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# New *JHK* Photometry of LS I +61 303

S. Martínez-Núñez and J. Fabregat

*Departamento de Astronomía, Universidad de Valencia, Spain*

**Abstract.** We present new *JHK* photometry of the Be/X-ray binary L SI +61 303, obtained during the period 1994-1998. The IR light curves do not show the modulation with the orbital period apparently present in the smaller photometry set analyzed by Paredes et al. (1994).

The reddening-corrected standard photometric values indicate that the circumstellar envelope is optically thick at infrared wavelengths, and much denser than those of isolated Be stars. It is argued that this higher density is produced by disk truncation due to the presence of the compact object in a close orbit.

## 1. Introduction

The Be/X-ray binary LS I +61 303 is the optical counterpart of the variable radio source GT 026+610A. It was discovered during a galactic plane radio survey by Taylor and Gregory (1978). Taylor and Gregory (1984) found that LS I +61 303 exhibits strong radio outbursts with a 26.496 $\pm$ 0.008 days period.

Paredes et al. (1994) presented results from radio, infrared and optical observations of this object. These results showed that a $\sim$ 26 days periodicity was present in the *V* band. In the *JHK* bands, they found clear evidence of a similar periodic modulation.

On the other hand, the existence of an IR excess in the early type Be star LS I +61 303 is clearly evident. Early type Be stars (B0-B2) are known to have an emission excess in the near-IR (Dougherty et al. 1994).

In this paper, we present new *JHK* photometry obtained between 1994-1998.

## 2. Photometric observations and results

The *JHK* photometric observations were obtained within the framework of the Southampton and Valencia Universities collaborative program on high-mass X-Ray binaries (Reig et al. 1997), during the period 1994-1998.

Paredes et al. (1994) found evidence of infrared variability with similar trends to that seen in the optical, but with high amplitude. Conversely, Hunt et al. (1994) did not find a clearly significant periodic variation at near-IR wavelengths.

We have a larger number of observations than previous authors. Our IR light curves do not show any modulation. In order to have higher statistical



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significance we present an analysis similar to the one done by Paredes et al. (1994). We have merged all the $JHK$ photometric observations after subtracting their respective mean and dividing by the corresponding r.m.s dispersion in each filter. This provides us with a data set of relative normalized infrared magnitudes, including 138 independent measurements. These 138 normalized points are plotted in Fig. 1 as a function of radio phase. We have carried out a PDM period analysis (Stellingwerf 1978) of these normalized points. The PDM analysis does not show a clear minimum. The modulation found by Paredes et al. (1994) seems to be produced by the coincidence in phase by chance of two observational periods during states of low IR emission, related to the long-term variability of the star.

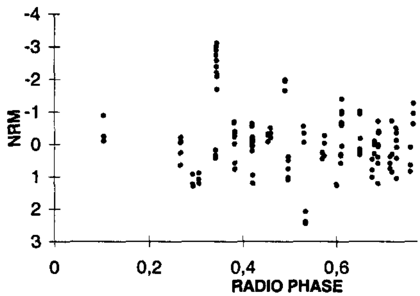


Figure 1. Normalized Relative Magnitude versus Radio Phase. Phase zero has been set at JD2443366.775.

## 3. Physical properties of the circumstellar envelope

### 3.1. Colour-magnitude diagrams

To obtain the intrinsic magnitudes and colours we have used a value of interstellar reddening (Reig 1996):

$$E(B-V)_{is} = 1.11 \pm 0.02$$

The colour-magnitude diagram is shown in Fig. 2. A large change in the $K$ magnitude is not associated with significant changes in the IR colours. According to the models of Dougherty et al. (1994), this should correspond to a very small disc with a very high density, such that it is optically thick at all near-IR wavelengths for continuum radiation. This fact was observed in other Be/X-ray systems, like 4U 0115+634 (Negueruela et al. in preparation) and V0332+53 (Negueruela et al. 1999).

In general, discs around Be stars in X-ray binaries are denser and smaller than those in isolated Be stars. The results of Reig et al. (1997) point towards a neutron star preventing the formation of an extended disc in systems with short orbital period, presumably due to tidal truncation.

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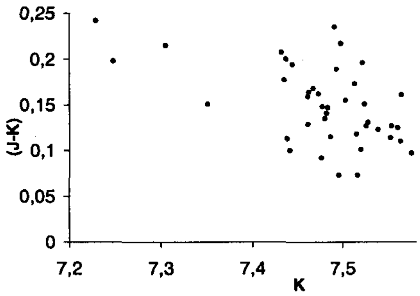


Figure 2. Colour($J - K$)-magnitude($K$) diagram

### 3.2. Colour-Colour diagram

The intrinsic colour-colour diagram is shown in Fig. 3. The intrinsic values for normal B-type stars between B0-B9, found by Dougherty et al. (1993), are also plotted.

LS I +61 303 presents a significantly redder colour than normal B-type stars. This is rather common in Be stars, where the IR excess is attributed to a dense circumstellar envelope (Slettebak 1988).

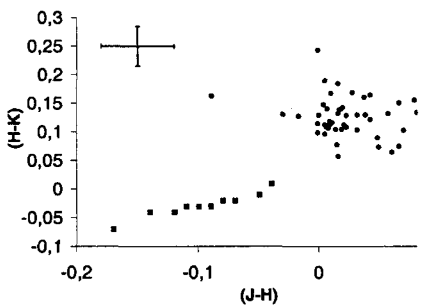


Figure 3. Near-IR colour-colour diagram. The square points represent the intrinsic colours for normal B-type stars (Dougherty et al.1993). The typical dispersion uncertainties is given in the upper left-hand corner of the figure

### 3.3. IR colour excess

To calculate the circumstellar excess we assume a spectral type of B0V (Steele et al. 1999). Intrinsic photospheric colours for a B0V star have been taken from

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Koorneef (1993). The near-IR excess colour-colour diagram for LS I +61 303 is shown in Fig. 4.

Dougherty et al. (1994) carried out a study about the near-IR excess emission of 144 Be stars. From their colour-colour diagrams it is possible to distinguish several groups of Be stars: stars with colours closely the same as 'normal' Be stars; stars that have significantly redder colours than normal Be stars; and a few stars with colour bluer than expected for normal B-type stars. We find evidence that LS I +61 303 belongs to the group of Be stars with significantly redder colours, as expected for an early-type Be star. The same situation is observed in the excess colour diagram.

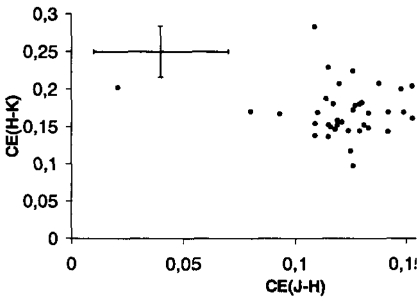


Figure 4. Near-IR excess colour-colour diagram. Typical dispersion uncertainties are shown in the upper left-hand corner of the figure.

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