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# The 2016 outburst of the unique symbiotic star MWC 560 (= V694 Mon), its long-term BVRI evolution and a marked 331 days periodicity

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## HIGHLIGHTS

- BVRI photometry obtained in 357 nights distributed between 2005 and 2016.
- Analysis of the long term photometric evolution and of the record breaking 2016 outburst.
- Detection of strong periodicities at 331 and 1860 days, and their relation to orbital period.

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## ABSTRACT

After 26 years from the major event of 1990, in early 2016 the puzzling symbiotic binary MWC 560 has gone into a new and even brighter outburst. We present our tight $BVR_CI_C$ photometric monitoring of MWC 560 (451 independent runs distributed over 357 different nights), covering the 2005–2016 interval, and the current outburst in particoular. A stricking feature of the 2016 outburst has been the suppression of the short term chaotic variability during the rise toward maximum brightness, and its dominance afterward with an amplitude in excess of 0.5 mag. Similar to the 1990 event when the object remained around maximum brightness for ~6 months, at the time Solar conjunction prevented further observations of the current outburst, MWC 560 was still around maximum, three months past reaching it. We place our observations into a long term contex by combining with literature data to provide a complete 1928–2016 lightcurve. Some strong periodicities are found to modulate the optical photometry of MWC 560. A period of 1860 days regulate the occourence of bright phases at $BVR_C$ bands (with exactly 5.0 cycles separating the 1990 and 2016 outbursts), while the peak brightness attained during bright phases seems to vary with a ~9570 days cycle. A clean 331 day periodicity modulate the $I_C$ lightcurve, where the emission from the M giant dominates, with a lightcurve strongly reminiscent of an ellipsoidal distortion plus irradiation from the hot companion. Pros and cons of 1860 and 331 days as the system orbital period are reviewed, waiting for a spectroscopic radial velocity orbit of the M giant to settle the question (provided the orbit is not oriented face-on).



## 1. Introduction

MWC 560 was first noted in the Mt. Wilson Catalog of emission line objects by Merrill and Burwell (1943) as a Be-type star with bright Balmer emission lines flaked, on the violet side, by wide and deep absorption lines. The presence of a cool giant, betrayed by strong TiO absorption bands visible in the red, was reported by Sanduleak and Stephenson (1973), who classify the giant as M4 and confirmed the presence next to the emission lines of deep, blue-shifted absorptions. A short abstract by Bond et al. (1984) informed that in early 80ies they measured terminal velocities up to – 3000 km sec$^{-1}$ in the Balmer absorption components, the absoption profiles were very complex and variable on timescales of one day, and flickering with an amplitude of 0.2 mag on a timescale of a few minutes dominated high-speed photometry. Interestingly, Bond et al. mentioned that near Hα the spectrum was dominated by the M giant, and no absorption componet was seen. Compared to post–1990 spectra in which the Hα absorption is outstanding and the visibility of the M giant spectrum is confined to $\lambda \geq 6500/7000$ Å, this indicates that, at the time of the observations by Bond et al. (1984), the luminosity of the hot component was significantly lower than typical for the last 25 years.

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In keeping up with the very slow pace at which MWC 560 was attracting interest, even the promising report by Bond et al. (1984) did not much to improve upon the anonymity of MWC 560, until all of a sudden, in early 1990, MWC 560 took the scene for a few months, with a flurry of IAU Circulars and near-daily reports conveying increasing excitement. All started when Tomov (1990) reported on the huge complexity he had observed in the Balmer absorption profiles on his January 1990 high resolution spectra, suggesting "discrete jet-like ejections with a relatively high degree of collimation and with the direction of the ejection near to the line of sight". Feast and Marang (1990) soon announced that optical photometry clearly indicated that the object was in outburst, immediately followed by Buckley et al. (1990) who reported terminal velocities up to – 5000 km sec$^{-1}$ for the Balmer absorptions, upward revised to – 6500 km sec$^{-1}$ by Szkody et al., 1990 a few days later. By the time Maran and Michalitsianos (1990) re-observed MWC 560 with the IUE satellite at the end of April 1990, the paroxysmal phase was ending.

The nature of MWC 560 as outlined by the 1990 outburst was reviewed by Tomov et al. (1990), while the preceding photometric history tracing back to 1928 was reconstructed, from archival photographic plates, by Luthardt (1991). A few observations reported by Doroshenko et al. (1993) extend the time coverage back to ~1900. Tomov et al. (1992) and Michalitsianos (1993) modelled MWC 560 with a non-variable M4 giant and an accreting – and probably magnetic – white dwarf (WD), surrounded by an (outer) accretion disk, and subject to a steady optically thick wind outflow and a complex pattern of mass ejection into discrete blobs. Stute and Sahai (2009) deduced however a non-magnetic WD from their X-ray observations. A fit with a variable collimated outflow that originates at the surface of the accretion disk and that is accelerated with far greater efficiency than in normal stellar atmospheres was considered by Shore et al. (1994). The collimated jet outflow was also investigated by Schmid et al. (2001). A strong flickering activity has been present at all epochs in the photometry of MWC 560, with an amplitude inversely correlated with then system brightness in the *U* band (Tomov, 1996). A search for a spectroscopic counterpart of the photometric flickering was carried out by Tomov et al. (1995) on high resolution and high S/N spectra taken during 1993–1994 when the object was in a quiescent state. In spite of the very large amplitude of the photometric flickering recorded on simultaneous *BV* observations (~0.35 mag in *B*, ~0.20 mag in *V*), no significant change in intensity and profile (at a level of a few %) was observed both for the emission lines and their deep and wide absorption components.

With MWC 560 at quiescence and not much going on with its photometric and spectroscopic behavior, the interest in the object progressively declined after the 1990 outburst. The situation could now reverse following our recent discovery (Munari et al., 2016) that MWC 560 is going through a new outburst phase, *brighter* than that of 1990. This has immediately prompted deep X-ray observations by Lucy et al. (2016) that found a dramatic enhancement in the soft ( < 2 keV) X-rays, compared to the observations by Stute and Sahai (2009) obtained in 2007 when MWC 560 was in quiescence. The report on the optical outburst also prompted VLA observations that detected for the first time radio emission from MWC 560 Lucy, Weston and Sokoloski (2016), at least an order of magnitude enhanced over a VLA non-detection on 2014 October 2, during the quiescence preceding the current outburst.

In this paper we present the results of our 2005–2016 $BVR_CI_C$ photometric monitoring of MWC 560, with an emphasis on the current outburst phase. This is placed into an historical context by combining with existing data that provides an optical lightcurve of MWC 560 covering almost a century. Finally, a search for periodicities is carried out, especially taking advantage of our unique set of $I_C$ data which is dominated by the emission from the M giant.

## 2. Observations

$BVR_CI_C$ optical photometry of MWC 560 is regularly obtained since 2005 with nine of the ANS Collaboration telescopes, all of them located in Italy. A total of 431 $BVR_CI_C$ independent runs are presented here, obtained during 357 different nights distributed between Feb 9, 2005 and Apr 29, 2016. The operation of ANS Collaboration telescopes is described in detail by Munari (2012) and Munari and Moretti (2012). The same local photometric sequence, calibrated by Henden and Munari (2001) against Landolt equatorial standards, was used at all telescopes on all observing epochs, ensuring a high consistency of the data. The $BVR_CI_C$ photometry of MWC 560 is given in Table 1, where the quoted uncertainty is the total error budget, which quadratically combines the measurement error on the variable with the error associated to the transformation from the local to the standard photometric system (as defined by the photometric comparison sequence). All measurements were carried out with aperture photometry, the long focal length of the telescopes and the absence of nearby contaminating stars not requiring to revert to PSF-fitting.

Low and high resolution spectra of MWC 560 are routinely obtained with the Asiago 1.22 m + B&C and 1.82 m + REOSC Echelle, and with Varese 0.61 m + Astrolight mk.III multi-mode spectrograph. One of the low resolution spectra is shown in Fig. 1 as representative of the typical appearance of MWC 560, broadly similar both in quiescence and outbursts, with the continuum from the M giant becoming rapidly dominant for $\lambda > 7000$ Å and over the Landolt's $I_C$ band. The results of the spectroscopic campaign on MWC 560 will be discussed elsewhere.

## 3. Long term photometric evolution

The $BVR_CI_C$ lightcurve of MWC 560 covering the last eleven years is presented in Fig. 2. This time interval corresponds to slightly more than two full cycles of the 1900÷2000 days periodicity frequently associated to MWC 560 (see Section 5 below). The presence of such a periodicity ( $\simeq$ 5.2 years) is evident in the *B*-band panel of Fig. 2, where the maxima of 2006, 2011, and 2016 clearly modulate the lightcurve. Contrary to what found by others (eg. Tomov (1996), their Fig. 1), our data in Fig. 2 show that the *B* - *V* color of MWC 560 remains essentially stable in spite of the large changes recorded in *B* band. A variation at the level of ~1 mag is instead observed in the *V* - $I_C$ color, with MWC 560 being redder when fainter at *B*. The lightcurve of MWC 560 in the $I_C$ band is completely different from those at shorter wavelengths, in particular: (*a*) the large scatter that dominates the *B* lightcurve, which is caused by the accretion flickering, is null at $I_C$, (*b*) the large amplitude maxima of 2006, 2011, and 2016 that dominates the *B*-band lightcurve are barely recognizable at $I_C$, and (*c*) a clear, large amplitude (~0.35 mag) and periodic modulation governs the $I_C$ lightcurve.

The above is consistent with a hot component that completely dominates the emission at *B* and *V*, and contributes the majority of the flux at $R_C$, while the M4 giant accounts for nearly all the brightness recorded in $I_C$. The hot component, presumably a massive accretion disc around the WD companion, is the one producing the continuum mimicking an A-type star which dominates shortward of 6000 Å in the spectrum of Fig. 1, while the TiO bands that dominate longward of 7000 Å come from the M4 giant. The M4 giant is intrinsically variable, and entirely responsible for the periodic changes seen in $I_C$. They could either be the result of an ellipsoidal distortion (in which case the M4 giant would fill the corresponding Roche lobe) or be caused by a radial pulsation (in which case the M4 giant would *not* fill its Roche lobe; see Section 5). The flickering that affects the emission from the hot component causes a large dispersion of the observations at $BVR_C$

**Table 1**
Our 2005–2016 $BVR_CI_C$ photometric observations of MWC 560. The full table is available electronically via CDS, a small portion is shown here for guidance on its form and content.

| HJD | UT date | $B$ | err | $V$ | err | $R_C$ | err | $I_C$ | err | id |
|---|---|---|---|---|---|---|---|---|---|---|
| 2456723.406 | 2014-03-06.906 | 10.611 | 0.006 | 10.139 | 0.007 | 9.564 | 0.004 | 8.397 | 0.005 | 62 |
| 2456725.343 | 2014-03-08.843 | 10.655 | 0.009 | 10.227 | 0.012 | 9.584 | 0.017 | 8.488 | 0.015 | 24 |
| 2456726.344 | 2014-03-09.844 | 10.628 | 0.006 | 10.368 | 0.004 | 9.682 | 0.004 | 8.502 | 0.006 | 125 |
| 2456727.345 | 2014-03-10.845 | 10.725 | 0.007 | 10.371 | 0.005 | 9.690 | 0.003 | 8.517 | 0.003 | 157 |
| 2456729.364 | 2014-03-12.864 | 10.656 | 0.010 | 10.345 | 0.017 | 9.737 | 0.013 | 8.552 | 0.020 | 24 |
| 2456734.375 | 2014-03-17.875 | 10.810 | 0.010 | 10.395 | 0.009 | 9.771 | 0.008 | 8.491 | 0.005 | 30 |

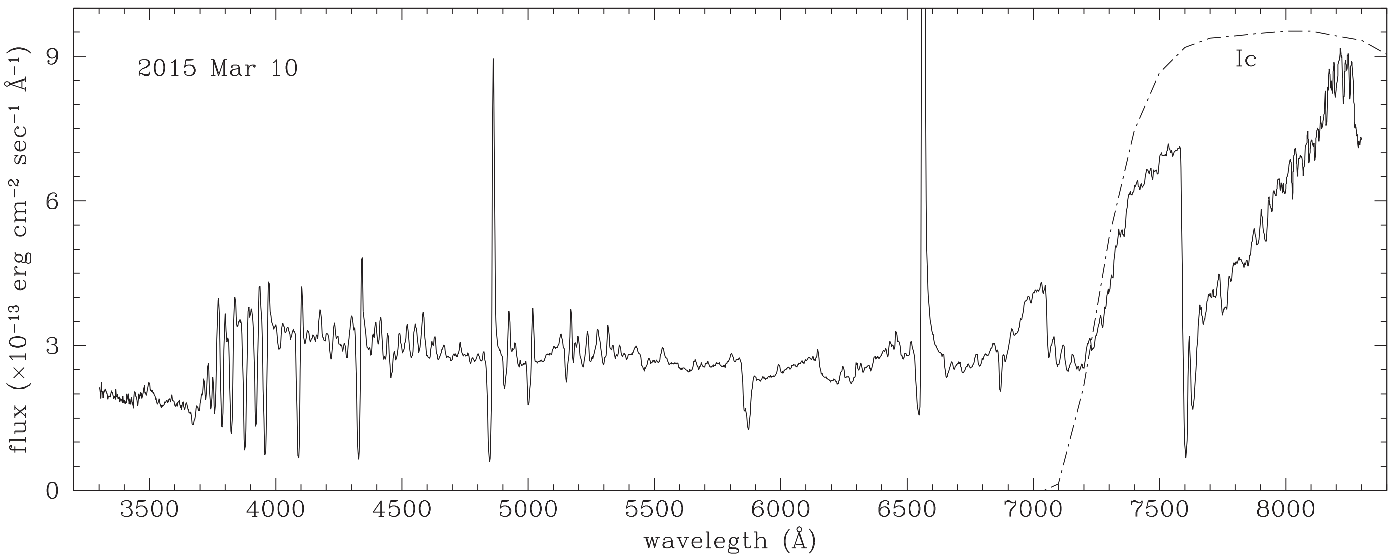


**Fig. 1.** Typical optical spectrum for MWC 560. The dotted-dashed line marks the transmission profile of Landolt $I_C$ photometric band.

bands, much larger than the observational errors. The dispersion is significantly lower in the $B$ - $V$ color (see Fig. 2), because the flickering affects in phase both bands.

To put things into context, in Fig. 3 we combine our 2005–2016 $B$-band photometry with 1928–1990 $m_{pg}$ photographic photometry from Luthardt (1991), with its zero point set according to Doroshenko et al. (1993) and the 1990–1995 $B$-band photometry by Tomov (1996). To fill the remaining 1995–2005 gap, we have used $V$-band ASAS CCD photometry and AAVSO visual estimates, both transformed to $B$ band, a safe approximation considering the constant $B$ - $V$ color displayed by MWC 560 throughout active and quiescence states. The AAVSO visual estimates were first averaged into 10-days bins to filter out the intrinsic noise, and a constant -0.1 mag was added to correct their zero point to that of $V$-band CCD observations. Finally, a $B$ - $V$ = +0.456 color (corresponding to the median value of our observations) was added to both ASAS and AAVSO data to transform them into $B$ values.

The $B$-band historical lightcurve in Fig. 3 shows that the 1990 outburst marked a transition in the mean brightness of MWC 560, its quiescence value being ~12 before and ~11 mag after. Estimates on a few older photographic plates by Doroshenko et al. (1993), suggest that the brightness of MWC 560 was ~13 before the 1928–1990 period covered by Luthardt (1991), which would indicate a marked secular trend toward brighter magnitudes superimposed to an always present large variability over a wide range of timescales.

## 4. The 2016 outburst

The record brightness attained by MWC 560 in early 2016 is obvious in the century-long lightcurve of Fig. 3. A zoomed view of the outburst light- and color-curves is presented in Fig. 4.

The outburst peaked at $B=$ 9.25 on 2016 Feb 7, and a second maximum was reached on April 3 at $B=$ 9.21. The complete flatness of $B$ - $V$ and $V$ - $R_C$ color-curves in Fig. 4 indicates that the spectral energy distribution of the outbursting component did not change, only the overall intensity varied. At peak brightness, the outbursting component was so bright to profusely leak into the $I_C$ band and dominate over the emission from the M4 giant.

A striking feature of the outburst is well visible in Fig. 4: on the rise toward the main peak of Feb 7, the $B$-band lightcurve is much smoother compared to its post-peak portion which is affected by a ~0.5 mag scatter. It is like if the always present flickering was momentarily suppressed during the rise to maximum, but soon after reaching it, the flickering re-appeared with an even larger virulence than in quiescence.

Even if MWC 560 has not displayed a flat maximum, nonetheless it has remained around maximum for the three months covered by our observations before they were interrupted by the Solar conjunction (cf Figs. 2 and 4). This is reminiscent of the behavior displayed at the time of the 1990 outburst, when the star lingered around maximum for six months before entering a sharp decline phase (cf. Tomov (1996), their Fig. 2).

## 5. Periodicities in the photometric behavior

### 5.1. 1860 days

Some authors have already reported on the presence in the optical lightcurve of MWC 560 of a period **between 1900 and 2000 days**, apparently regulating the occurrence of brightness peaks. The latter are ascribed to an increase in mass transfer during passages at periastron. It should be noted that a pre-requisite of this scenario is the presence of a highly eccentric orbit, when most

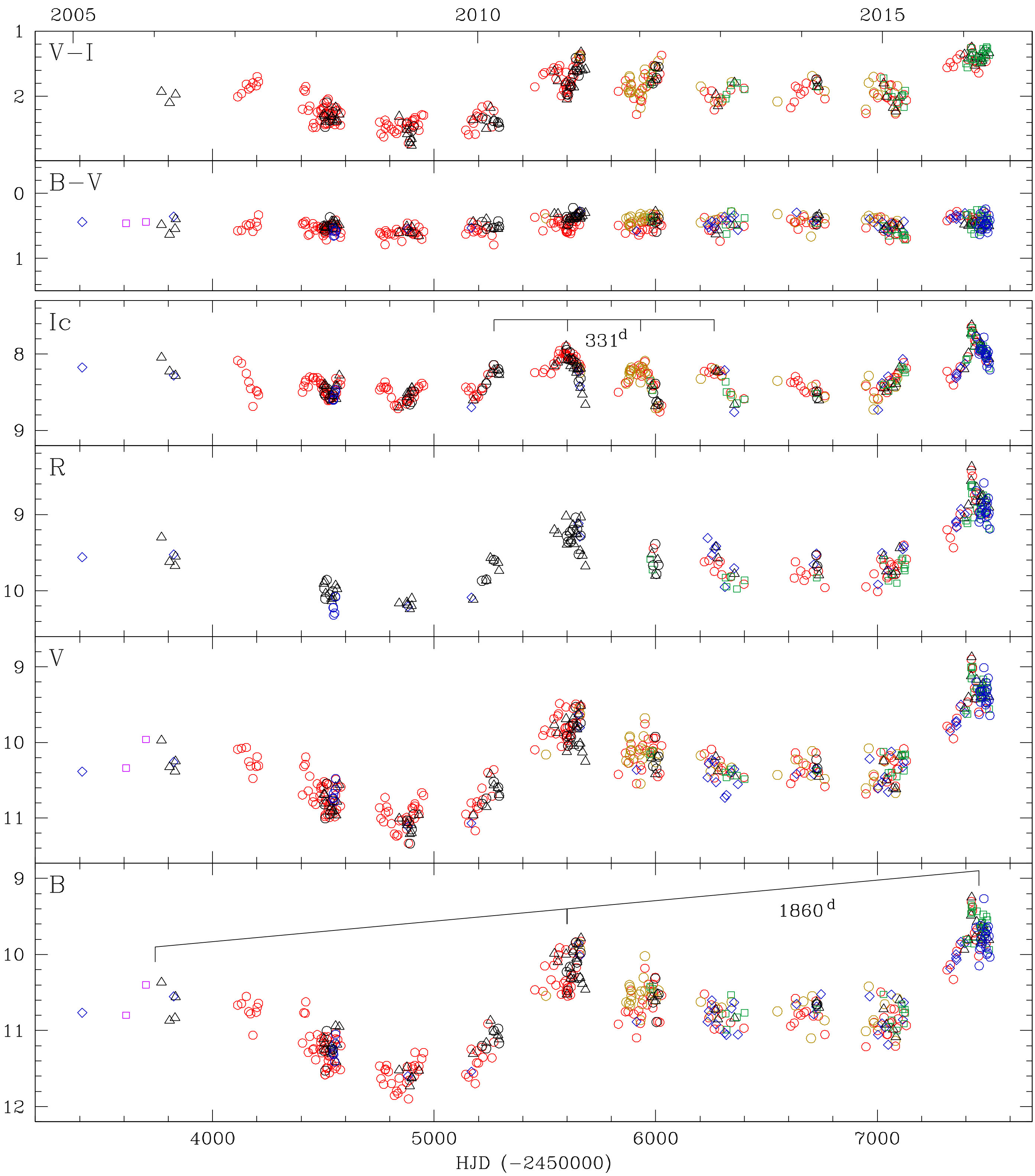


**Fig. 2.** Light and color evolution of MWC 560 from our 2005–2016 $BVR_CI_C$ observations. The varied symbols identify different telescopes.

of the symbiotic stars with a spectroscopic orbit show negligible eccentricities (eg. Fekel et al., 2000a; 2000b; 2001, and for only a small fraction of them the eccentricity is significant (eg. Fekel et al. (2015). Going into details, Tomov et al. (1992) and Frckowiak et al. (2003) reported for MWC 560 a period of ∼2000 days, Doroshenko et al. (1993) found 1930 days, while Leibowitz and Formiggini (2015) preferred 1943 days. All these investigations include, as the main body of data, the brightness estimates that Luthardt (1991) made on historical photographic plates exposed at Sonneberg Observatory during 1928–1990 (no information is provided on the wavelength sensitivity of the plates and/or the presence of photometric filters). Gromadzki et al. (2007) noted

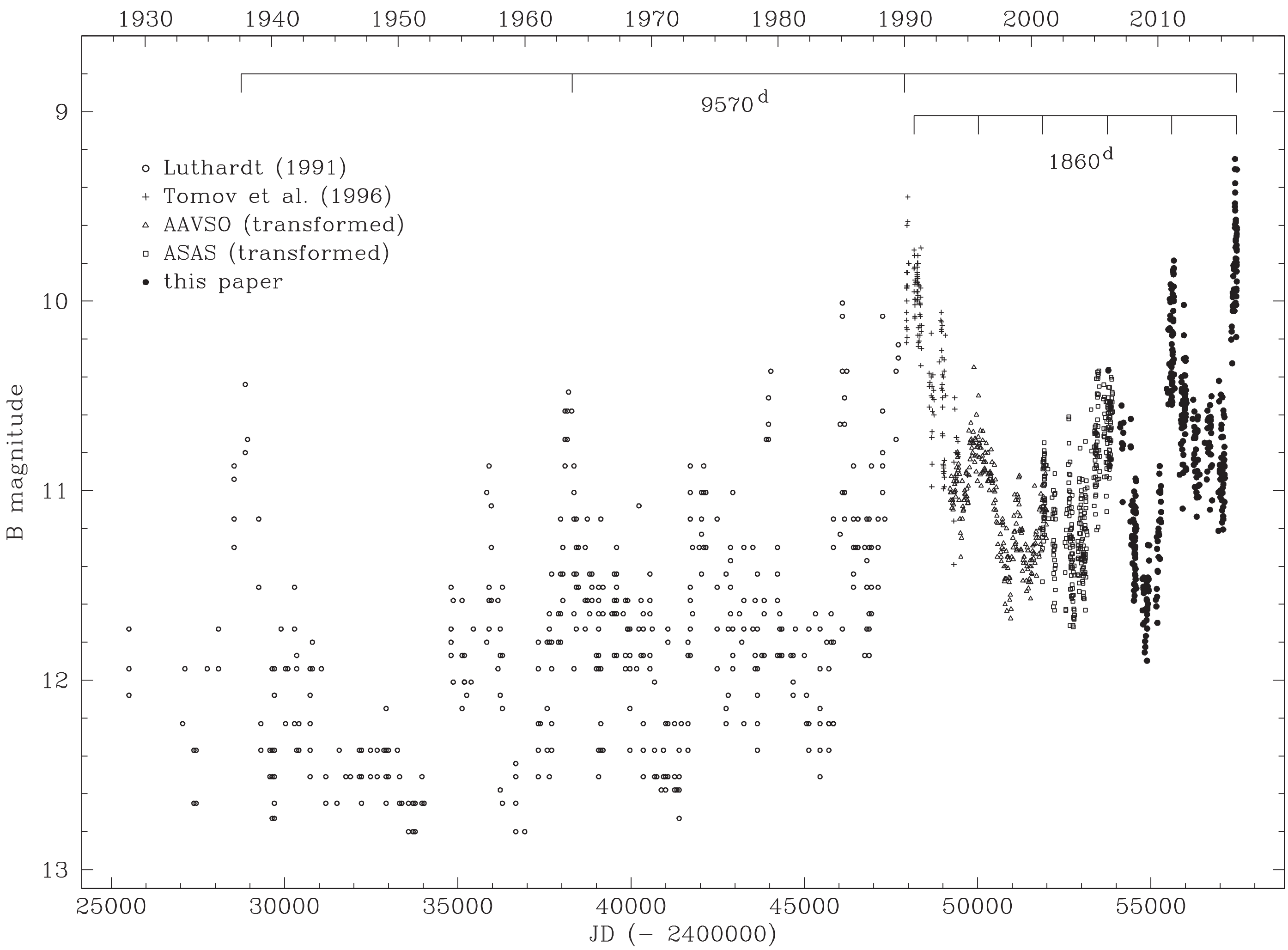


**Fig. 3.** Long term photometric evolution of MWC 560 in the *B* band.

a period of 1931 days from AAVSO visual estimates covering 1990–2001 and ASAS data distributed over 2000–2005, an interval of time covering three cycles of the proposed periodicity.

Looking at the 1990–2016 lightcurve of MWC 560 in Fig. 3, the time interval between brightness peaks seems significantly shorter than proposed in the studies just mentioned. A period of 1860 days accounts for exactly 5.00 cycles between the brightness peaks in 1990 and 2016, and also nicely fits the intermediate and less luminous maxima, as shown in Fig. 3. The ephemeris for the 1860 days period is:

$$\max = 2457460 + 1860 \times E \tag{1}$$

Is the P = 1860 days period due to orbital motion ? The interpretation in terms of periastron passages on a highly eccentric orbit is tempting, but there are some obstacles to accept it.

Doroshenko et al. (1993) pointed out how MWC 560 has sometimes remained at minimum when instead a maximum would have been expected, as it was for the 2600 day long interval between 1943 and 1950, the best and densely mapped period in the historical lightcurve, when MWC 560 remained at a flat minimum with no trace of cyclic variations, missing two of the expected maxima. It is also worth comparing the 1860 day period with the known orbital periods of symbiotic stars. In doing this we limit ourselves to the classical symbiotic stars containing a normal, non-Mira cool giant, as it is the case for MWC 560. A survey of the available literature returns validated orbital periods for ~50 such symbiotic stars. Their median value is 670 days, with a 25th percentile of 215 days. The longest orbital period is 1619 days for Y CrA. Thus an orbital period of 1860 days would be unusually long for a classic symbiotic binary with a normal, non-Mira giant.

Since the first spectroscopic observations by Merrill and Burwell (1943), the optical spectrum of MWC 560 has been invariably described similar to that shown in Fig. 1. This has the characteristics of a very bright (and therefore large and massive) accretion disk dominating over the emission of the M4 giant at $\lambda < 6000$ Å. Such a disk must be continuously fed by massive mass transfer from the M4 giant, as indicated by the reckless and large amplitude flickering that *always* dominates the optical photometry of MWC 560. This however requires the M4 giant to fill its Roche lobe along the whole orbit around the WD, and not just at periastron passages every ~5 years.

As a final remark on an orbital interpretation for the 1860 days period, this appears to be somewhat too long for an M4 giant to fill its Roche lobe in a circular orbit. Well known examples of symbiotic stars dominated by ellipsoidal distortions of the Roche-lobe filling giant are: the M3 in T CrB (orbital period P = 227 days), the M4 in QW Sge (P = 390 days), the M5 in AX Per (P = 682 days), the M6 in CI Cyg (P = 855 days). This sequence suggests that a viable orbital period to allow the M4 giant in MWC 560 to fit its Roche lobe and sustain the observed heavy mass transfer toward the companion should not exceed 500 – 600 days, with 1860 days well off scale. An higher-than-usual luminosity class (and therefore

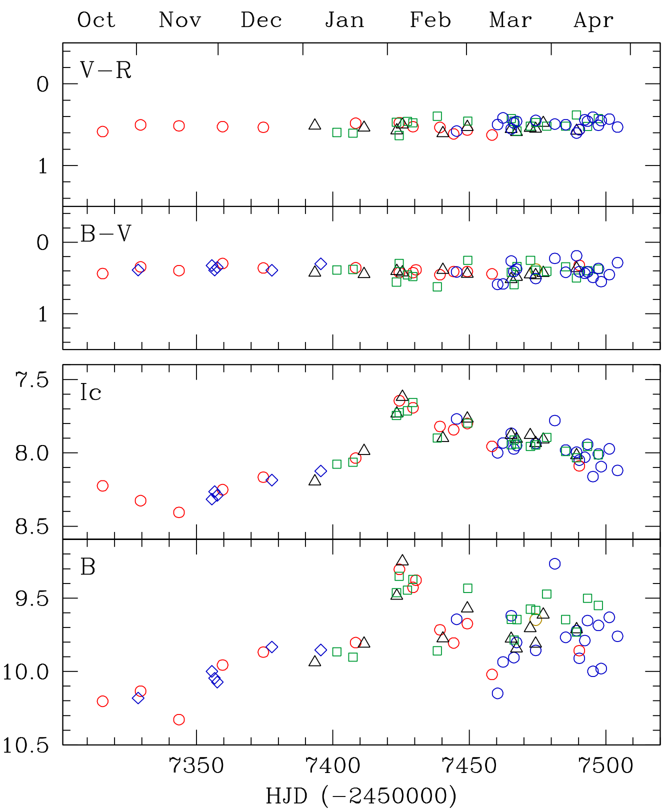


**Fig. 4.** Zoomed view of the portion of Fig. 2 covering the phase around maximum brightness in early 2016.

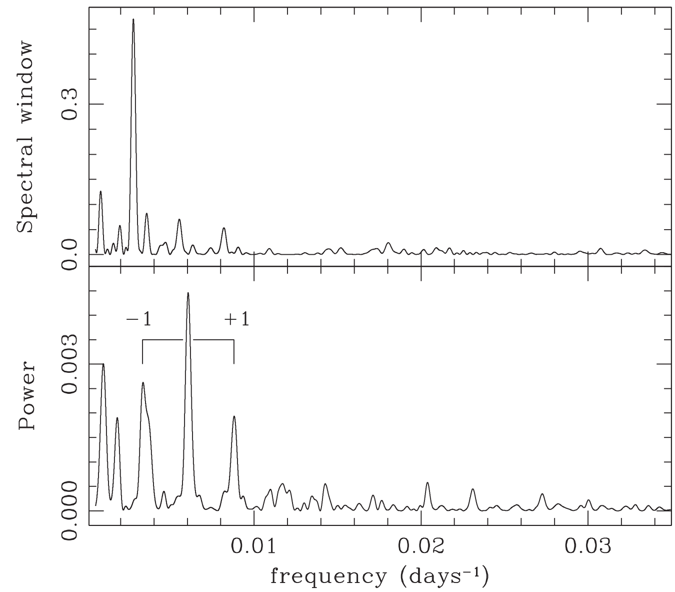


**Fig. 5.** Results of the Fourier analysis of the 2005–2016 $I_C$ data of MWC 560. The main peak corresponds to a period of 165.4 days (= 330.8/2, see Eq. 3), flanked by the + 1 and − 1 aliases from the 365 days sampling frequency (cf. top panel).

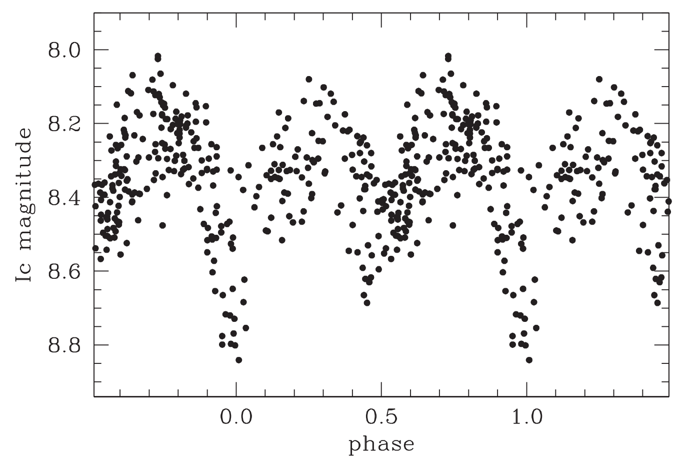


**Fig. 6.** The 2005–2016 $I_C$ data from Fig. 2 phase plotted against Eq. 3 ephemeris (period = 330.8 days).

larger radius) for the cool giant in MWC 560 could however complicate this simple picture.

### 5.2. 9570 days

The long term behaviour of MWC 560 presented in Fig. 3, suggests that a cycle of ~9570 days (not an integer multiple of 1860) could be modulating the overall system brightness and that of bright phases, in particoular during the last 26 years, from the outburst in 1990 to the present one in 2016. The two strongest brightness peaks in the historical data by Luthardt (1991), those in 1937 and 1963, happened in phase with such a 9570 days cycle. The corresponding ephemeris is:

$$\max = 2457460 + 9570 \times E \qquad (2)$$

The significance of such a period is still preliminary, the known photometric history of MWC 560 having covered just three such cycles (cf. Fig. 3).

### 5.3. 331 days

The spectrum of MWC 560 in Fig. 1 shows the rapid emergence longword of 7000 Å of the TiO bands from the M4 giant. The $I_C$ band centered at 8200 Å is largely dominated by the emission from the giant, and as remarked above, eye inspection of the 2005–2016 $I_C$ band lightcurve of MWC 560 in Fig. 2 immediately suggests the presence of a periodic pattern.

We have performed a Fourier search, with the Deeming (1975) code, on our $I_C$ band data in Table 1, excluding the most recent ones affected by the 2016 outburst. The resulting periodogram is shown in Fig. 5, where the dominant period is 165.4 days which appears together with the strong +1 and −1 year aliases. The phased lightcurve with twice this period, or 330.8 days, has a significantly lower dispersion and minima of different depths, and it is shown in Fig. 6. The ephemeris for primary minima is:

$$\min(\mathrm{I}) = 2456015 + 330.8 \times E \qquad (3)$$

This phased lightcurve has two maxima and two minima per orbital period, with maxima of similar brightness as in the case of ellipsoidal distortion of the M giant filling its Roche lobe, and minima on unequal depth as expected in presence of irradiation – by the hot companion – of the facing side of the giant. Should this be indeed the geometry of MWC 560, the above ephemeris would provide the times of orbital passage at inferior conjunction of the cool giant.

The amplitude of the modulation in Fig. 6 is ~0.35 mag. This value and the resulting lightcurve is identical to that observed for the symbiotic binary T CrB (Munari et al., 2016), where an M3 giant orbits the WD companion every 227.55 days and fills its Roche lobe in a $i \sim 68°$ inclined orbit, as the long term near-IR *JHK* lightcurve proves (Yudin and Munari, 1993).

The presence of a modulation of the far-red and near-IR photometry of MWC 560 has already been noted by Frckowiak et al. (2003) and Gromadzki et al. (2007), both reporting periodicities around the 166 and 331 days just discussed for our $I_C$ photometry.

Frckowiak et al. (2003) monitored MWC 560 in *UBVri* during 1992–1999, with non-standard *r* and *i* bands having effective wavelengths of 6390 and 7420 Å (for comparison, the corresponding values for M giants of Landolt's $R_C$ and $I_C$ bands are 6750 and 8130 Å). They found their *i* band photometry to behave separately from the other bands, ascribing this to the dominance by the direct emission of the M giant. Their Fourier analysis returned a period of ∼161 days. Unfortunately, Frckowiak et al. (2003) did not list or plot their individual observation, but presented only a phase-*averaged* lightcurve. This does not allow us to test if – even for their data – a period twice that indicated by the Fourier analysis would return a better lightcurve, with non-equal minima.

Gromadzki et al. (2007) reported near-IR *JHKL* photometry (89 observing dates) of MWC 560 unevenly distributed in time between 1984 and 2004. Their Fourier analysis returns a period of 339 days, with an additional peak at 1877 days. They also performed a Fourier analysis of AAVSO visual estimates + ASAS V-band photometry covering 1990–2006, that returns a period of 166 days plus its yearly aliases.

### 5.4. Other periodicities

Other possible periodicities, derived from Fourier analysis of mixed MWC 560 data, have been found by single investigations but have not been reported by other studies. They do not seem evident from direct inspection of the lightcurves. Doroshenko et al. (1993) mentioned Fourier minor peaks at 4570 and 11,410 days, Gromadzki et al. (2007) listed possible periodicities around 310 and 747 days, and Leibowitz and Formiggini (2015) reported about Fourier peaks at ∼19,000 and 722 days.

### 5.5. Which one is the orbital period ?

Summarizing the results of this section, there are two basic periodicities observed in MWC 560: 1860 days dominating over $BVR_C$ bands, and 331 days governing the behavior in $I_C$. One of the two is probably the orbital period of the system, but which one is not a clean choice.

The difficulties we noted above for the 1860 days being the orbital period include: (*a*) it is longer than validated known orbital periods for classical symbiotic stars not harboring a Mira variable, (*b*) the M4 giant could be too small to fill the corresponding wide Roche lobe along the whole orbit, a pre-requisite for the uninterrupted, long-term presence of a massive accretion disk and the always present large amplitude flickering, (*c*) such a bright accretion disk as seen in MWC 560 requires a massive mass-transfer, as attainable only is a close orbit, in which the donor star (over)fills its Roche lobe, and (*d*) if the orbital period is 1860 days, the 331 day should then be ascribed to a pulsation of the giant, but the shape of the lightcurve is not that typical for a pulsation and the pulsating periods of non-Mira giants in symbiotic stars are confined between 40 and 200 days (Gromadzki et al. 2013). In particular, point *b* point above appears critical, because it would be incompatible with the supposed high eccentricity orbit that drives the brightness peaks via enhanced mass transfer during periastron passages, when the cool giant come in contact with its Roche lobe.

The 331 days modulation of the $I_C$ band lightcurve in Fig. 6 and its uneven minima looks attractive. The shape of the lightcurve suggests a giant stably filling its Roche lobe and with an irradiated side, a standard condition for symbiotic stars not harboring a Mira variable. However, in order to produce the observed 0.35 mag amplitude for the ellipsoidal distortion, the orbital inclination of MWC 560 should be relatively high, $i \geq 60°$, which could contrast with the absence of changes observed in the radial velocity of emission lines on photographic spectra obtained at the time of the 1990 outburst (Tomov et al., 1992). A long-term check on modern spectra obtained with CCD detectors, of the constancy/variability in radial velocity of the emission lines in MWC 560 would certainly be worth pursuing. If the orbital period of MWC 560 is indeed 331 days, it would then be necessary to account for the regularity of the brightness peaks separated by 1860 days. For sake of discussion, it could be speculated that a beating between a non-synchronous axial rotation of the deeply convective M4 giant and a low orbital eccentricity could perhaps be able to modulate by a factor of 2 × the mass transfer rate which in turn could account for the 2 × increase in brightness seen during active states.

We are forced to conclude that the only *robust* way to derive the orbital period of MWC 560 seems to be a long-term monitoring of the radial velocity of the M giant, observed as far as possible into the red or near-IR to reduce or null the veiling from the hot companion. Hoping the orbital inclination is not anywhere close to $i = 0°$ and/or there is not much radial pulsation to interfere with the signature of orbital motion.

## Acknowledgements

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## Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.newast.2016.06.004

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