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THE HIGH-AMPLITUDE δ SCUTI STAR GP ANDROMEDAE

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GP And is a well-studied high-amplitude δ Scuti star. Its variability was discovered by Strohmeier et al. (1956). Lange (1969, 1970) derived the type and period of this variable and pointed to possible light curve variation with a modulation period of 0.2684 day. This announcement aroused our interest and we started the star's photoelectric photometry at Konkoly Observatory in 1970.

Since the early seventies photoelectric photometry of this variable has been carried out and published by Eggen (1978), Gieseking et al. (1979), Rodríguez et al. (1993) and Schmidt et al. (1995). Splittgerber (1976), Burchi et al. (1993) and the BAV group (Agerer & Hübscher, 1998, 2002, 2003; Agerer et al., 1999, 2001; Hübscher, 2005; Hübscher et al., 2005) published photoelectric/CCD times of maximum light.

The Hipparcos photometry and the NSVS (Wozniak et al., 2004) provide useful data sets to study the period changes and the possible light curve modulation of the star. Having taken into account the heliocentric corrections normal maxima could be constructed from these data sets:

1) from the Hipparcos photometry: $\mathrm{HJD_{max}}$ 2448448.1856 and

2) from the NSVS data: $\mathrm{HJD_{max}}$ 2451484.7904.

Apart from the rather accurate photoelectric/CCD observations a great number of photographic and visual measurements are found in the literature. In our discussion, however, we disregard these inaccurate data.

Our observations extended from 1970 to 1997. Observations at Konkoly Observatory were made with the 60 cm Newtonian reflector (10 nights) and the 50-cm Cassegrain telescope (10 nights) each equipped with an uncooled UBV photometer, and with the 1-m RCC telescope equipped with an $UBV(RI)_C$ refrigerated photoncounting photometer (5 nights).† CCD observations were obtained with the 60/90/180-cm Schmidt telescope using a Photometrics camera (thermoelectrically cooled Kodak KAF-1600 1024 × 1536 chip) on one night without filter and two nights in the V colour band.

Observations at Leopold Figl-Observatory of the Astronomical Institute of the University of Vienna have been carried out in the V and B band using an uncooled photometer (with standard Corning filters) attached to the 60-cm RC telescope on 13 nights.

Throughout our observations we used GSC 01739-01584 lying $\sim 5'$ west from the variable as comparison star.

†The 1-m RCC $UBV(RI)_C$ observations (Table 1) are available at the IBVS website as 5718-t1.txt.

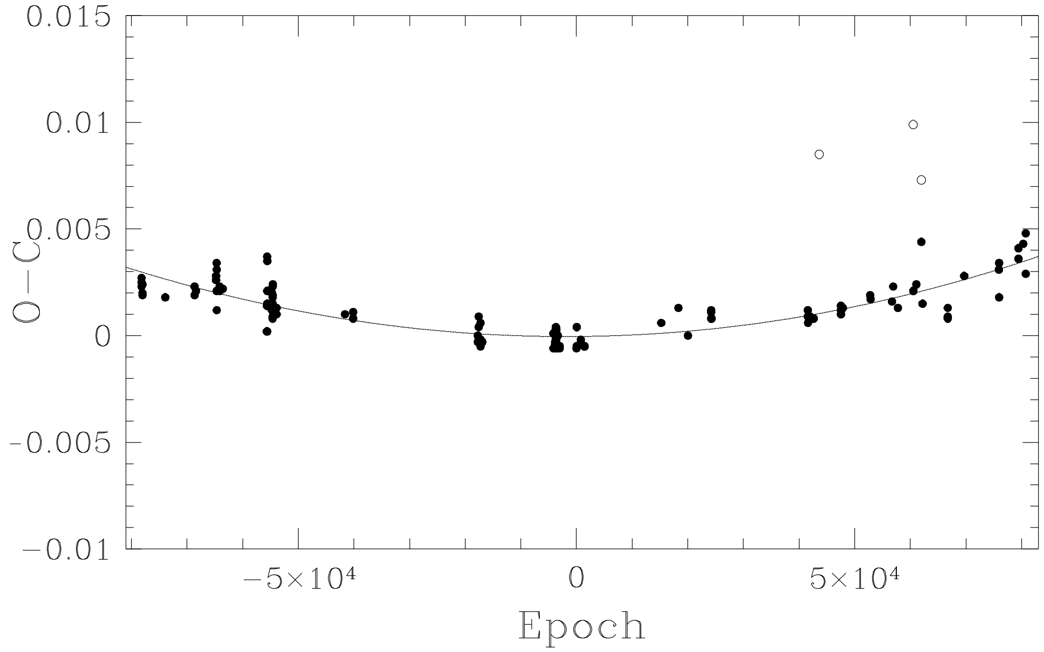

Figure 1. $O-C$ diagram with quadratic fit. The open circles denote uncertain data not taken into account in the fit

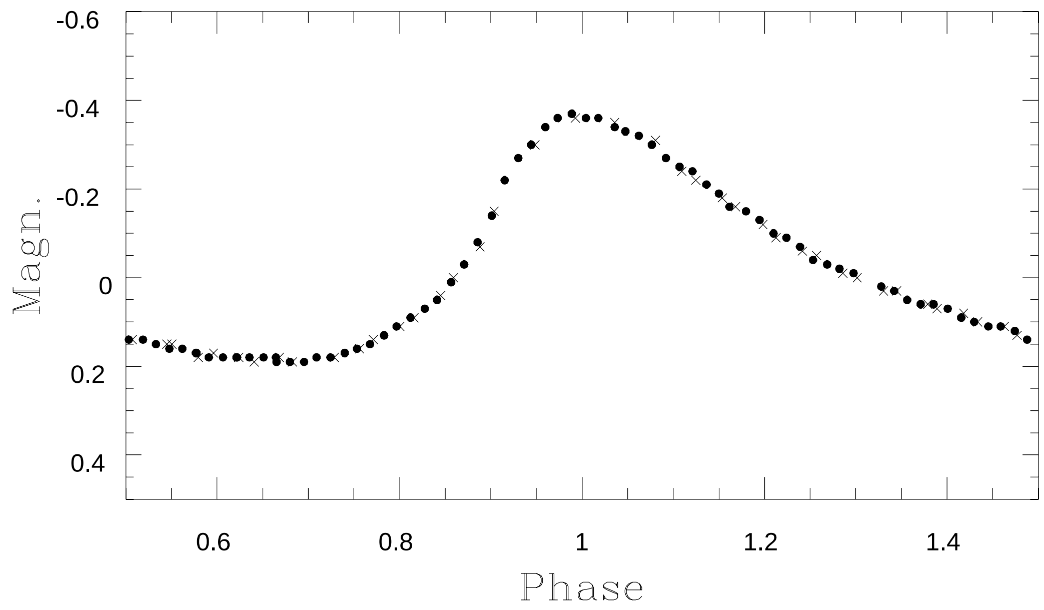

Figure 2. Folded V light curve of two nights (five cycles) of CCD observations (JD 2450746: dots; JD 2450772: crosses)

Table 2. Times of light maximum observed at Leopold Figl and Konkoly Observatories

HJD_{max} 2400000 +	Rem.	HJD_{max} 2400000 +	Rem.	HJD_{max} 2400000 +	Rem.	HJD_{max} 2400000 +	Rem.
40854.4352	[1]	43848.3910	[1]	46704.5745	[3]	46720.5464	[3]
40854.5135	[1]	45609.4674	[2]	46705.4394	[3]	46722.5134	[3]
40854.5923	[1]	45609.5464	[2]	46705.5182	[3]	46743.3650	[2]
40867.4962	[1]	45622.4513	[2]	46713.3867	[3]	46769.3297	[3]
40867.5745	[1]	45622.5294	[2]	46713.4657	[3]	46769.3298	[2]
40869.3841	[1]	45634.4885	[2]	46713.5443	[3]	50277.4810	[4]
41189.4655	[1]	45648.4154	[2]	46714.4882	[3]	50278.5036	[4]
41604.5175	[1]	45648.4939	[2]	46714.5675	[3]	50279.5262	[4]
41604.5958	[1]	45649.4391	[2]	46717.3997	[3]	50310.5275	[4]
41625.4469	[1]	45653.4512	[2]	46717.4778	[3]	50360.4909	[4]
41960.5570	[1]	45674.4594	[2]	46717.5565	[3]	50745.3285	[5]
41960.6355	[1]	46679.4740	[3]	46718.4220	[3]	50745.4074	[5]
42004.3832	[1]	46679.5533	[3]	46718.5008	[3]	50745.4863	[5]
42697.4208	[2]	46680.4975	[3]	46719.3669	[3]	50746.3514	[5]
42697.4986	[2]	46702.4496	[3]	46719.4457	[3]	50746.4303	[5]
42697.5775	[2]	46702.5288	[3]	46719.5239	[3]	50746.5089	[5]
42712.4485	[1]	46702.6067	[3]	46720.4686	[3]	50772.4744	[5]
43848.3126	[1]	46704.4953	[3]				

Remark: [1] Konkoly N 60-cm, [2] Konkoly C 50-cm, [3] Figl RC 60-cm, [4] Konkoly RCC 100-cm, [5] Konkoly Schmidt 60/90-cm CCD

On the whole 70 times of maximum light could be determined from our observations. Each light maximum was derived as an average over the B and V bands since the times of maximum for these colour bands are not perceptibly shifted to each other. (Except some cases, when observations were made only in one colour band.)

The times of maximum light derived from our observations are given in Table 2. The complete list of times of maximum light (Table 3) used to construct the $O-C$ diagram and to study the period changes of the variable is only available electronically through the IBVS website as file 5718-t3.txt.

The $O-C$ values have been calculated by the formula:

$$C = 2447005.6146 + 0\overset{\text{d}}{.}07868276 \times E$$

and plotted against E in Fig. 1. A quadratic least-squares fit provides the new ephemeris:

$$\begin{array}{l} C_{\text{new}} = 2447005.61456 + 0\overset{\text{d}}{.}0786827620 \times E + 5.20 \times 10^{-13} \times E^2. \\ \qquad\qquad \pm .00009 \quad \pm .0000000012 \qquad\quad \pm .27 \end{array}$$

Three uncertain, outlier points (at JD 2450438.4732, 2451768.528 and 2451882.458) were not taken into account in the fit.

The observations of the years 1970 and 1971 do not support the cubic solution of Pop et al. (2005), but the deviation of these data from the quadratic fit may hint at the reality of the higher order fit or a sine-like solution (Pop et al., 2003) notwithstanding that the slow period increase $1/P(\mathrm{d}P/\mathrm{d}t) = 6.1 \times 10^{-8}$ y^{-1} is not in serious conflict with evolutionary theories (Breger & Pamyatnikh, 1998).

Gieseking et al. (1979) noted that some disturbances were present in the fundamental pulsation. From four nights of photometry they found variability of some 0.1 mag in the amplitude with a period of 0.64 days, furthermore they pointed out that the mean brightness of the star and the shape of the light curve strongly varied from cycle to cycle, while an 18 minute wave superposed on the light curve was present. Rodríguez et al.'s (1993) photometry of high accuracy, however, did not show these kinds of disturbances.

As our photoelectric photometry also exhibited variability in the shape and amplitude of the light curve we decided to go into the matter in more detail. The Fourier analysis of the Hipparcos, the NSVS and our 1983 BV and 1998 $BVRI$ data sets, however, did not prove the existence of any additional frequencies with amplitude higher than 0.01 mag The folded CCD V light curve of two nights (five cycles) presented in Fig. 2. also shows a regular light variation characteristic of stable high amplitude δ Scuti stars.

Since GP And has a 1.5 mag fainter (in minimum, Eggen, 1978) very close visual companion with 11″ separation (Morlet et al., 2000) its photometry through a 20–30″ diafragm becomes uncertain. Therefore we incline to presume that the observed disturbances are rather (at least in significant part) the defect of the photometry.

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