A brief history of cosmology

● **Basic concepts**

▸ **spatial extent**
  ▸ **finite (with edges)**
  ▸ **finite (unbounded)**
  ▸ **infinite**
▸ **our location**
  ▸ **Earth at centre**
  ▸ **Sun at centre**
  ▸ **solar system near centre**
  ▸ **solar system far from centre**
  ▸ **no centre**

▸ **past and future**
  ▸ **both finite (creation, future destruction)**
  ▸ **both infinite (no beginning, no end)**
  ▸ **finite past, infinite future**
▸ **dynamics**
  ▸ **static**
  ▸ **expanding**
  ▸ **cyclic**

Early ideas: astronomy

● **Clearly understood concepts in Greek and Hellenistic astronomy**

▸ shape and size of the Earth (Eratosthenes, BC 276-197)

▸ size and distance of the Moon (Aristarchos, BC 310-230)

▸ Sun is much larger than Earth (Aristarchos)

  ▸ **exact value was wrong by a large factor: method sound in principle, impossible in practice!**
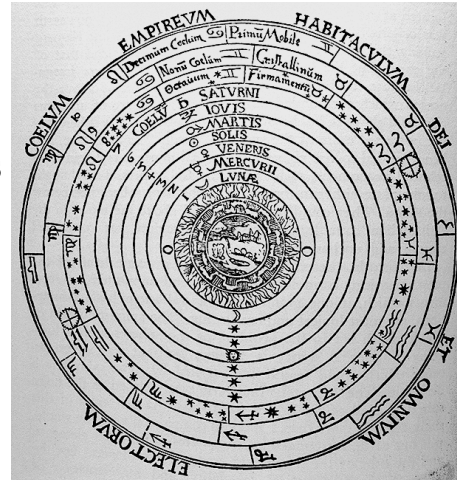
● **Ideas raised but not generally accepted**

▸ Earth rotates on its axis (Heraclides, BC 387-312)

▸ Sun-centred solar system (Aristarchos)

Early ideas: cosmology

- **Aristotle/Ptolemy**
  - ▸ **Earth-centred, finite, eternal, static**
- **Aristarchos/Copernicus**
  - ▸ **Sun-centred, finite, eternal, static**
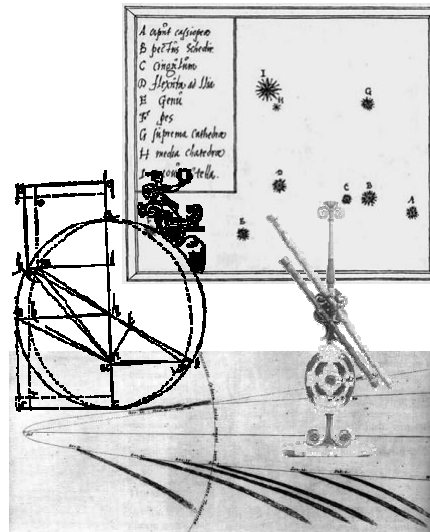- ☞ *At this time, little observational evidence for Sun-centred system!*

Renaissance

- **Birth of modern science**
  - ▸ **scientific method**
    - ▸ **Galileo**
  - ▸ **better observations**
    - ▸ **Tycho, Galileo**
  - ▸ **development of mathematical analysis**
    - ▸ **Kepler, Galileo, Newton**
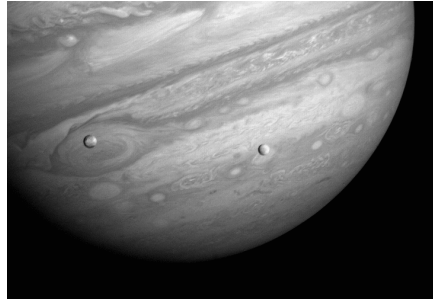- ➔ **Newtonian cosmology**

Newtonian Cosmology

- **Newton's *Philosophiae Naturalis Principia Mathematica*, 1687**
  - ▸ **Newtonian gravity, $F = GMm/r^2$, and second law, $F = ma$**
  - ▸ **Approximate size of solar system (Cassini, 1672)**
    - ▸ **from parallax of Mars**
  - ▸ **Finite speed of light (Ole Rømer, 1676)**
    - ▸ **from timing of Jupiter's moons**
  - ▸ **No distances to stars**
  - ▸ **No galaxies**

Newtonian Cosmology

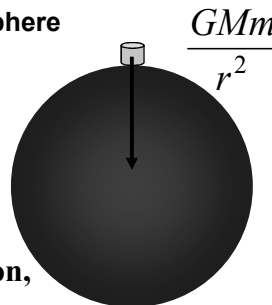- **Newton assumed a static universe**
  - ▸ **Problem: unstable unless completely homogeneous**
    - ▸ **Consider mass *m* on edge of sphere of mass *M* and radius *r***
    - ▸ **mass outside sphere does not contribute (if spherically symmetric)**
    - ▸ **mass inside behaves like central point mass**
  - ▸ **if there exists an overdense region, everything will fall into it**

$$\frac{GMm}{r^2}$$

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Olbers' Paradox

- **Named for Wilhelm Olbers, but known to Kepler and Halley**
  - ▸ **Consider spherical shell of radius *r* and thickness d*r***
  - ▸ **Number of stars in this shell is $4\pi r^2 n\, dr$, where *n* is number density of stars**
  - ▸ **Light from each star is $L/4\pi r^2$, therefore light from shell is $nL\, dr$, independent of *r***
  - ▸ **therefore, in infinite universe, night sky should be infinitely bright (or at least as bright as typical stellar surface – stars themselves block light from behind them)**
- **Why is the sky dark at night?**

Resolution(s)

- **Light is absorbed by intervening dust**
  - ▸ **suggested by Olbers**
    - ▸ **doesn't work: dust will heat up over time until it reaches the same temperature as the stars that illuminate it**
    - ▸ **(I'm not sure 17th century astronomers would have realised this)**
- **Universe has finite size**
  - ▸ **suggested by Kepler**
    - ▸ **this works (integral is truncated at finite *r*)**
    - ▸ **but now Newtonian universe will definitely collapse**

- **Universe has finite age**
  - ▸ **equivalent to finite size if speed of light finite**
    - ▸ **light from stars more than *ct* distant has not had time to reach us**
    - ▸ **(currently accepted explanation)**
- **Universe is expanding**
  - ▸ **effective temperature of distant starlight is redshifted down**
    - ▸ **this effect not known until 19th century**
    - ▸ **(does work, but does not dominate (for stars) in current models)**

Olbers + Newton could have led to prediction of expanding/contracting universe

Further developments

- **James Bradley, 1728: aberration**
  - ▶ **proves that the Earth orbits the Sun**
    - ▶ **also allowed Bradley to calculate the speed of light to an accuracy of better than 1%**
- **Friedrich Bessel, 1838: parallax**
  - ▶ **distances of nearby stars**
    - ▶ **a discovery whose time had come: 3 good measurements in the same year by 3 independent people, after 2000 years of searching!**
- **Michelson and Morley, 1887: no aether drift**
  - ▶ **the speed of light does not depend on the Earth's motion**

State of Play ~1900

- **We know**
  - ▶ **speed of light**
  - ▶ **distance to nearby stars**
  - ▶ **the Earth is at least several million years old**
- **Our toolkit includes**
  - ▶ **Newtonian mechanics**
  - ▶ **Newtonian gravity**
  - ▶ **Maxwell's electromagnetism**

- **We don't know**
  - ▶ **galaxies exist**
  - ▶ **the universe is expanding**
  - ▶ **the Earth is several billion years old**
- **We are worried about**
  - ▶ **conflict between geology and physics regarding age of Earth**
    - ▶ **about to be resolved**
  - ▶ **lack of aether drift**