Cosmology from Antarctica

Sasha Rahlin, University of Chicago

Matt Young


Aman Chokshi

Hubble Extreme Deep Field

Looking into the Past

Light takes time to travel
300,000 km/s
186,282 mi/s
9.5 *trillion* km /year

Looking into the Past

Friend you're talking to:
few nanoseconds ago

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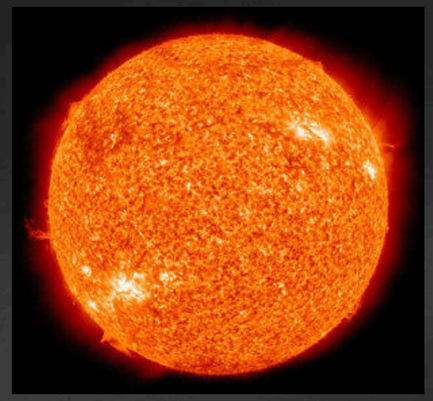
few nanoseconds ago

Sun:
8 minutes ago



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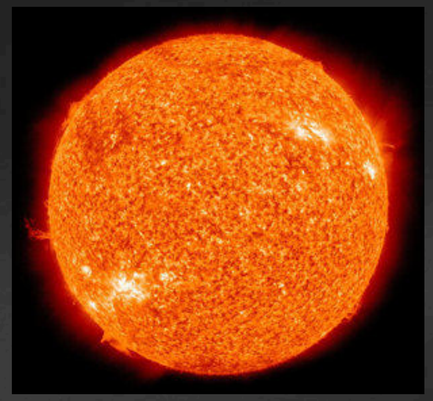

Sun:
8 minutes ago

Alpha Centauri:
4 years ago

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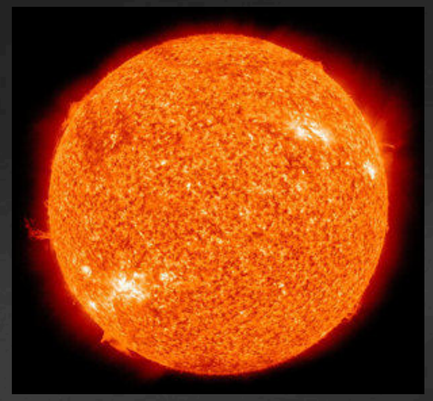

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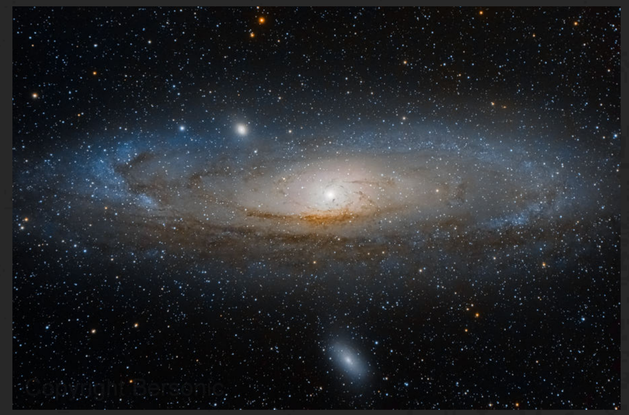
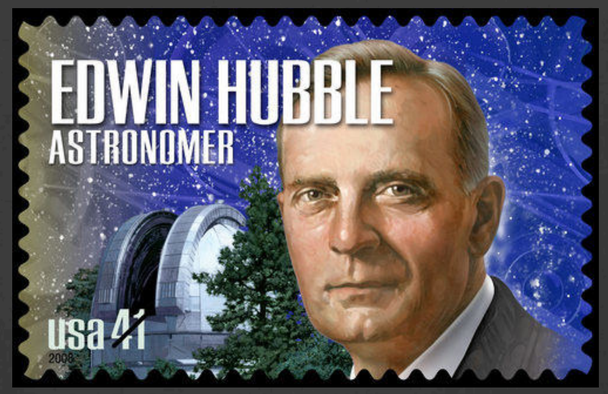
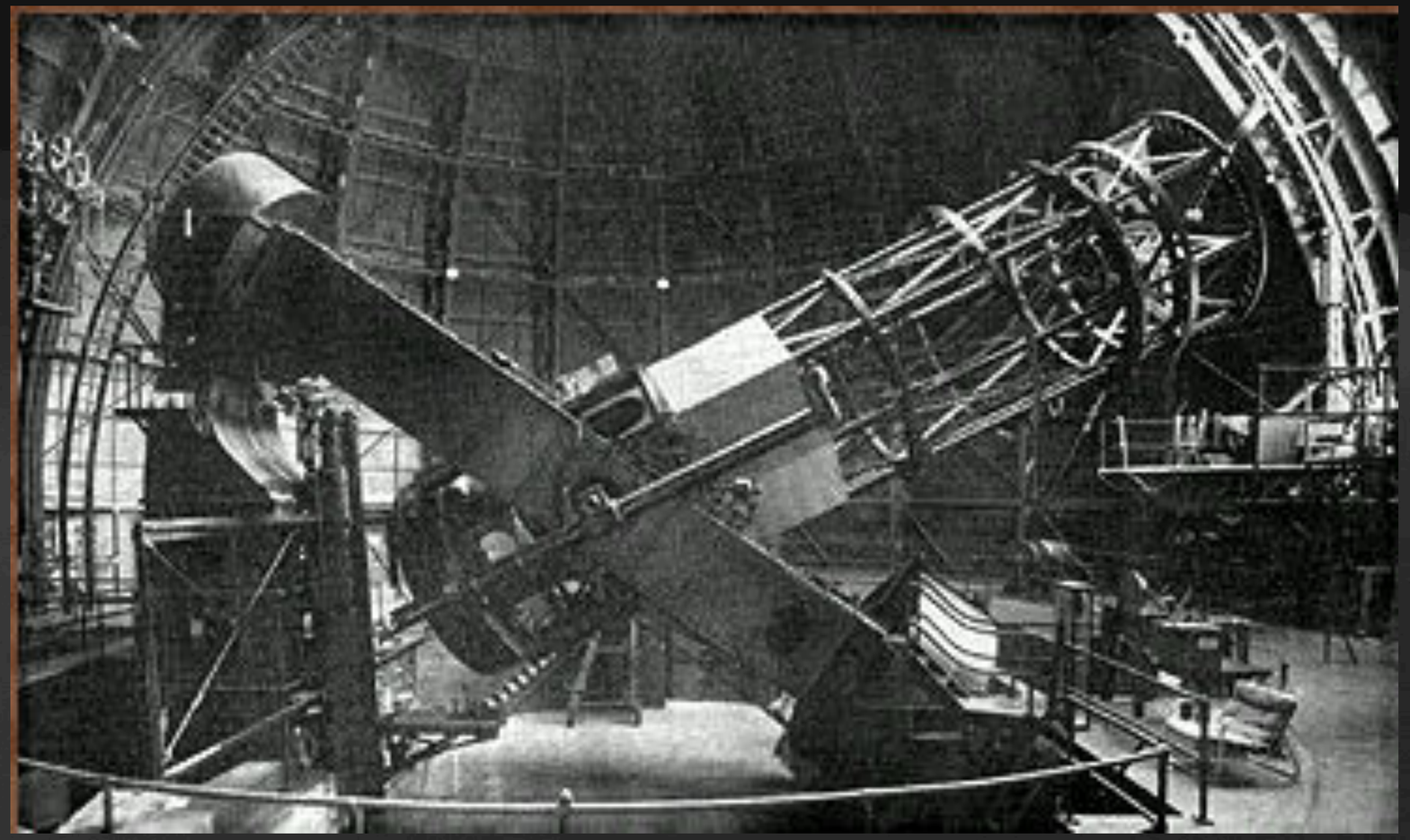


Andromeda galaxy:
2 million years ago

The Expanding Universe



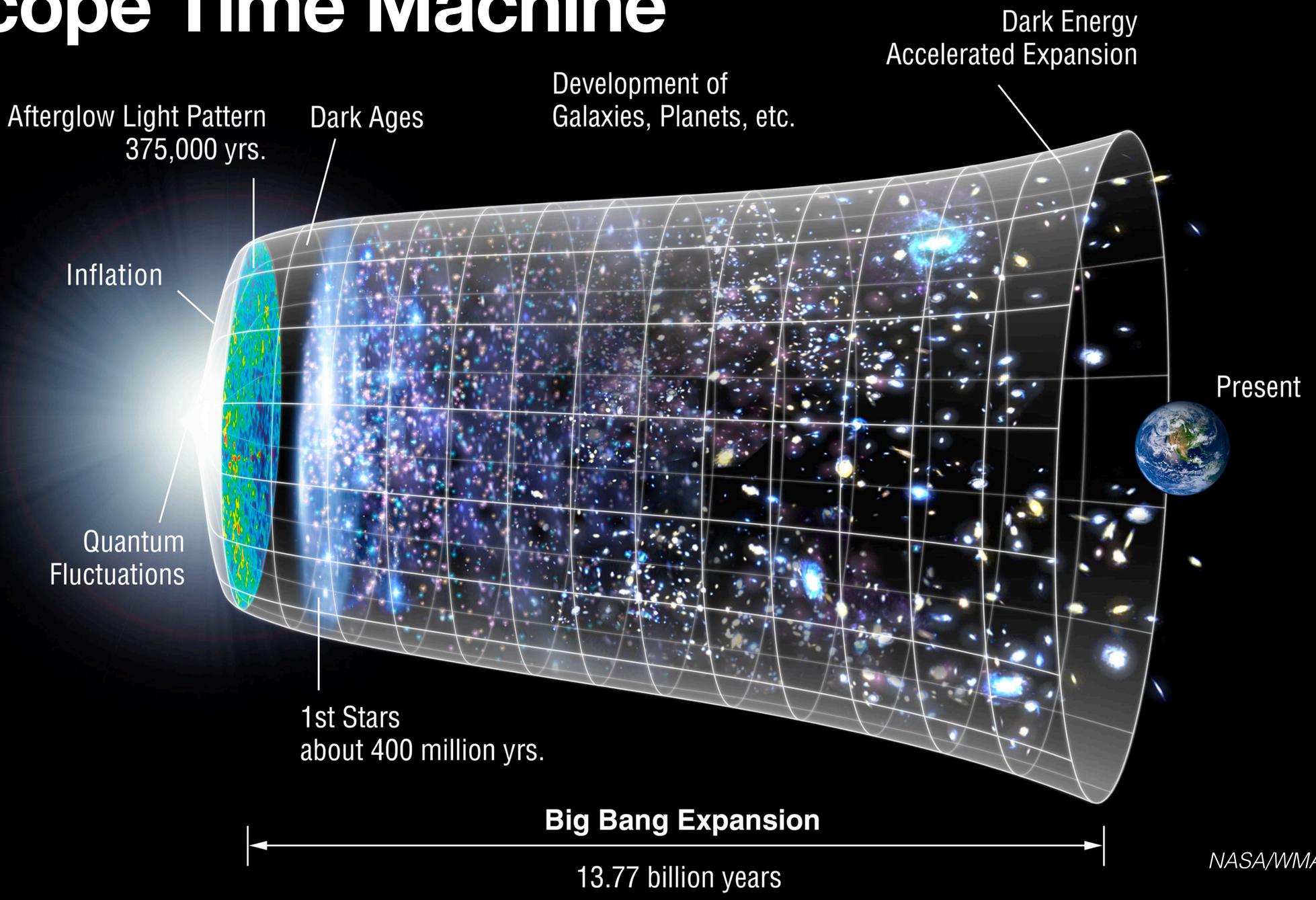


Palomar 200” telescope

Hubble Extreme Deep Field

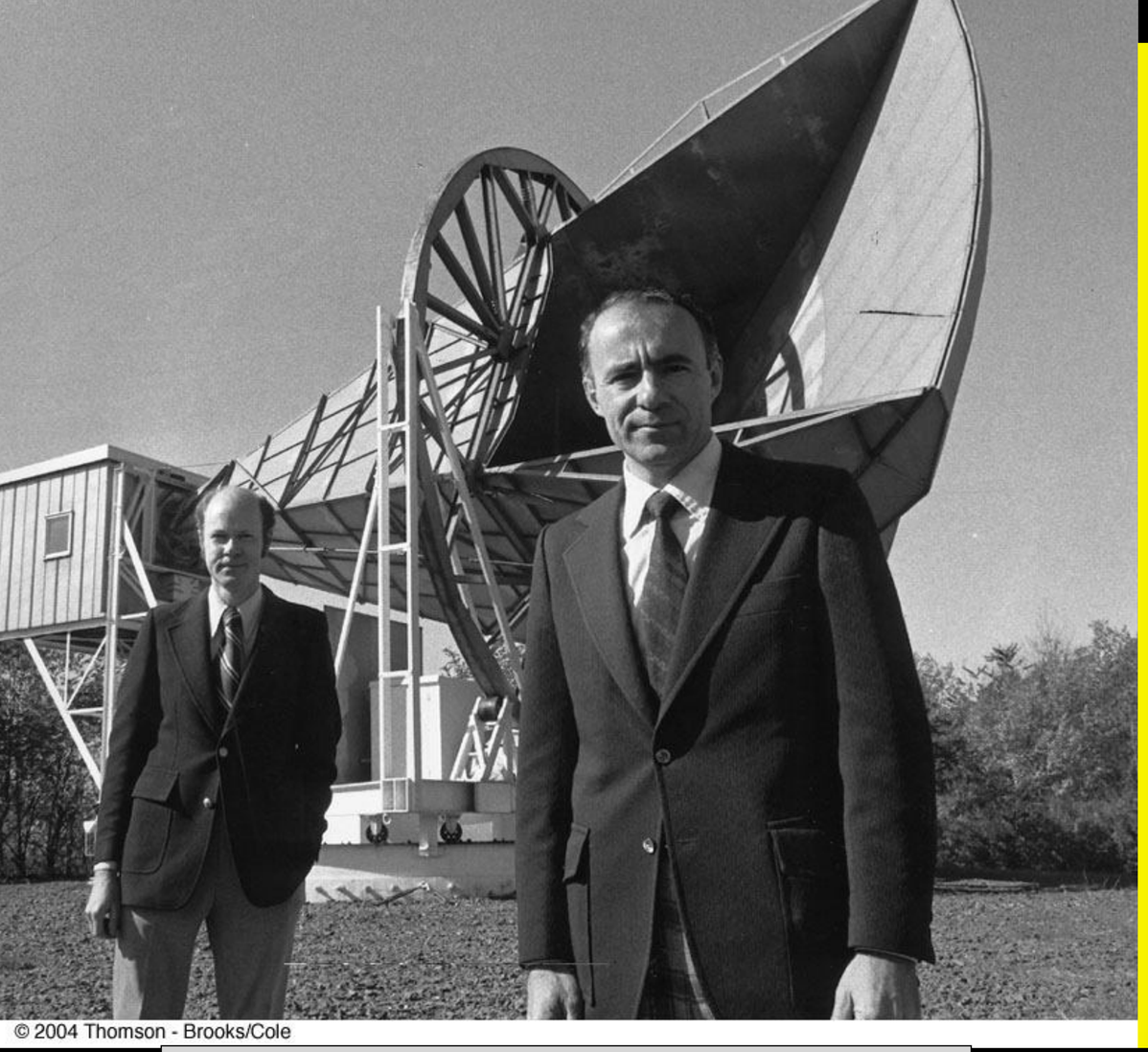
Hubble Extreme Deep Field

Telescope Time Machine

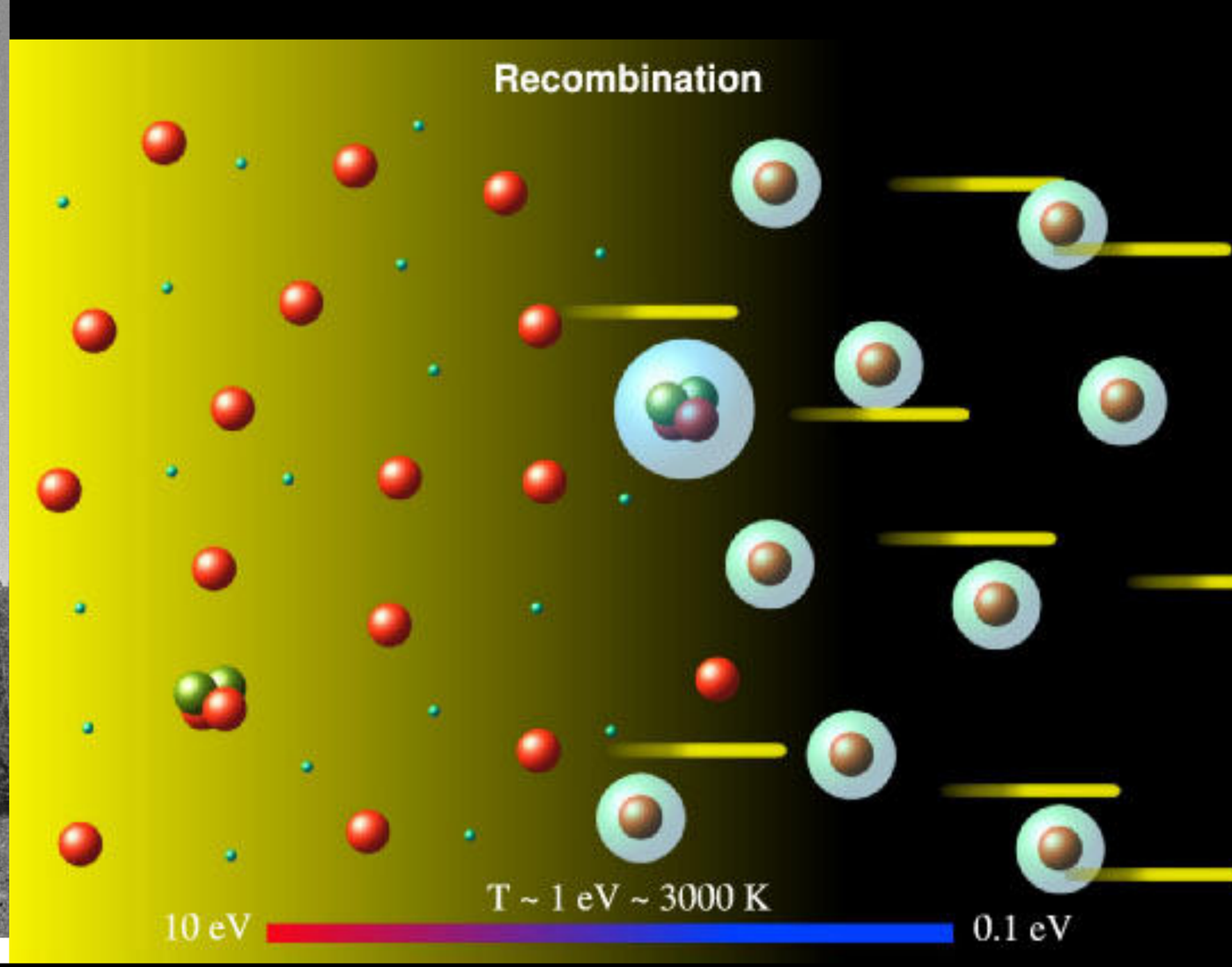


NASA/WMAP Science Team


The whole Universe was once as hot as the surface of a star (>3000 Celsius)
… and we can still see the glow!



Arno Penzias & Robert Wilson, Bell Labs, NJ



Prediction: Alpher & Herman, 1948

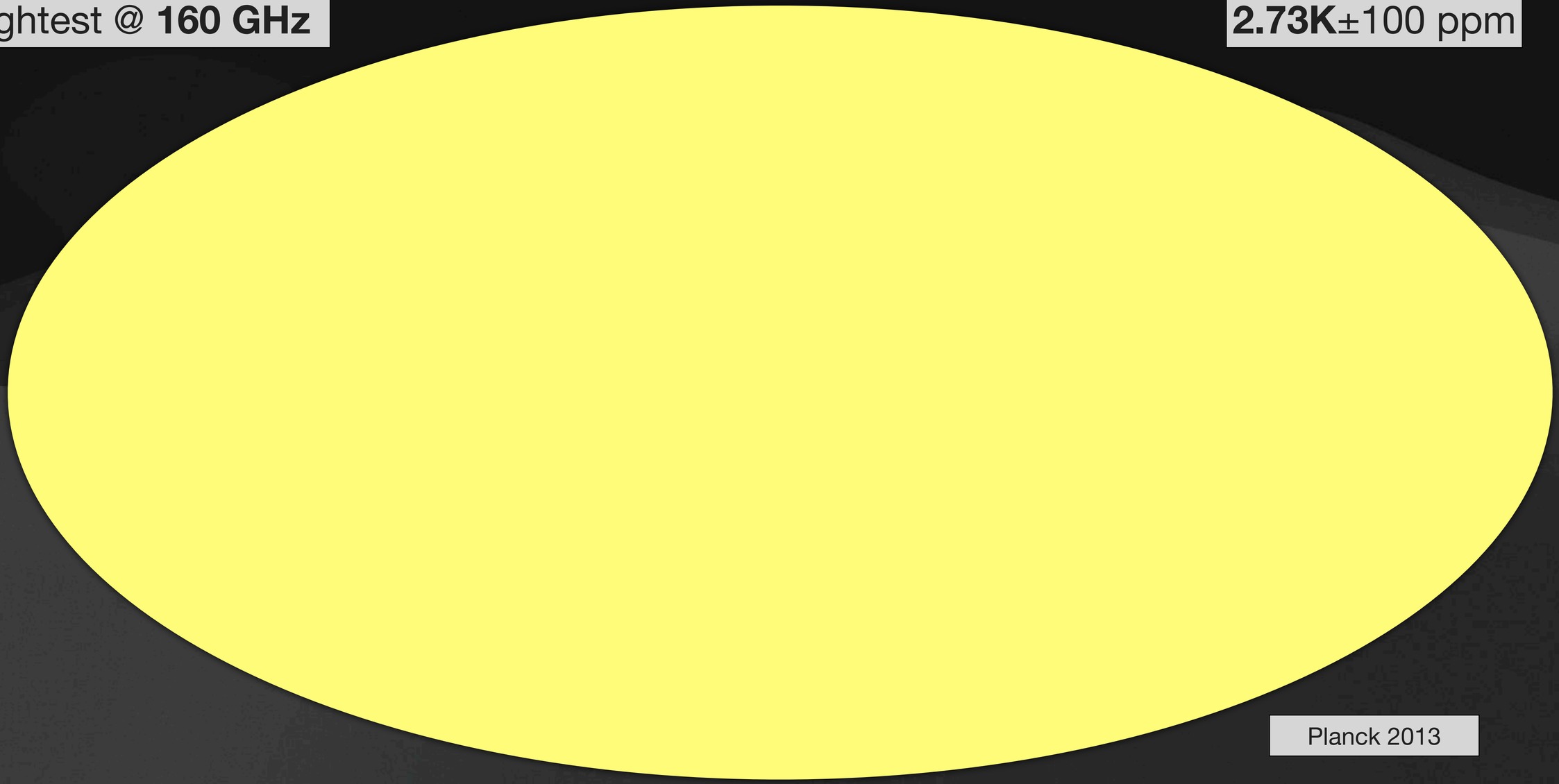
Discovery: Penzias & Wilson, 1964

Nobel Prize in Physics,1978 *(and a related Nobel in 2006)*

The Cosmic Microwave Background

Brightest @ **160 GHz**

2.73K±100 ppm



Planck 2013

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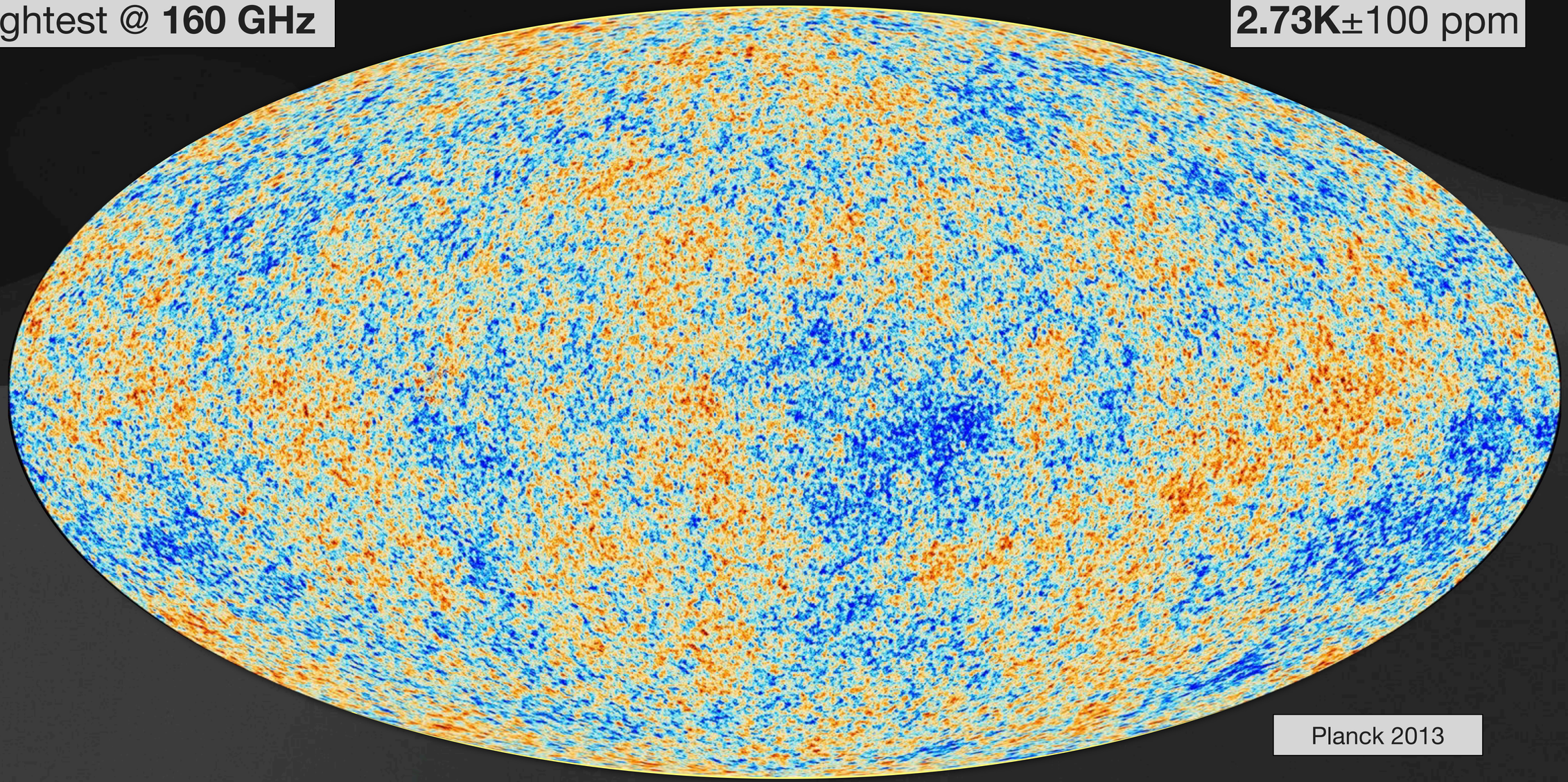
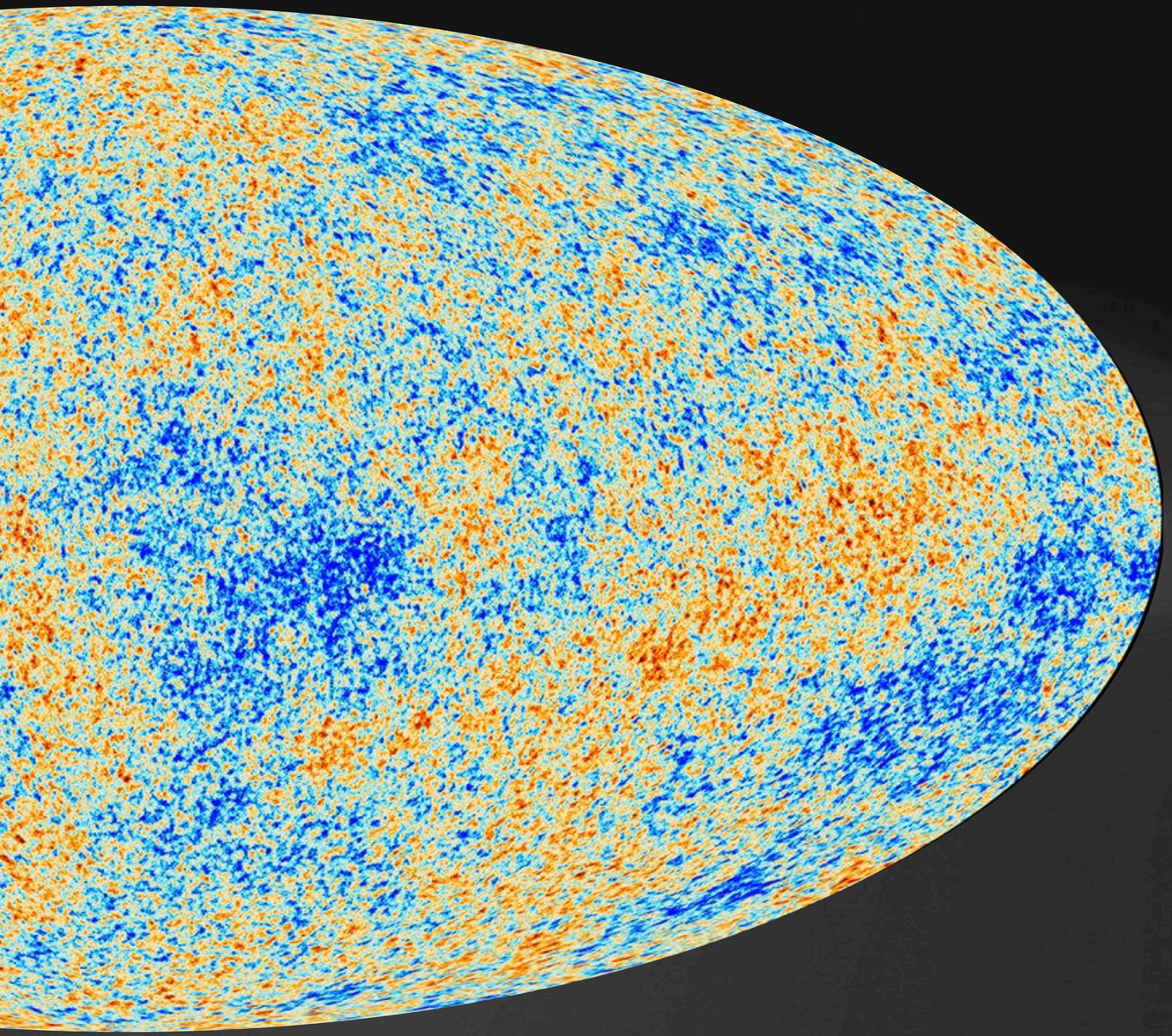
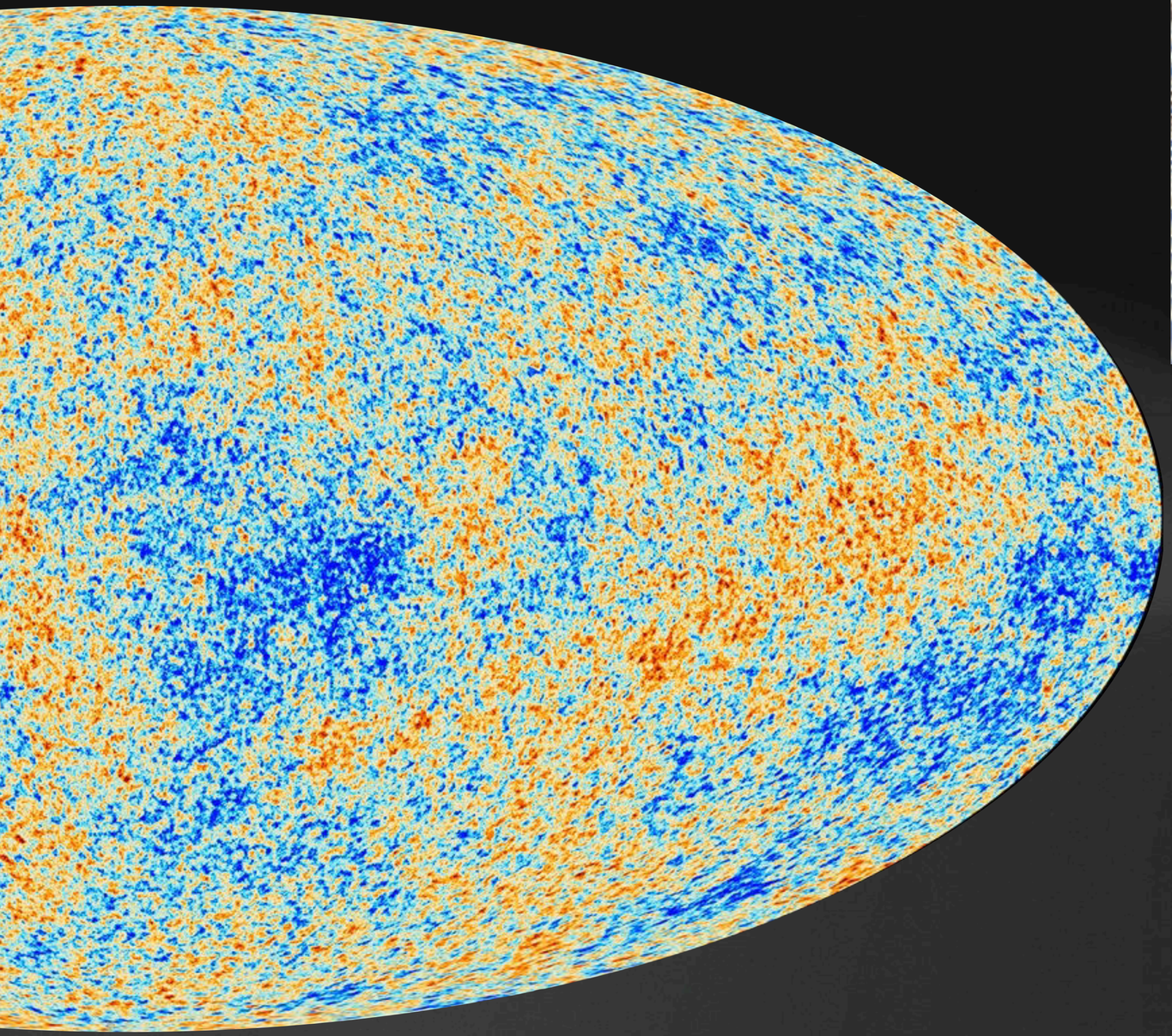
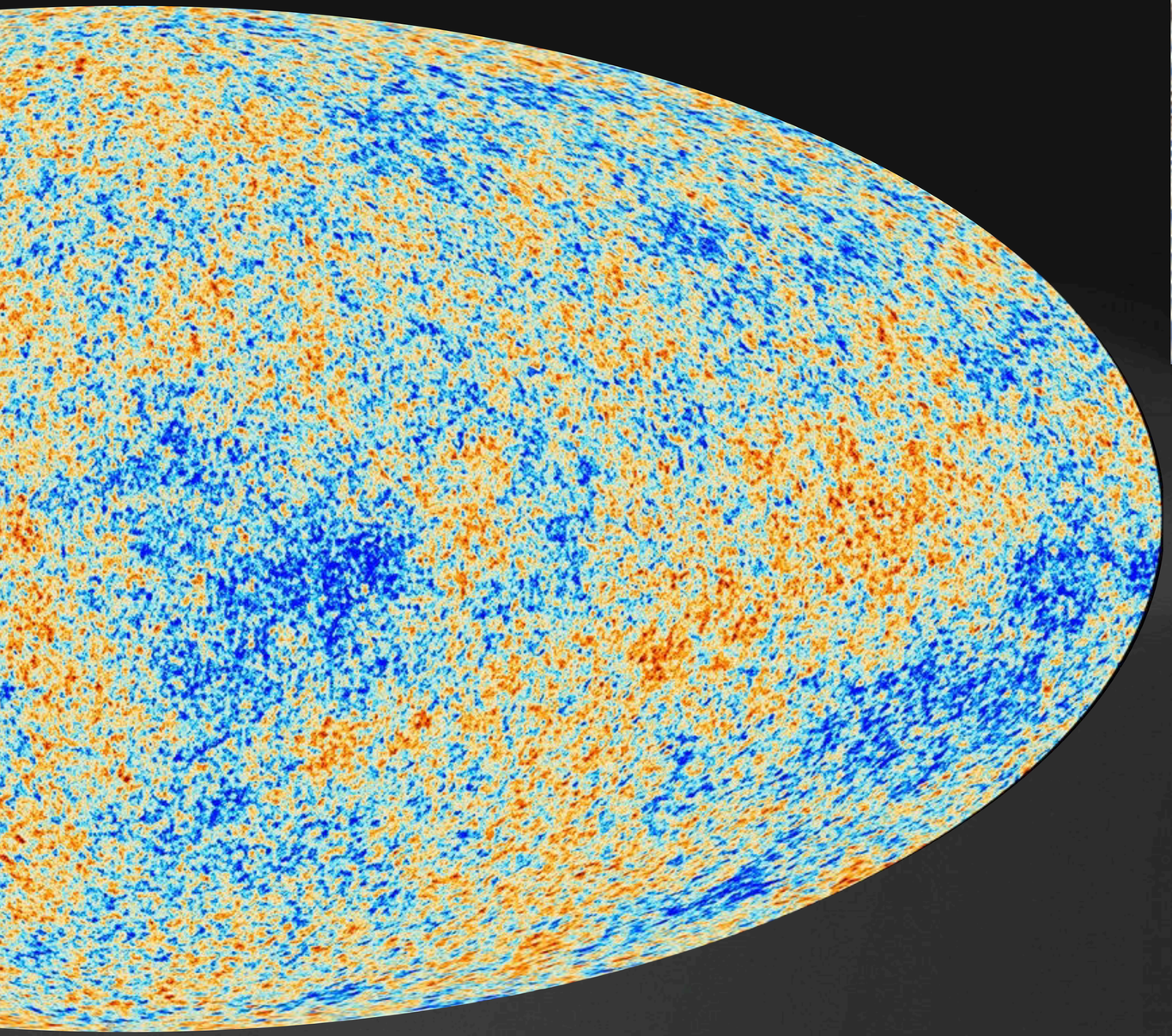
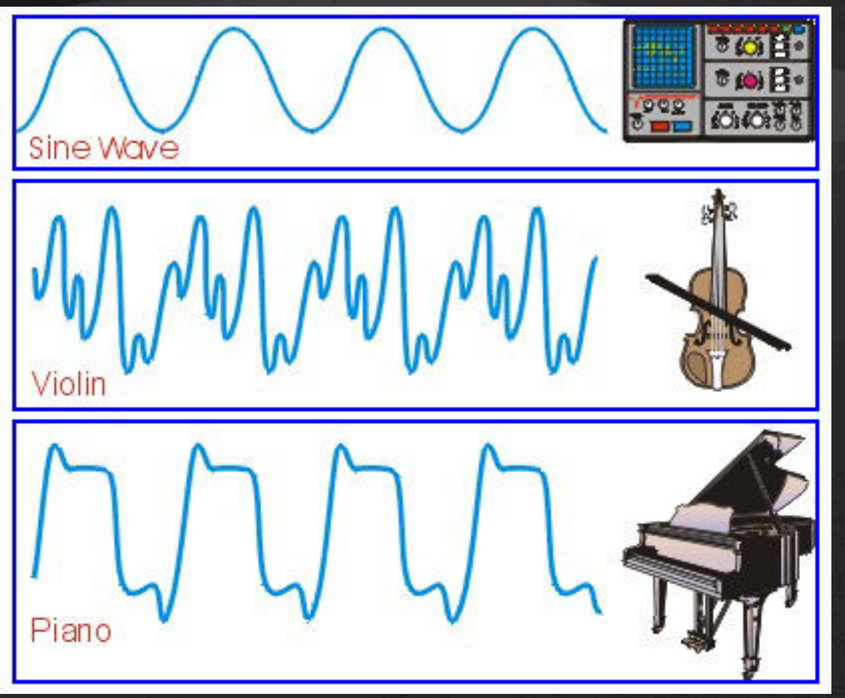


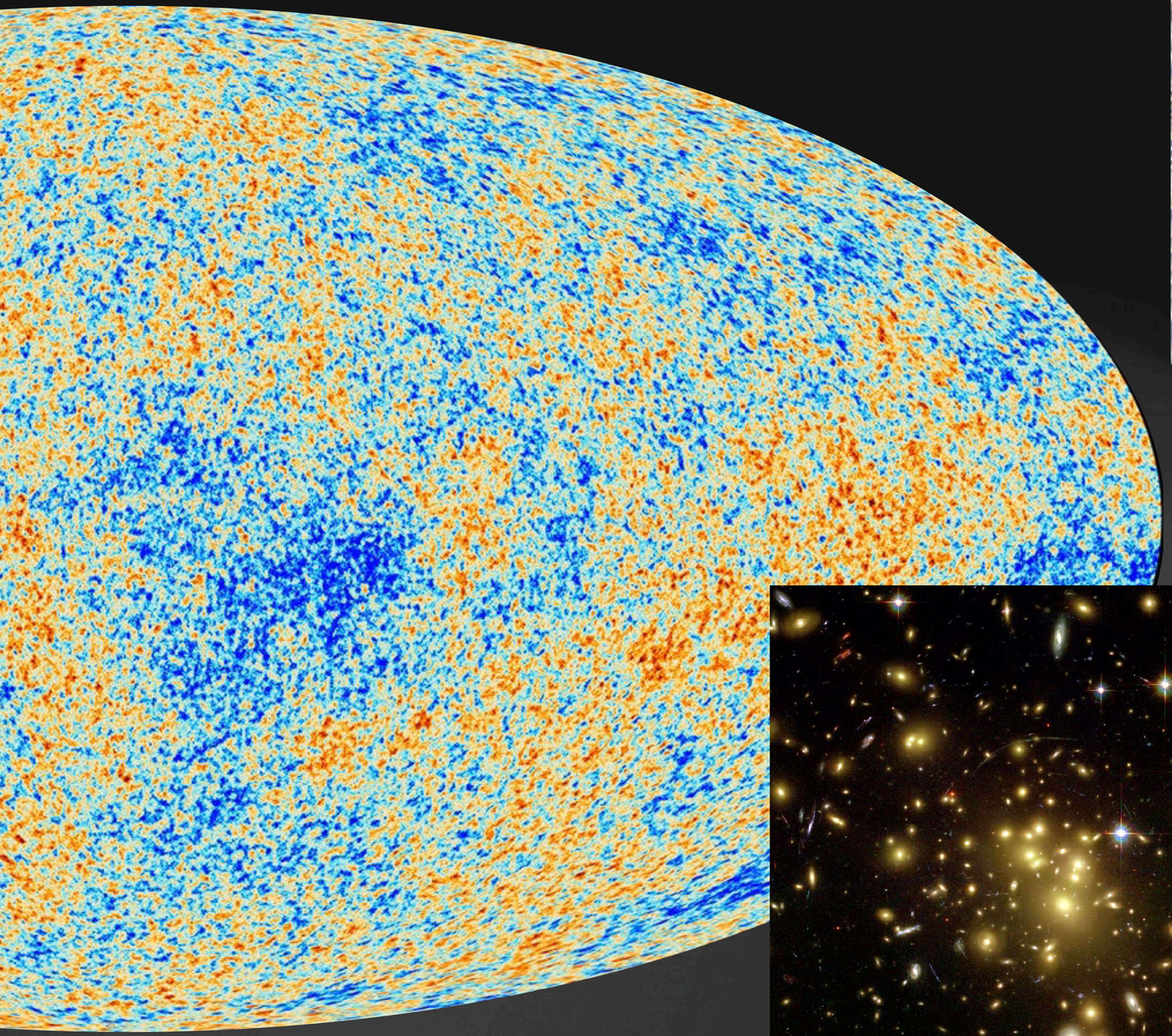
Planck 2013

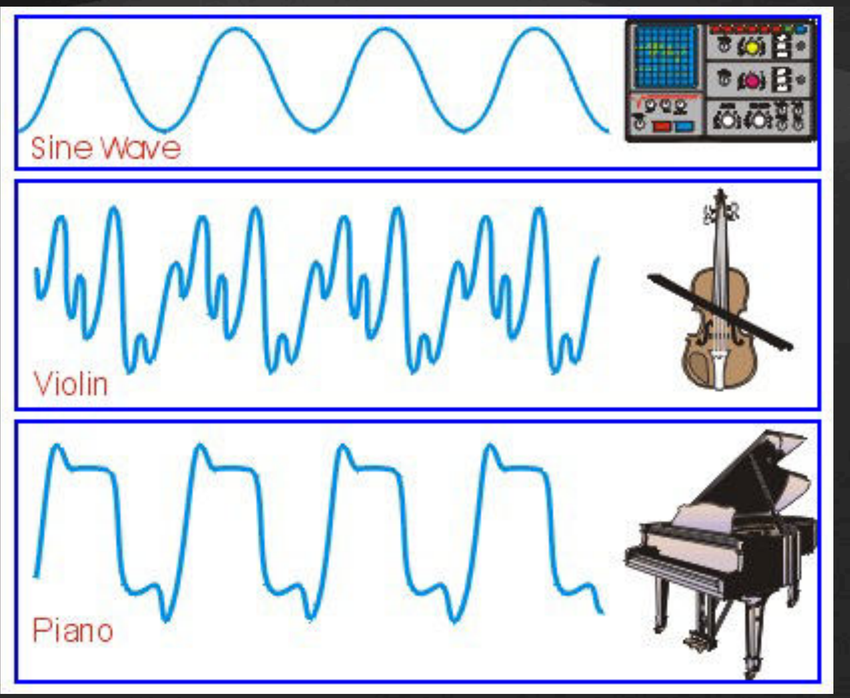







Sine Wave
Violin
Piano

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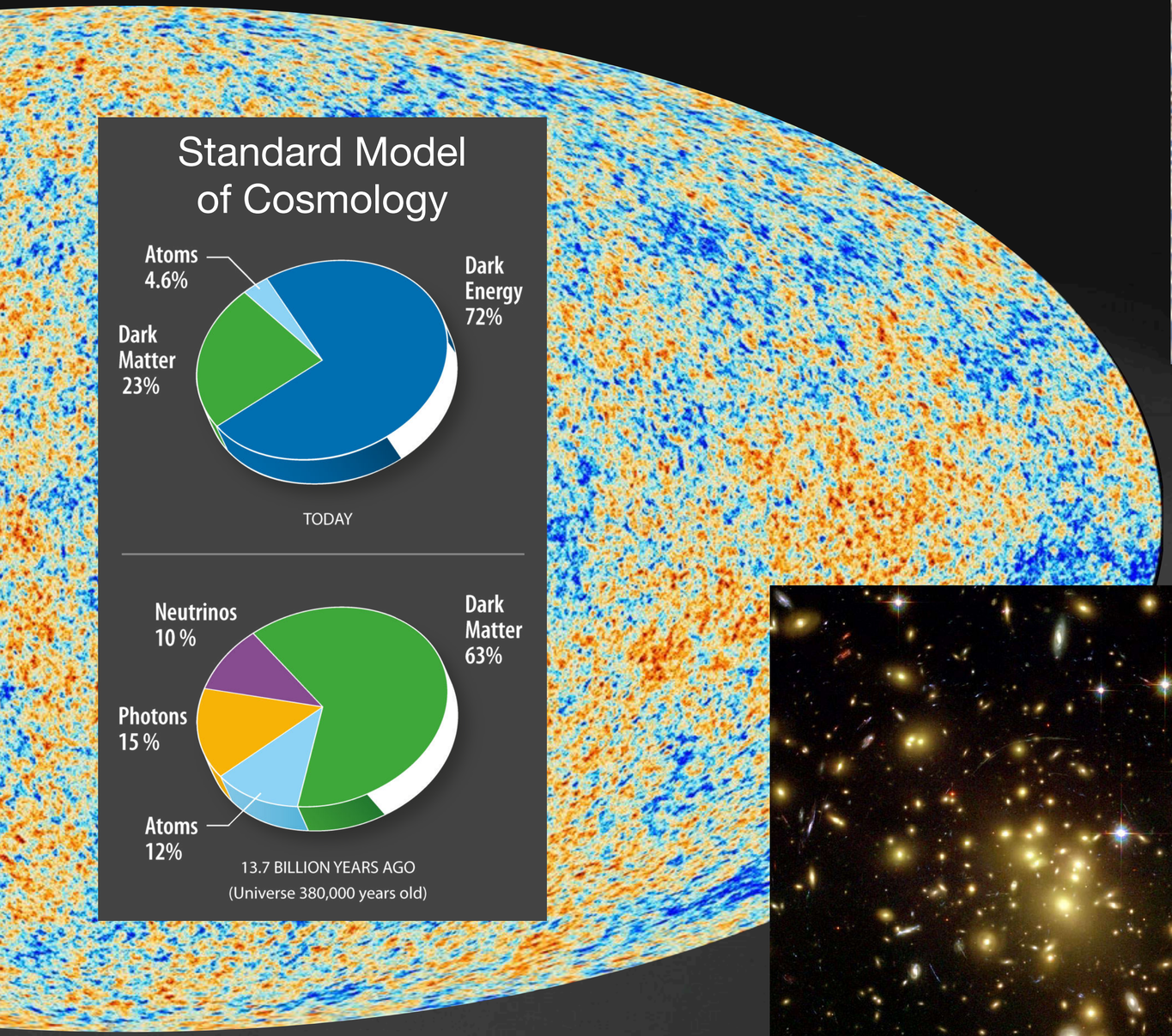
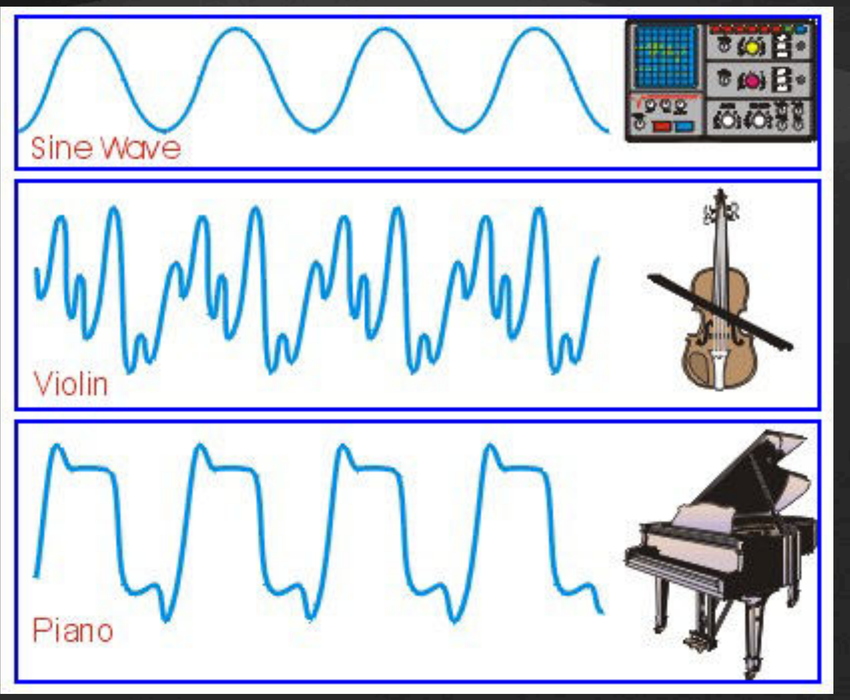
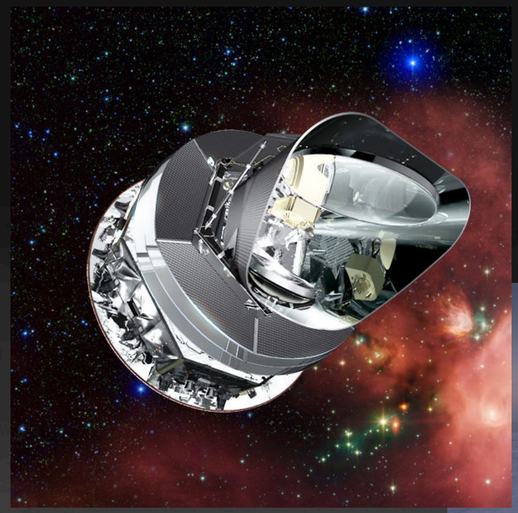
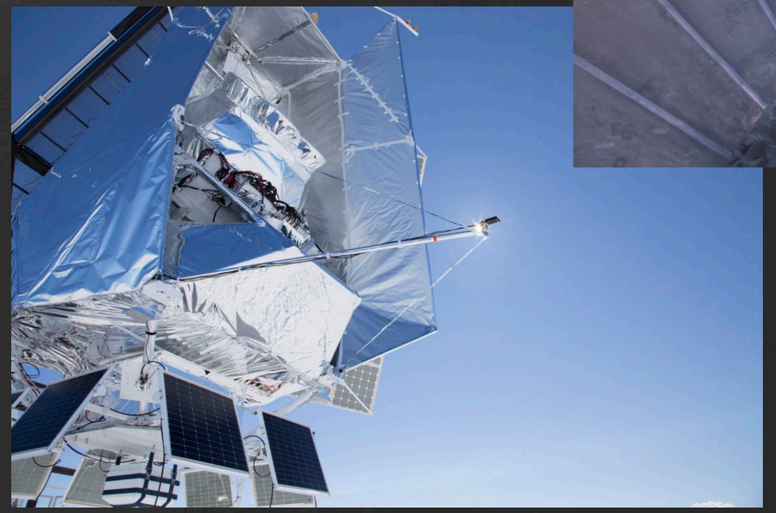

Standard Model
of Cosmology
Atoms
4.6%
Dark
Matter
23%
Dark
Energy
72%
TODAY
Neutrinos
10 %
Photons
15 %
Atoms
12%
Dark
Matter
63%
13.7 BILLION YEARS AGO
(Universe 380,000 years old)


Sine Wave
Violin
Piano

The Cosmology Community

- **Space**
  - WMAP
  - Planck
  - Litebird
  - ...
- **Ground**
  - ACT
  - BICEP, Keck
  - Polarbear
  - **SPT**
  - Simons Observatory
  - CMB-S4
  - ...
- **Balloon**
  - EBEX
  - **SPIDER**
  - Taurus
  - ...





SPIDER

Largest cryostat ever flown on a balloon

1300 liters *of liquid helium*

Most sensitive microwave receiver ever built at these frequencies

Six *cold refracting telescopes*

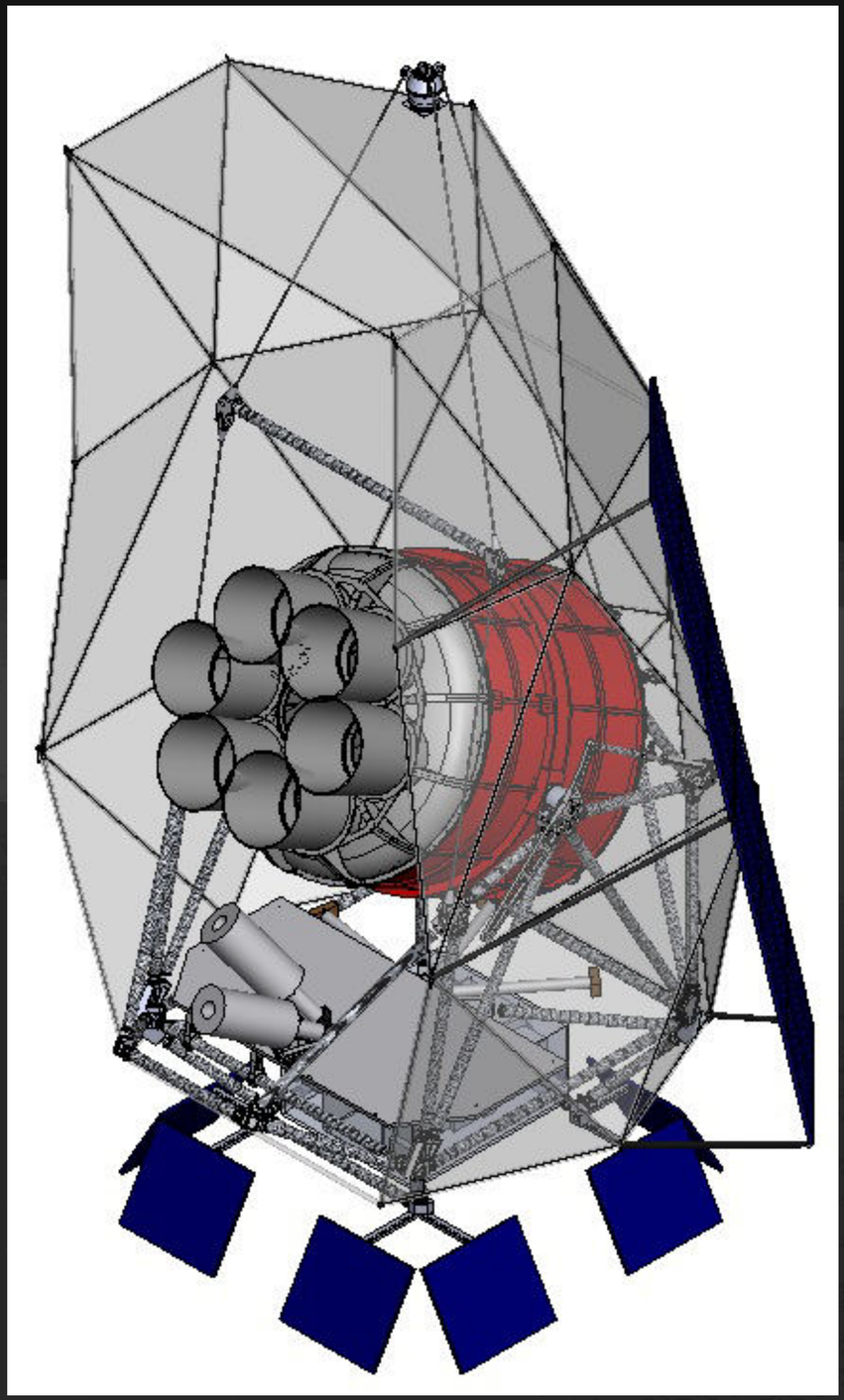
Total of ***2400*** *superconducting sensors*

Half-degree angular resolution

Attitude control system

Solar power **2kW**, mylar sun shield

Total weight: **2900 kg**



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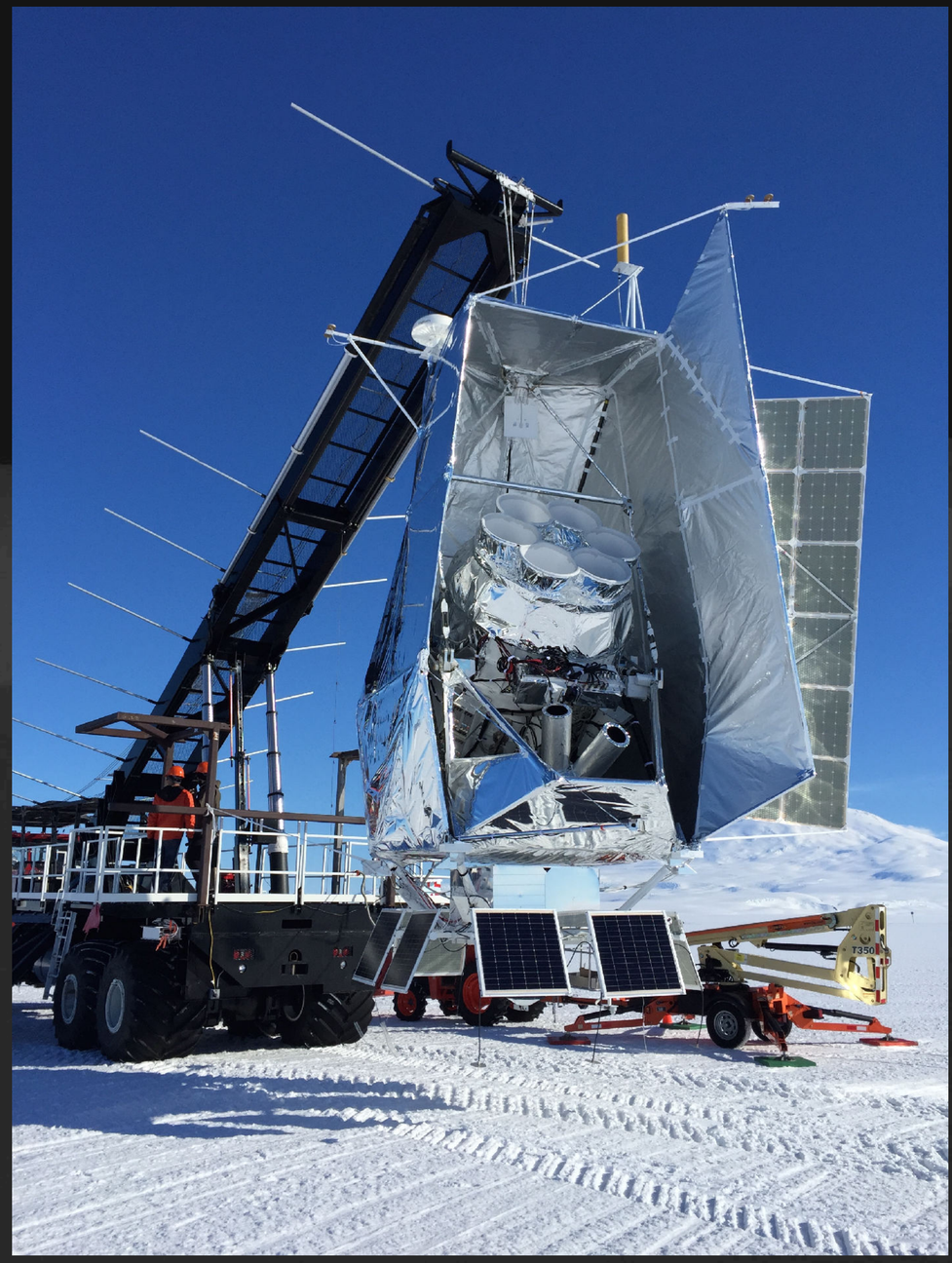
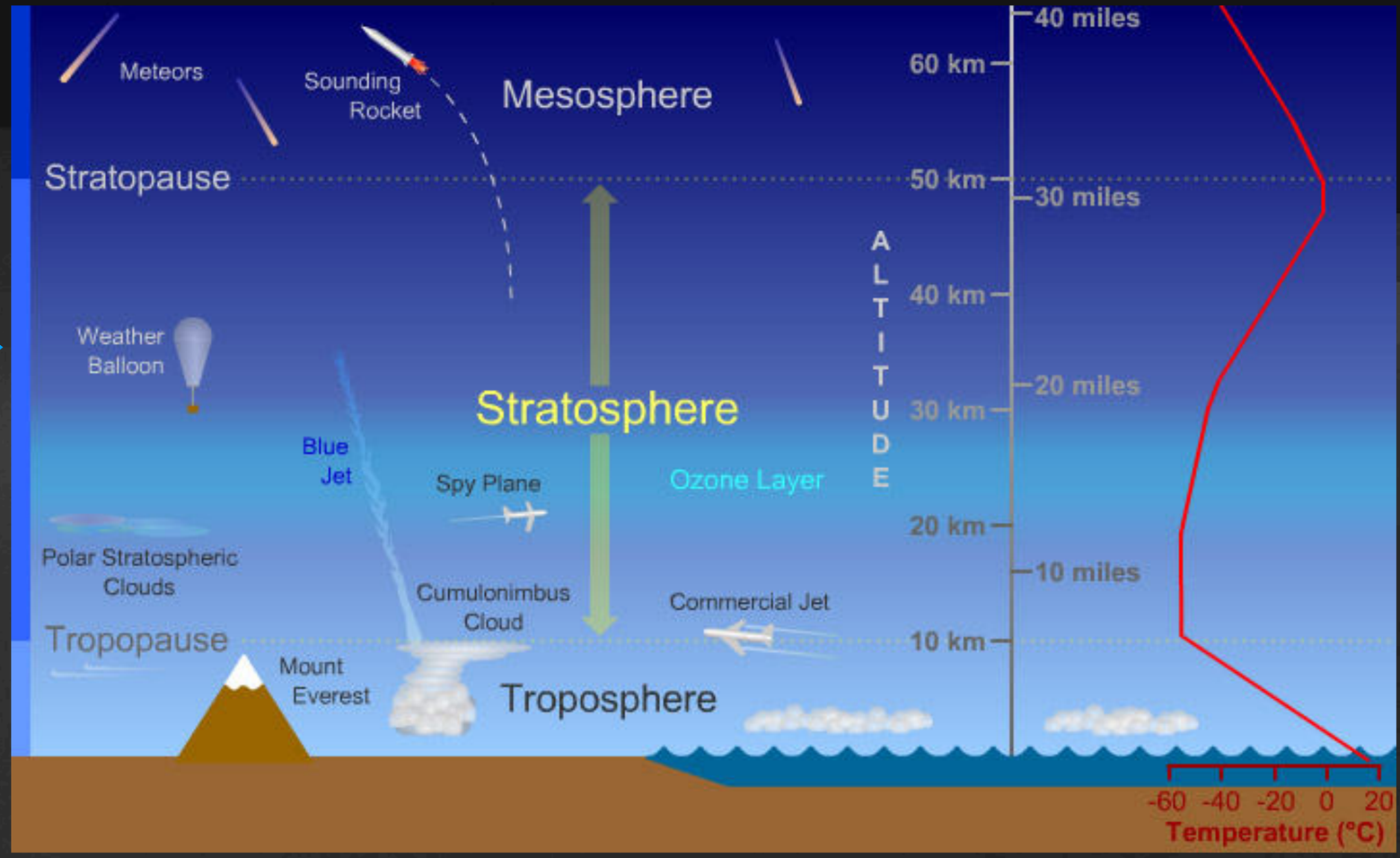
Flights: 2015 and 2022



Clear Skies from the Stratosphere

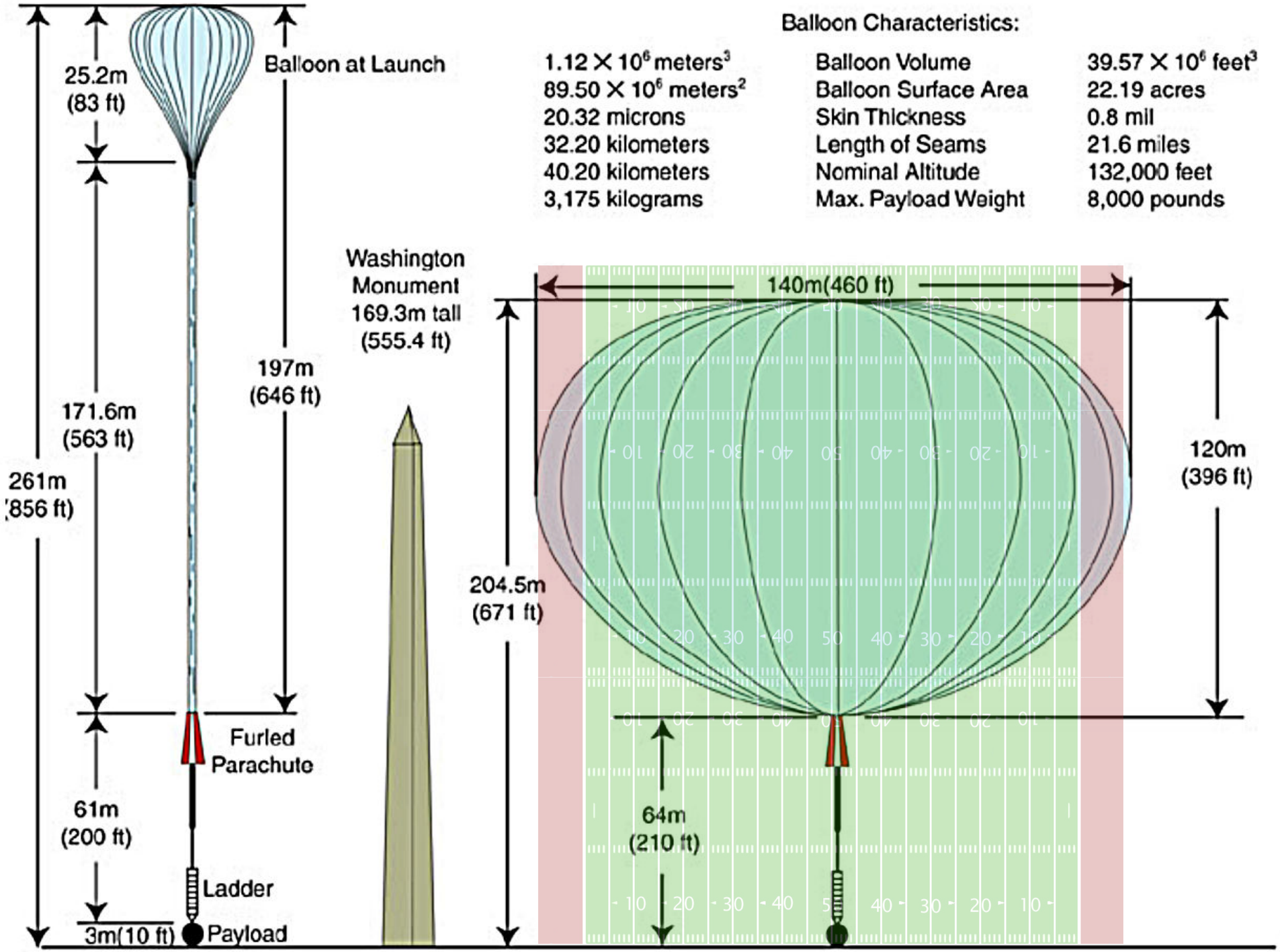


High and dry

Typical alt: 35-40 km (**21-25 miles**)

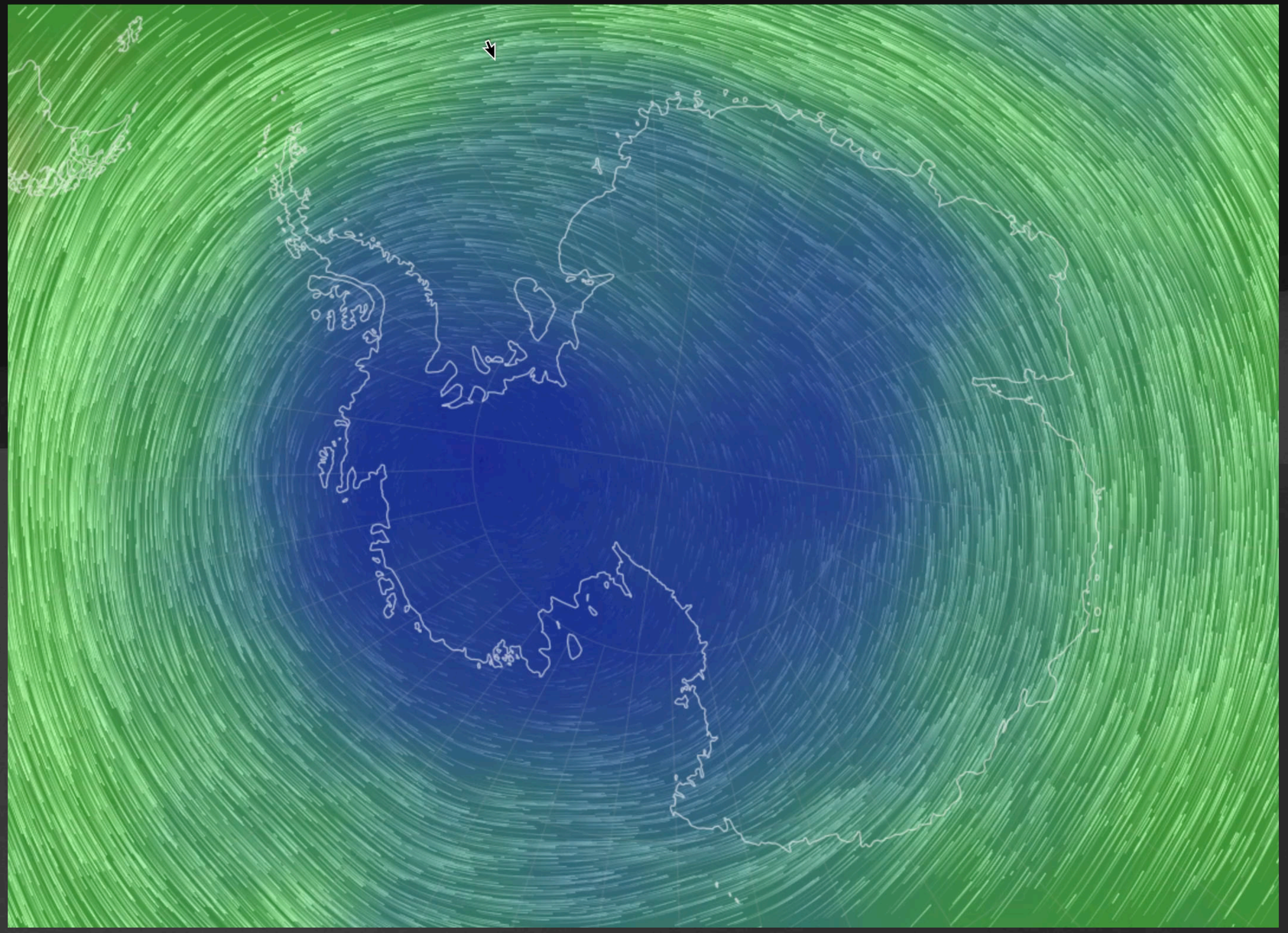
Above >99% of atmosphere

Unobstructed view for microwave instruments!



NASA Wallops

Antarctica is Special



Polar vortex
Payloads stay over solid ground for *weeks*!

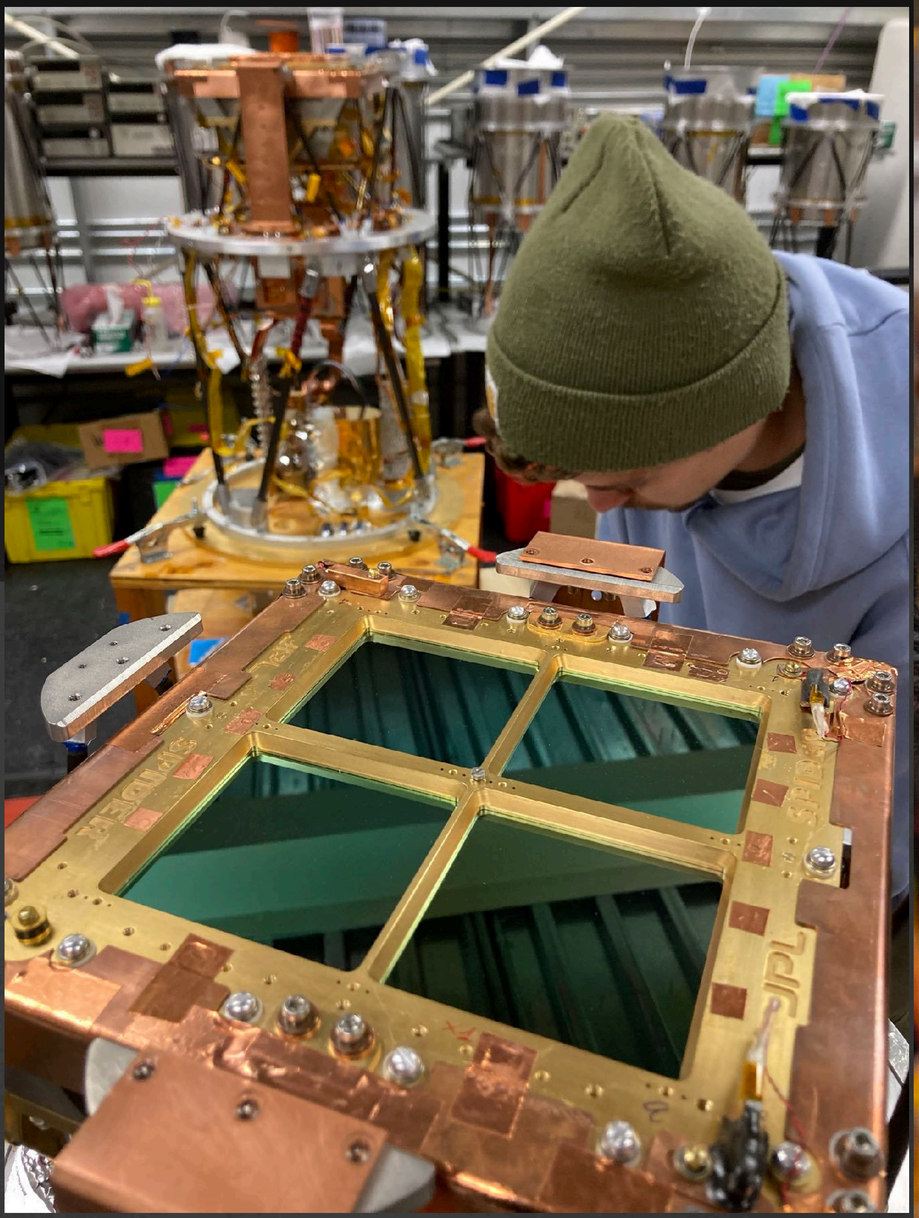
24h of sunlight
Minimal day/night temperature change (*helium loss*)

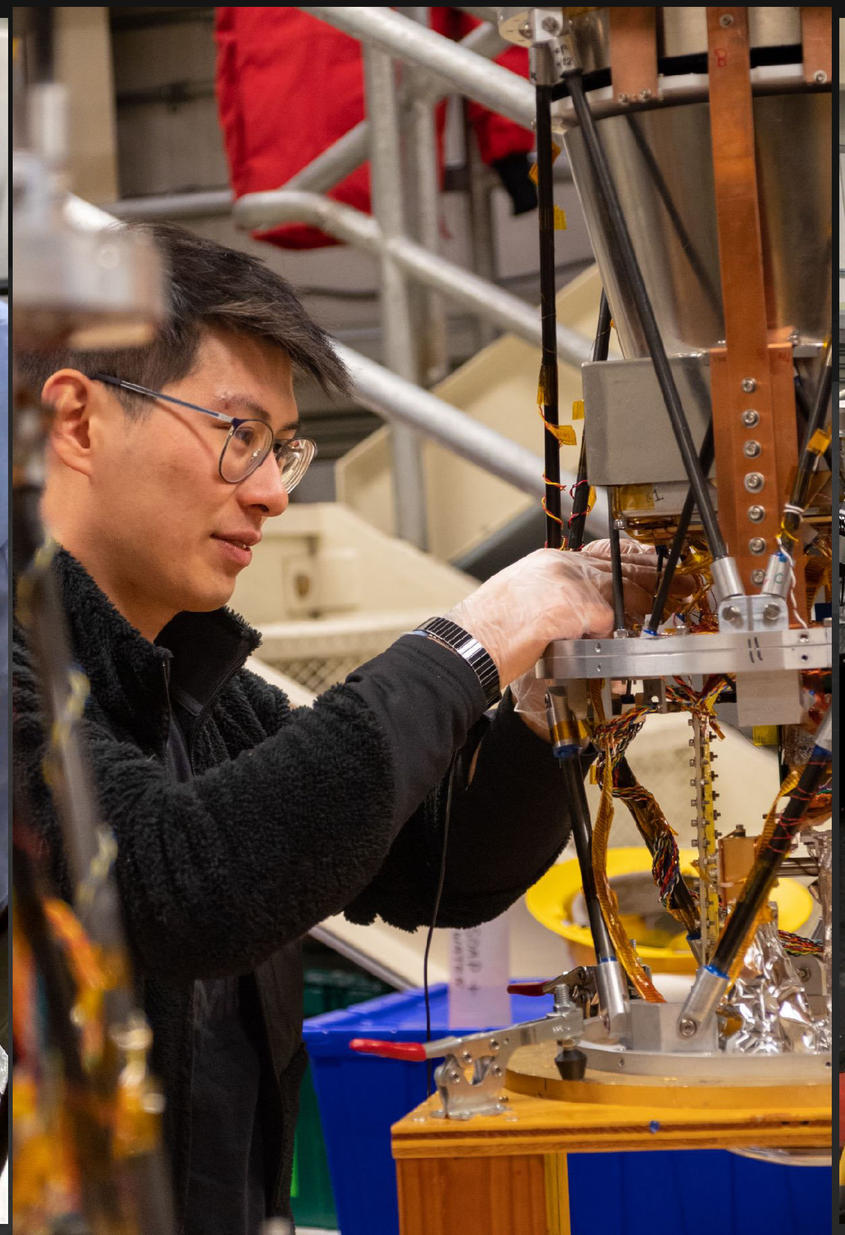
Continuous solar power

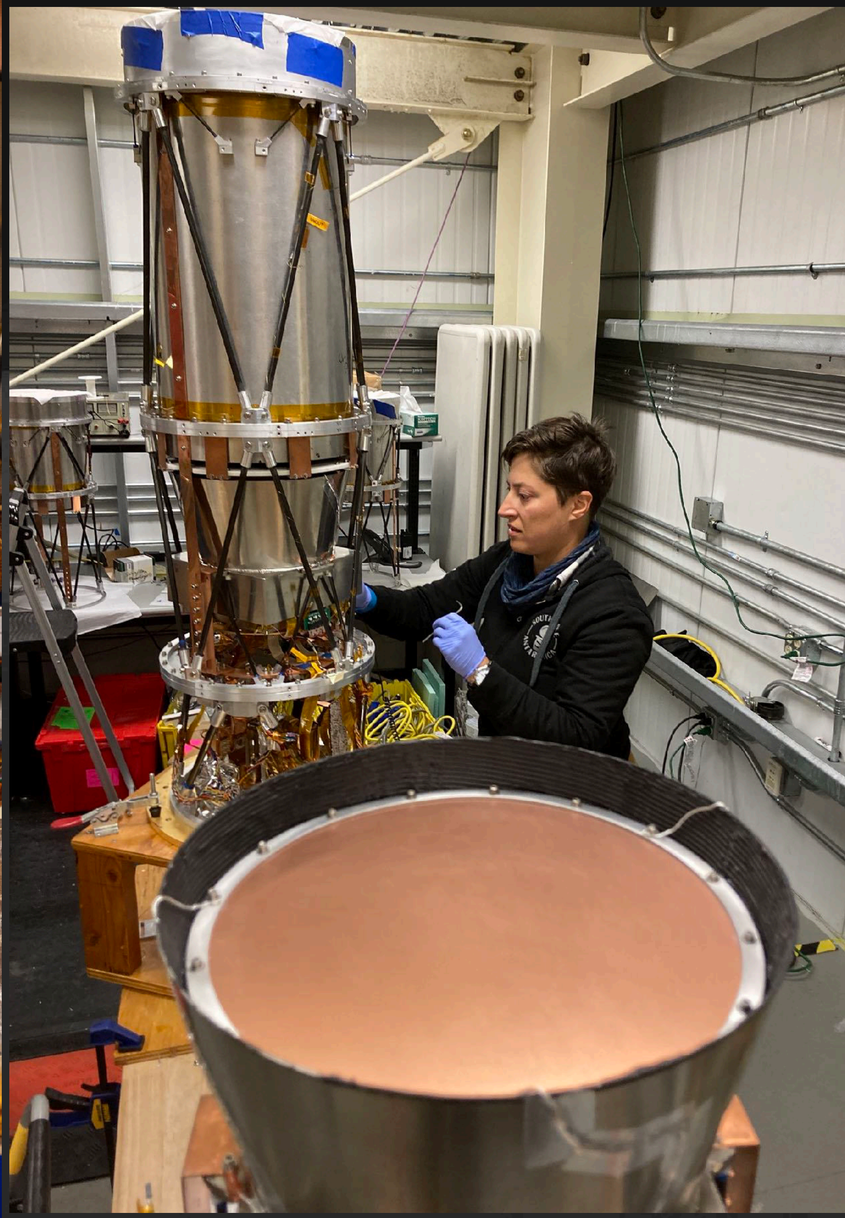
Winds @ 10 hPa (85,000 ft)
January 1, 2015
earth.nullschool.net

The Road to the Stratosphere: 2022

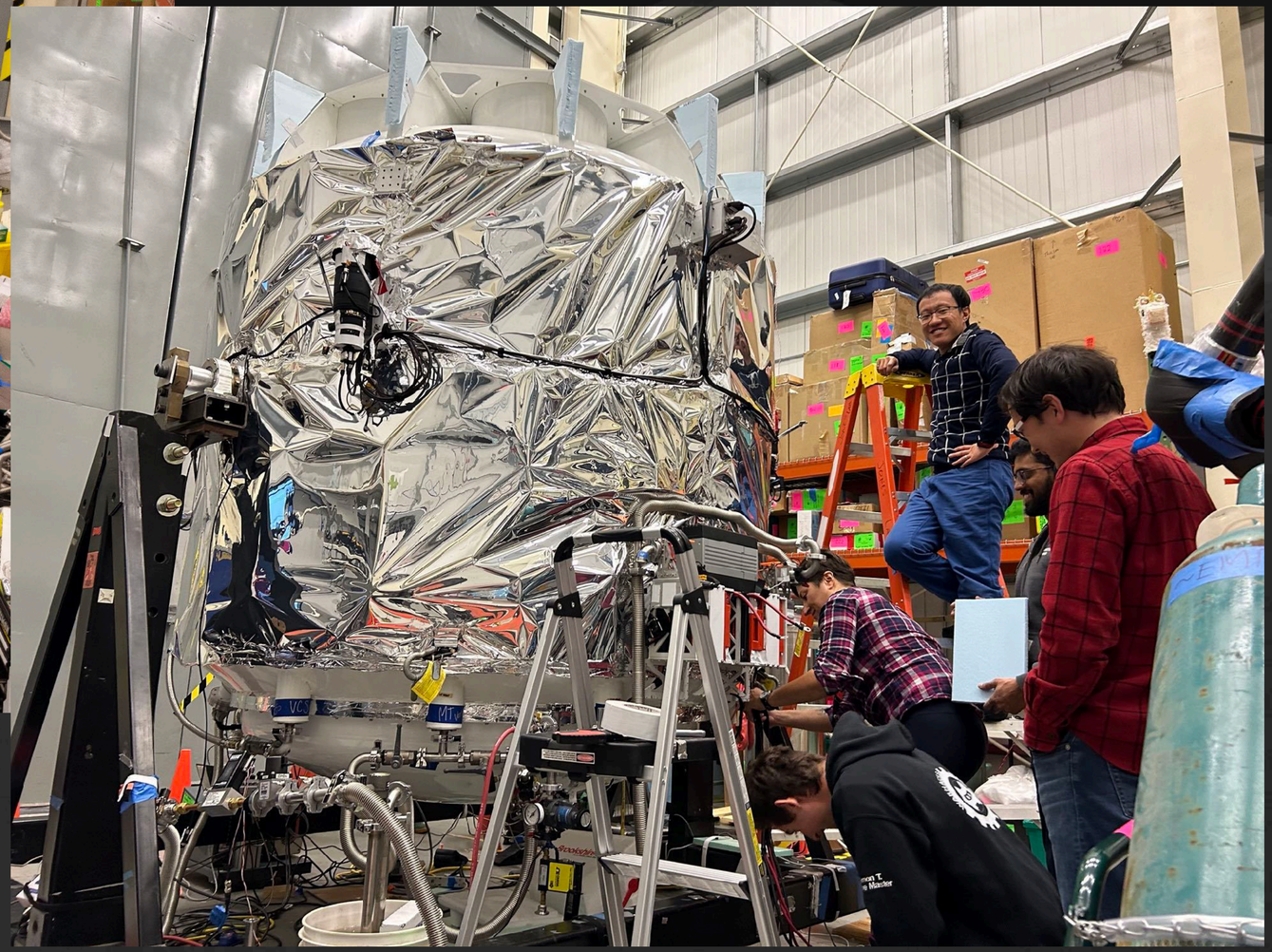
The Road to the Stratosphere: 2022



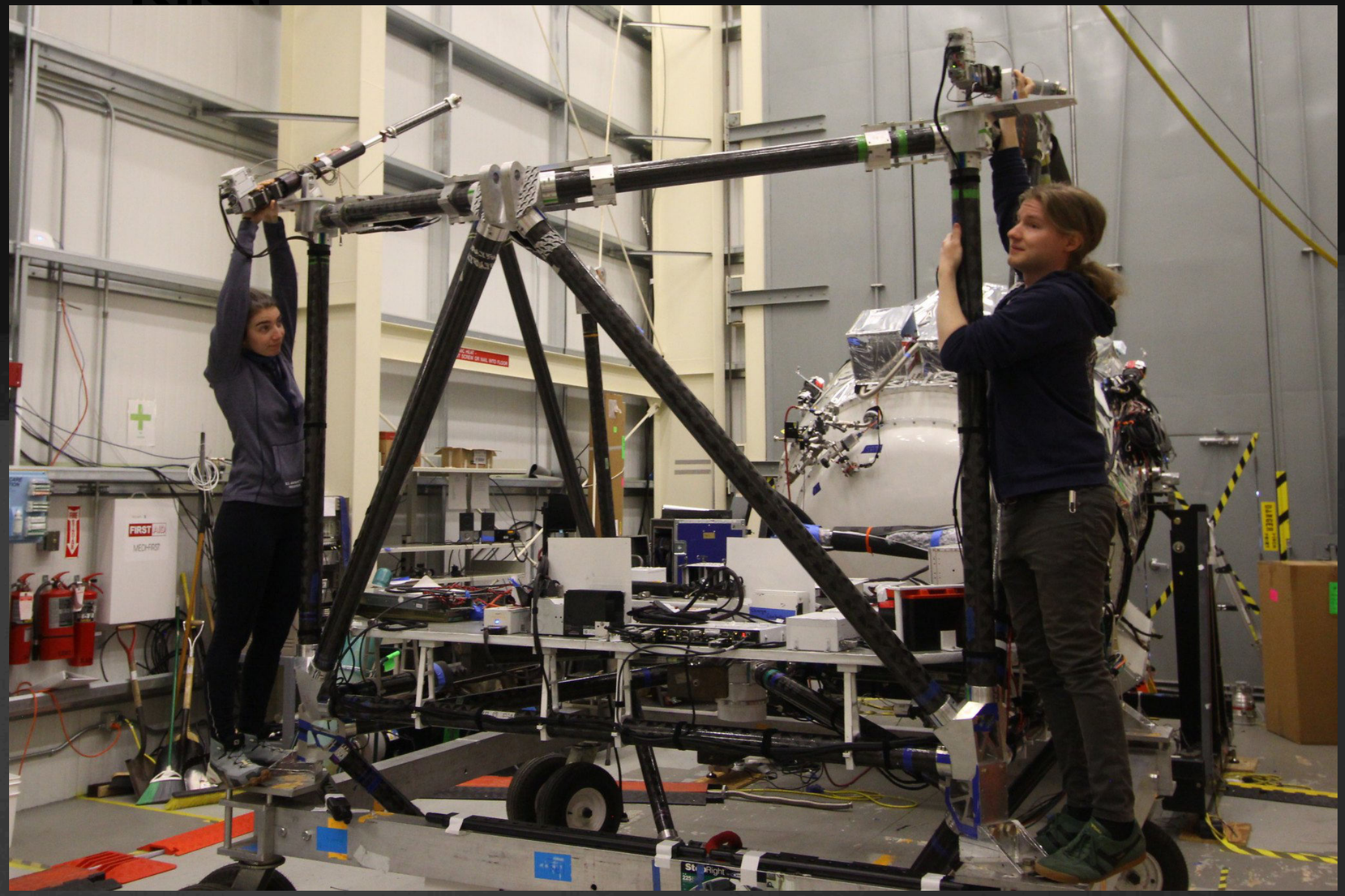


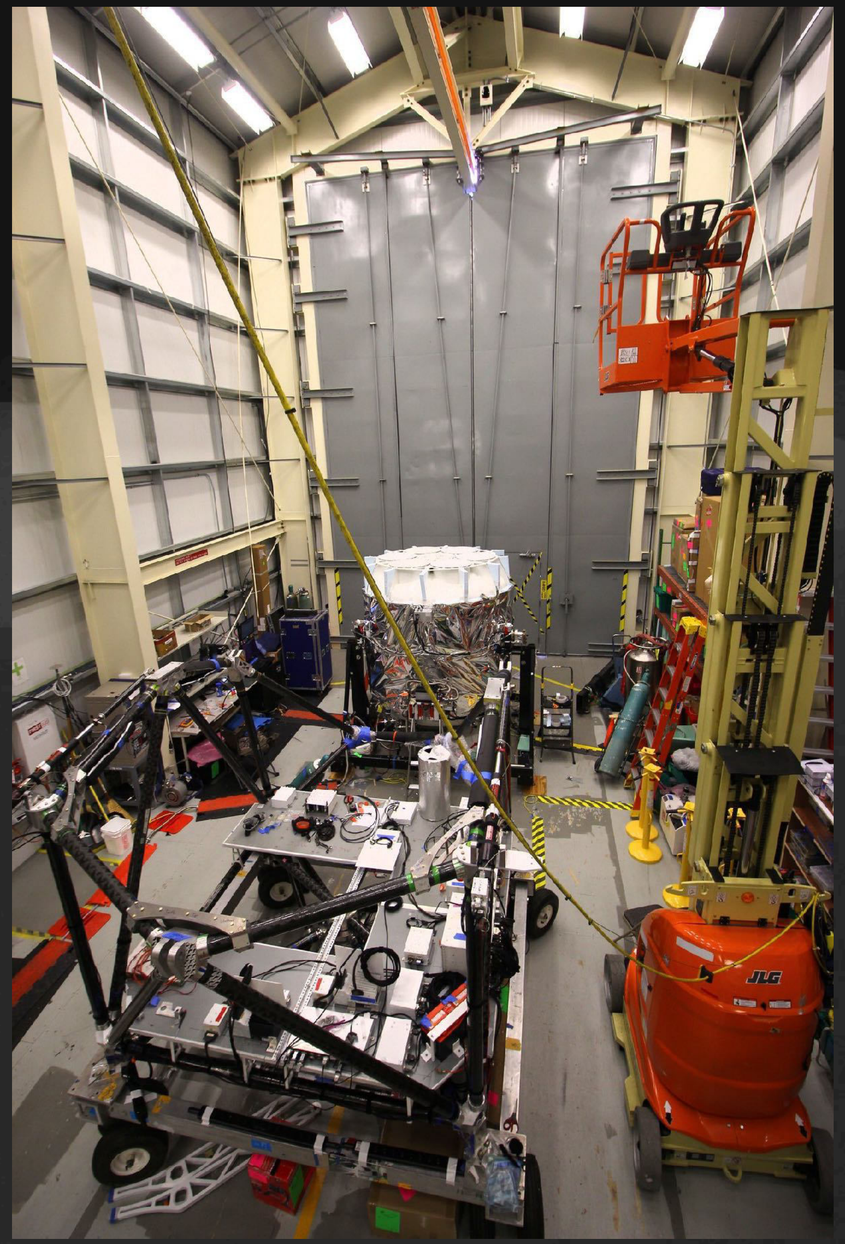


The Road to the Stratosphere: 2022



The Road to the Stratosphere: 2022





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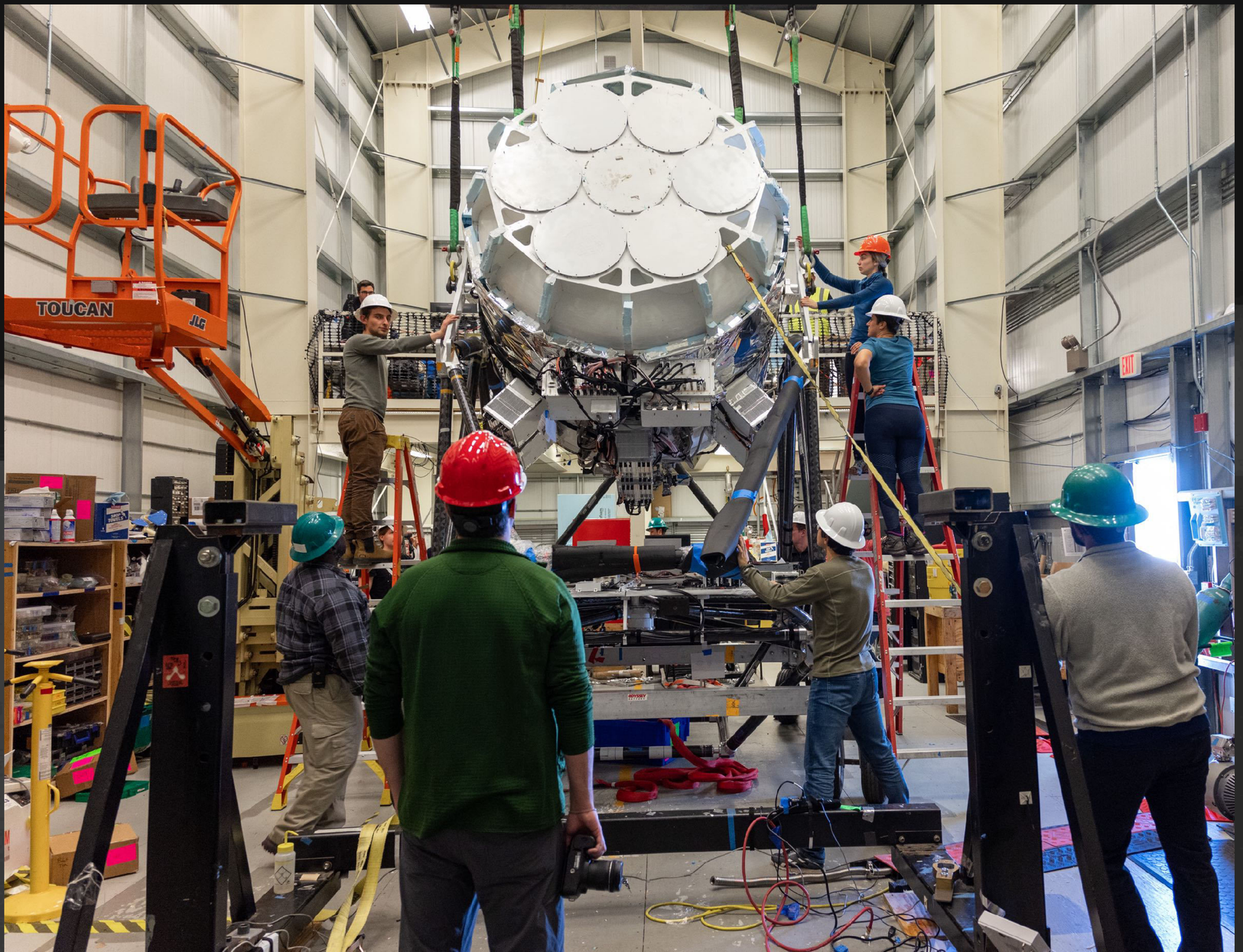
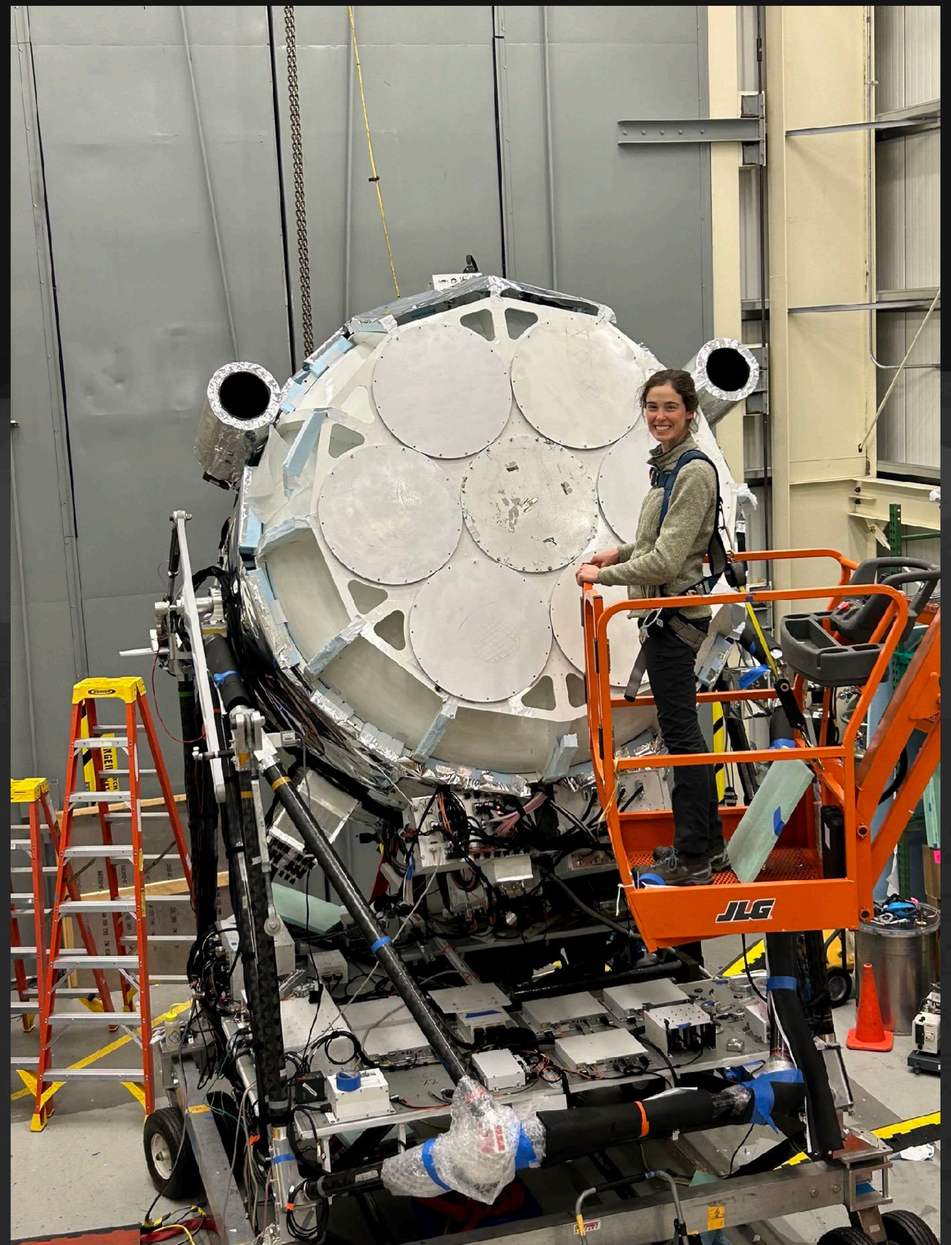
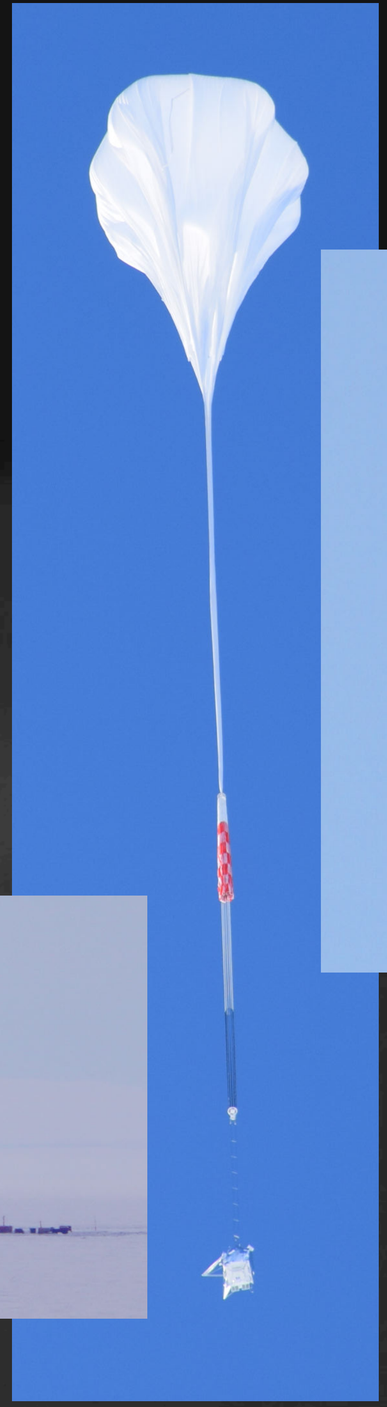


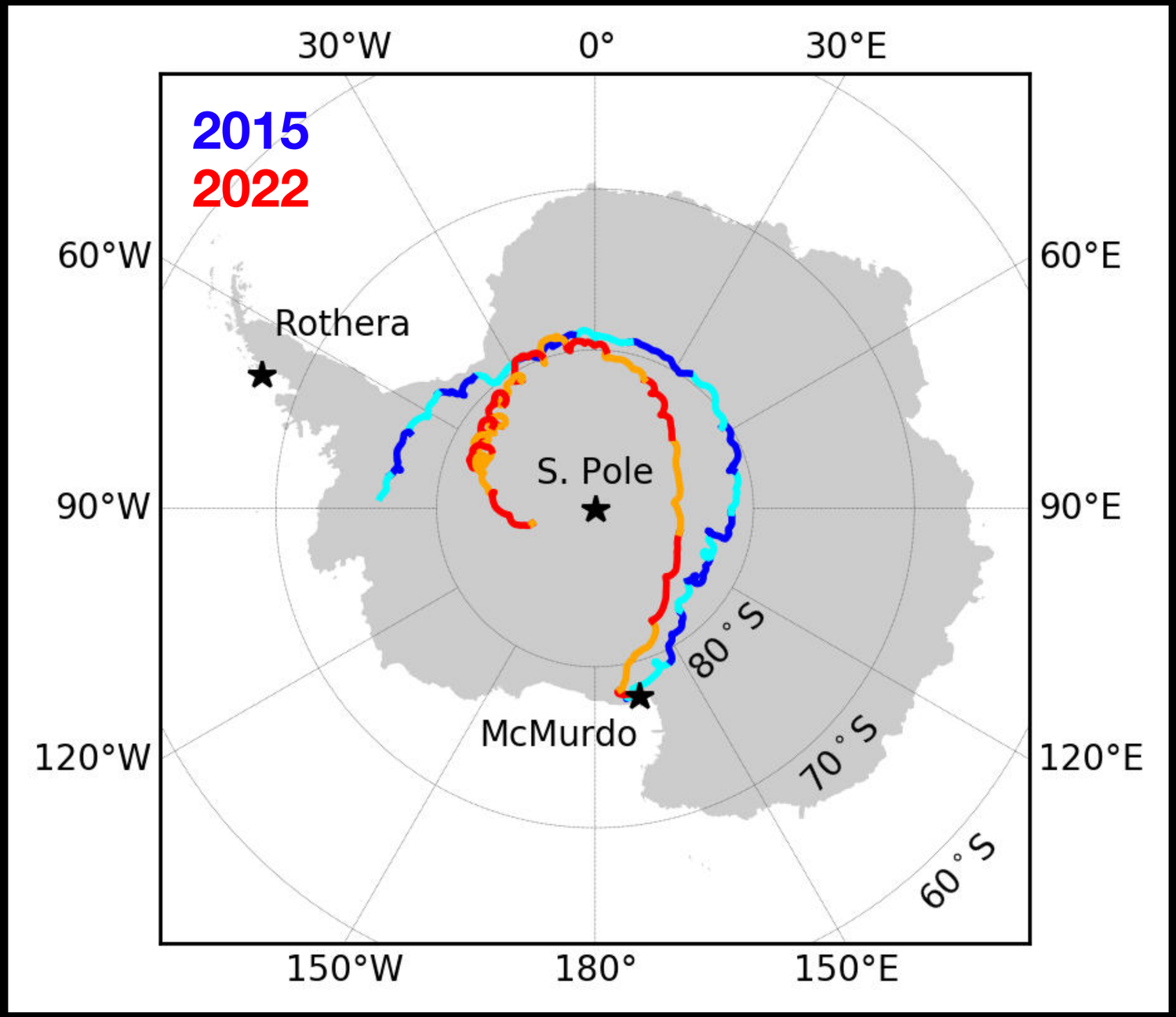


Launch Day: 22 Dec 2022

SPIDER Aloft!




Cape Bird
Mt. Terror
Cape Royds
Mt. Erebus
Cape Crozier
Erebus Ice Tongue
Windless Bight
Hut Point Peninsula
McMurdo Ice Shelf
Black Island
White Island

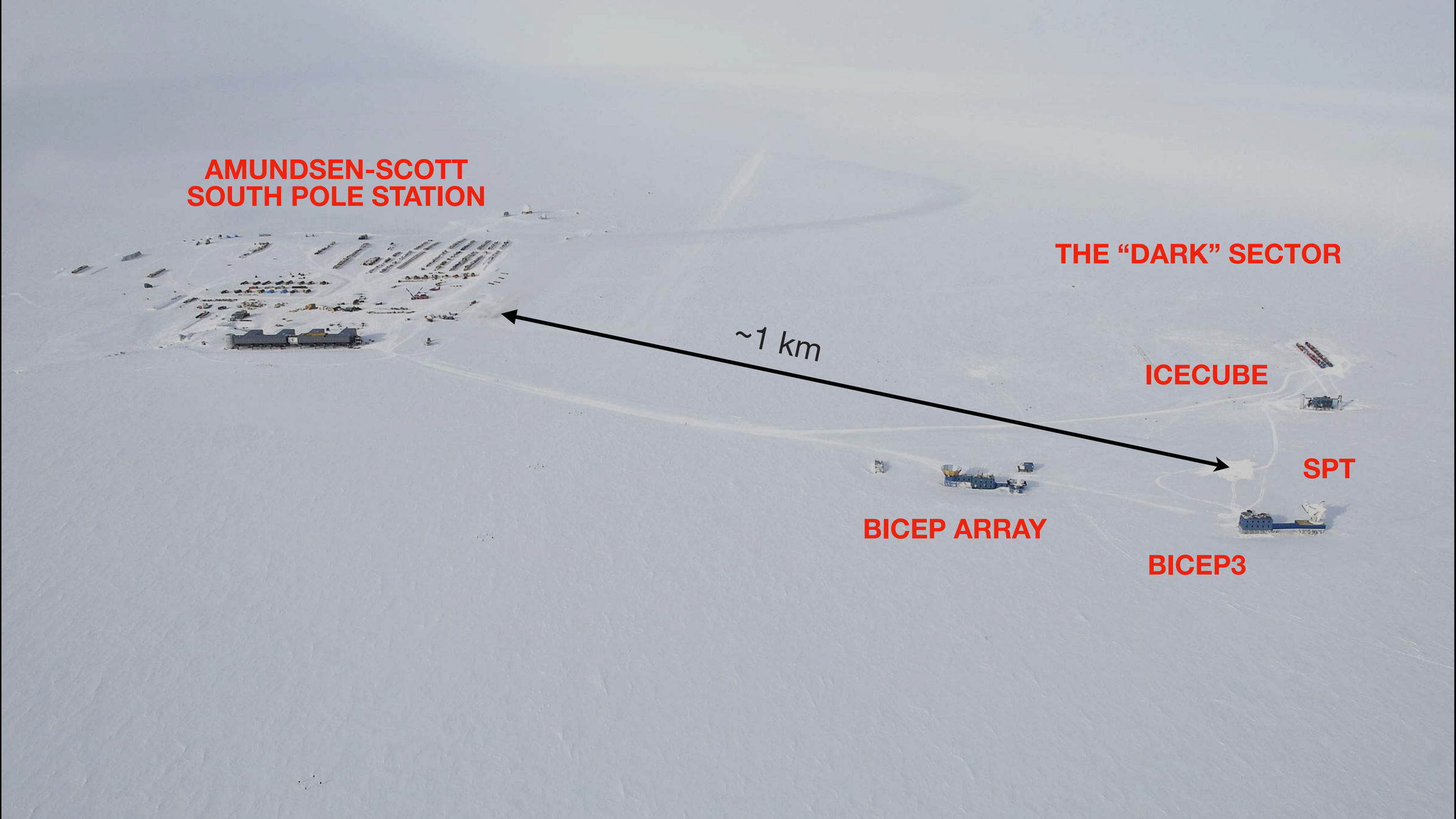

2015
2022
30°W
0°
30°E
60°W
60°E
Rothera
S. Pole
90°W
90°E
80°S
McMurdo
70°S
120°W
120°E
60°S
150°W
180°
150°E

Recovery Day 1: Priority Hardware

Recovery Day 2: Everything Else!


Kenn Borek Air
C-FBKB

STAY TUNED FOR RESULTS!

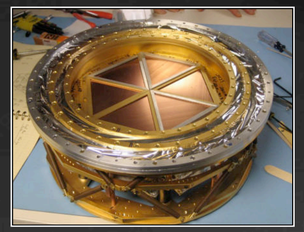

AMUNDSEN-SCOTT
SOUTH POLE STATION
THE “DARK” SECTOR
~1 km
ICECUBE
SPT
BICEP ARRAY
BICEP3

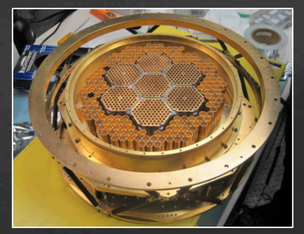
The South Pole is the Best Place in the World to Observe the CMB

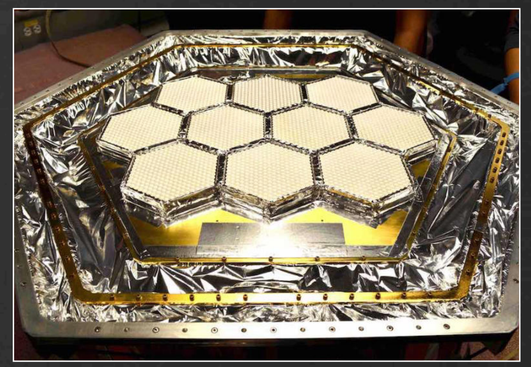
- High Altitude (~3,000 m)
- Extremely Dry
  - Precipitable water vapor in winter is ~4x less than Chile, ~6x less than Hawaii
- Stable Atmosphere
  - During 6-month night, the sky is ~30x more stable than ALMA-site in Chile

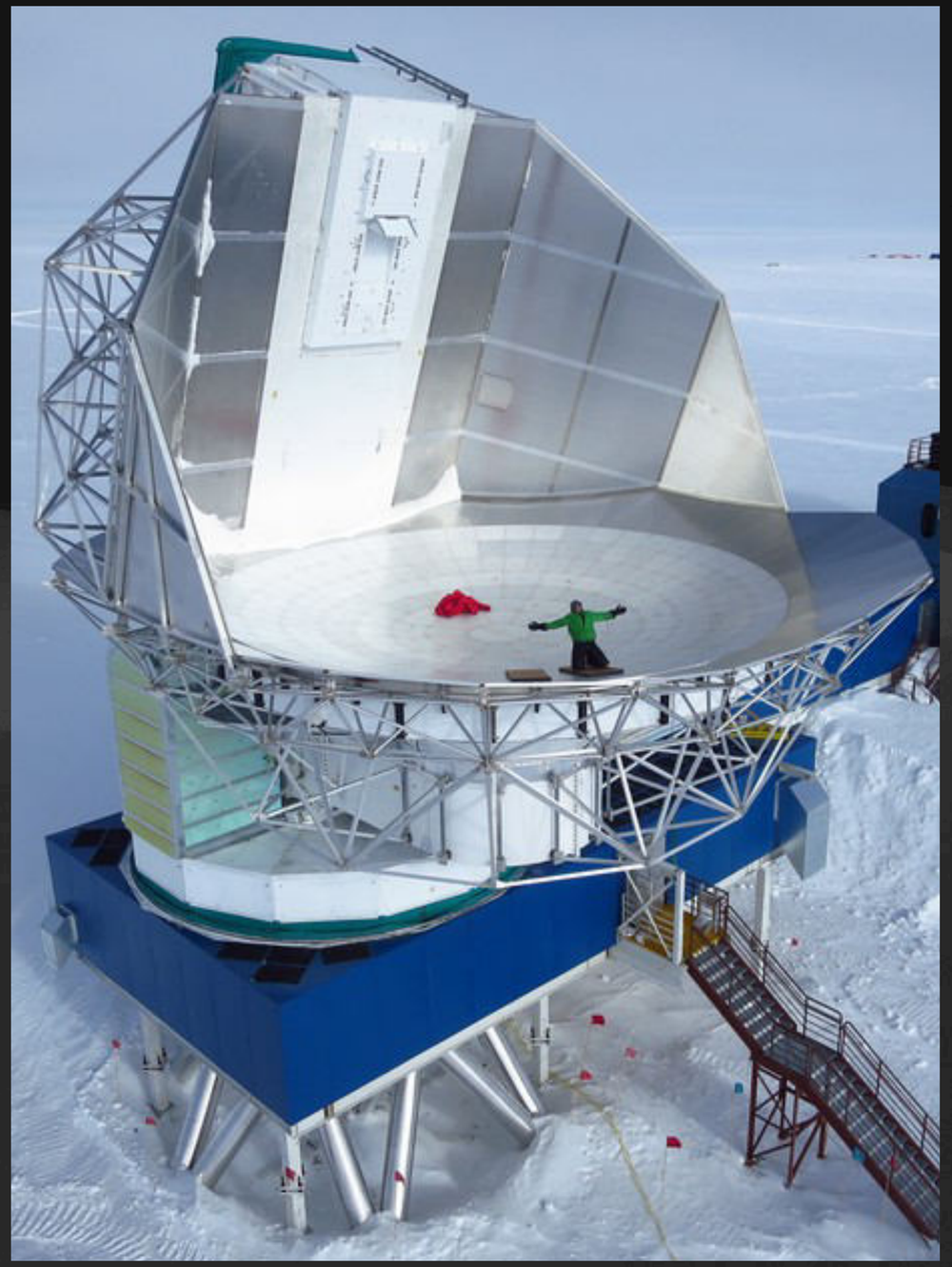
The South Pole Telescope

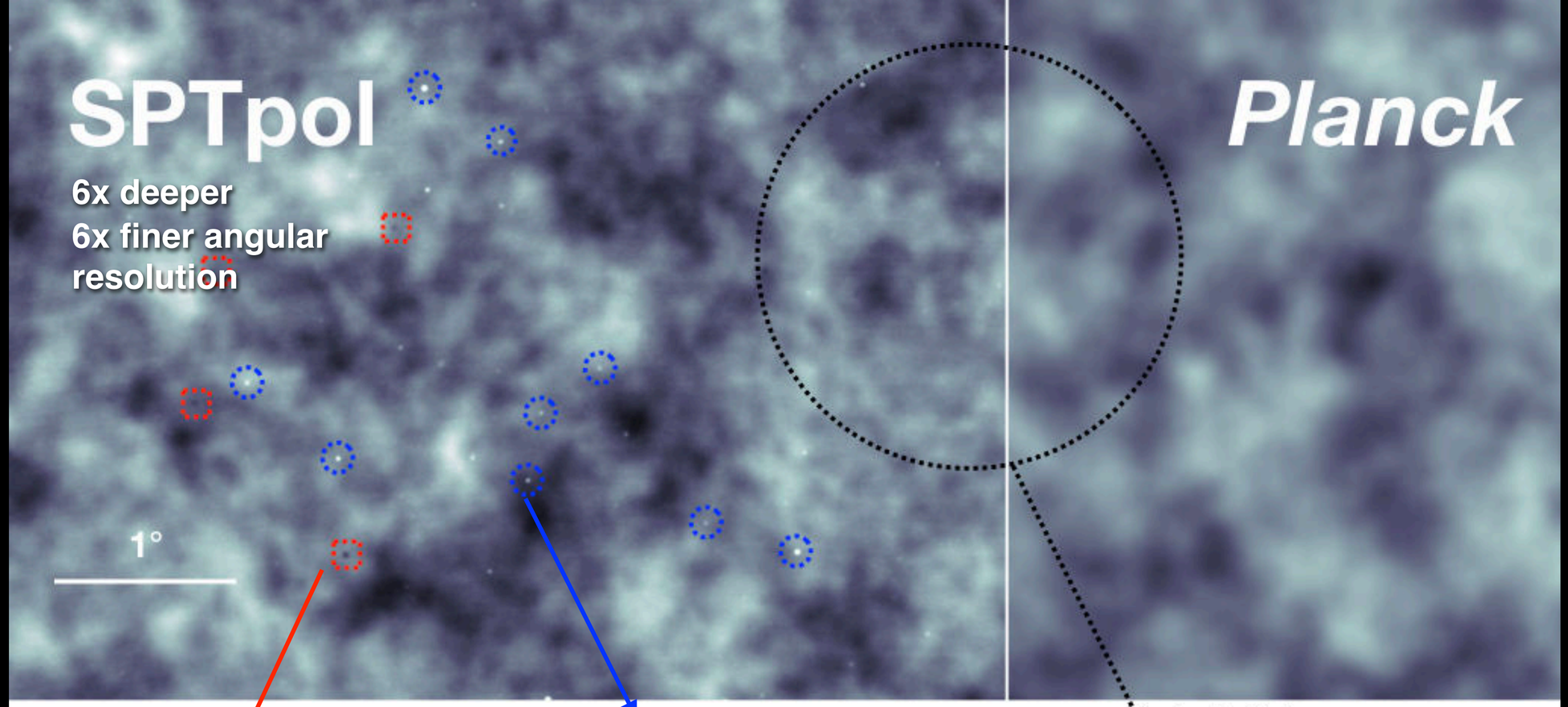
- 10-m submm-quality wavelength telescope
  - 90, 150, 220 GHz
  - 1.6, 1.2, 1.0 arcmin resolution
- **2007: SPT-SZ**
  - 960 detectors
  - 90, 150, 220 GHz
- **2012: SPTpol**
  - 1600 detectors
  - 90, 150 GHz
  - +polarization
- **2017: SPT-3G**
  - ~16,200 detectors
  - 90, 150, 220 GHz
  - +polarization

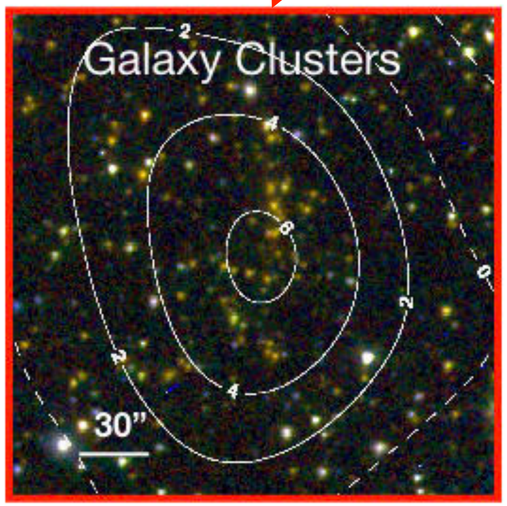


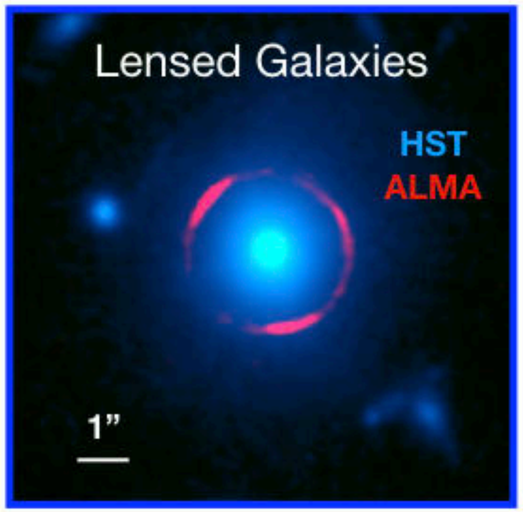


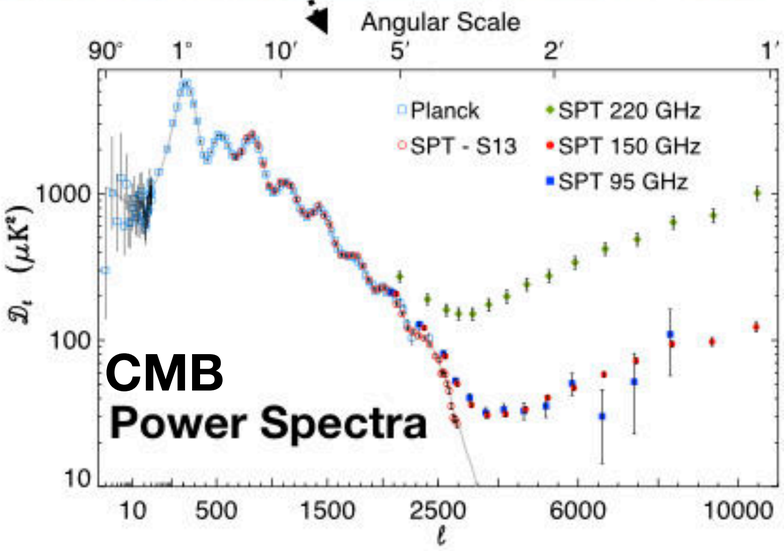




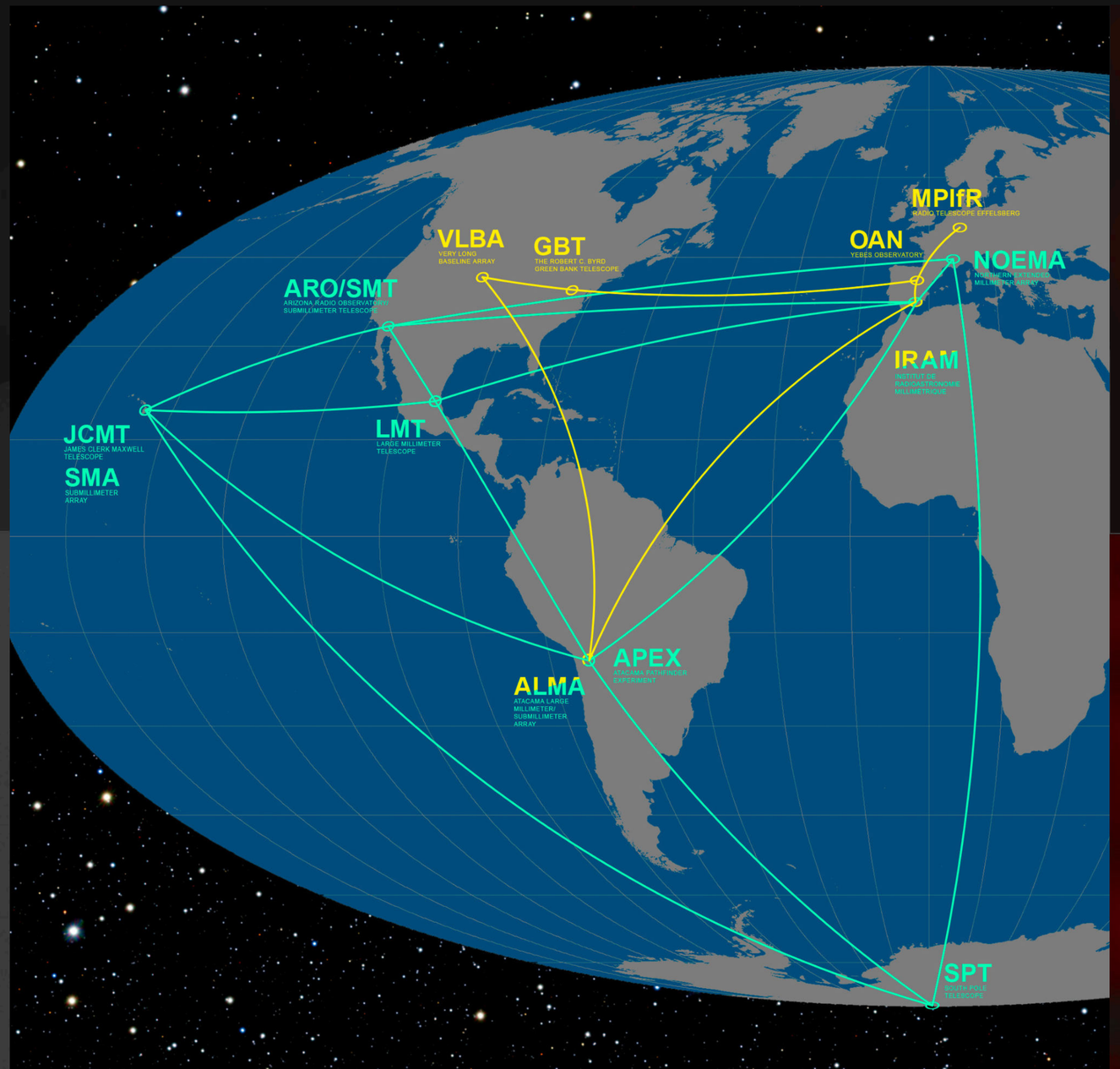

SPTpol
6x deeper
6x finer angular resolution
Planck
1°

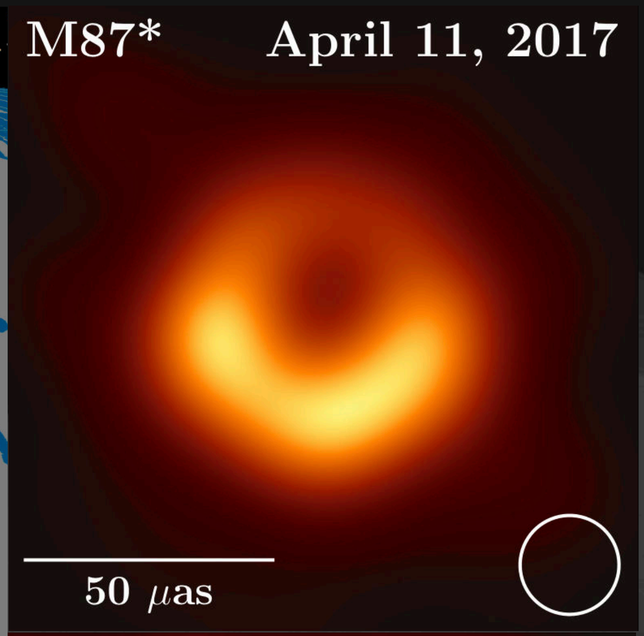

Galaxy Clusters
30”

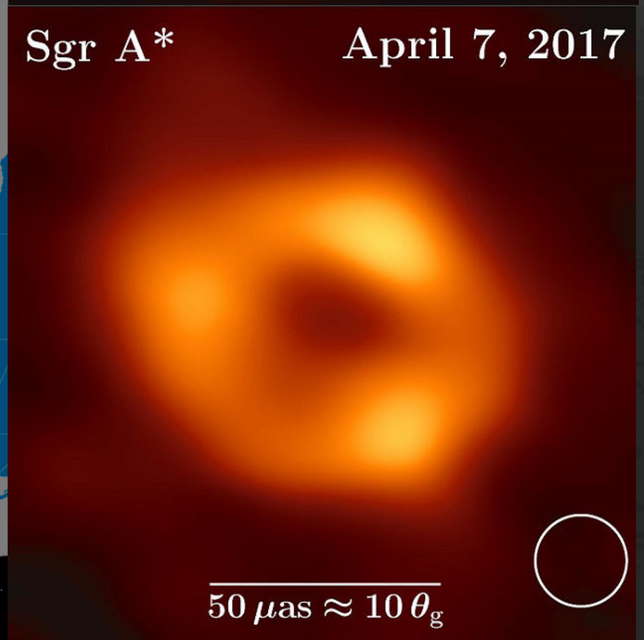

Lensed Galaxies
HST
ALMA
1”


Angular Scale
90°
1°
10′
5′
2′
1′
Planck
SPT - S13
SPT 220 GHz
SPT 150 GHz
SPT 95 GHz
1000
100
10
$\mathcal{D}_\ell$ (μK^2)
CMB
Power Spectra
10
500
1500
2500
6000
10000
ℓ

Event Horizon Telescope







"Wintering Over"

"Wintering Over"

- Station closed February 15 to October 15 yearly
- Winter population in 2021: 39 people
  - 7 women
  - 10 scientists (two for SPT)
  - Remainder staff (medical, kitchen, IT, maintenance, ...)
- Sunset March 21, sunrise September 21 yearly
- Minimum temperature about -100F / -73C
- Fewer people have wintered (<1700) than have scaled Mount Everest (>4000)
  - Even fewer women (<300)


Matt Young

Matt Young


Matt Young

Midwinter Celebration (June 21)


Aman Chokshi

Aman Chokshi


Matt Young


Matt Young


Matt Young


@JoeSpinsTheGlobe
Walk
to the
Dark Sector


Thank you!