


ASTR/PHYS 5590: High Energy Astrophysics



Week 7

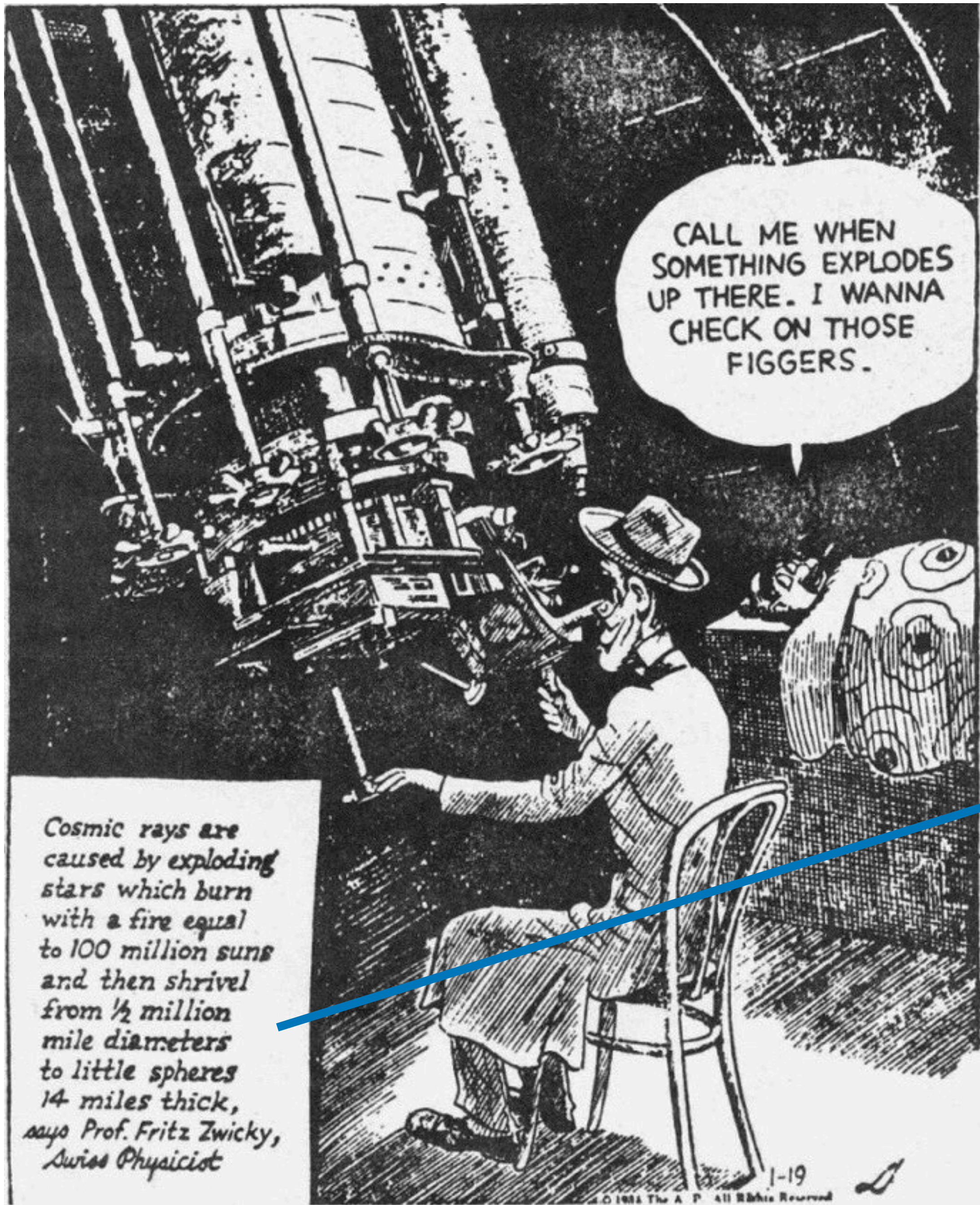
HW05 due on Thursday

Projects: <http://www.astro.utah.edu/~wik/courses/astr5590spring2020/projects.html>

Supernovae (Ch. 13.1)

White Dwarfs (Ch. 13.2) & Neutron Stars (Ch. 13.5)

Supernovae



ON SUPER-NOVAE
BY W. BAADE AND F. ZWICKY
MOUNT WILSON OBSERVATORY, CARNEGIE INSTITUTION OF WASHINGTON AND CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA
Communicated March 19, 1934

A. *Common Novae.*—The extensive investigations of extragalactic systems during recent years have brought to light the remarkable fact

“This, in all modesty, I claim to be one of the most concise triple predictions ever made in science. More than 30 years were to pass before this statement was proved to be true in every respect.”
- Fritz Zwicky, 1968

MOUNT WILSON OBSERVATORY, CARNEGIE INSTITUTION OF WASHINGTON AND CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA
Communicated March 19, 1934

A. *Introduction.*—Two important facts support the view that cosmic rays are of extragalactic origin, if, for the moment, we disregard the possibility that the earth may possess a very high and self-renewing electrostatic potential with respect to interstellar space.

WD thermonuclear explosion



Core Collapse

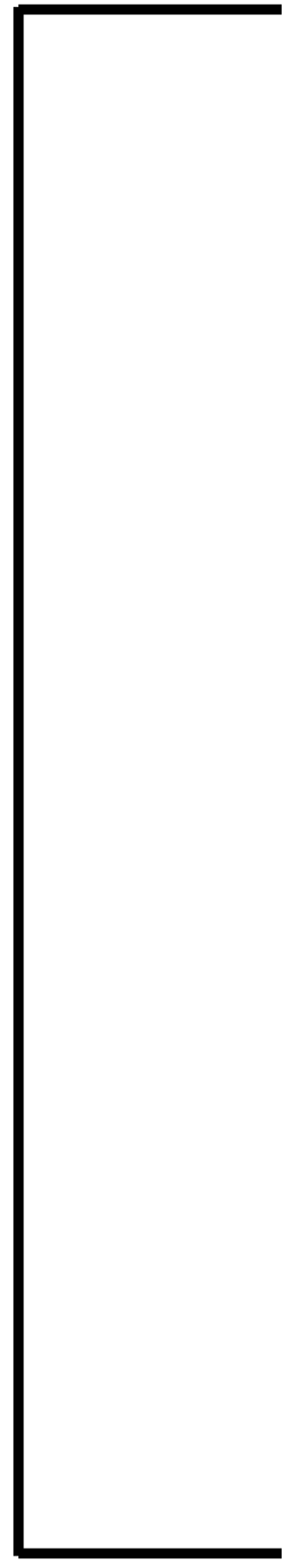
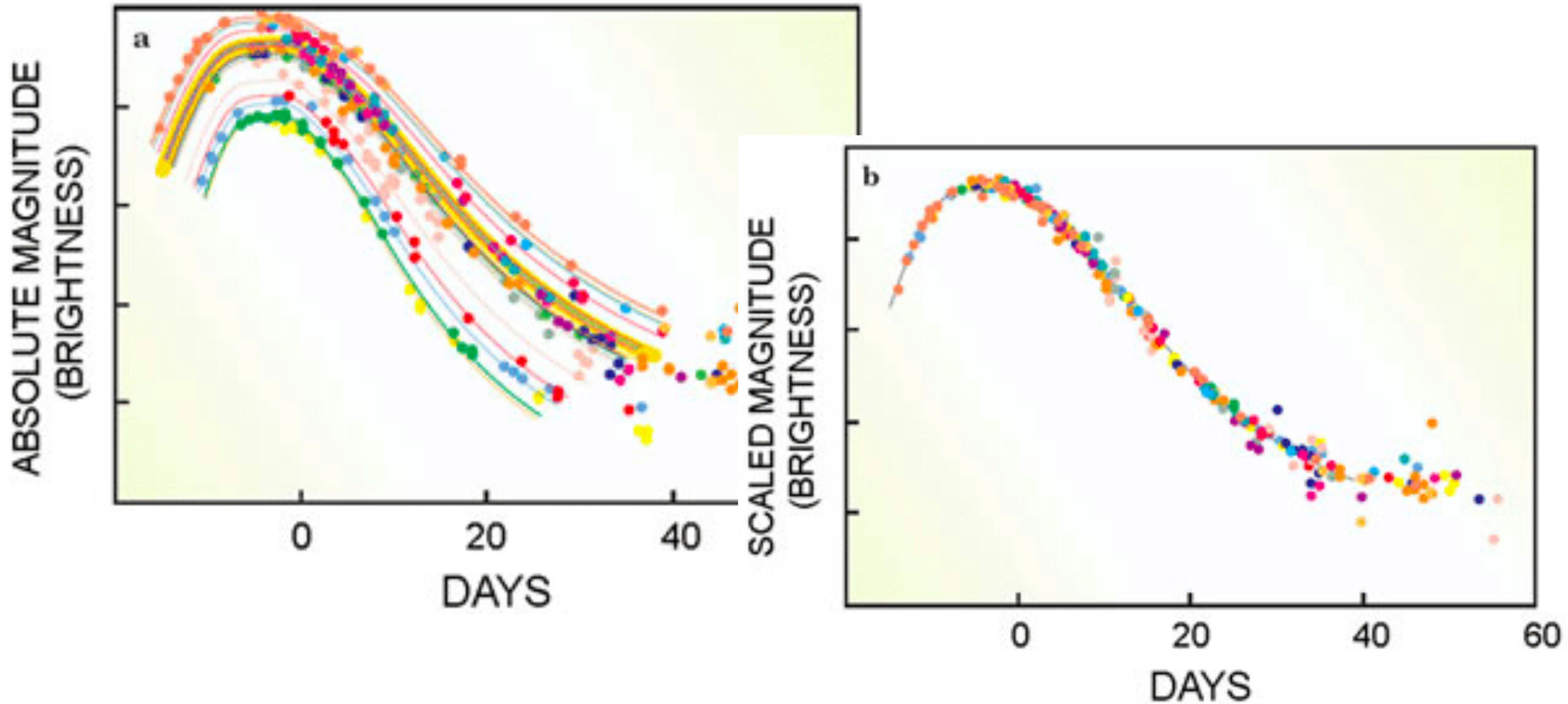


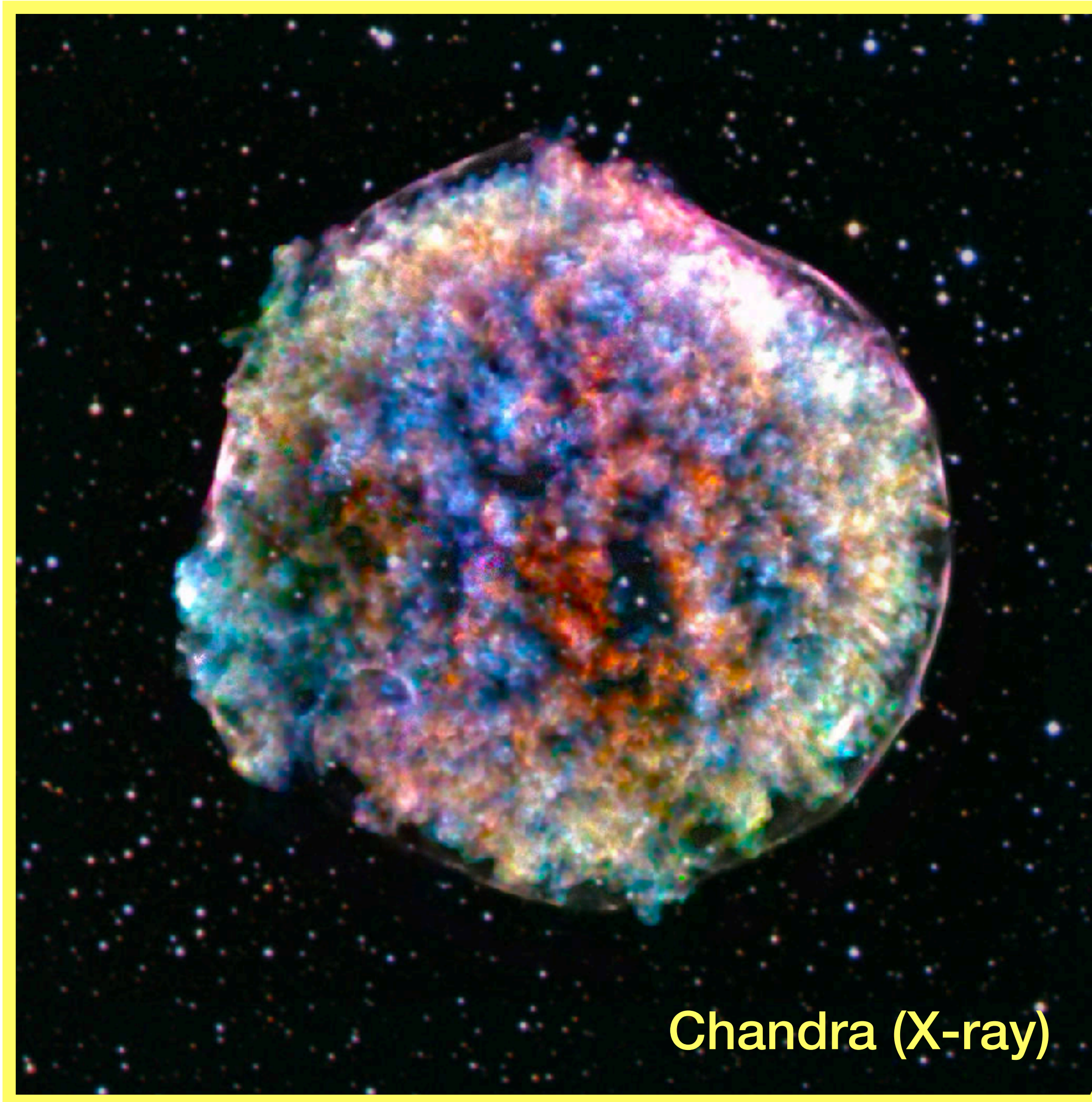
Table 13.1 Supernovae Types I and II.

| Type | Characteristics |
|--|---|
| Type I – absence of hydrogen lines in optical spectrum | |
| Type Ia | Absence of hydrogen lines in spectrum; singly ionised silicon Si II at 615.0 nm observed near peak light. |
| Type Ib | Neutral helium (He I) line at 587.6 nm observed but no strong silicon absorption feature at 615.0 nm. |
| Type Ic | Helium lines are weak or absent; no strong silicon absorption feature 615.0 nm. |
| Type II – hydrogen lines present in optical spectrum | |
| Type IIP | Reaches a ‘plateau’ in its light curve. |
| Type IIL | Displays a linear decrease in its light curve |
| Type IIn | These supernovae contain relatively narrow features compared with the usual broad emission lines of Type II supernovae. |
| Type IIb | These supernovae have spectra similar to Type II at early times but to Type Ib/c at later times. |

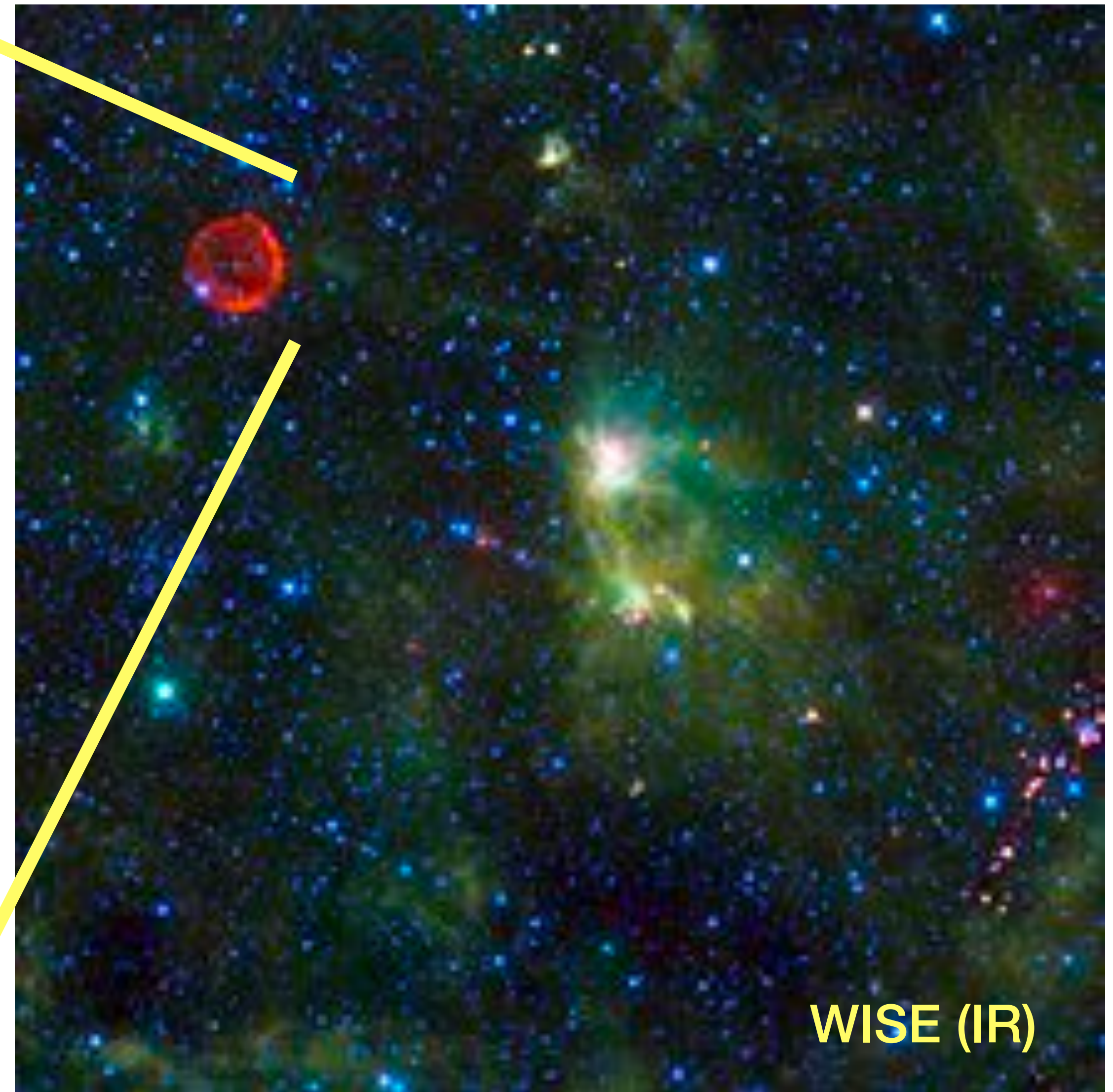
Supernova Type Ia light curves



Tycho SNR - SN of 1572



Chandra (X-ray)



WISE (IR)



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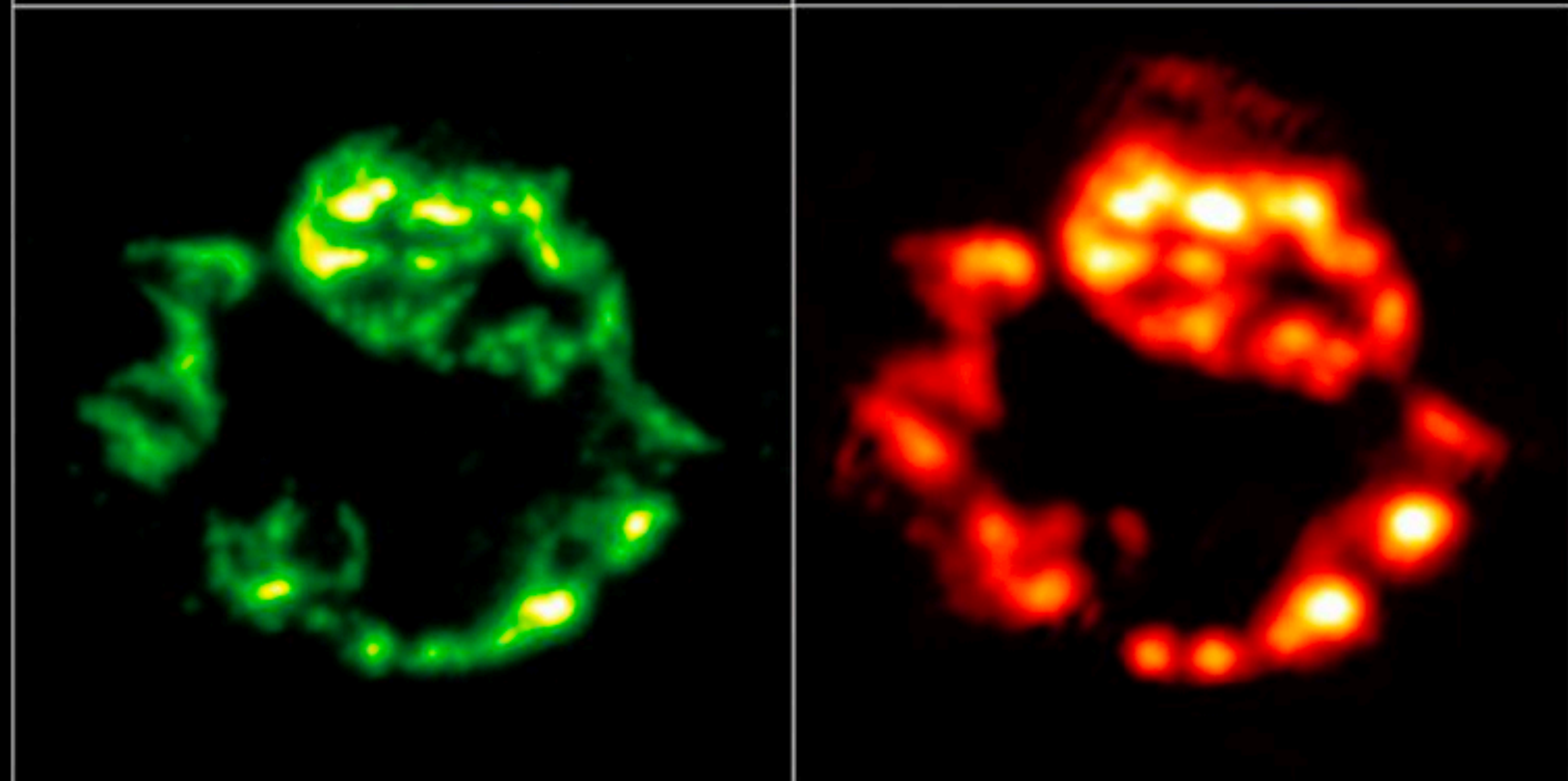
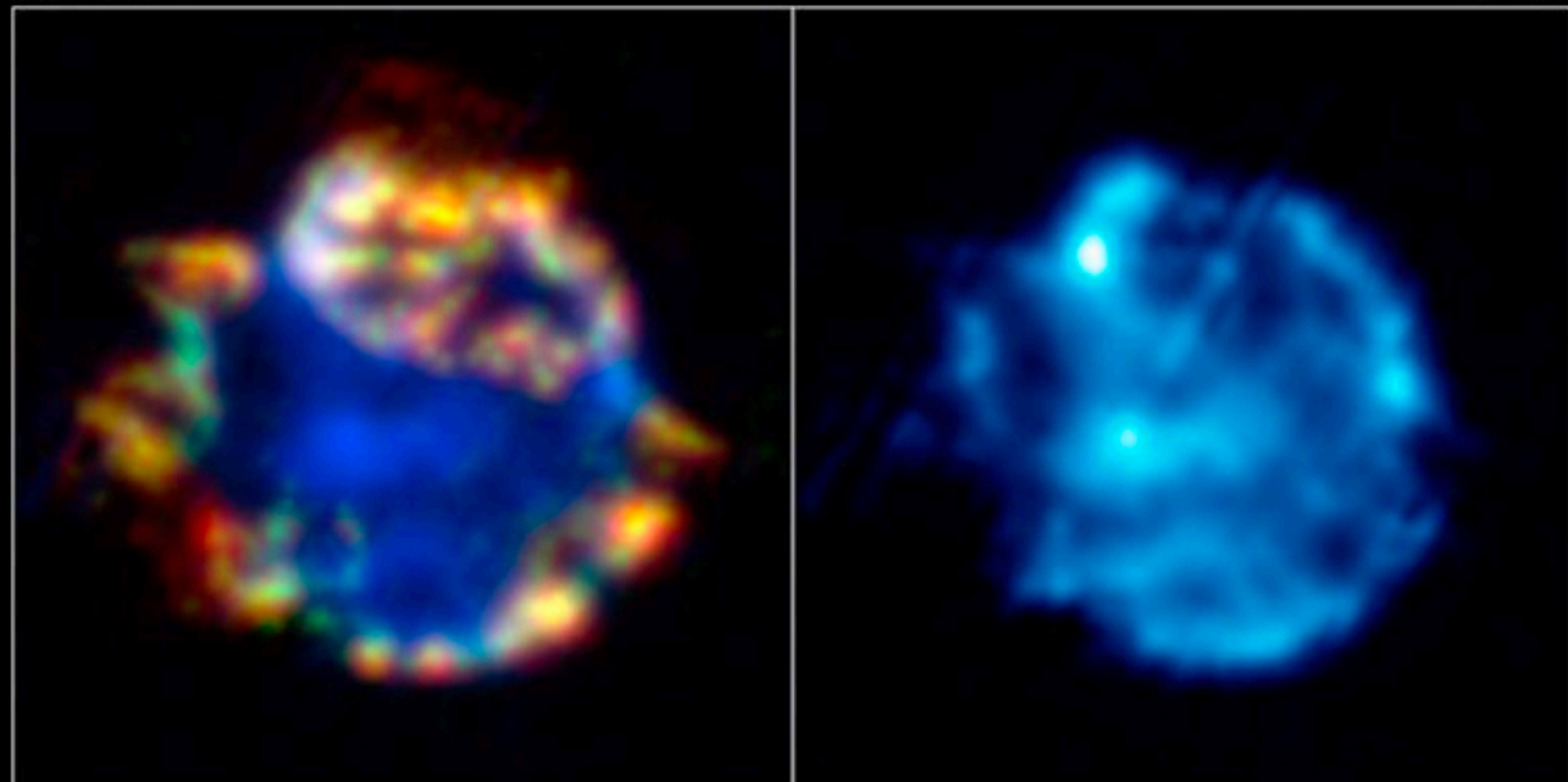
Table 13.2 Evolution of a $15M_{\odot}$ star. Most of the table is from the paper by Woosley and Janda (2005), but the specific nuclear reactions are from the review by Arnett (2004).

| Stage | Time Scale | Reaction | Ash or product | Temperature (10^9 K) | Density (gm cm^{-3}) | Luminosity (solar units) | Neutrino losses (solar units) |
|--------------------|------------|---|----------------------|-------------------------|---------------------------------|--------------------------|-------------------------------|
| Hydrogen | 11 My | pp CNO | He He, N, Na | 0.035 | 5.8 | 28,000 | 1800 |
| Helium | 2.0 My | $3\alpha \rightarrow {}^{12}\text{C}$ ${}^{12}\text{C}(\alpha, \gamma){}^{16}\text{O}$ | C O | 0.18 | 1390 | 44,000 | 1900 |
| Carbon | 2000 y | ${}^{12}\text{C} + {}^{12}\text{C}$ | Ne, Na Mg, Al | 0.81 | 2.8×10^5 | 72,000 | 3.7×10^5 |
| Neon | 0.7 y | ${}^{20}\text{Ne}(\gamma, \alpha){}^{16}\text{O}$ | O, Mg, Al | 1.6 | 1.2×10^7 | 75,000 | 1.4×10^8 |
| Oxygen | 2.6 y | ${}^{16}\text{O} + {}^{16}\text{O}$ | Si, S, Ar, Ca | 1.9 | 8.8×10^6 | 75,000 | 9.1×10^8 |
| Silicon | 18 d | ${}^{28}\text{Si}(\gamma, \alpha)$ | Fe, Ni, Cr, Ti... | 3.3 | 4.8×10^7 | 75,000 | 1.3×10^{11} |
| Iron core collapse | 1 s | Neutronisation | Neutron star | >7.1 | $>7.3 \times 10^9$ | 75,000 | $>3.6 \times 10^{15}$ |

Infrared

Combined

Silicon



Argon

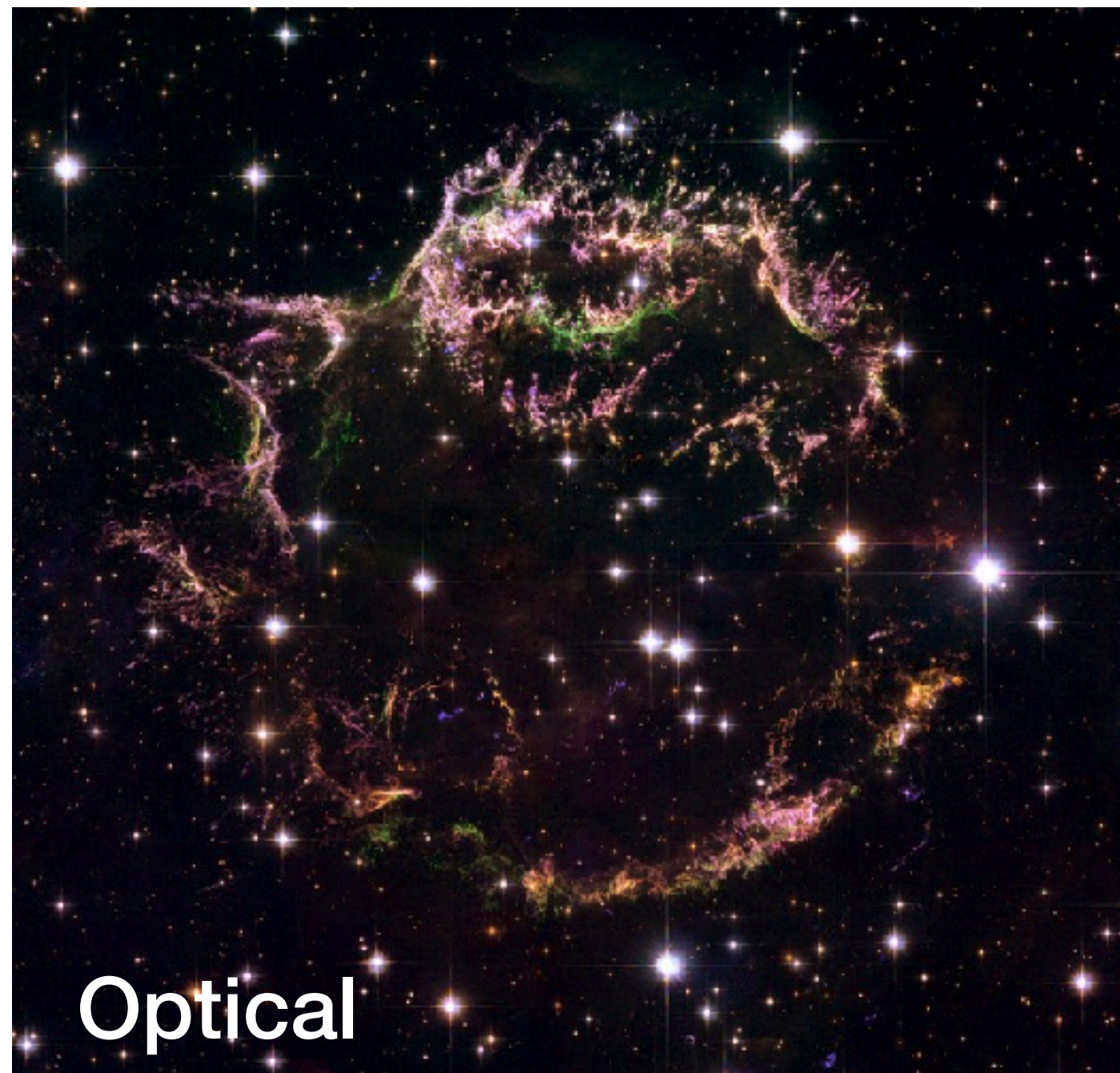
21 Micron Dust Feature

Dust & Gas in the Casseopia A Supernova Remnant
Spitzer Space Telescope • IRS

NASA / JPL-Caltech / J. Rho [Caltech-SSC]

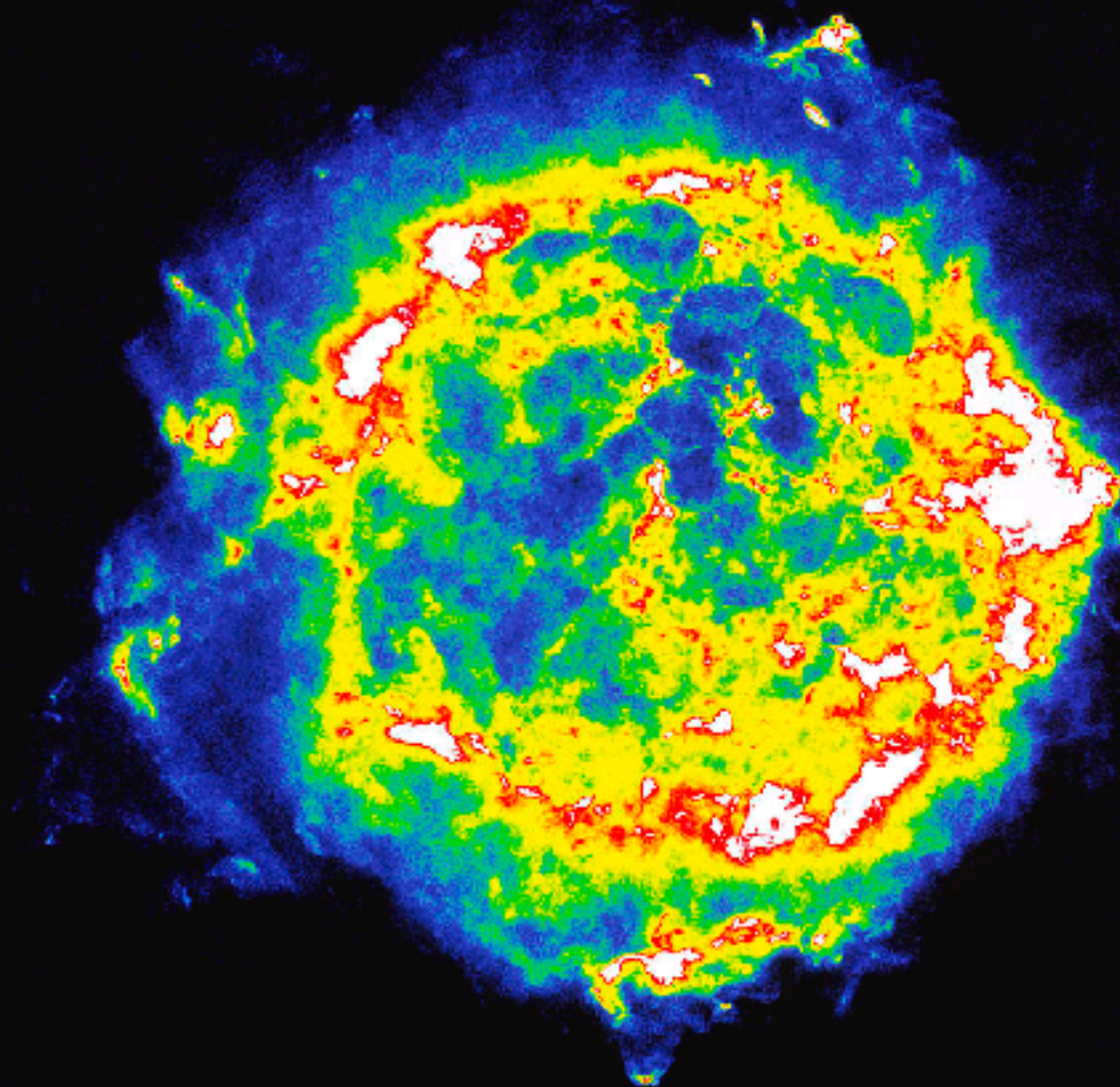
ssc2007-20a

Cas A

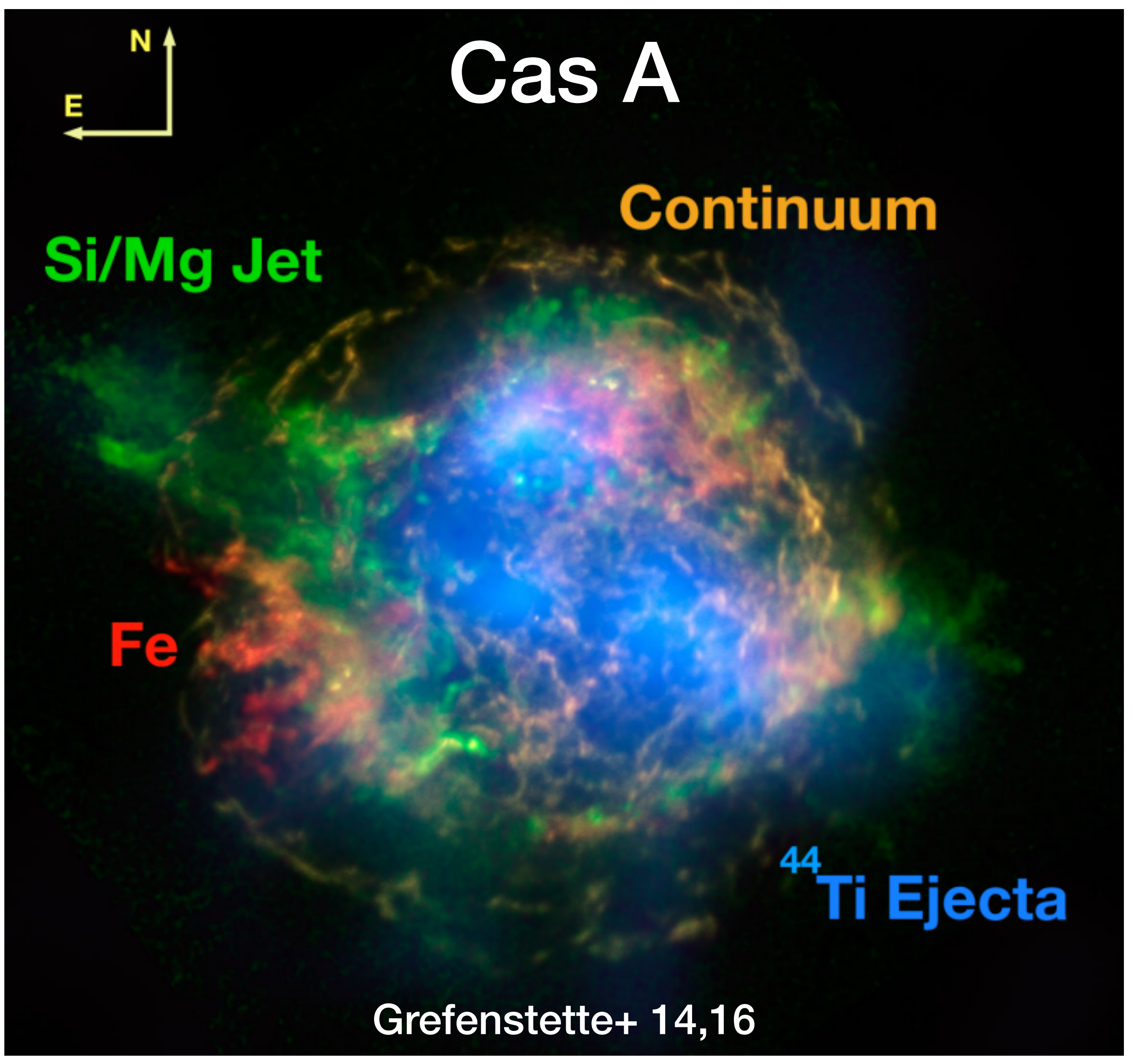
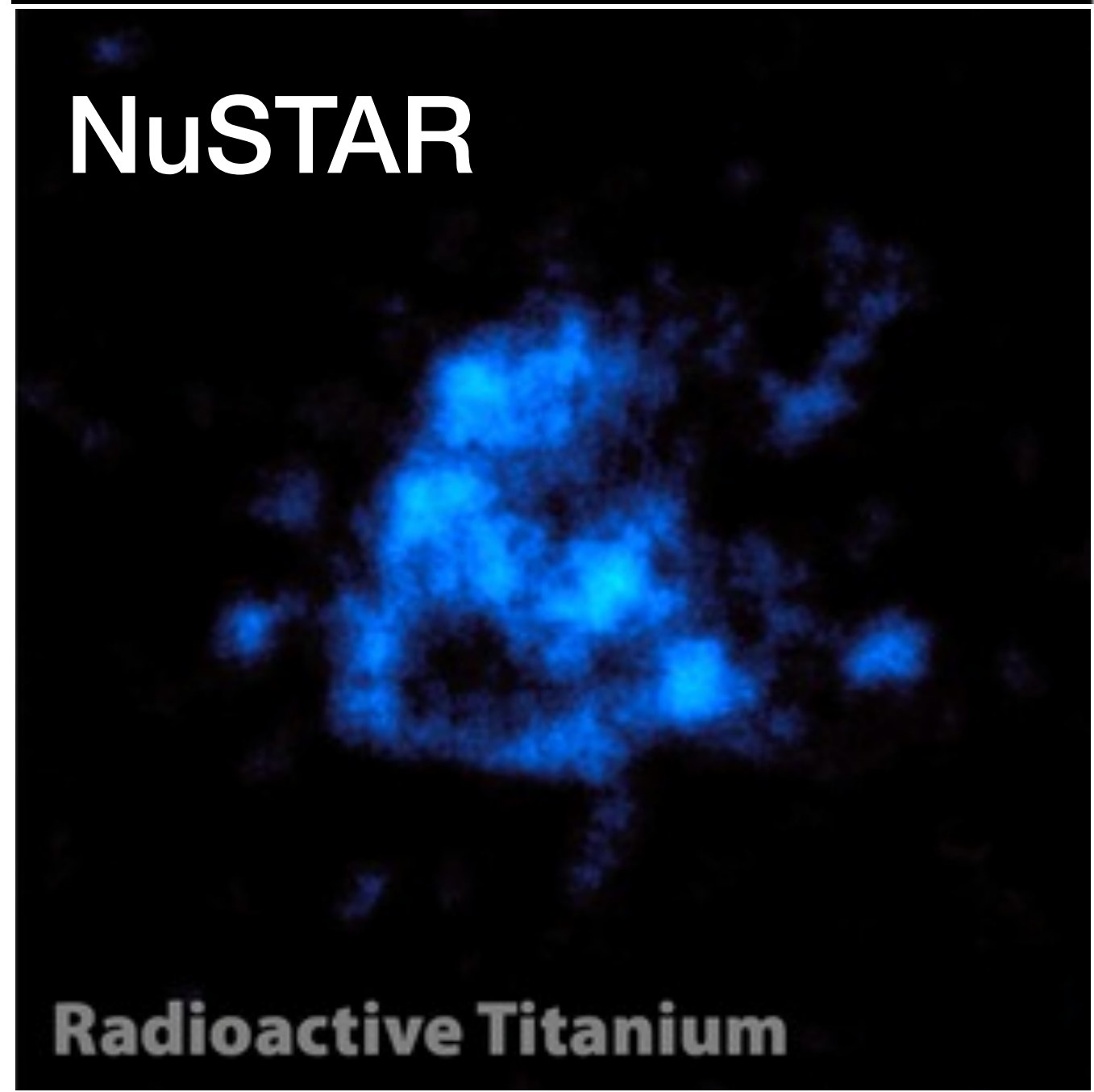
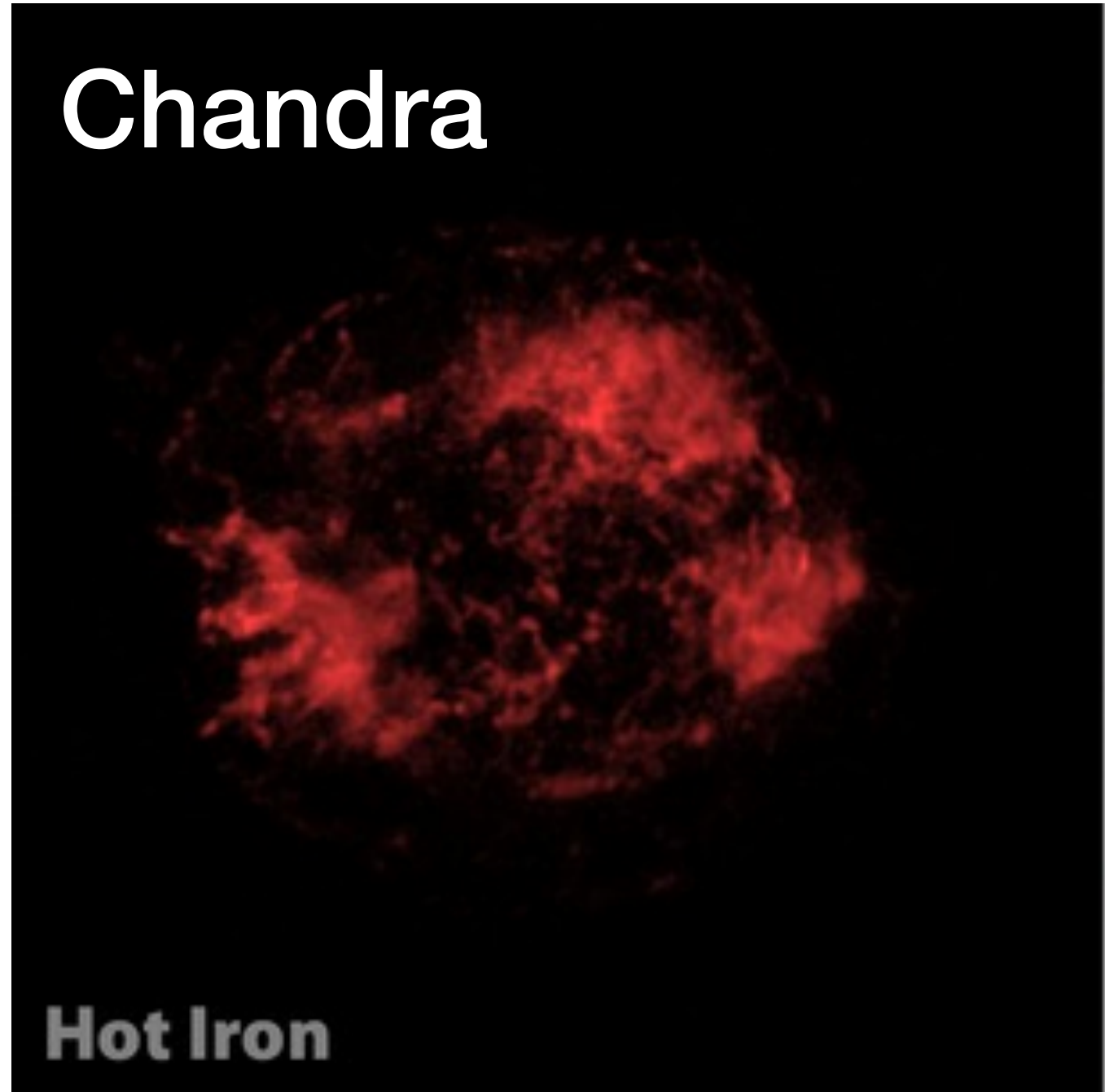


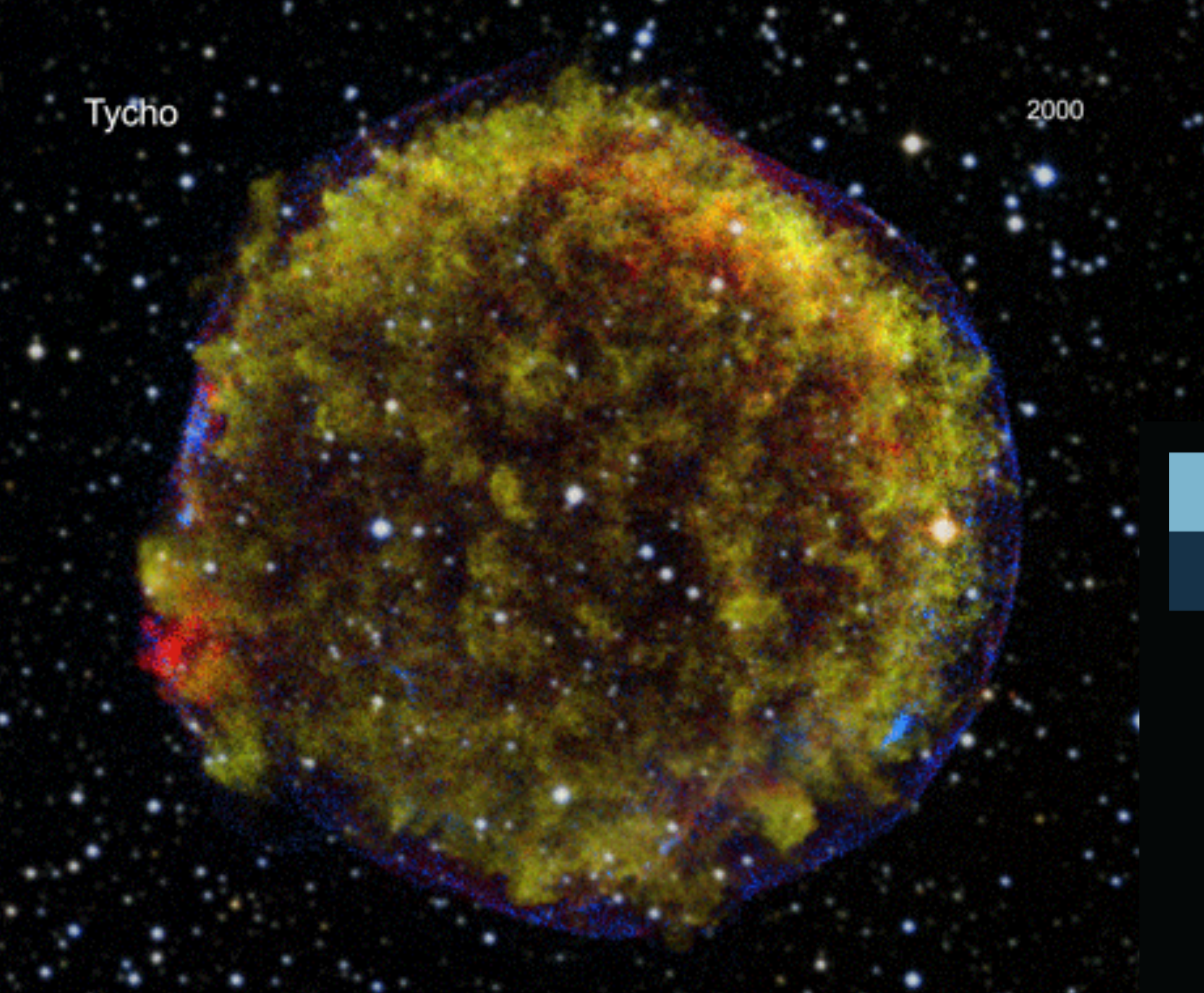
Optical

Radio




X-ray





Exploded 1572

Exploded ~1680



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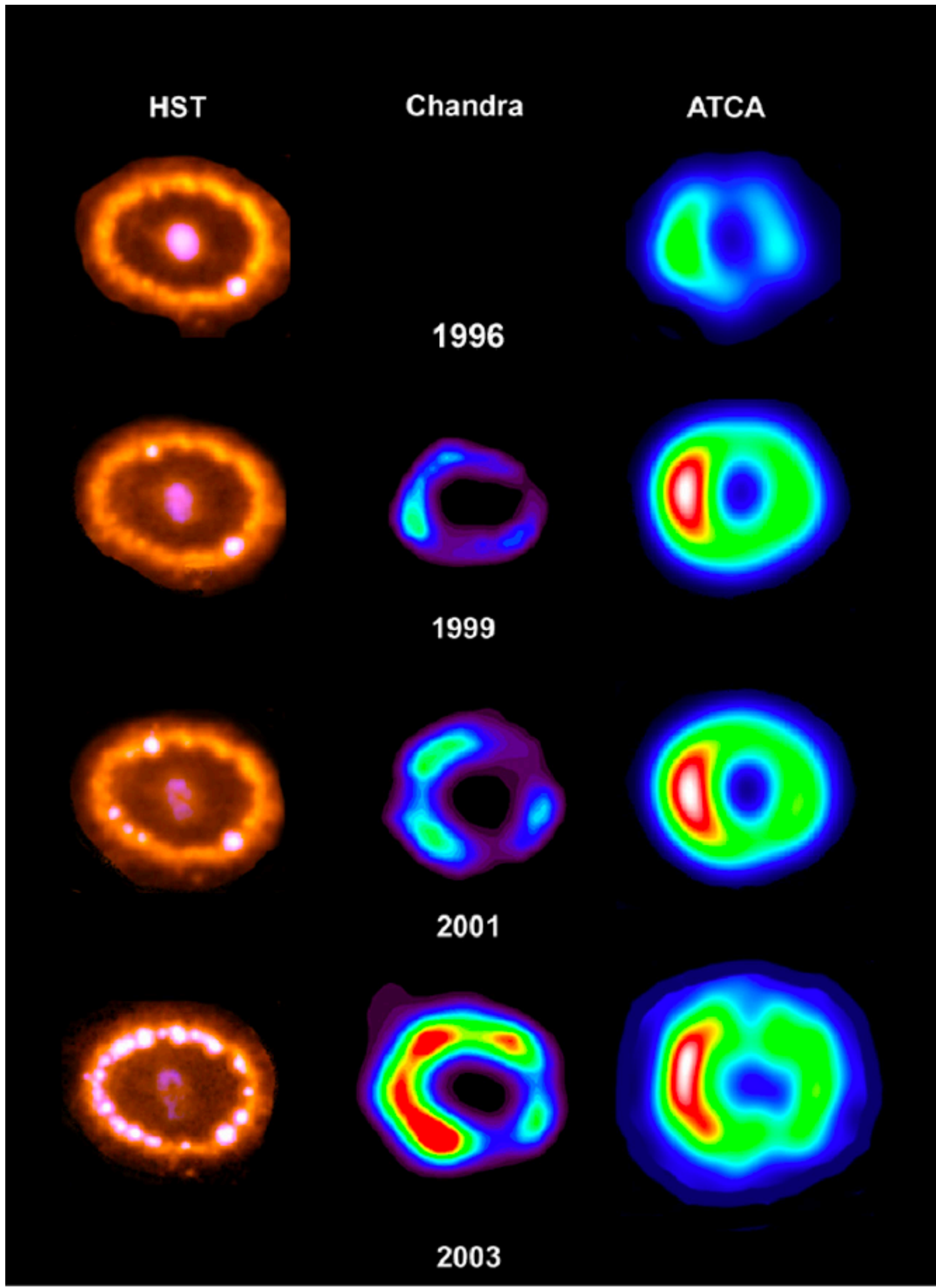
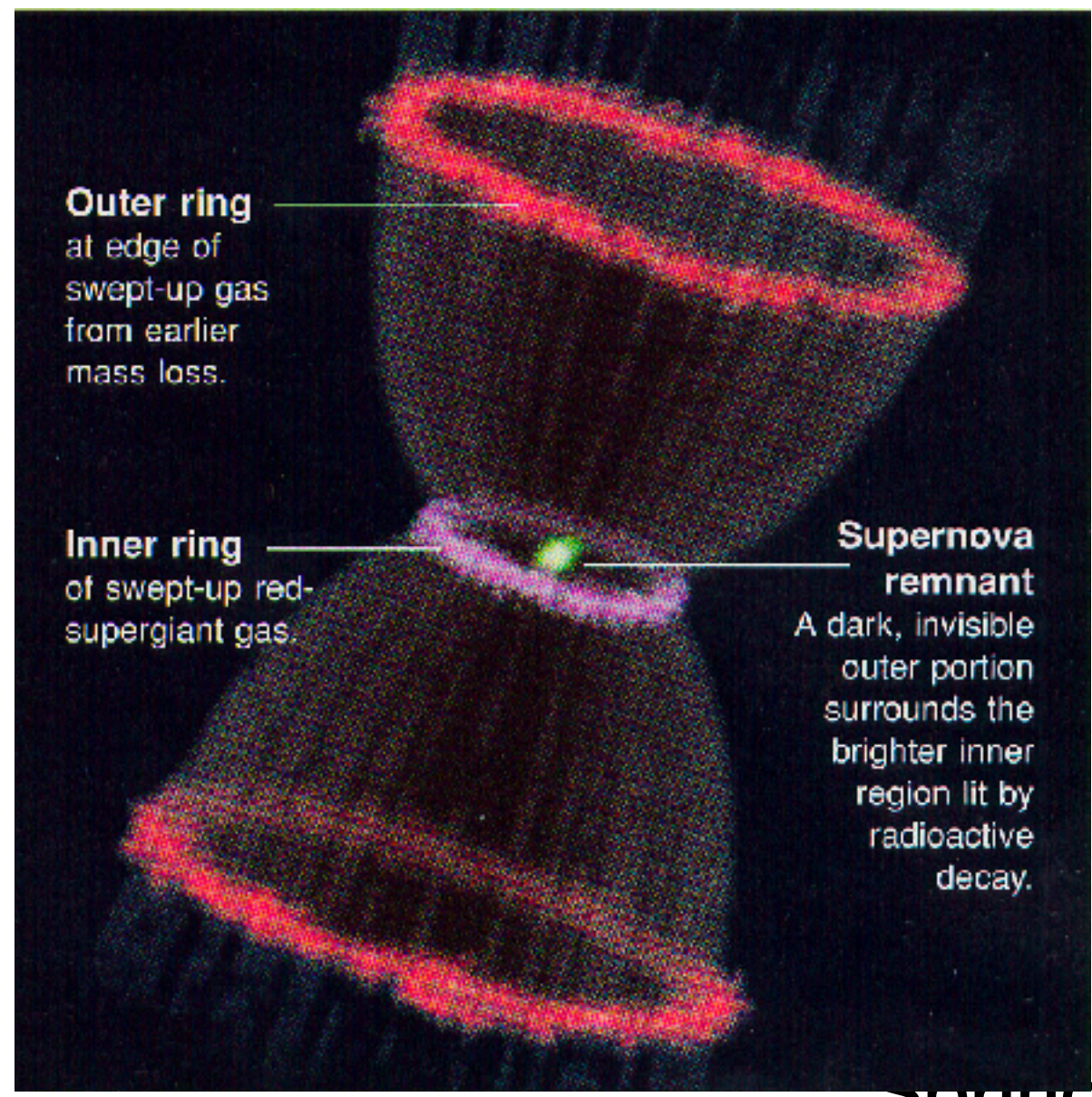
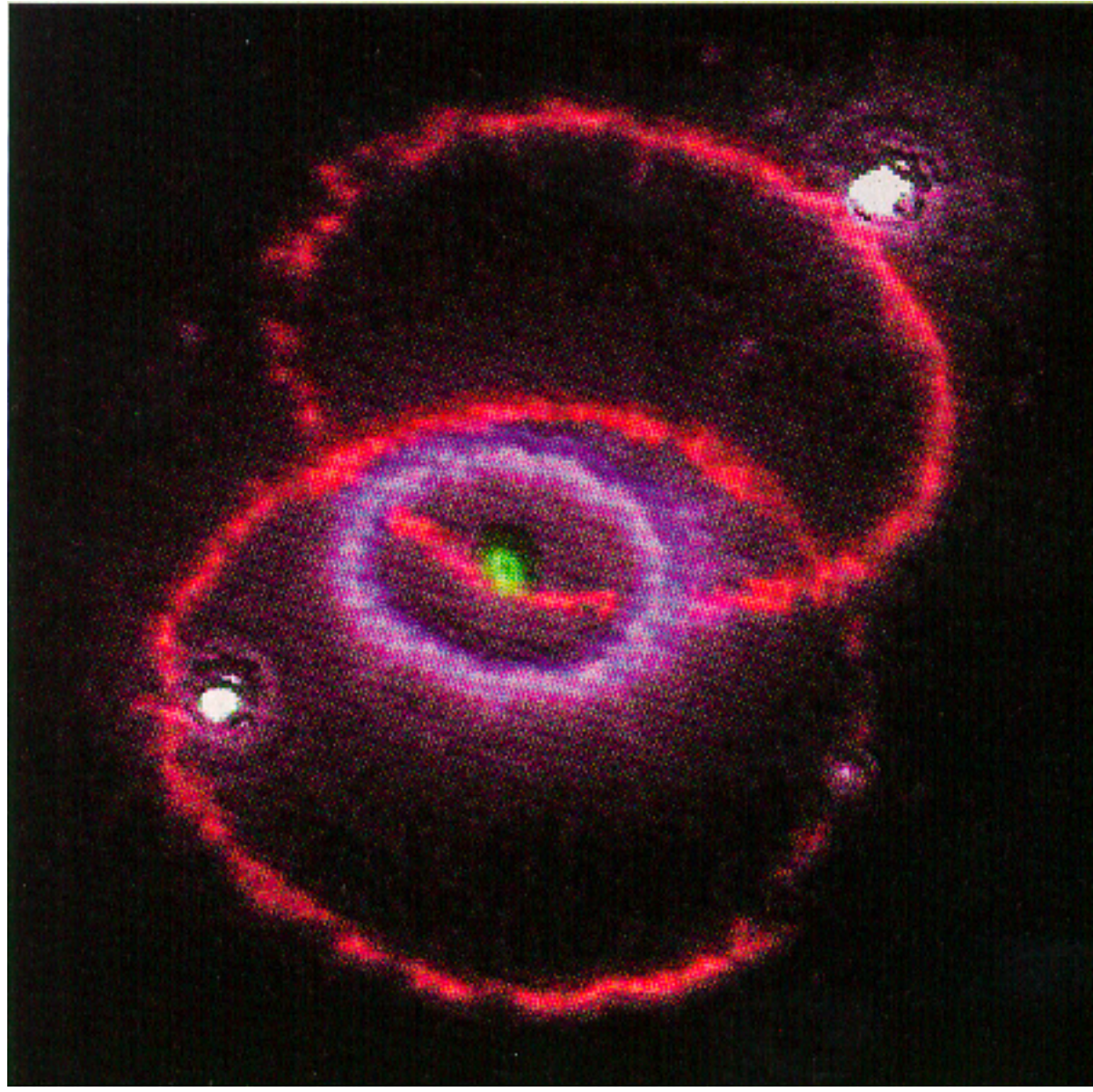
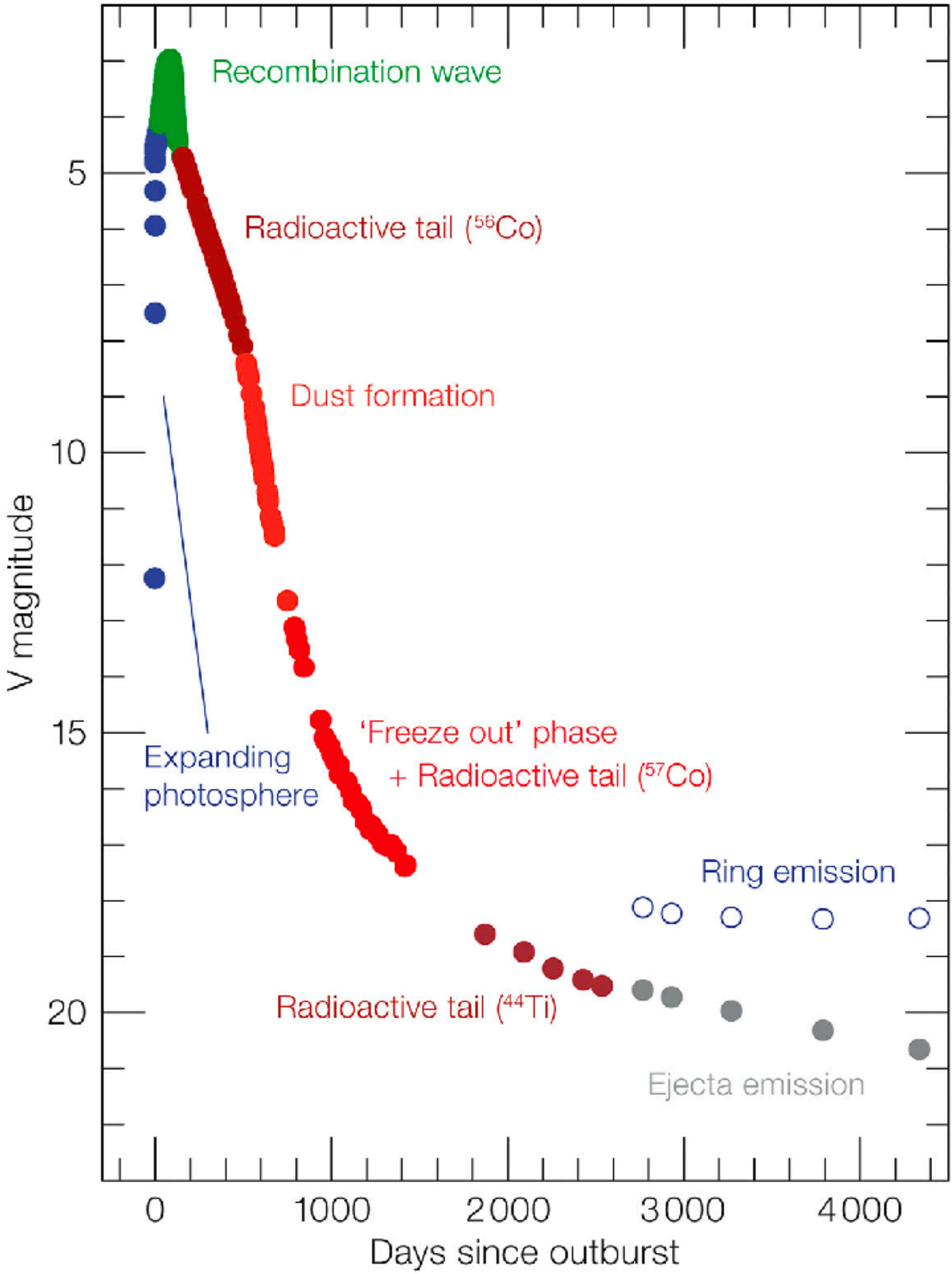
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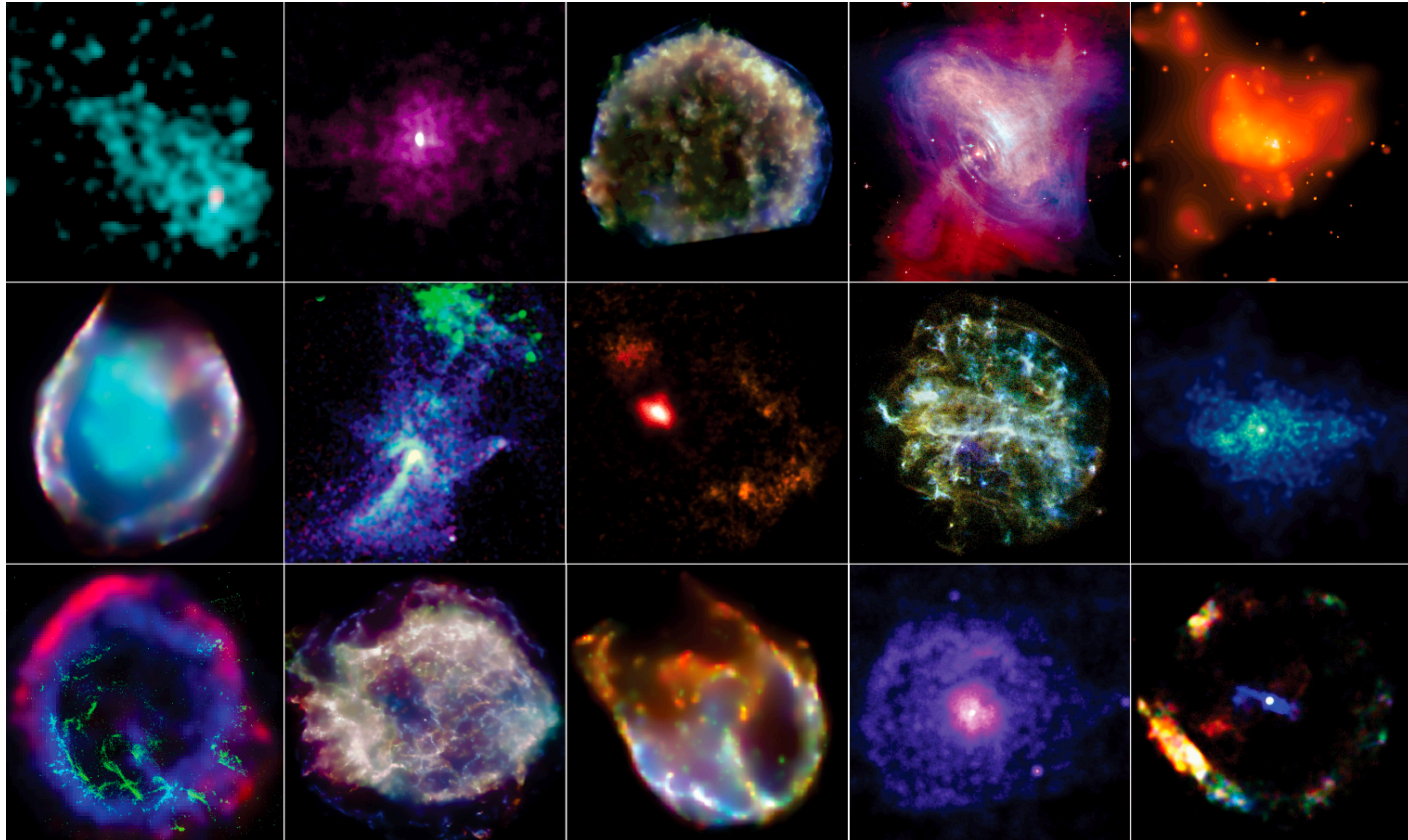
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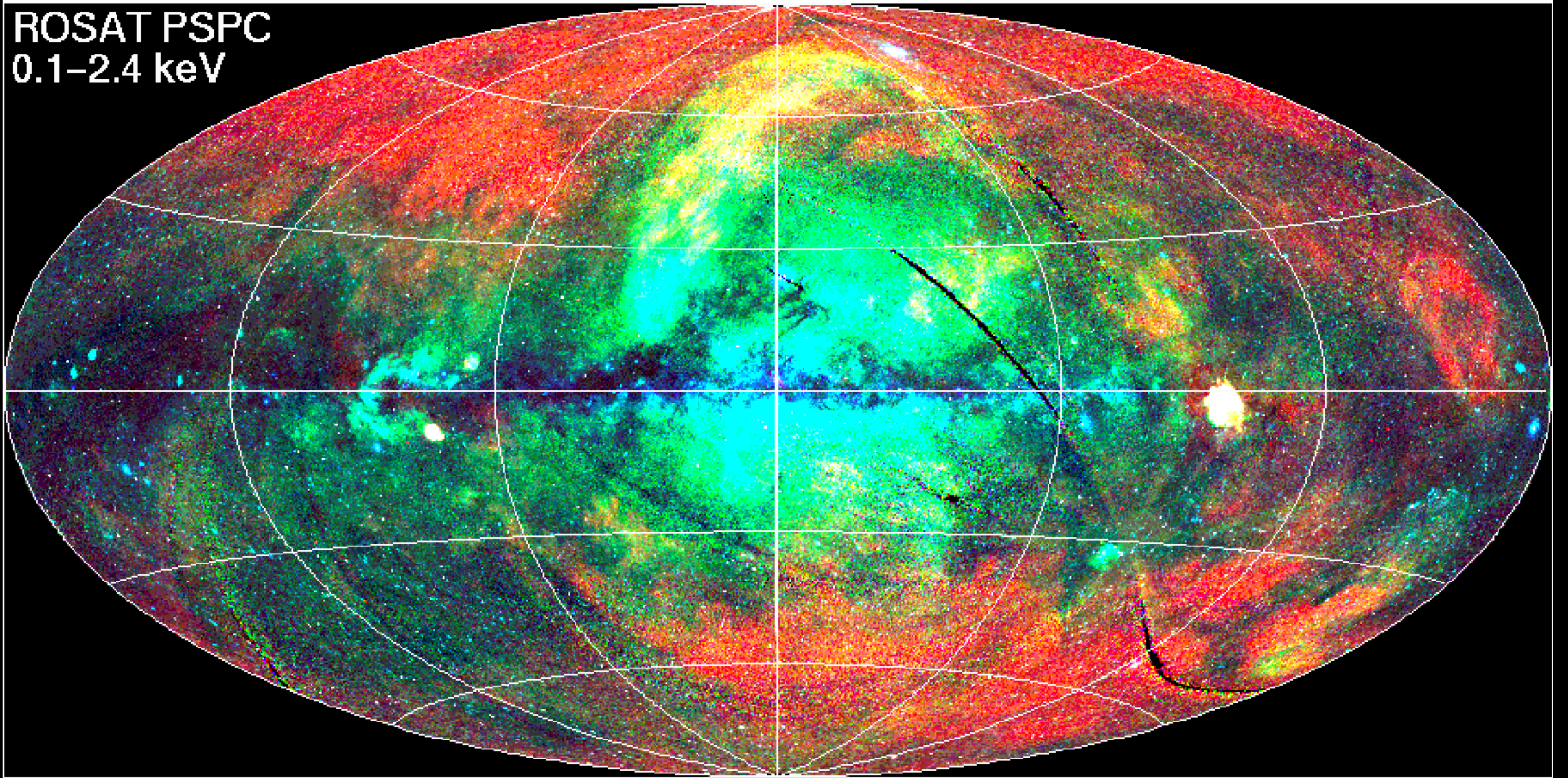
SN 1987A



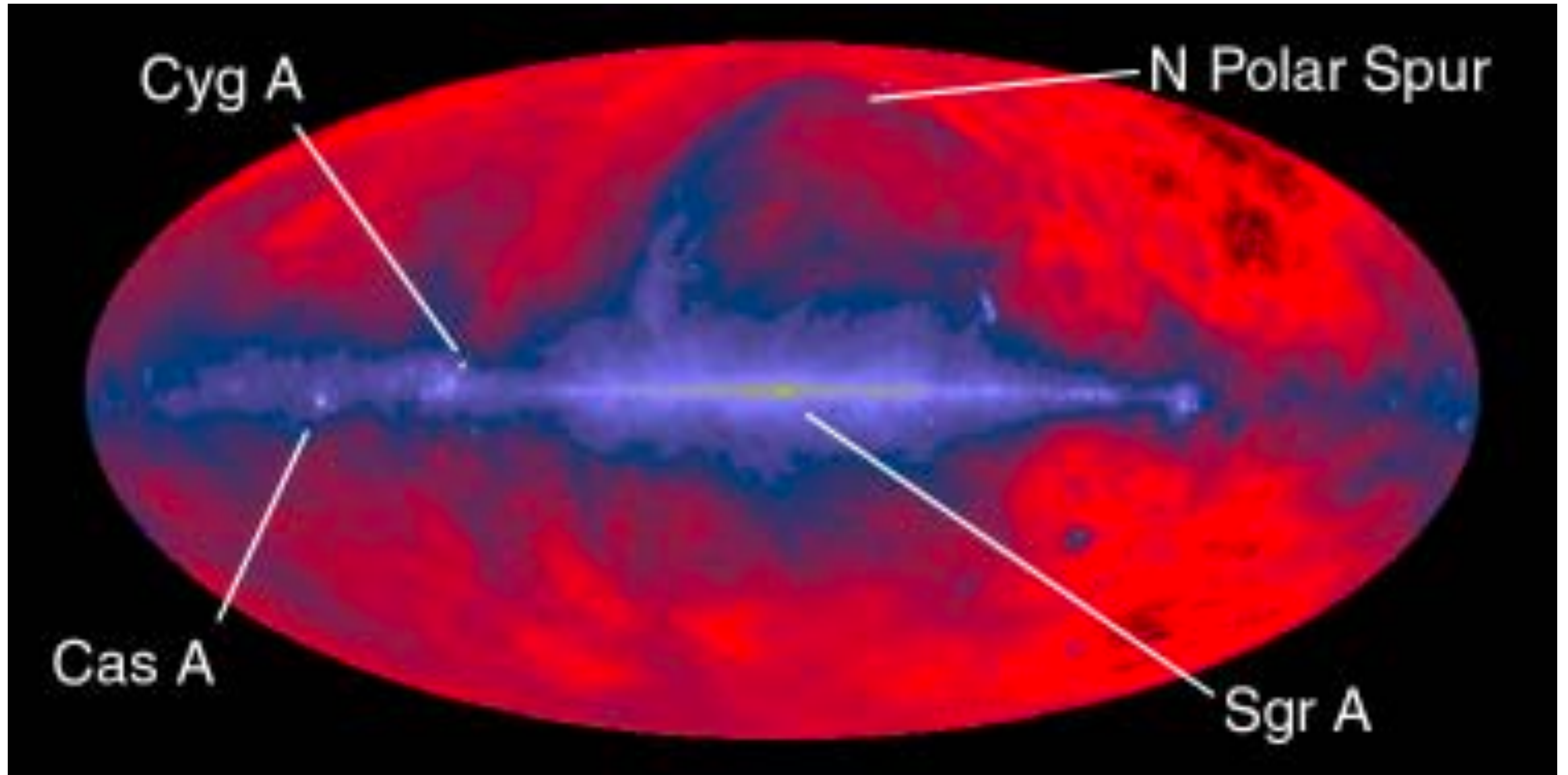
Supernova Remnants: Chandra



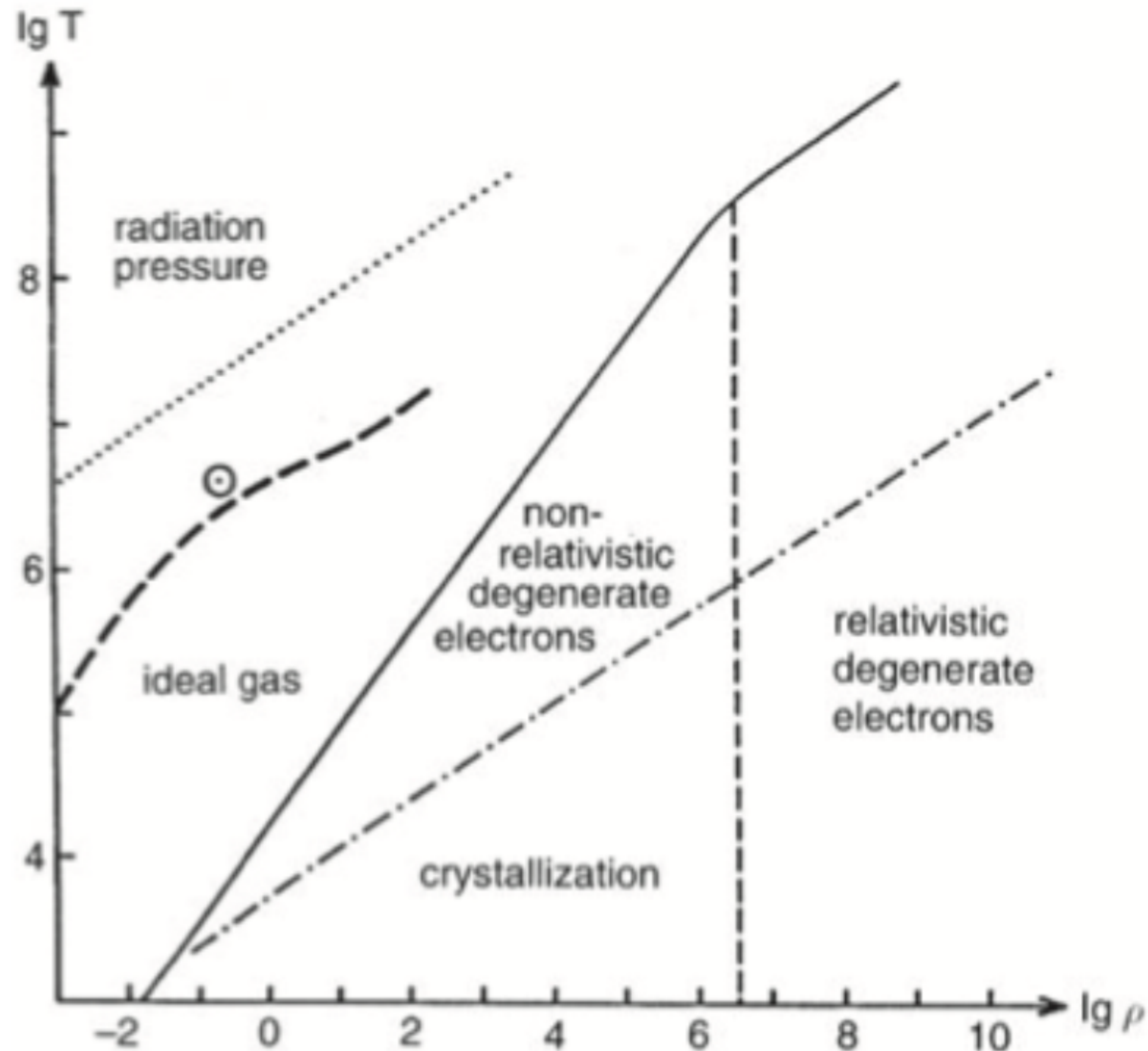
ROSAT PSPC
0.1–2.4 keV



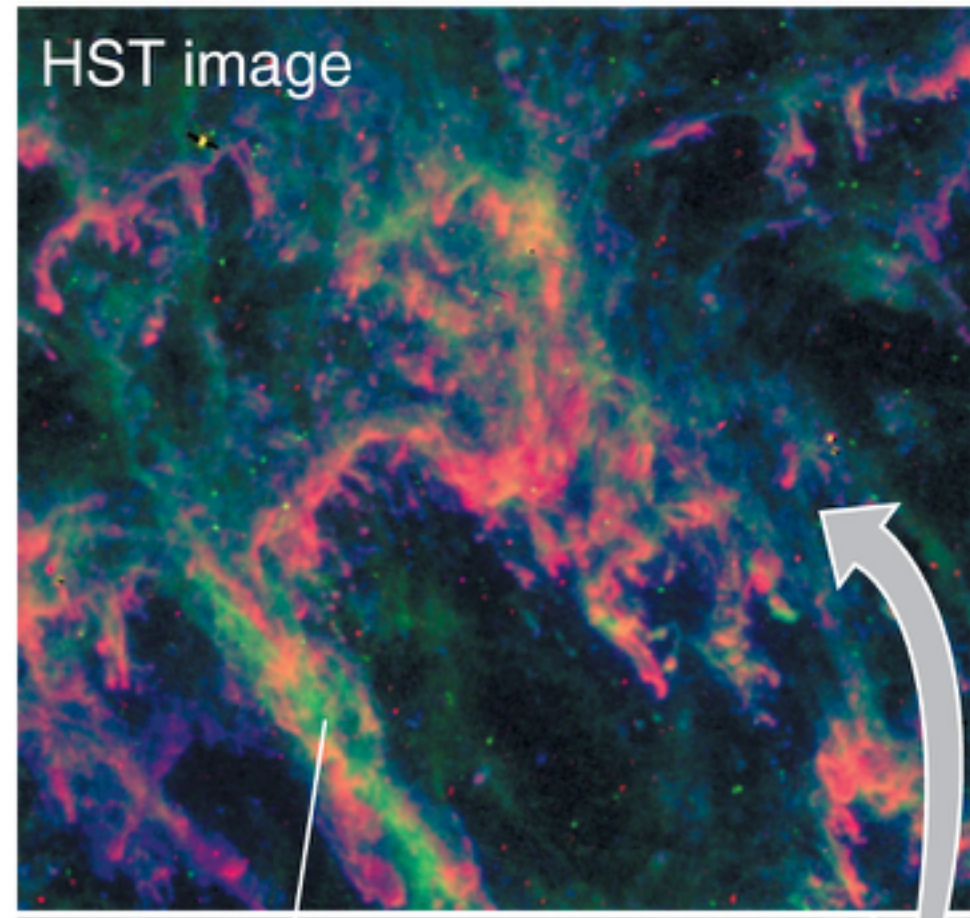
Radio Synchrotron (continuum emission)





EoS Temp.-Density for Degenerate Matter

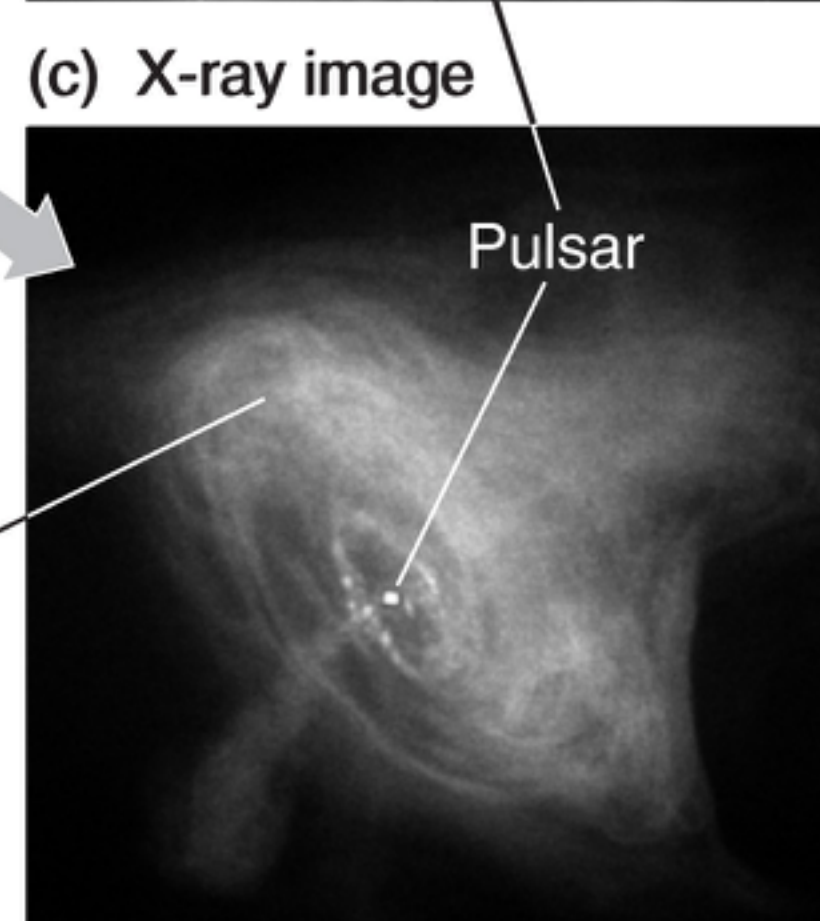
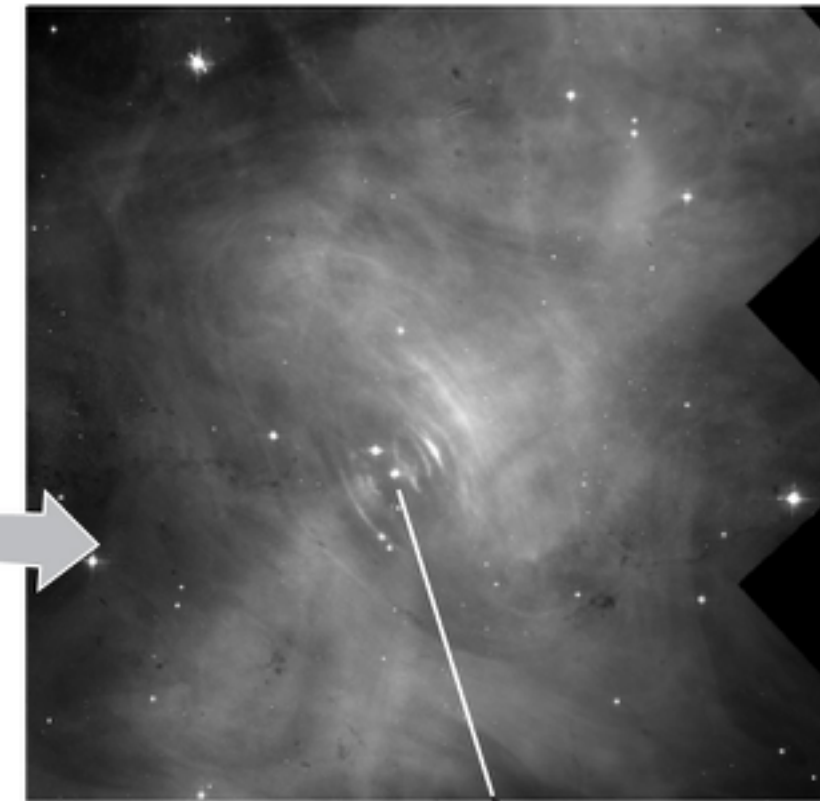
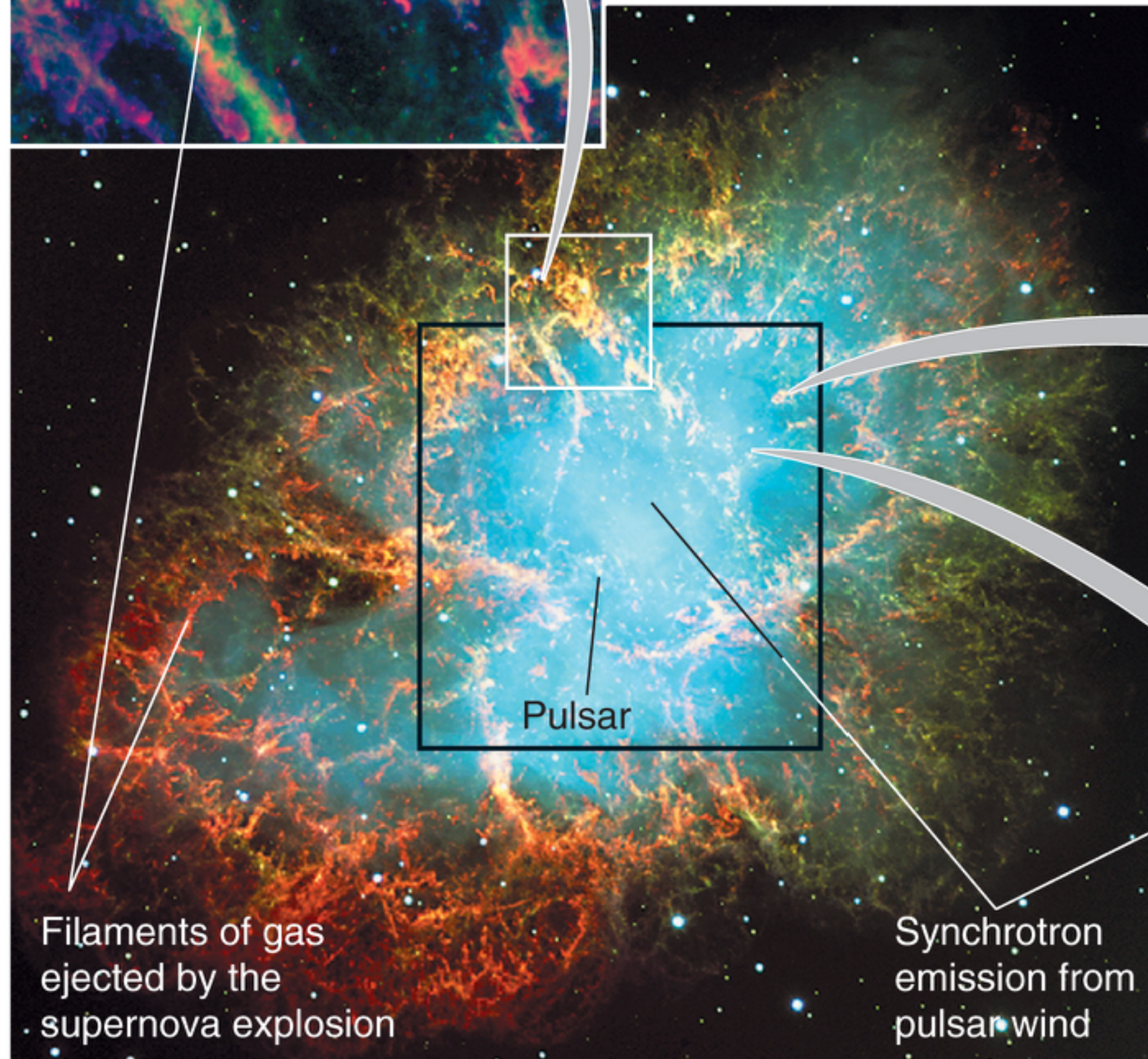


Pulsars: Crab Nebula

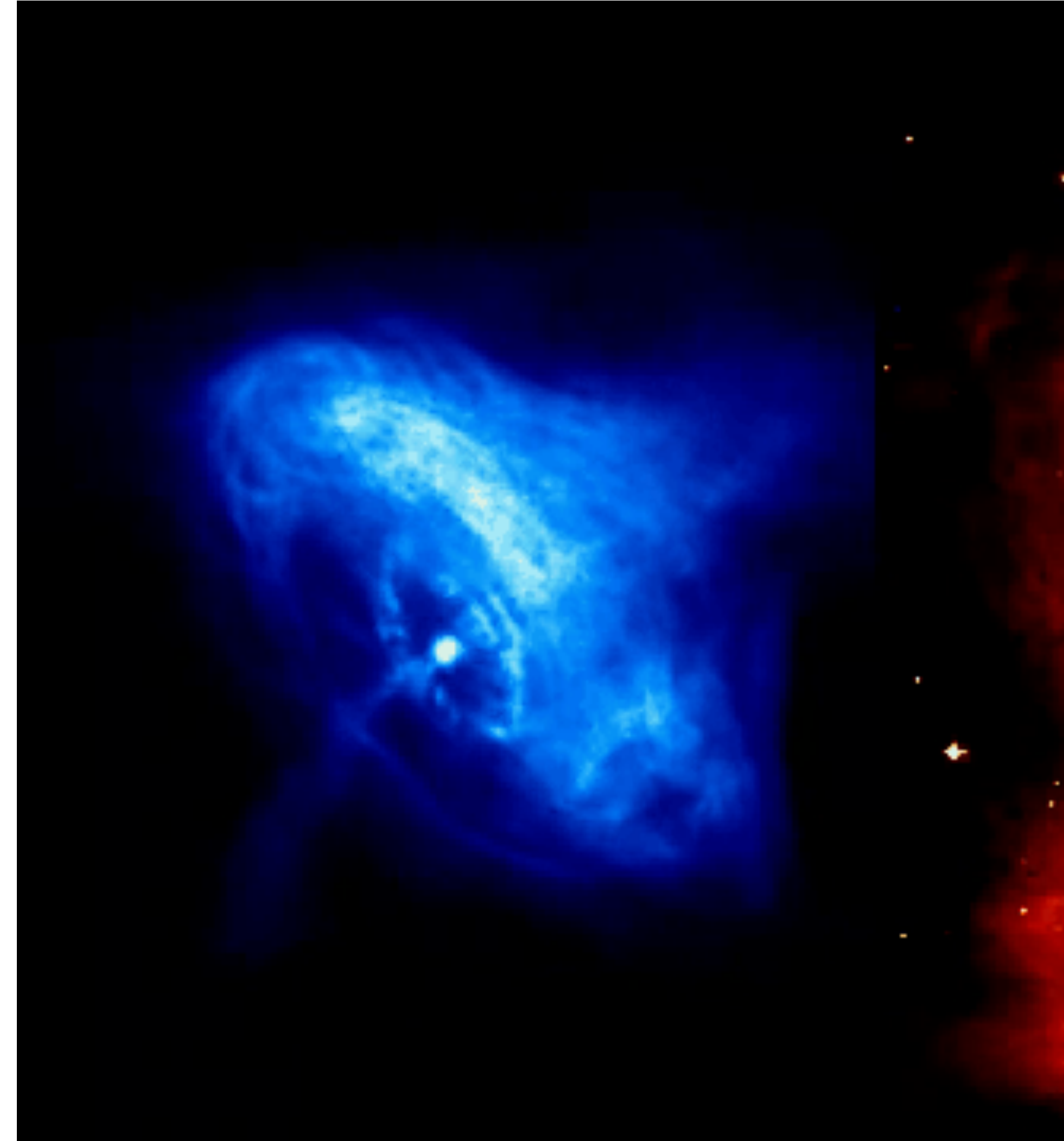



(a) Ground-based image


(b) Visible-light image




G X U V I R




www.youtube.com/watch?v=t5uA1RJsDhw&feature=related



Crab Nebula Expansion

https://www.youtube.com/watch?v=_KCCKI9SB90

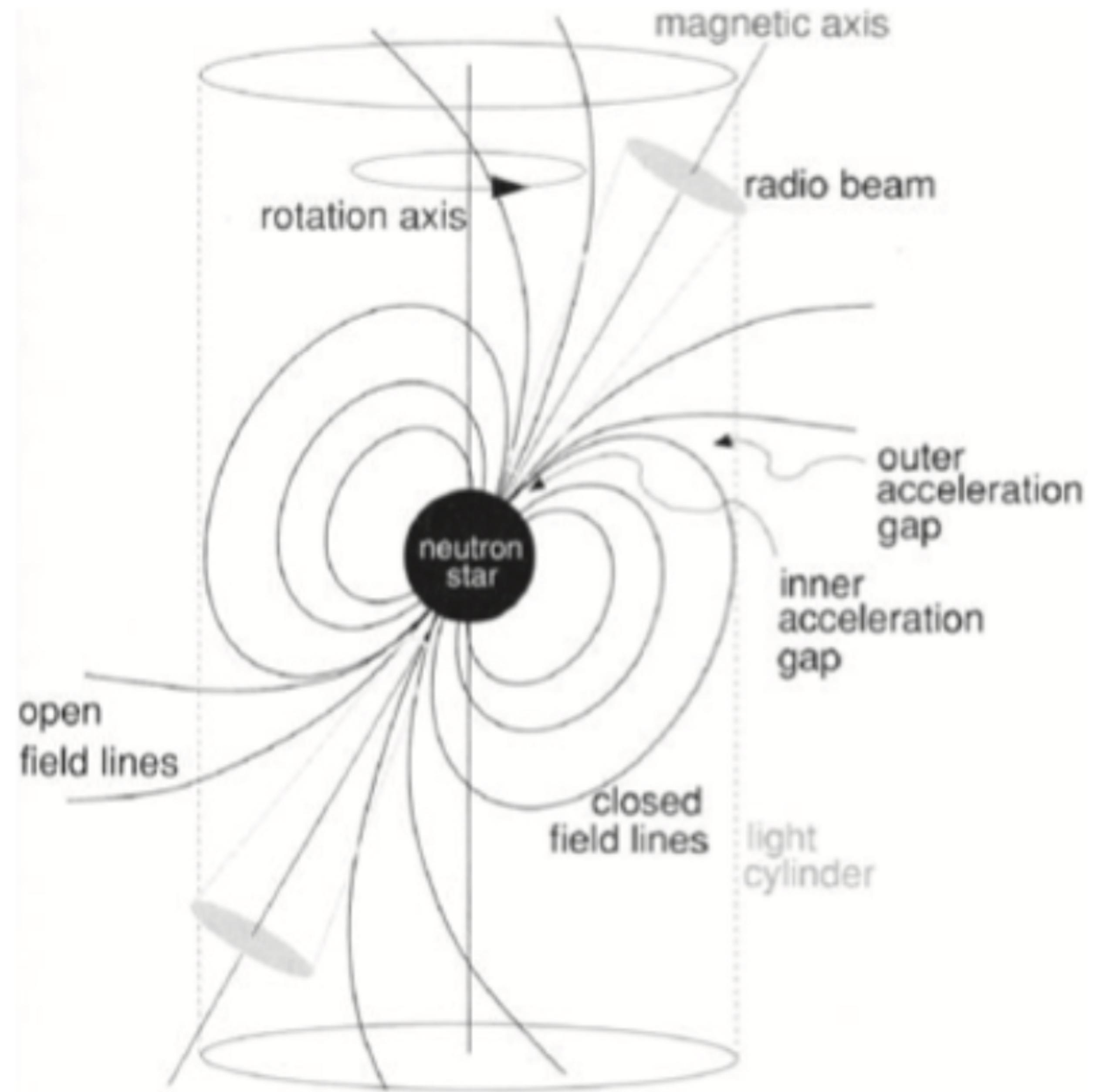


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Pulsar Computer Simulation

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