Introdução à Astronomia

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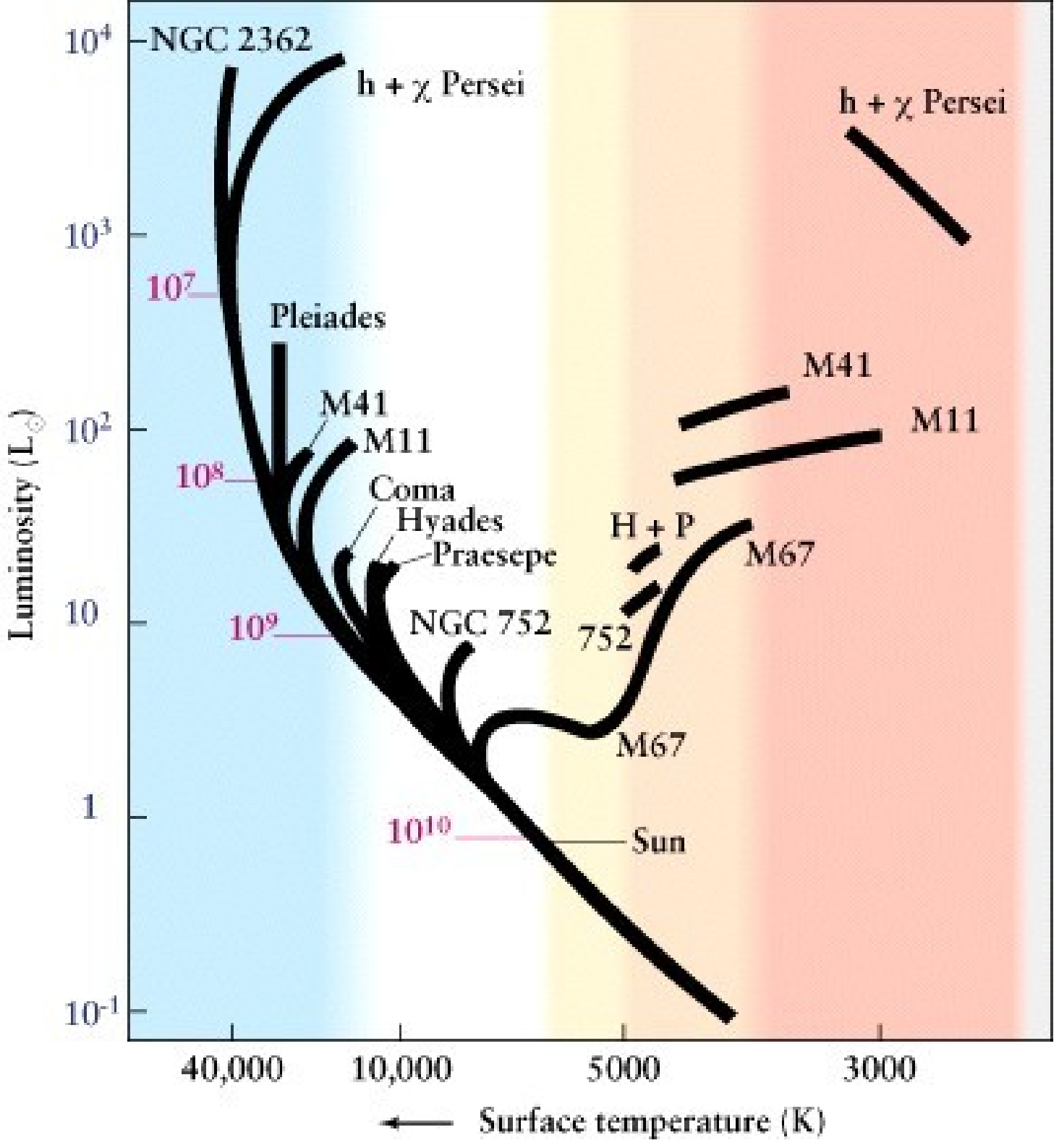
M 67
NGC 188
Absolute magnitude ⟶
⟵ Temperature


NGC 2362
h + χ Persei
h + χ Persei
Pleiades
M41
M11
M41
M11
Coma
Hyades
Praesepe
H + P
M67
NGC 752
752
M67
Sun
10^7
10^8
10^9
10^10
10^4
10^3
10^2
10
1
10^-1
Luminosity (L⊙)
40,000
10,000
5000
3000
Surface temperature (K)

Mostrar diagrama HR de aglomerado recém formado.

Hoje vamos falar da evolução das estrelas.

Em primeiro lugar voltemos às duas fontes de energia apresentadas na aula passada:

Gravitacional

Nuclear

Quanto cada uma guarda?

Gravitacional: $E_t = -1/2 E_g = -GM^2/R$

Nuclear: a cadeia próton-próton / a cadeia CNO

Gravitacional:

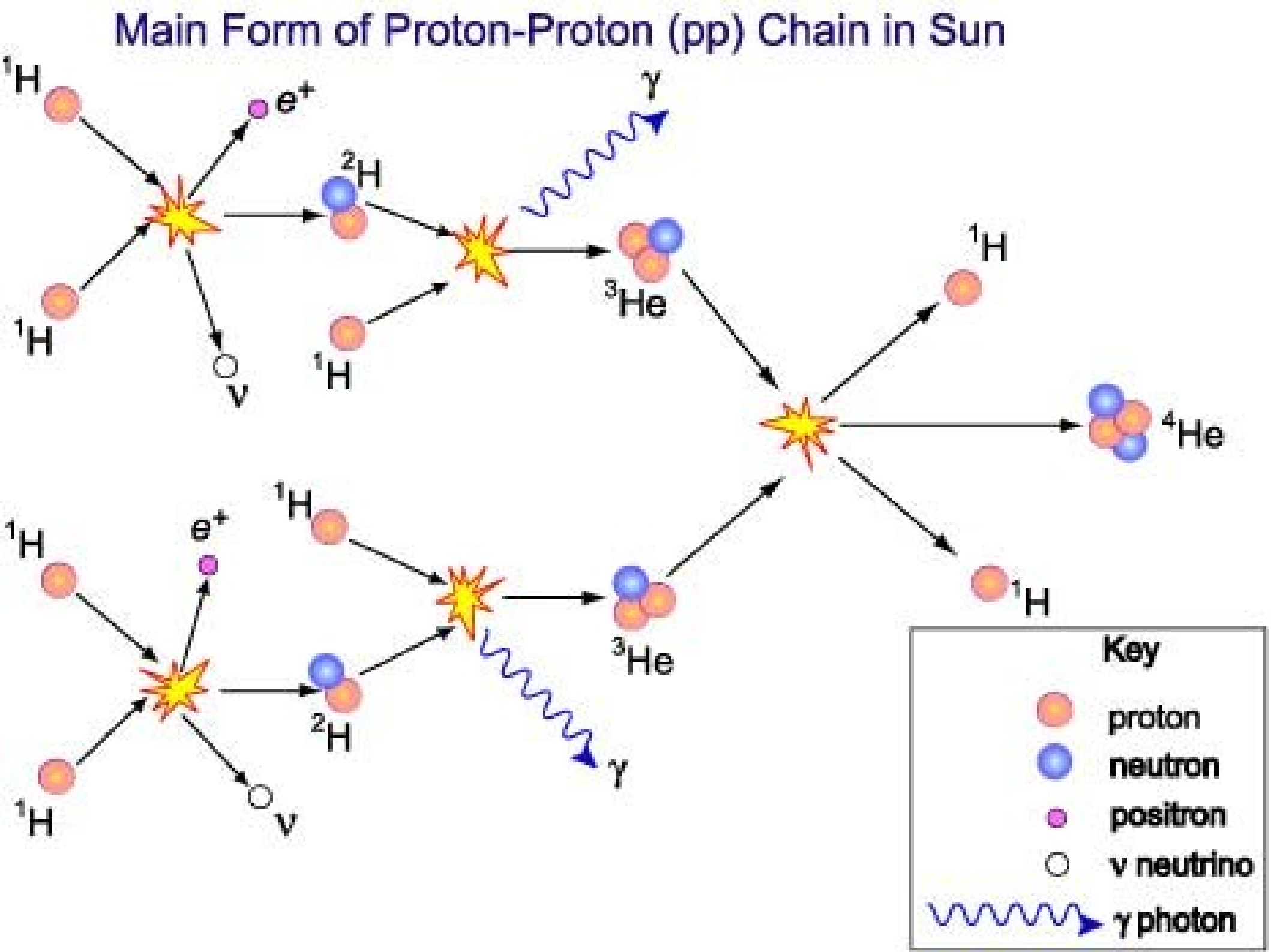
t_vida = Eg/2 / L = 10^7 anos

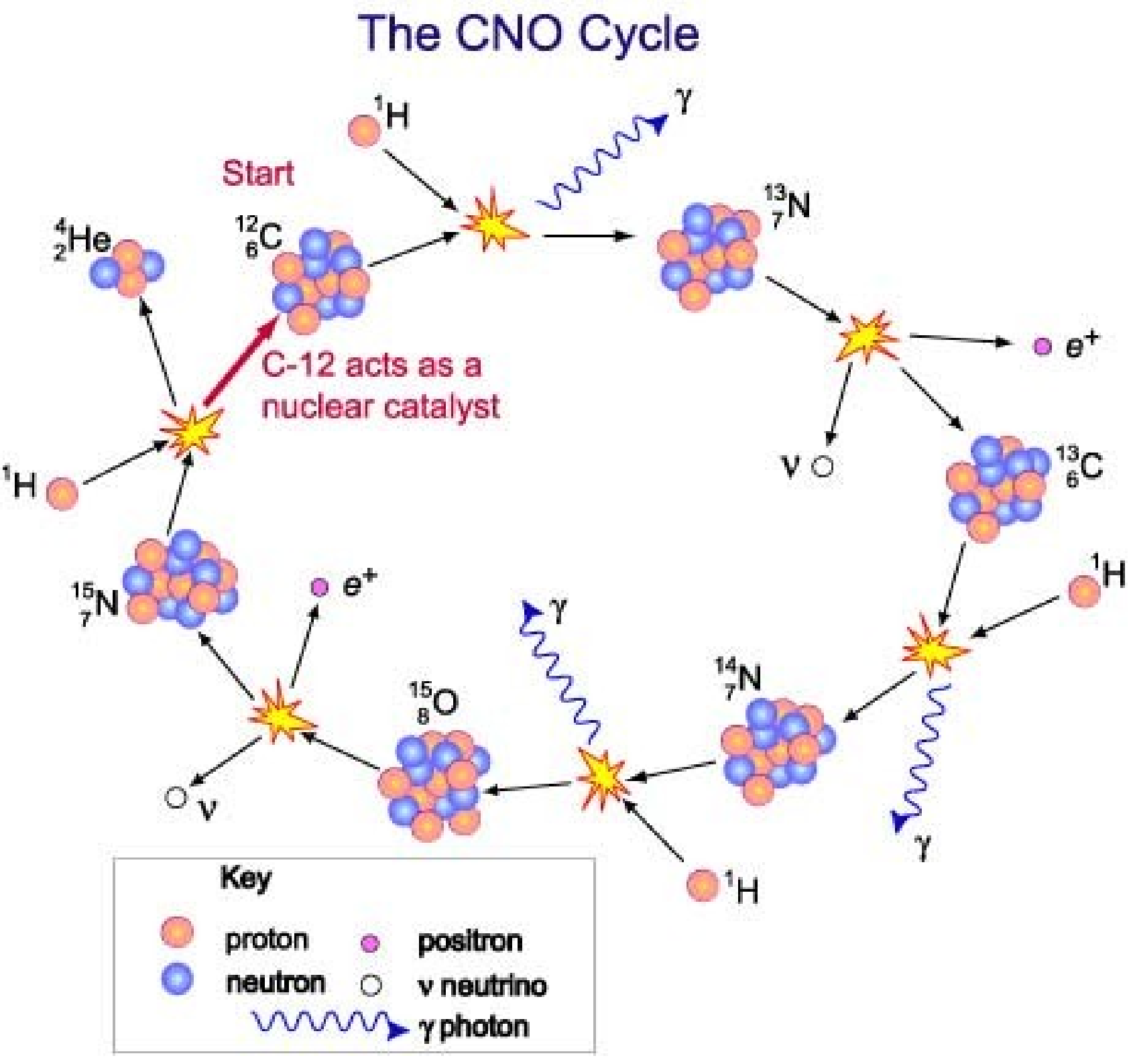
Nuclear:

Qual a diferença de massa entre um átomo de hélio e quatro de hidrogênio? (E=mc^2)

Suponha que isso aconteça no interior do Sol.

Calcule a duração do Sol.


Main Form of Proton-Proton (pp) Chain in Sun
^{1}H
^{1}H
e$^+$
ν
^{2}H
^{1}H
γ
^{3}He
^{1}H
^{4}He
^{1}H
^{1}H
e$^+$
^{1}H
^{2}H
ν
^{3}He
γ
^{1}H
Key
proton
neutron
positron
ν neutrino
γ photon


The CNO Cycle
Start
$^{1}_{1}H$
γ
$^{4}_{2}He$
$^{12}_{6}C$
$^{13}_{7}N$
C-12 acts as a
nuclear catalyst
e^{+}
ν
$^{13}_{6}C$
$^{1}_{1}H$
$^{1}_{1}H$
$^{15}_{7}N$
e^{+}
γ
$^{14}_{7}N$
$^{1}_{1}H$
$^{15}_{8}O$
ν
γ
$^{1}_{1}H$
Key
proton
positron
neutron
ν neutrino
γ photon

vejam:
http://outreach.atnf.csiro.au/education/senior/astrophysics/stellarevolution_mainsequence.html

ppI: 4H-1 → He-4 + 2e+ + 2ν + 2γ
ppII: 4H-1 + e- → He-4 + e+ + 2ν + 2γ
ppIII: 4H-1 → He-4 + 2e+ + 2ν + 3γ

CNO: 4H-1 → He-4 + 2e+ + 2ν + 3γ

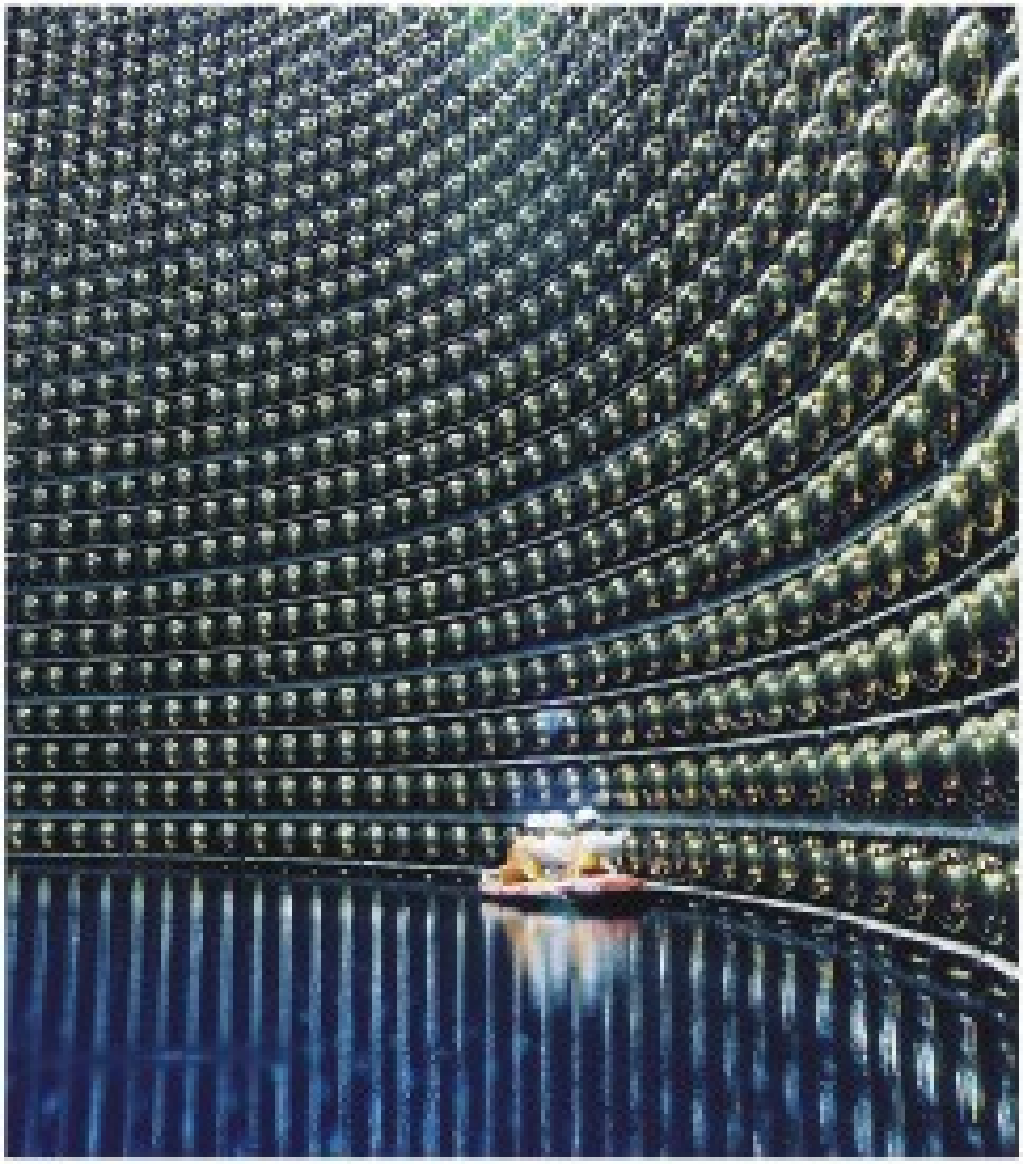
E = Δm c^2 so substituting in values gives
E = 0.0286(1.66 × 10-27)(3 × 108)2
∴E = 4.3 × 10-12 J

Etotal = (mass defect per He nucleus produced) × c2 × (mass of H in core)
∴Etotal = 0.0071(9 × 10^16)(0.1 × 2.0 × 1030)
= 1.28 × 10^44 J

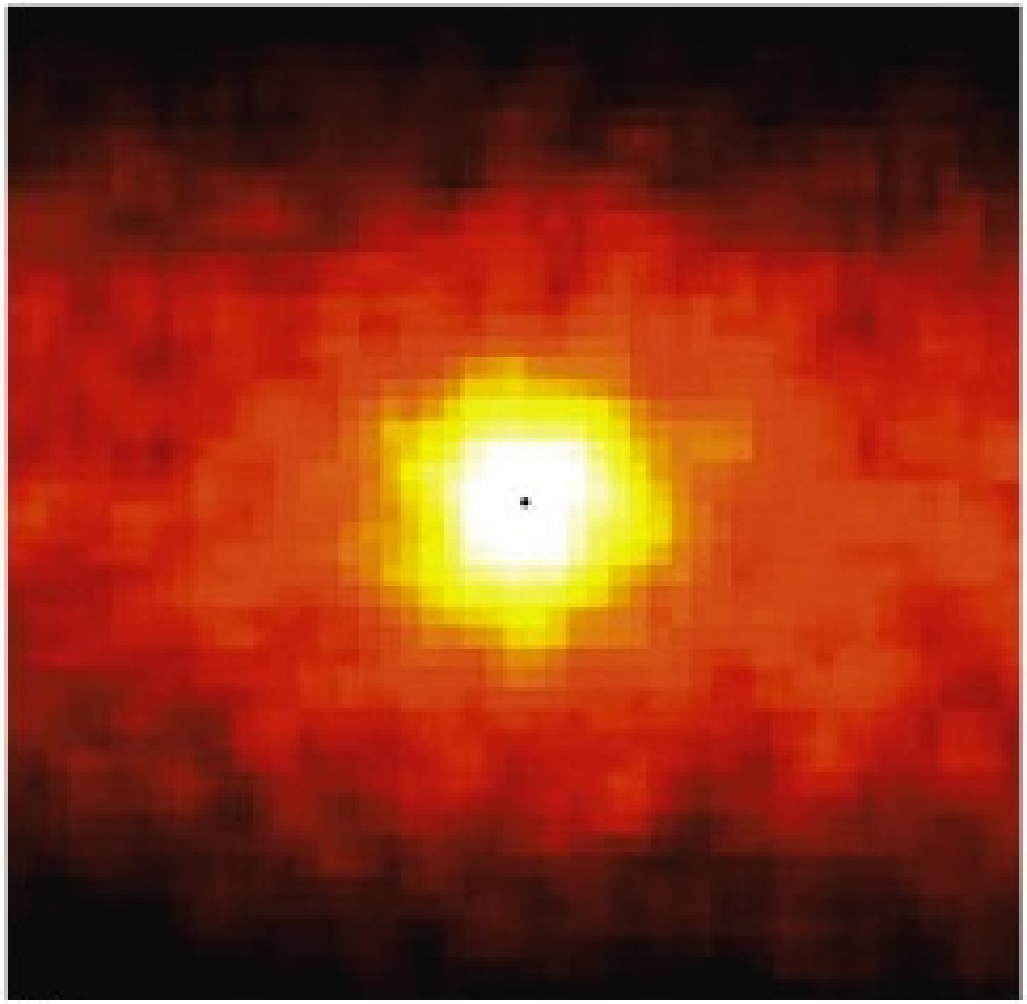
t_vida = E / L = ???

L = 3.90 × 10^26 J. s-1

Vejam também:



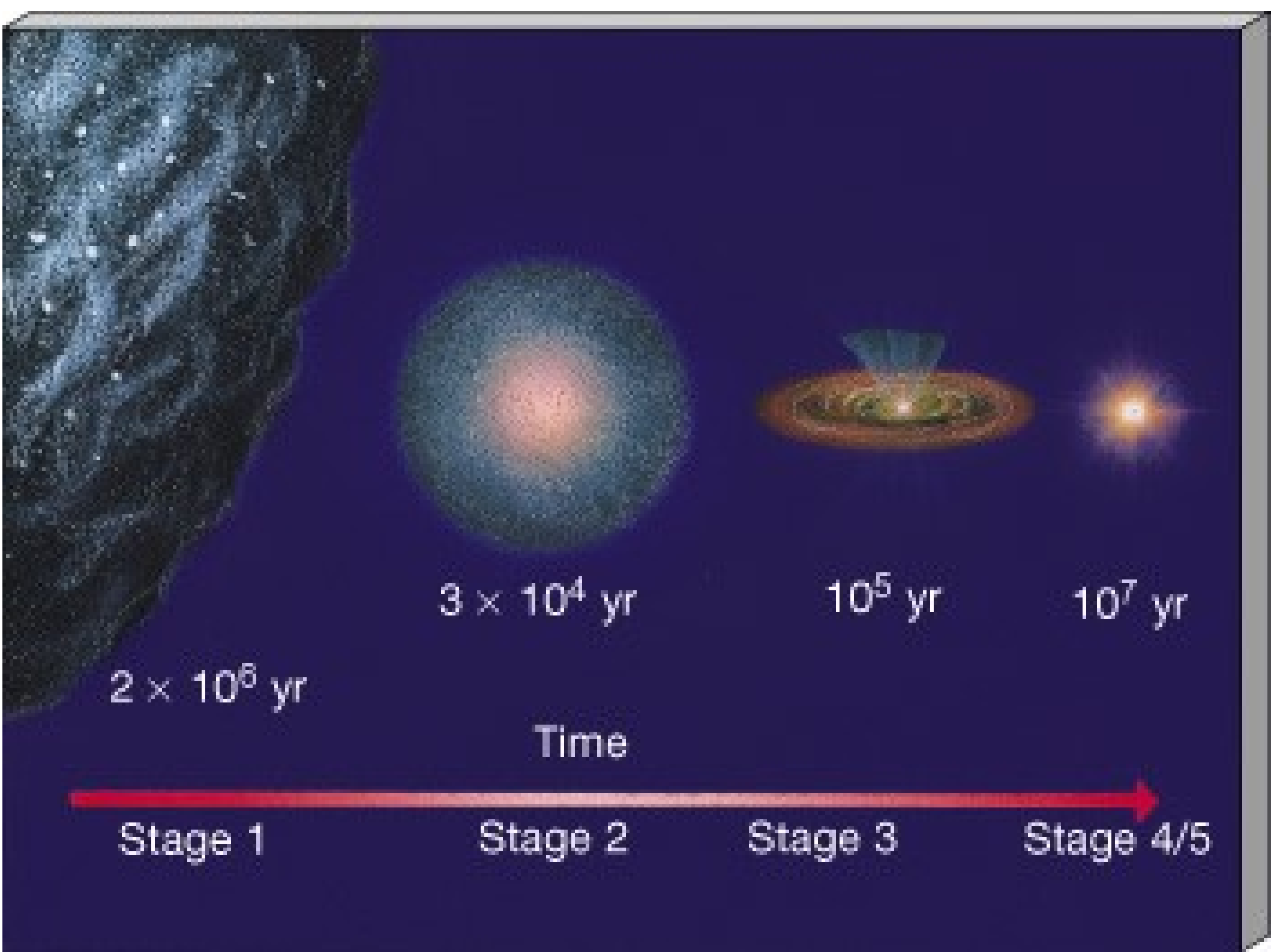
(a)

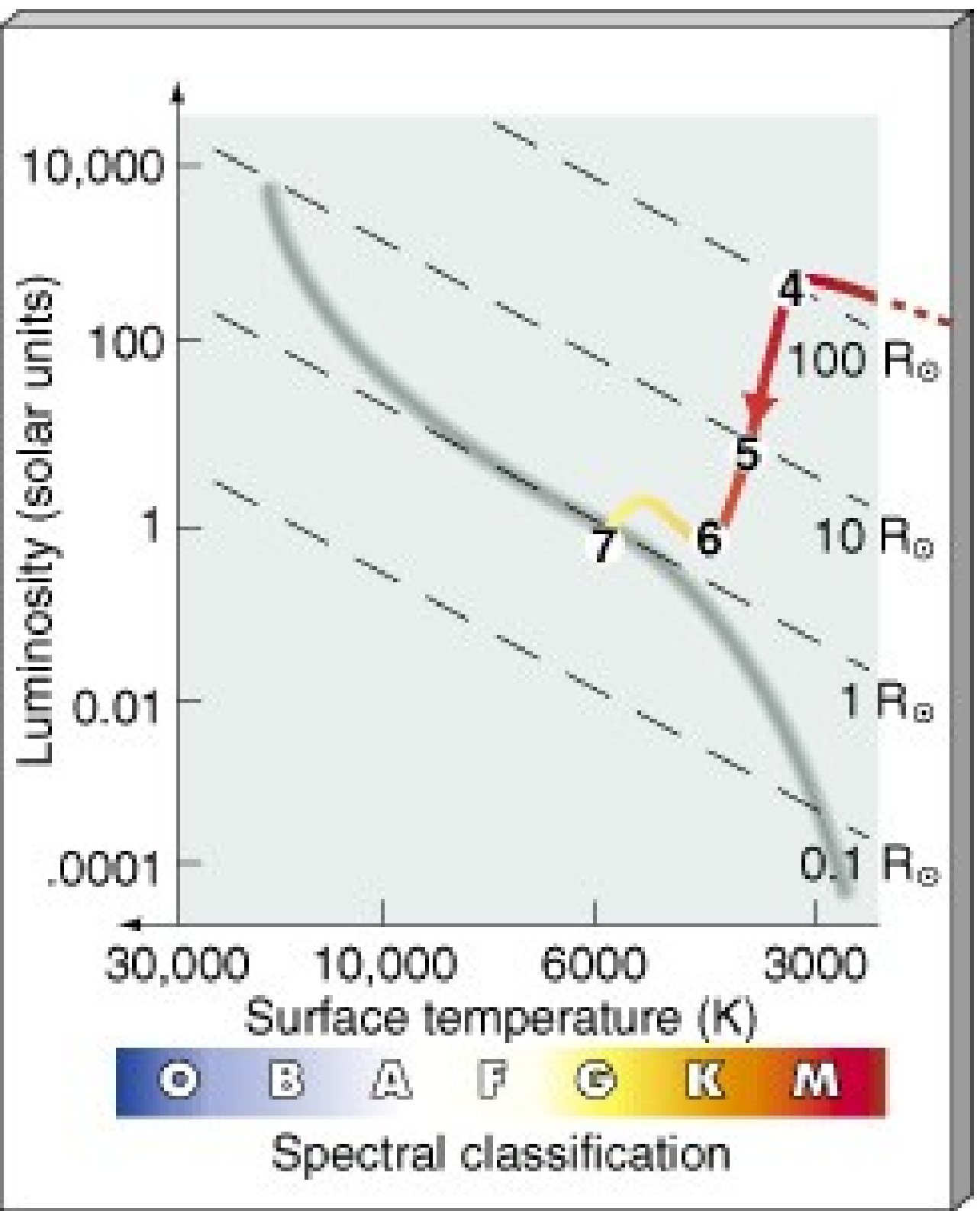


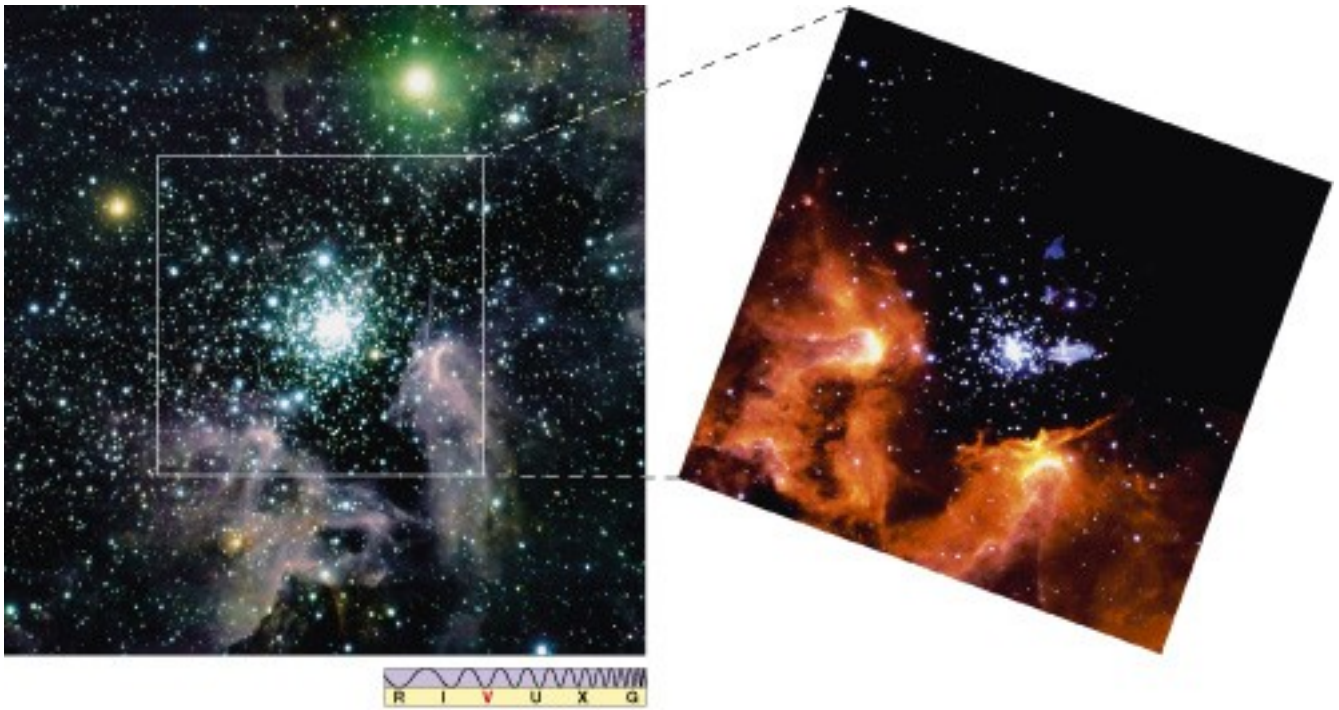
(b)

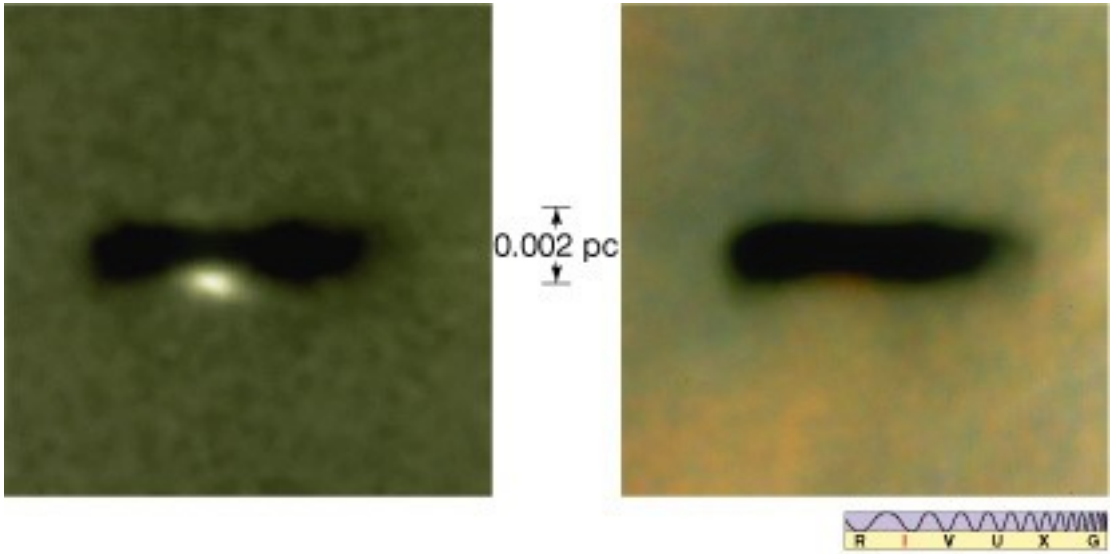
Início:

achar diagrama HR de região jovem


2×10^6 yr
3×10^4 yr
10^5 yr
10^7 yr
Time
Stage 1
Stage 2
Stage 3
Stage 4/5

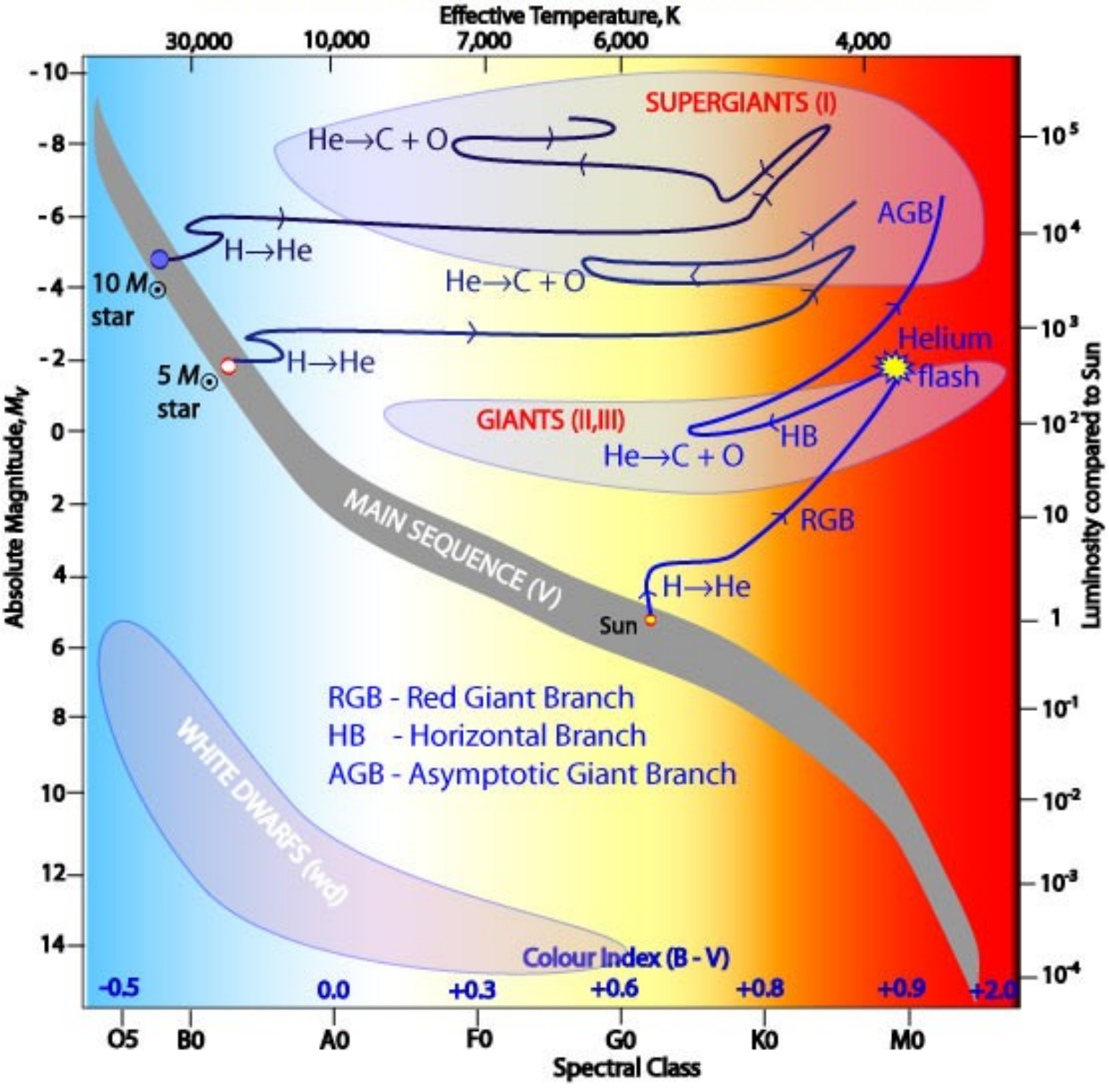

10,000
100
1
0.01
.0001
Luminosity (solar units)
4
5
6
7
100 R⊙
10 R⊙
1 R⊙
0.1 R⊙
30,000
10,000
6000
3000
Surface temperature (K)
O
B
A
F
G
K
M
Spectral classification


R I V U X G


0.002 pc
R I V U X G

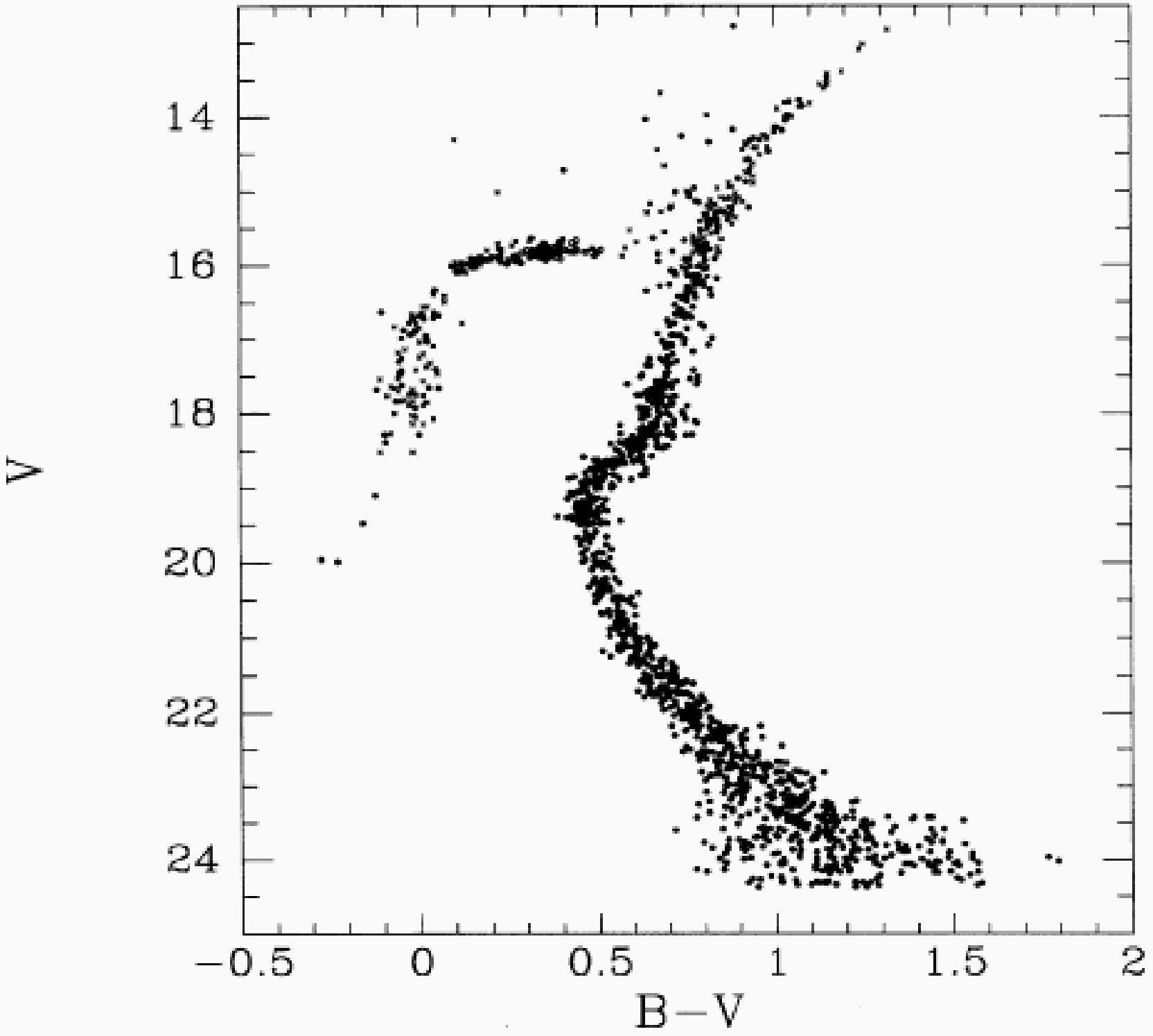
Meio:

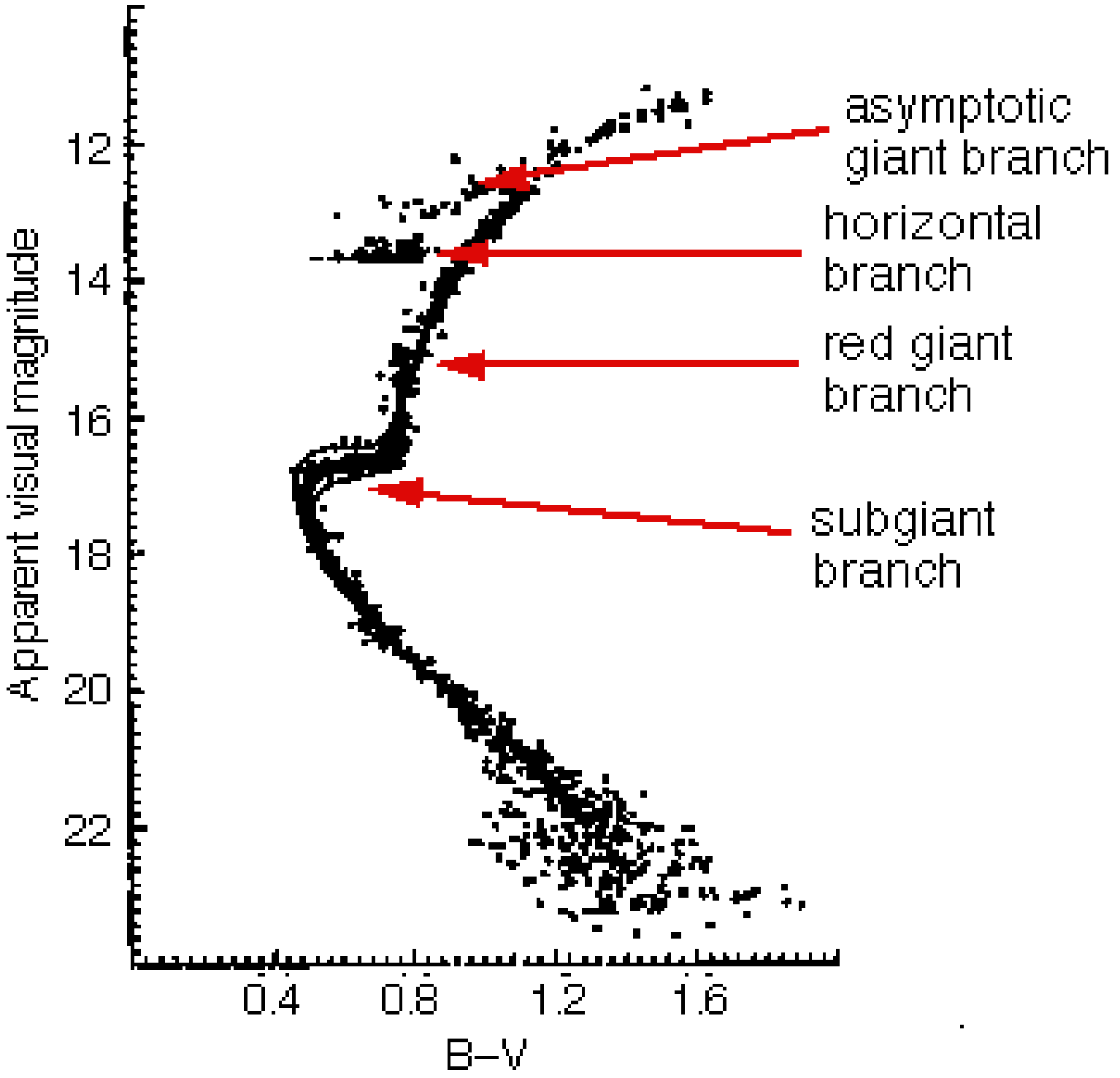
Evolutionary Tracks off the Main Sequence

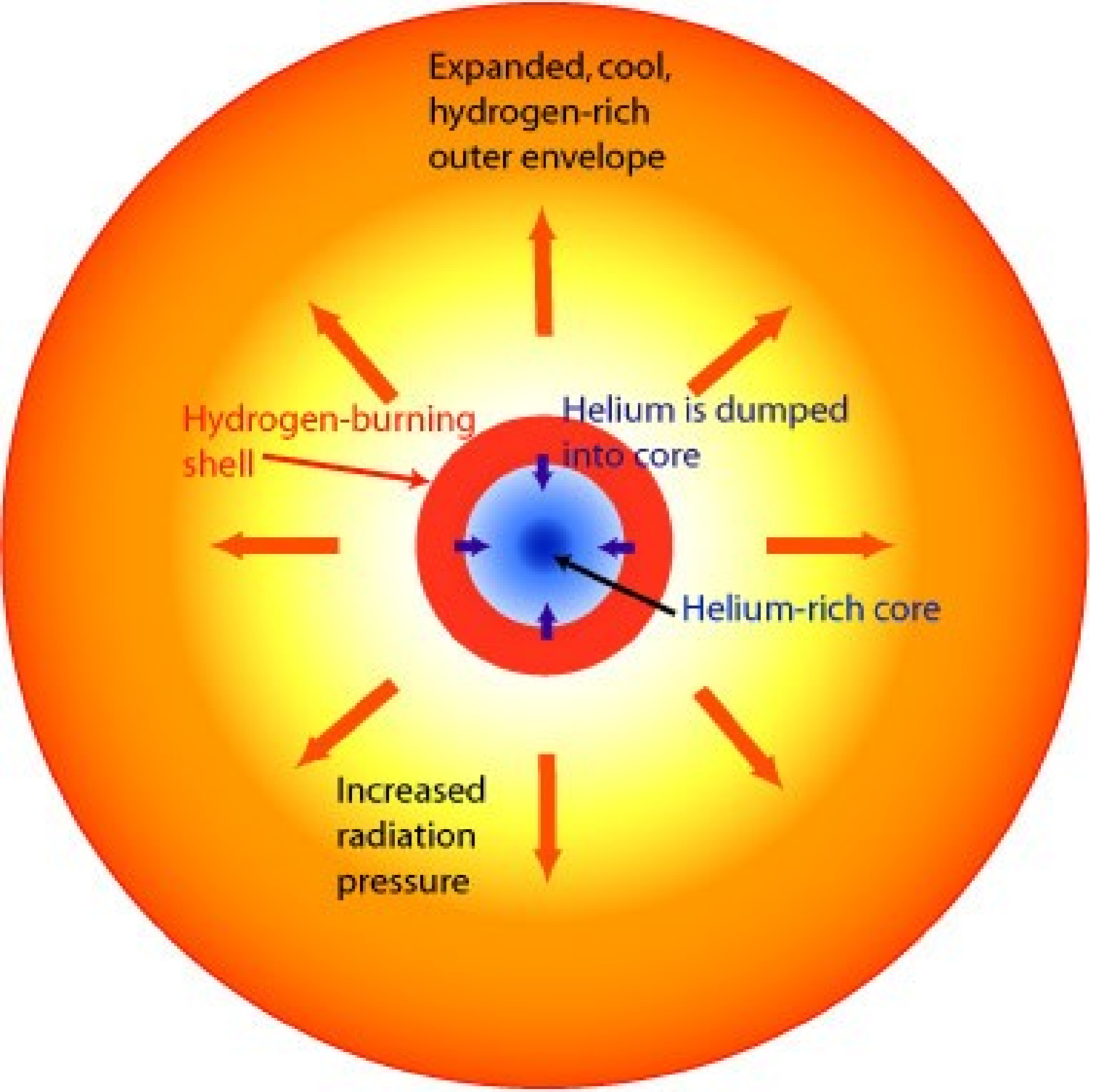


Quem quiser entrar em um pouco mais de detalhes:

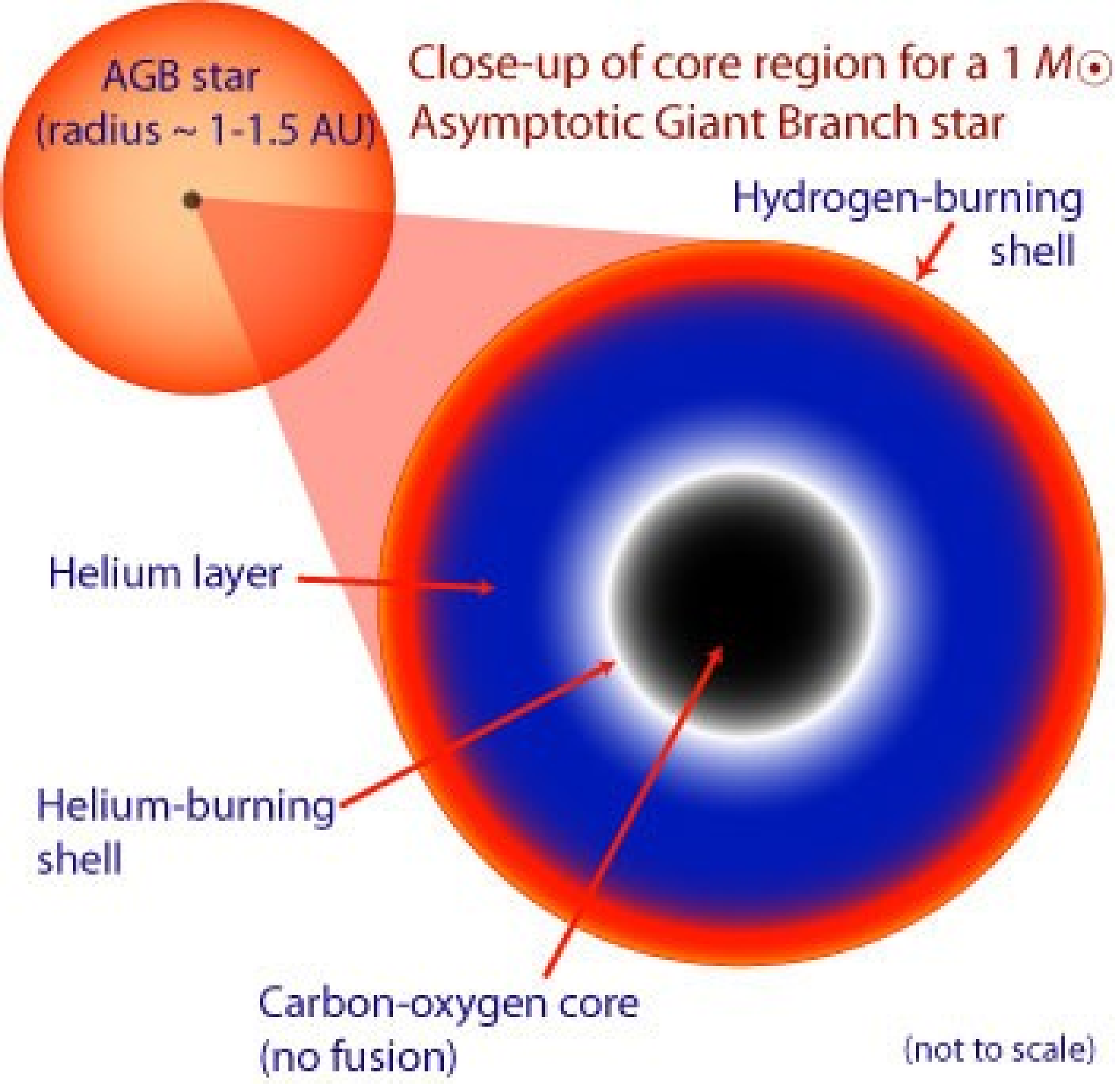
Shu, Frank; The Physical Universe, an introduction to Astronomy

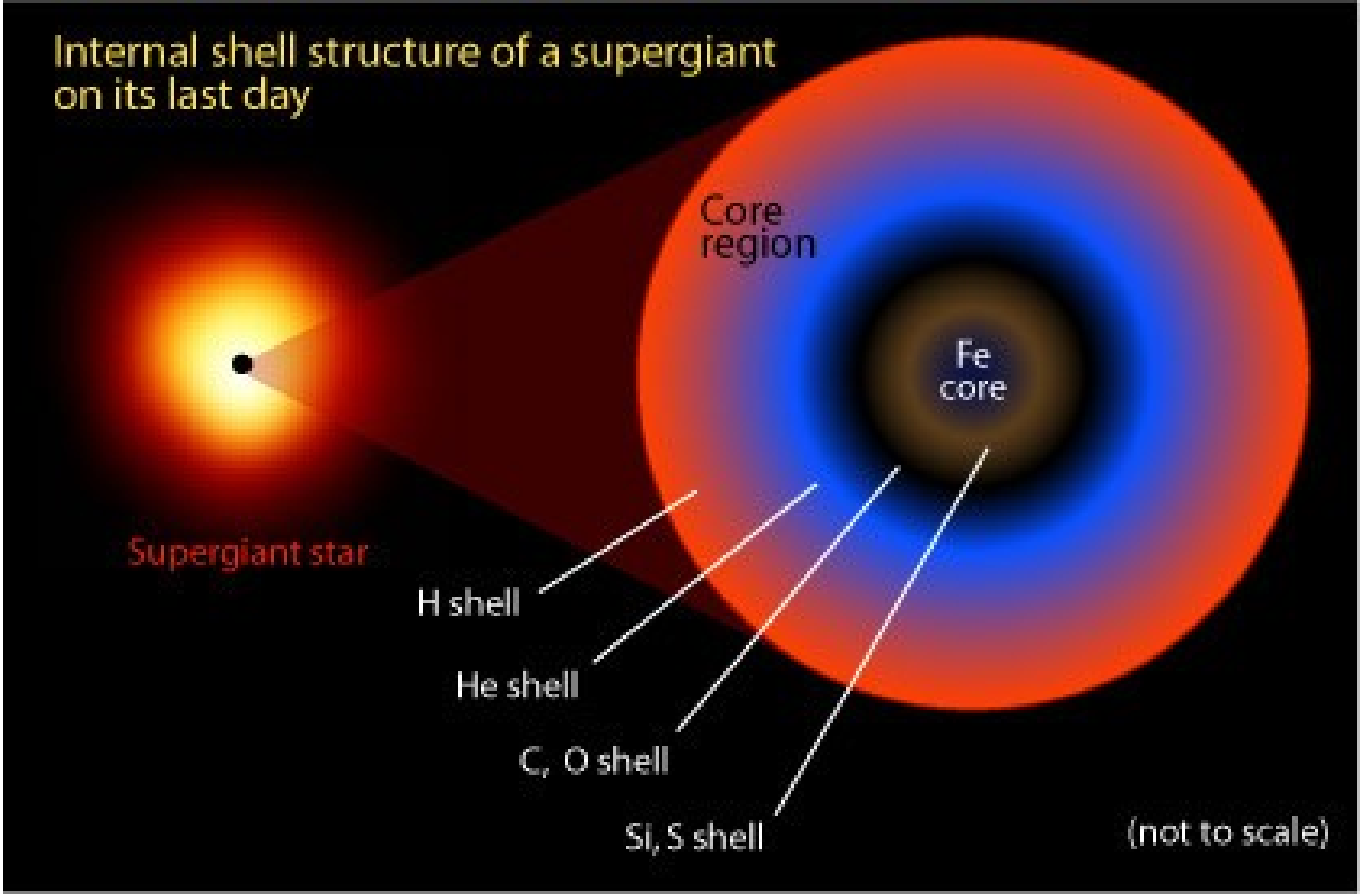

14
16
18
20
22
24
V
−0.5
0
0.5
1
1.5
2
B−V


asymptotic
giant branch
horizontal
branch
red giant
branch
subgiant
branch
Apparent visual magnitude
12
14
16
18
20
22
0.4
0.8
1.2
1.6
B–V



Hydrogen Shell Burning on the Red Giant Branch


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


Internal shell structure of a supergiant on its last day
Core region
Fe core
Supergiant star
H shell
He shell
C, O shell
Si, S shell
(not to scale)

Fim: