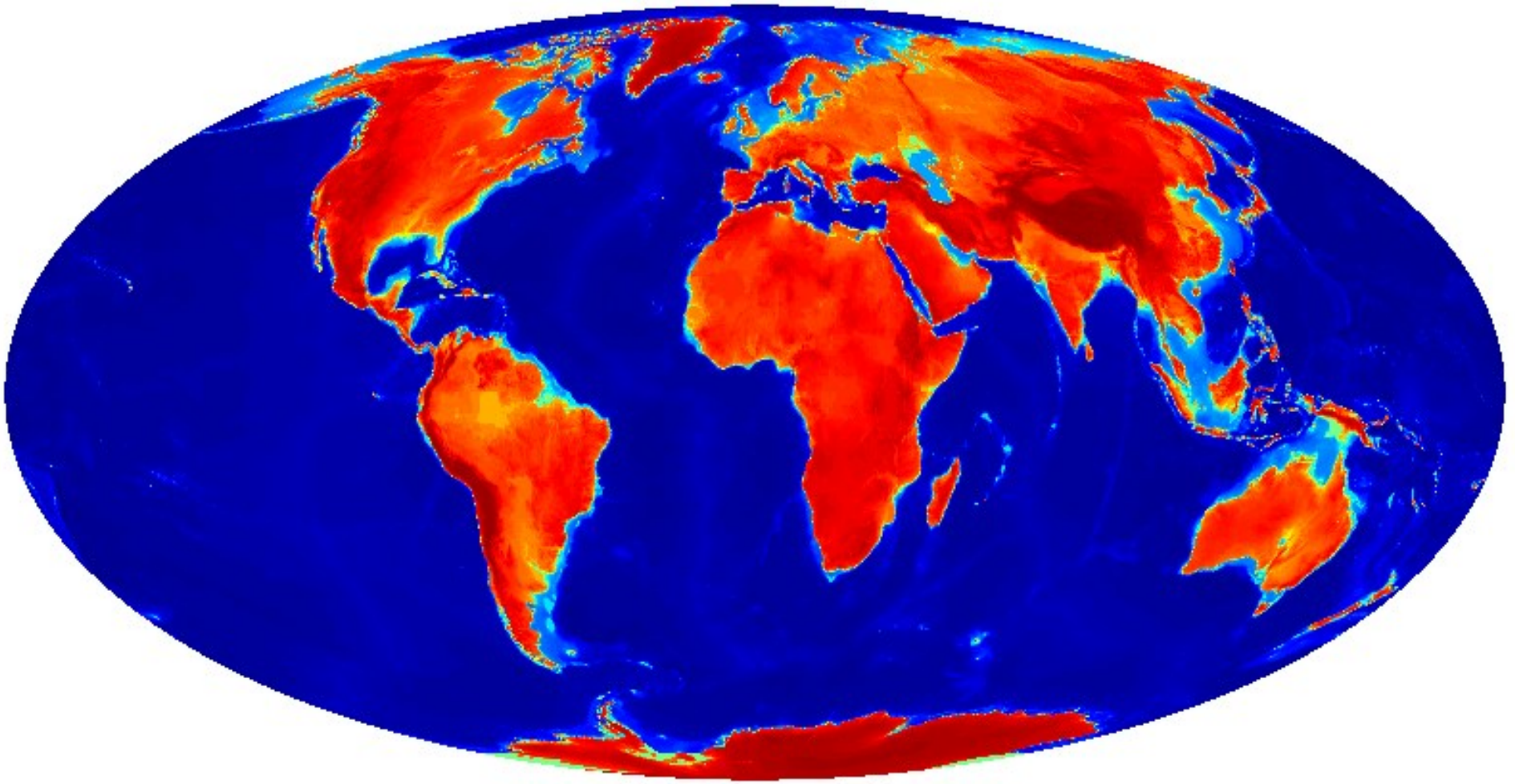
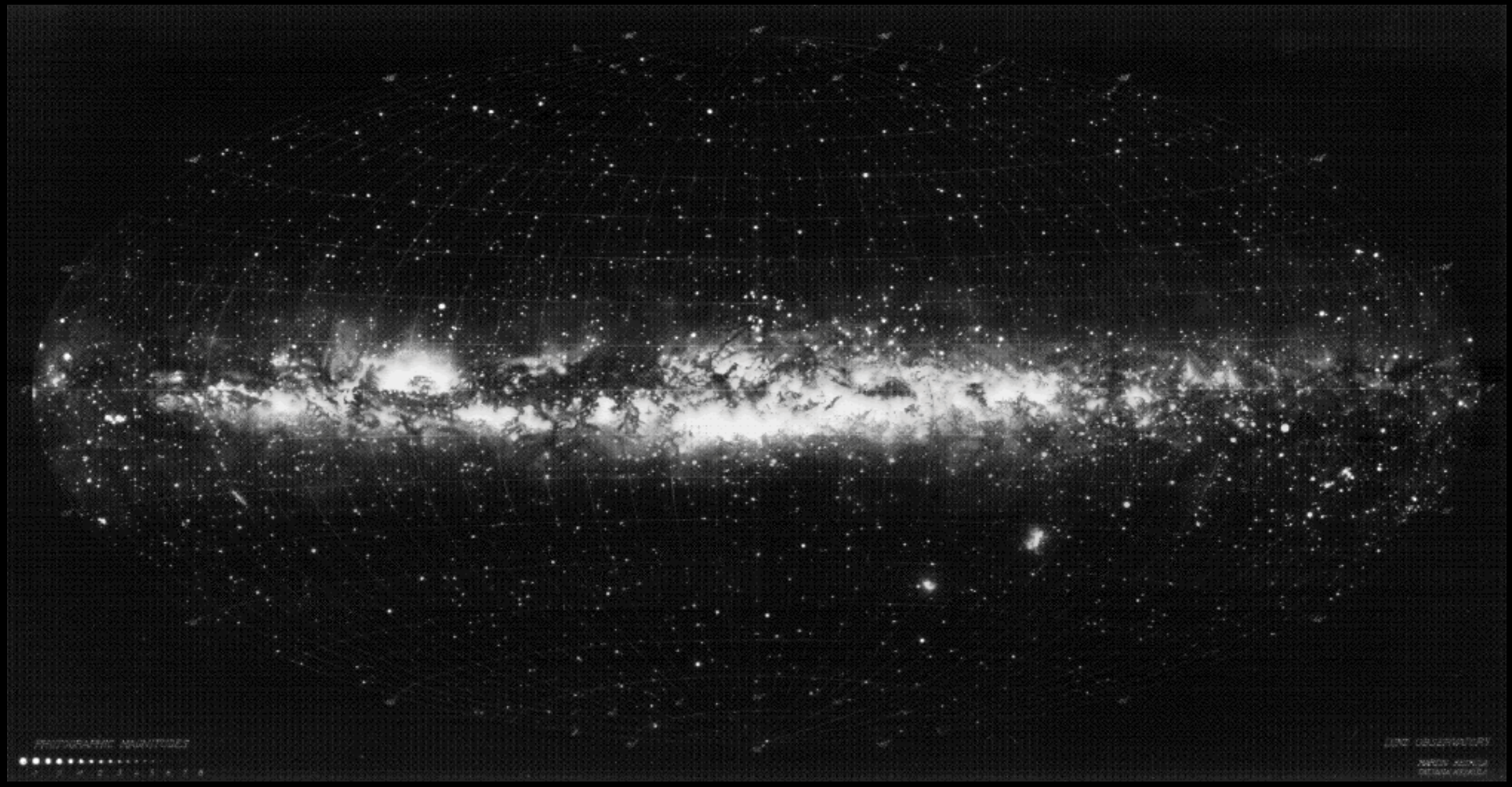


Star map of the whole sky

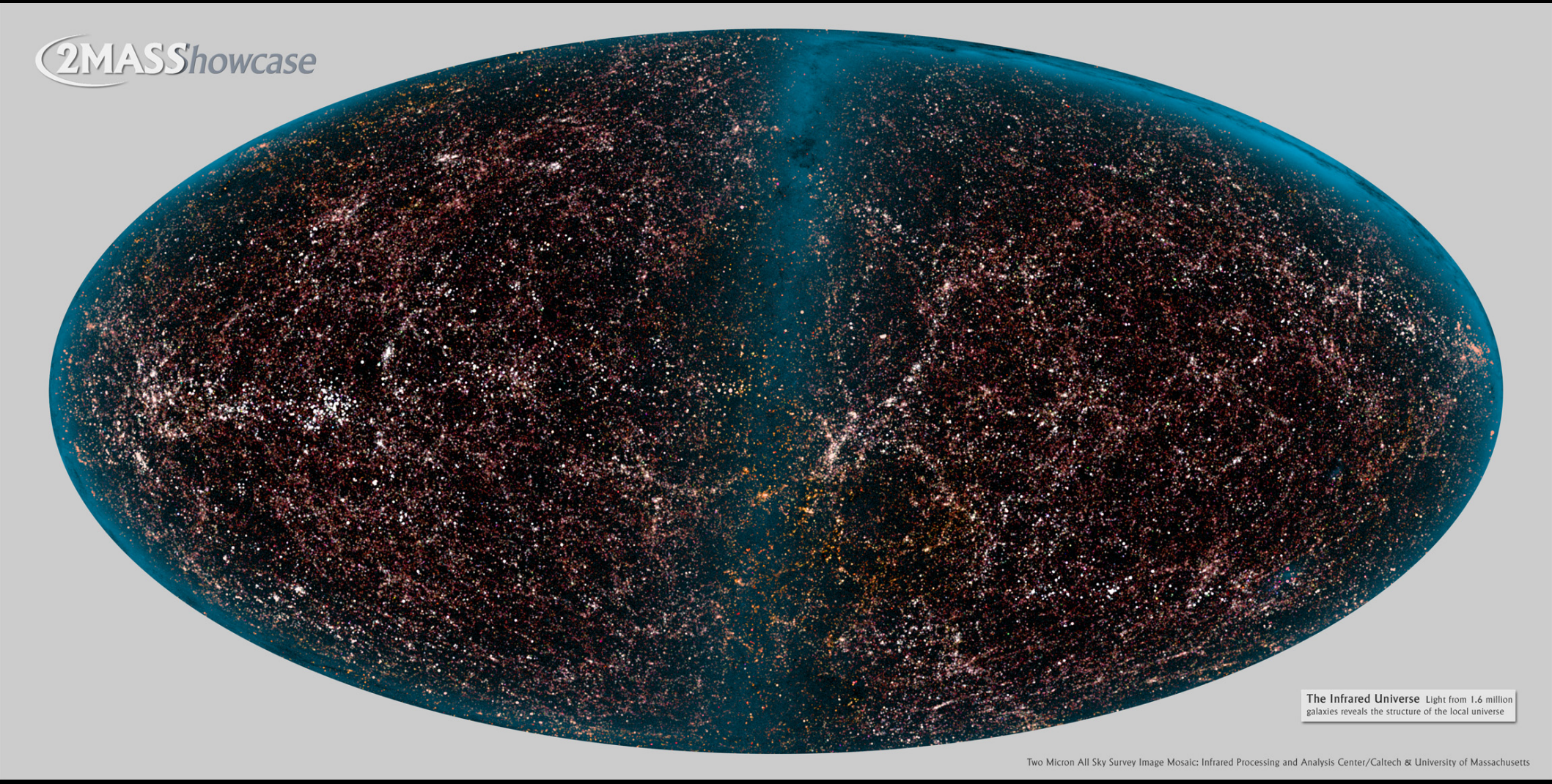


..out to 10,000 light-years

The Andromeda Nebula: our biggest neighbour

..out to 2,000,000 light-years

A galaxy map of the whole sky



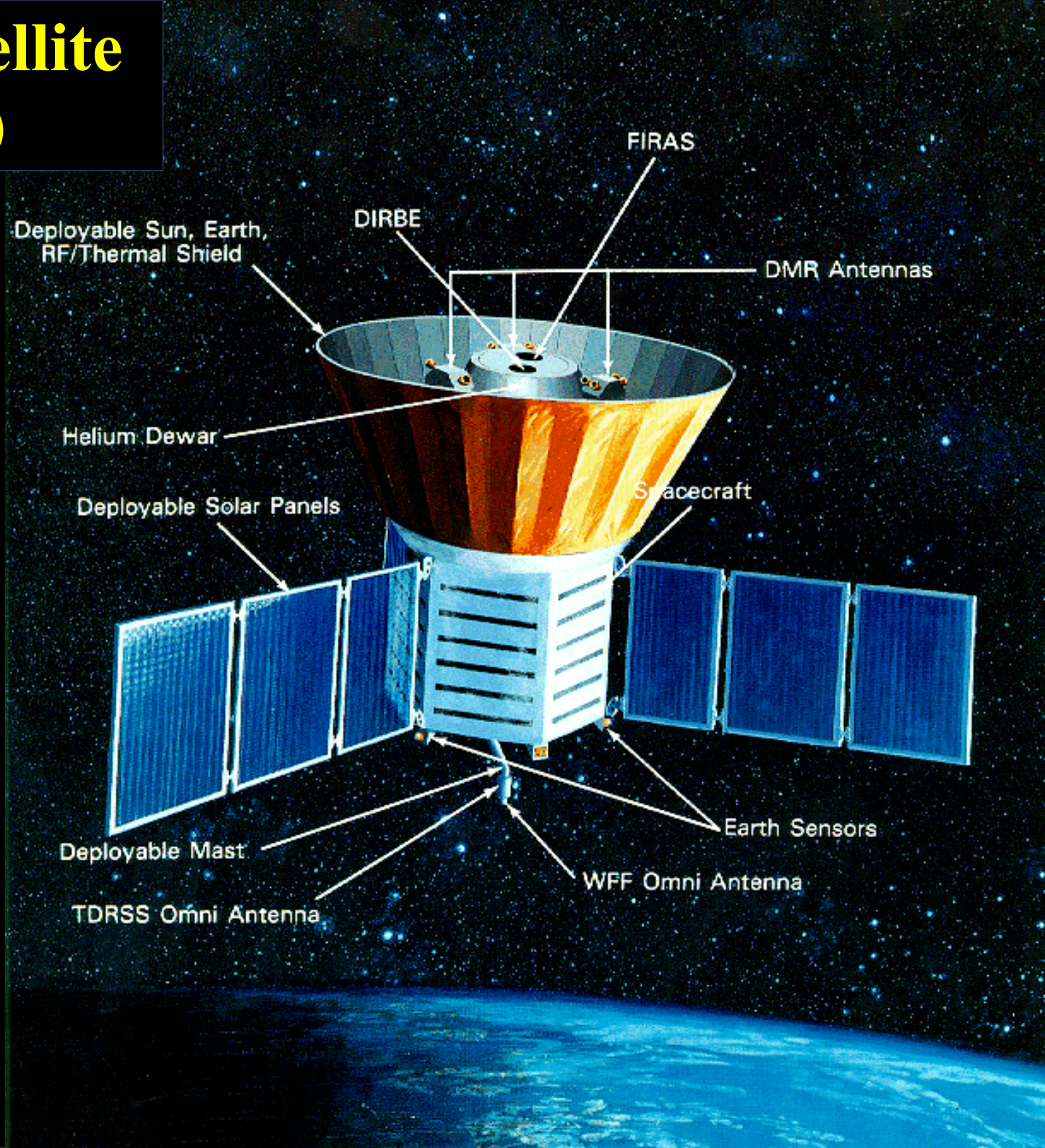
..out 1,000,000,000 light-years

A 300 hour exposure with the Hubble Space Telescope

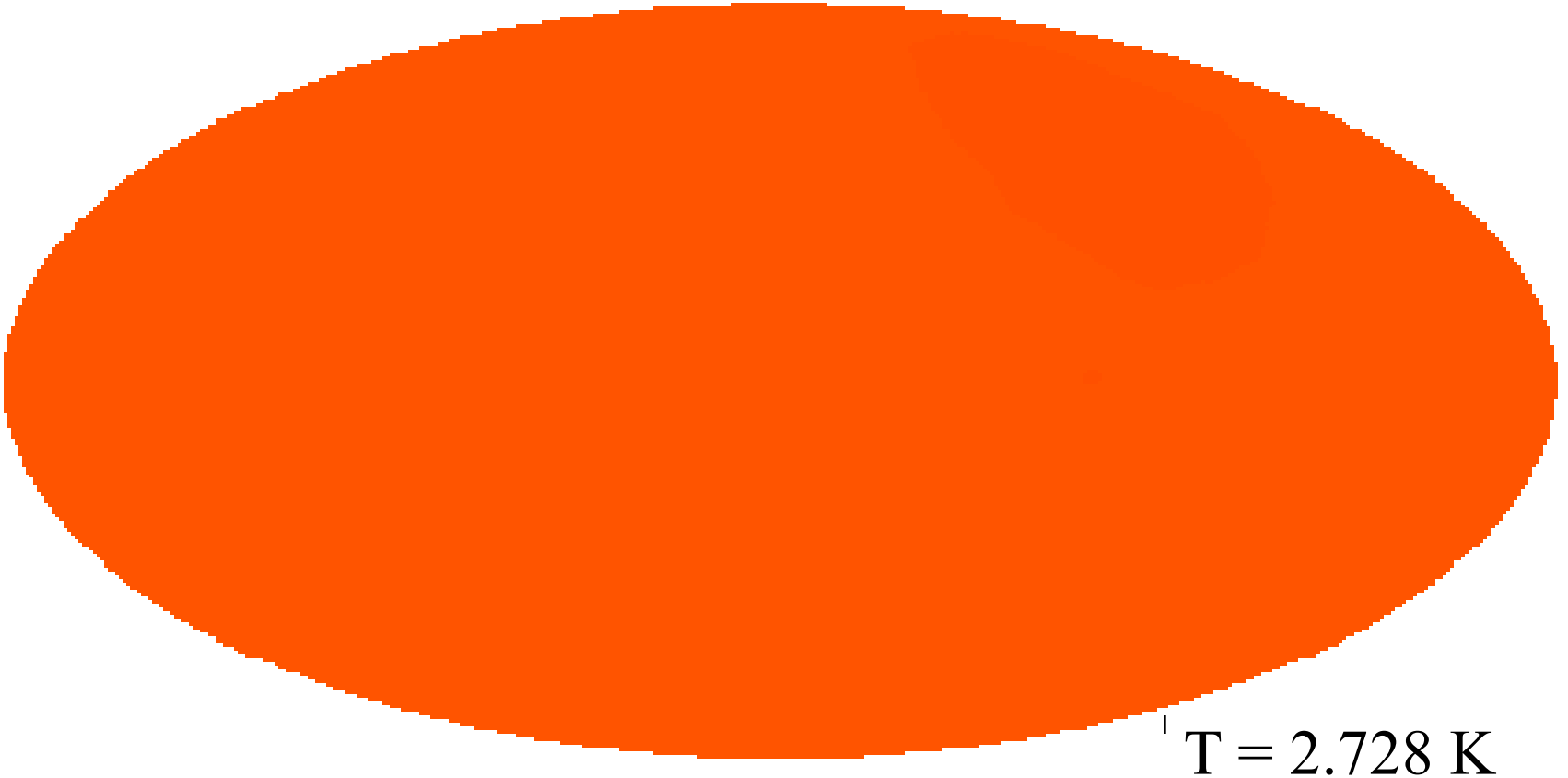
The COBE Satellite (1989 - 1993)

- Mapped the whole sky in microwaves

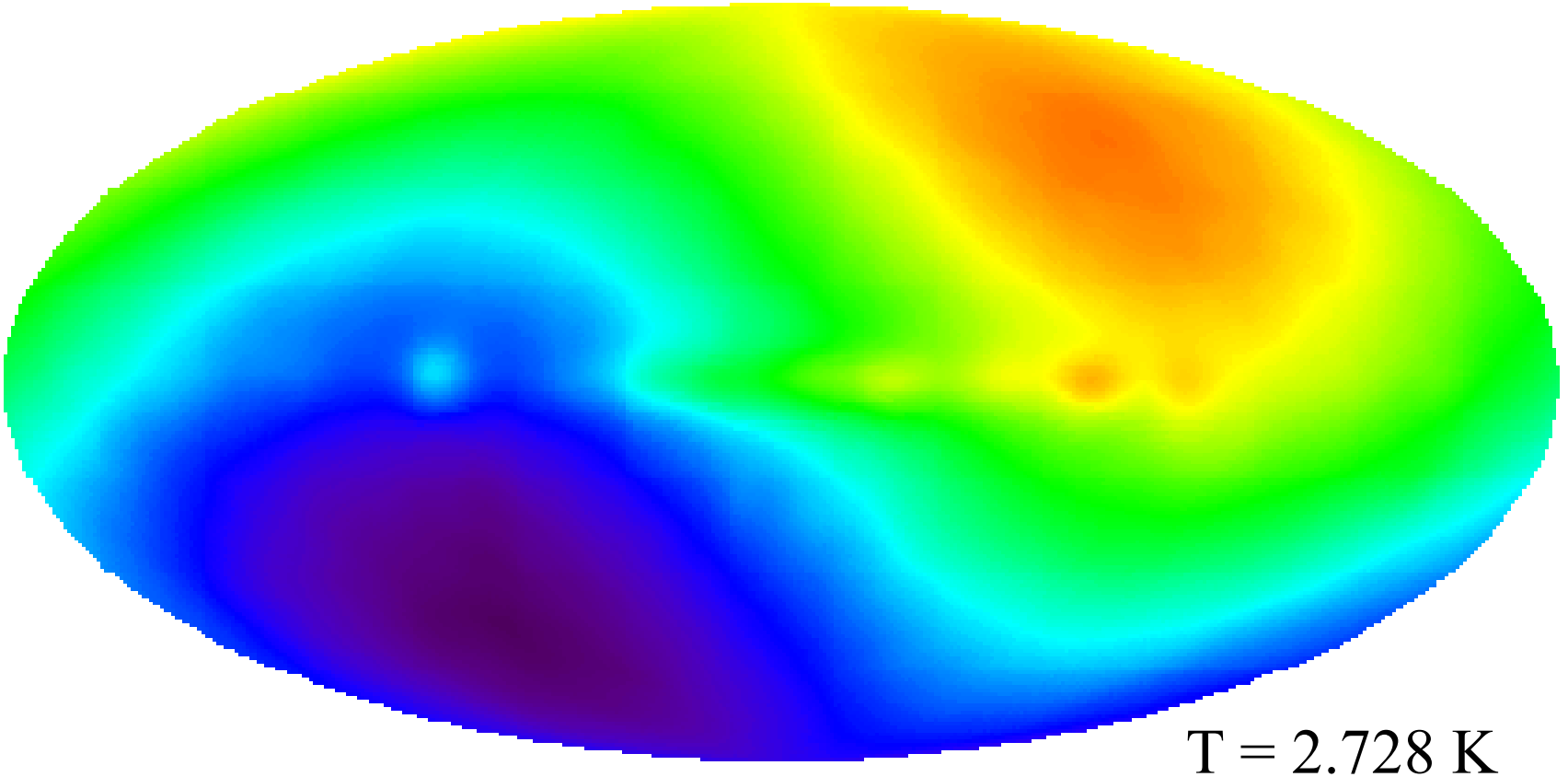
Nobel Prize 2006



COBE's temperature map of the whole sky



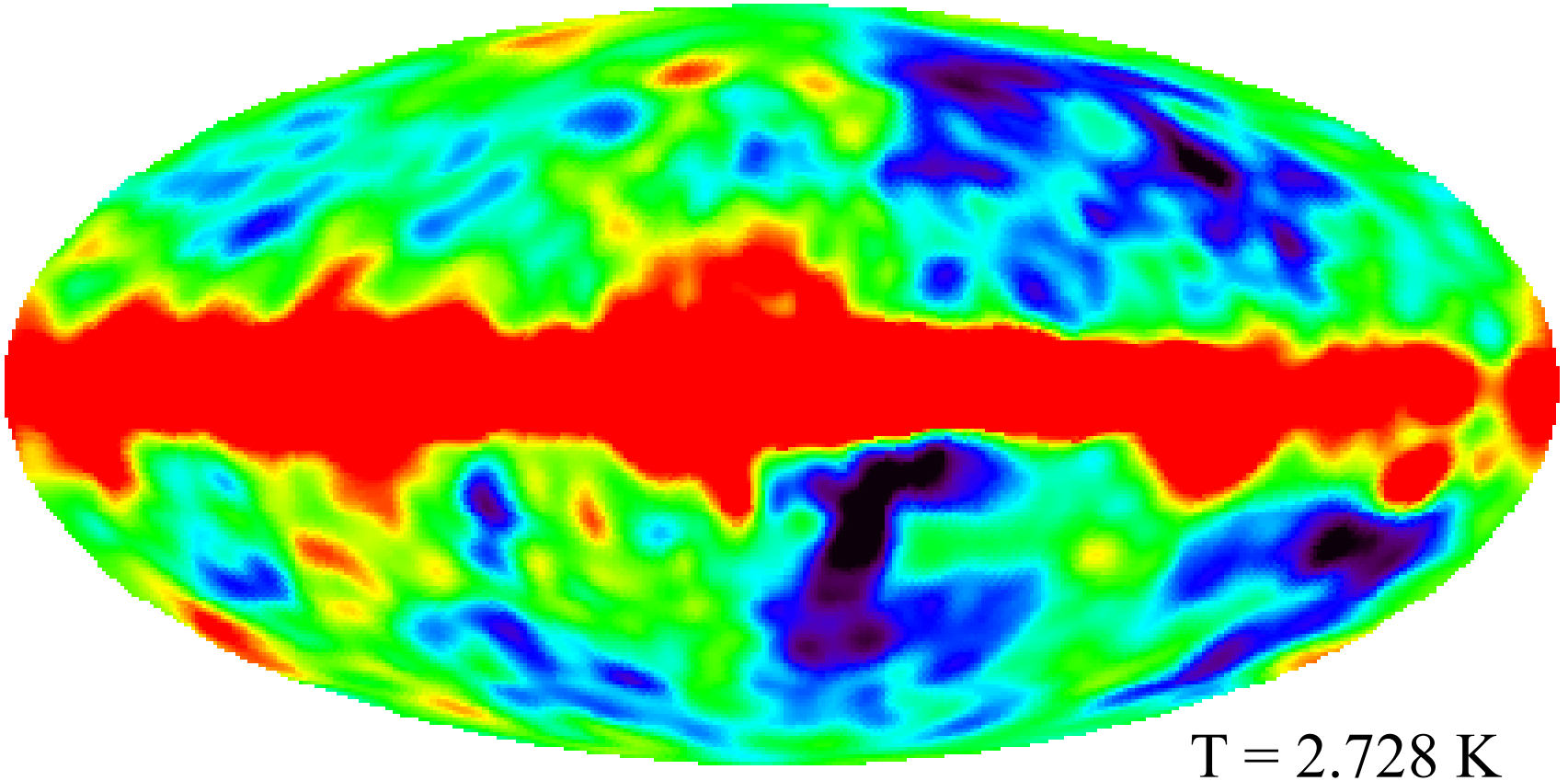
COBE's temperature map of the whole sky



$T = 2.728$ K

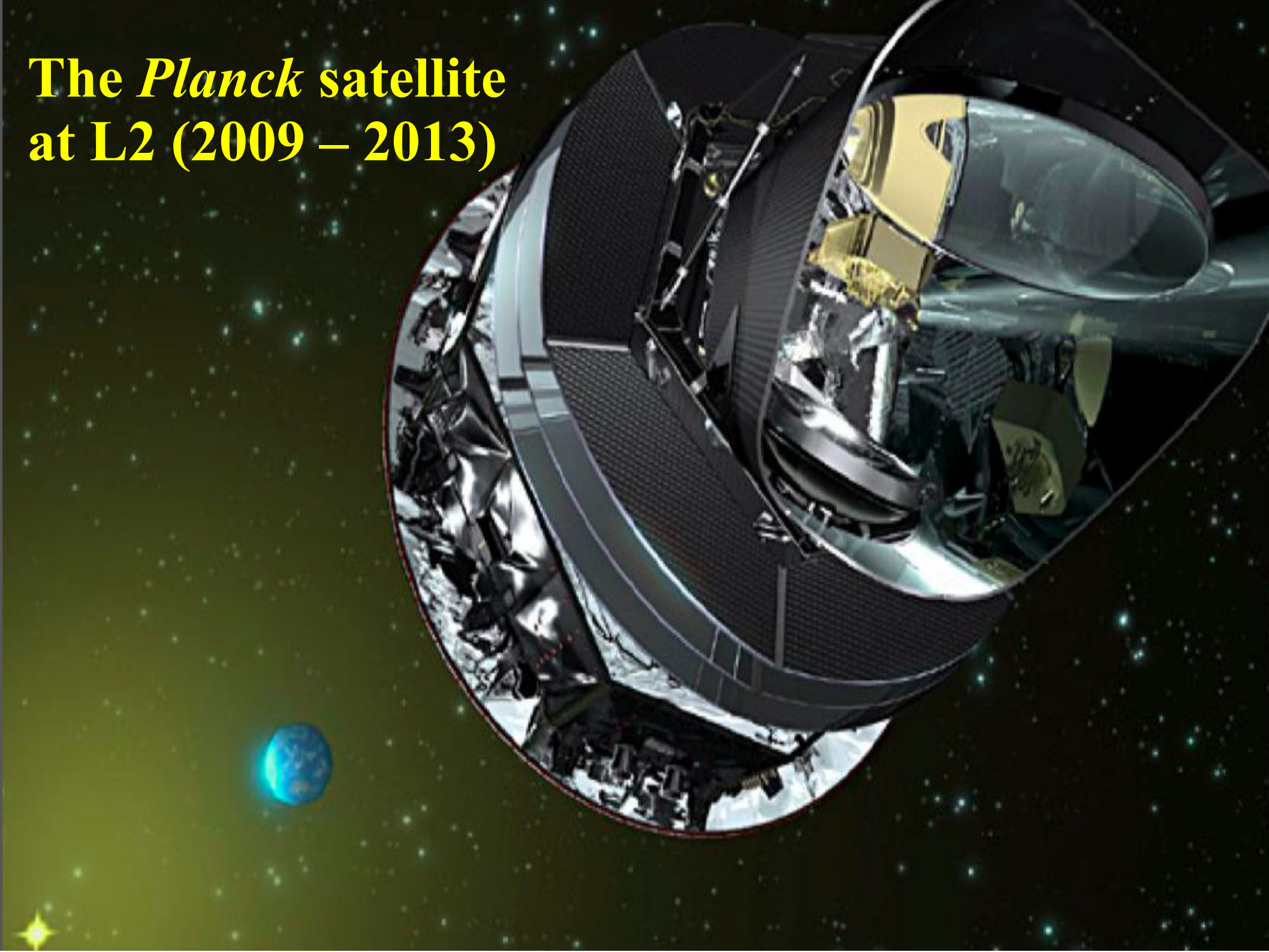
$\Delta T = 0.0034$ K

COBE's temperature map of the whole sky

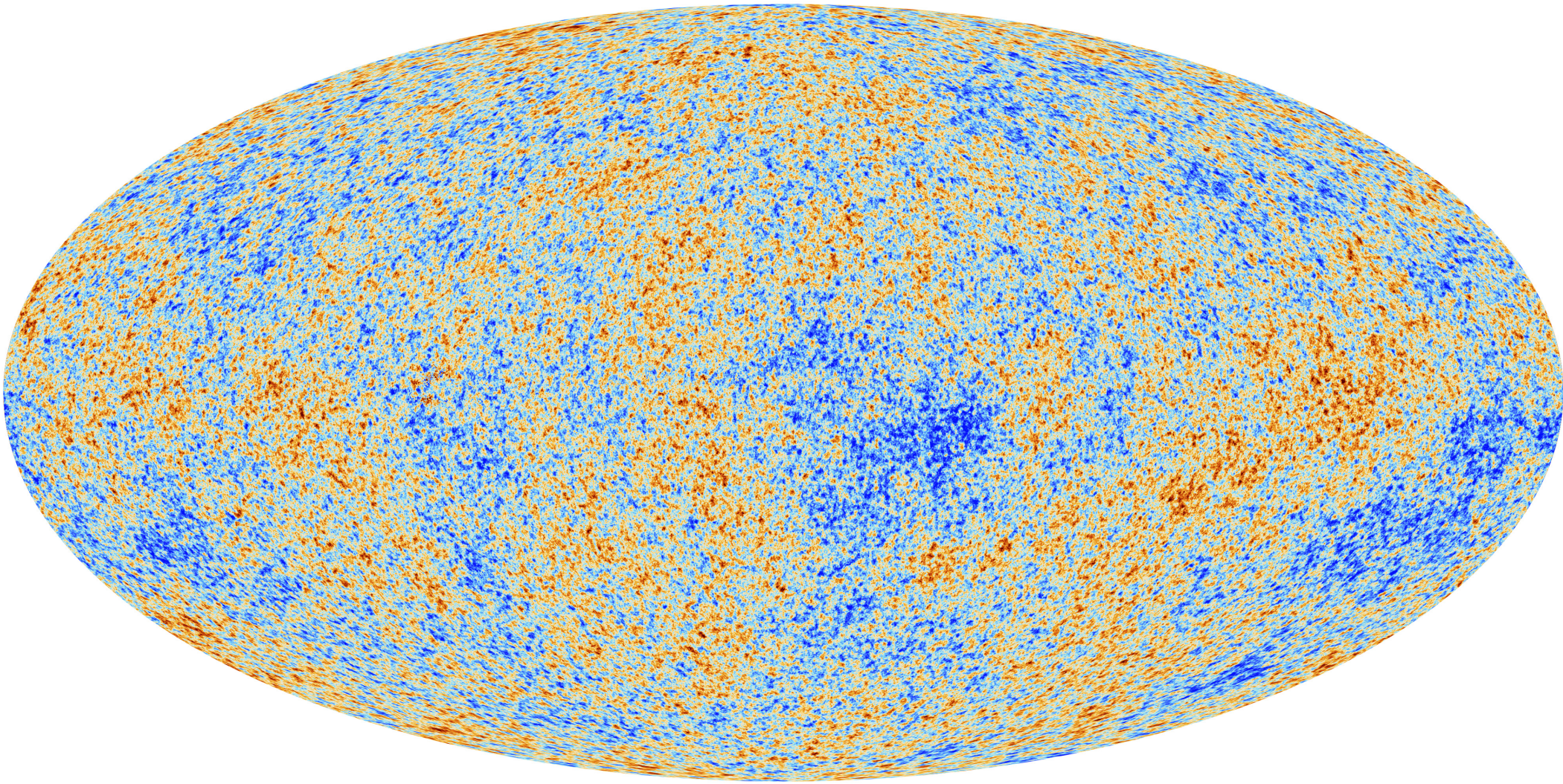


T = 2.728 K

$\Delta T = 0.00002$ K


The *Planck* satellite
at L2 (2009 – 2013)

The *Planck* map of the microwave background



An image of the boundary of the observable Universe

Structure in the microwave background

Where is the structure?

In cosmic clouds at the far edge of the visible Universe

What are we seeing?

Weak sound waves in the clouds

At what epoch are we seeing these clouds?

When the Universe was just 400,000 years old, and was 1,000 times smaller and 1,000 times hotter than today

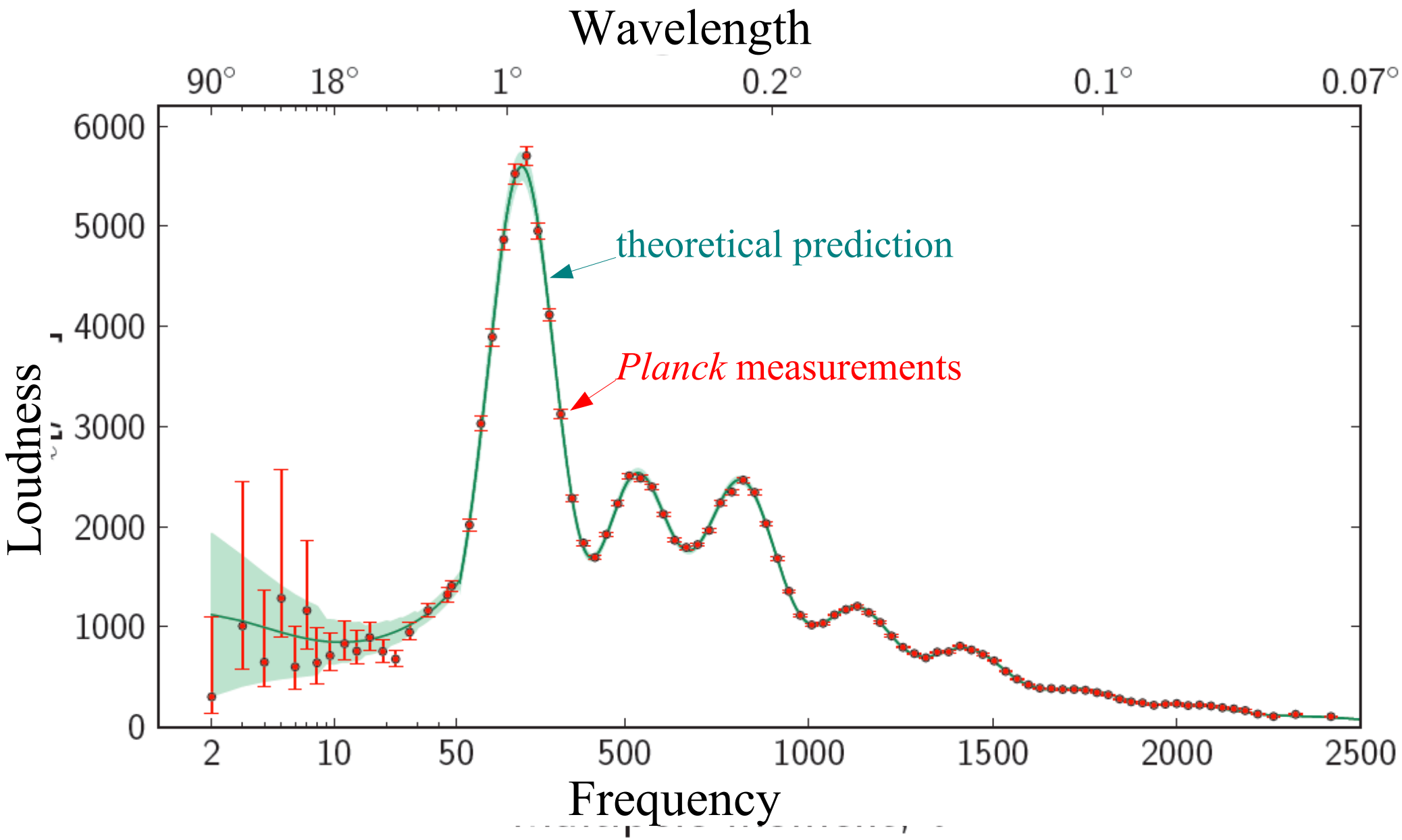
When was this structure created?

A tiny fraction of a second after the Big Bang

What has this structure become?

Everything we see around us (galaxies, stars, planets, people...)

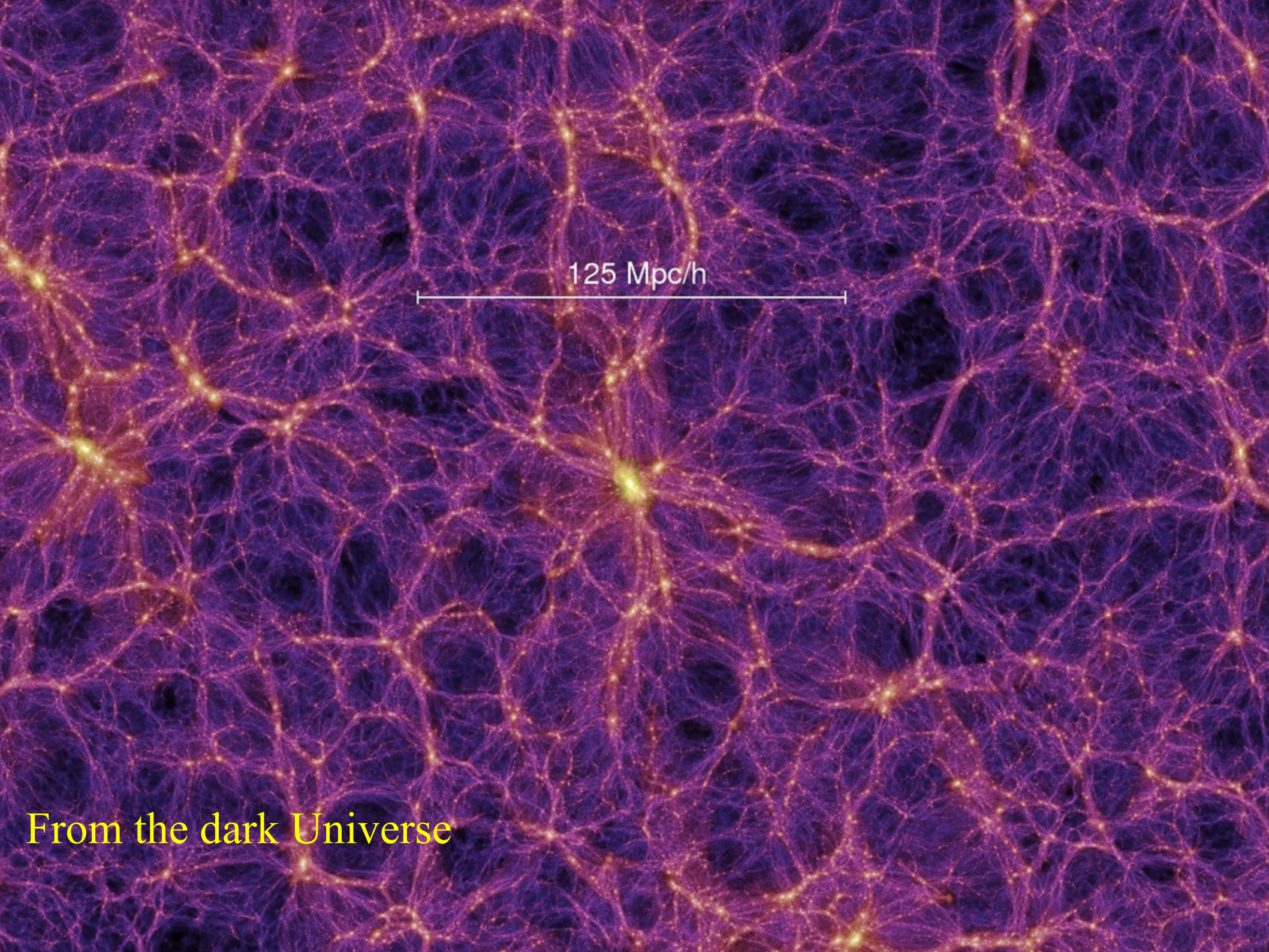
Sound content of the cosmic clouds according to *Planck*



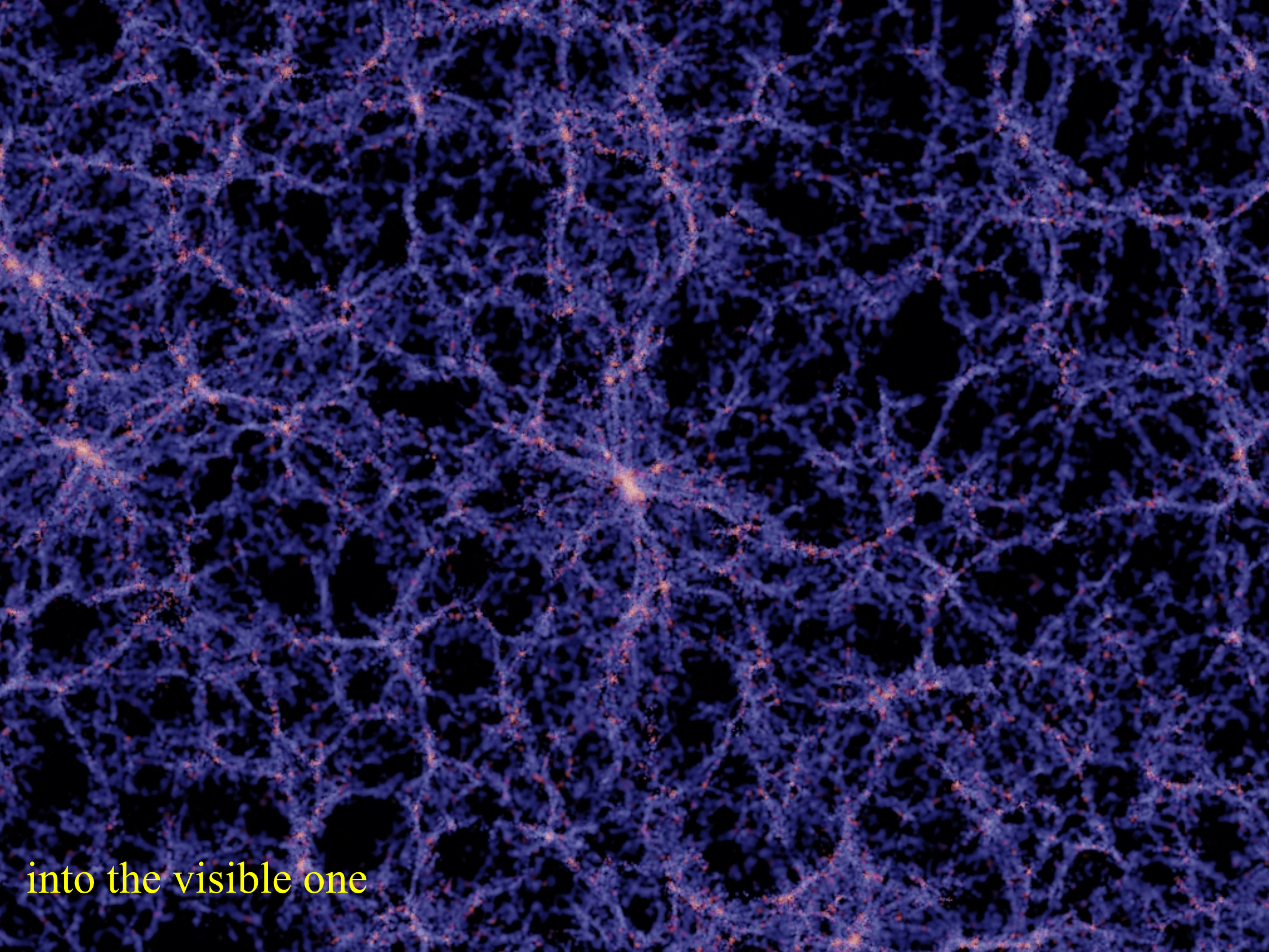
What have we learned from the CMB?

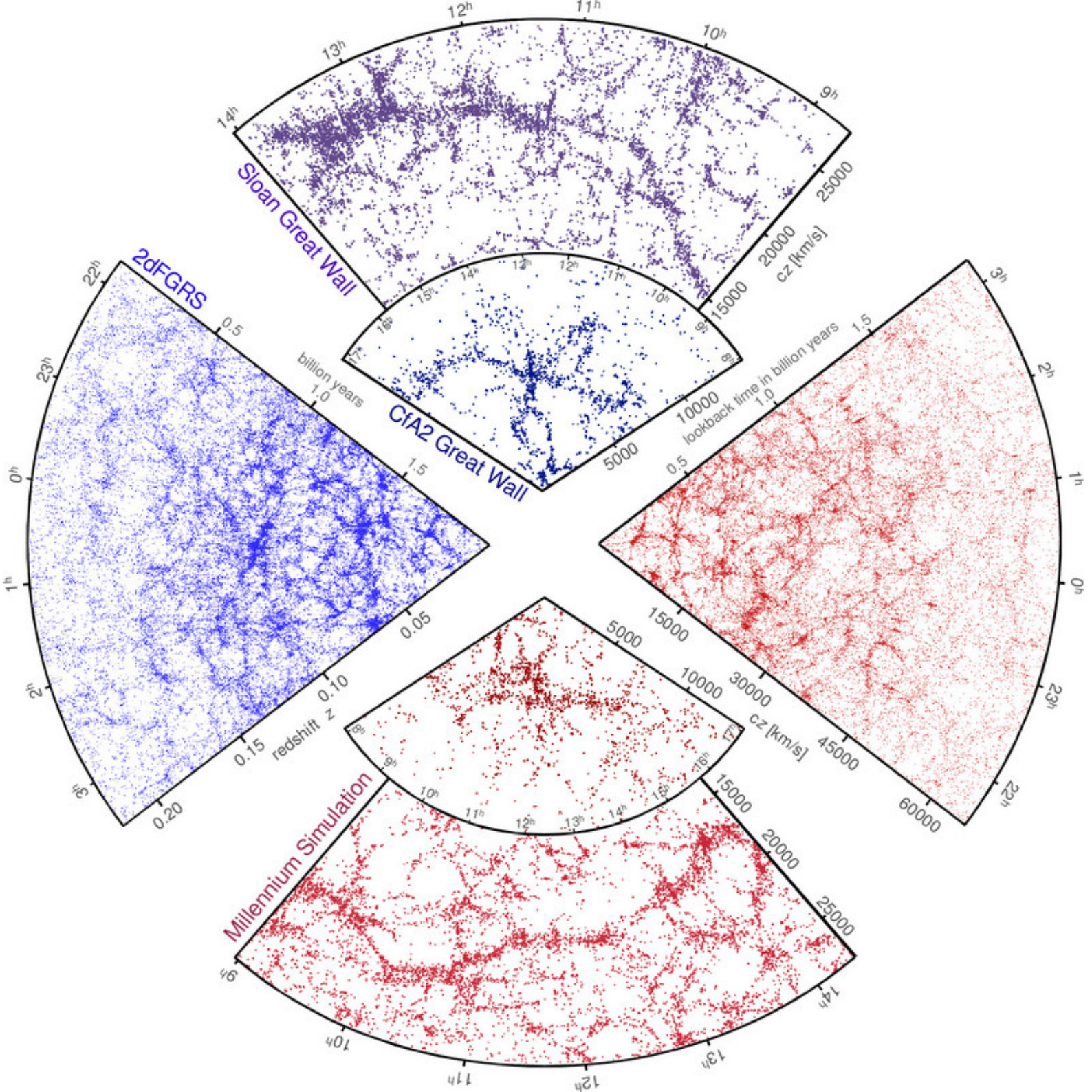
- Our Universe is flat – its geometry follows Euclid's laws
- Only a small fraction – 4.9% – is made of ordinary matter
- Much more – 26.8% – is non-baryonic Dark Matter
- The rest consists of a new form of energy – Dark Energy – that is responsible for the accelerated expansion of today's Universe
- All cosmic structure arose through quantum fluctuations of the *vacuum* at a ***very*** early time, perhaps 10^{-30} s after the Big Bang

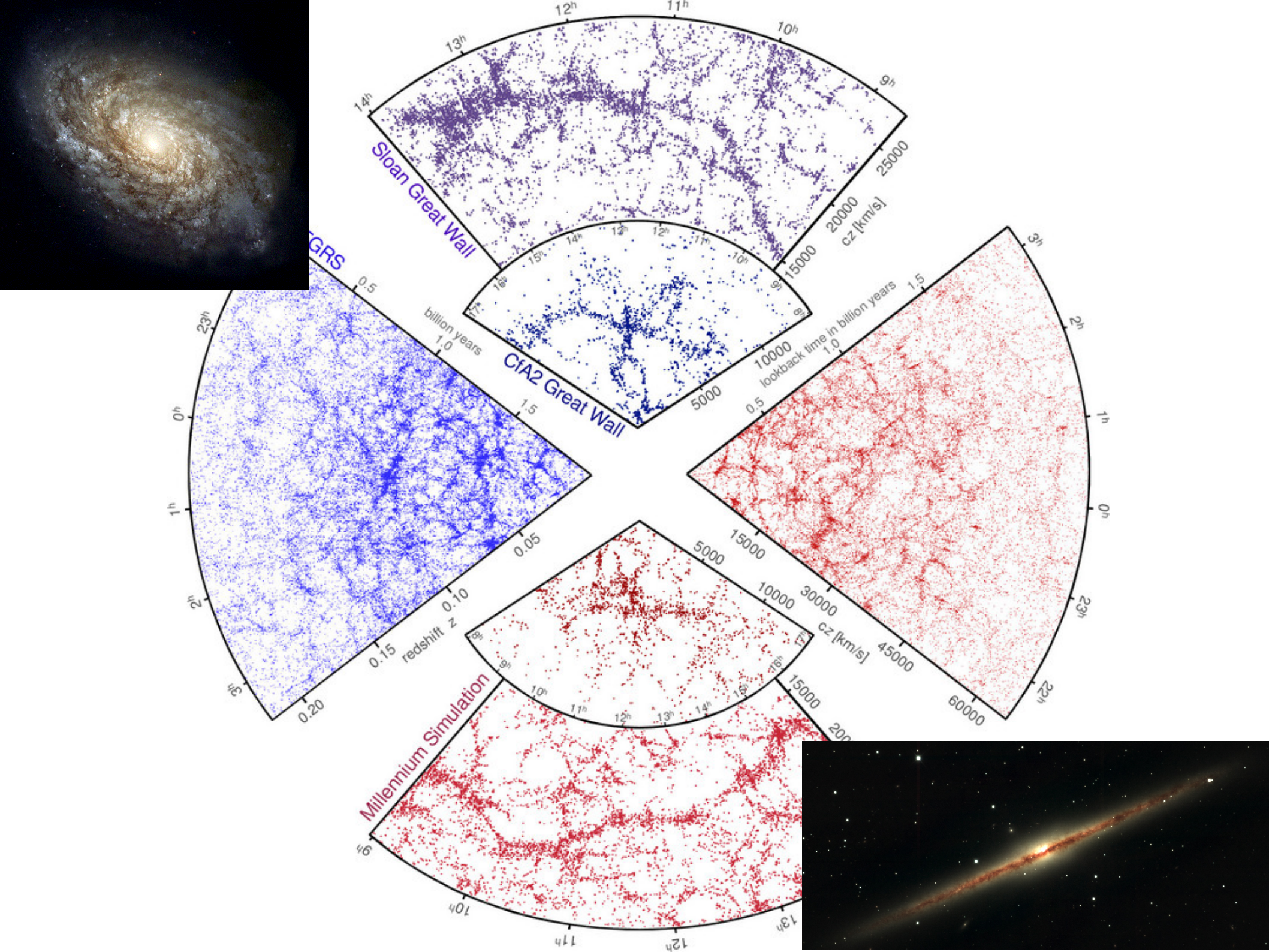
Everything formed from the Vacuum!



From the dark Universe


into the visible one


Sloan Great Wall
2dFGRS
CfA2 Great Wall
Millennium Simulation
billion years
lookback time in billion years
redshift z
cz [km/s]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