X-ray, Gamma-ray and Radio Observations of LSI+61 303 and the Nature of the Electron Population and of the Emission Mechanisms

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Abstract

LSI+61 303 is an unusual binary system which was discovered by its periodic 26-day radio outbursts, then subsequently identified with a COS-B gamma-ray source. Extensive radio and x-ray observations have been carried out since, the latter including ROSAT, ASCA, and RXTE satellite observation campaigns. It has also been identified as a CGRO/EGRET gamma-ray source. The evidence is that the radio emission is synchrotron and the x-ray through gamma-ray emission is inverse-Compton. Here the various observations are collected and used to determine the properties of the relativistic electron population.

1. Introduction

LSI+61 303 is one of a small but important group of radio emitting x-ray binary systems. The Be star LSI+61 303 is the optical counterpart of the periodic radio source GT 0236+610. The radio source is highly variable, exhibiting outbursts every 26.496 days which have rise times of ∼1 day and last ∼10 days [1],[8]. Two-frequency radio monitoring indicates a flat spectral index, and the emission has been interpreted as optically-thin synchrotron radiation for most of the outburst, with indication that the source becomes self-absorbed for a short time at the beginning of the outburst rise [9]. VLBI observations show that at its maximum size the emitting region has a dimension of $\sim 5 \times 10^{13}$ cm, and an expansion velocity (2.0 – 6.4) $\times 10^7$ cm s^{-1} [5]. The phase of peak flux varies between 0.4 – 1.0 of the radio ephemeris (phase 0 arbitrarily defined as MJD 43366.275, period equal to 26.496 days), most often occurring at phase ∼0.6 [6],[7]. The radio peak occurs after the x-ray peak by ~ 0.4 period [2],[4].

2. The electron energy spectrum and emission processes

The x-ray through gamma-ray observations are summarized in [3],[2]. Figure 1 shows the fluxes (νf_ν) vs. energy. The high energy spectrum is fit with a powerlaw in f_ν with index -0.7. The low energy (ROSAT to ASCA/PCA) spec-

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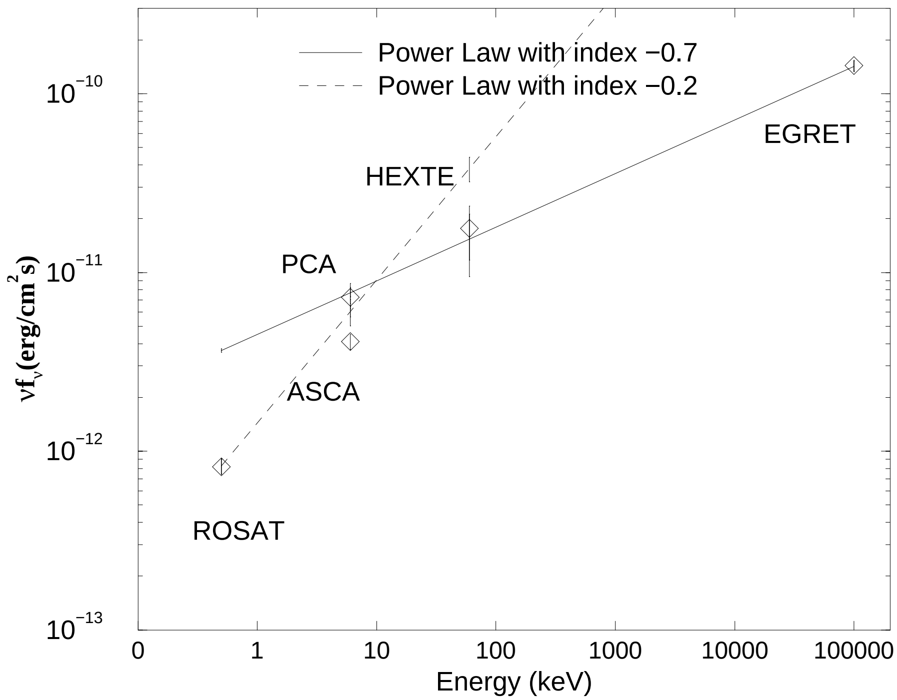

Fig. 1. X-ray to gamma-ray flux measurements of LSI+ 61 303.

trum is fit with a powerlaw in f_ν with index -0.2. The powerlaw index needed to connect the ROSAT flux averaged over an orbital cycle, to the radio flux (taking a radio flux at 2 GHz of 20 mJy) is -0.58. This can be compared to the radio 2.25 to 8.3 GHz spectral index which varies from 0 to -0.5 over an orbital cycle [7]. However, as discussed in [4],[2], the x-ray to gamma-ray emission is probably due to stellar photons inverse-Compton upscattered in energy by the electrons which are emitting radio synchrotron photons. The inverse-Compton spectrum with spectral index, -α, reflects the underlying electron spectrum, which allows one to deduce the electron energy spectrum index, -γ, using $\alpha = (\gamma - 1)/2$ or $\gamma = 2.4$ for $\alpha = 0.7$. The turnover in x-rays below a few keV probably is due to a turnover in the electron spectrum to a flatter index $\gamma = 1.4$ below an electon energy of $6 \times 10^{-6} erg$. An electron spectral index change of unity consistent with the x-ray to gamma-ray observations, as just explained, is expected for energy loss mechanisms which have $dE/dt = const \times E^2$, which applies for both synchrotron and inverse-Compton losses. Which of the two mechanisms is more important for LSI+61 303 depends sensitively on the magnetic field strength and the distance of the electrons from the optical star.

The synchrotron loss timescales for radio emitting electrons are long even for high magnetic fields. E.g. for B=1 Gauss and observing frequencies of 1.4 GHz and 200 GHz the electron lifetimes are 850 days and 77 days, resp. Thus

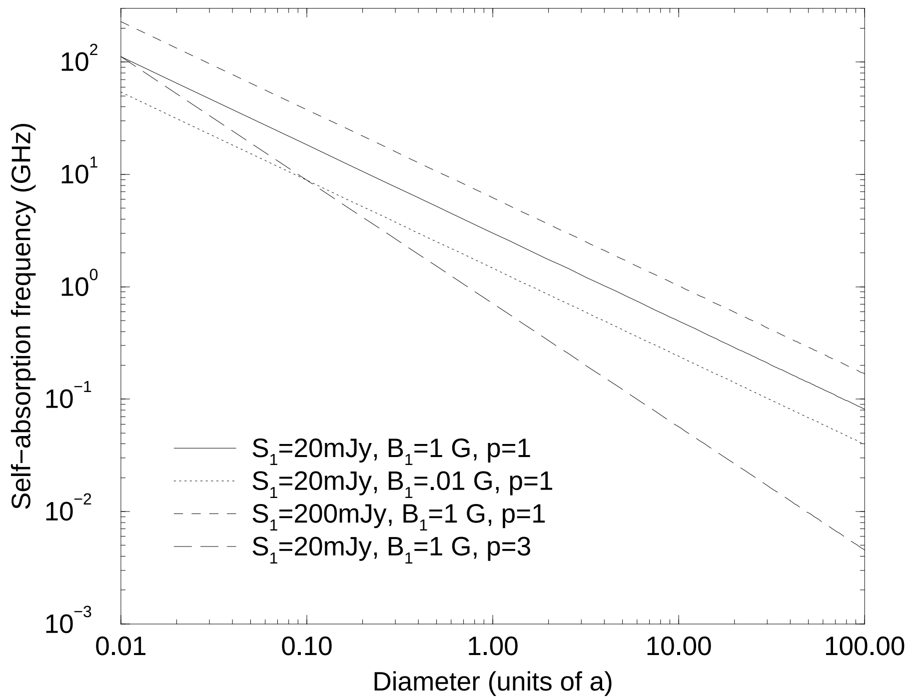

Fig. 2. Synchrotron self-absorption frequency for an expanding spherical source.

the change in radio spectral index observed is not due to synchrotron losses. One alternate likely mechanism is synchrotron self-absorption, so that the observed radio spectral index does not directly indicate the electron energy spectrum. In Fig. 2 the synchrotron self-absorption frequency is plotted for an expanding spherical source emitting a given flux at 5 GHz. The source has an initial magnetic field as indicated and the magnetic field decreases as the source expands as r^{-p} with r the source radius (initial value of r is $0.01a$, with a the semi-major axis of the system). As the source gets larger the self-absorption frequency drops into the observed range, but as the source gets as large as a it is no longer near-spherical, complicating the interpretation of spectral index. Adiabatic losses in the expanding electron cloud are important and can also affect the radio spectrum. Fig. 3 shows the adiabatic break energy as a function of time for a model of an expanding cloud for two cases of expansion velocity, as well as the energy of electrons emitting various radio frequencies. It is seen that adiabatic losses are important and must be modelled carefully.

3. Summary and Conclusion

The emission from LSI+61 303 is synchrotron in radio and inverse-Compton in x-ray to gamma-ray. The electron population is constrained by observations

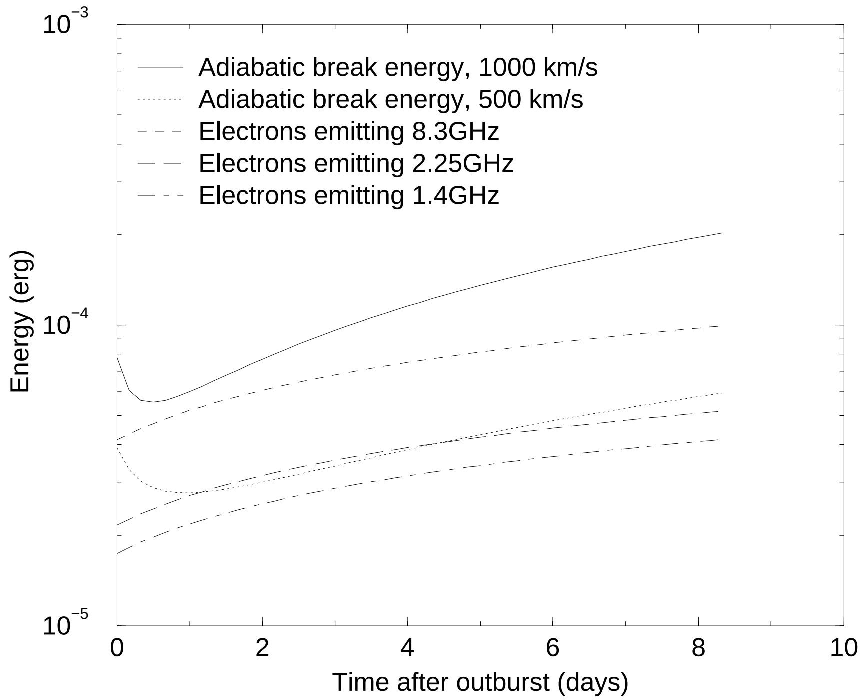

Fig. 3. Adiabatic break electron energy and electron energy for specified radio frequencies for an expanding spherical source.

but more modelling is needed to get detailed information such as the electron injection rate, the magnetic field and expansion rate of the electron cloud. Spherical models have been computed and give some insight, but 3-D models, which are currently being computed, are needed to make realistic physical interpretations of the data.

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