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

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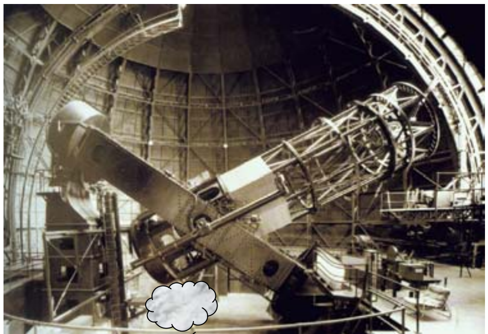
Astronomy in 1926



100 inch telescope
Completed 1918

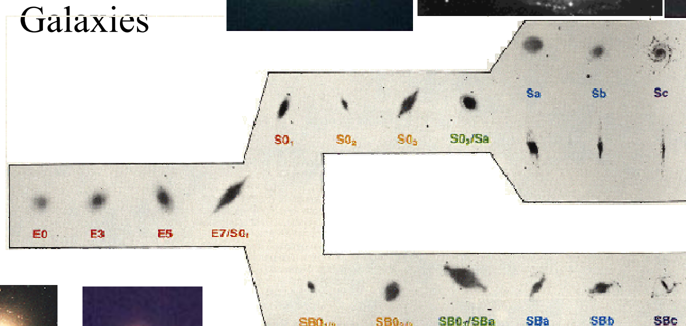
Edwin Hubble

- ~1770: Messier catalogue
- 1888: NGC, IC catalogues
- Van Maanen's "contribution"
- 1920: Curtis-Shapley debate
- 1923: Hubble measured distance to M31
- 1926: Hubble's E, S, I galaxy classification scheme.

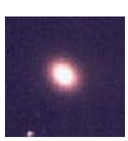
- 1929 Expanding Universe
- 1936: *Realm of the Nebulae* described Hubble classification system.

The Types of Galaxies

Spirals

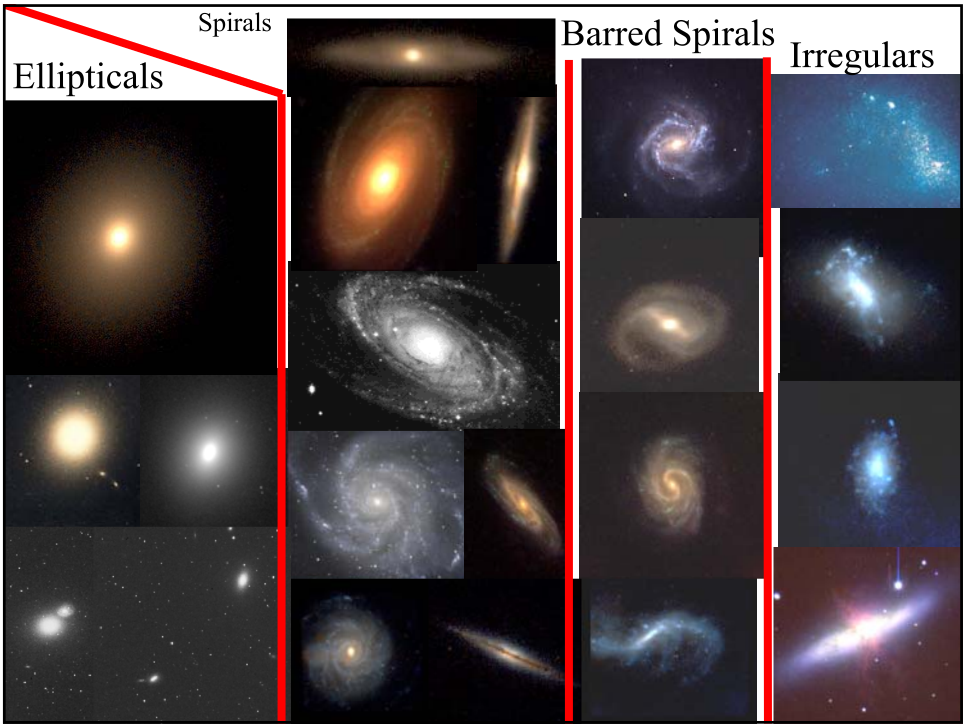


Also…
Irregulars



Ellipticals

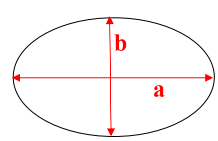
Barred Spirals



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

E0➔E7
10*(1-b/a)

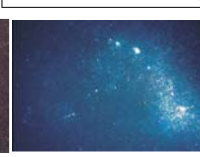


General Properties of Galaxy Types

- **E**
  - M_B = -8 to less than –23
  - Mass = $10^7 – 10^{13}\ M_\odot$
  - diameters <1 kpc – hundreds of kpc
- **S**
  - M_B = -16 to –23
  - Mass = $10^9 – 10^{12}\ M_\odot$
  - luminous diameters 5-100 kpc
- **Irr**
  - M_B = -13 to –20
  - Mass = $10^8 – 10^{10}\ M_\odot$
  - luminous diameters 1–10 kpc

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

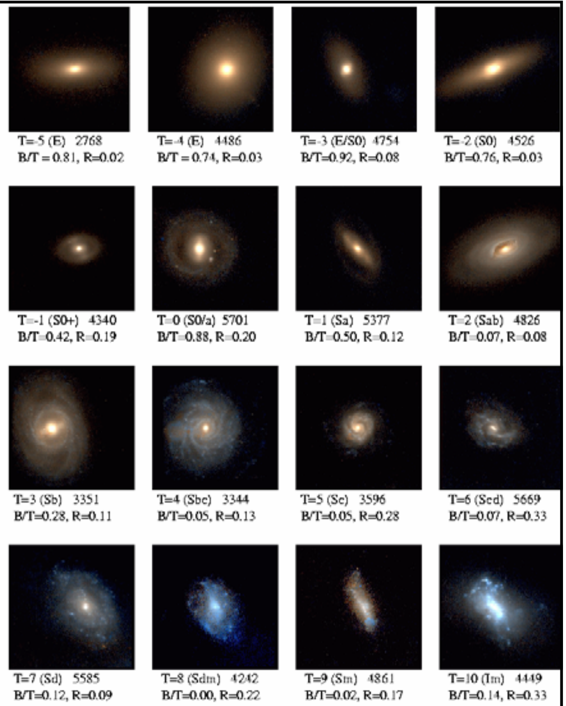

LMC (Irr I, SBm)

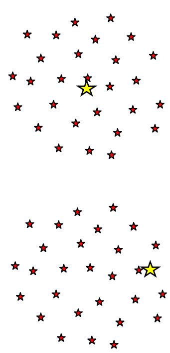

SMC (Irr I, Im)


M82 (Irr II, Ir)

Morphological Types of Local Galaxies

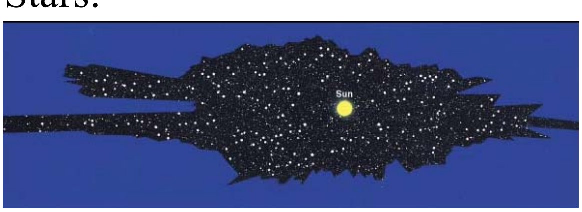
(images taken from Frei, Guhathakurta, Gunn & Tyson 1996)





Mapping our Galaxy up until ~1920

Counting Stars:



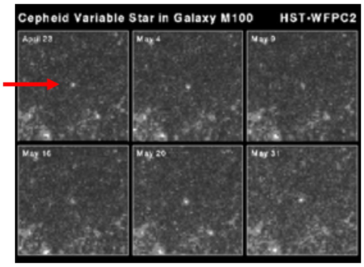
Sun near center of small universe.

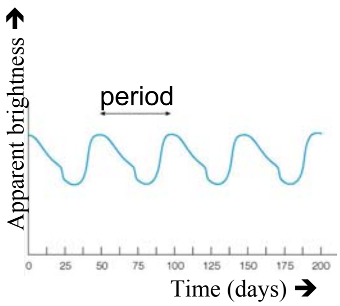
(Herschel, 1784 ➔ Kapteyn, early 1900's)

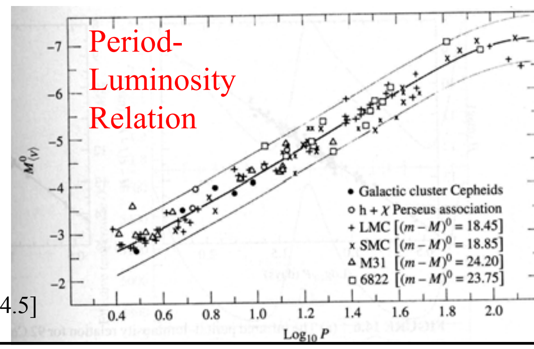
Lick 36" Refractor 1888

Pulsating Variable Stars

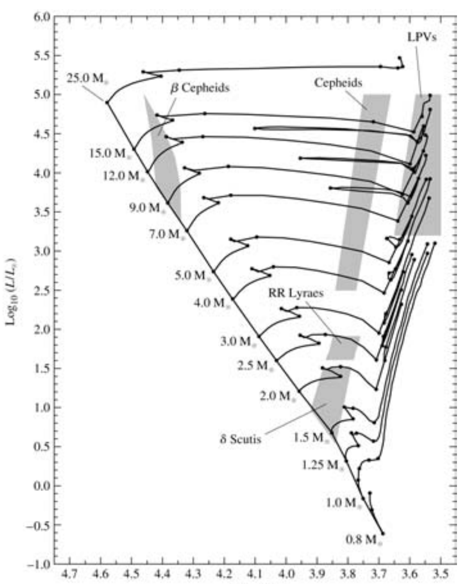
- These stars regularly expand & contract.
- Like a big spring.
- Change in size ➔
  - change in temperature
  - change in luminosity

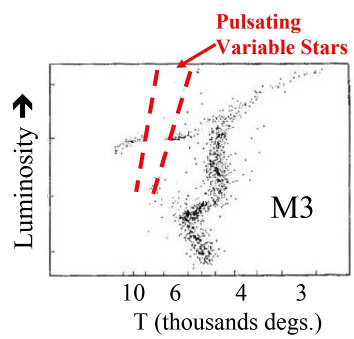






[Fig. 14.5]

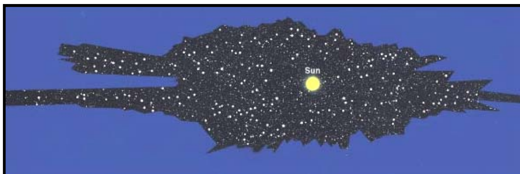




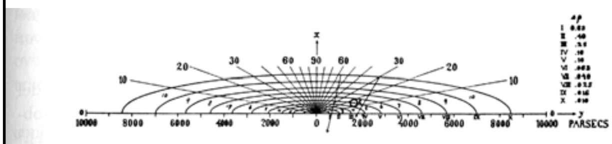
The Instability Strip

- In populations of old stars.
- For example, Globular Clusters
- Occurs during He burning

Mapping Our Galaxy



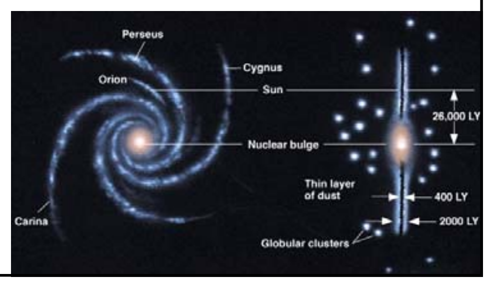
Herschel (1784)



Kapteyn (1922). Surfaces of constant star density.

From star counts

Shapley (1920)
RR-Lyraes in Globular Clusters



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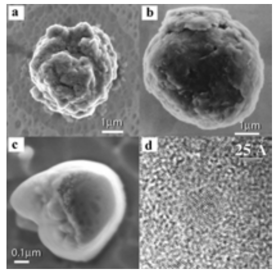
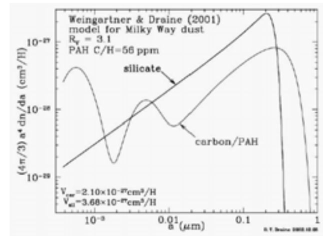
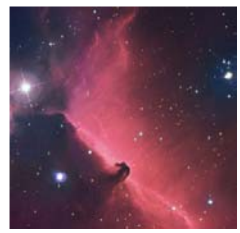
Dust [12.1]

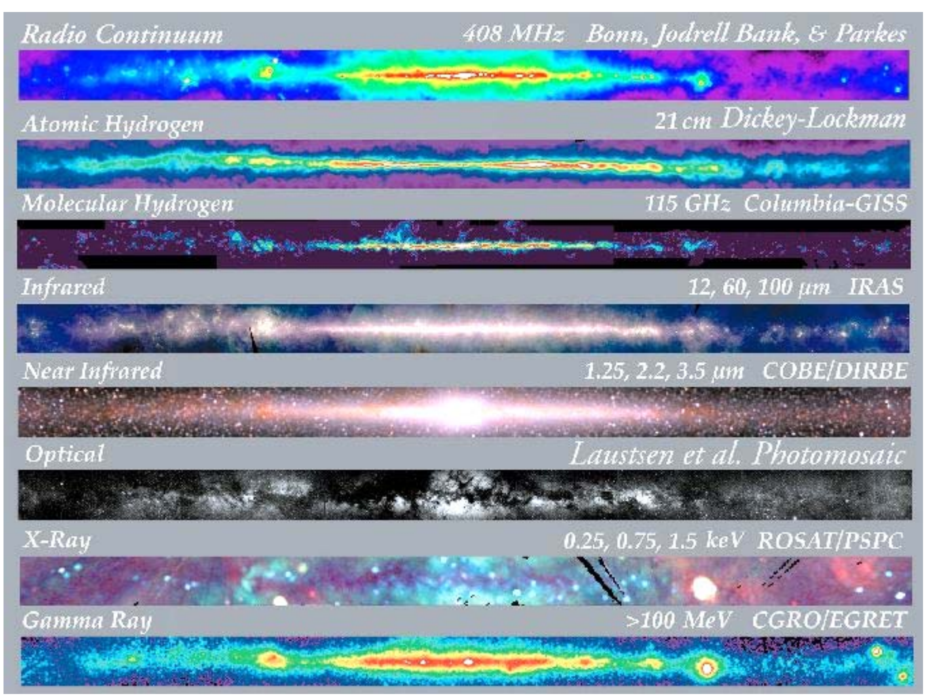




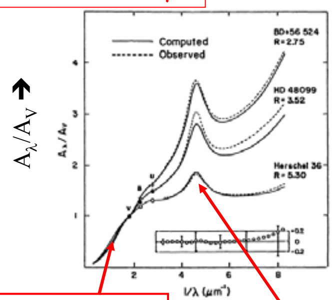
Model size distribution
(Draine 2003, ARA&A, 41, 241)

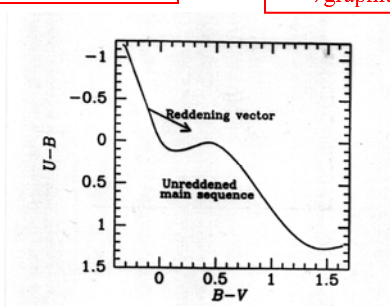
- Tiny grains
  - $\leq 1\mu m$
- Cores consisting of
  - Graphite
    or
  - Silicates ($Mg_xFe_{1-x}SiO_3$; $Mg_{2x}Fe_{2-2x}SiO_4$; etc)
- Ices can condense on surface: molecules of most common elements after hydrogen and helium
  - C,O combined with H
- Depletion of C, O, Fe, Si
- Absorb and scatter light
  - Effect strongest in blue, less in red.
  - We cannot see very far through disk of galaxy except at infrared, and (better yet) radio wavelengths.





Particle size ~ 0.01 – 0.1 μm





$$I_\lambda = I_{o,\lambda}\, e^{-\tau_\lambda}$$

in magnitudes

$$A_\lambda = -2.5 \log_{10}(I_\lambda / I_{o,\lambda})$$

$$= -2.5 \log_{10} e^{-\tau_\lambda}$$

$$= 1.08\, \tau_\lambda$$

Determine τ_λ from change in color

$$A_V = R_V \cdot E(B-V)$$

$$E(B-V) = (B-V) - (B-V)_o$$

$R_V \sim 3$ but different in different places.