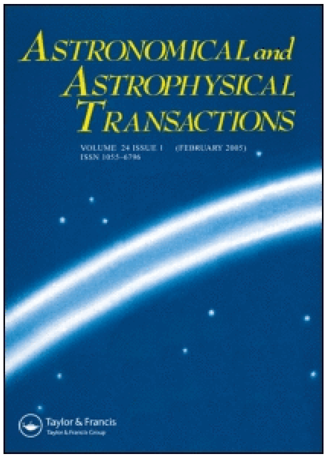

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STROMGREN ZONES OF SUPERNOVAE

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STROMGREN ZONES OF SUPERNOVAE

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The minimum emission measures observed in the directions toward pulsars or supernova remnants are inversely proportional to the pulsar or supernova remnant ages. It is concluded that the ionized gas in the vicinities of a number of pulsars and supernova remnants was formed during the first 1000 years after supernova explosions.

Keywords: Interstellar medium; Pulsars; Supernovae remnants

It is thought usually that pulsars form as a result of evolution of massive early-type stars, which are born in dense molecular clouds. This suggests that we should expect the volume density of pulsars to be correlated with concentration of interstellar gas. Such correlation has been detected between the surface density of pulsars on the celestial sphere N/S, where N is the number of pulsars in a particular area S (in square degrees) and emission measure EM (Pynzar', and Shishov, 2001). However old pulsars can move far from the place of their birth during their lifetimes and we must expect a correlation between young pulsars and H II regions. To test this hypothesis, a relation between ages of pulsars and the emission measure EM in the directions toward them was investigated in the paper (Pynzar', and Shishov, 2001). The results are shown in Figure 1 by solid circles, where the horizontal axis plots pulsar age t (in years) and the vertical axis plots the emission measure EM in the area of sky onto which the pulsar is projected. At ages less than 10^6 years, we can clearly see a lower boundary line for the plotted points. Unfortunately pulsar data are deficient for pulsar ages less than 10^4 years.

To improve statistics for small ages we used data for supernova remnants (SNR) with Galactic latitude $b \leq 1.5^\circ$ (Pynzar', and Shishov, 2002, Milne, 1987, Clark, and Caswell, 1976, Lozinskaya, 1986, Rho, 1995). We believe that the selected objects are associated with type II supernova explosions. In Figure 1 the data for emission measure EM to the directions near the supernova remnants in the dependence on the remnants ages are shown by crosses. We see the good correspondence between the pulsar and SNR data. Total diagram shows clearly seen lower boundary that can be described by the next equation

$$EM_{\min} \cong 1000(t_0/t\,\text{years})\text{pc}\cdot\text{cm}^{-6}, \quad t \geq t_0 = 1000 \text{ years} \tag{1}$$

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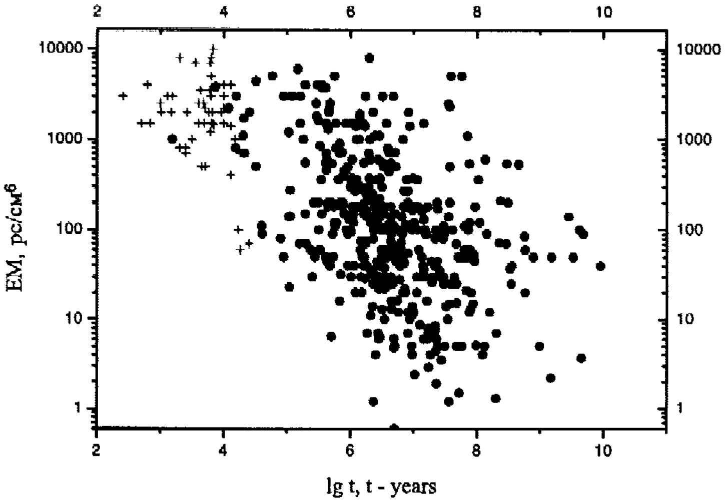

FIGURE 1 The emission measure EM of the Galactic background in the directions of II type supernovae remnants (crosses) and pulsars (solid circles) as a dependence on age of the objects t.

We clearly see that $EM_{\min}$ increases with decreasing t up to $t = 1000$ years. Therefore for the objects near this lower boundary the main part of radiation that forms the H II region is produced during the first one thousand years after a supernova explosion.

To investigate the structure of the ionized gas, we separated pulsars in the boundary area near the Eq. (1) and determined their dispersion measures $DM_{\min}$. A plot of $DM_{\min}$ as a function of pulsar age, t is shown in Figure 2 by open circles. Then we used data for pulsars closely-spaced to supernova remnants at distances less than 1°. These data are shown

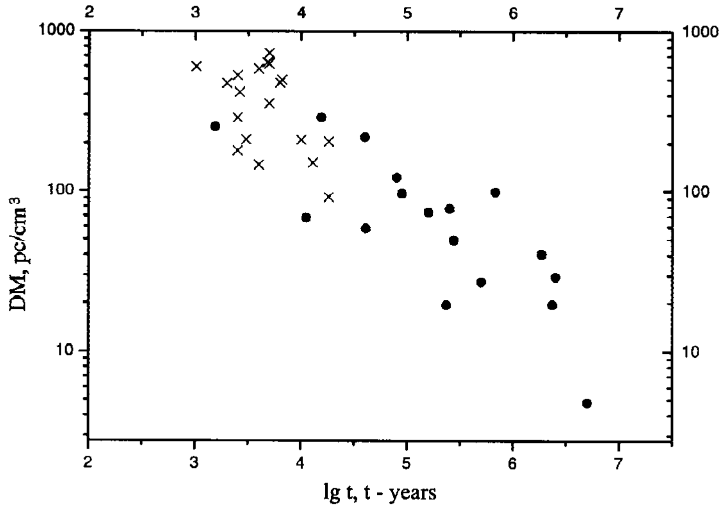

FIGURE 2 Dependence of the dispersion measure DM of pulsars on the pulsar ages t for pulsar near lower boundary in Figure 1 (solid circles). Crosses denote data for pulsars nearby supernova remnants as a dependence on age of the SNR.

by crosses. For this case t is the age of the supernova remnant. The experimental data can be approximated by the equation

$$DM_{\min} \cong DM_{SN} + DM_{\text{ground}}$$
$$DM_{\text{ground}} \cong 30/, \text{pc} \cdot \text{cm}^{-3}$$
$$DM_{\min} \cong 200/(t_0/t)^{1/2} \text{pc} \cdot \text{cm}^{-3} \qquad (2)$$

Using the Eqs. (1) and (2) we will derive the size of the region of ionized gas $L \cong 200$ pc and the electron density $N_e \cong 2(t_0/t)^{1/2}$ cm^{-3}. When estimating EM, we took the background electron temperature $T_e \cong 10,000$ K. If we assume that $T_e = 10^6$ K, the value of EM in the Eq. (1) must be increased by a factor 5. For this case $L \cong 30$ pc and the electron density $N_e \cong 10(t_0/t)^{1/2}$ cm^{-3}.

We can identify this type of H II region with Stromgren zone formed by supernova. The energy of such zone is order of 10^{51} ergs. A possible source of this energy is hot emission losses of supernova envelope after it's collision with the envelope formed due to the mass losses of the presupernova at the stage of supergiant.

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