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HISTORIC LIGHT CURVE OF V890 Cas

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Introduction

The star V890 Cas (01:07:44.6 +59:03:02, J2000) was discovered to be variable by the Japanese amateur astronomer Akira Takao (Kita-kyushu, Japan) in the year 2001 with an average (unfiltered) ~13 mag (Kazarovets et al. 2003). It is a strong infrared source, detected by IRAS, 2MASS, MSX, WISE, AKARI. Wright et al. (2009) report this star as Hα emitter, listed in the IPHAS survey as ERSO 27, with a spectral type SX/6e: no special remarks were reported by the authors on this star, though they were aware of its variability. This star is flagged as a Mira-type variable in the General Catalog of Variable Stars (Samus et al. 2013) but without a quoted period.

In the Asiago plate archive I found 87 plates of the Schmidt telescope (65/92/215) taken with I-N emulsion and RG5 filter, reproducing the Cousins I_C band. These plates, centred on γ Cas, were taken between 1967 and 1984, in the framework of a large project of search for late-type variables on the Galactic equator (Maffei 1975, 1977; Gasperoni et al. 1991). Most plates of γ Cas ranged from 1967 to 1975 with a typical limiting magnitude of I ~15 in the USNO-B1 scale. Blue plates were also secured on the same night in most cases for comparison. The results of the red variables search for the γ Cas field have never been published, at variance with the other fields (M16/M17, γ Cyg, IC 1805).

Comparison sequence

To determine the light curve of V890 Cas I used the digitized version of the plates, made with an EPSON 1680 Pro of the University of Perugia at 1600 dpi in transparency mode (Nesci et al. 2014). Sixteen nearby stars were selected from the USNO-B1 catalog, ranging from I=11 to I=15, to provide a photometric sequence covering the full variability range, and aperture photometry was made with IRAF/apphot. The stars brighter than I ~11 are overexposed, with a "decrease" of intensity in the very central pixels, as if they were somehow solarized. V890 Cas at maximum is brighter than this limit, showing a dip in the centre. Stars are generally not well detected below I ~15, so fainter values are very uncertain and must be better considered as upper limits. A finding chart is shown in Fig. 1.

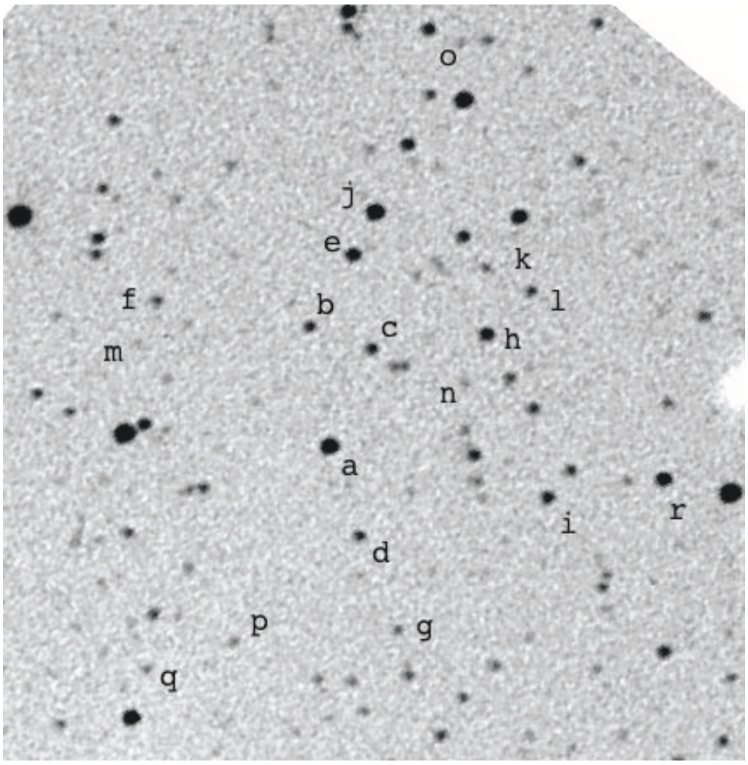

Figure 1. Finding chart of the comparison stars around V890 Cas. The variable is labelled a and is at maximum (I=11.29).

A parabolic fit to the instrumental *vs* catalog magnitudes in the useful range provided a good calibration curve, with typical rms deviations of 0.14 magnitudes. To increase the photometric accuracy, I intercalibrated the reference stars from the whole set of plates and computed again the calibration curve for each plate, finding a substantial decrease of the rms deviation (0.09) of the parabolic fit to the instrumental magnitudes. Then I compared the magnitudes so derived (Asiago magnitudes) with the original (USNO-B1) ones: the differences were always small (rms 0.065 mag) save for two stars (i and l), with differences >0.2 mag. The internal spread of the measured magnitudes of these stars in the dataset is not larger than the other ones, so there is no reason to suppose that they are variable: I assume therefore a mistake in the USNO-B1, which is anyway within the quoted catalog accuracy (0.4 mag). As a check, I made a comparison of the Asiago magnitudes with those in the UCAC4 catalog: 15 of the reference stars are present in this catalog, but only 10 have an i'-band magnitude. A scatter plot of the Asiago magnitudes with the UCAC4 i' ones gives a linear fit with slope 1, with a zero point offset of 0.75 mag, UCAC4 magnitudes being fainter: an offset is expected because the i' zero point is on the Sloan magnitude scale, not on the Cousins (Vega) one. The two discrepant stars (i and l) have UCAC4 magnitudes in agreement with the Asiago ones, taking the offset into account, confirming the self-consistency of our comparison sequence.

A further check was attempted with the GSC2.3.2 catalog: unfortunately only 6 stars of the sequence have an N magnitude in this catalog. On average, Asiago magnitudes are 0.3 mag brighter than the GSC2 values and a linear correlation has a slope of 1.09, again supporting the goodness of the intercalibration. V890 Cas is present in both USNO-B1 and GSC2.3.2 with magnitude 13.63 and 13.99 respectively, consistently with the offset found for the comparison stars. Table 1 reports the J2000 coordinates (in degrees), the star labels, the original USNO-B1 I magnitudes, the intercalibrated (Asiago) I magnitudes, the UCAC4 i' magnitudes and the GSC2.3.2 N magnitudes.

The intercalibration process was also used to estimate the photometric error to be assigned to the variable at different magnitude levels. The rms deviations of each star with respect to its average value is reported in Fig. 2: as expected, it increases for fainter stars, ranging from 0.1 at I=11 to 0.2 at I=15. For I <11 the error may be larger due to saturation problems.

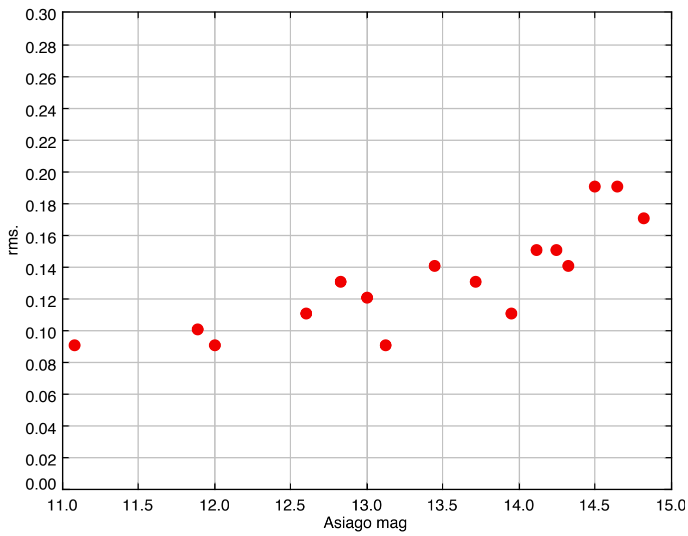

Figure 2. The trend of the rms deviation of the comparison stars as a function of the star magnitude.

Light curve

The light curve of V890 Cas between 1967 and 1975, when the coverage was well sampled (81 points), is reported in Fig. 3. The whole data set is listed in the electronic table. I have checked the quality of the plates where the star is faintest finding them of good quality.

The shape of the light curve is typical of Mira variables; both maxima and minima do not reach strictly the same magnitude in each cycle. These features are present in several other Miras (e.g. Templeton et al. 2005; Kiss & Szatmáry 2002).

To derive the best period I adopted the DFT technique (Deeming 1975): both the original Deeming's FORTRAN code and the PERIOD04 code (Lenz and Breger 2005) were used for the analysis. The power density spectrum is reported in Fig. 4 and shows a strong main peak at 0.002028 d^{-1} (493 d), with a full width at half maximum of about 40 days. The spectrum also shows a few minor peaks: this is not unexpected because it is well known that Mira variables are not strictly periodic nor with constant overall variability amplitude: in a Fourier transform this is numerically indicated with the presence of further lower amplitude frequencies. The sampling (window) function shows basically a peak around the yearly frequency, as expected, and its alias at double frequency. A clear monthly frequency is also present, due to the fact that the Schmidt telescope was not used around the full Moon. These frequencies do not interfere significantly with the stellar light curve frequencies.

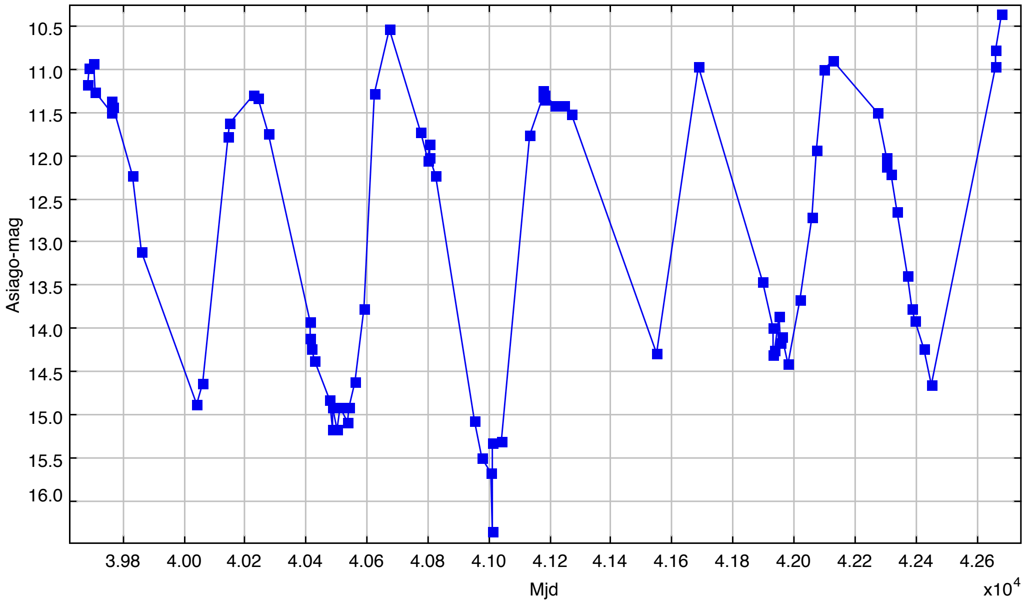

Figure 3. The light curve of V890 Cas in the years 1967-75. The observations cover 7 maxima and 2998 days.

The phased light curve based on the main frequency is reported in the lower panel of Fig. 5 and shows a dispersion larger than the expected photometric errors. Doubling the adopted period gives the phased light curve shown in the upper panel of the same figure. From the comparison of the two curves it is not evident that doubling the period produces a significant improvement.

For a deeper analysis, I subtracted the best fitting sinusoidal light curve of 493 d from the observed data and performed a new DFT analysis of the residuals: the power spectrum is shown in Fig. 6.

The strongest peak has a period of about 3700 days, longer than the available baseline and therefore of limited physical meaning: noticeably, several other low frequencies of comparable intensity are present, up to a frequency double than the basic 0.002028 d^{-1} of the original light curve. A fit of the residuals with the 3700 days period shows an rms deviation of 0.4 mag (see Fig. 7).

It seems therefore unlikely that this star undergoes amplitude variations, like e.g. R Cyg (Kiss & Szatmáry 2002).

Period check and color index

Adopting a period of 493 d, the resulting ephemeris for the maxima is MJD= $n \times 493 + 40228$. A first check of the ephemeris was made using 6 Asiago data in the years 1981-84, which were not used in determining the period. The data of 1981 were quite fainter than the expected values, while the maximum of 1984 (n=5) was well predicted.

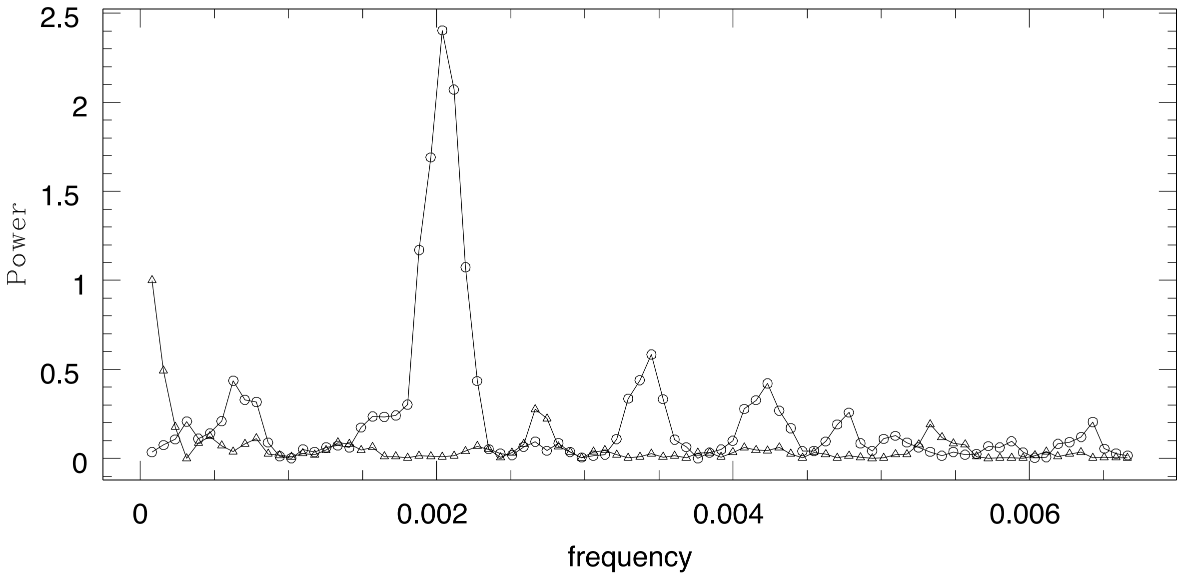

Figure 4. The power spectrum of the light curve of V890 Cas: circles refer to the star while open triangles are the window function.

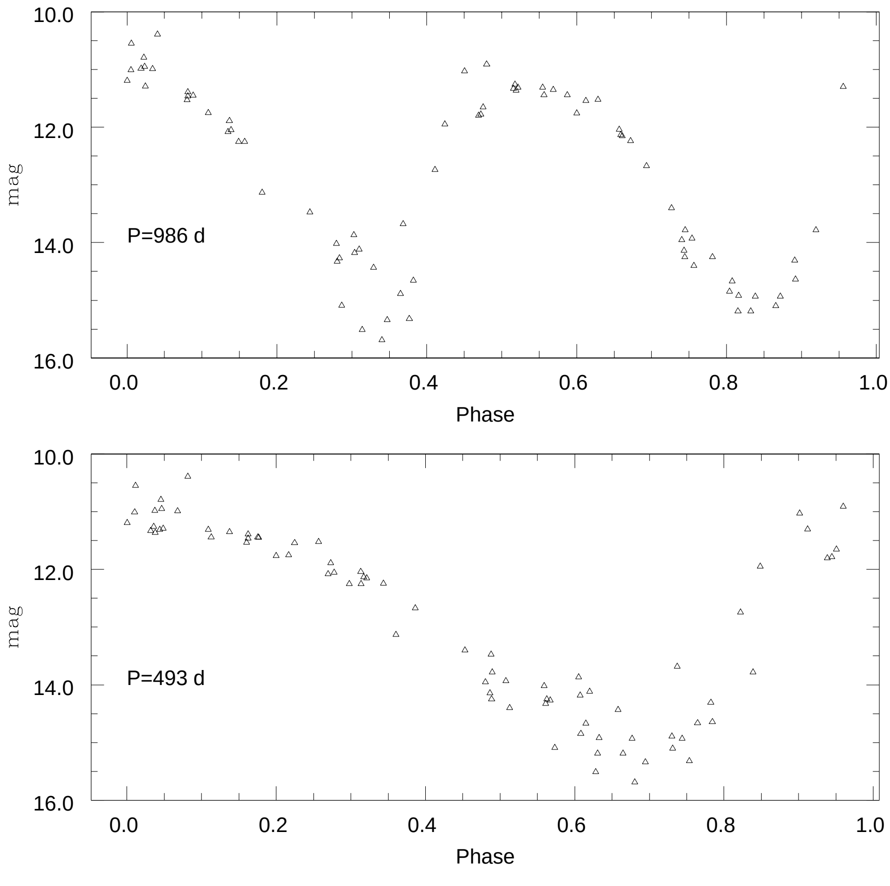

Figure 5. Lower panel: the phased light curve of V890 Cas in the years 1967-1975 adopting the period of 493 days. Upper panel: the phased light curve adopting a doubled period of 986 d.

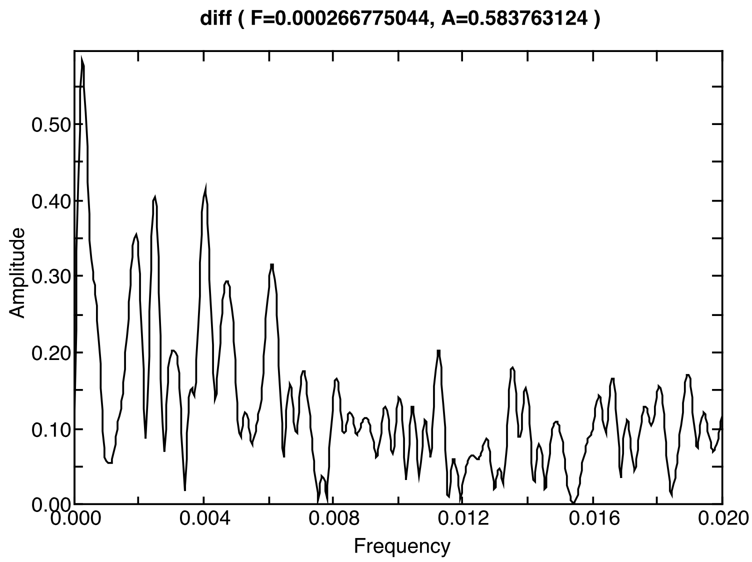

Figure 6. The power density spectrum of the light curve after subtraction of the best-fit sinusoidal curve of 493 d period.

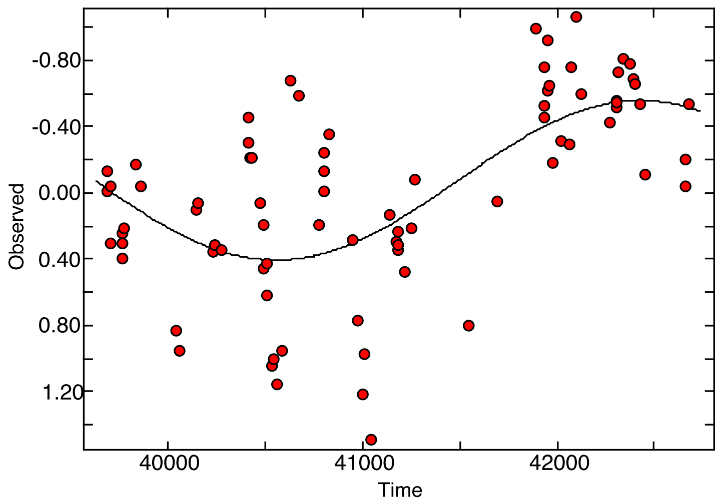

Figure 7. The light curve of V890 Cas after subtraction of the main sinusoidal component of 493 d period. Strong residuals with respect to a 3700 d long term component are evident, suggesting its limited relevance.

A second check can be done using the POSS N plate, taken on 1993-09-07 (MJD ∼49237) used for the USNO-B1 catalog: at that epoch the star was at phase 0.38 and its magnitude fits nicely in the falling branch of the phased light curve (Fig. 5). This test is however ambiguous because a good fit would also be found if the phase were around 0.7.

A better check can be done using the photometric data form VSNET archive (T. Kato, VSNET) which cover about one year and record densely a maximum around MJD 52169. This is about 24 cycles after the adopted epoch MJD 40228. These VSNET magnitudes are quoted as CCD-unfiltered, without indication of the comparison stars adopted, so it is not possible to include them in the Asiago dataset and perform an all-inclusive DFT analysis, due to the certain presence of a systematic offset in the magnitudes. Taking the above quoted ephemeris, the nearest maximum around MJD 52169 would be either at 52060 (cycle 24) or 52553 (cycle 25): agreement with the first date would require an average period of 497 d (0.00201 d^{-1}), well within the resolution of the main Asiago peak.

A DFT analysis of the VSNET data alone gives a best period of 445 d (frequency 0.002245), suggesting that small period changes at 10% level happen in this star. It is not unusual for long period variables not to be strictly periodic: as discussed above, also in the Asiago dataset there are indications in this sense.

I looked for the star in the Asiago blue plates around the maxima but it was always below the detection threshold (B∼18).

A measure of the color index of V890 Cas around maximum can be made using a plate taken on 1984-12-25 in the R band (103aE+RG1): in the same night, plates were taken also in the other bands (U, B, V) but the star was not visible. Using the USNO-B1 $R1$ magnitudes for comparison the result is R=16.21, giving $R - I$=4.99 (±0.3), a result fully consistent with the very late spectral type of the star. This is also in broad agreement with the result reported by Wright et al. (2009) $r' - i'$=5.46, which correspond to $R_C - I_C$=5.67 (Jester et al. 2005), measured when the star was in a fainter (i'=14.7) and probably cooler state.

Overall, the ∼17 years time span of the Asiago archive plates fully support the Mira-type variability of V890 Cas indicated by the VSNET data.

Table 1. Comparison stars for V890 Cas

RA2000 degrees	DEC2000 degrees	ident	USNO I mag	Asiago I mag	UCAC4 i' mag	GSC2.3.2 N mag
16.9424	+59.0800	b	13.00	12.97	13.769	
16.9136	+59.0724	c	12.71	12.80	13.593	
16.9239	+59.0281	d	13.16	13.10		
16.9198	+59.0966	e	11.81	11.88	12.507	
17.0143	+59.0882	f	13.74	13.70	14.349	
16.9088	+59.0052	g	13.99	14.12	14.889	14.28
16.8588	+59.0755	h	11.97	11.98	12.645	
16.8338	+59.0353	i	12.23	12.58	13.320	
16.9092	+59.1068	j	11.21	11.09	11.248	
16.8576	+59.0917	k	13.94	13.94		14.22
16.8365	+59.0854	l	13.65	13.43	14.148	
17.0249	+59.0777	m	14.98	14.90		15.37
16.8704	+59.0640	n	14.58	14.53		14.87
16.8639	+59.1466	o	14.76	14.70		
16.9862	+59.0045	p	14.32	14.35	15.010	14.63
17.0277	+58.9988	q	14.28	14.26		14.55

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