Galaxies & their Structure

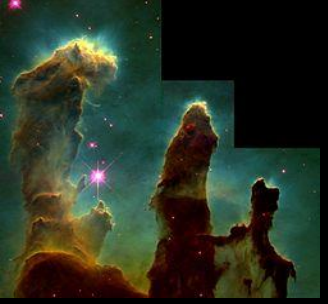
S N Hasan
MANUU, Hyderabad


Shedir
Alpheratz
Mirach
Almaak


Caph
γ Cas
Shedir
Cassiopeia
Alpheratz
Andromeda
Mirach
Almaak
Mirphak
Pisces


Shedir
Alpheratz
Mirach
Almaak


μ And



Nebula (pl. Nebulae)

- Nebula – from Latin - "cloud"
- In the past – the word Nebula was used for extended, fuzzy astronomical objects

- Star forming regions'
- Supernova remnants
- Planetary Nebulae
- Globular Clusters
- Galactic Clusters
- Galaxies

Nebula is an interstellar cloud of dust, hydrogen, helium and other ionized gases. Nebulae are often star-forming regions, such as in the Eagle Nebula or Stellar remnants such as Crab Nebula


μ And


ν And

Galaxies: Large collection of Stars, Dust and Gas

billions

- Typical Mass:

  10^9 - 10^{12} M_{sun}

  M_{sun}~ 10^{30} kg
- Typical Size

  30 kpc

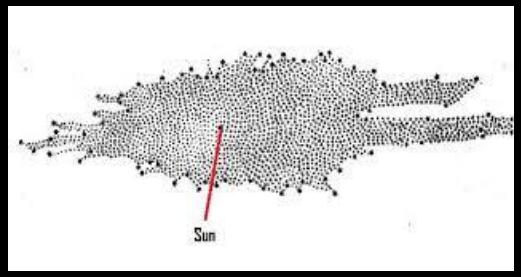
  1 kpc = 1000 pc.

  1 pc ~ 3.26 lt. yrs.

  1 lt. yr = distance traveled by light in 1 year.

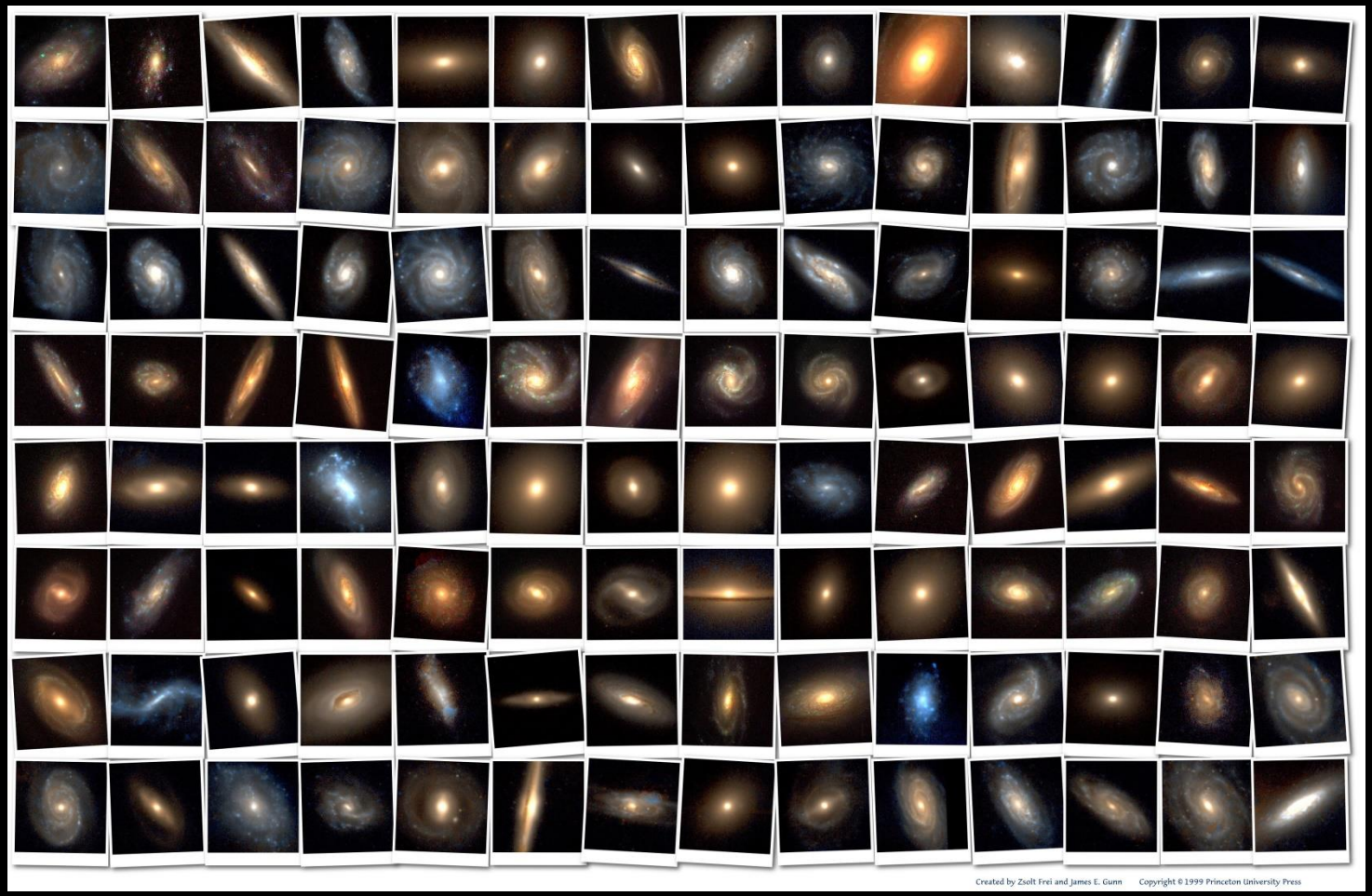
Historical Perspective

- Geocentric
- Heliocentric (Copernicus, 1543)
  accepted in ~ mid 17th century
- Galileo (1610) turned his telescope to the Milky Way.
- William Herschel late 18th century
- Shapley (1918) shows that Sun is **not** in the center of the Milky Way galaxy



- Single Galaxy (1900-1920)
  Shapley-Curtis debate
- Many Galaxies (1920-1930)
  Hubble resolves stars in the Andromeda Galaxy,
  Spectroscopic measurements of
  Slipher & works of Humason & Hubble

Galaxy Zoo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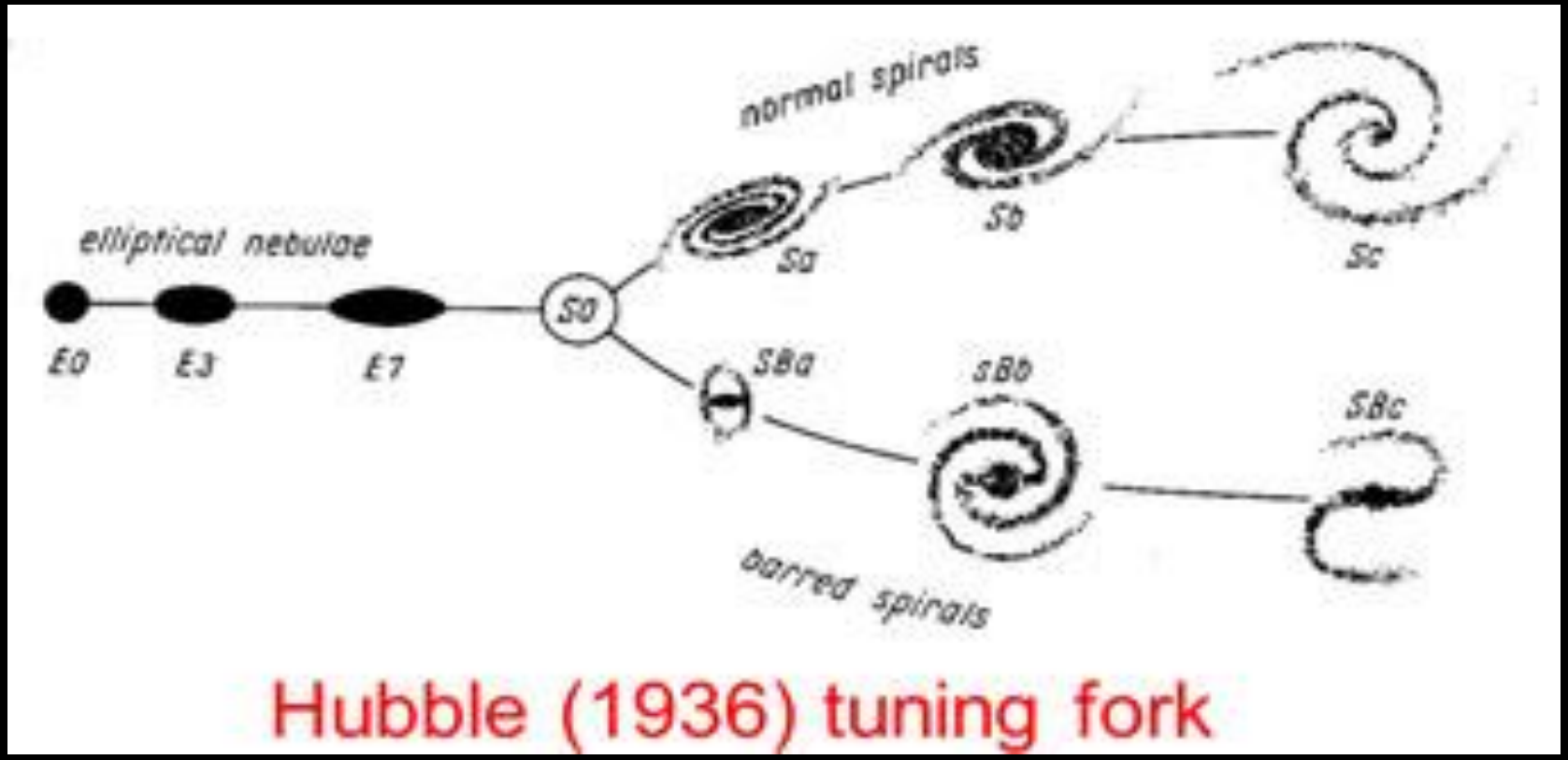
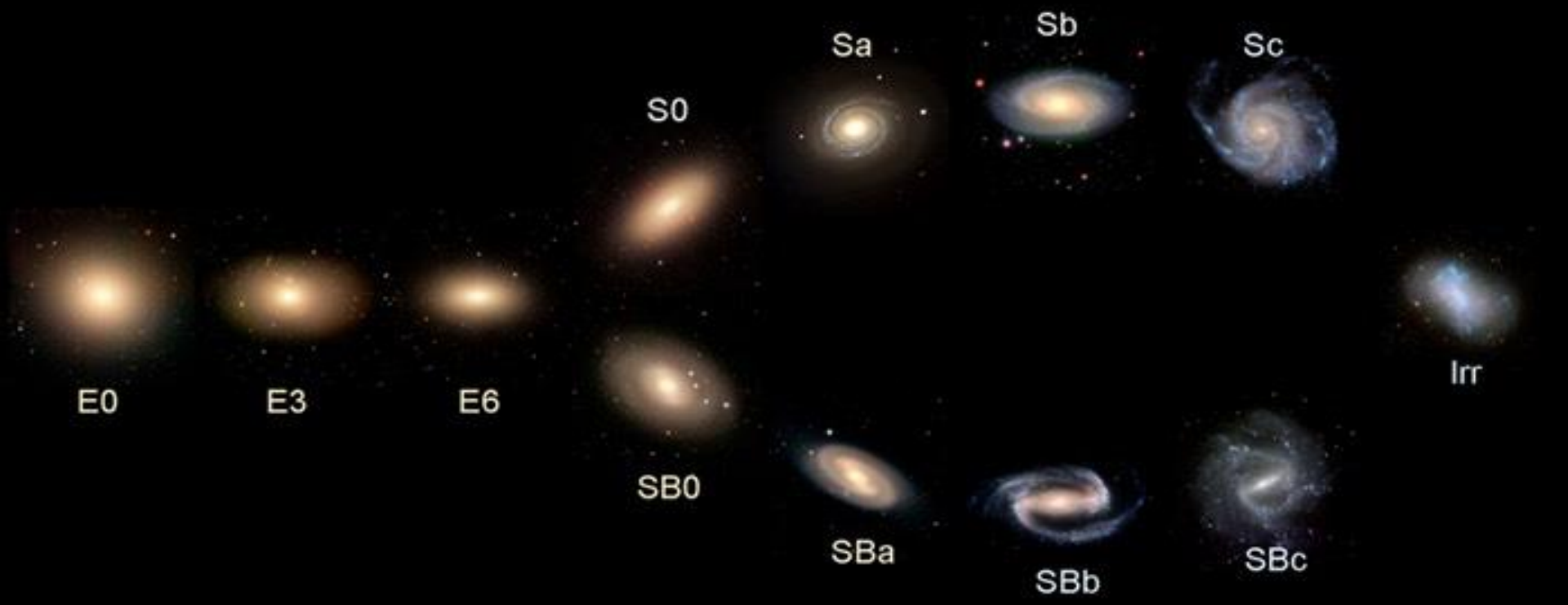
Galaxies a closer look

Hubble's Tuning Fork Diagram



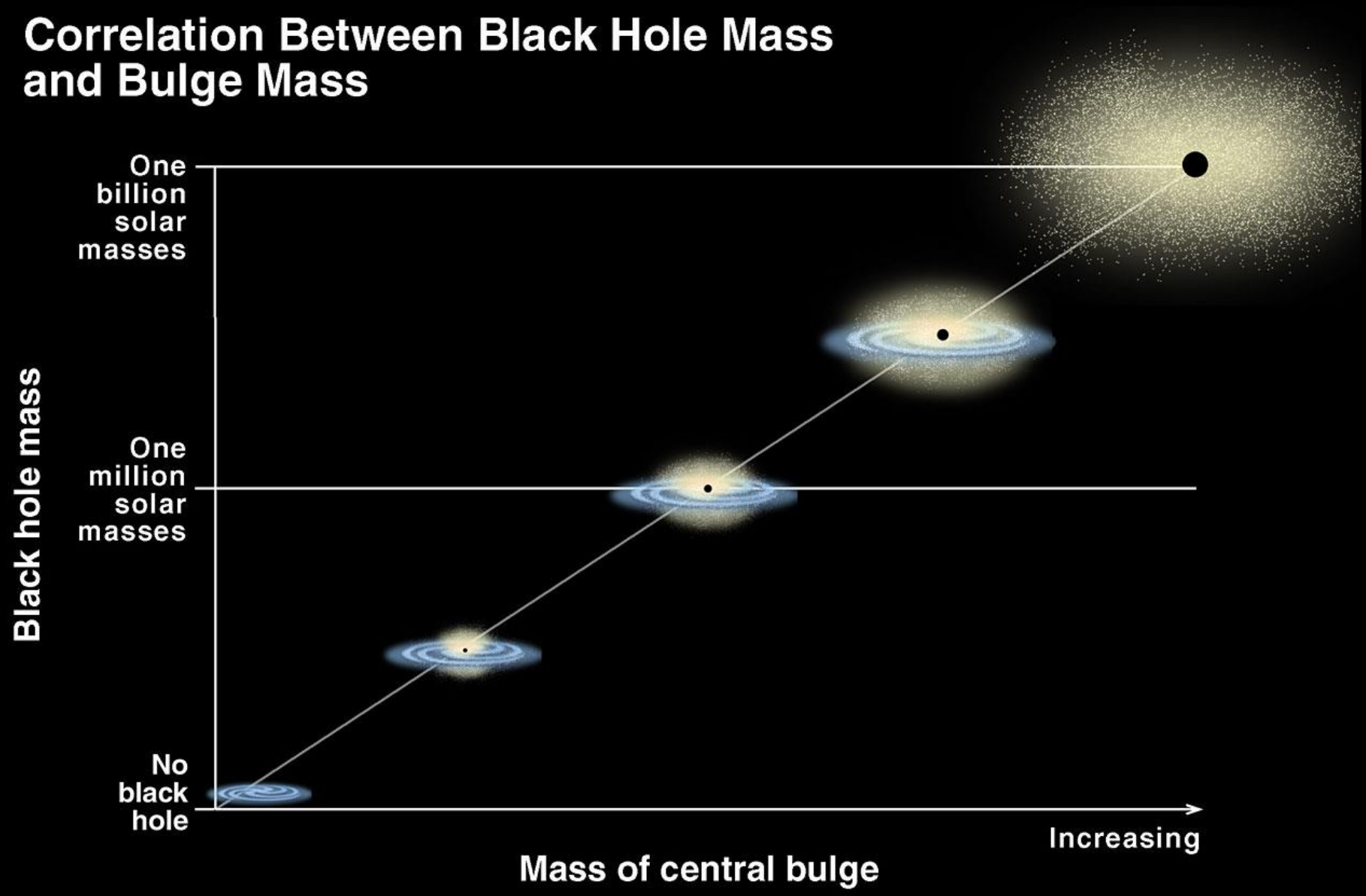
Hubble (1936) tuning fork

Hubble's Galaxy Classification Scheme



Why do galaxies have different morphologies?

Correlation Between Black Hole Mass and Bulge Mass



Interacting Galaxies

Background & Early History

Galaxies were seen as isolated, mostly un-evolving island universes.

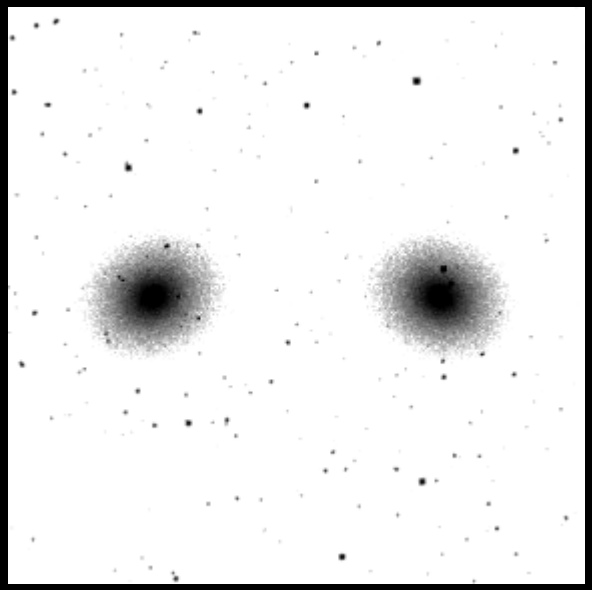
- Lack of high quality imaging & spectroscopic data in various wavebands.
- Detailed theories of stellar evolution & nucleosynthesis were not discovered

  – **Blind Spot:** Sheer disbelief that gravity could produce such exotic structures such as tails, bridges, etc.

A look at the past:

NGC 4038/4039 Antennae

NGC 4038/4038 – The Antennae

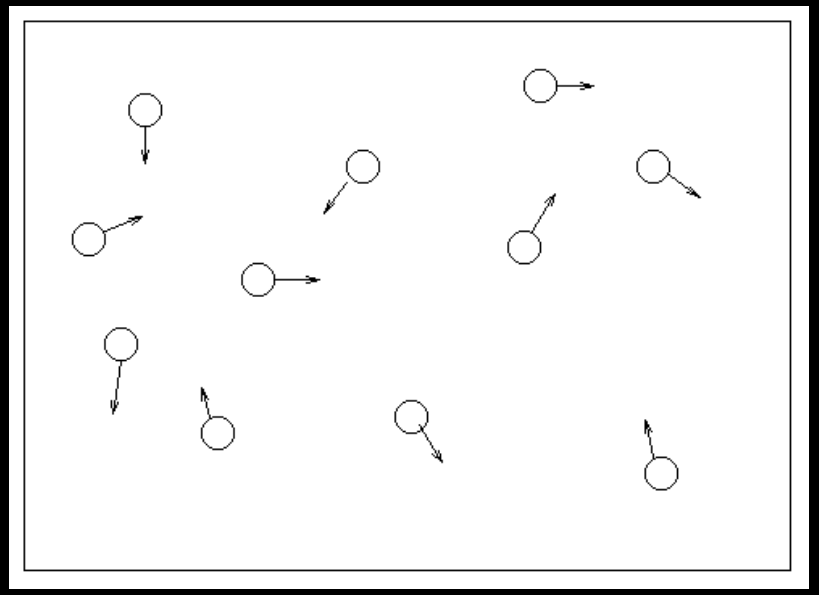


- NGC 4038/4039
- allow us to set limits on the total amount of dark matter in the interacting galaxies.
- 2 million years

The N-body problem

The study of the motion of N bodies moving under mutual gravitational attraction.

$$\ddot{\vec{r}}_i = -\sum_{(i \neq j)=1}^{N} \frac{G m_j \vec{r}_{ij}}{r_{ij}^3}$$



$M_1 \sim M_2 \sim 10^{12} M_{sun}$
$M_{gals} = 2 \times 10^{42}$ kg
$V_{rel} = 300$ km /sec
$E \sim 10^{53}$ J

Energies comparable to binging energies

" A near miss is as good as a hit in this field."

- Involve a tremendous amount of energy
- Results in important evolutionary effects
- Not a high energy phenomenon
  - Velocities are small
  - Extremely slow

~ 0.1 % c

3×10^8 yrs.

When galaxies come close

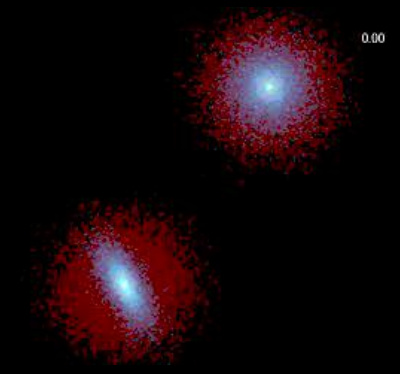
Tidal forces act at gigantic scales- resulting in the formation of:

- Tails
- Bridges

Conditions for the formation of tails & bridges:

- Galaxies should approach each other in parabolic or highly eccentric orbits
- Prograde orbits
- Galaxies should not penetrate much.

Galaxy Mergers



- The galaxies should approach each other with small relative velocities
- Depending upon the initial conditions stars gain or loose energy.
- Stars which gain energy move outward

  those which loose fall inward.
- In general a star gains energy.
- The increase in overall energy loosen them and make them disrupt.
- The increase of internal energy of the galaxies is at the expense of orbital energy- resulting in a Merger.

Some interestin collisions

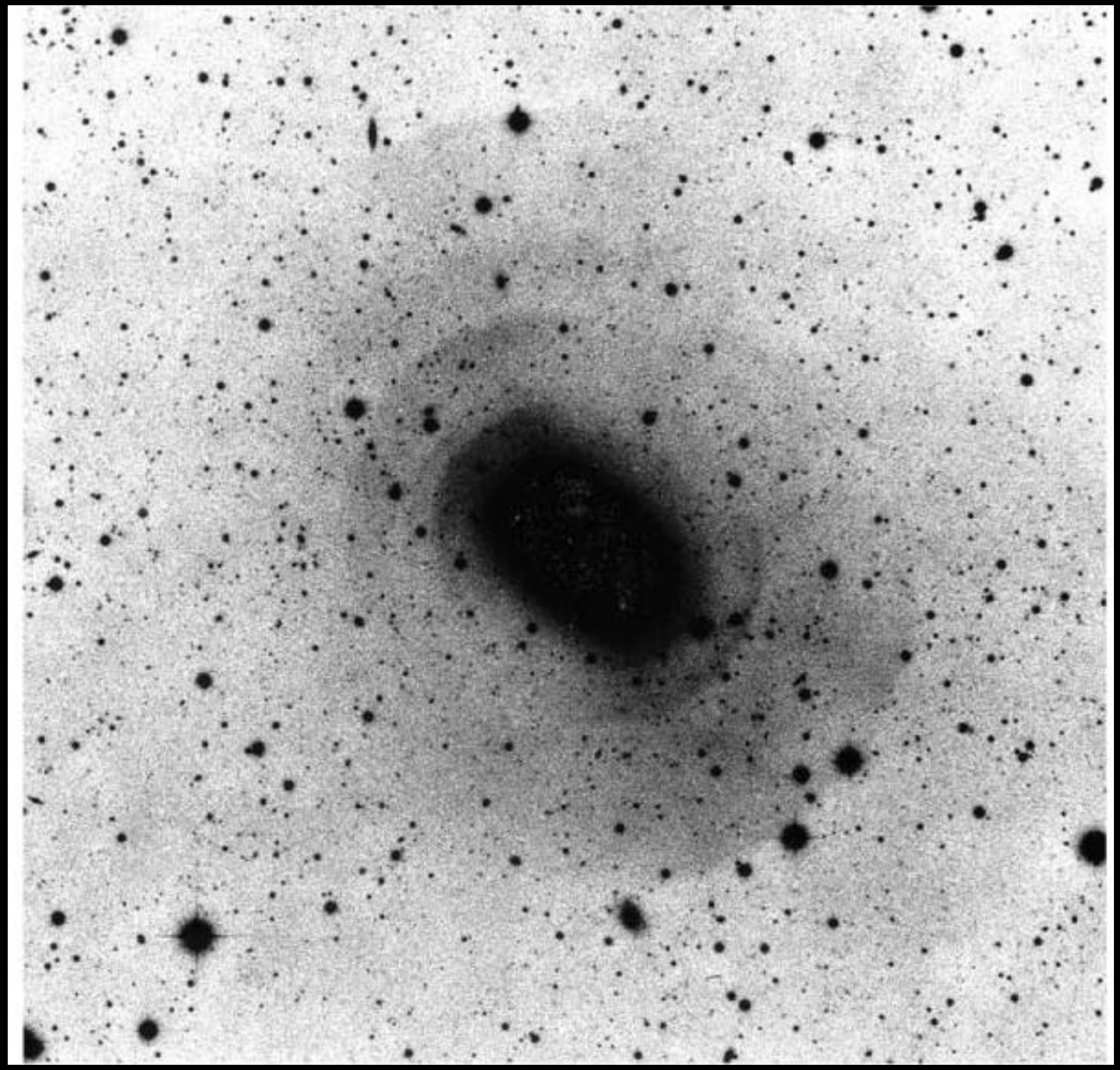
- Most of the m with ar ng.
- Small probability for direct star – star collisions.
  Collision probability ~ 10^{-15}
- Gas components collide in gas rich galaxies

Cross section Sun 10^{17} m^2
Surface density of stars near Sun
~ 10 per light yr sqr.
i.e 10^{-32}

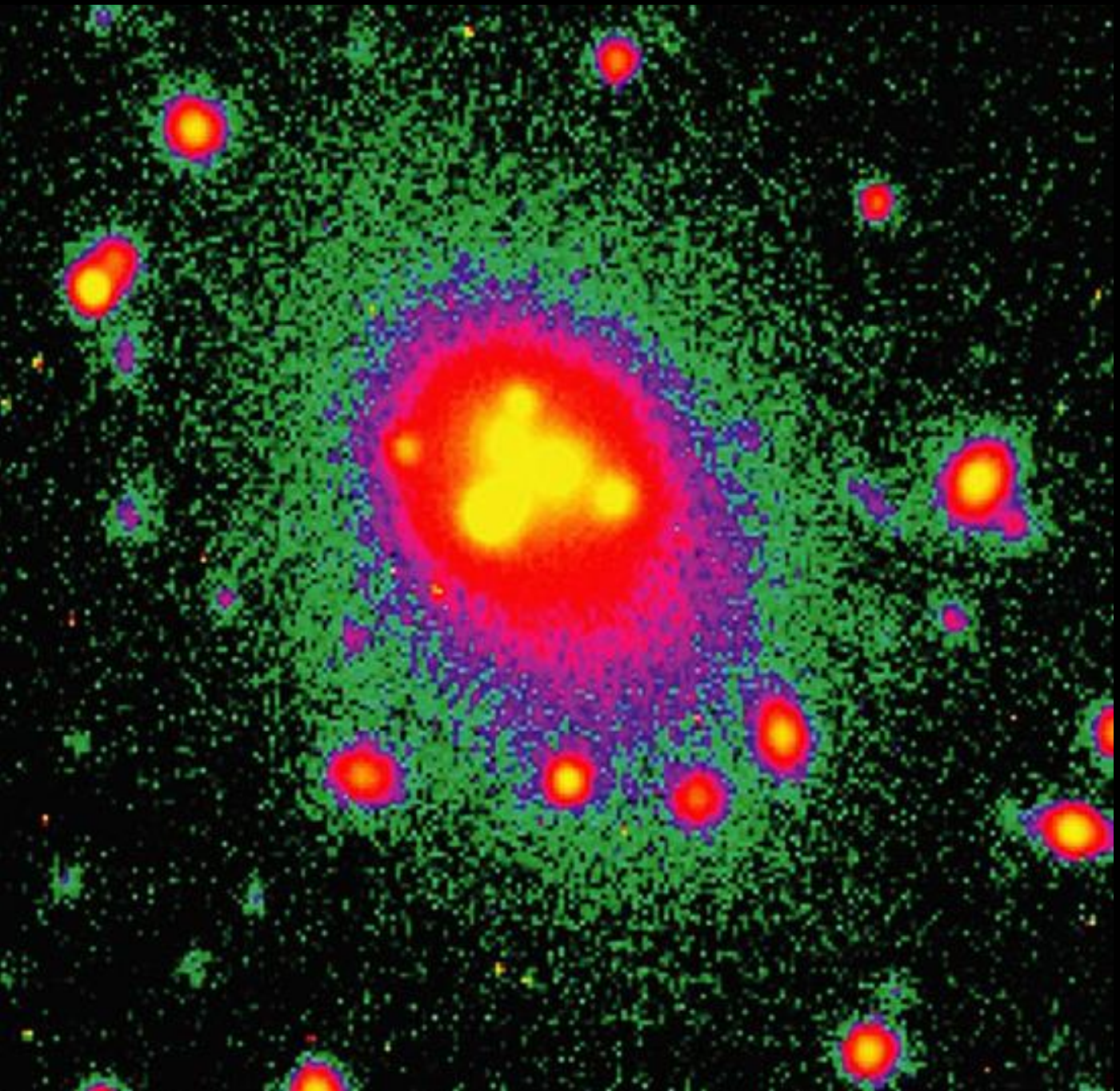
Thermal state

Simulating the Mice (NGC 4676)

Merger of Spirals to form an Elliptical Galaxy



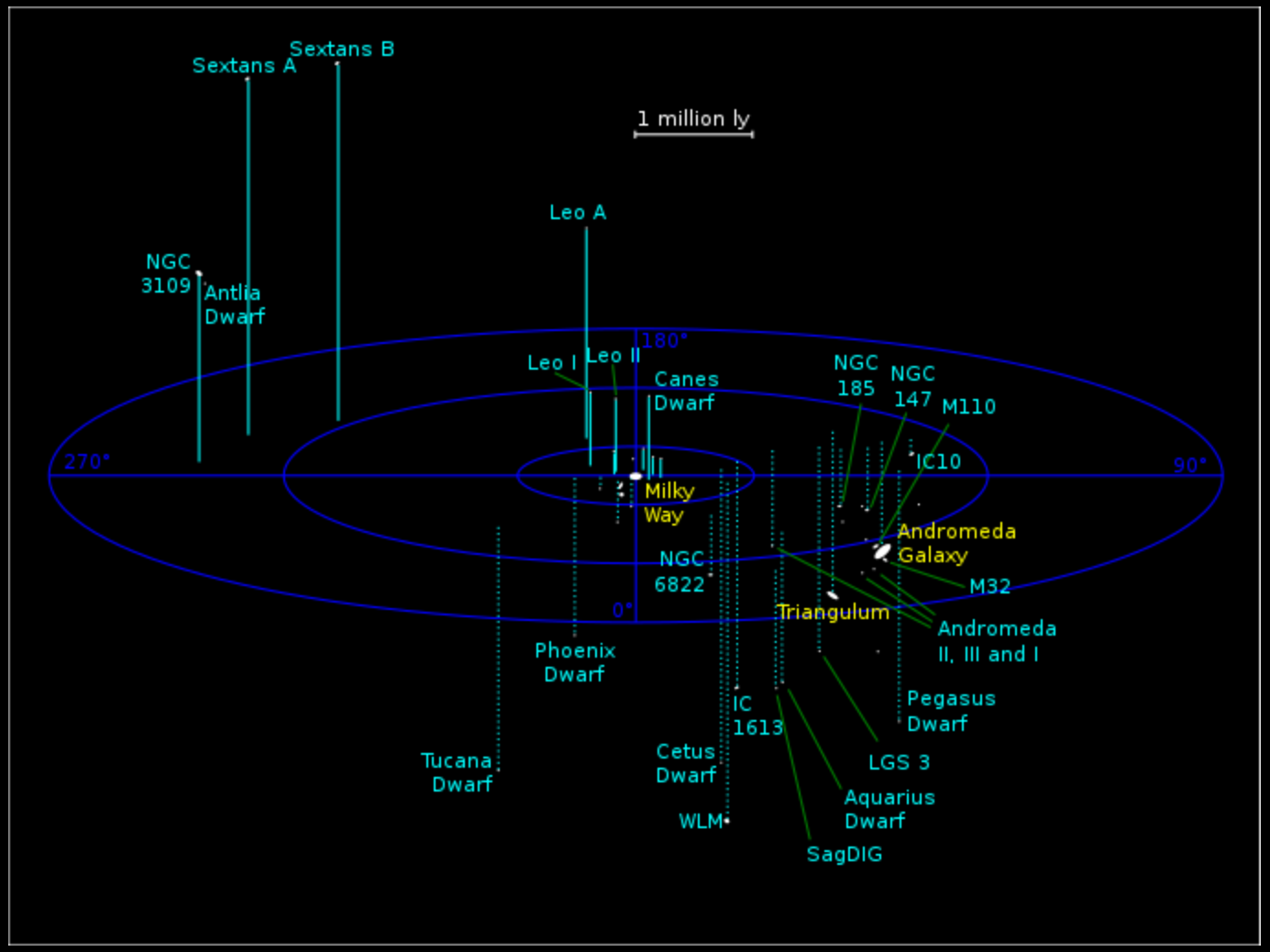
Shells of stars observed around some elliptical galaxies are probably the remains of past collisions



Giant elliptical galaxies at the centers of clusters seem to have consumed a number of smaller galaxies

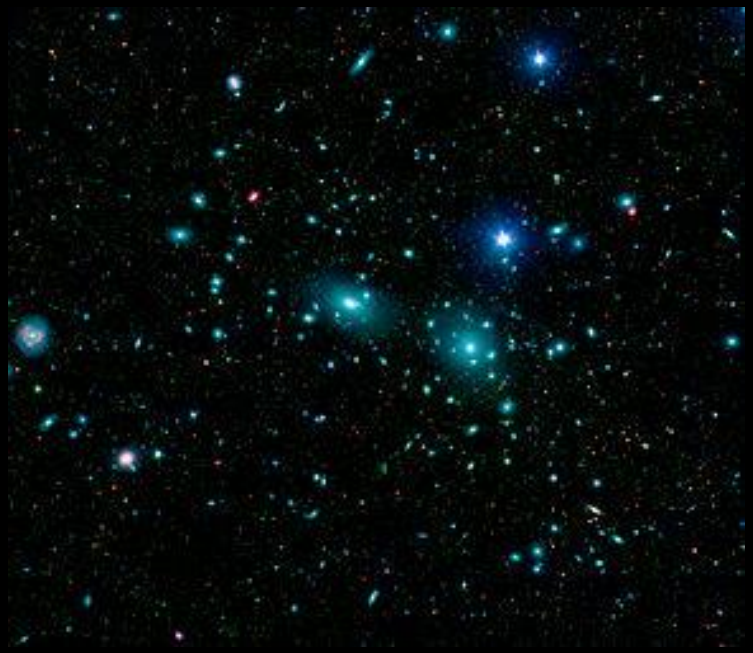
Effect of the Environment on Galaxy morphology and evolution

Local Group



Comprises more than 54 galaxies, most of them dwarf galaxies

Galaxy Clusters



Coma Cluster

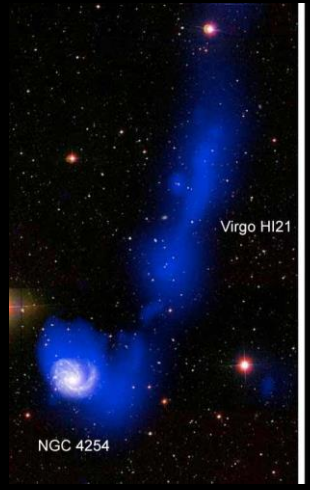
over 1,000 identified galaxies.
mostly elliptical and S0 galaxies
a few spirals of younger age and many of them probably near the outskirts of the cluster

Virgo Cluster

Comprising ~ 1300 (and possibly up to 2000) galaxies
fairly heterogeneous mixture of spirals and ellipticals.

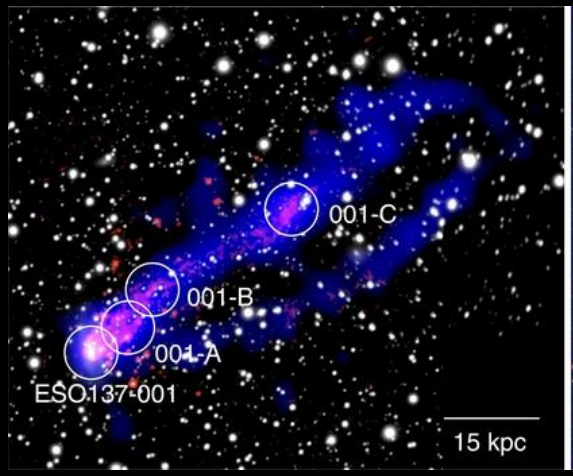
Environmental processes I: Ram-pressure stripping

Spiral galaxy ESO 137-001 as it moves through the heart of the galaxy cluster Abell 3627.



ESO 137-001 a spiral galaxy zipping through a crammed cluster of galaxies. Gas is being pulled from its disc in a process called ram pressure stripping. The galaxy appears to be losing gas as it plunges through the Norma galaxy cluster.

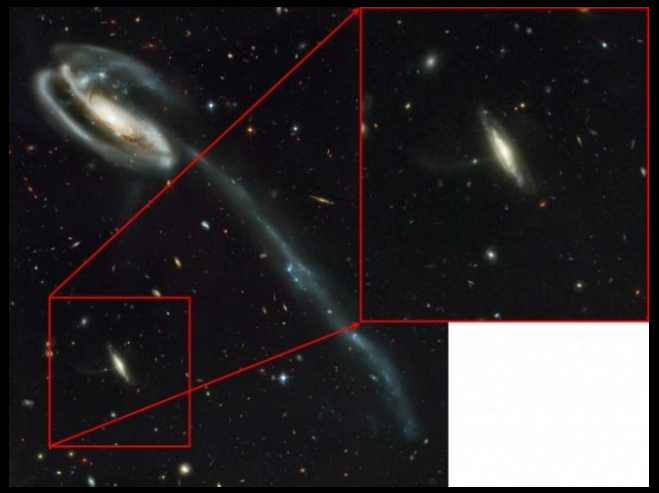
Animation



Environmental processes :

Dynamical

- Harassment
- Starvation – Strangulation
- Cannibalism



Thank you