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The Unusual Photometric Variability of the PMS Star GM Cep

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Abstract

Results from *UBVRI* photometric observations of the pre-main sequence star GM Cep obtained in the period 2011 April–2014 August are reported in the paper. Presented data are a continuation of our photometric monitoring of the star started in 2008. GM Cep is located in the field of the young open cluster Trumpler 37 and over the past years it has been an object of intense photometric an spectral studies. The star shows a strong photometric variability interpreted as a possible outburst from EXor type in previous studies. Our photometric data for a period of over six years show a large amplitude variability ($\Delta V \sim 2.3$ mag) and several deep minimums in brightness are observed. The analysis of the collected multicolour photometric data show the typical of UX Ori variables a colour reversal during the minimums in brightness. The observed decreases in brightness have a different shape, and evidences of periodicity are not detected. At the same time, high amplitude rapid variations in brightness typical for the classical T Tauri stars also present on the light curve of GM Cep. The spectrum of GM Cep shows the typical of classical T Tauri stars wide Hα emission line and absorption lines of some metals. We calculate the outer radius of the Hα emitting region as 10.4±0.5 $R_\odot$ and the accretion rate as 1.8×10^{-7} $M_\odot$ yr^{-1}.

Keywords: GM Cep – pre-main sequence stars – T Tauri stars

1 INTRODUCTION

Photometric variability is a fundamental characteristic of the pre-main sequence (PMS) stars, which manifests as transient increases in brightness (outbursts), temporary drops in brightness (eclipses), irregular or regular variations for a short or long time scales. Both types of PMS stars the widespread low-mass ($M \leq 2M_\odot$) T Tauri Stars (TTSs) and the more massive Herbig Ae/Be (HAEBE) stars indicate photometric variability with various amplitudes and periods Herbst et al. (1994, 2007). The TTSs can be separated into two subclasses: Classical T Tauri (CTT) stars surrounded by a massive accretion disk and Weak line T Tauri (WTT) stars without indications of disk accretion Bertout (1989). According to Herbst et al. (2007) the large amplitude variability of CTT stars is caused by magnetically channeled accretion from the circumstellar disk onto the stellar surface.

Some PMS stars show variability in brightness with very large amplitudes, dominated by fading or bursting behaviour. The large amplitude outbursts can be grouped into two main types, named after their respective prototypes: FU Orionis (FUor) and EX Lupi (EXor) Reipurth & Aspin (2010). Both types of eruptive stars seems to be related to young stellar objects with massive circumstellar disks, and their outbursts are commonly attributed to a sizable increase in the disc accretion rate onto the stellar surface Hartmann & Kenyon (1996). During the quiescence state FUors and EXors are normally accreting TTSs, but due to thermal or gravitational instability in the circumstellar disk accretion rate enhanced by a few orders of magnitude up to $\sim10^{-4}$ $M_\odot$ yr^{-1}.

A significant part of HAEBE stars and early type CTT stars show strong photometric variability with sudden quasi-Algol drops in brightness and amplitudes up to 2.5 mag (V) Natta et al. (1997); van den Ancker, de Winter, & Tjin A Djie (1998). During the deep minimums of brightness, an increase in polarisation and specific colour variability (called 'blueing effect') are observed. The prototype of this group of PMS objects with intermediate mass named UXors is UX Orionis. The widely accepted explanation of its variability is a variable extinction from dust clumps or filaments passing through the line of sight to the star Dullemond et al. (2003); Grinin et al. (1991). Normally, the star becomes redder when its light is covered by dust, but when the obscuration rises sufficiently, the part of the scattered light in the total observed light become considerable and the star colour gets bluer.

The PMS star GM Cep lie in the field of the young open cluster Trumpler 37 (~4 Myr old) at a distance of 870 pc Contreras et al. (2002) and most likely is a member of the cluster Marschall & van Altena (1987); Sicilia-Aguilar et al. (2005). The early long-term photographic observations of the star performed by Suyarkova (1975) and Kun (1986) indicate for a large amplitude photometric variability (the observed amplitudes are $\Delta m_{pg} = 2.2$ mag and $\Delta V = 2.15$ mag respectively). A multicolour photometric study based on optical, infrared and millimeter observations of GM Cep was reported by Sicilia-Aguilar et al. (2008). The authors found the star much brighter in 2006 than in 1990 and conclude that the most probable explanation for the brightness increase is an EXor type outburst.

According to Sicilia-Aguilar et al. (2008) GM Cep is a PMS star with solar mass ($M \sim 2.1$ M$_\odot$) from *G7V–K0V* spectral type and with radius between 3 and 6 R$_\odot$. The observed strong IR excesses have been explained by the presence of a very luminous and massive circumstellar disk. The Hα emission line in the spectrum of GM Cep has a strong P Cyg profile and the equivalent width of the line vary significantly from 6 to 19 Å Sicilia-Aguilar et al. (2008). A variable accretion rate (up to $\sim 10^{-6}$ M$_\odot$ year^{-1}) are also detected in the study of Sicilia-Aguilar et al. (2008).

A long-term photometric study of GM Cep for several decades period was performed by Xiao, Kroll, & Henden (2010). The photographic plate archives from Harvard College Observatory and from Sonneberg Observatory are used to construct the long-term B and V light curves of the star. The results suggest that GM Cep do not show fast rises in brightness typical of EXor variables and the light curves seem to be dominated by dips superposed on the quiescence state. Evidences for periodicity of observed dips in brightness were not found in the study of Xiao et al. (2010).

In our first paper Semkov & Peneva (2012), the results from $BVRI$ optical photometric observations of the star collected in the period 2008 June–2011 February are reported. During out photometric monitoring two deep minimums in brightness are observed. The collected multicolour photometric data show the typical of UXor variables a colour reversal during the minimums in brightness. Chen et al. (2012) reported results from intensive BVR photometric monitoring of GM Cep during the period 2009–2011. They confirm the UXor nature of variability and suggest an early stage of planetesimal formation in the star environment. Chen & Hu (2014) suggest a periodicity of about 300 days at the observed deep declines in brightness.

Recent $BVRI$ CCD photometric observations of GM Cep collected in the period 2011 April–2014 August are reported in the present paper. The multicolour observations give us the opportunity to clarify the mechanism of the brightness variations.

2 OBSERVATIONS

Our photometric CCD data were obtained in two observatories with four telescopes: the 2-m Ritchey-Chrétien-Coudé (2-m), the 50/70-cm Schmidt (Sch) and the 60-cm Cassegrain (60-cm) telescopes of the National Astronomical Observatory Rozhen (Bulgaria) and the 1.3-m Ritchey-Crétien (1.3-m) telescope of the Skinakas Observatory[1] of the Institute of Astronomy, University of Crete (Greece). The technical parameters and chip specifications for the cameras used with the 2-m RCC, the 1.3-m RC and the 50/70-cm Schmidt telescopes are summarised in Semkov & Peneva (2012). Observations with the 60-cm Cassegrain telescope were performed with FLI PL09000 CCD camera (3056 × 3056 pixels, 12μm pixel size, 16.8×16.8 arcmin^2 field, 8.5 e$^-$rms RON) As references, we used the comparison sequence of fifteen stars in the field around GM Cep published in Semkov & Peneva (2012).

All frames were taken through a standard Johnson-Cousins set of filters. Twilight flat fields in each filter were obtained each clear evening. All frames obtained with the ANDOR and Vers Array cameras are bias subtracted and flat fielded. CCD frames obtained with the FLI PL16803 and FLI PL09000 cameras are dark subtracted and flat fielded. Aperture photometry was performed using DAOPHOT routines. All the data were analysed using the same aperture, which was chosen as 6 arcsec in radius, while the background annulus was from 10 to 15 arcsec.

A medium-resolution spectrum of GM Cep was obtained on 2008 June 27 with the 1.3-m RC telescope in Skinakas Observatory. The focal reducer, ISA 608 spectral CCD camera (2000 × 800 pixels, 15×15 μm pixel size), 1300 lines mm^{-1} grating and 160 μm slit were used. The combination of used CCD camera, slit and grating yield a resolving power $\lambda/\Delta\lambda \sim 1300$ at Hα line. The exposure of GM Cep were followed immediately by an exposure of an FeHeNeAr comparison lamp.

3 RESULTS AND DISCUSSION

3.1. Photometric monitoring

The results of our photometric CCD observations of GM Cep are summarised in Table 1. The columns provide the Julian date (JD) of observation, $IRVB$ magnitudes, and the telescope used. In the column Tel abbreviation 2-m denote the 2-m Ritchey-Chrétien-Coudé, Sch - the 50/70-cm Schmidt, 60-cm - the 60-cm Cassegrain and 1.3-m the 1.3-m Ritchey-Crétien telescope. The typical instrumental errors from $IRVB$ photometry are reported in our previous study Semkov & Peneva (2012). In addition, we present in Table 2 data from observations in U filter for the whole period of our photometric monitoring (2008–2014). The values of

[1] Skinakas Observatory is a collaborative project of the University of Crete, the Foundation for Research and Technology – Hellas, and the Max-Planck-Institut für Extraterrestrische Physik.

Table 1. Photometric *IRVB* observations of GM Cep during the period April 2011–August 2014.

JD (24...)	*I*	*R*	*V*	*B*	Tel	JD (24...)	*I*	*R*	*V*	*B*	Tel
55 656.458	11.61	12.53	13.38	14.70	Sch	55 896.222	12.62	13.79	14.70	16.00	Sch
55 659.492	11.73	12.62	13.47	14.87	2-m	55 925.200	12.74	13.90	14.87	16.14	Sch
55 683.557	11.83	12.76	13.68	15.10	2-m	55 928.207	12.41	13.57	14.54	15.94	Sch
55 703.359	11.67	12.65	13.48	14.78	Sch	55 957.187	12.06	13.01	13.95	–	2-m
55 704.370	11.62	12.56	13.43	14.74	Sch	55 958.211	12.01	12.95	13.88	15.33	2-m
55 705.376	11.57	12.50	13.34	14.66	Sch	56 003.528	12.19	13.31	14.29	15.72	Sch
55 706.362	11.59	12.52	13.36	14.67	Sch	56 015.536	12.22	13.26	14.28	15.74	2-m
55 707.358	11.62	12.55	13.42	14.74	Sch	56 030.460	12.12	13.19	14.13	15.50	Sch
55 721.357	11.71	12.64	13.54	14.95	2-m	56 060.390	12.19	13.34	14.31	15.68	Sch
55 722.396	11.62	12.56	13.45	14.81	Sch	56 068.375	12.11	13.20	14.18	15.63	Sch
55 734.452	11.78	12.77	13.69	15.07	Sch	56 091.418	12.01	13.06	14.00	15.35	Sch
55 735.410	11.82	12.83	13.75	15.12	Sch	56 092.406	11.97	13.00	13.93	15.30	Sch
55 736.407	11.98	13.06	14.00	15.35	Sch	56 094.469	12.21	13.21	14.18	15.60	2-m
55 737.425	12.02	13.10	14.05	15.39	Sch	56 096.423	11.96	12.99	13.94	15.31	Sch
55 739.553	11.85	12.81	13.71	–	60-cm	56 120.397	11.84	12.78	13.70	15.06	Sch
55 770.389	11.84	12.86	13.78	15.14	Sch	56 121.291	11.89	12.87	13.76	15.14	Sch
55 785.307	–	12.47	–	–	Sch	56 122.352	11.93	12.91	13.81	15.18	Sch
55 786.268	–	12.47	13.26	14.54	Sch	56 123.416	11.98	12.95	13.86	15.23	Sch
55 787.286	–	12.37	13.19	14.45	Sch	56 137.318	11.74	12.67	13.51	14.79	Sch
55 788.314	–	12.40	13.22	14.47	Sch	56 139.292	11.80	12.75	13.63	14.97	1.3-m
55 789.321	–	12.44	13.28	14.55	Sch	56 139.305	11.81	12.79	13.62	14.92	Sch
55 790.250	11.52	12.38	13.21	14.53	1.3-m	56 141.385	11.72	12.64	13.50	14.86	1.3-m
55 790.261	–	12.41	13.22	14.46	Sch	56 142.256	11.73	12.64	13.51	14.85	1.3-m
55 791.277	11.48	12.34	13.17	14.47	1.3-m	56 145.555	11.62	12.54	13.34	14.49	60-cm
55 791.292	11.48	12.37	13.17	14.44	Sch	56 157.592	11.76	12.68	13.54	14.88	1.3-m
55 792.244	11.53	12.38	13.22	14.54	1.3-m	56 159.371	11.67	12.56	13.42	14.76	Sch
55 792.279	11.52	12.43	13.23	14.50	Sch	56 160.352	11.58	12.46	13.29	14.60	Sch
55 797.343	11.48	12.35	13.16	14.45	Sch	56 161.374	11.59	12.50	13.31	14.63	Sch
55 798.328	11.47	12.35	13.16	14.45	Sch	56 162.357	11.65	12.55	13.38	14.69	Sch
55 799.342	11.51	12.41	13.24	14.52	Sch	56 166.267	11.66	12.56	13.40	14.70	Sch
55 814.349	12.01	13.03	13.98	15.30	Sch	56 167.300	11.59	12.50	13.31	14.60	Sch
55 815.276	11.88	12.88	13.81	15.23	1.3-m	56 168.310	11.54	12.42	13.26	14.55	Sch
55 815.316	–	12.87	–	–	Sch	56 169.287	11.58	12.45	13.30	14.62	Sch
55 816.326	11.86	12.86	13.80	15.18	Sch	56 173.360	11.48	12.32	13.11	14.40	1.3-m
55 816.433	11.86	12.87	13.70	15.25	1.3-m	56 174.338	11.41	12.24	13.03	14.30	1.3-m
55 817.244	11.87	12.90	13.85	15.24	Sch	56 178.311	11.43	12.25	13.04	14.32	1.3-m
55 818.275	–	12.90	–	–	Sch	56 179.485	11.55	12.41	13.22	14.53	1.3-m
55 819.246	11.88	12.92	13.87	15.24	Sch	56 180.346	11.55	12.41	13.24	14.54	1.3-m
55 820.276	–	13.16	–	–	Sch	56 181.273	11.44	12.27	13.07	14.33	60-cm
55 821.246	11.98	13.07	14.04	15.35	Sch	56 182.268	11.43	12.26	13.06	14.33	1.3-m
55 822.238	11.88	12.93	13.90	15.30	Sch	56 183.280	11.43	12.25	13.04	11.25	60-cm
55 824.237	11.89	12.93	13.88	15.29	1.3-m	56 183.393	11.44	12.27	13.07	14.33	1.3-m
55 828.281	11.75	12.77	13.71	15.13	Sch	56 192.311	11.46	12.29	13.11	14.36	60-cm
55 842.306	11.68	12.65	13.55	14.95	1.3-m	56 193.308	11.54	12.39	13.21	14.51	1.3-m
55 848.297	11.76	12.79	13.69	15.09	1.3-m	56 193.360	11.51	–	–	–	Sch
55 864.275	12.14	13.11	14.10	15.59	2-m	56 194.341	11.56	12.43	13.24	14.56	Sch
55 865.268	11.99	12.96	13.92	15.38	2-m	56 195.270	11.45	12.28	13.09	14.36	Sch
55 866.218	12.03	12.96	13.93	15.38	2-m	56 208.248	11.86	12.82	13.71	15.09	Sch
55 890.202	12.33	13.51	14.50	15.68	60-cm	56 209.251	11.98	12.97	13.87	15.26	Sch
55 892.232	12.39	13.43	14.50	15.98	2-m	56 210.242	11.98	12.95	13.86	15.22	Sch
55 895.212	12.64	13.80	14.75	16.07	Sch	56 212.281	11.74	12.66	13.57	14.92	60-cm
56 214.252	11.73	12.60	13.47	14.85	2-m	56 513.419	11.76	12.71	13.58	14.94	60-cm
56 226.374	11.62	12.51	13.38	14.73	Sch	56 514.386	11.68	12.59	13.48	14.86	60-cm
56 231.280	11.79	12.76	13.71	15.07	60-cm	56 540.346	11.61	12.48	13.32	14.63	Sch
56 249.272	11.64	12.56	13.42	14.77	Sch	56 541.380	11.61	12.47	13.32	14.62	Sch
56 250.226	11.65	12.58	13.45	14.79	Sch	56 542.420	11.65	12.52	13.38	14.70	Sch
56 275.302	11.71	12.59	13.45	14.82	2-m	56 543.376	11.70	12.55	13.38	14.69	2-m
56 276.259	11.64	12.51	13.35	14.67	2-m	56553.326	11.77	12.70	13.56	14.91	1.3-m
56 292.368	11.58	12.47	13.34	14.70	60-cm	56 577.469	11.57	12.45	13.30	14.65	60-cm
56 294.303	11.51	12.41	13.31	14.60	60-cm	56 578.482	11.60	12.46	13.31	14.68	60-cm

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Table 1. Continued.

JD (24...)	I	R	V	B	Tel	JD (24...)	I	R	V	B	Tel
56 295.349	11.56	12.45	13.30	14.62	60-cm	56 604.444	11.65	12.63	13.55	–	60-cm
56 296.327	11.61	12.49	13.37	14.72	60-cm	56 636.280	11.93	12.96	14.00	15.51	2-m
56 309.254	11.75	12.67	–	–	Sch	56 655.226	12.32	13.54	14.55	15.94	Sch
56 312.252	11.72	12.65	13.58	15.00	2-m	56 656.234	12.34	13.56	14.57	15.91	Sch
56 329.210	11.71	12.67	13.57	14.93	Sch	56 657.212	12.39	13.59	14.60	15.97	Sch
56 330.218	11.82	12.81	13.75	15.13	Sch	56 681.239	12.25	13.43	14.44	15.87	Sch
56 356.261	11.52	12.41	13.30	14.58	60-cm	56 694.239	12.23	13.28	14.32	15.83	2-m
56 369.561	11.52	12.34	13.16	14.42	2-m	56 738.547	12.38	13.55	14.51	15.81	Sch
56 392.487	11.50	12.35	13.17	14.46	Sch	56 799.494	12.12	13.25	14.16	15.58	Sch
56 394.432	11.48	12.35	13.17	14.42	Sch	56 801.344	11.93	12.92	13.88	15.32	2-m
56 415.444	12.22	13.20	14.10	15.44	Sch	56 832.325	11.60	12.54	13.43	14.85	2-m
56 417.414	11.82	12.69	13.59	14.99	2-m	56 834.319	11.67	12.59	13.53	14.94	2-m
56 443.440	12.00	12.94	13.84	15.19	Sch	56835.481	11.66	12.60	13.55	14.92	2-m
56 444.410	11.95	12.90	13.78	15.14	Sch	56 837.392	11.79	12.82	13.77	15.13	Sch
56 478.411	11.68	12.58	13.44	14.83	2-m	56 838.374	11.82	12.85	13.79	15.14	Sch
56 506.411	11.72	12.58	13.40	14.73	2-m	56 859.459	11.67	12.71	13.62	14.96	60-cm
56 507.408	11.85	12.71	13.55	14.88	2-m	56 860.469	11.69	12.71	13.60	14.95	60-cm
56 508.446	11.90	12.77	13.60	14.93	2-m	56 863.425	11.83	12.84	13.84	15.22	Sch
56 509.344	12.01	12.93	13.78	15.08	Sch	56 873.349	11.72	12.74	13.68	15.05	Sch
56 510.411	12.27	13.25	14.14	15.43	60-cm	56 874.377	11.75	12.75	13.68	15.08	Sch
56 511.435	12.11	13.08	13.95	15.24	Sch	56 888.403	11.65	12.61	13.49	14.80	Sch
56 511.452	12.10	13.06	13.93	15.28	60-cm	56 889.338	11.64	12.61	13.47	14.81	Sch
56 512.441	11.90	12.85	13.70	15.03	60-cm	56 899.325	11.64	12.63	13.50	14.84	1.3-m

instrumental errors of U band photometry are in the range 0.04-0.08 mag.

The $UBVRI$ lights curves of GM Cep from all our observations (Semkov & Peneva (2012) and the present paper) are shown in Figure 1. On the figure triangles denote I-band data; squares - R-band, circles - V-band; diamonds - B-band, and the pluses - U-band.

The new photometric data showed continued strong brightness variability of GM Cep as the registered in the previous studies Sicilia-Aguilar et al. (2008); Xiao et al. (2010); Semkov & Peneva (2012); Chen et al. (2012). Out of deep minimums GM Cep shows significant brightness variations in the time scale of days and months. In our first paper Semkov & Peneva (2012) we presented data about two observed deep minimums in brightness. During the period 2011 April–2014 August, three new well defined minimums in brightness are observed. The third registered minimum is very extended covering the period from the end of 2011 to mid-2012. The fourth minimum has a duration of only 8–9 days and it is registered in 2013 August . A drop in brightness with 0.74 mag (V) for a period of four days and a rise to the maximum level for the same time was observed. The fifth minimum is registered in the period from 2013 December to 2014 June and it resembles in duration and amplitude the minimum of 2011/2012.

The summarised results of over six years period of observations show very strong photometric variability. We have registered five deep minimum in brightness in the light curve of GM Cep. The first two minimums observed in 2009 and 2010 have a duration of between one and two months, the third (2011/2012) and the fifth (2013/2014) minimum have duration at about half an year, and the fourth minimum (2013 August) has at one week duration (Figure 2). Other drops in brightness with duration of about a week have not been surely registered in our photometric study, but the occurrence of such short events cannot be ruled out. Our photometric data do not confirm the existence of a long-term periodicity, as suggested by Chen & Hu (2014). Eclipses in the light curve of the star are probably caused by objects of different sizes and densities. Such objects could be massive dust clumps orbiting the star, inhomogeneous structures of the circumstellar disk or planetesimals at different stages of formation.

Another important result of our study is the change in colour of GM Cep at the deep minimums. Using data from our $UBVRI$ photometry the four colour-magnitude diagrams ($U-B/B$, $B-V/V$, $V-R/V$ and $V-I/V$) of the star are constructed and displayed on Figure 3. The existence of a turning point of each of the diagrams is seen on the figure. In accordance with the model of dust-clump obscuration, the observed colour reversal is caused by the scattered light from small dust grains. Generally, the star becomes redder when its light is covered by dust clumps on the line of sight. But when the obscuration rises enough, the part of the scattered light in the total observed light becomes significant and the star colour gets bluer. For each colour, such a turning point occurs at different stellar brightness, for example on $V/B-V$ diagram the turning point occurs at V$\sim$14.0 mag, while on $V/V-I$ diagram at V$\sim$14.6 mag. As we mentioned in our first paper Semkov & Peneva (2012), 'the observed change of colour indices suggest for existence of a colour reversal in the

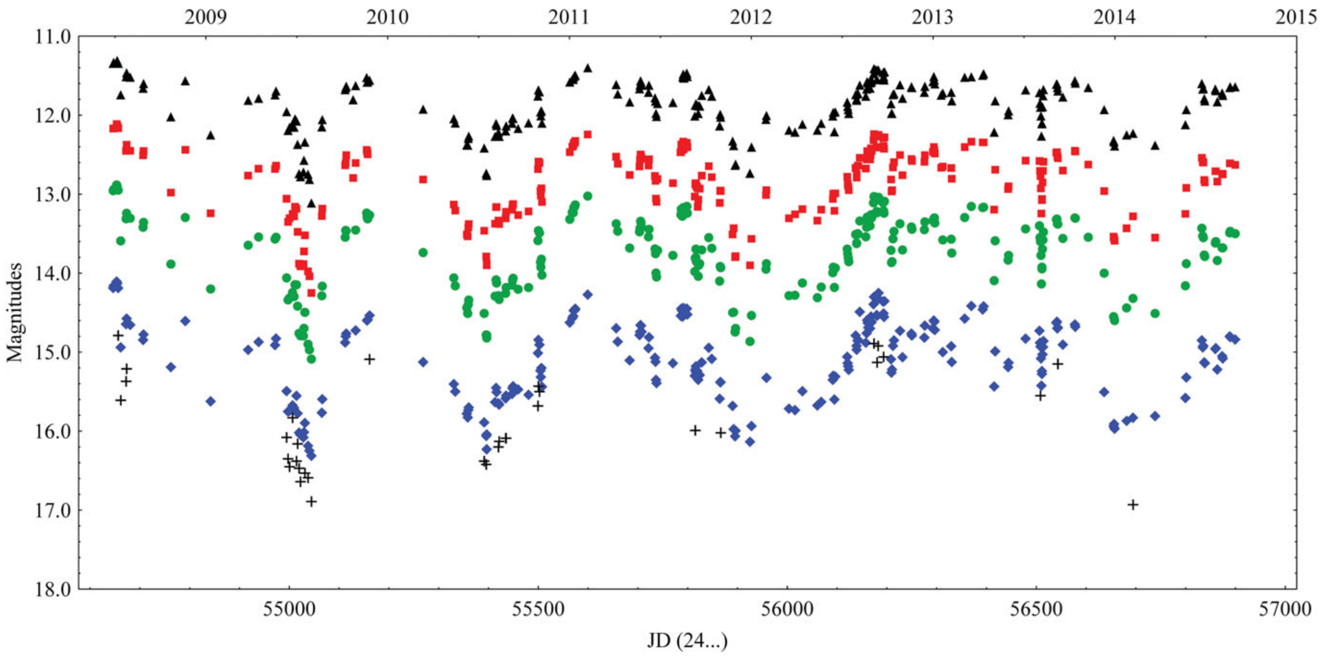

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Figure 1. *UBVRI* light curves of GM Cep for the whole period of our photometric monitoring (2008–2014).

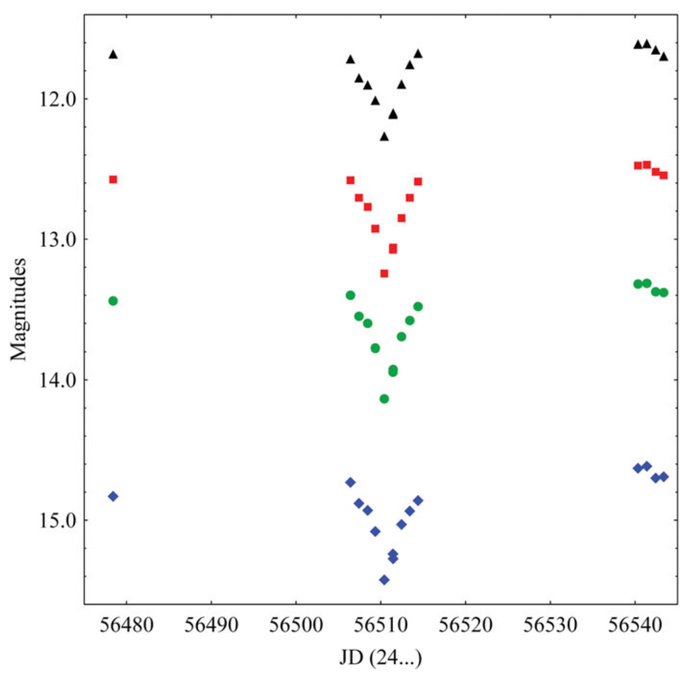

Figure 2. *BVRI* light curves during the deep minimum on August 2013.

minimum light, a typical feature of the PMS stars from UXor type'. The new data confirm the presence of 'blueing effect' at minimum light and they are independent evidence that the variability of GM Cep is dominated by variable extinction from the circumstellar environment.

After analysis of data collected our conclusion is that the photometric properties of GM Cep can be explained by superposition of both: (1) highly variable accretion from the circumstellar disk onto the stellar suffice, and (2) occultation from circumstellar clumps of dust, planetesimals or from features of the circumstellar disk. Our photometric results for the period 2008 June–2014 August suggest that the variable extinction dominates the variability of GM Cep. In low accretion rates both types of variability can act independently during different time periods and the result is the complicated light curve of GM Cep.

Due to the complex circumstellar environment around PMS stars, such a mixture of different types of photometric

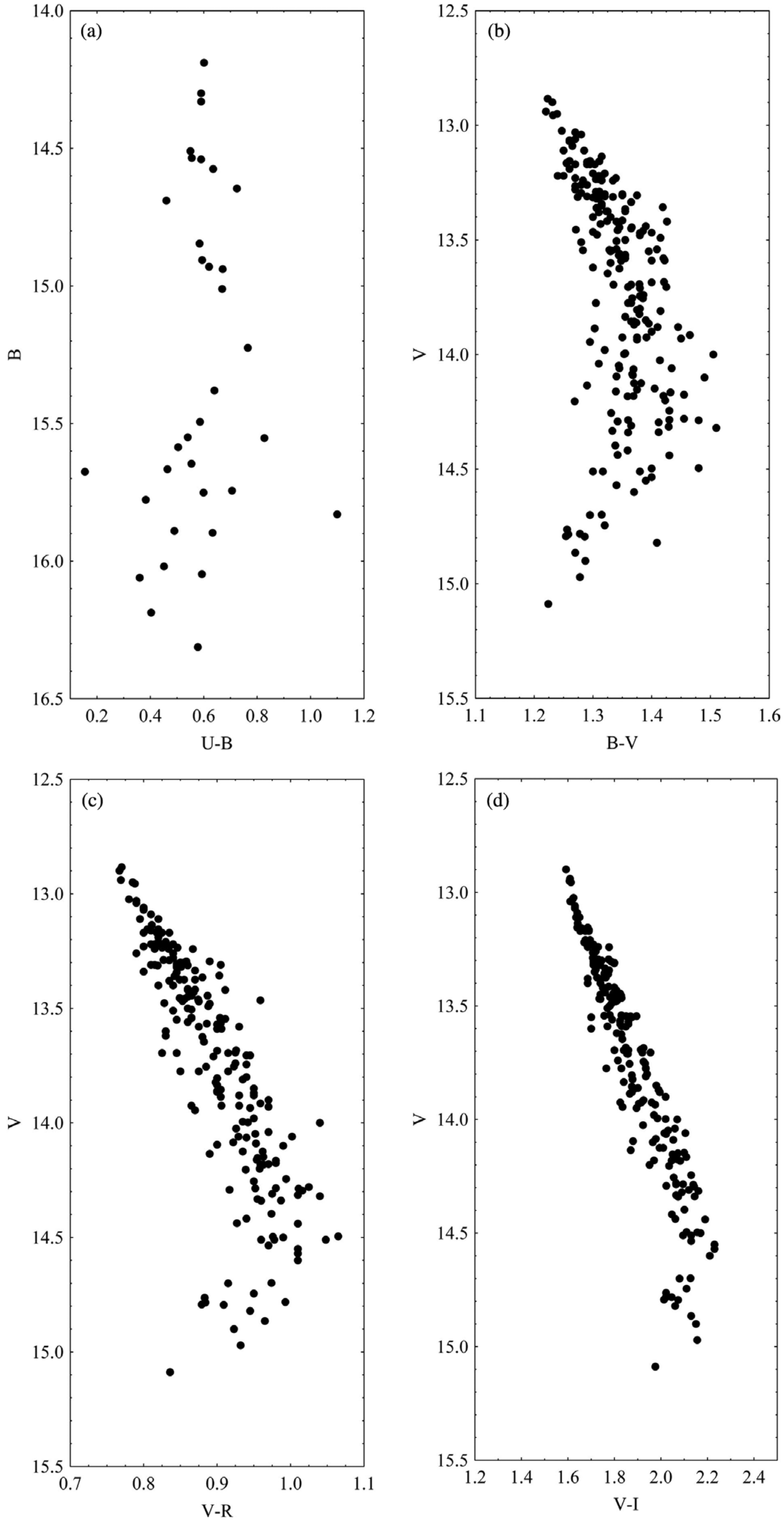

Figure 3. The colour-magnitude diagrams of GM Cep in the period of observations 2008 June–2014 June.

Table 2. Data from U band observations of GM Cep during the period July 2008–February 2014.

Date	JD (24...)	U	Tel	CCD
2008 Jul 08	54 656.464	14.79	1.3-m	ANDOR
2008 Jul 13	54 661.428	15.61	1.3-m	ANDOR
2008 Jul 24	54 672.335	15.37	1.3-m	ANDOR
2008 Jul 25	54 673.355	15.21	1.3-m	ANDOR
2009 Jun 11	54 994.581	16.08	1.3-m	ANDOR
2009 Jun 14	54 997.531	16.35	1.3-m	ANDOR
2009 Jun 17	55 000.584	16.45	1.3-m	ANDOR
2009 Jun 23	55 006.517	15.83	1.3-m	ANDOR
2009 Jul 01	55 014.517	16.38	1.3-m	ANDOR
2009 Jul 03	55 016.576	16.16	1.3-m	ANDOR
2009 Jul 06	55 019.512	16.47	1.3-m	ANDOR
2009 Jul 09	55 022.521	16.64	1.3-m	ANDOR
2009 Jul 18	55 031.504	16.53	1.3-m	ANDOR
2009 Jul 24	55 037.526	16.59	1.3-m	ANDOR
2009 Jul 31	55 044.366	16.89	1.3-m	ANDOR
2009 Nov 25	55 161.217	15.09	2-m	VA
2010 Jul 13	55 391.338	16.38	2-m	VA
2010 Jul 17	55 395.341	16.42	2-m	VA
2010 Aug 11	55 420.051	16.20	1.3-m	ANDOR
2010 Aug 12	55 421.367	16.13	1.3-m	ANDOR
2010 Aug 25	55 434.316	16.09	1.3-m	ANDOR
2010 Aug 26	55 435.352	16.09	1.3-m	ANDOR
2010 Oct 29	55 499.295	15.68	2-m	VA
2010 Oct 30	55 500.238	15.43	2-m	VA
2010 Nov 01	55 502.259	15.50	2-m	VA
2011 Sep 10	55 815.276	15.99	1.3-m	ANDOR
2011 Oct 31	55 866.218	16.02	2-m	VA
2012 Sep 03	56 174.338	14.89	1.3-m	ANDOR
2012 Sep 09	56 180.346	15.13	1.3-m	ANDOR
2012 Sep 11	56 182.268	14.92	1.3-m	ANDOR
2012 Sep 22	56 193.308	15.06	1.3-m	ANDOR
2013 Aug 03	56 508.446	15.55	2-m	VA
2013 Sep 07	56 543.376	15.15	2-m	VA
2014 Feb 05	56 694.239	16.93	2-m	VA

variability can be expected. In recent studies, a similar superposition of the both types of variability is seen on the long-term light curve of others PMS stars: V1184 Tau Semkov et al. (2008); Barsunova, Grinin, & Sergeev (2006), V1647 Ori Aspin et al. (2009), V582 Aur Semkov et al. (2013) and V2492 Cyg Hillenbrand et al. (2013). Recently, the results of two long-term photometric studies in the field of NGC 7000/IC 5070 Findeisen et al. (2013); Poljančić Beljan et al. (2014) has shown that the eclipsing phenomena are widespread type of variability in among the PMS stars. It seems that the time variable extinction is characteristic not only of HAEBE and early type CTT stars but is also a common phenomenon during the evolution of all types of PMS stars.

3.2. Spectral data

The medium-resolution spectrum of GM Cep obtained in Skinakas Observatory is shown in Figure 4. At the time of spectral observations (2008 June) the star was at the maximal level of brightness (V ∼ 12.9 mag). The analysis of spectrum was made using the standard procedures in IRAF. We fits the line profiles with Gaussian and estimate the equivalent width of the lines. The spectrum shows the typical of CTT stars absorption lines of iron, calcium, sodium and other metals and a very broad Hα emission line.

Table 3. The parameters of the two peaks and the central dip of the Hα line. Given are as follows: equivalent width (EW) of the line, full width at half maximum (FWHM) and the radial velocity ($V_{\rm rad}$).

	EW [Å]	FWHM [Å]	$V_{\rm rad}$ [km s^{-1}]
Blue peak	−1.09±0.02	3.00±0.02	−392.3±0.1
Central dip	+0.23±0.02	1.06±0.02	−231.5±0.1
Red peak	−5.39±0.02	5.05±0.02	5.9±0.1

The double-line profile of the Hα line suggest that the line is formed in a disk-like region Horne & Marsh (1986). There are similarities between the profiles of the Hα lines of GM Cep and some Be/X-ray binary stars, e. g. LS I +61 303 Zamanov et al. (2013). The circumstellar disks in Be/X-ray binaries are formed from the fast rotation of the Be star, non-radial pulsations and slow and dense equatorial wind. The PMS stars are characterised with strong stellar winds. In case of GM Cep, the wind probably form disk-like structure near the surface of the star. The depth of the central absorption of Hα line suggest that the inclination of the star to the line of sight is $i \sim 75°$ Hanuschik (1996). In Table 3, the measured parameters of the Hα line are given.

For rotationally dominated profiles, the peak separation can be regarded as a measure of the outer radius of the Hα emitting disk Huang (1972):

$$R_{\rm disk} = \frac{GM_{*} \sin^2 i}{(0.5\,\Delta V)^2}, \qquad (1)$$

From the spectrum we estimate $\Delta\ V = 379.4 \pm 0.3$ km s^{-1} (the distance between the blue and red peaks of Hα). This velocity is connected with the outer edge of the disk. Using mass of the star $M_{*} = 2.1\ M_{\odot}$ and inclination angel $i = 75°$, we calculate the outer radius of the Hα emitting region to be $10.4 \pm 0.5\ R_{\odot}$.

Using the correlation between the Hα velocity wings at 10% of the maximum ($V_{H\alpha 10\%}$) and $\dot{M}_{\rm ac}$, we can estimate the accretion rate Natta et al. (2004):

$$\log \dot{M}_{\rm ac} = -12.89(\pm 0.3) + 9.7(\pm 0.7) \times 10^{-3} V_{H\alpha 10\%} \qquad (2)$$

where $V_{H\alpha 10\%}$ is in km s^{-1} and $\dot{M}_{\rm ac}$ is in $M_{\odot}$ yr^{-1}.

For measured velocity 633 km s^{-1} on 10% of the maximum, the accretion rate is $1.8 \times 10^{-7}\ M_{\odot}$ yr^{-1}, which is close to the value $3 \times 10^{-7}\ M_{\odot}$ yr^{-1}, obtained by Sicilia-Aguilar et al. (2008).

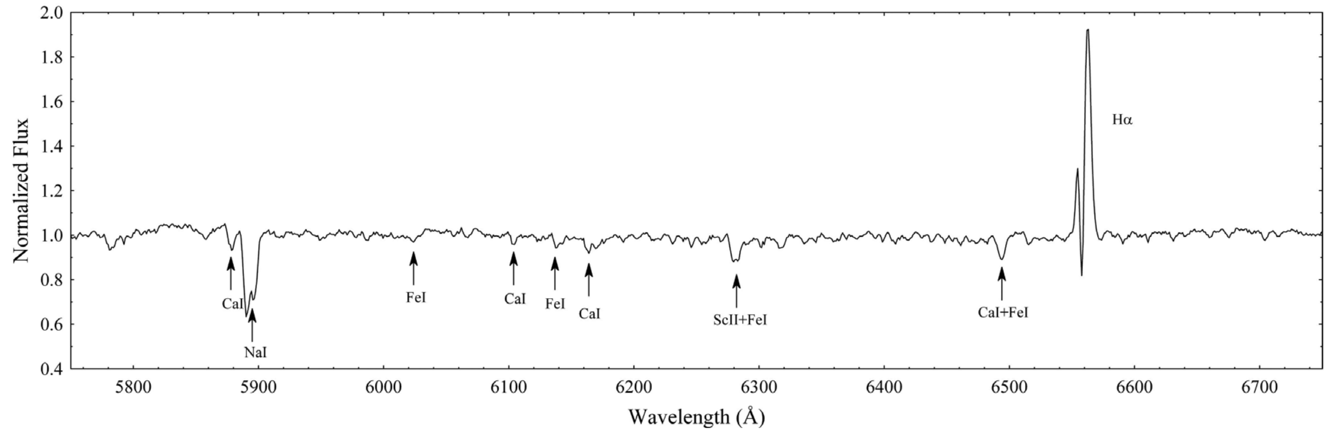

Figure 4. Spectrum of GM Cep obtained on 2008 June 27 with the 1.3-m RC telescope in Skinakas Observatory.

4 CONCLUSION

Photometric and spectral data presented in this paper show the usefulness of systematically monitoring of PMS stars with large amplitude variability. On the basis of our photometric monitoring over the past six years, we have confirmed that the variability of GM Cep is dominated by fading events rather than by bursting events. The effect of a colour reversal at the minimum light is evidence of variable extinction from the circumstellar environment. We plan to continue our photometric monitoring of the star during the next years and strongly encourage similar follow-up observations.

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