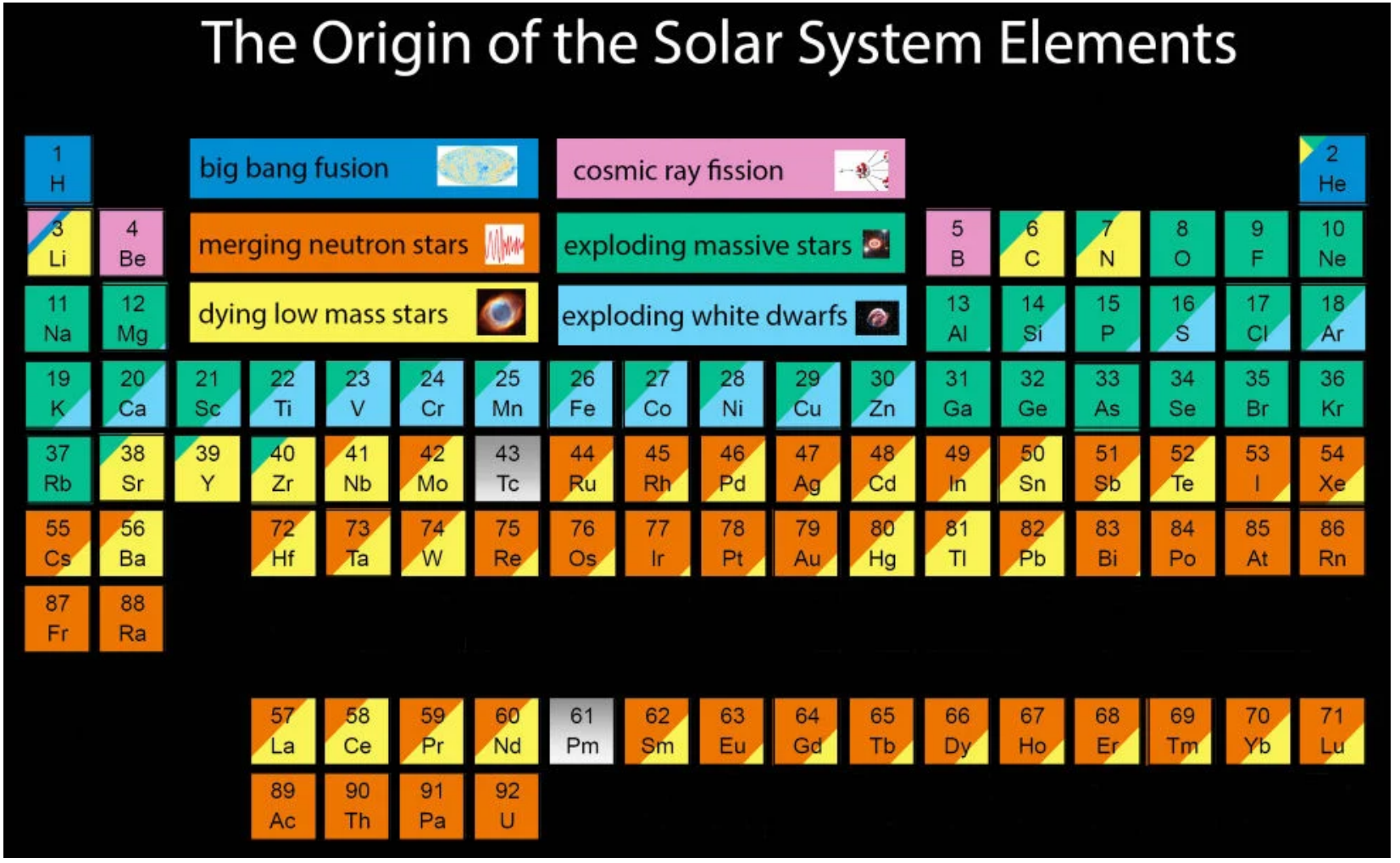
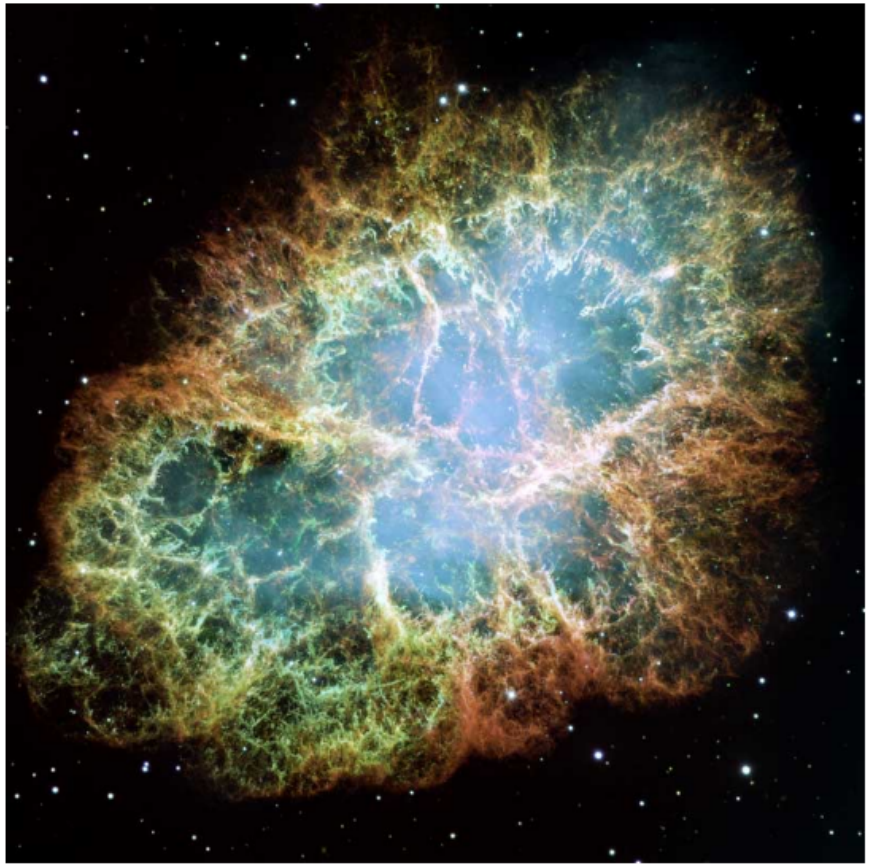
Supernovae & Gamma Ray Bursts

Outline

- Introduction
- Supernovae Ia
- SN Ia models: Single vs Double Degenerate
- Core collapse Supernovae
- Supernova Remnants
- Gamma Ray Bursts

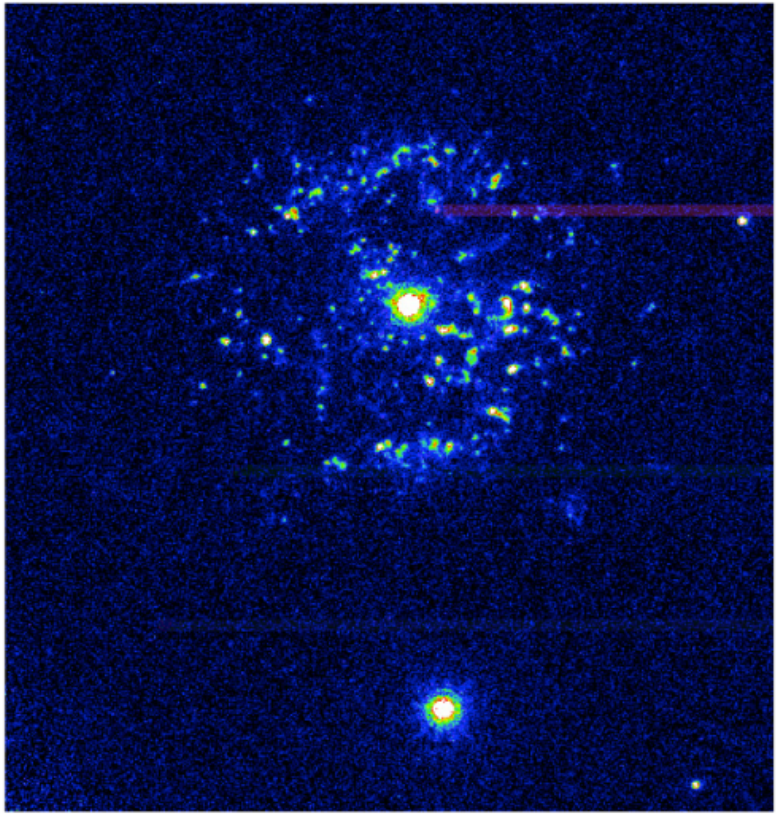
The Origin of the Solar System Elements



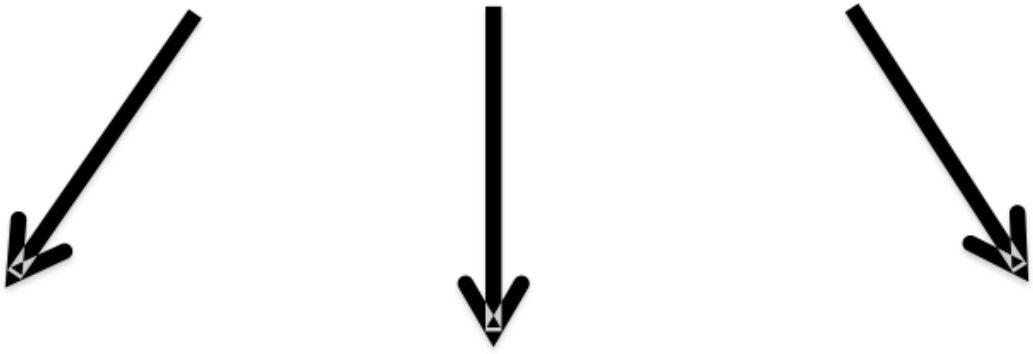


CRAB NEBULA (ESO)
Supernova remant and pulsar
SN from 1054
6500 light yrs = 2.5 kpc (distance)

T Pyx: nova (HST)
d>4.5 kpc



STELLAR EXPLOSIONS



ORIGIN OF THE ELEMENTS

TRIGGER STAR FORMATION

DYNAMICS OF THE GALAXY

Gamma-ray emission related to nucleosynthesis and matter- antimatter annihilation

- Diffuse gamma-ray line (and also continuum) emission related with "radioactivities in the Galaxy"
  - Electron-positron annihilation: 511 keV line plus positronium continuum
  - ^{26}Al and ^{60}Fe: related with massive stars and their explosions
  - ^{44}Ti: related with supernova remnants

X-rays and gamma-rays from stellar explosions

- Explosions: novae, supernovae and their remnants:
  - Ø Nucleosynthesis and ejection of radioactive nuclei: **gamma**
  - Ø Fast ejecta interacting with CSM (shocks), particle acceleration (inverse Compton, synchrotron radiation): **X and HE gamma**
- Also in non-explosive phenomena radioactive nuclei are formed: nucleosynthesis in stars ejected into the ISM (massive stars, AGB)

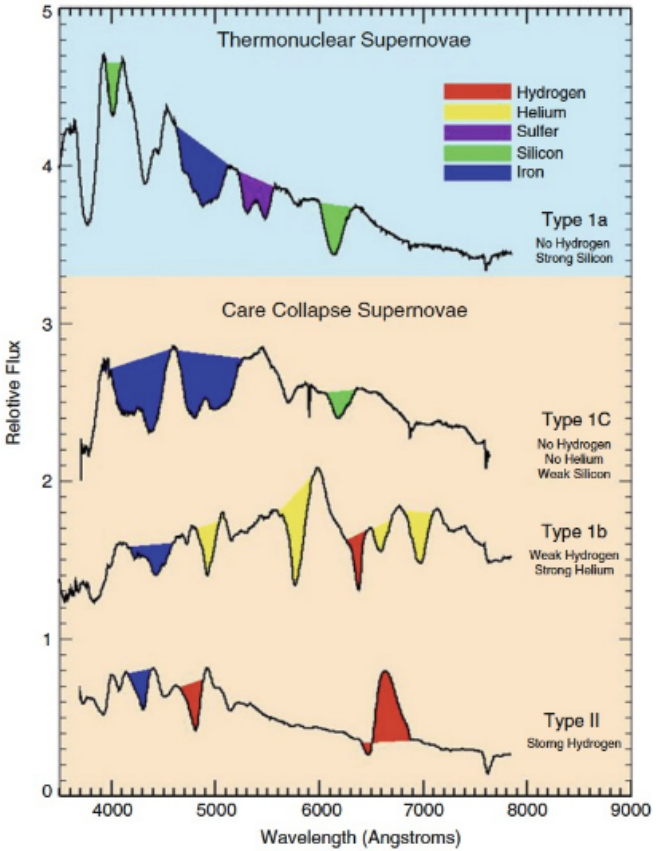
Summary of supernova types

Thermonuclear Supernovae (SN Ia):

- white dwarf explosion
- no remnant
- no H
- origin of explosion: thermonuclear energy

Core collapse supernovae / gravitational SNe (SN II, Ib, Ic)

- massive star explosion
- remnant: neutron star or black hole
- H (in general)
- origin of explosion: gravitational energy



From Handbook of Supernovae

Synthesis of radioactive isotopes in supernovae

Short-lived isotopes: **^{56,57}Ni** (all), **^{44}Ti** (SN II and Ib/c; also in sub-Chandra SN Ia), **^{60}Co** (SN II and Ib/c)

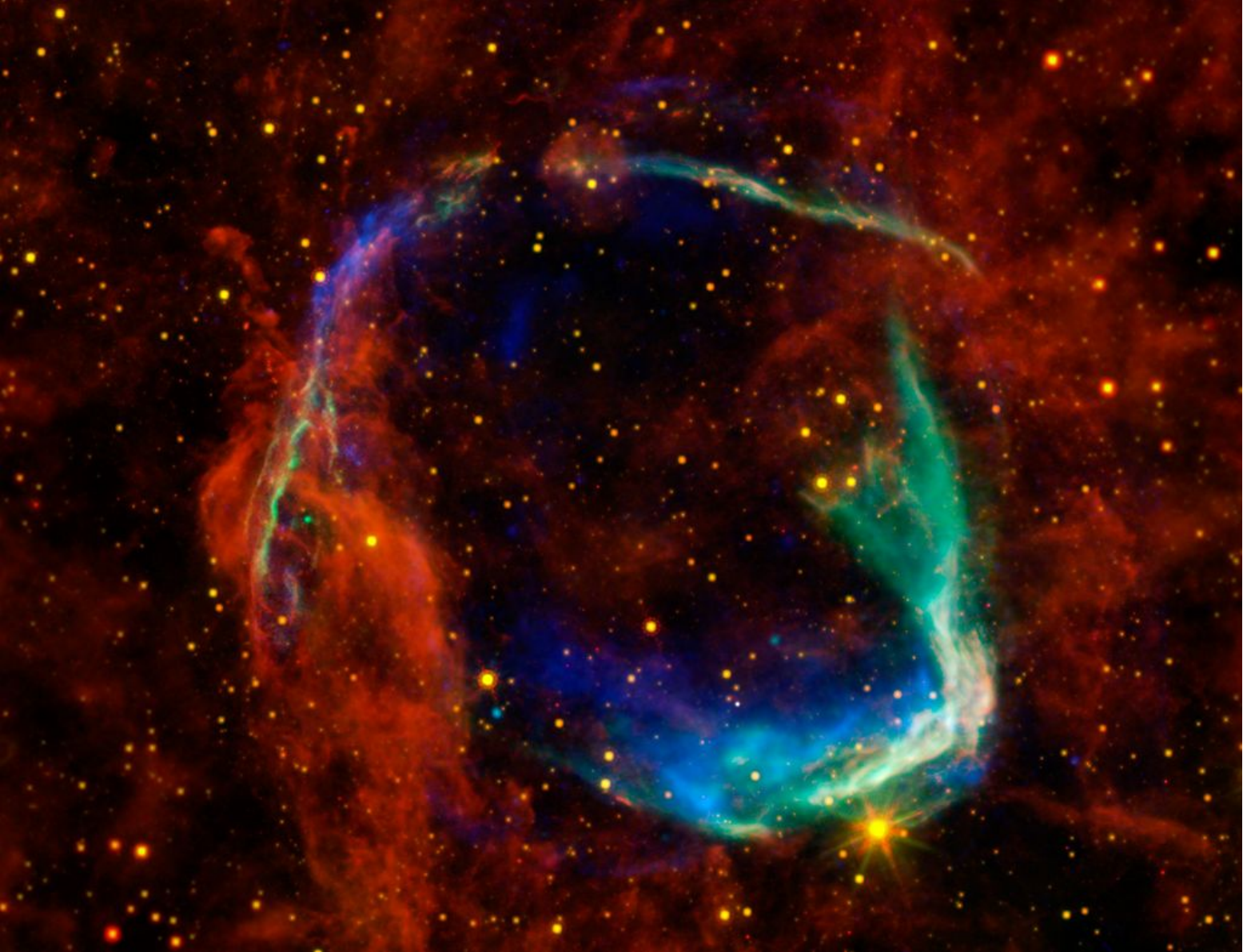
→ diagnostic of models: observation of individual objects

- γ-ray lines: ^{56,57}Ni and ^{44}Ti yields (better in SN Ia; detected in SN 1987A)
- bolometric light curves

Long-lived isotopes: **^{26}Al** and **^{60}Fe** (SN II and Ib/c)

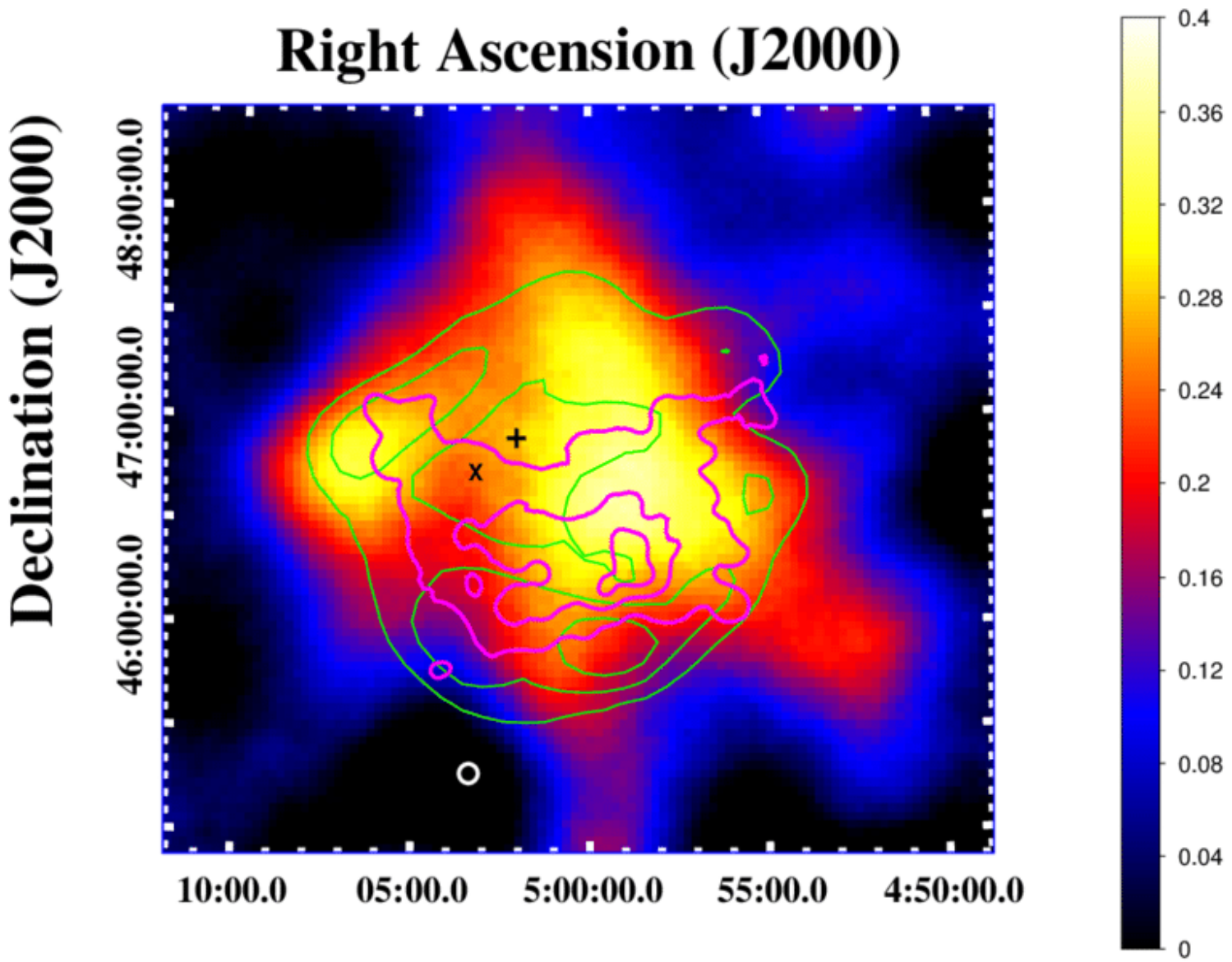
→ diagnostic of models: observation of accumulated emission in the Galaxy

γ-ray line astronomy could provide crucial insights on supernova models



SN 185
First supernova recorded (185 AD, by Chinese astronomers)

Possibly a Type Ia supernova



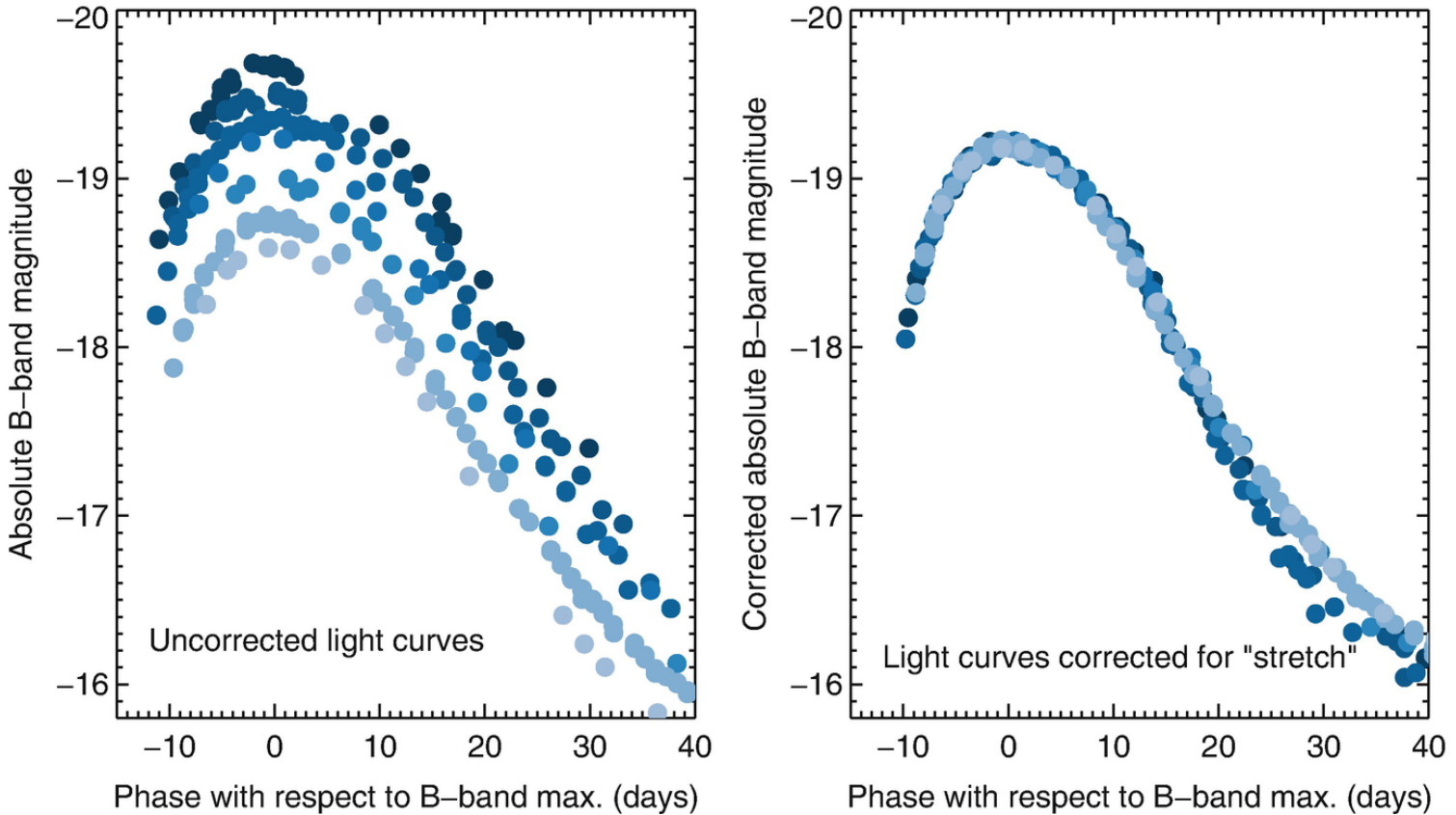
HB9
Possibly the first supernova ever recorded by humans

Figure 1: Photograph of stone Carving from Burzahom (Courtesy IGNCA) along with a sketch of the same.

Some work Joglekar, Vahia & Sule (2011) suggests this supernova was recorded in cave paintings during the neolithic in 4,500 +- 1,000 BC

Type Ia Supernovae

Type Ia Supernovae are Standard Candles



Stellar explosions of White Dwarfs

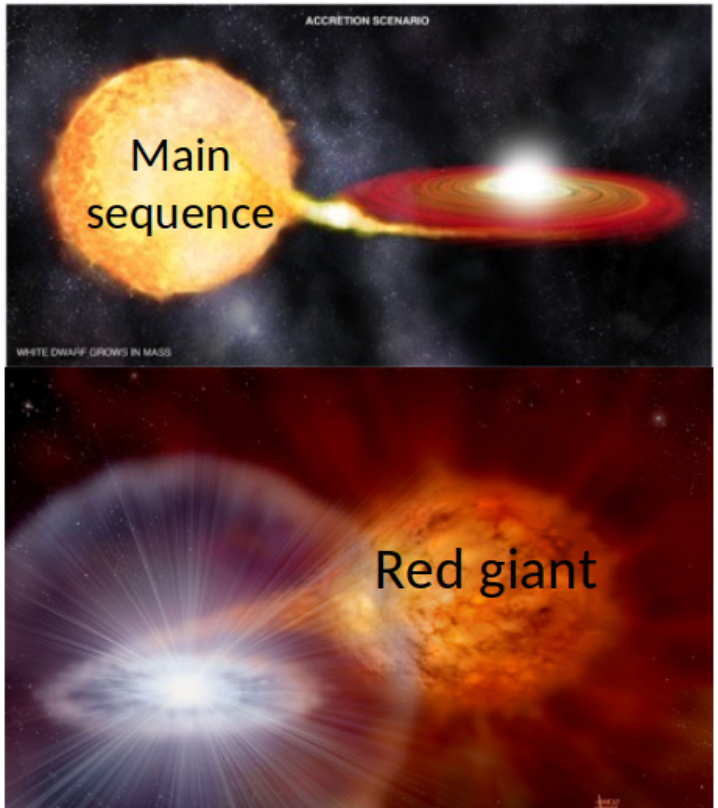
- Endpoints of stellar evolution ($M < 10 M_{\odot}$): no E_{nuc} available; compression until electrons become degenerate
- Chemical composition: He, CO, ONe; masses: typical 0.6 $M_{\odot}$, maximum: $M_{Chandrasekhar}$ ($\sim 1.4 M_{\odot}$)
- When isolated, they cool down to very low L ($\sim 10^{-4.5} L_{\odot}$):

⇒ "fossils" allowing to do "stellar archeology" (age of the Galaxy, star formation rate)

- When in interacting binary systems, they can be "rejuvenated" and eventually explode

Stellar explosions: WDs in close binary systems
Scenarios/Progenitors of SNIa

Single degenerate:
WD+MS or WD+RG



Double degenerate: merging
of two white dwarfs