SPHEREˣ First Light

Designed to Explore

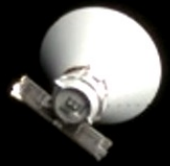
- Origin of Water in Planetary Systems
- Origin and History of Galaxies
- Origin of the Universe

First All-Sky Near-IR Spectral Survey

A Rich Legacy Archive for Astronomy
with 100s of Millions of Stars and Galaxies

Simple Unique Design

- Single Observing Mode
- No Moving Parts in Instrument

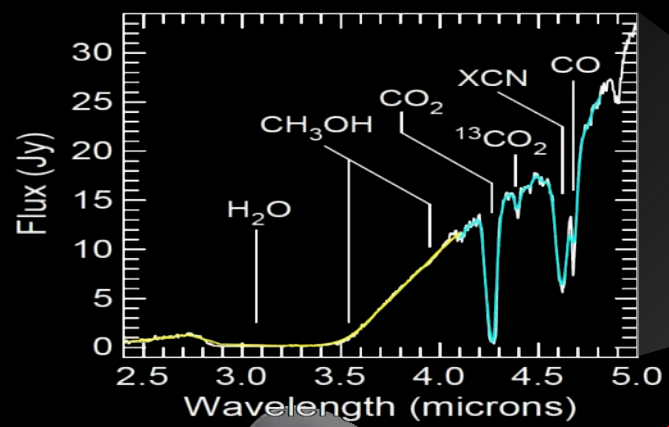


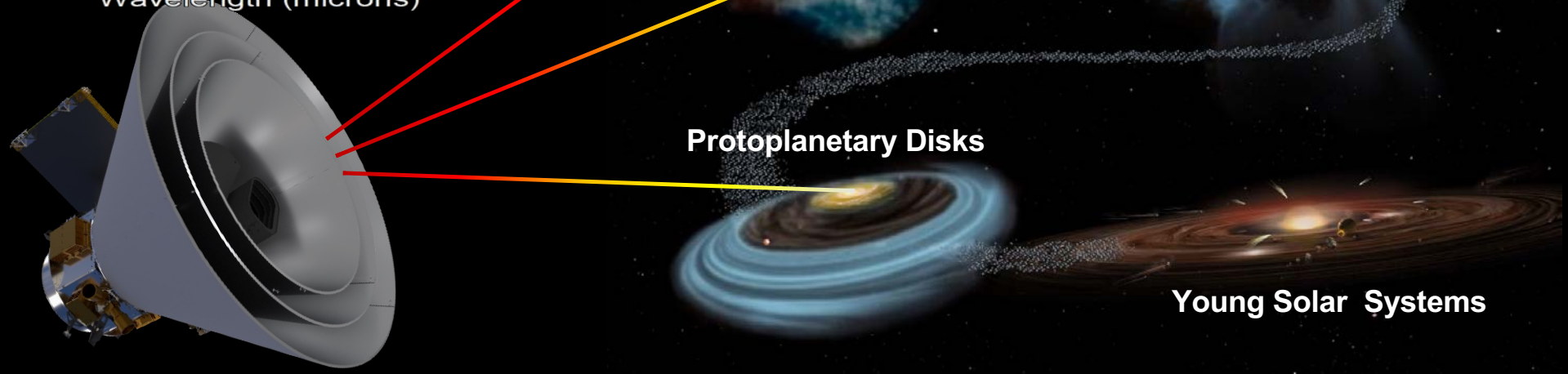
Jamie Bock

Marvin L. Goldberger Prof. of Physics
California Institute of Technology

Senior Research Scientist & Fellow
Jet Propulsion Laboratory, California Institute of Technology

WHERE IS THE WATER IN OUR GALAXY?

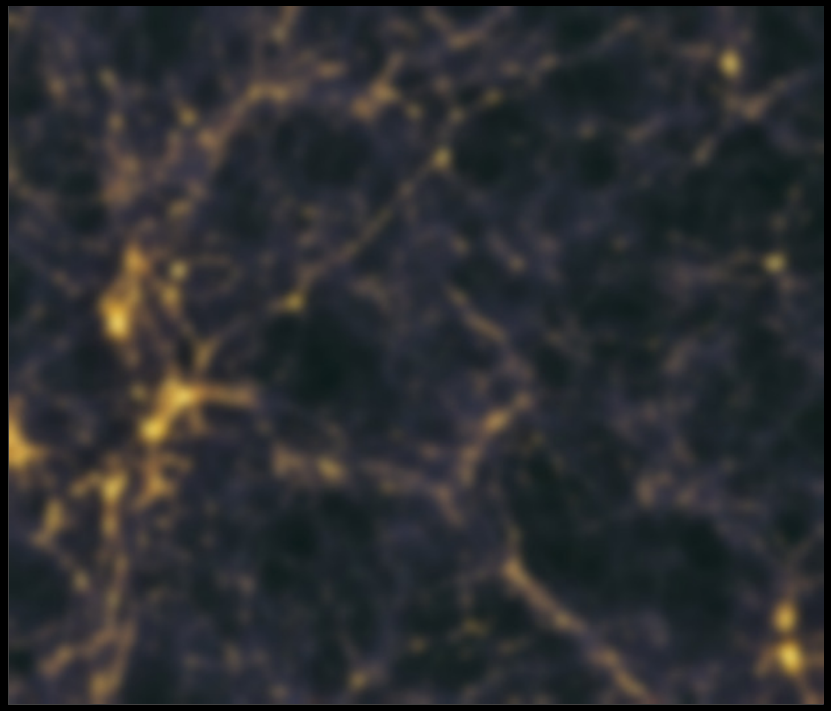




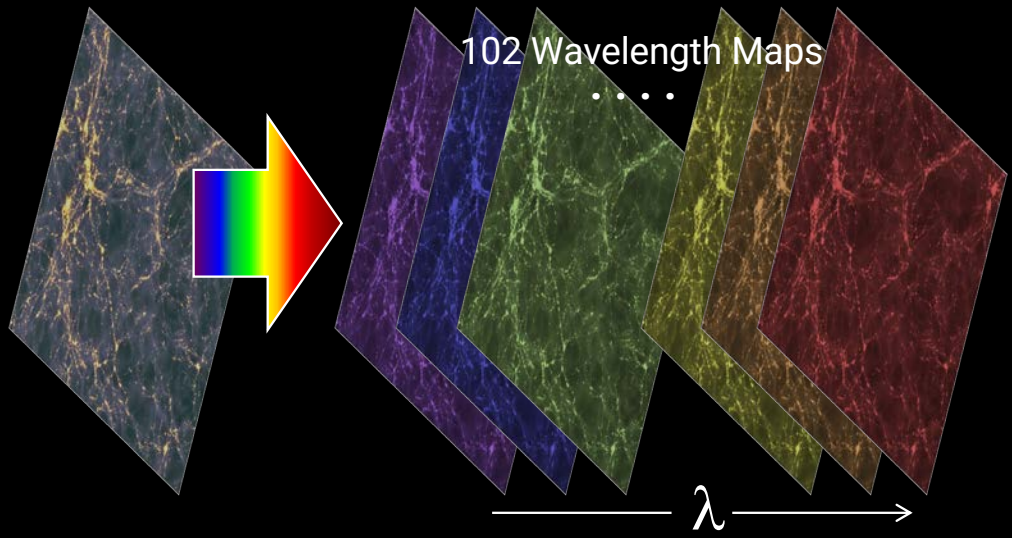
More than 99 % interstellar water is locked in ice: *'Follow the Water'* means *'Follow the Ice'*

MEASURING COSMIC HISTORY OF LIGHT PRODUCTION

Intensity Mapping Traces Total Light



Spectroscopy is Key for Untangling Cosmic History



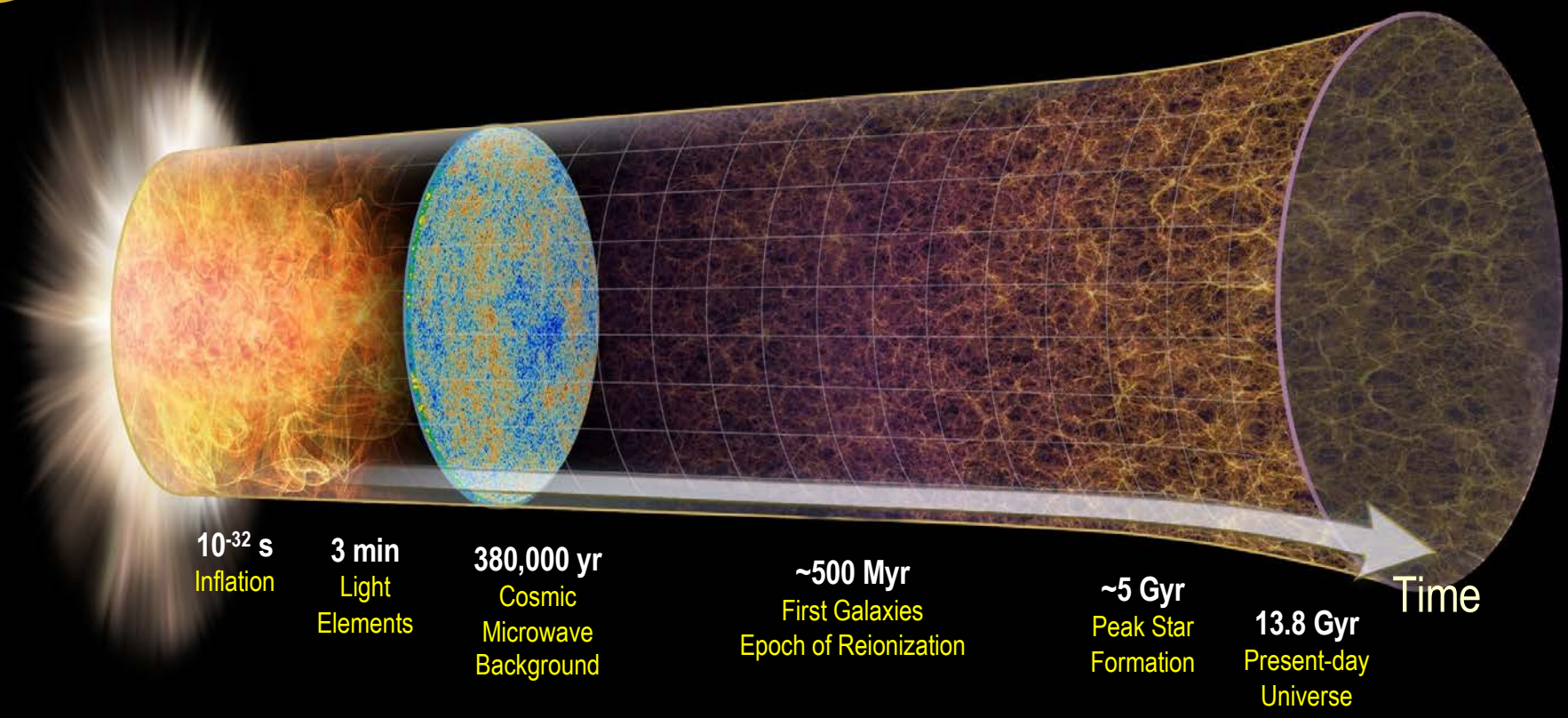
Spectral Decomposition Determines

- Emission from all galaxies
- Dwarf galaxies responsible for reionization
- Diffuse emission from stripped stars
- Dark matter decay (?)

• Complements galaxy-by-galaxy surveys

Intensity Mapping captures the light emitted from *everything that gravitationally clusters*

HOW DID THE UNIVERSE BEGIN?

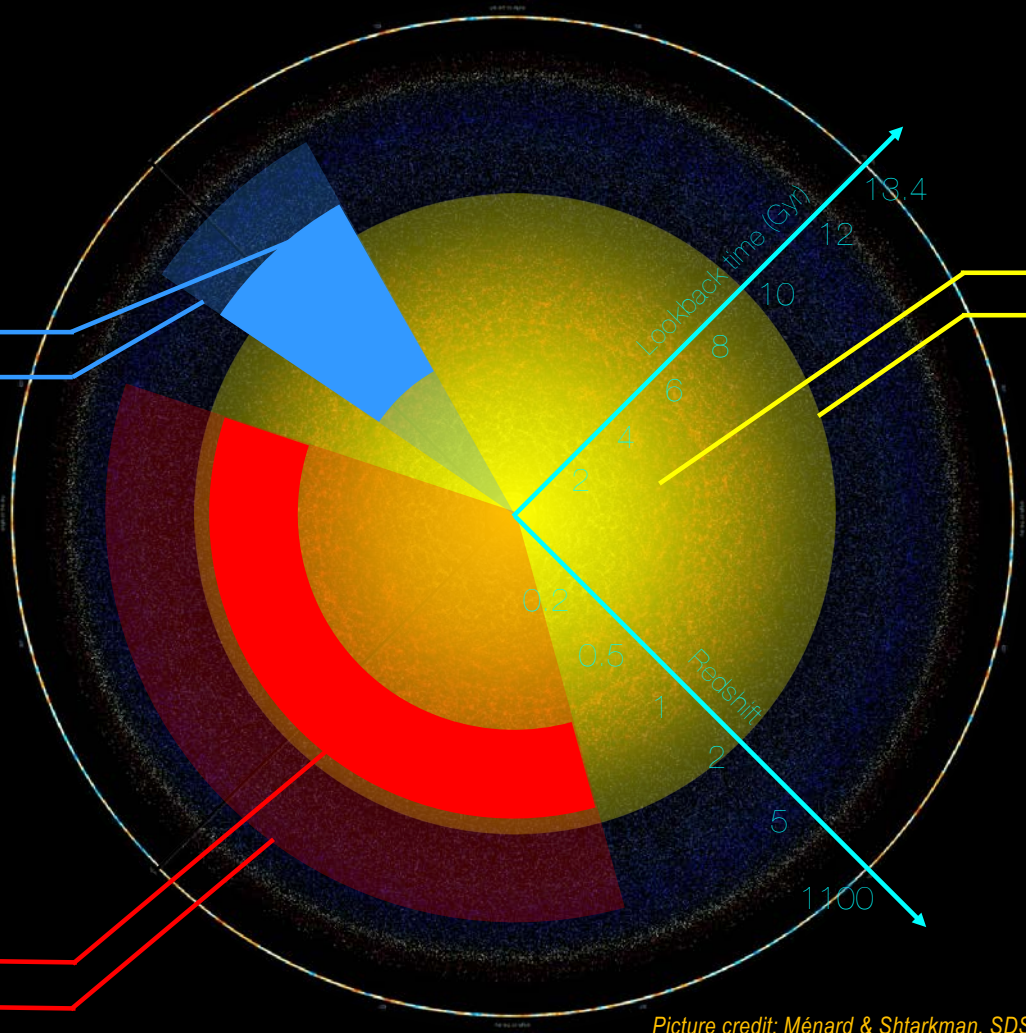


SPHEREx observes the 3D distribution of galaxies to *probe inflationary non-Gaussianity*

MAPPING THE COSMOS

Roman
BAO and lensing survey
Science targets dark energy
2,000 – 4,000 sq. deg. area
~25M spec-zs
~2B photo-zs

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

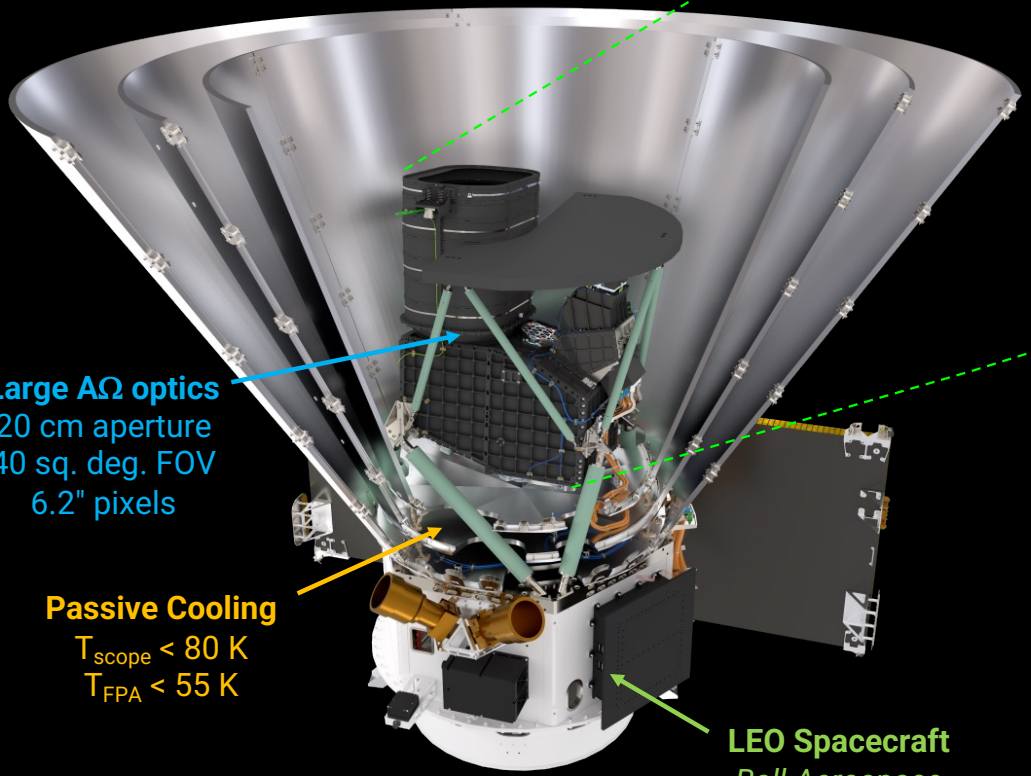


Picture credit: Ménard & Shtarkman, SDSS

SPHEREx
All-sky spectroscopic survey
Science targets inflation
40,000 sq. deg. area
15M high-accuracy spec-zs
500M low-accuracy spec-zs

Target is non-Gaussianity
$\sigma(f_{NL}) < 1\ (2\sigma)$

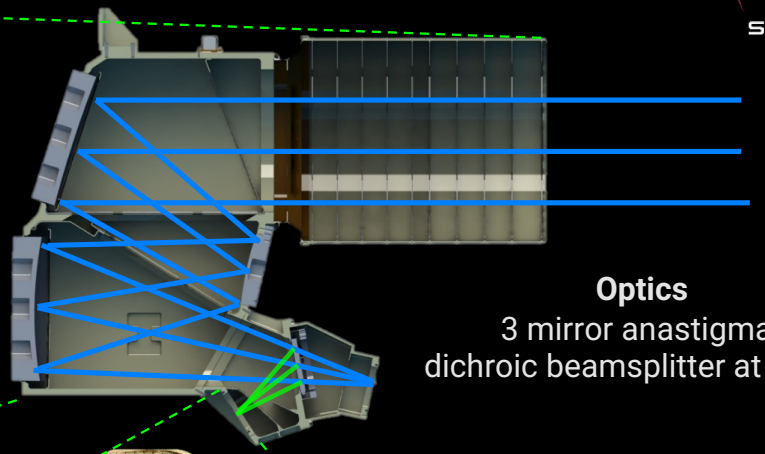
SPHEREˣ IN A NUTSHELL



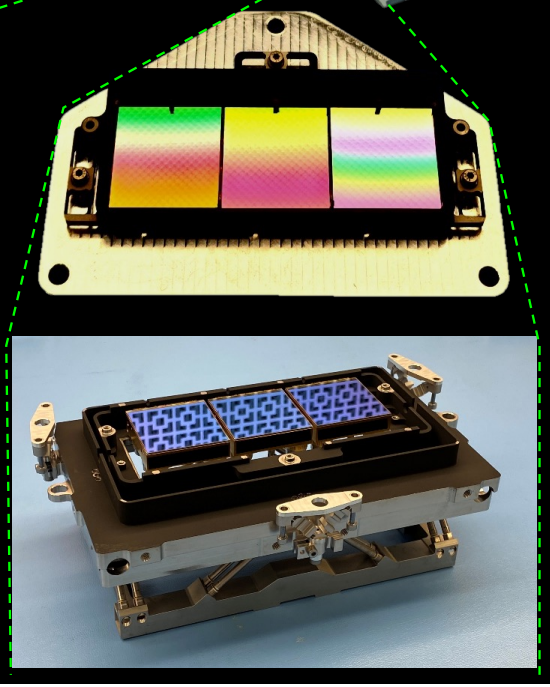
Large AΩ optics
20 cm aperture
40 sq. deg. FOV
6.2" pixels

Passive Cooling
T_{scope} < 80 K
T_{FPA} < 55 K

LEO Spacecraft
Ball Aerospace
Now BAE Systems

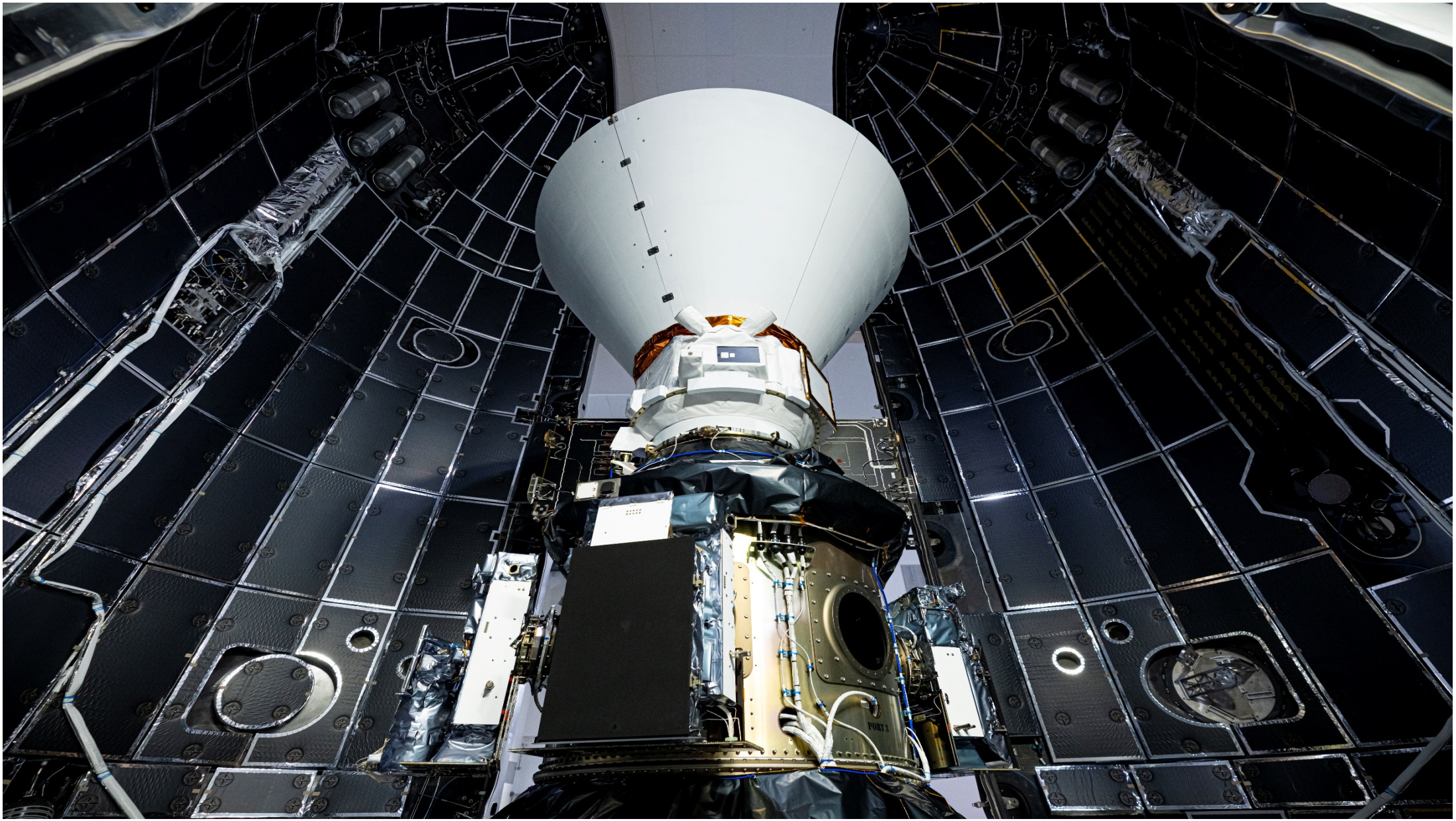


Optics
3 mirror anastigmat
dichroic beamsplitter at 2.4um



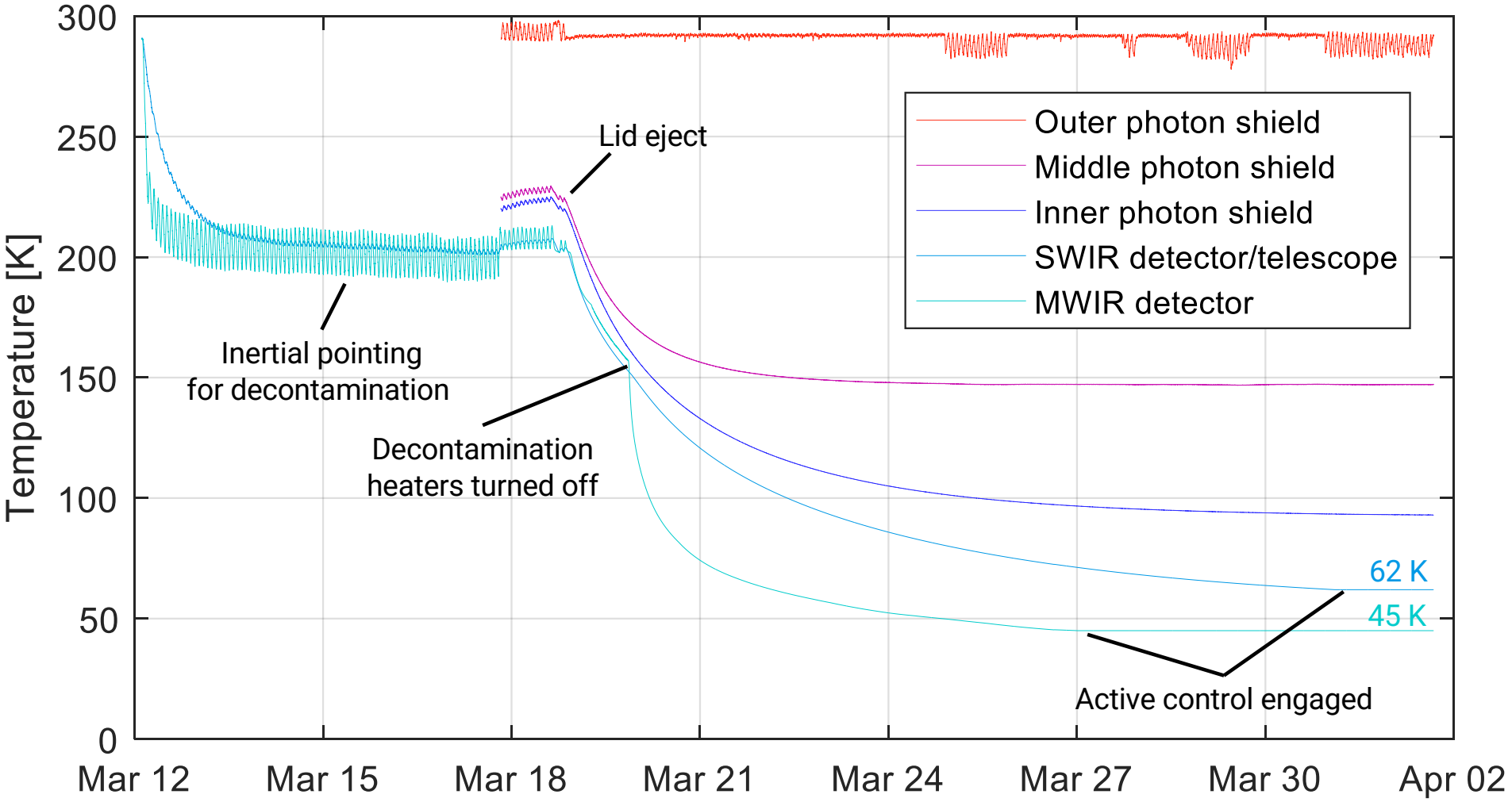
Linear Variable Filter Spectroscopy
λ = 0.75 – 5 μm
$\Delta\lambda/\lambda$ = 35 – 130
Spread across two focal planes

Two 3xH2RG Mosaics
Arrays located directly behind the LVFs

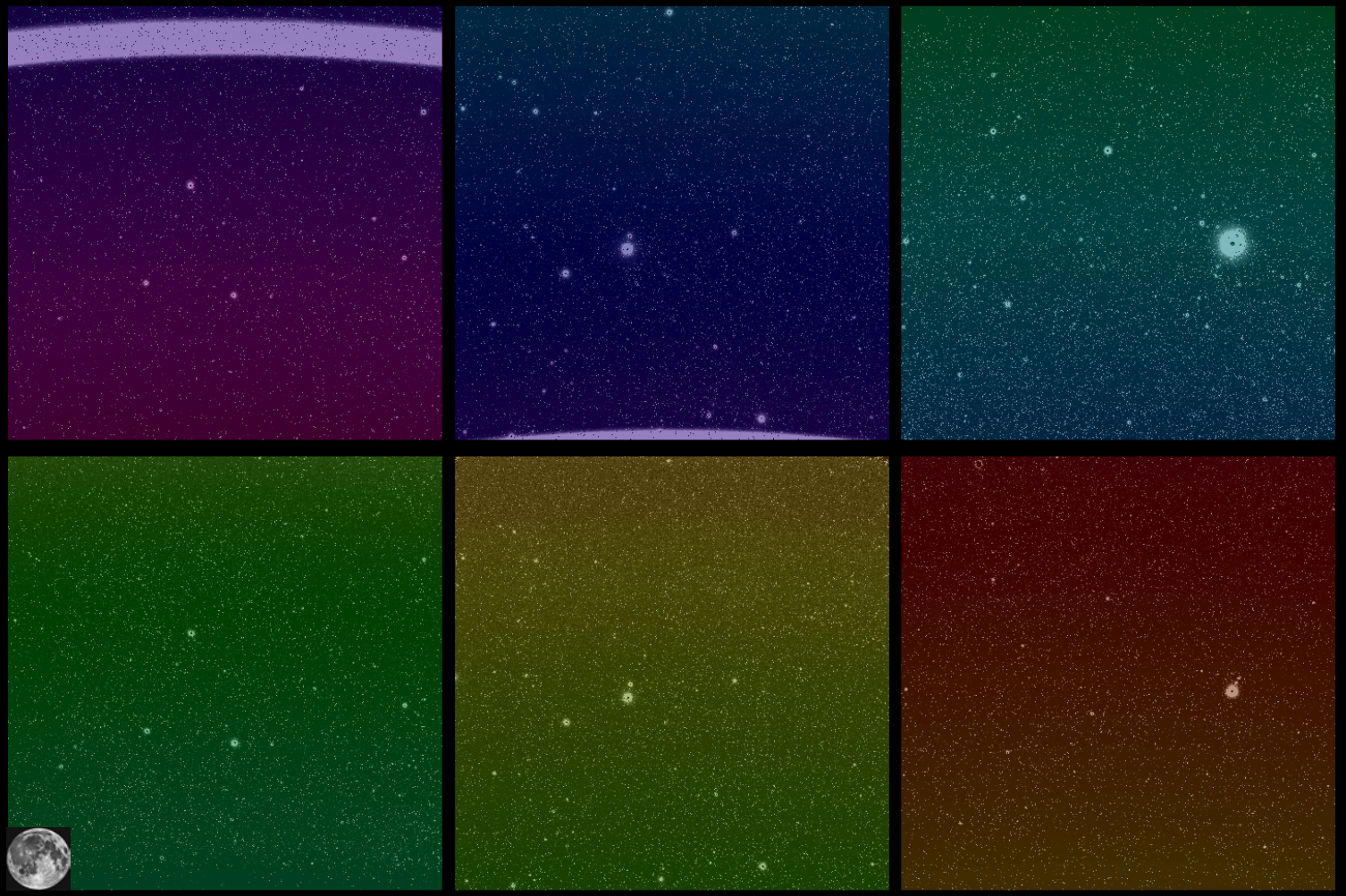

PORT 3


SPEED
0
KM/H
ALTITUDE
0.1
KM
STAGE 1 TELEMETRY
STARTUP
LIFTOFF
MAX-Q
MECO
FAIRING
BOOSTBACK
STRONGBACK RETRACT
T - 00:00:03
SPHEREX / PUNCH

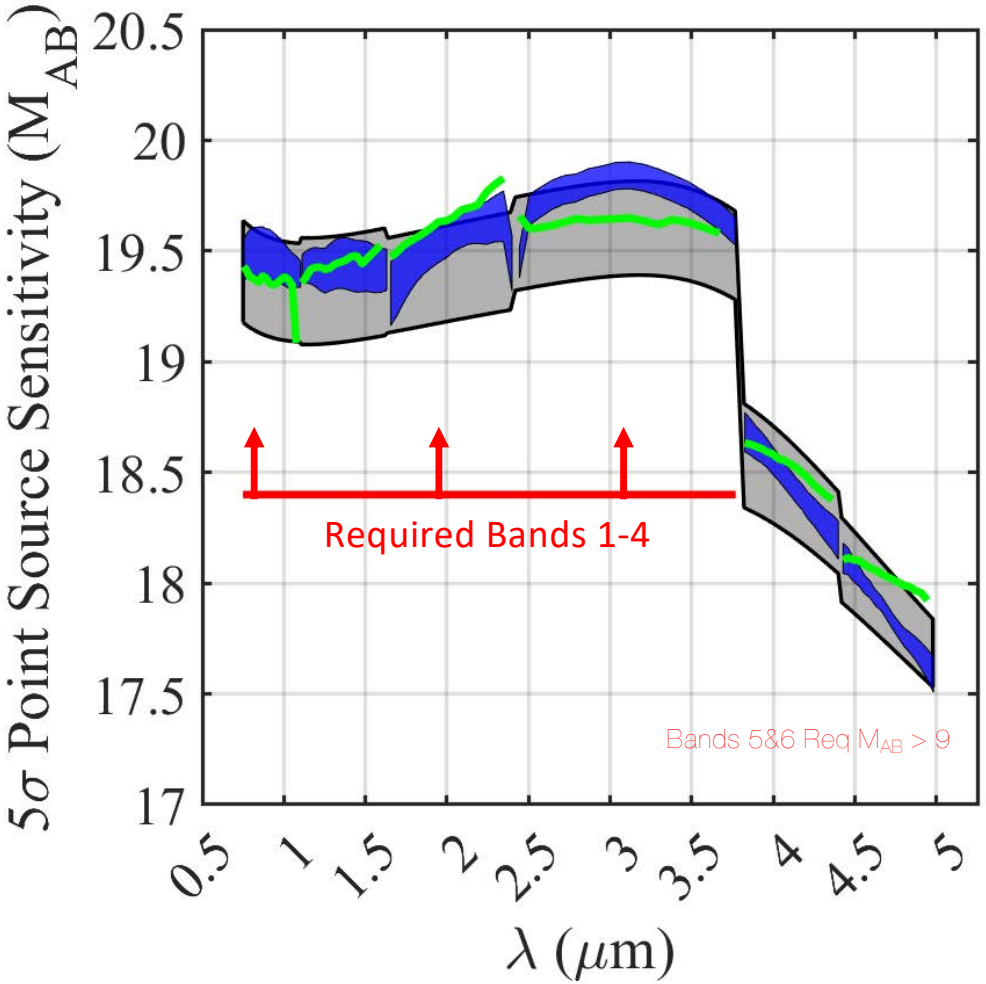
INSTRUMENT COOLDOWN



SPHEREX FIRST LIGHT MARCH 27



POINT SOURCE SENSITIVITY



CSR –Level Estimate ca. 2018

- Vendor negotiated detector specifications
- Vendor negotiated efficiencies
- Simulated Optical Performance
- Simulated Spacecraft ADCS Performance
- Modelled Sky Brightness

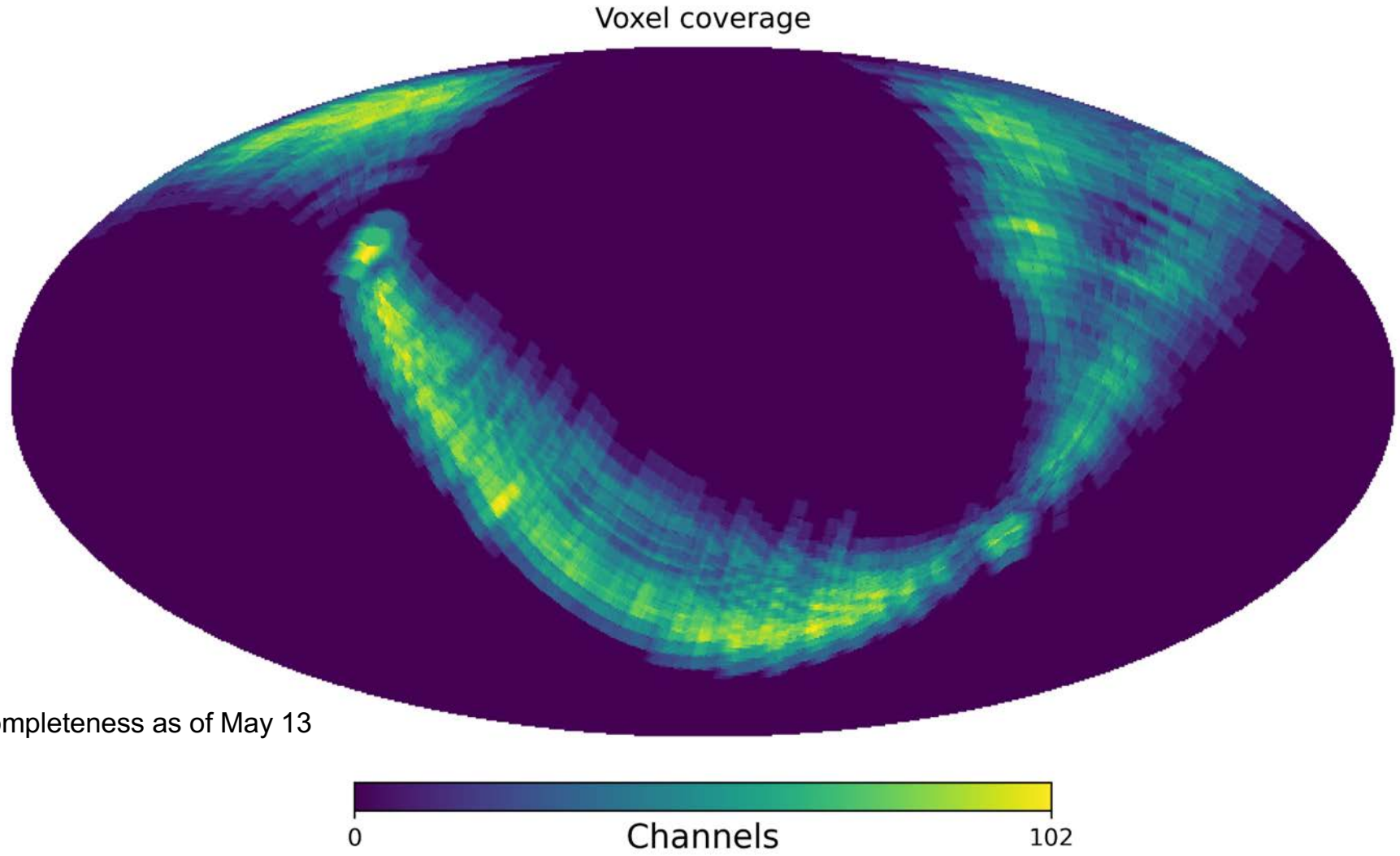
Instrument I&T Completion ca. 2023

- Lab measured detector performance
- Component measured efficiencies
- Measured Focus + Simulated Optical Performance
- Simulated Spacecraft ADCS Performance
- Modelled Sky Brightness

In Orbit

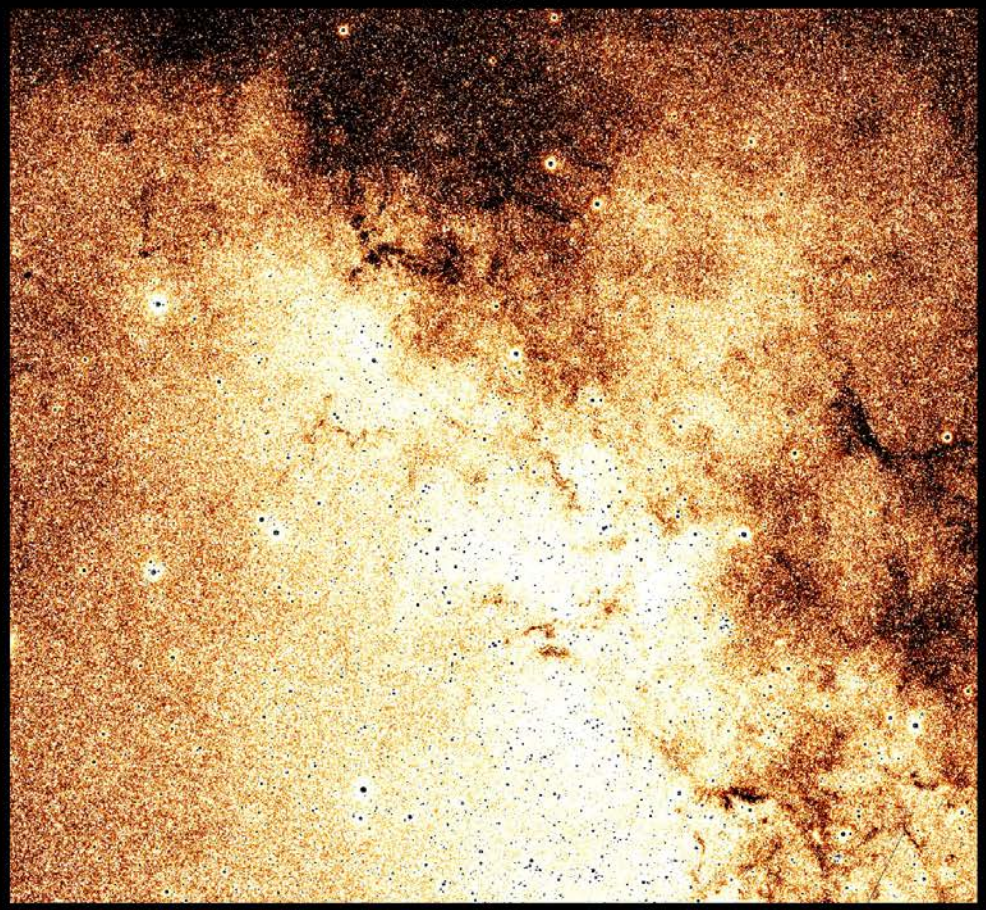
- Number of effective pixels from stars
- Noise from image differences
- Absolute calibration from calibration stars
- Sky median photocurrent

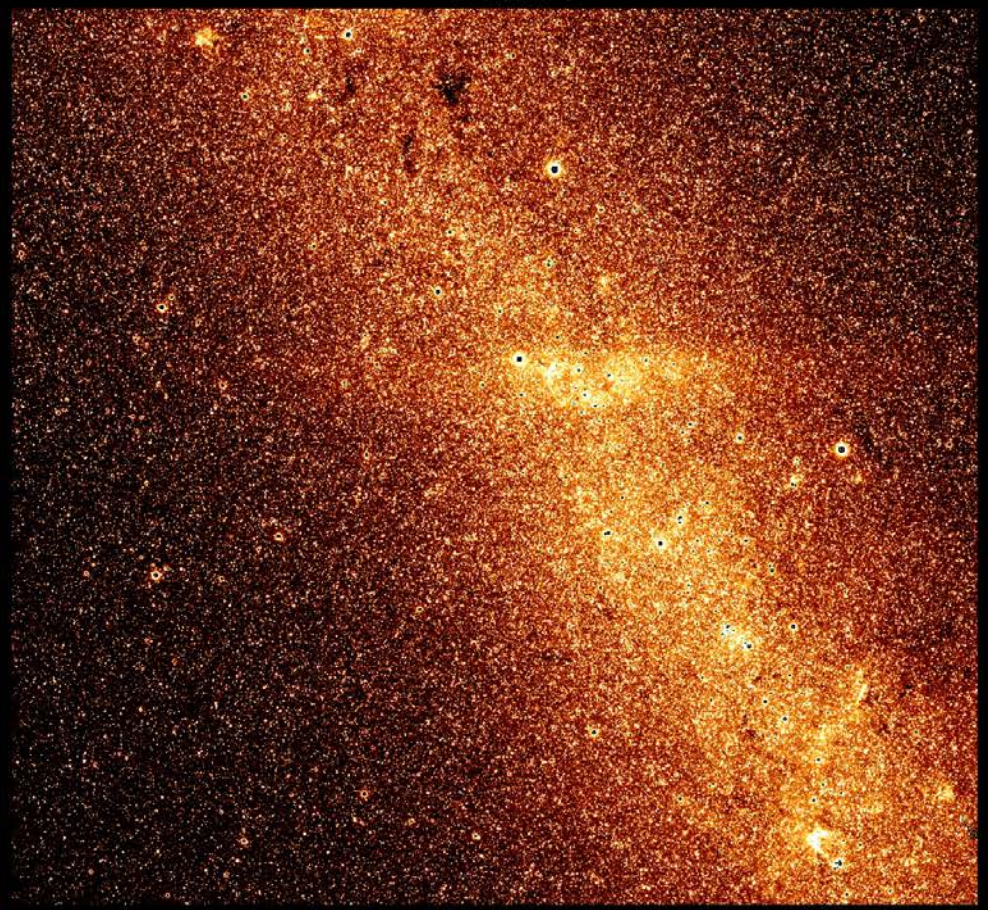
SCIENCE OBSERVATIONS BEGAN 1 MAY

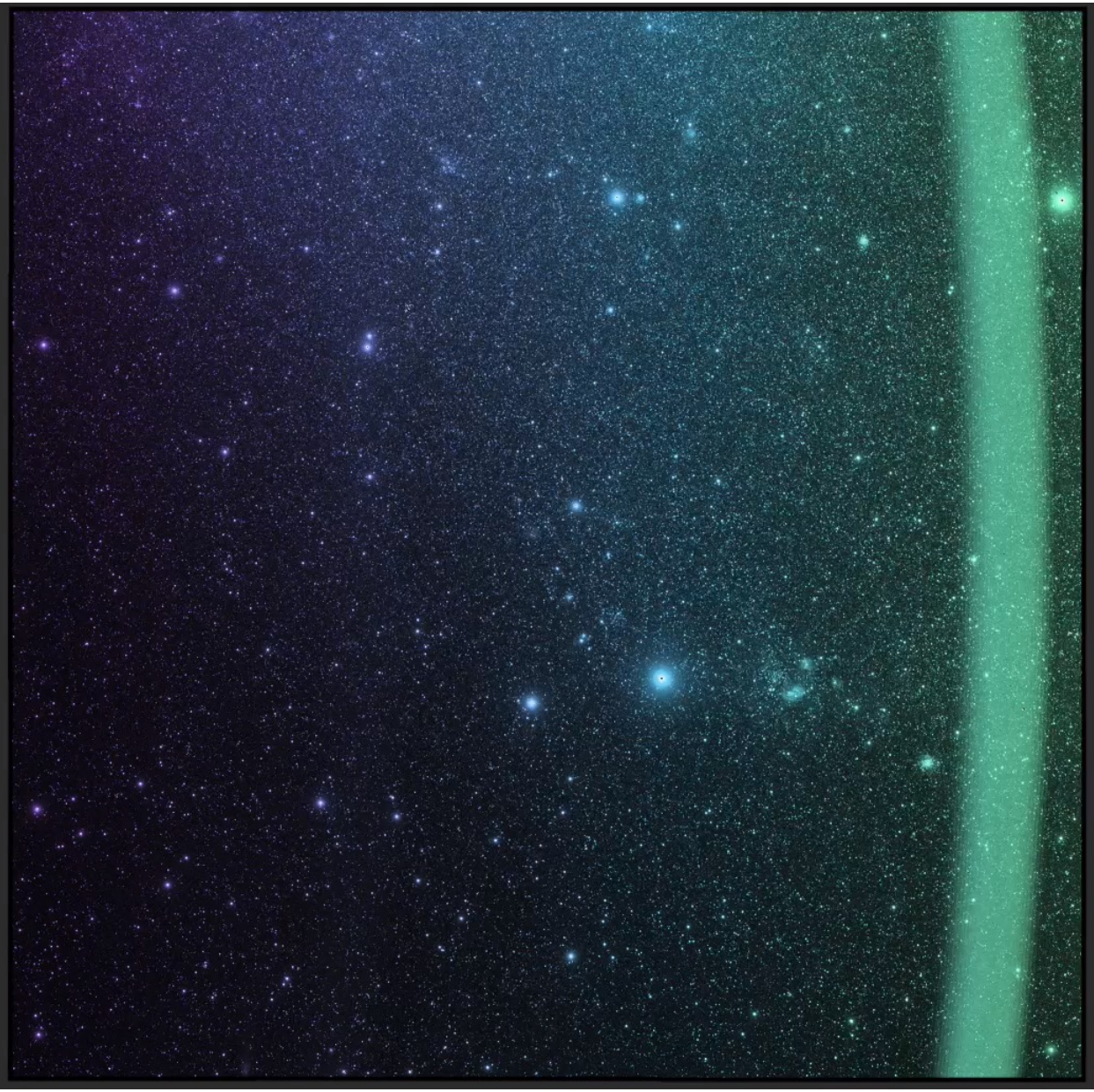


Voxel completeness as of May 13

TWO SPECTRAL IMAGES OF THE GALACTIC PLANE








Thanks for Listening!

BACKUP

SPHEREX ADDRESSES 3 CENTRAL QUESTIONS

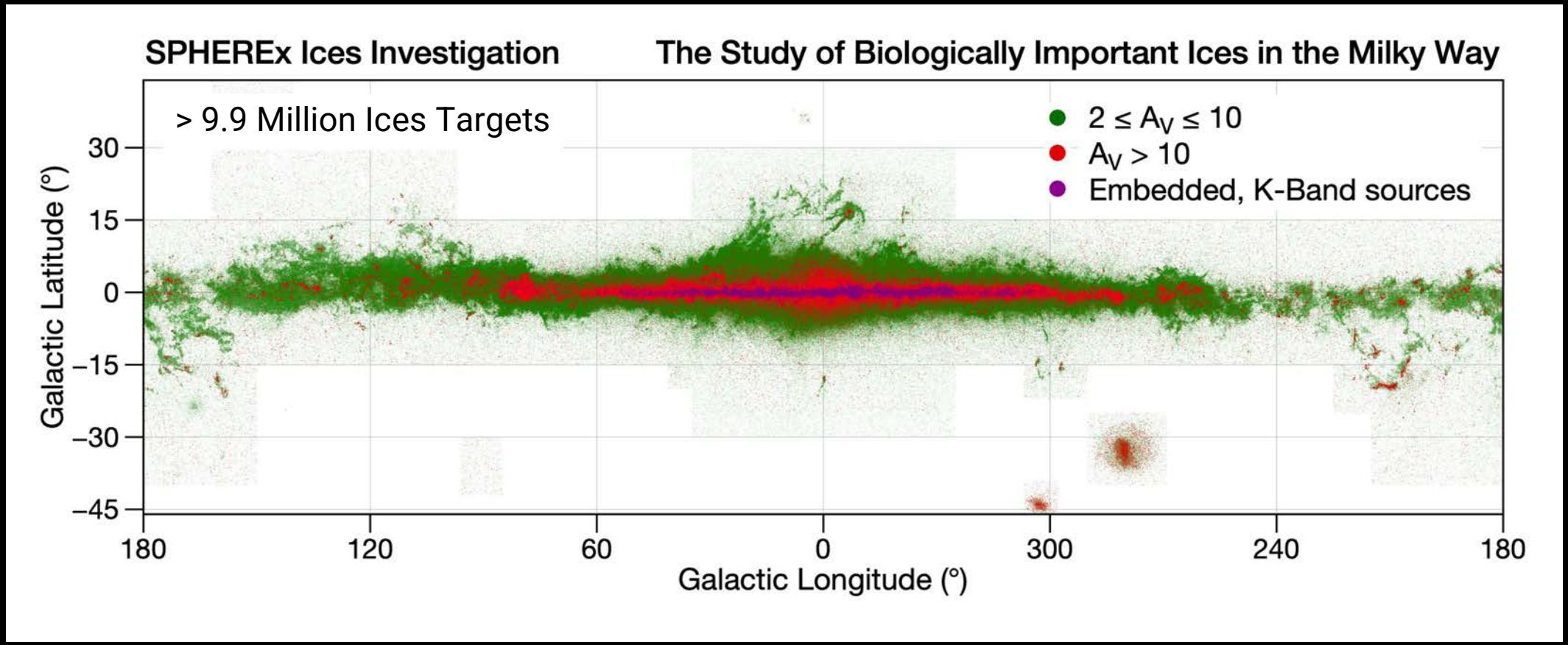
Where is the Water in our Galaxy?

How Did Galaxies Begin?

How Did the Universe Begin?

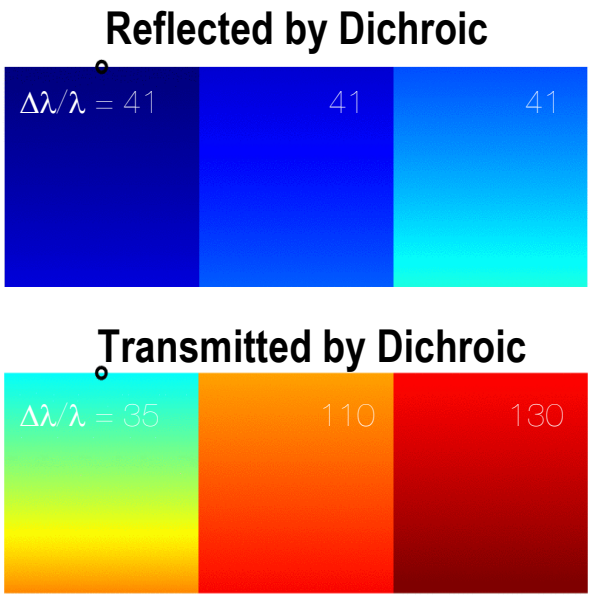
…While Creating a Unique All-Sky Spectral Survey

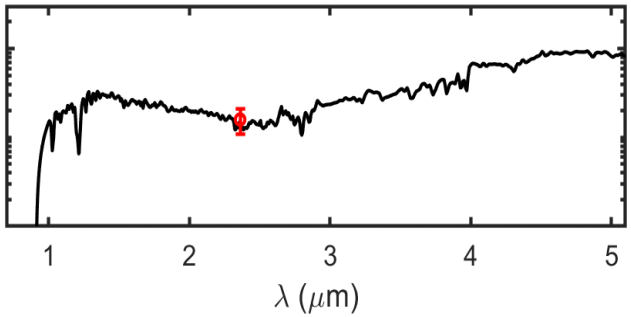
SPHEREX CONDUCTS A COMPREHENSIVE ICES SURVEY



Pre-selected sources from WISE: embedded, isolated, and with SPHEREx SNR > 100 per channel

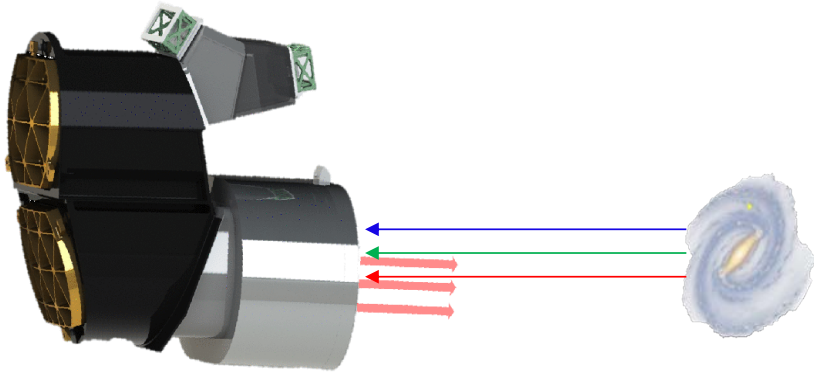
SPECTROSCOPY WITH LINEAR VARIABLE FILTERS (LVFs)

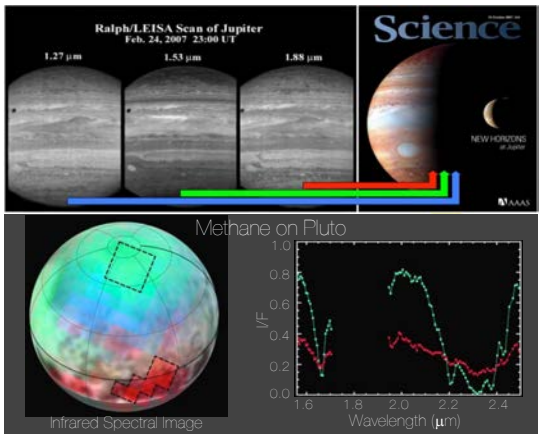




A complete spectrum in 51 exposures
Each exposure takes ~112s
1 complete spectrum every 6 months

Shifting the spacecraft pointing modulates the wavelength at which an object is observed.

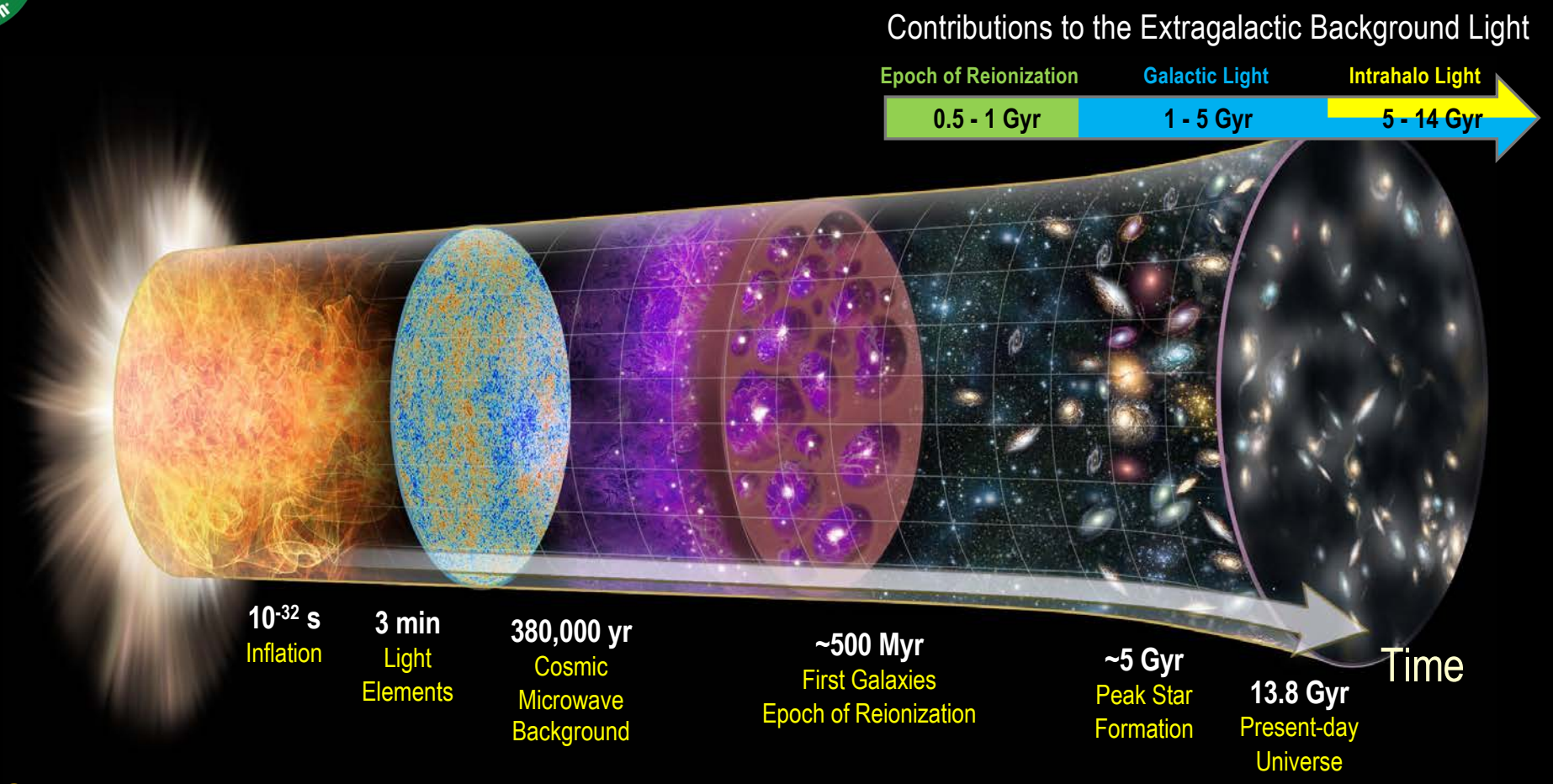




LVF surveys are novel to astrophysics but have been used for great results in planetary science

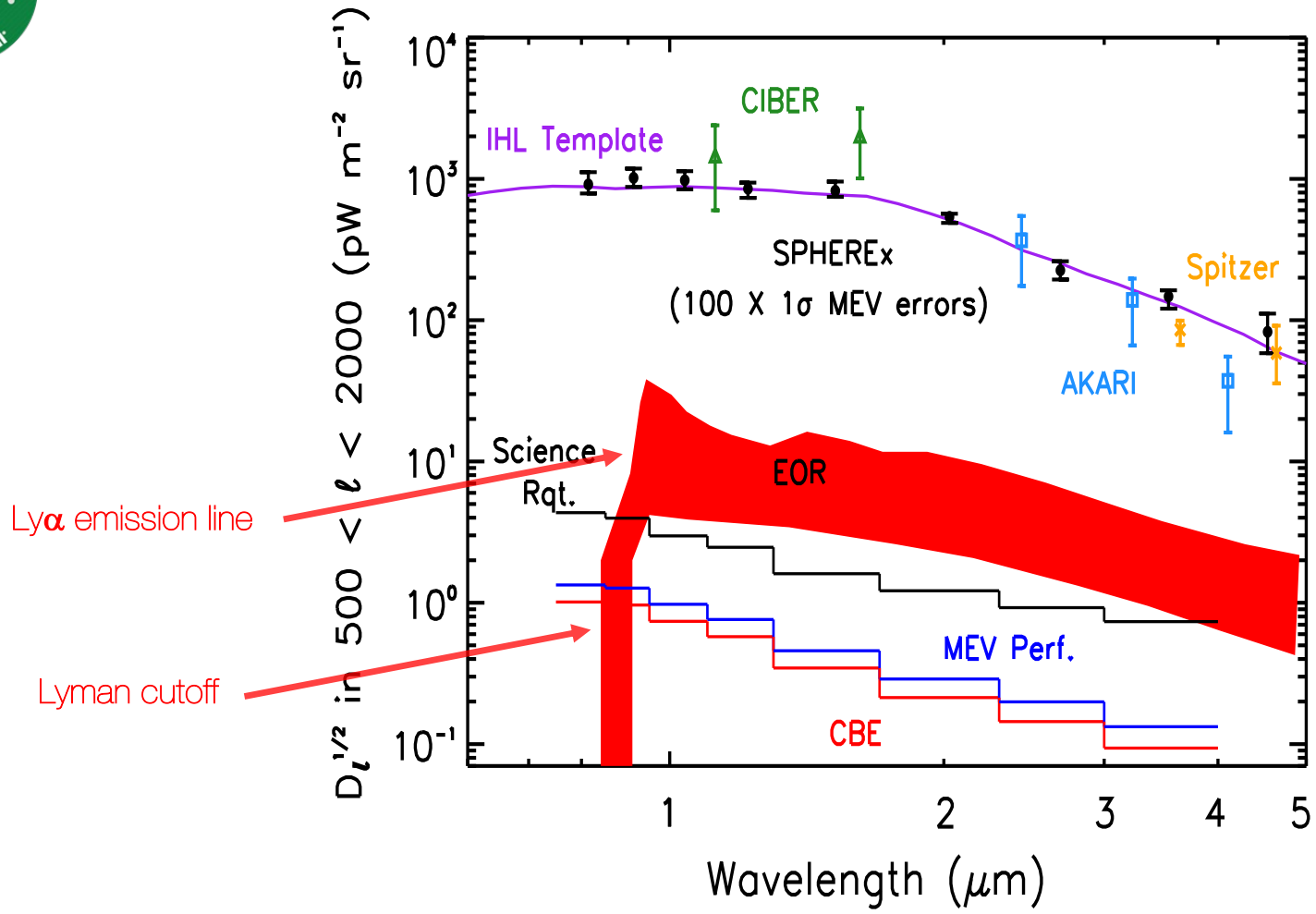
LEISA - New Horizons

HOW DID GALAXIES BEGIN?



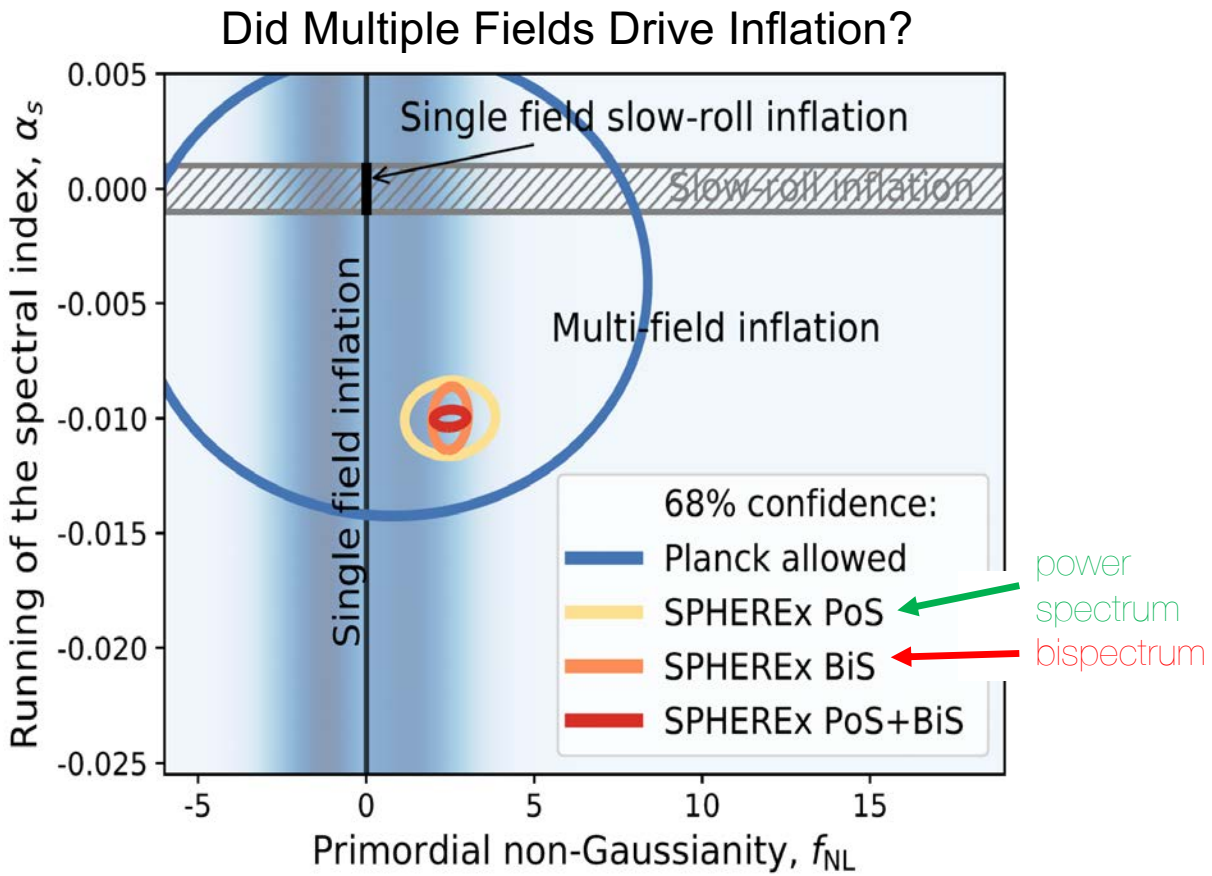
SPHEREx extragalactic background light measurements determine the *total light emitted by galaxies*

MEASURING THE COSMIC HISTORY OF LIGHT PRODUCTION



SPHEREx TESTS INFLATIONARY NON-GAUSSIANITY

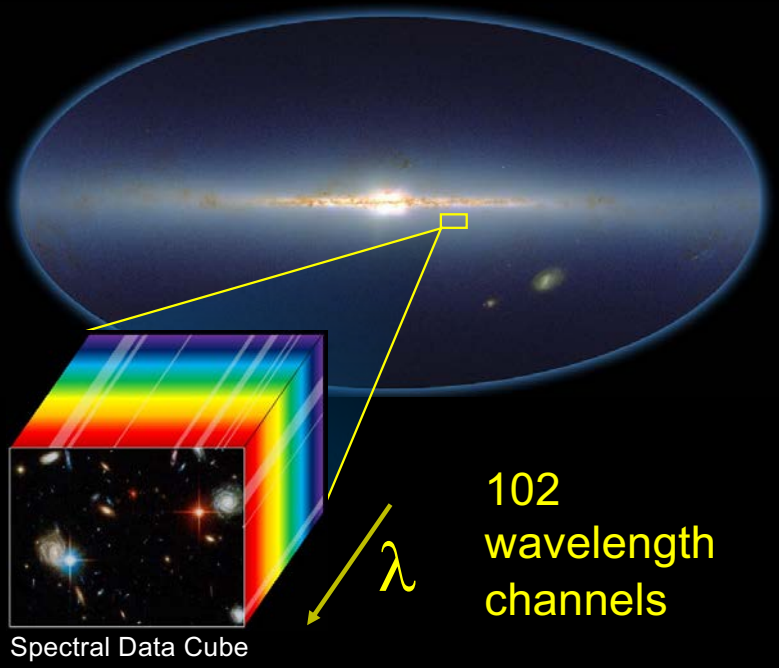
- Single-field models
  predict $f_{NL} < 0.01$
- Multi-field models
  predict $f_{NL} \gtrsim 1$
- Non-inflationary models
  (Steinhardt *et al.*) predict $f_{NL} \sim 1$



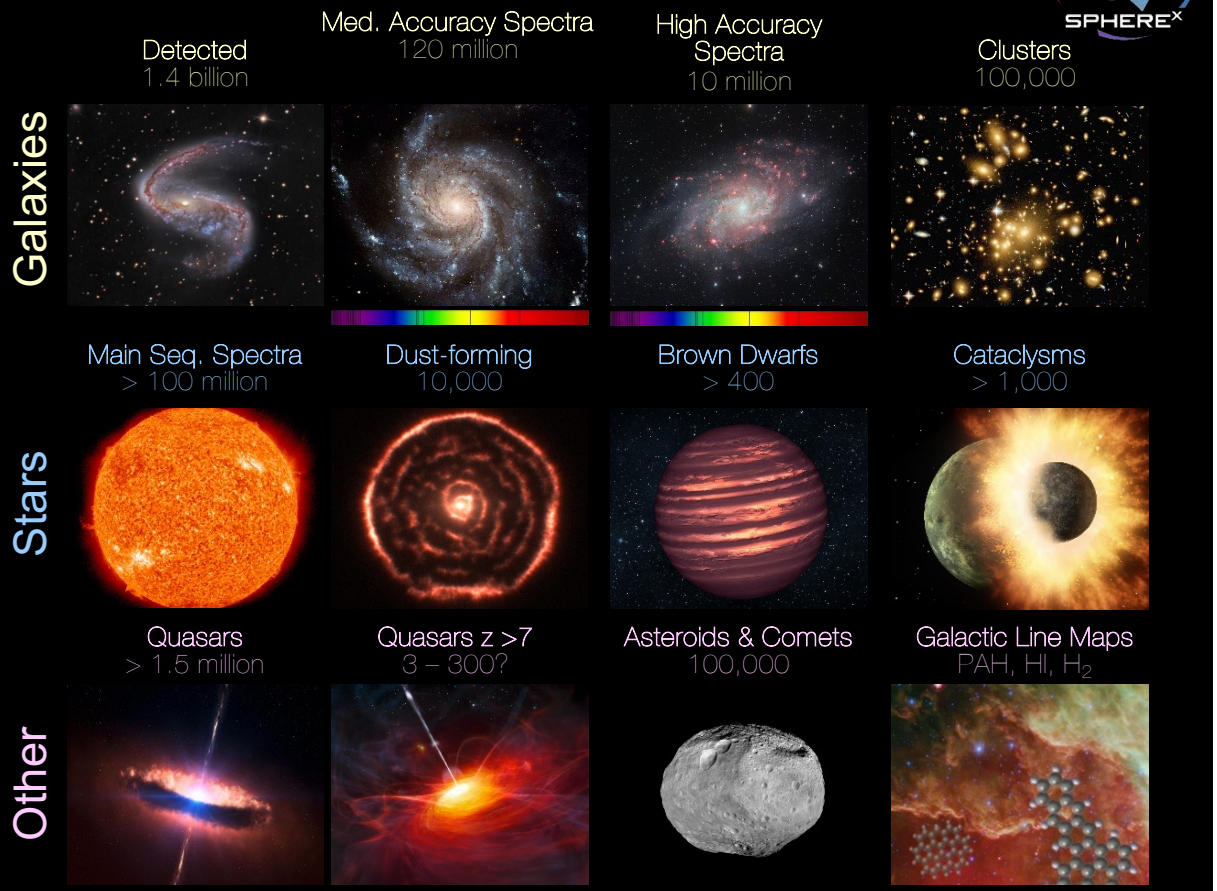
*Multi-tracer analysis exploiting LPNG bias (b_ϕ) may offer further improvement!

SPHEREX PROVIDES A RICH ALL-SKY SPECTRAL CATALOG

All-Sky Survey



SPHEREx provides a new and unique dataset
a complete near-infrared spectrum for every 6” pixel on the sky

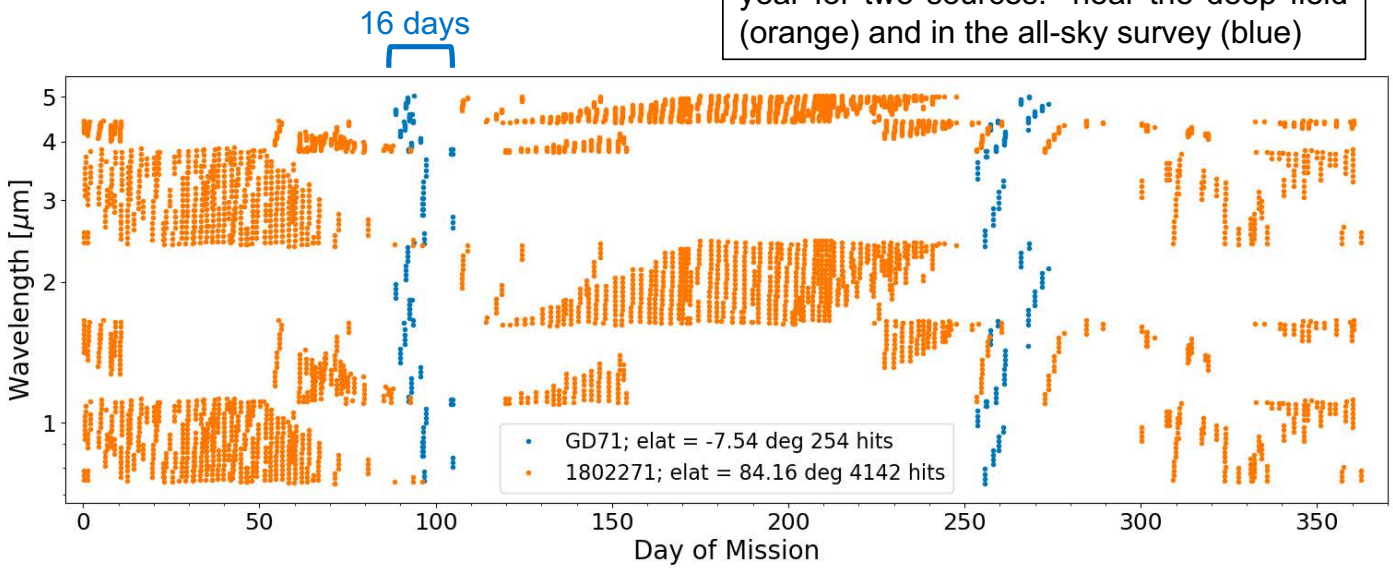


- All-Sky surveys demonstrate high scientific return with lasting data legacy used across astronomy (COBE, IRAS, GALEX, WMAP, Planck, WISE)
- Many exciting discoveries will come from the community
- Great potential for follow-up with NASA’s observatories

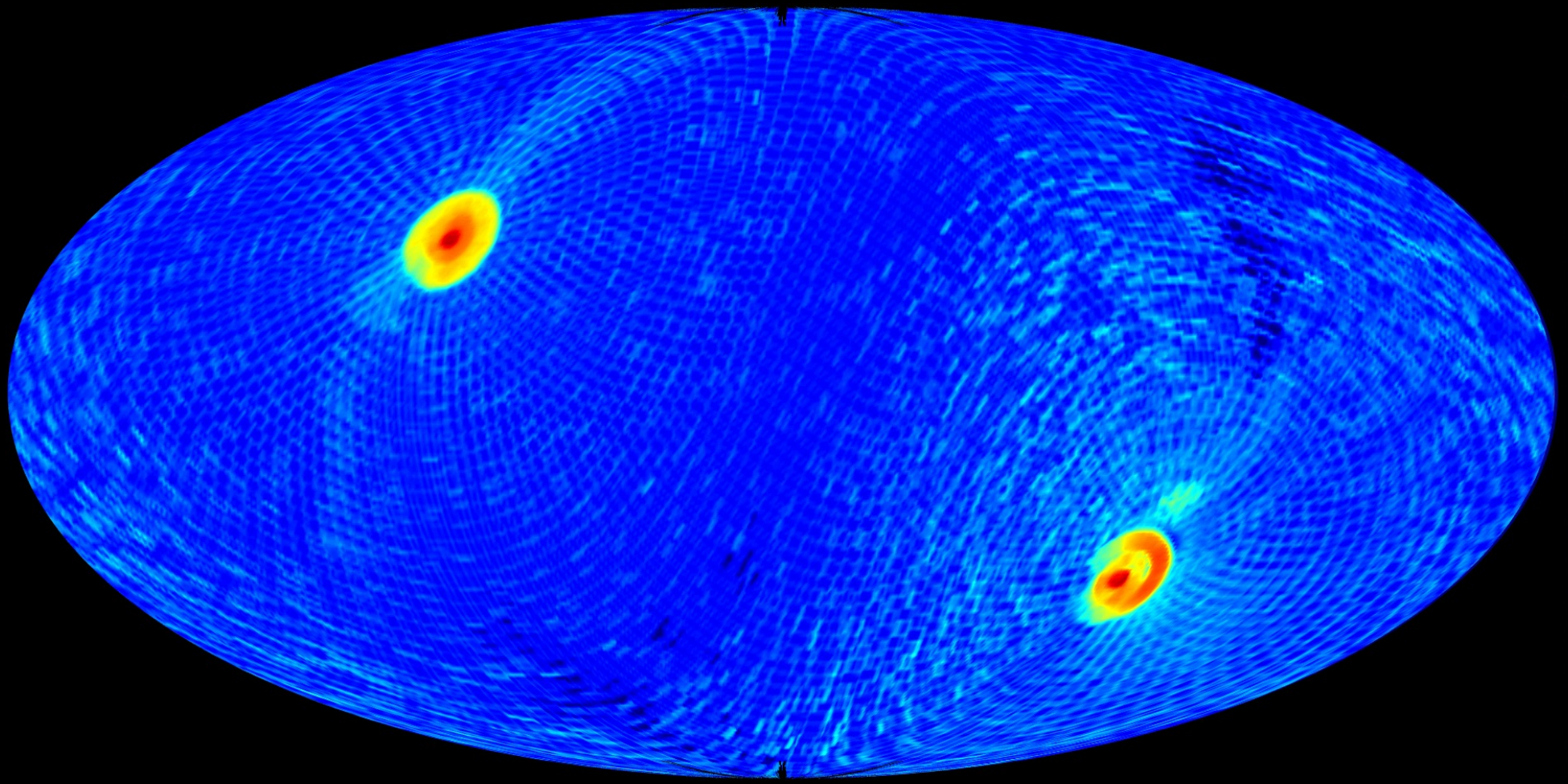
SPHEREx AND TIME-DOMAIN ASTRONOMY

- The SPHEREx all-sky survey will have 102 channels from 0.75 to 5 microns and 6” pixels
- In the two-year prime mission, the whole sky will be observed 4 times and deep fields at the NEP and SEP hundreds of times
  - SPHEREx deep fields are in the JWST continuous viewing zones
- SPHEREx utilizes linear variable filters, so the spectral measurements for each pixel are staggered in time
- Data will be available in 2 formats:
  - Primary measurements tagged with exact wavelength and time
  - Measurements time-averaged and interpolated onto a wavelength grid
- Spectra will be released in the High Reliability Source Catalog (after Survey 3 and after Survey 4) and users can also use the Spectrophotometry tool at IRSA to generate their own
- Example relevant science areas
  - Dust emission around main sequence and young stars
  - Comets and asteroids
  - Infrared variability of X-ray sources

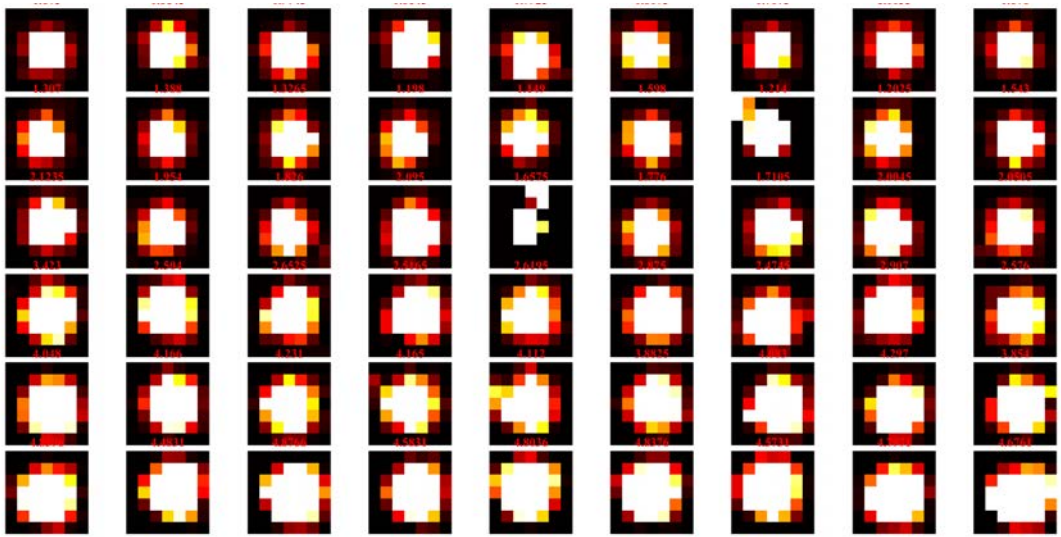
Example of spectral sampling timing over 1 year for two sources: near the deep field (orange) and in the all-sky survey (blue)



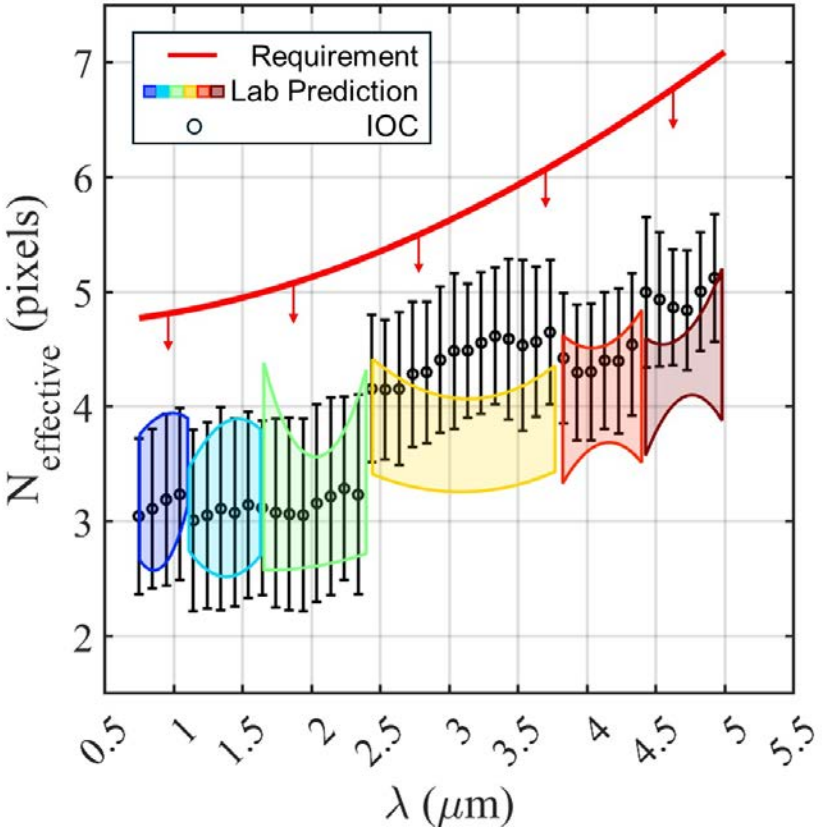
DESIGN SKY COVERAGE



TELESCOPE FOCUS



Using ~1M bright isolated stars, calculate the effective number of pixels used to measure a point source N_{eff}



COMPOSITE IMAGE OF THE N11 REGION

Image Credit: Robert Hurt, IPAC