Some Recent Progress on the Studies of Supernova Remnants

Jian-Wen Xu

Key Laboratory of Frontiers in Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100080, China

xjw@itp.ac.cn

ABSTRACT

We briefly reviewed some recent progress on the studies of supernova remnants (SNRs), including the radio SNRs (the structure, polarization, spectrum etc.), observational characteristics of X-ray emission, pulsar wind nebulae (PWNe), association properties between SNR and PSR, interaction of SNR and interstellar medium (ISM), cosmos ray and the SNRs in external galaxies, etc.. Correspondingly to the continue improvement of space and spectrum resolution of the on-ground and in-space astronomical equipments at wavelengths as radio, optical, X-ray and so on, we know about SNRs more and deeper.

Subject headings: ISM: supernova remnants – radio continuum: ISM – cosmos ray

1. Introduction

SNRs are obviously the most bright radio source detected. The firstly confirmed remnant reported by Bolton et al. (1949), i.e. the Crab nebula connected with Taurus A. Thereafter more SNRs are detected and studied at radio wavelength, and extensively analyzed recently because of the observation at X-ray (review, Bernd & Aschenbach, 2002). SNRs have an important influences on the properties of interstellar medium, to some great extent the evolution of the host galaxy. They enhanced the abundant of heavy elements in ISM. Their blast waves change and heat ISM, compress the ISM magnetic field. Their shock waves effectively accelerate the high energy cosmos rays, and so on. In Milk Way the confirmed SNRs numbers have surpassed 270. Combining the observational radio data and X-ray once can help to the establishment of the SNR model.

In general, shell-type supernova remnants evolve through four stages: free-expansion phase, Sedov-phase, radiative-phase (or snow-plough phase) and dispersion-phase. The SNRs age at first stage is less than 200 years, their linear diameter is less than 1.3 pc. A major of the detected SNRs are at adiabatic phase. SNRs at first-phase or at fourth-phase are almost undetectable.

Researches to the remnants evolution in uniform ISM have already been fruitful. SNRs evolution in stable stellar wind (with density $\rho \propto r^{-2}$) has also been a studied topic. Chevalier & Liang (1989) analyzed the evolution in the bubble blown by circumstellar wind. Numerical researches have been completed by Tenorio-Tagle et al. (1991) and Franco et al. (1991). In the recent few years, the numerical model about SNRs structure and evolution have reach an unprecedented refinements. However, the analyzed model is still play an important role when needing study the general properties of supernova remnants, and needing to obtain the direct connections between the purely observational parameters (for example, the sizes, fluxes etc.) and the intrinsic physical parameters.

Two useful SNRs catalogues could been found by internet. The first one is the catalog of 275 SNRs edited through the literatures and materials until the December, 2009 by David Green [http://www.mrao.cam.ac.uk/surveys/snr], including the radio fluxes, spectrum and conferences etc.. Another useful one of the SNRs database store was provided by Sergei Trushkin

---

1Postdoctor, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100080, China.
It also includes the observational information at optical, red-infrared and X-ray wavelengths. Only limited numbers of SNRs are detected at optical, red-infrared and X-ray. We have detected more SNRs since the improvement of the observational sensitivity, in particular the ROSAT all-sky surveys based on X-ray we detected a great deals of the SNRs candidates (Busser, 1996). Therefore, the currently only 30% per cent rate of the SNRs at X-ray will increase following this, in spite of the confinements induced by its short calculation time, relatively soft energy spectrum and the remarkable absorbed efficiency to the distant objects on Galactic plane. However, in many cases, thereafter radio observations could confirm the supernova (SN) origin of the SNRs candidates discovered by ROSAT survey (Schaudel et al. 2002). The data in SNRs catalogs ether come from special researches, or from the continue radio sky survey. How about the completeness of the detected data? According to the statistics, there should be 40 SN events in Milky Way in recent 2000 years, but only 8 events had been observed. Tow predicted most highly energy SNRs, i.e. the most bright radio sources are Cas A and Crab nebula, born separately in C.D. 1680 and 1054. At present the sensibility at radio sky survey is good enough to detect the SN burst sources under the typical interstellar circumstances in the whole Galaxy. But there has still been the problem that one can not distinguish the SN origin SNR or the one not.

The history to study SNRs has surpassed half century. Wojtjer (1972) and Mills (1974) etc. had reviewed the research situation of the Supernova remnants in detail. We briefly introduce some recent progress in the studies of the SNRs based on the literatures after the year 1990.

2. **Radio supernova remnants**

2.1. **Radio SNRs — structure**

In general, the radio SNRs can be classified as 3 types: shell-type (S-type), plerion-type (P-type) and composite-type (C-type). The S-type remnants usually exist in uniform ambient medium, the majority of the detected SNRs belong to this sort. C-type remnants composed of a plerion component surrounding a shell outside. The plerion remnants are irregular in form, and seldom be observed in Galaxy.

SNRs are the nebulae origin from the massive stars outburst. The released total energy is usually about $10^{53}$ ergs. Most of its energy are carried away by neutrino. The neutrino origin at the degeneracy debris (neutron star) forming stage after collapsing of a protostar. Small part of the energy (about 1 per cent) lead to blast waves. The waves sweep up the outer layer of the star, and producing violent shock waves traveling through the ambient medium. The details of the expanding process depend on a group of different physical parameters — the total mass and energy of the ejections, the distribution density and property in surrounding medium (Dwarkadas & Chevalier 1998; Featherstone et al. 2001; Blondin et al. 1996), and the energy loss rate of decreases of the neutron star rotation and the velocity of proper motion (Chatterjee & Cordes 2002; Frail et al. 1994). Therefore in principe we can foresee the structure variety in the pulsar wind nebulae (PWN)-SNR system.

In general, the supernova remnants take on a spherical form, but in fact there is always a deviation from that form. The deviation extent will be bigger when the SNR shock waves pushing upon a dense nebula (Levenson, Granham & Walters 2003). Larger deviation means bigger density of the ISM. The shock waves formed in the stellar nebula generally emit radiations, inducing the cooling of the shock waves gas. Most of the energies are vanished by the radiative transformation. The large deviation of the spherical form could be caused by the gas blow-out when the shock waves collide with a block of dense molecular clouds.

Some SNRs show fill-center structure, a typical example is the Crab nebula, but we also currently discover other similar SNRs. They are called Plerions, or Crab-like SNRs. They are so called Plerionnot only because of their forms, but also their other properties, i.e. flat power law spectrum at radio wavelength, the spectra index ranging from 0.0 to 0.3; highly radio polarization, owning neatly form, but not all the plerions show such: the power law spectrum at X-ray, the energy spectrum index is near about $-2$ (Asaoka & Koyama 1990); A detected PSR associated with it (some plerions have no PSR).

Although we do not know much in very details about the properties and structure of the plerions, but the followings are well-known: pleron is
a bubble in expanding, mainly composed of the magnetic field and relativistic electrons, the detected synchrotron radiations come from this two components; in order to explain the typical synchrotron emissions and the higher frequency radiations, one introduces continue magnetic fluxes and relativistic electrons. At the high frequency radiations, the life time of the synchrotron particles is obviously shorter than the SNR evolution ages.

Regarding a simple approximation, we suppose that in the plerions bubble the magnetic field and particles distribution is uniform: it is usually enough to explain the whole spectrum evolution of the nebula. However, the uniform suppose seems to be not correct. The newly born particles released from the associated pulsar, justly located near the terminal shock waves of the PWN. Therefore the uniform degree relies on the validity of the propagating particles among the remnant.

Furthermore, the magnetic field structure may be very complicated. Regarding from the magnetohydrodynamics (MHD), the spherical model is not enough to interpret the magnetic field structure: it probably have the cylindrical symmetry (Begelman & Li 1992), but more complex structure type is detected. Important information of the plerion structure can be gotten by comparison of the high resolution images at different wavelengths, and also provide the clue which ruled the process of the magnetic field evolution and particles distribution.

2.2. Radio SNRs — polarization

Usually SNRs own linear polarization about 10%-20%. Therefore the linear polarization exits or not is another useful criterion about weather a source is a SNR or not.

Soon after detecting the linear polarization from the radio object sources, we easily discover that the whole galactic disc is an important source of the polarization emissions (Seeger & Westerhout 1961). This sort of radiations have at least two components (Duncan et al. 1997a) — a polarized emission coming from discrete remnants, and another more discrete background polarization radiation. The later produced from the interactions between the relativistic electrons in ISM and the Galactic magnetic field.

The electron synchrotron emissions in the uniform magnetic field own highly orientation. Therefore they should be linear polarization (Moffett & Reynolds 1994). In the ideal case, the magnetic field location can be determined by the polarized position angle. Here we assumed the vacuum magnetic field is a regular one. We now have already known that the comparatively younger SNRs owning relatively larger depolarization affection, which is caused by the irregular arrangement of the magnetic field of the source itself (Moffett & Reynolds 1994a, b).

The polarization degree is an important physical parameter on the supernova remnants, because it is an indicator about the magnetic field regularity. For uniformly distributed magnetic field, the synchrotron polarization degree (P) directly connected with the spectrum index (α) and do not relied on its frequency: \( P = (3 - 3\alpha)/(5 - 3\alpha) \).

2.3. Radio SNRs — spectrum

In Galaxy the SNRs calculated radio continue spectrum from meter wavelength to centimeter wavelength or more shorter wavelength usually takes on a power law. The spectrum index scope is \( \alpha \approx -0.5 (S \propto \nu^{\alpha}) \) for shell-type remnants, and \( \alpha \approx -0.1 \), and also many mixed radio radiations with middle spectrum value. However, at the frequency lower than 100 MHz, Lacey et al. (2001) point out that about two third of the SNRs show broken-spectrum, denotes the thermal absorption. The continuum optical depth and spectrum broken has no connection with the very uncertain remnants distance. All these above do not support the point of view that the absorption comes from the spherically distributed thermally ionized medium (with number density \( n \sim 0.1 \text{ cm}^{-3} \)). The instead view is that the absorption must come from the local ionized zones with comparatively larger density \( (n \geq 1 \text{ cm}^{-3}) \), but the zones size is still unknowable, the filled factor very small \((\leq 1\%)\). Therefore the reasonable interpretation should be that the absorption material is the extended HII areas (EHEs), the ionized gas surrounded by a normal HII region, just as the result derived through observational comparison between the centimeter waves and meter waves radio recombined lines (RRL). The absorption also may be induced by the superimposed materials of many small normal HII areas or planetary nebulae.
Among the SNRs basic physical parameters—the distance to the observer, linear diameter, Height to the Galactic disc, evolved age, luminosity, fluxes density and radio spectrum index, etc. the most important and significant one is the spectrum index. The remnants radio spectrum takes on the power law which indicate that the SNRs radiation process is not the thermal emissions but the synchrotron one. This is very important in the SNRs physics.

3. X-ray radiations

Supernova remnant is a protagonist among the interstellar materials. They eject high energy substances and emit cosmos rays. Because the SNR shock waves velocity reaches the scope of hundreds and thousands of kilometers per minute, the gas is heated to the high temperature of some millions degree. Therefore the majority of emissions is at X-ray. X-ray observations become the best method to study the gas mass.

In 1999 new generation of X-ray telescopes (Chandra & XMM-Newton) had been launched, providing good space and spectral resolution for the first time, which make it possible to plot the emission line spectrum of the heavy mental elements. Among the young SNRs, this could give a clue to the nuclear synthesize of the SNR protostar, make a theoretical estimates of their main elements absolute contents and the distribution of their radius and azimuth angles.

With its angle resolution of arc-second, Chandra could make clear about the radial movement of gas shock waves of the young remnants. The radial distribution profile of the matter densities and temperature at the interval space of the traveling shock waves and reflection shock waves, is directly corrected with the distribution of matter densities and temperature after the SNe outburst.

The foresee products of a supernova outburst from the nucleus collapse of a massive star includes a shock waves expanding to the interstellar or circum-stellar medium, expanding post-shockwave metal-rich ejector from the protostar, and relic from the star nucleus collapse (usually a rapid-rotated magnetic neutron star). These relics show a bright shell with radio emissions (being out-moving shock waves) and the hot shockwave gas inside the shell, protostar ejector emitting thermal X-ray, a short-period radio/X-ray/γ-ray pulsar and a central bright nebula, which formed by the relativistic out-flow particles of a pulsar and pushing outside. Until now more than 1300 pulsars in Galaxy have been detected (Manchester et al. 2002), more than 230 radio SNRs (among them more than 80 SNRs emitting X-rays), and about 24 pulsar wind nebulae (PWNe, Kaspi & Helfand 2002).

Recently the observational images higher than 3.5 keV leads to the discovery of the X-ray synchrotron emission nebulae in the remnant.

The X-ray observations of the Crab-like and composite-type SNRs provide important information of the less-known original distribution of the pulsar magnetic field, rotational period and ages, supernova remnants dynamics etc..

The Crab Nebula plays an important role for us to know the pulsar wind nebula. The basic X-ray observational characteristics is a pulsar at center, an ellipse ring and two out-flow ejectors but without shell around. The X-ray ring is the post-shockwave equatorial wind coming from the central pulsar (Weisskopf et al. 2000), and the out-flowers come from the pulsar two rotational polar regions (Aschenbach 1992). Observational characters and its models let us know more about the high energy and geometry properties of the PWNe and the physics of extra-relativistic shock waves and particle acceleration.

However, the Crab morphologic is rather unique. We have not discovered any other SNRs owning all of the X-ray basic observational characters like the Crab nebula until now (Gaensler 2001). The PWNe around Vela pulsar and PSRB1509-58 have X-ray arcs, but these arcs are not the complete once like the Crab, and both them located in the diffuse and bright hot ejector (Helfand et al. 2001; Gaensler et al. 2002).

Through the X-ray spectrum analysis we know that the central component emissions of a majority of the composite-type SNRs is the thermal radiation. Therefore White & Long (1991) figured out a physical model showing that the SNRs character is the X-ray thermal emission with a peaked center, which caused by the vaporized cloud after the remnants blast waves travel through. This model had been applied to some SNRs, although debates still be there about it is true or not.
More and more Galactic SNRs revealed the non-thermal emissions at X-ray. The non-thermal emission do not connect with a pulsar. These emissions could occupy the most or entire remnants, such as follow: SN1006 (Dyer et al. 2001), G266.2–1.2 (RXJ0852.0–4622; Slane et al. 2001), G347.3–0.5 (Slane et al. 1999; Uchiyama et al. 2003) and AXJ1843.8–0352 (Ueno et al. 2003). In the sensitive range of RXTE PCA hard X-rays (until 60 keV), the thermal emissions of some SNRs (Cas A, Kepler, Tycho, SN1006 and RCW86) were detected. A majority of the cases among these examples confirmed that the X-ray non-thermal emissions are synchrotron radiations.

SNRs are the sources which the high cosmos rays most likely come from. Its evidence is that we detected the X-ray synchrotron emissions from some SNRs shell (Koyama et al. 1995, 1997; Slane et al. 2001), and detected the TeV energy rank γ-rays from some SNRs (Tanigori et al. 1998; Muraishi et al. 2000; Enomoto et al. 2002). Electrons are accelerated to high energy about 1 TeV or higher, the acceleration mechanism possibly is one order Fermi-acceleration. Because the energy enhanced rate of the accelerating electrons is proportion to the magnetic field $B$, but the energy loss rate of synchrotron radiations is proportion to $B^2$, the high energy electrons producing the X-ray synchrotron emissions most likely exit in the SNRs shell with weak magnetic field, where the radio fluxes are very low (radio fluxes are proportion to $B^2$).

4. Pulsar wind nebulae (PWNe)

When the pulsar relativistic wind of a pulsar is constrained, a synchrotron pulsar wind nebula (PWN) is formed. Because the life time of the synchrotron high energy electrons are very short, we could directly trace the pulsar energy fluxes from the X-ray emissions of a PWN. Therefore, from the spectrum and morphological characters of a X-ray PWN we could reveal the PWN structure and chemistry buildup, even extrapolate the direction of the pulsar self-rotated axis or the velocity vector. For the PWN which the associated pulsar is not detected, only through observations to the PWN radiations we can peek into the position and energy of the source interior.

There was such a PWN just at the center of the SNR G0.9+0.1 without detected pulsar inside. This PWN firstly confirmed at radio wavelength, but recently it is also detected at X-ray by BeppoSAX (Mereghetti et al. 1998; Sidoli et al. 2000). On these observations the X-ray emissions show the power-law spectra with its energy spectral index of $\Gamma = 2.0 \pm 0.3$ (Here $N \propto E^{-\Gamma}$), the fluxes at $2 - 10$ keV of $f_x = 6.6^{+1.3}_{-0.8} \times 10^{-12}$ ergs s$^{-1}$ cm$^{-2}$.

The most well-known PWN driving by the pulsar is the Crab nebula. Observations by long terms show that the Crab is very different with a majority of other SNRs. It is compounds of a synchrotron nebula and an associated pulsar, but without any shell around outside.

5. Association of SNRs and PSRs

We all know that both the SNRs and PSRs are formed from the supernova outburst. However, the events both them associated are very seldom. Such events could provide very important information of both connection and interaction. In particular, for the case that the associated pulsar is still inside the remnant, the high pressure could constrain the pulsar relativistic wind. This leads to the synchrotron emission, and a detectable PWN is formed.

In nearly 15 years, we know that only two SNRs, the Crab Nebula and the Vela remnant, are associated with the pulsar. The third SNR-PSR associated example only was found out after the detection of a X-ray, γ-ray and radio pulsar, PSR B1509–58, with 150 millisecond period inside SNR G320.4–1.2 (MSH 15–52). The PSR rotation parameters were used to estimate the characteristic age of the associated SNR of $\tau_c = 1700$ yr.

In the past years, the SNRs and PSRs associated examples have enhanced to near 30, as the result of following series of new detected methods -- search survey for the young PSRs at high frequency, the mutual correlation of SNR catalogue and PSR atlas, intensively search for the PSRs or SNRs around the SNRs or PSRs (Lorimer et al. 1999).

Association of SNRs and PSRs make it possible to measure some physical parameters of both. But it is not so when both them separately exit. Because we assume the PSR born at the remnant center, combining the PSR characteristic age and
the deviation of the PSR from the SNR, one could estimate the transverse velocity of the pulsar (Frail et al. 1994). Measure the direction of the proper motion of this pulsar could confirm or exclude the pulsar associated with SNR or not, the proper motion extent could independently fix the PSR age (Gaensler et al. 2000).

6. Interaction between SNR and ISM

The interactions between the remnants shock waves and the stellar clouds is a basic topics on interstellar gas dynamics which plays an important role in studying the ISM evolution. The main physical problems include following some: 1) How much are there the mass rate and total mass of the nebula swept-up by shock waves? 2) How much are there the moments transformed to the nebula? 3) How about the outlooks of the nebula disturbed by shock waves? How about its morphological and velocity distribution? 4) What role is played to the nebula evolution by the element of vortex dynamics? 5) Could the interactions with ISM lead to the new generation stars formation? Highly none-linear interaction studies could not solve these problems, numerical methods are needed to multi-dimensionally and in details to study the shock wave nebula dynamics. Klein et al. (1994) make use of the later method discovering that the gas clouds could been destroyed by series of gas instabilities disturbed by the shock waves. Recently, Levenson et al. (1997) observed the Cygnus Loop remnant in details making use of the ROSAT high resolution imager (HRI). In Cygnus Loop the interactions between the ISM and shock waves play an important role, and providing important observational evidences for the key role played on the remnants morphological by the ISM non-uniformity.

Supernova remnants are regarded as the energy sources of the local ISM dynamics, forcing the gas constantly move on and returning the dense clouds material to the more dispersion interstellar medium or galactic halo. The violent shock waves traveling among the interstellar clouds compress and heat interstellar materials, change their chemistry components and induce the star formation. Although we foresee the tightly association of the II type SNe and clouds, we currently know only a few examples of the supernovae and clouds interaction. At the molecular clouds edge or nearby, the blast waves would quickly pass through the thin regions of the mass medium and push the slowed shock waves into the denser medium mass. For the SNRs inside dense matter, the infrared rays are in particular useful diagnose tool, because the infrared rays fine structure were born from the dense gas behind the shock waves with radiations. It also could track and measure all the abundances of the ground-state elements.

Magnetic field can buffer the action of the shock waves to the clouds. In the case without magnetic field, the SN blast waves could heat, compress and decompose or even totally destroy the clouds at last (Klein et al. 1994). But the intervening magnetic field could deduce this effects, limit the compression, enhance the stability and the gas cloud remains there, and even induce the formation of a new generation stars (Miesch & Zweibel 1994; Mac Low et al. 1994).

Making use of the OH molecular emission line at 1720.53 MHz, Brogan et al. (2000) explored the interactions between SNR and molecular clouds. We have already detected the OH maser of about 20 SNRs which occupy about 10% of the total known SNRs (Koralesky et al. 1998). This sort of maser lines are produced through the collision with $H_2 (n \sim 10^4 \text{ cm}^{-3}, T \sim 80 \text{ K})$ behind the shock waves of composite-type SNR. Only by the side of the shock wave fronts one can detect the strong maser lines, this constrain our judgement to the shock waves geometry. These describes on observation support the OH-(1720 MHz)-excite-theory-model (Lockett et al. 1999; Wardle et al. 1999; Wardle 1999).

The Crab Nebula, 3C58 and other plerions are without any rapidly ejecting shell or conora. This is possibly because that they located inside a low density ambient medium and can not form the detectable shock waves. The HI bubble surrounding some plerions are the evidence supporting this assumption (Wallace et al. 1994). But the outcome of SNR G21.5−0.9 is still shown uncertain.

7. SNRs and cosmos rays

SNRs are regarded as the first candidates of the cosmos ray accelerators. They are able to enhance the cosmos rays to the energy valve point ($E \approx 3000 \text{ TeV}$). Although the relation between
the SNRs and cosmos rays have been extensively concerned (Jones & Ellison 1991; Malkov & Drury 2001), a majority of them are limited on the theoretical studies, only in minor cases the observational data are considered. One of the important unsolved issues concerning with the SNRs accelerating cosmos rays is that how much the highest energy values \( E_{\text{cut off}} \) can the cosmos rays particles be accelerated by the remnant shock waves fronts. For the young shell-type SNRs in Milk Way and Large Magellanic Cloud (LMC) the highest energy values of the accelerated cosmos rays electrons \( E_{\text{cut off}} \leq 200 \, \text{TeV} \) (Reynolds & Keohane 1999) and \( E_{\text{cut off}} \leq 80 \, \text{TeV} \) (Hendrick & Reynolds 2001), both them are greatly lower than the valve point of the cosmos rays energy spectra. The angle resolution and spectrum resolution shortages of the remnants X-ray observations limited the progress on the acceleration processes researches.

However, since the launches recently of the X-ray astronomical satellites such as ROSAT, ASCA, Chandra and XMM etc., there are very high resolutions on the SNRs observations at X-ray energy scope. These high resolution observations are useful for the high space resolution spectrum studies of the X-ray emissions from SNRs, especially for the investigates and studies on the edge areas of bright luminosity emissions corrected with the SNRs expanding shock wave fronts. At the shock wave fronts the interstellar or circum-stellar media are swept up, where one could explore the cosmos rays acceleration process by the details spectrum analysis to the X-ray emissions from the SNRs edge regions. Most original works make use of the ROSAT, ASCA and RXTE observations to study the high energy X-ray radiation from Cas A and SN1006 (Willingale et al. 1996; Allen et al. 1997; Keohane 1998; Dyer et al. 2001; Allen & Gotthelf 2001). For more, to study the SNRs at more complete wavelengths is needed in order to understand the cosmos rays acceleration process in details.

In fact, only recently the \( \gamma \)-ray-image-telescope based on the ground directly provides the evidence that the TeV high energy relativistic particles (most probably the electrons) exit among the shock waves of 3 shell-type SNRs: SN1006 (Tanimori et al. 1998), Cas A (Aharonian et al. 2001) and RXJ1713.7−3946 (namely G347.3−0.5; Muraiishi et al 2000). Although the former reports (Aharonian & Atoyan 1999; Combi et al. 2001) ponder that the detected \( \gamma \)-rays at the SNR direction are possibly because of the baryon interactions, but this can not exclude that the detected radiations come from the high energy electrons or the nearby pulsar (e.g. Brazier et al. 1996; De Jager & Mastichiadis 1997; Gaisser et al. 1998).

8. SNRs in external galaxies

In general, we emphasize on looking for the SNRs in Galaxy. But because the absorption and extinction of the Galactic disk interstellar media and the Sun location at the galactic plane these sorts of researches are very difficult. On the contrary, it would be better to look for the SNRs in external galaxies, especially the near face-on and high galactic latitude galaxies, its interior absorption and Galactic absorption are very less.

The already known SNRs in M31 and M33 are more than 300. Such great deal of database provide quite important clue for us to solve the key problem of the SNRs evolution and the interaction between SNR and ISM in M31 and M33.

In recent more than 20 years, we have already done extensive researches to the SNRs X-ray radiations from the Galaxy. For many SNRs the observational space resolution before the Chandra launch is fine enough which had discovered many different sorts of the SNRs morphologic. However, the Galactic SNRs researches are constrained because the lack of the reliable estimated distance values and usually the great absorption of the interstellar medium. There would be no such limit to study the external galaxies SNRs. Chandra can decern the SNR structure in details in the nearest galaxies (LMC and SMC) (for example, Hughes 2001).

M31 is the nearest galaxy with Galaxy-like shape and size (\( \sim 800 \, \text{kpc} \)). It is the best candidate to study the SNRs by comparison. The typical method for us to confirm SNR in M31 through optical survey is based on the [SII] and \( H\alpha \) observational images (e.g. Braun & Walterbos 1993; Magnier et al. 1995). These surveys have already detected about 200 SNR candidates, among them 27 SNRs have been confirmed by the spectroscopic measures. Recently, Supper et al. (2001) confirmed 16 SNRs on the area of \( \sim 10.7 \, \text{square de-} \)
gree by the extensive ROSAT Position-Sensitive-Proportion-Counter (PSPC) survey to M31 and by the correlation with optical atlas. Their X-ray luminosities (0.1−2.4 KeV) range from \( \sim 10^{36} \) to \( \sim 10^{37} \) erg s\(^{-1}\).

More recently, Kong et al. (2002) detected 2 SNRs (XOCM31 J004327.7+411829 and CXOM31 J004253.5+412553) in the region of \( \sim 17' \times 17' \) at the M31 center with Chandra. Both SNRs had once been confirmed before by ROSAT. It is worth to mention that XOCM31 J004327.7+411829 had also once been detected by Einstein Observatory.

One of the aims to study SNR is to explore the protostar properties by making use of the SNR related characters. This characters, for example, the rich Fe abundance in the partial neutral gas or ejectors at the ambient medium have been taken to illustrate that some SNRs origin from Ia Type supernova. Hughes et al. investigate the SNR DEML71 (0505-67.9) in the LMC. This remnant owns the two characters just mentioned above. Based on the Einstein Observatory X-ray survey on LMC, Davies et al. (1976) pointed out at first time that DEML71 is a supernova remnant. Thereafter, the optical spectroscopy confirmed it for further more, which shows the SNR emission lines are mainly the Balmer lines (Smith et al. 1991). In other words, the optical spectrum of the SNR is mainly the hydrogen emission lines, but seldom or without [0III] or [SII] forbid lines radiations.

9. Conclusion

The high resolution images comparison among different frequencies could provide rich information about the plerions, helping to make clear some publicly well-known issues on this sort of objects. For example, how, where and how many particles with different radiation processes in the plerion interior are accelerated? How do they propagate in the nebulae? How about the magnetic field structure? How do the evolution of the plerions and their associated neutron star affect the synchrotron emission?

The great step toward to help understanding these topics is the emerge of the new generation of X-ray telescopes. They have the angle resolution of arc-second, forming spectrum images. The life time of the X-ray electrons is quite short, typically the time which the light travels through a nebula. Therefore, we could directly gain the position information where currently the particles pushing into from the X-ray spectrum image.

The millimeter wavelength is another wavelength scope which could effectively detect the remnants physics. One of the different spectrum broken point just located near this wavelength. Therefore, the spectrum figures could indicate the varied situation of the spectrum space at broken point, and offer the structure information of the magnetic field.

For composite-type remnants and plerions the high frequency and high resolution polarization observation is in particular important. But despite of the great efforts, the detected source numbers are still very few. In order to constrain some parameters of the weaker sources among the two sorts of SNRs, high sensitivity observations are demanded.

Despite of the great numbers of currently known shell-type SNRs, there are still more and more SNRs sources continuously being confirmed, especially the large diameter and low surface brightness objects. Confirming these sources at high frequency is ether difficult or consuming lots of time. At the longer wavelength, the combined data of the aperture synthesis telescopes and the single antenna could reduce the constraint by the mixing background sources from external galaxies, which is a successful method.

REFERENCES
Aharonian F A, Atoyan A M, Astron. Astrophys., 1999, 351: 330
Aharonian F, et al. Astron. Astrophys., 2001, 370: 112
Allen G E, et al. ApJ, 1997, 487: L97
Allen G E, Petre R, Gotthelf E V, ApJ, 2001, 558: 739
Anantharamaiah K R, Astron. Astrophys., 1986, 7: 131
Asaoka I, Koyama K, Publ. Astron. Soc. Japan, 1990, 42: 625
Aschenbach B, the Proceedings of the 270.WE-Heraeus Seminar on Neutron Stars, Pulssars and Supernova Remnants, 2002,(astro-ph/0208492)
Aschenbach B, Zeiss-Inf. mit Jenaer Rundsch., 1992, 1 : 6
Begelman M C, Li Z -Y, ApJ, 1992, 397: 187
Blondin J M, Lundqvist P, Chevalier R A, ApJ, 1996, 472: 257
Bolton J G, Stanley G J, Slee O B, Austr. J. Sci. Res. 2 A, 1949, 139
Braun R, Walterbos R A M, Astron. Astrophys. Suppl., 1993, 98: 327
Busser J -U, Egger R, Aschenbach B, MPE Report 263, 1996, 239B
Chatterjee S, Cordes J M, ApJ, 2002, 575: 407
Chevalier R A, Blondin J M, ApJ, 1995, 444:312
Chevalier R A, Liang E P, ApJ, 1989, 344: 332
Combi J A, et al. Astron. Astrophys., 2001, 366: 1047
Davies R D, Elliott K H, Meaburn J, Men R. Astron. Soc., 1976, 81: 89
De Jager O C, Mastichiadis A, ApJ, 1997, 482: 874
Duncan A R, et al. MNRAS, 1997, 291: 279
Dwarkadas V V, Chevalier R A, ApJ, 1998, 497: 807
Dyer K K, et al. ApJ, 2001, 551: 439
Enomoto R, et al. Nature, 2002, 416: 823
Featherstone N, Blondin J M, Borkowski K, Astron. Astrophys. Suppl., 2001, 199: 126
Frail D A, Goss W M, Whiteoak J B Z, ApJ, 1994, 437: 781
Franco J, et al. ASP, 1991, 103: 803
Gaensler B M, et al. ApJ, 2002, 569,(astro-ph/0110454)
Gaensler B M, Frail D A, Nature, 2000, 406, 158
Gaensler B M, in AIP Conf.Proc.565, Young Supernova Remnants, ed. S.S. Holt & U. Hwang (New York: AIP),2001, 295
Green D A, VizieR On-line Data Catalog 7th/227, Cambridge, United Kingdom(2001)
Helfand D J, Gotthelf E V, Halpern J P, ApJ, 2001, 556:380
Hendrick S P, Reynolds S P, ApJ, 2001, 559: 903
Hughes J, in AIP Conf. Proc. 565, Young Supernova Remnants, ed. S S Holt & U Hwang ( New York: AIP), 2001, 19
Hughes J P, et al. ApJ, 1995, 444: L81
Hughes J P, Hayashi I, Koyama K, ApJ, 1998, 505: 732
Jones F C, Ellison D C, Space Sci. Rev., 1991, 58: 259
Kaspi V, Helfand D J, in ASP Conf.Ser.271, Constraining the Birth Events of Neutron Stars, ed. P.O. Slane & B.M. Gaensler (San Francisco:ASP), 2002, 3
Keohane J W, PhD thesis, Univ. Minnesota, 1998
Klein R I, McKee C F, Colella P, ApJ, 1994, 420: 213
Kong A K H, et al. ApJ, 2002, 577: 738
Koralesky B, et al. AJ, 1998, 116: 1323
Koyama K, et al. Nature, 1995, 378: 255
Koyama K, et al. PASJ, 1997, 49: L7
Lacey C K, et al. ApJ, 2001, 559: 954
Levenson N A, et al. ApJ, 1997, 484: 213
Levenson N A, Graham J R, Walters J L, RevMexAA(SC), 2003, 15: 252
Lockett P, Gauthier E, Elitzur M, ApJ, 1999, 511: 235
Lorimer D R, Lyne A G, Camilo F, ptgr. Conf., 1999, 125L
Mac Low M -M, et al. ApJ, 1994, 433: 757
Magnier E A, et al. Astron. Astrophys. Suppl., 1995, 114: 215

Malkov M A, Drury L O C, Rep. Prog. Phys., 2001, 64: 429

Manchester R N, et al. In ASP Conf.Ser.271, Young Pulsars from the Parkes Multibeam Pulsar Survey and Their Associations, ed. P.O. Slane & B.M. Gaensler (San Francisco:ASP), 2002, 31

Mereghetti S, Sidoli L, Israel G L, Astron. Astrophys., 1998, 331, L70

Miesch M S, Zweibel E G, ApJ, 1994, 432: 622

Mills B Y, IAUS, 1974, 60, 311

Moffett D A, Reynolds S P, ApJ, 1994a, 425: 668

Moffett D A, Reynolds S P, ApJ, 1994b, 437: 705

Muraishi H, et al. Astron. Astrophys., 2000, 354: L57

Reynolds S P, Keohane J W, ApJ, 1999, 525: 368

Schaudel D, et al. MPE Report 278, 2002, 26S

Seeger C L, Westerhout G, AJ, 1961, 66: 294

Sidoli L, et al. Astron. Astrophys., 2000, 361, 719

Slane P, et al. ApJ, 1999, 525: 357

Slane P, et al. ApJ, 2001, 548: 814

Smith R C, et al. ApJ, 1991, 375: 652

Supper R, et al. Astron. Astrophys., 2001, 373: 63

Tanimori T, et al. ApJ, 1998, 497: L25

Tenorio-Tagle G, et al. MNRAS, 1990, 244: 563

Tenorio-Tagle G, et al. MNRAS, 1991, 251: 318

Trushkin S A, Proceedings of the 4th INTEGRAL Workshop: Exploring the Gamma-Ray Universe, Alicante, Spain., 2000, 109T

Uchiyama Y, Aharonian F A, Takahashi T, Astron. Astrophys., 2003, 400: 567

Ueno M, et al. ApJ, 2003, 588: 338

Ulmer M P, et al. ApJ, 1993, 417, 738

Wallace B J, Landecker T L, Taylor A R, Astron. Astrophys., 1994, 286: 565

Wang L, et al. ApJ, 2002, 579: 671

Wardle M, Yusef-Zadeh F, Geballe T R, in ASP Conf. Proc. 186, The Central Parsecs, ed. H. Falcke, et al. (San Francisco: ASP), 1999, 432

Wardle M, ApJ, 1999, 527: L109

Weisskopf M C, et al. ApJ, 2000, 536: L81

White R L, Long K S, ApJ, 1991, 373: 543

Willingale R, et al. MNRAS, 1996, 278: 749

Woltjer L, Ann. Rev. Astron. Astrophys., 1972, 10, 129

This 2-column preprint was prepared with the AAS L\TeX macros v5.2.