Moments That Shaped Modern Astronomy

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Top 5 List

- the expanding Universe
- development of Quantum mechanics
- Special & General Relativity
- Space telescopes
- CMB

The Expanding Universe

- Edwin Hubble
  - (1925) announces discovery that ‘nebulae’ were actually distant galaxies
  - (1929) formulation of Hubble Law using Slipher redshift measurements and Cepheid distances
  - determined H_0 = 500 km/s/Mpc
  - consistent w/ GR prediction of homogeneous, isotropic expansion
  - first observational support for Big Bang

Development of QM

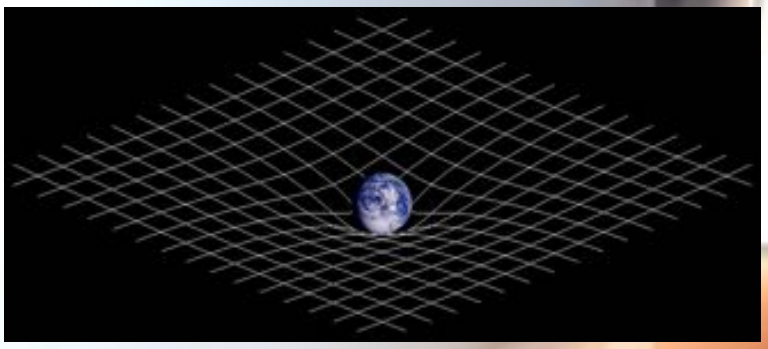
- underlying framework for many fields (e.g., chemistry, particle/nuclear physics, EM)
- foundations by Heisenberg, Planck, de Broglie, Bohr, Schrödinger, Born, Dirac, Einstein,…
- explanations for atomic/subatomic phenomena not explained by classical physics
  - spectral lines (energy levels, hyperfine splitting)
  - stimulated emission
  - radioactive decay
  - nuclear fusion
  - degeneracy pressure
  - uncertainty principles

Development of QM

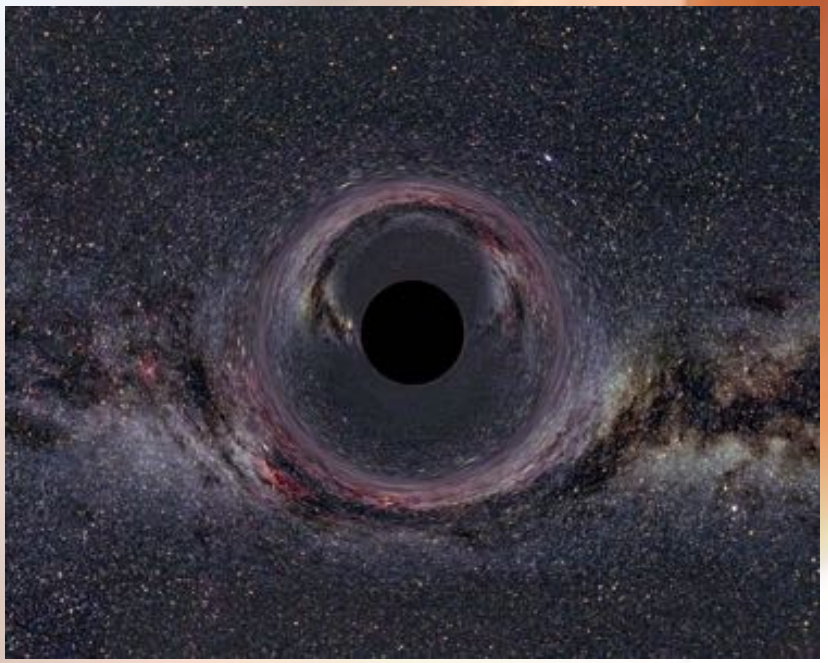
- significance astronomy
  - compact objects (e.g., WD, NS)
  - spectroscopy (Kirchoff's Laws)
  - quantum electrodynamics
  - quantum statistical mechanics
  - nucleosynthesis processes
  - astrochemistry
  - early Universe

Special & General Relativity

- Albert Einstein
  - Special Relativity (1905)
  - General Relativity (1915)



- observational evidence
  - solar eclipse test by Eddington (1919)
  - perihelion shift of Mercury
  - Hulse-Taylor PSR (1974)
  - gravitational redshift
- modern applications
  - GPS
  - satellite orbits

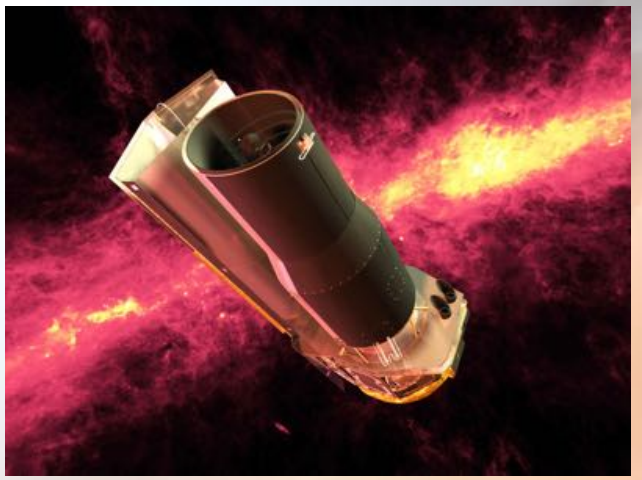


Special & General Relativity

- significance to astronomy
  - cosmological constant
  - solutions to Einstein's equations (Kerr BHs, Schwarzschild BHs, FRW metric, GWs)
  - relativistic beaming, Doppler boosting
  - superluminal motion
  - gravitational lensing
  - orbits

Space Telescopes

- 1st – UHURU (‘freedom’) in 1970
- NASA Great Observatories
  - Compton GRO
  - Hubble
  - Chandra
  - Spitzer
  - James Webb



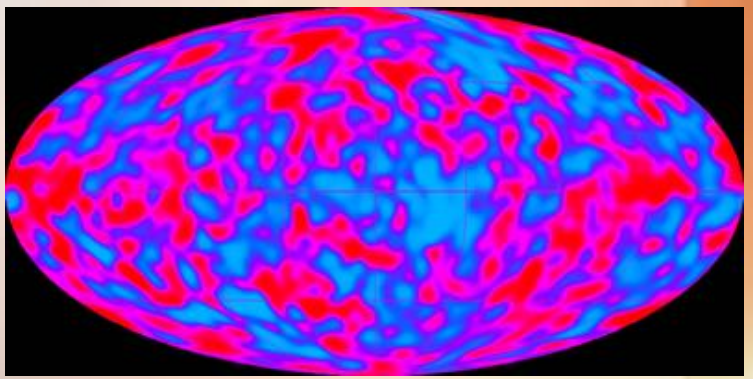
- others
  - SWIFT, XMM-Newton, Einstein, ROSAT, FUSE, IUE, GALEX, Suzaku, WMAP, COBE,…

Space Telescopes

- multiwavelength astronomy
- key discoveries
  - CMB anisotropies (COBE, WMAP)
  - PSRs & SNRs (Chandra)
  - HDF, HUDF
  - Spitzer constraints on quasar population
  - protoplanetary disks
- other space-based astronomy
  - Galileo, Cassini, Voyager probes

The CMB

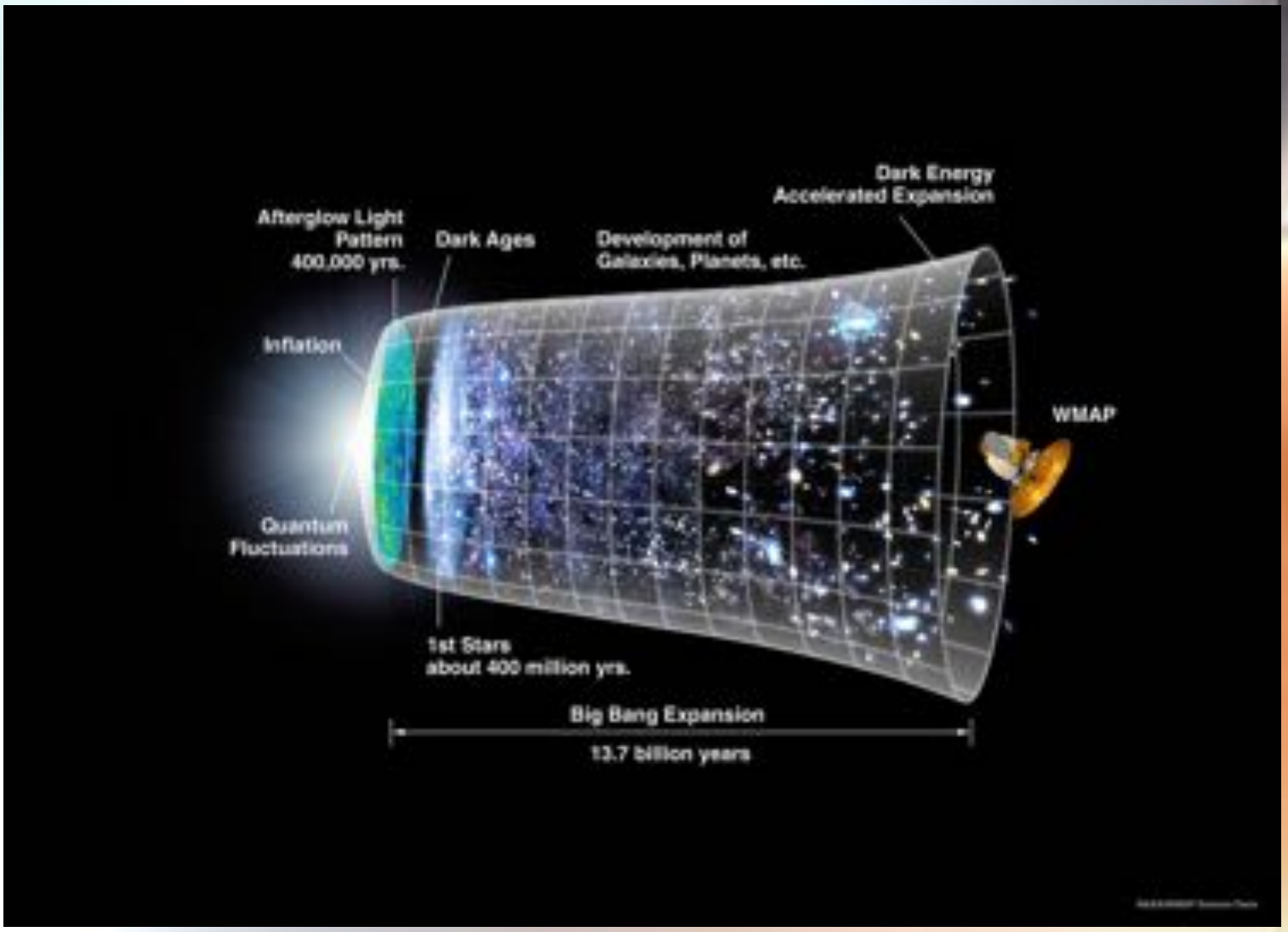
- discovery
  - (1965) Penzias & Wilson accidental discovery
  - Wilson, Peebles, & Dicke interpret as signature of Big Bang
- COBE
  - launched 1989
  - mapped CMB anisotropies to 1 part in 10^5 (31.5, 53, & 90 GHz)
  - solidified Big Bang model
  - CMB perfect BB at 2.7K
  - IR background
  - constrained early SFR



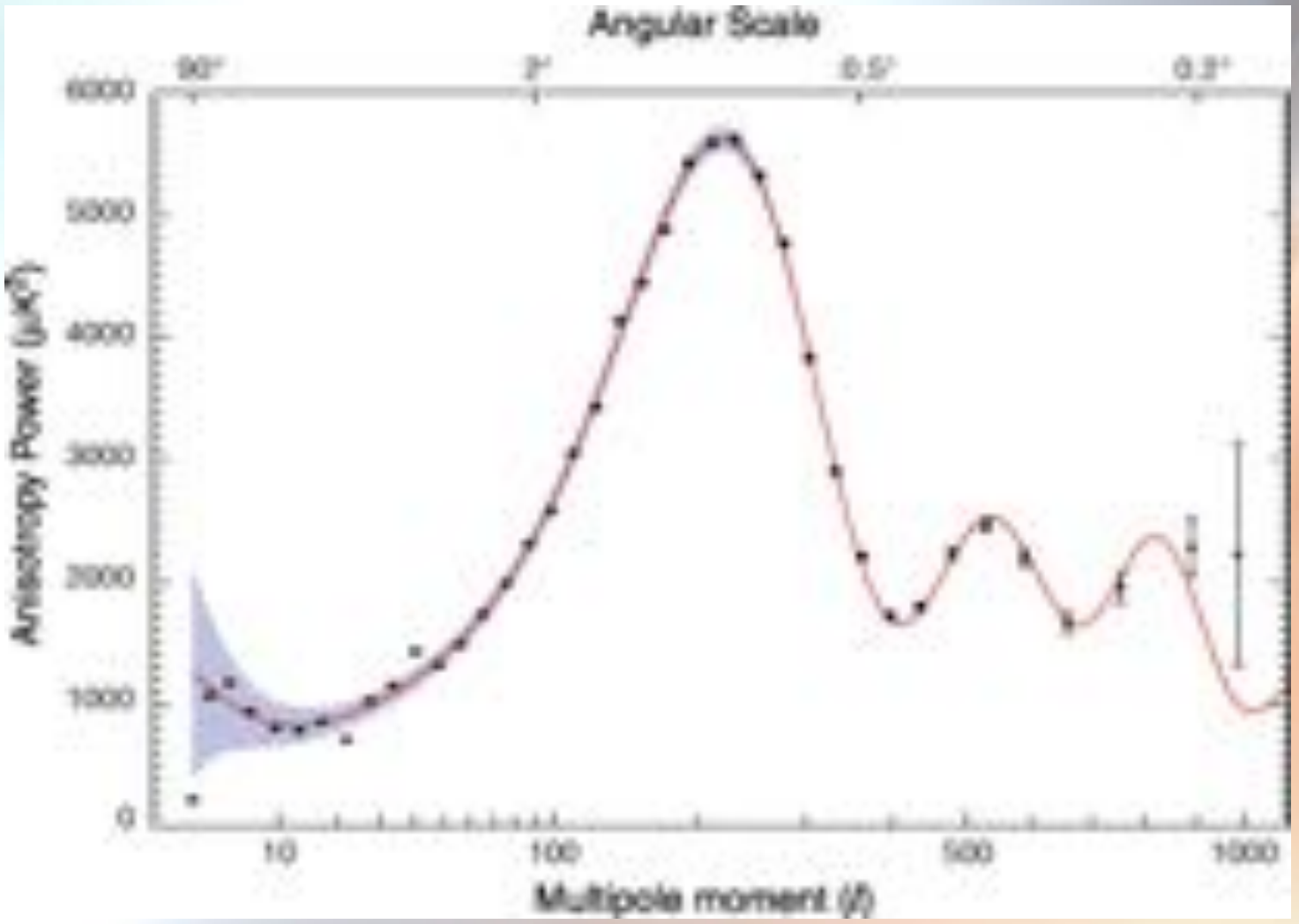
The CMB

- WMAP
  - 45x more sensitivity, 33x more angular resolution than COBE
  - favored certain inflation models for the early Universe

The CMB

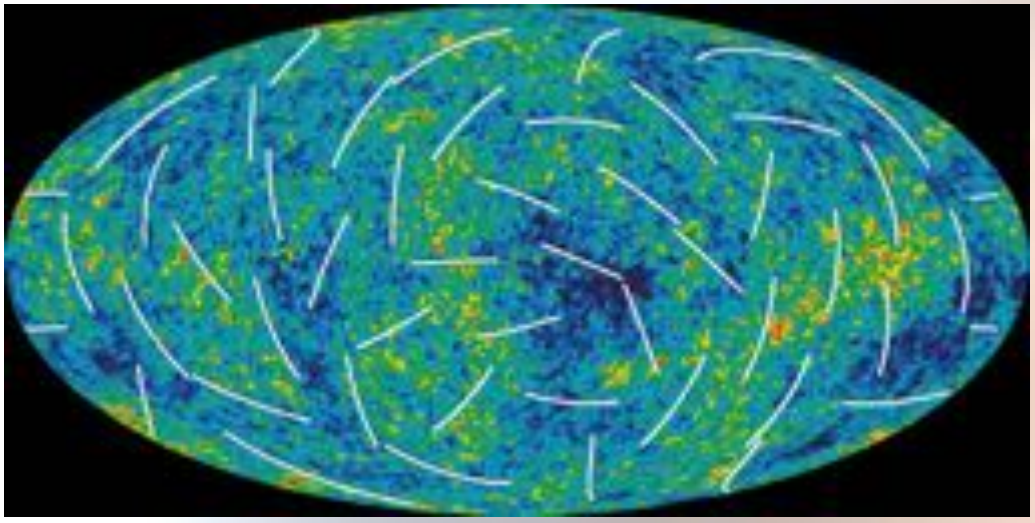

Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

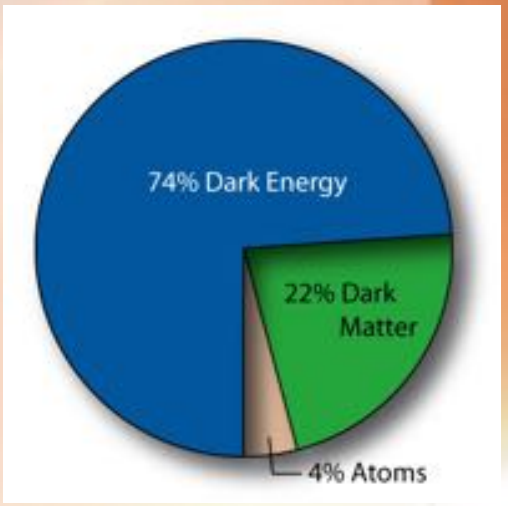
The CMB


Angular Scale
90°
2°
0.5°
0.2°
6000
5000
4000
3000
2000
1000
0
Anisotropy Power (μK²)
10
100
500
1000
Multipole moment (l)

The CMB

- WMAP
  - 45x more sensitivity, 33x more angular resolution than COBE
  - favors certain inflation models for the early Universe
  - inflation predicts imprint of primordial GWs on CMB polarization → future





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