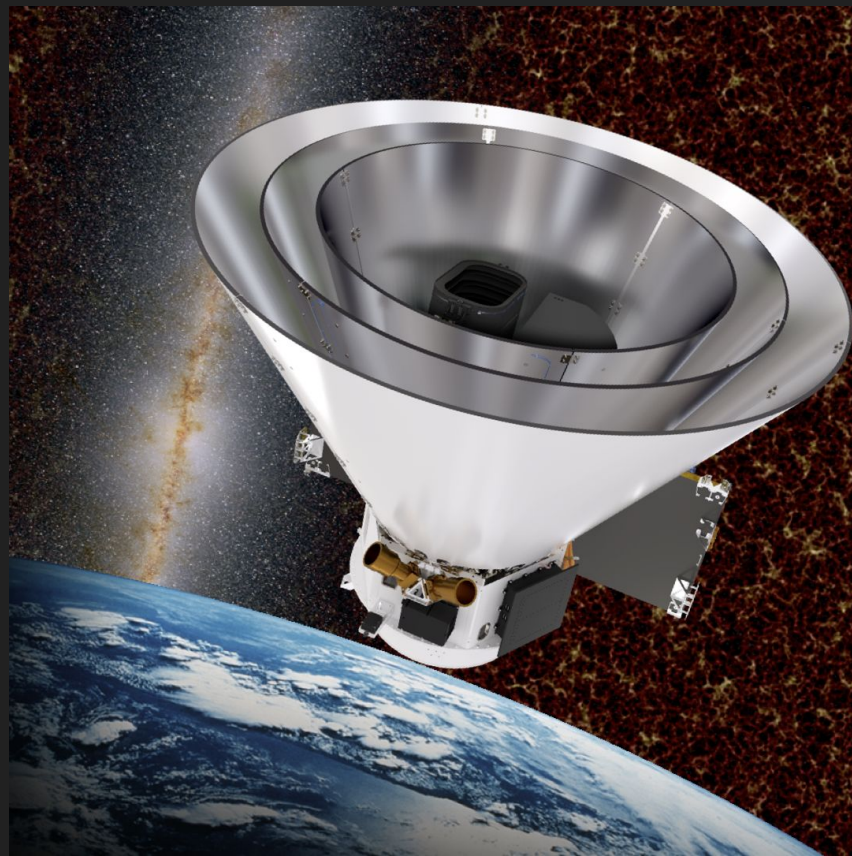


SPHEREx

An all-sky spectral
survey

Ari Cukierman
Caltech

Feb. 21/22, 2024
SAGI





What I hope you remember a week from now

SPHEREx

Launching in **early 2025**

A near-infrared spectrum for **every 6"** pixel on the sky

Scientific motivations



How did the Universe begin?



How did galaxies form?



How did life form?



Legacy catalog of galaxies, stars, asteroids and more

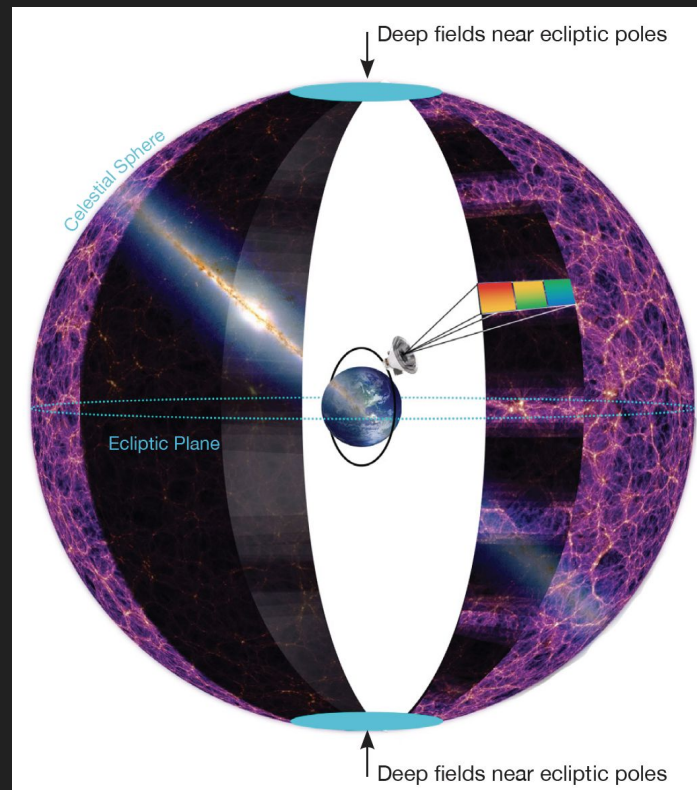
A little more detail...

Medium-class explorer (MIDEX)

- PI: **Jamie Bock** (Caltech/JPL)

All-sky spectral survey

- Near infrared: 0.5-5 μm
- Mid-resolution: 6" pixels, $R \sim 35-130$



A little more detail...

Medium-class explorer (MIDEX)

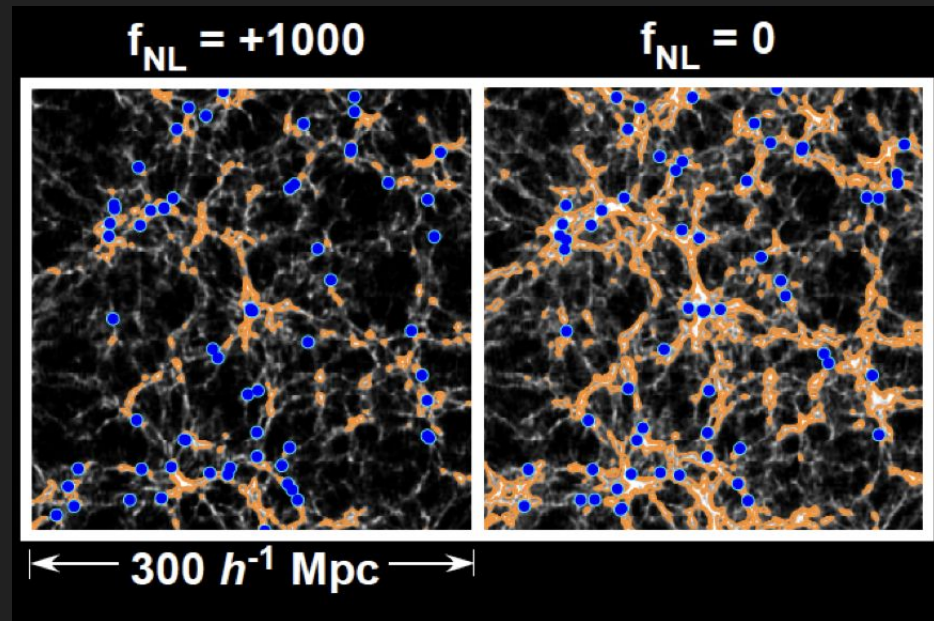
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Galaxy redshifts \rightarrow **non-Gaussianity**



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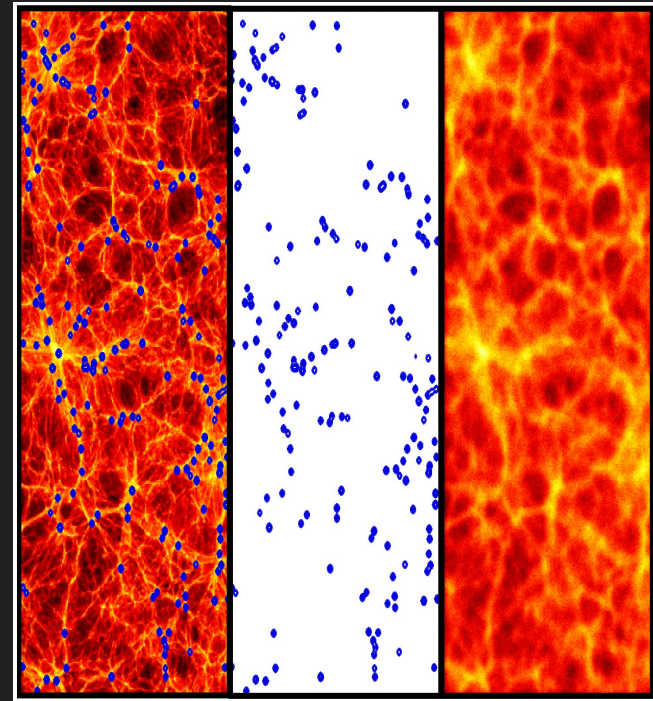
- Near infrared: 0.5-5 μm
- Mid-resolution: 6" pixels, $R \sim 35-130$



Galaxy redshifts \rightarrow **non-Gaussianity**



Intensity mapping \rightarrow **galaxy formation**



Total =
galaxies +
diffuse

Galaxy
survey

Intensity
mapping

A little more detail...

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- Near infrared: 0.5-5 μm
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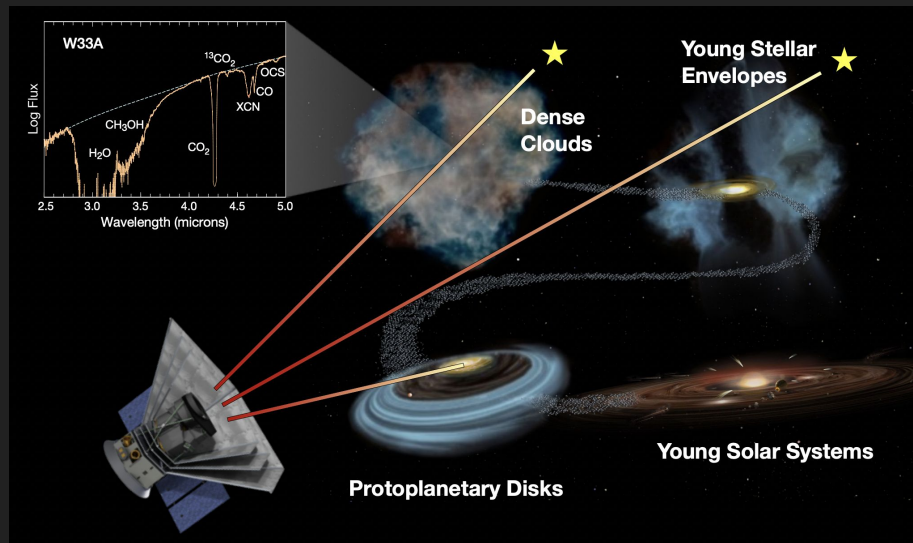
Galaxy redshifts \rightarrow **non-Gaussianity**



Intensity mapping \rightarrow **galaxy formation**



Absorption spectra \rightarrow **interstellar ices**



A little more detail...

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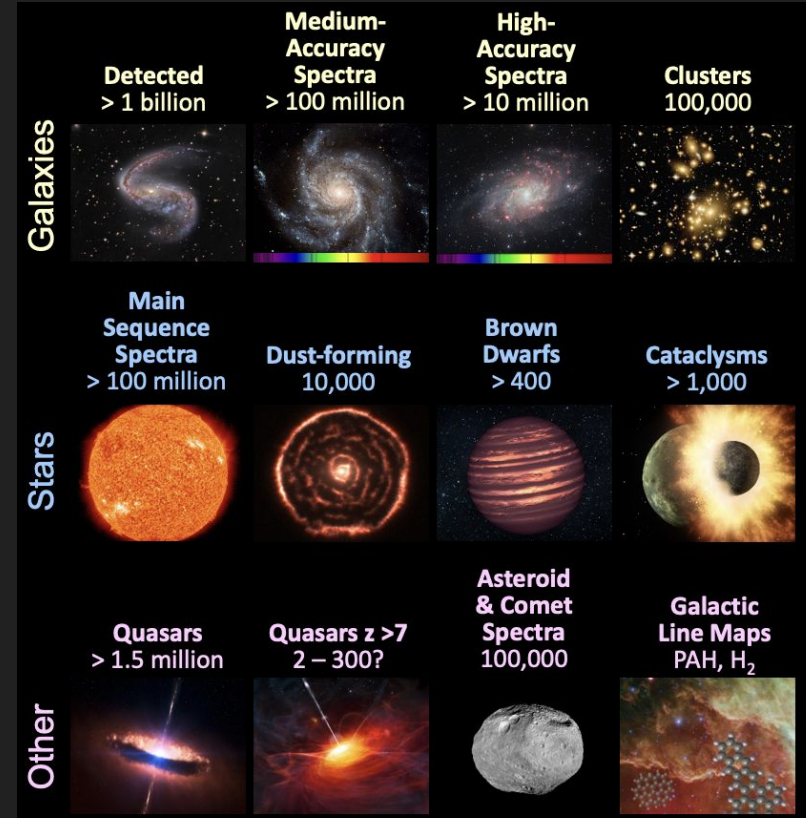
Intensity mapping \rightarrow **galaxy formation**



Absorption spectra \rightarrow **interstellar ices**



All-sky spectral archive





SPHEREx – Ari Cukierman (Caltech)



Back to the beginning...

SPHEREx

- Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer
- Medium-class explorer (MIDEX)
 - Selected 2019
 - Launching in **early 2025**

Thomas Zurbuchen ✓
@Dr_ThomasZ

This afternoon while at @NASAJPL, I notified Jamie Bock, @Caltech professor and the future SPHEREx mission Principal Investigator, that his proposal will become a NASA mission. I'm happy I could tell him this exciting news in person. Watch:

Mission info: go.nasa.gov/2Eawfll



2:01 PM · Feb 13, 2019

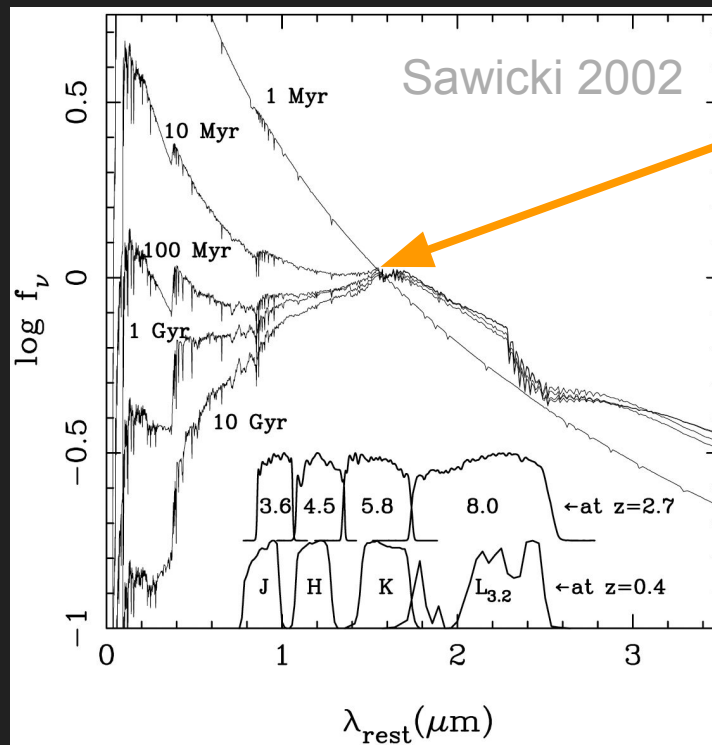
0:13 / 3:38

The video thumbnail shows three men sitting around a wooden conference table in an office. The man on the left is wearing a dark suit and tie. The man in the middle is wearing a blue polo shirt. The man on the right is wearing a grey suit jacket. They are all smiling and appear to be in a positive conversation. On the table in front of them is a book or brochure with a space-themed cover. The background shows a bookshelf with various items, including a model of a rover or satellite.

Why near-infrared?

1.6-um bump

- Redshift indicator



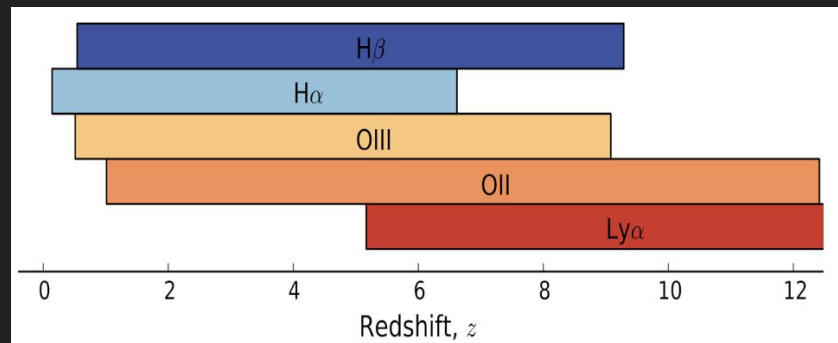
1.6-um
bump

Why near-infrared?

1.6-um bump

- Redshift indicator

Redshifted line emission



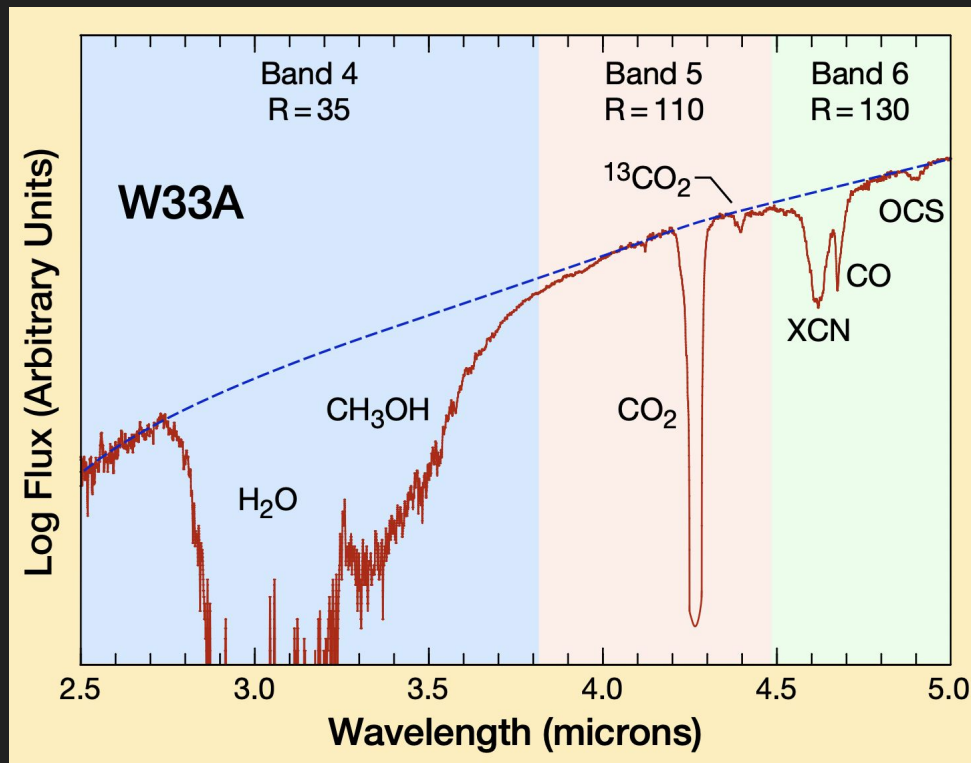
Why near-infrared?

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Redshifted line emission

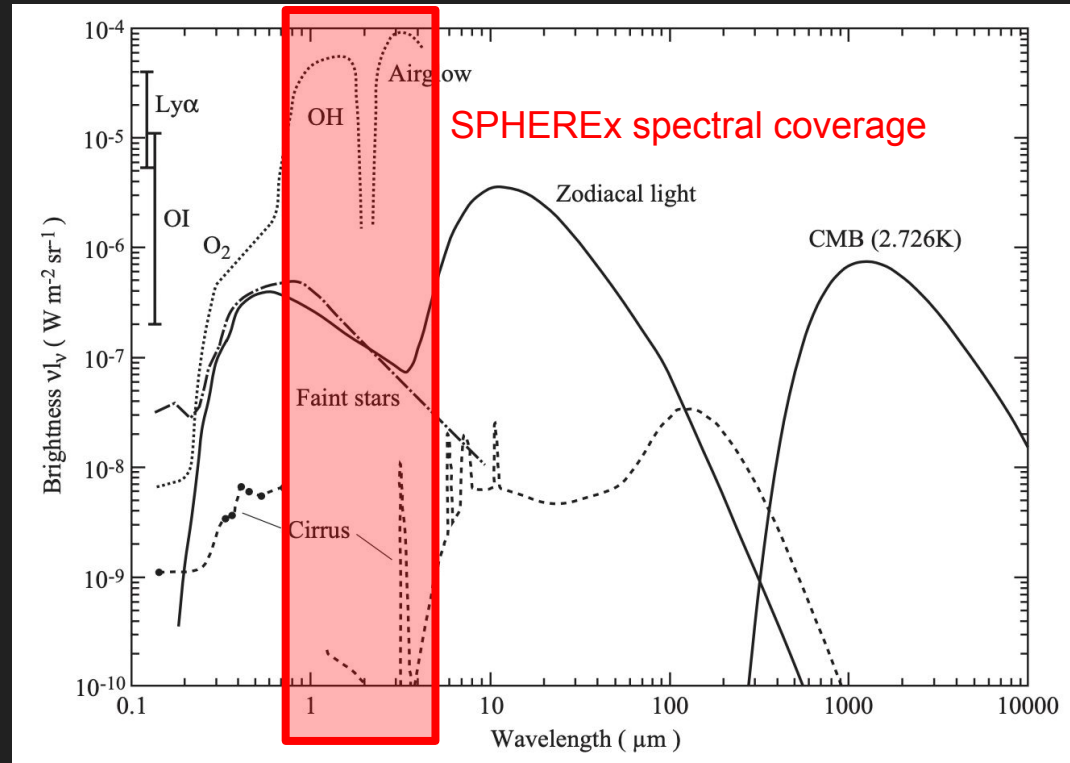
Biogenic ice absorption



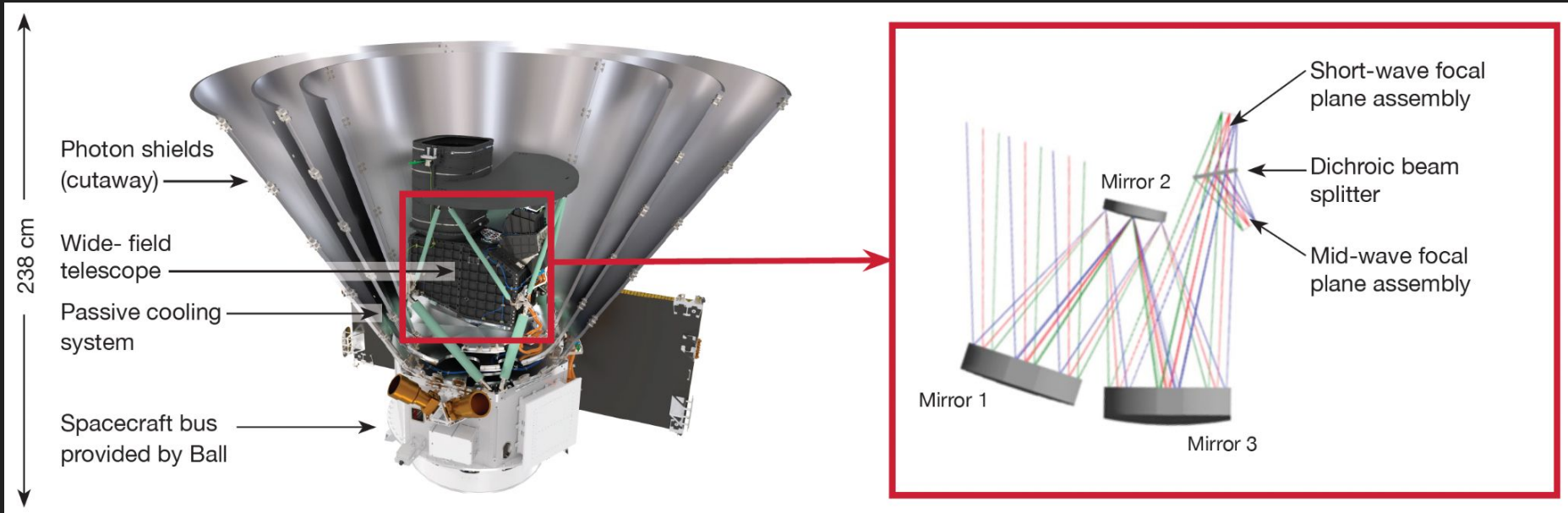
Why space?



"The 1997 reference of diffuse night sky brightness"
Leinert+ 1998



Instrument







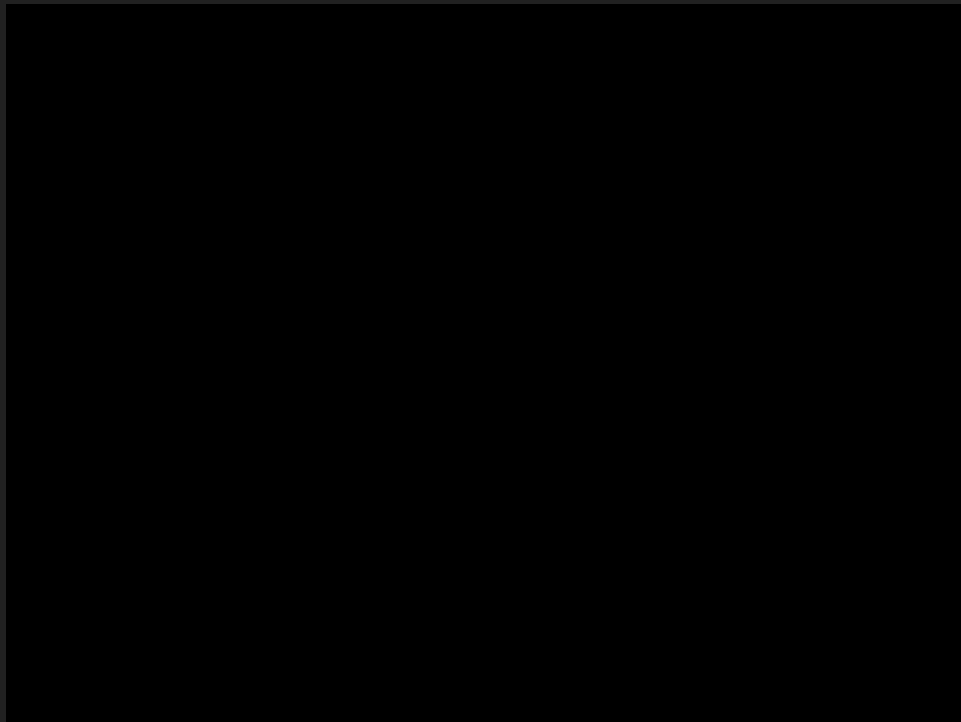
SPHEREx – Ari Cukierman (Caltech)



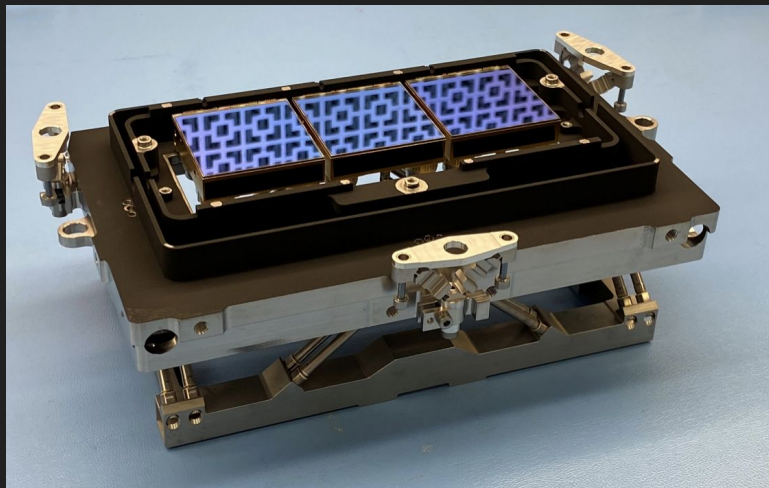
Where is SPHEREx now?

Basement of Cahill Center for
Astronomy and Astrophysics

- Completed thermal and vacuum testing
- Soon shipping to Ball Aerospace for spacecraft integration

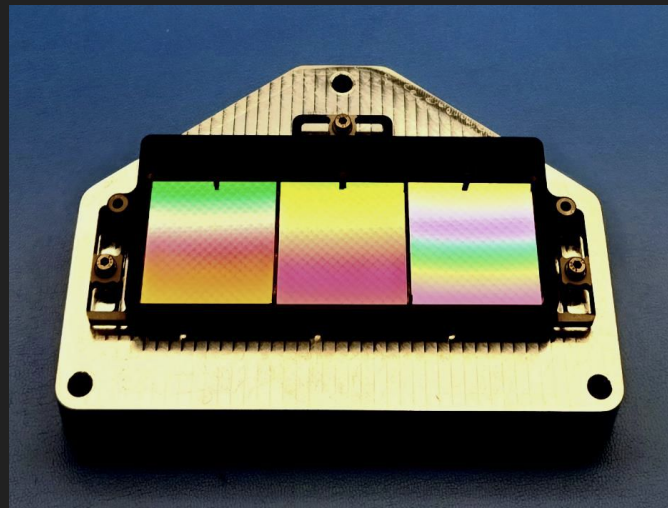


Spectroscopy without a spectrometer



Teledyne H2RG detectors

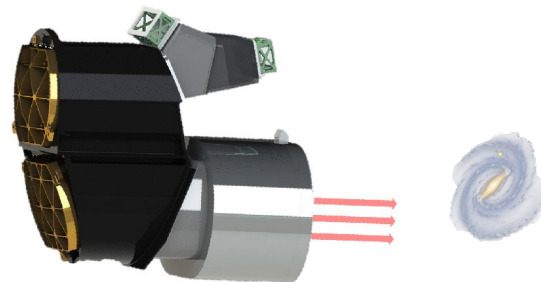
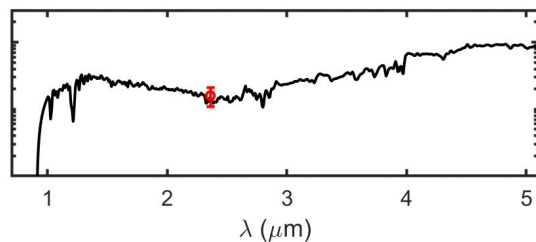
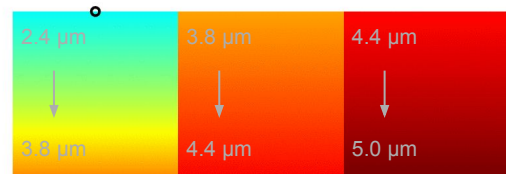
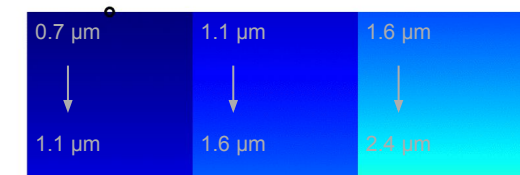
- Also on *James Webb Space Telescope*



Linear variable filter (LVF)

- Also on *New Horizons*

How SPHEREx constructs galaxy spectra

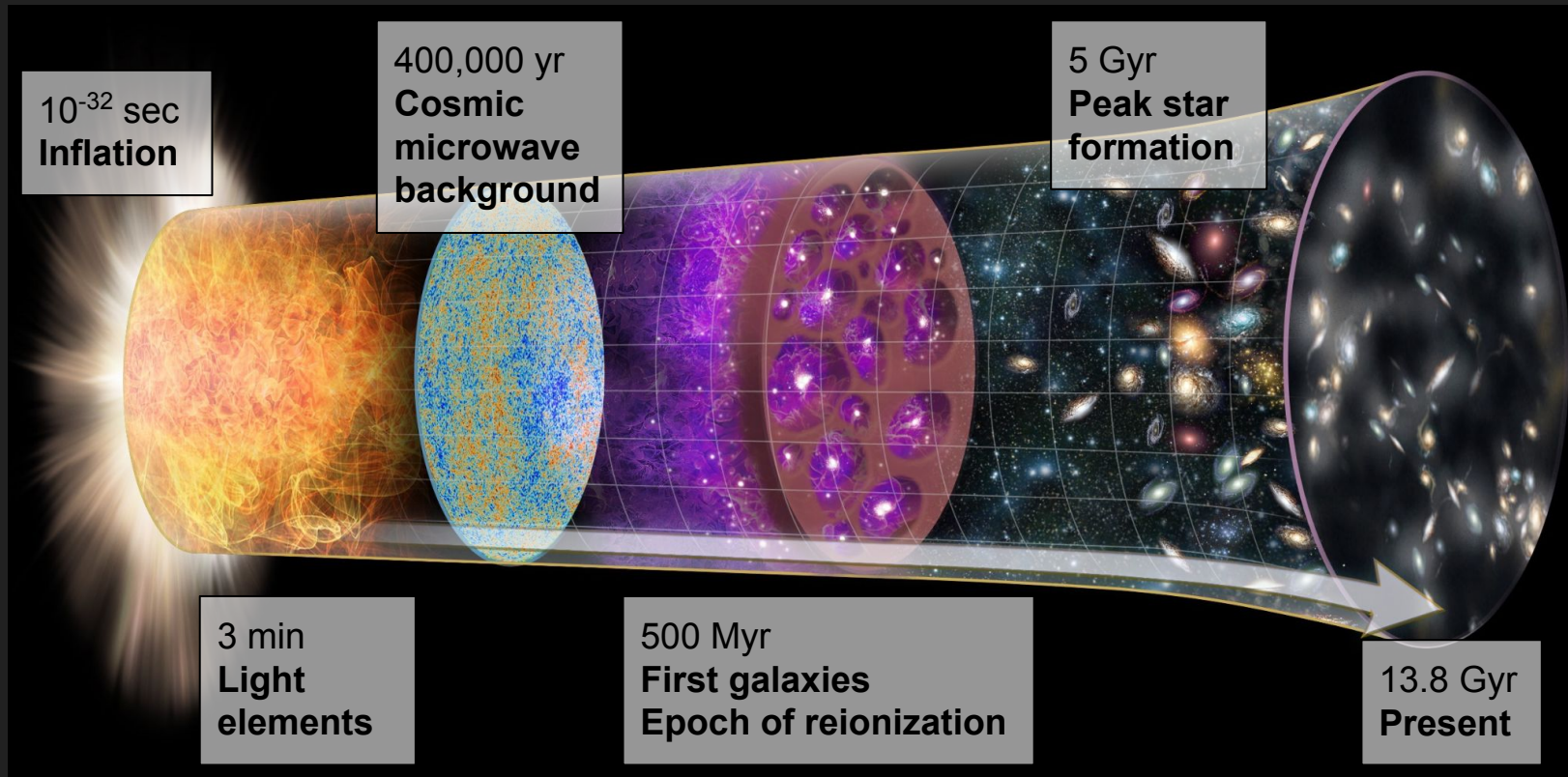






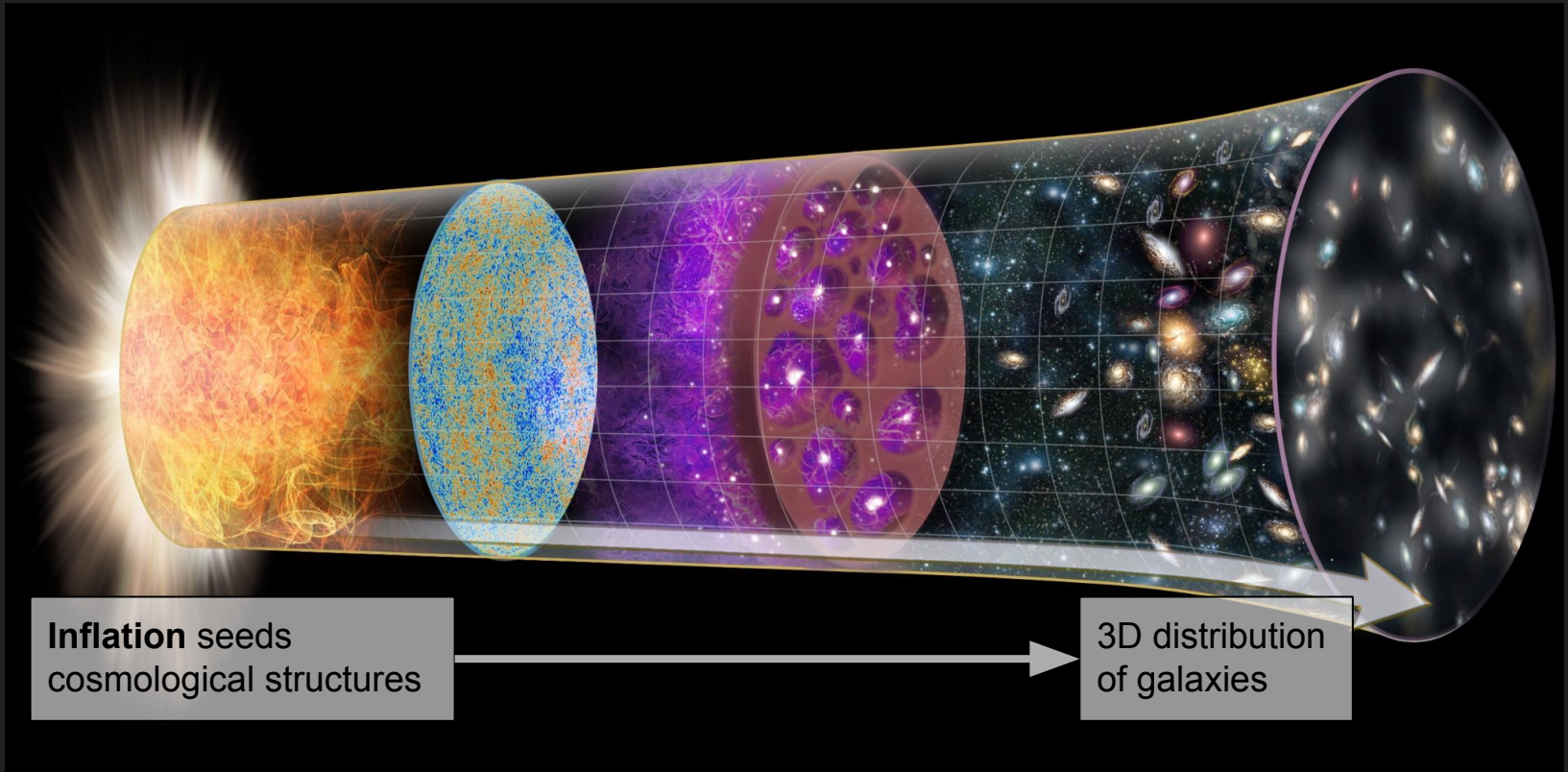
SPHEREx – Ari Cukierman (Caltech)

A brief history of the Universe





How did the Universe begin?



Inflation seeds
cosmological structures

3D distribution
of galaxies

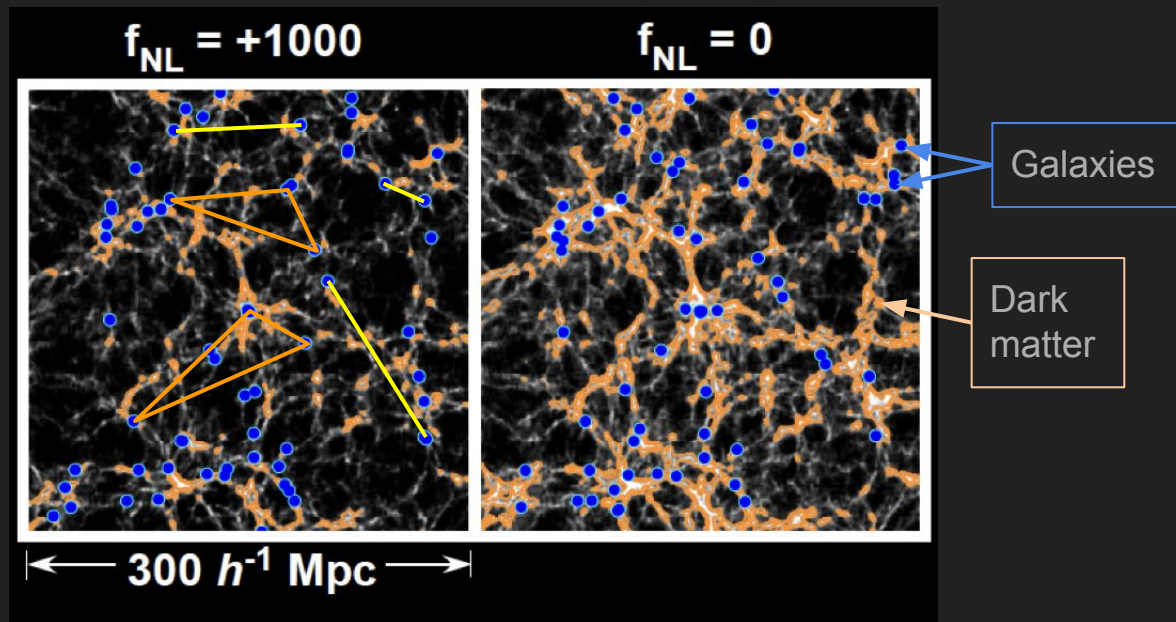
Primordial non-Gaussianity

2-point statistics

- Power spectrum

3-point statistics

- Bispectrum



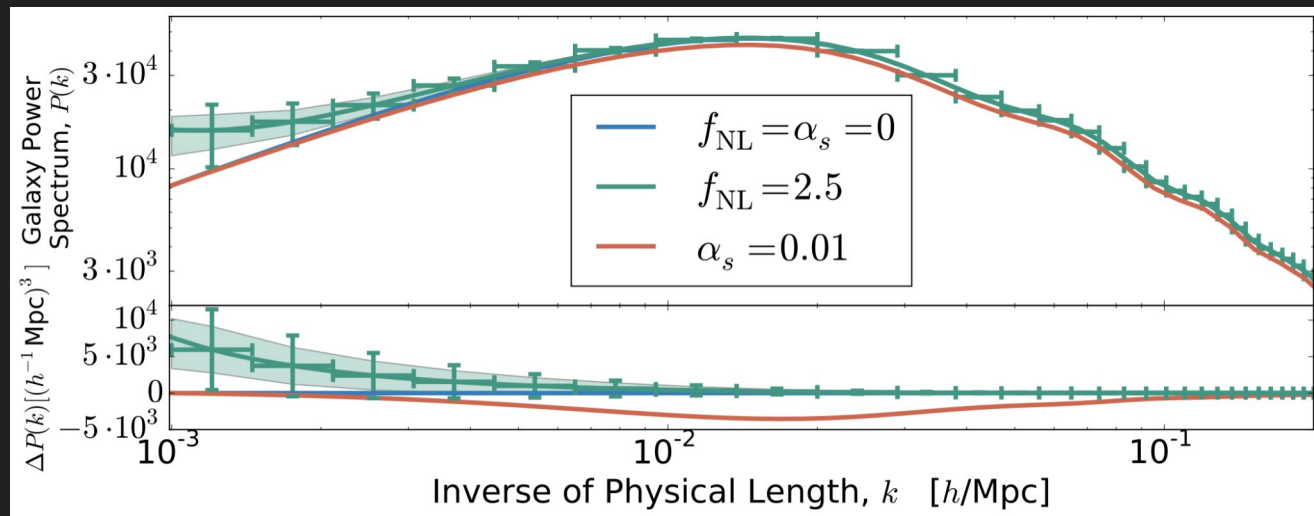
Primordial non-Gaussianity

2-point statistics

- Power spectrum

3-point statistics

- Bispectrum



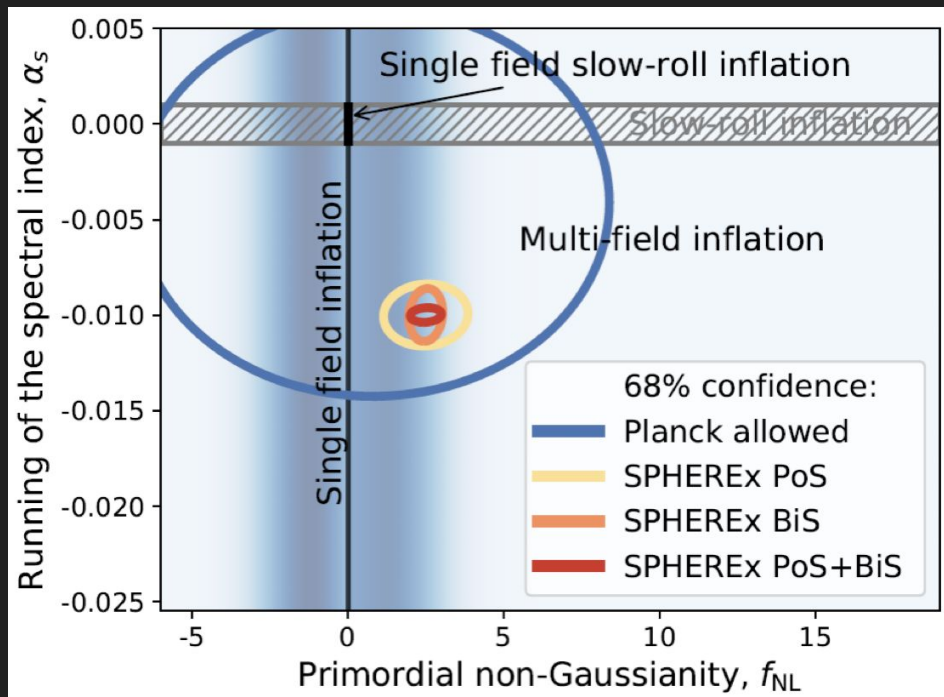
Primordial non-Gaussianity

2-point statistics

- Power spectrum

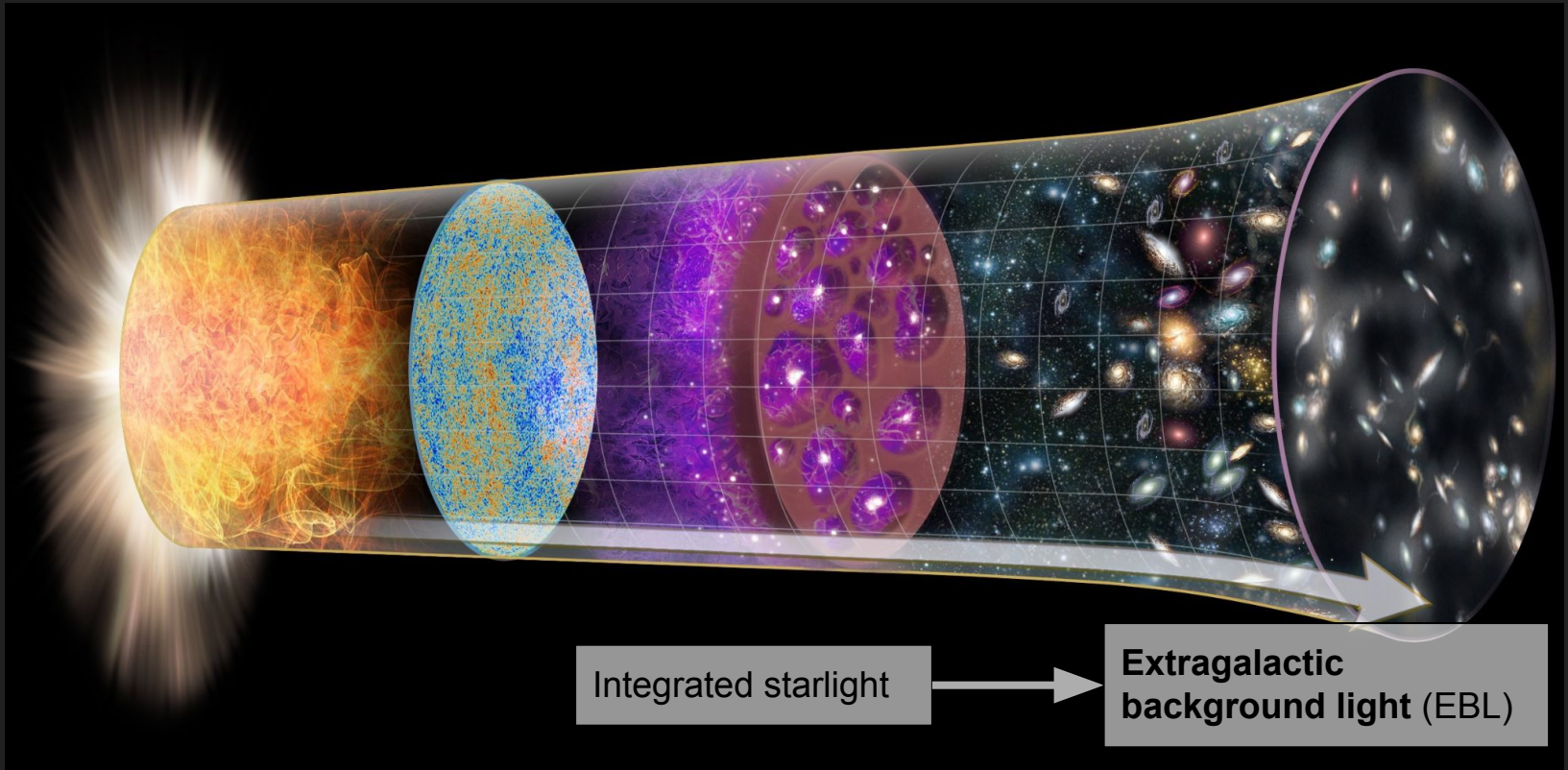
3-point statistics

- Bispectrum



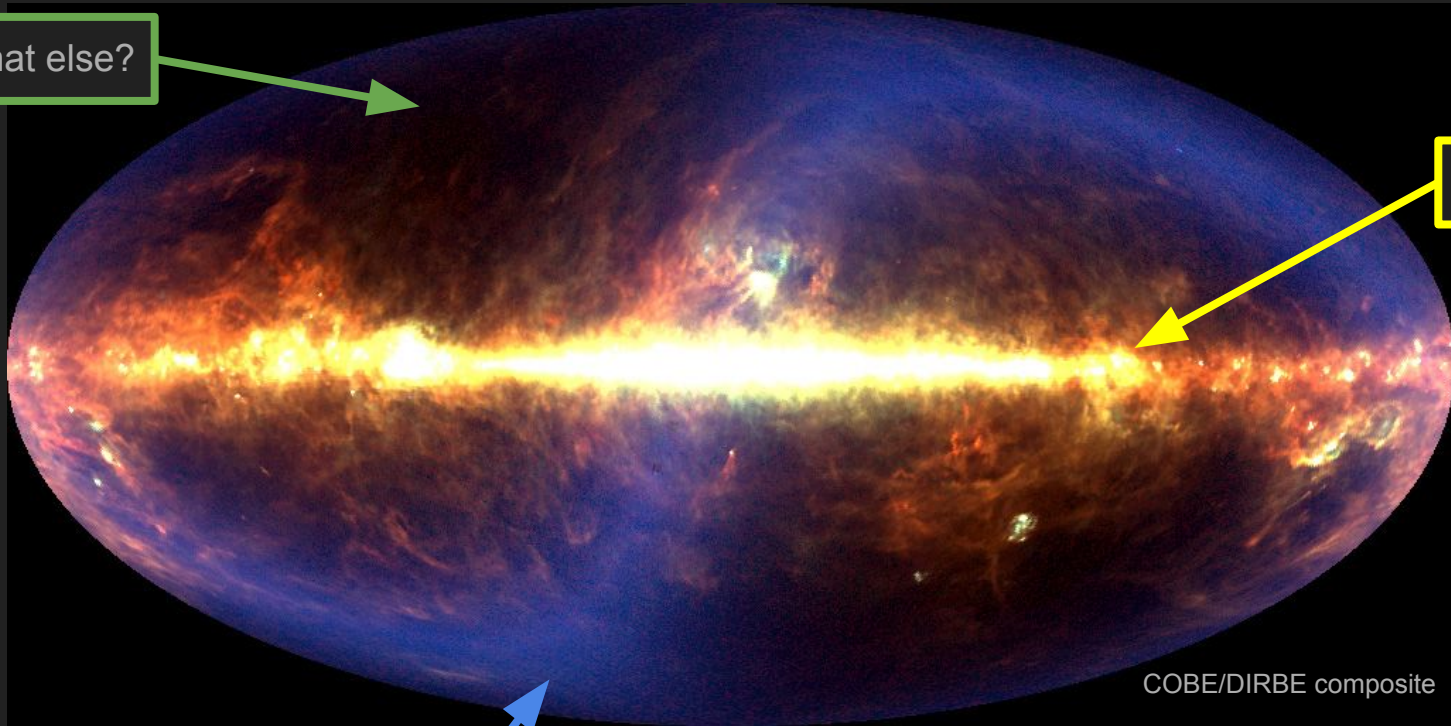


How did galaxies form?



Extragalactic background light (EBL)

What else?



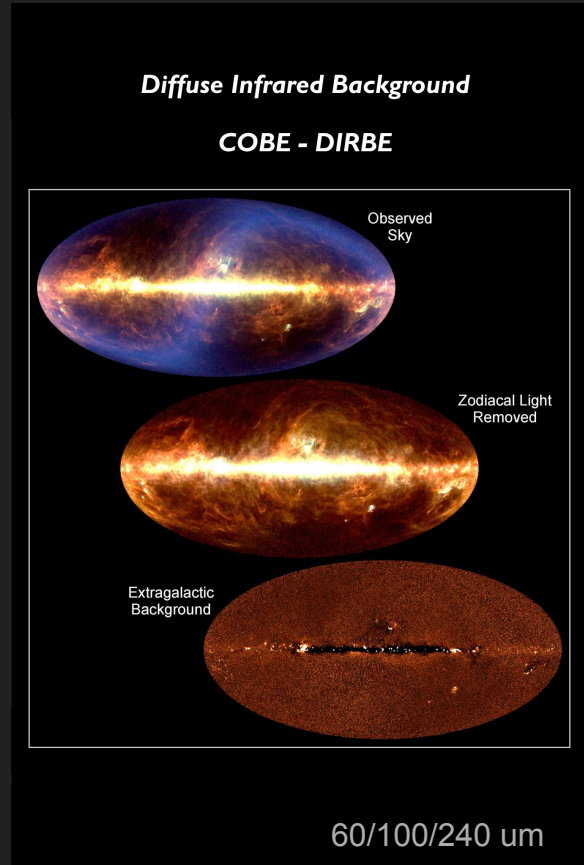
Milky Way

Zodiacal light



Extragalactic background light (EBL)

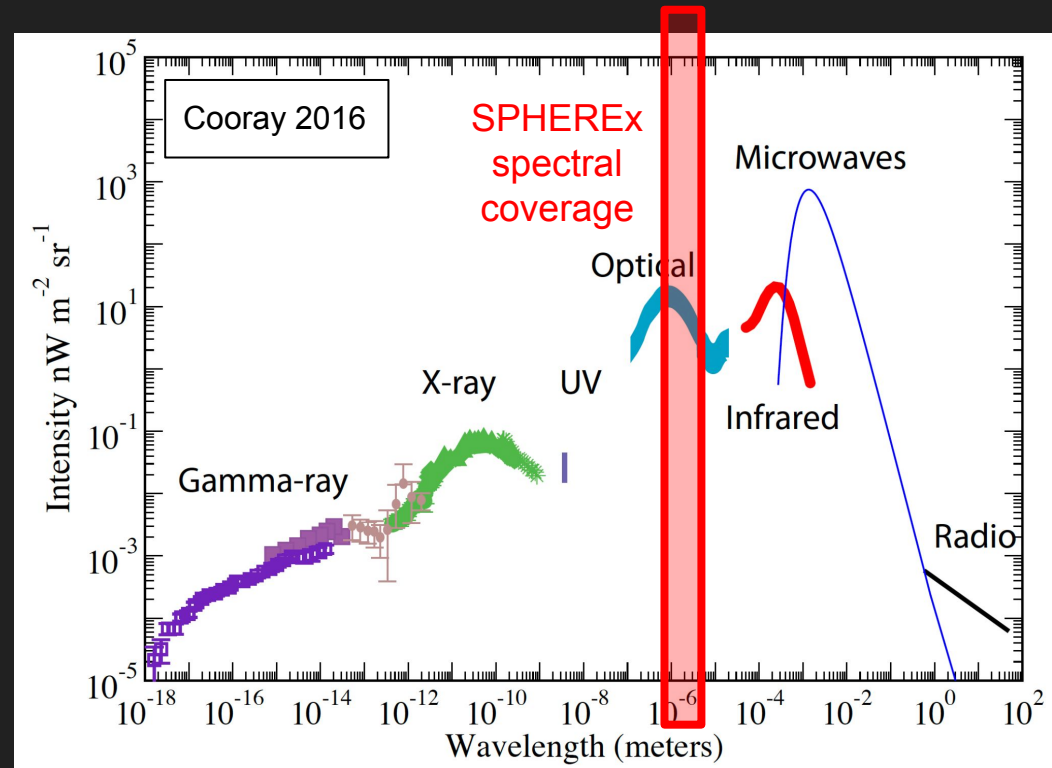
Census of cosmic light production





Extragalactic background light (EBL)

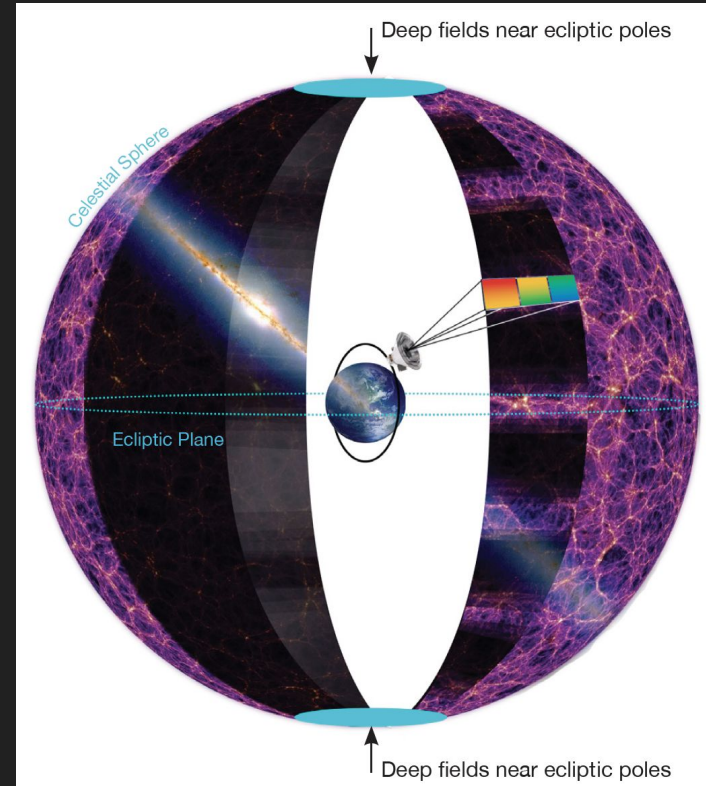
Census of cosmic light production



Extragalactic background light (EBL)

Census of cosmic light production

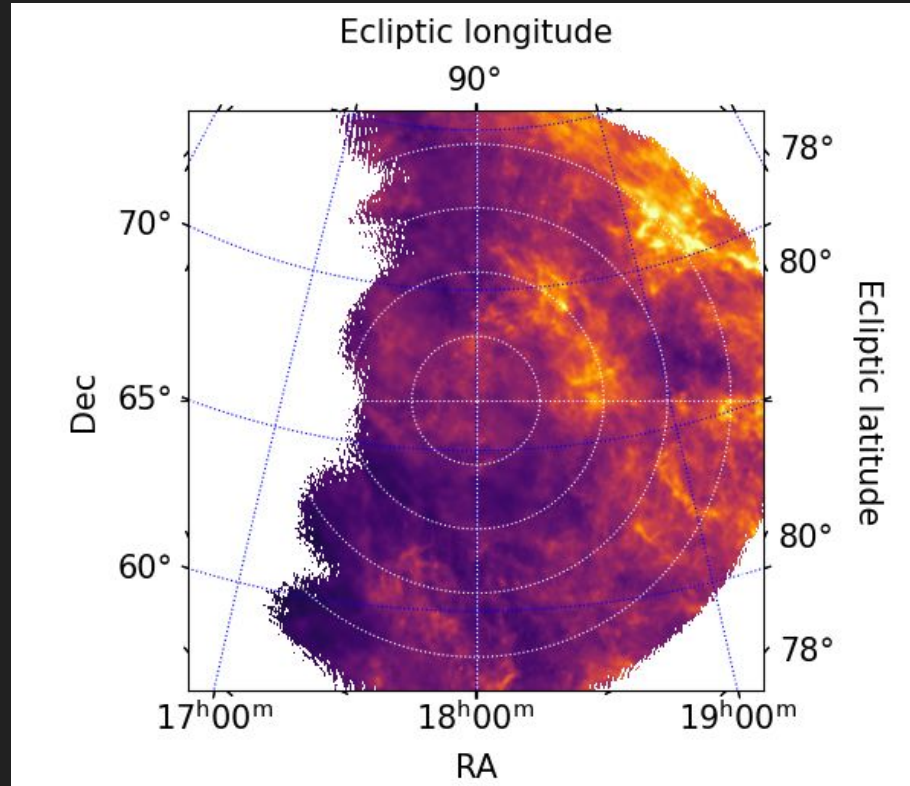
Deep fields near ecliptic poles



Extragalactic background light (EBL)

Census of cosmic light production

Deep fields near ecliptic poles



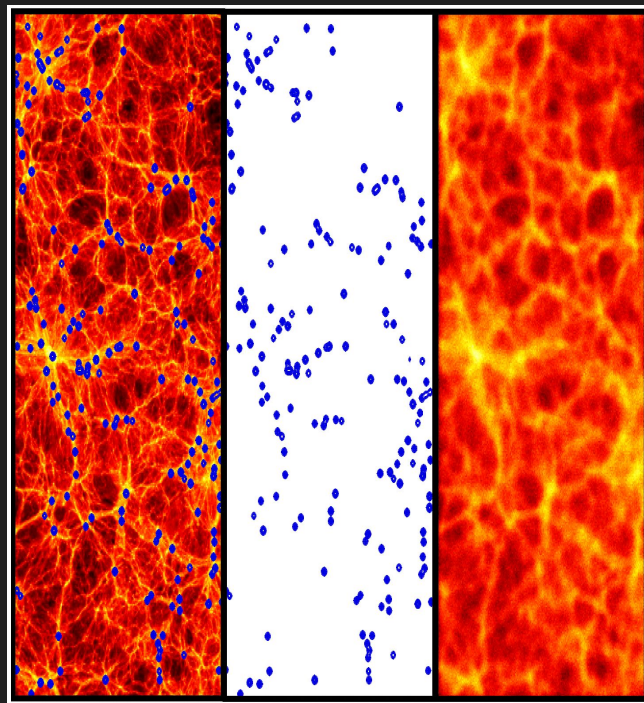
Extragalactic background light (EBL)

Census of cosmic light production

Deep fields near ecliptic poles

Intensity mapping

- Dwarf galaxies
- Stripped stars (intrahalo light)
- High-redshift galaxies



Total =
galaxies +
diffuse

Galaxy
survey

Intensity
mapping

Extragalactic background light (EBL)

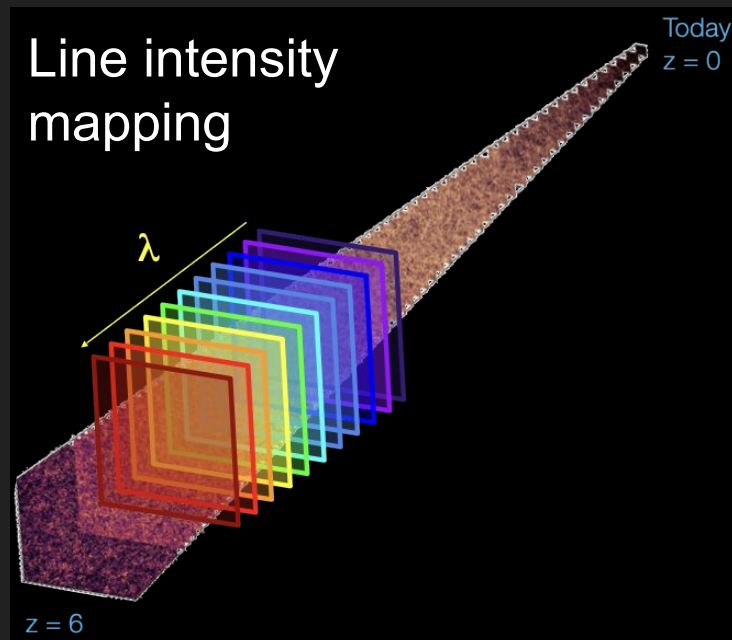
Census of cosmic light production

Deep fields near ecliptic poles

Intensity mapping

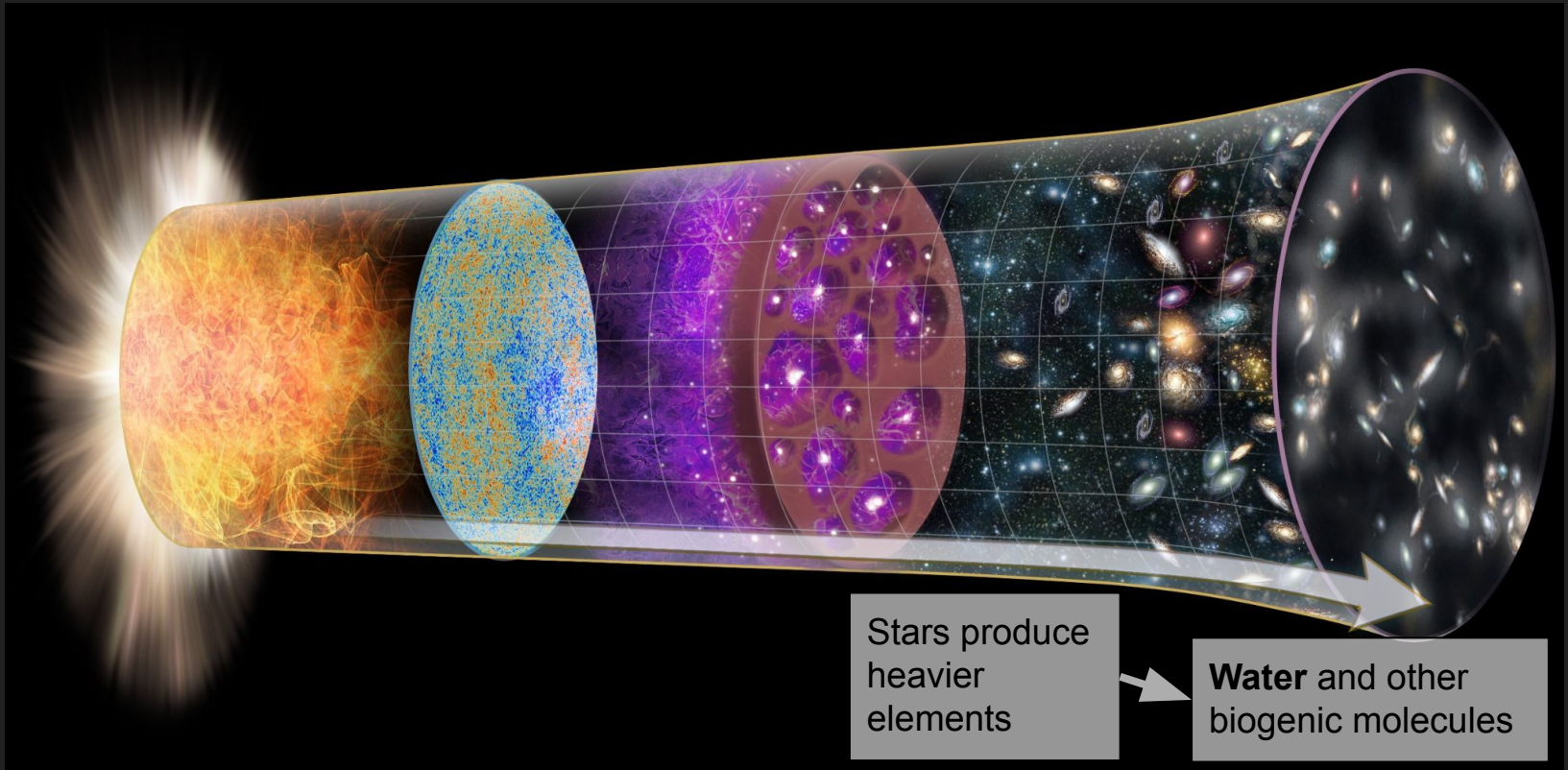
- Dwarf galaxies
- Stripped stars (intrahalo light)
- High-redshift galaxies

~100 wavelengths





How did life form?



Stars produce heavier elements

Water and other biogenic molecules

Interstellar ices



Nature, Vol. 221, Feb. 15, 1969

Detection of Water in Interstellar Regions by its Microwave Radiation

From Hat Creek Observatory

by

A. C. CHEUNG
D. M. RANK
C. H. TOWNES

Department of Physics,
University of California, Berkeley

D. D. THORNTON
W. J. WELCH

Radio Astronomy Laboratory and
Department of Electrical Engineering,
University of California, Berkeley

A report of the detection of microwave radiation from water molecules in space, by the group which recently detected interstellar ammonia emission.

MICROWAVE emission from the $6_{1,6} \rightarrow 5_{2,3}$ rotational transition of H_2O has been observed from the directions of Sgr B2, the Orion Nebula and the W49 source. This radiation, at 1.35 cm wavelength, was detected with the twenty foot radio telescope at the Hat Creek Observatory using techniques described earlier for the detection of the NH_3 spectrum¹. In the case of Sgr B2, the H_2O emission is from the same direction in which considerable NH_3 is observed (unpublished work of A. C. C. *et al.*), although there is reason to believe the two molecular species may not be closely associated. Strong H_2O radiation producing an antenna temperature of 14° K is observed from the Orion Nebula (where no NH_3 was detected), and an antenna temperature at least as high as 55° was found for H_2O radiation from W49.

velocity found for one of the OH emission and broad OH absorption features observed in this region², the 62 km s⁻¹ Doppler velocity of a small nearby HII region³, and the velocity of about 58 km s⁻¹ found for NH_3 (unpublished work of A. C. C. *et al.*) observed in this direction. The results shown in Fig. 1 were obtained with filters producing a spectral resolution of about 1.3 MHz.

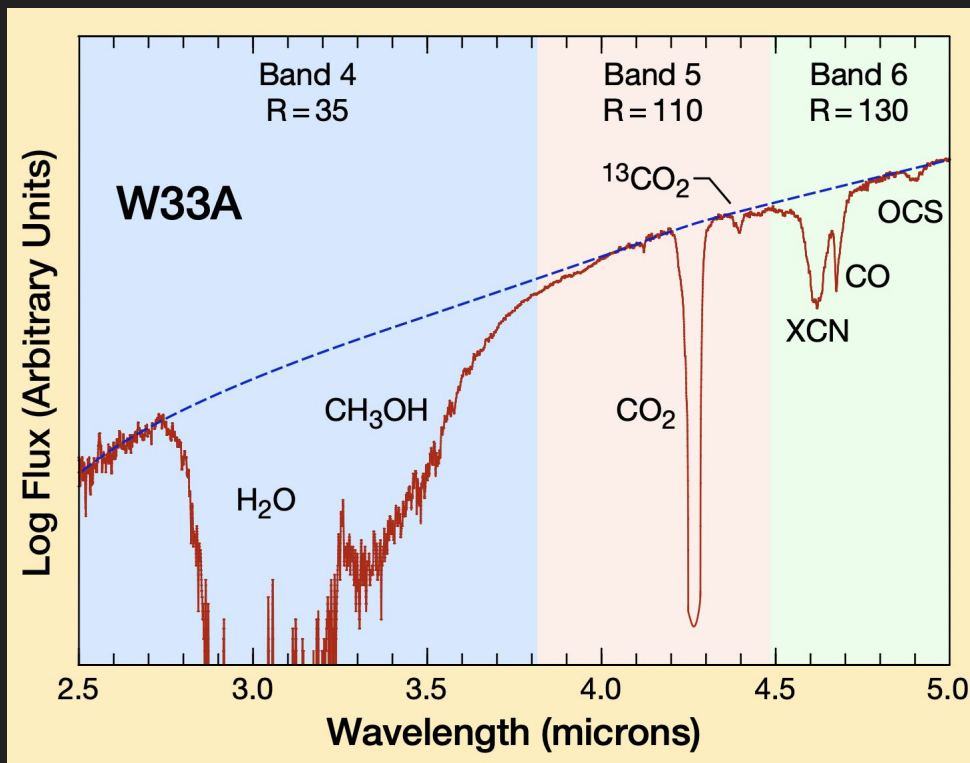
Fig. 2 shows the antenna temperature as a function of Doppler velocities observed in the Orion Nebula at $\alpha_{1950} = 5 \text{ h } 32 \text{ m } 57 \text{ s } \pm 4 \text{ s}$ and $\delta_{1950} = -5^\circ 25.5' \pm 1.0'$. In Orion, the radiation intensity was sufficiently high to make practical the use of filters producing a spectral resolution of about 350 kHz. In Fig. 2 the solid line represents the continuum temperature as it was measured with filters of width 2 MHz; the plotted points represent

Interstellar ices

99% of interstellar water is ice

“Follow the **water**” → “Follow the **ice**”

*Follow the **ices**

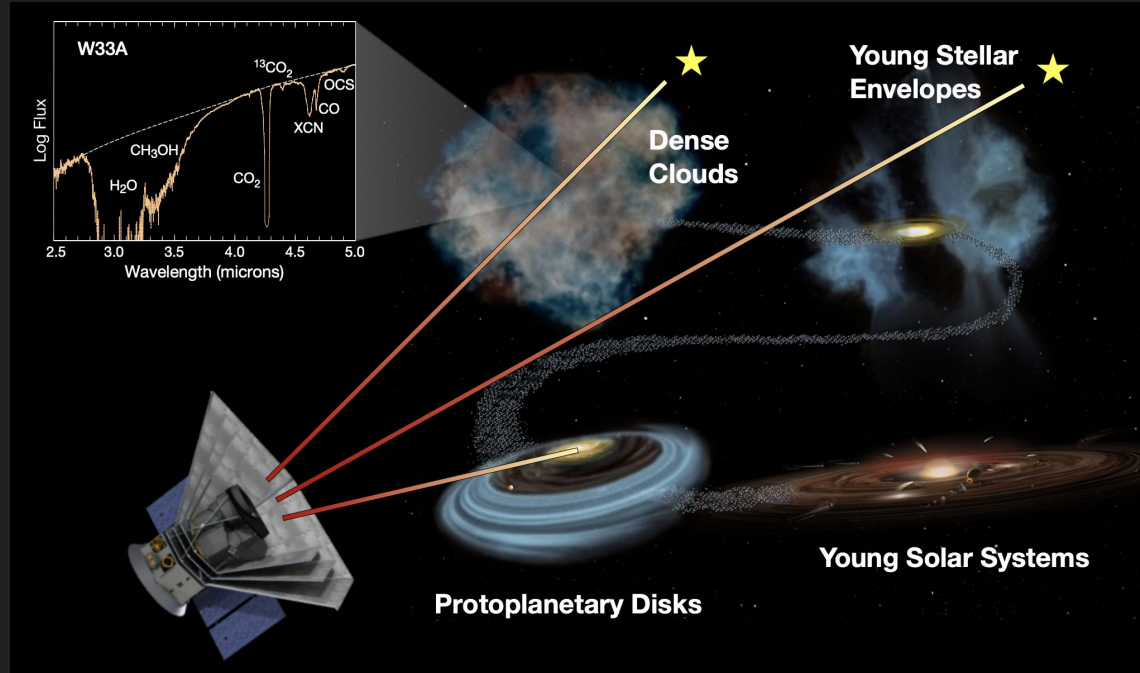


Interstellar ices

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Interstellar ices

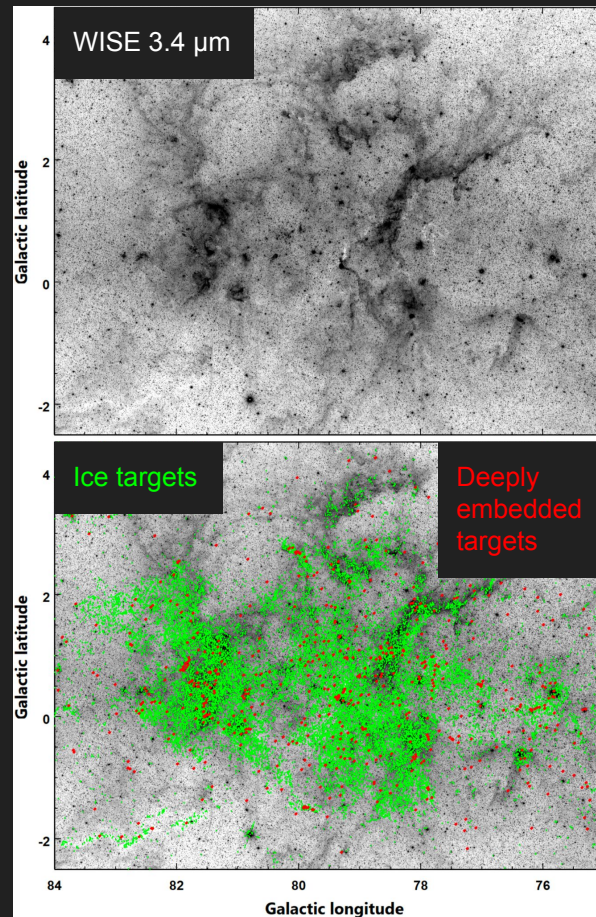
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SPLICES

- SPHEREx target List of ICE Sources



Interstellar ices

99% of interstellar water is ice

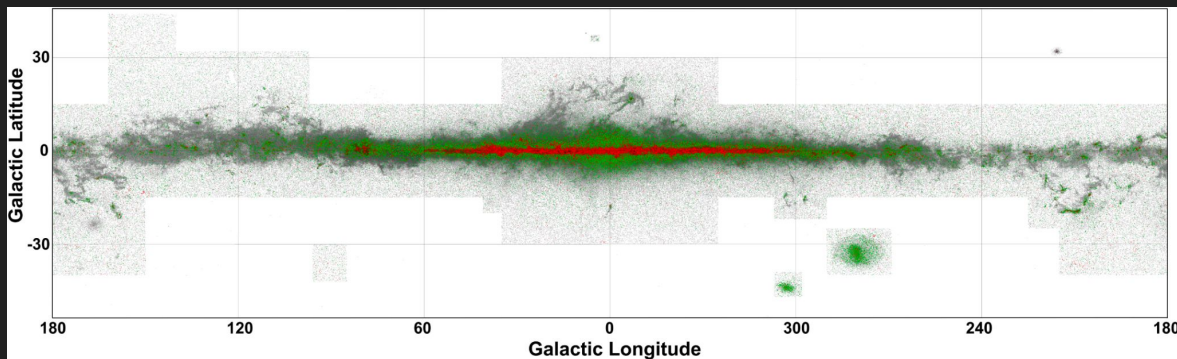
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SPLICES

- SPHEREx target List of ICE Sources

8.6 million targets



You can also ask me about...

CMB detectors

Nanofabrication



You can also ask me about...

CMB detectors

Nanofabrication

Microwave multiplexing

South Pole

You can also ask me about...

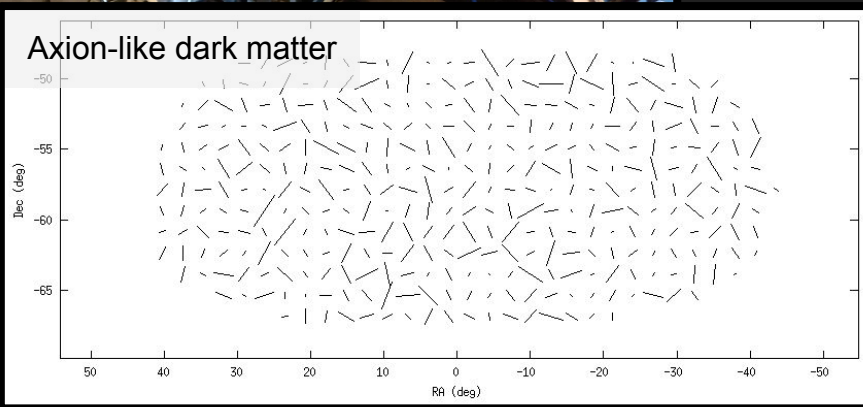
CMB detectors

Nanofabrication

Microwave multiplexing

Axion-like dark matter

South Pole



You can also ask me about...

CMB detectors

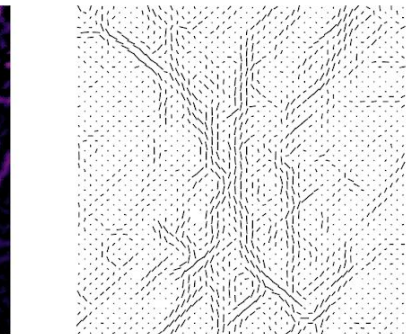
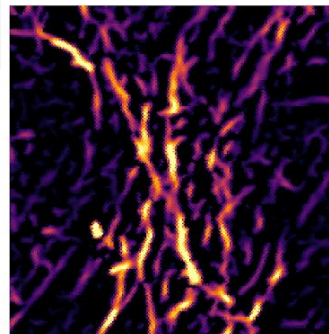
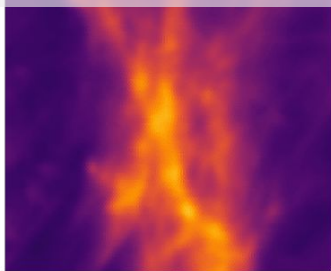
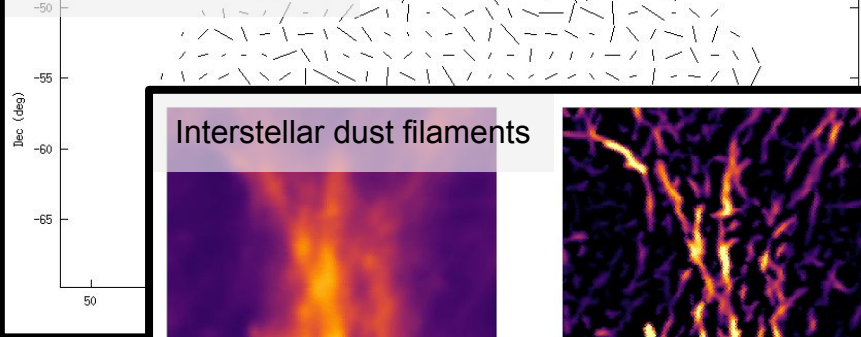
Nanofabrication

Microwave multiplexing

Axion-like dark matter

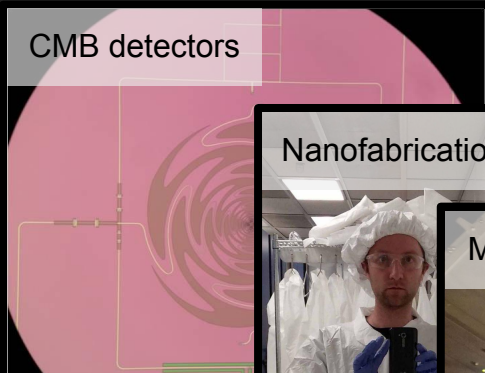
South Pole

Interstellar dust filaments



You can also ask me about...

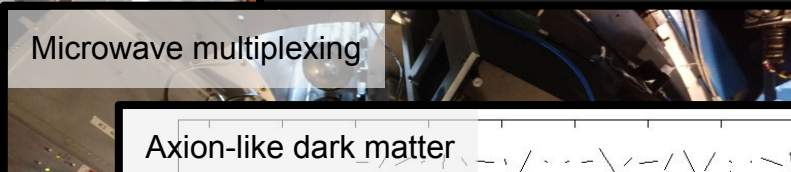
CMB detectors



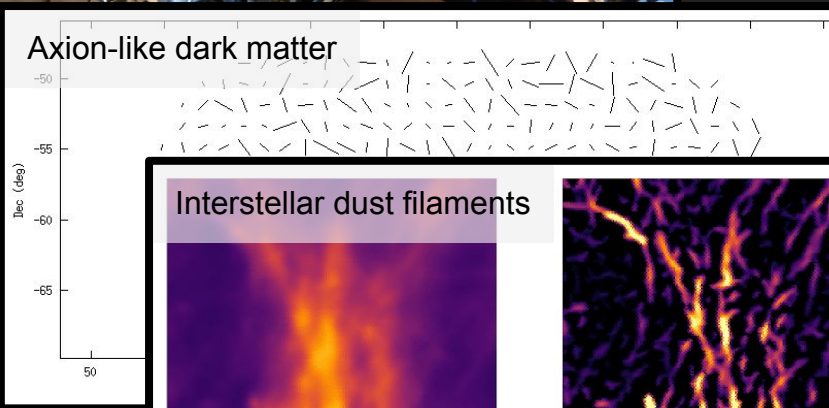
Nanofabrication



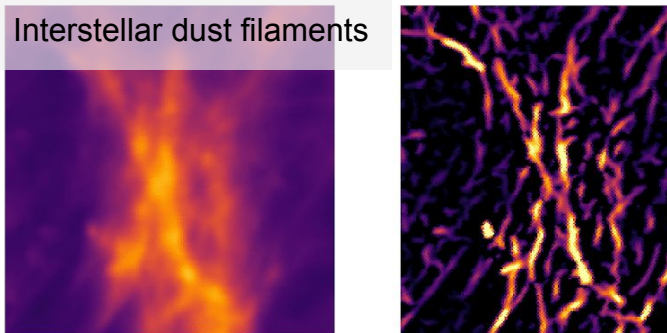
Microwave multiplexing



Axion-like dark matter



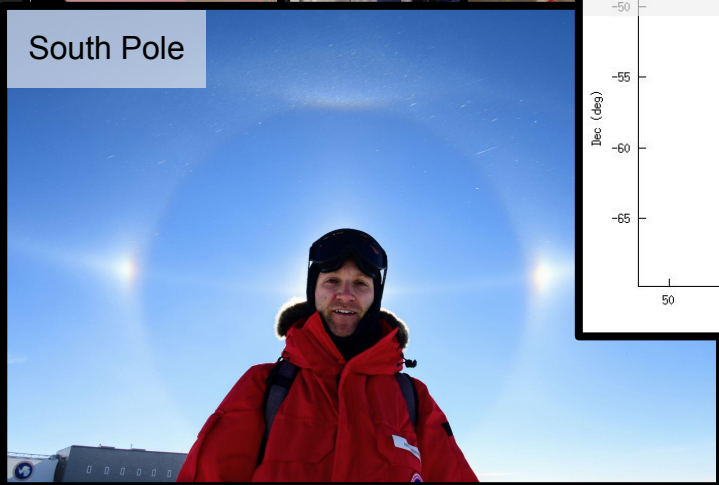
Interstellar dust filaments



Cycling



South Pole





If you remember nothing else...

SPHEREx is launching in 2025

A near-infrared spectrum for every 6" pixel on the sky



Galaxy redshifts → **non-Gaussianity**



Intensity mapping → **galaxy formation**



Absorption spectra → **interstellar ices**



All-sky spectral archive

