Stellar evolution
നക്ഷത്രപരിണാമം

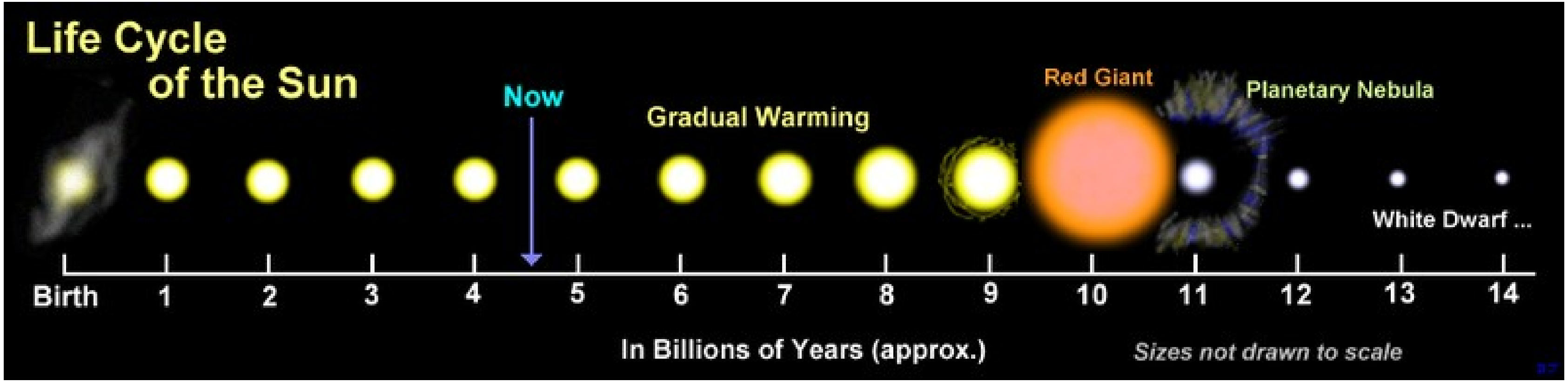
KSSP – കേരള ശാസ്ത്രസാഹിത്യ പരിഷത്ത്.

When is a star born?

A star is born when nuclear fusion begins in a gaseous cloud under gravitational compression.

When is a star dead?

A star is dead when nuclear fusion stops.



സൂര്യൻ –

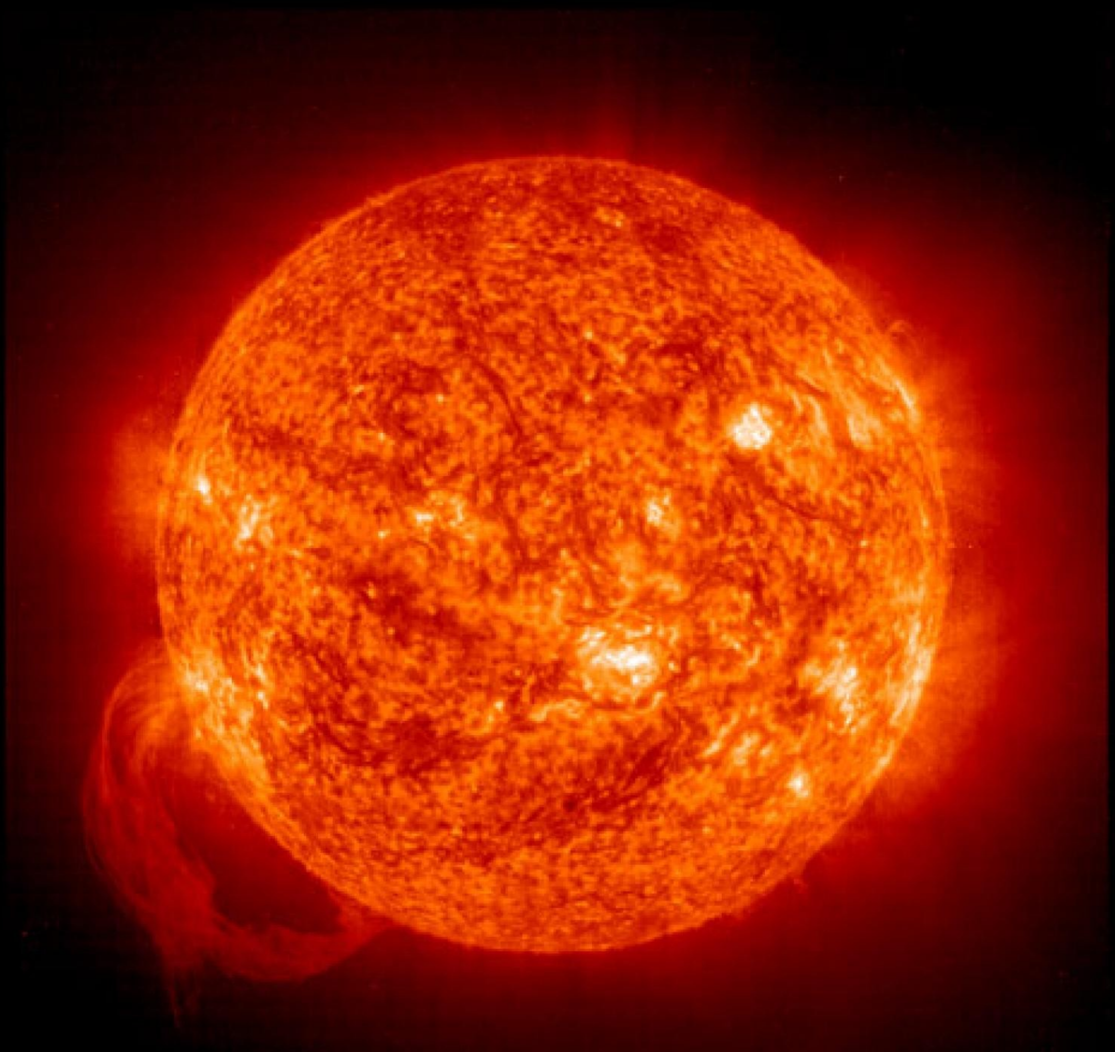
450 കോടി വർഷമായി പ്രകാശം

ചൊരിഞ്ഞു കൊണ്ടിരിക്കുന്നു.

ഇനിയും ഒരു 500 കോടി വർഷം

ഇതു തുടരുമെന്ന് ശാസ്ത്രജ്ഞർ

കണക്കാക്കുന്നു.



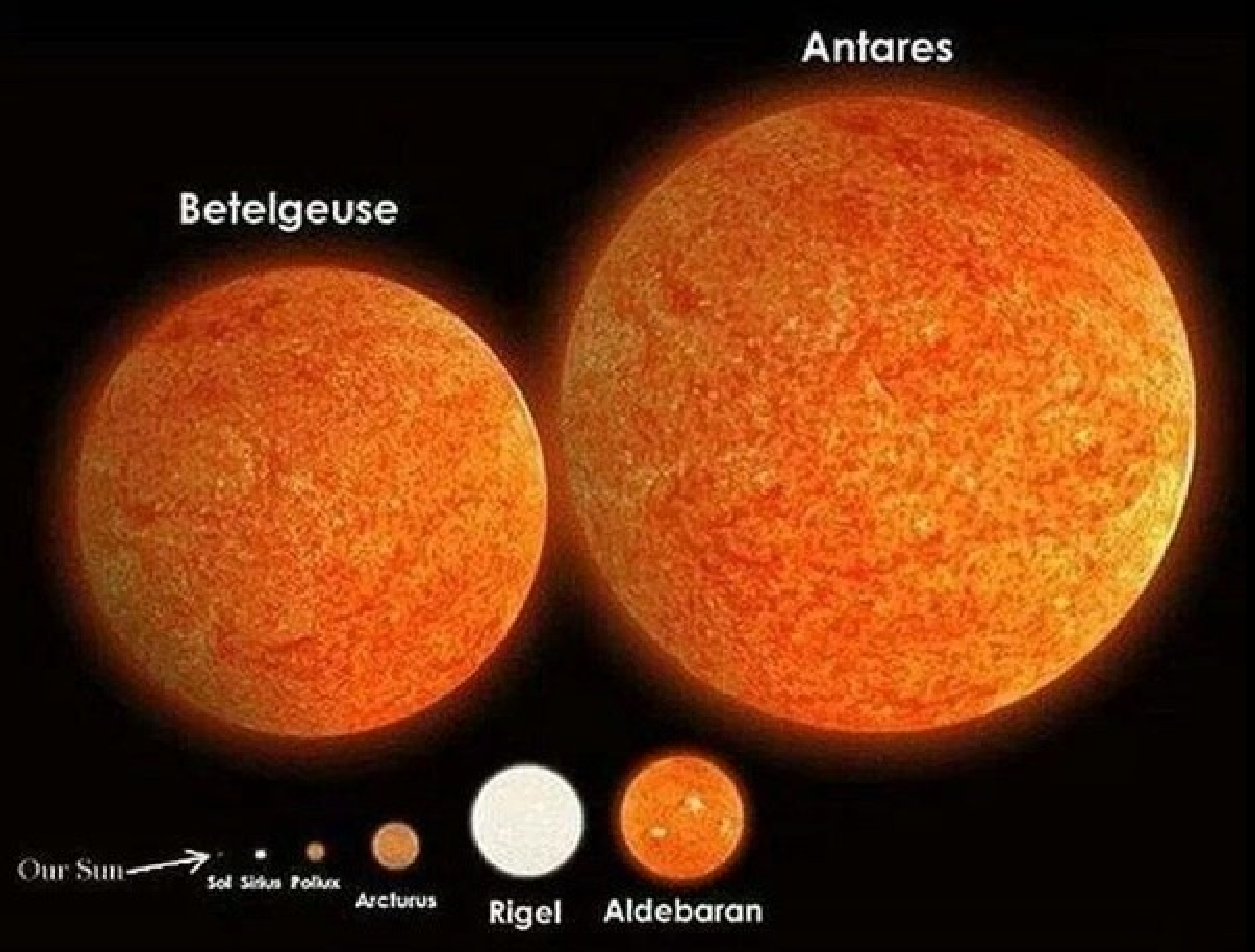
സൂര്യന്റെ വ്യാസം ഭൂമിയുടേതിന്റെ 100 ഇരട്ടിയിലധികം.

വ്യാപ്തം 1,30,000 ഇരട്ടി.

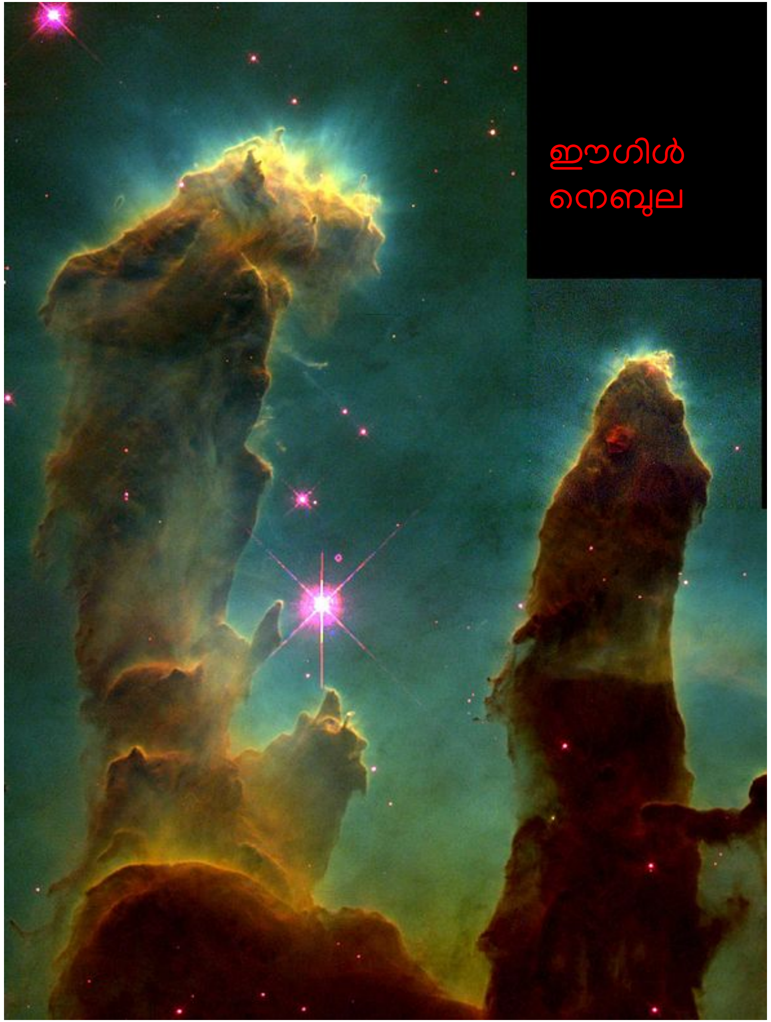
Total power output of Sun 3.8×10^{26} W.

Every second 43 lakh tons of mass get converted to energy.

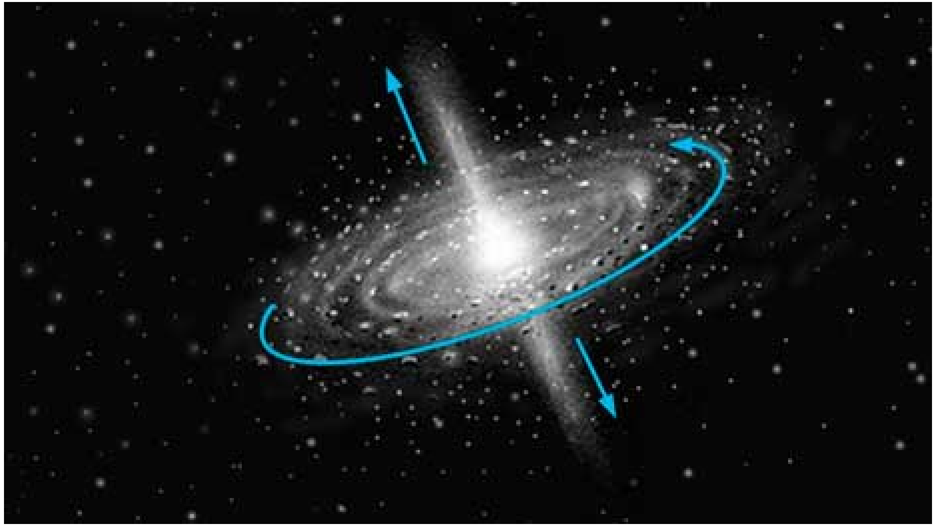
Earth's surface receives 1400 watts of power per square metre at noon.


Antares
Betelgeuse
Our Sun
Sol
Sirius
Pollux
Arcturus
Rigel
Aldebaran

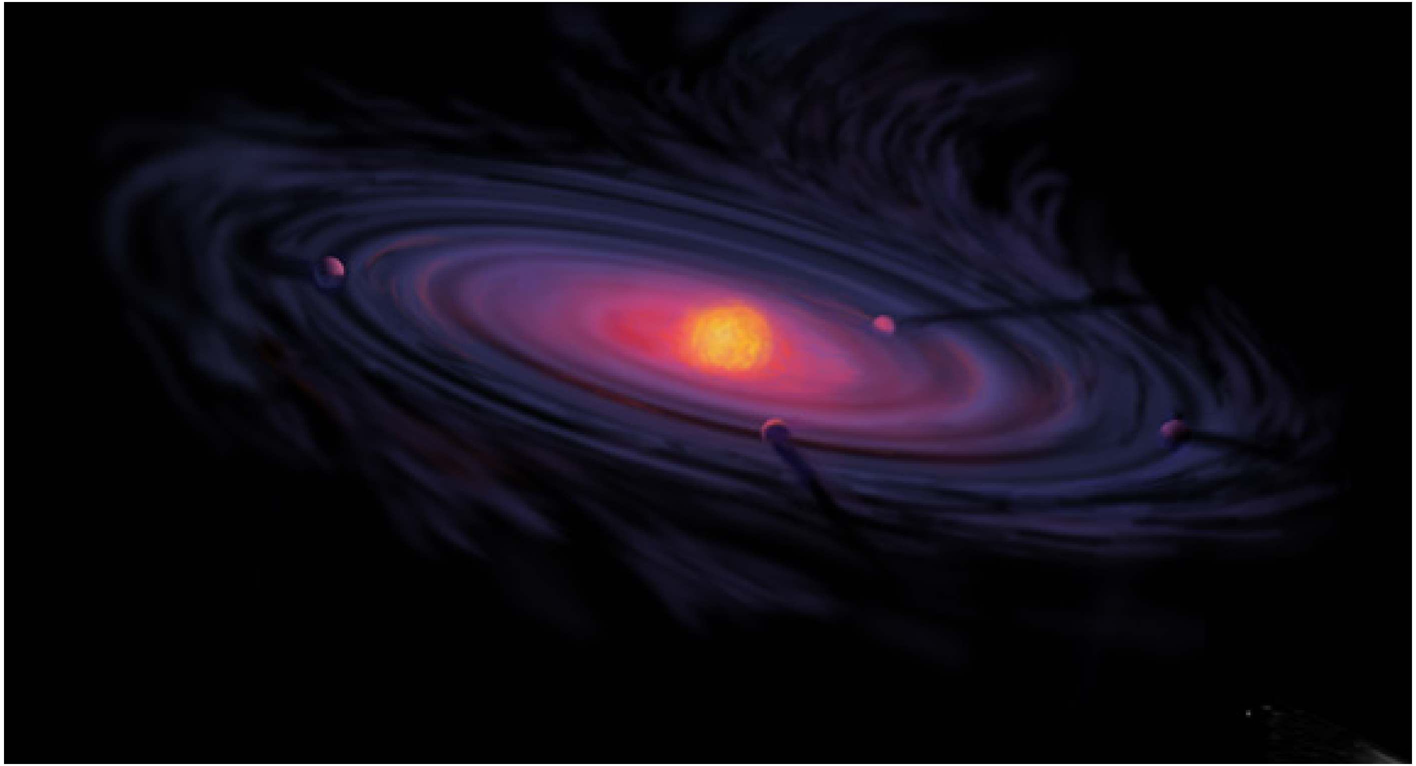

ഒറിയോൺ നെബുല


ഈഗിൾ
നെബുല

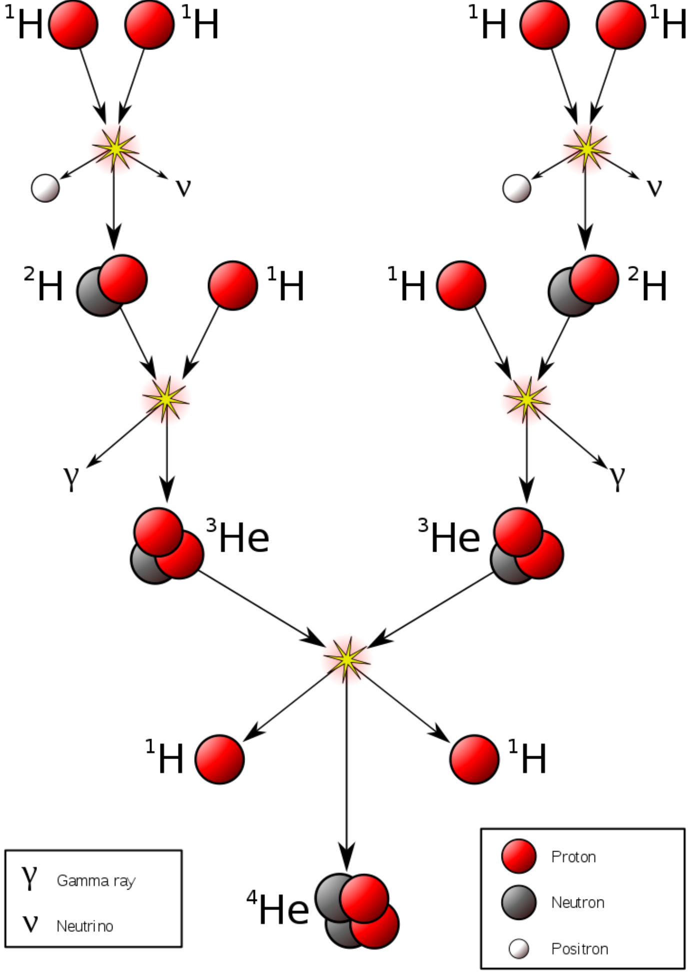
Protostar പ്രാഗ് നക്ഷത്രം



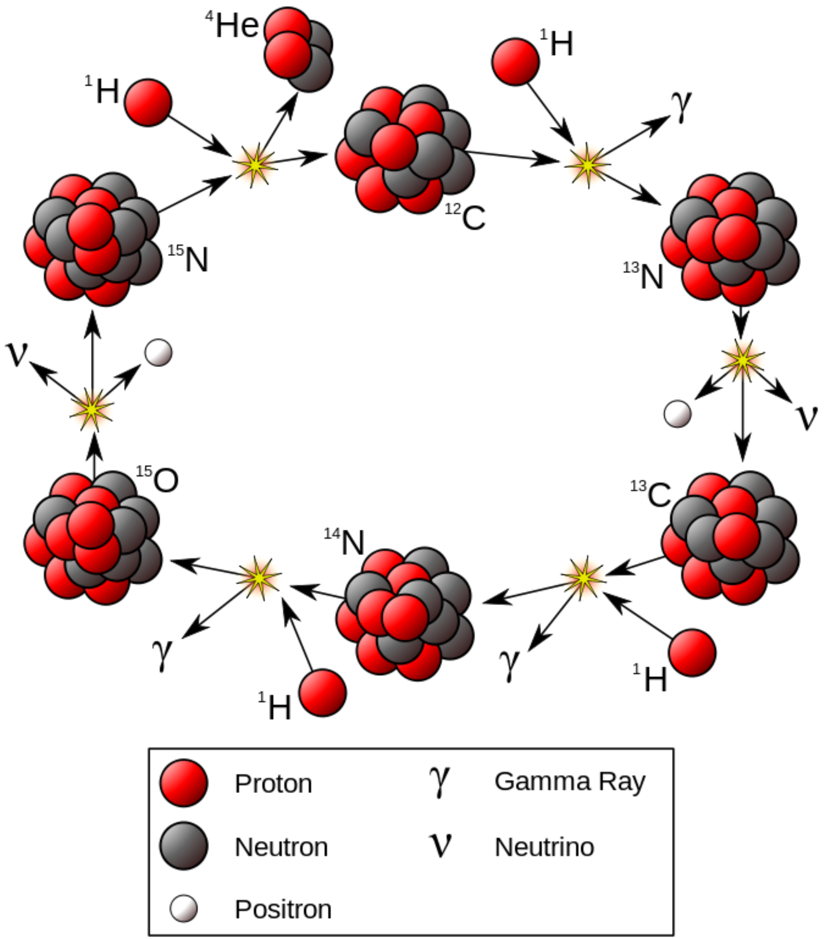
Protoplanetary disk



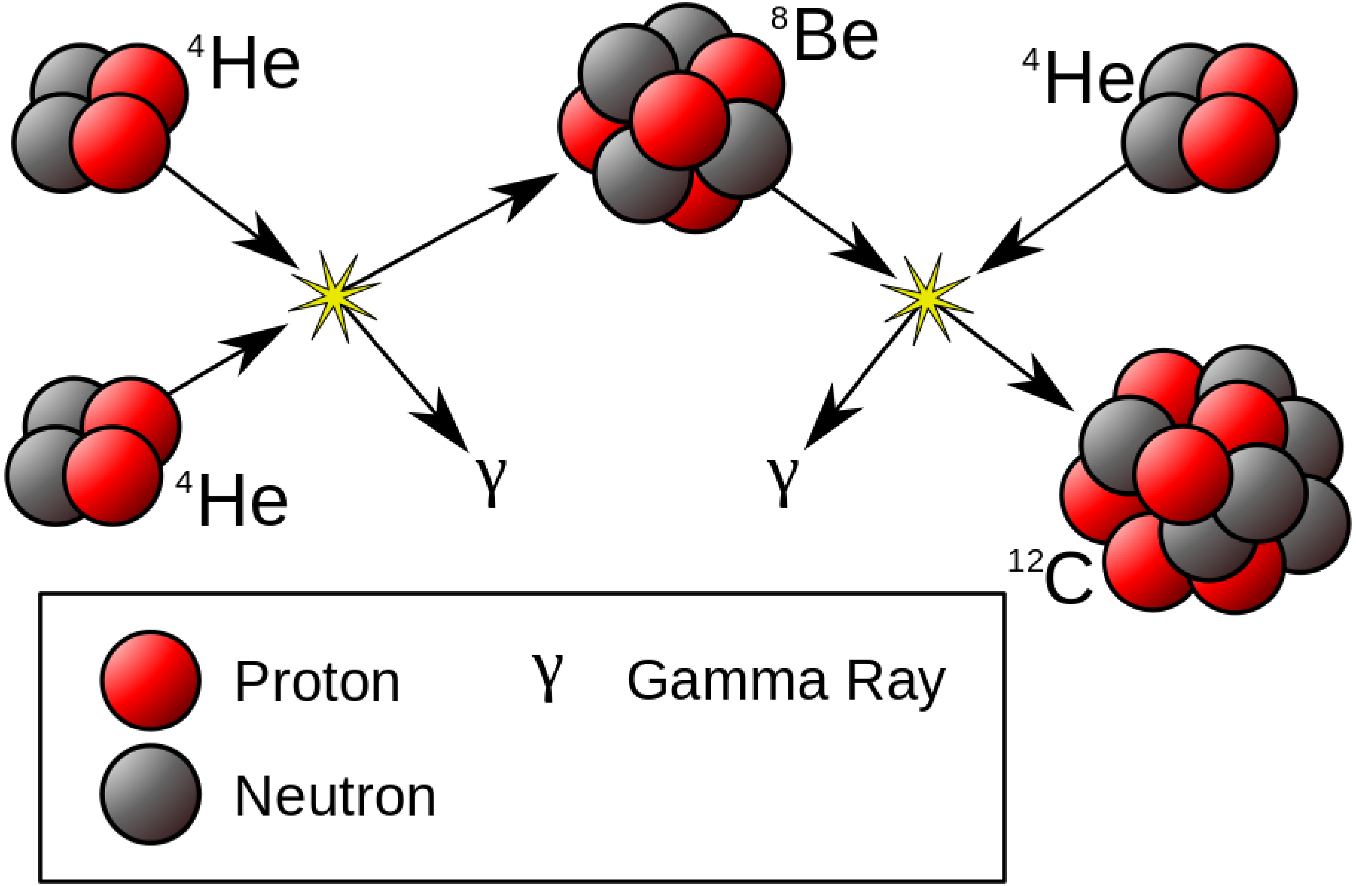
കാർത്തിക
കൂട്ടത്തിലെ
നക്ഷത്രങ്ങൾ
ഇവയെല്ലാം
10 കോടിയിൽ താഴെ
വർഷം പ്രായമുള്ളവ.



P - P ചക്രം

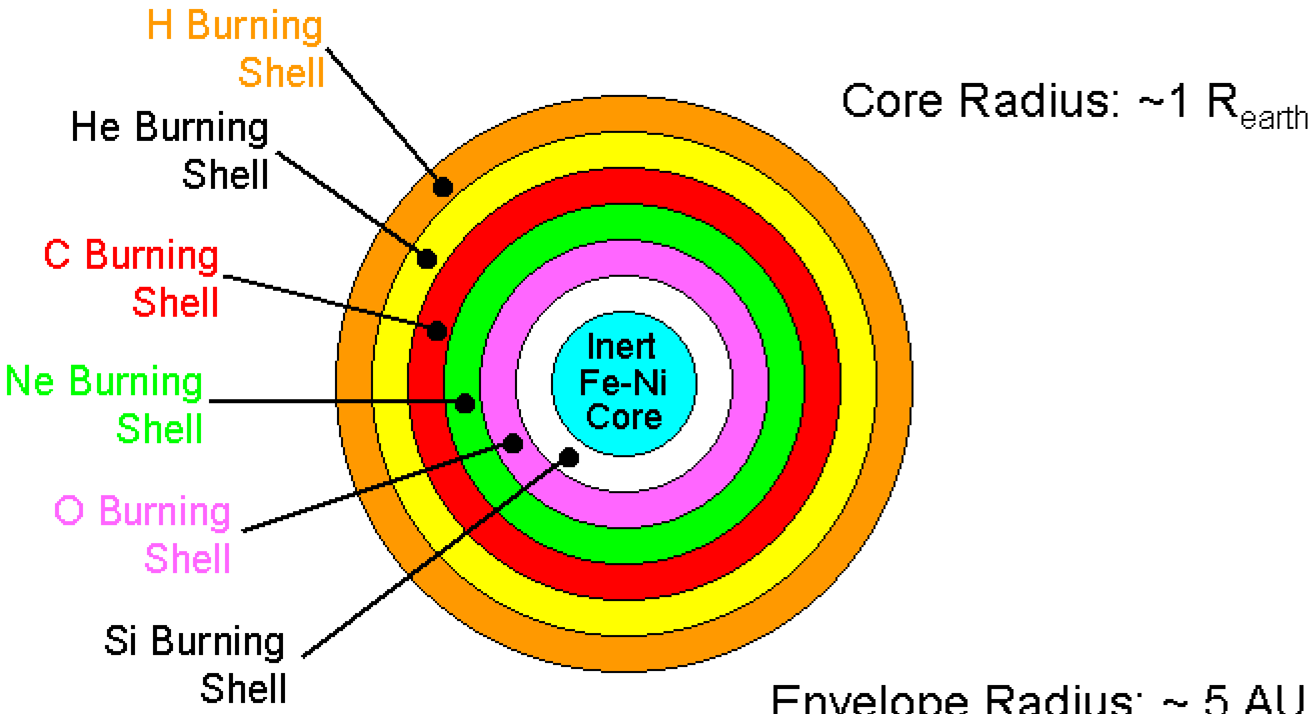


CNO ചക്രം

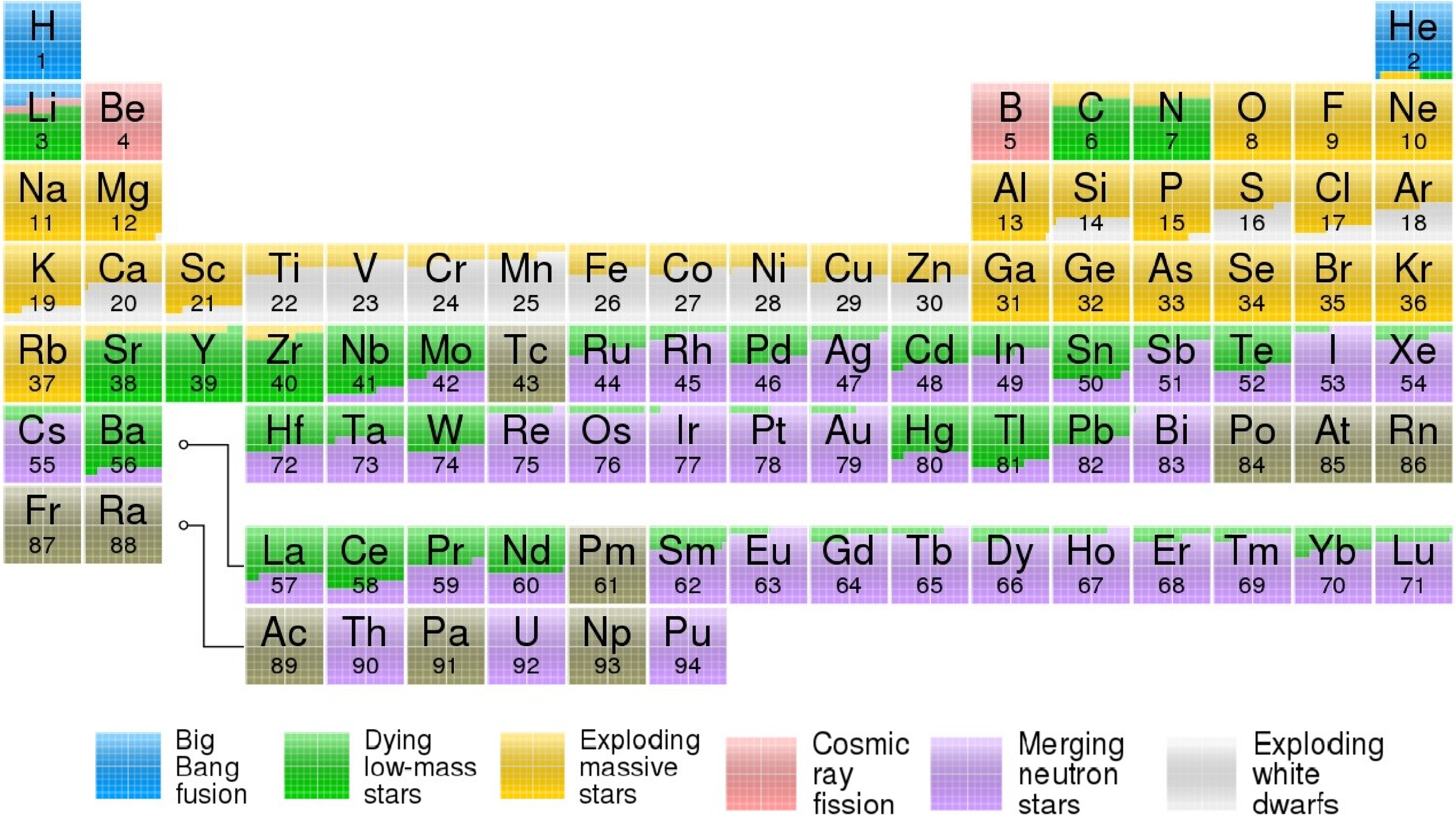


^{4}He
^{4}He
^{8}Be
^{4}He
^{12}C
γ
γ
Proton
Neutron
γ Gamma Ray

Core of a massive star at the end of Silicon Burning:

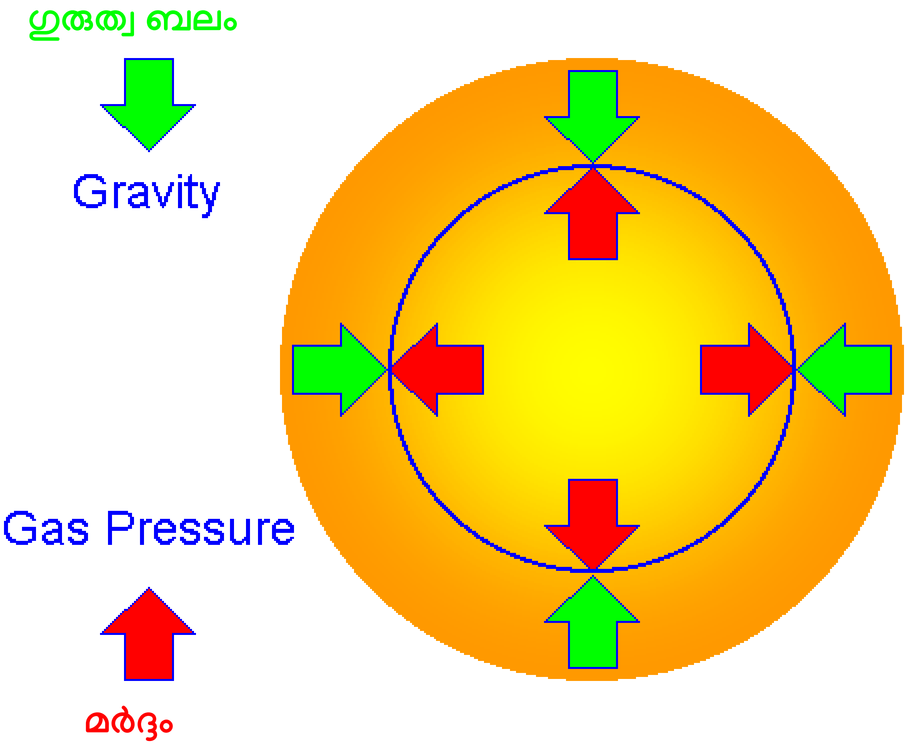


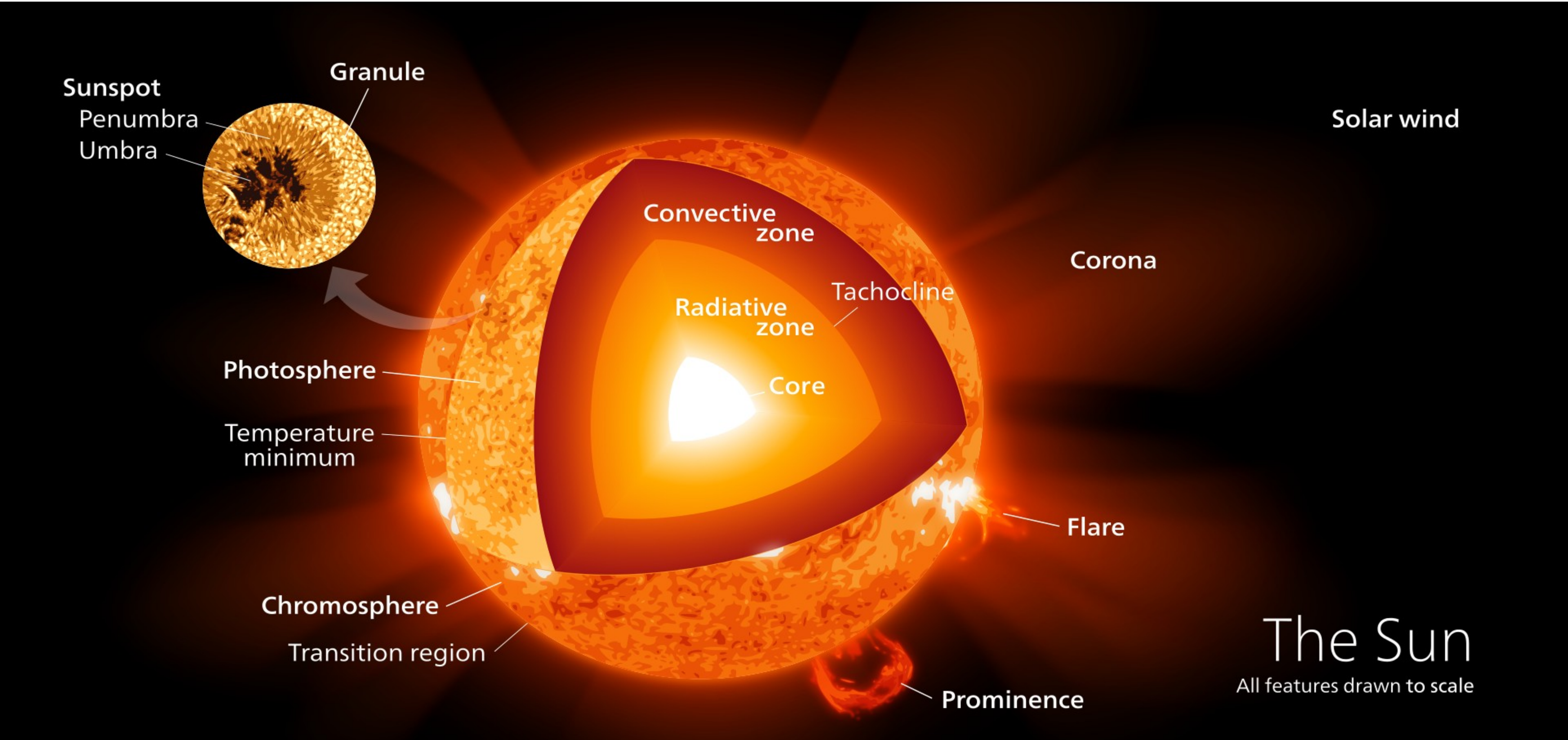
$$^{12}_{6}C + ^{4}_{2}He \longrightarrow ^{16}_{8}O + \gamma \qquad E = 7.16 \text{ MeV}$$
$$^{16}_{8}O + ^{4}_{2}He \longrightarrow ^{20}_{10}Ne + \gamma \qquad E = 4.73 \text{ MeV}$$
$$^{20}_{10}Ne + ^{4}_{2}He \longrightarrow ^{24}_{12}Mg + \gamma \qquad E = 9.32 \text{ MeV}$$
$$^{24}_{12}Mg + ^{4}_{2}He \longrightarrow ^{28}_{14}Si + \gamma \qquad E = 9.98 \text{ MeV}$$
$$^{28}_{14}Si + ^{4}_{2}He \longrightarrow ^{32}_{16}S + \gamma \qquad E = 6.95 \text{ MeV}$$
$$^{32}_{16}S + ^{4}_{2}He \longrightarrow ^{36}_{18}Ar + \gamma \qquad E = 6.64 \text{ MeV}$$
$$^{36}_{18}Ar + ^{4}_{2}He \longrightarrow ^{40}_{20}Ca + \gamma \qquad E = 7.04 \text{ MeV}$$
$$^{40}_{20}Ca + ^{4}_{2}He \longrightarrow ^{44}_{22}Ti + \gamma \qquad E = 5.13 \text{ MeV}$$
$$^{44}_{22}Ti + ^{4}_{2}He \longrightarrow ^{48}_{24}Cr + \gamma \qquad E = 7.70 \text{ MeV}$$
$$^{48}_{24}Cr + ^{4}_{2}He \longrightarrow ^{52}_{26}Fe + \gamma \qquad E = 7.94 \text{ MeV}$$
$$^{52}_{26}Fe + ^{4}_{2}He \longrightarrow ^{56}_{28}Ni + \gamma \qquad E = 8.00 \text{ MeV}$$

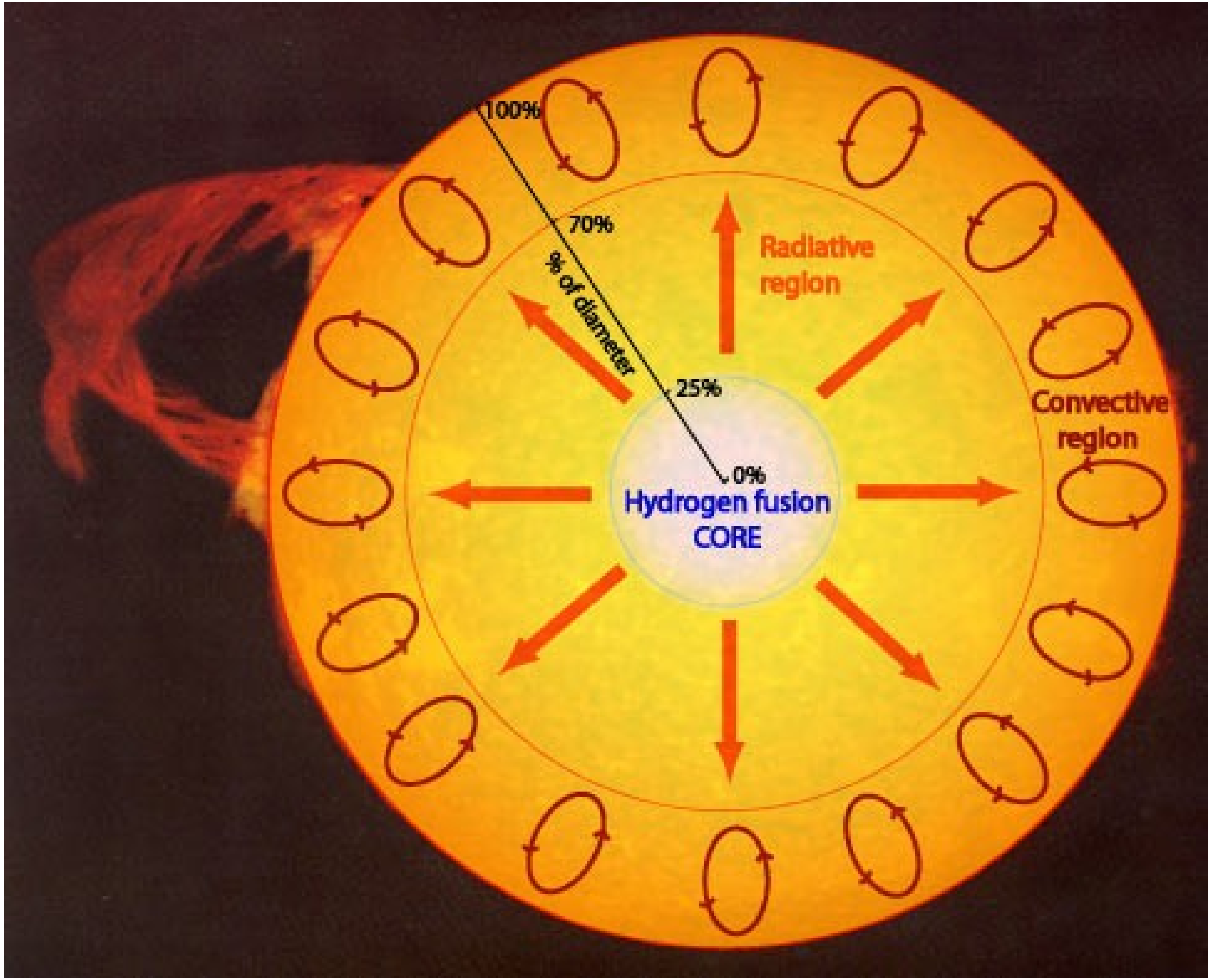


H 1
He 2
Li 3
Be 4
B 5
C 6
N 7
O 8
F 9
Ne 10
Na 11
Mg 12
Al 13
Si 14
P 15
S 16
Cl 17
Ar 18
K 19
Ca 20
Sc 21
Ti 22
V 23
Cr 24
Mn 25
Fe 26
Co 27
Ni 28
Cu 29
Zn 30
Ga 31
Ge 32
As 33
Se 34
Br 35
Kr 36
Rb 37
Sr 38
Y 39
Zr 40
Nb 41
Mo 42
Tc 43
Ru 44
Rh 45
Pd 46
Ag 47
Cd 48
In 49
Sn 50
Sb 51
Te 52
I 53
Xe 54
Cs 55
Ba 56
Hf 72
Ta 73
W 74
Re 75
Os 76
Ir 77
Pt 78
Au 79
Hg 80
Tl 81
Pb 82
Bi 83
Po 84
At 85
Rn 86
Fr 87
Ra 88
La 57
Ce 58
Pr 59
Nd 60
Pm 61
Sm 62
Eu 63
Gd 64
Tb 65
Dy 66
Ho 67
Er 68
Tm 69
Yb 70
Lu 71
Ac 89
Th 90
Pa 91
U 92
Np 93
Pu 94
Big Bang fusion
Dying low-mass stars
Exploding massive stars
Cosmic ray fission
Merging neutron stars
Exploding white dwarfs

Hydrostatic Equilibrium

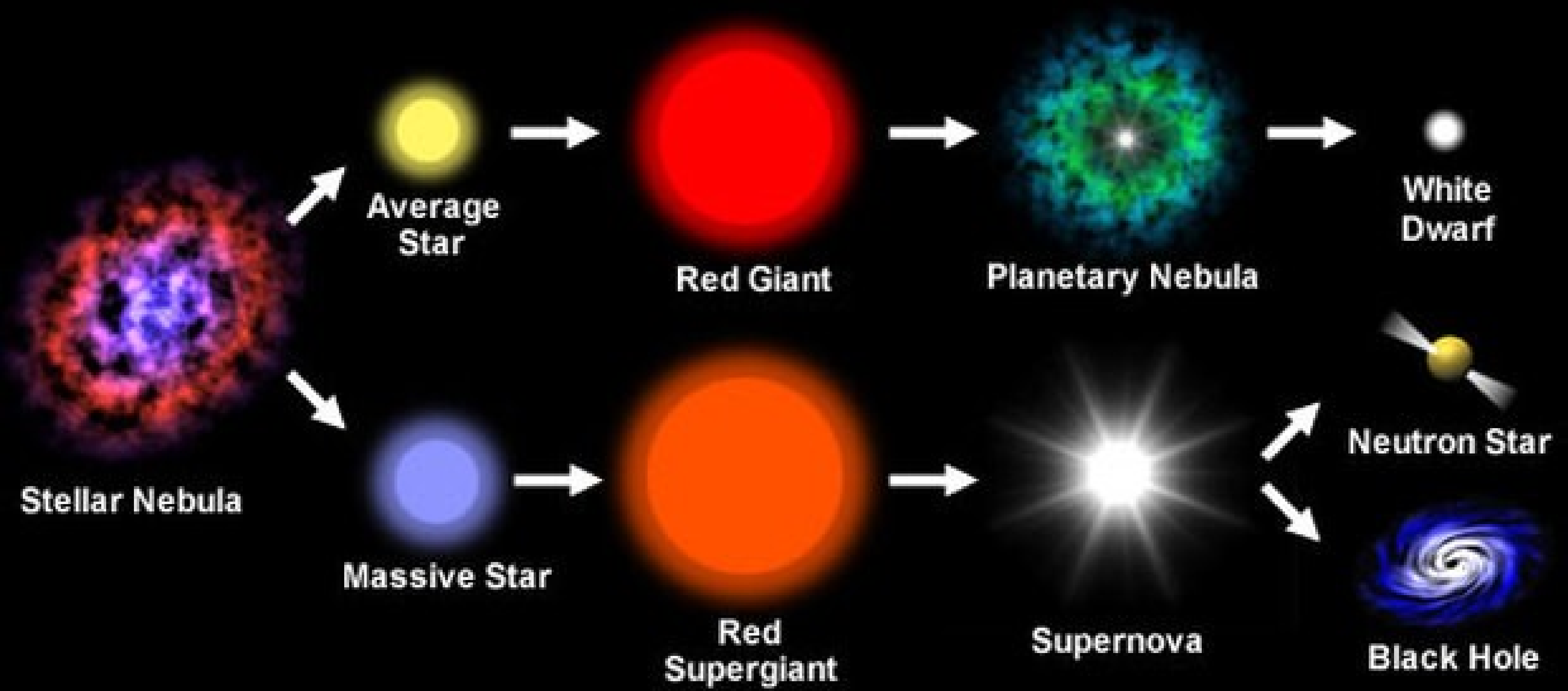


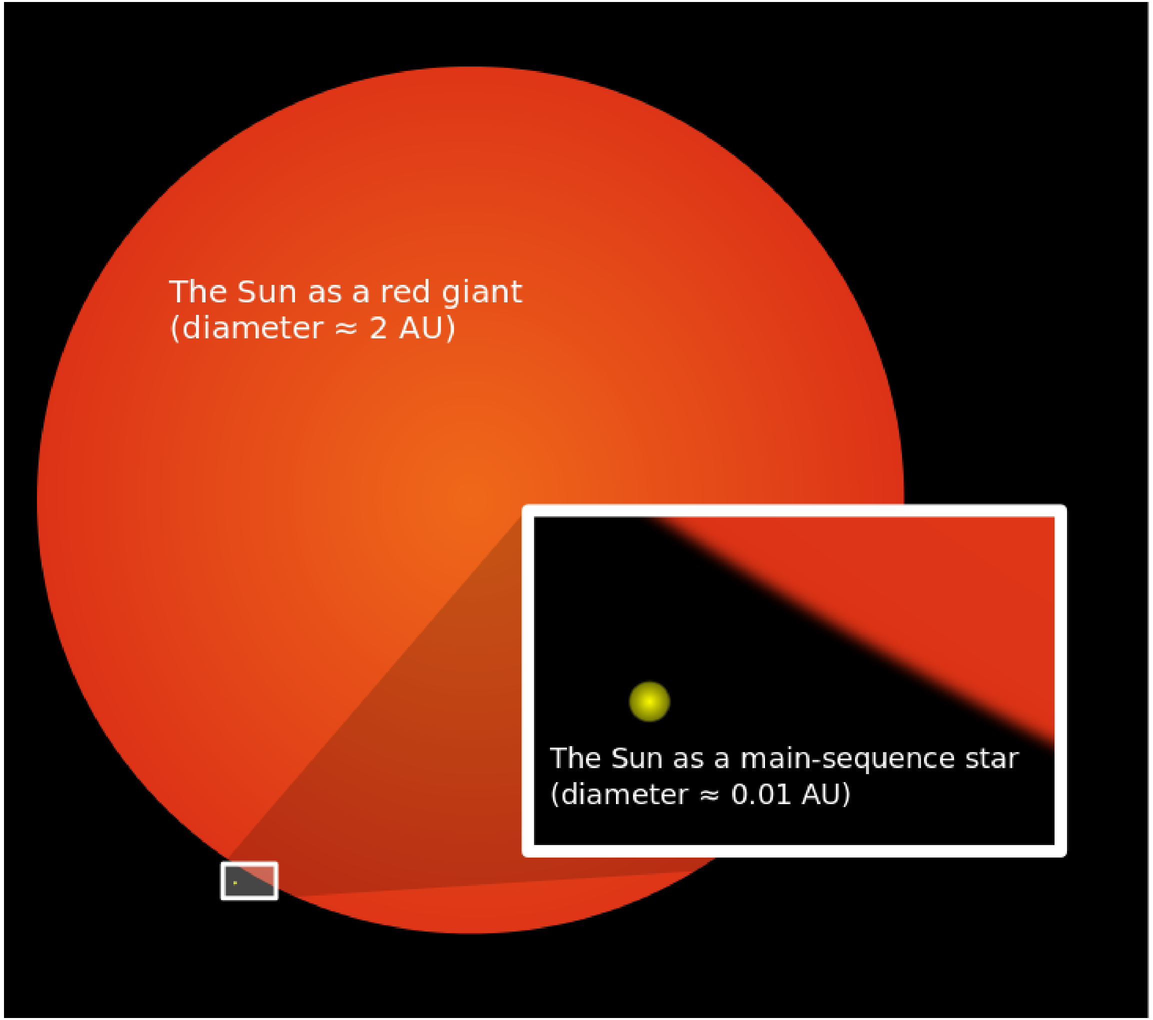

Sunspot
Penumbra
Umbra
Granule
Solar wind
Convective zone
Corona
Tachocline
Radiative zone
Photosphere
Core
Temperature minimum
Flare
Chromosphere
Transition region
The Sun
All features drawn to scale
Prominence

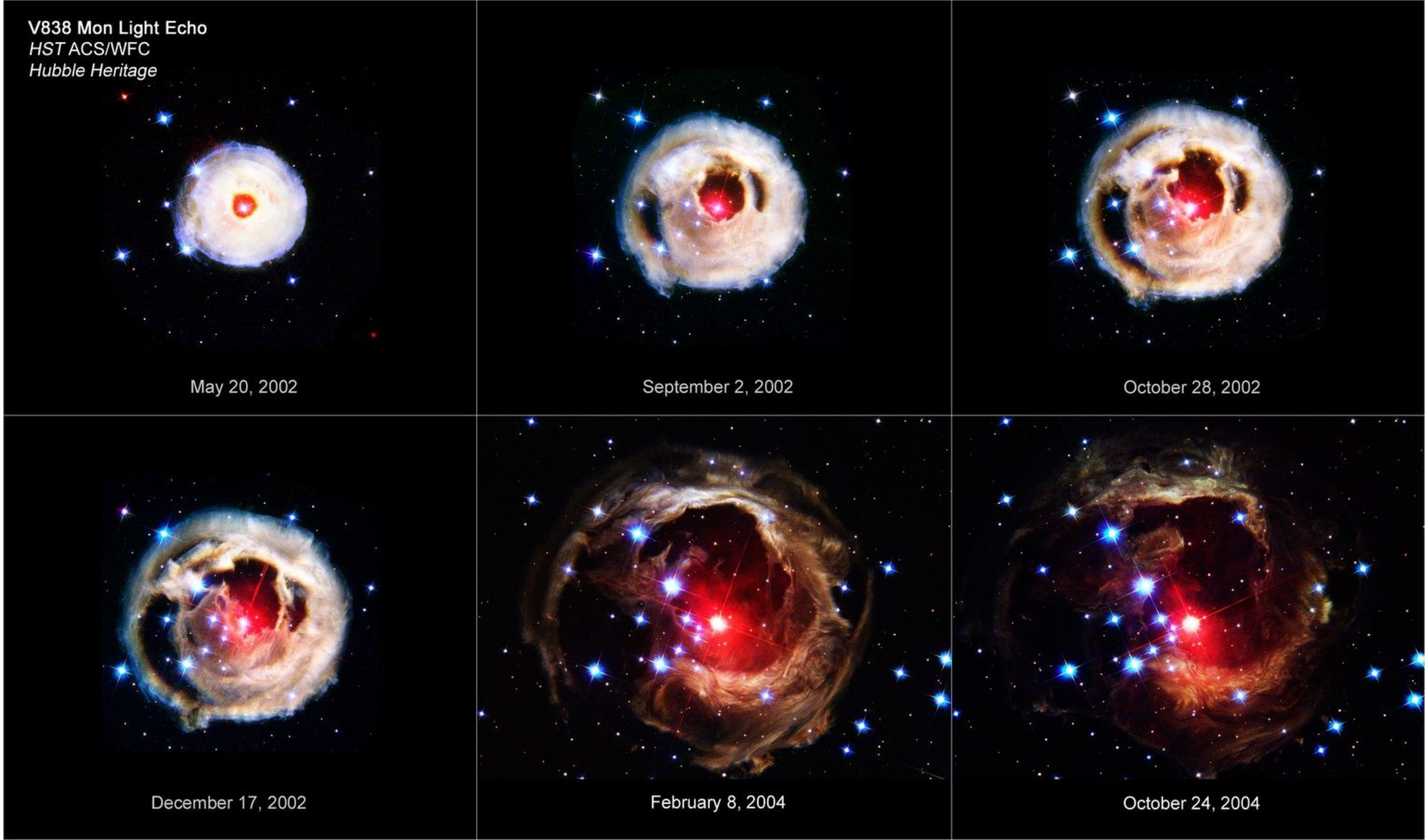


Energy transport in Stars

Life Cycle of a Star

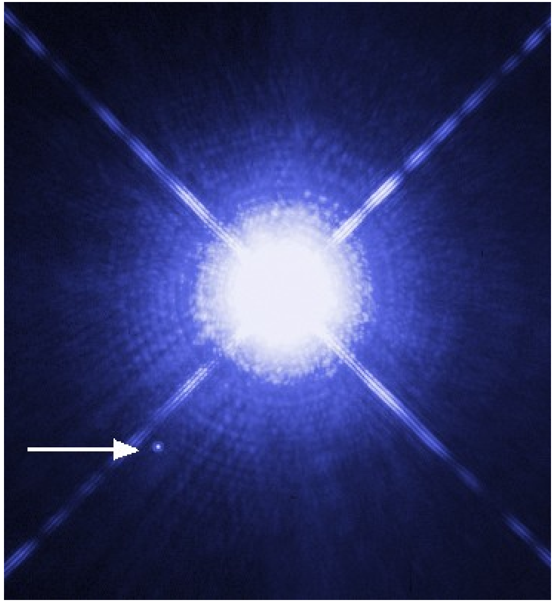



The Sun as a red giant
(diameter ≈ 2 AU)
The Sun as a main-sequence star
(diameter ≈ 0.01 AU)


V838 Mon Light Echo
HST ACS/WFC
Hubble Heritage
May 20, 2002
September 2, 2002
October 28, 2002
December 17, 2002
February 8, 2004
October 24, 2004

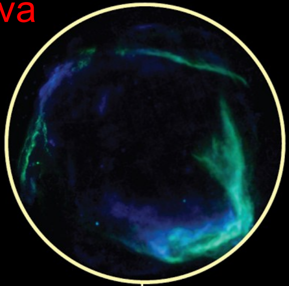
White Dwarf (വെള്ളക്കുള്ളൻ, ശ്വേതവാമനൻ)

1. Last stage in the evolution of low mass stars.
2. Sun will eventually become a white dwarf. Most of the other stars in the Milky way galaxy also would end up as white dwarfs.
3. When it becomes a white dwarf it will have the size comparable to Earth, but mass will not be much less.
4. In white dwarf stars gravitational pull is balanced by degeneracy pressure of electrons.
5. Maximum possible mass of a white dwarf star is called Chandrasekhar limit.
6. White dwarfs are dead stars, i.e. no fusion takes place in them.



What we see as Sirius actually consists of two stars, one of which is a white dwarf, Sirius-B very close to Sirius-A.

Supernova



A.D.185

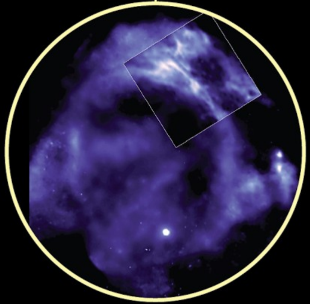
RCW 86

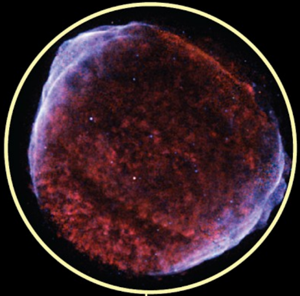
Historical Observers: Chinese
Likelihood of Identification: Possible
Distance Estimate: 8,200 light years
Type: Core collapse of massive star

A.D. 393

G347.3-0.5

Historical Observers: Chinese
Likelihood of Identification: Possible
Distance Estimate: 3,000 light years
Type: Core collapse of massive star



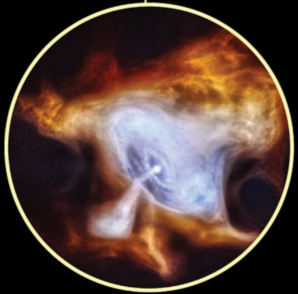


A.D. 1006

SN 1006

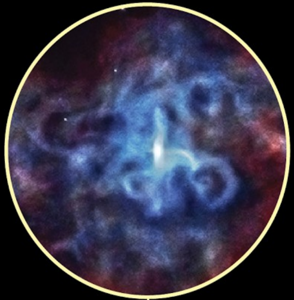
Historical Observers: Chinese, Japanese, Arabic, European
Likelihood of Identification: Definite
Distance Estimate: 7,000 light years
Type: Thermonuclear explosion of white dwarf

A.D. 1054



Crab Nebula

Historical Observers: Chinese, Japanese, Arabic, Native American
Likelihood of Identification: Definite
Distance Estimate: 6,000 light years
Type: Core collapse of massive star



A.D. 1181

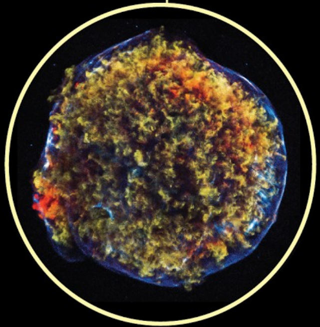
3C58

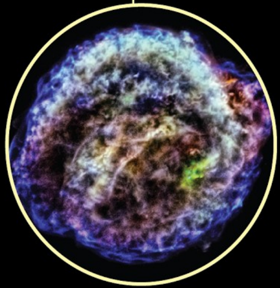
Historical Observers: Chinese, Japanese
Likelihood of Identification: Possible
Distance Estimate: 10,000 light years
Type: Core collapse of massive star

A.D. 1572

Tycho's SNR

Historical Observers: European, Chinese, Korean
Likelihood of Identification: Definite
Distance Estimate: 7,500 light years
Type: Thermonuclear explosion of white dwarf





A.D. 1604

Kepler's SNR

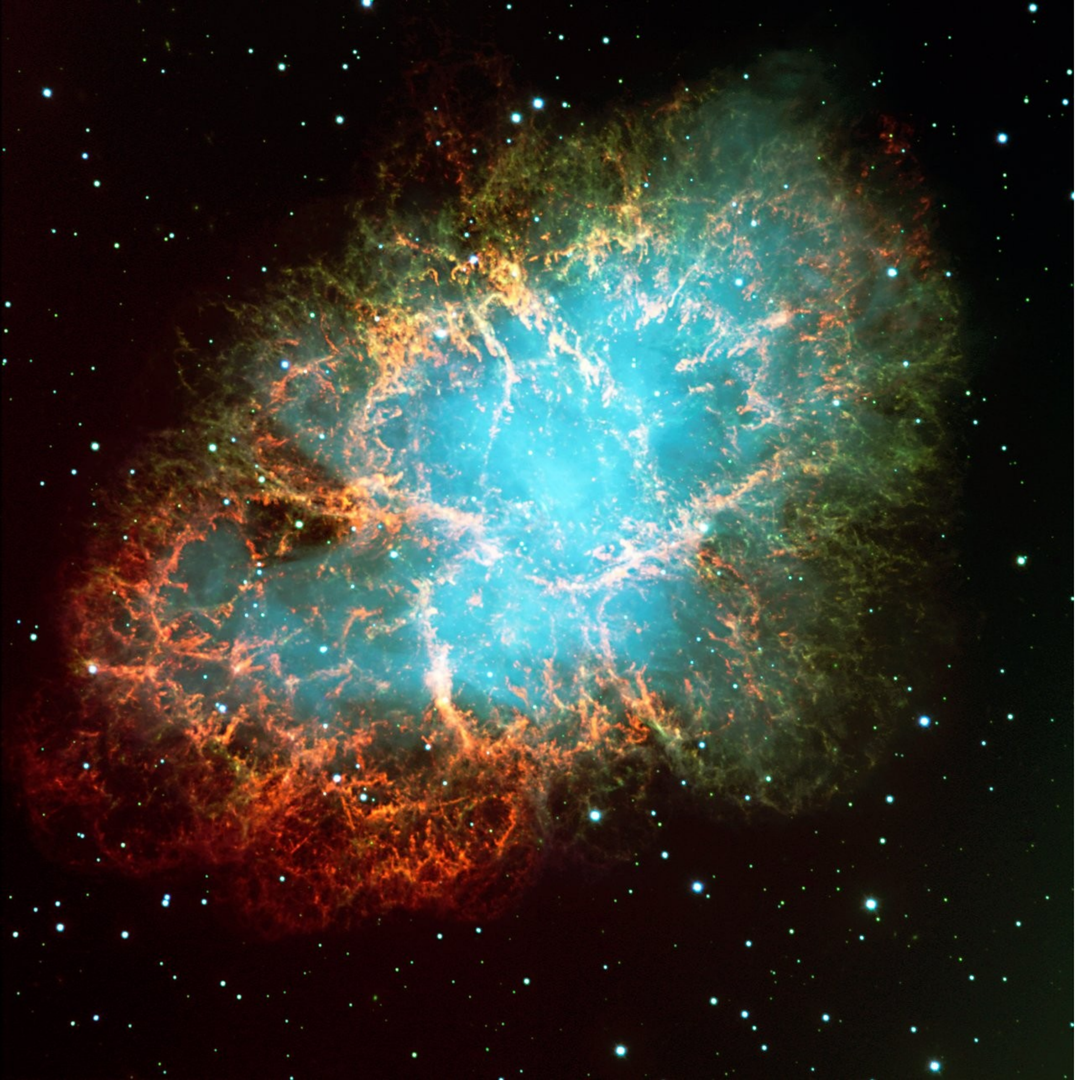
Historical Observers: European, Chinese, Korean
Likelihood of Identification: Definite
Distance Estimate: 13,000 light years
Type: Thermonuclear explosion of white dwarf?

A.D. 1680

Cassiopeia A

Historical Observers: European?
Likelihood of Identification: Unlikely
Distance Estimate: 10,000 light years
Type: Core collapse of massive star

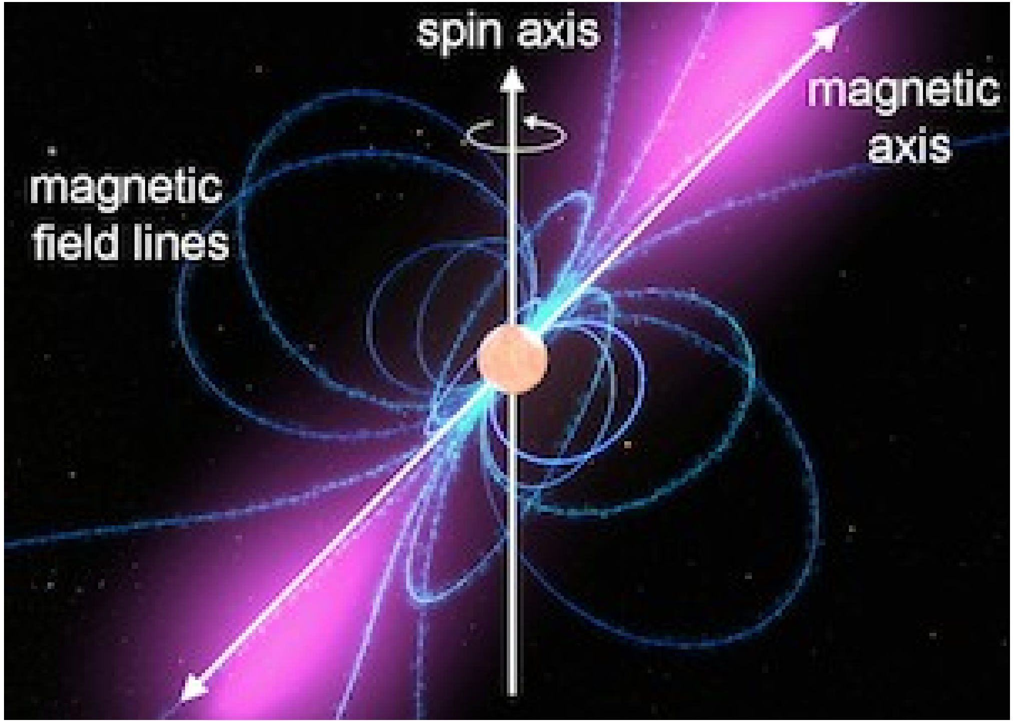
* LIGHT YEAR: the distance that light, moving at a constant speed of 300,000 km/s, travels in one year. One light year is just under 10 trillion kilometers.



Crab Nebula

Neutron Stars

1. Last stage in the evolution of massive stars.
2. Neutron stars will have the size comparable to a city
3. In neutron stars gravitational pull is balanced by degeneracy pressure of neutrons.
4. Maximum possible mass of a neutron star is called Tolman–Oppenheimer–Volkoff limit..
5. Pulsars are neutron stars.




Jocelyn Bell Burnell

Black hole (തമോദ്വാരം)

1. Last stage in the evolution of very massive stars.
2. Nothing escapes from a black hole
3. Predicted by General theory of relativity
4. In black holes gravitational pull is not balanced by anything.
5. Merging black holes are a source for gravitational waves.