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OBSERVATIONAL DATA ON GALACTIC SUPERNOVA REMNANTS: II. THE SUPERNOVA REMNANTS WITHIN l = 90° - 270°

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SUMMARY: We have collected all the available data on Galactic supernova remnants given in the literature. The data of Galactic supernova remnants located in the Galactic longitude interval l=90°–270° in all spectral bands are represented in this work. We have adopted distance values for the SNRs by examining these data. The data of various types on neutron stars connected to these supernova remnants are also represented. Remarks of some authors and by ourselves regarding the data and some properties of both the supernova remnants and the point sources are given.

Key words. Catalogs – ISM: supernova remnants – Stars: neutron

1. INTRODUCTION

This is the second of a series of papers which present all the available data of Galactic supernova remnants (SNRs) from radio to gamma-ray bands together with the data of point sources connected to these SNRs. In this paper, the data of the SNRs (and the related point sources) located in the Galactic longitude interval 90°–270° are given. In the other two papers, the data of the SNRs (and the related point sources) in the intervals 0°–90° (Guseinov et al. 2003a) and 270°–360° (Guseinov et al., in preparation) are represented.

A catalogue of Galactic SNRs was presented by Green (2004). Green's catalogue includes 231 SNRs and about 20 SNR candidates. The data of SNRs in the radio band given by Green are as follows: angular size, flux at 1 GHz, spectral index, morphological type of SNR, and in some cases, distance. Since angular sizes of SNRs cannot be determined easily (particularly for SNRs with low surface brightness), many of the SNRs flux values and angular sizes are denoted by question marks. There are 179 S-type, 28 C-type and 9 F-type SNRs including roughly determined or dubious types (e.g. S?); for 15 of the SNRs the types are given as unknown.

There are some additional SNRs (together with their available data) in this work which are not present in Green (2004). The SNR types given in Green (2004) are due to the data in the radio band only, so that a SNR which is known to be pure S-type in the radio band may be, for example, C-type when the X-ray data are considered together with the radio data. The data in the γ-ray, X-ray, and optical bands given in the literature are not present in Green (2004); only some remarks and references about such data are given. Our aim is to collect all the available data of Galactic SNRs, to adopt distances of these SNRs as precisely as possible, and to make a preliminary analysis of the data on the SNRs. Since, there is no catalogue, other than Green

(2004), which contains data on SNRs, in this work all the data of SNRs were put together for the first time. In Whiteoak and Green (1999) radio maps of some SNRs are presented.

In this work, we present all the available observational data of SNRs (complete up to the present day). We have collected the radio and the X-ray data, in many cases the infrared observations to show existence of molecular clouds and maser sources. In some cases the data in visual and ultraviolet bands are also given to get information about the chemical abundance and filaments of SNRs. These data can be used to examine the explosion energies, the densities of the ambient media in which the SNRs evolve, the initial masses of the progenitors, the changes in the parameters of the SNRs during their evolution, different types of point sources in the SNRs, and the mechanisms which led to differences in the types of these point sources. The chemical abundance may give us some information about the mass of the progenitor.

As known, SNRs are the sources of cosmic rays and it is important to examine SNRs to get information about the accelerations of electrons and protons. Here, it is necessary to have information about the character of X-ray radiation and the origin of γ-ray radiation. Therefore, we also present the data on the 'hard' radiations. We have not only collected the data of SNRs which were determined directly from observations, but we also included the data found using various models and approaches. In particular, we have used the data presented in this work to construct an improved Σ–D relation, where Σ is the surface brightness of the SNR and D is its diameter. We have adopted distances for all the Galactic SNRs by considering the distances found from our Σ–D relation together with all the distance values given in the literature found by various different methods, and the data related with the distance and the density of the environment (Guseinov et al. 2003b). Radio data of SNRs (morphological type, spectral index, angular size and 1 GHz flux), given in parentheses after the name of the SNR, are taken from Green (2004). Σ values, also given in the parentheses, were calculated using the 1 GHz flux and angular size values given in Green (2004). For all the other data, except the adopted distance values and the distances found from our Σ–D relation (Guseinov et al. 2003b), the references are given. The abbreviations used in the text for commonly used observed quantities of SNRs are as follows (the units are given in parenthesis):

1) **SNR type (radio):** S = Shell; F = Filled Center (Plerion); C = Composite
2) **The angular size of the SNR:** θ (arcmin)
3) **Radio spectral indices of the shell, the plerionic part, and the whole SNR:** α
4) **Distance:** d (kpc)
5) **Column density of neutral hydrogen:** N_{HI} (cm^{-2})
6) **Interstellar optical absorption:** A_V (mag)
7) **Spectral indices for the X-ray radiation of the shell, the plerionic part, and the whole SNR:** SI
8) **Radio flux at 1 GHz:** F (Jy)
9) **Flux in X-ray band:** F_x (erg cm^{-2} s^{-1})
10) **Temperature in the shell or the plerionic part:** kT (keV)
11) **Velocity of the shock front or the expansion velocity:** V (km/s)
12) **Surface brightness (at 1 GHz):** Σ (W m^{-2} Hz^{-1} sr^{-1})
13) **Luminosity in X-ray band:** L_x (erg/s)
14) **For SNR environment density and clouds:**
a) **Molecular cloud:** MC
b) **Maser source (due to interaction of SNR with MC):** MS
c) **Dust cloud:** DS
d) **Number density of particles in front of the SNR, in the shell, in the plerionic part, or in different types of clouds and filaments:** n (cm^{-3})
15) **Kinetic energy of the shell or the plerionic part:** E_k
16) **Age of the SNR:** t (kyr)
17) **Explosion energy of the SNR:** E (erg)
18) **X-ray radiated mass:** M_x ($M_\odot$)
19) **Ejected mass:** M_{Ej} ($M_\odot$)
20) **Swept-up mass:** M_s ($M_\odot$)
21) **Magnetic field:** B (mG)

Abbreviations for data of the point sources connected to SNRs are given as:

1) **Type of the point source:**
a) **Radio pulsar:** PSR
b) **X-ray pulsar:** XRP
c) **X-ray point source:** XPS
d) **Neutron star:** NS
2) **Ratio of the angular distance of the point source from the geometric center of the SNR to the average angular radius of the SNR:** $\beta \equiv 2\Delta\theta/\theta$
3) **Spin period:** P (s)
4) **Derivative of spin period:** $\dot{P}$ (s/s)
5) **Characteristic age of point sources:** τ (kyr)
6) **Dispersion measure:** DM (pc/cm^3)
7) **Radio flux values at 400 MHz and 1400 MHz:** F_{400}, F_{1400}
8) **Radio luminosity at 1400 MHz:** L_{1400} (Jy kpc^2)
9) **Pulsar wind (powered) nebula:** PWN
10) **Spectral index:** SI
11) **Photon index:** Γ
12) **Space velocity:** V (km/s)
13) **Visual apparent magnitude:** m_V (mag)
14) All other physical quantities of point sources are presented in the form similar to SNRs'.

2. OBSERVATIONAL DATA OF SNRs AND POINT SOURCES

SNR G93.3+6.9 (DA 530, S, α=0.54, θ=27×20, F=9, Σ=2.51×10^{-21})

d=3.8 kpc [1], d=2.2 kpc (HI obs.) [2], d=5.8 kpc (Σ-D), d=3.8 kpc adopted (taking into account that this SNR is in a very low density medium, the position of the SNR must be well below the Σ-D line).

N_{HI}=5.7×10^{21} cm^{-2} [1]; E=3.9×10^{50} erg [1].

Remark: The Ia type supernova occured 5000 yrs ago [1].

[1] Landecker et al. 1999; [2] Green 2004.

SNR G93.7-0.2 (CTB 104A, DA 551, S, α=0.4, θ=80, F=65, Σ=1.53×10^{-21})

d=1.8 kpc (Σ-D), d=1.6 kpc adopted.

n_e=9.6 cm^{-3} [1]; B=2.3 μG [1].

[1] Uyaniker et al. 2002.

SNR G94.0+1.0 (3C434.1, S, α=0.44, θ=30×25, F=15, Σ=3.01×10^{-21})

d=4.7 kpc (Σ-D), d=4.7 kpc adopted.

SNR G106.3+2.7 (?, α=0.6, θ=60×24, F=6, Σ=6.27×10^{-22})

C-type SNR [2], α=0.1±0.1 (for plerionic part) [2], S-type in radio (but α is very flat) [3], α=0.57 [1].

d=4.4 kpc (Σ-D), d=5.5 kpc adopted.

F_{1400}=90 mJy (for plerionic part) [2], F_x=1.3×10^{-12} erg/cm^{2}s (2-10 keV, for plerionic part) [3]; t=10^4 yrs [3].

Remarks: The SNR is expanding in a HI bubble in the environment of a molecular cloud and it is close to the boundary of the bubble [2]. In the direction of the SNR, at 950 pc, there is Cep OB2 association [2].

The incomplete radio shell that surrounds PSR J2229+6114 is unique in having an extremely flat spectrum (α∼0) even though it has shell morphology [5].

Point Source PSR J2229+6114
(strong X-ray, γ-ray, and radio PSR) [3]

d=6.1 kpc [4], d=3±1 kpc (from X-ray absorption) [5], d=12 kpc [5], d=0.8 kpc [2]; P=51.6 ms, $\dot{P}$=7.83×10^{-14} s/s [3]; τ=10.39 kyr [3]; DM=200 cm^{-3} [3]; SI=1.51 [3]; N_{HI}=(6.3±1.3)×10^{21} cm^{-2} [5]; F_{1400}=0.25 mJy [3]; $\dot{E}$=2.2×10^{37} erg/s [3]; Log L_{1400}=0.95 [4]; $L_x/\dot{E}$=8×10^{-5} (for d=3 kpc) [5].

Remarks: L_x of the neutron star (i.e. L_x from the plerionic part) in 2-10 keV is 29% of the whole L_x from the SNR. There is EGRET source 3EG J2227+6122 near the PSR, but this EGRET source may be the X-ray binary source 4U 2238+60 which includes a Be-type star [3]. PSR J2229+6114 has PWN [3].

If the distance to the SNR is 800 pc, the size of the nebula near the PSR is 0.8 pc and the sizes of the SNR is 14×6 pc [2].

N_{HI}=6.3×10^{21} cm^{-2} which leads to the result that d=3 kpc [3].

The distance of the SNR may be 800 pc because of a huge number of neutral hydrogen being present around the SNR. Supernova explosion energy is found to be 7×10^{49} erg by equating age of the SNR to age of the PSR. If density in the shell is 100 cm^{-3}, the expansion velocity must be 1100 km/s [2].

Distance of the PSR can not be less than 3 kpc due to the DM value of the PSR.

PSR J2229+6114 is a compelling identification for the EGRET source 3EG J2227+6122 in which error circle it resides [5].

In the CHANDRA X-ray image, there are an incomplete elliptical arc and a possible jet, similar to the structures that dominate the appearance of the Vela PWN [5].

Approximately 70% of the 2-10 keV X-ray emission comes from a centrally peaked diffuse nebula of radius 100″ with a power-law spectrum of photon index 1.45±0.19. The pulsar itself has a marginally harder spectrum with photon index 0.99±0.27 [5].

PSR J2229+6114 is one of the brightest pulsars at 1 MeV, even while it is inconspicuous at radio through X-ray wavelengths, and as steep as the Crab above 100 MeV [5].

There is X-ray PWN [5].

[1] Pineault and Joncas 2000; [2] Kothes et al. 2001; [3] Halpern et al. 2001; [4] Guseinov et al. 2004; [5] Halpern et al. 2002.

SNR candidate G106.6+2.9

Remarks: G106.6+2.9 is evidently a PWN [1]. SNR G106.3+2.7 incorporates the proposed smaller remnant G106.6+2.9 [2]. PSR J2229+6114 can be associated with G106.6+2.9.

[1] Halpern et al. 2001; [2] Green 2004.

SNR G109.1-1.0 (CTB 109, S, α=0.50, θ=28, F=20, Σ=3.84×10^{-21})

d=4 kpc [1], d=3.6 kpc [2], d=4 kpc [7], d∼3 kpc (at the closer edge of the Perseus spiral arm) [16], d=4.4 kpc (Σ-D), d=4 kpc adopted.

A_V=2.5-3.8 mag [3], E(B-V)=0.79-1.2 mag [3]; N_{HI}=(8-10)×10^{21} cm^{-2} [4], N_{HI}=4×10^{21} cm^{-2} [5]; F_x=7.8×10^{-11} erg/cm^{2}s (0.2-2.4 keV) [7]; kT=0.95 keV [6], kT=0.9 keV [8], kT∼1 keV [5], kT=0.17-0.56 keV [7]; L_x=3.2×10^{37} erg/s [7]; MC [6,8]; n_0=20 cm^{-3} (for the clouds in front) [3,14], n_0=0.25 cm^{-3} (the average in front of the SNR) [5]; t=3×10^3 yrs [6], t=10^4 yrs [1,5], t=(3-10)×10^3 yrs [7]; E=10^{51}-10^{52} erg [5].

Remark: In the SNR, jet has been observed in the X-ray band [5].

Point Source AXP 1E 2259+586

d=5.6 kpc [9], d=4 kpc [22], d=3.6 kpc [23,24], d=6 kpc [25]; β=0.2-0.3 [1,7], β=0.2 [10], β<0.2 [15]; P=6.978977(24)s (11 January 2000) [13], P=6.98 s [14,17,18], P=6.45 s [19]; $\dot{P}$=0.06×10^{-11} [14,17,20], $\dot{P}$=0.048×10^{-11} [21], $\dot{P}$=0.049×10^{-11} [22]; τ=200 kyr; N_{HI}=9×10^{21} cm^{-2} [7], N_{HI}=9.3×10^{21} cm^{-2} (0.5-20 keV) [13], N_{HI}=8.5×10^{21} cm^{-2} [7], N_{HI}=(3-12)×10^{21} cm^{-2} [6], N_{HI}=(6-8)×10^{21} cm^{-2} (0.5-4 keV) [24], N_{HI}=10^{22} cm^{-2} (2-10 keV) [21]; SI=4.0 [7],

SI=3.6 [13], SI=3.9 [7], SI=1.46-3.9 [6], SI=4.02 (2-10 keV) [21]; kT=0.43 keV (blackbody) [7], kT=0.41 keV (blackbody) [13], kT=0.44 keV (blackbody) [6]; $F_x=7.9\times10^{-11}$ erg/cm^{2}s (1.2-20 keV) [23], $F_x=(2.5\text{-}3.2)\times10^{-12}$ erg/cm^{2}s (1-10 keV) [6,13,22]; $L_x=1.2\times10^{35}$ erg/s (1.2-20 keV) [23], $L_x\sim2\times10^{35}$ erg/s (0.5-4 keV) [24], $L_x=10^{35}$ erg/s (1-10 keV) [22]; $F_{1500}<50$ μJy [12,13]; V=300 km/s if t=10^4 yrs [10]; $m_V>24$ [27], $m_R>25.7$ [25], $m_I>24.3$ [25], $m_R>26.4$ [11], $m_I>25.6$ [11], $m_K>21.7$ [11].

Remarks: The τ value of the AXP is considerably larger than the age of the SNR. If a_x Sin i $<$ 70 lt-ms, no orbital period in the range 170-5000 s [13].

Optical radiation from the location of the neutron star has been observed. K=21.7±0.2 mag, the optical radiation is not from the accretion disk, similar to 4U 0142+61 [12].

The pulse fraction values measured for this AXP are: ~30% [26], ~35% (1-10 keV) [6,7], 22% (1-10 keV) [22].

[1] Green 1989; [2] Braun et al. 1989; [3] Fesen and Hurford 1995; [4] Rho and Petre 1993; [5] Morini et al. 1988; [6] Parmar et al. 1998; [7] Rho and Petre 1997; [8] Tatematsu et al. 1990; [9] Hughes et al. 1984; [10] Marsden et al. 1999; [11] Hulleman et al. 2001; [12] Coe et al. 1994; [13] Patel et al. 2001; [14] Gotthelf and Vasisht 1998; [15] Gaensler et al. 2001; [16] Kothes et al. 2002; [17] Baykal and Swank 1996; [18] Fahlman and Gregory 1981; [19] Israel et al. 2002; [20] Kaspi et al. 1999; [21] Gavriil and Kaspi 2002; [22] Mereghetti et al. 2002; [23] Koyama et al. 1989; [24] Hanson et al. 1988; [25] Hulleman et al. 2000; [26] Mereghetti 2001a; [27] Coe and Pightling 1998.

SNR G111.7-2.1 (Cas A, SN 1667, S, α=0.77, Oxygen-rich, γ-ray radiation, θ=5, F=2720, $\Sigma=1.64\times10^{-17}$)

d=3.4 kpc (Optical expansion + proper motions) [1], d=3.4 kpc (by examining the SNR's dynamics) [2], d=0.8 kpc (Σ-D), d=3.4 kpc adopted.

$N_{HI}=1.2\times10^{21}$ cm^{-2} [6]; kT=1.3 keV [5,19], kT=0.65-2.8 keV [6], kT=2.56±0.05 keV [20]; V=3200 km/s (expansion velocity of the bright shell) [7], V=5200 km/s (expansion velocity of the blast wave) [7], V=5000-5300 km/s (for the knots) [2], V>10000 km/s (for the knots) [8,9], V=6700 km/s [22]; n=10^3 cm^{-3} (for the knots) [7]; $M_{Ej}=2\text{-}4$ $M_\odot$ if d=3.4 kpc [6], $M_s+M_{Ej}=7\text{-}12$ $M_\odot$ [6], $M_{Ej}\sim4$ $M_\odot$, $M_s+M_{Ej}\sim12$ $M_\odot$ [7]; $E_{exp}\sim(2\text{-}3)\times10^{51}$ erg [7,19].

Remarks: Cas A is not projected on the OB associations, but also none of the OB associations, which are in the directions close to the direction of Cas A, has a distance exceeding 3 kpc [3,4].

The distance value found from the Σ-D relation is 0.8 kpc. When constructing the Σ-D relation we did not consider Cas A as a calibrator SNR, because, though the distance of this SNR is known relatively precisely, it has an extraordinarily high surface brightness. As Cas A was formed as a result of the supernova explosion of a massive star in a dense interstellar medium, we have adopted a distance value of 3.0 kpc for this SNR.

When the power-law component is added, ratio of the abundance of some chemical elements to the abundance of oxygen increases 3 factors, ejected and swept up masses decrease [6].

From the pictures in the X-ray band it is seen that there are highly energetic electrons having continuum spectrum and the morphology of the continuum spectrum is very different compared to the morphology of the line-spectrum [7].

In the X-ray band, expansion of the SNR's shell in 17 years was observed and velocity of the expansion is 0.20% year^{-1}. This is 2 times the one observed in the radio band [9].

The increase in the radius with respect to time is $r\sim t^{0.73}$ in the X-ray band and $r\sim t^{0.35}$ in the radio band. So, the expansion velocity is 3500 km/s in the X-ray band, whereas it is 1750 km/s in the radio band [9].

The X-ray and the radio morphologies of this SNR are similar to each other and this may be related to the rate of change of the magnetic energy and the rate of change of the thermal energy being the same in the SNR [10].

Cas A, Kepler and Crab have a low Hα/|NII| ratio and a high density, while old, decelerated SNRs have Hα/|NII| ratio of about 2.0 and a |SII| ratio close to the low density limit ($\leq$100 cm^{-3}). HII regions have a Hα/|NII| ratio higher than SNRs have and a density generally lower than 1000 cm^{-3} [21].

TeV radiation has been observed from this SNR [27].

Point Source DRQNS CXO J2323+5848

$\beta\sim0$ [11]; P=0.012 s (?) [24]; d=3.4 kpc [2,18]; $N_{HI}=1.1\times10^{22}$ cm^{-2} [14], $N_{HI}=1.7\times10^{22}$ cm^{-2} [23]; $A_V=5^m$ [18]; SI=2.8-3.6 (0.1-10 keV) [14], SI=4.1 (0.1-10 keV) [17], SI=2.6-4.1 (0.1-5 keV) [23]; $F_{1435}<1.3$ mJy [16] (Log L<1.18); kT=0.3-0.5 keV (0.1-10 keV band) [14], kT=0.49 keV (0.1-10 keV band) [17]; kT=0.5-0.7 keV [23,25]; V=930 km/s [11], V=200 km/s [12], V~1000 km/s [13]; $F_x=4\times10^{-13}$ erg/cm^{2}s (absorbed, 0.5-2.4 keV) [18], $F_x=3.6\times10^{-13}$ erg/cm^{2}s (absorbed, 0.3-2.4 keV) [23], $F_x=6.5\times10^{-13}$ erg/cm^{2}s (absorbed, 0.3-4 keV) [23], $F_x=8.2\times10^{-13}$ erg/cm^{2}s (absorbed, 0.3-6 keV) [23]; $L_x=(1\text{-}5)\times10^{33}$ erg/s (0.1-10 keV) [14], $L_x=10^{33}\text{-}10^{35}$ erg/s (0.1-10 keV, using different spectral and environmental absorption models) [17], $L_x=(7\text{-}160)\times10^{33}$ erg/s (0.1-10 keV) [14], $L_x=(2\text{-}60)\times10^{34}$ erg/s (0.1-5 keV) for d=3.4 kpc [23]; $L_{600}<530$ mJy kpc^2 if d=3.4 kpc [15], $L_{1435}<15$ mJy kpc^2 at 3-4 kpc [16].

Remarks: RQNS CXO J2323+5848 is close to the center of the SNR [11].

No synchrotron nebula was observed around the neutron star [16].

A very small probability for the period of the neutron star having been observed as 12.16 ms [17].

For the point source $R\geq25^m$ [18].

Chandra observations of Cas A revealed a central radio-quiet X-ray source [23].

The pulse fraction value for this source is <35% [14]. The transverse velocity of the X-ray point source is about 330 km/s at a distance of 3.4 kpc [26].

[1] Green 2004; [2] Reed et al. 1995; [3] Humphreys 1978; [4] Garmany and Stencel 1992; [5] Braun et al. 1989; [6] Favata et al. 1997; [7] Vink et al. 1998; [8] Fesen et al. 1988; [9] Koralesky et al. 1998; [10] Keohane et al. 1998; [11] Brazier and Johnston 1999; [12] Cordes and Chernoff 1998; [13] Petre et al. 1996; [14] Chakrabarty et al. 2001; [15] Lorimer et al. 1998; [16] McLaughlin et al. 2001; [17] Murray et al. 2002a; [18] Kaplan et al. 2001; [19] Wright et al. 1999; [20] Bleeker et al. 2001; [21] Sabbadin 1976; [22] Crawford et al. 2002a; [23] Pavlov et al. 2000; [24] Murray and Ransom 2001; [25] Pavlov et al. 2002b; [26] Thorstensen et al. 2001; [27] Aharonian et al. 2001.

SNR G114.3+0.3 (S, α=0.3?, θ=90×55, F=6?, $\Sigma=1.82\times10^{-22}$)

d=3.0-3.8 kpc (possible association with HI features) [1], d=2.5-3 kpc [2,3], d=2.9 kpc (Σ-D), d=2.8 kpc adopted.

$n_0=0.1$ cm^{-3} (the average value for the medium) [6]; t=(1-2)×10^4 yrs [6], t=10^4 yrs [7].

Remarks: Three weak filaments were observed in the optical band [3]. The SNR's shell has been expanded inside an HII region and has just reached the boundary of the HII region [6]. This SNR is inside a superbubble together with the SNRs G116.5+1.1 G116.9+0.2 (CTB1) [6]. In the direction of this SNR (l=115°.5, b=0°.25), at d=2.3 kpc, there is Cas 5 OB association [9].

Point Source PSR J2337+6151 [7]
(X-ray and radio PSR)

d=2.5 kpc (21 cm HI line) [8], d=2.8 kpc [4], d=2.5 kpc [5]; β=0.08 [7,10]; DM=58.38 pc/cm^3 [4]; P=0.4953 s [4]; $\dot{P}=1.92\times10^{-13}$ [4]; SI=2 [8]; V=170 km/s (the perpendicular component) for d=3 kpc [7]; Log L_{1400}=1.04 [4]; $L_x=5.3\times10^{31}$ erg/s if d=2.5 kpc [8]; $\tau=4.1\times10^4$ yrs [4].

Remark: The PSR is close to the center of the SNR and it is genetically connected to the SNR [7].

[1] Green 2004; [2] Reich and Braunsfurth 1981; [3] Fesen et al. 1997; [4] Guseinov et al. 2004; [5] Taylor et al. 1996; [6] Fich 1986; [7] Furst et al. 1993; [8] Becker et al. 1996; [9] Melnik and Efremov 1995; [10] Lorimer et al. 1998.

SNR G116.5+1.1 (S, α=0.8?, θ=80×60, F=11?, $\Sigma=3.45\times10^{-22}$)

d=3.6-5.2 kpc (possible association with HI features) [1], d=4.4 kpc [2,3], d=2.7 kpc (Σ-D), d=3.5 kpc adopted.

Remarks: In the direction of this SNR, the arm of the Galaxy is passing through at about 3-4 kpc [4]. Neither at 2.2 kpc nor at 5 kpc is there a star formation region in this direction [4]. At d=3.4-4.4 kpc, in a low density region of the interstellar medium, diameter of this SNR can be 90 pc [4].

The superbubble which includes this SNR also contains SNRs G114.3+0.3 and G116.9+0.2.

[1] Green 2004; [2] Reich and Braunsfurth 1981; [3] Lorimer et al. 1998; [4] Fesen et al. 1997.

SNR G116.9+0.2 (CTB 1, S, α=0.5?, θ=34, F=9?, $\Sigma=1.17\times10^{-21}$)

d=3.1 kpc [1], d=2.3 kpc [2], d=2.8-4 kpc (possible association with HI features) [3], d=2.7 kpc (mean optical velocity) [3], d=4.5 kpc (Σ-D), d=3.5 kpc adopted.

t=(1-1.5)×10^4 yrs [1]; $N_{HI}=7\times10^{21}$ cm^{-2} [5].

Remarks: X-ray radiation from the direction of the SNR's center is intense [5,8], the SNR may be C-type in X-ray.

In the direction of this SNR, at 2.5 kpc, there is O6 type star HD/BD 108. For this star $N_{HI}=3\times10^{21}$ cm^{-2} [4]. So, the SNR must be located at a distance >2.5 kpc.

In this direction, there is no star formation region beyond 3 kpc. If the distance of this SNR is ~2.7 kpc, then it may be in the star formation region where Cas OB2 and Cas OB5 associations are located (at larger distances there is no such region). But, in this direction, at ~3.7 kpc, there is the open cluster C2355+609 which has an age of t=4×10^7 yrs. A_V=2.2-3.2 [6].

For the stars in this direction, which have distances in the range d=1-4 kpc, A_V value is almost constant (~2^m) and does not reach to a value of 3^m [7].

This SNR is expanding within the low density superbubble which also includes SNRs G114.3+0.3 and G116.5+1.1. The shock wave front does not have a regular but a discontinuous shape and its velocity is V>100 km/s [6].

[1] Hailey and Craig 1994; [2] Braun et al. 1989; [3] Green 2004; [4] Diplas and Savage 1994; [5] Craig et al. 1997; [6] Fesen et al. 1997; [7] Neckel and Klare 1980; [8] Rho 1995.

SNR G117.7+0.6

S-type in radio [1,2]; d~3 kpc [1], d=3 kpc (the faint partial shell SNR) [2], d=3 kpc adopted.

$N_{HI}>3.2\times10^{21}$ cm^{-2} [2]; $n_0\sim0.02$ cm^{-3} (the average value in front of the SNR) [2]; t=2×10^4 yrs [1], t=(1-2)×10^4 yrs [2].

G117.7+0.6 is given as a possible/probable SNR not listed in the catalog of Green [3].

Point Source RX J0002+6246
(γ-ray source) [2]

$\alpha=00^h\ 02^m\ 54^s.1$, $\delta=62^o\ 46'\ 23''$ (J2000) [2]; d=3.5 kpc [2]; $N_{HI}=7\times10^{21}$ cm^{-2} [2]; kT~0.1 keV [2]; V=150-200 km/s [2]; $F_x=1.7\times10^{-13}$ erg/cm^{2}s (0.5-2 keV) [2], $F_x=2\times10^{-13}$ erg/cm^{2}s (0.1-2.4 keV) [1]; $L_x\cong2\times10^{32}$ erg/s (0.5-2 keV) at d=3.5 kpc [2]; P=0.24181 s [2].

[1] Brazier and Johnston 1999; [2] Hailey and Craig 1995; [3] Green 2004.

SNR G119.5+10.2 (CTA 1, S, α=0.6, Oxygen-rich, θ=90?, F=36, $\Sigma=6.69\times10^{-22}$)

Plerionic part is seen in the X-ray band [3]; d=1.4 kpc [1,2,3,4,5], d=1.9 kpc (Σ-D), d=1.4 kpc adopted. $N_{HI}=2.8\times10^{21}$ cm^{-2} [3], $N_{HI}=(1.1\text{-}2.5)\times10^{21}$ cm^{-2}

(0.1-2.4 keV) [2], $N_{HI}=3.8\times10^{21}$ cm^{-2} [7]; $A_V=1.3$ [5]; kT=0.16-1.14 keV [7], kT=0.22 keV (0.1-2.4 keV) [2]; V$\sim$400 km/s (for the blast wave) [9]; $L_x=(5\text{-}8)\times10^{34}$ erg/s (0.1-2.4 keV) at d=1.4 kpc [2]; MC [7]; $n_0\sim1$ cm^{-3} (for the clouds in front of the SNR) [5], $n_0\sim0.03$ cm^{-3} (the average value for the medium in front of the SNR) [5], $n_0\sim0.02$ cm^{-3} (the average value in front of the SNR) [2]; $t=(5\text{-}10)\times10^3$ yrs [3,6], $t=1.5\times10^4$ yrs [2], $t=2.4\times10^4$ yrs [5]; $E=3\times10^{49}$ erg [2]; $M_s=13$ $M_\odot$ [2]; $B=2.9\times10^{-6}$ G [2].

Remarks: Strong OIII lines show that for the filaments V>100 km/s and n$\sim$200 cm^{-3}. Angular radius of the SNR is 59′ [5].

The OIII emission line (λ=5010 A, $\Delta\lambda$=28 A) is very strong (as in the cases of SNRs G65.3+5.7 and G126.2+1.6) [8].

Normally, for the shock waves the value of OIII/H$_\beta$ does not exceed 9, but for this SNR this value is 5-20 [5].

Point Source DRQNS RX J0007.0+7302 [6]

$\Delta\theta=15'$ [6]; $\beta=0.33$ [6]; $F_x=9\times10^{-14}$ erg/cm^{2}s (0.1-2.4 keV) [6], $F_{1400}<0.3$ mJy [6]; V=700 km/s [6]; $L_x=1.5\times10^{31}$ erg/s (0.1-2.4 keV) at d=1.4 kpc, Log $L_{1400}<-0.2$.

[1] Pineault et al. 1993; [2] Seward et al. 1995; [3] Slane et al. 1997; [4] Brazier et al. 1998; [5] Mavromatakis et al. 2000; [6] Brazier and Johnston 1999; [7] Rho and Petre 1998; [8] Fesen et al. 1981; [9] Tuohy and Garmire 1980.

SNR G120.1+1.4 (Tycho, SN 1572, S, α=0.61, θ=8, F=56, $\Sigma=1.32\times10^{-19}$)

d=2.2 kpc [1], d=2.4 kpc (from the optical proper motion and the shock-wave velocity) [2], d=2-5 kpc (HI absorption) [2], d=4.6 kpc [3], d=3 kpc (in X-ray from Ginga satellite) [4], d=3.7 kpc (Σ-D), d=3.3 kpc adopted.

$A_V=2.1\pm0.5$ [6]; V$\sim$2000 km/s [5], V_s=1940-2300 km/s (from optical observations and model) [11,12]; kT=2.3±0.3 keV [10].

Remarks: In the direction of this SNR, there are Cas OB4 association at 2.9 kpc and Cas OB7 association (l = 121°.7–125°.2, b = –0°.9 - +2°.6) at 2.5 kpc. If this SNR actually is nearer than 3 kpc, its diameter must be about 6 pc. Can such a young S-type SNR have such a surface brightness value which is not the Σ value corresponding to its diameter, but a very smaller one? If the actual distance value of Tycho is close to 4 kpc, then the density in the ambient medium may be low and because of this the surface brightness of Tycho can be small [7,8].

If d=2.2-4.5 kpc, taking into account the proper motion, V=3200-6500 km/s [7,8].

As it is known, the relation between the radius and the age of SNRs is roughly given as $R\sim t^k$. In the free expansion phase k=1, in the adiabatic (Sedov) phase k=0.4, and in the radiative phase k$\cong$0.4-0.25. For Tycho k=0.47±0.03 [8,9].

The radio flux and the polarization of this SNR did not change between the years 1984-1994 [8].

Balmer-dominated shock has been detected in SNR Tycho [12].

[1] Albinson et al. 1986; [2] Green 2004; [3] Schwarz et al. 1995; [4] Fink et al. 1994; [5] Ghavamian et al. 2000; [6] Chevalier et al. 1980; [7] Reynoso et al. 1999; [8] Reynoso et al. 1997; [9] Tan and Gull 1985; [10] Decourchelle et al. 2001; [11] Ghavamian et al. 2001; [12] Sollerman et al. 2003.

SNR G126.2+1.6 (S?, α-varies, θ=70, F=7, $\Sigma=2.15\times10^{-22}$)

d=2.9 kpc (Σ-D), d=2.5 kpc adopted.

SNR G127.1+0.5 (R5, S, α=0.6, θ=45, F=13, $\Sigma=9.66\times10^{-22}$)

d=1.2-1.3 kpc (considering the SNR to be associated with the open cluster NGC 559) [1]; d=3.5 kpc (Σ-D), d=2.5 kpc adopted.

Remarks: Since, there is a huge star formation region in this direction between 2-3 kpc, we have adopted a distance value of 2.5 kpc for this SNR. If a smaller distance value is adopted, then this SNR will be well below the Σ-D relation.

[1] Green 2004.

SNR G130.7+3.1 (3C 58, SN 1181, F-type similar to Crab SNR, α=0.10, θ=9×5, F=33, plerionic in the X-ray band, Nitrogen-rich, $\Sigma=1.10\times10^{-19}$)

3C 58 = SN 1181 [18].

d=3.2 kpc [1,2,3,4,5], d=2.2 kpc [6], d=2.6 kpc [7,19], d=3.2 kpc adopted.

$N_{HI}=1.8\times10^{21}$ cm^{-2} (2-10 keV) [1,8], $N_{HI}=2\times10^{21}$ cm^{-2} (0.5-4.5 keV) [9], $N_{HI}=3\times10^{21}$ cm^{-2} [3], $N_{HI}<3\times10^{21}$ cm^{-2} [20], $N_{HI}=(3.75\pm0.11)\times10^{21}$ cm^{-2} [25]; SI=2.2-2.4 [10], SI=2.19 (1.2-17.9 keV) [20], SI=1.73±0.07 [25]; kT=5.9±1.0 keV (1.2-17.9 keV) [20]; $F_x=1.9\times10^{-11}$ erg/cm^{2}s (0.5-10 keV) [10]; $L_x=1.5\times10^{33}$ erg/s (0.5-4.5 keV) [9], $L_x=8.7\times10^{33}$ erg/s (0.1-4 keV) at d=2.6 kpc [3], $L_x=2.4\times10^{34}$ erg/s (0.5-10 keV) at d=3.2 kpc [10], $L_x=2.9\times10^{34}$ erg/s (0.08-10 keV) at d=2.6 kpc [17]; $t=8\times10^2$ yr [3,4,8]; $B=3\times10^{-3}$ G [10]; $M_{Ej}=0.1$ $M_\odot$ [14,22].

Remarks: The SNR's radio flux increases 0.284% per year at 86 Hz [12] and 0.32% per year at 408 MHz [13].

3C 58 is older than SN 1181 [23,24].

Point Source RX J0201.8+6435 [3]

and radio pulsar J0205+6449 [16]

$\beta\sim0.14$; d=3.2 kpc [1,10,21], d=2.6 kpc [17]; P=0.06569 s [16,21], P=0.06568 s (from Chandra X-ray observations) [17]; $\dot{P}=1.939\times10^{-13}$ s/s [16,21], $\dot{P}=1.93\times10^{-13}$ s/s [17]; τ=5.38 kyr [17]; DM=140.7 cm^{-3}pc [16,21]; $F_{1400}\sim0.045$ mJy, $F_{800}\sim0.13$ mJy [16,21]; $L_x=2.06\times10^{32}$ erg/s (0.08-10 keV) [17], $L_x=1.5\times10^{33}$ erg/s (0.5-10 keV) at d=3.2 kpc [10], $L_x<1.8\times10^{32}$ erg/s (blackbody, 0.5-10 keV) [14], $L_x=6.7\times10^{32}$ erg/s [9], log L_x(NS)=33.0 [26,27]; $L_{1400}\sim0.5$ mJy kpc^2 [21]; $N_{HI}=(3\text{-}4)\times10^{21}$ cm^{-2} [10], $N_{HI}=3\times10^{21}$ cm^{-2} [17]; $F_x=1.2\times10^{-12}$ erg/cm^{2}s (blackbody, 0.5-10 keV) [10], $F_{1400}<0.15$ mJy [4,15]; $T=5.1\times10^6$ K (blackbody, 0.47 keV)

[10], kT=0.3 keV [3]; Log $L_{1400}<0.19$; SI=2.1±0.6 [21], SI(averaged, PWN)=1.92±0.11 (0.2-10 keV) [26,27], SI(pulsed+unpulsed)=1.73±0.15 (0.2-10 keV) [26,27]; $B\sim3\times10^{13}$ G [3].

Remarks: The X-ray radiation is ∼7% of the SNR's, the magnetodipole radiation is expected to be $\dot{E}\sim(0.1\text{-}4)\times10^{36}$ erg/s [3].

The pulsar in SN 1181 with an age of 820 years has an initial spin period P∼0.06 s [17].

The pulse fraction values for this pulsar are: <50% [3], <55% [10], and ∼100% [17].

The majority of equations of state yield an effective neutron star radius larger than 12 km for any range of masses for J0205+6449 [25].

For a radius at infinity of 12 km, the upper limit to the blackbody temperature is 1.13×10^{6} K, consistent with the limit obtained through spectral modeling for J0205+6449 [25].

The distance required to match the standard cooling predictions is ∼6 kpc, a value inconsistent with that inferred from HI measurements [25].

[1] Roberts et al. 1993; [2] Frail and Moffett 1993; [3] Helfand et al. 1995; [4] Lorimer et al. 1998; [5] Green 2004; [6] Braun et al. 1989; [7] Allakhverdiev et al. 1986; [8] Davelaar et al. 1986; [9] Becker et al. 1982; [10] Torii et al. 2000; [11] Neckel and Klare 1980; [12] Aller and Reynolds 1985a; [13] Green 1987; [14] Bocchino et al. 2001; [15] Brazier and Johnston 1999; [16] Camilo et al. 2002; [17] Murray et al. 2002b; [18] Clark and Stephenson 1976; [19] Green and Gull 1982; [20] Asaoka and Koyama 1990; [21] Camilo et al. 2002; [22] Chevalier 2003; [23] Stephenson and Green 2002; [24] Bietenholz et al. 2001; [25] Slane et al. 2002; [26] Gotthelf and Olbert 2002; [27] Gotthelf 2003.

SNR G132.7+1.3 (HB3, S, α=0.6, θ=80, F=45, $\Sigma=1.06\times10^{-21}$)

d=2.2±0.2 kpc (21 cm HI line) [1], d=2.2 kpc (interaction with surroundings suggests) [2], d=2.7 kpc [3], d=2.2 kpc (optical data), d=1.9 kpc (Σ-D), d=2.3 kpc adopted.

$N_{HI}\sim3\times10^{21}$ cm^{-2} [5], $N_{HI}=6.9\times10^{21}$ cm^{-2} [6], $N_{HI}=4.3\times10^{21}$ cm^{-2} [9]; E(B-V)=0.71 [7]; kT∼0.6 keV [5], kT=0.18 keV [6], kT=0.33 keV [9]; V=380 km/s [6]; $L_x=3.7\times10^{36}$ erg/s (0.3-3 keV) at d=2 kpc [6], $L_x=1.3\times10^{35}$ erg/s (0.3-2.2 keV) [6], $L_x=1.3\times10^{35}$ erg/s [3]; $n_0=0.27$ (preshock) [6]; $t=2.1\times10^{4}$ yr [6]; $E_0=3.1\times10^{50}$ erg [6].

Remarks: The central part of the SNR is bright in X-ray [5].

The SNR is interacting with the gas in the star formation region [1].

There are HII regions around the SNR [4].

The SNR is expanding in a dense medium [5].

Point Source PSR J0215+6218

$\beta\sim1$; d=2.3 kpc [8], d=3.2 kpc [10]; DM=84.22 pc/cm^{3} [10]; Log $L_{1400}=1.579$ [10]; P=0.5489 s [10]; $\dot{P}=6.61\times10^{-16}$ [10]; Log τ=7.12 [10].

Remark: Since the β value is large (PSR J0215+6218 seems to be on the boundary of the SNR) the probability of a connection between the SNR and the PSR is low.

[1] Routledge et al. 1991; [2] Green 2004; [3] Braun et al. 1989; [4] Gray et al. 1999; [5] Rho et al. 1998; [6] Galas et al. 1980; [7] Fesen et al. 1995; [8] Lorimer et al. 1998; [9] Rho and Petre 1998; [10] Guseinov et al. 2004.

SNR G156.2+5.7 (S, α=0.5, θ=110, F=5, $\Sigma=6.22\times10^{-23}$)

Remark: The data from ROSAT X-ray satellite were examined under consideration of the Sedov model. Taking into account the information found from this analysis and the fact that $N_{HI}=8.8\times10^{20}$ cm^{-2}, d=3 kpc [1,3].

d=1.3 kpc [4], d=2.3 kpc (Σ-D), d=2 kpc adopted

D=100 pc if d=3 kpc [4]; $N_{HI}=9\times10^{20}$ cm^{-2} [2,3].

Remarks: In the direction of this SNR, although no star formation region is present, there is an open cluster with unknown distance. The height of the SNR from the Galactic plane (i.e. z) is exceeding 100 pc for all the possible distance values (e.g. for d=1.3 kpc z=130 pc). The fact that there is no star formation region in the direction of this SNR and the distance of the SNR from the Galactic plane being large (z>130 pc) show that the SNR must be in a low-density medium. So, its diameter (and its distance) being larger than the diameter (and distance) value found from the Σ-D relation is not realistic. In actuality, the distance of the SNR may be less than the value found from the Σ-D relation that d=2 kpc is adopted.

[1] Pfeffermann et al. 1991; [2] Yamauchi et al. 1993; [3] Reich et al. 1992; [4] Yamauchi et al. 1999.

SNR G160.9+2.6 (HB9, S, α=0.6, $\theta=140\times120$, F=110, $\Sigma=9.85\times10^{-22}$)

d=1.7 kpc [1], d<4 kpc [2], d=1.2 kpc (Σ-D), d=1.2 kpc adopted (since, there is no star formation region in this direction).

[1] Braun et al. 1989; [2] Green 2004.

SNR G166.0+4.3 (VRO 42.05.01, S, α=0.4?, $\theta=55\times35$, F=7?, $\Sigma=5.47\times10^{-22}$)

The central part of the SNR is bright in X-ray [6,7,8].

Remark: d=5 kpc is very small for this SNR [1].

d=4.5 kpc (HI indicates) [2], d=3 kpc [3,4], d=3.9 kpc (Σ-D), d=3.8 kpc adopted.

$N_{HI}=2.9\times10^{21}$ cm^{-2} [5].

Remarks: There is no known star formation region at this distance in this direction, but the outer arm of the Galaxy is passing through in this direction. There is AUR OB2 association (l = 172° - 174°, b = −1°.8 - +2°.0) at 3.2 kpc. At 4.5 kpc the distance of the SNR from the Galactic plane is 340 pc. So, the density of the ambient medium of the SNR is expected to be low. A distance value of 3.9 kpc is found from the Σ-D relation that we have adopted d=3.8 kpc.

The SNR is expanding in a low-density cavity [8].

[1] Landecker et al. 1989; [2] Green 2004; [3] Allakhverdiev et al. 1986; [4] Braun et al. 1989; [5] Guo and Burrows 1997; [6] Pineault et al. 1987; [7]

Rho et al. 1994; [8] Fesen et al. 1997.

SNR G166.2+2.5 (OA 184, S, α=0.5, θ=90×70, F=11, $\Sigma=2.63\times10^{-22}$)

d=8 kpc [1,2], d=4.5 kpc [3], d=2 kpc [4], d=2.5 kpc (Σ-D), d=2.7 kpc adopted.

Remark: Since, there is no star formation region in this direction at these distances, the position of this SNR in the Σ-D diagram can not be very high above the Σ-D relation.

[1] Routledge et al. 1986; [2] Green 2004; [3] Landecker et al. 1989; [4] Braun et al. 1989.

SNR G179.0+2.6 (S?, α=0.4, θ=70, F=7, $\Sigma=2.15\times10^{-22}$)

d=2.9 kpc (Σ-D), d=2.9 kpc adopted.

SNR G180.0-1.7 (S147, S, α-varies, θ=180, F=65, $\Sigma=3.02\times10^{-22}$)

d=0.8 kpc [1], d=1 kpc (using the 'prints' of this SNR on the spectra of the stars in front of and behind the SNR) [2], d=1.1 kpc (Σ-D), d=1 kpc adopted.

t$\sim10^5$ yr [4].

Remark: d=1 kpc given by [2] is relatively much more reliable, because the distances of the stars are used in this method in order to find the distance of the SNR.

The optical expansion velocity V≅80 km/s [3].

Point Source PSR J0538+2817 [4]

(Radio and X-ray Pulsar)

$\beta\cong0.3$ [4]; d=1.2 kpc [4,5]; P=0.143 s [4]; $\tau=6\times10^5$ yr [4,5]; kT(blackbody)=0.159±0.0017 keV [4], T(blackbody)=$(2.12^{+0.04}_{-0.03})\times10^6$ K [5]; $N_{HI}=(3.1\pm0.2)\times10^{21}$ cm^{-2} [4], $N_{HI}=2.5\times10^{21}$ cm^{-2} [5]; F_x(0.5-5 keV,unabsorbed)$\cong1.6\pm0.4\times10^{-14}$ erg/cm^{2}s (for the full torus) [4]; L$\cong2\times10^{33}$d$^2_{1.2}$ erg/s (thermal luminosity) [4]; V=140 km/s [4].

Remarks: There is evidence for a faint PWN surrounding PSR J0538+2817 in CXO-ACIS imaging [4].

Comparison of the SNR age, X-ray cooling age and characteristic age suggests a birth spin period greater than or approximately equal to 130 ms [4].

The PWN position angle supports the connection with S147 [4].

PSR J0538+2817 is relatively slow with V≅140 km/s and P$_0$≅130 ms [4].

The luminosity of $\sim2\times10^{33}$d$^2_{1.2}$ erg/s, interpreted as full surface cooling agrees well with the flux in standard cooling scenarios near 10^5 yr [4].

At P$_0\sim$130 ms (t$_5\sim$1) this PSR has one of the slowest initial spins known [4].

Pulsed X-rays have been detected by XMM-Newton from the source at a frequency which is consistent with the predicted radio frequency [5].

The pulse profile is broad and asymmetric with a pulse fraction of 18±3% [5].

The source is believed to be associated with the SNR S147 as the distance to the pulsar and the SNR are consistent, as are their ages [5].

The spectra of PSR J0538+2817 can be well-fit with a blackbody. The value for the emitting radius indicates that the emission is from a region which is smaller than the surface of the neutron star, i.e. a hot spot. There is no evidence for a non-thermal component in the spectra of PSR J0538+2817 [5].

Whether the mechanism for X-ray emission is via non-thermal magnetospheric synchrotron or thermal emission from the hot surface is not clear, as the broad asymmetric pulse shape found for PSR J0538+2817 does not favor either model. However, the absence of a power law component may indicate that the emission is thermal in origin [5].

[1] Braun et al. 1989; [2] Phillips et al. 1981; [3] Kirshner and Arnold 1979; [4] Romani and Ng 2003; [5] McGowan et al. 2003.

SNR G182.4+4.3 (S, α=0.4, θ=50, F=1.2, $\Sigma=7.22\times10^{-23}$)

d=4.8 kpc (Σ-D), d=3.5 kpc adopted.

SNR G184.6-5.8 (Crab, SN 1054, F, α=0.30, θ=7×5, F=1040, $\Sigma=4.47\times10^{-18}$)

d=2 kpc (proper motions + radial velocities) [1], d=2 kpc adopted.

$N_{HI}=3\times10^{21}$ cm^{-2} [5]; E(B-V)=0.52 [5]; m$_R$=3.1 [5]; $\Sigma<4.3\times10^{-22}$ Wm^{-2}Hz^{-1}ster^{-1} (if the SNR has a shell) [2]; E$\sim10^{49}$ erg [5]; L$_x=10^{37}$ erg/s (2-10 keV) [7], L$_x=2.5\times10^{37}$ erg/s [8].

Remarks: F continuously decreases 0.167±0.015% per year [3,4].

The 1550 A line of CIV ion shows the possibility that there may be a shell moving with a speed of 2500 km/s. The lower limit for the mass of this shell may be 0.3 M$_\odot$ and its kinetic energy may possibly be 1.5×10^{49} erg [5].

The radio size of the Crab nebula is $\sim$3 times larger than its X-ray size [9,10].

Cas A, Kepler and Crab have a low Hα/|NII| ratio and a high density, while old, decelerated SNRs have Hα/|NII| ratio of about 2.0 and a |SII| ratio close to the low density limit ($\leq$100 cm^{-3}). HII regions have a Hα/|NII| ratio higher than SNRs have and a density generally lower than 1000 cm^{-3} [11].

Point Source J0534+2200 (radio, optical,

X-ray, and γ-ray pulsar)

$\beta\sim0.1$ [6]; d=2 kpc [12]; DM=56.791 pc/cm^3 [12]; P=0.0335 s [12]; $\dot{P}=4.21\times10^{-13}$ [12]; log L$_{1400}$=1.748 [12], log L$_x$(NS)=35.9 [13], log L$_x$(PWN)=37.3 [13]; SI(averaged, PWN)=2.11±0.05 (0.2-10 keV) [13,14], SI(pulsed+unpulsed)=1.63±0.09 (0.2-10 keV) [13,14], SI(pulsed)=1.86±0.07 (0.2-10 keV) [13,14]; log τ=3.10 [12].

[1] Green 2004; [2] Frail et al. 1995; [3] Aller and Reynolds 1985b; [4] Woltjer et al. 1997; [5] Sollerman et al. 2000; [6] Lorimer et al. 1998; [7] Davelaar et al. 1986; [8] Becker et al. 1982; [9] Bietenholz and Kronberg 1990; [10] Weisskopf et al. 2000; [11] Sabbadin 1976; [12] Guseinov et al. 2004; [13] Gotthelf and Olbert 2002; [14] Gotthelf 2003.

SNR G189.1+3.0 (IC 443, C, α=0.36, θ=45, F=160, $\Sigma=1.19\times10^{-20}$)

d=1.5 kpc [1,2,3], d=1.5-2 kpc (from the interaction with the molecular cloud which includes the SNR) [13], d=0.7-1.5 kpc (mean optical velocity suggests) [13], d=1.7 kpc (Σ-D), d=1.5 kpc adopted.

N_{HI}=(1-3)$\times 10^{21}$ cm^{-2} [3]; F_X=9$\times 10^{-11}$ erg/cm^{2}s (2-20 keV) [14]; kT=0.9 keV [4,14]; Average V=65-100 km/s [10]; L_X=2.1$\times 10^{35}$ erg/s (0.2-4 keV) if d=1.5 kpc [3], $L_X \sim 2\times 10^{34}$ erg/s (2-10 keV) if d=1.5 kpc [4]; MC [7,8]; MS [17]; n=10-20 cm^{-3} (the average value in front of the SNR) [10], n>200 cm^{-3} (dense clumps of shocked HI gas) [7]; t=10^3-5$\times 10^3$ yr [14]; B=500 μG [4].

Remarks: Since the spectrum of this SNR in the 0.5-10 keV band is known [4], its luminosity value in the 0.2-4 keV band given in [3] can be used if d=1.5 kpc.

The cosmic ray in the shock wave is seen to be accelerated up to TeV energies [4,5,6].

Not an H_2O maser source [9].

In the near infrared, the SNR's luminosity is 1.3$\times 10^{36}$ erg/s [10].

In the northeastern part V$\cong$100 km/s and the density in front of the SNR is 10-10^3 cm^{-3} [10].

V$\cong$30 km/s and in the southern part the density in front of the SNR is 10^4 cm^{-3} [10].

For some parts of the SNR, the synchrotron radio spectrum is very flat: α<0.24 [11].

In the direction of the SNR, at d=1.34-1.65 kpc, there is Gem OB1 association which includes 16 massive stars [15,16].

The gamma-ray flux, E>100 MeV, from the region of SNR IC 443 is (5.0$\pm$0.4)$\times 10^{-7}$ photons/cm^{2}s [18].

The X-ray temperature and luminosity are indicative of an intercloud shock velocity $\leq$1200 km/s in material with density about 0.3 cm^{-3} [19]. CO data indicate H_2 densities between 10^2–10^3 cm^{-3}. The shock will propagate into such a cloud with a velocity <100 km/s, consistent with the observed OH and HI velocities [7].

Point Source CXOU J061705.3+222127 [12]

N_{HI}=1.3$\times 10^{21}$ cm^{-2} [4,12]; $F_{0.37}\cong$200 mJy; kT=0.71 keV (blackbody) [12]; V=250 km/s [12]; L=6.5$\times 10^{31}$ erg/s [12].

Remarks: There is a point X-ray source in this region [4].

The radio flux of the point X-ray source at 327 MHz is not higher than 2 mJy [12].

The soft X-ray radiation of the point source is seen more clearly for kT<2.1 keV [12]

Centre of the radio flux of the compact synchrotron nebula is 6″ apart from the northeastern part of the point X-ray source [12].

From the positions of the point source and the center of the SNR: $\beta \sim 0.6$.

[1] Fesen 1984; [2] Allakhverdiev et al. 1986; [3] Asaoka and Aschenbach 1994; [4] Keohane et al. 1997; [5] Sturner et al. 1997; [6] Asvarov et al. 1990; [7] Denoyer 1979; [8] Frail et al. 1996; [9] Claussen et al. 1999; [10] Rho et al. 2001; [11] Kovalenko et al. 1994; [12] Olbert et al. 2001; [13] Green 2004; [14] Wang et al. 1992; [15] Melnik and Efremov 1995; [16] Blaha and Humphreys 1989; [17] Claussen et al. 1997; [18] Esposito et al. 1996; [19] Malina et al. 1976.

SNR G189.6+3.3

d=1.5 kpc adopted.

N_{HI}=(5-7)$\times 10^{21}$ cm^{-2} [1].

Remarks: This SNR has been found by the ROSAT X-ray satellite. The SNR has not been examined in the radio band. Since, this SNR is in the same region as SNR IC 443 and interacting with the same clouds, its distance must be 1.5 kpc [1].

[1] Asaoka and Aschenbach 1994.

SNR G192.8-1.1 (PKS 0607+17, S, α=0.6?, θ=78, F=20?, Σ=4.95$\times 10^{-22}$)

d=2.3 kpc (Σ-D), d=2.3 kpc adopted.

SNR G205.5+0.5 (Monoceros, S, α=0.5, θ=220, F=160, Σ=4.98$\times 10^{-22}$)

d=0.8 kpc (from optical data) [1], d=1.6 kpc (from radio data) [1], d=1.6 kpc [2], d=0.8 kpc (Σ-D), d=1 kpc adopted.

Remarks: Surface brightness may be as low as (1.2$\pm$0.05)$\times 10^{-22}$ W m^{-2} Hz^{-1} sr^{-1} and the angular diameter is 4.2°$\pm$0.5° [3]. In such a case, distance of the SNR may be a bit larger.

Near the SNR there are molecular clouds at distances 0.8-0.95 kpc [4]. So, the location of this SNR in such a dense region is in accordance with a distance of about 1 kpc.

[1] Green 2004; [2] Odegard 1986; [3] Urosevic and Milogradov-Turin 1998; [4] Oliver et al. 1996.

SNR G206.9+2.3 (PKS 0646+06, S?, α=0.5, θ=60$\times$40, F=6, Σ=3.76$\times 10^{-22}$)

d=3.7 kpc (Σ-D), d=3.4 kpc adopted.

SNR G260.4-3.4 (Puppis A, S, α=0.5, θ=60$\times$50, F=130, Σ=6.52$\times 10^{-21}$, Oxygen-rich)

d=1.5 kpc [1], d=2 kpc [2], d=2.2$\pm$0.3 kpc (HI line) [3,4], d=0.5-1.9 kpc (OH absorption/emission in the vicinity implies) [4], d=1.9-2.5 kpc [10], d=$1.3^{+0.6}_{-0.8}$ kpc [17], d=1.8 kpc (Σ-D), d=2 kpc adopted.

N_{HI}=(2-6)$\times 10^{21}$ cm^{-2} [9], N_{HI}=(2.9-4.7)$\times 10^{21}$ cm^{-2} [10,12], N_{HI}=(2-6)$\times 10^{21}$ cm^{-2} [11], N_{HI}=1.4$\times 10^{21}$ cm^{-2} [13]; kT=0.26-0.52 keV [11,13], T=3$\times 10^6$ K (0.25 keV) [1]; V=650 km/s (for the shock) [12], V=160-180 km/s (for the filaments) [12], V=1870 km/s (for the shock) [7], V=1300 km/s (for the filaments) if d=1.9 kpc [7], V_s=9300 km/s [21]; L_X=10^{35} erg/s (0.2-4 keV) at d=1.5 kpc [1]; $n_0\cong$0.4-0.5 cm^{-3} (average value in front of the SNR) [3], n=100 cm^{-3} (where X-ray radiation is coming from) [1], n_0=10-1000 cm^{-3} (for the clouds) [3], n_0=3 cm^{-3} (average value in front of the SNR) [11], n_0=1 cm^{-3} [13]; t=3.4$\times 10^3$ yr [5], t=3.7$\times 10^3$ yr [1,6,7,8].

Remarks: For the B0.7Ib type star HD 69882 (l = 259°.5, b = −3°.9, d=2.1 kpc), which is in the same region as Puppis A, N_{HI}=1.6$\times 10^{21}$ cm^{-2} [14].

Puppis A is in the direction of Vela X and it is below the geometrical plane of the Galaxy like the star formation regions in this part of the Galaxy.

Puppis A, unlike Vela, is not exactly in the direction of the star formation regions. Distances of the OB associations in the star formation region do not exceed 1.5-1.8 kpc [15,16].

Distribution of neutral hydrogen (HI) at 21 cm in the Galaxy show that the cold clouds in the direction of Puppis A have in general distances less than 1.5-1.8 kpc [1].

Diameter of this SNR has reached to 32 pc and the SNR has gone out of the HII region which the SNR was once in. Eastern part of the remnant is interacting with a neutral hydrogen cloud [3].

There are OH clouds in front of the SNR, but no sign of interaction of the SNR with these clouds has been found [17].

The SNR is N-, O-, and Ne-rich [2].

Point Source RX J0822-4300
(J0821-4300 [22]) [18]

$\beta=0.25$ [8]; d=2 kpc [2]; $R\geq23.6^{m}$ [2], $B>25^{m}$ [2], $R>26^{m}$ [20]; $N_{HI}=(4\text{-}8)\times10^{21}$ cm^{-2} (0.1-2.4 keV) [2]; SI=4.3 (0.1-2.4 keV) [2]; $F_{1460}<0.75$ mJy [2], $F_{1400}<0.3$ mJy [8,20]; $F_{x}=3\times10^{-12}$ erg/cm^{2}s (0.1-2.4 keV) [2,8]; $L_{x}=1.2\times10^{33}$ erg/s (0.1-2.4 keV) [2,8]; kT=0.3 keV (blackbody) [2,24], kT=0.15 keV (blackbody) [10], kT=0.44 keV [23]; kT=0.6 keV (Bremsstrahlung) [2]; V≅1000 km/s [2].

Remarks: The region ($\leq30''$) around the pulsar in the SNR has been examined. Upper limit on the radio luminosity of a possible pulsar-powered nebula is three orders of magnitude less than what would be expected if RX J0822-4300 was an energetic young radio pulsar beaming away from us. RX J0822-4300 has very different properties compared to most of the young radio pulsars [19].

No pulse in the 0.003–3000 seconds range [22].

The pulse fraction values for this pulsar are: <20% [8] and <10% [22].

No PWN has been found [19].

No sign of a PWN has been found from observations with Chandra HRC [22].

[1] Braun et al. 1989; [2] Petre et al. 1996; [3] Reynoso et al. 1995; [4] Green 2004; [5] Winkler et al. 1988; [6] Kaspi et al. 1996; [7] Dechristopher and Winkler 1994; [8] Brazier and Johnston 1999; [9] Winkler et al. 1981b; [10] Zavlin et al. 1999; [11] Winkler et al. 1981a; [12] Blair et al. 1995; [13] Berthiaume et al. 1994; [14] Diplas and Savage 1994; [15] Melnik and Efremov 1995; [16] Humphreys 1978; [17] Woermann et al. 2000; [18] Pavlov et al. 1999; [19] Gaensler et al. 2000; [20] Becker et al. 1995; [21] Crawford et al. 2002a; [22] Pavlov et al. 2002a; [23] Pavlov et al. 2002b; [24] Gotthelf et al. 1997.

SNR G261.9+5.5 (S, $\alpha=0.4$?, $\theta=40\times30$, F=10?, $\Sigma=1.25\times10^{-21}$)

d=4.3 kpc (Σ-D), d=3.3 kpc adopted.

SNR G263.9-3.3 (Vela, C, α-varies, $\theta=255$, F=1750, $\Sigma=4.05\times10^{-21}$)

d=0.3 kpc (parallax) [1], d=250±30 pc [1,2], d∼280 pc [3], d=0.5 kpc (Σ-D), d=0.4 kpc adopted.

$V_{sh}=110$ km/s [8], $V_{expa}=170$ km/s [11]; kT=0.086-0.17 keV [10]; t=1.1×10^{4} yr [6]; E=$(1\text{-}2)\times10^{51}$ erg [6]; $A_{V}=0.56^{m}$ [11]; $L_{x}=0.01\times10^{35}$ erg/s [12], $L_{x}=0.07\times10^{35}$ erg/s [13], $L_{x}=0.055\times10^{35}$ erg/s (2-10) [14]; $B\sim6\times10^{-5}$ G [7], $B=(50\text{-}85)\times10^{-6}$ G [8].

Remarks: Recent estimates of the distance of Vela SNR are as follows: d=0.25 kpc [4], d=0.25±0.03 kpc [2], d∼0.28 kpc [3], and d=0.25±0.03 kpc [6]. In estimating the distance, one should also consider that Vela SNR expands in a dense environment. Its magnetic field is $B\sim6\times10^{-5}$ G [7] and its explosion energy is $(1\text{-}2)\times10^{51}$ erg [6]. Of course these values have really large errors, however, they themselves are large, too. If we take into account all of these values, in the Σ-D diagram, it is not acceptable to put Vela at the same position with SNR G327.6+14.6 (remnant of Ia-type supernova explosion at 500 pc above the Galactic plane [17]) which expands in a low-density medium. Thus, in the Σ-D diagram, Vela must be put close to the positions of the other SNRs which expand in dense media.

The stars in front of and behind Vela and the stars interacting with Vela have been identified. The distance of Vela is 250±30 pc [6].

There are several OB-associations in the direction of Vela SNR.

None of the open clusters in the direction of Vela SNR has a distance as small as 0.25 kpc. For 2 of these open clusters the distances are well known: Pismis 4 (l = 262°.7, b = −2°.4) is 0.6 kpc distant and Pismis 6 (l = 264°.8, b = −2°.9) is 1.6 kpc distant from the Sun [5].

In the direction of Vela SNR, none of the young open clusters and OB associations have distances as small as 0.25 kpc [18,19,20]. Distance of the open cluster Pismis 4 (l = 262°.7, b = −2°.4), which belongs to the nearest OB association Vela OB2, is 0.6 kpc [20].

Since, progenitors of SNRs (or pulsars) are massive stars, one would expect Vela to be closer to the star formation region, instead of having a distance value of 0.25 kpc.

Low-energy γ-ray radiation has been observed from Vela SNR. This shows that, in the 0.061-0.4 MeV range, the radiation is power-law with SI = -1.6±0.5 and electrons with energies $>3\times10^{14}$ eV are present within this SNR [7].

Two parts of the matter which was thrown out during the supernova explosion rapidly moved in different directions and they are out of the shell. In these nebulae, abundances of O and Si are 0.34 and 3 times the abundances in the Sun, respectively. The thrown-out matter is cooling in the last $\sim10^{4}$ yr. Such thrown-out matter has been encountered also in other very young SNRs (for example, in SNRs Tycho and Cas A). For the SNR Cas A, space velocities of the matter thrown out during the explosion are 4000-9000 km/s [9].

Point Source PSR J0835-4510

$\beta=0.29$ [15], $\beta=0.3$ [16]; d=0.45 kpc [21]; DM=67.87 pc/cm^{3} [21]; Log $L_{1400}=2.306$ [21]; P=0.0893 s [21]; $\dot{P}=1.25\times10^{-13}$ [21]; Log $\tau=4.05$ [21]; log L_{x}(NS)=31.2 (0.2-10 keV) [22], log L_{x}(PWN)=32.6 (0.2-10 keV) [22]; SI(averaged, PWN)=1.50±0.04 (0.2-10 keV) [22,23], SI(pulsed+unpulsed)=0.95±0.24 (0.2-10 keV)

[22,23], SI(pulsed)=0.93±0.26 (0.2-10 keV) [22,23].
Remarks: If the distance value of 0.45 kpc is accepted for Vela, then the average electron density along the line of sight must be $n_e=0.172$ cm^{-3}. The PSR with the second largest n_e value ($\sim$0.113 cm^{-3}) belongs to PSR J1302-6350 (l = 304°.2, b = –0°.9, companion is Be type star, d=1.3 kpc, variable wind in the environment). The next largest n_e value (0.107 cm^{-3}) belongs to PSR J1644-4569 (l = 339°.2, b = –0°.2). Since, the flux of PSR J1644-4569 at 1400 MHz is larger than the flux of any other known PSR, we can estimate its distance to be not more than 4.5 kpc. The average value of n_e for the rest of the PSRs is around 0.04. So, it is impossible to accept a distance value of 0.25 kpc for Vela PSR and Vela SNR. We can at most reduce the former distance estimate of 0.5 kpc down to 0.4 kpc.

[1] Green 2004; [2] Cha et al. 1999; [3] Bocchino et al. 1999; [4] Ogelman et al. 1989; [5] Ahumada and Lapasset 1995; [6] Danks 2000; [7] deJager et al. 1996; [8] Bocchino et al. 2000; [9] Miyata et al. 2001; [10] Kahn et al. 1985; [11] Raymond et al. 1997; [12] Becker et al. 1982; [13] Braun et al. 1989; [14] Davelaar et al. 1986; [15] Lorimer et al. 1998; [16] Allakhverdiev et al. 1997; [17] Hamilton et al. 1997; [18] Efremov 1989; [19] Berdnikov and Efremov 1993; [20] Aydin et al. 1997; [21] Guseinov et al. 2004; [22] Gotthelf and Olbert 2002; [23] Gotthelf 2003.

SNR G266.2-1.2 (S, α=0.3?, θ=120, F=50?, $\Sigma=5.23\times10^{-22}$)

d=200 pc [1,4], d≤1 kpc [8], d=1.5 kpc (Σ-D), d=1.3 kpc adopted.

$N_{HI}=3.7\times10^{21}$ cm^{-2} [3], $N_{HI}=1.1\times10^{22}$ cm^{-2} [3]; SI=3.6 (1.8-10 keV) [2], SI=2 [3], SI=2.6 [3]; $F_x\sim6\times10^{-13}$ erg/cm^{2}s [2], $F_x=2\times10^{-12}$ erg/cm^{2}s (0.5-10 keV) [3], $F_x=6.7\times10^{-12}$ erg/cm^{2}s (0.5-10 keV) [3]; kT=0.5 keV (for the shell) [3], kT=1.3 keV [2], kT=0.7 keV (for the central part) [3]; t=680 yr [1,4].

Remarks: γ-ray radiation (1.156 MeV) of Titanium 44 from this SNR has been observed. Since, the half-life of this isotope is 90 years, the SNR must be very young [1,2,4].

If this SNR had been formed due to a nearby supernova explosion, the explosion itself should have absolutely been observed, and also, if there had been a neutron star in this SNR, it should have been observed in the X-ray band (as it must be a very young and nearby neutron star) [2].

Non-thermal X-ray radiation is dominant and this shows that there is very strong accelerating mechanism. Radiative properties of this SNR are similar to the SNRs SN1006 and G347.3-0.5. It is known that there are giant MCs at 1-2 kpc in the direction of Vela. In this direction, beyond 1-2 kpc, $N_{HI}>10^{22}$ cm^{-2}, so that, d=1 kpc [3,5].

The radiation coming from the shell of this SNR is not thermal and the absorption shows that distance of the SNR is 1-2 kpc. So, age of the SNR must be a few times 10^3 years [2,3,5].

For northeastern, northwestern and western parts of the SNR, the N_{HI} values are 5.3×10^{21}, 4×10^{21} and 1.4×10^{21} cm^{-2} and the F_x values are 2.9×10^{-11}, 4.2×10^{-11} and 2.1×10^{-11} erg/cm^{2}s, respectively [3].

Point Source DRQNS SAX J0852.0-4615 [2]

$\beta\sim0.1$; P=0.301 s [7]; $\tau\sim$1-3 kyr [6], $\tau\sim$1 kyr [7]; $V\cong15^m$ [2]; $F_x/F_{radio}\geq0.1$ [2]; SI=2.7 [6]; kT=0.53 keV [6], kT=0.4 keV (0.5-10 keV) [6], kT=0.46 keV [7]; $N_{HI}=8\times10^{21}$ cm^{-2} (for power-law) [6], $N_{HI}=3\times10^{21}$ cm^{-2} (for blackbody) [6], $N_{HI}=4\times10^{21}$ cm^{-2} (0.4-6 keV) [6]; $F_x=10^{-12}$ erg/cm^{2}s (0.5-10 keV) for blackbody [6], $F_x=1.4\times10^{-12}$ erg/cm^{2}s (0.5-10 keV) for the power-law [6], $F_x=2\times10^{-12}$ erg/cm^{2}s (0.4-6 keV) [6]; $L_x\sim10^{32}$-10^{34} erg/s (0.5-10 keV) at d=1 kpc [6].

Remarks: The nonthermal X-ray radiation from the SNR may be coming from the synchrotron nebula near the neutron star [2].

This SNR must have been born as a result of the evolution of a massive star and the SNR is inside a cavity. If the distance is 1 kpc, then V=5000 km/s. So, distance of the SNR must be much less than 1 kpc. The compact X-ray source at the central part of the SNR may be a massive star. The information about the distance and the central point source are dubious [3].

Optical counterpart as B>22.5 and R≥21.0 [6].

Similar to Cas A SNR, this SNR also has a dim radio quiet neutron star [6].

[1] Aschenbach 1998; [2] Mereghetti 2001b; [3] Slane et al. 2001; [4] Aschenbach et al. 1999; [5] Tsunemi et al. 2000; [6] Pavlov et al. 2001; [7] Pavlov et al. 2002b; [8] Crawford et al. 2002b.

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ПОСМАТРАЧКИ ПОДАЦИ О ГАЛАКТИЧКИМ ОСТАЦИМА ЕКСПЛОЗИЈА СУПЕРНОВИХ ЗВЕЗДА: II. ОСТАЦИ СУПЕРНОВИХ ЗА $l = 90° - 270°$

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Стручни рад

Сакупили смо све расположиве податке из литературе о Галактичким остацима експлозија супернових звезда. У овом раду смо представили податке из свих спектралних опсега, о остацима супернова који се налазе у интервалу Галактичке лонгитуде од 90° до 270°. Установили смо вредности растојања до остатака супернових испитујући одговарајуће даљине. Подаци за различите типове неутронских звезда повезаних са остацима супернова су такође приказани. Осим што су приказани подаци, дати су и коментари других аутора, као и наши сопствени, а у вези података и неких особина остатака супернова и тачкастих извора.