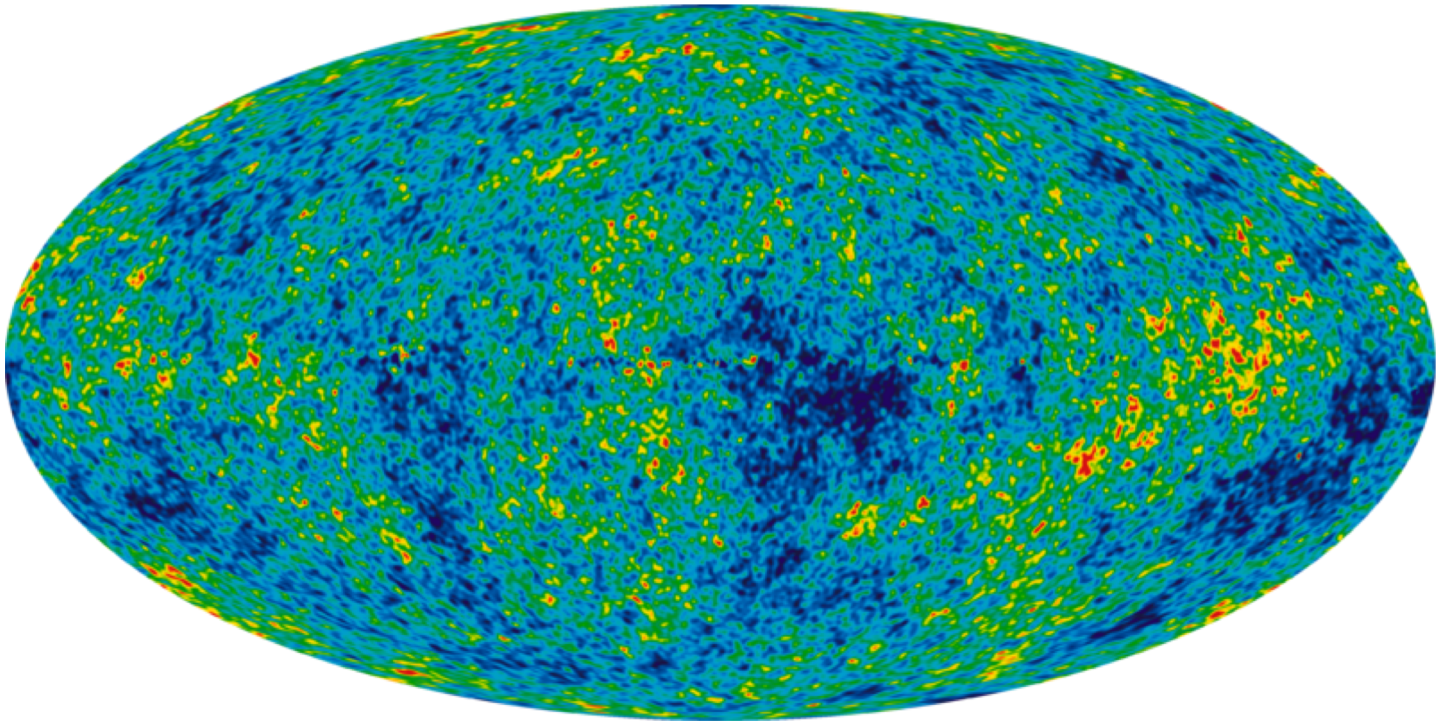


PHY 375/475—An Introduction to Cosmology

Syllabus

- Text: *Introduction to Cosmology, 2nd Ed*, Barbara Ryan
- Course Components
  - Homework. About 5—7 sets
    - Two pass grading system
  - Reading quizzes
    - On *D2L*
    - At least once a week, perhaps more as material demands
  - One Mid Term
  - Presentation and Paper
    - From list generated by me
    - Topic due by third week
    - Bibliography due by 7th week
    - Paper and Presentation due 10th week
  - Final: March 18th 2:30—4:45

Need to change the time for Jan 22 meeting. I'll send out a doodle poll by tomorrow, please respond by *Friday*

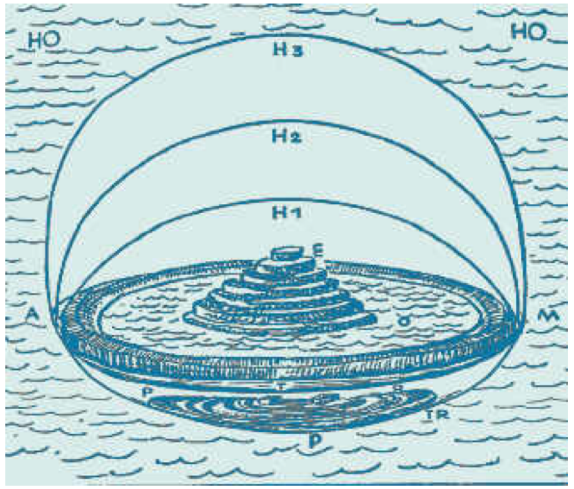
This era may become known as the *golden age of cosmology* because observational data has allowed us to move from *idle speculation* to *exciting, bold, and testable ideas*.

But what is cosmology?

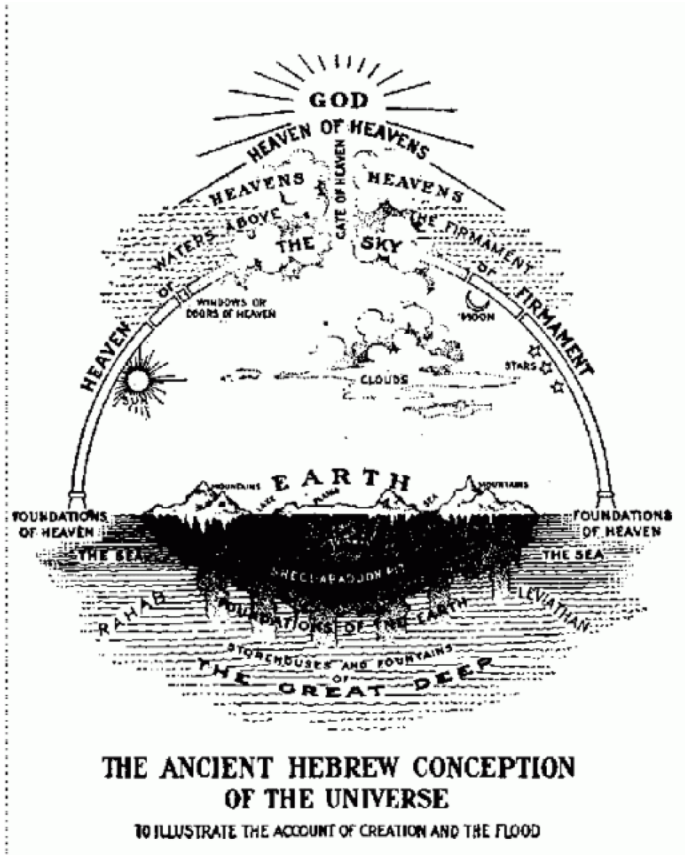
The study of the Universe—its origin, evolution, geometry, and destiny

Do question 1 on the worksheet and S T O P

And it is not new.

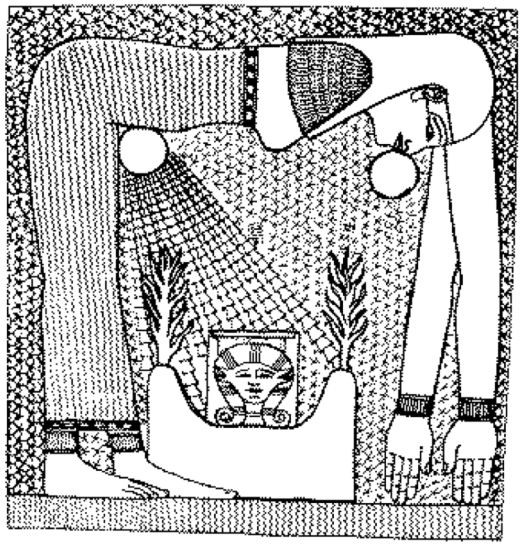


Babylonian Cosmology



THE ANCIENT HEBREW CONCEPTION OF THE UNIVERSE

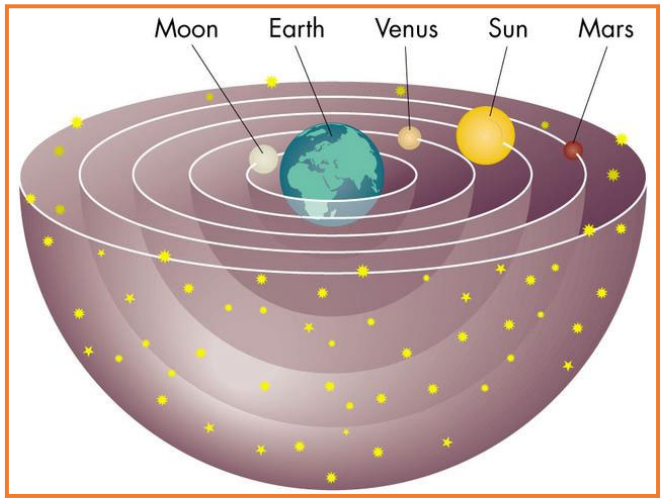
TO ILLUSTRATE THE ACCOUNT OF CREATION AND THE FLOOD

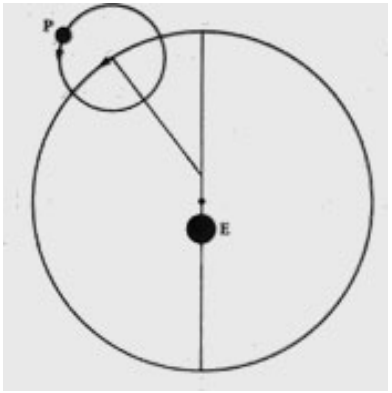


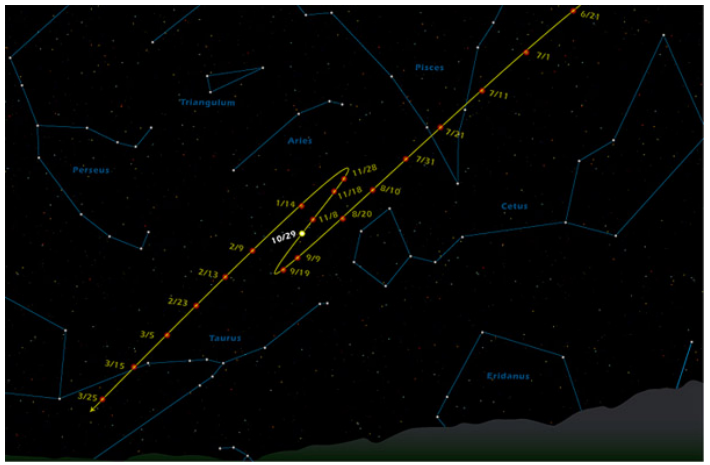
Egyptian Cosmology

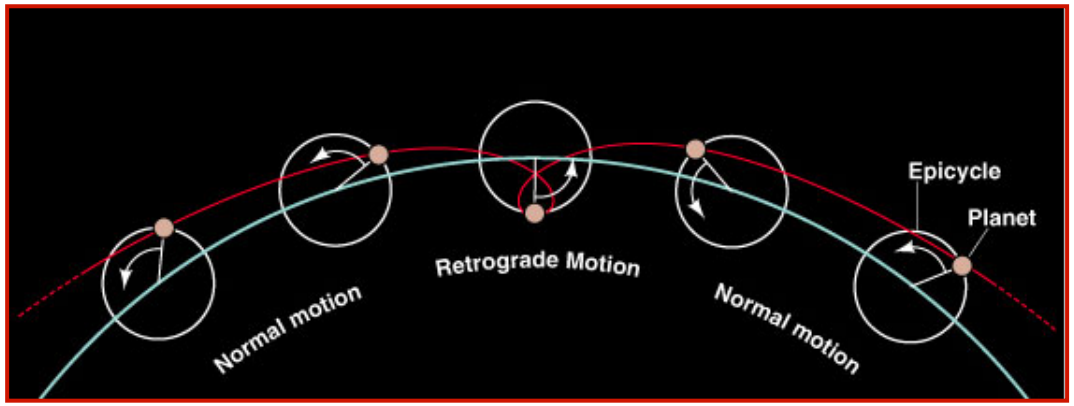
The Western History of Cosmological Thinking.

- Ptolemy (100-170 AD), The Earth-Centered Model
- It ran into trouble in predicting the positions of the planets
- Solutions: Epicycles







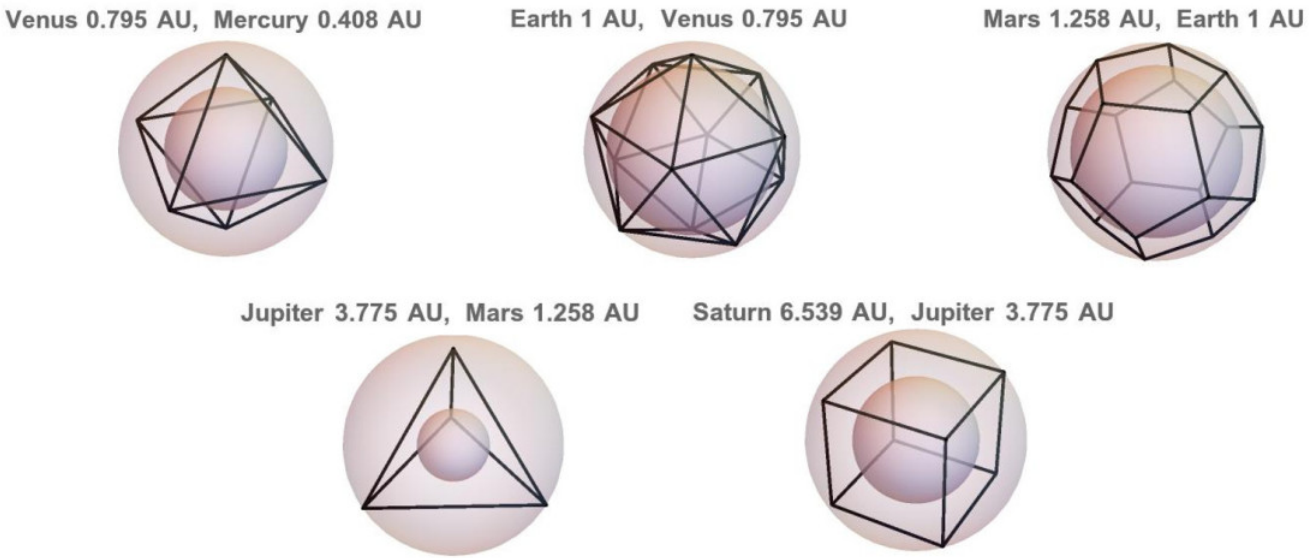


The Copernican Model (Nicolaus Copernicus (1543 AD)

- Sun-Centered Model
- It didn't do any better than Ptolemy's model! (in fact, in some cases it did worse)
- Do question (2) on the worksheet and S T O P

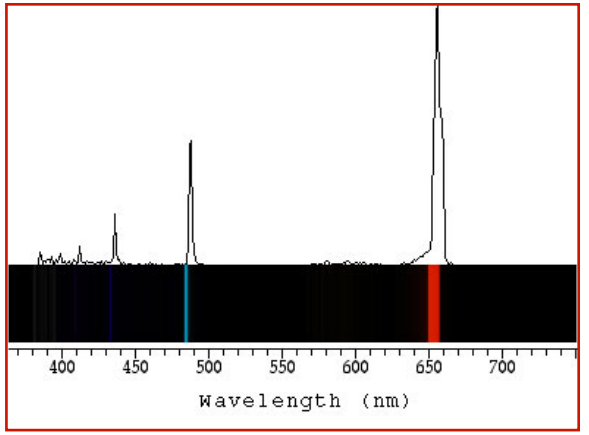
Solution—Kepler (1571—1630)

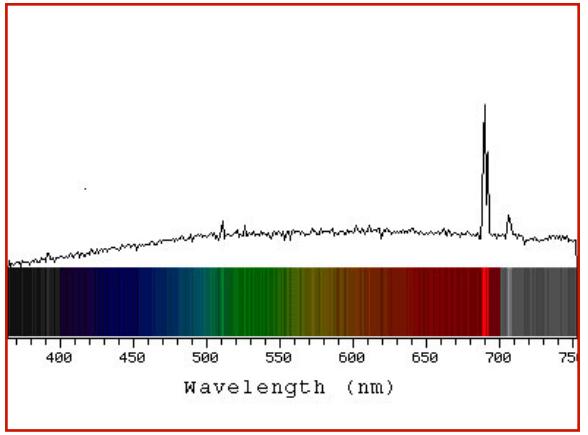
- Kepler published his ideas in, *Mysterium Cosmographicum*, in 1596. He was a mystic and his thinking is hard (for me) to follow exactly, but it went something like this.
  - the distance relationships between the six known planets could be represented by six spheres separated by the five Platonic solids
  - each planet is on a sphere, the inner sphere of a polyhedron whose outer sphere contains the next planet.
  - This, eventually leads to *elliptical,* not circular orbits.

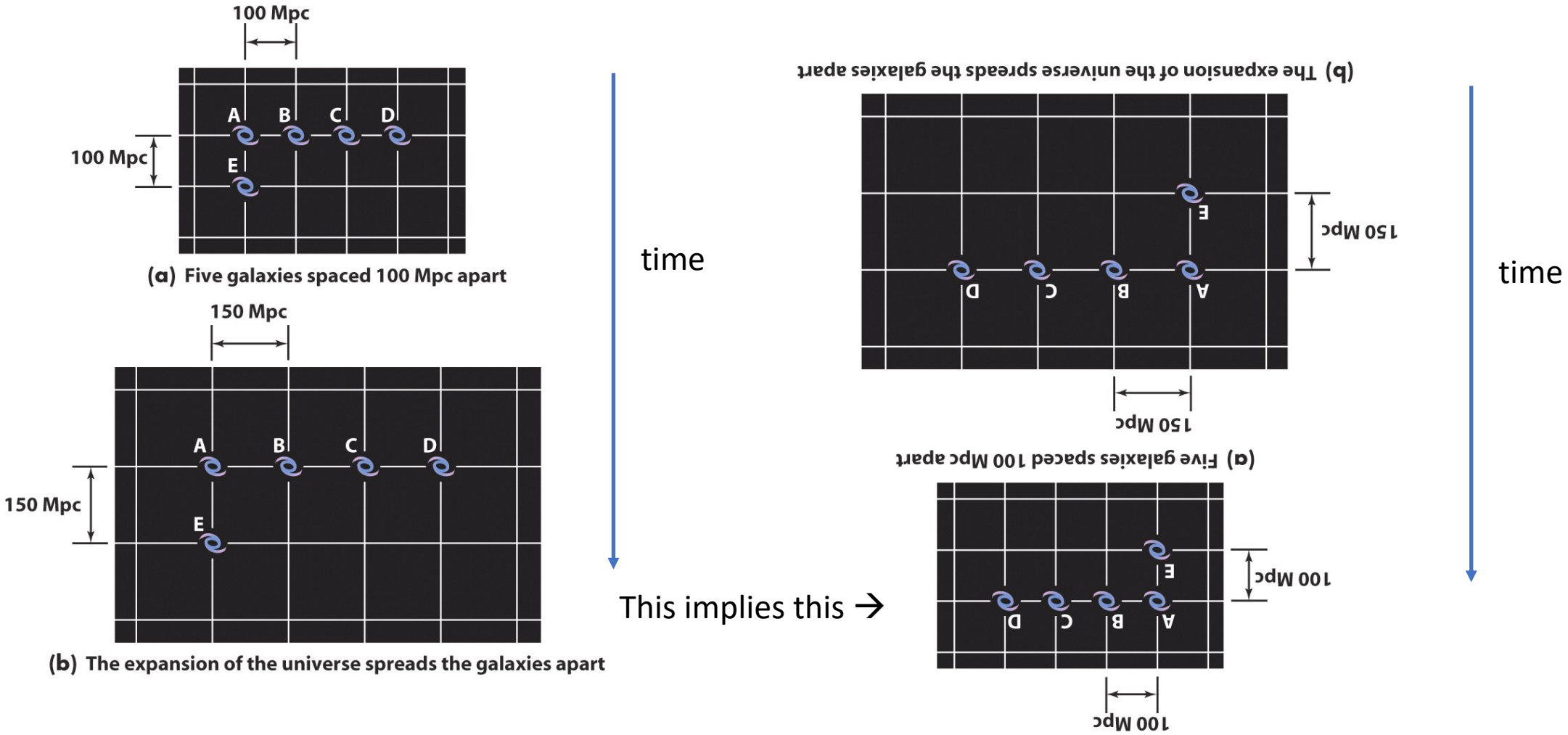


The Modern Era

- The Shapley-Curtis debate (1920)
  - Shapley believed that distant *nebulae* were relatively small and lay within the outskirts of Earth's home galaxy, while Curtis held that they were in fact independent galaxies, implying that they were exceedingly large and distant.
  - The nebulae were actually other galaxies
  - Nobody actually *won* the debate. The data were just not available.
- Edwin Hubble, Einstein, Gamow, etc.
  - Expanding Universe Cosmology



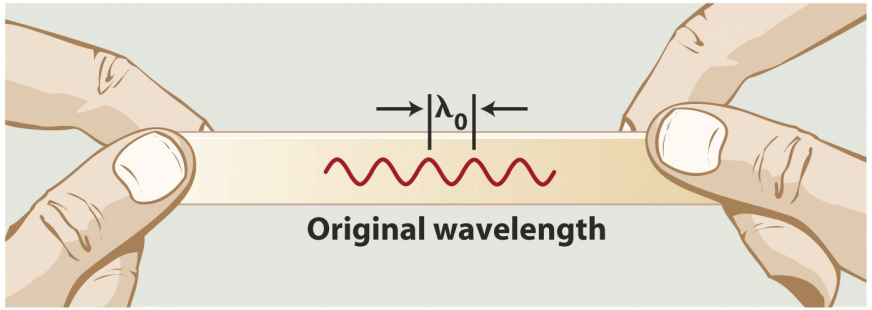




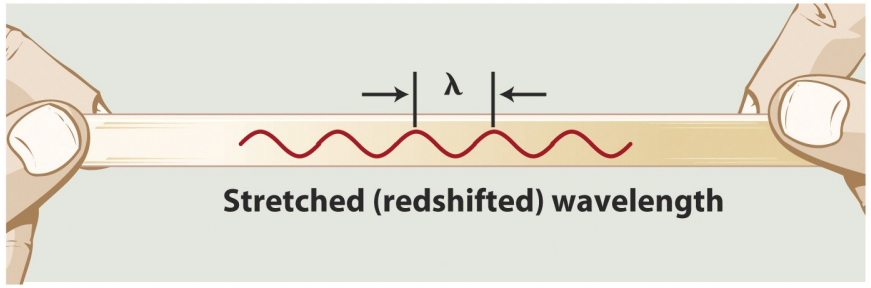
Gamow: *The universe was denser and hotter in the past.*

Evidence of this should still be seen in the universe, but now much *cooler*

Then



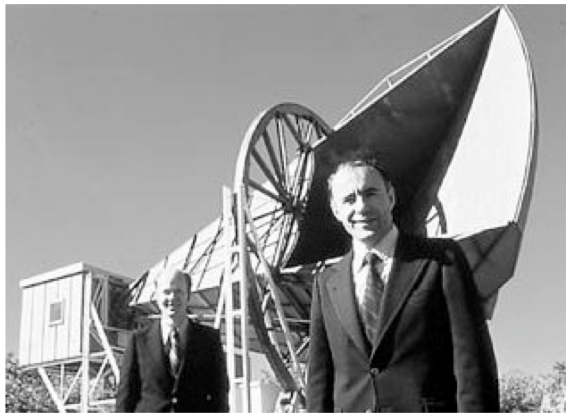
A wave drawn on a rubber band …



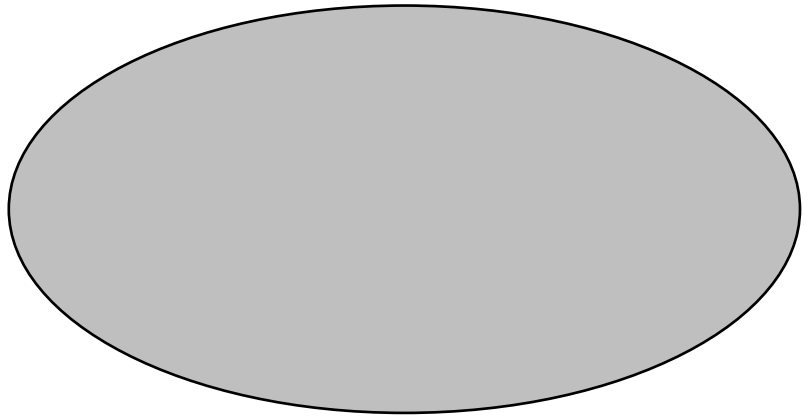
… increases in wavelength as the rubber band is stretched.

Now

Arno Penzias



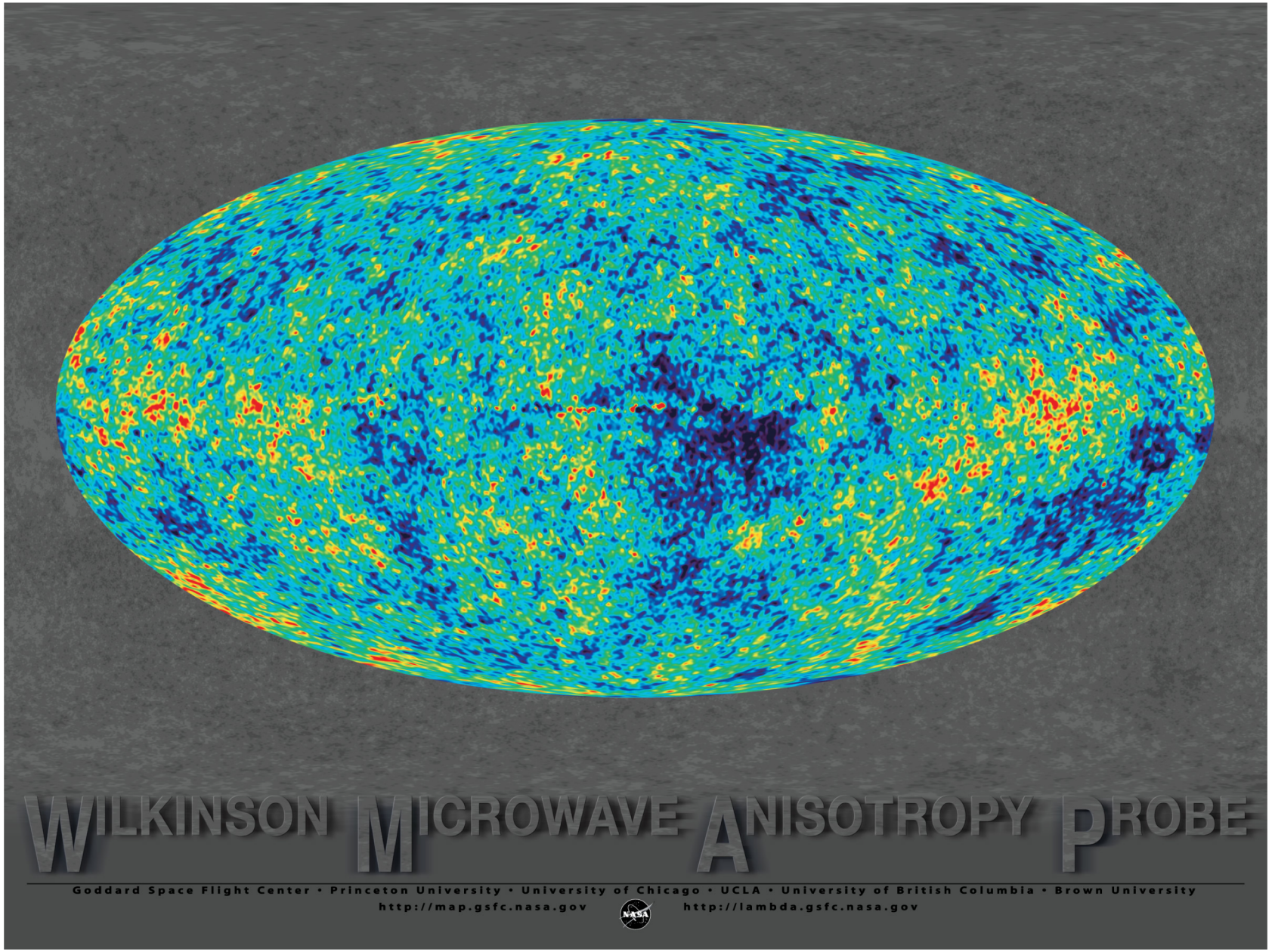
Robert Wilson



A MEASUREMENT OF EXCESS ANTENNA TEMPERATURE
AT 4080 Mc/s

Measurements of the effective zenith noise temperature of the 20-foot horn-reflector antenna (Crawford, Hogg, and Hunt 1961) at the Crawford Hill Laboratory, Holmdel, New Jersey, at 4080 Mc/s have yielded a value about 3.5° K higher than expected. This excess temperature is, within the limits of our observations, isotropic, unpolarized, and free from seasonal variations (July, 1964–April, 1965). A possible explanation for the observed excess noise temperature is the one given by Dicke, Peebles, Roll, and Wilkinson (1965) in a companion letter in this issue.

Do question (3) on worksheet and S T O P



The Astrophysical Journal, 517:565–586, 1999 June 1

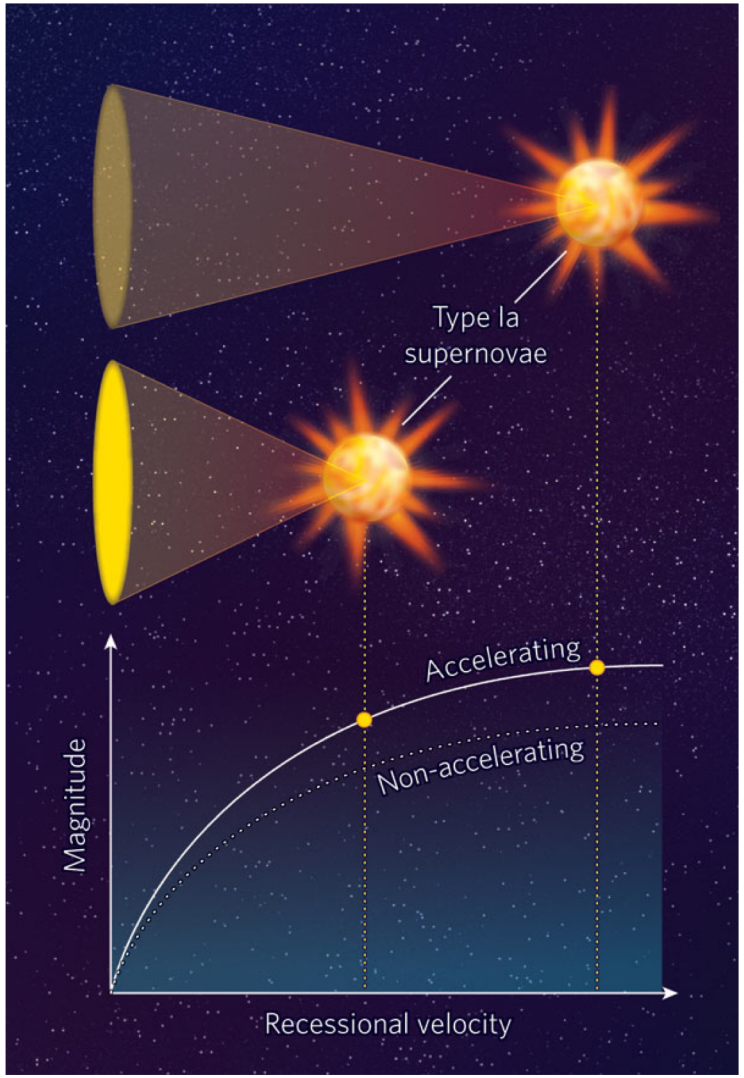
MEASUREMENTS OF Ω AND Λ FROM 42 HIGH-REDSHIFT SUPERNOVAE

S. Perlmutter,[1] G. Aldering, G. Goldhaber,[1] R. A. Knop, P. Nugent, P. G. Castro,[2] S. Deustua, S. Fabbro,[3] A. Goobar,[4] D. E. Groom, I. M. Hook,[5] A. G. Kim,[1,6] M. Y. Kim, J. C. Lee,[7] N. J. Nunes,[2] R. Pain,[3] C. R. Pennypacker,[8] and R. Quimby
Institute for Nuclear and Particle Astrophysics, E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720
C. Lidman
European Southern Observatory, La Silla, Chile
R. S. Ellis, M. Irwin, and R. G. McMahon
Institute of Astronomy, Cambridge, England, UK
P. Ruiz-Lapuente
Department of Astronomy, University of Barcelona, Barcelona, Spain
N. Walton
Isaac Newton Group, La Palma, Spain
B. Schaefer
Department of Astronomy, Yale University, New Haven, CT
B. J. Boyle
Anglo-Australian Observatory, Sydney, Australia
A. V Filippenko and T. Matheson
Department of Astronomy, University of California, Berkeley, CA
A. S. Fruchter and N. Panagia[9]
Space Telescope Science Institute, Baltimore, MD
H. J. M. Newberg
Fermi National Laboratory, Batavia, IL
and
W. J. Couch
University of New South Wales, Sydney, Australia
(The Supernova Cosmology Project)

The Astronomical Journal, 116:1009–1038, 1998 September

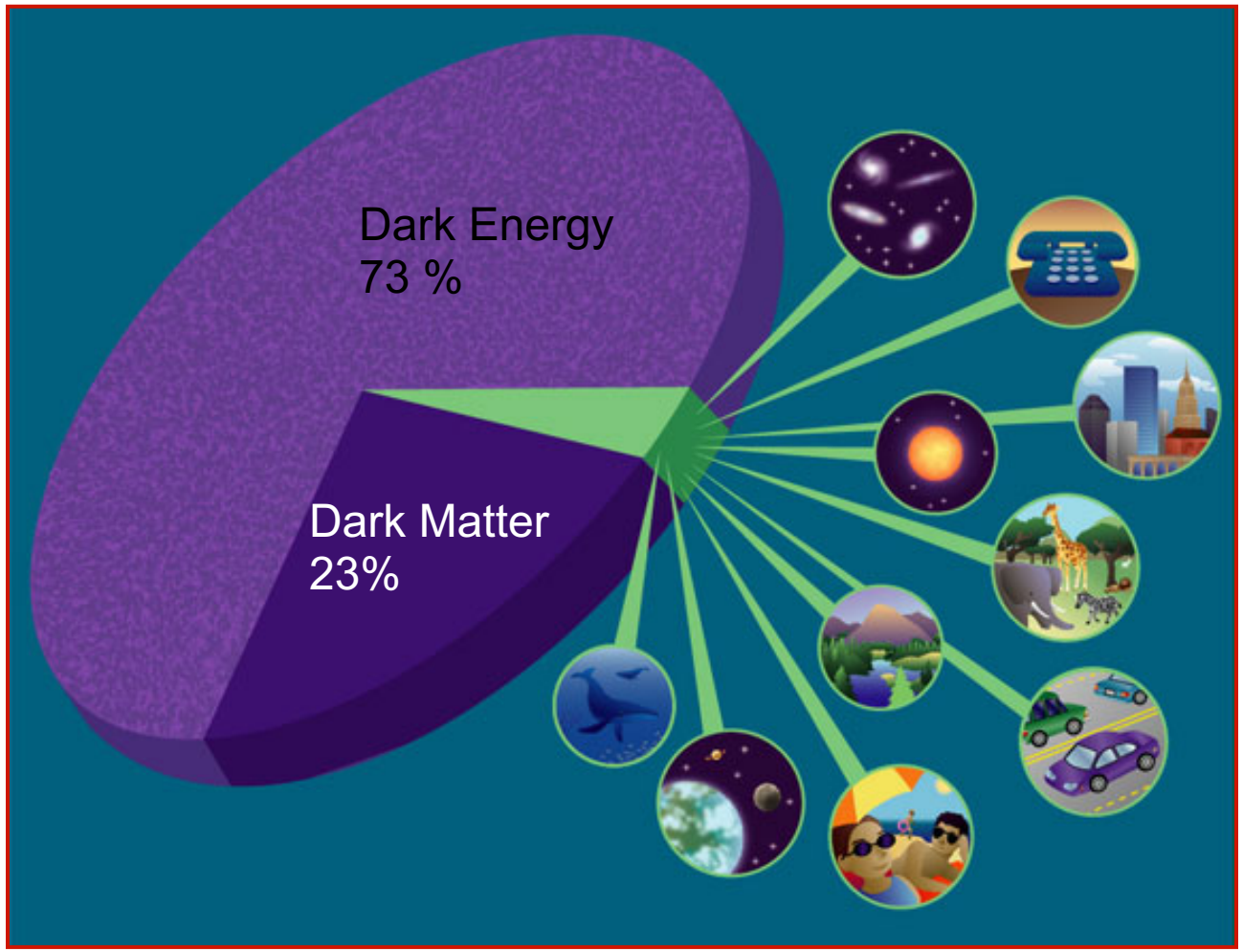
OBSERVATIONAL EVIDENCE FROM SUPERNOVAE FOR AN ACCELERATING UNIVERSE AND A COSMOLOGICAL CONSTANT

Adam G. Riess,[1] Alexei V. Filippenko,[1] Peter Challis,[2] Alejandro Clocchiatti,[3] Alan Diercks,[4] Peter M. Garnavich,[2] Ron L. Gilliland,[5] Craig J. Hogan,[4] Saurabh Jha,[2] Robert P. Kirshner,[2] B. Leibundgut,[6] M. M. Phillips,[7] David Reiss,[4] Brian P. Schmidt,[8,9] Robert A. Schommer,[7] R. Chris Smith,[7,10] J. Spyromilio,[6] Christopher Stubbs,[4] Nicholas B. Suntzeff,[7] and John Tonry[11]



Known intrinsic brightness

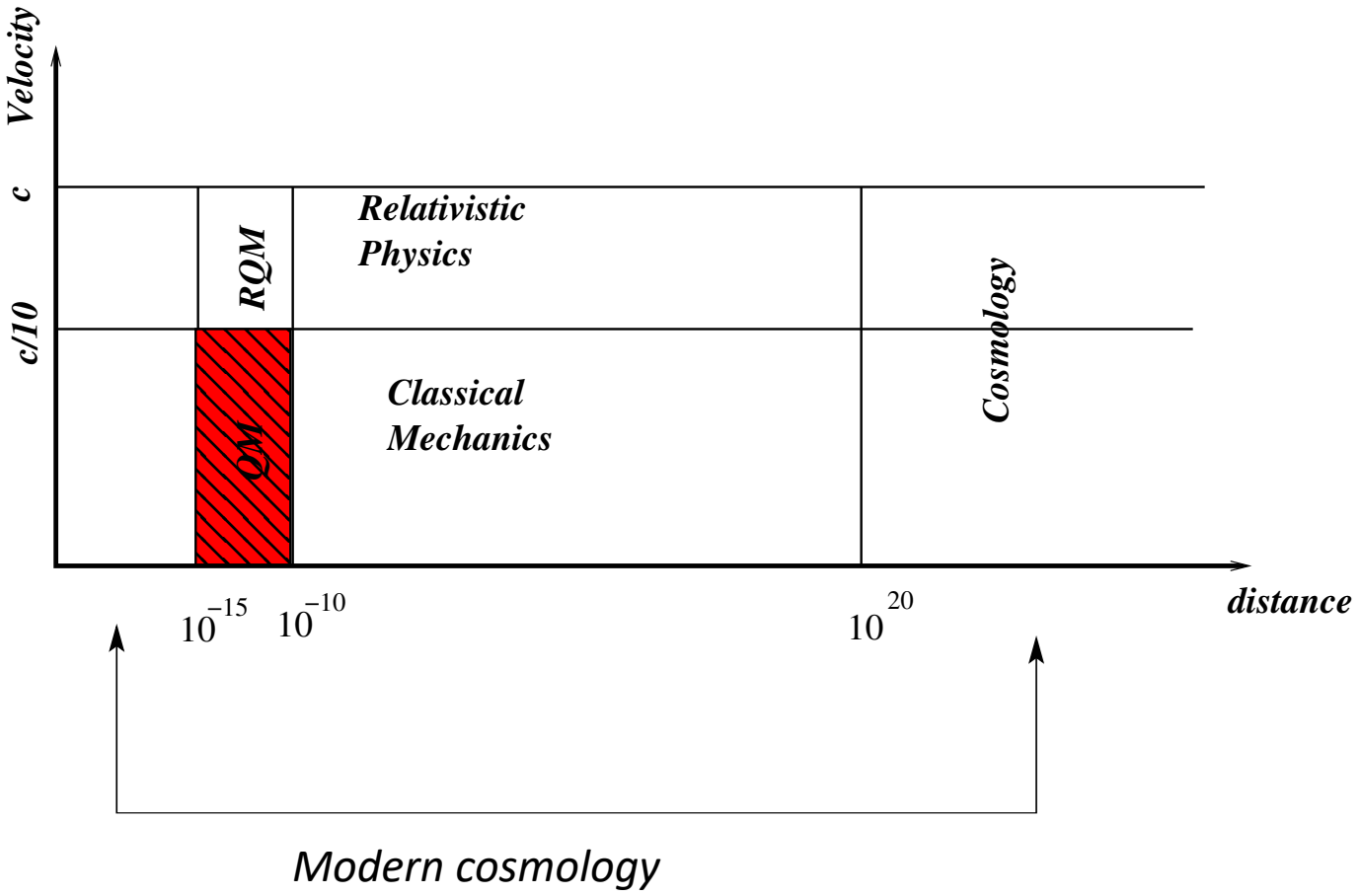
We don’t know squat!



Before we explore these observations in detail, let’s step back and ask what is it we are doing.

What is physics? Fundamentally it is putting into context the measuring of three quantities:

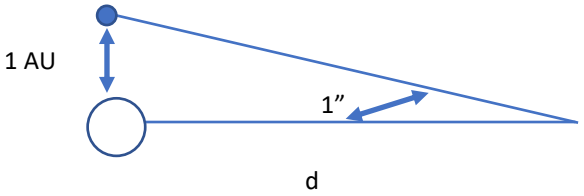
1. *Length (*or distance between objects)
2. *Time*
3. *Mass*



Units

Length:

- *Astronomical Unit (AU)* (mean distance between earth and sun (1.5 x 10^{11} meters)
- *Light year(Ly)*, the distance light travels in one year
- *Parsec (pc), when 1 AU* subtends 1 arcsecond
- *Megaparsec (Mpc)* 1 million pc (3.1 x 10^{22} m)
- Do question (4 a, b) on worksheet and S T O P



$$\tan 1'' = \frac{1\text{AU}}{d} \Rightarrow d = \frac{1\text{AU}}{\tan 1''}$$

Finish problem 4 and S T O P

Time:

- Seconds (s)
- Gyr, 10^9 years or 3.2 x 10^{16} s

Mass:

$$1M_\odot = 2.0 \times 10^{30}\ \mathrm{kg}$$

$$M_{gal} \approx 10^{12} M_\odot$$

Derived Unit: Energy

- Joules (J)
- 1 eV = 1.6 x 10^{-19} J

Temperature

- Kelvin (K)

Natural units

By using universal constants, one can construct a system of units that is more *natural* since its constructed of the 3 same constants:

- *G = 6.67 x 10^{-11}* N m^2/ kg^2
- $\hbar$ = 1.056 x 10^{-34} J s
- *c = 3.00 x 10 ^{8} m/s*

$$l_p = \left(\frac{G\hbar}{c^3}\right)^{1/2} = 1.6 \times 10^{-35}\ \mathrm{m}$$ Planck Length

$$t_p = \left(\frac{G\hbar}{c^5}\right)^{1/2} = 5.4 \times 10^{-44}\ \mathrm{s}$$ Planck Time

$$m_p \gg lp \gg t_p$$

$$m_p = \left(\frac{\hbar c}{G}\right)^{1/2} = 2.2 \times 10^{-8}\ \mathrm{kg}$$ Planck Mass

Do question (5) on the worksheet and S T O P