Supernovae

RAC Presentation

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Outline

- Introduction
- Supernova Type Ia
- Other Supernova Types
- Massive Star Evolution
- Supernova Examples
- Summary
- Questions

Acknowledgements: This material was copied from Wikipedia & other public sources for non-profit, educational use only.

Introduction

Supernova (SN); plural Supernovae or Supernovas

Hypernova

•20 x SN Type Ia
•Gamma ray burst from collapse of extremely massive stars

Supernova

Collapse of massive star or accretion by white dwarf & runaway C fusion

Nova

White dwarf accretes hydrogen and goes to runaway H fusion, uses 1/10,000 of star mass

A Hubble Space Telescope image of the supernova remnant N 63A in the Large Magellanic Cloud.

Supernova Definition

The word supernova was coined by Walter Baade and Fritz Zwicky in 1931, Mount Wilson Observatory

- **Supernova**
  - A stellar explosion that is much more energetic than a nova.
  - Extremely luminous and often briefly outshines an entire galaxy
  - Normally fades from view over several weeks or months
  - Radiates as much energy as the Sun in its entire life
  - Explosion expels most or all of a star at velocities as high as 30,000 km/s, (10% c) & up to 70% c

- The shock wave sweeps up an expanding shell of gas and dust called a "supernova remnant"

- Supernovae can be triggered in two ways:
  1. Sudden re-ignition of nuclear fusion in a degenerate star -- White Dwarf (ignites Carbon fusion – runaway nuclear fusion – Type Ia Supernova):
     a) Binary Star merger
     b) Accretion from companion Star
  2. Collapse of the core of a massive star – Red Giant –Fe core (Type Ib, Ic, and II Supernova)

Credit: Wikipedia, Sept 2012

Supernovae Type I Model

Type I supernovae have a sharp maxima and smooth decay of light.

Type I supernova can be modeled as an explosion of a carbon white dwarf.

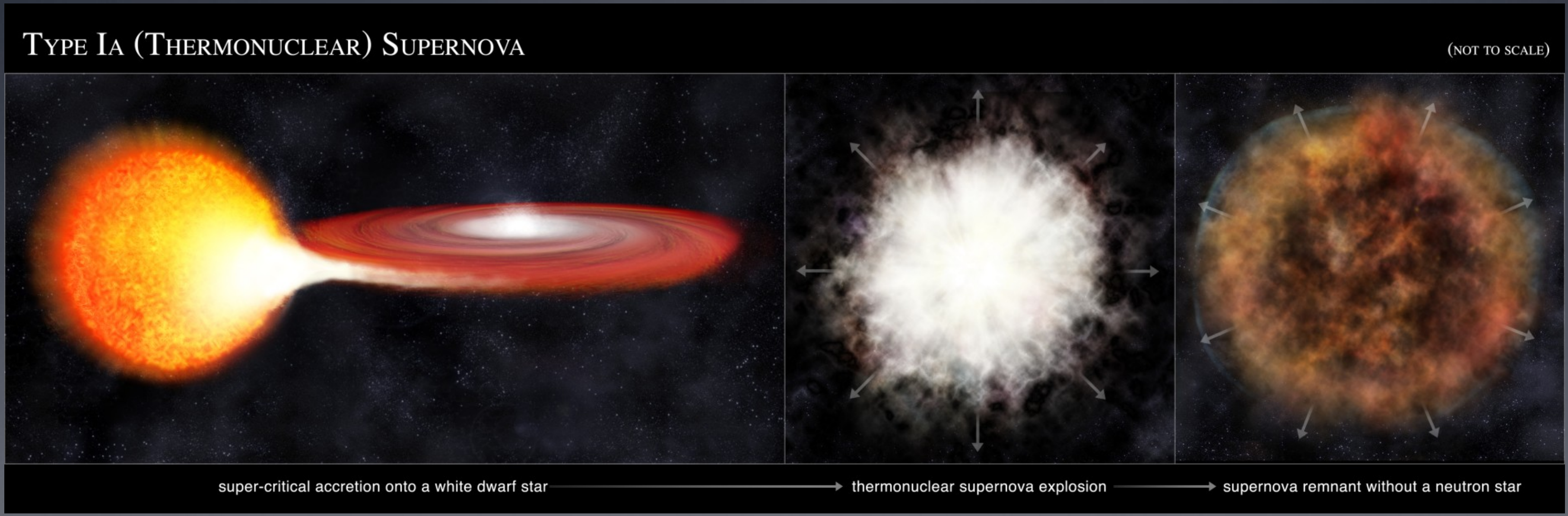
The white dwarf is crushed under the pressure of electron degeneracy.

A white dwarf accumulates enough mass that it exceeds the Chandrasekhar limit of 1.4 solar masses (star's core can no longer resist gravitational collapse).

The core temperature of the white dwarf rises dramatically, setting off chains of nuclear fusion reactions that essentially blow the star up. This model is consistent with the fact that Type I supernovae are hydrogen deficient, since white dwarves contain nearly zero hydrogen.

Furthermore, the slow decay of light is consistent with the model, because the radioactive decay of unstable heavy elements produced by the supernova produces most of the energy.

Type Ia Supernova



Type Ia Supernova

- The maximum mass of a stable white dwarf star is about 1.38 solar masses
- However, the current view is that the Chandrasekhar limit is not normally attained because increasing temperature and density inside the core ignite Carbon fusion as the star approaches the Chandrasekhar limit (1.44 solar mass)
- The White Dwarf undergoes nuclear fusion in a few seconds releasing enough energy to unbind the star in a supernova explosion
- Luminosity reaches a magnitude about 5 billion times brighter than the Sun, with little variation (Standard Candle)
- However, the spin of the white dwarf star can increase the mass before collapse (maybe up to 2 solar masses)

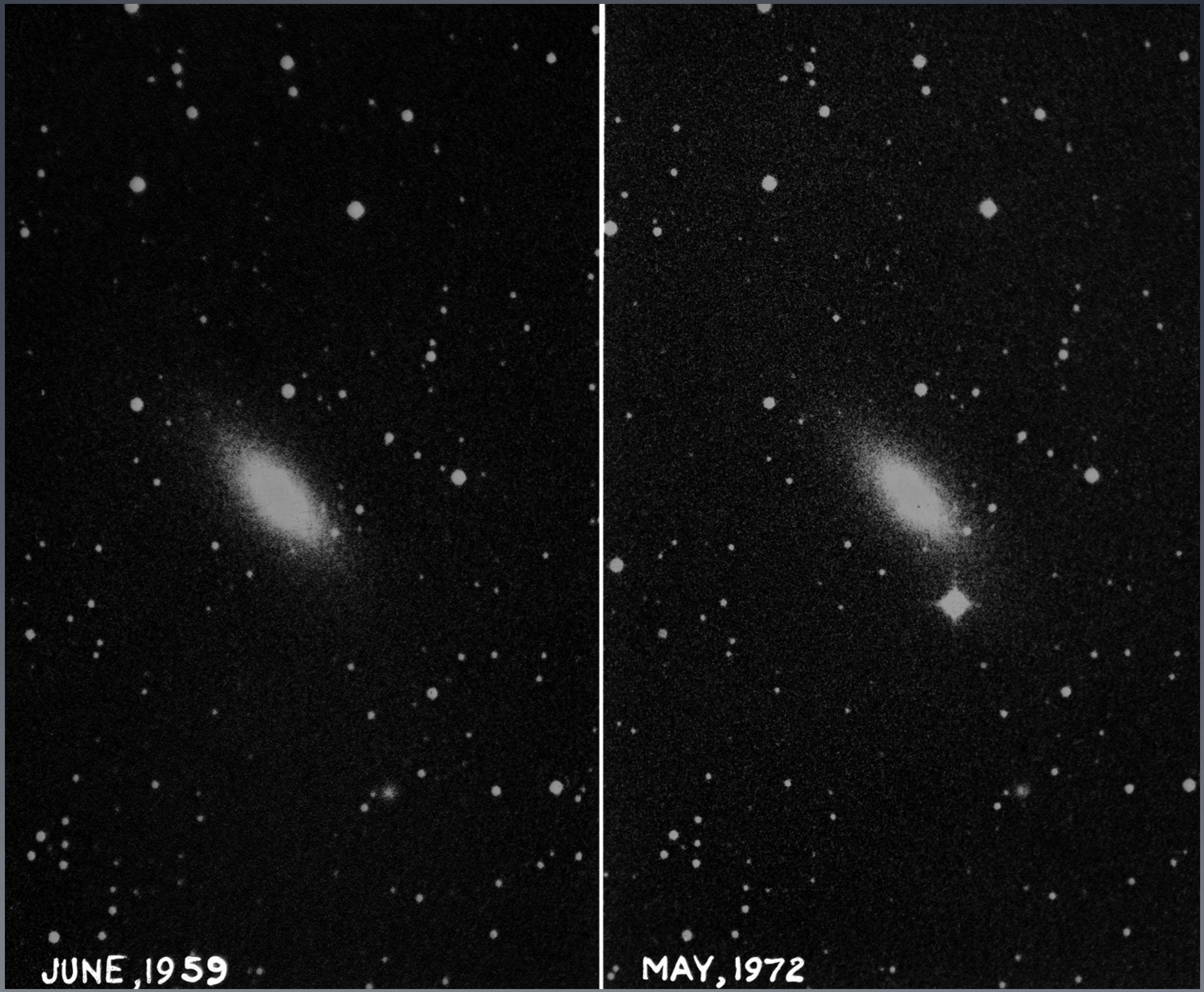
Credit: Wikipedia, Sept 2012

Supernova SN1972E

Photos of the galaxy NGC 5253

This particular supernova (SN 1972e) was classified as a Type Ia supernova, which is thought to occur with the explosion of a dead star known as a white dwarf.

This SN1972 became the standard candle for measuring the size of the universe.



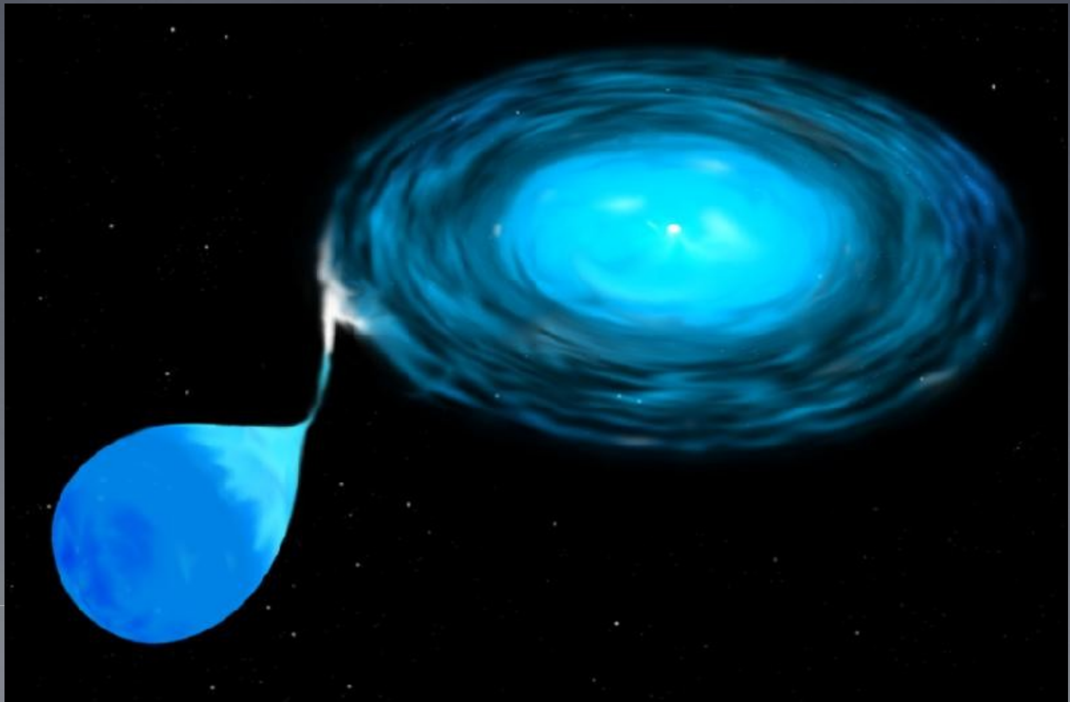
Close Type Ia Supernova PTF 11kly

Credit: Peter Nugent and the Palomar Transient Factory

The arrow marks PTF 11kly in images taken on the Palomar 48-inch telescope over the nights of, from left to right, Aug. 22, 23 and 24. The supernova wasn't there Aug. 22, was discovered Aug. 23, and brightened considerably by Aug. 24.

White Dwarfs as Binary Stars

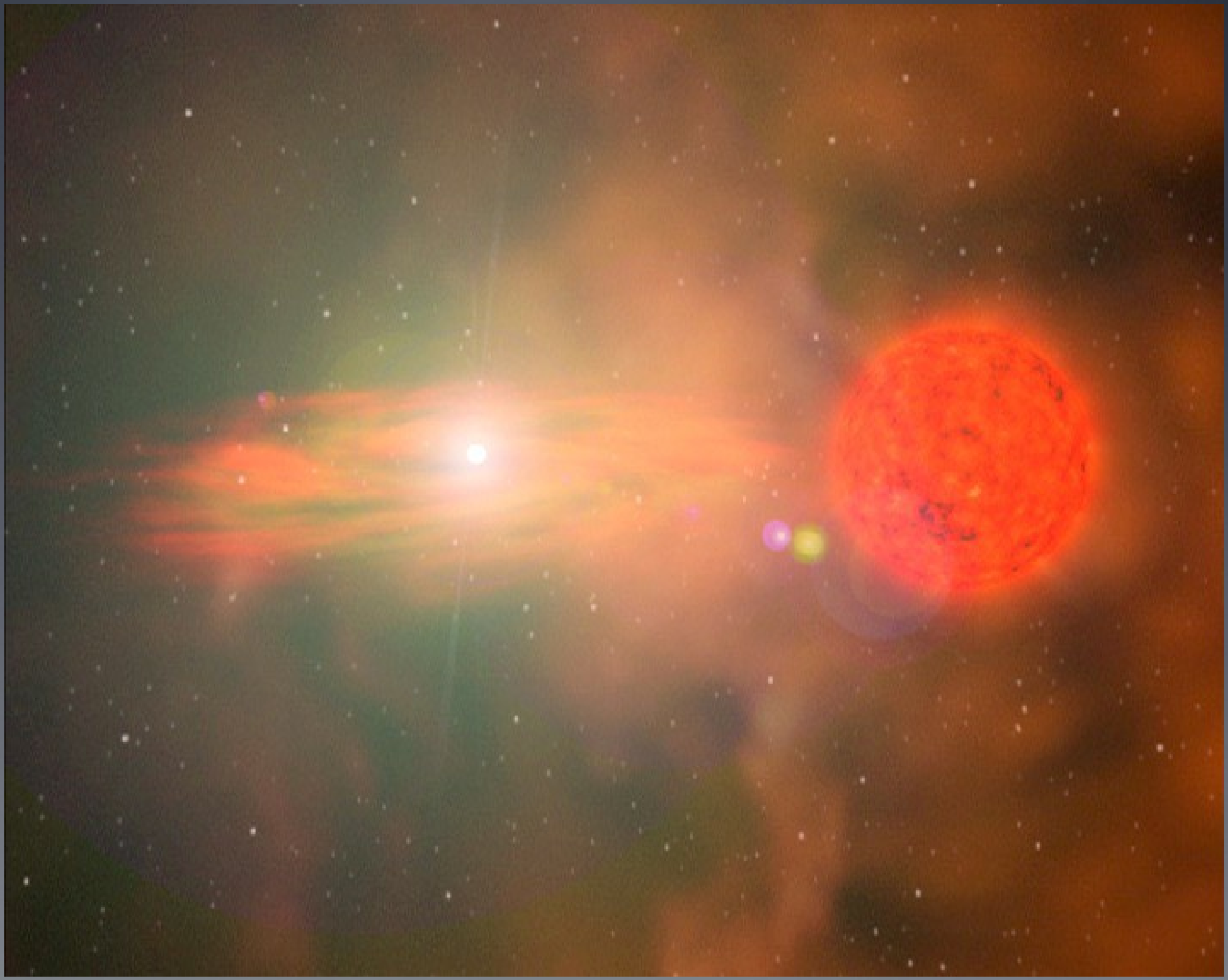
A white dwarf is a stellar remnant that has ceased nuclear fusion (or in final stages). It typically can weigh up to 1.4 times as much as our Sun — a figure called the Chandrasekhar mass. If it gets heavier, from accretion, gravity overwhelms the forces supporting the white dwarf, compacting it and igniting runaway nuclear fusion that blows the star apart--Supernova*



* Astronomy Magazine, 6 Sep 2011

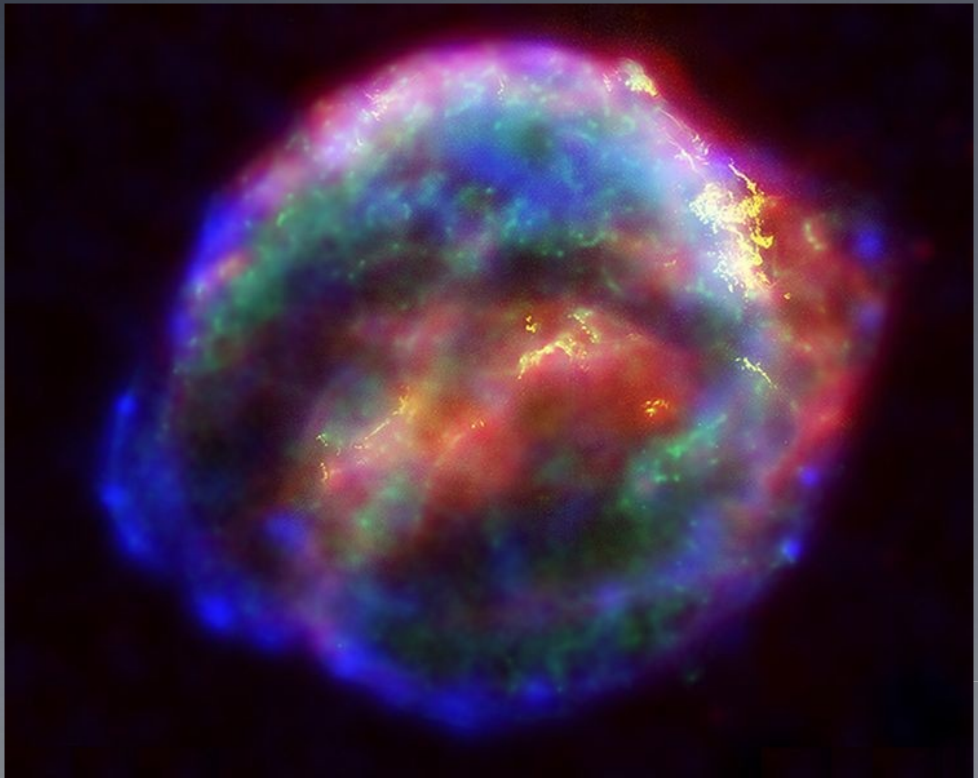
White Dwarf to Supernova

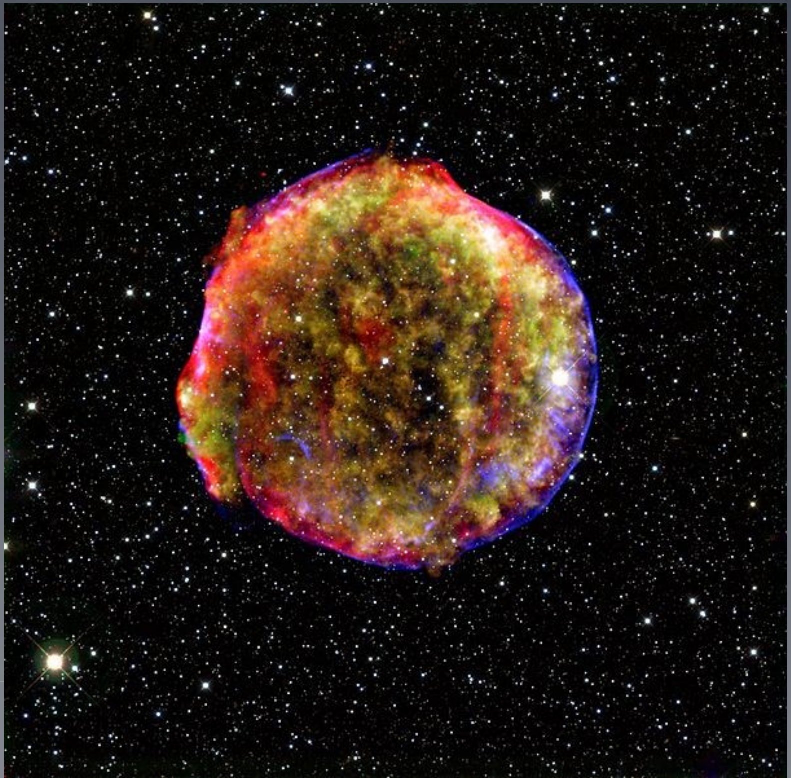
A red giant star sheds material, which is drawn in by a nearby white dwarf in this artist's conception. The white dwarf eventually exceeds its maximum stable mass, triggering a supernova.
Image: Romano Corradi/Instituto de Astrofísica de Canaria



Supernovae or Supernovas

- Supernovae are classified iaw their spectral characteristics:
  - Type II contains Hydrogen
  - Otherwise, it is Type I





Supernova Types

- The type I supernovae are subdivided on the basis of their spectra:
  - Type Ia provide "Standard Candles" because they derive from runaway nuclear fusion of a White Dwarf with accretion to about 1.38 solar masses
  - Type Ia shows a strong ionized Silicon absorption line
  - Type Ib, Helium line, but weak or no Silicon
  - Type Ic, weak or no Silicon, weak or no Helium
- Type II supernovae with normal spectra are dominated by broad hydrogen lines (super velocity material)
- Supernovae types other than Type Ia derive from the collapse of a massive star (>9 solar masses)

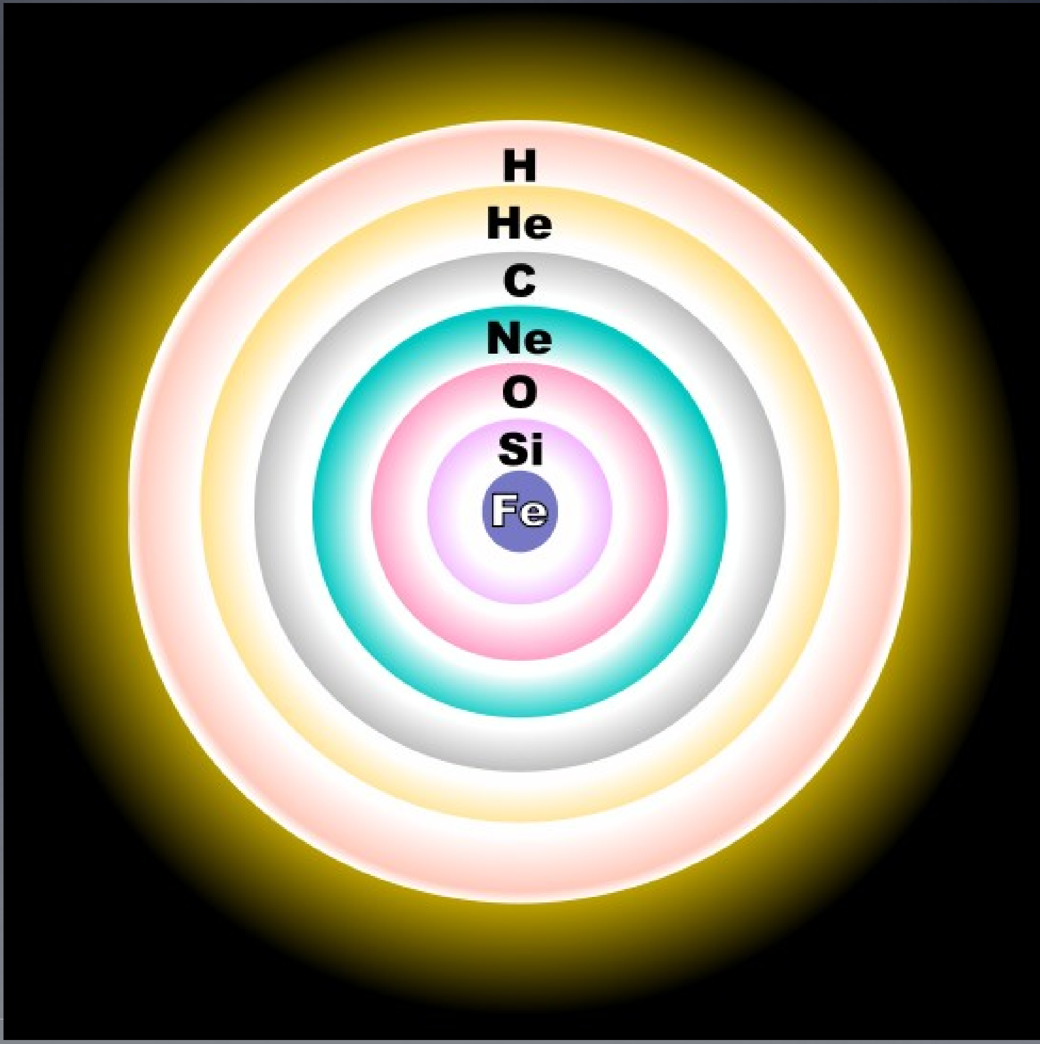
Credit: Wikipedia, Sept 2012

Star Fusion Shells

Once the the fusion process reaches Iron-56 it consumes energy and the star collapses to form a Neutron Star or a Black Hole

Through a process that is not completely understood, some of the gravitational potential energy released by this core collapse is converted into a Type Ib, Ic or II Supernova

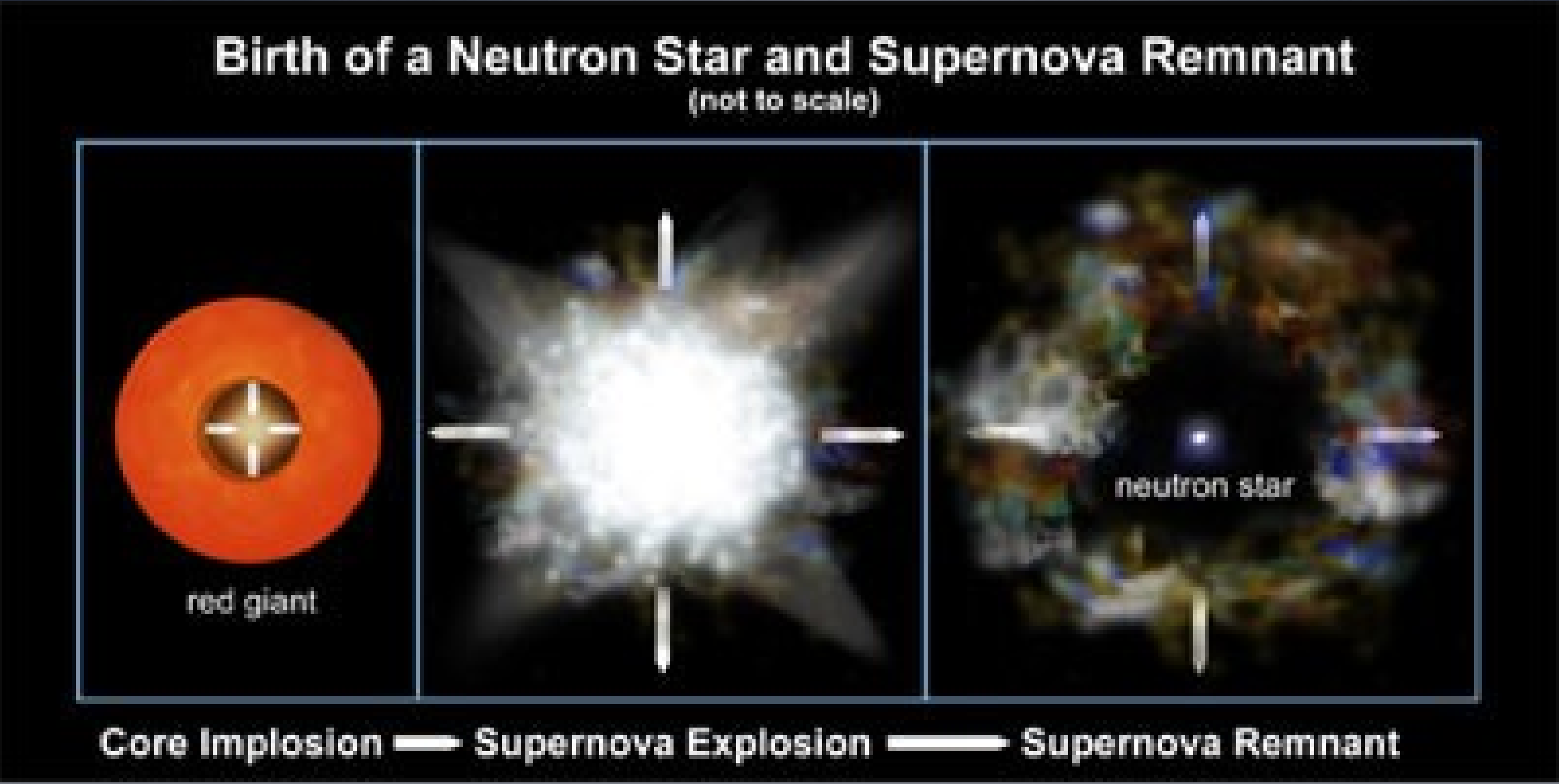
A spectrum of heavier-than-iron material including the radioactive elements up to uranium are created by this collapse and Supernova "explosion"



The Nuclear Impasse

- Iron (Fe) is the most tightly bound nucleus
- Fusion of nuclei lighter than Fe releases energy
- Fusion of nuclei heavier than Fe absorbs energy
- Once an Fe core forms, there are no new fusion reactions
- No Fe fusion energy to resist gravity

Red Giant to Supernova



Massive Star Fusion

- Stars with Mass > 9 M_{sun} (Ms)
  - Burn Carbon, Neon, Oxygen & Silicon
  - Build up a heavy Iron Core & burning shells.
  - Final stage occurs when the Iron core begins to catastrophically collapse
  - Neutron core is formed
  - Collapsing material bounces (explodes) off the neutron core and forms heavy elements above Fe
  - Supernova Type II
- Stars below 9 Ms never go to Supernova– go to White Dwarfs--- then can go to Type Ia Supernova

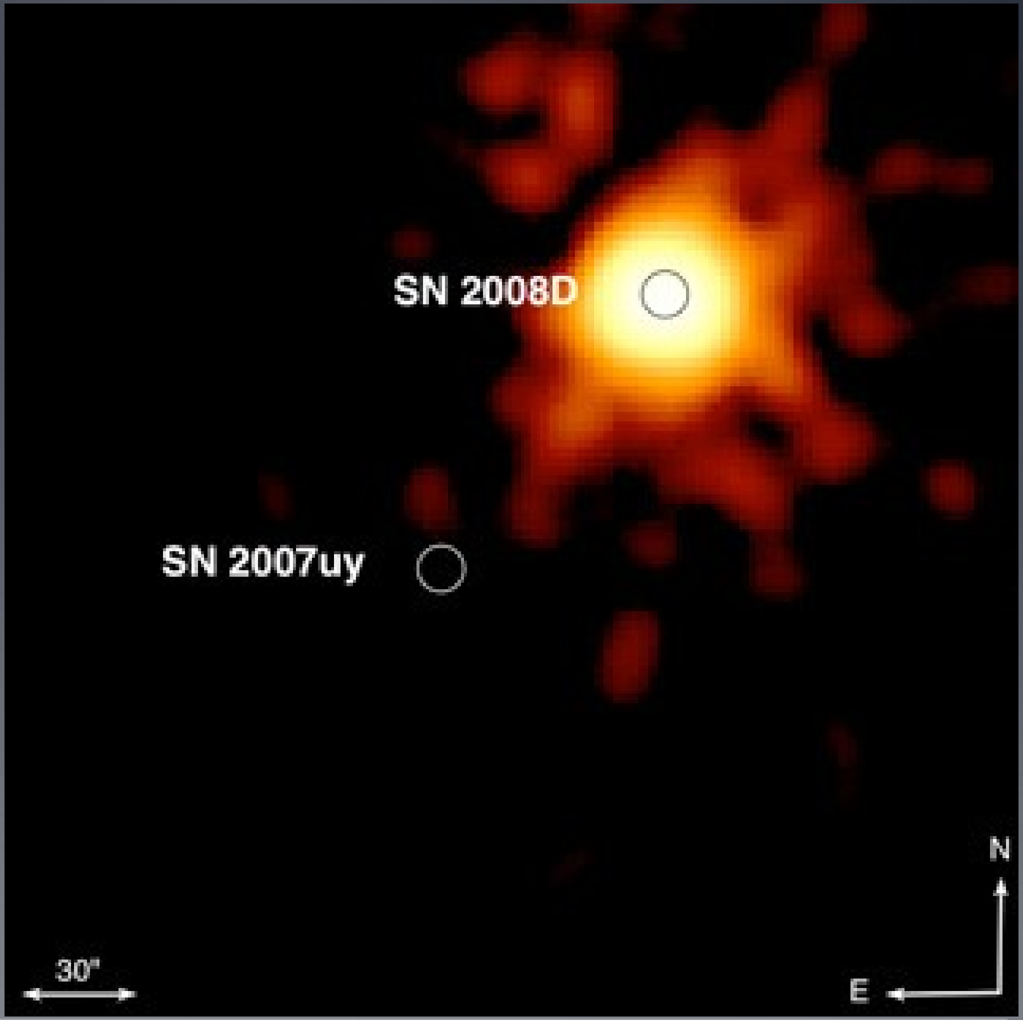
End of the Road

- At the end of Silicon Burning:
  - Build up an inert Fe core and Onion Skin of nested nuclear burning shells
  - Finally, the Fe core exceeds 1.2-2 M_{sun}
  - Fe core begins to contract & heat up -- forms Neutron core
  - Collapsing material bounces off the neutron core: Supernova
  - Heavy elements formed by the explosion
  - Our world comprises Star and Supernova remnant material

Supernova First Moments

Although the x-ray outburst lasted only seven minutes, it flashed 100 billion times brighter than the sun in that time. Based on that brightness and the duration of the flash, researchers conclude that the star (SN 2008D) was approximately 20 times the size of the sun and was blown apart by a shock wave expanding outward at 70 % c.

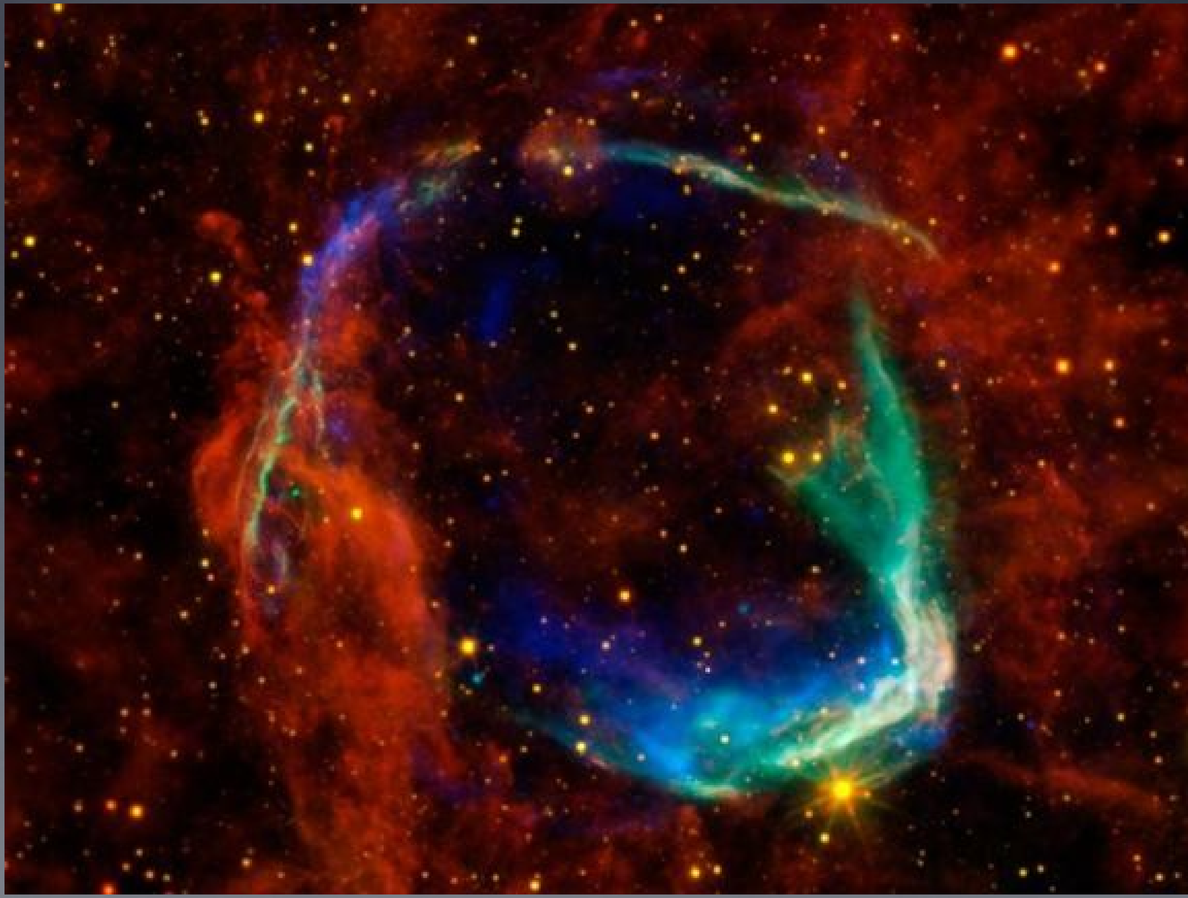
Ref: JR Minkel, Scientific American, May 2008 issue
Credit: Dana Berry/NASA



Supernova SN185 (RCW 86)

RCW 86 - First Documented Supernova
Credit: NASA/ESA/JPL-Caltech/UCLA/CXC/SAO
This image combines data from four different space telescopes to create a multi-wavelength view of all that remains of the oldest documented example of a supernova, called RCW 86. The Chinese witnessed the event in 185 A.D., documenting a mysterious "guest star" that remained in the sky for eight months.

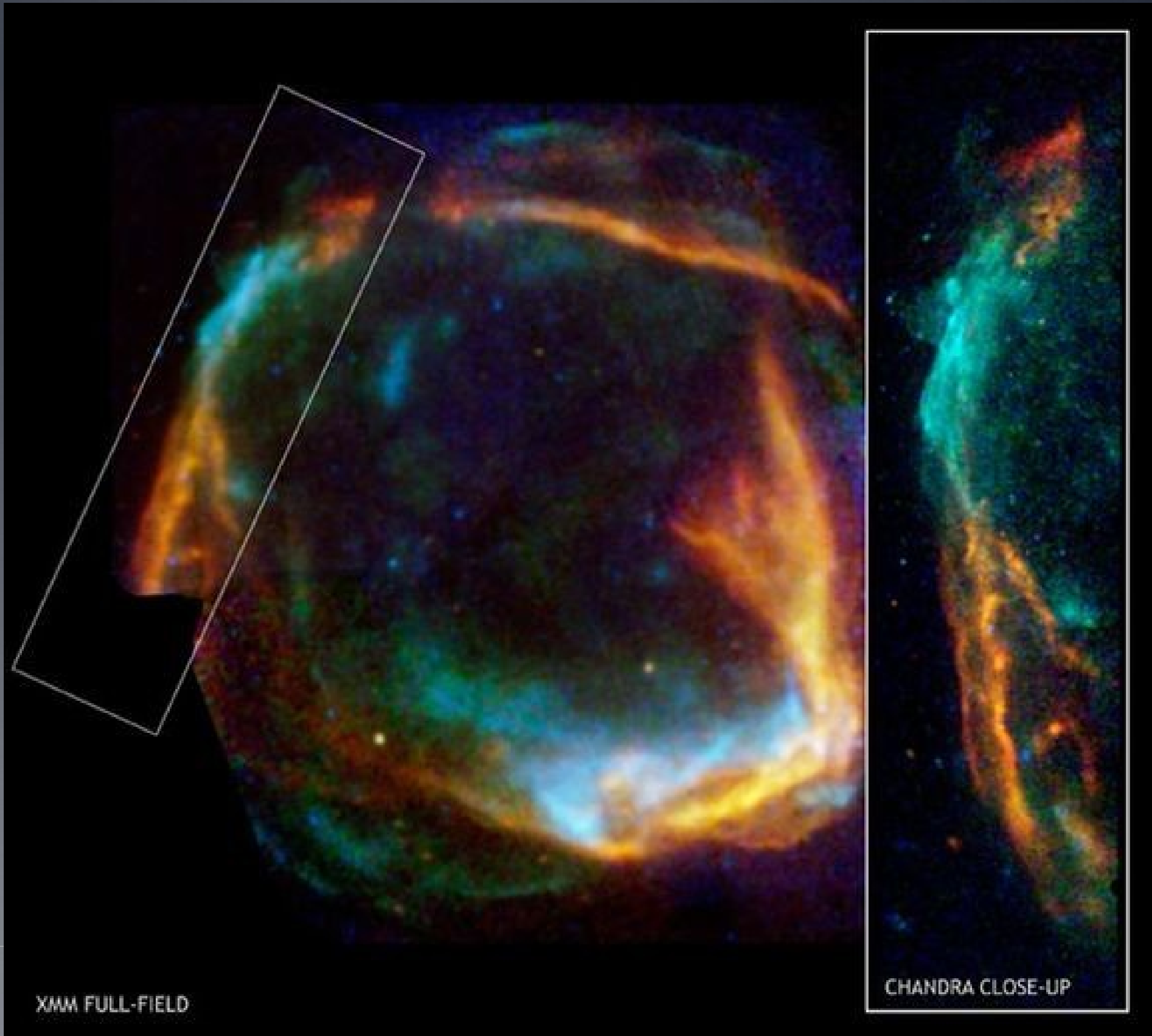
Was probably a Type Ia



Astronomers Find Supernova SN185 (RCW 86) of 2,000 Years Ago

Credit: Chandra: NASA/CXC/University of Utrecht/J.Vink et al. XMM-Newton: ESA/University of Utrecht/J.Vink et al.

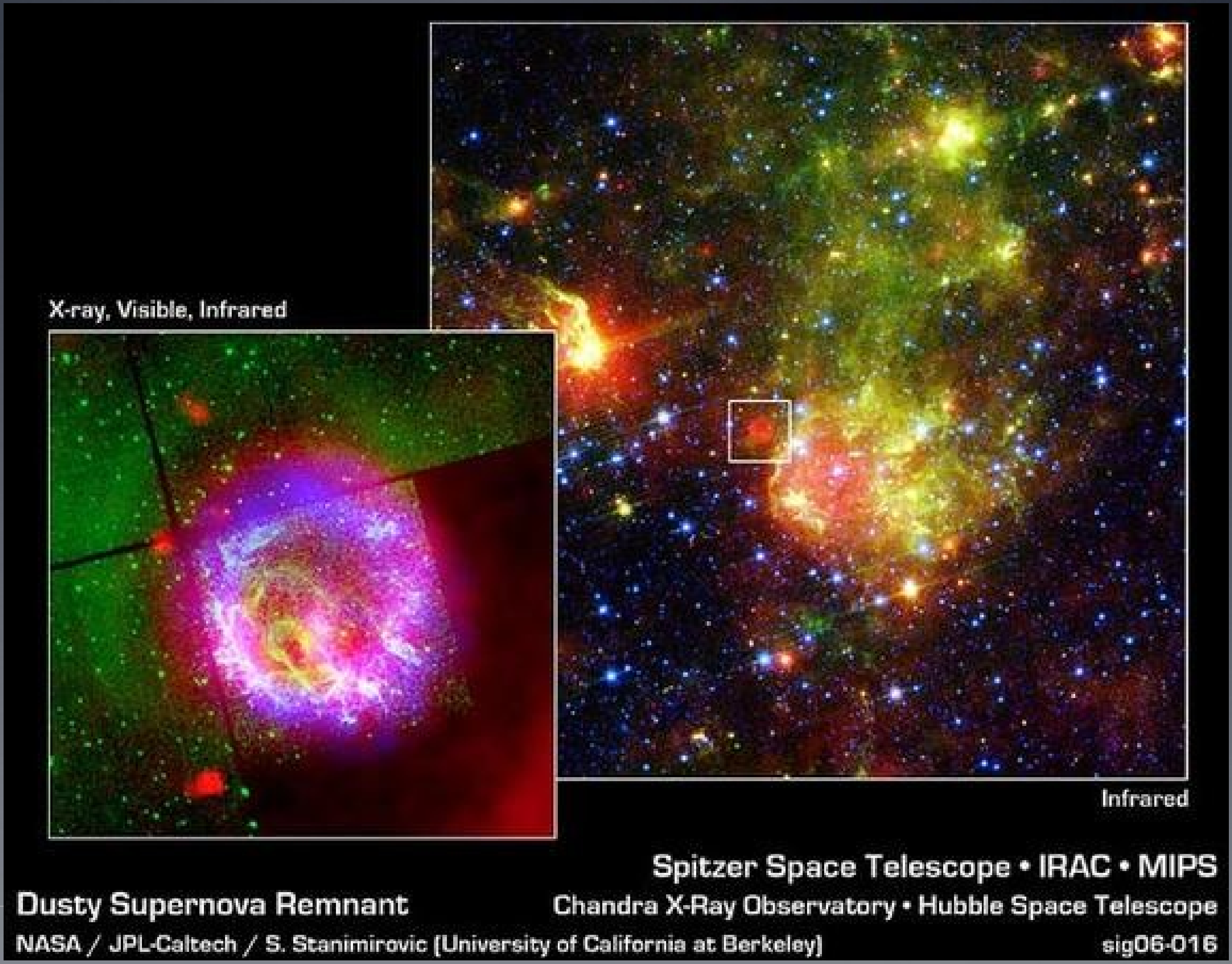
The combined image from the Chandra and XMM-Newton X-ray observatories of RCW 86 shows the expanding ring of debris created after a supernova.



Supernova Remnant E0102

Credit: NASA/JPL-Caltech/S. Stanimirovic (UC Berkeley)

An infrared image of the portion of the Small Magellanic Cloud containing supernova remnant E0102, plus a composite X-ray, optical and infrared image of E0102.

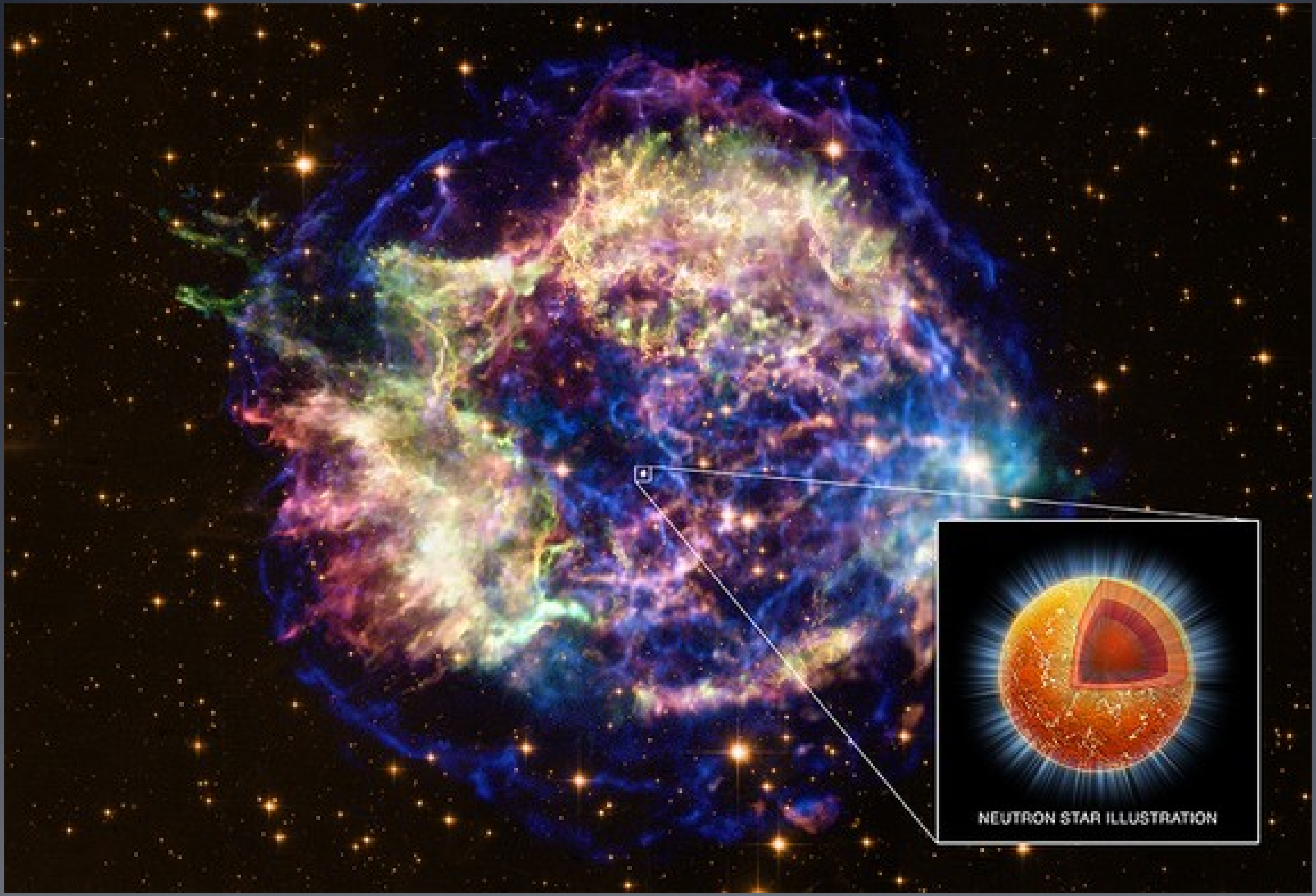


X-ray Stripes in Tycho Supernova

Credit: X-ray: NASA/CXC/Rutgers/K.Eriksen et al.; Optical: DSS

This image comes from a very deep Chandra observation of the Tycho supernova remnant. Low-energy X-rays (red) in the image show expanding debris from the supernova explosion and high energy X-rays (blue) show the blast wave, a shell of extremely energetic electrons. These high-energy X-rays show a pattern of X-ray "stripes" never previously seen in a supernova remnant.

Supernova Remnant Casseopeia A



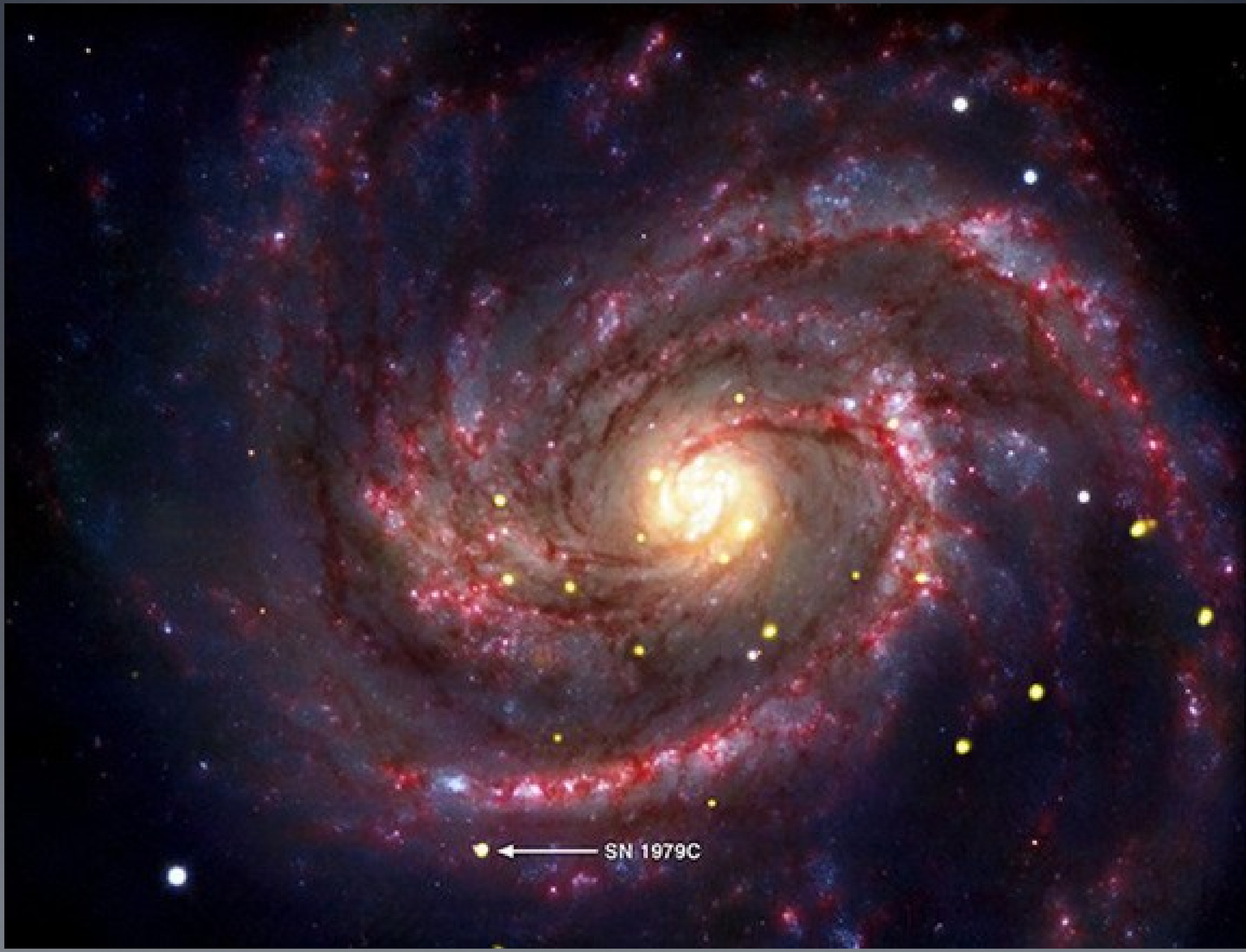
Credit: X-ray: NASA/CXC/xx; Optical: NASA/STScI; Illustration: NASA/CXC/M.Weiss
This image presents a composite of X-rays from Chandra (red, green, and blue) and optical data from Hubble (gold) of Cassiopeia A, the remains of a massive star that exploded in a supernova. Inset: A cutout of the interior of the neutron star, where densities increase from the crust (orange) to the core (red) and finally to the region where the "superfluid" exists (inner red ball).

Evidence Found for Youngest Black Hole Ever Seen in Supernova SN1979C

Credit: NASA/CXC/SAO/D.Patnaude et a Optical: ESO/VLT, Infrared: NASA/JPL/Caltech

This composite image shows a supernova within the galaxy M100 that may contain the youngest known black hole in our cosmic neighborhood.

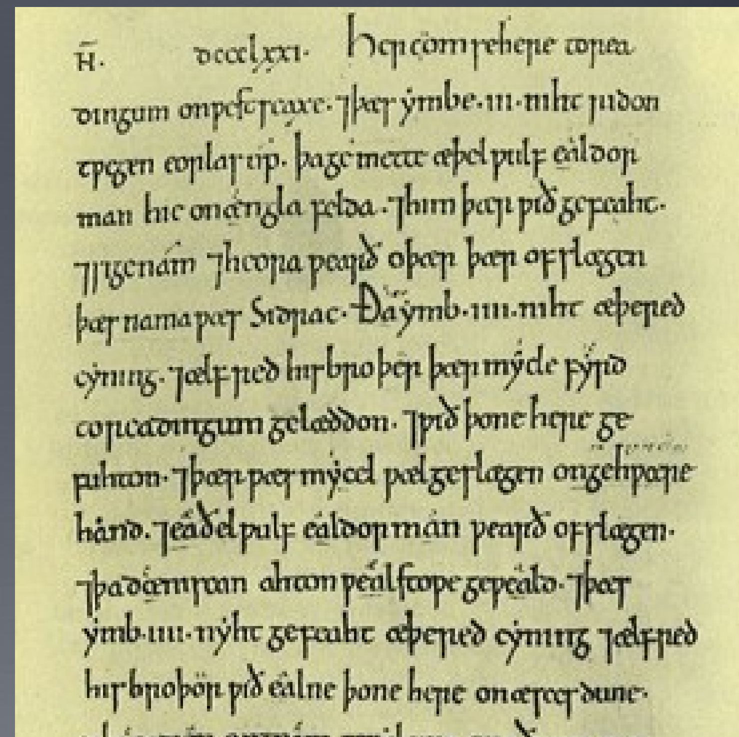
The black hole would be about 30 years old and was born from the supernova SN1979C.



Supernova in 774?

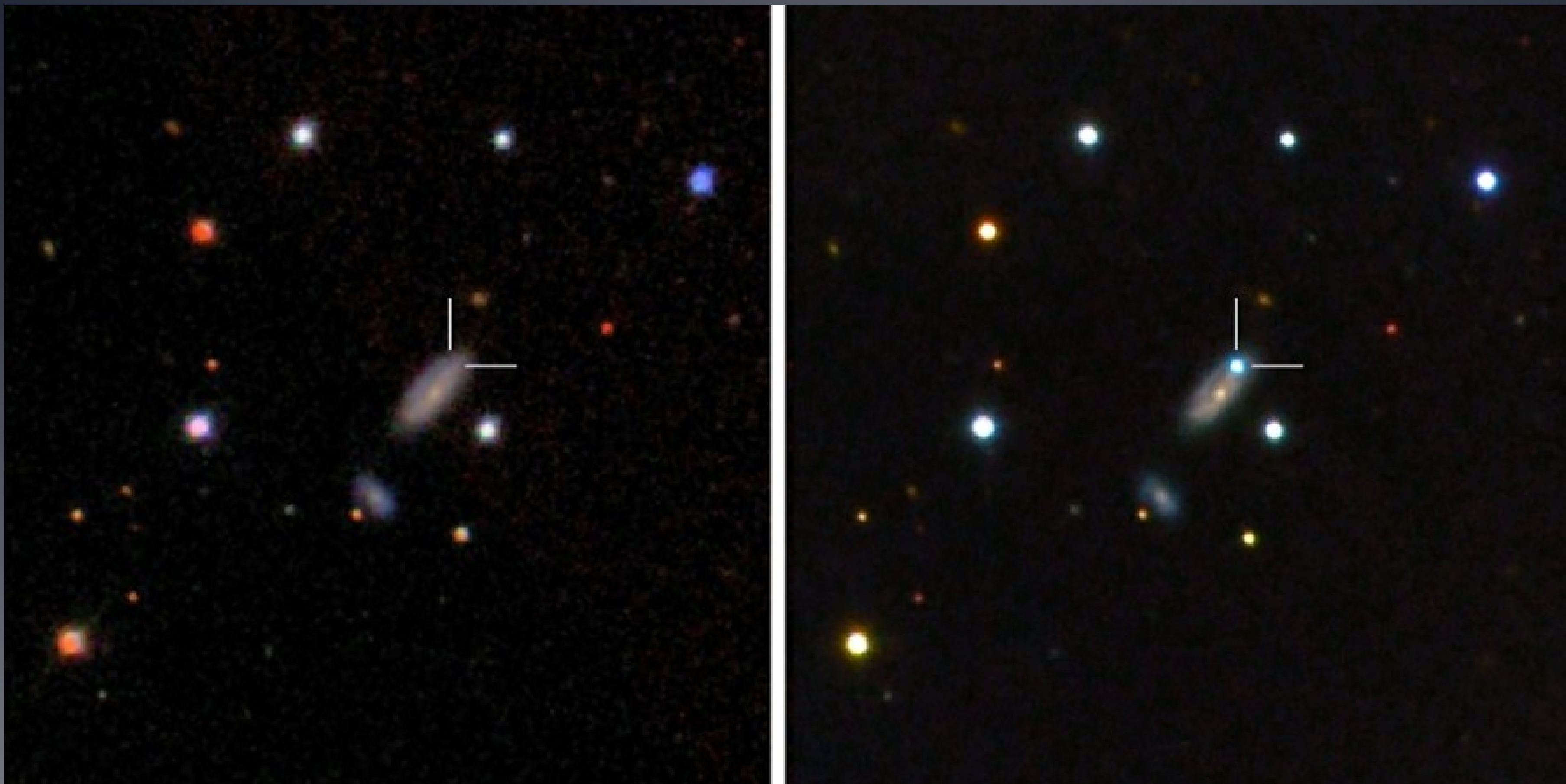
An eerie "red crucifix" seen in Britain's evening sky in ad 774 may be a previously unrecognized supernova explosion — and could explain a mysterious spike in carbon-14 levels in that year's growth rings in Japanese cedar trees. The link is suggested in a *Nature Correspondence by a US undergraduate student.*

Credit: Nature, June 27, 2012



Supernova in Constellation Lynx from a Nova

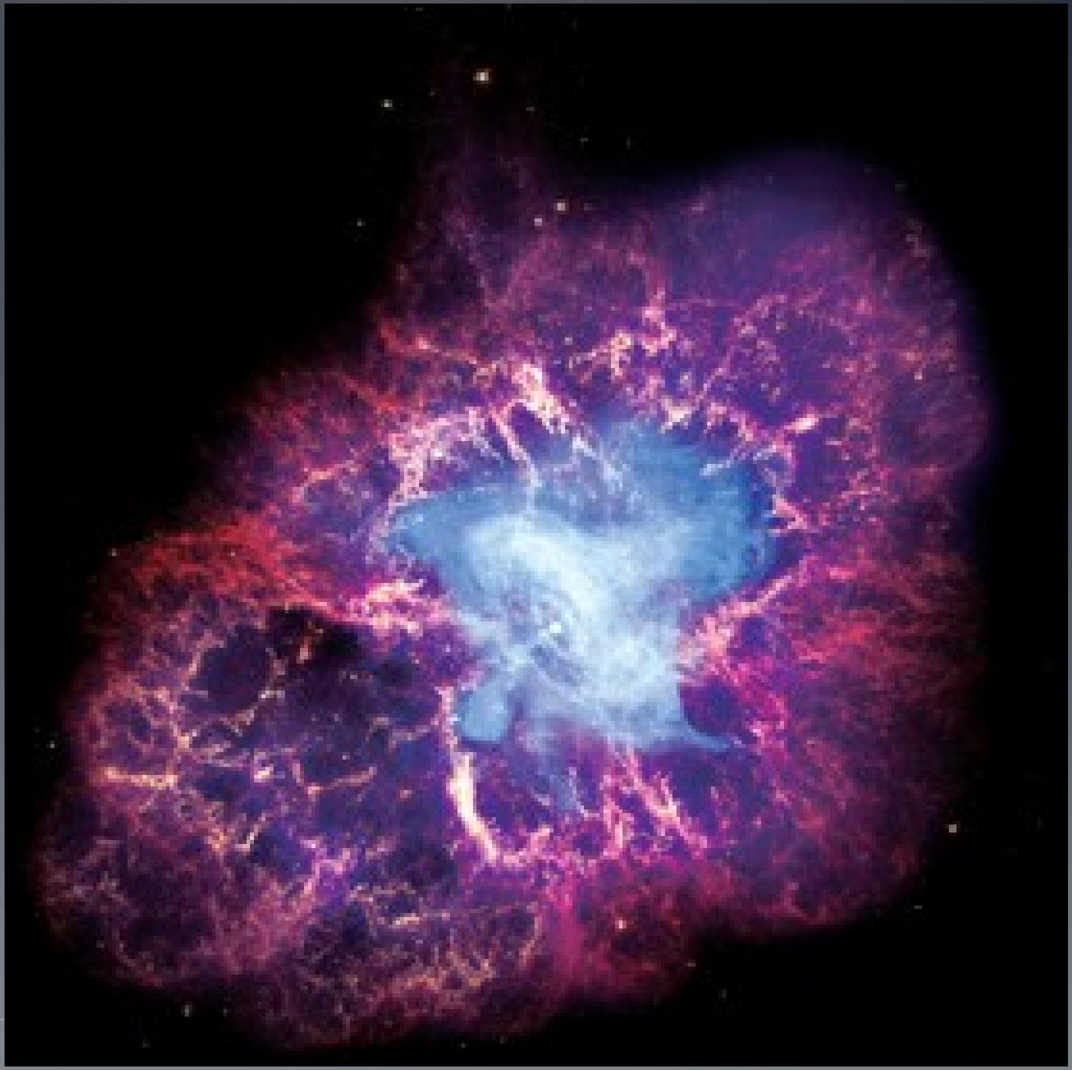
By University of California, Santa Barbara — Published: August 24, 2012



Left: Host galaxy of PTF11kx before the supernova exploded as seen from the Sloan Digital Sky Survey. Right: The blue dot is the supernova near peak brightness as seen with LCOGT's Faulkes Telescope North. The supernova is 600 million light-years away in the constellation Lynx.

A new type of supernova

If the star is really big— more than 130 solar masses—the collapse happens so fast and gathers so much inertia that even fusing oxygen can't stop it. So much energy develops in such a little space that eventually the whole thing blows up, leaving no remnant behind.



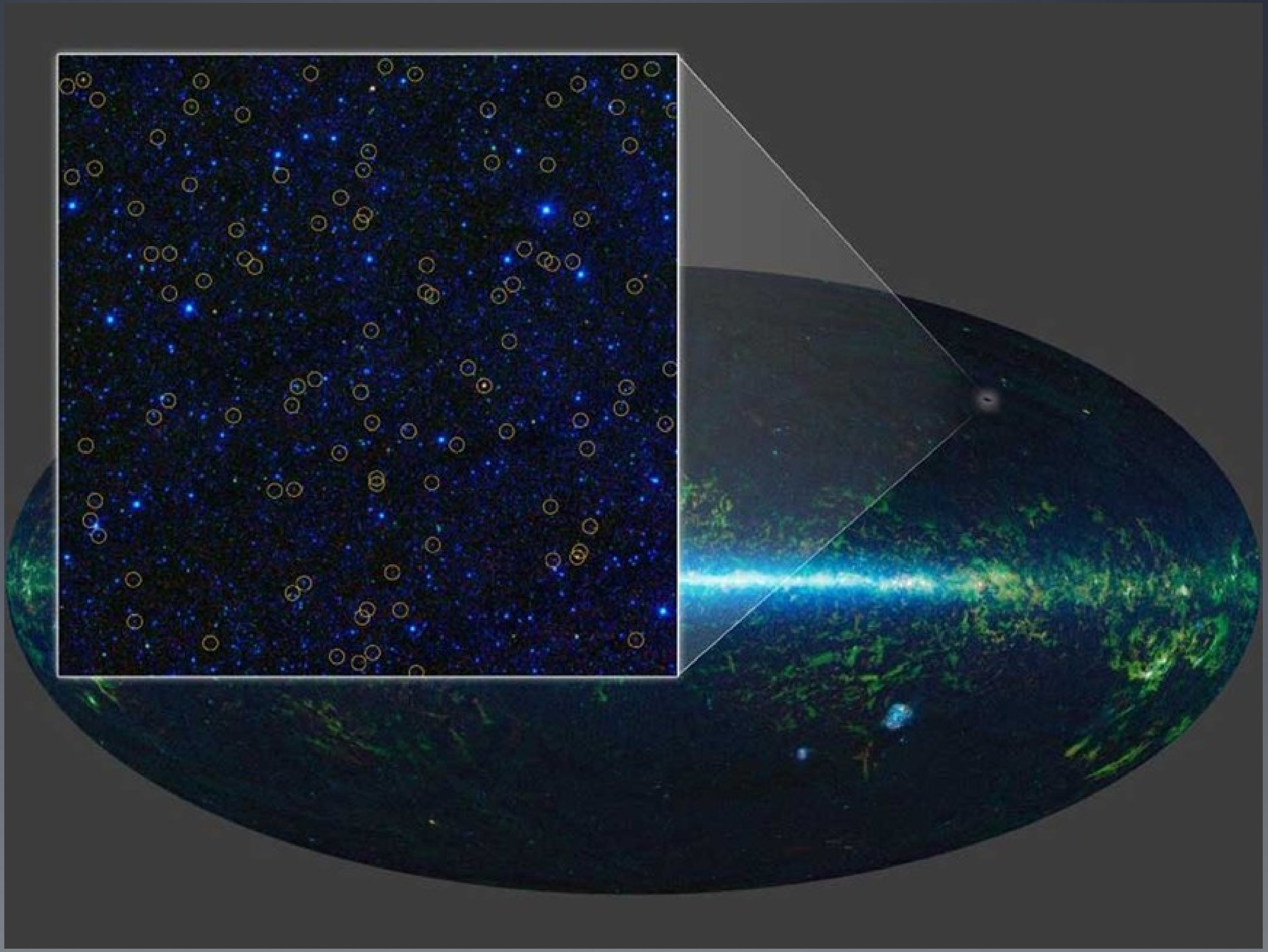
Credit: By Michael Moyer, Scientific American, Sept 2010 issue

One more thing:

WISE finds millions of Black Holes

NASA's Wide-field Infrared Survey Explorer (WISE) mission has led to a bonanza of newfound supermassive black holes and extreme galaxies called dust-obscured galaxies (hot DOGS).

Credit: *NASA Headquarters, Washington, D.C. — Published: August 30, 2012*



Summary

- Supernovae are born either from collapsing massive stars >9Ms (Type II, etc.) or accreting White Dwarfs (Type Ia)
- Supernovae Type Ia are the Standard Candle to “size” the Universe
- White Dwarfs of > 1.38 Ms collapse to Neutron Stars and produce Supernovae
- Supernovae radiates as much energy as the Sun in its entire life
  - Type Ia Supernova is 5 Billion times brighter than the sun
  - Heavy elements are formed
  - Star material ejected at 10 to 70 % c (speed of light)
  - Supernovae dim out in weeks to months
  - Our world is made of star and supernovae remnant material
- Chinese witnessed oldest documented supernova, RCW 86, in 185 A.D.

Questions