The spectroscopic orbits and other parameters of the symbiotic binary FN Sgr

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Abstract.
We present an analysis of optical and near infrared spectra of the eclipsing symbiotic system FN Sgr. In particular, we have determined for the first time spectroscopic orbits based of the radial velocity curves for both components. A set of blue absorption lines resembling an A-F type star is present in all our spectra. They seem to be associated with the hot component but the best orbital fitting corresponds to a larger eccentricity. We have also studied spectral changes and photometric variations in function of both the hot component activity and the orbital motion.

1. Introduction

This work is part of a major project in which we determine periods and spectroscopic orbits of symbiotic binaries in base of observational data collected at CASLEO (San Juan, Argentina) along more than ten years. Selecting the southern S-type symbiotic star FN Sgr, we chose to use visual photometry from the Variable Star Section Circulars of The Royal Astronomical Society of New Zealand through 20 years of these circulars (1975–2001; Fig.1) and high resolution spectra obtained with the 2.15 m telescope of CASLEO during the period 1990–2001.

We have measured the radial velocities of the cool component from the M-type absorption lines, specially FeI, TiI, NiI, SiI and CoI. We have also identified and measured the blue cF-type absorption lines corresponding to CrII, FeII, TiII and YII which are believed to be linked to the hot companion (e.g. Mikolajewska & Kenyon 1992; Quiroga et al. 2002). The individual radial velocities were obtained by gaussian fitting of the line profiles and a mean value was calculated...
Figure 1. (top) Visual light curve of FN Sgr in 1975−2002. Dots: visual observations from RASNZ, open circles: V magnitudes calculated from our spectra and derived from FES counts. (bottom) Evolution of emission line fluxes of Hα, HeII 4686 and [OIII 5007] in 1988−2002. Bars mark times of photometric minima/times of inferior spectroscopic conjunction of the red giant.

for each spectrum. In addition, we have determined the radial velocities of the broad emission wings of Hα, Hβ and HeII λ4686 which are formed in the inner region of the accretion disk or in an extended envelope near the hot component (e.g. Quiroga et al. 2002). For this we have used the method outlined by Schneider & Young (1980).

Optical emission line fluxes were also derived, either by integrating the line profile or by fitting Gaussian profiles, as well as the [TiO]1 and [TiO]2 indices as defined by Kenyon & Fernandez-Castro (1987).

2. Orbital period

We have analyzed the RASNZ visual photometry using the period-search method described by Schwarzenberg-Czerny (1997). A period of about 568 days was obtained from all visual data presented in Fig.1. The radial velocities, emission line fluxes, and [TiO]1 indices, all show the same periodicity, which we attribute to the orbital period. In all cases, the most regular changes have been obtained with 568-day period, giving the ephemeris

$$\text{Min} = JD 2450270 \pm 2 + 568.3 \pm 0.3 \times E.$$  (1)

3. Spectroscopic orbits

The broad emission line wings of Hα, Hβ and HeII 4686 and the blue cF type absorption lines show the highest amplitude and a mean velocity similar to the
Figure 2. Phased radial velocity data and orbital solutions for FN Sgr. (top) The broad emission wings of HI and HeII lines. (bottom) The M giant (dots) and the hot component (open circles). The solid and dashed lines repeat the circular orbit of the M giant and the hot component (blue absorption system), respectively. The dotted line gives the best elliptical fit to the blue absorption system ($e = 0.20$).

Table 1. Orbital solutions for FN Sgr

<table>
<thead>
<tr>
<th>Elements</th>
<th>M giant</th>
<th>Blue absorptions</th>
<th>HeII wings</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K$ [km/s]</td>
<td>10.5 ± 0.4</td>
<td>10.6 ± 0.3</td>
<td>21.7 ± 1.0</td>
</tr>
<tr>
<td>$\gamma_0$ [km/s]</td>
<td>-53.7 ± 0.2</td>
<td>-53.7 ± 0.2</td>
<td>-50.9 ± 0.9</td>
</tr>
<tr>
<td>$e$</td>
<td>0</td>
<td>0.07 ± 0.03</td>
<td>0</td>
</tr>
<tr>
<td>$\omega$ [°]</td>
<td>320</td>
<td>257 ± 8</td>
<td>261 ± 13</td>
</tr>
<tr>
<td>$T_0$ [JD 24...]</td>
<td>50355</td>
<td>50541</td>
<td>50561</td>
</tr>
<tr>
<td>$\Delta T$ [day]</td>
<td>7.4</td>
<td>13</td>
<td>3.4</td>
</tr>
<tr>
<td>$a \sin i$ [R⊙]</td>
<td>118</td>
<td>118</td>
<td>243</td>
</tr>
<tr>
<td>$f(M)$ [M⊙]</td>
<td>0.0689</td>
<td>0.0694</td>
<td>0.5996</td>
</tr>
</tbody>
</table>

$T_0$ – time of the passage through periastron; $\Delta T = T_{sp \, conj} - T_{phot \, min}$.

The best orbital solution for the blue absorption system (as well as those for the broad emission line wings) leads to significant eccentricity whereas the red giant orbit is circular or nearly circular.

Combining the semi-amplitudes of the M giant and the blue absorption component for the circular orbit (Table 1) gives a mass ratio $q = M_g/M_h = 2.1 ± 0.2$, the component masses of $M_g \sin^3 i = 1.4 M_⊙$ and $M_h \sin^3 i = 0.66 M_⊙$, and the binary separation $a \sin i = 360 R_⊙$. 

red giant systemic velocity. They are clearly in antiphase with the M-giant curve which suggest that they are formed in a same region very near to the hot component (Fig.2).
4. Activity

Most of our spectroscopic observations were taken during the optical outburst phase (Fig.1). The outburst behaviour is similar to that observed in other classical symbiotic stars (e.g. CI Cyg and AX Per). The rise in optical brightness was first accompanied by a large increase in the [OIII] emission lines, and broadening of the emission line wings. The permitted HI and HeI emission lines were also increasing although not as much as the forbidden lines, whereas HeII 4686 was decreasing. Then, near the visual maximum (1996–1998) the [OIII] emission decreased, and HeII 4686 practically disappeared. At the same time the permitted emission lines have maximum widths. In 1999, the visual brightness began gradually declining; the [OIII] and HeII emission lines were increasing again. The [OIII] nebular emission reached maximum intensity in July—September 2000, and after that was declining following the visual magnitudes. HeII 4686 emission reached maximum intensity in September—October 2000, somewhat later than the forbidden line emission.

The emission line changes indicate a decrease in the hot component temperature at the optical maximum to $\lesssim 50000$ K, possibly because of increasing optical depth in the hot component wind. On the other hand, the presence of the blue shell absorption system apparently associated with the hot component in all our spectra, including periods where the strong high-ionization features are present, suggests a double-temperature structure of the hot component. The emission line fluxes, if due to a photoionization, require the hot component temperature and luminosity of $T_h \sim 150000$ K, $L_h \sim 1000 L_\odot$ at quiescence, and $T_h \sim 50000$ K, $L_h \sim 2000 L_\odot$ at the optical maximum. The optical observed during the 1996-98 maximum is consistent with a presence of continuum source with $T_{\text{eff}} \sim 7000 - 8000$ K and $L \sim 2000 - 1000 L_\odot$ (assuming a distance $d = 5$ kpc).

We note here that similar behavior was observed during the optical outbursts of AX Per (Mikołajewska & Kenyon 1992), and other active symbiotic systems, in particular, in AR Pav (Quiroga et al. 2002, and references therein), and it can be explained by a presence of optically thick accretion disks.

5. Acknowledgments

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References