Razvoj zvezd

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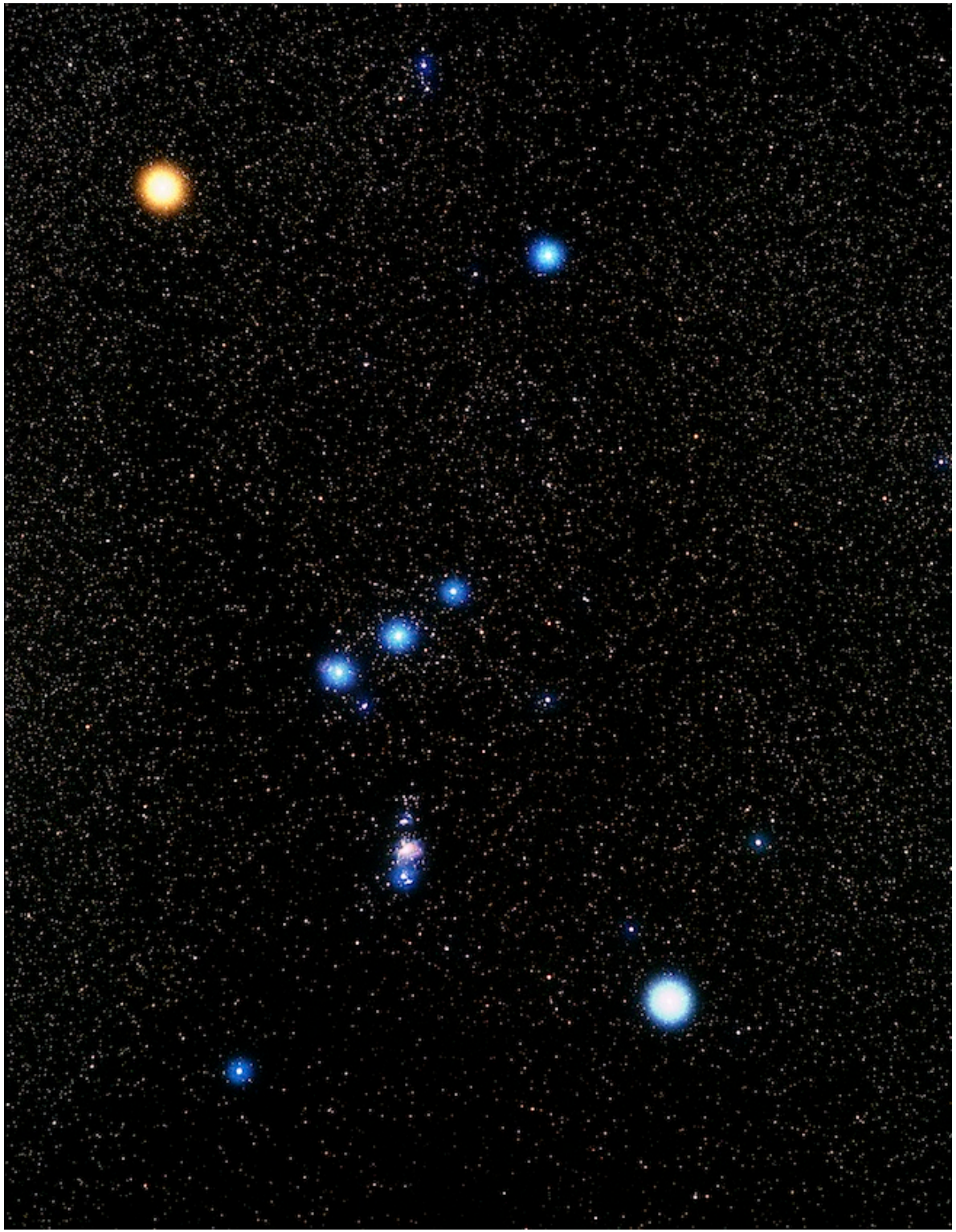
CO Vesolje-si

1. 12. 2011, FMF



Kaj so zvezde?

1. zvezde veže lastna gravitacija:

   sferične ali sferoidne

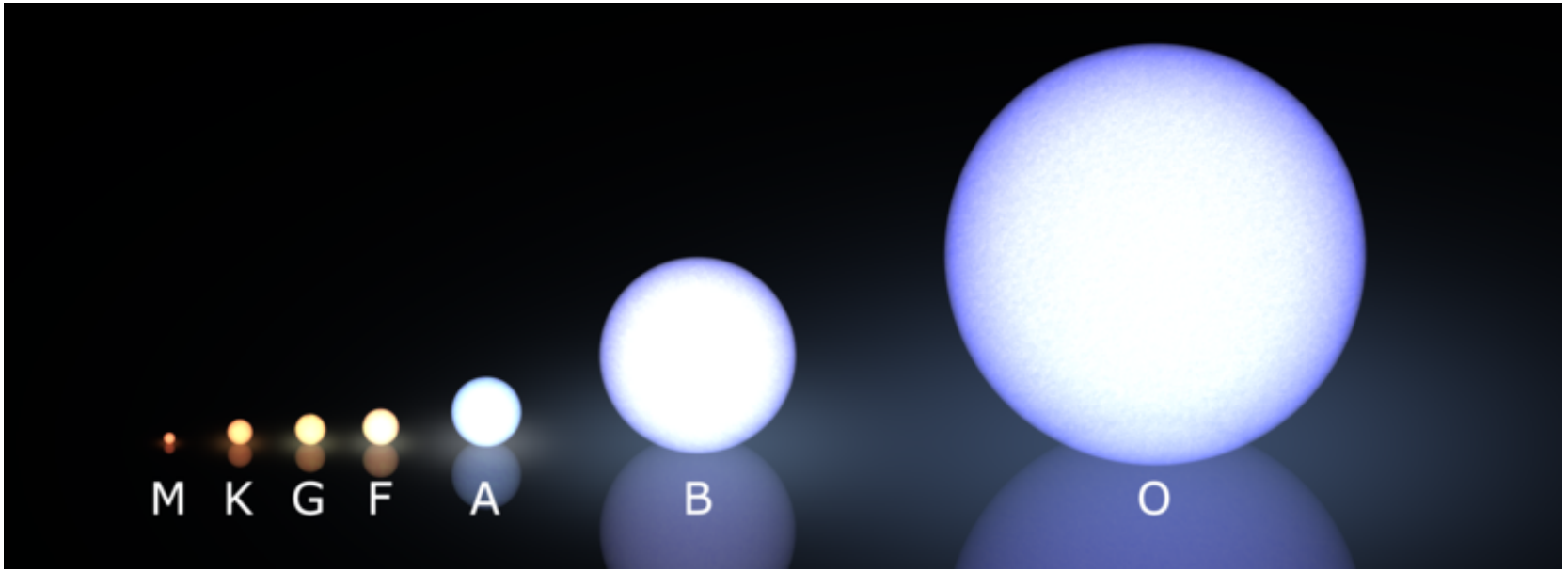
2. proizvajajo energijo:

   v jedrskih reakcijah, včasih tudi gravitacijsko krčenje

zvezda umre, ko ne velja 1. ali 2. ali oboje

Kakšne so?

- izsev L : $(10^{-5}\ L_S - 10^5\ L_S)$, $L_S = 3.85 \times 10^{26}$ W
- površina T_{eff} : T_S=5800 K; 3000 – 40.000 K
- masa : 0.1 –150 M_S
- radij : 0.01 – 1000 R_S



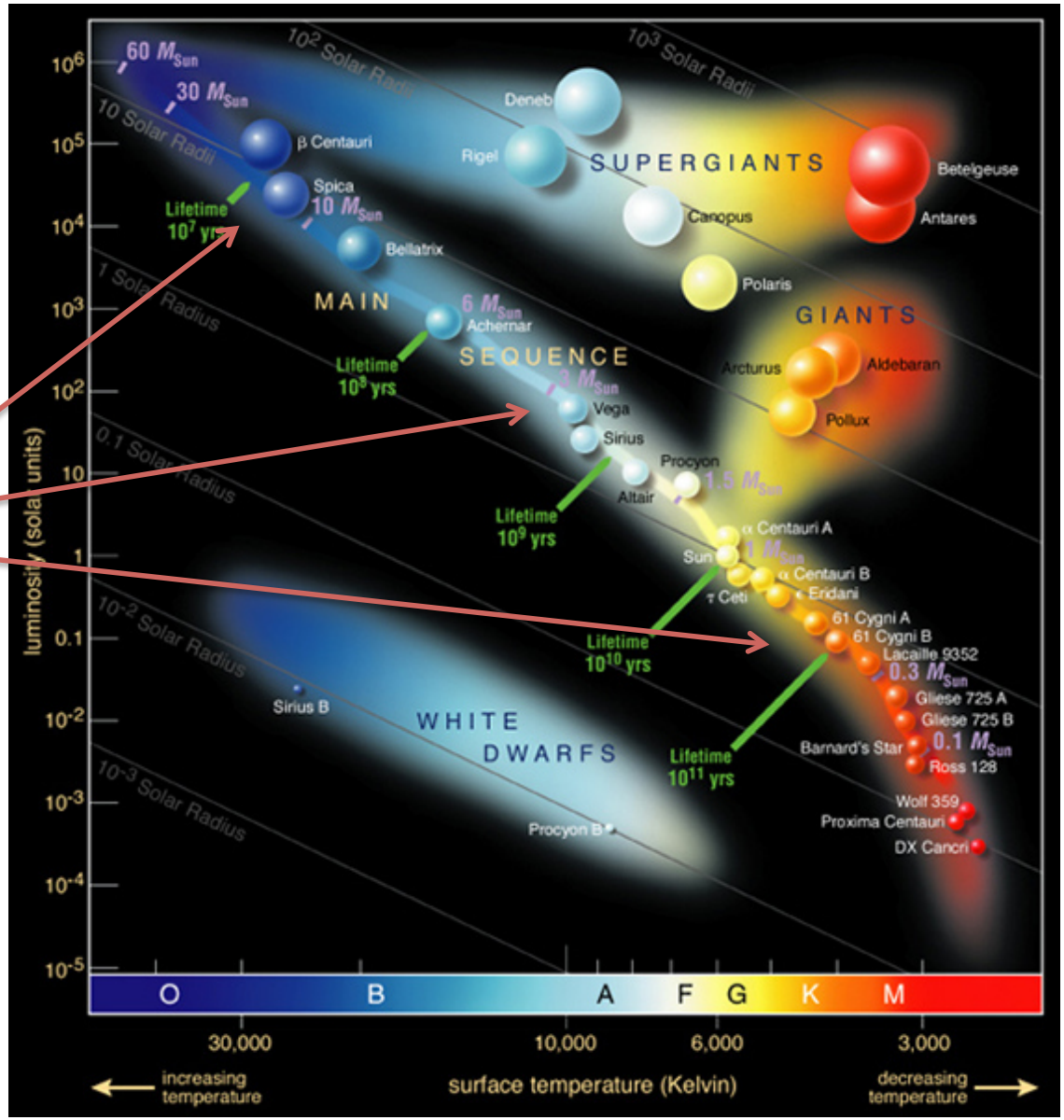
HR diagram

okrog 1910:
Ejnar **H**ertzsprung in
Henry Norris **R**ussel

glavna veja
HR diagrama

glavni parameter,
ki določa zvezdo
je masa!

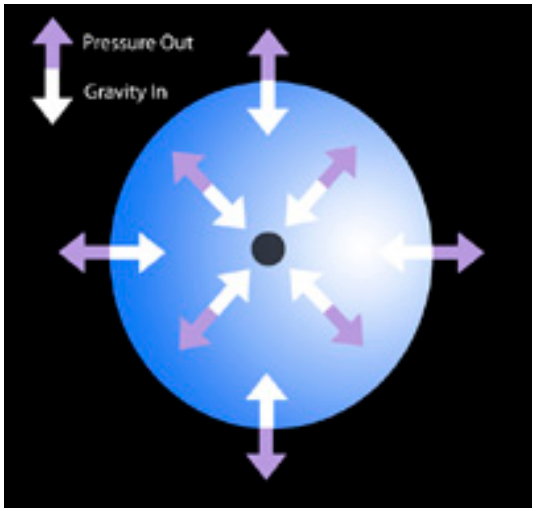
v grobem velja:
$L \propto M^{3.8}$



Nastanek zvezd

- življenje zvezd v enem stavku:

  boj gravitacije proti tlaku



- oblak medzvezdnega plina – molekularni vodik, helij (oglikov monoksid, amoniak…)

Vesoljski teleskop Hubble

Krčenje oblaka

- stabilnost oblaka
- virialni teorem: $E_{gravitacijska} = -2\, E_{notranja}$
- pogoj za krčenje:

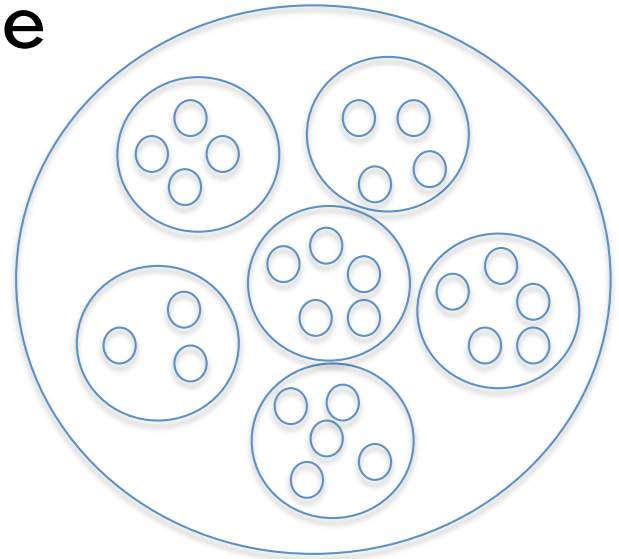
$$M > M_{Jeans} \propto T^{3/2}/\rho^{1/2}$$

tipična $M >> M_{Sonca}$:

iz enega oblaka nastane večje število zvezd

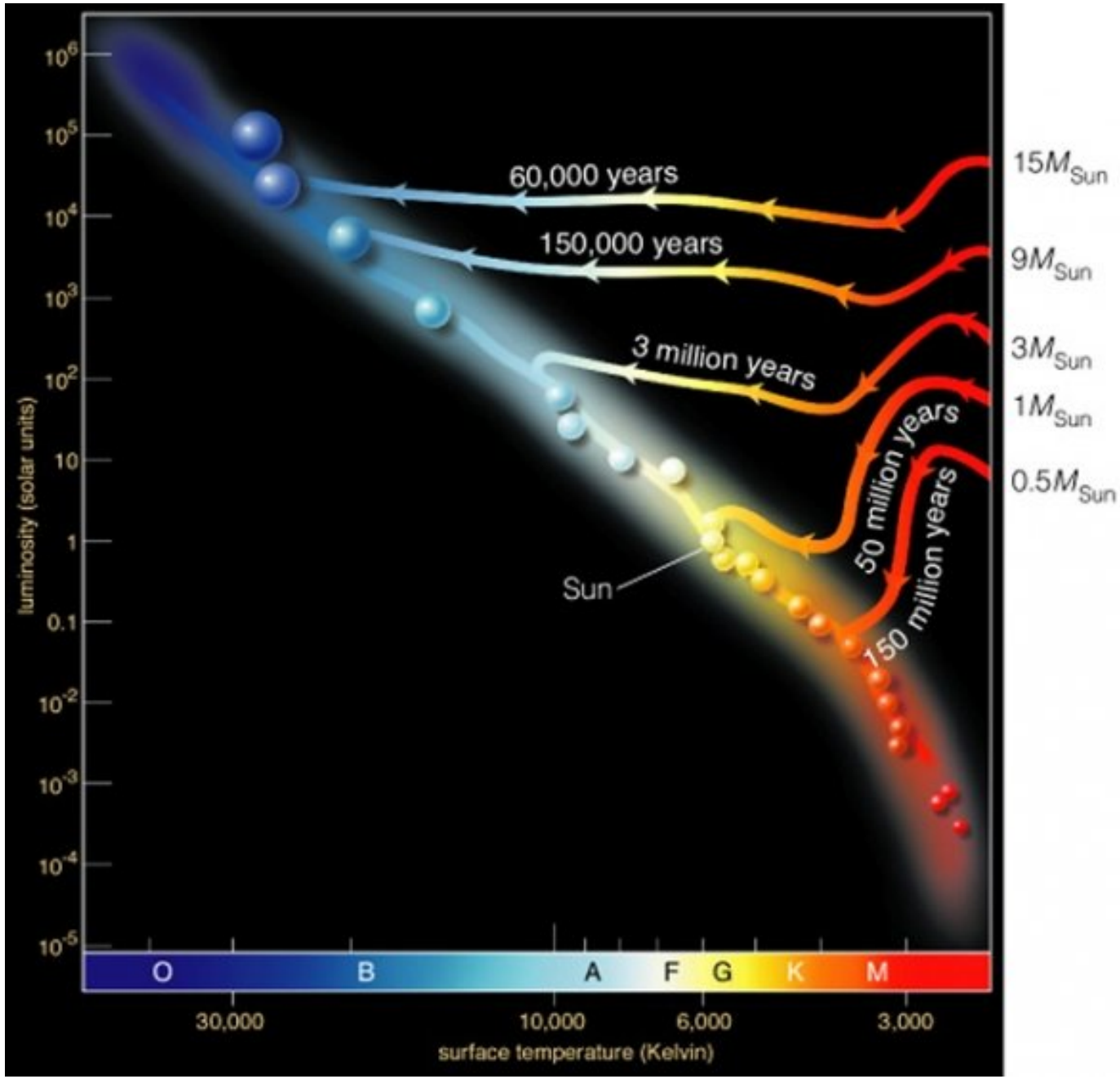
Fragmentacija oblaka

- izotermno krčenje – M_{Jeans} pada – fragmenti
- gosti, postaja neprozoren $M > M_{Jeans} \propto T^{3/2}/\rho^{1/2}$
- T narašča – M_{Jeans} narašča
- fragmentacija se ustavi – zametki zvezd
- krčenje protozvezd se nadaljuje
- še naprej segrevajo…

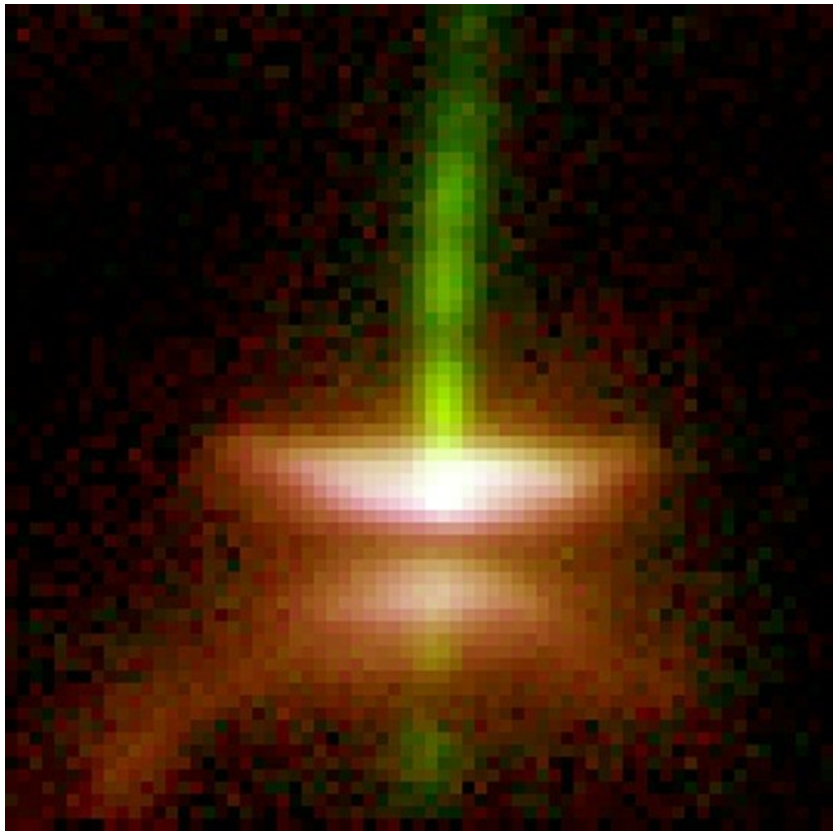


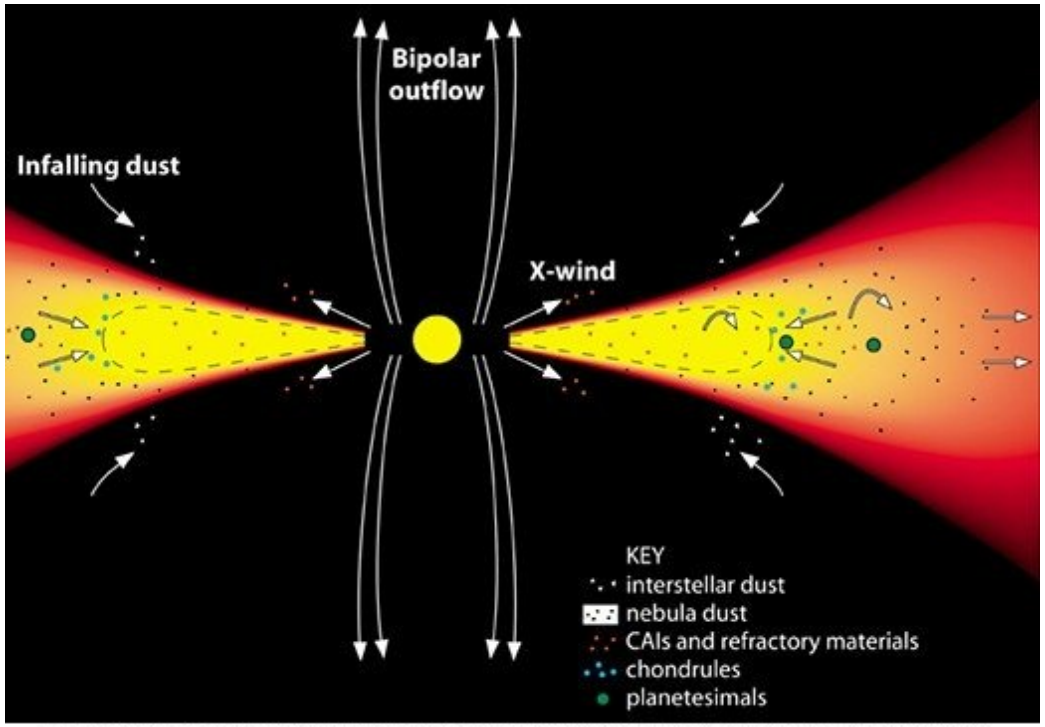
- vir energije – krčenje
- energija se prenaša s konvekcijo, nato tudi s sevanjem – T na površini narašča

- T narašča tudi v sredici – stečejo jedrske reakcije zlivanja H v He – zvezda!

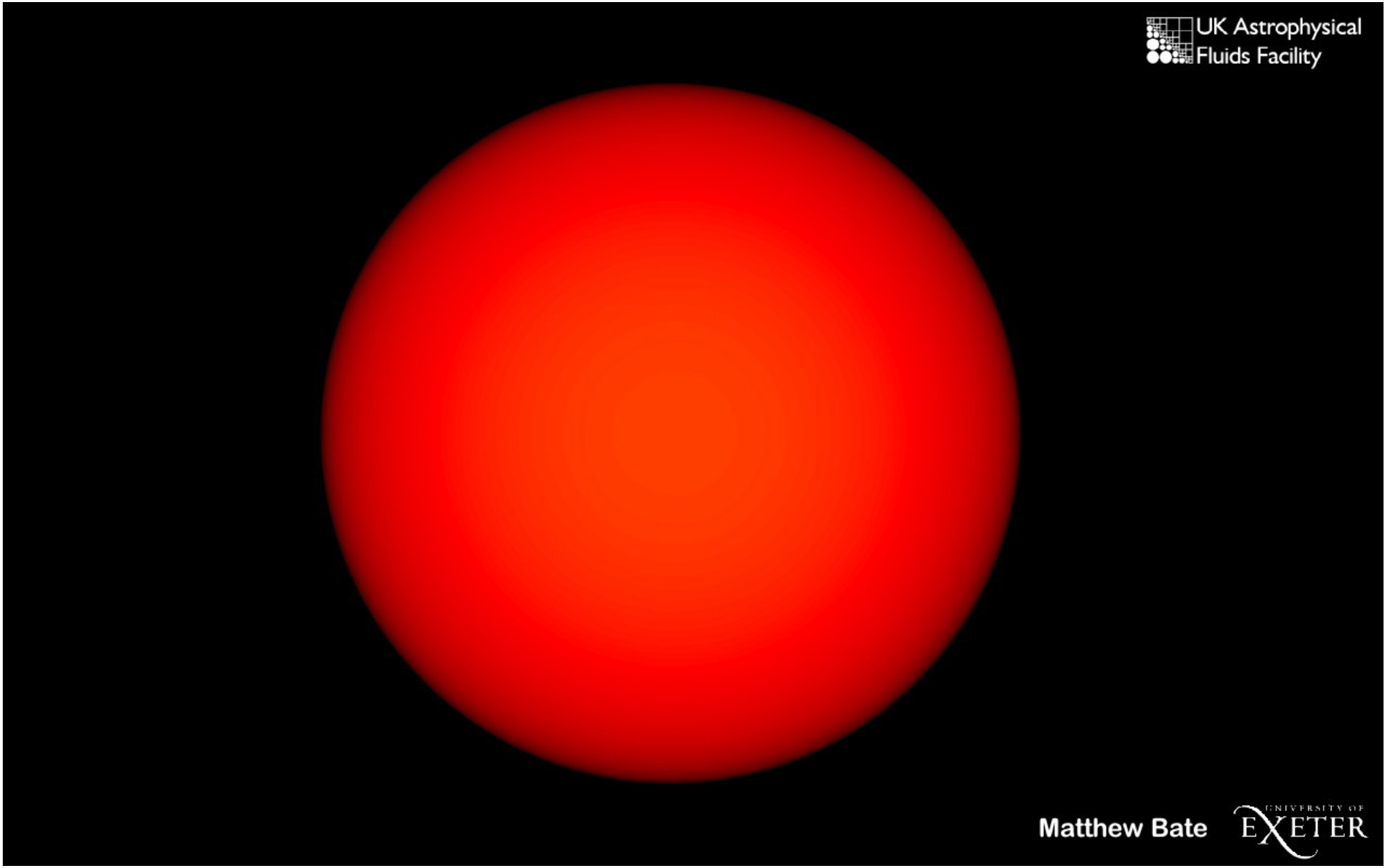


plin in prah okoli mladih zvezd

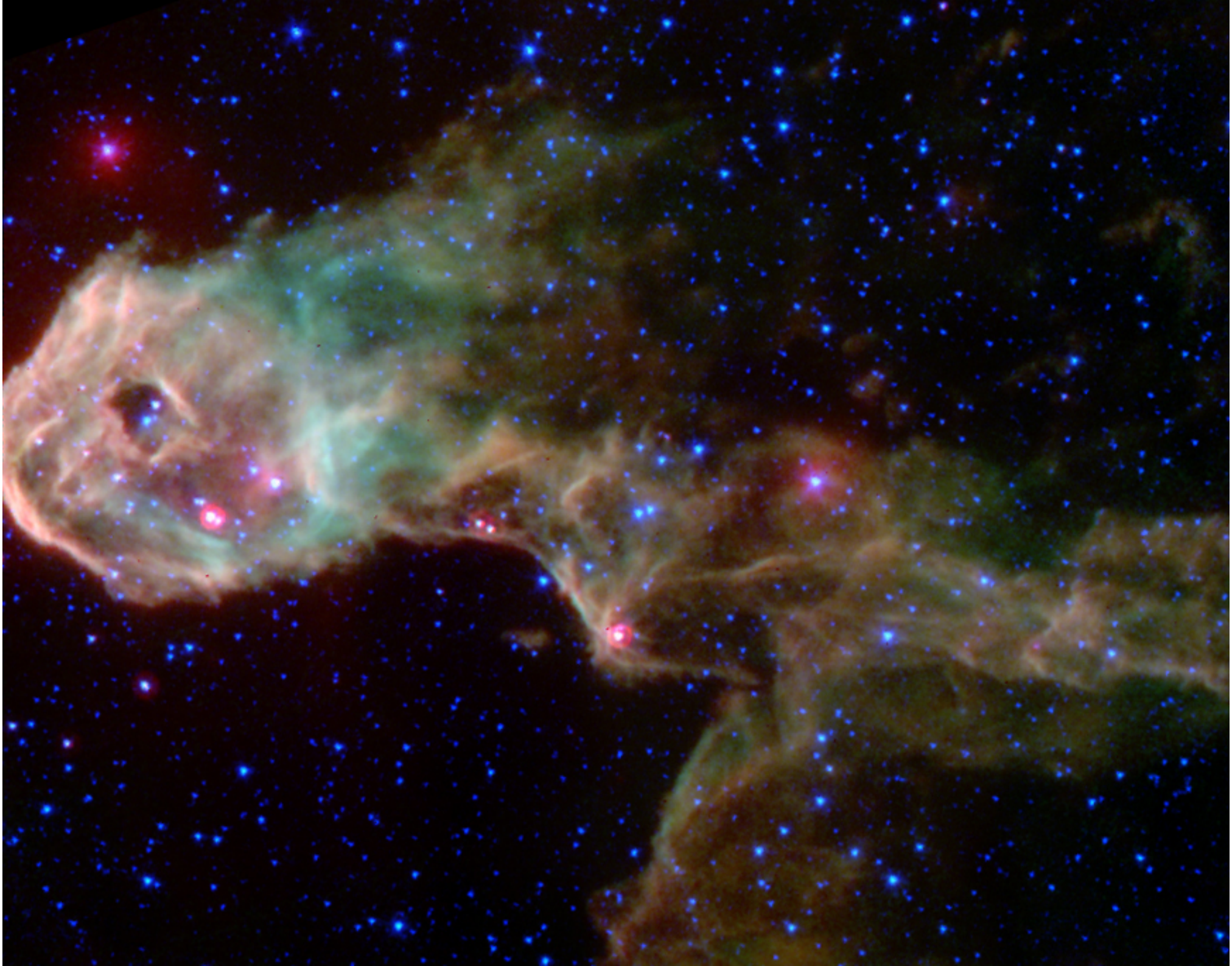




(PSRD graphic by Nancy Hulbirt, based on a conceptual drawing by Edward Scott, Univ. of Hawaii.)

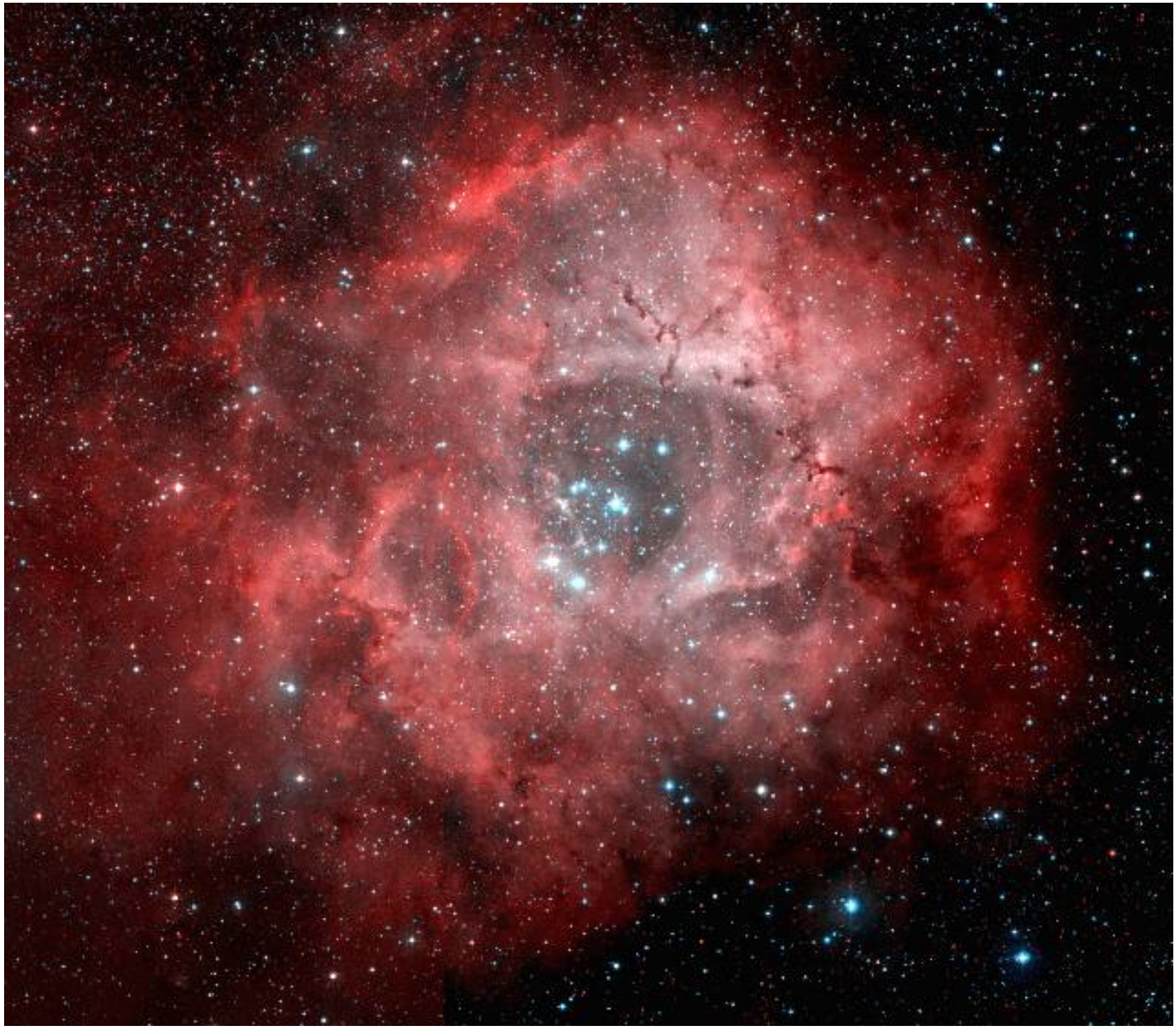


http://www.astro.ex.ac.uk/people/mbate/Research/Cluster/cluster500RT.html



UV
Strömgre
nova sfera

meglica
Rozeta

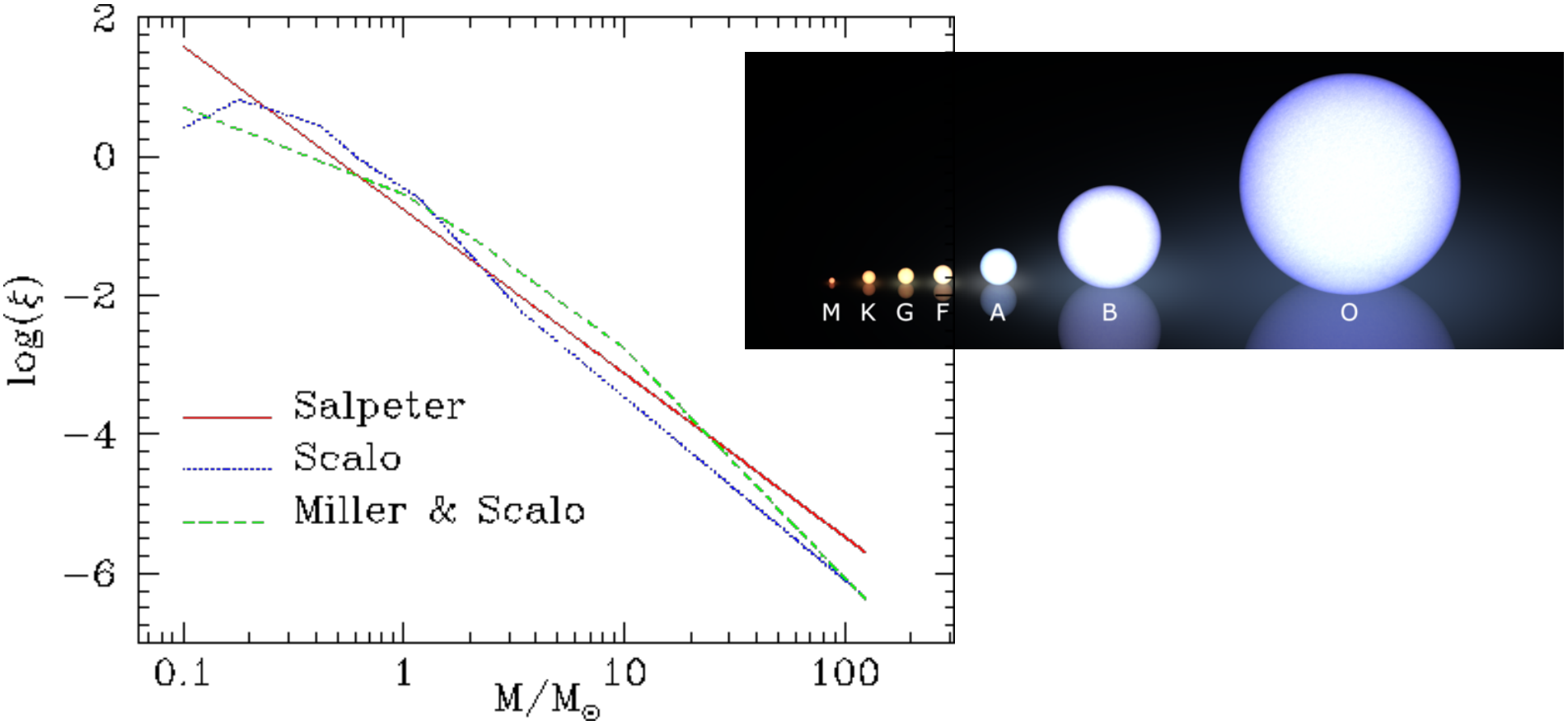


skupina zvezd, ki se v ≈100 Mlet razsuje (kroglaste dalj)

v skupini so zvezde z različnimi masami:

0.08 M_S (rjava pritlikavka)- 150 M_S

veliko manj masivnih, malo masivnih:

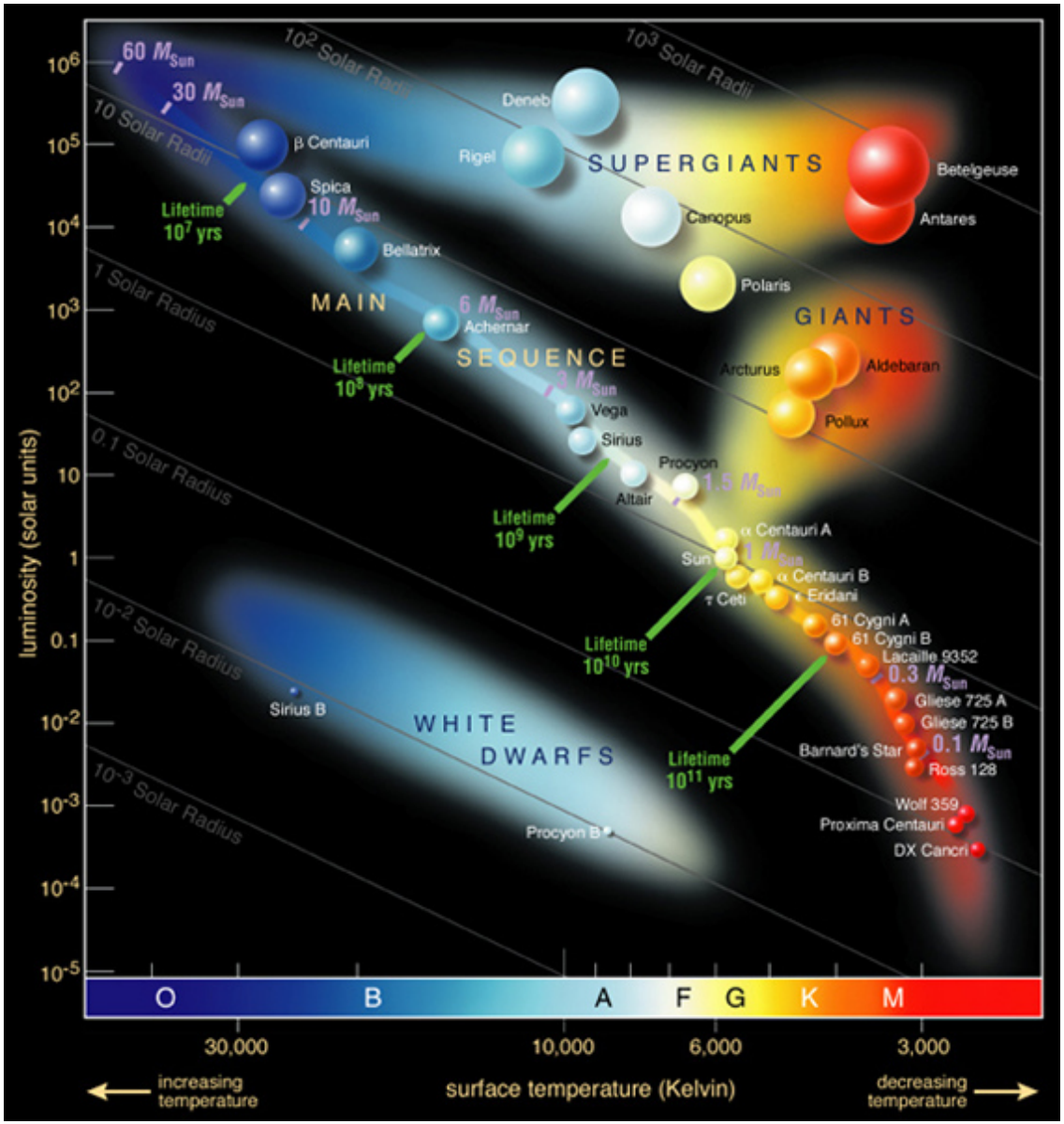


Glavna veja HR diagrama

najbolj mirna faza življenja zvezde

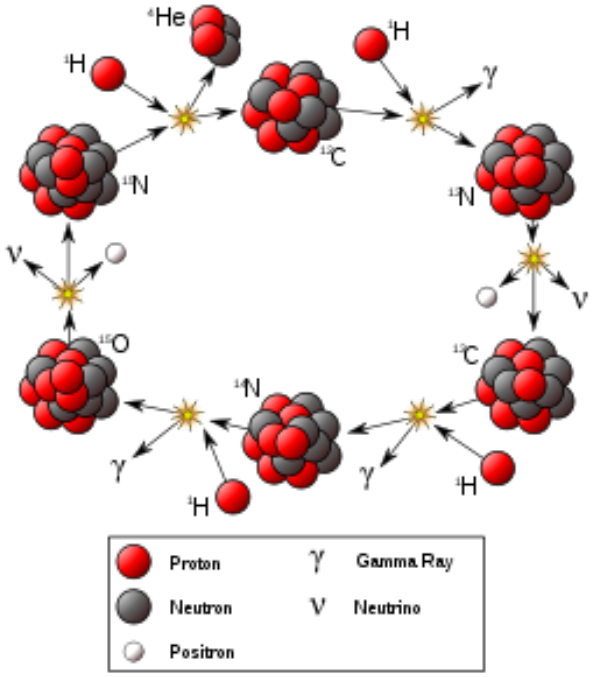
glavni parameter, ki določa zvezdo je masa

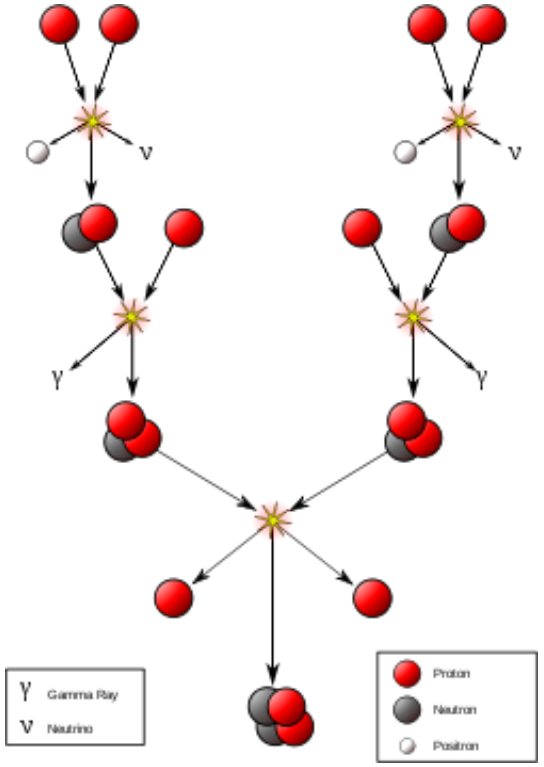
v grobem velja:
$L \propto M^{3.8}$



zlivanje H v He

- p-p veriga
- CNO cikel





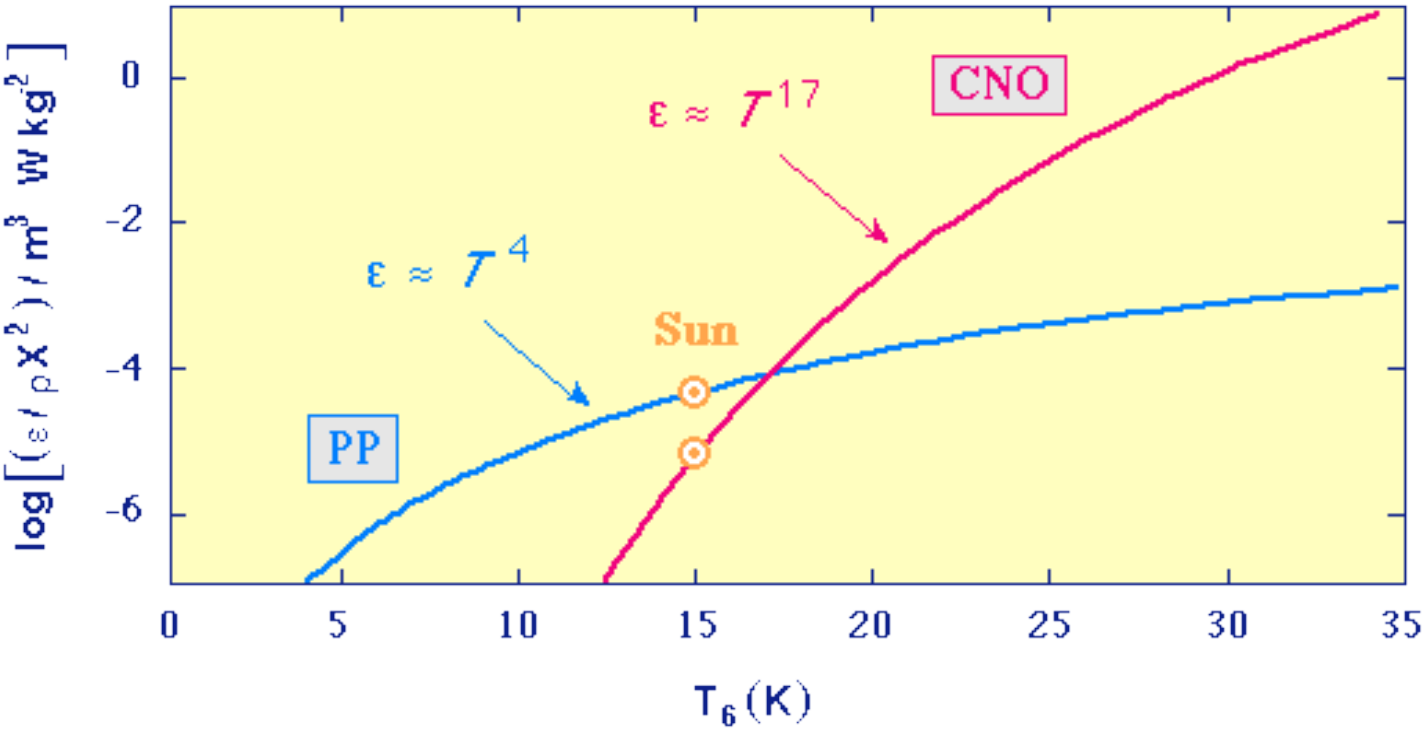
Skupni rezultat: $4\ {}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\ e^{+} + 2\ \nu_e + \gamma + 26.8\ MeV$

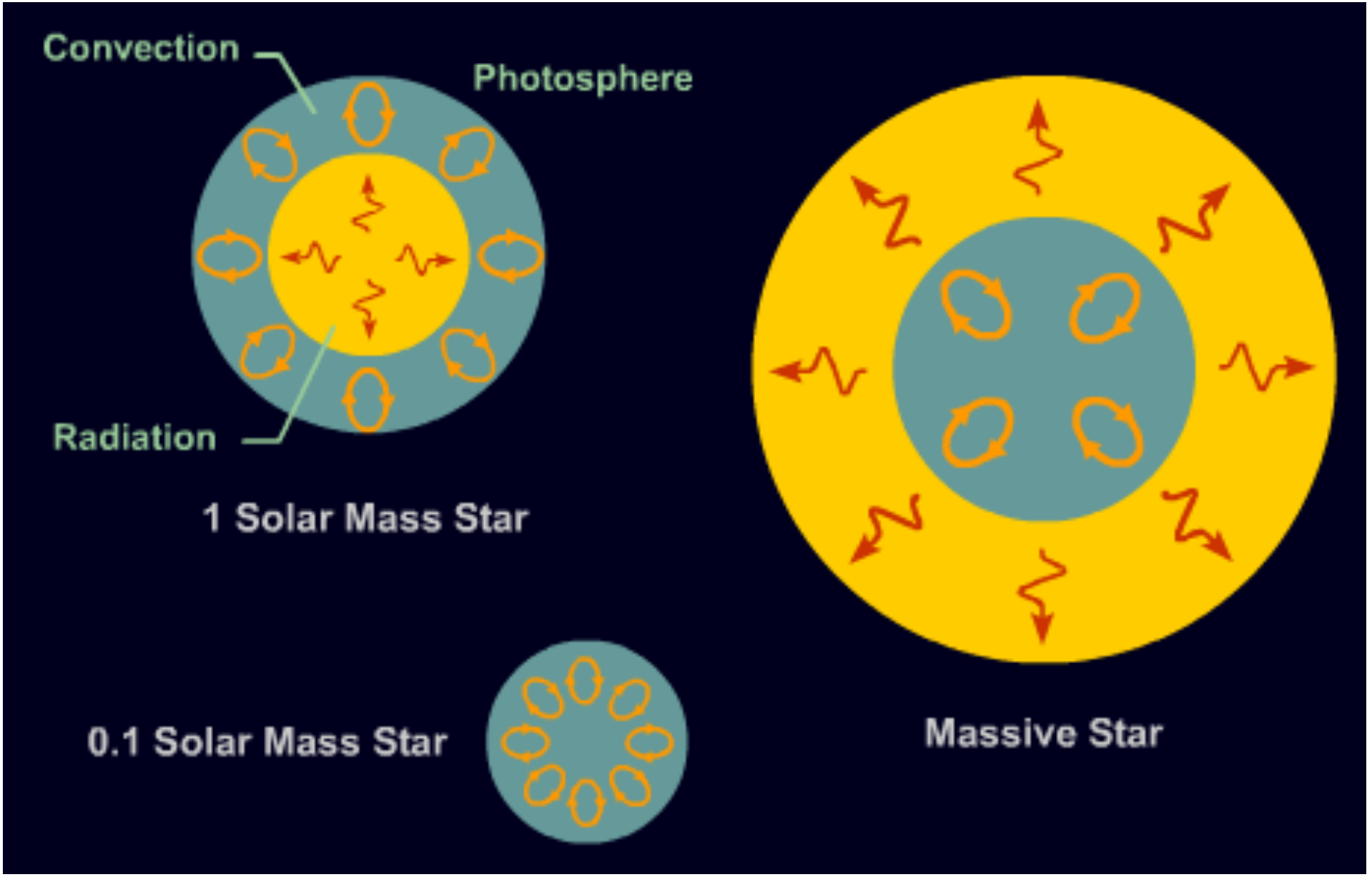
- p-p veriga: začne pri T~4 MK

  $\varepsilon \propto T^4$ (ε=E/m)

- CNO cikel: začne pri T~13 MK

  $\varepsilon \propto T^{20}$ - v masivnih zvezdah (M>1.3M_s)!




Convection
Photosphere
Radiation
1 Solar Mass Star
0.1 Solar Mass Star
Massive Star

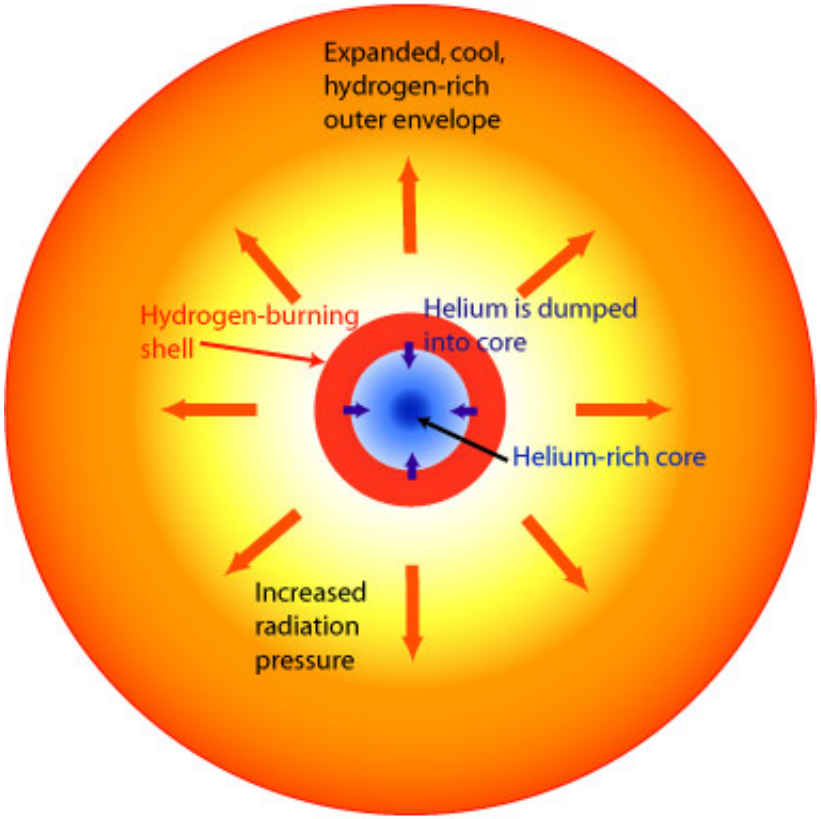
masivne zvezde svetijo veliko močneje in hitreje izčrpajo zalogo goriva:

Spectral Class:	Solar Masses:	Solar Luminosity:	Temperature:	Solar Radii	Time on Main Sequence (million years):
O5	40	400,000	40,000 K	13	1.0
B0	15	13,000	28,000 K	4.9	11
A0	3.5	80	10,000 K	3.0	440
F0	1.7	6.4	7,500 K	1.5	2,700
G0	1.1	1.4	6,000 K	1.1	8,000
K0	0.8	0.46	5,000 K	0.9	17,000
M0	0.5	0.08	3,500 K	0.8	56,000

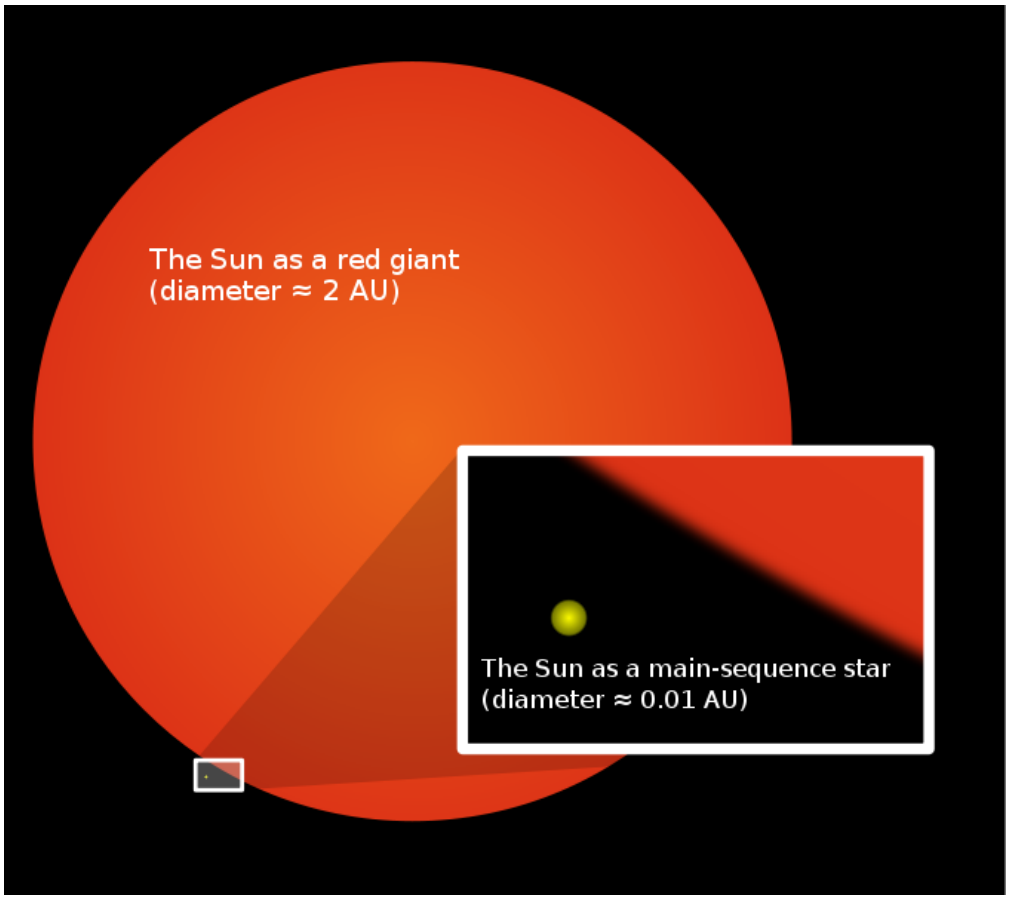
masivne zvezde živijo na glavni veji kratek čas!

ko zmanjka vodika….

- sredica krči, T narašča, gorenje vodika v ovojnici, zunanje plasti napihujejo – rdeča orjakinja



Hydrogen Shell Burning on the Red Giant Branch



vžig He

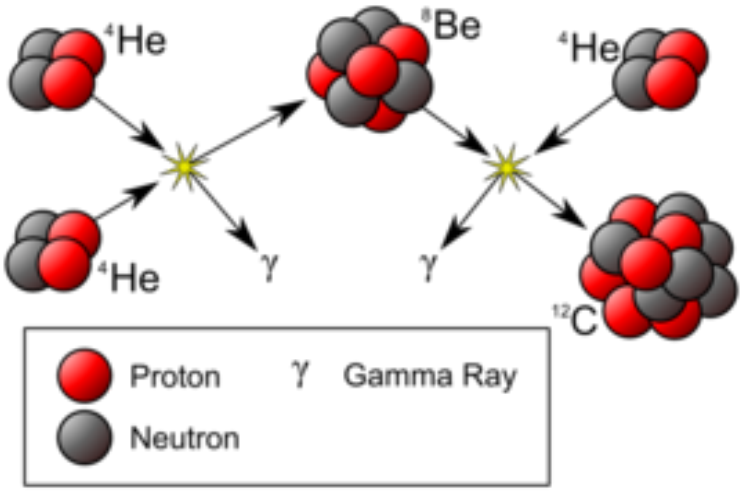
- He sredica se veča do maksimalne možne, nato se krči in segreva
- vžig (bližč) helija pri T~100 MK

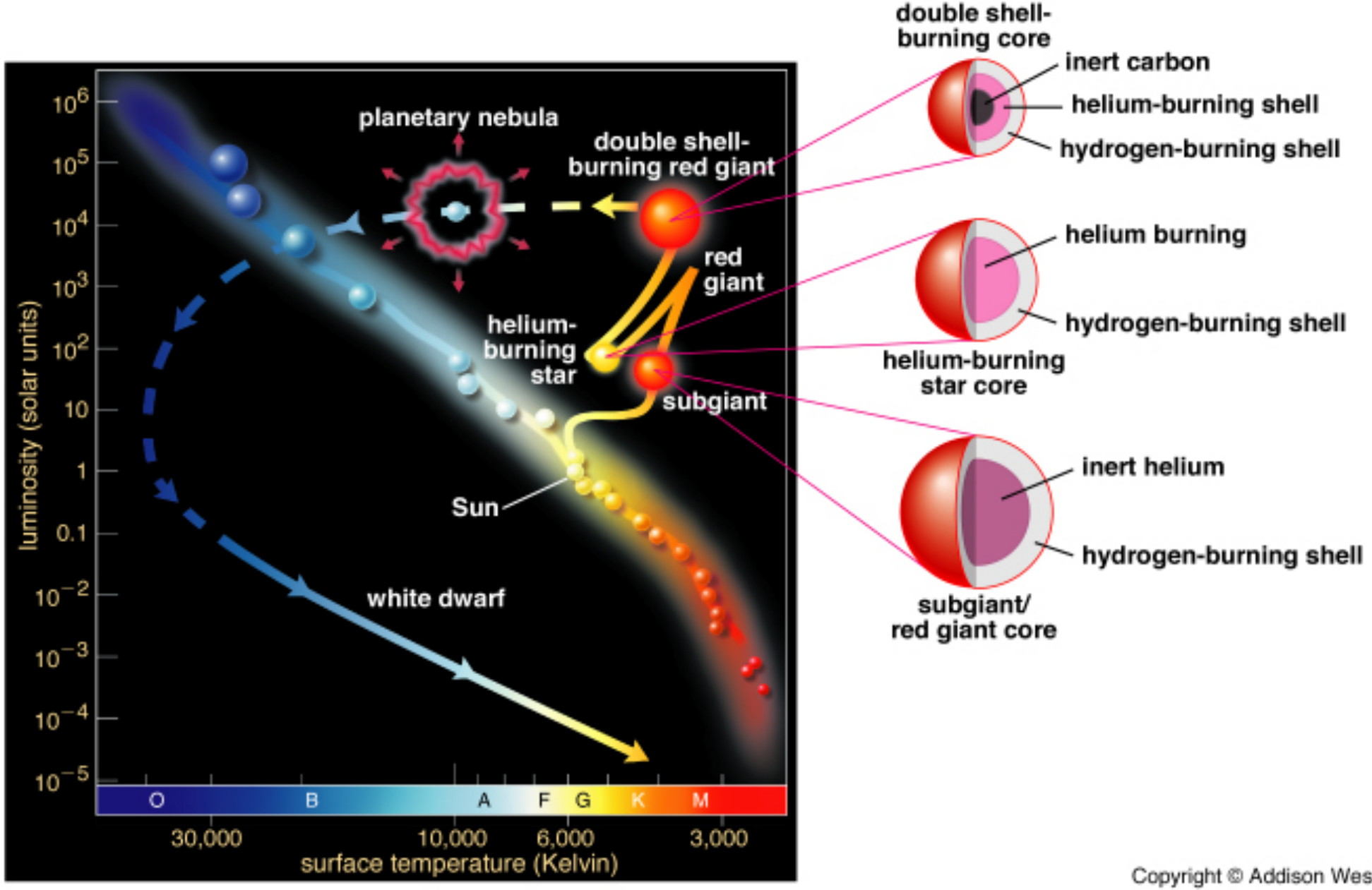
$^{4}_{2}He + {}^{4}_{2}He \rightarrow {}^{8}_{4}Be$ (−92 keV)

$^{8}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + e^{+} + e^{-}$

trojni alfa proces

Be razpada!





planetarna meglica
sredica – bela pritlikavka

končno stanje manj masivnih zvezd

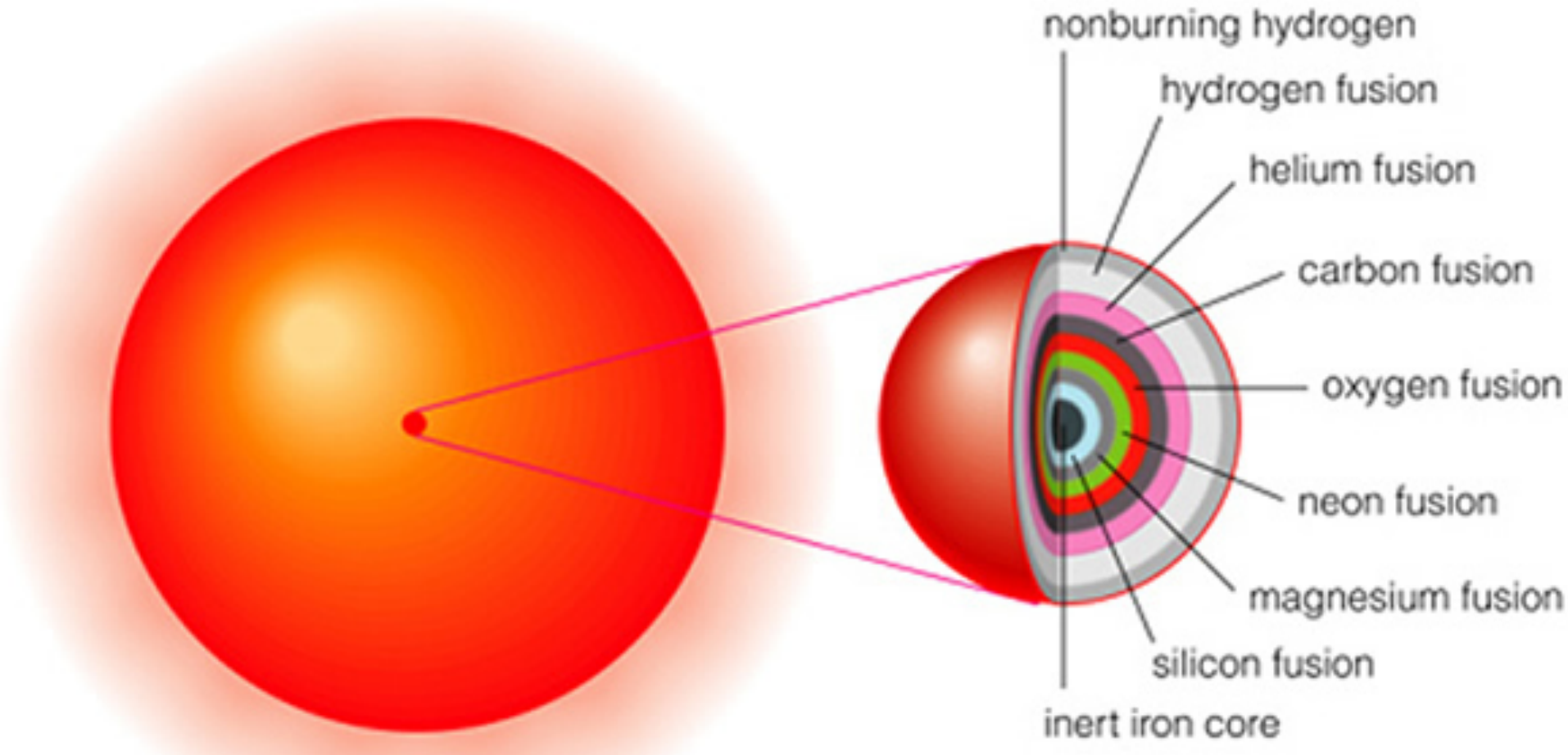
$M \leq 1.4\ M_S$

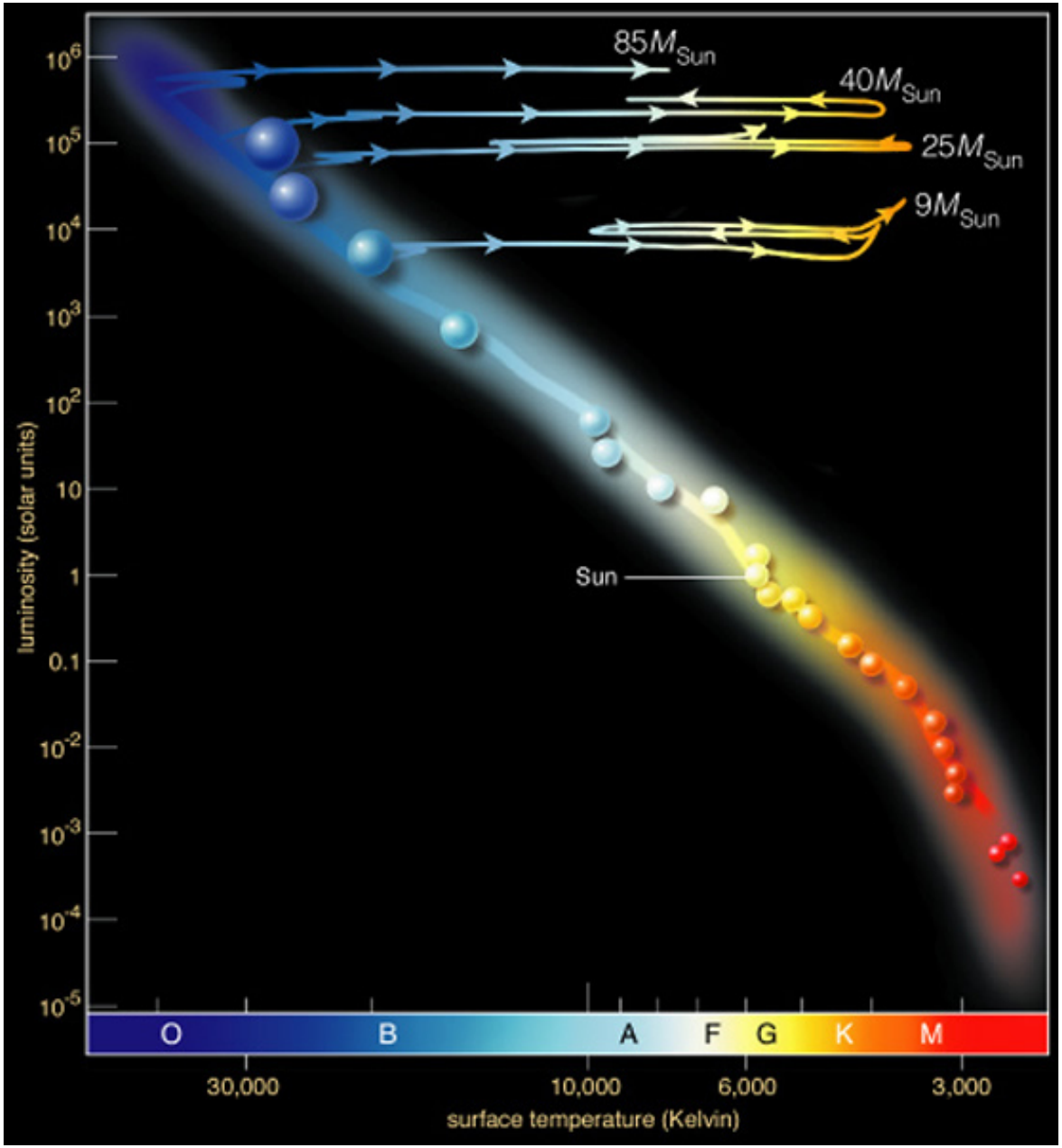
masivne zvezde

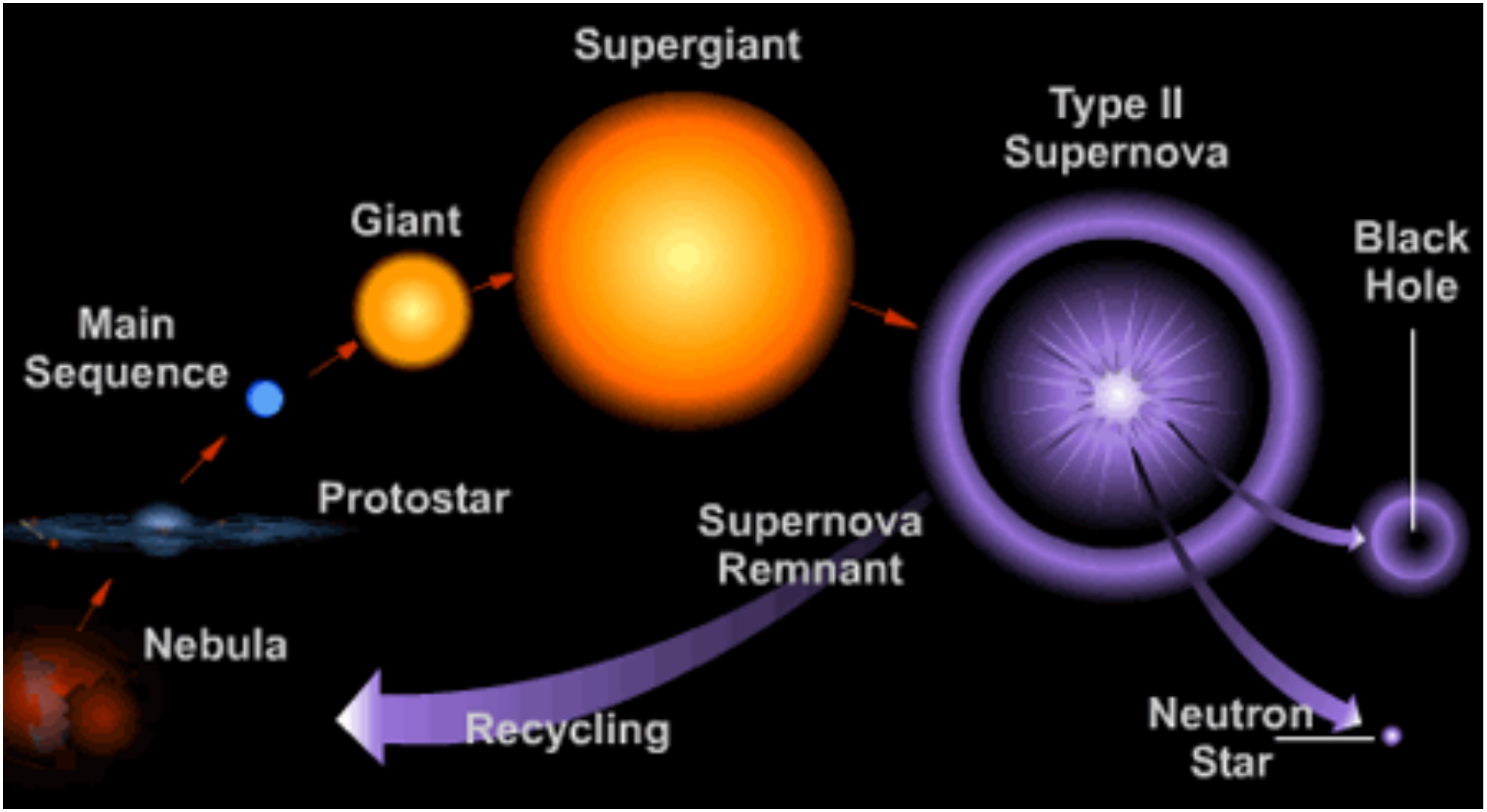
- gredo skozi višje cikle gorenja – ogljik, neon, kisik, silicij
- višja T in ρ, višja M
- krajši čas

- zlivanje se ustavi pri železu
- končni produkt:

^{56}Ni :β razpad z τ=6.02 dni $\rightarrow$ ^{56}Co z τ=77.3 dni $\rightarrow$ ^{56}Fe

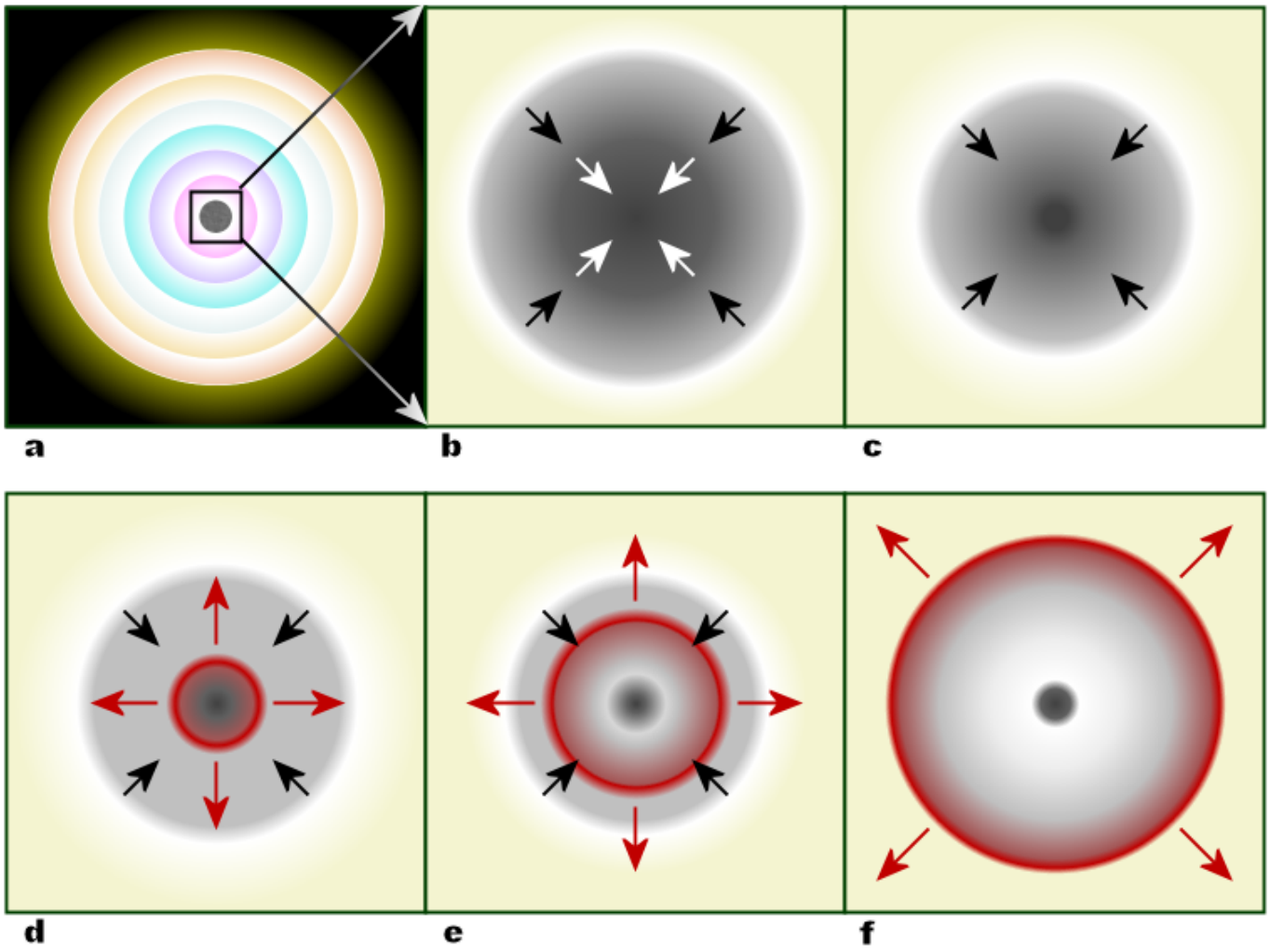

nonburning hydrogen
hydrogen fusion
helium fusion
carbon fusion
oxygen fusion
neon fusion
magnesium fusion
silicon fusion
inert iron core

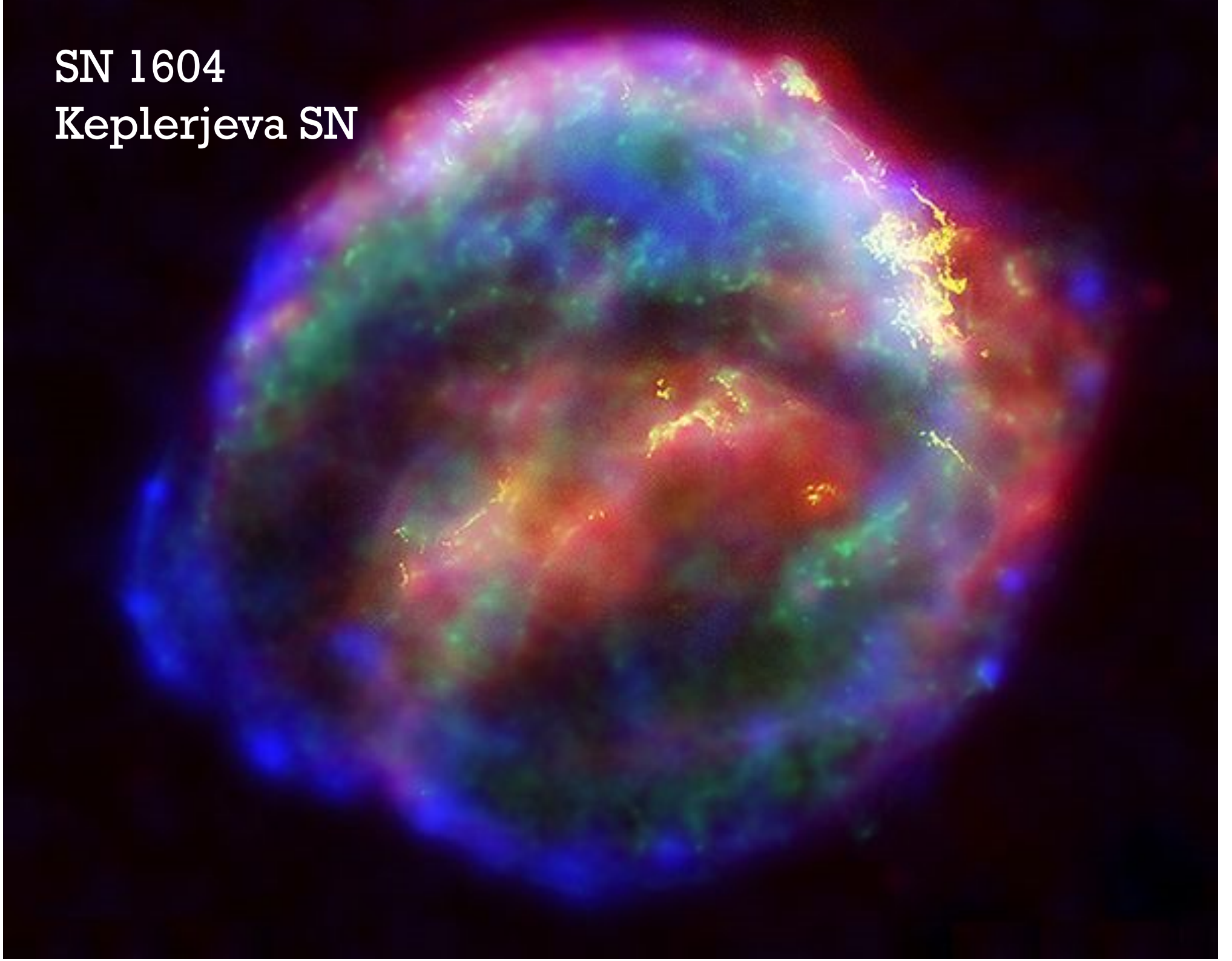

85M_{Sun}
40M_{Sun}
25M_{Sun}
9M_{Sun}
Sun
luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
O
B
A
F
G
K
M
30,000
10,000
6,000
3,000
surface temperature (Kelvin)

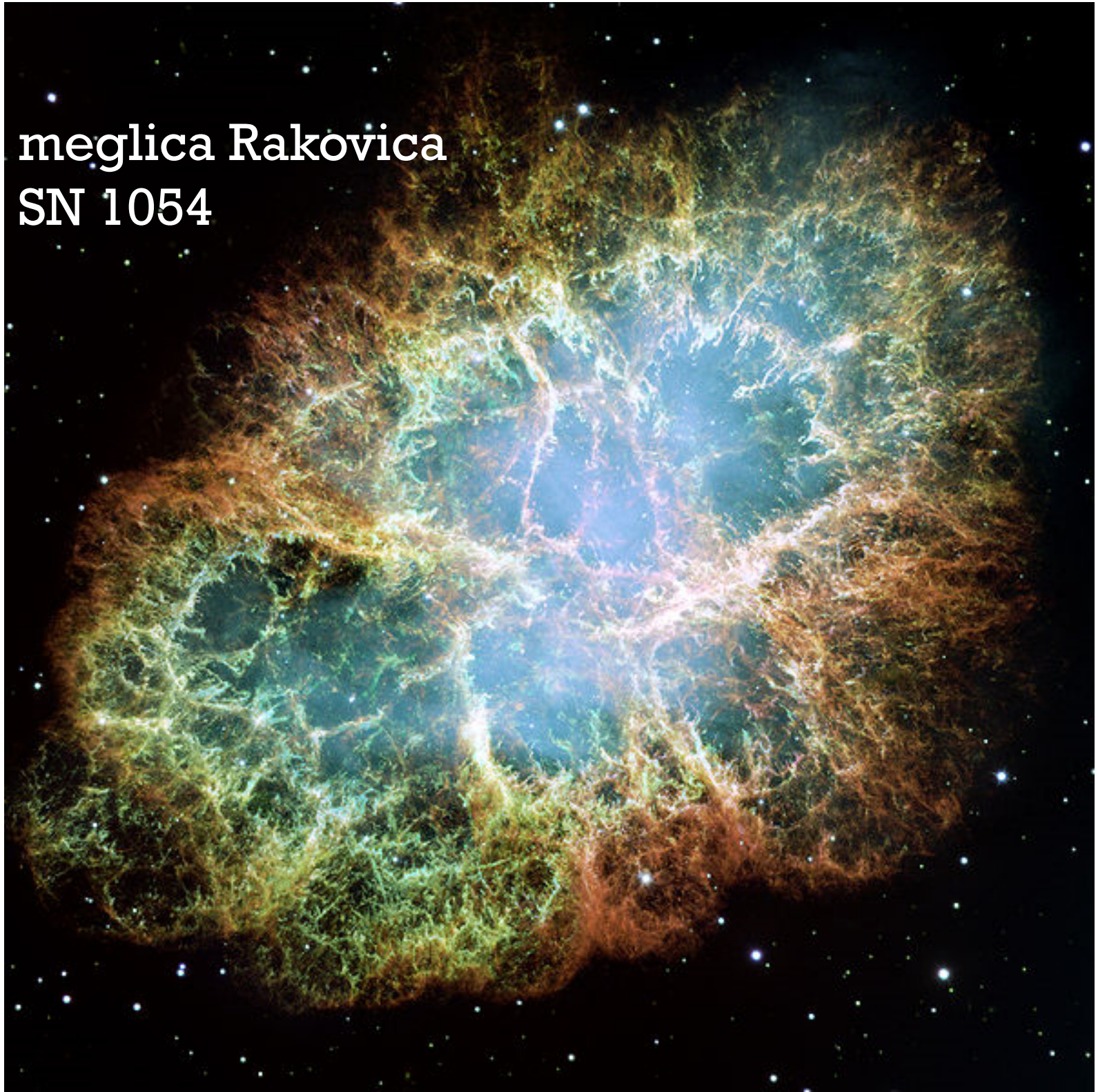

Supergiant
Type II
Supernova
Giant
Black
Hole
Main
Sequence
Protostar
Supernova
Remnant
Nebula
Recycling
Neutron
Star

Eksplozija supernove

- goriva zmanjka, sredica se skrči na nekaj 10 km→ ogromna gravitacijska energija
- eksplozija supernove: Tip II, Tip Ib, Ic
- sredica – nevtronska zvezda ali črna luknja – končni stanji masivnih zvezd



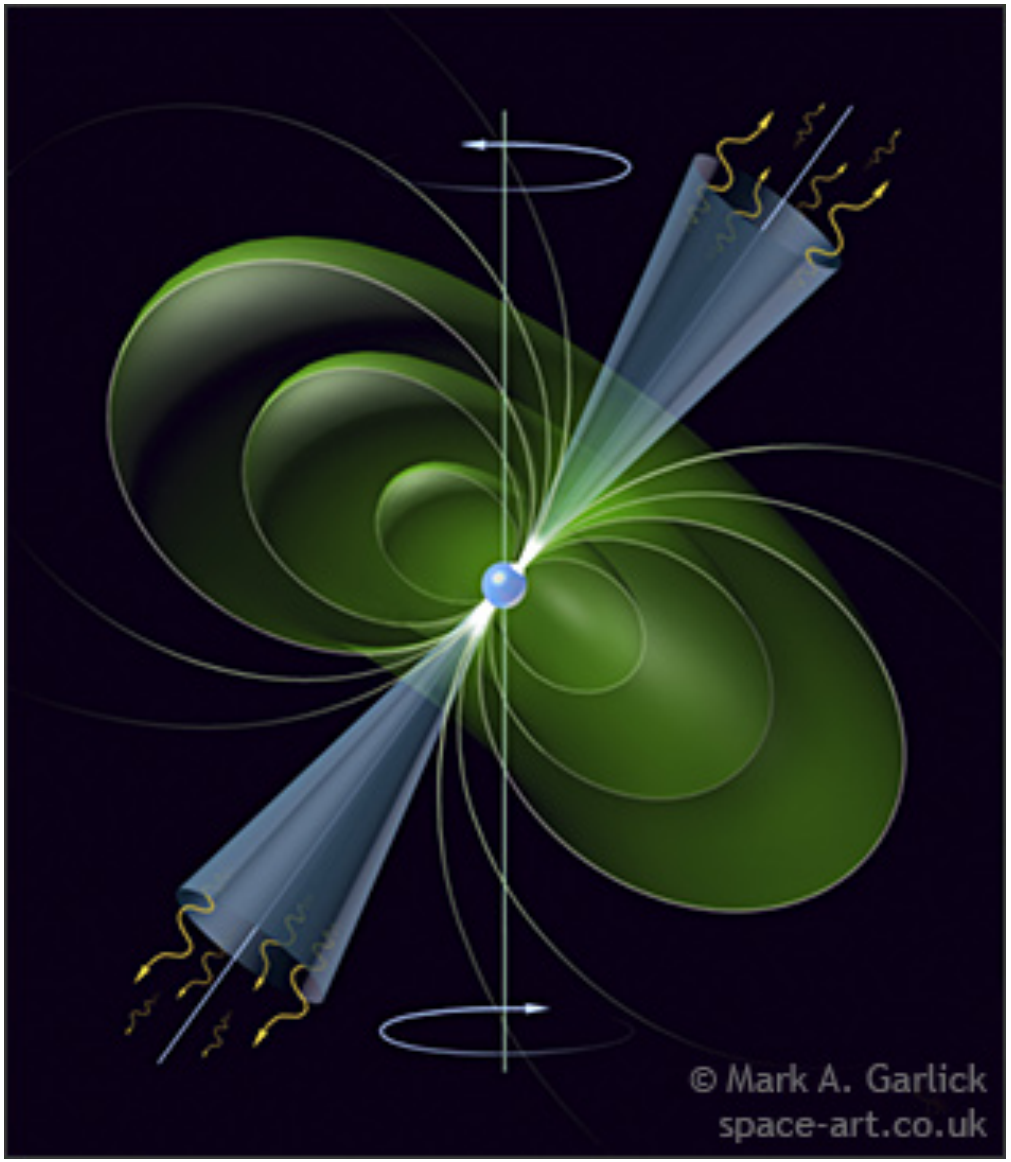

SN 1604
Keplerjeva SN


meglica Rakovica
SN 1054

nevtronska zvezda

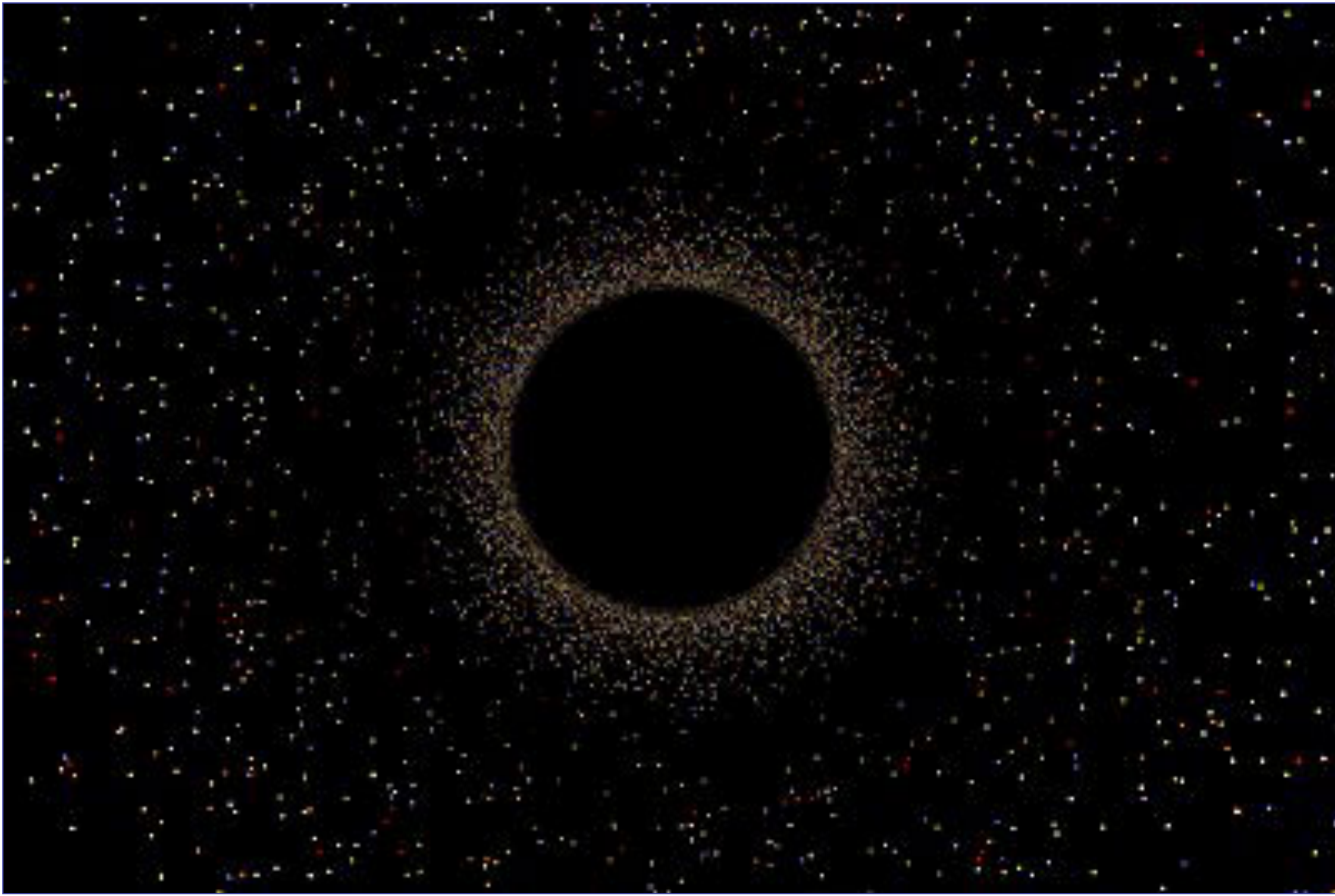
- mlada nevtronska zvezda z močnim magnetnim poljem – pulzar

- $1.4\ M_S < M \leq\approx 2\ M_S$

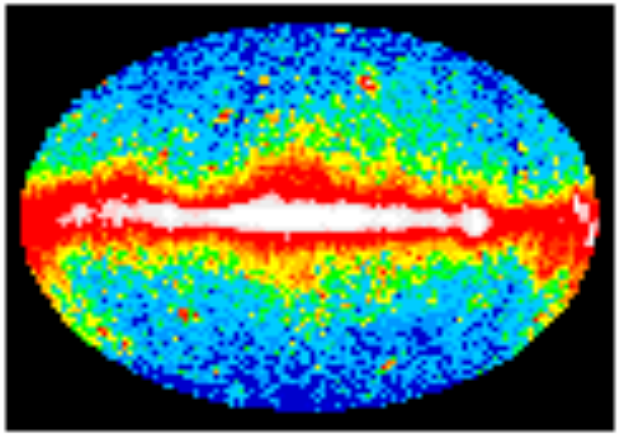


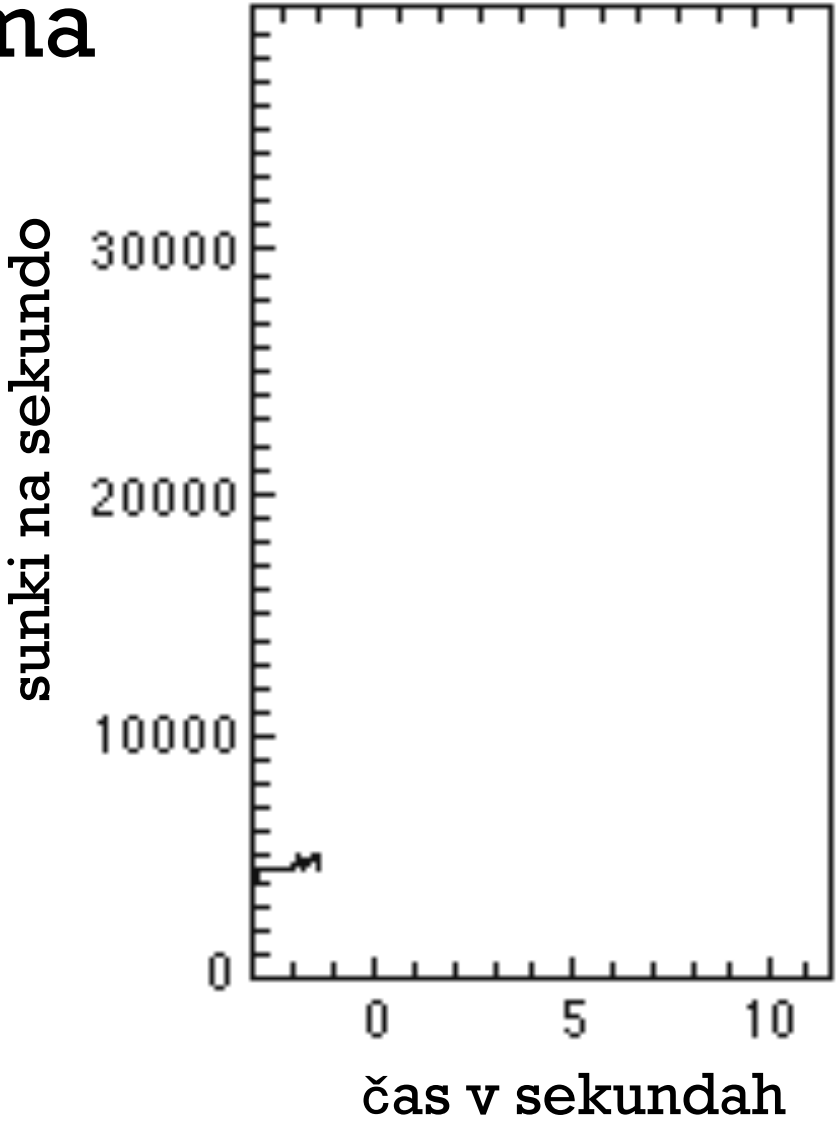
črna luknja

?



Izbruhi sevanja gama

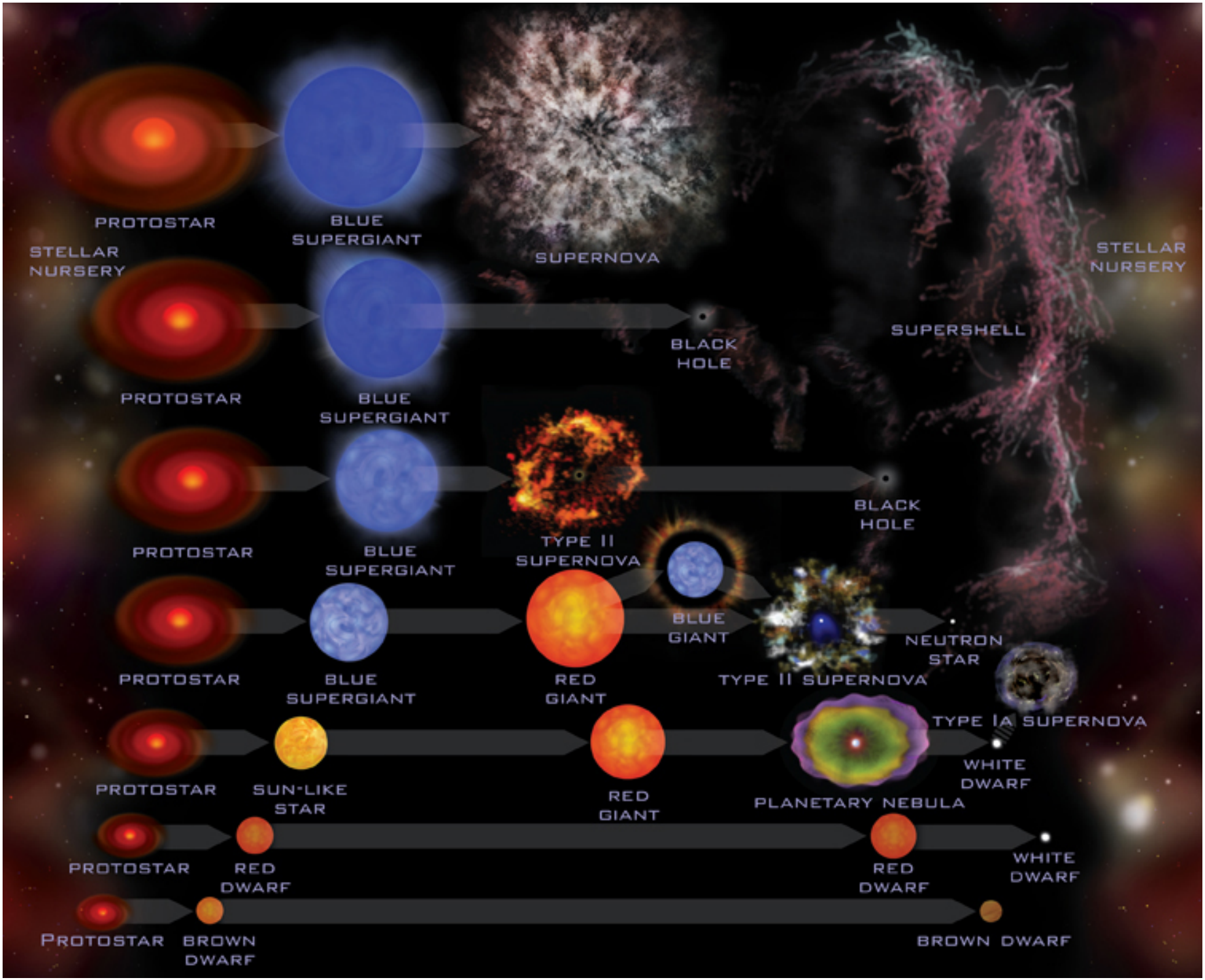




Vir: NASA

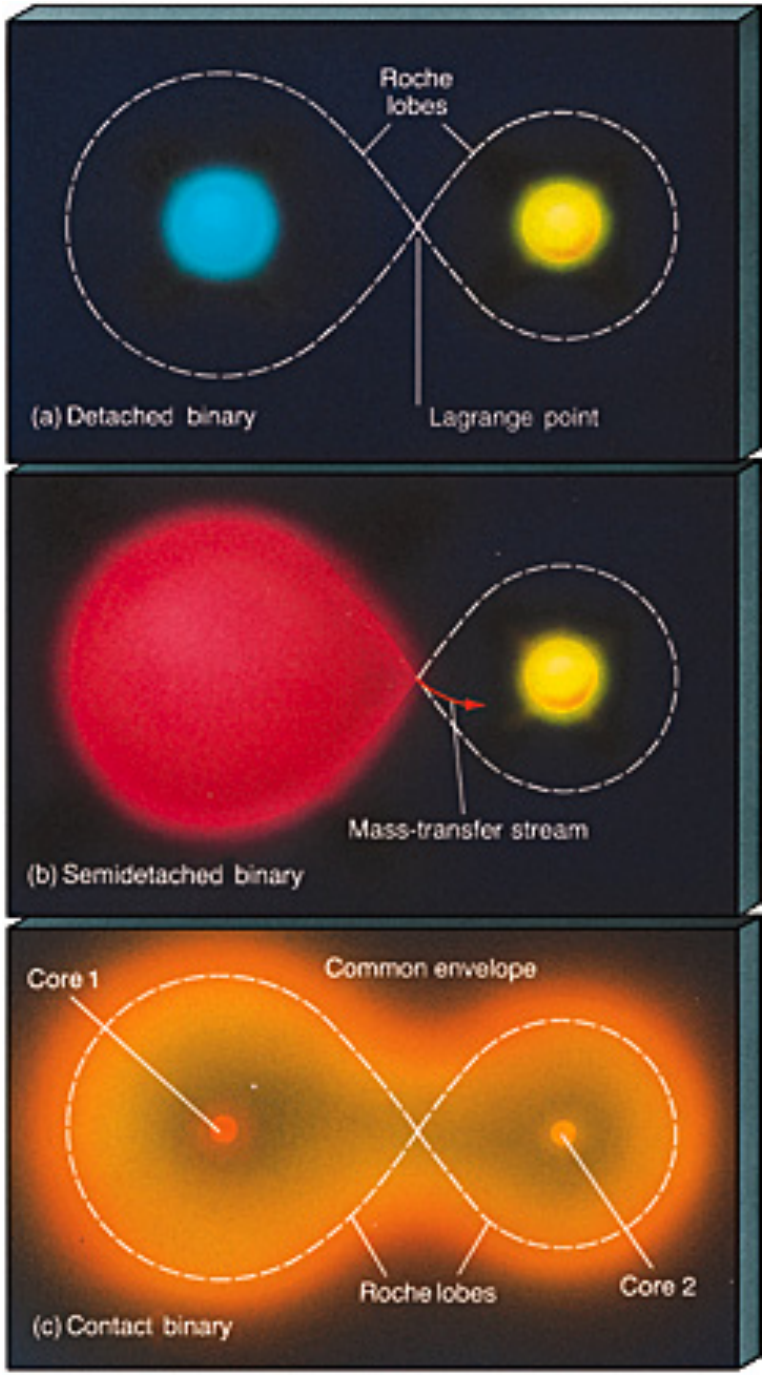
kolaps zvezde

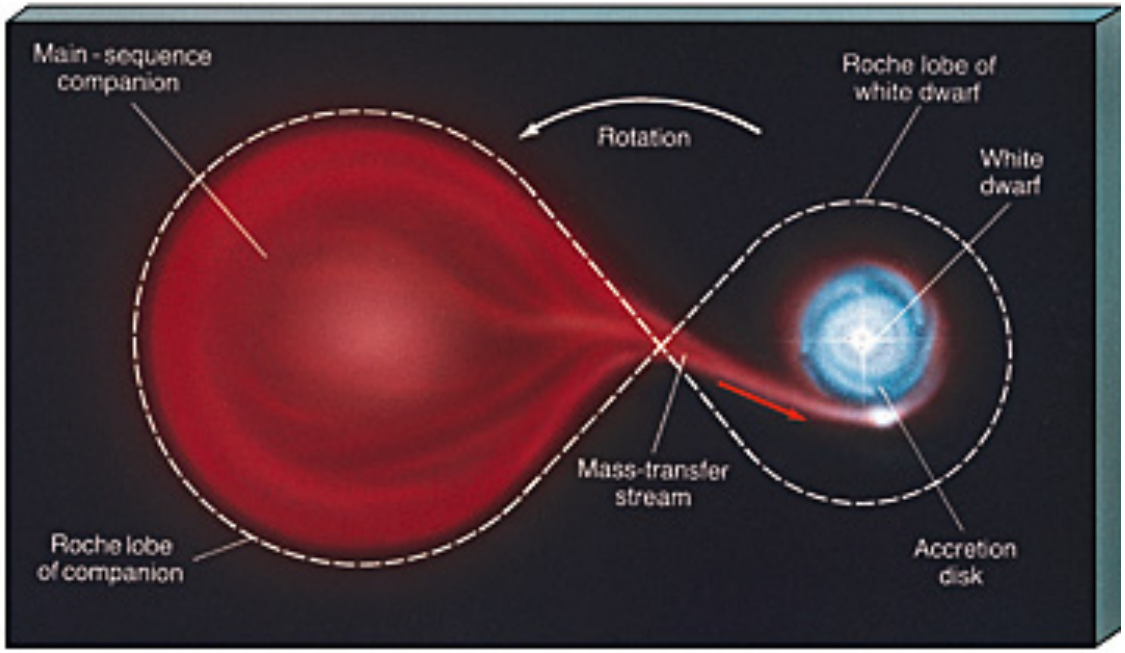
http://www.nasa.gov/mpg/69479main_collapsar.mpg


PROTOSTAR
BLUE SUPERGIANT
SUPERNOVA
STELLAR NURSERY
STELLAR NURSERY
BLACK HOLE
SUPERSHELL
PROTOSTAR
BLUE SUPERGIANT
PROTOSTAR
BLUE SUPERGIANT
TYPE II SUPERNOVA
BLACK HOLE
PROTOSTAR
BLUE SUPERGIANT
RED GIANT
BLUE GIANT
NEUTRON STAR
TYPE II SUPERNOVA
PROTOSTAR
BLUE SUPERGIANT
RED GIANT
TYPE Ia SUPERNOVA
PROTOSTAR
SUN-LIKE STAR
RED GIANT
WHITE DWARF
PLANETARY NEBULA
PROTOSTAR
RED DWARF
RED DWARF
WHITE DWARF
PROTOSTAR
BROWN DWARF
BROWN DWARF

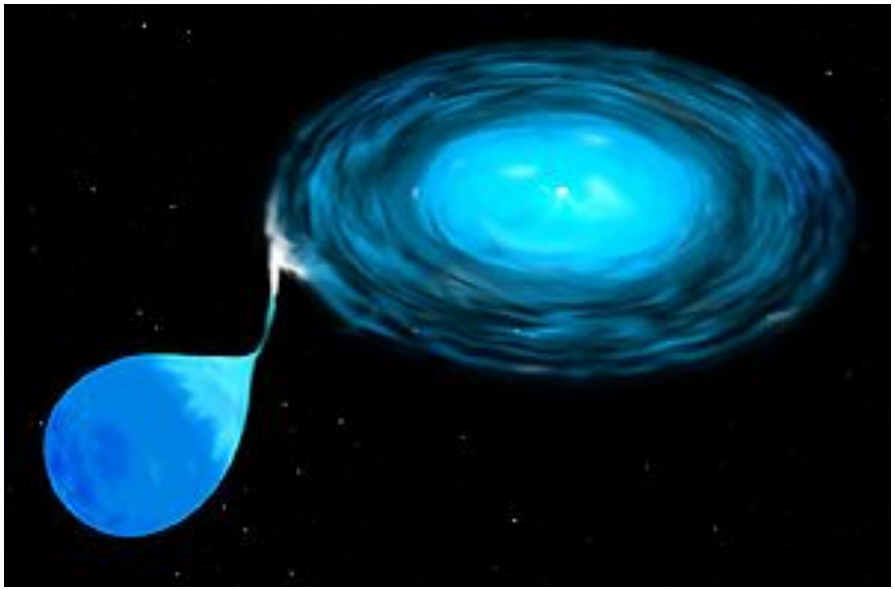
Razvoj dvojnih zvezd

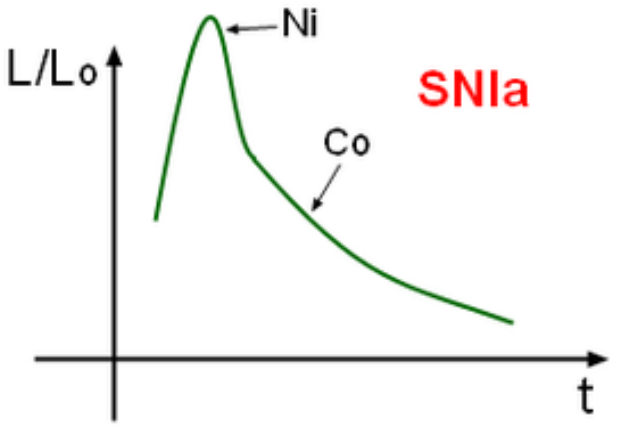
- medsebojni vpliv,

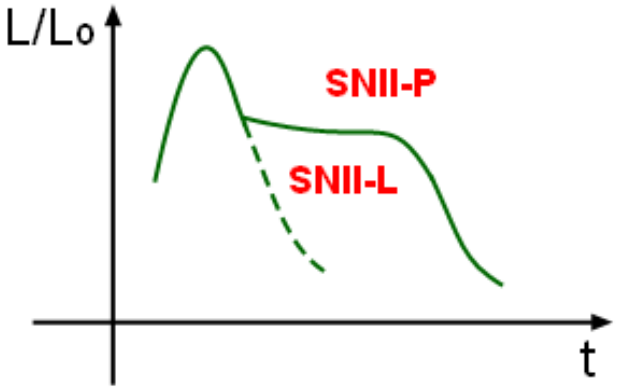




supernova Tip Ia



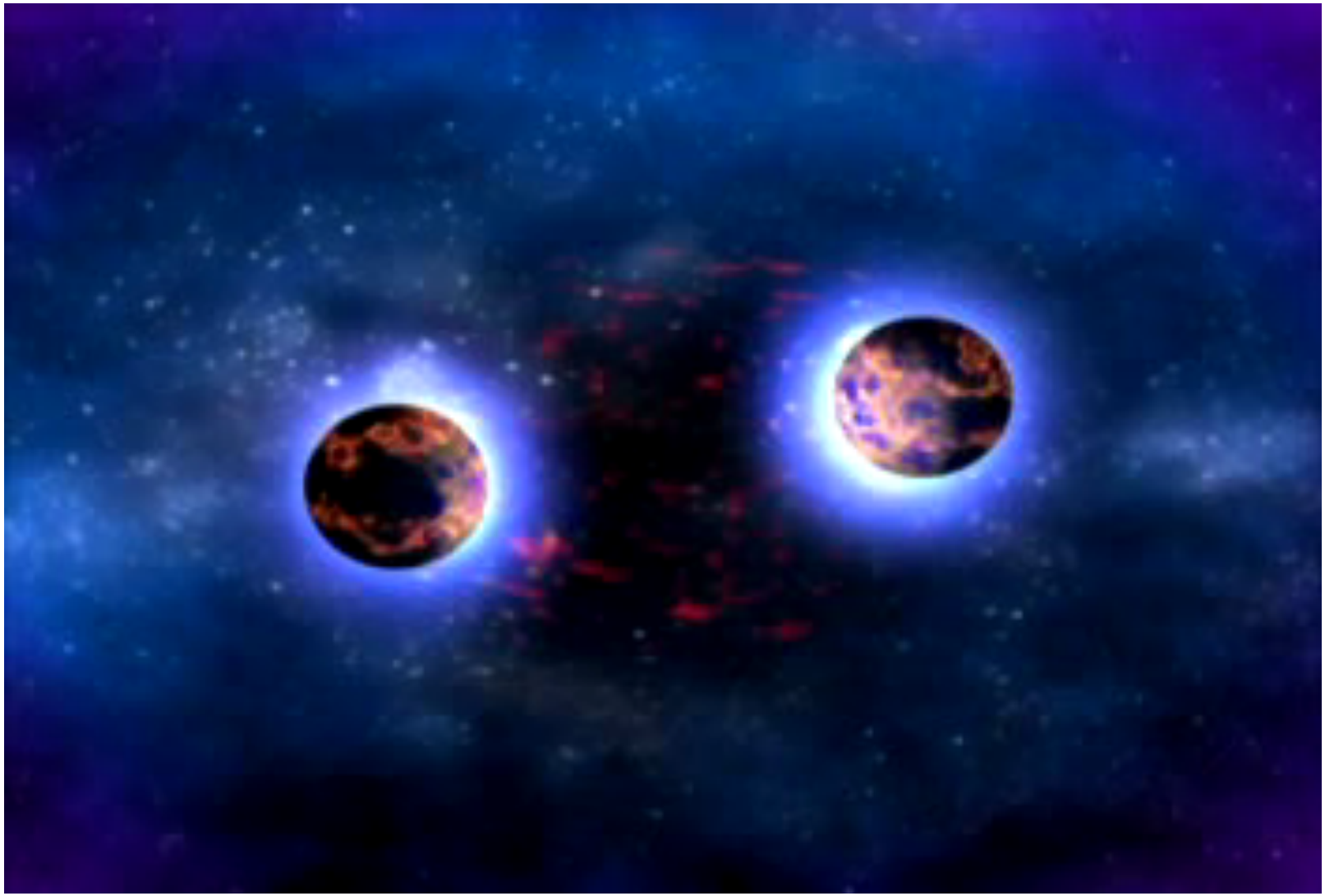




standardni svetilniki – merjenje razdalj v vesolju

Nobelova nagrada za fiziko 2011

zlitje nevtronskih zvezd



http://www.nasa.gov/mpg/69476main_binary_merger.mpg

Razvoj zvezd in kemijski elementi

- v zvezdah nastanejo elementi do železa,
- v supernovah višji – do A=254
- eksplozija raztrese in obogati medzvezdni plin – naslednja generacija zvezd
- ljudje (v masnih %):
- ~ 50% C
- ~ 20% O
- ~ 8.5% N
- ~ 10% težjih elementov
- ~ 11.5% H

Hvala za pozornost!

Viri slik:

http://shaktipotep.files.wordpress.com/2010/12/orion-constellation.jpg
http://upload.wikimedia.org/wikipedia/commons/8/8b/Morgan-Keenan_spectral_classification.png
http://www.daviddarling.info/encyclopedia/H/HRdiag.html
http://upload.wikimedia.org/wikipedia/commons/b/b2/Eagle_nebula_pillars.jpg
http://www.nasa.gov/multimedia/imagegallery/image_feature_643.html
http://astronomyonline.org/
http://hubblesite.org/gallery/
http://news.softpedia.com/newsImage/Hubble-Sees-Amazing-Jewel-Box-in-Space-2.jpg/
http://outreach.atnf.csiro.au/education/senior/astrophysics/stellarevolution_postmain.html
http://en.wikipedia.org/wiki/File:Sun_red_giant.svg
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