

AS1001: Galaxies & Cosmology

Simon Driver, Theatre B

spd3@st-andrews.ac.uk

<http://www-star.st-and.ac.uk/~spd3>

Text: Astronomy, A Physical Perspective
Chapters 17-21

Course Outline

- Galaxies (distances, components, spectra)
- Evidence for Dark Matter
- Black Holes & Quasars
- Development of Cosmology
- Hubble's Law & Expansion of the Universe
- The Hot Big Bang
- Hot Topics

But what's in the exam?

- Two questions on this course: answer one
- Descriptive & numeric parts
- All equations, except Hubble's Law, in Stars & Elementary Astrophysics
- Lecture notes contain all information needed for the exam. Use book chapters for more details, background, & problem sets
- Lectures will alternate between “numeric” and “descriptive”...

TUESDAYS: SUMS; FRIDAYS: STORIES

Lecture 1: Distances to Galaxies

- How do we measure distances to galaxies?
- Standard candles
- Use distance modulus equation
- Example questions

A brief history

- 1611: Galileo supports Copernicus

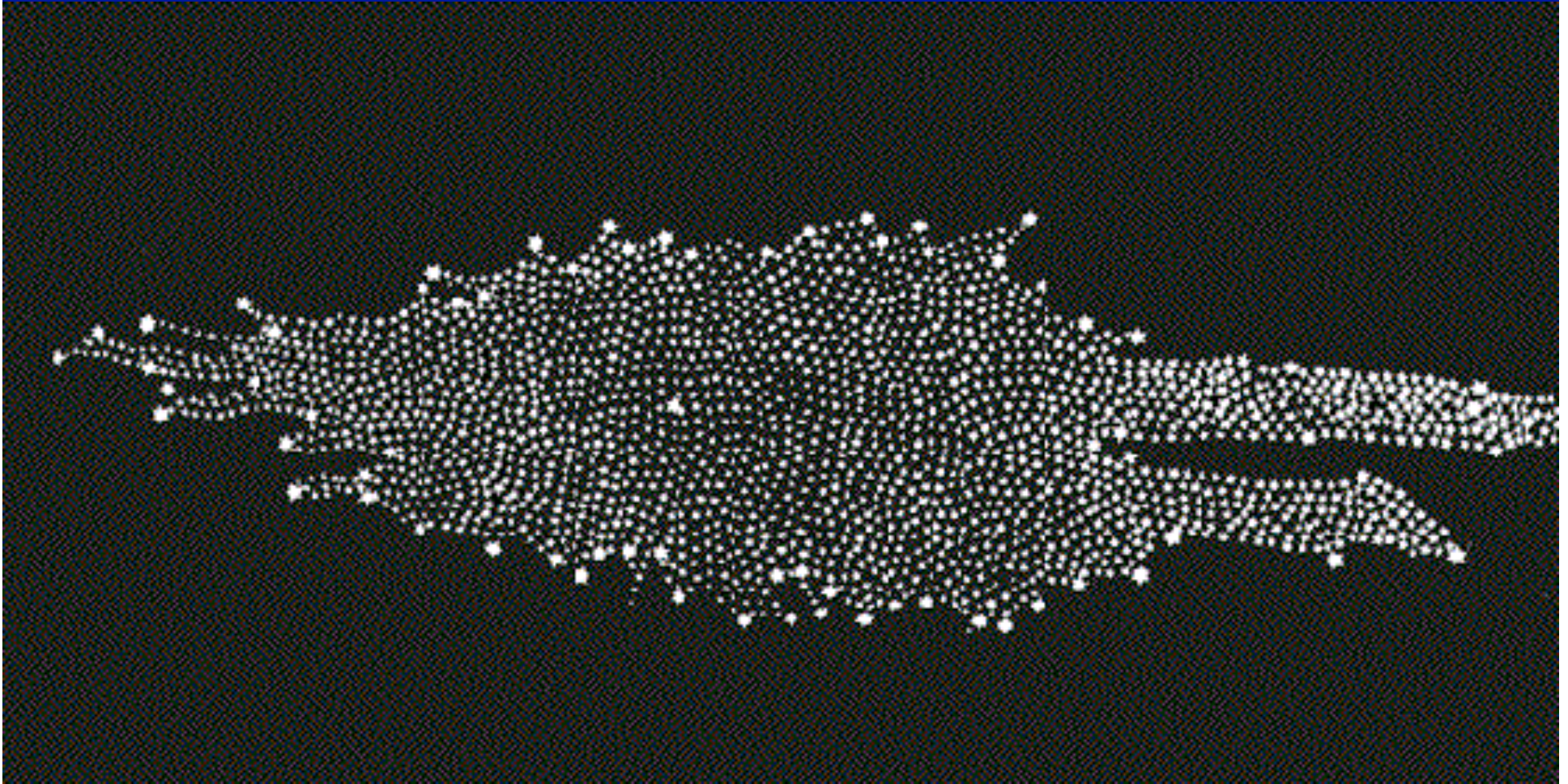
COPERNICAN COSMOLOGY BEGINS

- 1742: Maupertius identifies nebulae
- 1784: Messier catalogue established (103)
- 1864: Huggins measures first spectrum for a nebula
- 1908: Leavitt studies Cepheids in LMC
- 1924: Hubble measures distance to Andromeda via Cepheids
- 1929: Hubble discovers the expansion of the local universe
- 1929: General relativity adopted
- **MODERN ERA OF COSMOLOGY**
- 1948: Gamov predicts background radiation from “Big Bang”
- 1965: Penzias & Wilson discover Cosmic Background Radiation

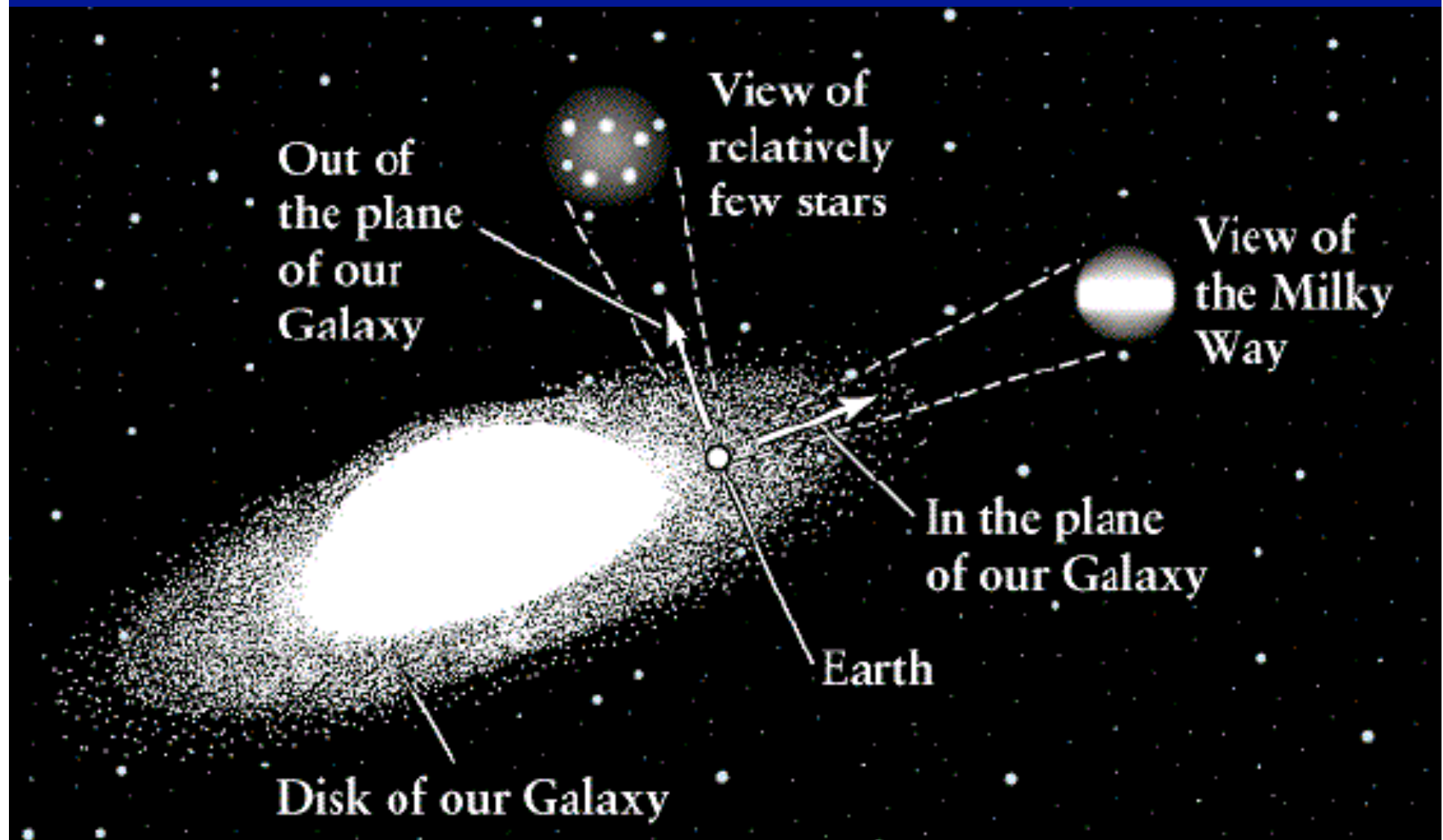
ADOPTION OF THE BIG BANG THEORY

- 1975: Computers make first Nucleosynthesis calculations
- 1985: Observations confirm predictions from Nucleosynthesis
- 1992: CMB observatories: COBE, BOOMERANG, WMAP

Herchsel's view of the Galaxy in 1860

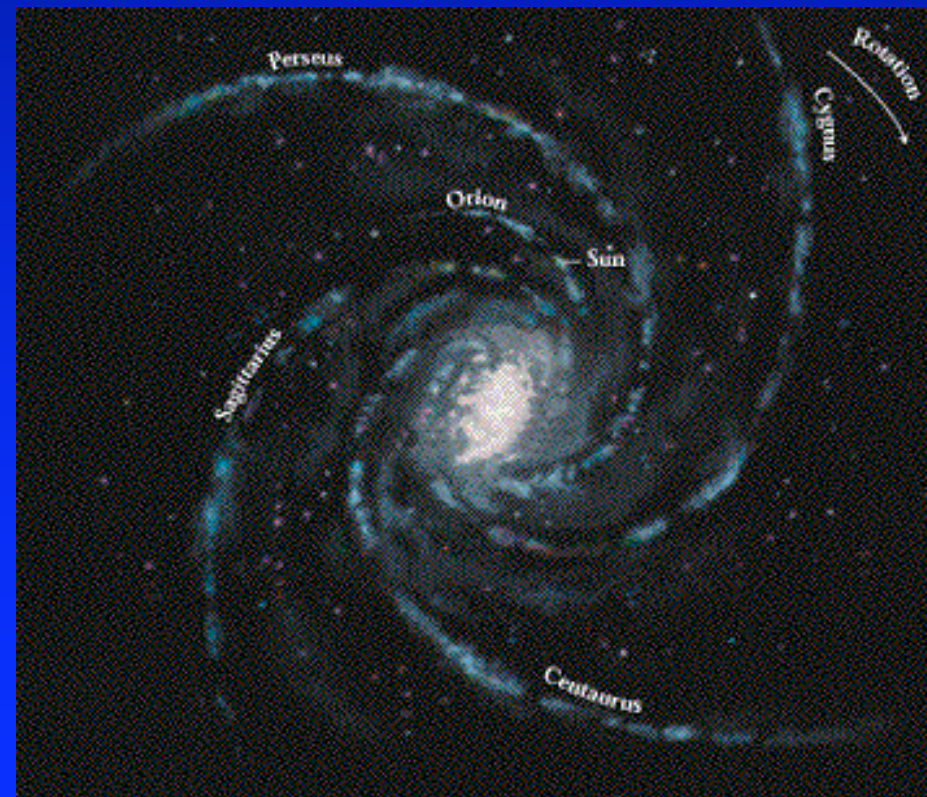
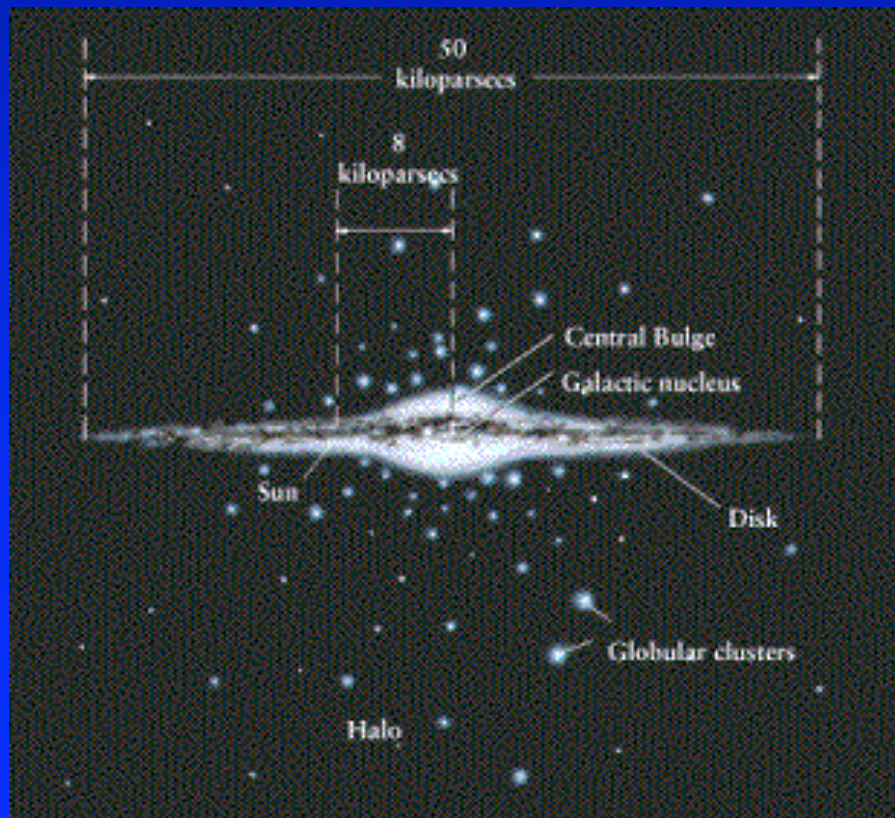


Mapping the Galaxy from the stars



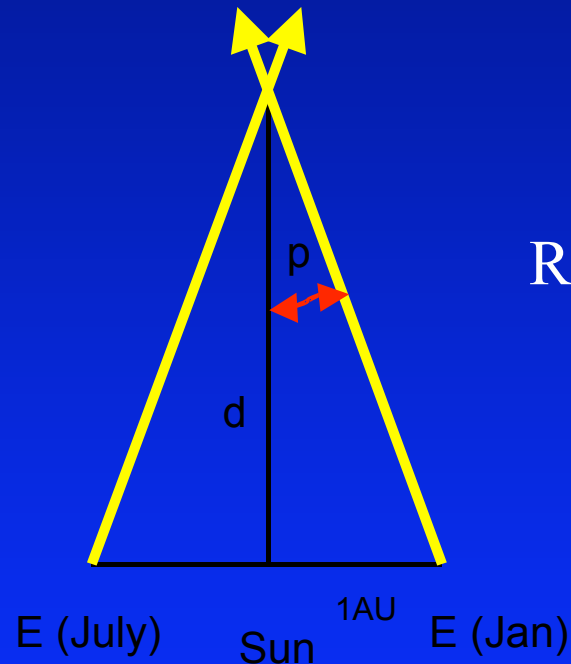
Our Galaxy

- Bulge, disk, globular clusters, spiral arms
- Diameter $\sim 50\text{kpc}$; Sun $\sim 8\text{kpc}$ from centre



Measuring Distances

- Parallax: 2 measurements, 6 months apart



$$d (\text{pc}) = 1 / p (")$$

Range: limited by atmospheric effects
100s of parsecs (*Hipparcos*)

- Extragalactic distances: angles are very small so need another measuring technique

Standard Candles

$$f = \frac{L}{4\pi d^2}$$

$$m_1 - m_2 = -2.5 \log f_1 / f_2$$

$$m = M + 5 \log_{10} d - 5$$

- Intrinsic: Luminosity (Watts), absolute magnitude
- Measure: Flux (Watts/Area), apparent magnitude
- e.g., lightbulbs of known wattage (green=100W, blue=200W, red=500W): measure flux, get distance
- Astronomy: need some object where its intrinsic luminosity can be determined...

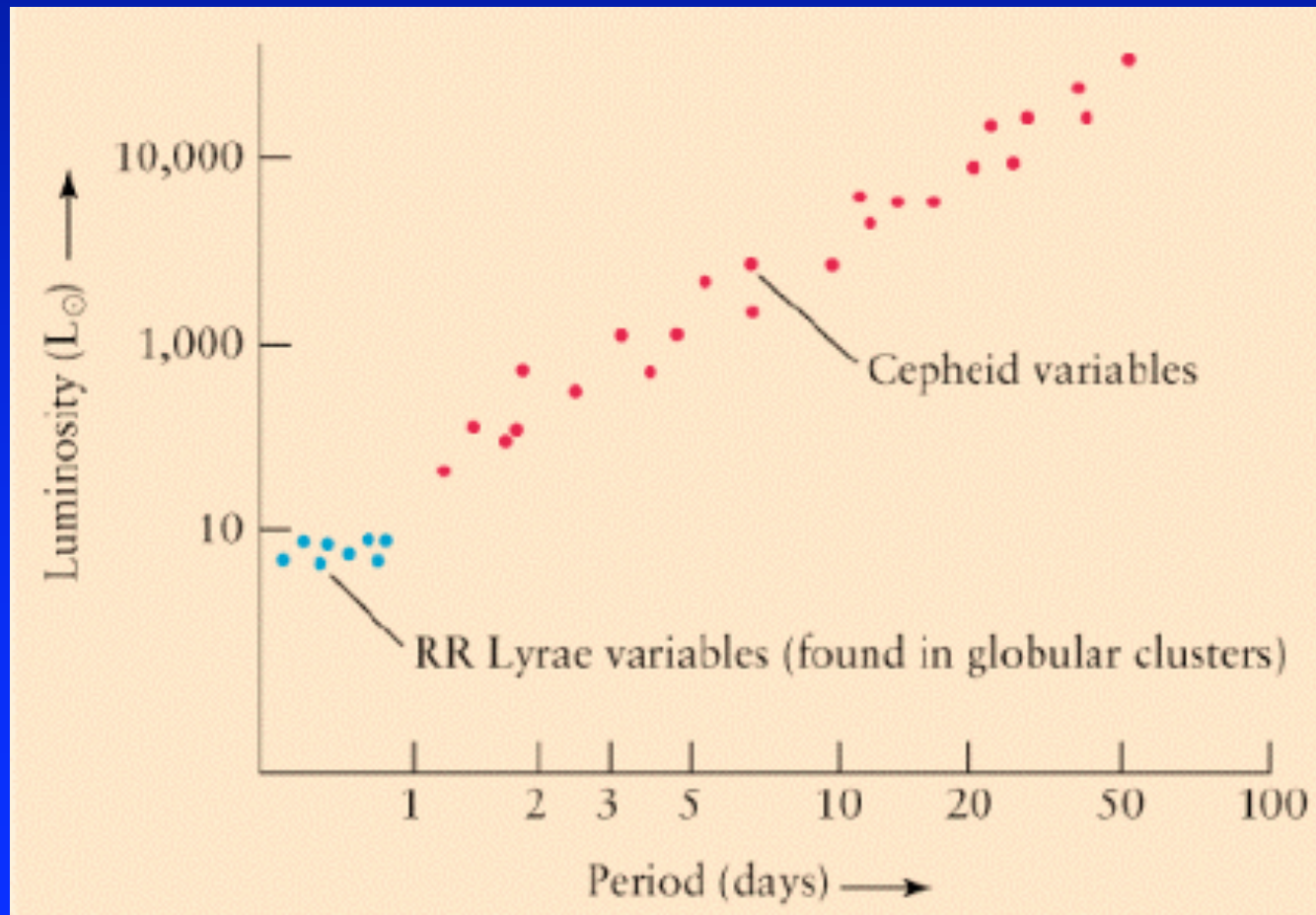
Tutorial Question 3

Use magnitude/luminosity equations and assume all stars have same luminosity and the galaxy luminosity is:

$$L_G = N_* L_*$$

The Period-Luminosity Relation for Cepheids

Henrietta Leavitt (Harvard, 1912)



Cepheid Variable Stars

- Well studied stellar objects
- Very bright ($M_v \sim -2$)
- Pulsate regularly (\sim few days)
- Pulsation period depends on luminosity
- P-L relation is calibrated within a single star cluster of known distance
- e.g. Hyades where distance is known empirically (via parallax)

Distances from Cepheids

$$\log_{10} P + 0.394M_V = -0.657$$

↑ ↑
DAYS V Abs. Mag. (From Hyades)

Once this Equation has been calibrated (as above) we can use it to measure distances to other clusters.

STRATEGY:.

- Observe a star cluster
- Find Cepheids (via light curves)
- Measure P
- Measure V app. Mag peak
- Calculate M_V
- Calculate distance ($m = M + 5\log_{10}(d) - 5$)

Andromeda: The nearest spiral



Example: Cepheid Distances

- If a Cepheid is observed to pulsate with a period of 2.5 days and has an apparent peak magnitude of 18.6 V mags, how far away is it ?

USE:

$$\log_{10} P + 0.394M_V = -0.657$$

REARRANGE:

$$M_V = \frac{-0.657 - \log_{10}(P)}{0.394}$$

GIVES:

$$M_V = -2.68 \text{ mags}$$

USE:

$$m = M + 5 \log_{10}(d) - 5$$

REARRANGE:

$$d = 10^{0.2(m-M+5)}$$

GIVES:

$$d = 0.18 \text{ Mpc}$$

The Distance to Andromeda

- Andromeda (M31) is our nearest giant galaxy. It lies 0.9Mpc away. What would be the apparent magnitude of a 3 day Cepheid ?

AS BEFORE:

$$M_V = \frac{-0.657 - \log_{10}(P)}{0.394}$$

$$M_V = -2.88 \text{ mags}$$

$$m = -2.88 + 5 \log_{10}(0.9) + 25$$

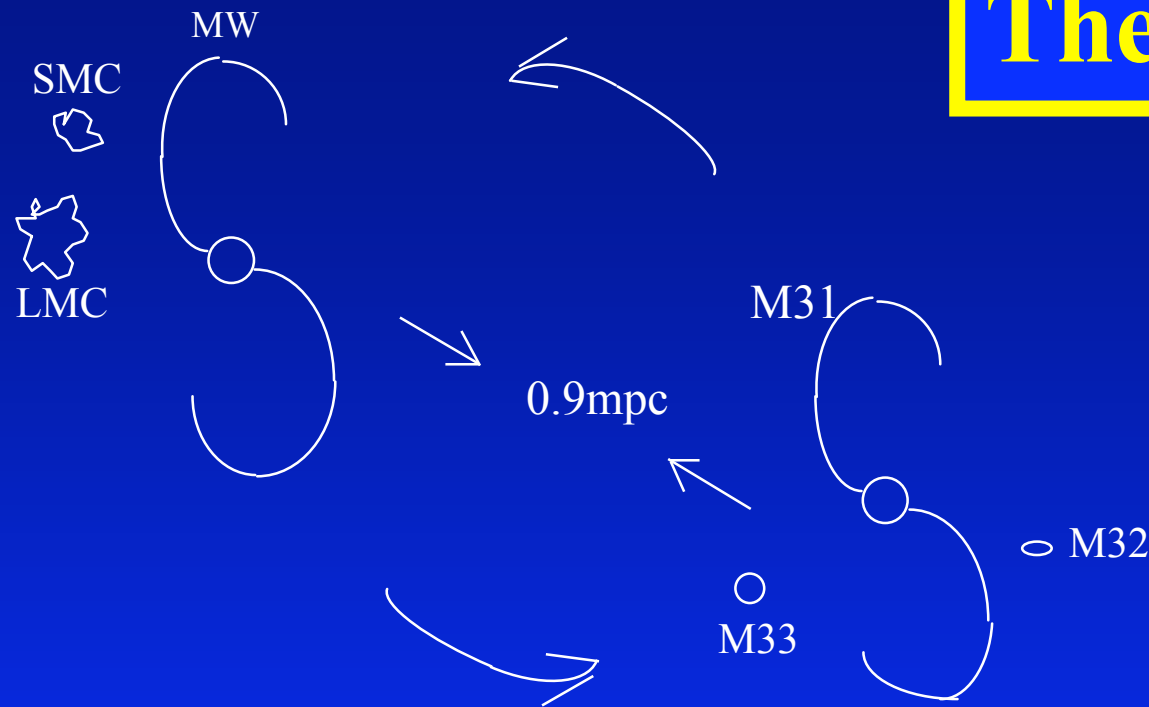
$$m = 21.9 \text{ mags}$$

**HUBBLE NEEDED A LARGE TELESCOPE:
100'' Hooker Telescope on Mt Palomar**

Local Group Trivia

- ~50 galaxies from $M_V = -21$ to $M_V = -6$ within 2Mpc radius
- New member found every ~18 months
- MW+M31 dominate the light and mass of the local group
- M31 coming towards us at about 85 km/s
- Collision in ~10 billion years
- LG will eventually merge to form one giant elliptical.
- LG is infalling into the Virgo cluster

The Local Group



2 Giant Spirals (MW and M31)

1 Compact Elliptical (M32)

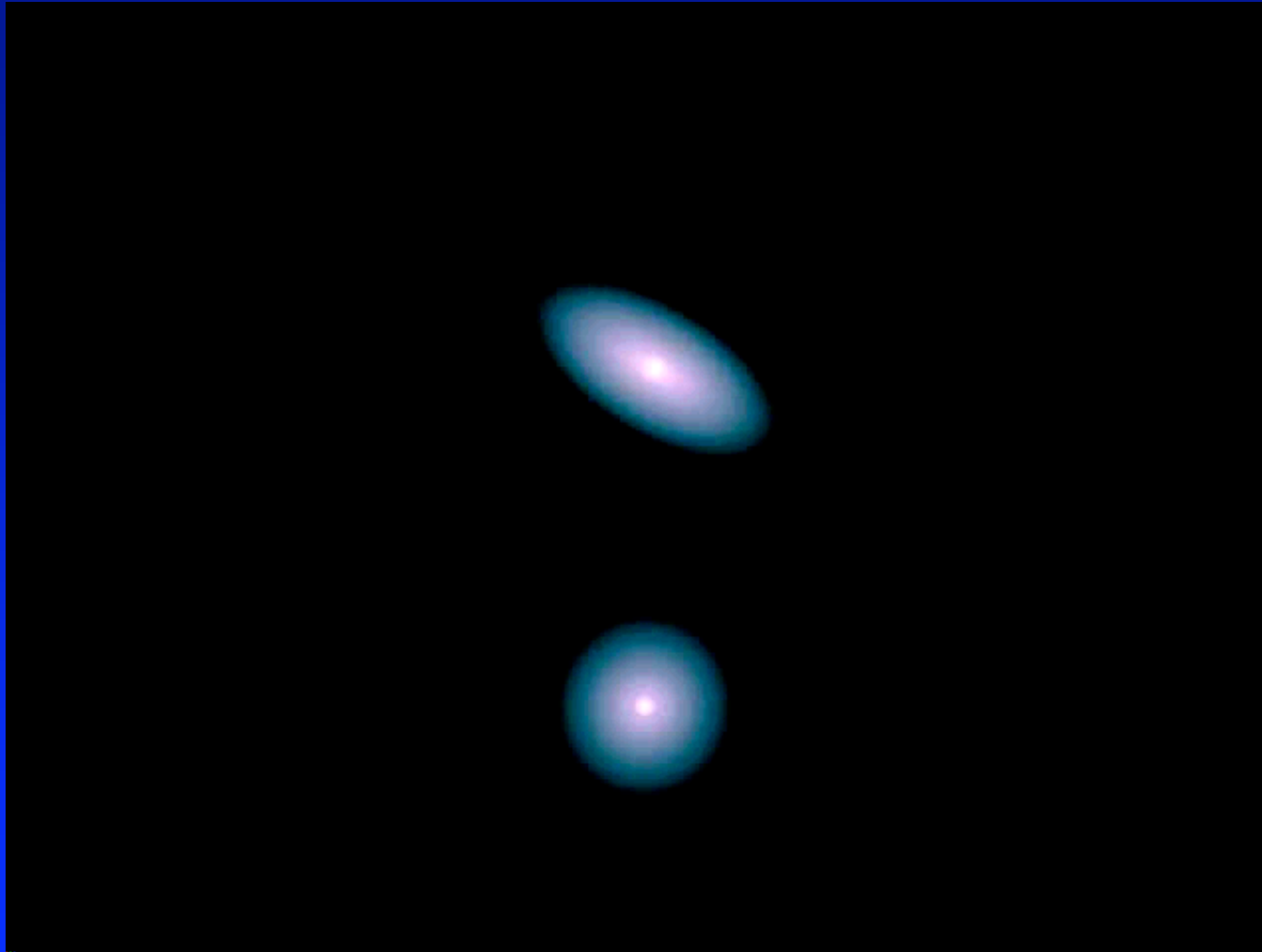
Irregulars (LMC & SMC)

47 Dwarf Ellipticals

Dwarf Irregulars

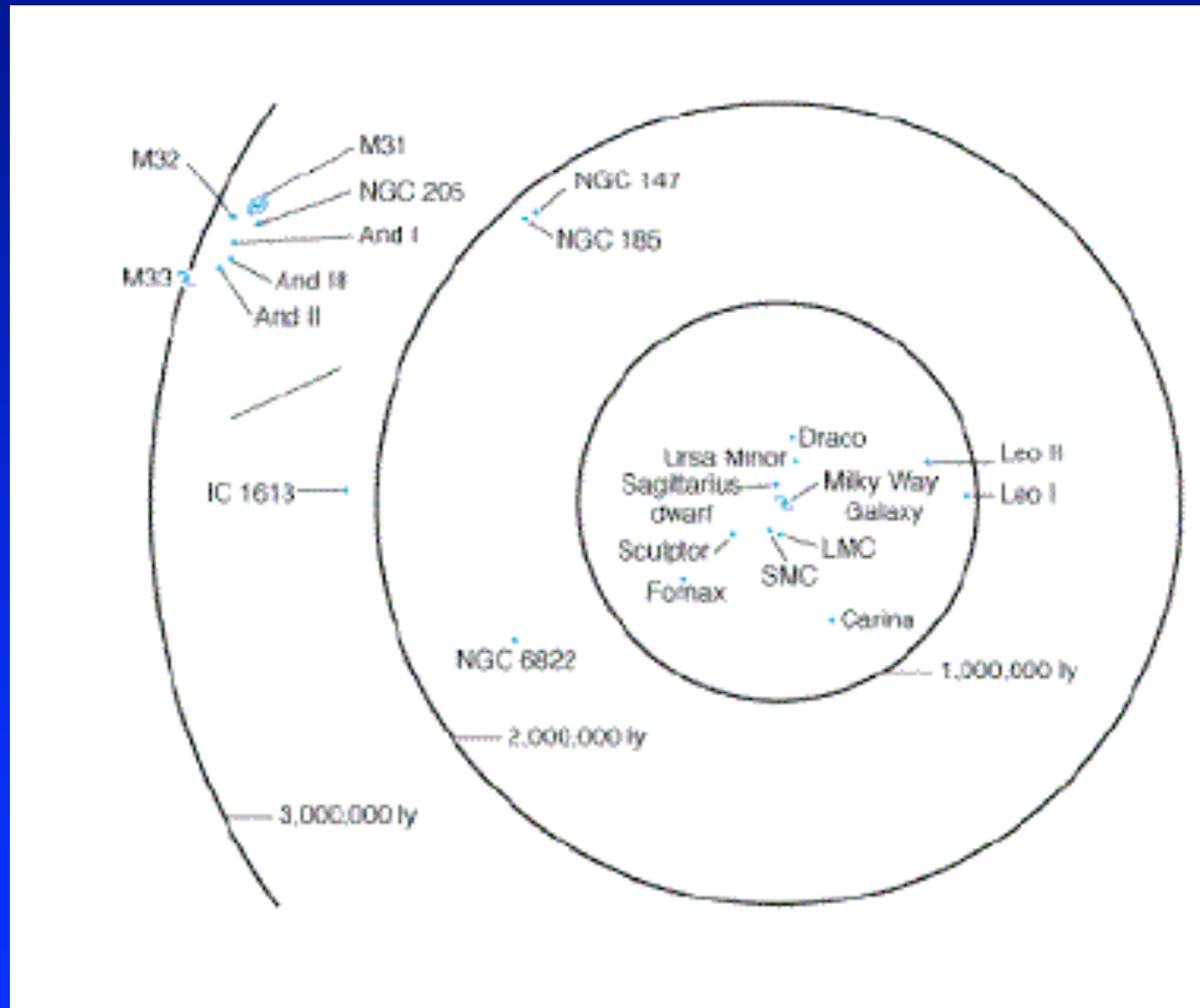
GRAVITATIONALLY
BOUND, COLLISION
INEVITABLE!

Milky Way/Andromeda Simulation



John Dubinski: www.cita.utoronto.ca/~dubinski

Layout of the Local Group



Large Scale Structure and Coma

