RADIO EMISSION FROM X-RAY SOURCES

(Letter to the Editor)

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Abstract. The radio emission from some point X-ray sources is suggested to be due to plasma oscillations in the region where the inflowing stream through the inner Lagrange point impinges on the accreting disk around a neutron star in a binary system.

Recently, Duldig et al. (1979) systematically looked for radio counterparts of galactic X-ray sources. Earlier searches have revealed about ten such radio sources (Braes and Miley, 1973; Hjellming, 1974; Sanduleak and Dolan, 1974; Seaquist, 1977). Duldig et al. (1979) have found ten more variable radio sources coincident with X-ray objects. To this list, perhaps, should be added several radio sources (which have been clearly identified as supernova remnants – Culhane (1977) – which either have point or extended X-ray emission, and also several radio binaries from which X-ray emission has been observed (Schnopper et al., 1976; Walter et al., 1978). There is a reasonable understanding of the radio emission from supernova remnants and H II regions, and if we eliminate these from the list, we are left with a class of point radio sources which are coincident with point X-ray objects. The radio emission from radio binaries seems to be of the synchrotron type and requires a model to account for the high-energy electrons responsible for the emission. A subset of the point radio-X-ray sources are those which produce very high intensity flares such as Cyg X-3; there is no satisfactory explanation of the origin of the flares. The quasiperiodic radio behaviour of Cir X-1 again requires special explanation. Here we consider the point X-ray sources with faint variable radio sources (typical of which is 2S 1735-44), and suggest that the radio emission occurs due to plasma oscillations in the outer region of an accretion disk around a neutron star in a binary system where inflow of matter through the inner Lagrange point impinges. We shall be able to demonstrate only the plausibility of this suggestion as there are too many parameters which cannot be fixed accurately; however, we suggest a test of the hypothesis.

The radio flux density from 2S 1735-44 is about 15 mJy (Duldig et al., 1979) at 2 cm wavelength. It is identified with a faint blue star at an estimated distance of about 5 kpc (McClintock et al., 1978). The radio emission is then calculated to be about $5 \times 10^{39}$ erg s$^{-1}$. This clearly cannot be from the blue star and should be associated with the neutron star (or its disk), which is generally assumed to be in binary orbit around the blue star, in order to explain the X-ray emission. The dimension of the

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neutron star and its disk systems is \( \lesssim 10^{11} \) cm, yielding at 2 cm a radio brightness temperature corresponding to the flux above \( T_b \approx 10^{13} \) K. Thus, the radio emission can either be of synchrotron type or it is a coherent process like plasma oscillations or a gyro-maser (Melrose and White, 1979). In the case of synchrotron emission, the brightness temperature implies electron energy greater than 1 GeV, which in turn implies magnetic field \( \lesssim 3 \times 10^{-3} \) G and energy in the GeV electrons in excess of \( 10^{48} \) erg. These conditions are unlikely to occur near an accreting neutron star and the synchrotron emission is most probably not responsible for the radio emission. In the case of gyro emission the observed radio wavelength implies a magnetic field of about \( 5 \times 10^{3} \) G. Such a field strength will occur at about \( 10^{9} \) cm from the centre of the neutron star, assuming a surface magnetic field of about \( 5 \times 10^{12} \) G. Also, this region is outside the Alfvén surface and conditions for the operation of a gyro-maser (see Melrose and White, 1979) are unlikely to obtain. The most likely origin of the radio emission appears to be coherent plasma radiation. The plasma circular frequency \( \omega_p \) corresponding to the radio wavelength 2 cm implies an electron density of \( N_e \approx 2 \times 10^{12} \) cm\(^{-3} \) in the radio emitting region. Such a density occurs in the outer regions of an accretion disk around the neutron star. We use the distance of the outer edge of the disk \( R \approx 10^{11} \) cm. The excitation of plasma oscillations takes place where the gas stream from the inner Lagrange point impinges on the accretion disk. The conversion of plasma oscillations into electromagnetic radiation to generate emission at the plasma frequency has been considered by Ginzburg and Zheleznyakov (1958). The order of magnitude of the energy is electromagnetic waves emitted is

\[
P_\omega \approx \frac{e^3 N_e V}{m_e c^3} E_0^2,
\]

where \( e \) and \( m_e \) are, respectively, the electron charge and mass, \( c \) is the velocity of light, \( V \) the volume of the plasma oscillation region, and the electric field \( E_0 \) is given by

\[
E_0 \approx \frac{m_\omega}{2e v_0} \left[ \frac{16 \tau_0^2 m_e N_e^2}{3 kT_e N_e^2} \right]^{1/2},
\]

where \( \omega (= \omega_p) \) is the circular radio frequency, \( T_e \) the temperature of the streaming gas, \( k \) the Boltzmann constant, \( v_0 \) the velocity of the impinging gas, and \( N_e \) the electron density in the gas stream. We use the Keplerian velocity at \( R \approx 10^{11} \) cm for \( v_0 \) and a temperature \( T_e \approx 10^4 \) K. \( N_e \) is estimated from the rate of accretion of \( 10^{17} \) gm s\(^{-1} \) implied by X-ray emission to be about half of \( N_e \). Using these values, \( E_0 \approx 6 \). The volume of emission \( V \) is taken to be \( 2 \times 10^{33} \) cm\(^3 \), which yields \( P_\omega \approx 5 \times 10^{30} \) erg s\(^{-1} \), which is the observed value. Thus, our suggestion – i.e., that plasma oscillations near the region where the incoming gas stream impinges on the accretion disk can be the source of radio radiation in these X-ray sources – seems plausible.

Duldig et al. (1979), however, have failed to detect radio radiation from several other point like X-ray sources. A number of these could be explained due to low radio luminosity inferred from the X-ray flux since a strong relation exists between the two