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LETTER

Letter to the Editor

The symbiotic system AG Dra: an unexpected photometric period

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Abstract. A photometric period of about 380 days is found in 6810 visual magnitude estimates of AG Dra. This is unexpected, since the orbital period of the system is about 552 days. The period is confirmed by Hipparcos photometry. The new periodicity provides an additional constraint on physical models for AG Dra. Detailed observations before the end of the present outburst phase may help to clarify its nature.

Key words: symbiotic stars – AG Dra

1. Introduction

AG Dra is a well-studied bright symbiotic binary. The SIMBAD database lists 173 bibliographic references between 1983 and 1997. The orbital period of about 550 days is well established from radial-velocity data (e.g. Garcia & Kenyon 1988). The orbital inclination was determined by Schmid & Schild (1997) from variations in the polarization of optical Raman lines. On the basis of the high radial velocity (-140 km/s), the low metallicity ([Fe/H]$\simeq$-1.5) and the faintness of CNO lines in IUE spectra, Schmid & Nussbaumer (1993) assigned the system to the old halo population. The cool component is a K giant which is well within its Roche limits (Garcia & Kenyon 1988). It is enriched in heavy s-process elements (Schmid & Schild 1997). The white dwarf has a surface temperature of about 120 000 K (e.g. Greiner et al. 1996).

The optical variability of AG Dra used to be characterized by small irregular variations and, in addition, bright outburst phases. The burst phases repeat in intervals of about 15 years (1936, 1951, 1966, 1980-82, 1994-97), with only one small interloper (1985). In the visible spectral range there is no photometric signature of the orbital period (which was determined by radial-velocity measurements for the cool component), but it clearly shows up in the near UV (Meinunger 1979, Skopal & Chochol 1994, Skopal 1994) in the form of minima at the lower conjunction of the cool component (Skopal 1994 and references therein).

The photometric periodicity to be reported in the following was suspected already in 1994 (Bastian 1995) at the start of the present outburst phase, in a call for observations to amateurs. The present paper presents the confirmation of that suspicion by the behaviour of the system in the two years since then, and by the use of Hipparcos photometry.

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2. Observations and results

Fig. 1 shows a visual light curve of AG Dra from 6810 eye estimates by amateurs. It ranges from 1973 till mid 1997, i.e. over 24 years. The data were taken from the public data base of the *Association Francaise des Observateurs d'Etoiles Variables (AFOEV)* at CDS, Strasbourg (ftp://cdsarc.u-strasbg.fr/pub/afoev). The figure displays 22-day means over the individual magnitudes. The tick marks show the times of maxima as predicted by the ephemeris derived below. Ten maxima adhering to this ephemeris can clearly be seen. One of them, no. 8, is very small, and one of them, no. 2, is a hump on the declining slope of the preceding one. Maximum no. 16 was used in the analysis although it had not been fully completed at the time of data extraction. Maxima nos. 9 and 10 are insignificant in the visual data. They are marked for comparison with Fig. 2 only. The decrease of the scatter in the diagram around 1980, and again around 1995, is due to strongly increasing numbers of magnitude estimates. The two outburst episodes have drawn much observational attention on this object.

The Hipparcos satellite (ESA 1997) observed AG Dra photometrically from 1989 to 1993. The Hipparcos measurements started shortly after maximum no. 8 and included maxima nos. 9 to 11 (counting as in Fig. 1). The spectral response of the main instrument on board comprised the range of the Johnson B and V bands, plus a low red wing extending to about 700 nm. The results are shown in Fig. 2. It is obvious that the 380-day variability is also present during this time span, but too small to be detected by eye estimates. The phase agrees perfectly with that of the stronger bursts seen by the amateurs (see

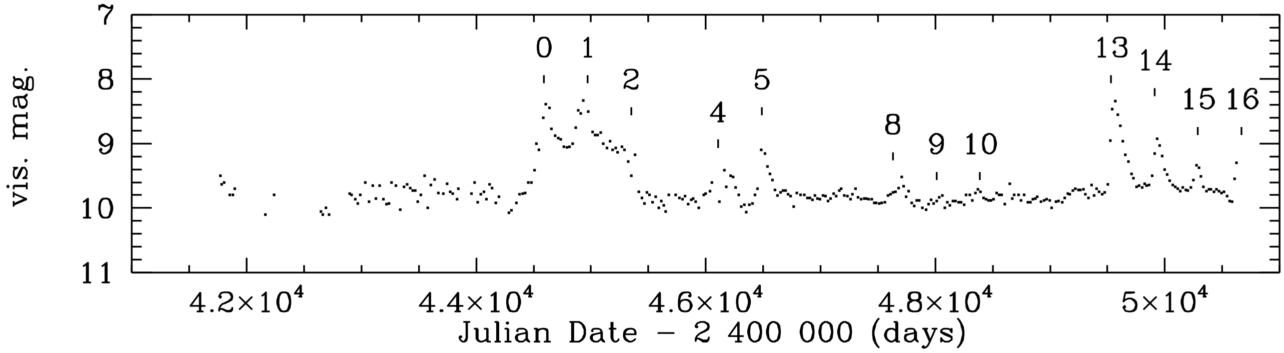

Fig. 1. Visual light curve of AG Dra 1973-97; 22-day averages over 6810 observations are displayed. The numbered tick marks indicate the 380-day ephemeris from Eq. 1.

also Fig. 3, to be discussed further below). The three slight oscillations observed by Hipparcos are not perfectly periodic, but have definitely differing shapes.

There are two more independent data sets indicating the 380-day periodicity: One is the photoelectric V photometry of Skopal and Chochol (1994). Close inspection of their Fig. 1 reveals maxima nos. 6 to 10 as very slight humps. - The other one is the radial-velocity data compiled by Mikolajewska et al. (1995). After removing the radial-velocity effect of a best-fit spectroscopic orbit, a 380-day wave with a full amplitude of about 3 km/s is seen in the residuals between JD 2448500 and 2449300. (H.M. Schmid, Heidelberg, 1997, private communication). Like the Hipparcos observations, these data cover a part of the quiet phase before the start of the 1994-6 outburst phase.

An ephemeris for the periodic brightness maxima of AG Dra was derived in the following way: The times of the ten obvious maxima from Fig. 1 were manually read from a large-scale plot, as were the three maxima nos. 9, 10 and 11 from Fig. 2. A constant period was adjusted to the 13 maxima, using equal weights. The result is:

$$\mathrm{JD}(max) = 2\,448\,010.1 \ + 379.9 \times E, \tag{1}$$

with standard errors of 2.1 days in the period and 11 days in the starting epoch. The latter corresponds to maximum no. 9 in Figs. 1 and 2. The rms scatter of the individual maxima timings around the ephemeris is 37 days. This value is to be compared with an expectation value of 110 days for a random distribution of timings relative to a 380-day ephemeris. Thus the statistical significance of the periodicity is confirmed.

Not surprisingly, the largest timing residuals (see Fig. 3) are due to maxima nos. 2 (the hump) and 8 (the smallest visual maximum). Omitting these two, an improved ephemeris results:

$$\mathrm{JD}(max) = 2\,448\,010.2 \ + 378.5 \times E, \tag{2}$$

where now the standard errors of the period and starting epoch are 1.6 days and 9 days, respectively. The rms scatter of the individual maxima is reduced to 27 days.

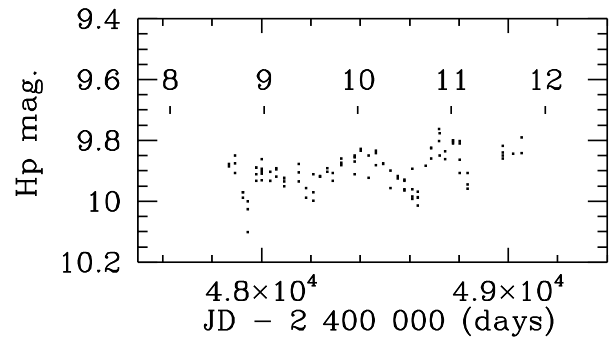

Fig. 2. Hipparcos light curve of AG Dra 1989-93; individual measurements by the main Hipparcos instrument are displayed. Note the strongly enlarged vertical scale compared to Fig. 1. The numbered tick marks have the same meaning as in Fig. 1.

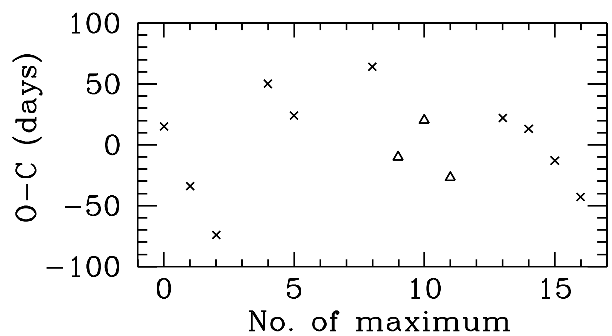

Fig. 3. O-C diagram for the observed times of maxima with respect to the ephemeris given by Eq. 1. The crosses denote the times of maxima read from the visual light curve, the triangles denote the Hipparcos data. The abscissa corresponds to the numbering of tick marks in Fig. 1.

3. Discussion

The nature of the 380-day periodicity cannot be derived from broad-band photometry. The main purpose of the present paper is thus to initiate relevant additional observations before the end of the present outburst phase of AG Dra.

Accretion events have often been suggested as the cause of outbursts in symbiotic systems (e.g. by Kafatos et al., 1993).

An obvious scenario for the cause of the periodicity would be low-amplitude pulsations of the giant component, leading to corresponding modulations in the density of the material flowing towards the white dwarf. Such fluctuations could be expected regardless of the precise mechanism leading to the flow (be it the giant wind alone, or direct Roche overflow). This scenario can be tested by more extensive and more precise radial-velocity measurements for the cool giant component, and probably by precise photometry in the red or near-IR spectral range. In passing, it should be noted that the scatter of the individual outburst maxima around the linear ephemeris is well in the range of the irregularities of pulsating giants.

One could also imagine an unstable self-excited oscillation of the mass flow due to the back-heating of the giant's surface by the radiation from the burning white dwarf. A chance increase of the heat flux from the white dwarf could cause an expansion of the giant's atmosphere, thus producing increased mass flow and - in turn - increased energy output from the white dwarf.

A third possibility are independent oscillations of the hydrogen-burning envelope of the white dwarf, unrelated to the giant component, as can often be seen in novae after the initial eruption.

The two latter scenarios can be tested by detailed observations of the white dwarf in the blue/UV spectral range. Whatever the mechanism leading to the periodicity in the outburst maxima may be, its investigation will provide new constraints on astrophysical models for this symbiotic system.

In addition to potentially being interesting astrophysically, the discovery of the 380-day periodicity is a good example for the possible uses of visual data that still exist today. Visual observations of variable stars clearly have big disadvantages compared to photoelectric measurements. The random error of the individual observation is large (0.1 to 0.2 mag), the absolute calibration is uncertain, and the photometric passband is broad and ill-defined. Nevertheless, for the purpose of studying light variations on long time scales, visual observations can offer a most suitable data base. The main reasons for this were very well summarized by Richman et al. (1994): 'This is primarily because amateur astronomers outnumber professionals by factors of 100-1000. This ensures a steady supply of data over many years, unlike the typical research programs of the professional astronomer, which produce high-quality data for a while, but are eventually scuttled by disinterest, death, or disappearance of observing capability. These hazards do not afflict visual observations of amateur astronomers.... Finally, the response curve of the average human eye can be expected to remain constant over any relevant time scales, unlike scientific instruments. ... The large random error can be overcome simply by amassing a very large amount of data.'

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