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Low-Mass Star

Giant Molecular Cloud in Orion.

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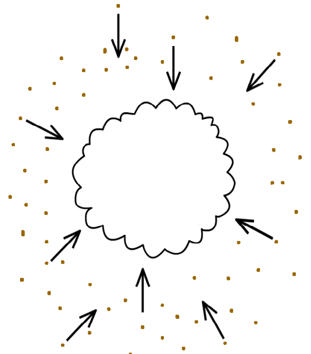
Low-Mass Star



Portion of Giant Molecular cloud begins collapse by gravitational attractions, perhaps triggered by nearby supernova explosion.

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Low-Mass Star

Years in Stage: 10 million

T = 10 - 20 K

L = 0 (collapsing gas and dust)

R = 1 - 3,000 ly

M = 1 m⊙

Other - Dozens or even hundreds of stars can form in a cloud.

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High-Mass Star

The dark areas in the **Orion nebula**—giant molecular clouds—are where stars are born.

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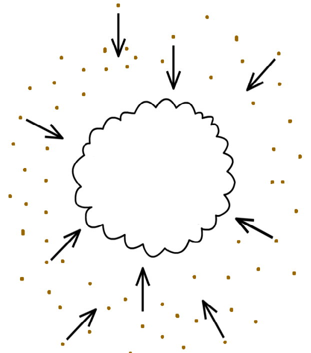
High-Mass Star



Supernova shockwave triggers collapse and begins the accumulation of material by gravitational attraction.

P P

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High-Mass Star

Years in Stage: 1 million

T = 10 - 20 K

L = 0 (dark gas and dust)

R = 1 - 3,000 ly

M = 10 m⊙

Other - Dozens, even hundreds of stars can form in a cloud.

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2 2

Low-Mass Star

An infrared picture of the the **Elephant Trunk nebula**. Proto-stars are seen peeking through their dust clouds.

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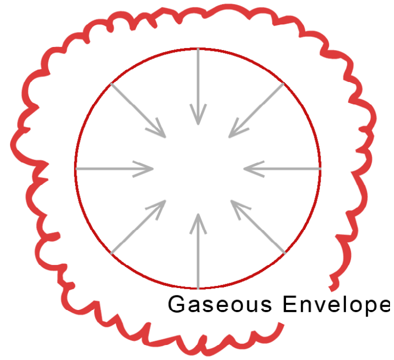
2 2

Low-Mass Star



Heating by gravitational collapse and accretion of particles. No internal fusion.

P P

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Low-Mass Star

Years in Stage: 5 million

T = 2 - 3,000 K

L = low (covered by a shell of dust)

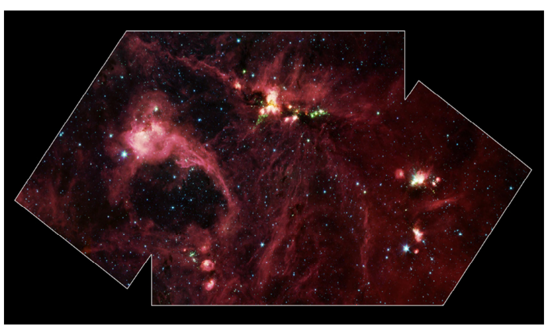
R = >5 $R_{\odot}$

M = 1 $M_{\odot}$

C C

2 2

High-Mass Star



Massive stars form in clusters. The first stars to form blow away the gas and dust, surrounding them.

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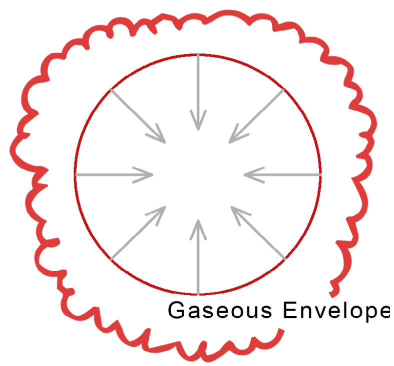
High-Mass Star



Heating by gravitational collapse and accretion of particles. No internal fusion.

P P

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High-Mass Star

Years in Stage: 2 million years

T = 2 - 3,000 K

L = low (covered by a shell of dus)

R = 100 $R_{\odot}$

M = 10 $M_{\odot}$

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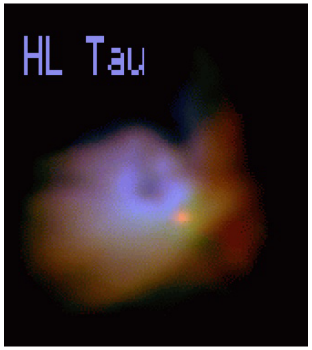
3 3

Low-Mass Star



T Tauri Stars

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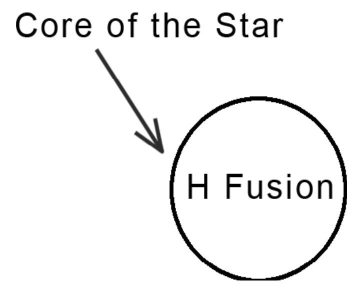
Low-Mass Star



Initiation of hydrogen fusion in core of star.
$4\ {}^{1}_{1}H \rightarrow {}^{4}_{2}He$ + energy

P P

? ?

Low-Mass Star

Years in Stage: 50 million

T = 2 - 3,000 K

L = > 2L☉

R = 1R☉

M = < 3M☉

Other - Star is still contracting and often have large accretion disks - with future planets - surrounding them.

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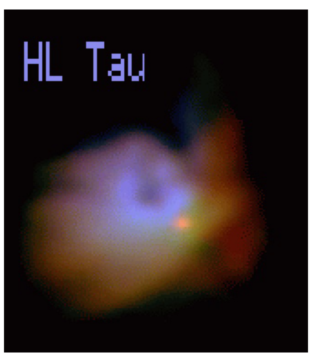
High-Mass Star



Rigel - A B star on the main sequence.

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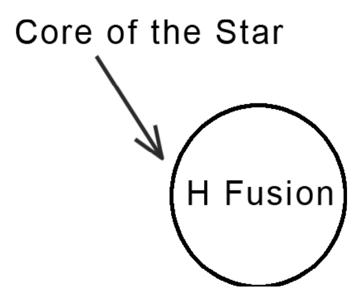
High-Mass Star



Fusion begins - CNO cycle produces helium in core.

P P

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High-Mass Star

Years in Stage: 10 million

T = 20,000 K

L = 100 L☉

R = 10 R☉

M = 10 M☉

Other - Peak wavelength of the star in the ultraviolet.

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4 4

Low-Mass Star

A yellow main-sequence star.

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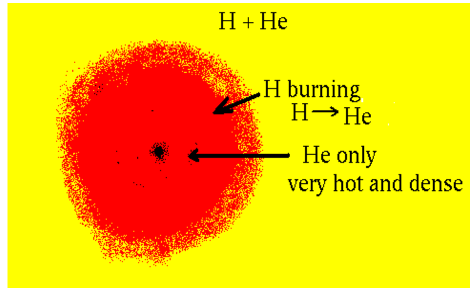
4 4

Low-Mass Star



Hydrogen builds up helium in the core.
Not enough for helium to fuse.

P P

? ?

Low-Mass Star

Years in Stage: 8 billion

$T = 5{,}800$ K

$L = 1\odot$

$R = 1\,R\odot$

$M = 1\,M\odot$

Other - Luminosity of the star changes from the time the star arrives on the main sequence until it leaves.

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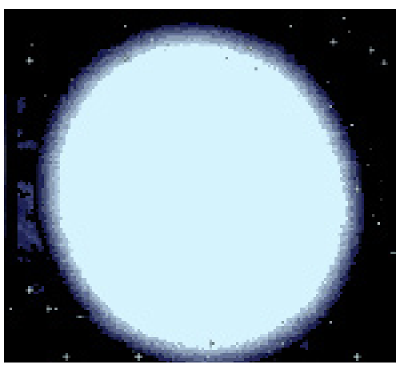
4 4

High-Mass Star



Blue main sequence stars go through stages of fusion quickly.

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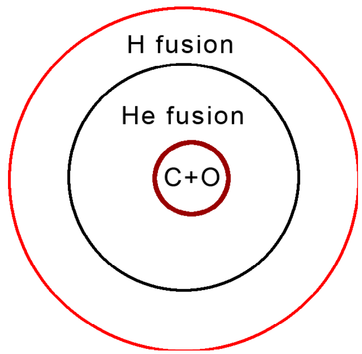
High-Mass Star



Helium fusion produces C + O in the core.

$3\,{}^{4}_{2}He \rightarrow {}^{12}_{6}C$ + energy

$4\,{}^{4}_{2}He \rightarrow {}^{16}_{8}O$ + energy

P P

? ?

High-Mass Star

Years in Stage: 10 million

$T = 9{,}000$ K

$L = 10{,}000\,L\odot$

$R = 100\,R\odot$

$M = 10\,M\odot$

Other - No Helium flash; each stage of fusion is faster than the last.

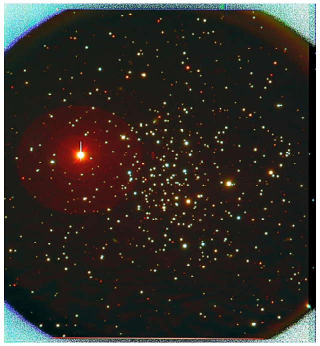
C C






5 5

LOW-MASS STAR



Red Giant Star

O O

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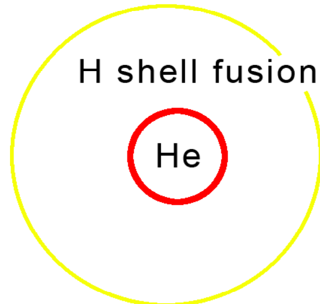
LOW-MASS STAR



Hydrogen shell fusion; helium in core not hot enough to fuse.

P P

? ?

LOW-MASS STAR

Years in Stage: 2 billion

T = 2500 - 3500 K

L = 1,000 - 10,000 $L_\odot$

R = 20 - 500$L_\odot$

M = 1 $M_\odot$

Other - Often variable. Star pulsates and throws off outer layers of gas.

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HIGH-MASS STAR

Yellow Supergiant Star
Most high mass stars go through a Cephid variable star stage.

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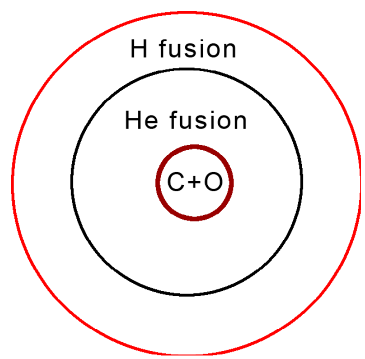
HIGH-MASS STAR



Carbon and oxygen fusion produce magnesium, sulfur, neon, and finally silicon.

P P

? ?

HIGH-MASS STAR

Years in Stage: 1 million

T = 5,000 K

L = 50,000 $L_\odot$

R = 100 - 200 $R_\odot$

M = 10 $M_\odot$

Other - Very regular pulsations with a period between 1 and 100 days.

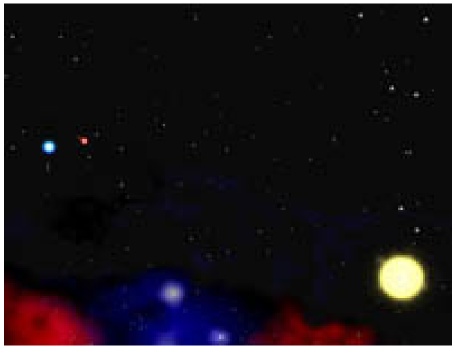
C C






6 6

Low-Mass Star

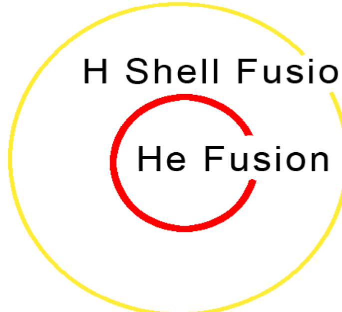


Yellow Giant Star

O O

6 6

Low-Mass Star



"Helium Flash"
Onset of helium fusionin the core as internal temperature = 100 million K.
$^{4}_{2}He+^{4}_{2}He+^{4}_{2}He \rightarrow {}^{12}_{6}C+E$
or: $4^{4}_{2}He \rightarrow {}^{16}_{0}O+E$

P P

? ?

Low-Mass Star

Years in Stage: 200 million

T = 5 - 6,000 K

L = 2,000 - 10,000 L⊙

R = 10 - 400 R⊙

M = < 1 M⊙

Other - Sometimes variable, star contracts and gets hotter.

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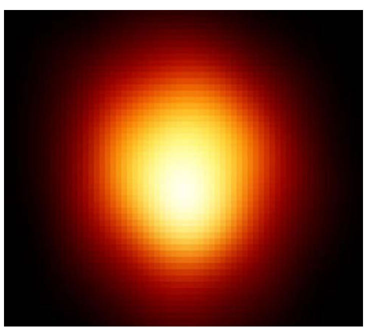
High-Mass Star

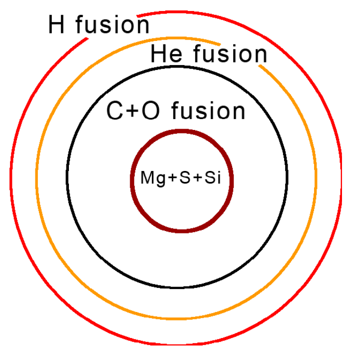


Betelguese is an M11a red supergiant star 1,000 times the diameter of the sun.

O O

6 6

High-Mass Star



After a succession of shell burning episodes, silicon fusion produces iron in the core of the star.

P P

? ?

High-Mass Star

Years in Stage: 100,000

T = 3,000 K

L = 50,000 L⊙

R = 7,500 R⊙

M = < 10 M⊙

Other - Iron absorbs energy, outward heat pressure drops dramatically.

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Low-Mass Star

2[nd] Red Giant Stage

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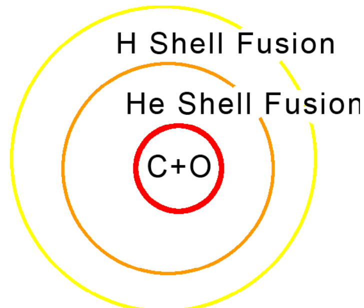
7 7

Low-Mass Star



The carbon / oxygen core never gets hot enough to fuse.

P P

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Low-Mass Star

Years in Stage: 1 billion

T = 3 - 4,000 K

L = 500 - 5,000 $L_\odot$

R = 10 - 500 $R_\odot$

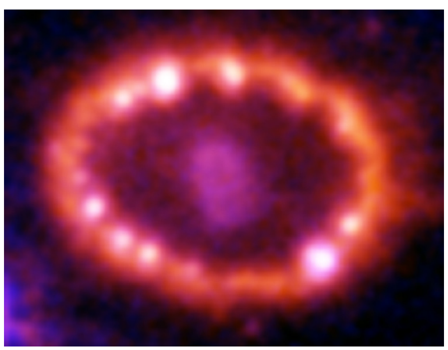
M = <.9$M_\odot$

Other - 2nd red giant phase, usually a variable star with irregular pulsations.

C C

7 7

High-Mass Star



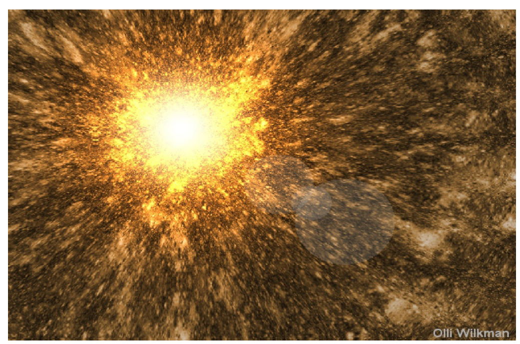
Supernova 1987a

Material from supernova expands into space, sometimes colliding with dust shells.

O O

7 7

High-Mass Star



Supernovae release the energy of a billion stars in a few seconds. Elements are fused during the explosion.

P P

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High-Mass Star

Years in Stage: a few seconds

T = billions of degrees

L = 100 billion $L_\odot$

R = 19 km core diameter

M = disperses

Other - Star collapses on core and rebounds. Shock wave induces fusion of heavy elements at billions of degrees.

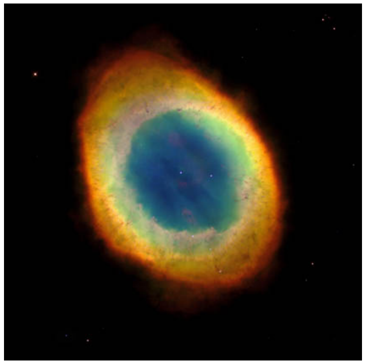
C C






8 8

Low-Mass Star



The gas thrown off by dying stars is called a planetary nebula because in small telescopes these objects look like planets.

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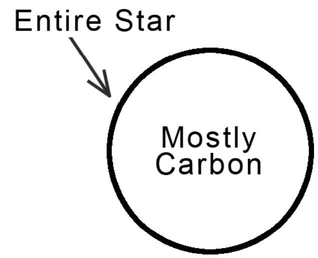
Low-Mass Star



Fusion stops, core white hot.

P P

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Low-Mass Star

Years in Stage: 50,000

T = Up to 100,000 K for central star

L = < .1 $L_\odot$

R = Gas shells dozens to hundreds of light years in diameter.

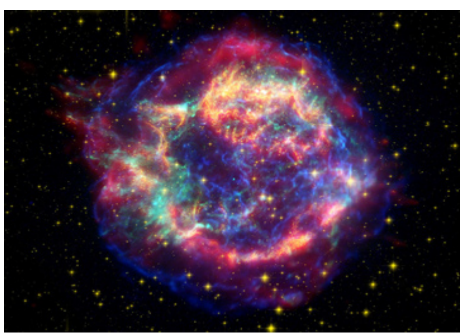
M = .5 $M_\odot$

Other - Ejected material forms envelope of gas. Central star is Earth-sized.

C C

8A 8A

High-Mass Star

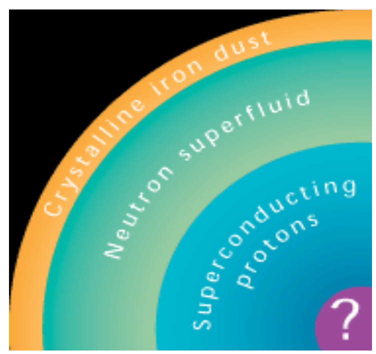


Cassiopeia is a supernova remnant. The neutron star, the leftover core, is the aqua blue dot in the center of the gas cloud.

O O

8A 8A

High-Mass Star



Neutron stars are degenerate matter - a ball of neutrons with an iron crust.

P P

? ?

High-Mass Star

Years in Stage: billions of years

T = 1 million degrees

L = invisible to eye, but visible using x-ray and gamma ray detectors.

R = size of the island of Manhattan
M = 1.4 - 2.5 $M_\odot$

Other - Pulsars are neutron stars that spin at an incredible rate of 100 - 5,000 rev/sec!

C C






9 9

Low-Mass Star

White dwarf star.

O O

9 9

Low-Mass Star

Heat slowly leaks away as star cools until only a black dwarf - a charcoal briquet in space - remains.

P P

? ?

Low-Mass Star

Years in Stage: 50 billion

T = 20 - 50,000 K, eventually less than 10K

L = < .01 $L_\odot$

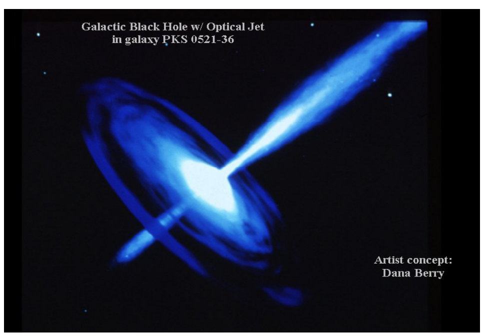
R = size of Earth

Other - The universe is not old enough for any stars to have evolved to black dwarf.

C C

8B 8B

High-Mass Star

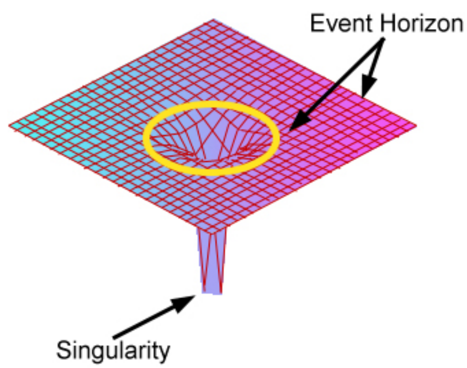


A black hole cannot be seen. Only when a black hole is in a binary system can its presence be detected.

O O

8B 8B

High-Mass Star



A black hole is an intense gravitational source, a kind of infinitely deep well.

P P

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High-Mass Star

Years in Stage: varies

T = undefined

L = 0

R = 0

M = > 3$M_\odot$

C C