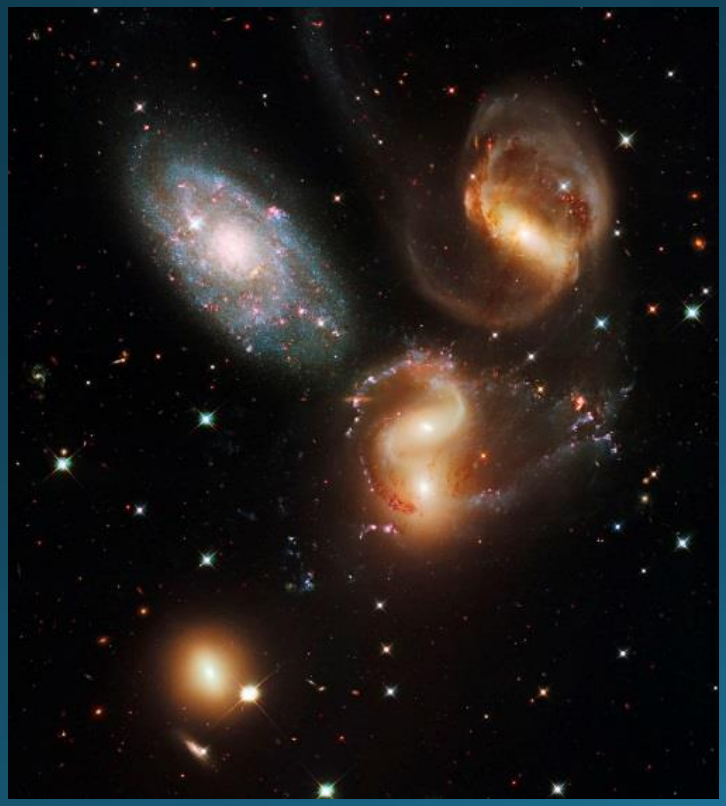
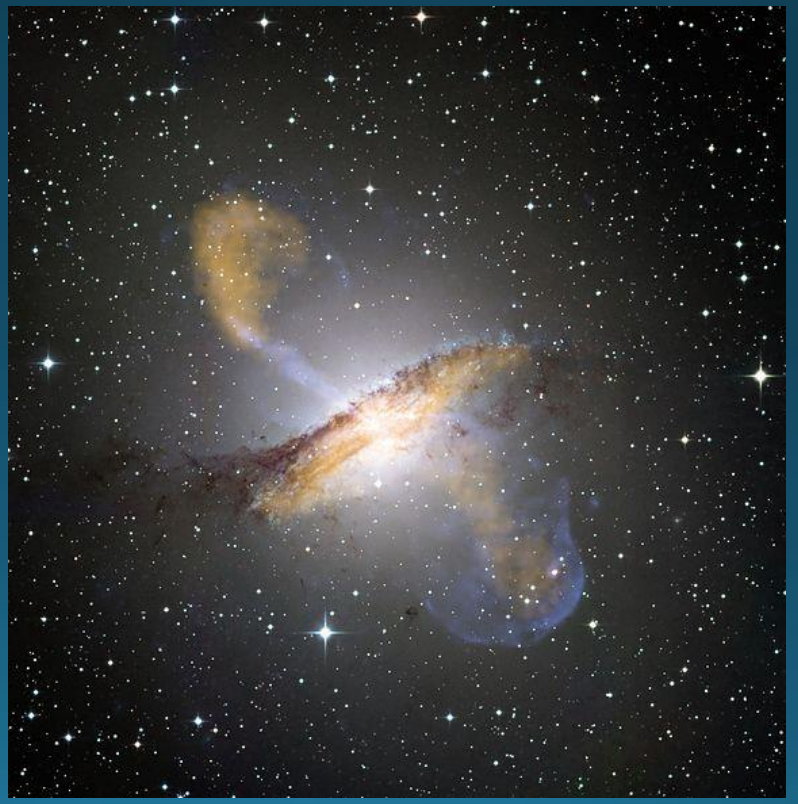
Physics of Galaxies 2020
Lecture 1

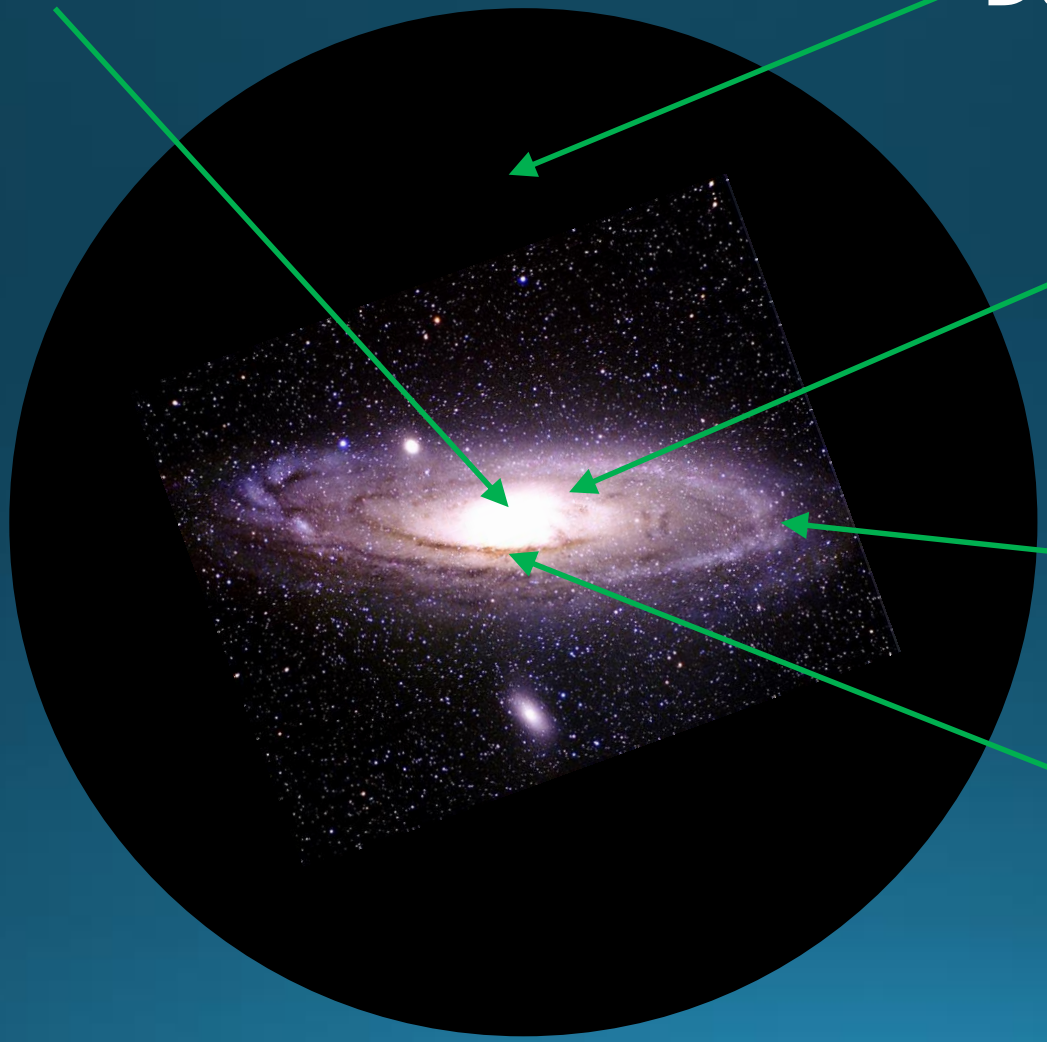




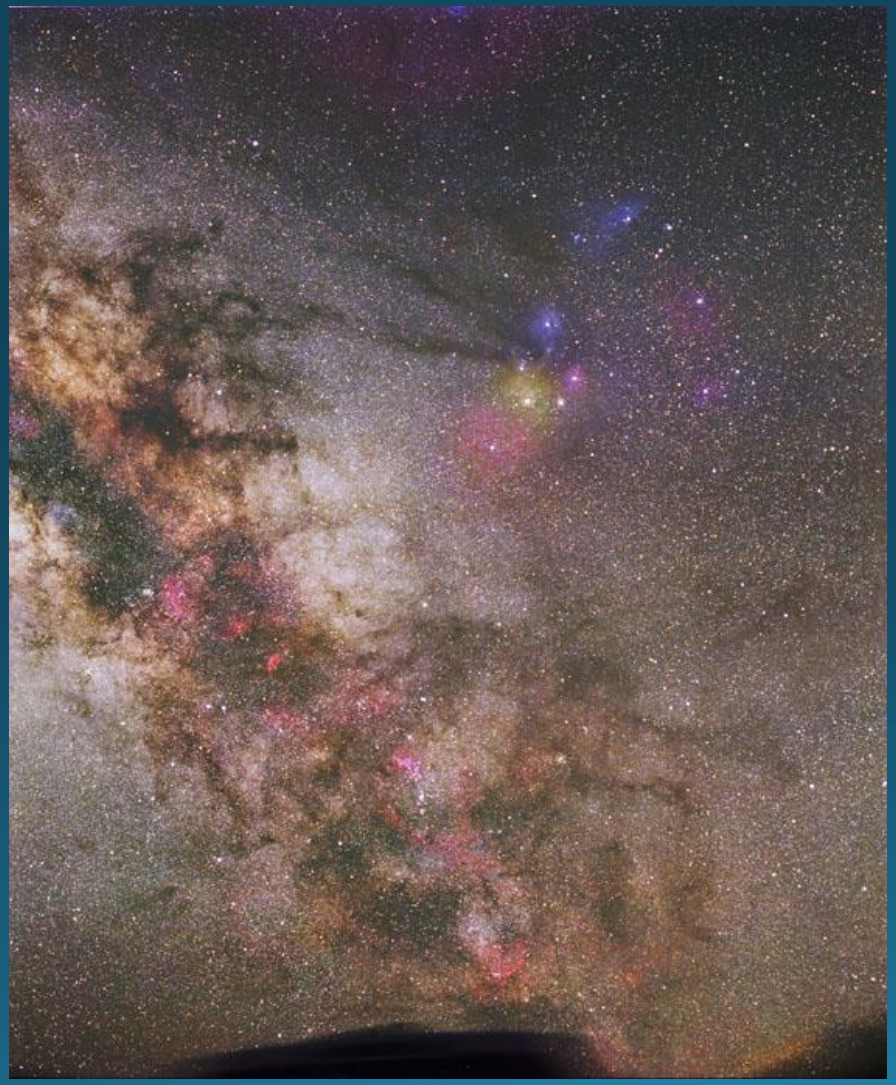
Outline for today

- What is a Galaxy?
- Historical Background
- Galaxy Classification
- The Cosmological Framework

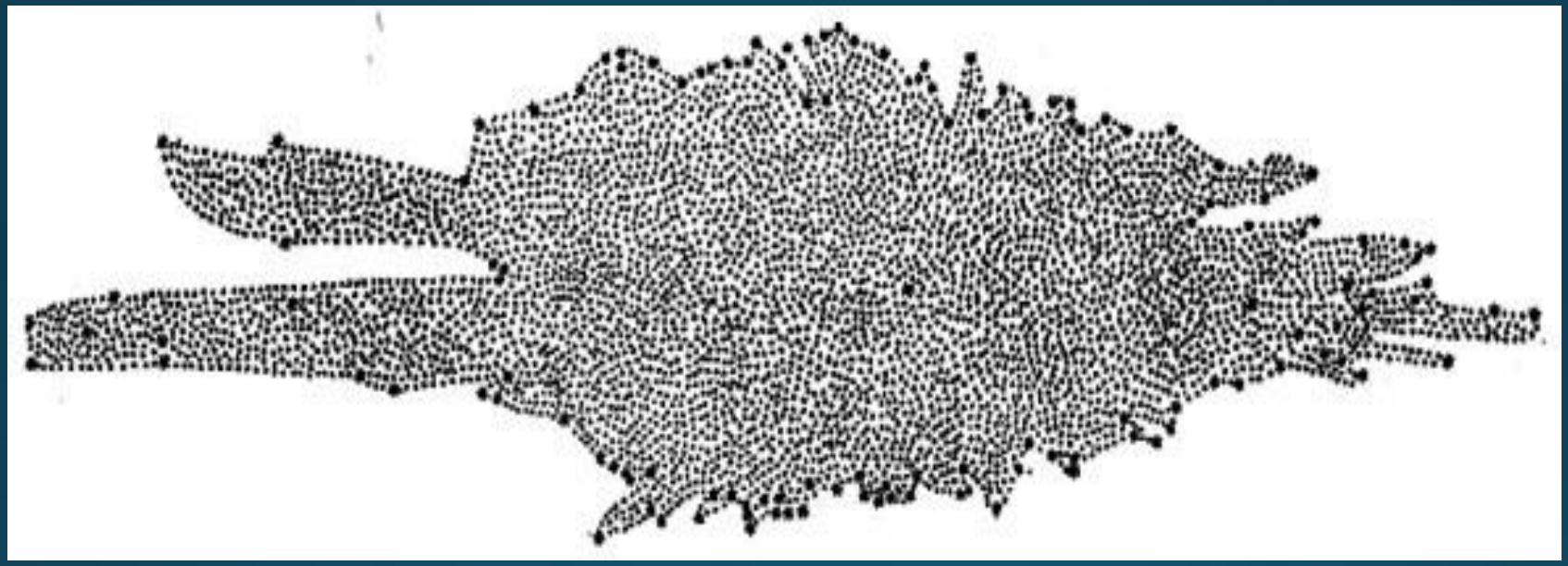
The Anatomy of Galaxies



Historical Background: The Milky Way

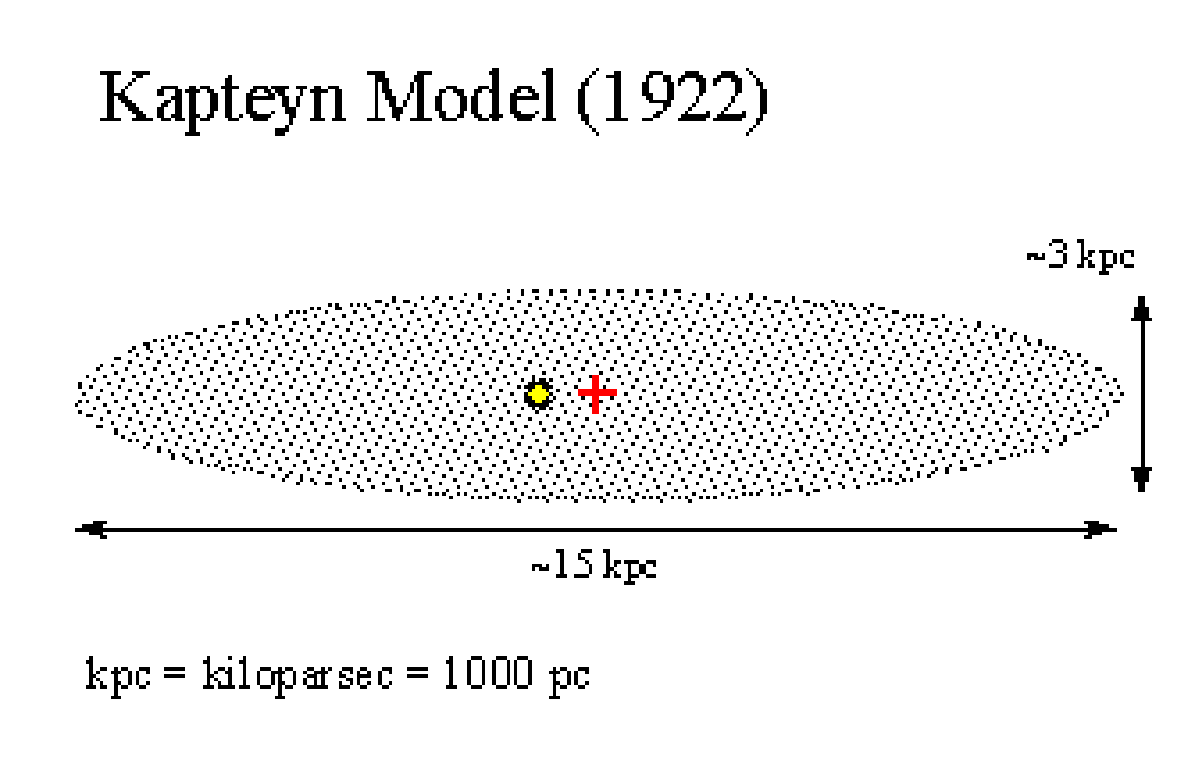


Historical Background: The Milky Way



- The "Herschel Universe" (late 1700s): Sun almost in the centre of Milky way
- Dust obscuration towards centre of the Milky Way (left side of figure) not accounted for

Historical Background: The Milky Way

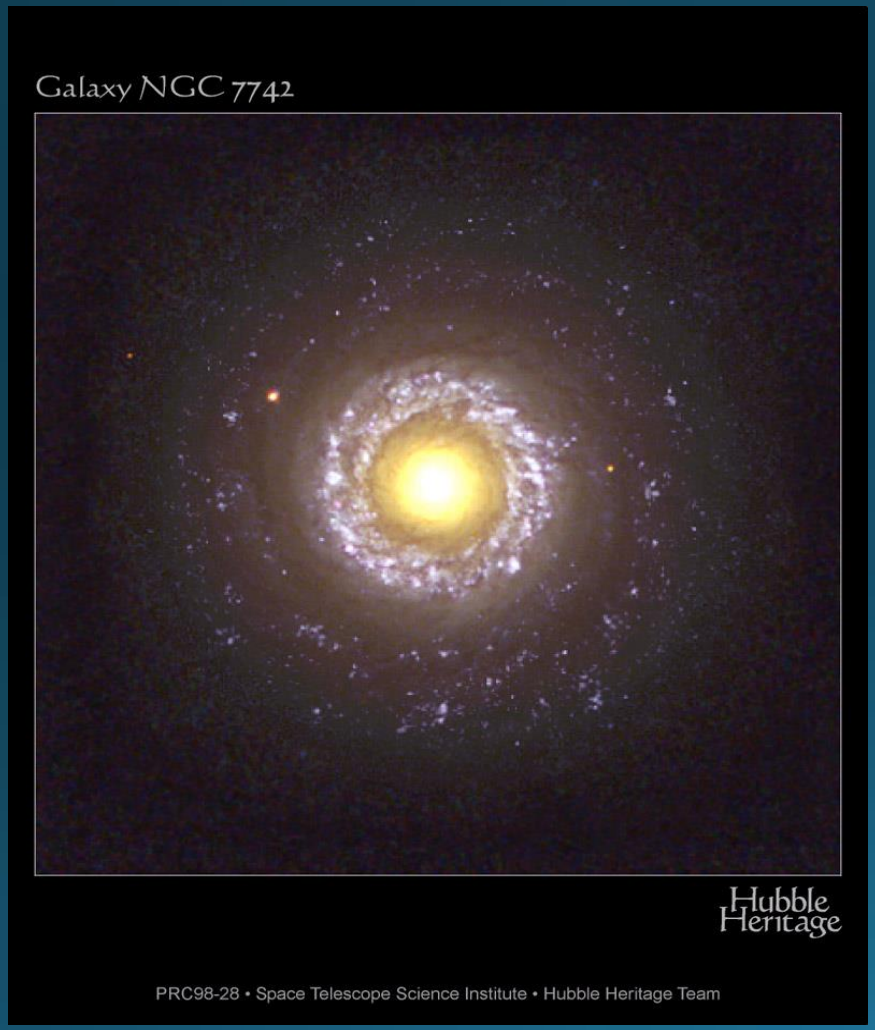


- Sun offset from centre
- Dust obscuration still not accounted for → wrong scale

Historical Background: Other Galaxies

- Mid-1800s: William Parsons (Lord Rosse) discovers spiral structure in nebulae
- 1912: Henrietta Leavitt discovers period-luminosity relation for Cepheids
- 1920s – The Great Debate
  - Shapley (local objects) VS Curtis (outside Milky Way)
  - Outcome: Spiral Nebulae are external galaxies
- 1929 – Expansion of the Universe (Hubble's law)

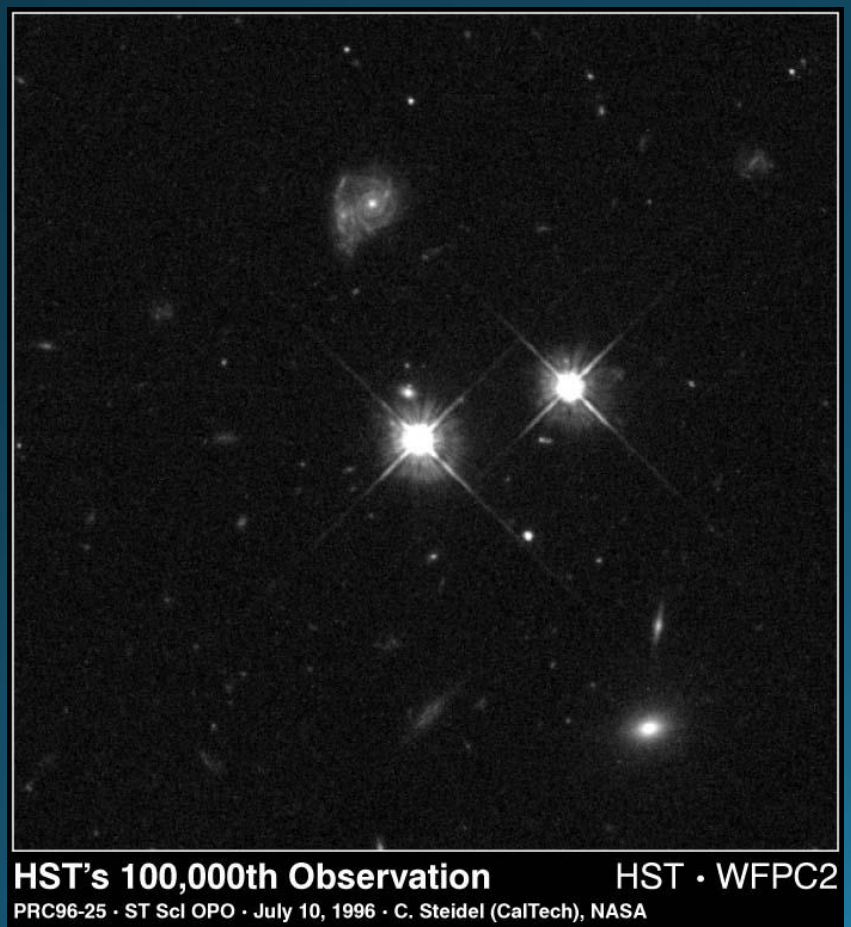
Historical Background: Active Galaxies

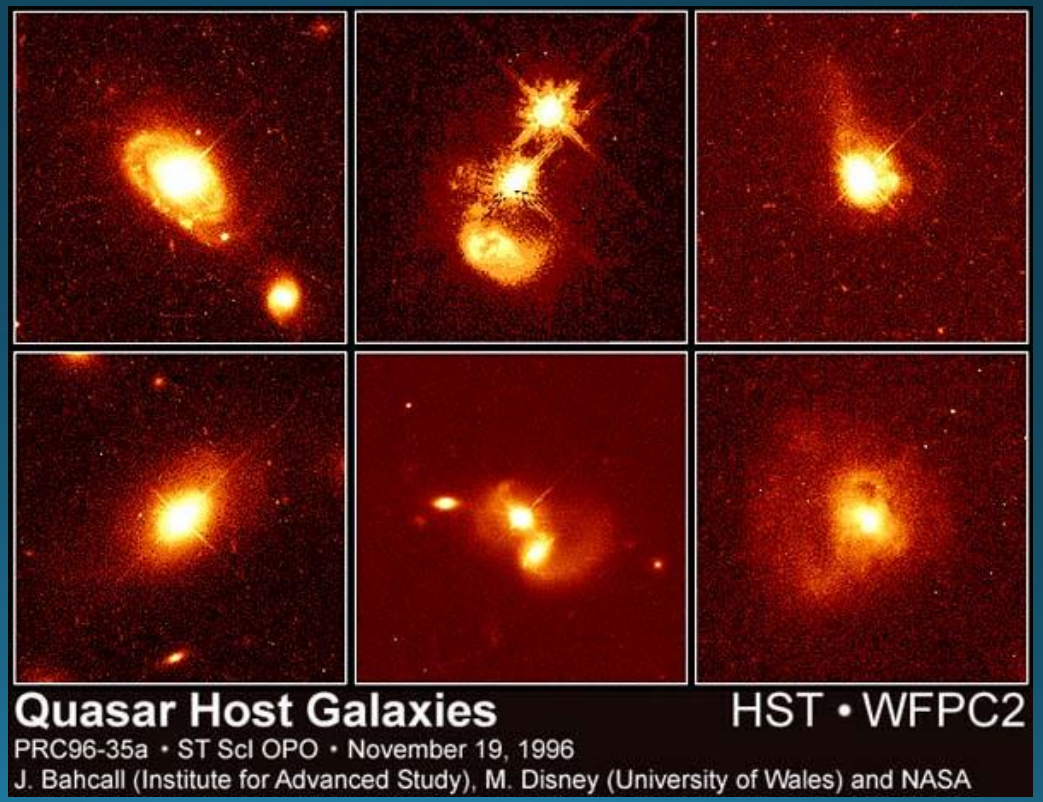


- 1943 - Seyfert Galaxies

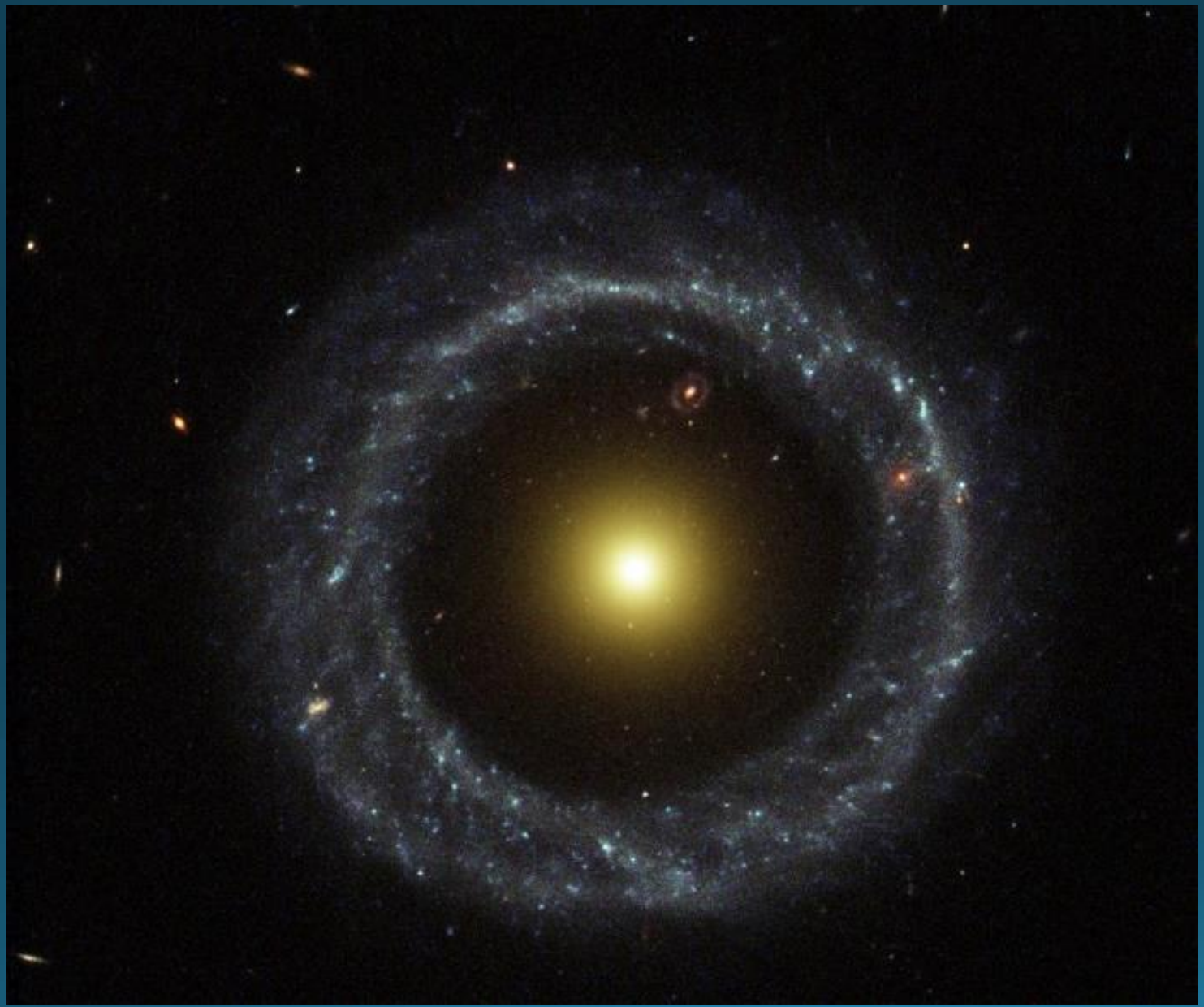
Historical Background: Quasars/QSO

- 1960s – Radio Galaxies, Quasars
- Quasi-Stellar Object: QSO, Quasar

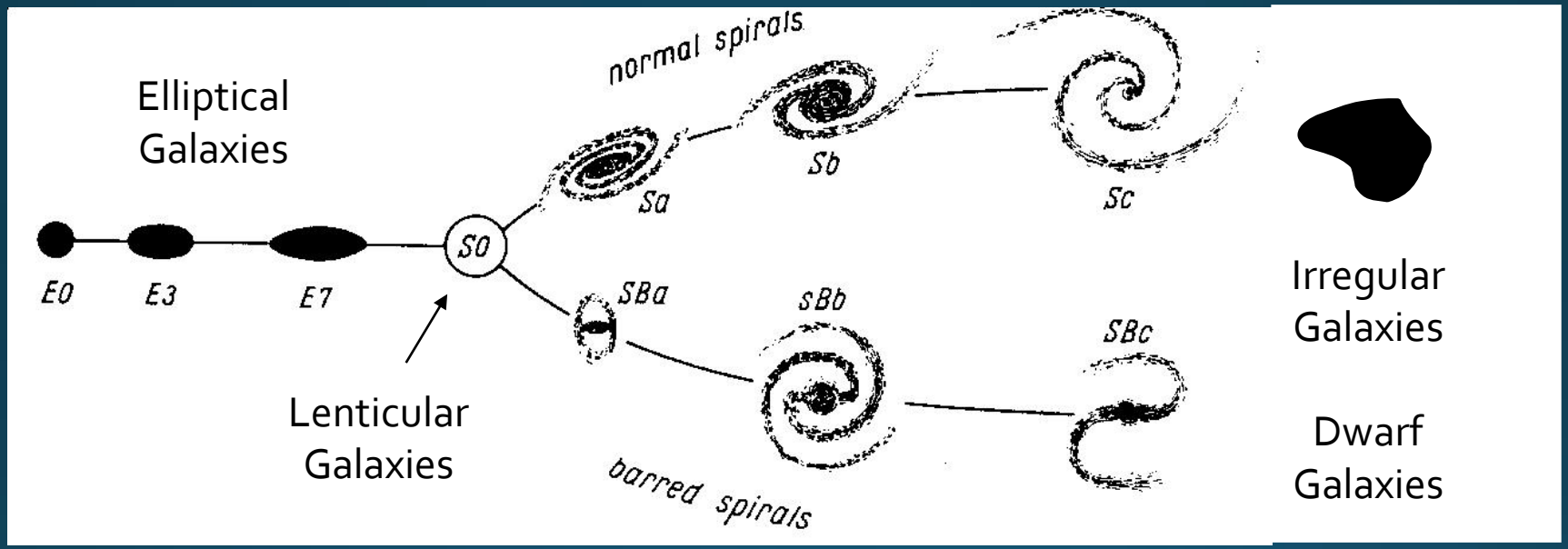




Intermission: What is this?



Galaxy Classification
The Hubble Tuning Fork



Other famous classification schemes:

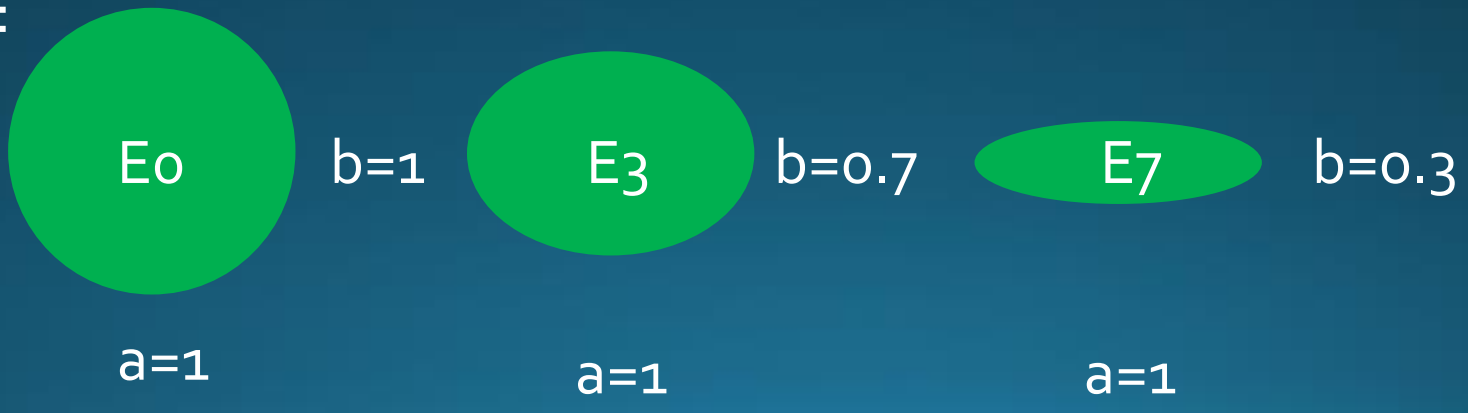
- de Vaucoleur
- van den Bergh
- Vorontsov-Velyaminov

Galaxy Classification

Elliptical galaxies

- Type: E*n*, $n = 10\,(a - b) / a$.
- Major and minor axes: a and b
- $\rightarrow$ E0 circular, E7 galaxies the most flattened.

Examples:

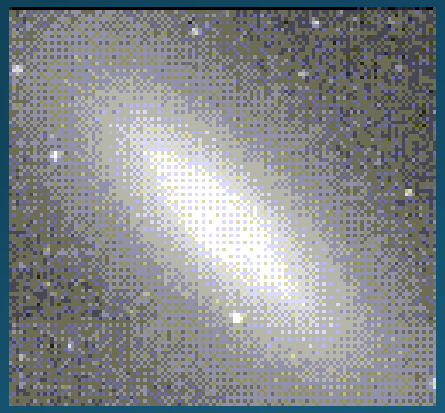


Galaxy Classification

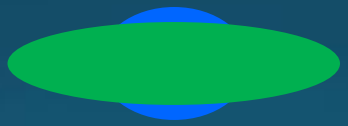
Lenticular galaxies

- Disk and central bulge, but no spiral arms
- SBo if barred, So otherwise

Examples:



So

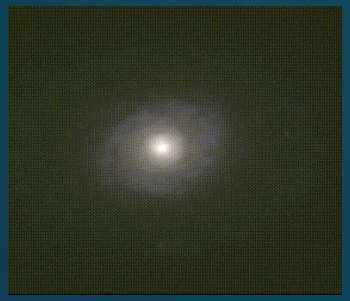


Edge-on

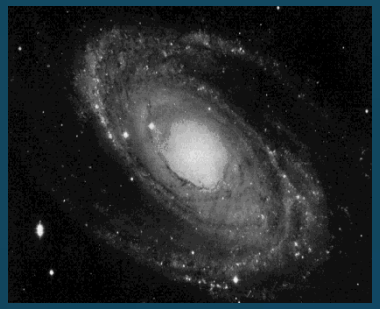
Face-on

Galaxy Classification

Normal Spirals



Sa

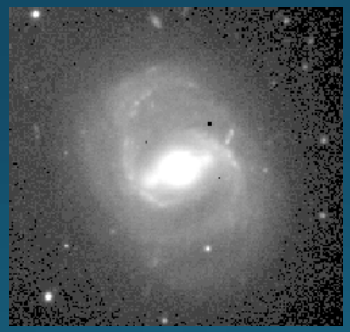


Sb

Sc

Barred Spirals

SBa



SBb

SBc

- Large bulges
- Tightly wound spiral arms
- Few star-forming regions in arms

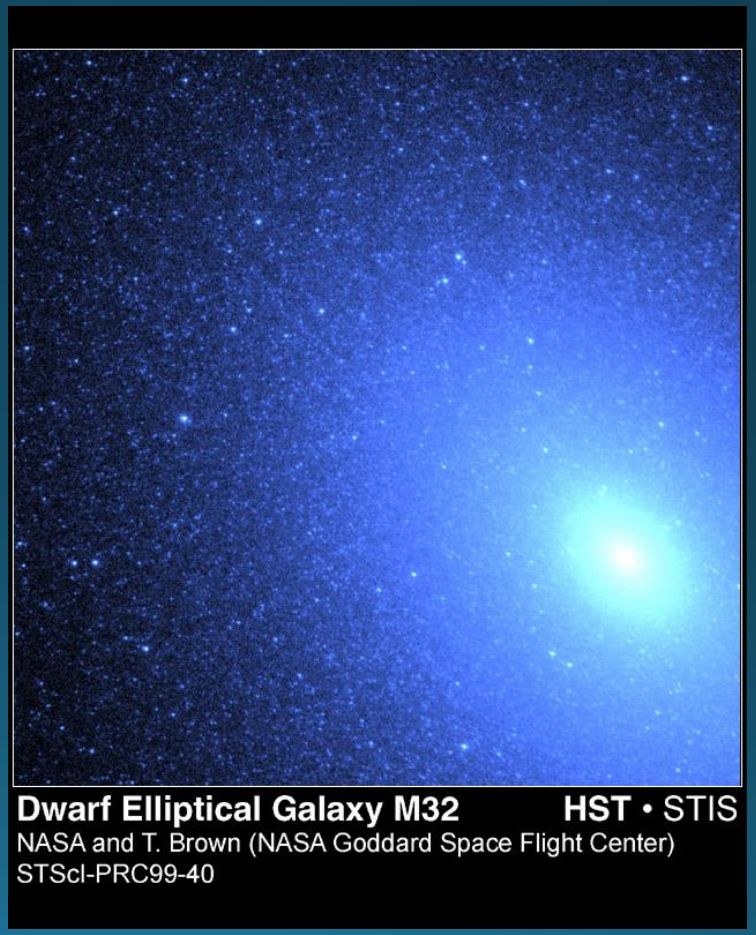
- Small bulges
- Loosely wound spiral arms
- Many star-forming regions in arms

Galaxy Classification

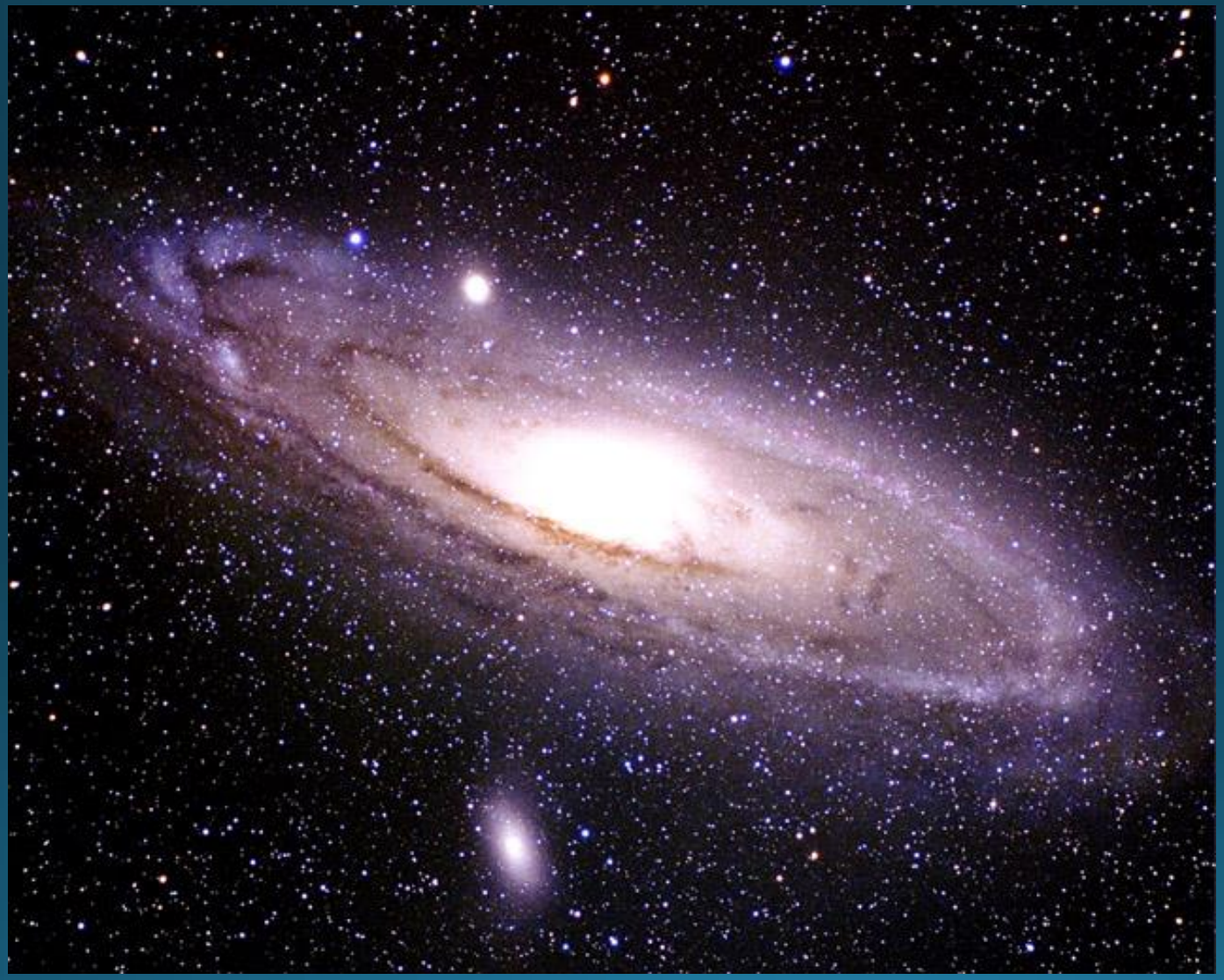
Irregular galaxies (I)

Galaxy Classification

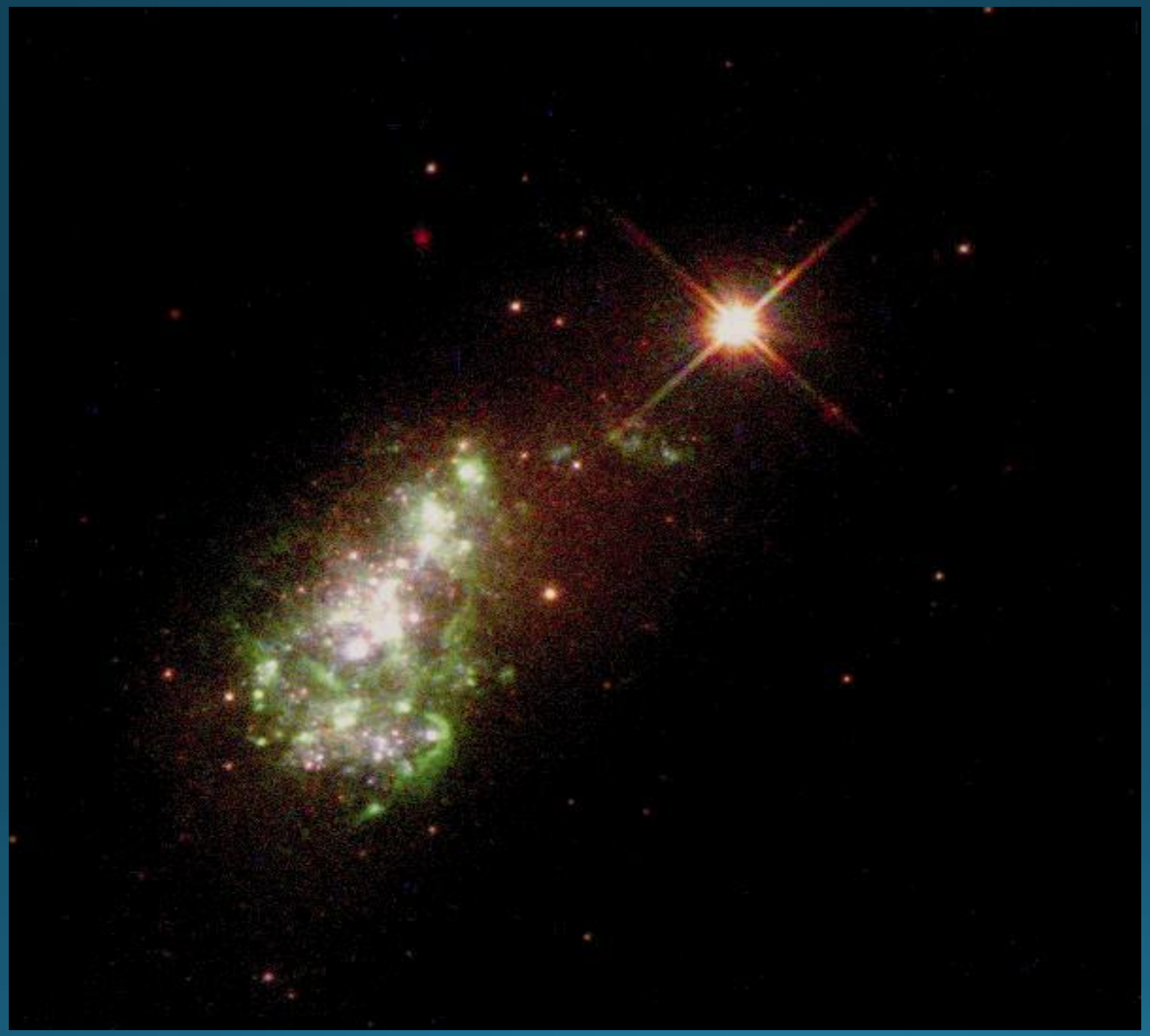
Dwarf galaxies (dE, dSph, dI…) – Low-luminosity objects



Morphological Type?



Morphological Type?

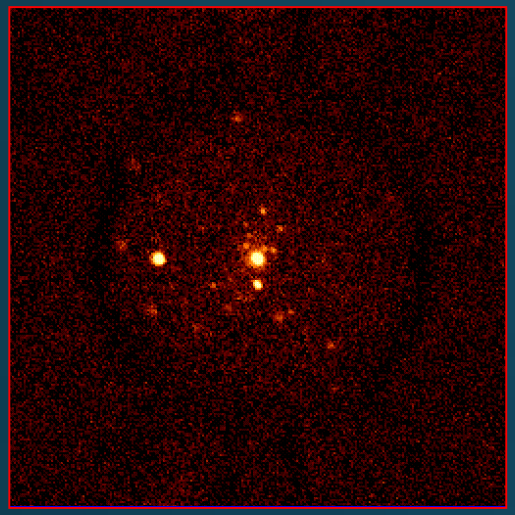


What is the Point of Morphological Classification?

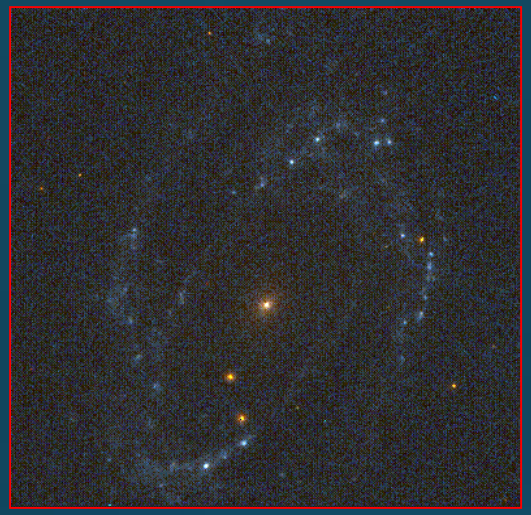
Hubble class correlates with:

- Gas content
- Dust content
- Star-forming properties
- Spectrum
- Metallicity

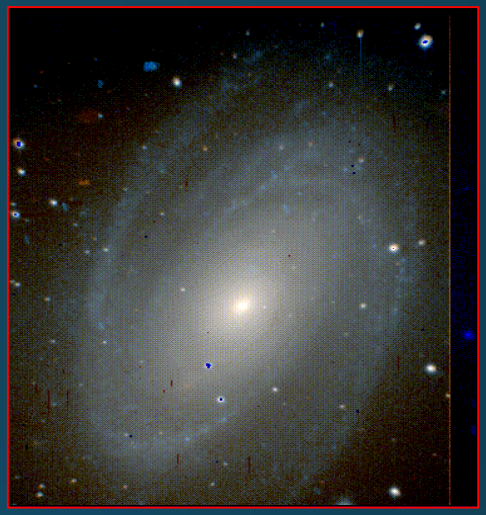
Morphological Complications



X-rays

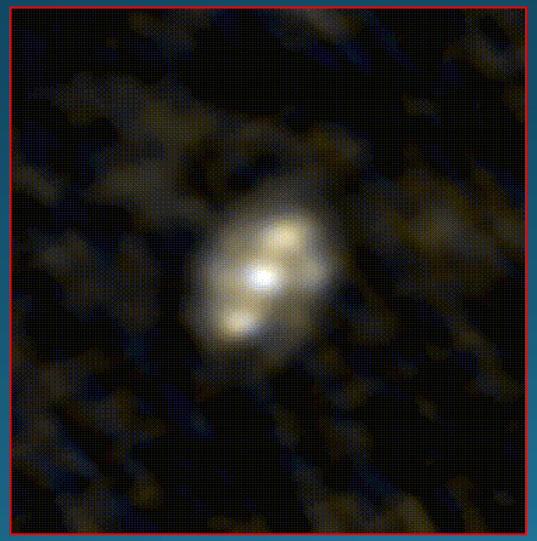


UV



Optical

Near-IR



Far-IR

Same galaxy (M81) at different wavelengths!

Morphological Complications

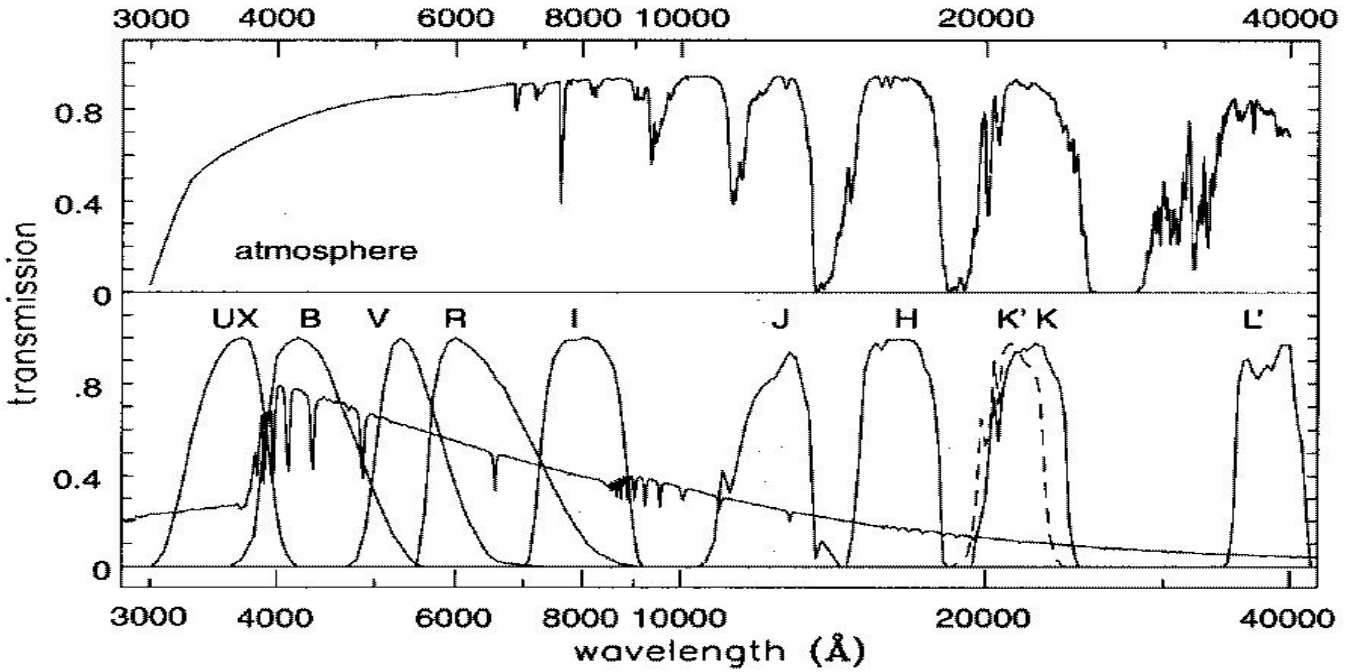
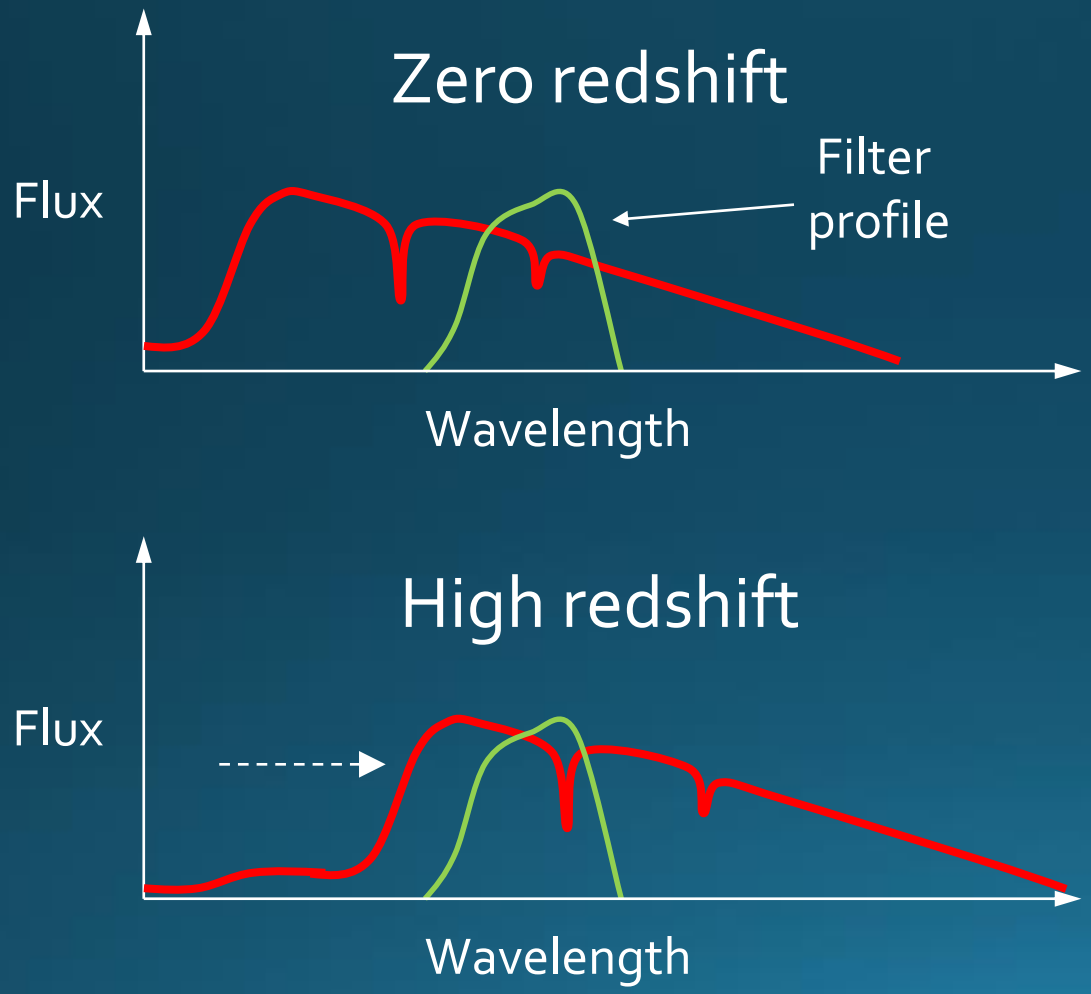


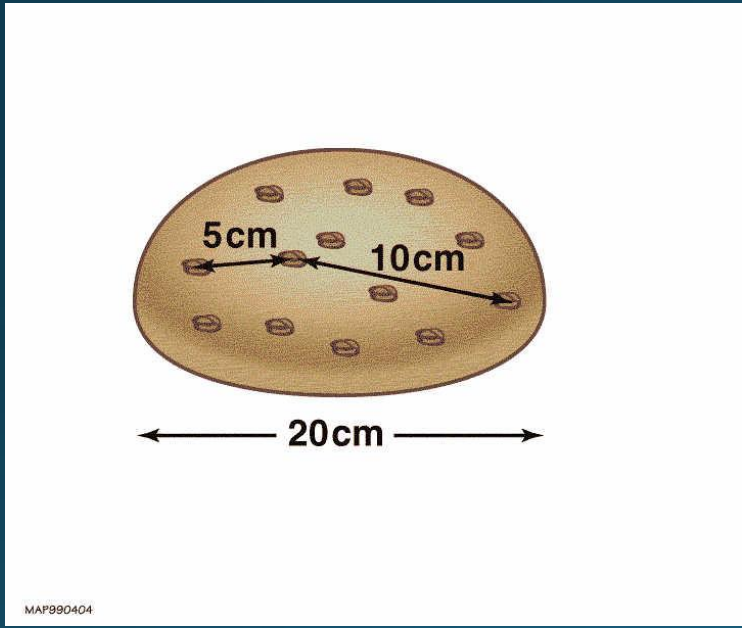
Figure 1.7 Above, atmospheric transmission in the optical and near-infrared. Below, flux F_λ of a model A0 star, with transmission curves $\mathcal{T}(\lambda)$ for standard filters from Bessell, PASP 102, 1181; 1990. UX is a version of the U filter that takes account of atmospheric absorption. For $JHK'KL'$, $\mathcal{T}(\lambda)$ is for transmission through the atmosphere and subsequently through the filter.

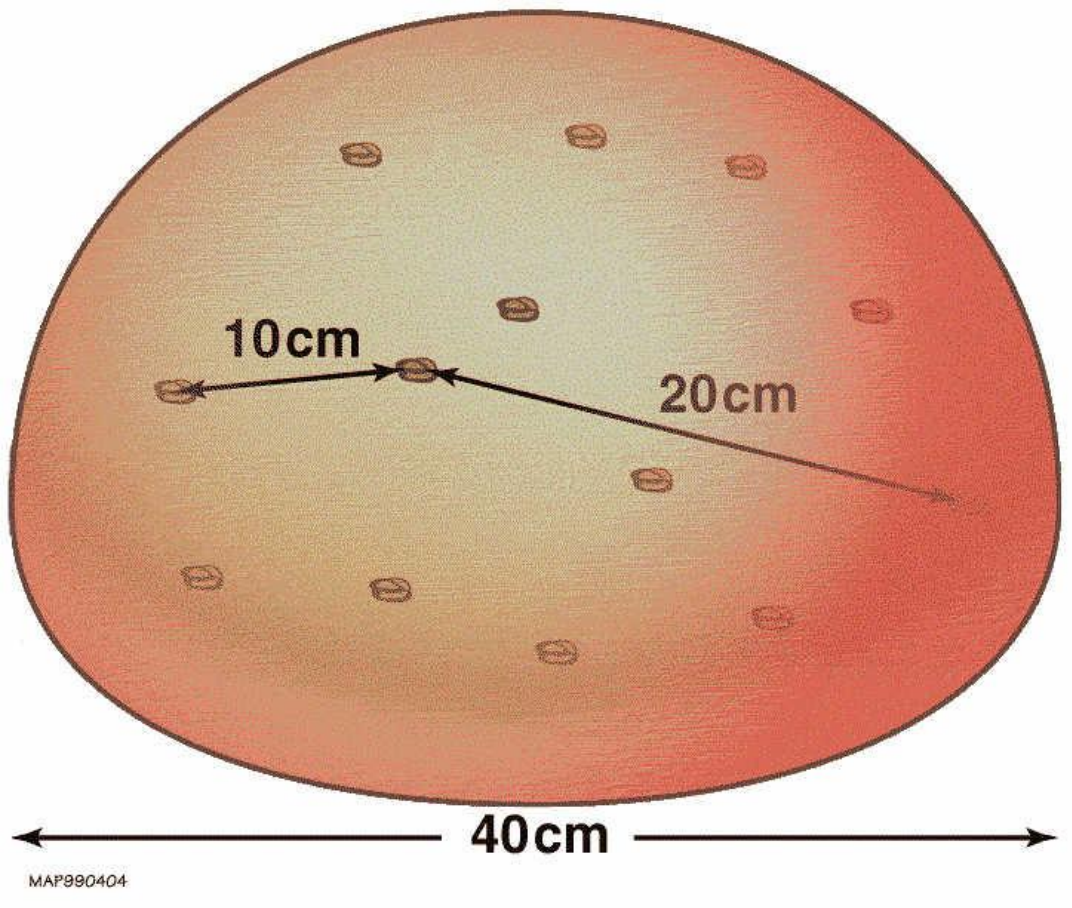
Morphological Complications



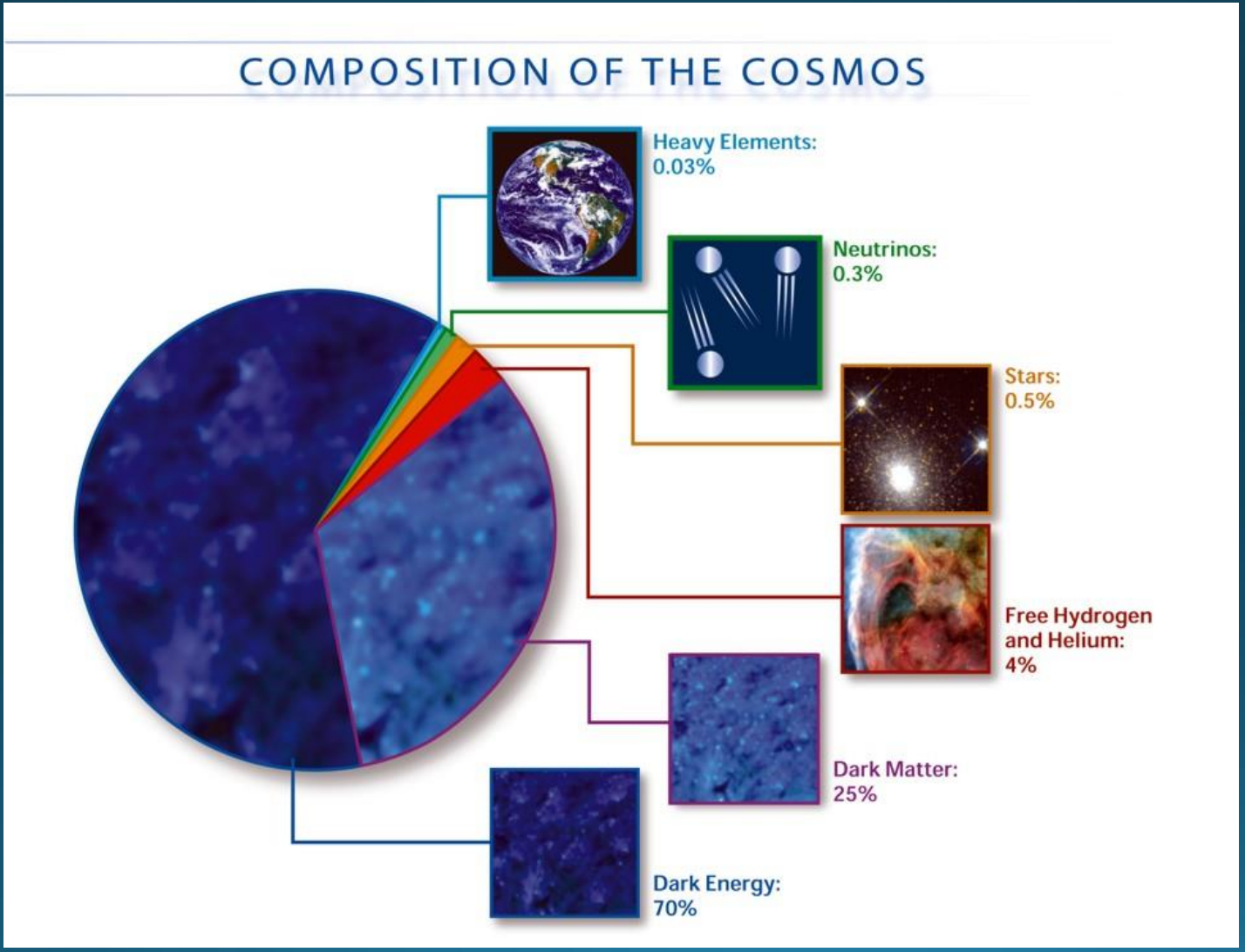
- Same filter probe different parts of spectrum at high and low redshifts
- Two galaxies with identical morphologies at a given rest wavelength may appear to have different morphologies

The Cosmological Framework I

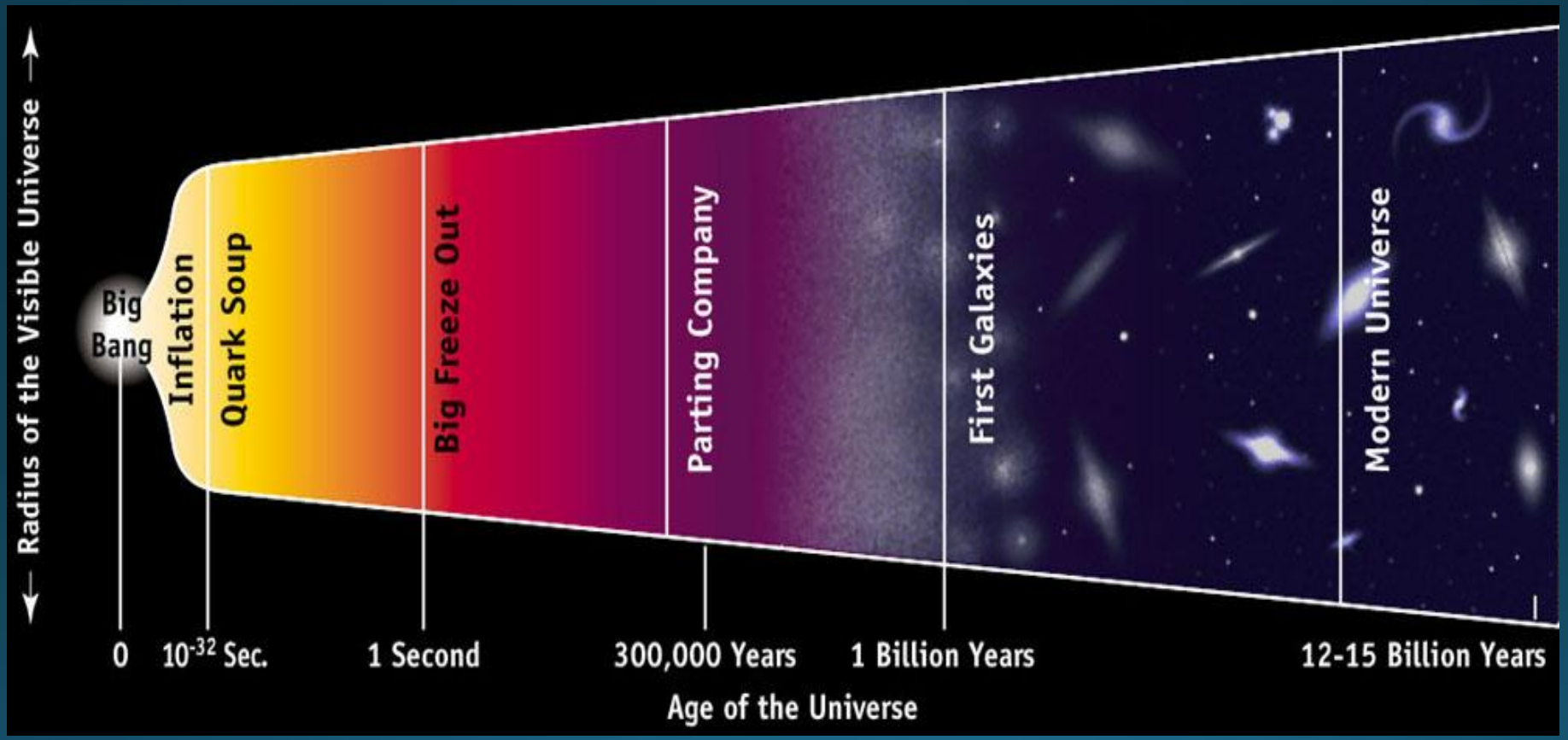




The Cosmological Framework II



The Cosmological Framework III



The Cosmological Framework IV

- $\Omega_i = \rho_i / \rho_c$
- ρ_c = critical density of the Universe
- $\Omega_{tot} \approx 1.0$
- $\Omega_{Baryons} \approx 0.04$
- $\Omega_M \approx 0.3$
- $\Omega_\Lambda \approx 0.7$