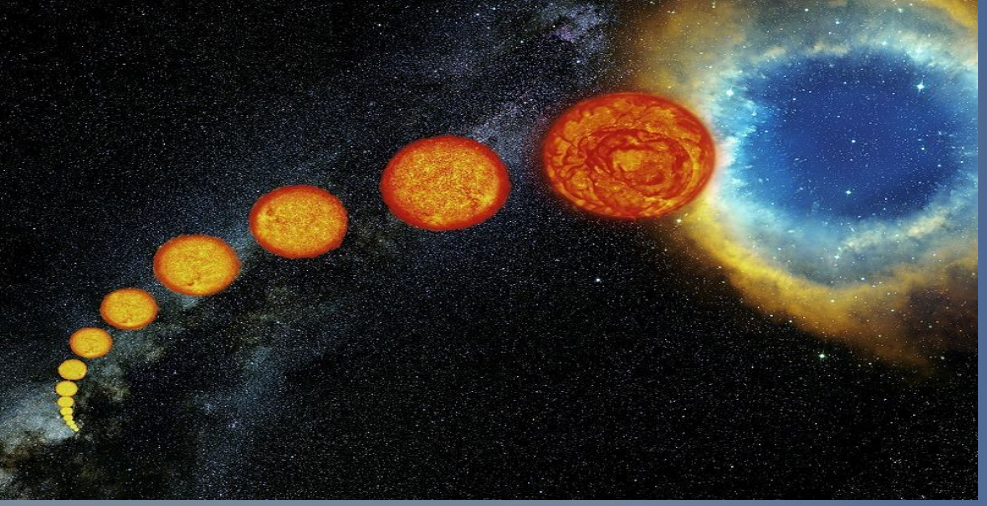


Evolución estelar y agujeros negros

Gil Jannes

Universidad Complutense de Madrid

FECYT FUNDACIÓN ESPAÑOLA PARA LA CIENCIA Y LA TECNOLOGÍA

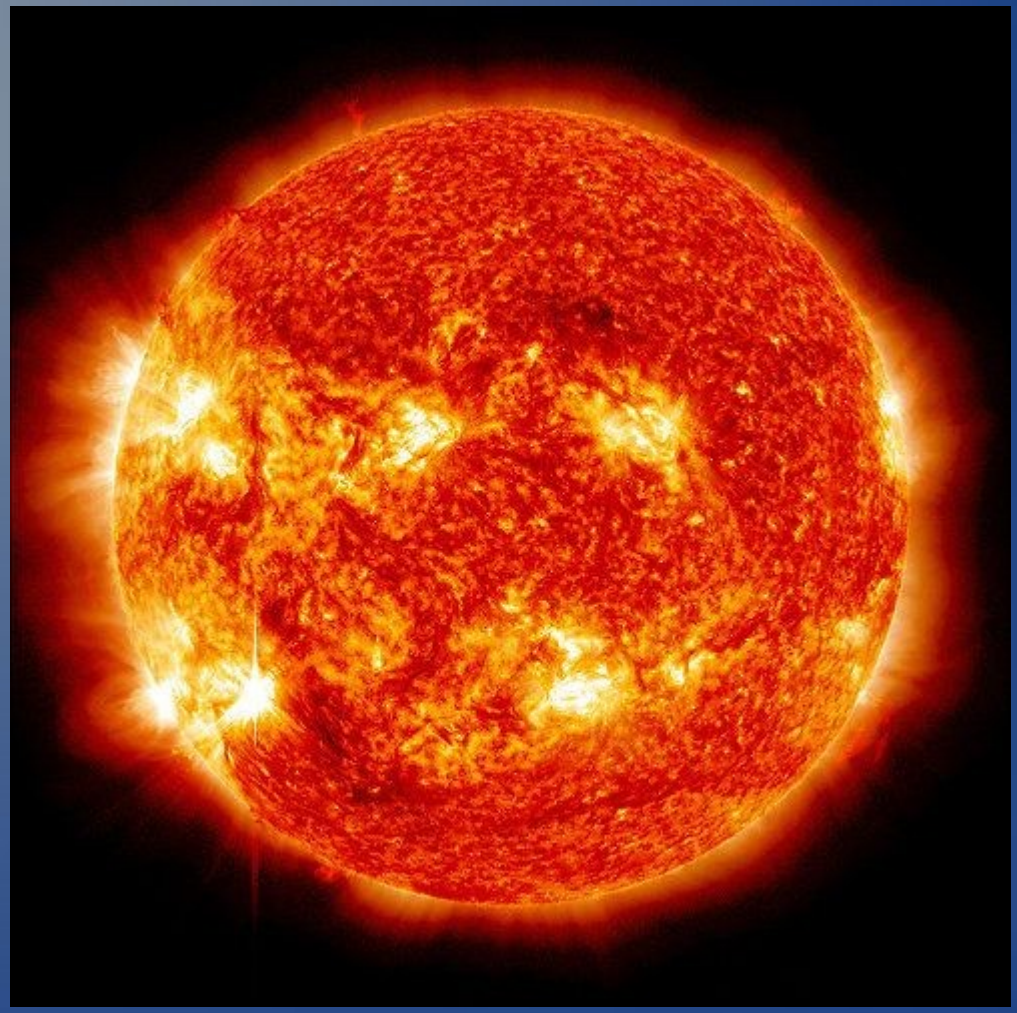
Semana de la Ciencia
2018
IEM – CSIC

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

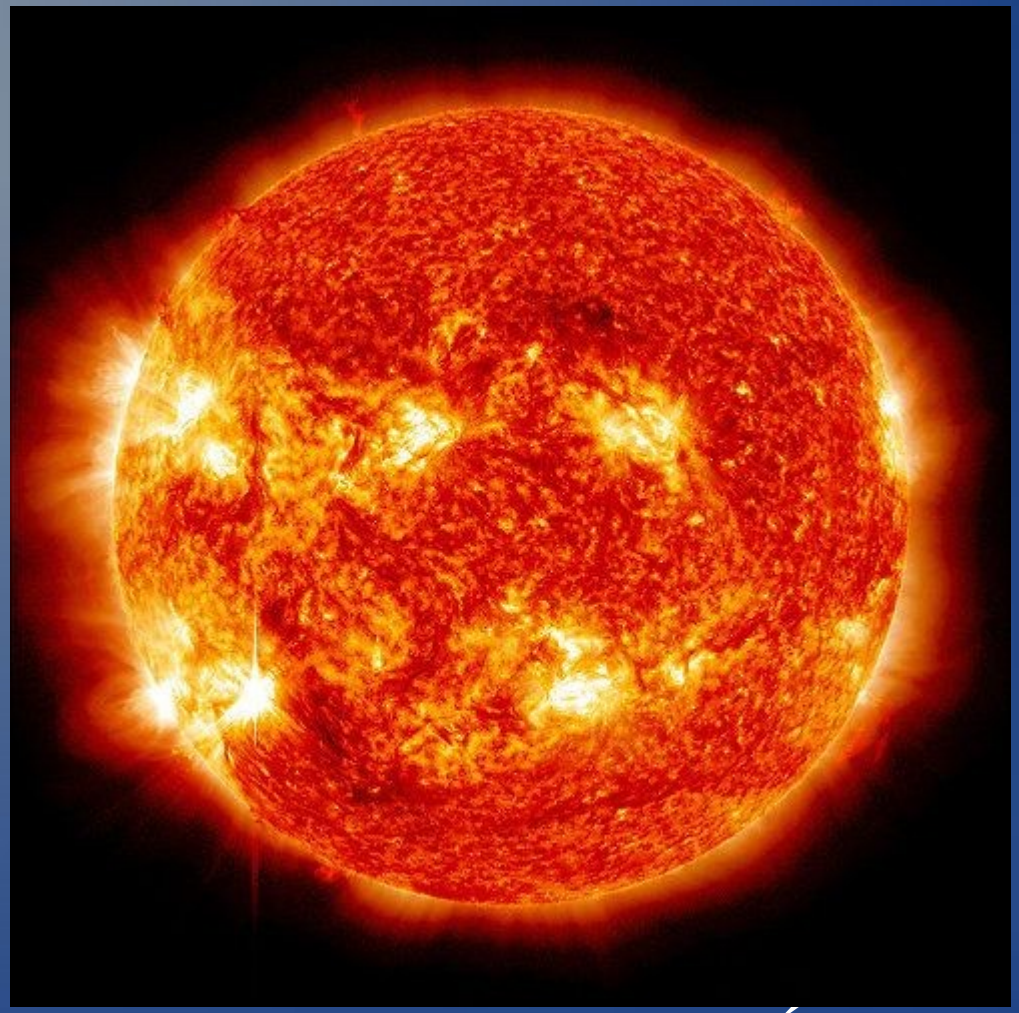
Contenido

- El nacimiento de las estrellas
- Evolución estelar
- La muerte de las estrellas:
  Enanas blancas, estrellas de neutrones y…
  Agujeros negros

¿Qué es una estrella?

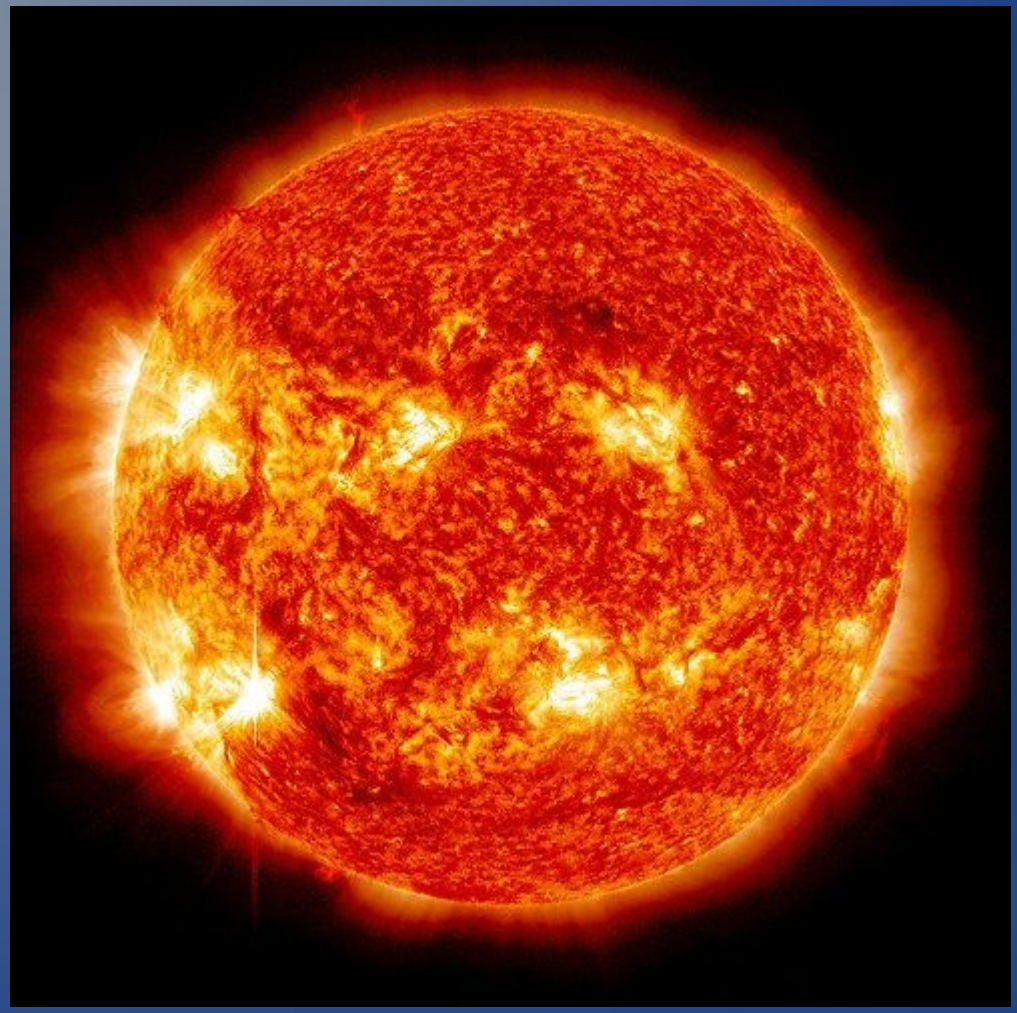


¿Qué es una estrella?



[wikipedia] UNA ESTRELLA (DEL LATÍN: STELLA) ES UNA ESFERA LUMINOSA DE PLASMA QUE MANTIENE SU FORMA GRACIAS A SU PROPIA GRAVEDAD.

¿Qué es una estrella?



BOLA DE FUEGO

Triángulo del fuego

Combustible → GAS (plasma)
Calor ??? (–270.5ºC)
Oxígeno ???

Las estrellas están hechas de gas

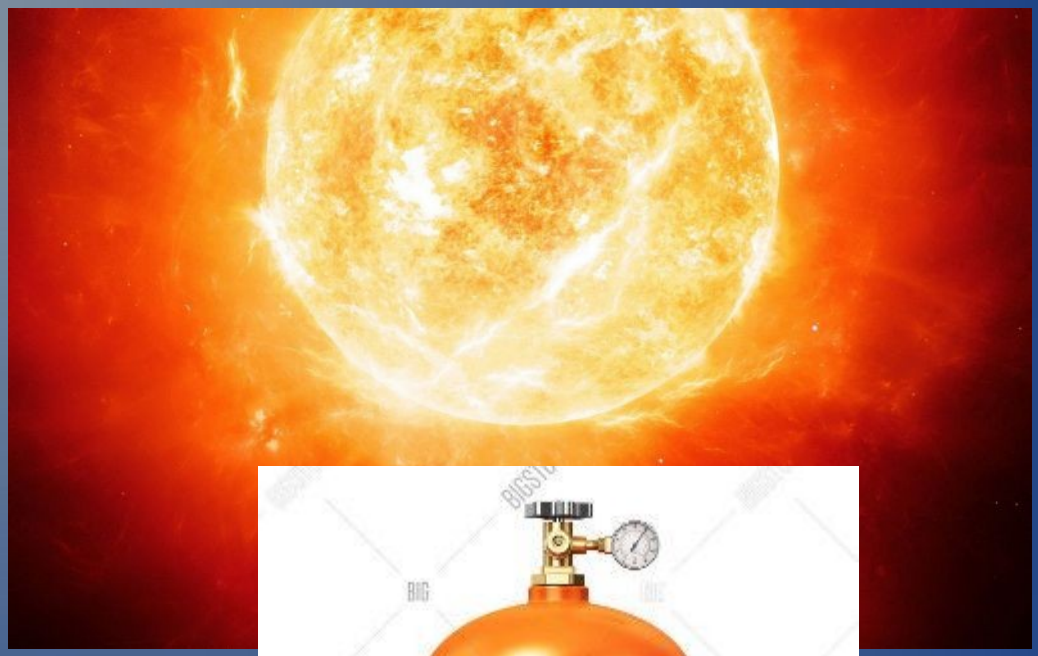
¿Qué gas?

Las estrellas están hechas de gas

¿Qué gas?

¿butano o propano?

Las estrellas están hechas de gas

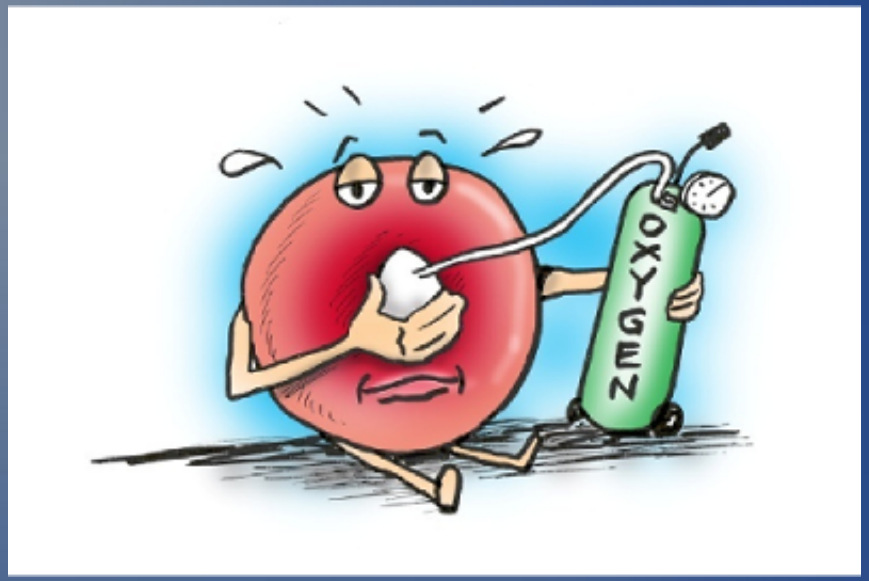


¿Qué gas?

¿Por qué arden las estrellas?

¿Cómo se encienden?

¿Qué tipo de fuego?



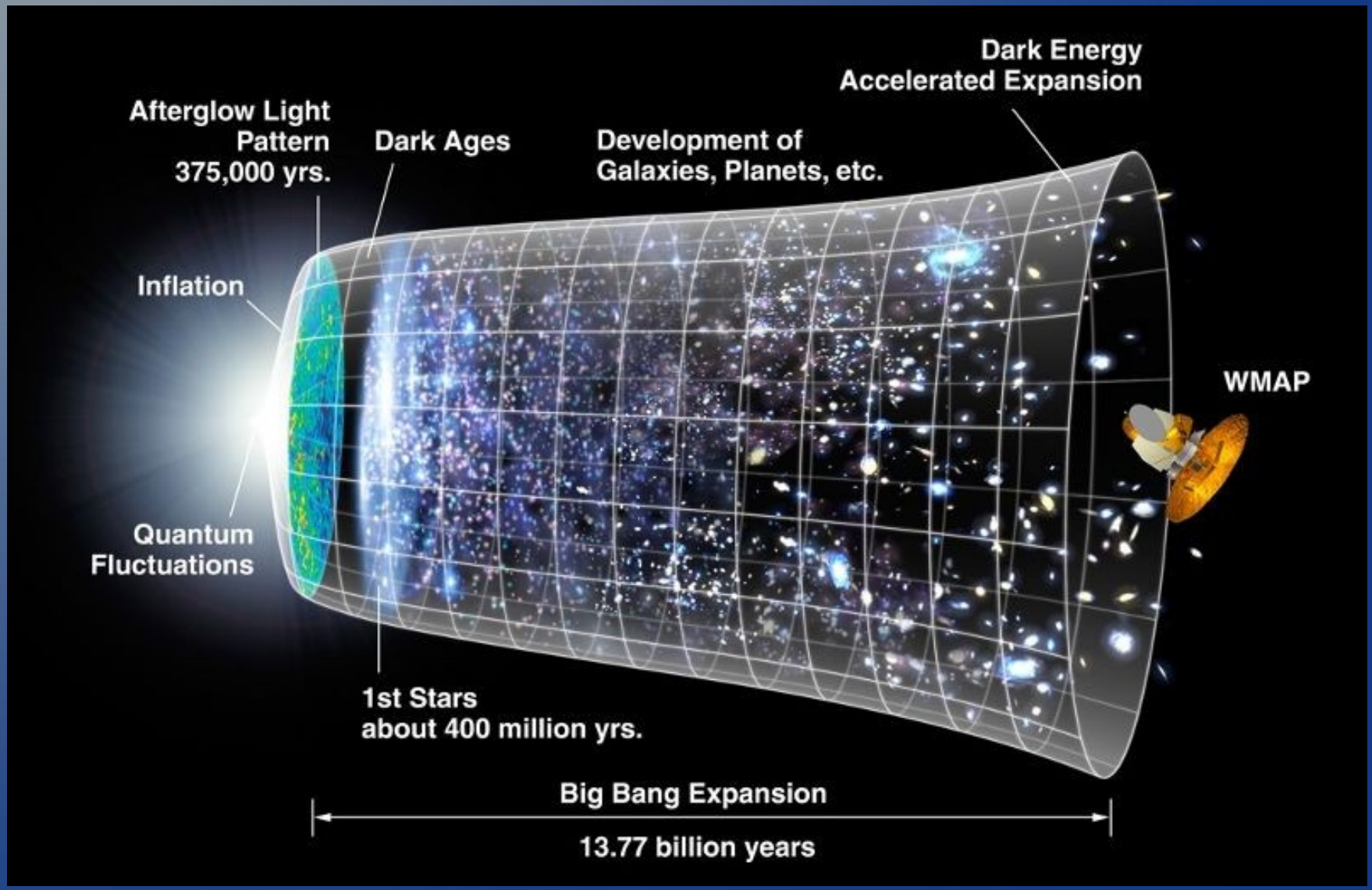
¿De dónde viene el oxígeno?
o ¿no hace falta?

NACIMIENTO

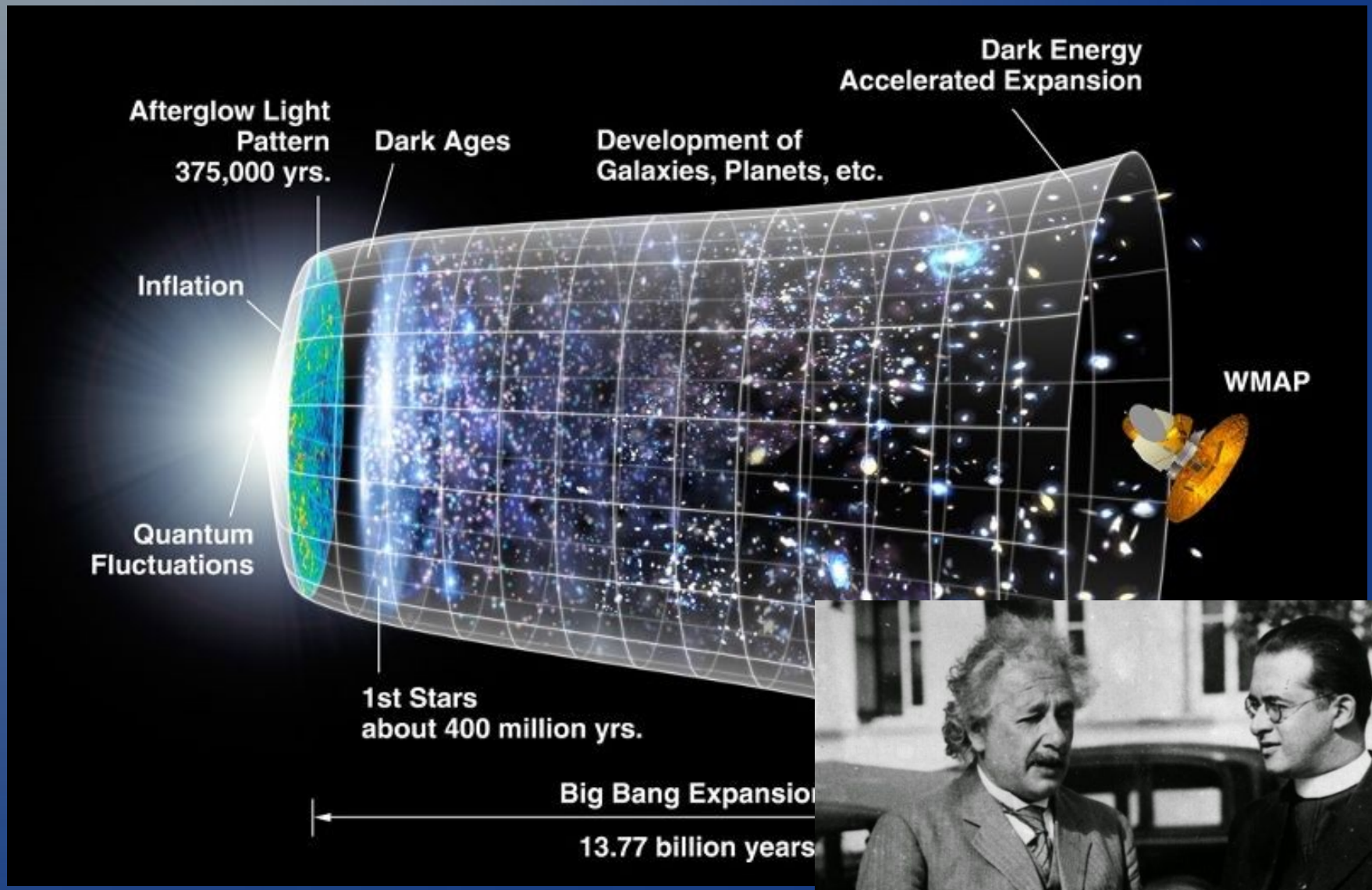
NACIMIENTO

NACIMIENTO

Universo primigenio



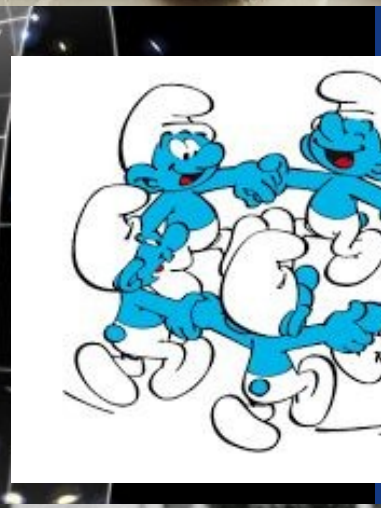
Universo primigenio



so primi

Ac

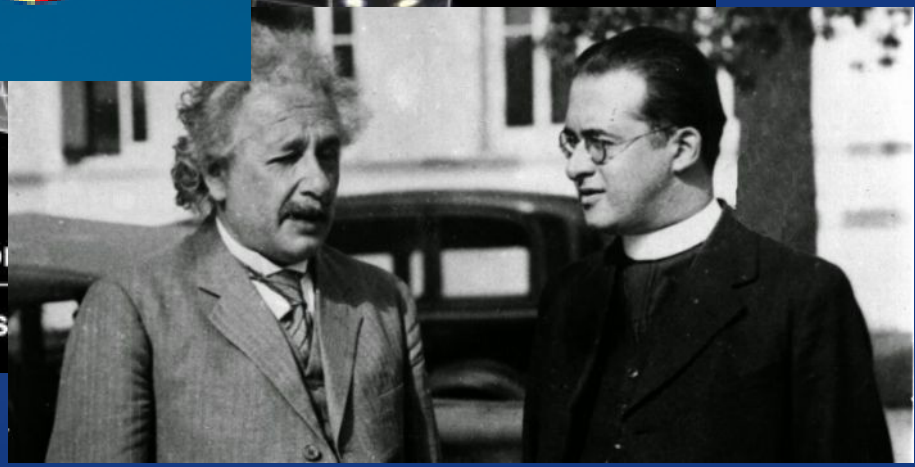
Development of
Galaxies, Planets, etc



st Stars
bout 400 million yrs.

Big Bang Expansio

13.77 billion years



FORMACIÓN DE ESTRUCTURA

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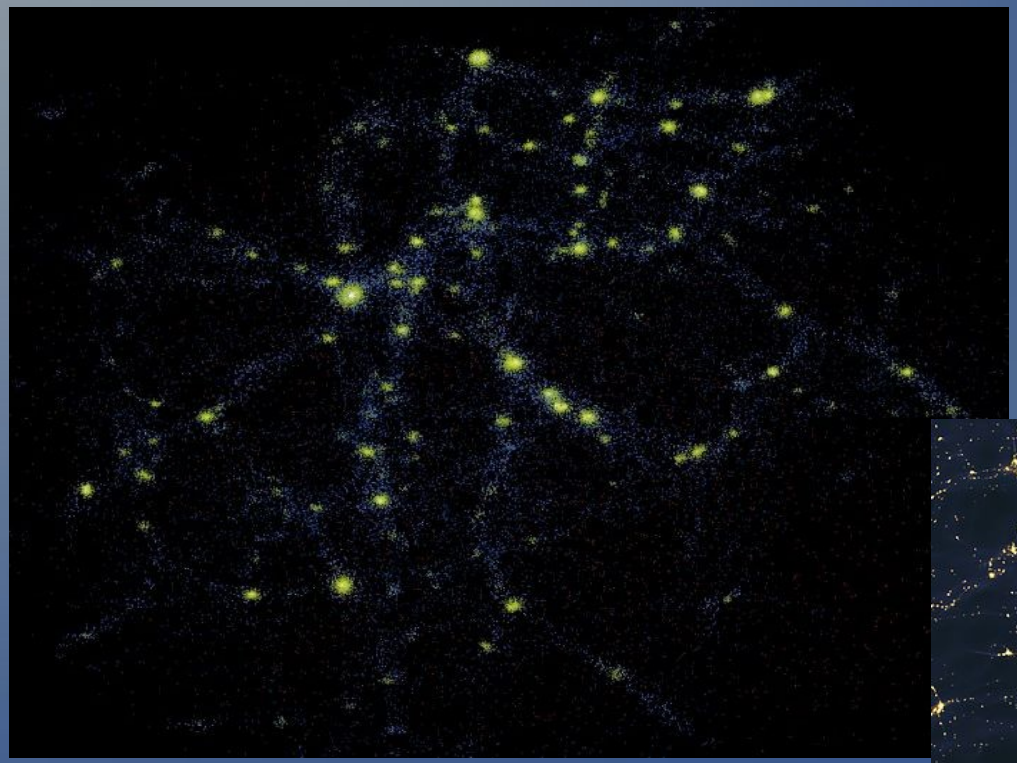

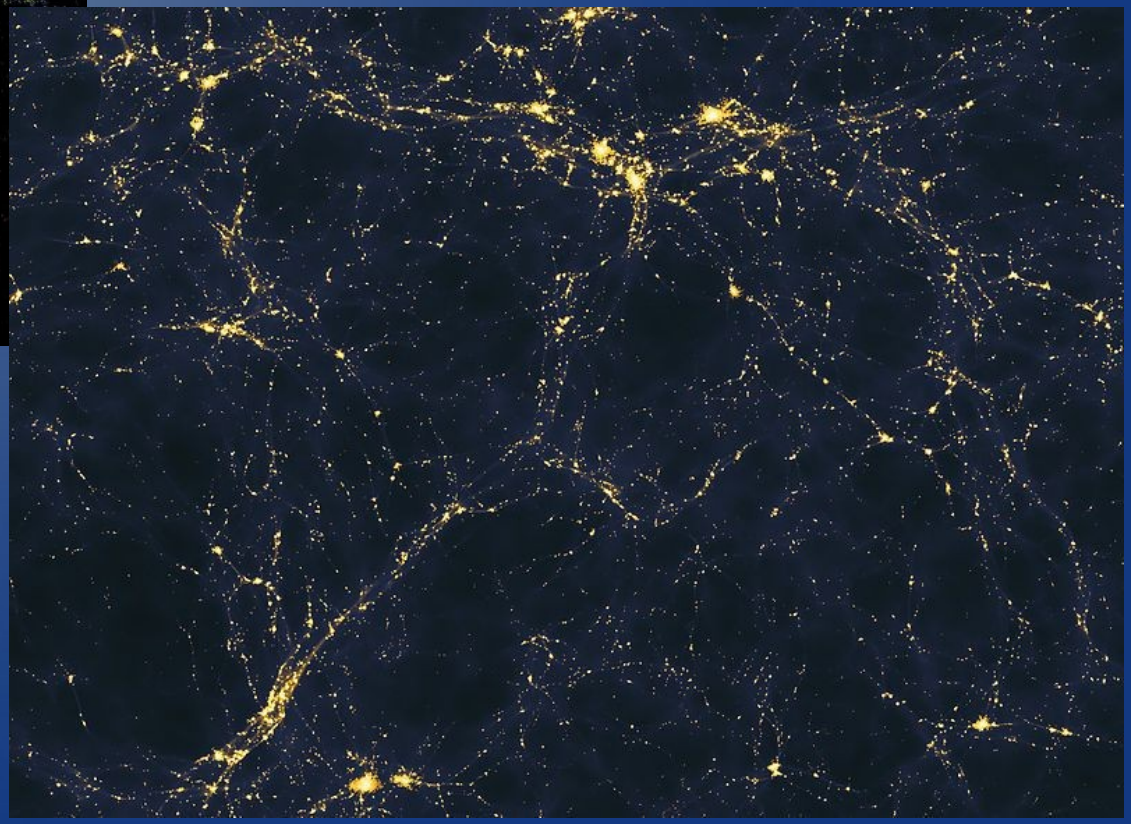

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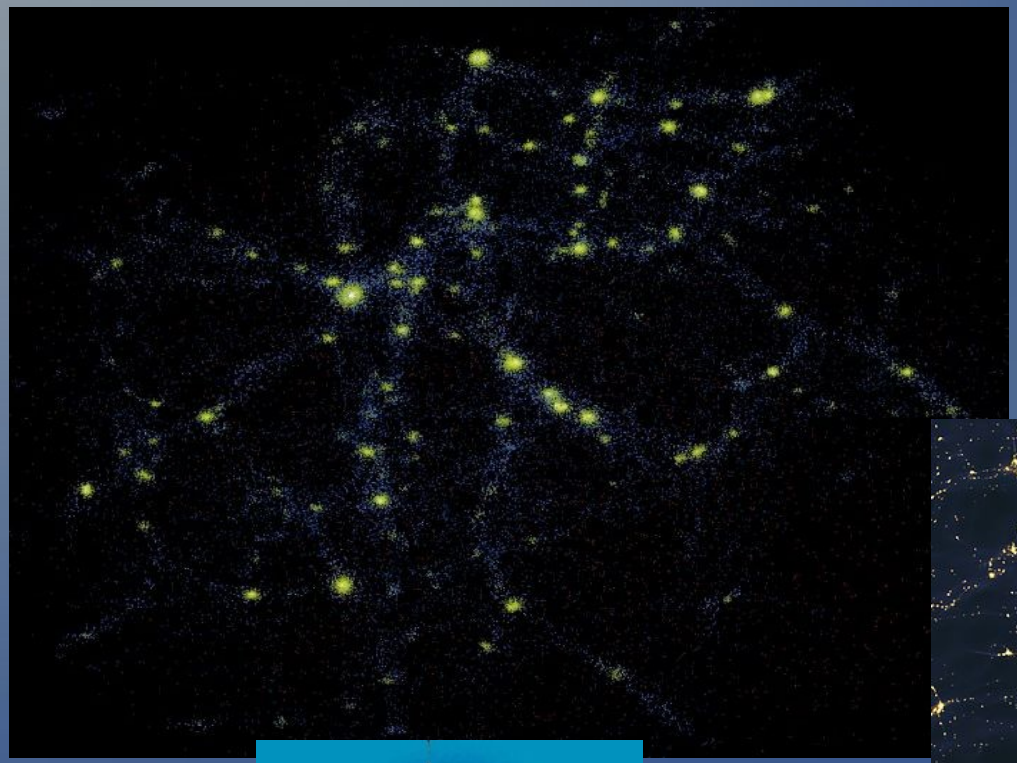
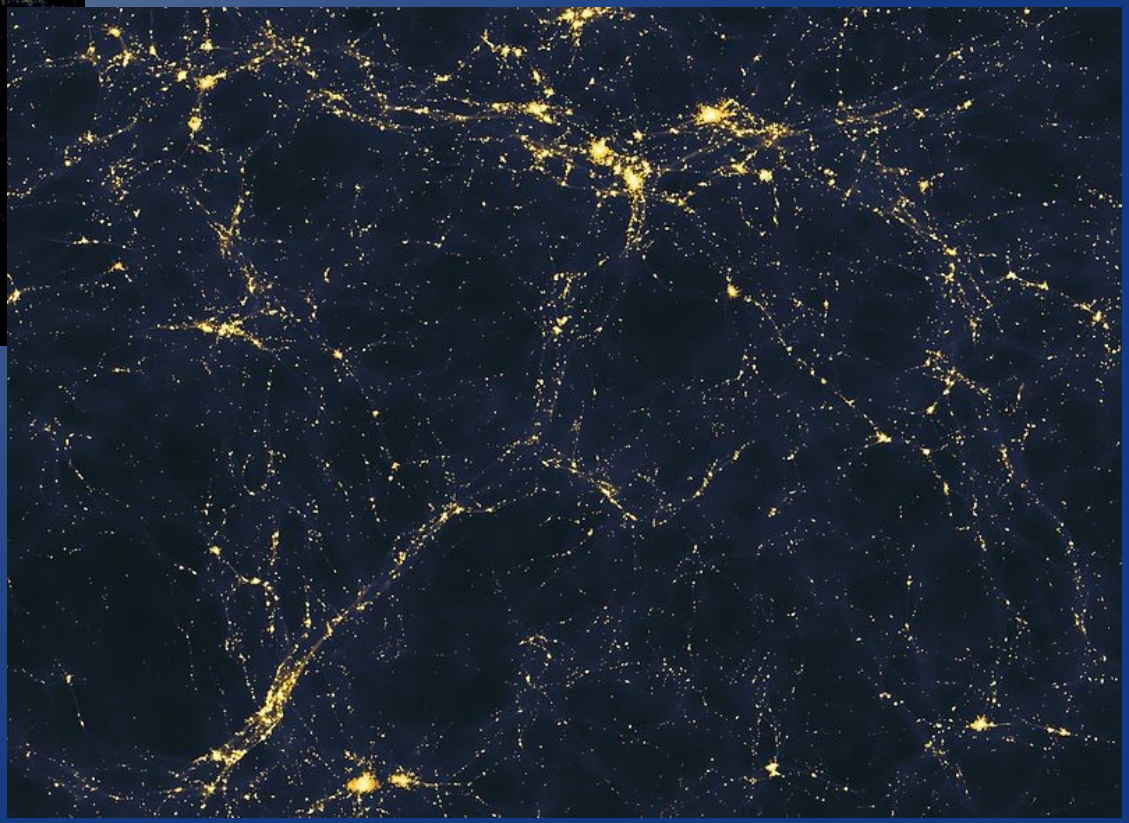
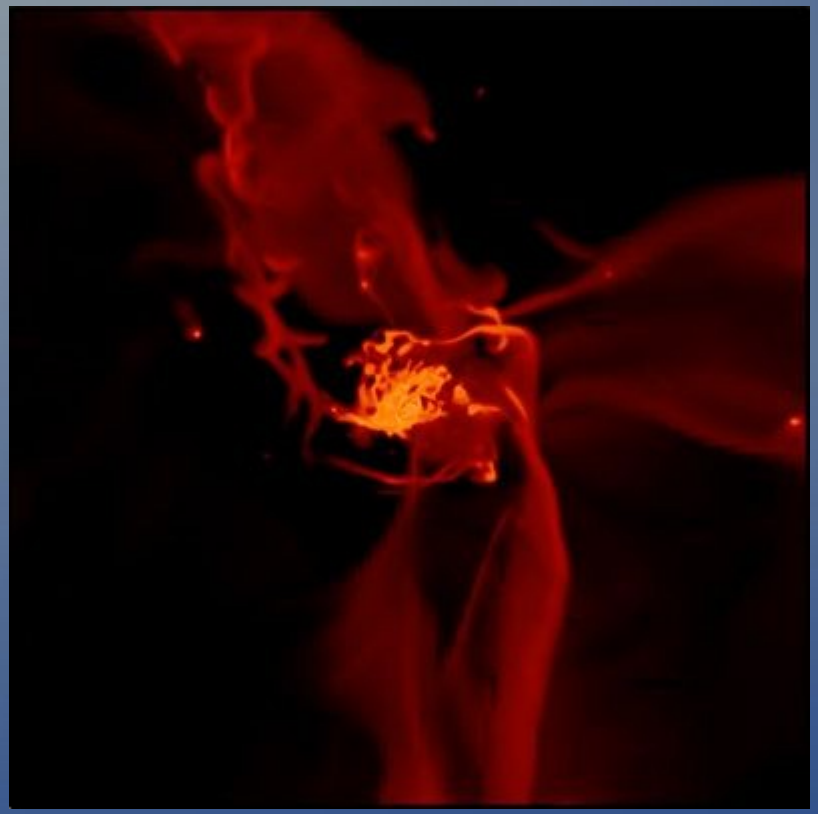


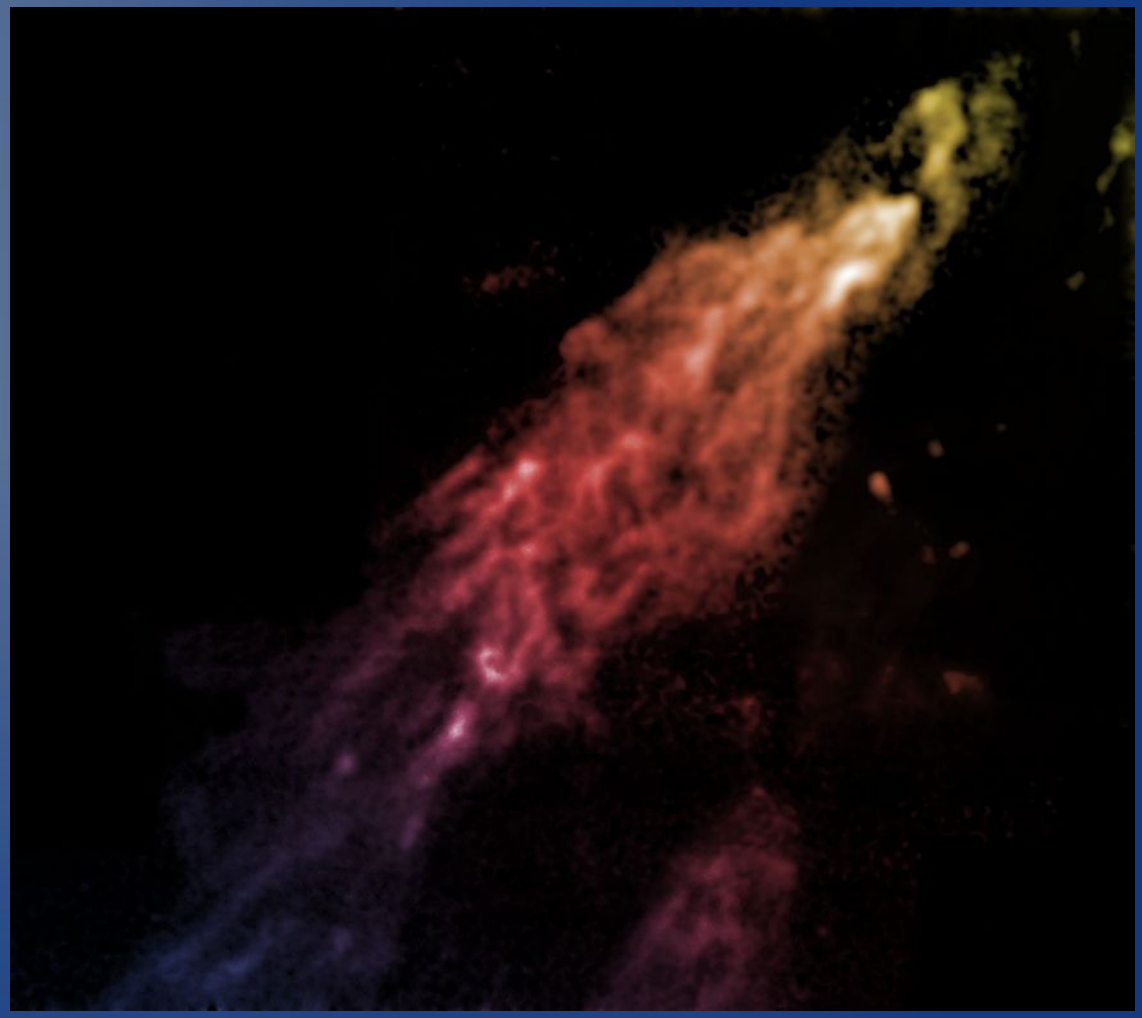


GRAVEDAD

NUBES PRIMORDIALES



Vision artística



Nube de Smith

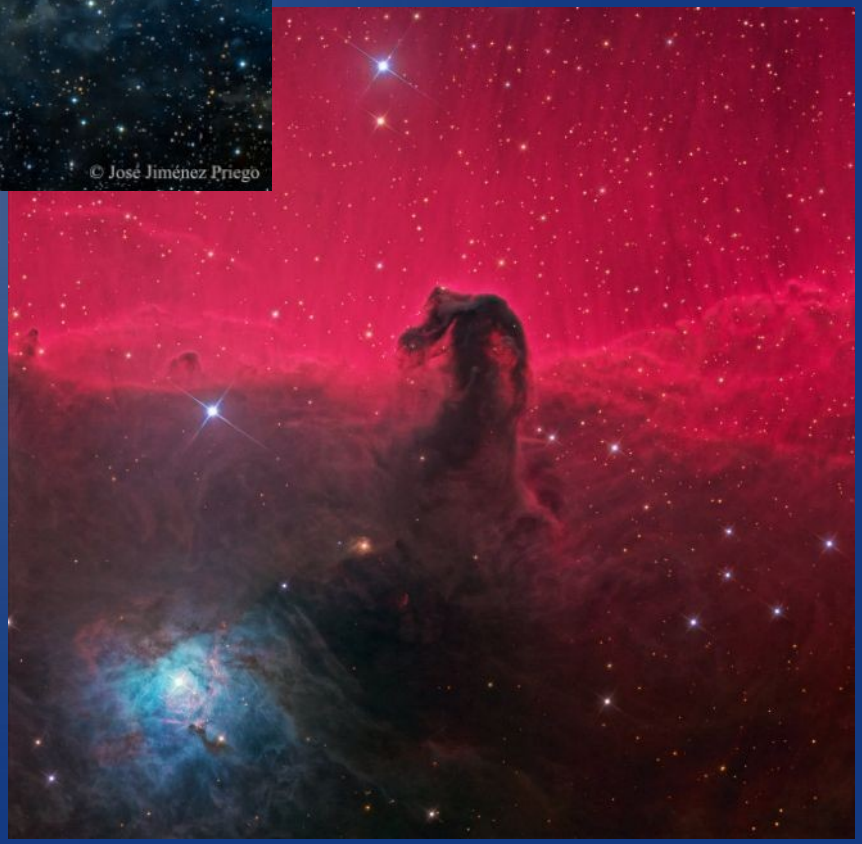
NUBES ACTUALES
(nebulosas interestelares)

Bow shock nebula
Zeta Ophiuchi

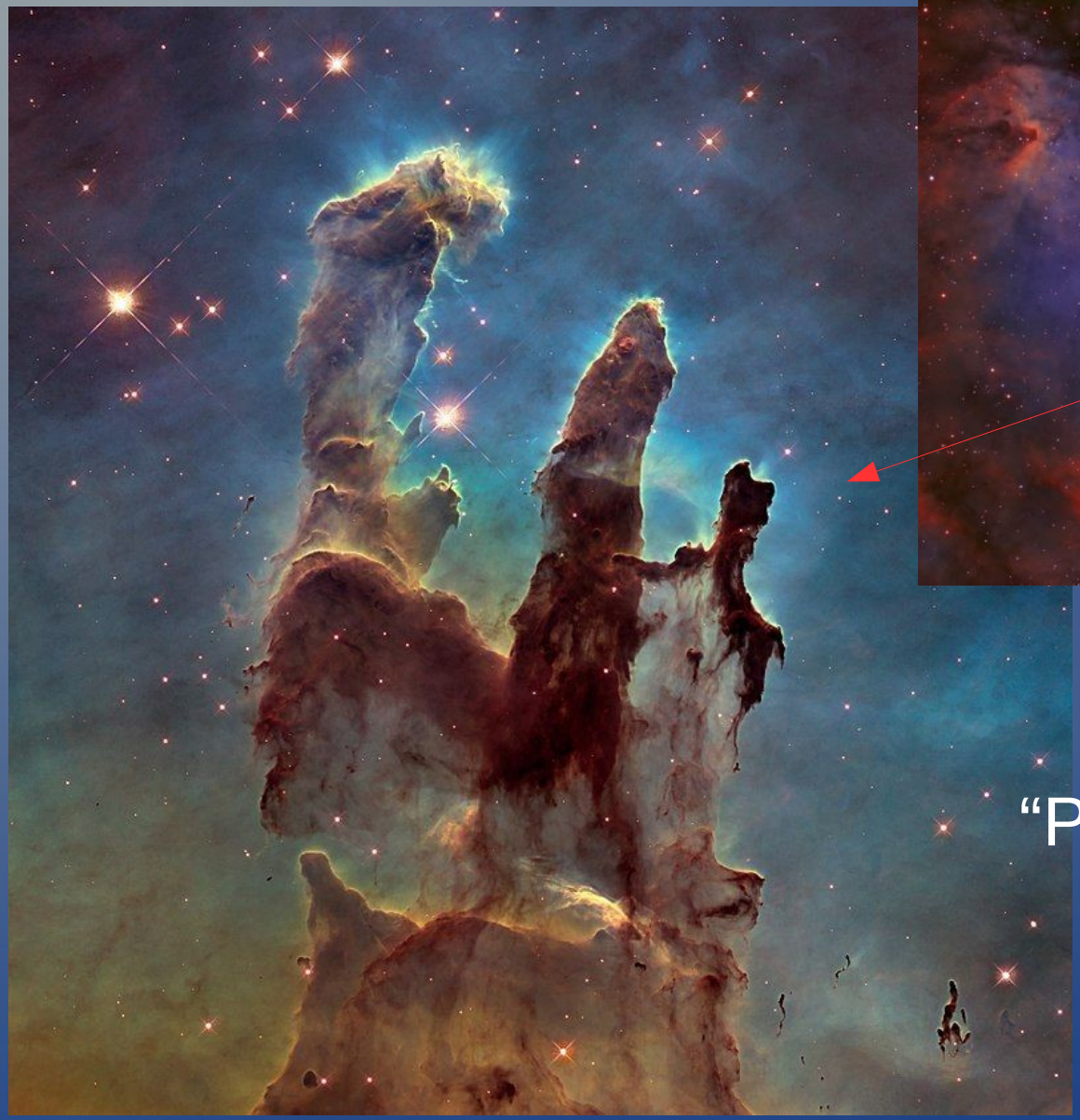
Lagoon nebula

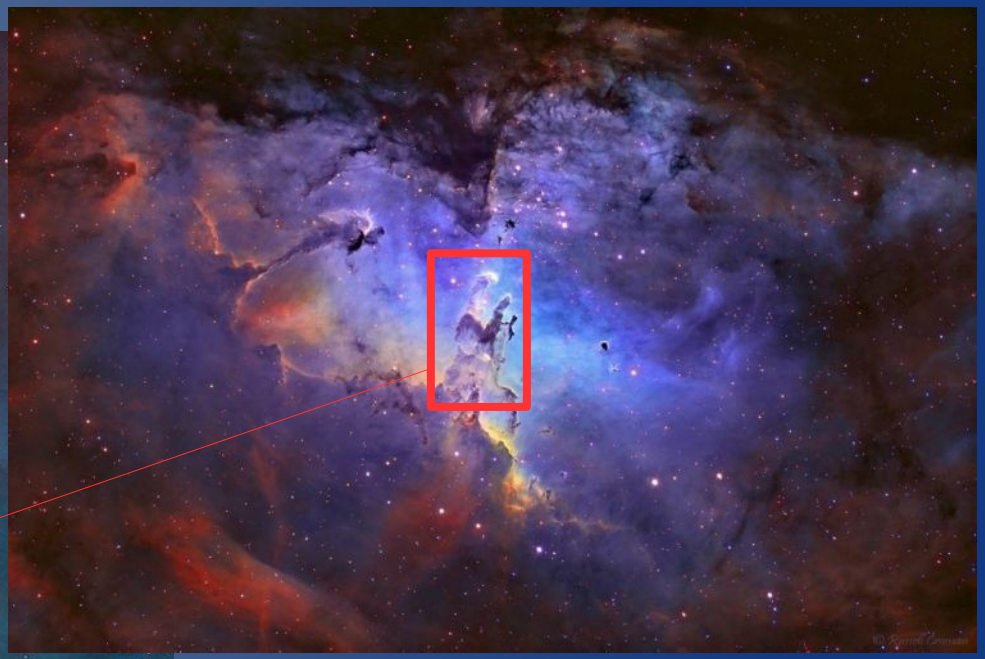
Más nebulosas interestelares

Horse head nebula



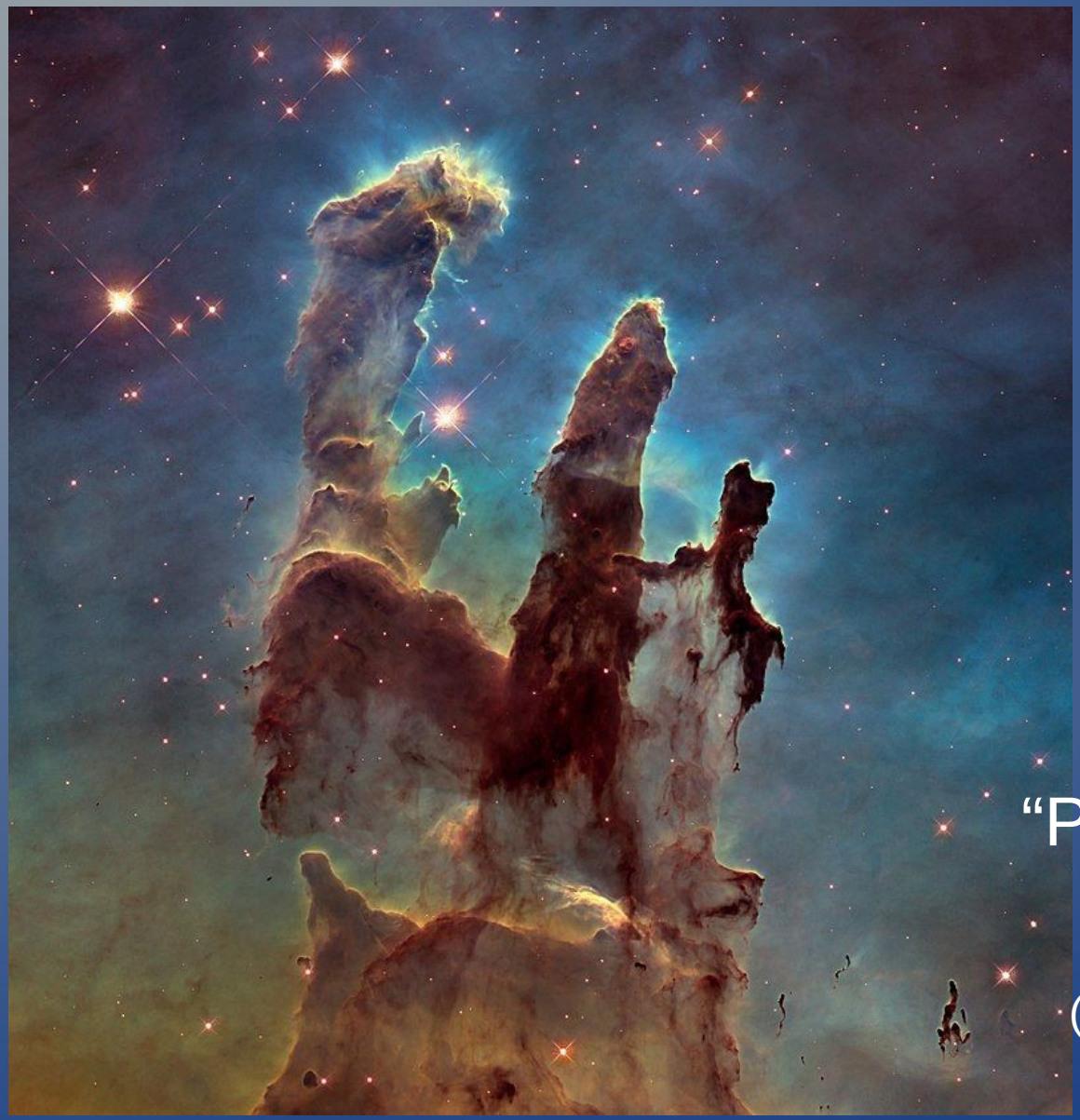
Más nebulosas interestelares





“Pilares de la creación”

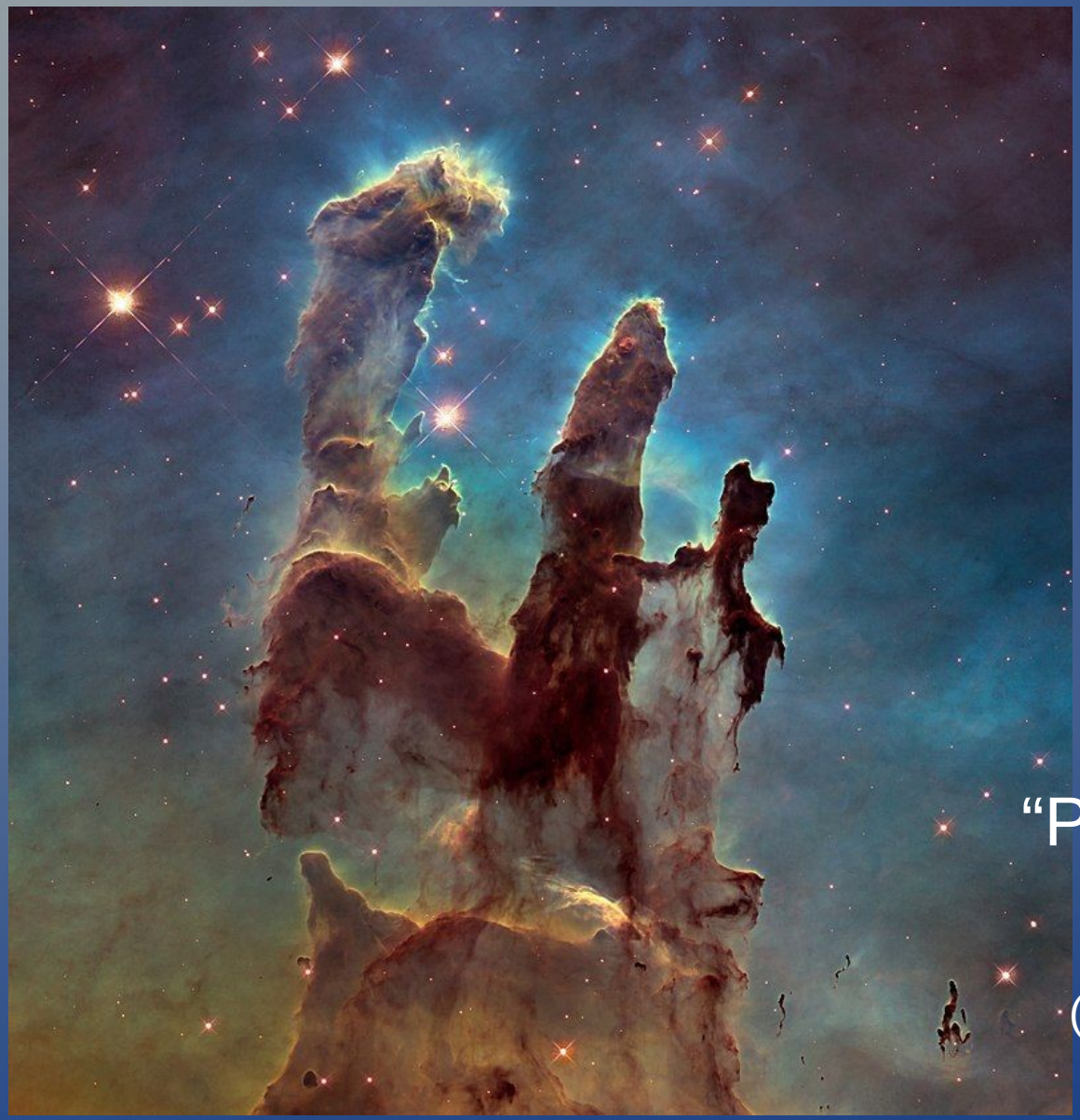
Más nebulosas interestelares



"Pilares de la creación"

- tamaño: 5 años luz
(300 000 veces distancia T-sol)
- distancia: 7000 años luz
(5M veces distancia al sol)
- se especula que ya no existe
(destruido en explosión supernova hace 6000 años)

Más nebulosas interestelares



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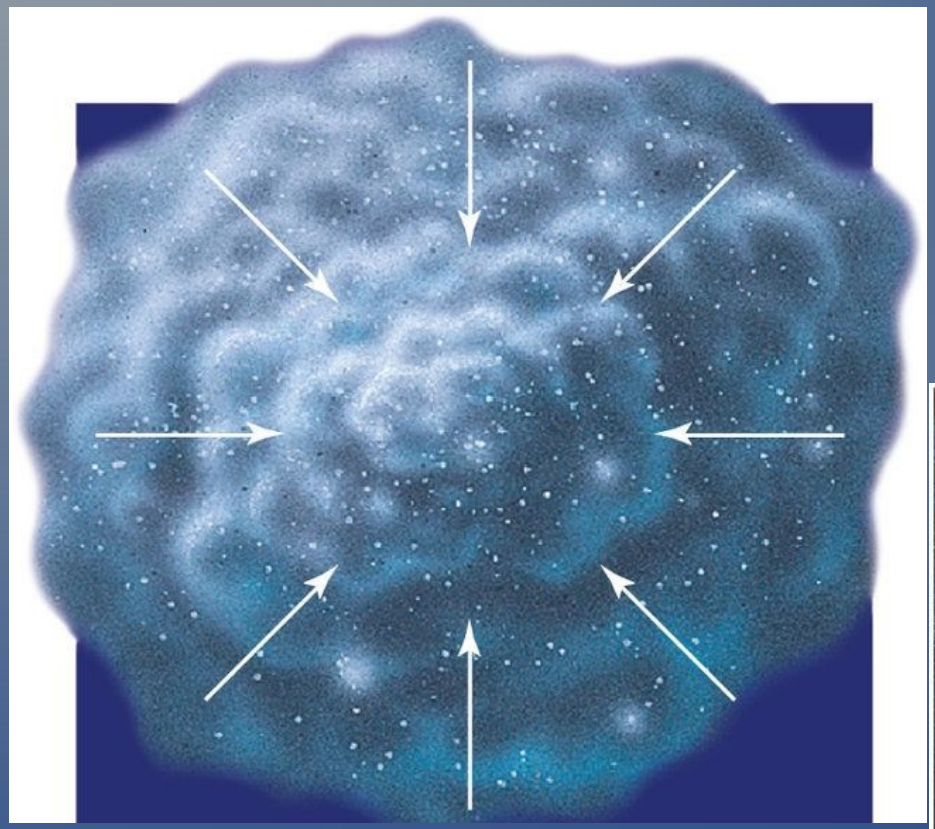
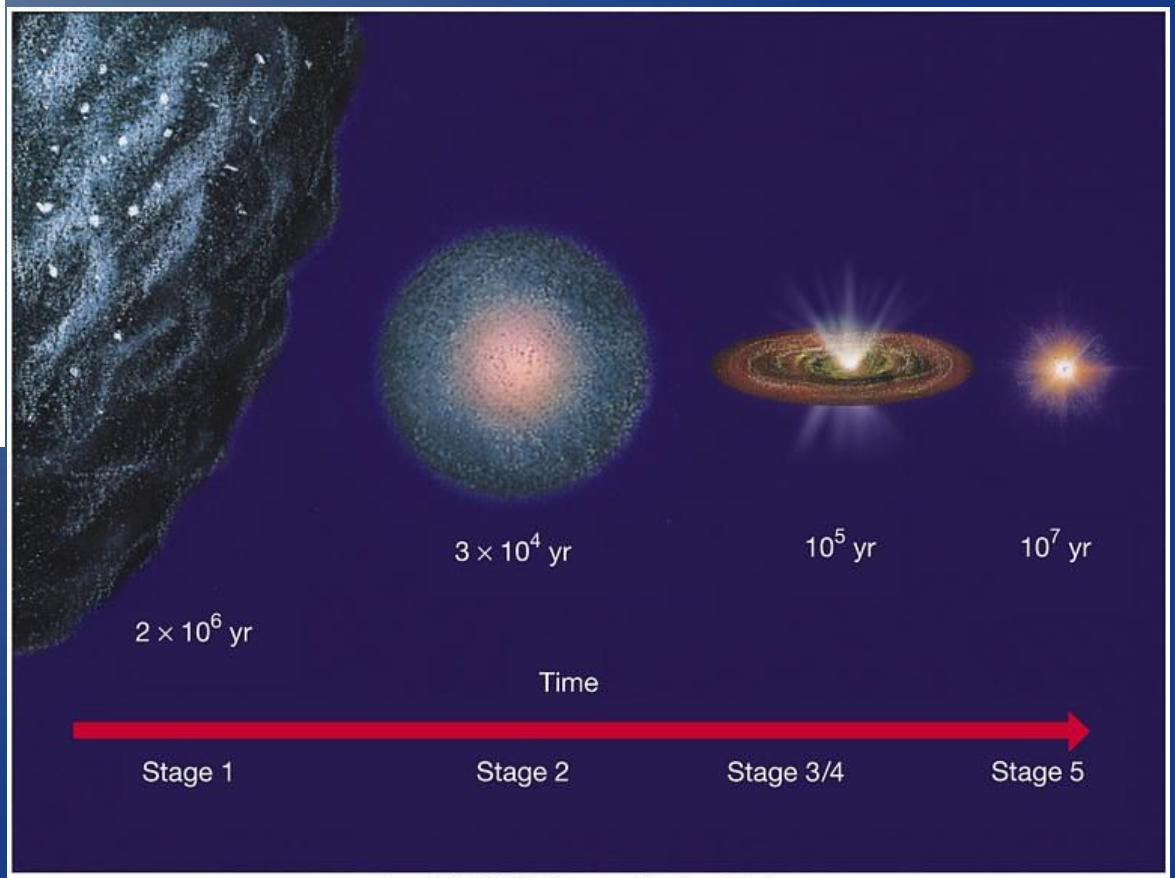
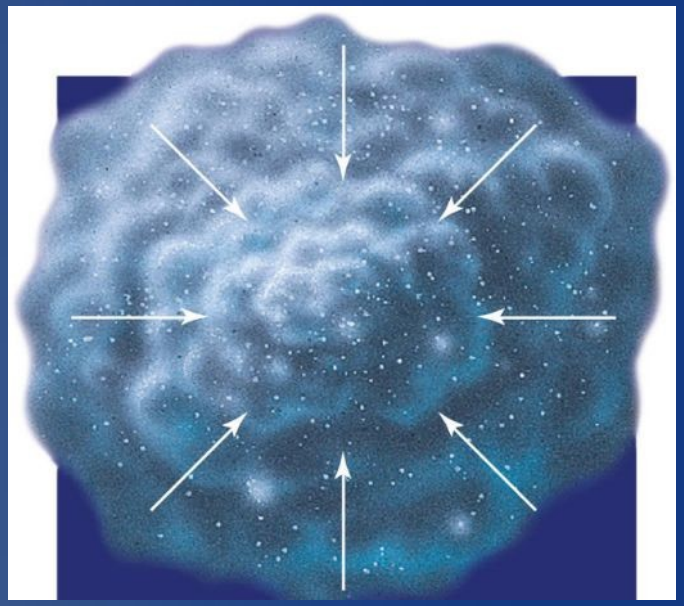
(5M veces distancia al sol)
- se especula que ya no existe
(destruido en explosión supernova hace 6000 años)
lo sabremos con seguridad dentro de 1000 años...

NUBES COLAPSAN (autogravedad)





Autogravedad

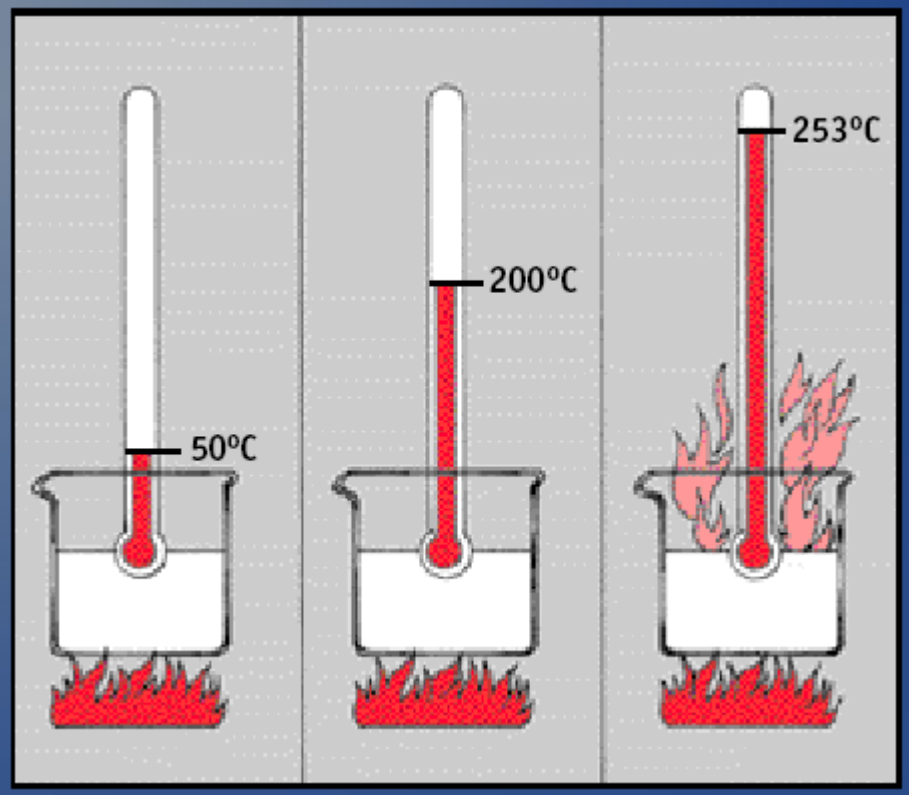


$$F = G\frac{M_1 M_2}{r^2}$$

nube suficientemente grande siempre termina colapsando ($M \sim r^3$)

IGNICIÓN

IGNICIÓN ESPONTÁNEA



IGNICIÓN ESPONTÁNEA REQUIERE TEMPERATURA ALTA

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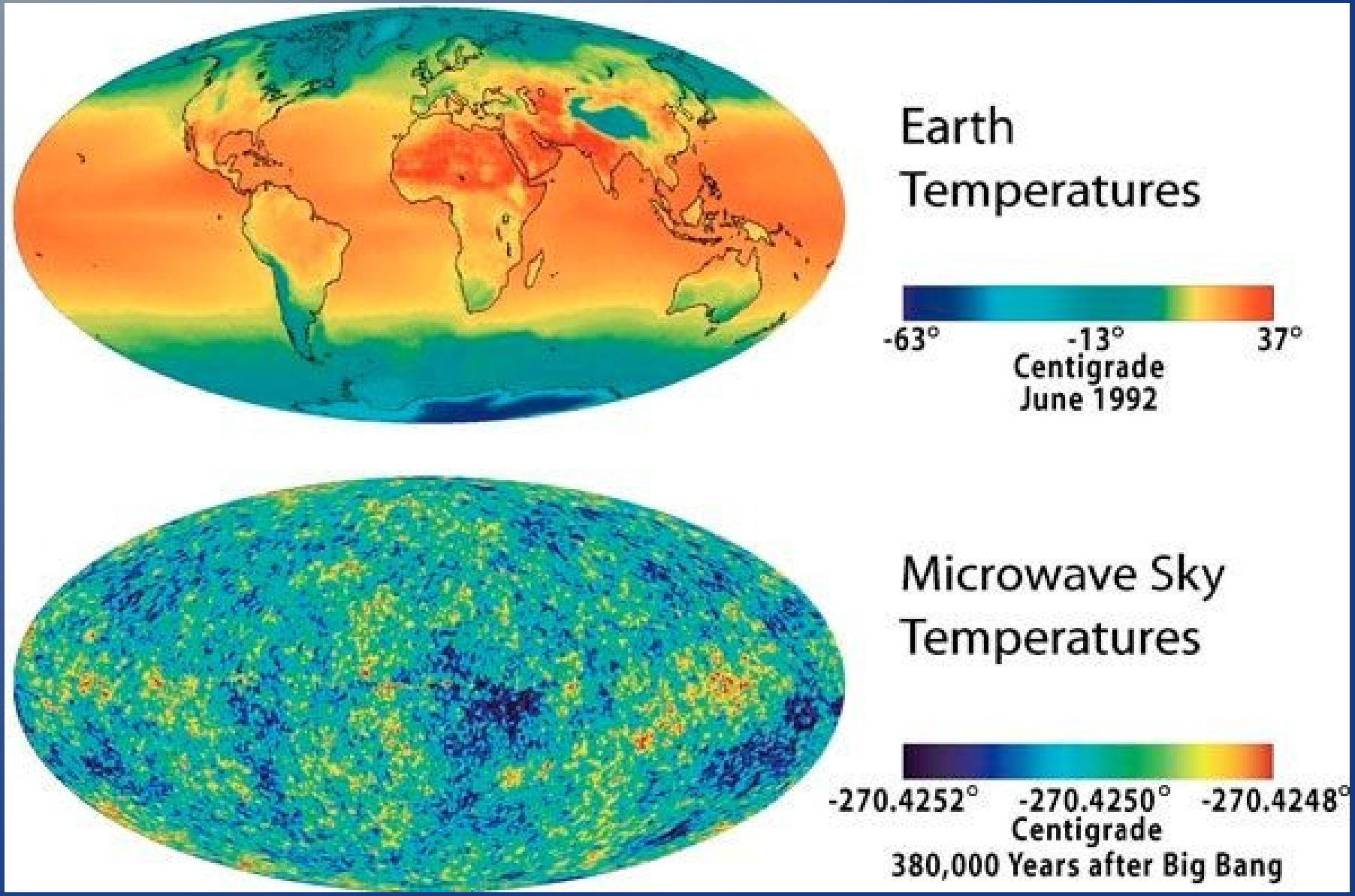

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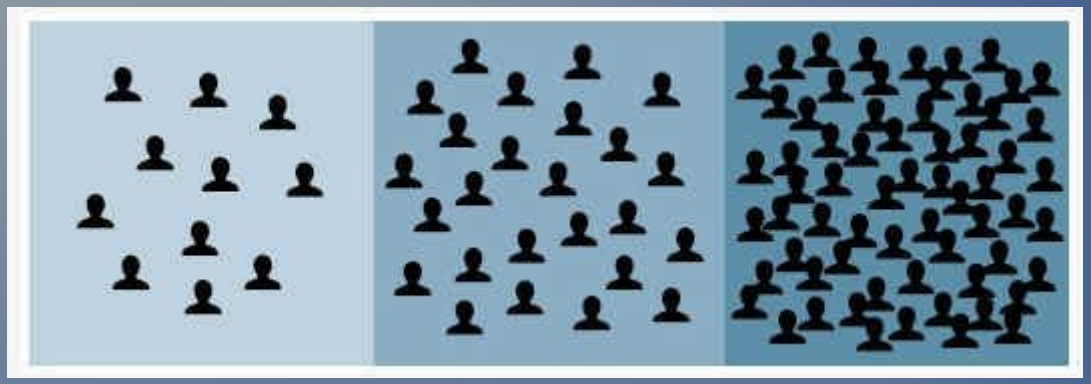
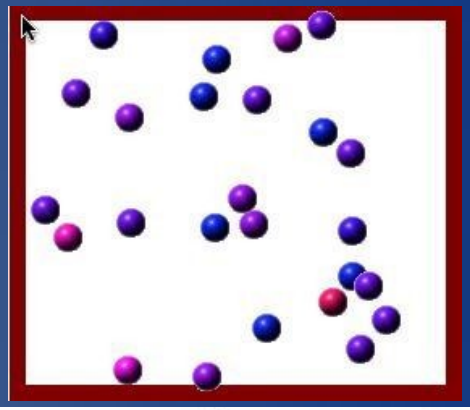
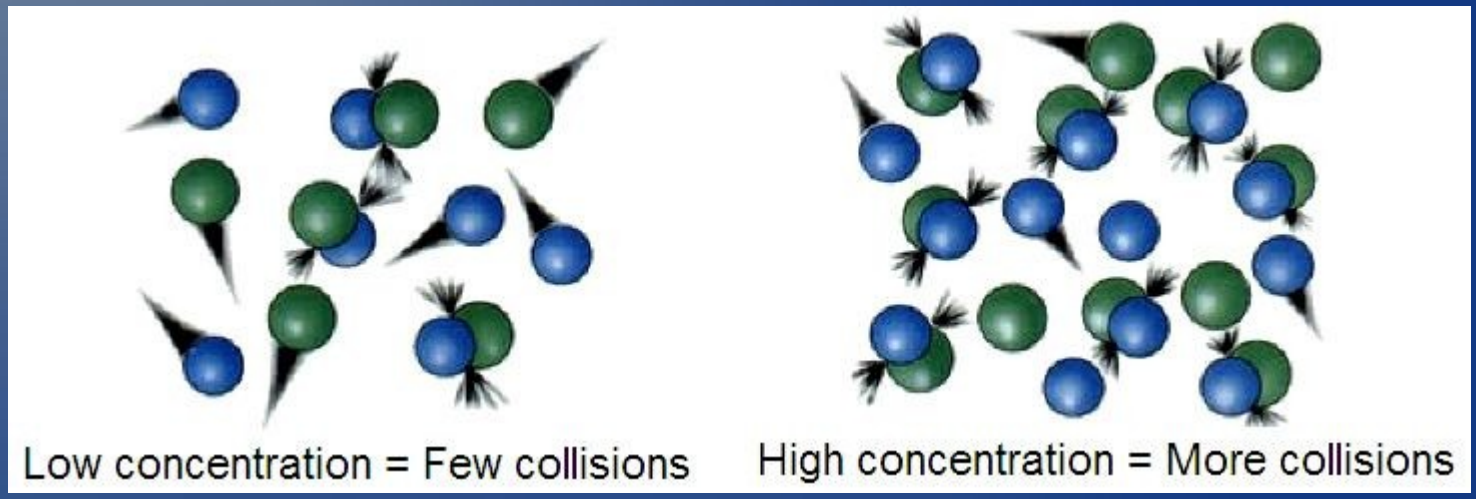
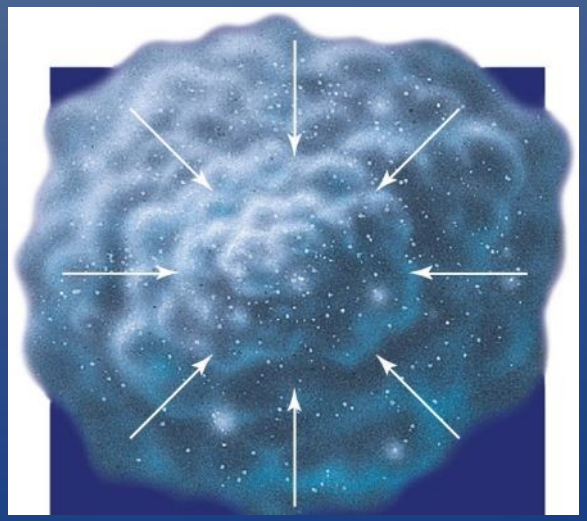


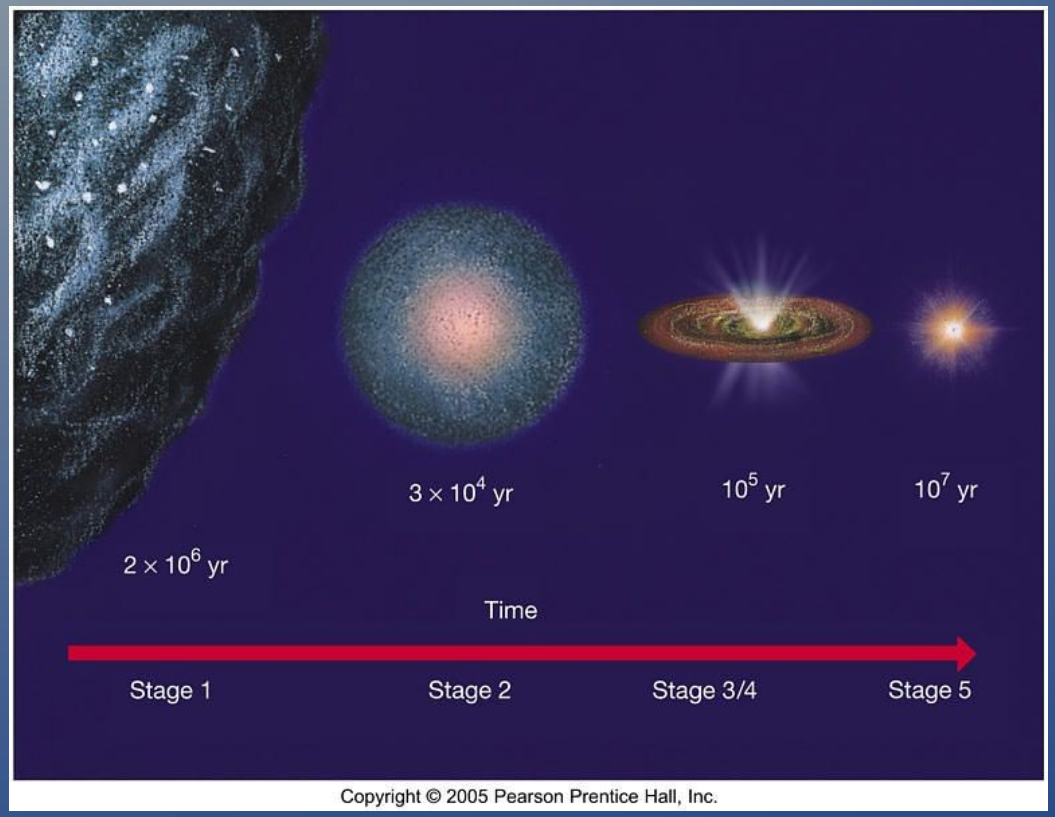


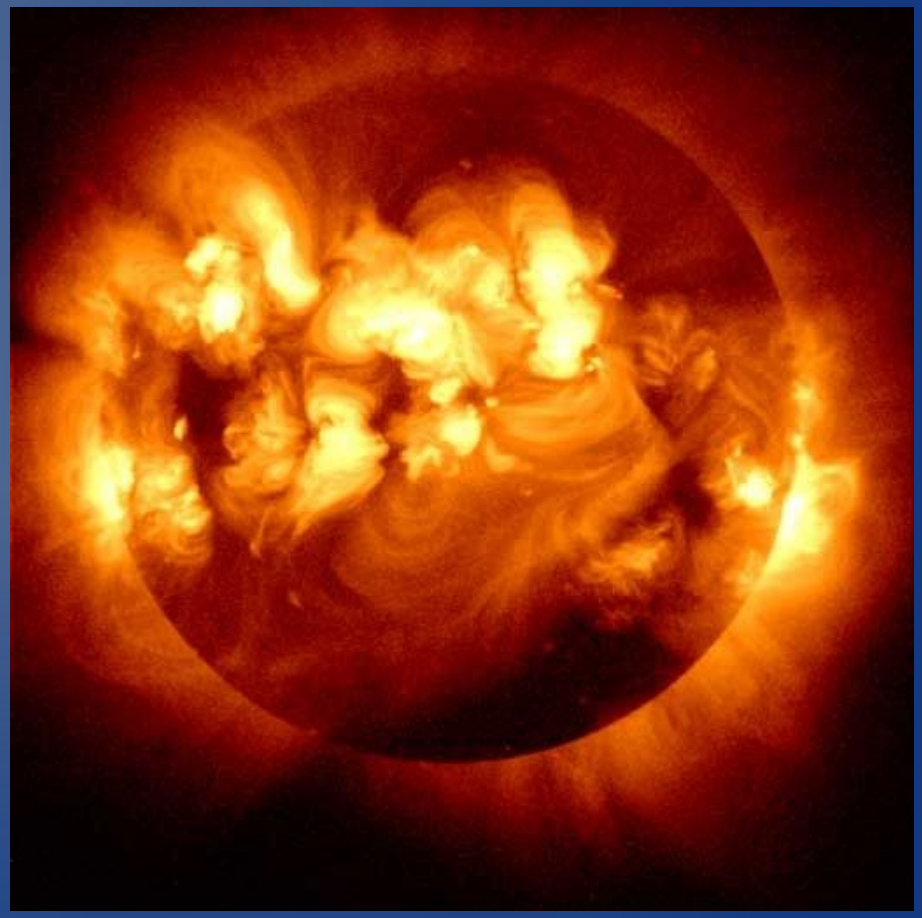




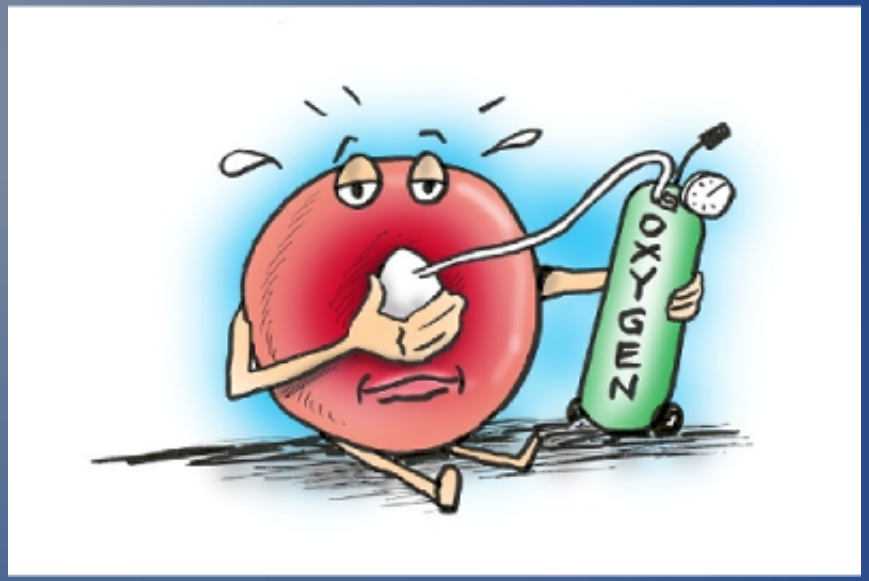
Autogravedad

Ignición estelar





¿Qué tipo de fuego?

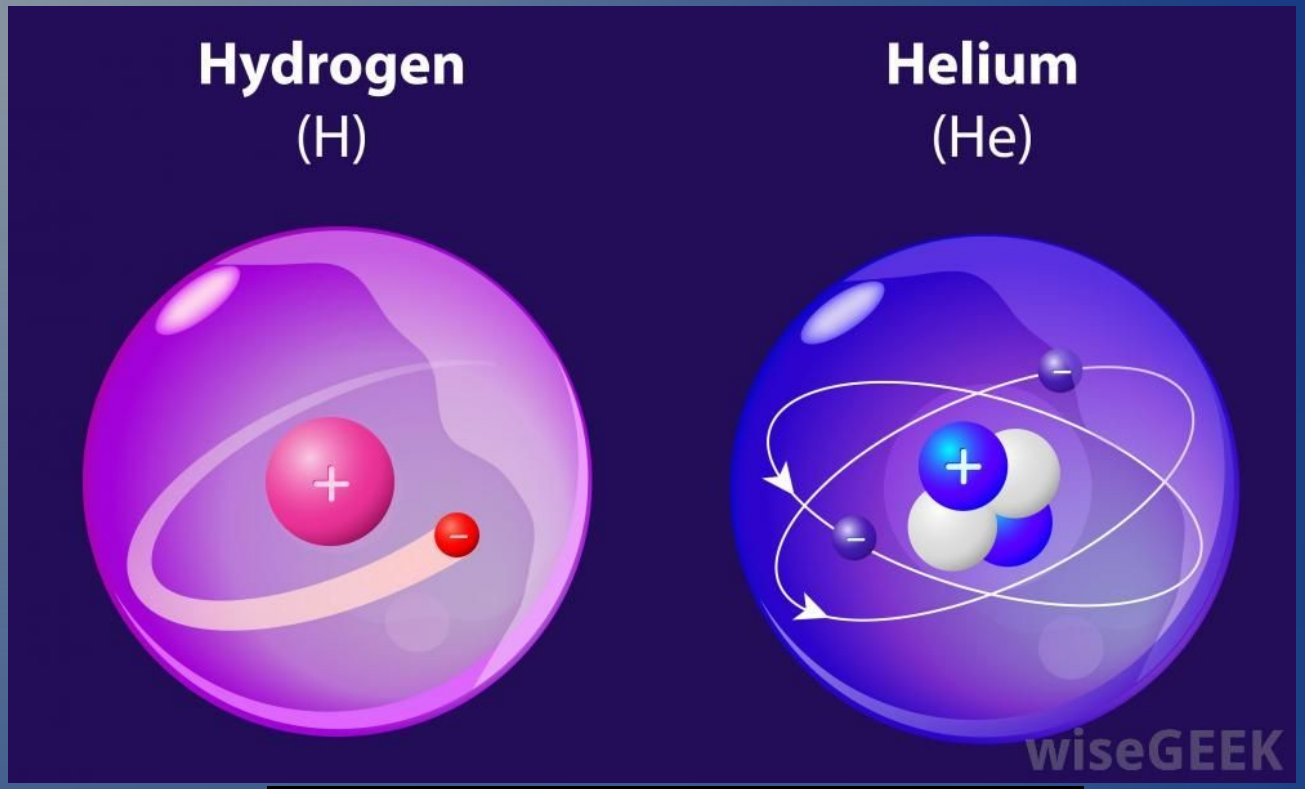


¿De dónde viene el oxígeno?
o ¿no hace falta?

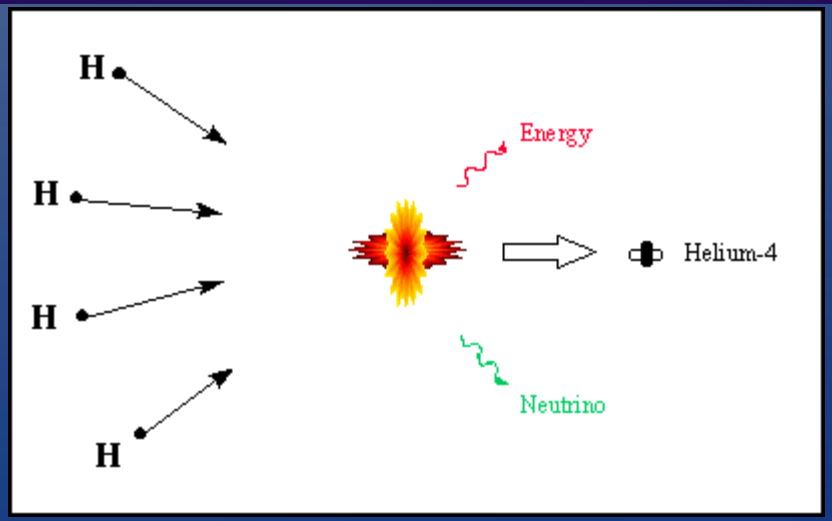
¿Qué tipo de fuego?

¿De dónde viene el oxígeno?
o ¿no hace falta?

“Fuego” → Fusión nuclear (1930)



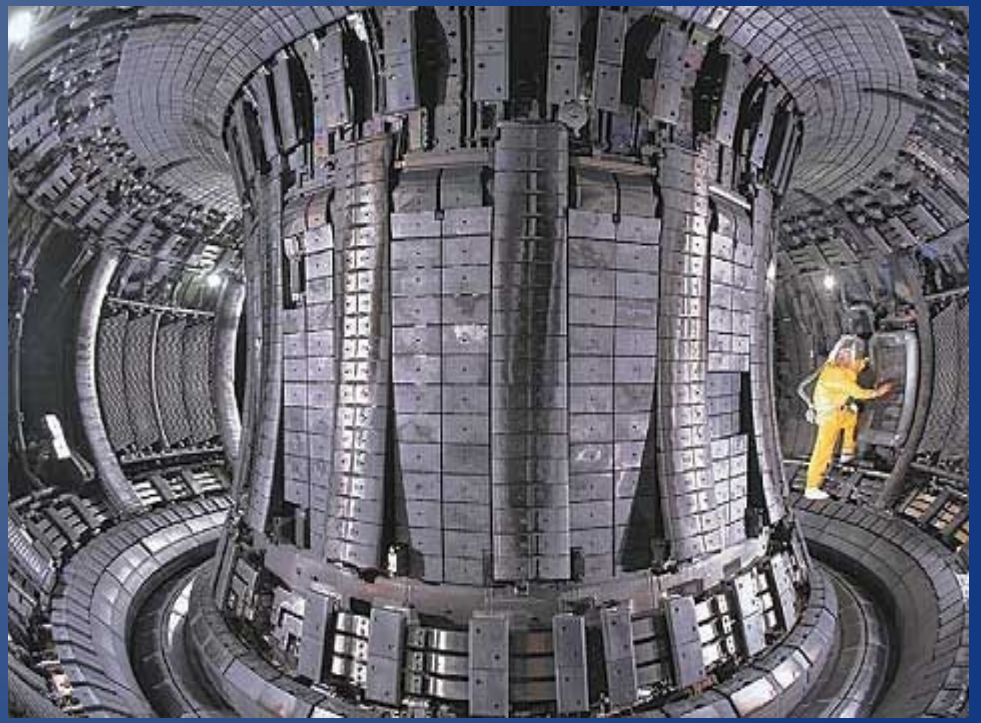
T~13MºC



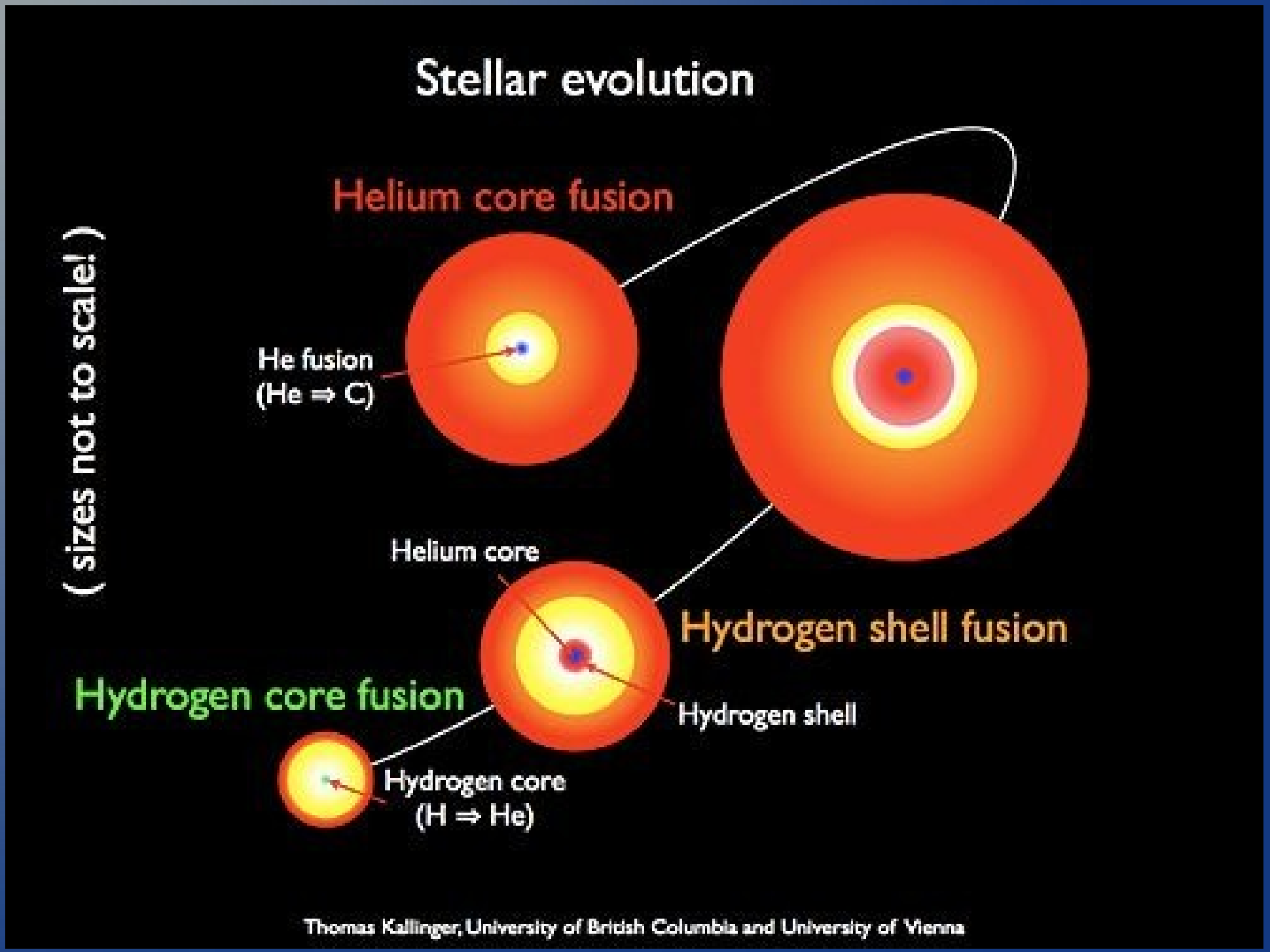
$E=mc^2$
(c=300 000 km/s)

Fusión nuclear

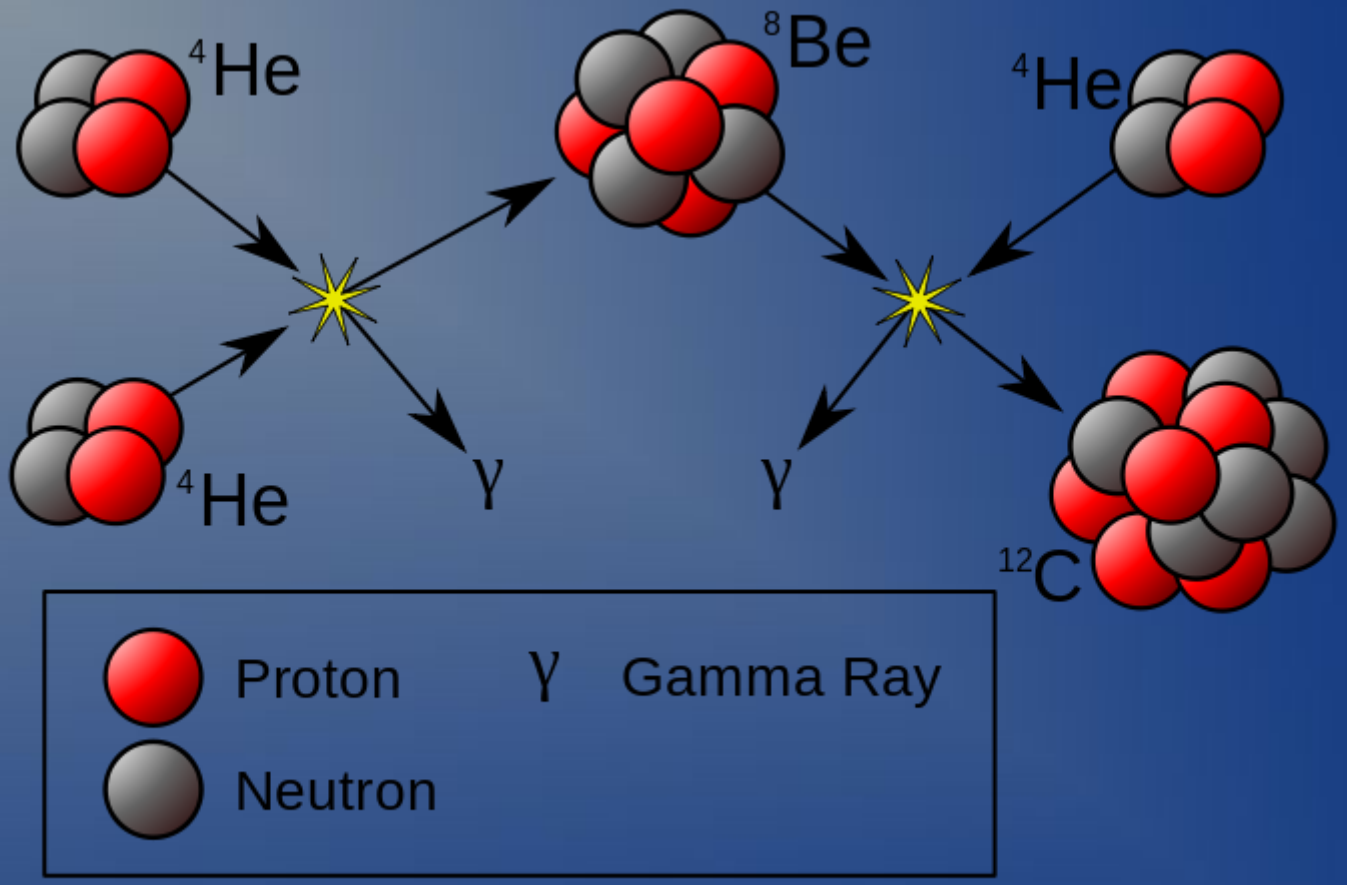
Bomba H



ITER


Stellar evolution
(sizes not to scale!)
Helium core fusion
He fusion
(He ⇒ C)
Helium core
Hydrogen shell fusion
Hydrogen shell
Hydrogen core fusion
Hydrogen core
(H ⇒ He)
Thomas Kallinger, University of British Columbia and University of Vienna

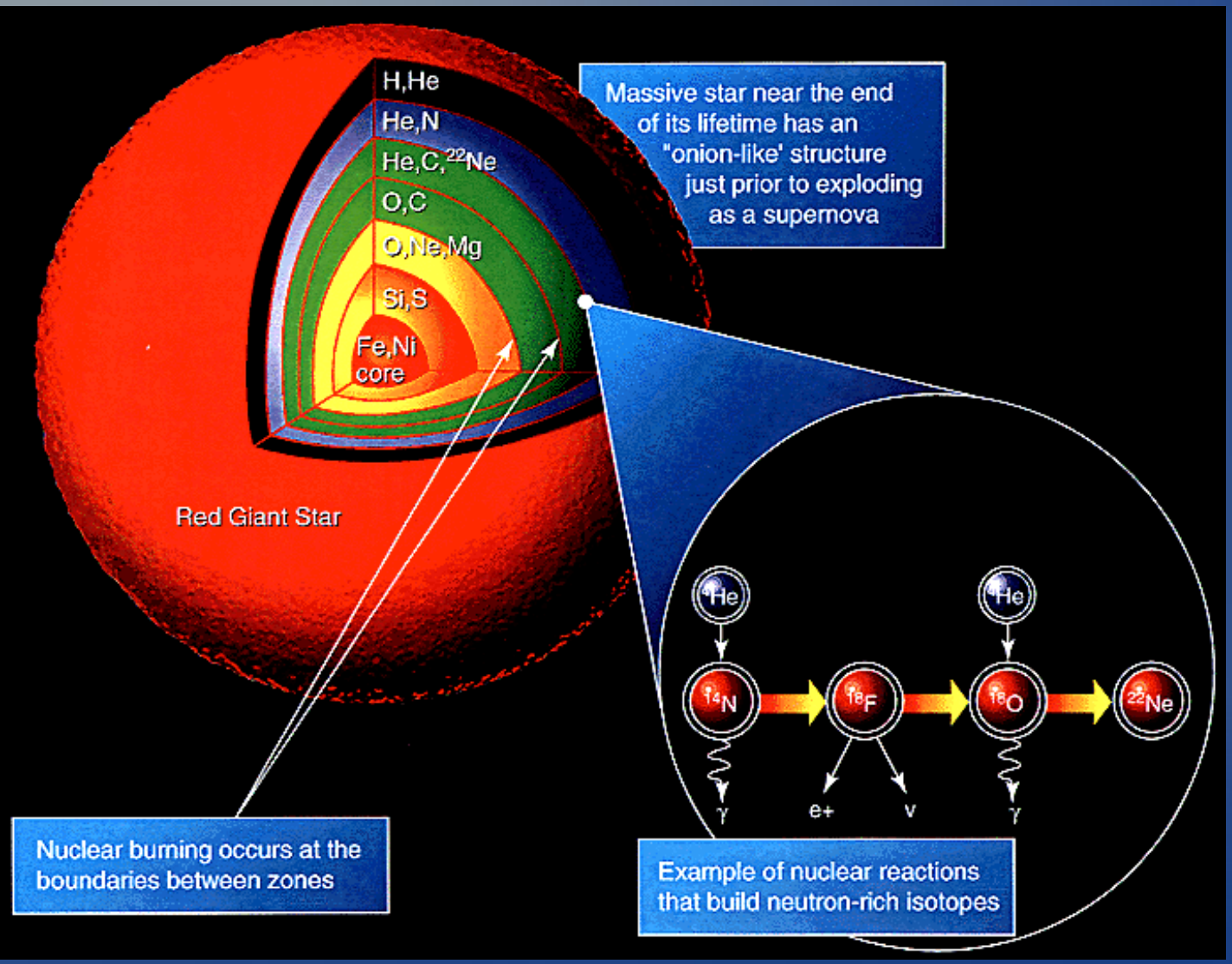
Fusión de Helio

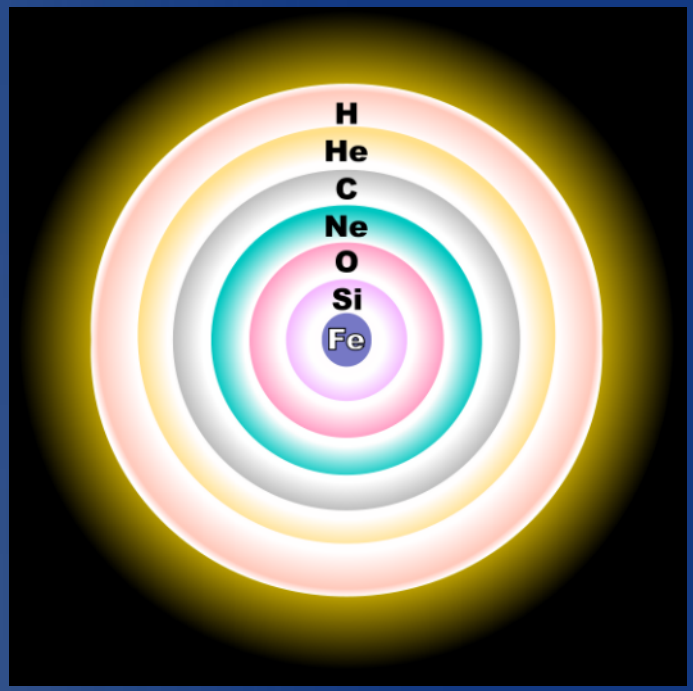


"Triple Alfa"

Requiere una T incluso mucho mayor (~100MºC)

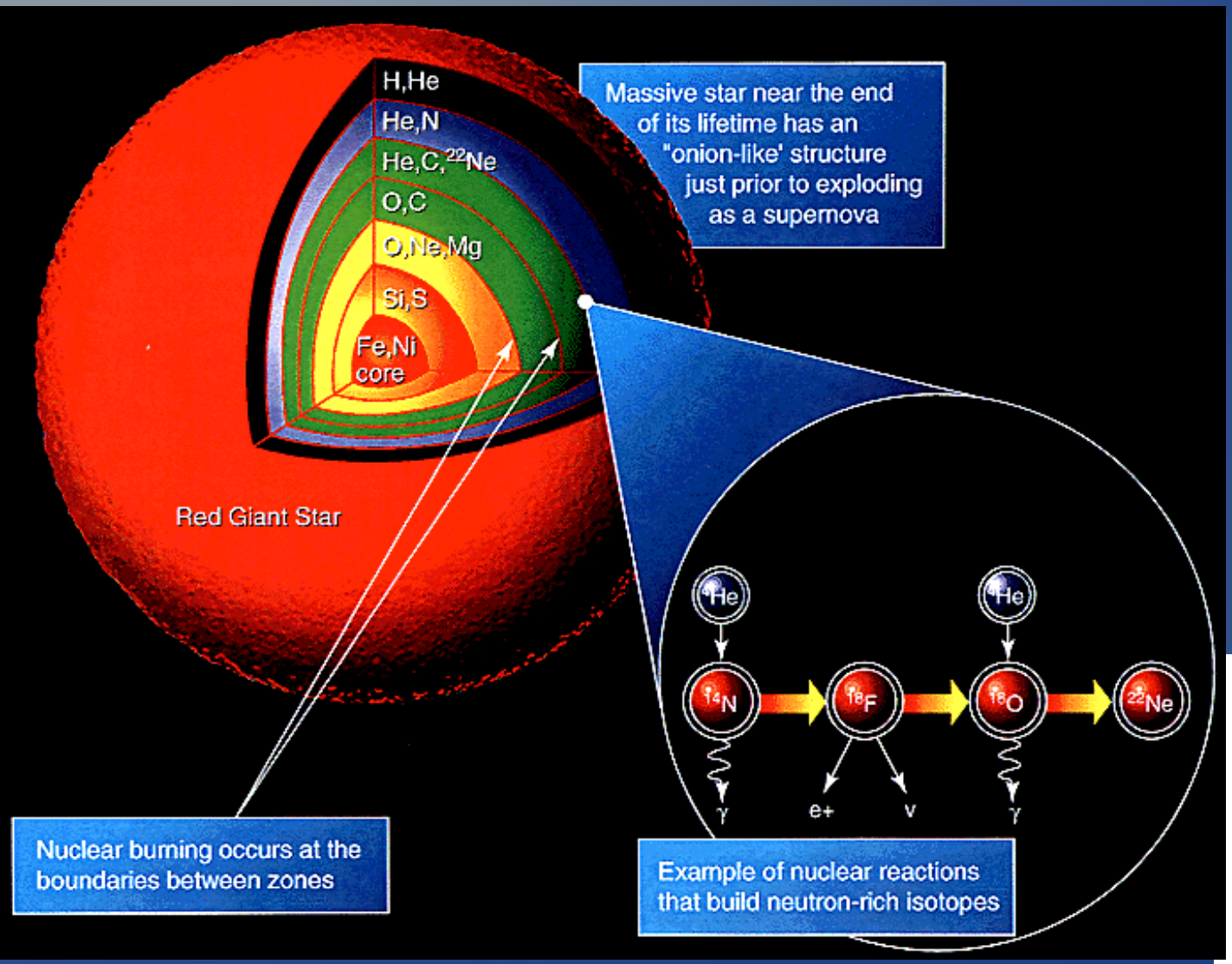
Etcétera

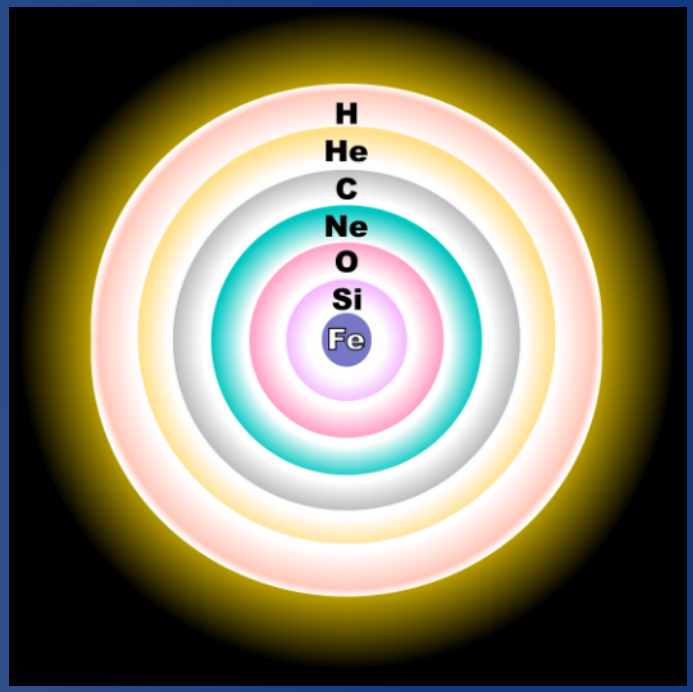




Cada paso requiere T mayor (Si → Fe: ~3x10^9 ºC)

Etcétera

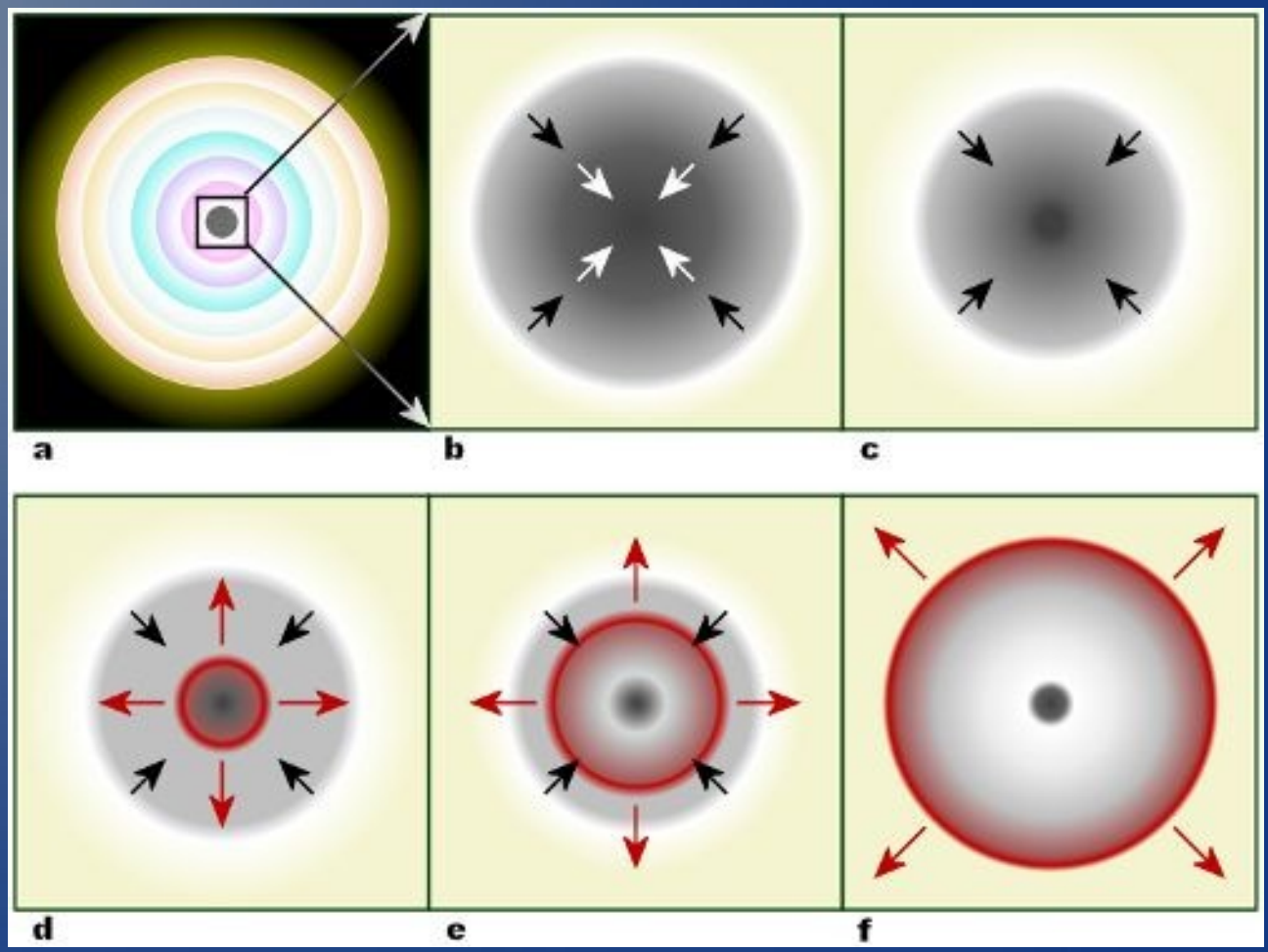




Cada paso requiere T mayor

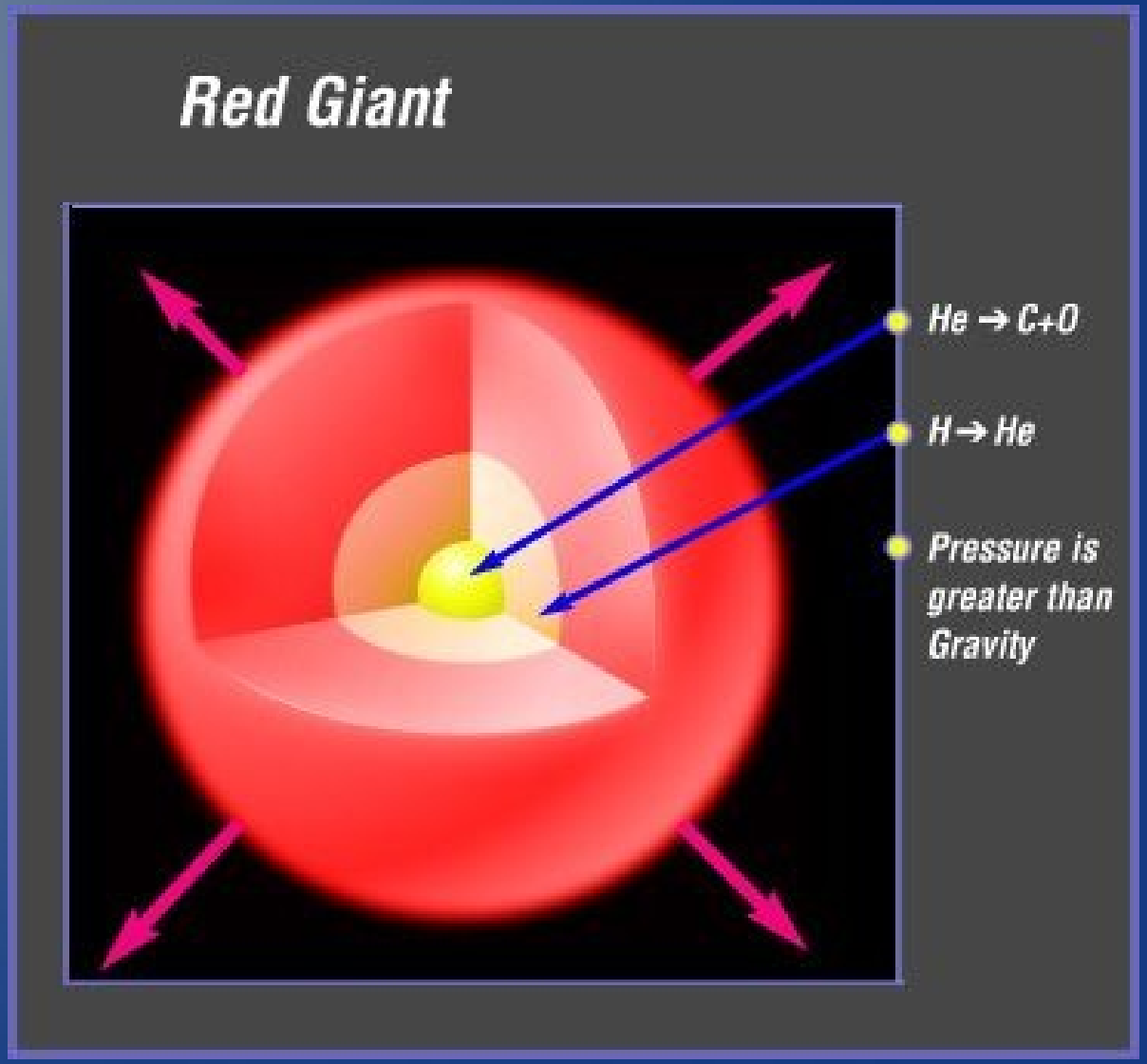
Entre etapas:
colapso parcial + expansión

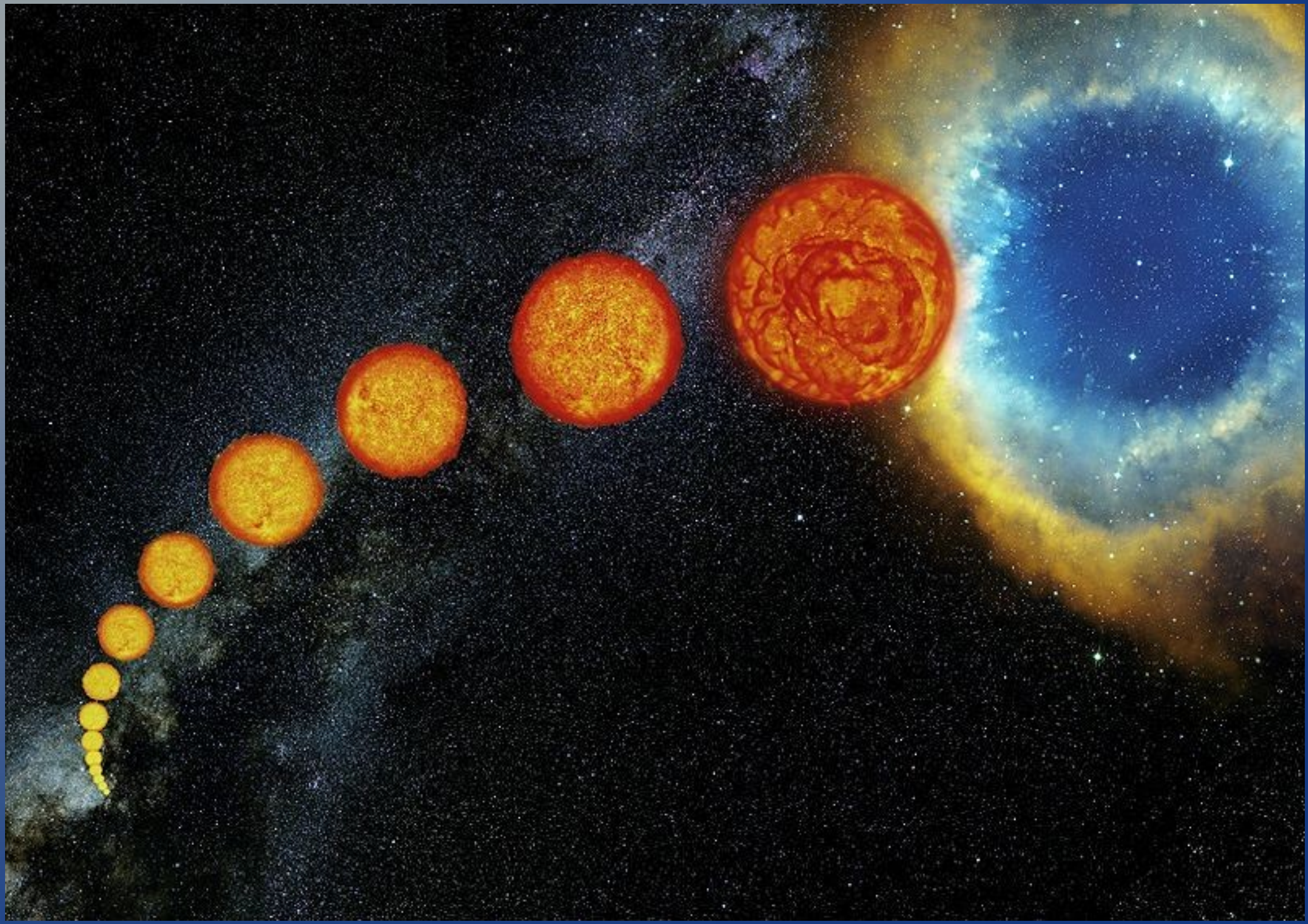
Equilibrio

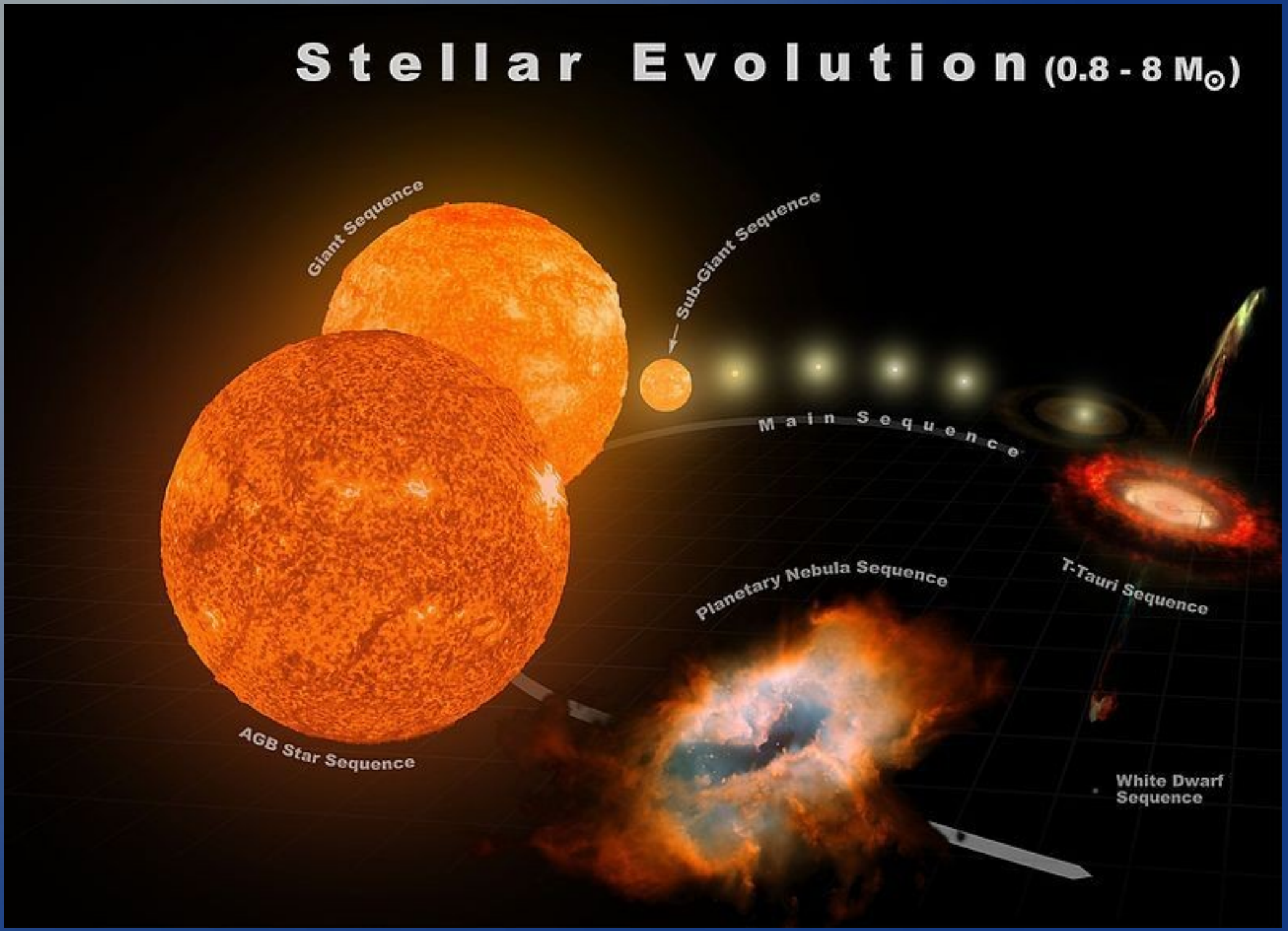


Entre etapas:
colapso parcial + expansión

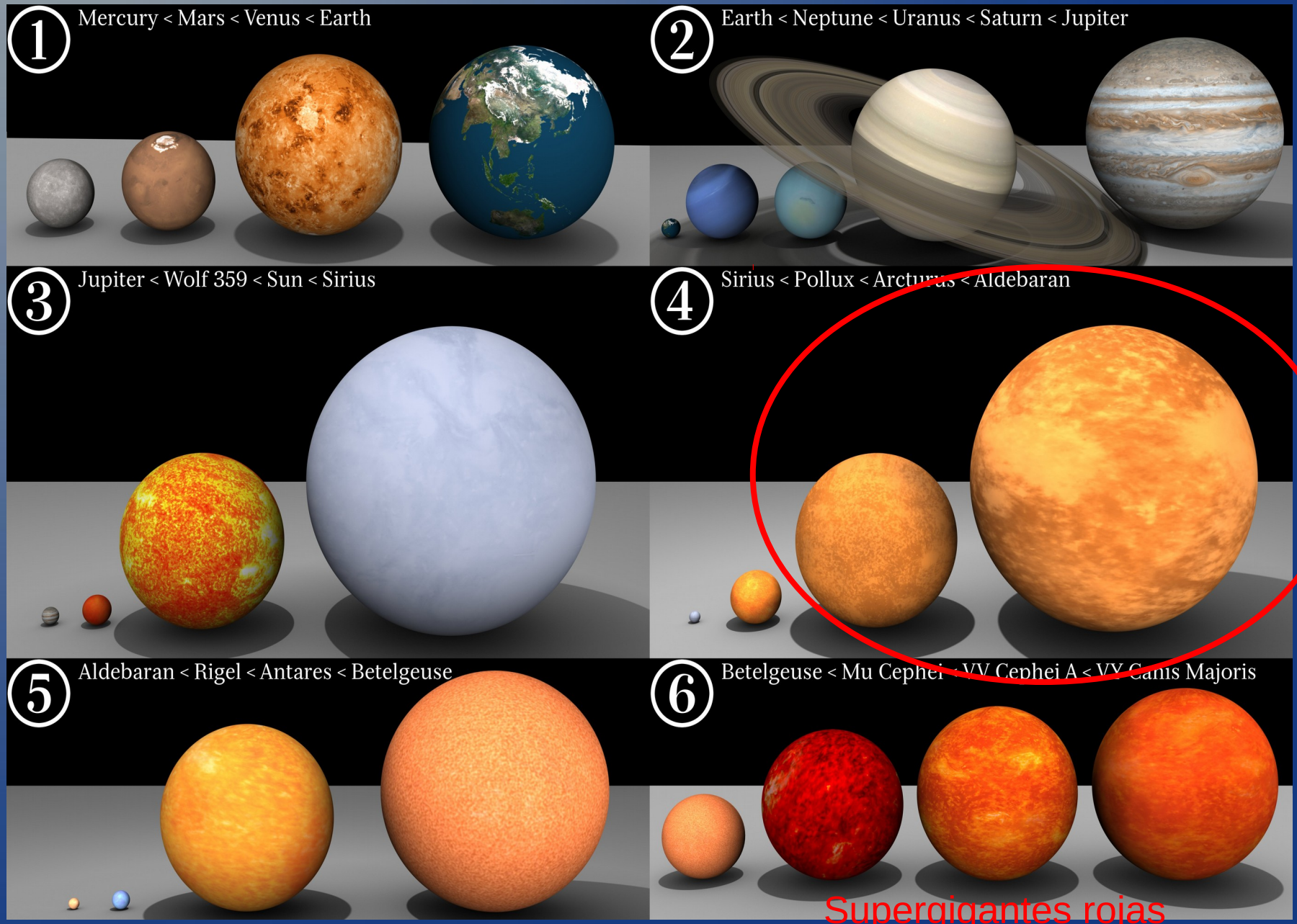
Equilibrio



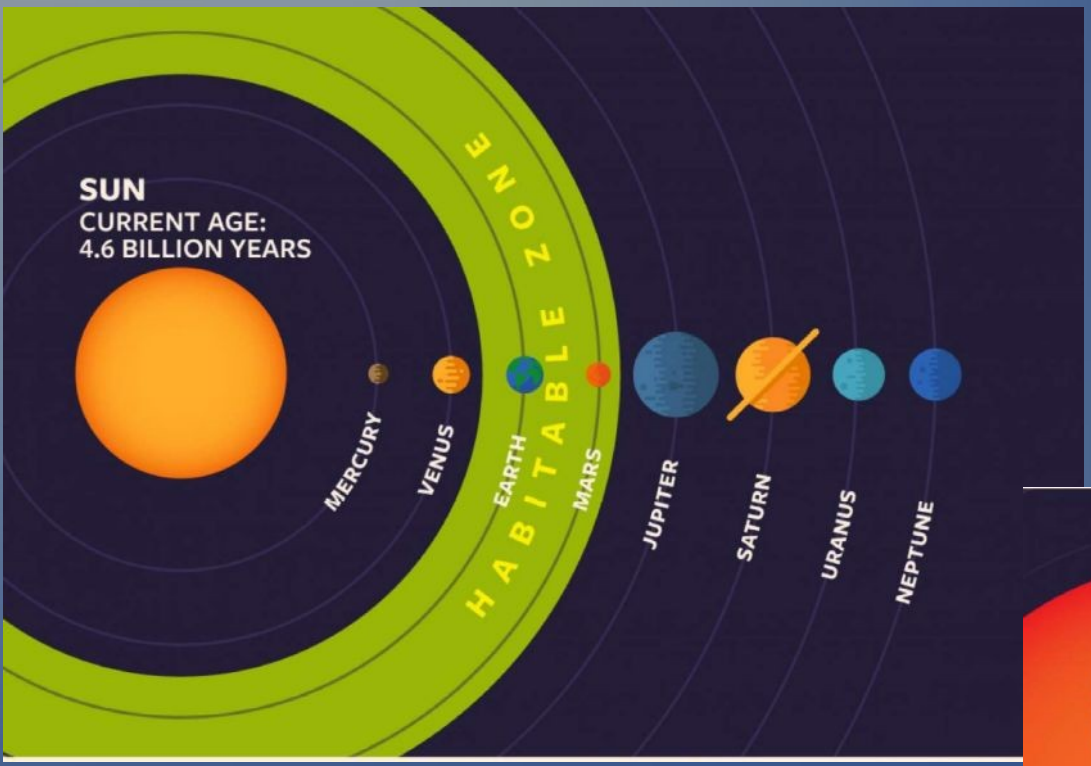


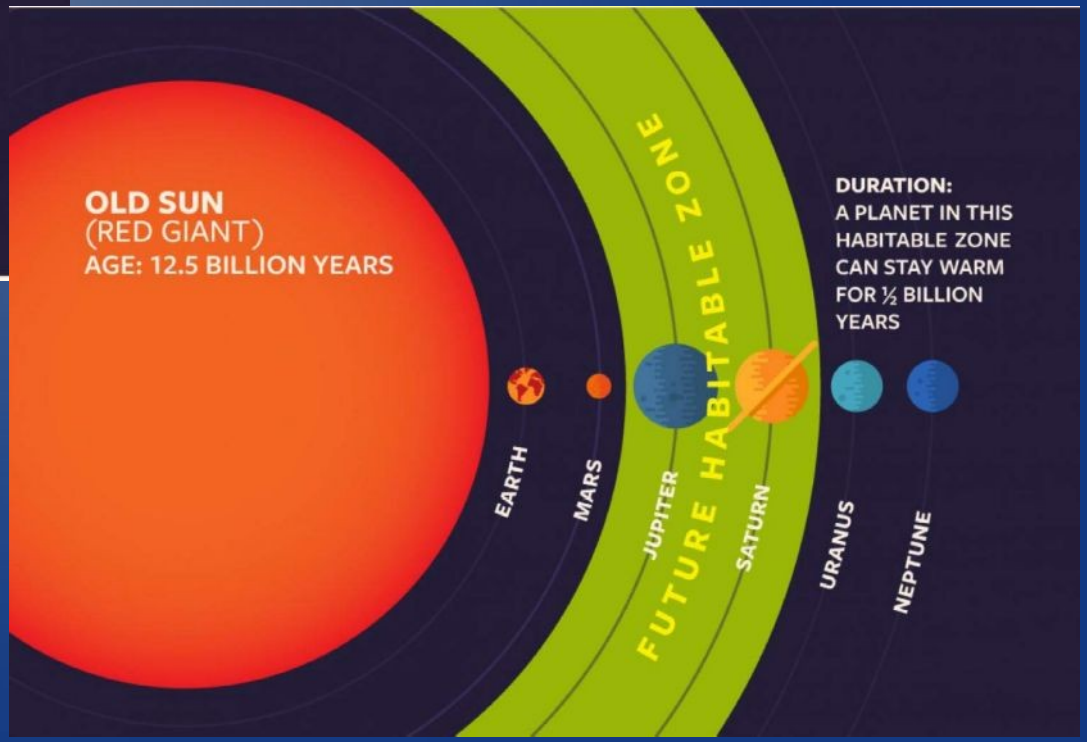

Stellar Evolution (0.8 - 8 M⊙)
Giant Sequence
Sub-Giant Sequence
Main Sequence
T-Tauri Sequence
Planetary Nebula Sequence
AGB Star Sequence
White Dwarf Sequence

¿“Gigantes” rojas?

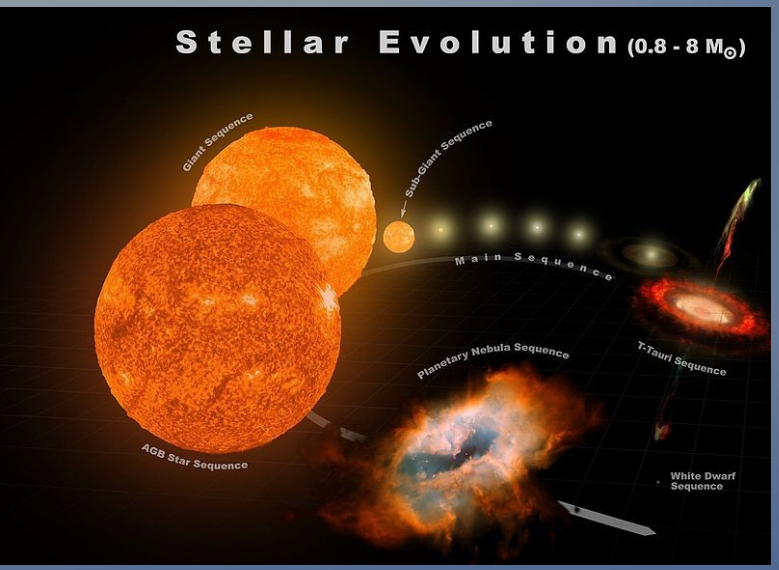


El sol como gigante roja



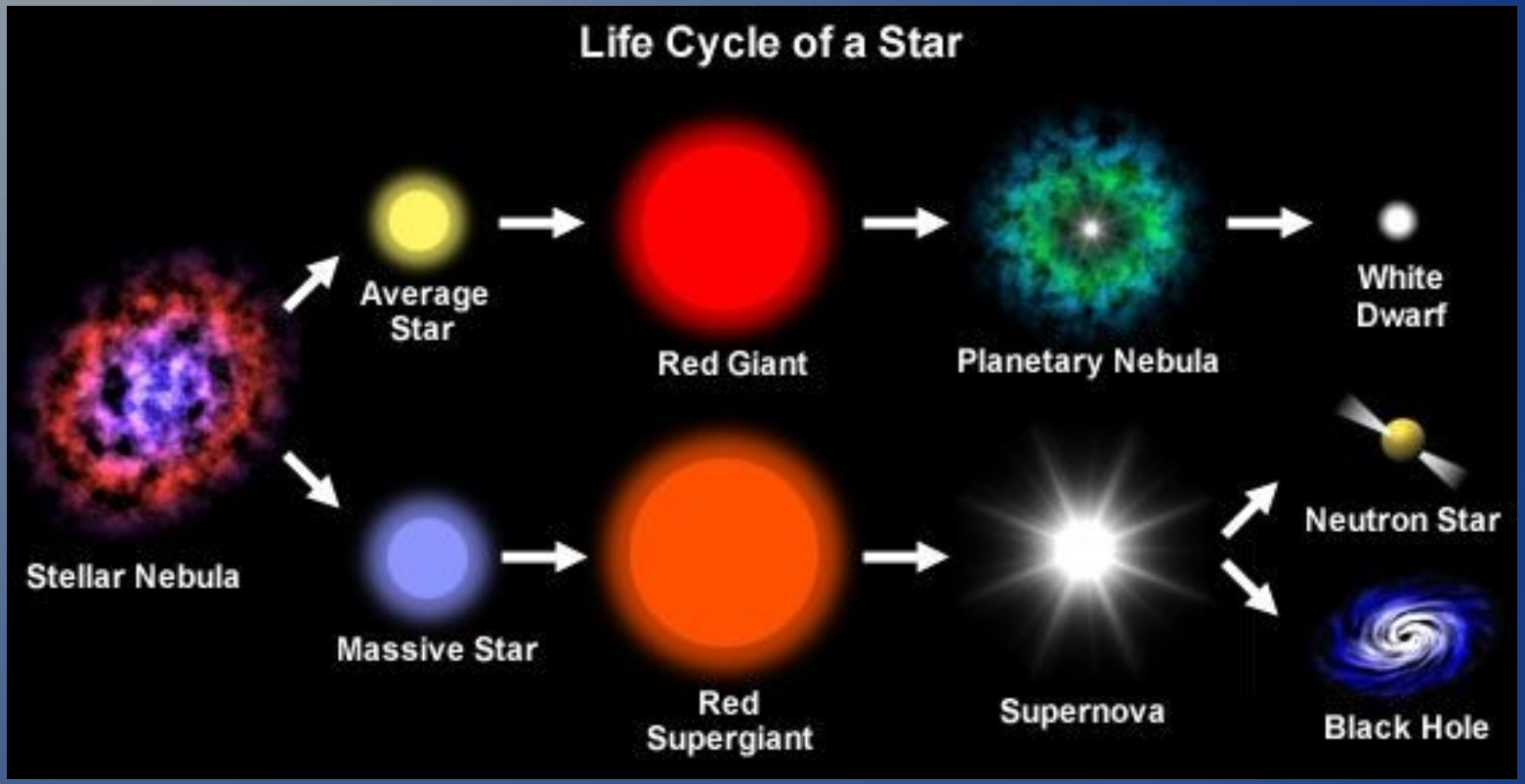


Nebulosa “planetaria” (1780)



“Ojo de gato”

¿Todas las estrellas terminan así?



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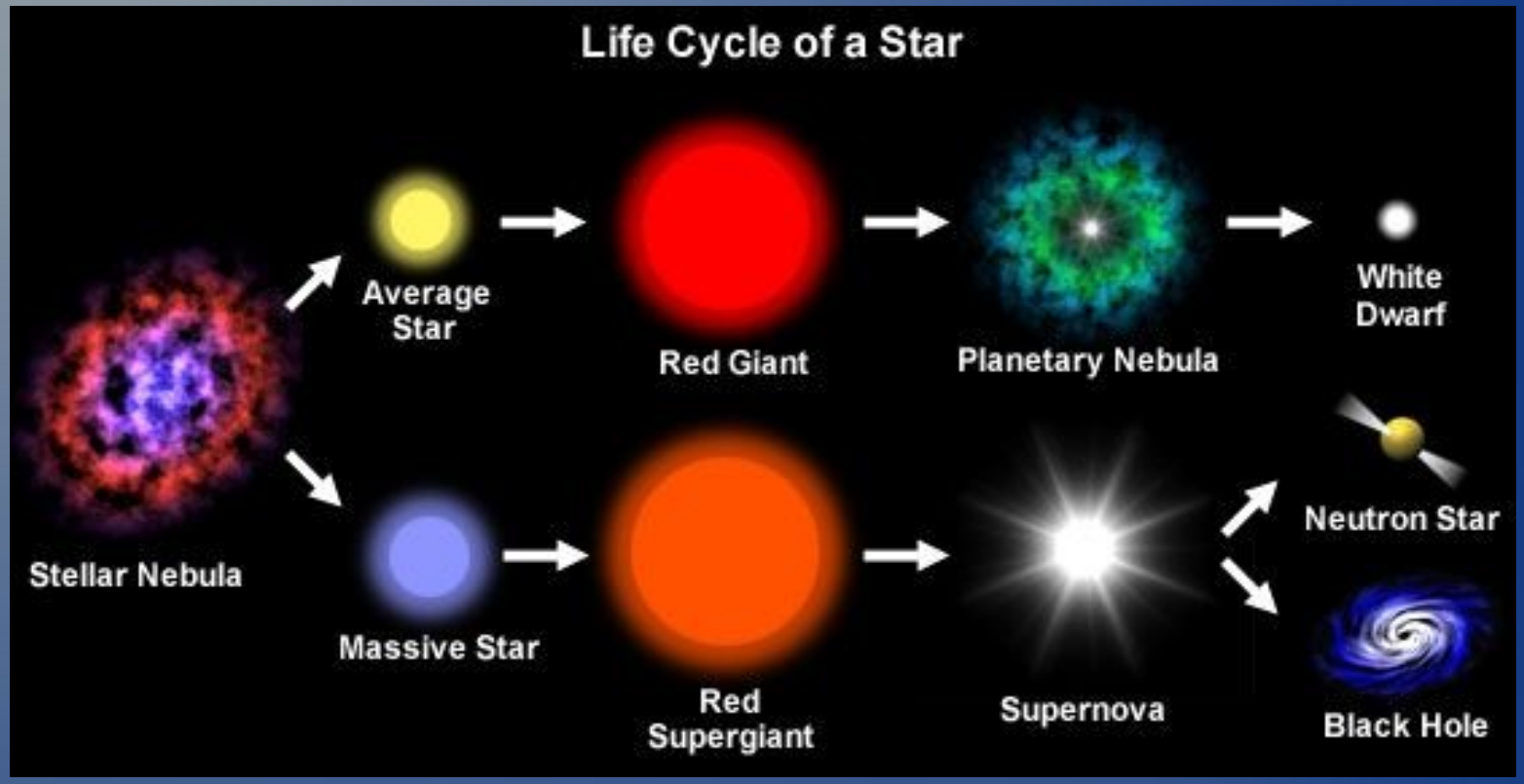

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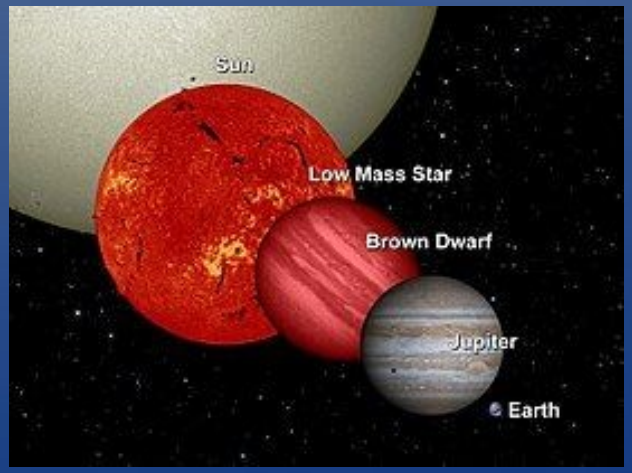
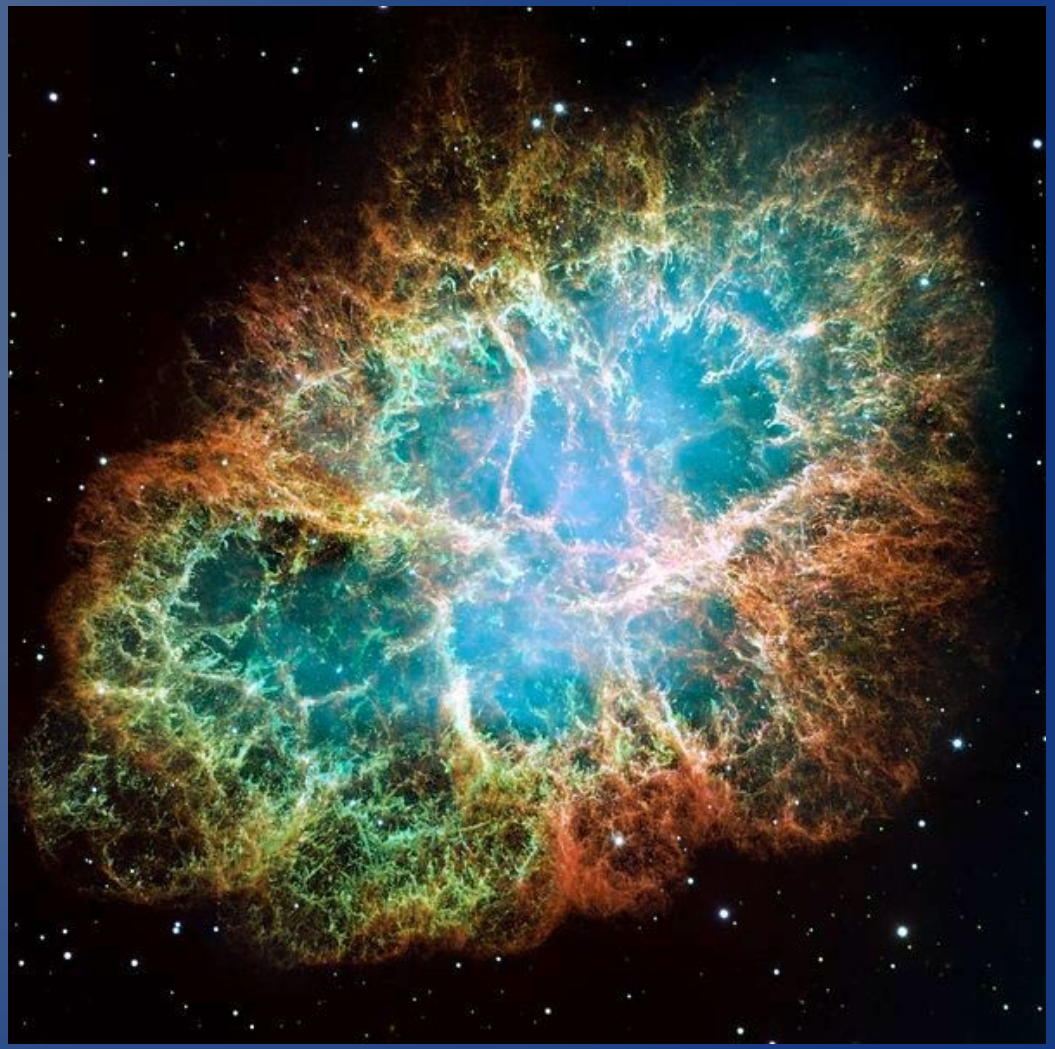


(IAC 1995)

Supernova

Luminosidad > galaxia



“Nebulosa del Cangrejo”
(resto de SN1054)

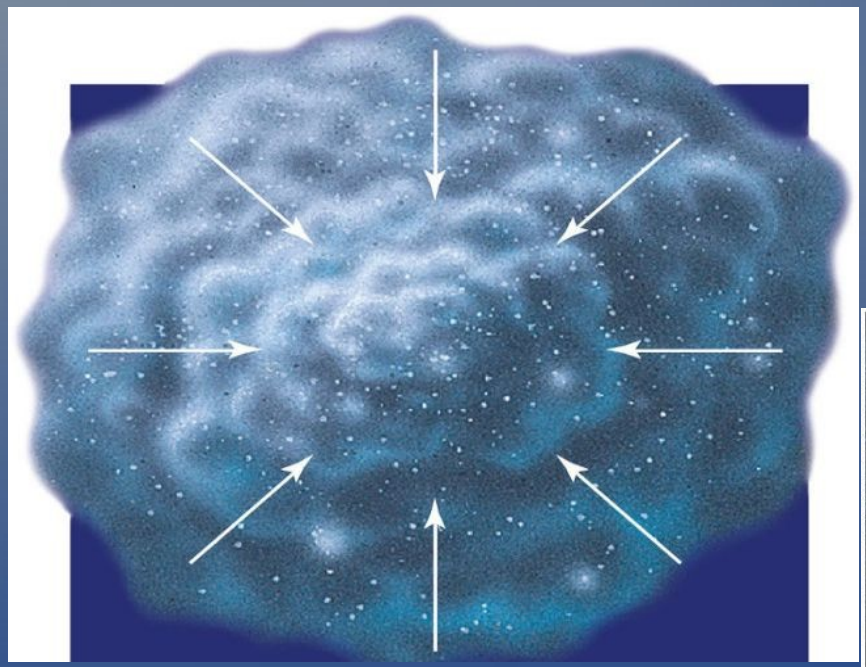
Luminosidad > galax

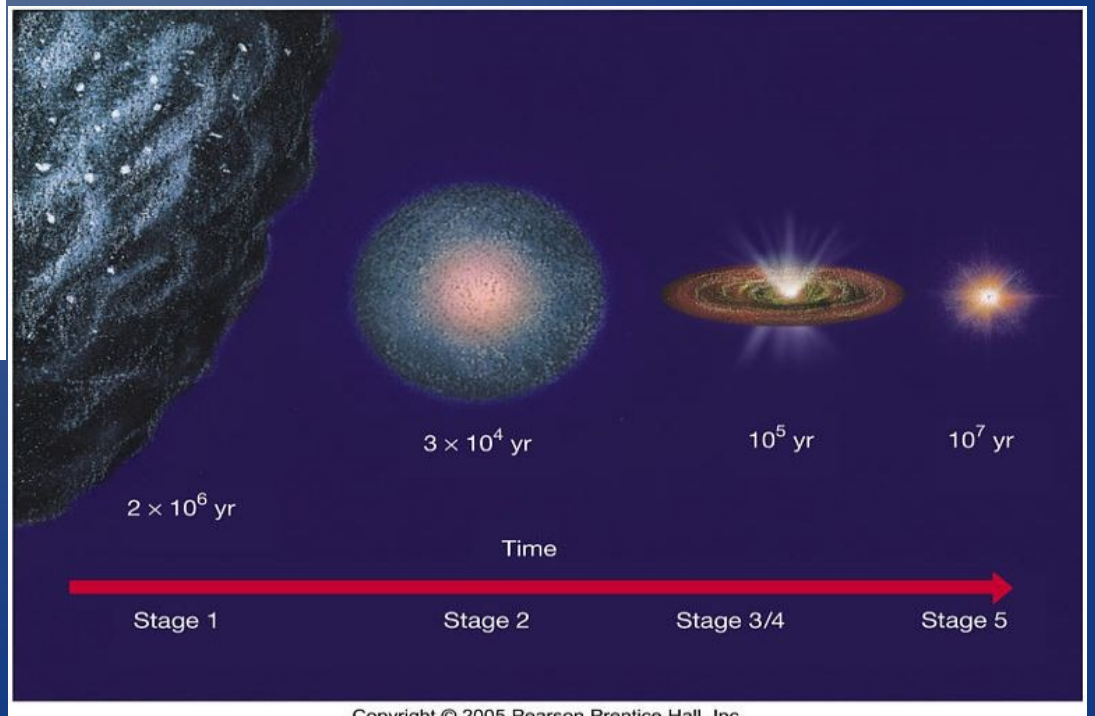
“Nebulosa del Cangrejo”
(resto de SN1054)

Y empezamos de nuevo...

Y empezamos de nuevo...

NUBES COLAPSAN (autogravedad)





Etcétera...

“Sol = estrella de 3ª generación”

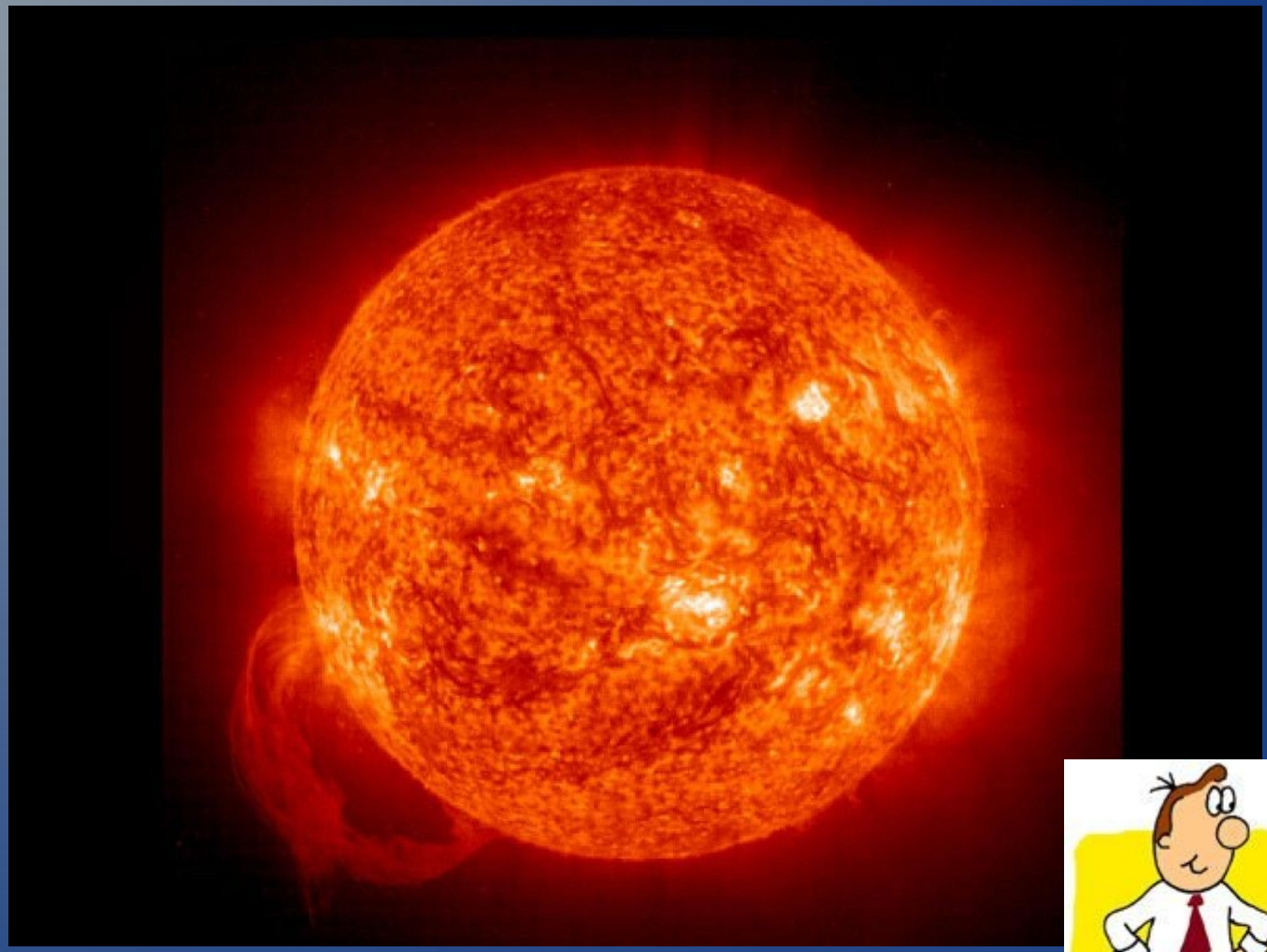
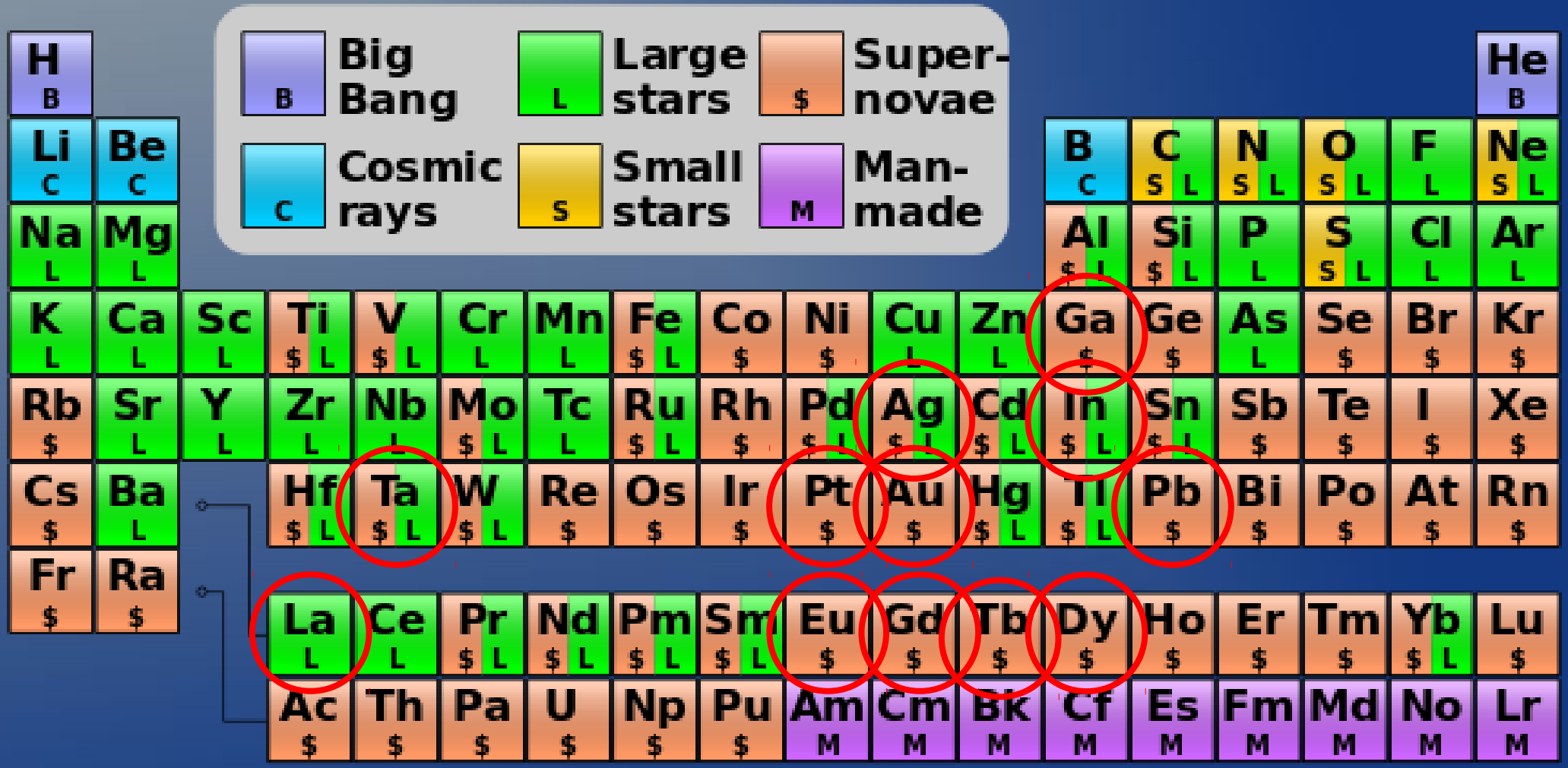


Tabla periódica

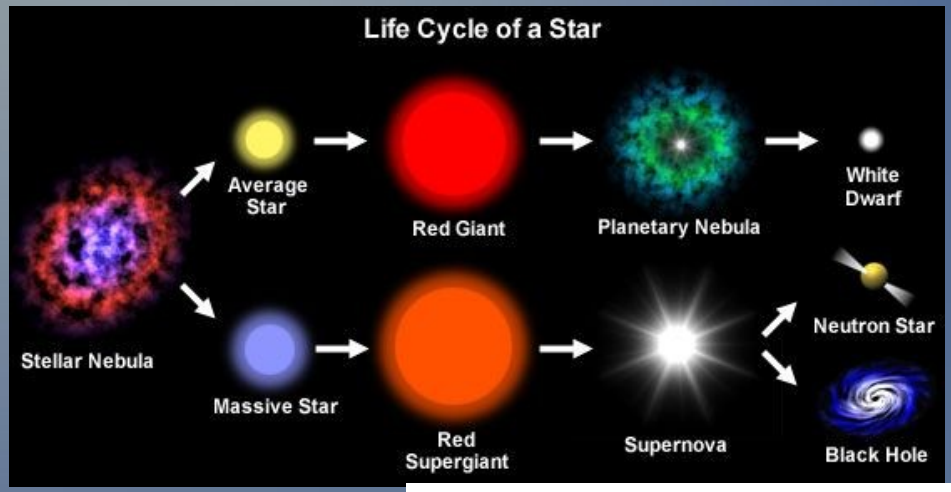


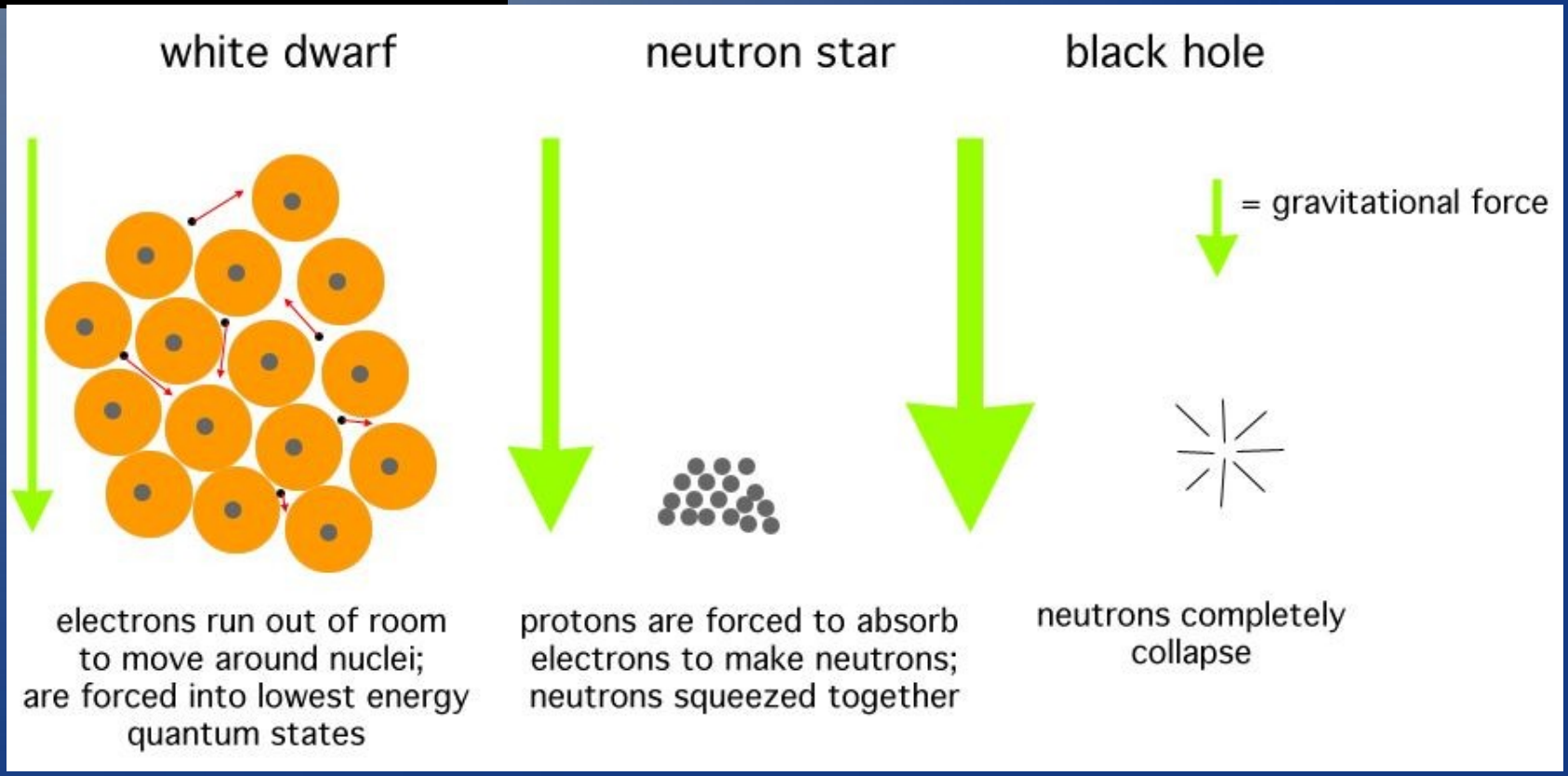
...

Tabla periódica

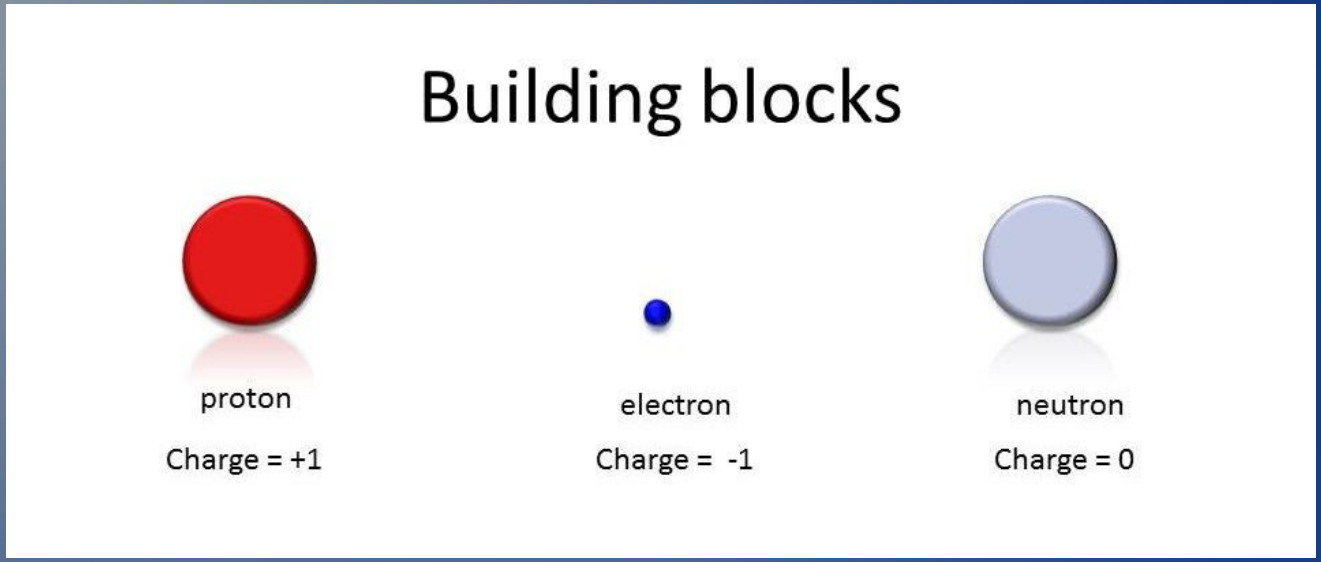
...

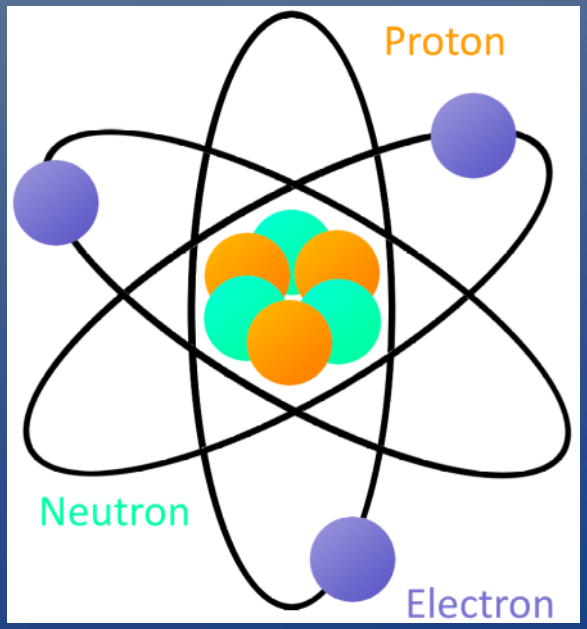
¿Qué queda de la estrella original?



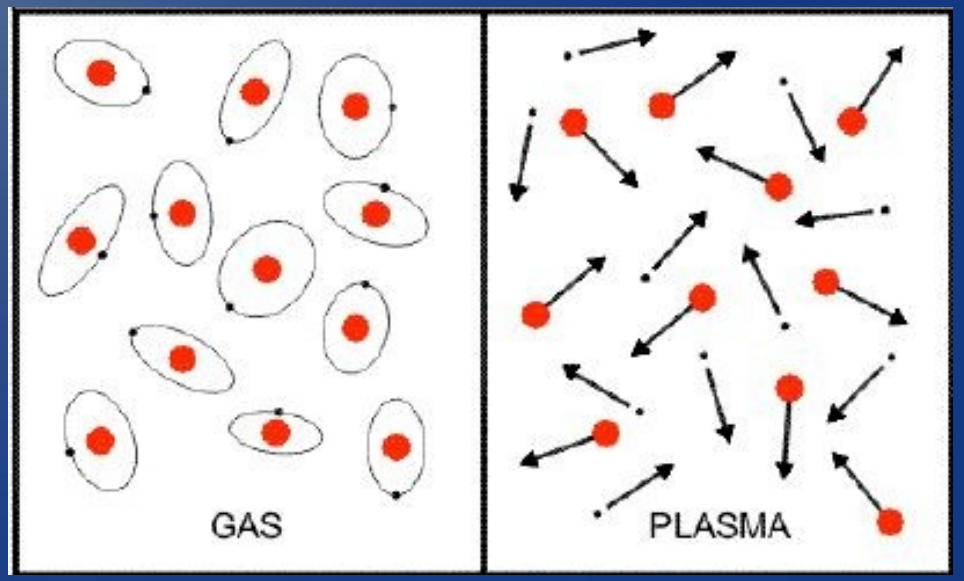


Constituyentes



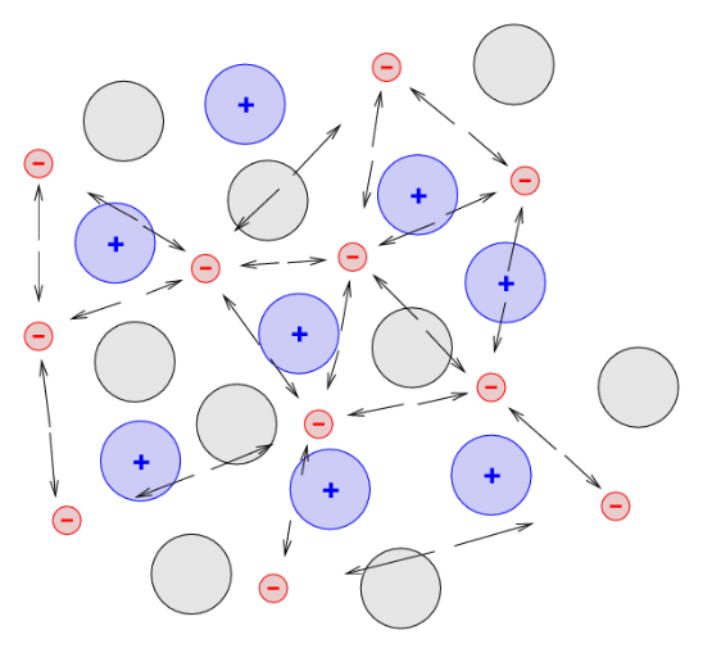


Materia “normal”

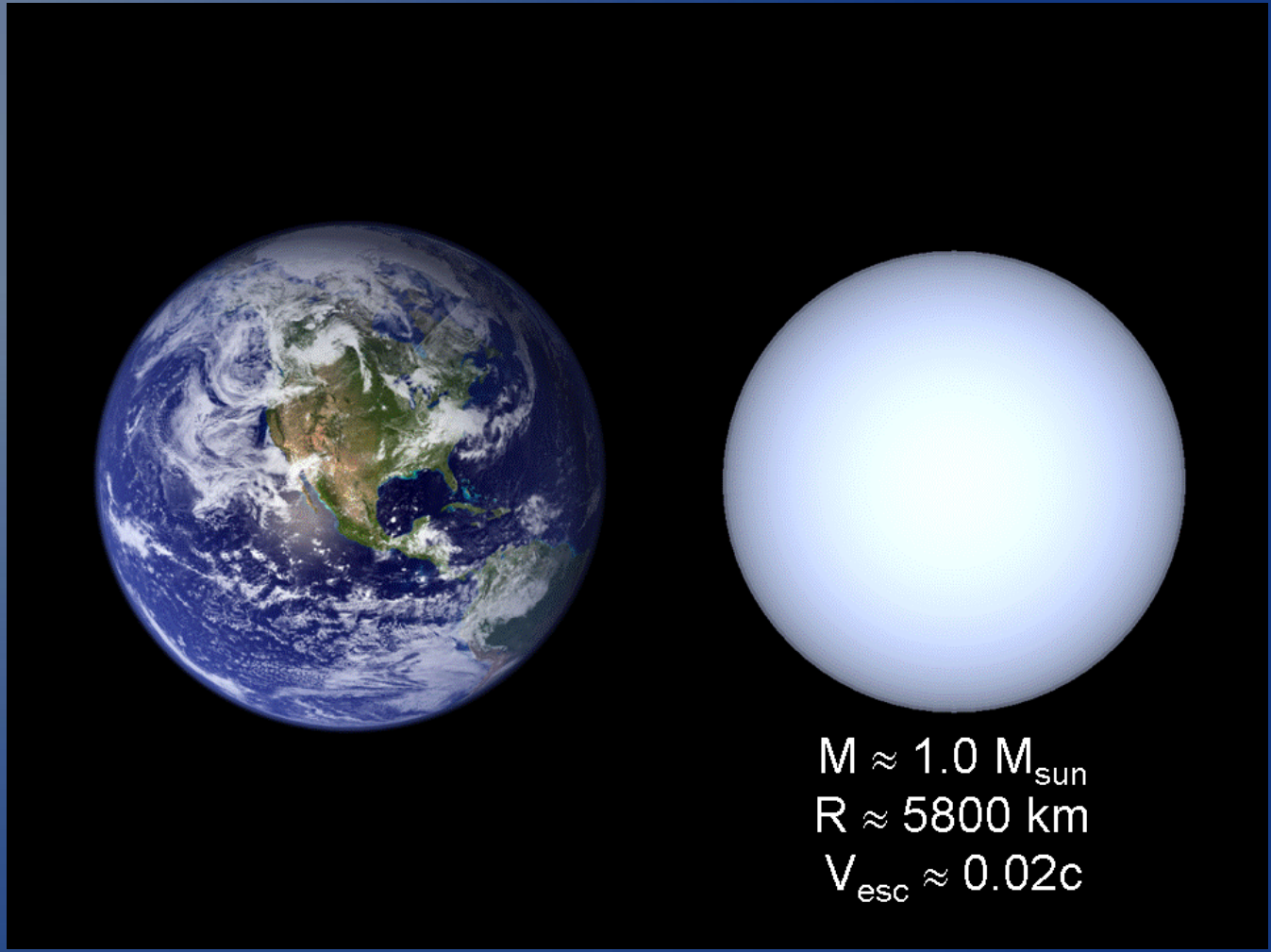


Plasma: e^- libres

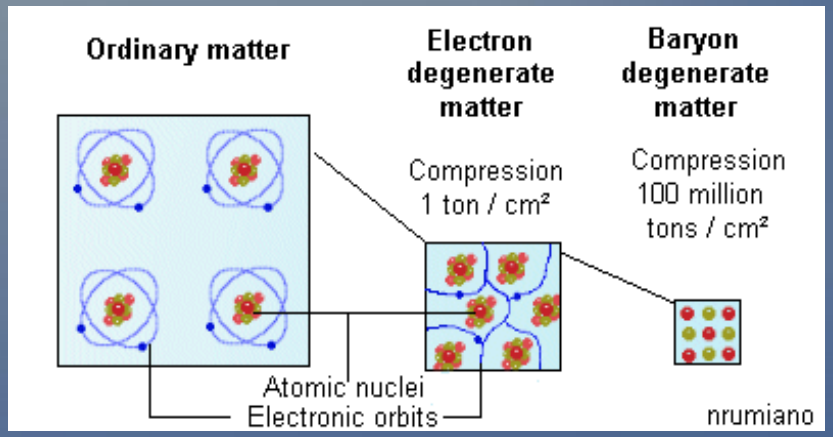
Enanas blancas



Presión de degeneración electrónica
(presión cuántica)



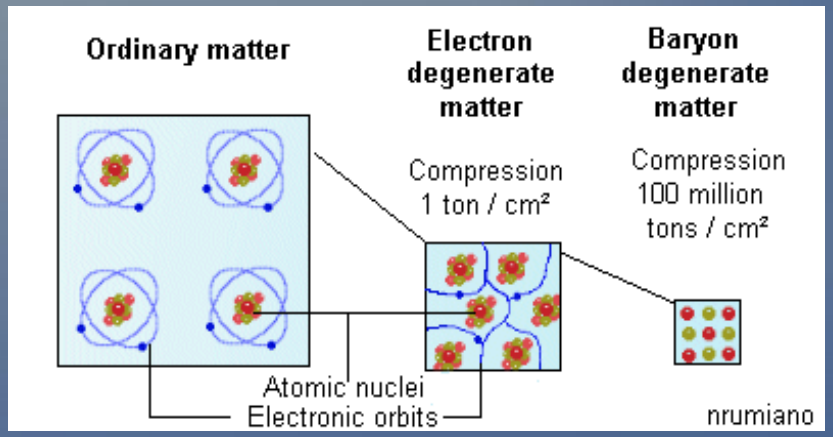
Estrella de neutrones



$$p + e^- \rightarrow n + \nu_e$$

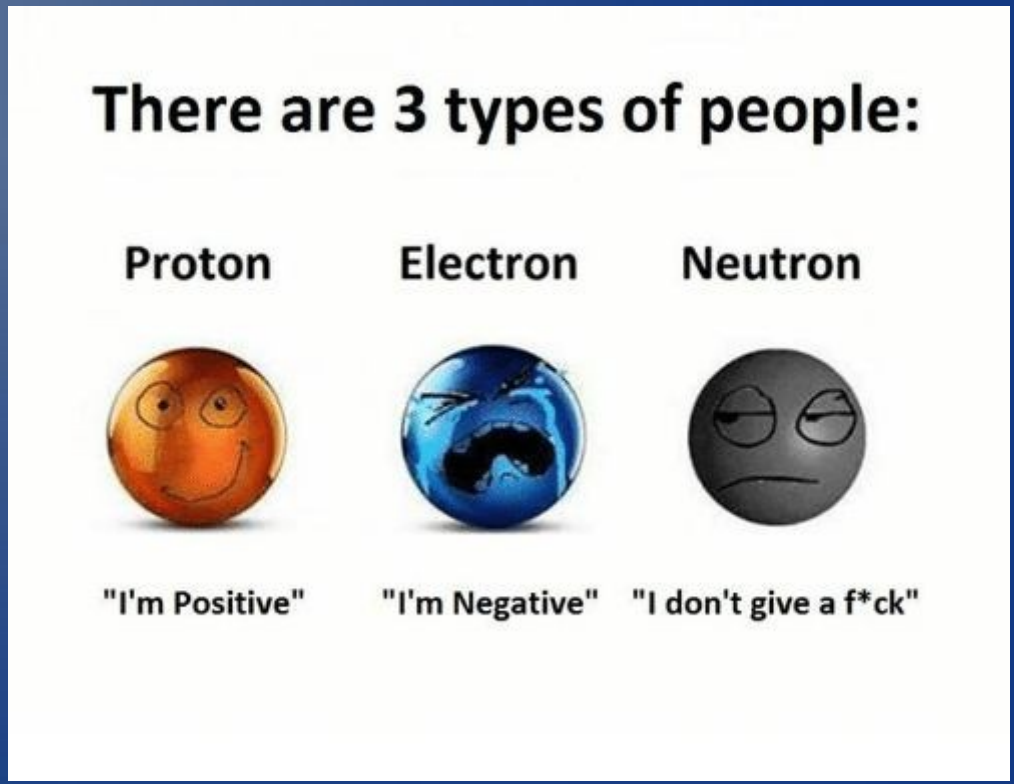
Presión de degeneración de neutrones

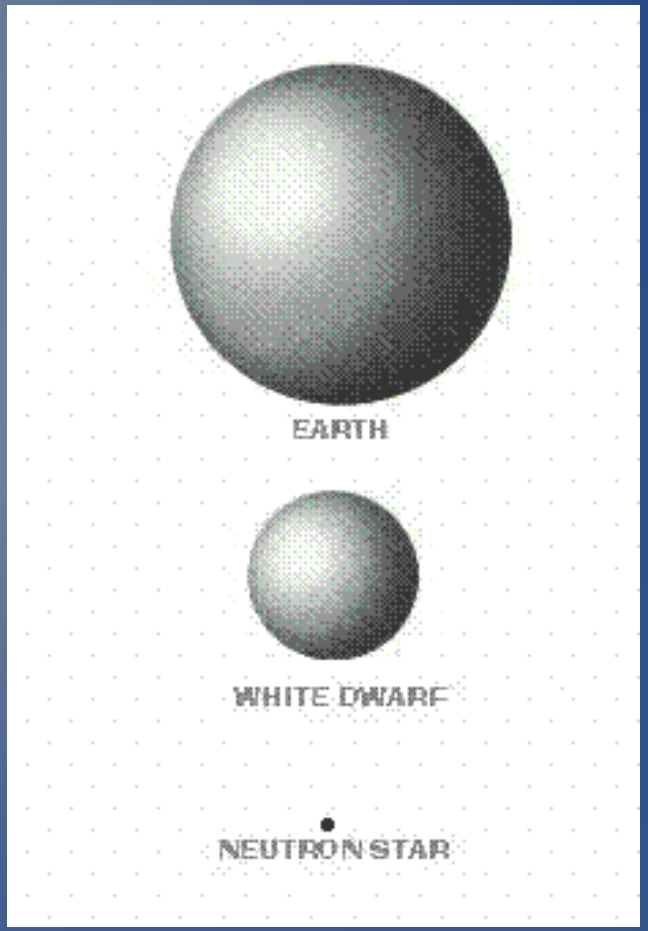
Estrella de neutrones



Presión de degeneración de neutrones

$$p + e^- \rightarrow n + \nu_e$$



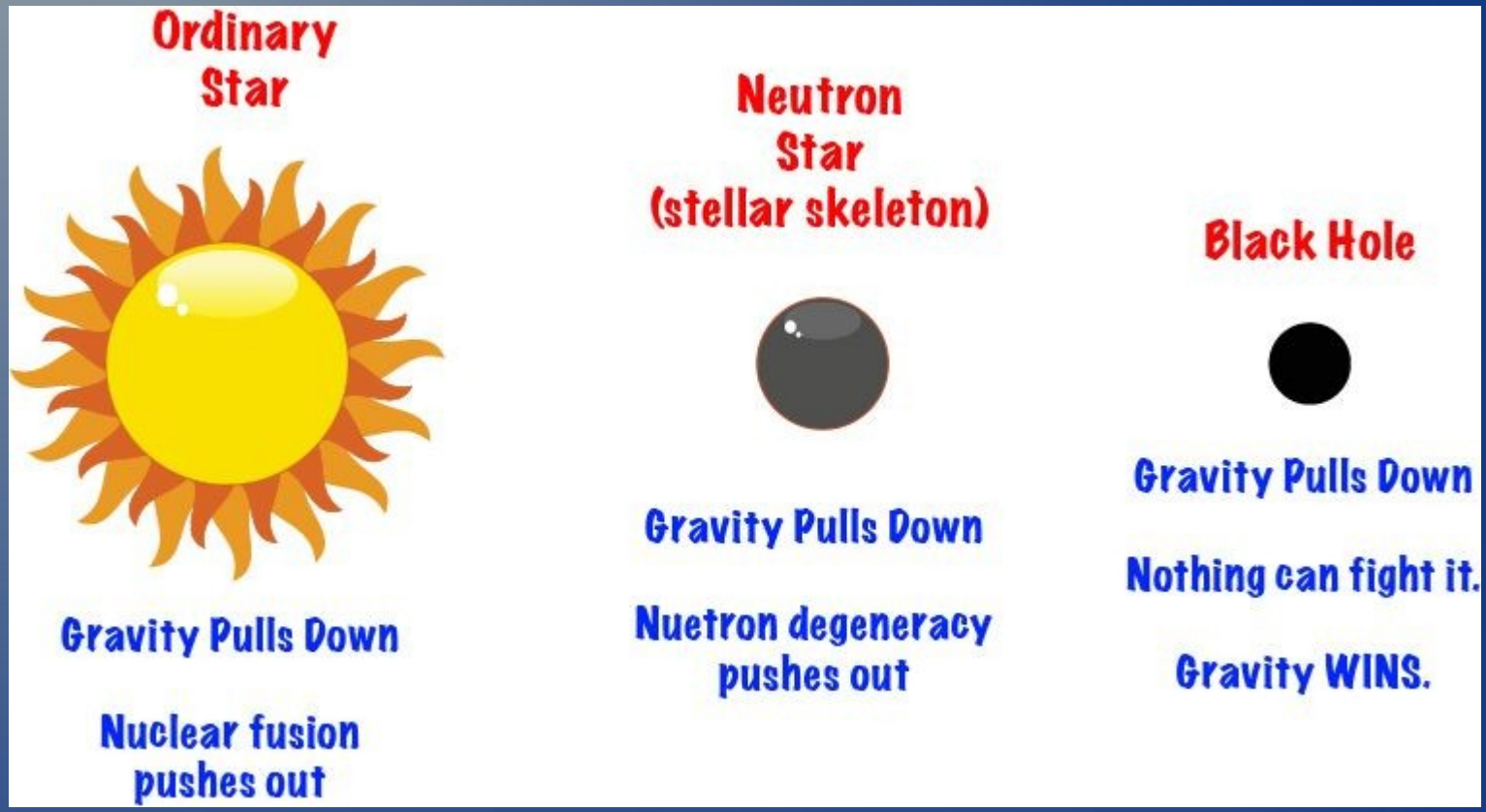


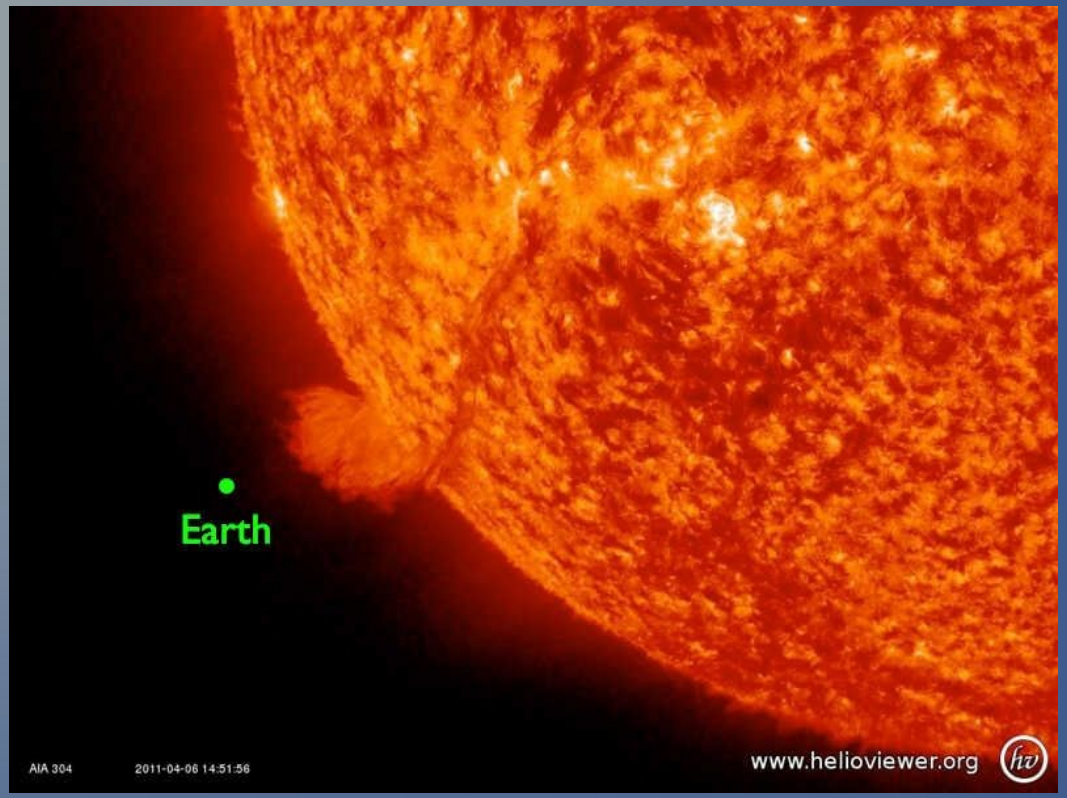
TIERRA: d=12.000 km

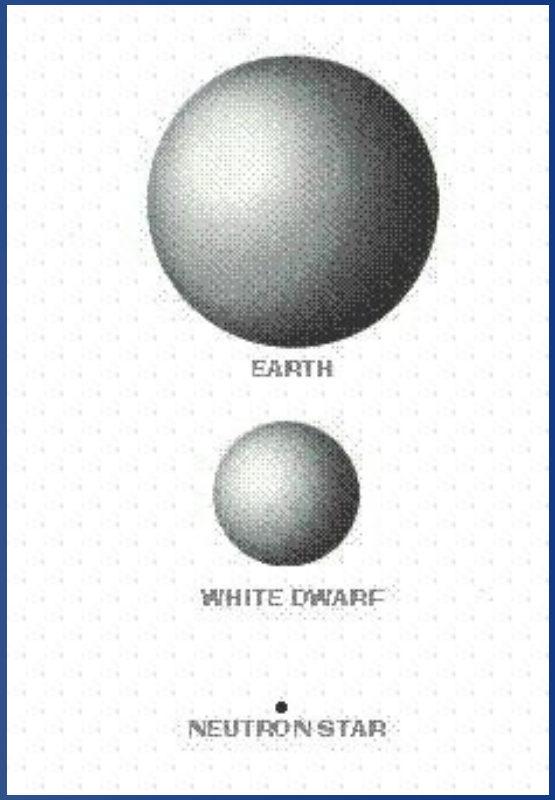
ENANA BLANCA: d=10.000 – 15.000 km

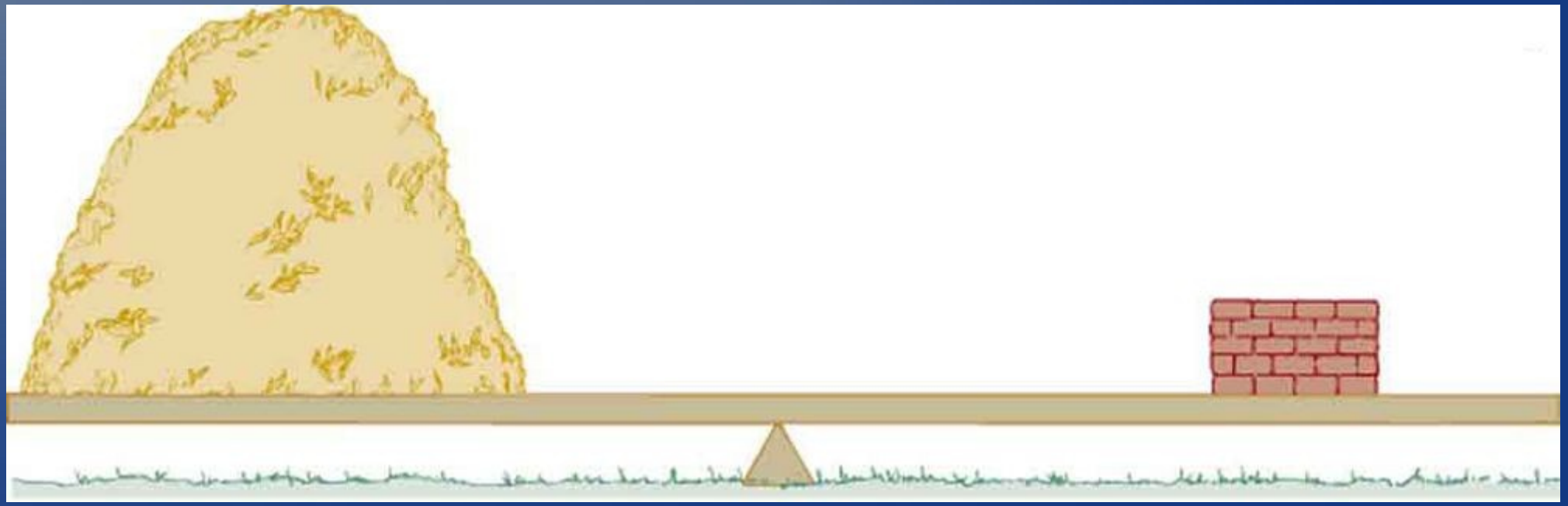
ESTRELLA DE NEUTRONES: 20 km

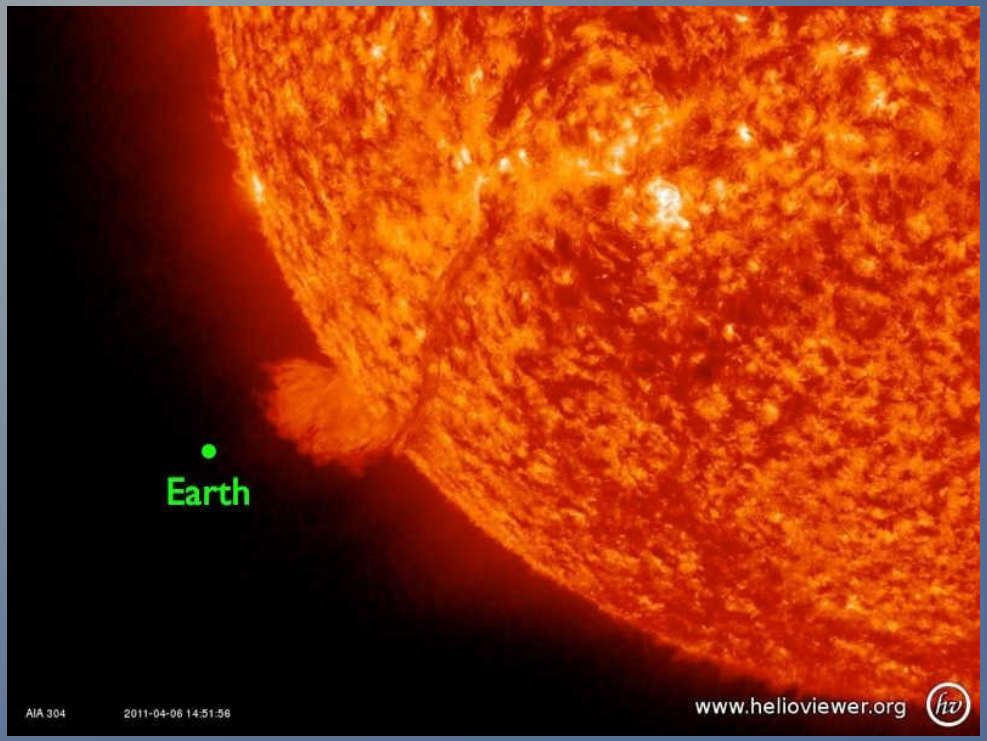
Agujero negro

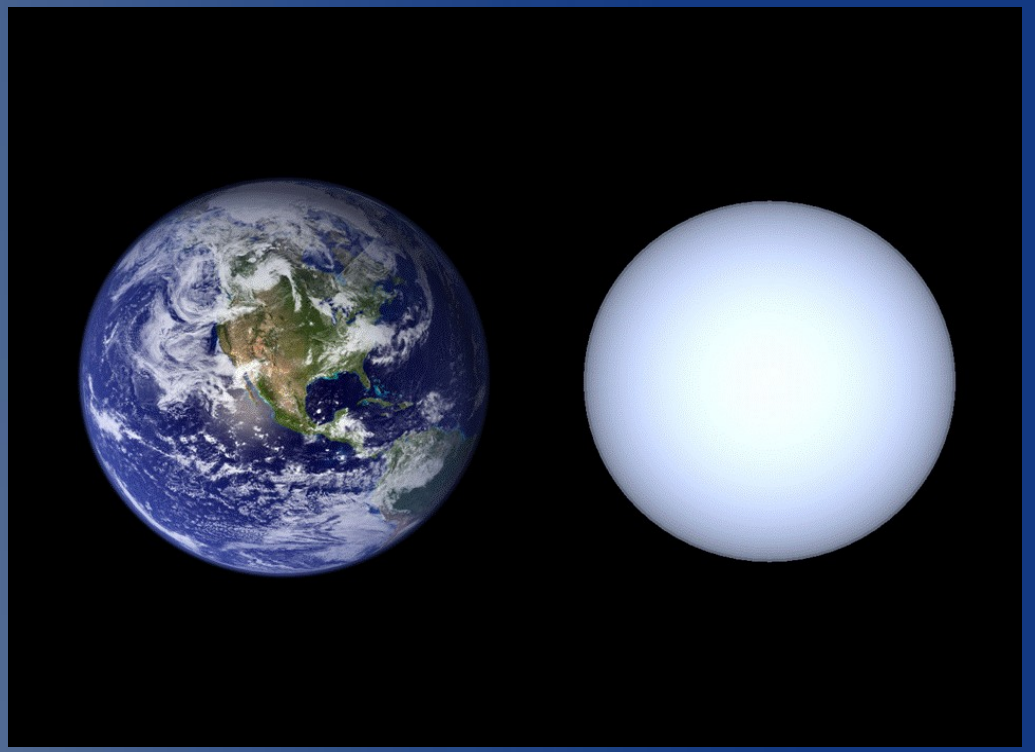



Earth
AIA 304
2011-04-06 14:51:56
www.helioviewer.org

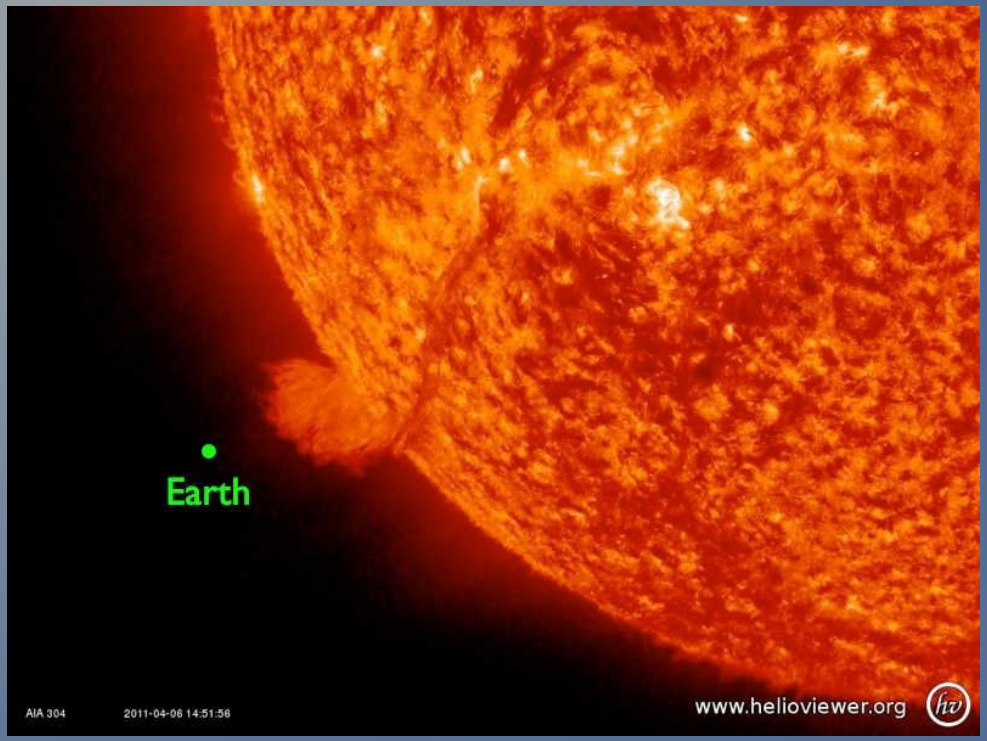

EARTH
WHITE DWARF
NEUTRON STAR

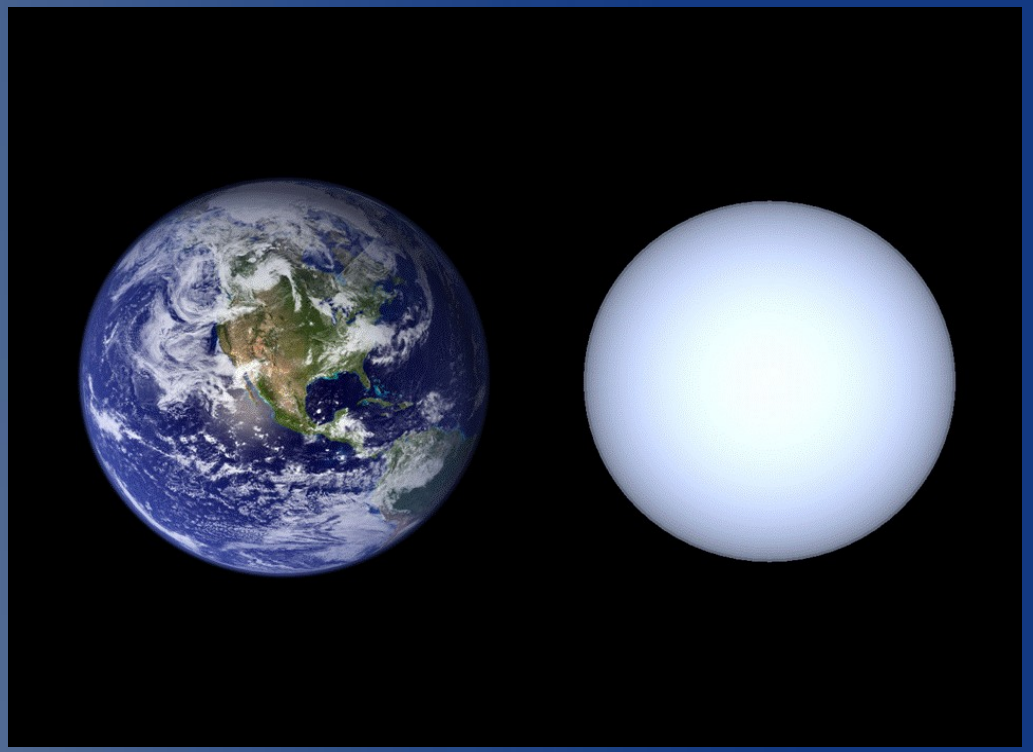






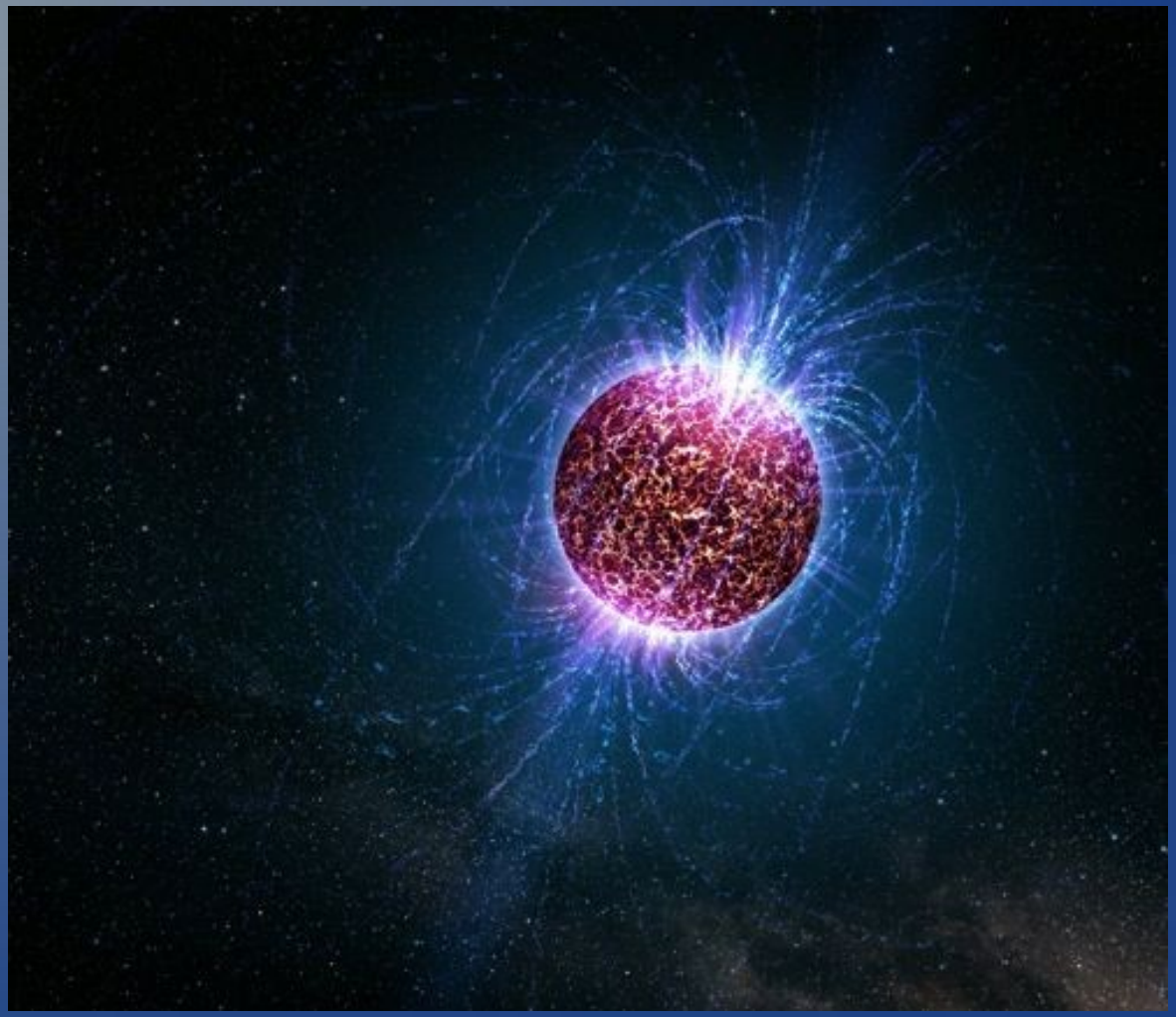
ENANA BLANCA

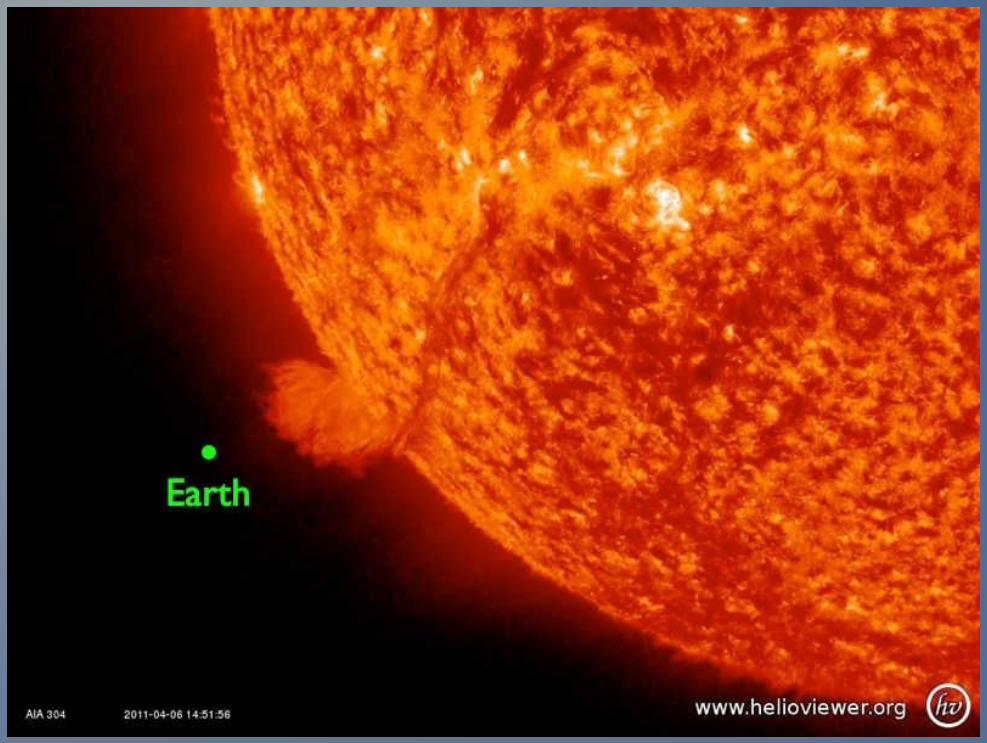




ENANA BLANCA

ESTRELLA DE NEUTRONES

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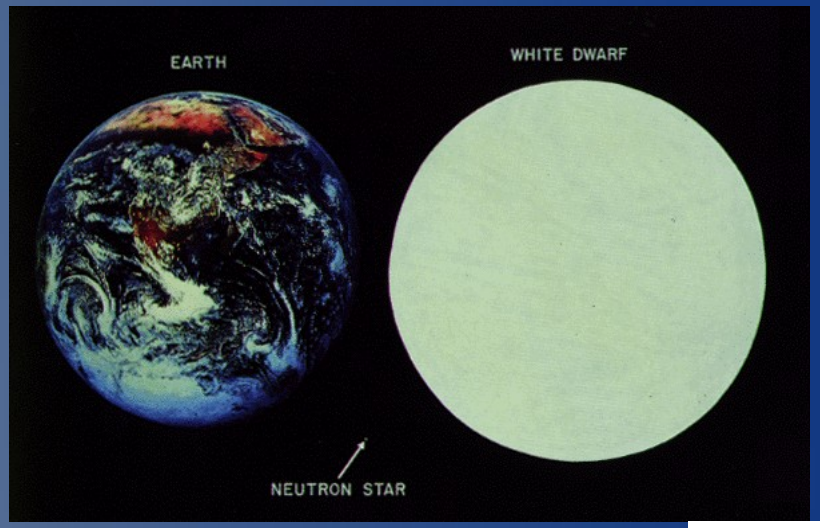
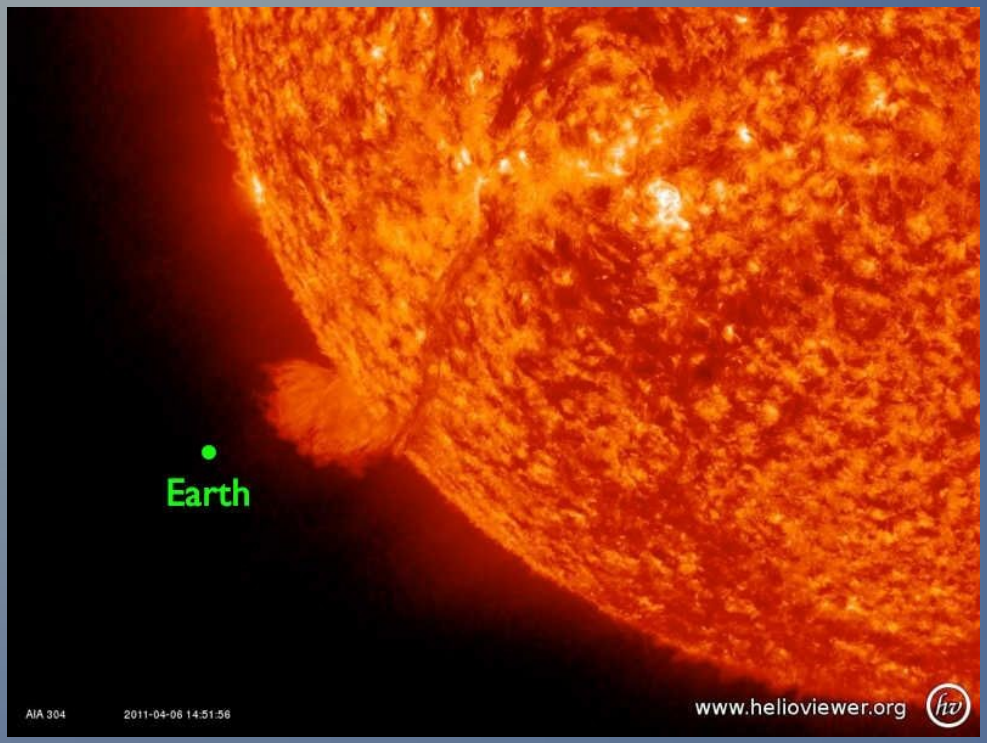
www.helioviewer.org


EARTH
WHITE DWARF
NEUTRON STAR


MADRID


Earth
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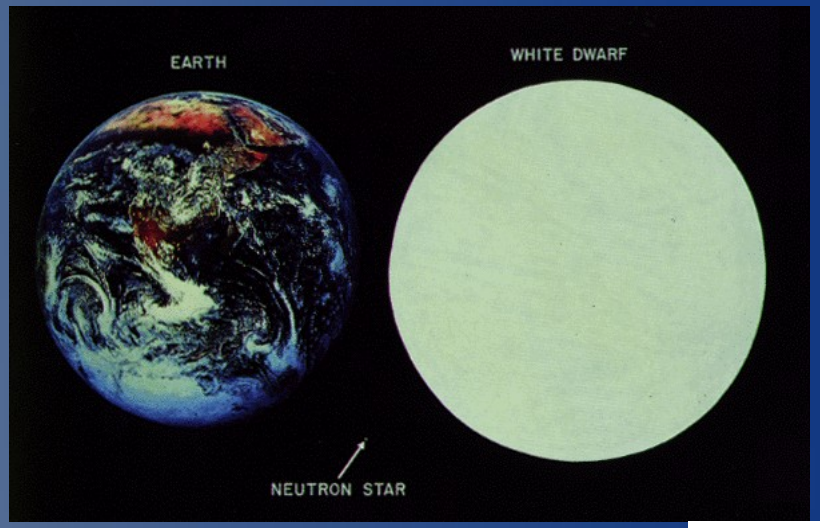
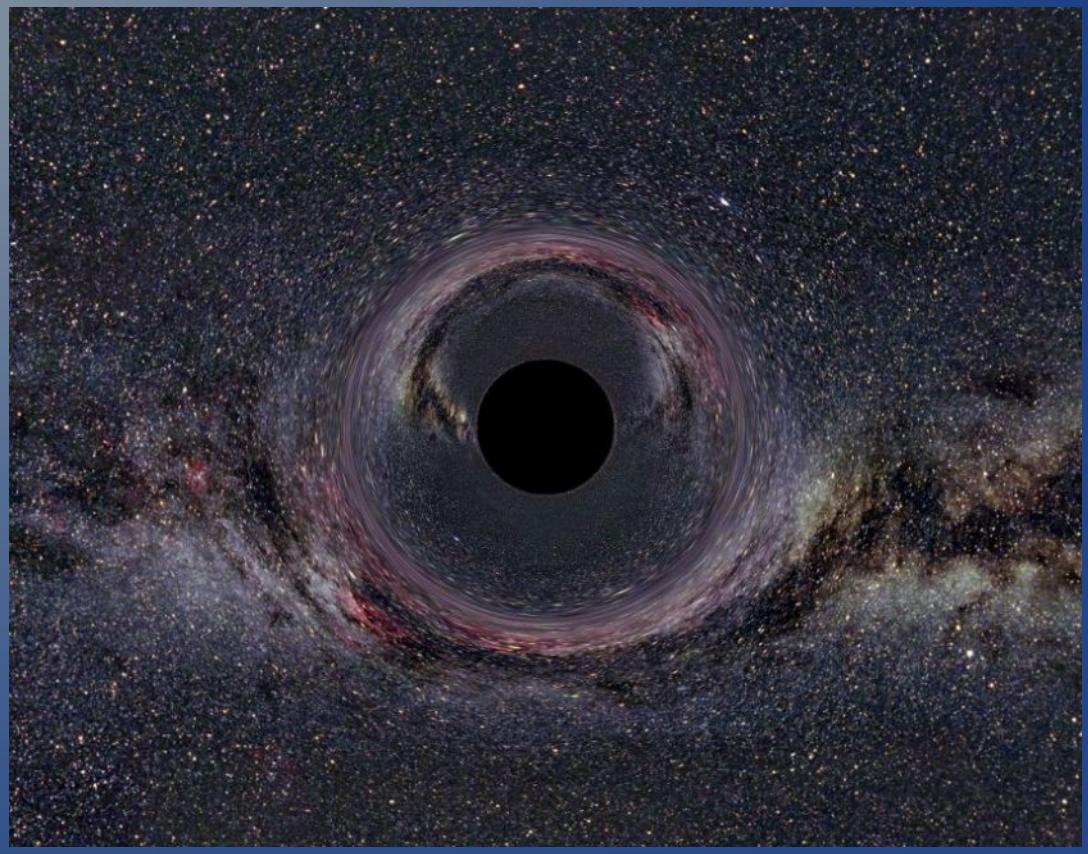
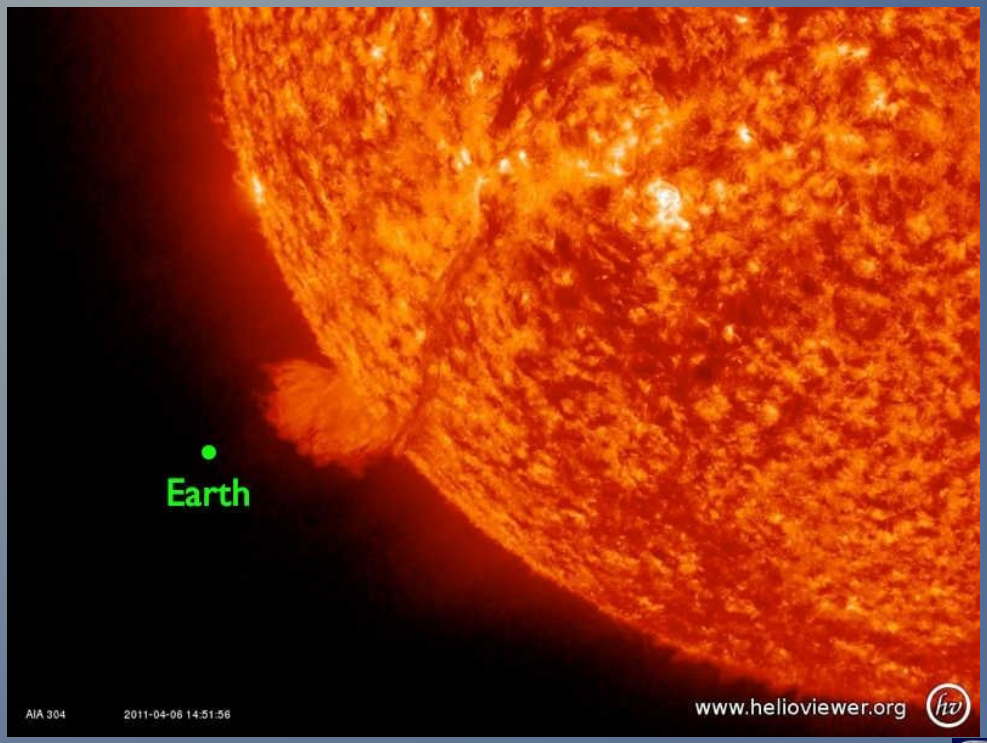
www.helioviewer.org


EARTH
WHITE DWARF
NEUTRON STAR


MADRID

AGUJERO NEGRO

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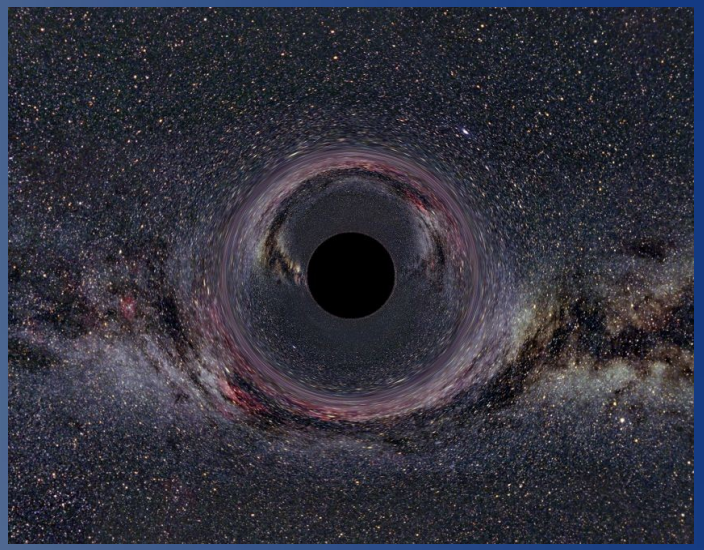
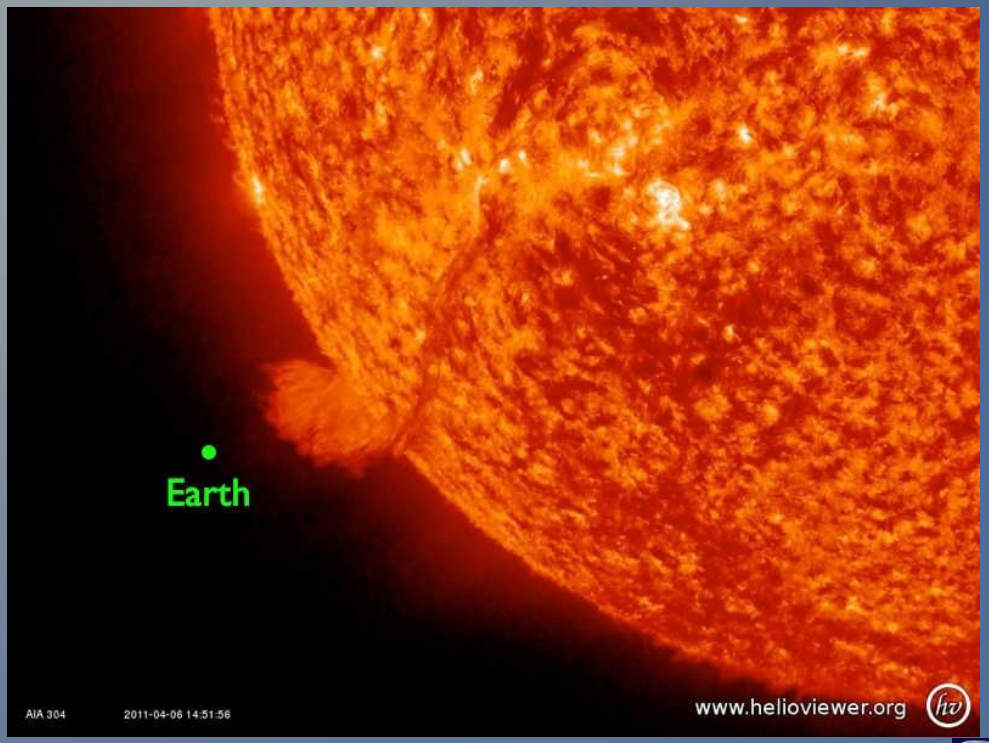
www.helioviewer.org

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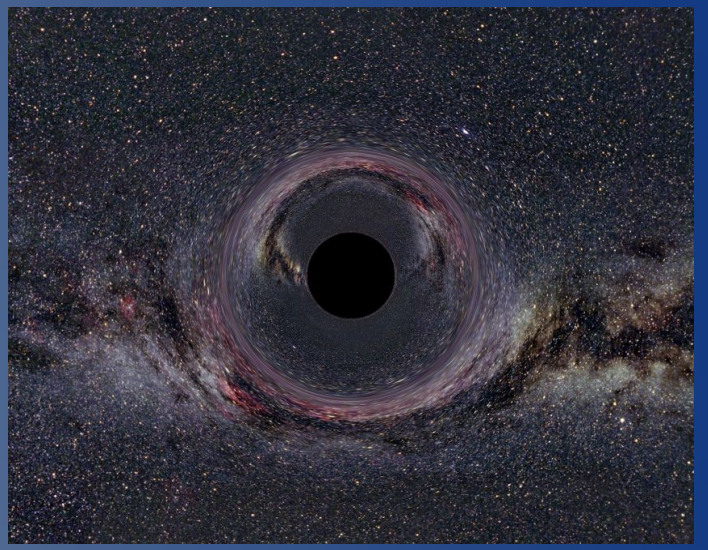
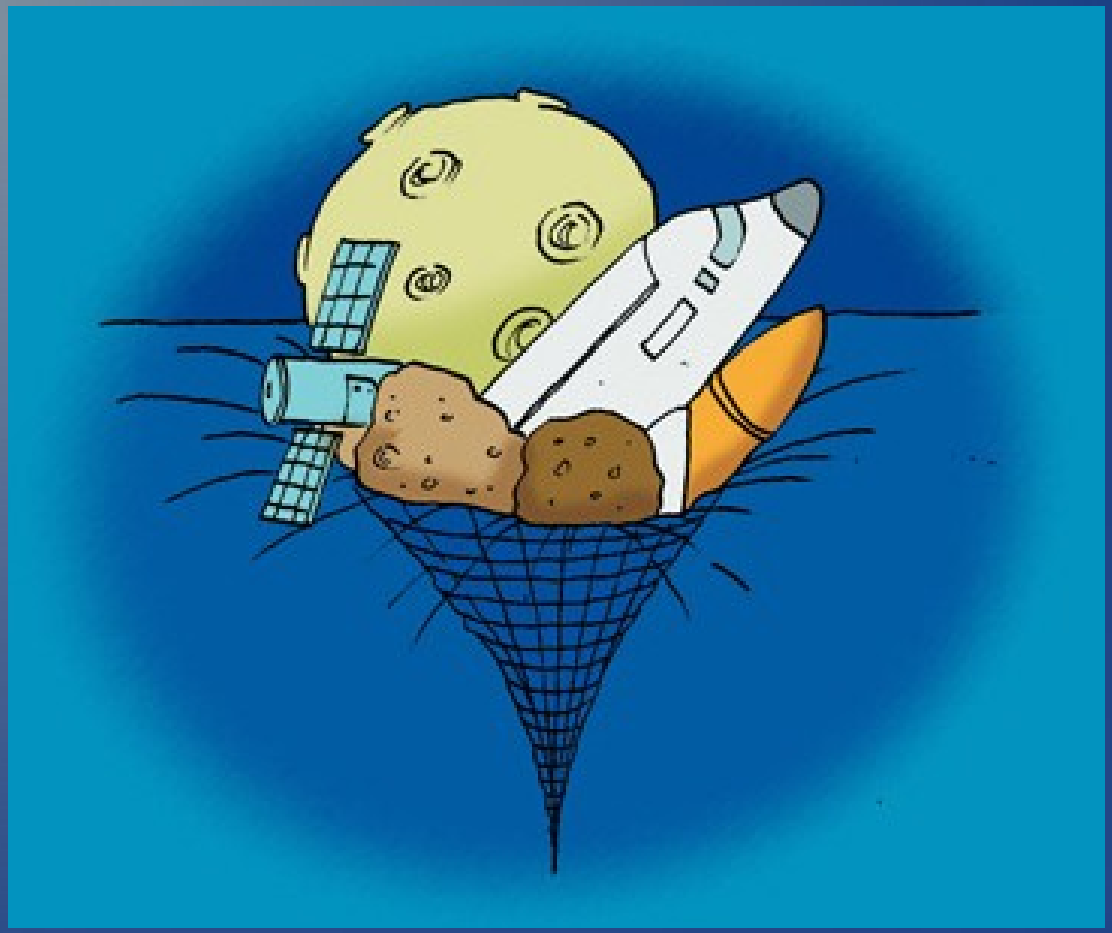
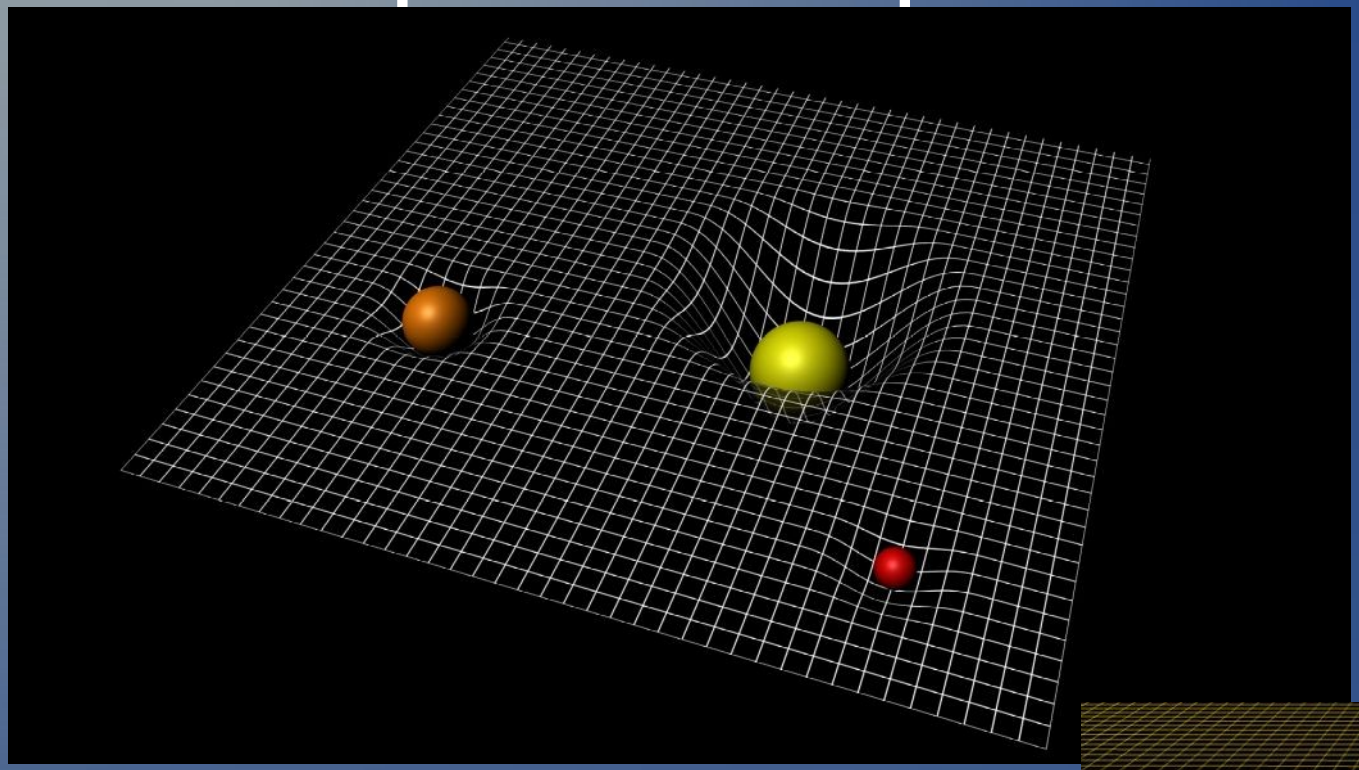
www.helioviewer.org

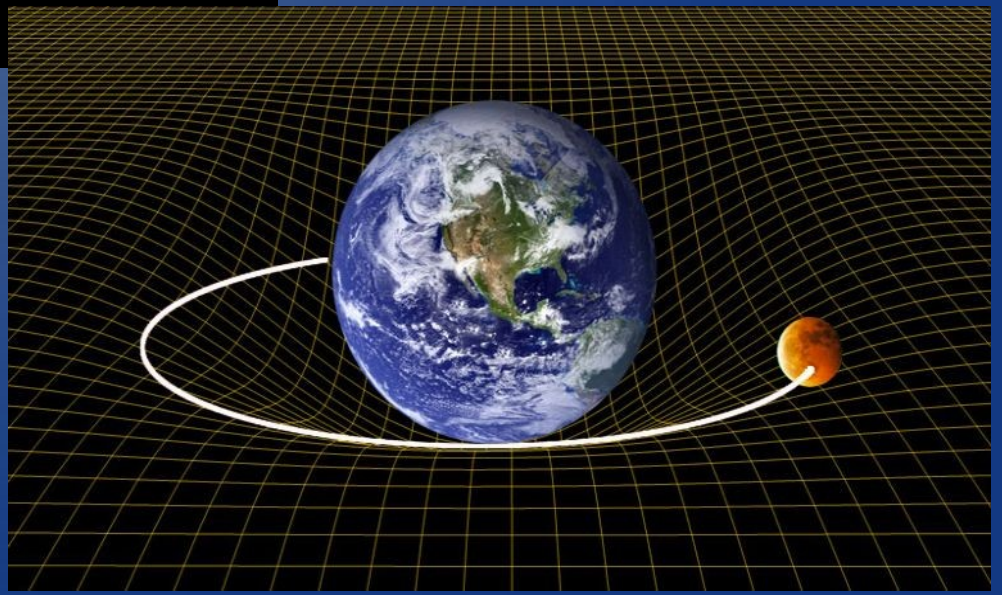


¿Por qué “agujero negro”?



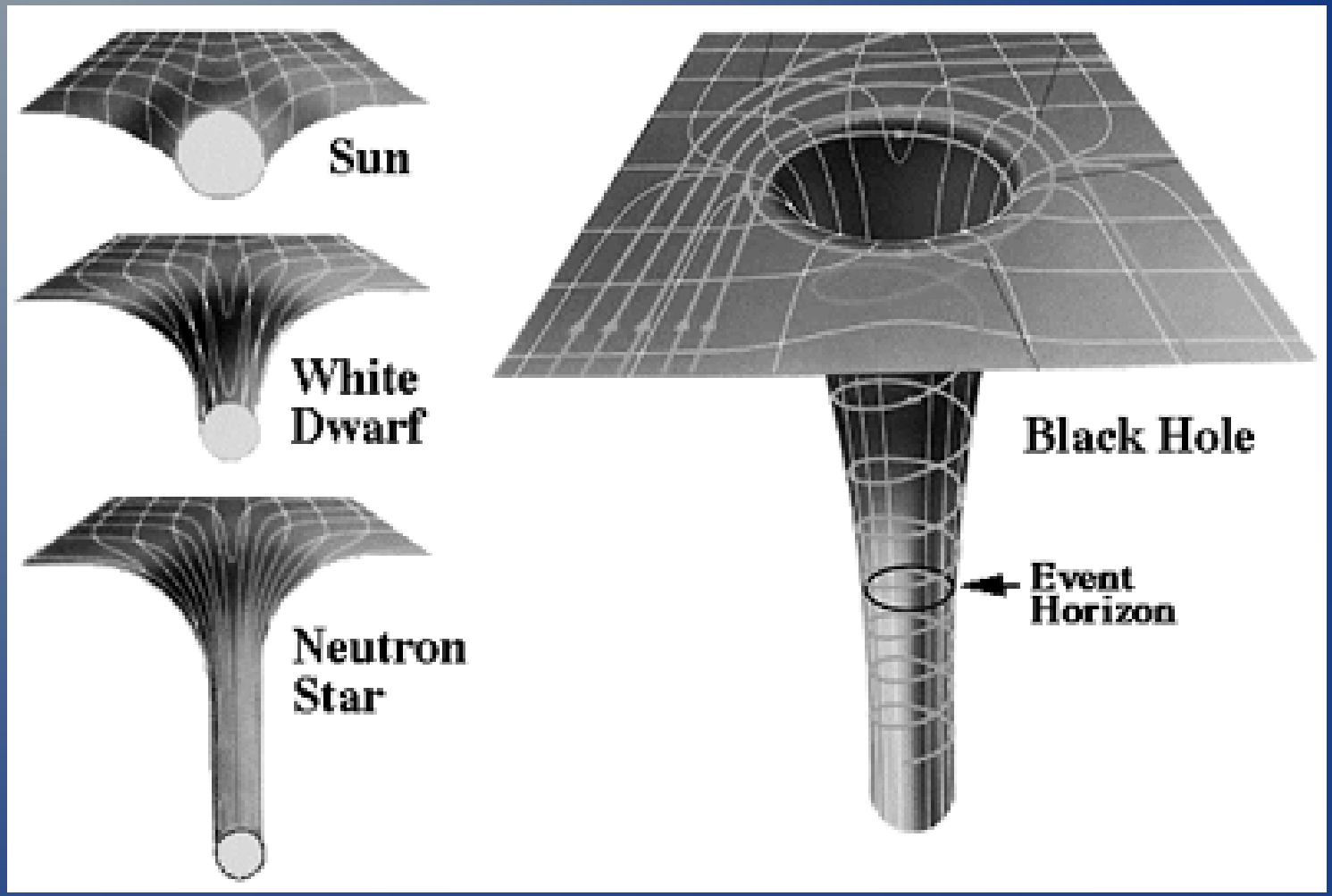
Espaciotiempo en Relatividad



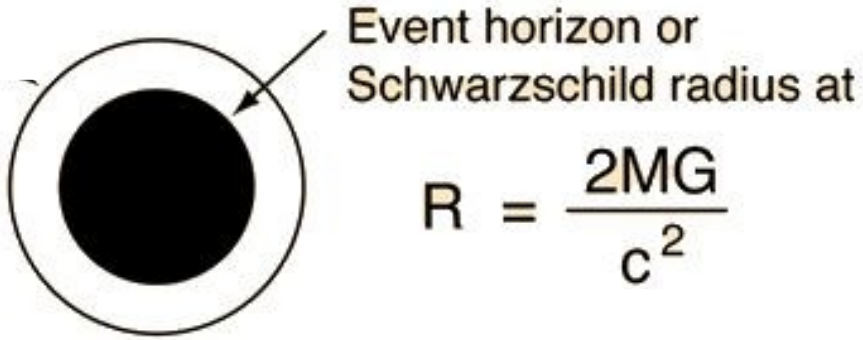


“Spacetime tells matter how to move; matter tells spacetime how to curve.”

(J.A. Wheeler)


Sun
White
Dwarf
Neutron
Star
Black Hole
Event
Horizon

Radio de Schwarzschild

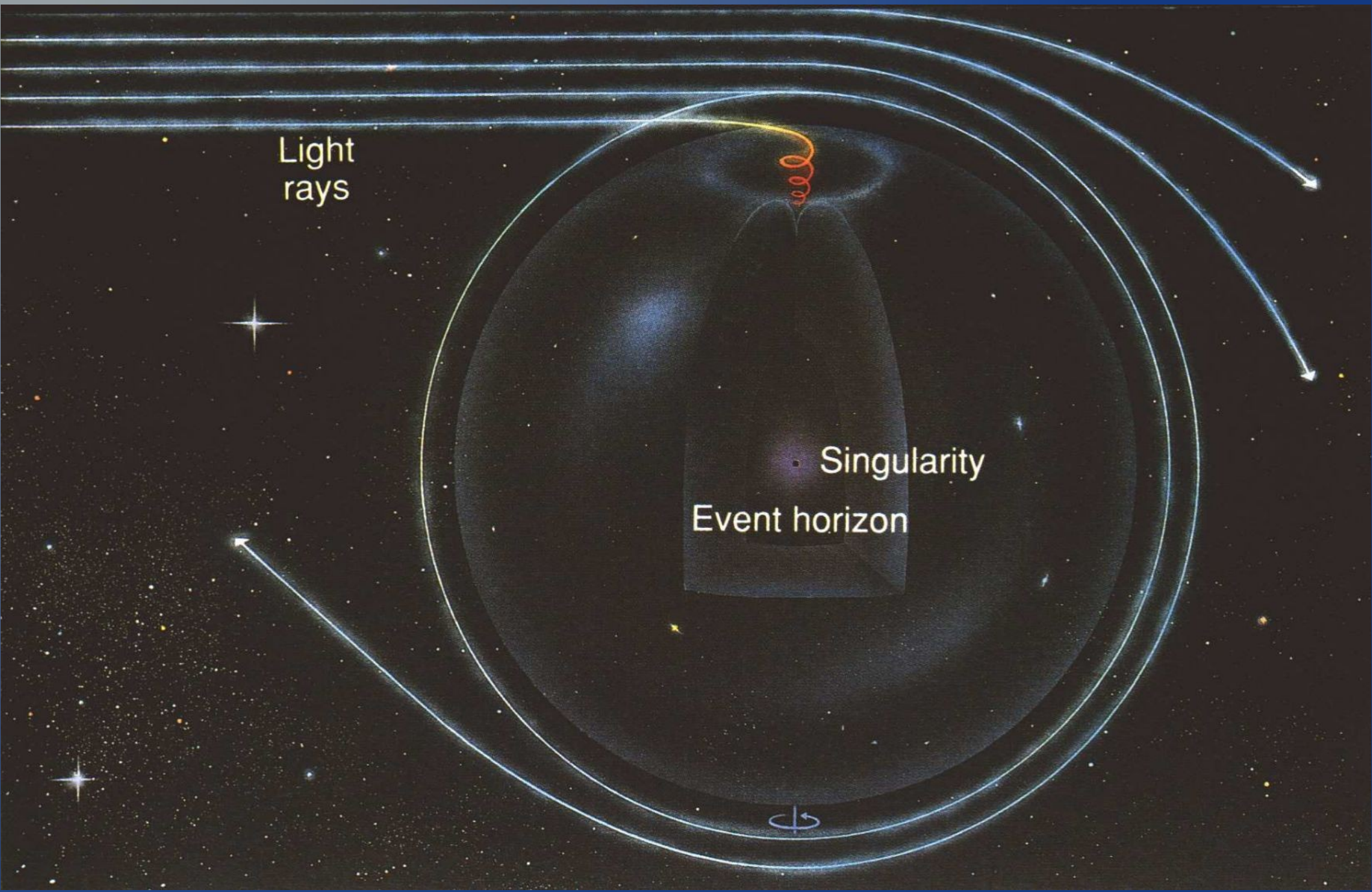


Radio de Schwarzschild

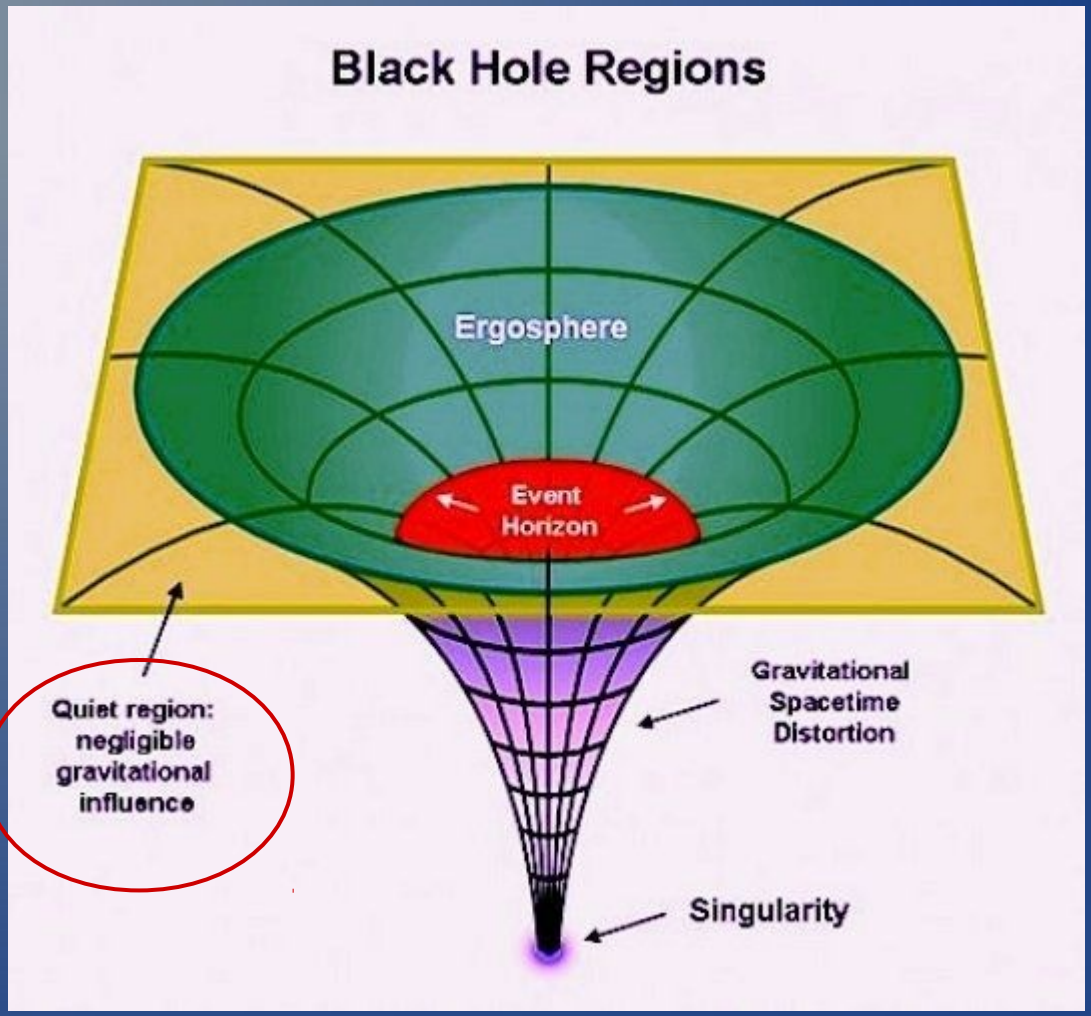
Event horizon or
Schwarzschild radius at

$$R = \frac{2MG}{c^2}$$

R = 3 km for Sun
R = 9 mm for Earth's mass

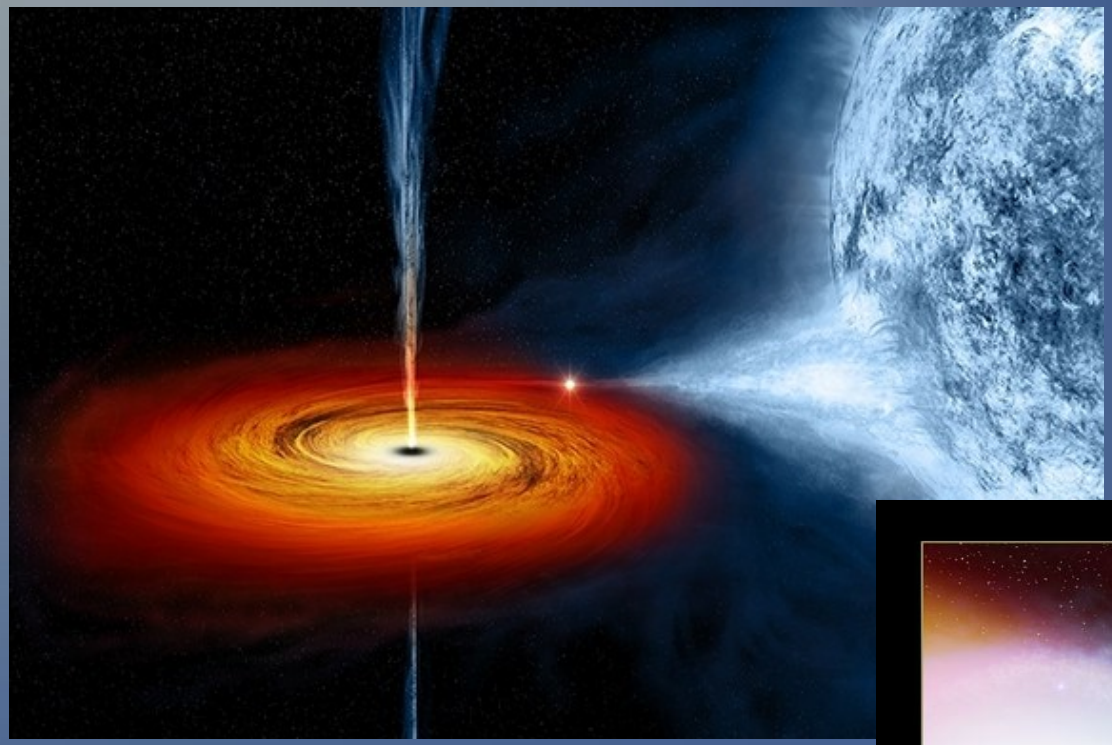

Light
rays
Singularity
Event horizon

¿Un AN absorbe todo?



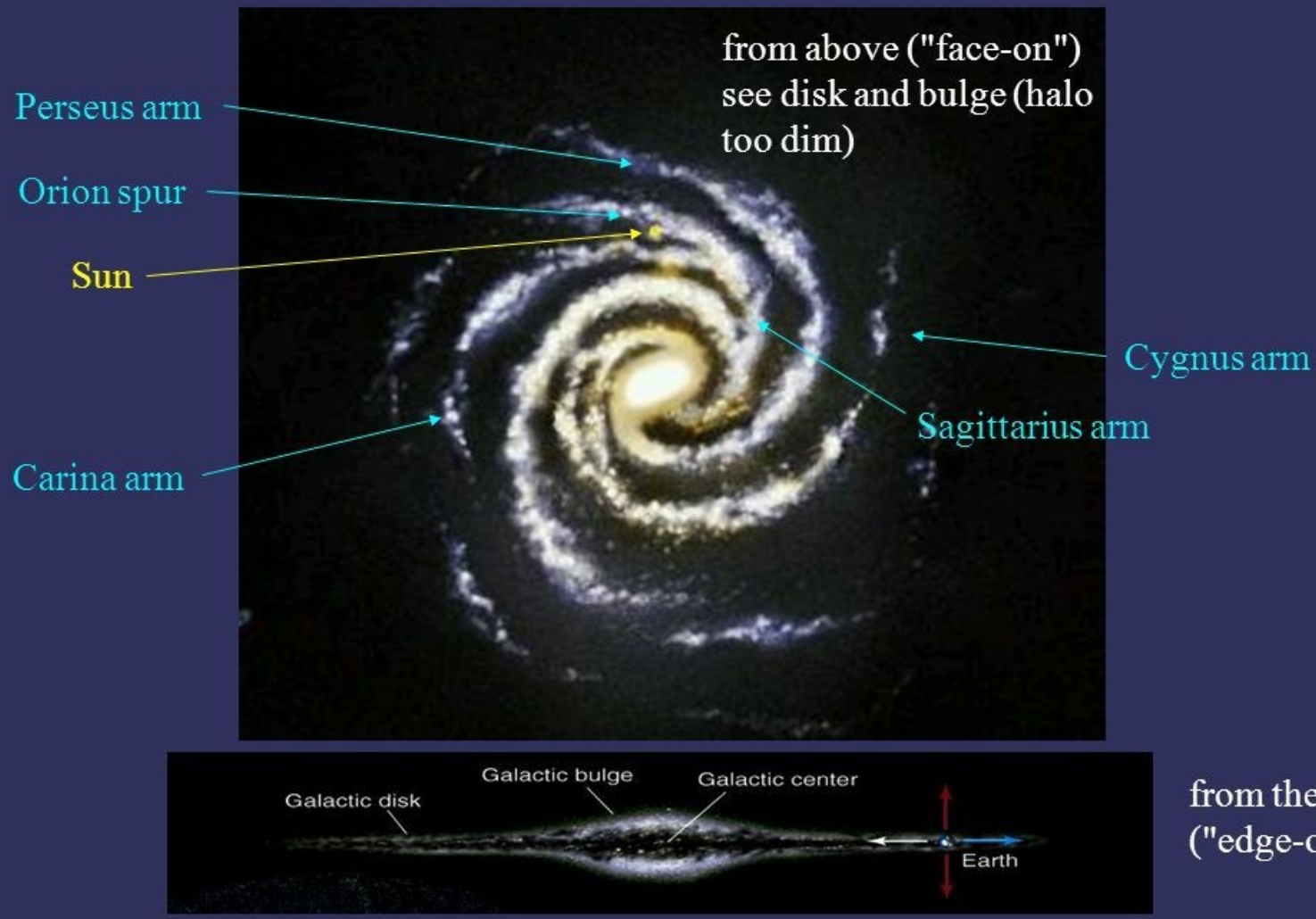
Sí, pero sólo lo que está suficientemente cerca

Cygnus X-1



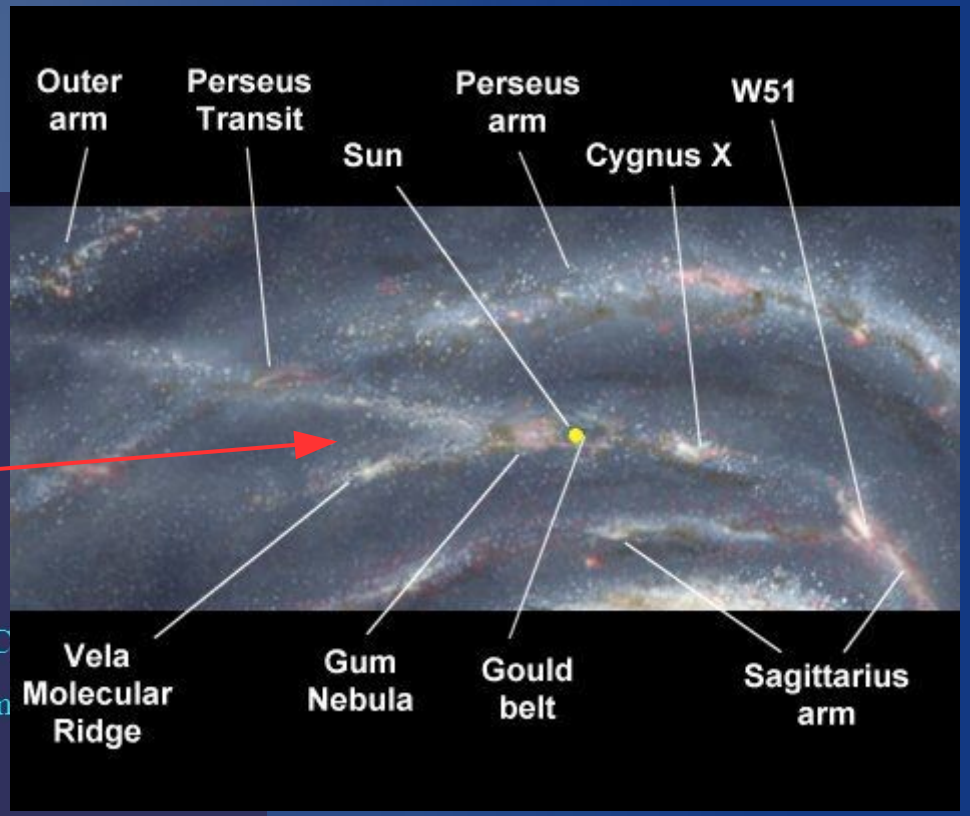
Sol vs Cygnus X-1

Vía Láctea



Cygnus X-1

from the side
("edge-on")

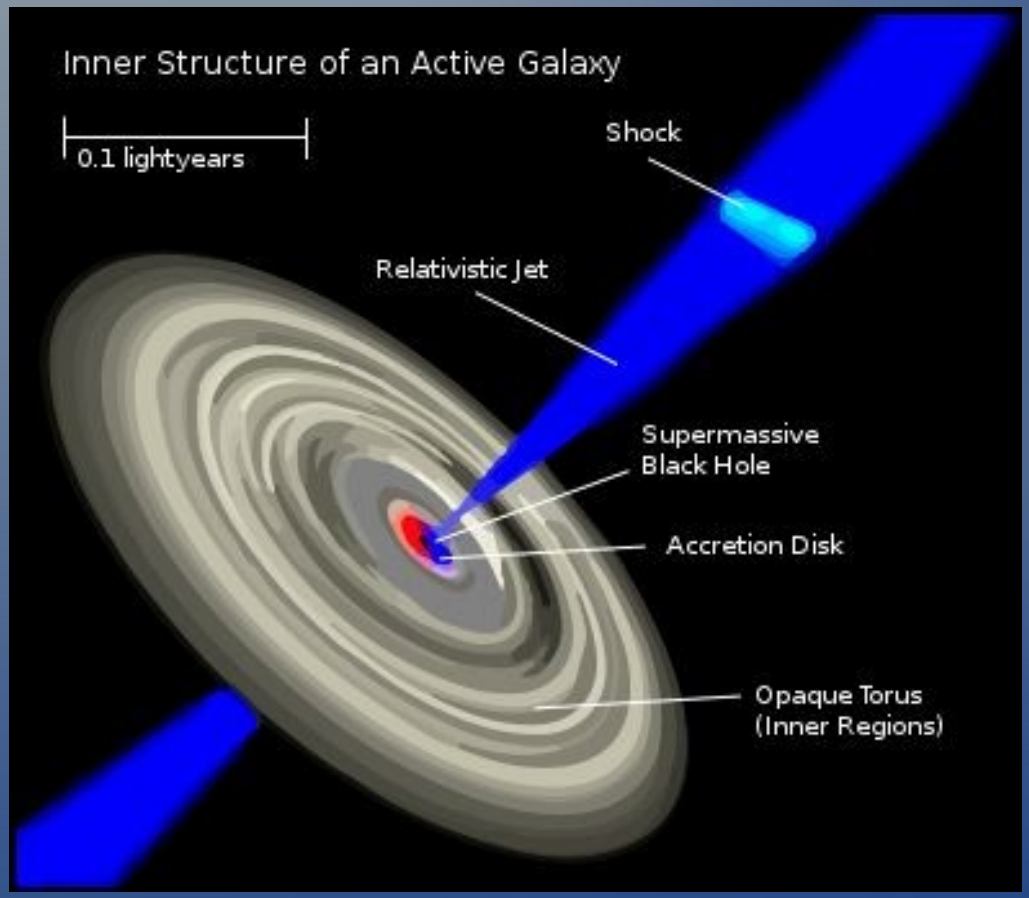


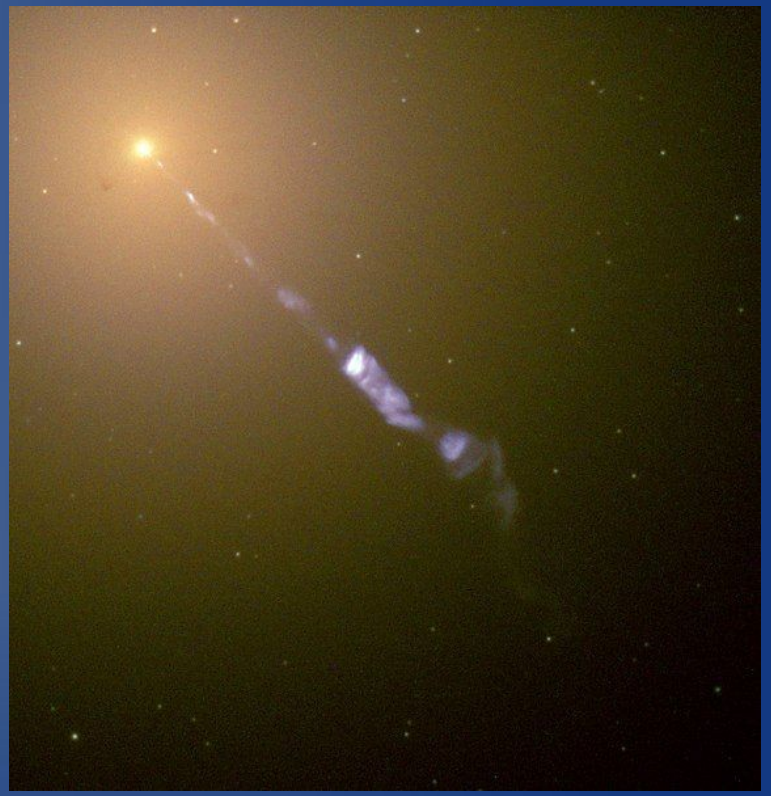
~6000 años luz

(A0620-00 / V616 Monocerotis: : 3000a.l.)

AN Supermasivos

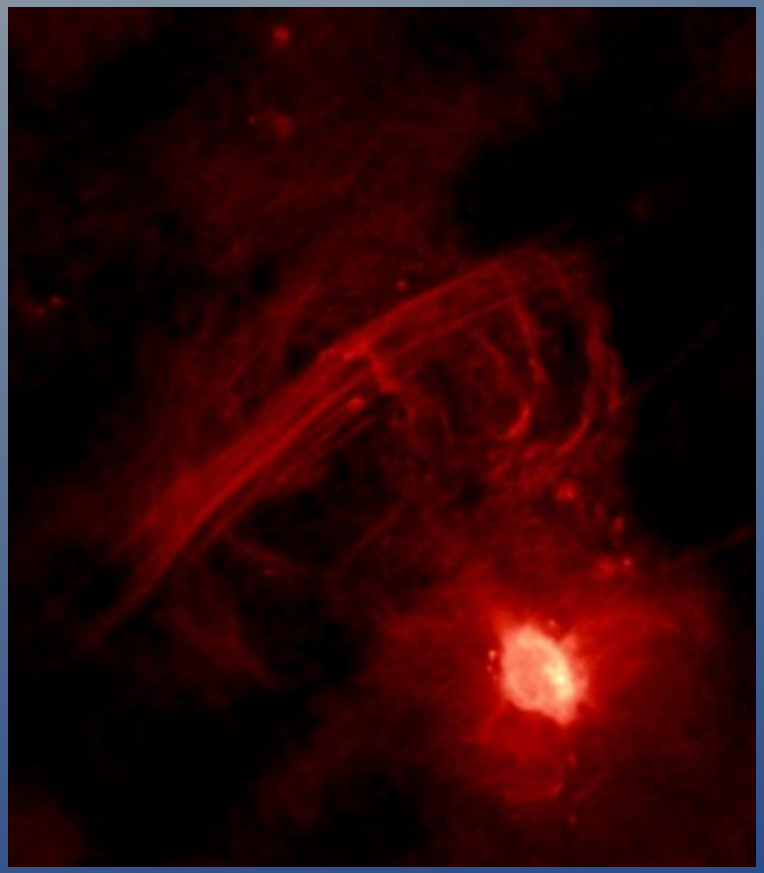
AN Supermasivos y Núcleos Activos de Galaxia

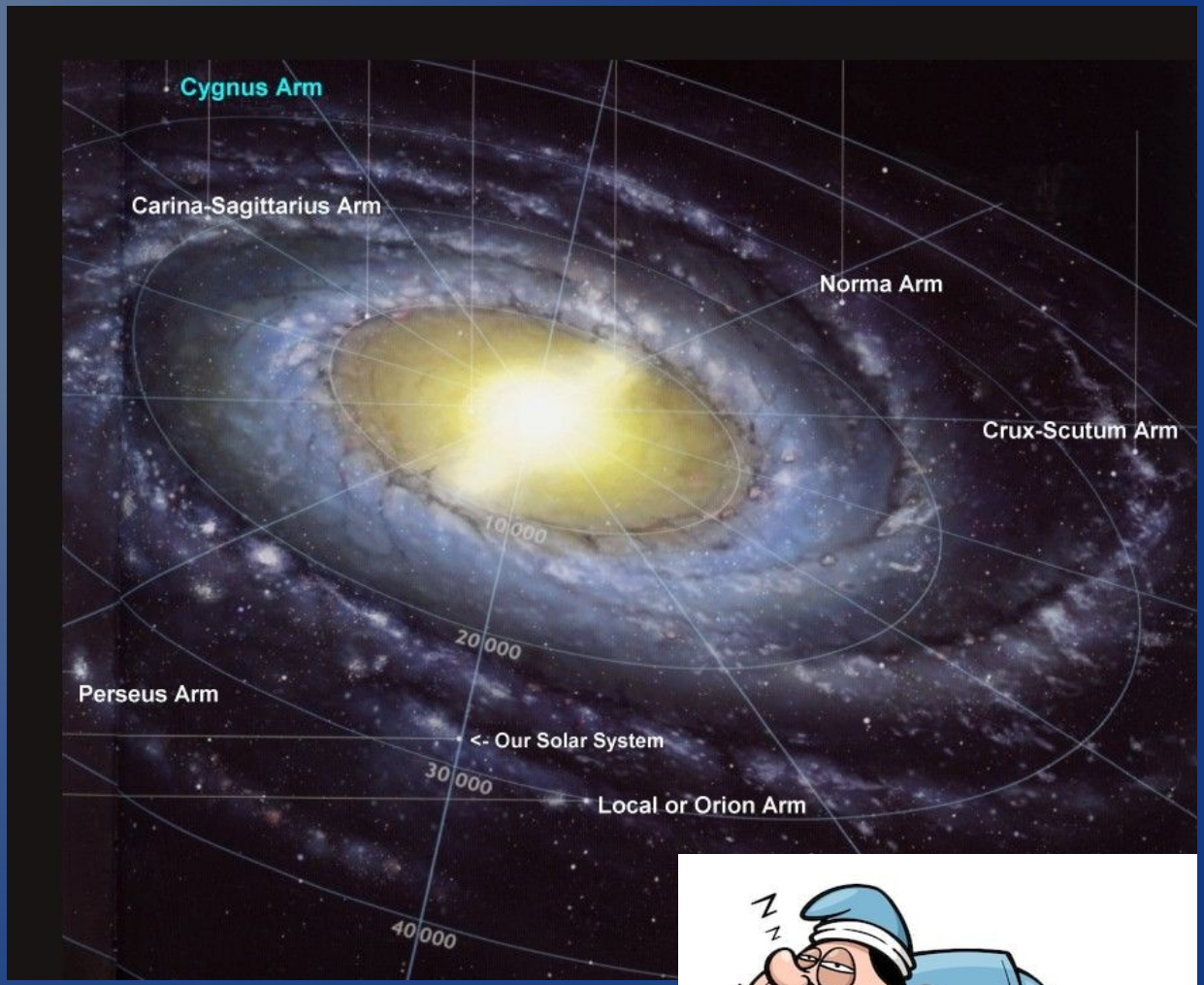




Galaxia M87
Jet de longitud: 5000 años luz

AN en el centro de la Vía Láctea



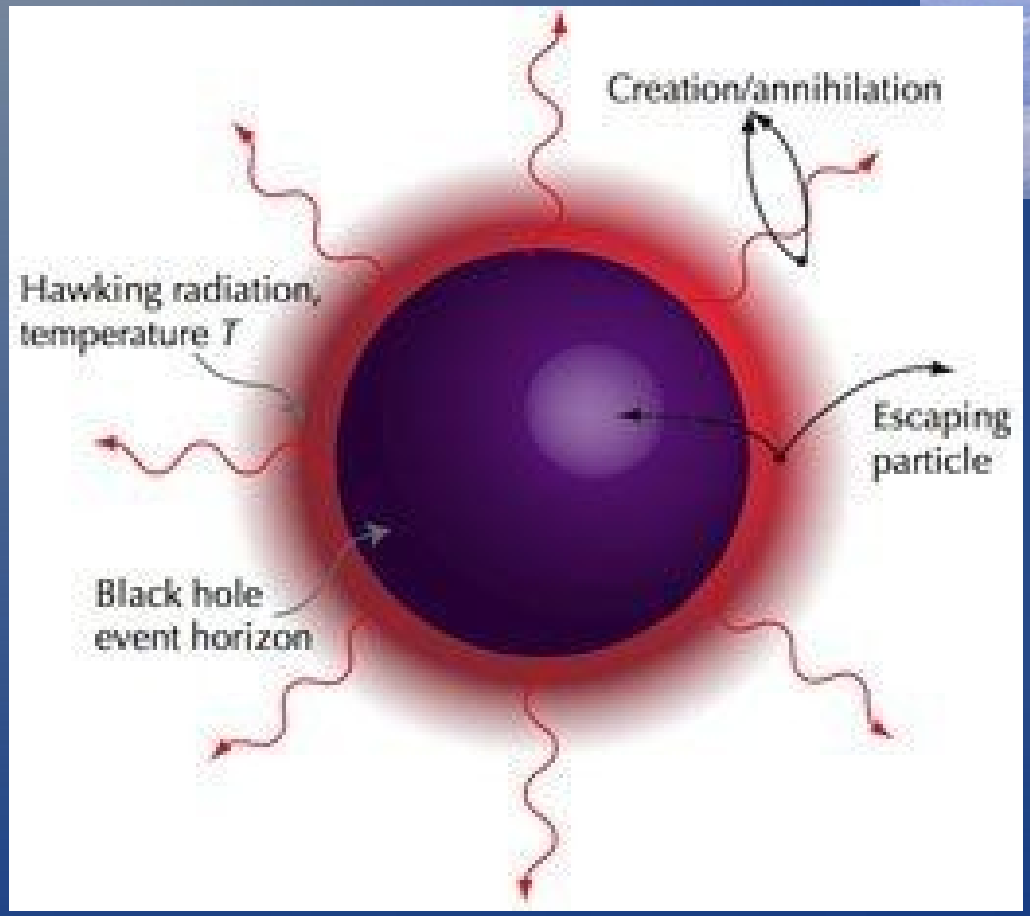


Sagitario A* (~27.000 años luz)

Radiación de Hawking

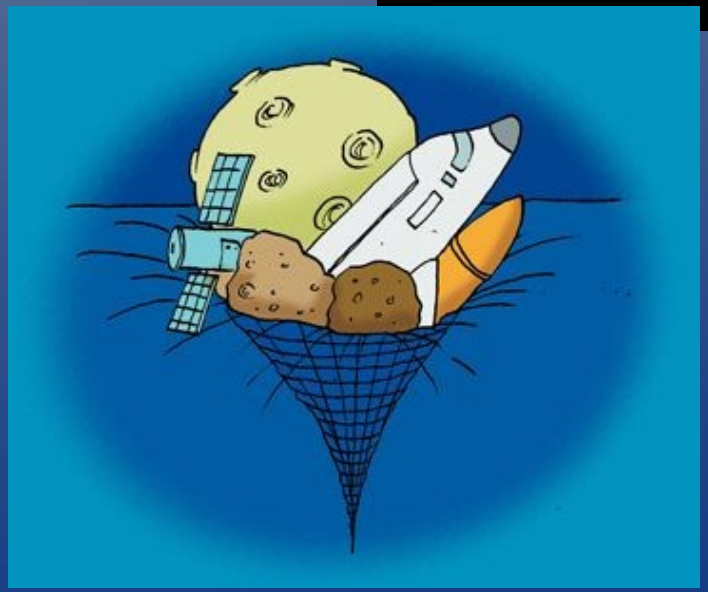
Radiación de Hawking

R.I.P. 2018

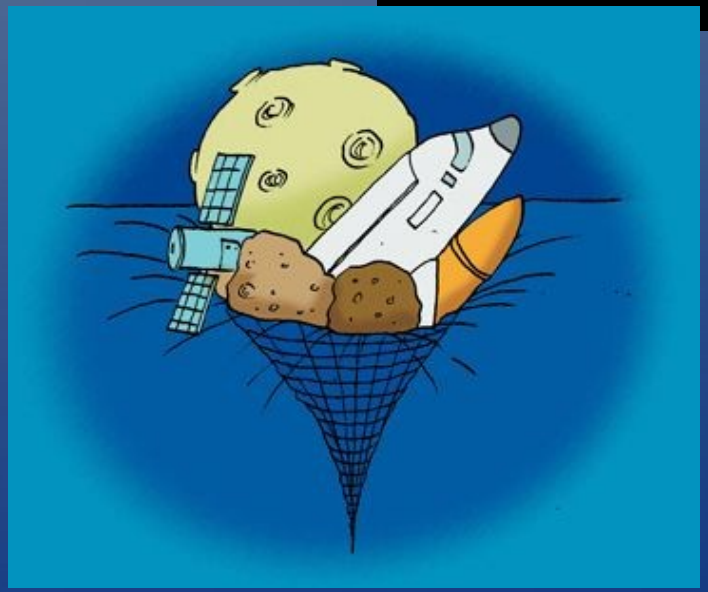


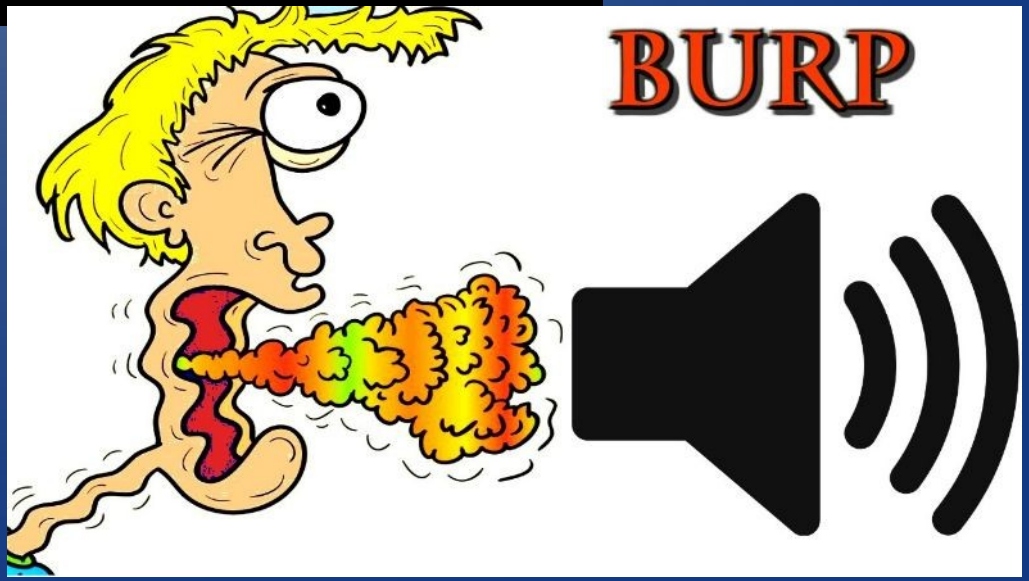
Radiación de Hawking

Radiación de Hawking



Radiación de Hawking





Radiación de Hawking

T(Hawking)~nK–mK vs T(CMB)=2.7K

(evaporación total tardaría miles de M de años)


FIN.