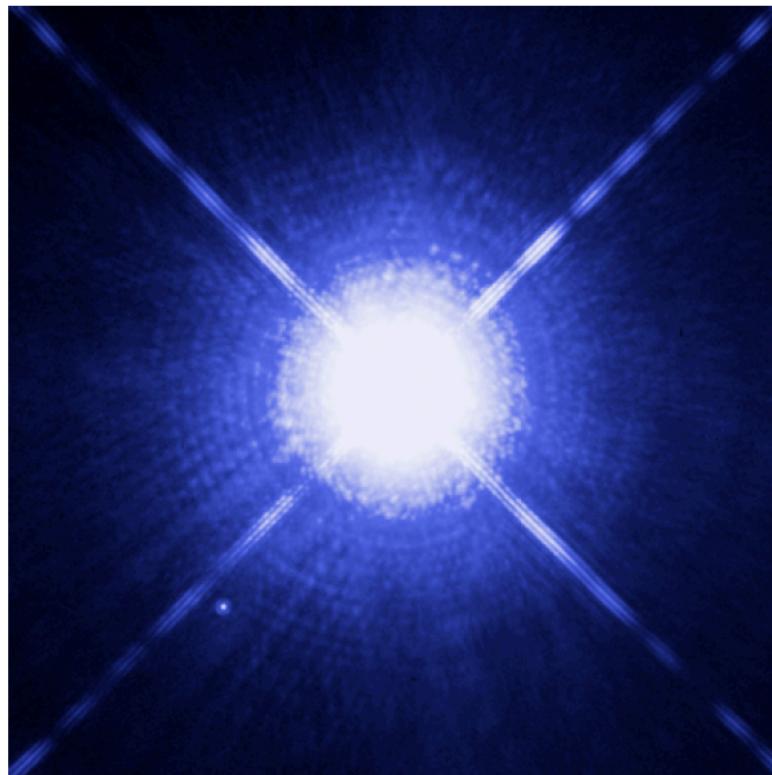
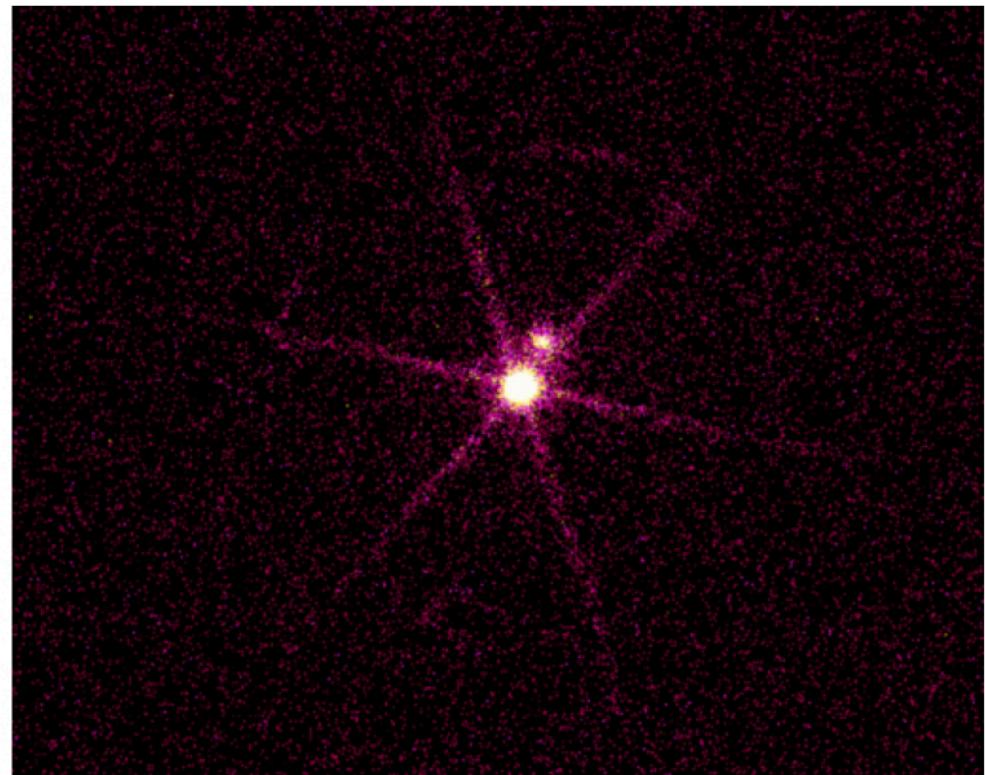


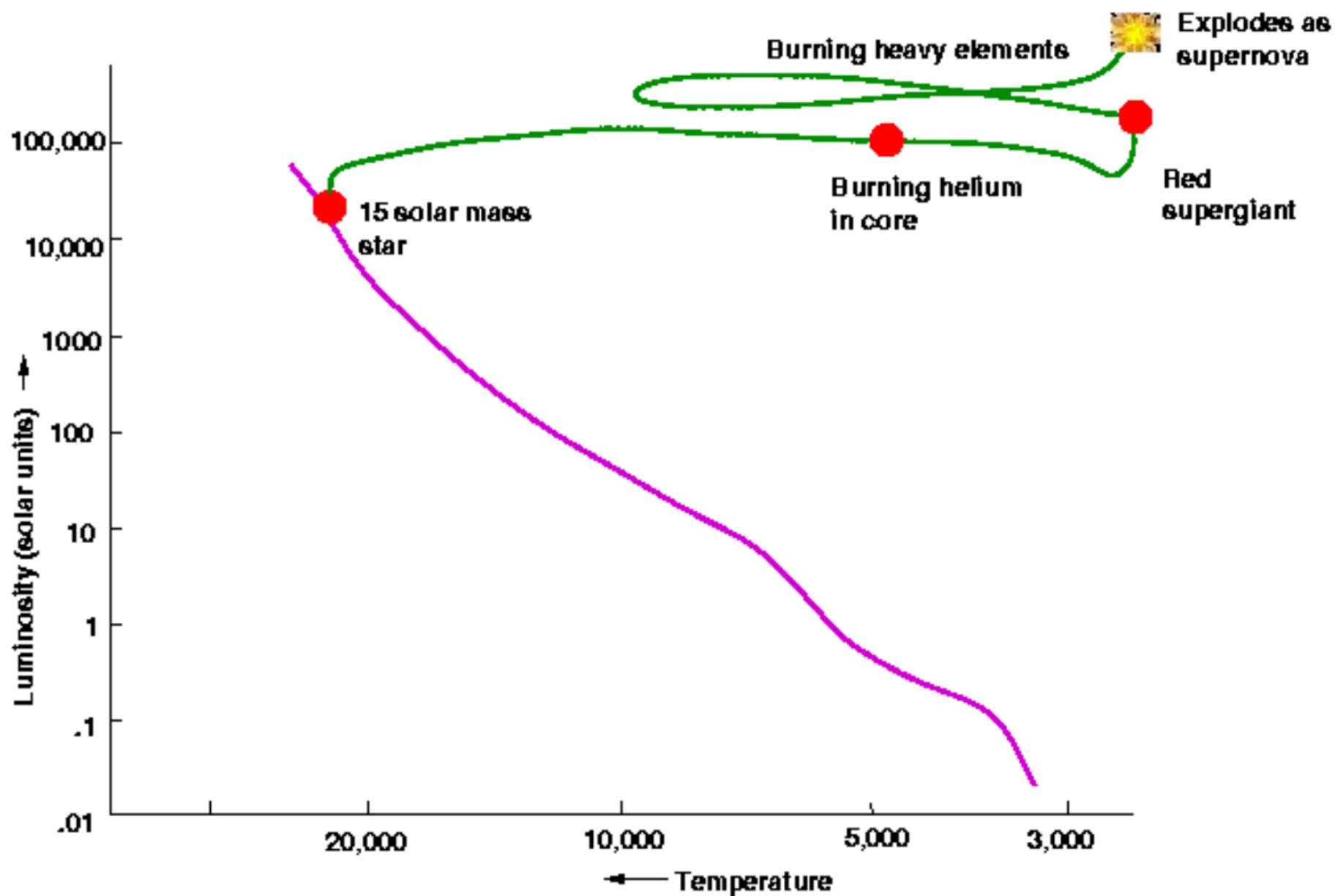
Sirius B white dwarf in optical, X-rays

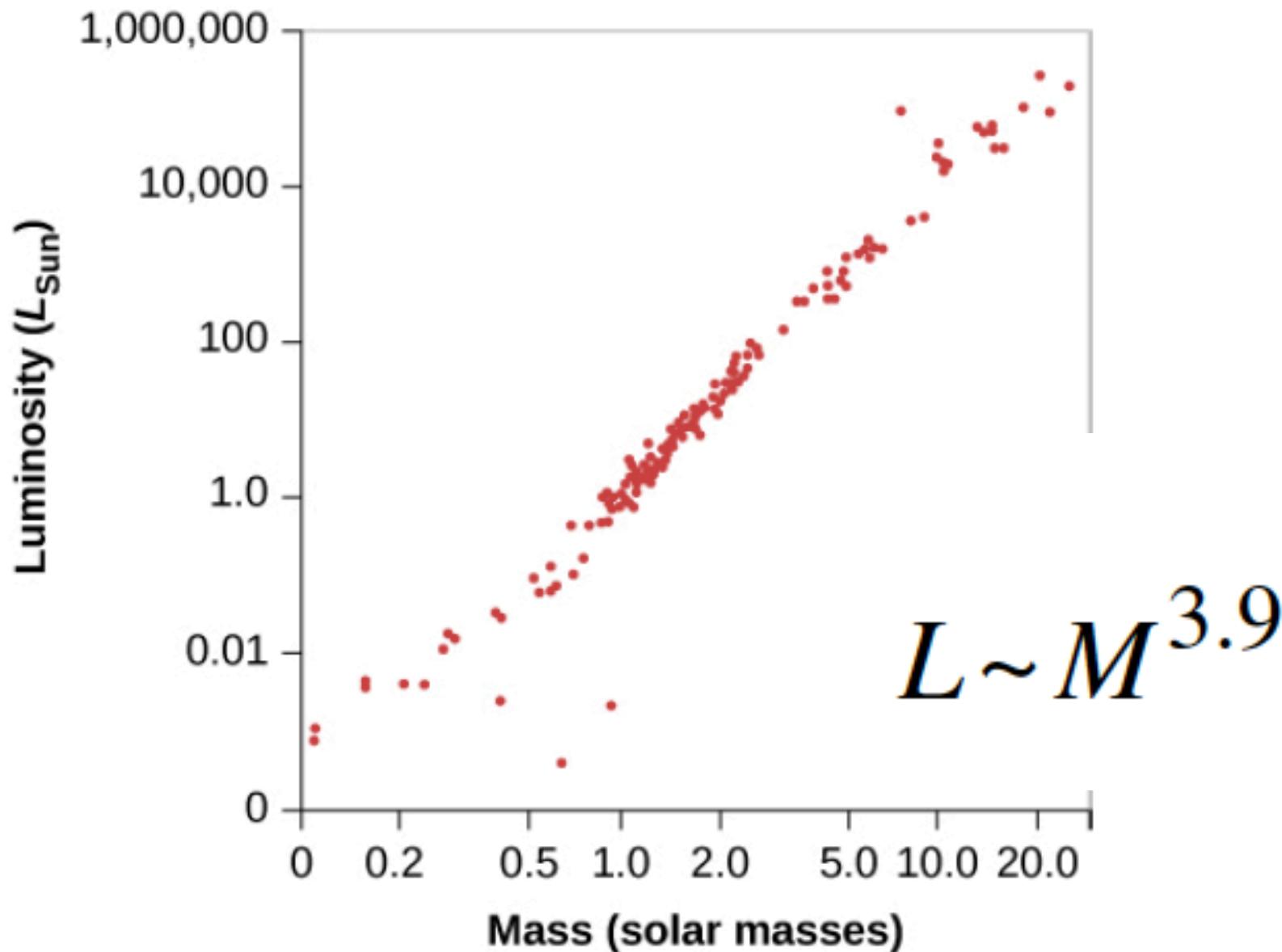


(a)

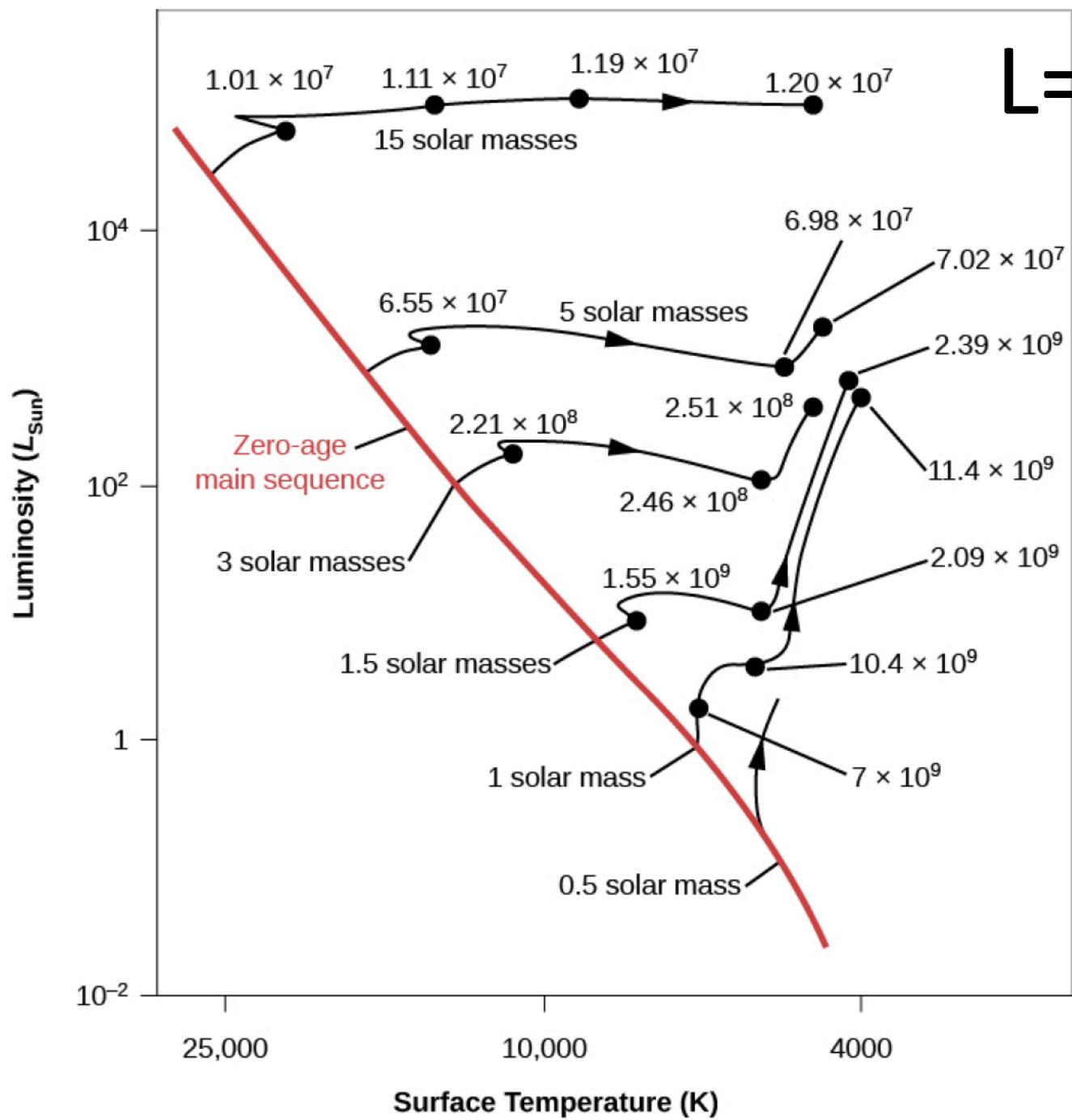


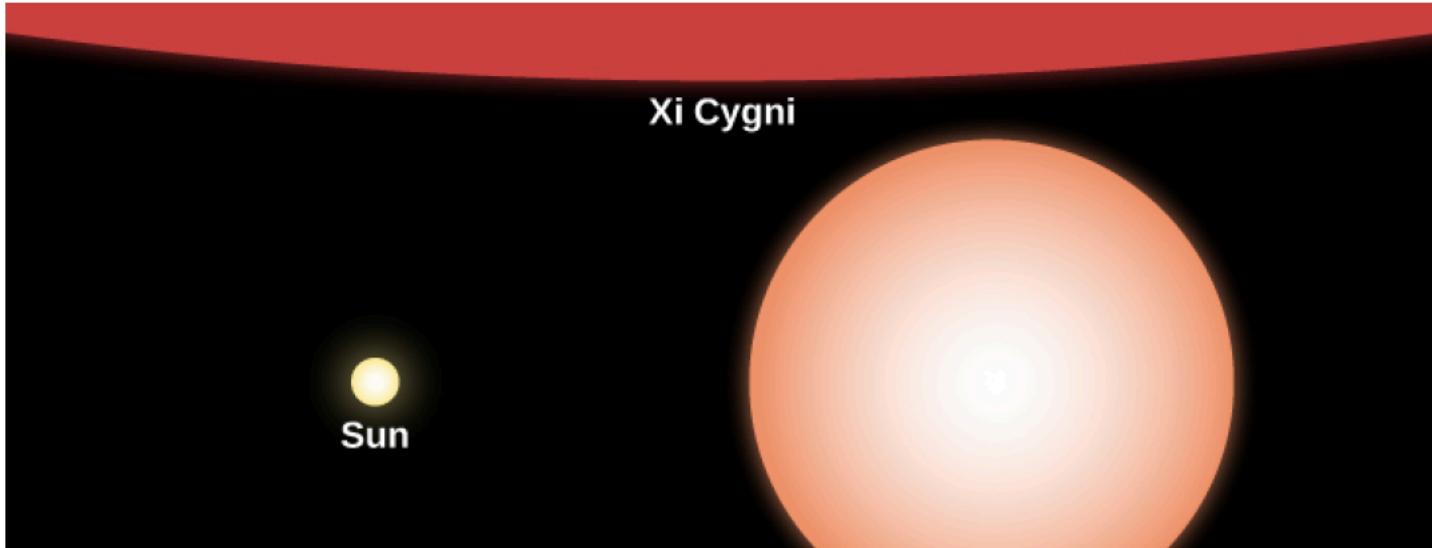
(b)





$$L = R^2 T^4$$

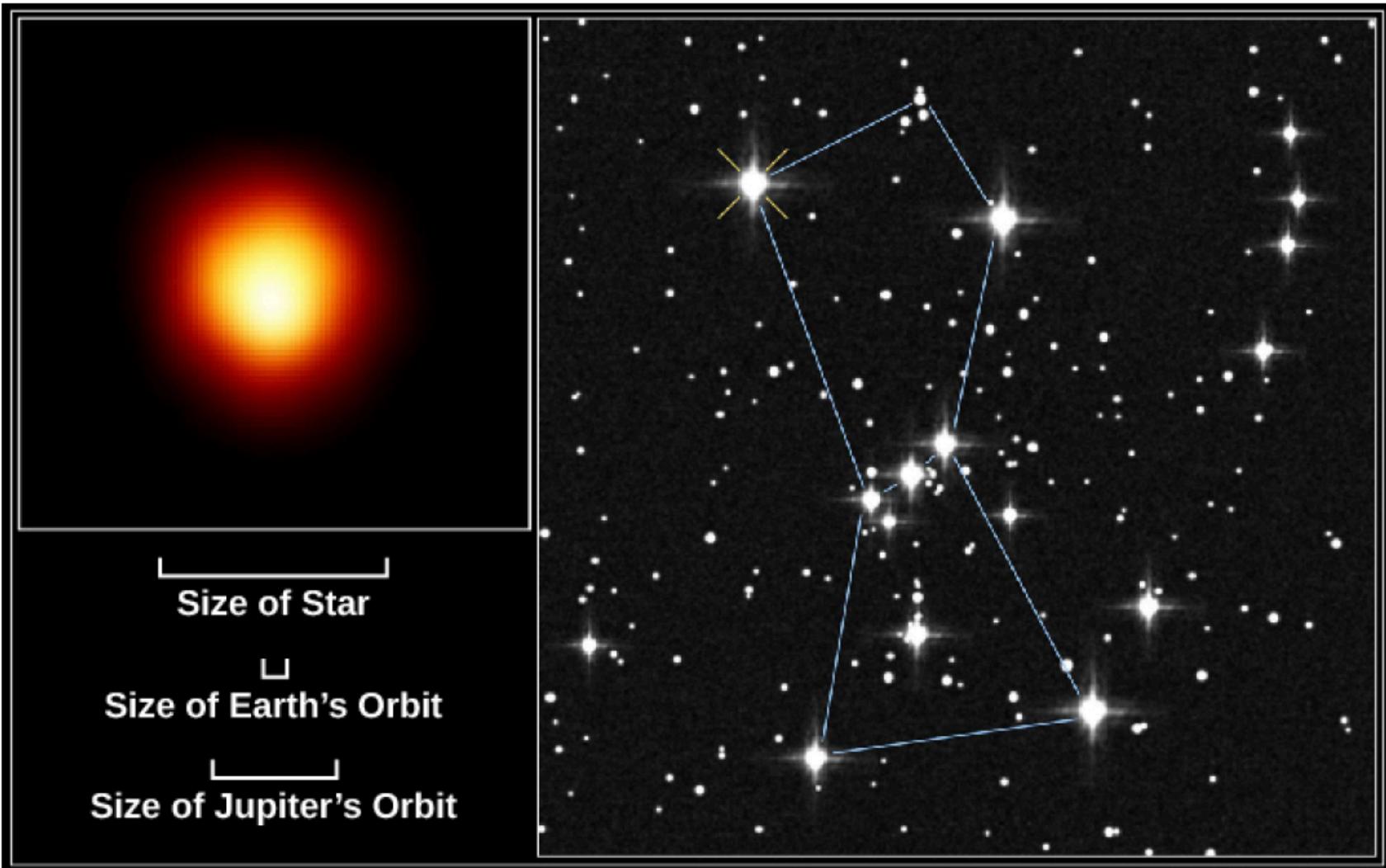




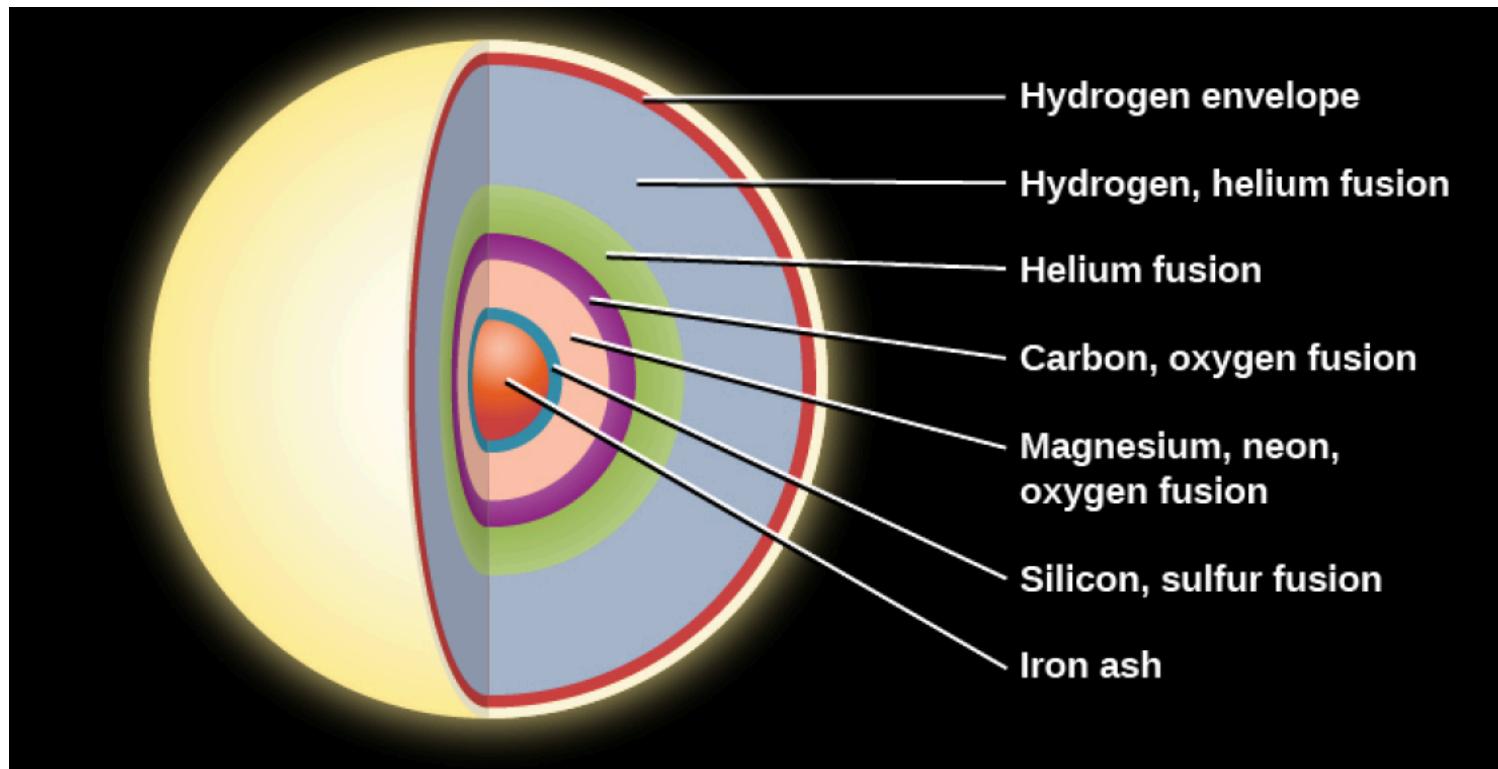
Comparing a Supergiant with the Sun

Property	Sun	Betelgeuse
Mass (2×10^{33} g)	1	16
Radius (km)	700,000	500,000,000
Surface temperature (K)	5,800	3,600
Core temperature (K)	15,000,000	160,000,000
Luminosity (4×10^{26} W)	1	46,000
Average density (g/cm ³)	1.4	1.3×10^{-7}
Age (millions of years)	4,500	10

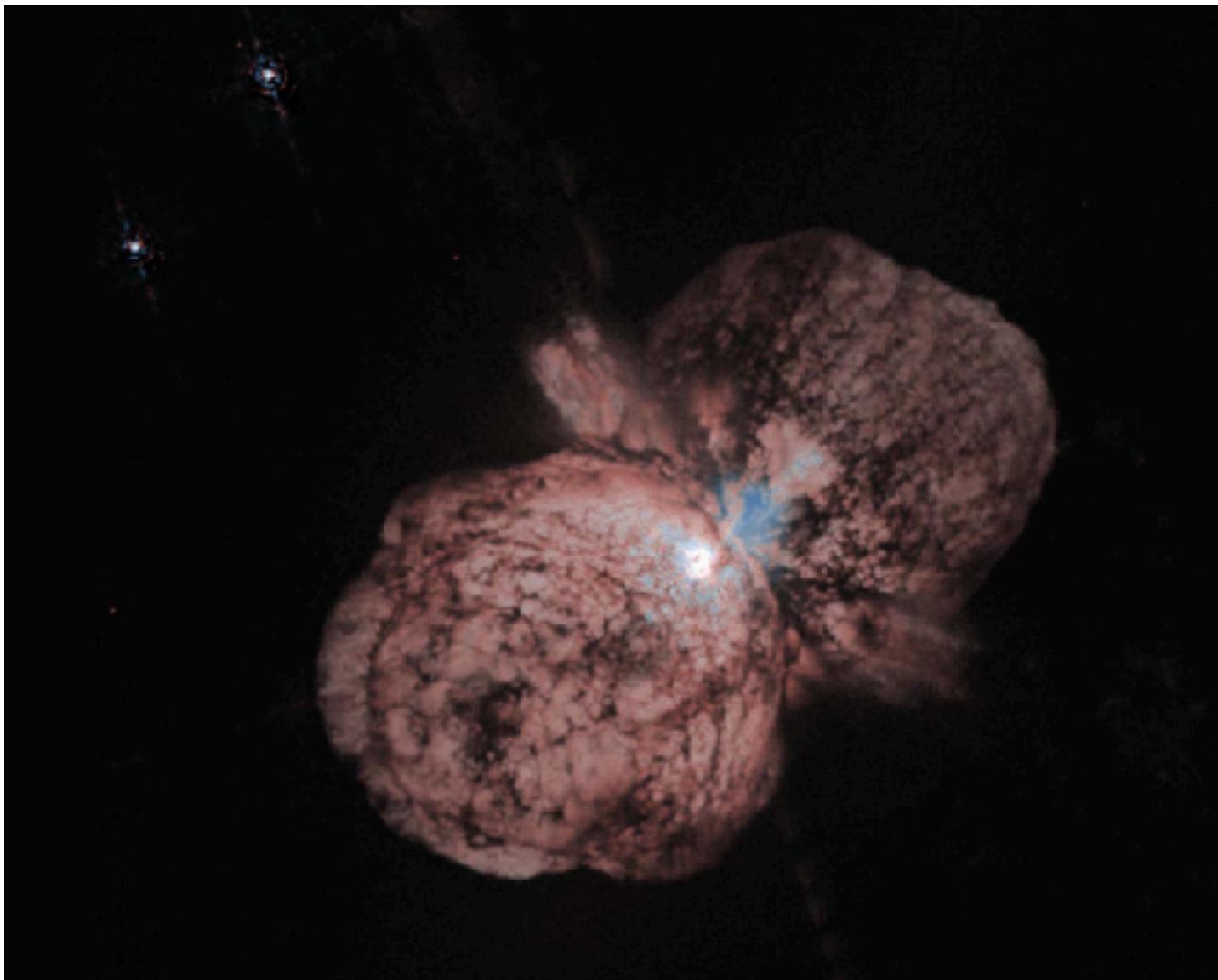
The supergiant star Betelgeuse

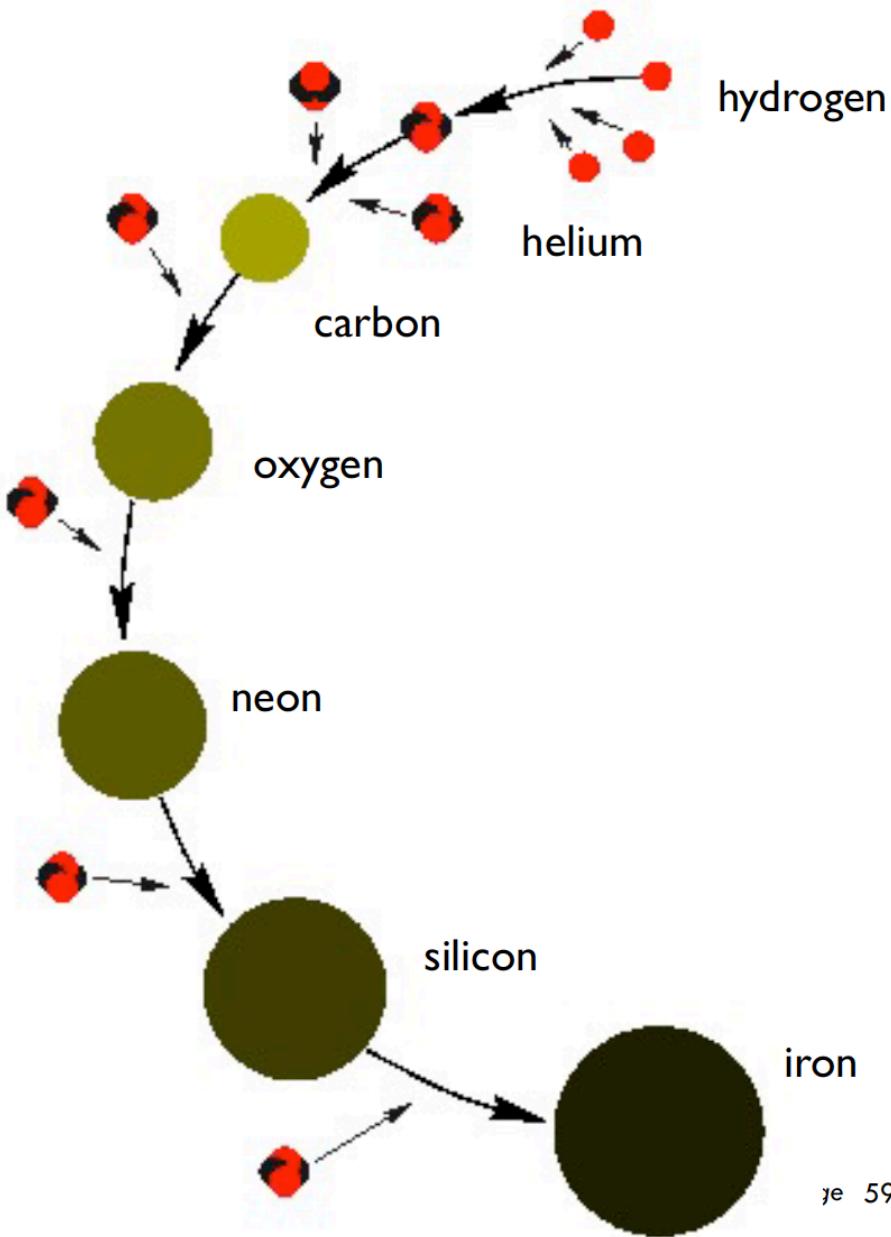


Planetary nebula: lost envelopes, only core is left; we see lost material



Eta Carina: what a 100 Msun star looks like





Phase	Central Temperature (K)	Central Density (g/cm ³)	Time Spent in This Phase
Hydrogen fusion	40×10^6	5	8×10^6 years
Helium fusion	190×10^6	970	10^6 years
Carbon fusion	870×10^6	170,000	2000 years
Neon fusion	1.6×10^9	3.0×10^6	6 months
Oxygen fusion	2.0×10^9	5.6×10^6	1 year
Silicon fusion	3.3×10^9	4.3×10^7	Days
Core collapse	200×10^9	2×10^{14}	Tenths of a second

Supernova 1987A (brightest in modern times)



© Anglo-Australian Observatory

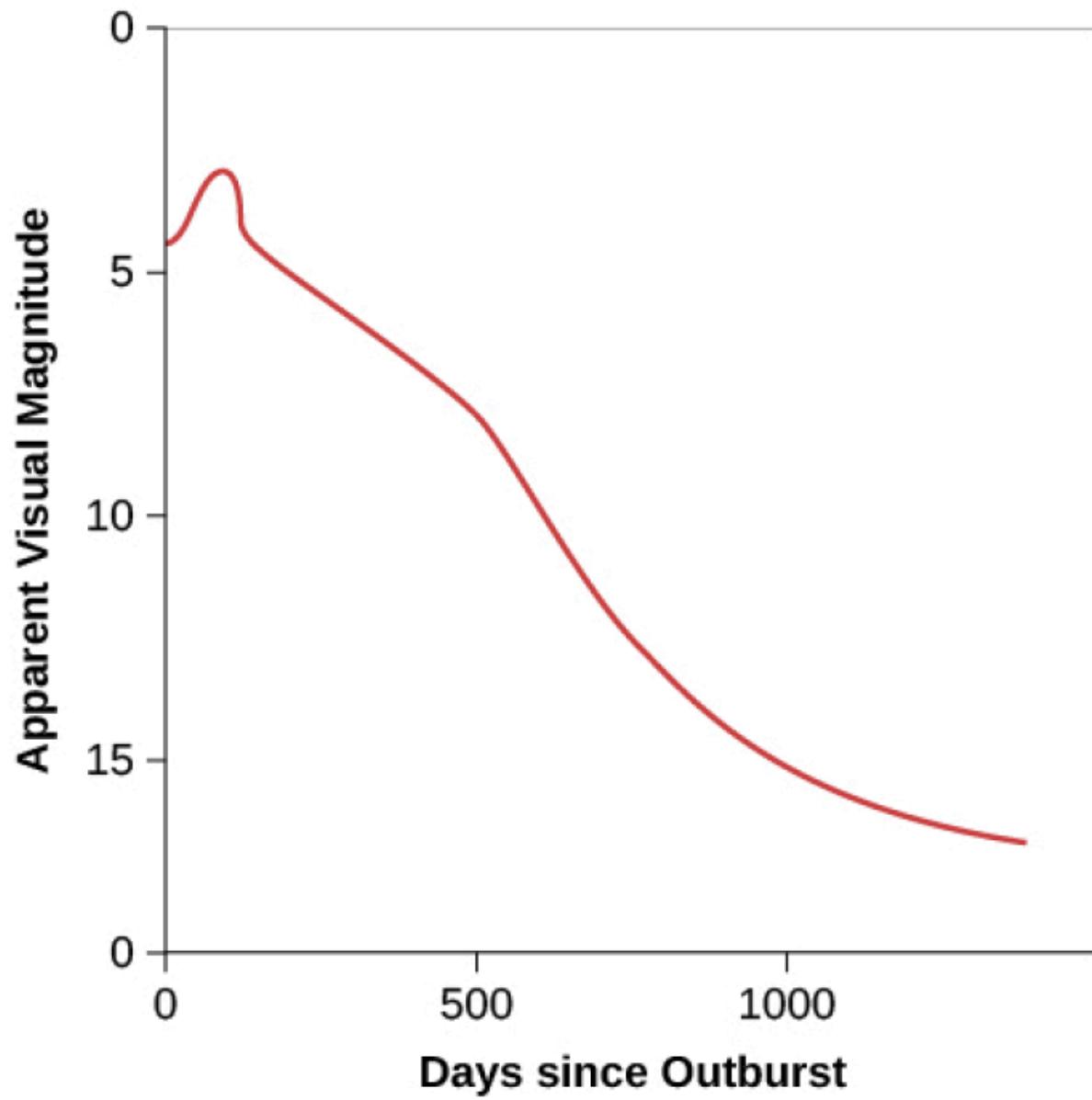


“On the Jisi day, the 7th day of the month, a big new star appeared in the company of the Ho star.”

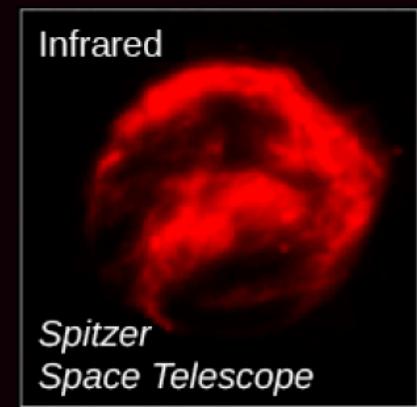
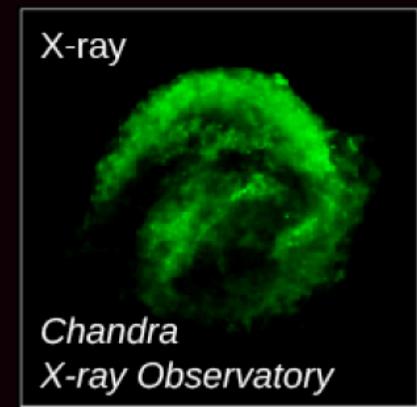
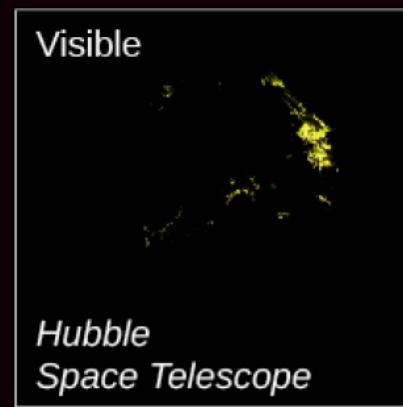
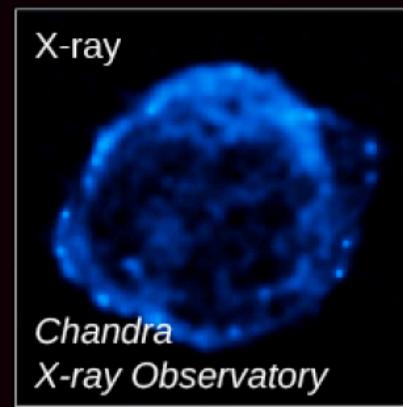
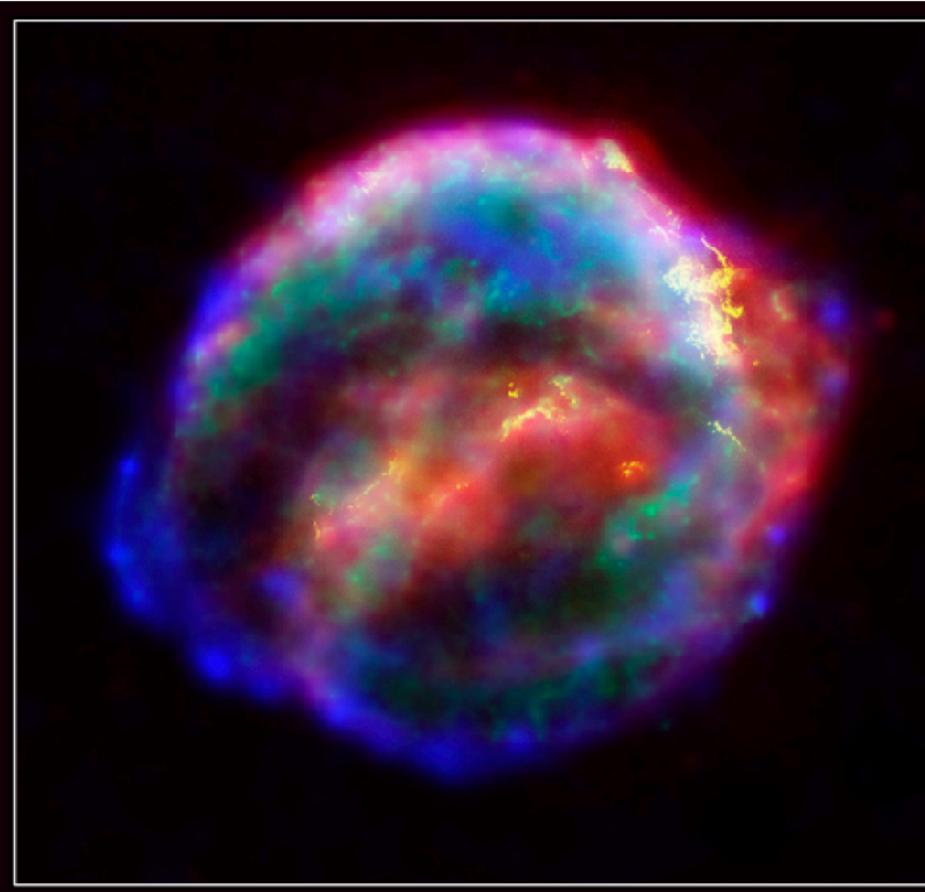
“On the Xinwei day the new star dwindled.”



Year	Where observed	Brightness
185	China	Brighter than Venus
369	China	Brighter than Mars or Jupiter
1006	China, Japan, Korea, Europe, Arabia	Brighter than Venus
1054	China, SW India, Arabia → Crab Nebula	Brighter than Venus
1572	Tycho	Nearly as bright as Venus
1604	Kepler	Brighter than Jupiter
1987	Ian Shelton (Chile)	-



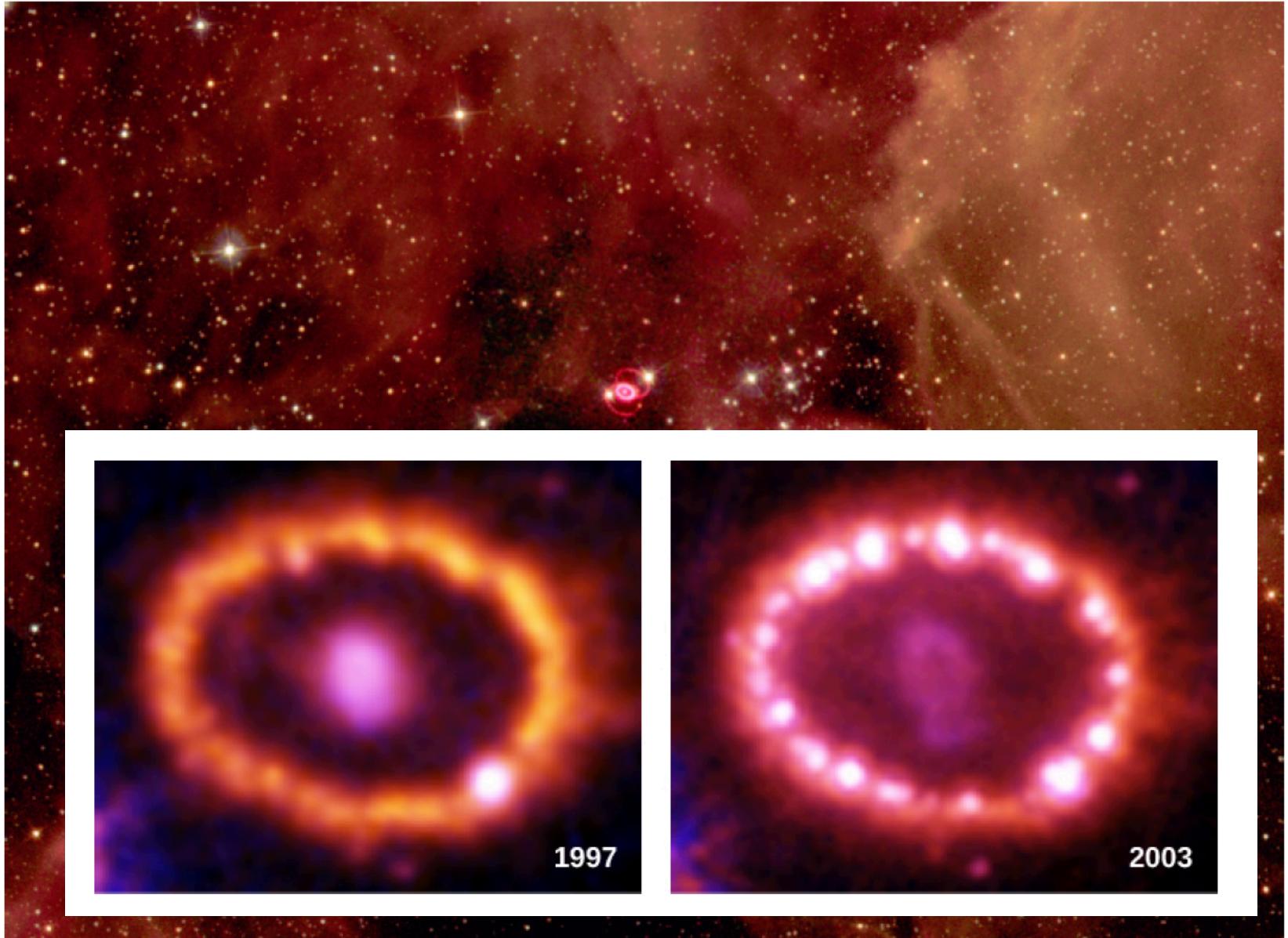
Supernova remnant



Supernova remnant



Supernova remnant



Initial Mass (Mass of Sun = 1)^[1]	Final State at the End of Its Life
< 0.01	Planet
0.01 to 0.08	Brown dwarf
0.08 to 0.25	White dwarf made mostly of helium
0.25 to 8	White dwarf made mostly of carbon and oxygen
8 to 10	White dwarf made of oxygen, neon, and magnesium
10 to 40	Supernova explosion that leaves a neutron star
> 40	Supernova explosion that leaves a black hole

