



# Universidad Nacional de Río Negro

## Int. Partículas, Astrofísica & Cosmología - 2019

- **Unidad**      03 – Astrofísica: cálido y frío
- **Clase**        U03 C01
- **Fecha**        05 Nov 2019
- **Cont**          Estructura a gran escala
- **Cátedra**      Asorey



# Contenidos: un viaje en el tiempo

**HOW DID OUR UNIVERSE BEGIN?**

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.

**COSMIC QUESTIONS**

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.

**WHAT IS OUR UNIVERSE MADE OF?**

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

**HOW DID OUR UNIVERSE BEGIN?**

**Infation**  
In less than a nanosecond a massive energy field inflates space by a factor of a thousand. It fills it with a soup of subatomic particles called quarks.  
**Age:**  $10^{-3}$  milliseconds  
**Size:** Infinitesimal to golf ball

**Early building blocks**  
The universe expands, cools. Quarks clump into protons and neutrons. Electrons form blocks of atomic nuclei. Perhaps dark matter forms.  
**Age:**  $10^{-2}$  milliseconds  
**Size:** 0.1-millionth present size

**First nuclei**  
As the universe continues to cool, the light of hydrogen atoms begins to arise. This light is as far back as our instruments can see.  
**Age:** .01 milliseconds  
**Size:** Present size

**First atoms, first light**  
Quarks begin orbiting nuclei, creating atoms. The glow from their inflection points is unveiled. This light is as far back as our instruments can see.  
**Age:** .0009 years  
**Size:** .0009 present size

**The "dark ages"**  
For 300 million years this continues. Light is the only light. Clumps of dark matter that will become galaxies glow brightest.  
**Age:** 380,000 to 300 million years  
**Size:** .0009 to 0.1 present size

**Gravity wins: first stars**  
Dense gas clouds collapse under their own gravity. Clumps of dark matter that will become galaxies and stars form galaxies and stars. Fusion lights up the stars.  
**Age:** 300 million years  
**Size:** 0.1 present size

**Antigravity wins**  
After being slowed for billions of years, cosmic expansion accelerates again. The culprit: dark energy. Its nature: unclear.  
**Age:** 10 billion years  
**Size:** .77 present size

**Today**  
The universe continues to expand, becoming ever less dense. As a result, fewer new stars and galaxies are forming.  
**Age:** 13.8 billion years  
**Size:** Present size

**Unidad 3 Cosmología**  
*No es lo que se ve  
Sino lo que se palpa*

**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.

**DO WE LIVE IN A MULTIVERSE?**

What came before the big bang? Maybe other big bangs. The uncertainty principle holds that even the vacuum of space has density fluctuations. Inflation theory says our universe exploded from such a fluctuation—a random event that, odds are, had happened many times before. Our cosmos may be one in a sea of others just like ours—or nothing like ours. These other cosmos will very likely remain forever inaccessible to observation, their possibilities limited only by our imagination.

**HOW 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.

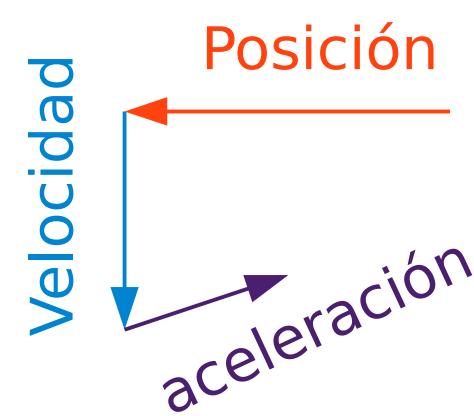
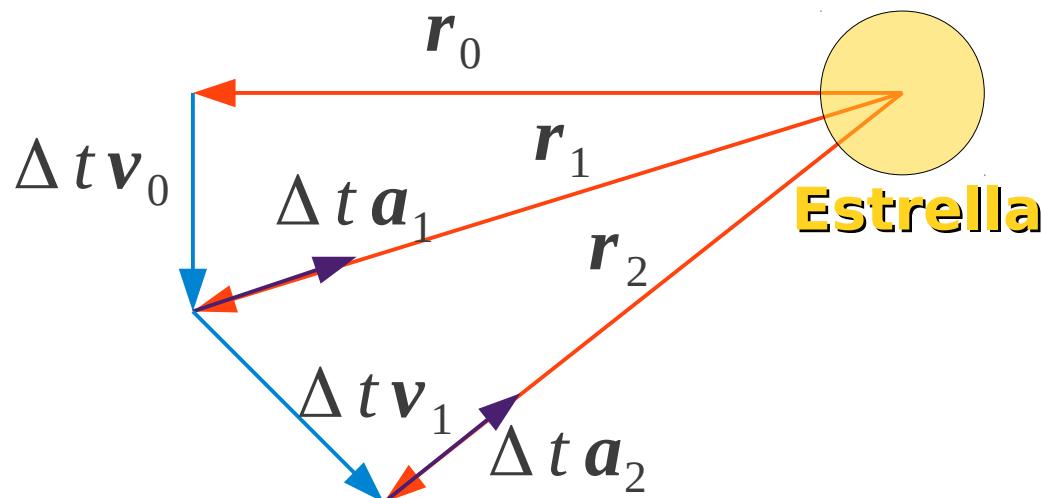
**Unidad 2 Astrofísica Cálido y frío**

**Unidad 1 Partículas 1 todo es relativo**

LAWRENCE FENSTER, NICK STAFFORD, FABRIZIO GEMMELLARO, ART MONTAGNA DESIGN SOURCES: CHARLES BENNETT, JOHN HESTER, ANDREW LINSLEY, JEFFREY NEWTON, UNIVERSITY OF CHICAGO; ANDREW LINSLEY, NATIONAL GEOGRAPHIC SOCIETY

# ¿cómo se mueve un planeta?

- El movimiento no es circular, pero L es constante
- Si L es constante  $\rightarrow L = mr\mathbf{v} \rightarrow r\mathbf{v} = \text{"cte"}$ 
  - Aumenta r, disminuye v; disminuye r, aumenta v



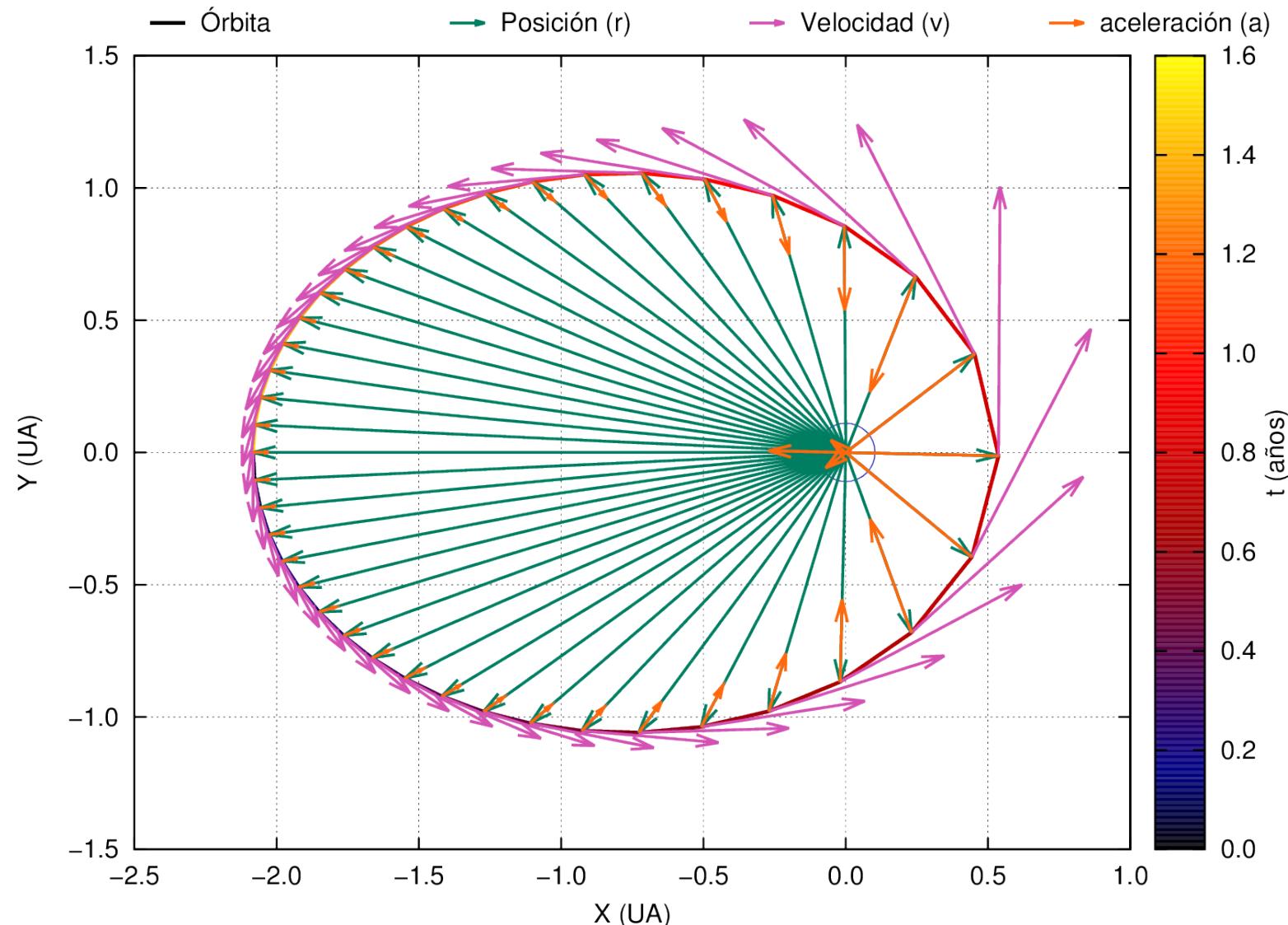


# Tercera Ley

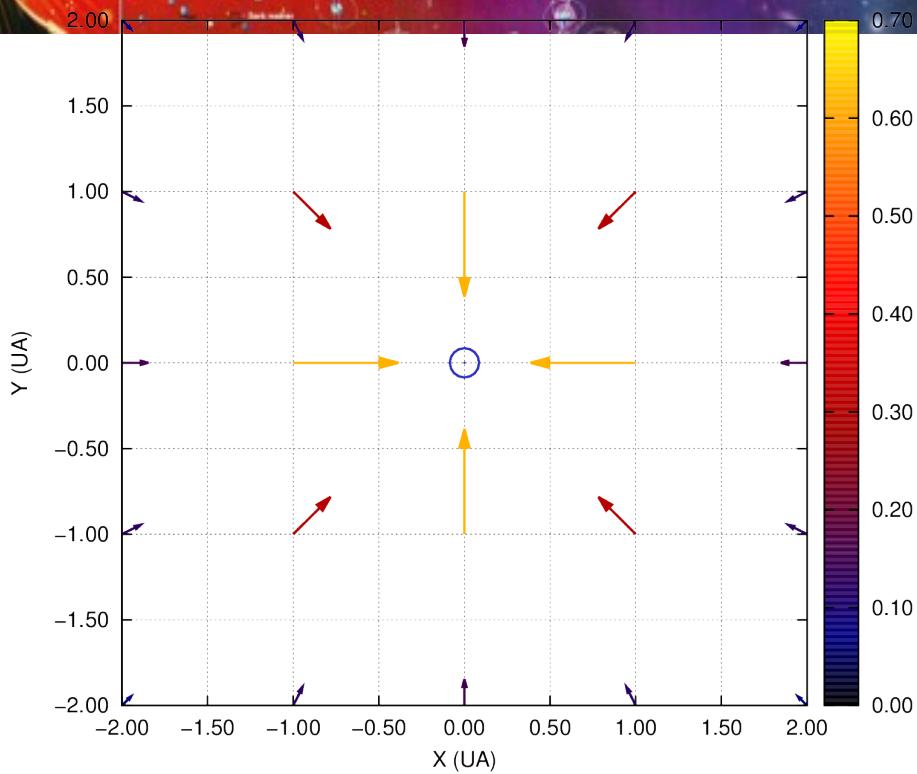
- Y vale para cualquier sistema orbital. Por ejemplo
  - calcule la masa de la Tierra sabiendo que el periodo orbital lunar es de 27,4 días y la distancia media es  $a=384800$  km
  - calcule el radio de la órbita de lo sabiendo que su periodo orbital es de 43h y la masa de Júpiter es  $1.899 \times 10^{27}$  kg.

$$\frac{T^2}{a^3} = \left( \frac{4\pi^2}{G m_{\text{central}}} \right) = \text{cte}$$

# Órbita+posición+velocidad+aceleración



# Muevo la masa de prueba en el plano z=0 → “Campo gravitatorio”



**$\mathbf{g}(\mathbf{r})$**  es un *campo vectorial*.  
A cada punto  $\mathbf{r}$  del espacio le  
asigna el vector  **$\mathbf{g}(\mathbf{r})$**

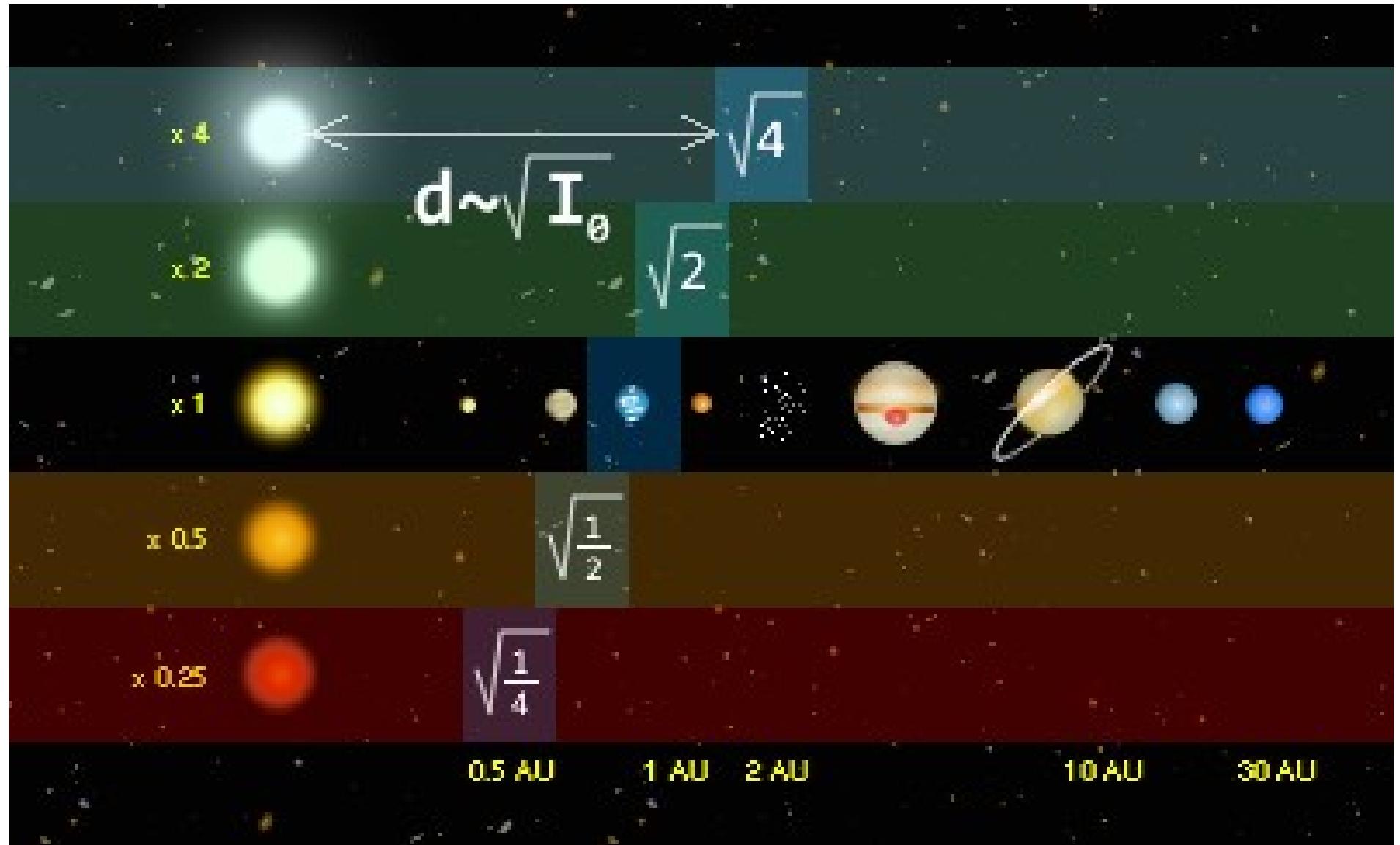
$$\vec{F}(r) = \frac{G M m}{|\vec{r}|^2} \hat{r}$$

$$\vec{F}(r) = m \left[ \left( \frac{G M}{|\vec{r}|^2} \right) \hat{r} \right]$$

$$\vec{F}(r) = m \mathbf{g}(r)$$

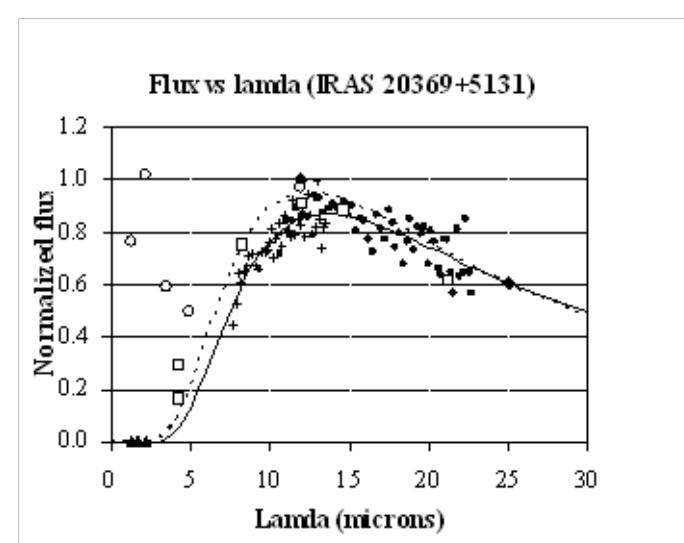
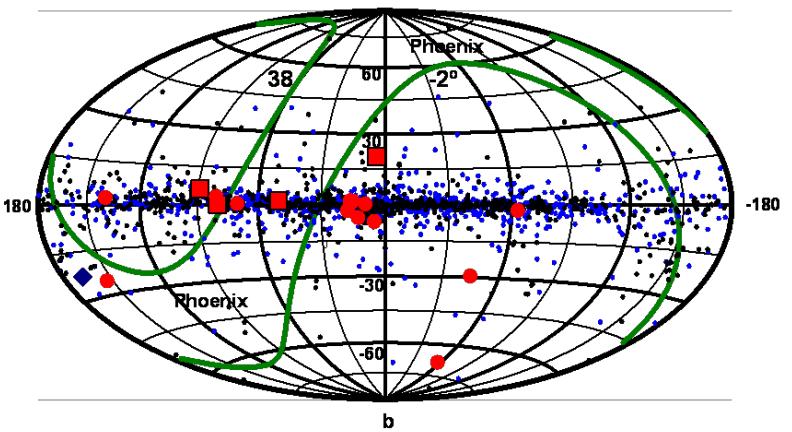
$$\vec{g}(r) = \left( \frac{G M}{|\vec{r}|^2} \right) \hat{r}$$

# Zona habitable: Agua líquida (volveremos...)



# IRAS (InfraRed Astronomical Satellite)

[http://home.fnal.gov/~carrigan/infrared\\_astronomy/Termilab\\_search.htm](http://home.fnal.gov/~carrigan/infrared_astronomy/Termilab_search.htm)





# Qué es la Vida? E. Schrödinger

- La vida no viola las leyes de la termodinámica, aumentan su complejidad a costa de aumentar la entropía general en los procesos que hacen parte de esta
- La química de la herencia debe basarse en secuencias aperiódicas con la necesidad de una secuencia informativa que debe ser transmitida





# Galaxias

- Una **galaxia** es un sistema autogravitatorio que se compone de:
  - Estrellas
  - Remanentes estelares
  - Un medio interestelar formado por gas y polvo...
  - ... y materia oscura
- Tamaños:
  - Enanas (~1000 estrellas, 1000 pc)
  - Gigantes (100000 pc,  $10^{14}$  estrellas)
- Y están separadas por distancias ~Megaparsec

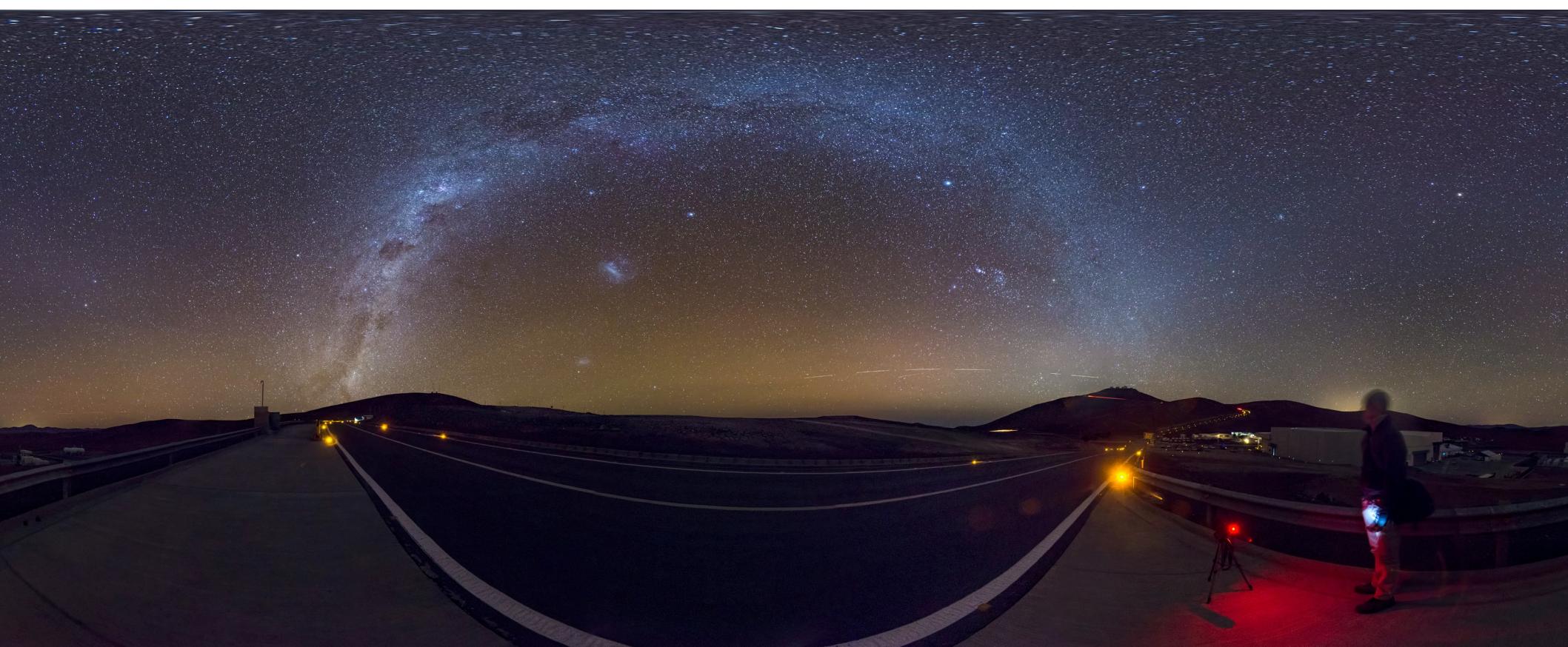
# La Vía Láctea



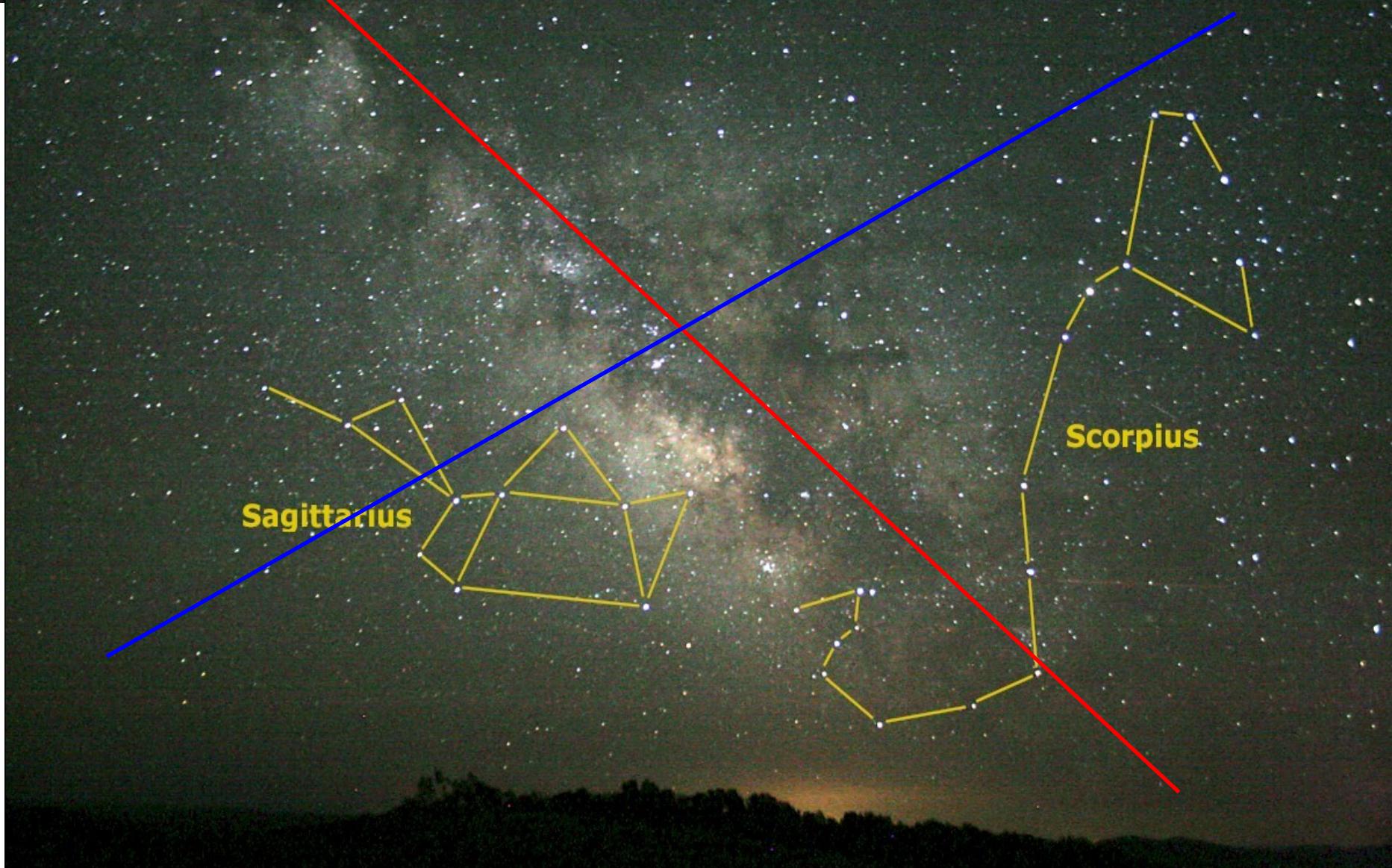




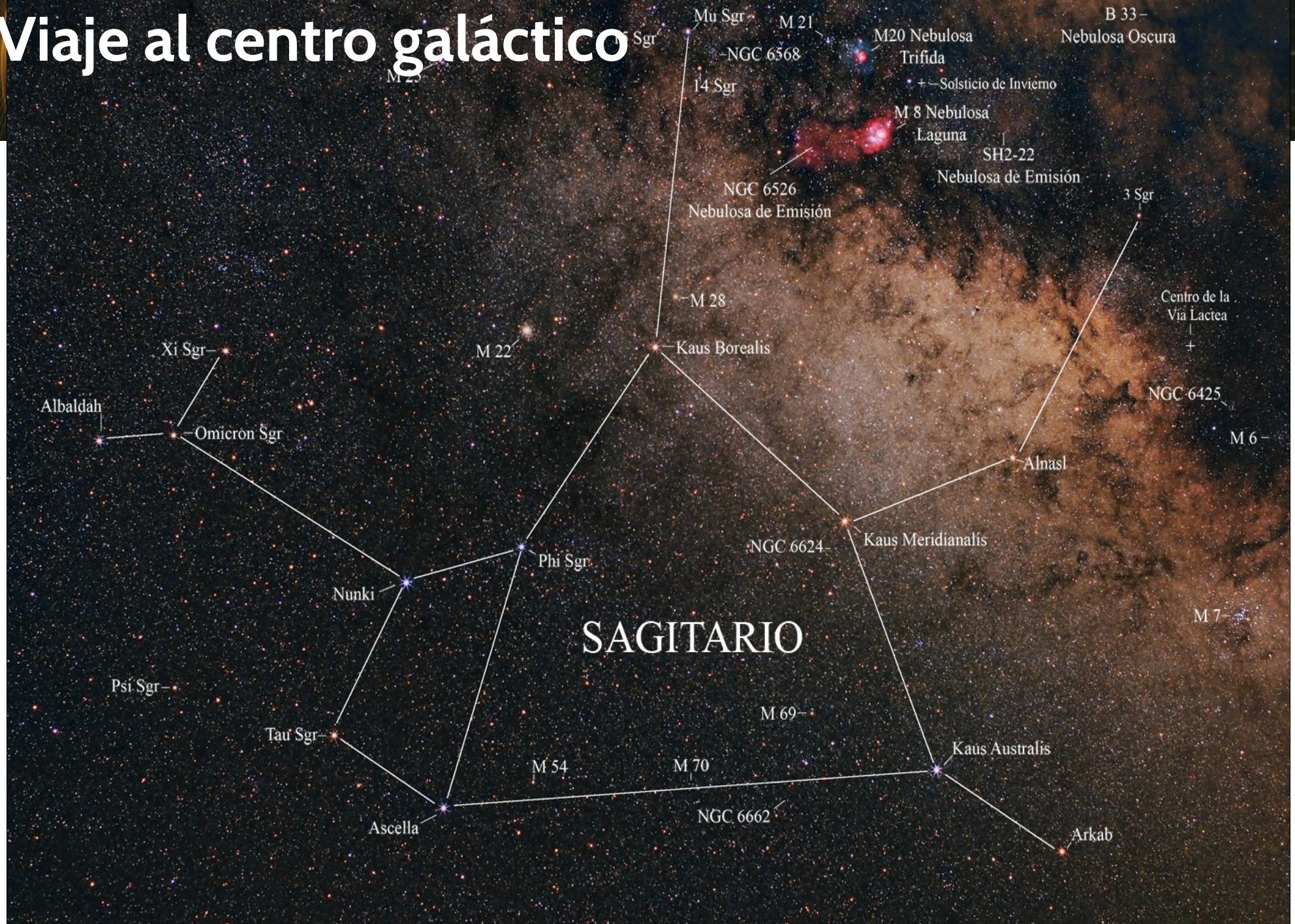
# La Vía Láctea desde Cerro Paranal



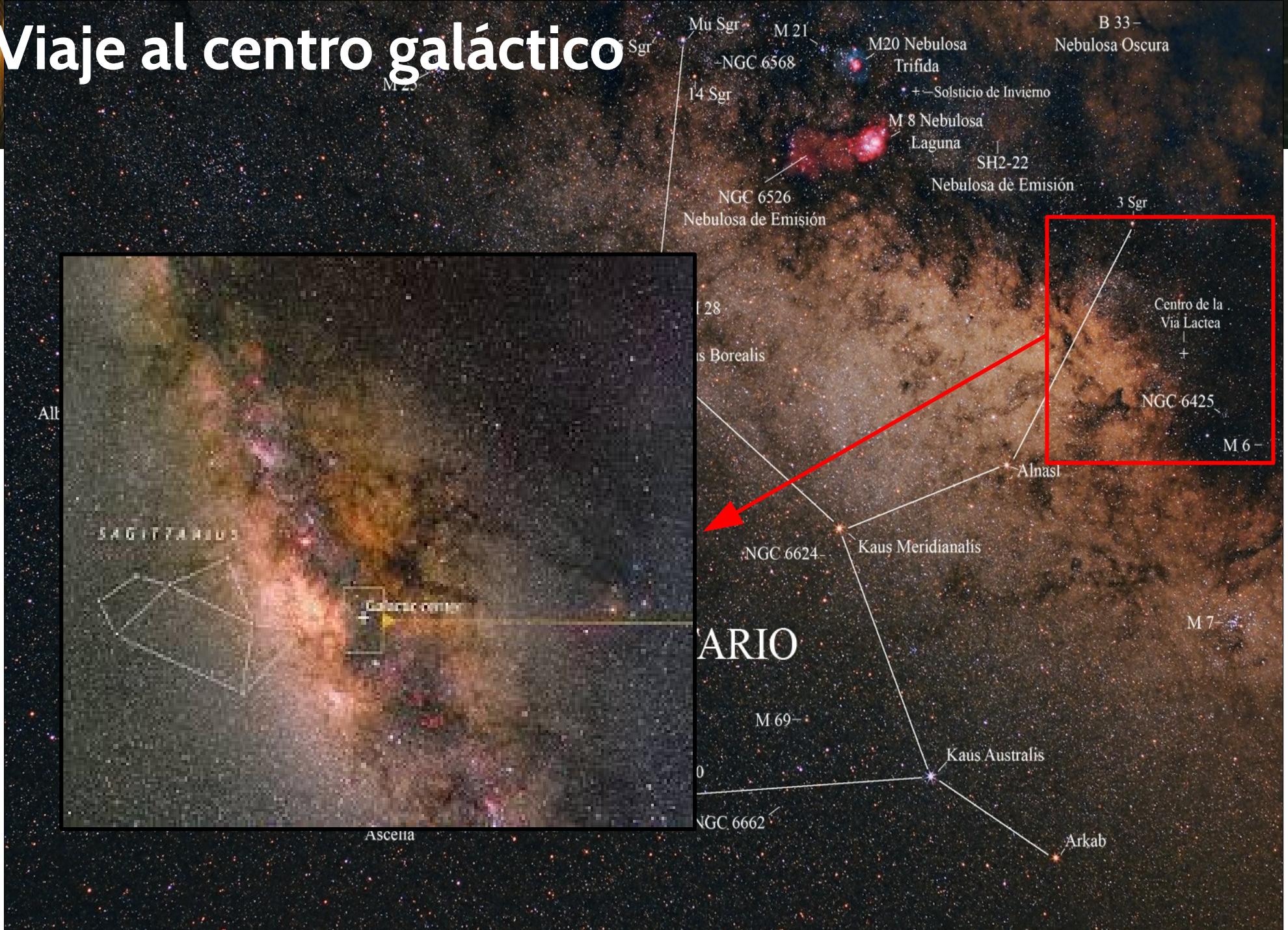
Inclinada ~60°, respecto del Ecuador Celeste



# Viaje al centro galáctico



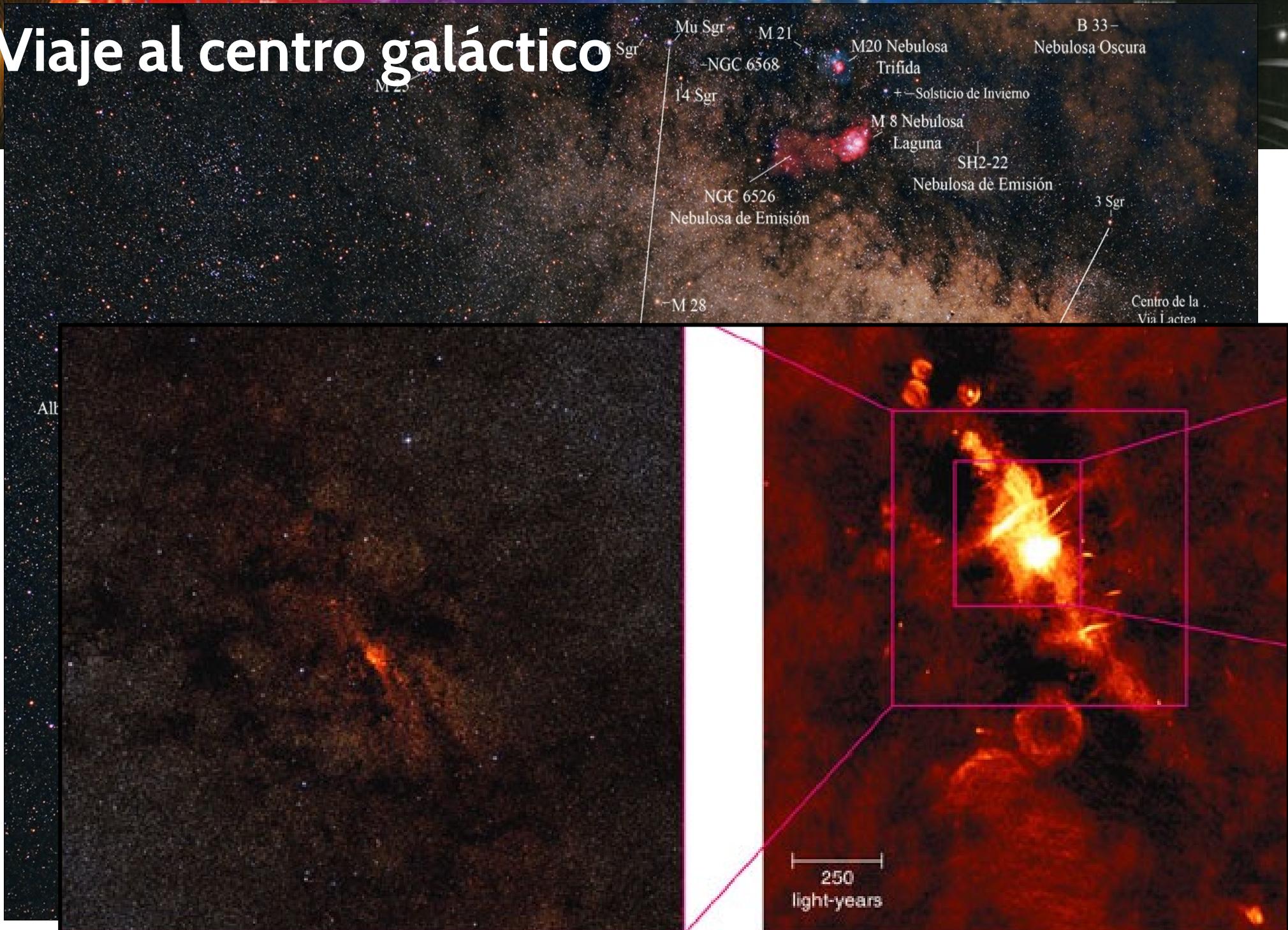
# Viaje al centro galáctico



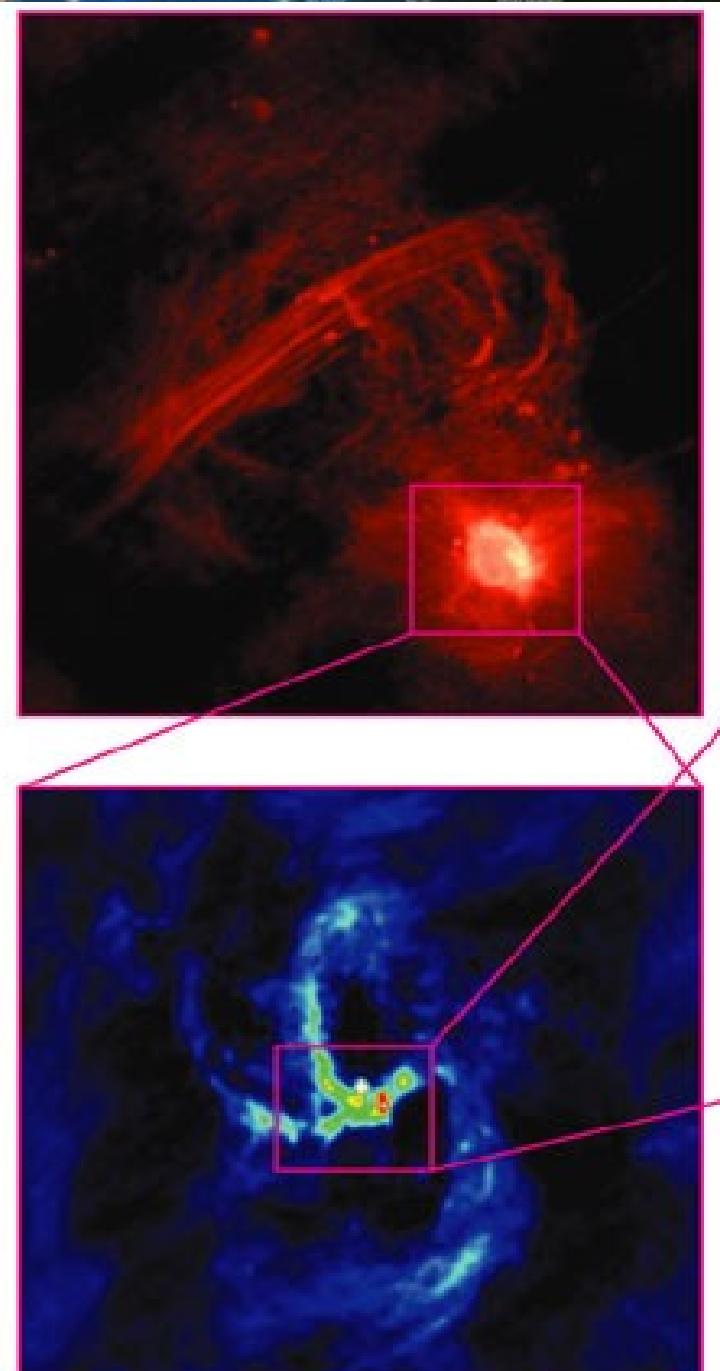
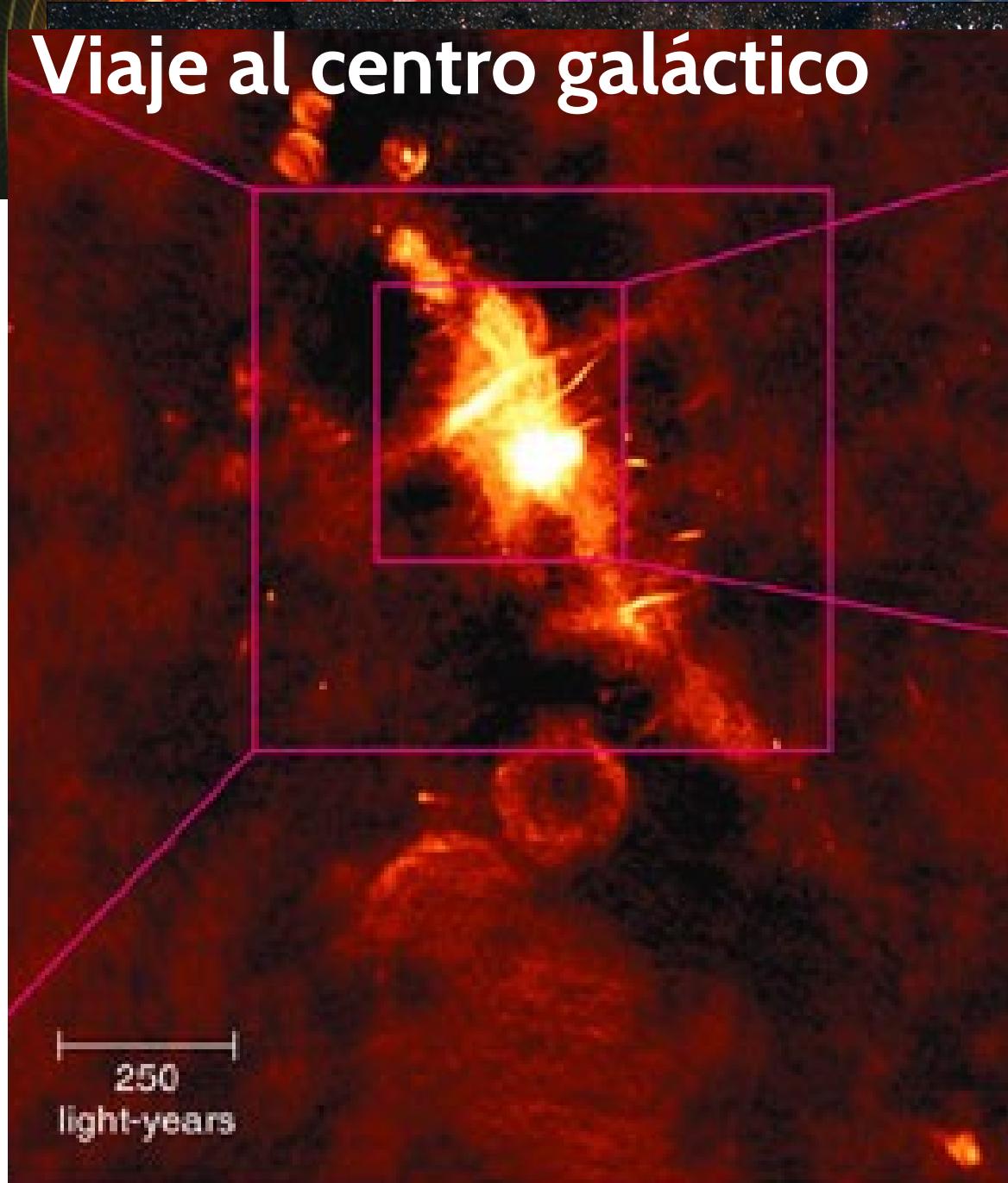
# Viaje al centro galáctico



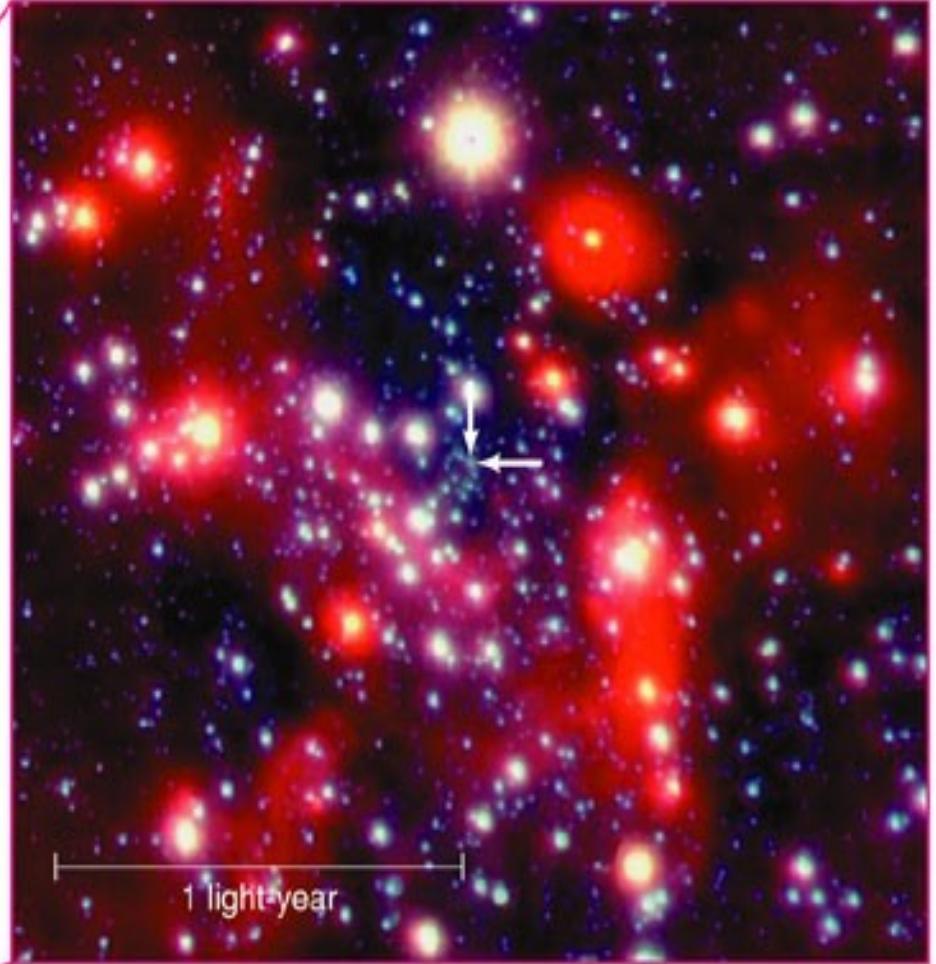
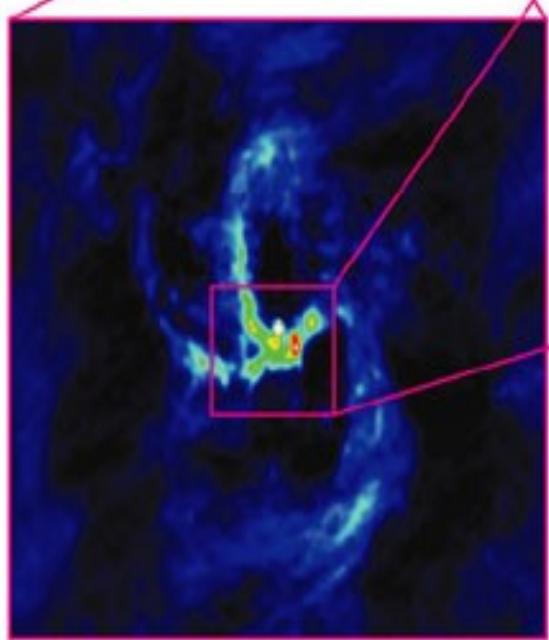
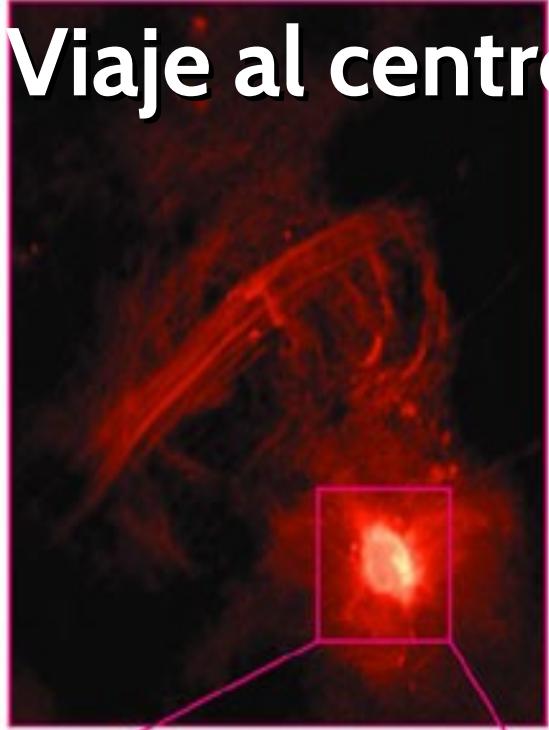
# Viaje al centro galáctico



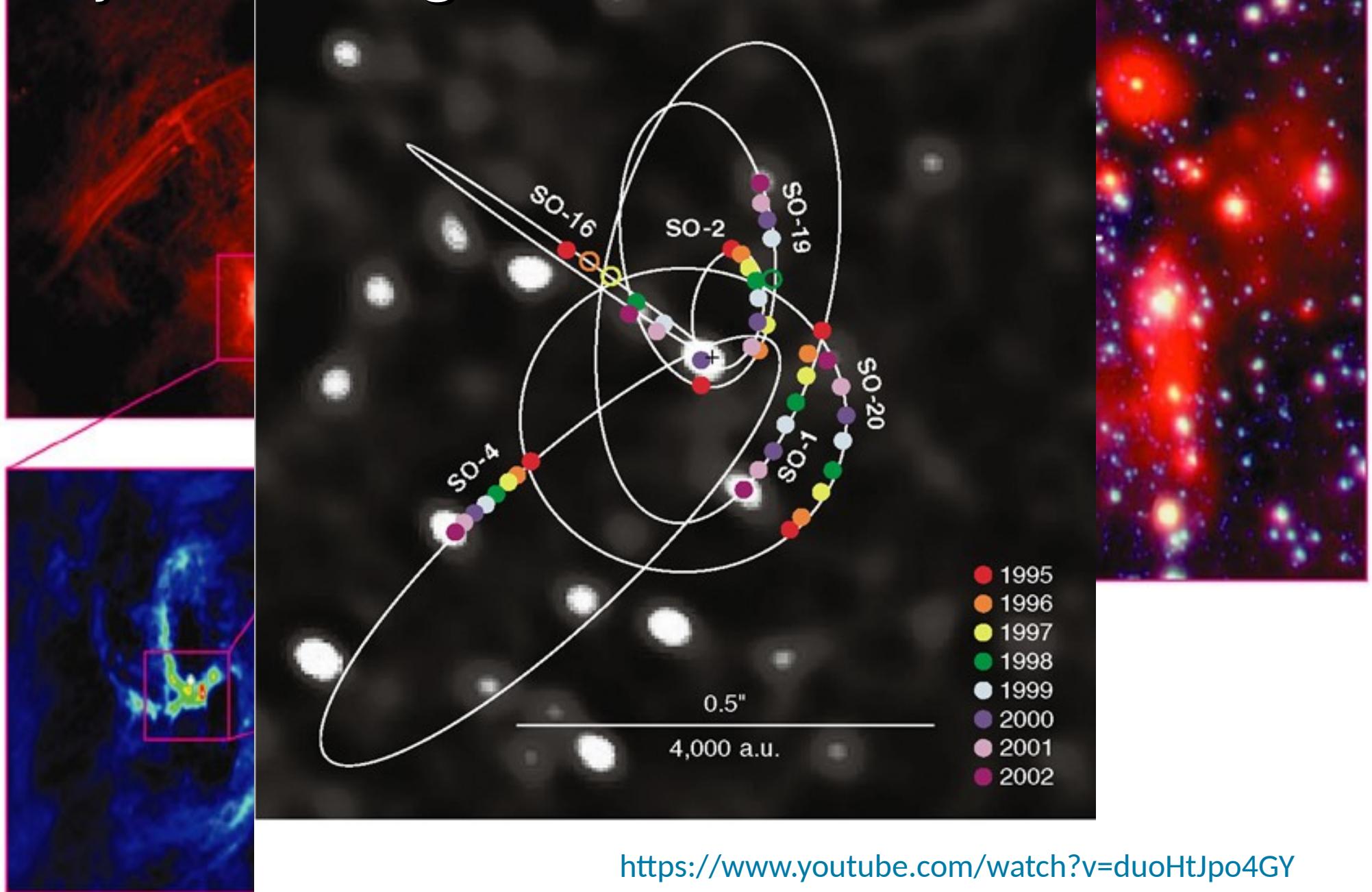
# Viaje al centro galáctico



# Viaje al centro galáctico



# Viaje al centro galáctico

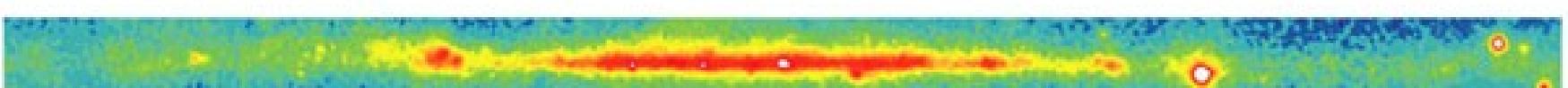
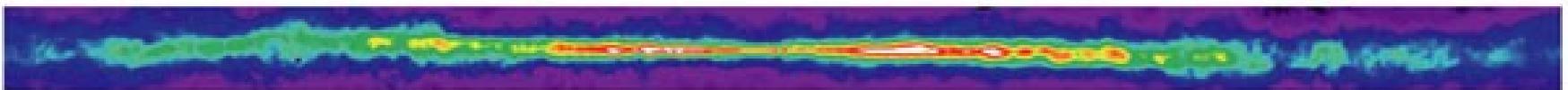


<https://www.youtube.com/watch?v=duoHtJpo4GY>

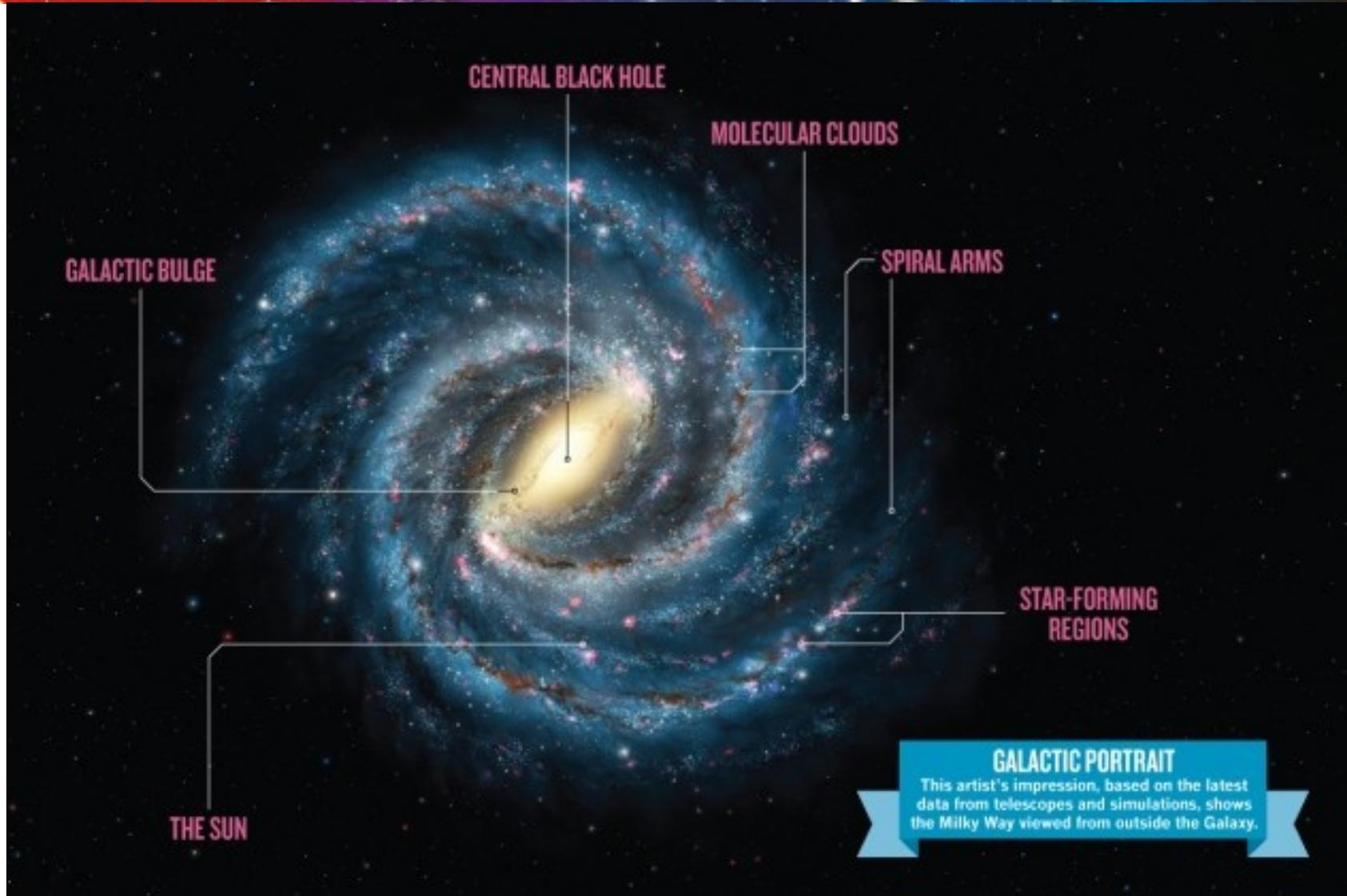


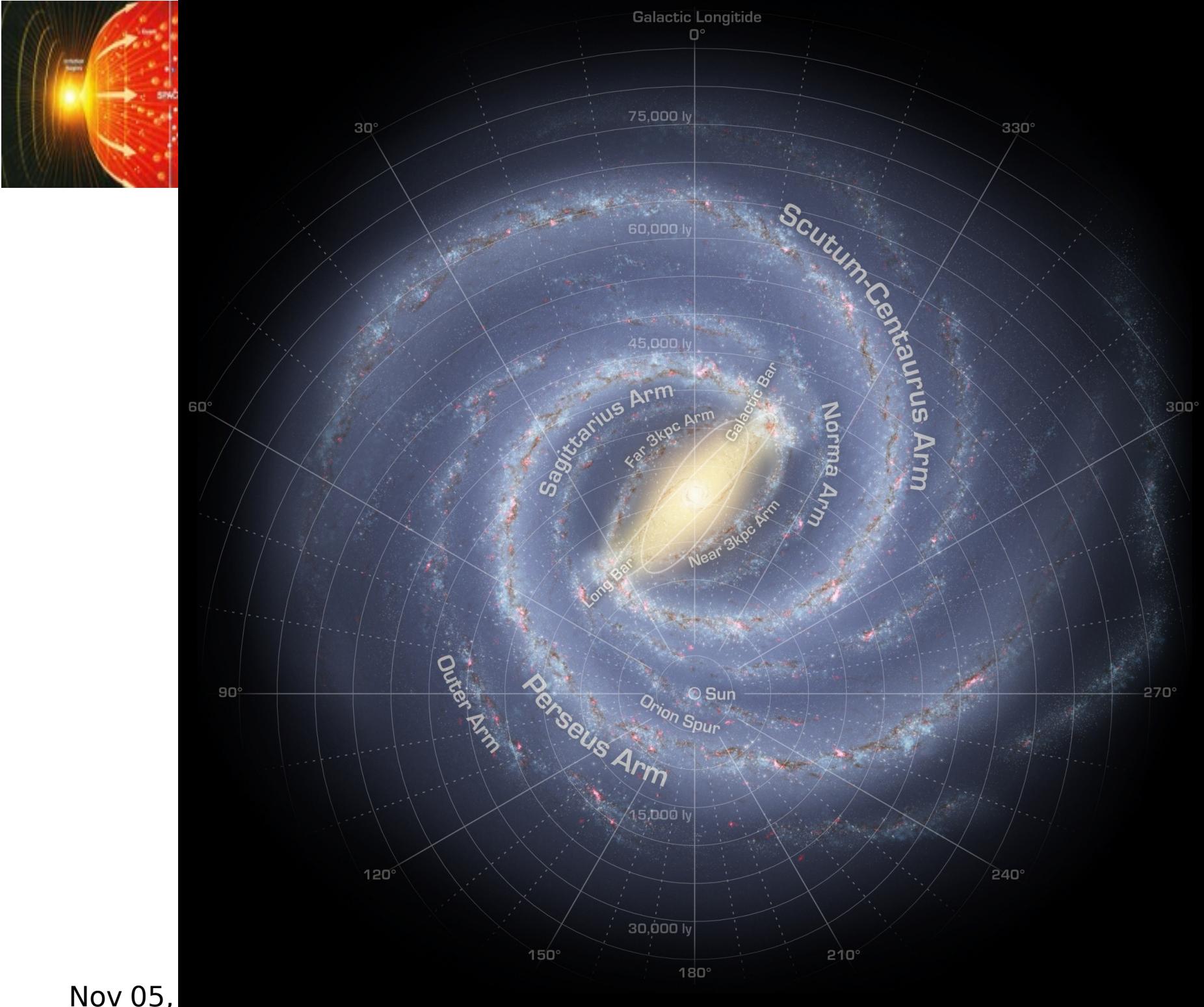
# El agujero negro central

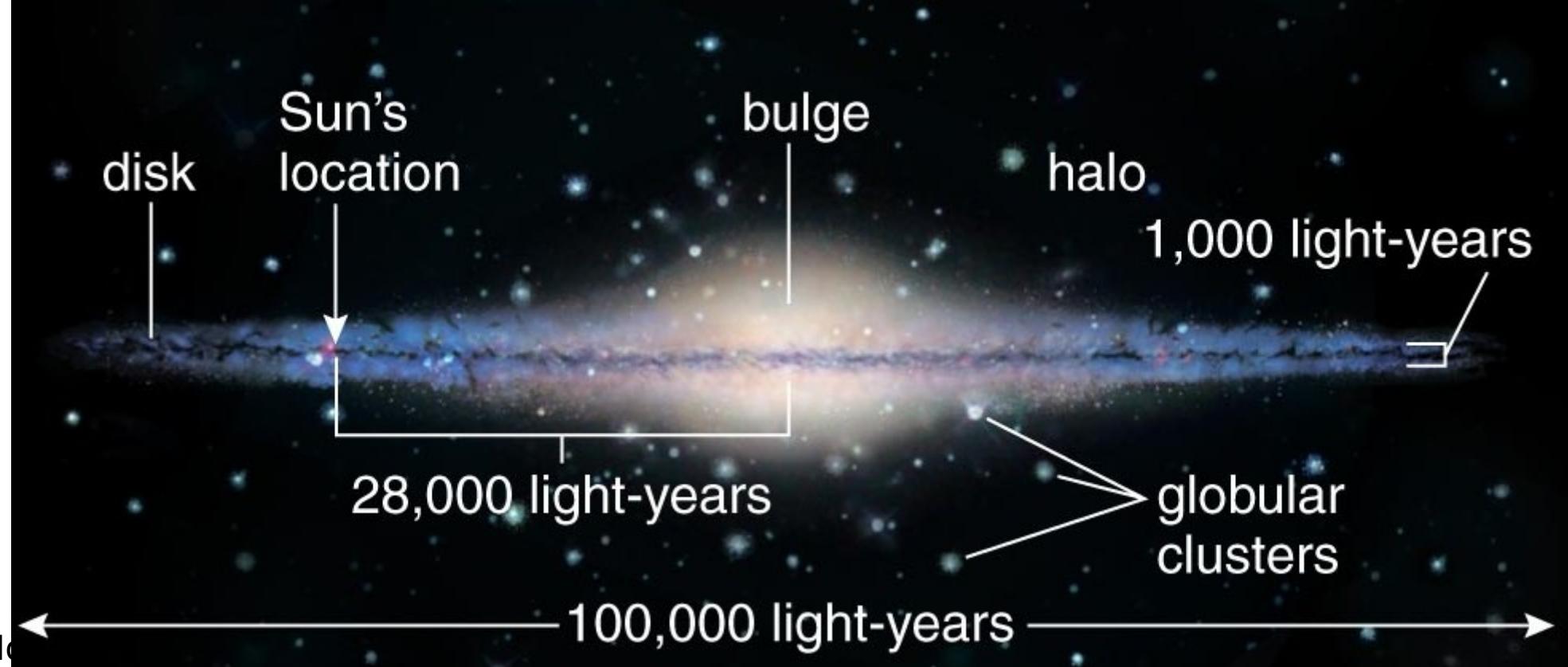
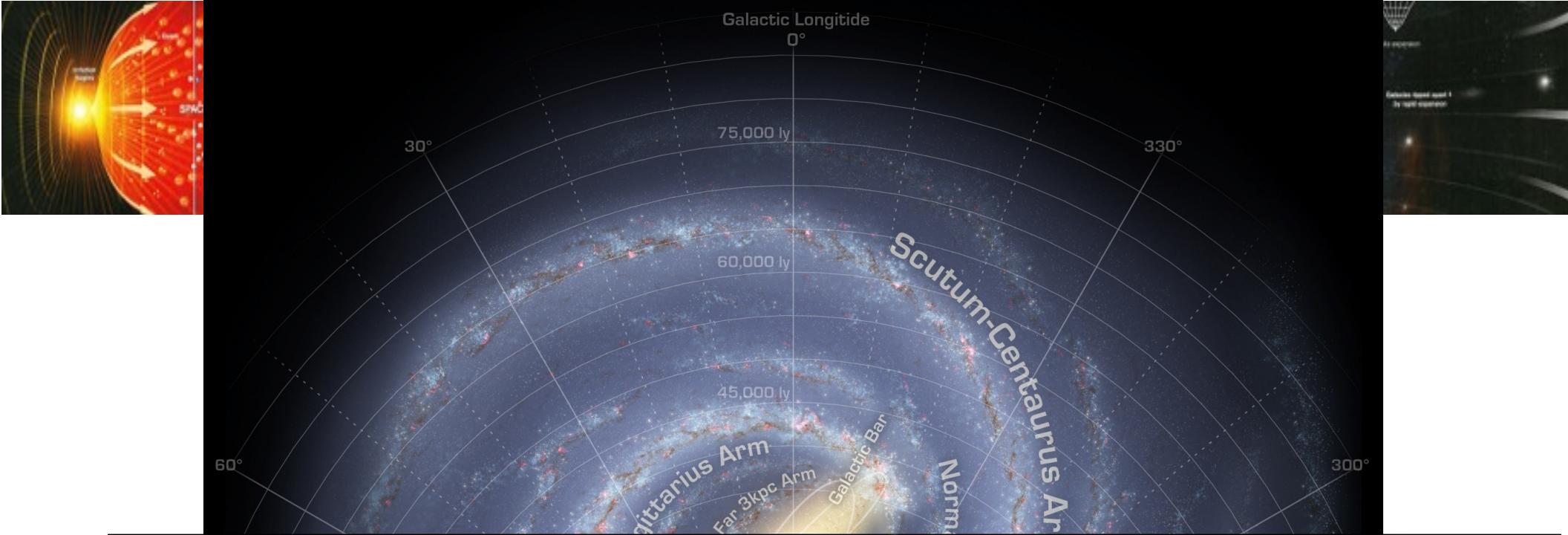
Observations with the VLT



[http://en.wikipedia.org/wiki/File:Infrared-visible\\_light\\_comparison\\_of\\_VISTA's\\_gigapixel\\_view\\_of\\_the\\_centre\\_of\\_the\\_Milky\\_Way.ogv](http://en.wikipedia.org/wiki/File:Infrared-visible_light_comparison_of_VISTA's_gigapixel_view_of_the_centre_of_the_Milky_Way.ogv)



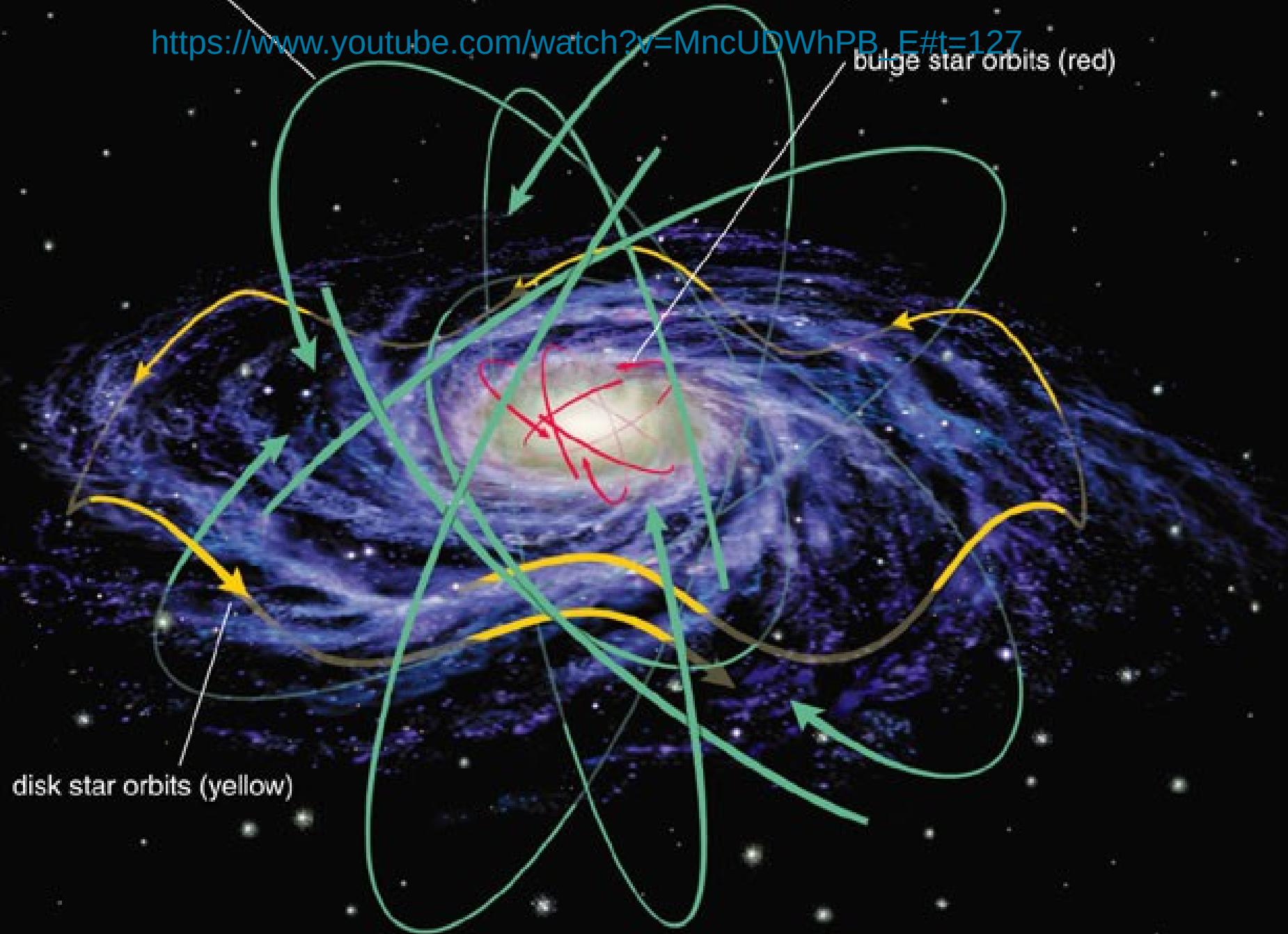




halo star orbits (green)

[https://www.youtube.com/watch?v=MncUDWhPB\\_E#t=127](https://www.youtube.com/watch?v=MncUDWhPB_E#t=127)

bulge star orbits (red)

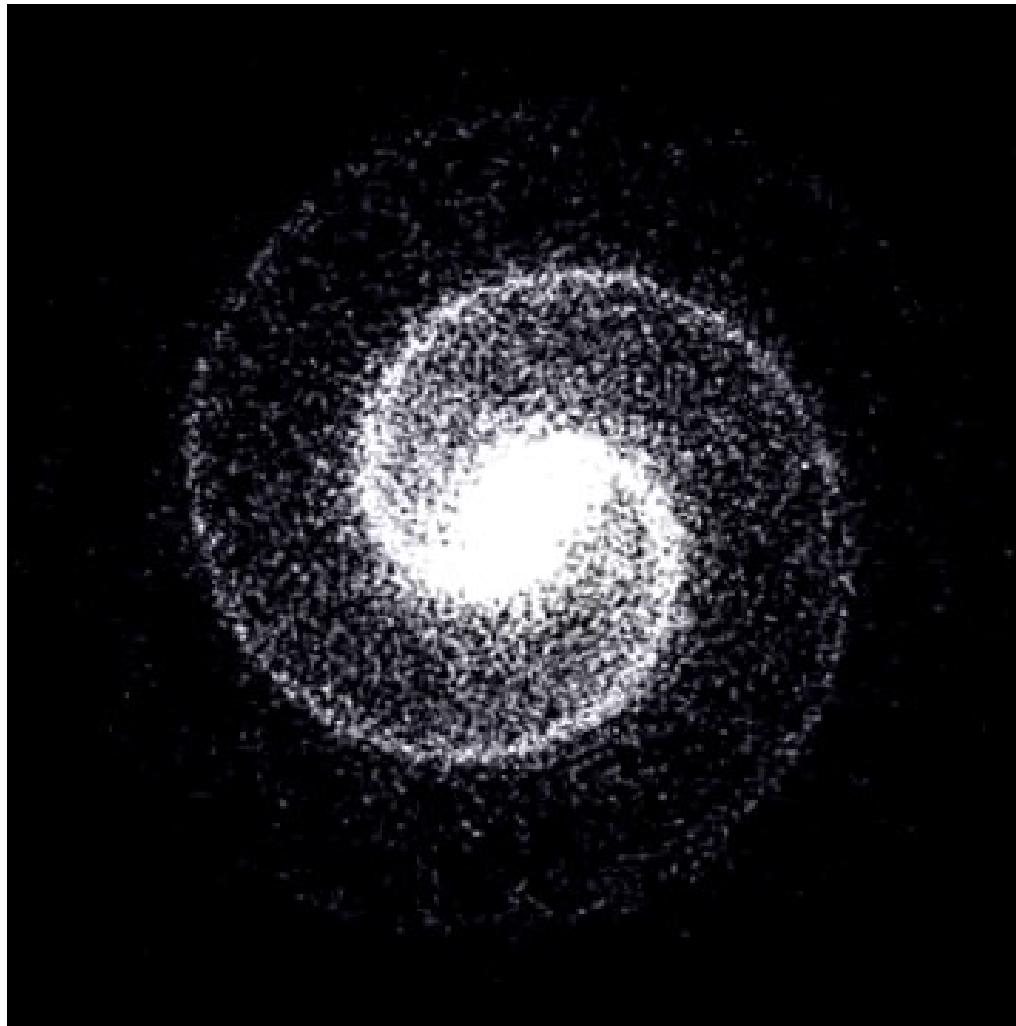




# Si Andrómeda fuera más brillante...

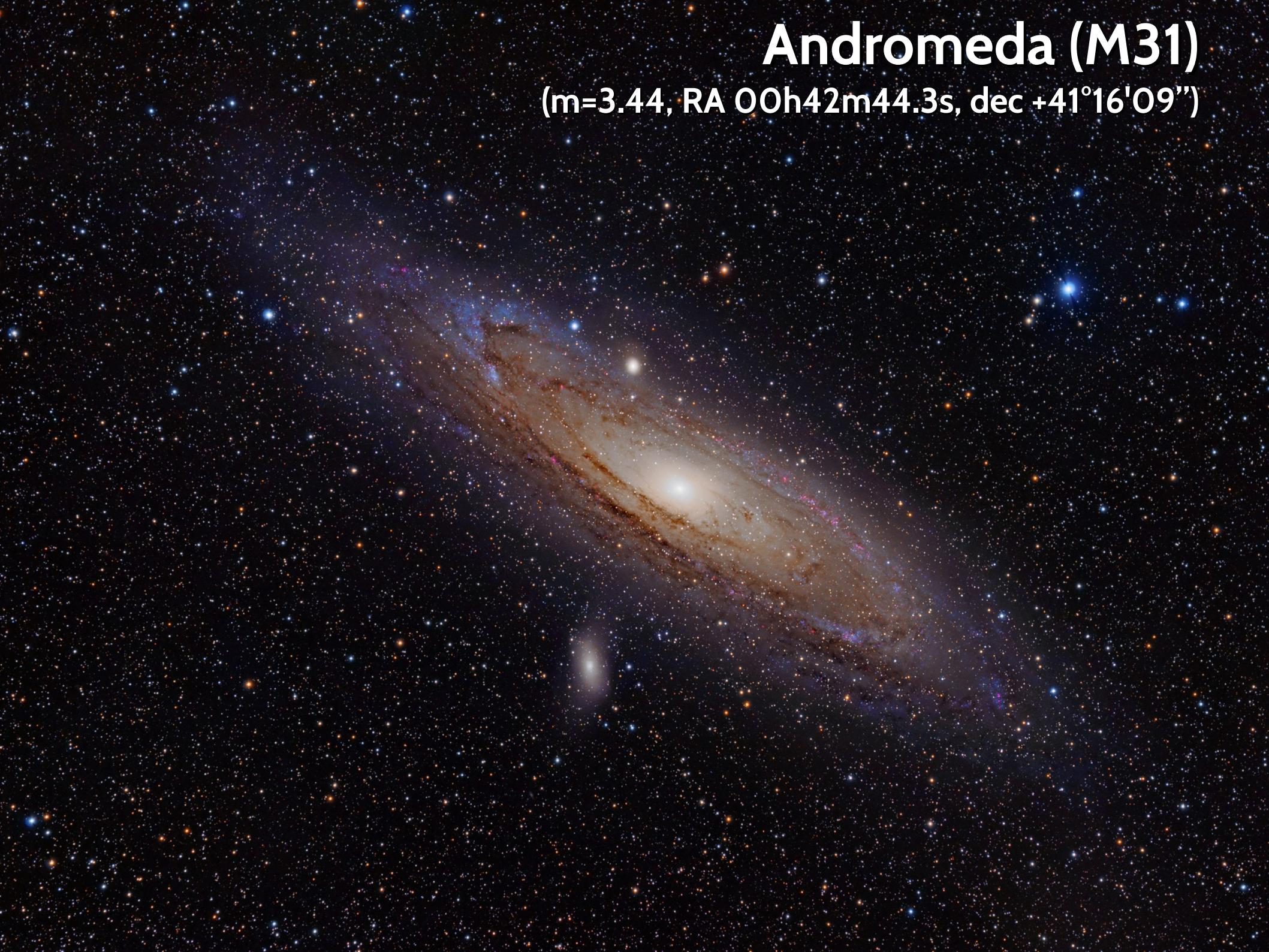


# Brazos espirales → atracción entre vecinos



# Andromeda (M31)

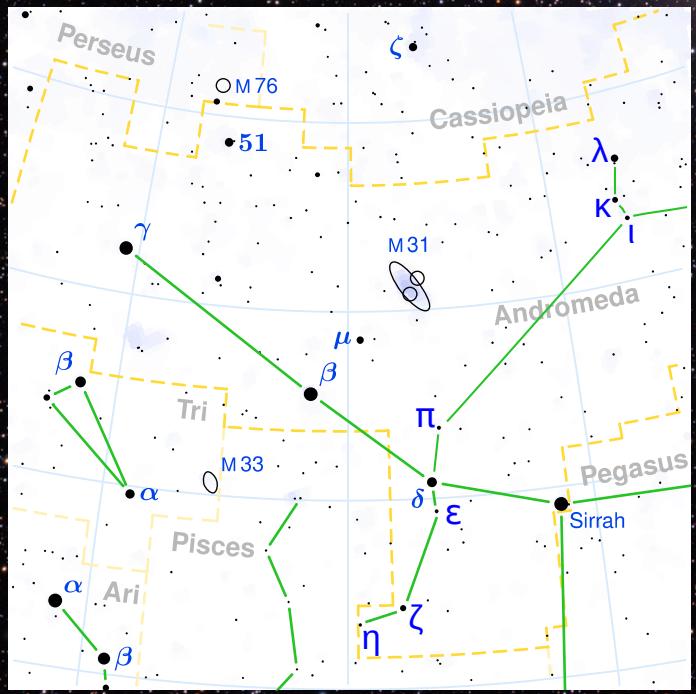
(m=3.44, RA 00h42m44.3s, dec +41°16'09")



# Andromeda (M31)

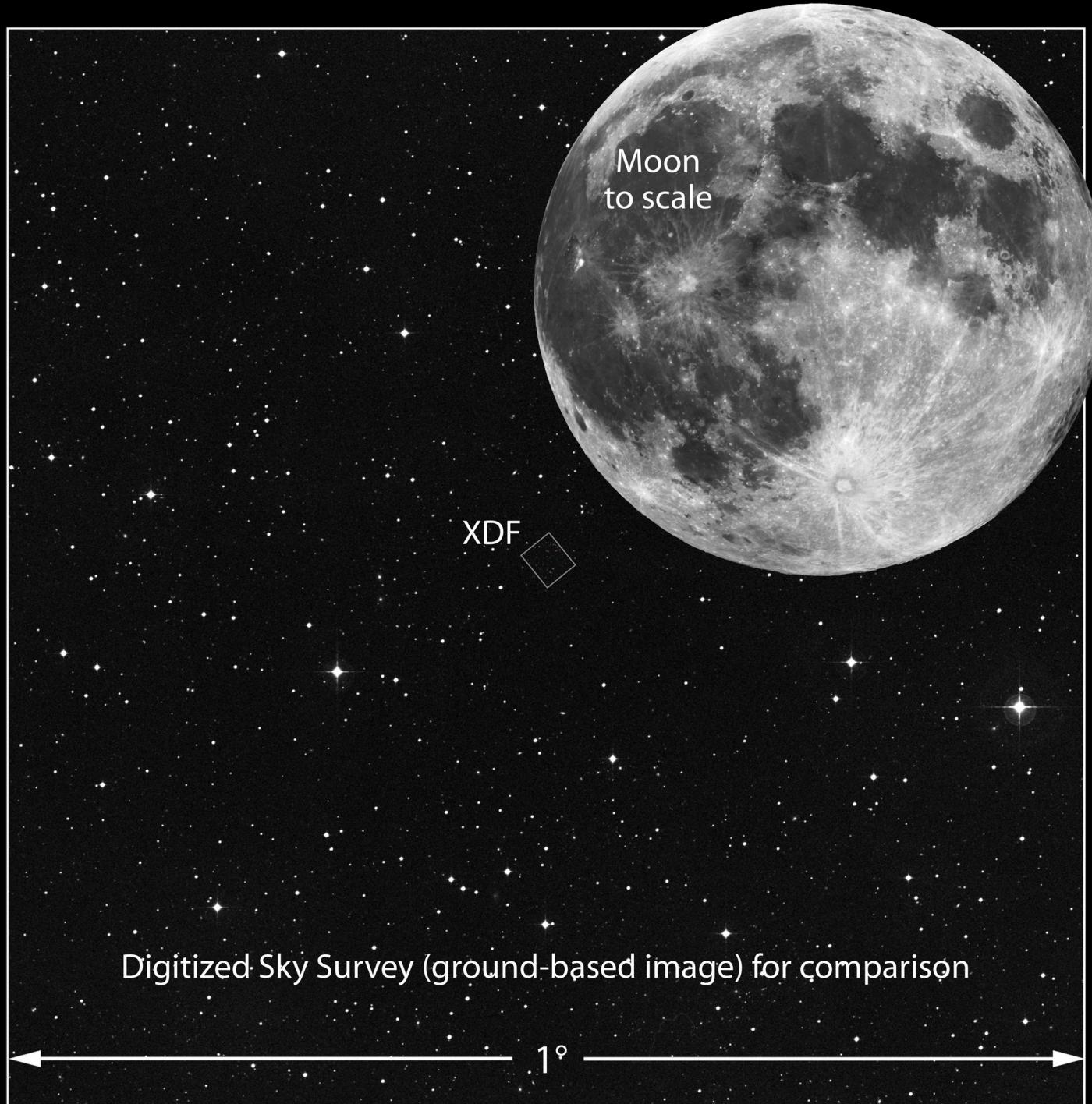
(m=3.44, RA 00h42m44.3s, dec +41°16'09")

- Ubicada a 780 kpc
- Visible con binoculares (noches sin luna y oscuras a simple vista como una mancha borrosa)
- Es la galaxia más masiva del Grupo Local:  $1.5 \times 10^{12} M_{\odot}$





# Size of Hubble eXtreme Deep Field on the Sky





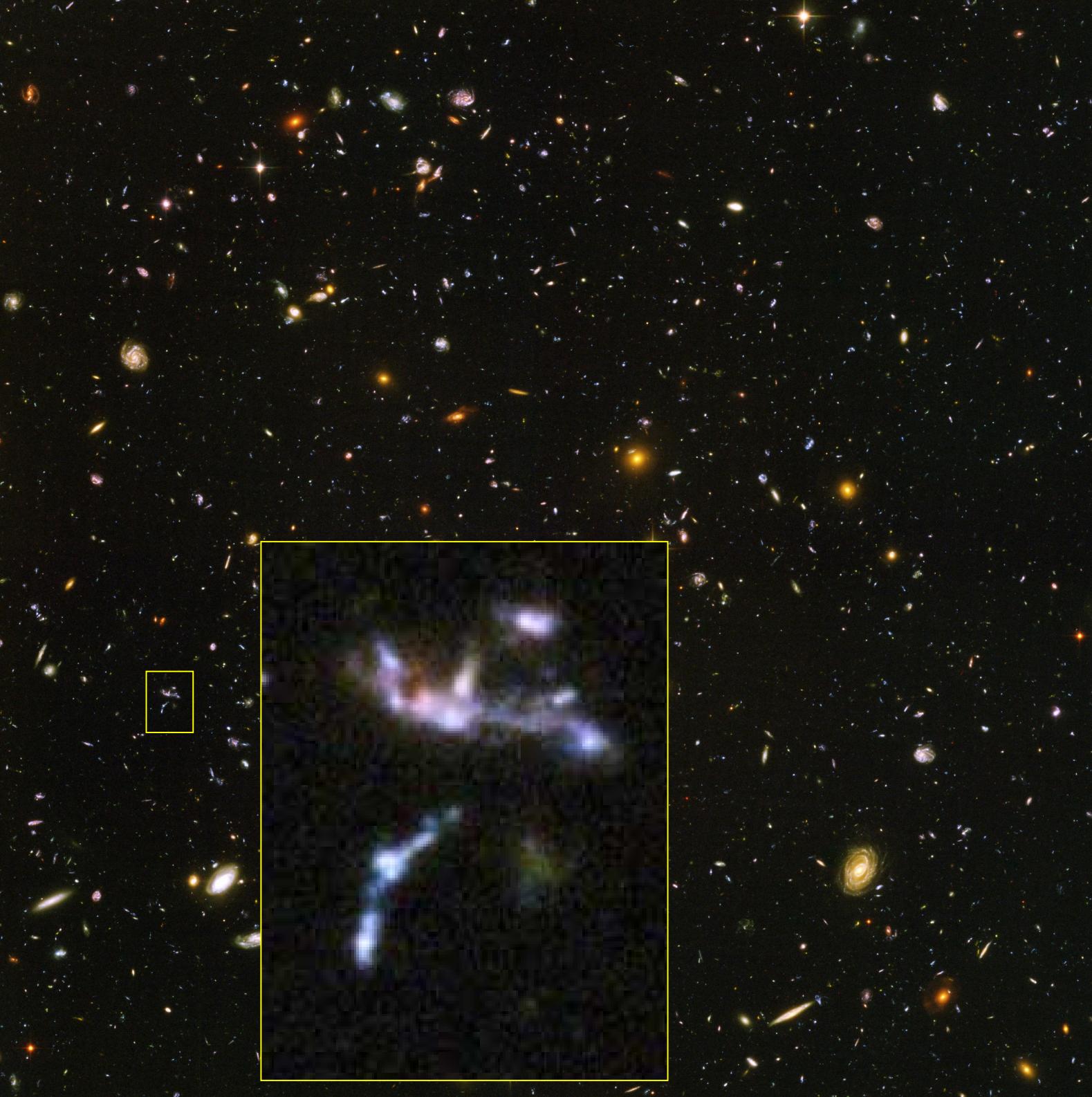


Galaxia Eliptica



en Galáctica





# Clasificación Galáctica



# Clasificación Galáctica





# Clasificación Galáctica



# Clasificación Galáctica



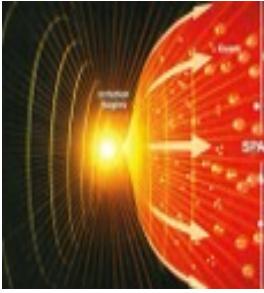
# Clasificación Galáctica (Antennae NGC4038/9)



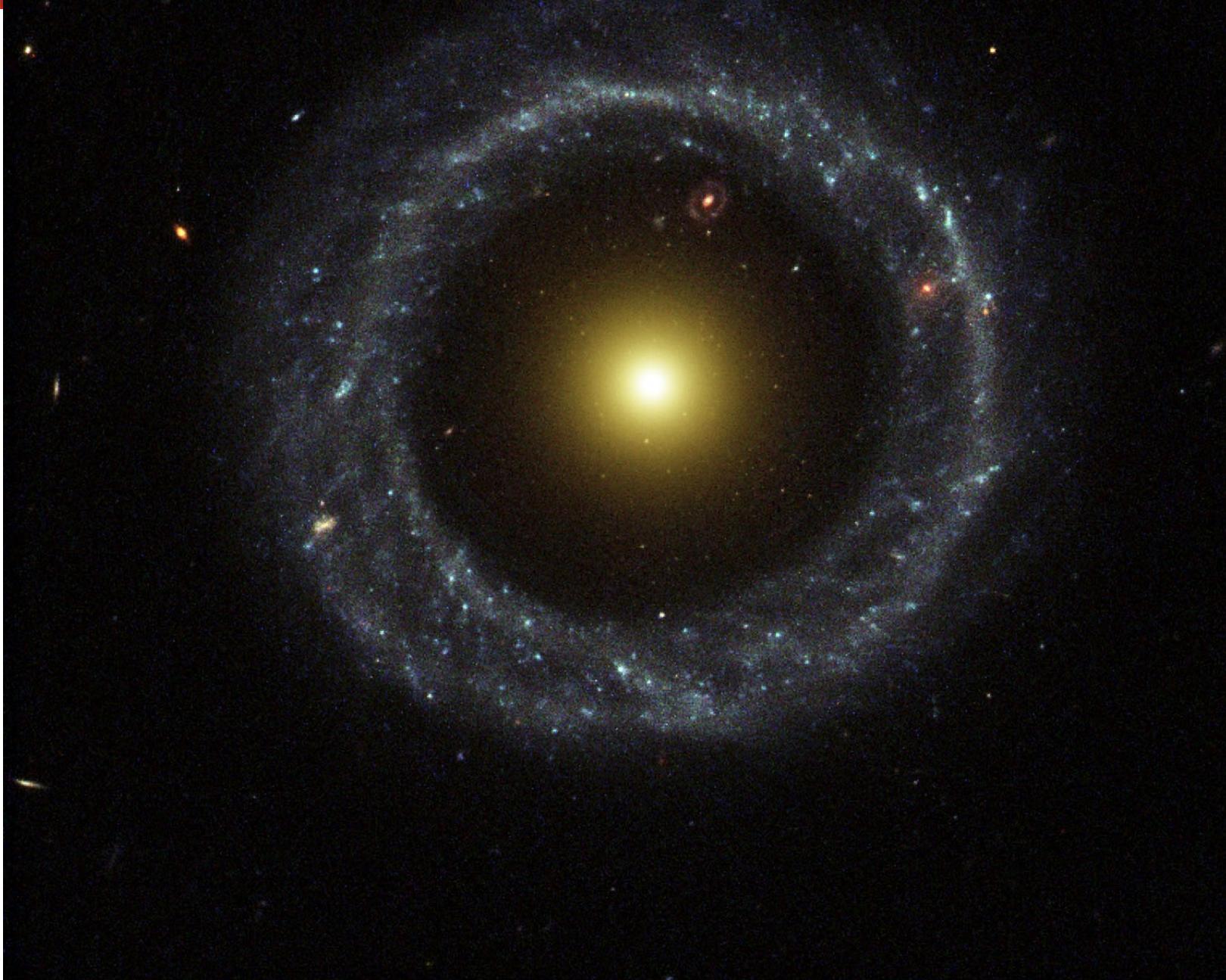


# Colisión de Galaxias





# Galaxia de Anillo (Hoag)



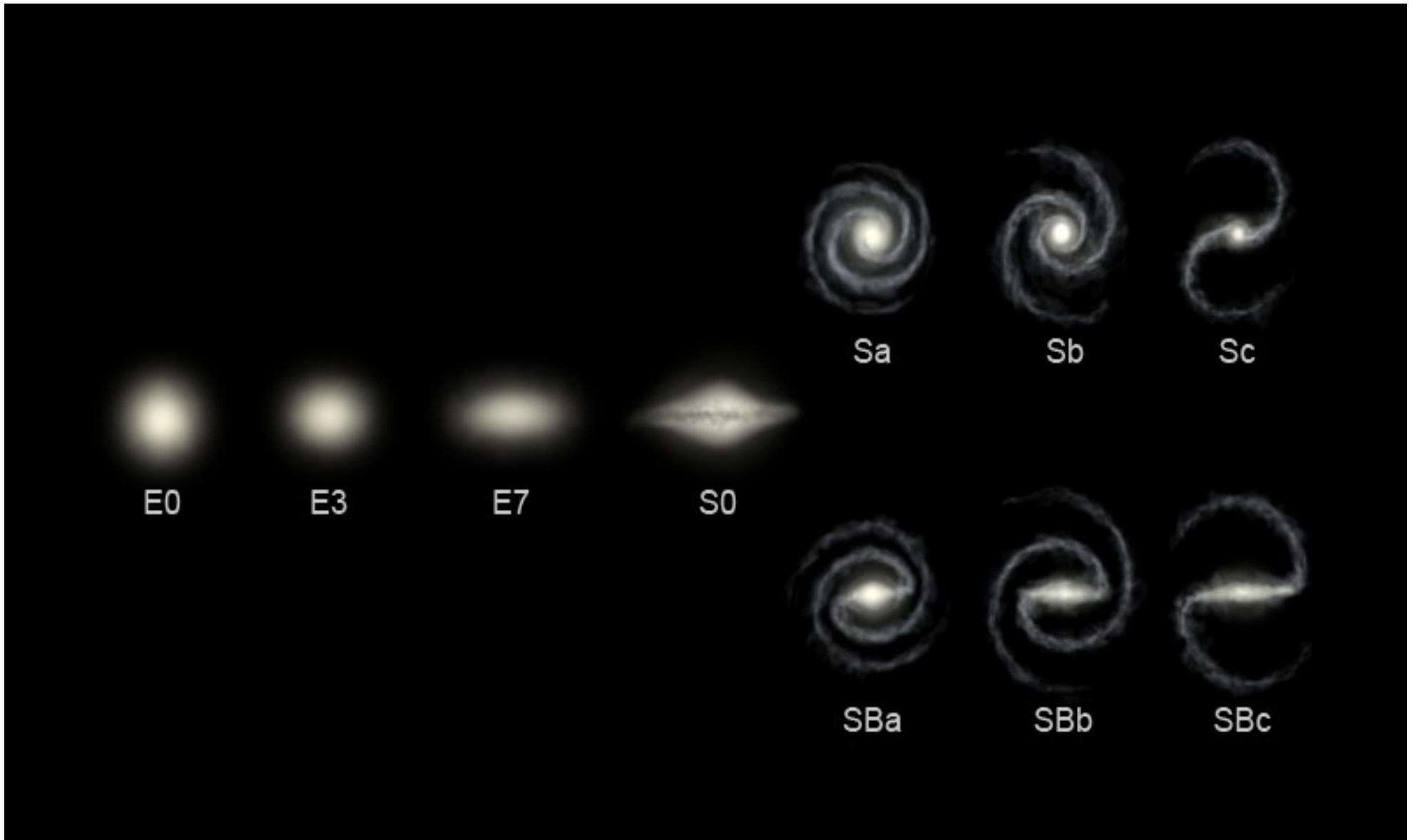
# Colisión galáctica (NGC4676 - Mice galaxies)



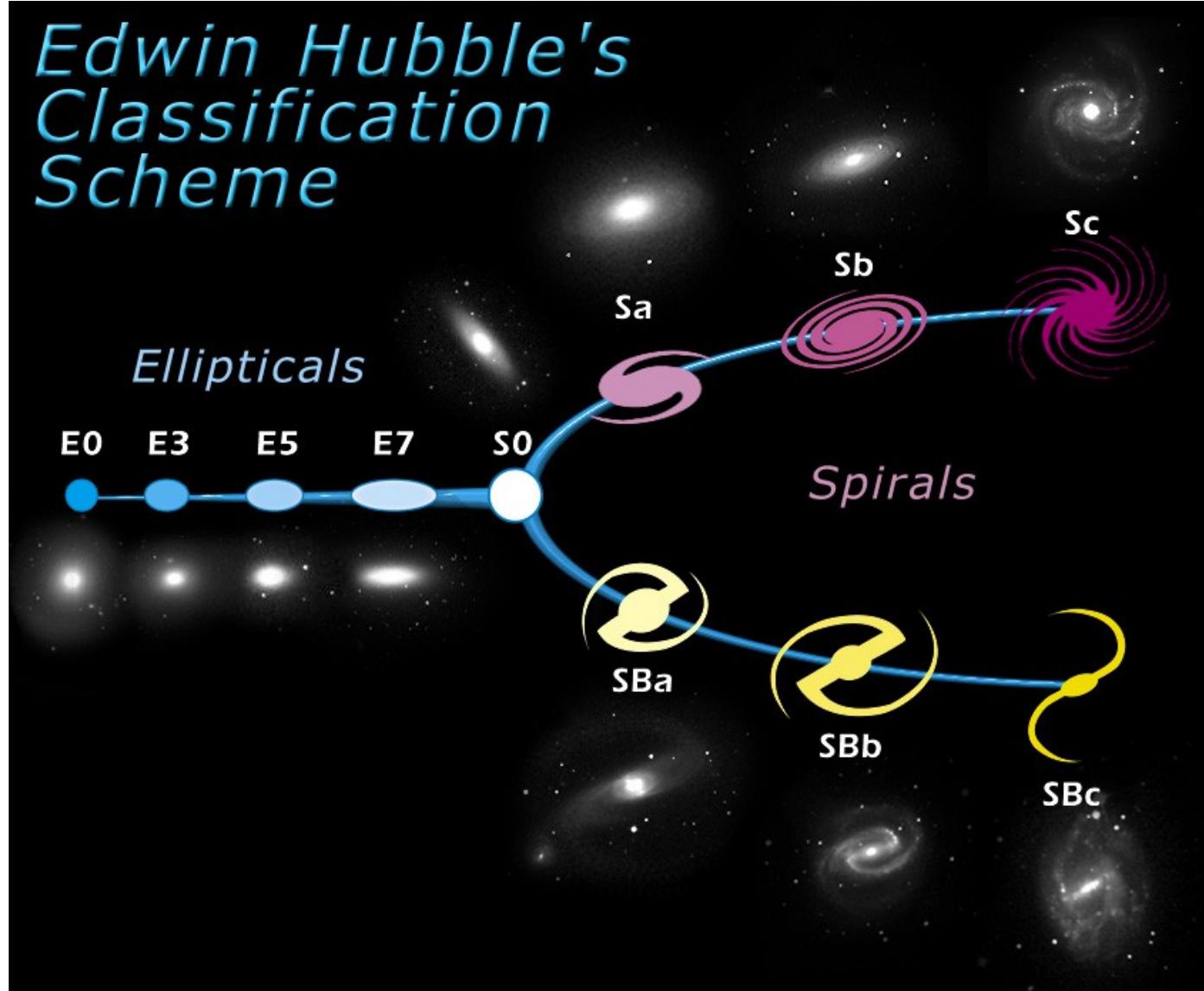
# Colisión galáctica: ARP 273

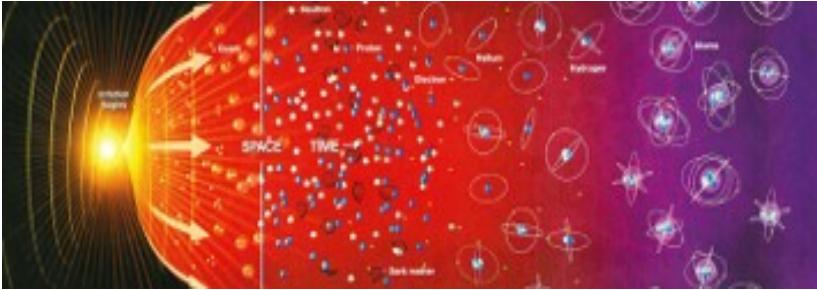


# Clasificación



# Clasificación galáctica



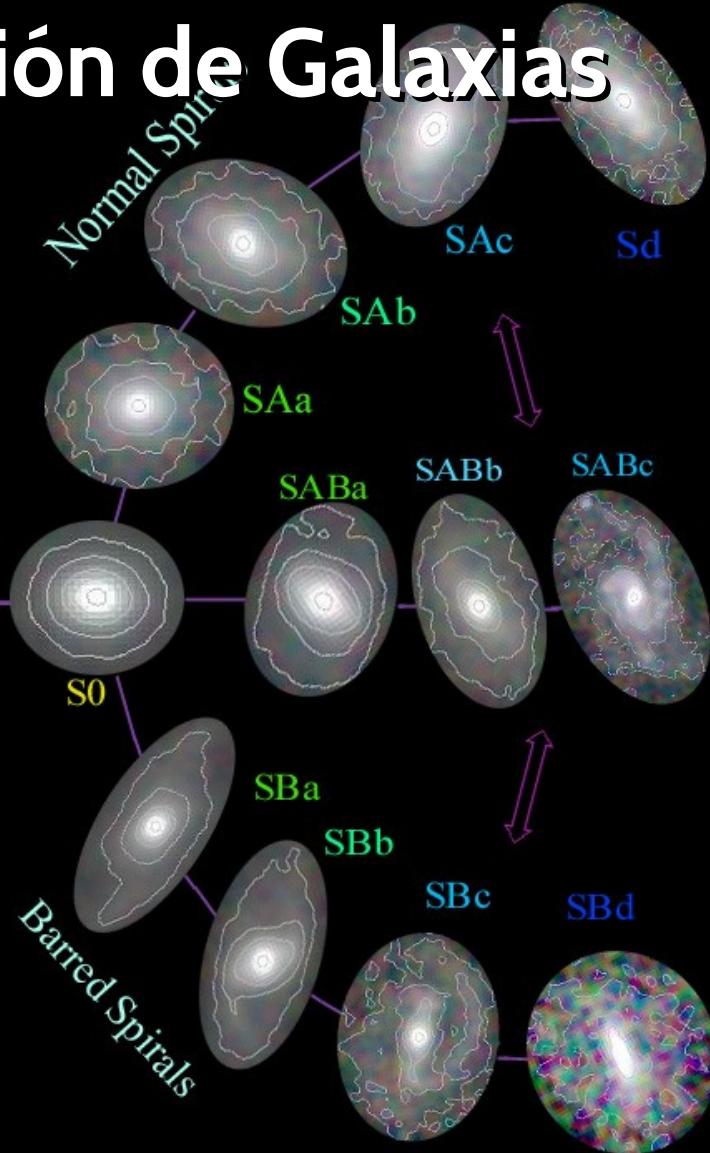


# Near-Infrared Galaxy Morphology

# Clasificación de Galaxias

Elliptical Galaxies

E0 E2 E4 E6 S0





Galaxy Zoo

Galaxy Zoo  
Galaxy Zoo

<http://www.galaxyzoo.org>

**Un viaje hacia los confines del Universo...**

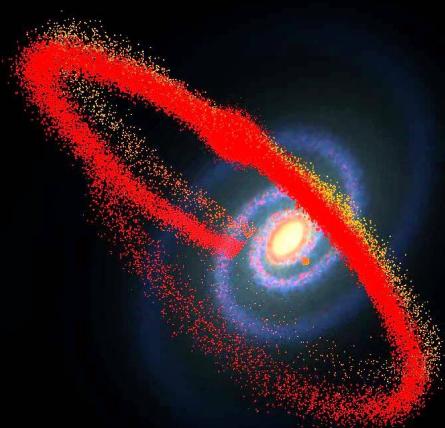
# La Vía Láctea

# Los satélites de la Vía Láctea

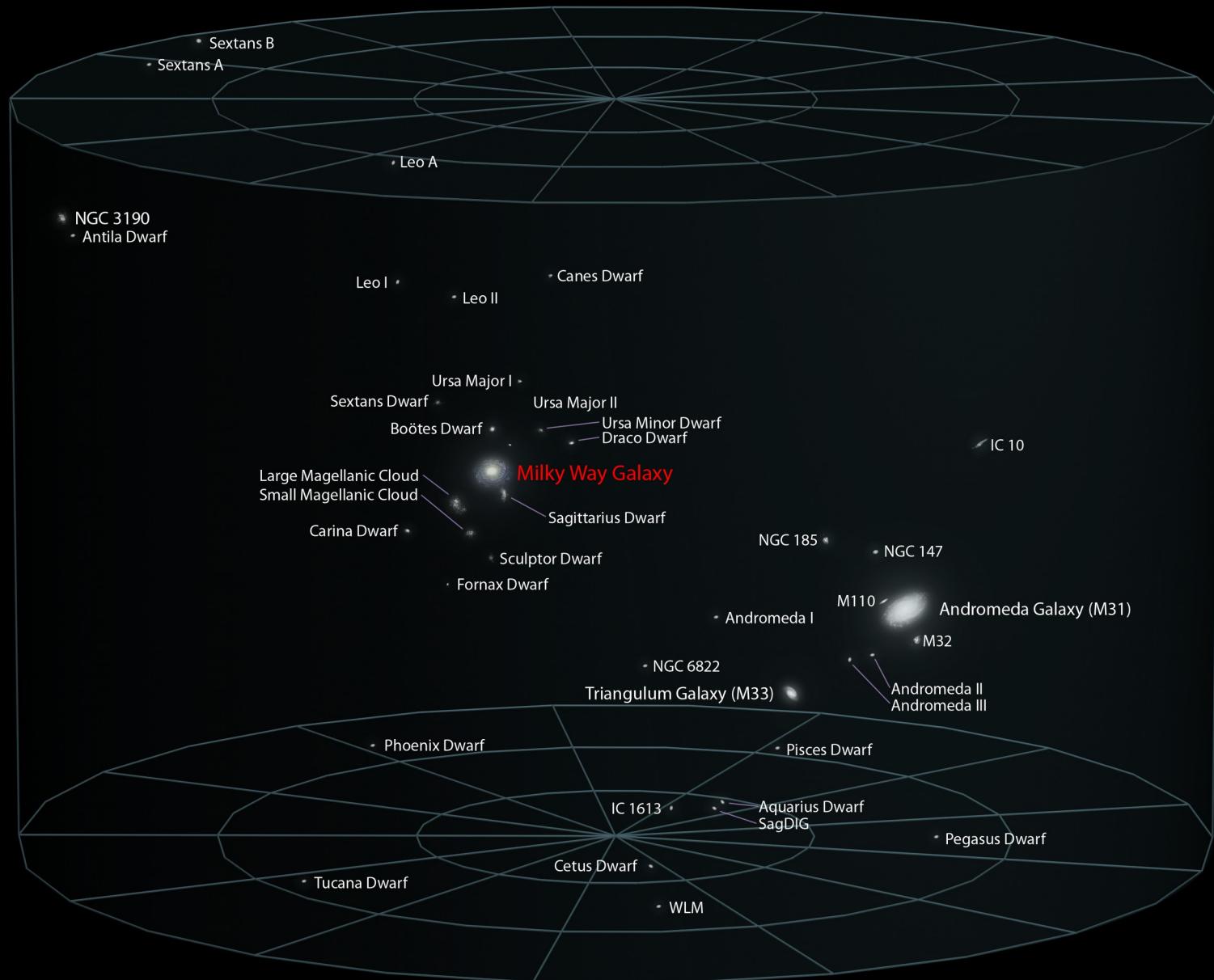


# Los satélites de la Vía Láctea

- Subgrupo de la Vía Láctea
  - ~25 galaxias pequeñas unidas gravitatoriamente a la Vía Láctea
  - Nubes de Magallanes son visibles a simple vista, aunque aún no se sabe si son satélites de la Vía Láctea (2006)
  - Galaxia Enana sub-esférica de Sagitario es el mayor satélite conocido

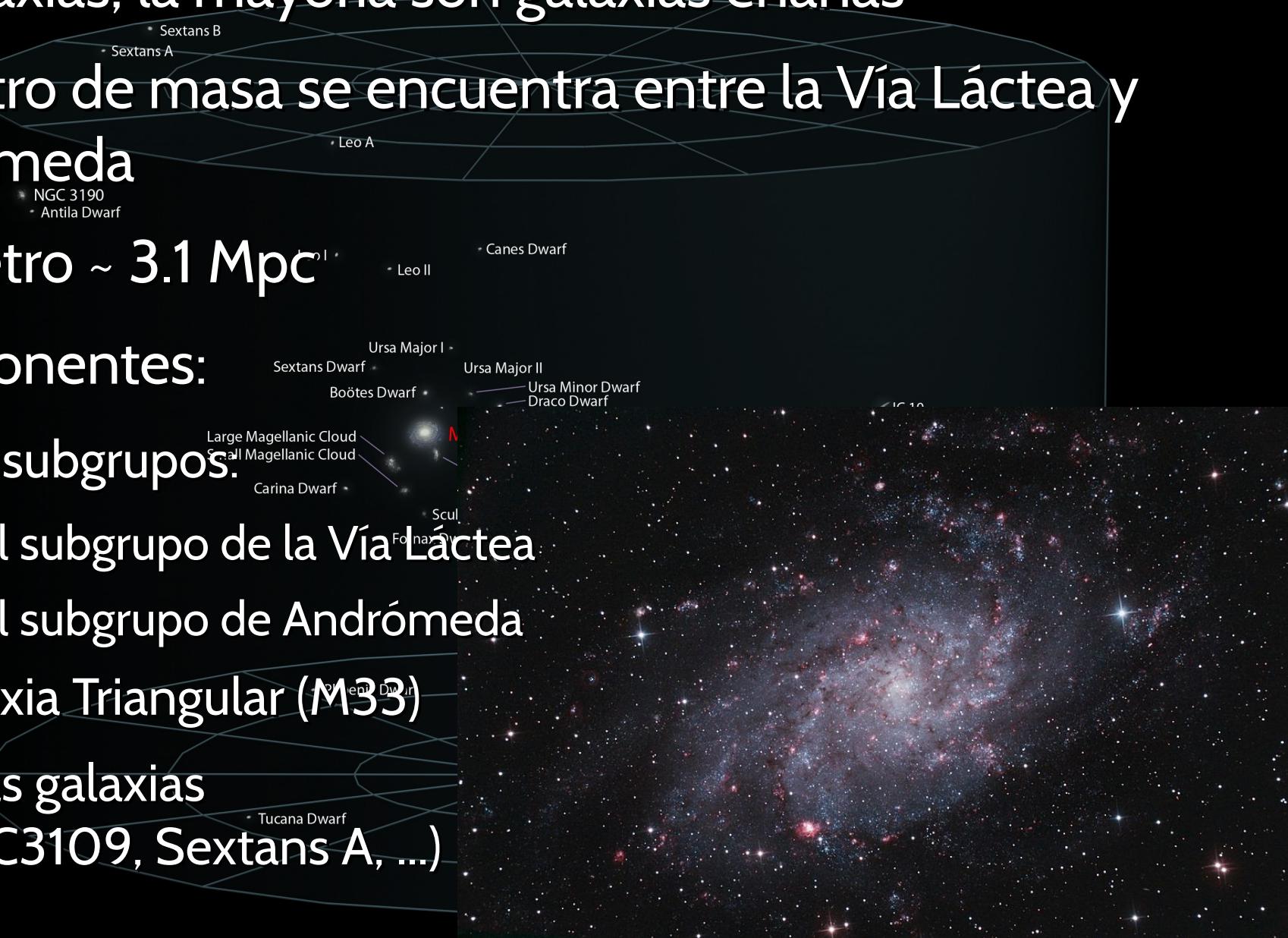


# Grupo Local

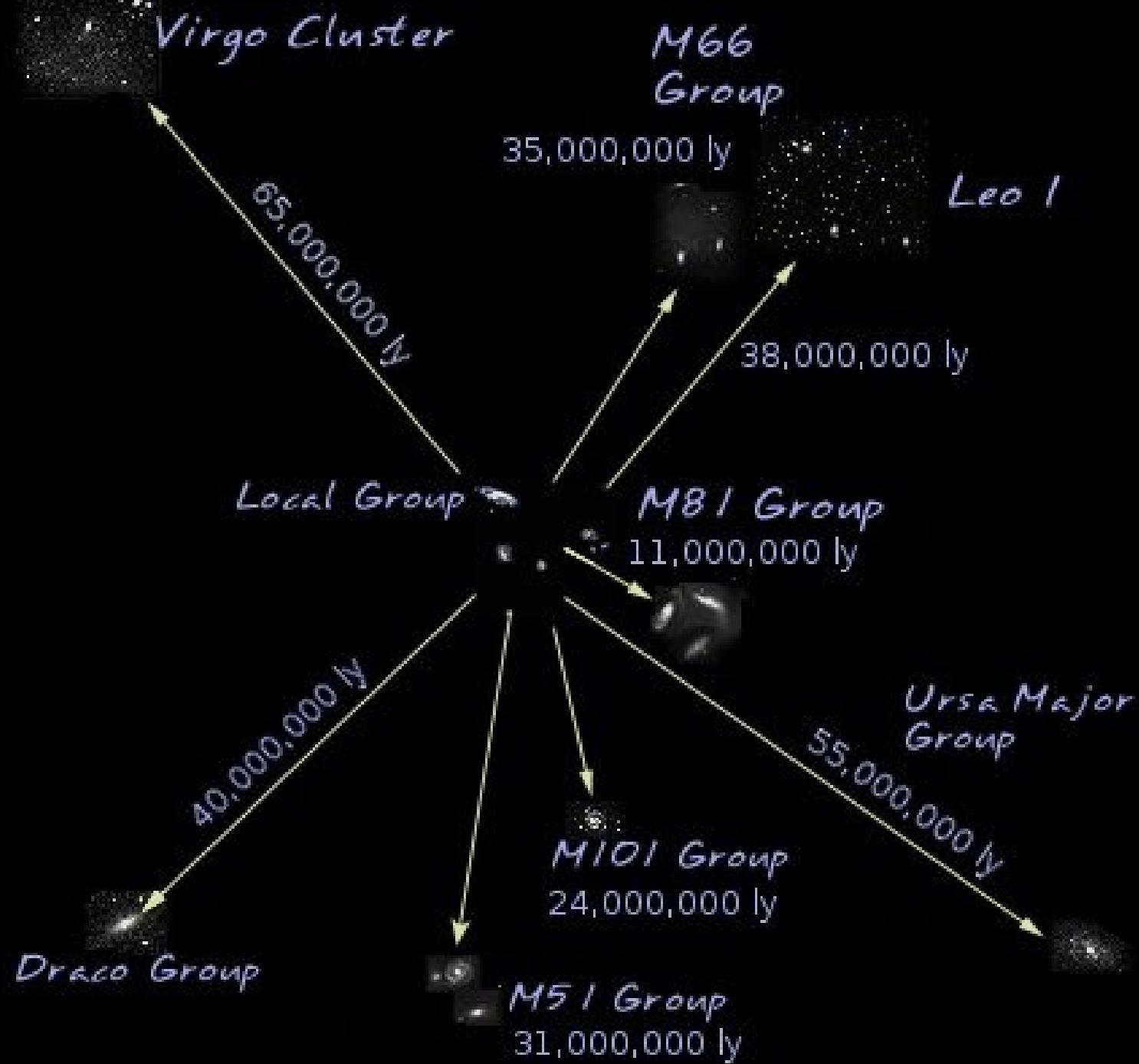


# Grupo Local

- 54 galaxias, la mayoría son galaxias enanas
- El centro de masa se encuentra entre la Vía Láctea y Andrómeda
- Diámetro ~ 3.1 Mpc
- Componentes:
  - Dos subgrupos:
    - El subgrupo de la Vía Láctea
    - El subgrupo de Andrómeda
  - Galaxia Triangular (M33)
  - Otras galaxias (NGC3109, Sextans A, ...)



# Supercúmulo de Virgo (o Local)



# Supercúmulo de Virgo

*Virgo Cluster*

*M66*

- Concentración de galaxias que incluyen al Cúmulo de Virgo y al Grupo Local

35,000,000 ly

*Leo I*

- Hay millones de supercúmulos como este en el Universo

- 100 grupos de galaxias en 33 Mpc

*Local Group*

- $\sim 10^{15} M_S$  y  $\sim 3 \times 10^{12} L_S$ . Se desplaza a  $\sim 600$  km/s hacia el Cúmulo de Norma (Abel3627  $\rightarrow$  Gran Atractor)

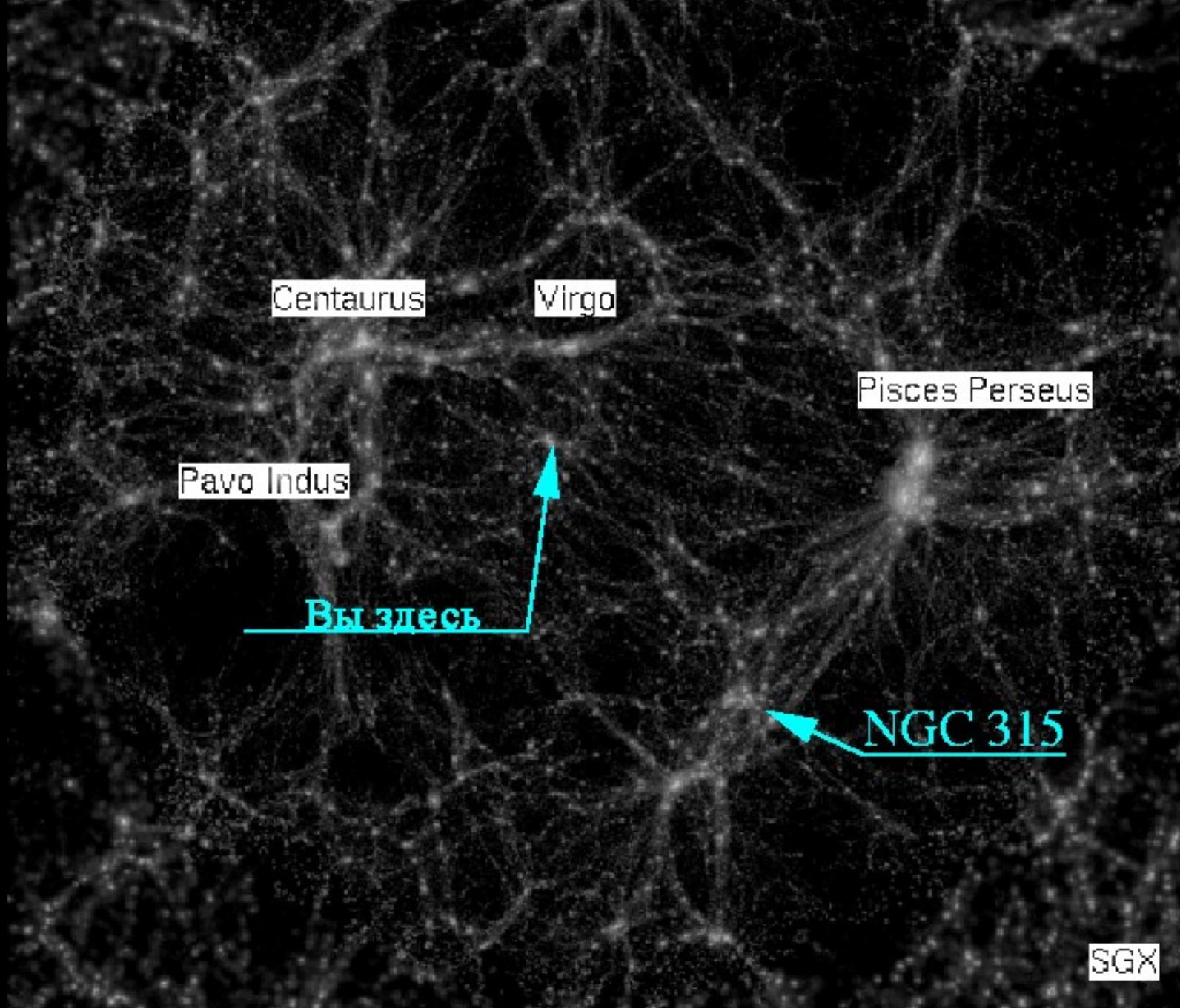
40,000,000 ly

*Draco Group*

SGY

Coma

# Supercúmulo de Laniakea (2014)

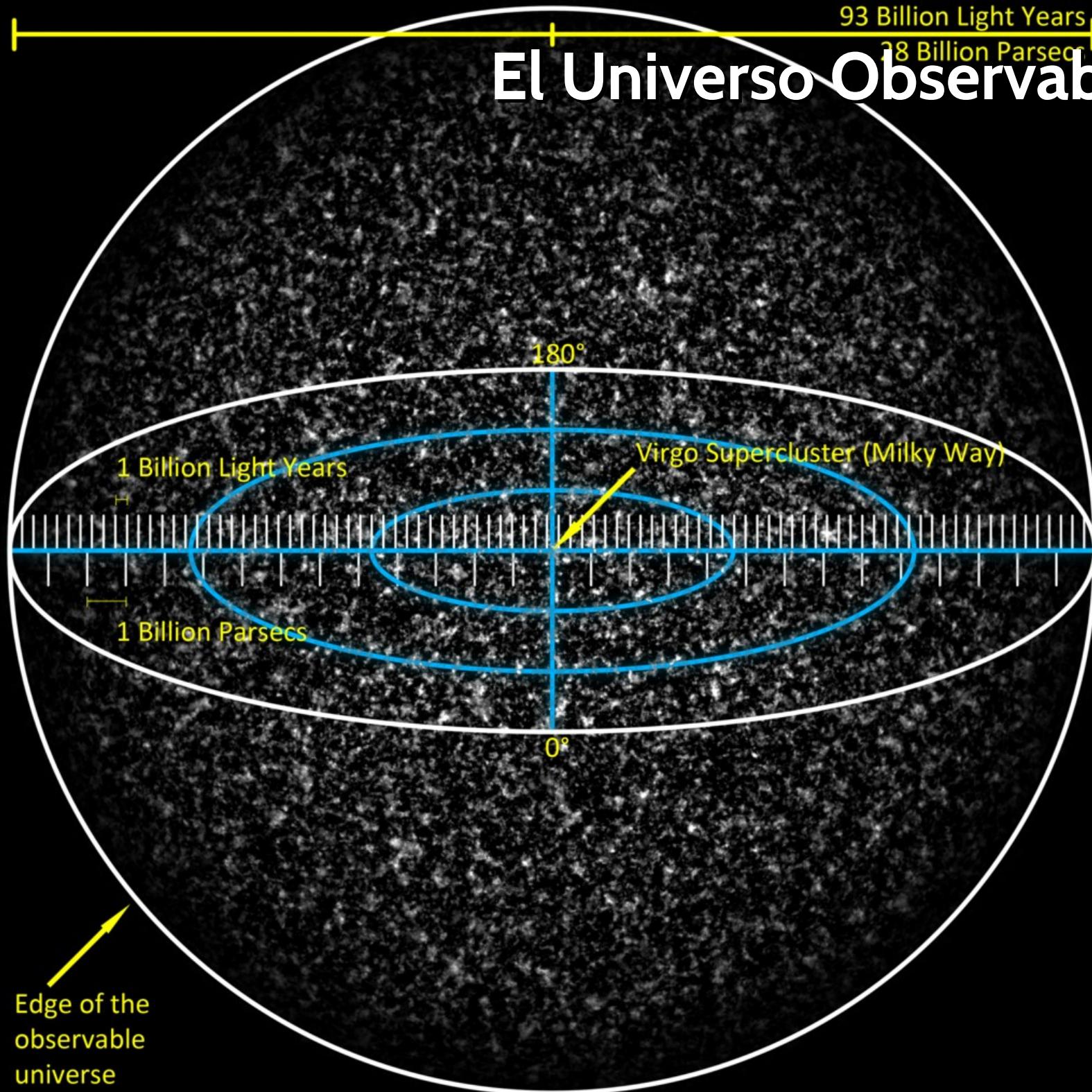


# Supercúmulo de Laniakea (2014)

- Entre 300 y 500 cúmulos de galaxias
- 100000 galaxias en 160 Mpc
- $\sim 10^{17} M_s$  y  $\sim 5 \times 10^{14} L_s$ .
  - Supercúmulo de Virgo
  - Supercúmulo Hydra-Centauro (incluye el Gran Atractor)
  - Supercúmulo Pavo-Indus
- Supercúmulos vecinos:
  - Shapley, Hercules, Coma, Perso-Piscis NGC 315

93 Billion Light Years  
28 Billion Parsecs

# El Universo Observable





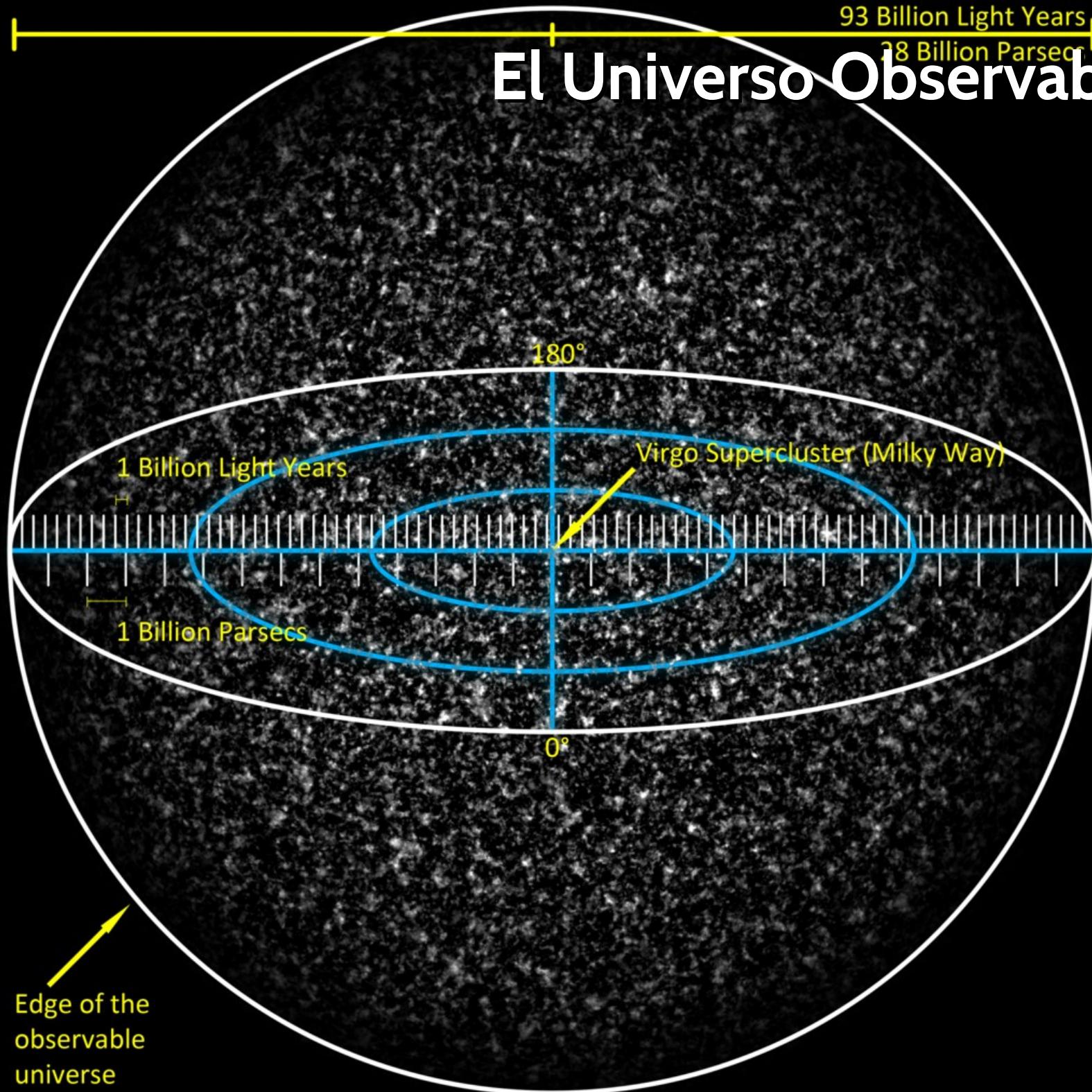
# Alto, ¿Qué significa “observable”?

- **Universo observable →  $r \sim 46.5$  mil millones años luz**
  - **Es una esfera centrada en la Tierra que contiene a todos los objetos que pueden ser vistos desde la Tierra ahora.**
  - La luz emitida por estos objetos ha tenido tiempo suficiente para alcanzar a la Tierra
  - **Edad del Universo:  $1.37 \times 10^{10}$  años → El Universo observable NO tiene  $13.7 \times 10^9$  a.l. → universo en expansión (volveremos)**
- **Radio de Hubble → es la distancia que viaja la luz en un tiempo igual al tiempo de Hubble**

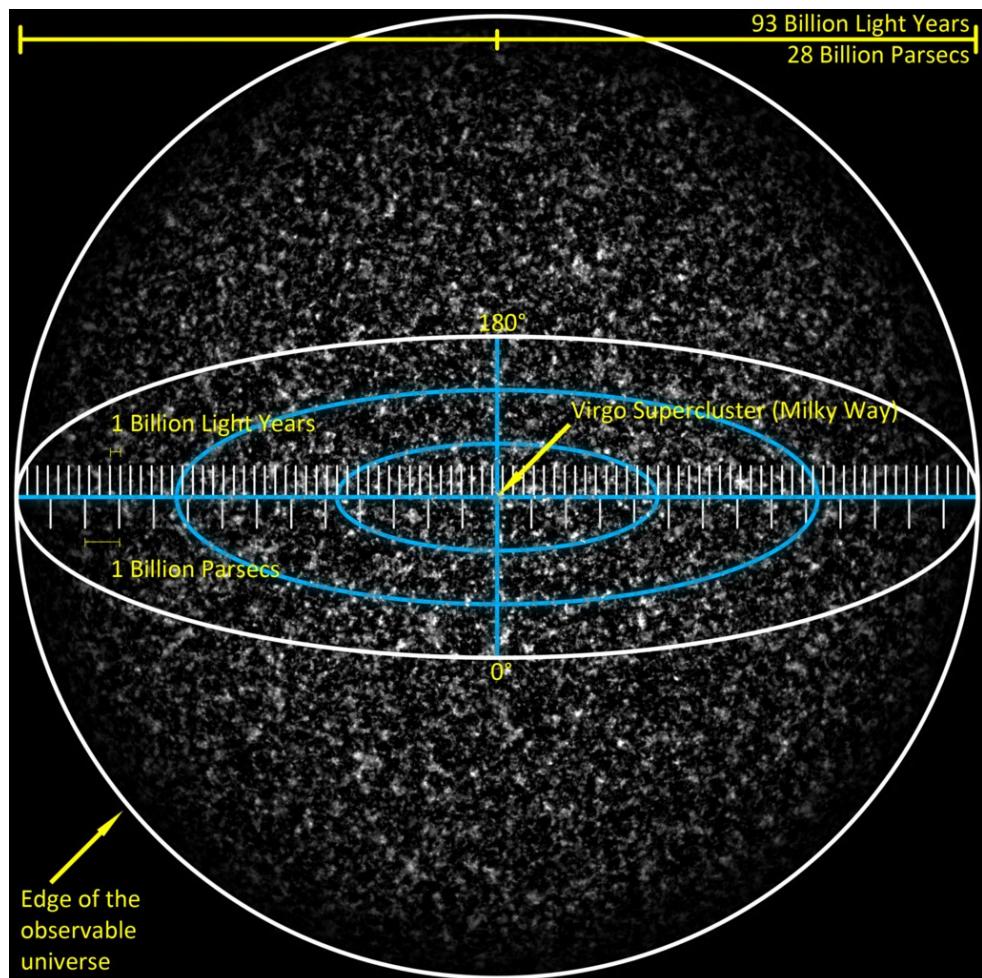
$$r_{H_0} = ct_{H_0} = \frac{c}{H_0} \simeq 1.37 \times 10^{10} \text{ años luz}$$

93 Billion Light Years  
28 Billion Parsecs

# El Universo Observable



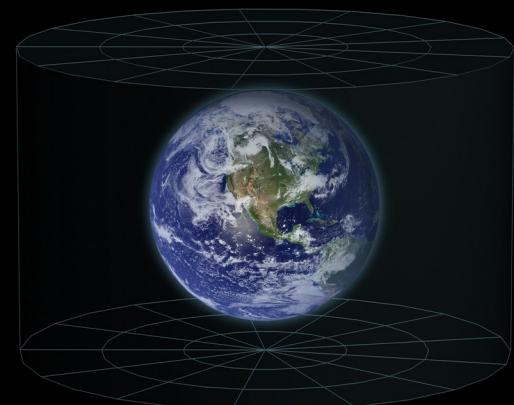
# ¿Cómo se distribuye?



- ¡¡¡A las escalas más grandes el Universo es isótropo y homogéneo!!!
- *parejito* dirían por ahí...
- Esto tiene consecuencias observaciones que veremos en la próxima unidad

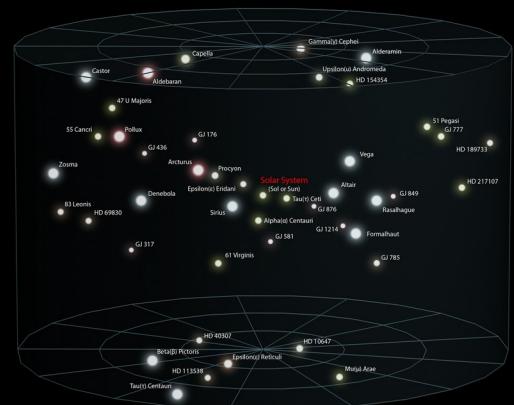
# El Universo Observable

Earth

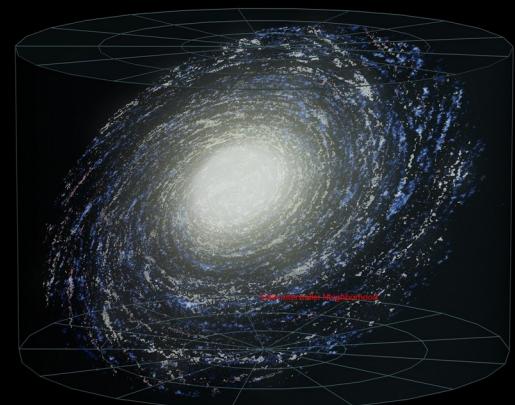


## Solar System

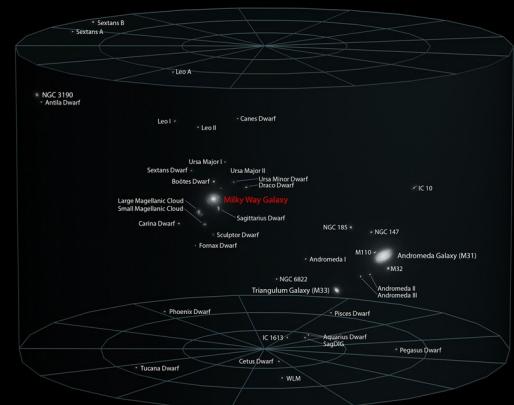
# Solar Interstellar Neighborhood



# Milky Way Galaxy

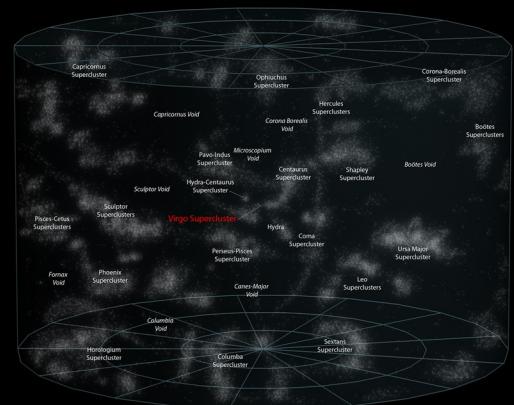


## Local Galactic Group



Virgo Supercluster

# Local Superclusters



# Observable Universe