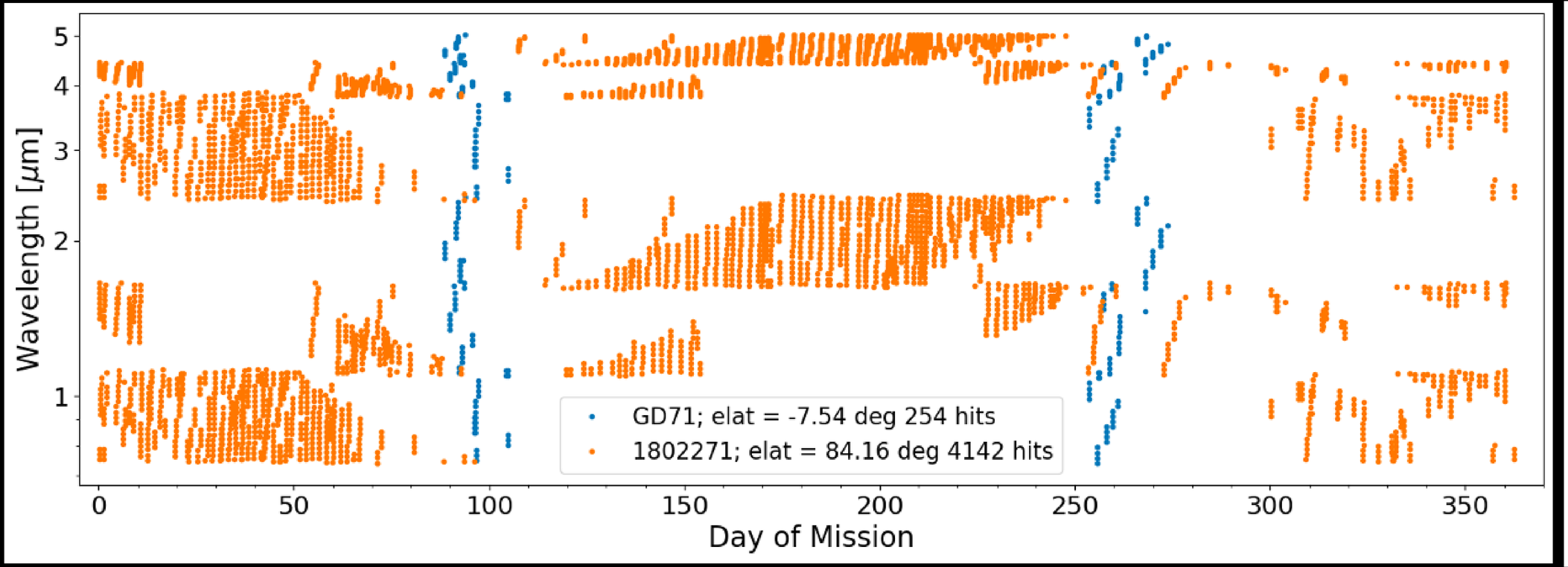


Cheng & Chang 2022

Time domain astrophysics?

Spectral coverage of a source over time staggered due to LVFs.

Each pixel and spectral channel covered once every 6 months, so all-sky survey repeated 4x in 2 year mission. However, pixels in deep fields covered at higher cadence.

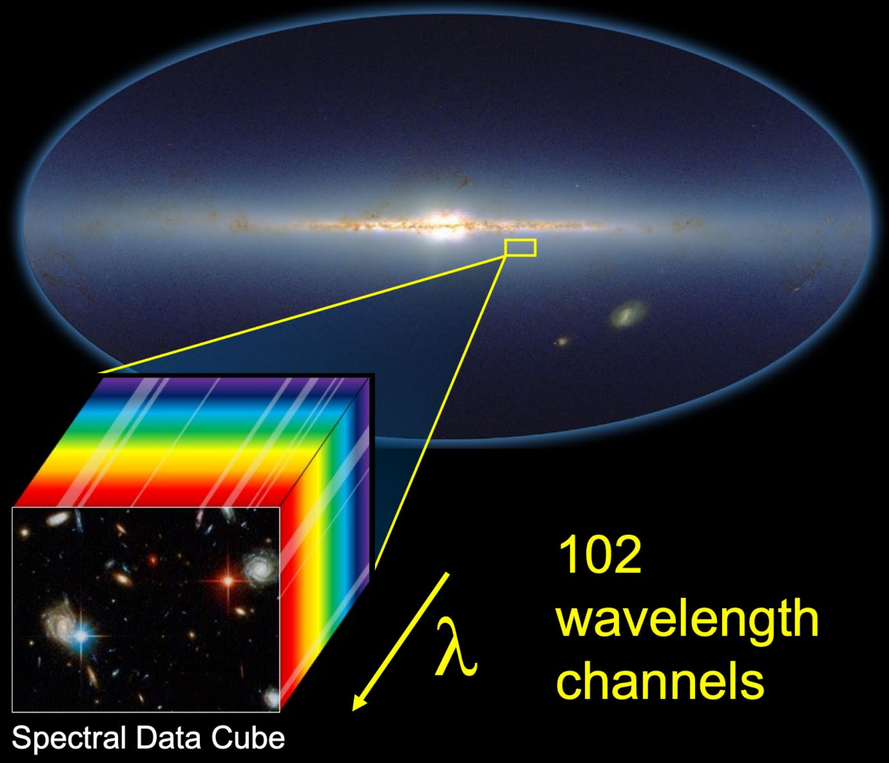


Example of spectral sampling over 1 year for two sources: one near deep field (orange) and one close to the ecliptic plane (blue).

SPHEREX PROVIDES A RICH ALL-SKY SPECTRAL CATALOG

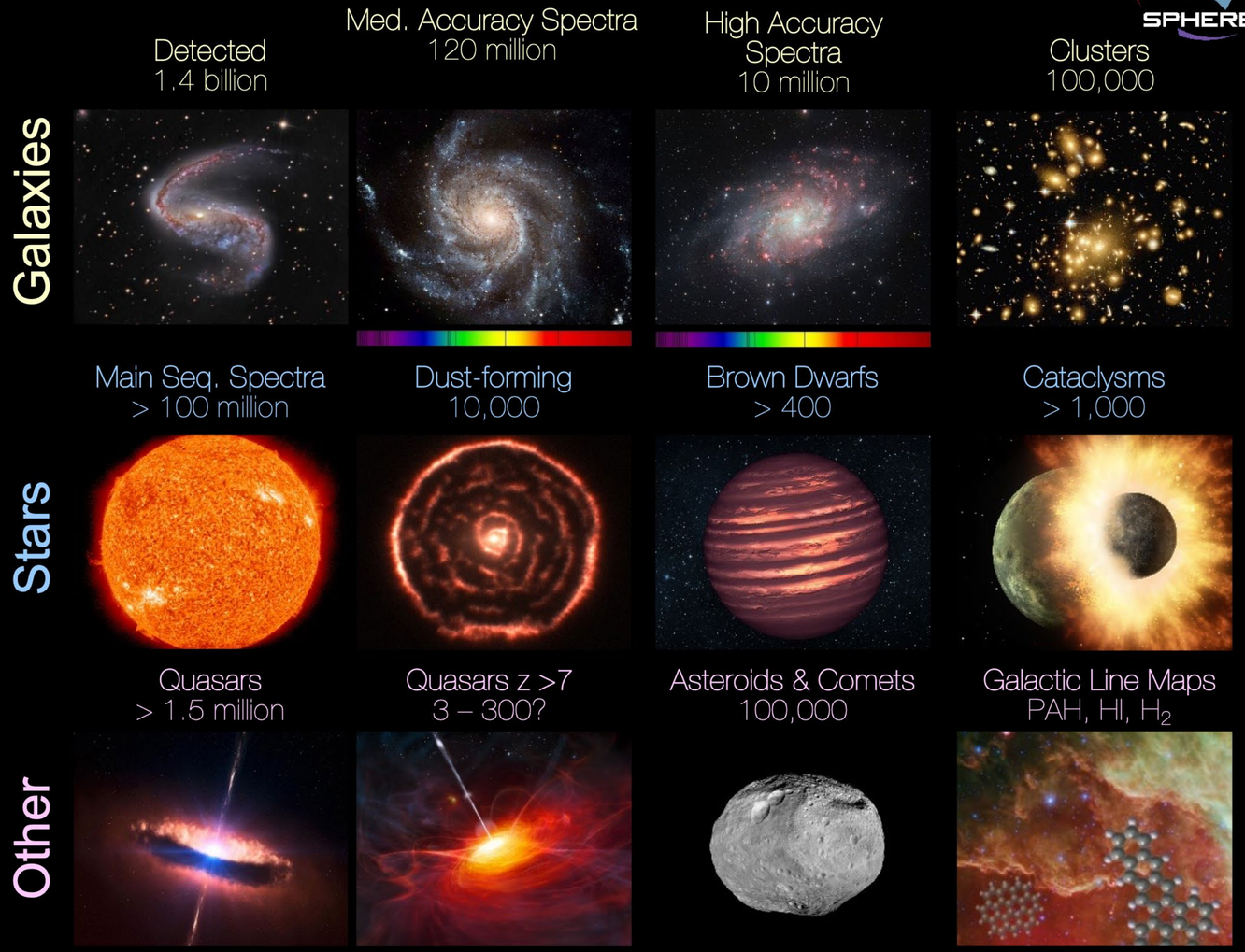
This document has been reviewed and approved for unlimited release

All-Sky Survey



SPHEREx provides a new and unique dataset

a complete near-infrared spectrum for every 6″ pixel on the sky



We expect many exciting discoveries to come from the community

- IPAC rapidly delivers calibrated ‘spectral images’ to public
- IPAC also provides basic photometry tools for public use