Estructura y Evolución de las Estrellas

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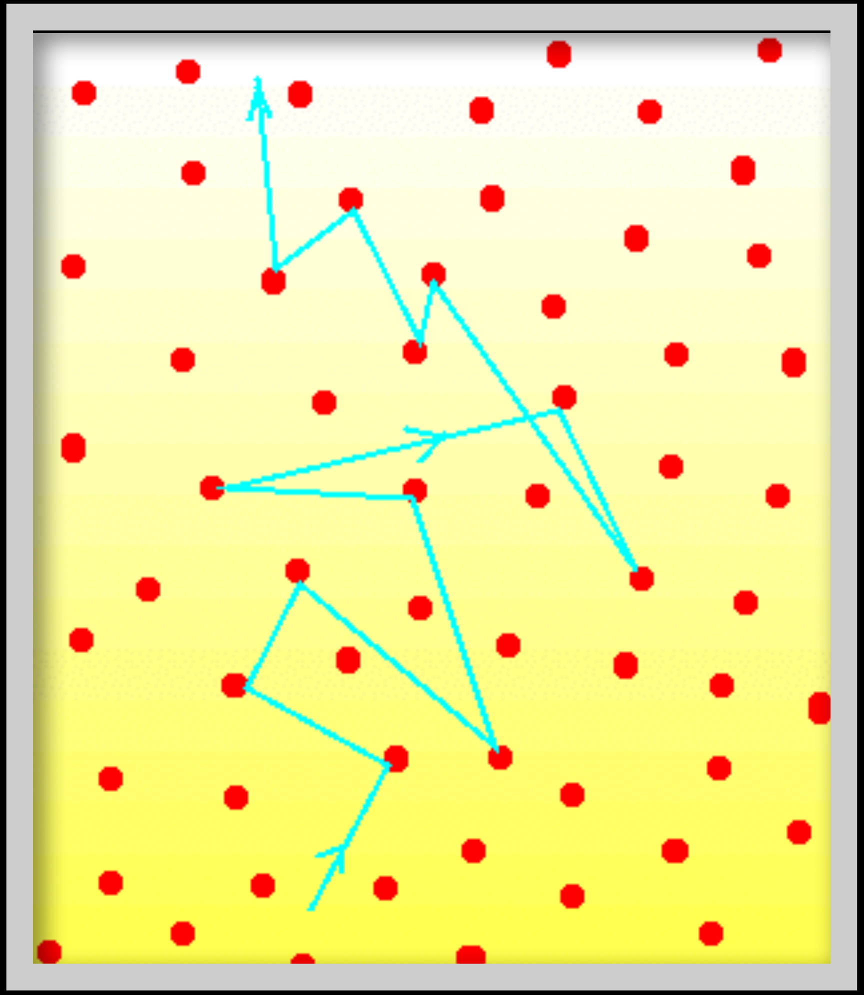
SECUENCIA PRINCIPAL:

QUEMADO de H

Conducción versus Convección



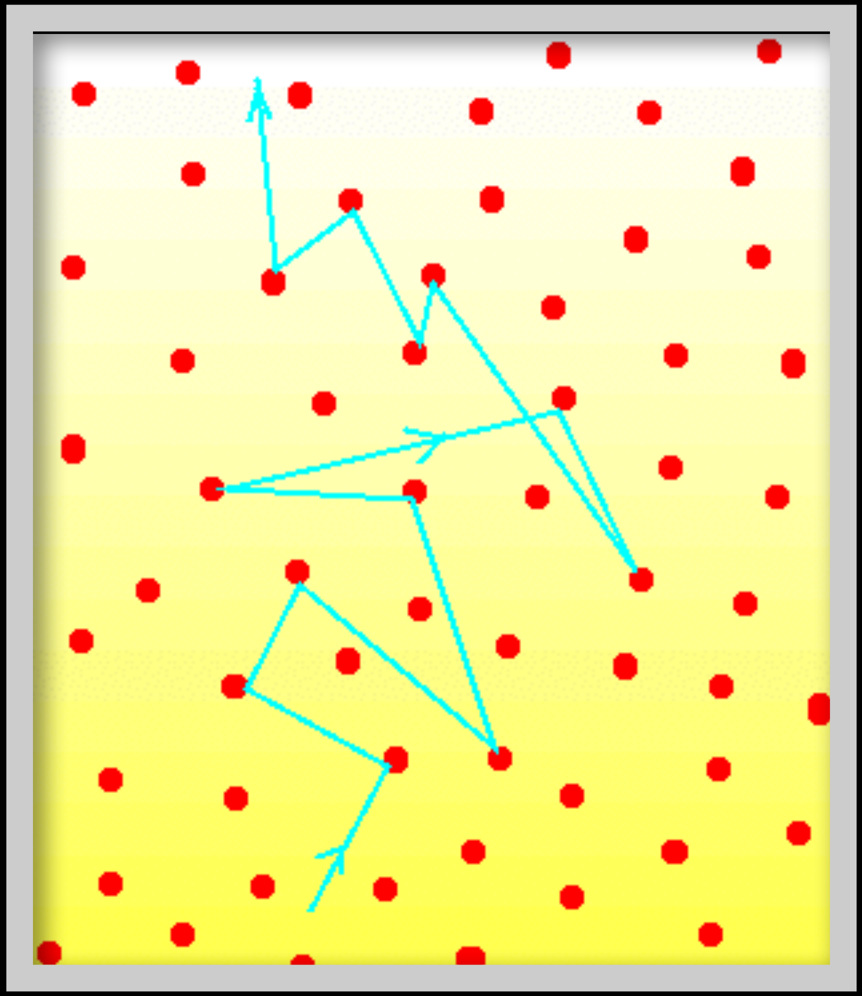
Factores que inducen convección:

Alta opacidad (ocurre en capas frías)

Alto flujo de calor que los fotones no alcanzan a transportar

Transporte radiativo: **fotones** de la región caliente se mueven hacía la región fría. En su camino sufren colisiones con otras partículas: **OPACIDAD**

Conducción versus Convección



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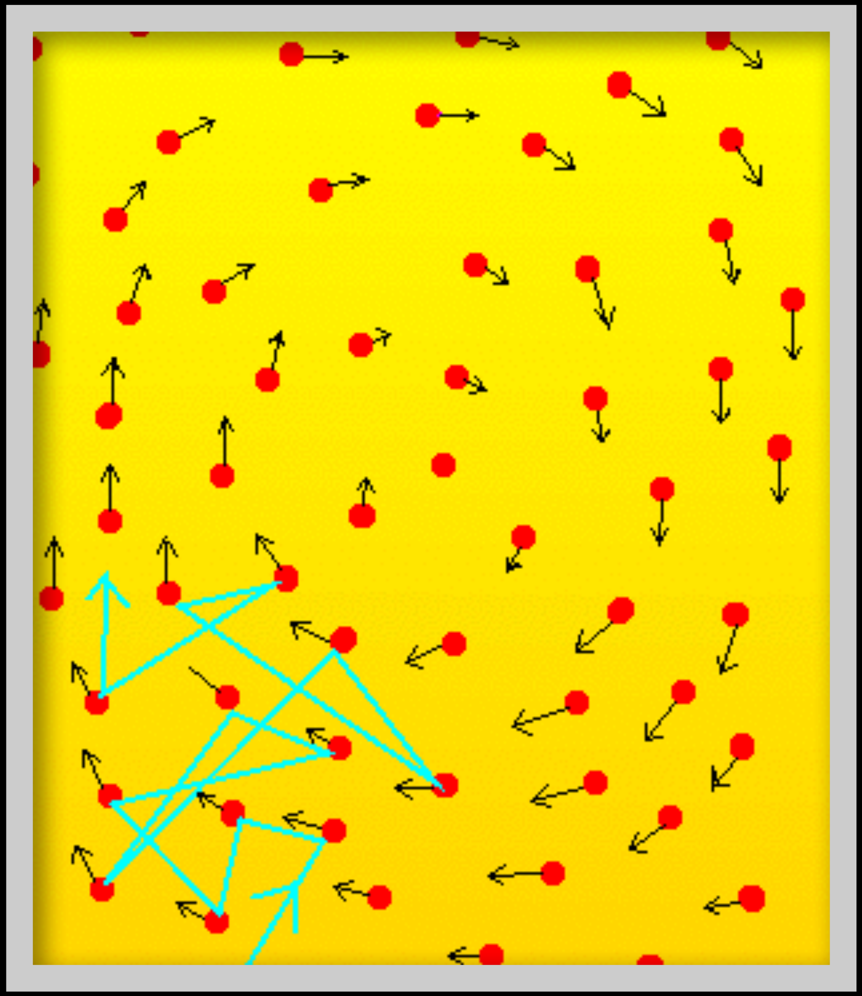
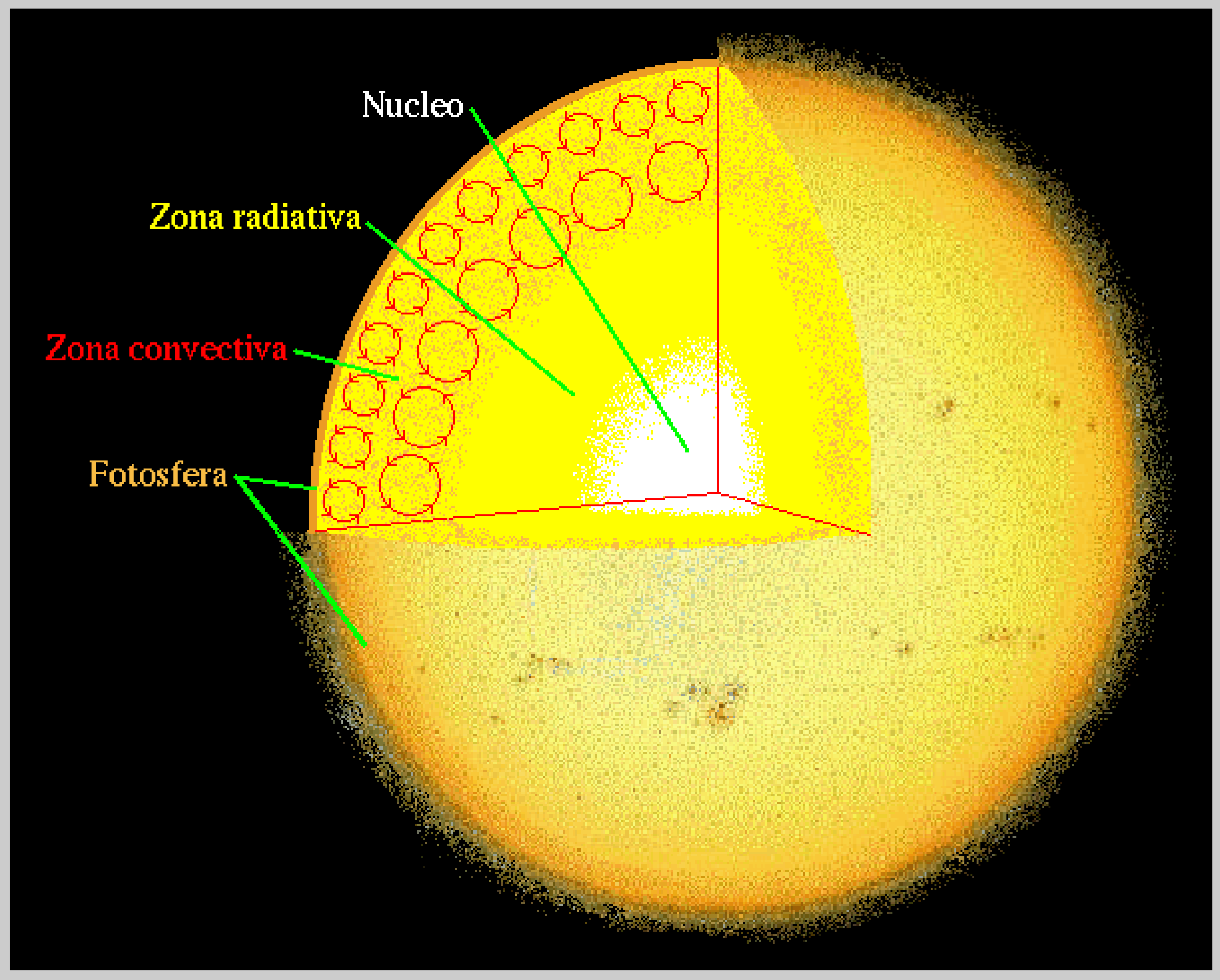


Transporte radiativo: **fotones** de la región caliente se mueven hacía la región fría. En su camino sufren colisiones con otras partículas: **OPACIDAD**

Transporte convectivo: la misma materia caliente se mueve hacía arriba, se enfría y vuelve a bajar.

Estructura Interna del Sol



El campo Magnético del Sol: Resultado de la Convección

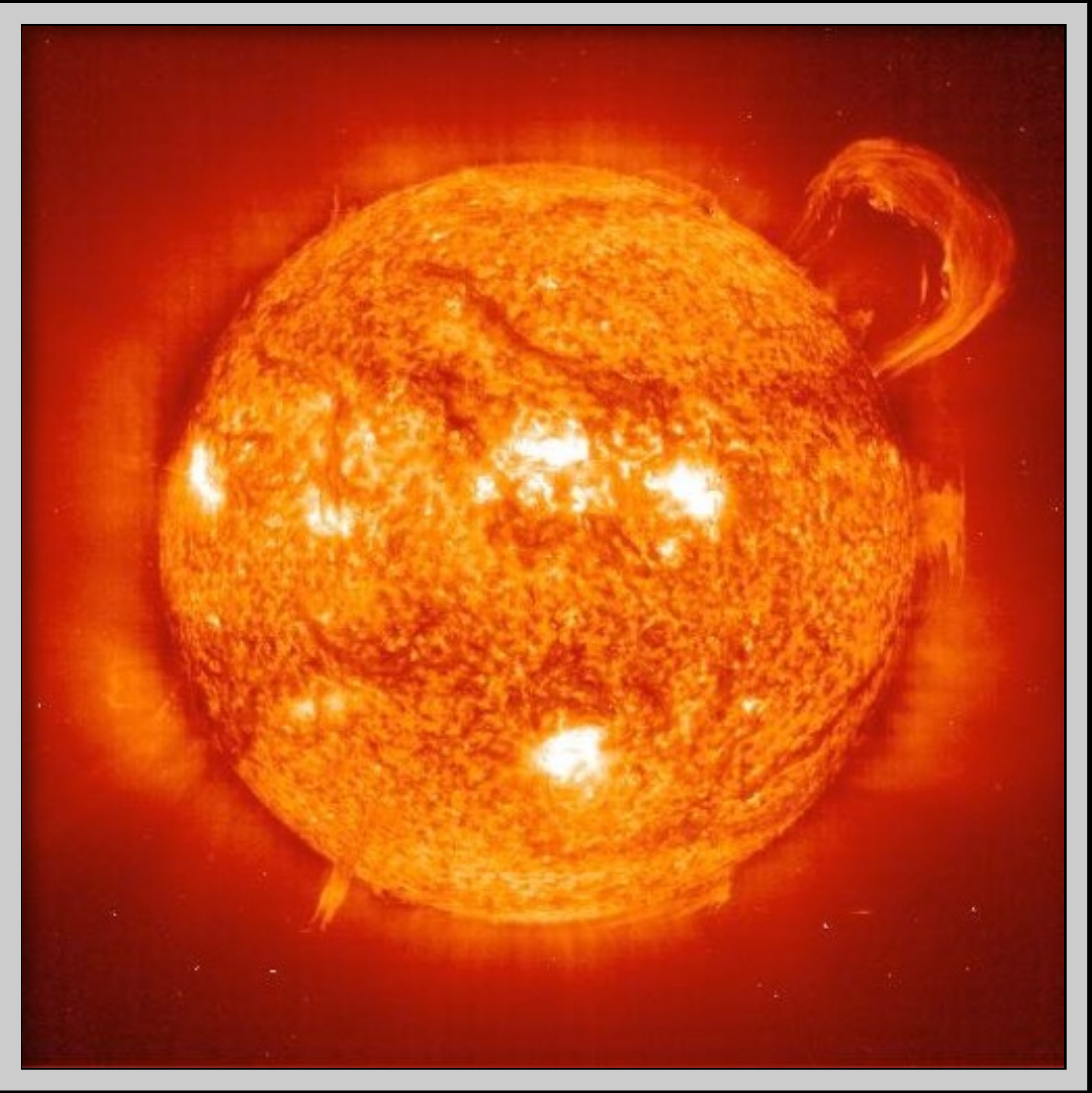
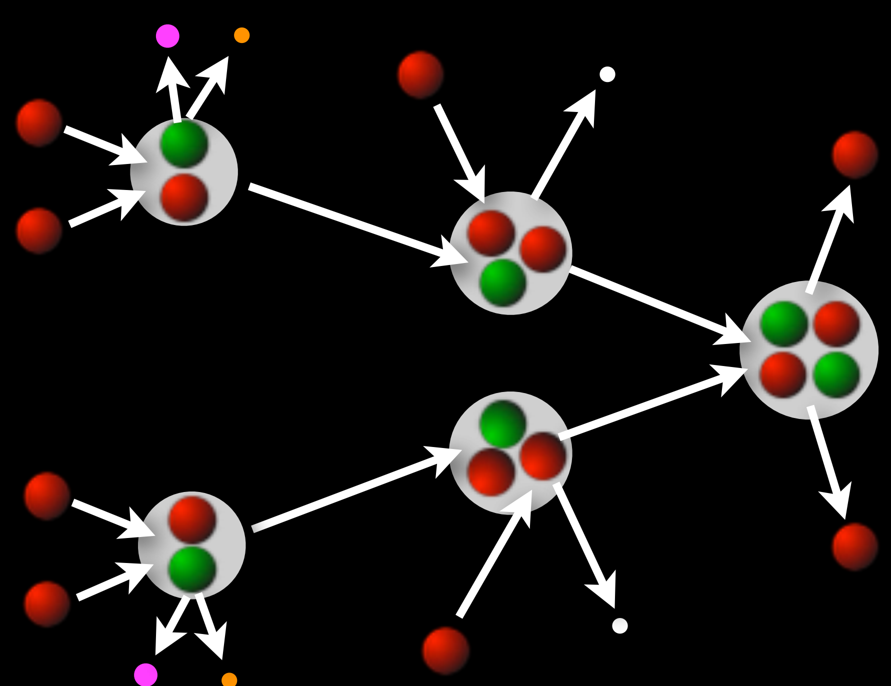


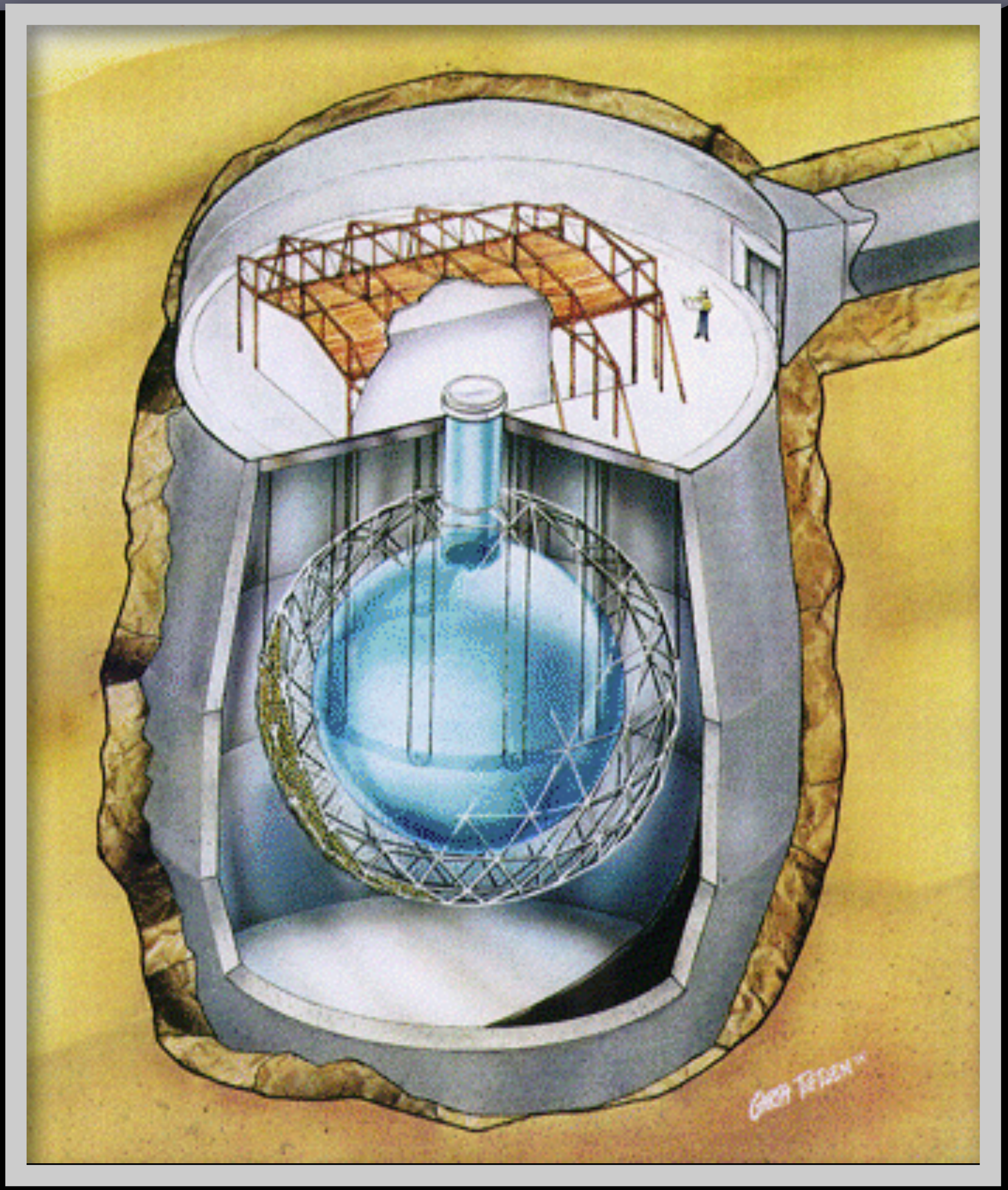
Imagen ultravioleta del satélite SOHO

(SOlar & Heliosphere Observatory

Los Neutrinos Solares

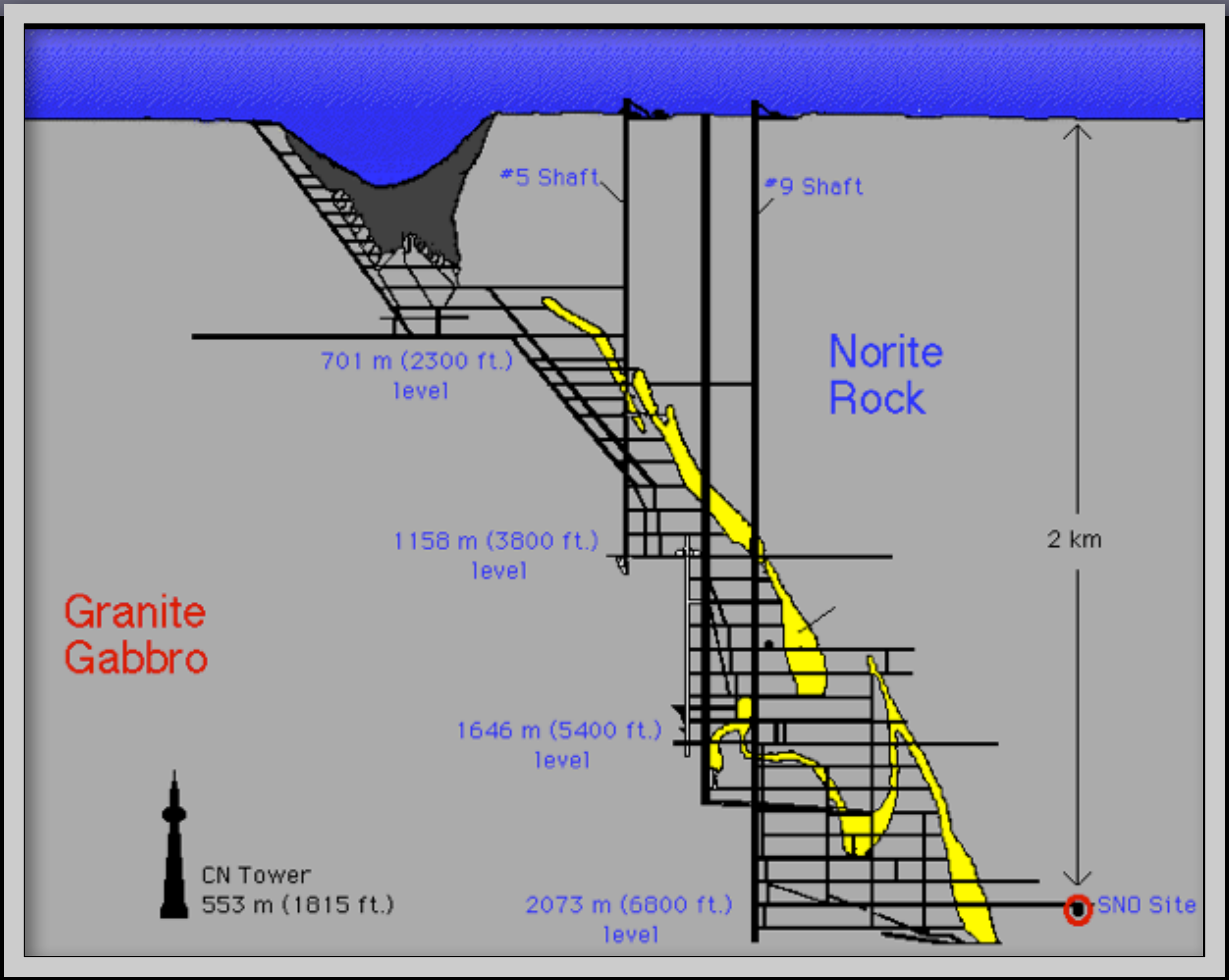
$$2\,(p + p \;\rightarrow\; {}^2H + e^+ + \nu)$$
$$2\,({}^2H + p \;\rightarrow\; {}^3He + \gamma)$$
$${}^3He + {}^3He \;\rightarrow\; {}^4He + 2p$$





El detector de neutrinos de Sudbury (Canada)

La Mina de Sudbury y SNO

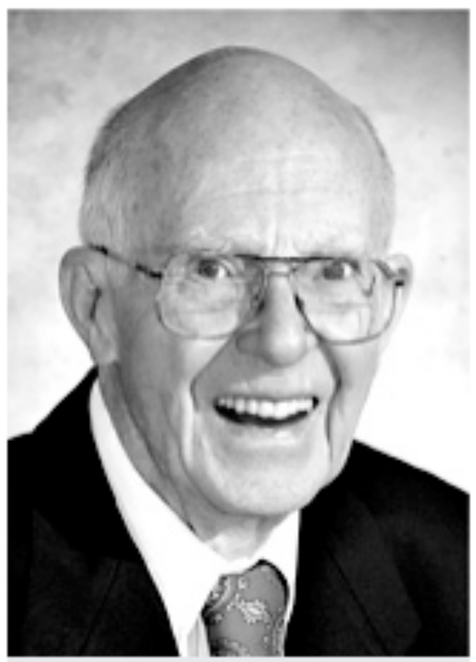


Dada la dificultad de detectar neutrinos, los detectores siempre están ubicados a gran profundidad para evitar la contaminación por los rayos cósmicos.

The Nobel Prize in Physics 2002

"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"

"for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"



Raymond Davis Jr.

1/4 of the prize

USA

University of Pennsylvania
Philadelphia, PA, USA

b. 1914
d. 2006

Masatoshi Koshiba

1/4 of the prize

Japan

University of Tokyo
Tokyo, Japan

b. 1926

Riccardo Giacconi

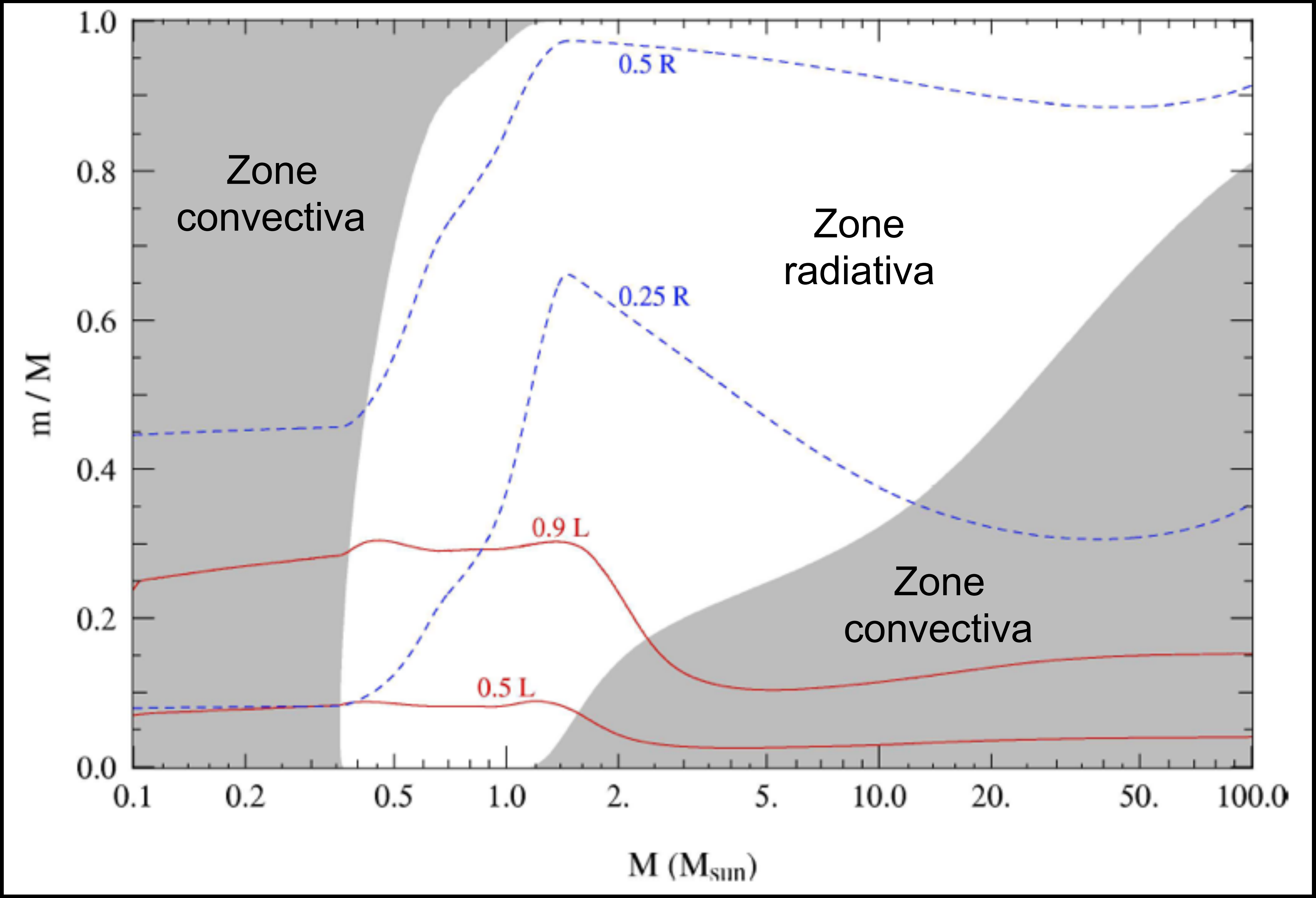
1/2 of the prize

USA

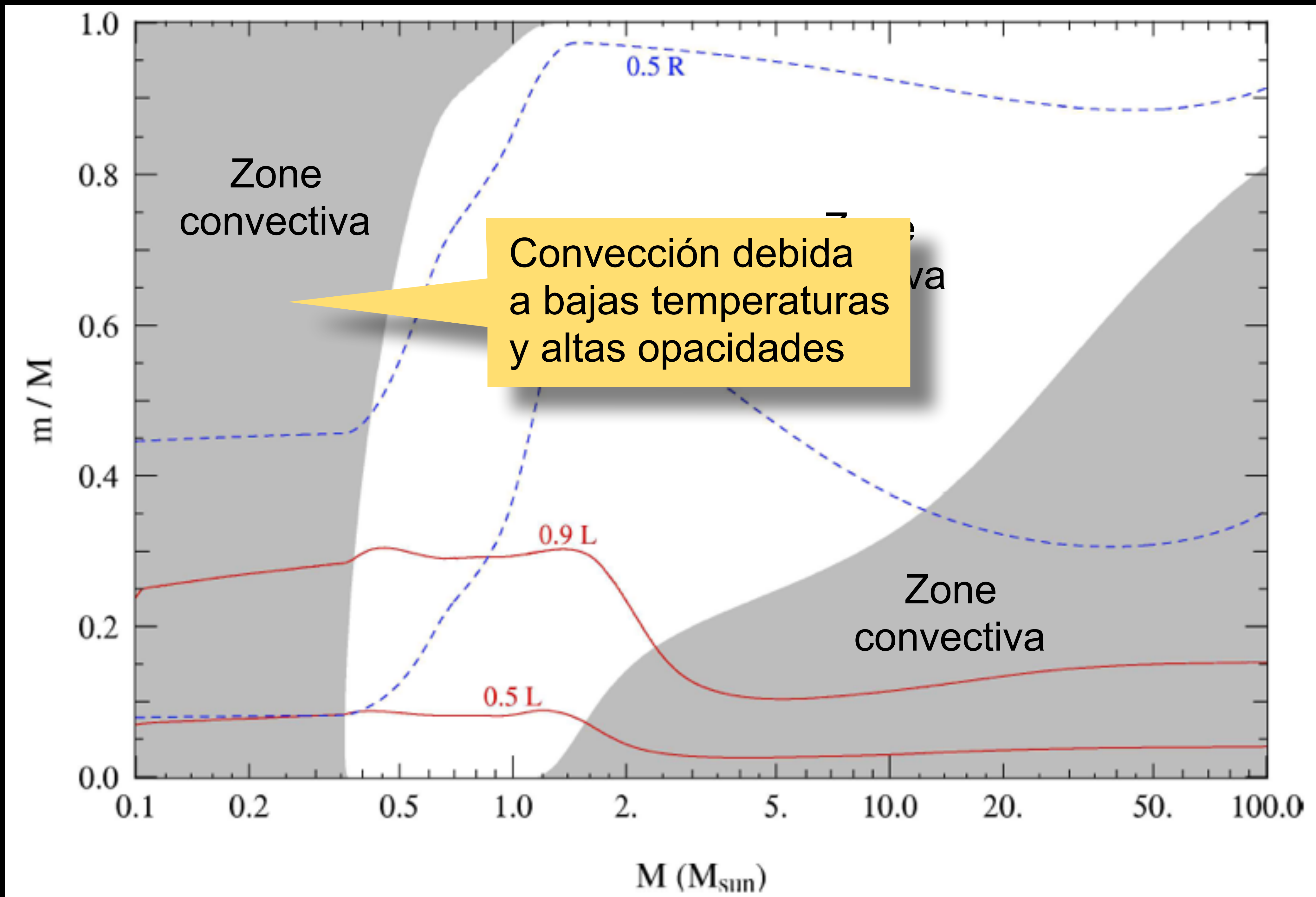
Associated Universities Inc.
Washington, DC, USA

b. 1931
(in Genoa, Italy)

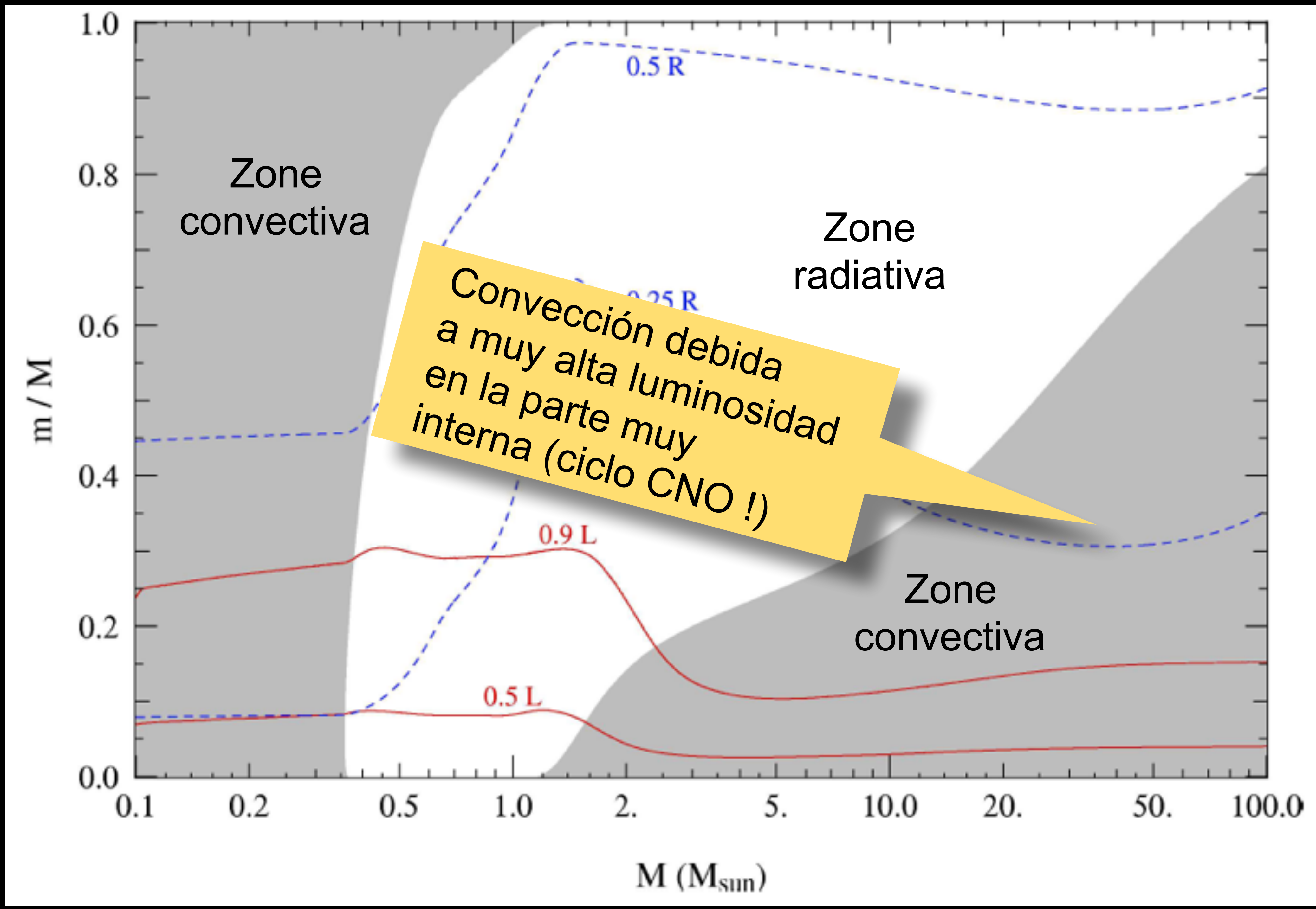
Convección en la Secuencia Principal



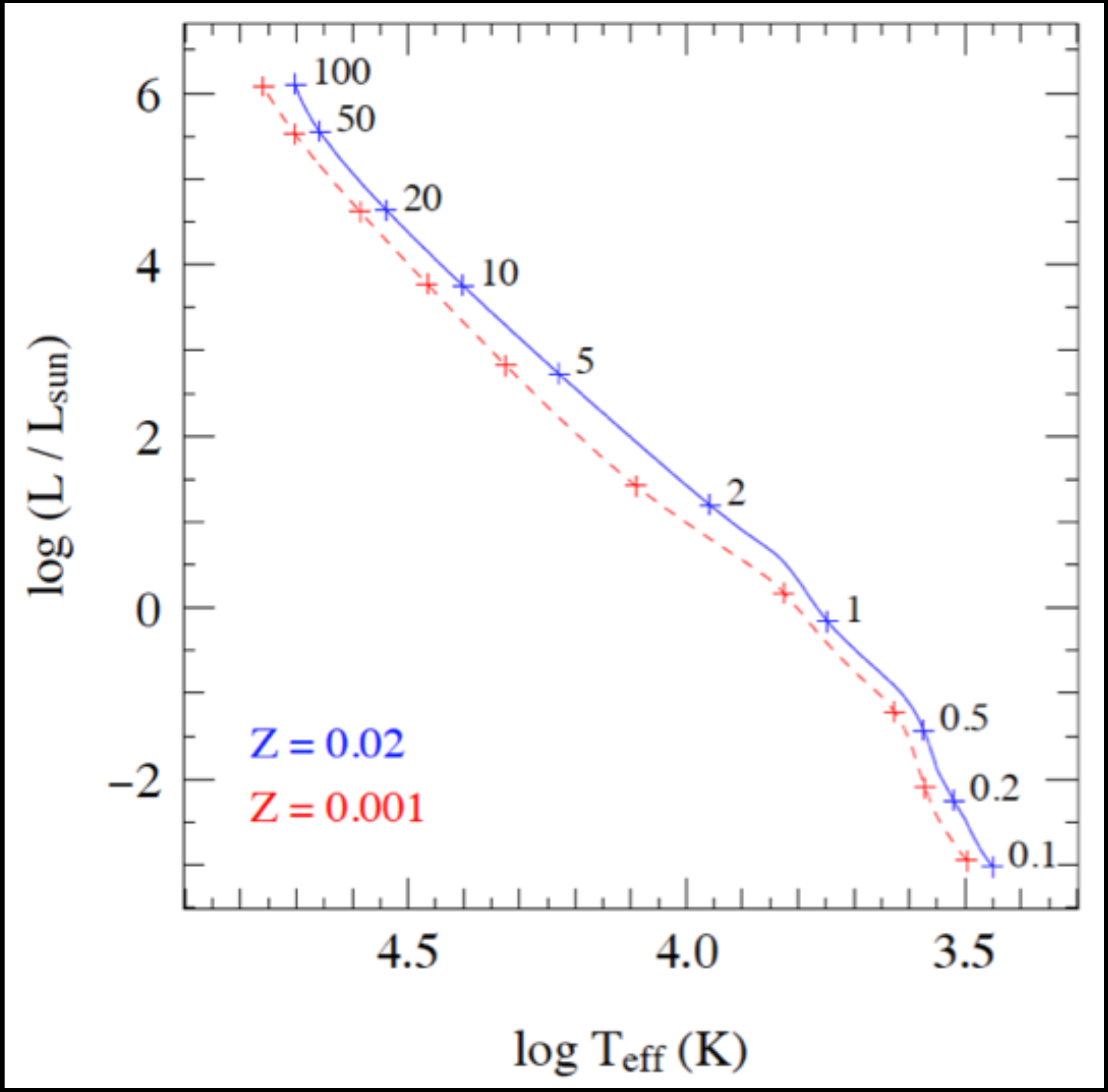
Convección en la Secuencia Principal



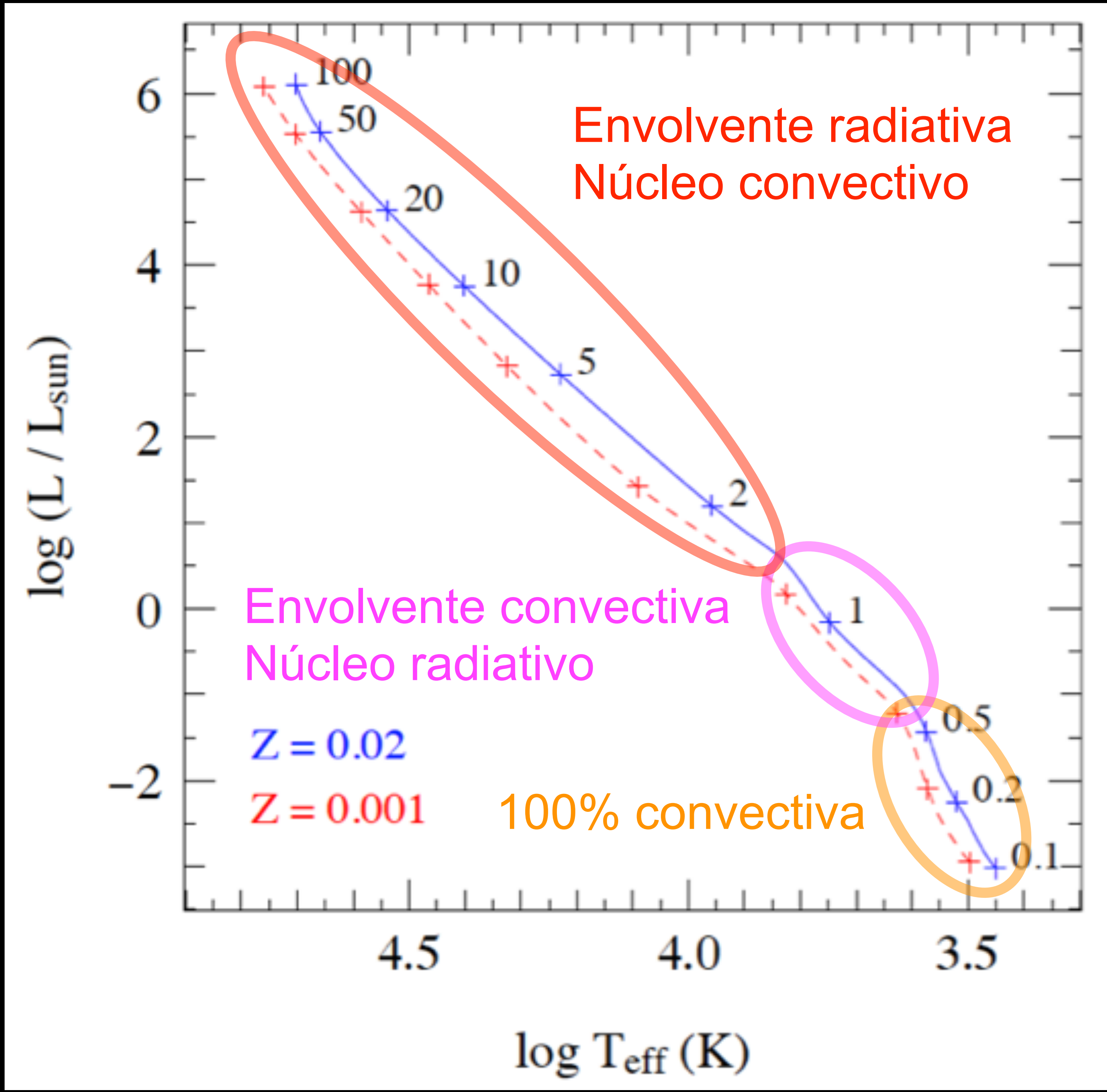
Convección en la Secuencia Principal



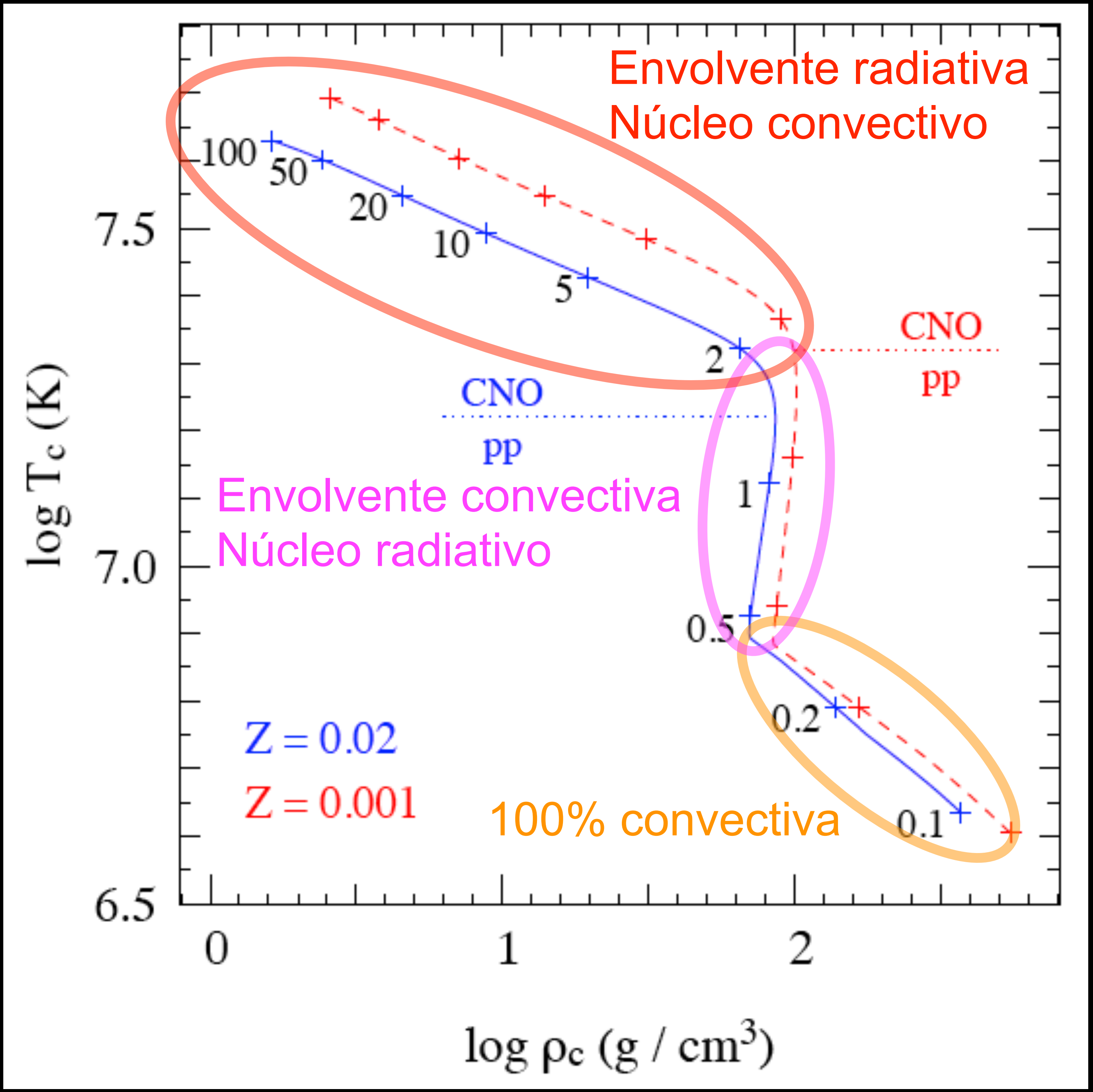
L vs T_{eff} en la Secuencia Principal Cero



L vs T_{eff} en la Secuencia Principal Cero



T_c vs ρ_c en la Secuencia Principal Cero



Secuencia Principal: Perfiles

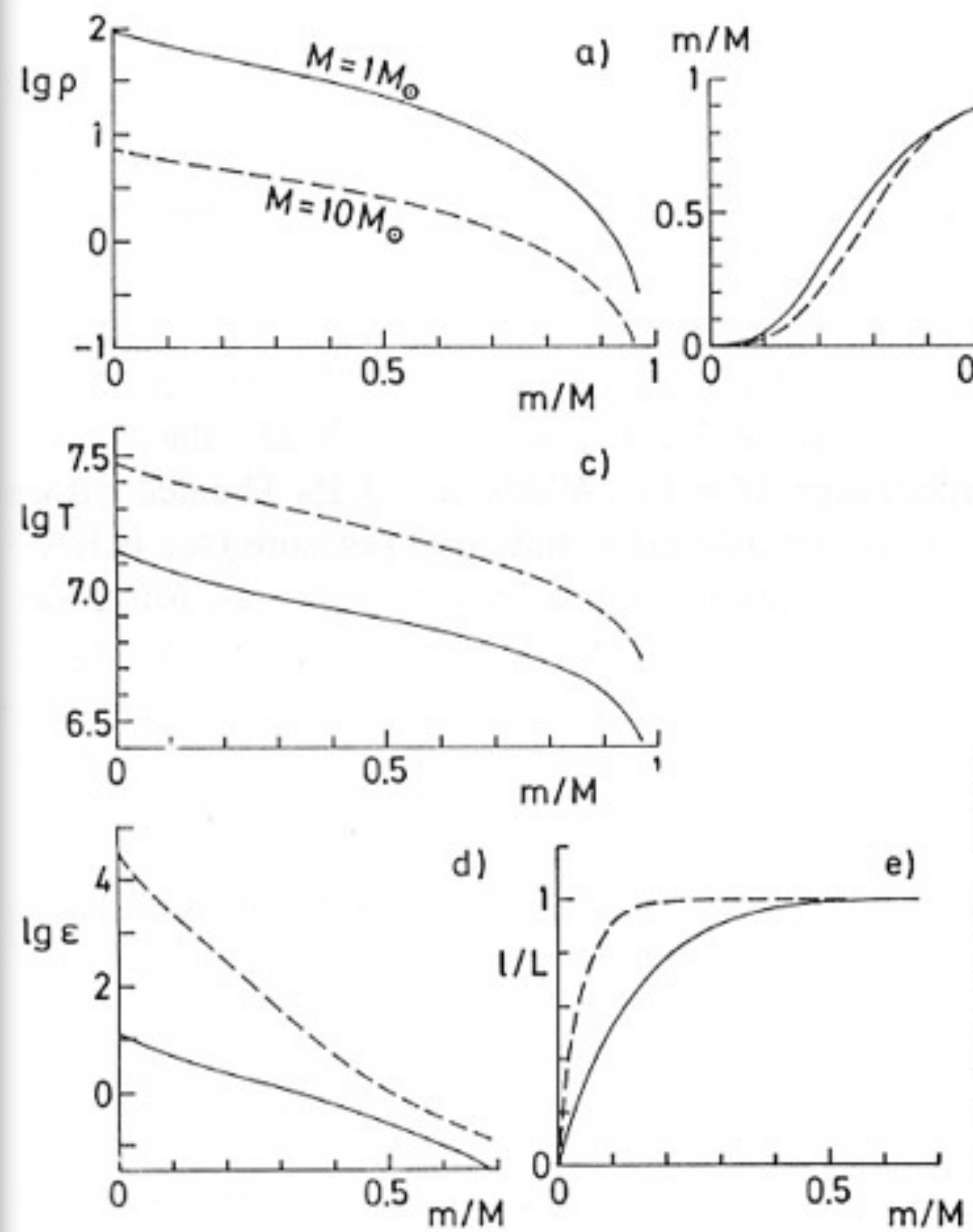


Fig. 22.4. a, b The run of some functions inside zero-age main-sequence models for $M = 1M_\odot$ (*solid lines*) and $M = 10M_\odot$ (*dashed lines*) with the same composition as in Fig. 22.1 ($X_H = 0.685$, $X_{He} = 0.294$); **(a)** density ϱ (in g cm^{-3}), **(b)** radial mass distribution $m(r)$, **(c)** temperature T (in K), **(d)** nuclear energy production (in erg g^{-1} s^{-1}), **(e)** local luminosity l

Evolución de la Fracción de H en la Secuencia Principal

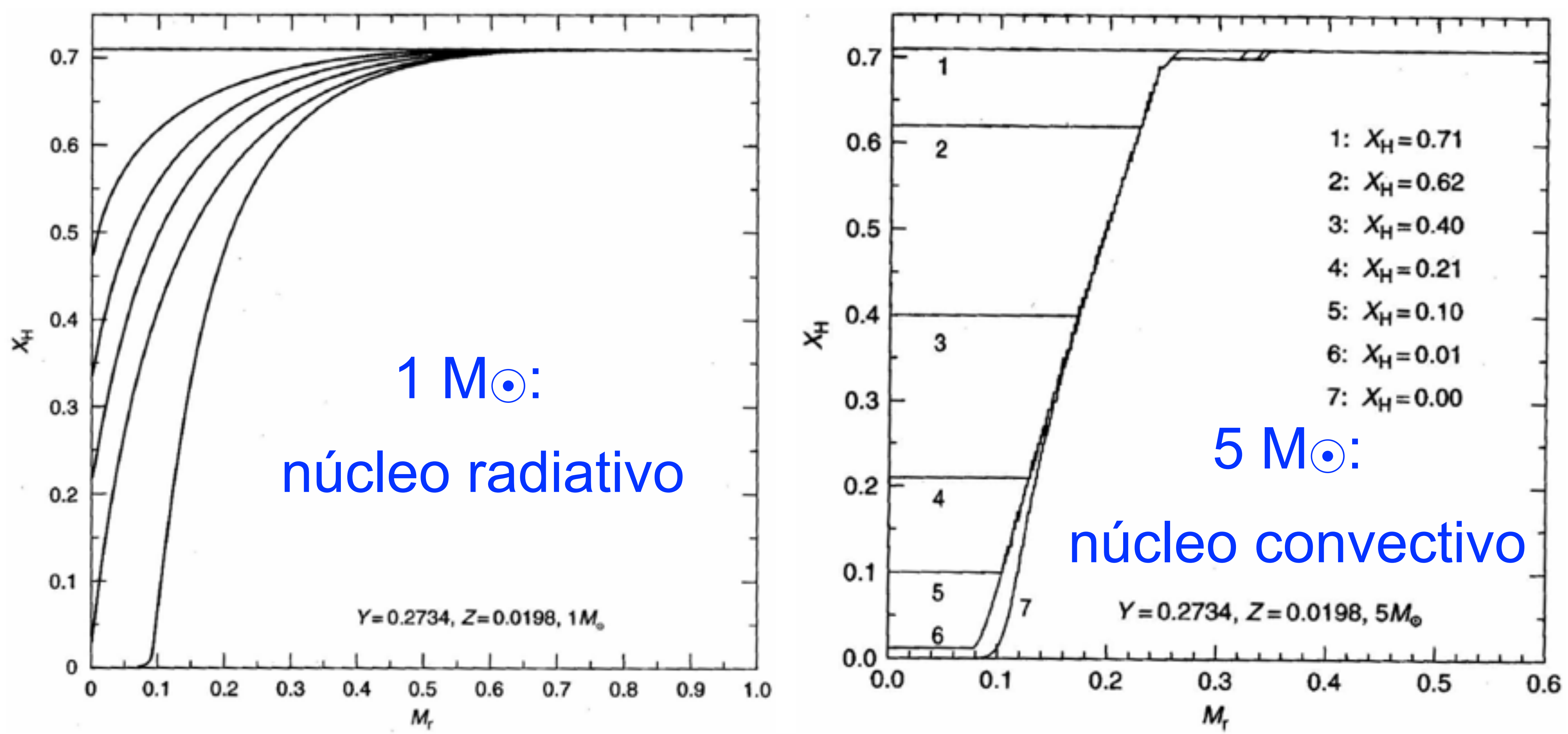


Figure 9.10. Hydrogen abundance profiles at different stages of evolution for a 1 $M_{\odot}$ star (left panel) and a 5 $M_{\odot}$ star (right panel) at quasi-solar composition. Figures reproduced from Salaris & Cassisi.

Evolución en la Secuencia Principal - 1

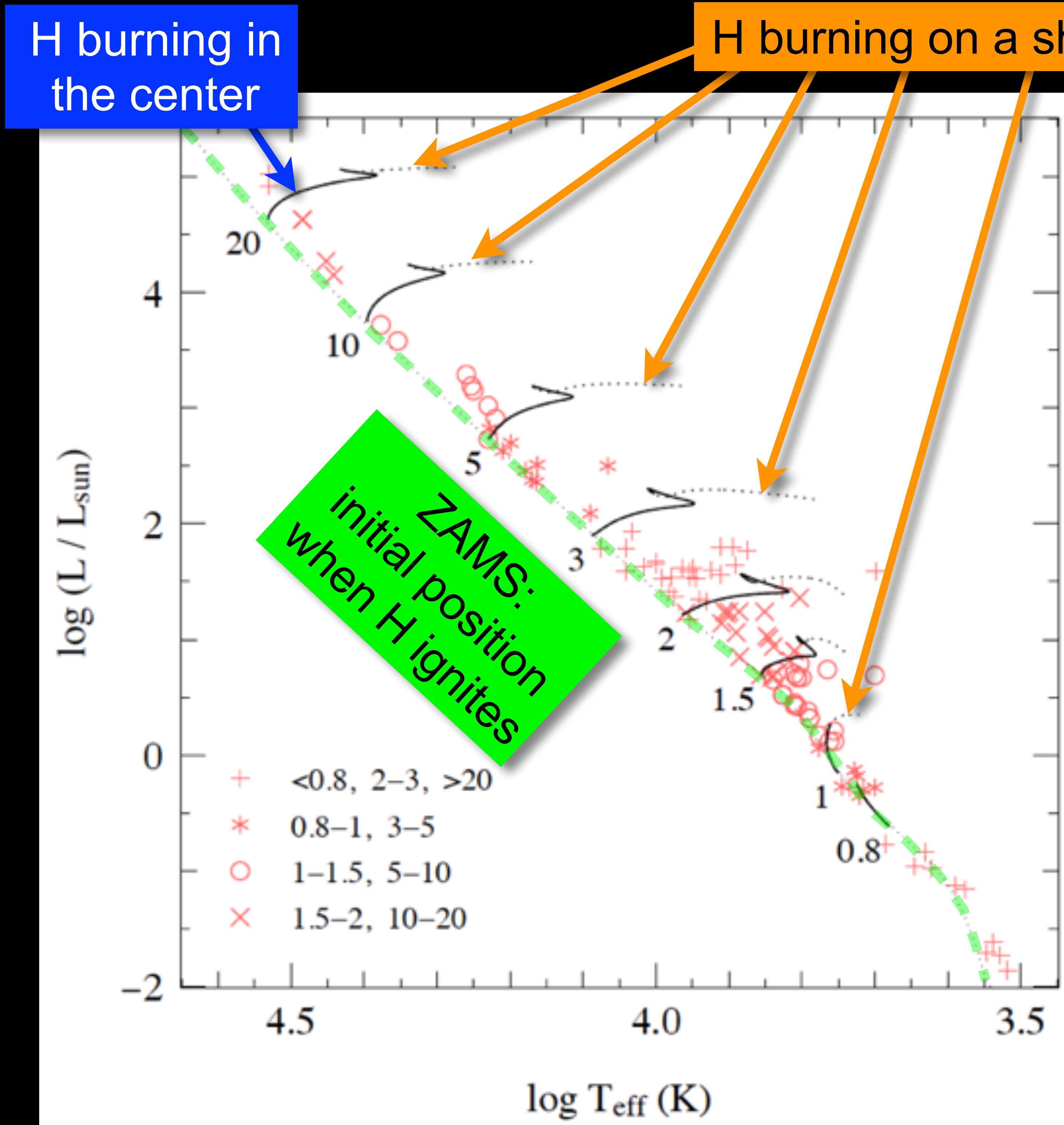
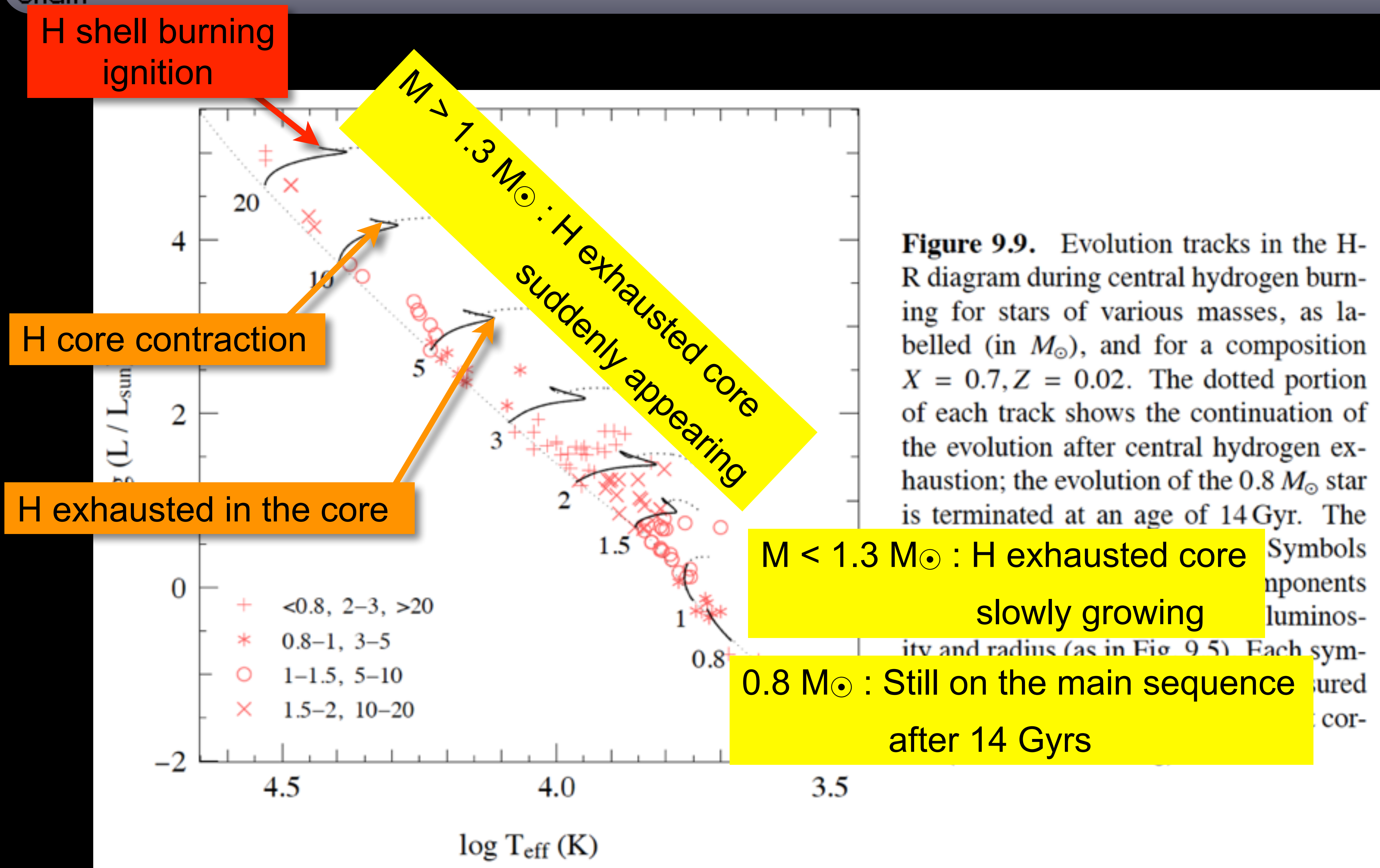
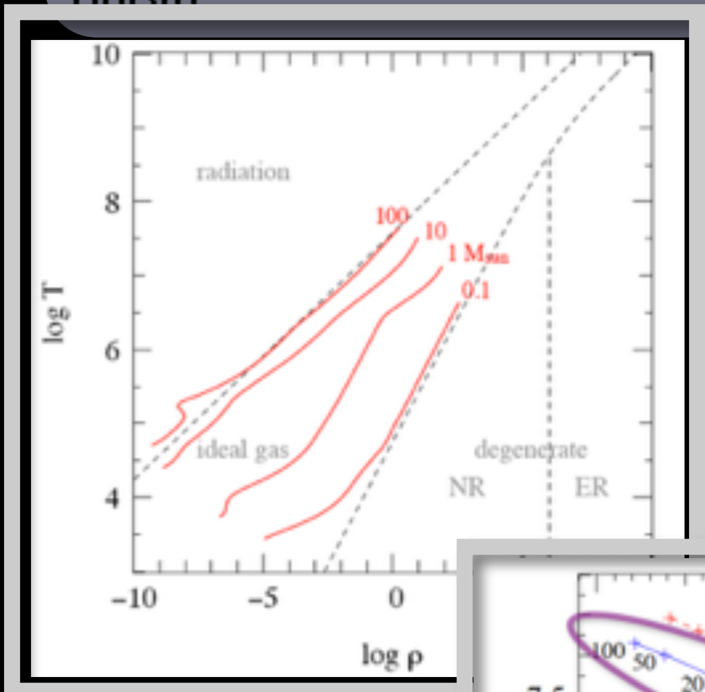


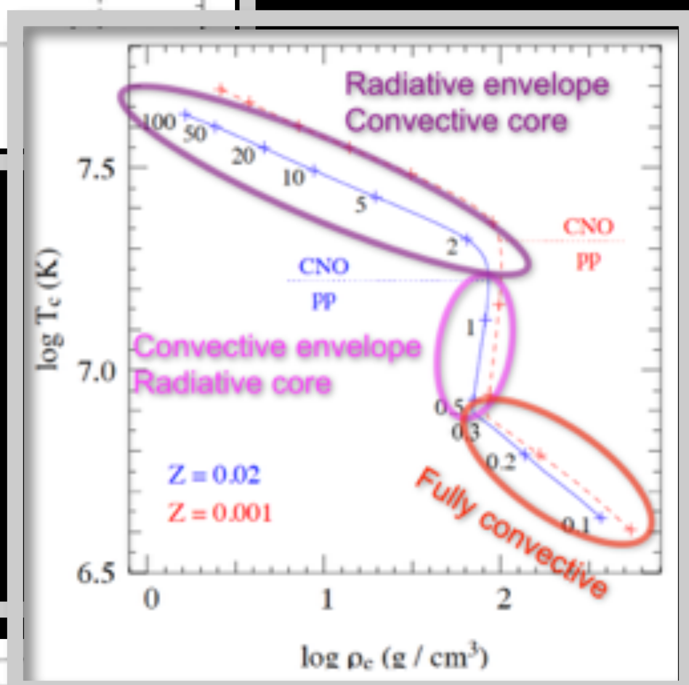
Figure 9.9. Evolution tracks in the H-R diagram during central hydrogen burning for stars of various masses, as labelled (in $M_\odot$), and for a composition $X = 0.7, Z = 0.02$. The dotted portion of each track shows the continuation of the evolution after central hydrogen exhaustion; the evolution of the 0.8 $M_\odot$ star is terminated at an age of 14 Gyr. The thin dotted line in the ZAMS. Symbols show the location of binary components with accurately measured mass, luminosity and radius (as in Fig. 9.5). Each symbol corresponds to a range of measured masses, as indicated in the lower left corner (mass values in $M_\odot$).

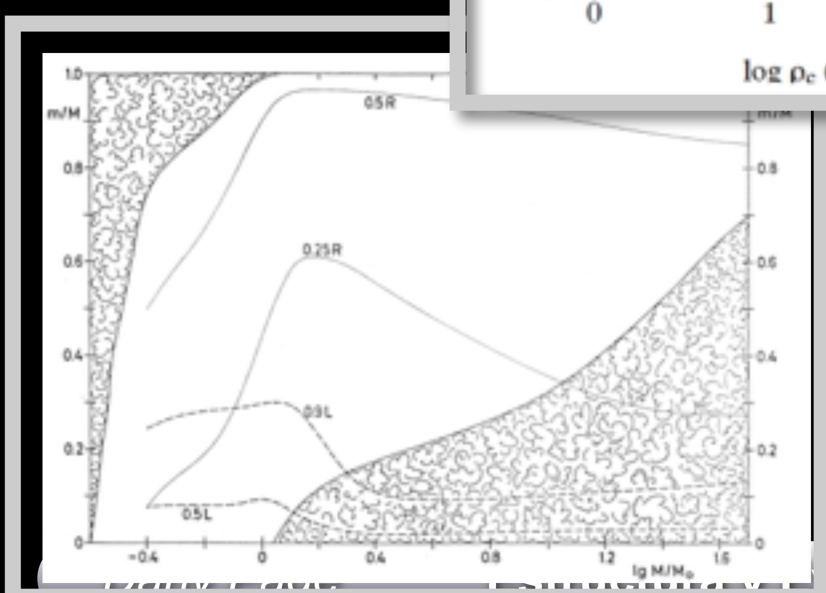
Evolución en la Secuencia Principal - 2



Masas Límites en la Secuencia Principal







~ 100 $M_\odot$: approximate upper mass above which stars are unstable (dominated by P_{rad} with γ=4/3).

~ 1.3 $M_\odot$: shift from pp chain to CNO cycle and convective envelope to convective core

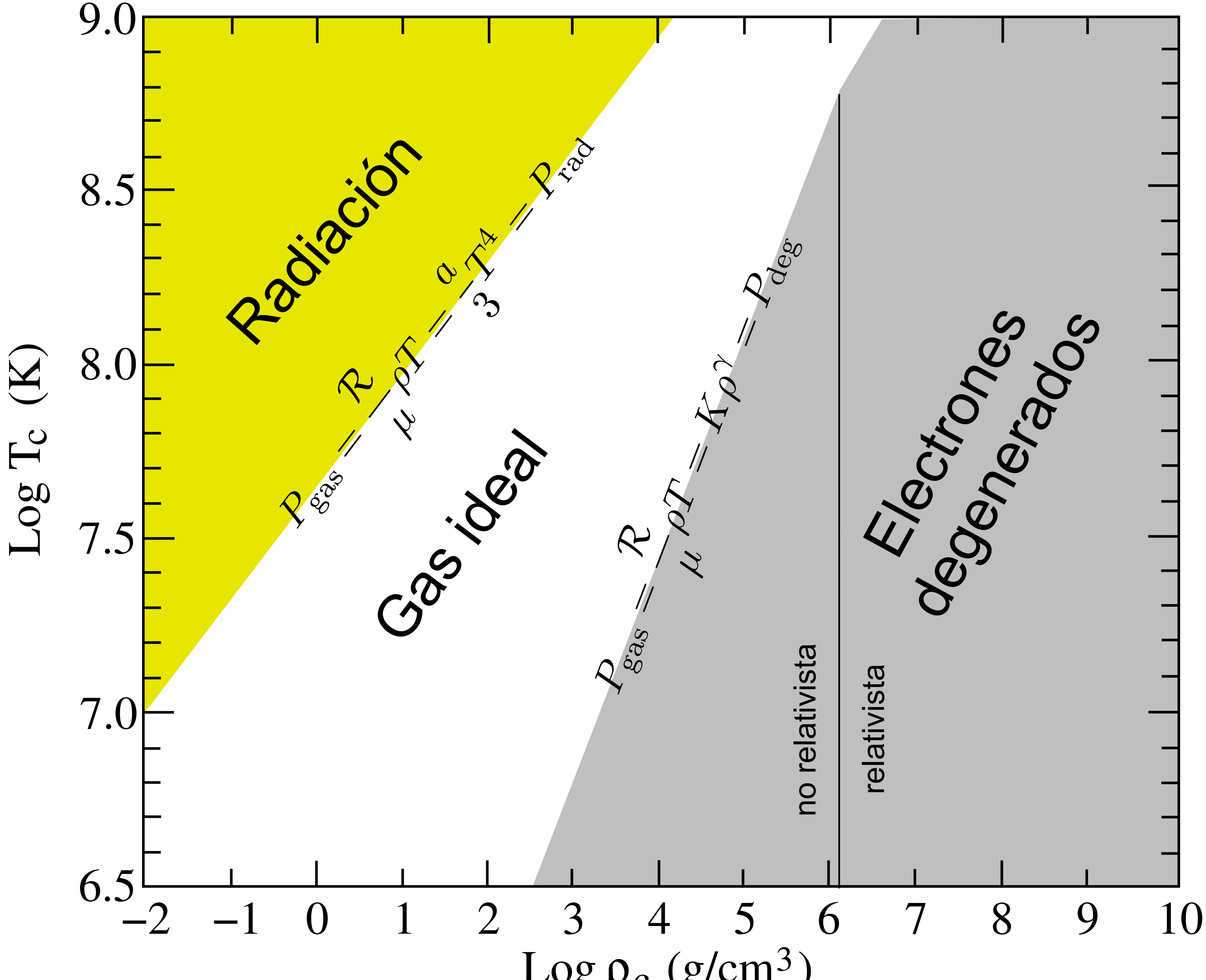
~ 0.5 $M_\odot$: shift from wholly convective to convective envelope and radiative core.

~ 0.1 $M_\odot$: below this mass T does not reach threshold for H ignition: brown dwarfs.

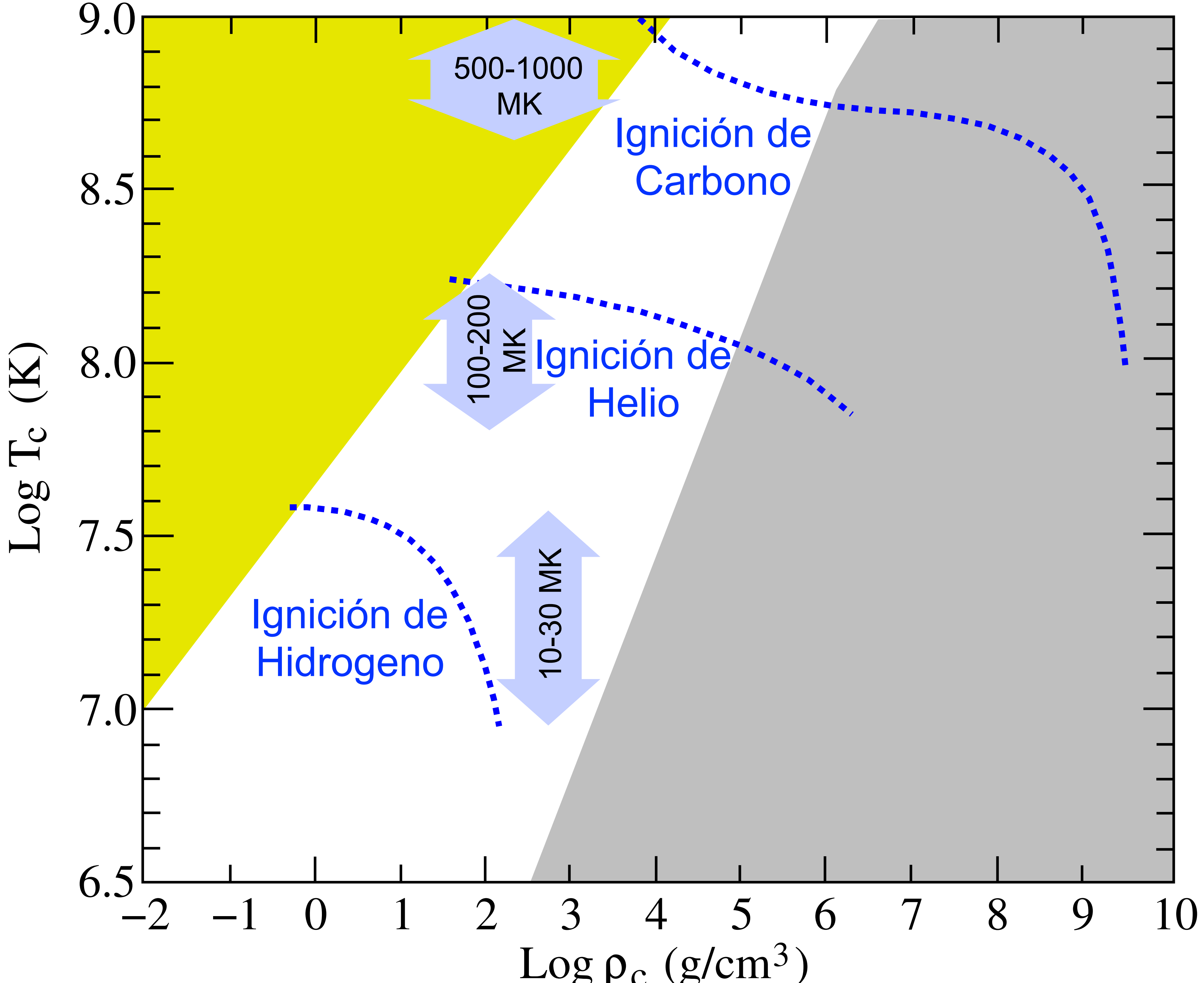
POST - SECUENCIA PRINCIPAL:
$M < 8\ M_{\odot}$

QUEMADO de He
(y también H !)

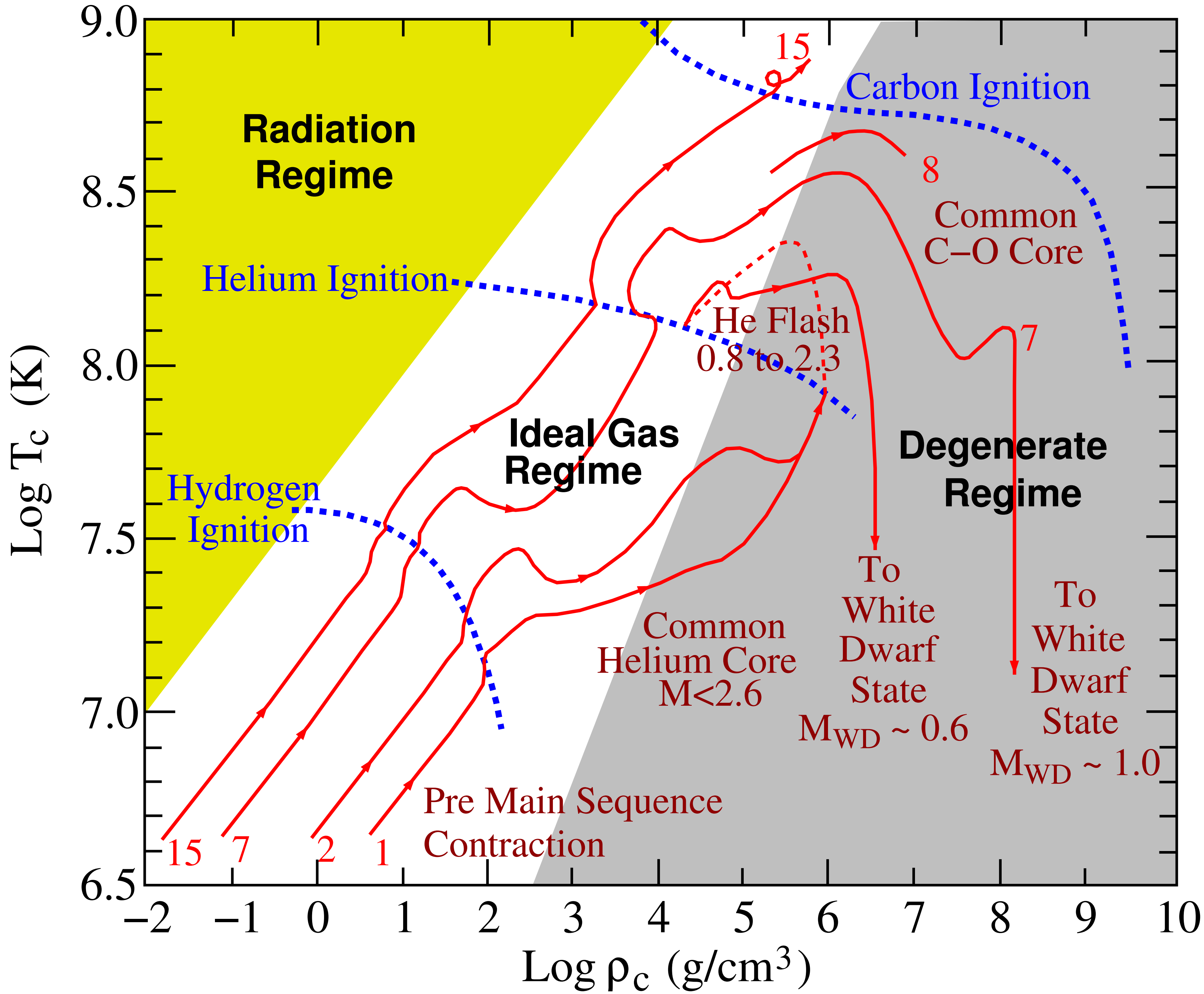
Trayectorias en el Plano T_c-ρ_c: Ecuación de Estado



Trayectorias en el Plano T_c-ρ_c: Quemado Nuclear



Trayectorias en el Plano T_c-ρ_c (final)



3 Types of Stars depending on their mass:

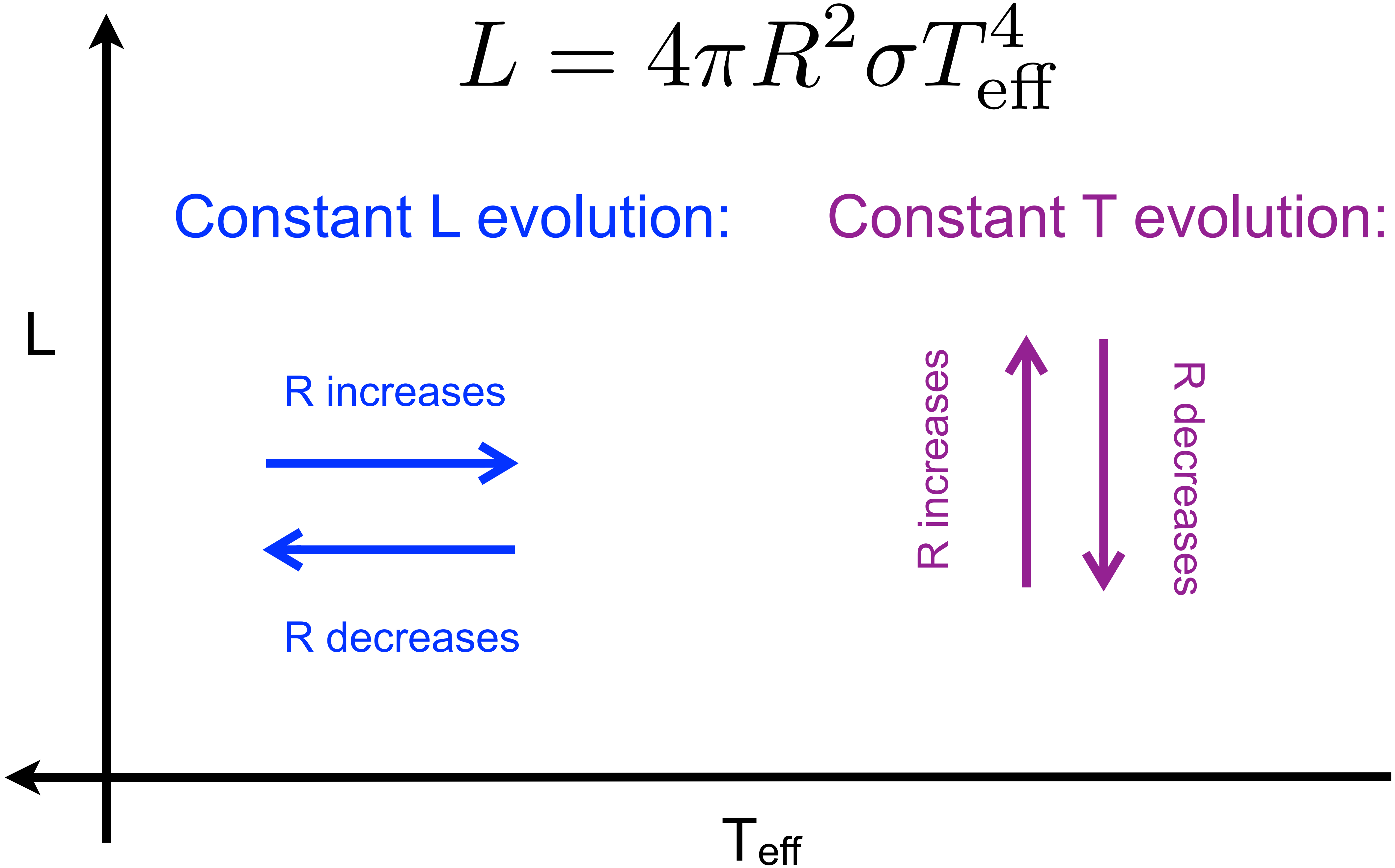
$M < 2\,M_\odot$: **low-mass stars** are those that develop a degenerate helium core after the main sequence, leading to a relatively long-lived *red giant branch* phase. The ignition of He is unstable and occurs in a so-called *helium flash*. This occurs for masses between $0.8\,M_\odot$ and $\approx 2\,M_\odot$ (this upper limit is sometimes denoted as $M_{\rm HeF}$).

$2\,M_\odot < M < 8\,M_\odot$: **intermediate-mass stars** develop a helium core that remains non-degenerate, and they ignite helium in a stable manner. After the central He burning phase they form a carbon-oxygen core that becomes degenerate. Intermediate-mass stars have masses between $M_{\rm HeF}$ and $M_{\rm up} \approx 8\,M_\odot$. Both low-mass and intermediate-mass stars shed their envelopes by a strong stellar wind at the end of their evolution and their remnants are CO white dwarfs.

$8\,M_\odot < M$: **massive stars** have masses larger than $M_{\rm up} \approx 8\,M_\odot$ and ignite carbon in a non-degenerate core. Except for a small mass range ($\approx 8-11\,M_\odot$) these stars also ignite heavier elements in the core until an Fe core is formed which collapses.

Cambios de Radio en el Diagrama H-R

$$L = 4\pi R^2 \sigma T_{\rm eff}^4$$



Trazas Evolutivas Post-Secuencia Principal

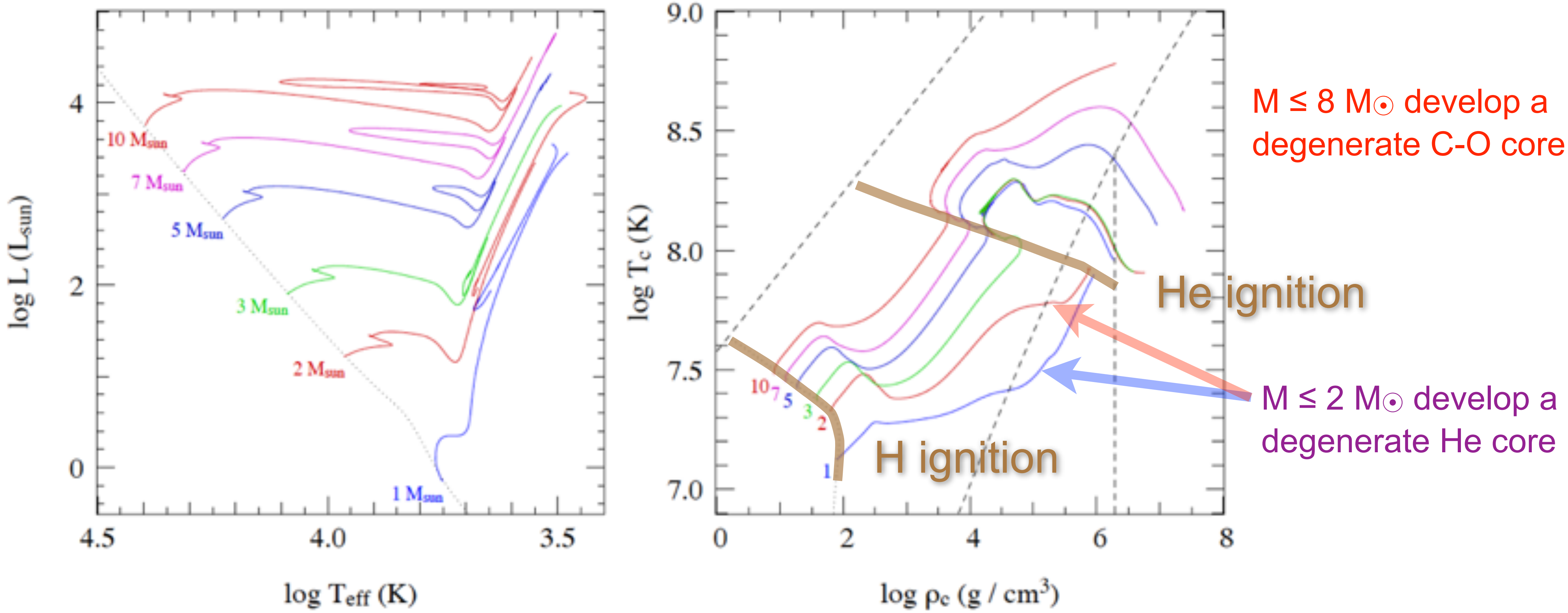
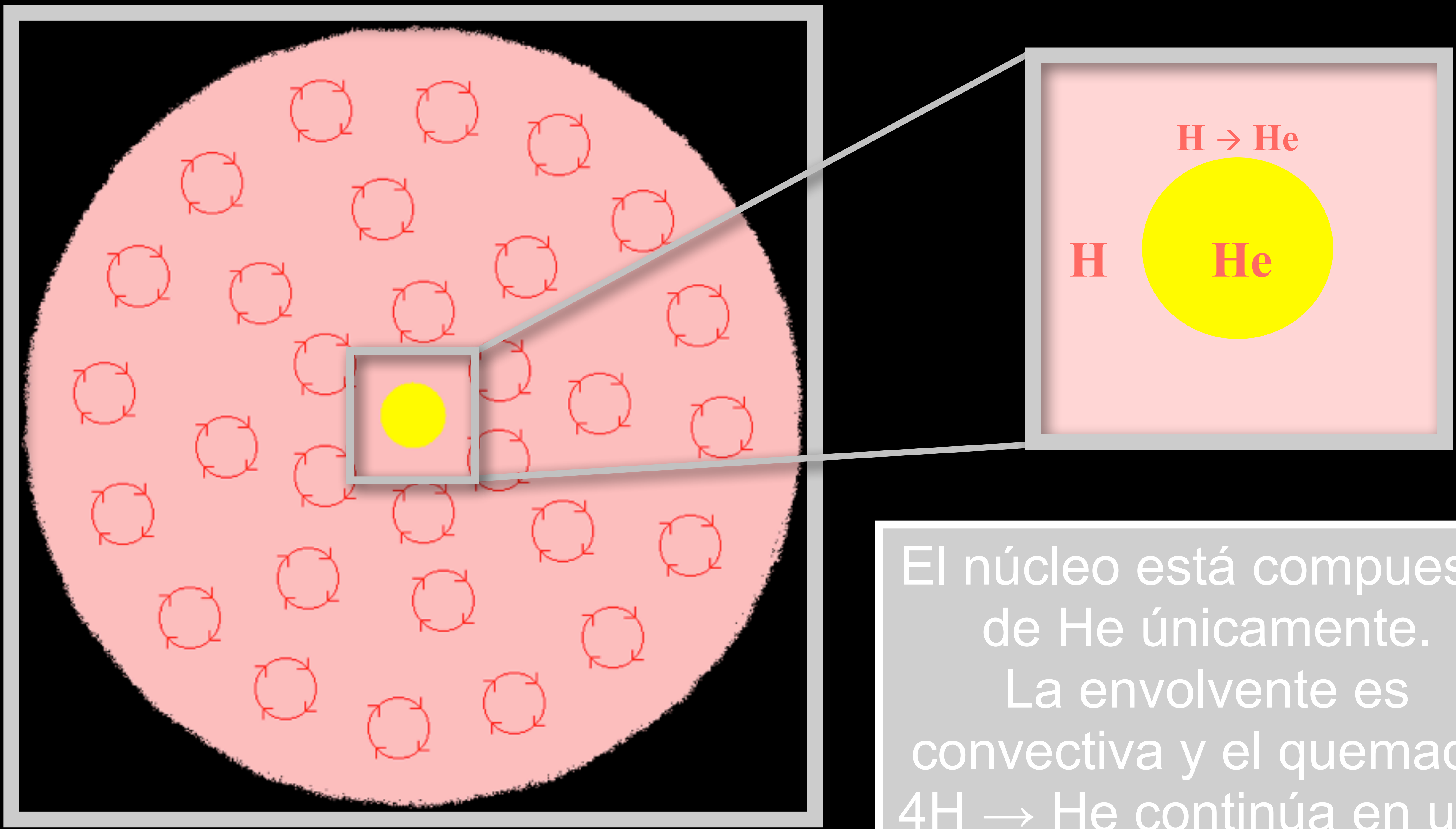


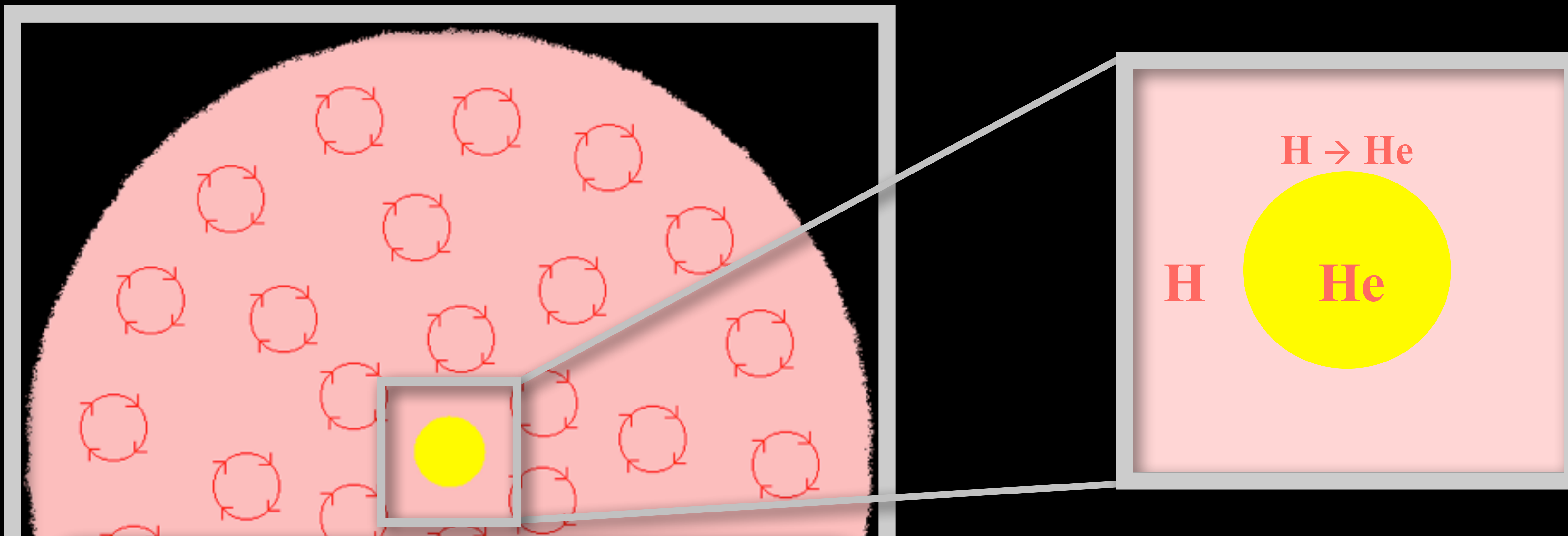
Figure 10.1. Evolution tracks for stars of quasi-solar composition ($X = 0.7$, $Z = 0.02$) and masses of 1, 2, 3, 5, 7 and 10 $M_\odot$ in the H-R diagram (left panel) and in the central temperature versus density plane (right panel). Dotted lines in both diagrams show the ZAMS, while the dashed lines in the right-hand diagram show the borderlines between equation-of-state regions (as in Fig. 3.4). The 1 $M_\odot$ model is characteristic of low-mass stars: the central core becomes degenerate soon after leaving the main sequence and helium is ignited in an unstable flash at the top of the red giant branch. When the degeneracy is eventually lifted, He burning becomes stable and the star moves to the *zero-age horizontal branch* in the HRD, at $\log L \approx 1.8$. The 2 $M_\odot$ model is a borderline case that just undergoes a He flash. The He flash itself is not computed in these models, hence a gap appears in the tracks. The 5 $M_\odot$ model is representative of intermediate-mass stars, undergoing quiet He ignition and He burning in a loop in the HRD. The appearance of the 7 and 10 $M_\odot$ models in the HRD is qualitatively similar. However, at the end of its evolution the 10 $M_\odot$ star undergoes carbon burning in the centre, while the cores of lower-mass stars become strongly degenerate. (Compare to Fig. 8.4.)

Estructura de un Gigante Roja



El núcleo está compuesto de He únicamente.
La envolvente es convectiva y el quemado 4H → He continúa en una capa

Estructura de un Gigante Roja



El terminar combustión de H en el núcleo este se contrae y se calienta:

Contracción
⇒ degeneración

Calentamiento
⇒ la capa de quemado 4H→He es muy caliente
⇒ alta luminosidad

El núcleo está compuesto de He únicamente.
La envolvente es convectiva y el quemado 4H → He continúa en una capa

Post-Secuencia Principal: 1M⊙
A: Quemado de H en Capa

A: ZAMS

B: $X_{center} \approx 10^{-3}$: star contracts

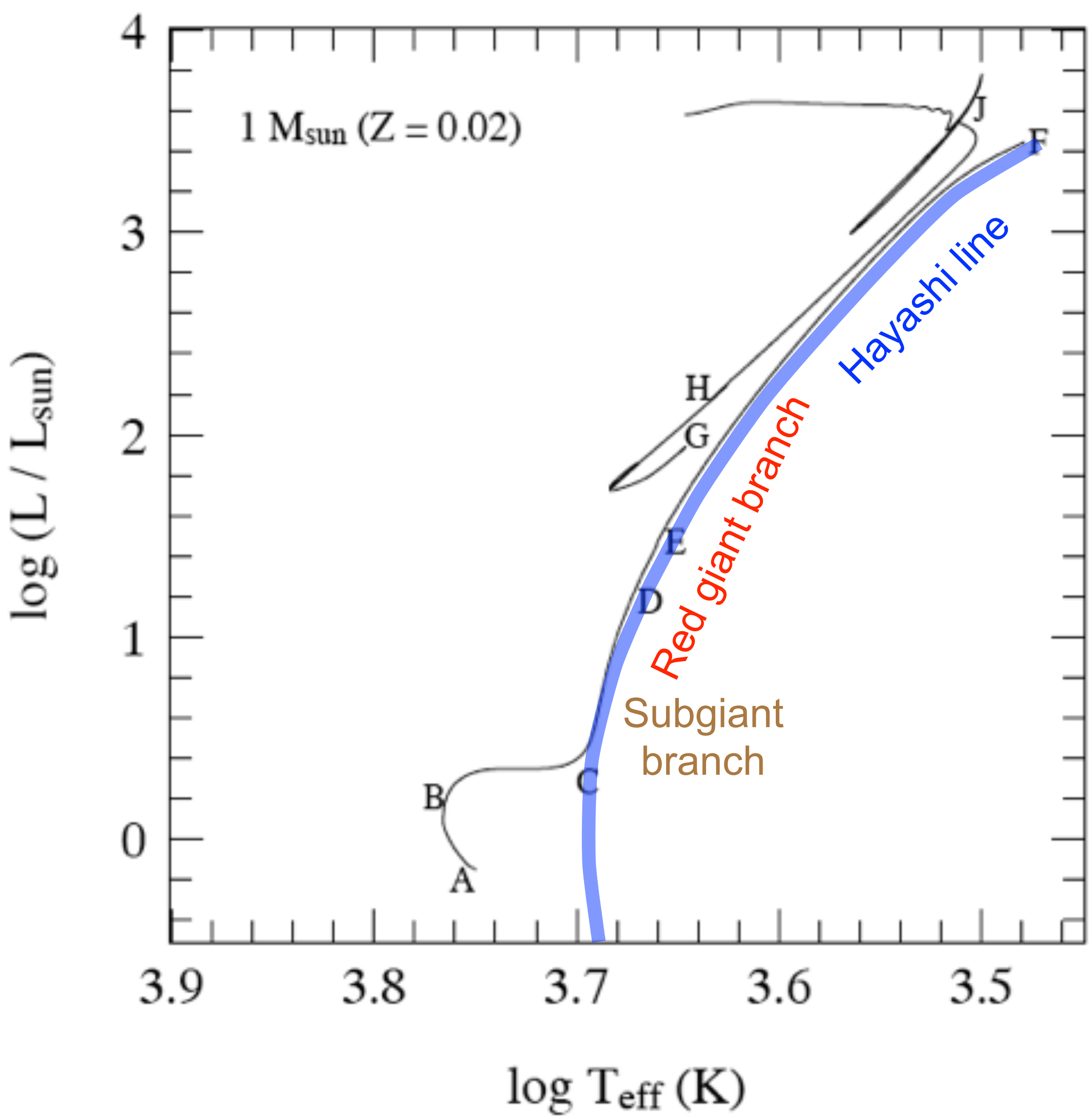
B-C: H burning in a thick shell
He core grows and slowly contracts
⇒ Envelope expands and stars moves toward Hayashi line.
Star in hydrostatic & thermal equilibrium:
B-C last 2×10^9 yrs.

C: He core is degenerate
Initially $M_c < M_{SC}$ and when $M_c > M_{SC}$ core is degenerate: no SC limit and no Hertzsprung gap for low mass stars.

Evolution on the RG branch depends only on the He core mass.

F: $M_c = 0.45\ M_\odot$ and $T_c = 10^8$K:

Helium ignition in a **degenerate** core
⇒ Helium flash



Post-Secuencia Principal: $1M_\odot$
B: Quemado de He en el Núcleo

instituto de astronomia
unam

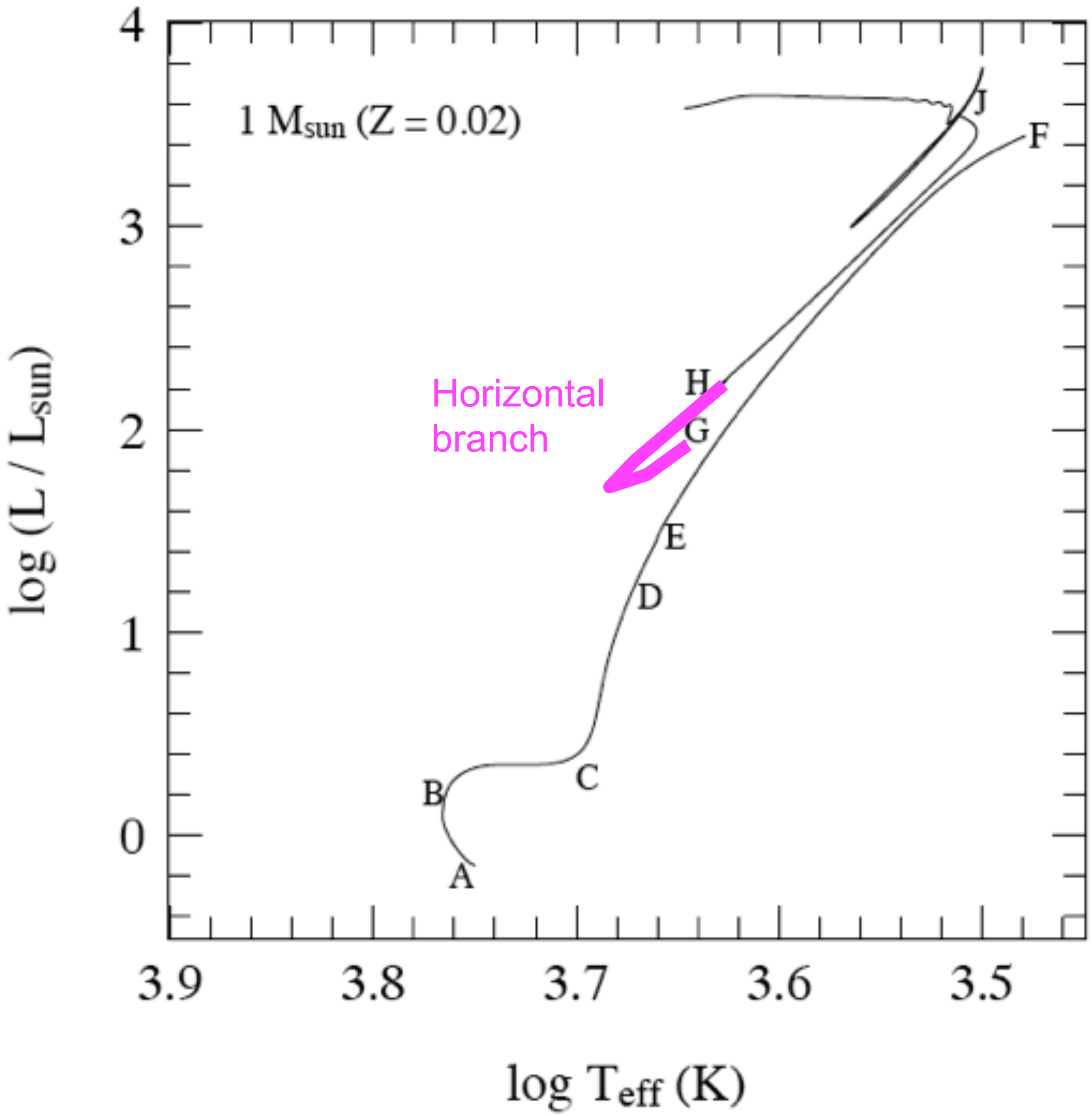
F: $M_c = 0.45\ M_\odot$ and $T_c = 10^8$K:

Helium ignition in a **degenerate** core
⇒ Helium flash

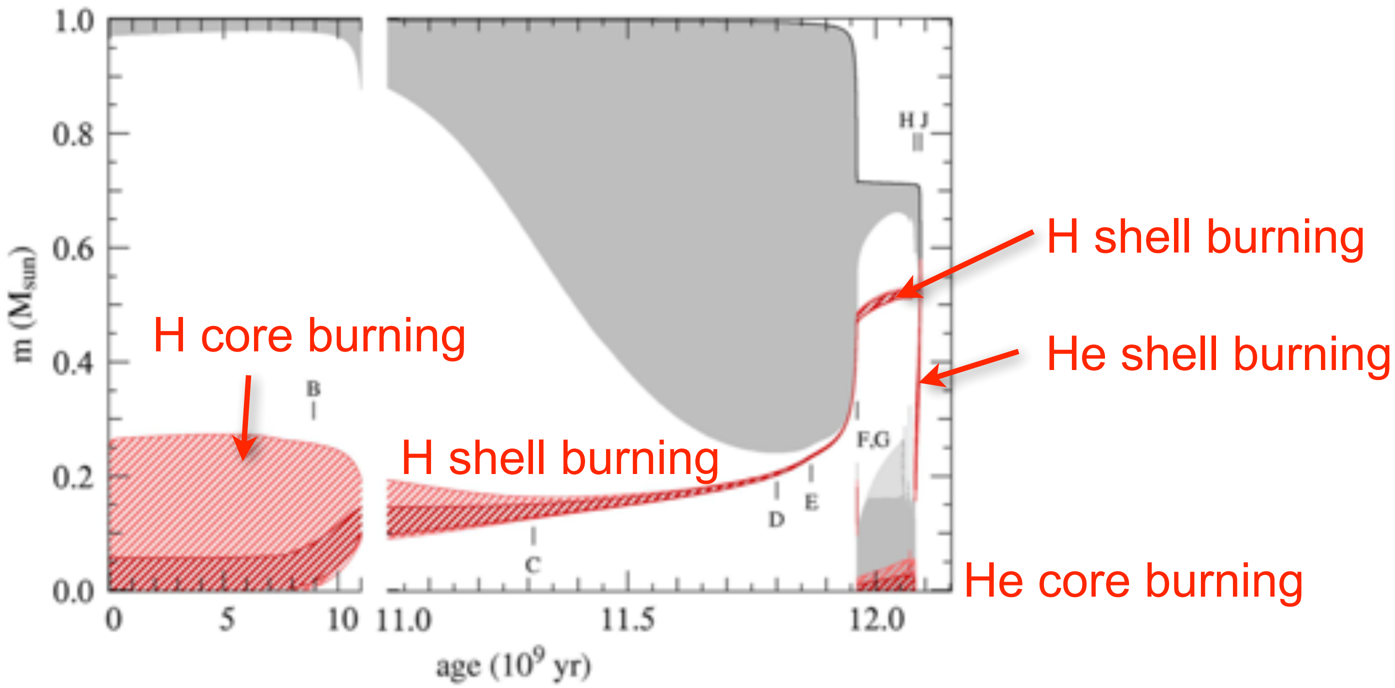
L ~ $10_{10} L_\odot$! For a few seconds only.

G-H: Helium core burning in a non degenerate core.

H: He exhaustion in the core



Post-Secuencia Principal: 1M☉
Estructura Interna



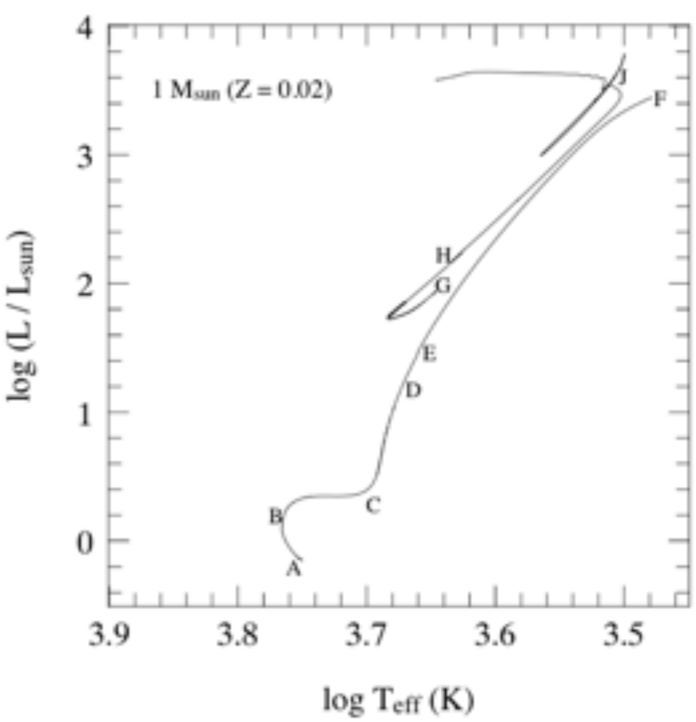


Figure 10.5. Evolution of a 1 $M_\odot$ star of initial composition $X = 0.7$, $Z = 0.02$. The top panel (a) shows the internal structure as a function of mass coordinate m. Gray areas are convective, lighter-gray areas are semi-convective. The red hatched regions show areas of nuclear energy generation: $\epsilon_{nuc} > 5\,L/M$ (dark red) and $\epsilon_{nuc} > L/M$ (light red). The letters A…J indicate corresponding points in the evolution track in the H-R diagram, plotted in the bottom panel (b). See text for details.

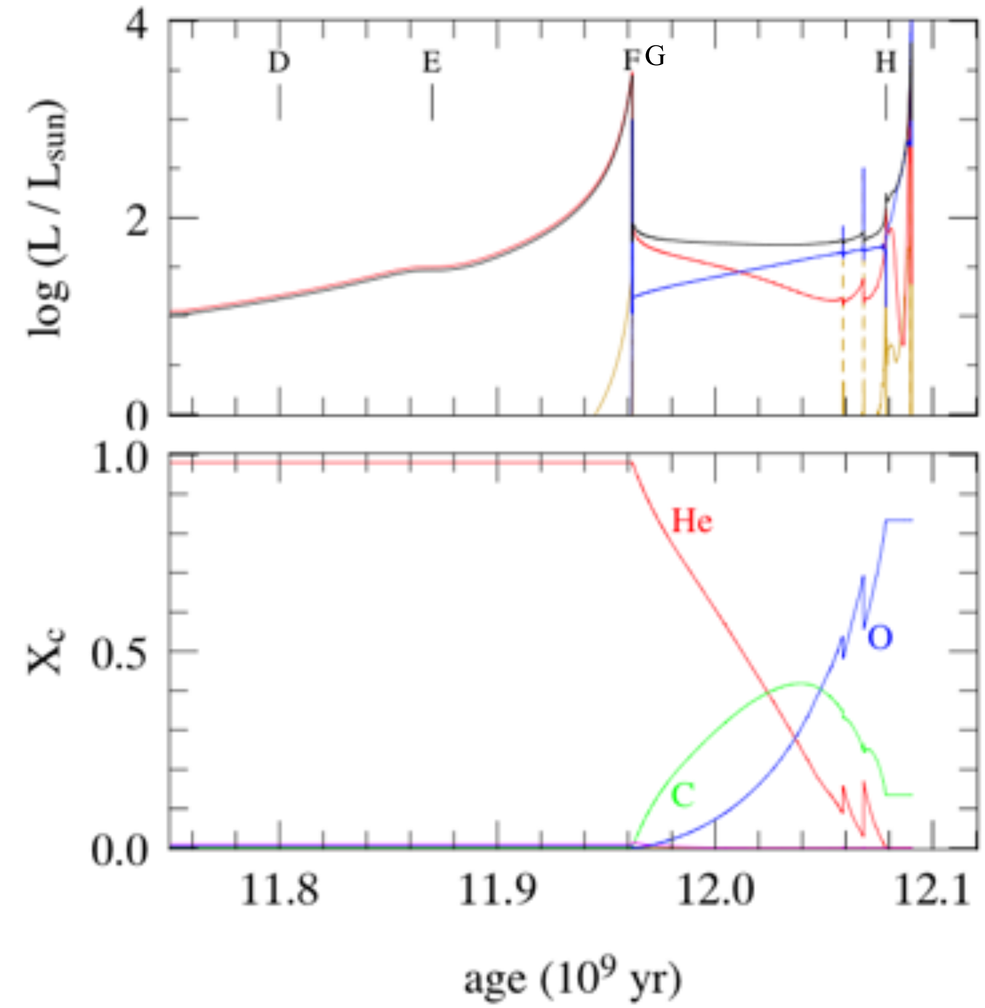


Figure 10.8. Evolution with time of the luminosities and central abundances in a 1 $M_\odot$ star during the late part of the red giant branch and during helium burning. Letters D…H correspond to the same evolution phases as in Fig. 10.5.

Masas Límites Pos-Secuencia Principal

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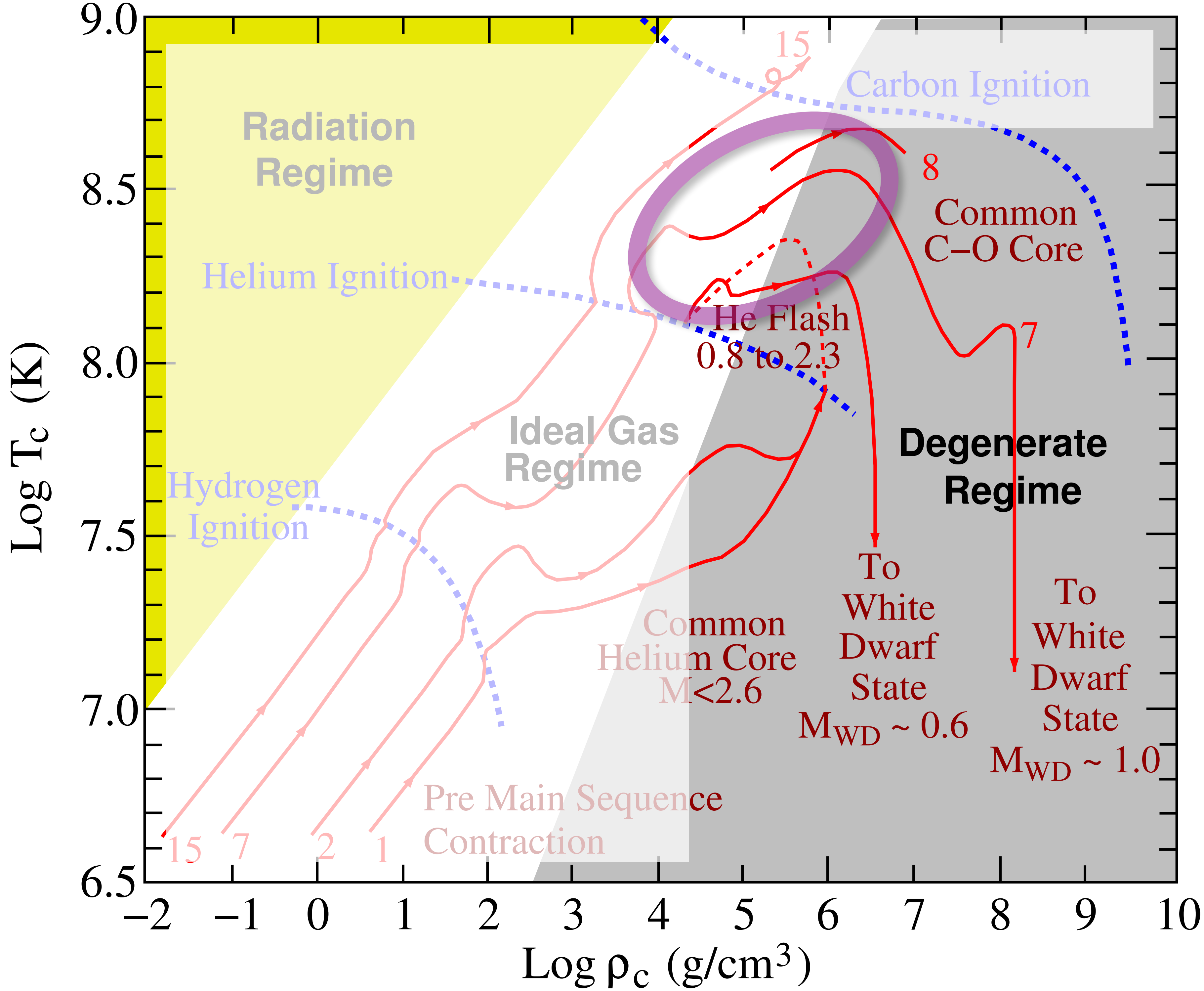
M < 2 M$_\odot$: **low-mass stars** are those that develop a degenerate helium core after the main sequence, leading to a relatively long-lived *red giant branch* phase. The ignition of He is unstable and occurs in a so-called *helium flash*. This occurs for masses between 0.8 $M_\odot$ and ≈ 2 $M_\odot$ (this upper limit is sometimes denoted as $M_{\rm HeF}$).

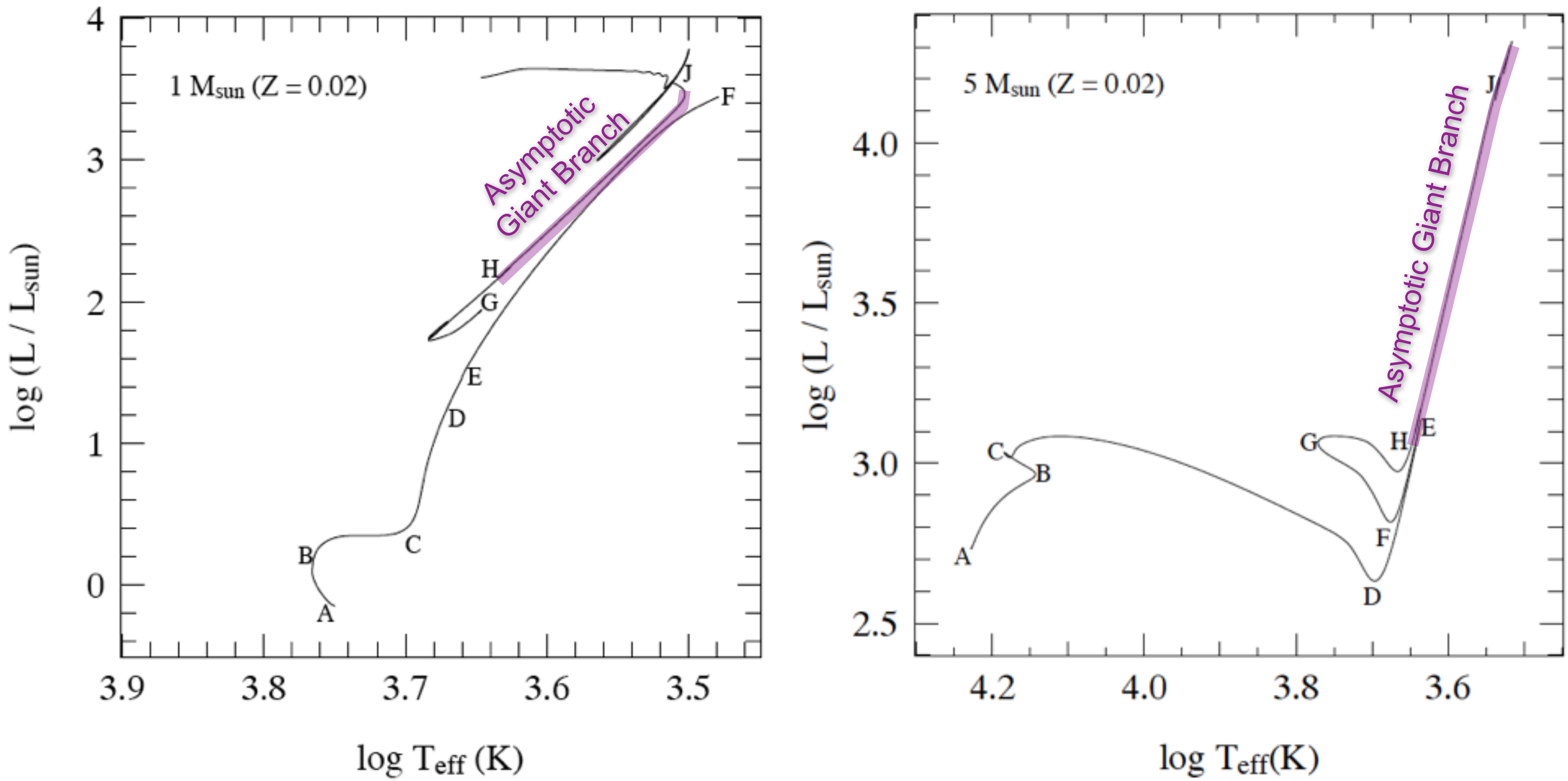
2 M$_\odot$ < M < 8 M$_\odot$: **intermediate-mass stars** develop a helium core that remains non-degenerate, and they ignite helium in a stable manner. After the central He burning phase they form a carbon-oxygen core that becomes degenerate. Intermediate-mass stars have masses between $M_{\rm HeF}$ and $M_{\rm up} \approx 8\,M_\odot$. Both low-mass and intermediate-mass stars shed their envelopes by a strong stellar wind at the end of their evolution and their remnants are CO white dwarfs.

8 M$_\odot$ < M : **massive stars** have masses larger than $M_{\rm up} \approx 8\,M_\odot$ and ignite carbon in a non-degenerate core. Except for a small mass range (≈ 8 – 11 $M_\odot$) these stars also ignite heavier elements in the core until an Fe core is formed which collapses.

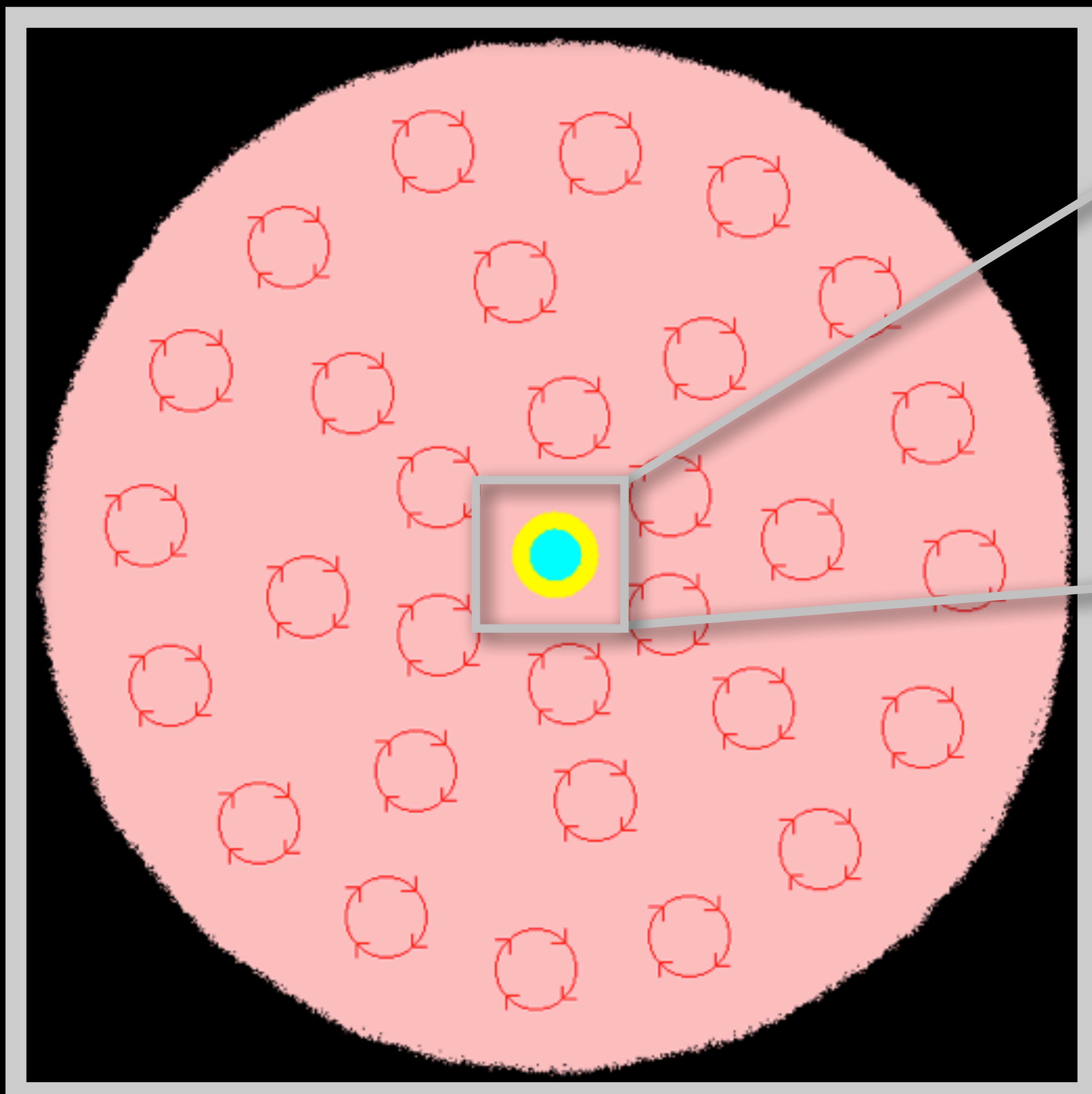
Evolución Tardia: Quemado de He en Capa

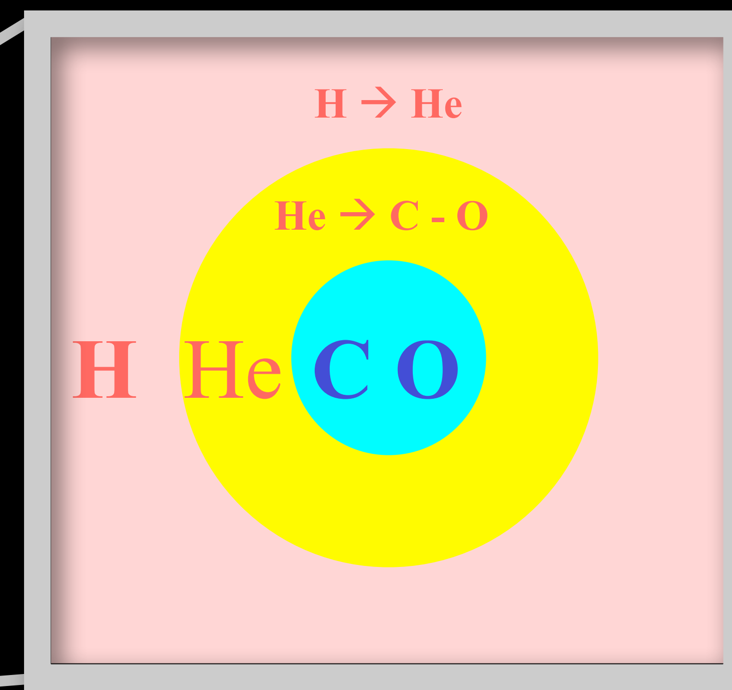


Rama Asintotica de las Gigantes



Estructura de una Gigante de la Rama Asintotica





El núcleo está compuesto de C y O, rodeado de una capa de He.
La envolvente es convectiva y los quemados 4H → He y 3H → C continúan en capas (estructura de "cebolla")

Evolución Evolución Comparativa

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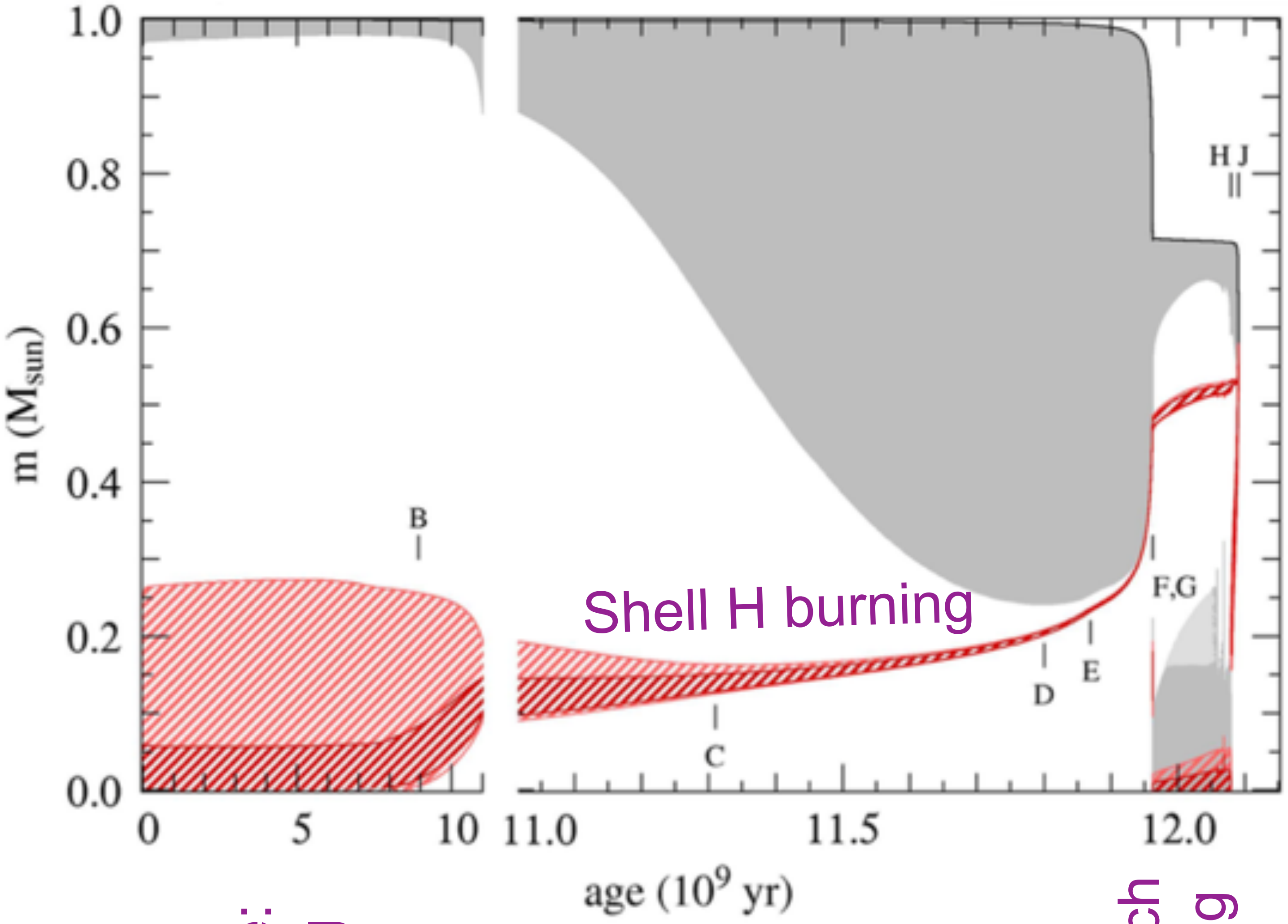
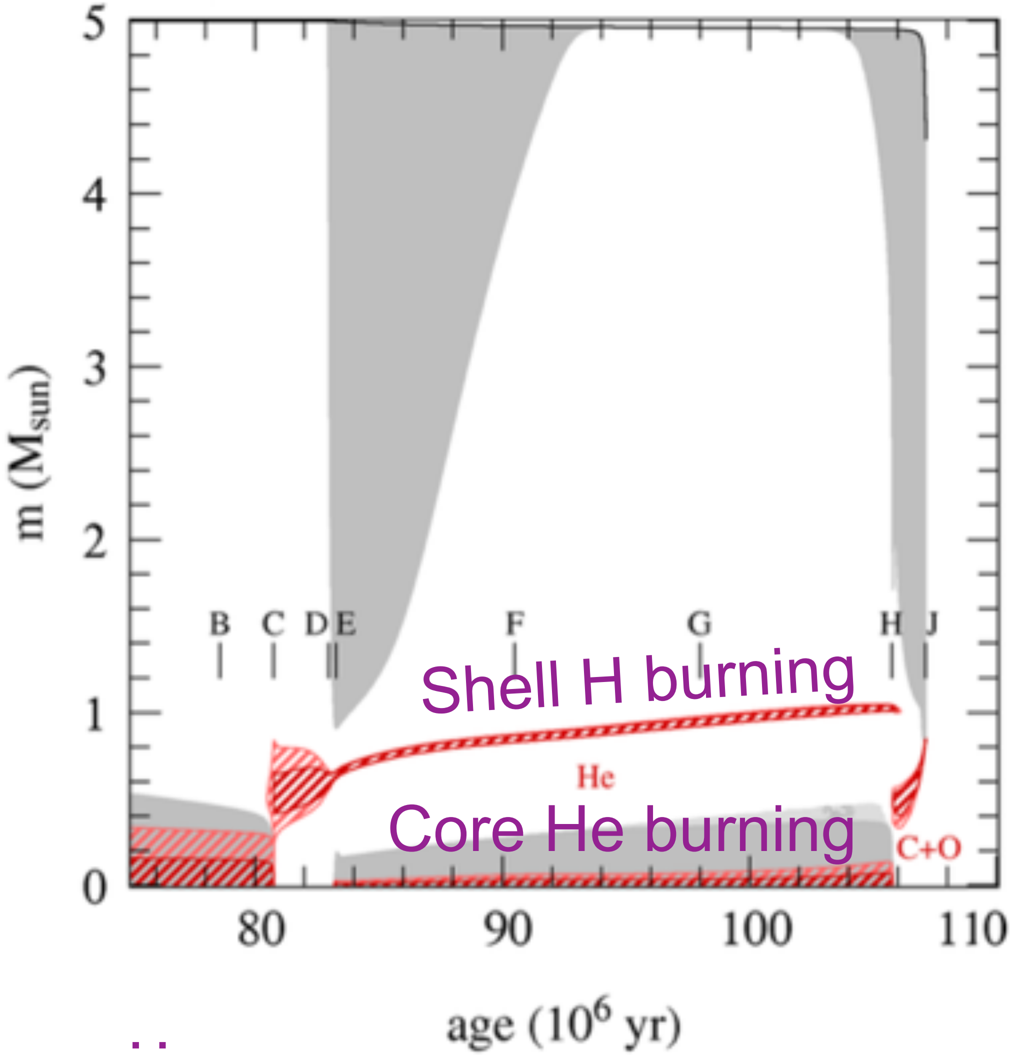
1 M☉



5 M☉

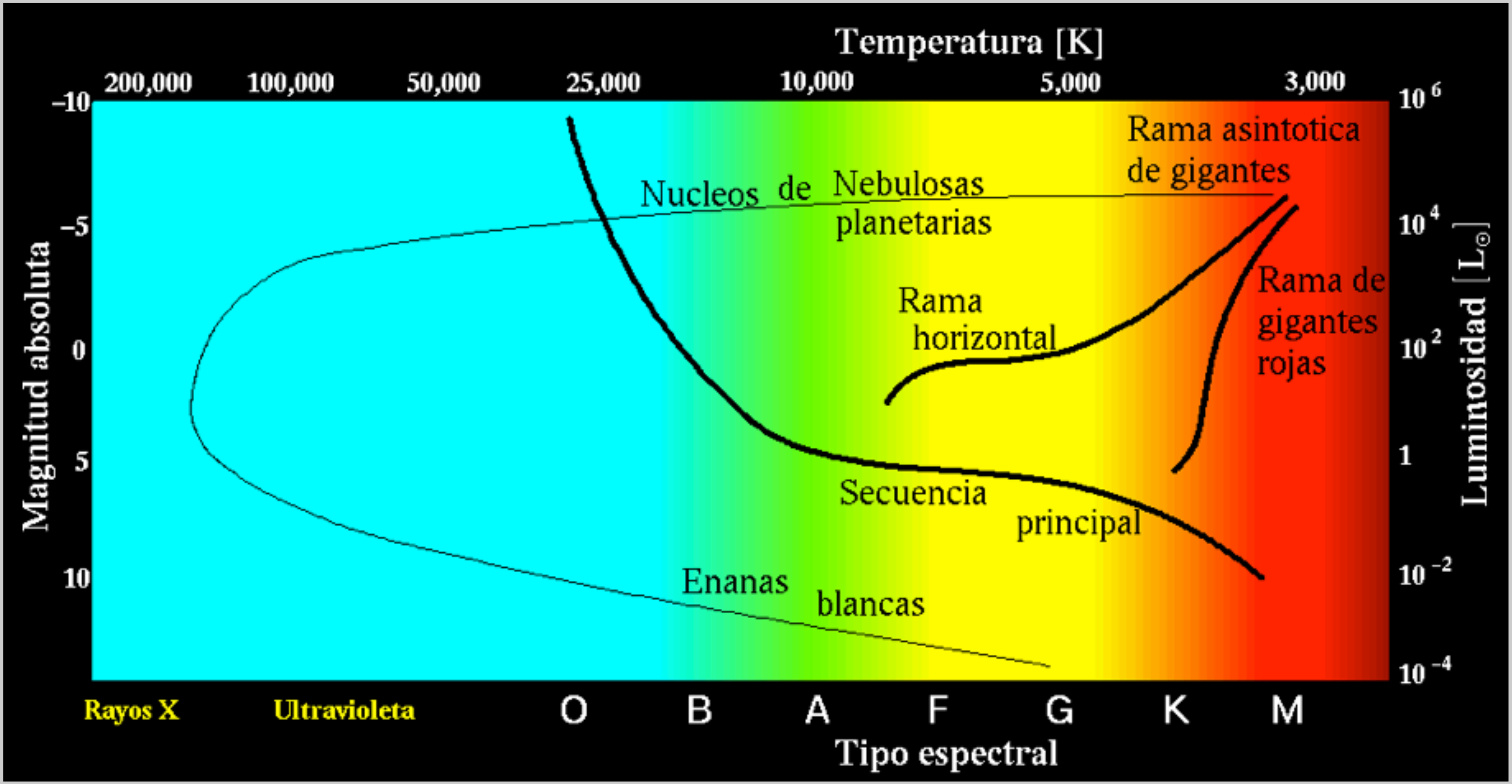


Main sequence:
core H burning

Horizontal branch
Core He burning

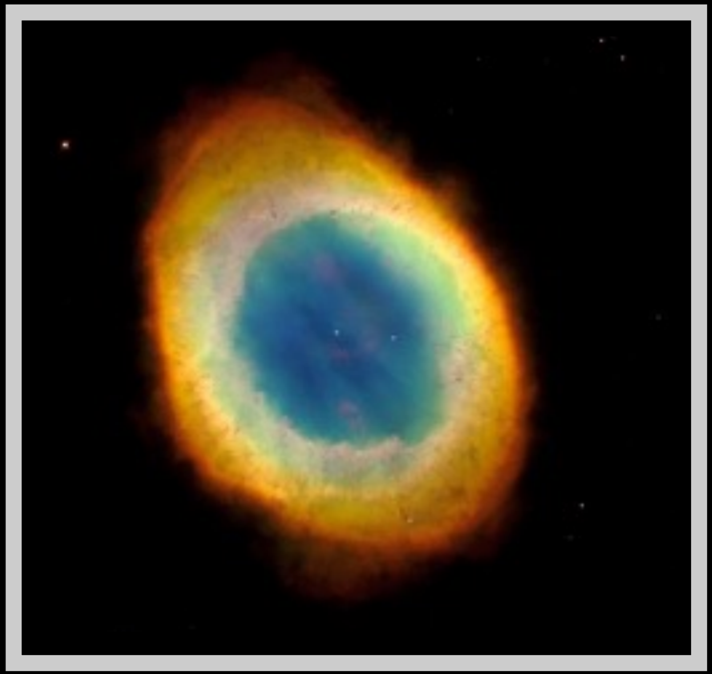
Main sequence:
core H burning

Fin de las Estrellas de Masa M < 8M$_\odot$



M < 8 M$_{Sol}$: Nebulosa Planetaria → Enana Blanca

Nebulosas Planetarias



M57

“Saturno”

“El Esquimal”

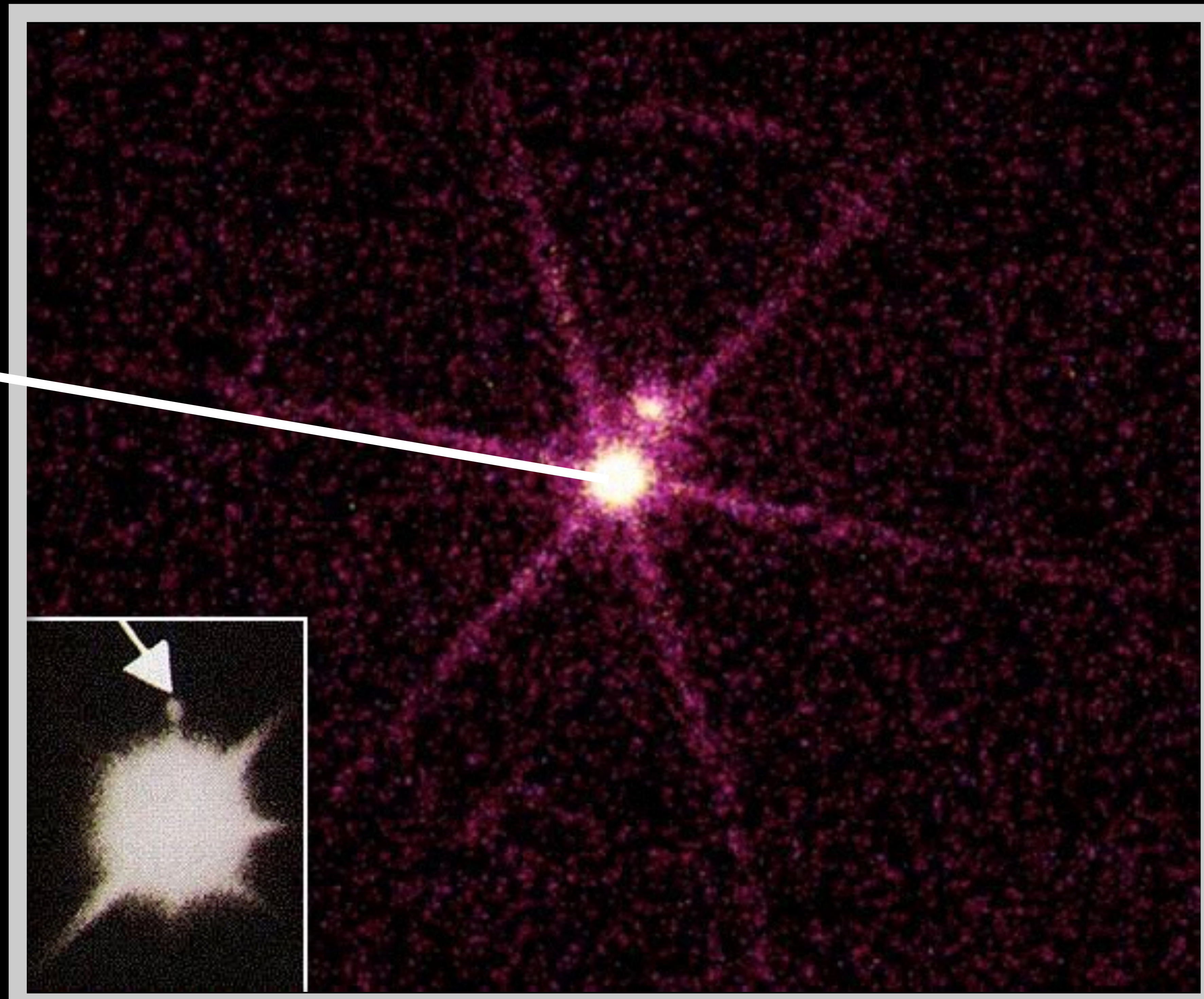
“Ojo de Gato”

“El Reloj de Arena”

“El Espirografo”

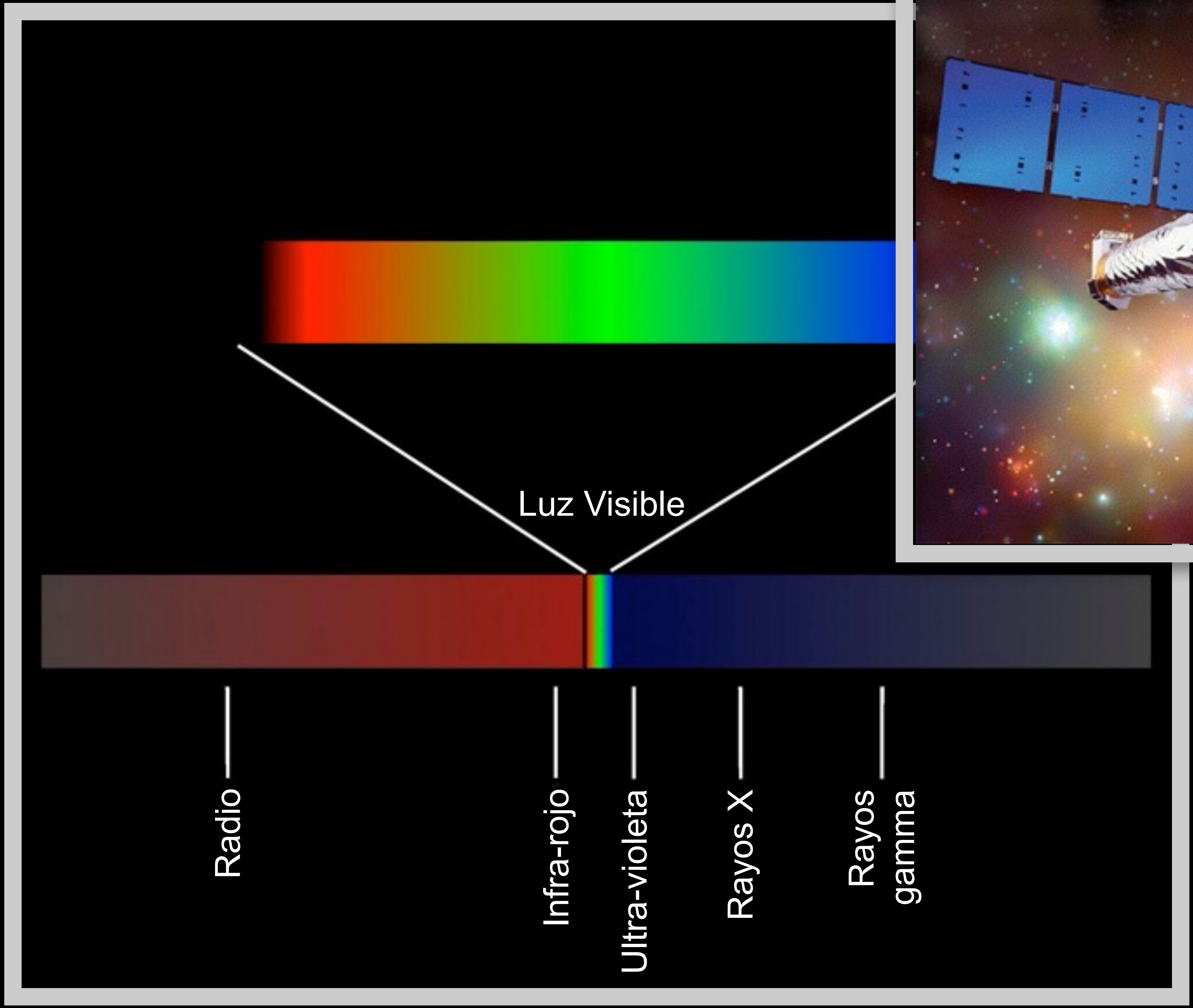
Una enana Blanca: Siriuo B

Sirio B
en
rayos-X
(Chandra)

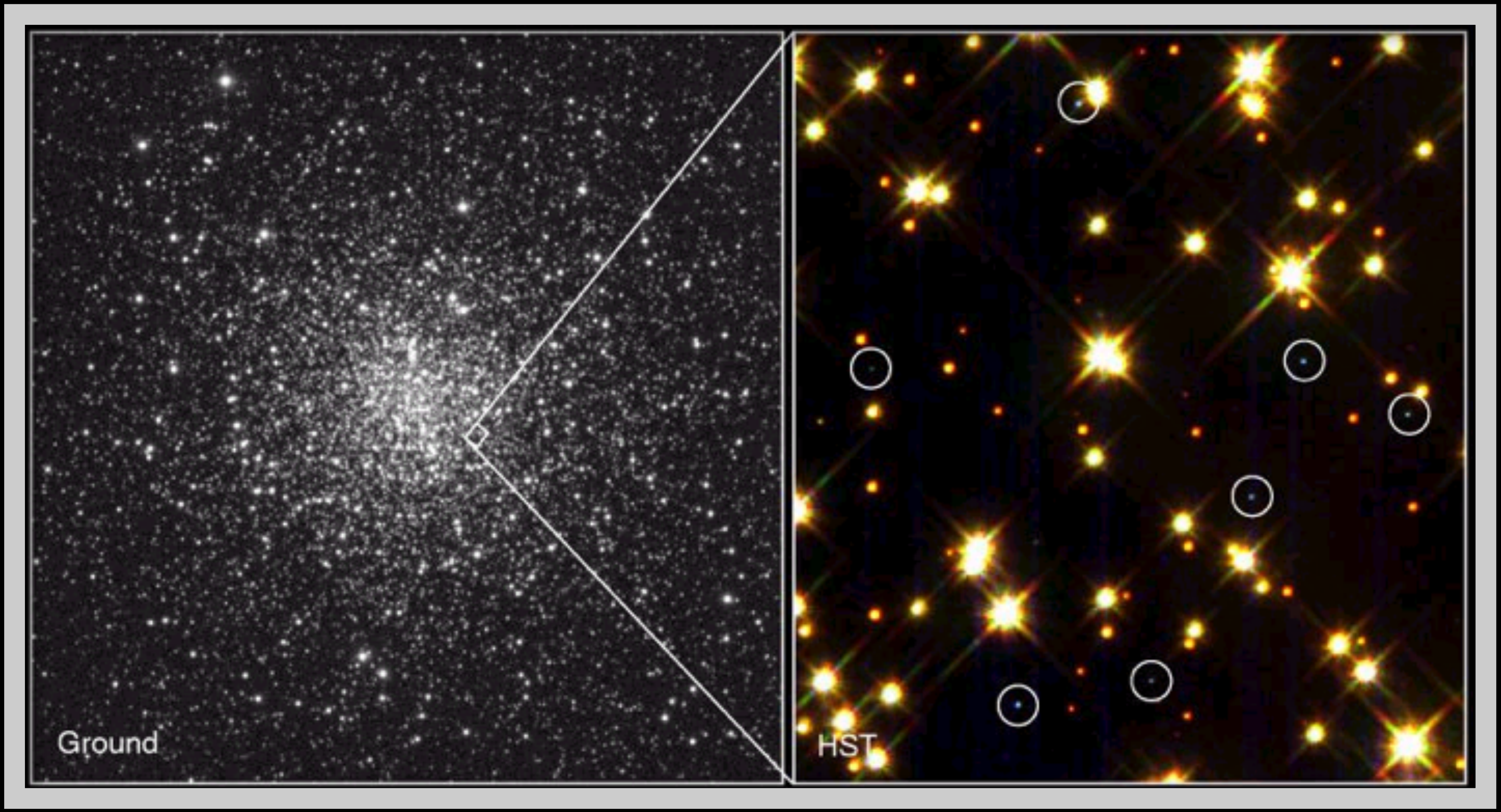


Sirio B
en el
óptico
(HST)

“Chandra”: Satélite de Rayos X



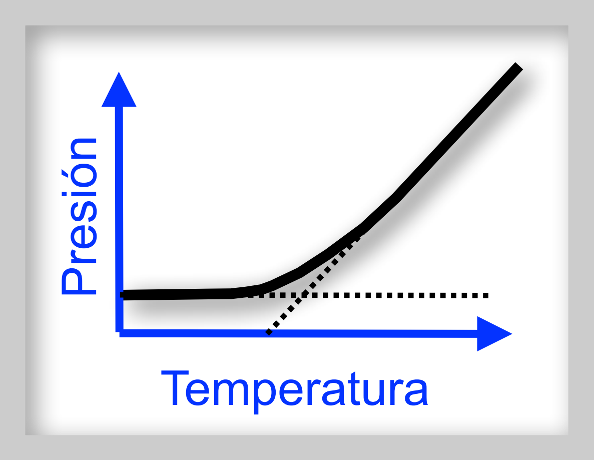
Ennas Blancas en el Cúmulo Globular M4

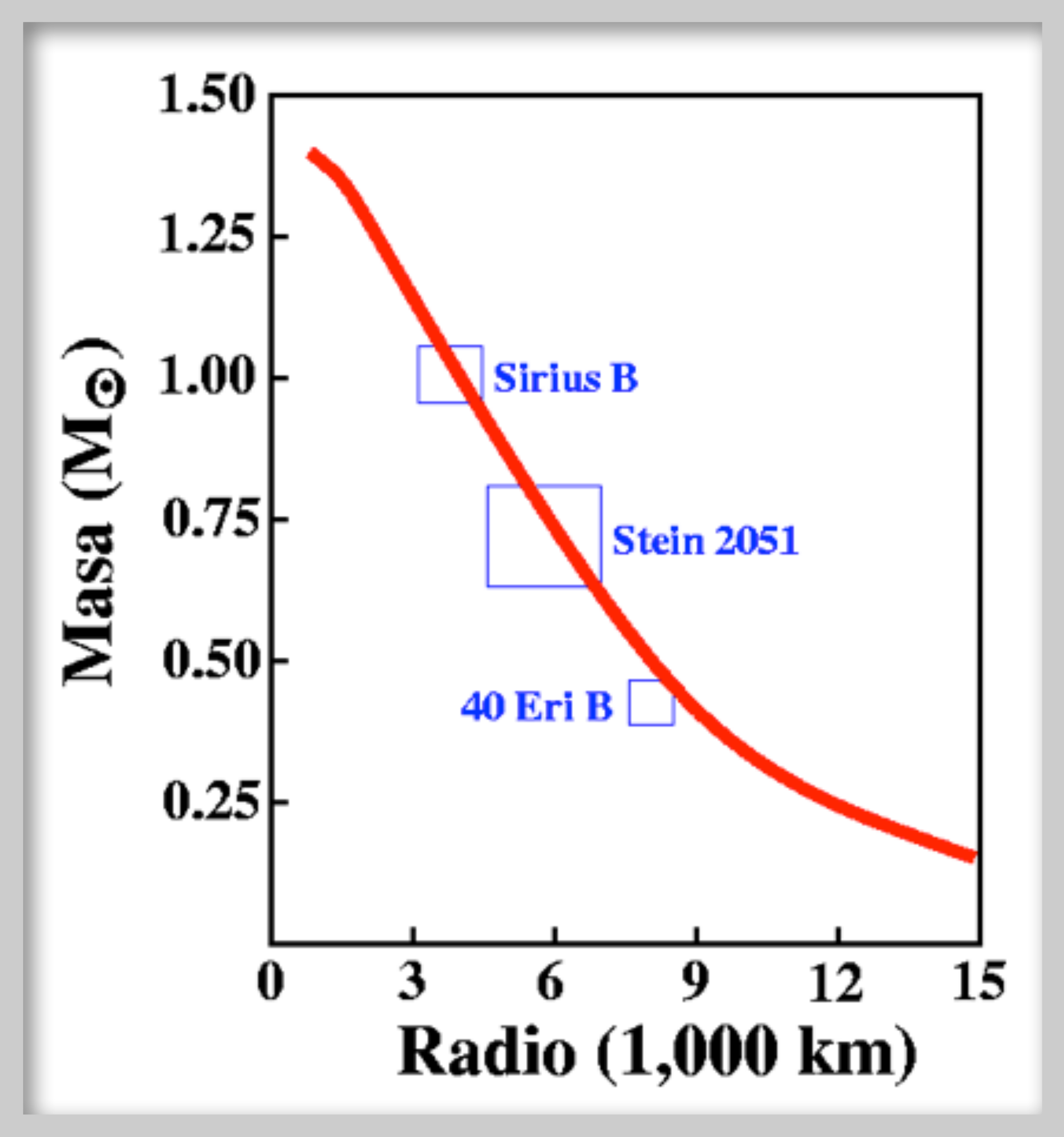


Relación Masa-Radio de Enanas Blancas

La densidad central de una enana blanca puede alcanzar 10^9 g/cm^3 (mil toneladas/cm^3)
La presión soportando esta densidad es debida a la degeneración de los electrons

Ecuación de estado para materia degenerada





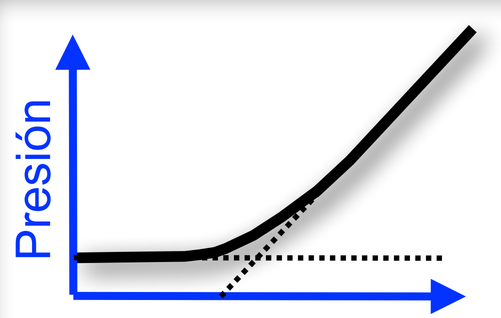
Relación Masa-Radio de Enanas Blancas

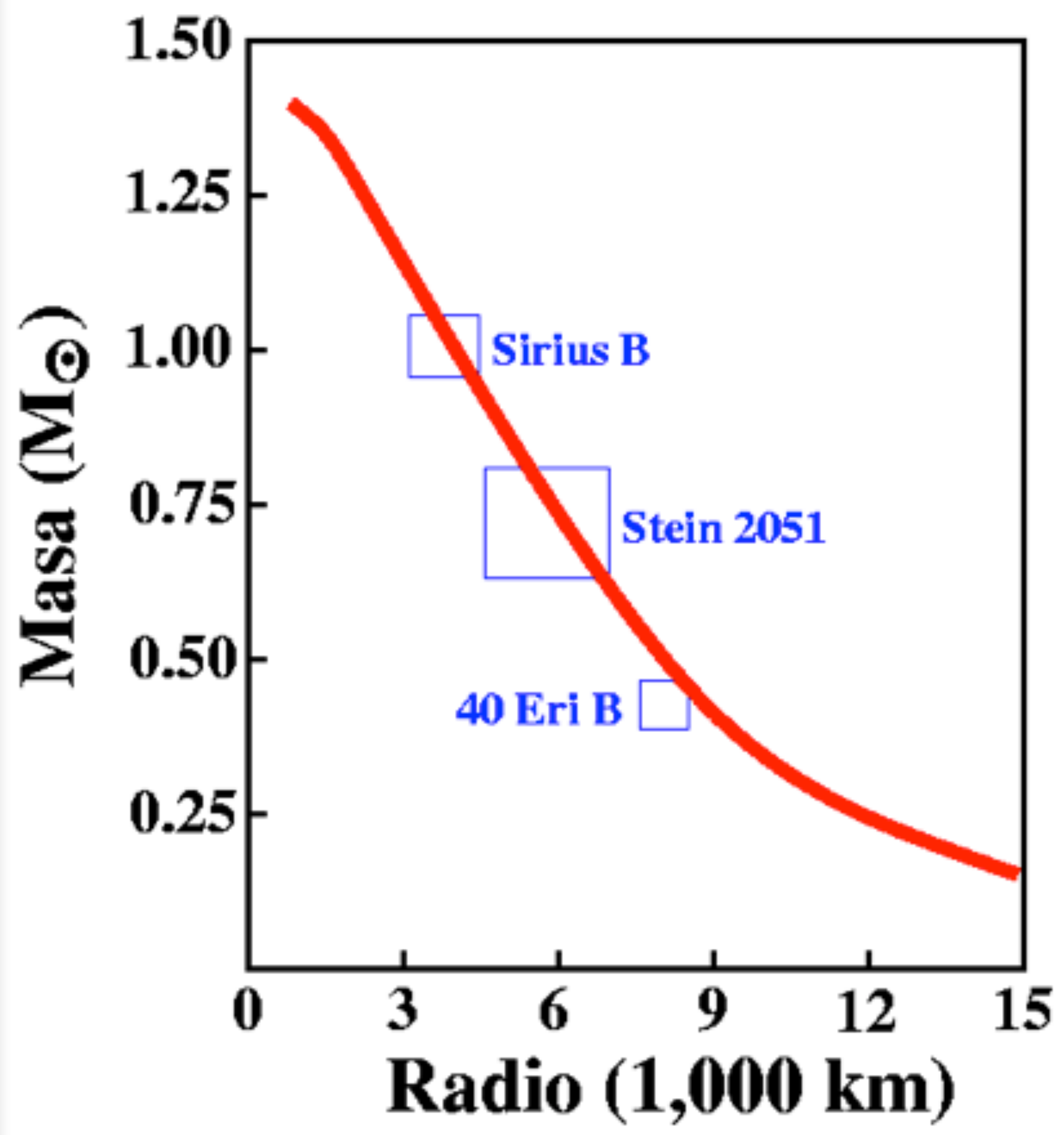
Chandrasekhar demostró que la masa máxima que puede soportar la presión de degeneración de electrones es de

~ 1.4 $M_{Sol} \equiv M_{Ch}$

(Masa de Chandrasekhar)

Ecuación de estado para materia degenerada





The Nobel Prize in Physics 1983

"for his theoretical studies of the physical processes of importance to the structure and evolution of the stars"

"for his theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements in the universe"

Subramanyan Chandrasekhar

1/2 of the prize

USA

University of Chicago
Chicago, IL, USA

b. 1910
(in Lahore, India)
d. 1995

William Alfred Fowler

1/2 of the prize

USA

California Institute of Technology (Caltech)
Pasadena, CA, USA

b. 1911
d. 1995

POST - SECUENCIA PRINCIPAL:
$M > 8\ M_{\odot}$

Hacía la SUPERNOVA

Masas Límites Pos-Secuencia Principal

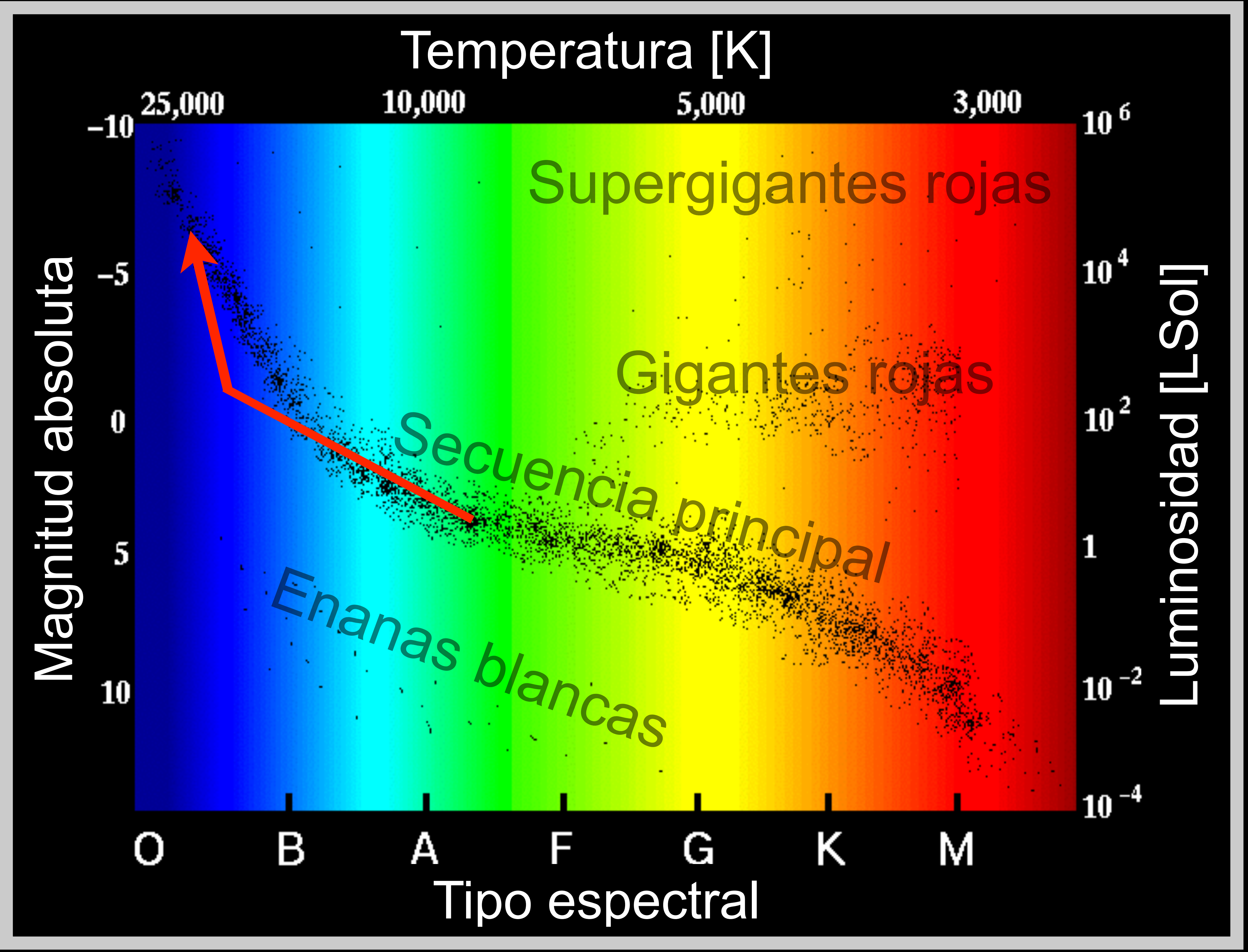
3 Types of Stars depending on their mass:

$M < 2\,M_\odot$: **low-mass stars** are those that develop a degenerate helium core after the main sequence, leading to a relatively long-lived *red giant branch* phase. The ignition of He is unstable and occurs in a so-called *helium flash*. This occurs for masses between $0.8\,M_\odot$ and $\approx 2\,M_\odot$ (this upper limit is sometimes denoted as $M_{\rm HeF}$).

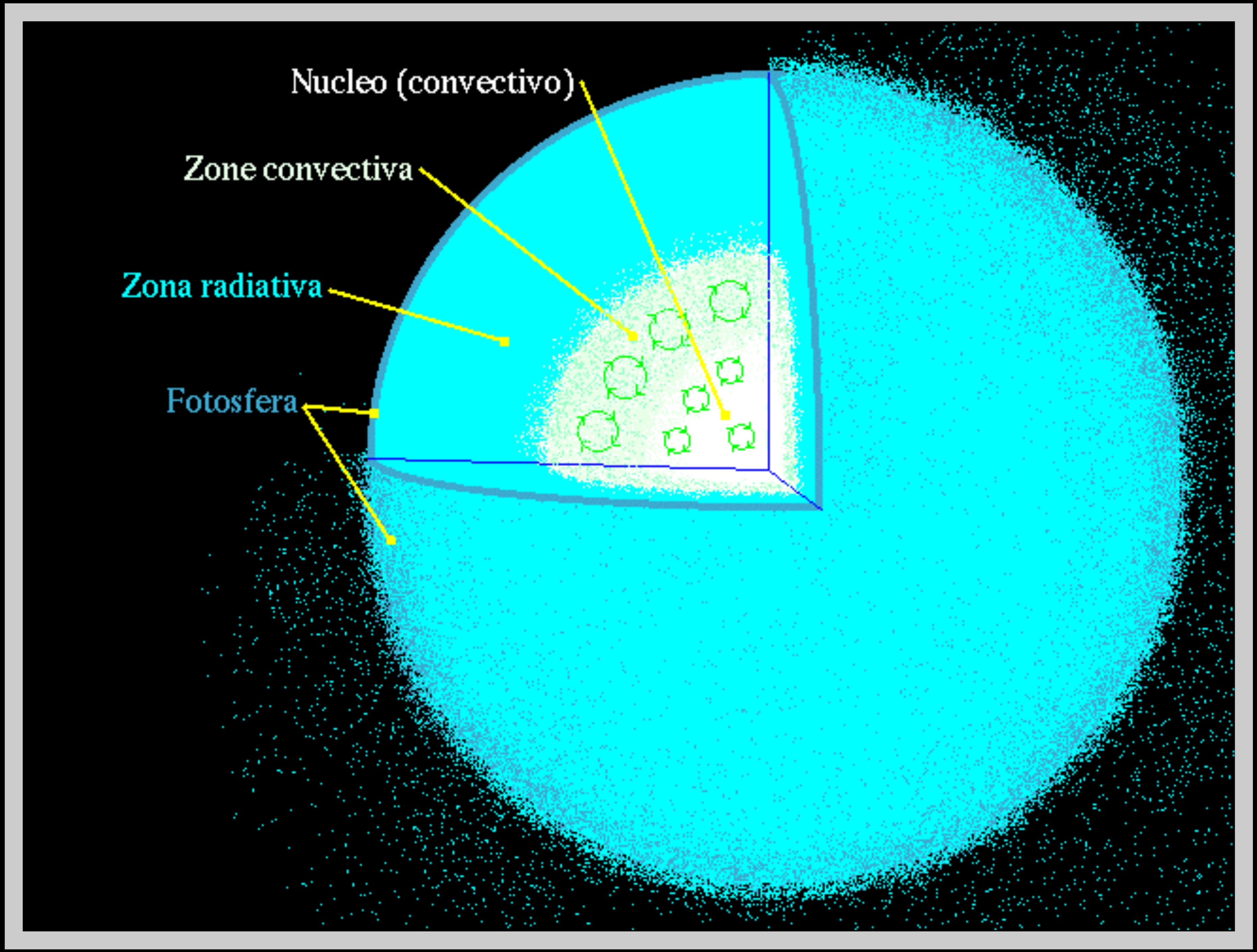
$2\,M_\odot < M < 8\,M_\odot$: **intermediate-mass stars** develop a helium core that remains non-degenerate, and they ignite helium in a stable manner. After the central He burning phase they form a carbon-oxygen core that becomes degenerate. Intermediate-mass stars have masses between $M_{\rm HeF}$ and $M_{\rm up} \approx 8\,M_\odot$. Both low-mass and intermediate-mass stars shed their envelopes by a strong stellar wind at the end of their evolution and their remnants are CO white dwarfs.

$8\,M_\odot < M$: **massive stars** have masses larger than $M_{\rm up} \approx 8\,M_\odot$ and ignite carbon in a non-degenerate core. Except for a small mass range ($\approx 8 - 11\,M_\odot$) these stars also ignite heavier elements in the core until an Fe core is formed which collapses.

El Diagrama de Herzprung-Russell



Estrella de 10 M_{Sol}: Estructura Interna en la Secuencia Principal



Post-Secuencia Principal: M < 8M☉

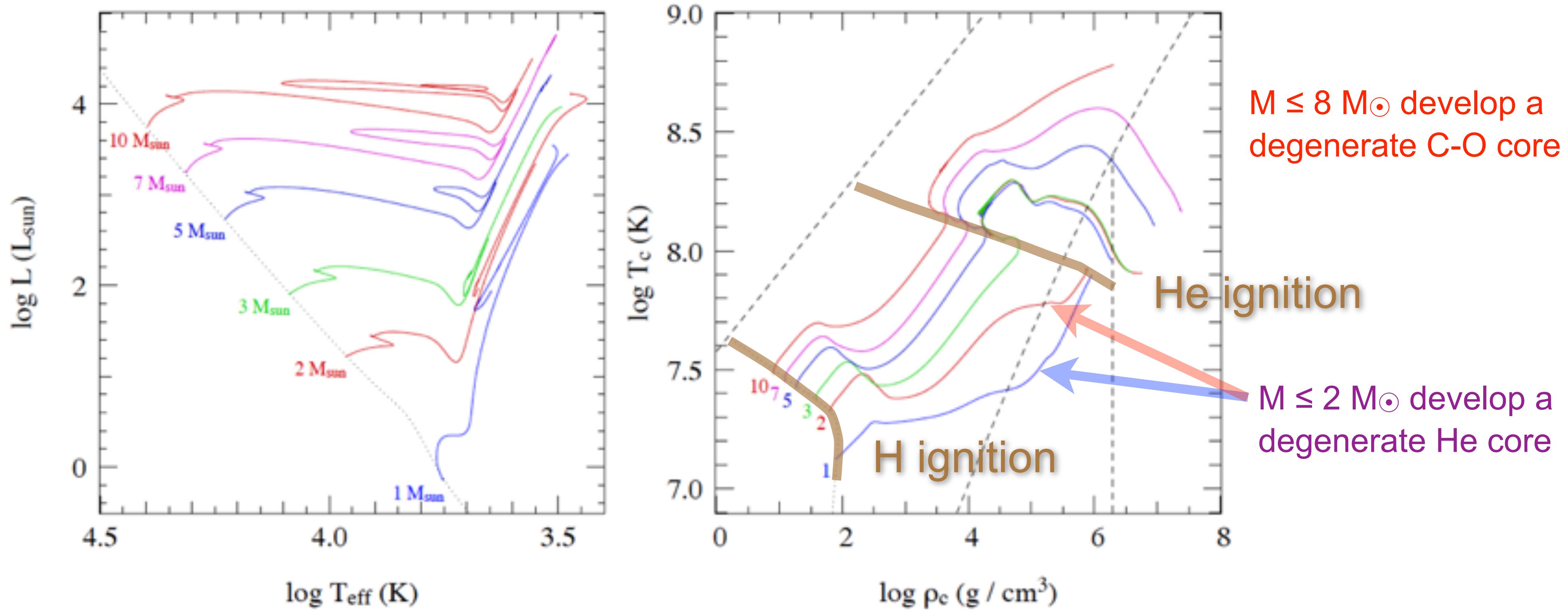


Figure 10.1. Evolution tracks for stars of quasi-solar composition ($X = 0.7$, $Z = 0.02$) and masses of 1, 2, 3, 5, 7 and 10 $M_\odot$ in the H-R diagram (left panel) and in the central temperature versus density plane (right panel). Dotted lines in both diagrams show the ZAMS, while the dashed lines in the right-hand diagram show the borderlines between equation-of-state regions (as in Fig. 3.4). The 1 $M_\odot$ model is characteristic of low-mass stars: the central core becomes degenerate soon after leaving the main sequence and helium is ignited in an unstable flash at the top of the red giant branch. When the degeneracy is eventually lifted, He burning becomes stable and the star moves to the *zero-age horizontal branch* in the HRD, at $\log L \approx 1.8$. The 2 $M_\odot$ model is a borderline case that just undergoes a He flash. The He flash itself is not computed in these models, hence a gap appears in the tracks. The 5 $M_\odot$ model is representative of intermediate-mass stars, undergoing quiet He ignition and He burning in a loop in the HRD. The appearance of the 7 and 10 $M_\odot$ models in the HRD is qualitatively similar. However, at the end of its evolution the 10 $M_\odot$ star undergoes carbon burning in the centre, while the cores of lower-mass stars become strongly degenerate. (Compare to Fig. 8.4.)

Post-Secuencia Principal: M > 8M$_\odot$

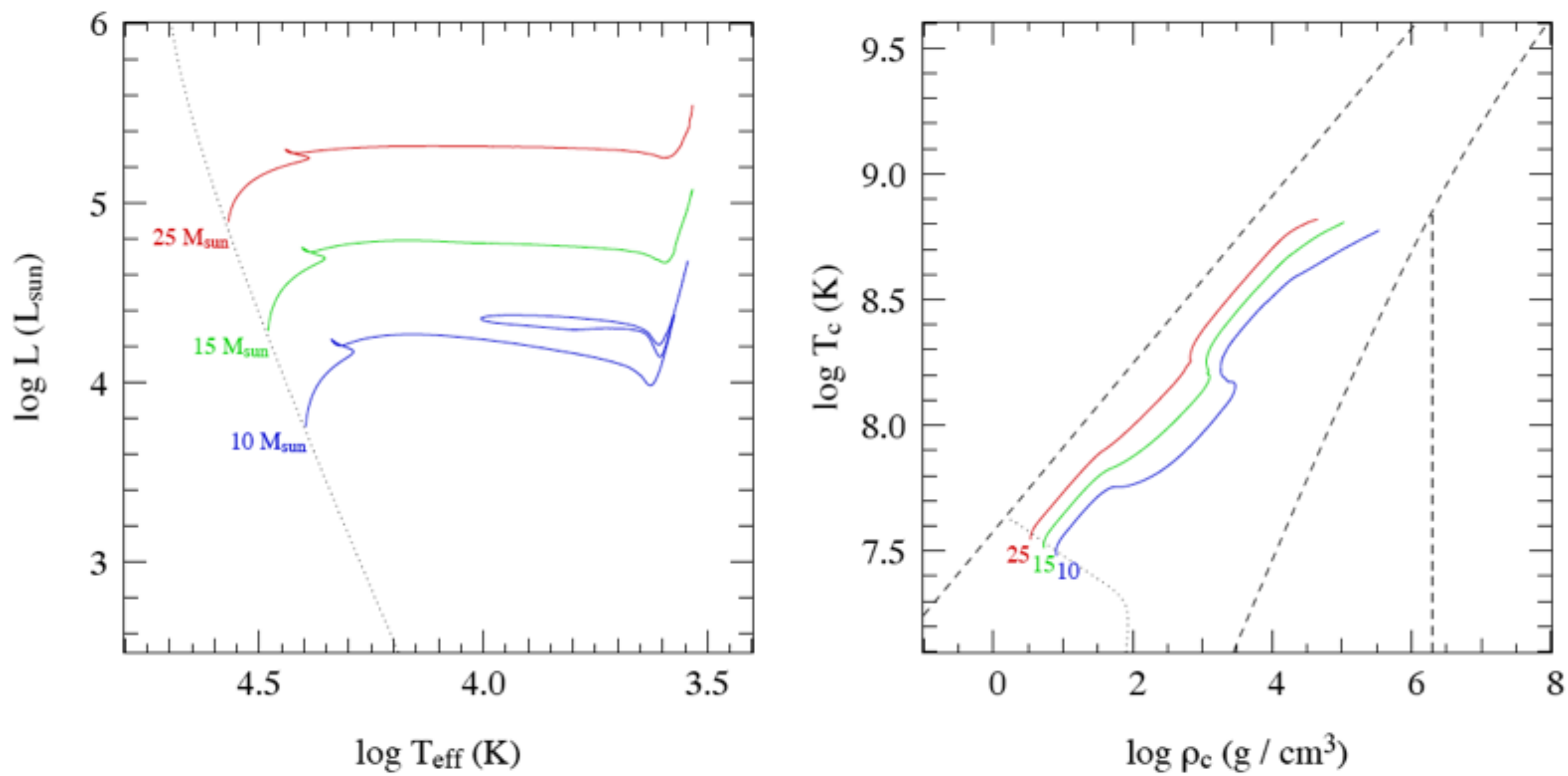


Figure 12.1. Evolution tracks in the HR diagram (left panel) and in the $\log \rho_c$-$\log T_c$ diagram (right panel) for stars with $Z = 0.02$ and $M = 10, 15$ and $25\ M_\odot$, computed with a moderate amount of overshooting. The tracks end when carbon is ignited in the centre, under non-degenerate conditions.

Evolución hasta el Núcleo de Fierro

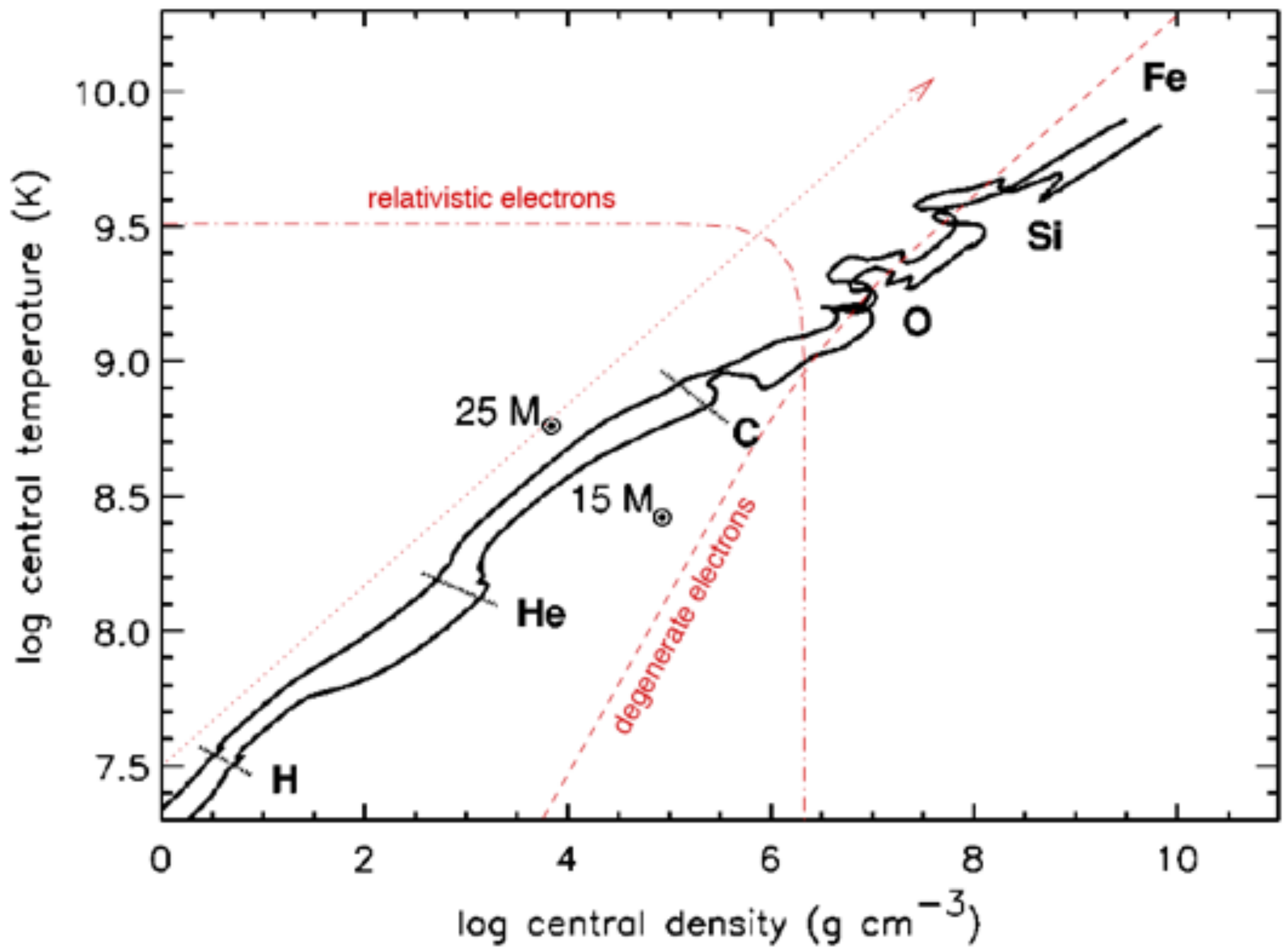
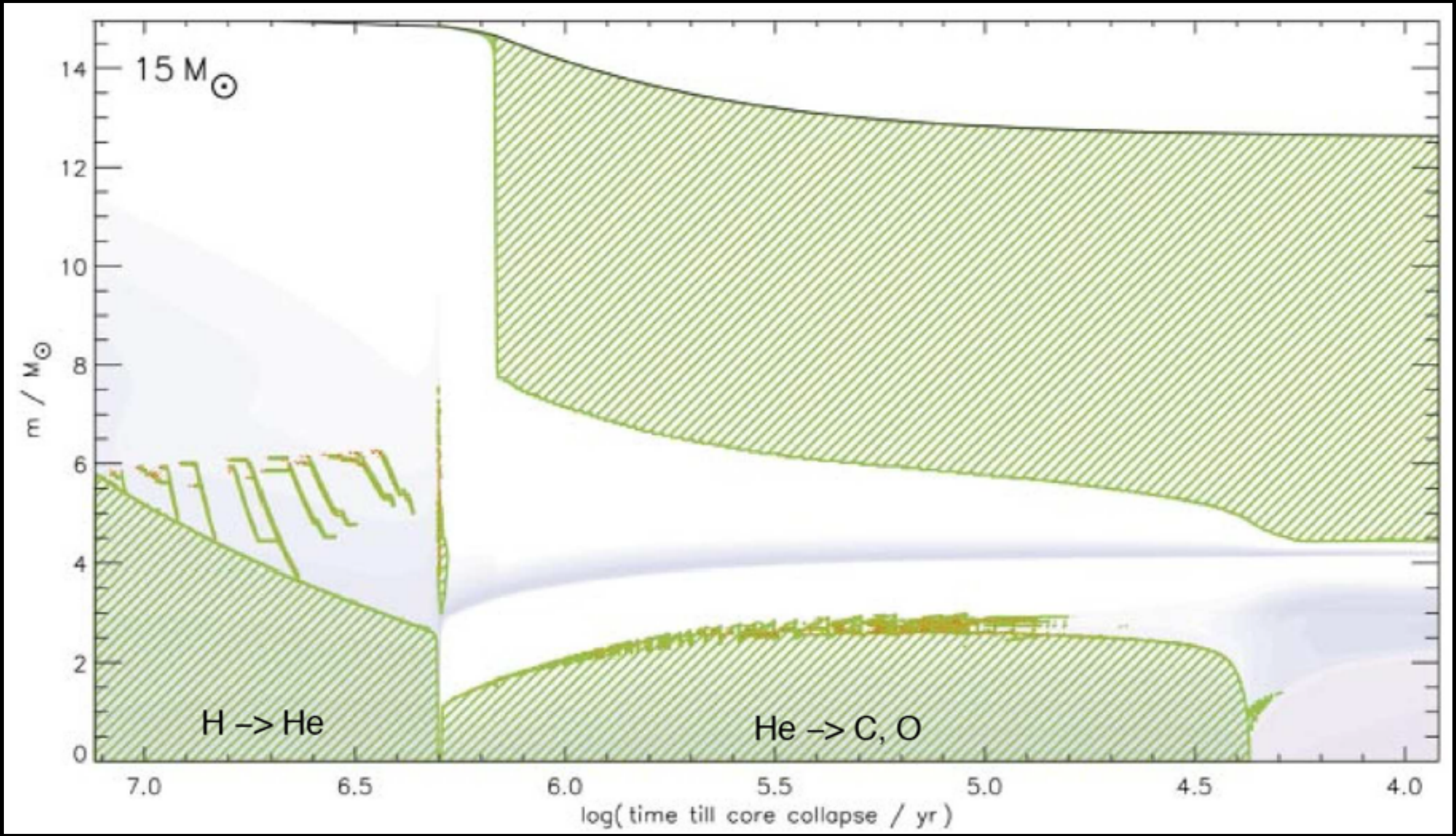
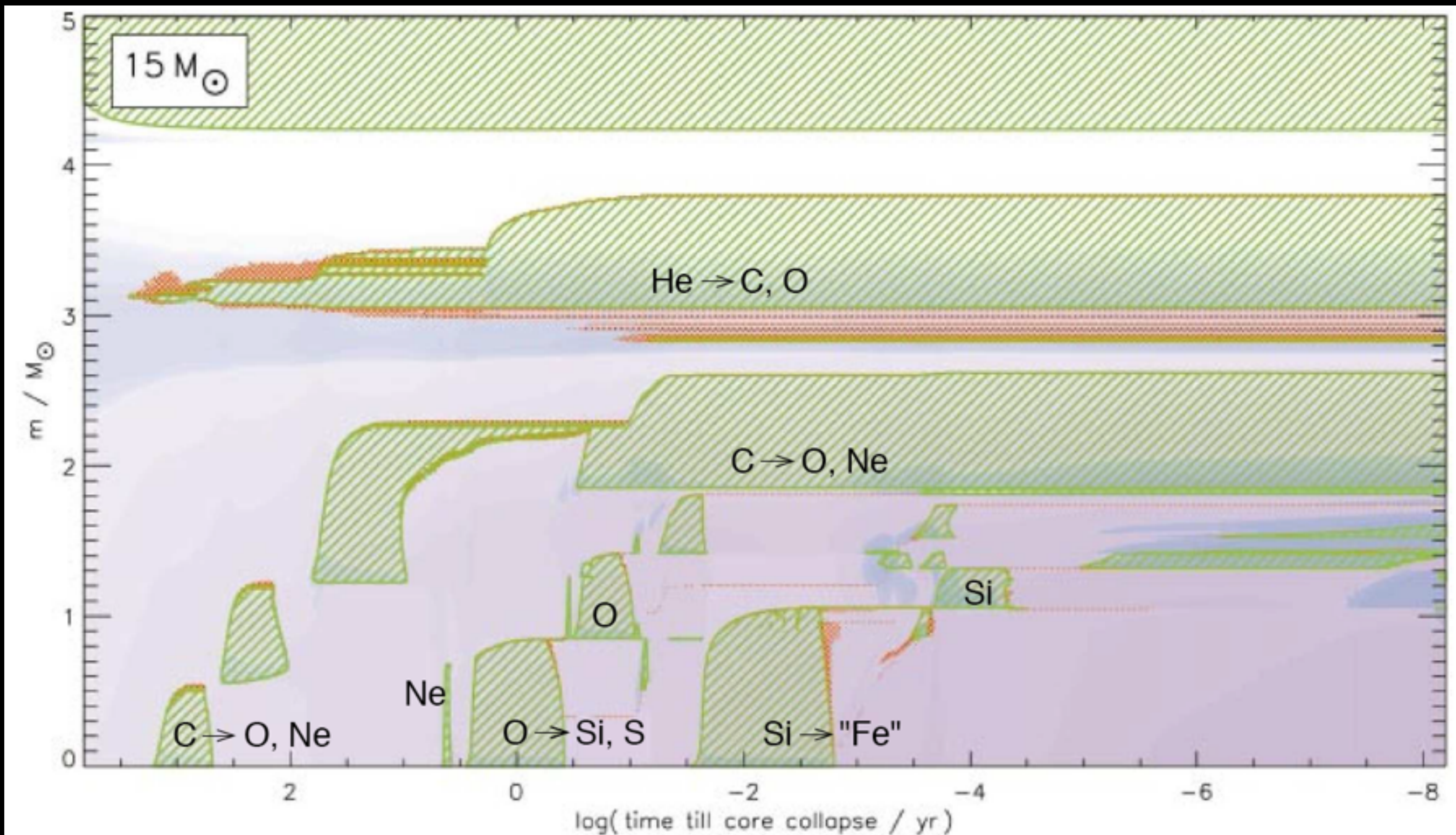


Figure 12.5. Evolution of central temperature and density of 15 $M_\odot$ and 25 $M_\odot$ stars at $Z = 0.02$ through all nuclear burning stages up to iron-core collapse. The dashed line indicated where electrons become degenerate, and the dash-dotted line shows where electrons become relativistic ($\epsilon_e \approx m_e c^2$). The dotted line and arrow indicates the trend $T_c \propto \rho_c{}^{1/3}$ that is expected from homologous contraction. Non-monotonic (non-homologous) behaviour is seen whenever nuclear fuels are ignited and a convective core is formed. Figure adapted from Woosley, Heger & Weaver (2002, Rev. Mod. Ph. 74, 1015).

15M☉: Quemado de H y He en el Núcleo

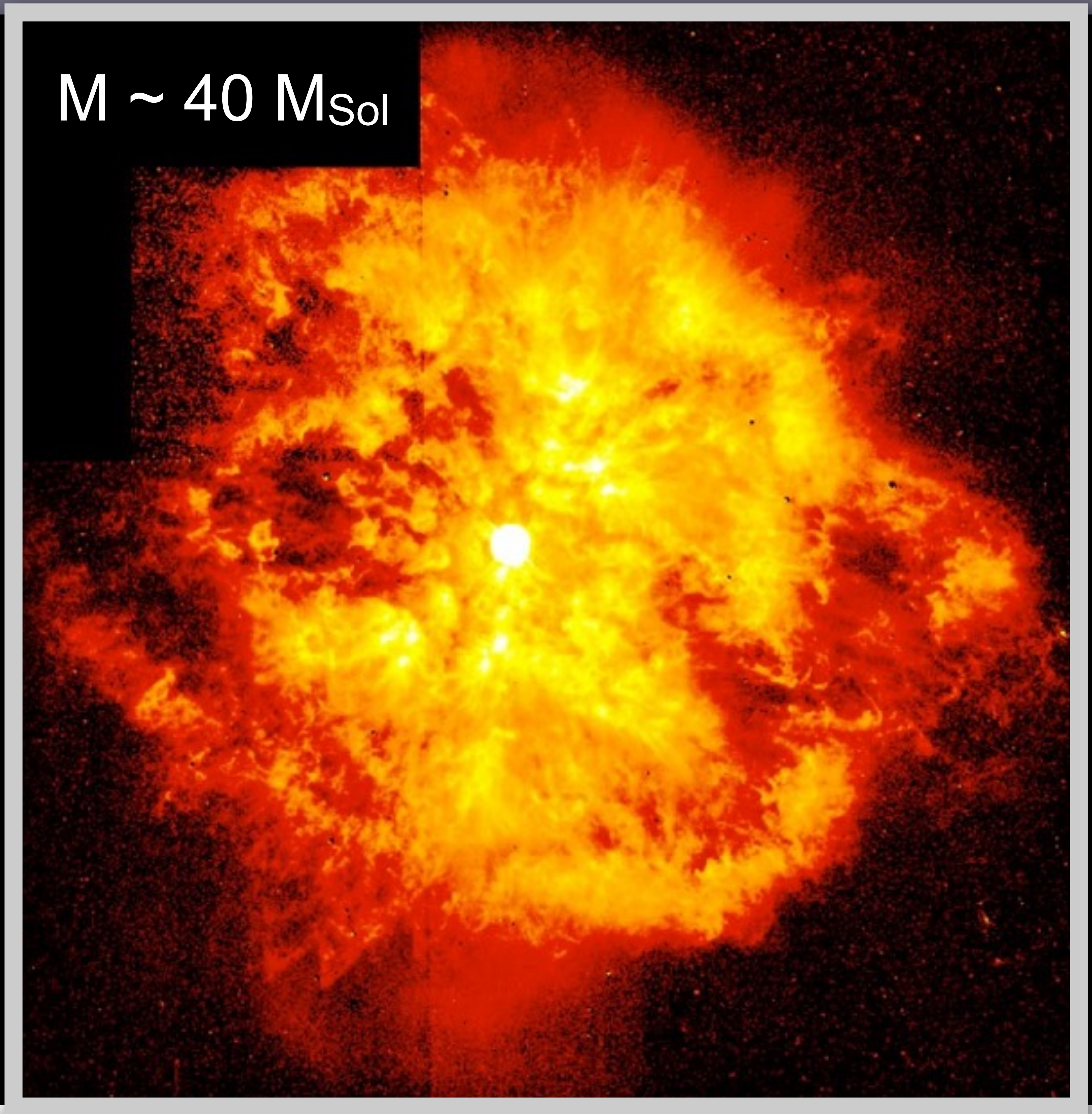


15M⊙: Ultimas Etapas hacia el Colapso

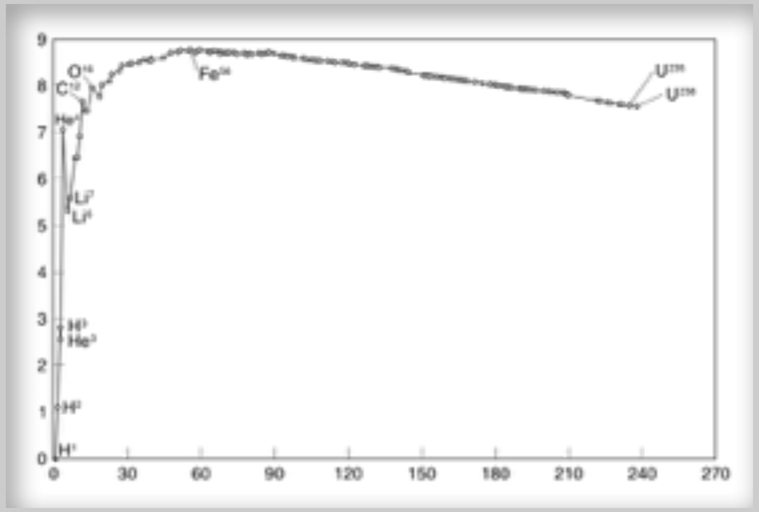


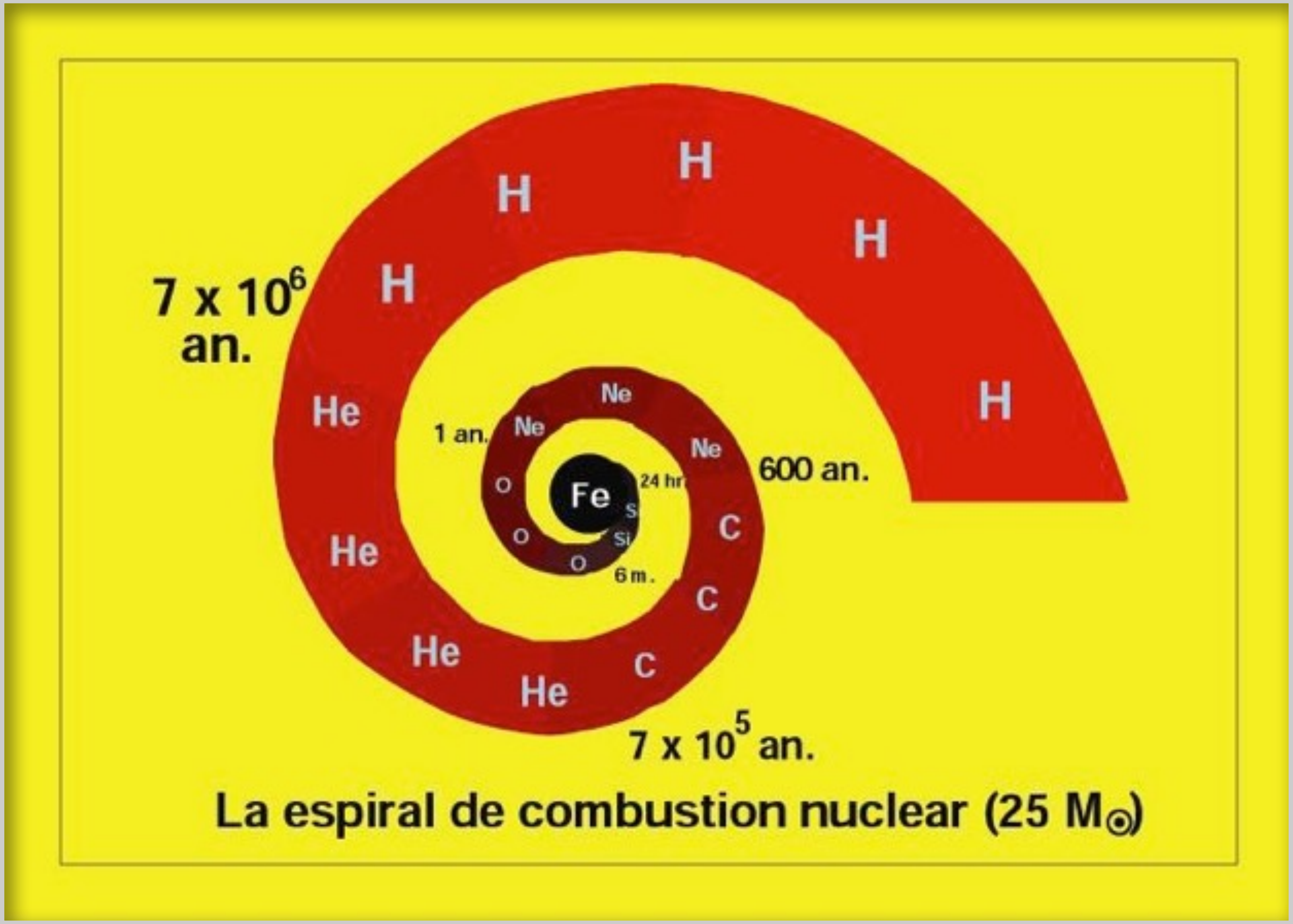
¿ La Estrella mas Másiva de la Vía Láctea: Eta Carinae?

Una Estrella Wolf-Rayet: WE124

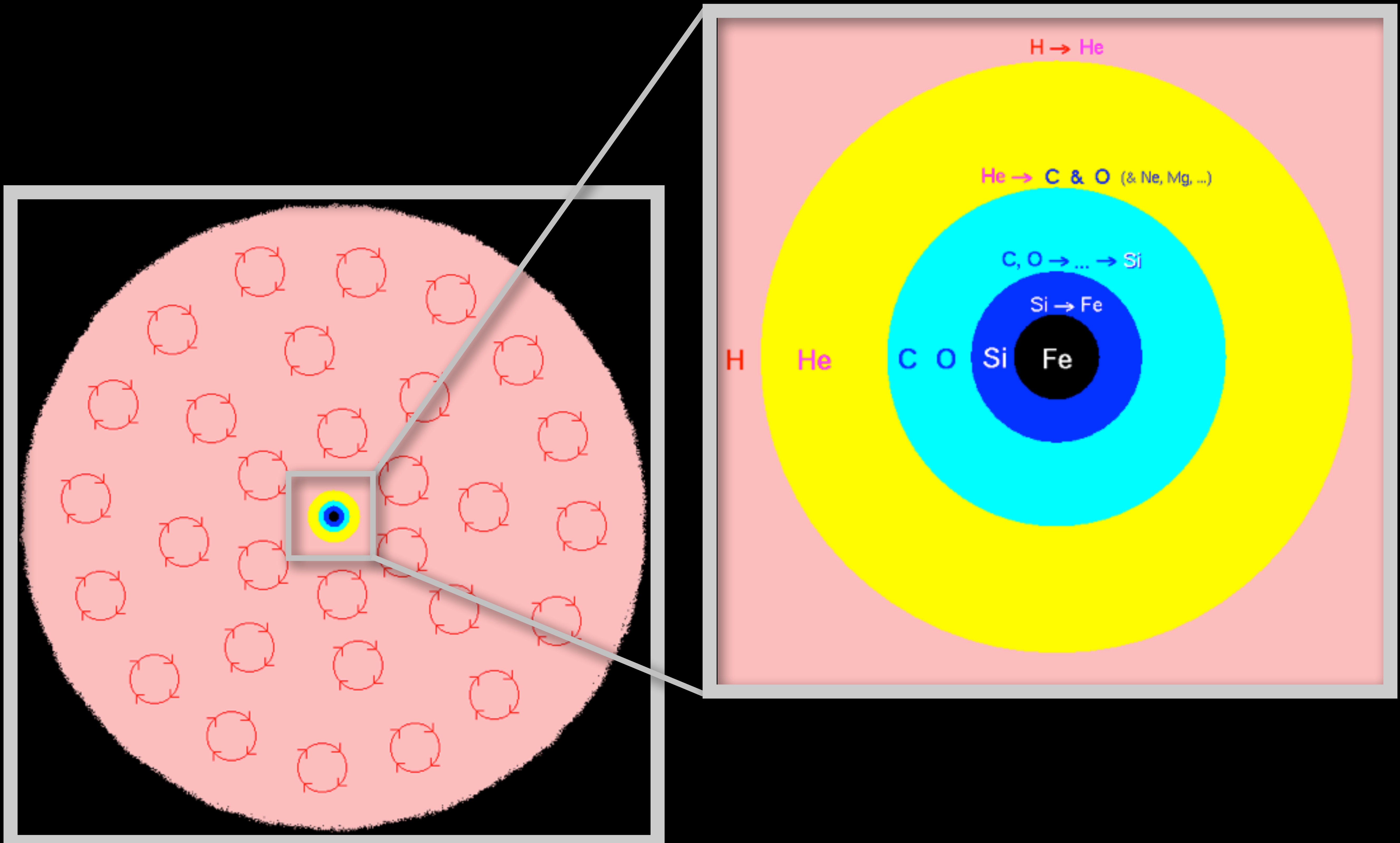


La Vida Nuclear de Una Estrella





Estructura Final de una Estrella Másiva



Betelgeuse: una Super-Gigante Roja

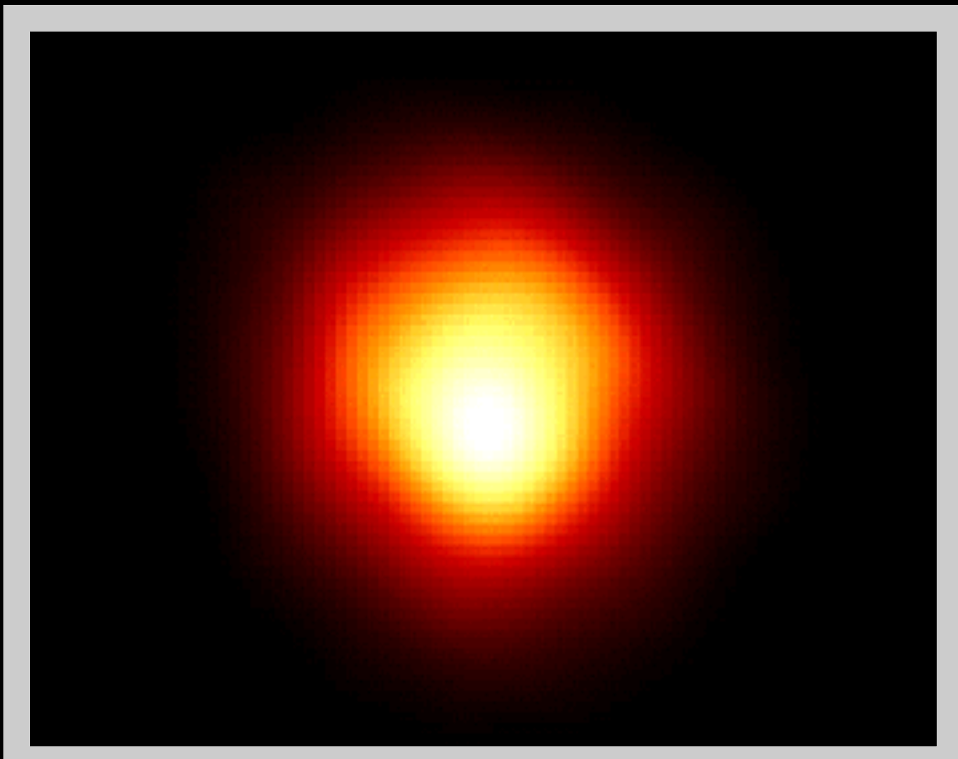
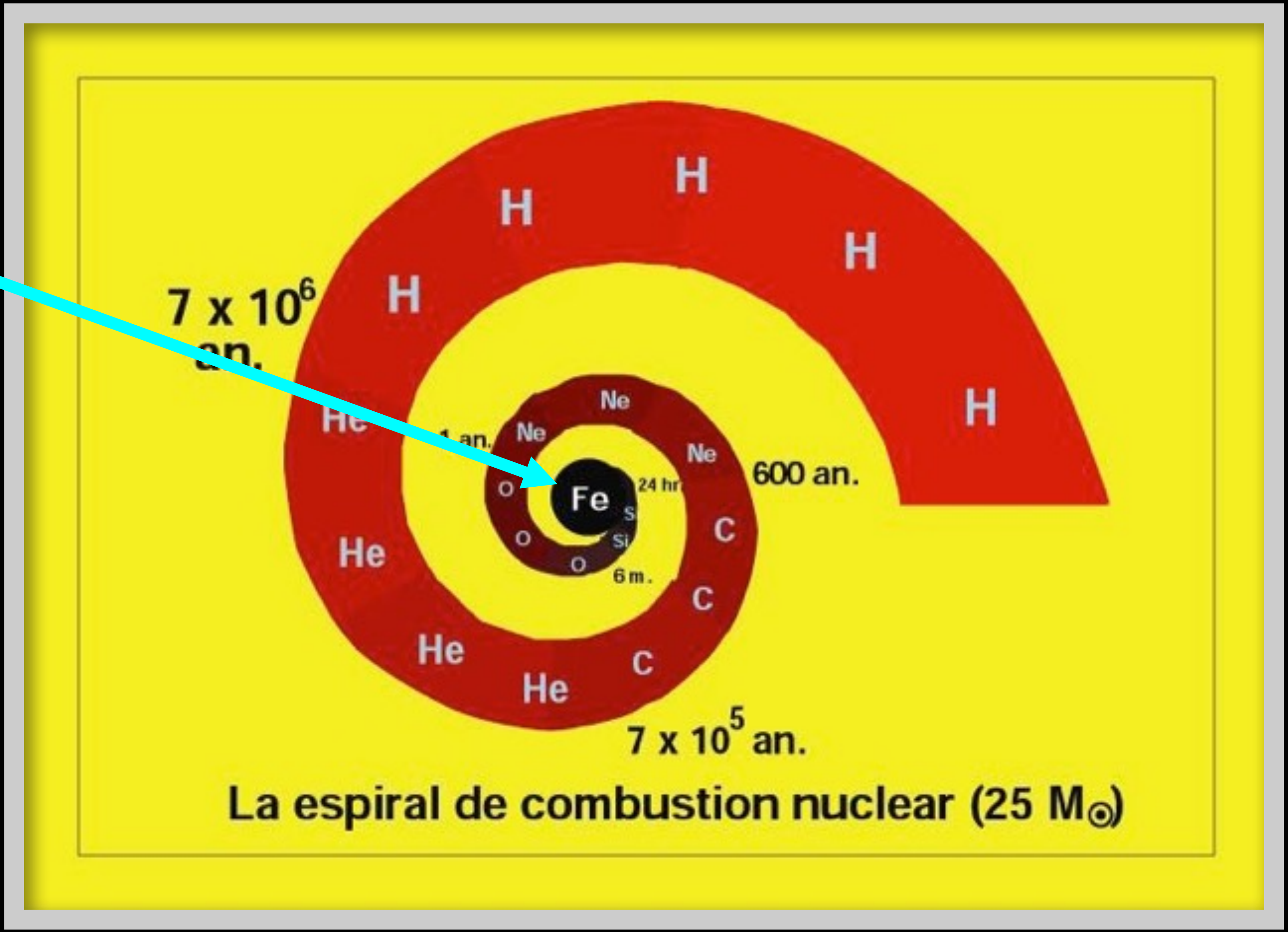


Imagen del Telescopio Espacial (HST)

Betelgeuse

Fin de la Vida de Una Estrella Másiva

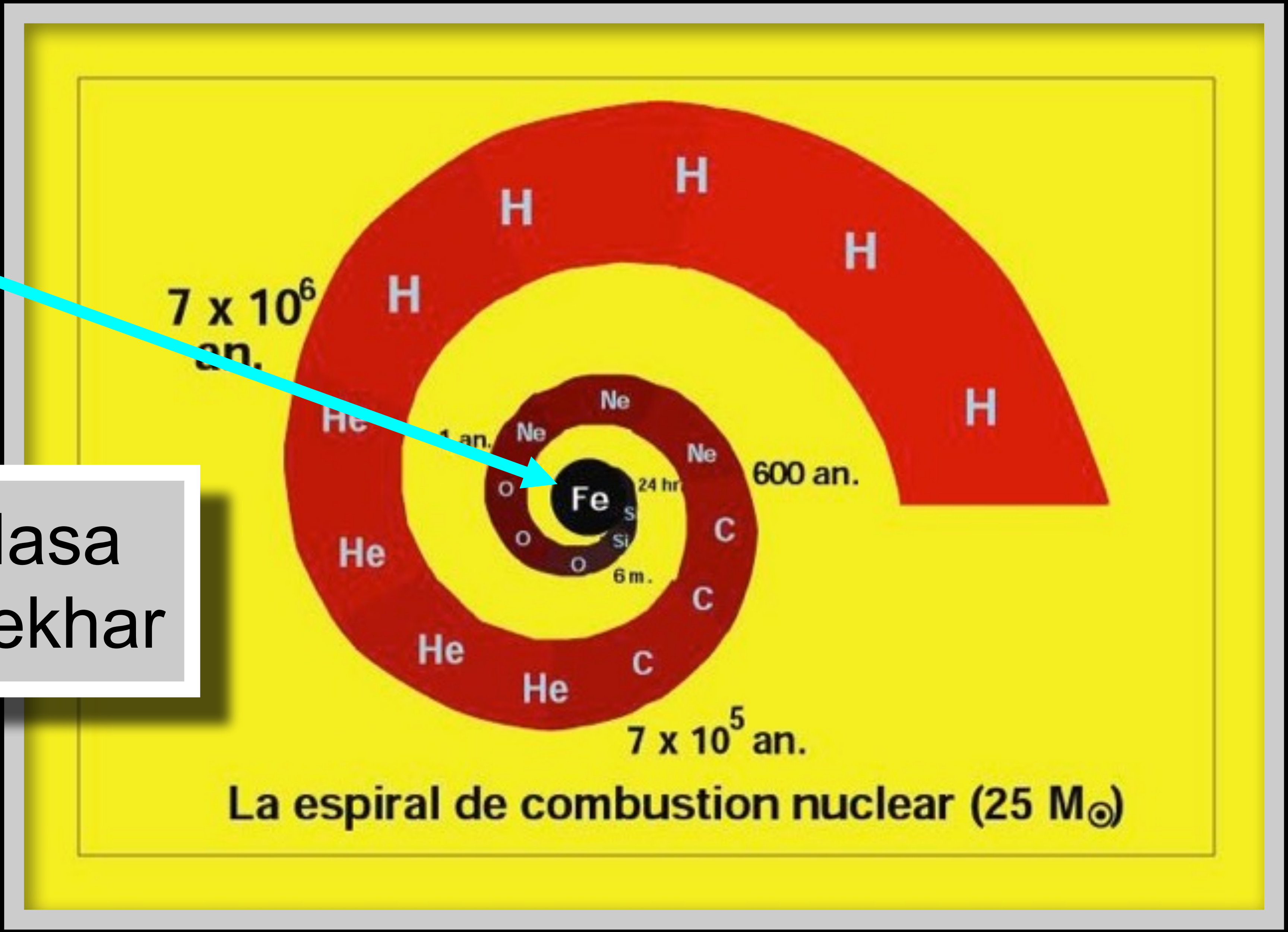
Problema



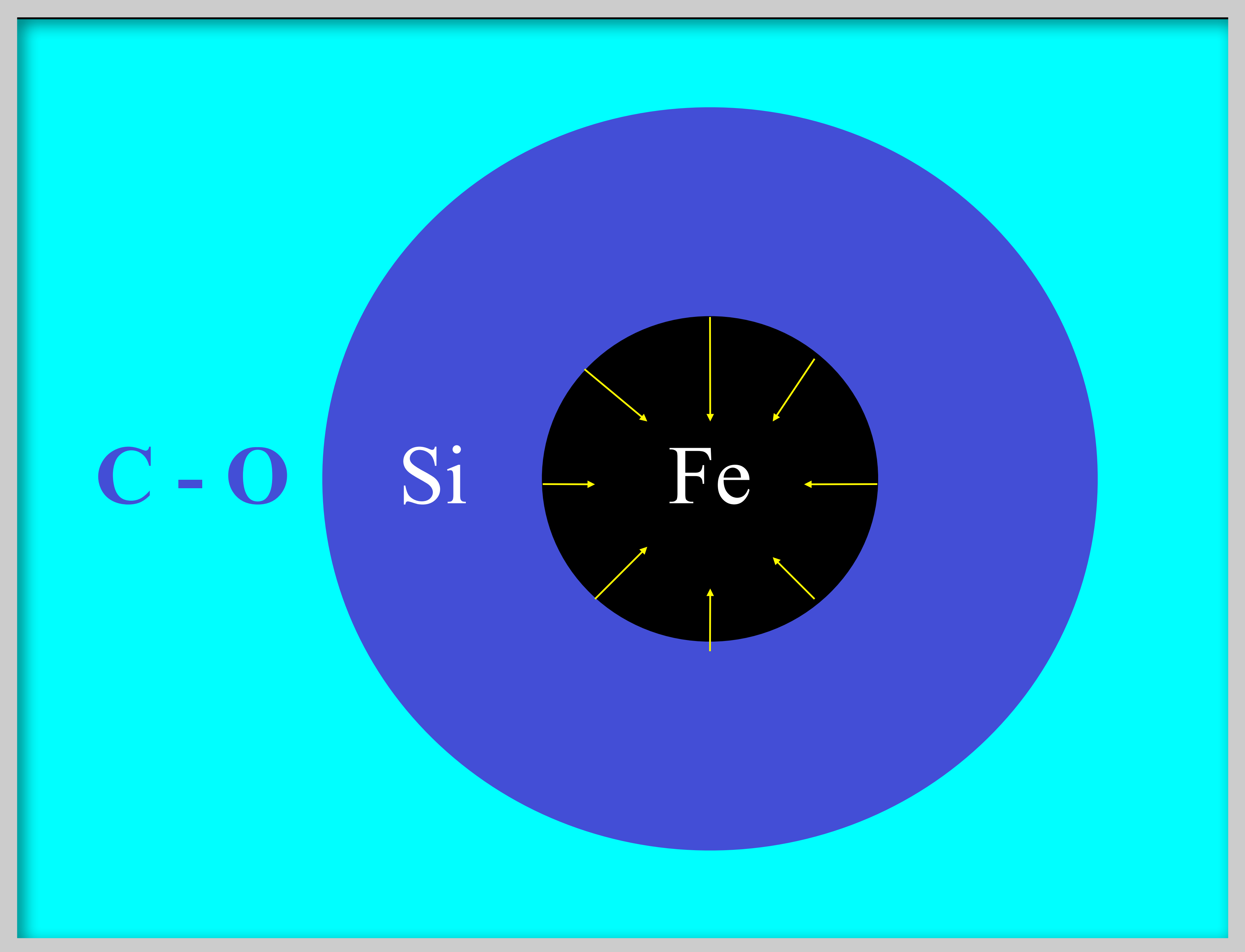
Fin de la Vida de Una Estrella Másiva

Problema

1.4 M_{Sol} = Masa de Chandrasekhar

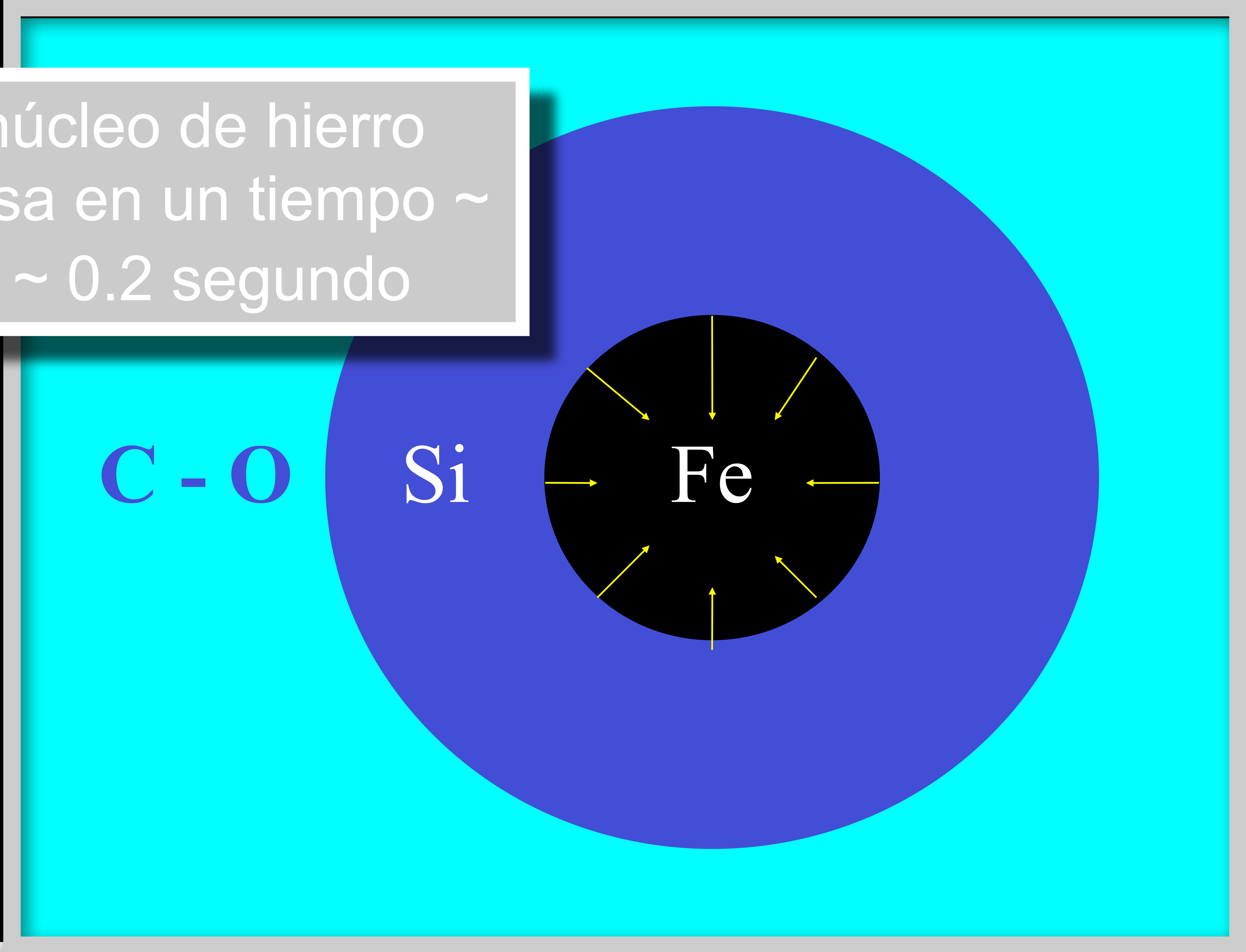


El Núcleo de Hierro alcanza la Masa de Chandrasekhar

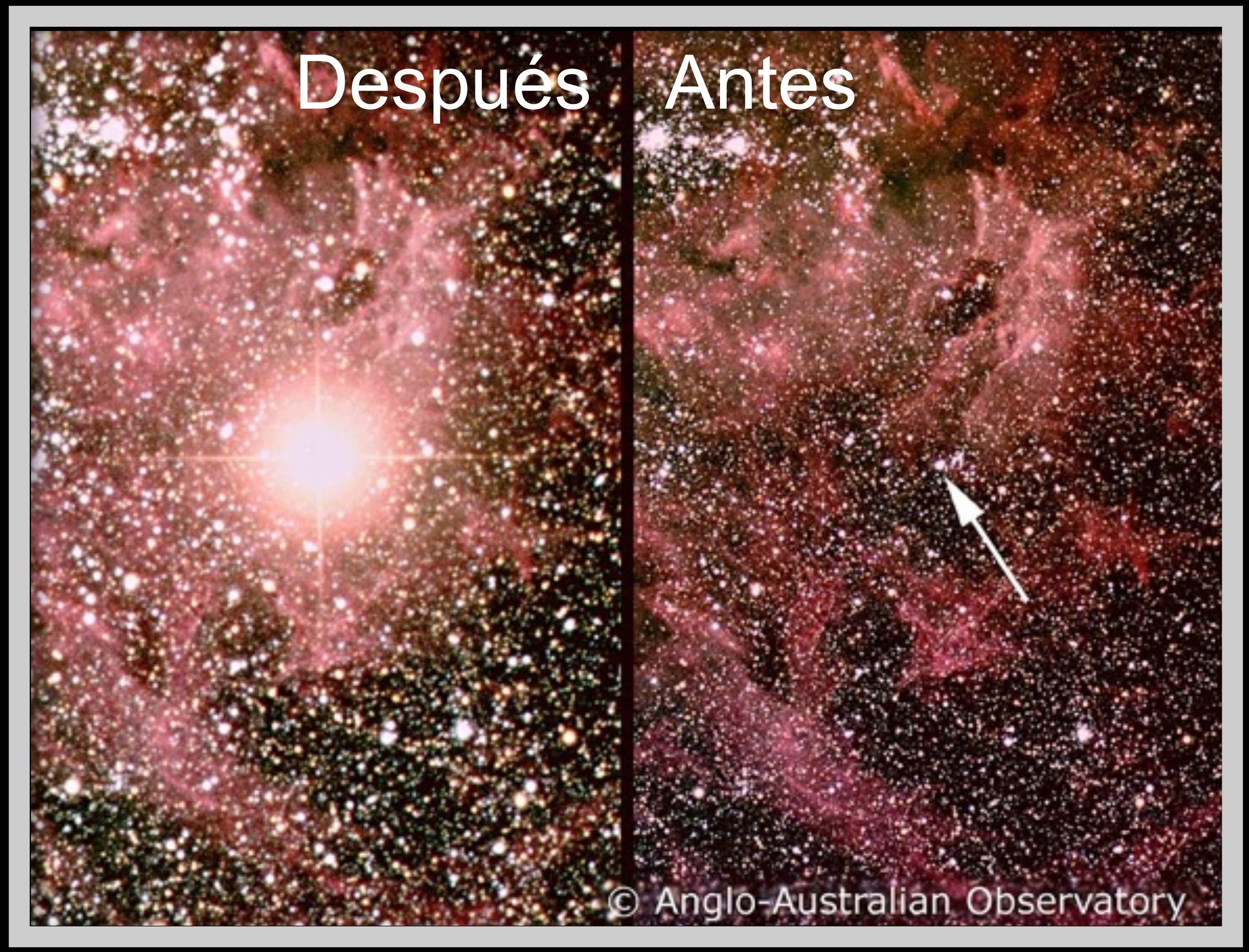


El Núcleo de Hierro alcanza la Masa de Chandrasekhar

El núcleo de hierro colapsa en un tiempo ~ τ_{col} ~ 0.2 segundo

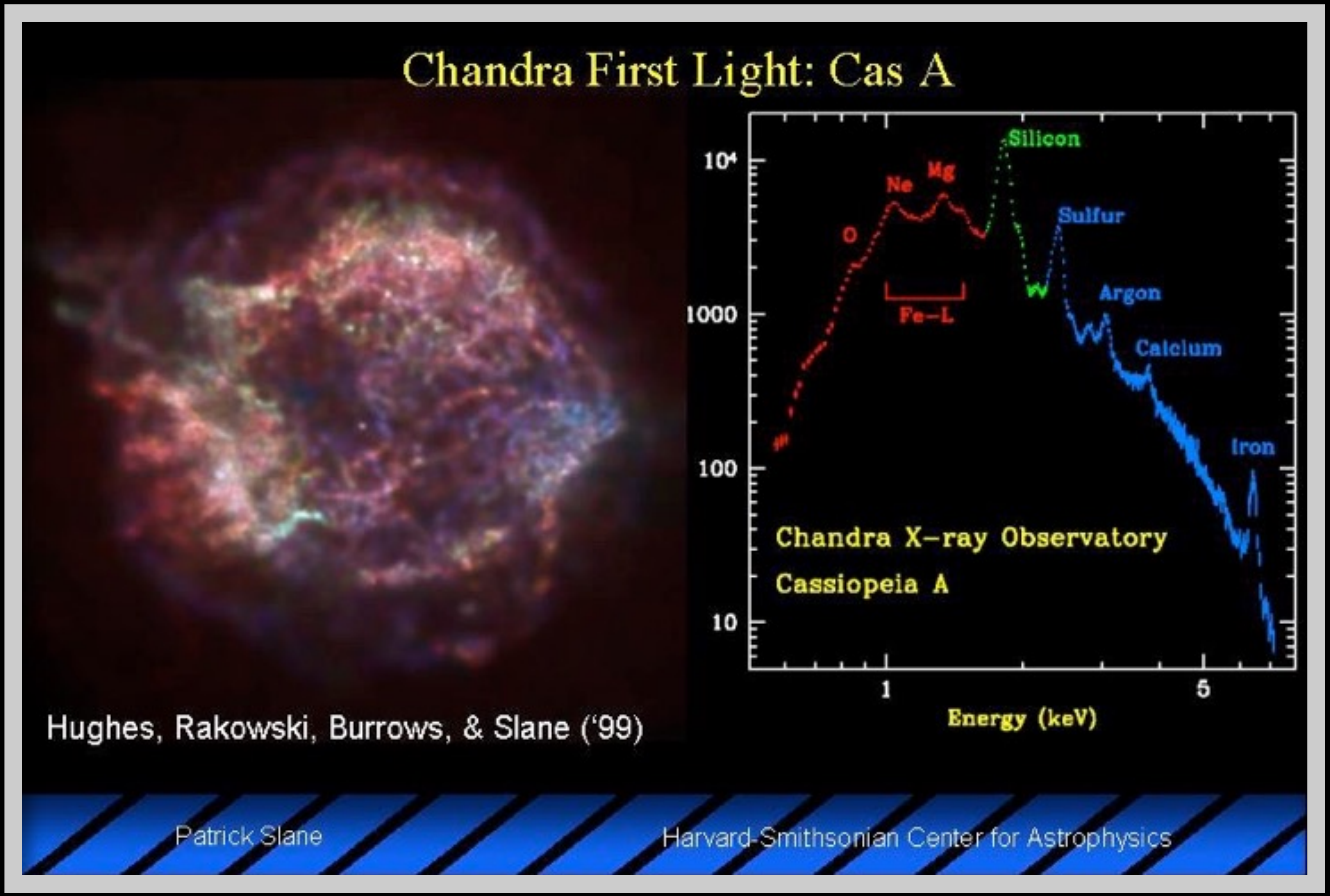


La Supernova SN 1987A



Una supernova emita mas luz (durante unos días) que toda un galaxia.

El Remanente de Supernova Cassiopeia A



Cassiopeia A en el óptico por el HST

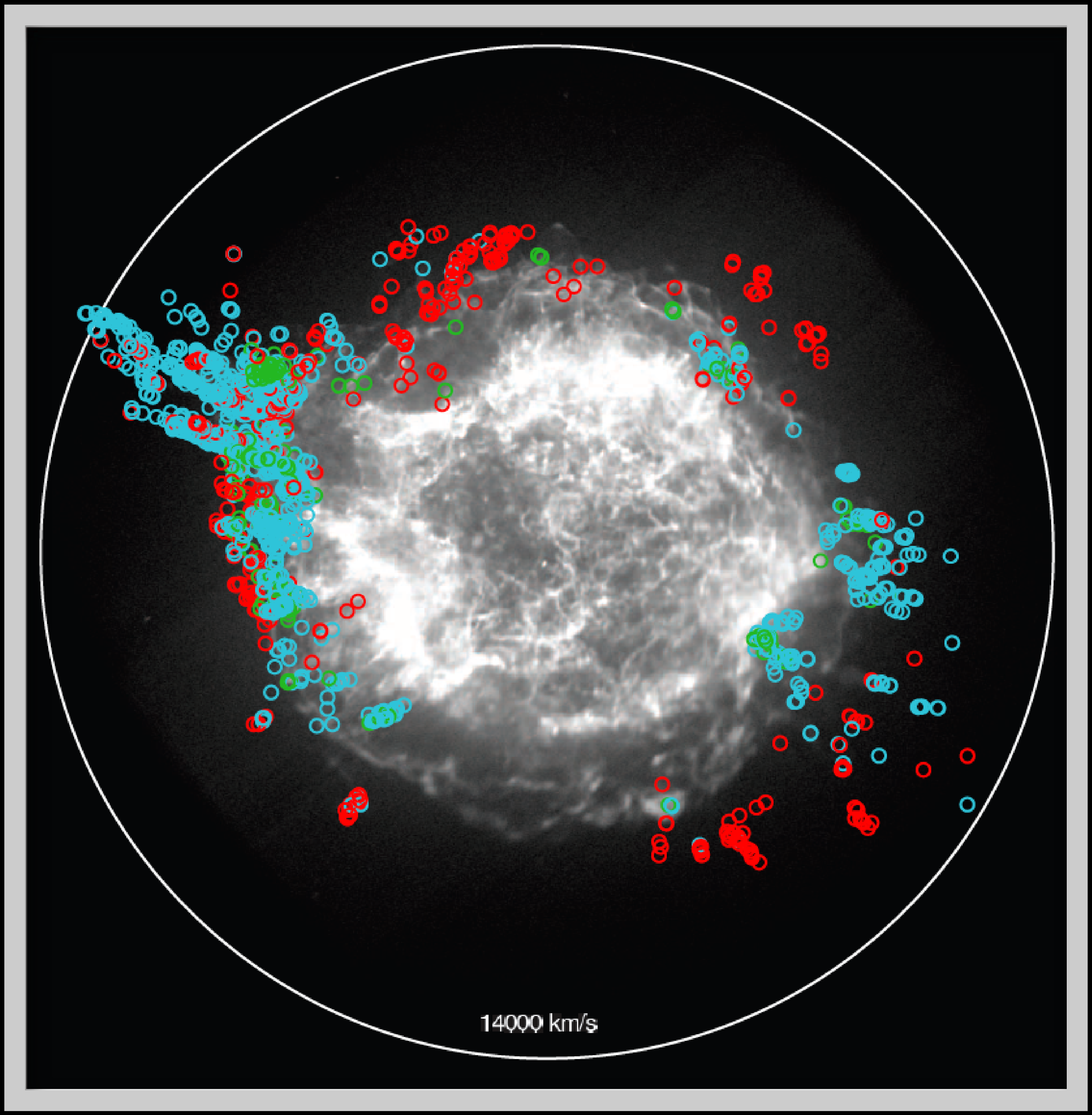
Cassiopeia A: “nodos” ópticos + rayos X

“Nodos”: identificados por lineas de emisión:

N II

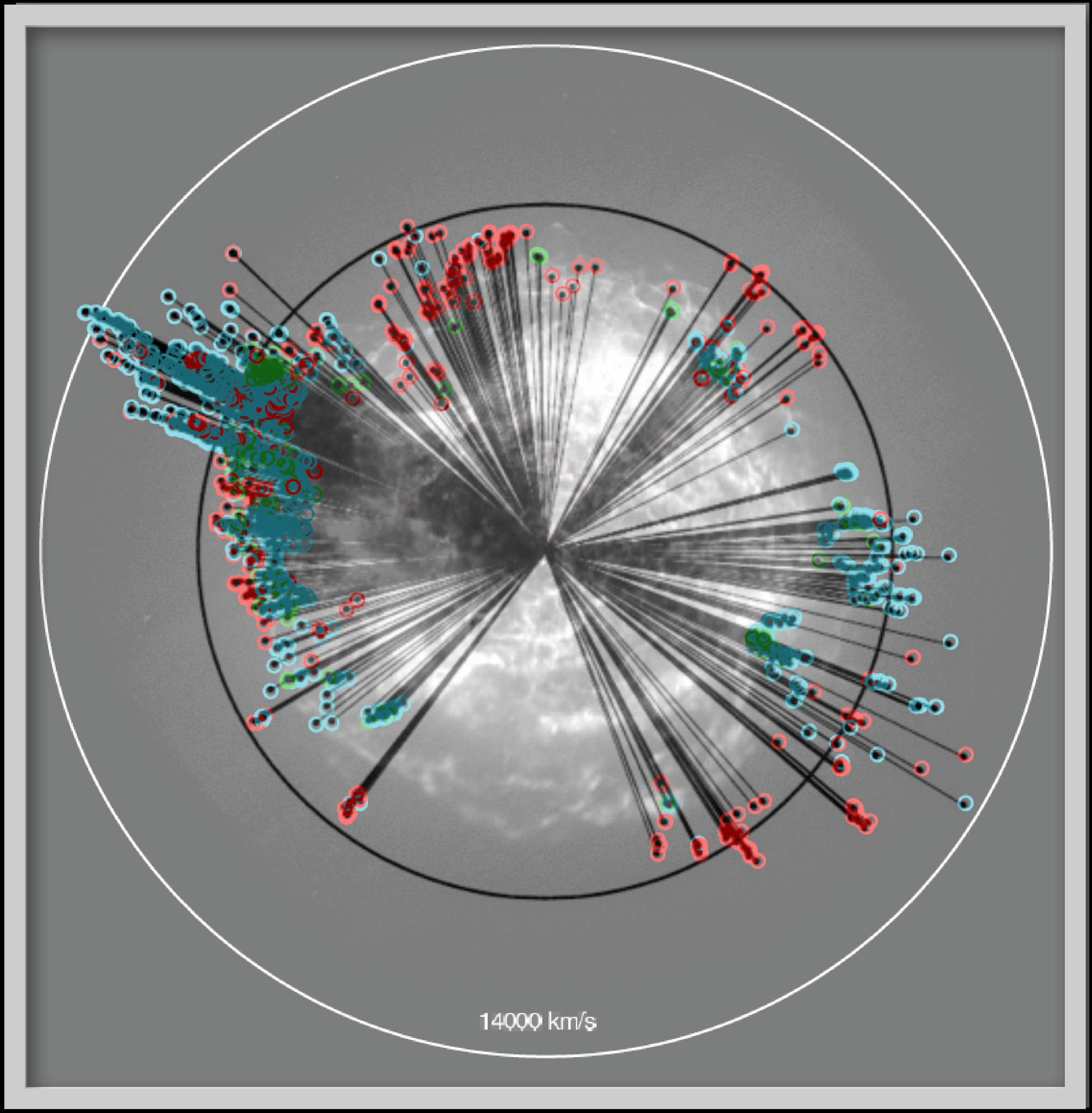
O II

S II



Cassiopeia A: expansión por la explosión

Expansión de los "nodos" entre marzo y diciembre 2004 (HST)



Explosión:

en el año

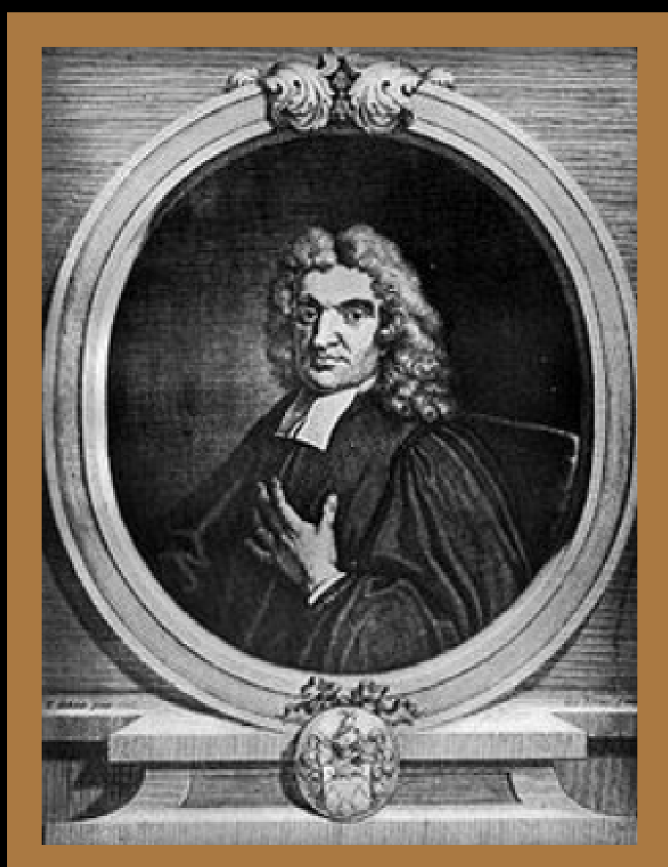
1662 ± 27

instituto de astronomia
unam

¡ Observación de la supernova !

John Flamsteed

(19 ago. 1646 - 31 dic. 1719)
Primer **Astronomer Royal**
(1675 - 1719)



In Constellatione CASSIOPEÆ.

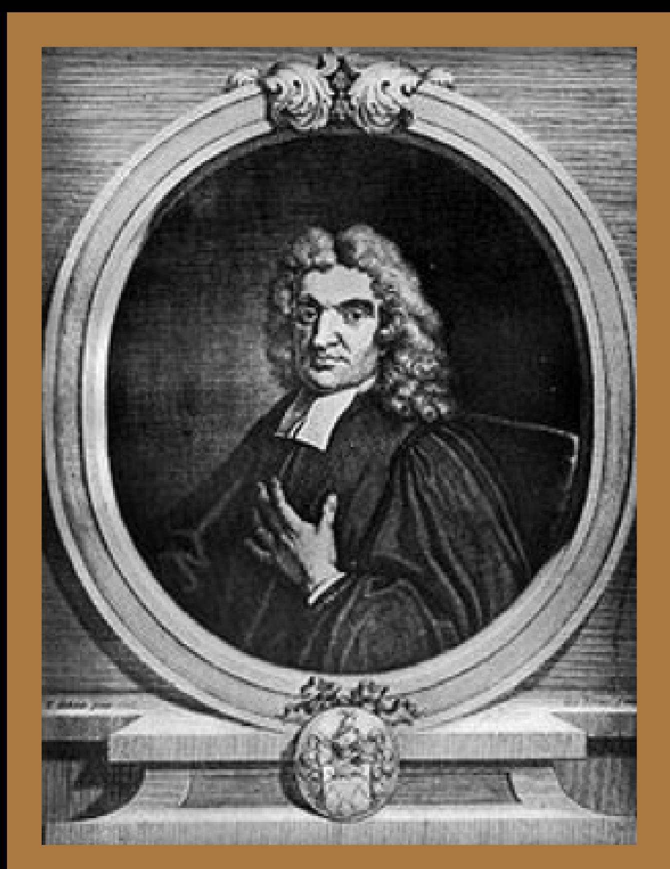
ORDO Ptol.	ORDO Tych.	STELLARUM Denominatio.	Bayer. Cha.	Ascensio Recta. ° ′ ″	Distantia à Polo B. ° ′ ″	Longitudo. s ° ′ ″	Latitudo. ° ′ ″	Varia. Asc.R. ′ ″	Varia. D. à P. ′ ″	Magnitud.
		Quæ est	ι	343 25 0	32 14 20	♈ 21 6 45	56 46 0 B.	44 4	22 48	6
				344 7 30	32 20 0	21 29 16	56 26 10	44 32	22 55	7
				347 37 0	33 1 30	23 5 5	54 38 32	46 57	22 20	6
			d	347 49 30	29 24 30	27 42 49	57 10 12	45 53	23 17	5
	14		τ	353 1 30	33 3 30	26 46 31	52 39 50	50 21	23 40	5

FIG. 1. The positions of the first five Cassiopeia stars, as given in Flamsteed's 1725 catalogue and as depicted in his atlas of 1729.[5] The Flamsteed numbers on the star map have been added.

¡ Observación de la supernova !

John Flamsteed

(19 ago. 1646 - 31 dic. 1719)
Primer **Astronomer Royal**
(1675 - 1719)



In Conſtellatione CASSIOPEÆ.

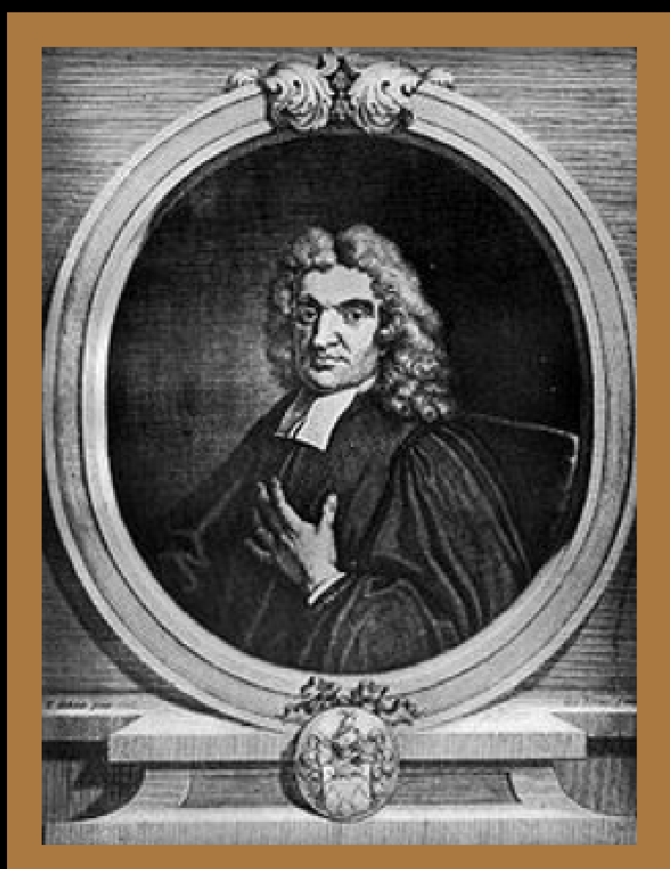
ORDO Ptol.	ORDO Tych.	STELLARUM Denominatio.	Bayer. Cha.	Aſcenſio Recta. ° ′ ″	Diſtantia à Polo B. ° ′ ″	Longitudo. s ° ′ ″	Latitudo. ° ′ ″	Varia. Aſc.R. ′ ″	Varia. D. à P. ′ ″	Magnitud.
		Quæ eſt	ε	343 25 0	32 14 20	♈ 21 6 45	56 46 0 B.	44 4	22 48	6
				344 7 30	32 20 0	21 29 16	56 26 10	44 32	22 55	7
				347 37 0	33 1 30	23 5 5	54 38 32	46 57	22 20	6
			d	347 49 30	29 24 30	27 42 49	57 10 12	45 53	23 17	5
	14		τ	353 1 30	33 3 30	26 46 31	52 39 50	50 21	23 40	5

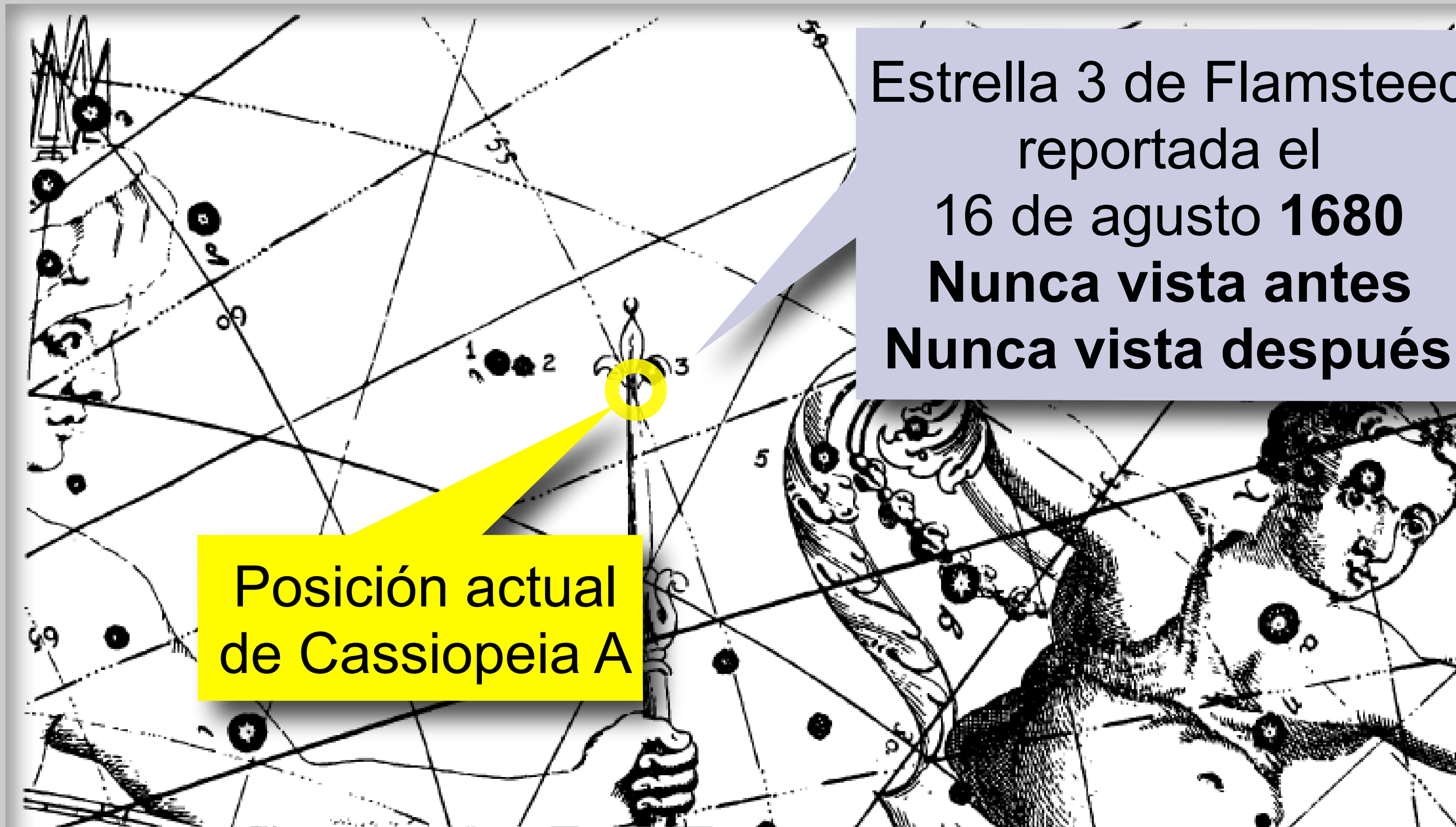
FIG. 1. The positions of the first five Cassiopeia stars, as given in Flamsteed's 1725 catalogue and as depicted in his atlas of 1729.[5] The Flamsteed numbers on the star map have been added.

¡ Observación de la supernova !

John Flamsteed

(19 ago. 1646 - 31 dic. 1719)
Primer **Astronomer Royal**
(1675 - 1719)



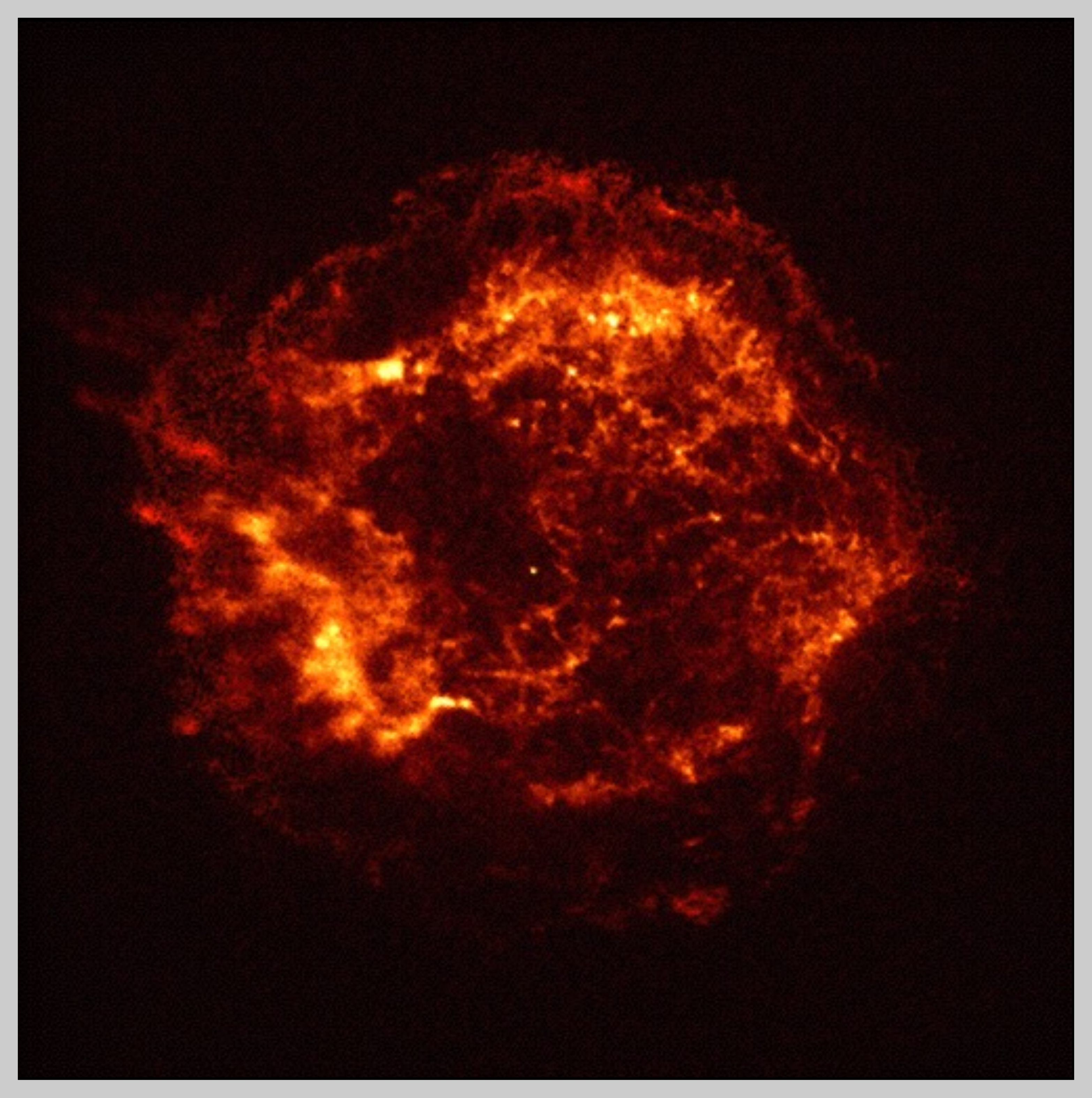


In Conſtellatione CASSIOPEÆ.

ORDO Ptol.	ORDO Tych.	STELLARUM Denominatio.	Bayer. Cha.	Aſcenſio Recta. ° ′ ″	Diſtantia à Polo B. ° ′ ″	Longitudo. s ° ′ ″	Latitudo. ° ′ ″	Varia. Aſc.R. ′ ″	Varia. D. à P. ′ ″	Magnitud.
		Quæ eſt	ε	343 25 0	32 14 20	♈ 21 6 45	56 46 0 B.	44 4	22 48	6
				344 7 30	32 20 0	21 29 16	56 26 10	44 32	22 55	7
				347 37 0	33 1 30	23 5 5	54 38 32	46 57	22 20	6
			d	347 49 30	29 24 30	27 42 49	57 10 12	45 53	23 17	5
	14		τ	353 1 30	33 3 30	26 46 31	52 39 50	50 21	23 40	5

FIG. 1. The positions of the first five Cassiopeia stars, as given in Flamsteed's 1725 catalogue and as depicted in his atlas of 1729.[5] The Flamsteed numbers on the star map have been added.

¡ Reaparece la estrella !



Agosto 1999

¡ Reaparece la estrella !

Agosto 1999

The Nobel Prize in Physics 2002

"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"

"for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"

Raymond Davis Jr.

1/4 of the prize

USA

University of Pennsylvania
Philadelphia, PA, USA

b. 1914
d. 2006

Masatoshi Koshiba

1/4 of the prize

Japan

University of Tokyo
Tokyo, Japan

b. 1926

Riccardo Giacconi

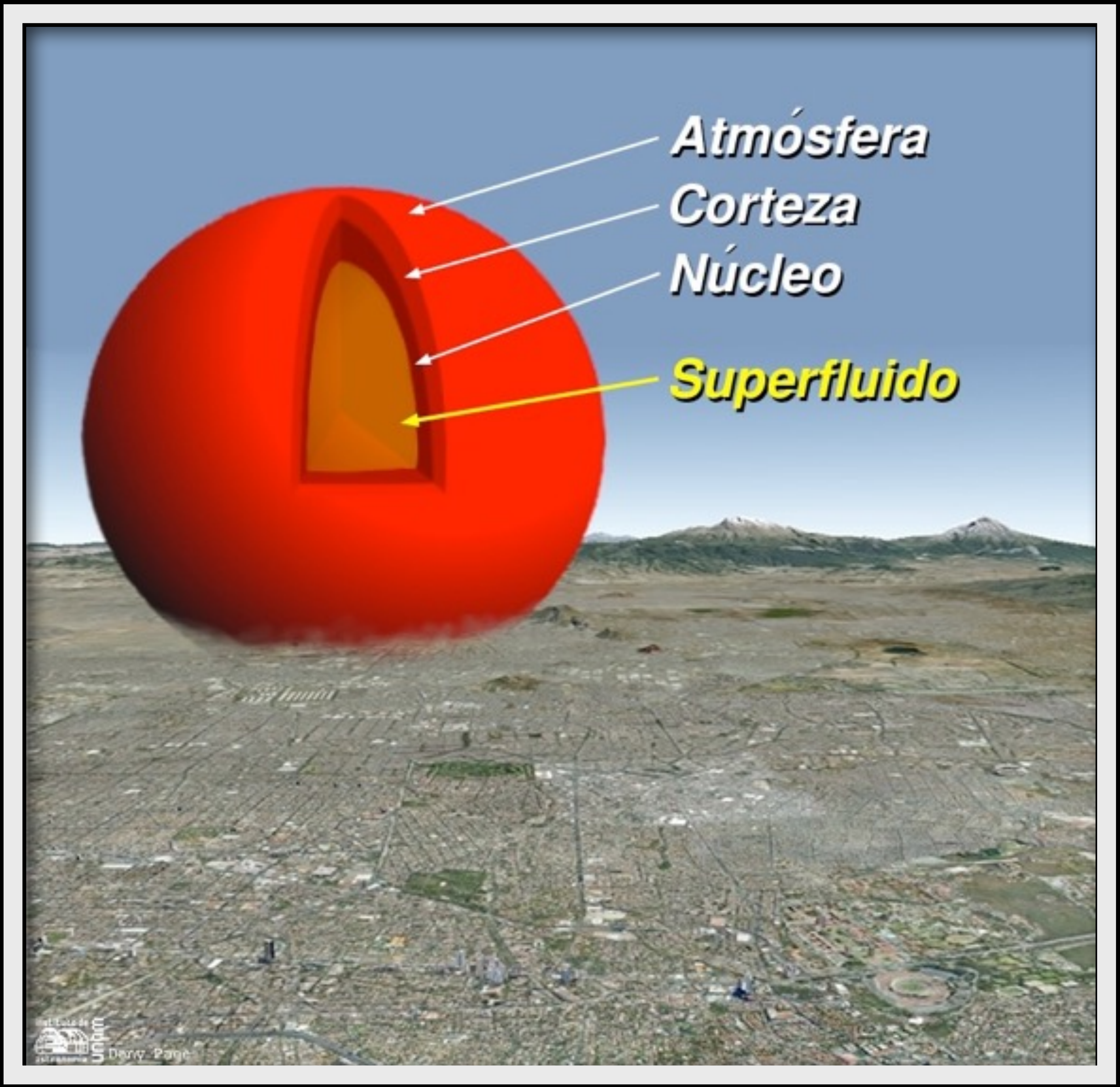
1/2 of the prize

USA

Associated Universities Inc.
Washington, DC, USA

b. 1931
(in Genoa, Italy)

Una estrella de neutrones y el D.F.

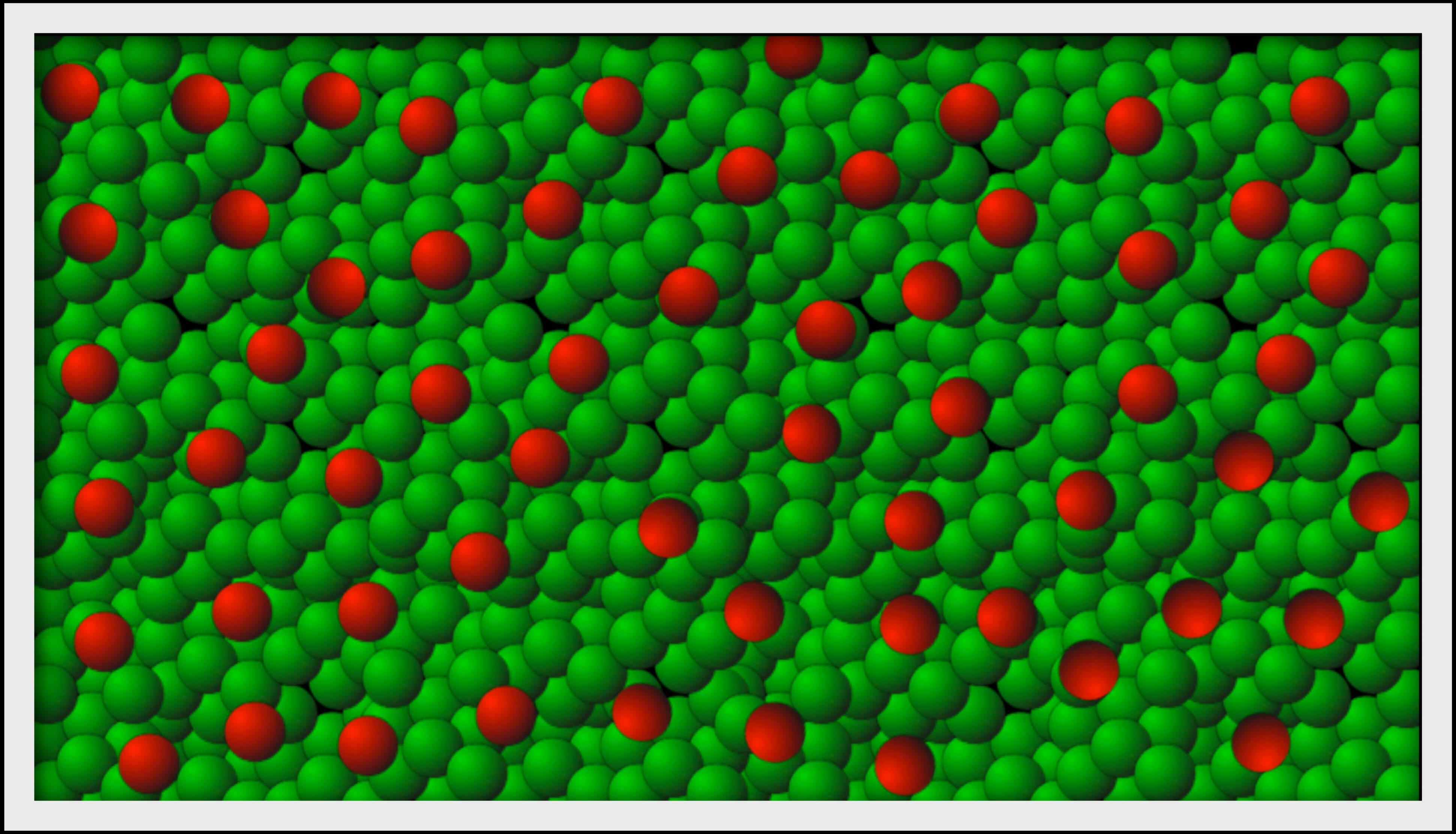


Es un núcleo atómico del tamaño de una metrópolis

Masa: 1-2 M_{Sol}
Diámetro: 20-30 km

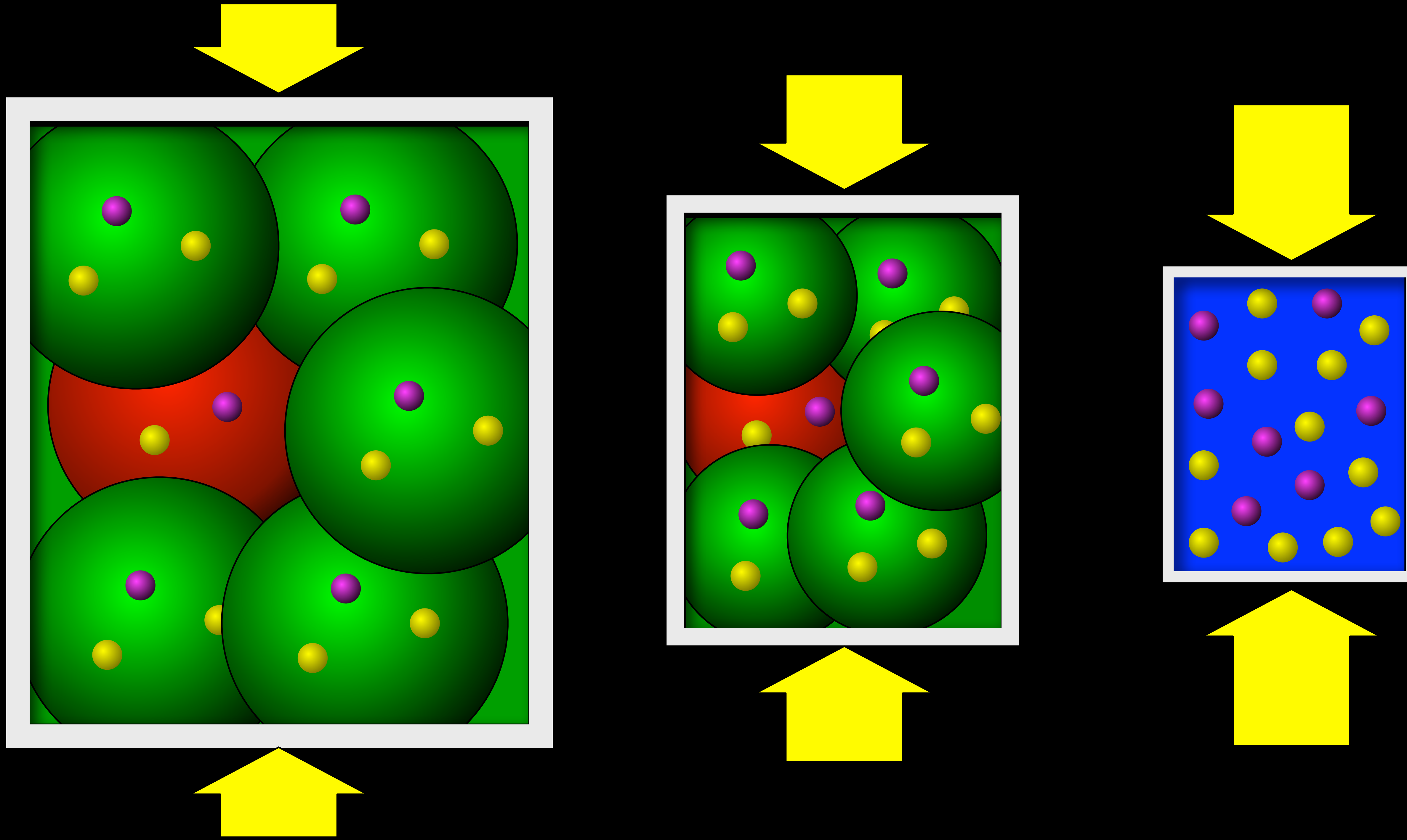
Densidad:
10^{15} g/cm^3 =
mil millones de toneladas por cm^3

El interior de una estrella de neutrones

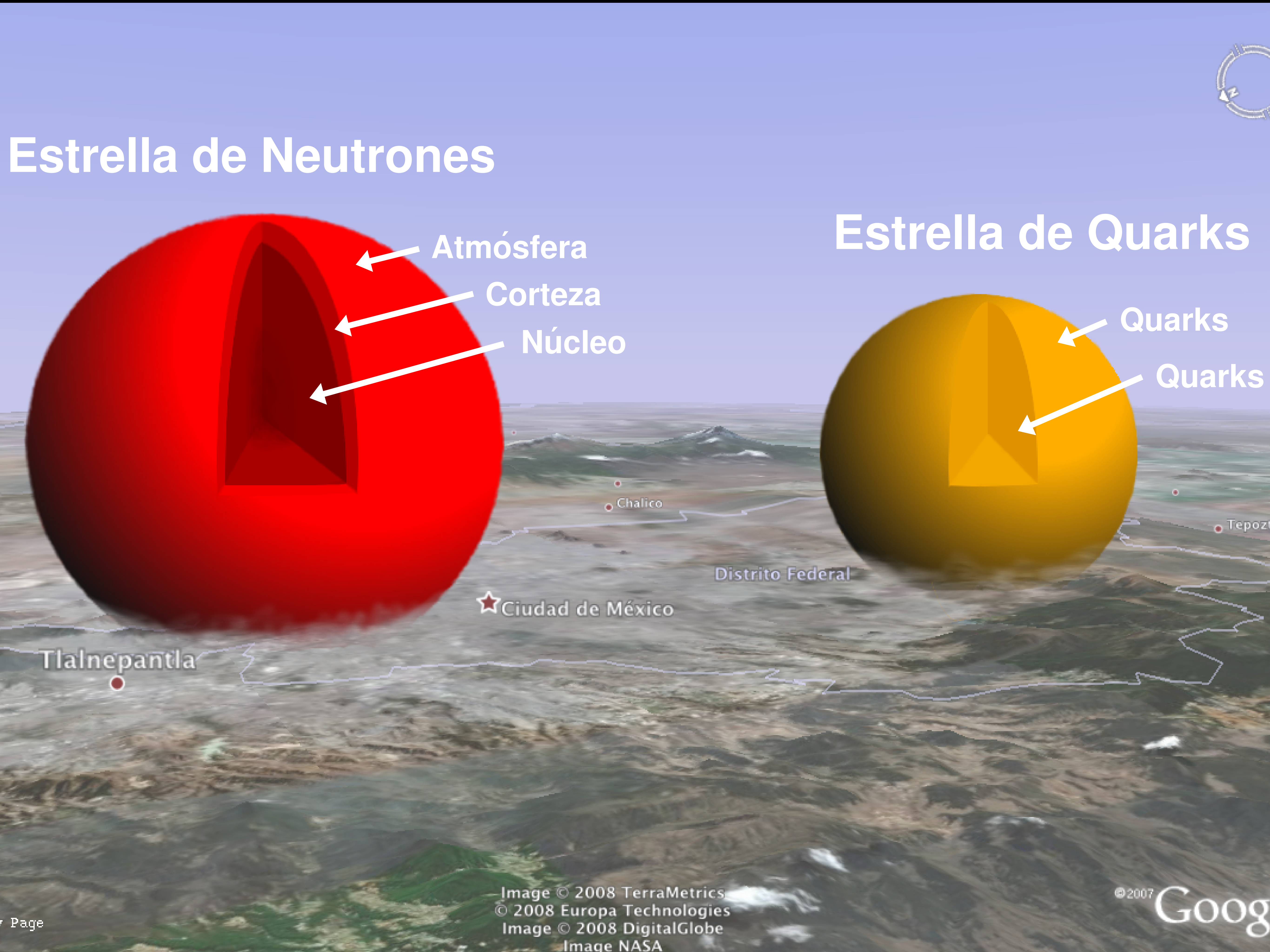


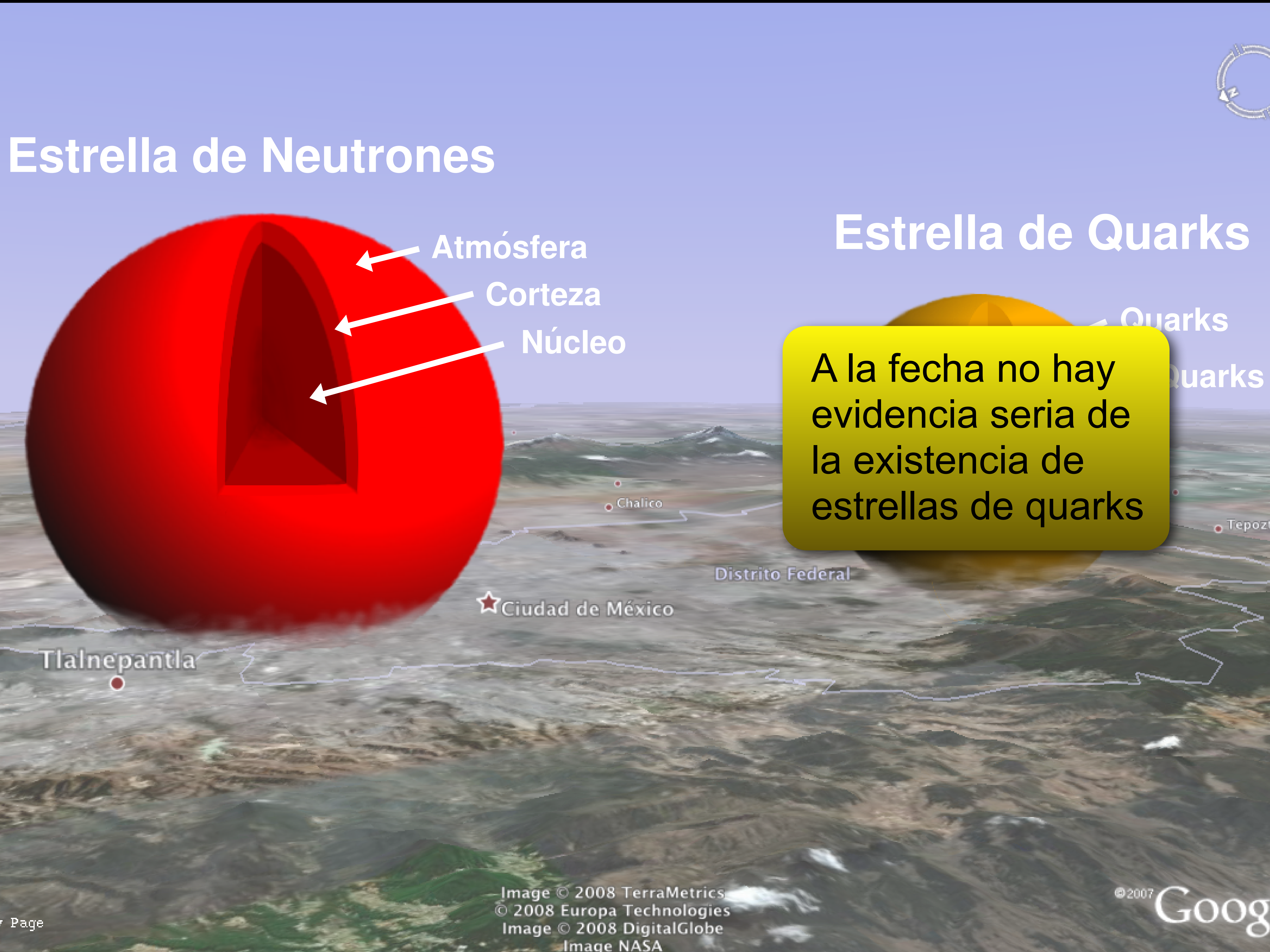
Contiene un 90% de neutrones y un 10% de protones

¿ De nucleones a quarks ?

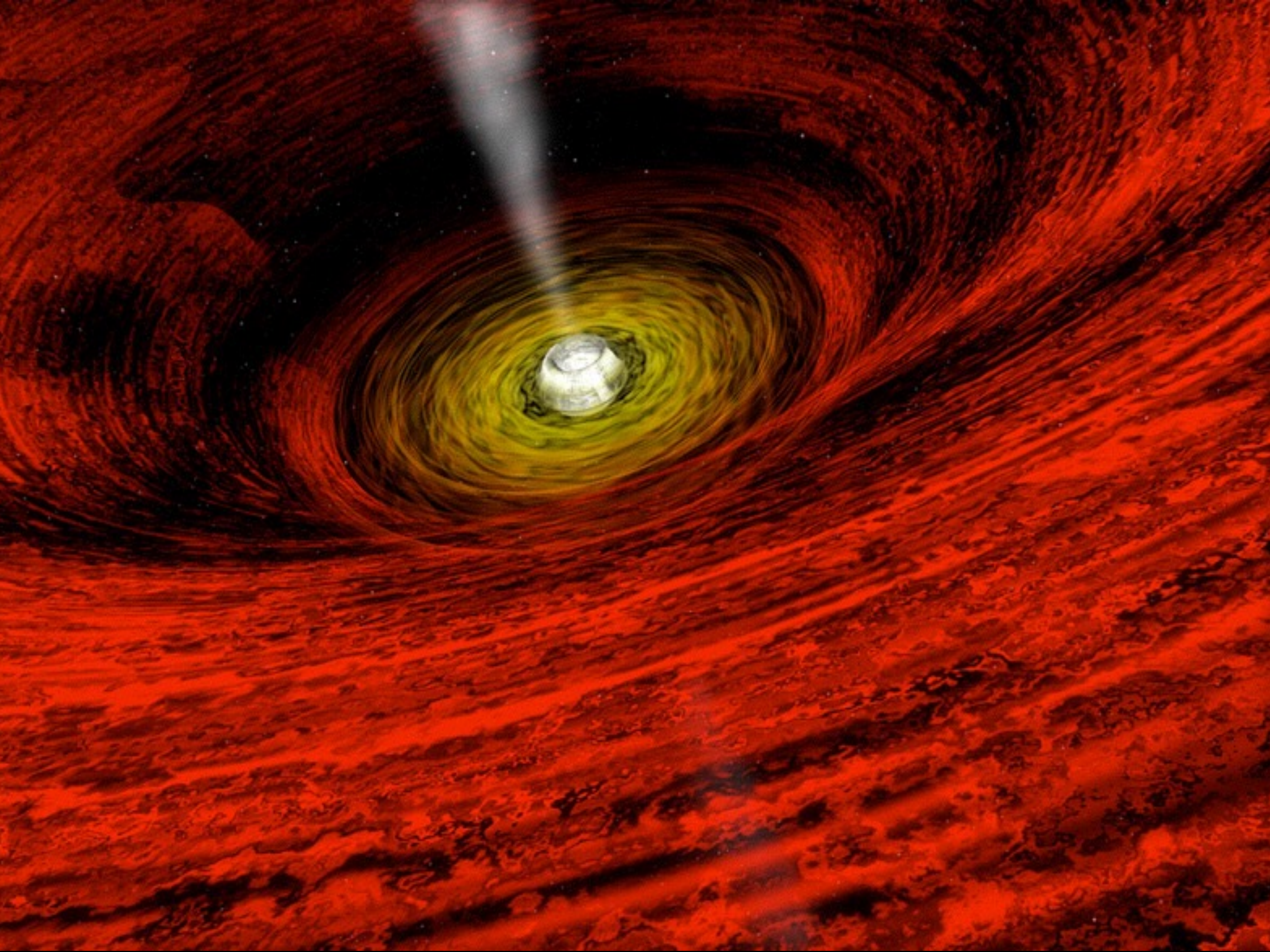


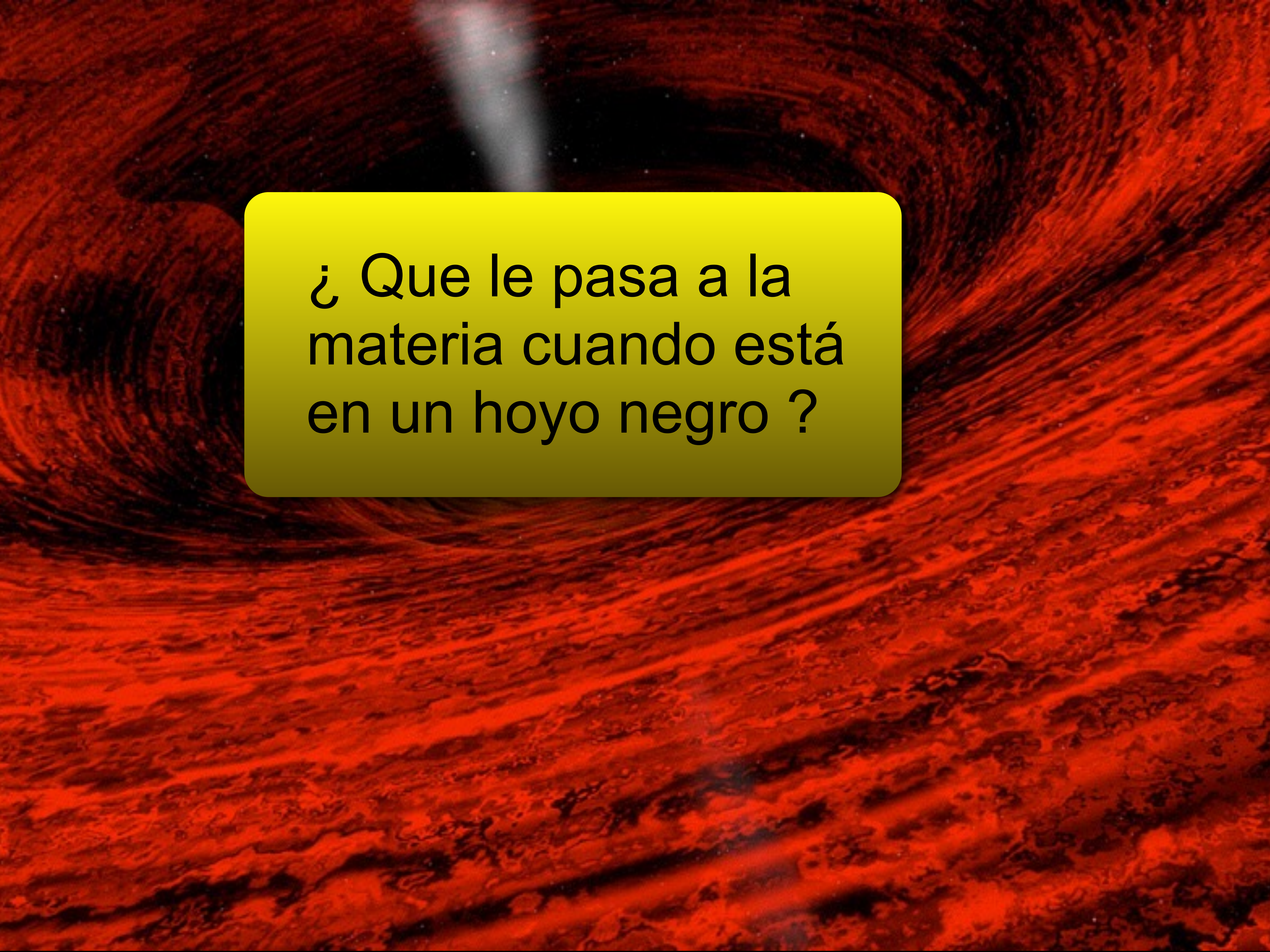
El aumento de presión por la gravedad en el centro puede llevar al desconfinamiento de los quarks

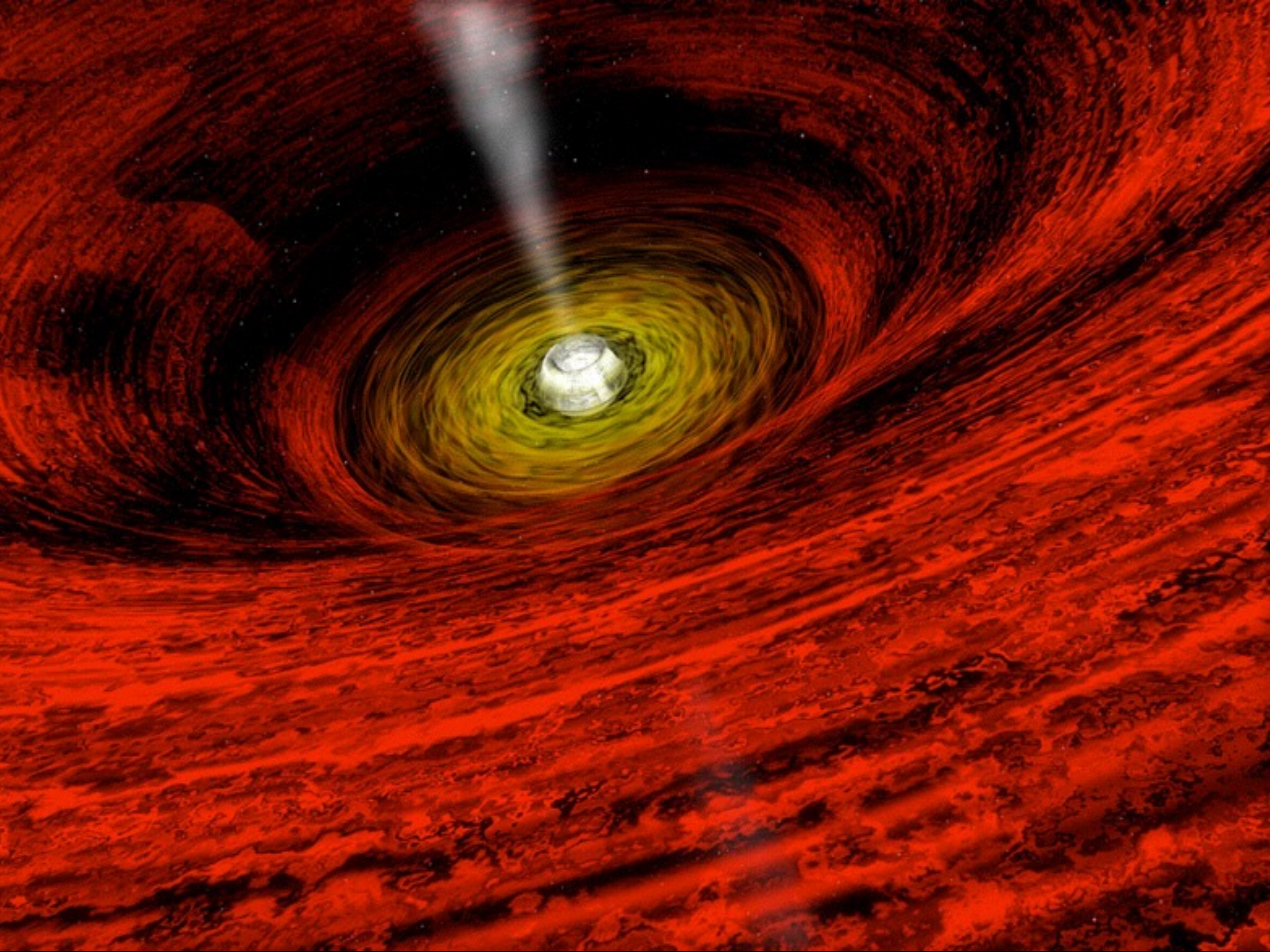

Estrella de Neutrones
Atmósfera
Corteza
Núcleo
Estrella de Quarks
Quarks
Quarks
Chalico
Distrito Federal
Ciudad de México
Tlalnepantla
Image © 2008 TerraMetrics
© 2008 Europa Technologies
Image © 2008 DigitalGlobe
Image NASA



Estrella de Neutrones
Atmósfera
Corteza
Núcleo
Estrella de Quarks
Quarks
A la fecha no hay evidencia seria de la existencia de estrellas de quarks
Chalico
Distrito Federal
Ciudad de México
Tlalnepantla
Image © 2008 TerraMetrics
© 2008 Europa Technologies
Image © 2008 DigitalGlobe
Image NASA
©2007




¿ Que le pasa a la materia cuando está en un hoyo negro ?




"That's all Folks!"