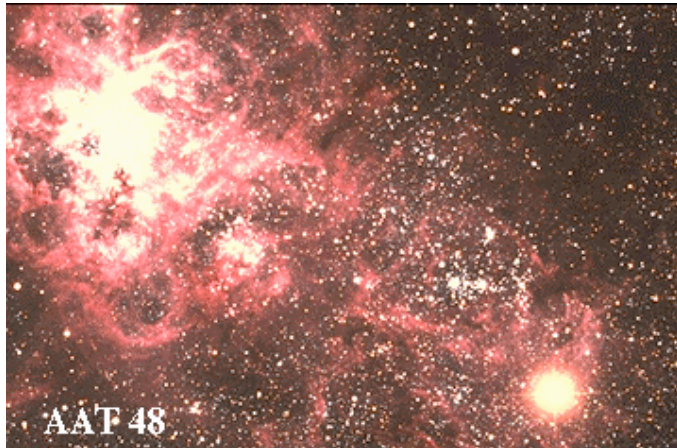


Large Magellanic Cloud

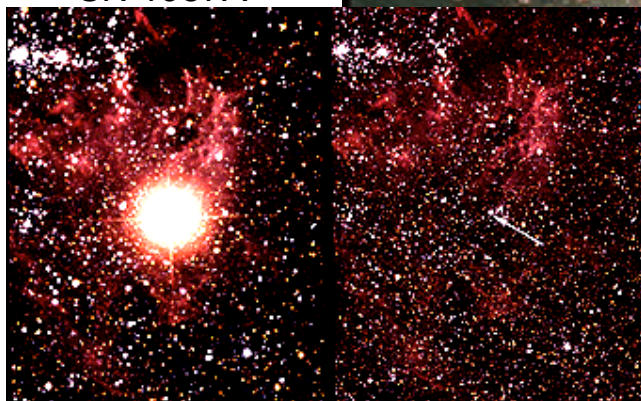
Satellite galaxy of Milky Way
150,000 light-years away



AAT 48

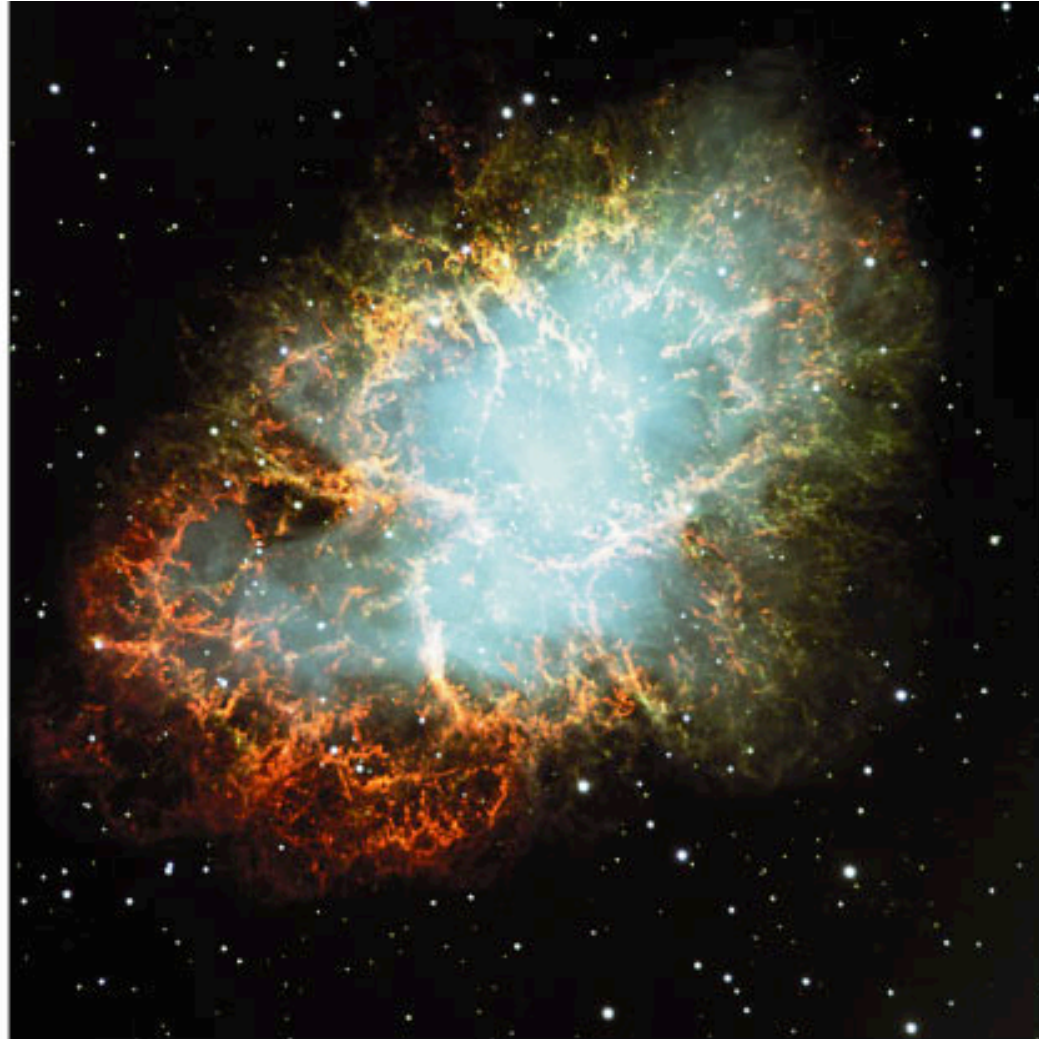
30 Doradus
Tarantula Nebula

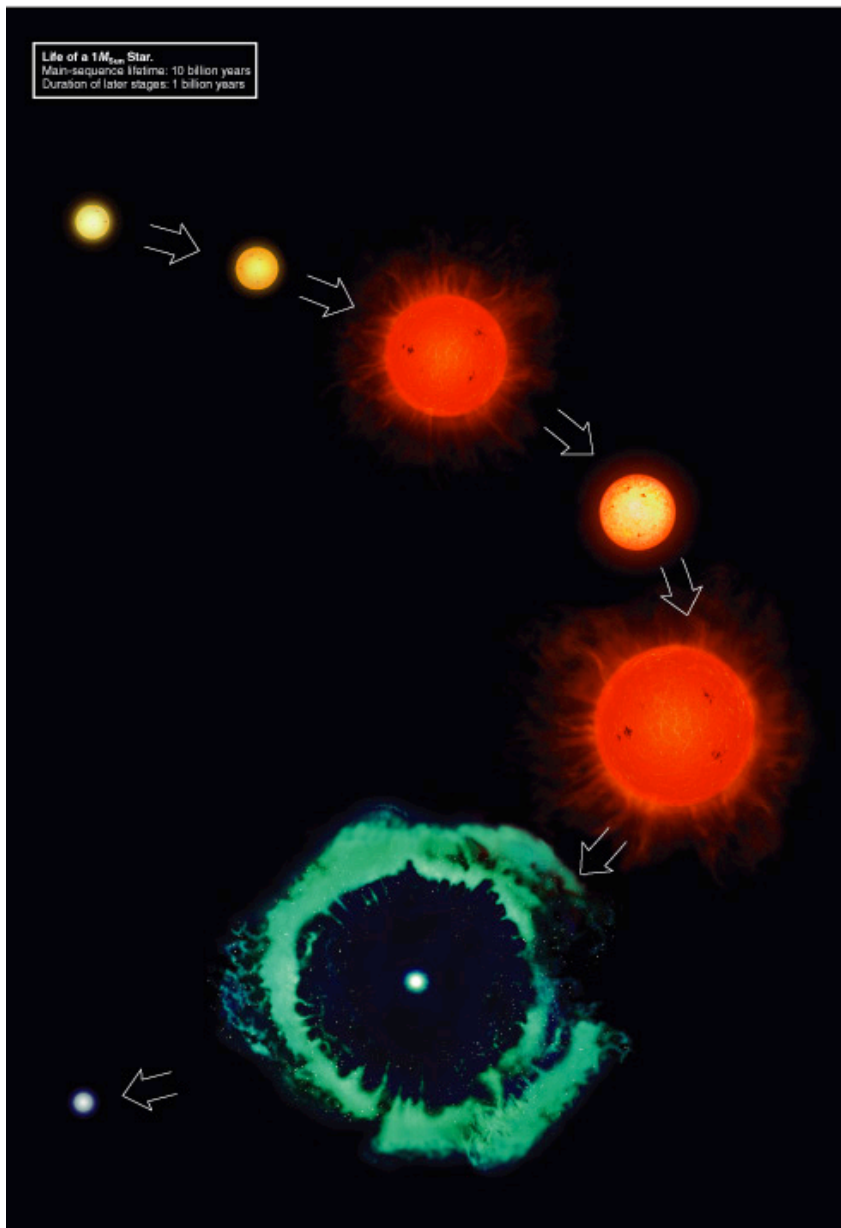
SN 1987A



UKS 14

How do massive stars die?





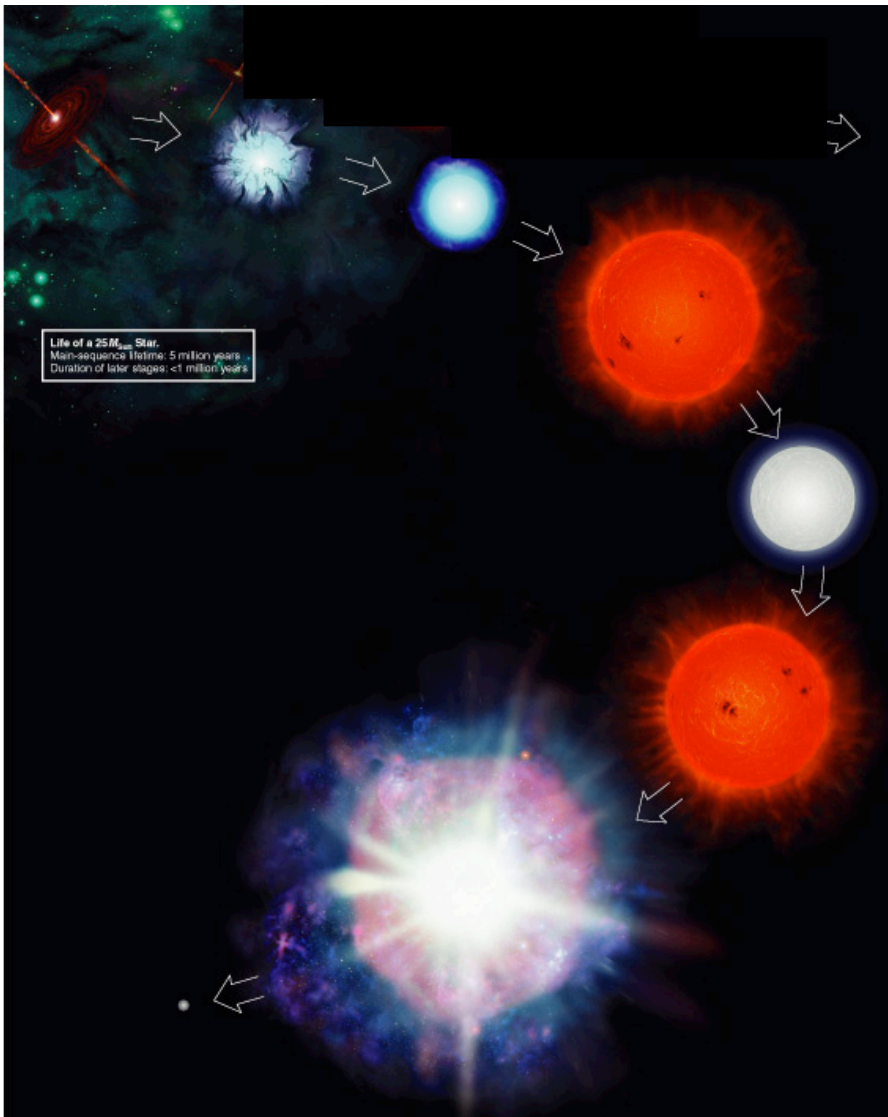
Not to scale!

Low Mass Star Summary

1. Main Sequence: H fuses to He in core
2. Red Giant: H fuses to He in shell around He core
3. Helium Core Burning: He fuses to C in core while H fuses to He in shell
4. Double Shell Burning: H and He both fuse in shells
5. Planetary Nebula leaves white dwarf behind

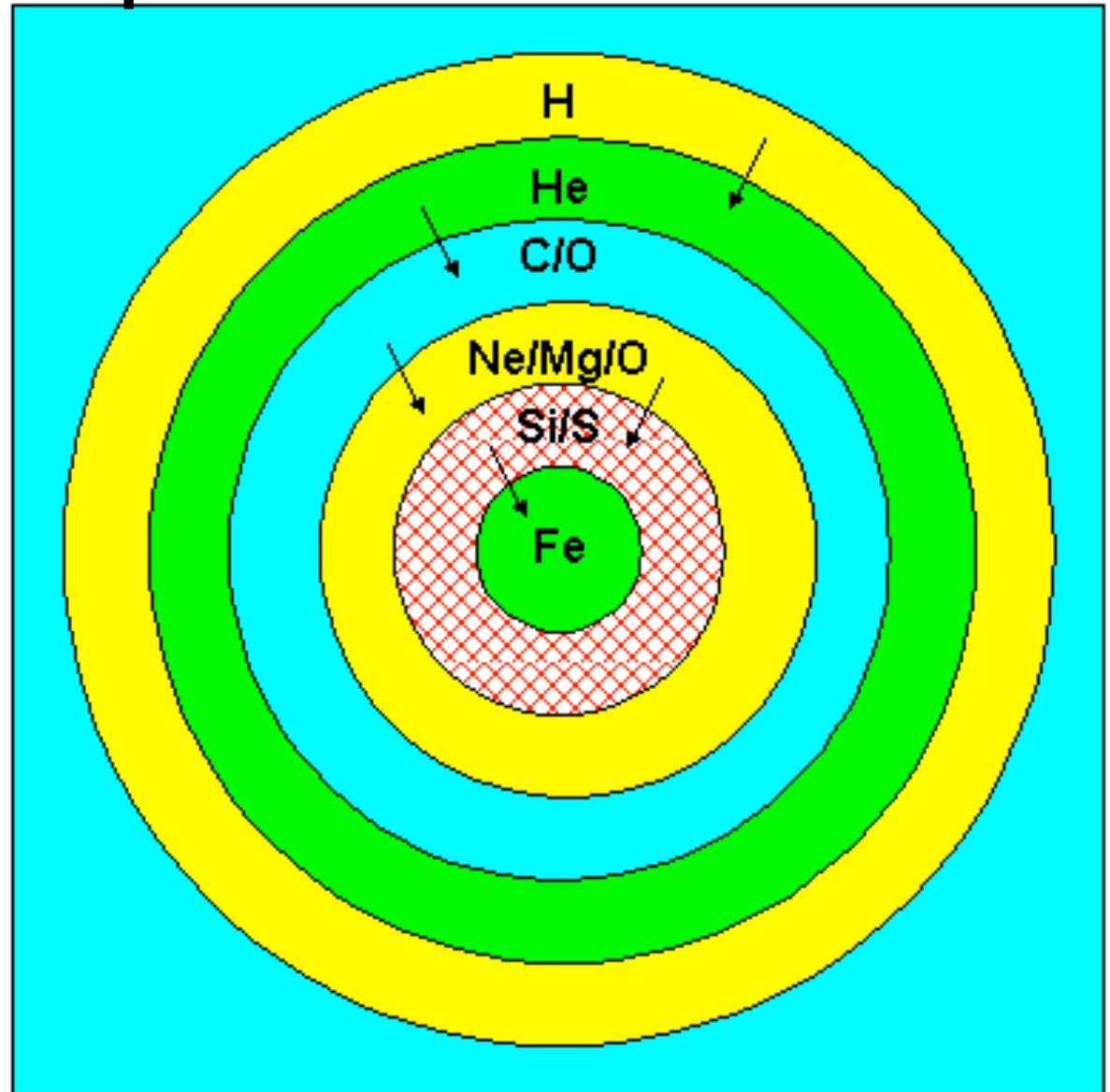
High Mass Star Summary

1. Main Sequence: H fuses to He in core
2. Red Supergiant: H fuses to He in shell around He core
3. Helium Core Burning: He fuses to C in core while H fuses to He in shell
4. Multiple Shell Burning: Many elements fuse in shells
5. Supernova leaves neutron star behind

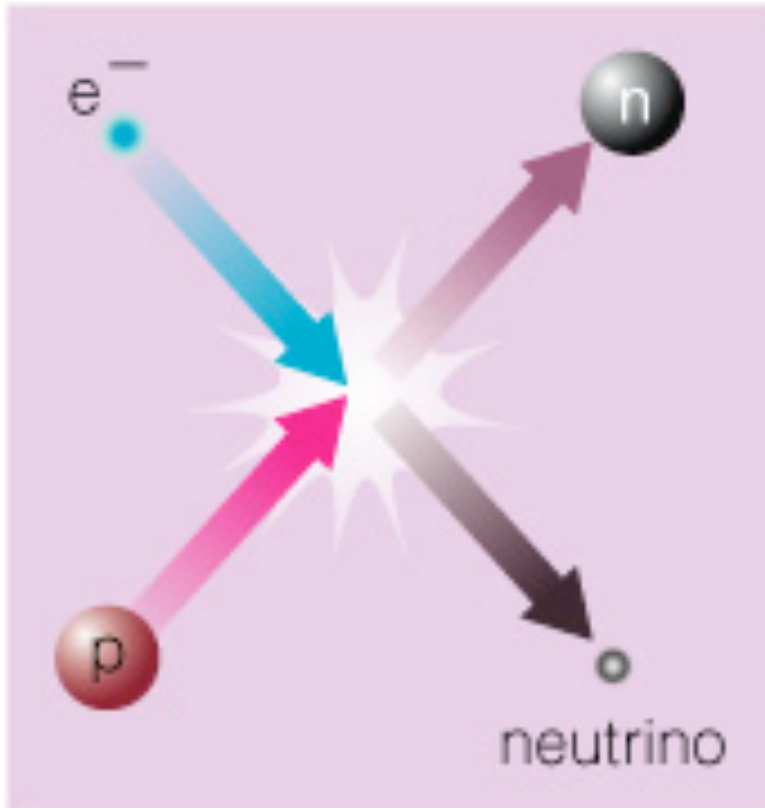


Not to scale!

Onion-like Structure of a Pre-Supernova Star



Supernova Explosion



- Core degeneracy pressure goes away because electrons combine with protons, making neutrons and neutrinos
- Neutrons collapse to the center, forming a **neutron star**

Key

12	Atomic number
Mg	Element's symbol
Magnesium	Element's name
24.305	Atomic mass*

*Atomic masses are fractions because they represent a weighted average of atomic masses of different isotopes—in proportion to the abundance of each isotope on Earth.

1 H Hydrogen 1.00794	2 He Helium 4.003																																
3 Li Lithium 6.941	4 Be Beryllium 9.01218	5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.988	10 Ne Neon 20.179																										
11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 Al Aluminum 26.98	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948																										
19 K Potassium 39.098	20 Ca Calcium 40.08	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.69	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.59	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Fr Francium 83.80																
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.9059	40 Zr Zirconium 91.224	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.75	52 Te Tellurium 127.60	53 I Iodine 126.905	54 Xe Xenon 131.29																
55 Cs Cesium 132.91	56 Ba Barium 137.34	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.2	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.96657	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)																	
87 Fr Francium (223)	88 Ra Radium 226.0254	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Uun Ununnilium (269)	111 Uuu Unununium (272)	112 Uub Ununbium (277)																							

Lanthanide Series

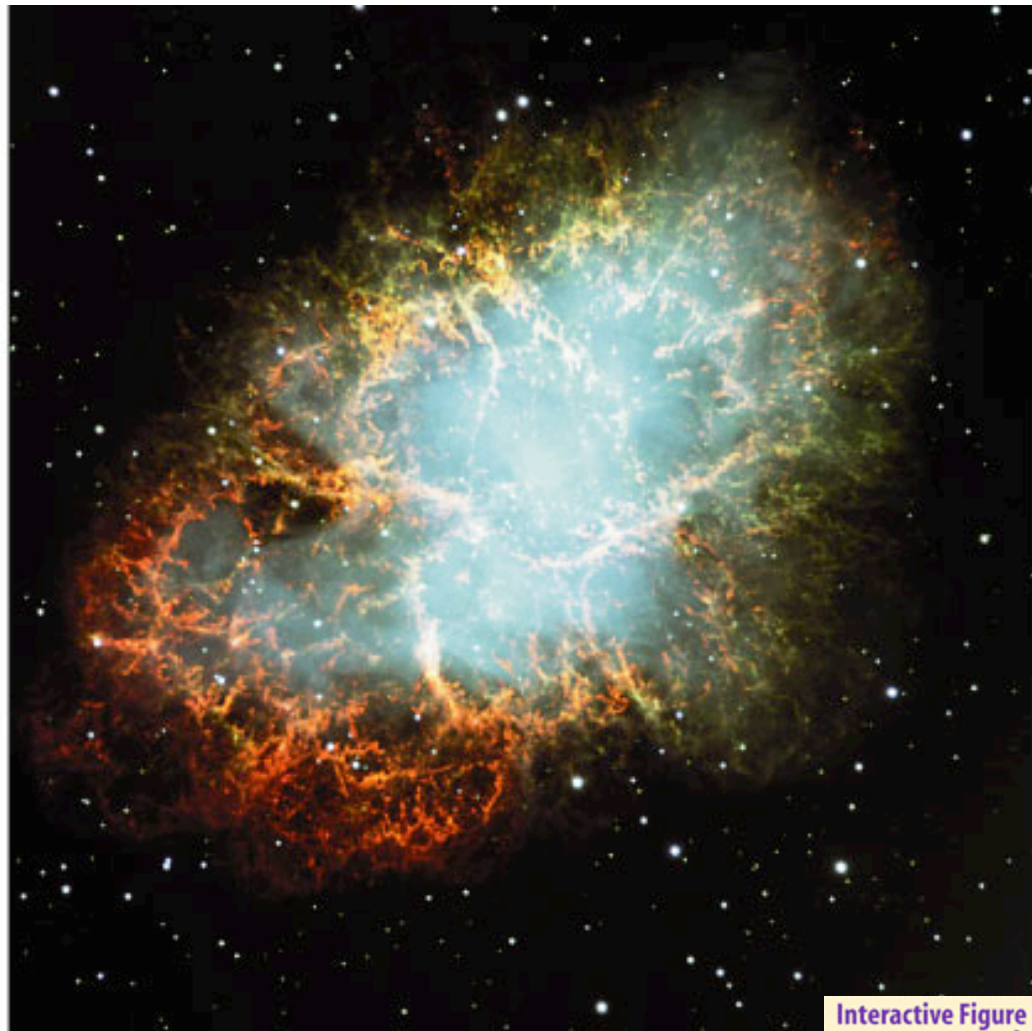
57 La Lanthanum 138.906	58 Ce Cerium 140.12	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
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Actinide Series

89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)
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Energy and neutrons released in supernova explosion enable elements heavier than iron to form, including Au and U

Supernova Remnant



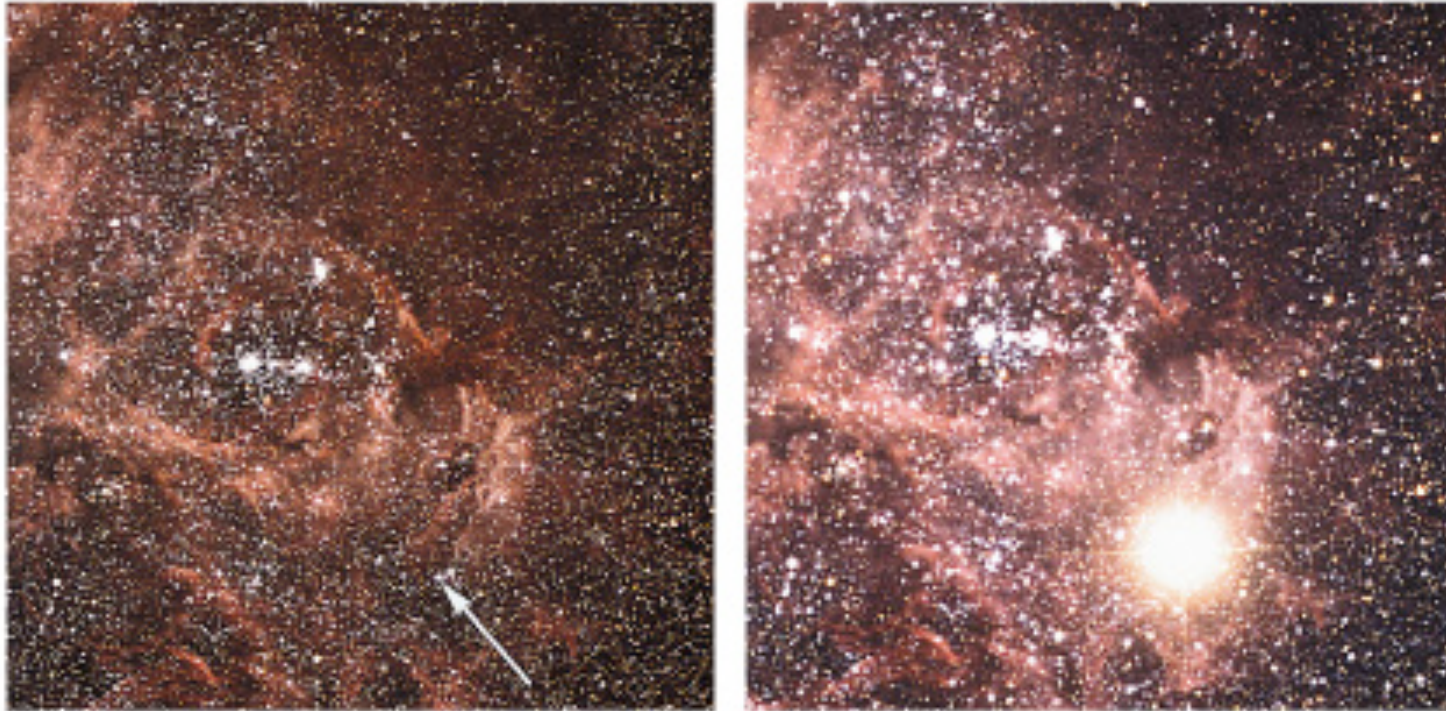
Interactive Figure

- Energy released by collapse of core drives outer layers into space
- The Crab Nebula is the remnant of the supernova seen in A.D. 1054

SN 1054: Chaco Canyon Petroglyph

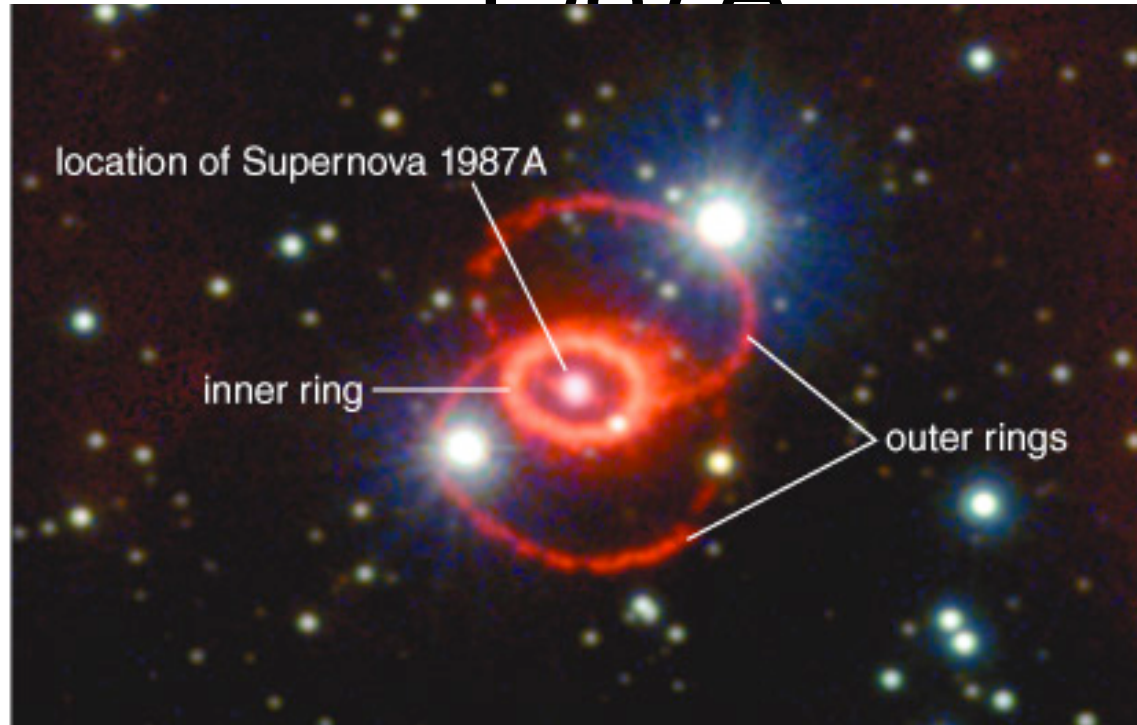


Supernova 1987A



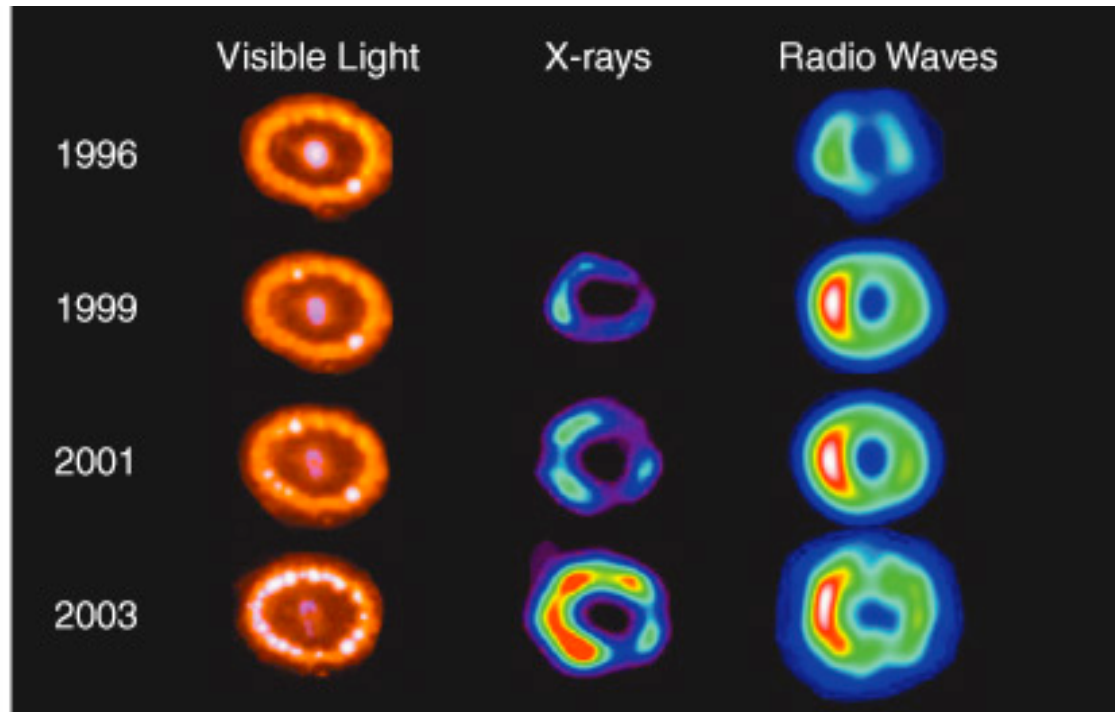
- The closest supernova in the last four centuries was seen in 1987

Rings around Supernova 1987A



- The supernova's flash of light caused rings of gas around the supernova to glow

Impact of Debris with Rings



- More recent observations are showing the inner ring light up as debris crashes into it

