Non-pulsed emission from the binary system PSR B1259-63

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Abstract. PSR B1259-63 is the only known binary system with a radio pulsar from which the non-pulsed radio and X-ray emission was detected. The companion star in this system is a Be star SS 2883. A rapidly rotating radio pulsar is expected to produce a wind of relativistic particles. Be stars are known to produce highly asymmetric mass loss. Due to the interaction of the pulsar wind and the Be star wind the system of two shocks between the pulsar and the Be star forms. In this paper we show that the observed non-pulsed radio emission from the system is a result of the synchrotron emission of the relativistic particles in the outflow beyond the shock wave and that the non-pulsed X-ray emission is due to the inverse Compton scattering of the Be star photons on this particles.

Keywords: pulsars:individual:PSR B1259-63

1. Introduction

PSR B1259-63 is the only known binary system with a radio pulsar from which the non-pulsed radio and X-ray emission was detected. The radio pulsar PSR B1259-63 of spin period $P=47.76\text{ms}$ was discovered in a high-frequency survey of the southern Galactic plane. Spindown luminosity is equal to $L_p = 9 \times 10^{35}\text{erg/s}$. Pulsar timing confirmed by later observations revealed that the pulsar is in a high-eccentricity ($e=0.87$), long-orbital period ($T=3.4\text{year}$) binary system with a massive companion. Its companion is a 10th mag Be star SS2883 of luminosity $L_* = 5.8 \times 10^4L_\odot$, estimated radius $R_* \sim (6-10)R_\odot$, mass $M \sim 10M_\odot$. The distance to the Earth is about 2 kpc, the binary separation at periastron is equal to $10^{13}\text{cm}$. Assuming a pulsar mass of $1.4M_\odot$ the implied inclination angle of the binary orbit to the plane of sky is $36^\circ$. The longitude of periastron is equal to $138^\circ$ (Johnston et al. 1996). Timing measurements have shown that the disc of the Be star is likely to be highly inclined to the orbital plane (Wex et al., 1988).

The extensive radio observations of PSR B1259-63 were carried out during the 1994 and 1997 periastron passage at frequencies 1.5, 2.3, 4.8 and 8.4 GHz (Johnston et al. 1996, 1999). It turned out that when the pulsar is far from the periastron the pulsar emission is highly linear polarized and its intensity is practically independent on the pulsar orbital position. But as the pulsar approaches to the periastron the properties of the pulsar emission start to change. The depolarization of pulsed emission, the increase of the dispersion measure and the absolute value of the rotation measure near the periastron occurs. The pulsar was not detected in 1.5 GHz data on 1993 December 20
(20 days before the periastron) and reappeared only on 1994 February 4 (24 days after the periastron). During the 44 days eclipse no pulse emission was detected in extensive observations at 1.5 and 8.4 GHz. In the works of Lipunov et al. (1994) and Johnston et al. (1996) it was shown that the observed eclipse is due to the free-free absorption of the pulsar emission in the Be star disk.

During the 1994 and 1997 periastron passage the observations of the unpulsed radio emission coming from the system were made using the Molonglo Observatory Synthesis Telescope (MOST) and the Australia Telescope Compact Array (ATCA) at five frequencies between 0.84 and 8.4 GHz (Johnston et al. 1999). The first significant data at all frequencies were received 21 days before the periastron. Since that time the intensity of the non-pulsed emission by and large gradually increases until the 20th day after the periastron. That day it reaches its maximum (57 mJy at 1.4 GHz) and then it starts to decline. The source remained significant in the ATCA data until about 60 days after the periastron and until about hundred days after the periastron in the MOST data. At times when the pulsar emission is eclipsed, there is no evidence of polarized emission in any of the observations in either 1994 or 1997.

Since its discovery the PSR B1259-63 system was observed several times by X-ray instruments (see review in Tavani et al. 1997, Hirayama et al. 1999). It was shown that the X-ray spectrum of the system is consistent with a power-law of photon index $\sim -1.7$. No significant X-ray pulsations with the pulsar spin period were detected.

The aim of this paper is to explain the origin of the non-pulsed radio and X-ray emission. It is well-known that pulsars lose rotational energy in the form of relativistic MHD winds (Michel 1969, Arons 1992). The wind carries energy flux in the form of electromagnetic fields and the kinetic energy of the relativistic electrons and positrons. The energy flux in the pulsar wind $F_w$ at distance $r$ well over the light cylinder is equal to

$$F_w = \frac{L_p}{4\pi r^2} = \frac{cB_w^2}{4\pi \sigma}.$$  

$B_w$ is a magnetic field in the wind, $\sigma \ll 1$ is a pulsar wind magnetization, i.e. the upstream ratio of electromagnetic energy density and particle kinetic energy density. For the Crab Nebula $\sigma \sim 0.005$ (Kennel & Coroniti, 1984).

Be stars are well-known to be the source of the strong highly anisotropic matter outflow. Both a dilute polar wind and a denser equatorial disk have been invoked to reconcile models for IR, UV and optical observations of Be stars (Waters et al. 1988). Due to the interaction of the pulsar and Be-star winds the system of two shocks arises and the relativistic particles flowing at first radially from the pulsar turn after passing the shock and start to outflow along the contact surface. In the paper of Tavani et al. (1997) the non-pulsed X-ray emission was explained as a result of the synchrotron emission of the highly relativistic pulsar wind particles with Lorentz factor $\gamma \sim 10^6$. In this model the origin of the unpulsed radio emission is unclear. Here we propose a model in which Lorentz factor is supposed to be much more moderate, $\gamma \sim 10$, and show that in this case the unpulsed radio emission is a result of the synchrotron radiation of the relativistic particles in the outflow beyond the
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Figure 1. The geometry under consideration. Point $P$ marks the position of the pulsar, point $Be$ - the position of the Be star. Curves $S_1$, $S_2$ represent the shock waves, curve $c$ - the contact surface. Curve $U$ is a curve of the constant density (see text). Points $A$ and $B$ mark the intersection of the curve $U$ with the shocks $S_1$ and $S_2$, point $C$ is the point of the shock $S_2$ intersection with the binary axis. $ED$ is a small arc centred at the point $P$.

shock and that the non-pulsed X-ray emission is due to the inverse Compton scattering of the Be star photons on this particles.

2. Colliding winds

In order to calculate the unpulsed emission coming from PSR B1259-63 it is necessary to know the structure of the shock waves arising in the system due to the interaction of the relativistic pulsar wind and a non-relativistic Be star wind.

The structure of the colliding winds in the system PSR B1259-63 is very complicate. But the origin of the unpulsed emission can be understood with the help of the rather simple model. For the simplicity we suppose that the polar wind of the Be-star occupies all the region outside the disk and that
in that region it is homogeneous. The pulsar wind we suppose to be spherically symmetric. The observations of the inner regions of the Crab Nebula (Hester et al. 1995) approves this assumption. Then for the most part of the pulsar orbit the geometry of the problem reduces to the interaction of the two spherically symmetric winds.

The interaction of the relativistic and non-relativistic winds is still poor investigated but it seems that it is closely analogous to the case of the interaction of two non-relativistic winds (e.g. Melatos et al. 1995). For the non-relativistic case it was shown by Lebedev & Myasnikov (1990) that if the dynamical pressures of the two winds are of the same order then the form of the shocks converges to a hollow cone at distances bigger then the distance between the pulsar and a contact surface.

Equating the dynamical pressures of the winds we find under the assumption of the winds isotropy the distance to the contact surface from the pulsar:

\[ r_c = a \frac{\sqrt{\alpha}}{1 + \sqrt{\alpha}}, \quad \alpha = \frac{L^p}{c v_0 M} \]  

(2)
a is a binary separation, \( \dot{M} \) is a Be star mass outflow rate, \( v_0 \) is a Be star polar wind termination velocity, \( c \) is a light velocity. In the paper of Snow (1982) it was found out that the rate of the Be star mass loss is connected with its luminosity. From that dependence it follows that the rate of SS2883 mass loss should be about \( \dot{M} = 10^{-8} M_{\odot} \) year. The typical terminal velocity of the Be star polar wind is about \( v_0 = 10^8 v_8 \) cm/c (Snow 1981). Thus we find that for PSR B1259-63 \( \alpha = 0.45/v_8 \dot{M}_{-8} \). Hence the winds have comparable values of the dynamical pressure and the contact surface crosses the binary axis somewhat closer to the pulsar then to the Be star.

In the beginning both the relativistic and non-relativistic winds are radial but after passing the shock winds turn and start to flow along the contact surface. Both winds are highly supersonic and thus both shocks arising in the system are strong and MHD shock conditions states that the normal component of the particles velocity after the shock is lowered by a factor 3 and 4 for relativistic and non-relativistic particles correspondingly (Landau & Lifshitz 1986). The big difference in the velocities of the winds at different sides of the contact surface can lead to the growth of instability and the two winds will be macroscopically mixed between the shocks. In this case the region between the shocks will be filled with the two-phase outflow composed of volumes with relativistic and volumes with non-relativistic particles. Then the heavy non-relativistic wind slows down the volumes filled by the relativistic electrons and positrons and they acquire essentially non-relativistic hydrodynamic drift velocity \( v_d \) along the shock while the energy of electrons and positrons does not changes significantly. The non-relativistic plasma in its turn accelerates and acquire the velocity of the order of \( v_d \). The analysis of the observational data leads to the conclusion that the similar situation occurs in systems G70.7+1.2 (Kulkarni et al. 1992) and LSI 61°303 (Maraschi & Treves 1981) and that the observed emission from these systems is generated in the regions filled with the two-phase flow.
3. Generation of the non-pulsed X-ray emission

The observed power-law spectrum of the non-pulsed X-ray emission coming from the system PSR B1259-63 suggests a power-law energy distribution of the relativistic particles in the outflow after the shock \( \frac{dN}{d\varepsilon} = K_\varepsilon \varepsilon^{-s}, \varepsilon > \varepsilon_{\text{min}} \) (Chernyakova & Illarionov 1999). Such a distribution can be either the result of the intrinsic power law distribution of the electrons and positrons in the pulsar wind (e.g. Tademaru 1973; Lominadze et al. 1983), or in the case of the particle acceleration at the shock (e.g. Gallant et al. 1994).

The soft photons, emitting by the Be-star would scatter on the relativistic particles, outflowing with the drift velocity \( v_d \). The scattered photons form a wide spectrum from the X-ray band up to the gamma-ray band. Applying the results of the work (Chernyakova & Illarionov 1999) to the system PSR B1259-63 we estimate that for \( \varepsilon_{\text{min}} = 10mc^2, s = 2, v_d = 10^9 \text{cm/s} \) during the periastron passage the photon flux density of the unpulsed X-ray emission from the system at Earth should be about

\[
F \sim 5 \times 10^{-3} \left( \frac{\varepsilon}{100 \text{keV}} \right)^{-1.7} \text{ph/s/cm}^2/\text{MeV},
\]

while the observations give at 100 keV the value \( F_{\text{obs}} = (2.8 \pm 0.7) \times 10^{-3} \text{ph/s/cm}^2/\text{MeV} \) (Grove et al. 1995).

4. Non-pulsed radio emission as a result of the synchrotron emission of the electrons of a pulsar wind

Under the assumption of the relativistic particles power law energy distribution \( dn_\varepsilon = K_\varepsilon \varepsilon^{-2.4} d\varepsilon, \varepsilon > 10mc^2 \), (the parameter \( K_\varepsilon \) characterize the density of relativistic particles), the flux density detected at the Earth from the synchrotron emission on a frequency \( \nu \) (throughout the text \( \nu \) is measured in GHz) from the small volume \( dV = dldS = dV_{39} \times 10^{39} \text{cm}^3 \) (with the side \( dl \) along the line of sight) with a magnetic field \( B \) is equal to (Corchak, Terleckiy 1952)

\[
dI_E = \frac{J_\nu dV}{4\pi D^2} = 3.23 \times 10^5 \frac{K_\varepsilon dV_{39}}{4\pi D^2} (B \sin \chi)^{1.7} \nu^{-0.7} \text{mJy},
\]

where \( \chi \) is an angle between the magnetic field and the direction to the observer, \( D = D_2 \times 2 \text{kpc} \) is a distance to the system and \( J_\nu \) characterizes the energy emitted from a unit volume per a unit time.

The coefficient of self-absorption is equal to (Ginzburg et al. 1969)

\[
\mu = 1.1 \times 10^{-8} K_\varepsilon B^{2.2} \nu^{-3.2} \text{cm}^{-1}
\]

In order to calculate the flux density with formulas (4), (5) it is necessary to know the density of the relativistic particles in the outflow \( K_\varepsilon \) and the magnetic field \( B \). To calculate the parameters of the relativistic outflow at

\footnote{In that work there is a misprint - in (27) the value of \( v_d = 10^9 \text{cm/s} \) was taken.}
an arbitrary point \( I \) located between the two shocks we use a simplifying assumption of the parameters constancy across the shock (along the surface \( U \), Fig.1).

**4.1. The relativistic particles density**

The density of the relativistic particles at the surface \( U \) can be estimated from energy conservation law. Let us consider contour \( ABCDE \) (Fig.1). The energy flow through the closed surface arising from the rotation of the contour \( ABCDE \) about the binary axis is equal to zero. Equating the inflowing flux density \( L \rho \Omega / 4\pi \) to outflowing one \( K_e S_U v_d / 0.4 \epsilon_{min}^{0.4} \) we find the parameter \( K_e \):

\[
K_e = \frac{0.4 L \rho \Omega^{0.4}}{4\pi S_U v_d},
\]

here \( S_U \) is the surface \( U \) area and \( \Omega = 2\pi(1 - \cos \zeta) \), where \( \zeta \) is an angle \( \angle APC \) (Fig 1). Far from the pulsar \( S_U = 2\pi R_U^2 \left( \cos \theta_1 - \cos \theta_2 \right) \), \( R_U \) is a distance from the Be star to the surface \( U \).

**4.2. Magnetic field**

At distances much bigger then the radius of the light cylinder the magnetic field in the pulsar wind may be considered as a toroidal one. From (1) it follows that at a distance \( r \) from the pulsar it is equal to \( B_w = \frac{1}{4} \sqrt{\sigma L \rho c} \). To calculate the structure of a magnetic field in the outflow we use the equation of the frozen magnetic field that in the stationary case have form (Lundquist 1951)

\[
\text{rot}[\vec{v} \times \vec{B}] = 0.
\]

Let us introduce the cylindrical coordinate system \((\eta, \varphi, z)\) with \( z \) along the binary axis, chosen so that \( \varphi_{obs} = 0 \). Assuming that the outflow is azimuthal symmetrical about the binary axis, that is \( v_\varphi = 0 \), we find from (7):

\[
B_\varphi = \frac{\sqrt{\cos^2 \alpha + \sin^2 \alpha \cos^2 (\varphi - \varphi_p)}}{v_d \int_{\theta_1}^{\theta_2} \frac{u \sin \theta}{\sin \theta} d\theta},
\]

the integration in the denominator is done along the surface \( U \) at a constant \( \varphi \), \( \eta_U \) is a distance between the elements of the surface \( U \) and the binary axis, vector \( \vec{e}_p \) with the coordinates \((\sin \alpha, \varphi_p, \cos \alpha)\) in our cylindrical coordinate system is aligned with the pulsar axis.

In the degenerate case of the coincidence of the binary axis and the axis of the pulsar \((\alpha = 0)\) the magnetic field has only \( \varphi \)-component.

In general case the magnetic field in the outflow also have a component \( B_d \) along the drift velocity and a component \( B_U \) along the surface \( U \). The condition of the frozen magnetic field suppose that the variation of \( B / n_e \) at a volume with a given particles in a course of motion is proportional to the stretching of a magnetic field line passing through this volume (Lundquist 1951).
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With the help of (6) we find that $B_\varphi$ and $B_U$ are proportional to $r^{-1}$ and that $B_d \sim r^{-2}$. However if the mixing of the two winds takes place then the direction of the component perpendicular to $\vec{e}_\varphi$ changes all the time in the course of motion, this component damps faster then the $B_\varphi$ and at a large distance from the pulsar the $\varphi$-component of the magnetic field dominates.

If the mixing of the wind doesn’t occur, then far from the pulsar, in the region where the form of the shock waves $S_1$, $S_2$ is approximately a cone, $B_d$ is small and we find from (6) the value of $B_U$:

$$B_U = -\frac{\sqrt{\sigma c L_p}}{\sin \theta_2 - \sin \theta_1} \frac{\zeta}{R_U v_d} \frac{\sin^2 \alpha \cos(\varphi - \varphi_p) \sin(\varphi - \varphi_p)}{\sqrt{\cos^2 \alpha + \sin^2 \alpha \cos^2(\varphi - \varphi_p)}} \tag{9}$$

4.2.1. The intensity of the non-pulsed radio emission

With the help of formulas (4), (5), (6), (8) and (9) we can calculate the resulting synchrotron emission from the system. The differential equation describing the change of the flux density $I_\nu$ along the line of view crossing the emitting region is

$$\frac{dI_\nu}{dl} = J_\nu(l) - I_\nu(l) \mu(l), \tag{10}$$

where $l$ is a coordinate along the line of sight. The total emission that would be observed at the Earth is equal to:

$$I_E = \frac{1}{4\pi D^2} \int \int_{l_0}^{l_e} J_\nu(l) \exp \left[-\int_{l_1}^{l_e} \mu(l_1)dl_1 \right] dldS. \tag{11}$$

To calculate the observed flux we should choose the limits of integration $l_0$ and $l_e$ so that this intercept totally covers that part of the line of sight where the emission is generated and to integrate over the $l$ and over the area in the plane perpendicular to the line of sight chosen so that it embraces all the lines of sight crossing the emission region.

Figure 2 represents the spectra calculated for different parameters in the case of a pulsar with $\alpha = 0$ located at a position 30 days before the periastron passage. In our calculations we follow the work of Melatos et al. (1995) and approximate the form of the shock waves $S_1$, $S_2$ with hyperboloids with half-opening angles $\theta_1$, $\theta_2$. It turns out that the bulk of radiation comes from the regions away from the pulsar, where the drift velocity depends only slightly on the position along the layer and for the simplicity we treat it as a constant. The separation of the region generating the bulk of the observed emission from the pulsar also leads to the weak dependence of the result on the form of the shock waves in the vicinity of the pulsar. For the comparison the observational spectra that were received by Johnston et al. (1999) 3 days before the periastron passage and 16 days after are also shown.

Figure 2 shows that the flux density of the emission highly depends on the value of the drift velocity $v_d$ and the magnetization parameter $\sigma$. The lower the drift velocity is and the higher is the value of $\sigma$ the more intensive is the resulted emission.
Figure 2. The model spectra of the unpulsed radio emission coming from the system 30 days from the periastron. In calculations the pulsar axis was assumed to be directed along the binary axis. 1. $v_d = c/15$, $\sigma = 5 \times 10^{-3}$, $\theta_1 = 10^\circ$, $\theta_2 = 70^\circ$ 2. $v_d = c/10$, $\sigma = 5 \times 10^{-3}$, $\theta_1 = 10^\circ$, $\theta_2 = 70^\circ$ 3. $v_d = c/10$, $\sigma = 10^{-3}$, $\theta_1 = 10^\circ$, $\theta_2 = 70^\circ$ 4. $v_d = c/3$, $\sigma = 10^{-3}$, $\theta_1 = 20^\circ$, $\theta_2 = 55^\circ$. Curves with error bars are the spectra observed from the system 3 days before the periastron and 16 days after (Johnston et al. 1999).

In the case of the arbitrary position of the pulsar axis the estimation of the value of the magnetic field along the layer is rather difficult. However as we saw in the previous section if the mixing occurs then at large distances from the pulsar the $\varphi$-component of the magnetic field dominates and its value is close to the one in the degenerate case. The wide range of the results received in the case of a pulsar with an axis along the binary axis by variation of parameters shows that observed radio emission can be explained with a synchrotron mechanism.

4.2.2. Polarization properties

The degree of polarization $\Pi$ of the relativistic electrons with the power-law energy distribution $dn_{\pm} = K_e \varepsilon^{-2.4}d\varepsilon$ is given by (Corchak, Terleckiy 1952):

$$\Pi = \frac{\sqrt{Q_E^2 + U_E^2}}{I_E}$$

(12)

Here $I_E$ is given by (11) and the formulas for $Q_E$ and $U_E$ can be received from (11) by a substitution of $0.72J_\nu(l)\cos2\chi$ and $0.72J_\nu(l)\sin2\chi$ for $J_\nu(l)$ correspondingly. $\chi$ is an angle between the arbitrary fixed direction in the plane perpendicular to the line of sight and the direction along the $\vec{e}_1 = \hat{B} \times \vec{e}_o$, where $\vec{e}_o$ is a unit vector along the line of sight.
On Figure 3 the dependence of the degree of polarization on the angle between the line of sight and the binary axis is shown. This dependence was calculated according to (12) for the different positions of the pulsar axis. It can be seen from the Figure 3 that the observed unpulsed radio emission should be highly polarized. However in formula (12) the effect of the Faraday rotation was not taken into account. The emission is totally depolarized if the strong Faraday rotation is taken place in the emission region (Burn, 1966):

\[ \Delta \varpi = \frac{0.236}{\nu^2} \int nB \cos \chi dl_{13} \gg 1. \]  

(13)

Here \( \nu \) is measured in GHz, \( B \) in Gs, \( n \) in cm\(^{-3} \) and \( l_{13} \) in 10\(^{13}\) cm.

If beyond the shock wave the winds stirring takes place, then the electrons density in (13) is the density of non-relativistic electrons \( n_{nr} \) and the magnetic field is a magnetic field of the Be-star \( B_{Be} \). In the outflow \( B_{Be} \) is about 1G and \( n_{nr} \) can be estimated from the particles conservation law

\[ n_{nr} = \frac{\dot{M}(1 - \cos \theta_2)}{4 \pi \nu v_{nr} R_U (\cos \theta_1 - \cos \theta_2)} = 3 \times 10^5 \frac{\dot{M}_{-8}(1 - \cos \theta_2)}{v_{nr} R_U^{13} (\cos \theta_1 - \cos \theta_2)} \text{cm}^{-3}. \]  

(14)

Here \( v_{nr} = v_{nr} 10^9 \text{ cm/s} \) is a drift velocity of the non-relativistic plasma beyond the shock wave and \( \dot{M} = \dot{M}_{-8} M_\odot / \text{year} \) is the rate of Be star mass loss. \( R_U = R_{U13} 10^{13} \text{ cm} \) is a distance from the Be-star to the surface U. The value of \( n_{nr} \) varies along the shock wave but in the region of interest it is, as it can be seen from (14), high and depolarization takes place. If the mixing doesn’t occur and shock waves have such a form that the line of sight doesn’t pass through the region filled with the non-relativistic electrons then from (1), (8), (9) and (13) it follows that \( \Delta \varpi \sim 1 \), the effect of the Faraday rotation is not strong and the radio emission would be polarized. Unfortunately the degree of polarization in this case is not measured yet as the intensity of the non-pulsed radiation in this case is low (see Fig.2).

5. The light curve

The observations of the PSR B1259-63 show that far from the periastron there is no evidence for any unpulsed radiation in the off-pulse bins down to a limit of several mJy. The examination of the synchrotron emission of the pulsar wind relativistic particles in the outflow beyond the shock leads us to the conclusion that the drift velocity of the relativistic particles is high and there is no mixing of the relativistic and non-relativistic winds beyond the shock. According to our analysis the arising unpulsed radio emission is polarized with the degree of the polarization about 30%.

The detectable non-pulsed radio emission from the system appears only 20 days before the periastron passage and approximately at the same time the pulsed emission disappears. It testifies that at this time the pulsar crosses the disk of Be-star first time and the pulsed emission is absorbed by the matter of
Figure 3. The dependence of the degree of polarization on the angle $\theta_{\text{obs}}$ between the line of sight and the binary axis. Angles $\alpha$ and $\varphi_p$ define the position of the pulsar axis relative to the binary axis and the observer (see text). It was calculated under the assumption that the effect of the Faraday rotation is negligible.

The non-pulsed radio emission is generated rather far from the pulsar and crosses the disk at its low-density part. Thus the free-free absorption of the non-pulsed emission by a disk matter is negligible.

The interaction with the pulsar leads to the partial destruction of the Be star disk (Ivanov et al. 1998). The matter ejecting from the disk increases the instability in the outflow beyond the shocks leading to the mixing of the relativistic and non-relativistic winds and to the deceleration of the relativistic particles drift velocity. As it can be seen from the Figure 2 the decreasing of the drift velocity leads to the increase of the intensity of the generated non-pulsed radio emission. The observed intensity can be explained with the drift velocity about $v_d \sim c/10$. The mixing of the winds leads to the increase of the electron density on the line of sight and the emission becomes unpolarized. The free-free optical depth along the line of sight is given by $\tau_{\text{ff}} = 5.7 \times 10^{-13} \nu^{-2} T_{e5}^{-3/2} \int n_e^2 dl_{13}$ ($\nu$ is measured in GHz, $l_{13}$ in $10^{13}$cm, $n_e$ in cm$^{-3}$ and $T_{e5}$ in 10$^5$K). From (14) we see that $\tau_{\text{ff}} \ll 1$.

The observed maximum of the unpulsed radio emission intensity occurs at the time of the second pulsar intersection with the Be star disk. After that the ejection of the matter from the disk continues for some time but the farther the pulsar is from the disk the less is the influence of the ejected matter on the winds outflow properties and at some moment the winds are not mixing anymore. The unpulsed radio emission becomes again polarized but weak.

By this means we show that the observed properties of the non-pulsed radioemission from the system PSR B1259-63 can be explained by the synchrotron emission of the pulsar wind relativistic particles in the outflow be-
yond the shock wave and that the non-pulsed X-ray emission is due to the inverse Compton scattering of the Be star photons on this particles.

Acknowledgements

Authors are grateful to A.V. Myasnikov for the helpful remarks. We acknowledge the valuable comments of the anonymous referee. This work was supported by RFBR grant 97-02-16975

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