

# What we have learned from the baby Universe

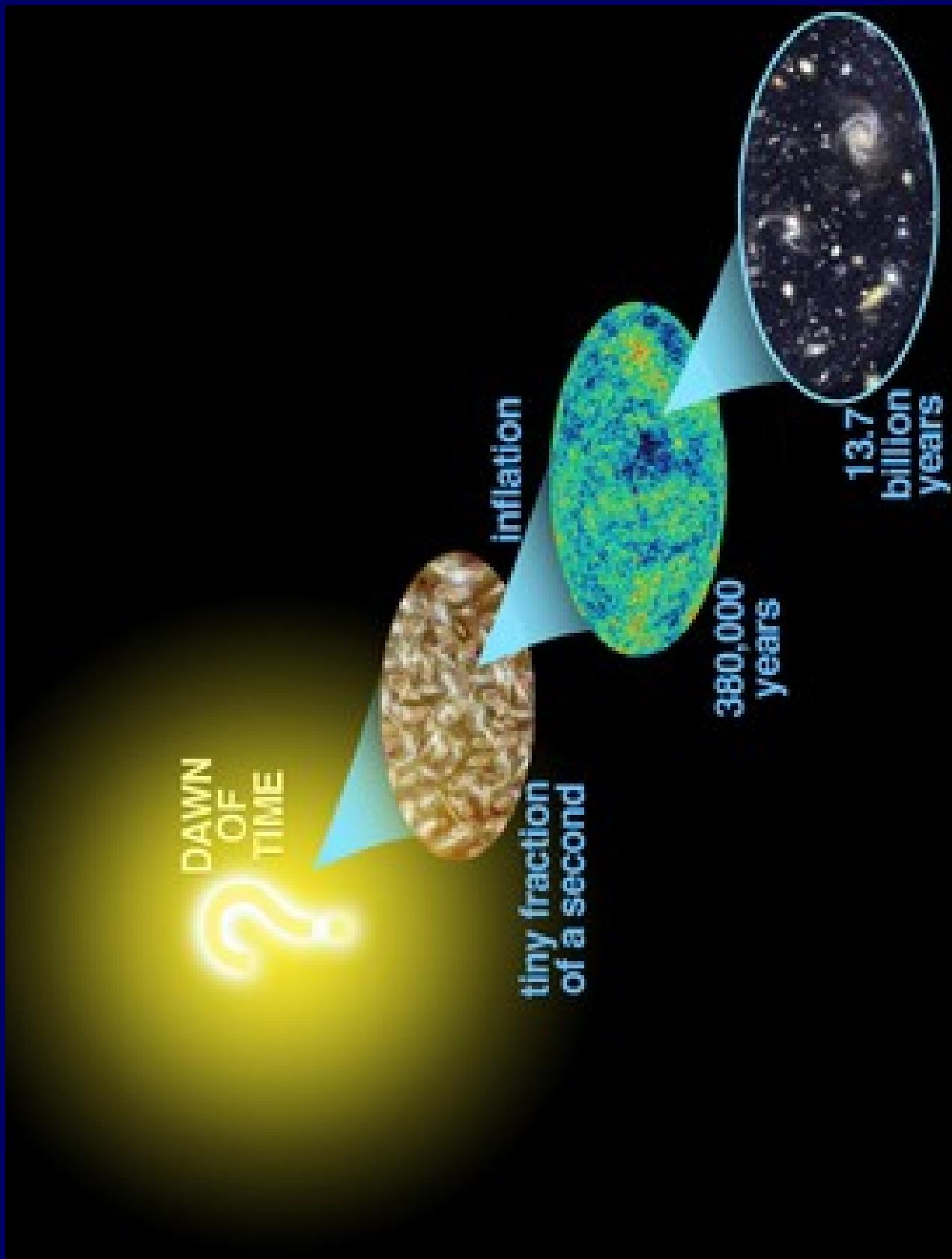


Amir Hajian

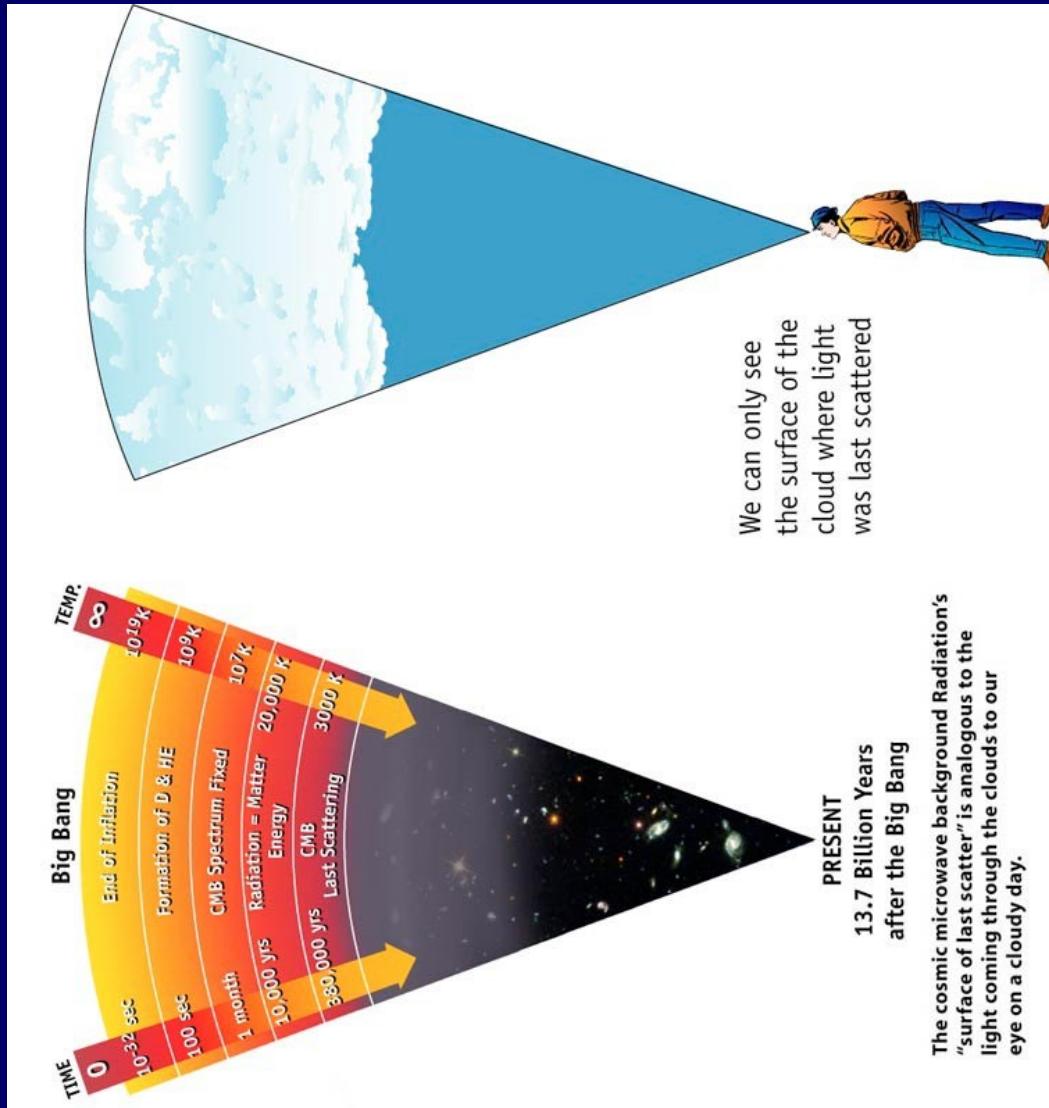
Canadian Institute For Theoretical Astrophysics

In the beginning...





# Cosmic Microwave Background (CMB)



George Gamow, 1948

# Journey in time



# DISCOVERY OF COSMIC BACKGROUND



Microwave Receiver



Arno Penzias



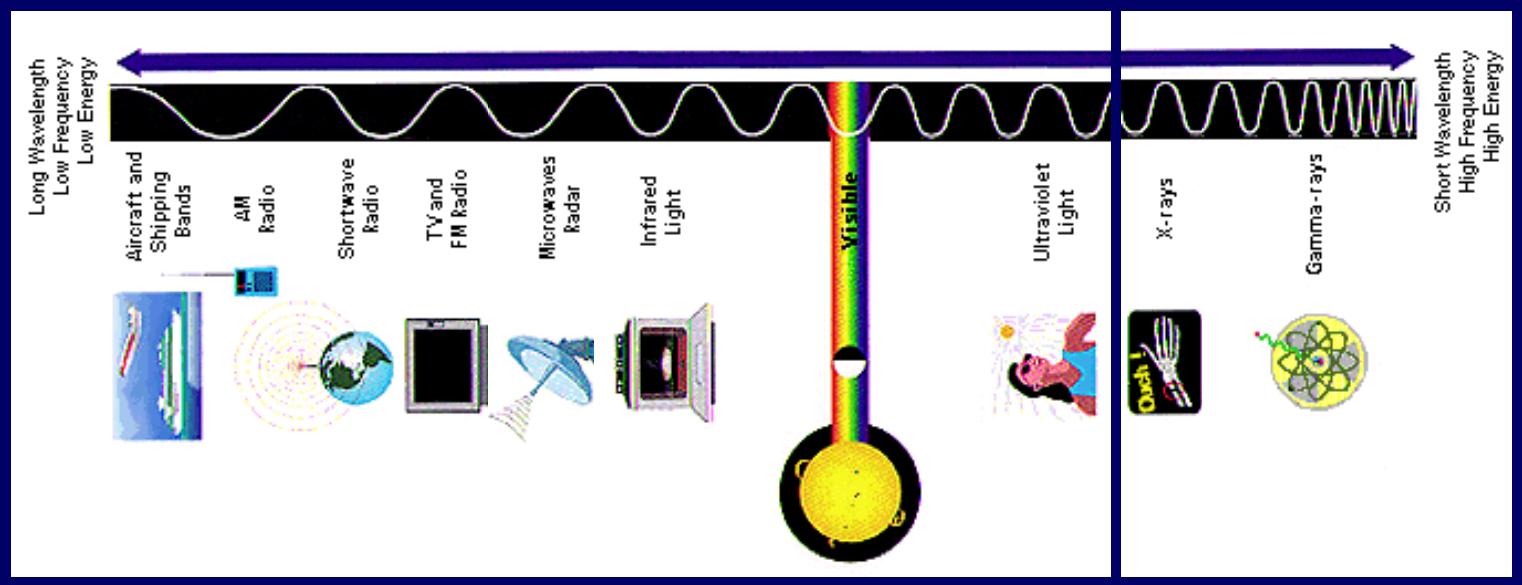
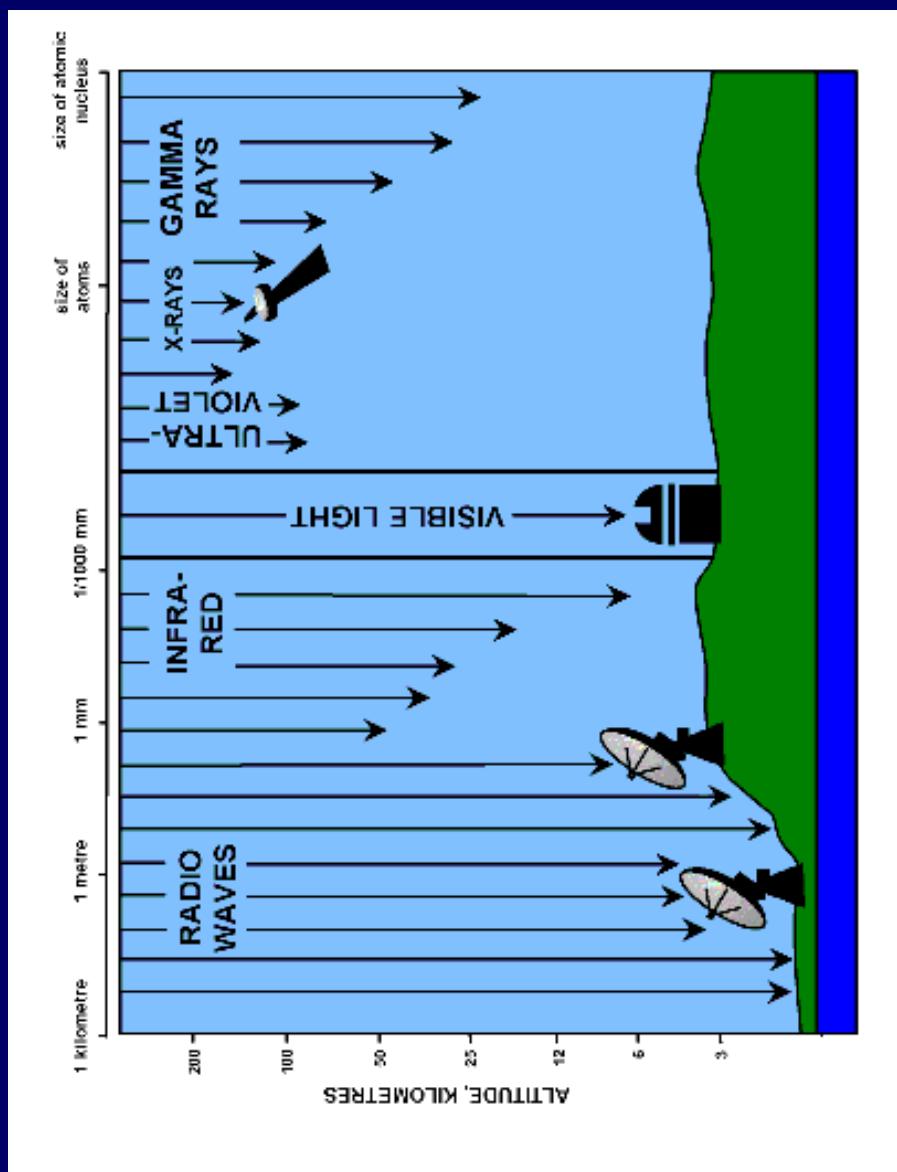
Robert Wilson

MAP990045

# Cosmic Microwave Background (CMB)



# Observing the CMB



## The Problem With Ground-Based Cosmology

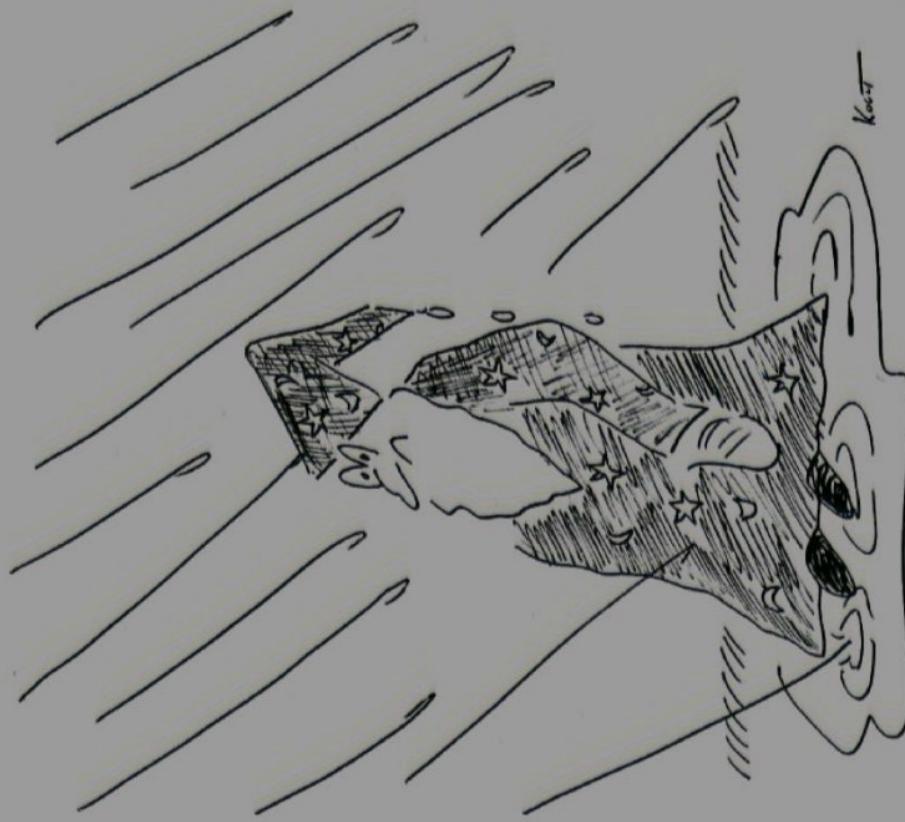
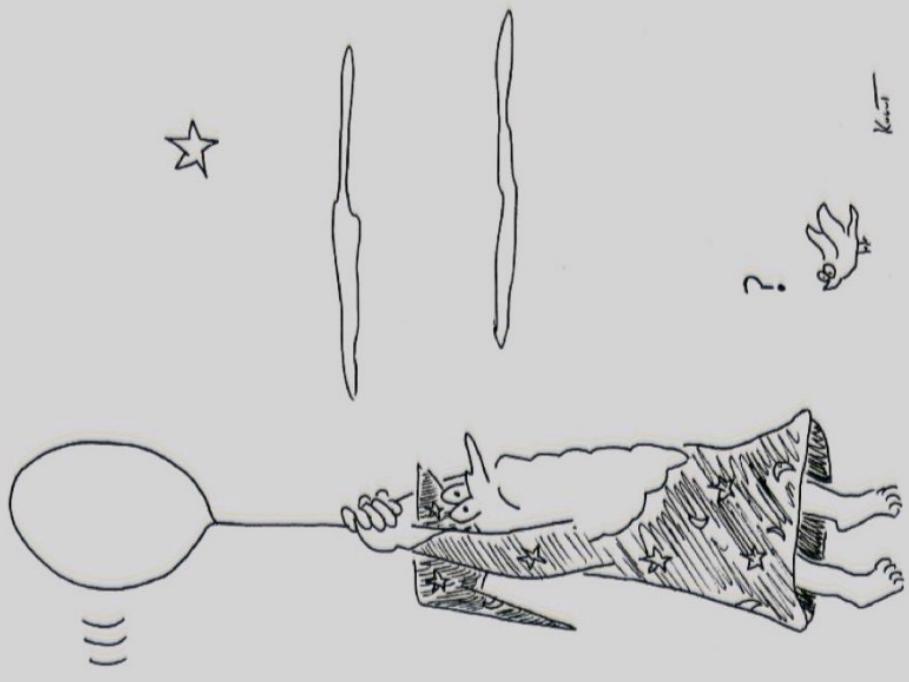


Figure courtesy of Al Kogut

Balloons Help, But Only A Little ...

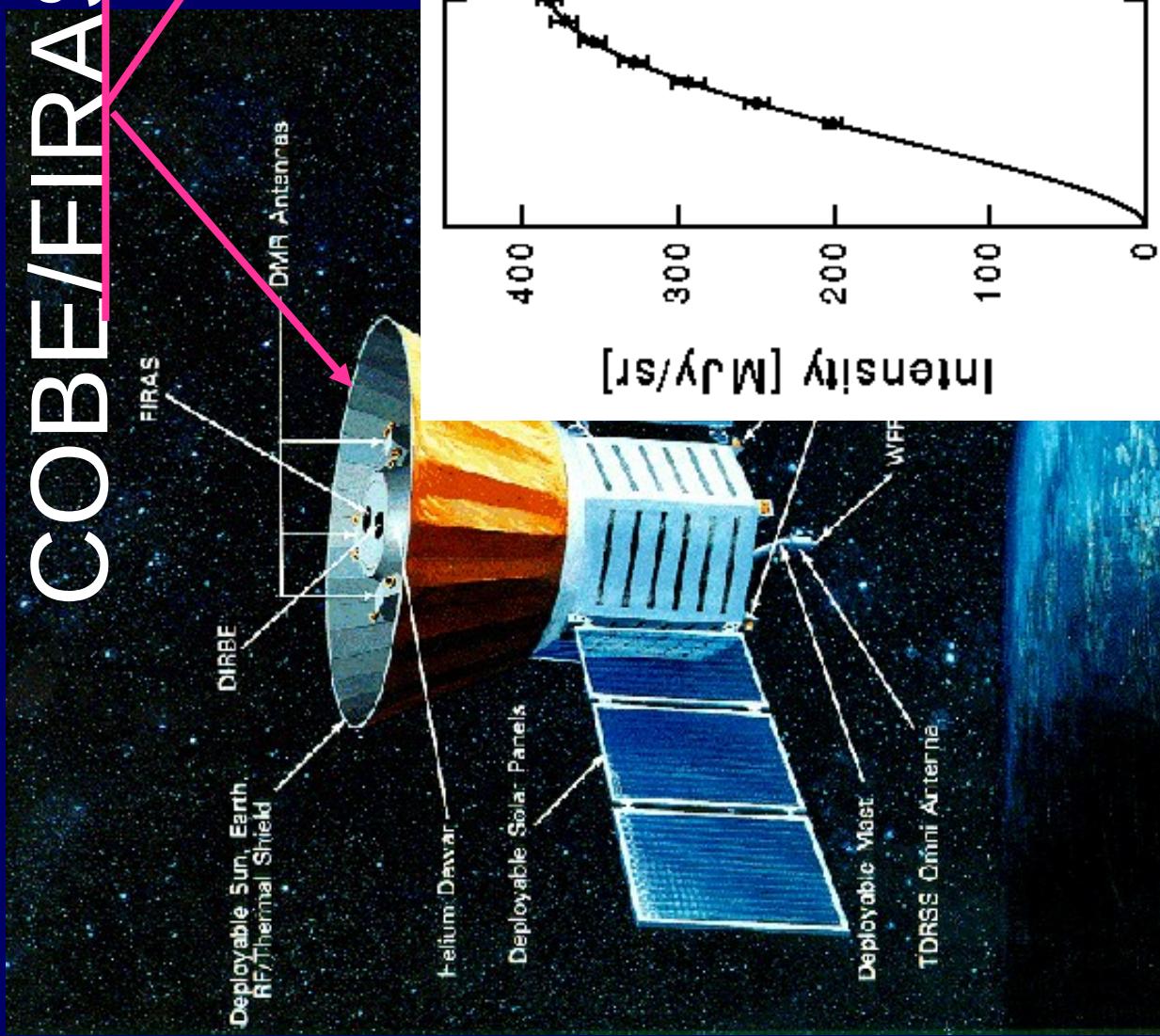


# The Obvious Solution





# COBE/FIRAS, 1990



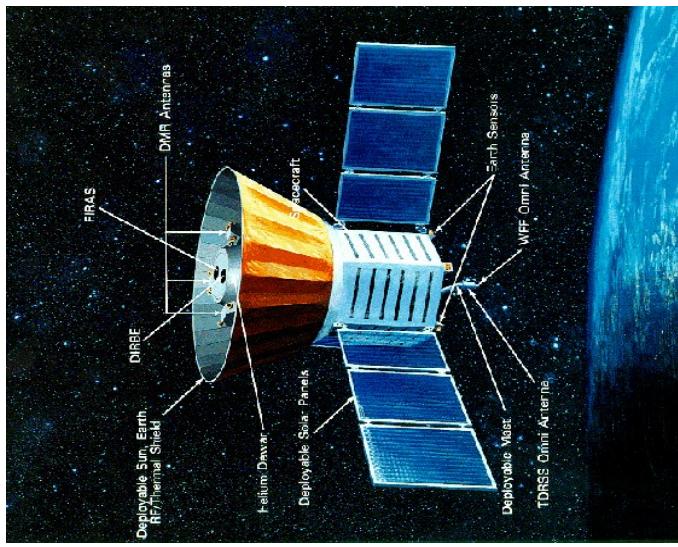
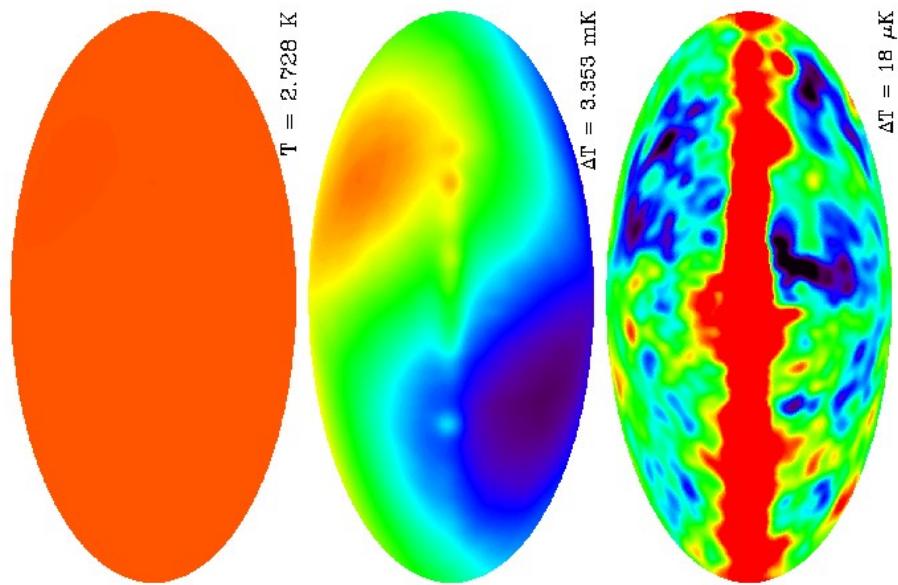
Perfect blackbody = Thermal equilibrium = Big Bang

# Full Sky Microwave Map

**COBE/FIRAS:**  
 $T = 2.725 \text{ K}$

Uniform, “Fossil” Light from the Big Bang

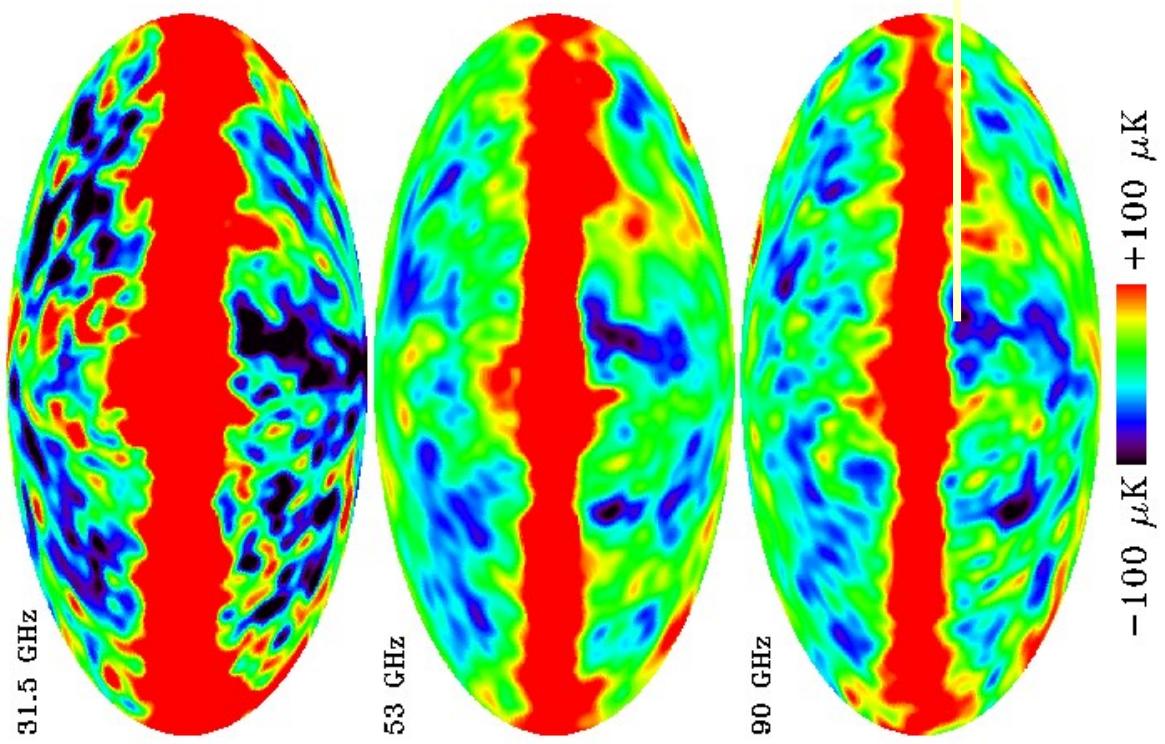
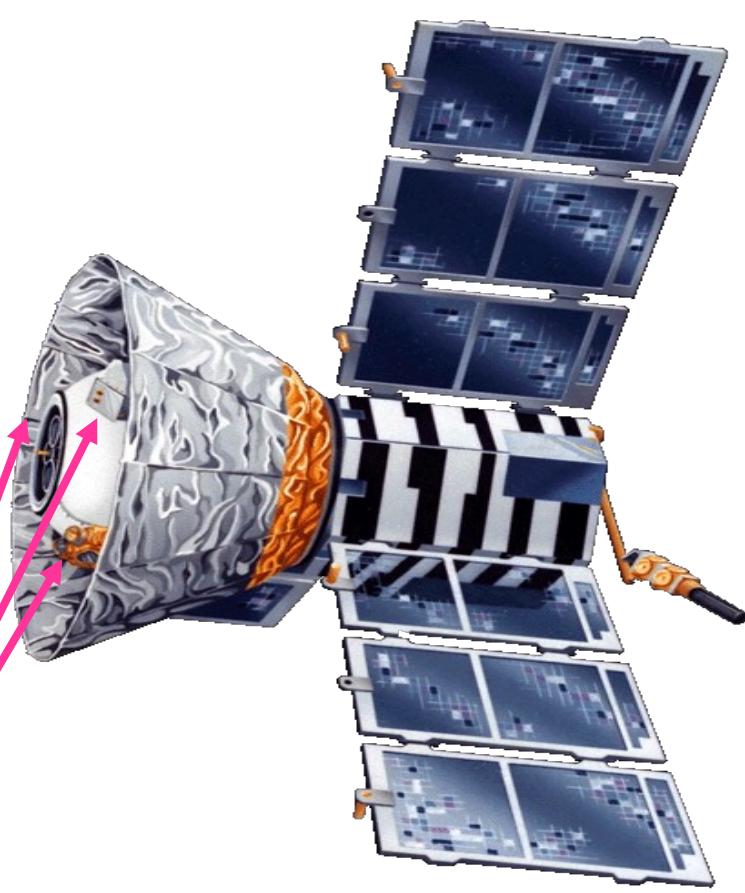
Cosmic Microwave Background Radiation



# Sky Projection

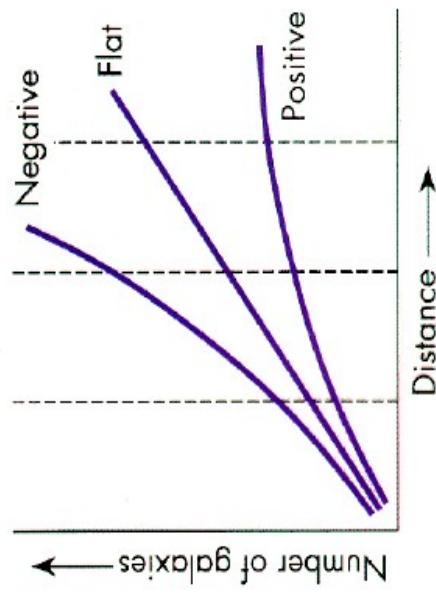
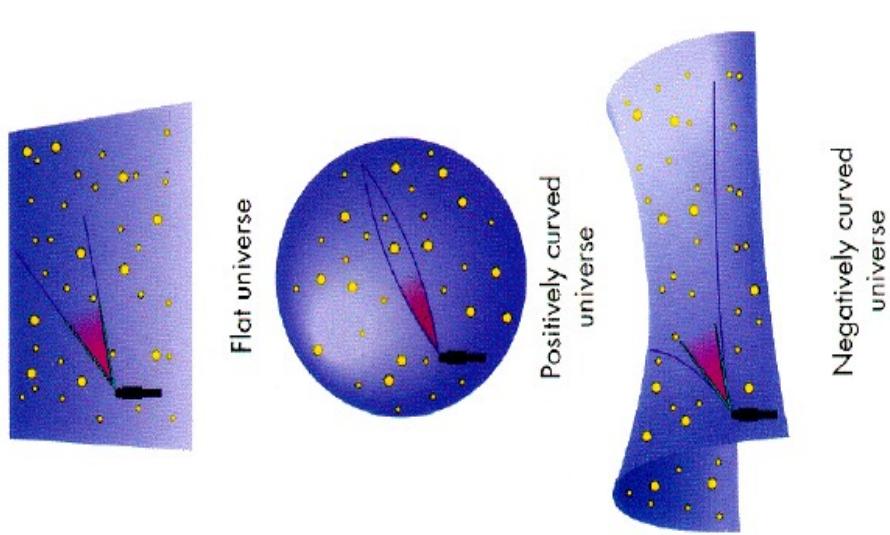


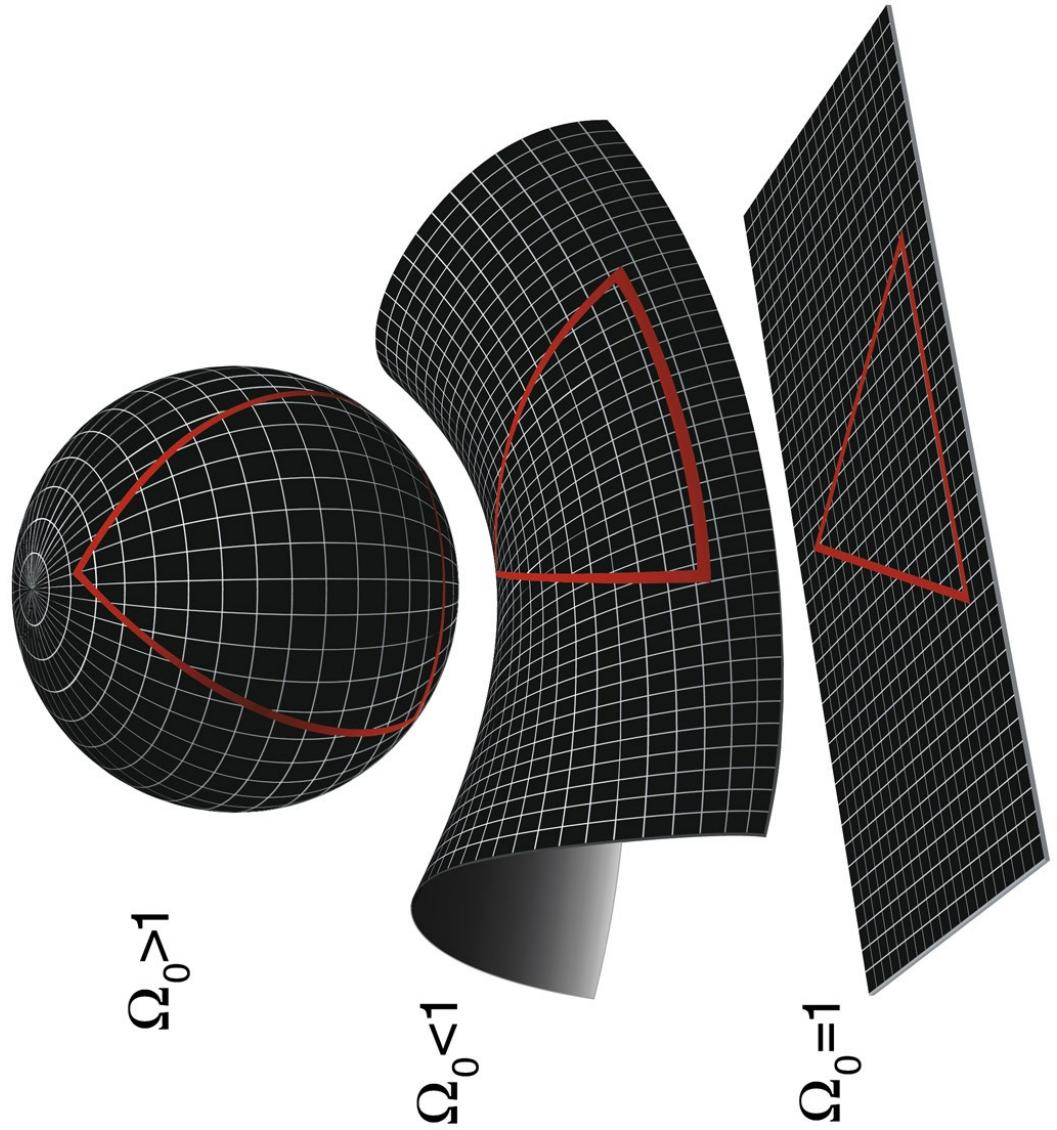
# COBE/DMR 1992



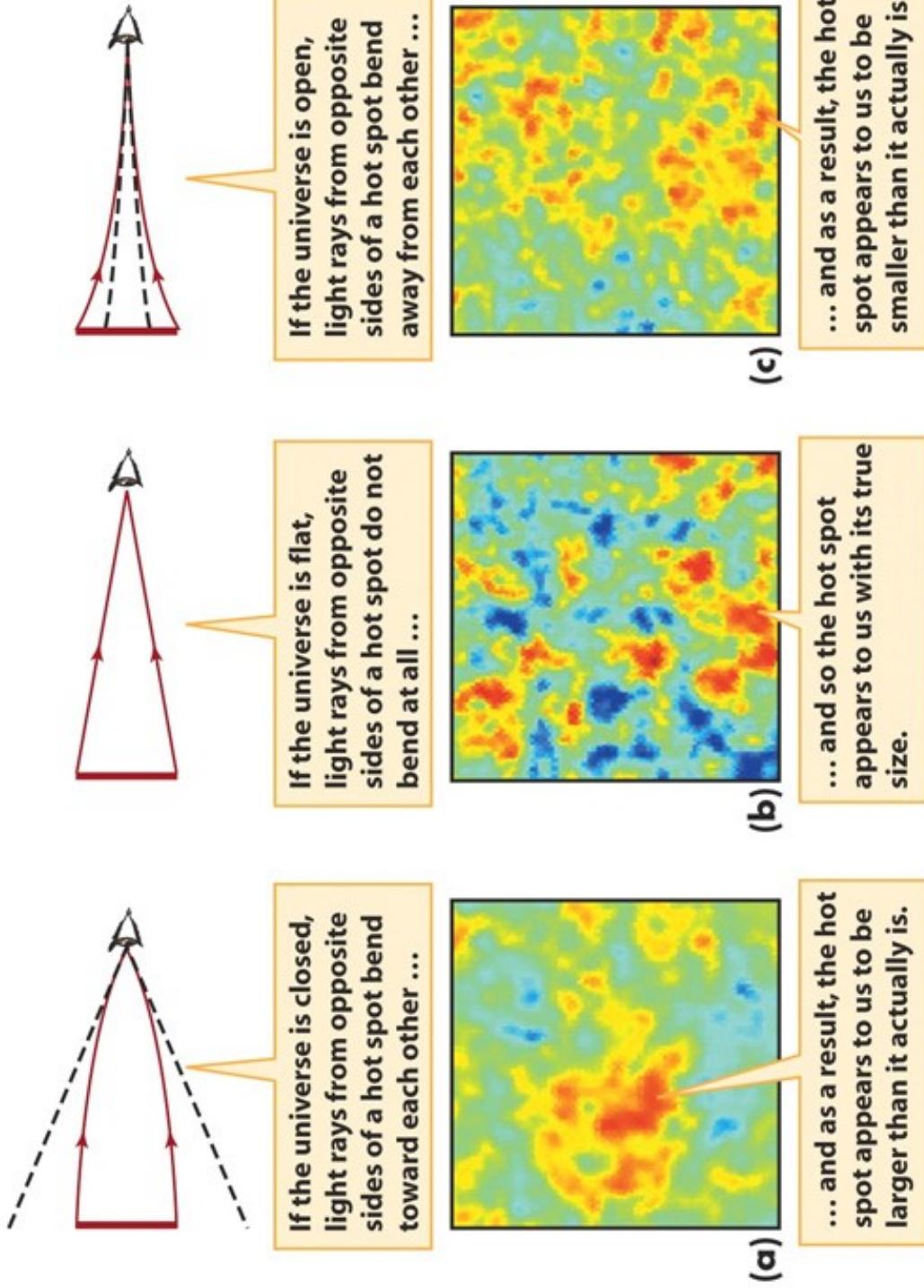
Gravity is STRONGER in  
cold spots:  $\Delta T/T \sim \Phi$

# Geometry of the Universe

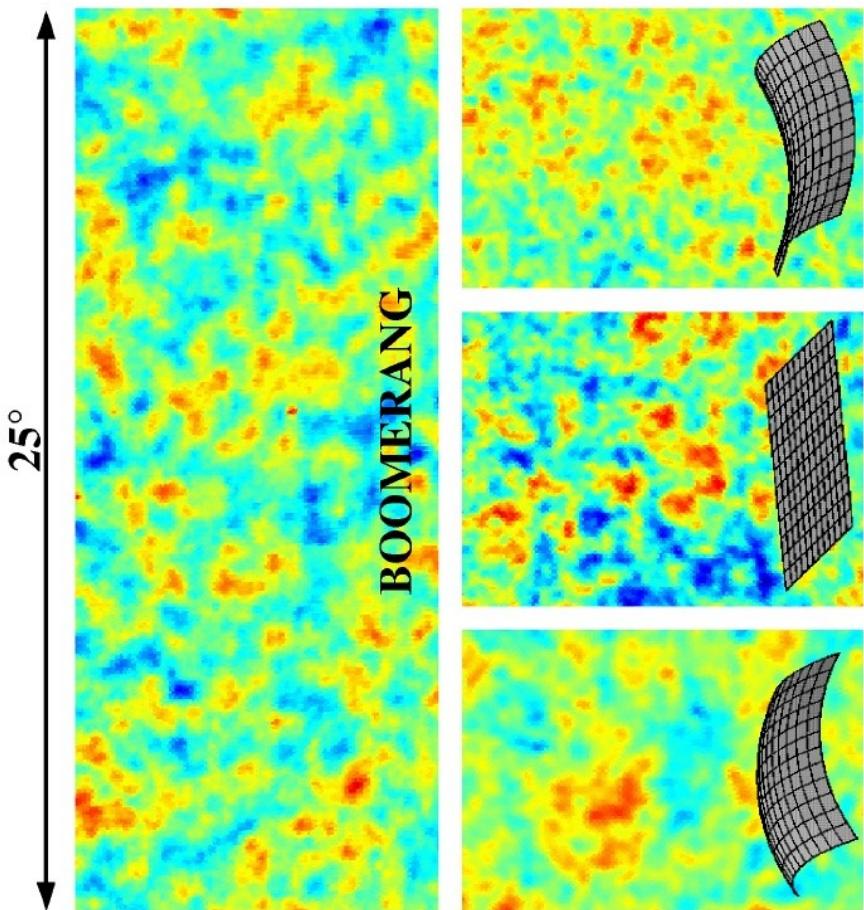




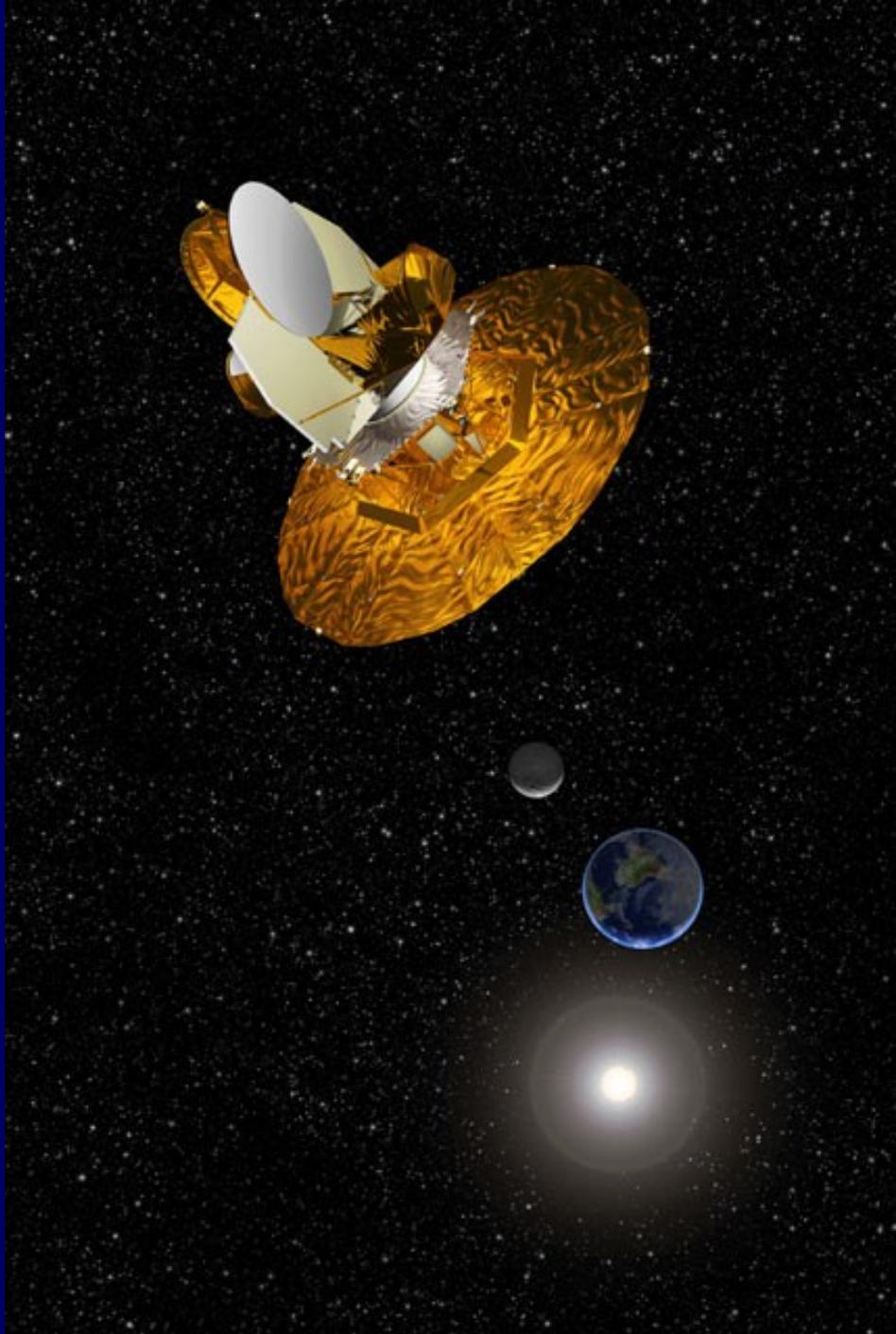
# Geometry of the Universe



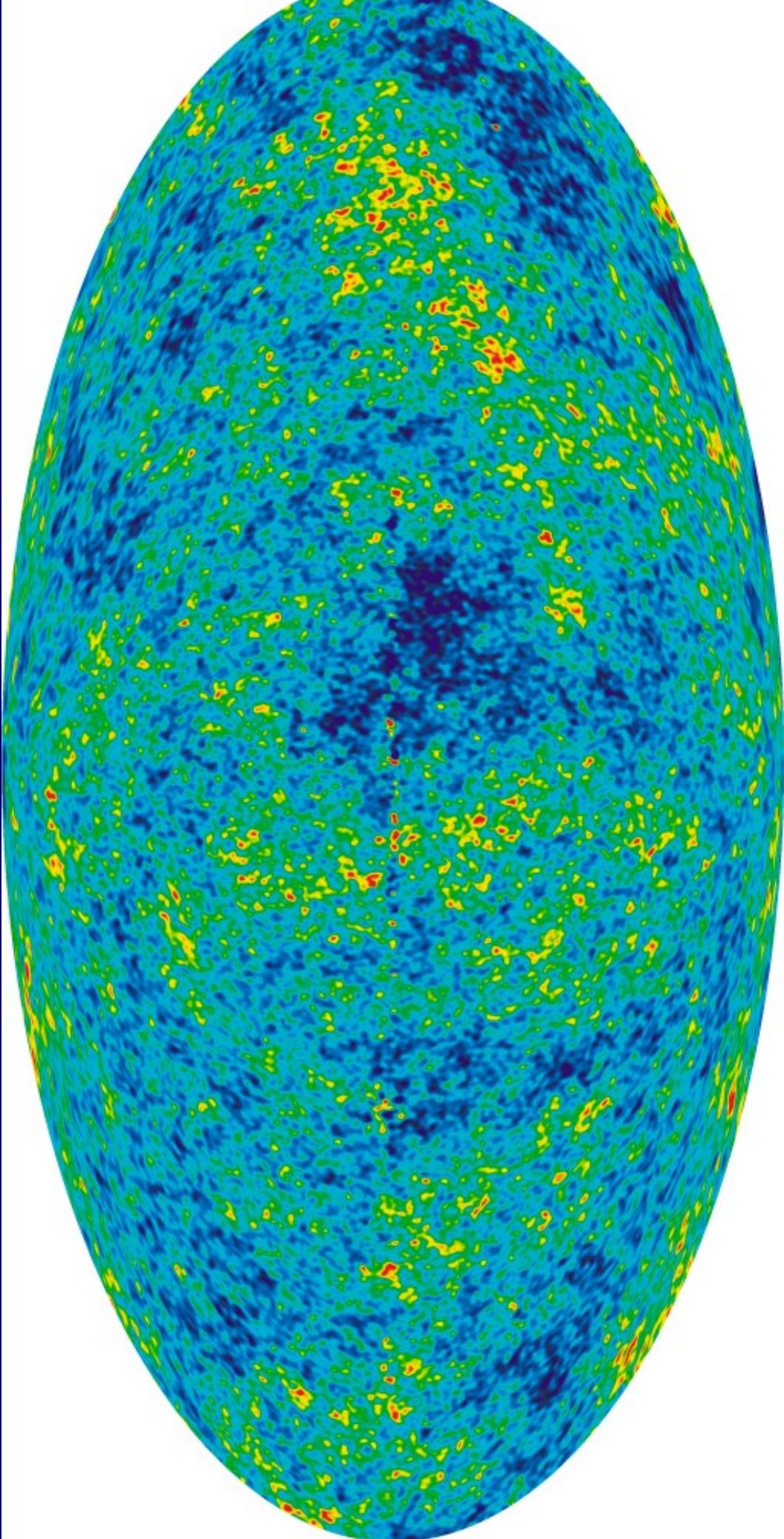
# Boomerang



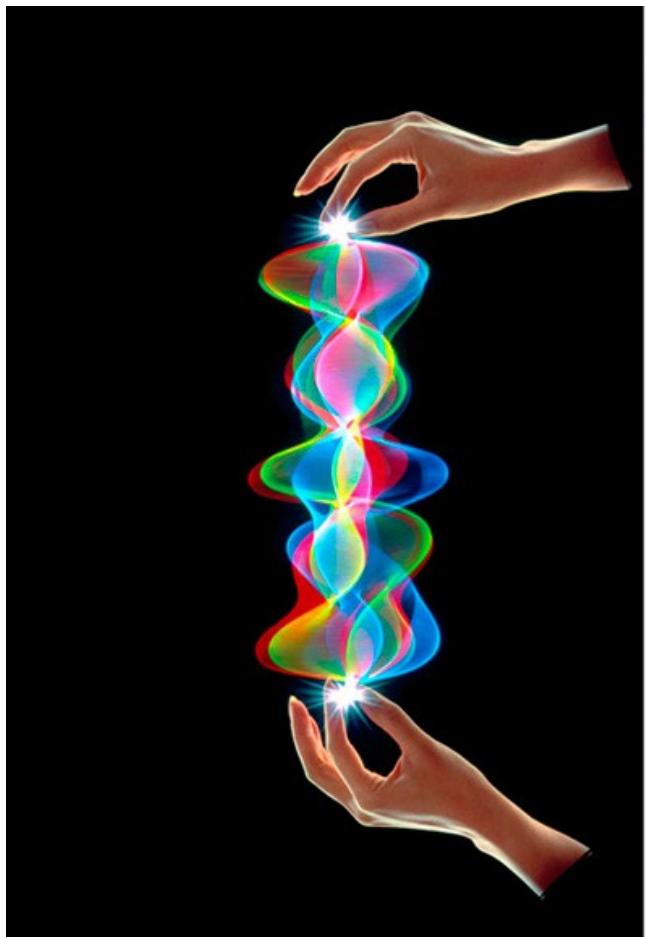
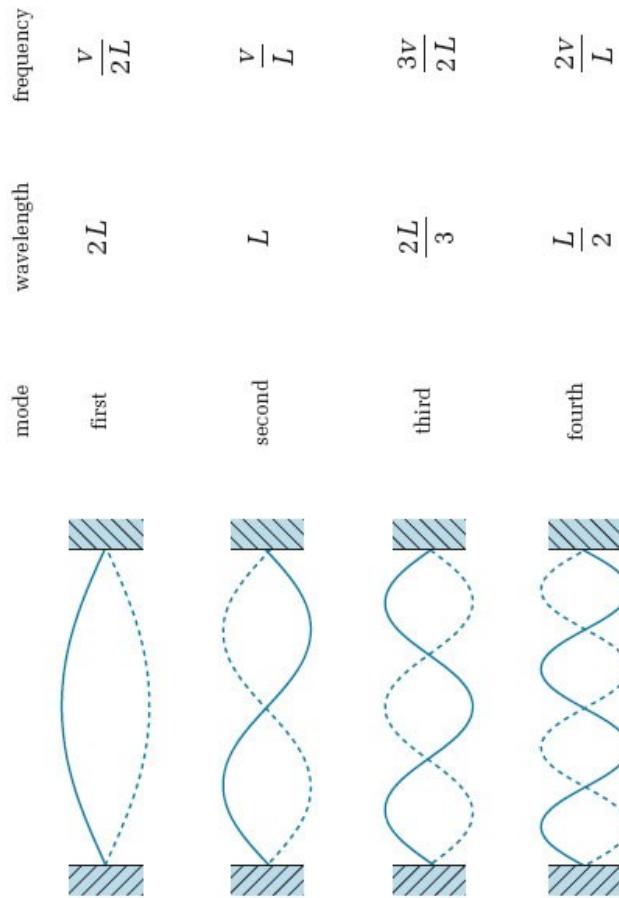
WMAP



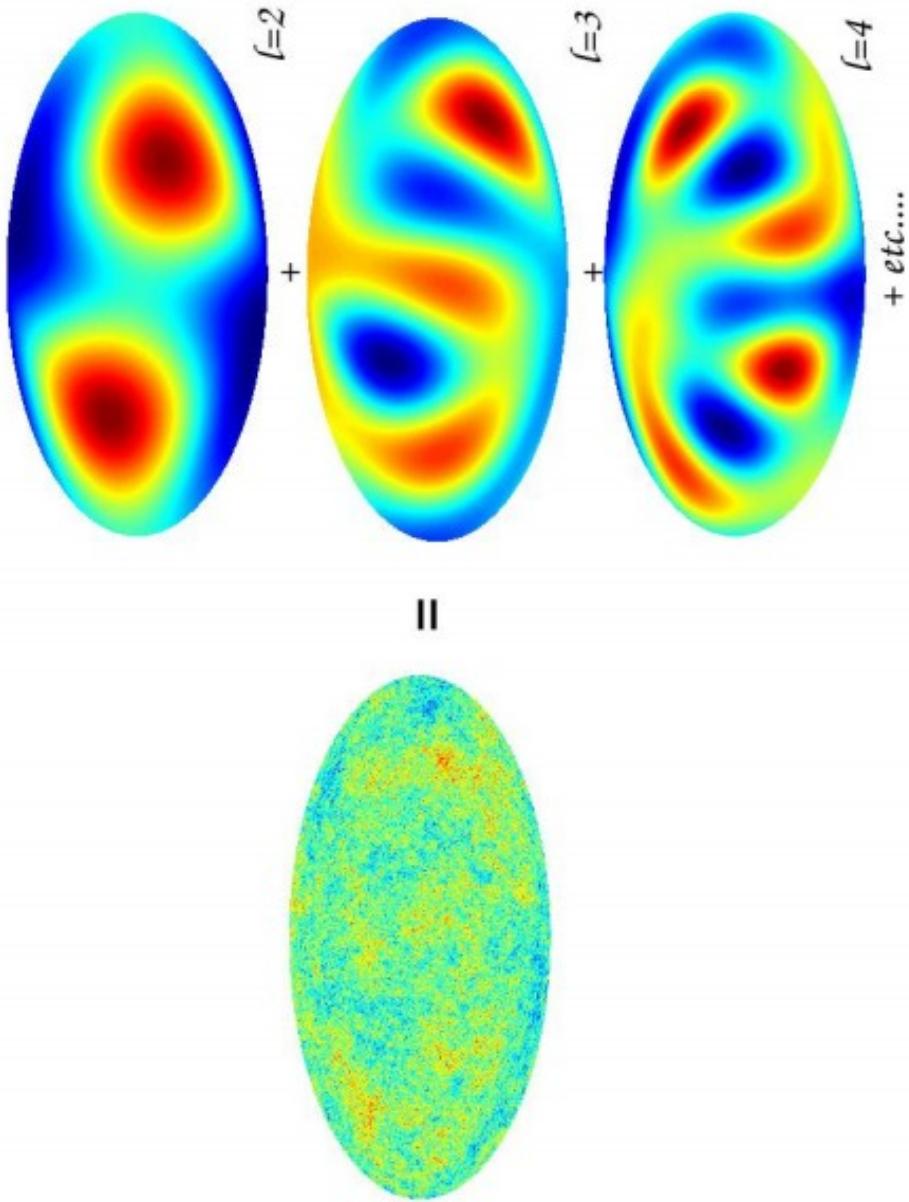
WMAP



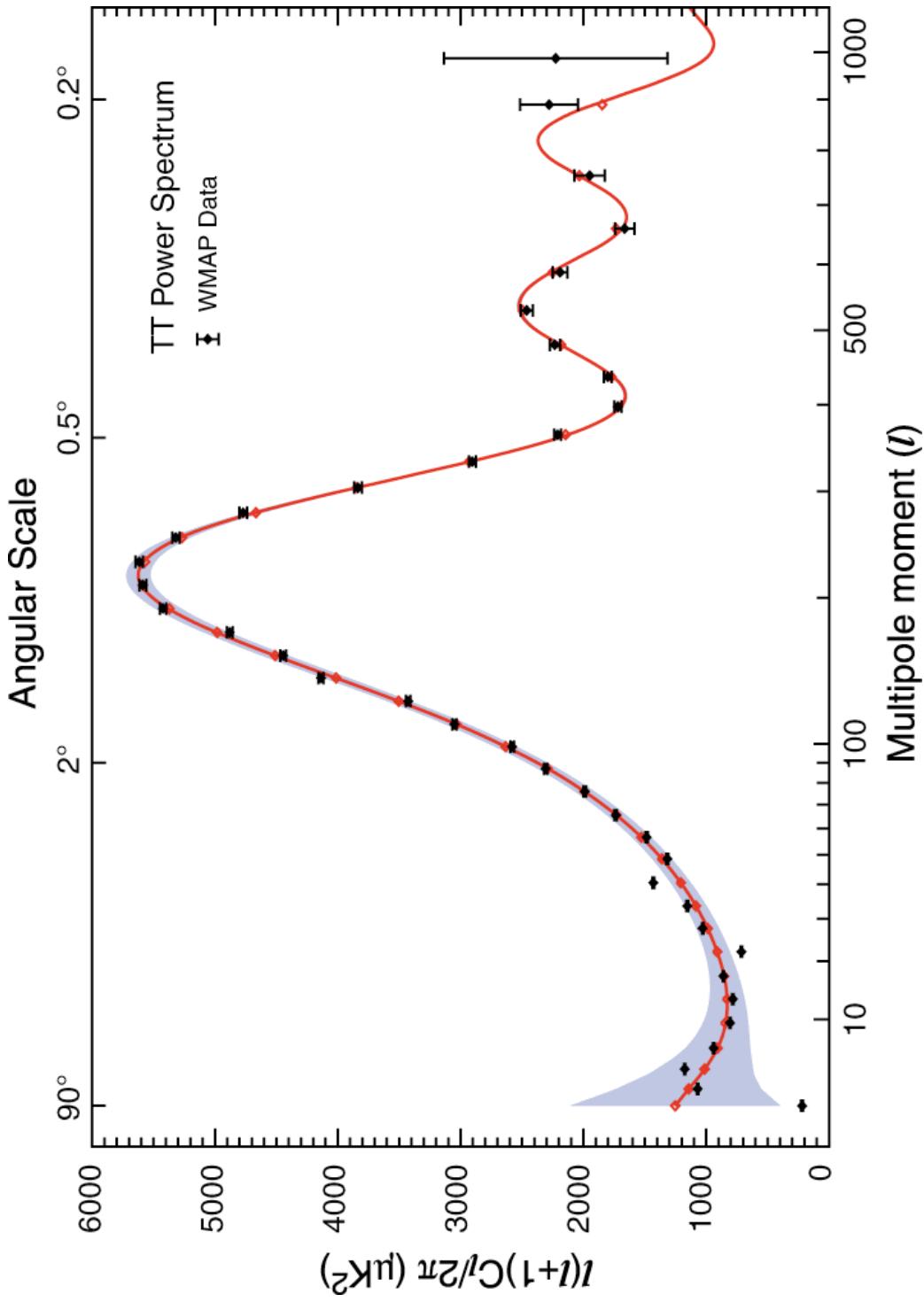
# Modes and Harmonics in 1D



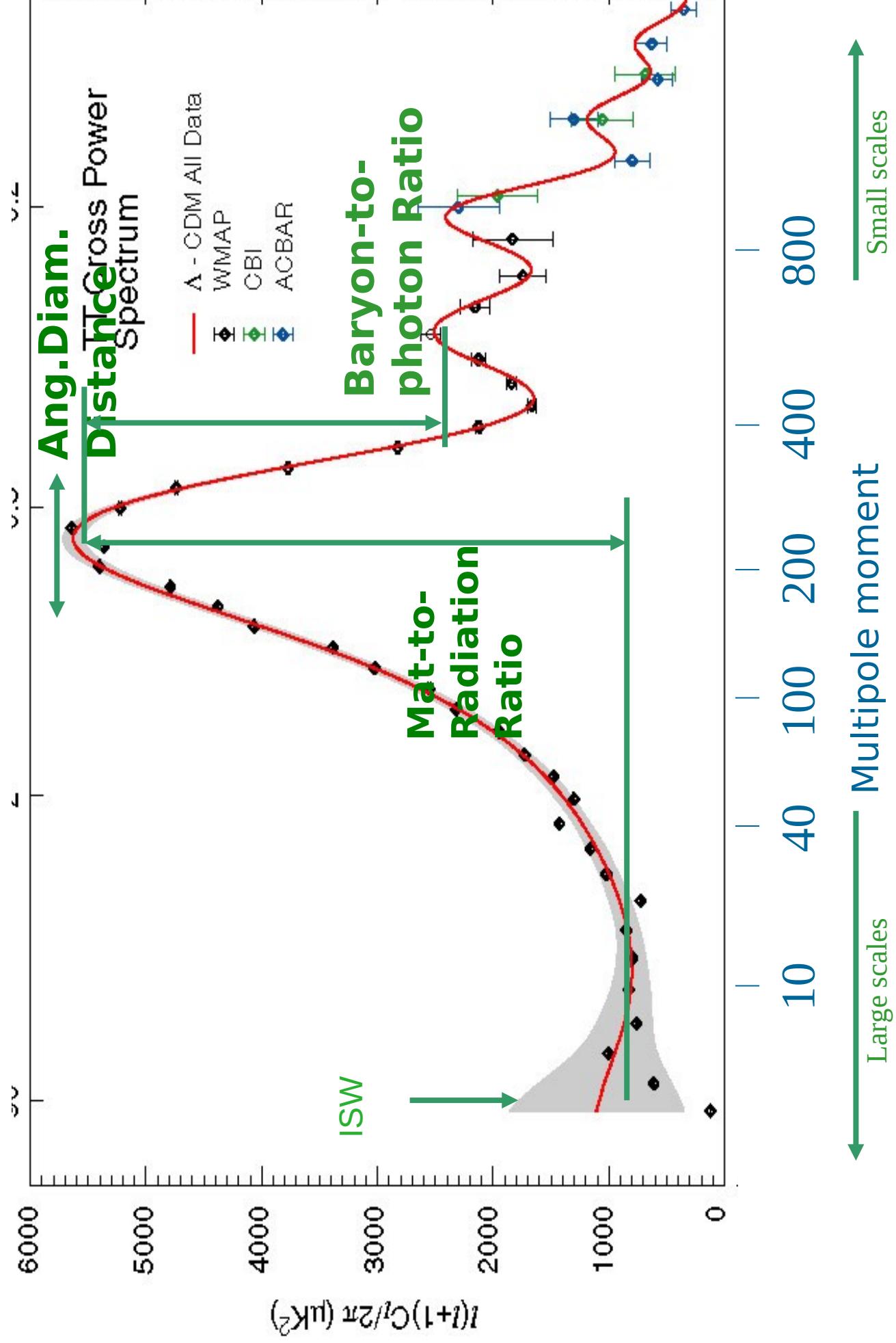
# Modes and Harmonics in 2D



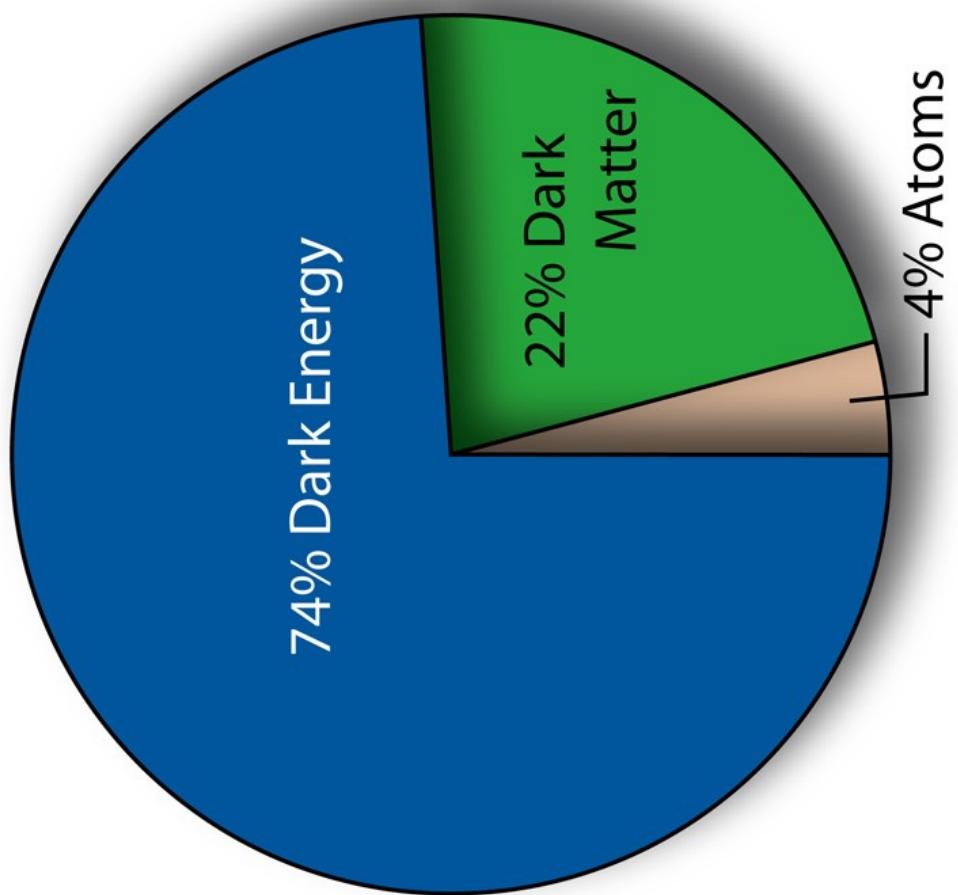
# WMAP 3-yr Power Spectrum



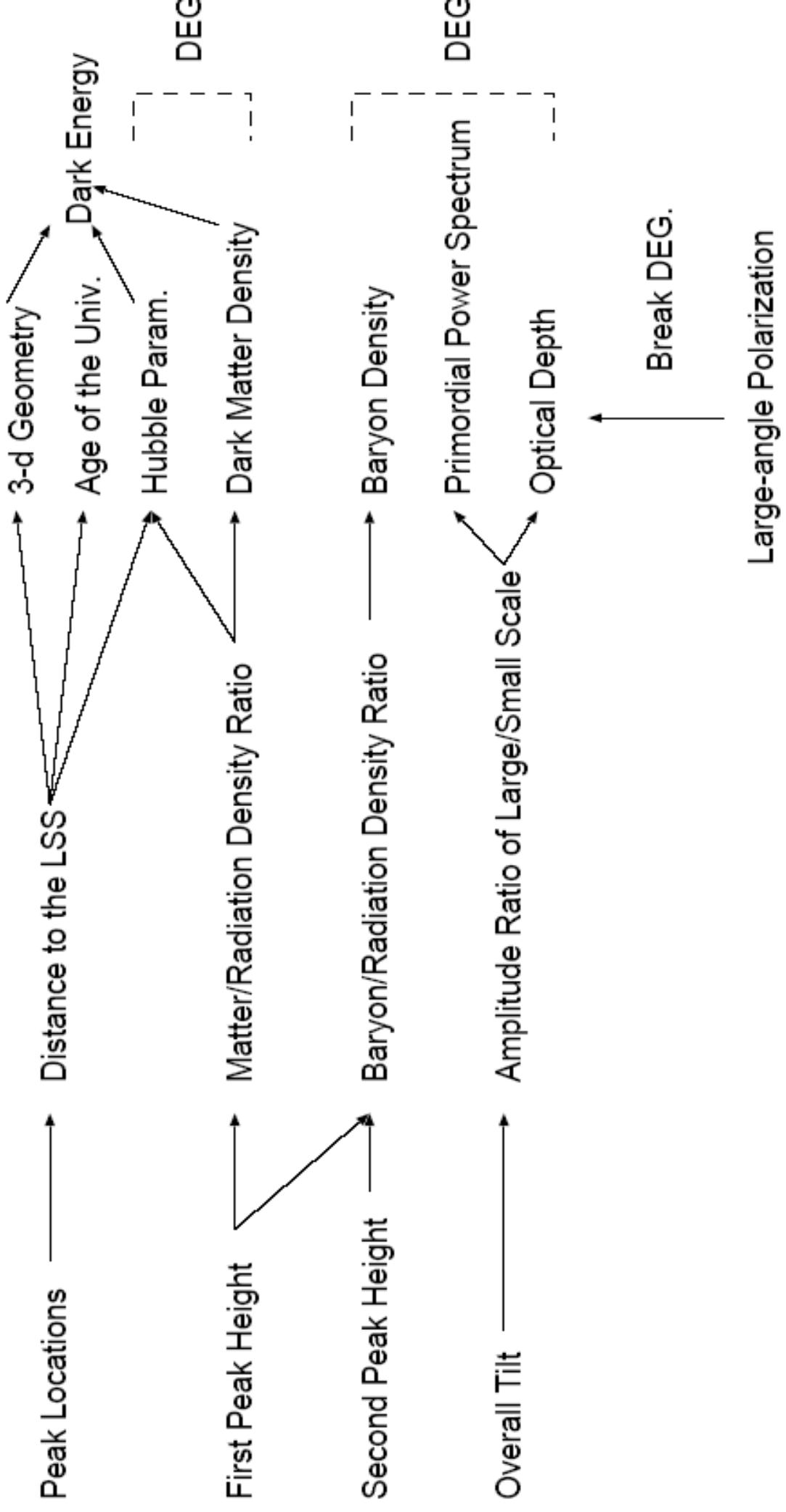
# What CMB Measures



Ampitude of temperature fluctuations at a given scale,  $l(l+1)C_l/2\pi (\mu\text{K}^2)$



# CMB to Parameters





# ACT

# Atacama

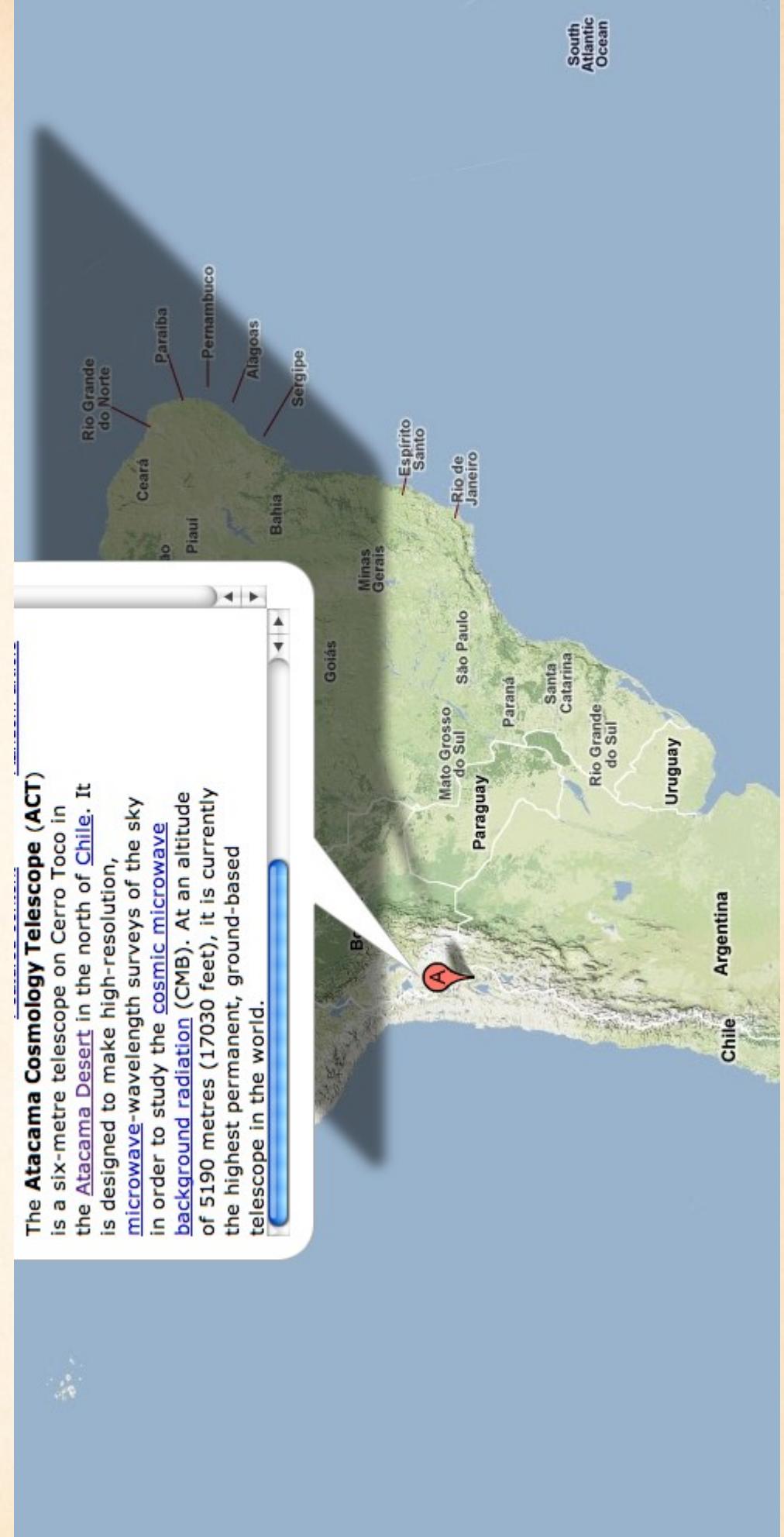
# Cosmology

# Telescope

# THE TELESCOPE



The **Atacama Cosmology Telescope (ACT)** is a six-metre telescope on Cerro Toco in the **Atacama Desert** in the north of **Chile**. It is designed to make high-resolution, **microwave-wavelength** surveys of the sky in order to study the **cosmic microwave background radiation** (CMB). At an altitude of 5190 metres (17030 feet), it is currently the highest permanent, ground-based telescope in the world.



# THE TELESCOPE



ACT Telescope

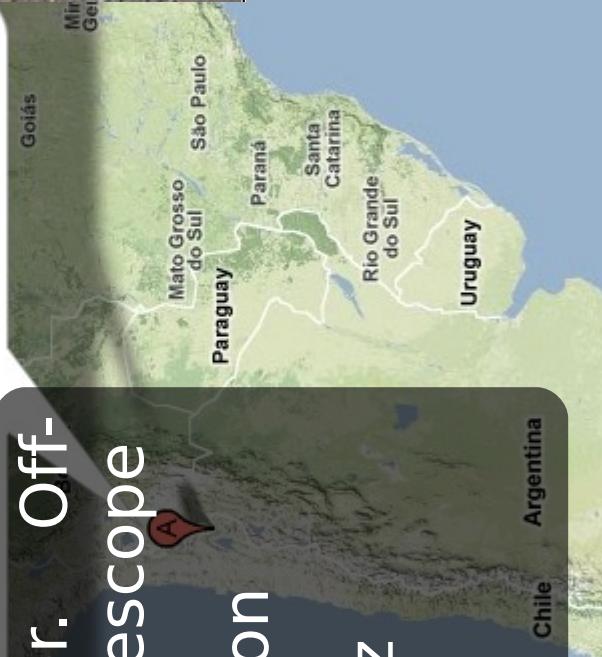


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South Atlantic Ocean

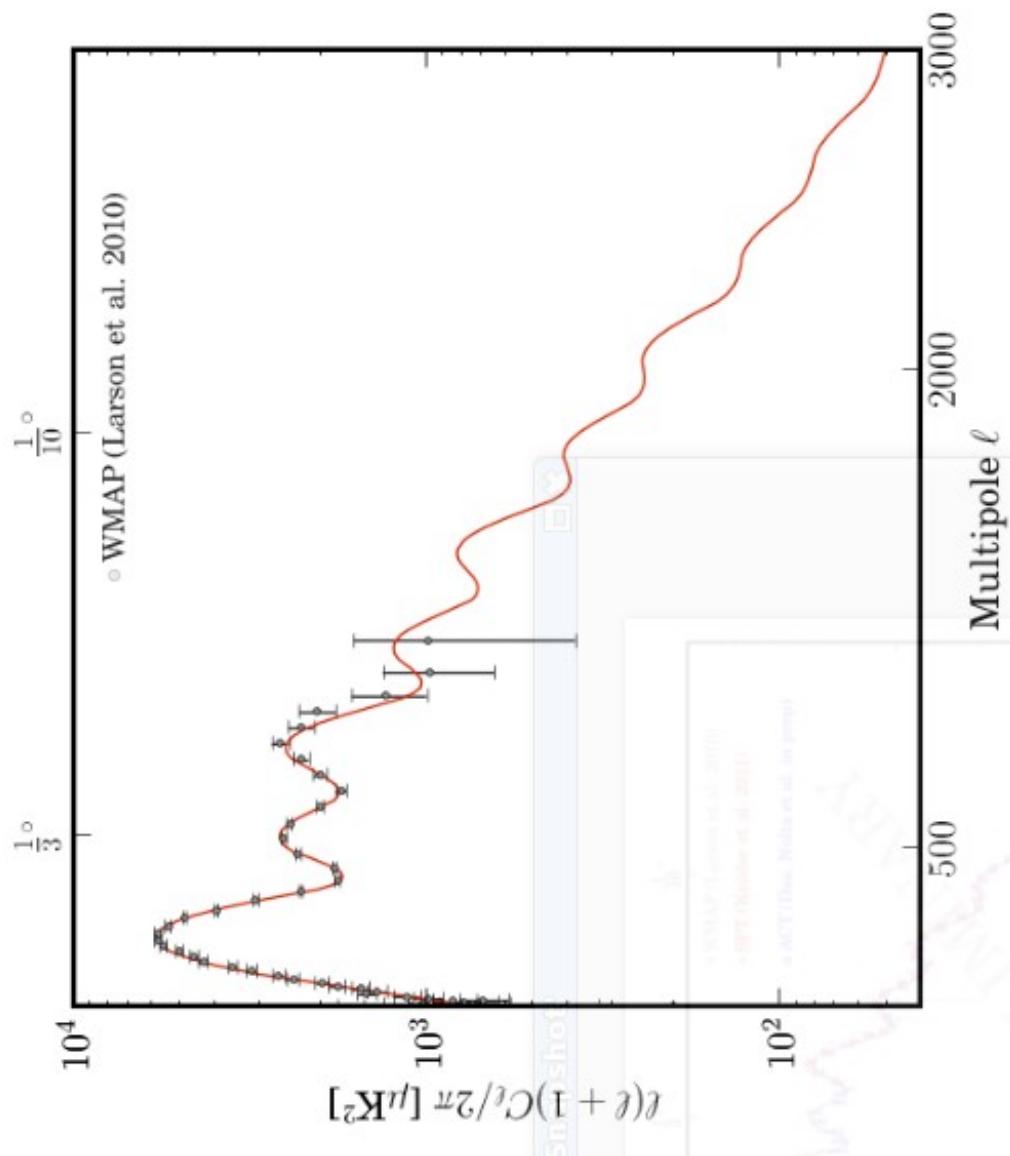
6 m primary mirror. Off-axis Gregorian telescope  
~1 arcmin resolution  
148, 218, 277 GHz channels

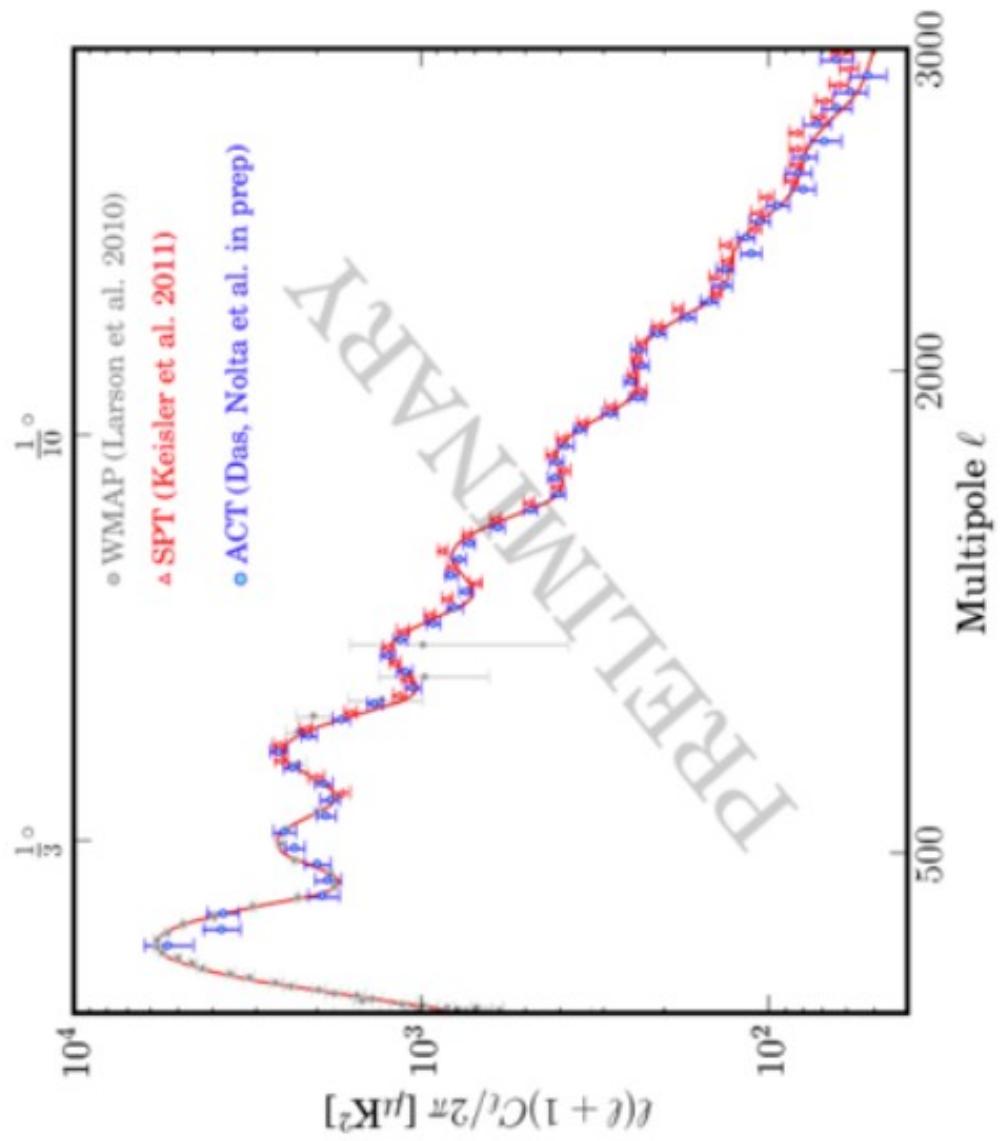


Argentina

Chile

South Atlantic Ocean







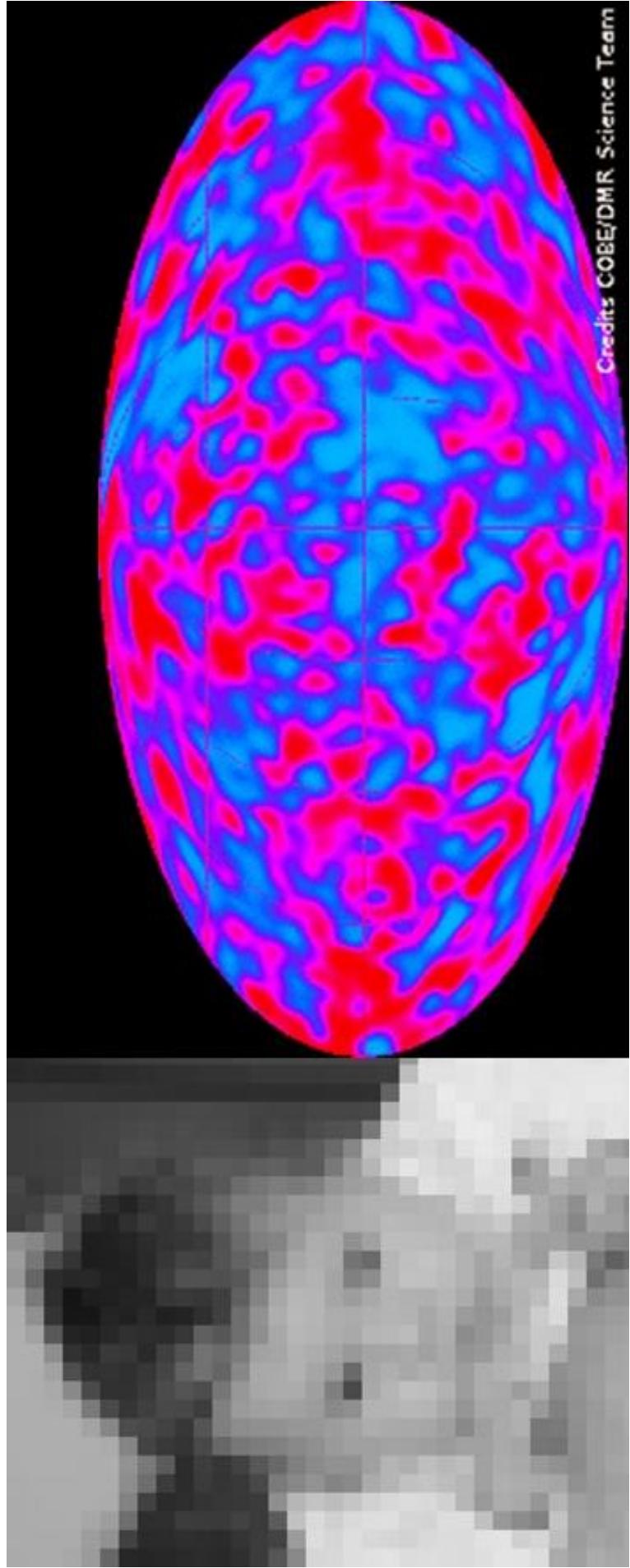
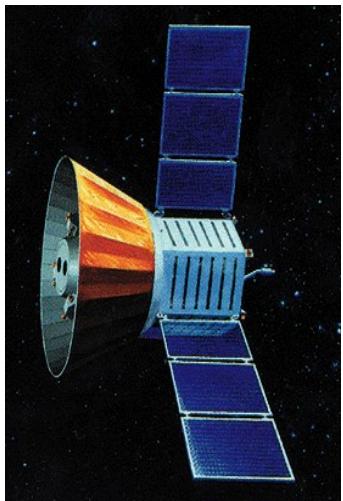
# Penzias & Wilson (1965)

**ISOTROPY OF THE COSMIC  
MICROWAVE BACKGROUND**

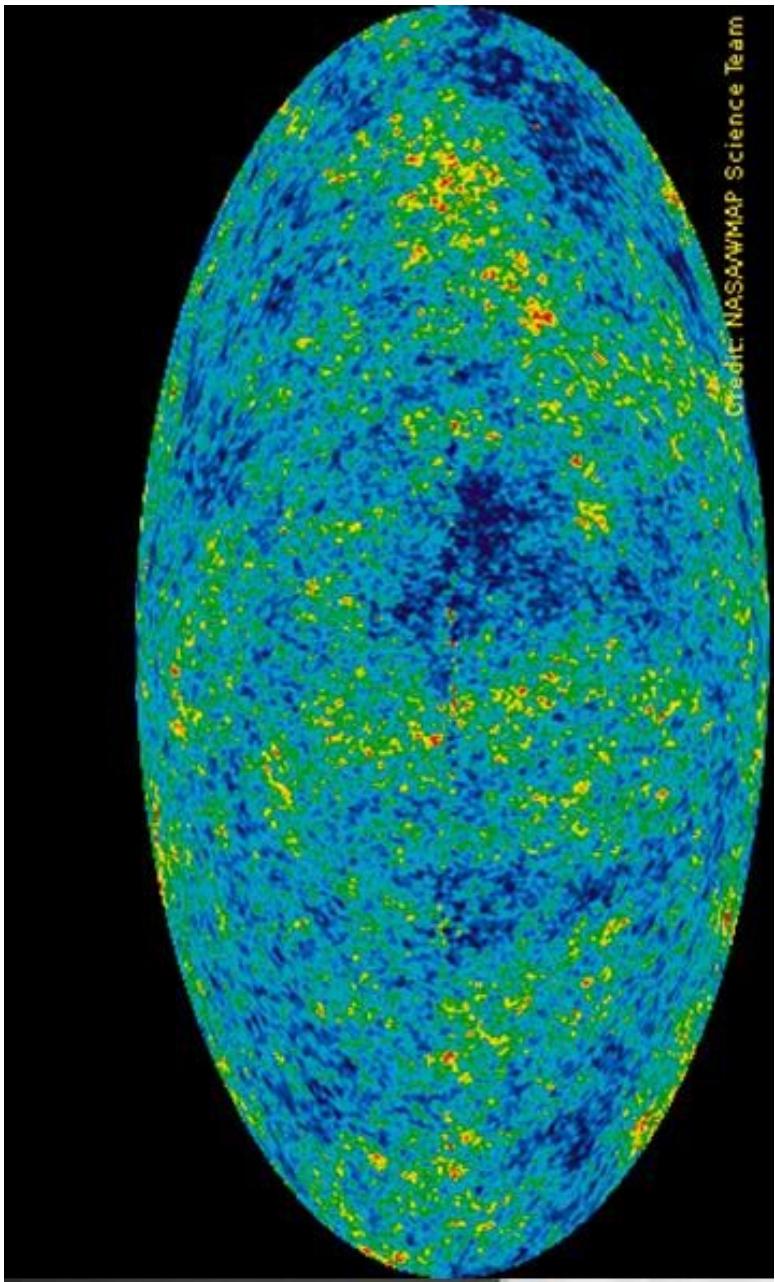
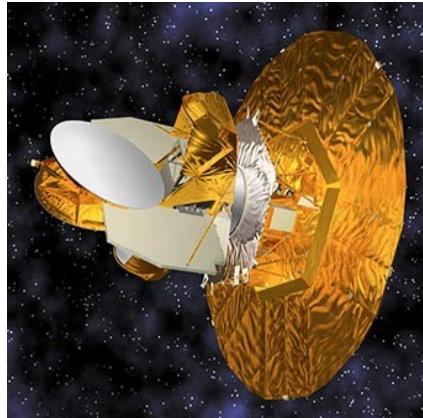


MAP990004

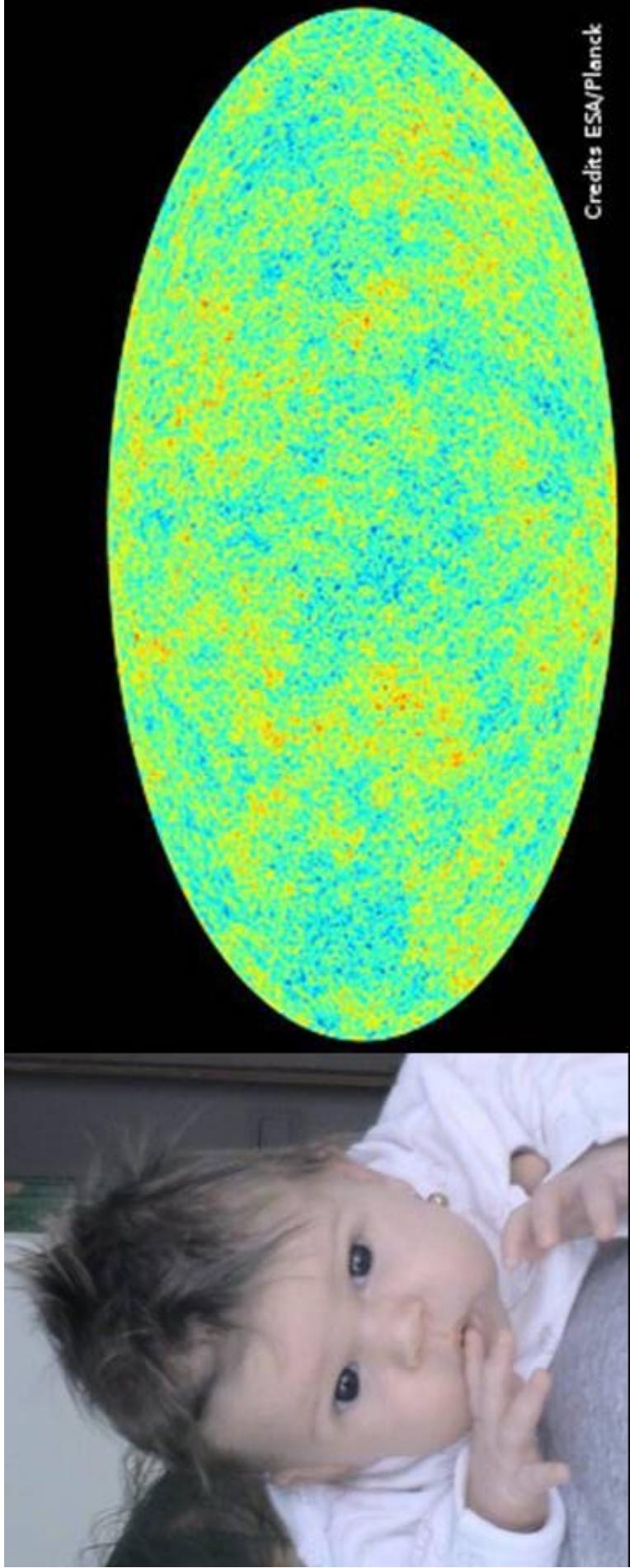
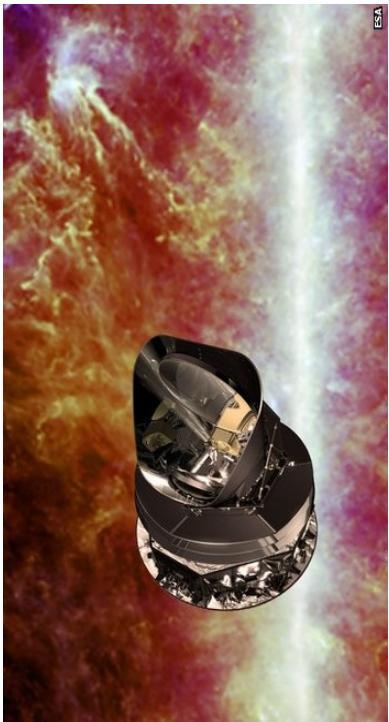
# COBE (1992)



# WMAP 2003

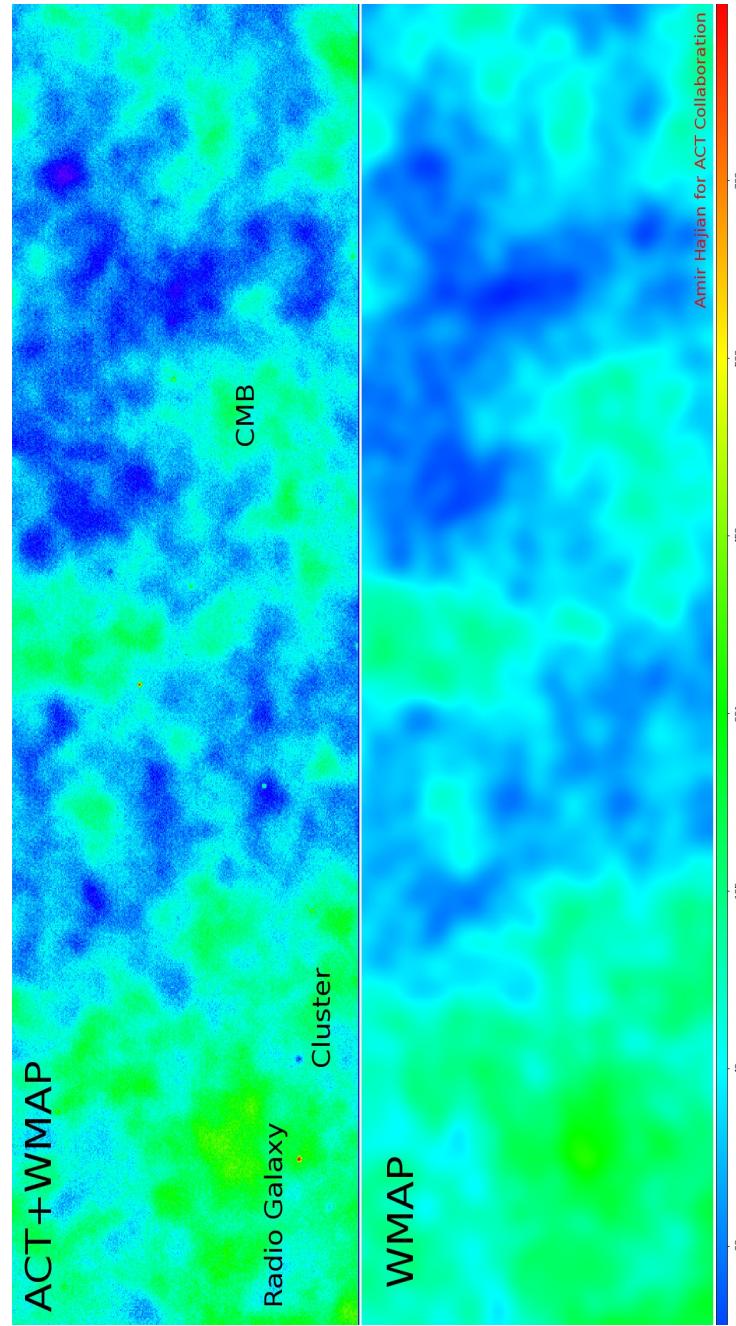
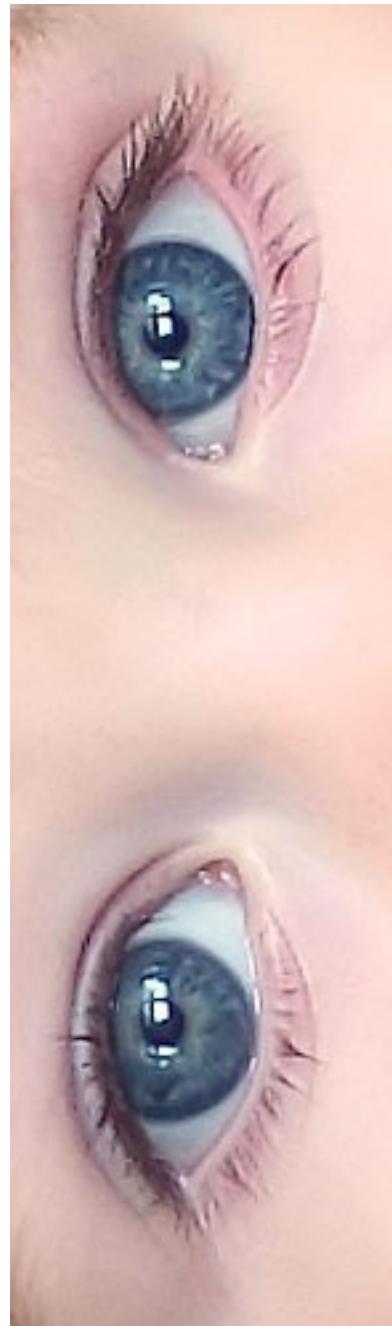


# Planck (2013)



Credits ESA/Planck

# ACT (2008+)



Polarized Light  
Un-filtered



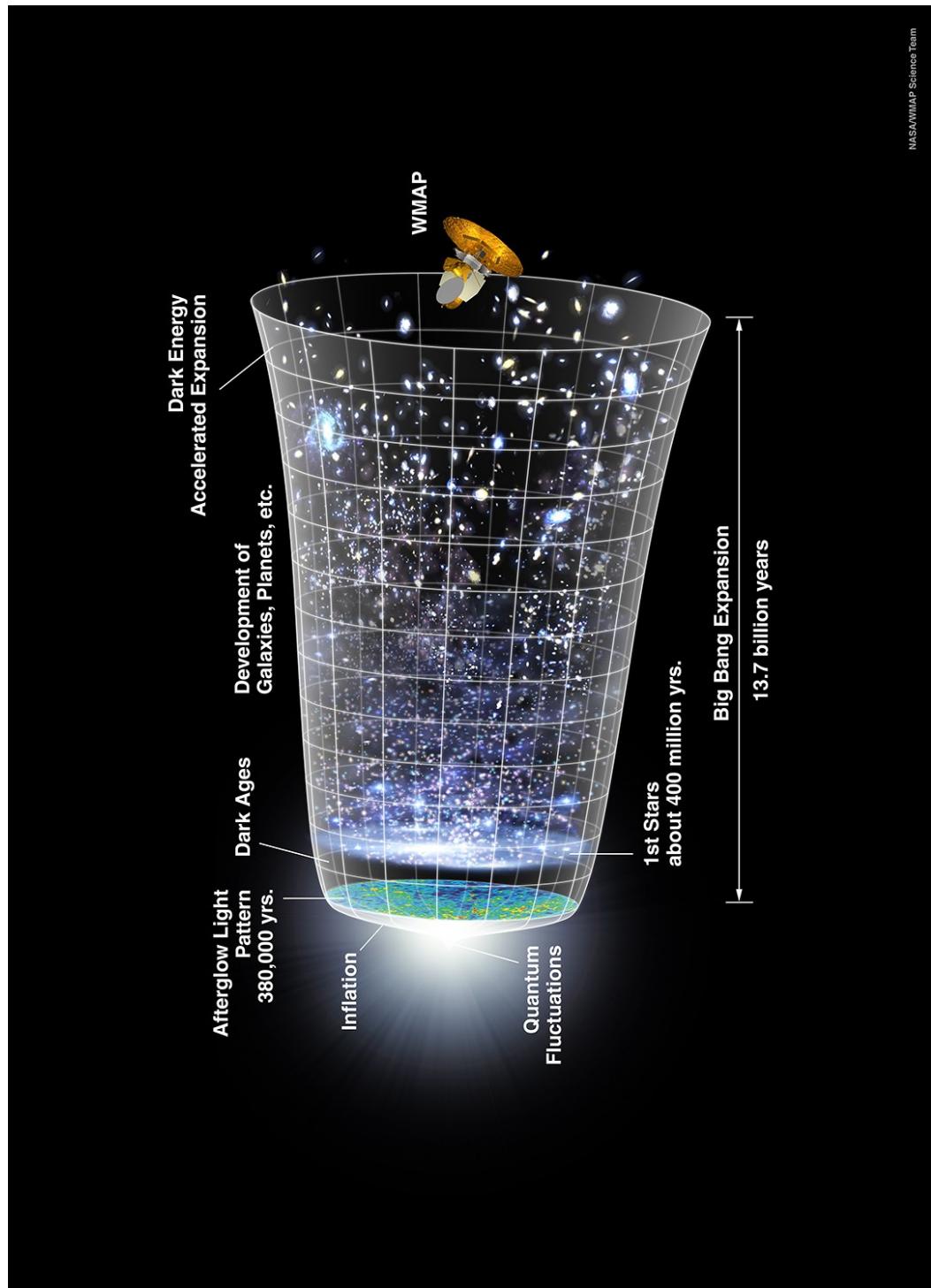
*Without PolaVisor*

Polarized Light  
Filtered



*as seen through PolaVisor*

# Secondary Anisotropies



NASA/WMAP Science Team

# Summary of (some of) the results

