

# Distance

What's the best distance indicator for:

- 1) A Local Group Galaxy?
- 2) A Globular Cluster?
- 3) A distant galaxy

- A) Geometric Parallax
- B) Spectroscopic Parallax
- C) Cepheid Variables
- D) Super Nova

# Overview

## A. The Great Debate

1. What was the debate about?
2. Who settled it and how?
3. What ELSE did Edwin find?
4. What is the implication of his discovery?

## B. Galaxies

1. What are the primary galaxy types?
2. What characterizes an Elliptical galaxy?
3. What characterizes the spiral galaxies?
4. What about irregulars?
5. What are groups and clusters?

# Overview

## C. Galaxy Evolution

1. How do we study galaxy evolution?
2. What are the primary formation scenarios?
3. What evidence do we have for each?

# The Great Debate



Shapley

You wanna  
fight about it?

Do you ever  
stop?



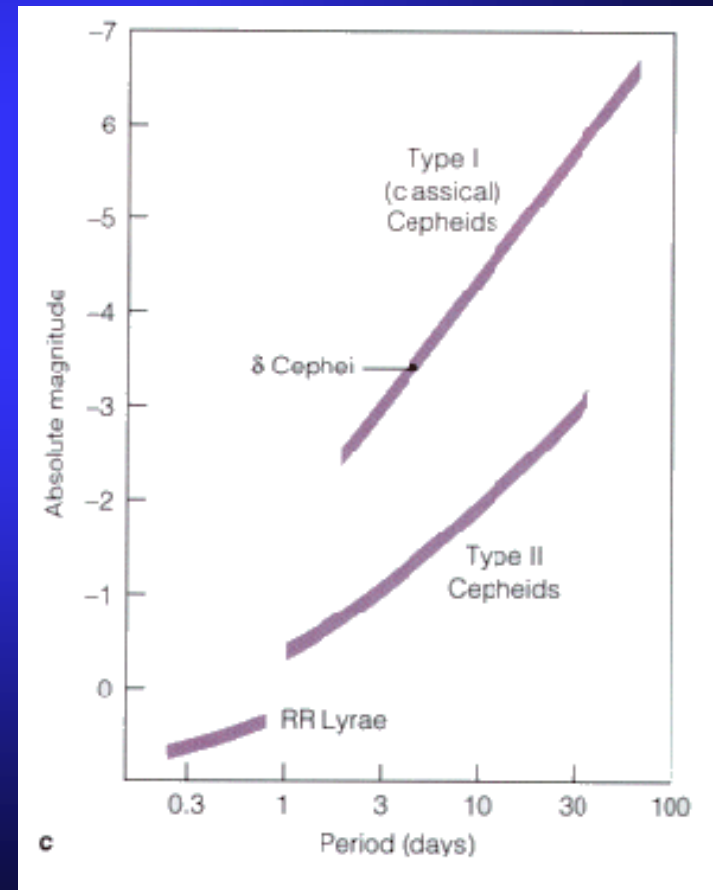
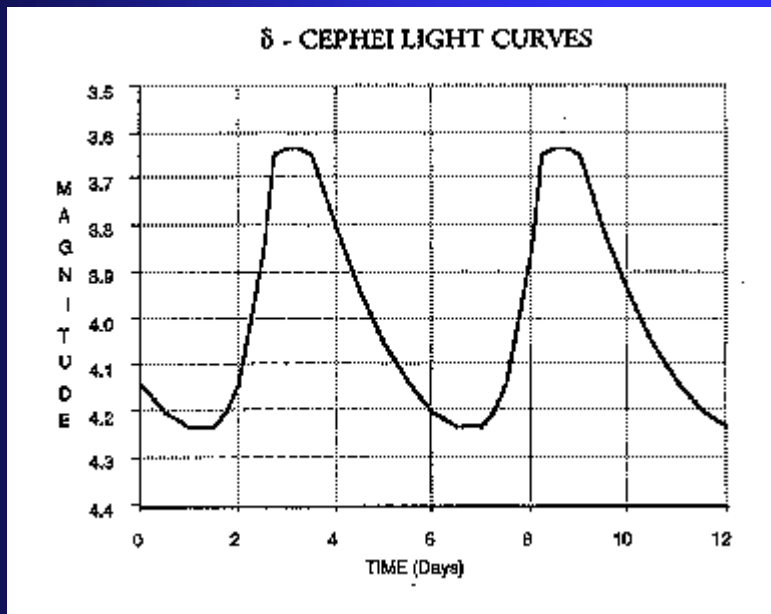
Curtis

**Shapley:** The universe is one big “galaxy”  
and the spiral nebula are within it.

**Curtis:** Galaxies are island universes and  
the Milky Way is but one of them.

# Cepheid Variables

Cepheids have a luminosity-period relationship

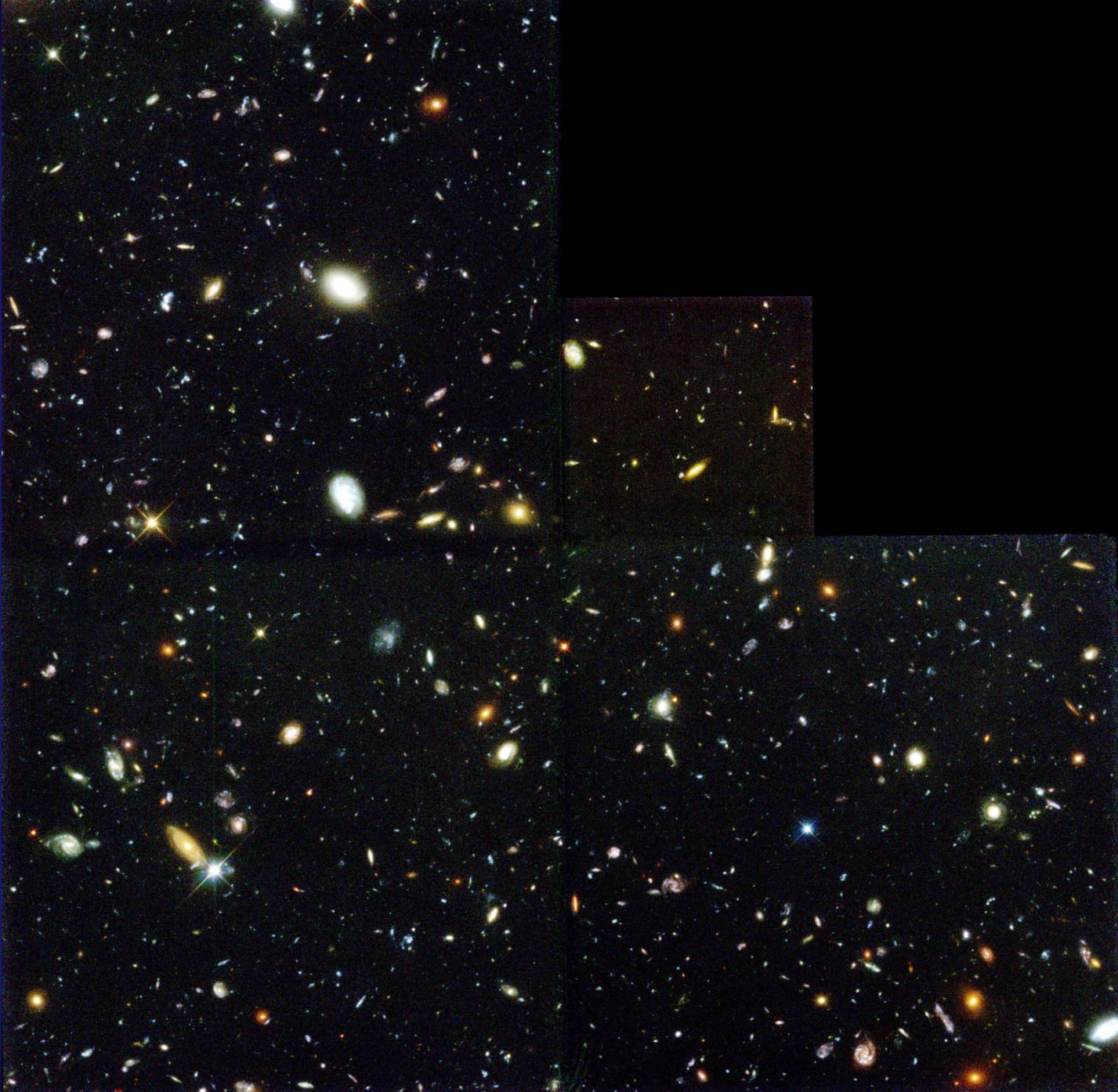


# M31 is Far Away

Edwin Hubble found a Cepheid in M31



M31 is beyond even large estimates of the size of the Milky Way

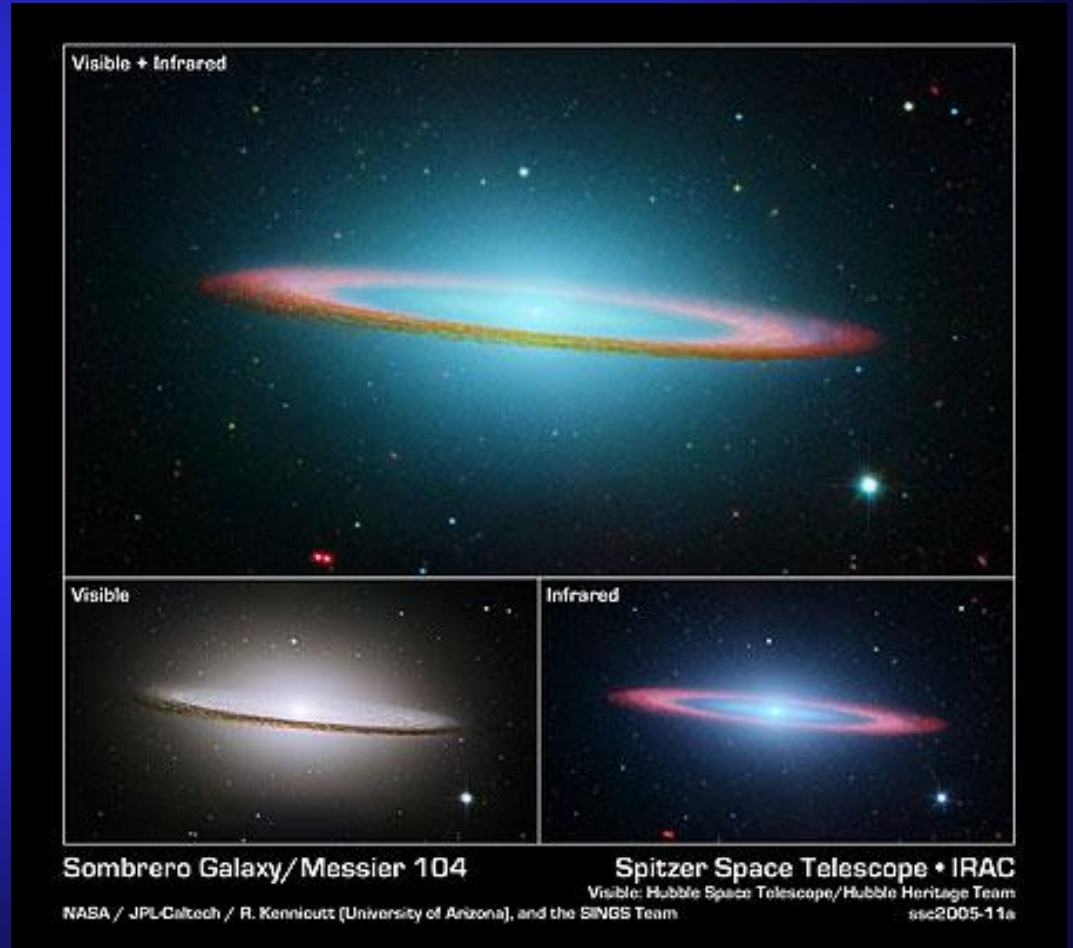


**Hubble Deep Field**

ST ScI OPO January 15, 1996 R. Williams and the HDF Team (ST ScI) and NASA

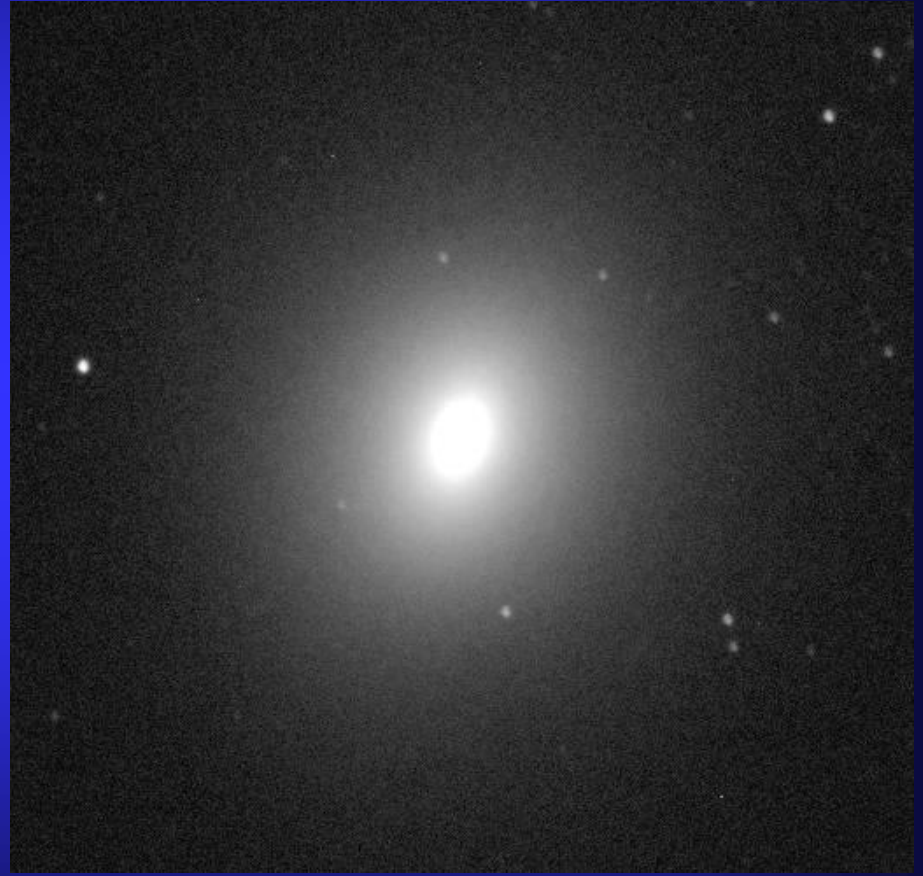
**HST** **WFPC2**

# Spirals





# Elliptical



# Spirals versus Ellipticals



Which type almost no O stars?

Which type almost no M stars?

Which type contains little dust?

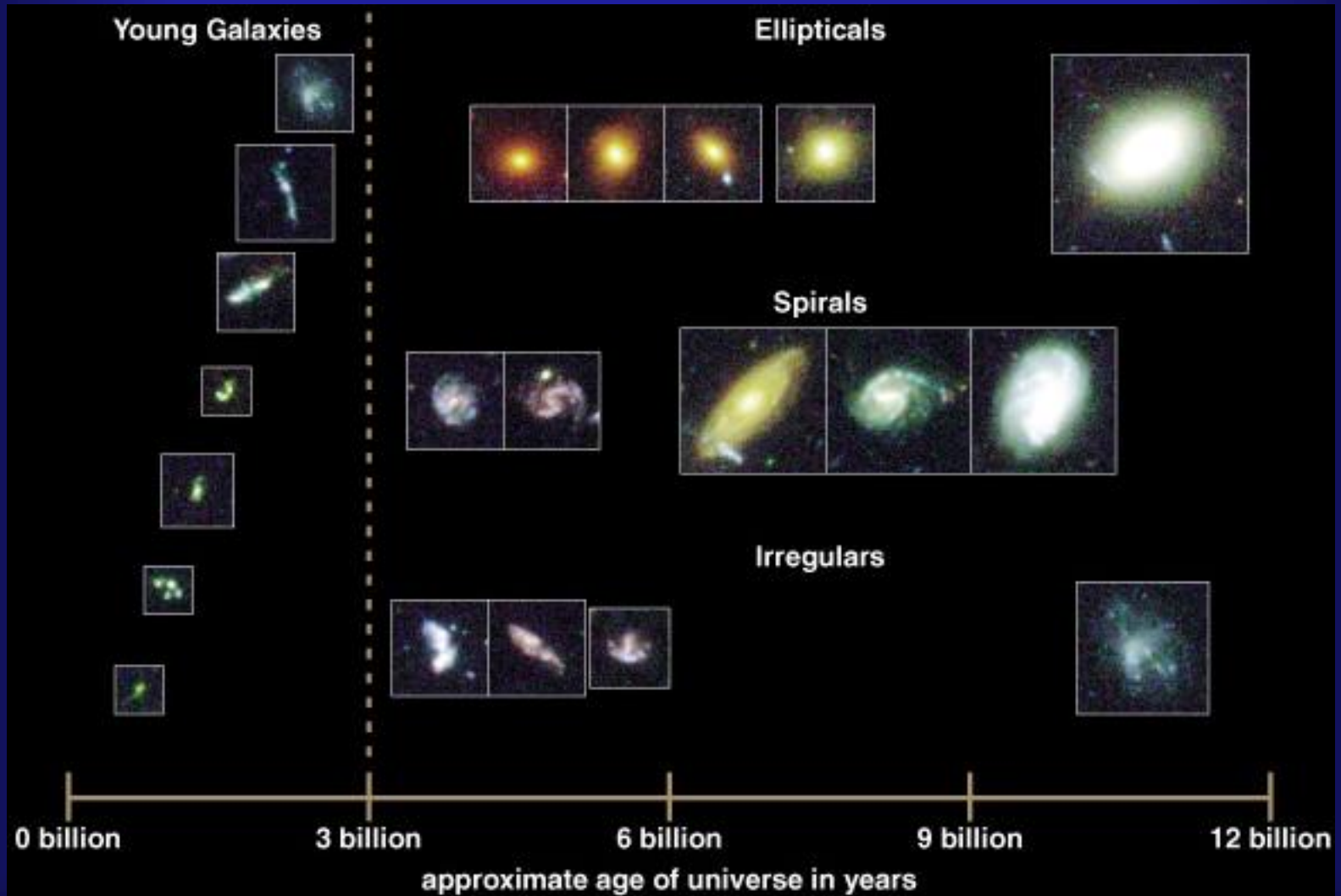
Which type forms the most new stars?

# Irregulars

They don't seem to fit in

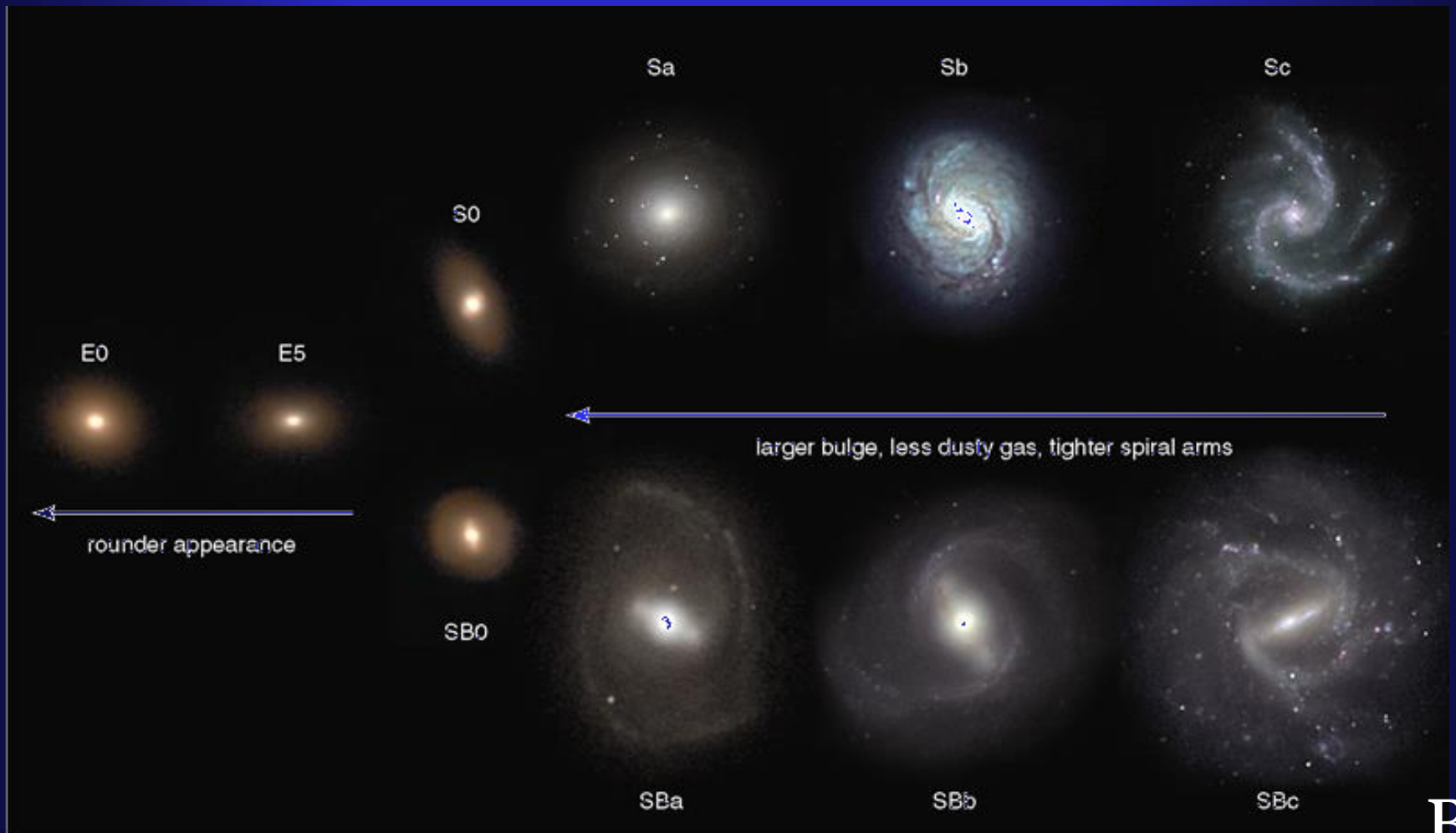


# Galaxy Evolution



# Galaxies

## The Tuning Fork



# Light

A light year is a unit of:

- A) Distance
- B) Time
- C) Velocity
- D) Acceleration

A) Distance. It's the distance that light can go in one year.

# Age

Judi lives 5 Lyr from you.

Beth lives 10 Lyr from you.

They transmit pictures to you on the day of their 12<sup>th</sup> birthday.

If you receive both pictures at the same time, who is older?

A) Judi

B) Beth

# Super Nova

When you need something  
REALLY bright

500 times  
brighter than  
Cepheids

Cross your fingers  
and wait for one  
to happen

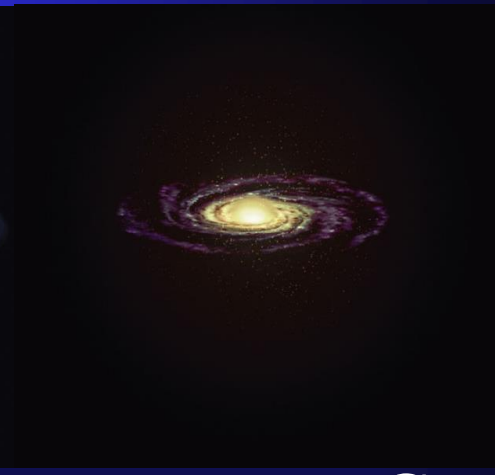
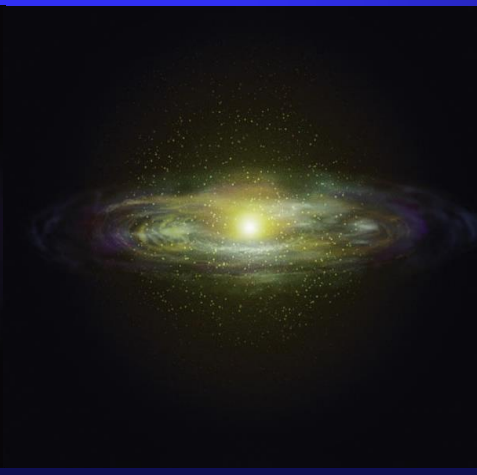
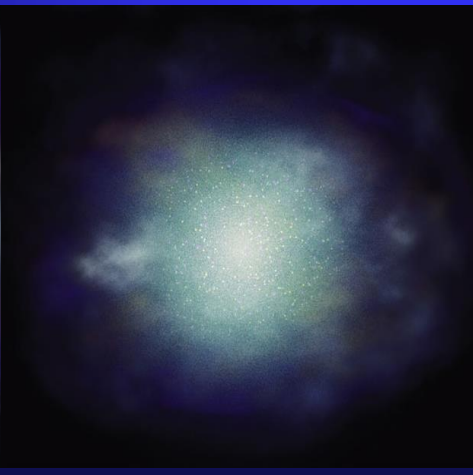
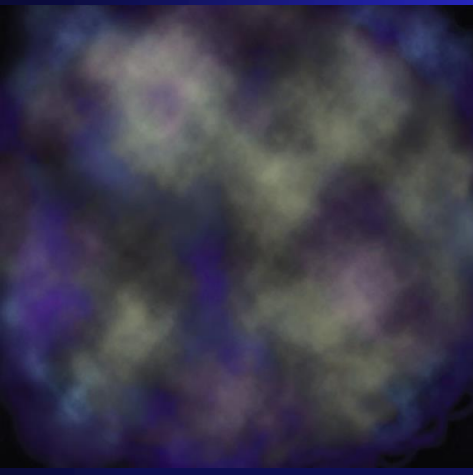




# Galaxy Formation-Top Down

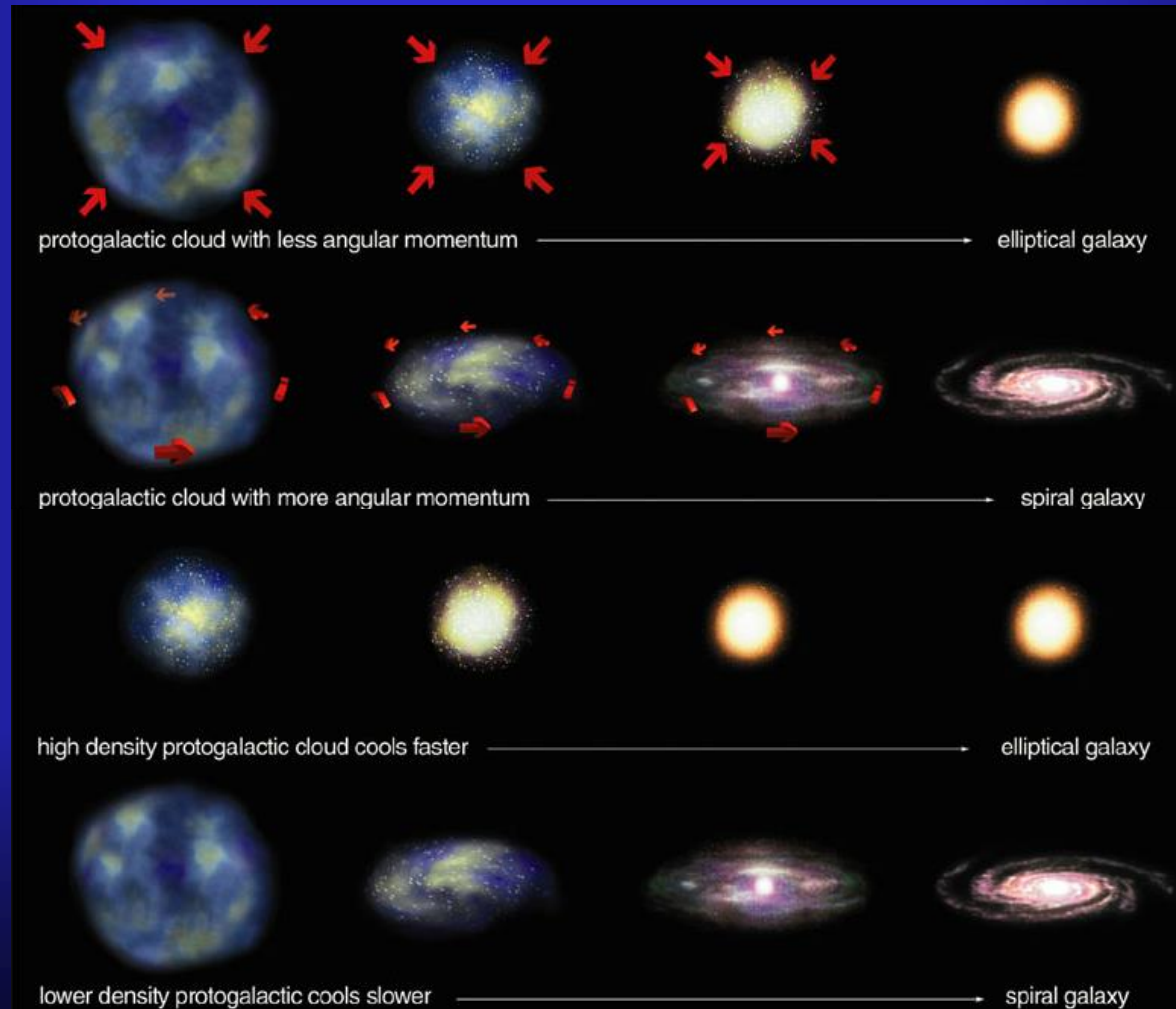
## Assumptions

- The early universe was uniformly filled with hydrogen and helium
- Well... Mostly uniform



# Galaxy Differences

## The top down model



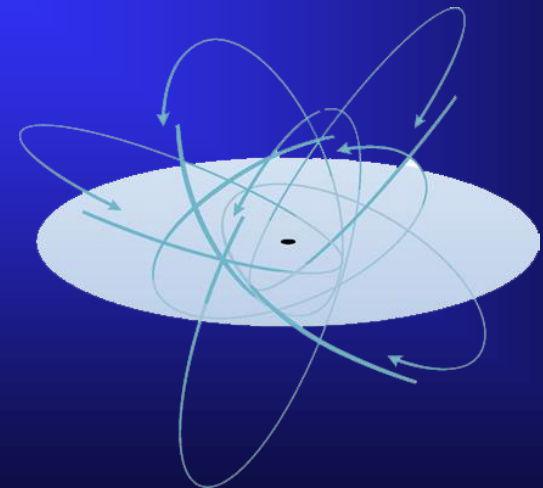
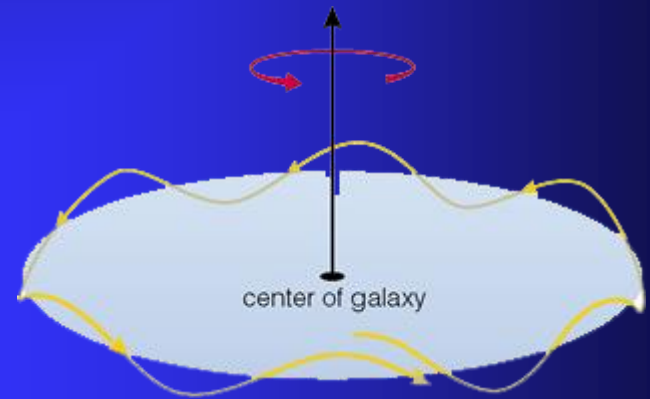
# Supporting Evidence



Colors

Metallicity?

## Orbits



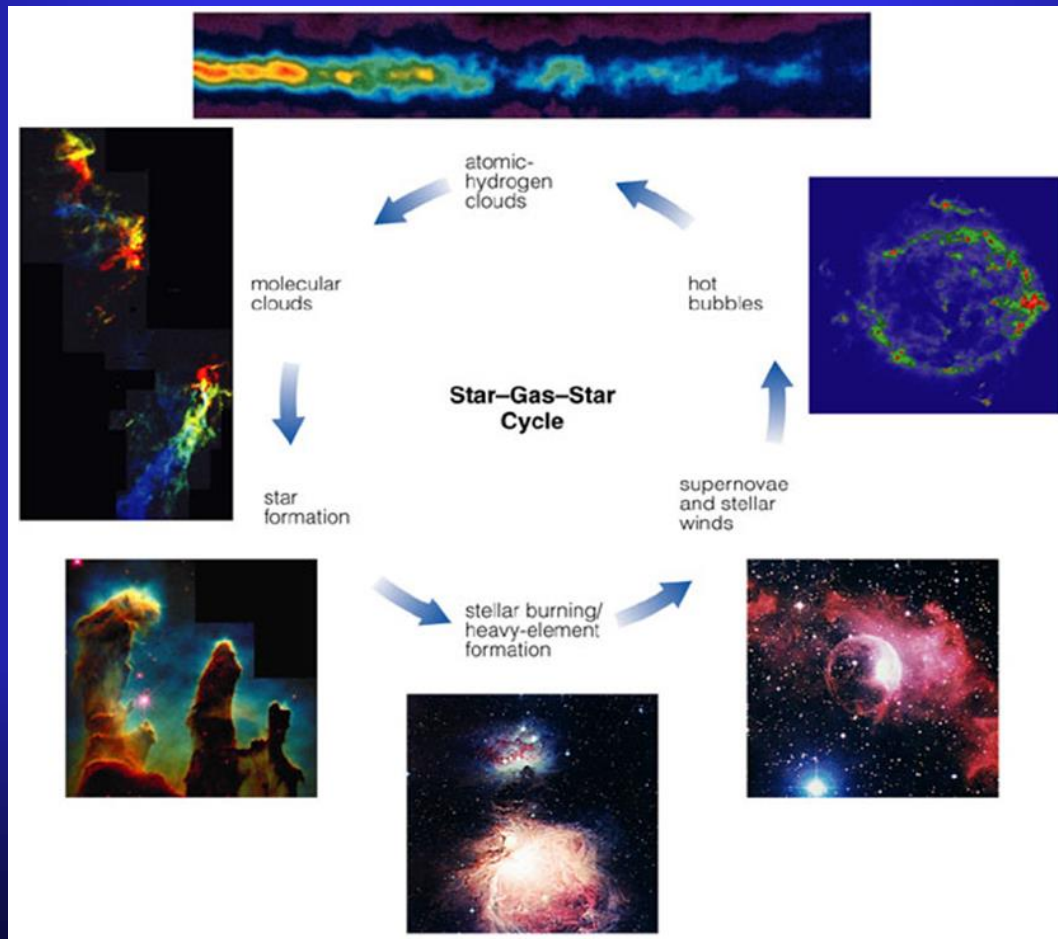
# History of Matter

**The Galaxy's metal content**

- A)** has been decreasing since its formation
- B)** has not changed since its formation
- C)** has been increasing since its formation
- D)** is not something we can measure

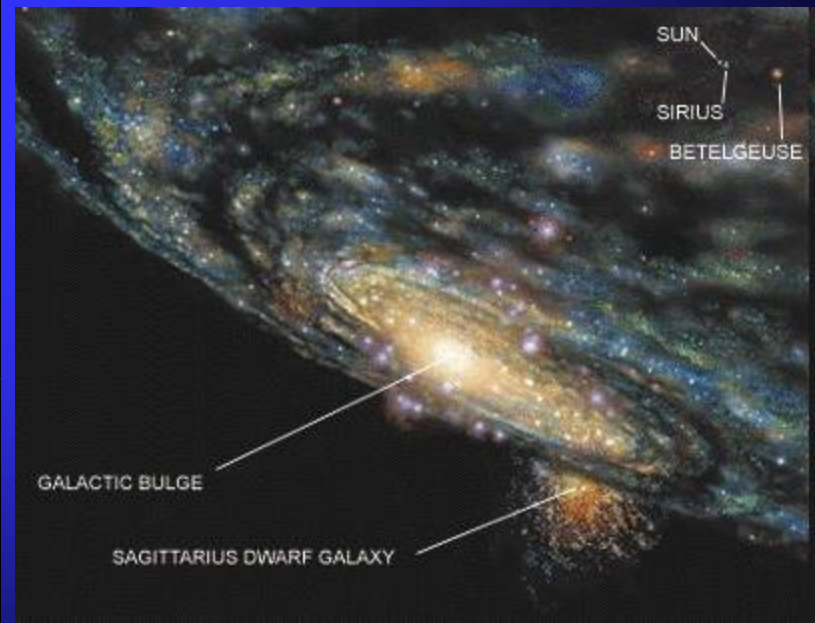
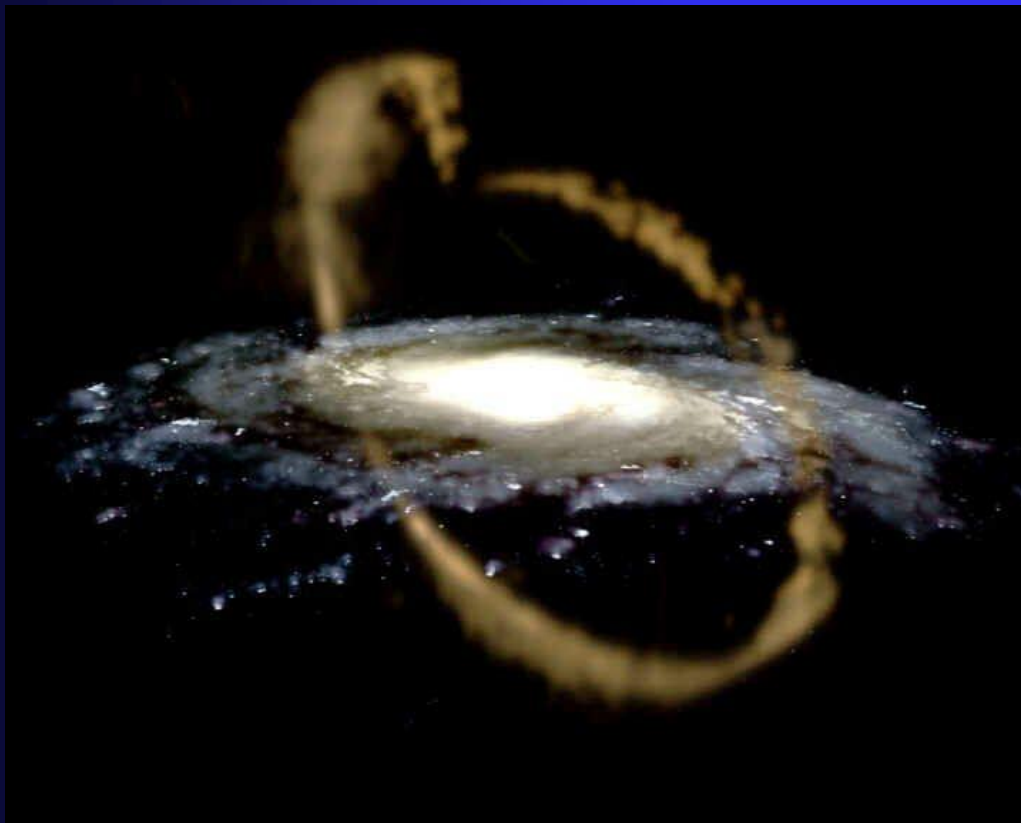
# Galactic Recycling Program

Material gets cooked in stars and ejected back into the disk



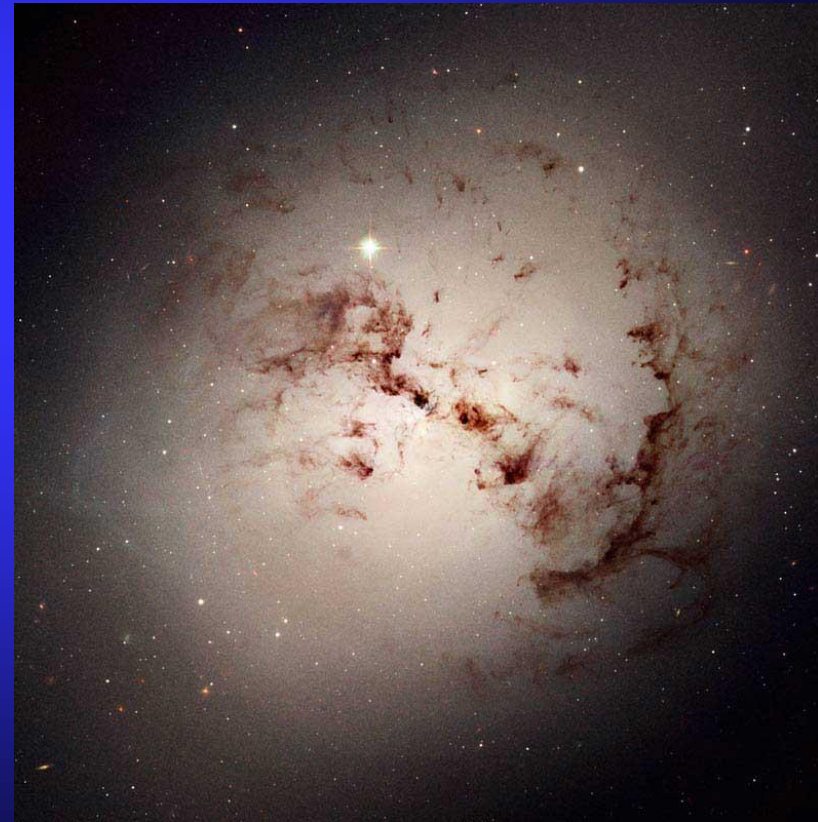
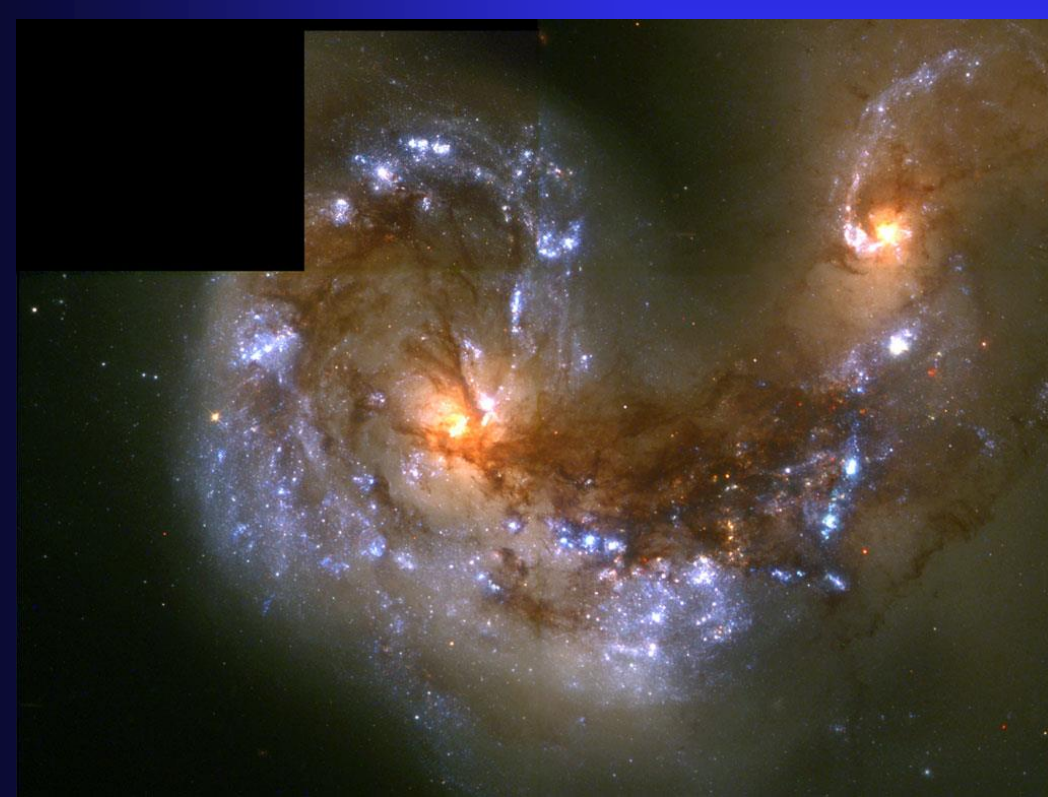
# Heirarchical Formation

Our halo does not appear to have formed from a single proto-galactic cloud



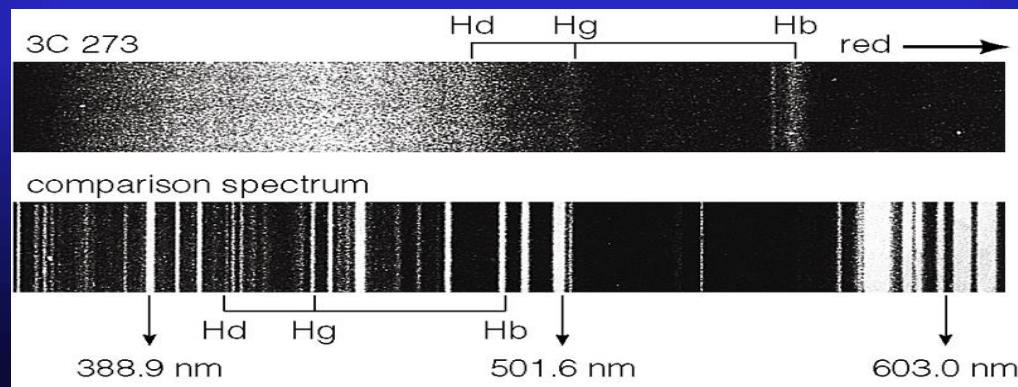
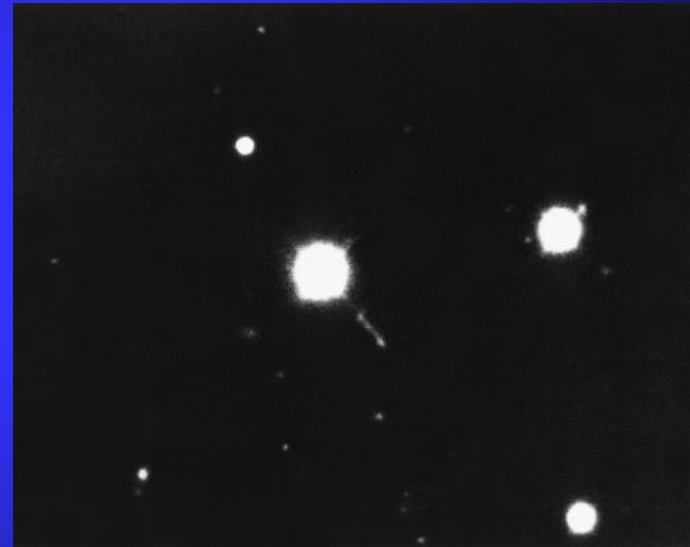
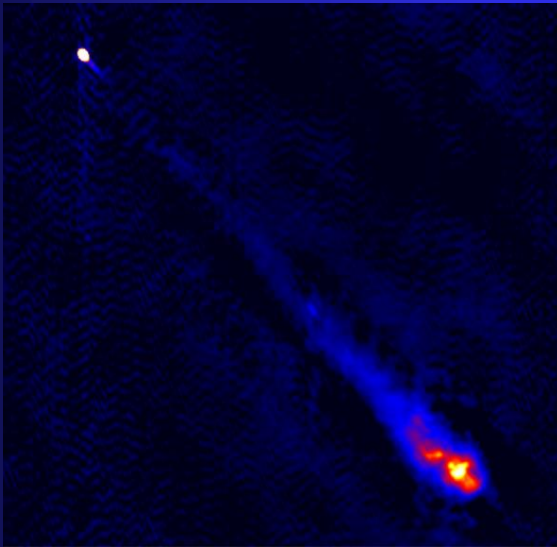
# Collisions

## When Spirals Collide



# 3C273

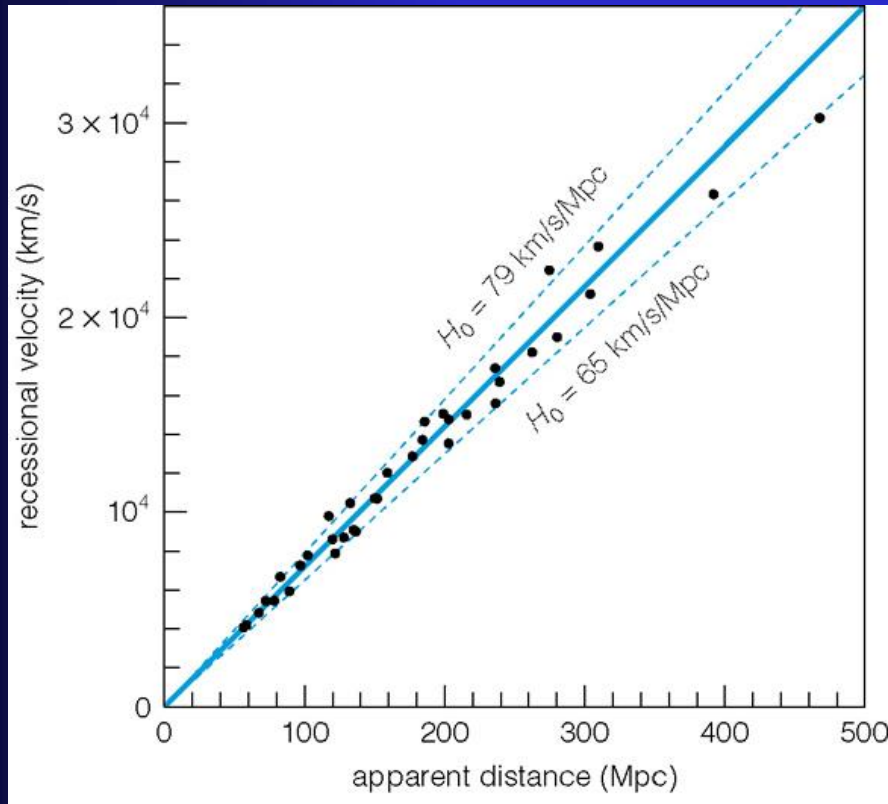
A radio source with unusual optical emission lines





# Hubble's Law

Galaxies are moving away from us



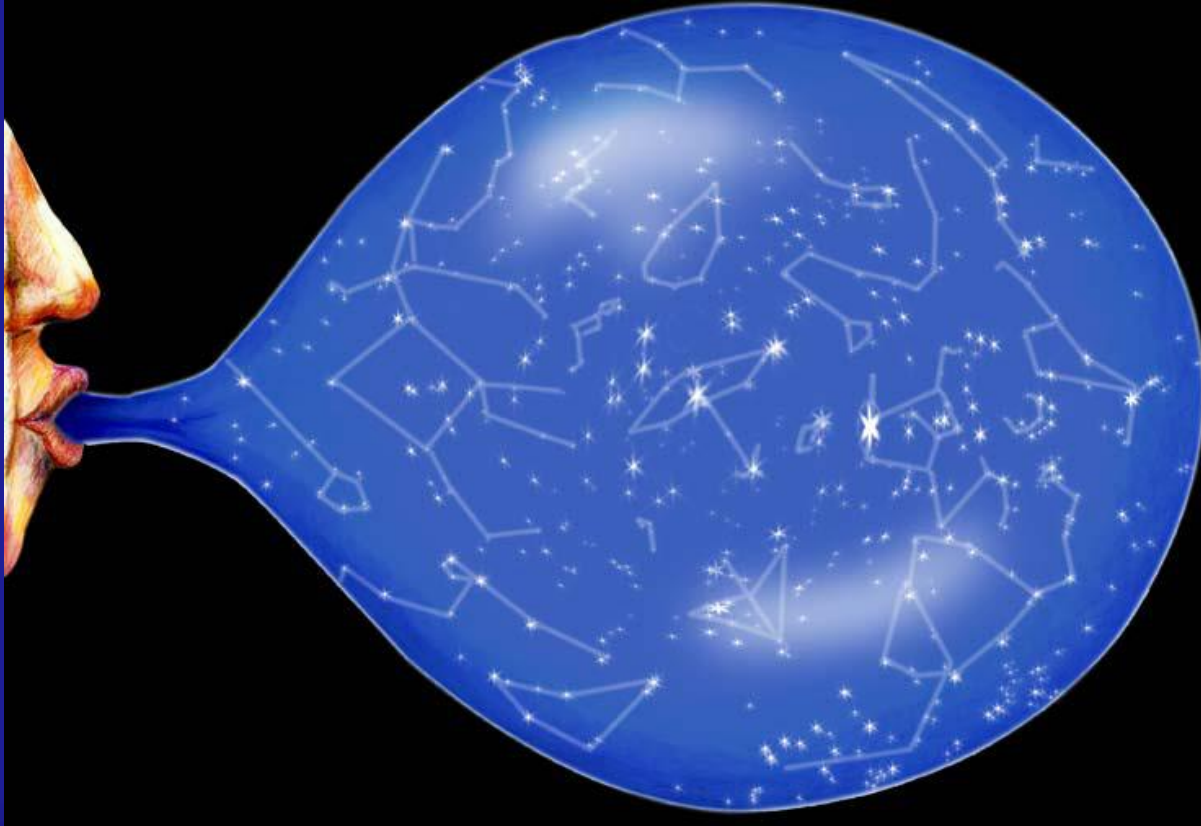
$$V = H_0 D$$



Farther = Faster

# Expanding Universe

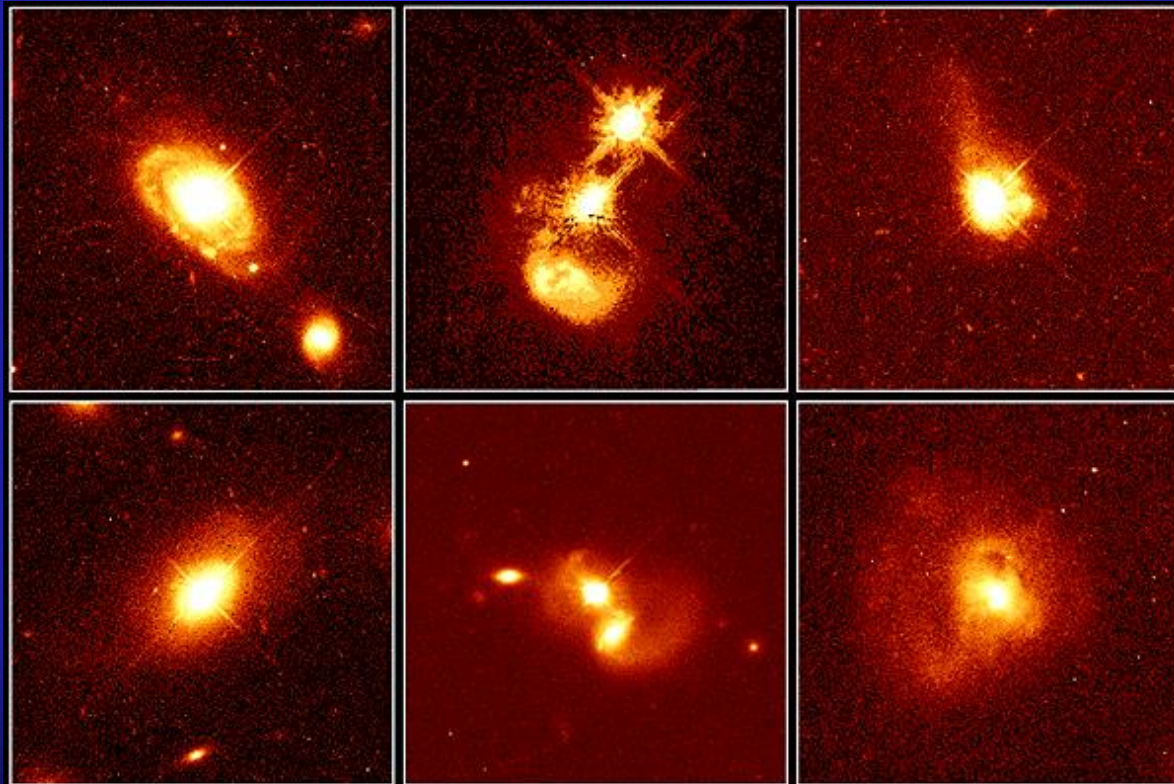
Are we at the center?



Is the answer ever yes?

# Quasars

They are at the centers of  
**extremely distant galaxies**



**Quasar Host Galaxies**

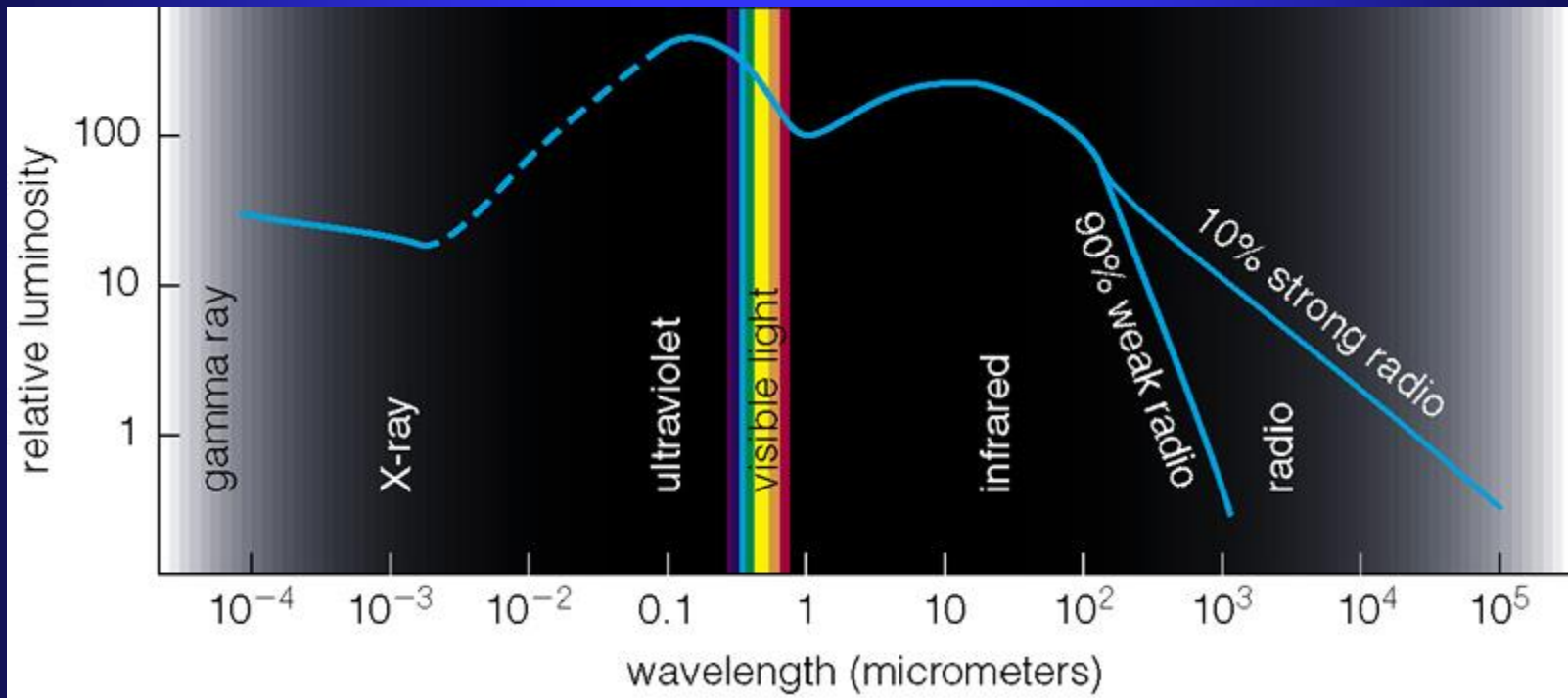
**HST • WFPC2**

PRC96-35a • ST Scl OPO • November 19, 1996

J. Bahcall (Institute for Advanced Study), M. Disney (University of Wales) and NASA

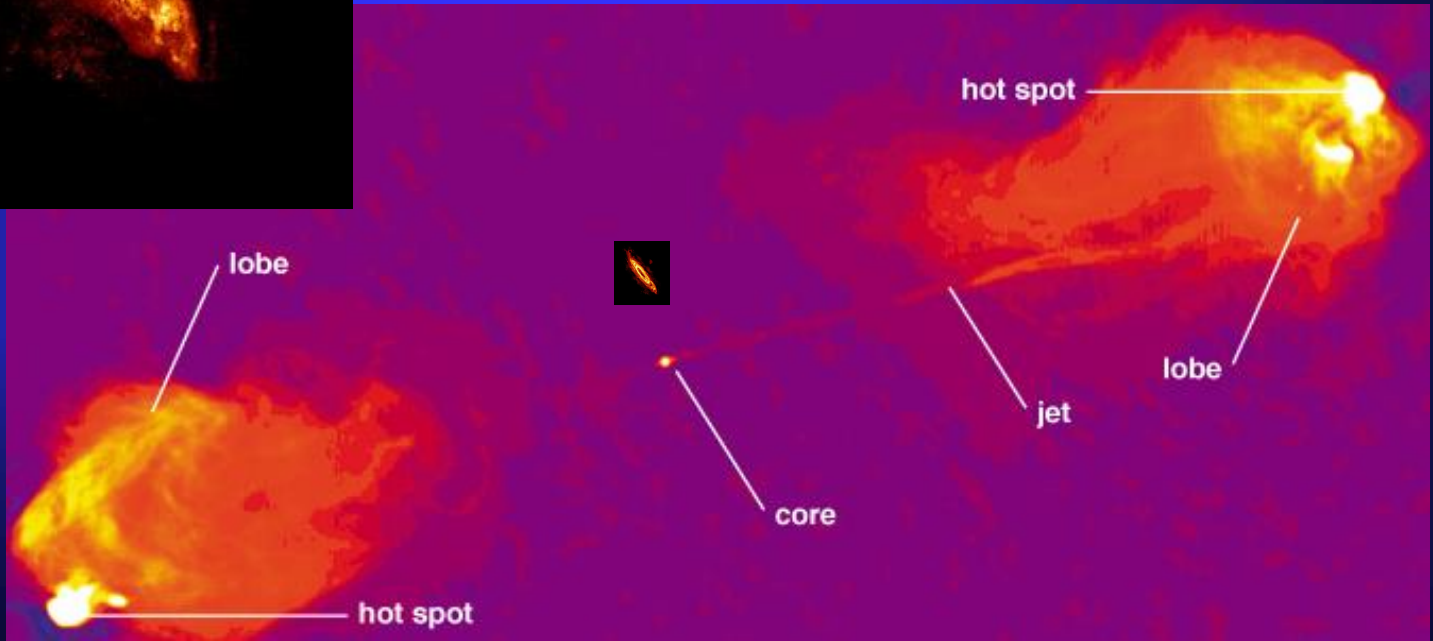
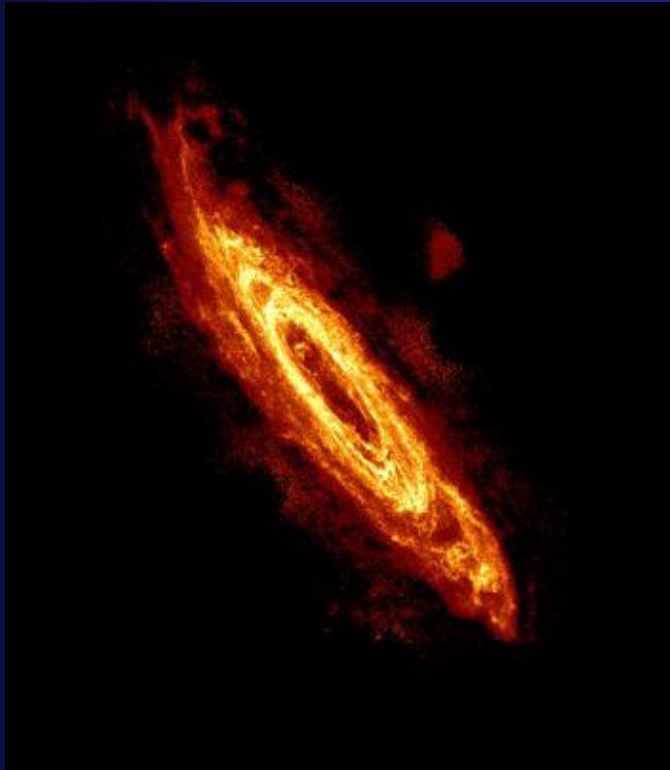
# Active Galactic Nuclei

Nearby galactic centers with  
quasar like characteristics



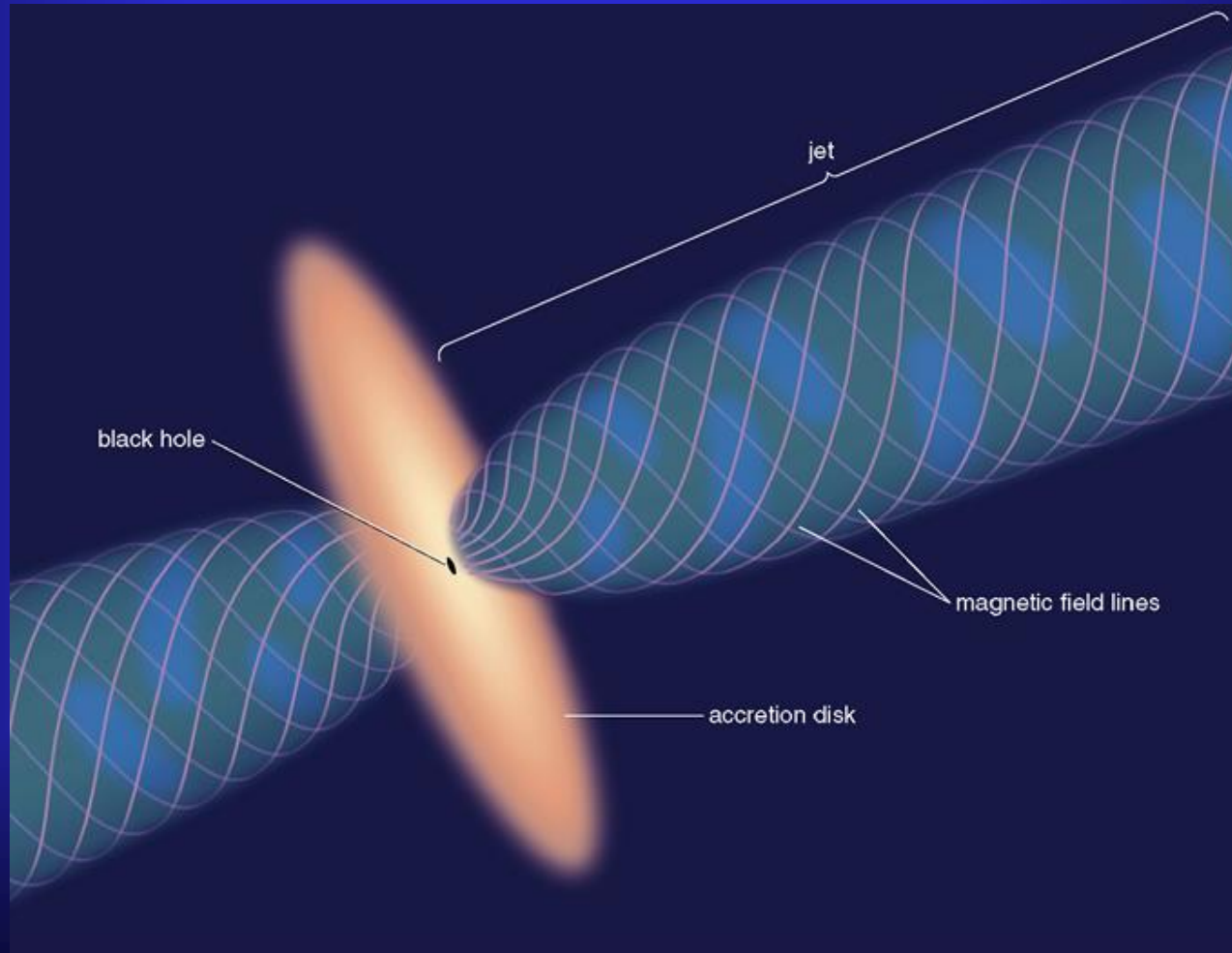
# AGN

The radio emission comes from jets



# Super Massive Black Holes

Gravitational potential into light



# Groups and Clusters

Galaxies like company

