Research Note

Optical variability of SAO 91772: a serendipitous X-ray source

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Abstract. During the course of systematic observations of known or suspected chromospherically active stars carried out at Catania Astrophysical Observatory by a 0.8-m Automated Photometric Telescope (APT), the variability of SAO 91772, the optical counterpart of the serendipitous X-ray source 1E0009.0+1417, was discovered. We detected a quasi-sinusoidal variation with a period of 1.84±0.02 days and a V-band peak-to-peak amplitude of about 0.08 magnitudes. The variation of the color indices suggests that the light change is due to photospheric cool spots, whose visibility on the projected stellar disk facing the observer is modulated by the star rotation. Moreover, long-term variability of the global spot covering factor is strongly suspected.

Key words: stars: activity – stars: late-type – stars: individual: SAO 91772 – binaries: close – X-rays: stars

1. Introduction

The term "chromospherically active stars" is generally referred to single or binary stars showing Ca II H and K and other chromospheric and transition region emission lines. Moreover, quasi-periodic wide-band optical variability, suggesting the presence of photospheric cool spots, is often observed. In particular, the RS CVn-type stars are tidally coupled rapidly rotating close binaries. As defined by Hall (1976), these binary systems usually include at least one evolved component of luminosity class IV or III. Afterward, Bopp & Fekel (1977) defined the BY Dra-type variables, that could be either single or binary, as late-type fast rotating dwarfs showing strong chromospheric activity. Finally, Fekel et al. (1986) suggested that from an evolutionary point of view F and G dwarf binaries should be classified as BY Dra-type rather than RS CVn-type variables. Apart from spectroscopic studies, as those carried out by Bidelman & MacConnell (1973) and Bidelman (1983, 1985a), a very efficient method for discovering chromospherically active stars is through all-sky X-ray survey (Caillault et al. 1986; Silva et al. 1987; Fleming et al. 1988,1989; Cutispoto et al. 1992; Tagliaferri et al. 1992). SAO 91772 (BD+13 13 = GC 217) has been identified as the optical counterpart of the serendipitous X-ray source 1E0009.9+1417 detected by the Einstein satellite during the Extended Medium Sensitivity Survey. SAO 91772 has been classified as a suspected RSCVn-type binary on the basis of the large X-ray to optical luminosity ratio, the variable radial velocity, and the typical emission features of chromospherically active stars in the UV spectrum (Bergoffen et al. 1988; Fleming et al. 1989). More recently, SAO 91772 was also detected in the EUV spectral range by the Wide Field Camera on the ROSAT satellite (Pounds et al. 1991).

2. Observations

A programme of systematic photometry of known or suspected active stars is being carried out at Catania Astrophysical Observatory since the early sixties (cf. Rodonò 1992; Rodonò & Cutispoto 1992; Cutispoto 1992 and reference therein). This programme is currently being continued by using a 0.8-m Automated Photometric Telescope (APT) that started regular operation in late 1992 at the mountain station of Catania Observatory on Mt. Etna (1750 m a.s.l.). The Catania-APT feeds a single-channel charge-integration photometer equipped with an uncooled Hamamatsu R1414 SbCs photomultiplier and standard UBV filters.

SAO 91772 (v) was observed over the period 20-30 November 1992. The observations were corrected for atmospheric extinction and transformed into the UBV standard system; they are listed in Table 1. HD 1352 and HD 874, which were used as comparison (c) and check (ck) stars, respectively, did not show appreciable variability (Fig. 1, panel a). Some observations of the field stars HD 405, HD 1168 and HD 87 were also
Table 1. Mean heliocentric Julian Day and nightly differential magnitudes obtained for SAO 91772. The standard deviations of these averaged values are of the order of 0.015, 0.010 and 0.007 magnitudes for the U, B and V bands, respectively. Phases are reckoned from the ephemeris HJD=2448947.0 + 1.84-E.

<table>
<thead>
<tr>
<th>HJD</th>
<th>Phase</th>
<th>ΔU</th>
<th>ΔB</th>
<th>ΔV</th>
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<tbody>
<tr>
<td>2448947.3104</td>
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<td>1.793</td>
<td>1.522</td>
<td>1.209</td>
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<tr>
<td>2448949.3244</td>
<td>.2633</td>
<td>1.819</td>
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<tr>
<td>2448950.3595</td>
<td>.8258</td>
<td>–</td>
<td>–</td>
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<tr>
<td>2448952.2992</td>
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<td>1.477</td>
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<td>1.836</td>
<td>1.554</td>
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</tbody>
</table>

Table 2. Mean V magnitudes and color indices obtained for the comparison (c), check (ck) and field (f) stars. The accuracy is of the order of 0.01, 0.01 and 0.02 magnitudes for V, B-V and U-B, respectively.

<table>
<thead>
<tr>
<th>Star</th>
<th>V</th>
<th>B-V</th>
<th>U-B</th>
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<tr>
<td>f</td>
<td>HD 87</td>
<td>5.55</td>
<td>0.90</td>
</tr>
<tr>
<td>f</td>
<td>HD 405</td>
<td>7.87</td>
<td>1.13</td>
</tr>
<tr>
<td>ck</td>
<td>HD 874</td>
<td>6.55</td>
<td>1.05</td>
</tr>
<tr>
<td>f</td>
<td>HD 1168</td>
<td>8.43</td>
<td>1.33</td>
</tr>
<tr>
<td>c</td>
<td>HD 1352</td>
<td>7.22</td>
<td>0.47</td>
</tr>
</tbody>
</table>

obtained from time to time. Each photoelectric measurement consisted of 20s integration time in each filter, according to the colour sequence U-B-V. A complete observation sequence, one on each night, consisted of sequential f,ck,c,v,v,c,v,c,v,c,ck,f measurements, where f is a field star. The sky background was measured, at a fixed position from each star, before the star was measured. Differential v-c and ck-c magnitudes were derived from these data. Due to the relatively short duration of an observation sequence (≈31 minutes), the v-c and ck-c values were finally averaged to obtain one single data point for each night. The typical standard deviations of these averaged v-c differential magnitudes are of the order of 0.015, 0.010 and 0.007 magnitudes for the U, B and V bands, respectively. From the magnitude and colors reported for the comparison, check and field stars in the SIMBAD database and from our differential photometry, the mean V magnitude and colors listed in Table 2 were computed. To obtain V magnitudes and colors of the variable star we simply added, as usual, the mean ΔU, ΔB and ΔV between the variable and comparison star to the magnitude of the comparison star. The accuracy of the standard magnitude and U-B and B-V colour determinations of comparison, check and field stars are of the order of 0.01, 0.01 and 0.02 magnitudes, respectively.

3. Discussion

The Catania-APT observations clearly show that SAO 91772 is definitely variable. The number of observations is not sufficient, however, to allow us to perform an accurate period determination by Fourier or periodogram analysis. From the available V data we estimated a preliminary period of 1.84±0.02 days. The folded V-band light curve and U-B and B-V color indices are shown in Fig. 1 (panel b, c and d, respectively). The light curve is single-peaked but strongly asymmetric, indicating the presence of at least two active regions. There are weak, but clear B-V and U-B color variations. However, the B-V minimum is not in phase with the V-light minimum, but occurs close to the middle of the V-light curve descending branch. The U-B minimum occurs close to the V-light minimum.

There are few previous photometric observations of SAO 91772 in the literature. Sandage & Kowal (1986) give V=8.59, B-V=0.81 and U-B=0.27; Bergoffen et al. (1988) give V=8.50, B-V=0.81, U-B=0.26, (V-R)_c=0.50 and (V-I)_c=0.90. It is interesting to note that the V values we obtained are always brighter than V=8.50, even at light minimum, thus indicating a reduced degree of spottedness during the time interval of our observations. This suggests that spot activity on SAO 91772 undergoes long-term possibly cyclic changes. The mean B-V and U-B from our data are 0.78 and 0.26, respectively. These color data indi-
cate that the star was somewhat bluer than in previous epochs,
in agreement with the above conclusion on the decrease of the
total spot area.

SAO 91772 has been classified as G4 by Bidelman (1985b)
and as G5V by Bergoffen et al. (1988). However, the mean
colors reported by Bergoffen et al. (1988) are too red for a
"normal" G5V star. This could be due either to a very high
degree of spottedness or, more likely, to the presence of a K-
type companion. Fleming et al. (1989) reported a $v\sin i$ of 22
km/s. Due to the relatively large peak-to-peak amplitude of
the light curve, we assume that the inclination of the rotation axis
should be quite high, at least of the order of 45 degrees. In this
hypothesis the computed period of 1.84 days is consistent with a
system being formed by two late G-K components of luminosity
class close to V. Therefore, according to Pekel et al. (1986)
suggestion, SAO 91772 should be classified as a BY Dra-type
variable. Further photometric and spectroscopic observations
are scheduled at Catania Observatory to derive a better value of
the variability period and to understand the nature of this
short-period active star.

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