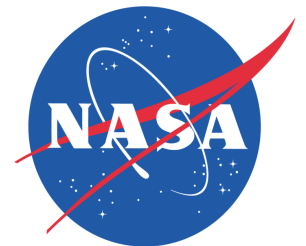
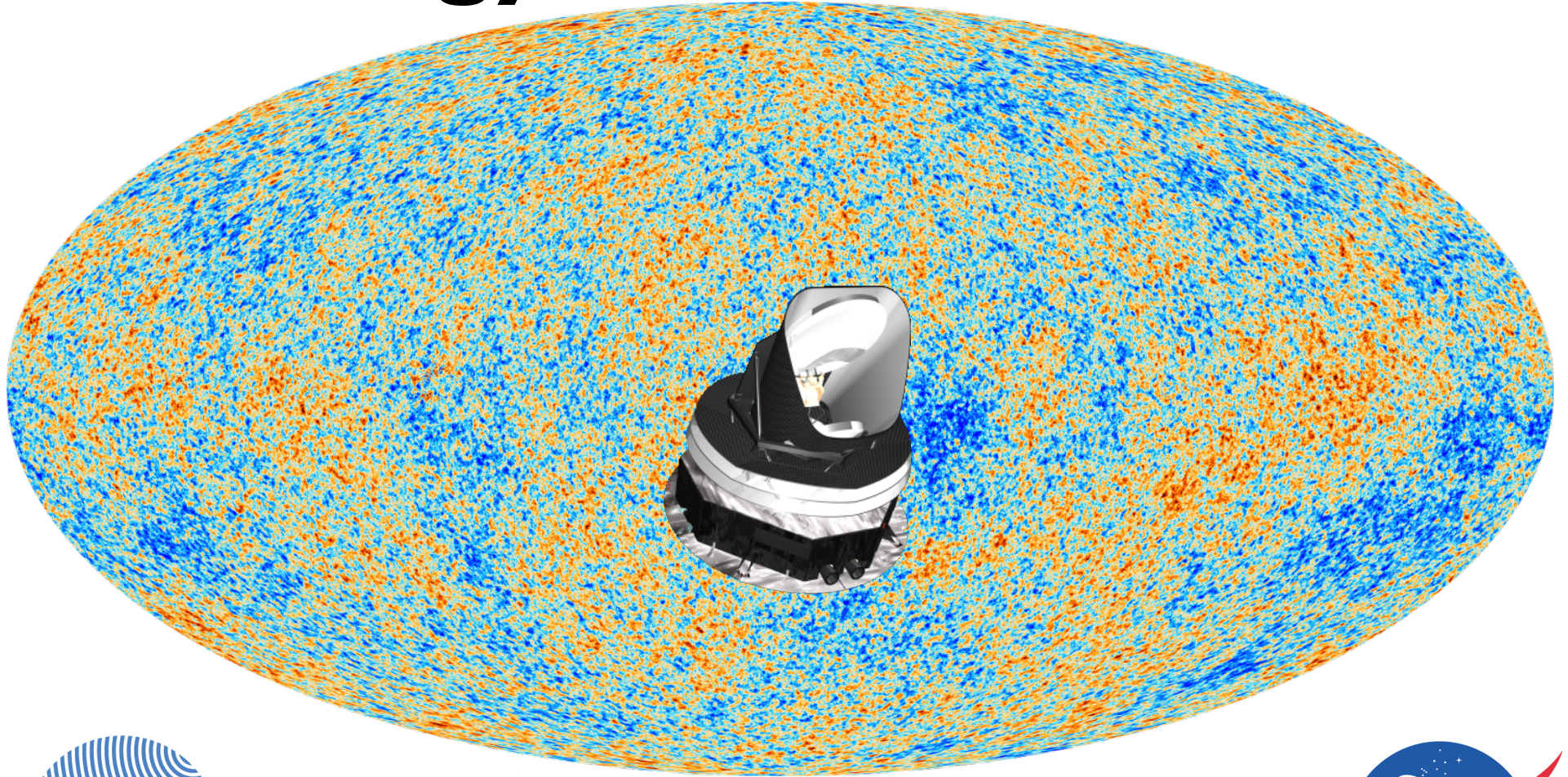
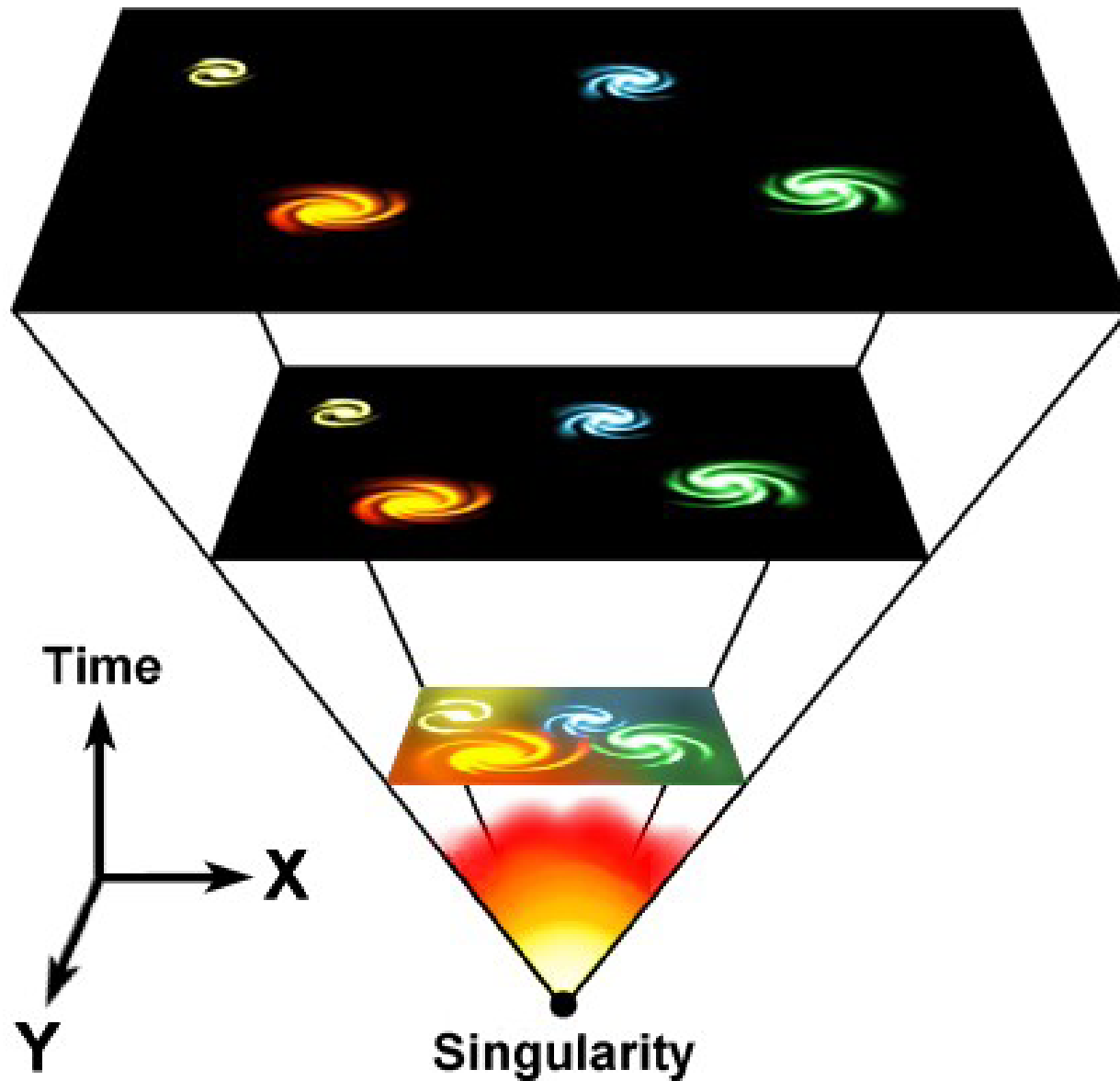


The Universe's Baby Picture: Cosmology Results from Planck



 Kevin Huffenberger, *University of Miami*

Expanding universe & the Big Bang



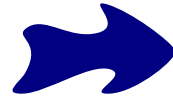
Hot, dense objects glow



Blackbody radiation - Planck Spectrum

Cosmic Microwave Background

Hot, dense initial state

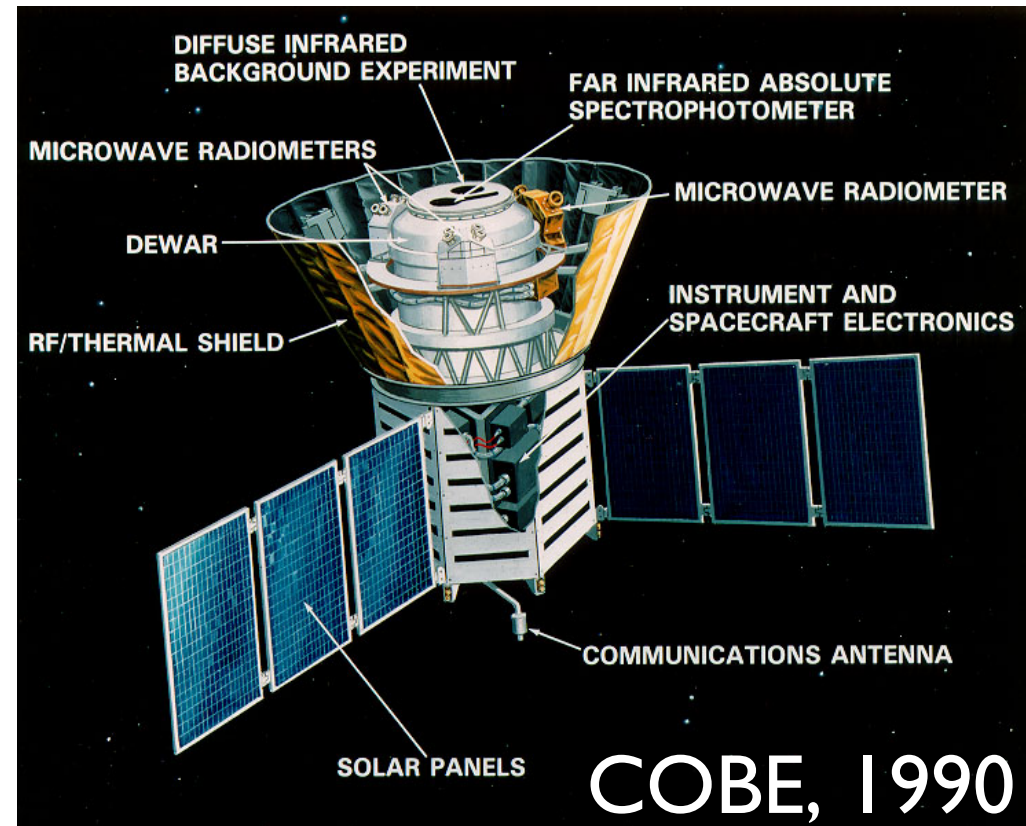
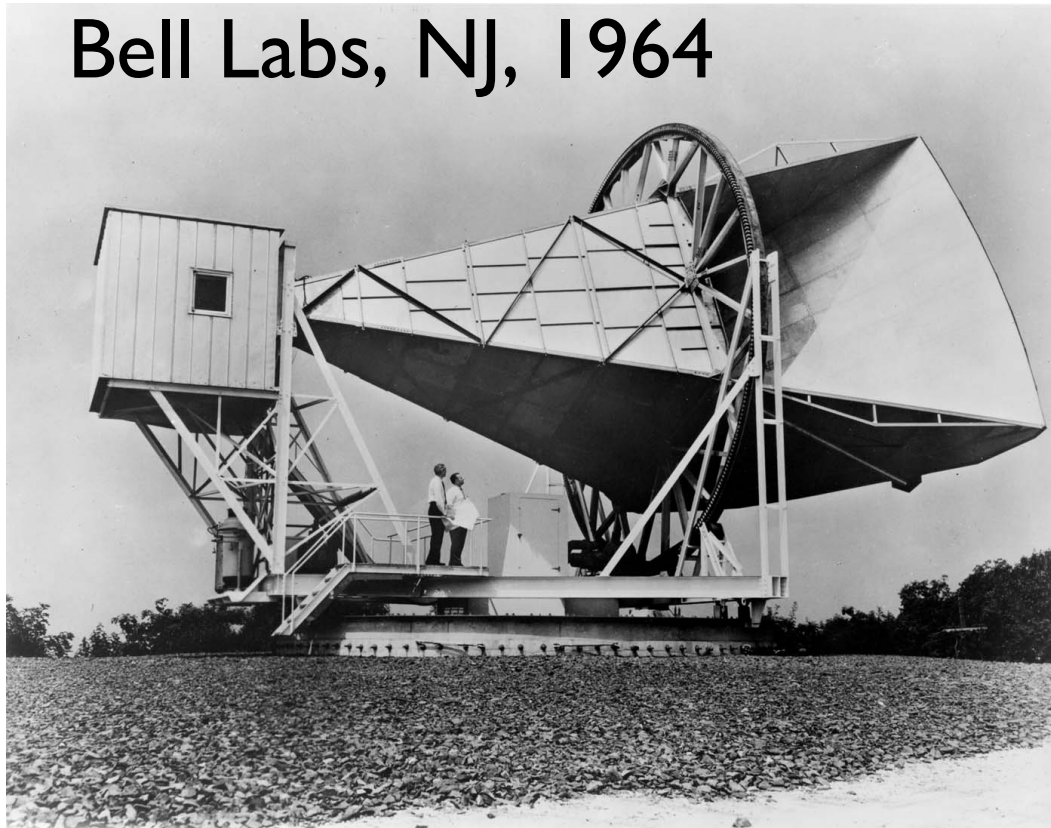


Relic Background Radiation

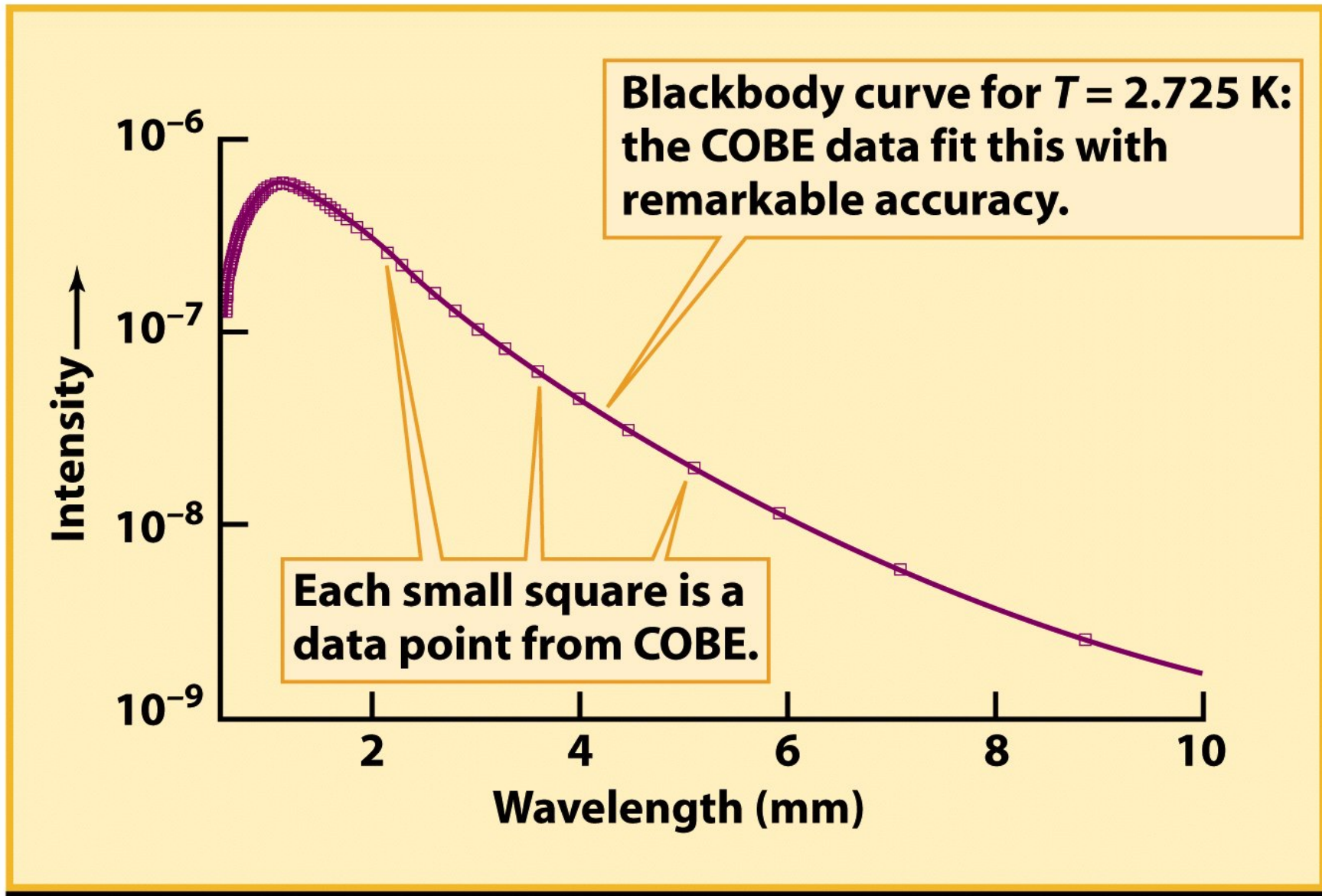
Redshifted to microwaves

Cold: ~ 3 K above abs. zero

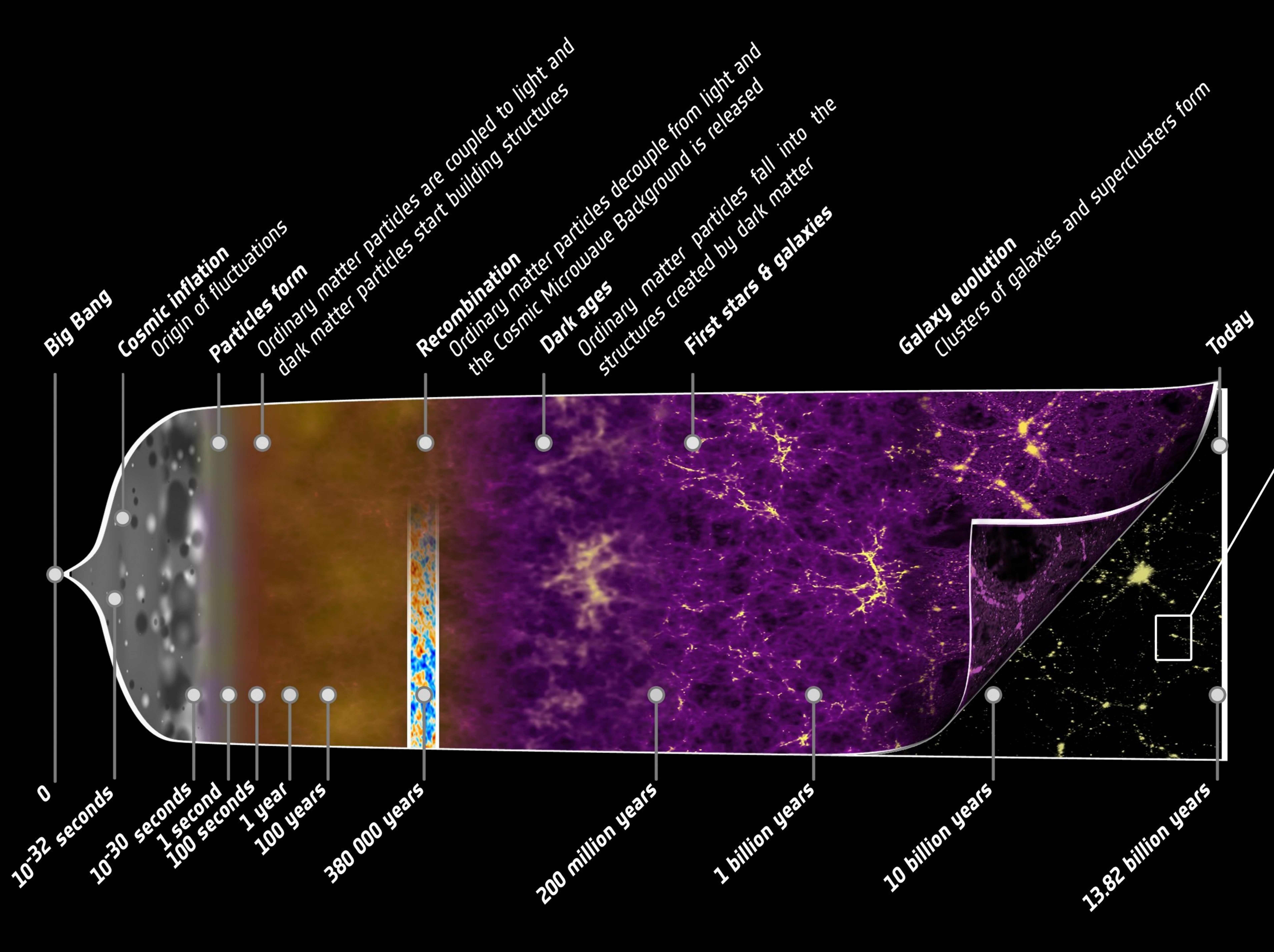
Bell Labs, NJ, 1964



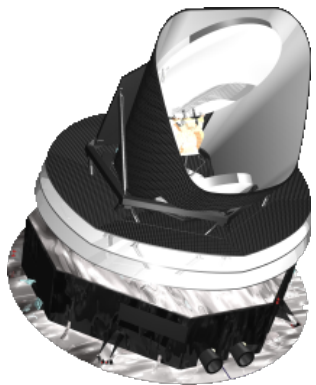
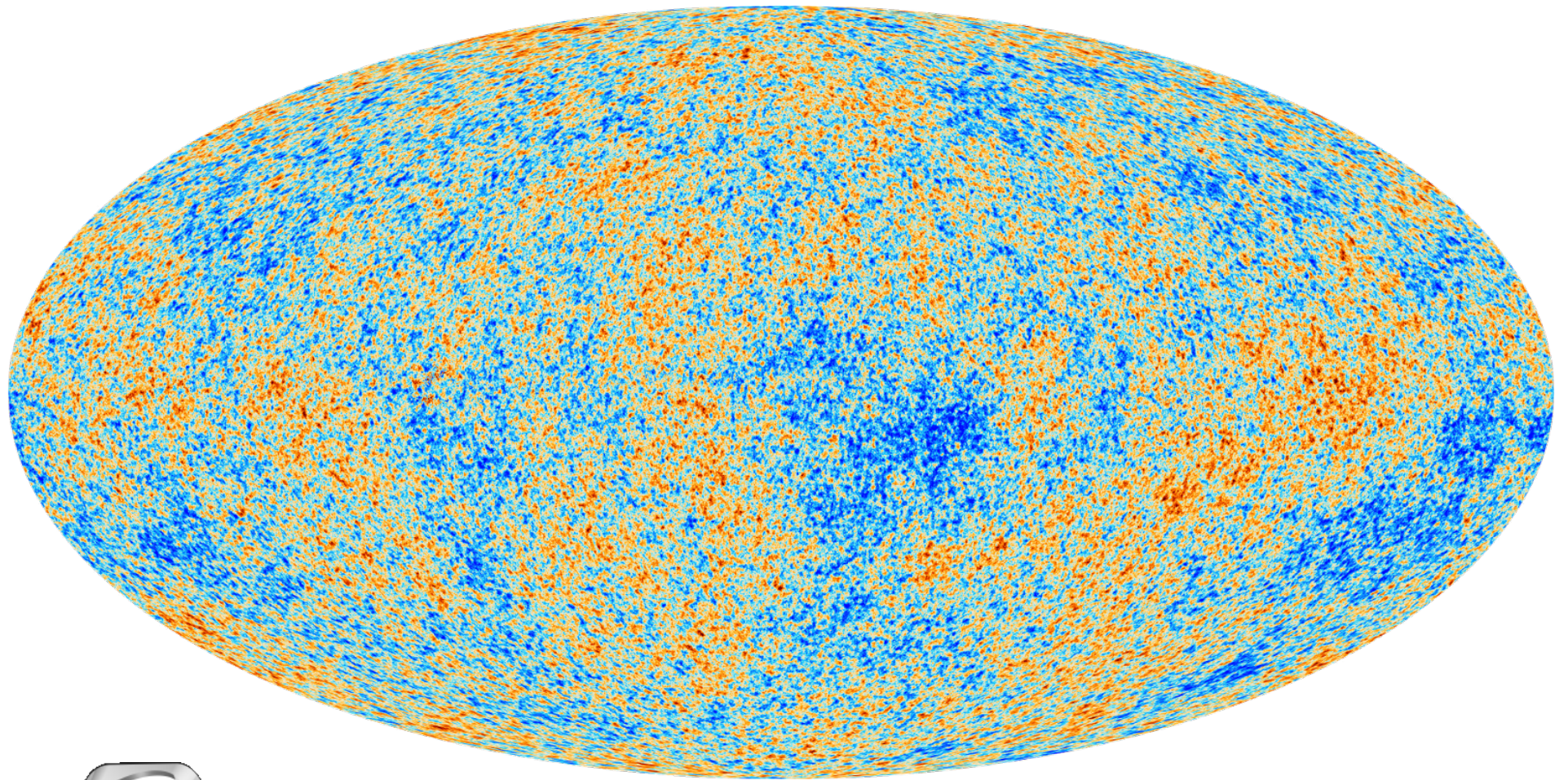
Each resulted in a
Nobel prize!



The spectrum of the cosmic microwave background



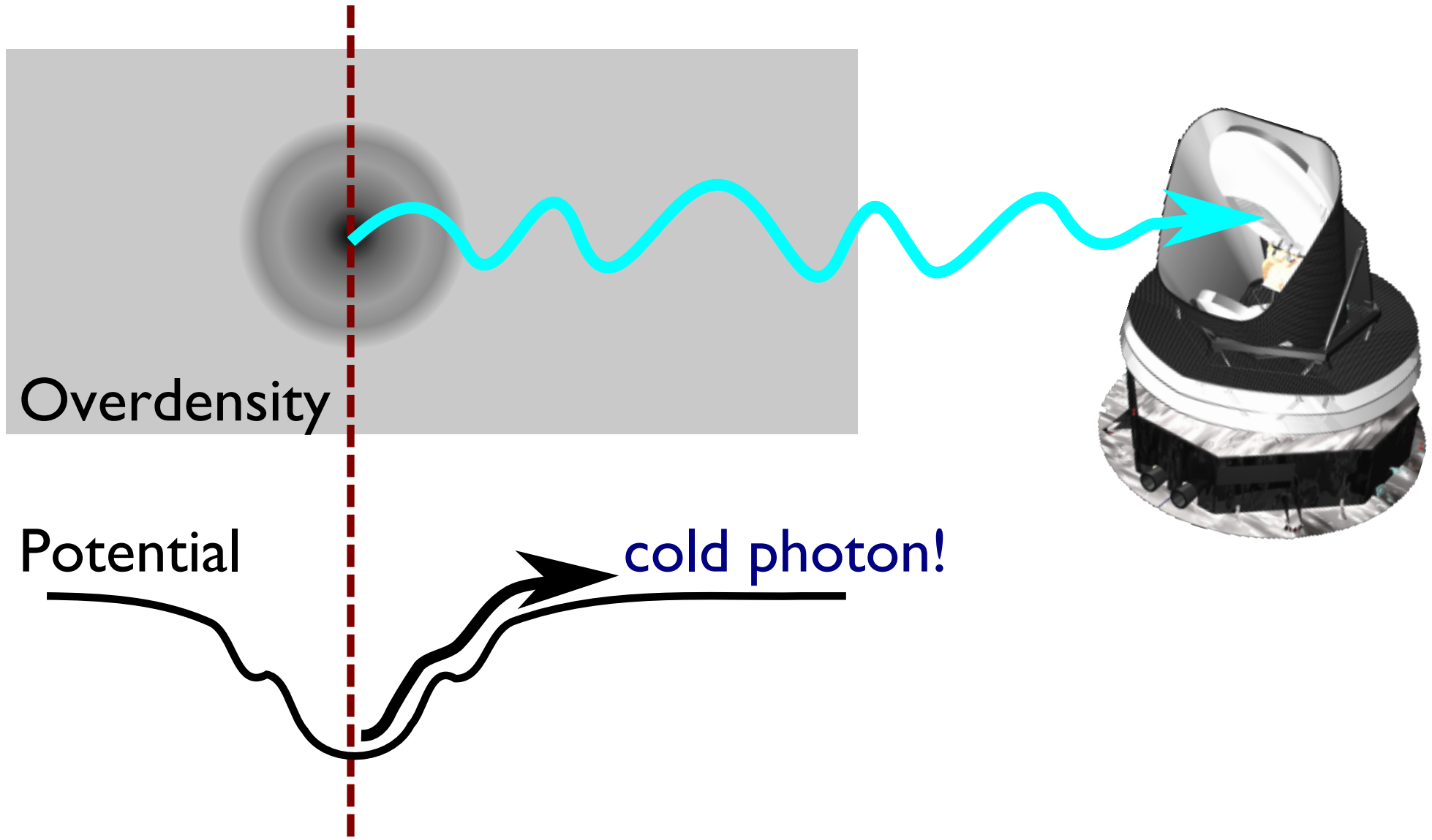
CMB fluctuations



~ few hundred μK around mean T

Probing gravitational potential

Recombination



Inflation and initial fluctuations

Unknown physics at high energies causes $\exp(60)$ -fold expansion could explain:

spatial flatness

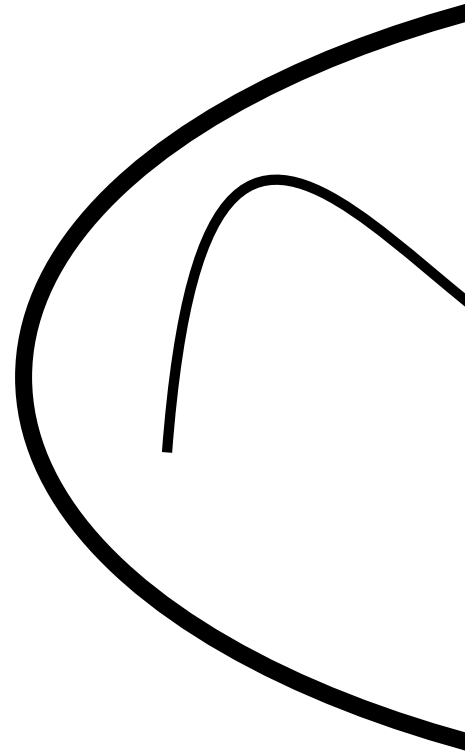
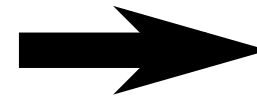
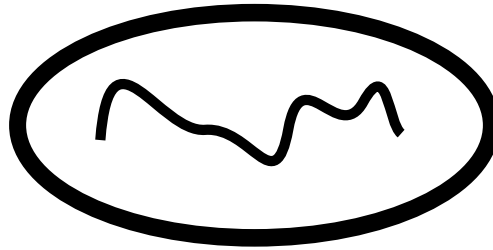
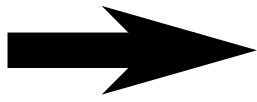
rarity of magnetic monopoles

uniformity of CMB sky

Expand by 10^{26} in 10^{-32} s (!) driven by a scalar field (?)

Inflaton

Inflation and initial fluctuations



quantum
fluctuations
in field value

macroscopic

cosmological

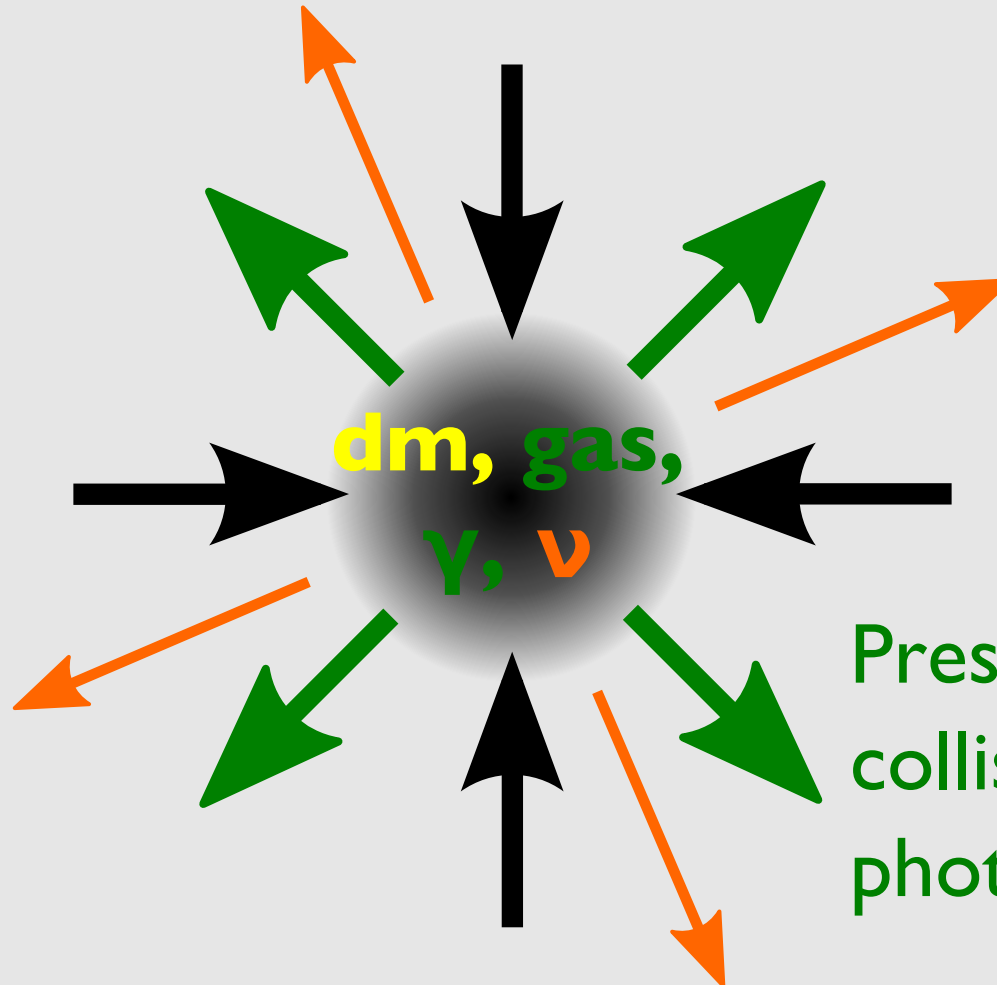
Nearly scale-free spectrum of initial fluctuations

Evolution of overdensity

Expansion of
the universe

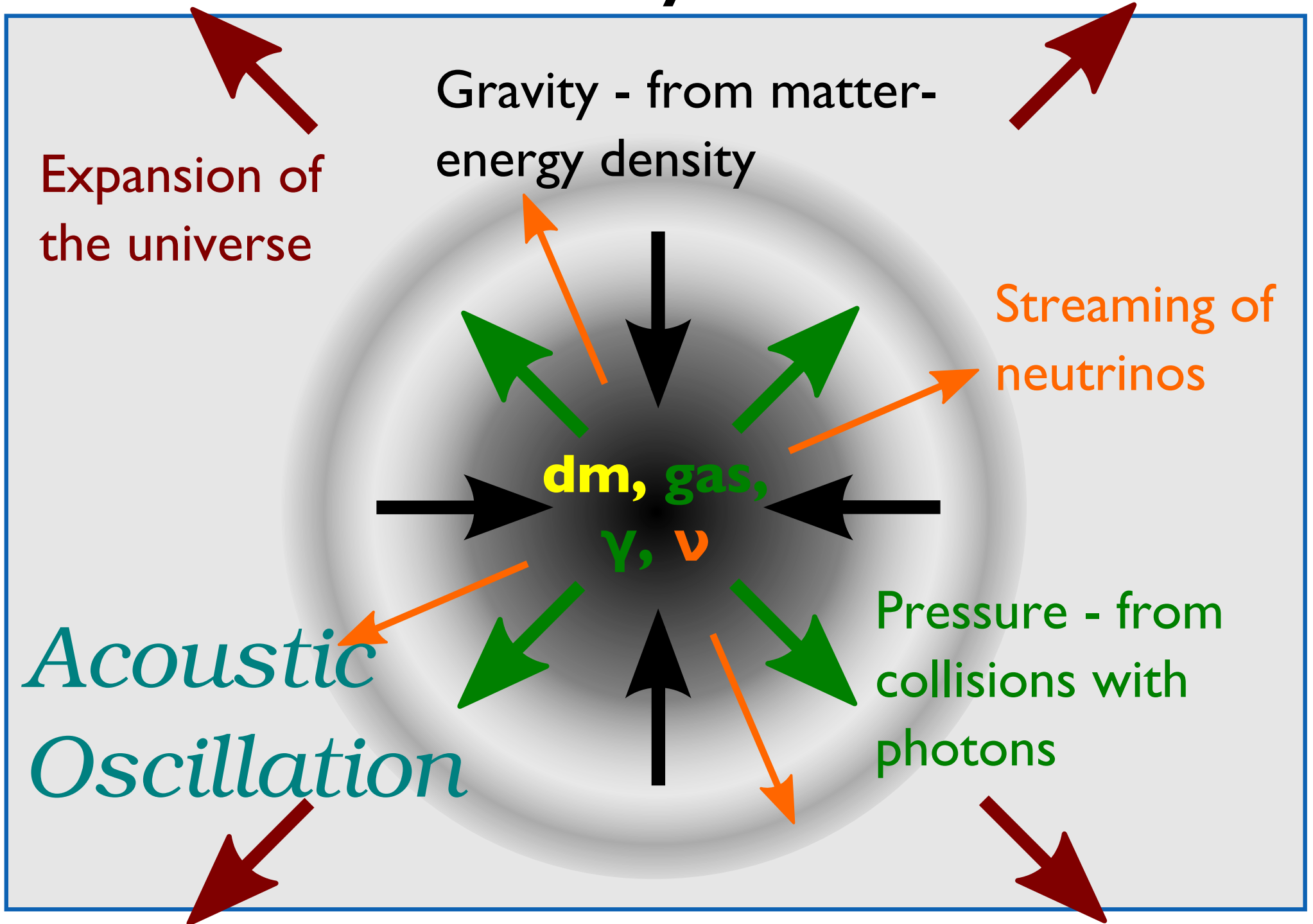
Gravity - from matter-
energy density

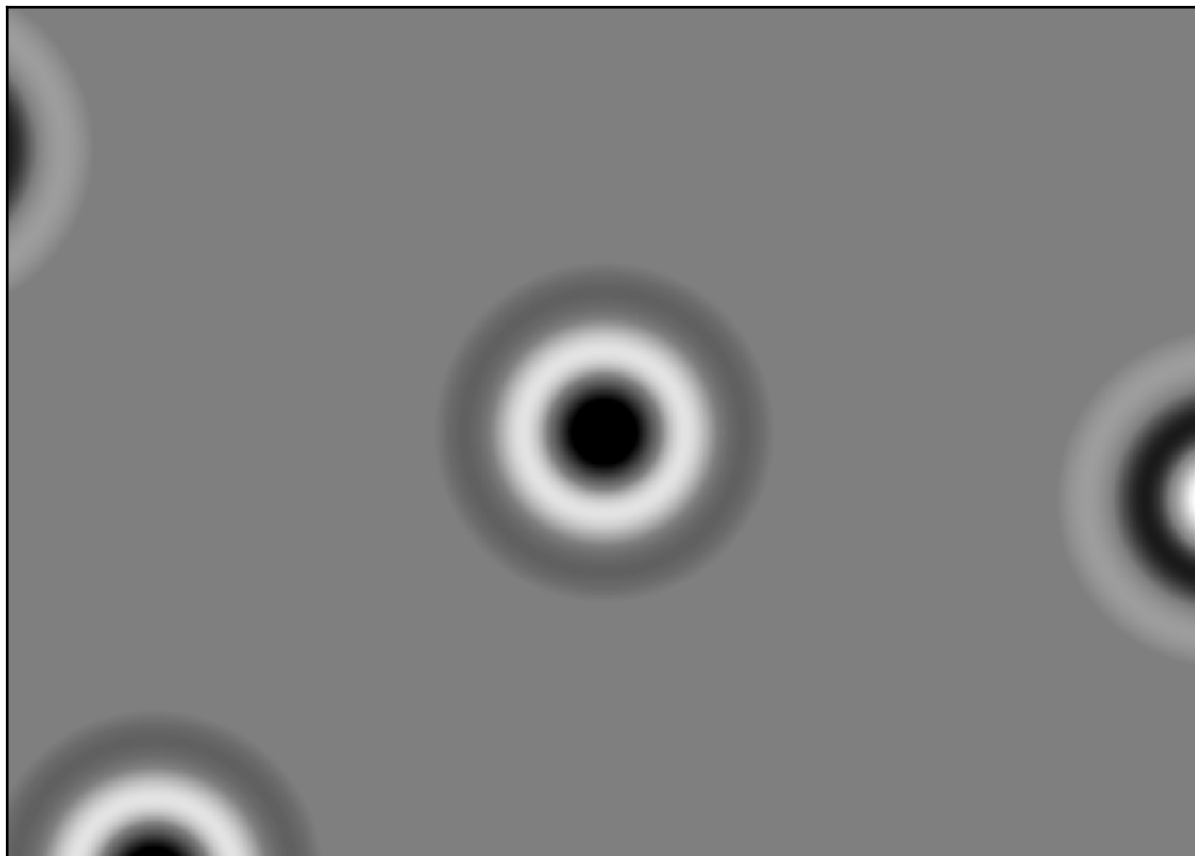
Streaming of
neutrinos

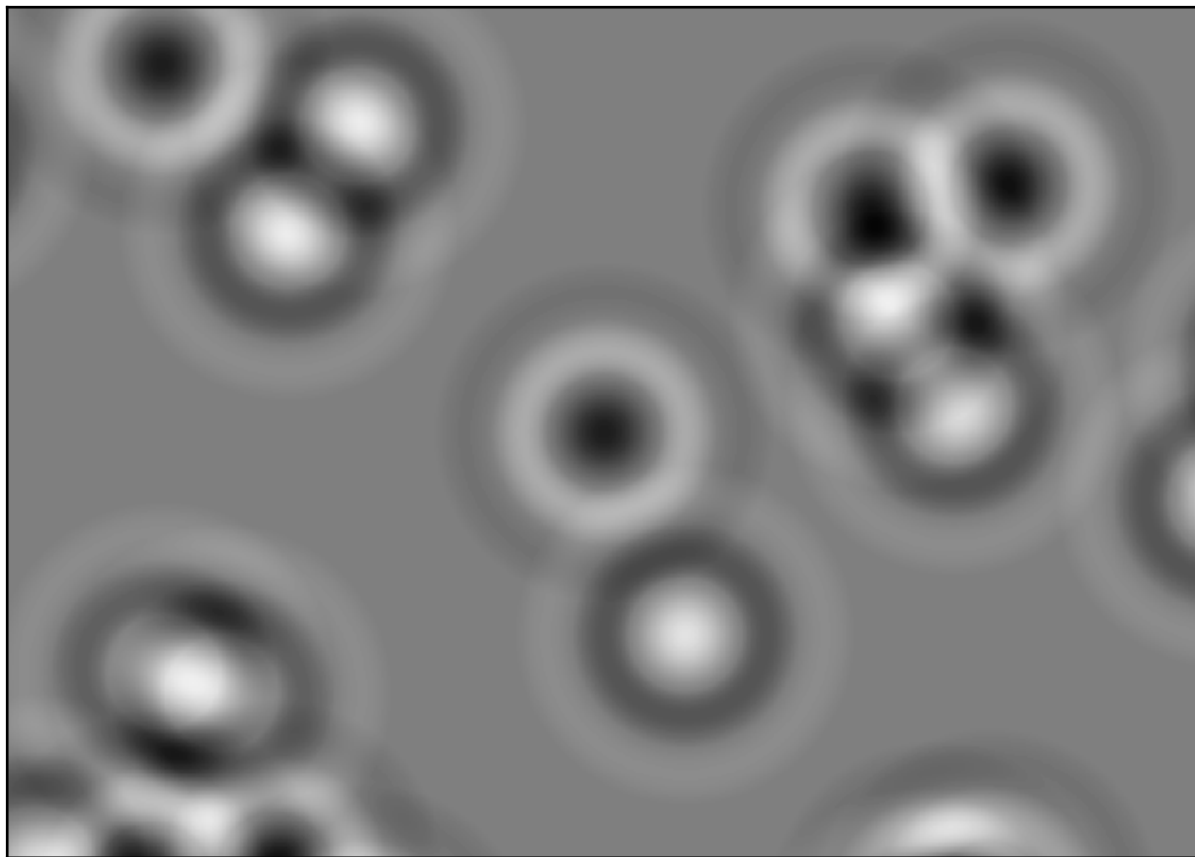


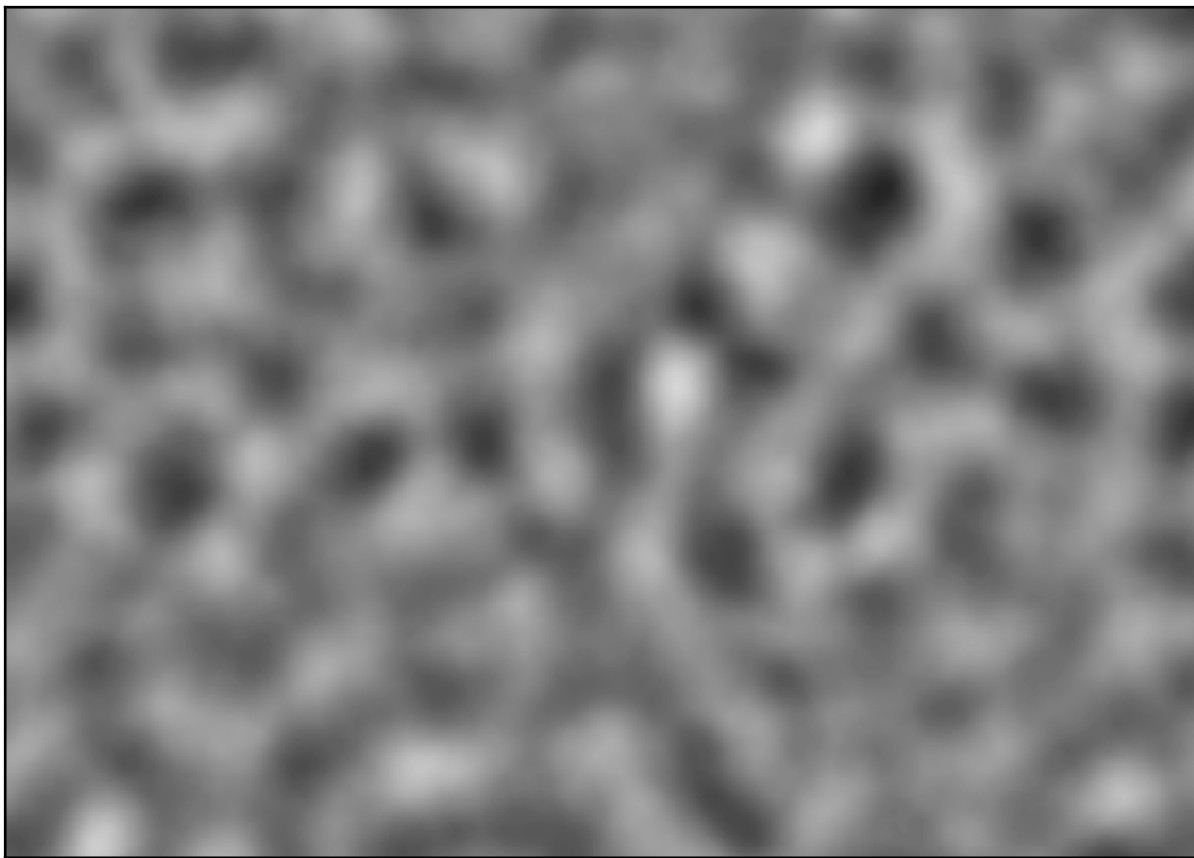
Pressure - from
collisions with
photons

Evolution of overdensity

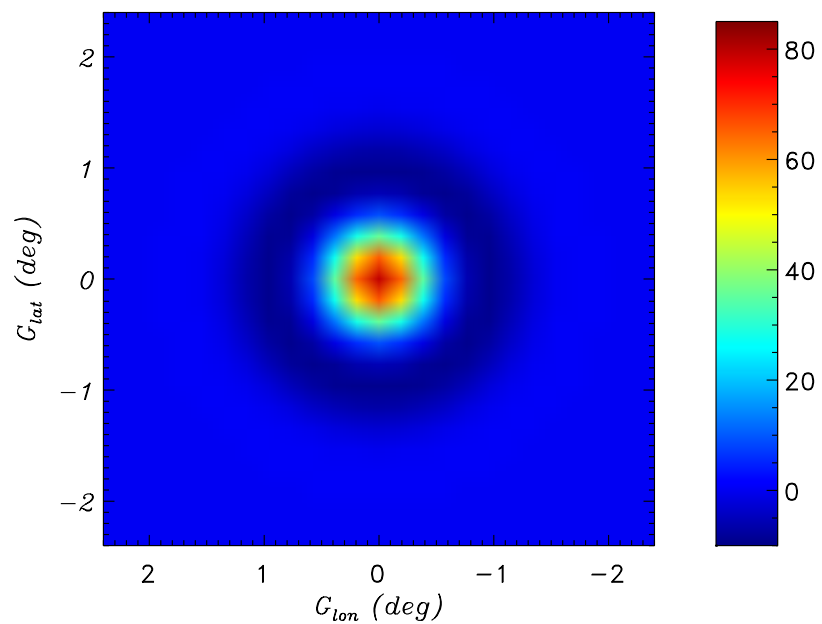
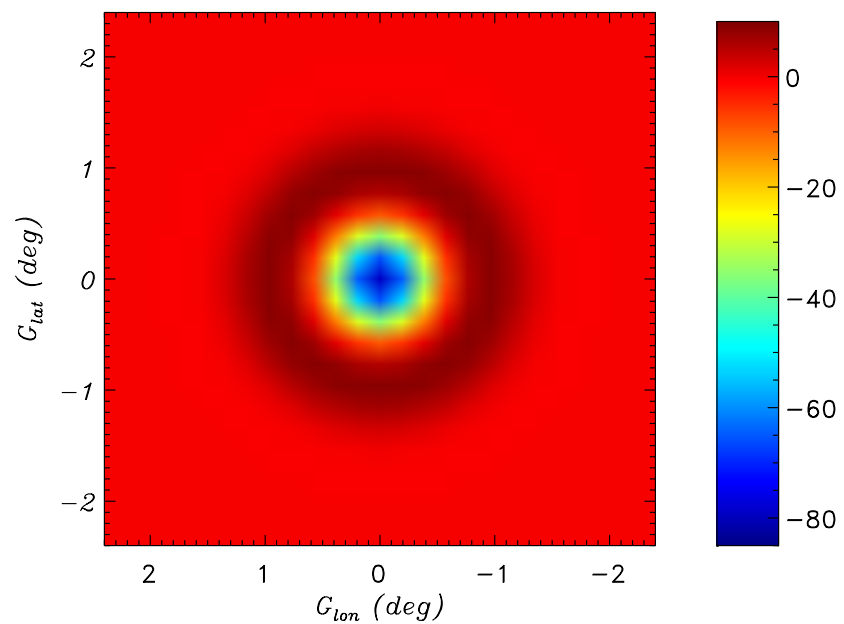
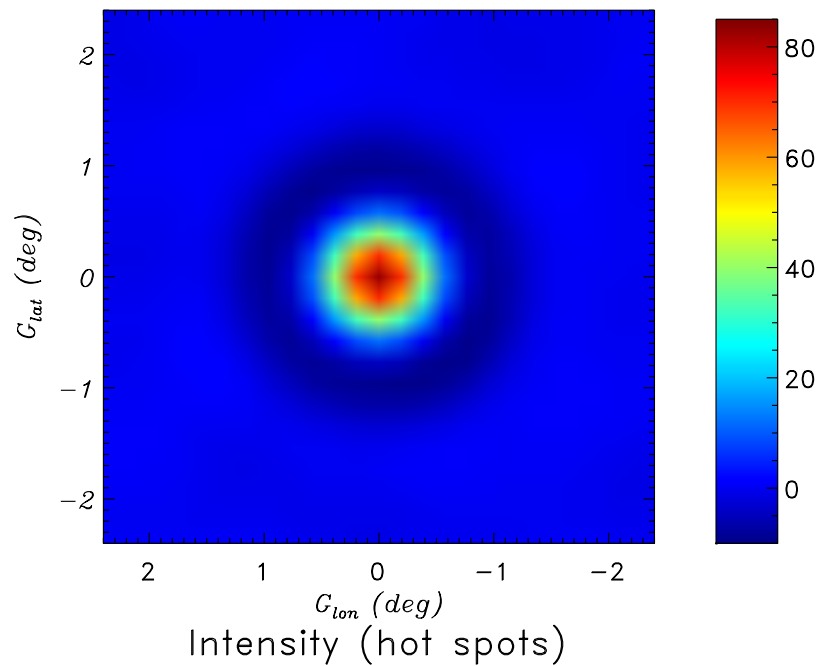
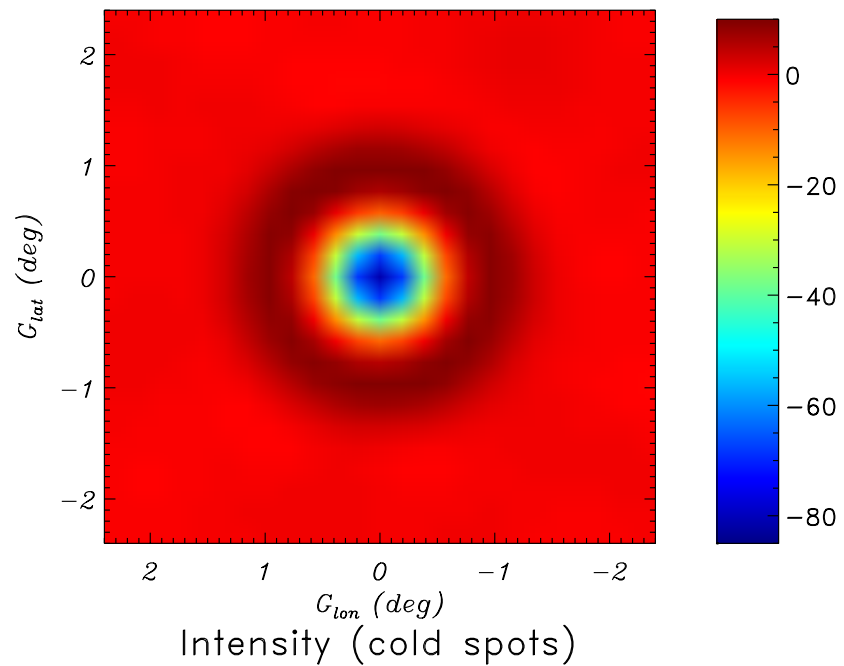




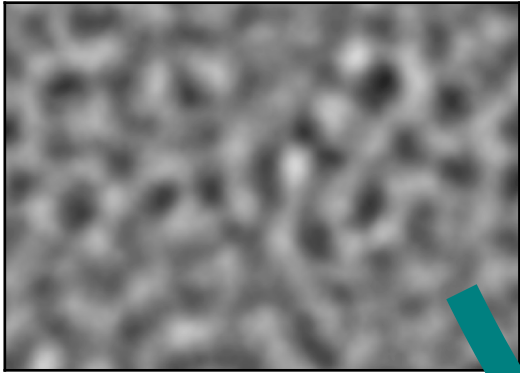




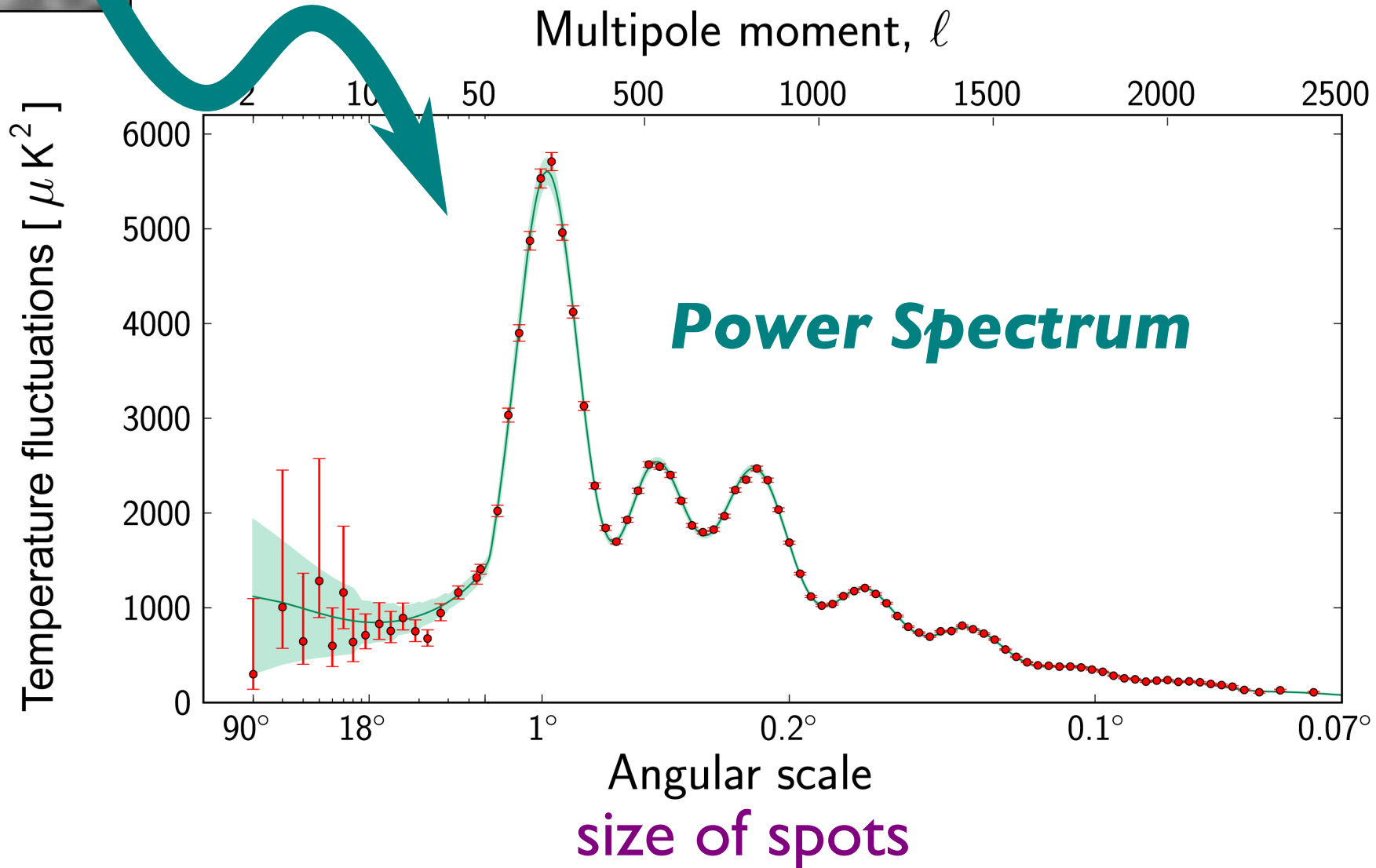
Average Planck map around extrema



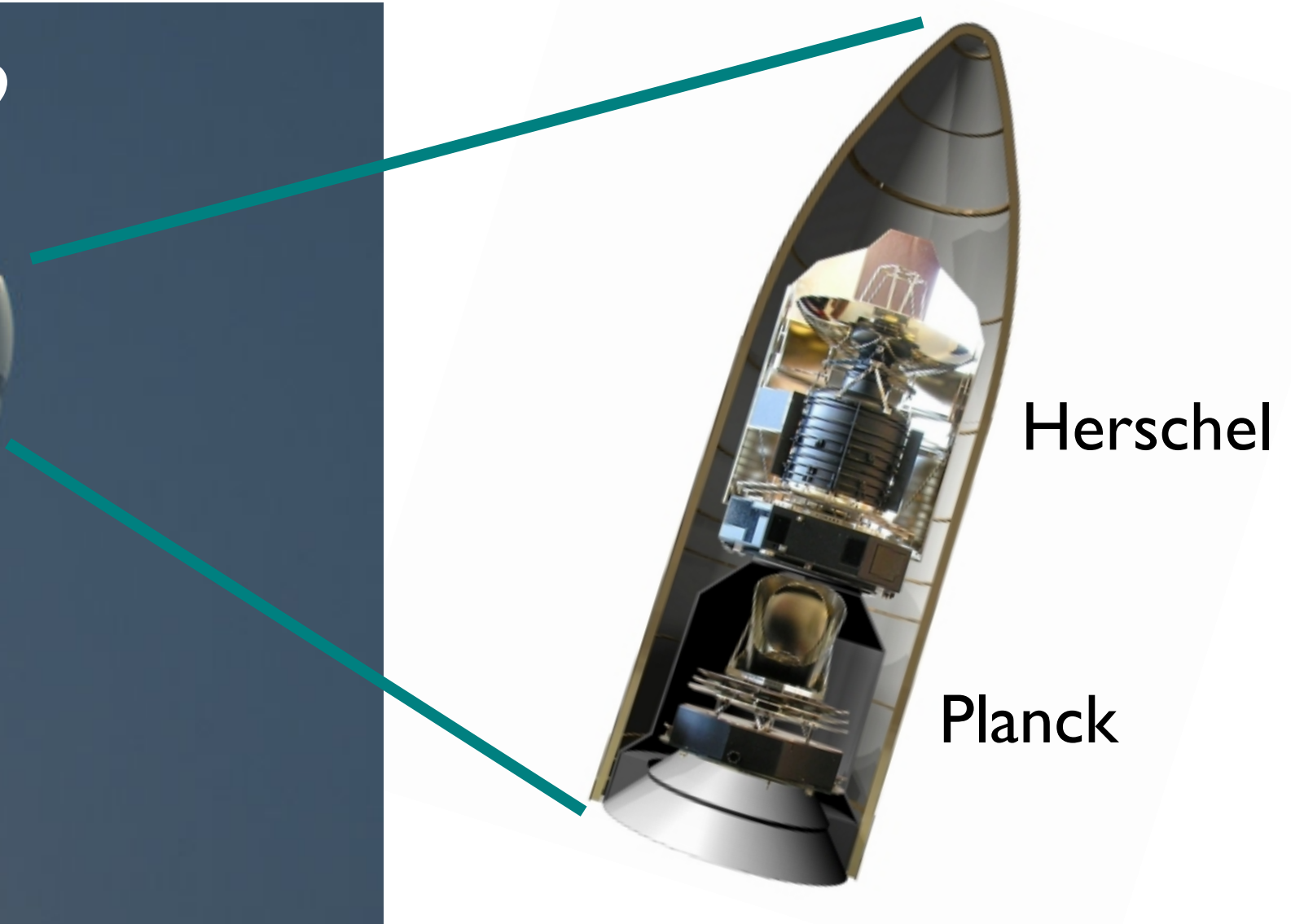
Correlations in a single graph



intensity
of
hot & cold
spots



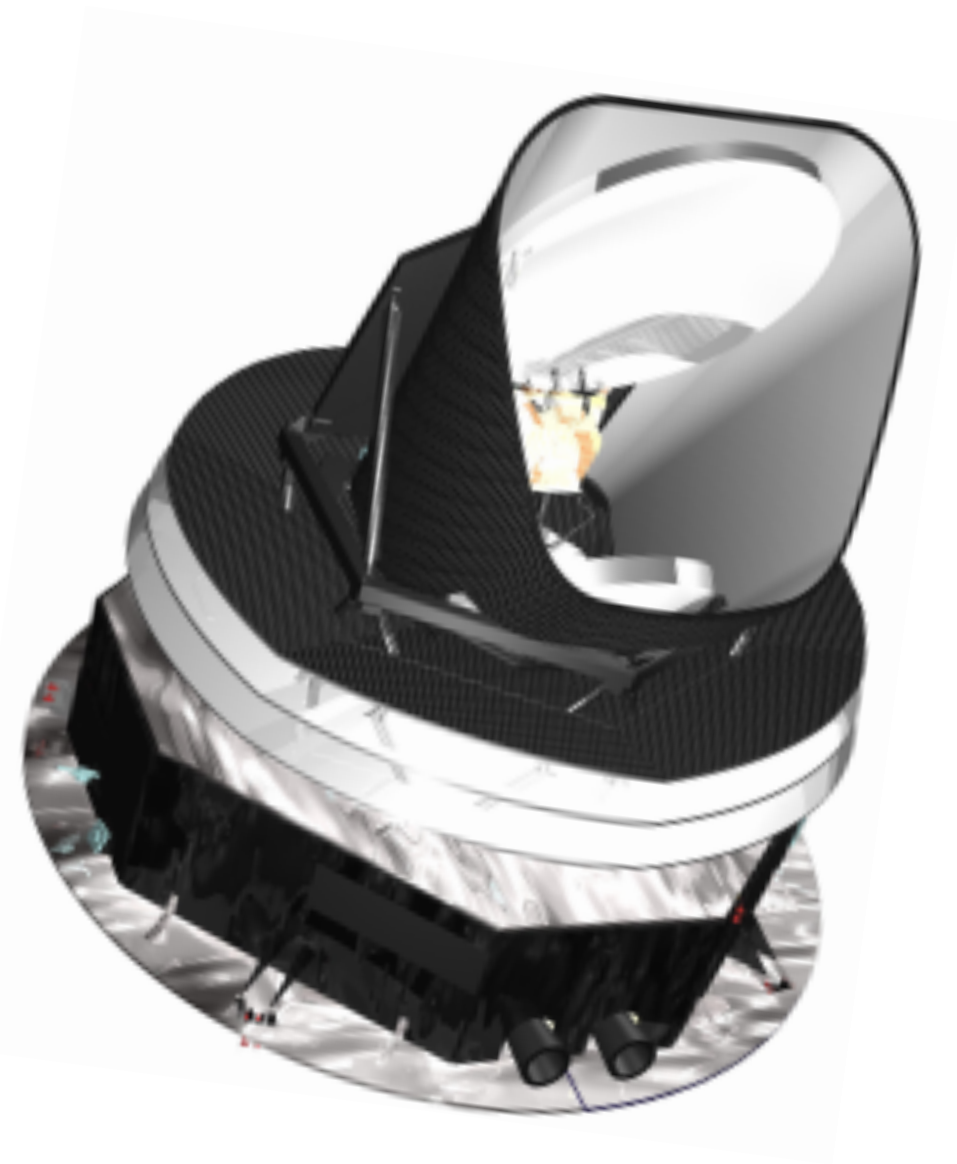
14 May 2009



1.5 million km away at L2

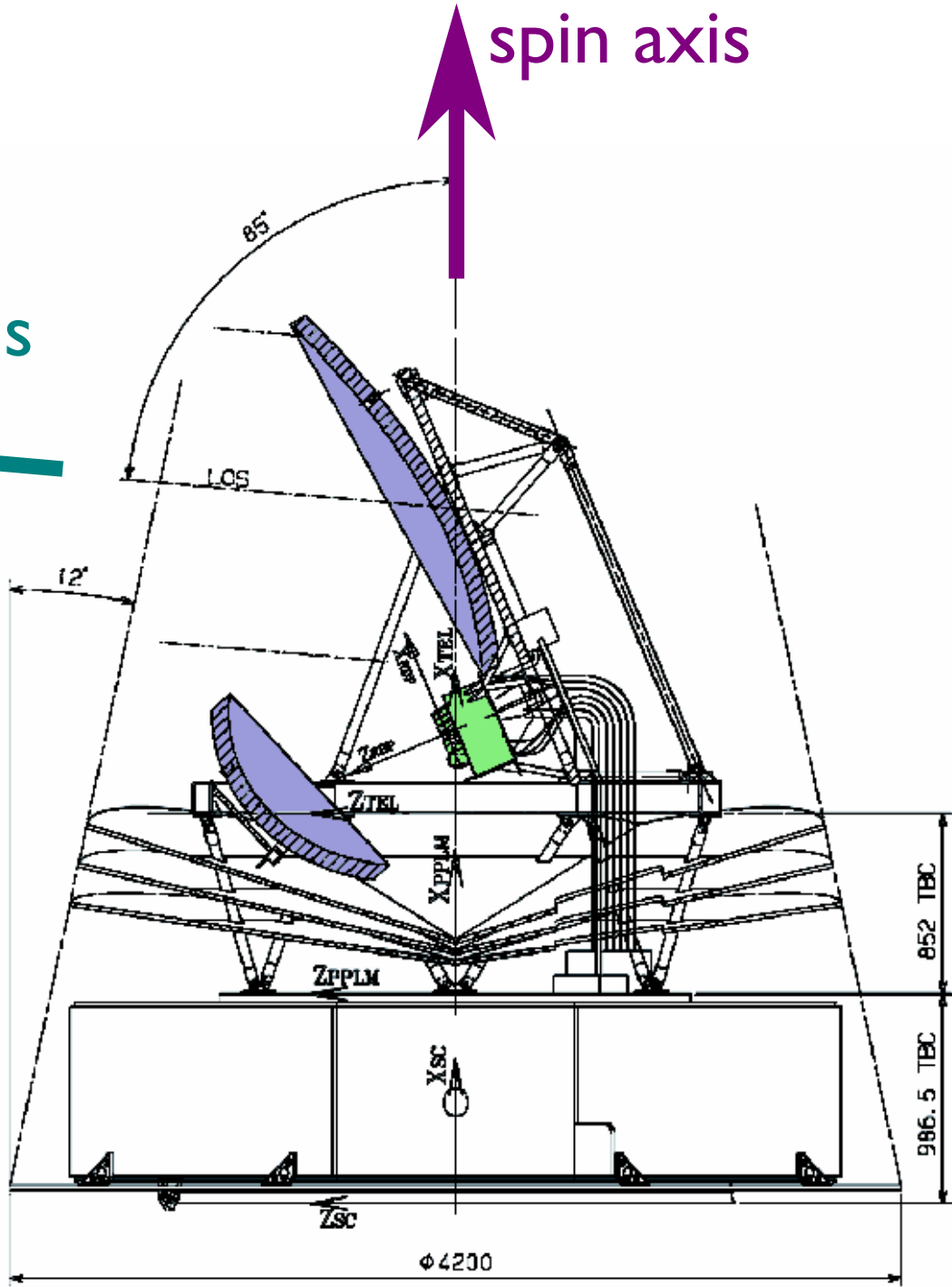


(movies)



optical axis

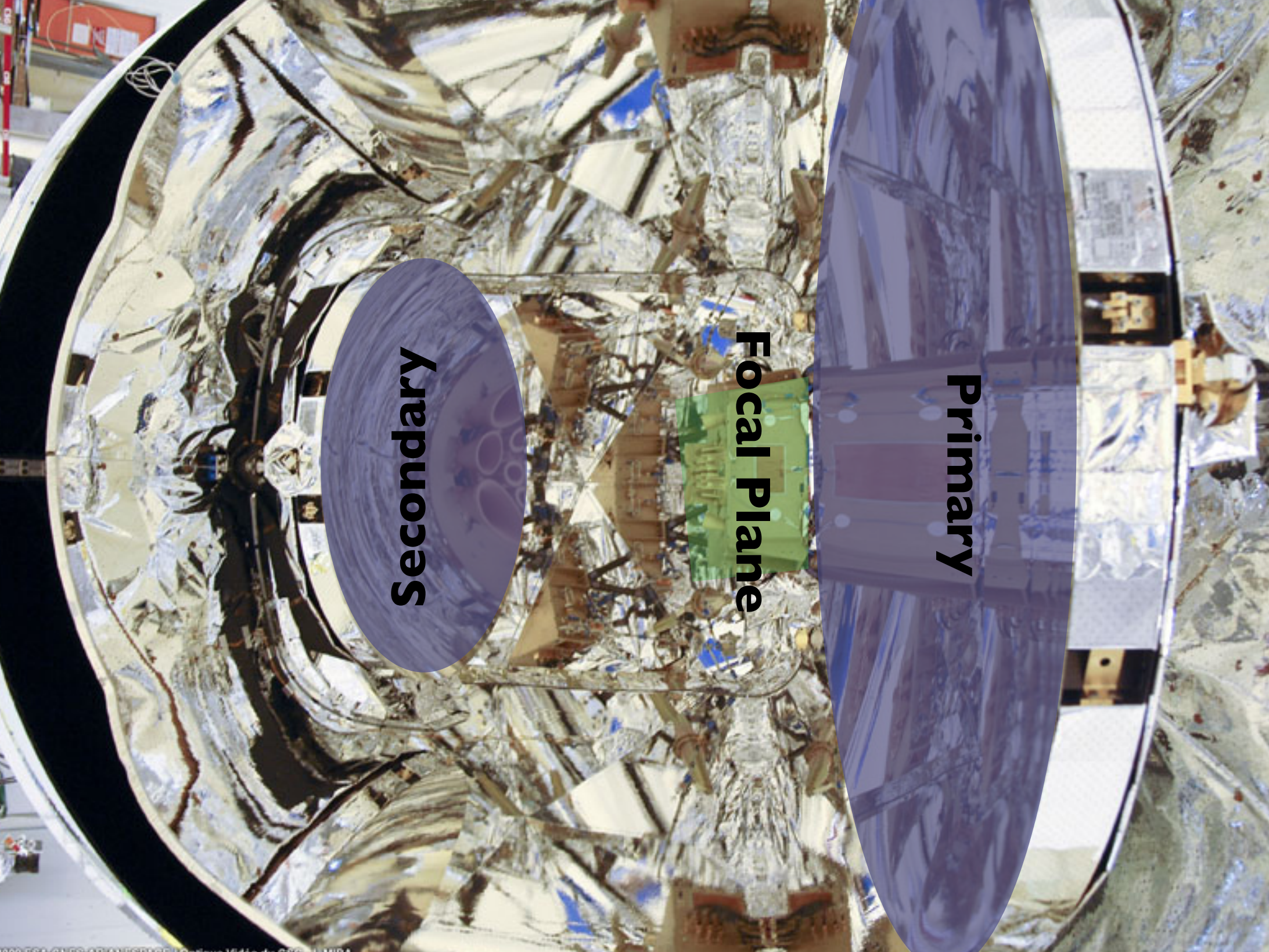
spin axis



Sunlight



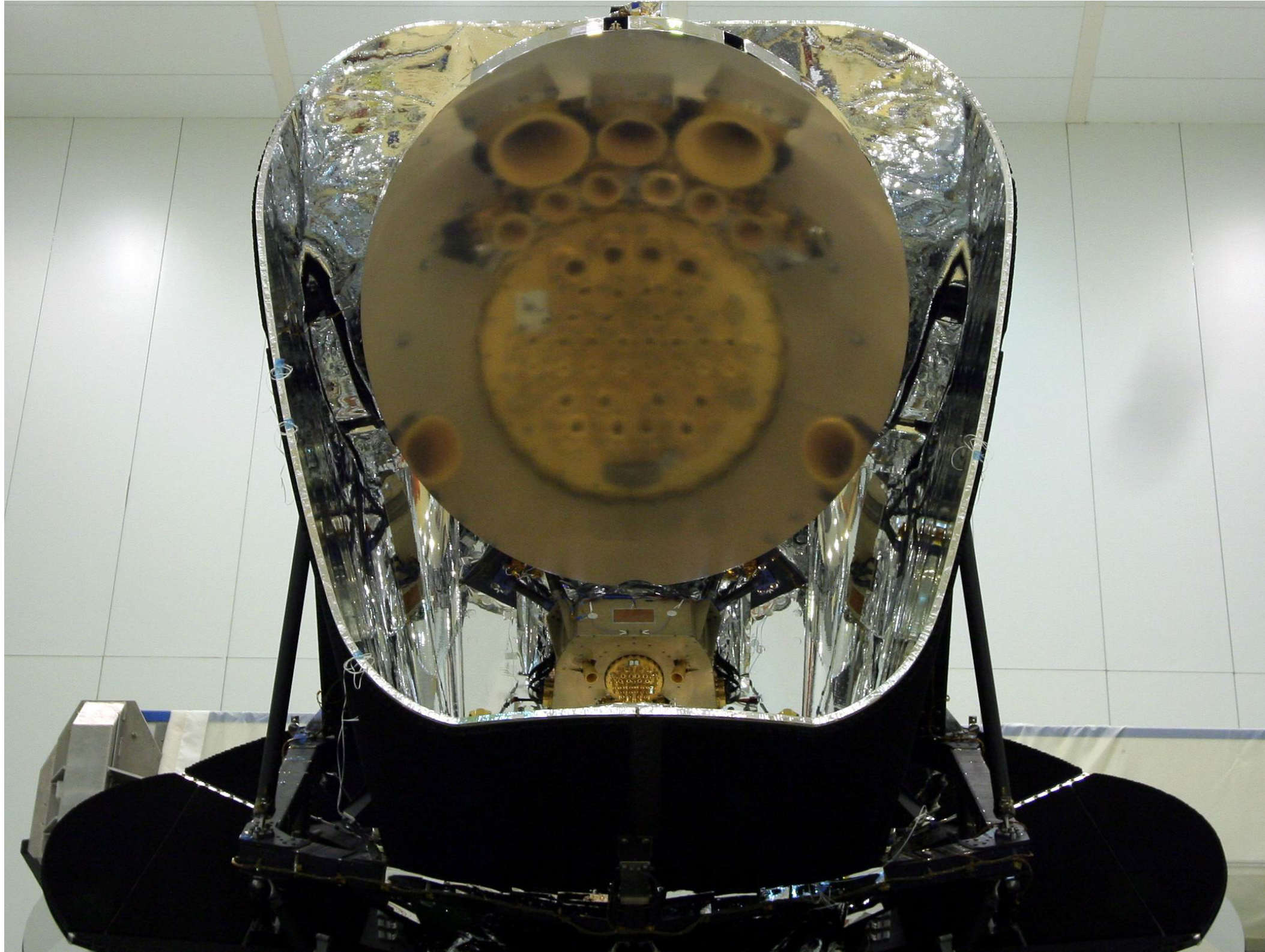




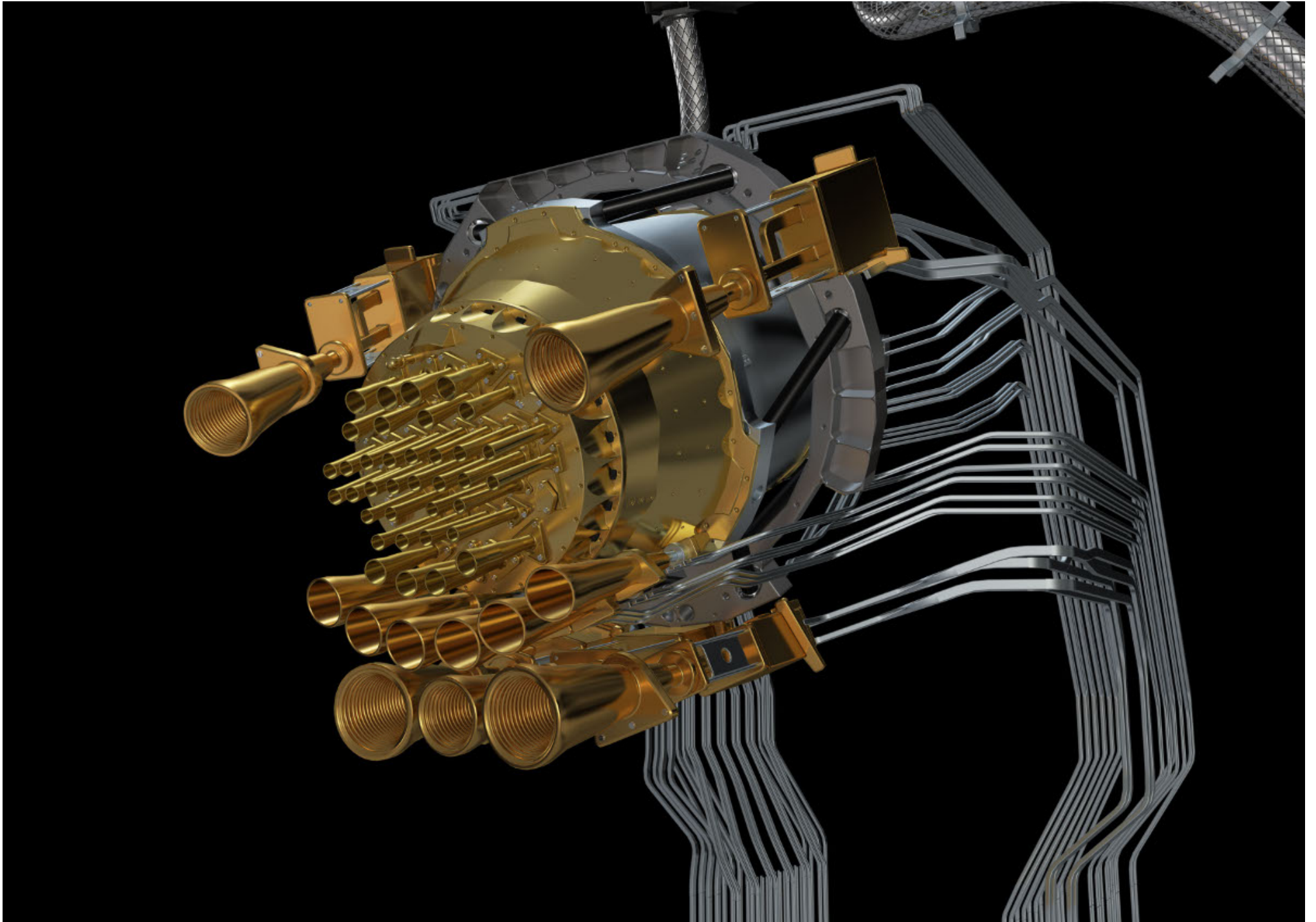
Primary

Focal Plane

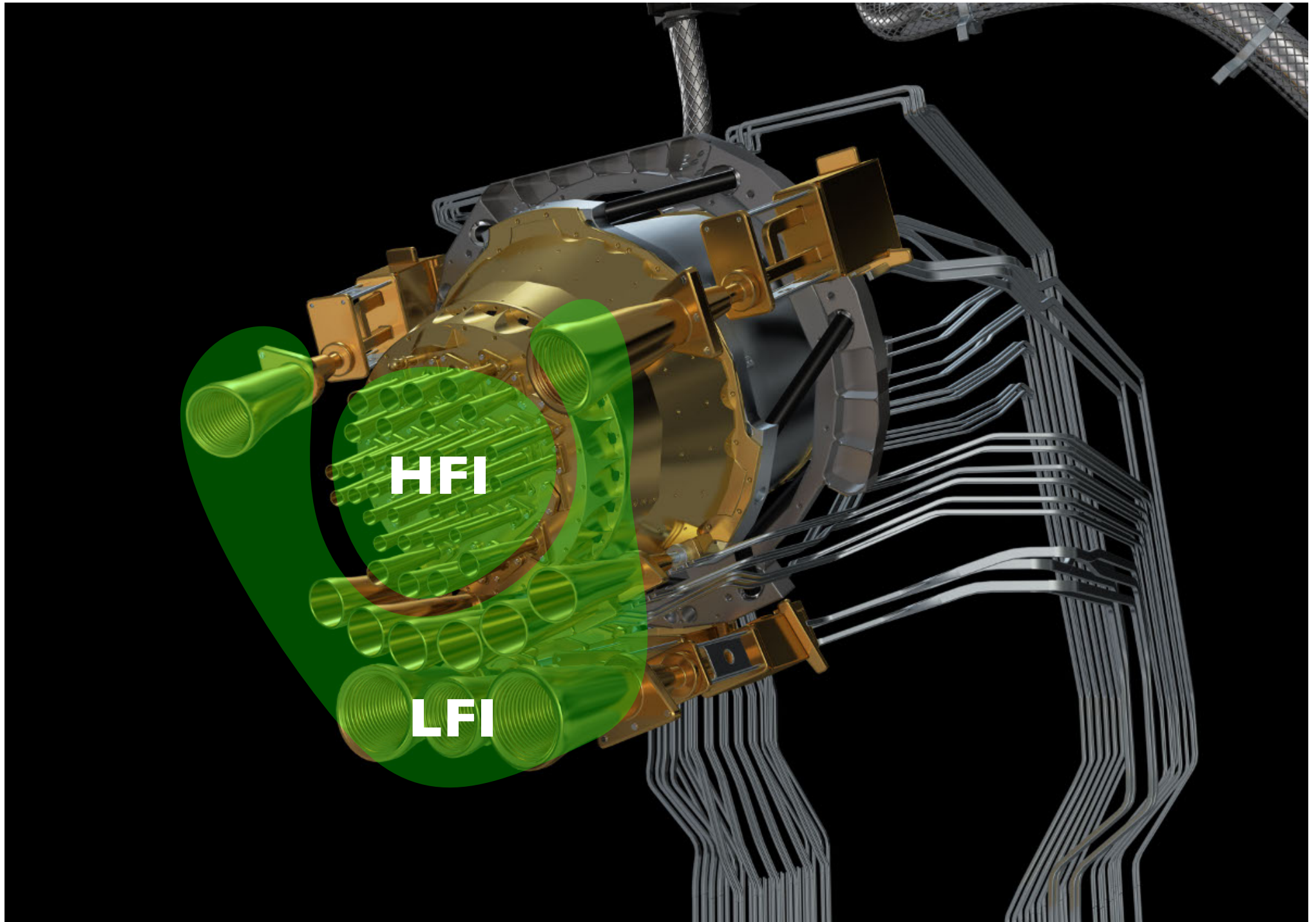
Secondary



Focal plane



Focal plane



Capabilities

Planck: 9 channels

30 44 70

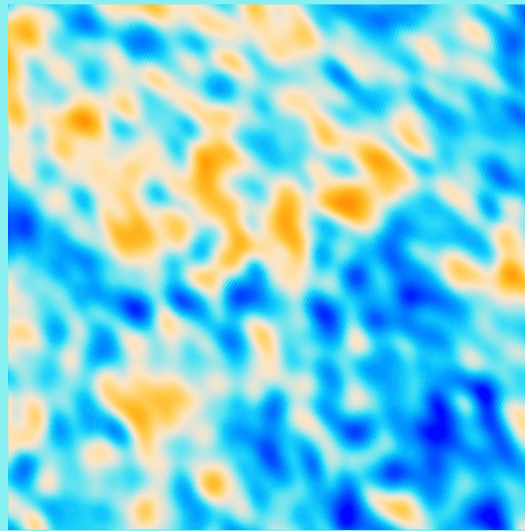
LFI

100 143 217 353 545 857 GHz

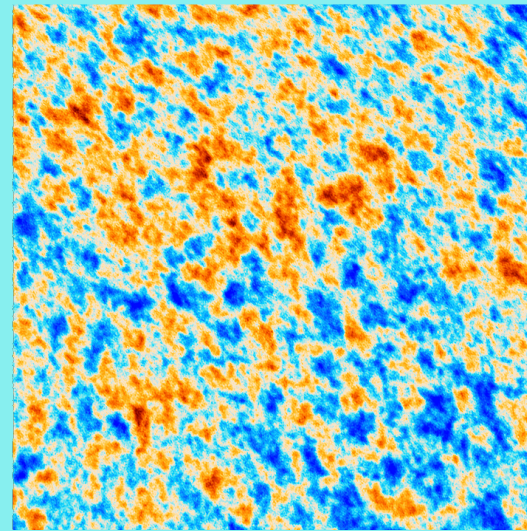
HFI

(20-30% bandwidth)

WMAP



Planck



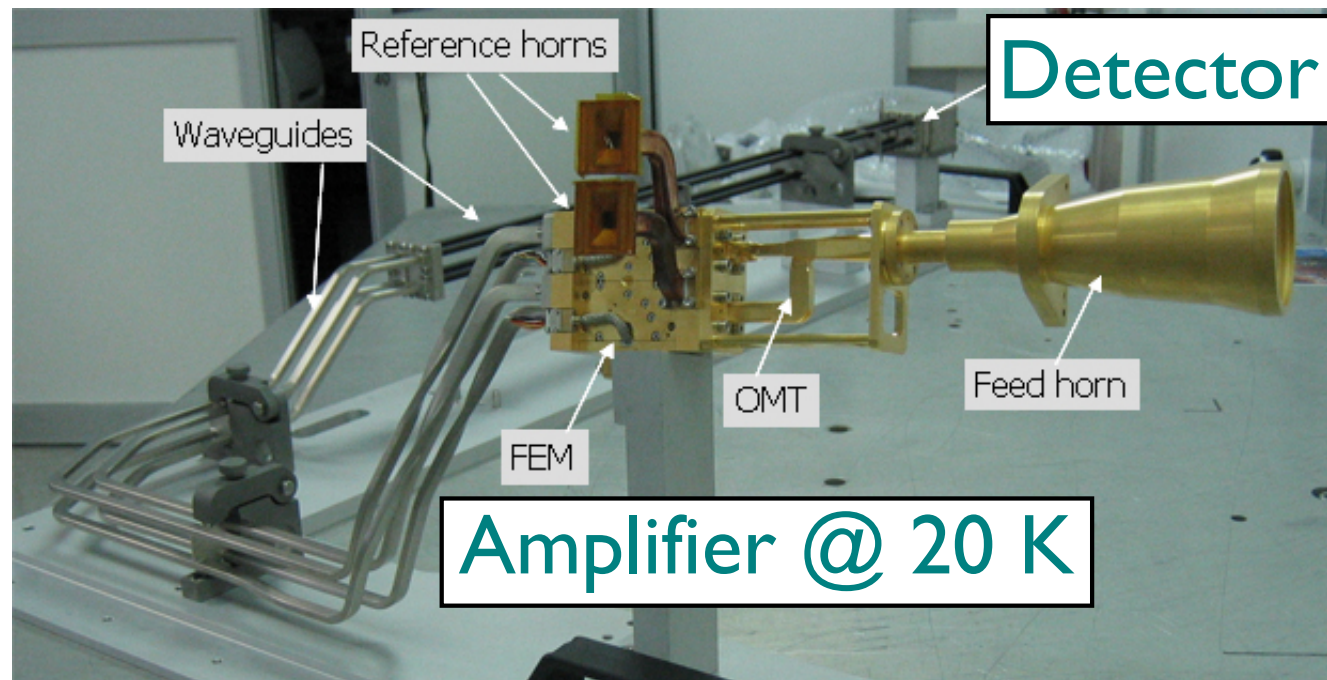
"3 times better resolution

&

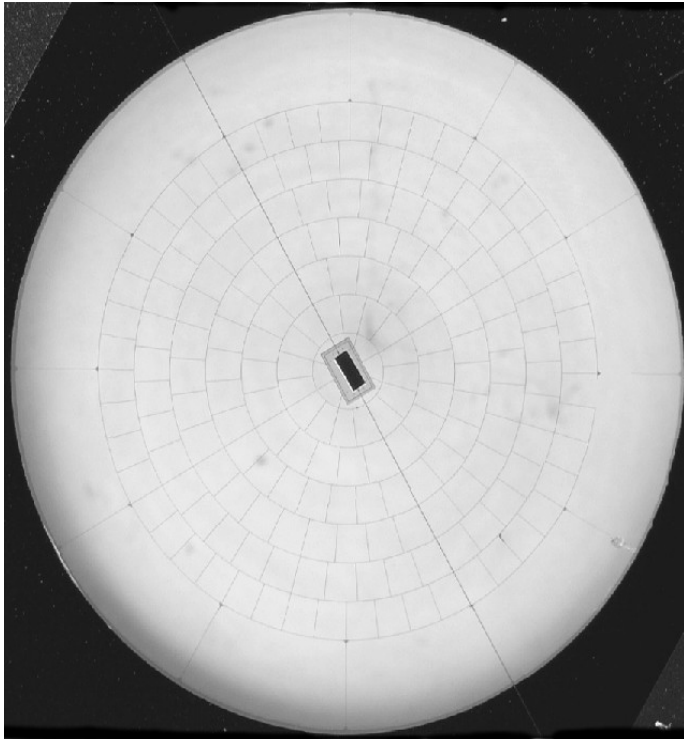
10 times lower noise than WMAP"

Technology - Low Frequency Instrument

Polarization sensitive radiometer



Technology - High Frequency Instrument

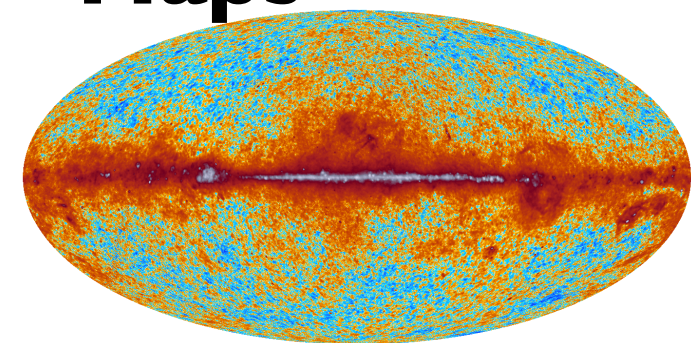


@ 0.1 K

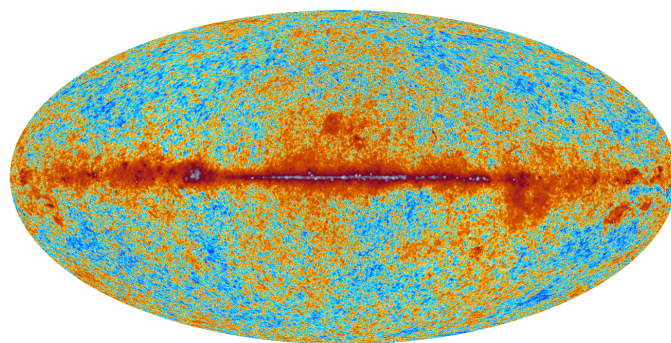
*O Langley invented the **bolometer**,
Which is really a kind of thermometer.
You can measure the heat
Of a polar bear's seat
At a distance of half a kilometer.*



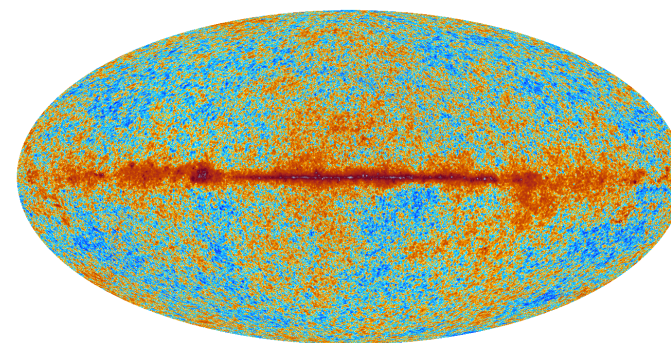
Maps



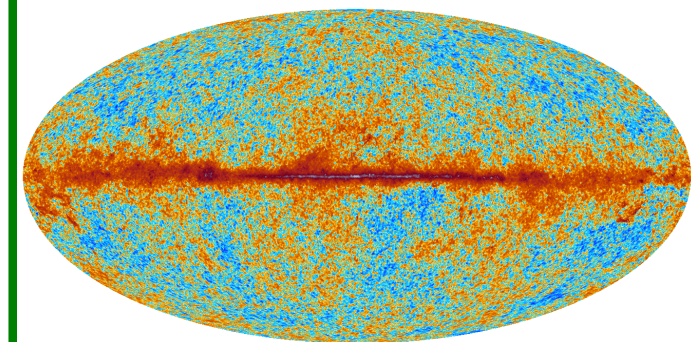
30



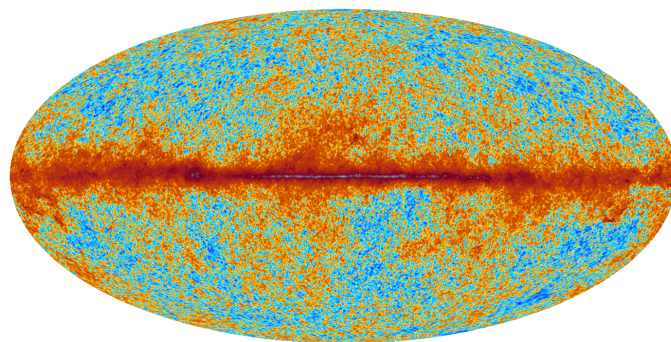
44



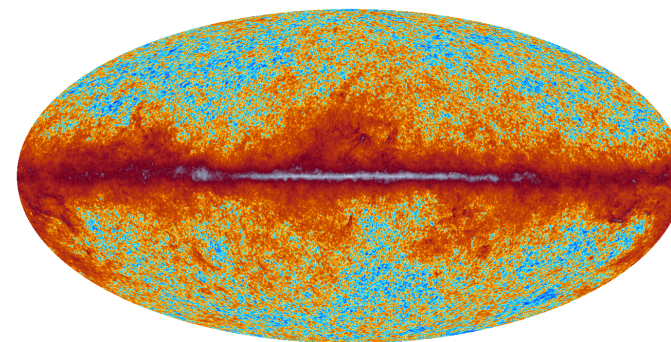
70



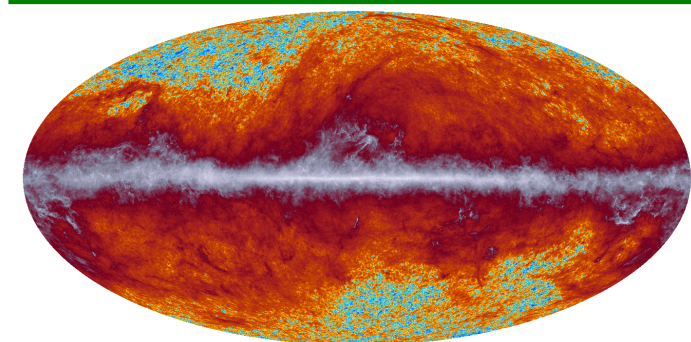
100



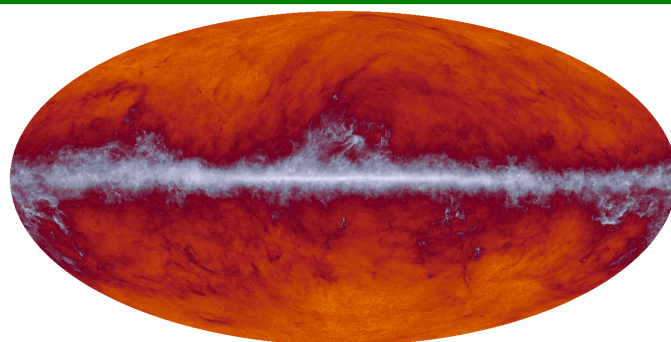
143



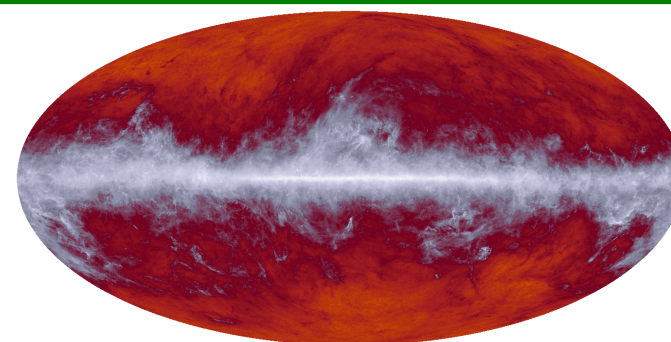
217



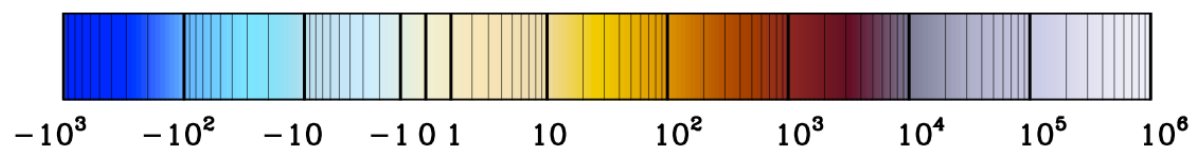
353



545



857



30–353 GHz: δT [μK_{CMB}]; 545 and 857 GHz: surface brightness [kJy/sr]

"All the News
That's Fit to Print"

The New York Times

National Edition

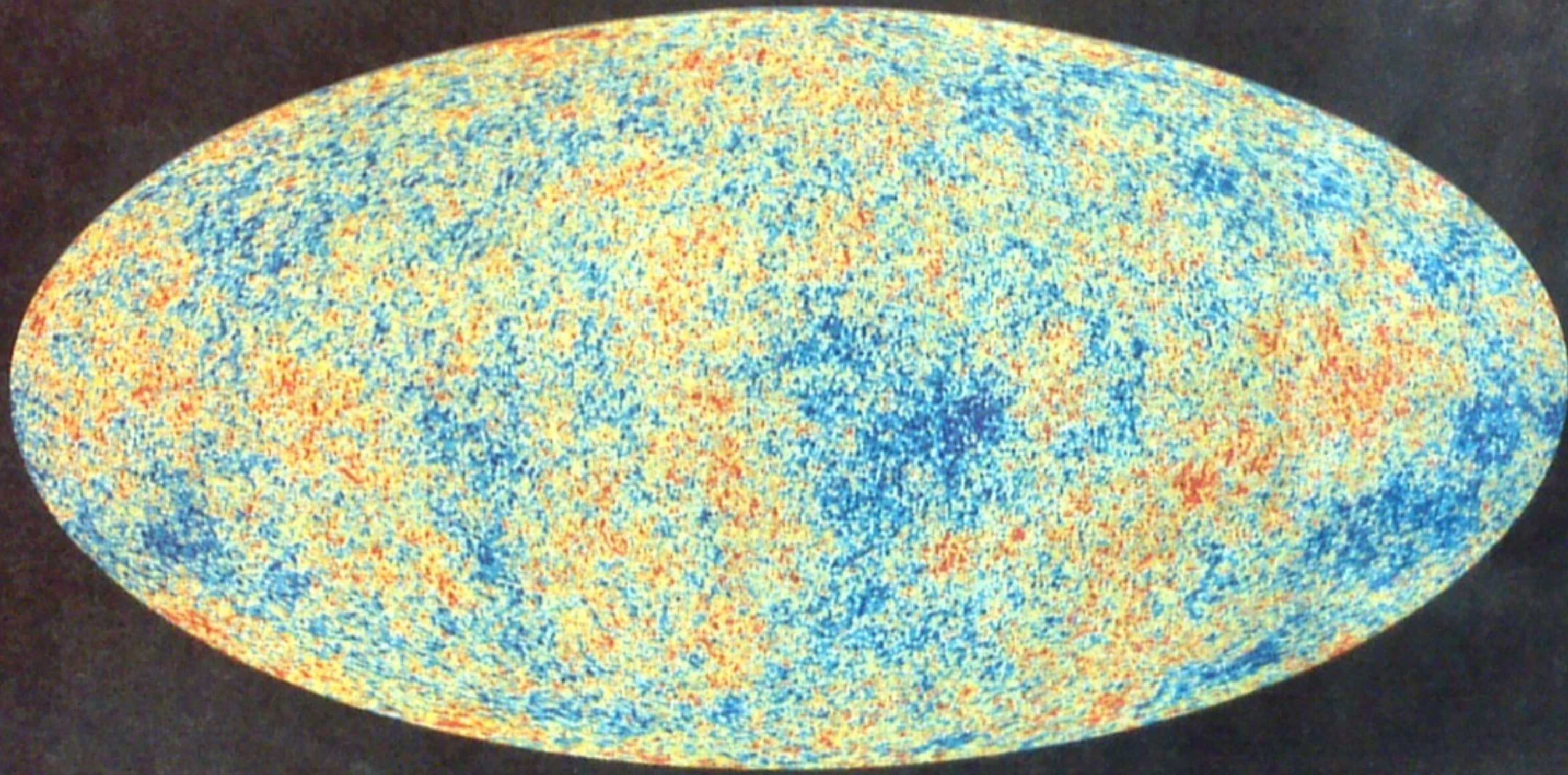
Florida. A mix of sun and clouds. Afternoon showers. Highs 70s to near 80. Showers central and north tonight. Partly cloudy south. Lows 50s to 70s. Weather map, Page B10.

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ESA, PLANCK COLLABORATION VIA NASA, VIA ASSOCIATED PRESS

The Cosmos, Back in the Day

An image from data recorded by a European Space Agency satellite shows a heat map of the universe as it appeared 370,000 years after the Big Bang. Page A10.

PRESIDENT URGES ISRAELIS TO PUSH EFFORT FOR PEACE

APPEAL AIMED AT YOUNG

In Jerusalem, He Eases
Stance on Settlement
Halt Before Talks

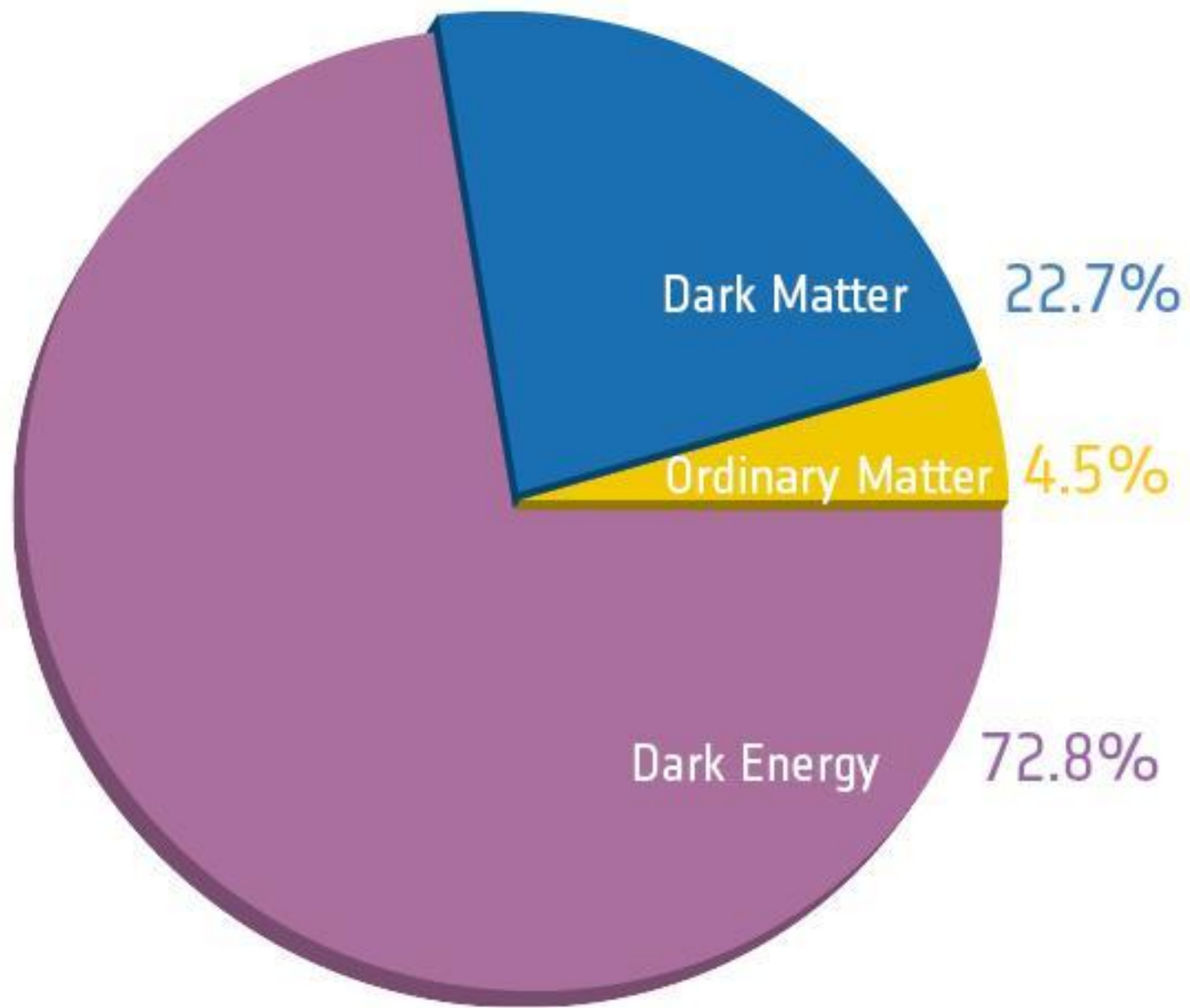
By MARK LANDLER

JERUSALEM — President Obama, appealing to very disparate audiences to solve one of the world's thorniest problems, moved closer on Thursday to the Israeli government's position on resuming long-stalled peace talks with the Palestinians, even as he passionately implored young Israelis to get ahead of their own leaders in the push for peace.

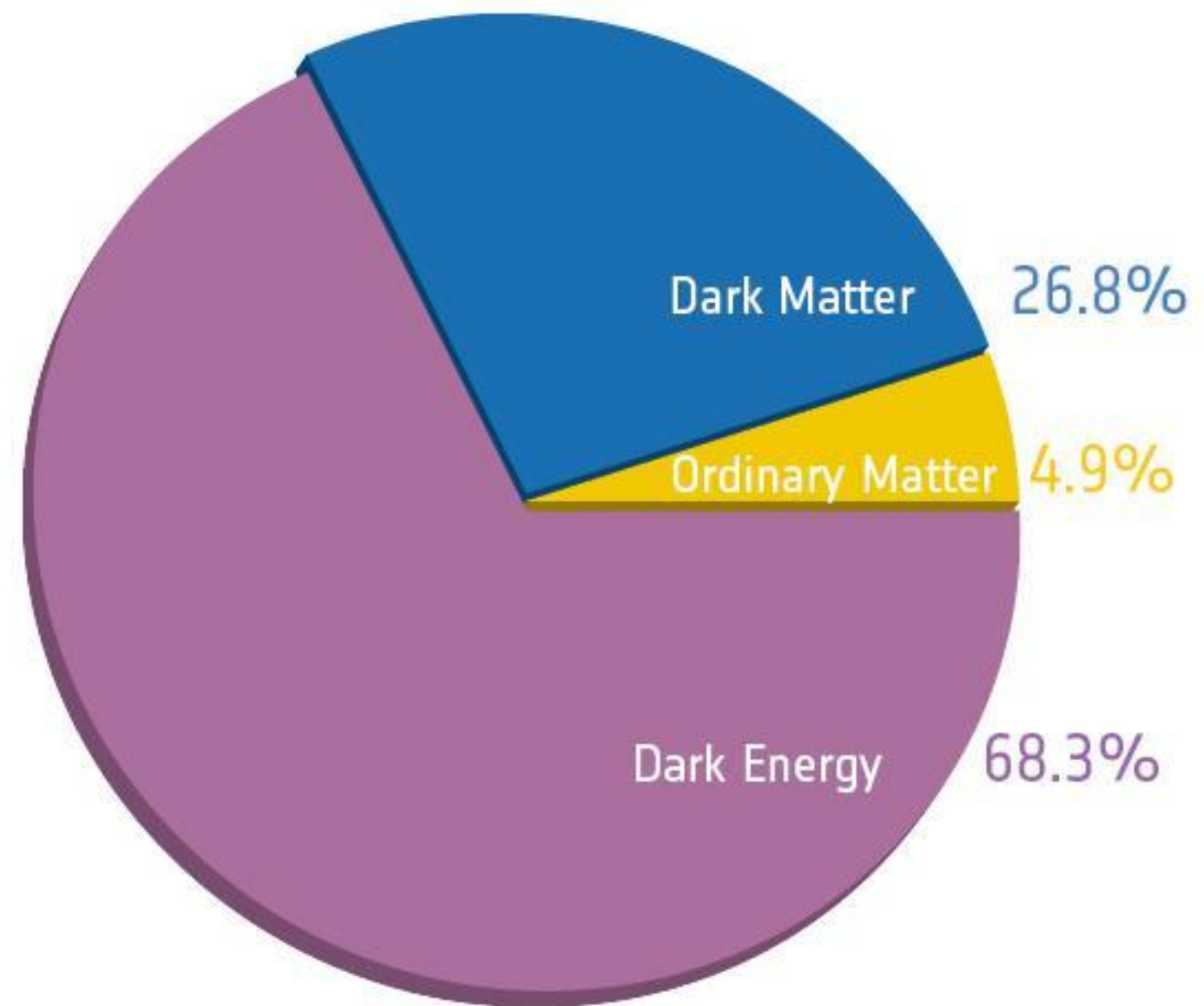
Addressing an enthusiastic crowd of more than 2,000, Mr. Obama offered a fervent, unsparing case for why a peace agreement was both morally just and in Israel's self-interest. Younger Israelis, Mr. Obama said, should empathize with their Palestinian neighbors living under occupation — or, as he put it, "look at the world through their eyes."

As Pollution Worsens in China,

Once Few, Women Hold More Power in Senate



Before Planck



After Planck

 RECENT NEWS

Universe Older, Wider Than Previously Thought

AMERICAN VOICES · Opinion · ISSUE 49·12 · Mar 22, 2013

 167  86  4

Astronomers determined that the universe is actually 13.8 billion years old, about 80 to 100 million years older than previously believed, and that it is also a bit wider than once thought. What do *you* think?



"How embarrassing."

Victoria Rosegard –
Street Cleaner

"Typical. You give birth to a few trillion galaxies and then people just talk about how old and fat you've gotten."

Francois Jenevein –
Hide Trimmer

"Just like it says in Leviticus."

Chris Vanderhorst –
Systems Analyst

Future Christian Drinking And Doing Drugs And Thinking It's One Big Joke

Fast-Talking Computer Hacker Just Has To Break Through Encryption Shield Before Uploading Nano-Virus

JCPenney CEO's Severance Package Includes 34,000 Pea Coats

Kim Jong-Un Wonders If Nuclear Threats Distracting Him From Real Goal Of Starving Citizenry

China Announces Plans To Build International Space Prison

Man Not Certain What Any Of His Coworkers' Names Are

NATO Airstrike Destroys Key Taliban Day Care Center

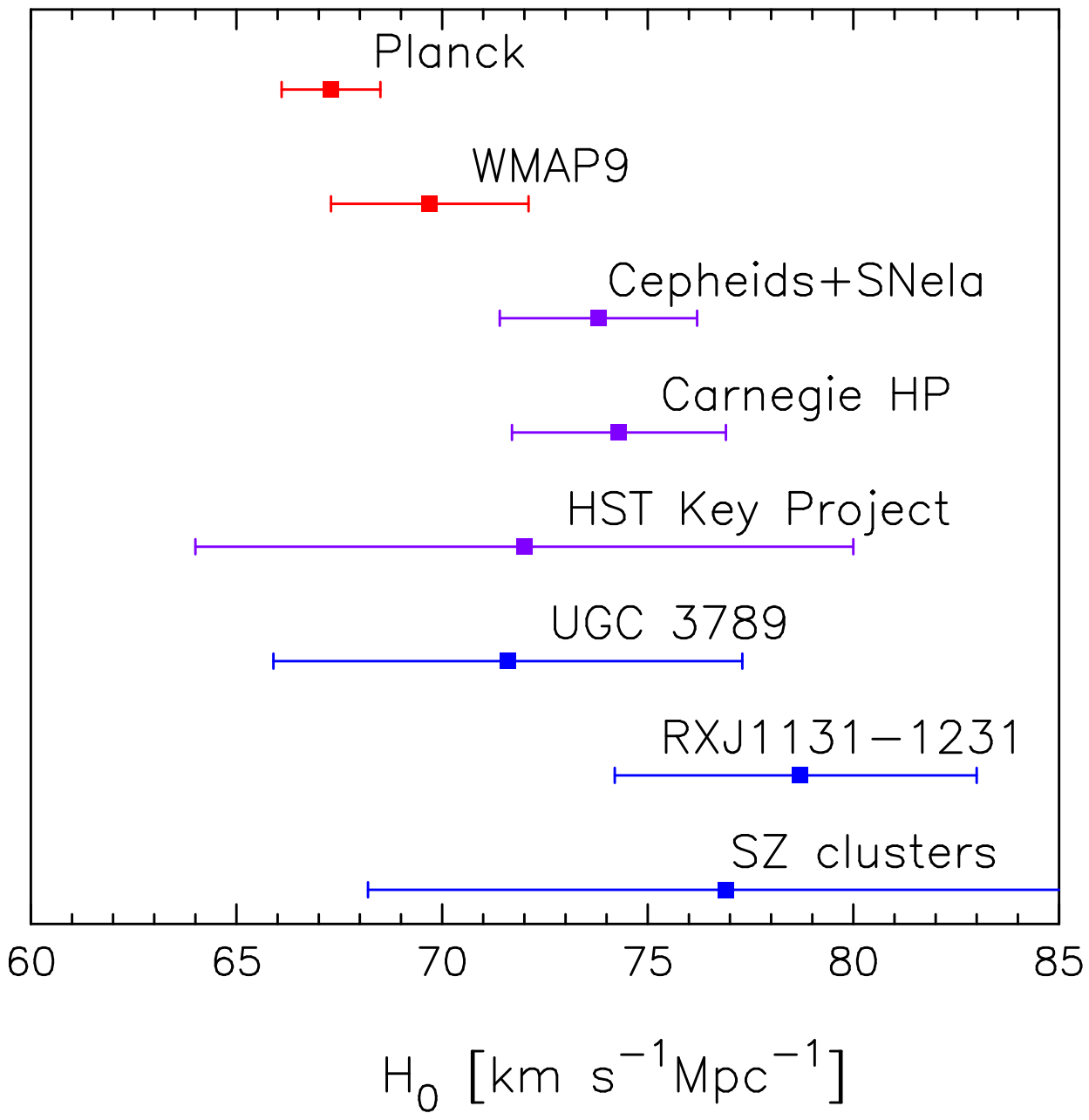
 RECENT VIDEOS



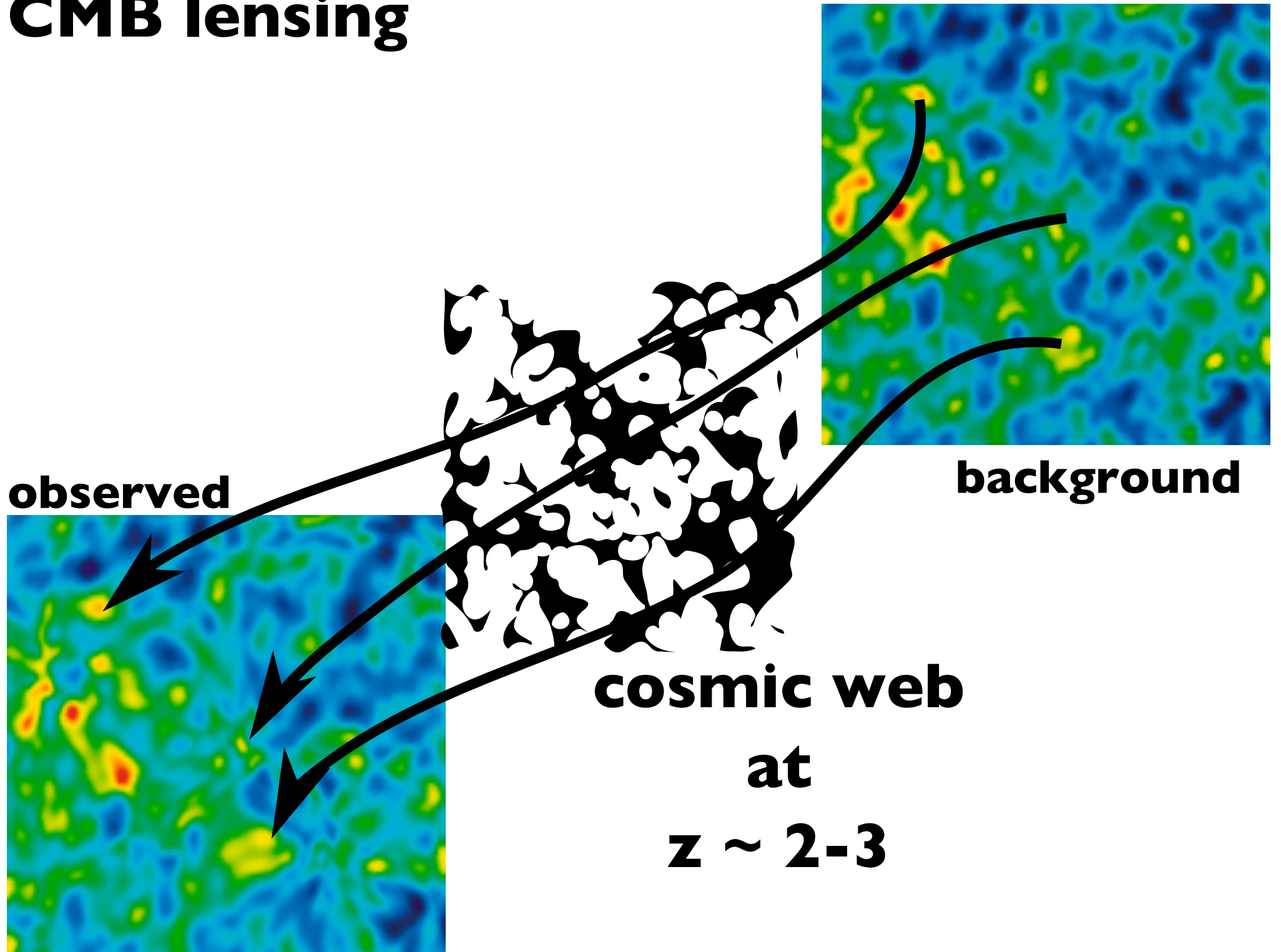
Popular Children's Book Author Reveals The 'Spooky Truth' About Creepy Conspiracy Theories 

 [Ian McKellen Officiating Patrick Stewart's Wedding](#)

[CDC: 1 In Every 50 U.S. Schoolchildren ...](#) 

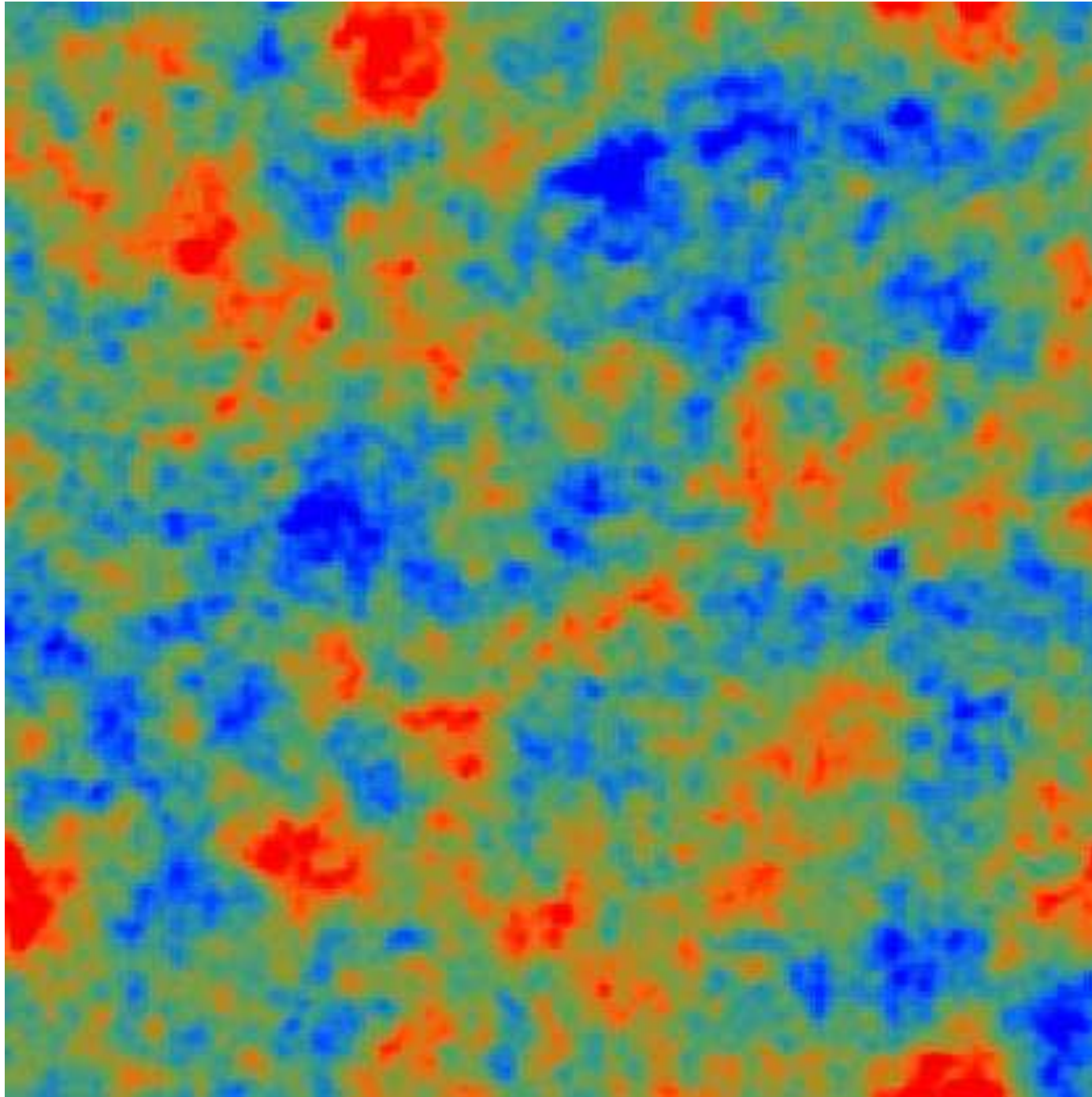


CMB lensing



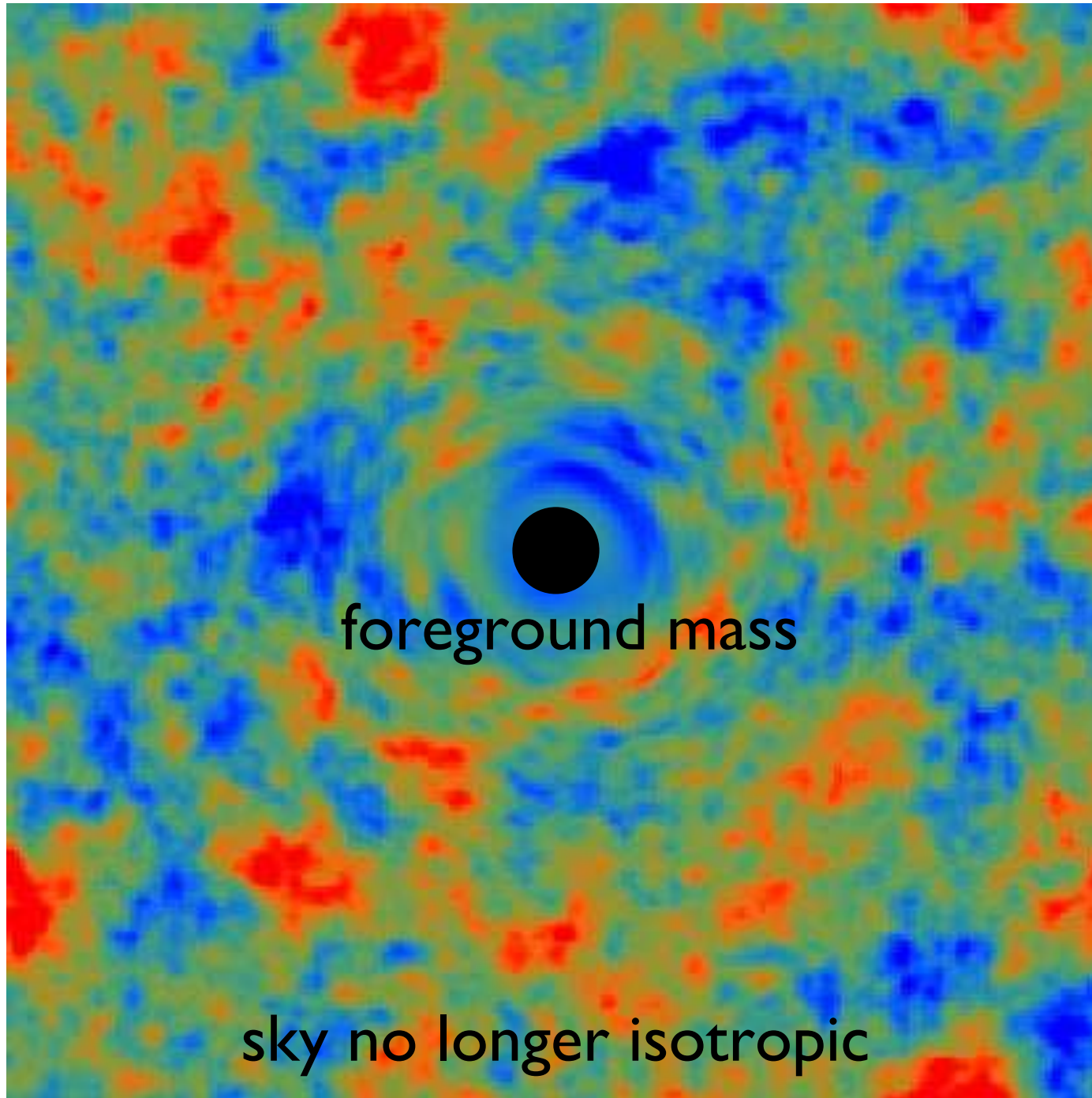
CMB

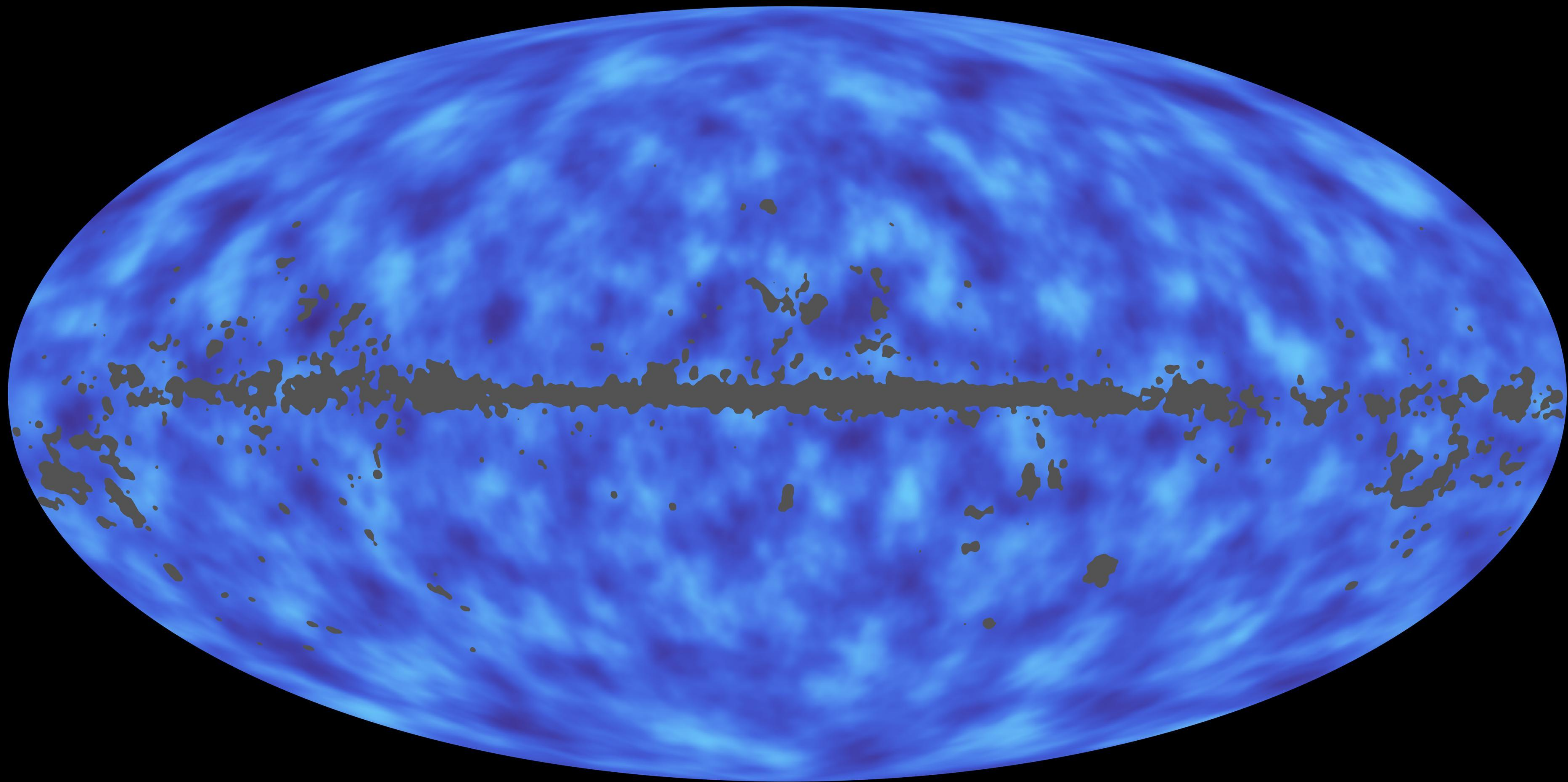
(Hu & Okamoto 2001)



CMB lensed

(Hu & Okamoto 2001)



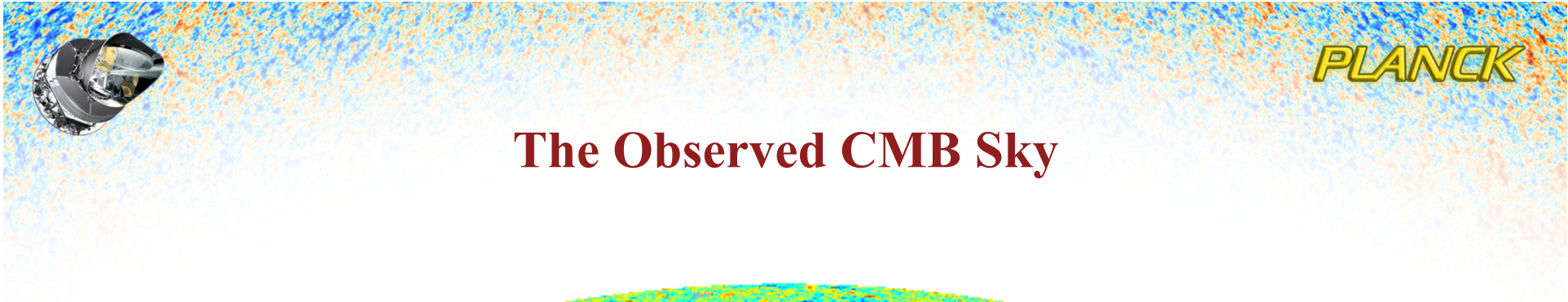


Conclusions

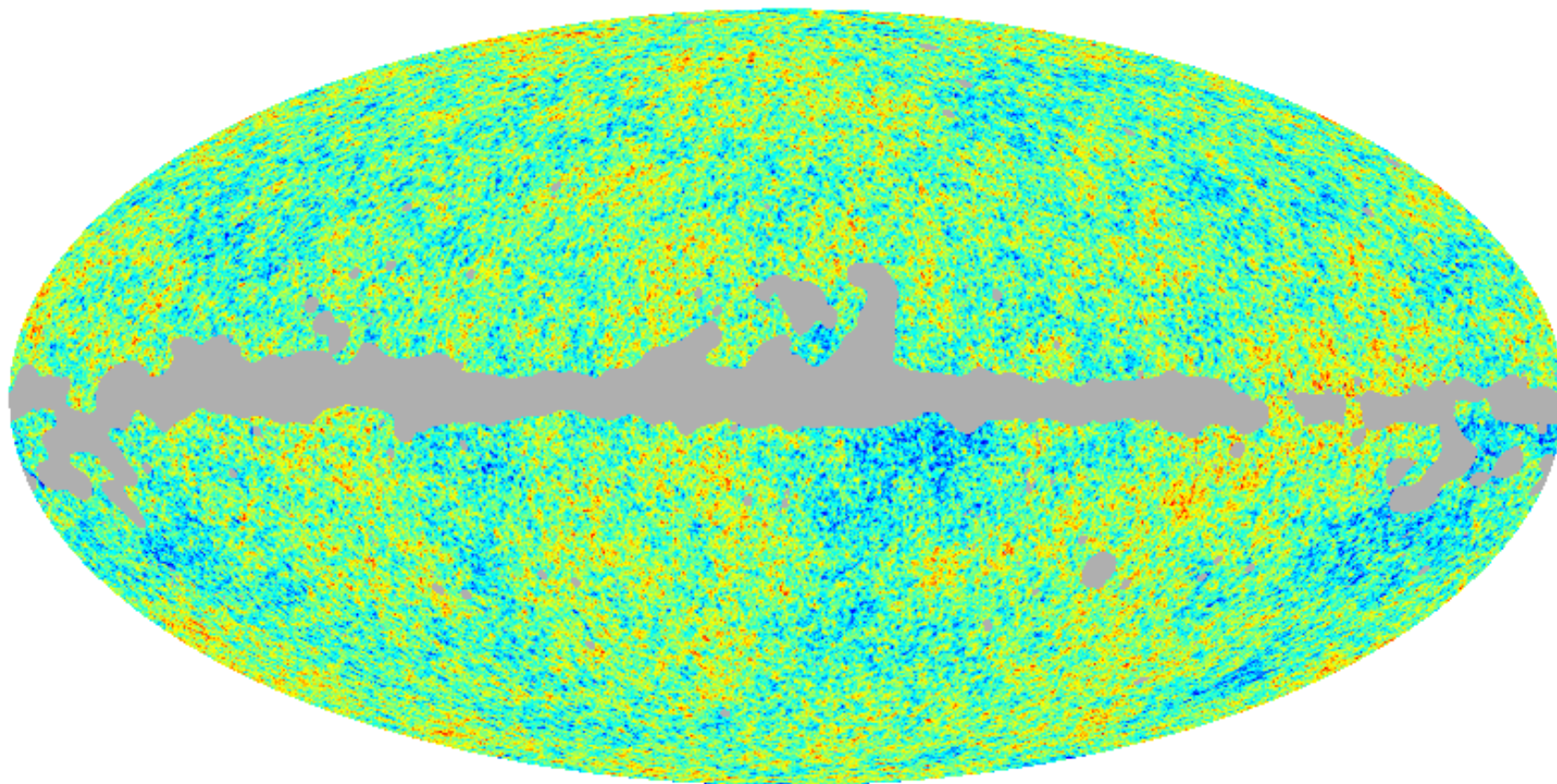
Planck has produced a rich store of data and cosmological results.

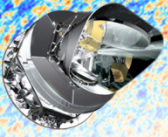
Next: Polarization

Large scale anomalies?



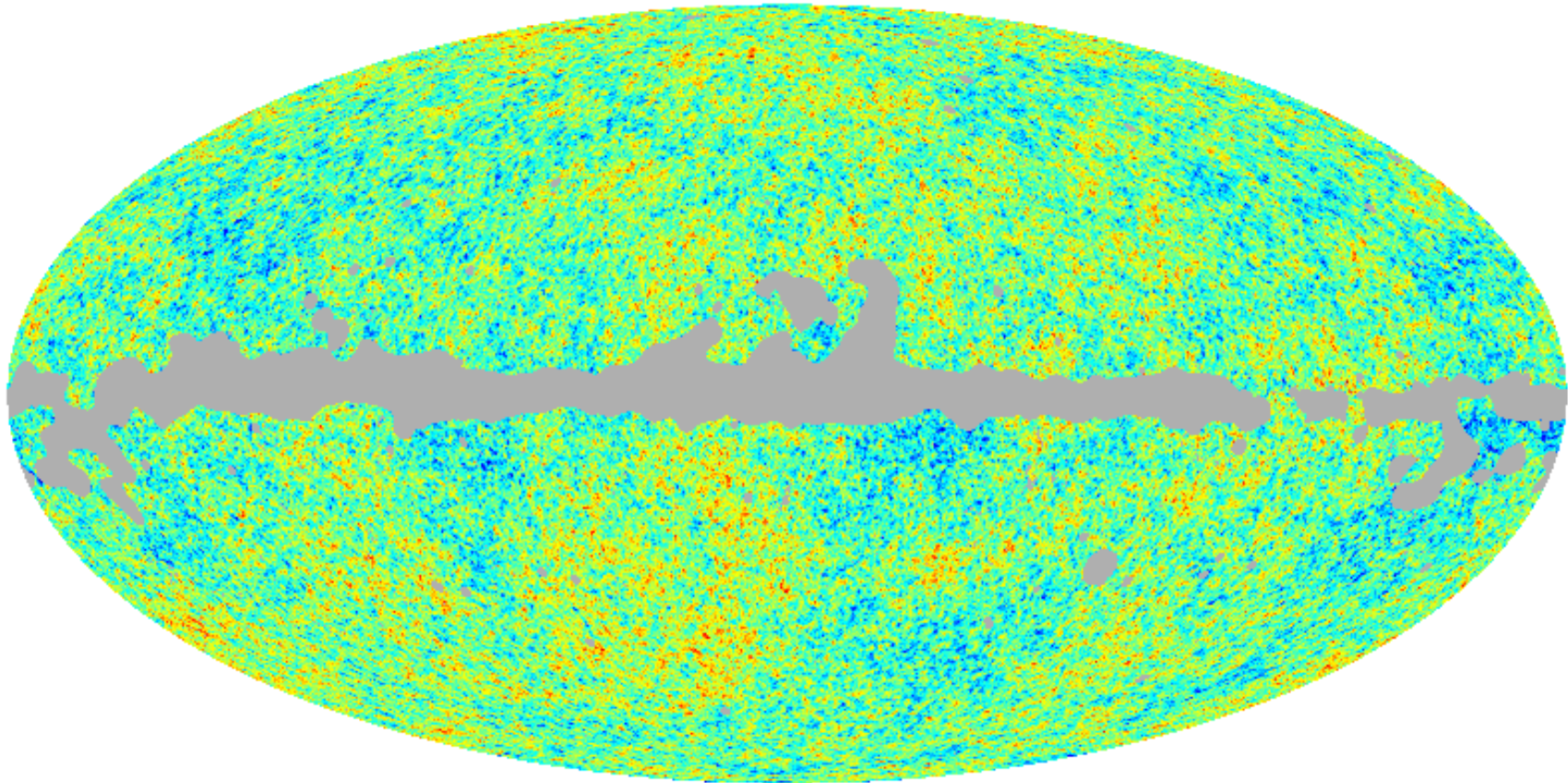
The Observed CMB Sky

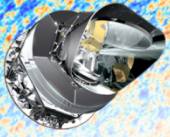




PLANCK

The Corrected, More Manifestly Isotropic CMB Sky



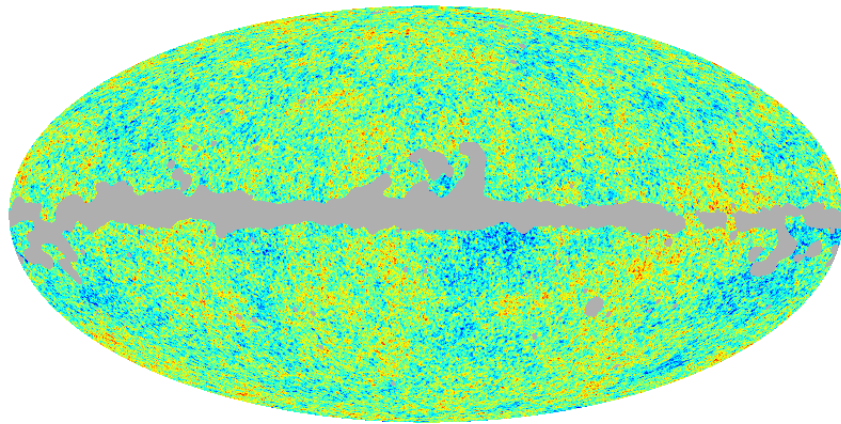


PLANCK

A Paradoxical “solution” to the Idiosyncratic Appearance of Our CMB Sky

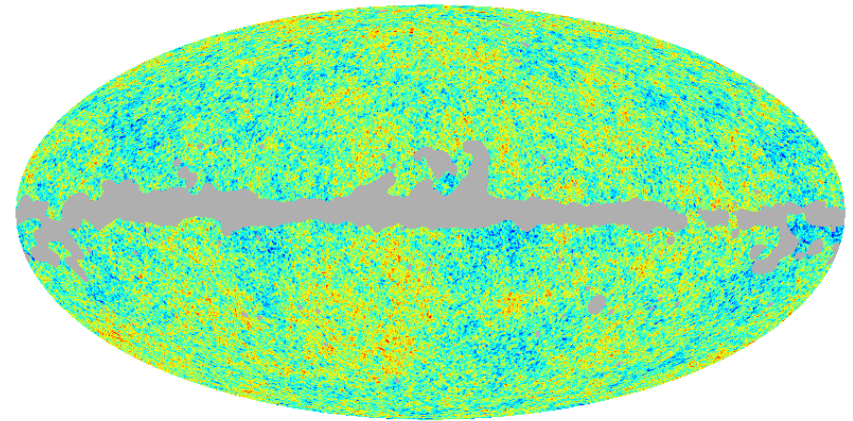
The Bianchi model **must be open** to fit the data, and cannot be merged with the overall flat cosmology that describes the observed universe

Real CMB Sky



-500. +500.

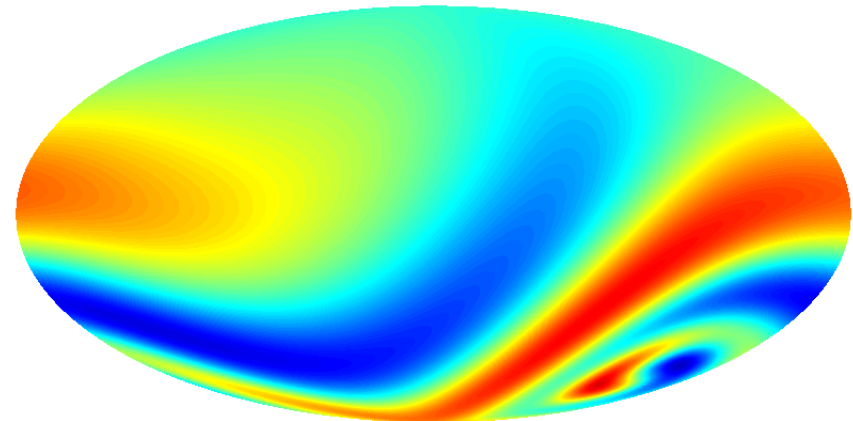
Corrected CMB Sky



-500. +500.

=

+



-60.0 +60.0

Correction that fits the sky:
a homogeneous, anisotropic Bianchi VII_h model