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*Letter to the Editor*

# A search for infrared pulsations from PSR 1951+32

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**Summary.** Observations have been conducted on the recently discovered short period pulsar PSR 1951+32 in the radio nebula CTB 80 in an attempt to detect pulsed infrared emission. A strong upper limit is placed on any pulsed, infrared component below that expected from a formally proposed optical candidate for the pulsar. This limit is consistent with proposed scaling laws for high–energy emission.

**Key words:** pulsars: PSR 1951+32, infrared radiation

## 1. Introduction

Recent radio observations of the radio nebula CTB 80 by Strom (1987) revealed the presence of a possible young, fast pulsar. Motivated by this, and the fact that young pulsars (eg. the Crab pulsar) are sufficiently energetic to produce detectable pulsed radiation in high energy wavebands, we conducted a search at infrared wavelengths in an attempt to detect pulsed emission. More recent pulse searches at radio wavelengths (Clifton *et al.*, 1987; Kulkarni *et al.*, 1987) have since indicated the presence of a new pulsar (designated PSR 1951+32) with a rotation period of 39.5 msec. This pulsar appears to be (or is) physically associated with the surrounding nebula CTB 80 which is most likely a composite of old supernova remains and material that has recently been excited by the pulsar emissions (Kulkarni *et al.*, 1987).

Observations with the *Einstein* Observatory by Becker *et al.*(1982) detected an unresolved X–ray source in the flat–spectrum radio core of CTB 80 suggestive of high-energy emission from a collapsed stellar remnant. Subsequent optical photometry and astrometry (Fesen and Gull, 1985; Blair and Schild, 1985) revealed two possible optical counterparts to the X–ray source, one of which coincides, within astrometric errors, to the pulsar radio position of Strom (1987). The search for infrared pulsations was conducted on a field centred on this $m_V \sim 19.9$ source – optical candidate 1 of Blair and Schild (1985)

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## 2. Observations and Analysis

Observations were conducted on 9th July 1987 at the $F/70$ focus of the 200-inch Hale telescope. An InSb detector was employed at $H$–band: centre wavelength 1.6 $\mu$m and bandwidth 0.3 $\mu$m. Using a 7 arcsec diameter aperture centred at RA 19h 51m 02.6s, Dec +32° 44' 50.2" (epoch 1950), the detected signal was digitised and sampled at 1 kHz for 40 minutes and written to magnetic tape. In an off–line analysis of this data–stream, two consecutive $2^{20}$–point Fourier transforms were performed, and each spectrum was examined for significant events. A harmonic averaging algorithm was employed to improve the search sensitivity to pulsed signals with duty cycles as low as 6%, but no periodic signal was detected. Following the detection of pulsed emission at radio wavelengths (Clifton *et al.*, 1987), we re–analyzed our data using the pulsar ephemeris obtained from radio observations (Frutcher *et al.*, 1987) by synchronously averaging the entire dataset at the expected pulse period. This is, in general, a more sensitive test because *all* of the signal's harmonic content is summed in phase, as opposed to the incoherent addition of an arbitrary number of harmonics attempted with the harmonic averaging scheme mentioned above. Despite this, a negative result was again obtained. The coherence of data acquisition was verified by a thorough analysis on a channel of WWVB timing signals acquired in parallel with the program source.

## 3. Results and Discussion

As a result of these analyses, a $6\sigma$ upper limit can be placed on any pulsed infrared flux from the field of view corresponding to approximately 4 $\mu$Jy averaged over the pulse period. When corrected for extinction (which is 1.4 magnitudes at $V$), this limit becomes 5 $\mu$Jy. Assuming that the candidate star in the centre of the field has a spectrum between $V$ and $H$ similar to that of the Crab pulsar (Becklin *et al.*, 1973), we would have expected a flux density of 30 $\mu$Jy. We can therefore rule out any infrared pulsations from the optical candidate with a high degree of confidence. One possibility is that the object *is* the pulsar but the infrared emission is not pulsed. This is unlikely since only 2% of the Crab pulsar's optical emission is unpulsed.

An important point regarding this limit, prompted by the well–constrained spectrum of the Crab pulsar (Smith, 1981), is that the infrared emission is not expected to be a simple extrapolation of the radio spectrum to shorter wavelengths. Given a radio spectral index for PSR 1951+32 of $\alpha \sim -2$ (Strom, 1987) (where $S \propto \nu^{\alpha}$), the upper limit presented here would be eight orders of magnitude too high to expect a detection. We note that the Crab pulsar (PSR 0531+21) provides a useful comparison for PSR 1951+32 because they are at similar distances (as evidenced, for example, by their comparable dispersion measures) and they have comparable pulse periods. The flux density of PSR 0531+21 at 1400 MHz is $\sim$ 5 mJy and in the infrared and visible bands is $\sim$ 3 mJy, although the emission mechanism for the radio emission is entirely different from that at optical and infrared wavelengths (Smith, 1986). In contrast, PSR 1951+32 has a flux density of $\sim$ 1 mJy at 1400 MHz and an infrared flux density of less than 5 $\mu$Jy, which presumably is the result of a scaling law for the infrared luminosity proportional to some power of the pulsar period $P$ and period derivative $\dot{P}$.

These measurements, together with optical observations of other pulsars such as the Vela pulsar (PSR 0833−45) and PSR 1937+21 (the millisecond pulsar), confirm the theoretical expectations of Pacini and Salvati (1983). Their model involves incoherent synchrotron emission generated near the light cylinder, and leads to a scaling law for the optical luminosity given by $P^{-47/6}\dot{P}^{13/6}$. Using this relation scaled from the spectrum of the Crab pulsar, the expected infrared flux from PSR 1951+32 is less than 0.1 $\mu$Jy, consistent with the upper limit published here. The period derivative for PSR 1951+32 is $6.0 \times 10^{-15}$ s s$^{-1}$ (Frutcher *et al.*, 1987) which is a factor of 70 below that of the Crab pulsar. Our result confirms that $\dot{P}$ (or equivalently the neutron star magnetic field) is a significant factor in determining the luminosity of high energy pulsed emission.

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