

The First Three Minutes of the Universe

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Galaxy Cluster Abell 1689
Hubble Space Telescope • Advanced Camera for Surveys

NASA, N. Benitez (JHU), T. Broadhurst (The Hebrew University), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA
STScI-PRC03-01a

Cosmology

- ~ *kósmos* world; *lógos*, knowledge or science
- ~ The science of the world.

Cosmology – the study of the origin and evolution of the universe

In the beginning ...

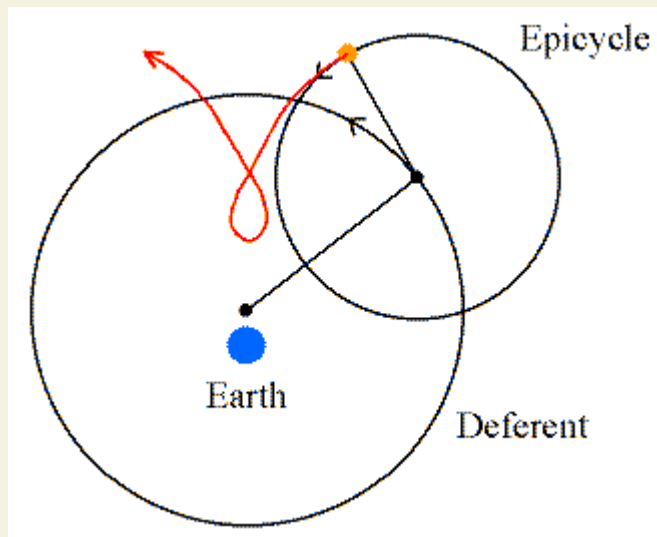
<http://www.spaceandmotion.com/cosmology-history-astronomy-universe-space.htm>

<http://www.sacred-texts.com/eso/sta/sta03.htm>

~ Pythagoras (ca. 560-480 BCE)

~ Aristotle (384-342 BCE)

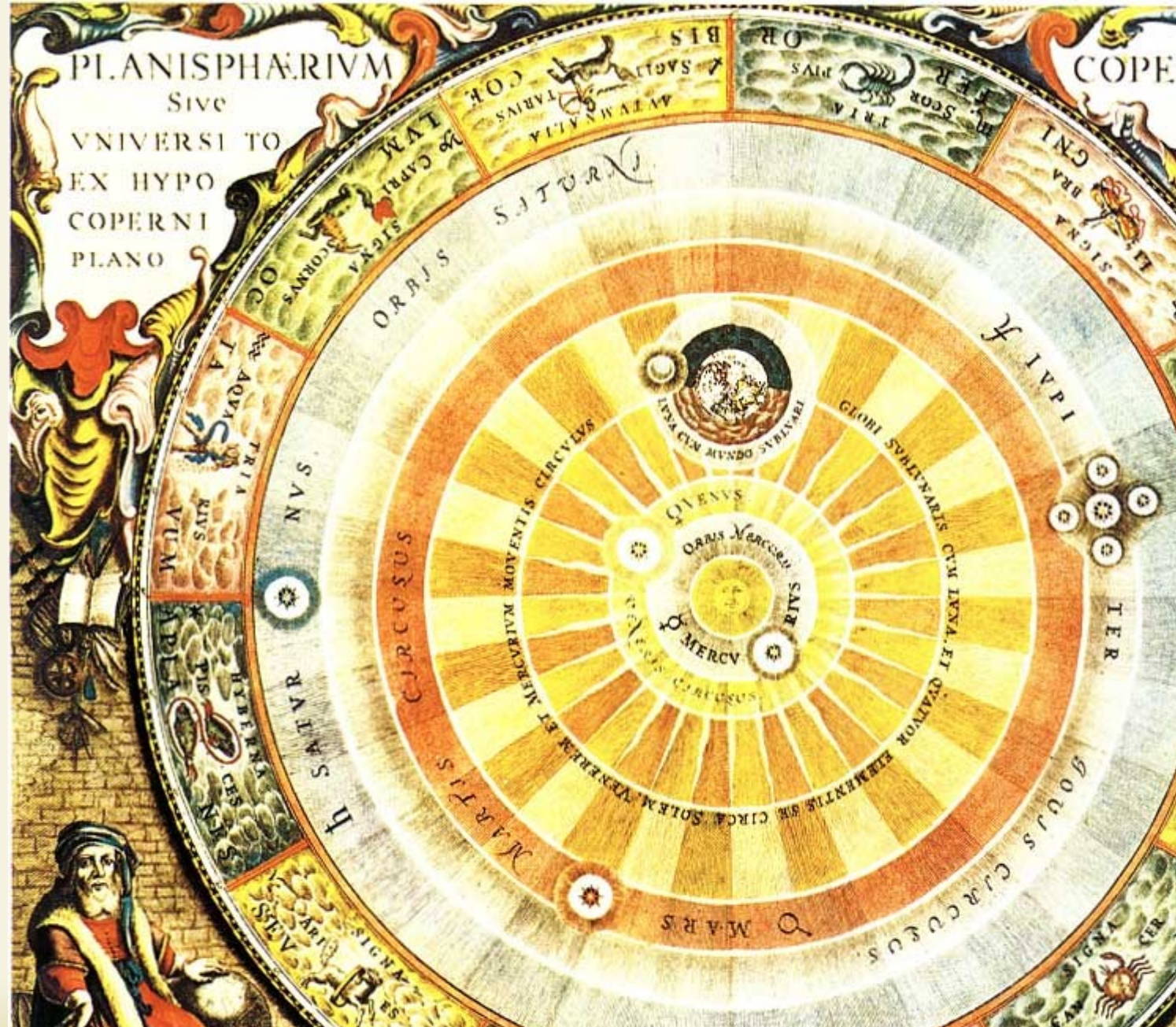
~ Ptolemy (ca. 100-170)



<http://www.daviddarling.info/images/epicycle.gif>

Heliocentric System

- ~ Copernicus (1473-1543)
- ~ Tycho Brahe (1546-1601)
- ~ Galileo Galilei (1564-1642)
- ~ Giordano Bruno (1548-1600)
(infinite universes)
- ~ Johannes Kepler (1571-1630)



The Clockwork Universe

Sir Isaac Newton (1642-1727)

~ **Principia (1689)**

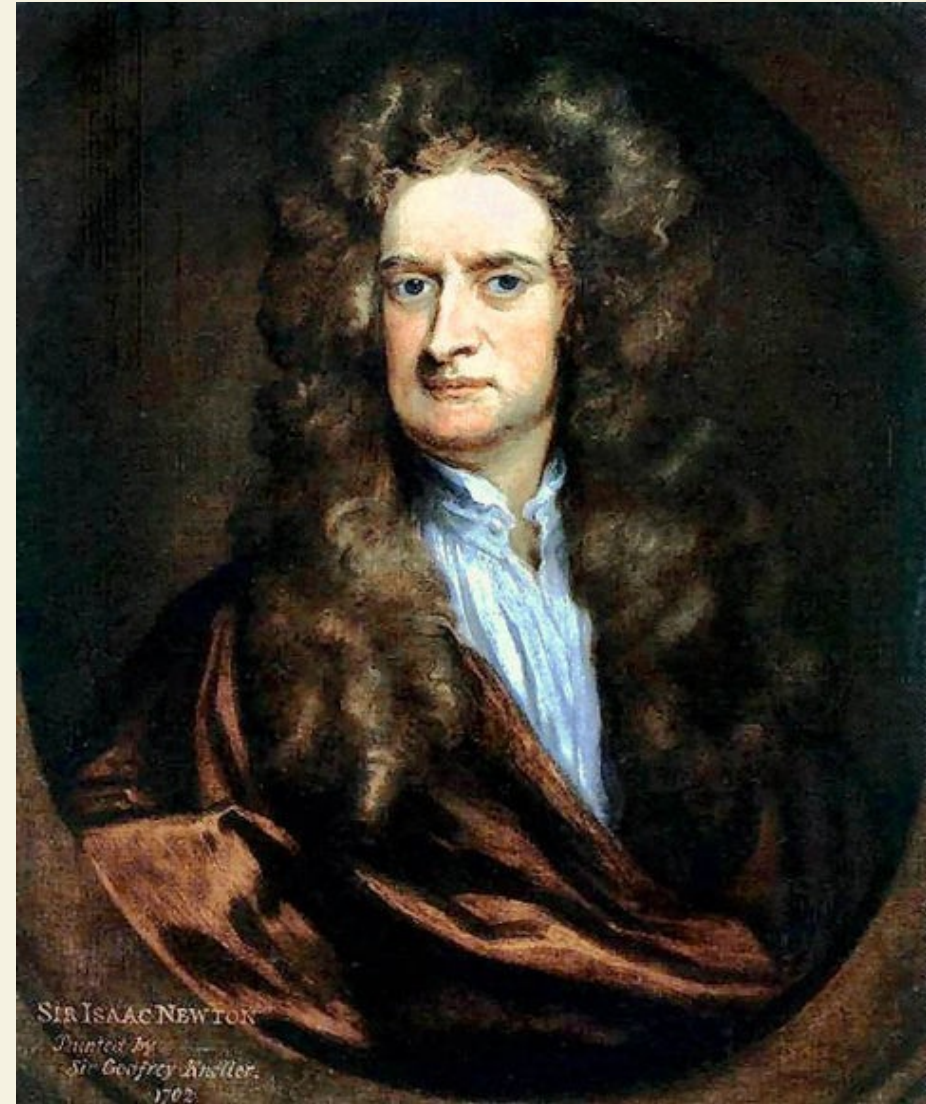
~ *Philosophiæ Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy)*
(1687)

~ **Laws of Motion**

~ **Law of Gravitation**

~ **Inverse Square Law**

~ **Kepler's Laws Explained**



Paradigm Shifts

~ Space

~ Non-Euclidean Geometry

~ Gauss, Riemann, Bolyai

~ Time

~ Special Relativity - Einstein

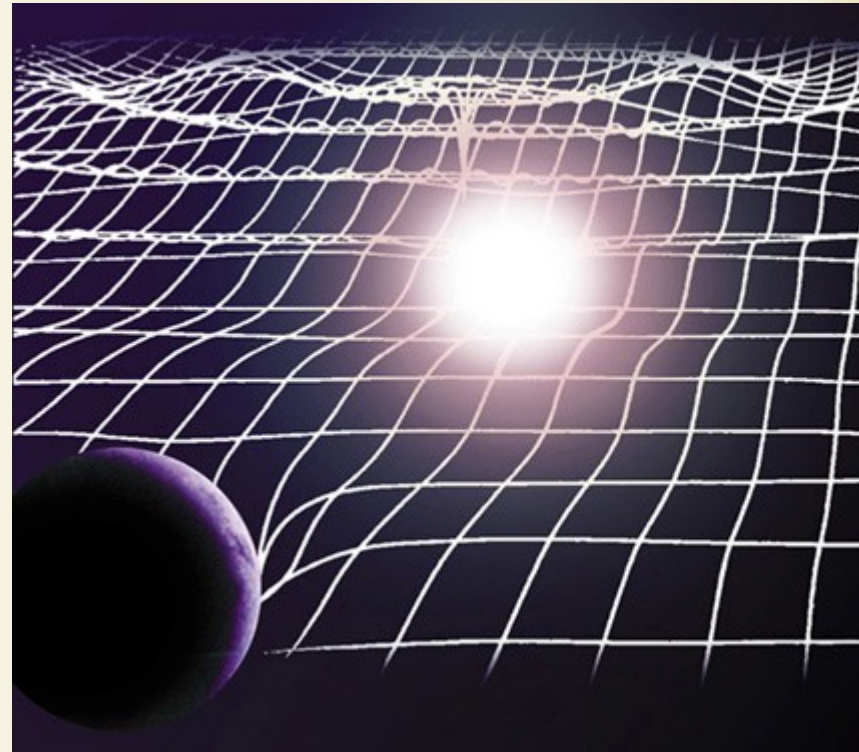
~ Gravitation

~ General Relativity - Einstein

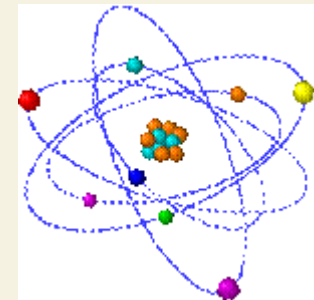
~ Determinism

~ Quantum Mechanics

~ Planck, Einstein, Bohr, Heisenberg, Schrodinger, ...

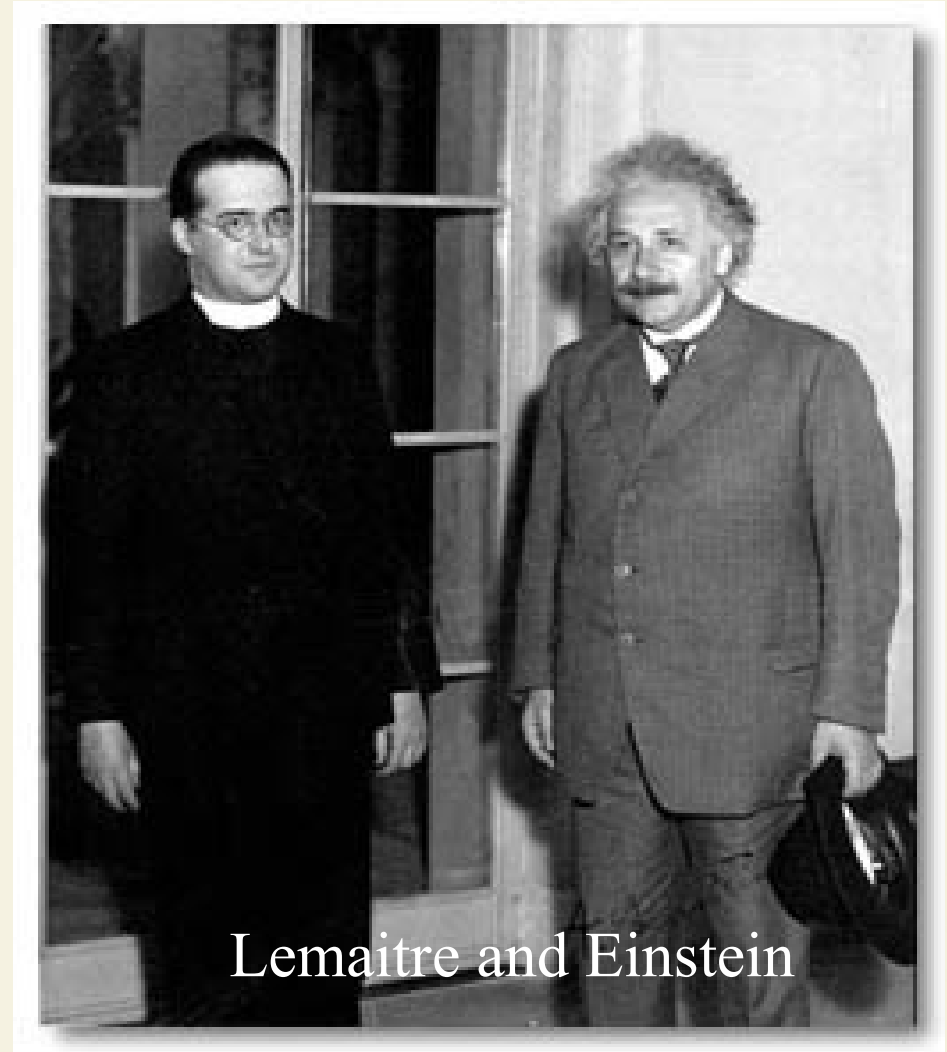


<http://www.zamandayolculuk.com/cetinb>



Pre-Modern Cosmology

- 1915 General Relativity
- 1916 Schwarzschild
- 1917 de Sitter
- 1922 Friedman
- 1927 Lemaitre
- 1929 Hubble
- 1932 Einstein-de Sitter
 - Dark matter?
- 1948 Gamow - CMB
 - Alpher-Bethe-Gamow theory
- 1950 Hoyle – Steady State
- 1965 Penzias and Wilson



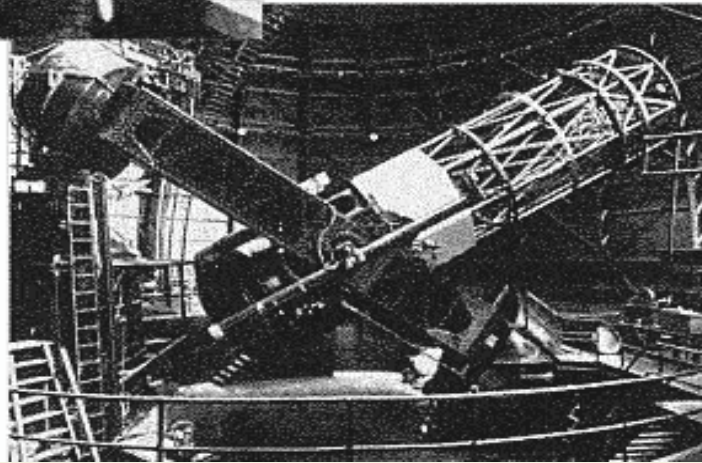
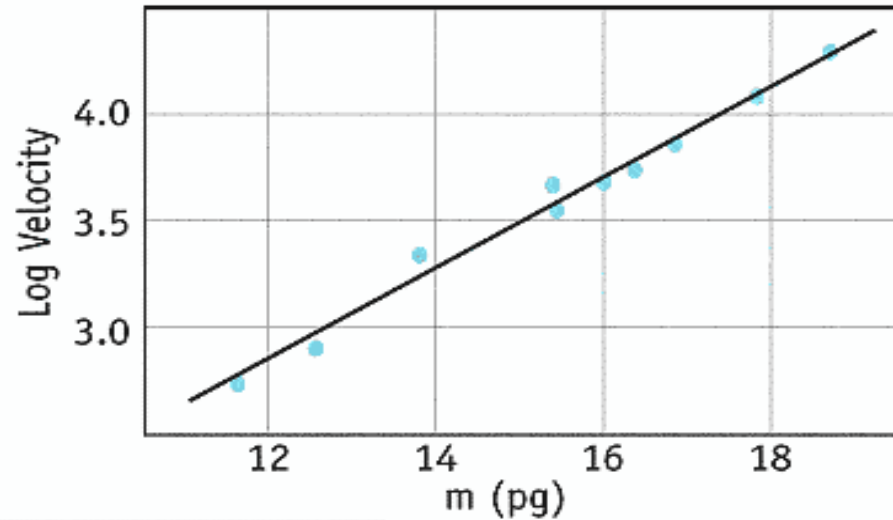
<http://www.catholiceducation.org/articles/science/sc0022.html>

Edwin Hubble

DISCOVERY OF EXPANDING UNIVERSE

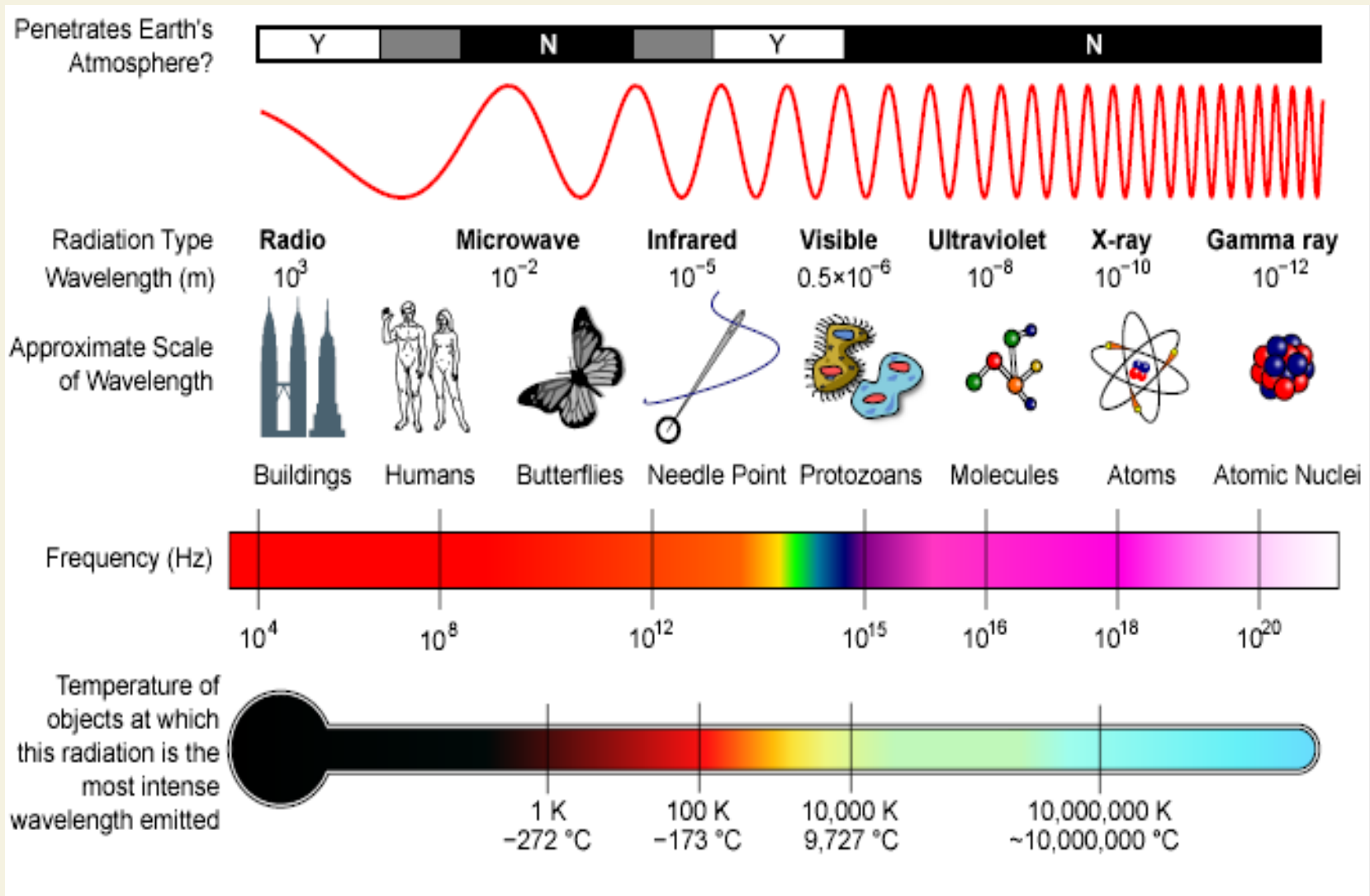


Edwin Hubble



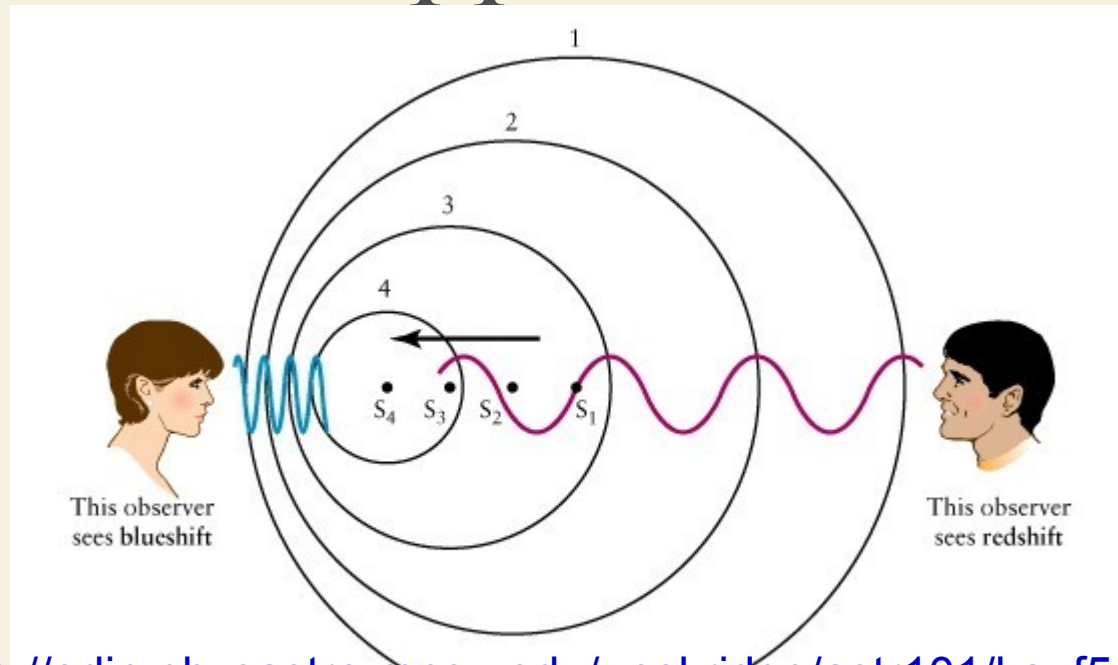
Mt. Wilson
100 Inch
Telescope

EM Spectrum

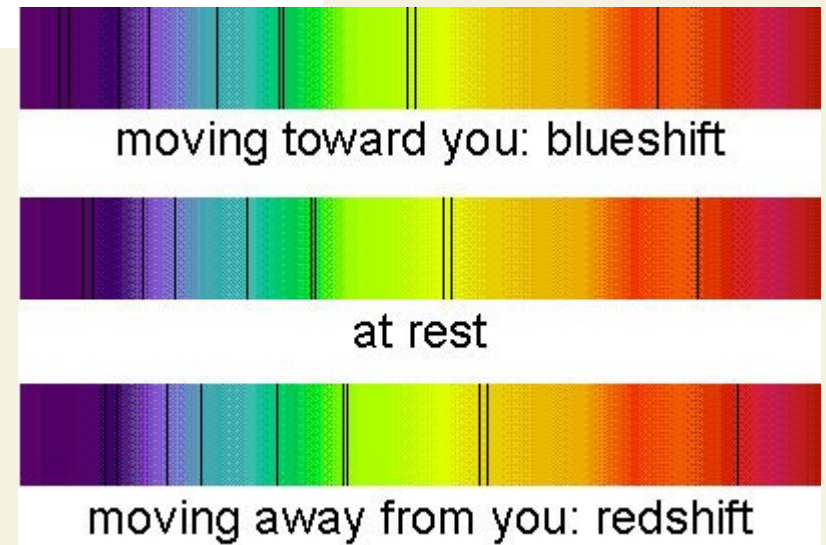
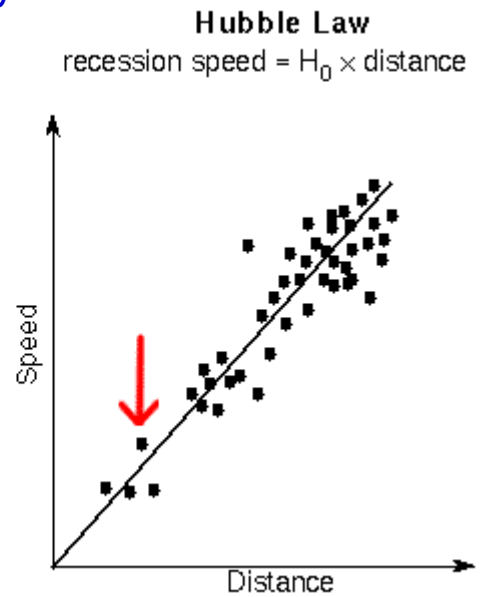
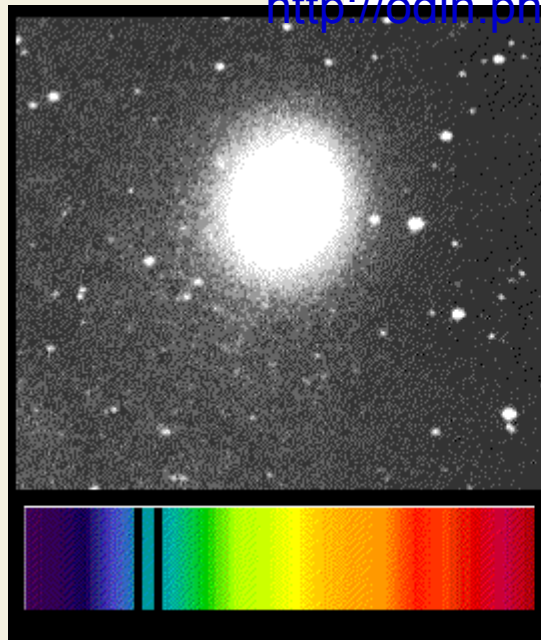


http://en.wikipedia.org/wiki/Electromagnetic_spectrum

Doppler Effect



http://odin.physastro.mnsu.edu/~eskridge/astr101/kauf5_23.JPG

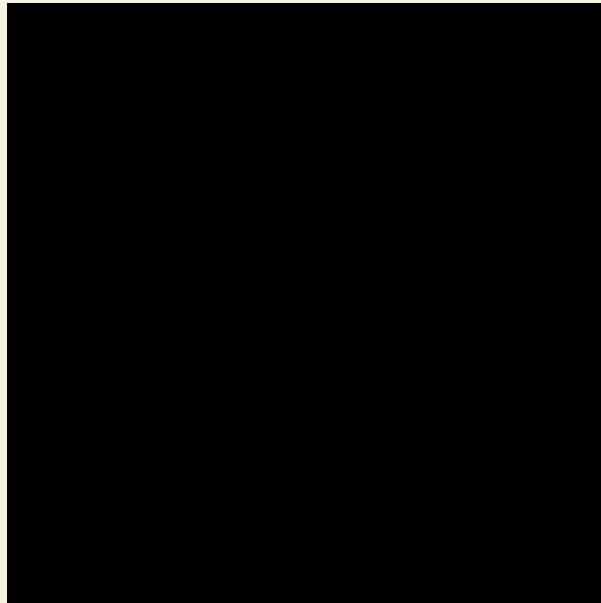


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Olber's Paradox 1823

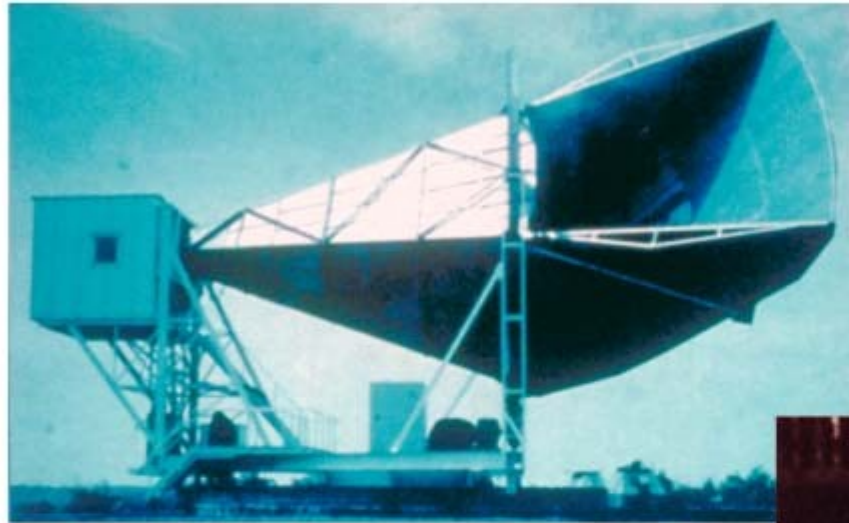
Why is the sky dark at night?



http://en.wikipedia.org/wiki/Olbers'_paradox

Arno Penzias and Robert Wilson

DISCOVERY OF COSMIC BACKGROUND

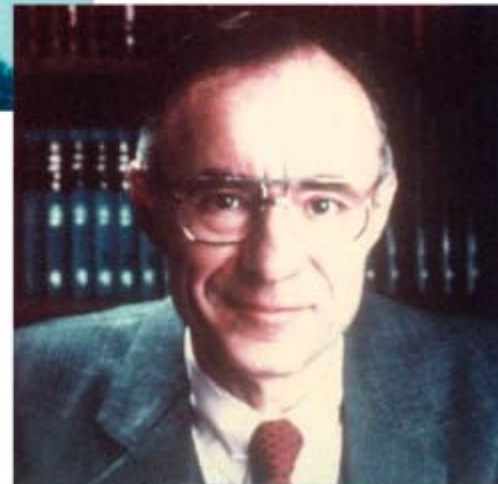


Microwave Receiver



MAP990045

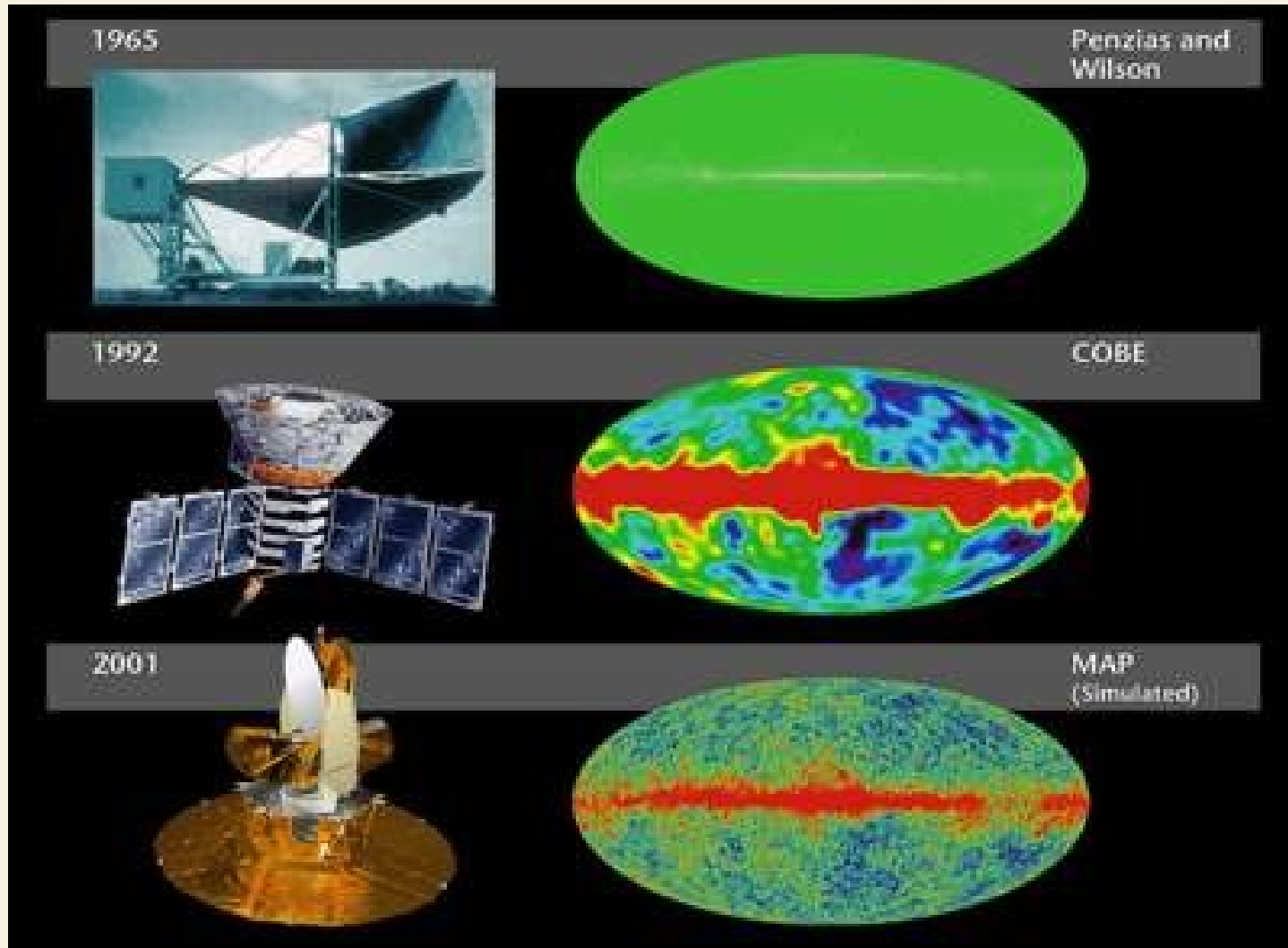
Robert Wilson



Arno Penzias

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Cosmic Microwave Background

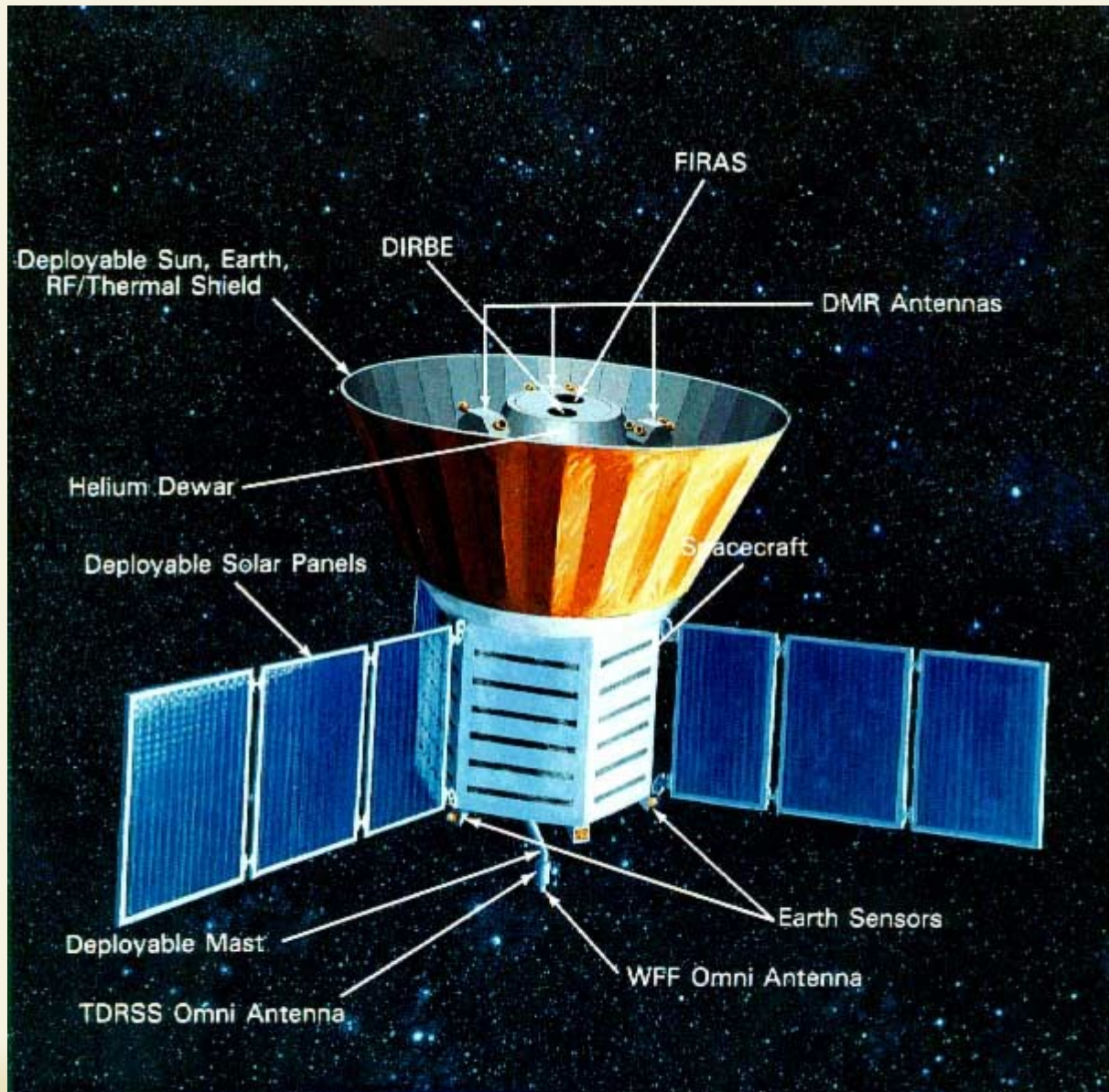


http://www.space.com/scienceastronomy/map_mission_basics_030211.html

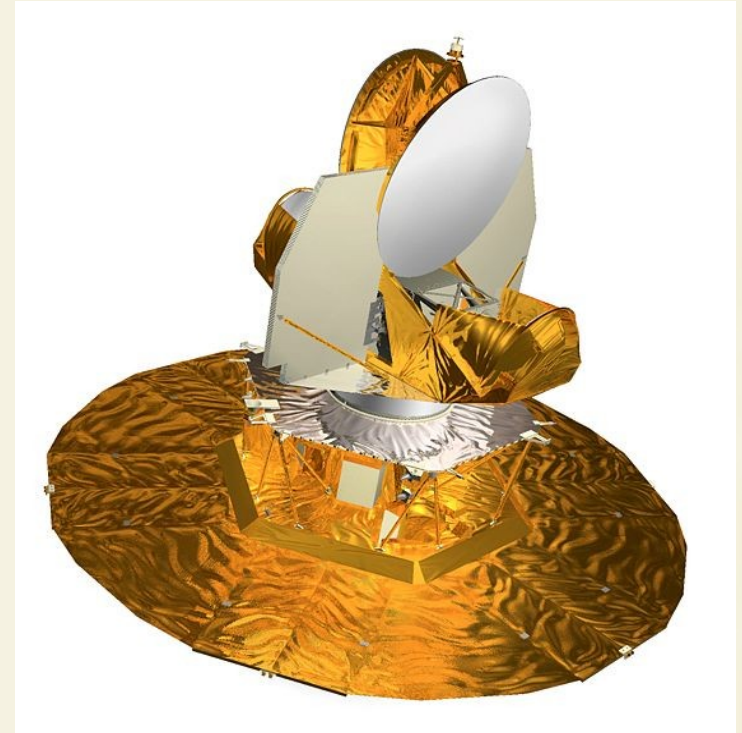
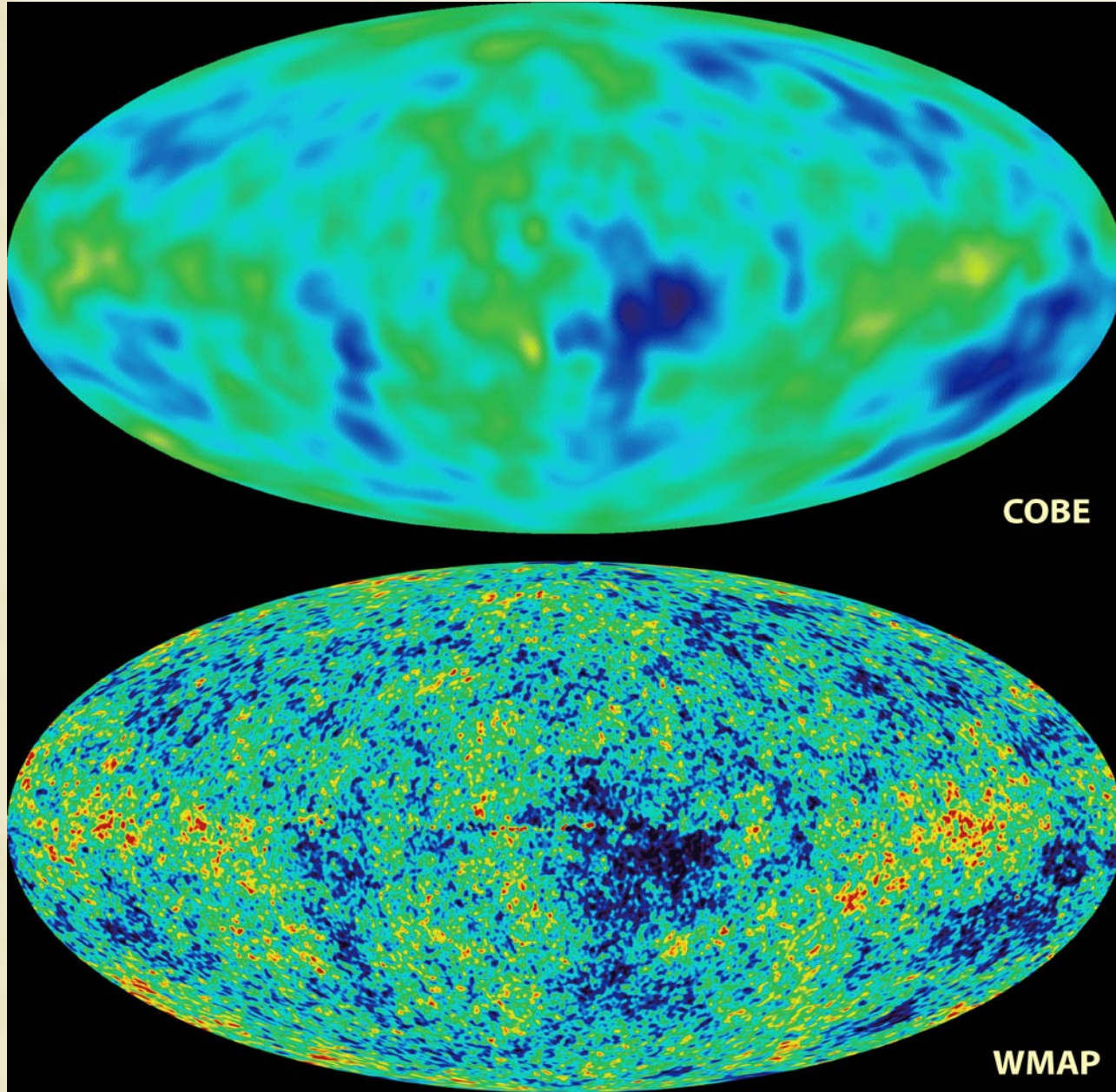
The First Three Minutes, UNC Wilmington, 2008

COBE

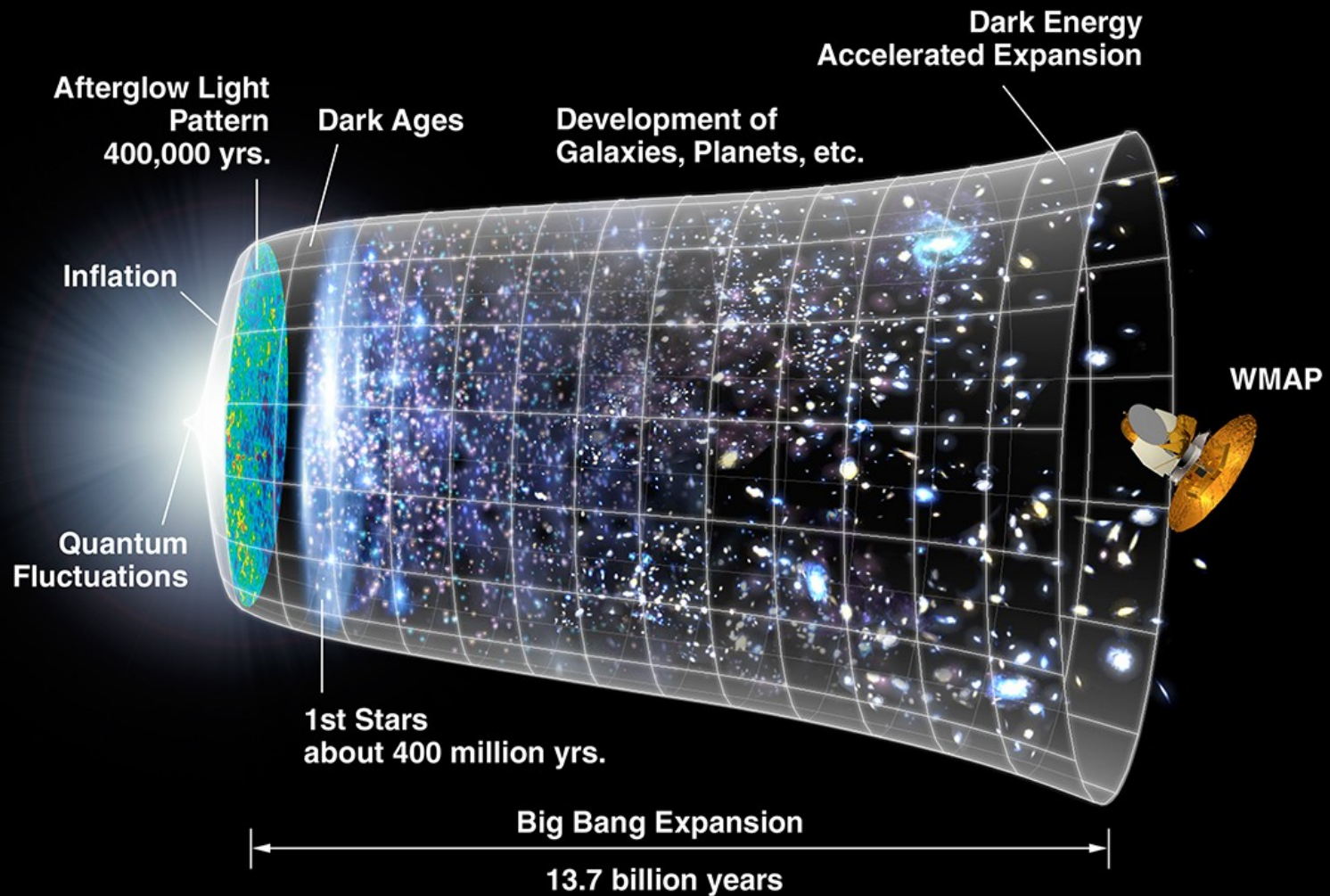
<http://commons.wikimedia.org/wiki/Image:Cobe.jpg>



WMAP



History of Universe



What We Know

- ~ Homogeneous
- ~ Isotropic
- ~ Age of Universe
- ~ Temperature
- ~ Energy \Rightarrow Matter + Antimatter (?)

Evolution

- ~ Quarks \Rightarrow Protons
- ~ Protons \Rightarrow H, He, ...
 - ~ Heavier elements are more complicated
- ~ Gravity \Rightarrow galactic clouds \Rightarrow stars
- ~ Star get hotter \Rightarrow forms heavy elements
 - ~ O ... Fe
- ~ Star Explodes and pollutes cosmos 500 billions years ago

Supernova 1987A

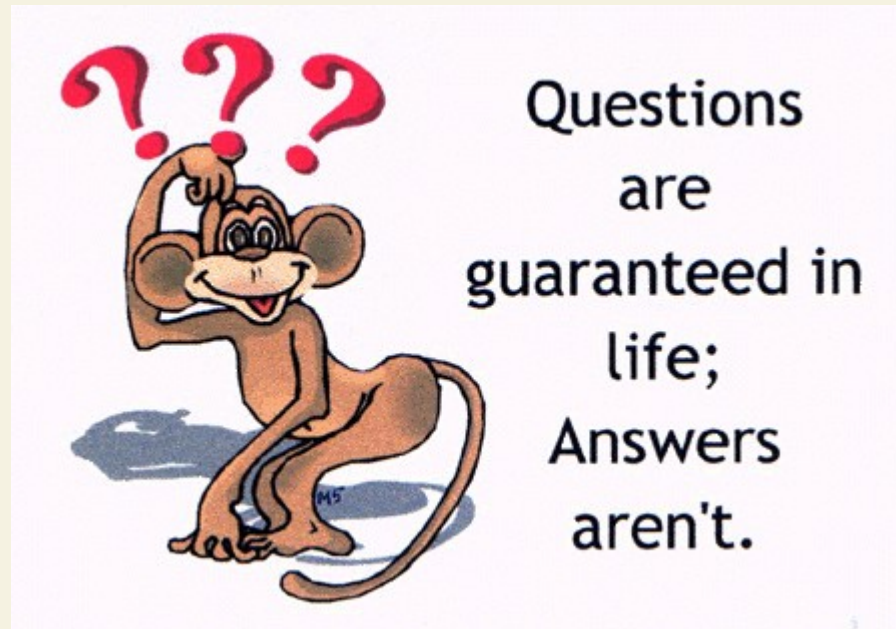


<http://www.oberlin.edu/physics/dstyler/Astronomy/S>



<http://science.nationalgeographic.com/staticfile>

What Don't We Know?



Principles ...

Cosmological Principle – the universe looks the same to observers everywhere ...

Copernican Principle – we are not at a privileged position in the universe

Anthropic Principle -

<http://www.answers.com/topic/anthropic-principle>