Astron. Astrophys. 338, 919–922 (1998)

ASTRONOMY AND ASTROPHYSICS

Research Note

Photometry of ET Andromedae and pulsation of HD 219891[⋆,⋆⋆]

W.W. Weiss[1], R. Kuschnig[1], D.E. Mkrtichian[2], A.V. Kusakin[3], T.J. Kreidl[4,⋆⋆⋆], S.J. Bus[4], D.J. Osip[4], Z. Guo[5], J. Hao[5], L. Huang[5], J.-P. Sareyan[6], M. Alvarez[7], S.G. Bedolla[8,†], J. Zverko[9], J. Žižňovský[9], P. Mittermayer[1], K. Zwintz[1], N. Polosukhina[10], A.V. Mironov[3], N.I. Dorokhov[2], V.P. Goranskij[3], T.N. Dorokhova[2], H. Schneider[11], and F. Hiesberger[1]

[1] Institut für Astronomie der Universität Wien, Türkenschanzstrasse 17, A-1180 Wien, Austria (e-mail: weiss@galileo.ast.univie.ac.at)
[2] Astronomical Observatory, Odessa State University, Shevchenko Park, 270014 Odessa, Ukraine
[3] Sternberg State Astronomical Institute, Universitetskij prospect, 13, 119899 Moscow, Russia
[4] Northern Arizona University, Box 5100, Flagstaff, AZ 86011, USA
[5] Beijing Astronomical Observatory, Zong-guan-cun 100080, Beijing, P.R. China
[6] Observatoire de la Cote d'Azur, Le Mont Gros, F-06003 Nice, France
[7] Observatorio Astronomico Nacional – UNAM, Apdo. Postal 877, Ensenada, B.C., 22800, Mexico
[8] Instituto de Astronomia – UNAM, Apdo. Postal 70-264, 04510 Mexico, Mexico
[9] Astronomical Institute of the Slovak Academy of Science, SK-05960 Tatranska Lomnica, Slovakia
[10] Crimean Astrophysical Observatory, p/o Nauchny, 334413 Crimea, Ukraine
[11] Universitätssternwarte, Geismarlandstrasse 11, D-37083 Göttingen, Germany

Received 8 June 1998 / Accepted 23 July 1998

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 $1\overset{\mathrm{d}}{.}618875$ 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 $10.0816\,\mathrm{d}^{-1}$, a semi–amplitude of 2.5 mmag, T_{eff} and M_{v} 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 = $48\overset{\mathrm{d}}{.}308$ (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 = $2441204\overset{\mathrm{d}}{.}54 + 1\overset{\mathrm{d}}{.}61887 \cdot$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 $4\,\mathrm{km\,s}^{-1}$ and a period of $0\overset{\mathrm{d}}{.}1989$. 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).

Send offprint requests to: W.W. Weiss

⋆ Based on observations obtained at the Bulgarian National Observatory, Crimean Astrophysical Observatory (Ukraine), Lowell Observatory (USA), Mauna Kea (USA), Mt. Dushak-Erekdak (Turkmenistan), San Pedro (Mexico), Skalnate Pleso (Slovakia), Tien Shan (Kazakhstan) and Wise Observatory (Israel)

⋆⋆ Dedicated to our esteemed colleague S.G. Bedolla whose untimely death greatly saddened us

⋆⋆⋆ *Current address:* Northern Arizona University, Box 5100, Flagstaff, AZ 86011, USA

Table 1. Synopsis of the photometric observations in 1988–1994. *Observers:* Al– M. Alvarez, Be– S.G. Bedolla, Do– N.I. Dorokhov, Da– T.N. Dorokhova, Go– A.P. Goranskij, Gu– Z. Guo, Ha– J. Hao, Hi– F. Hiesberger, Hu– L. Huang, Kr– T.J. Kreidl, Ku– A.V. Kusakin, Mi– A.V. Mironov, Mk– D.E. Mkrtichian, Pa– K. Panov, Po– N. Polosukhina, Sa– J.P. Sareyan, Sc– H. Schneider, We– W.W. Weiss, Zi– J. Ziznovsky, Zv– J. Zverko

Observer	Observatory			Filters
	period:	Oct. '88	Nov. '88	
Kr	Lowell	2.–3.	4.–7.	∼B
We	MKO	2.–10.		B, (V)
Zv, Zi	Skalnate	3.–22.	5–11.	B, (V)
Pa	BNAO		11.–12.	B
Po	CrAO	4.		UBV
	period:	Sept. '89	Oct. '89	
Gu, Ha, Hu	Xinglong		4.–16.	B, (V)
Al, Be, Sa	San Pedro		7.–14.	u,v,b,y
Kr	Lowell	22.–23.	9.	∼B
Zi, Zv	Skalnate	20.–27.	17.–24.	B, (V)
	period:	Nov. '90		
Ku, Mi	Tien Shan	28.		B, (V)
	period:	Feb. '91		
Ku	Tien Shan	21.–22.		B, (V)
	period:	Aug. '94	Sept. '94	
Al, Be, Sa	San Pedro		13.–17.	u,v,b,y
Da, Do, Mk	Mt. Dushak		10.–18	∼v
Go, Ku	Tien Shan	10.–16.	9.–16.	B, (V)
Hi, Sc	Wise		9.–13.	B,V

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 Hildebrand 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.

Table 2. Programme and comparison stars

Star	HD	HR	*V*	Type
ET And	219749	8861	6.48	B9p(Si)
C1	219891	8870	6.50	A5Vn
C2	219668	8857	6.43	K0IV
C3	218525	8806	6.56	A2IV

The main problem with the data of the 1988-89 observations clearly was the use of a single comparison star (C1), which happened to be located in the instability strip.

The following describes the sequence for the data reduction. 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 $1\overset{\rm d}{.}61887$ (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).

3. Rotation of ET And

The rotation period of ET And was discussed by Hildebrandt & Hempelmann (1981) and slightly improved to $1\overset{\rm d}{.}61887$ 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 $1\overset{\rm d}{.}6$ 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, the shape of the $1\overset{\rm d}{.}6$ light curve depends strongly on the filters used, much more than could be accounted for by temperature and luminosity variations due to radial and non-radial pulsation. Second, from our simultaneous multi-filter photometry we derive a null-wavelength at about 3700Å. Such a null-wavelength inherently is linked to photospheric inhomogeneities causing backwarming effects which vary with the visibility of different parts of the stellar atmosphere, and hence, become detectable only due to stellar rotation. Indeed, such photospheric inhomogeneities were determined – for Si and He – with the Doppler imaging technique (Piskunov et al. 1994).

4. Pulsation of HD 219891

The 143 mn peak at $f_1 = 10.084\,{\rm d}^{-1}$ is clearly evident in the amplitude spectrum of C1 (HD 219891) – C2 (HD 219668) magnitude differencies (Fig. 1, middle panel). A second frequency in the range from 8 to $12\,{\rm d}^{-1}$ might also be present, but the noise

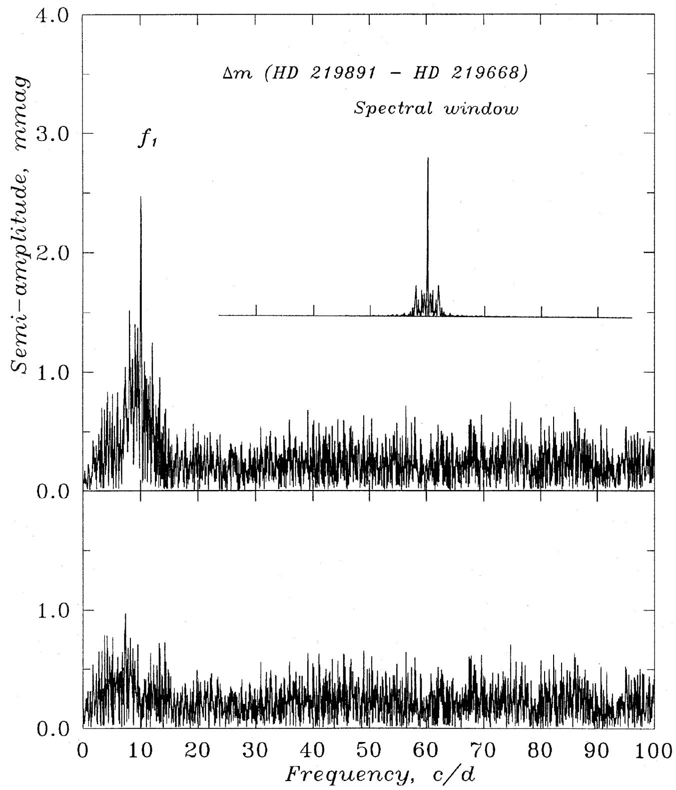

Fig. 1. Spectral window and amplitude spectra of 1994 B and v magnitude differences (C1:HD 219891–C2:HD 219668). Upper panel: spectral window, middle panel: original data, lower panel: amplitude spectrum after substraction of the 10.08 d^{-1}variability

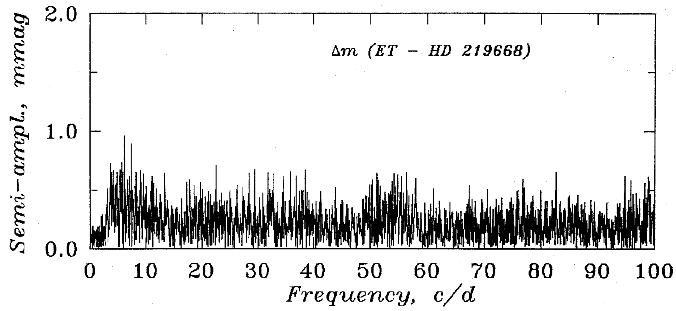

Fig. 2. Amplitude spectrum of ET And – C2 (HD 219668) magnitude differences of merged 1994 B and v data. The rotational modulation due to ET And is removed.

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 β = 2.834, and the empirical calibration of Breger (1989) we can estimate T_{eff} = 8270, M_{v} = 0.83 and $log\,\mathrm{g}$ = 3.777, which locates HD 219891 slightly above the ZAMS near the blue edge, but still inside the instability strip of δ 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 $-1.5°$ to $-5.3°$, confirming non-radial pulsation modes. The high rotational velocity ($v \sin i = 175\,\mathrm{km\,s}^{-1}$) and non-radial pulsation would be consistent with low photometric amplitudes in the visible, analogous to the rapidly rotating non-radially pulsating δ Sct 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 (Kuschnig 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 millimagnitudes, as were suspected by Panov (1985).

5. Conclusions

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

- Spectroscopy (T_{eff} = 12 000 K $\pm$ 250 K, $log\,\mathrm{g}$ = 3.65 $\pm$ 0.25: Piskunov et al., 1994, Kuschnig et al., 1995) as well as photometry (T_{eff} = 12 000 K, $log\,\mathrm{g}$ = 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_{eff} and M_{v} values put this star inside and close to the blue edge of the δ Scuti instability strip.

• HD 219891 is probably a δ Sct type pulsating star with the principal frequency of 10.082 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.

Acknowledgements. This research was performed within the working group *Asteroseismology along the main sequence – AMS*. The authors thank Don Kurtz, Cape Town, for identifying the problem of an insufficient comparison star. RK and WWW express their gratitude to the Austrian Fonds zur Förderung der wissenschaftlichen Forschung, grants No. 6927, 8776 and S-7303, and TJK acknowledges support from the National Science Foundation, grant No. AST-8716971 and the Lowell Observatory endowment. ZG, JH and LH were supported from the National Natural Science Foundation of China, grant No. 1870609, and KP from the Bulgarian Ministery of Education and Science, grant No. F-108. We also wish to thank A. Hempelmann for making his published PZR data accessible to us in computer readable form.

References

Balona L. 1984, MNRAS 211, 973
Breger M. 1979, PASP 91, 5
Breger M. 1989, *Communications in Astroseismology* 6, 1
Cramer N., Maeder A. 1979, A&A 78, 305
Dziembowski W.A., Mosalik P., Pamyatnykh A.A 1993, MNRAS 265, 588
Fitch W.S. 1981, ApJ 249, 218
Garrido R., Garcia-Lobo E., Rodriguez E. 1990, A&A 234, 262
Gerth E., Scholz G., Panov K.P. 1984, Astron. Nachr. 305, 79
Hauck B., North P. 1993, A&A 269, 403
Hildebrandt G., Hempelmann A. 1981, Astron. Nachr. 302, 155
Hildebrandt G., Schöneich W., Lange D., Zelwanowa E., Hempelmann A. 1985, Publ. Astrophys. Obs. Potsdam, Nr. 112
Hempelmann A., Hildebrandt G. 1990, Astron. Nachr. 311, 295
Kuschnig R., Weiss W. W., Kreidl T. J., et al., 1990, in *Confrontation between stellar pulsation and evolution*, ASP Conference Series, Carla Cacciani & Gisella Clementini edts., Vol. 11, pg.348
Kuschnig R., Ryabchikova T., Piskunov N., Weiss W.W., Le Contel J.M. 1995, A&A 294, 757
Kuschnig R., Weiss W.W., Gruber R., Bely P.Y., Jenkner H. 1997, A&A 328, 544
Mégessier C. 1988, A&ASS 72, 551
North P., Nicolet B., 1990, A&A 228, 78
Ouhrabka M., Grygar J., 1979, Inf. Bull. Var. Stars, No. 1600
Ouhrabka M., 1981, Publ.Special Aph. Obs, Acad.Sciences USSR, No.32, 45
Panov K.P., 1978, Publ. Astron. Inst. Czechoslov. Acad. Sciences, No.54, 19
Panov K. P., 1984, in Proc. *Magnetic Stars, 6-th Scientific Conference*, Institute of Physics, Latvian SSR Academy of Sciences, p. 77
Panov K.P., 1985, Inf. Bull. Var. Stars, No. 2825
Piskunov N.E., Ryabchikova T.A., Kuschnig R., Weiss W.W. 1994, A&A 291, 910
Rakosch K.D., Fiedler W. 1978, A&AS 31, 83
Renson P., Kobi D., North P. 1991, A&ASS 89, 61
Schneider H., Kreidl T.J., Weiss W.W. 1992, A&A 257, 130
Scholz G., Gerth E., Panov K.P. 1985, Astron. Nachr. 306, 329
Scholz G. 1986, Astron. Nachr. 307, 21
Schöneich W., Hildebrandt G., Fürtig W., 1976, Astron. Nachr. 297, 39
Stepien, K., Dominiczak, N. 1989, A&A 219, 197
Watson R.D. 1988, Ap&SS 140, 255
Weiss W.W., Kuschnig R., Kreidl T.J., Zverko J., Žižňovský J., Panov K., Polosukhina N., Hempelmann A., Matthews J., Yang S., Schneider H., Gerth E., Scholz G. 1989, Astron. Gesell. Abstract Series 3, 79
Weiss W.W., Schneider H. 1984, A&A 135, 148