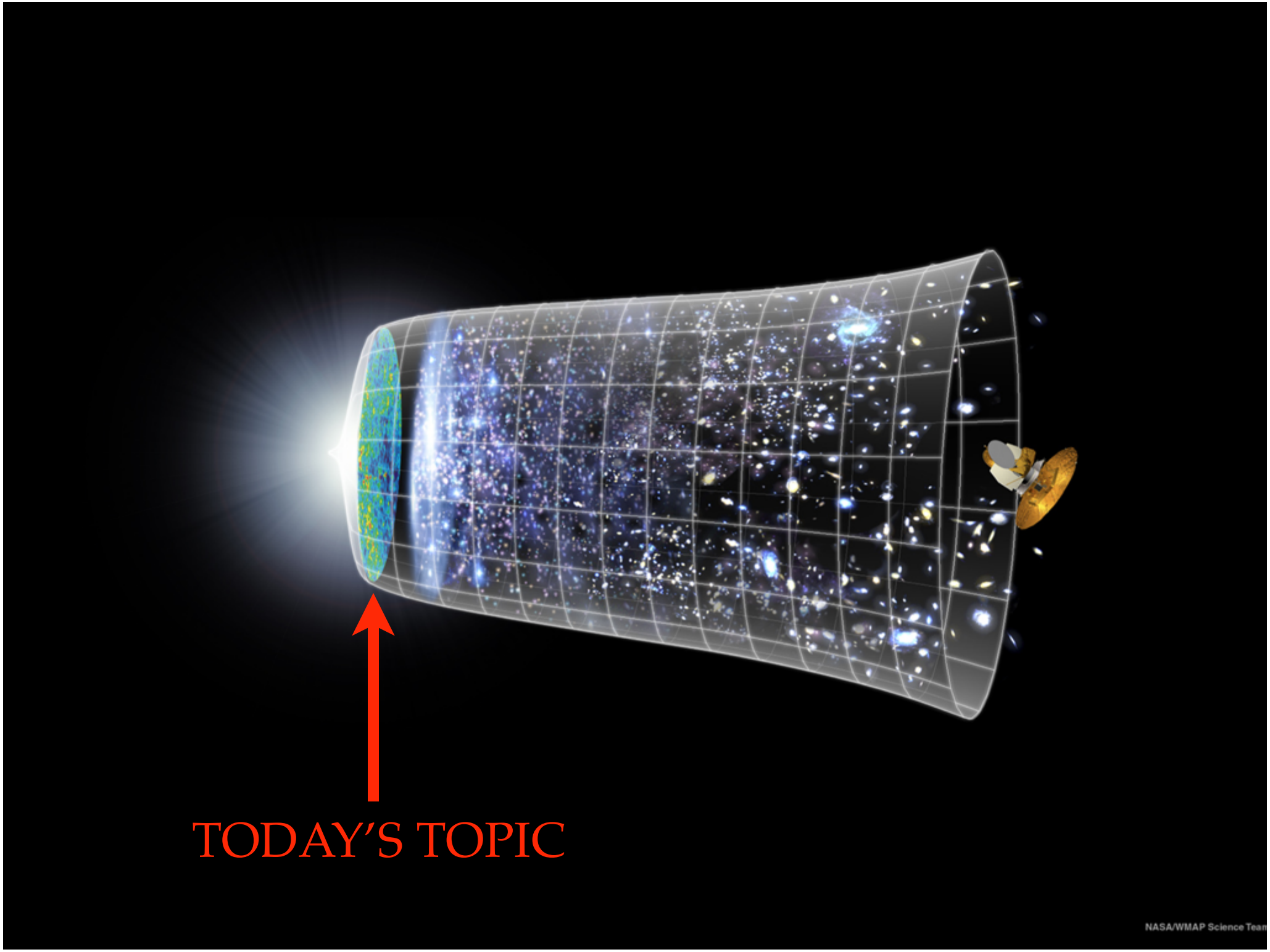
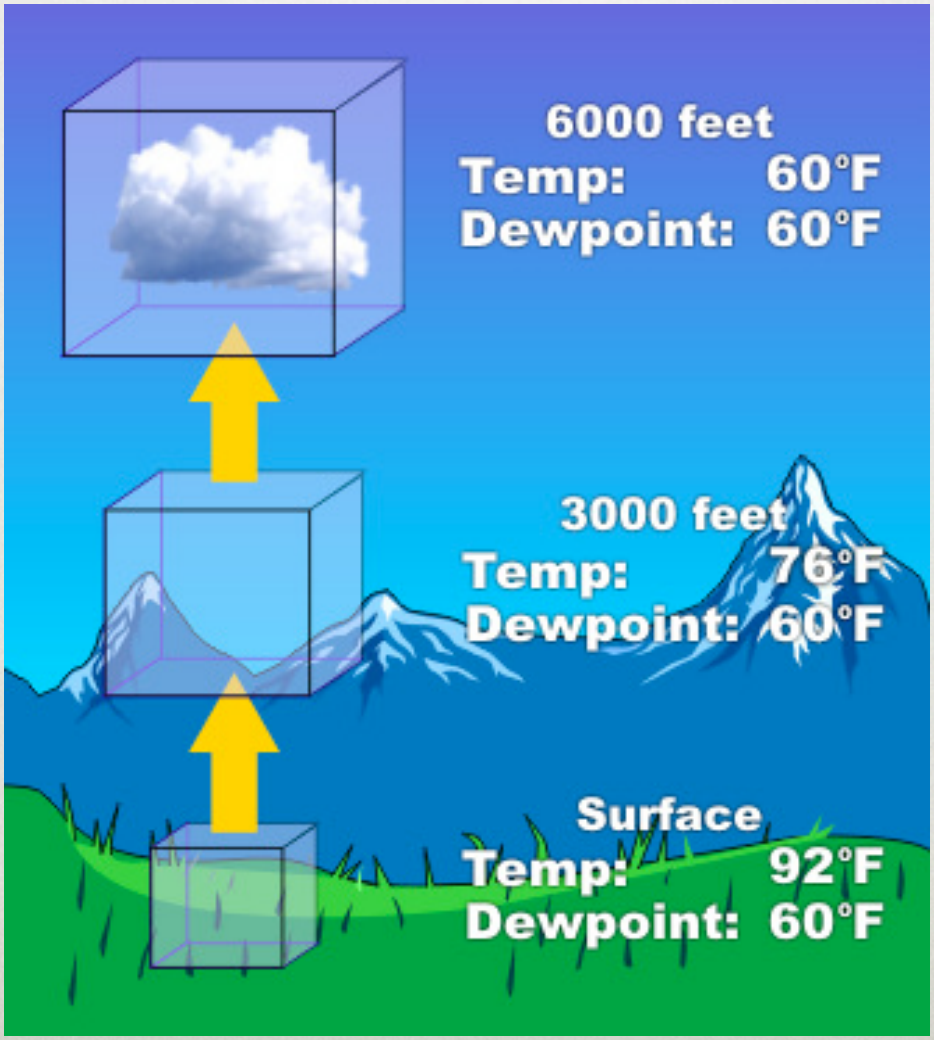
The Cosmic Microwave Background Radiation

Mark Wyman

74th Compton Lecture Series

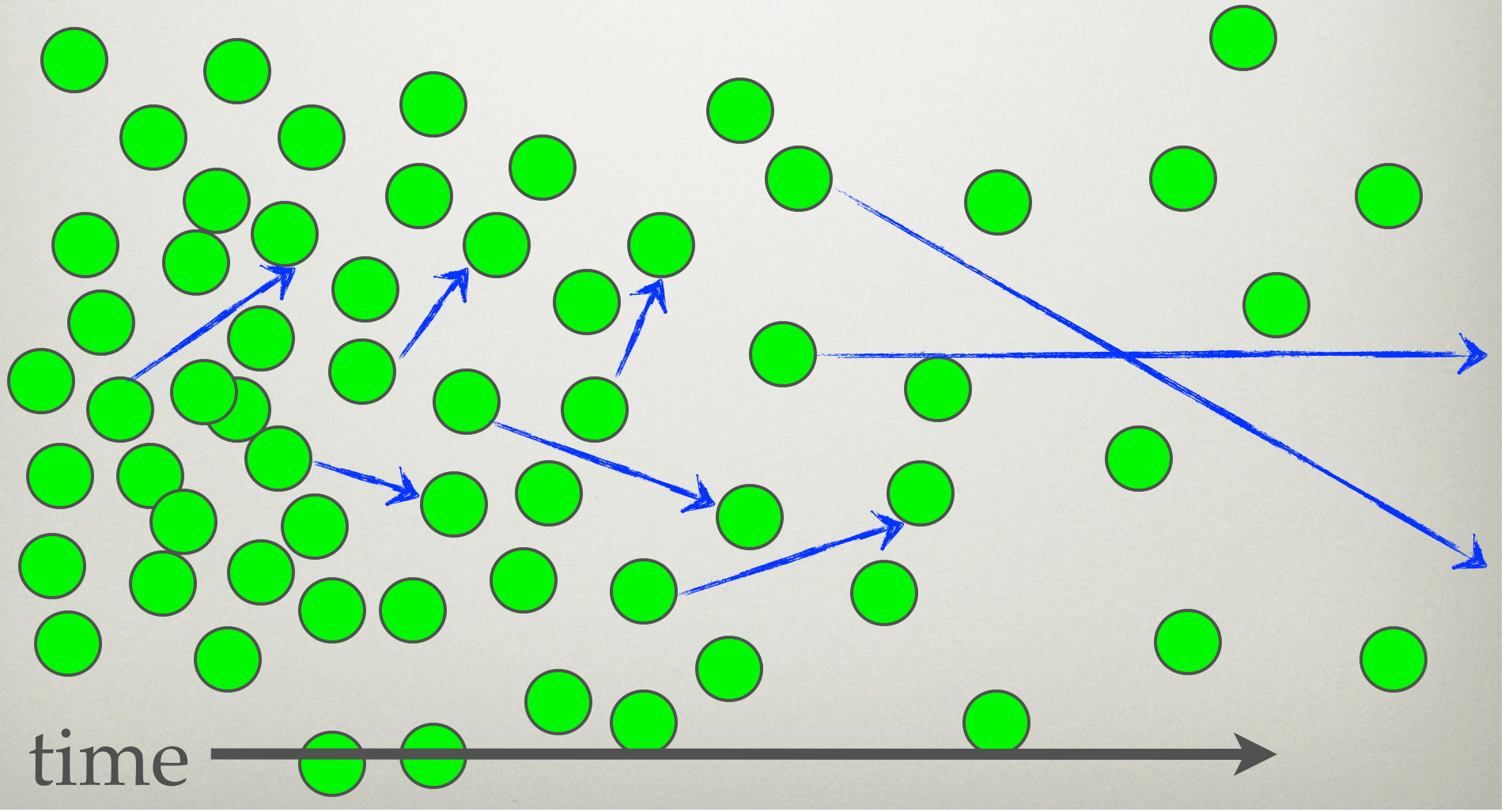

TODAY'S TOPIC
NASA/WMAP Science Team

Adiabatic Cooling

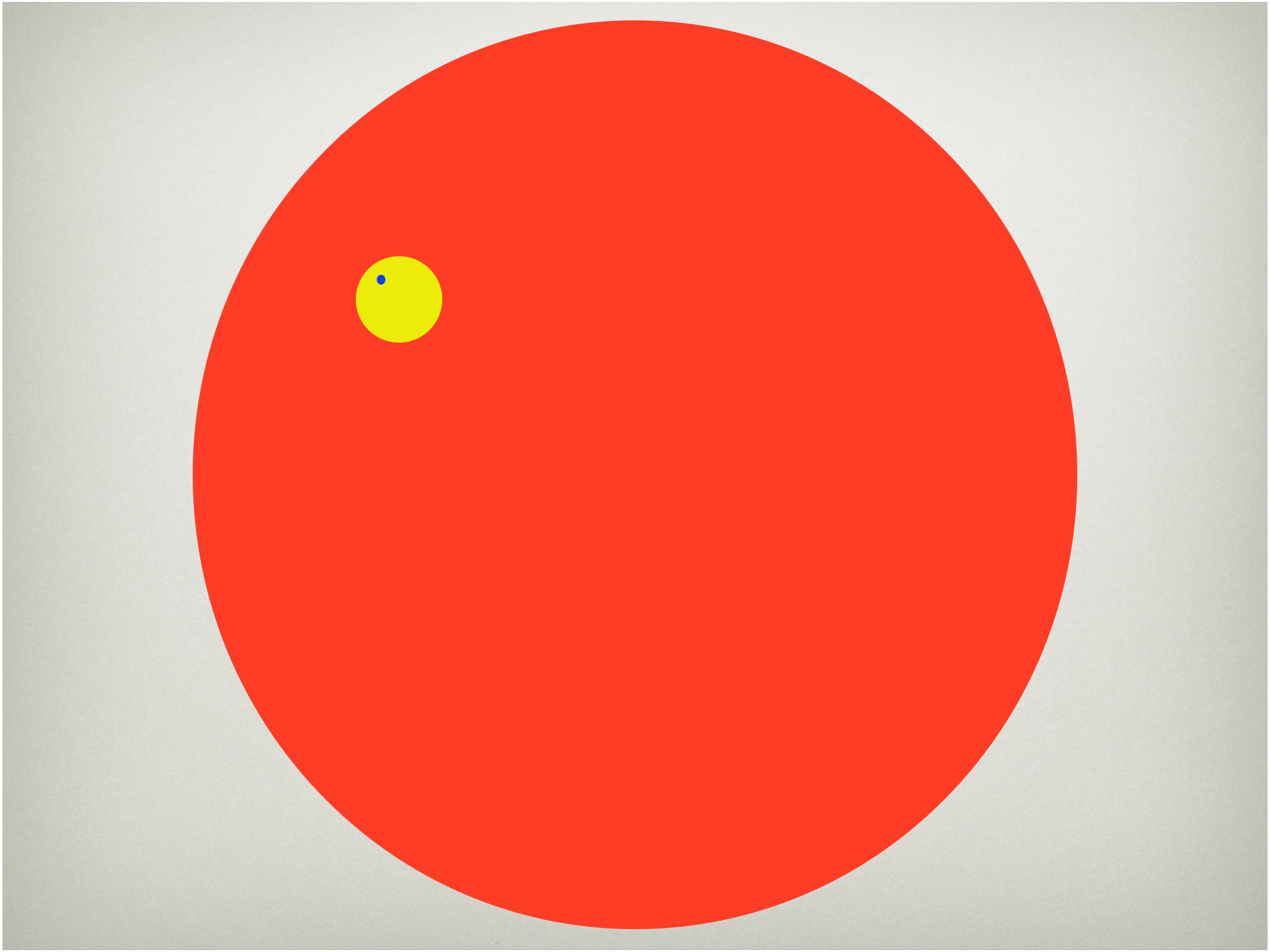


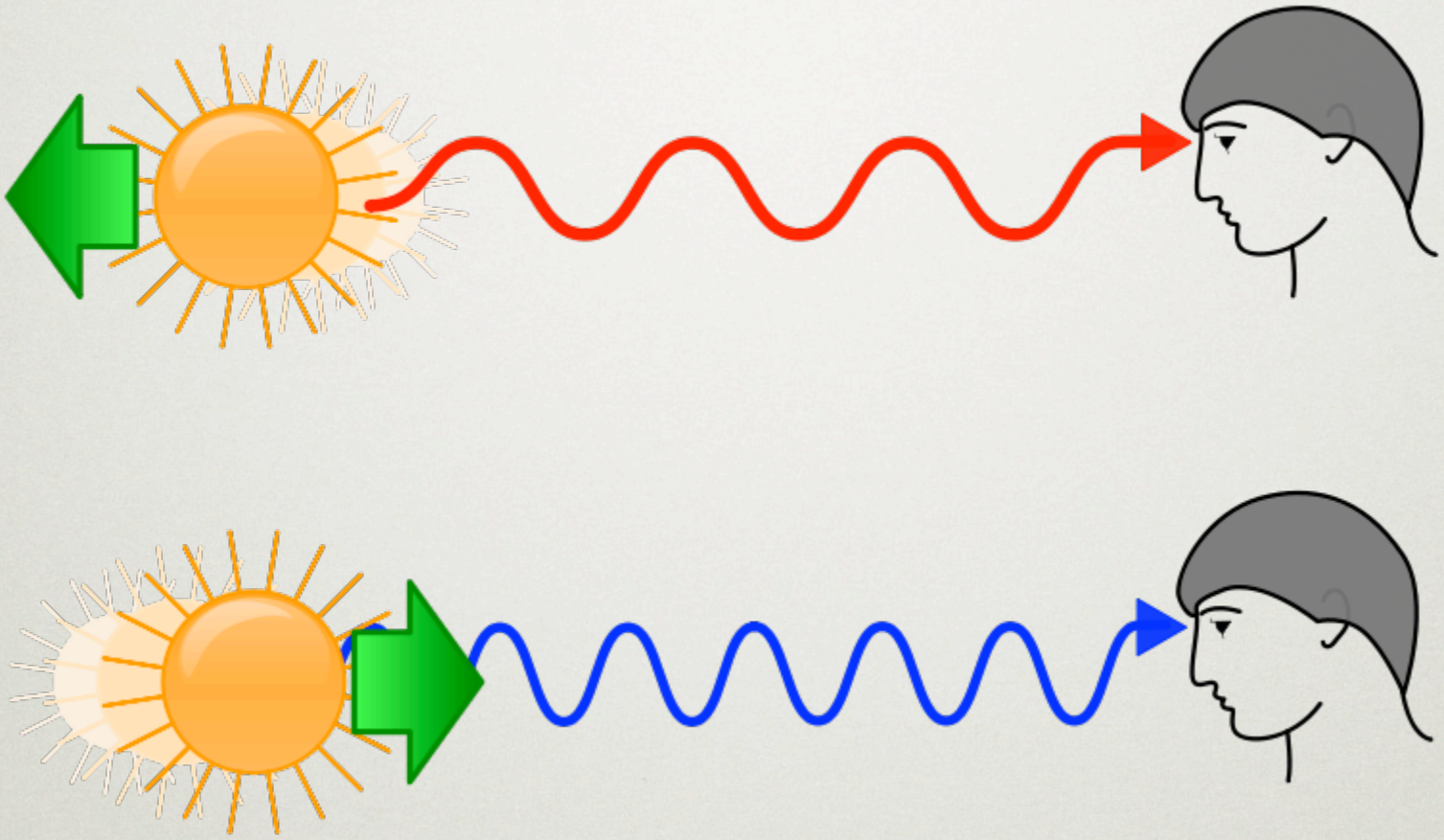
Transparency!

aka Last Scattering

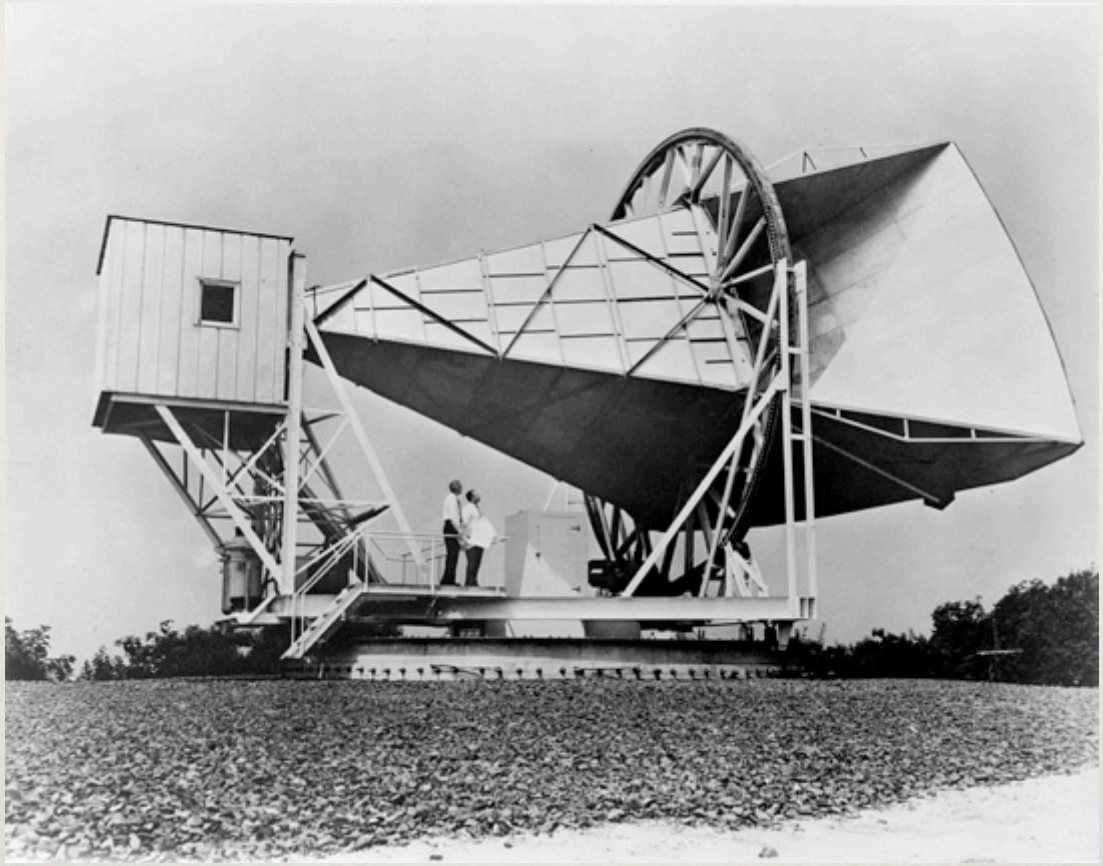


(this is how we see clouds, too)





Discovery of the CMB: 1964



Wilson

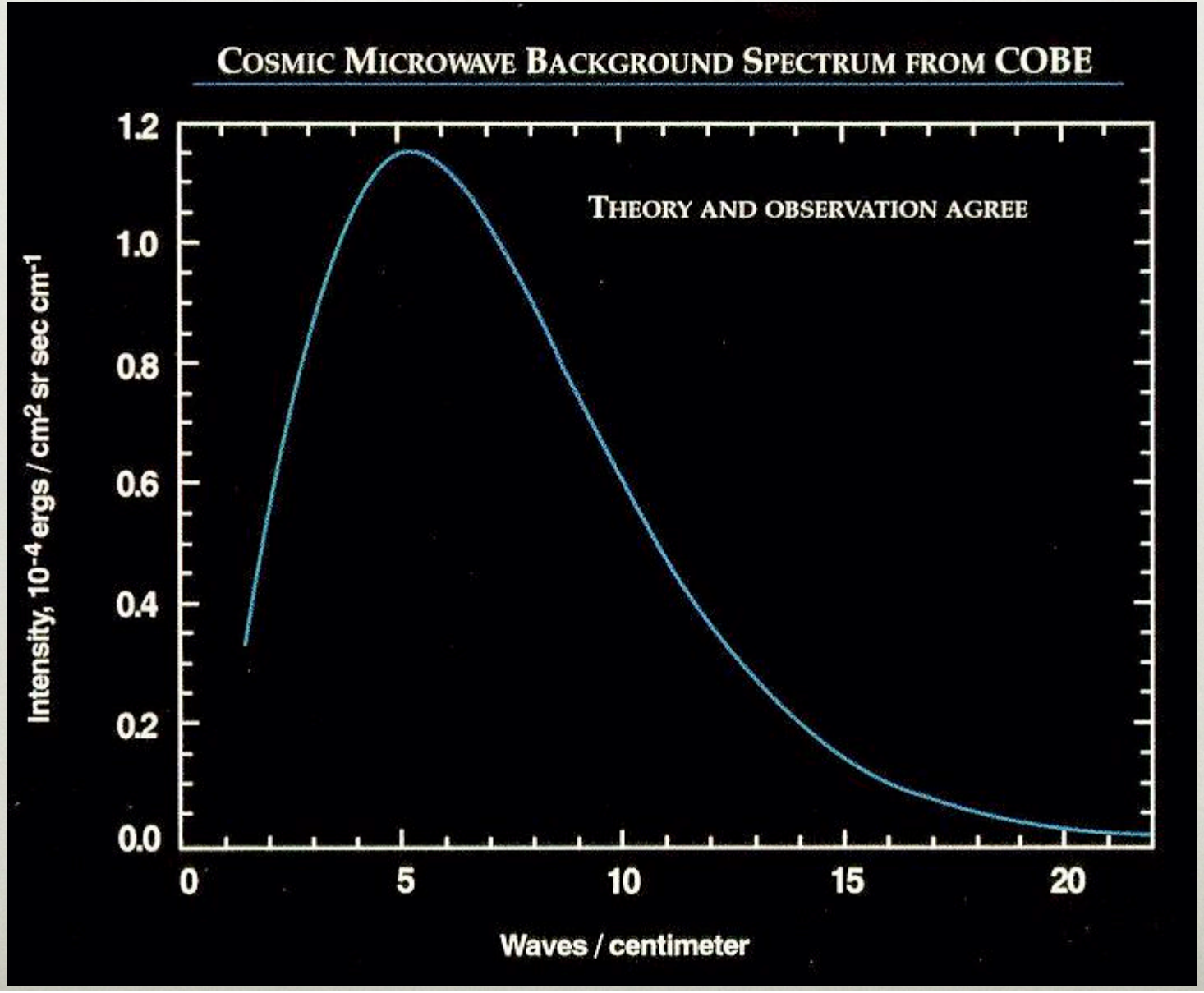
Penzias

Discovery of the CMB: 1964

Wilson

Penzias

A Perfect "Black Body"



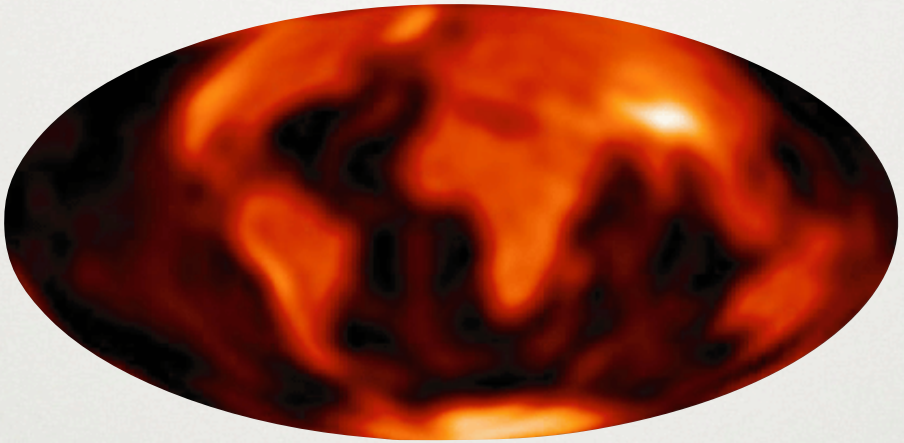
We've all detected the CMB!

TV Channel 69 (used to) broadcast at 800 MHz

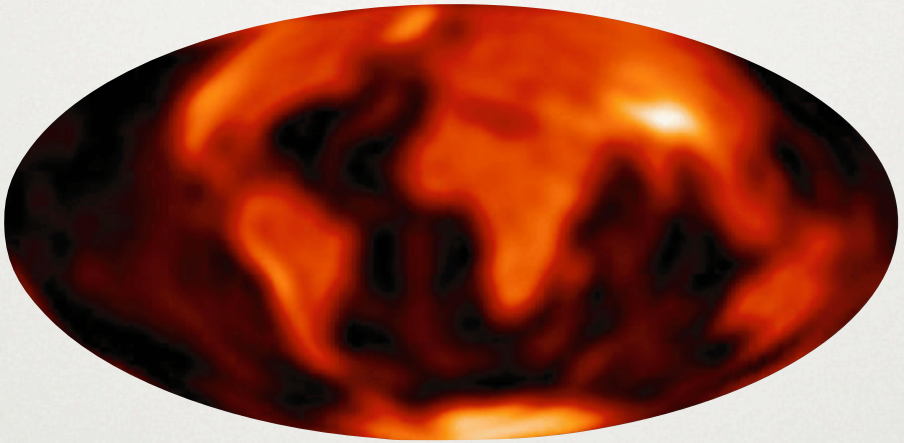
CMB approx 1% of TV noise!

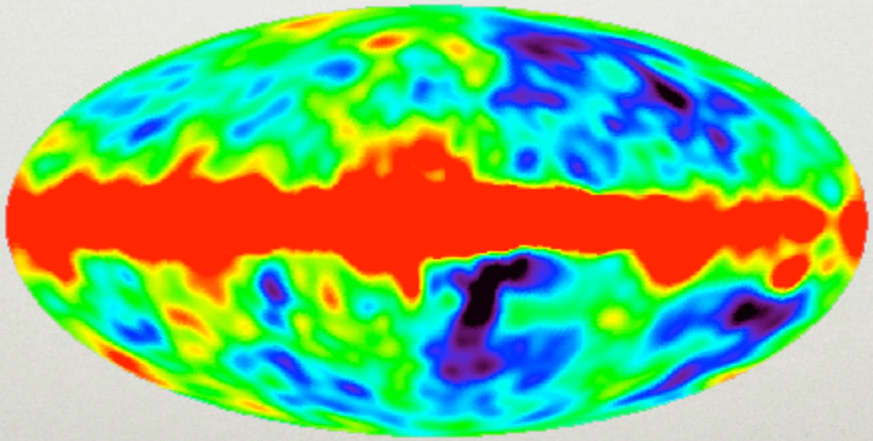
The CMB Revolution

Cosmic Background Explorer (1994)

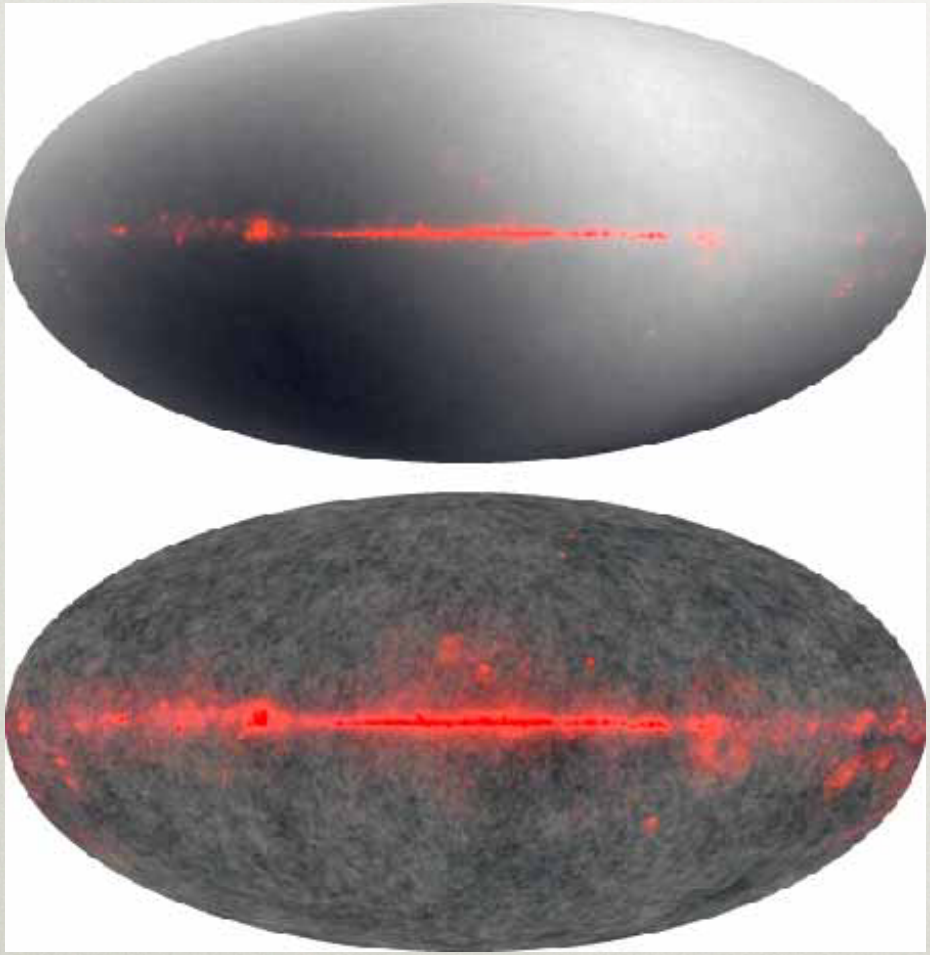


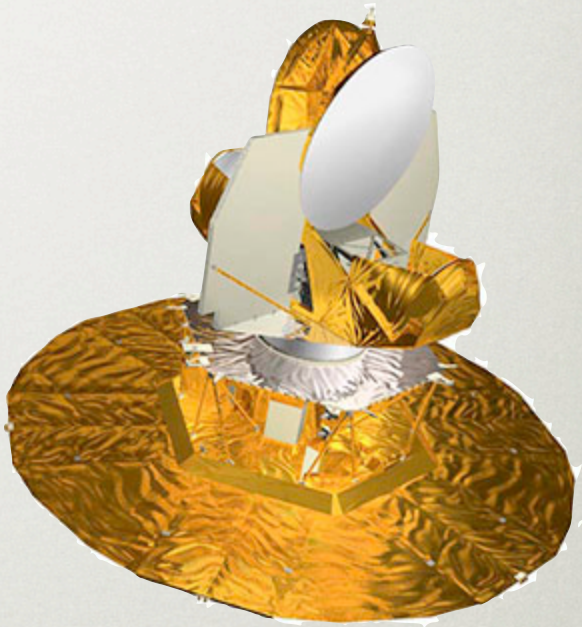
Cosmic Background Explorer (1994)



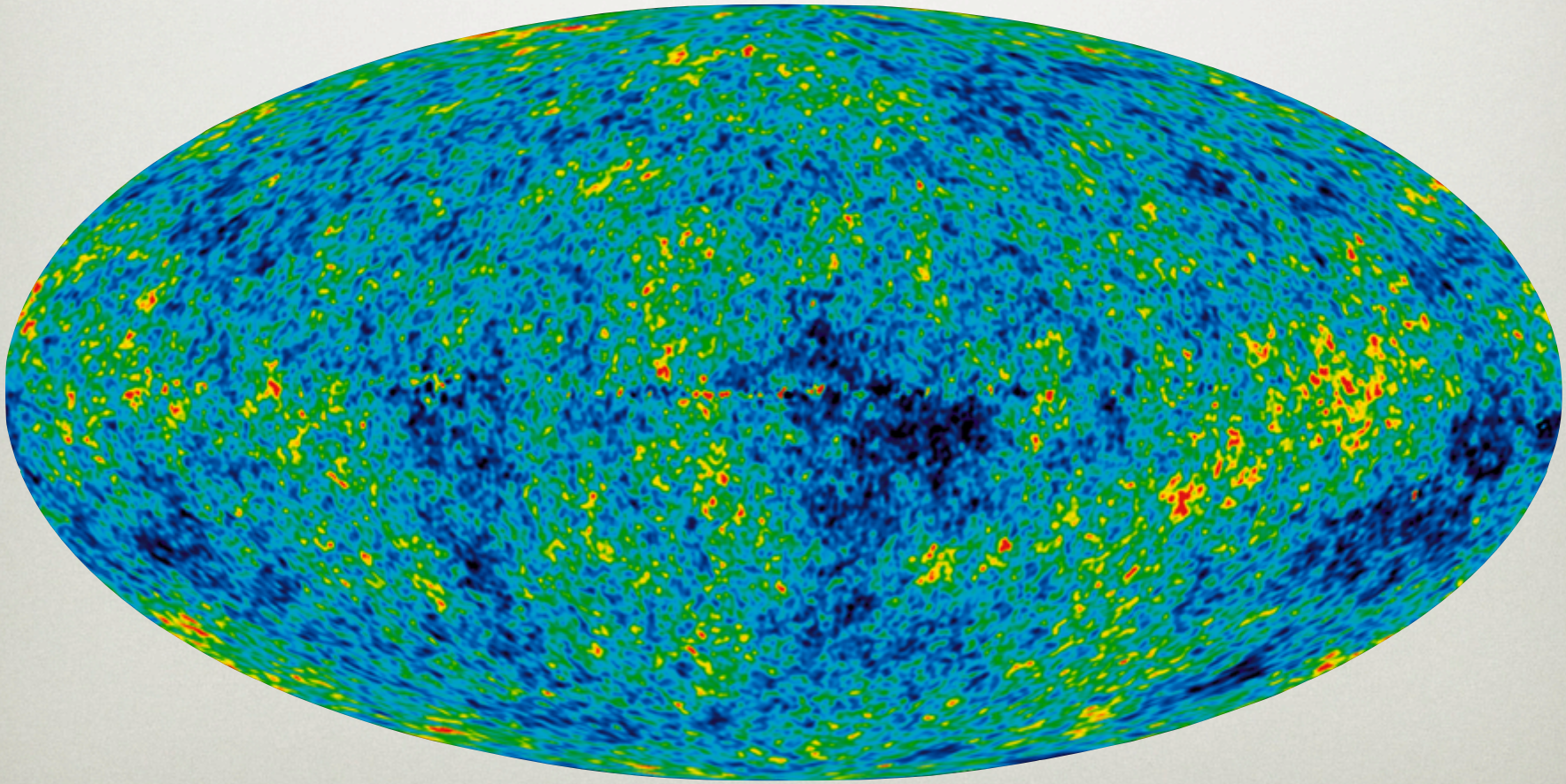


Wilkinson Microwave Anisotropy Probe (2003)

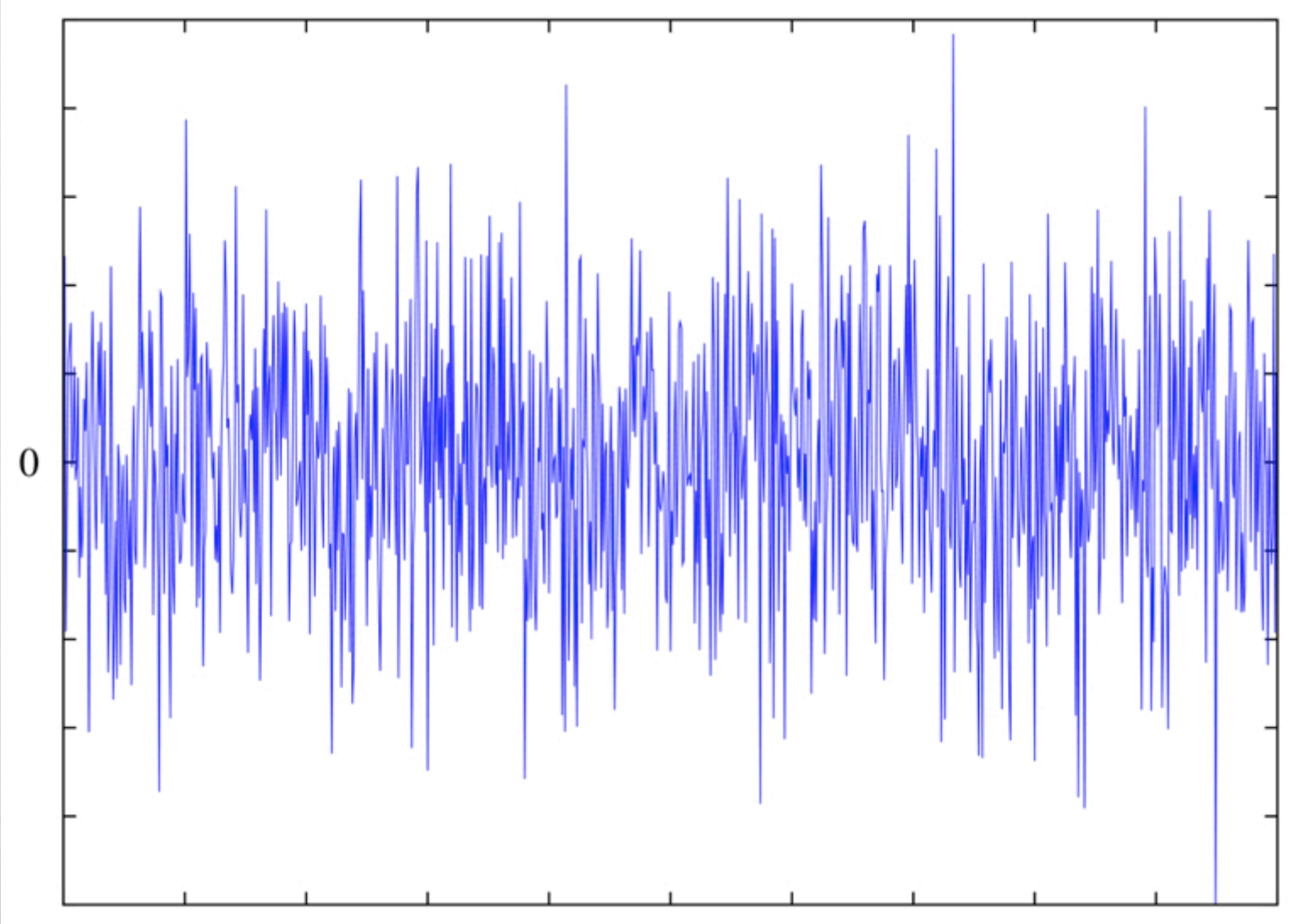


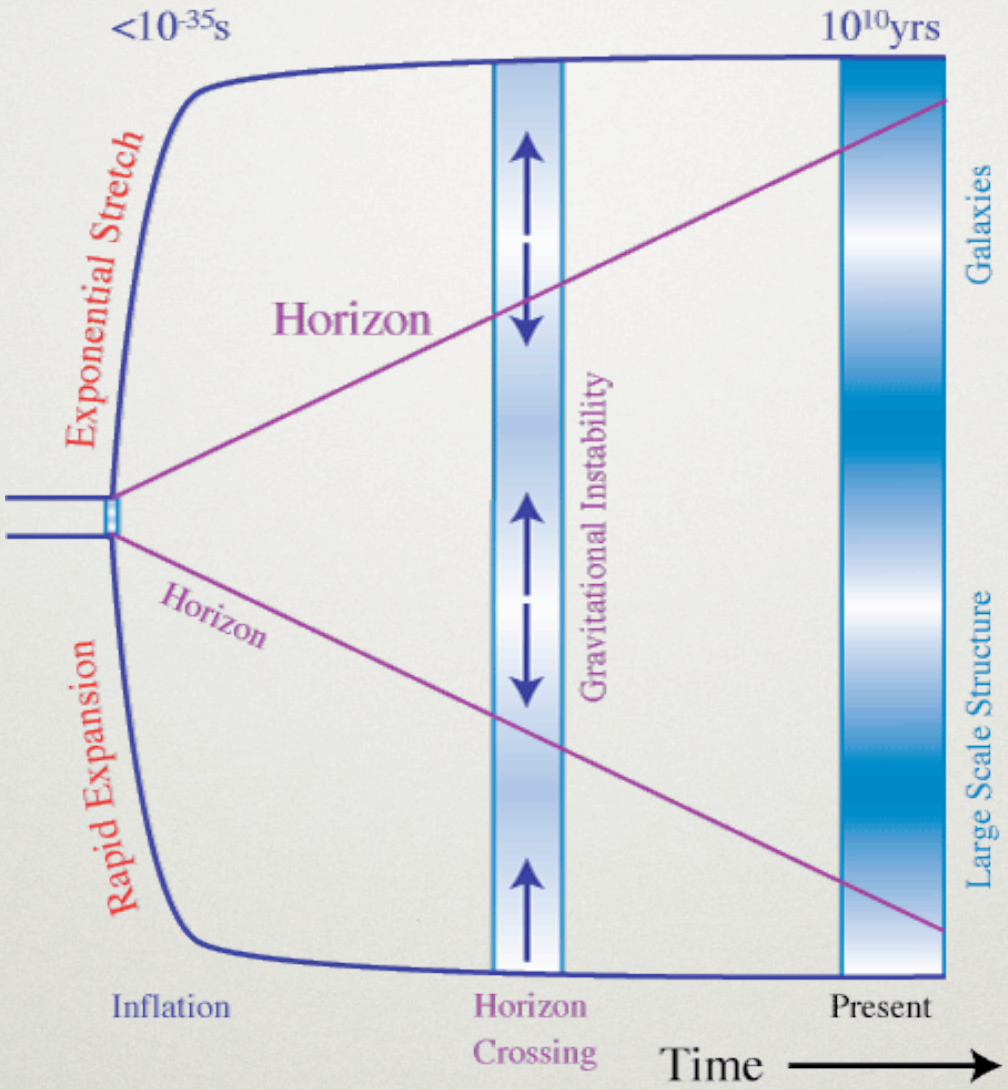


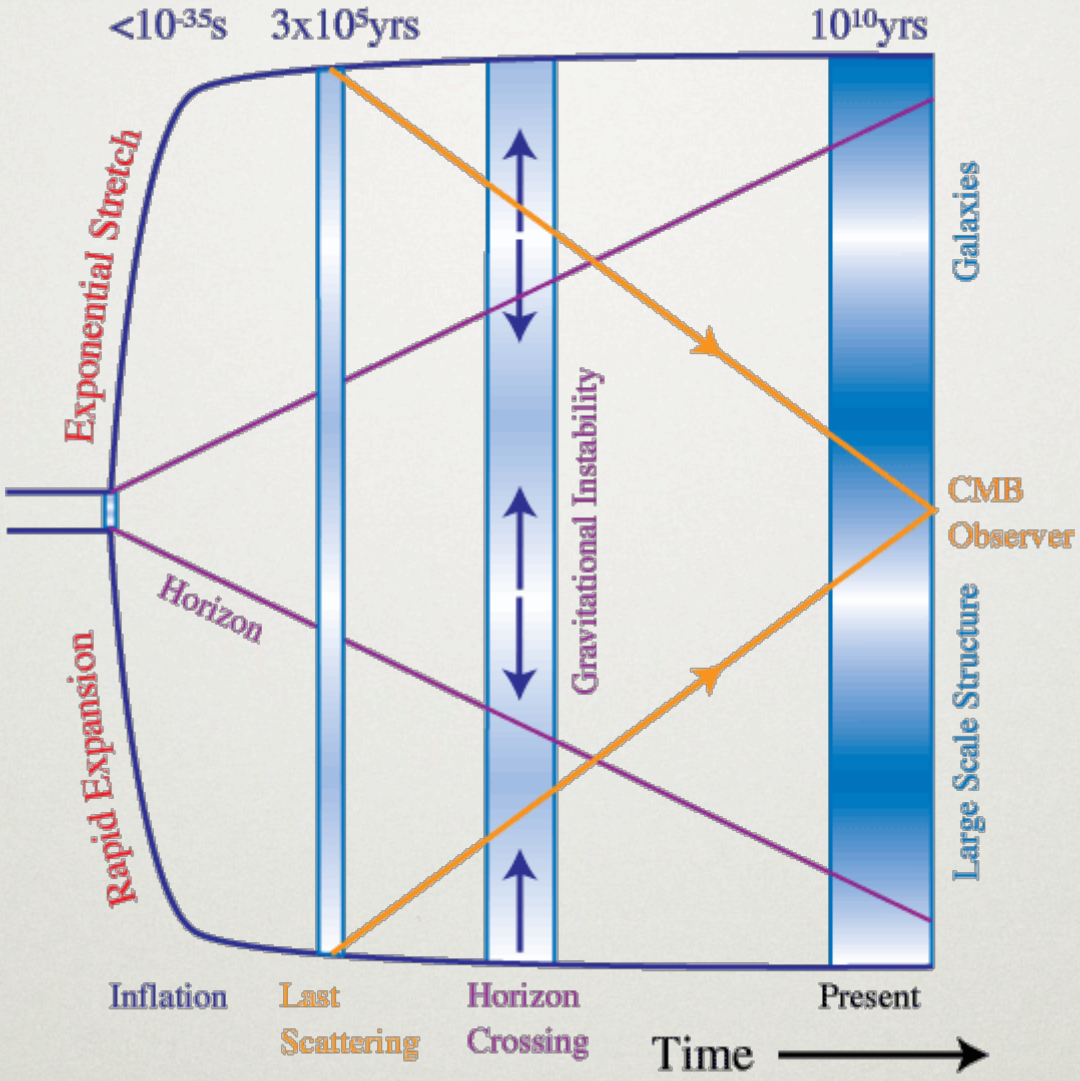
The cleaned WMAP sky



Inflation produces quantum Perturbations

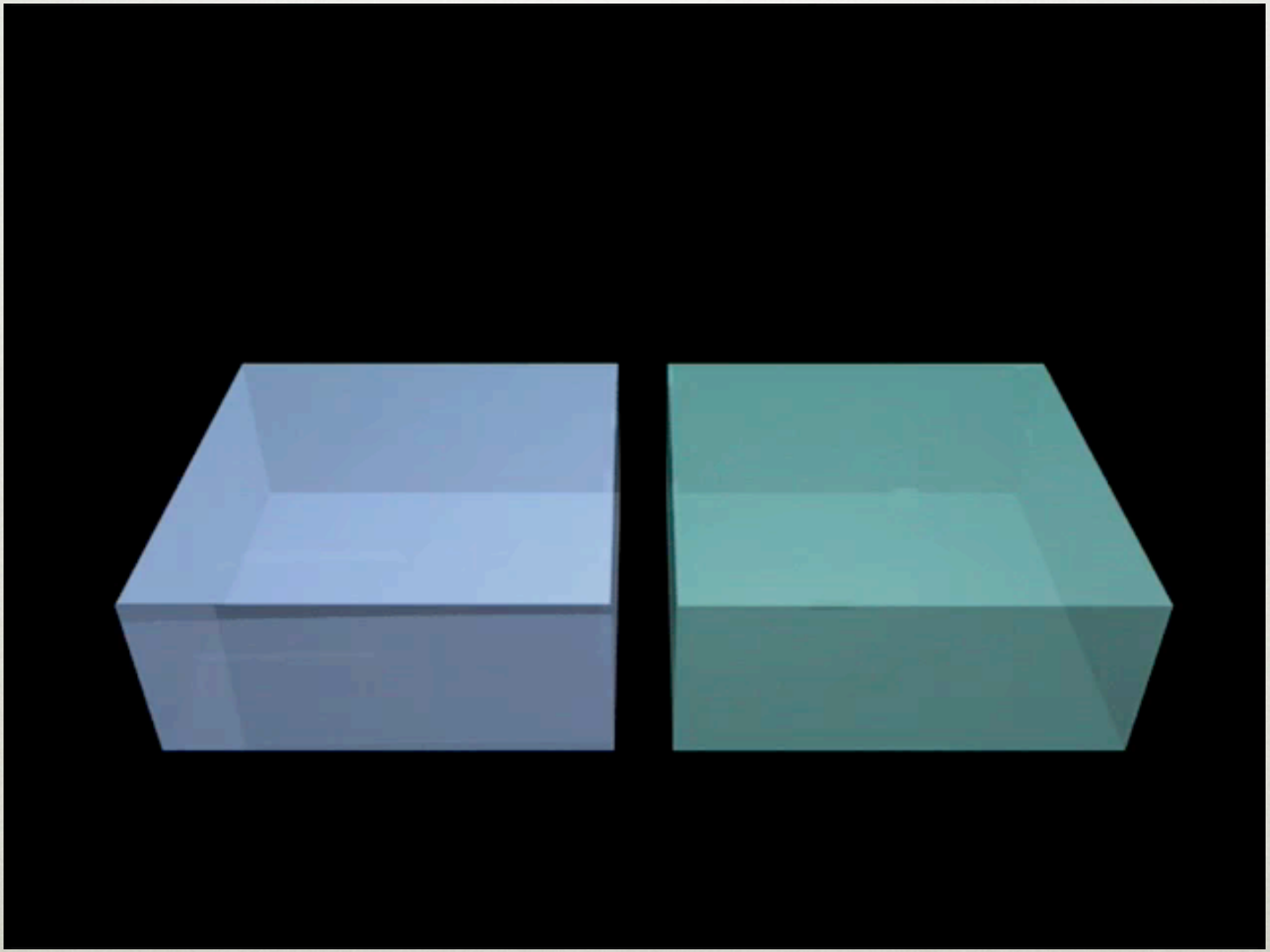



<10^-35s
10^10yrs
Exponential Stretch
Horizon
Gravitational Instability
Galaxies
Horizon
Rapid Expansion
Large Scale Structure
Inflation
Horizon Crossing
Present
Time

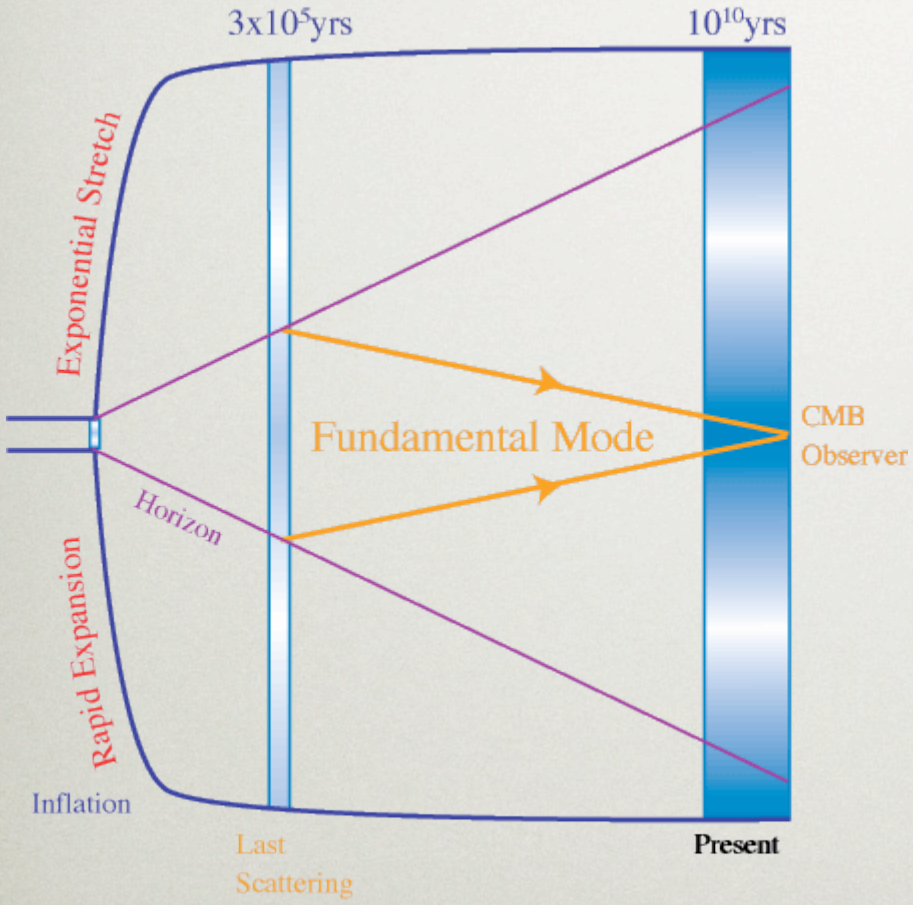

<10^-35s
3x10^5yrs
10^10yrs
Exponential Stretch
Rapid Expansion
Horizon
Gravitational Instability
Galaxies
CMB
Observer
Large Scale Structure
Inflation
Last
Scattering
Horizon
Crossing
Present
Time

Inflationary noise causes fluid perturbations

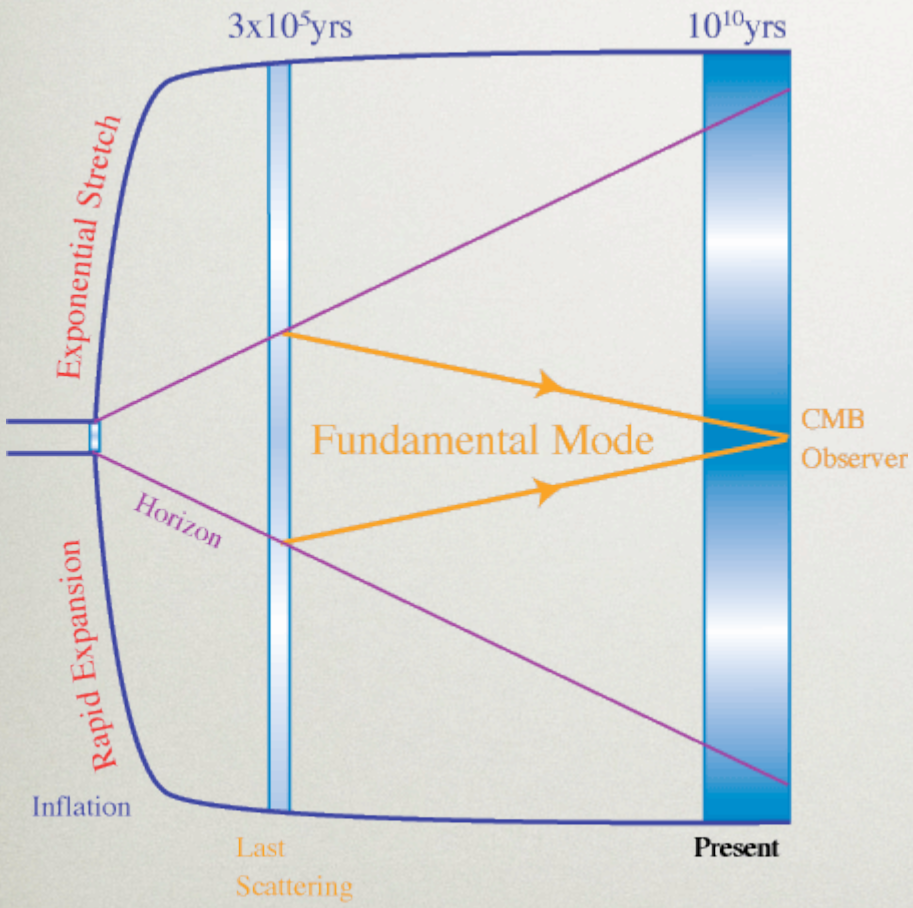
Inflationary noise causes fluid perturbations

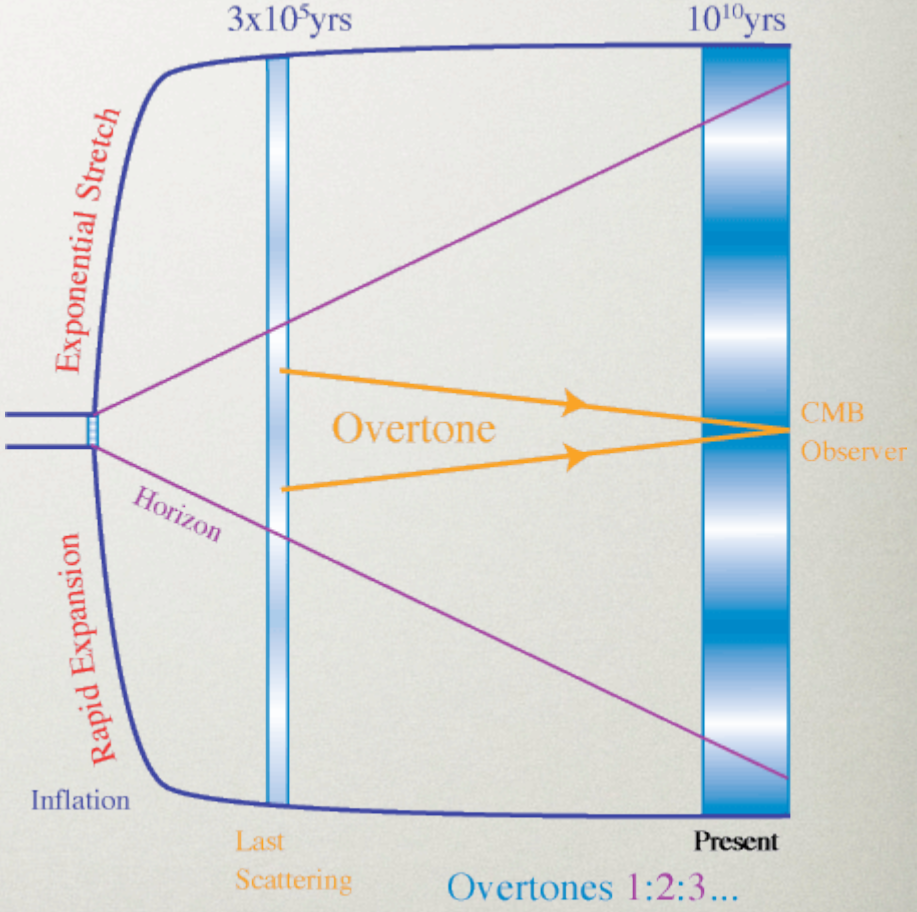


Acoustic oscillations

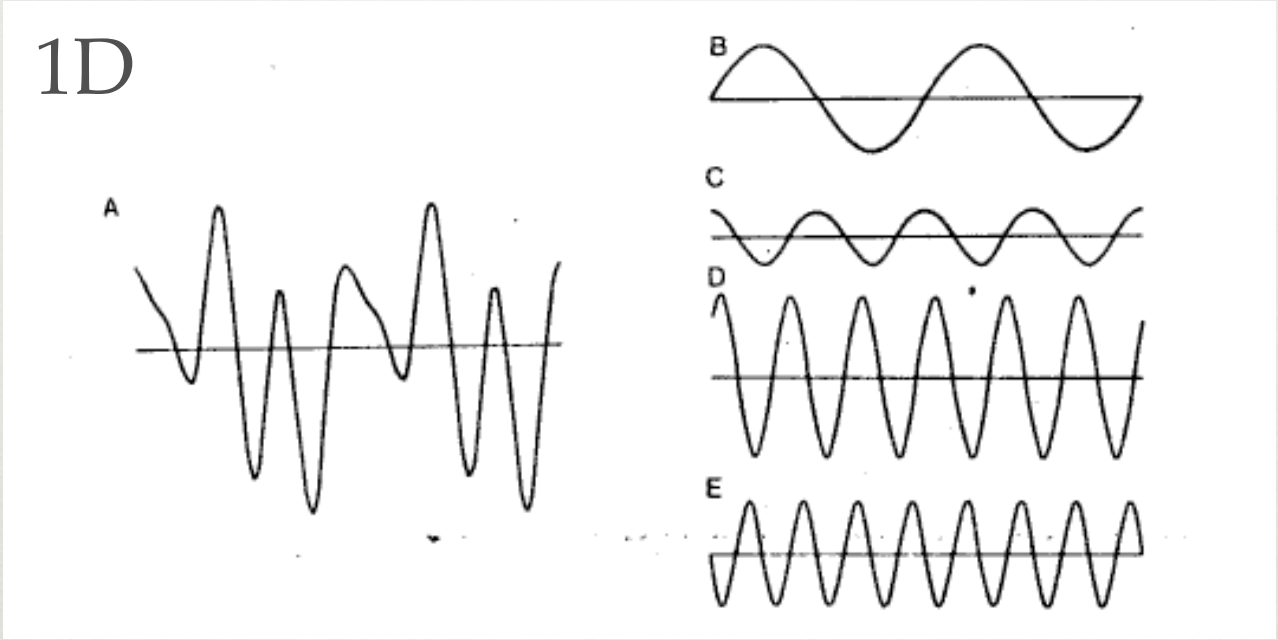


Acoustic oscillations



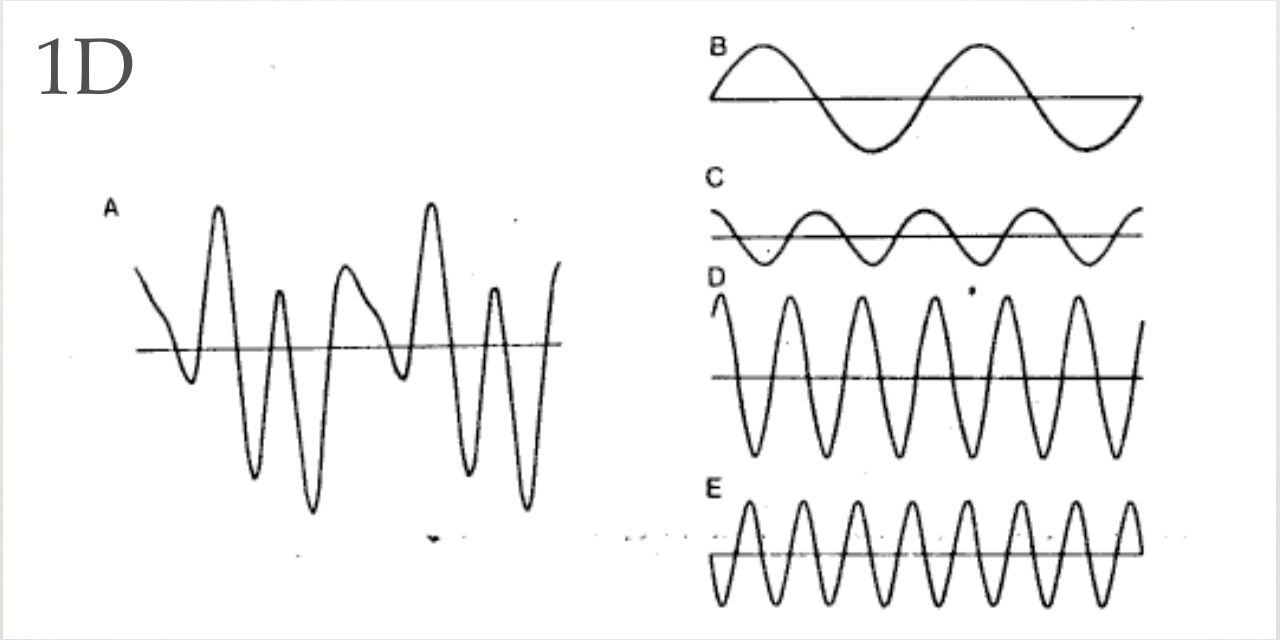


Power Statistics (like fourier analysis)

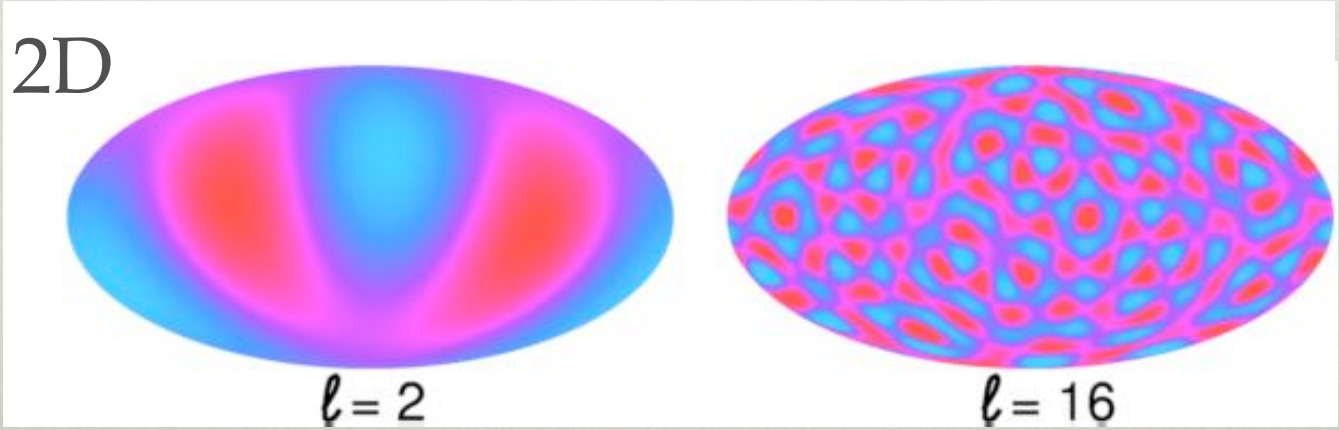


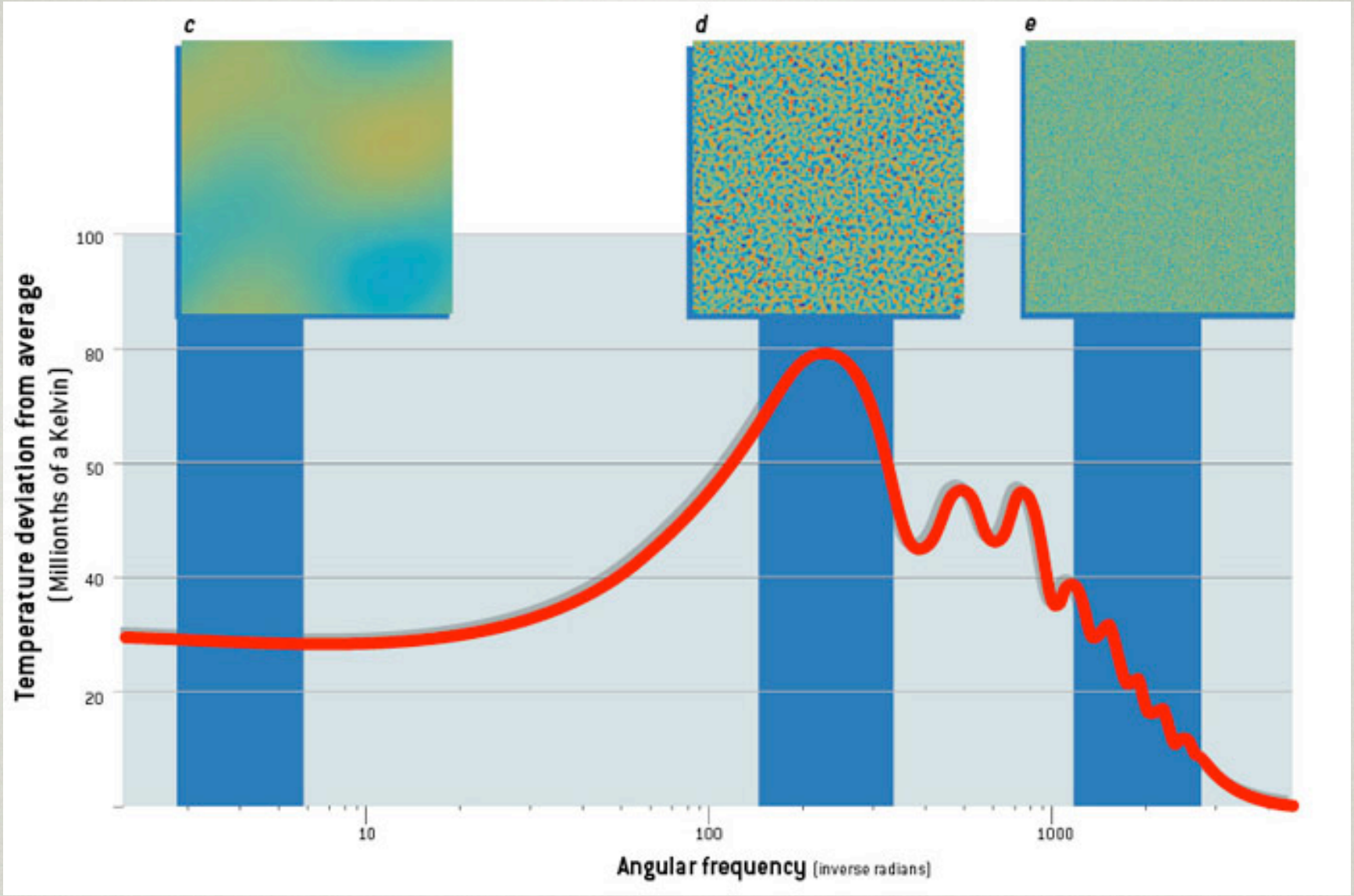
Power Statistics (like fourier analysis)

1D



2D

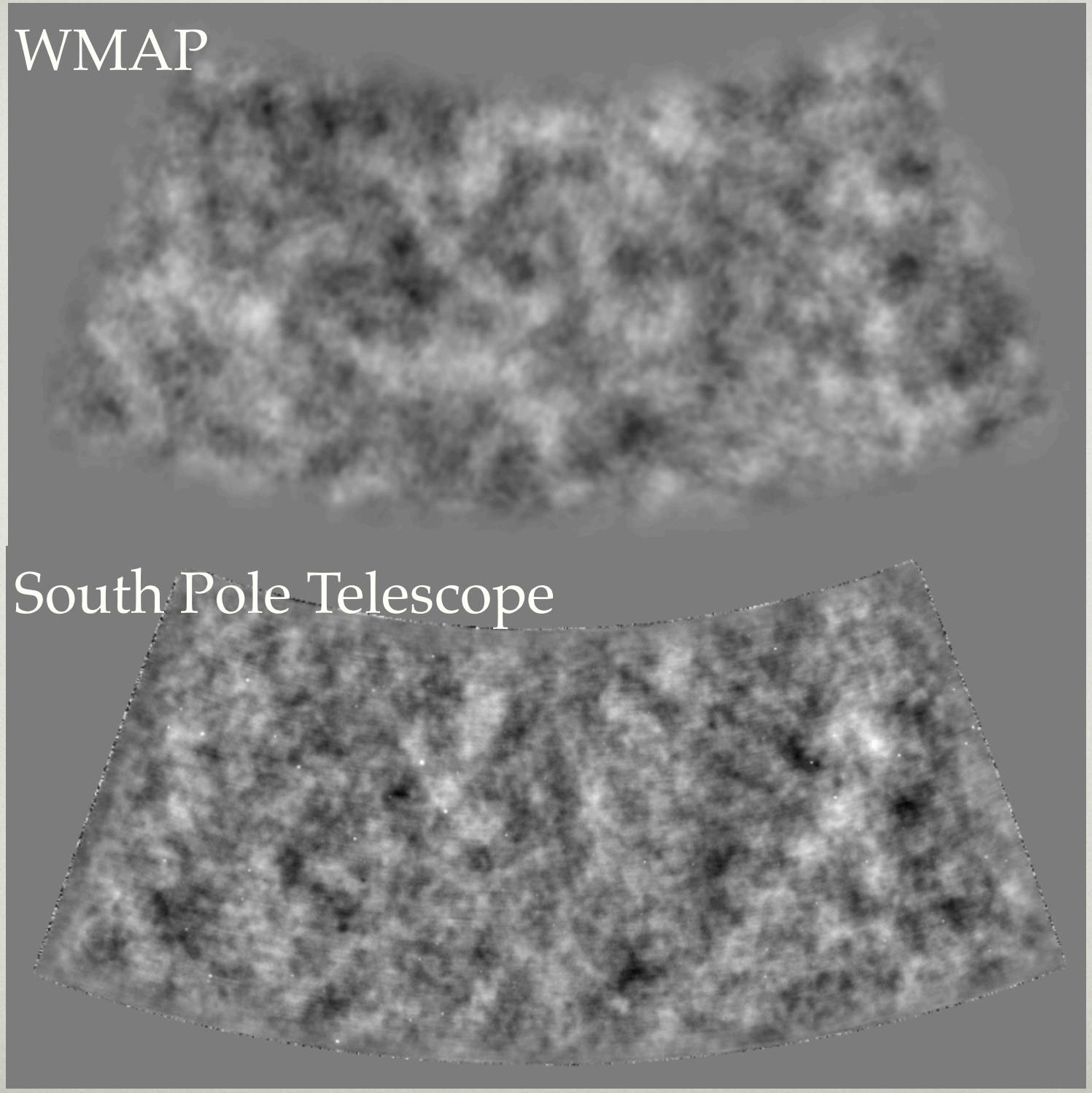




large angles

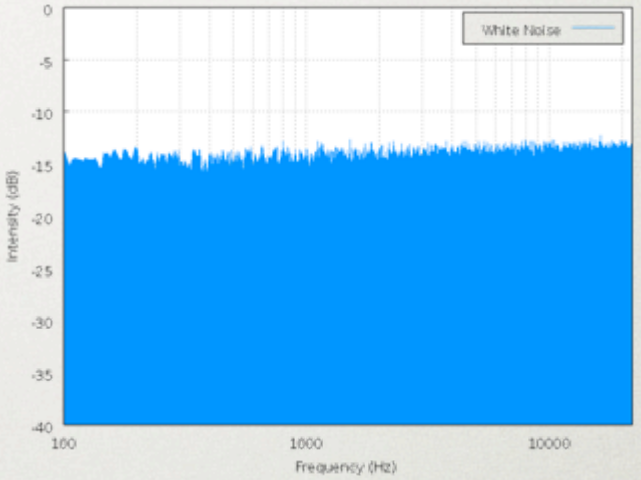
small angles

South Pole Telescope

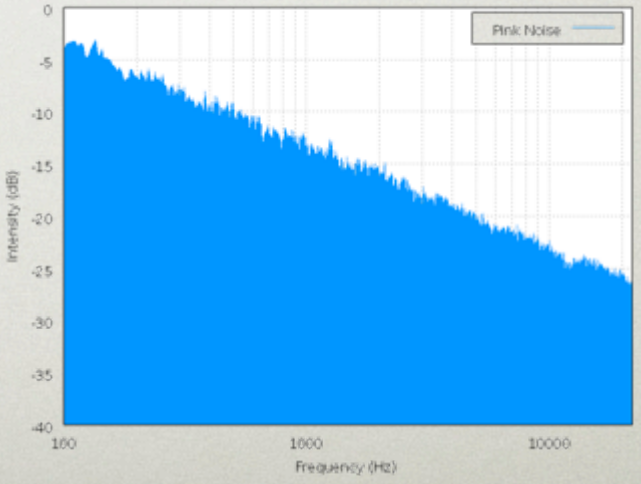

WMAP
South Pole Telescope

What color is the inflationary noise?

white noise



pink noise



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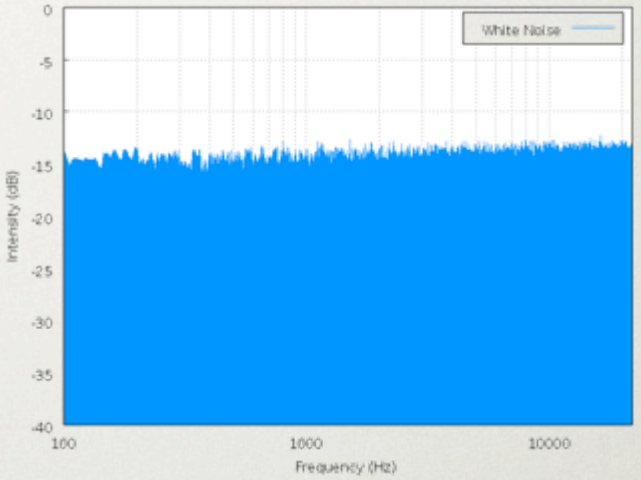
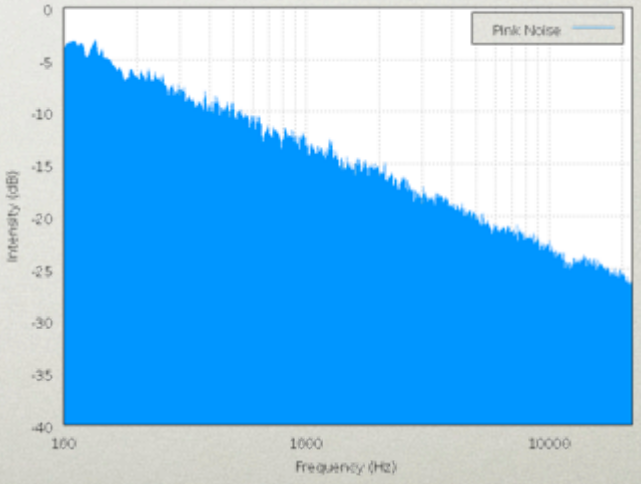


pink noise



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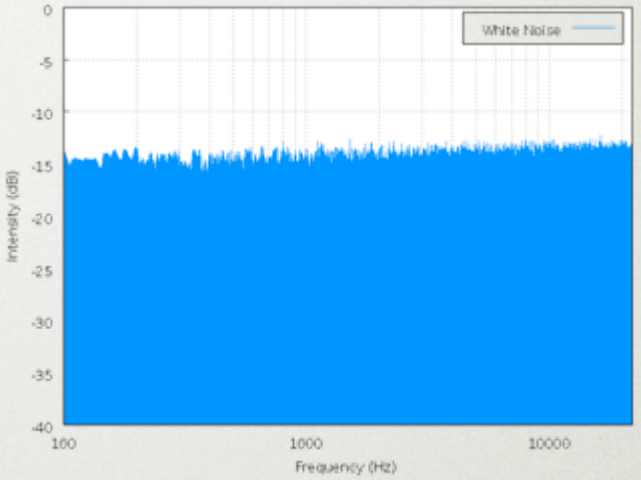
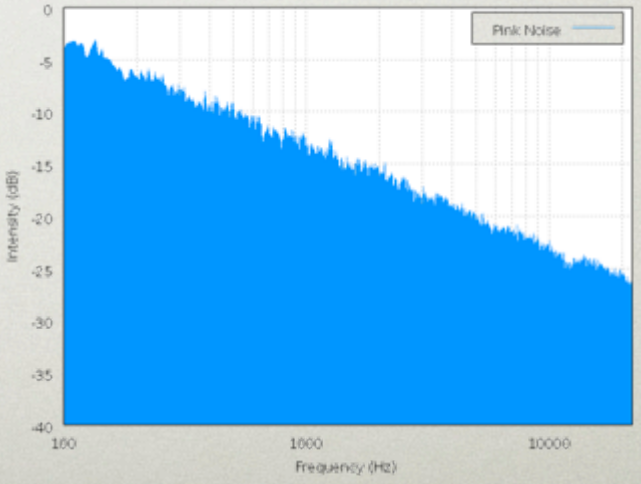
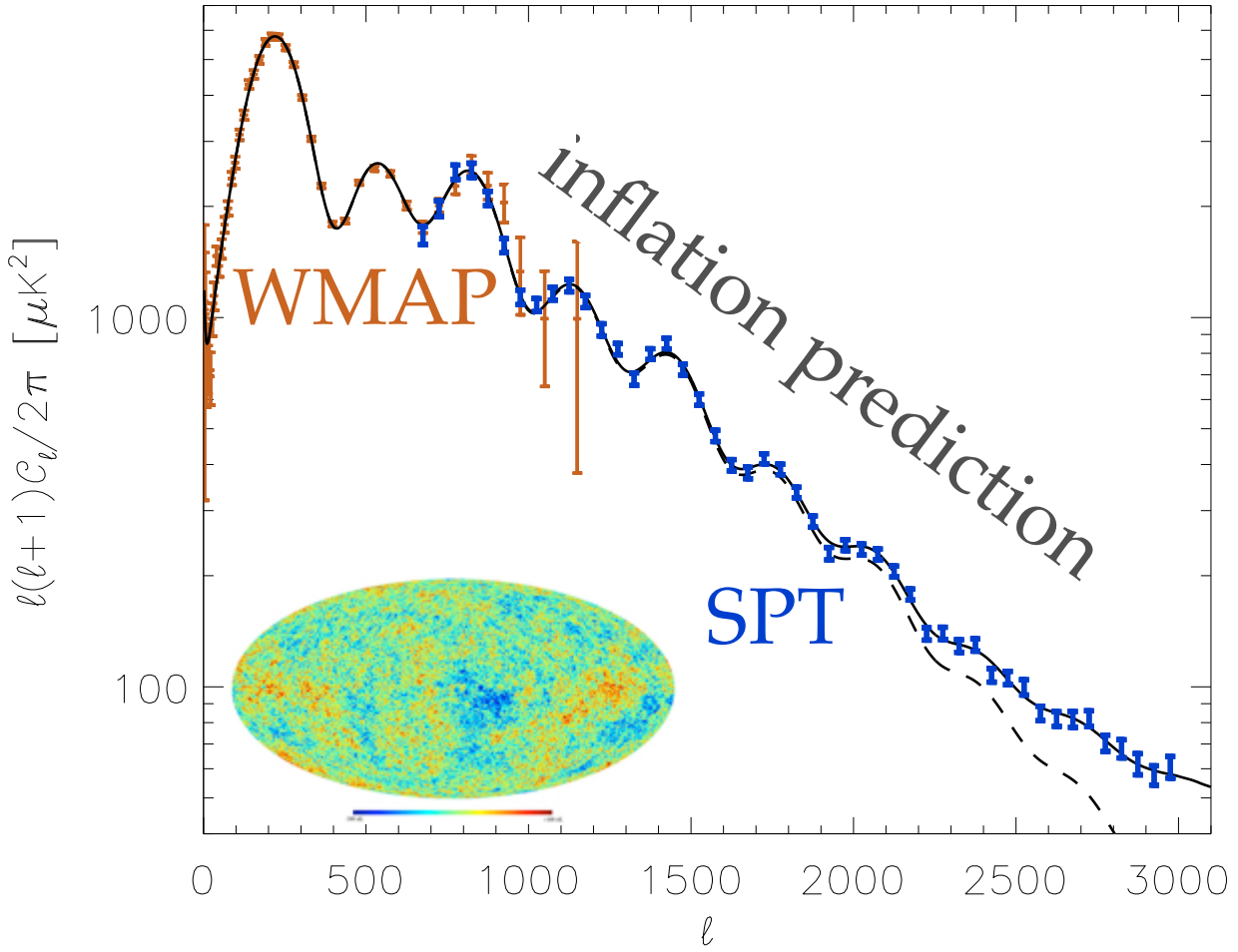


pink noise



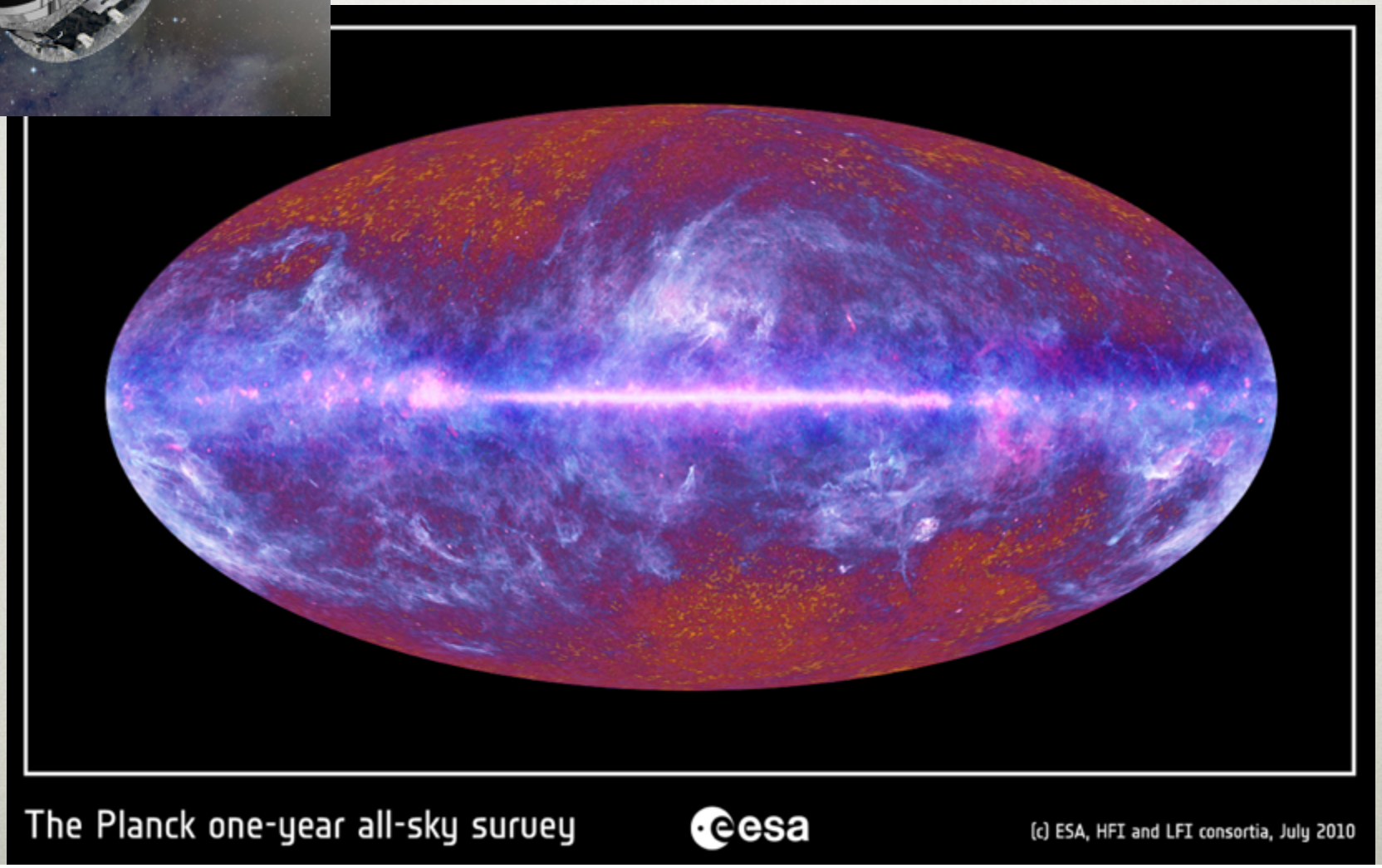
The pattern in the CMB

almost white noise, just a bit pink



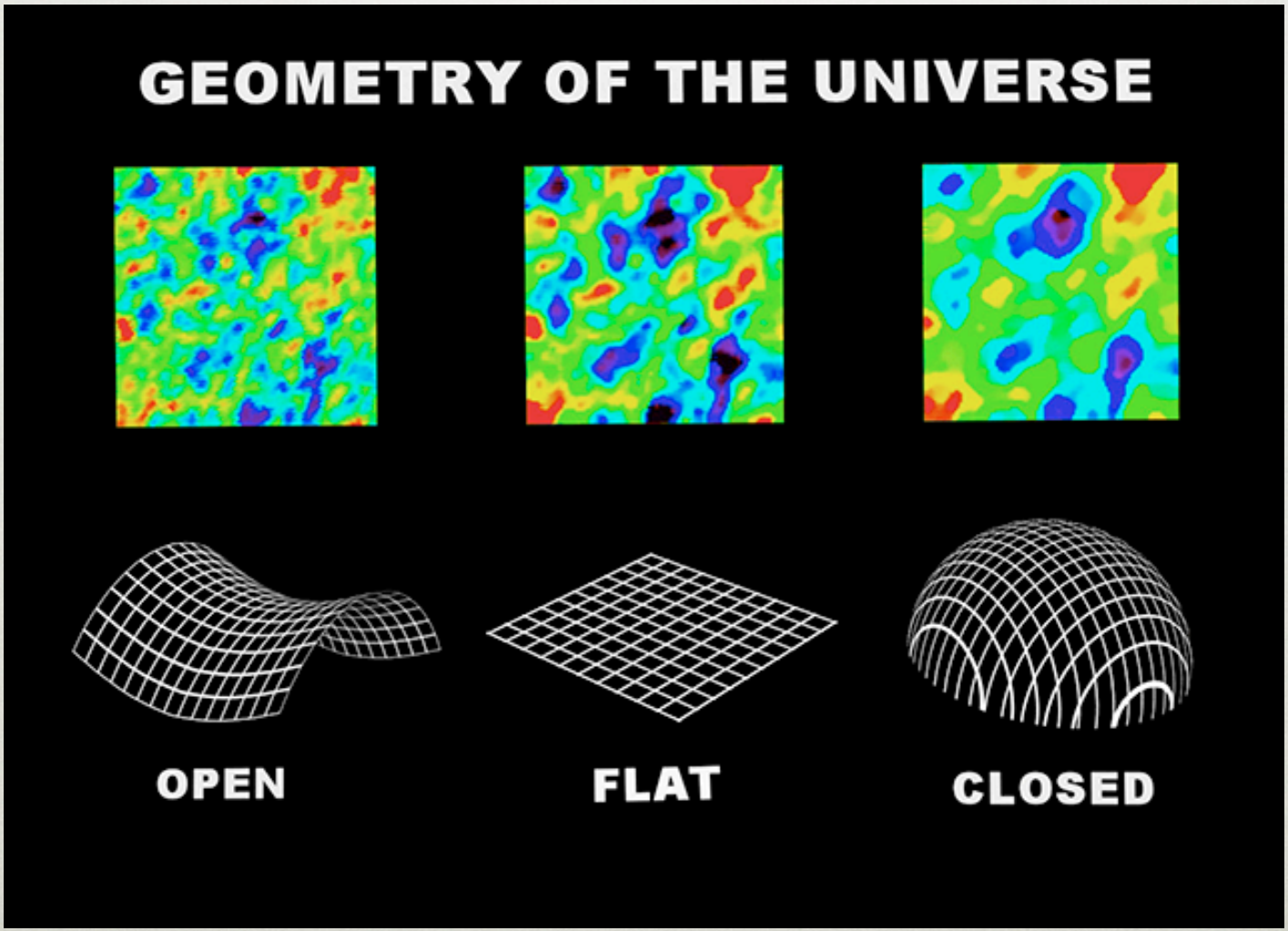
The Next Step: PLANCK!

Cosmology results:
January, 2013

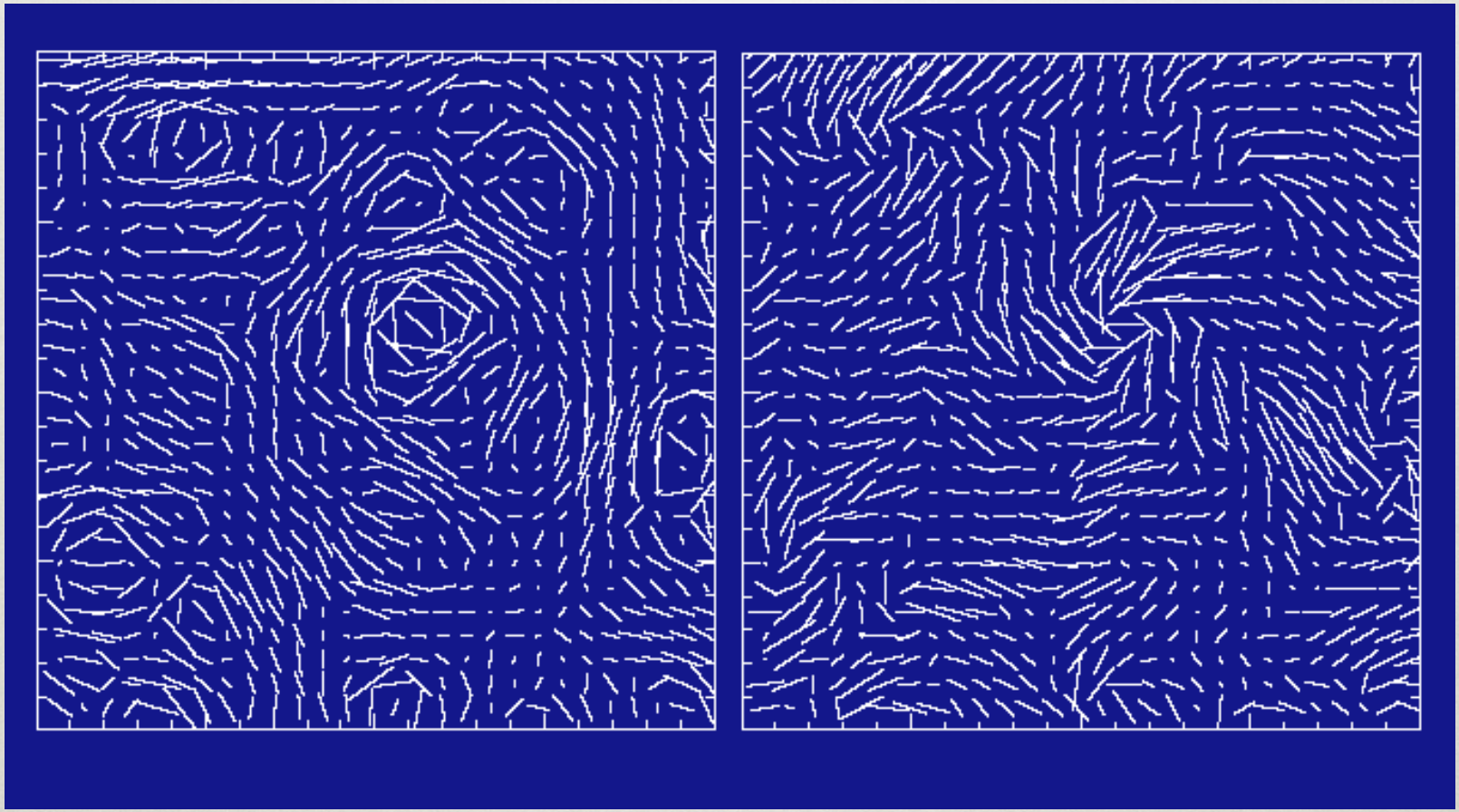


Other Physics from the CMB

The geometry of space is flat!

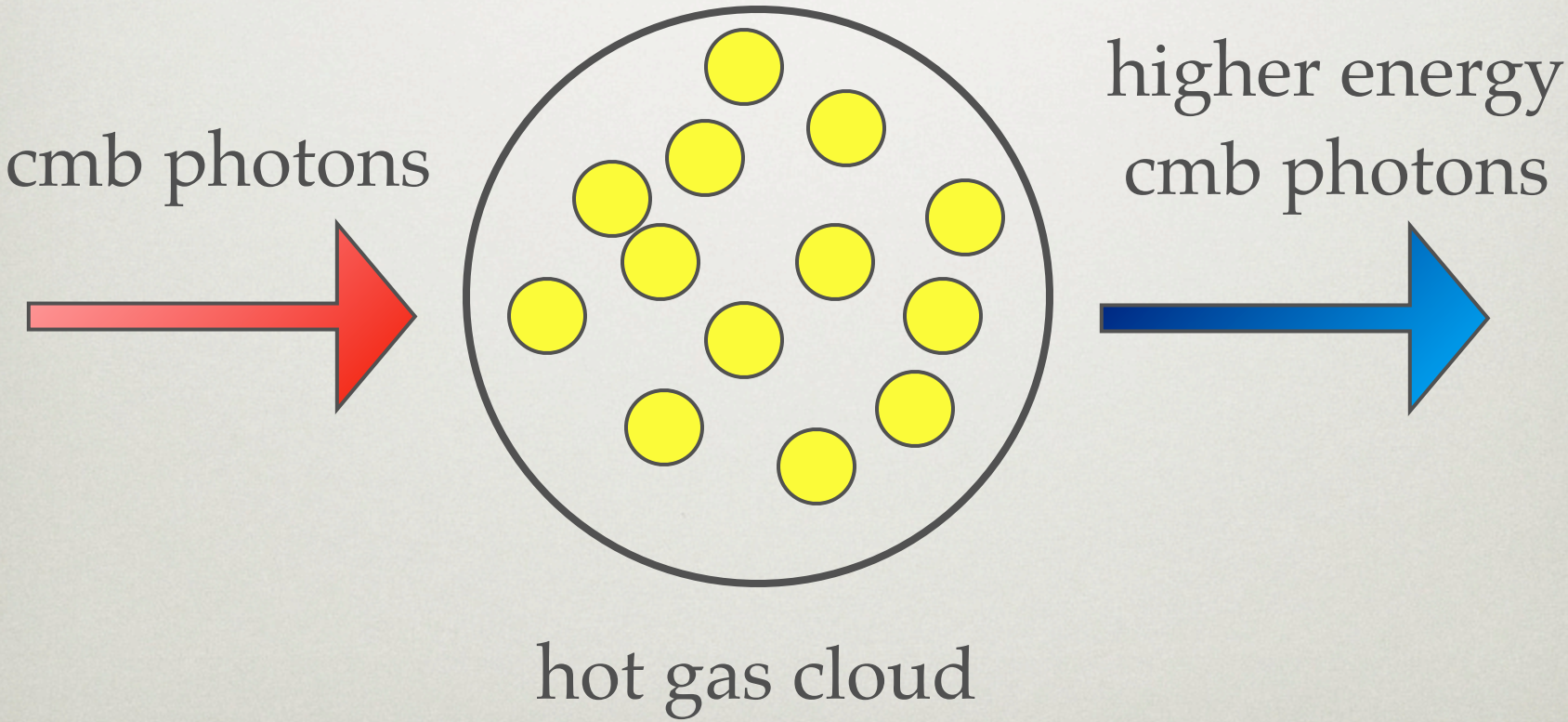


Polarization from Inflationary Gravitational Waves



ordinary polarization Gravity wave polarization

Sunyaev-Zeldovich effect



Sachs-Wolfe effect

photons blueshift
falling into
clusters

photons redshift
coming out of
clusters

alternate proof of accelerating expansion!