

*In the first year of the period Chih-ho, the fifth moon, the day chi-ch'ou, a guest star appeared approximately several [degrees] southeast of Thien-kuan. After more than a year it gradually became invisible. (1054)*

# Introductory Astronomy

## Week 5: Stellar Evolution

### Clip 13: Core Collapse

# The Center Cannot Hold

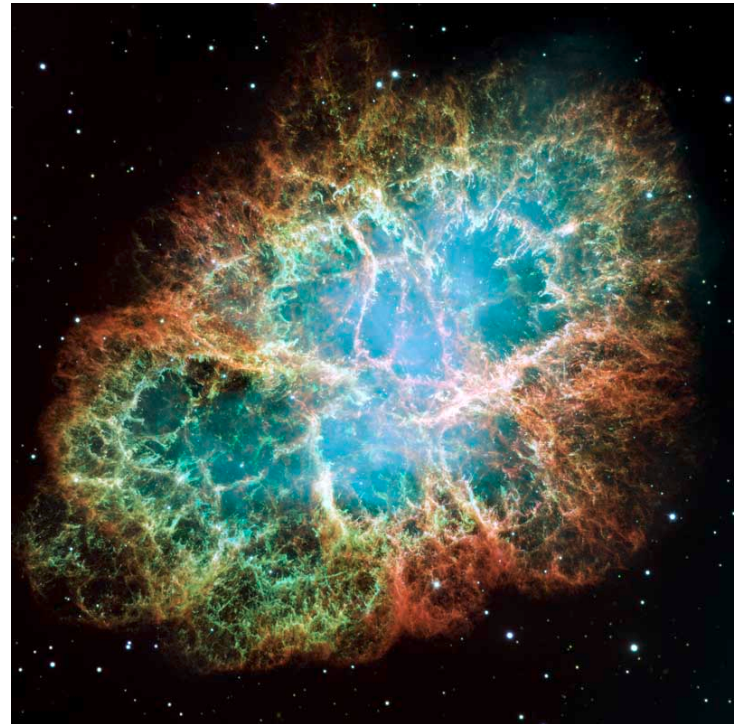
- As gravitational crush increases, iron core **collapses** from size of **Earth** to a **few km** in **0.1 s**
- In **core**,  $T_c \sim 3.5 \times 10^9 \text{ K}$  emits **γ rays** leading to **photodisintegration** of heavy nuclei
- Outer layers fall inward at speeds up to **0.15c**
- As core collapses **electron degeneracy** overcome
- Electrons forced into
$$p^+ + e^- \rightarrow n + \nu_e$$
- Left with a small, incredibly dense core that is mostly **neutrons**
- Does collapse **stop**?

# Boom!

- Within **0.25s** core is **neutrons** with radius **20 km** and super-nuclear density  $\rho \sim 8 \times 10^{17} \text{kg/m}^3$
- Very little light can escape, energy carried off by **neutrinos**. Power emitted in these exceeds **all known stars** for **10 s**
- At this density core **collapse** stops with **bounce**
- Colliding with infalling layers this triggers **shock wave** blowing outer star into space (**96%** of mass for  **$25M_{\odot}$**  star)
- In compressed heated shock wave **fusion** to **Fe** and **beyond** via **r-process**
- As ejecta thin light can escape. Luminosity reaches  **$3 \times 10^8 L_{\odot}$**
- Energy released  **$10^{47} \text{ J}$**  **type-II supernova** – **gravitational** in origin

# Seeing Them

- **Sung dynasty** history describes a **supernova** in **1054** whose remnant – **Crab nebula** in **Taurus** – is still visible (**M1**)
- Japanese, Arabic, Native American records concur
- **Milky Way** supernovae also in **1006, 1572, 1604**. Estimated every **300 years** but obscured by dust
- Many visible in other galaxies, currently some **20-30** bright ones

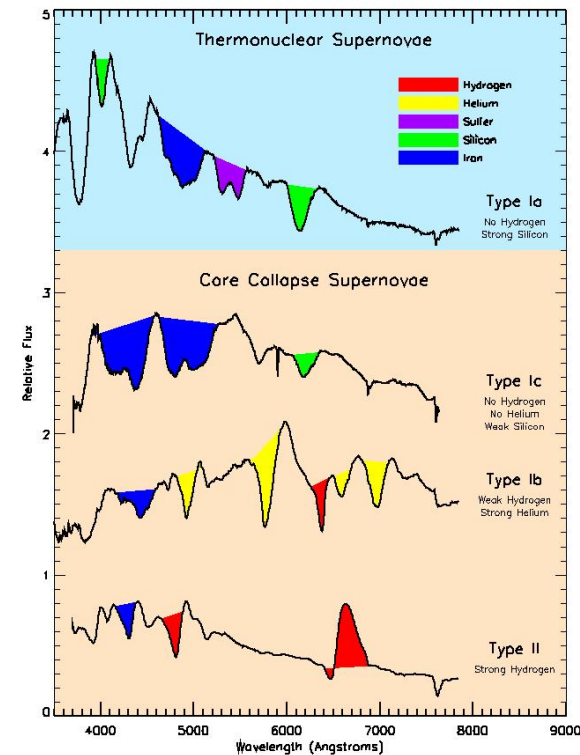


# SN 2011dh



# Classification

- SN classified by **spectrum**:
  - **Ia**: Strong **Si** no **H** **He**
  - **Ib**: Weak **H** Strong **He**
  - **Ic**: Weak **Si** no **H** **He**
  - **II**: Strong **H**
- **Ia** are **nuclear** explosion of **WD**
- **II Ib Ic** are **gravitational** core collapse with degrees of **envelope loss**



# Credits

- M1: NASA, ESA, J. Hester and A. Loll (Arizona State University)  
<http://hubblesite.org/newscenter/archive/releases/2005/37/image/a/>
- SN 2011dh: P. Wiggins, Salt Lake Astronomical Society  
[http://www.slas.us/gallery2/main.php?g2\\_itemId=4342&g2\\_imageViewsIndex=1](http://www.slas.us/gallery2/main.php?g2_itemId=4342&g2_imageViewsIndex=1)
- SN Types:  
[http://supernova.lbl.gov/~dnkasen/tutorial/graphics/sn\\_types.jpg](http://supernova.lbl.gov/~dnkasen/tutorial/graphics/sn_types.jpg)