

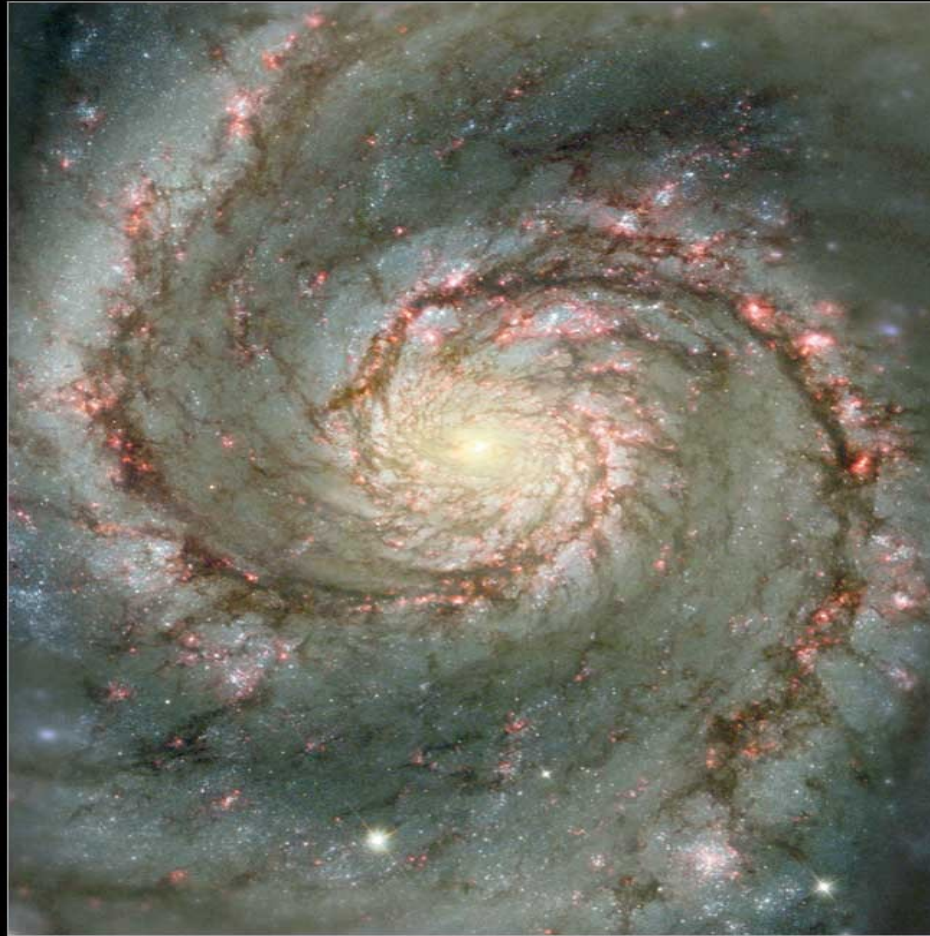
Formação e Evolução Estelar

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IF - UFRGS

Nuvens Moleculares Gigantes

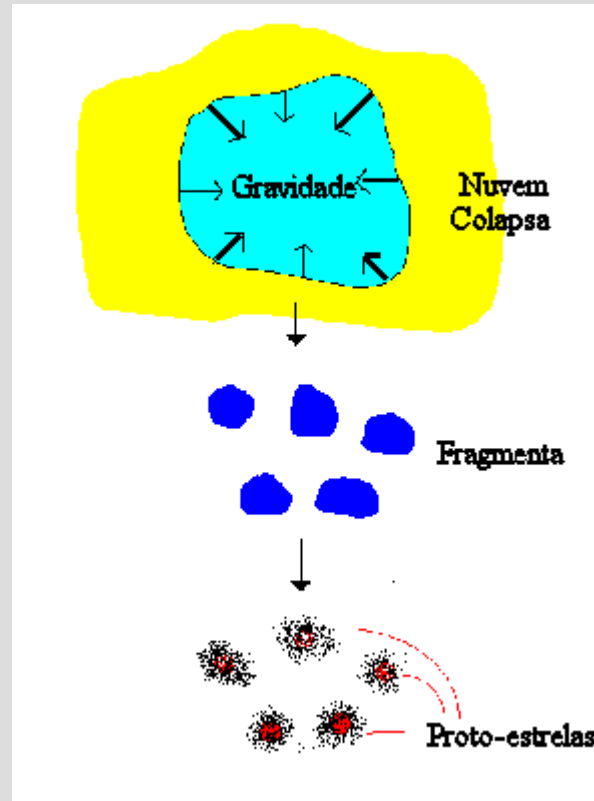
Whirlpool Galaxy • M51



Hubble
Heritage

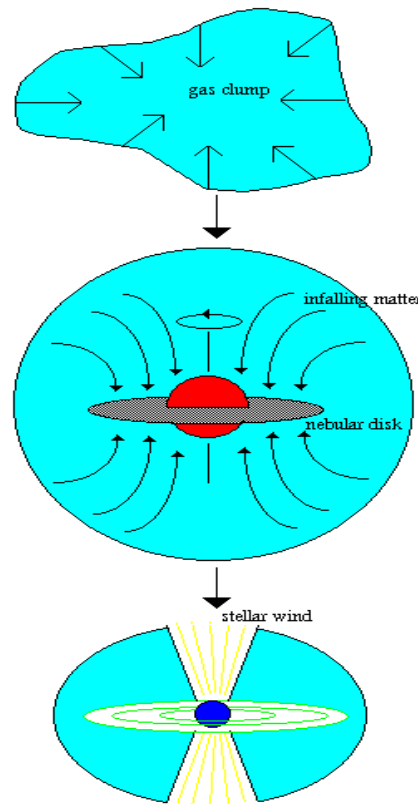
NASA and The Hubble Heritage Team (STScI/AURA)
Hubble Space Telescope WFPC2 • STScI-PRC01-07

Colapso de Nuvens Moleculares



Formação de proto-estrelas

Protostar Formation

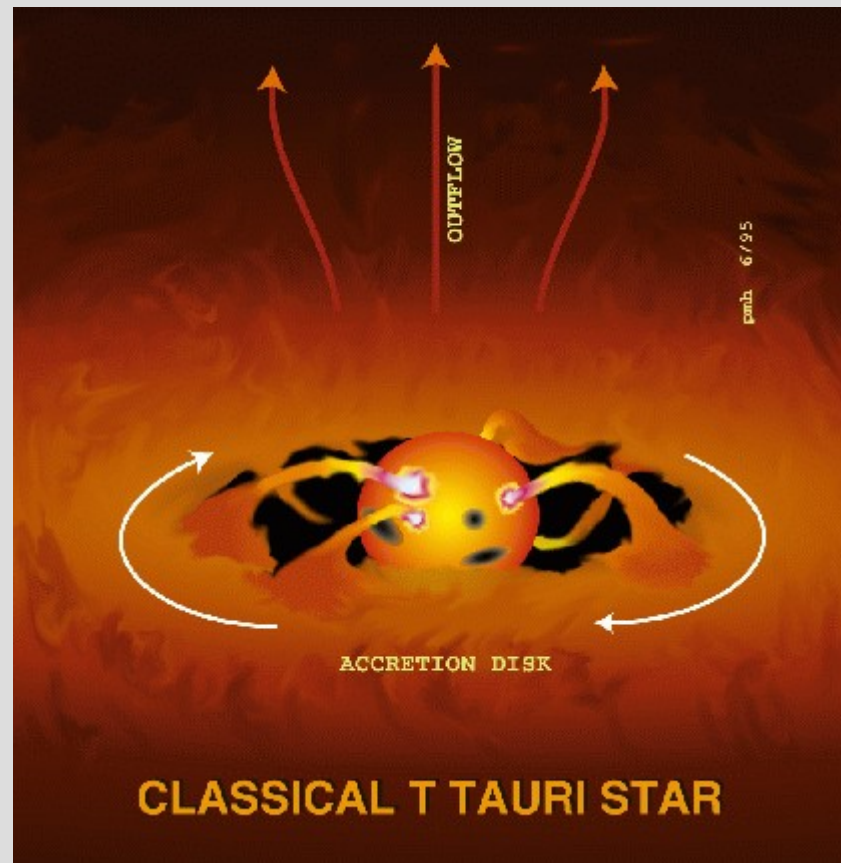


A dense gas clump breaks off from molecular cloud and collapses. Angular momentum turns the irregular clump into a rotating disk.

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.

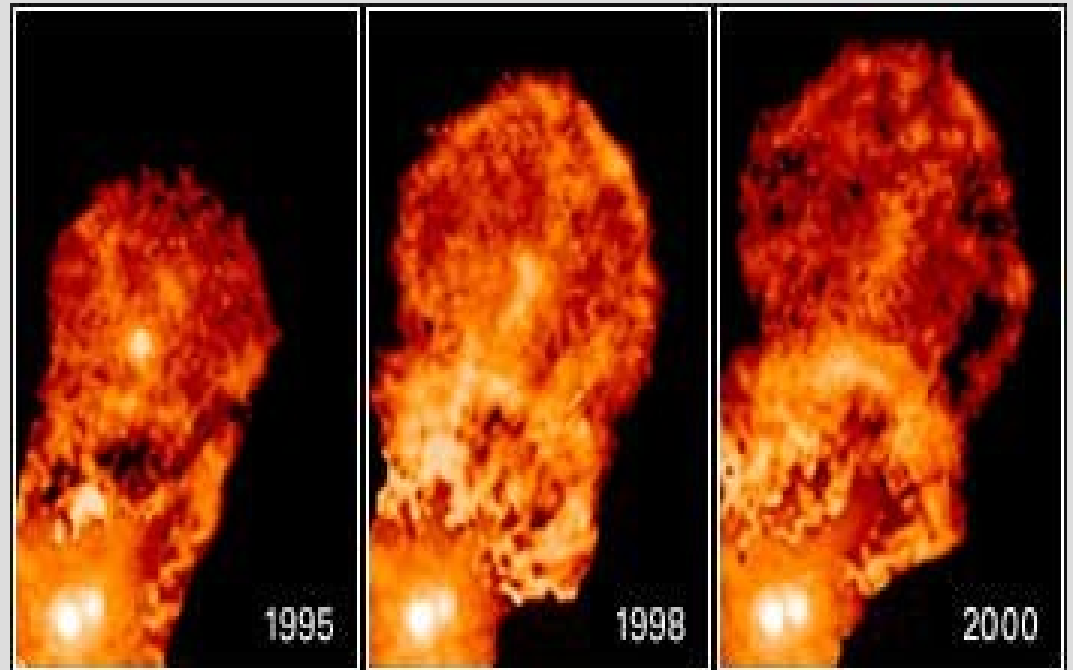
Infall is stopped when the protostar begins thermonuclear fusion and produces a strong stellar wind.

Formação de estrelas T Tauri



Estrelas T Tauri

Proto-estrelas, $m < 3M_{\odot}$, ainda em colapso, perda de massa.
Duração da fase: 10 milhões de anos.
Perda de masa total: $1M_{\odot}$.



Colapso gravitacional



Frente de choque em volta de
uma estrela - LL Ori

Nebulosas de Absorção



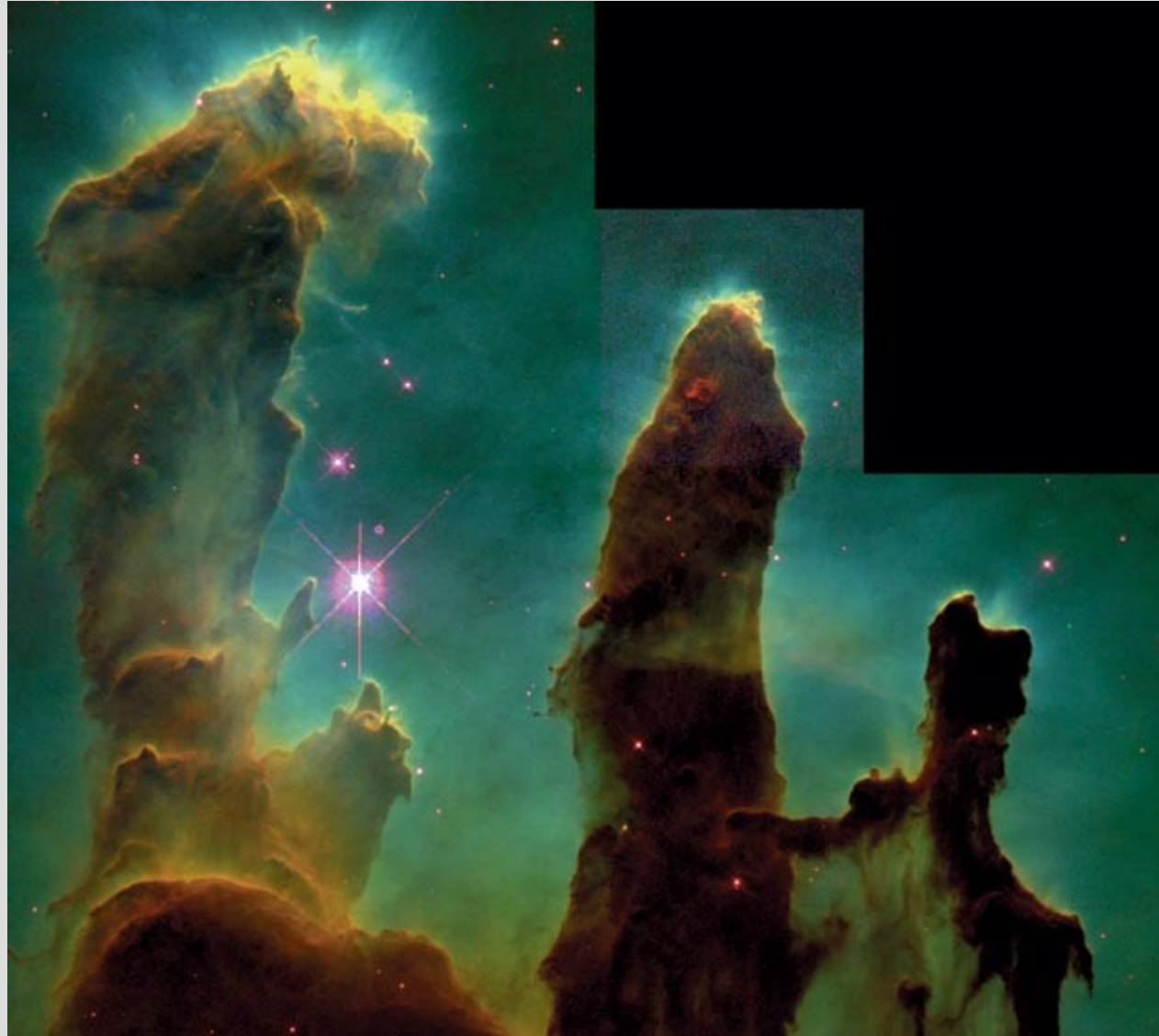
Cabeça de Cavalo

Nebulosas de Emissão



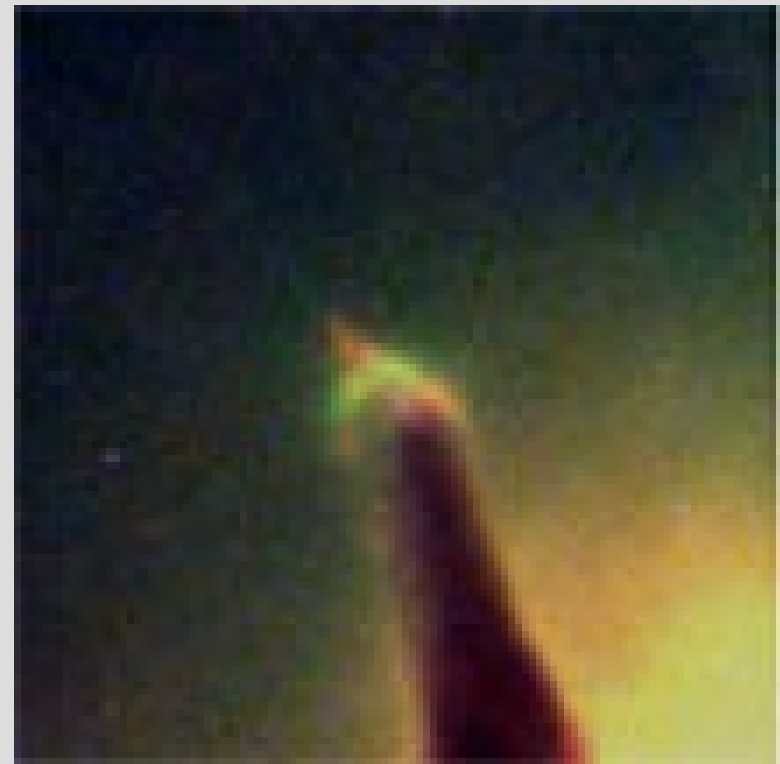
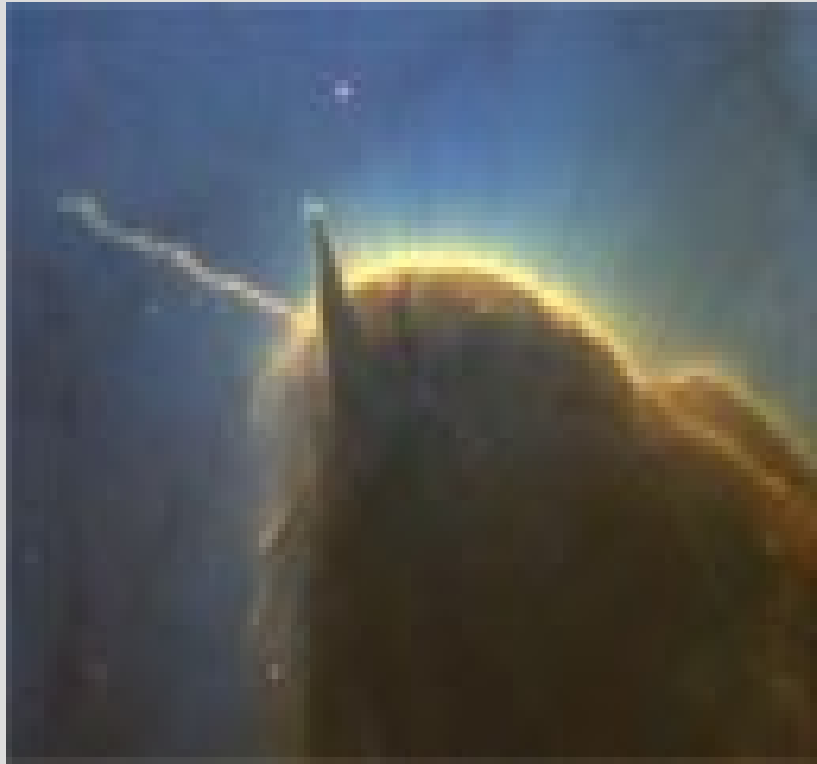
M42 - A grande nebulosa em Órion

M16 – Nebulosa da Águia

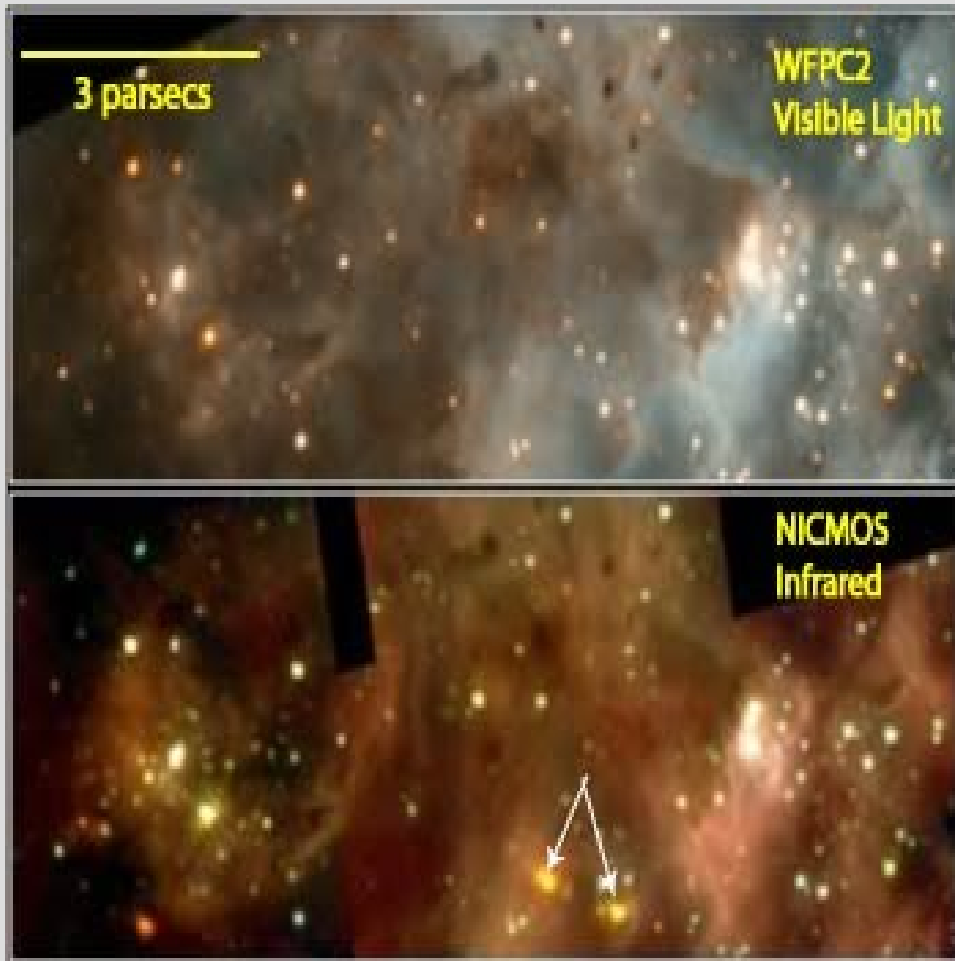




Regiões de formação estelar



Proto-estrelas em 30Dor (LMC)



Nebulosa Trífida



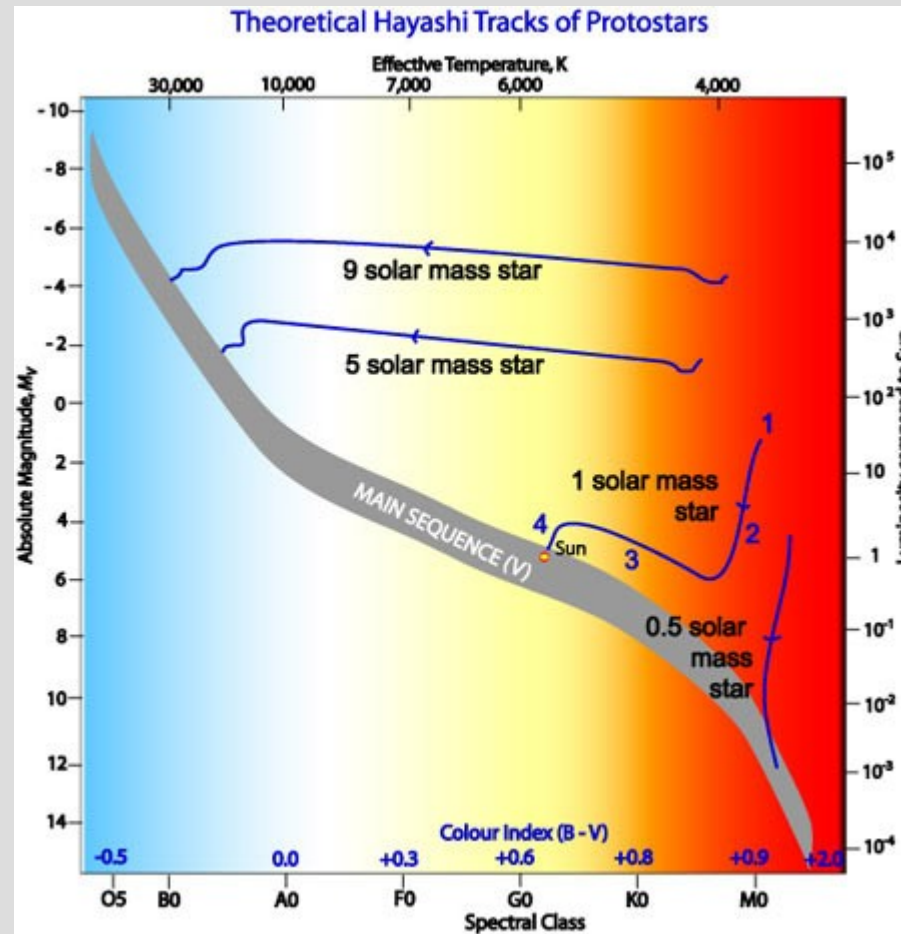
NGC 602



Região de formação estelar: N11B (LMC)



Tracks teóricos de proto-estrelas



Nasce uma estrela

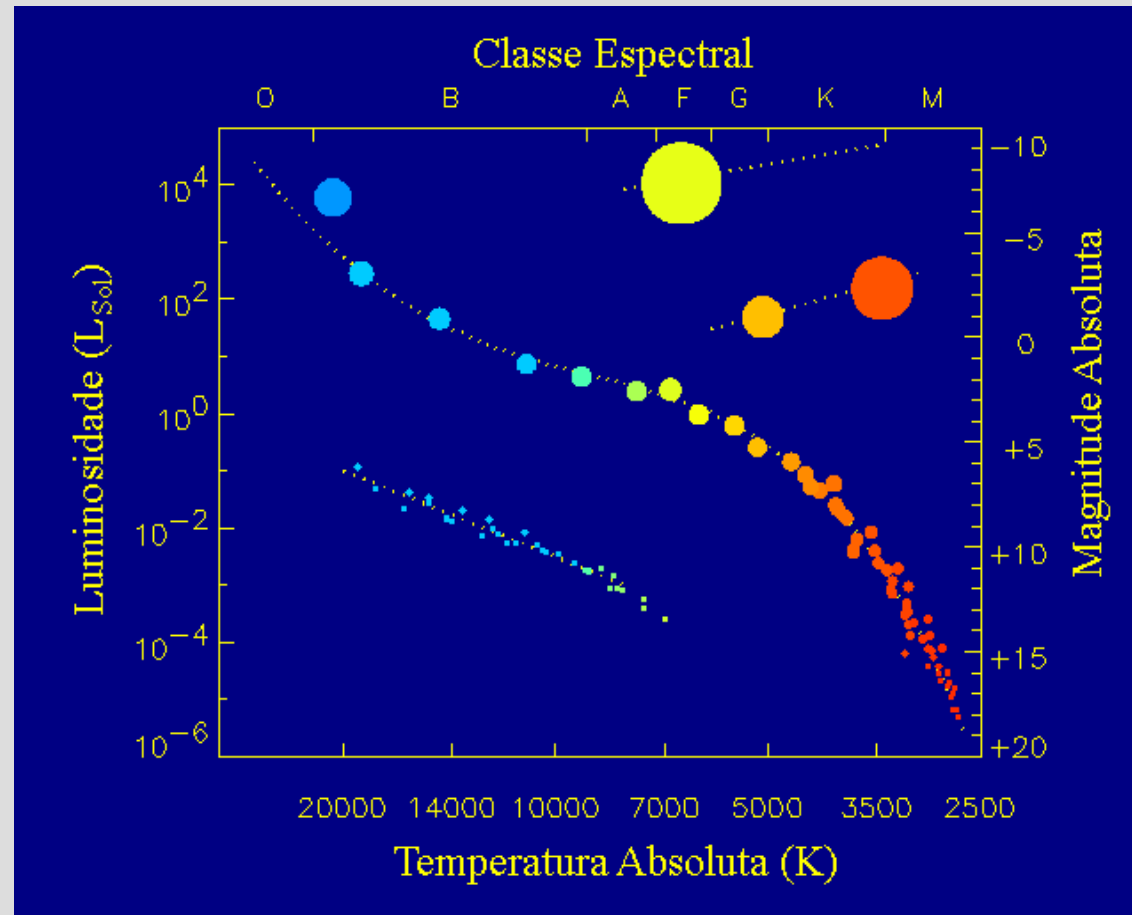
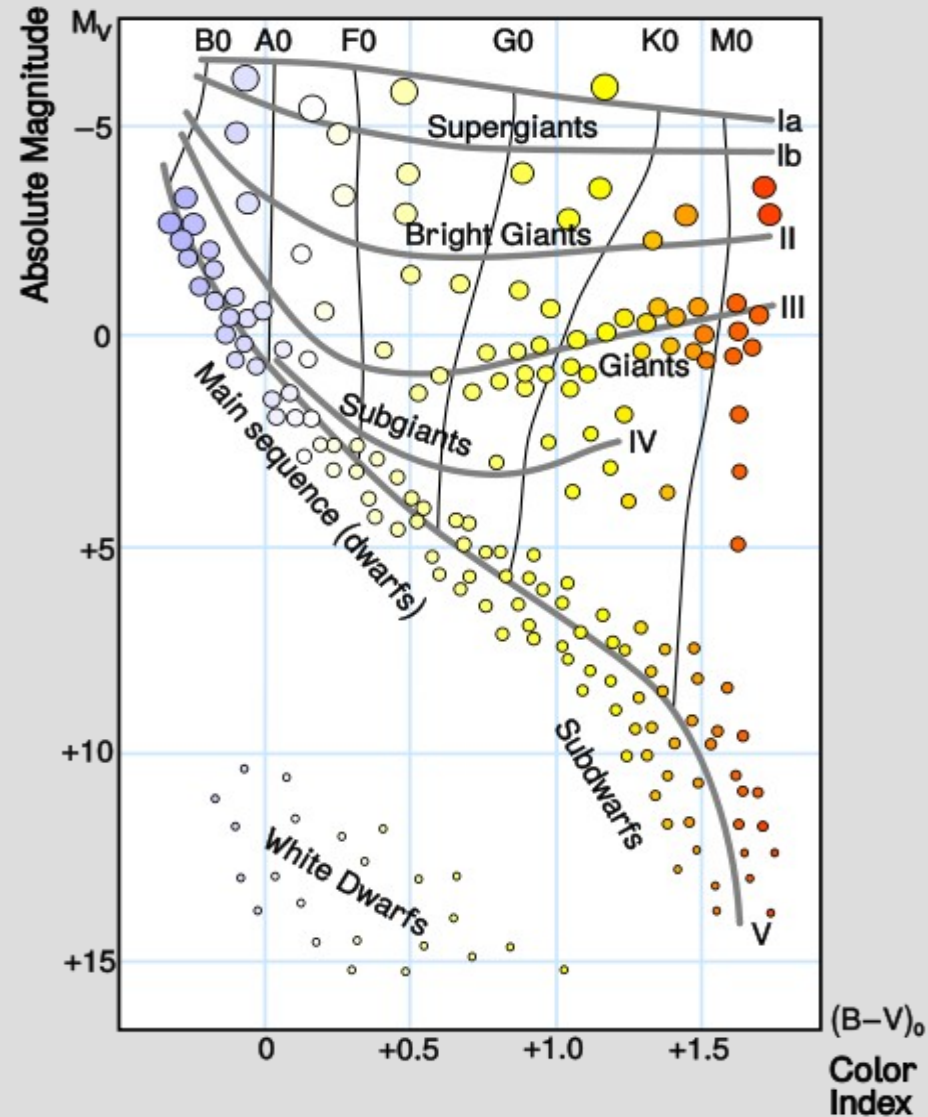
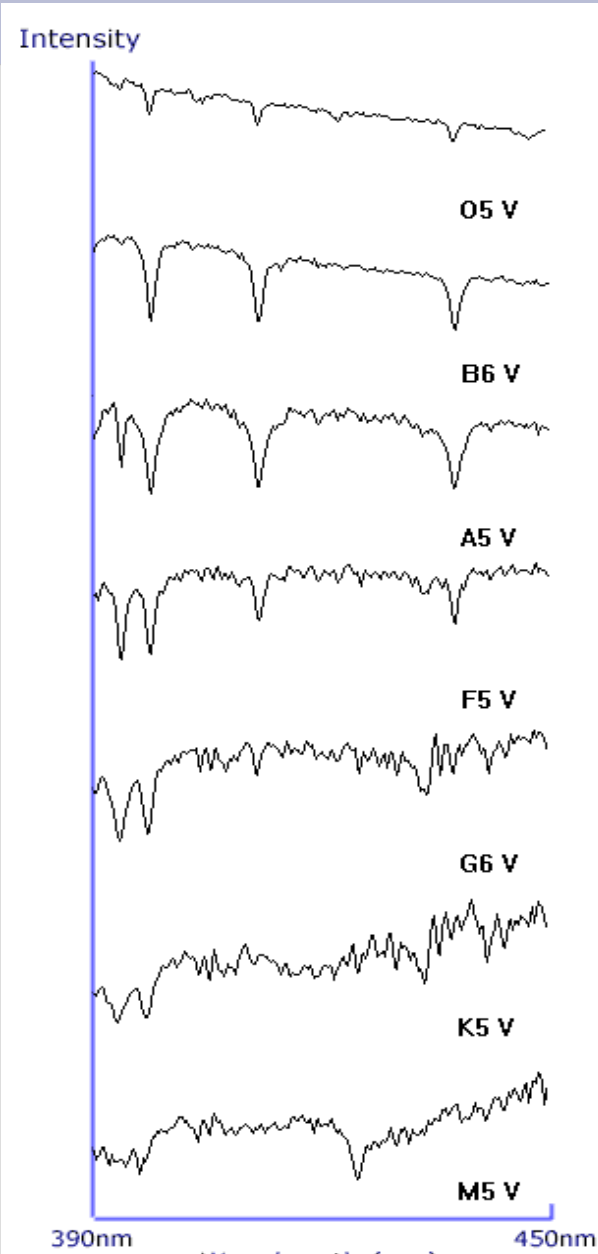


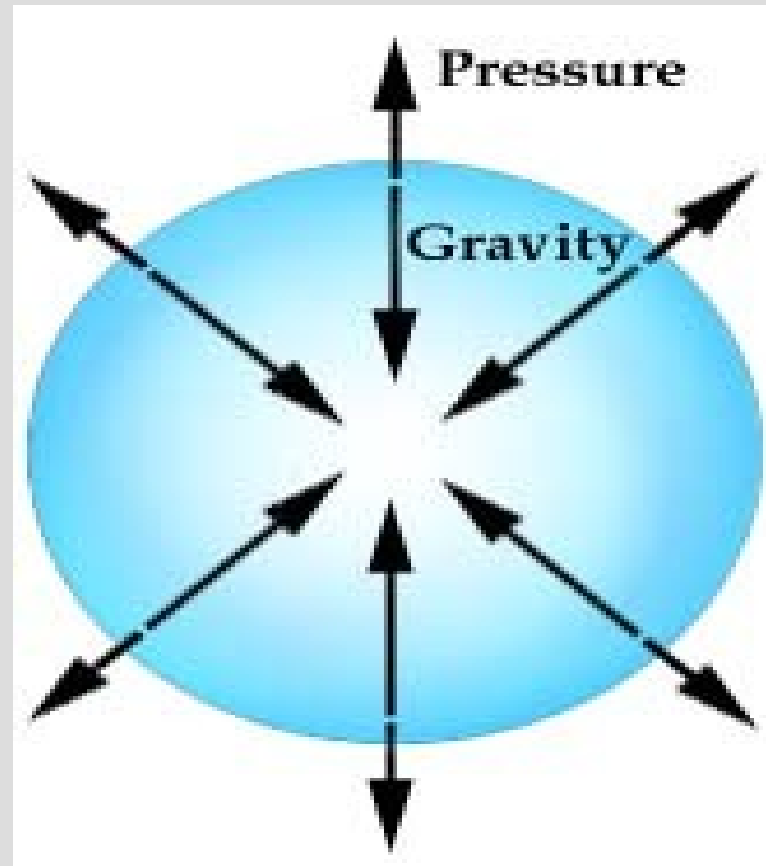
Diagrama Cor-Magnitude (HR)



Classes Espectrais



A eterna batalha contra o peso!



O Sol – nossa estrela particular!!!

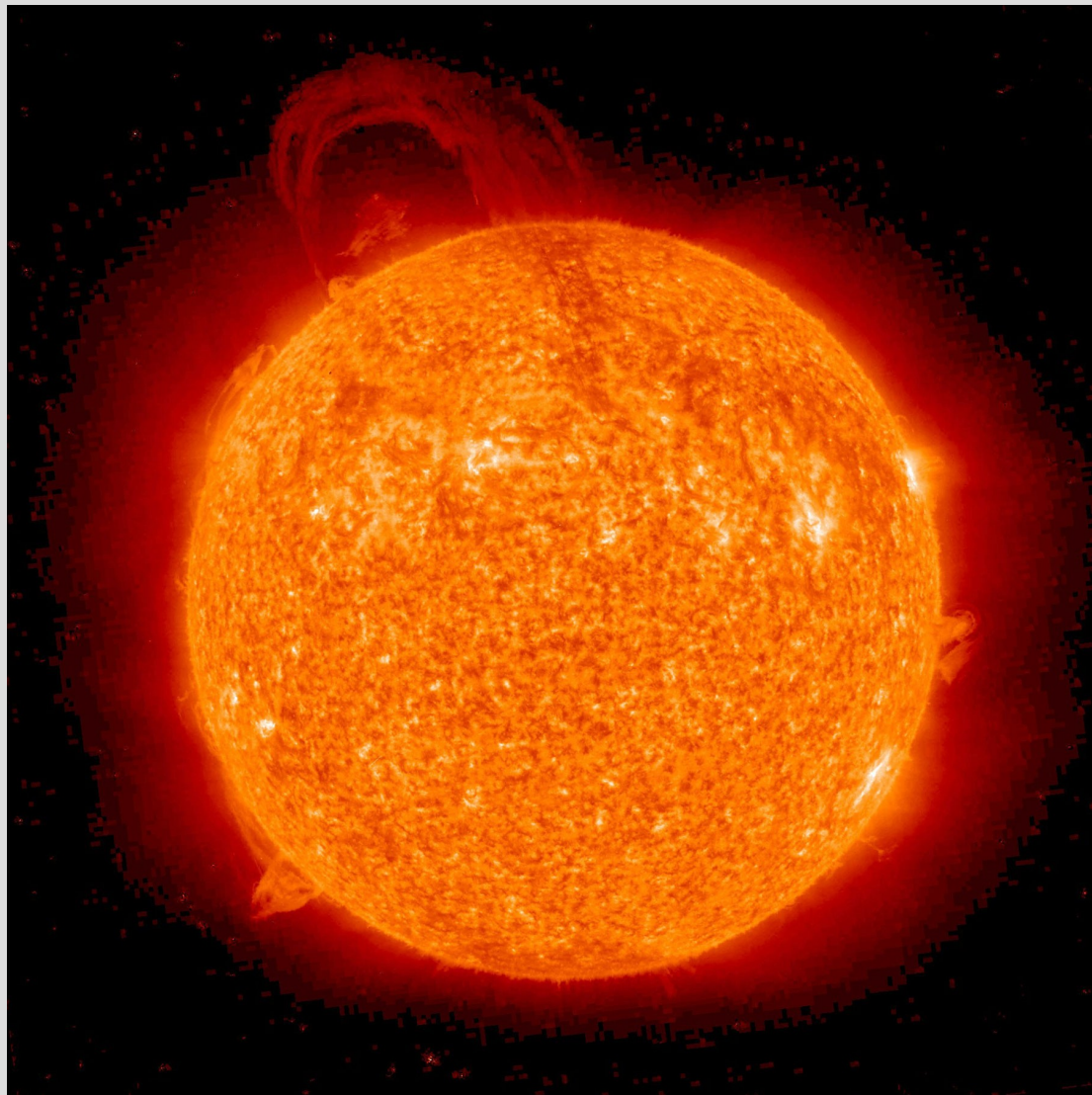
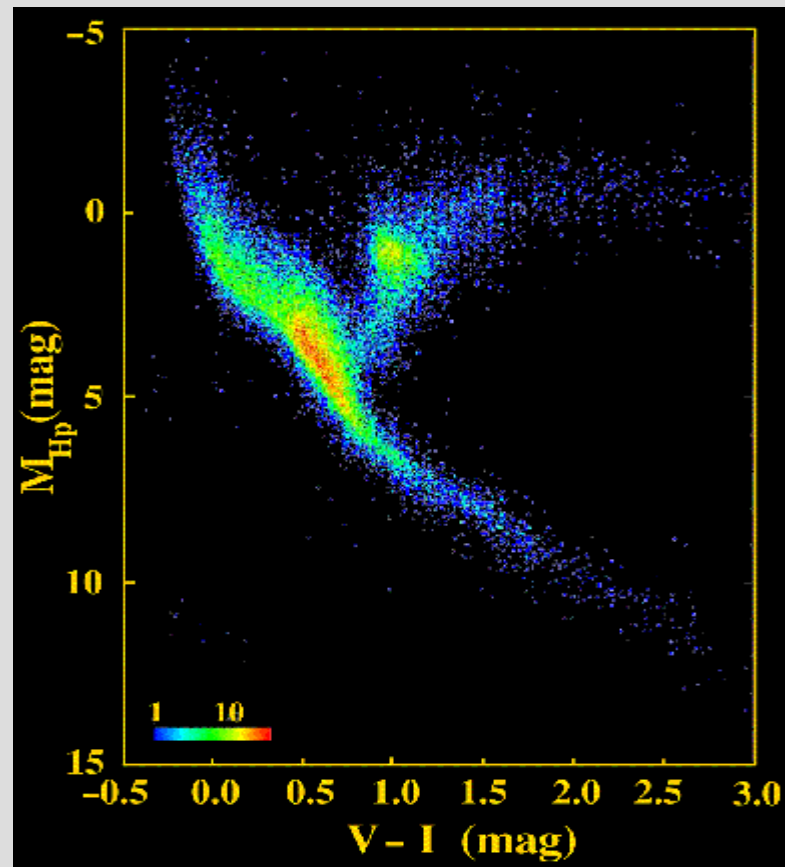
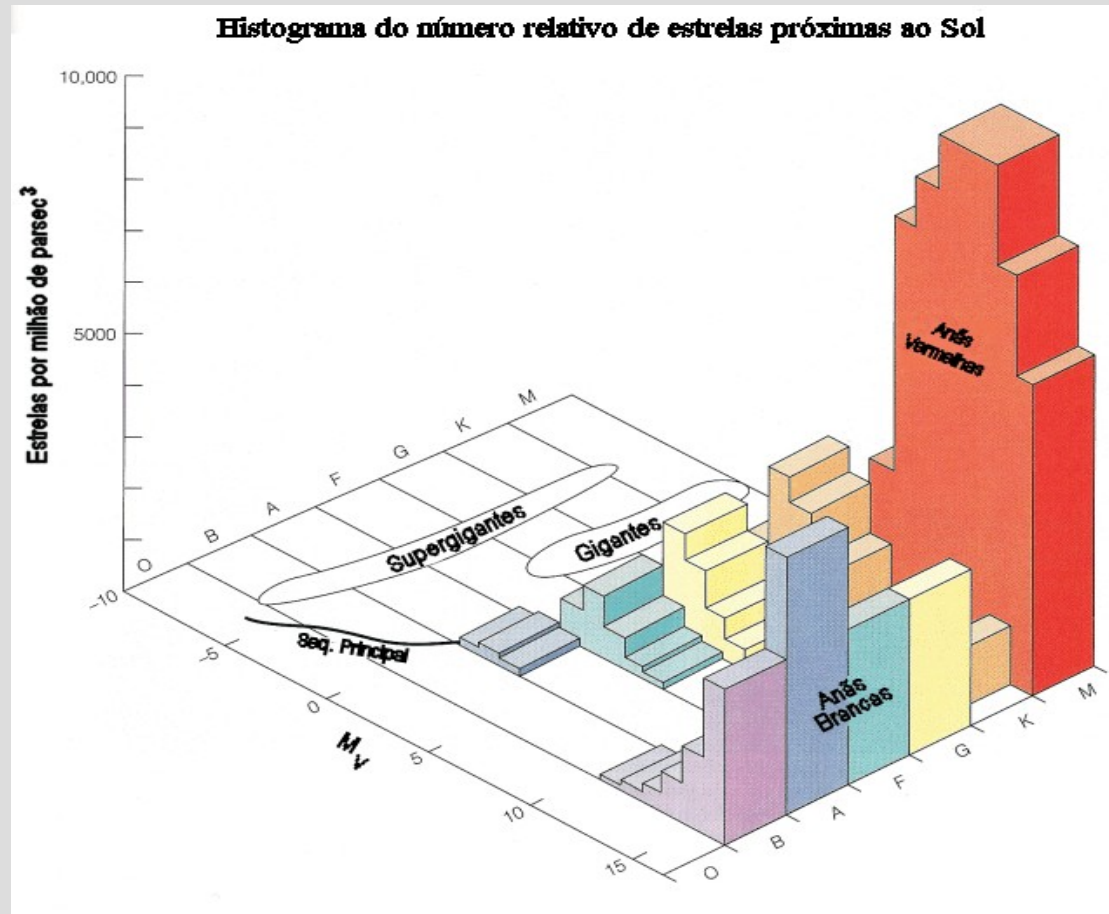


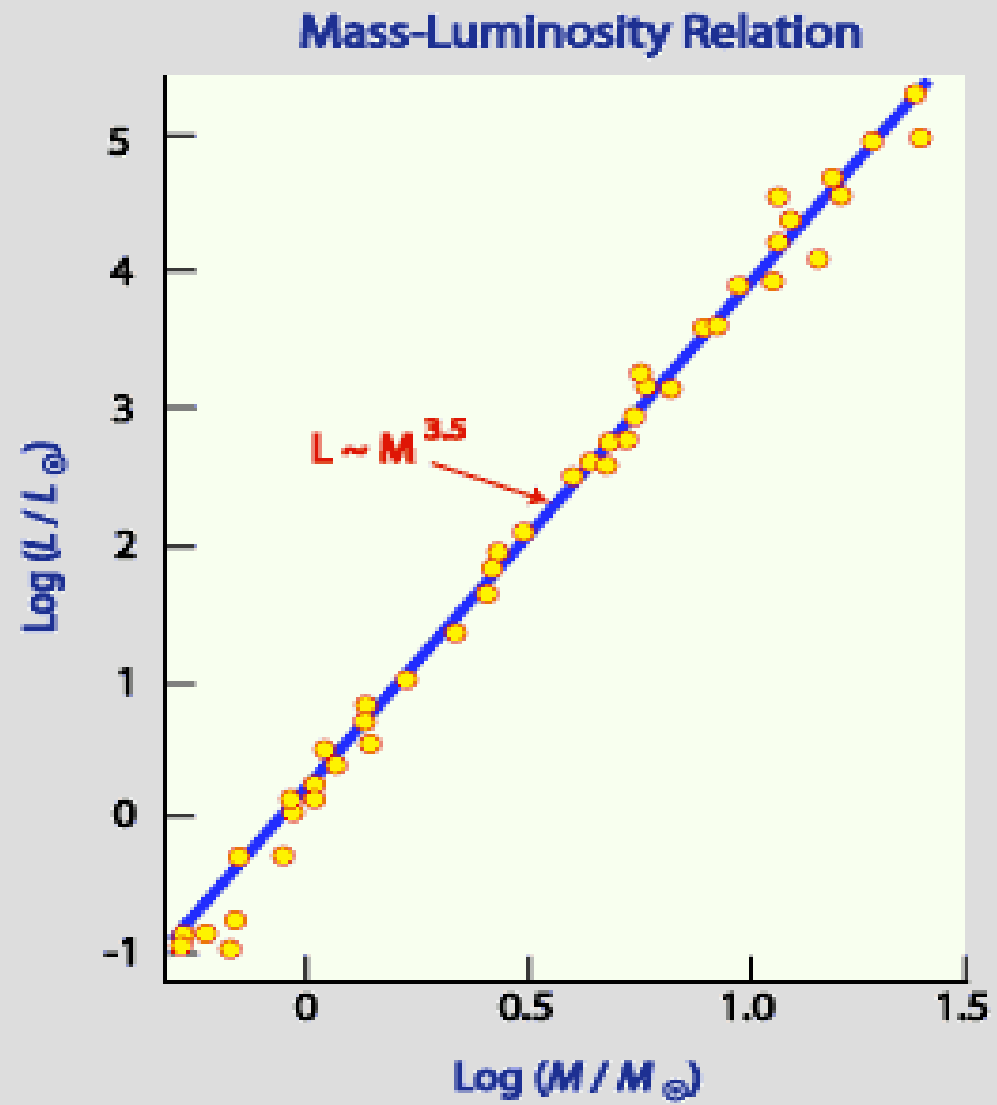
Diagrama HR das 41000 estrelas mais próximas ao Sol.



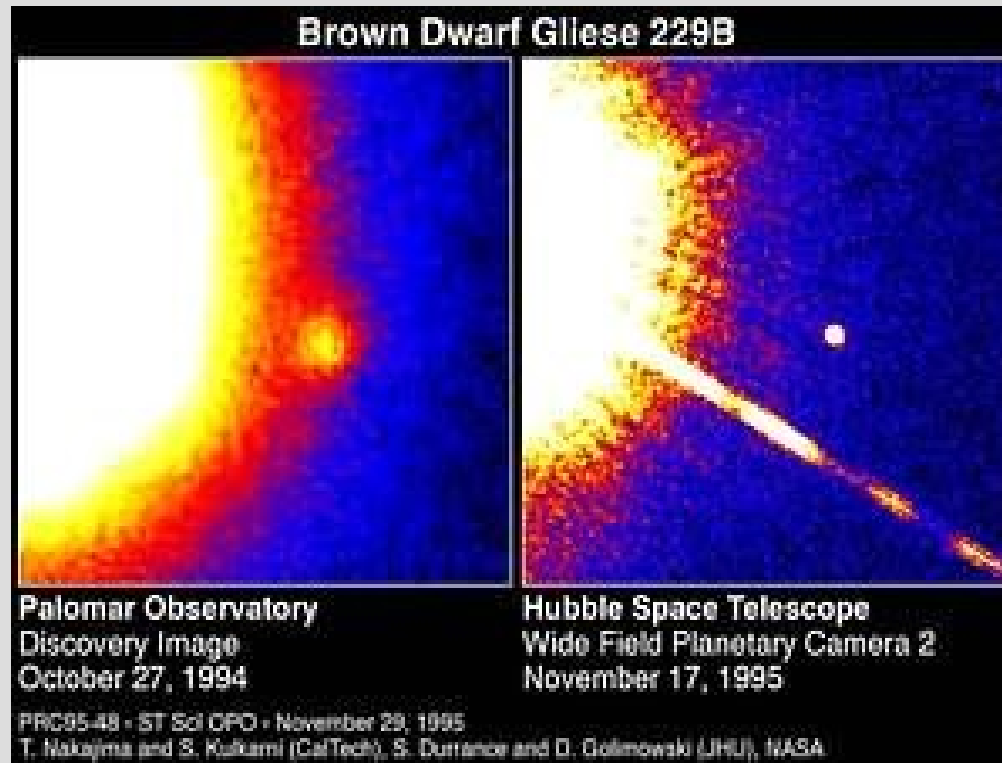
Estatística das estrelas vizinhas ao Sol



Relação Massa-Luminosidade



Anãs-marrons: estrelas falhadas!

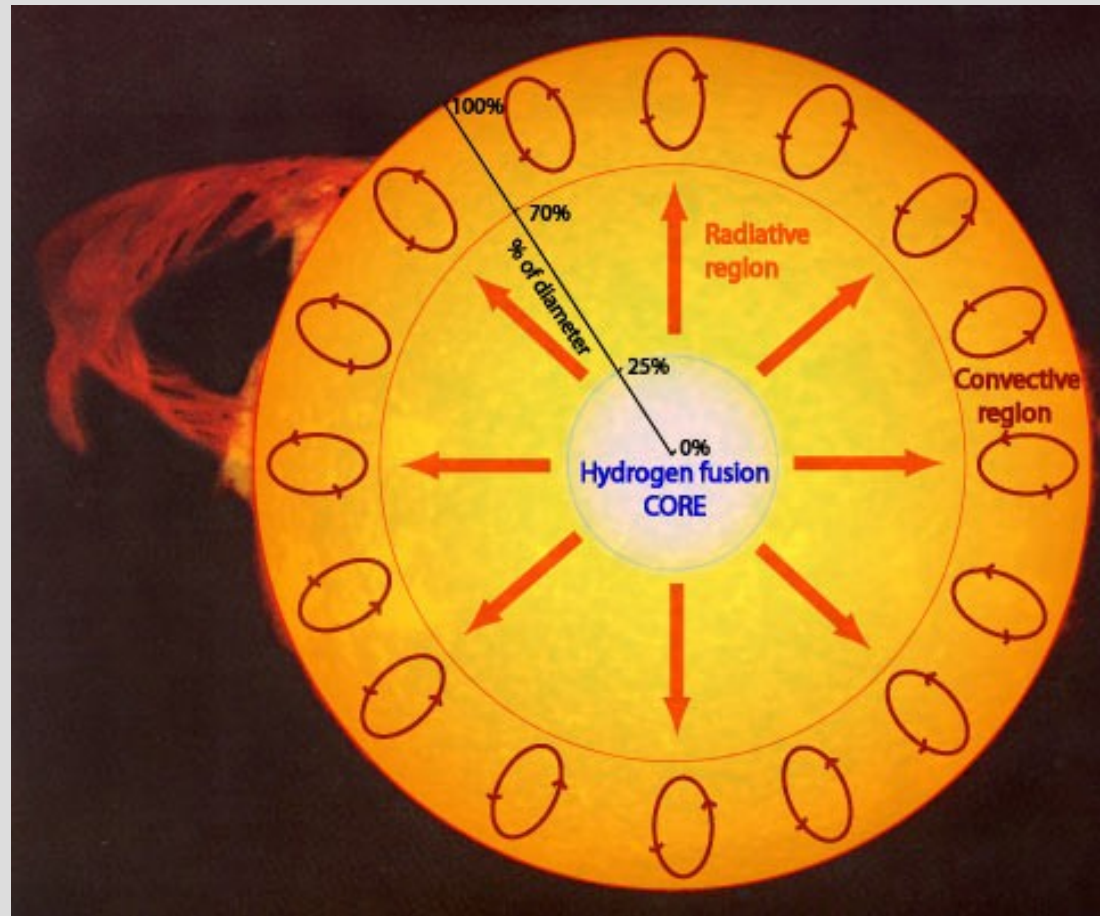


Gliese 229B - a 1a anã-marrom a ser descoberta (1995).

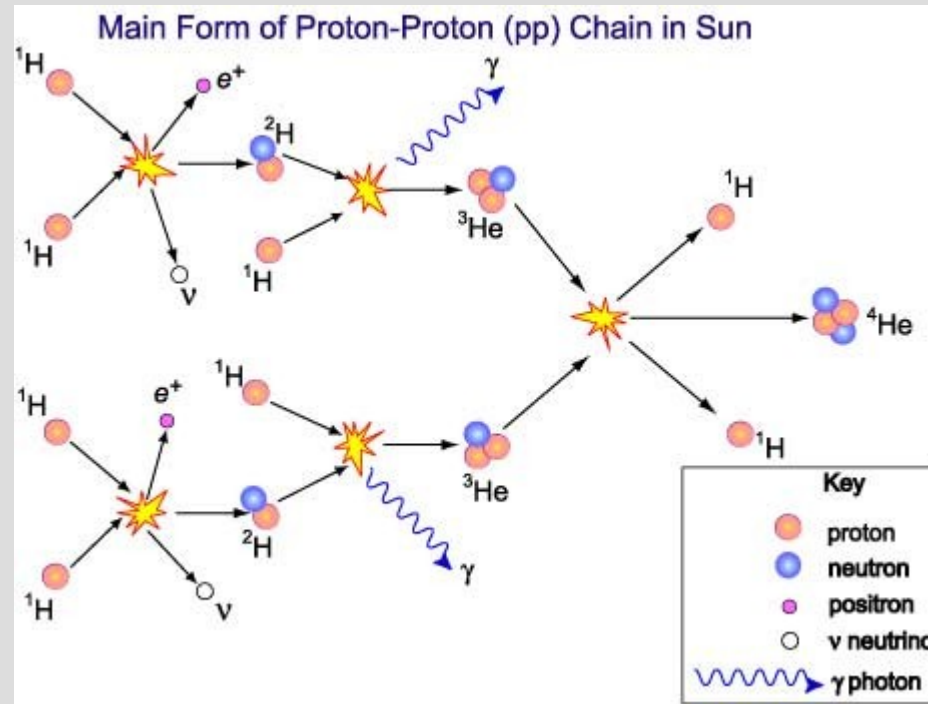
Propriedades da Sequência Principal

Mass/ M_{Sun}	Luminosity/ L_{Sun}	Effective Temperature (K)	Radius/ R_{Sun}	Main sequence lifespan (yrs)
0.10	3×10^{-3}	2,900	0.16	2×10^{12}
0.50	0.03	3,800	0.6	2×10^{11}
0.75	0.3	5,000	0.8	3×10^{10}
1.0	1	6,000	1.0	1×10^{10}
1.5	5	7,000	1.4	2×10^9
3	60	11,000	2.5	2×10^8
5	600	17,000	3.8	7×10^7
10	10,000	22,000	5.6	2×10^7
15	17,000	28,000	6.8	1×10^7
25	80,000	35,000	8.7	7×10^6
60	790,000	44,500	15	3.4×10^6

Interiores estelares

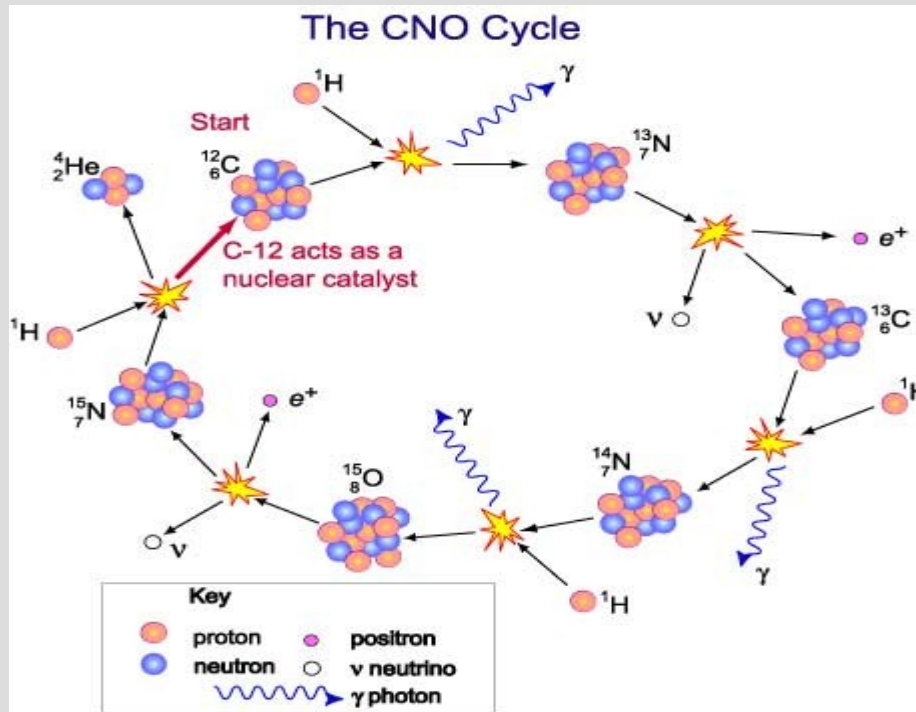


Fonte de energia: ciclo pp



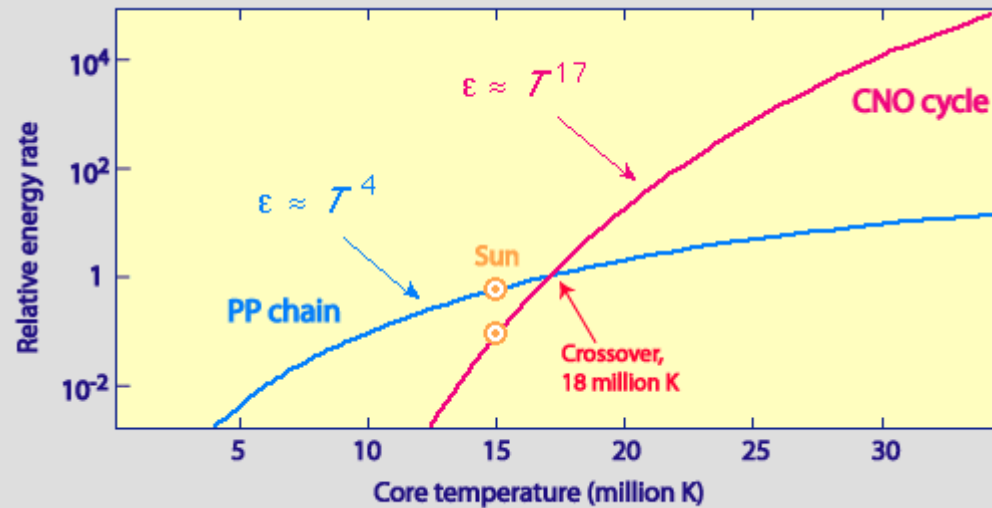
Estrelas com $m < 1.2 M_{\odot}$

Fonte de energia: ciclo CNO



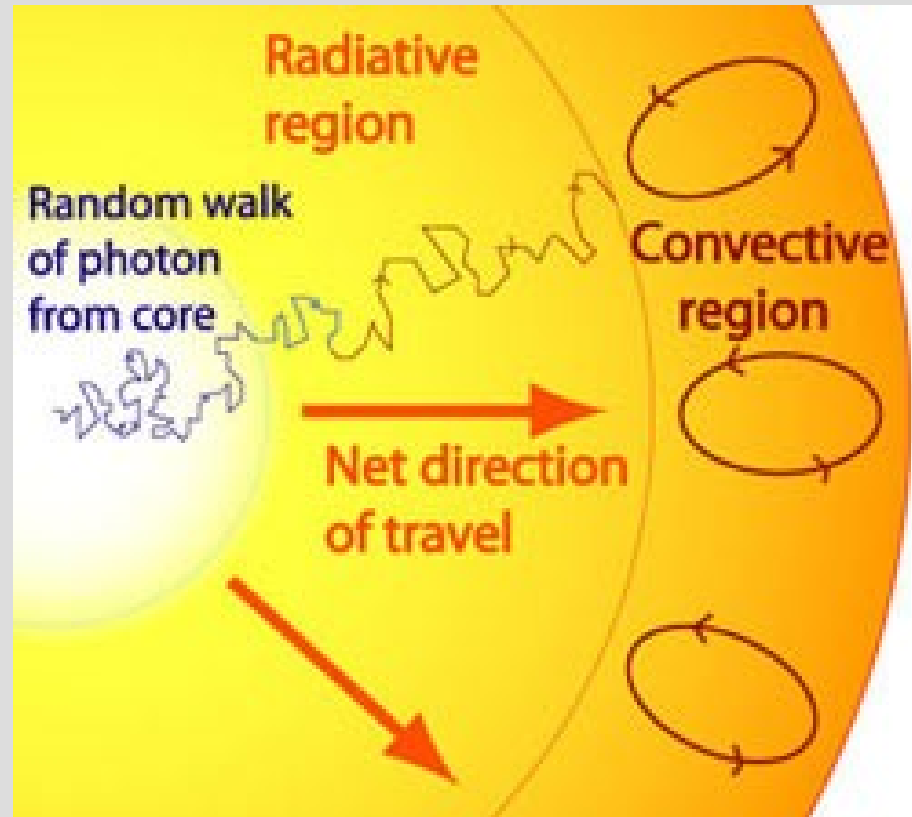
Estrelas com $m > 1.2 M_{\odot}$

Quem domina?



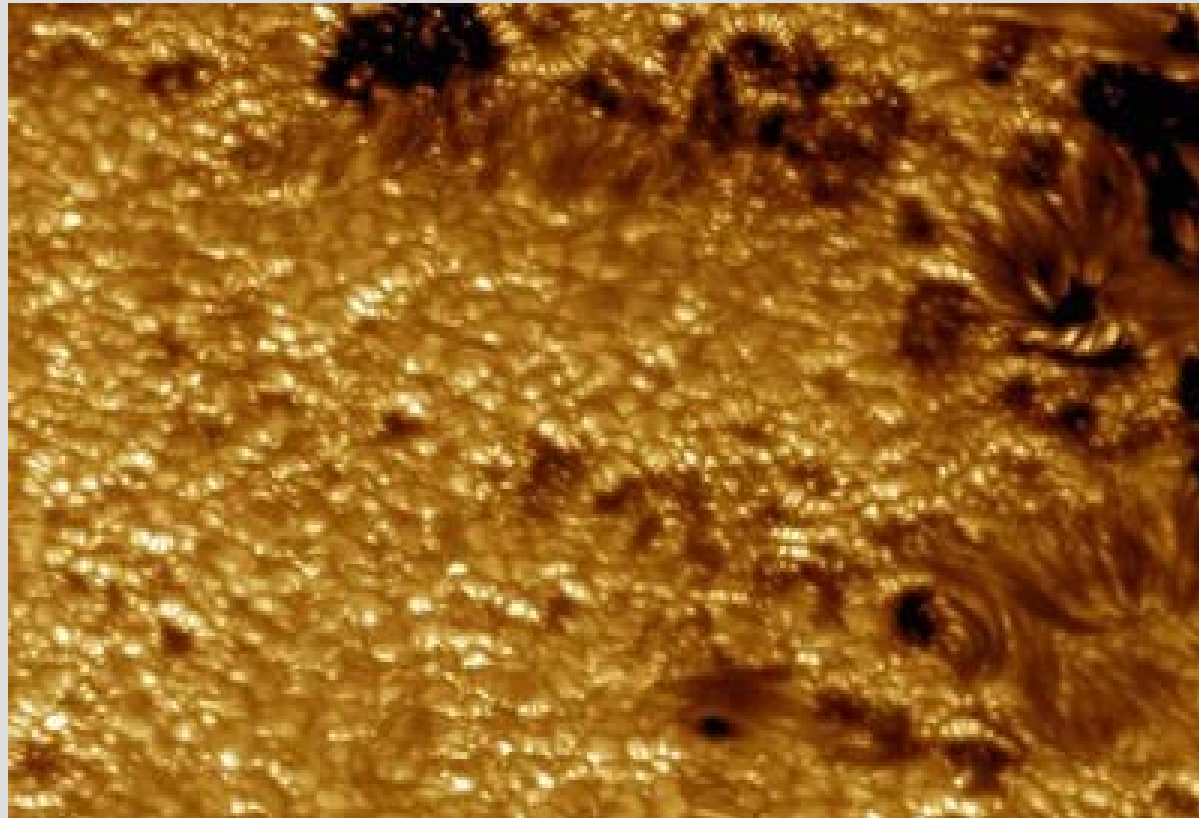
T=18 milhões K.
m = 1.2Mo

Transporte de energia no Sol



Tempo médio para um fóton sair do Sol: 10 milhões de anos!!

Superfície do Sol



Manchas solares e grânulos!

Evolução estelar



Super-gigante vermelha “engolindo” Júpiter!

Umas poucas equações

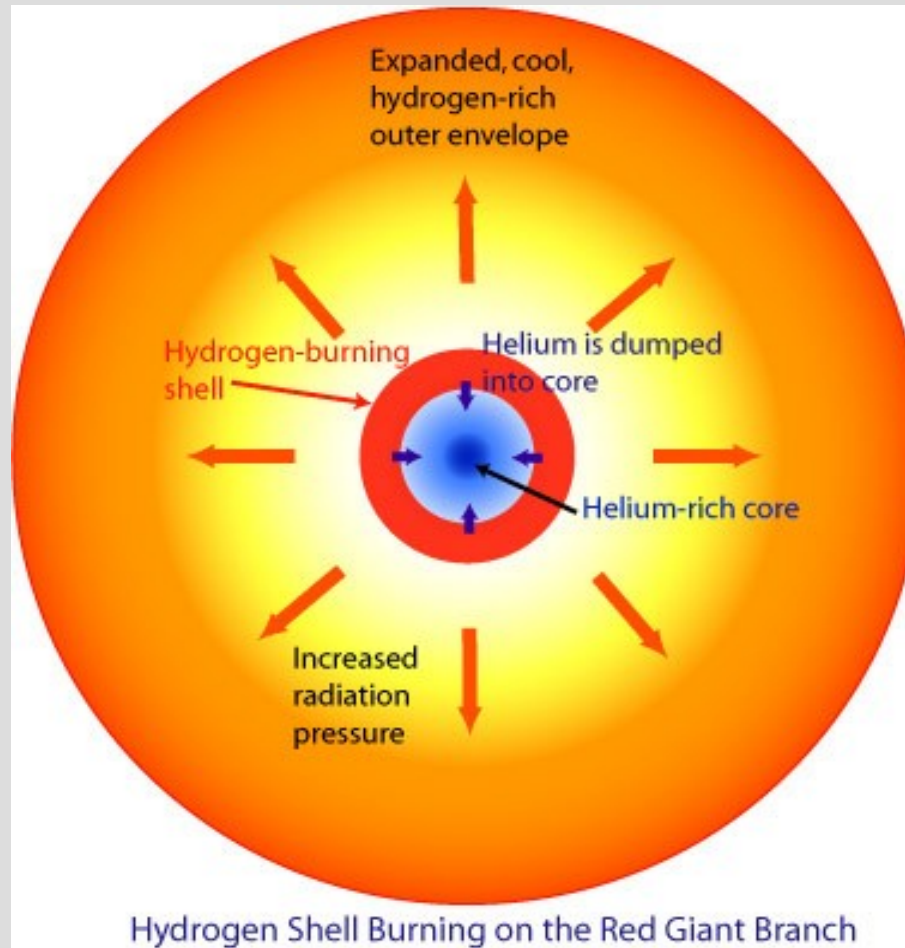
$$\frac{dM_r}{dr} = 4\pi r^2 \rho$$

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

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

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

Queima de H em camada - RGB



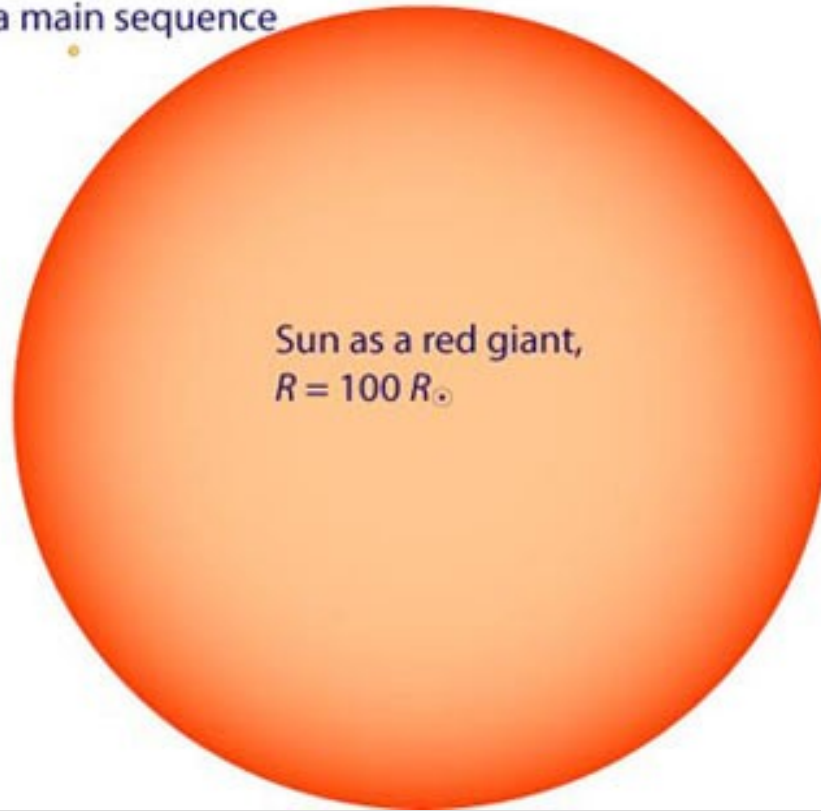
O futuro do Sol

Comparison in size of Sun as a main sequence star and a red giant

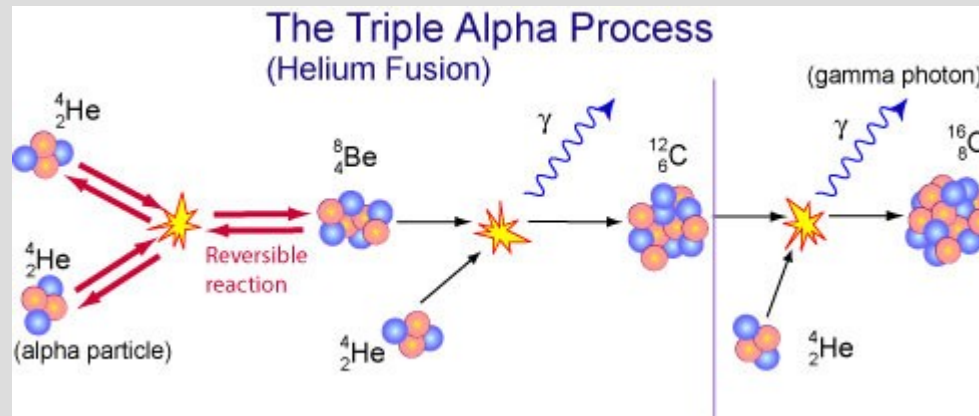
Sun as a main sequence star



Sun as a red giant,
 $R = 100 R_{\odot}$

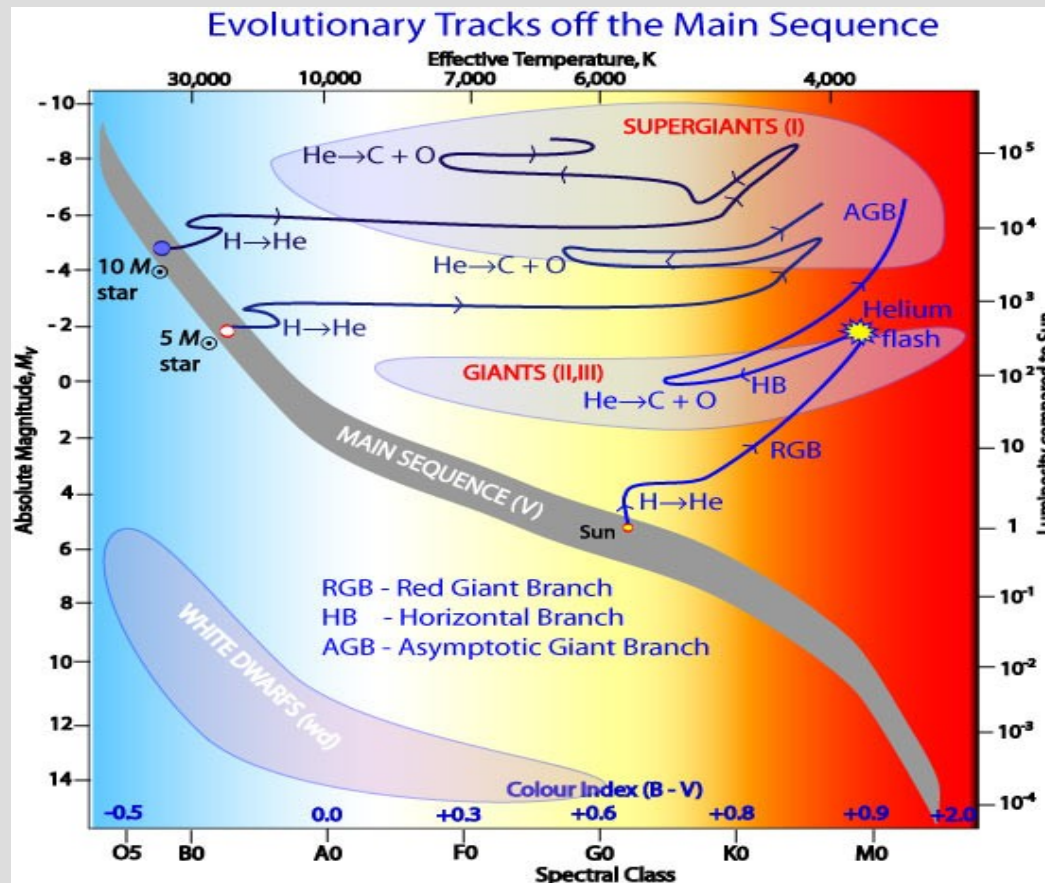


Queima de Hélio

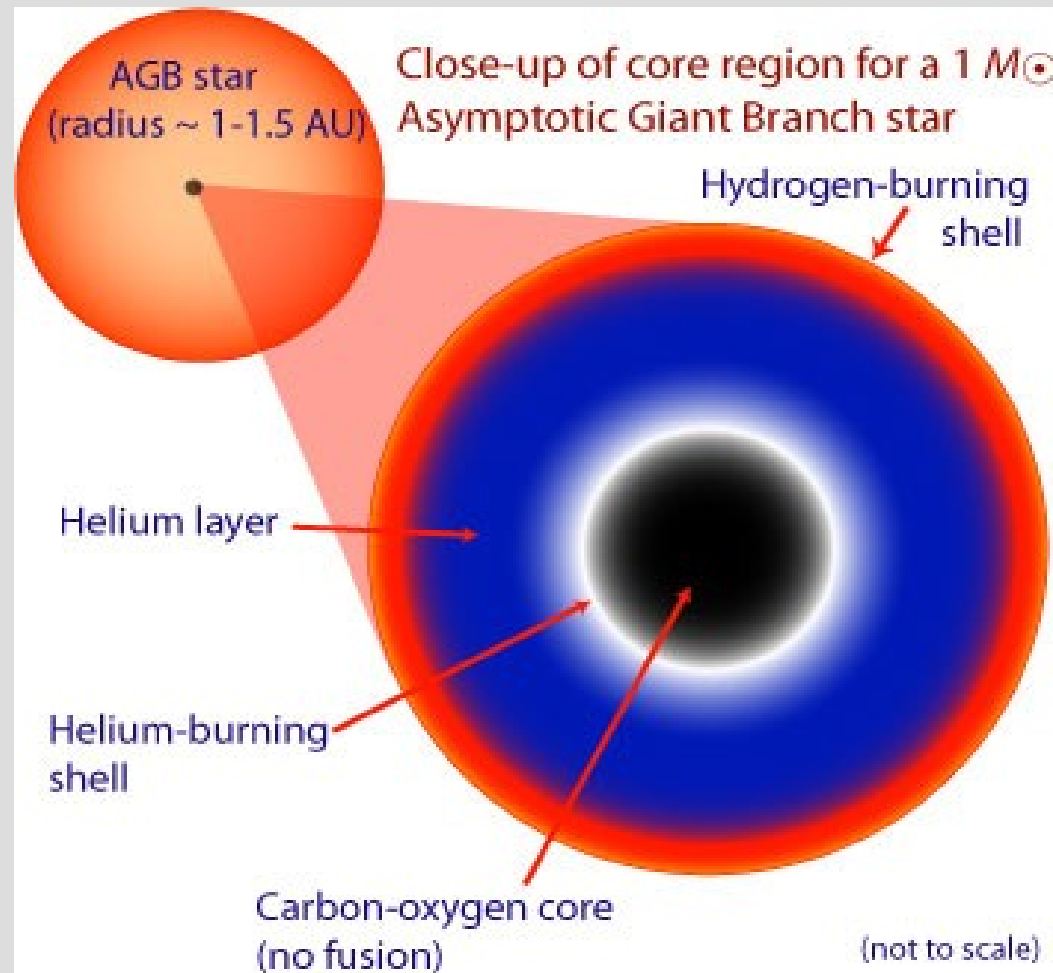


Fonte de energia em estrelas evoluídas.

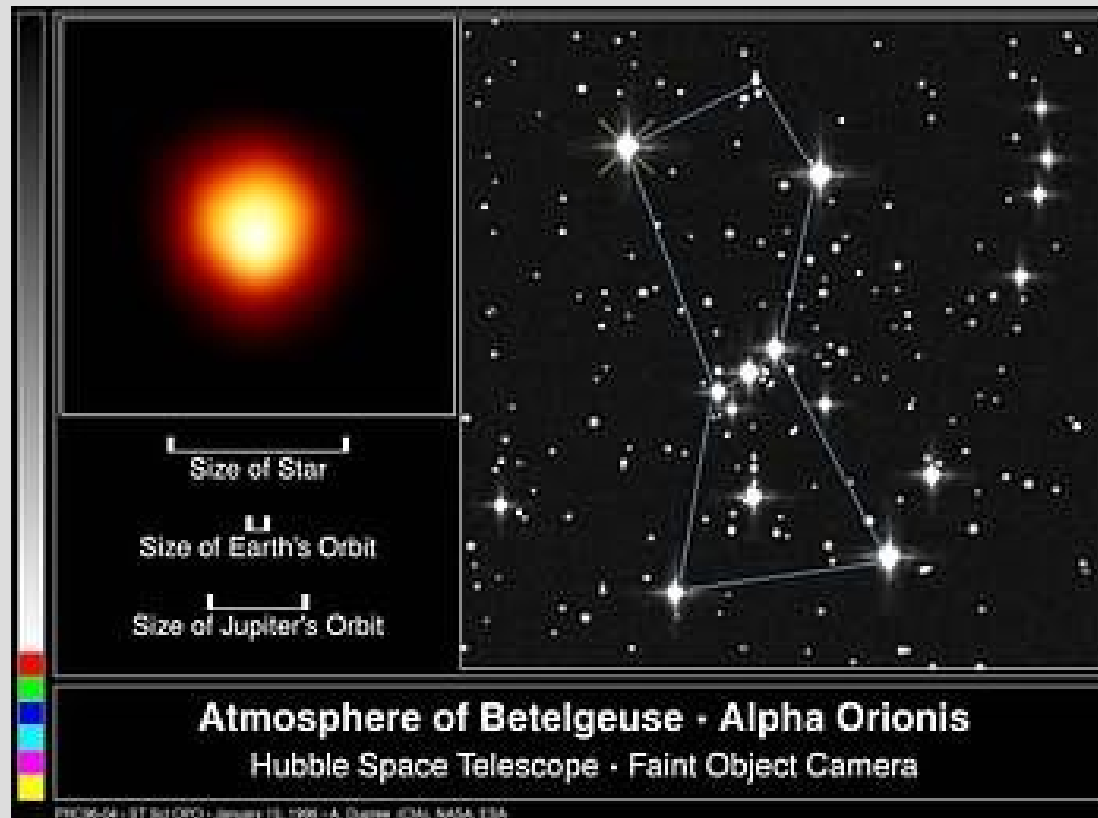
Evolução pós Sequência Principal



AGB – o caminho para as Supergigantes!!

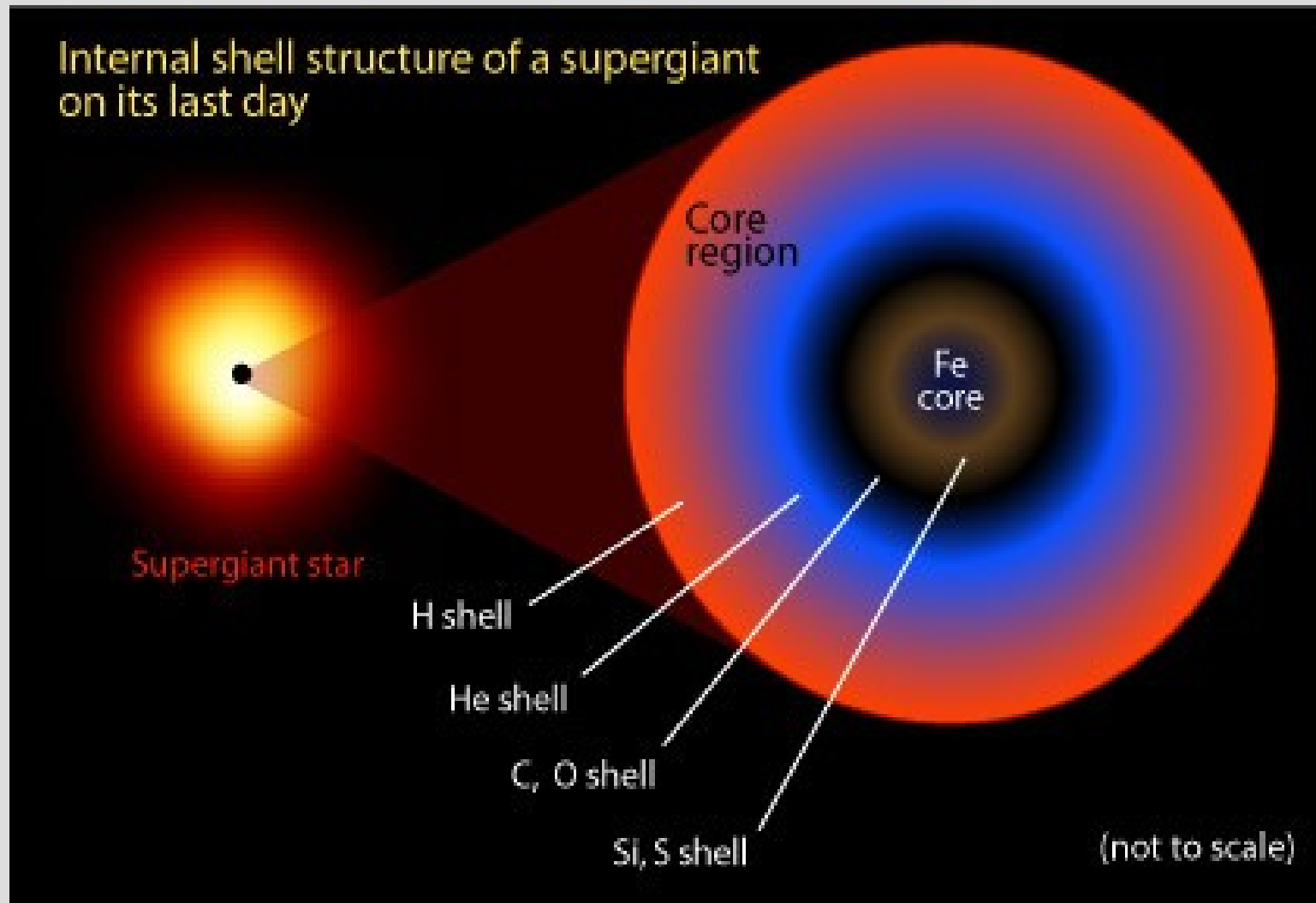


Betelgeuse – uma supergigante vermelha!

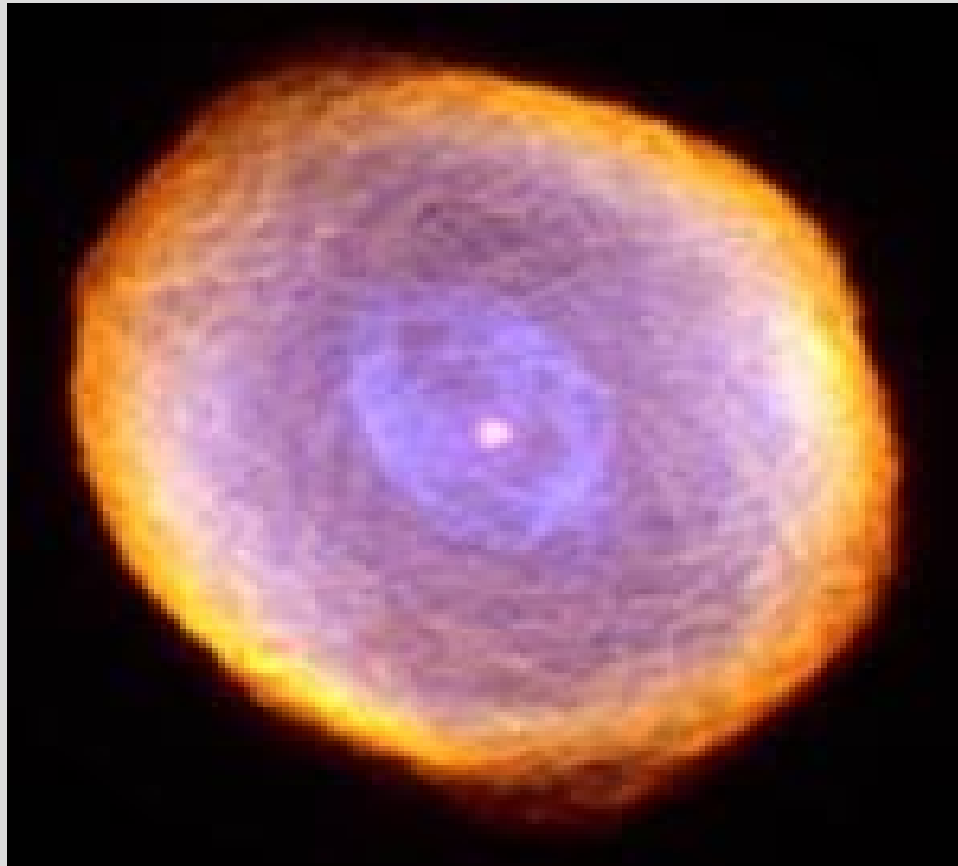


Massa = 13-17Mo.

Estrutura de uma RSG

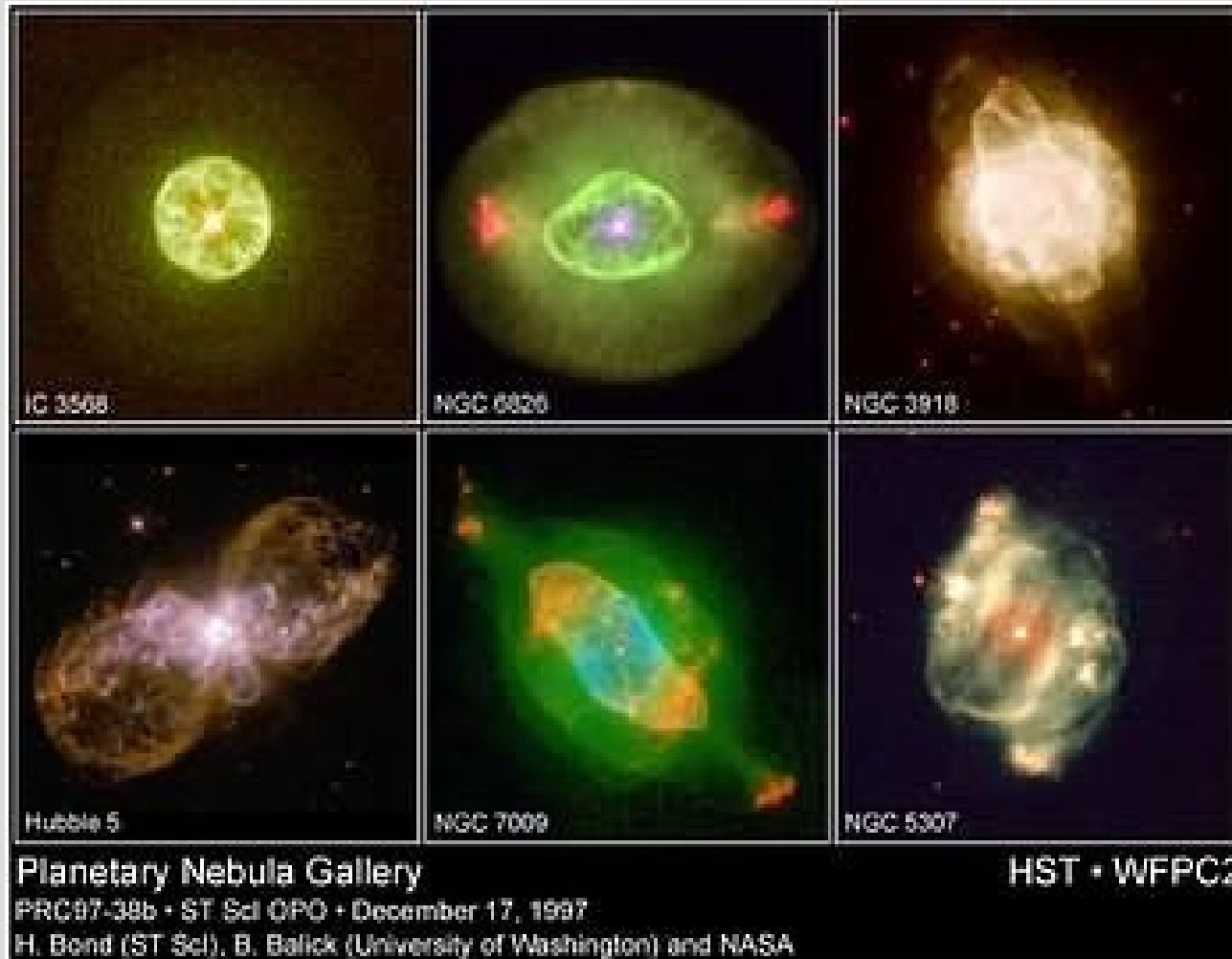


A morte de estrelas: Sol

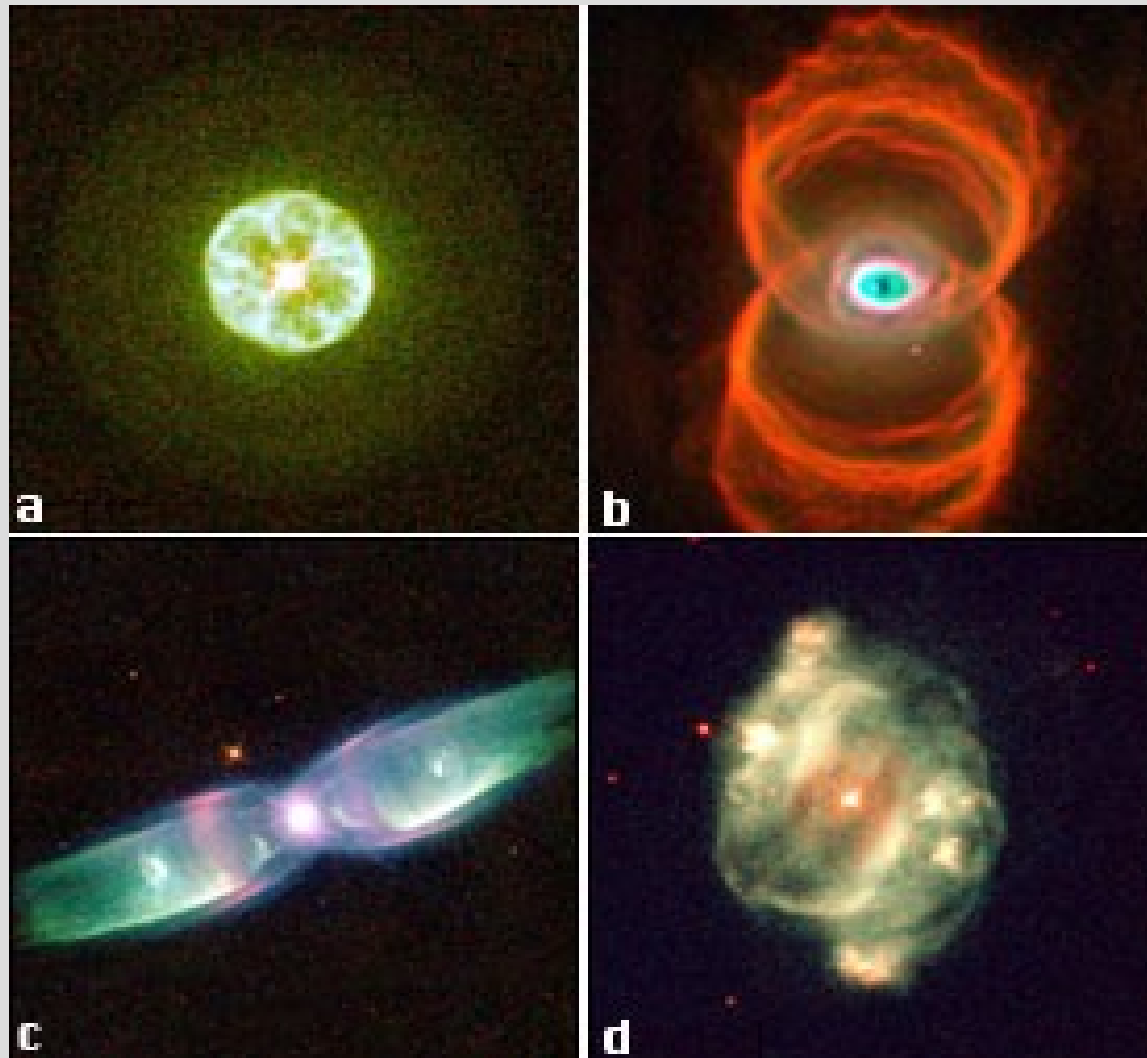


IC418 - uma nebulosa planetária!

Uma pequena galeria de Nebulosas Planetárias



Algumas mais...



...e outras!

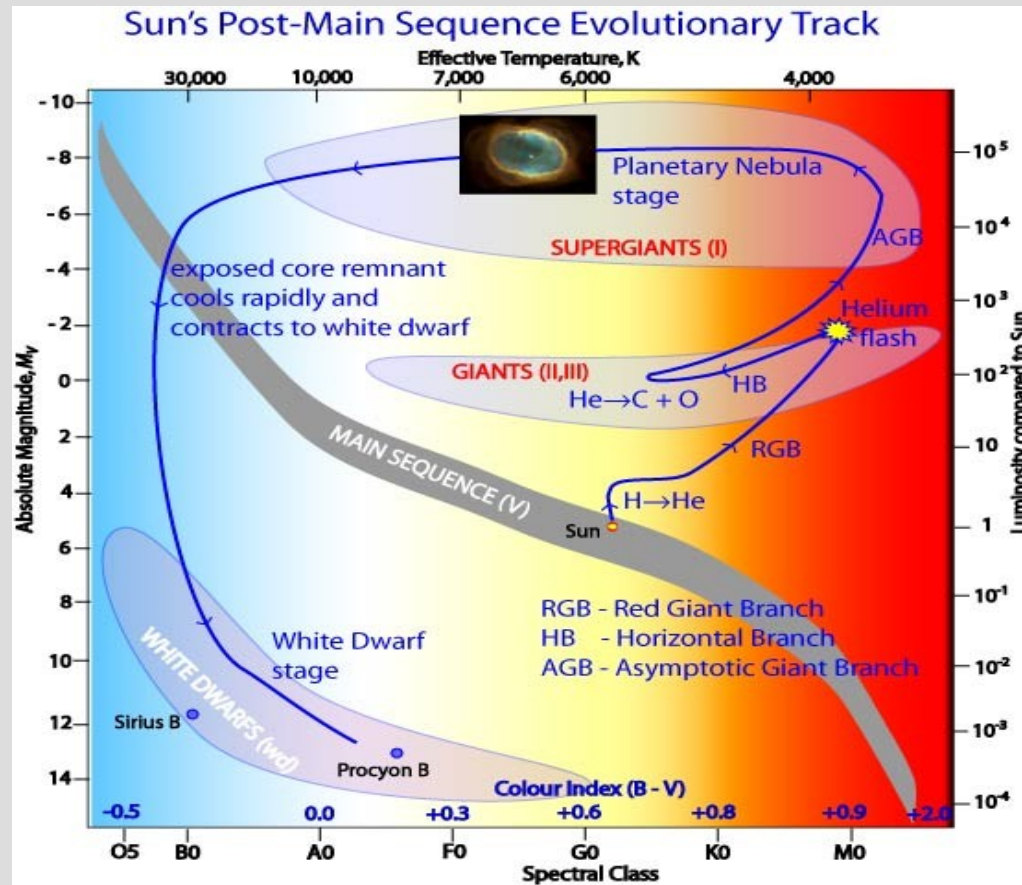


NGC 6543, the Cat's Eye Nebula

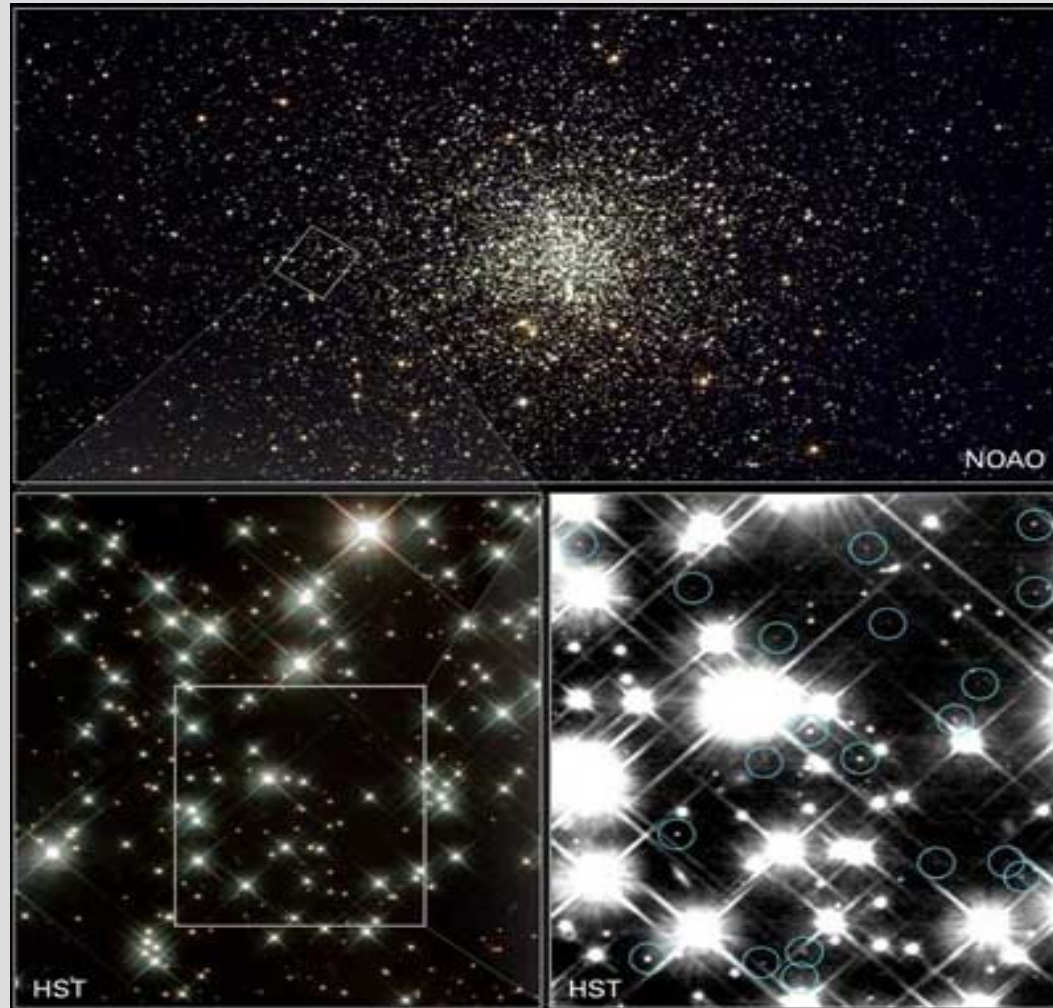


NGC 7293, the Helix Nebula

O caminho das Anãs Brancas

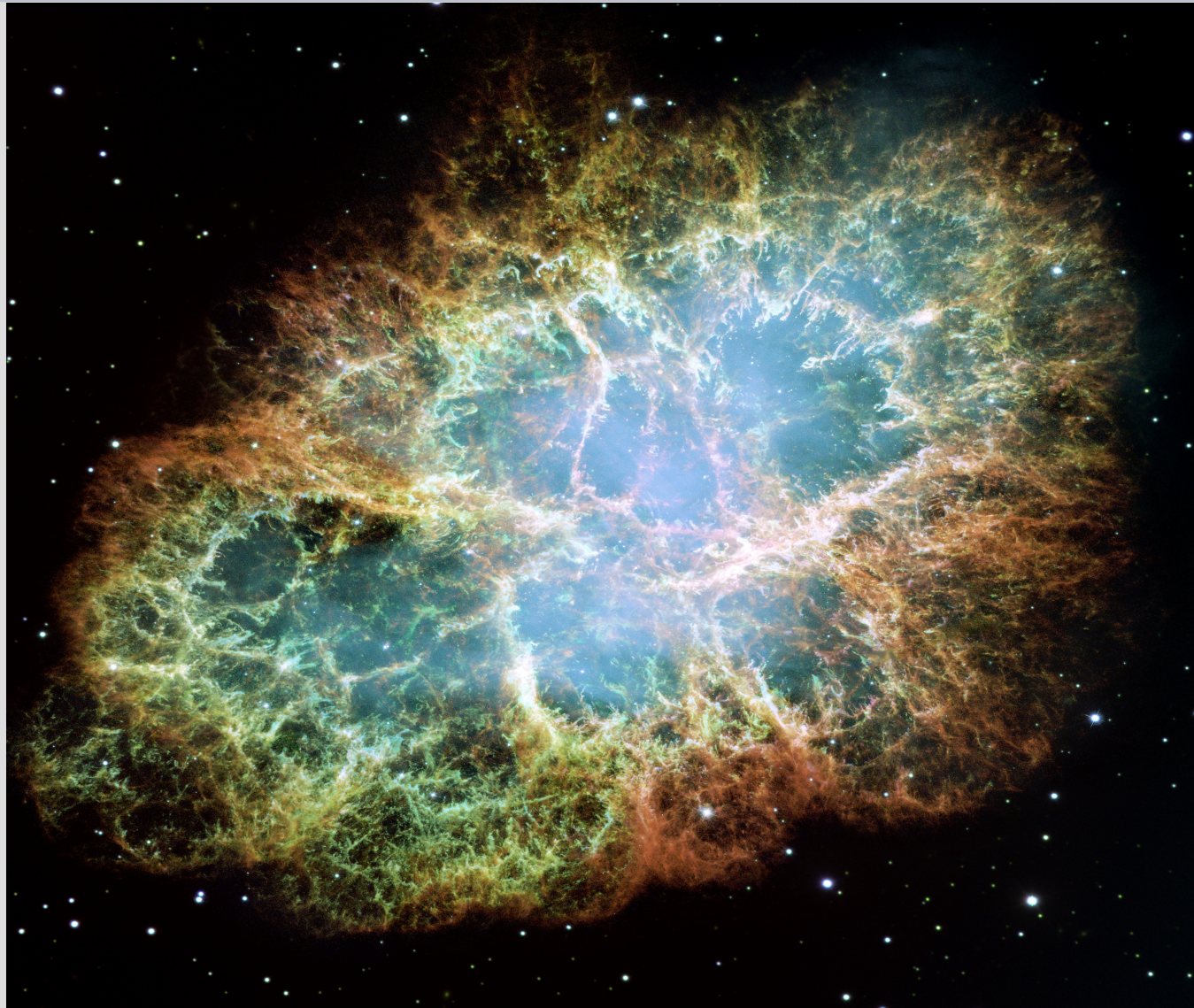


Anãs brancas em M4



A morte de estrelas: alta massa

Nebulosa do Caranguejejo - SNR

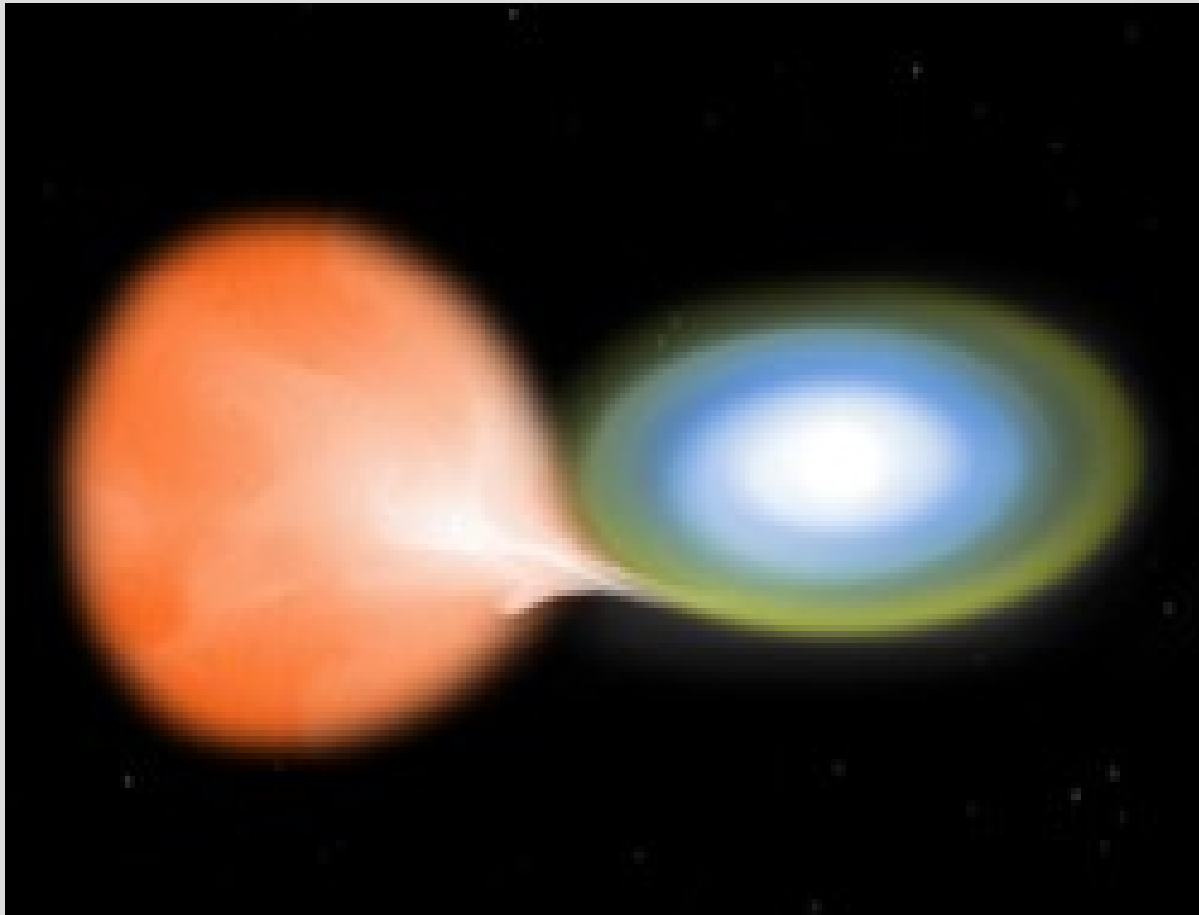


Supernovas: um final brilhante!!

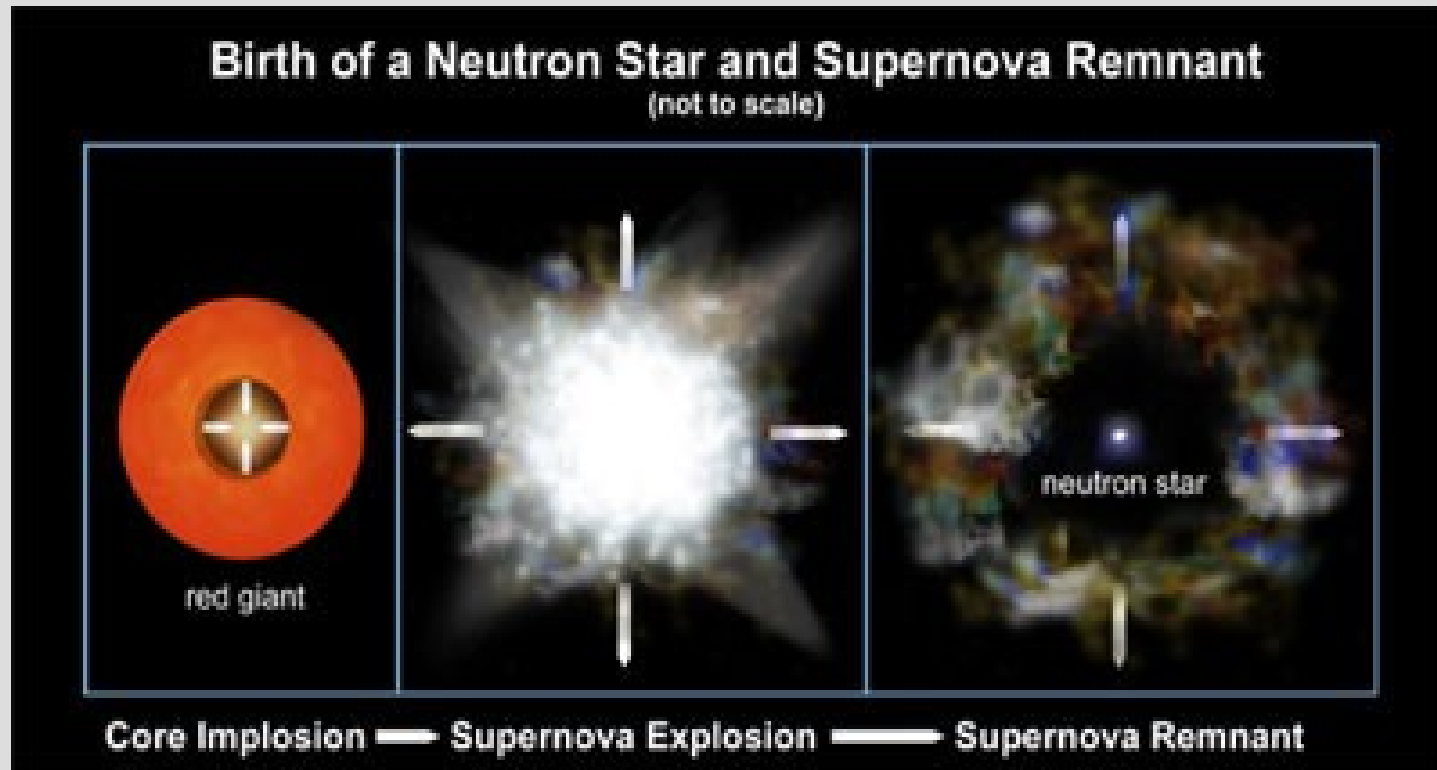
Supernova 1987A - LMC



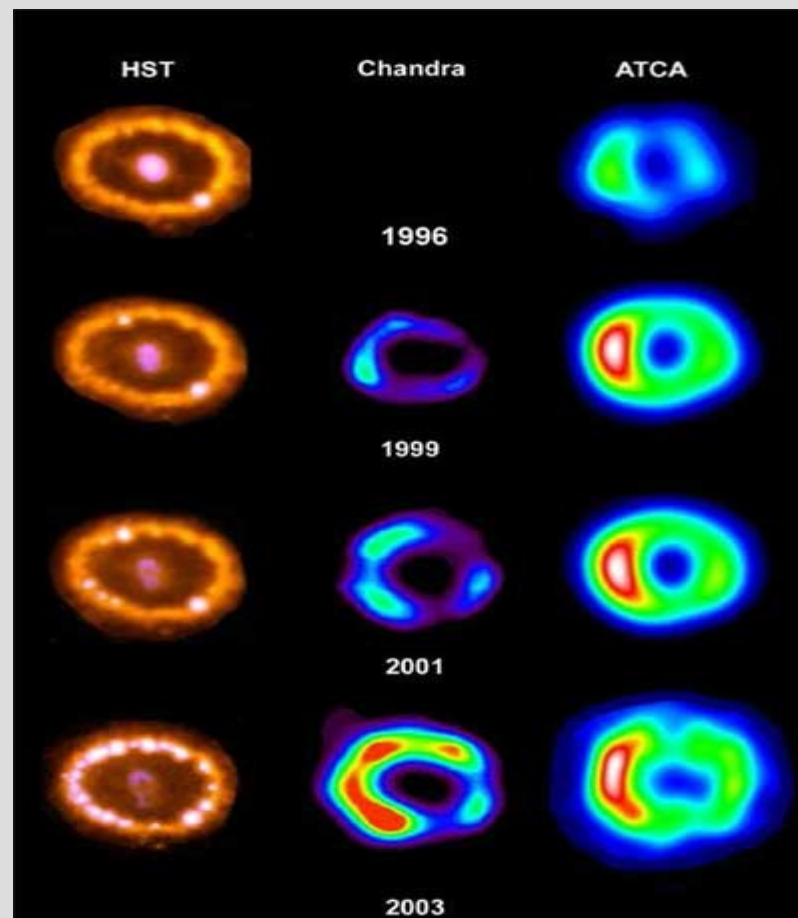
Supernova tipo 1A



Nascimento de estrelas de Nêutron



Expansão da SNR 1987A



Pulsar

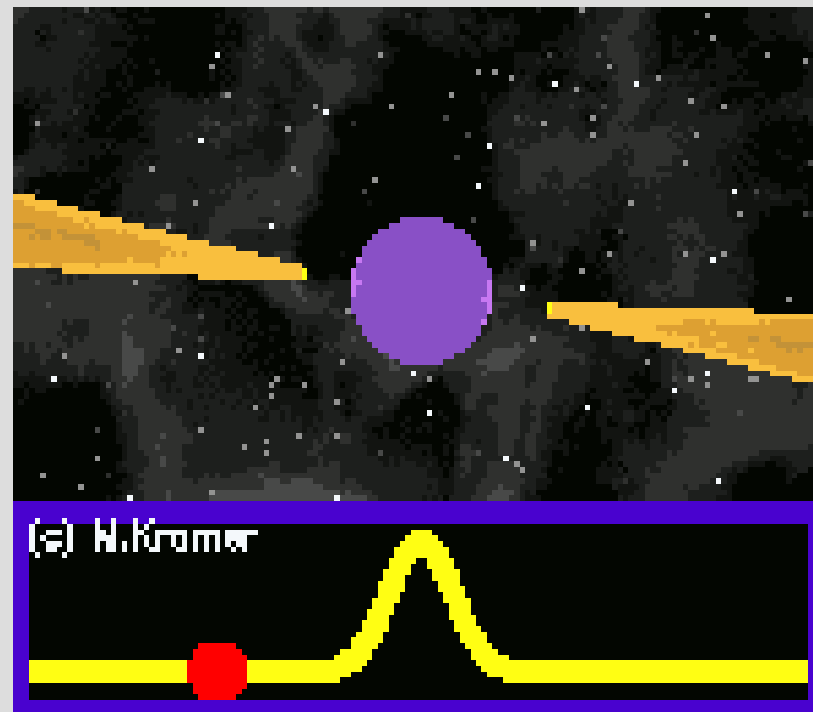
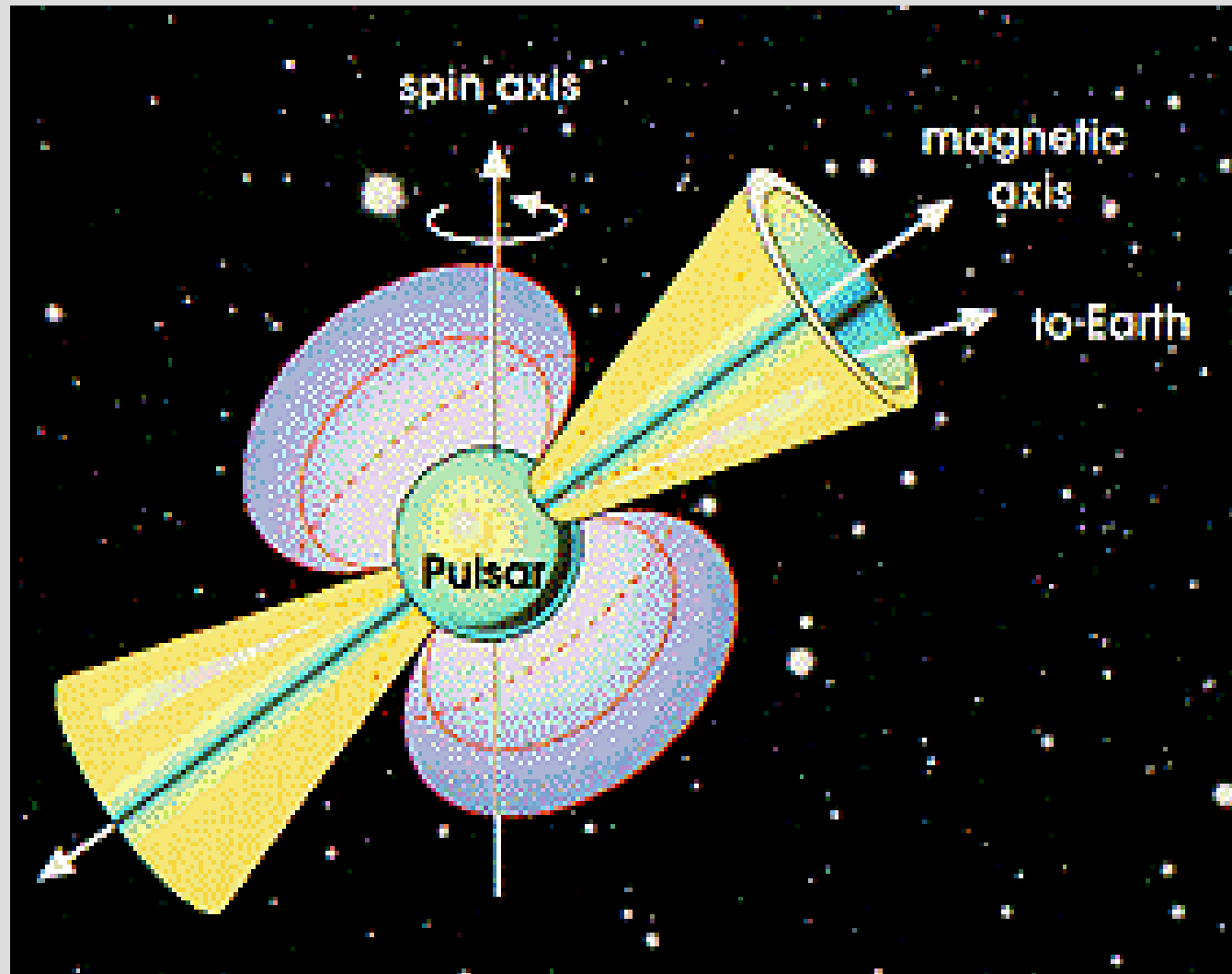


Diagrama esquemático de um Pulsar

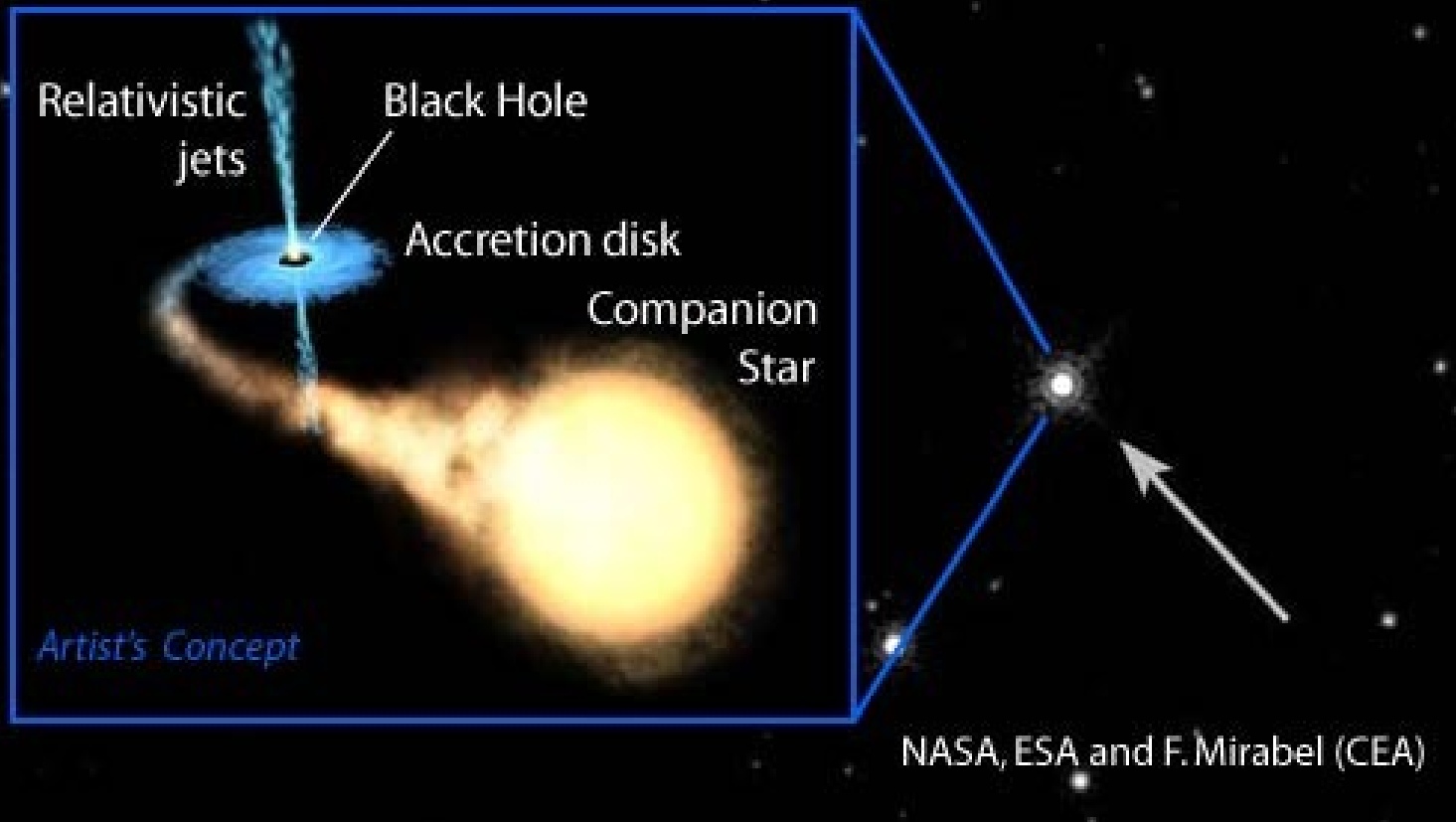


Visão artística de um buraco negro estelar

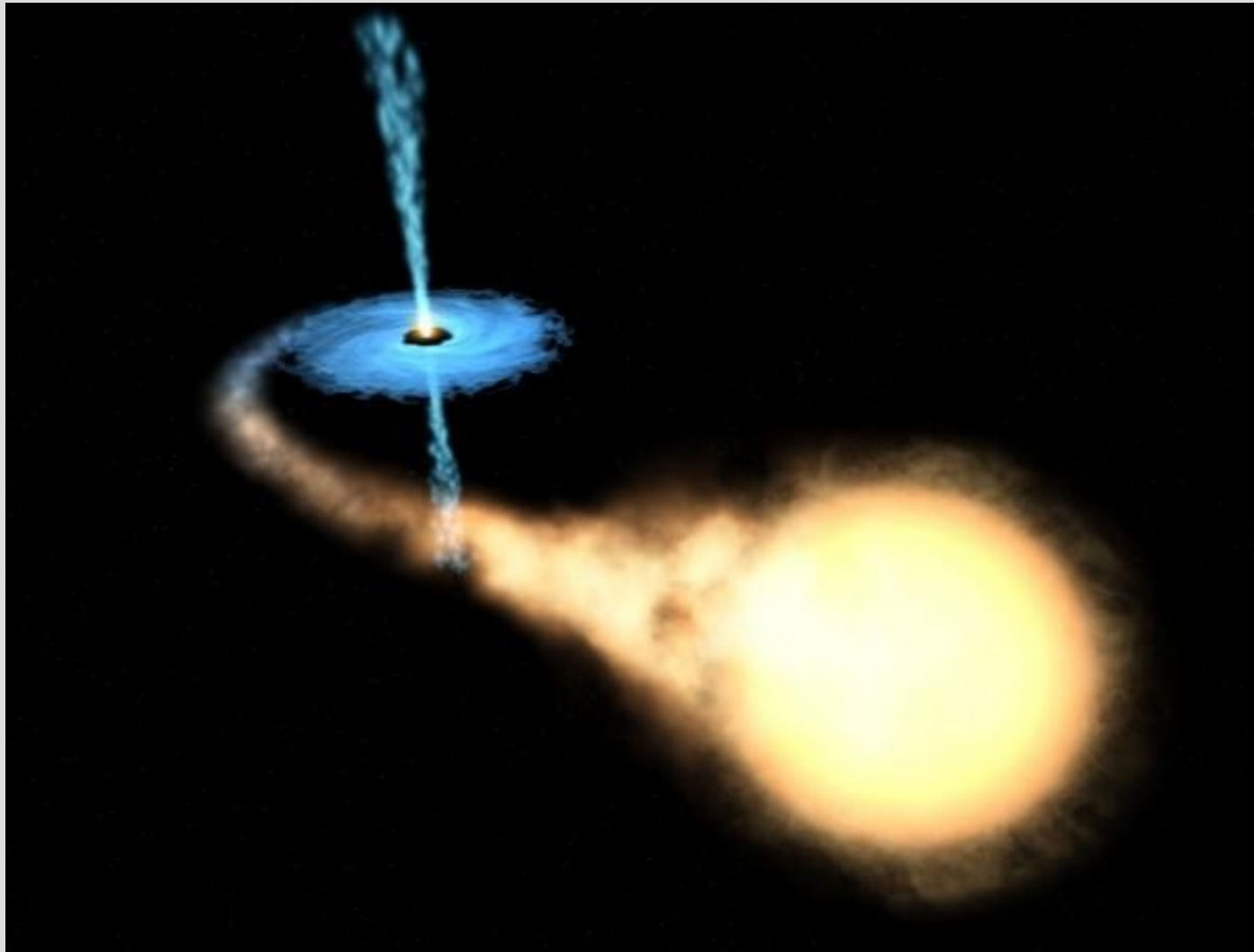


Buracos negros??

Black Hole Companion Star GRO J1655-40 HST -WFPC2



Visão artística de um buraco negro estelar



Visão artística de um buraco negro estelar

