The Great Debate: *The Size of the Universe* (1920)

Heber Curtis

- Our Galaxy is rather small, with Sun near the center.
  - 30,000 LY diameter.
- Universe composed of many separate galaxies
  - Spiral nebulae = "island universes"

The Judges?

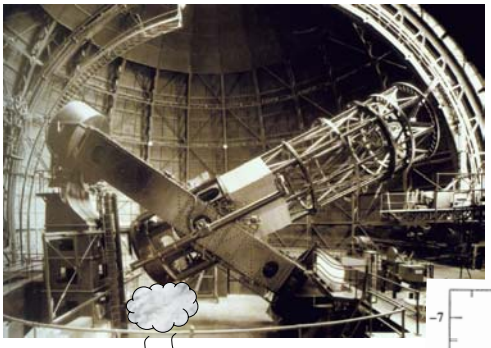
Harlow Shapley

- Our Galaxy is very large, with Sun far from center.
  - 300,000 LY diameter.
  - Sun 60,000 LY from center.
- Spiral Nebulae are inside our galaxy.
  - "nova" magnitudes
  - "Proper motion" ➔ rapid rotation.

Distances:
- Brightest stars, novae $F = \frac{L}{4\pi r^2}$
- Proper motions

Astronomy in 1926

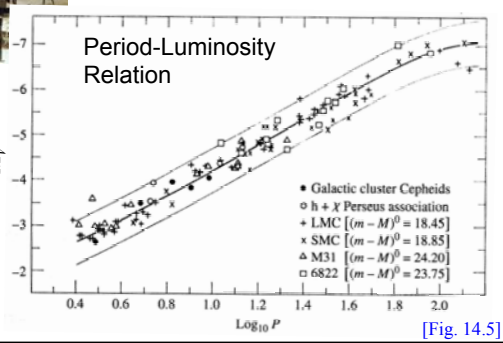
100 inch telescope
Completed 1918



Edwin Hubble

- ~1770: Messier catalogue
- 1888: NGC, IC catalogues
- 1916: Van Maanen's results
- 1920: Curtis-Shapley debate
- 1923: Hubble measured distance to M31
  - Pulsating variables

$$\langle F \rangle = \frac{\langle L \rangle}{4\pi r^2}$$



[Fig. 14.5]

Astronomy in 1926

100 inch telescope
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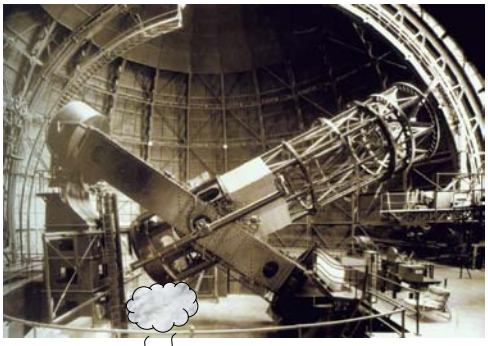

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- ~1770: Messier catalogue
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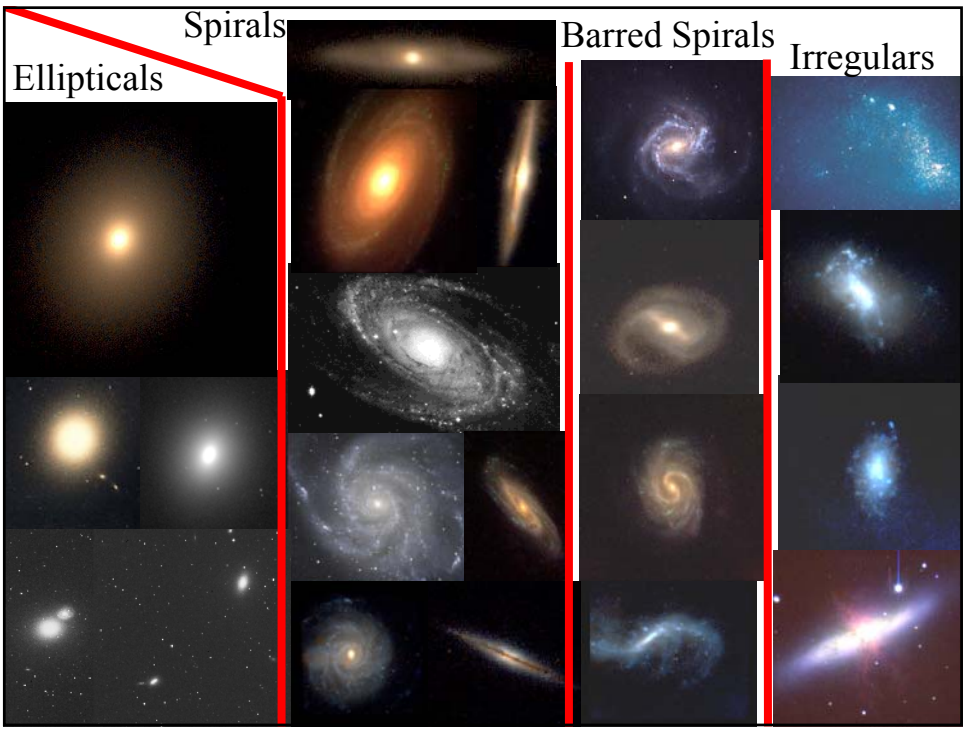
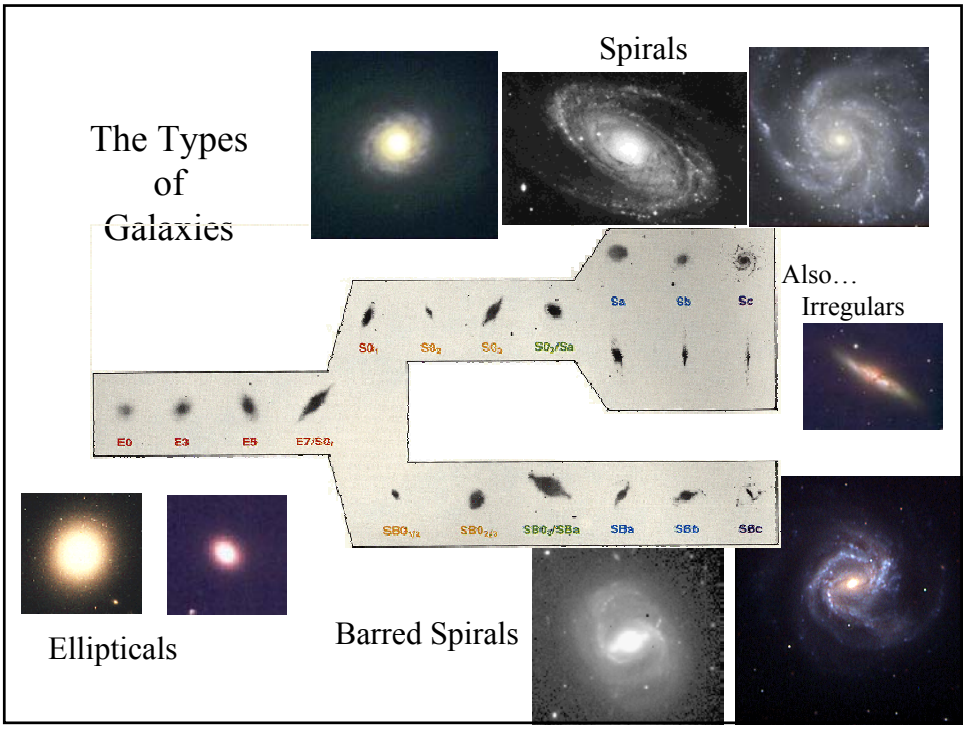
- 1926: Hubble's E, S, I galaxy classification scheme.
- 1929 Expanding Universe
- 1936: *Realm of the Nebulae* described Hubble classification system.





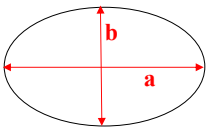
Usual classes used at current time:

- E0-E7
- S0, Sa, Sab, Sb, Sbc, Sc, Scd, Sd, Sdm, Sm, Im, Ir (or amorphous)
- SB0, SBa, SBab, SBb, SBbc, SBc, SBcd, SBd, SBdm, SBm

General Properties of Galaxy Types

- **E**
  - Luminosity (B) = 10^5 – $10^{12}\ L_\odot$
    M_B = -15 to -25
  - Mass = 10^7 – $10^{14}\ M_\odot$
  - Luminous dia. <1 kpc – hundreds of kpc
- **S**
  - $L = 10^8$ – $10^{11}\ L_\odot$
    M_B = -16 to -23
  - Mass = 10^9 – $10^{12}\ M_\odot$
  - Luminous dia. 5-100 kpc
- **Irr**
  - $L = 10^7$ – $10^{10}\ L_\odot$
    M_B = -13 to -20
  - Mass = 10^8 – $10^{10}\ M_\odot$
  - Luminous dia. 1–10 kpc

E0➔E7
10*(1-b/a)



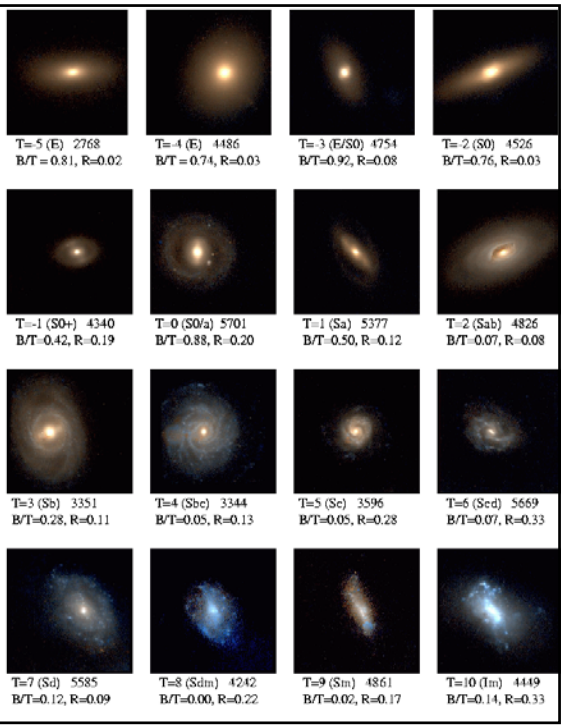
Sa➔Sc
- Bulge:disk ratio
- Tightness of winding
- Resolution of arms into star clusters & H II regions.

LMC (Irr I, SBm) SMC (Irr I, Im) M82 (Irr II, Ir)

Morphological Types of Local Galaxies

(images taken from Frei, Guhathakurta, Gunn & Tyson 1996, AJ, 111, 174)

A jpeg of this picture is on the course web site.



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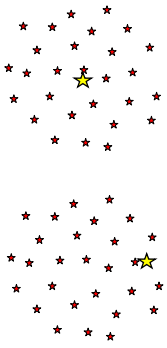
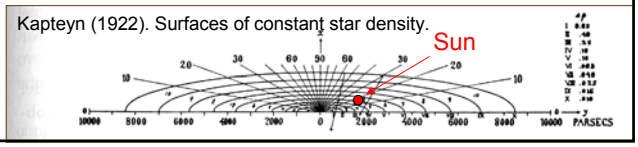
Mapping our Galaxy up until ~1920

Counting Stars:



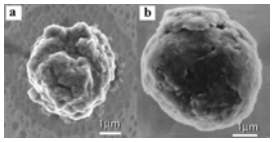
Lick 36" Refractor 1888

Sun near center of small universe.



Dust [12.1]

- Tiny grains (≤ 1μm)

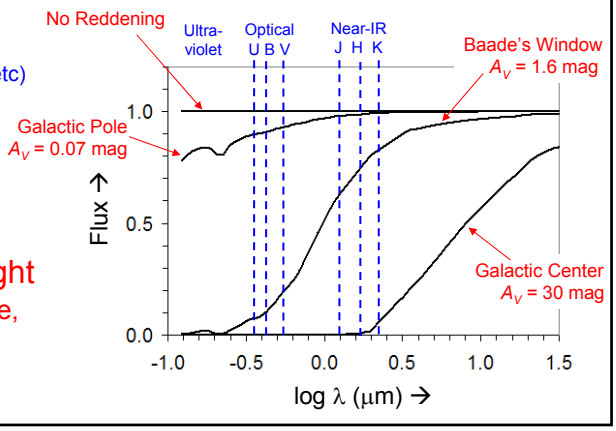


- Cores consisting of
  - Graphite
  - or Silicates

($Mg_xFe_{1-x}SiO_3$; $Mg_{2x}Fe_{2-2x}SiO_4$; etc)

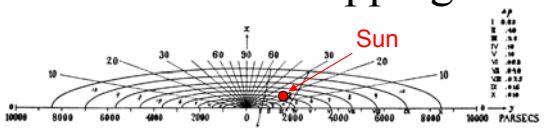
- Ices can condense on surface:
  - C,O combined with H

- Absorb and scatter light
  - Effect strongest in blue,
  - less in red,
  - zero in radio.

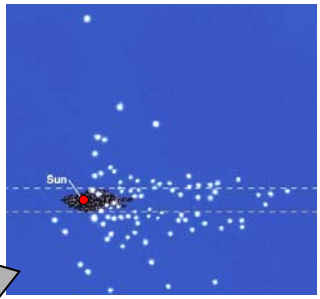


Mapping Our Galaxy

From star counts:



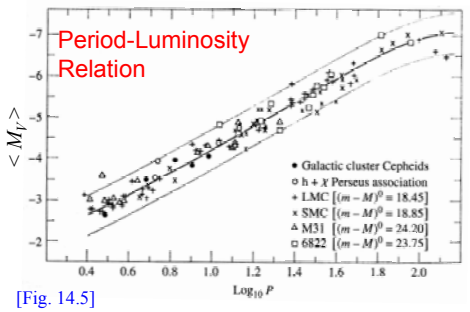
Kapteyn (1922). Surfaces of constant star density.



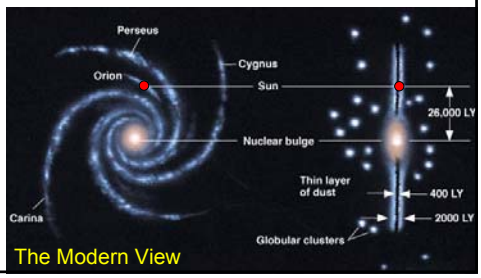
Shapley (1920) Globular Clusters
(distances using RR-Lyraes)

From distribution of Globular Clusters:

- Use pulsating variables to find clusters' distances.
- Clusters are out of MW disk ➔ little reddening.



[Fig. 14.5]



The Modern View