



Universidad Nacional de Río Negro

Int. Partículas, Astrofísica & Cosmología - 2016

- **Unidad** 02 – Astrofísica
- **Clase** 0204 – 09/16
- **Fecha** 13 Oct 2016
- **Cont** Galaxias
- **Cátedra** Asorey
- **Web** github.com/asoreyh/unrn-ipac
- **Youtube** próximamente
- **Archivo** a-2016-U02-C04-1013-galaxias



Contenidos: un viaje en el tiempo

HOW DID OUR UNIVERSE BEGIN?

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

Inflation
The universe expands, cools a repulsive energy field inflates space faster than light fills it with a soup of subatomic particles called quarks.

Age: 10^{-3} milliseconds
Size: Infinitesimal to golf ball

Early building blocks
Quarks clump into protons and neutrons, creating blocks of atomic nuclei. Perhaps dark matter forms.

Age: .01 milliseconds
Size: 0.1-millionth present size

First nuclei
As the universe continues to cool, the lightest nuclei of hydrogen and helium arise. A thick fog of particles blocks all light.

Age: .01 to 200 seconds
Size: 1-billionth present size

First atoms, first light
As electrons begin orbiting nuclei, creating atoms, the glow from their infalling orbits is unveiled. This light is as far back as our instruments can see.

Age: 380,000 years
Size: .0009 to 0.1 present size

The "dark ages"
For 300 million years this collection of gas and dust is the only light. Clumps of 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. Isolated of dark matter, they eventually form galaxies and stars. Galaxies glow brightest.

Age: 300 million years
Size: 0.1 present size

Antigravity wins
After being slowed for billions of years, gravity, 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.

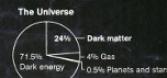
Age: 13.8 billion years
Size: Present size

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 dented. 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 23 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 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.



Unidad 2 Astrofísica Cálido y frío

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 quantum energy fluctuations. Inflation theory suggests universes 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 1 Partículas 1 todo es relativo



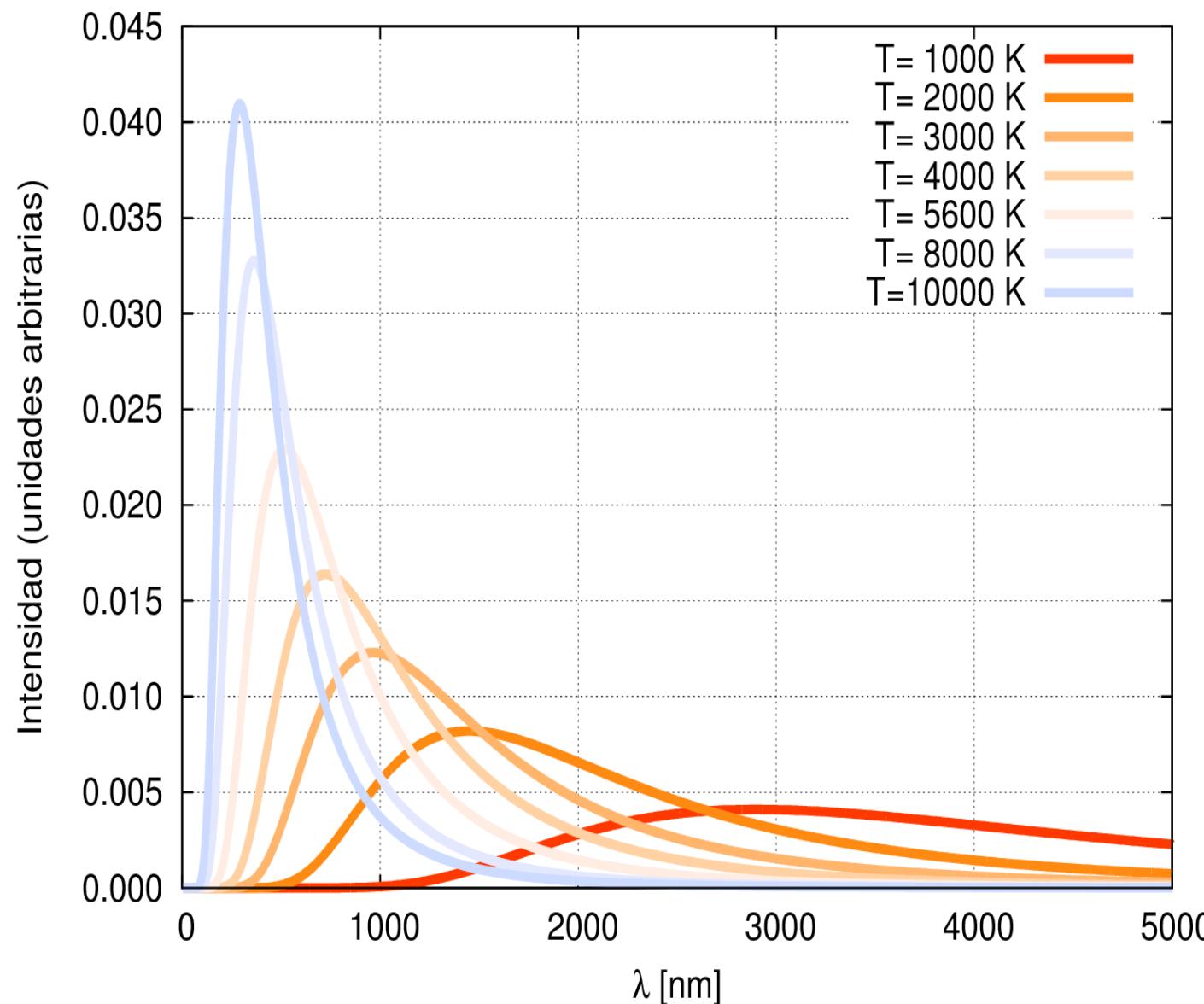
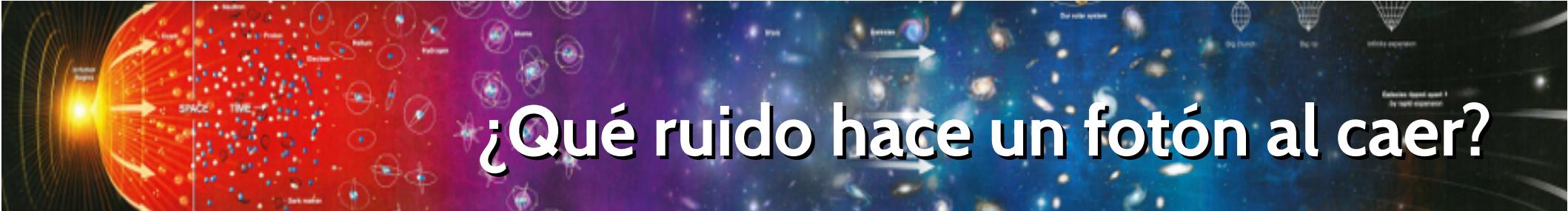
By through the universe on
our digital edition.
ILLUSTRATION: RICHARD HARRIS
ART: MICHAEL WILHELM
SOURCES: CHARLES BENNETT, JOHN
HUCHENCOVICH, ANDREW LISTER,
UNIVERSITY OF CHICAGO
CONTRIBUTOR: ROBERT KERR/NATIONAL
GEOGRAPHIC SOCIETY



Temas de monografía para trabajo final algunas ideas, lista no excluyente

- Cosmogonía de los pueblos originarios (elegir alguno)
- Cosmogonía y Constelaciones
- Evolución estelar (vida y obra de las estrellas)
- Objetos compactos (enanas blancas, estrellas de neutrones, agujeros negros)
- Ensayo sobre posibilidades de vida en Europa (luna de Júpiter)
- Vida basada en Amoníaco como disolvente
- El GalaxyZoo: principales resultados
- Otras Tierras: exoplanetas similares a la Tierra
- El impacto de Galileo Galilei en la concepción moderna de la Astronomía
- Spirit, Opportunity y Curiosity: explorando la superficie de Marte
- La sonda Cassini-Huygens: Saturno y Titán
- El Big Bang

¿Qué ruido hace un fotón al caer?



- Ley de Wien
 - Posición de λ_{\max}

$$\lambda_{\max} = \frac{b}{T}$$

$$b = 2.9 \text{ mm K}$$

- Ley de Stefan-Boltzmann

$$L \equiv \frac{\Delta E}{\Delta t} = \sigma A T^4$$

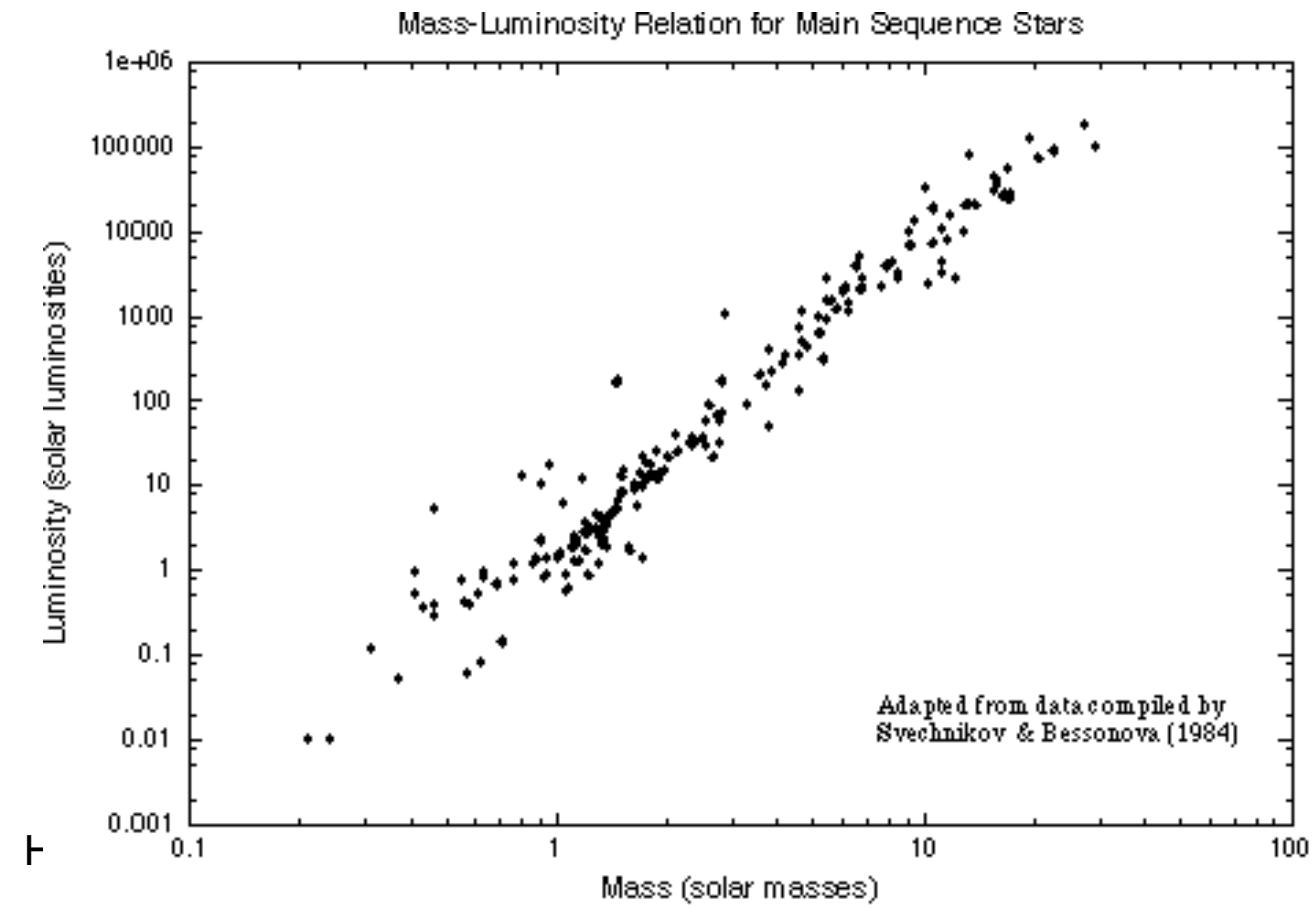
$$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$$

Luminosidad → Masa

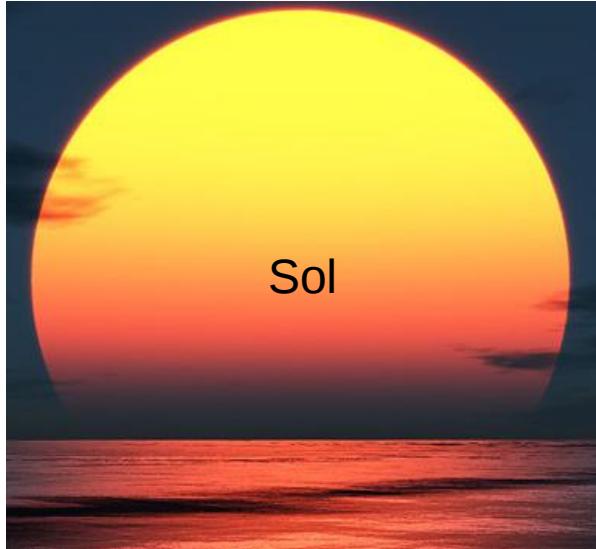
- Si: $(0.1 < \text{Masa Estelar} < 50)$ masas solares:
L es proporcional a la M^4
- Nota: En general, M^a , con a entre 3 y 4 (~ masa)

$$\left(\frac{L_{\text{Estrella}}}{L_{\text{Sol}}} \right) = \left(\frac{M_{\text{Estrella}}}{M_{\text{Sol}}} \right)^4$$

Oct 13, 2016



$Y: (\text{Luminosidad, Temperatura}) \rightarrow \text{Radio}$



- $T = 5700 \text{ K}$ (Amarilla)
- $L = L_S$
- $T = 3400 \text{ K}$ (Roja)
- $L = 135000 L_S$

Y: (Luminosidad, Temperatura) → Radio

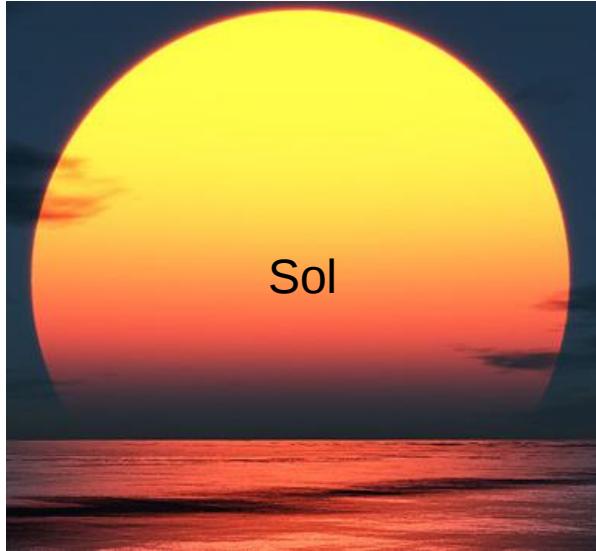


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**Menor temperatura,
menos emisión
Pero, la emisión es
mucho mayor**

Y: (Luminosidad, Temperatura) → Radio

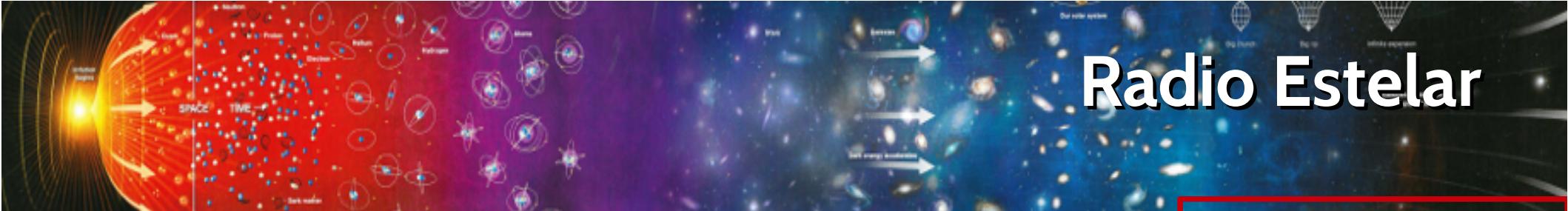


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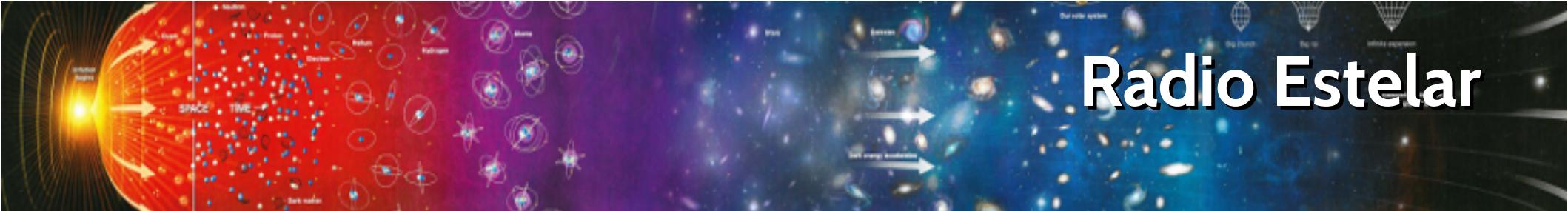
**Betelgeuse debe
ser mucho más
grande que el
Sol**



Radio Estelar

- Comparando las temperaturas
- ¡Pero también depende del radio!

$$L = 4\pi\sigma R^2 T^4$$



Radio Estelar

- Veamos.... $(T_B/T_S)^4$
 - $(3400 / 5700)^4 \sim = 1/7.8$
 - Si dependiera sólo de T, el Sol sería 7.8 veces más luminoso que Betelguese
- Pero...

$$L_B / L_S = [(4\pi R_B^2) \sigma T_B^4] / [(4\pi R_S^2) \sigma T_S^4]$$

$$135000 = (R_B/R_S)^2 (T_B/T_S)^4$$

$$135000 = (R_B/R_S)^2 / 7.8$$

$$1.053 \times 10^6 = (R_B/R_S)^2$$

- Veamos.... $(T_B/T_S)^4$

$$R_B = 1026 R_{\text{Sol}}$$

Betelgeuse es una supergigante roja

mas luminoso que Betelgeuse

- Pero...

$$L_B / L_S = [(4\pi R_B^2) \sigma T_B^4] / [(4\pi R_S^2) \sigma T_S^4]$$

$$135000 = (R_B/R_S)^2 (T_B/T_S)^4$$

$$135000 = (R_B/R_S)^2 / 7.8$$

$$1.053 \times 10^6 = (R_B/R_S)^2$$



Es cómodo medir las cosas en términos solares

- Masa Solar:

$$M_{\text{Sol}} = 1.989 \times 10^{30} \text{ kg} \simeq 1000 M_{\text{Júpiter}} \simeq 333000 M_{\text{Tierra}}$$

- Radio Solar:

$$R_{\text{Sol}} = 6.96 \times 10^8 \text{ m} = 696000 \text{ km} \simeq 110 R_{\text{Tierra}}$$

- Luminosidad Solar:

$$L_{\text{Sol}} = 3.83 \times 10^{26} \text{ W}$$

- Alto:

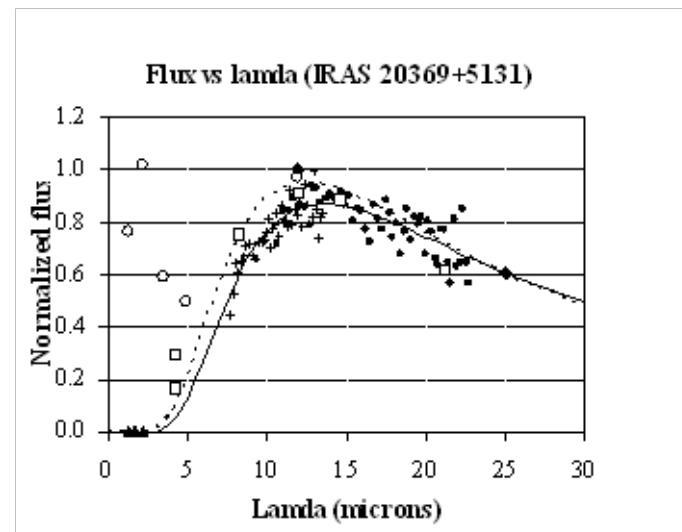
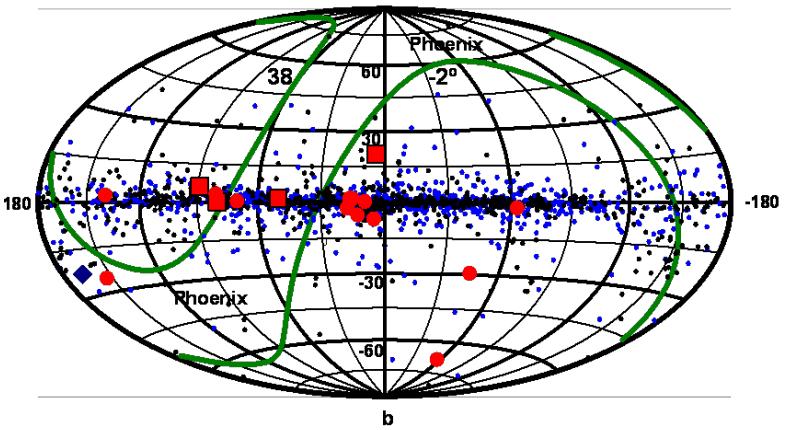
**1 segundo de energía liberada en el Sol
equivale a 800000 años de consumo humano (2013)**

Esferas de Dyson

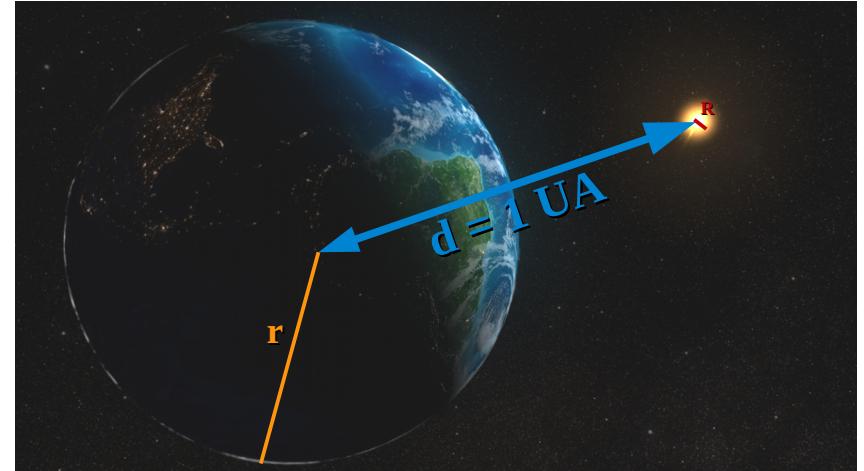


IRAS (InfraRed Astronomical Satellite)

http://home.fnal.gov/~carrigan/infrared_astronomy/Fermilab_search.htm



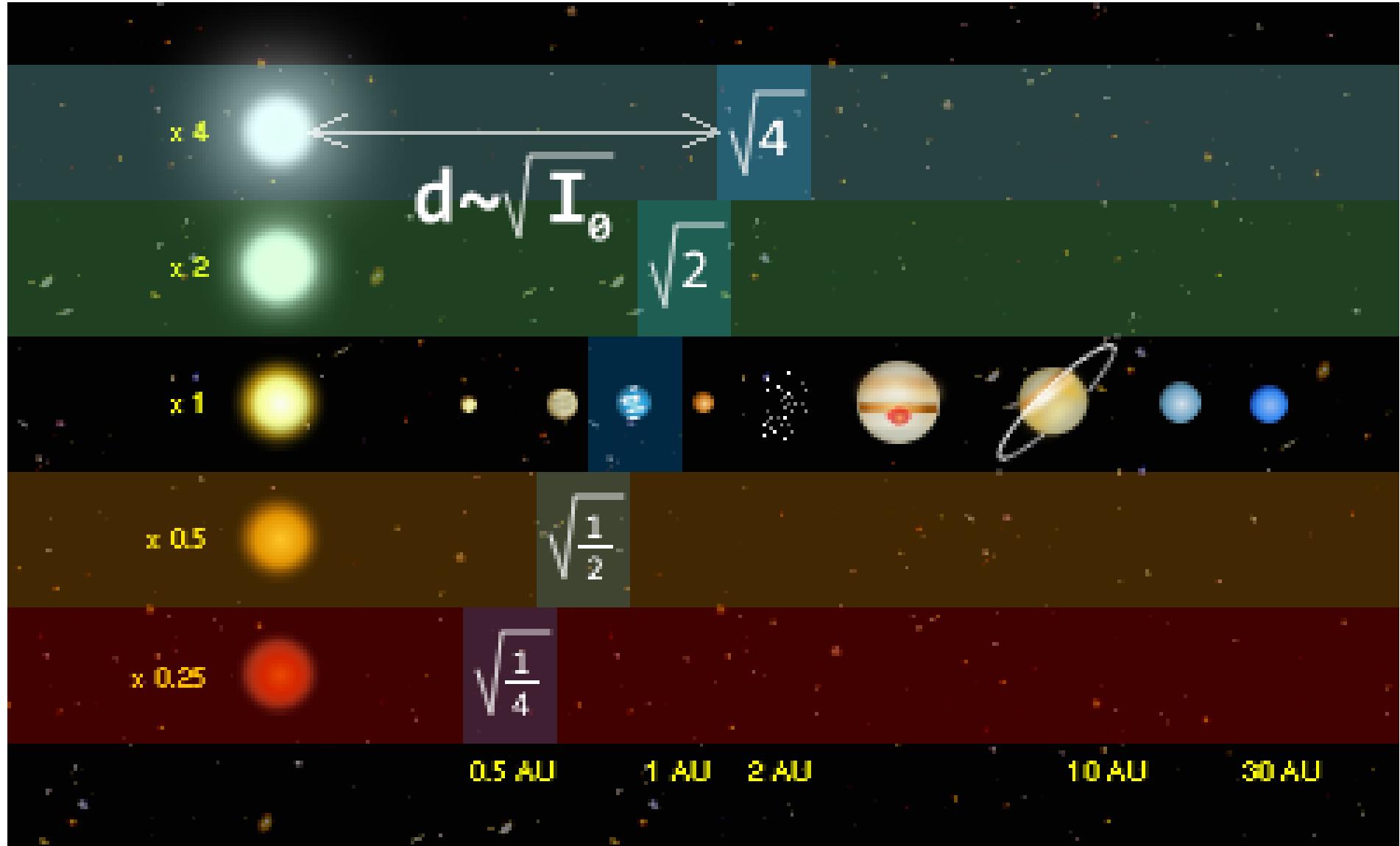
¿Y si fuera un planeta?



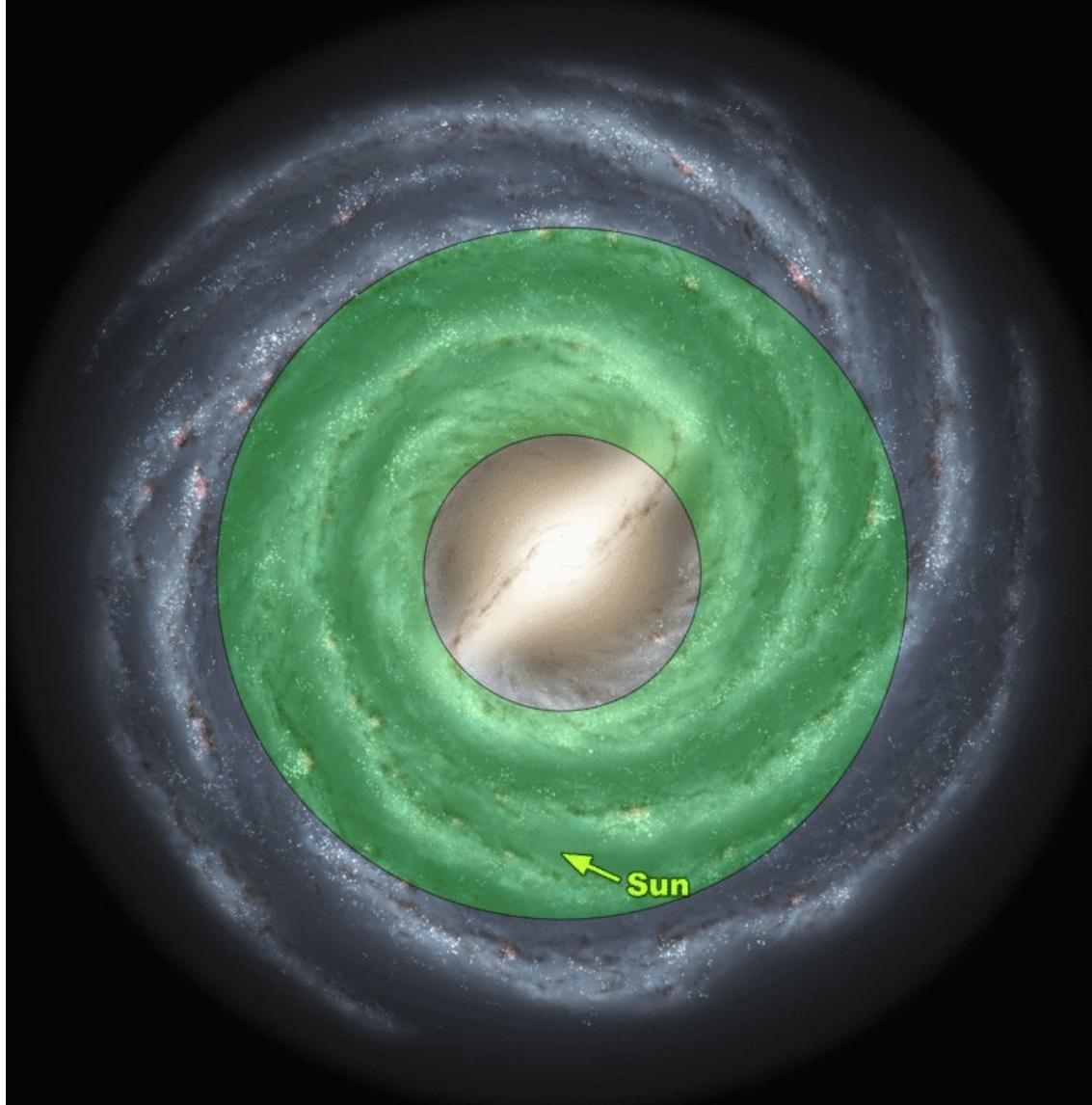
- ¿Qué fracción de la energía captura un planeta de radio r ?

$$T_{\oplus} = \sqrt[4]{\frac{L_{\odot}}{16\pi\sigma d^2}}$$
$$T_{\oplus} = \sqrt{\frac{R_{\odot}}{2d}} T_{\odot}$$
$$d = \frac{1}{2} \left(\frac{T_{\odot}}{T_{\oplus}} \right)^2 R_{\odot}$$

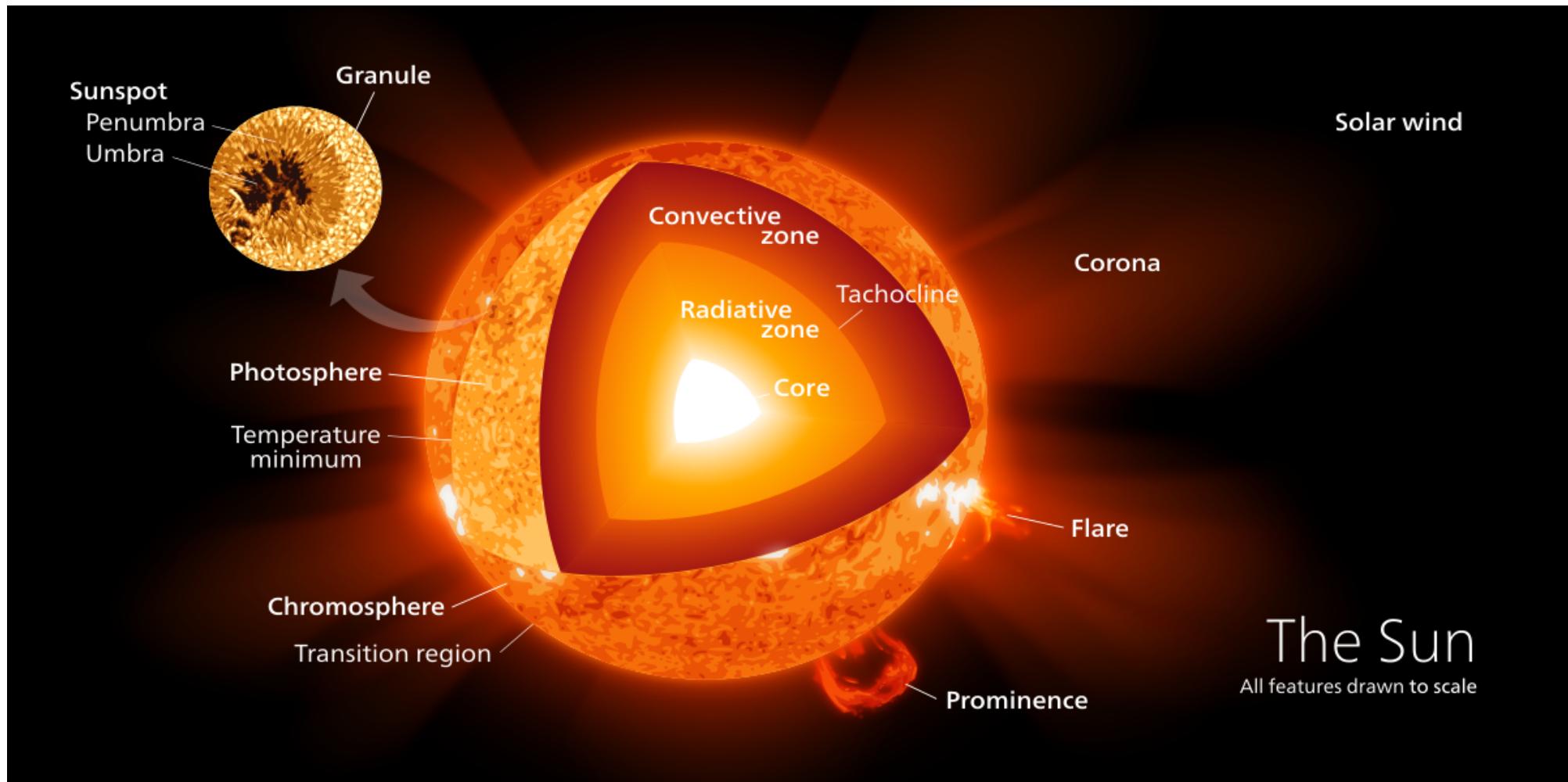
Zona habitable: Agua líquida (volveremos...)

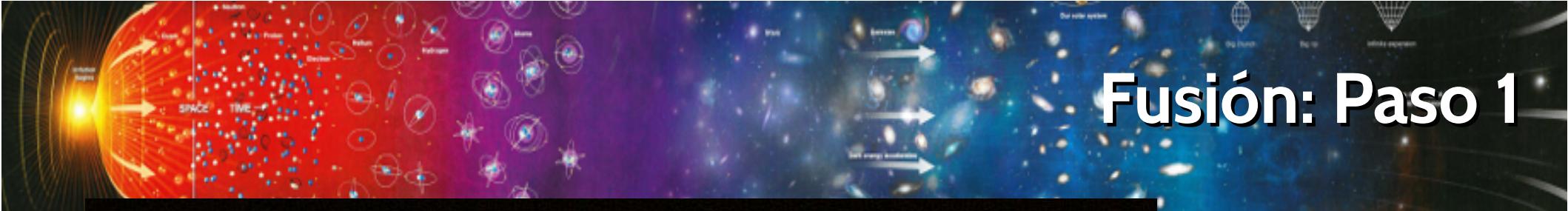


zona habitable... galáctica



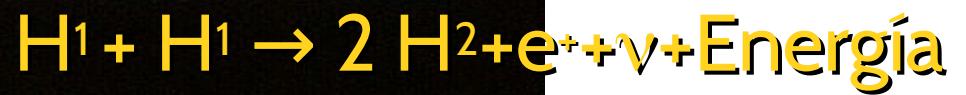
Estructura de una estrella típica (Sol)





Fusión: Paso 1

STEP 1



NASA/NSSTC/Hathaway

Fusión: Paso 2

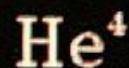
STEP 2

 D^2 $+$ H^1  γ $+$ He^3

NASA/NSSTC/Hathaway

Fusión: Paso 3

STEP 3



NASA/NSSTC/Hathaway



Fusión: Producción neta



Masa inicial: $1.003 \times 10^{-26} \text{ kg}$

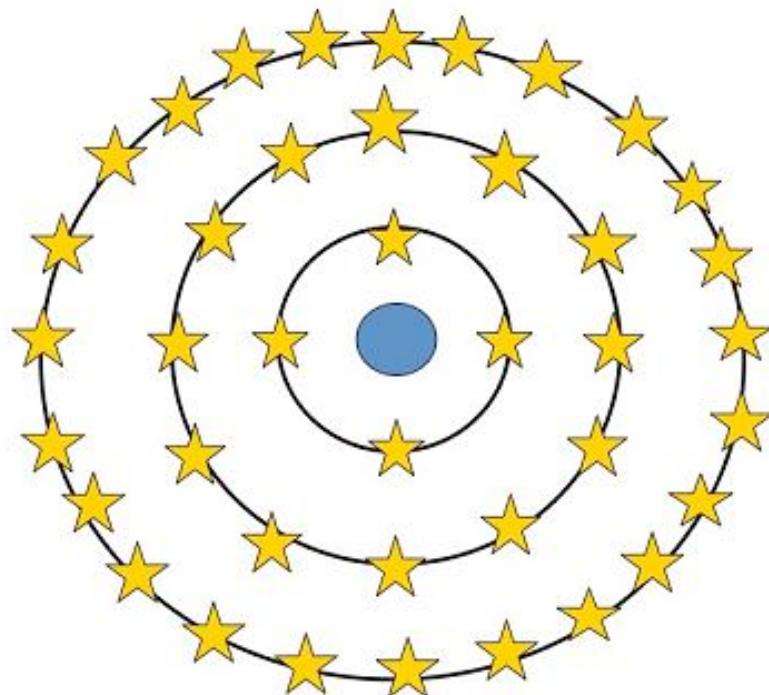
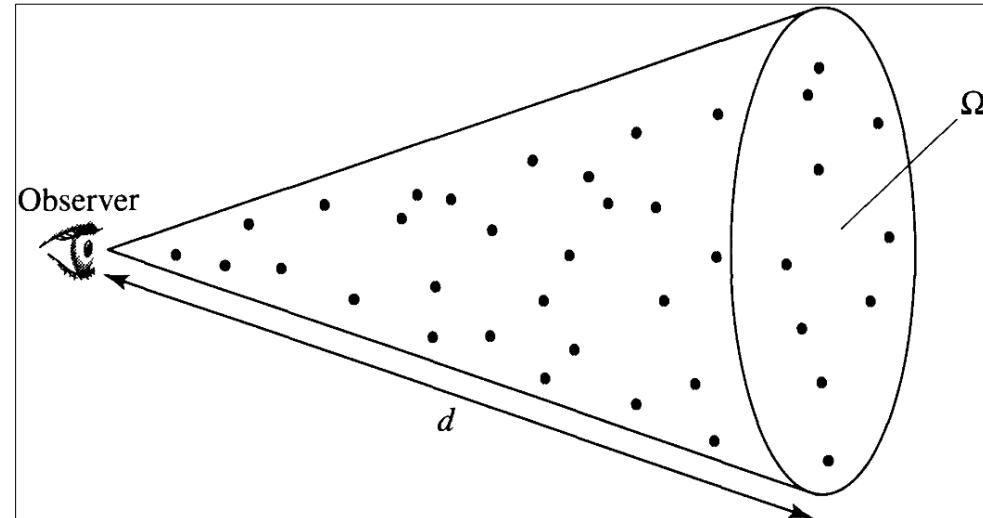
Masa final: $0.991 \times 10^{-26} \text{ kg}$

$$E=mc^2$$

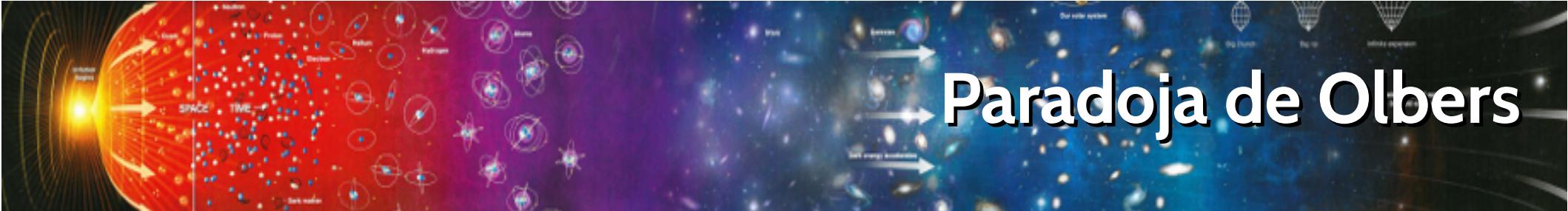
~ 27 MeV por reacción

Conversión 4.000.000 toneladas/seg

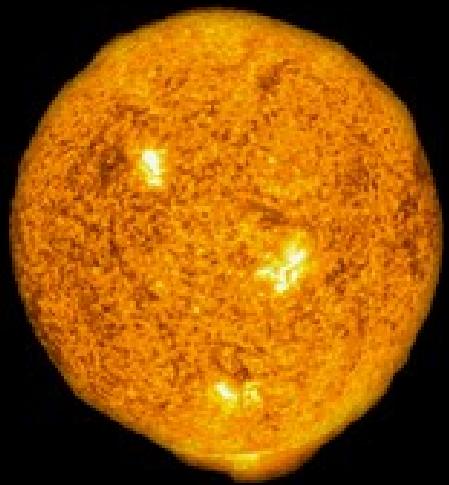
La paradoja de Olbers



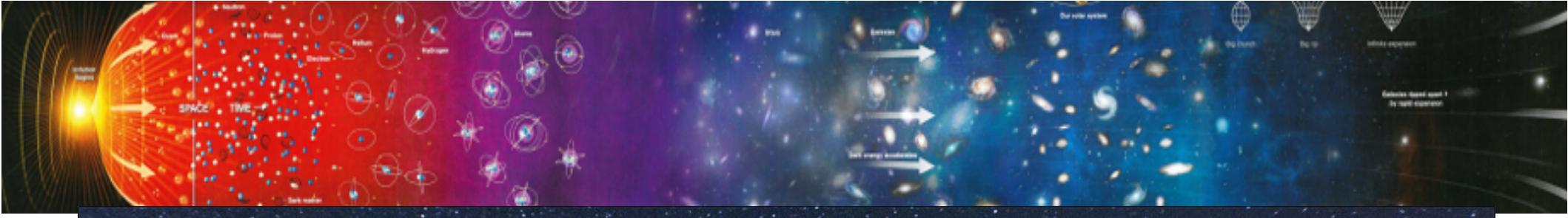
- Supongamos que hay infinitas estrellas...
- El número de estrellas en la superficie de un cono crece como d^2 .
- Pero el flujo disminuye como d^2 .
- Ergo, el flujo de energía de la superficie del cono es constante
- El cielo completo brillaría como las estrellas $\rightarrow T=5700 \text{ K}$



Paradoja de Olbers



- No hay infinitas estrellas
- Hay absorción en el espacio

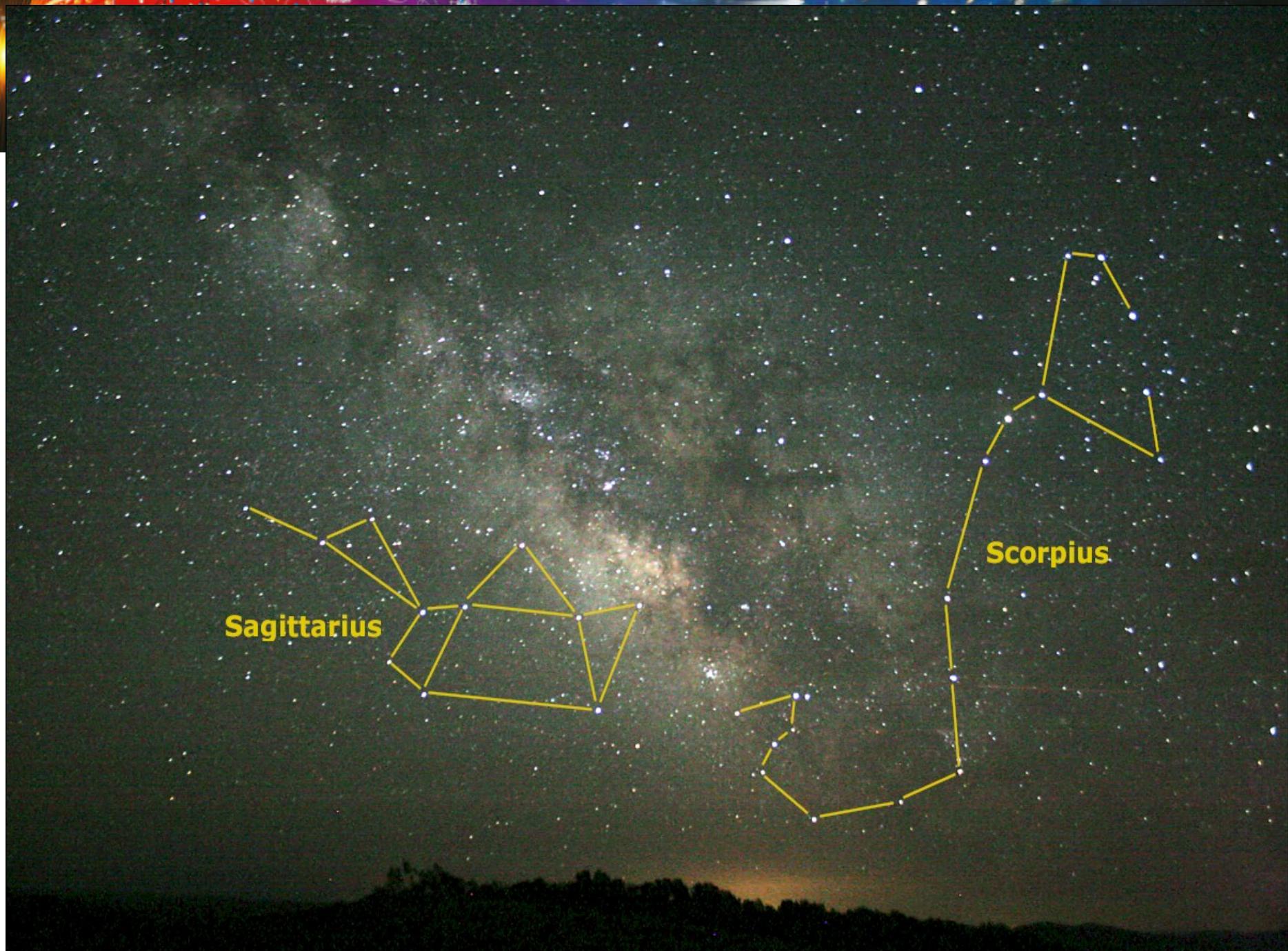


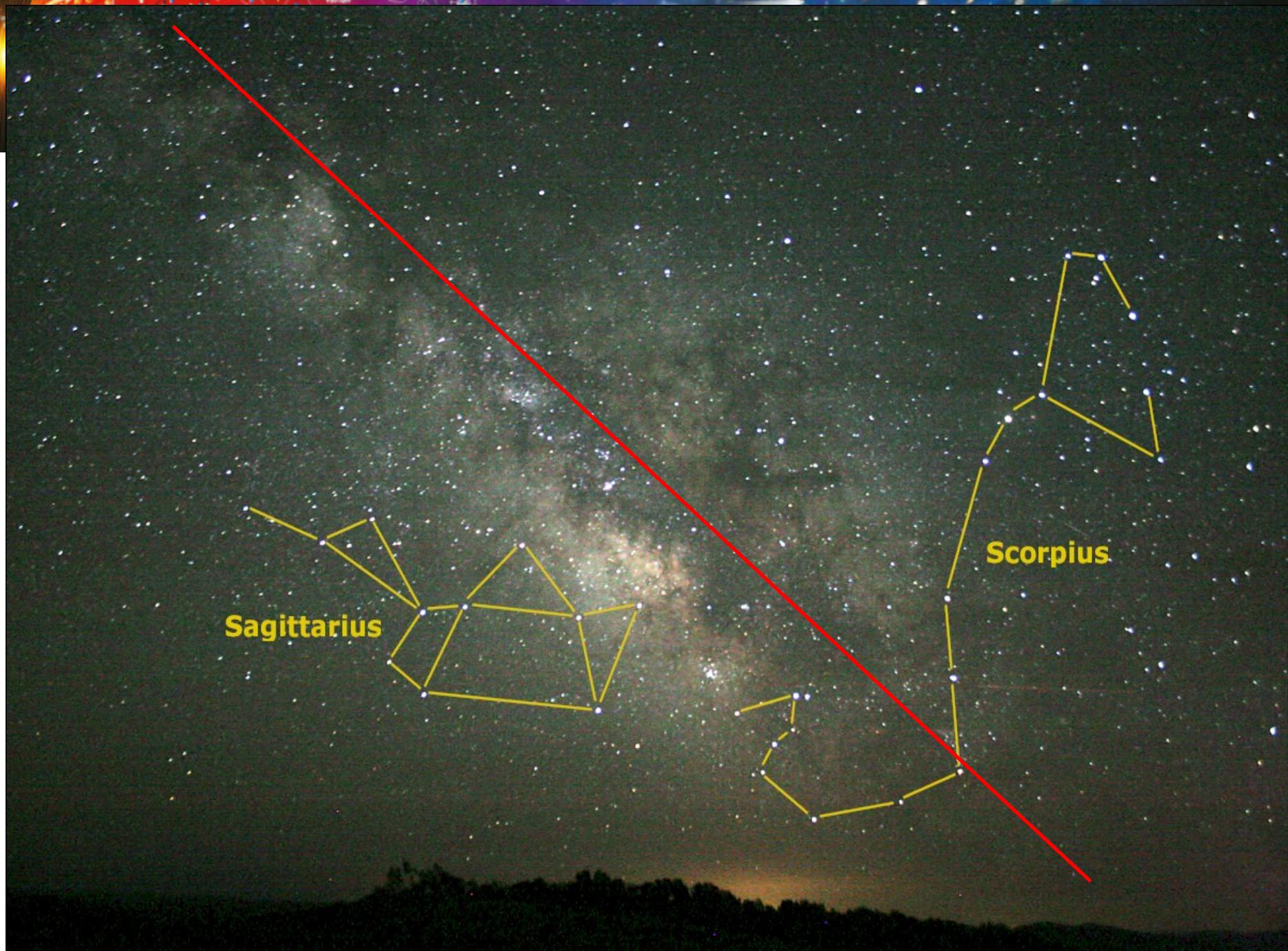




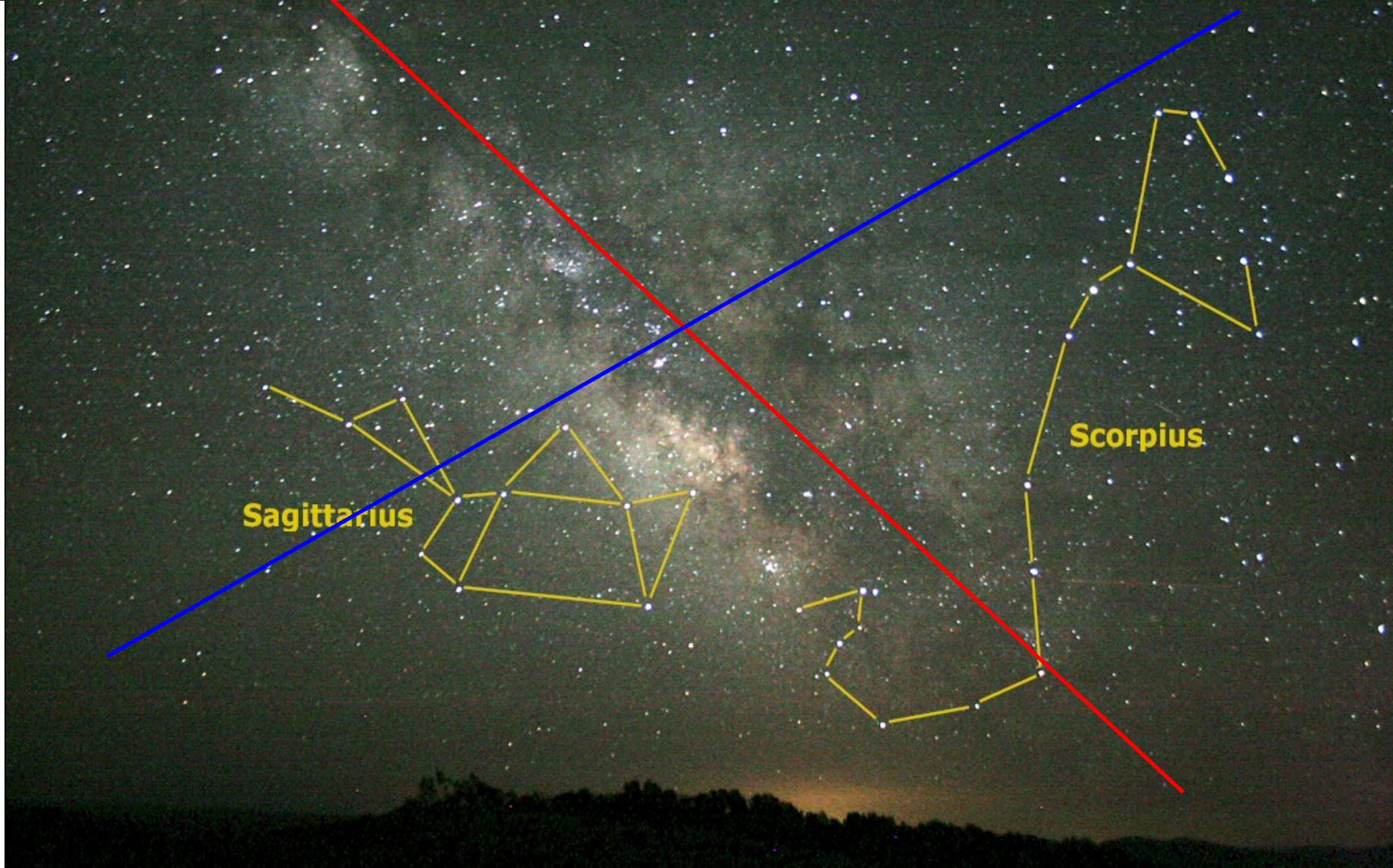
La Vía Láctea desde Cerro Paranal

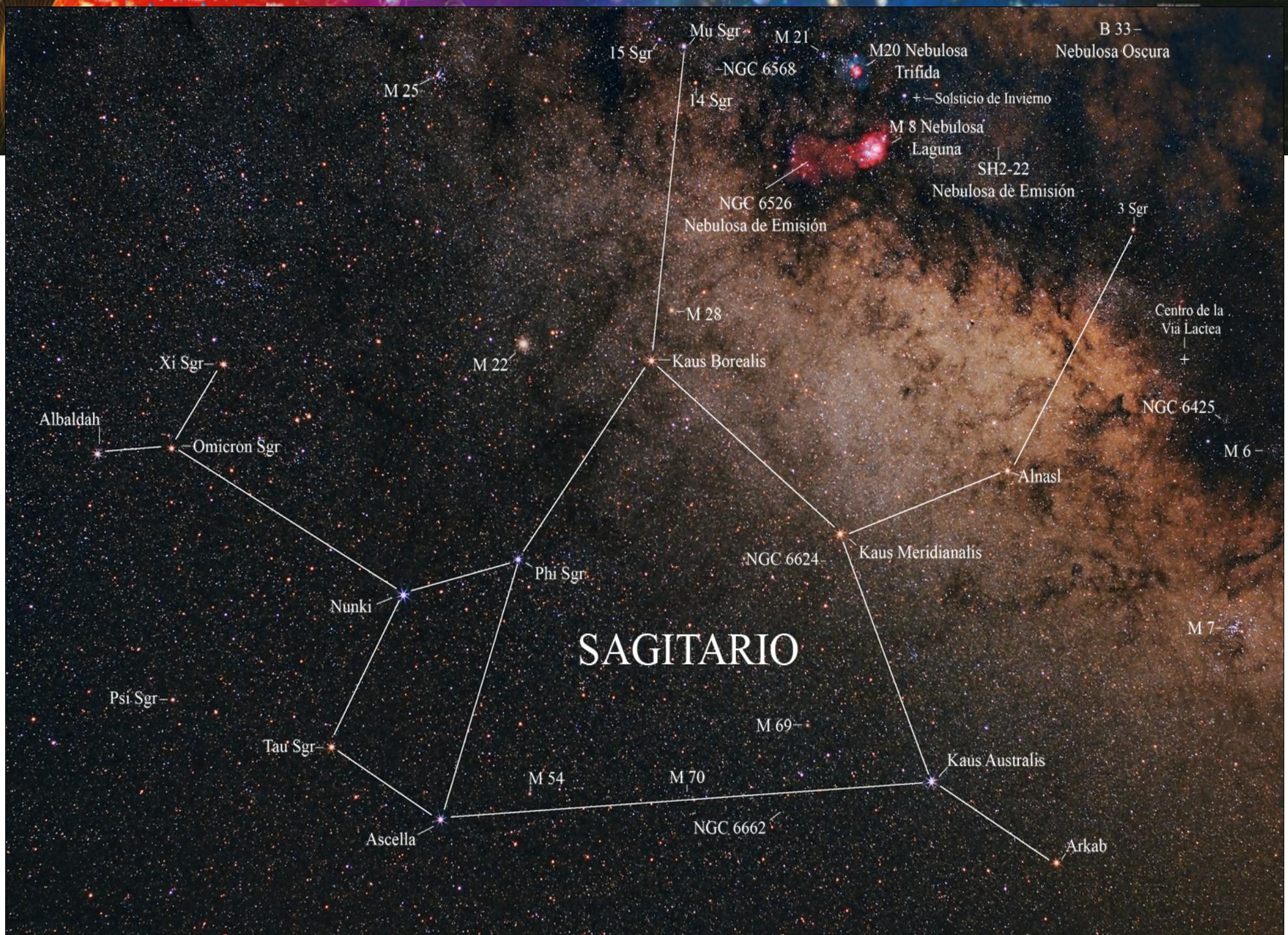


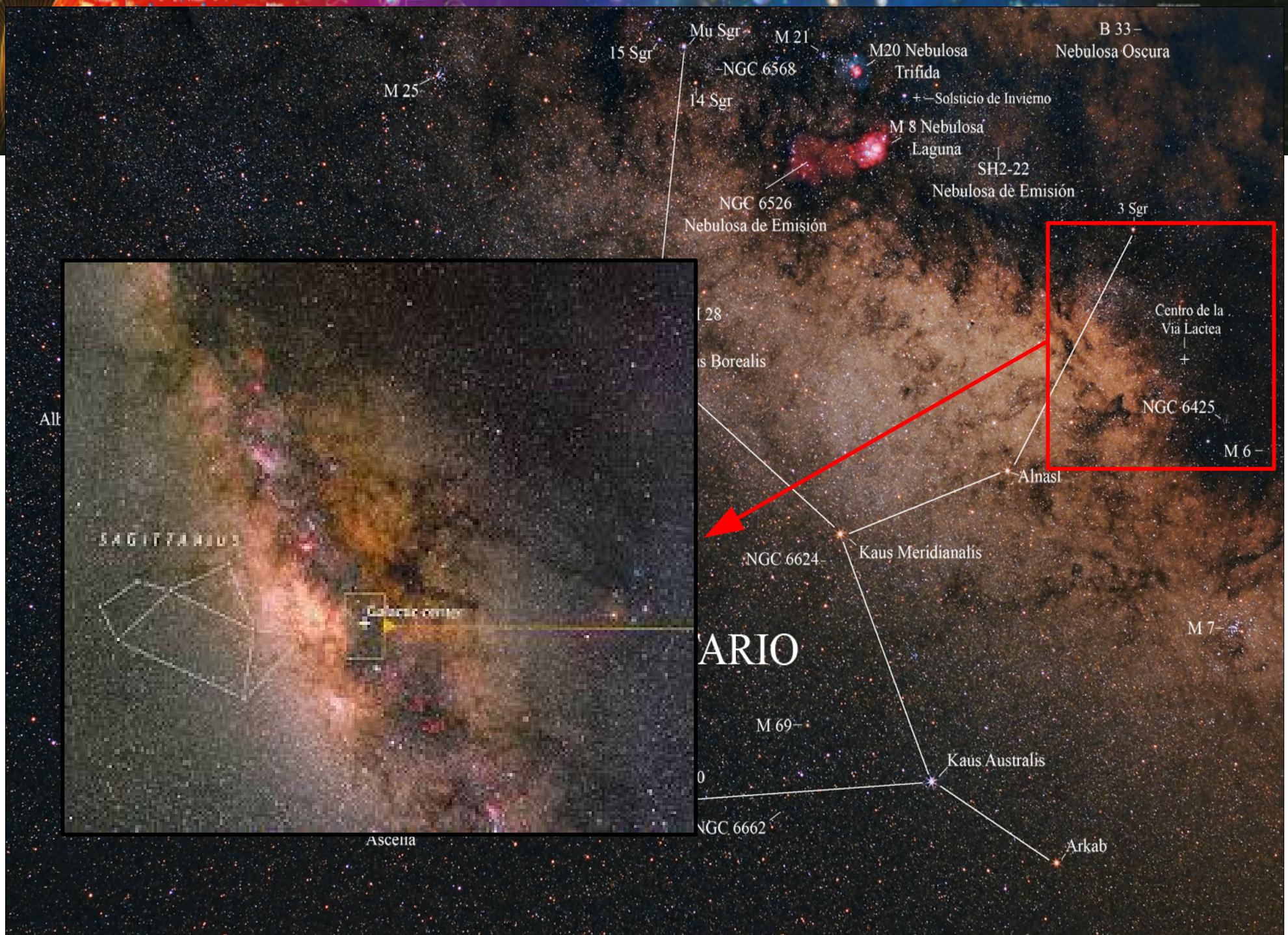


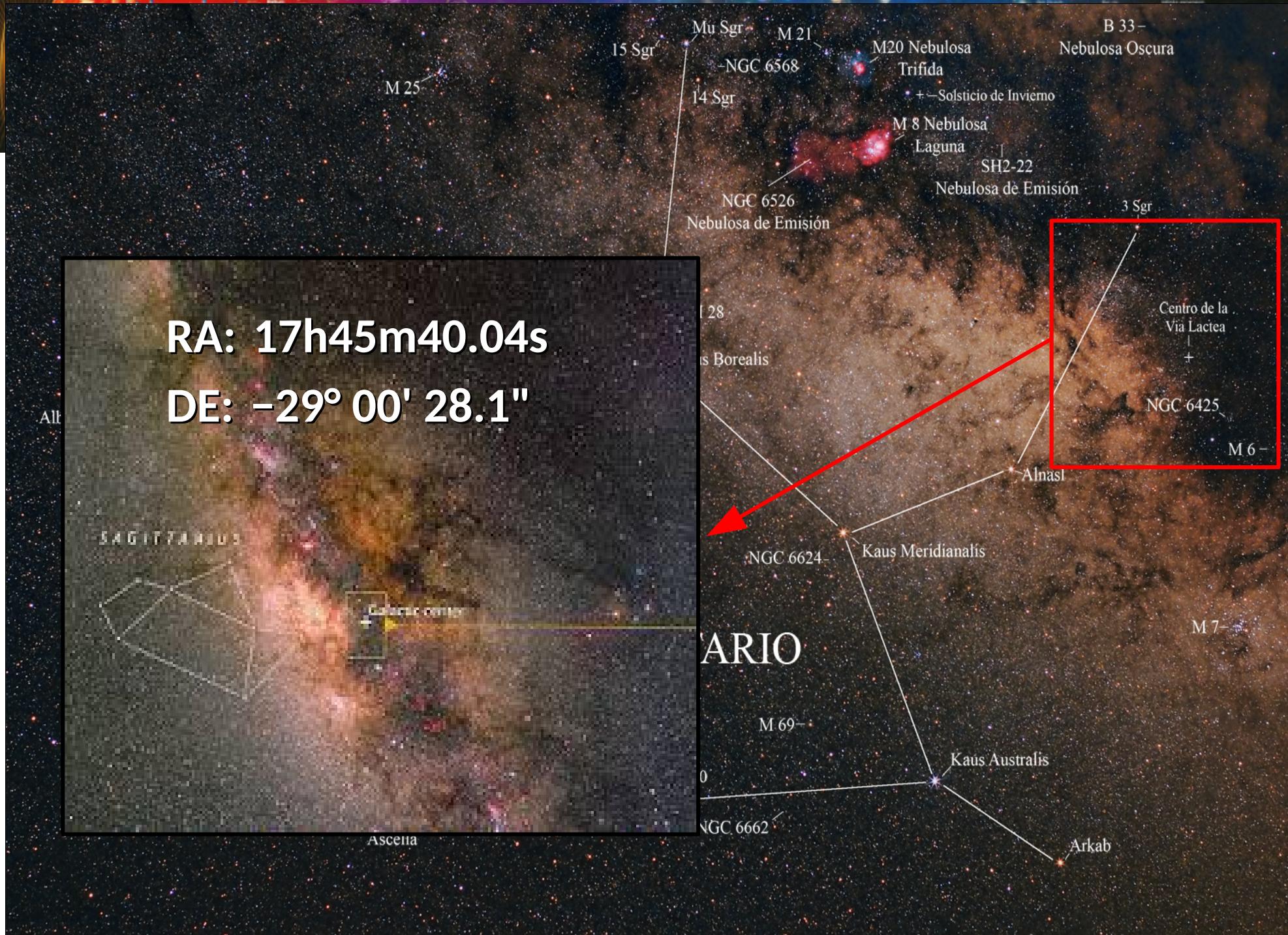


Inclinada ~60°, respecto del Ecuador Celeste





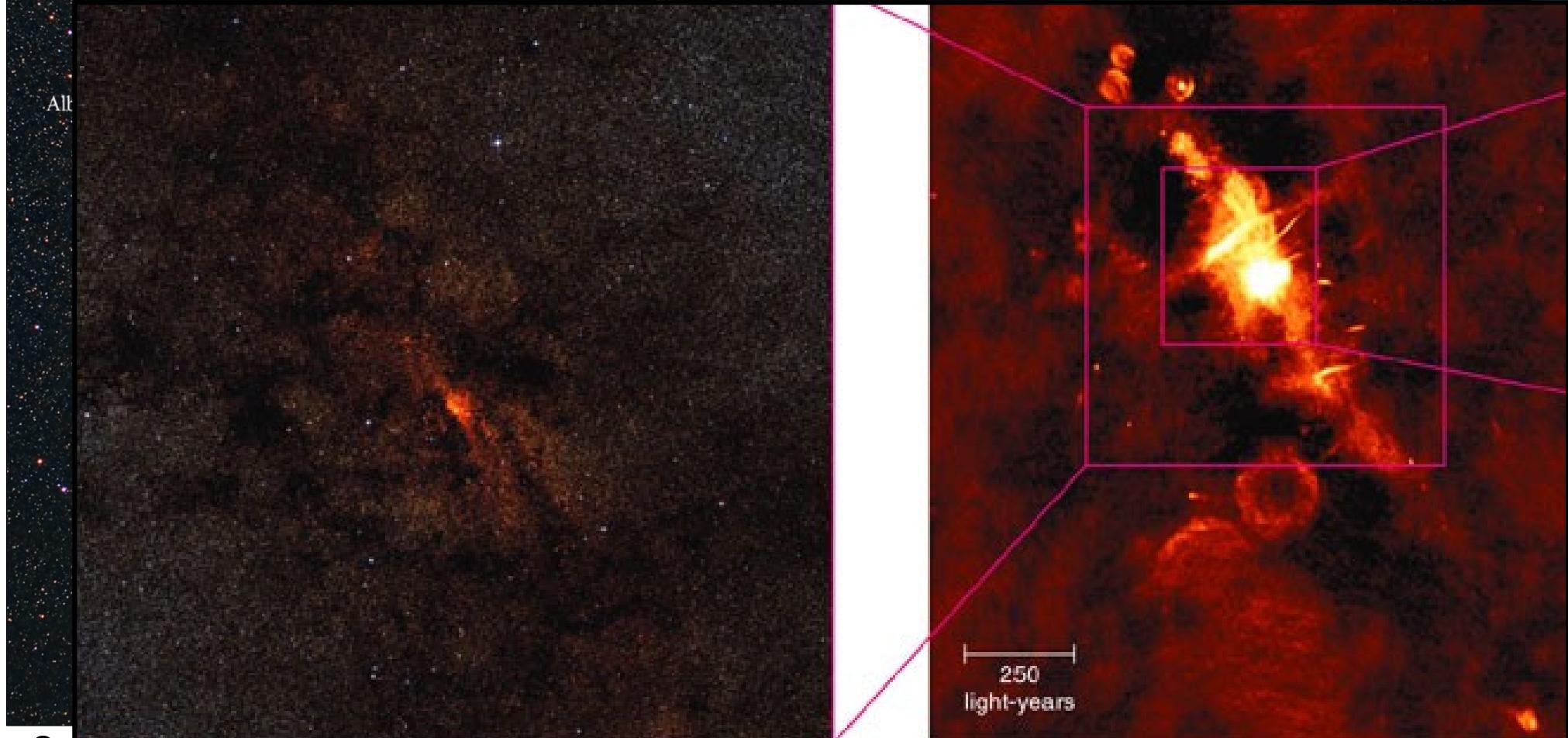
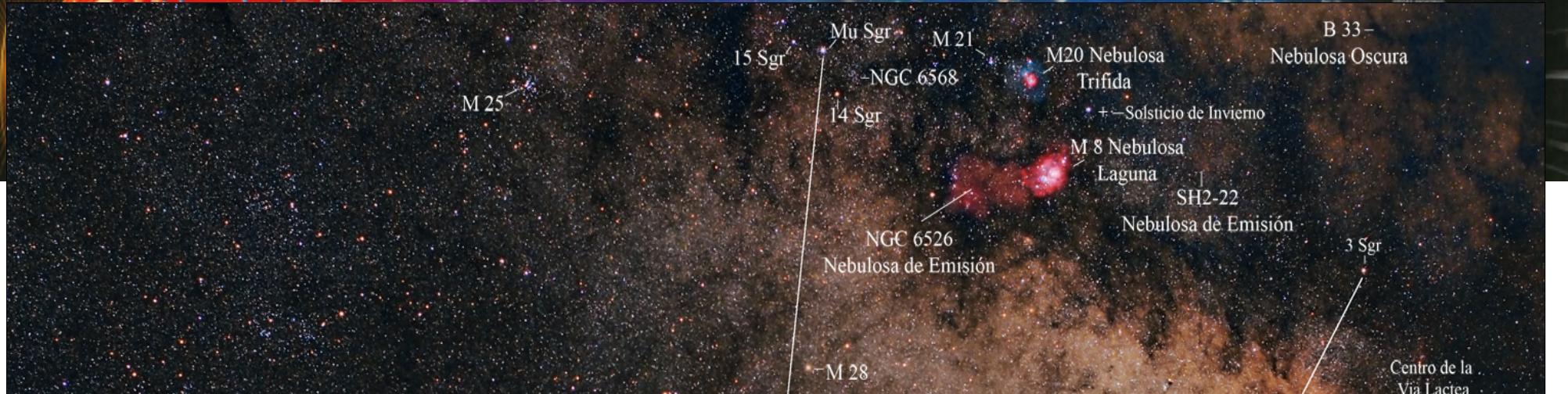


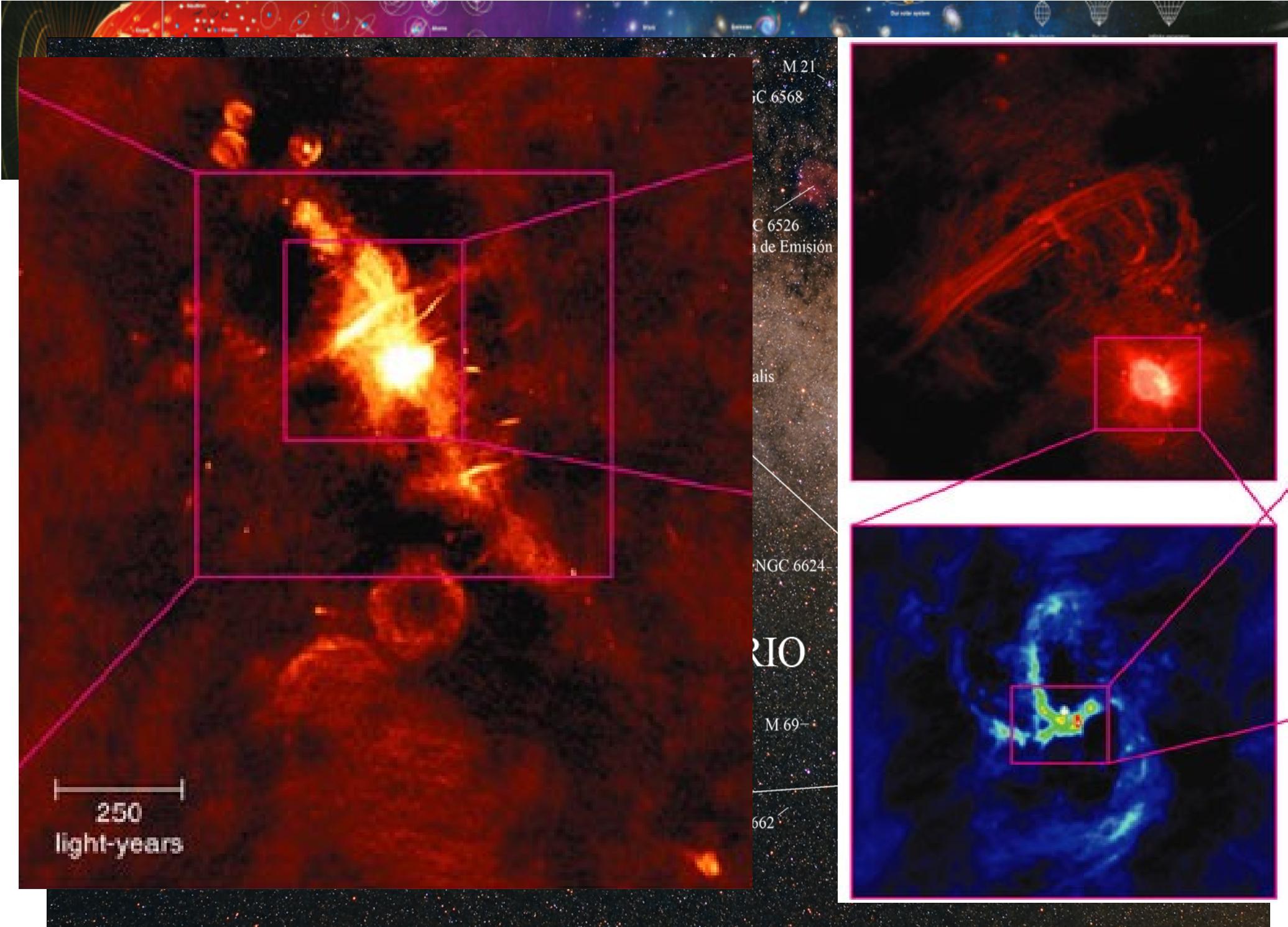


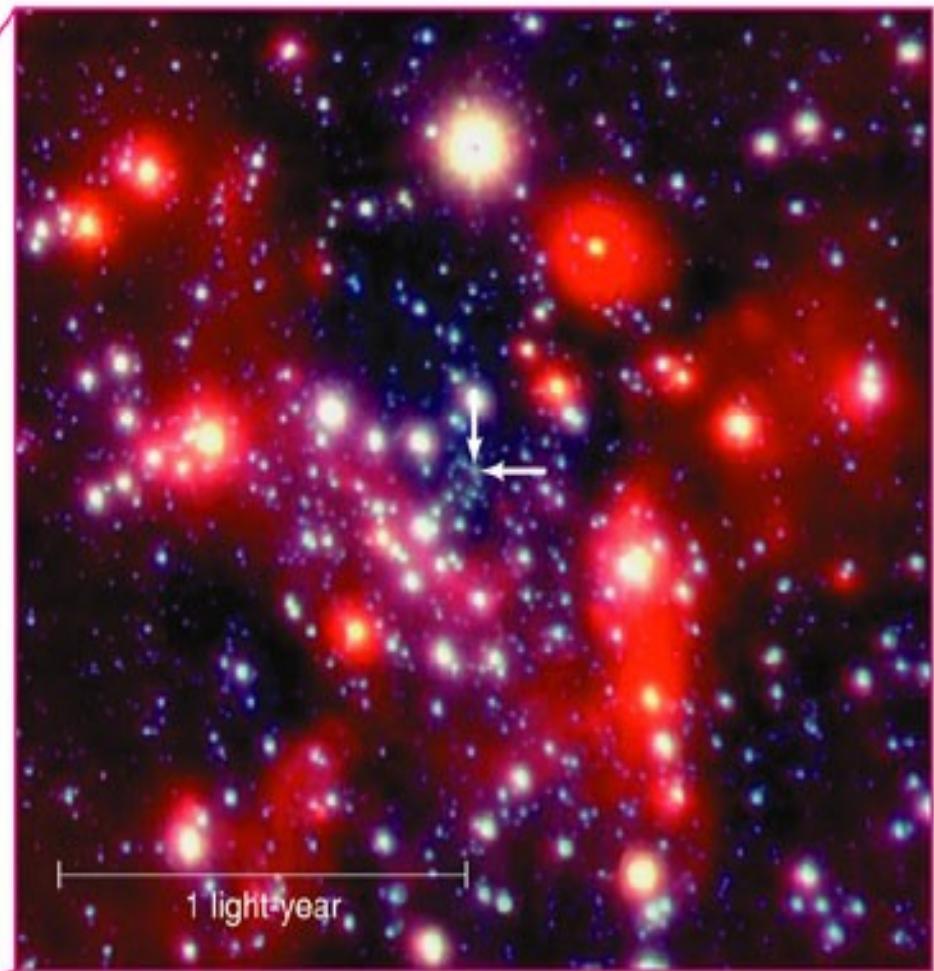
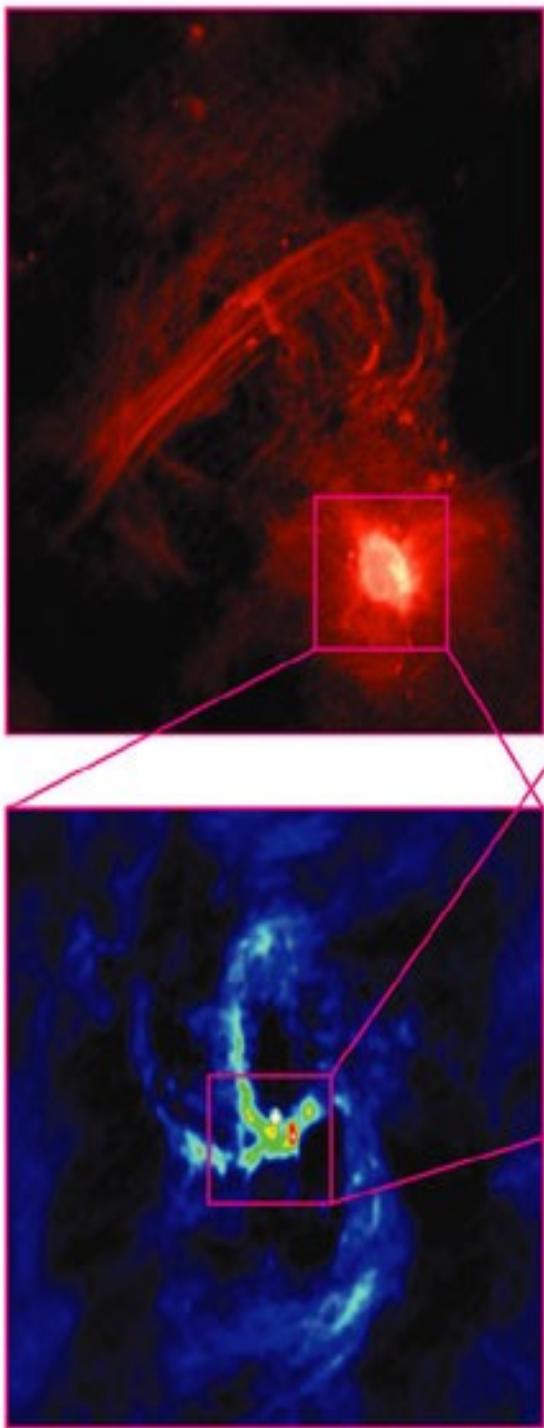
Oct 13, 2016

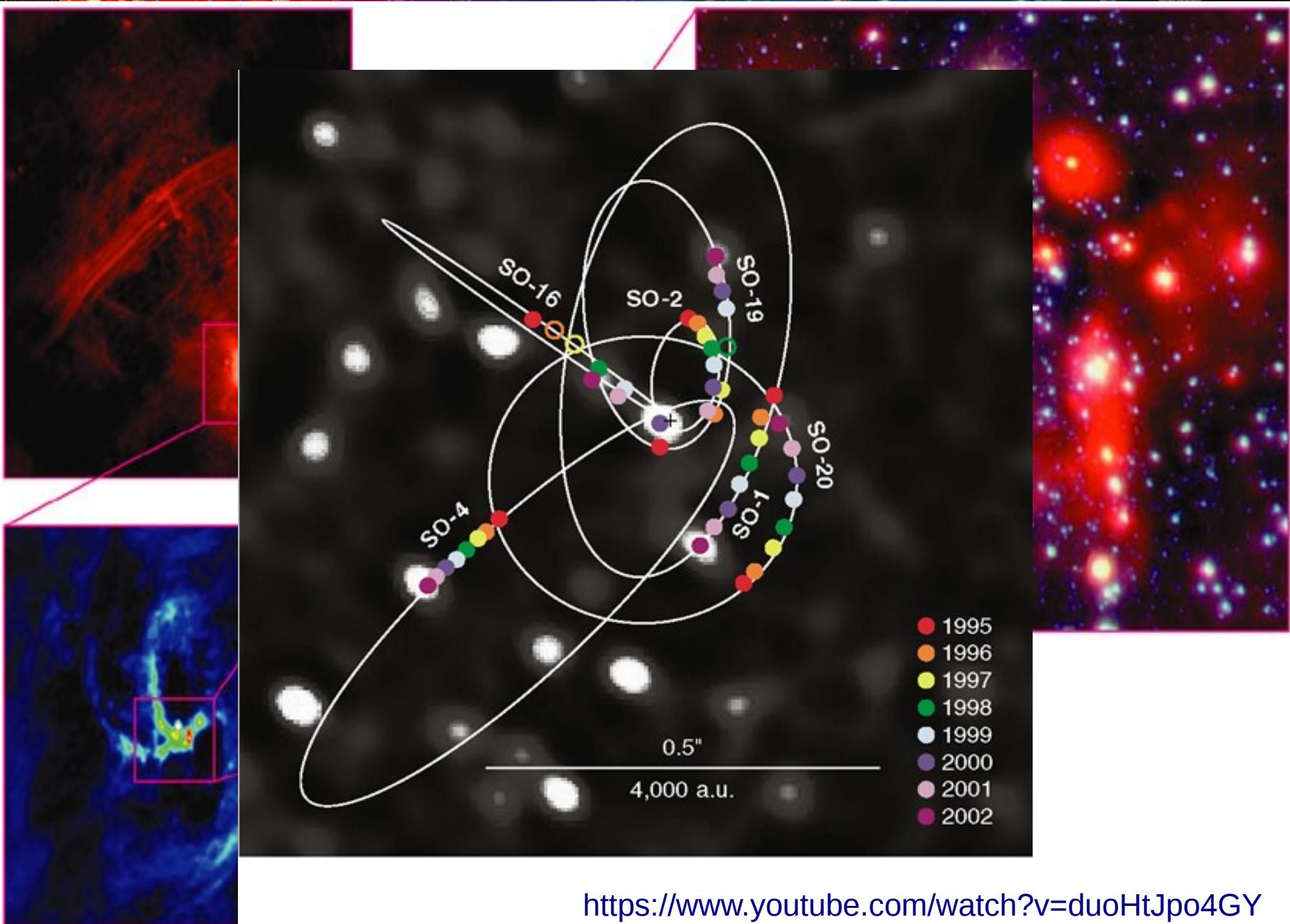
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33/61









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



El agujero negro central

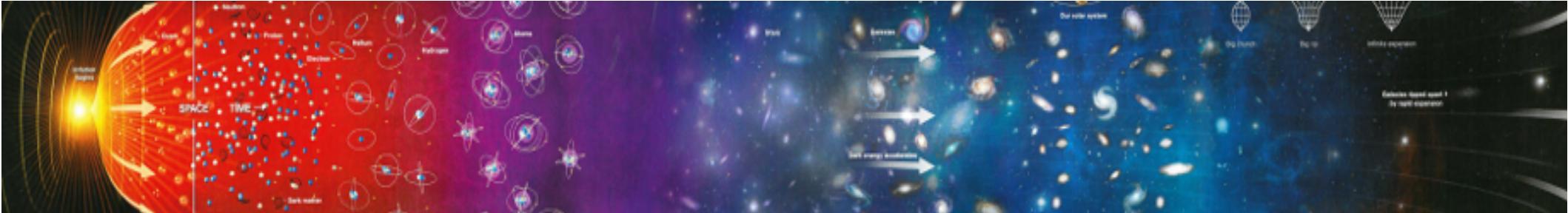
ESO Video News Reel 46/08

Unprecedented 16-year long study tracks
stars orbiting Milky Way black hole.

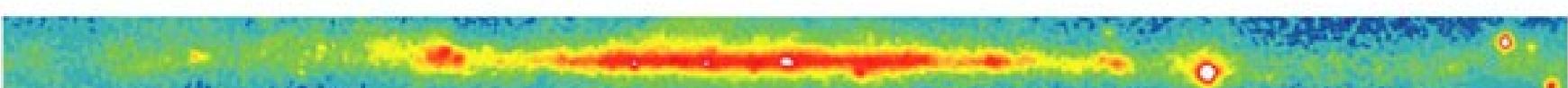
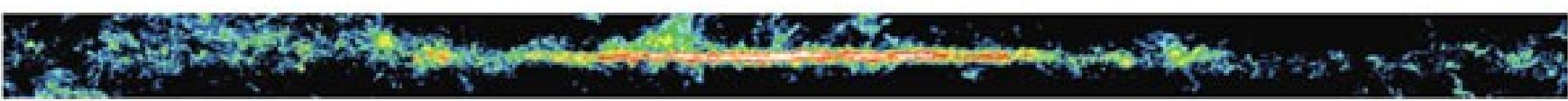
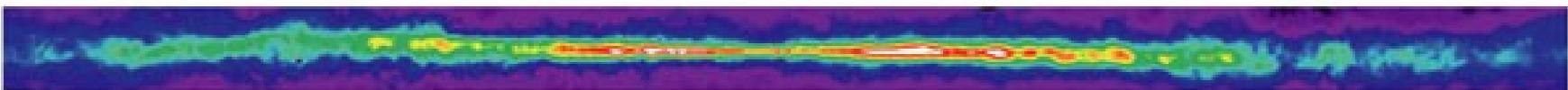
B-roll

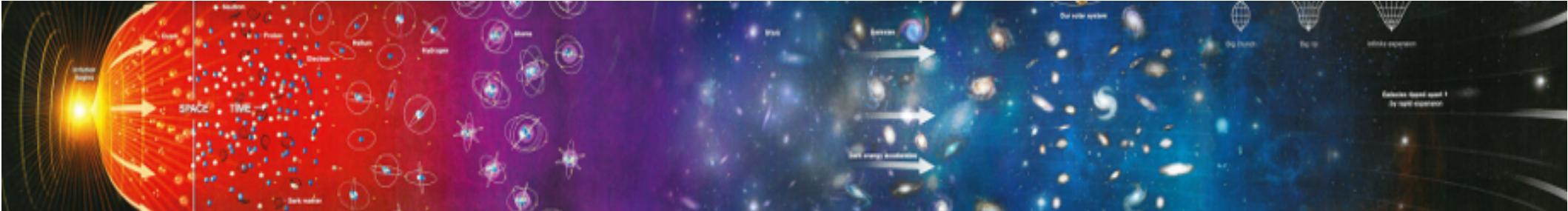
European Southern Observatory

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¿Y qué forma tiene nuestra galaxia?

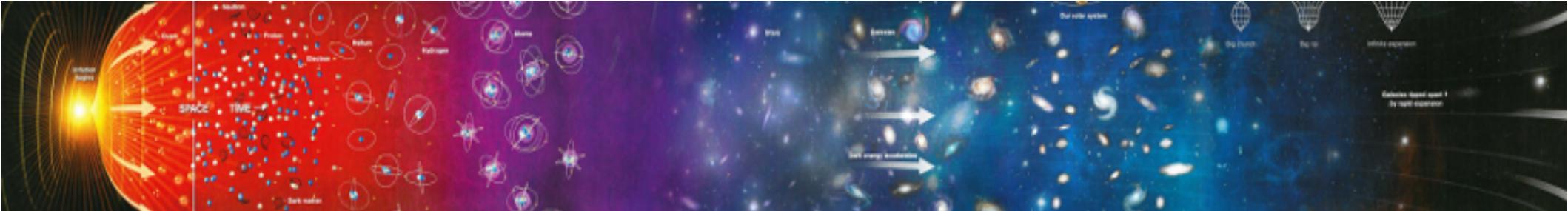




d Infrared ($1\text{--}4 \mu\text{m}$) emission from stars that penetrates most interstellar material.



e Visible light emitted by stars is scattered and absorbed by dust.



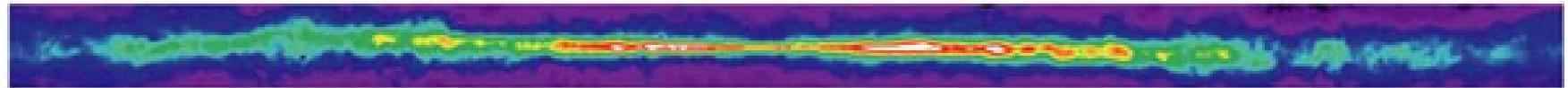
d Infrared (1–4 μm) emission from stars that penetrates most interstellar material.



e Visible light emitted by stars is scattered and absorbed by dust.



f X-ray emission from hot gas bubbles (diffuse blobs) and X-ray binaries (pointlike sources).



a 21-cm radio emission from atomic hydrogen gas.



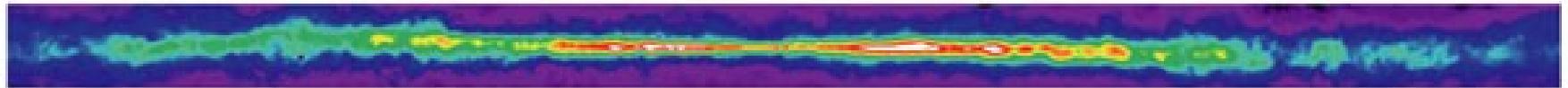
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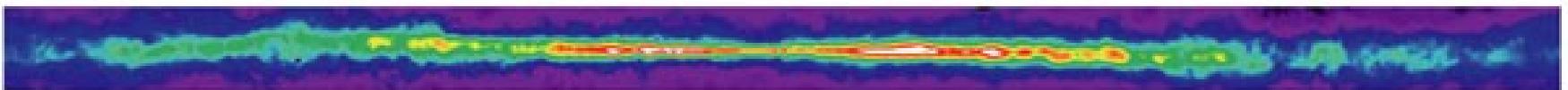


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a 21-cm radio emission from atomic hydrogen gas.



b Radio emission from carbon monoxide reveals molecular clouds.



c Infrared (60–100 μm) emission from interstellar dust.



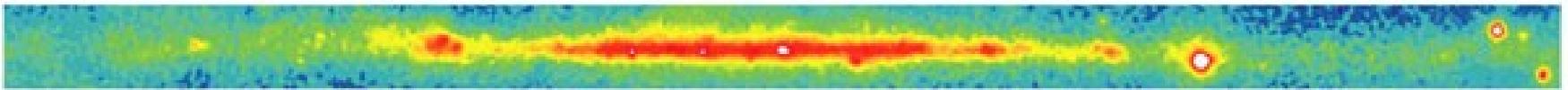
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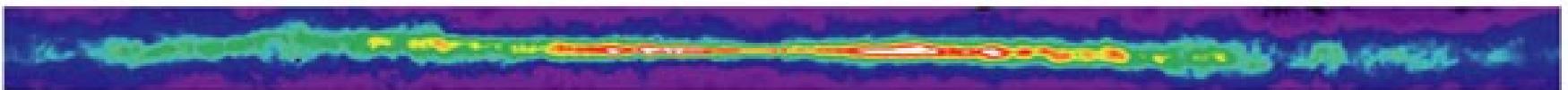
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g Gamma-ray emission from collisions of cosmic rays with atomic nuclei in interstellar clouds.



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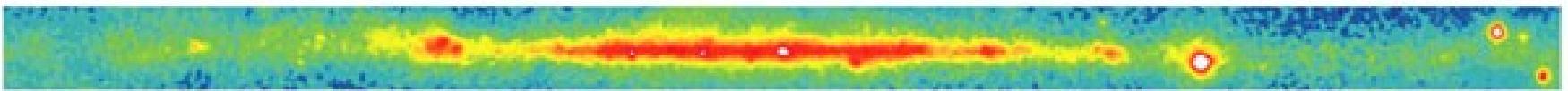
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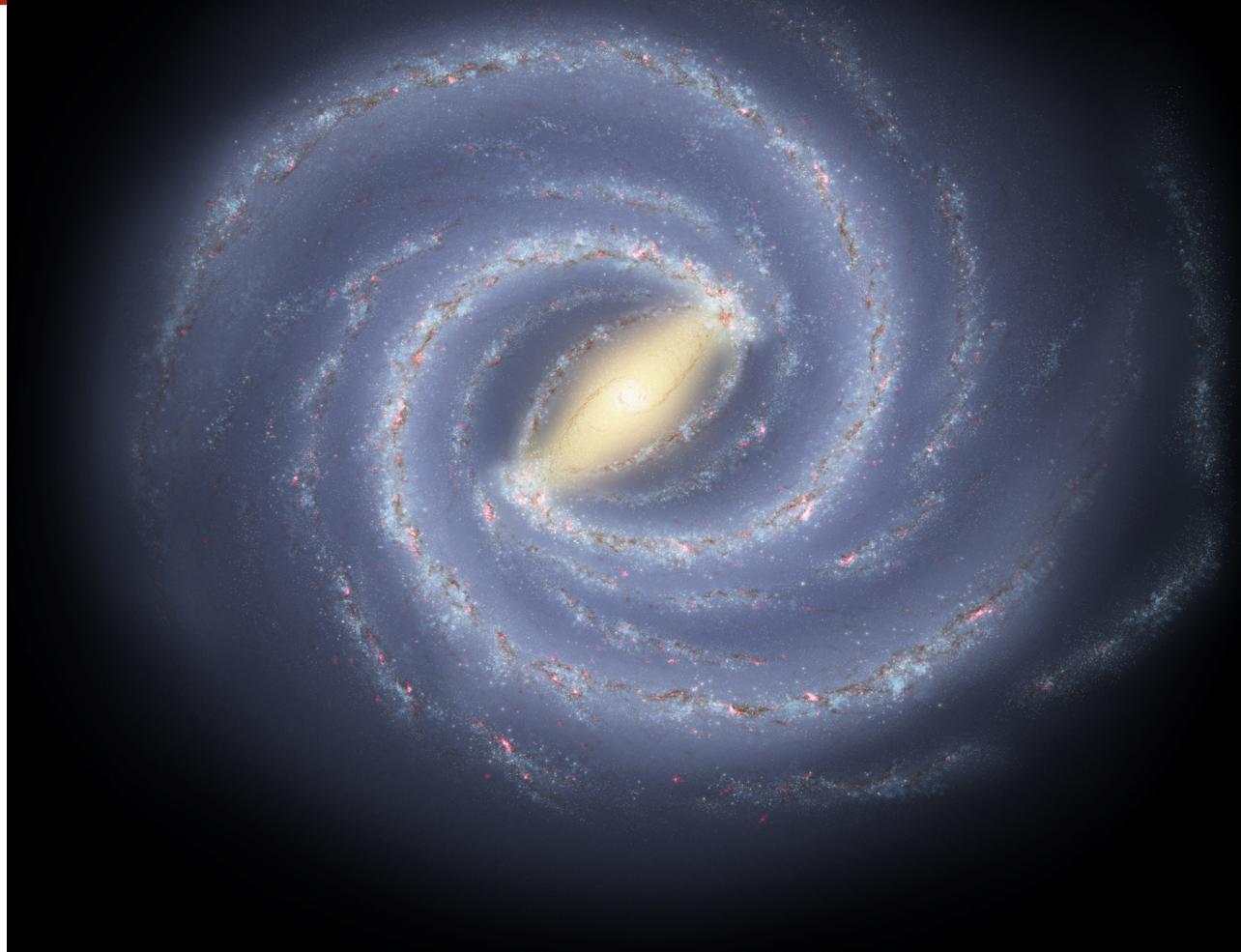


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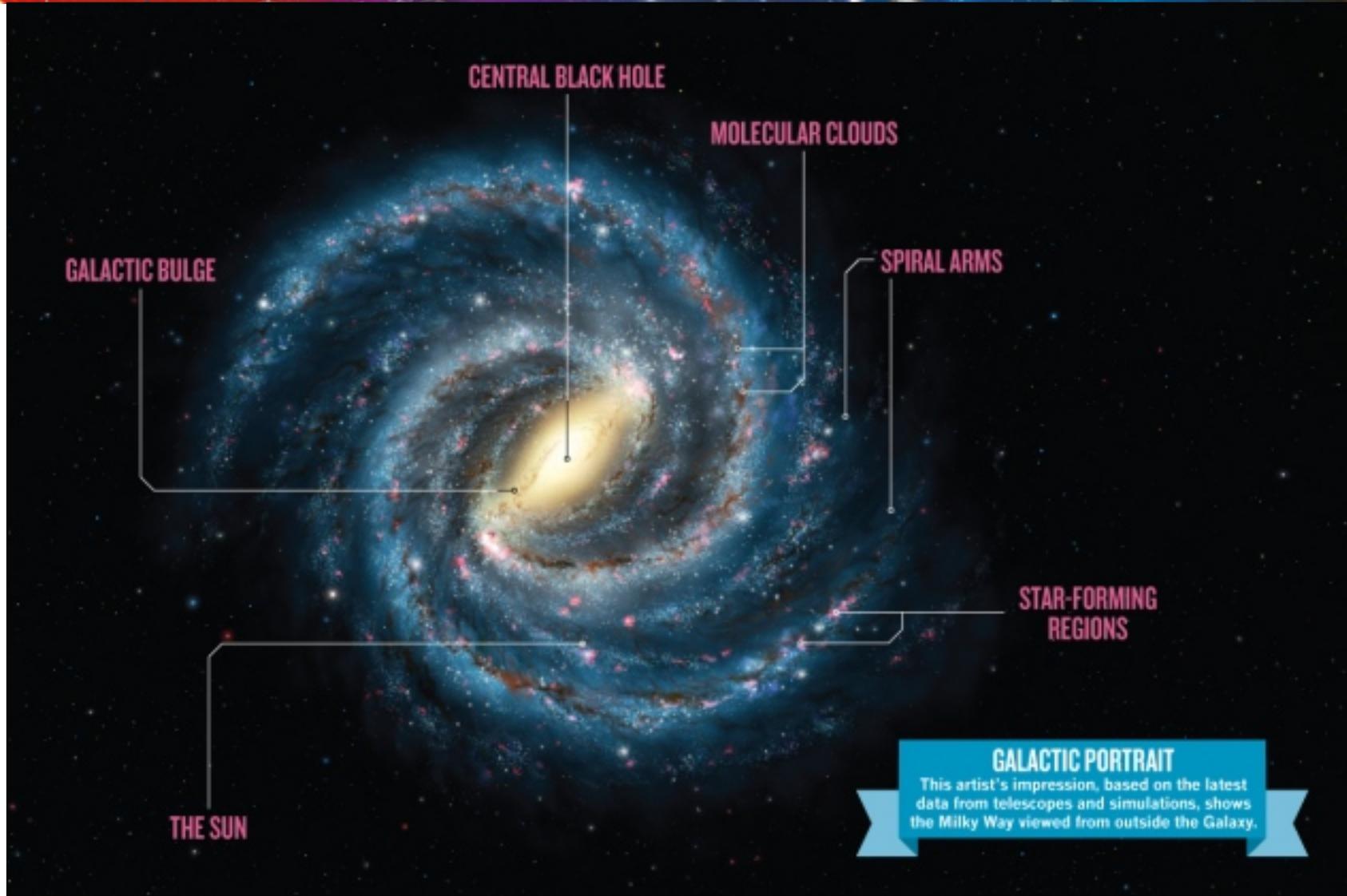
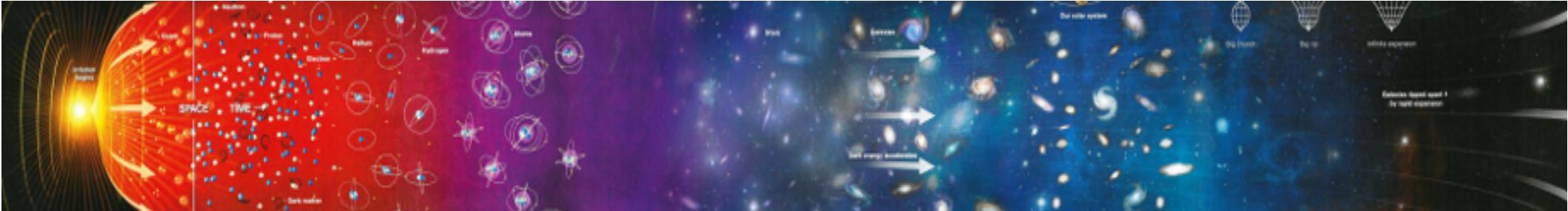
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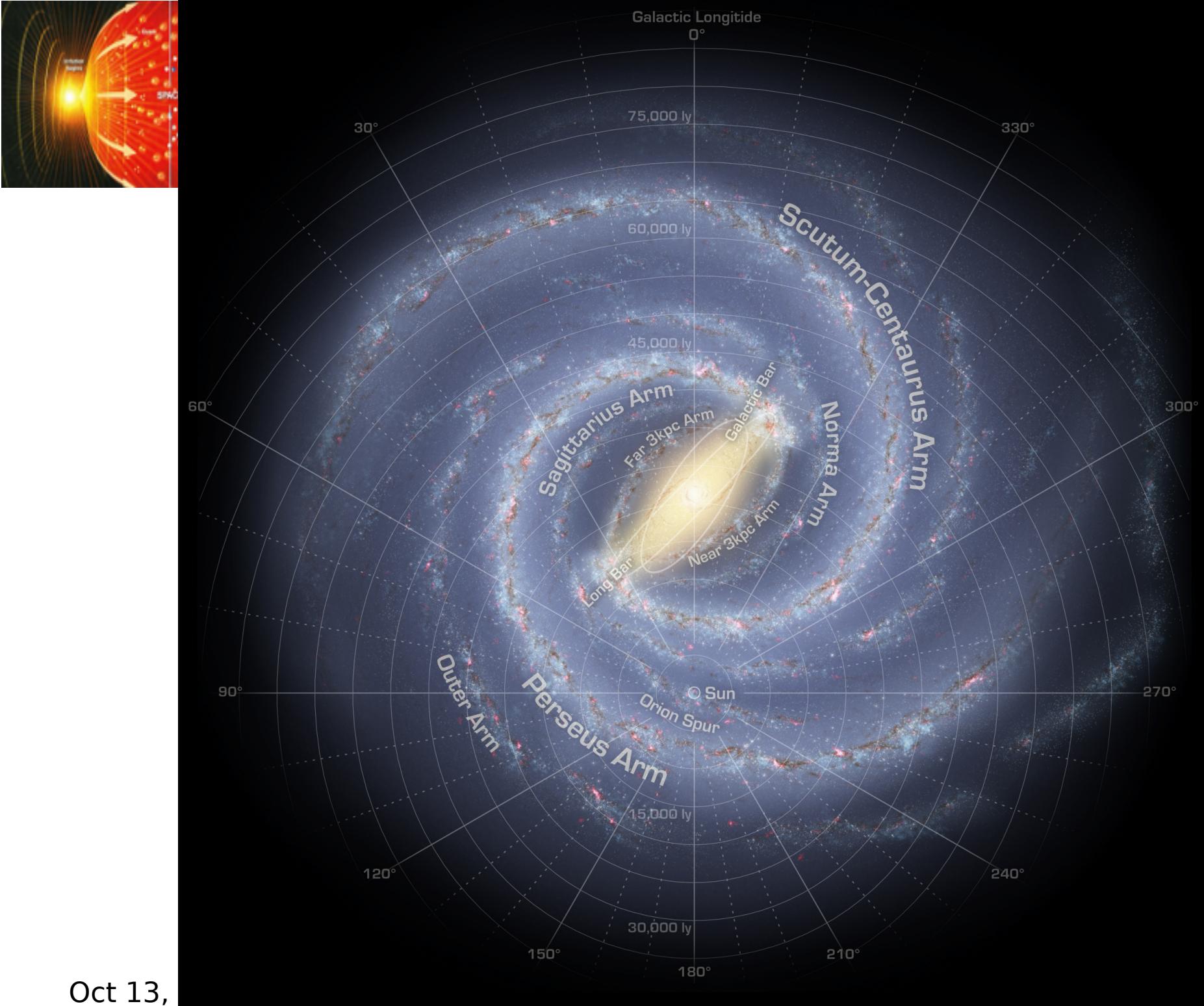


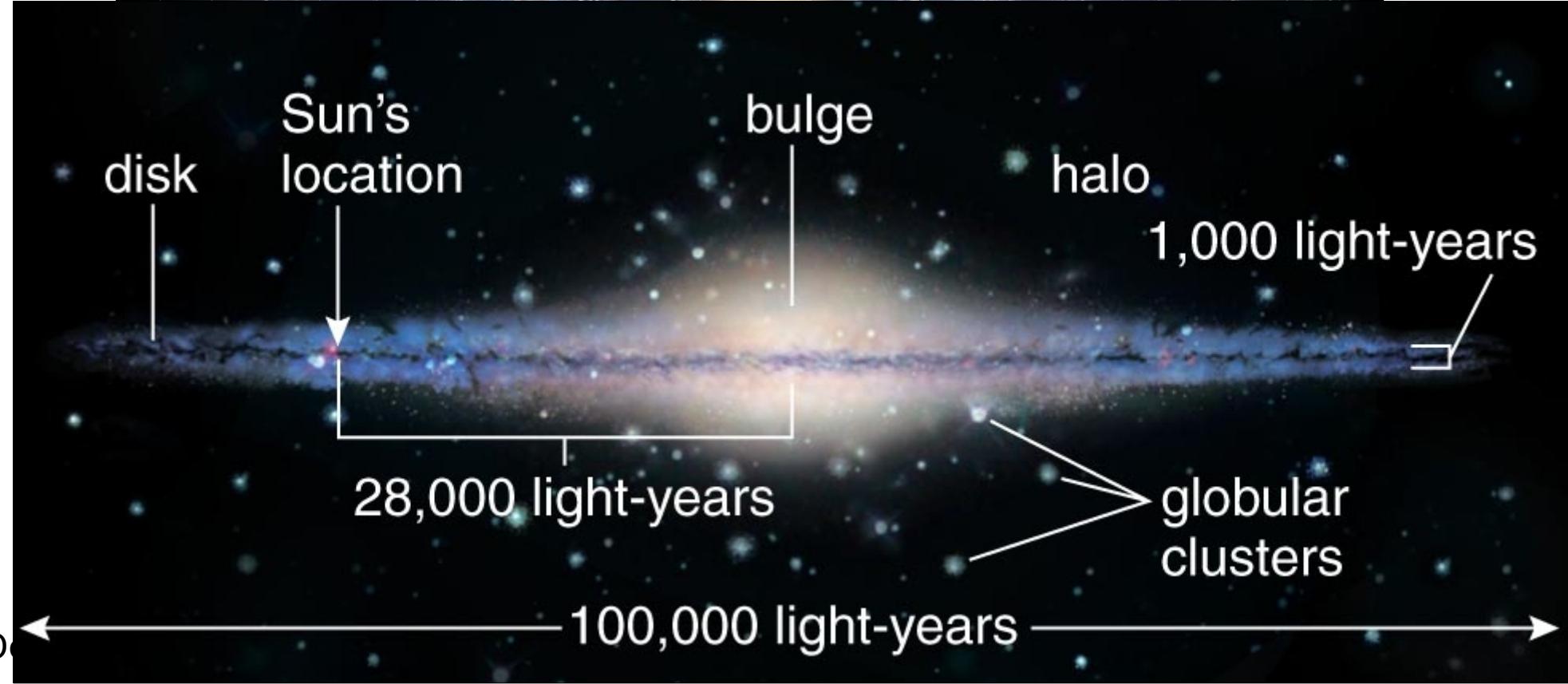
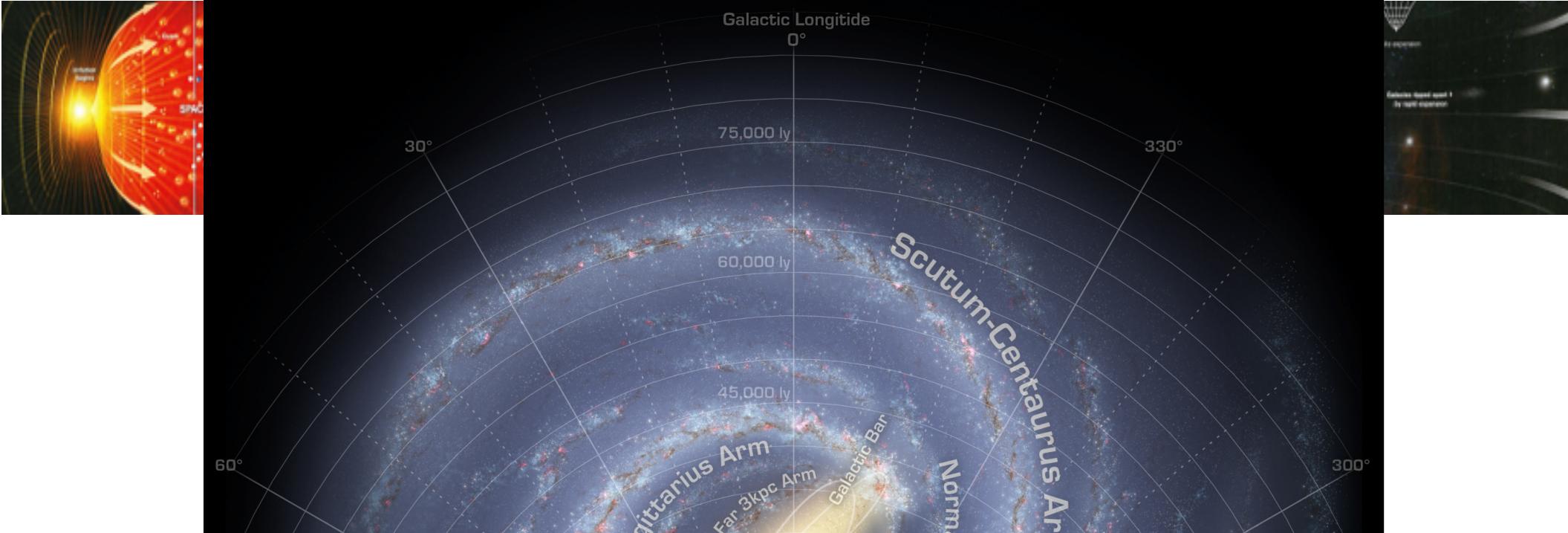
A Roadmap to the Milky Way (artist's concept)

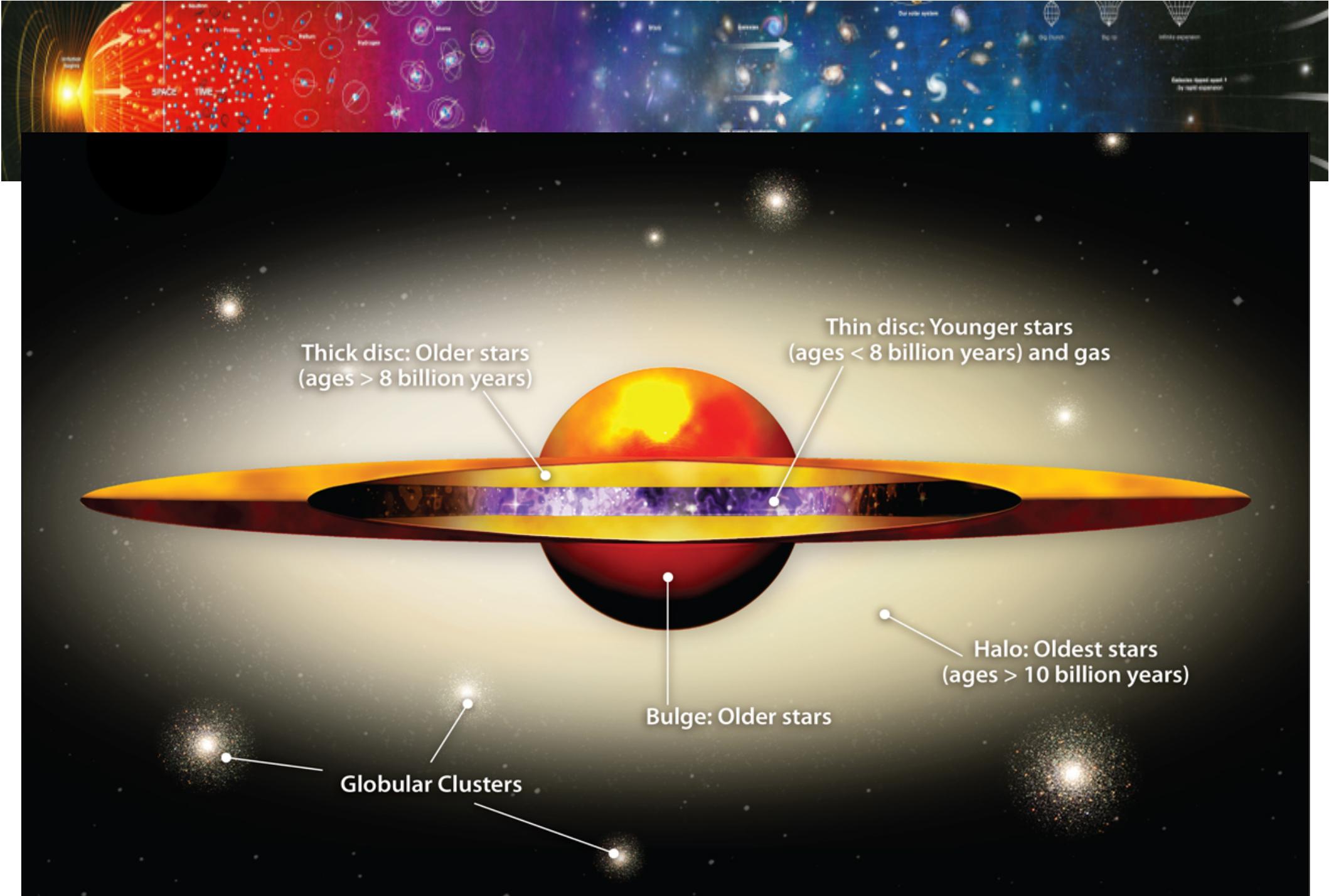
NASA / JPL-Caltech / R. Hurt (SSC-Caltech)

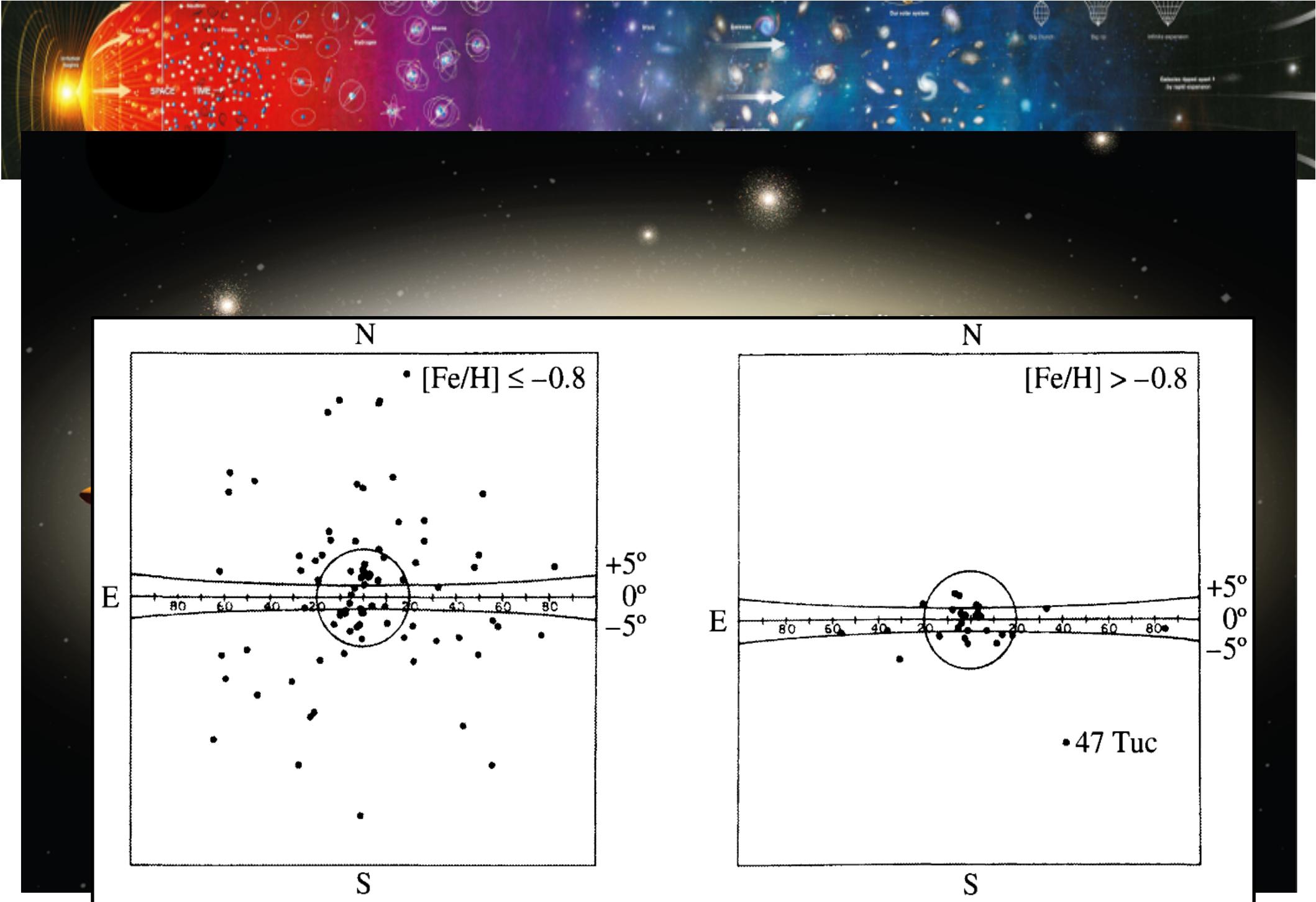
ssc2008-10a





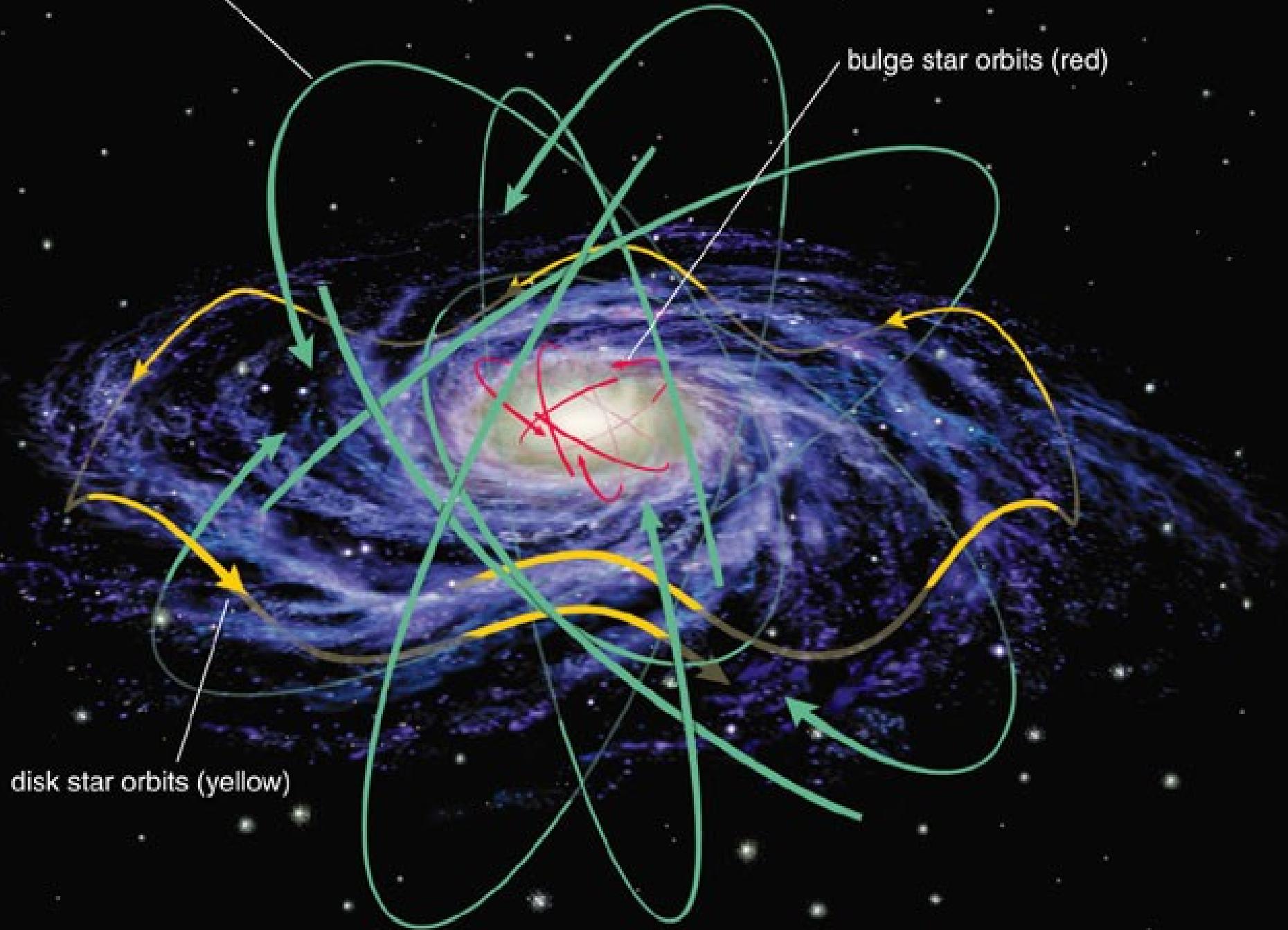






halo star orbits (green)

bulge star orbits (red)

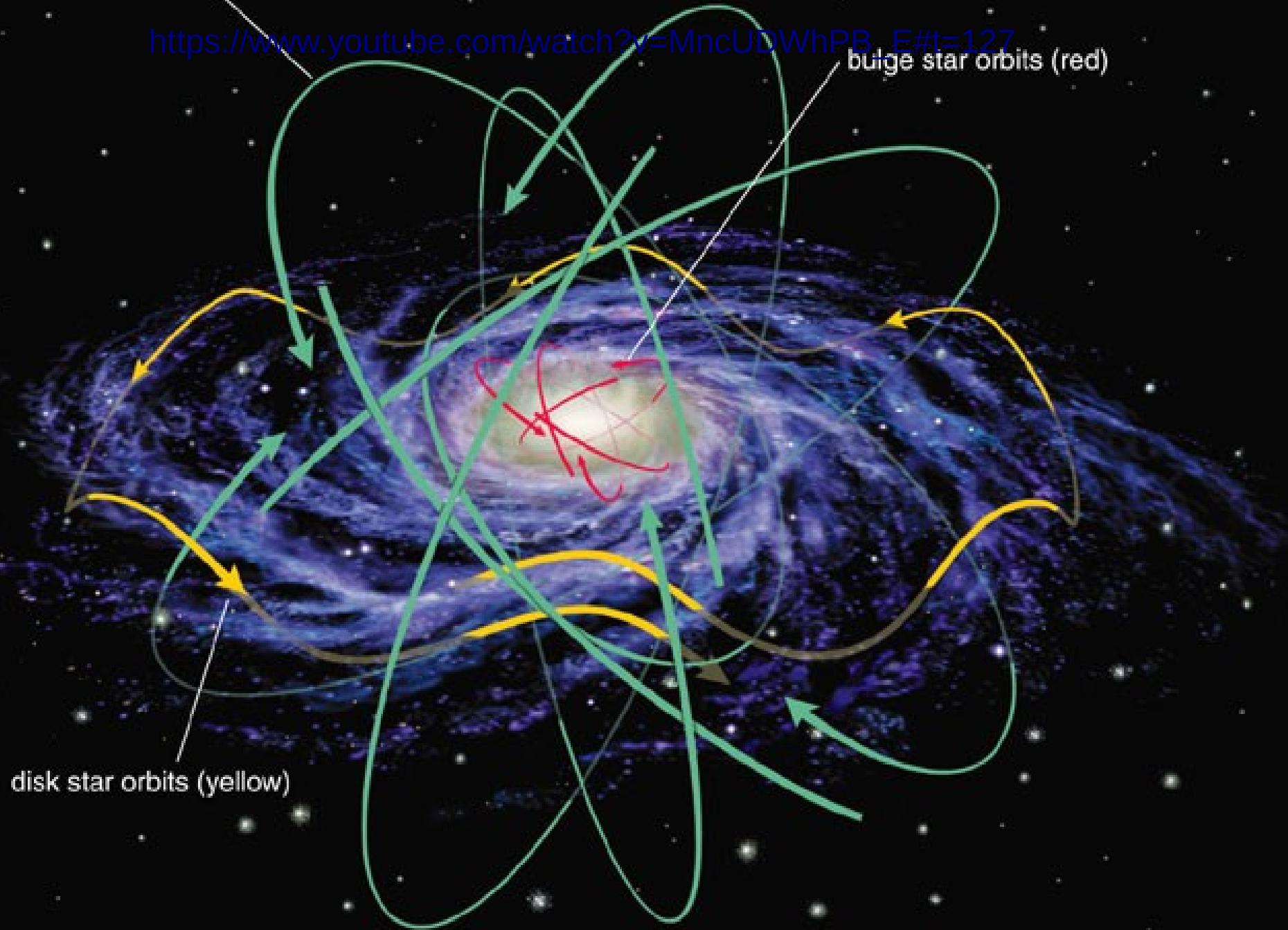


disk star orbits (yellow)

halo star orbits (green)

https://www.youtube.com/watch?v=MncUDWhPB_E#t=127

bulge star orbits (red)

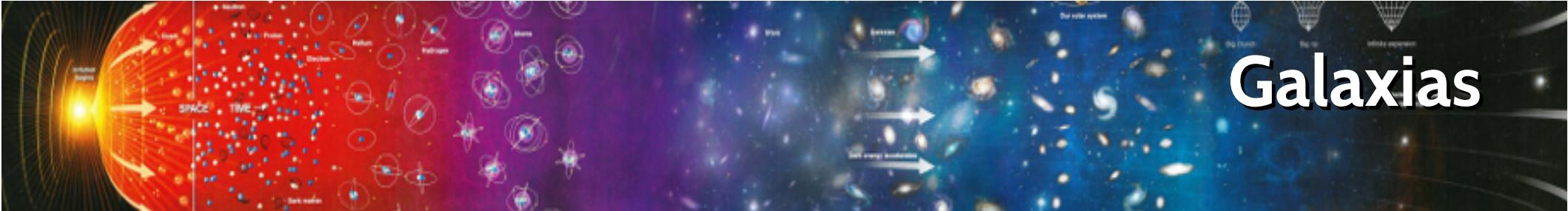


disk star orbits (yellow)



Si Andrómeda fuera más brillante...





Galaxias

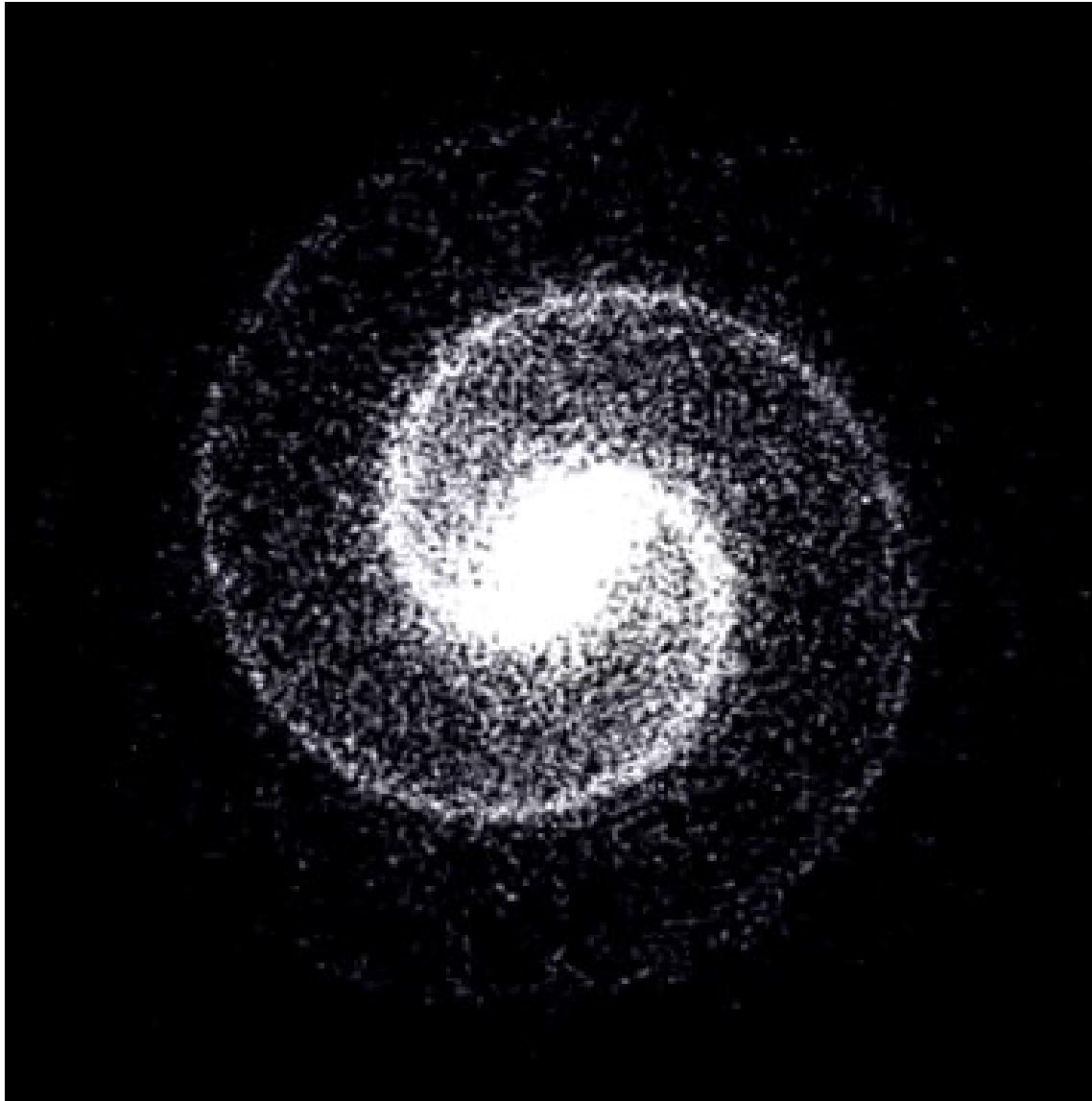
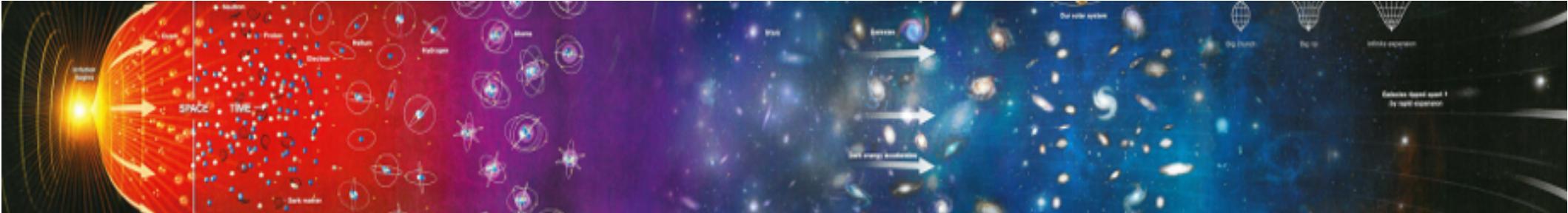
- Una **galaxia** es un sistema autogravitatorio que se compone de:
 - Estrellas
 - Remanentes estelares
 - Un medio interestelar formado por gas y polvo...
 - ... y materia oscura
- **Tamaños:**
 - Enanas (~1000 estrellas, 1000 pc)
 - Gigantes (100000 pc, 10^{14} estrellas)
- Y están separadas por distancias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

Brazos Espirales → si fuera sólo Kepler

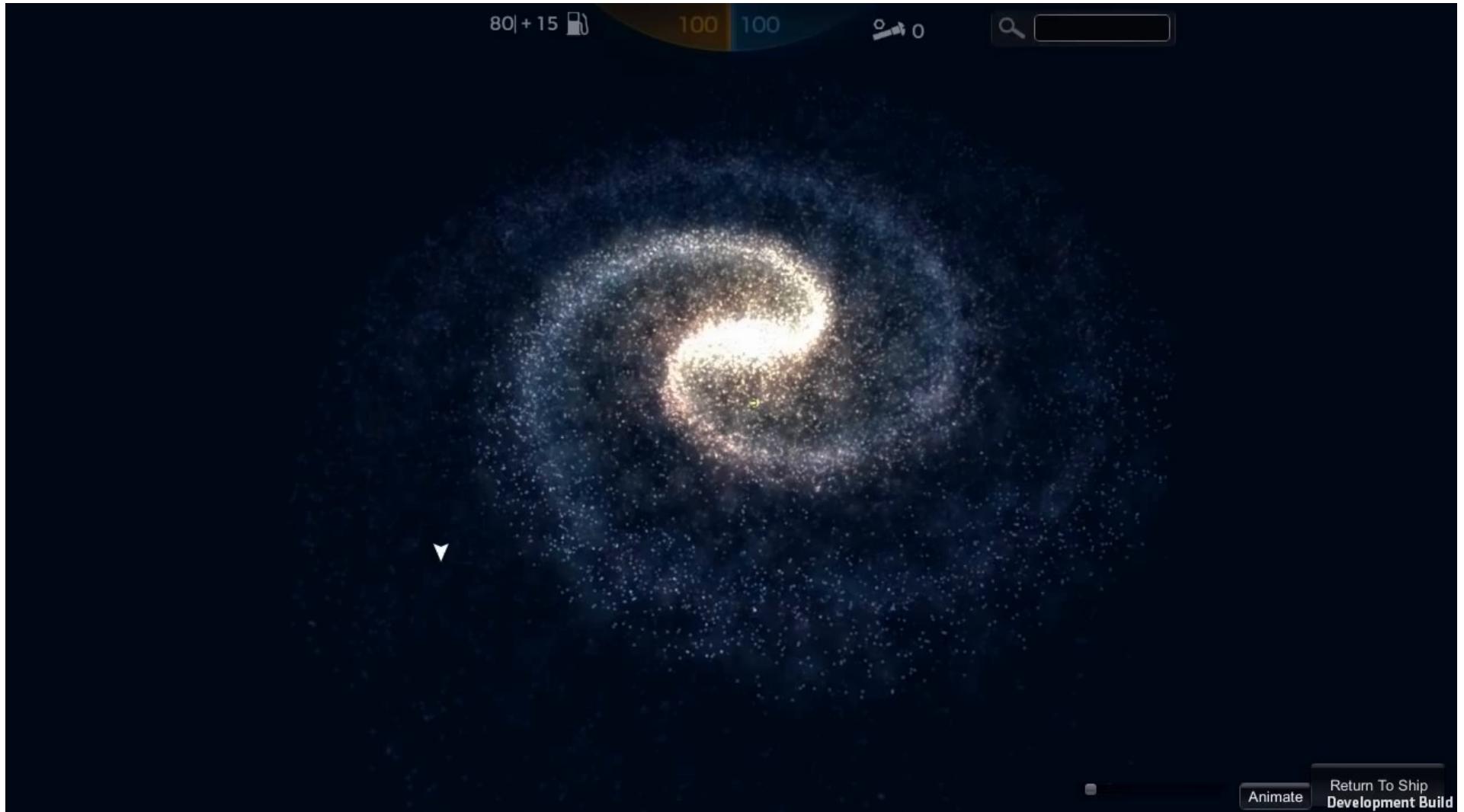
Spiral Galaxy Simulation
by Caleb Piercy

Keplerian Orbits

I couldn't figure out how to program Density Wave Theory :(

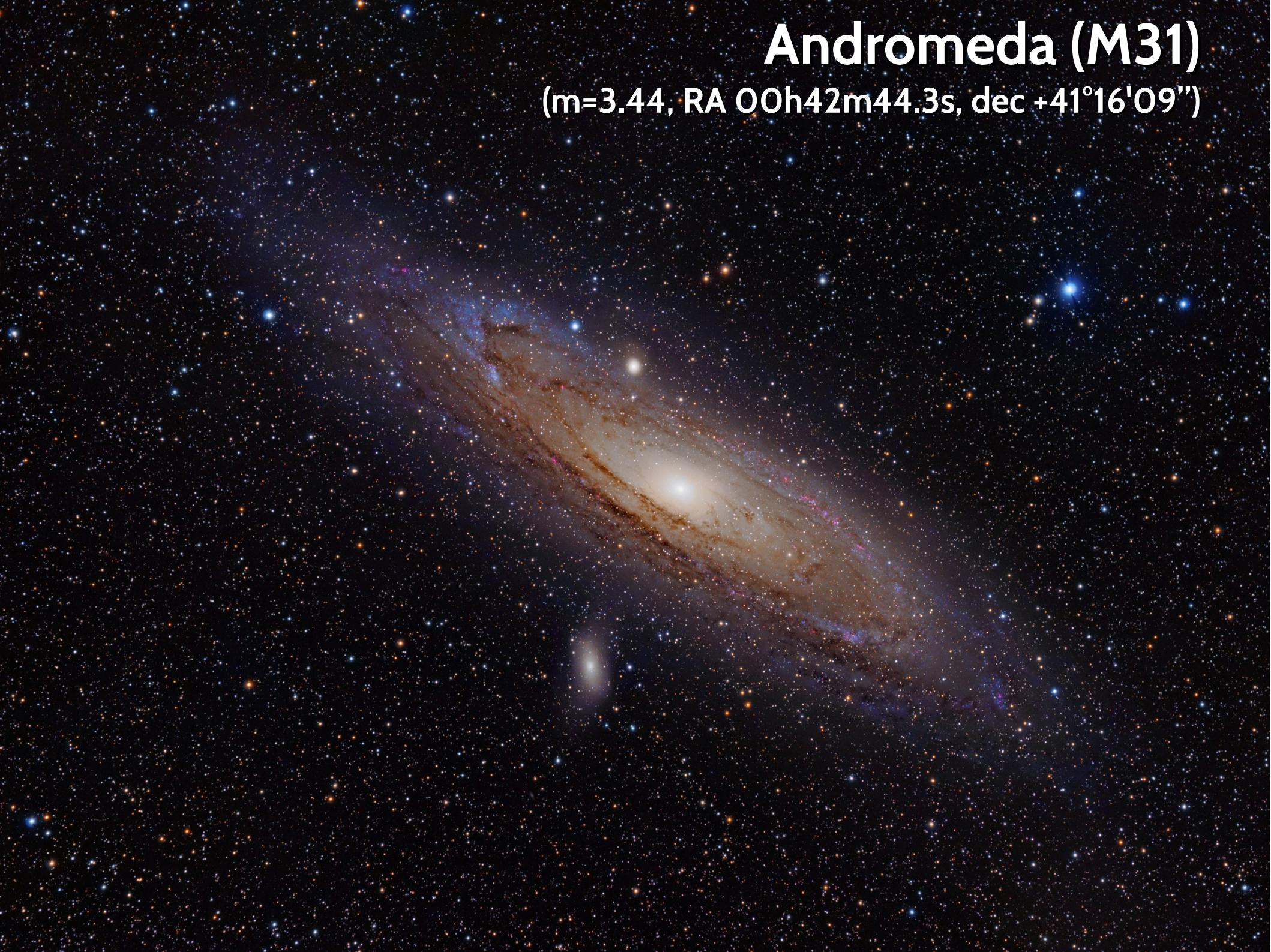


Brazos espirales → atracción entre vecinos



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: $1.5 \times 10^{12} M_S$

