



Universidad Nacional de Río Negro

Int Partículas, Astrofísica & Cosmología - 2021

- **Unidad** 03-Astrofísica, galaxias y Universo
- **Clase** UO3 C01 - 11/16
- **Fecha** 13 Oct 2021
- **Cont** Galaxias
- **Cátedra** Asorey





U3: Astrofísica, escalas grandes

4 encuentros, del 06/Oct al 27/Oct

- Relatividad General.
 - Introducción y conceptos básicos.
 - Solución de Schwarzschild.
 - Objetos compactos: enanas blancas, estrellas de neutrones y agujeros negros.
- Formación de estructuras
 - Galaxias: Modelos y formación. GalaxyZoo.
 - Galaxias de Núcleos activos. Clasificación.
 - Formación de estructuras. Corrimiento al rojo y el universo en expansión.
- Trabajo unidad → fecha máxima de entrega 12/Nov

Contenidos: un viaje en el tiempo y el espacio

HOW DID OUR UNIVERSE BEGIN?

Inflation
Some 13.8 billion years ago our entire visible universe was contained in an unimaginably hot, dense point, a billionth the size of a nuclear particle. Since then it has expanded—a lot—fighting gravity all the way.

Early building blocks
The universe expands, cools. In less than a nanosecond a massive energy field infuses space with particles that fill it with a soup of subatomic particles called quarks.

First nucleci
As the universe continues to cool, the light of hydrogen begins to arise. This light is as far back as our instruments can see.

First atoms, first light
Quarks clump into protons and neutrons, creating the building blocks of atomic nuclei. Perhaps dark matter forms.

The "dark ages"
For 300 million years this continues, with no light in sight. As electrons begin orbiting nuclei, creating atoms, the glow from their orbits begins to appear. This light is as far back as our instruments can see.

Gravity wins: first stars
Dense gas clouds collapse under their own gravity. Clumps of dark matter begin to form galaxies and stars. Fusion lights up the stars.

Antigravity wins
After being slowed for billions of years, cosmic expansion accelerates again. The culprit: dark energy. Its nature: unclear.

Today
The universe continues to expand, becoming ever less dense. As a result, fewer new stars and galaxies are forming.

COSMIC QUESTIONS

In the 20th century the universe became a story—a scientific one. It had always been seen as static and eternal. Then astronomers observed other galaxies flying away from ours, and Einstein's general relativity theory implied space itself was expanding—which meant the universe had once been denser. What had seemed eternal now had a beginning and an end. But what beginning? What end? Those questions are still open.

WHAT IS OUR UNIVERSE MADE OF?

Stars, dust and gas—the stuff we can discern—make up less than 5 percent of the universe. Their gravity can't account for how galaxies hold together. Scientists figure about 24 percent of the universe is a mysterious dark matter—perhaps exotic particles formed right after inflation. The rest is dark energy, an unknown energy field or property of space that counters gravity, providing an explanation for observations that the expansion of space is accelerating.

The Universe

71.5%	Dark energy
24%	Dark matter
4%	Gas
0.5%	Planets and stars

WHAT IS THE SHAPE OF OUR UNIVERSE?

Einstein discovered that a star's gravity curves space around it. But is the whole universe curved? Might space close up on itself like a sphere or curve the other way, opening out like a saddle? By studying cosmic background radiation, scientists have found that the universe is poised between the two: just dense enough with just enough gravity to be almost perfectly flat, at least the part we can see. What lies beyond we can't know.

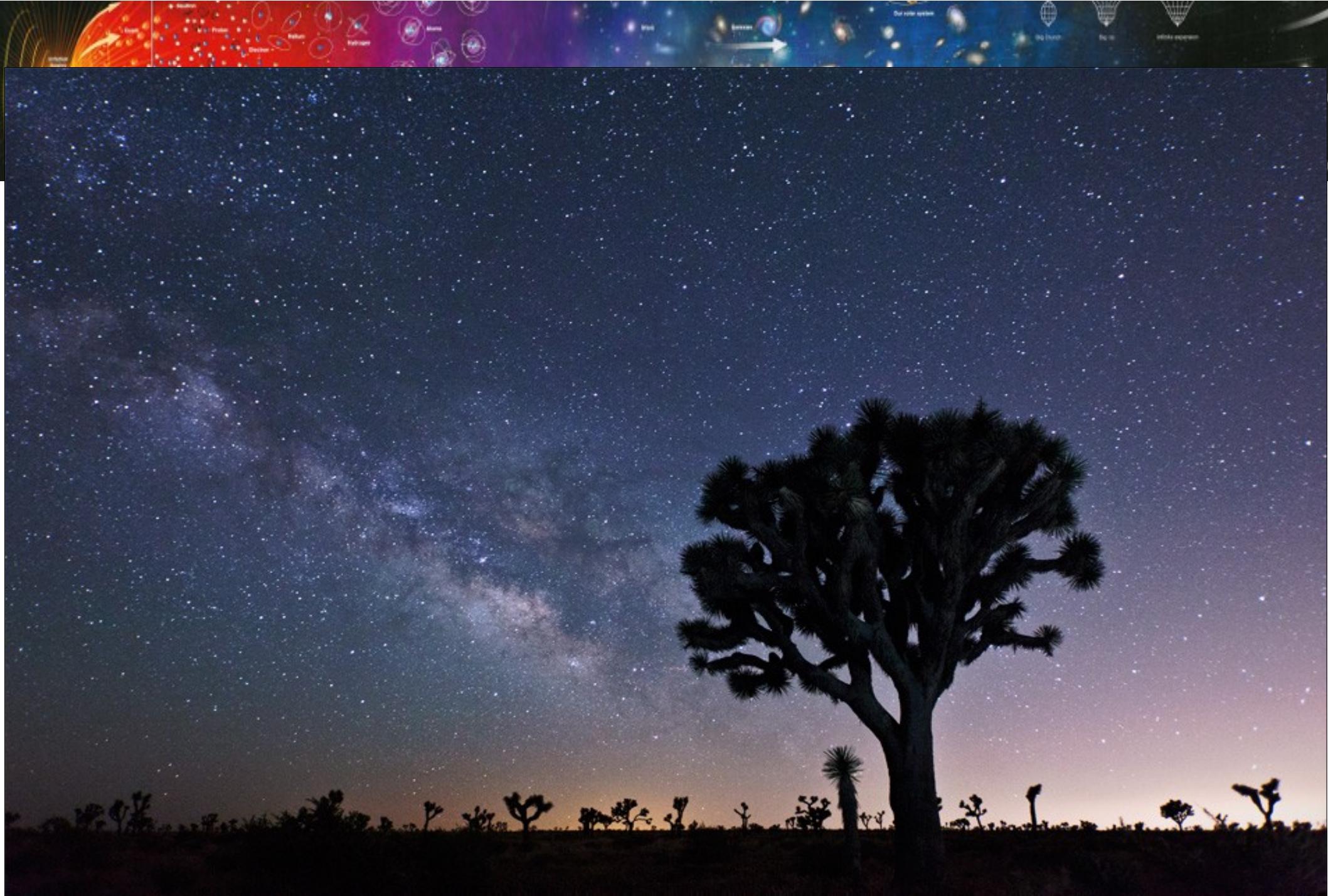
WHAT WILL IT END?

Which will win in the end, gravity or antigravity? Is the density of matter enough for gravity to halt or even reverse cosmic expansion, leading to a big crunch? It seems unlikely—especially given the power of dark energy, a kind of antigravity. Perhaps the acceleration in expansion caused by dark energy will trigger a big rip that shreds everything, from galaxies to atoms. If not, the universe may expand for hundreds of billions of years, long after all stars have died.

**Unidad 3
Astrofísica,
escalas grandes**

**Unidad 2
Astrofísica,
escalas medias**

**Unidad 1
Partículas,
lo más pequeño**

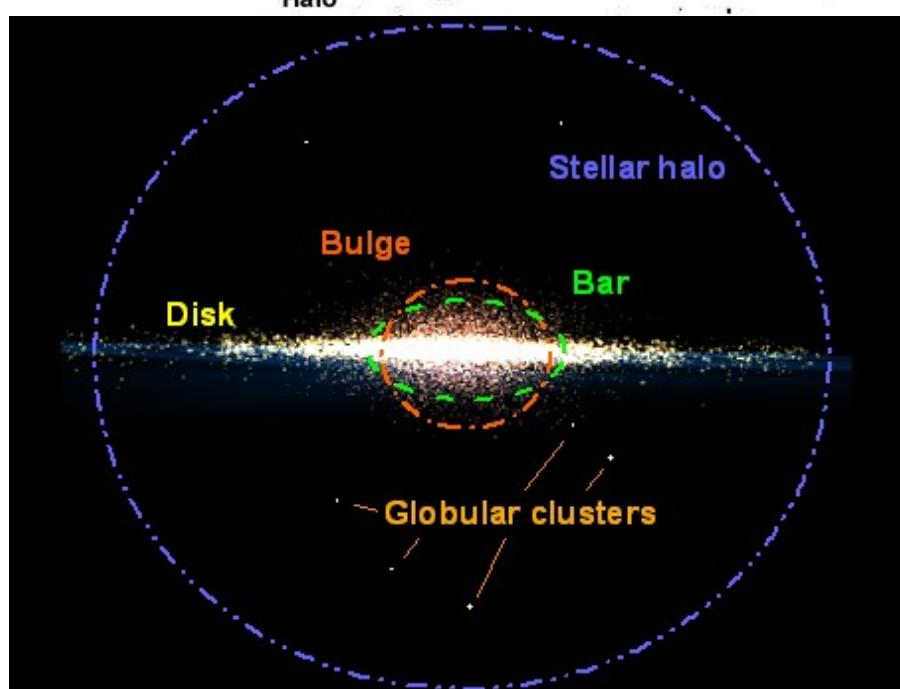
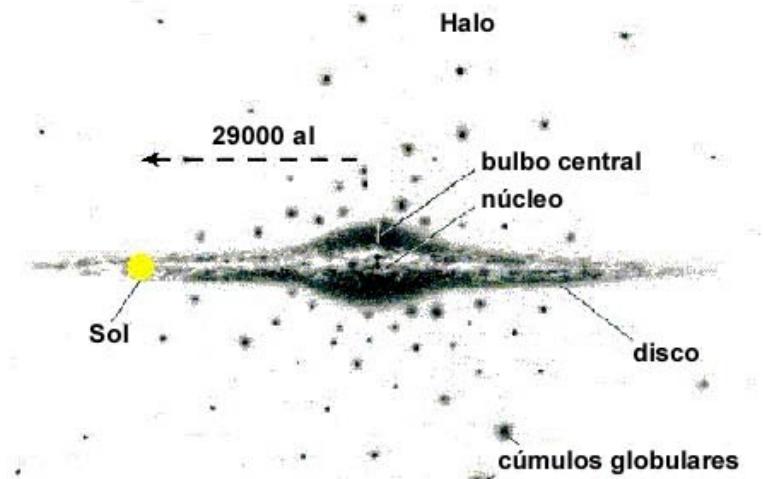




Galaxias

- Una **galaxia** es un sistema autogravitante compuesto por:
 - Estrellas (Vía Láctea: 10^{11} estrellas)
 - Remanentes estelares
 - Un medio interestelar formado por gas y polvo...
 - Un agujero negro central (no en todas, pero...)
 - Materia oscura (no está confirmada, pero...)
- **Tamaños:**
 - Enanas (~1000 estrellas, 1000 pc)
 - Gigantes (100000 pc, 10^{14} estrellas)
- Están separadas por distancias ~Mpc (1 Mpc ~ $3,1 \times 10^{22}$ m)

Componentes de una galaxia



- **Disco**

- Estrellas (solas o en cúmulos abiertos), polvo y gas distribuidos en forma de un disco delgado

- **Bulbo**

- Distribución esférica de estrellas viejas y rojizas cerca del centro.

- **Núcleo**

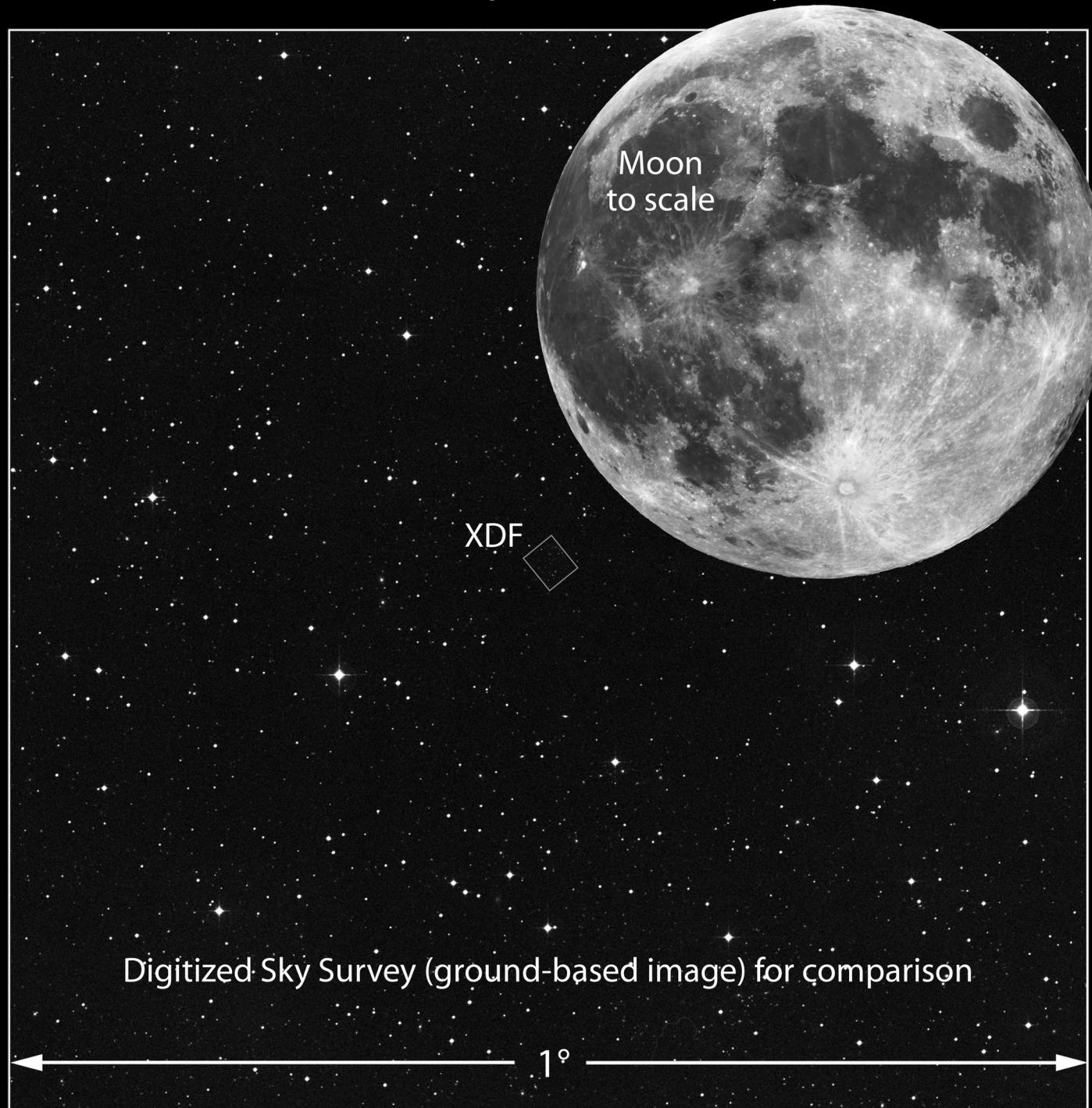
- Acumulación de estrellas en el centro de la galaxia. Usualmente hay un agujero negro muy masivo en el centro

- **Halo**

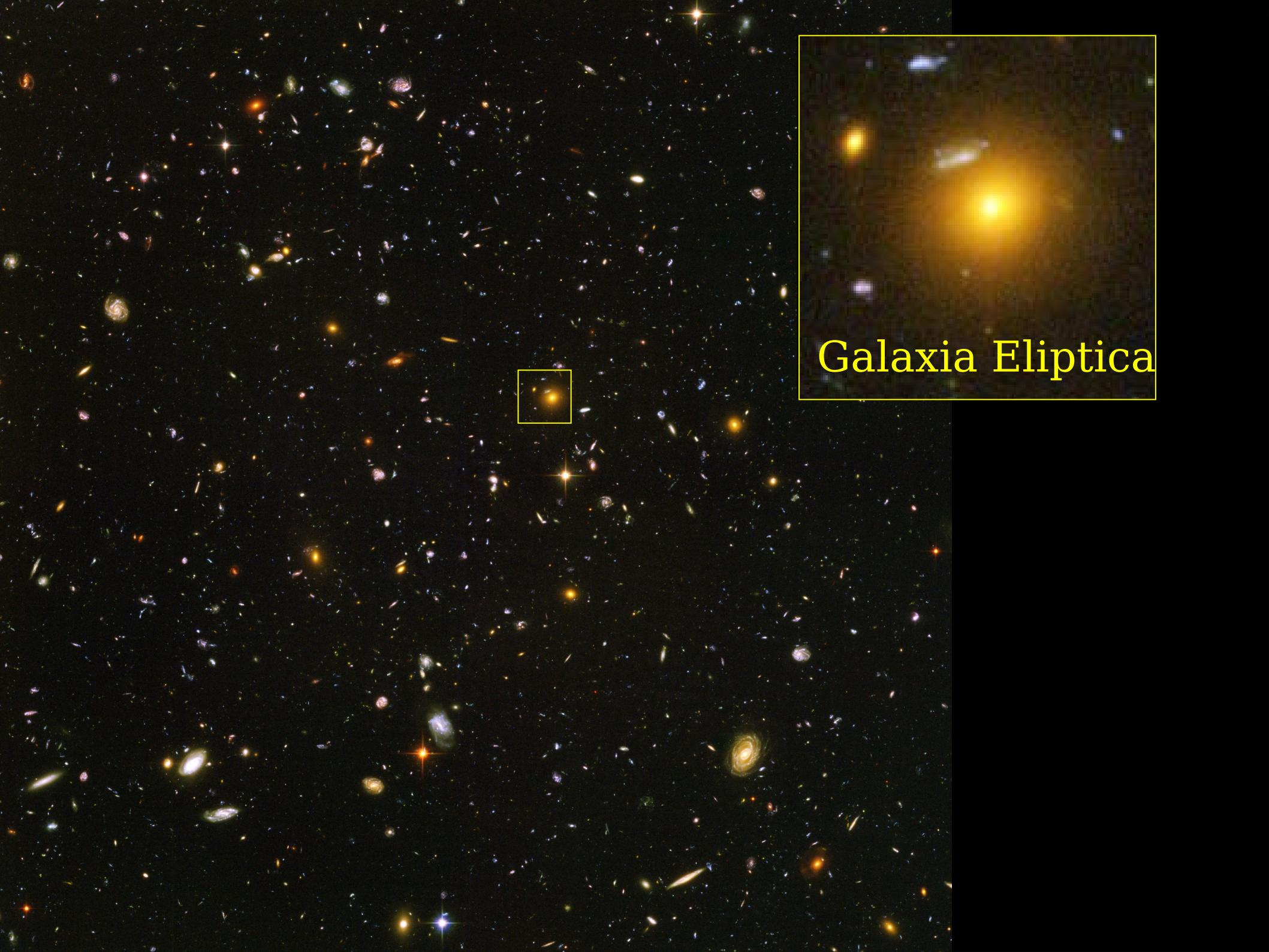
- Distribución esférica de estrellas y cúmulos globulares (cúmulos de millones de estrellas viejas (gigantes rojas))



Size of Hubble eXtreme Deep Field on the Sky





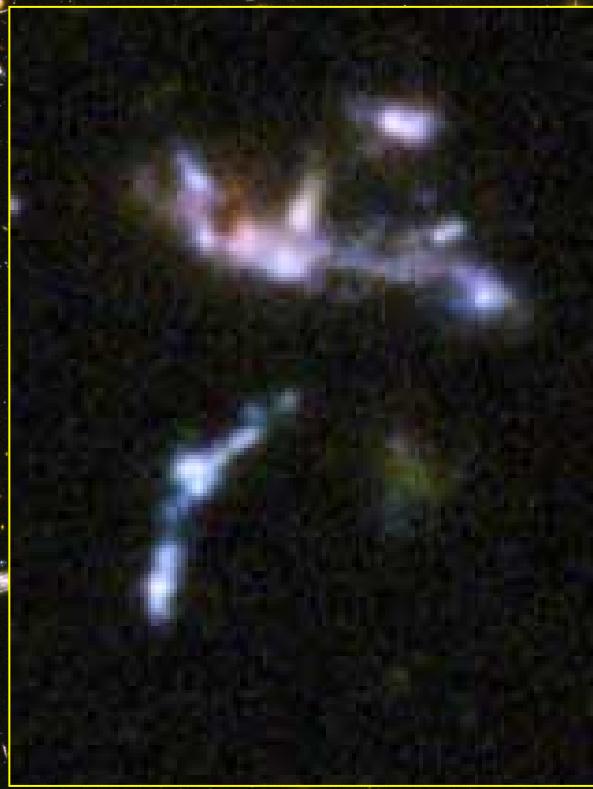
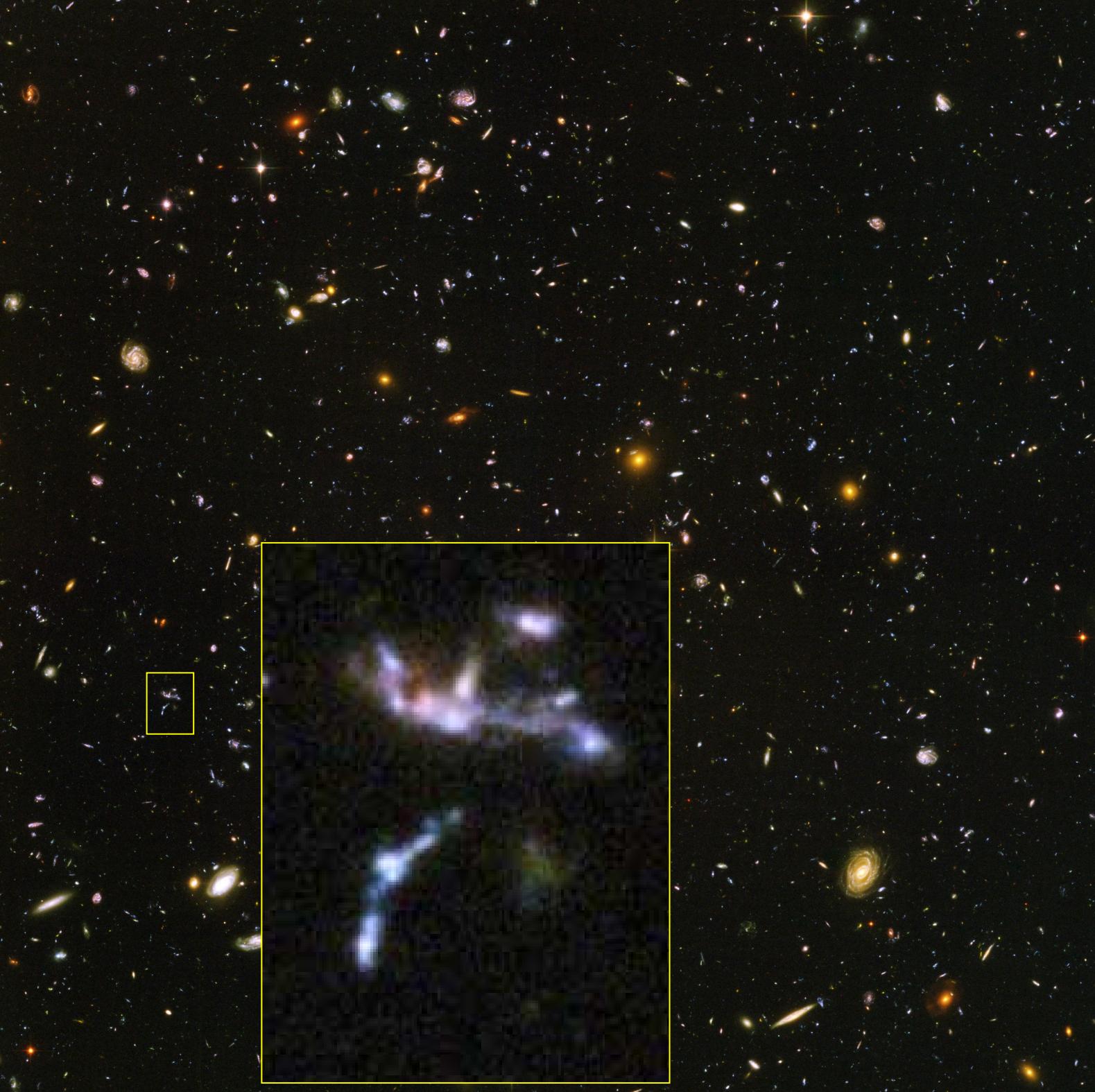


Galaxia Eliptica



en Galáctica





Clasificación Galáctica



Clasificación Galáctica



Clasificación Galáctica



The Sombrero Galaxy — M104



HUBBLESITE.org

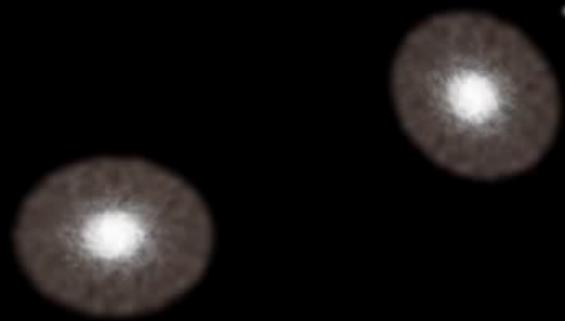
Clasificación Galáctica



Clasificación Galáctica (NGC4038/9)



Colisión de Galaxias



Galaxia de Anillo (Hoag)



Colisión galáctica (NGC4676 - Mice galaxies)

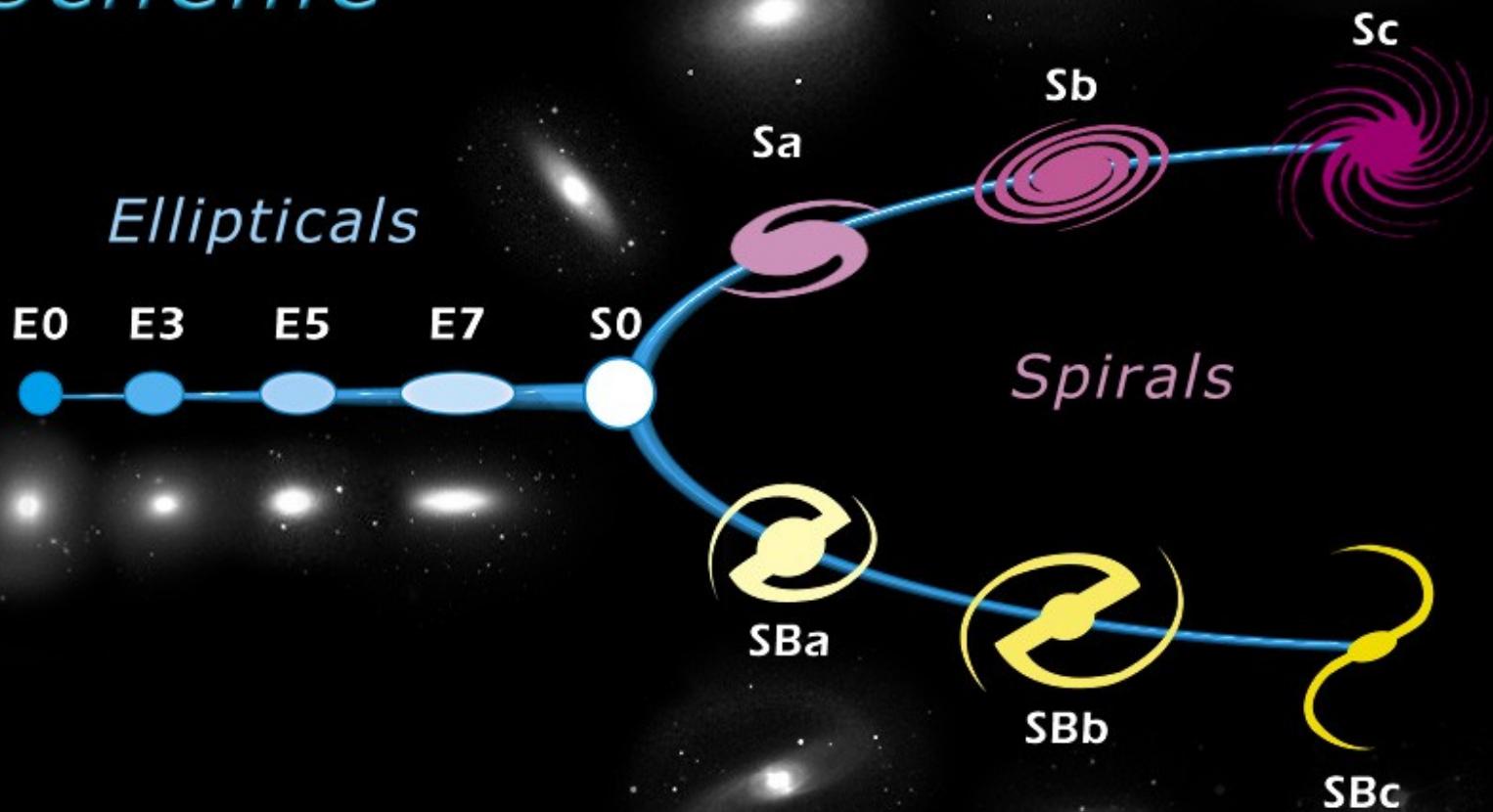


Colisión galáctica: ARP 273

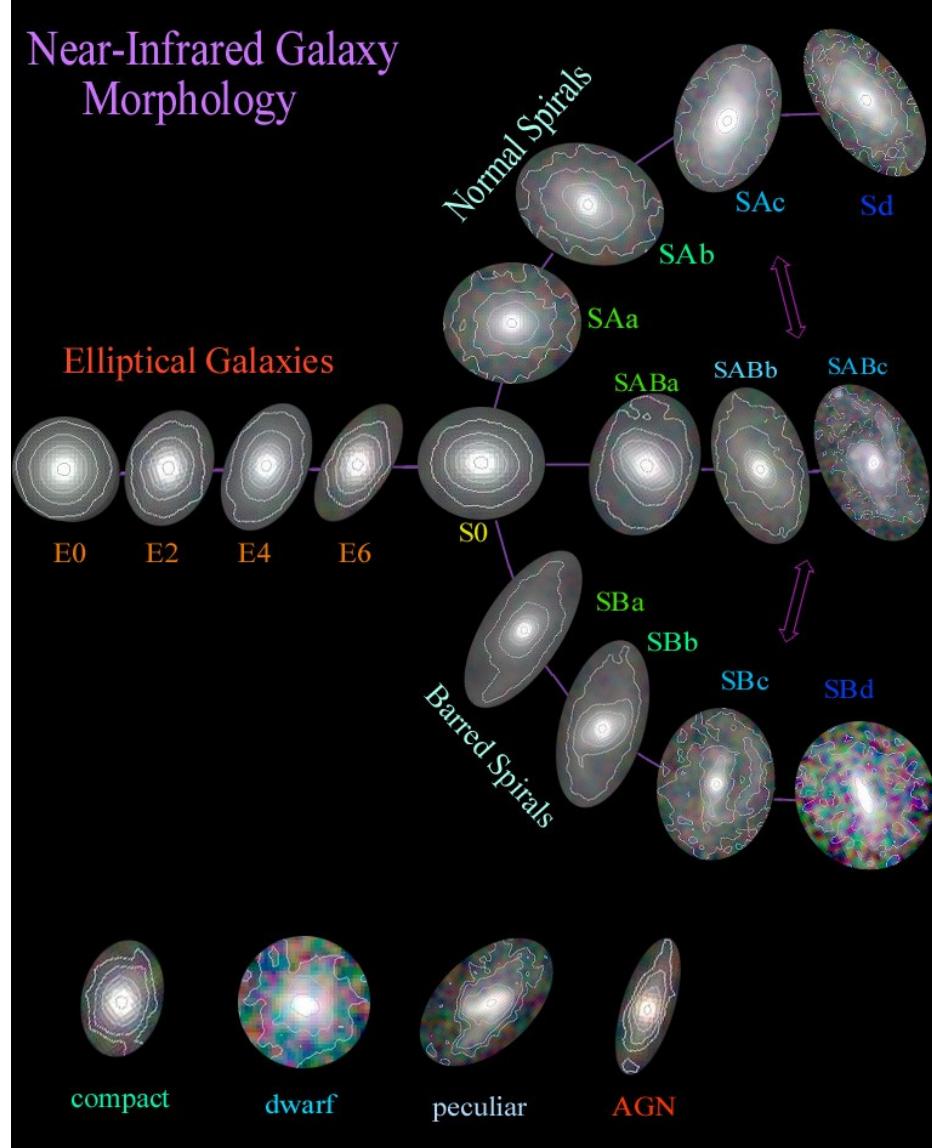


Clasificación galáctica, Hubble

Edwin Hubble's Classification Scheme



Clasificación galáctica



Tipo	Fracción
Espirales	60%
Elípticas	13%
Lenticulares	22%
Irregulares	3%
Peculiares	1%

- **Ley de De Vaucouleurs**
Variación de la intensidad luminosa como función del radio

$$I(r) = I_0 e^{-\sqrt[4]{r/r_0}}$$

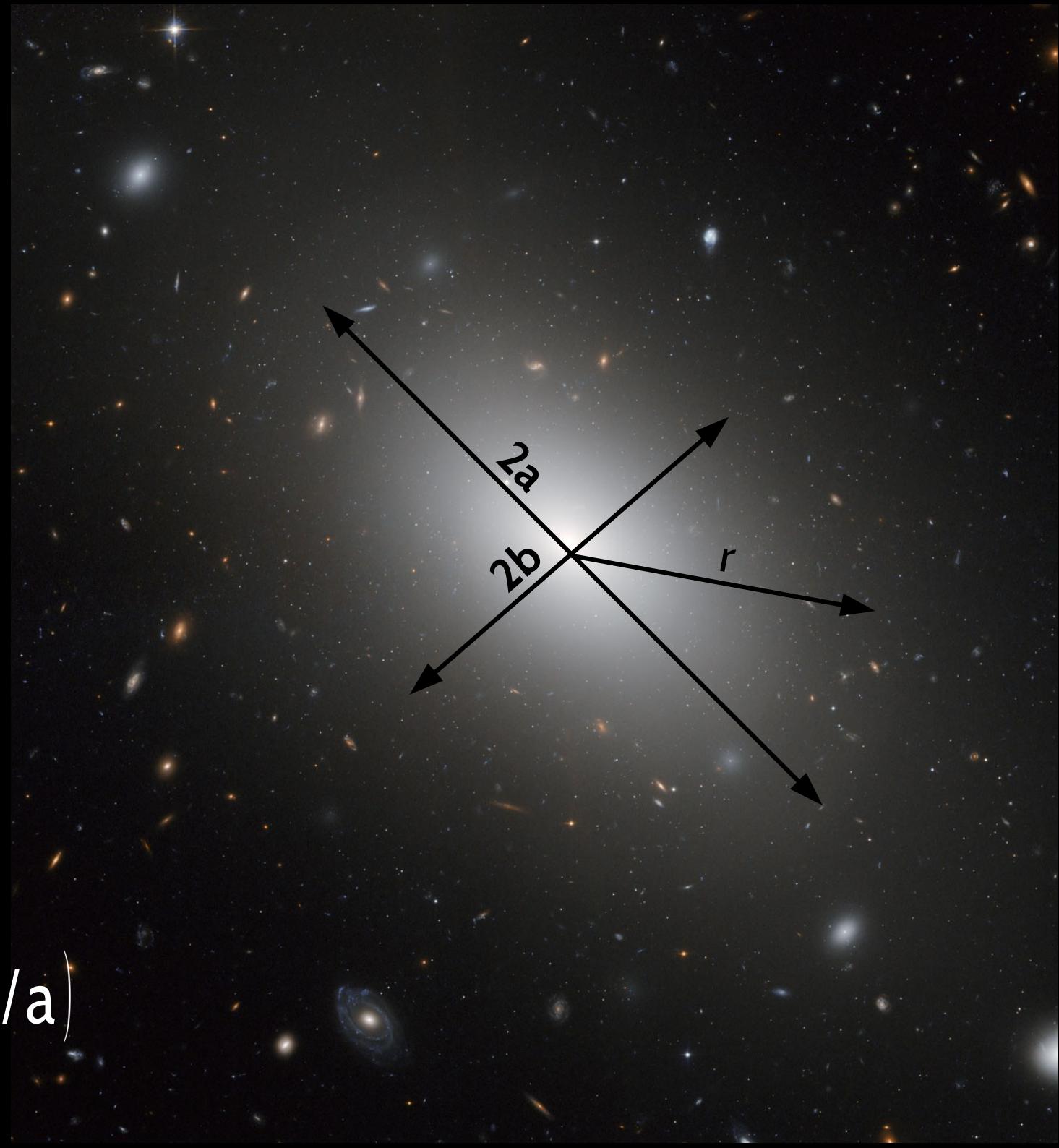
A dense field of galaxies of various shapes and colors against a dark background.

Galaxy Zoo

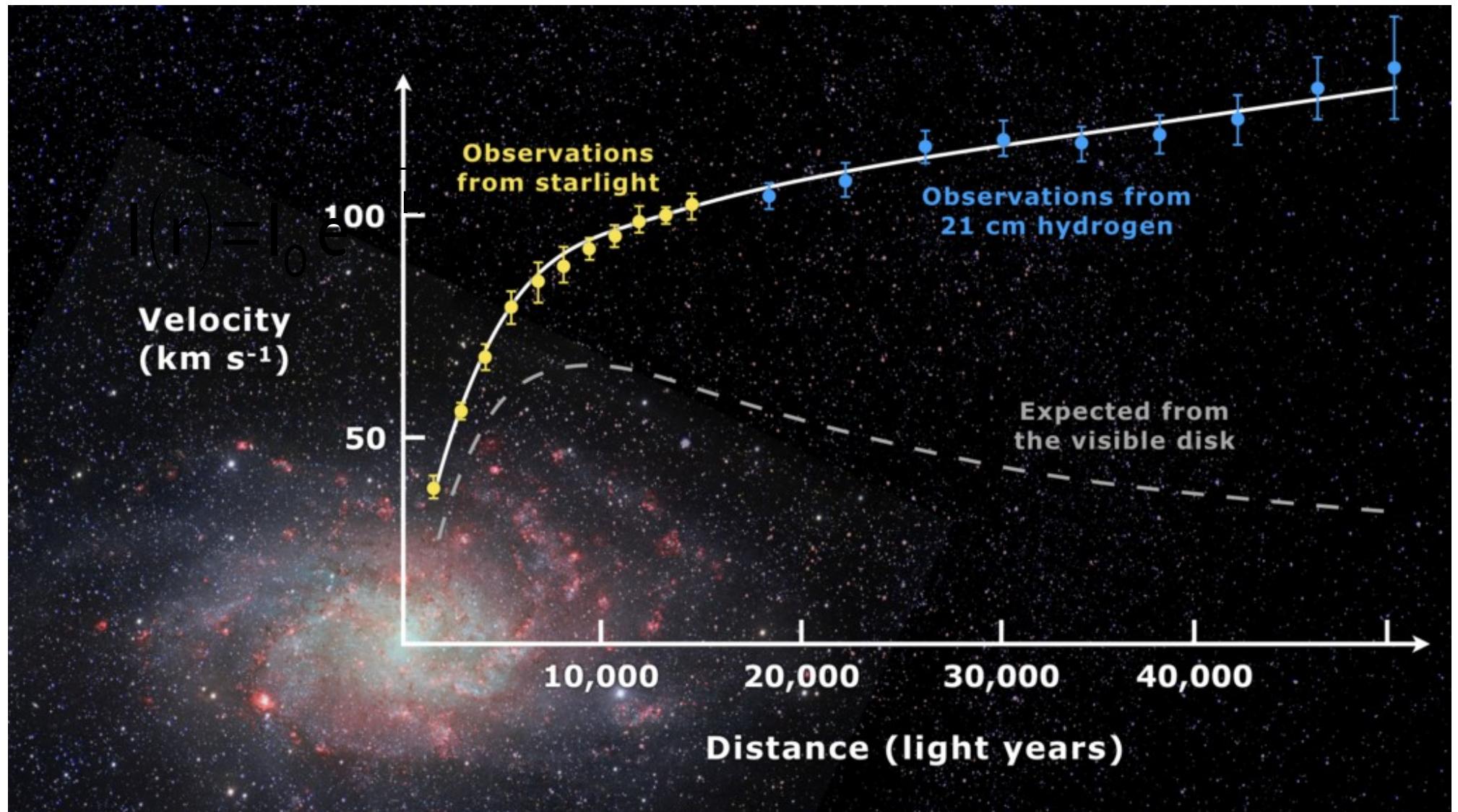
<http://www.galaxyzoo.org>

$$I(r) = I_0 e^{-\sqrt[4]{r/r_0}}$$

$$E_q \rightarrow E_q = 10(1 - b/a)$$



Curvas de rotación





Curvas de rotación

- Igualando la fuerza centrífuga y la fuerza gravitatoria:

$$v_\omega(r) = \sqrt{\frac{GM}{r}} \rightarrow M(r) = \frac{v_\omega^2}{G} r$$

- Pero en una galaxia típica

$$v_\omega(r) \approx \alpha \rightarrow M(r) = \frac{\alpha^2}{G} r \propto r (!!)$$

- Relación de Tully-Fisher

$$\omega \propto \sqrt[4]{L}$$



Materia oscura (no visible)

- Consideremos, p. ej, $\alpha \sim 250 \text{ km/s}$ y $r \sim 50 \text{ kpc}$

$$M = \frac{(250 \text{ km/s})^2 50 \text{ kpc}}{G} \simeq 8 \times 10^{11} M_{\odot}$$

- Pero según Tully-Fisher, $M_{\text{vis}} \simeq 10^{10} M_{\odot}$



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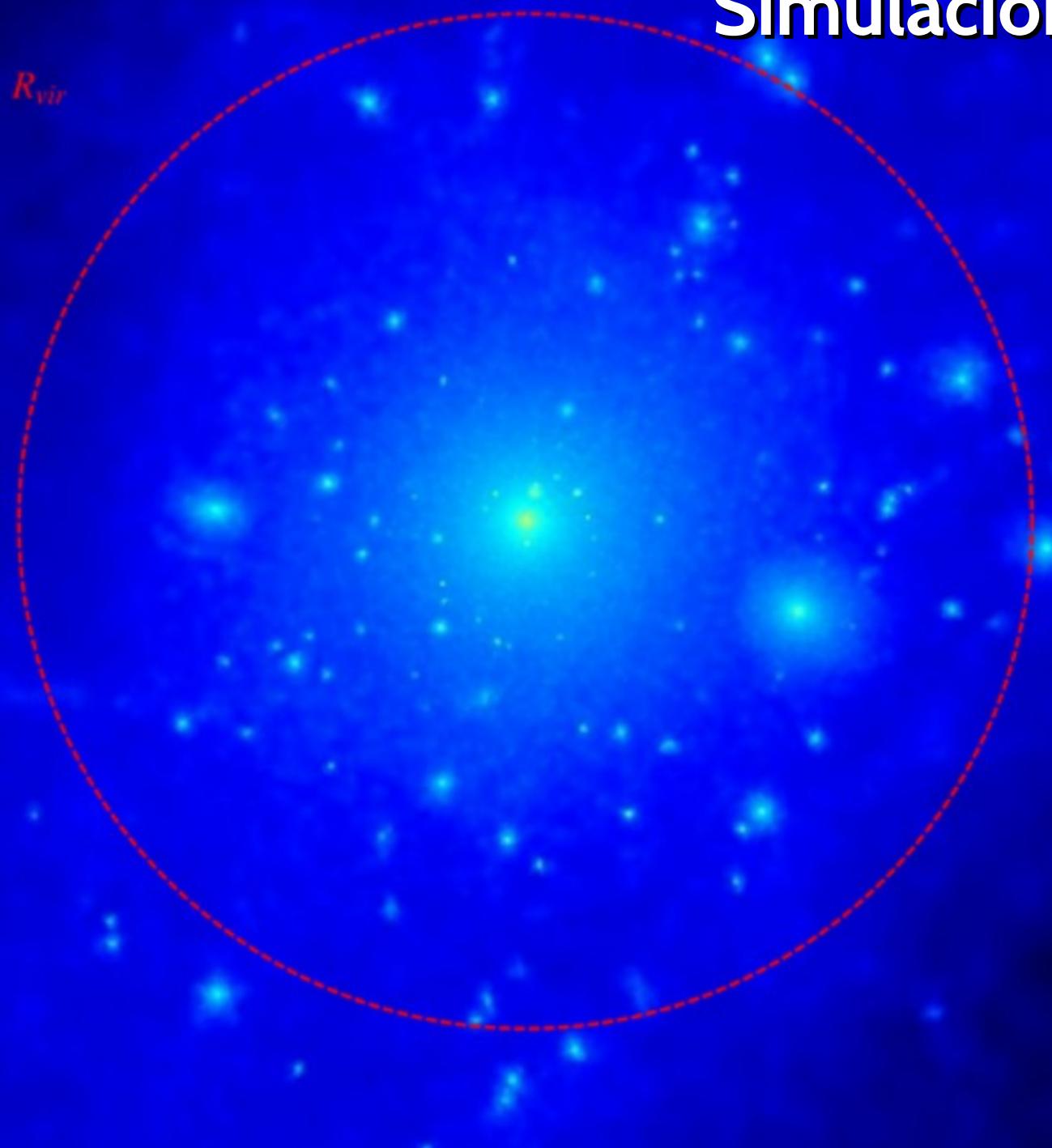
La masa galáctica es ~10-100 veces la masa observada

El tamaño galáctico es ~10-100 veces el radio observado

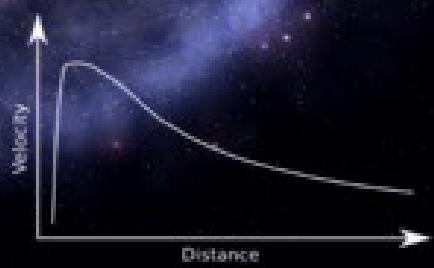
El “halo” de materia oscura



Simulaciones n-cuerpos



Curvas de rotación con y sin materia oscura



Otras explicaciones para explicar estos comportamientos:
distribución de masa en el disco galáctico (Newton)
MOND (MO Newtonian Dynamics)