Supernovae

Crab supernova remnant
Supernova observations

Only a three supernovae have been observed within the Milky way galaxy and five anywhere before the use of telescopes:

1. HB9 was marked on star charts from India about 5000 years ago.
2. SN 185 was viewed by Chinese astronomers in 185 CE
3. On about April 30, 1006 a magnitude -9 star suddenly appeared in the constellation Lupus, bright enough to be seen in daytime and to read by at night. It was reported by astrologers in Europe, the Middle East, and Asia.
4. July 4, 1054, Yang Wei-T'e documented a “guest star” in Taurus, which gradually became invisible after a year. It was also observed in Japan, Korea and Arabia. It was also visible in daylight. This supernova is the source of the Crab nebula (Crab supernova remnant). (Milky Way)
5. Tycho Brahe recorded a supernova in 1572. (Tycho's supernova) (Milky Way)

• Johannes Kepler (Tycho Brahe's student) recorded a supernova in 1604. (Kepler's supernova) (Milky Way)
• The closest supernova since Kepler's supernova occurred in the Large Magellanic Cloud in 1987. (SN 1987A)
Luminous Blue Variables
Eta Carinae was larger than the orbit of mercury.
Most of this is just dust; the star hasn’t really exploded yet, but it may “soon”.
Wolf-Rayet stars
Crab supernova remnant

Hubble space telescope, visible

Various wavelengths:
Sketches of supernova spectra near maximum light (about 1 week)

-2.5 log $f_{\lambda}$ + constant

Rest wavelength (nm)

Sketches of spectra from Carroll & Ostlie, data attributed to Thomas Matheson of National Optical Astronomy Observatory.
Spectral features seen in the light from supernovae of different types. The y-axis shows the relative flux. I nicked this image from Fritz's (Fritz Röpke) talk, but he clearly took it from somewhere else himself!

Seth Nadathur
track for 1M☉ star

Luminosity (L☉)

Temperature (x10³ K)

10¹⁰ years

white dwarf

main-sequence dwarf

horizontal branch

asymptotic giant

red giant

red supergiant

planetary nebula stage
FIGURE 13.4  A schematic diagram of the evolution of a low-mass star of 1 $M_\odot$ from the zero-age main sequence to the formation of a white dwarf star (see Section 16.1). The dotted phase of evolution represents rapid evolution following the helium core flash. The various phases of evolution are labeled as follows: Zero-Age-Main-Sequence (ZAMS), Sub-Giant Branch (SGB), Red Giant Branch (RGB), Early Asymptotic Giant Branch (E-AGB), Thermal Pulse Asymptotic Giant Branch (TP-AGB), Post-Asymptotic Giant Branch (Post-AGB), Planetary Nebula formation (PN formation), and Pre-white dwarf phase leading to white dwarf phase.
Evolution of a solar mass star

- Planetary Nebula formation
- Post-Asymptotic Giant Branch
- Superwind
  - First He shell flash
  - Second dredge-up
  - Early Asymptotic Giant Branch
  - He core exhausted
  - He core burning
  - H shell burning
  - Core contraction
  - H core exhausted
  - Sub-Giant Branch

- Zero Age Main Sequence
- Hydrogen fusion in core 90% of stellar lifetime

- Thermal Pulse Asymptotic Giant Branch
- Red Giant Branch
The highest point on the curve is iron, which is therefore the endpoint of both fusion and fission reactions.
Which elements
• have equal numbers of protons and neutrons
• have atomic mass number a multiple of 4
• are lighter than Iron?

• He (2/4)
• C (6/12) = 3 He
• O (8/16) = 4 He
• Ne (10/20) = 5 He
• Mg (12/24) = 6 He
• Si (14/28) = 7 He
• S (16/32) = 8 He
• Ca (20/40) = 10 He

If fusion from Helium is the source of the elements, we may expect these to be the most abundant elements.
From Wikipedia, abundance of the elements:

<table>
<thead>
<tr>
<th>Z</th>
<th>Element</th>
<th>Mass fraction (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hydrogen</td>
<td>739,000</td>
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<tr>
<td>2</td>
<td>Helium</td>
<td>240,000</td>
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<tr>
<td>8</td>
<td>Oxygen</td>
<td>10,400</td>
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<tr>
<td>6</td>
<td>Carbon</td>
<td>4,600</td>
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<tr>
<td>10</td>
<td>Neon</td>
<td>1,340</td>
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<tr>
<td>26</td>
<td>Iron</td>
<td>1,090</td>
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<td>7</td>
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<tr>
<td>14</td>
<td>Silicon</td>
<td>650</td>
</tr>
<tr>
<td>12</td>
<td>Magnesium</td>
<td>580</td>
</tr>
<tr>
<td>16</td>
<td>Sulfur</td>
<td>440</td>
</tr>
</tbody>
</table>

32,000 year old star chart? The human figure has the same proportions that the stars of Orion would have had at that time.