

A Study of the Nature and Representative Features of Supernova Remnants

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Abstract

Supernova Remnants (SNRs), as the name suggests are the remains of past supernova explosions. This paper outlines the existing body of knowledge at a high level - their classification, nature, structure, evolution, and the history of their observations are all outlined. The representative features of SNRs are described using known Galactic examples drawn from the standard catalogue (Green D.A. 2001). SN 1987A and its developing remnant are also considered due to their significance.

1 Introduction

The birth of a Supernova Remnant (SNR) is a spectacular event. SNRs are the remains of past supernova explosions. These occur when a star of initial mass above approximately 8 solar masses exhausts its nuclear fuel and further nuclear reactions are endothermic and require energy, or when a smaller star accretes enough material from a binary partner. The result is that the star can no longer sustain the pressure to prevent gravitational collapse. It implodes and the implosion rebounds from the core causing a violent explosion that blows the star apart. Supernovae are classified according to emission lines that are observed in the explosion as Type Ia, Ib, Ic, or II. The naming convention for supernovae is based on their light curves and came into existence before supernovae were understood. Types Ib, Ic and II are closely related (Moore D. 2001). A brief description of each type follows.

Type Ia

Exhibit no hydrogen or helium lines but show a prominent silicon (Si II) line. Believed to be caused by runaway carbon burning in a white dwarf with a binary companion, from which the required matter to cause the explosion is accreted. Other types of supernova are believed to have a single stellar progenitor. No central core is left behind in the remnant. These supernovae are important because they can be used as “standard candles” for distance determination of their host galaxy. They all are believed to reach an absolute blue (B) magnitude of around +19.7 (Branch D. and Miller D. L. 1993; *The Cosmic Distance Scale*), often temporarily matching or exceeding the brightness of the rest of the galaxy as seen from Earth. Energy release is in the order of 10^{51} ergs (10^{44} Joules).

Type Ib

Exhibit no hydrogen, but a strong helium (He I) line. The single progenitor star is thought to be a massive star (20 solar masses or greater) that has lost all of the hydrogen from its outer atmosphere and outer layers. These do not exhibit strong Si II lines.

Type Ic

Exhibit neither hydrogen nor helium lines. These are similar to type Ib supernovae except that the progenitor is thought to have lost both hydrogen and helium from its atmosphere and outer layers prior to the explosion.

Type II

Exhibit hydrogen emissions lines, indicating there is hydrogen present in the progenitor's atmospheres when the explosion occurs. These are typically around 2 orders of absolute magnitude less bright than type Ia supernovae. Type II are dividing into sub types IIP and IIL based on whether the light curve of the supernova plateaus (P) or is linear (L), but in reality a continuum between these two appears to exist (Cappellaro E. and Turatto M. 2000)



Figure 1 – A Type II Supernova – SN 1987A.

The area before the supernova, with the progenitor identified, is shown on the right. (Image Credit: David Malin, Anglo-Australian Observatory. Royal Observatory Greenwich Astronomy Information Service)

The violent supernova explosion reaches its peak brightness in between a few hours for Type II and approximately a day for Type Ia. The emission of the initial explosion fades quickly - within 100 days, the brightness will have decreased from this peak by approximately 4 magnitudes and continues to fall as radioactive isotopes created in the explosion decay. (Kaufman, W. J. III and Freedman, R. A. p. 557-560).

However, the shock wave from the supernova heats the dust and gas comprising the interstellar medium. The interaction of this energy dissipating through the interstellar medium causes heat and friction such that the material radiates at a variety of wavelengths from radio through to X-ray. The morphology and features of the resulting SNR, which is often visible for thousands of years, and temporal changes in this morphology, are both dictated by the physics of the initial explosion, and that of the surrounding interstellar material. This gives astronomers the ability to probe the remnant, despite the inherent complexity of the physics. Compared to the fleeting Supernova which will only last up to approximately one month, the remnant's developing structure may be observed for centuries or millennia, as can the interaction of the remnant with the surrounding medium and stellar neighbourhood.

The study of SNRs is vital to our understanding of the Universe due to the extreme conditions from which they originate. All elements with a higher atomic number than Iron require a supernova for their creation, and a supernova is required to create pulsars, neutron stars and black holes – the observation of which are our link between reality and the theoretical modelling of the way in which the Universe behaves at extremes and limits. The SNR is also a natural target as it is much larger target than its progenitor.

2 Historical Perspective

Nearby supernovae are relatively rare events on the timescale of human lifetimes. Table 1 lists supernova events that have been bright enough to have been noticed before the sophisticated instruments of the later half of the 20th Century were brought to bear. The most famous is probably the Crab Nebula– a particularly spectacular event that was visible in daylight for days. (Strom R.G. 1994) The Crab Nebula is visible at a variety of wavelengths including the optical almost 1000 years later, and in many ways has been the prototype for our understanding of SNRs.

Date (AD)	Name
185	MSH 14-63
386	G 11.2-03
1006	Arab supernova
1054	Crab Nebula (Taurus) supernova
1151	3C 58
1572	Tycho's supernova
1604	Kepler's supernova
1667	Casseopia A supernova

Table 1 – Historically Recorded Supernovae Explosions
(For details see Weisstein E.; Strom R.G. 1994; Moore D. 2001)

The nature of supernovae was not initially understood. They were referred to as “guest stars” and seen as omens in a variety of cultures in Asian and European countries. Approximately 231 confirmed nearby (Galactic) supernovae remnants exist, with a few dozen other heavily suspected. For a listing and summary see Green D.A. 2001. The remainder of this paper will focus on Galactic SNRs since they are the most accessible and easiest to study. The first extragalactic supernova was not observed until 1885 (SN1885A) and it is only in 1934 that Walter Baade and Fritz Zwicky first proposed Supernovae as a distinct class of objects. Baade proceeded to identify the Crab Nebula as a supernova remnant. Advances during and since the first half of the 20th Century have been given a vital theoretical basis for our understanding of supernovae and their remnants.

Over the last few decades 3 interrelated key advances in technology have made it possible to recognise, observe and study a wide variety of SNRs. These same technologies have revolutionized the whole of astronomy but it is worth mentioning their effect on SNR research. The technologies are:

- 1) Space technology - Beginning with balloons and rockets and progressing to orbital satellites have allowed for multi-frequency analysis. SNRs are often easier to detect at non-visible wavelengths. Radio waves are effective in searching for SNRs, but so too are X-Rays which are opaque to the atmosphere.
- 2) Detector technology – This has improved at all wavelengths. The study of SNRs is very much the study of detail. Detectors with improved resolution provide improved data with which to model SNRs and provide theorists with the hard facts required to construct and improve these models.

3) The computer revolution and computer modelling – The advent of the faster and more affordable machines – desktop through to supercomputer - has allowed for more complex and computationally intensive models to be built. They are ideally suited to modelling the physics of a supernova explosion, and the resulting remnant. The 1960s saw computers capable of the most basic of these calculations and the 1980s and 1990s introduced both more powerful computers and more affordable computers suited to personal use.

With this new technology available, the body of knowledge in this area will continue to improve as more relatively nearby supernovae are observed in their early stages and a record of the development of the remnant, from the earliest stages, is kept.

3 Nature and Structure

Galactic SNRs vary greatly in size, distance and structure, and in their emission characteristics. The 11000 year old Gum Nebula, 700 parsecs in diameter but only 100 parsecs distant has a large 40-60 degree angular diameter as seen from Earth. Other SNRs are completely invisible at optical wavelengths but emit strongly in X-ray or radio (Kaufman, W. J. III and Freedman, R. A. p. 560-561). Despite the complexity and extreme nature of SNRs and supernovae from which they originate, there are a number of common features among members of the small sample observed. Current classification schemes are morphological in nature.

3.1 Basic SNR Features

3.1.1 Remnant Core

Type Ia supernova leave no core behind. Types Ib, Ic and II do. The core may be a neutron star or pulsar - a fast rotating neutron star with a strong magnetic field, and jets of ejecta expelled at the poles which radiates its energy and slows down on timescales much larger than that of the remnant (An SNR may therefore be described as “pulsar driven”) - or if the mass of the core is above around 5 solar masses, a black hole. (Kaufman, W. J. III and Freedman, R. A. p. 585; Jones, T. W. et al 1998).

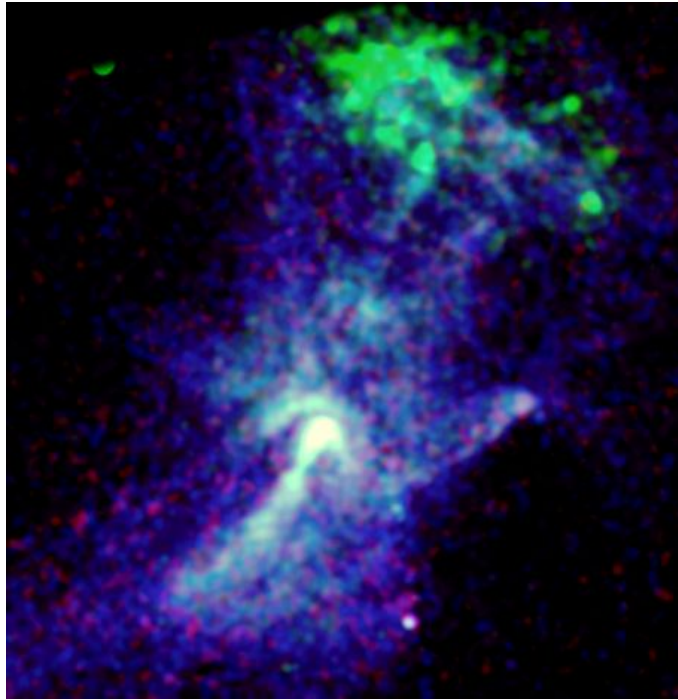


Figure 2 - X-Rays and the Circinus Pulsar

Credit: B. Gaensler et al., MIT, NASA

Taken from Astronomy Picture of the Day - <http://antwrp.gsfc.nasa.gov/apod/ap010913.html>

3.1.2 Interactions with Interstellar Medium, Shockwaves and Shells

The initial shockwave of the supernova explosion emits electromagnetic radiation as it expands, and as it collides with the interstellar medium. This material has a temperature measured in millions of degrees Kelvin, and dissipates its energy as it mixes with the interstellar medium. An uninterrupted spherical shockwave will cause a spherical shell to form. Looking along the edges of the shell there is more material at the edges, and the appearance may be of a ring. This shockwave shell may be interrupted by the core or a non-uniform interstellar medium, contributing to the resulting differences in morphology observed. Spectroscopy of the shell can indicate the velocity of the shell. If the distance to the SNR is known, its angular size and the velocity of the shell give an indicator of its age.

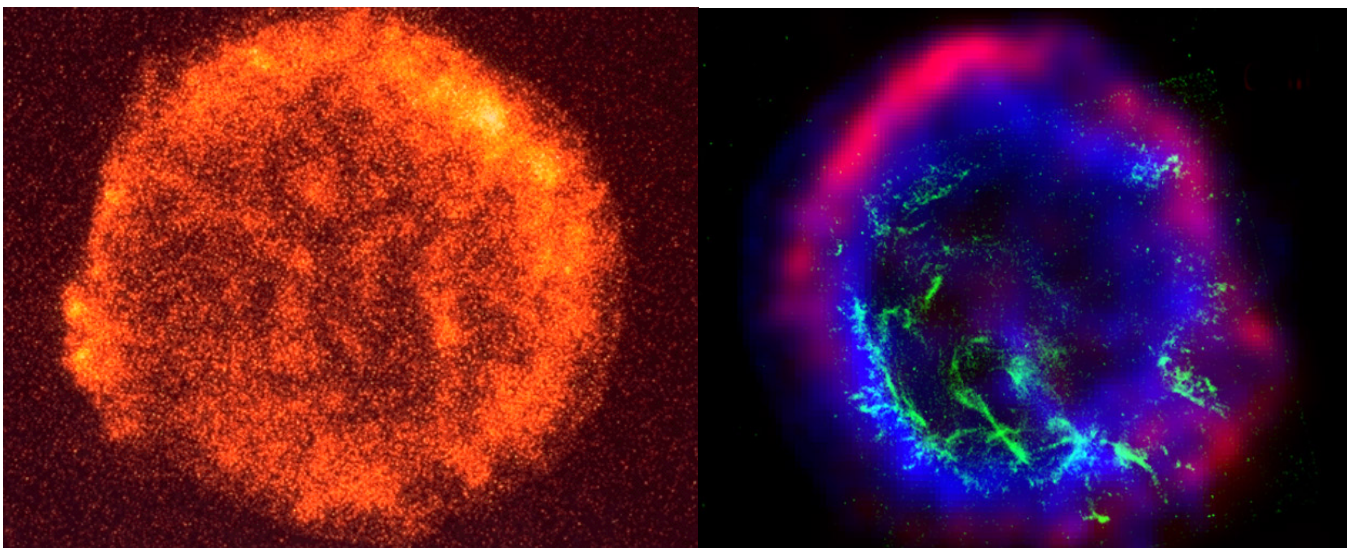


Figure 3 - Tycho's Supernova Remnant in X-ray

Credit: ROSAT, MPE, NASA

Taken from Astronomy Picture of the Day - <http://antwrp.gsfc.nasa.gov/apod/ap990307.html>

and
Supernova Remnant E0102-72 from Radio to X-Ray
Credit: X-ray (NASA/CXC/SAO); optical (NASA/HST); radio: (ATNF/ ATCA)
Taken from Astronomy Picture of the Day - <http://antwrp.gsfc.nasa.gov/apod/ap000414.html>

3.1.3 Filaments

The non-uniform nature of the interstellar medium surrounding the supernova explosion, the shockwave of the SNR, and the core if present all interact in a complex way to produce wisp like filaments of luminosity. Areas where the emission of the supernova is brighter indicating an increase in temperature, or greater density of material are referred to in the literature as hotspots.

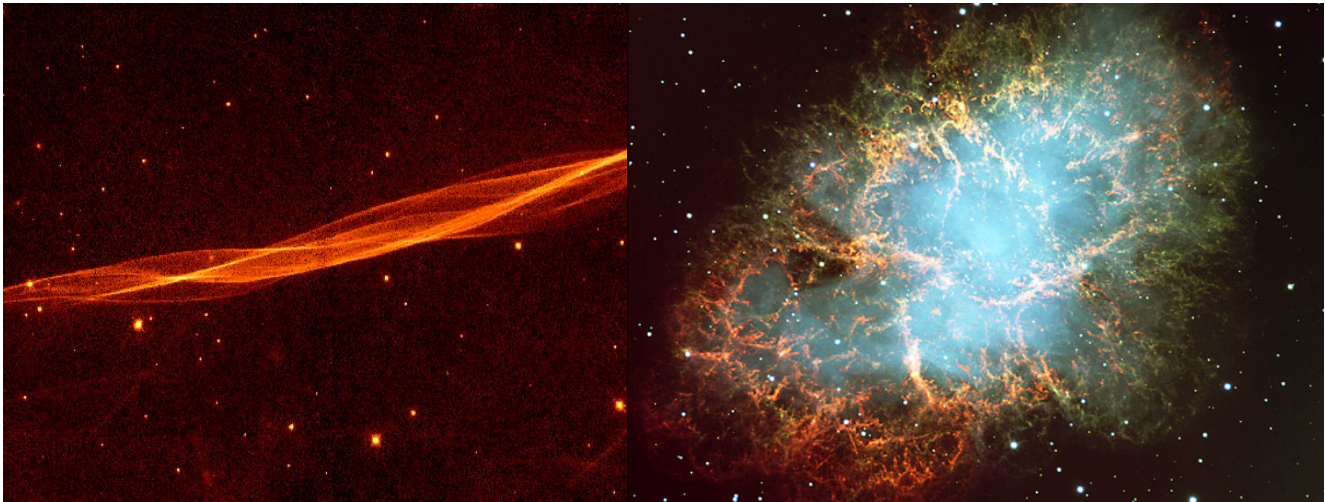


Figure 4 - Filaments In The Cygnus Loop
Credit: William P. Blair and Ravi Sankrit (Johns Hopkins University), NASA
Taken from Astronomy Picture of the Day - <http://antwrp.gsfc.nasa.gov/apod/ap000426.html>
and
The Crab Nebula from VLT
Credit: FORS Team, 8.2-meter VLT, ESO
Taken from Astronomy Picture of the Day - <http://antwrp.gsfc.nasa.gov/apod/ap020714.html>

3.2 Morphological Classification

Astronomers have adopted a morphological classification scheme for supernova remnants ie. they are classified as belonging to one of three classes based on their shape (Weiler K.W. and Panagia N. 1978; Weiler, K. W. 1983, Bhatnagar S. 2001). These are

- 1) Class S (Shell).
- 2) Class P (Plerionic), also referred to as Class F (Filled-Shell), or “Crab-Like”.
- 3) Class C (Combination or Composite)

According to Jones, T. W. et al 1998, 2 factors determine the morphology at the most basic level:

- 1) The supernova ejecta itself.
- 2) The ambient media.

Recent research indicates that it may be possible for some remnants to change morphological class throughout their lifetime (Sakhibov F.K. and Smirnov M.A. 1982).

3.2.1 Class S

More than 80% of SNRs belong to this group. They are characterized by a shell of expanding material, indicating an even heating of the interstellar medium. From earth a spherical or ring/halo like structure is seen because there is more material in our line of sight at the edges of the sphere. For this type of SNR to exist, there needs to be little or nothing to disrupt the shell in its expansion through the interstellar medium. (Weiler, K. W. 1983; Jones, T. W. et al 1998)

3.2.2 Class P/Class F

The majority of remaining SNRs belong to this group, and the Crab Nebula is the first prototype. What remains of the core of the progenitor is a Pulsar - a rotating neutron star. The rotating magnetic fields of the pulsar direct hot jets of gas outward, causing the pulsar signal and disrupting what might otherwise have been a Class S SNR. The resulting shape is distorted to be less symmetrical and instead of a shell a more “blob” like shape is observed. Additionally the same disruption may give the SNR a more “filled” shape, filaments in one or more bands, and the pulsar’s magnetic field cause polarization of the emitted light. (Weiler, K. W. 1983; Moore D. 2001)

3.2.3 Class C

This is by far the smallest group with a handful of known Galactic examples. Class C SNRs have a combination of features from Class S or Class P. These may include incomplete (eg. half) shells, partially “filled” shells, filaments, and polarization, and may or may not exhibit a central core. In a given waveband Class C SNRs may resemble one of the other two classes, while in different waveband, features may be consistent with the other. (Weiler, K. W. 1983; Moore D. 2001)

3.2.4 Irregular SNRs

SNR morphology is a largely subjective area. Whilst these morphologies are representative, it didn’t take long for others to point out that there have been SNRs discovered since the early 1980s that do not clearly belong to one of these groups. There have been attempts to fit all SNRs into one of the first two groups, and other attempts to create a new irregular class, reserved for those SNRs that are atypical. Interesting it is these “irregulars” that have provided the impetus for more complex SNR models, so that their shape might be comprehended.(Wang Z. 1998) A further complication is that SNRs do not always have the same shape or features at each of the wavelengths in which they are imaged.

The following table gives a good indication of the characteristics that typify and are used to classify SNRs based on observations at different wavelengths:

Type/Features	Optical	Radio	X-Ray
Class S	• Thermal line emitting filaments • Shell or partial shell organization of filaments • Shock wave generated	• Non-thermal emissions • Shell or partial shell form • Circumferential or tangential magnetic field • Weak linear polarization	• Thermal emissions • Both shell and filled centre forms seen • Shock wave generated
Class C	• Non-thermal emissions • Filled centre form. extended emission • Thermal line emitting	• Non-thermal emissions • Filled centre form. extended emission • Strong linear polarization	• Non-thermal emissions • Filled centre form. extended emission

	filaments • Central energy source	at high wavelength • Well organized magnetic field • Central energy source	• Compact Source Present • Central energy source
Class P/Class F	Combinations of the above classes	Combinations of the above classes	Combinations of the above classes

Table 2 - Identifying Properties of SNR Classes.
(Adapted from tables 1 and 2 of Weiler, K. W. 1983. Not all features are included here.)

3.3 Life Cycle

The classical model of Supernova evolution comprises 4 stages (Gull S.F. 1973; Moore D. 2001).

- 1) Free Expansion
- 2) Sedov or Adiabatic Phase
- 3) Snowplough or Radiative Phase
- 4) Dispersal

3.3.1 Free Expansion

Characterized by undecelerated motion of the supernova ejecta. This is because at this stage the mass of interstellar matter that has been swept up by the shock wave is much less than that of the ejecta, and the matter has not been impeded.

3.3.2 Sedov or Adiabatic Phase

The swept up material gradually increases to be much more than the ejecta. The shockwave is decelerated significantly. For the same reason, the ejecta begins to cool as it mixes with the surrounding medium. The main shell of ejecta becomes unstable and the mixing enhances the magnetic field.

3.3.3 Snowplough or Radiative Phase

Temperature of the shockwave eventually drops to 10^6K or so. Line emission and compression of the interstellar medium causes a denser “snowplough” like shockwave to form. Conservation of momentum arguments indicate the radius of the SNR at this stage is proportional to the fourth root of the time since the initial supernova explosion.

3.3.4 Dispersal

The snow plough slows to subsonic speeds and eventually the random velocities of the interstellar medium become more significant than the shockwave itself. As suggested by the name of this phase, the SNR disperses.

3.3.5 Limitations of the Classical Model

This model is largely theoretical and unfortunately there is currently evidence to suggest that the majority of supernovae do not follow this model at all. Three proposed reasons are the lack of uniformity of the interstellar medium, other interactions with pre-existing features of the SNRs surroundings, and the fact that known conditions can exist such that particular phases of the model occur simultaneously or do not occur at all.

3.4 Computer Modeling

While the variables and conditions differ between computer models of remnants, there is a great deal of commonality between all models successful in describing SNR observations. Describing these at a very high level all models consider:

- 1) The nature of supernova progenitor(s)
- 2) Details of the hydrodynamics (HD) or magneto-hydrodynamics (MHD) of the supernova explosion and shock waves including
 - a. An outer blast wave propagating into the interstellar medium
 - b. An inner (reverse) shock wave propagating back into the ejecta
 - c. Hydrodynamic instabilities

As the computing power available has increased, models have progressed from being 1 dimensional to being 2 and 3 dimensional in nature at the forefront of current research. (Jones, T. W. et al 1998) The detailed physics is beyond the scope of this paper.

4 A Sample of SNR Objects

The standard for naming Galactic SNRs is to give galactic the IAU Galactic co-ordinates of the centroid. (The name begins with a letter 'G' indicating the co-ordinates are Galactic, followed by a longitude, and a latitude eg. G205.5+0.5).

The following is a small sample of well known SNRs. Basic data is drawn from a variety of sources but the majority is summarized in Green D.A. 2001. (Also see Van Den Bergh S. et al. 1973). The exception is SN1987A which does not appear in the Galactic catalogue due to its location in the Large Magellanic Cloud, but is nonetheless well studied due to its importance. Green D.A. 2001 contains an extensive listing of literature, some of which is also an excellent source for obtaining publicly available images.

4.1 Supernova 1987A

The importance of the 1987A supernova to present day astronomy is difficult to overstate. It is the first naked eye supernova observed in 3 centuries, and the first opportunity theorists have had to study a nearby supernova, and the subsequent early development of an SNR, since our understanding of the phenomenon and the development of multi-frequency analysis. Predictions made by theoretical models over the past five or so decades could suddenly be verified against real data or reconsidered.

The supernova was discovered on Feb 24th, 1987, by Ian Shelton of the University of Toronto, while observing at the Las Campanas Observatory, Chile. Located in Large Magellanic Cloud, at a distance of approximately 170 thousand light years, the progenitor star was Sanduleak -69o 202, a blue supergiant. (Soper D.E. Unknown Date). Neutrino detectors also recorded the initial outburst.



Figure 5 – “A colour image of SN 1987A made by combining data taken through blue, green and red filters with the Wide Field Planetary Camera 2 of the Hubble Space Telescope in February and September 1994 and March 1995...Two bright stars near the outer rings have been removed using a computer model, leaving the small multi-coloured doughnut shapes.” Photo: Ben Sugerman, Steve Lawrence and Arlin Crotts (Columbia University). Taken from *First Ever 'Baby Pictures' Of Infant Supernova Remnant*

The three ringed appearance is due to the heating of gas, believed to have been shed by the progenitor approximately 20 000 years ago. The strength of the red colour is an indicator of the density of the gas impacted by the supernova shockwave. The core is clearly seen surrounded by a bright/hot region, then a cooler darker region, and another bright ring.

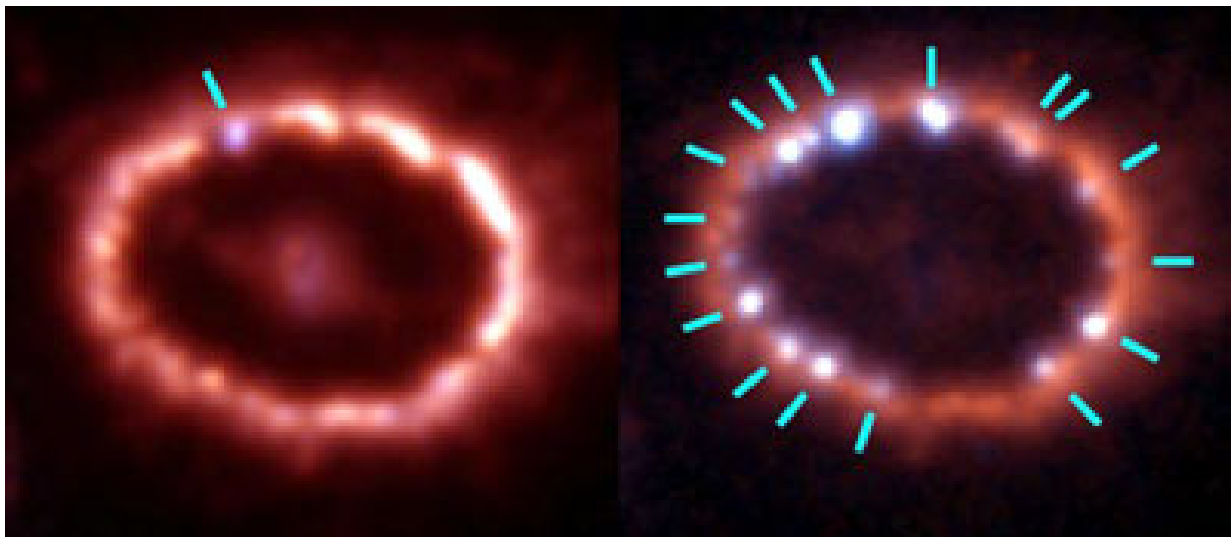


Figure 6 – “Colour images of SN 1987A made by combining data taken through narrow filters with the Wide Field Planetary Camera 2 of the Hubble Space Telescope. Taken in 1996-7 (left) and May 2002 (right), they show the growth of hot spot number from 1 to 17. Spot positions have been noted with tick marks. These narrow filters show

emission from hydrogen and nitrogen atoms. The ring is dominated by nitrogen emission, and is coloured red, while hot spots are brightest in hydrogen lines, and appear white. Both the ring and central supernova ejecta have faded over the last six years, however the image on the right has been scaled so faint hot spots are visible. In these images, north is up and east is to the left. Photo: Peter Challis (Harvard University) and the SInS collaboration.” Taken from *First Ever 'Baby Pictures' Of Infant Supernova Remnant*

1987a is considered a class S SNR. Study of its development continues to the present day, and will continue well into the future. Overall the last few years have seen the central shell start to fade but several hot-spots have developed in 1999 and 2000. (*First Ever 'Baby Pictures' Of Infant Supernova Remnant*)

4.2 Crab Nebula (G184.6-5.8)

The class P prototype, the Crab Nebula is also known as SN1054, and 3C144. It is 7 by 5 minutes of arc in angular size as seen from Earth and the centre lies at R.A. 05h34m31s, Dec +22d01m. It is approximately 2kpc distant. Strongly polarized filaments are seen in the optical part of the spectrum as is a faint jet. The filled shell is driven by central pulsar visible, along with a faint jet in the radio part of the spectrum. In the X-Ray part of the spectrum a torus is seen around the pulsar. See section 2 for details of the historical significance of this SNR.

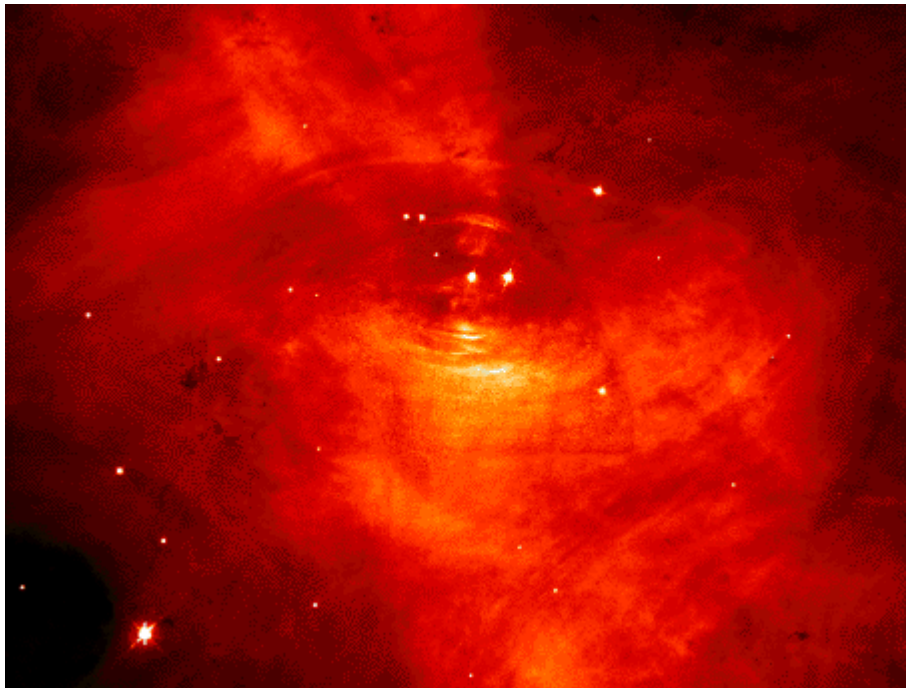


Figure 7 – Pulsar and nebulosity at the Centre of the Crab
Taken from Astronomy Picture of the Day - <http://antwrp.gsfc.nasa.gov/apod/ap960531.html>

4.3 Cassiopeia A (G111.7-2.1)

Also known as 3C461. This is a class S SNR, located at R.A. 23h23m26s Dec +58d48' and at a distance of 3.4 kpc, and its angular size is 5 minutes of arc as seen from Earth. Cas A is seen in the optical part of the spectrum as a flocculent knot with many filaments, and a prominent jet. In radio it appears as a bright shell with compact knots and in X-ray it is seen as an incomplete shell with a compact central core.



Figure 8 – Cassiopeia A – Hubble Space Telescope Image
 Taken from Astronomy Picture of the Day - <http://antwrp.gsfc.nasa.gov/apod/ap020712.html>

4.4 Vela (X,Y,Z) (G263.9-3.3)

This is a class C SNR, located at R.A. 08h34m00s Dec -45d50' at a distance of 0.25-0.3 kpc. Its angular size as seen from Earth is 255 minutes of arc. In the optical part of the spectrum, filaments are seen. In radio a large shell (Vela X) is seen. In X-ray it is a patchy shell with extensions, a central nebula and a pulsar with a one sided jet.

4.5 Puppis A (G250.4-3.4)

Also known as MSH08-44. This is a class S SNR, located at R.A. 08h22m10s Dec -43d00' and at a distance of 1.9-2.5 kpc. Its angular size as seen from Earth is 60 by 50 minutes of arc. In the optical part of the spectrum, only nebulosity and wisps are seen. In radio a shell and in X-ray a central source, possibly a pulsar.

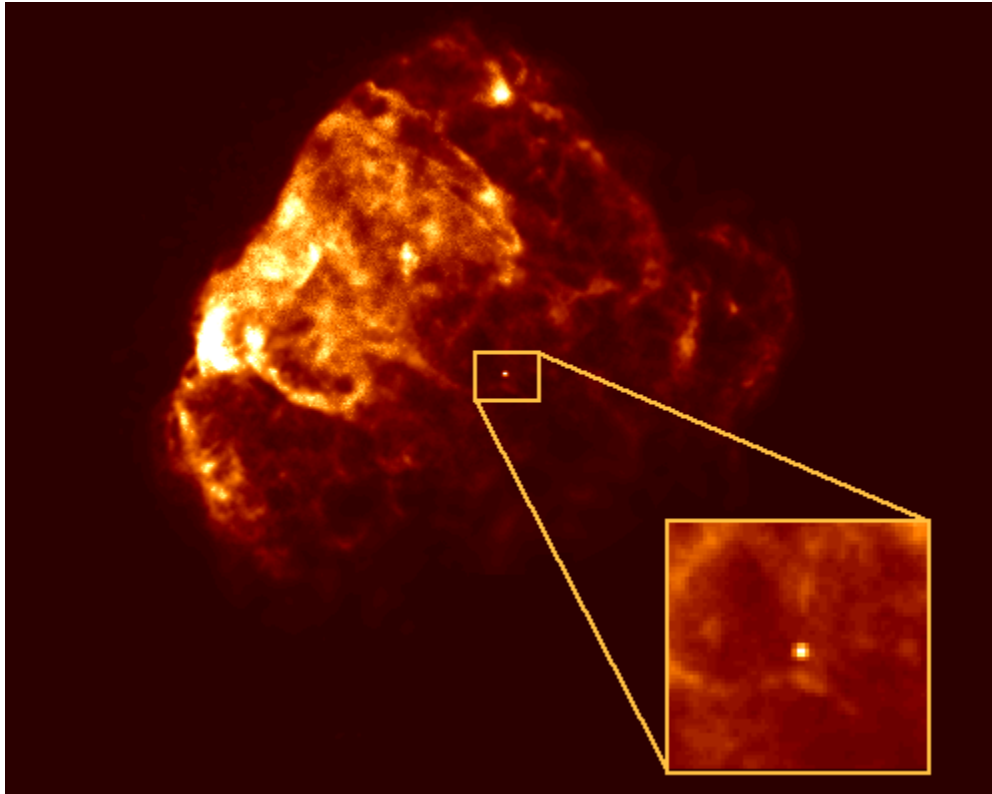


Figure 9 – Puppis A – ROSAT X-Ray Image
 Taken from Astronomy Picture of the Day - <http://antwrp.gsfc.nasa.gov/apod/ap961114.html>

4.6 The Monoceros Nebula (G205.5+0.5)

This is a class S SNR, located at R.A. 06h39m00s Dec +06d30' and at a distance of 0.8-1.6 kpc. Its angular size as seen from Earth is 220 minutes of arc. In the optical part of the spectrum, a large ring is observed. In radio a complex structure with possible HII regions is observed and in X-ray the SNR is difficult to detect.

4.7 The Cygnus Loop (G74.0-8.5)

This is a class S SNR, located at R.A. 20d51m00s Dec +30d40' and at a distance of around 0.44 kpc. Its angular size as seen from Earth is 230 by 160 minutes of arc. In the optical part of the spectrum, a large filamentary loop, well defined in one hemisphere, and less defined in the other is seen. In radio it is similar to the optical but with a breakout region. In soft X-ray it is seen as a shell. See figure 4 for a photograph of one of the filaments.

4.8 Kepler's SNR (G4.5+6.8)

Also known as SNR 1604. This is a class S SNR, located at R.A. 17h30m42s Dec -21d29' and at a distance of 2.9-6.4 kpc. Its angular size as seen from Earth is 3 minutes of arc. In the optical part of the spectrum, faint filaments are seen. In radio an incomplete shell brighter in one hemisphere than the other is seen. In X-ray a shell is also seen with one hemisphere brighter than the other.

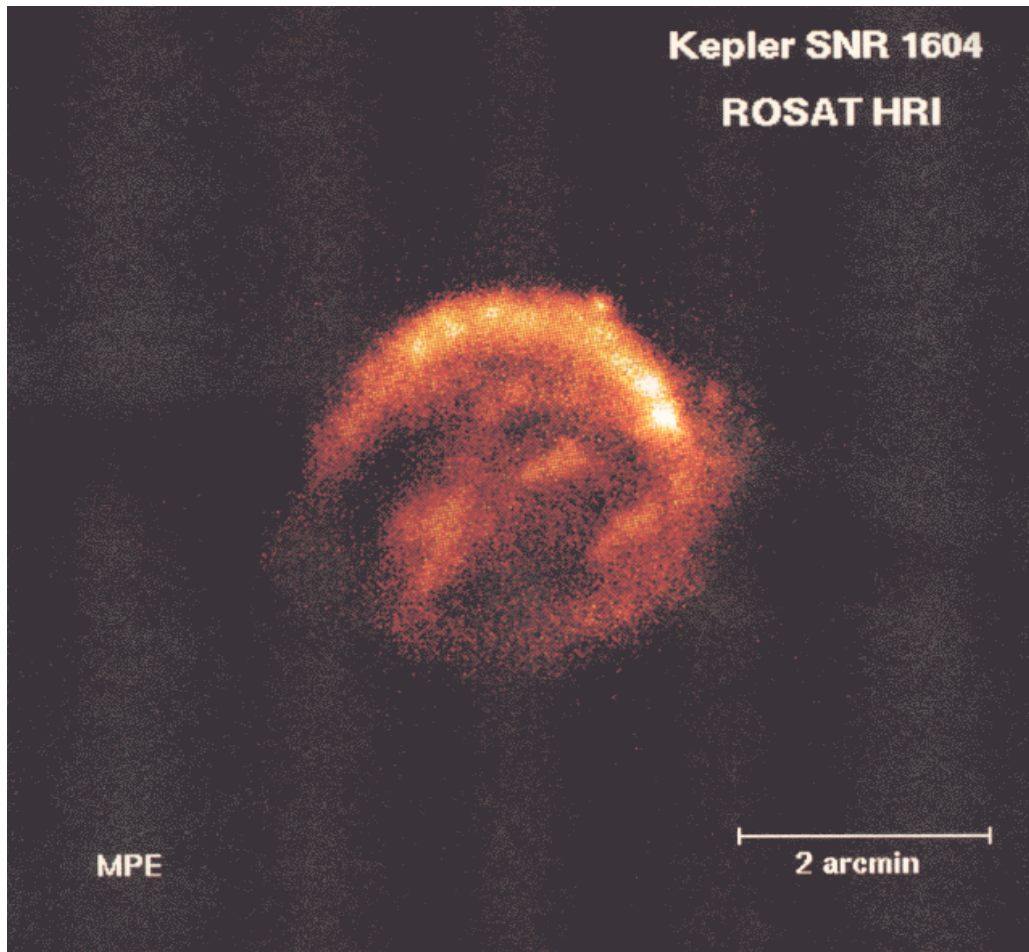


Figure 10 - ROSAT X-Ray Image of Kepler's SNR
 Taken from the ROSAT gallery at MPE. <http://wave.xray.mpe.mpg.de/rosat/calendar/1996/feb>

4.9 The Lupus Loop (G330.0+15.0)

This is a class S SNR, located at R.A. 15h10m00s Dec -40d00'. Its angular size as seen from Earth is around 180 degrees. In the optical part of the spectrum, it is not visible. In radio it is a HI shell with a loop of low brightness. In X-ray it is only faintly detected.

4.10 Tycho's SNR (G120.1+1.4)

Also known as 3C10 and SN1572. This is a class S SNR, located at R.A. 00h25m18s Dec +64d09' and at a distance of 2-5 kpc. Its angular size as seen from Earth is 8 minutes of arc. In the optical part of the spectrum, faint filaments and knots are observed. In radio it is a shell of uneven brightness. In X-ray a shell, coincident with the radio shell is observed. See figure 3 for an image.

5 Conclusion

This paper has presented a very brief outline of a growing field of astronomical research. Supernovae, while short lived compared to a human lifetime, produce long lived remnants which grow, evolve and eventually disperse. They provide a unique opportunity to verify theoretical models of the physics of stellar material under extreme conditions. Supernovae are the process by which all elements above Iron are created in our universe. Furthermore the complexity and intricacy of the remnants, and the diversity of their form, have captured the human imagination. We are in the early stages of understanding these objects. In less than a century, the basic nature of SNRs has come to be understood, we have developed the equipment to observe and record their evolution, made attempts to classify them, and built computer

models that are increasingly complex and successful at emulating observed behaviour. As the record of the development of specific examples develops, our understanding and fascination will only increase.

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<http://www.talkorigins.org/faqs/supernova/>
(*note that this FAQ was written to refute, not support, an extremist viewpoint, and references mainstream literature. From the FAQ: "This FAQ is written with the dual intention of both providing a general introduction to supernovae and supernova remnants, and addressing the YEC claims")

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