

Paradigm Shifts

~ Space

~ Non-Euclidean Geometry

~ Gauss, Riemann, Bolyai

~ Time

~ Special Relativity - Einstein

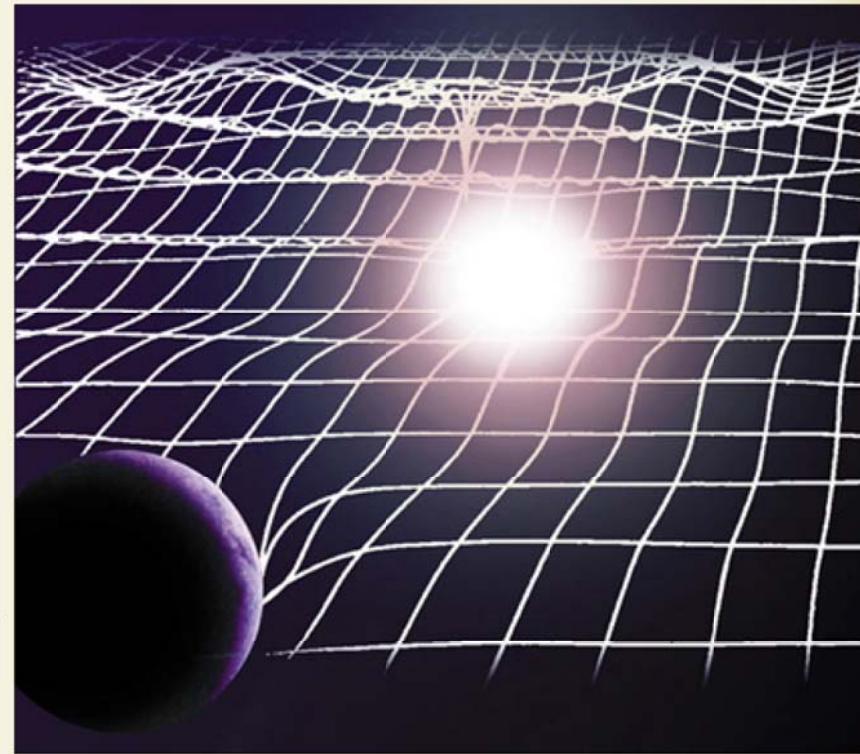
~ Gravitation

~ General Relativity - Einstein

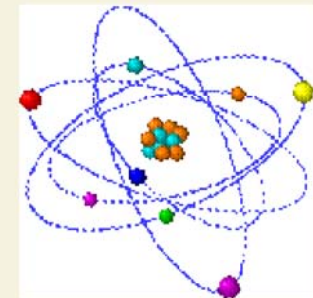
~ Determinism

~ Quantum Mechanics

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

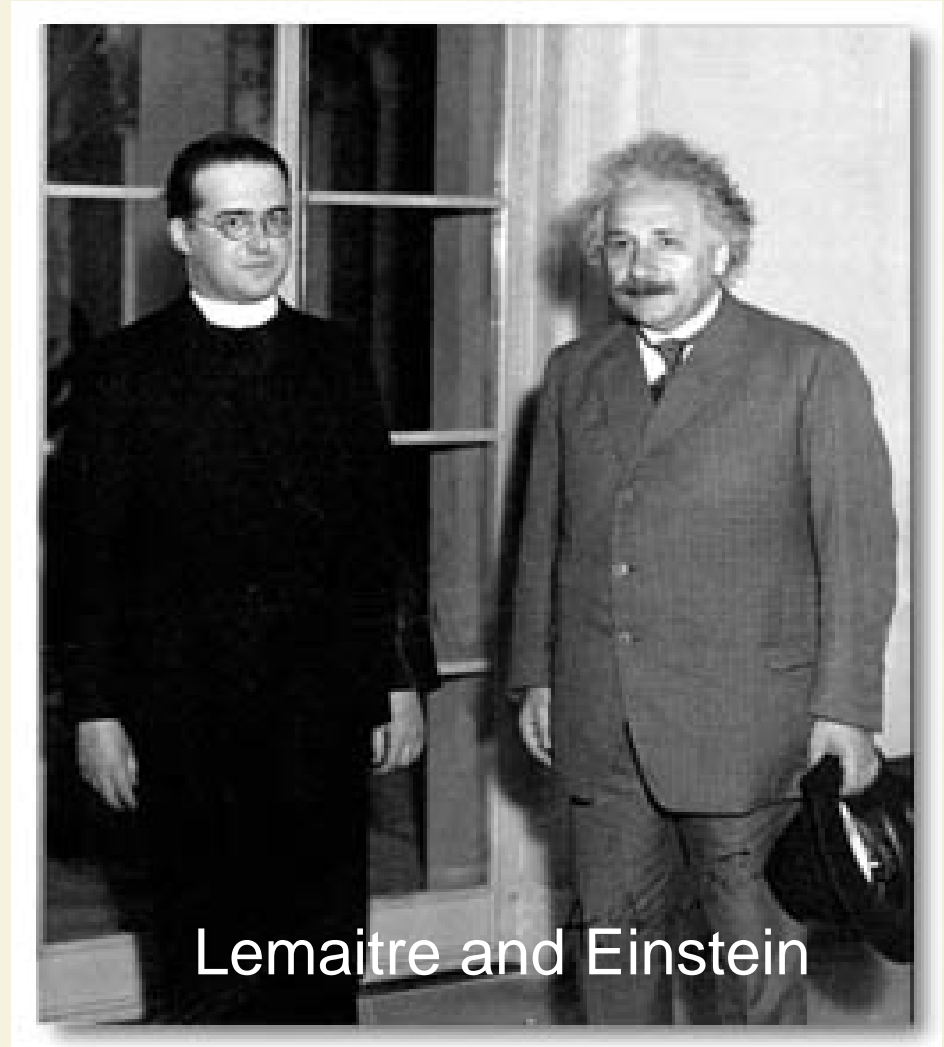


<http://www.zamandayolculuk.com/cetinb>



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>

General Relativity

~ 1915 Einstein

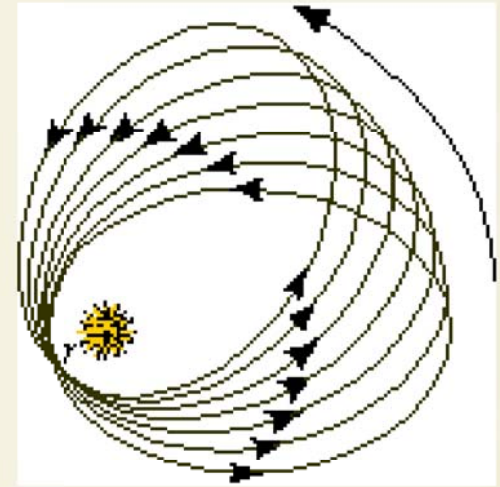
- ~ Newton's gravitational attraction replaced
- ~ Curvature of spacetime tells bodies how to move
- ~ Bodies curve spacetime

~ 1916 Karl Schwarzschild

- ~ Papers on spherical solution sent from WWI front
- ~ Einstein presented Feb 24, 1916

Testing of General Relativity

- ~ New Theories need to
 - ~ Derive known theoretical results
 - ~ Predict new results
- ~ Test 1 – Mercury's Orbit Precession
 - ~ 1858 Urbain Le Verrier – $53 \frac{1}{574}$ arcsec/century
 - ~ Nov 18, 1915 Einstein – GR gives 574!

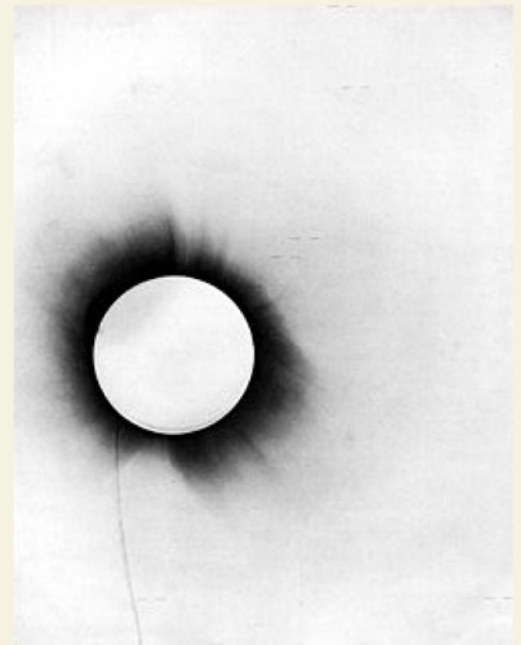
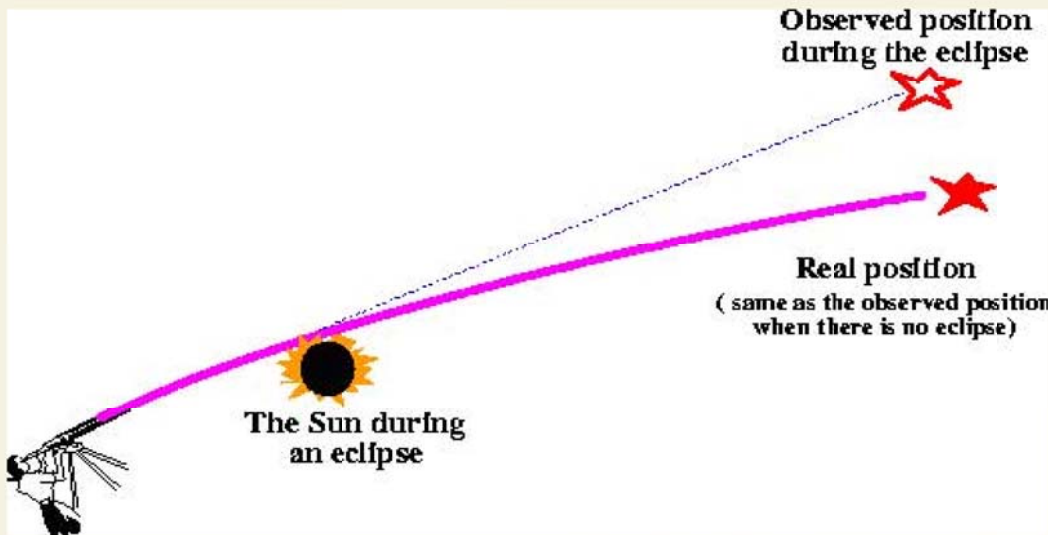


Test 2 – Bending of Light

- ~ Erwin Freundlich – 1912
 - ~ Crimea – Aug 21, 1914
- ~ Sir Arthur Eddington
 - ~ Brazil – May 29, 1919

**LIGHTS ALL ASKEW
IN THE HEAVENS**

**Men of Science More or Less
Agog Over Results of Eclipse
Observations.**



Cosmological Considerations

~ Feb 1917 - Einstein

*Cosmological Considerations of the
General Theory of Relativity*

~ Cosmological Principle

~ The universe is the same everywhere

~ Homogeneous

~ The universe looks the same from every point

~ Isotropic

~ The universe looks the same in every direction

The Universe is Changing

- ~ Einstein's Model
 - ~ The universe is unstable
 - ~ All bodies attract leading to collapse
- ~ Fudge Factor
 - ~ Einstein adds cosmological constant
 - ~ Provides a repulsion of masses
 - ~ Later Einstein calls “his greatest blunder”

New Theories

- ~ 1922 Alexander Friedmann
 - ~ Russian activist and mathematician
 - ~ Abandoned cosmological constant
 - ~ Gave universe an initial kick
 - ~ Initial density gave three scenarios
 - ~ Low density – forever expands
 - ~ High density – re-contracts
 - ~ Critical density – slows without halting
 - ~ Rejected by Einstein

Another Theory

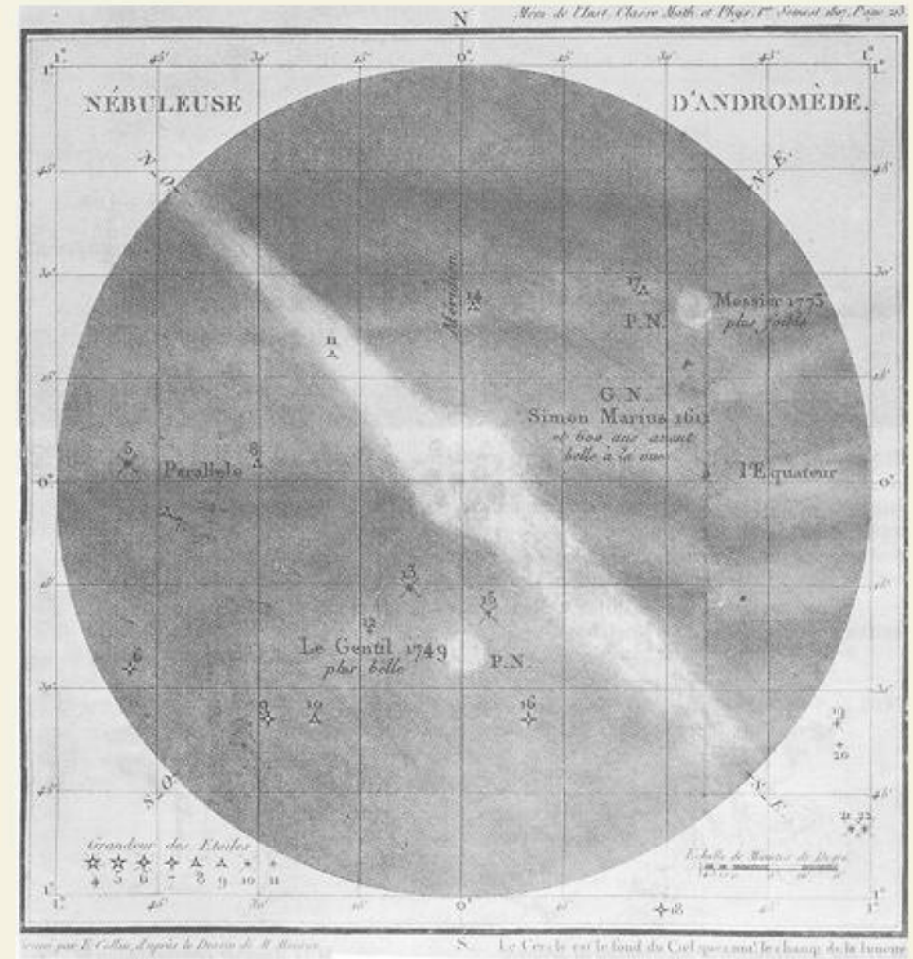
- ~ 1927 – George Lemaitre
 - ~ Physicist and Priest
 - ~ Worked with Eddington
 - ~ Rederived Friedmann's work
 - ~ Consequence
 - ~ traced back in time to moment of creation
 - ~ Proposed cosmic rays came from early universe
 - ~ Also rejected by Einstein!

Distances & the Milky Way Galaxy

- ~ William Herschel (1738-1822)
 - ~ Built telescopes, discovered Uranus
 - ~ Measured stellar distances
 - ~ Stars distributed in a pancake shape – Milky Way
 - ~ 1000 siriometers x 100 siriometers
 - ~ Based on distance to Sirius
- ~ Friedrich Wilhelm Bessel – 28 years
 - ~ Used parallax to establish stellar distances in km

Nebulae

- ~ Smudges of light
- ~ Charles Messier 1781
 - ~ Catalog of 103
 - ~ Crab Nebulae M1
 - ~ Andromeda N. M31
- ~ Are they in Milky Way or beyond?



Messier Catalog <http://www.seds.org/MESSIER/data2.html>

The Debate Begins

~ William Herschel

~ Cataloged 2500 nebulae

~ Sited star in some – perhaps solar system birth

~ Therefore, in Milky Way

~ Immanuel Kant

~ Believed nebulae were beyond Milky Way

~ More Observational Data

~ William Parsons, Third Earl of Rosse

~ 16.5 m long, 1 million lb \$\$\$ - 1845

The First Three Minutes, UNC Wilmington, 2008

~ George Hale – Mt Wilson, 1910

The Debate Ends – April 1920

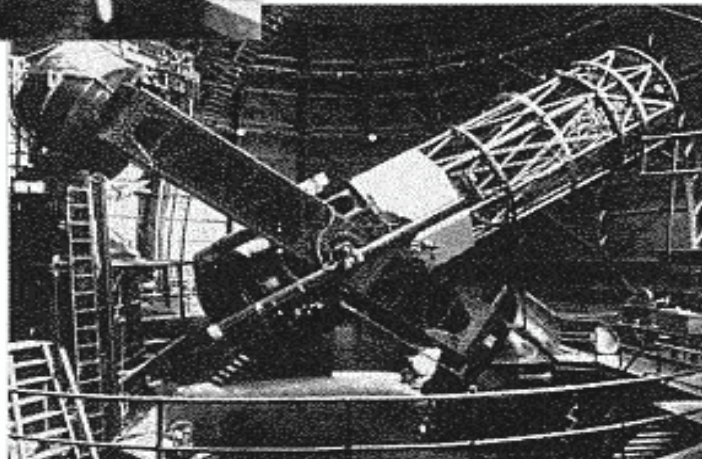
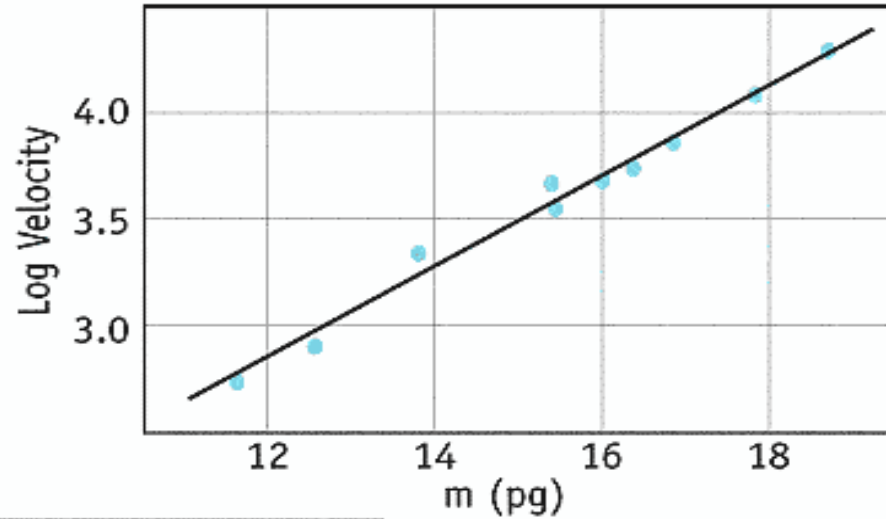
- ~ Harlow Shapely – within Milky Way
 - ~ Distribution of nebulae – zone of avoidance
 - ~ 1885 Nova in Andromeda
- ~ Heber Curtis – Outside Milky Way
 - ~ Zone was an illusion
 - ~ Nova was abnormal

Edwin Hubble

DISCOVERY OF EXPANDING UNIVERSE

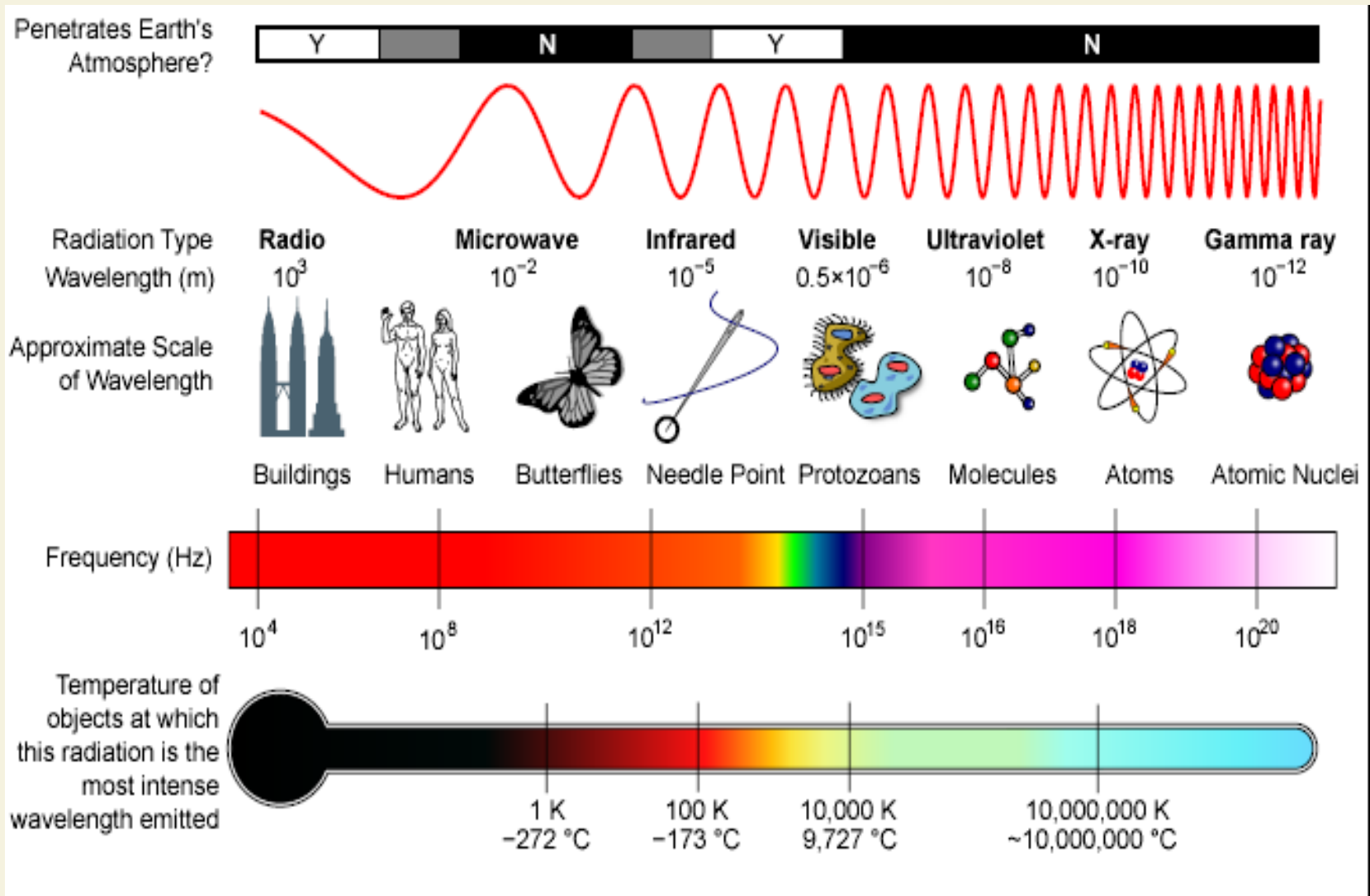


Edwin Hubble



Mt. Wilson
100 Inch
Telescope

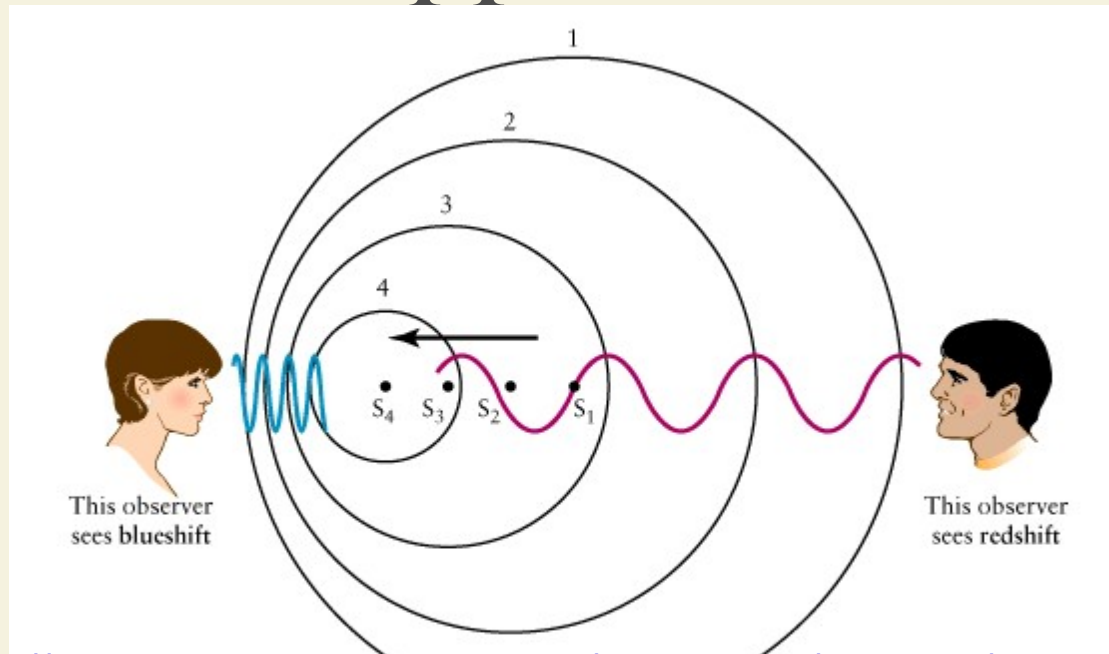
EM Spectrum



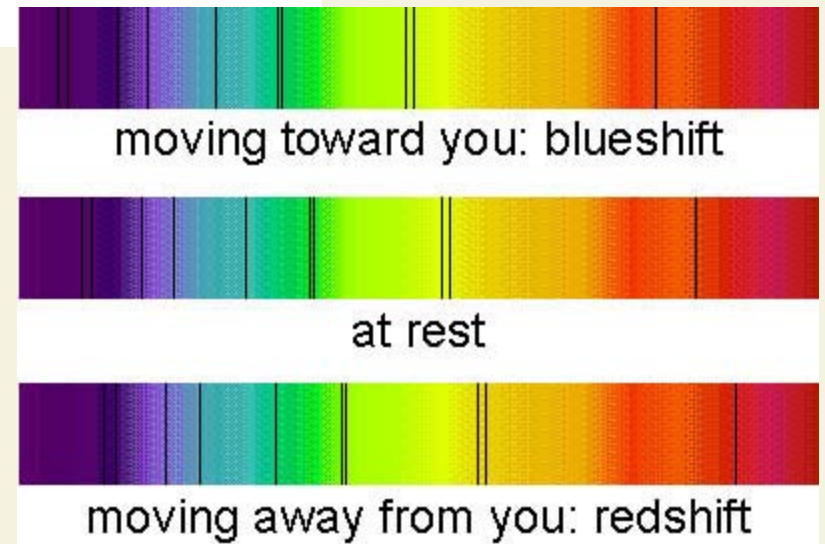
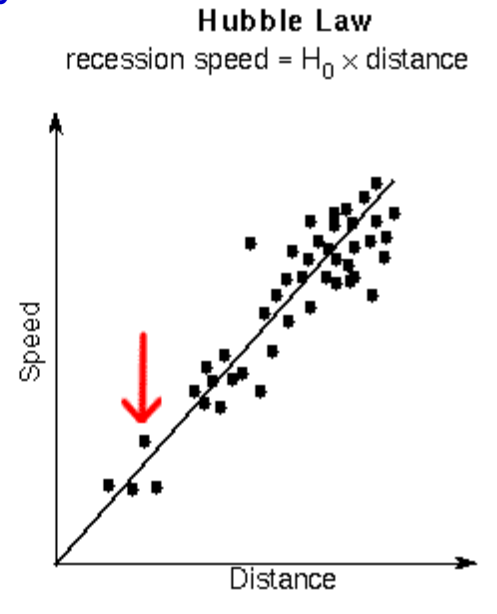
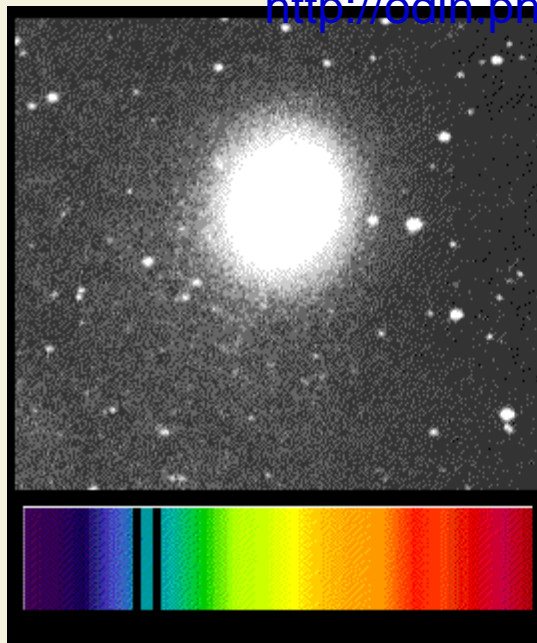
http://en.wikipedia.org/wiki/Electromagnetic_spectrum

The First Three Minutes, UNC Wilmington, 2008

Doppler Effect



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



The First Three Minutes, UNC Wilmington, 2008