Formação e Evolução Estelar

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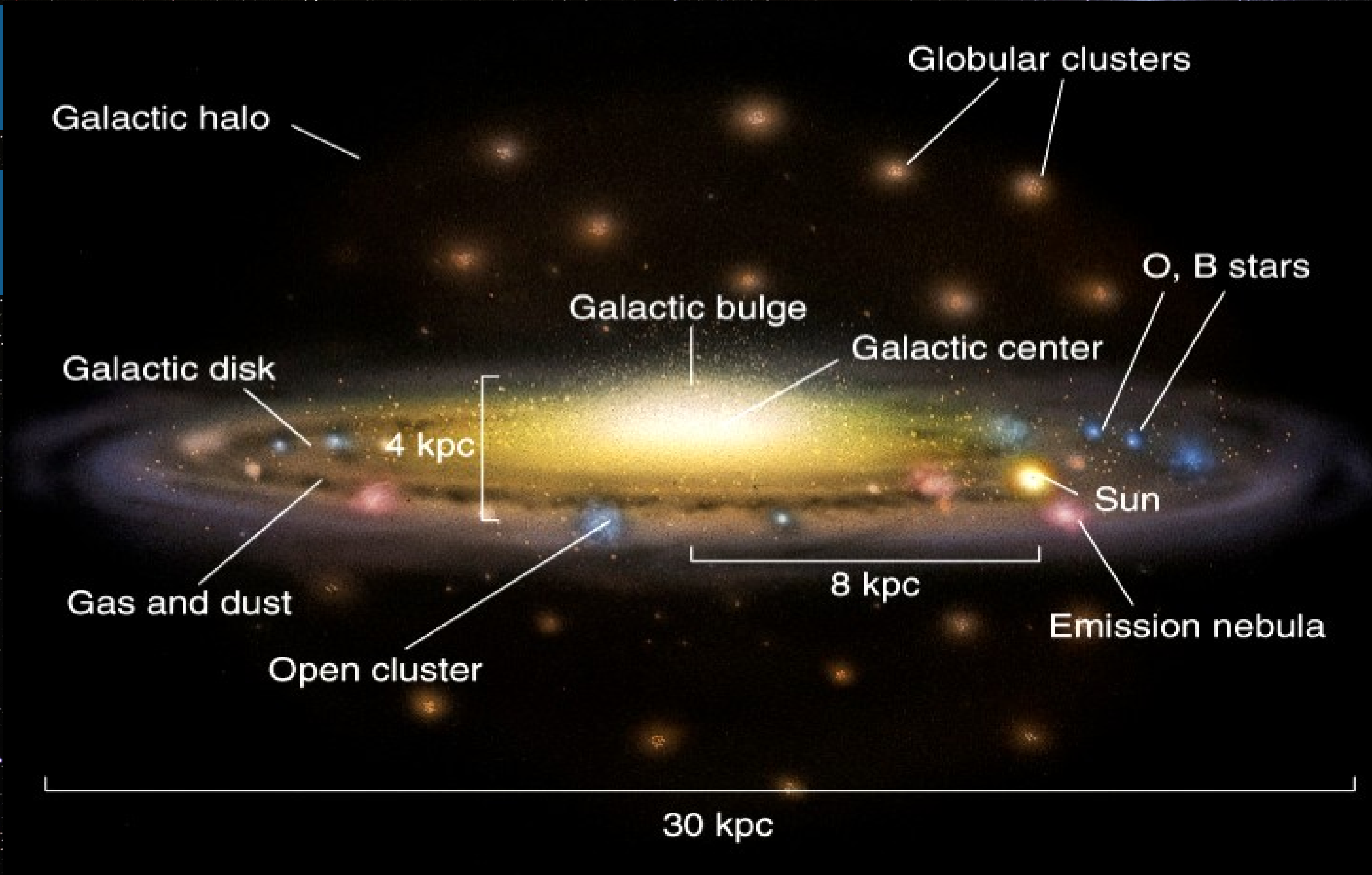
Populações Estelares na Via-Láctea



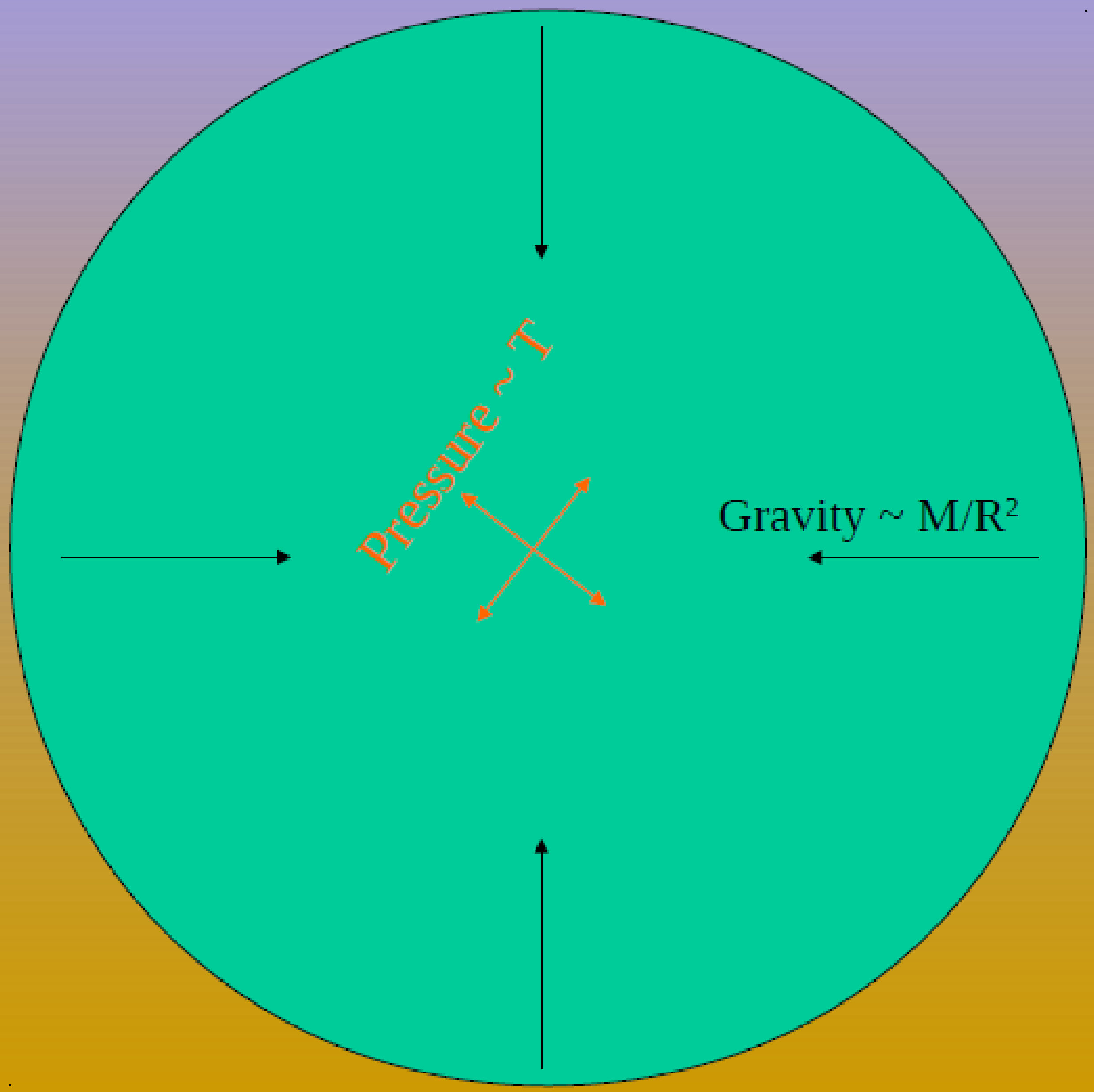
NGC1300: a single bar with two arms

Nuvens Moleculares Gigantes

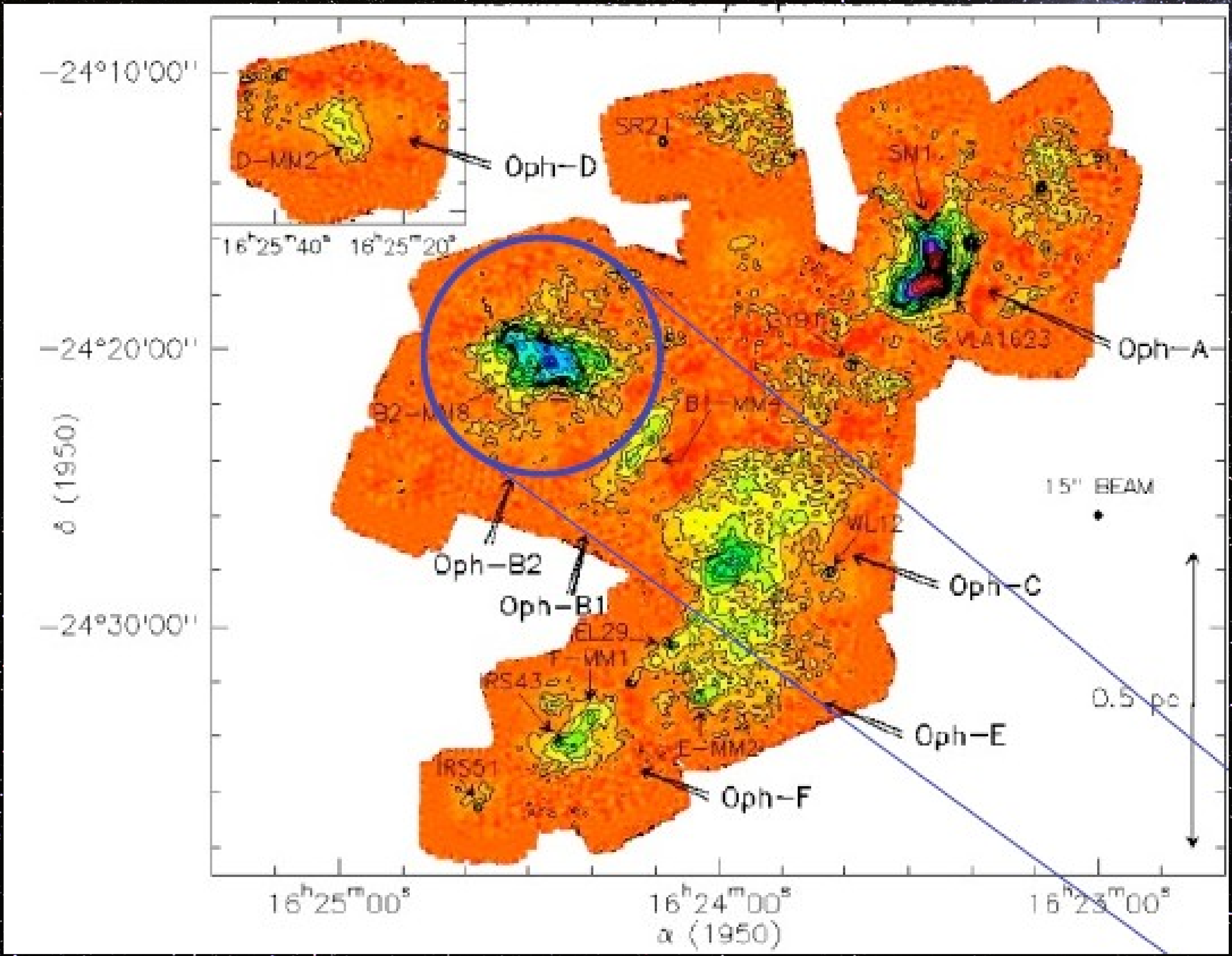
Nuvem Molecular x Estrela

Dens (cm^{-3}):	10^4 (~H_2)	X	10^{24} (~H)
Temp (K):	10 – 30	X	10^7
Raio (cm) :	10^{17}	X	10^{11}

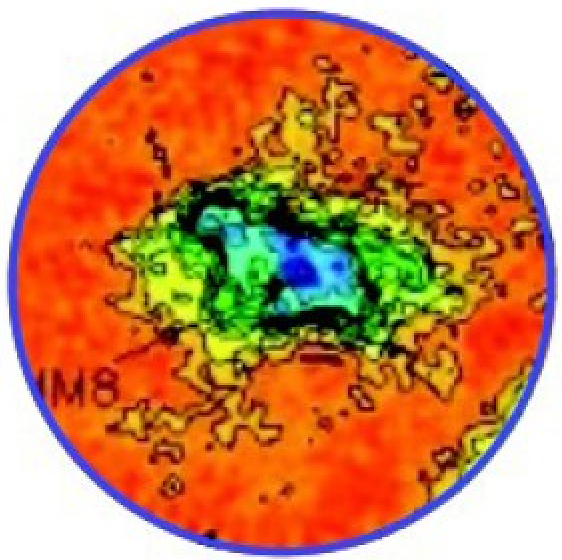
Nuvem Molecular

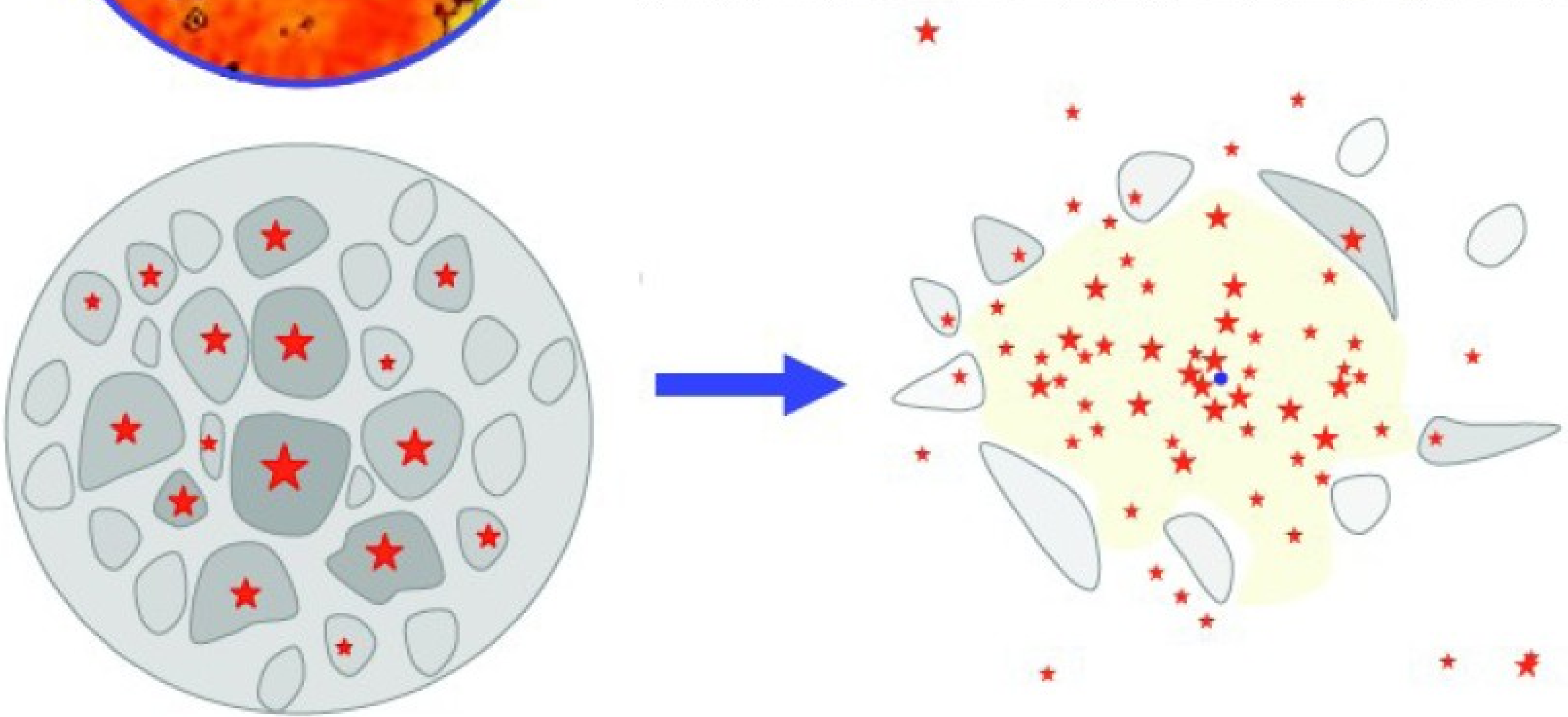


Estrutura de Nuvens Moleculares

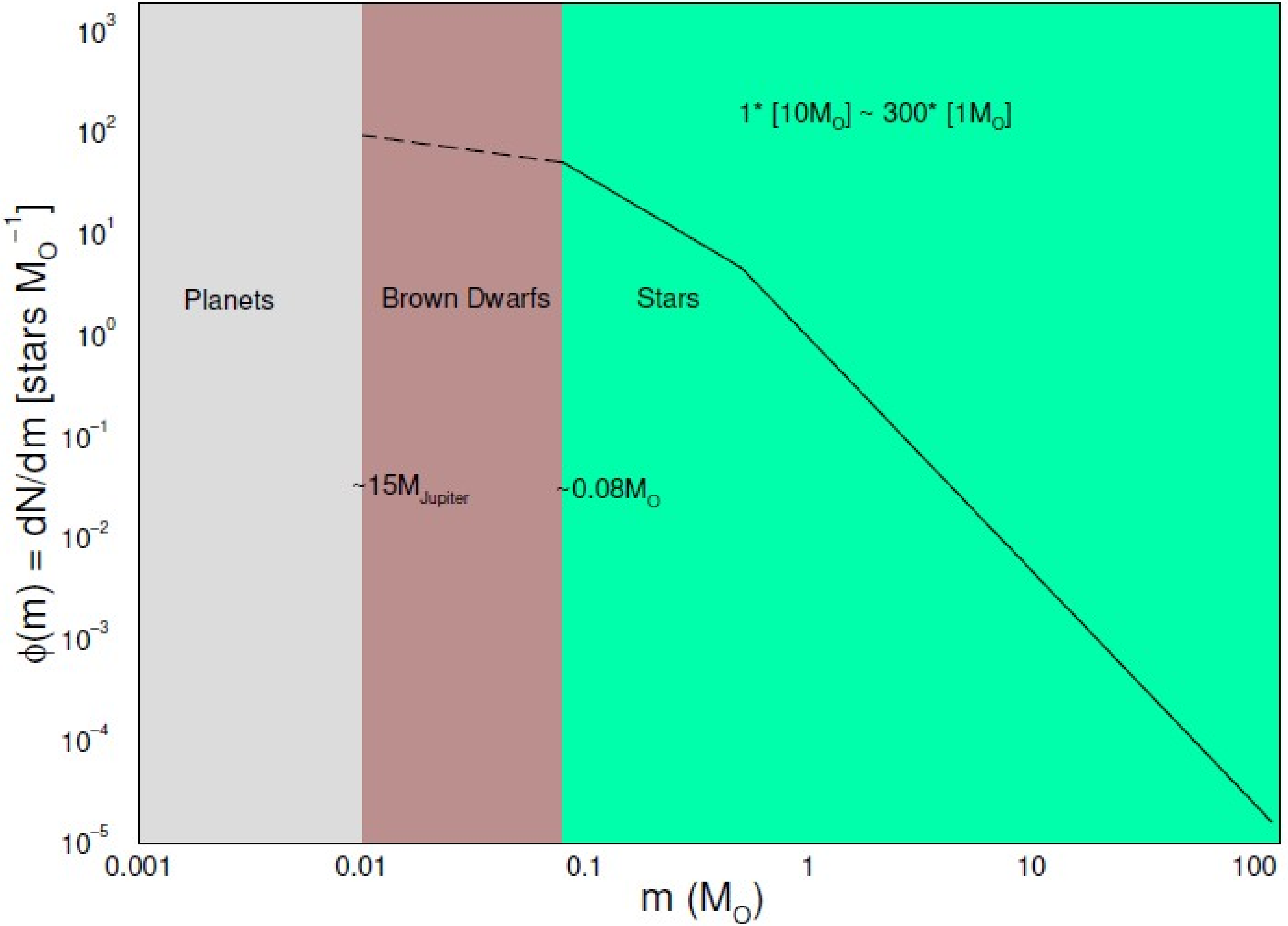


Colapso de Nuvens Moleculares

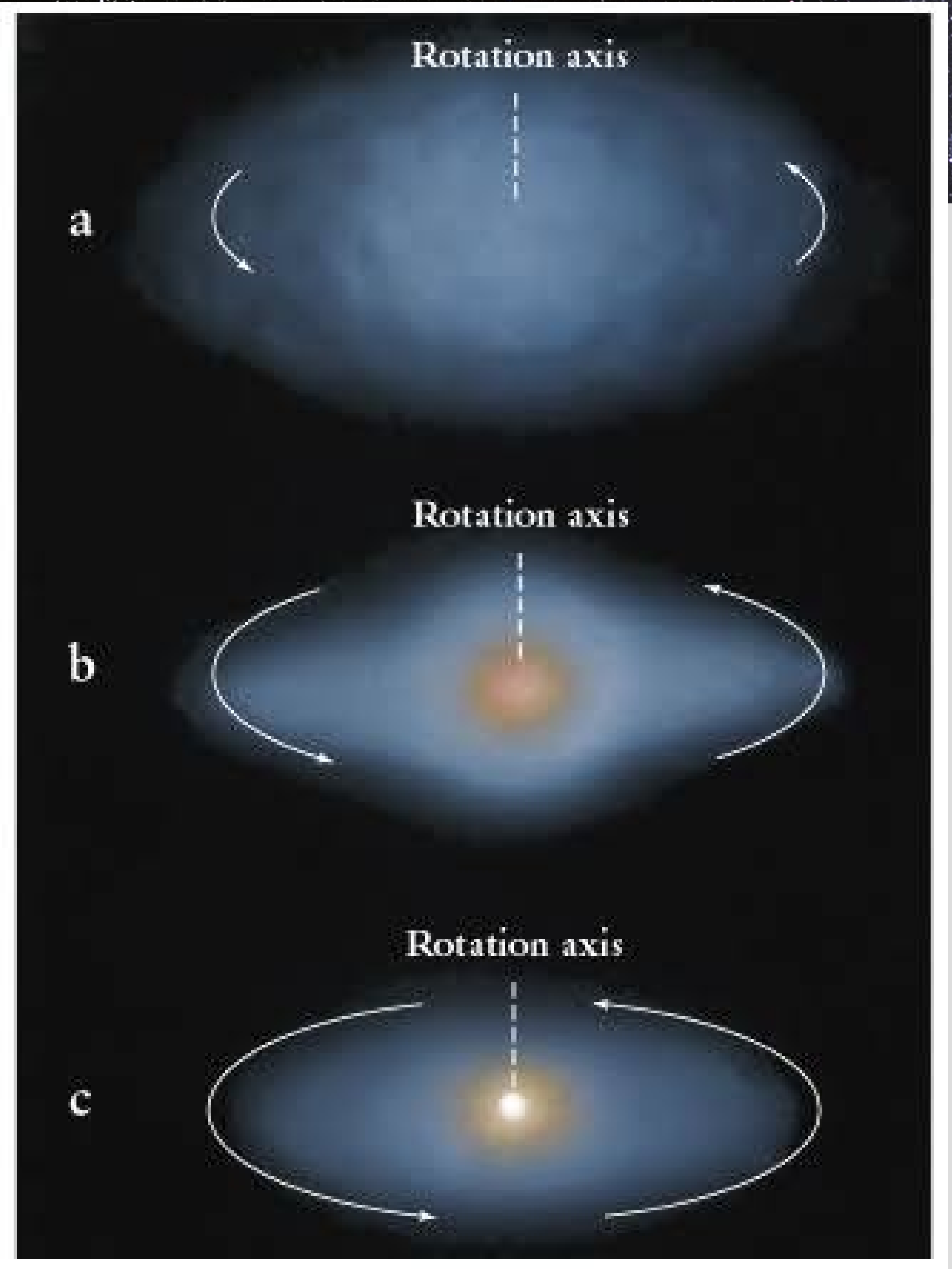




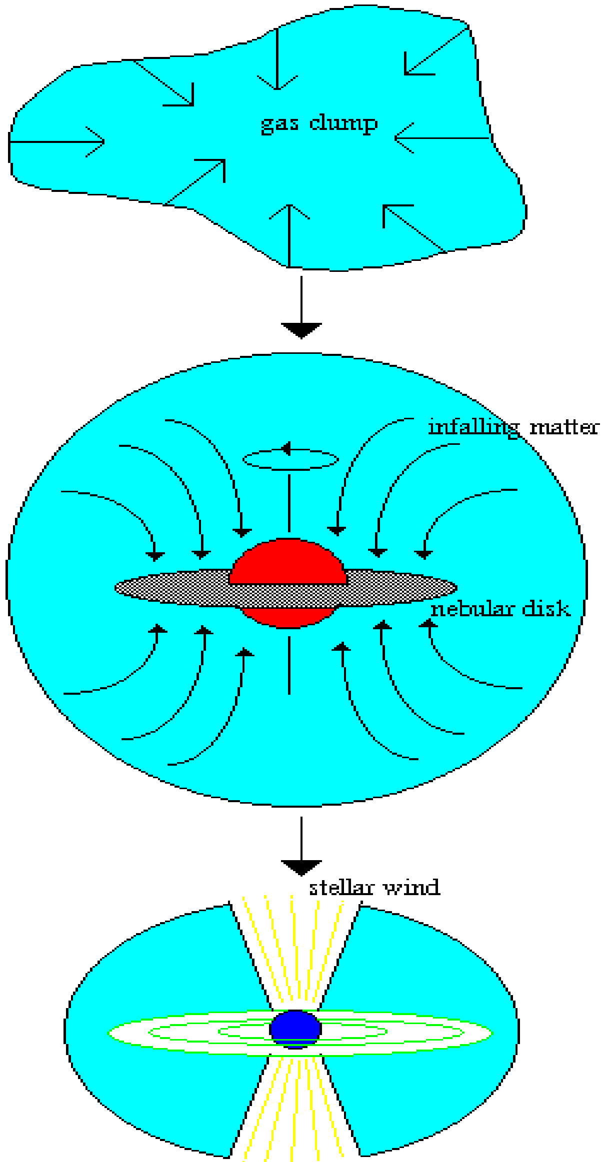
Initial Mass Function



Formação de proto-estrelas



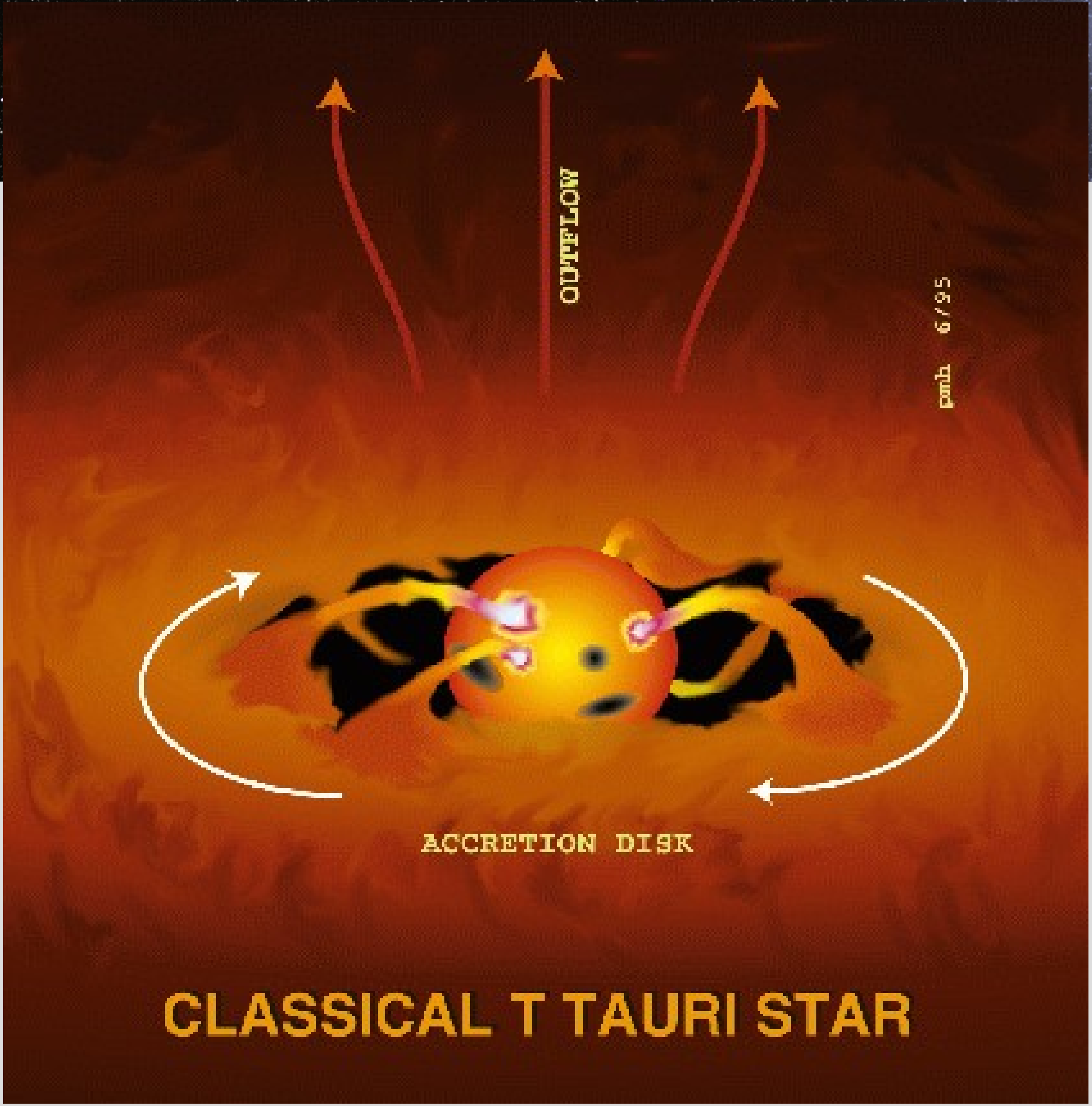
Protostar Formation



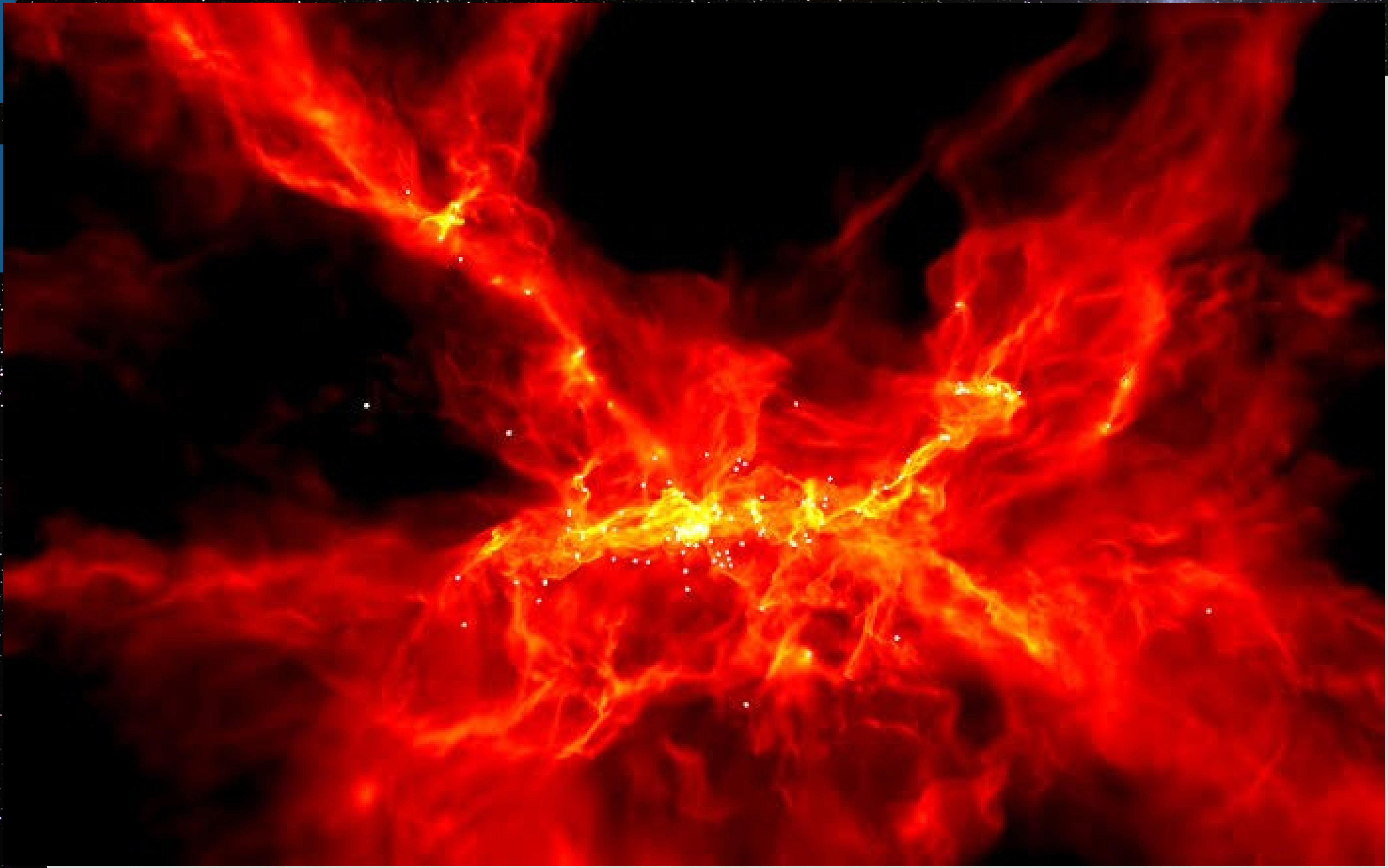
A dense gas clump breaks off from molecular cloud and collapses Angular momentum turns the irregular clump into a rotating disk

The central region is denser and forms into a protostar, the nebular disk forms slower to become a planetary system. Infalling matter increases the size of the protostar by a factor of 100

Infall is stopped when the protostar begins thermonuclear fusion and produces a strong stellar wind


OUTFLOW
pmb 6/95
ACCRETION DISK
CLASSICAL T TAURI STAR

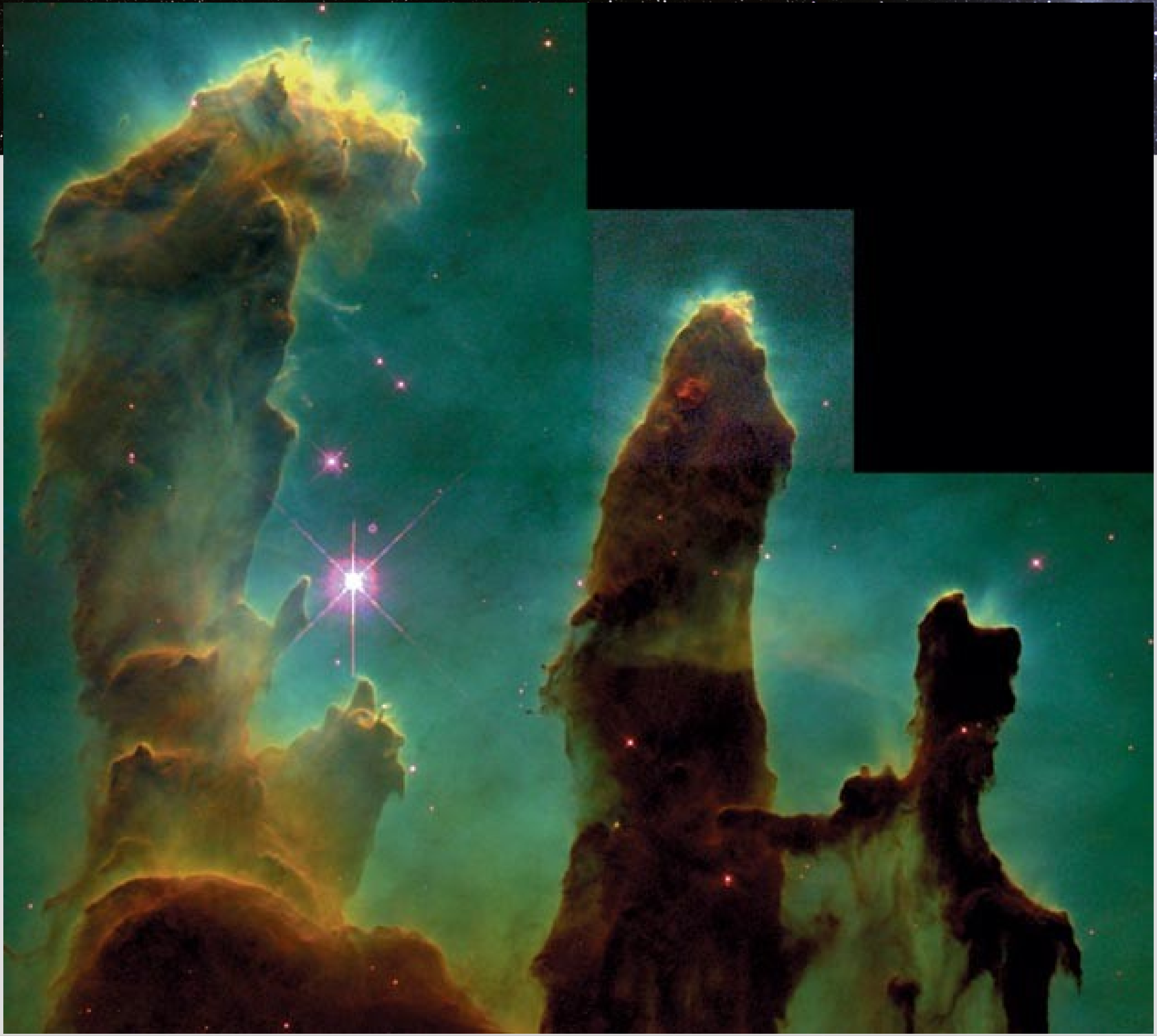
Nuvem Molec Colapsada: filamentos



Estrelas jovens em nuvens moleculares

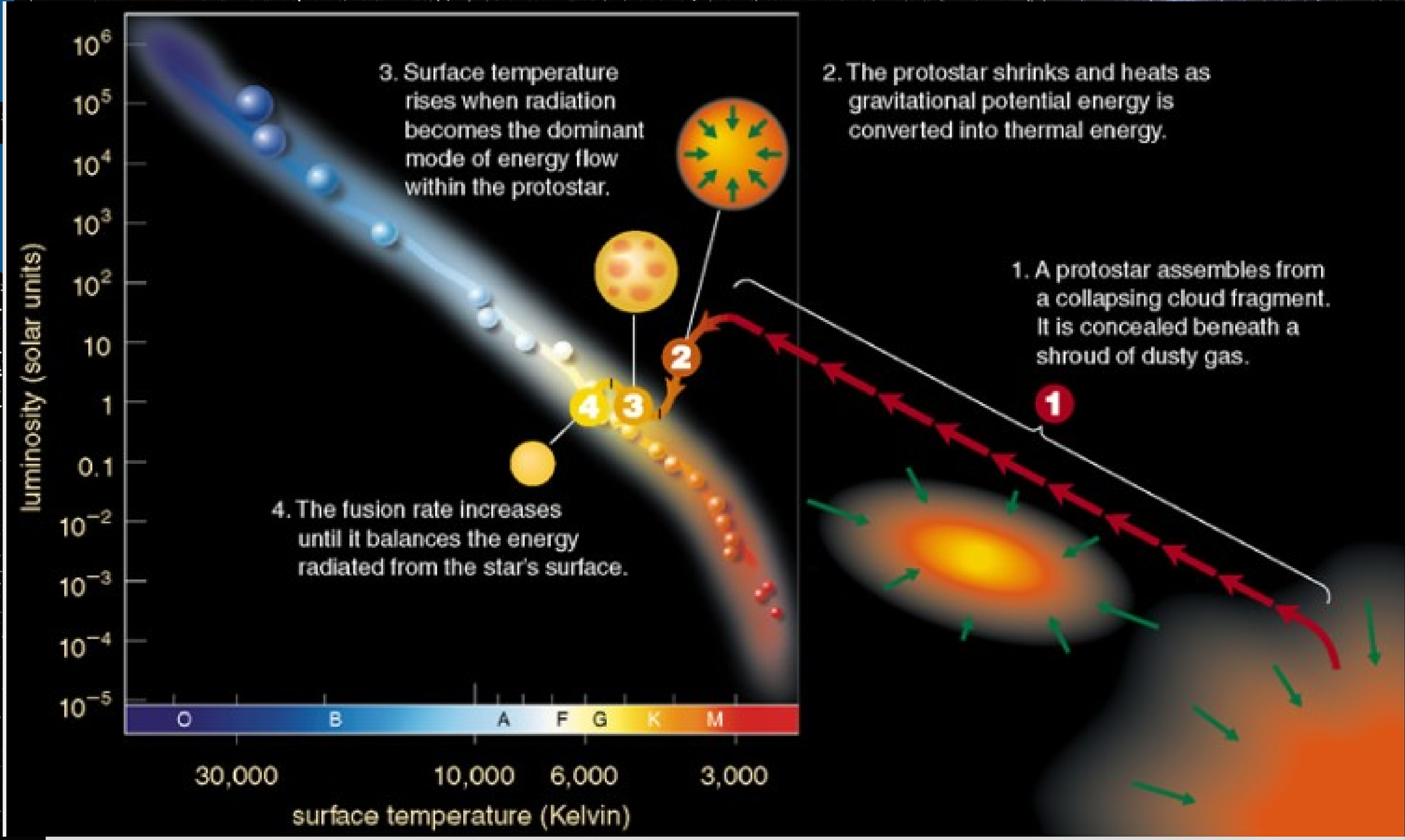
Nebulosas de Emissão [M42 - Orion]

M16 – Nebulosa da Águia

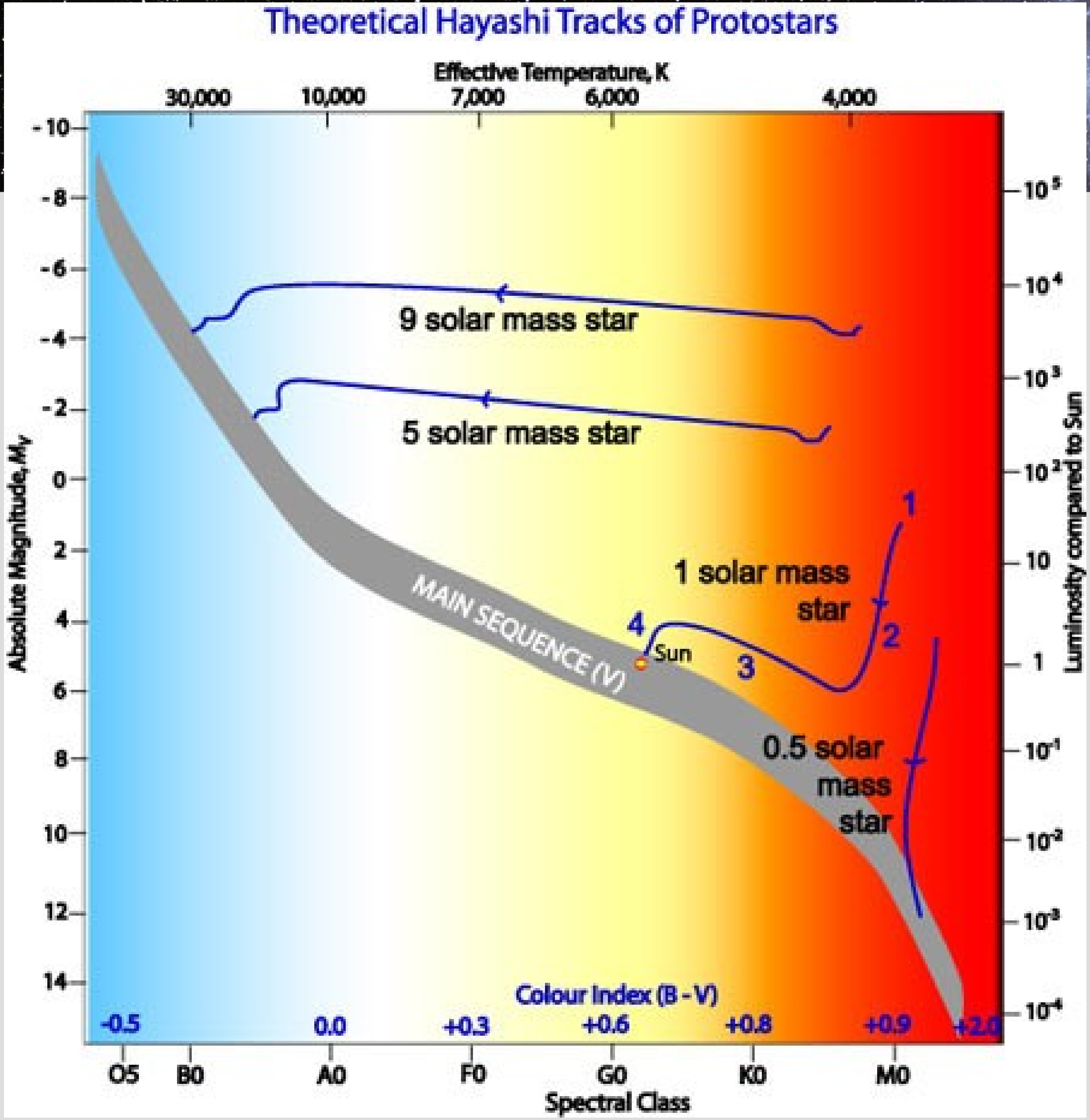


Nebulosa Trífida

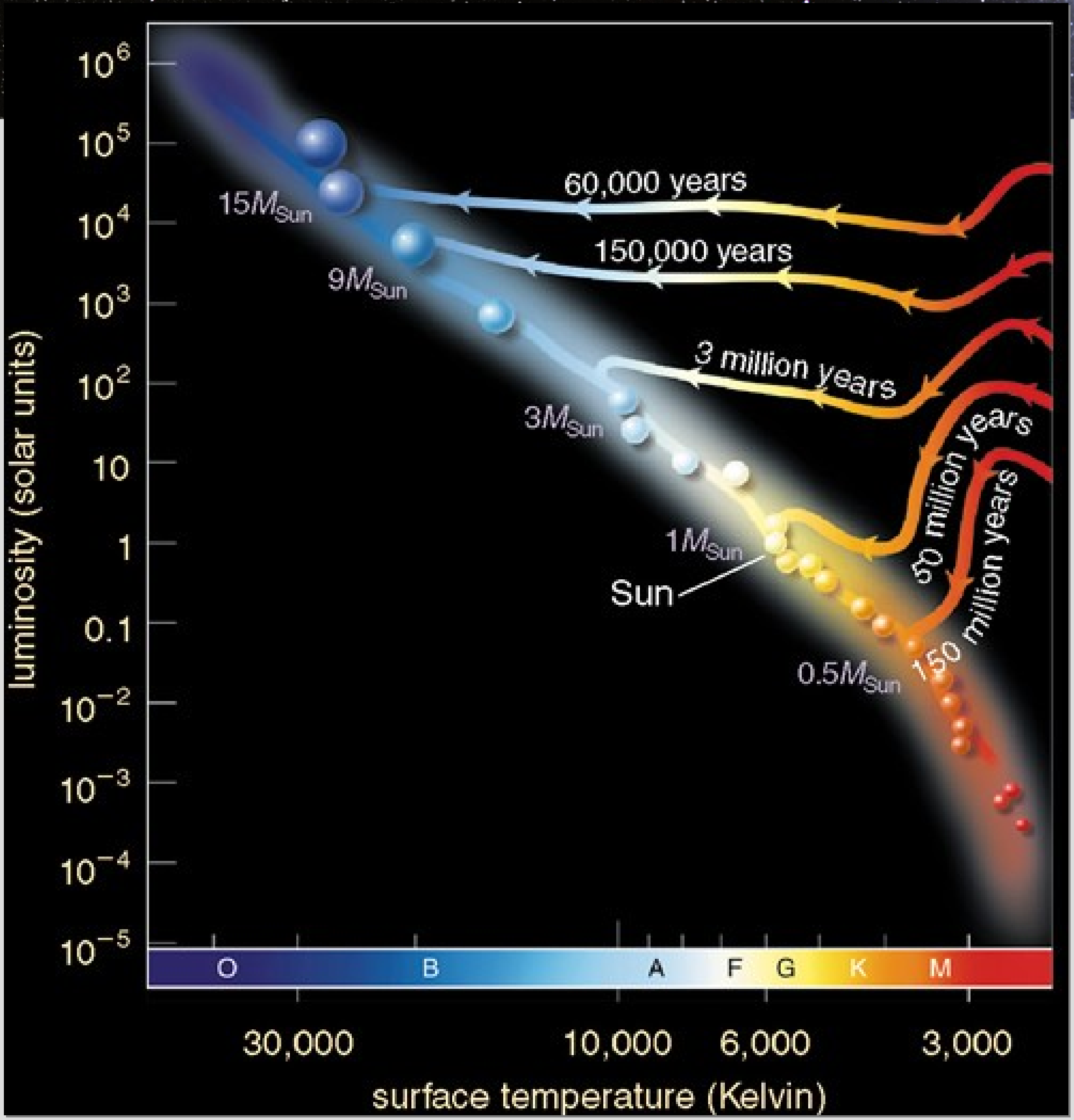
Do colapso à estrela



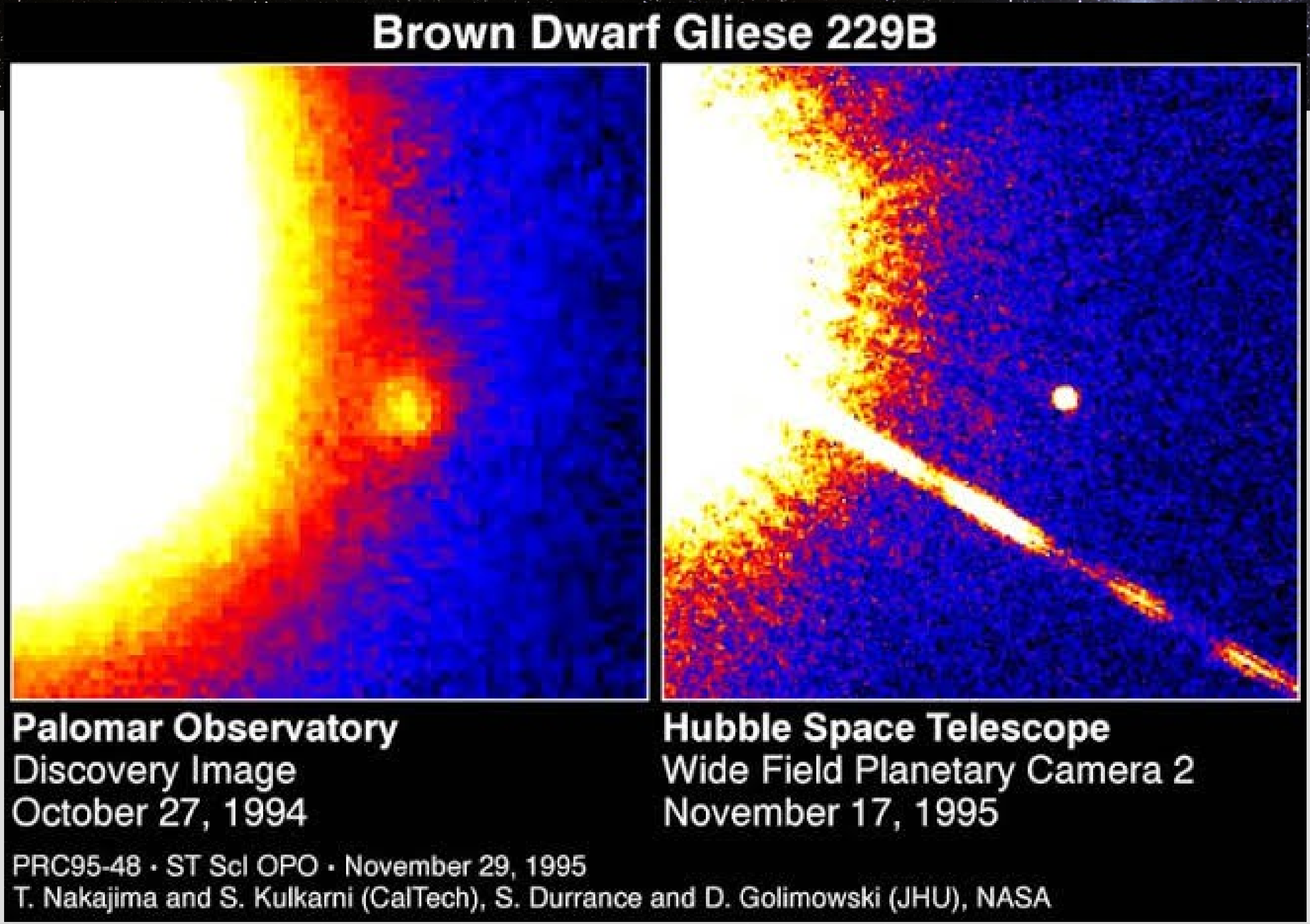
Evolução de proto-estrelas



Estrelas massivas se formam + rapidamente



Anãs-marrons: estrelas falhadas!
Gliese 229B – 1a BD descoberta

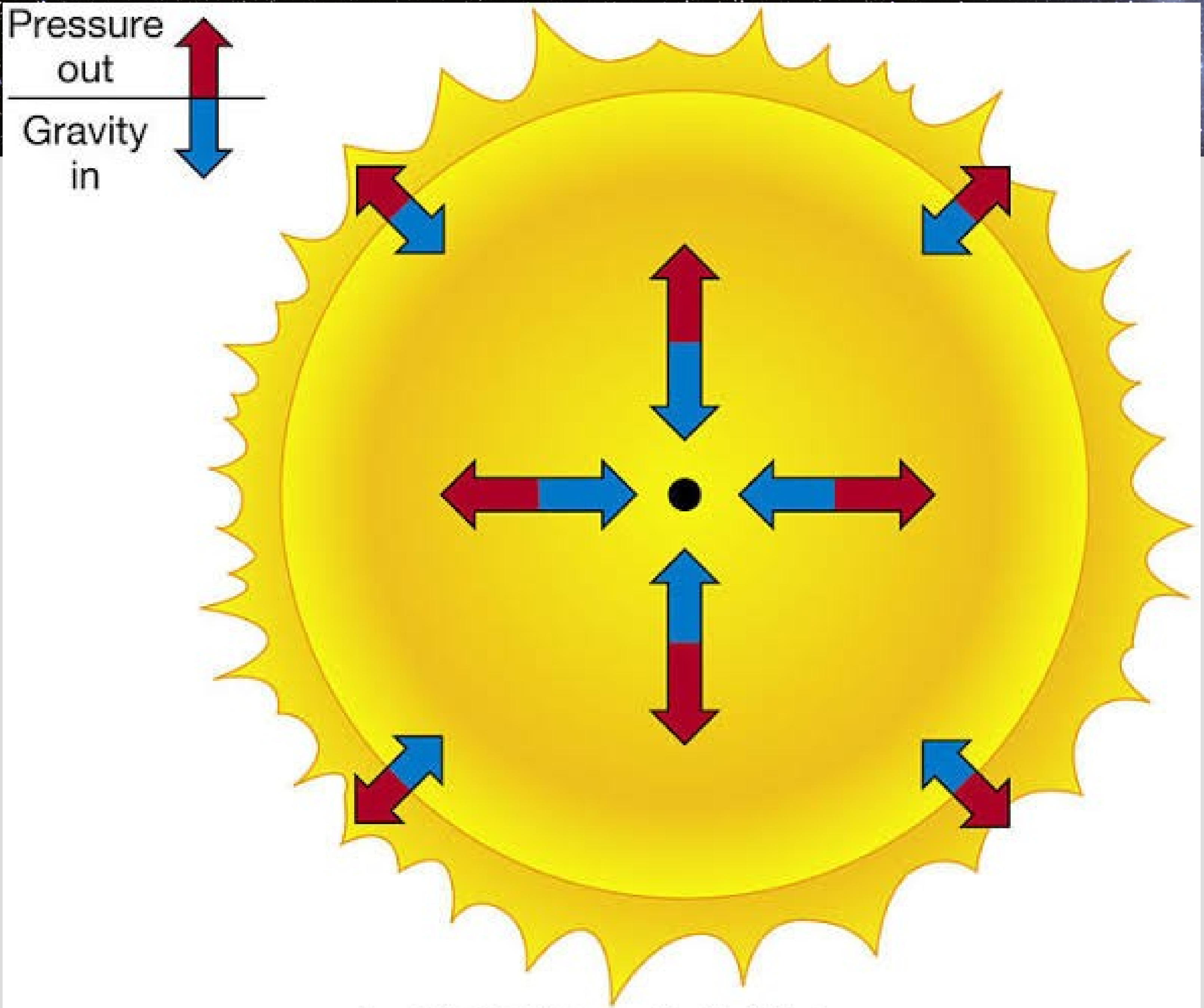


Estrelas buscam estabelecer Estados de Equilíbrio:

(i) – Hidrostático: volume ~ cte

(ii) – Térmico – luminosidade ~ cte

A eterna batalha contra o peso!



Umas poucas equações

$$\boxed{\frac{dM_r}{dr} = 4\pi r^2 \rho}$$

$$\frac{dT}{dr} = -\frac{3L_r K \rho}{4\pi r^2 4acT^3}$$

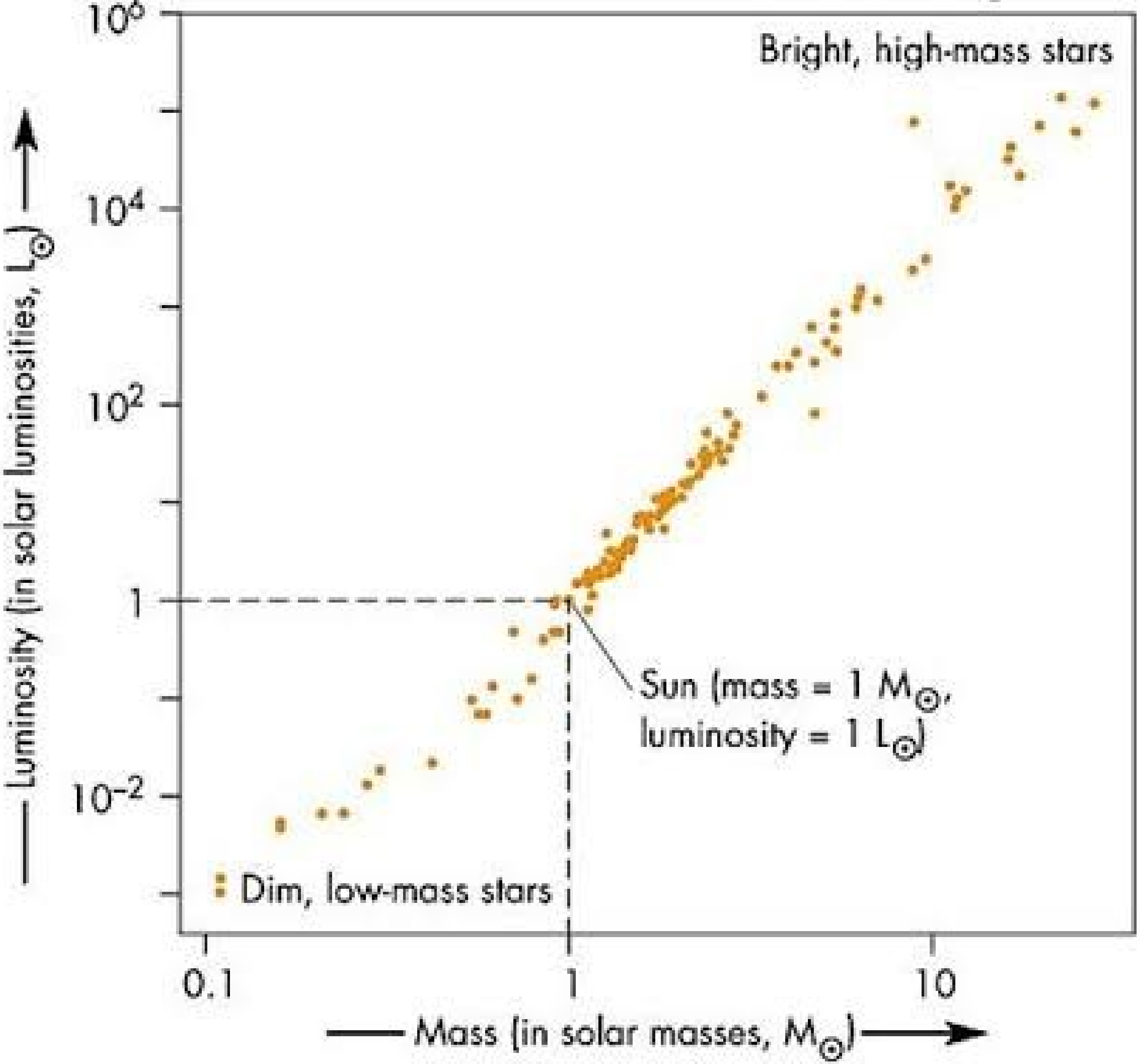
$$\boxed{\frac{dP}{dr} = -\rho \frac{GM_r}{r^2}}$$

$$\boxed{\frac{dL_r}{dr} = 4\pi r^2 \rho \left[\varepsilon - \frac{3}{2} \rho^{\frac{2}{3}} \frac{d}{dt} \left(\frac{P}{\rho^{\frac{5}{3}}} \right) \right]}$$

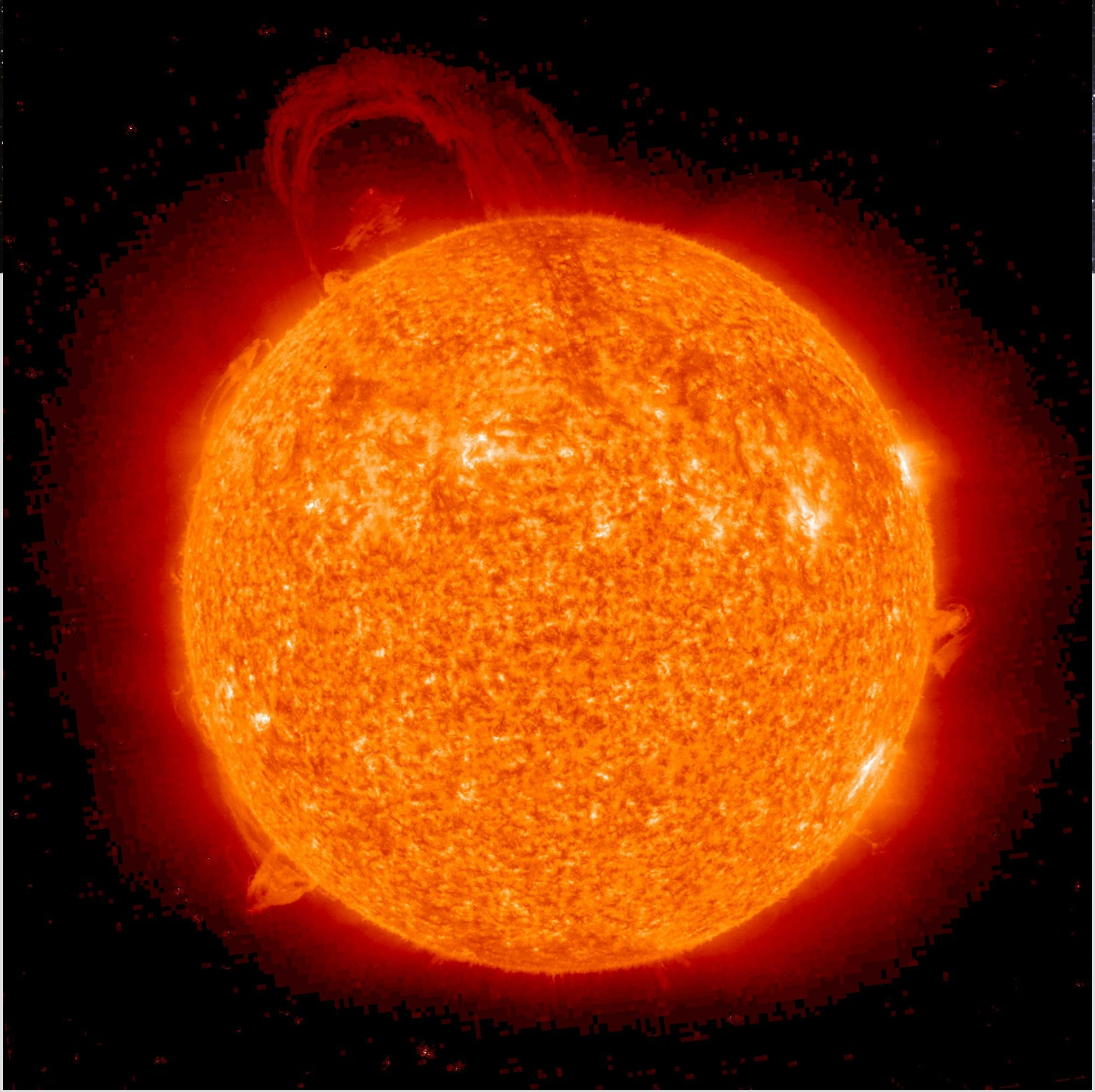
Table 9-2 | Main-Sequence Stars

Spectral Type	Mass (Sun = 1)	Luminosity (Sun = 1)	Years on Main Sequence
O5	40	405,000	1×10^6
B0	15	13,000	11×10^6
A0	3.5	80	440×10^6
F0	1.7	6.4	3×10^9
G0	1.1	1.4	8×10^9
K0	0.8	0.46	17×10^9
M0	0.5	0.08	56×10^9

Mass-Luminosity relation on the main sequence



$$\frac{L}{L_{\odot}} \approx \left(\frac{M}{M_{\odot}}\right)^{3.5}$$



Alguns parâmetros do Sol

Massa : $2x10^{30}$ Kg ~ 333000 x M_{Terra}

Raio : $7x10^{5}$ Km ~ 100 x R_{terra}

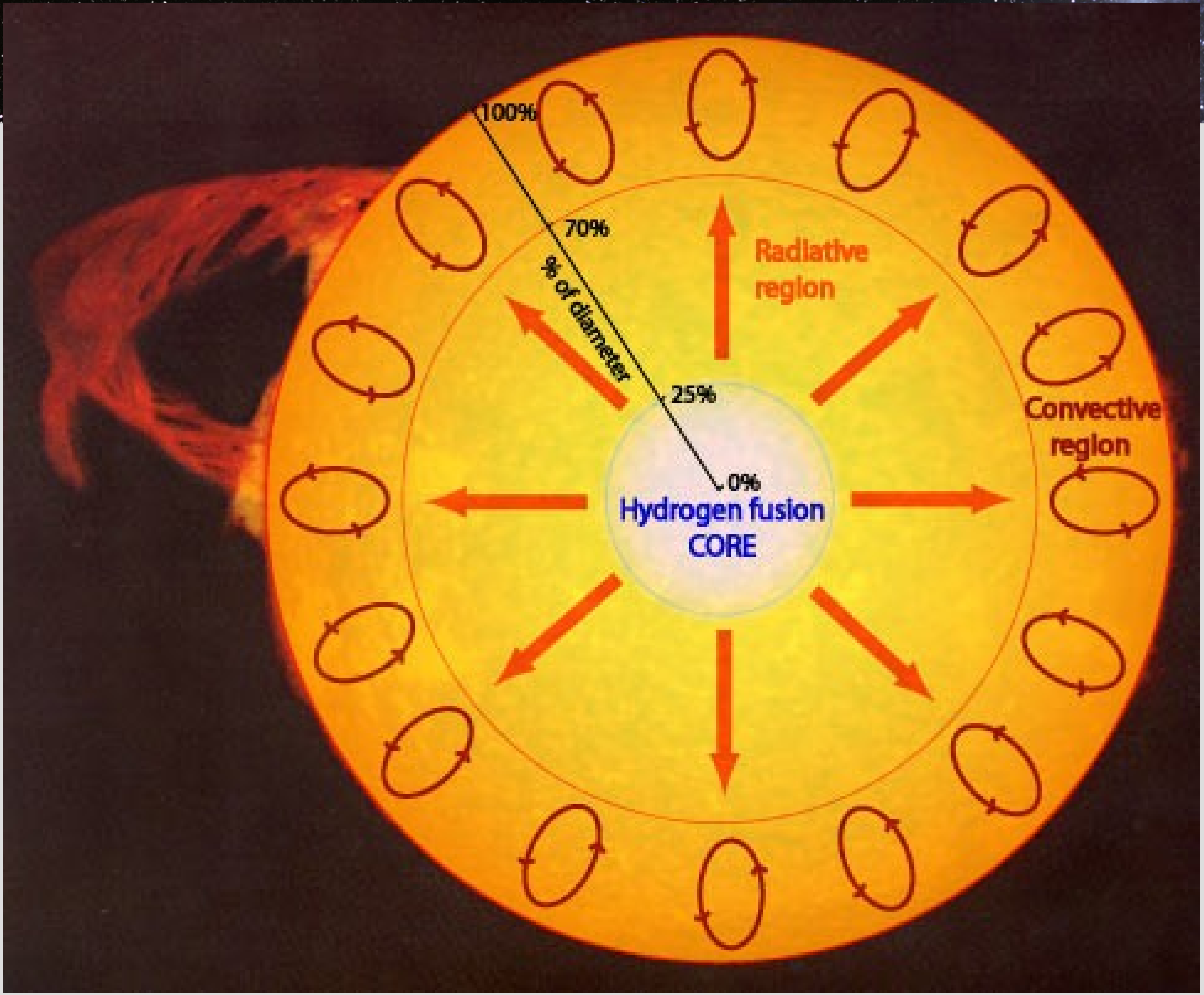
g_{sup} : 274 m s^{-2} ~ 28 x g_{Terra}

Lum : $3.9x10^{33}$ erg s^{-1} ~ 10^{26} W

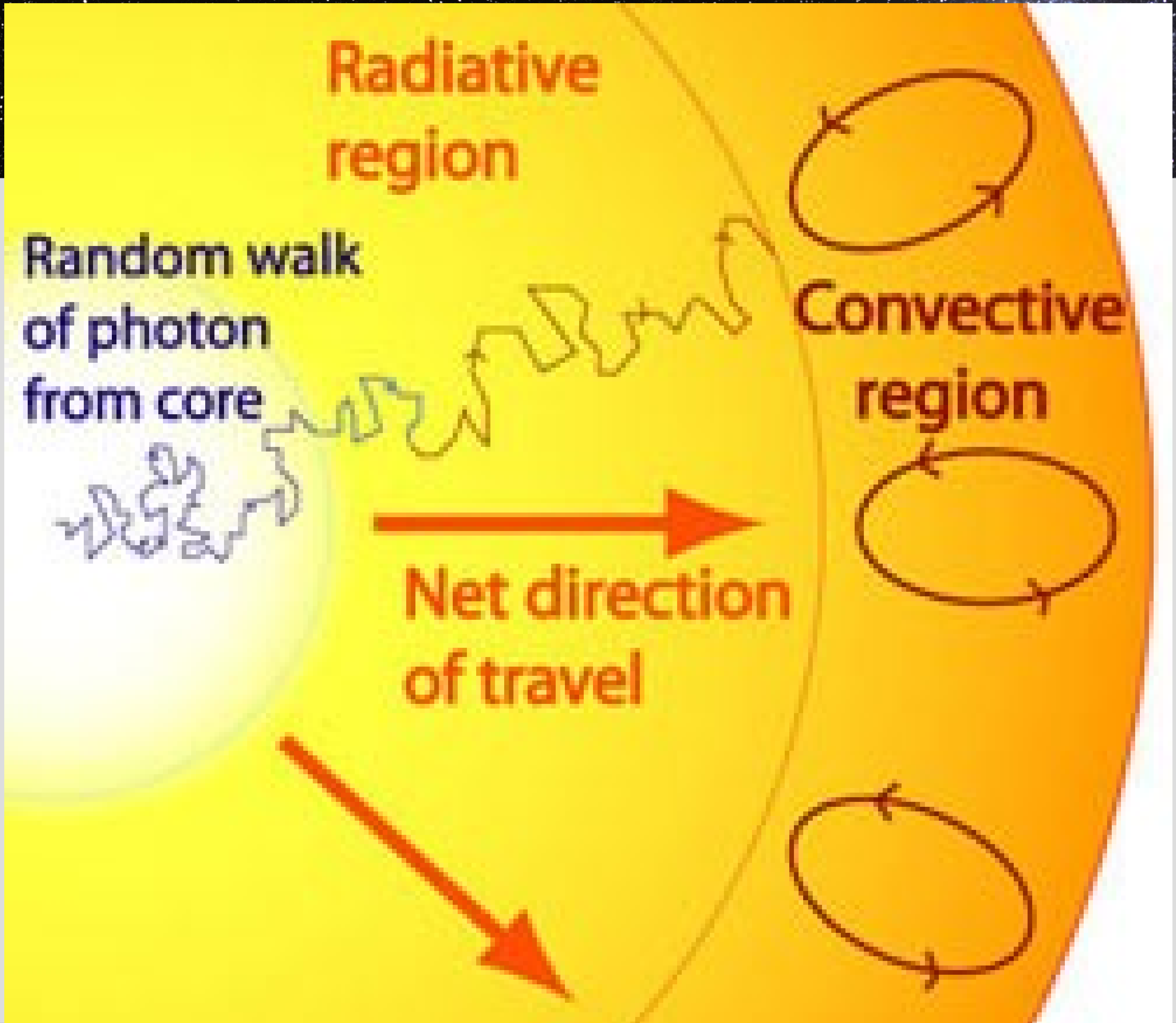
$Temp_{cent}$: ~ $14x10^{6}$ K

$Temp_{sup}$: ~ $5.8x10^{3}$ K

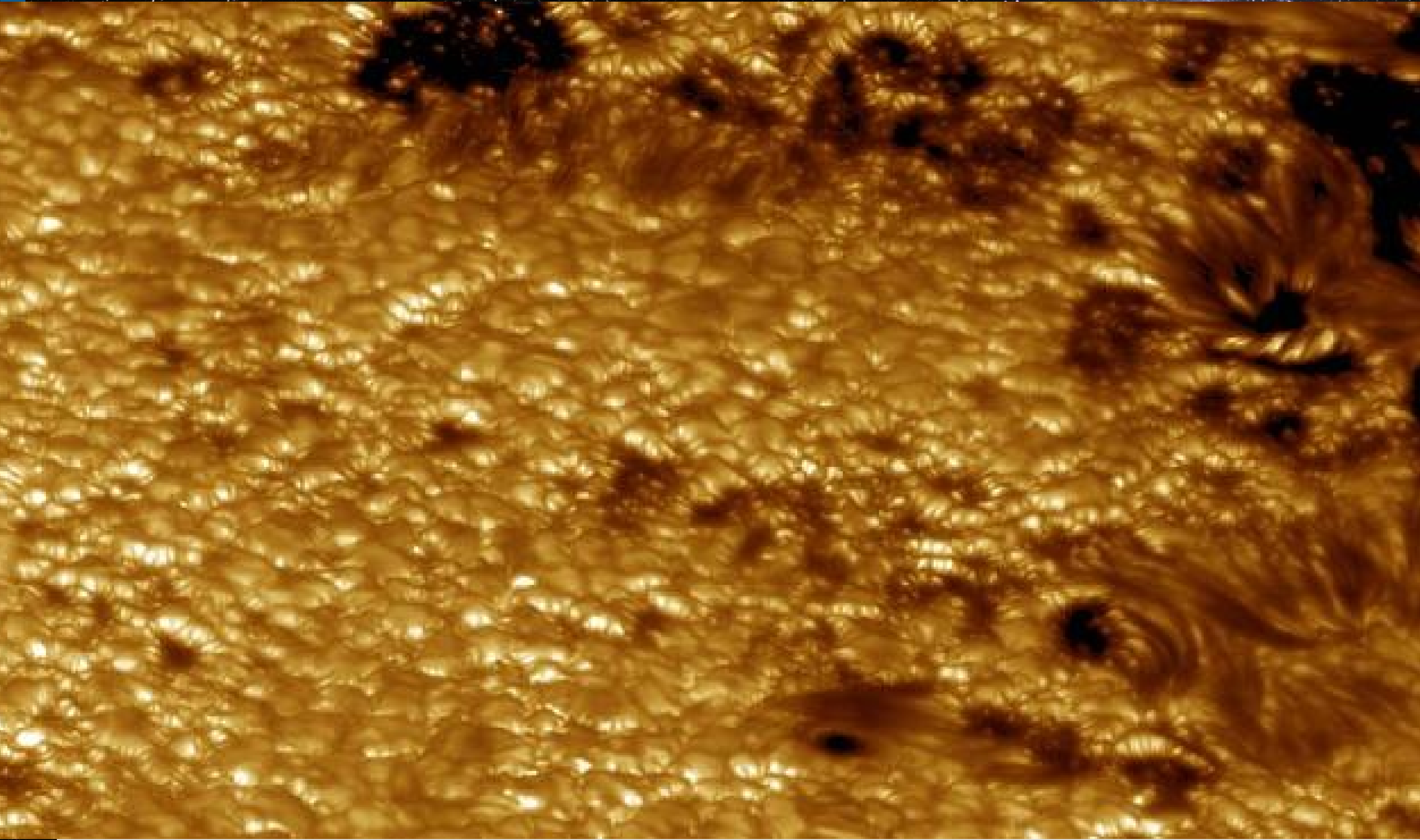
Interiores estelares



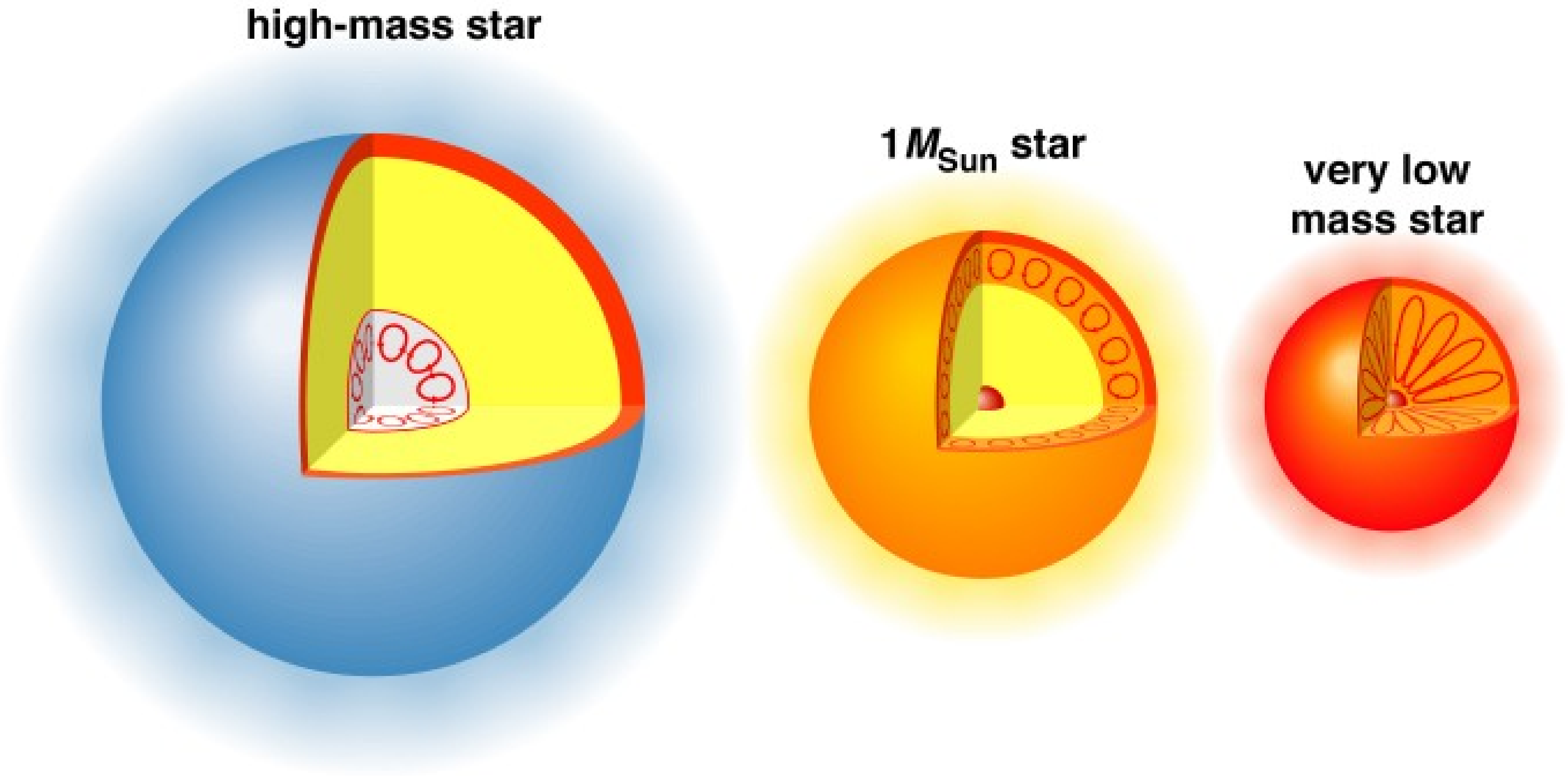
Transporte de energia no Sol



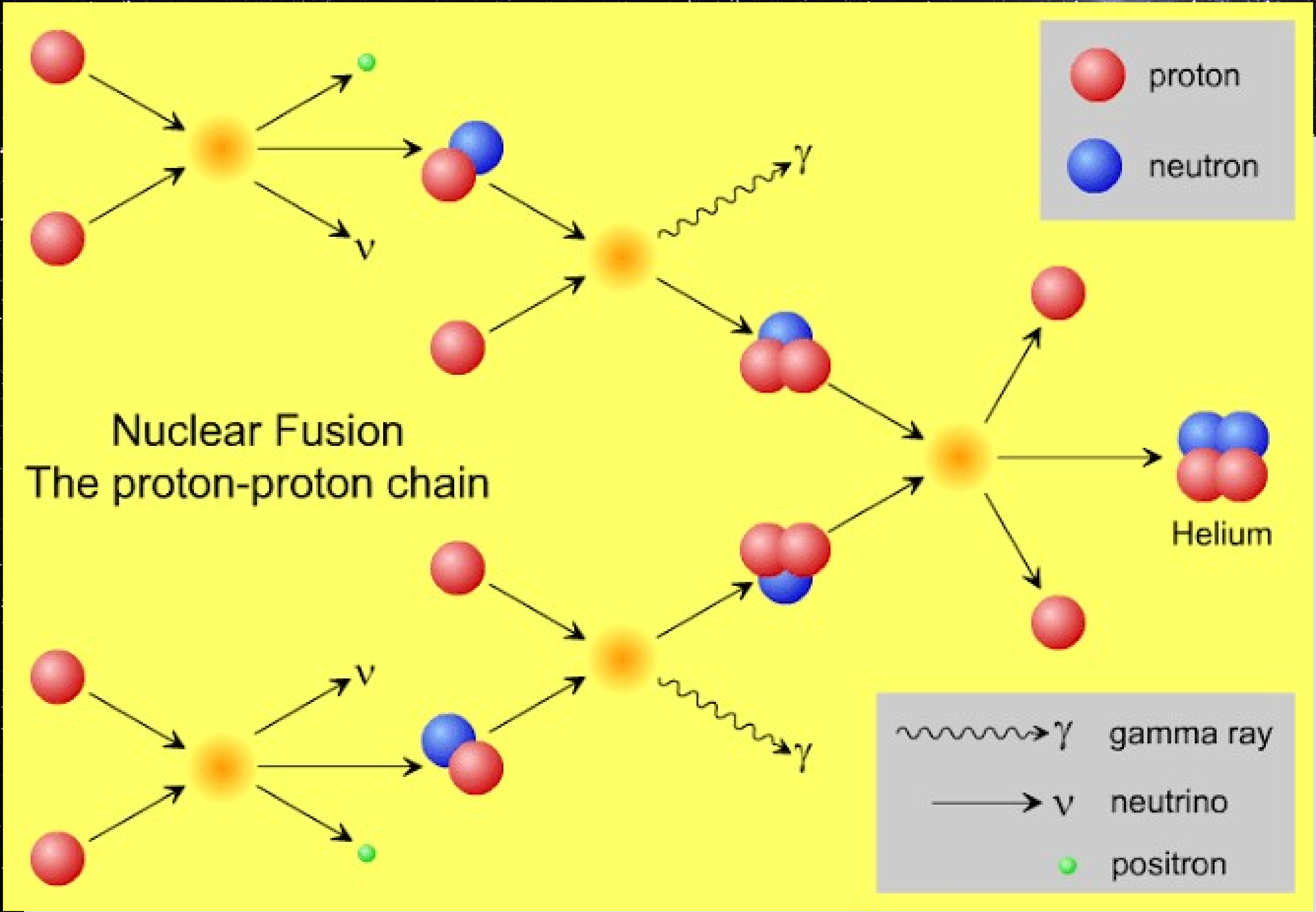
Superfície do Sol: Convecção

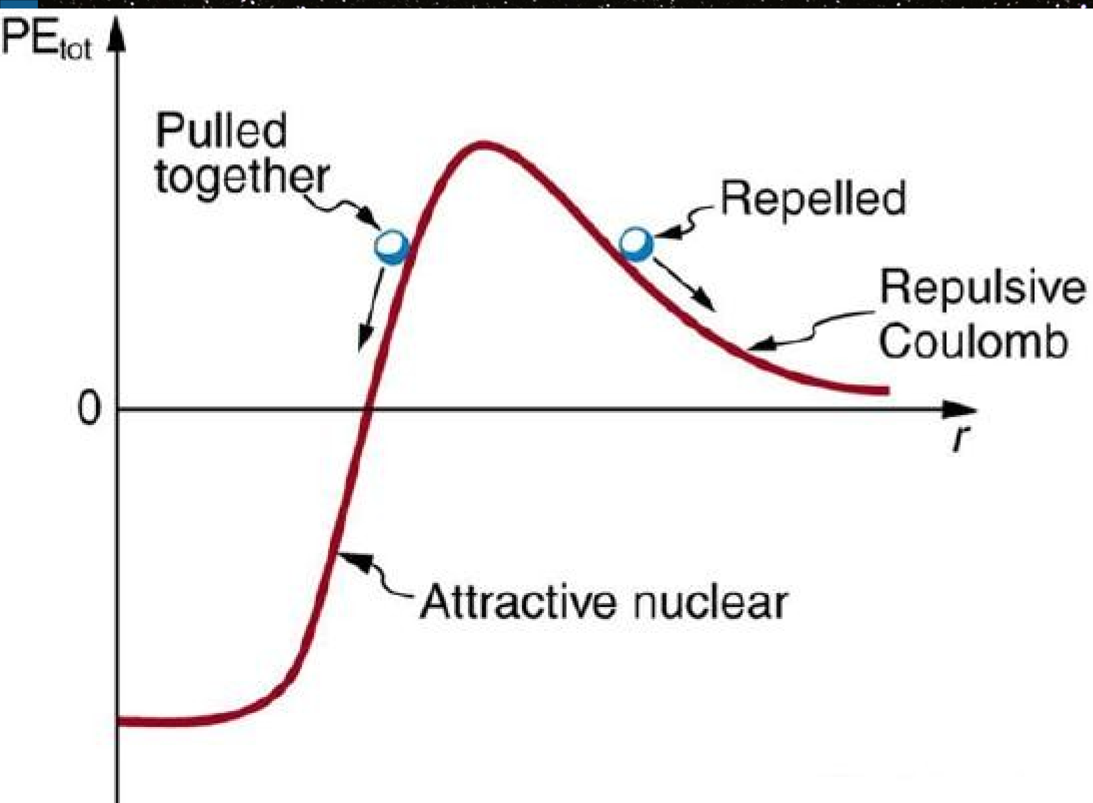


Estrutura interna

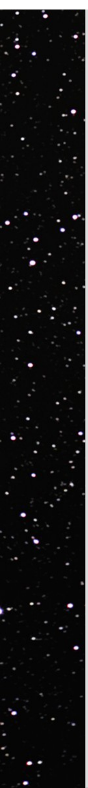


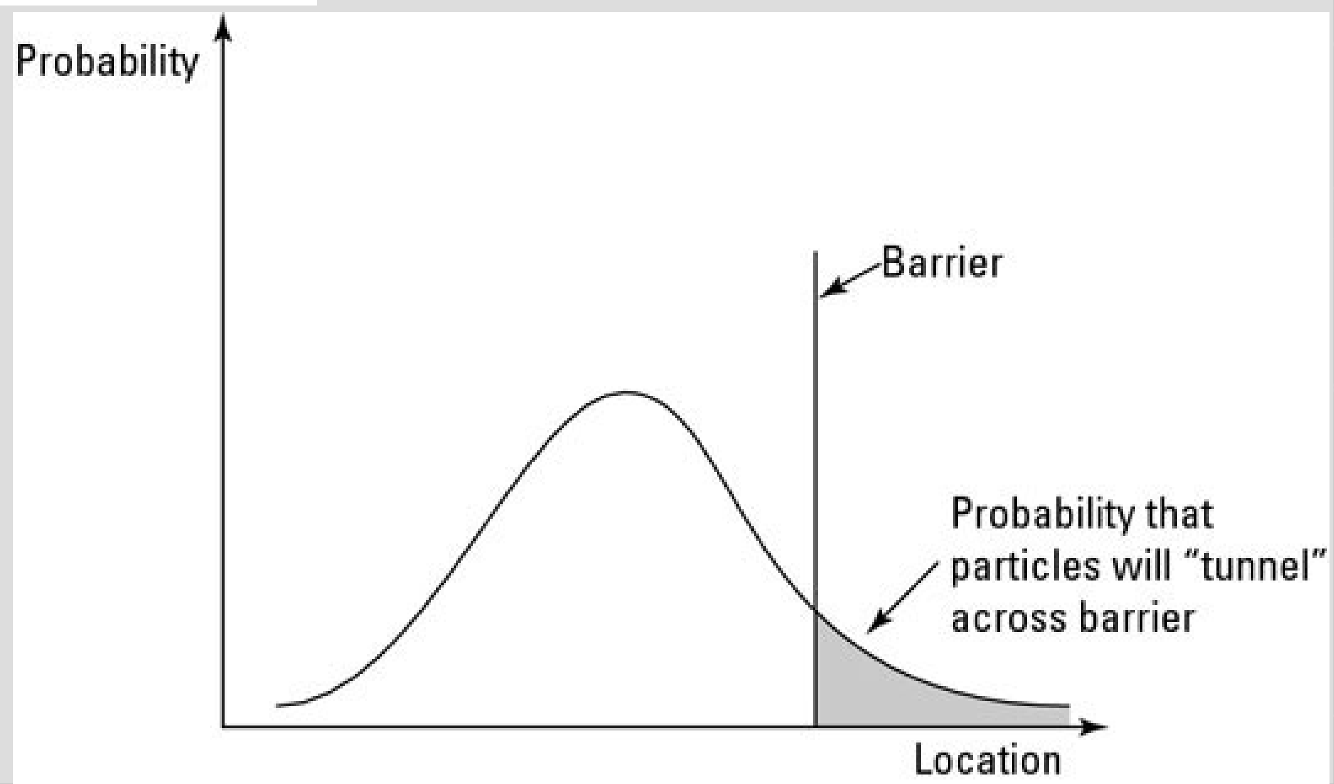
Fonte de energia: ciclo p-p



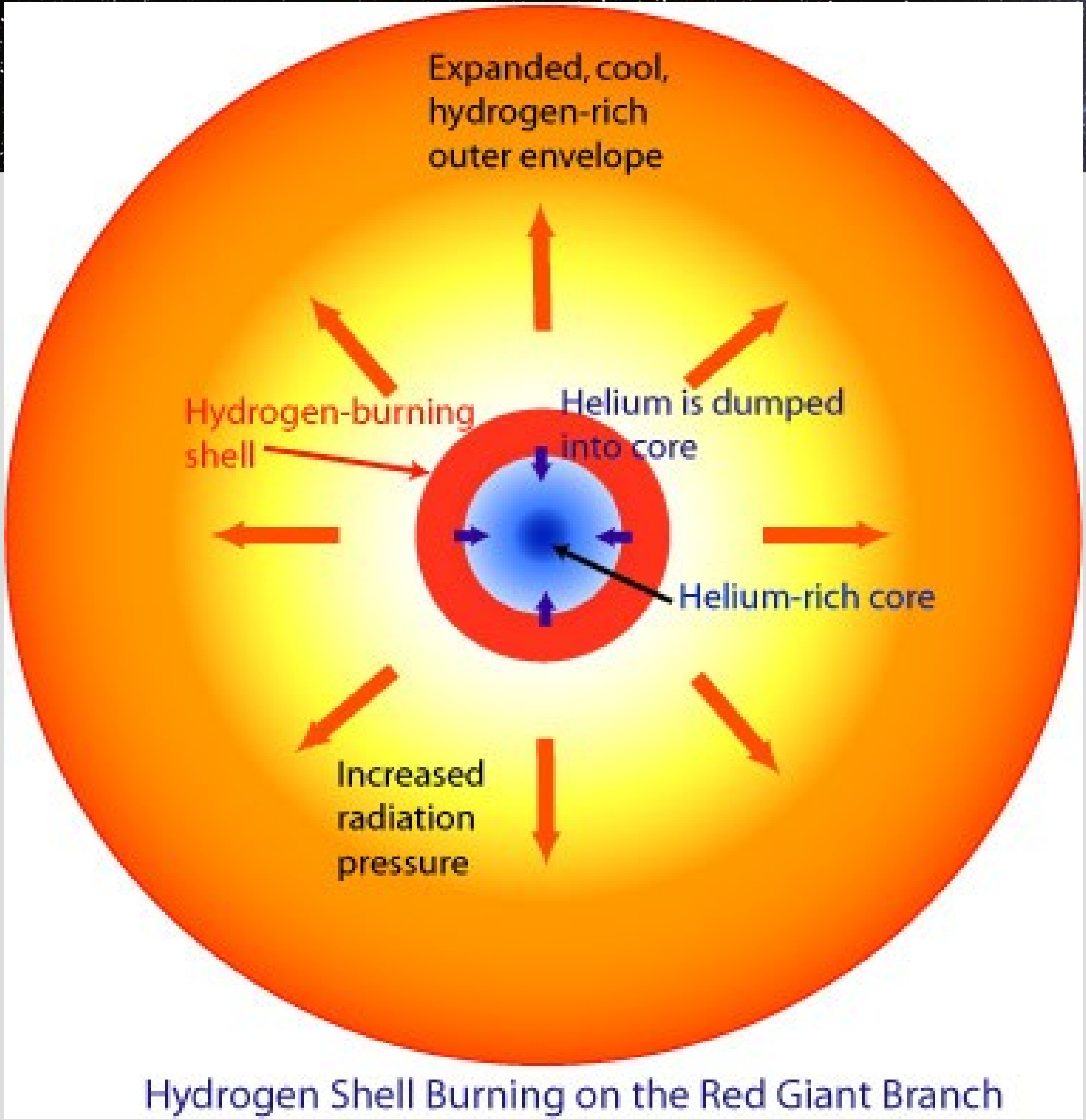

PE$_{tot}$
Pulled together
Repelled
Repulsive Coulomb
0
r
Attractive nuclear

$N_p \sim 10^{56}$

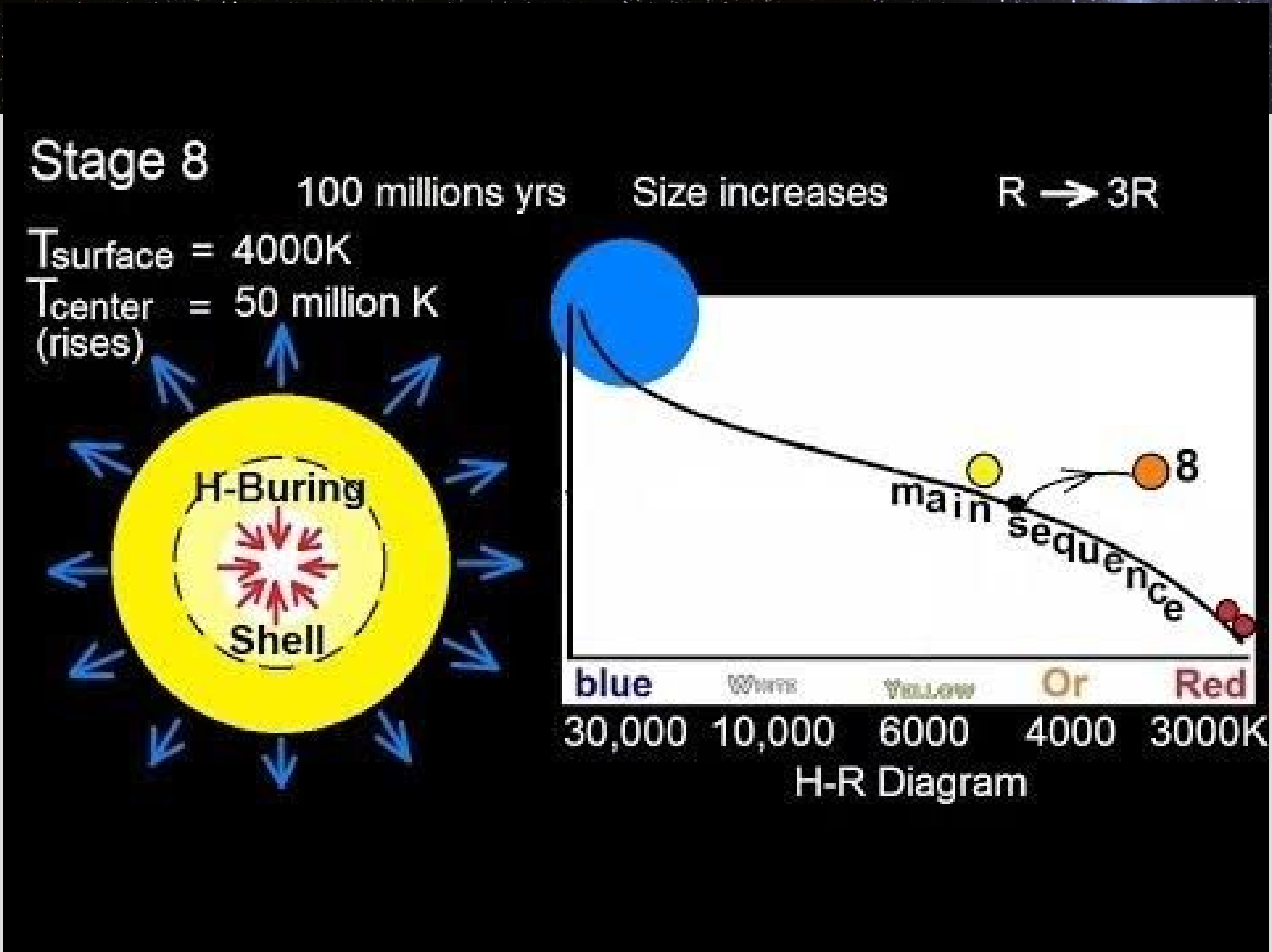



Probability
Barrier
Probability that particles will "tunnel" across barrier
Location

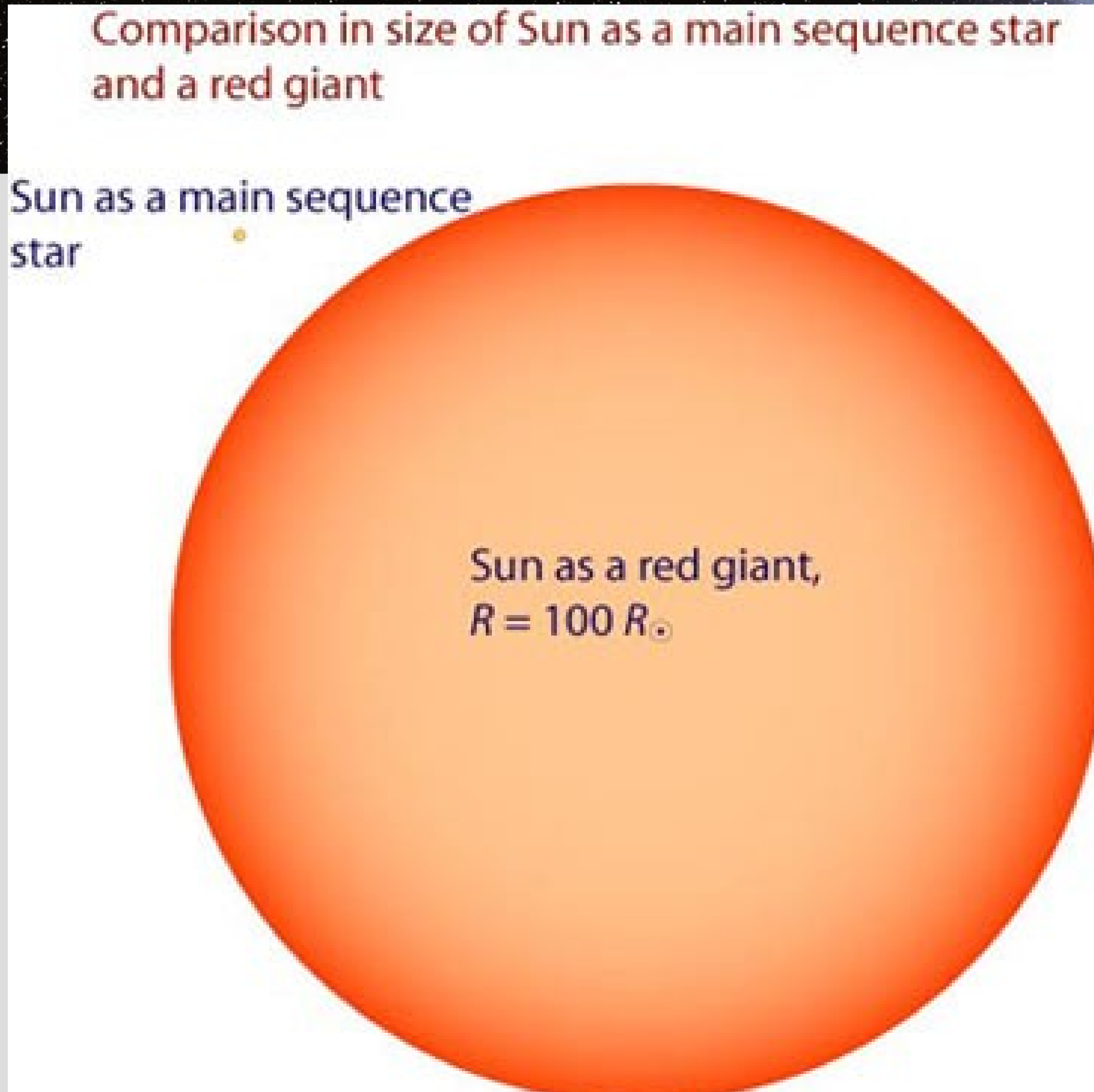
Queima de H em camada - RGB



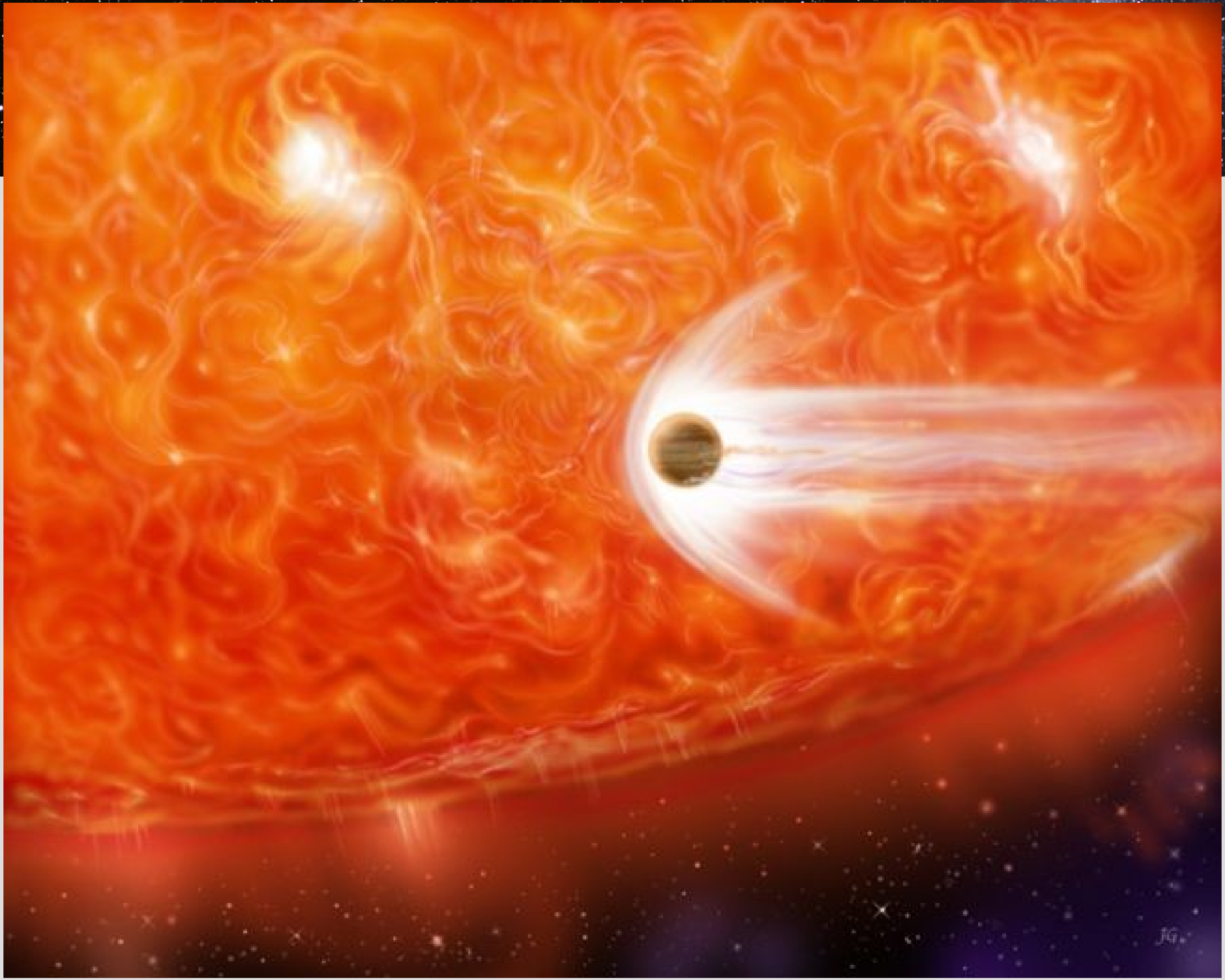
A caminho das sub-gigantes

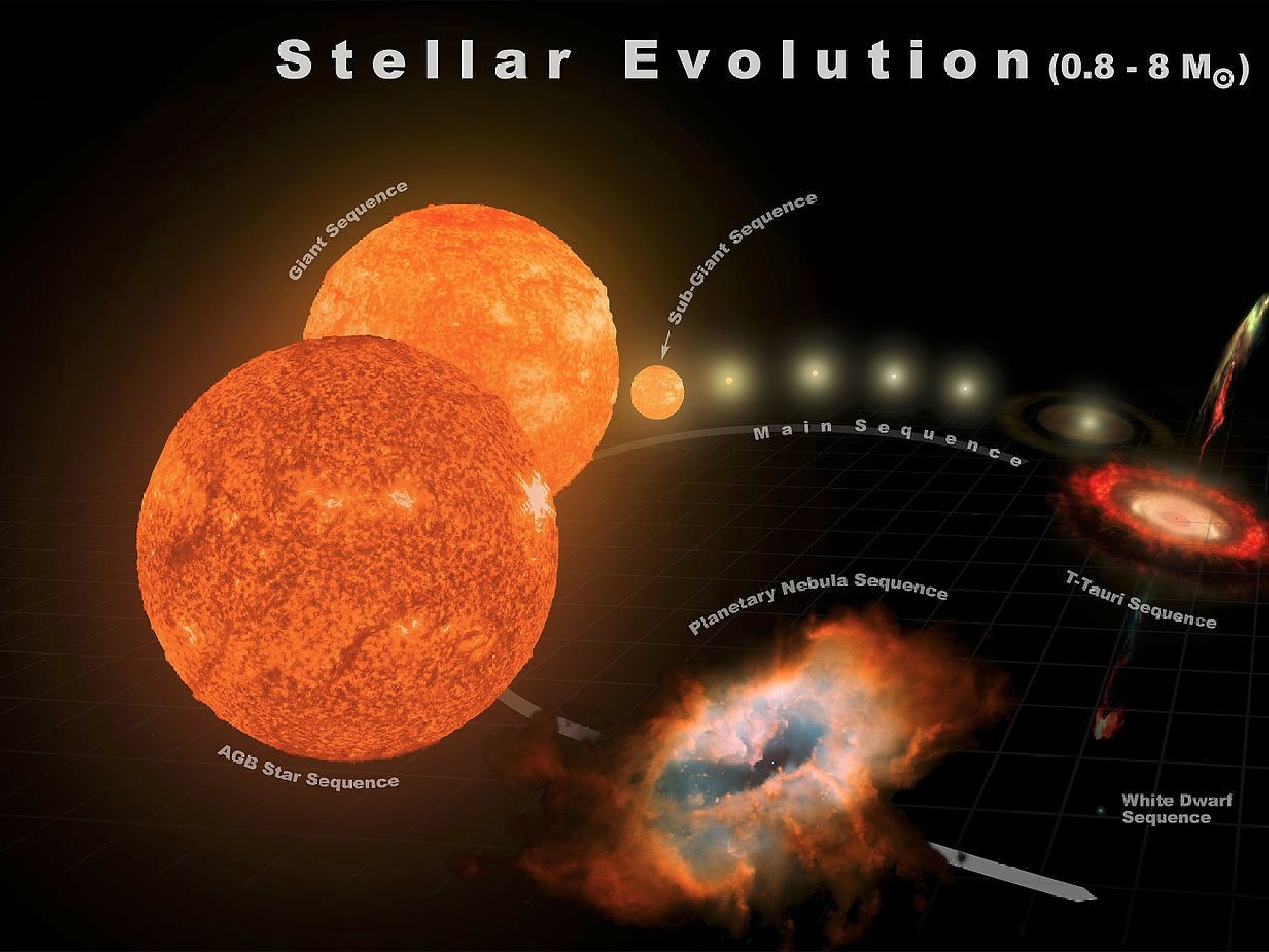


O futuro do Sol



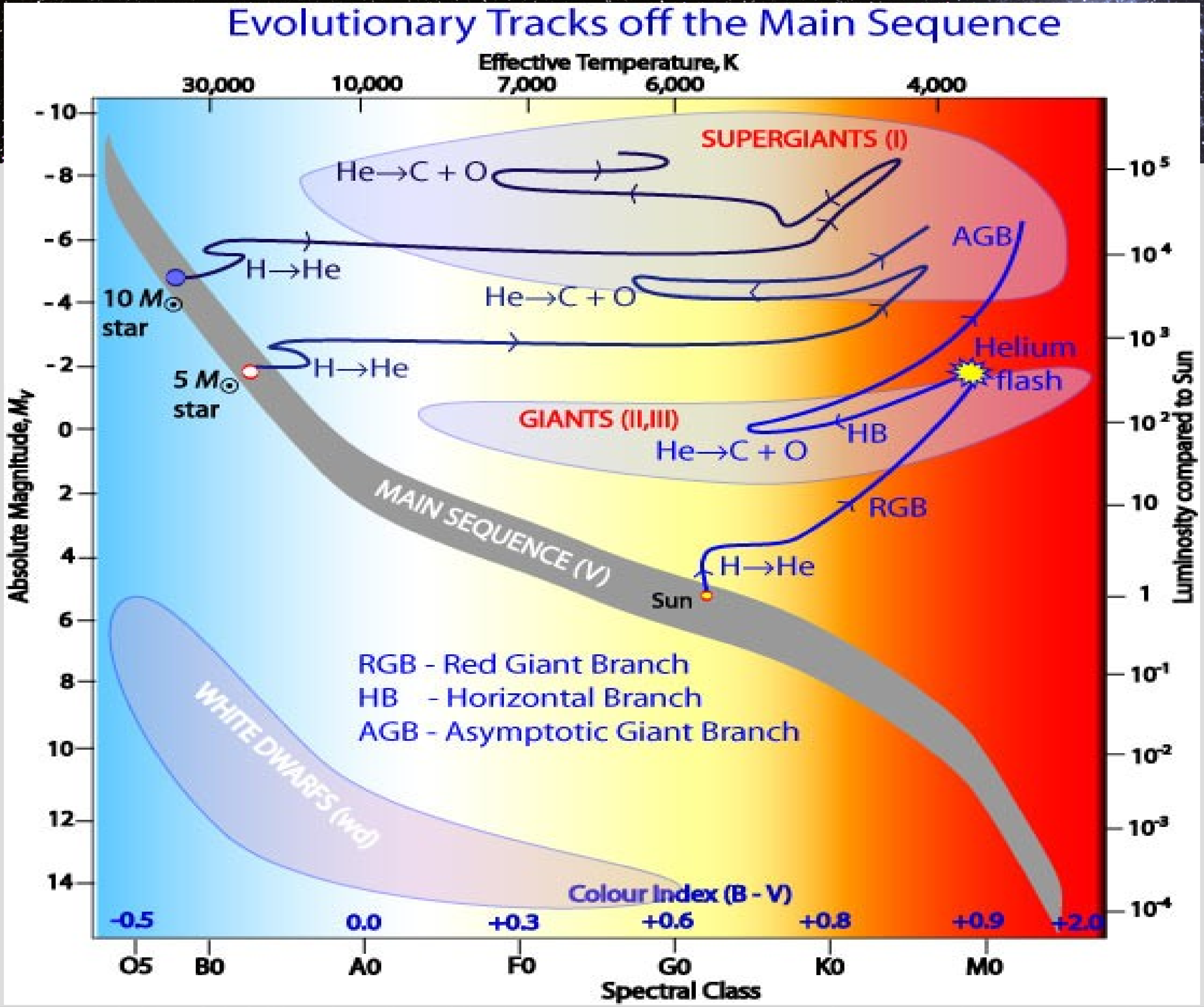
Se o Sol fosse mais massivo!

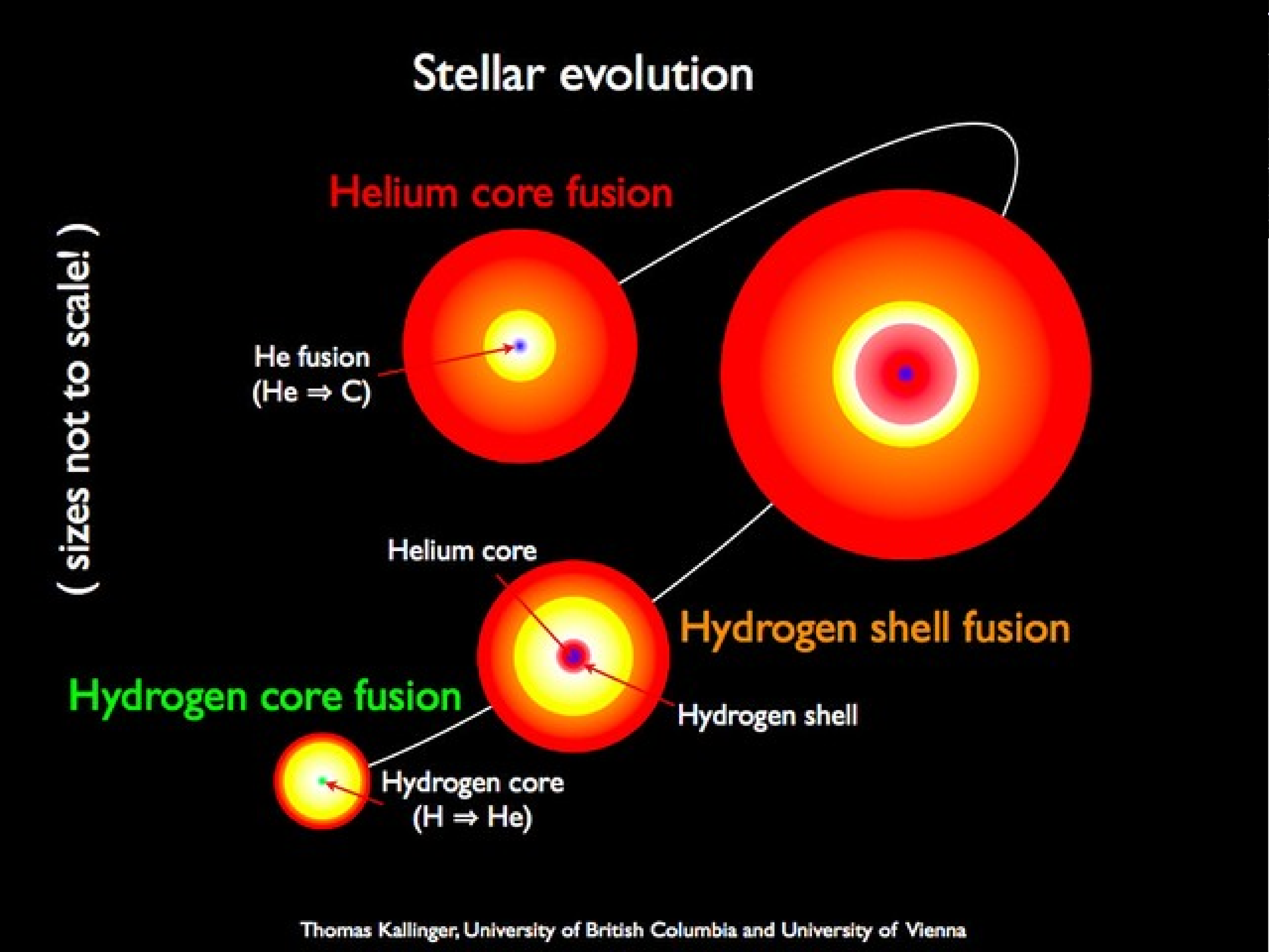


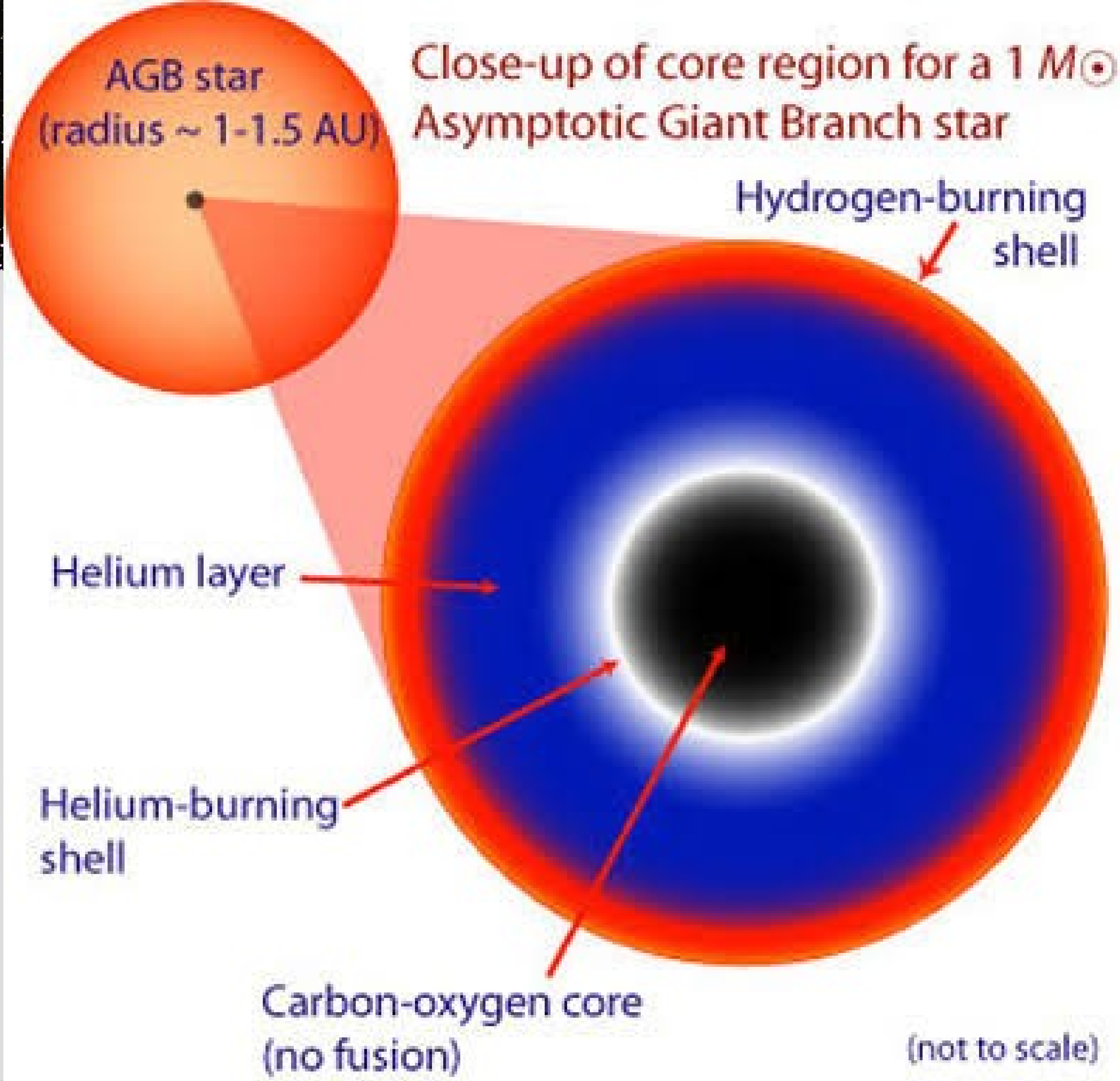


Stellar Evolution $(0.8 - 8\ M_\odot)$
Giant Sequence
Sub-Giant Sequence
Main Sequence
T-Tauri Sequence
Planetary Nebula Sequence
AGB Star Sequence
White Dwarf Sequence

Evolução pós Sequência Principal

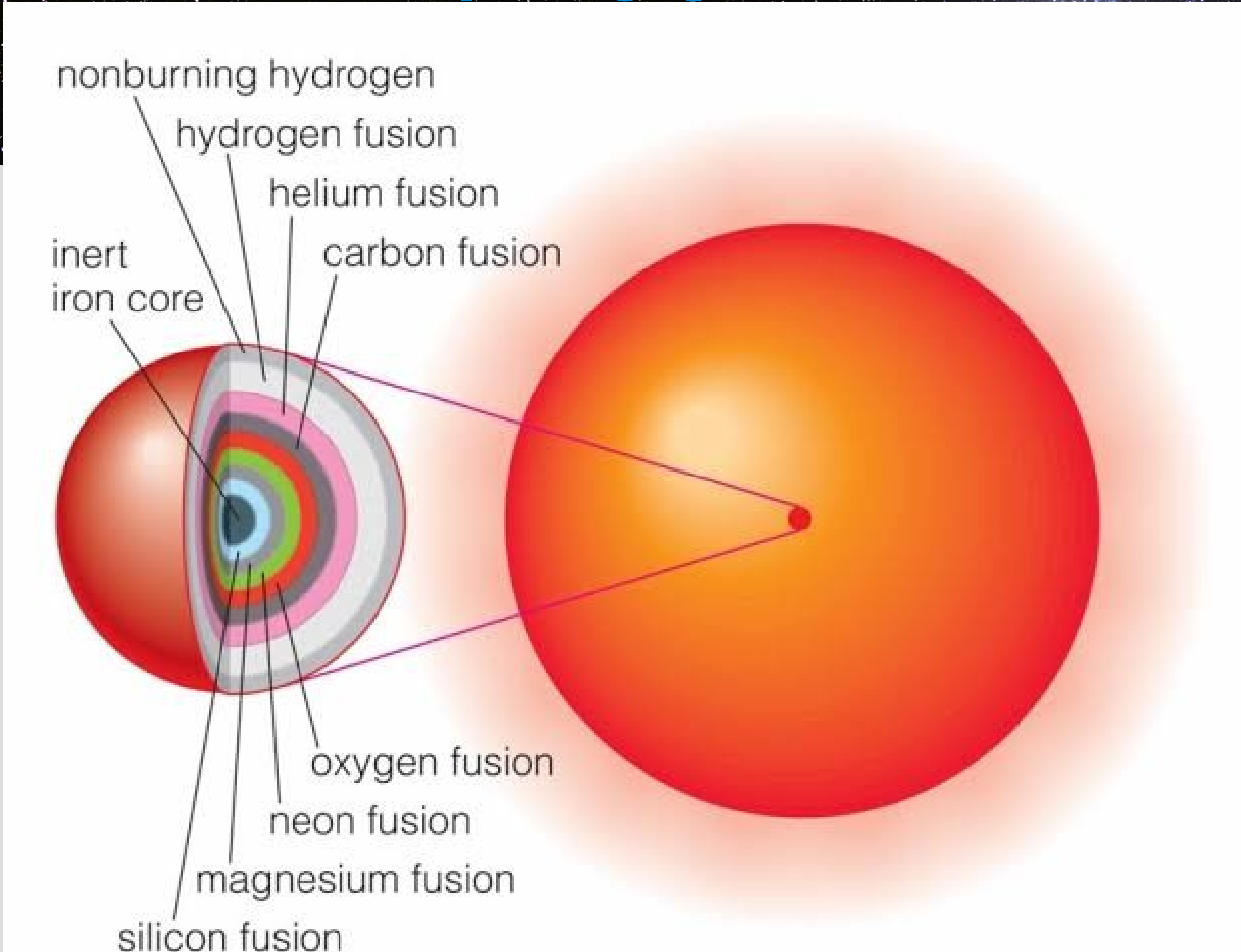


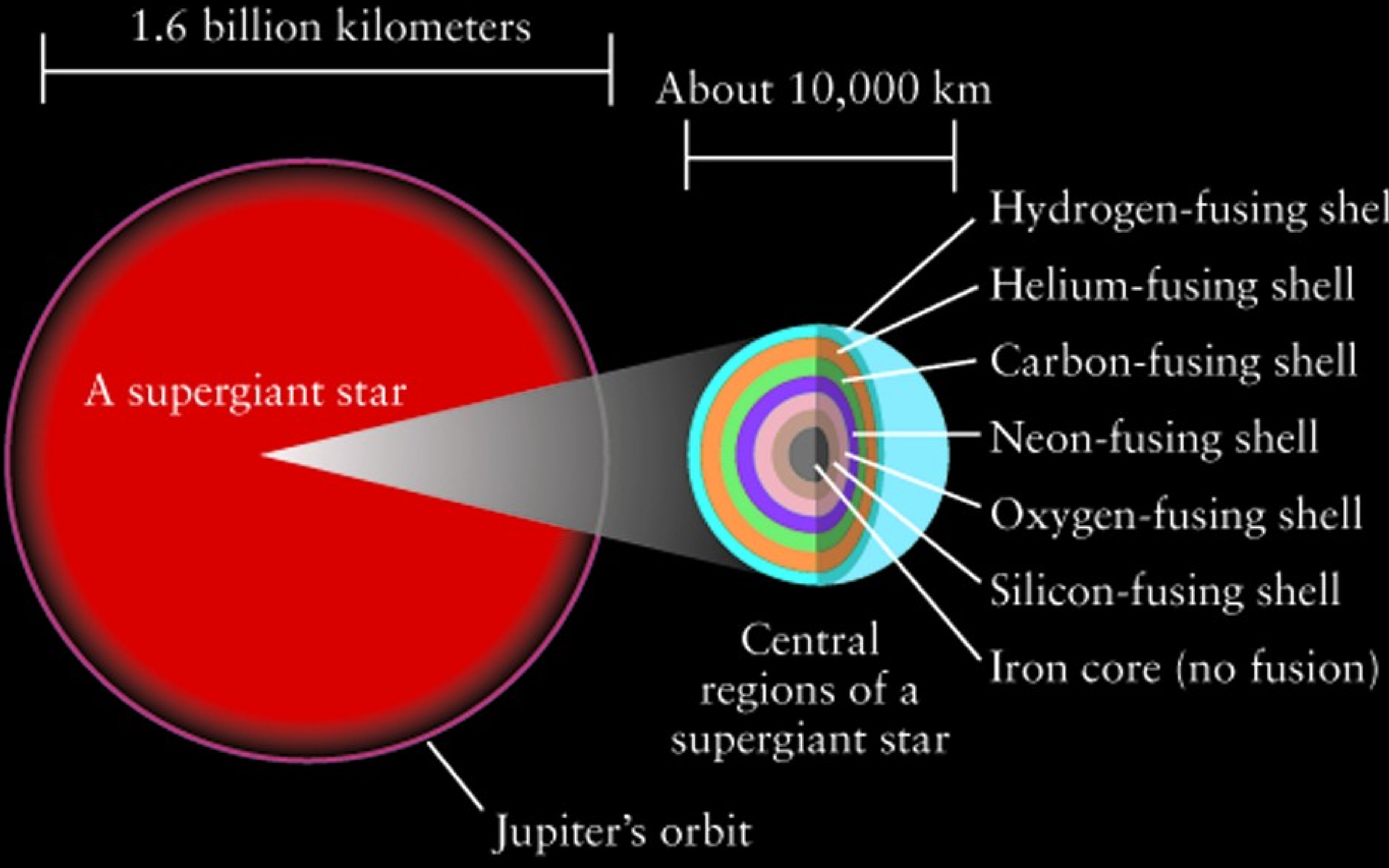

Stellar evolution
Helium core fusion
He fusion
(He ⇒ C)
(sizes not to scale!)
Helium core
Hydrogen shell fusion
Hydrogen core fusion
Hydrogen shell
Hydrogen core
(H ⇒ He)
Thomas Kallinger, University of British Columbia and University of Vienna



Close-up of core region for a 1 $M_\odot$
Asymptotic Giant Branch star
AGB star
(radius ~ 1-1.5 AU)
Hydrogen-burning
shell
Helium layer
Helium-burning
shell
Carbon-oxygen core
(no fusion)
(not to scale)

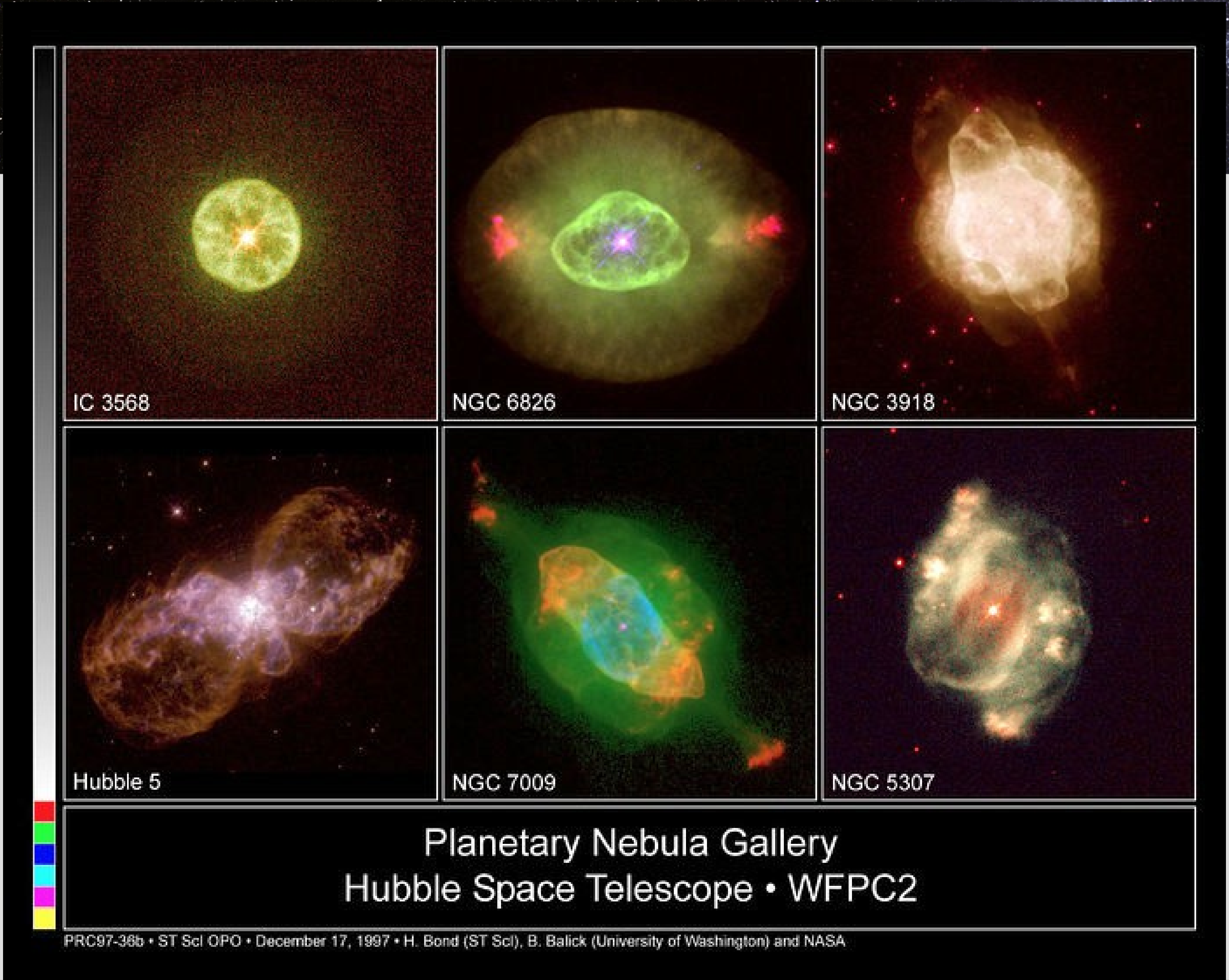
Estrutura: super-gigante vermelha




1.6 billion kilometers
About 10,000 km
A supergiant star
Hydrogen-fusing shel
Helium-fusing shell
Carbon-fusing shell
Neon-fusing shell
Oxygen-fusing shell
Silicon-fusing shell
Iron core (no fusion)
Central regions of a supergiant star
Jupiter's orbit

A morte de estrelas: Sol

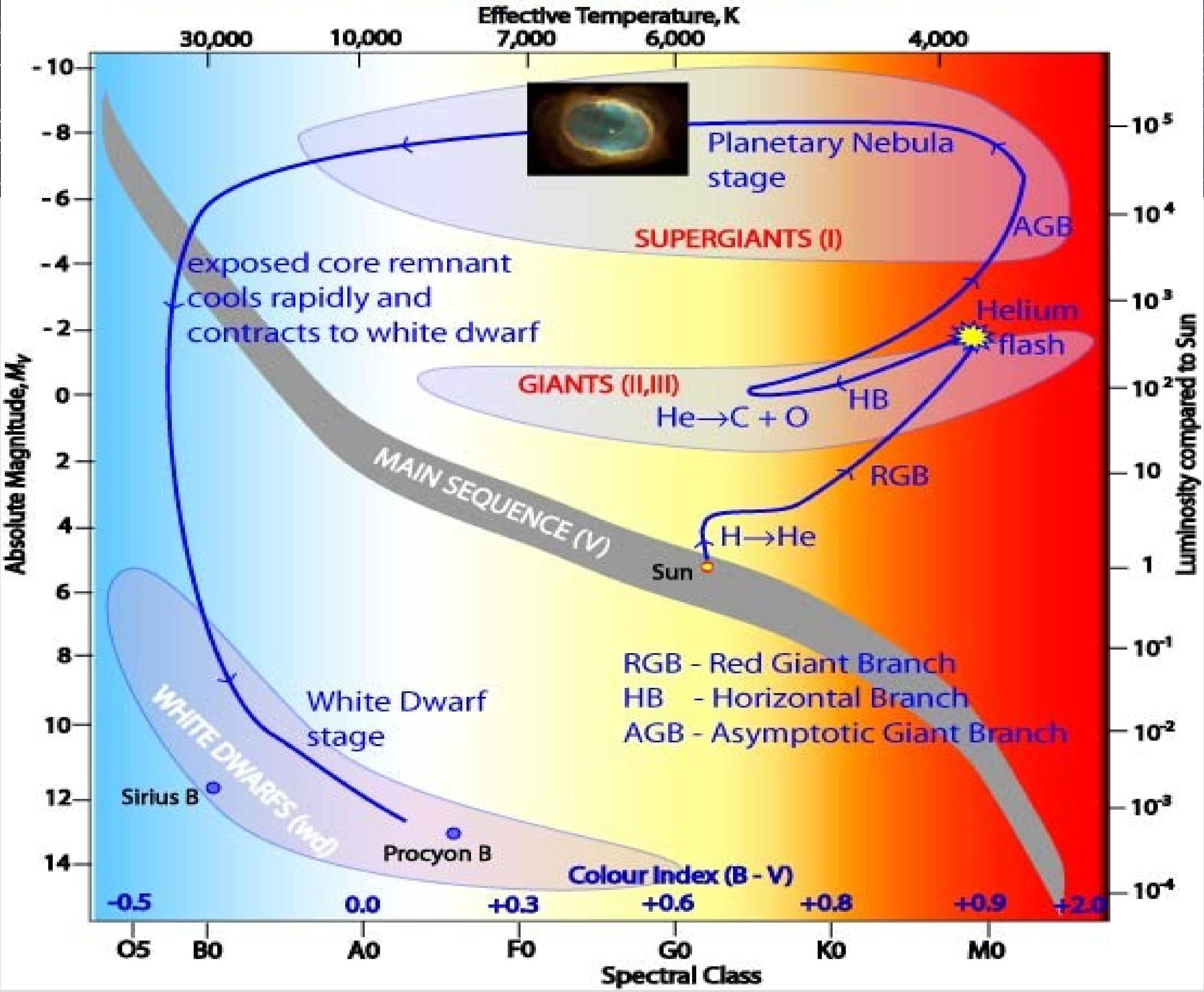
Nebulosas Planetárias





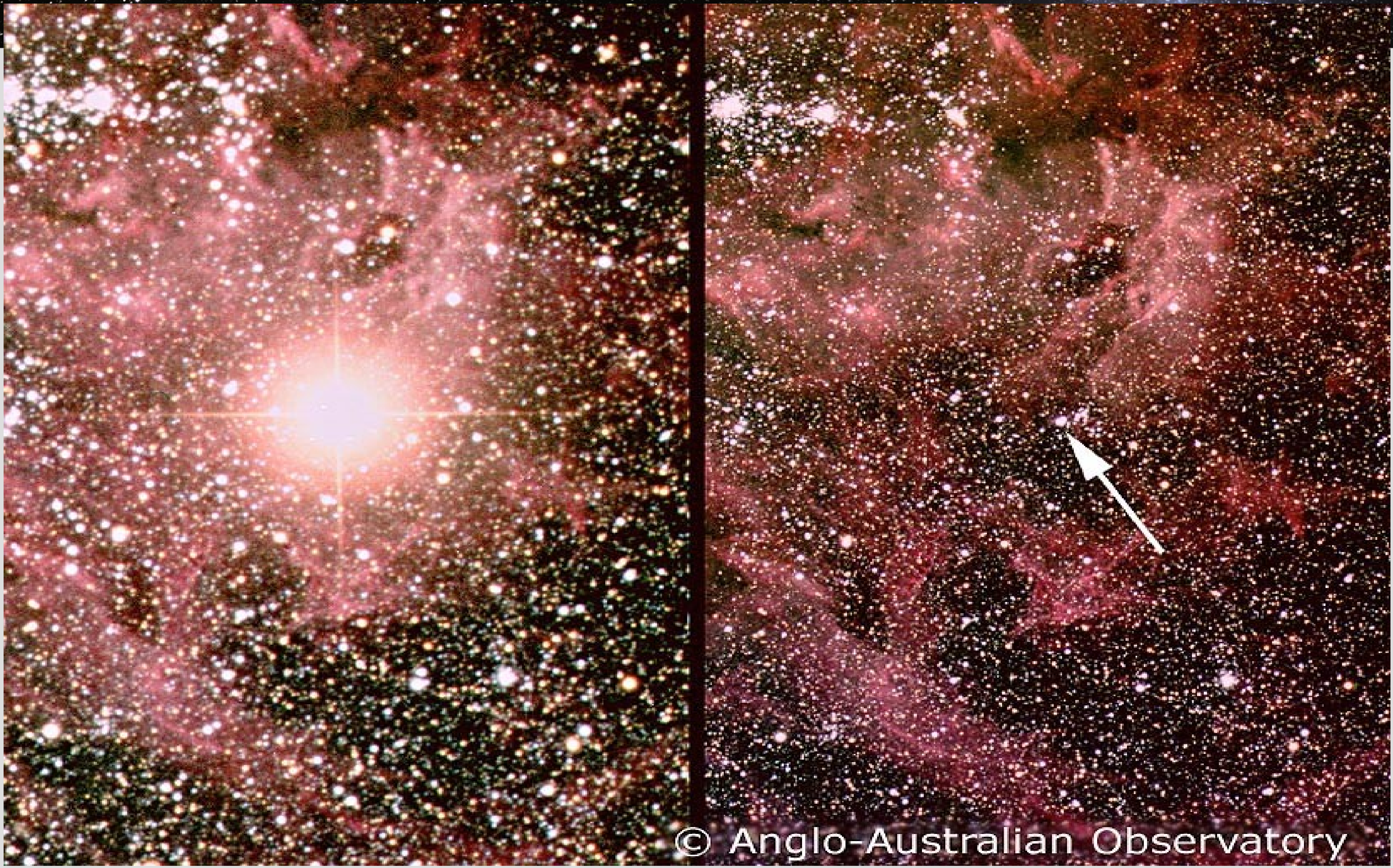


Sun's Post-Main Sequence Evolutionary Track

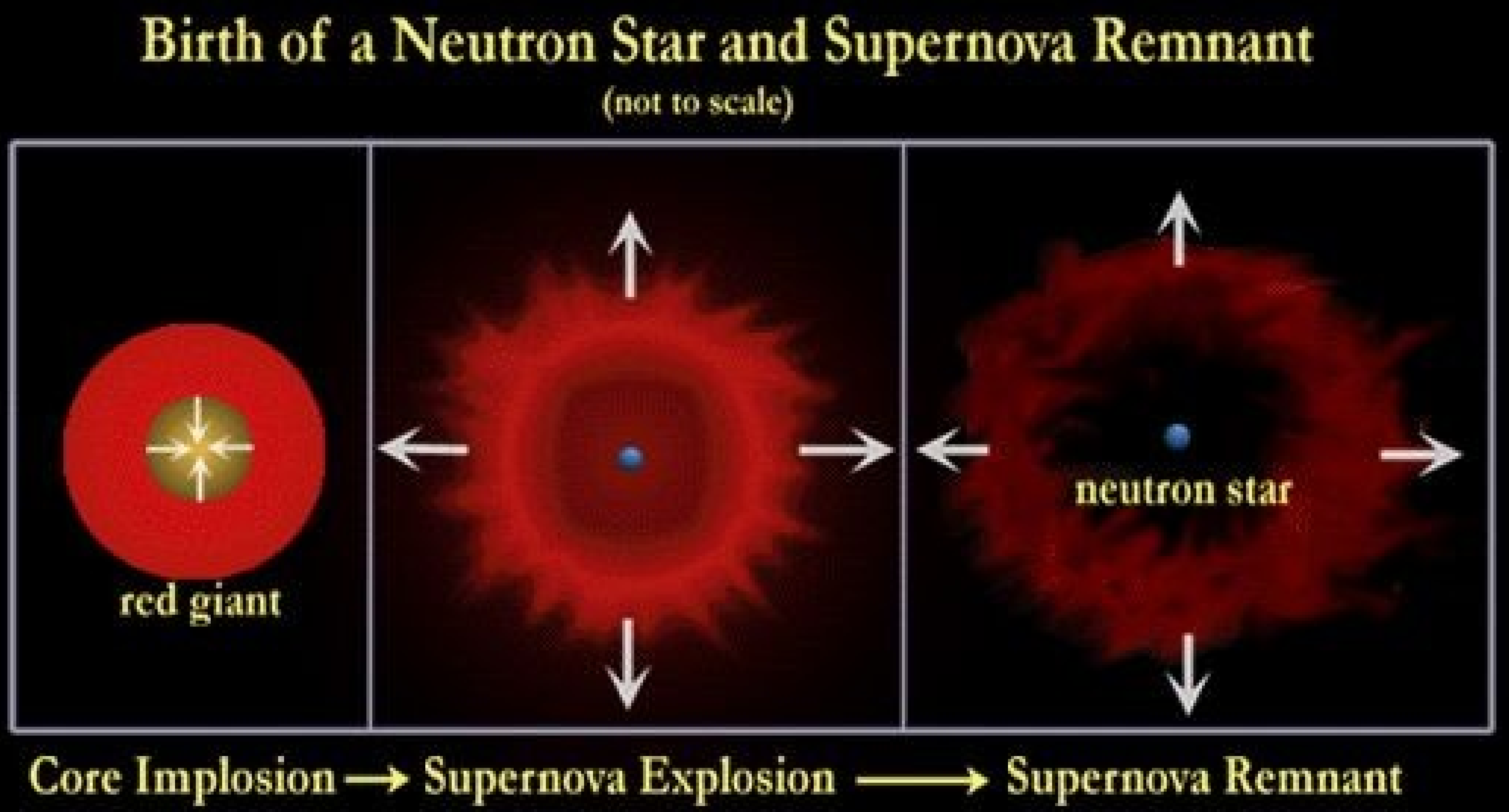


A morte de estrelas: alta massa
Nebulosa do Caranguejo - SNR

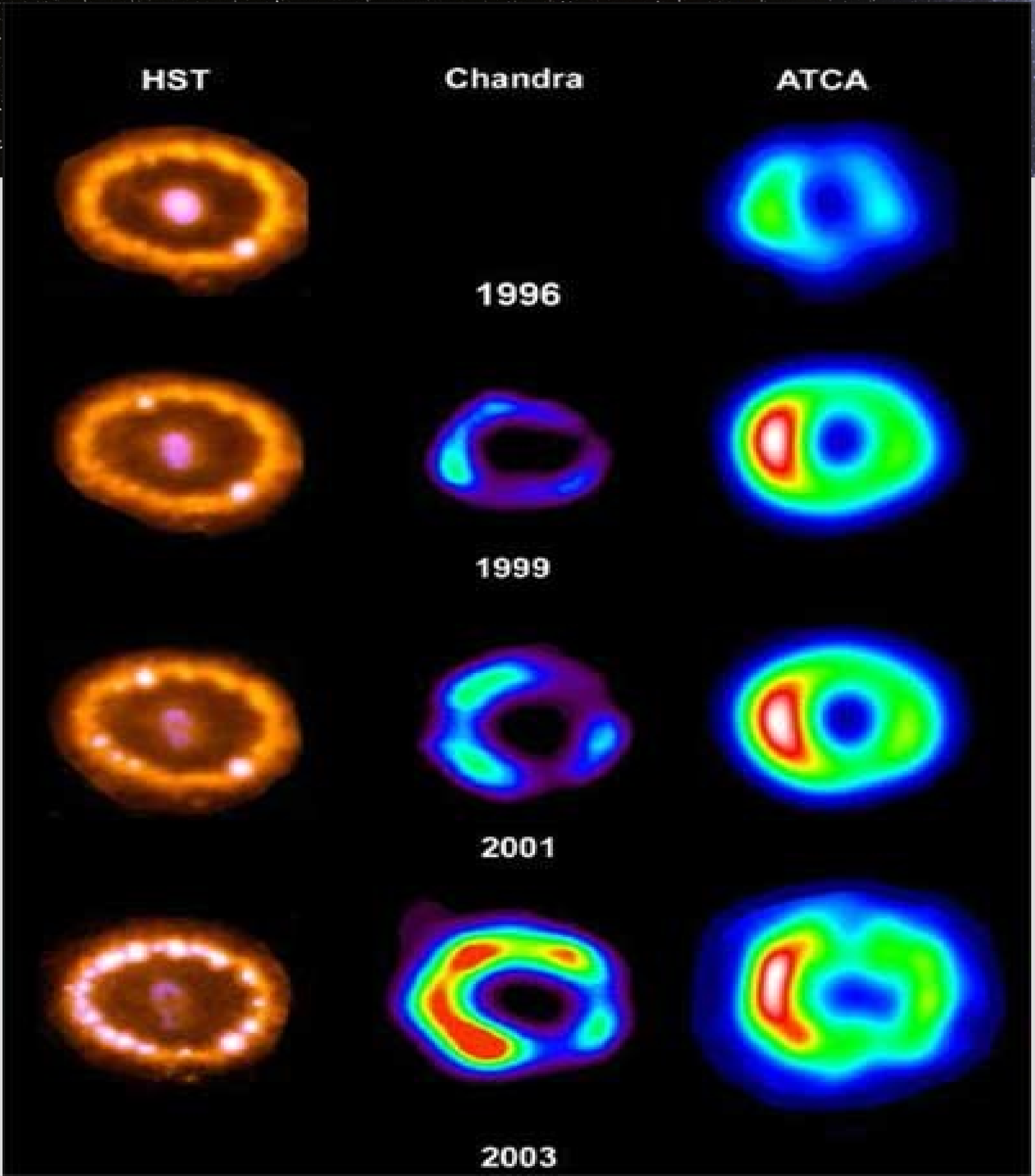
Supernovas: um final brilhante!!
Supernova 1987A - LMC



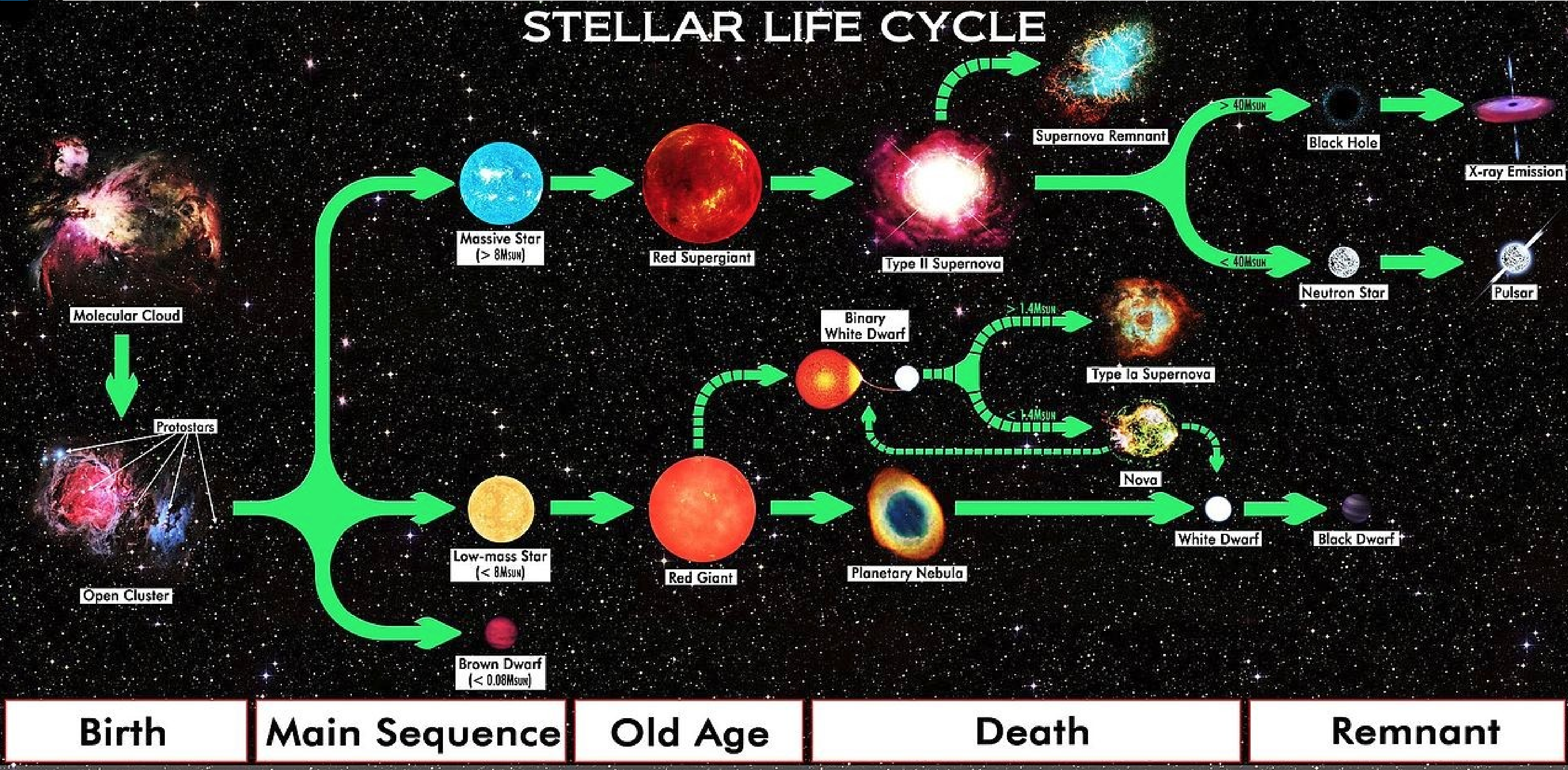
Nascimento de estrelas de Nêutrons



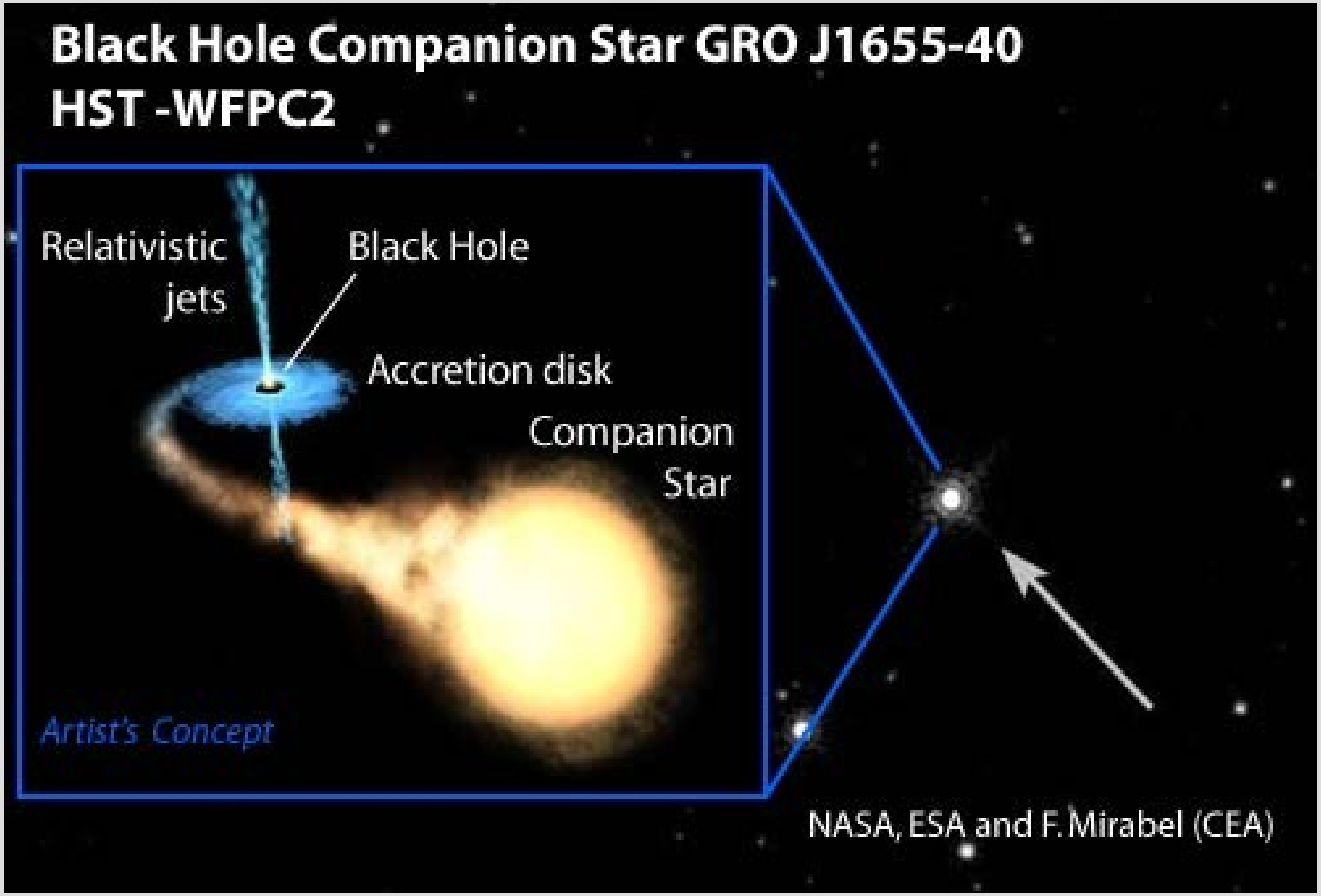
Expansão da SNR 1987A



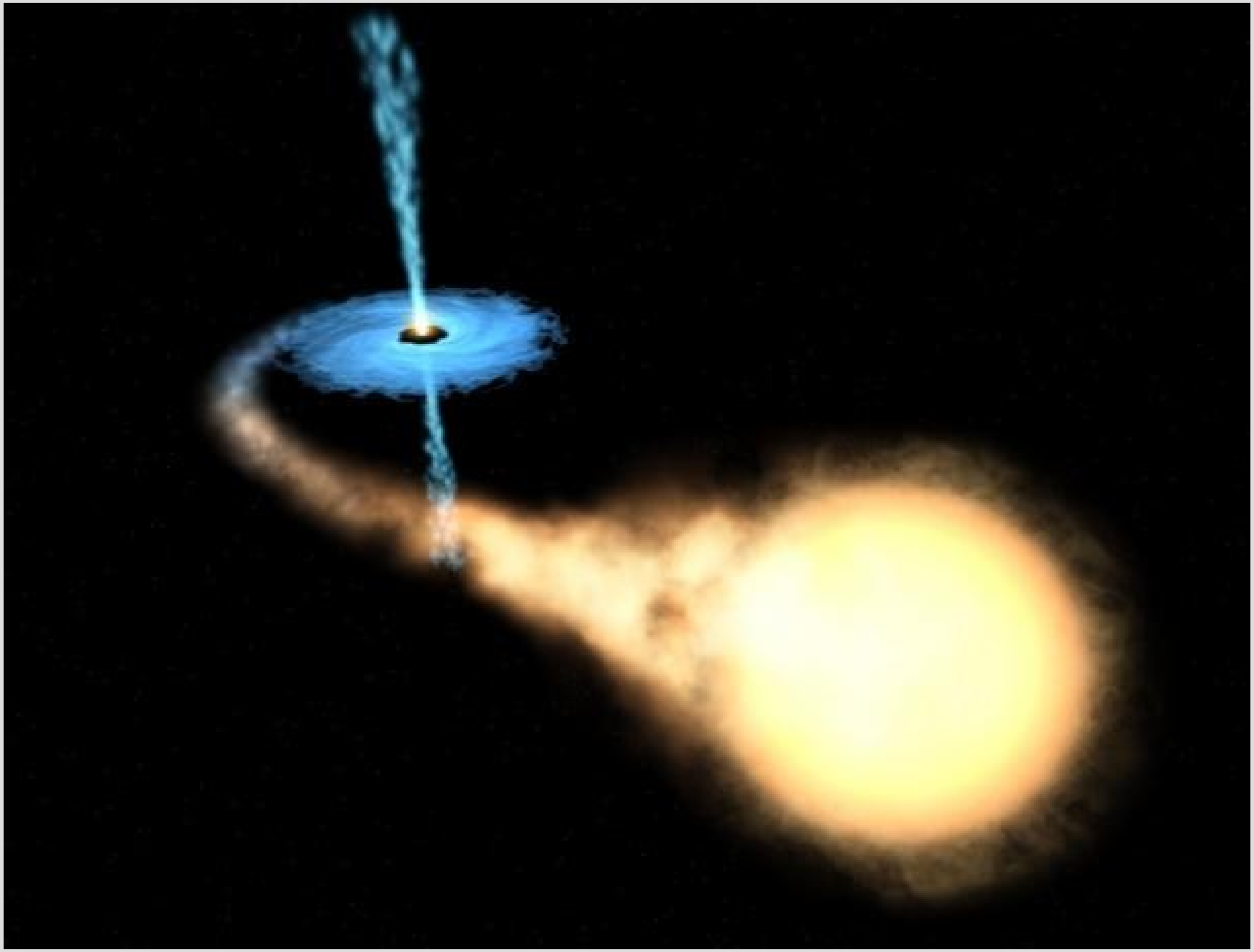
Ciclo de vida estelar



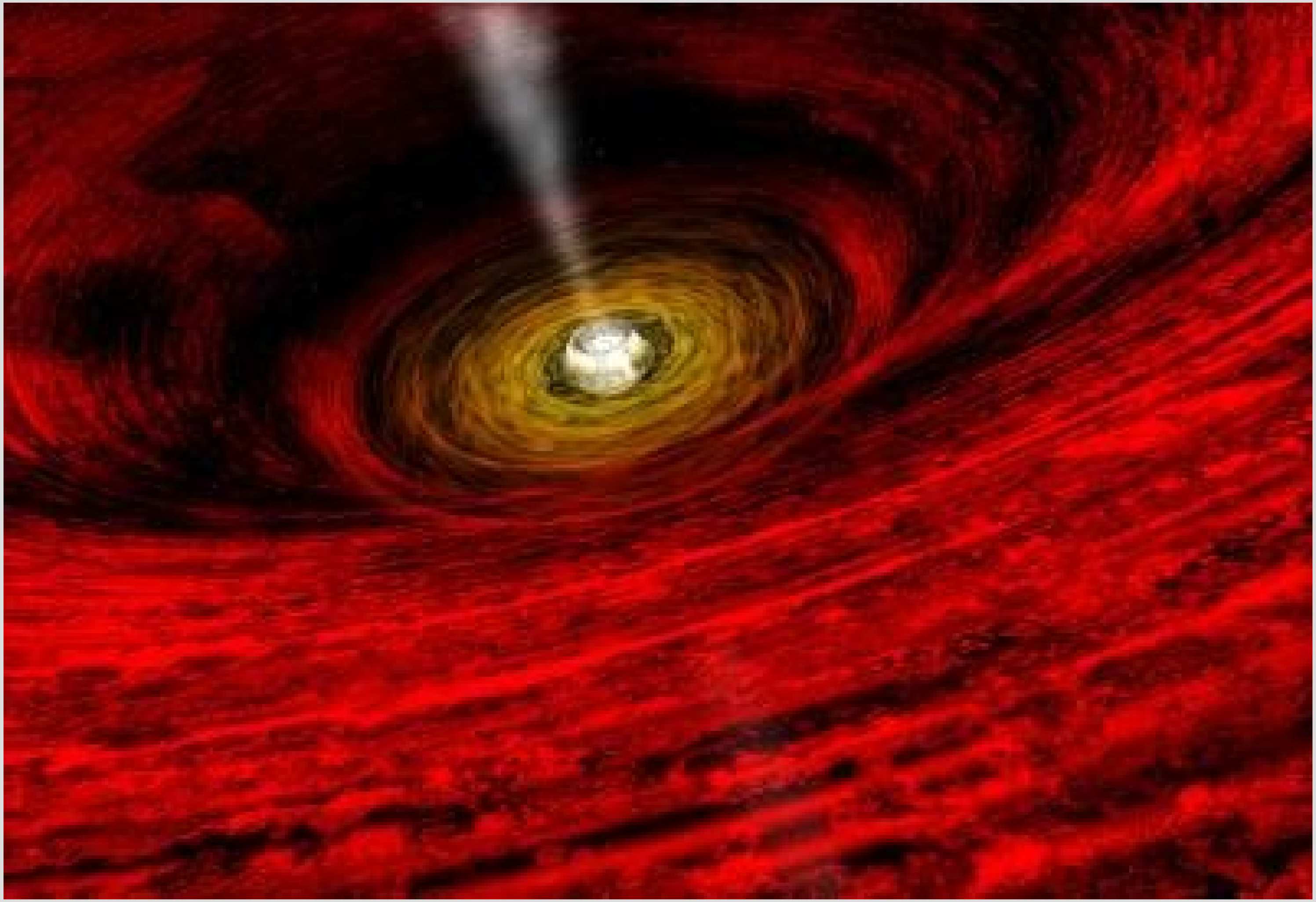
Visão artística de um buraco negro estelar


Black Hole Companion Star GRO J1655-40
HST -WFPC2
Relativistic jets
Black Hole
Accretion disk
Companion Star
Artist's Concept
NASA, ESA and F. Mirabel (CEA)

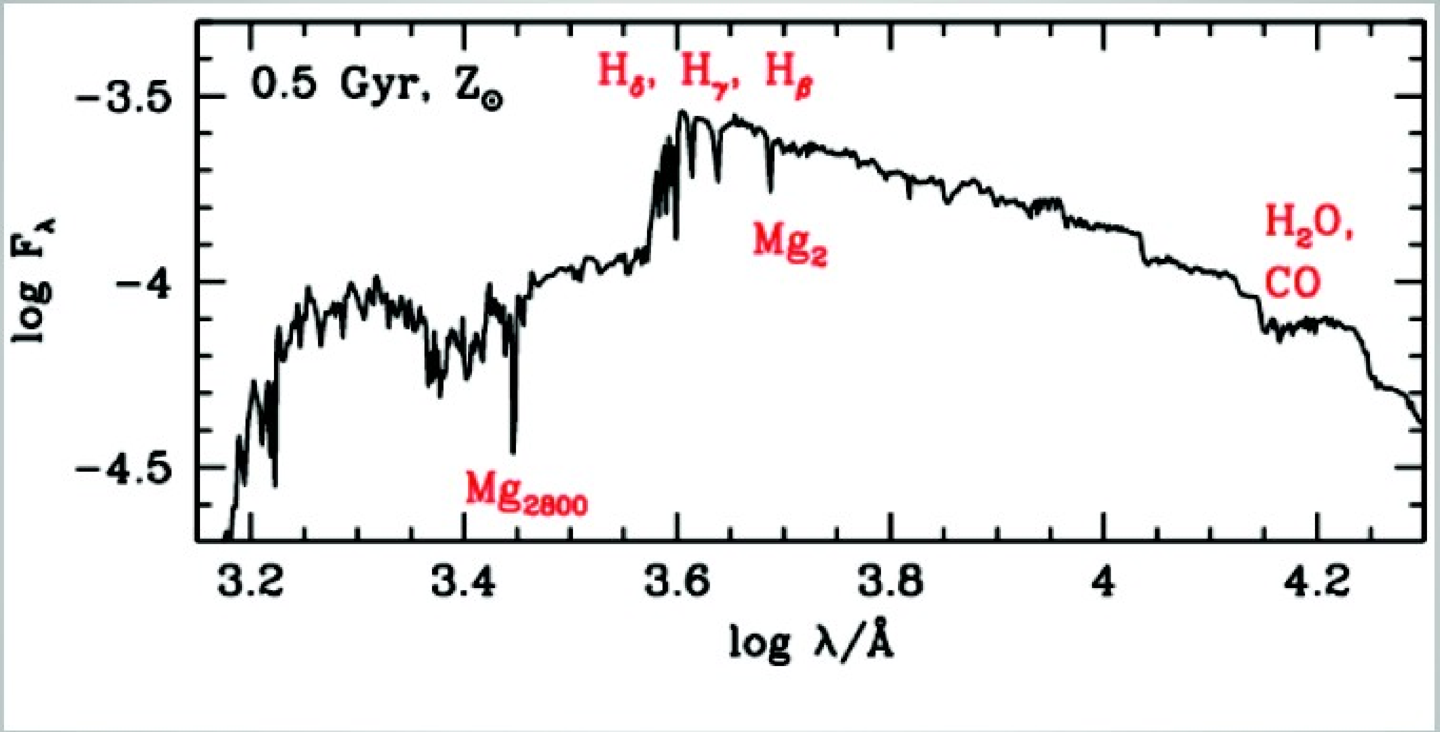
Visão artística de um buraco negro estelar



Visão artística de um buraco negro estelar

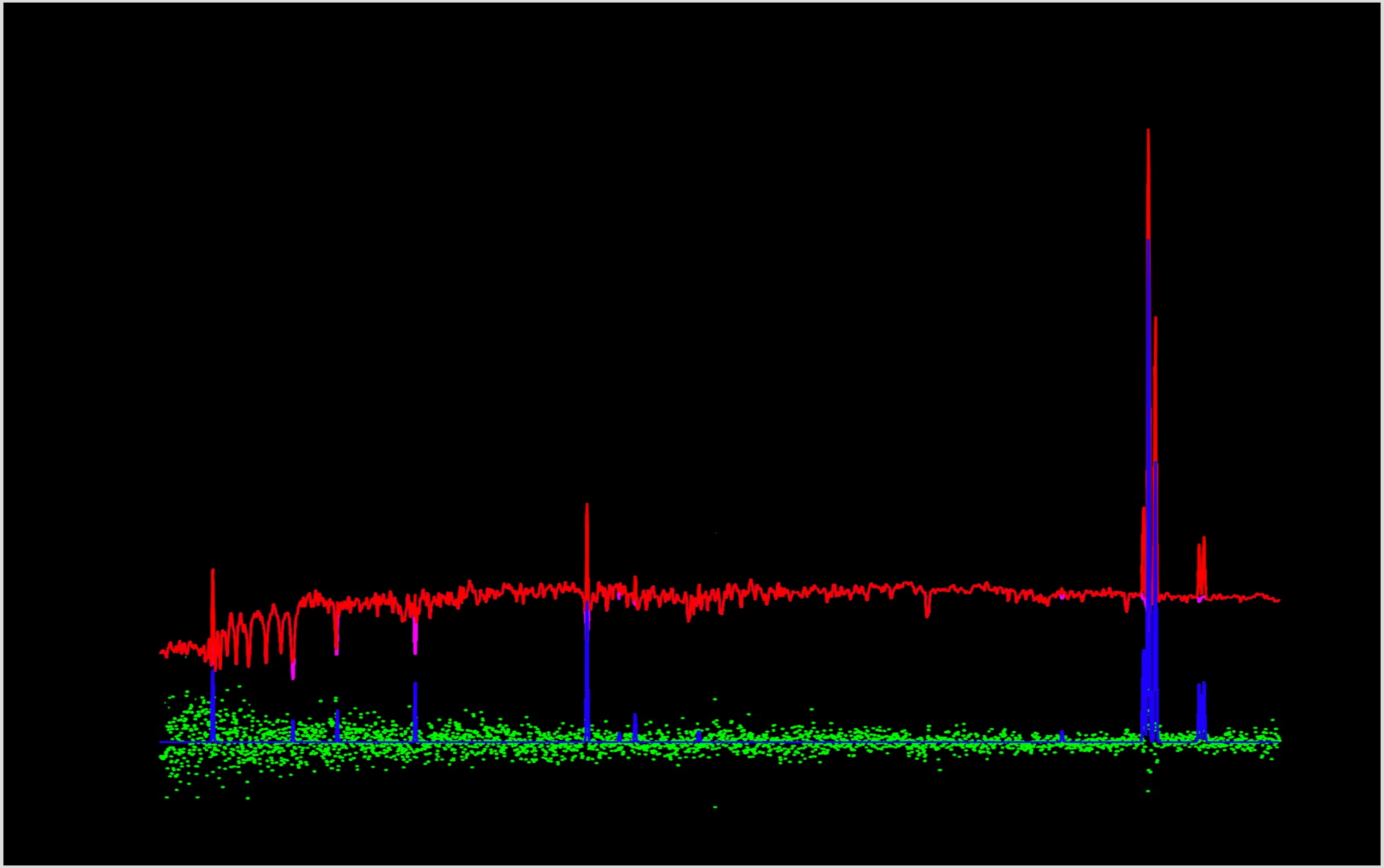


Stellar population model

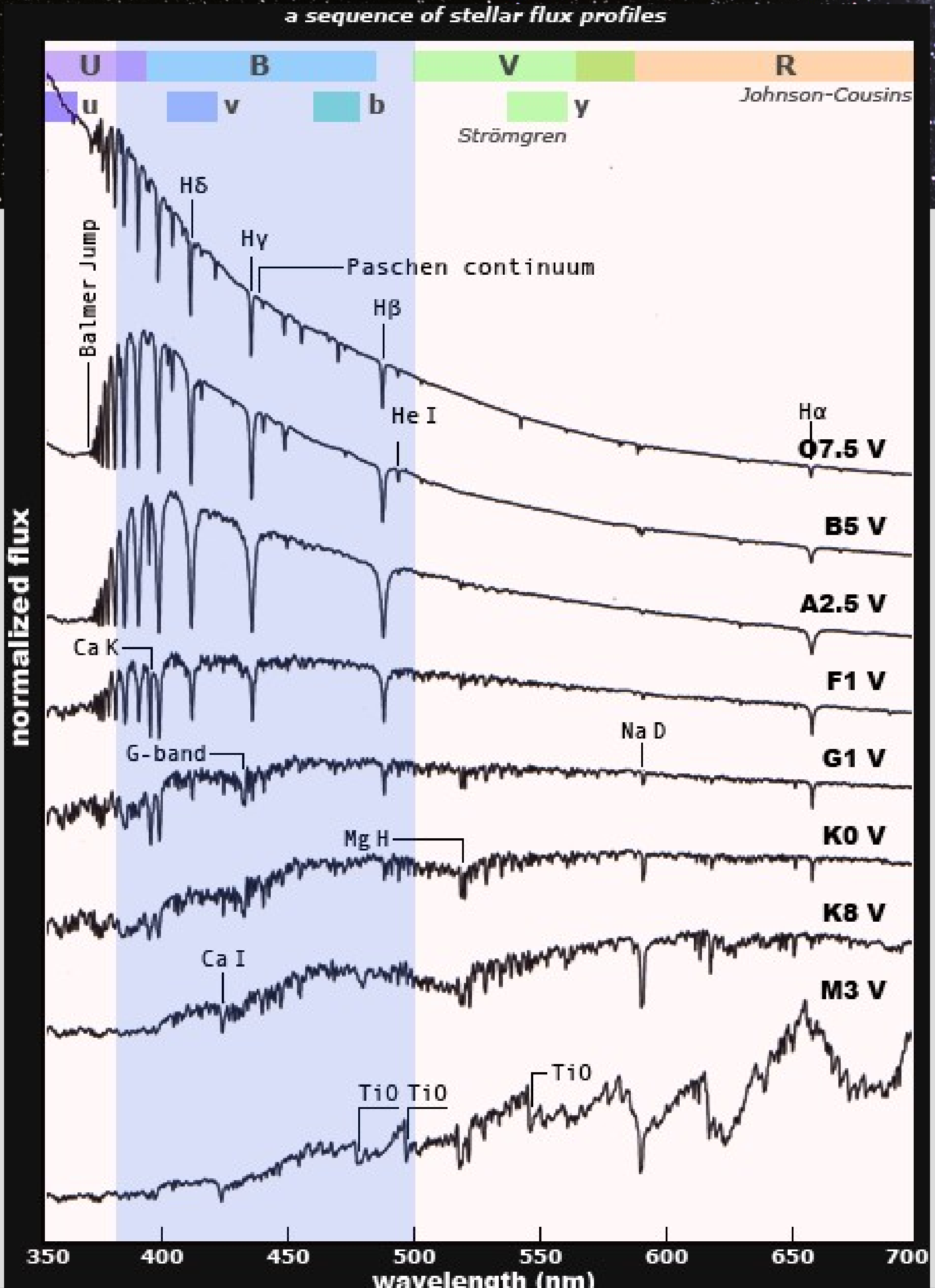


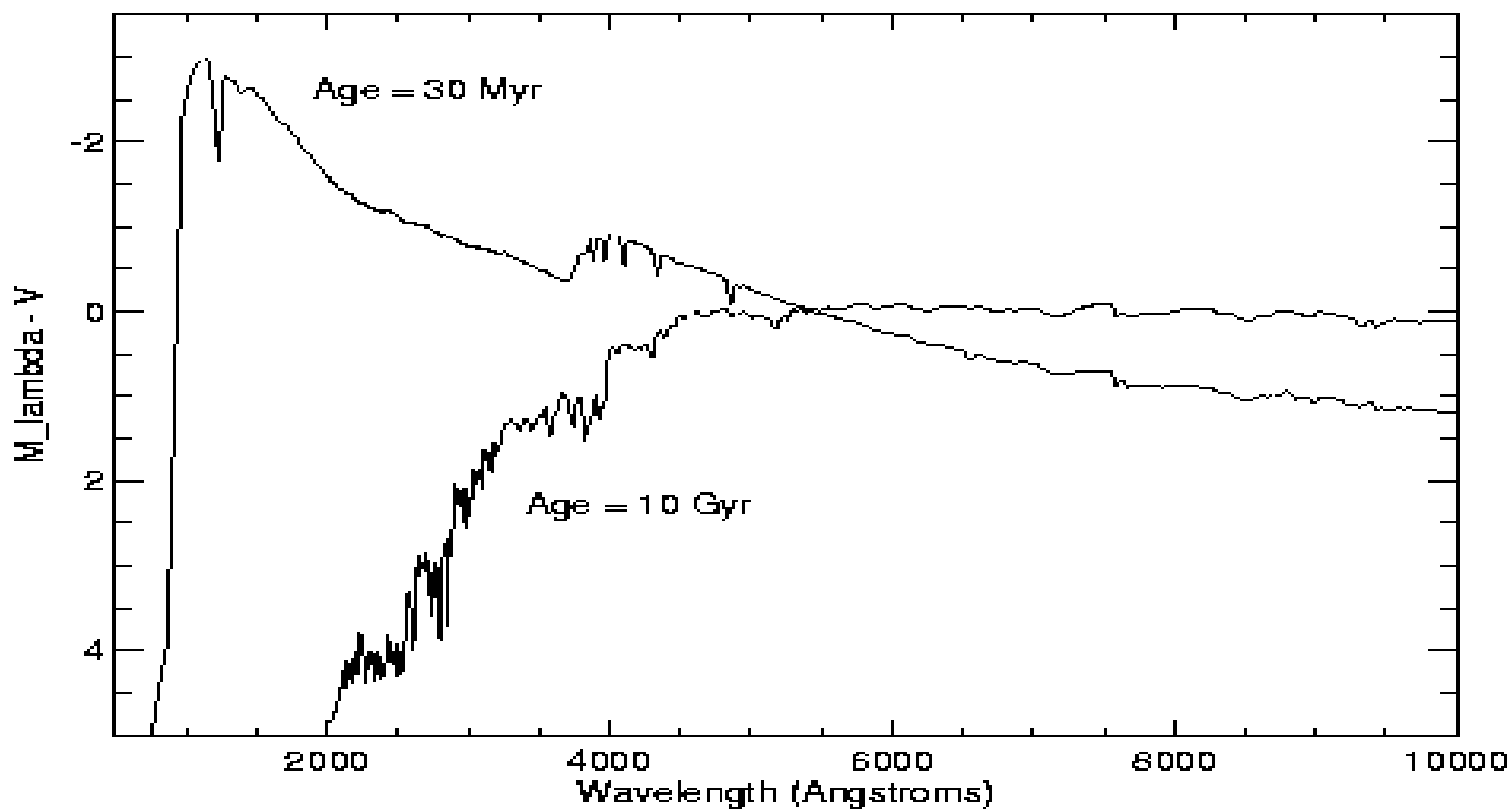
describes the integrated spectral energy distribution of a *"stellar population"* as a function of key parameters age, metallicity, element abundance ratios, star formation history, initial mass function, …

Young Starburst



Classes Espectrais




Age = 30 Myr
Age = 10 Gyr
M_lambda - V
-2
0
2
4
2000
4000
6000
8000
10000
Wavelength (Angstroms)

Typical Ellip. Galaxy Spectrum

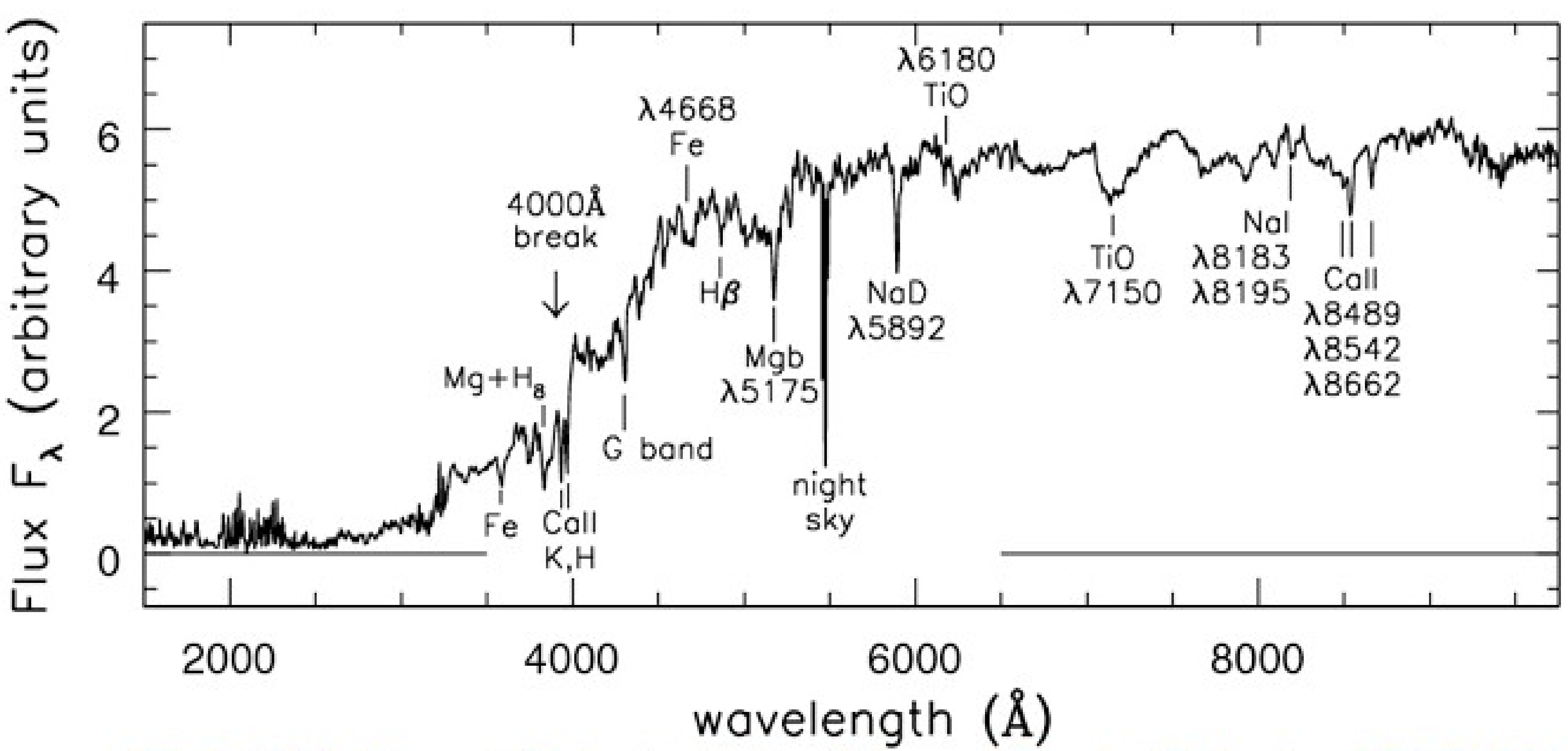


Fig 6.17 (A. Kinney) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Evolution of a single burst pop