Today's Topics

Wednesday, November 3, 2020 (Week 11, lecture 31) – Chapter 23.

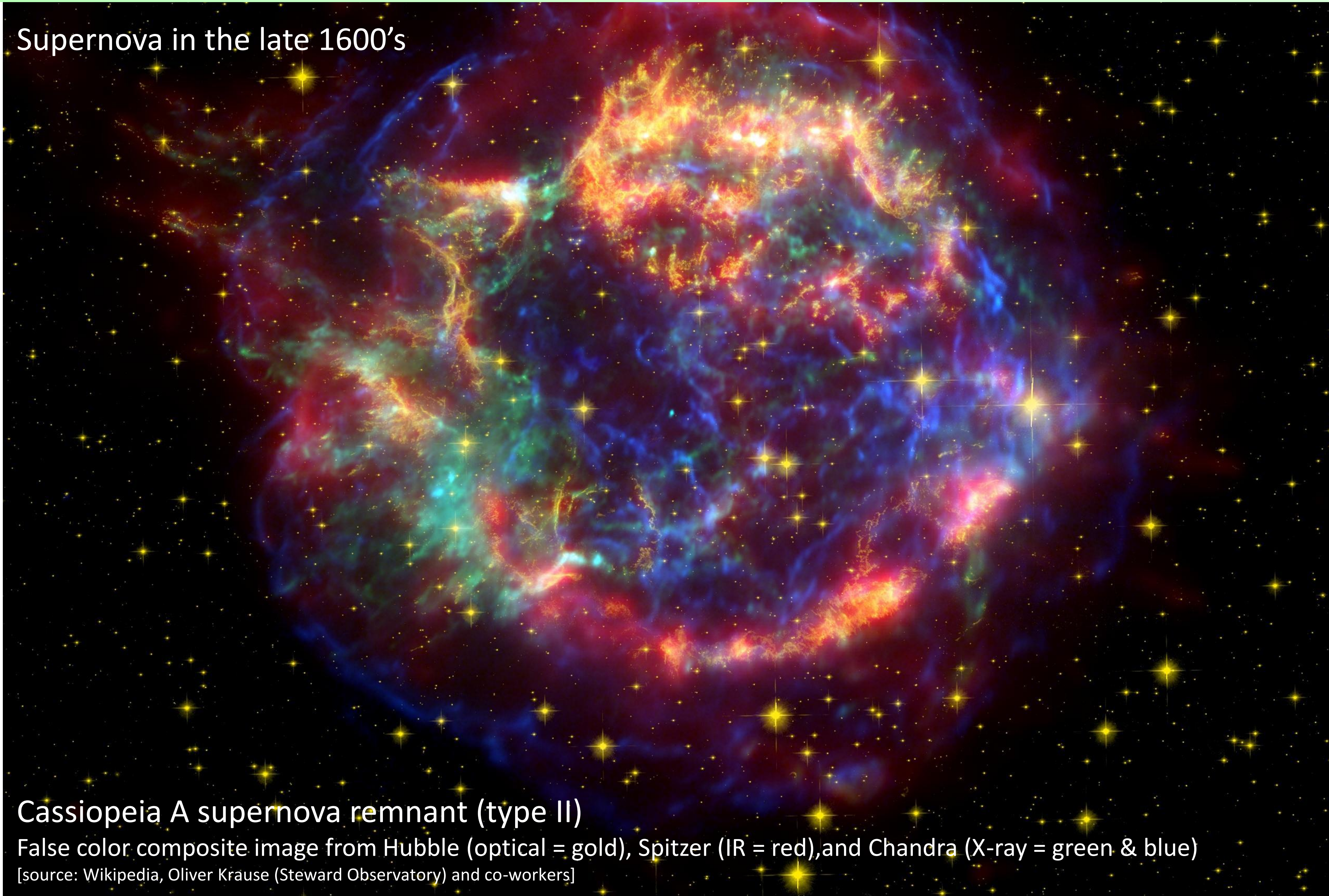
A. Supernova remnants.

B. Neutron stars.

C. Pulsars.

Cassiopeia A: Supernova Remnant

Supernova in the late 1600's

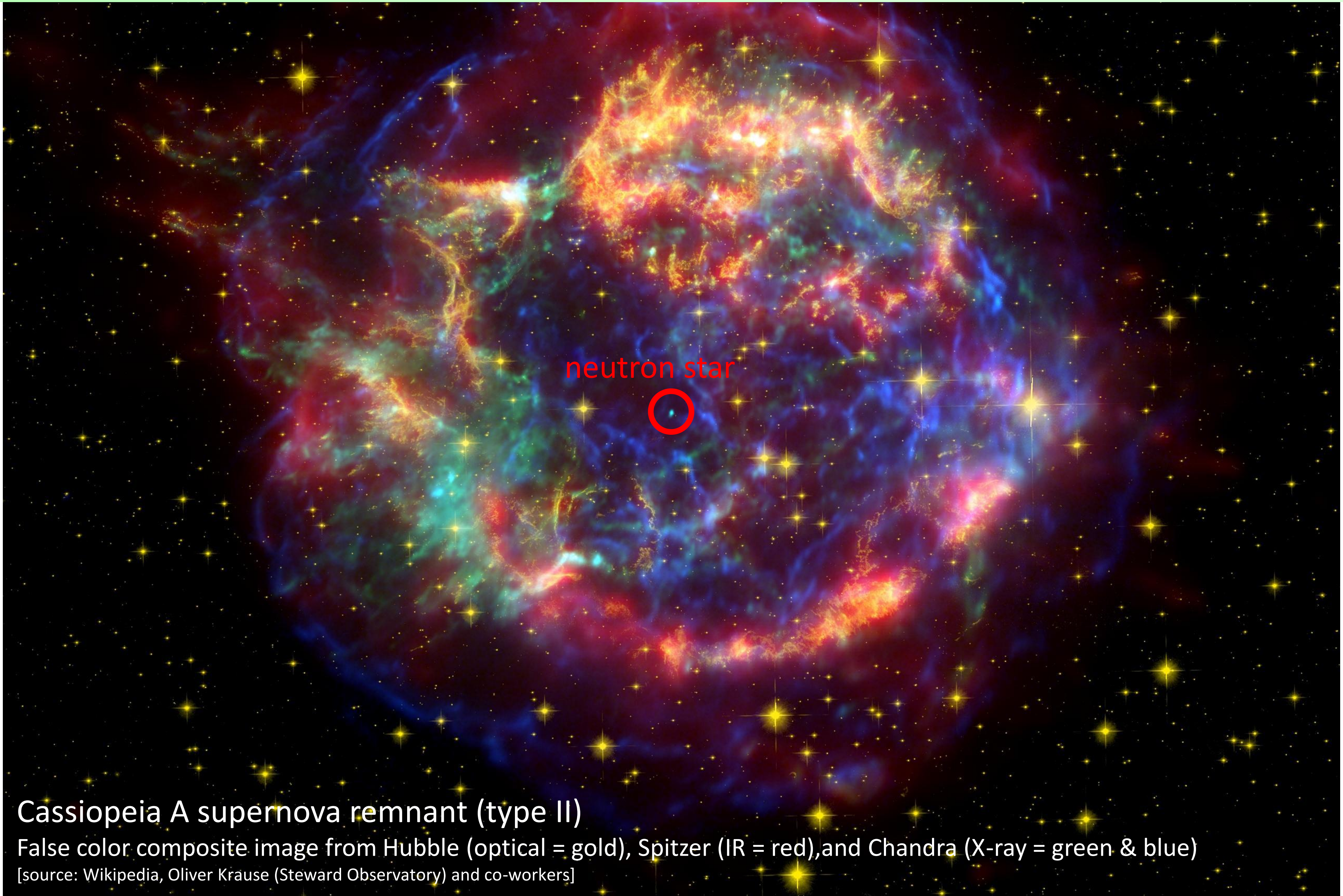


Cassiopeia A supernova remnant (type II)

False color composite image from Hubble (optical = gold), Spitzer (IR = red),and Chandra (X-ray = green & blue)

[source: Wikipedia, Oliver Krause (Steward Observatory) and co-workers]

Cassiopeia A: Supernova Remnant

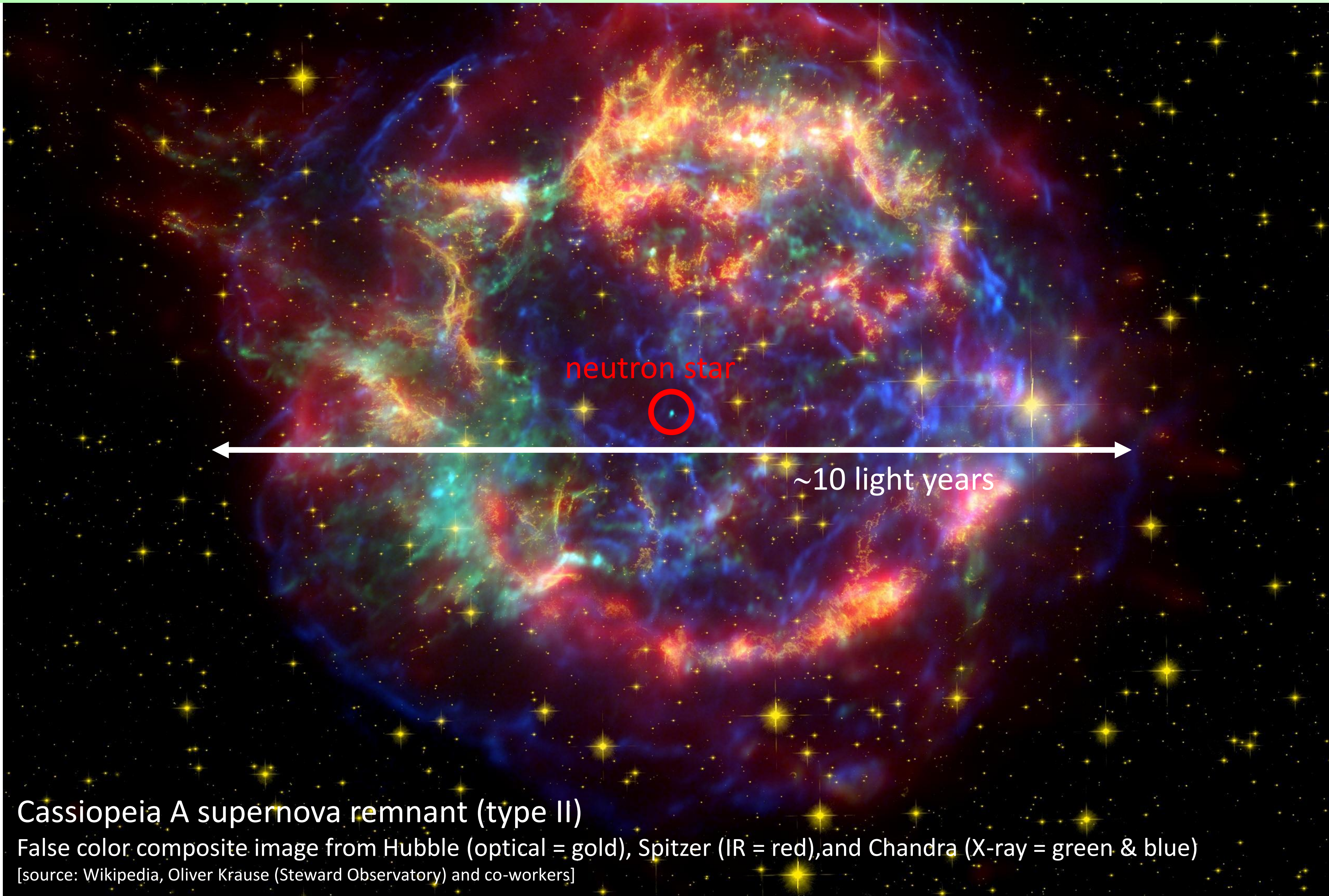


Cassiopeia A supernova remnant (type II)

False color composite image from Hubble (optical = gold), Spitzer (IR = red),and Chandra (X-ray = green & blue)

[source: Wikipedia, Oliver Krause (Steward Observatory) and co-workers]

Cassiopeia A: Supernova Remnant



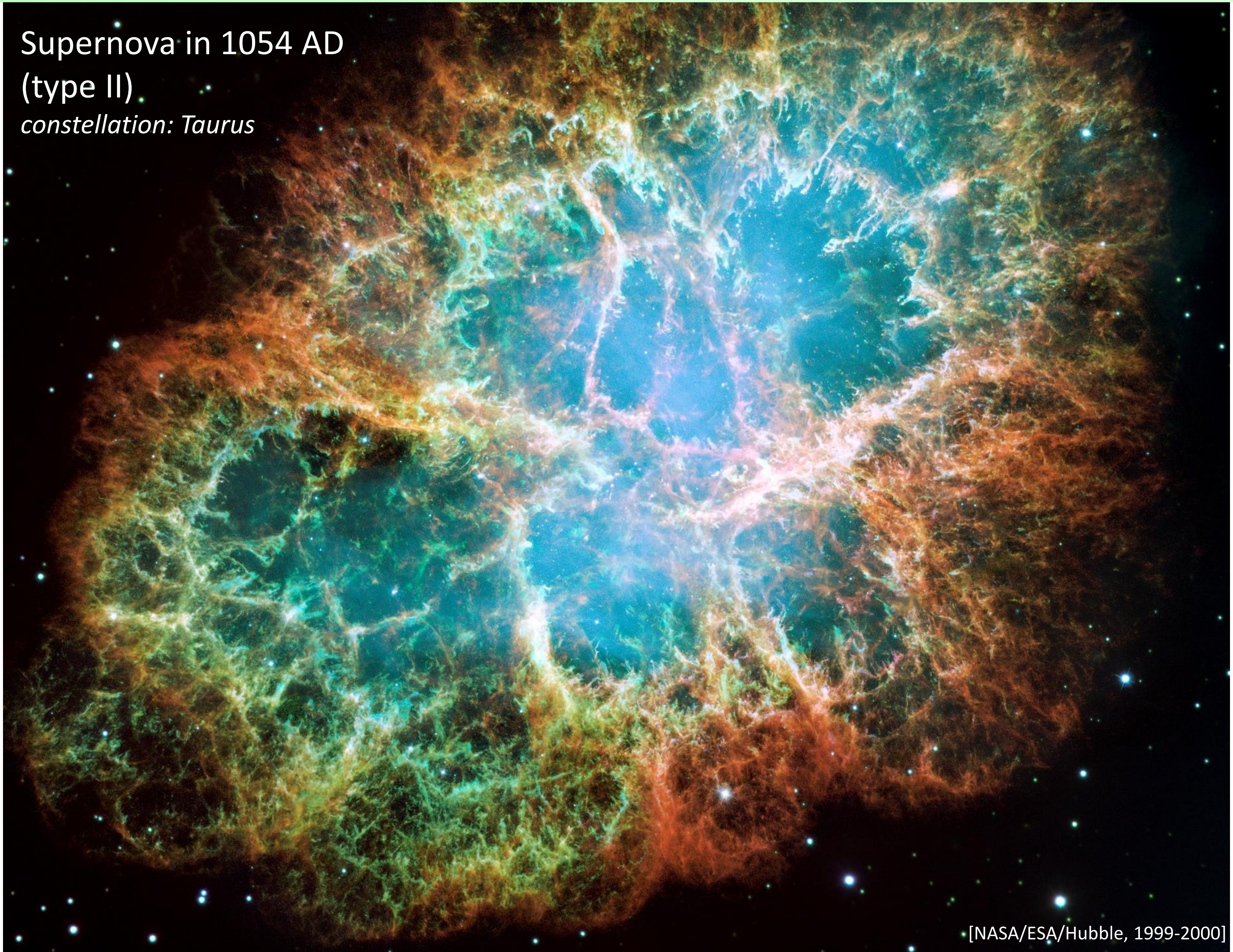
Cassiopeia A supernova remnant (type II)

False color composite image from Hubble (optical = gold), Spitzer (IR = red),and Chandra (X-ray = green & blue)

[source: Wikipedia, Oliver Krause (Steward Observatory) and co-workers]

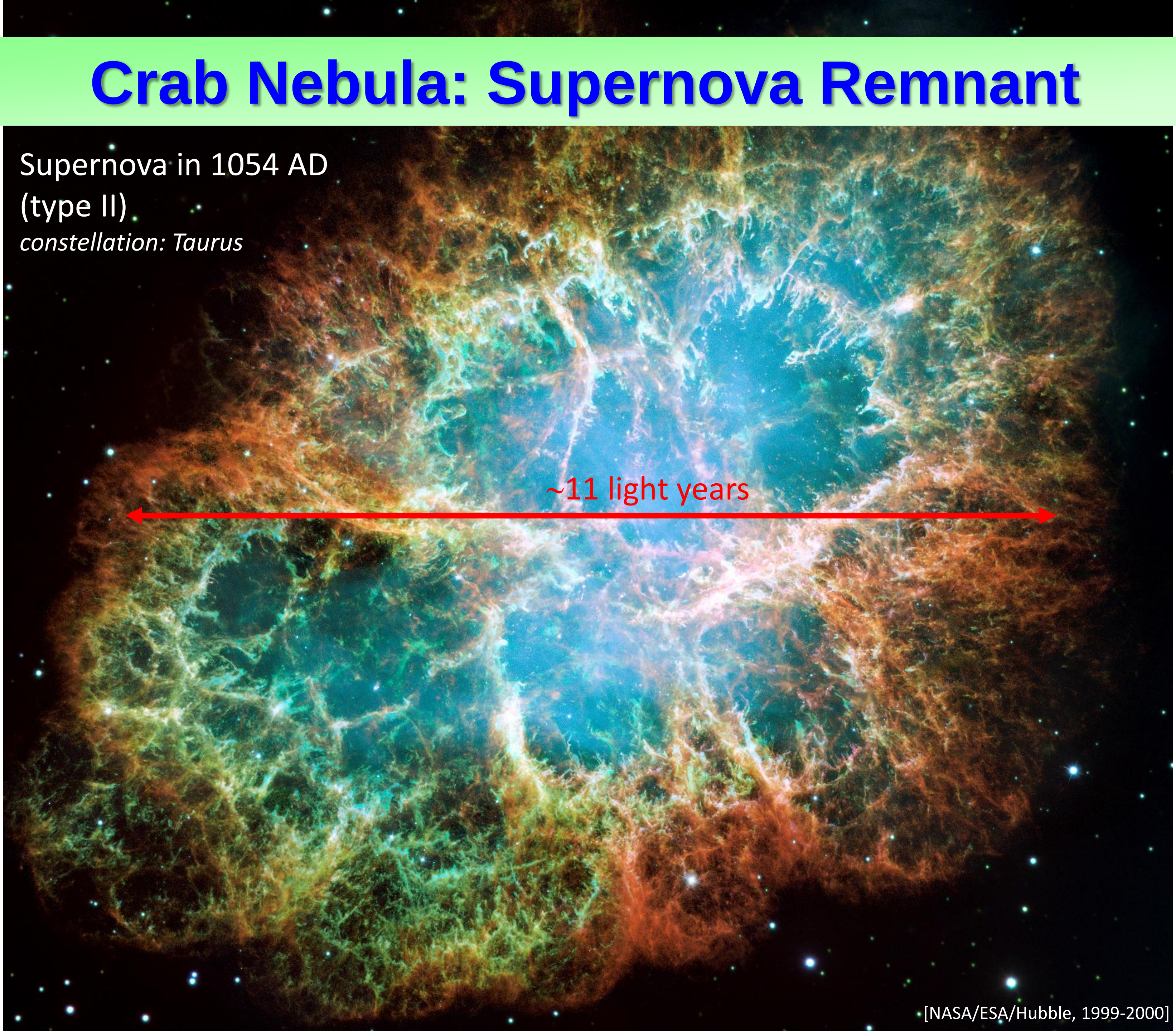
Crab Nebula: Supernova Remnant

Supernova in 1054 AD
(type II)
constellation: Taurus



[NASA/ESA/Hubble, 1999-2000]

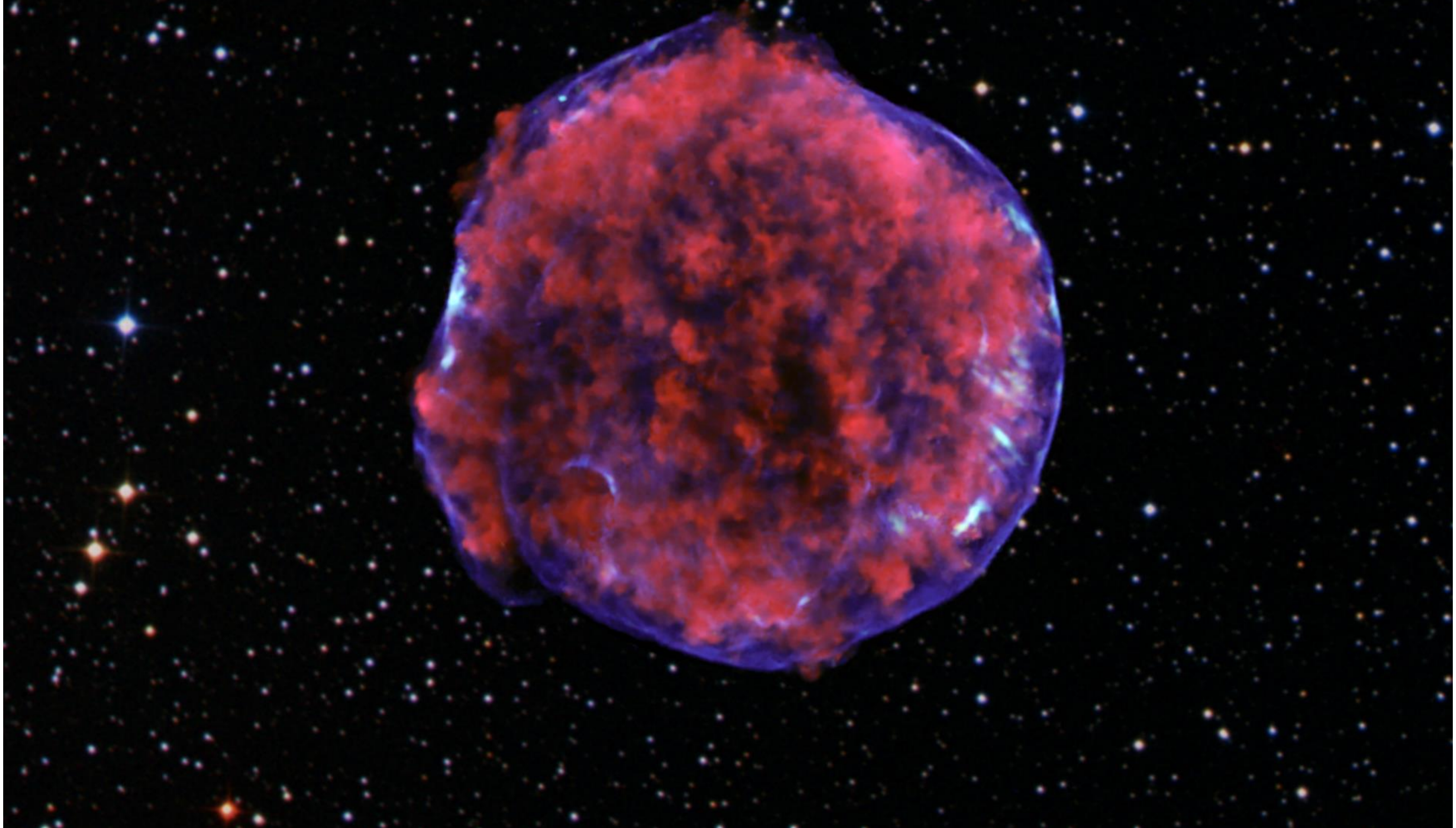
Crab Nebula: Supernova Remnant



Tycho’s Supernova Remnant

SN 1572 (type I = white dwarf + red giant binary explosion)

Constellation: Cassiopeia



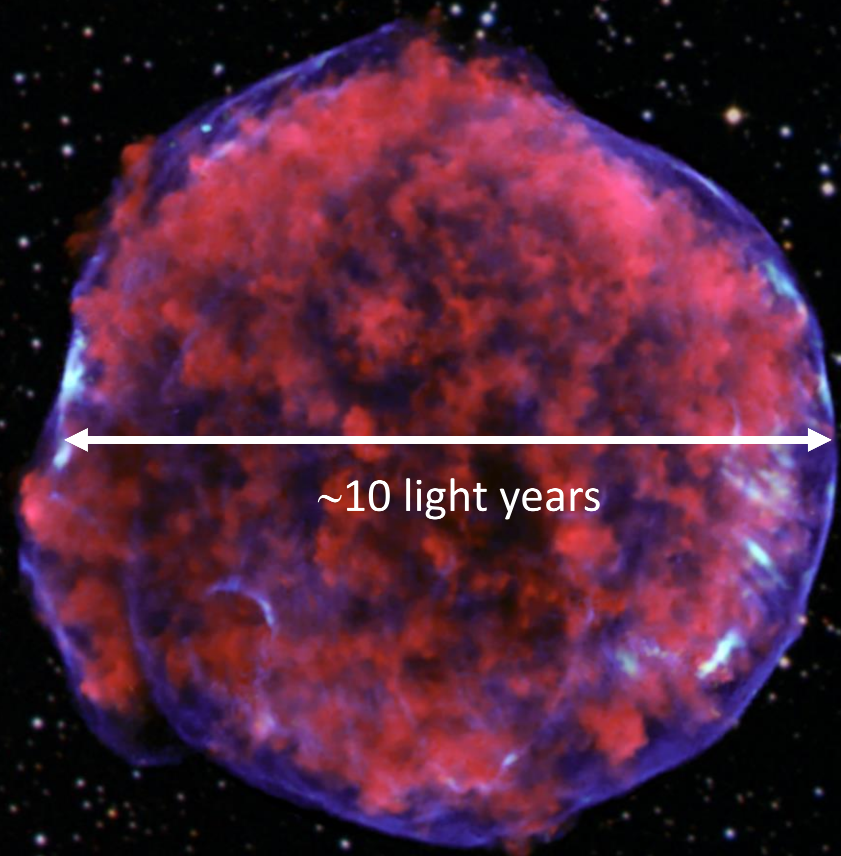
Composite image: blue = hard x-rays, red = soft x-rays, background stars = optical

[NASA/Chandra (2009)]

Tycho’s Supernova Remnant

SN 1572 (type I = white dwarf + red giant binary explosion)

Constellation: Cassiopeia

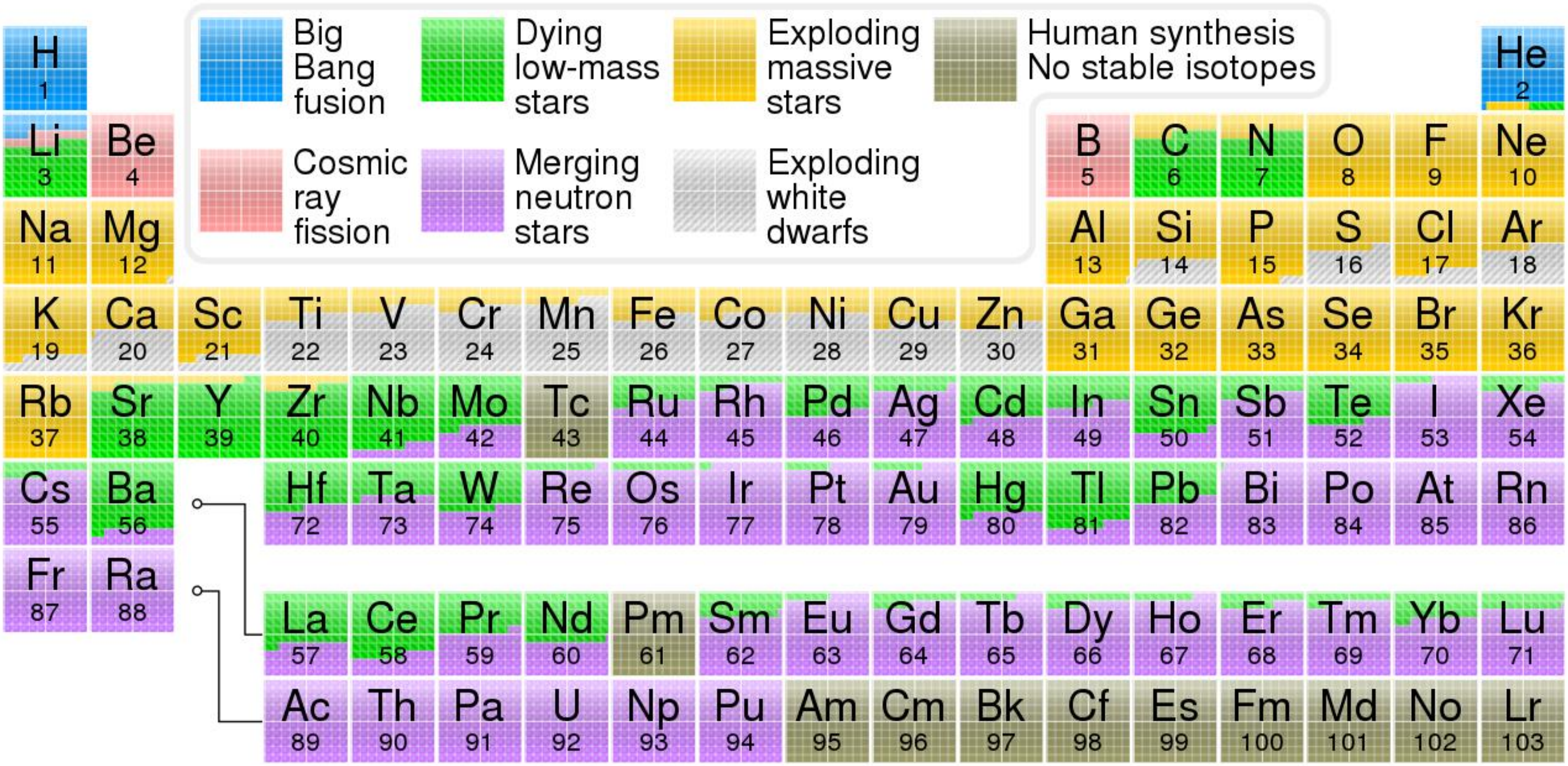


Composite image: blue = hard x-rays, red = soft x-rays, background stars = optical

[NASA/Chandra (2009)]

Where do heavy elements come from ?

- Supernovae are a major source of heavy elements
- Most of the iron core of a massive star is “dissolves” into protons in the core collapse.
  → the supernova explosion produces its own iron (and other heavier elements)



This table give the estimated origin of elements in the Solar System.

[Source: Wikipedia, Cmglee (2017)]

Type II Supernova: *What's Left ?*

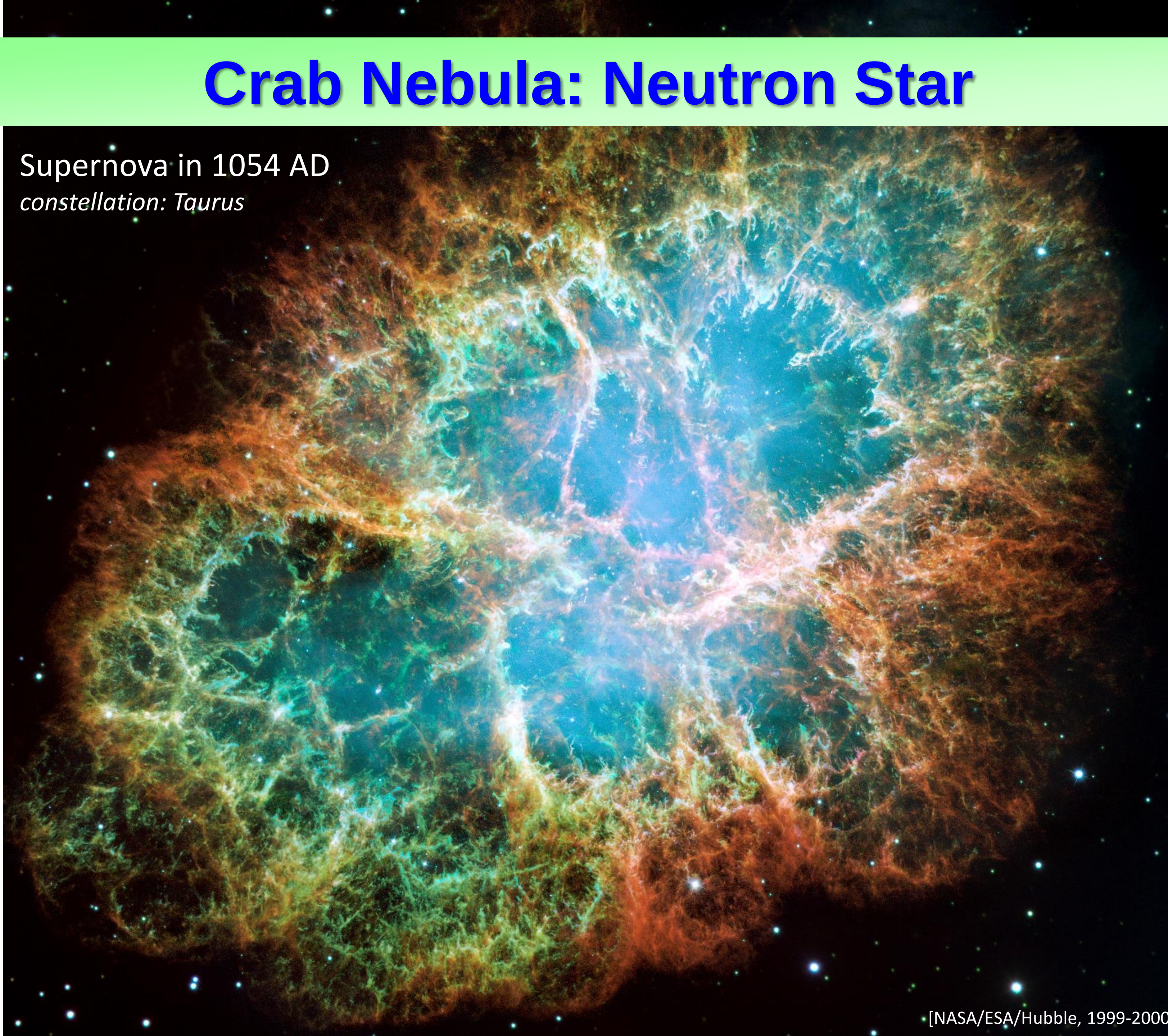
Initial Star Mass	Outcome	
10-40 M_{Sun}	Supernova → Neutron Star	
40-90 M_{Sun}	Supernova → Black Hole	
>90 M_{Sun}	Direct collapse to Black Hole	(no explosion)

Note: the exact outcome depends on the initial composition (metallicity) star.

Crab Nebula: Neutron Star

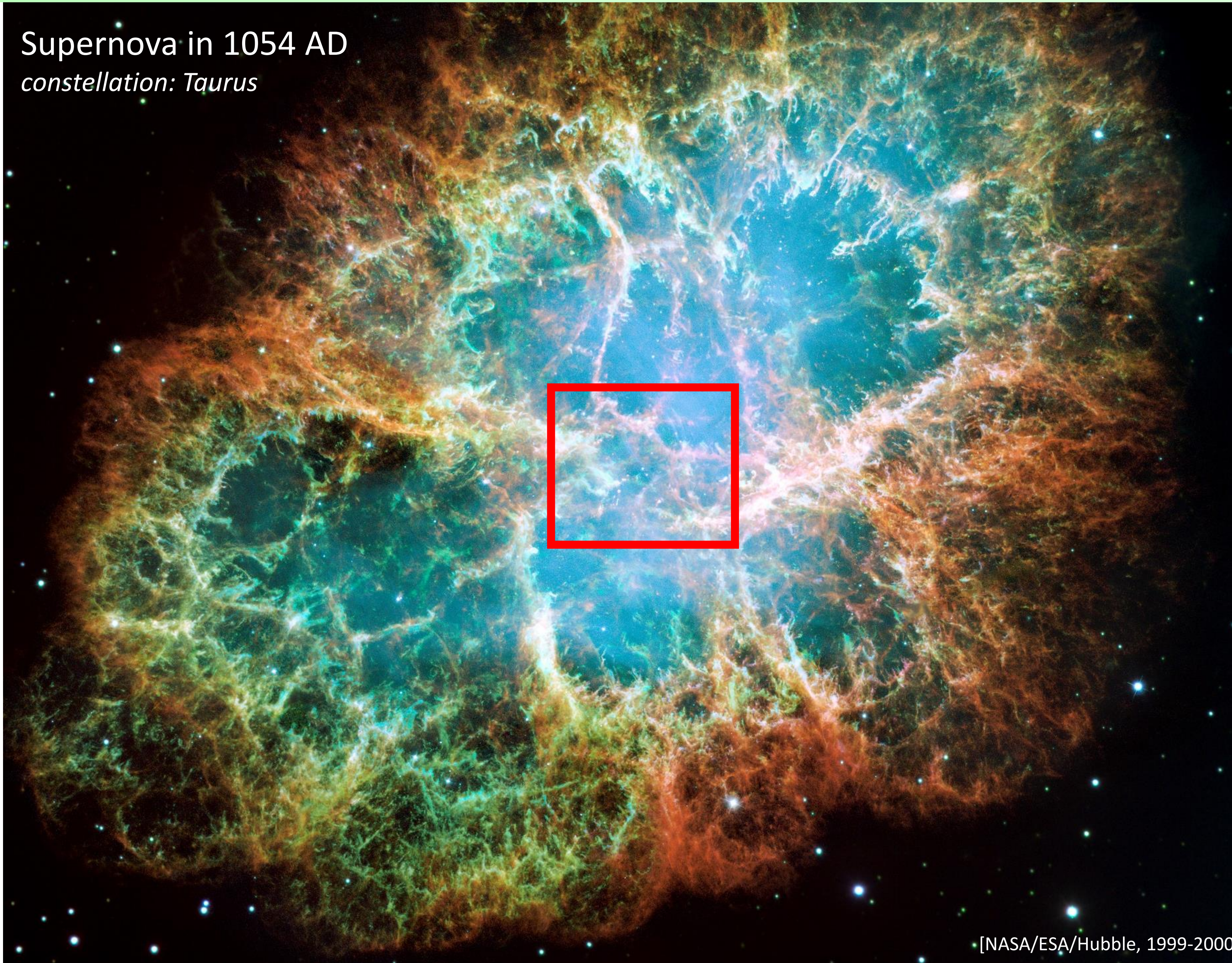
Supernova in 1054 AD

constellation: Taurus

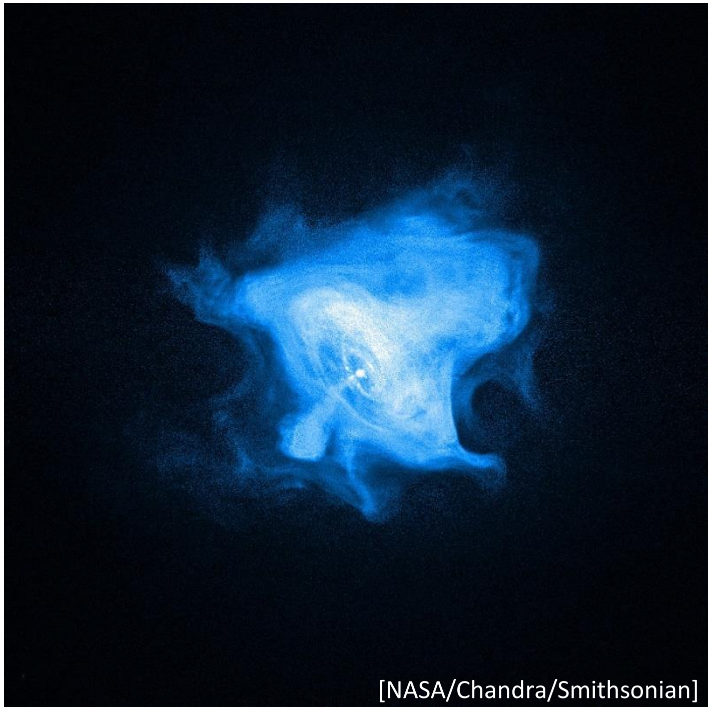


[NASA/ESA/Hubble, 1999-2000]

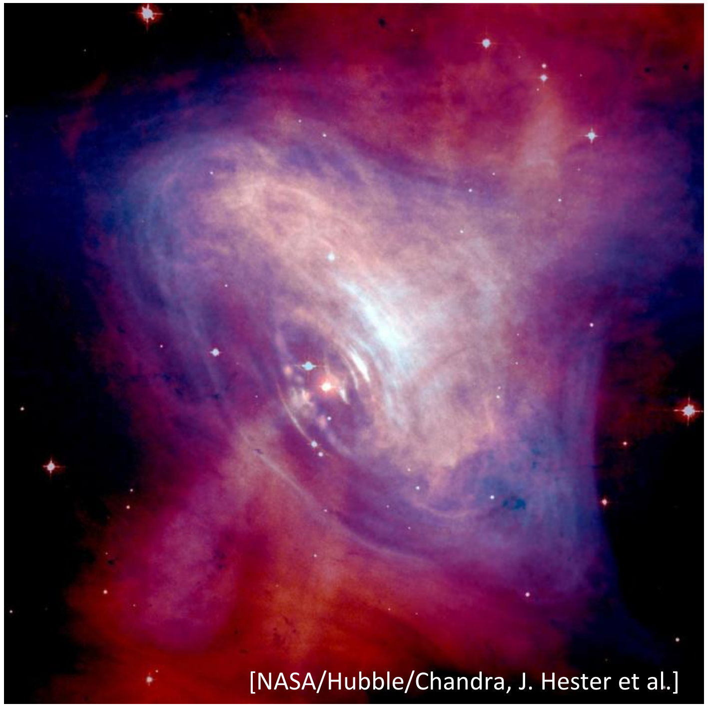
Crab Nebula: Neutron Star



Crab Nebula: Neutron Star



X-ray image of Crab Nebula neutron star, 2008



X-ray + optical images of Crab Nebula neutron star

Neutron Stars

[Table 23.3, OpenStax: Astronomy]

Property	White Dwarf	Neutron Star
Mass (Sun = 1)	0.6 (always <1.4)	Always >1.4 and <3
Radius	7000 km (Earth size)	10 km (city size)
Density	8×10^5 g/cm^3	10^{14} g/cm^3

Neutron Stars

[Table 23.3, OpenStax: Astronomy]

Property	White Dwarf	Neutron Star
Mass (Sun = 1)	0.6 (always <1.4)	Always >1.4 and <3
Radius	7000 km (Earth size)	10 km (city size)
Density	8×10^5 g/cm^3	10^{14} g/cm^3

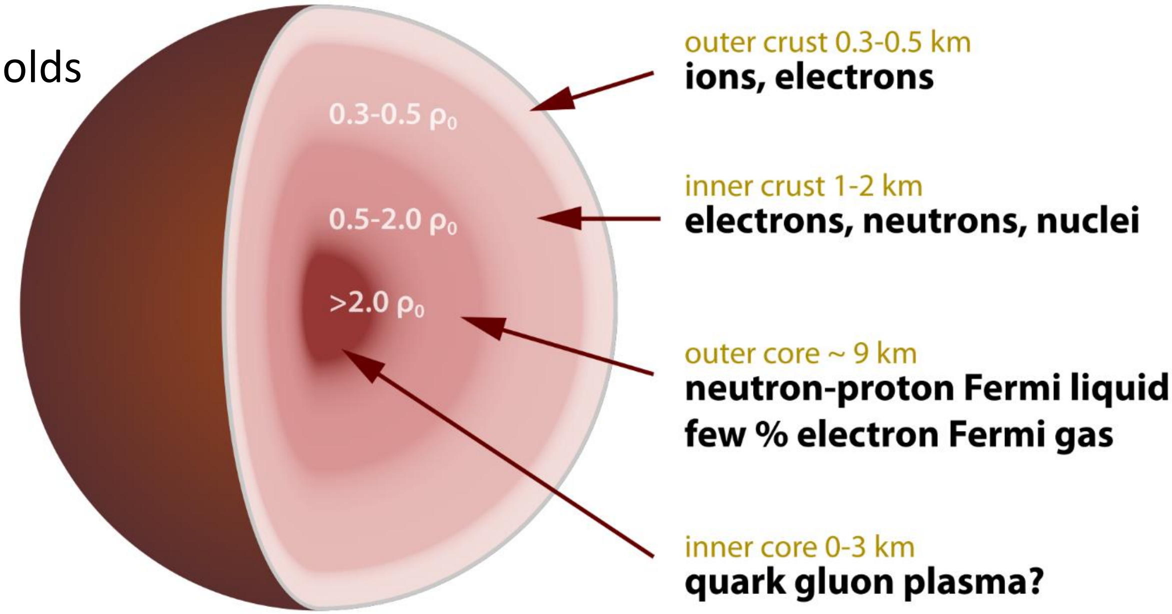
Neutron degeneracy pressure holds the star against gravitational collapse.

Neutron Stars

[Table 23.3, OpenStax: Astronomy]

Property	White Dwarf	Neutron Star
Mass (Sun = 1)	0.6 (always <1.4)	Always >1.4 and <3
Radius	7000 km (Earth size)	10 km (city size)
Density	8×10^5 g/cm^3	10^{14} g/cm^3

Neutron degeneracy pressure holds the star against gravitational collapse.



[Wikipedia: Robert Schulze]

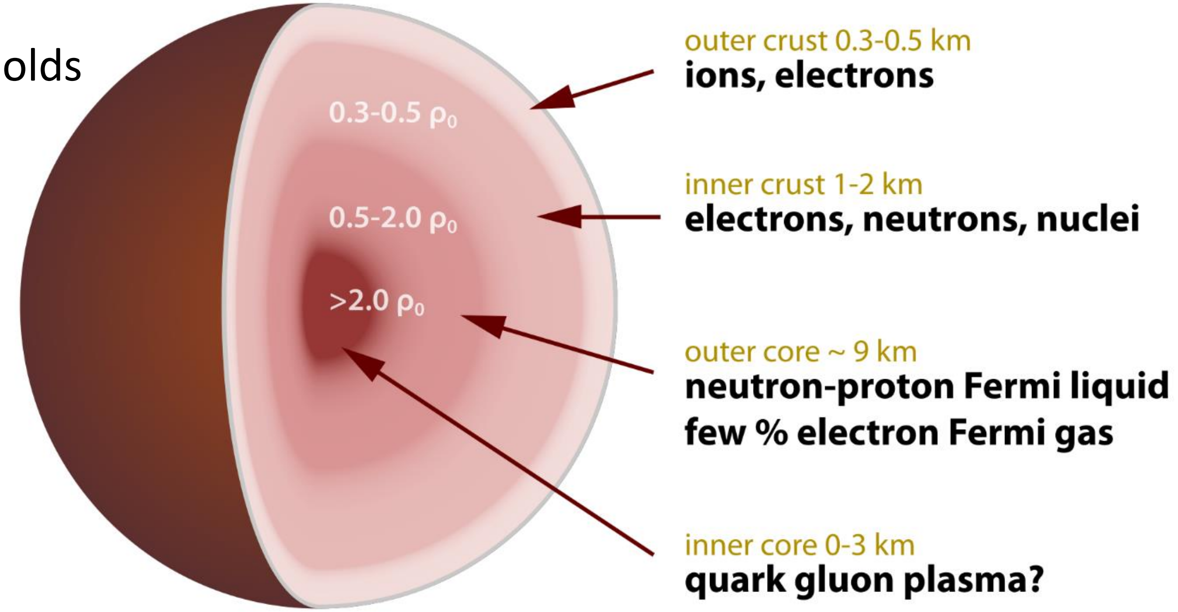
Neutron Stars

[Table 23.3, OpenStax: Astronomy]

Property	White Dwarf	Neutron Star
Mass (Sun = 1)	0.6 (always <1.4)	Always >1.4 and <3
Radius	7000 km (Earth size)	10 km (city size)
Density	8×10^5 g/cm^3	10^{14} g/cm^3

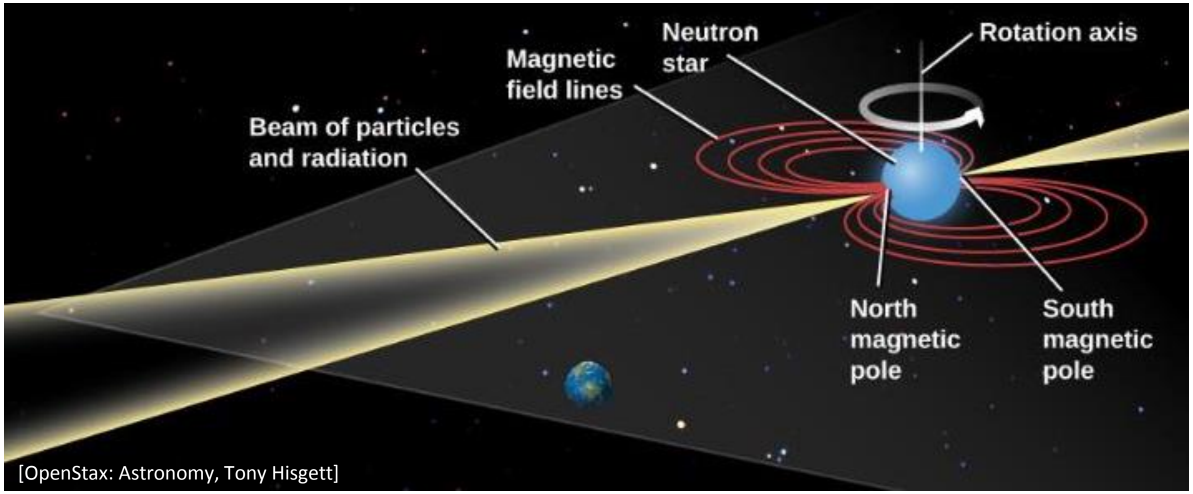
Neutron degeneracy pressure holds the star against gravitational collapse.

Neutron stars have a **very large magnetic field**: 10^8 to 10^{15} times stronger than Earth's



[Wikipedia: Robert Schulze]

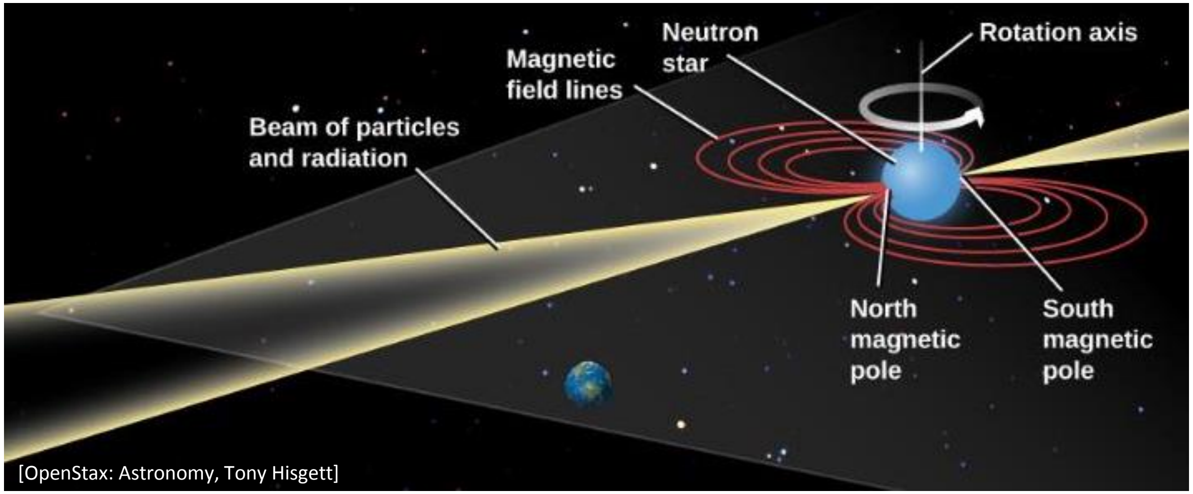
Pulsars: Rotating Neutron Stars



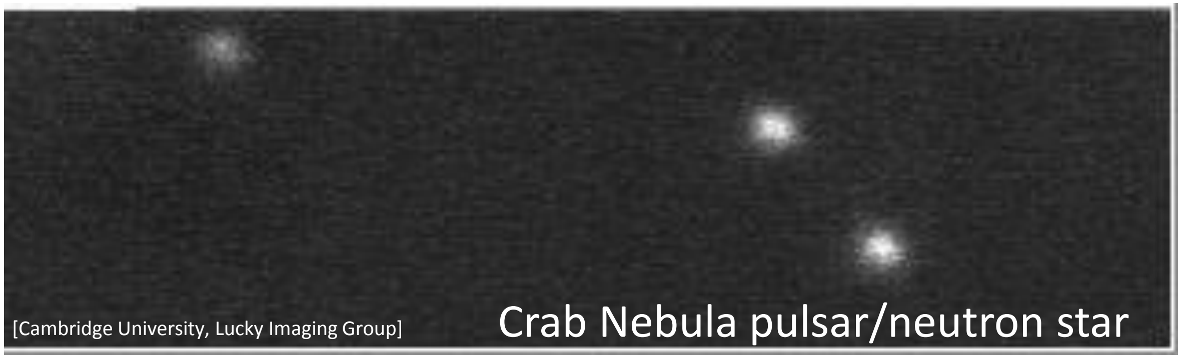
- **Beams of radiation from the magnetic poles** of a neutron star can give rise to pulses of emission as the star rotates.
- As each beam sweeps over Earth, we see a short pulse of radiation (like a lighthouse).

Jocelyn Bell Burnell
co-discoverer of pulsars (1967)

Pulsars: Rotating Neutron Stars



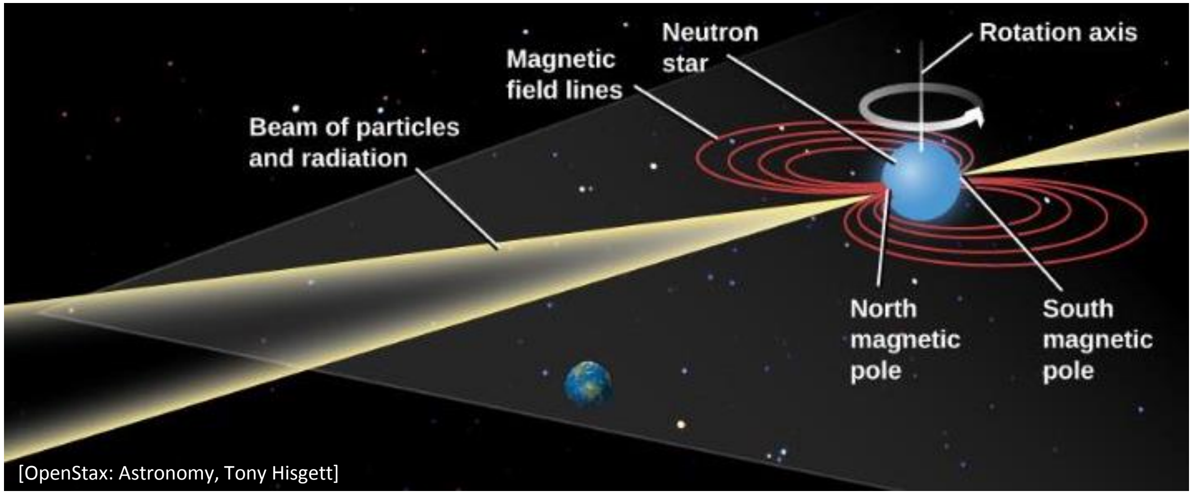
- **Beams of radiation from the magnetic poles** of a neutron star can give rise to pulses of emission as the star rotates.
- As each beam sweeps over Earth, we see a short pulse of radiation (like a lighthouse).



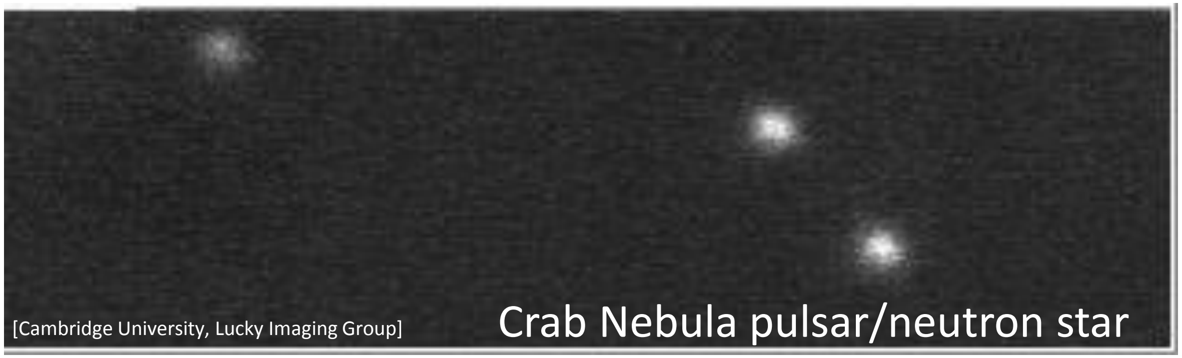
Crab Nebula pulsar/neutron star

Jocelyn Bell Burnell
co-discoverer of pulsars (1967)

Pulsars: Rotating Neutron Stars



- **Beams of radiation from the magnetic poles** of a neutron star can give rise to pulses of emission as the star rotates.
- As each beam sweeps over Earth, we see a short pulse of radiation (like a lighthouse).



Crab Nebula pulsar/neutron star

Jocelyn Bell Burnell
co-discoverer of pulsars (1967)

Typical rotation period:
- Very stable.
- ms to seconds.
- Can change abruptly during a "starquake."