Research Note

Photometry of ET Andromedae and pulsation of HD 219891*,**

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Abstract. ET And is a binary system with a B9p(Si) star as the main component. We report on the photometric observing campaigns in 1988, 1989 and 1994 which confirmed the rotation period of 1°618875 for ET And while refuting other published values. Furthermore, the controversial issue of pulsational stability of ET And is resolved since we have discovered pulsation for HD 219891, which was the main comparison star and sometimes exclusively used. The frequency of 10.0816 d⁻¹, a semi-amplitude of 2.5 mmag, T eff and Mv suggest this comparison star to be a δ Scuti variable close to the blue border of the instability strip. The pulsational stability of ET And could be clearly established and hence no need exists to derive new driving mechanisms for stars between the classical instability strip and the region of slowly pulsating B-type (SPB) stars.

Key words: stars: binaries: spectroscopic – stars: chemically peculiar – stars: individual: ET And – stars: oscillations – stars: rotation

1. Introduction

The B9p(Si) star ET And is peculiar and controversial in several aspects:

- It is a hot Si star and a member of an excentric binary system (e = 0.46) with an orbital period of P = 48.1308 (Ouhrabka & Grygar 1979, Ouhrabka 1981).
- ET And is a photometric variable with amplitudes of 0.02 mag(V), 0.03 mag(B), and 0.05 mag(U) and light minima at JD = 2441204.54 + 1°61887-E (Hildebrandt & Hempelmann 1981, Scholz et al. 1985).
- Evidence for short time scale variations was reported by Panov (1978) with a period of the order of 140 mn and an amplitude of about 0.01 mag in V and B, and of 0.02 mag in U, using HD 219891 as the comparison star. This was confirmed by Gerth, Scholz & Panov (1984). An additional surprising result was the detection of radial velocity variations with a semi-amplitude of about 4 km s⁻¹ and a period of 0°189. Photometry obtained by Hildebrandt et al. (1985, same comparison star) corroborate the existence of short periodic variations and the authors claim to have evidence for three more periods between 120 mn and 160 mn. Hempelmann & Hildebrandt (1990) published yet another short period of 180 mn. No such periods, however, were detectable in time series of high resolution spectra (Piskunov et al. 1994). It was also speculated that the amplitudes of the short periodic variations depend on rotation and orbital phase (Gerth, Scholz & Panov 1984).
- Rapid light oscillations with periods between 7 mn and 16 mn and with amplitudes of several millimagnitudes were claimed by Panov (1984).
Table 1. Synopsys of the photometric observations in 1988–1994.

<table>
<thead>
<tr>
<th>Star</th>
<th>HD</th>
<th>HR</th>
<th>V</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ET And</td>
<td>219749</td>
<td>8861</td>
<td>6.48</td>
<td>B9p(Si)</td>
</tr>
<tr>
<td>C1</td>
<td>219891</td>
<td>8870</td>
<td>6.50</td>
<td>A5v*</td>
</tr>
<tr>
<td>C2</td>
<td>219668</td>
<td>8857</td>
<td>6.43</td>
<td>K0v</td>
</tr>
<tr>
<td>C3</td>
<td>218525</td>
<td>8806</td>
<td>6.56</td>
<td>A2IV</td>
</tr>
</tbody>
</table>

The proof of pulsation for ET And would pose a serious challenge to theoretical astrophysics related to stellar models and opacities, because this star would clearly fall outside the hot border of the instability strip.

In conclusion, the situation concerning the photometric properties of ET And was very confusing in 1988 when we decided to focus our attention on this strange object by organizing international spectroscopic and photometric observing campaigns in 1988, 1989 and 1994 with results to be discussed in this paper.

2. Observations and data reduction

The first campaign in 1988 was based on the photometric evidence published by Hildebrandt et al. (1985) and the same comparison star (C1 = HD 219891) was chosen. For the 1989 campaign A.V.K. & A.V.M. at Tien Shan Observatory (Kazakhstan) added C2 (see Table[2]) as a second comparison star and found indications for C1 being variable with a period of about 0.1 days. The hypothesis of a variable primary comparison star was tested further at Tien Shan in 1990 and 1991. For a test of the variability of the comparison star and the stability of ET And towards pulsation a multisite campaign was organized in 1994 using HD 218525 as a third comparison star.

3. Rotation of ET And

The rotation period of ET And was discussed by Hildebrandt & Hempelmann (1981) and slightly improved to $1^d61887$ by Scholz et al. (1985). We have independently confirmed this value on the grounds of our 1988-1989 data which settles any dispute about other rotation periods.

Scholz (1986) speculated as to whether the period of $1^d6$ should not be attributed to g-mode pulsation because of the similarity of the period length to what is expected for SPB stars. For two reasons this interpretation appears unlikely to us. First, we determined the rotation light curve, which is the dominant signal in our photometry. For this purpose we needed to filter all the higher frequency signals and, in particular, the claimed 140 mn variations which would contribute to ‘noise’ in the rotation light curve. Hence, the data sets were averaged over 140 mn, which resulted in up to two independent data points per night. The main period of $1^d61887$ (Scholz et al. 1985) was confirmed, a phase plot generated, and a rotational light curve computed with a cubic spline fit. In a next step, the residuals of our photometric data were determined relative to this smooth light curve which resulted in the data set used for the investigation of short time scale variations (Weiss et al. 1989, Kuschnig et al. 1990).

4. Pulsation of HD 219891

The 143 mn peak at $f_1 = 10.084$ d$^{-1}$ is clearly evident in the amplitude spectrum of C1 (HD 219891) – C2 (HD 219668) magnitude differences (Fig[1] middle panel). A second frequency in the range from 8 to 12 d$^{-1}$ might also be present, but the noise...
level at these low frequencies is clearly larger than above 20 d$^{-1}$, which probably is caused by zero-point variations which are difficult to correct in this inhomogeneous data set.

The frequency analysis of the $B$ and $v$ data from 1994 shows that the amplitude at $f_1$ was similar during the previous years as was derived from ET And relative to C1 after subtraction of the rotational modulation due to ET And. As can be seen in Fig. 1 (lower panel) the amplitude spectrum of the residuals after prewhitening the data with $f_1$ does not contain any further significant peaks in the 0 to 100 d$^{-1}$ frequency domain.

Using the Strömgren indices for C1 (HD 219891): ($b-y)=0.094, m_1=0.184, c_1=1.051$ and $\beta=2.834$, and the empirical calibration of Breger (1989) we can estimate $T_{\text{eff}}=8270, M_v=0.83$ and $\log g=3.777$, which locates HD 219891 slightly above the ZAMS near the blue edge, but still inside the instability strip of $\delta$ Scuti stars. The pulsation constant $Q=0.0269$, together with the grid of theoretical pulsation models of A- to F- type stars (Fitch 1981) allows us to estimate the pulsation mode for $f_1$ to be the first overtone of a low degree mode.

From our simultaneous Strömgren photometry obtained at San Pedro we determined the amplitude ratios and phase shifts for different filters and we applied the mode identification technique described by Garrido et al. (1990) based on Watson (1988). All phase shifts are negative and range from $-1.5^\circ$ to $-5.3^\circ$, confirming non-radial pulsation modes. The high rotational velocity ($v \sin i = 175 \text{ km s}^{-1}$) and non-radial pulsation would be consistent with low photometric amplitudes in the visible, analogous to the rapidly rotating non-radially pulsating $\delta$ Scuti stars (Breger 1979).

The final proof for the primary comparison star C1 (HD 219891) being the pulsating variable is given in Fig. 2 where we plot the amplitude spectrum of the magnitude differences of ET And and C2 (HD 219668) for the $B$ and $v$ data after removal of the rotational modulation. The absence of a 10.08 d$^{-1}$ variability is clearly evident, as well as the lack of significant peaks in the 0 d$^{-1}$ to 100 d$^{-1}$ frequency domain. A slight increase of amplitudes below 10 d$^{-1}$ can again be related to zero point problems when merging inhomogeneous data.

A similar procedure applied to a data set which includes the observations with the highest intrinsic accuracy, largest duty cycle and frequency resolution (Lowell & MKO in 1988, Xinglong, San Pedro & Lowell in 1989) resulted in a mean noise level of 0.3 mmag($B$) from 10 d$^{-1}$ up to the Nyquist frequency of about 200 d$^{-1}$. No amplitude spike exceeds the 99% significance level, which is 3.6 times the mean noise amplitude (Kuchnig et al. 1997). Hence, we do not find in our data from 1988 to 1994 variability for ET And with periods between 7 mn and 13 mn and amplitudes of several millimagitudes, as were suspected by Panov (1985).

5. Conclusions

The results from our photometric campaigns on ET And can be summarized as follows:

- Spectroscopy ($T_{\text{eff}}=12 000 \text{ K} \pm 250 \text{ K}, \log g=3.65 \pm 0.25$: Piskunov et al., 1994, Kuchnig et al., 1995) as well as photometry ($T_{\text{eff}}=12 000 \text{ K}, \log g=3.90$: Renson et al. 1991) put ET And in the domain of late B stars and outside the classical instability strip.
- ET And is stable against pulsation, hence no problems exist concerning the pulsational stability found in this region of the HR-diagram by Dziembowski et al. (1993).
- The period and shape of the rotation light curve of ET And is consistent with observations during the last three decades.
- HD 219891 (C1) is slightly evolved and the $T_{\text{eff}}$ and $M_v$ values put this star inside and close to the blue edge of the $\delta$ Scuti instability strip.
HD 219891 is probably a δ Sct type pulsating star with the principal frequency of $10.082 \text{d}^{-1}$ and a (peak-to-peak) amplitude of close to 5 mmag($B$). This variability (attributed previously to ET And) seems to have been constant in amplitude and frequency since its discovery in 1977.

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