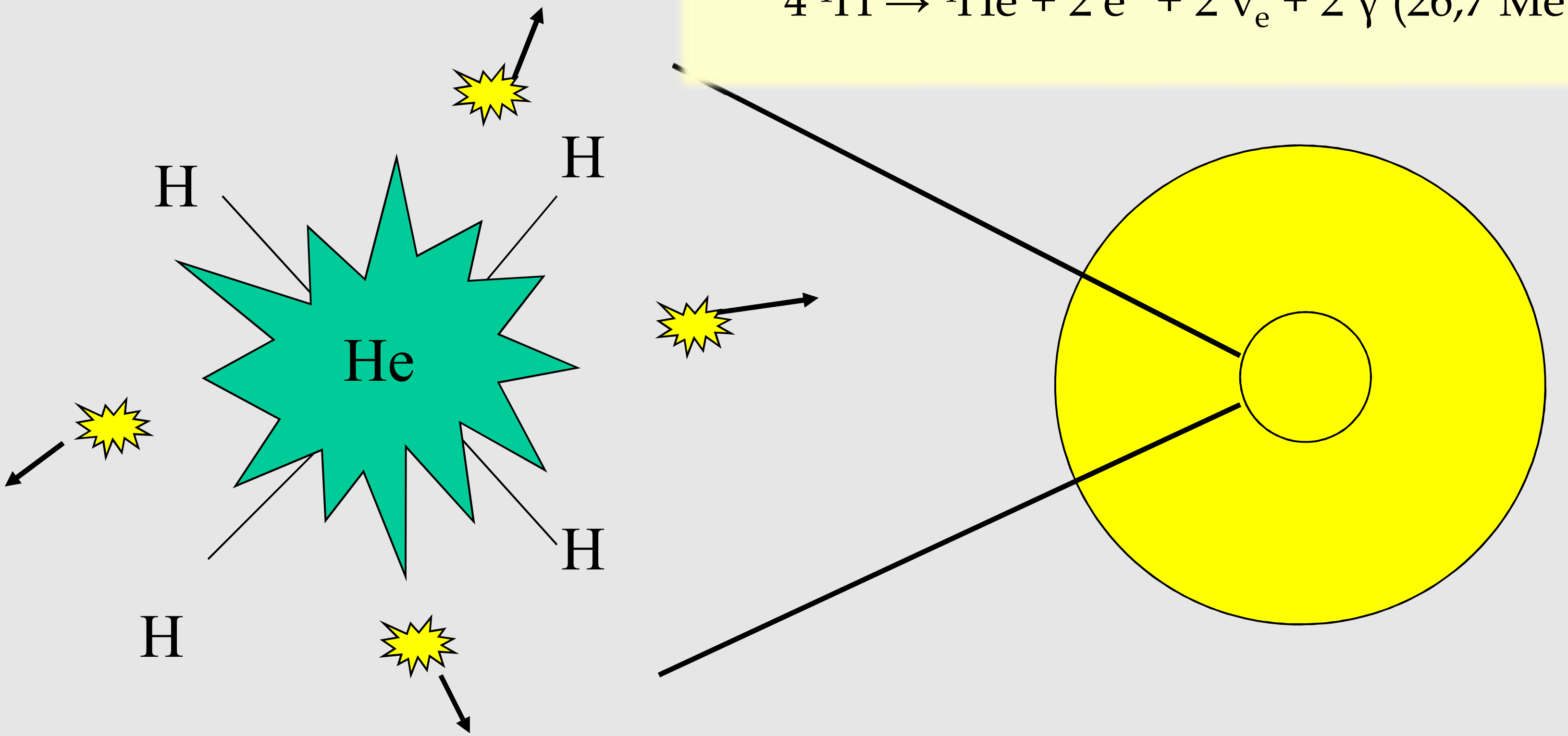
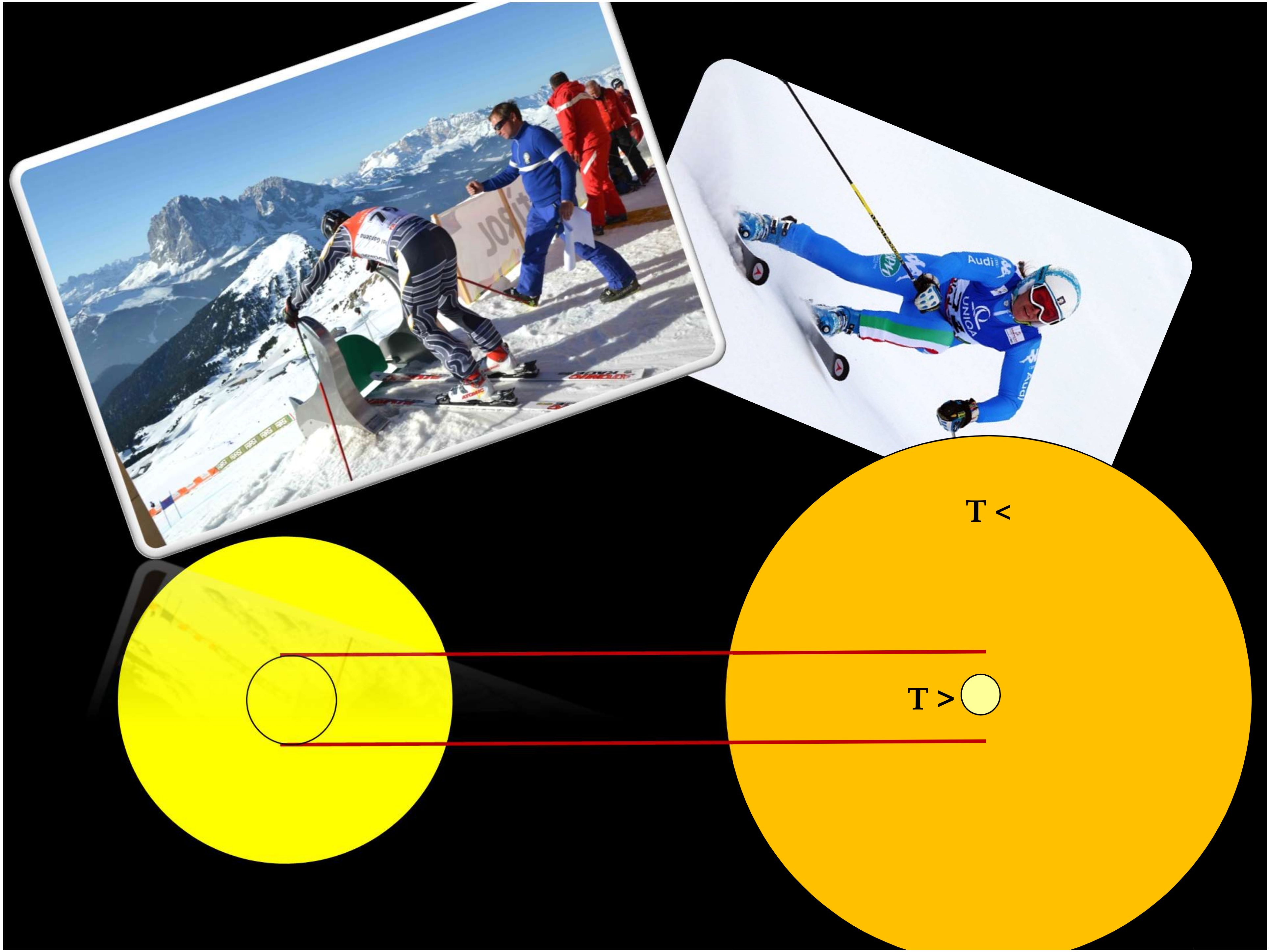
# All’interno della stella avvengono delle reazioni tra le particelle chiamate reazioni nucleari:

$4\,^{1}H \rightarrow 2\,^{2}H + 2\,e^{+} + 2\,\nu_e$ (4,0 MeV + 1,0 MeV)
$2\,^{1}H + 2\,^{2}H \rightarrow 2\,^{3}He + 2\,\gamma$ (5,5 MeV)
$2\,^{3}He \rightarrow\,^{4}He + 2\,^{1}H$ (12,9 MeV)

$4\,^{1}H \rightarrow\,^{4}He + 2\,e^{+} + 2\,\nu_e + 2\,\gamma$ (26,7 MeV)

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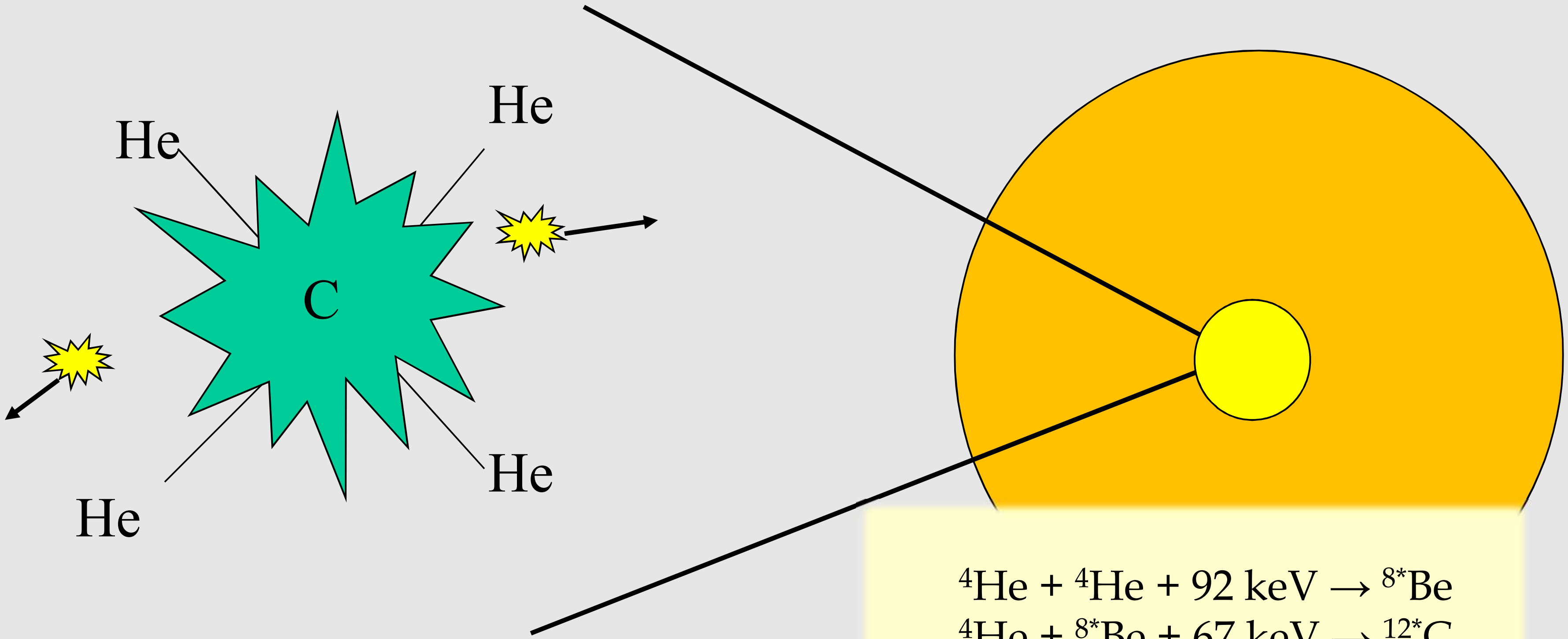
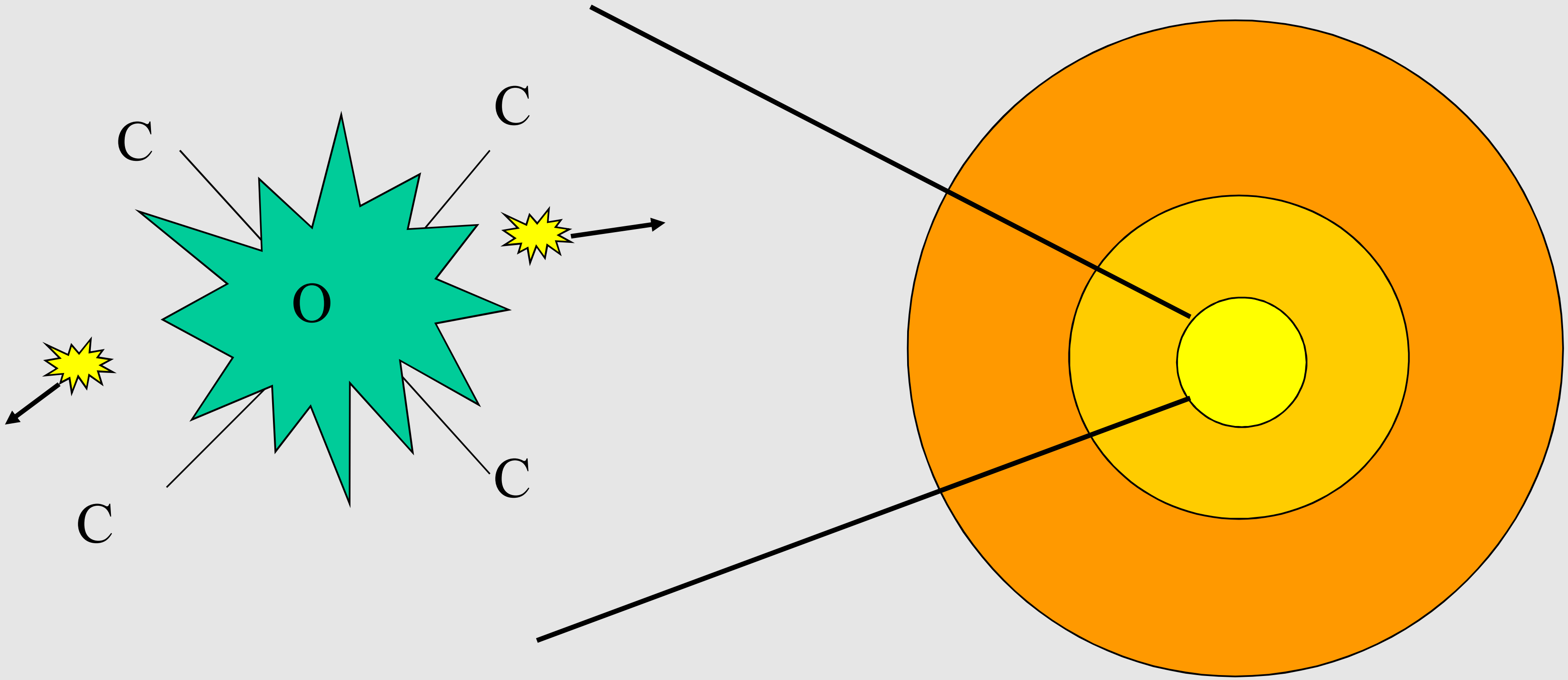
# Il Sole non andrà oltre queste reazioni nucleari e terminerà il combustibile tra miliardi di anni

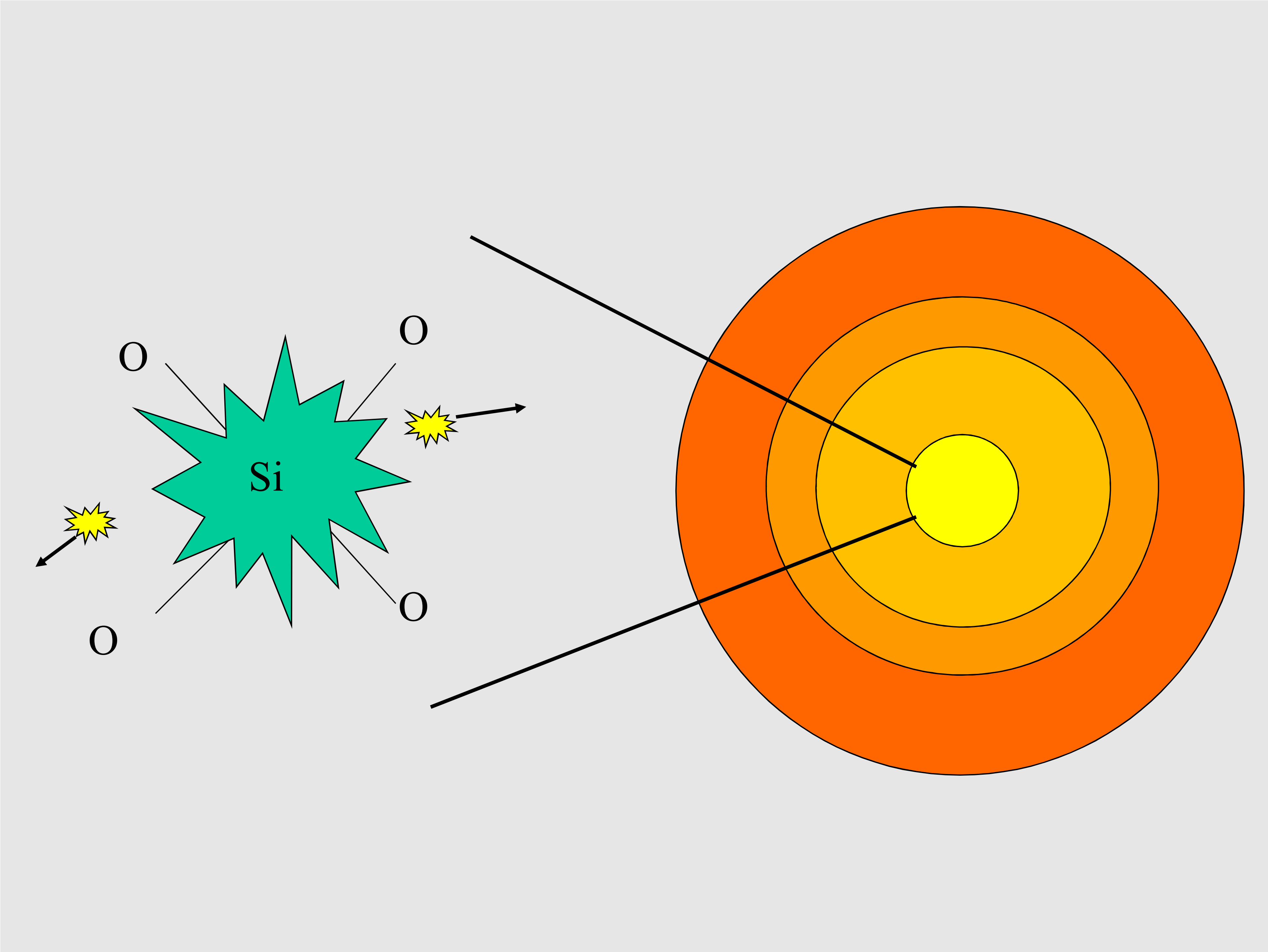



$$^{4}He + {}^{4}He + 92\ keV \rightarrow {}^{8*}Be$$
$$^{4}He + {}^{8*}Be + 67\ keV \rightarrow {}^{12*}C$$
$$^{12*}C \rightarrow {}^{12}C + \gamma + 7{,}4\ MeV$$

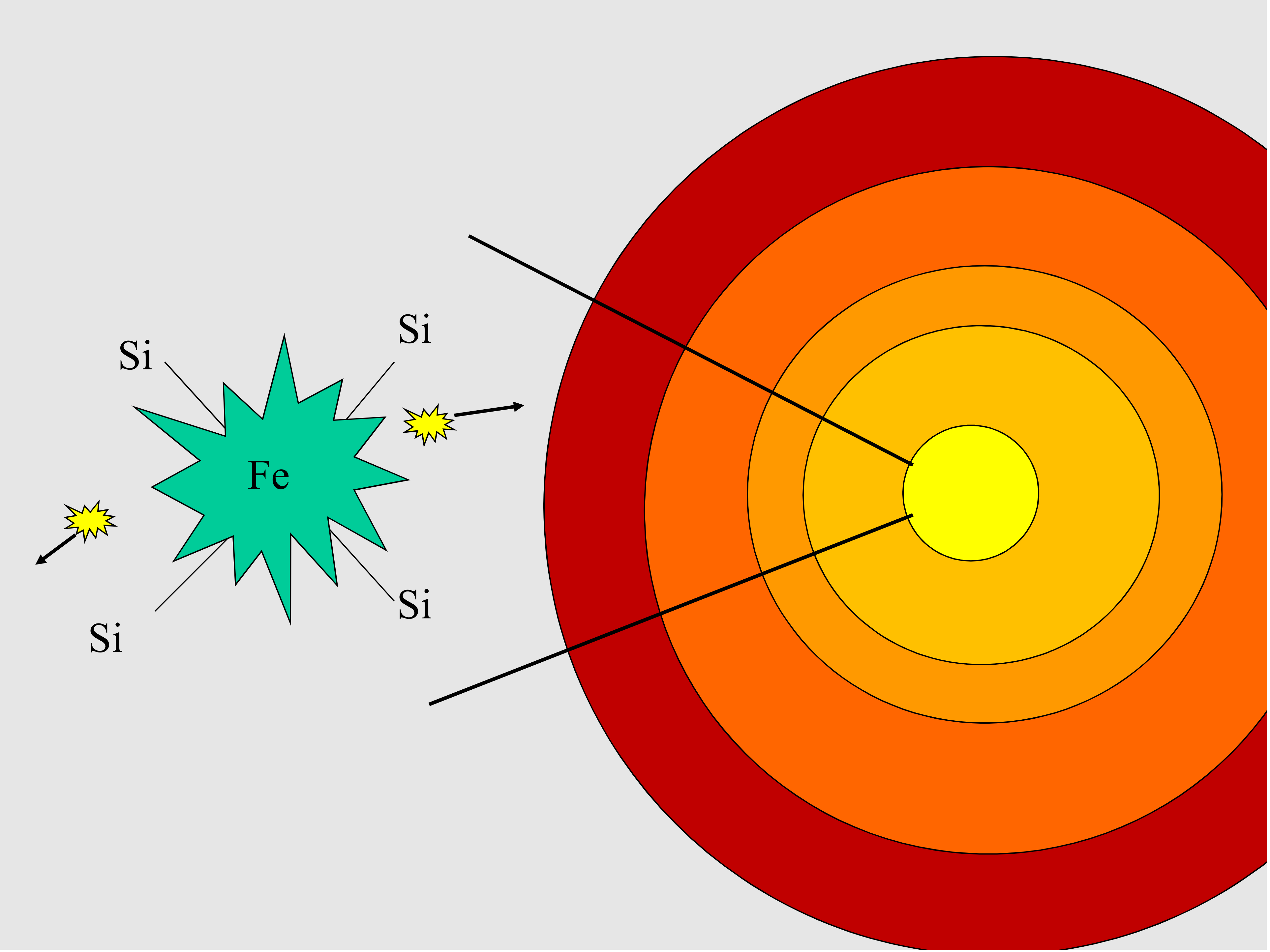
$$3\ {}^{4}He \rightarrow {}^{12}C + \gamma + 7{,}2\ MeV$$

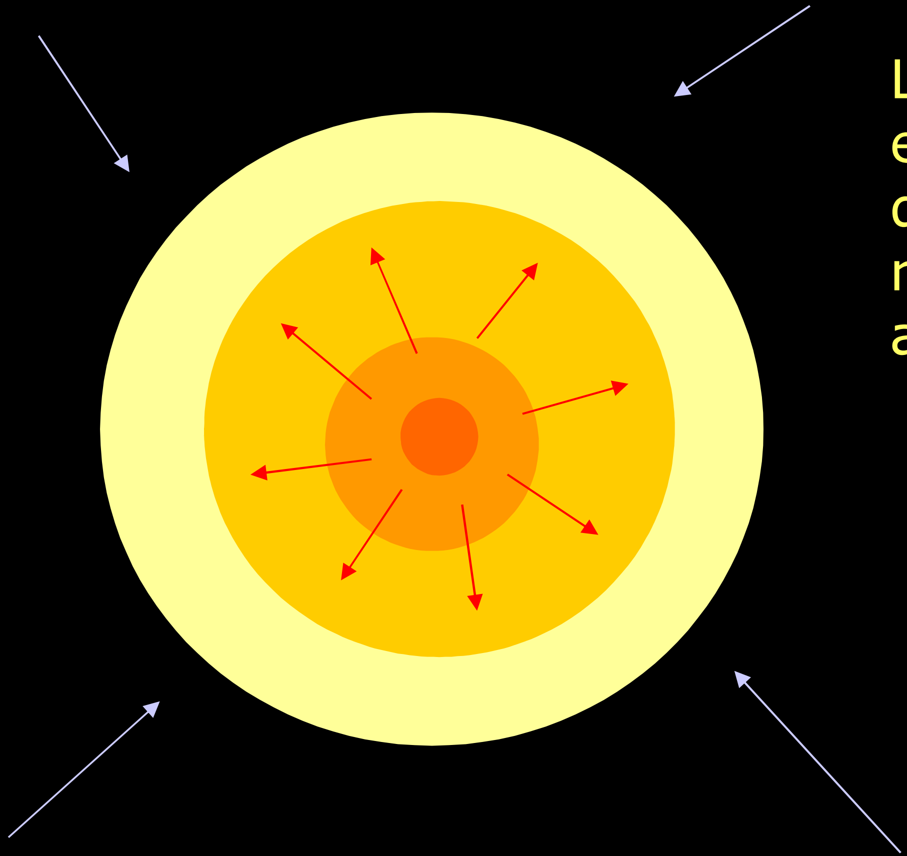
Se però la stella ha una massa > 8 volte la massa del sole





O
O
Si
O
O


Si
Si
Fe
Si
Si



La temperatura diventa così elevata che quando gli atomi di idrogeno si urtano non rimbalzano più ma si fondono assieme a formare elio

L’energia liberata durante queste reazioni aumenta la pressione del gas che controbilancia l’attrazione gravitazionale

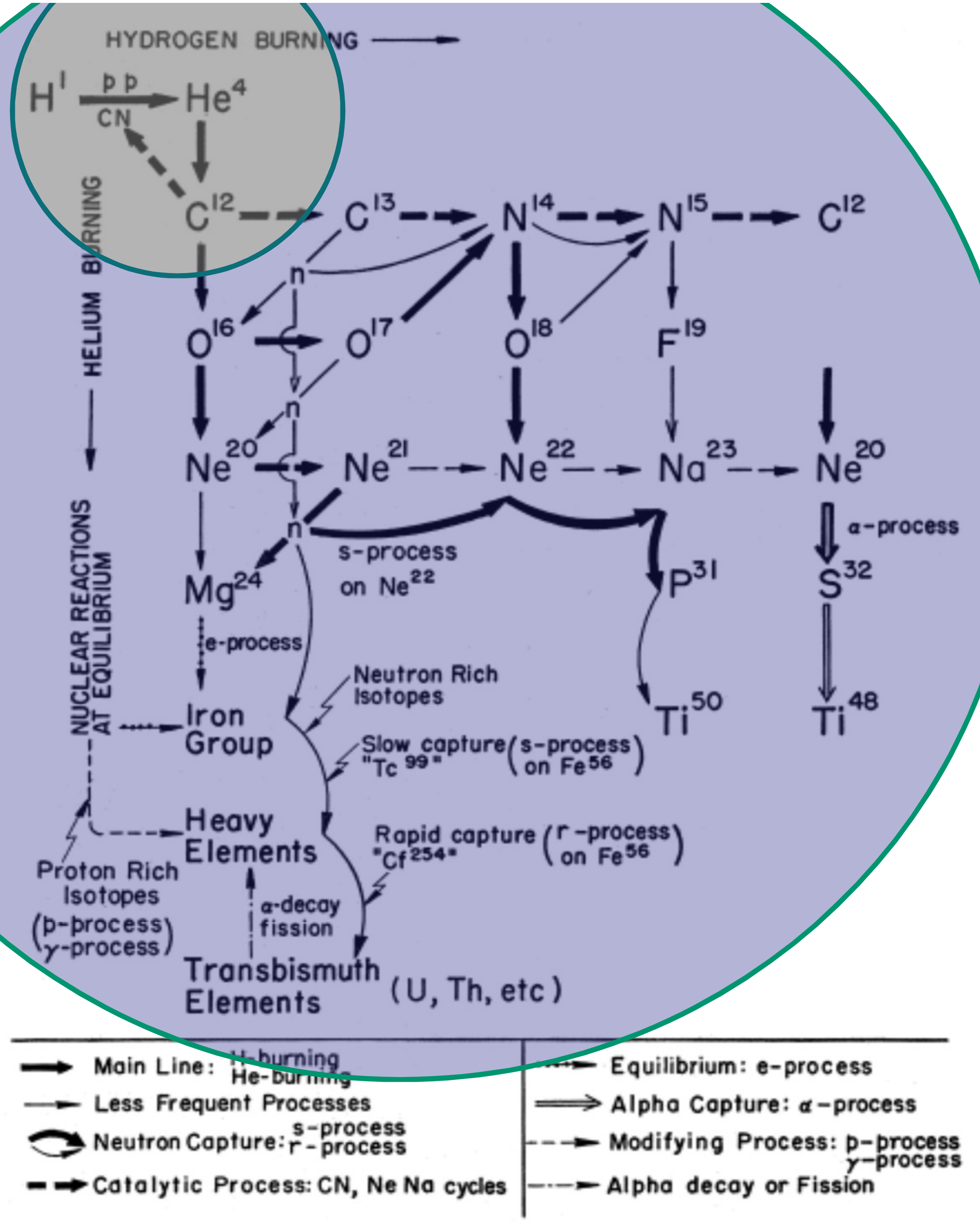
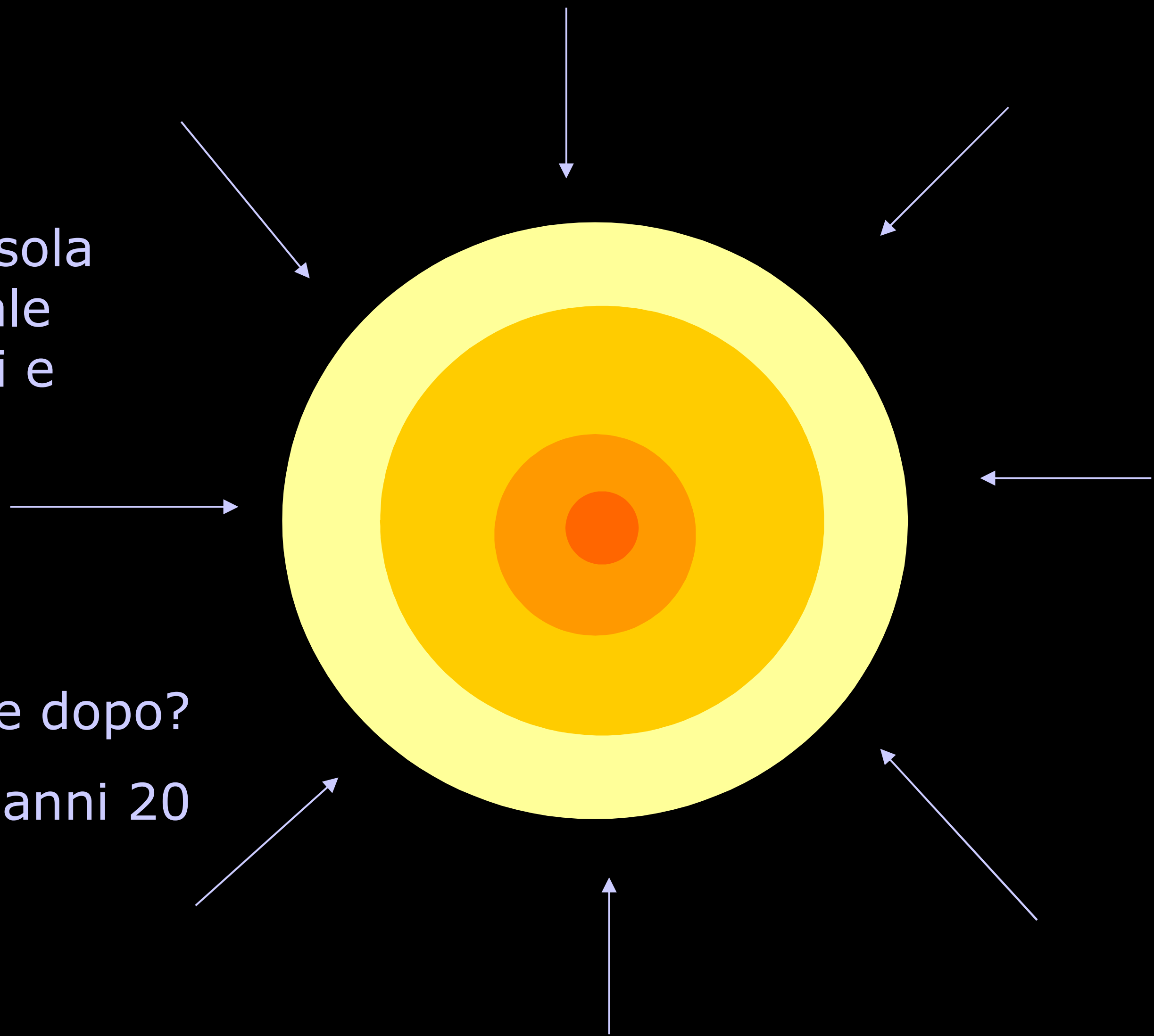



FIG. I,2. A schematic diagram of the nuclear processes by which the synthesis of the elements in stars takes place. Elements synthesized by interactions with protons (hydrogen burning) are listed horizontally. Elements synthesized by interactions with alpha particles (helium burning) and by still more complicated processes are listed vertically. The details of the production of all of the known stable isotopes of carbon, nitrogen, oxygen, fluorine, neon, and sodium are shown completely. Neutron capture processes by which the highly charged heavy elements are synthesized are indicated by curved arrows. The production of radioactive $Tc^{99}$ is indicated as an example for which there is astrophysical evidence of neutron captures at a slow rate over long periods of time in red giant stars. Similarly $Cf^{254}$, produced in supernovae, is an example of neutron synthesis at a rapid rate. The iron group is produced by a variety of nuclear reactions at equilibrium in the last stable stage of a star's evolution.

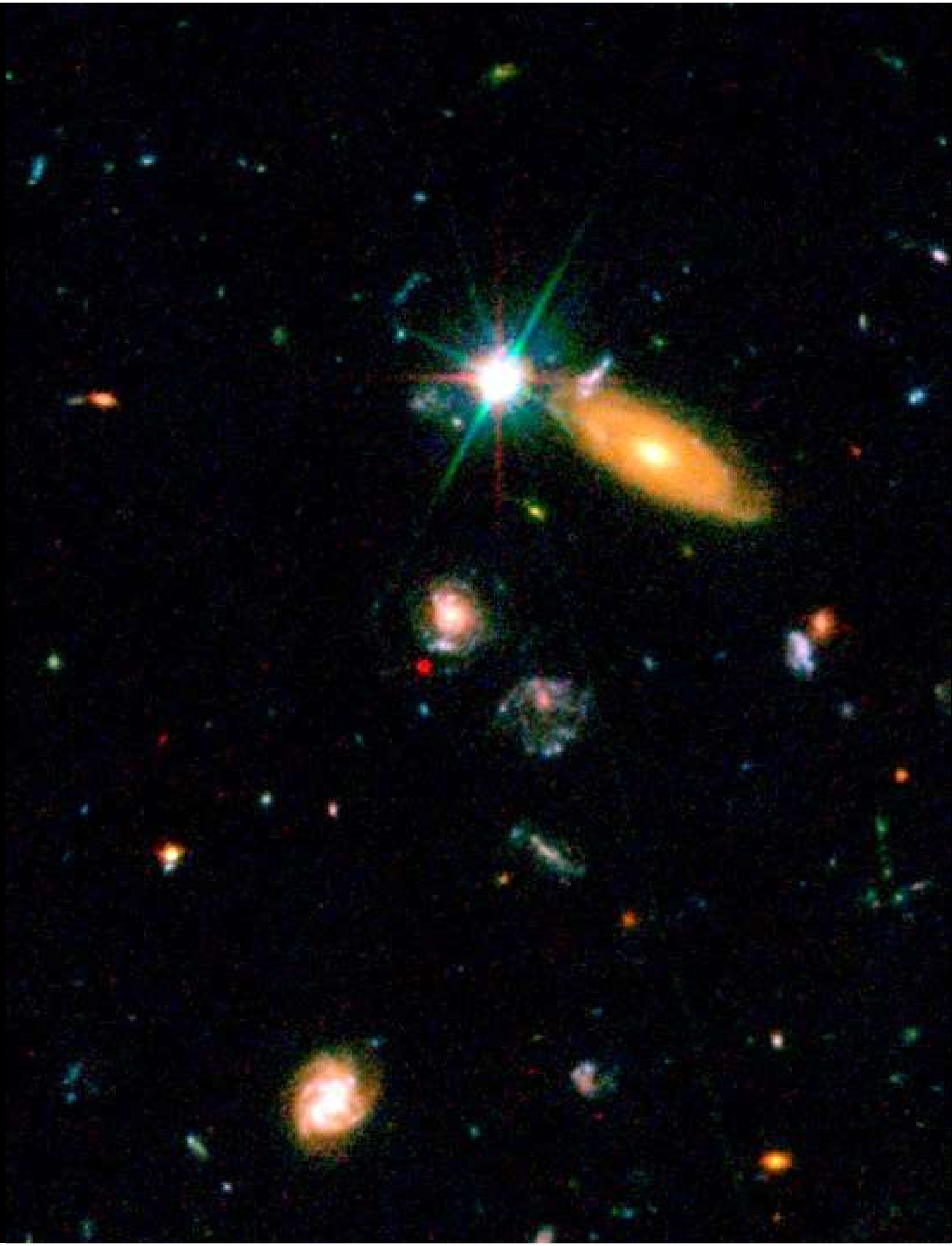
Alla fine esaurirà la riserva di idrogeno ed altri combustibili nucleari

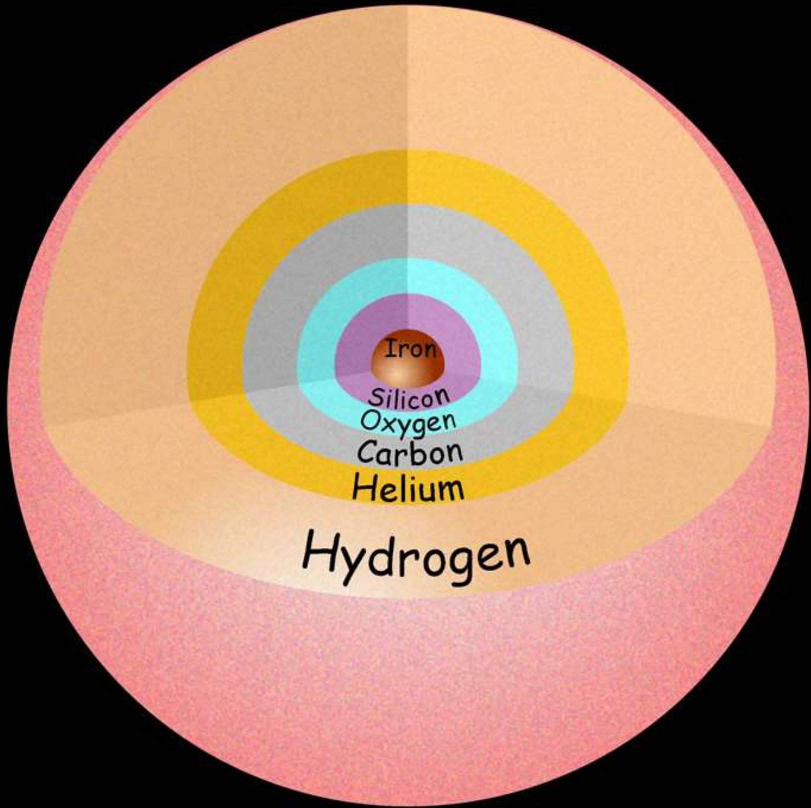
La stella in balia della sola attrazione gravitazionale comincia a raffreddarsi e contrarsi…

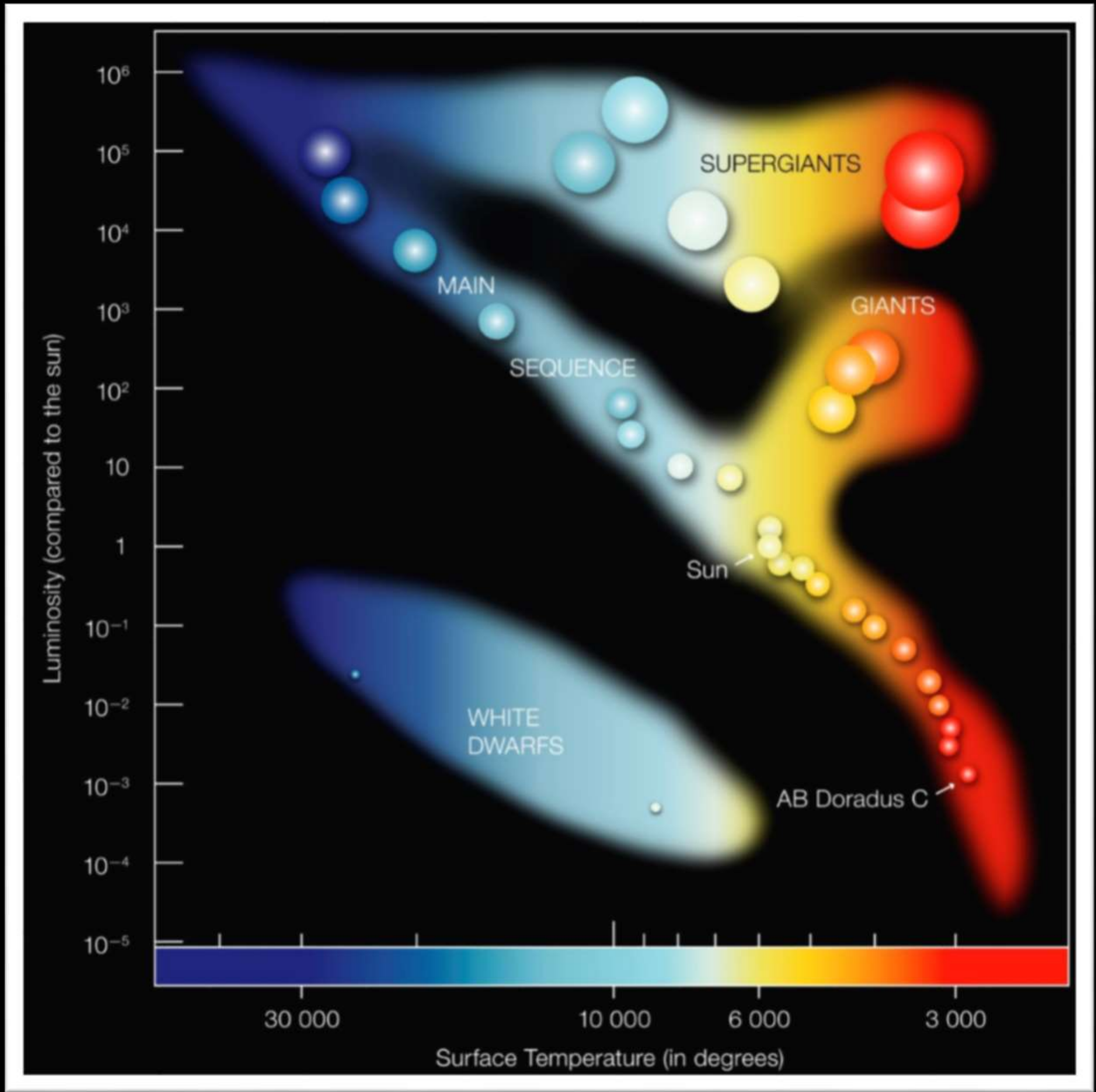


..cosa le accade dopo?

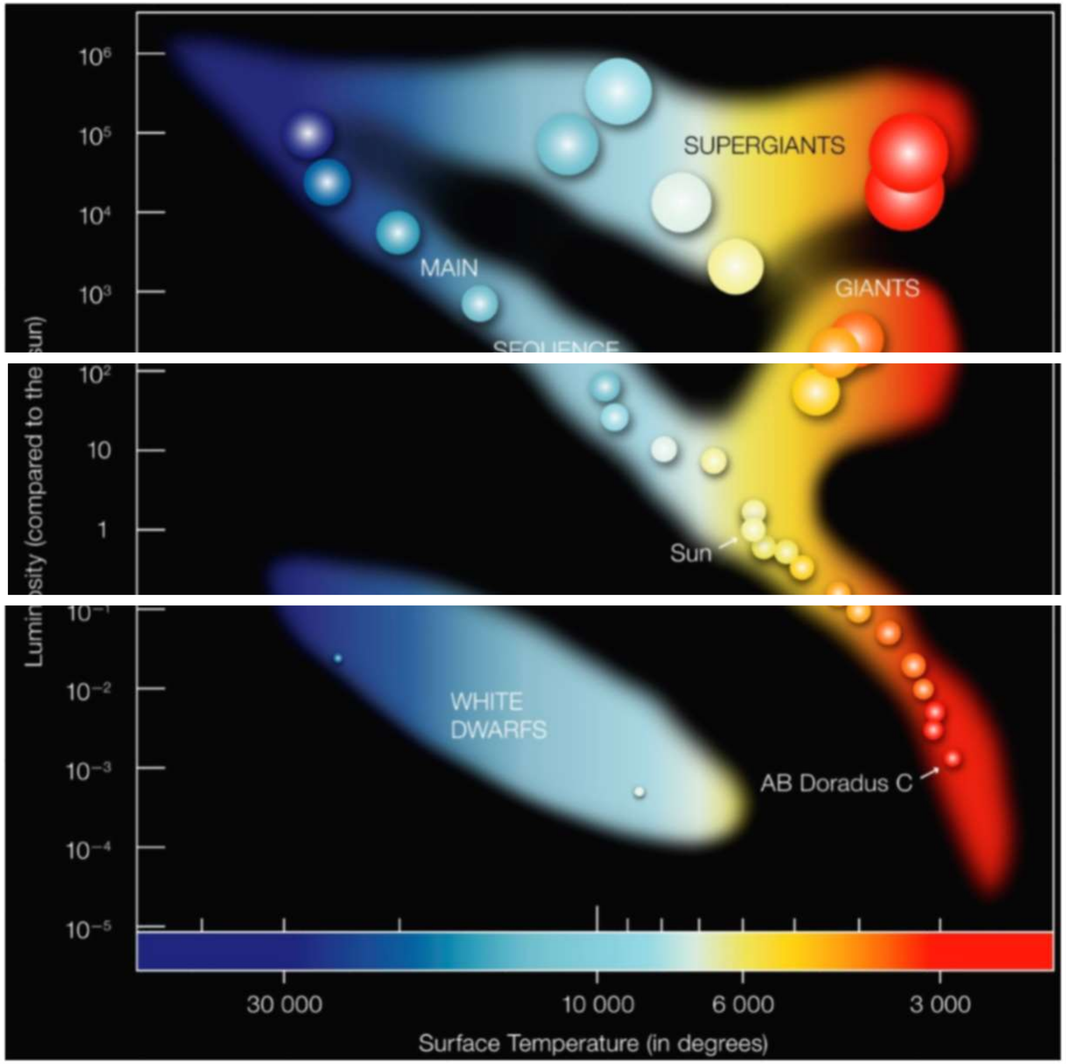
è la fine degli anni 20




Iron
Silicon
Oxygen
Carbon
Helium
Hydrogen

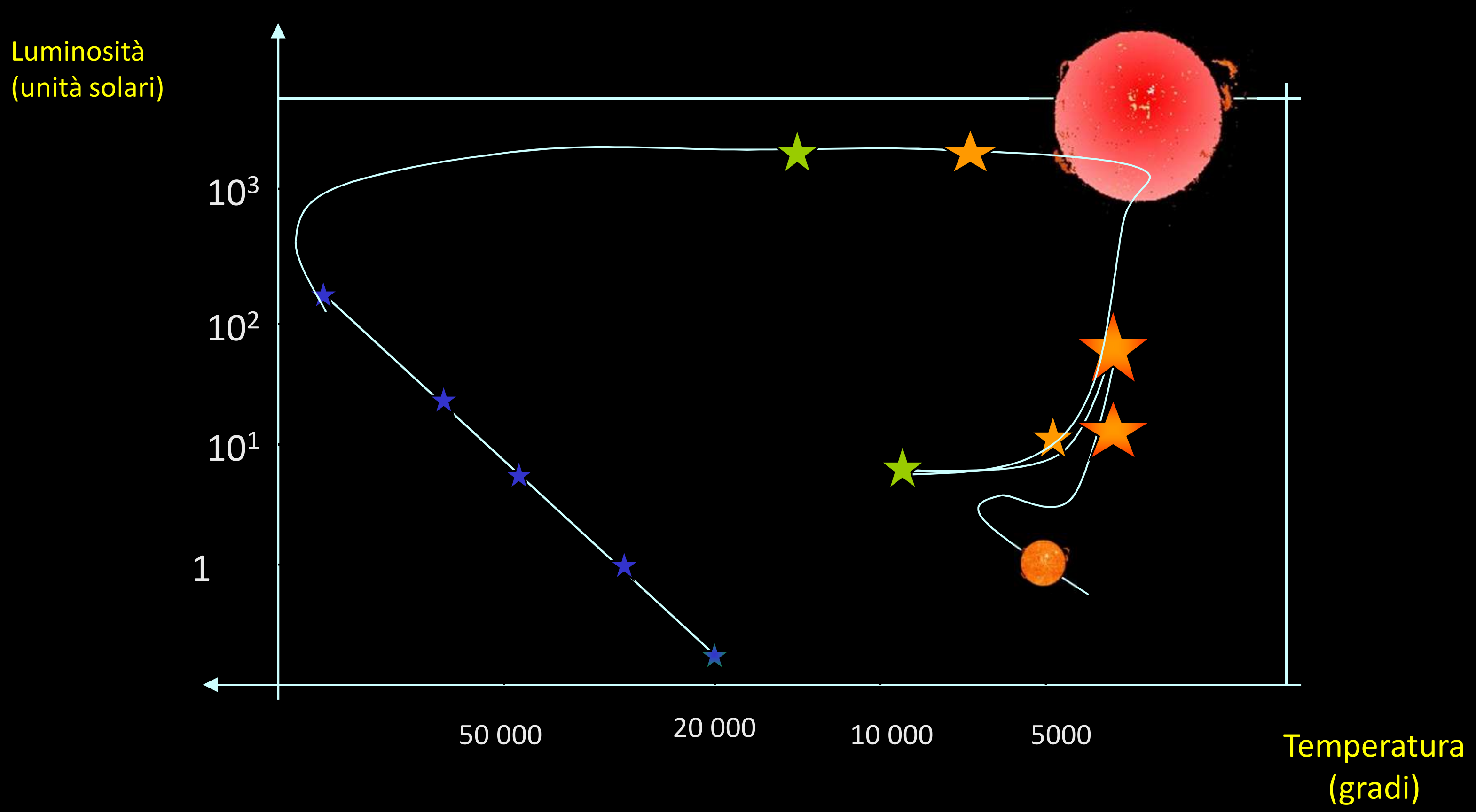


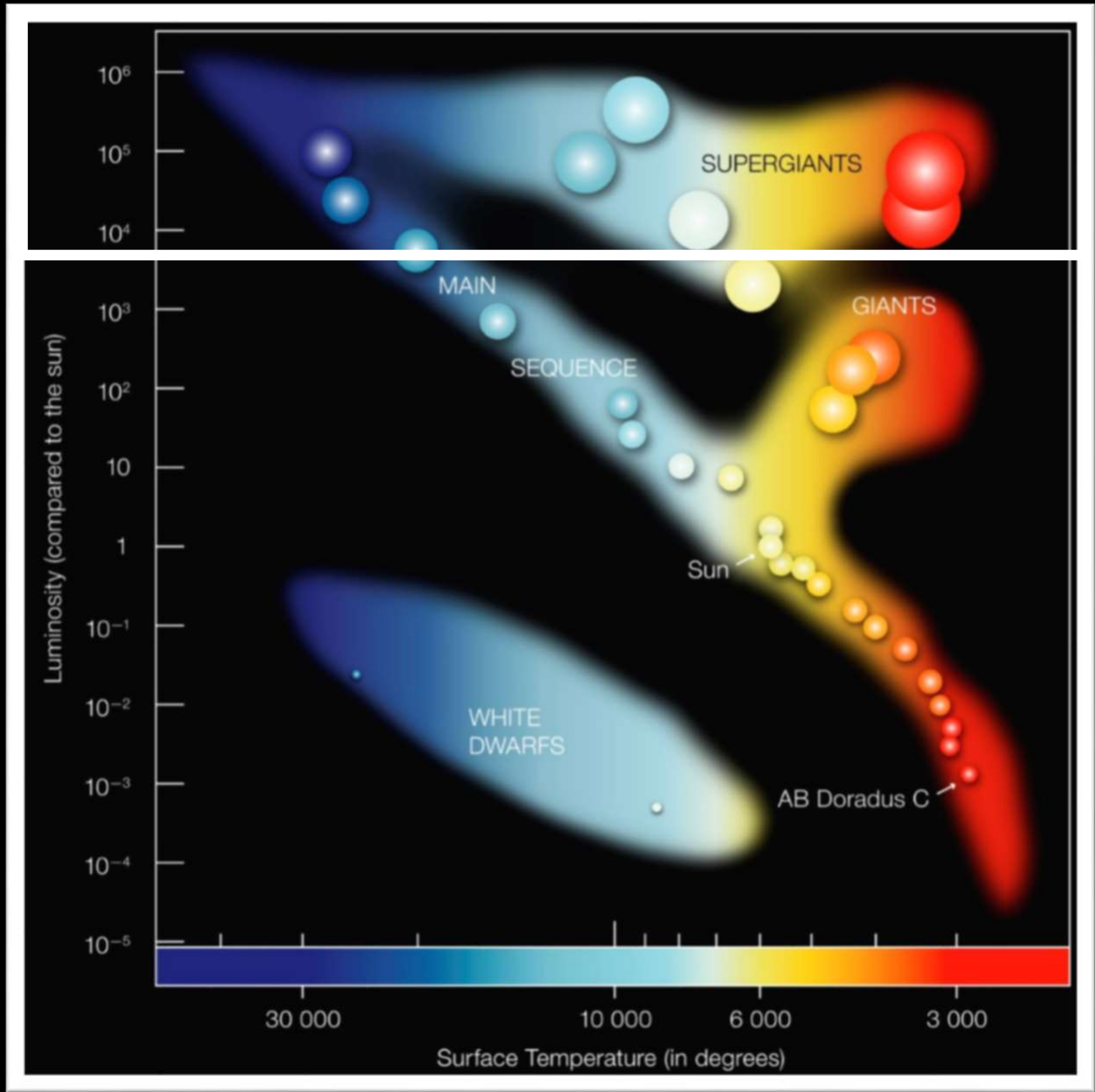
SUPERGIANTS
GIANTS
MAIN
SEQUENCE
Sun
WHITE
DWARFS
AB Doradus C
Luminosity (compared to the sun)
$10^6$
$10^5$
$10^4$
$10^3$
$10^2$
10
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
30 000
10 000
6 000
3 000
Surface Temperature (in degrees)



SUPERGIANTS
MAIN
GIANTS
Sun
WHITE DWARFS
AB Doradus C
$10^6$
$10^5$
$10^4$
$10^3$
$10^2$
10
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
30 000
10 000
6 000
3 000
Surface Temperature (in degrees)

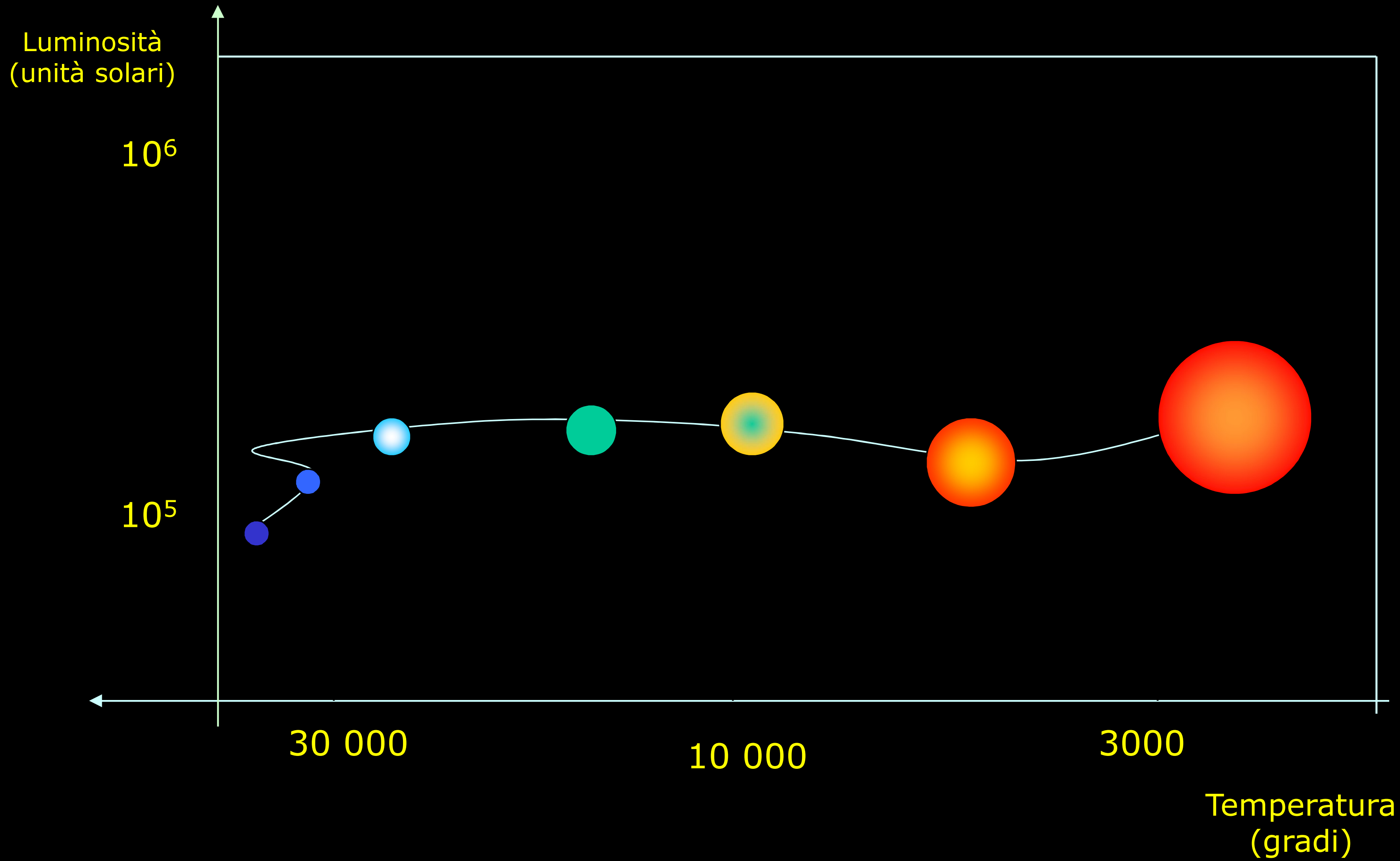
# *L'evoluzione di una stella come il Sole*





SUPERGIANTS
MAIN
SEQUENCE
GIANTS
Sun
WHITE
DWARFS
AB Doradus C
Luminosity (compared to the sun)
$10^6$
$10^5$
$10^4$
$10^3$
$10^2$
10
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
30 000
10 000
6 000
3 000
Surface Temperature (in degrees)

# *L'evoluzione di una stella di 25 masse solari*



| Massa originale (in $M_{\odot}$) | Luminosità nella SP (in $L_{\odot}$) | Durata della SP ($\times 10^{9}$ anni) | Prodotto finale della fusione | Fenomeno terminale | Massa espulsa (in $M_{\odot}$) | Natura del residuo | Massa del residuo (in $M_{\odot}$) | Densità del residuo ($\times 10^{3}$ kg $m^{-3}$) | Raggio del residuo (in m) | Accel. di gravità (in m $s^{-2}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 10 000 | 0,006 | ferro | supernova tipo Ib | 24 | buco nero | 6 | $3 \times 10^{15}$ | 6192,21 | $5,19 \times 10^{12}$ |
| 10 | 1 000 | 0,01 | silicio | supernova tipo II | 8,5 | stella di neutroni | 1,5 | $5 \times 10^{14}$ | 17861,44 | $2,5 \times 10^{12}$ |
| 3 | 100 | 0,30 | ossigeno | nebulosa planetaria | 2,2 | nana bianca | 0,8 | $2 \times 10^{7}$ | $2,67 \times 10^{6}$ | $1,49 \times 10^{7}$ |
| 1 | 1 | 10 | carbonio | nebulosa planetaria | 0,3 | nana bianca | 0,7 | $10^{7}$ | $3,22 \times 10^{6}$ | $8,99 \times 10^{6}$ |
| 0,3 | 0,004 | 800 | elio | vento stellare | 0,01 | nana bianca | 0,3 | $10^{6}$ | $5,22 \times 10^{6}$ | $1,46 \times 10^{6}$ |