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# The Unusual Photometric Variability of the PMS Star GM Cep

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#### 8 Abstract

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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 10 star started in 2008. GM Cep is located in the field of the young open cluster Trumpler 37 and over the past years it 11 has been an object of intense photometric an spectral studies. The star shows a strong photometric variability interpreted 12 as a possible outburst from EXor type in previous studies. Our photometric data for a period of over six years show a 13 large amplitude variability ( $\Delta V \sim 2.3$  mag) and several deep minimums in brightness are observed. The analysis of the 14 collected multicolour photometric data show the typical of UX Ori variables a colour reversal during the minimums in 15 16 brightness. The observed decreases in brightness have a different shape, and evidences of periodicity are not detected. 17 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 H $\alpha$  emission line 18 and absorption lines of some metals. We calculate the outer radius of the H $\alpha$  emitting region as 10.4 $\pm$ 0.5 R $_{\odot}$  and the 19 accretion rate as  $1.8 \times 10^{-7} M_{\odot} \text{ yr}^{-1}$ . 20

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

# 22 1 INTRODUCTION

Photometric variability is a fundamental characteristic of the 23 pre-main sequence (PMS) stars, which manifests as transient 24 increases in brightness (outbursts), temporary drops in bright-25 ness (eclipses), irregular or regular variations for a short or 26 long time scales. Both types of PMS stars the widespread 27 low-mass ( $M \le 2M_{\odot}$ ) T Tauri Stars (TTSs) and the more 28 massive Herbig Ae/Be (HAEBE) stars indicate photometric 29 variability with various amplitudes and periods Herbst et al. 30 (1994, 2007). The TTSs can be separated into two subclasses: 31 Classical T Tauri (CTT) stars surrounded by a massive ac-32 cretion disk and Weak line T Tauri (WTT) stars without 33 indications of disk accretion Bertout (1989). According to 34 Herbst et al. (2007) the large amplitude variability of CTT 35 stars is caused by magnetically channeled accretion from the 36 circumstellar disk onto the stellar surface. 37

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 43 stellar objects with massive circumstellar disks, and their 44 outbursts are commonly attributed to a sizable increase in 45 the disc accretion rate onto the stellar surface Hartmann 46 & Kenyon (1996). During the quiescence state FUors and 47 EXors are normally accreting TTSs, but due to thermal 48 or gravitational instability in the circumstellar disk accre-49 tion rate enhanced by a few orders of magnitude up to 50  $\sim 10^{-4} \,\mathrm{M_{\odot} \, yr^{-1}}.$ 51

A significant part of HAEBE stars and early type CTT 52 stars show strong photometric variability with sudden quasi-53 Algol drops in brightness and amplitudes up to 2.5 mag (V)54 Natta et al. (1997); van den Ancker, de Winter, & Tjin A 55 Djie (1998). During the deep minimums of brightness, an in-56 crease in polarisation and specific colour variability (called 57 'blueing effect') are observed. The prototype of this group 58 of PMS objects with intermediate mass named UXors is UX 59 Orionis. The widely accepted explanation of its variability is 60 a variable extinction from dust clumps or filaments passing 61 through the line of sight to the star Dullemond et al. (2003); 62 Grinin et al. (1991). Normally, the star becomes redder when 63 its light is covered by dust, but when the obscuration rises 64

- 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
- <sup>71</sup> cluster Marschall & van Altena (1987); Sicilia-Aguilar et al.
- 72 (2005). The early long-term photographic observations of
- <sup>73</sup> the star performed by Suyarkova (1975) and Kun (1986)
- <sup>74</sup> indicate for a large amplitude photometric variability (the
- <sup>75</sup> observed amplitudes are  $\Delta m_{pg} = 2.2$  mag and  $\Delta V = 2.15$ <sup>76</sup> mag respectively). A multicolour photometric study based on
- <sup>77</sup> optical, infrared and millimeter observations of GM Cep was
- <sup>78</sup> reported by Sicilia-Aguilar et al. (2008). The authors found
- <sup>79</sup> 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 82 a PMS star with solar mass (M  $\sim$  2.1  ${\rm M}_{\odot})$  from G7V– 83 KOV spectral type and with radius between 3 and 6  $R_{\odot}$ . 84 The observed strong IR excesses have been explained by 85 the presence of a very luminous and massive circumstel-86 lar disk. The H $\alpha$  emission line in the spectrum of GM Cep 87 has a strong P Cyg profile and the equivalent width of the 88 line vary significantly from 6 to 19 Å Sicilia-Aguilar et al. 89 (2008). A variable accretion rate (up to  $\sim 10^{-6} \text{ M}_{\odot} \text{ year}^{-1}$ ) 90 are also detected in the study of Sicilia-Aguilar et al. 91 (2008).92

A long-term photometric study of GM Cep for several 93 decades period was performed by Xiao, Kroll, & Henden 94 (2010). The photographic plate archives from Harvard Col-95 lege Observatory and from Sonneberg Observatory are used 96 to construct the long-term B and V light curves of the star. 97 The results suggest that GM Cep do not show fast rises in 98 brightness typical of EXor variables and the light curves seem 99 to be dominated by dips superposed on the quiescence state. 100 Evidences for periodicity of observed dips in brightness were 101 not found in the study of Xiao et al. (2010). 102

In our first paper Semkov & Peneva (2012), the results 103 from BVRI optical photometric observations of the star col-104 lected in the period 2008 June-2011 February are reported. 105 During out photometric monitoring two deep minimums in 106 brightness are observed. The collected multicolour photo-107 metric data show the typical of UXor variables a colour re-108 versal during the minimums in brightness. Chen et al. (2012)109 reported results from intensive BVR photometric monitor-110 ing of GM Cep during the period 2009-2011. They confirm 111 the UXor nature of variability and suggest an early stage of 112 planetesimal formation in the star environment. Chen & Hu 113 (2014) suggest a periodicity of about 300 days at the observed 114 deep declines in brightness. 115

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 observato-122 ries with four telescopes: the 2-m Ritchey-Chrétien-Coudé 123 (2-m), the 50/70-cm Schmidt (Sch) and the 60-cm Cassegrain 124 (60-cm) telescopes of the National Astronomical Observa-125 tory Rozhen (Bulgaria) and the 1.3-m Ritchey-Crétien (1.3-126 m) telescope of the Skinakas Observatory<sup>1</sup> of the Institute 127 of Astronomy, University of Crete (Greece). The technical 128 parameters and chip specifications for the cameras used with 129 the 2-m RCC, the 1.3-m RC and the 50/70-cm Schmidt tele-130 scopes are summarised in Semkov & Peneva (2012). Obser-131 vations with the 60-cm Cassegrain telescope were performed 132 with FLI PL09000 CCD camera ( $3056 \times 3056$  pixels,  $12\mu$ m 133 pixel size, 16.8×16.8 arcmin<sup>2</sup> field, 8.5 e<sup>-</sup>rms RON) As ref-134 erences, we used the comparison sequence of fifteen stars 135 in the field around GM Cep published in Semkov & Peneva 136 (2012).137

All frames were taken through a standard Johnson-Cousins 138 set of filters. Twilight flat fields in each filter were obtained 139 each clear evening. All frames obtained with the ANDOR and 140 Vers Array cameras are bias subtracted and flat fielded. CCD 141 frames obtained with the FLI PL16803 and FLI PL09000 142 cameras are dark subtracted and flat fielded. Aperture pho-143 tometry was performed using DAOPHOT routines. All the 144 data were analysed using the same aperture, which was cho-145 sen as 6 arcsec in radius, while the background annulus was 146 from 10 to 15 arcsec. 147

A medium-resolution spectrum of GM Cep was obtained 148 on 2008 June 27 with the 1.3-m RC telescope in Skinakas Ob-149 servatory. The focal reducer, ISA 608 spectral CCD camera 150  $(2000 \times 800 \text{ pixels}, 15 \times 15 \,\mu\text{m} \text{ pixel size}), 1300 \text{ lines mm}^{-1}$ 151 grating and 160  $\mu$ m slit were used. The combination of used 152 CCD camera, slit and grating yield a resolving power  $\lambda/\Delta\lambda$ 153  $\sim$  1300 at H $\alpha$  line. The exposure of GM Cep were followed 154 immediately by an exposure of an FeHeNeAr comparison 155 lamp. 156

## **3 RESULTS AND DISCUSSION**

#### 3.1. Photometric monitoring

The results of our photometric CCD observations of GM 159 Cep are summarised in Table 1. The columns provide the Ju-160 lian date (JD) of observation, IRVB magnitudes, and the 161 telescope used. In the column Tel abbreviation 2-m de-162 note the 2-m Ritchey-Chrétien-Coudé, Sch - the 50/70-cm 163 Schmidt, 60-cm - the 60-cm Cassegrain and 1.3-m the 1.3-164 m Ritchey-Crétien telescope. The typical instrumental errors 165 from *IRVB* photometry are reported in our previous study 166 Semkov & Peneva (2012). In addition, we present in Table 2 167 data from observations in U filter for the whole period of 168 our photometric monitoring (2008-2014). The values of 169

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<sup>&</sup>lt;sup>1</sup>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.

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55         55         565         962         12.72         13.79         14.70         6.60         Sch           55         659.422         11.73         12.62         13.47         14.87         2-m         55         92.5200         12.74         13.90         14.87         16.41         Sch           55         053.557         11.61         12.65         13.48         14.78         Sch         55         92.5207         12.41         13.01         13.95         -	JD (24)	Ι	R	V	В	Tel	JD (24)	Ι	R	V	В	Tel
55         65         67         13.47         14.87         2-m         55         92.200         1.2.74         13.90         14.87         16.14         15.94         Sch           55         03.359         11.67         12.65         13.48         14.78         Sch         55         92.97         12.41         13.01         13.95         -         -         2-m           55         705.376         11.67         12.50         13.34         14.476         Sch         55         13.21         14.21         13.31         14.29         15.72         Sch           57         707.358         16.2         12.52         13.42         14.47         Sch         50         13.19         14.13         15.68         Sch         55         73.440         12.29         13.24         14.18         15.60         Sch         55         73.442         11.78         12.47         13.69         14.05         Sch         56         13.01         13.01         13.03         15.03         Sch         56         13.04         14.01         15.33         Sch         56         13.04         14.10         15.33         Sch         56         13.34         14.41         15.33	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 68.557         11.83         12.76         13.68         14.74         Sch         55 79.157         12.61         13.05         -         -         2-m           55 703.359         11.67         12.56         13.43         14.74         Sch         55 79.178         12.01         12.95         13.88         15.33         2-m           55 706.350         11.57         12.26         13.43         14.74         Sch         56 003.90         12.19         13.31         14.28         15.74         2-m           55 70.6320         11.62         12.25         13.42         14.31         15.66         Sch           55 72.357         11.71         12.64         13.54         14.95         2-m         56 060.390         12.11         13.04         14.05         Sch         Sch         Sch 060.390         12.10         13.06         15.07         Sch         Sch 060.390         12.10         13.06         15.07         Sch         Sch 094.469         12.11         13.41         13.48         Sch         Sch 55         Sch 55         75.65         13.93         13.06         Sch         Sch 55         Sch 55         Sch 55         Sch 55         Sch 55         Sch 23.82         14.11         15.14	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
55 703.379         11.67         12.62         13.48         14.78         Sch         55 971.187         12.00         13.01         13.95         - <th< td=""><td>55 683.557</td><td>11.83</td><td>12.76</td><td>13.68</td><td>15.10</td><td>2-m</td><td>55 928.207</td><td>12.41</td><td>13.57</td><td>14.54</td><td>15.94</td><td>Sch</td></th<>	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
55 704.370         11.62         12.26         13.43         14.74         Sch         55 508.376         11.57         12.50         13.34         14.66         Sch         56 60 15.556         12.22         13.21         14.29         15.72         Sch           55 706.376         11.57         12.55         13.42         14.74         Sch         56 015.556         12.22         13.26         14.28         15.74         Sch           55 70.376         11.62         12.25         13.45         14.95         2-m         56 006.300         12.10         13.34         14.31         15.68         Sch           55 77.3450         11.62         12.26         13.45         14.81         Sch         56 092.406         11.97         13.00         13.03         15.00         Sch           55 73.452         12.02         13.10         14.00         15.35         Sch         56 094.469         12.11         13.20         14.48         I5.66         Sch         55 75.75.75         11.84         12.49         13.81         15.81         Sch         Sch         56 094.423         11.90         12.91         13.81         15.78         Sch         Sch         56 120.397         11.84         12.49         <	55 703.359	11.67	12.65	13.48	14.78	Sch	55 957.187	12.06	13.01	13.95	_	2-m
55 705.376         11.57         12.50         13.34         14.66         Sch         56 003.528         12.19         13.11         14.29         15.72         Sch         55 706.352         11.22         13.26         14.31         15.05         Sch         55 707.358         11.62         12.55         14.13         15.05         Sch	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
55 706.32         11.59         12.52         13.36         14.67         Sch.         56 015.356         12.12         13.19         14.31         15.50         Sch.           55 707.358         11.62         12.26         13.45         14.95         2m         56 060.300         12.19         13.34         14.31         15.68         Sch.           55 724.352         11.71         12.26         13.45         14.81         Sch.         56 060.300         12.19         13.34         14.31         15.68         Sch.           55 73.4452         11.78         12.27         13.16         14.00         15.35         Sch.         56 094.469         12.11         13.14         18.16         0.00         55           55 770.389         11.84         12.48         13.70         1.400         15.39         Sch.         56 094.429         12.21         13.19         1.400         1.535         Sch.         56 122.391         11.89         12.87         13.36         1.523         Sch           55 770.389         11.84         12.46         13.78         1.514         Sch         Sch         512.352         11.39         1.479         1.36         1.479         1.376         1.51         1	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       707.358       11.62       12.255       13.54       14.94       Sch       56       600.390       12.12       13.19       14.13       15.66       Sch         55       722.396       11.62       12.26       13.45       14.81       Sch       56       606.375       12.11       13.20       14.08       15.65       Sch       55       75.440       11.82       12.81       31.75       15.12       Sch       56       609.440       12.21       13.06       14.00       15.35       Sch       56       609.440       12.21       13.21       14.18       15.60       Sch       57       75.74.25       13.04       15.01       Sch       56       609.420       11.64       12.87       13.04       15.31       Sch       56       609.423       11.89       12.87       13.04       15.31       Sch       56       57.35.37       13.81       15.14       Sch       56       123.29       13.81       15.14       Sch       56       12.35       13.81       15.81       Sch       56       12.35       13.81       15.81       14.71       35.75       57.85.307       13.61       14.20       13.24       14.53       14.85       Sch       56       12.	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       71       11.71       12.64       13.45       14.81       Sch       56       6668.375       12.19       13.34       14.31       15.68       Sch         55       724.36       11.78       12.77       13.69       15.07       Sch       56       191.418       12.01       13.00       13.93       15.30       Sch         55       73.447       11.82       12.28       13.71       -       60.00       56       10.94       14.18       15.30       Sch         57       73.472       12.02       13.10       14.00       15.35       Sch       56       060.423       11.96       12.99       13.94       15.13       Sch         57       7.47       -       -       Sch       56       12.329       13.91       15.14       Sch         57       7.53.07       -       12.47       13.26       14.54       Sch       56       12.321       11.89       12.87       13.81       15.14       Sch         57       78.53.07       -       12.37       13.19       14.47       Sch       56       13.34       14.77       13.63       14.79       Sch       56       13.20       14.81       13.77	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       72.396       11.62       12.56       13.69       15.07       Sch       56       0691.418       12.11       13.20       14.18       15.63       Sch         55       735.410       11.82       12.83       13.75       15.12       Sch       56       092.406       11.97       13.00       14.00       15.35       Sch         55       736.407       11.89       12.81       13.71       15.12       Sch       56       094.409       12.21       13.21       14.18       15.04       Sch         57       73.745       12.81       13.71       -       0.0cm       56 122.391       11.89       12.81       13.76       15.14       Sch         57       7.0       -       12.47       13.26       14.54       Sch       56 122.352       11.98       12.81       13.76       15.14       Sch         57 87.266       -       12.47       13.26       14.45       Sch       56 137.318       11.74       12.67       13.61       14.79       13.86       15.37       Sch       57 85.207       -       12.44       13.54       14.88       13.87       57 85.207       13.61       14.85       Sch       56 137.318       11.71 <td>55 721.357</td> <td>11.71</td> <td>12.64</td> <td>13.54</td> <td>14.95</td> <td>2-m</td> <td>56 060.390</td> <td>12.19</td> <td>13.34</td> <td>14.31</td> <td>15.68</td> <td>Sch</td>	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       735.410       11.78       12.77       13.60       15.07       Sch       56       6091.406       11.97       13.00       13.03       15.30       Sch         55       735.410       11.82       12.23       13.75       15.12       Sch       56       6902.406       11.97       13.00       13.93       15.30       Sch         55       73.472       12.02       13.10       14.05       15.35       Sch       56       6004.423       11.84       12.78       13.70       15.06       Sch         55       770.389       11.84       12.74       -       Sch       56       12.237       13.81       15.14       Sch         5787.536       -       12.37       13.19       14.45       Sch       56       13.738       11.74       12.67       13.51       14.87       13.57         5787.364       -       12.37       13.19       14.45       Sch       56       13.932       11.81       12.74       13.63       14.97       13.36         5787.367       -       12.44       13.22       14.47       Sch       56       13.932       11.81       12.74       13.61       14.88       13.37       14.64	55 722.396	11.62	12.56	13.45	14.81	Sch	56 068.375	12.11	13.20	14.18	15.63	Sch
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$\begin{array}{llllllllllllllllllllllllllllllllllll$	55 739.553	11.85	12.81	13.71	_	60-cm	56 120.397	11.84	12.78	13.70	15.06	Sch
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	55 770.389	11.84	12.86	13.78	15.14	Sch	56 121.291	11.89	12.87	13.76	15.14	Sch
$\begin{array}{llllllllllllllllllllllllllllllllllll$	55 785.307	_	12.47	_	_	Sch	56 122.352	11.93	12.91	13.81	15.18	Sch
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 786.268	_	12.47	13.26	14.54	Sch	56 123.416	11.98	12.95	13.86	15.23	Sch
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 787.286	_	12.37	13.19	14.45	Sch	56 137.318	11.74	12.67	13.51	14.79	Sch
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	55 788.314	_	12.40	13.22	14.47	Sch	56 139.292	11.80	12.75	13.63	14.97	1.3-m
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 789 321	_	12.44	13.28	14.55	Sch	56 139 305	11.81	12.79	13.62	14.92	Sch
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	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
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	55 790 261	_	12.41	13.22	14.46	Sch	56 142 256	11.73	12.64	13.51	14.85	1.3-m
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	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
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	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
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 792 244	11.53	12.37	13.22	14.54	1.3-m	56 159 371	11.67	12.56	13.42	14.76	Sch
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 792 279	11.55	12.30	13.22	14 50	Sch	56 160 352	11.58	12.50	13.12	14.60	Sch
$\begin{array}{c} 57 \ y_{5}, y_{5$	55 797 343	11.52	12.15	13.16	14.45	Sch	56 161 374	11.50	12.10	13.31	14.63	Sch
$ \begin{array}{c} 57 \ 799.32 \\ 57 \ 799.32 \\ 11.51 \ 12.41 \ 13.24 \ 14.52 \ 5ch \ 56 \ 166.257 \ 11.66 \ 12.56 \ 13.40 \ 14.70 \ 5ch \ 55 \ 816.349 \ 12.01 \ 13.03 \ 13.98 \ 15.30 \ 5ch \ 56 \ 167.300 \ 11.59 \ 12.50 \ 13.31 \ 14.60 \ 5ch \ 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 \ 5ch \ 55 \ 815.316 \ - \ 12.87 \ - \ - \ 5ch \ 56 \ 169.287 \ 11.58 \ 12.45 \ 13.30 \ 14.62 \ 5ch \ 55 \ 816.326 \ 11.86 \ 12.86 \ 13.80 \ 15.18 \ 5ch \ 56 \ 173.360 \ 11.48 \ 12.32 \ 13.11 \ 14.40 \ 1.3^{-m} \ 55 \ 816.326 \ 11.48 \ 12.25 \ 13.04 \ 14.32 \ 1.3^{-m} \ 55 \ 816.326 \ 11.48 \ 12.22 \ 13.04 \ 14.32 \ 1.3^{-m} \ 55 \ 816.327 \ - \ 12.90 \ - \ - \ 5ch \ 56 \ 179.485 \ 11.55 \ 12.41 \ 13.22 \ 14.54 \ 1.3^{-m} \ 55 \ 812.246 \ 11.88 \ 12.92 \ 13.87 \ 15.24 \ 5ch \ 56 \ 180.346 \ 11.55 \ 12.41 \ 13.24 \ 14.54 \ 1.3^{-m} \ 55 \ 812.246 \ 11.88 \ 12.92 \ 13.87 \ 15.24 \ 5ch \ 56 \ 180.346 \ 11.55 \ 12.41 \ 13.24 \ 14.54 \ 1.3^{-m} \ 55 \ 820.276 \ - \ 13.16 \ - \ - \ 5ch \ 56 \ 181.273 \ 11.44 \ 12.27 \ 13.07 \ 14.33 \ 60\ -cm \ 55 \ 822.238 \ 11.88 \ 12.92 \ 13.88 \ 15.29 \ 1.3^{-m} \ 56 \ 182.268 \ 11.43 \ 12.26 \ 13.06 \ 14.33 \ 1.3\ -m \ 55 \ 824.237 \ 11.88 \ 12.93 \ 13.88 \ 15.29 \ 1.3\ - \ 56 \ 182.268 \ 11.43 \ 12.27 \ 13.04 \ 14.54 \ 1.3\ -m \ 55 \ 824.237 \ 11.88 \ 12.93 \ 13.88 \ 15.29 \ 1.3\ -m \ 56 \ 182.268 \ 11.43 \ 12.27 \ 13.04 \ 14.54 \ 1.3\ -m \ 55 \ 824.237 \ 11.88 \ 12.93 \ 13.88 \ 15.29 \ 1.3\ -m \ 56 \ 183.393 \ 11.44 \ 12.27 \ 13.04 \ 11.25 \ 60\ -cm \ 55 \ 824.237 \ 11.88 \ 12.93 \ 13.88 \ 15.29 \ 1.3\ -m \ 56 \ 183.393 \ 11.44 \ 12.27 \ 13.04 \ 11.25 \ 60\ -cm \ 55 \ 824.237 \ 11.68 \ 12.39 \ 13.21 \ 1.43 \ 12.26 \ 13.04 \ 11.25 \ 13.04 \ 11.25 \ 13.44 \ 12.27 \ 13.07 \ 14.33 \ 1.3\ -m \ 55 \ 824.2306 \ 11.68 \ 12.68 \ 11.43 \ 12.26 \ 13.04 \ 11.25 \ 60\ -cm \ 55 \ 824.2306 \ 11.68 \ 12.43 \ 13.24 \ 14.56 \ 5ch \ 14.43 \ 12.24 \ 13.04 \ 11.25 \ 55 \ 864.275 \ 13.45 \ 1.3\ -m \ 56 \ 192.311 \ 11.46 \ 12.29 \ 13.11 \ 1.3\ -m \ 55 \ 824.230 \ 11.68 \$	55 798 328	11.40	12.35	13.16	14.45	Sch	56 162 357	11.55	12.50	13.31	14.69	Sch
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	55 799 342	11.17	12.55	13.10	14 52	Sch	56 166 267	11.65	12.55	13.40	14 70	Sch
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	55 814 349	12.01	13.03	13.98	15.30	Sch	56 167 300	11.50	12.50	13 31	14.60	Sch
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	55 815 276	11.88	12.88	13.81	15.23	1 3-m	56 168 310	11.59	12.30	13.26	14 55	Sch
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 815 316	-	12.00	-	-	Sch	56 169 287	11.54	12.42	13.20	14.55	Sch
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 816 326	11.86	12.07	13.80	15 18	Sch	56 173 360	11.50	12.15	13.11	14.40	1 3-m
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 816 433	11.00	12.00	13.00	15.10	1 3-m	56 174 338	11.40	12.52	13.03	14.40	1.3 m
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 817 244	11.00	12.07	13.85	15.25	Sch	56 178 311	11.41	12.24	13.03	14.30	1.3 m
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 818 275	11.07	12.90	15.05	15.24	Sch	56 179 485	11.45	12.25	13.04	14.52	1.3-m
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 810 246	11.88	12.90	13.87	15.24	Sch	56 180 346	11.55	12.41	13.22	14.55	1.3-m
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 820 276	11.00	12.72	15.07	15.24	Sch	56 181 273	11.55	12.71	13.24	14.33	60 cm
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 821 246	11.08	13.10	14.04	15 35	Sch	56 182 268	11.44	12.27	13.07	14.33	1 3-m
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 822 238	11.90	12.07	13.00	15.30	Sch	56 183 280	11.43	12.20	13.00	11.35	60 cm
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 824 237	11.00	12.95	13.90	15.30	1.3 m	56 183 303	11.43	12.23	13.04	14.33	1.3 m
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 824.257	11.09	12.95	12.00	15.12	Soh	56 102 211	11.44	12.27	12.11	14.33	60 am
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	55 842 206	11.75	12.77	12.55	14.05	1.2 m	56 102 208	11.40	12.29	12.11	14.50	1.2 m
5.5       848.297       11.70       12.79       15.09       15.09       1.5411       56       193.300       11.31       - </td <td>55 842.500</td> <td>11.08</td> <td>12.05</td> <td>13.33</td> <td>14.95</td> <td>1.3-III 1.2 m</td> <td>56 102 360</td> <td>11.54</td> <td>12.39</td> <td>15.21</td> <td>14.31</td> <td>1.5-III Sob</td>	55 842.500	11.08	12.05	13.33	14.95	1.3-III 1.2 m	56 102 360	11.54	12.39	15.21	14.31	1.5-III Sob
53       804.273       12.14       15.11       14.10       15.39       2-11       56       194.341       11.36       12.43       15.24       14.36       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       12.97       13.86       15.22       Sch         55       895.212       12.64       13.80       14.75       16.07       Sch       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       514.38	55 964 075	12.14	12.79	13.09	15.09	1.5-III 2 m	56 104 241	11.51	12.42	12.24	-	Sch
53       803.208       11.99       12.90       13.92       13.38       2-11       56       193.270       11.43       12.28       13.09       14.30       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.	55 865 268	12.14	12.11	14.10	15.39	2-111 2 m	56 105 270	11.30	12.45	13.24	14.30	Sch
53 800.218       12.03       12.90       13.93       13.38       2-11       50 208.248       11.80       12.82       13.71       13.09       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       12.97       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       12.48       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       1	55 866 218	11.99	12.90	13.92	15.30	2-111 2 m	56 208 248	11.43	12.20	12.09	14.50	Sch
35 890.202       12.53       15.51       14.50       15.68       60-cm       56 209.251       11.98       12.97       15.87       15.26       Sch         55 892.232       12.39       13.43       14.50       15.98       2-m       56 210.242       11.98       12.97       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       14.63       Sch         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	55 800.218	12.05	12.90	13.95	15.50	2-111 60. am	56 200 251	11.00	12.62	12.71	15.09	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       56 543.376       11.70       12.55       13.38       14.69       2-m         56 275.302       11.71       12.59	55 890.202	12.33	13.51	14.50	15.08	ou-cm	56 209.251	11.98	12.97	13.8/	15.20	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       56 543.376       11.70       12.55       13.38       14.69       2-m         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	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
56 214.252       11.73       12.60       15.47       14.85       2-m       56 513.419       11.76       12.71       15.38       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         56 275.302       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       1	55 895.212	12.64	13.80	14.75	16.07	Scn	56 212.281	11.74	12.66	13.57	14.92	60-cm
30 220.374       11.02       12.51       13.38       14.73       Scn       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         56 275.302       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       56 578.482       11.60       12.46       13.31       14.68       60-cm         56 294.303       11.51       12.41 <td< td=""><td>56 226 274</td><td>11./3</td><td>12.60</td><td>13.47</td><td>14.85</td><td>2-m</td><td>56 51 3.419</td><td>11.70</td><td>12./1</td><td>13.38</td><td>14.94</td><td>ou-cm</td></td<>	56 226 274	11./3	12.60	13.47	14.85	2-m	56 51 3.419	11.70	12./1	13.38	14.94	ou-cm
50 251.250       11.79       12.76       15.71       15.07       60-cm       56 540.346       11.61       12.48       15.32       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         56 275.302       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	50 220.374	11.62	12.51	15.38	14.73	Sch	50 514.386	11.68	12.59	13.48	14.86	60-cm
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	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
50 220.226       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         56 275.302       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	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 2/5.302       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	56 250.226	11.65	12.58	13.45	14.79	Sch	56 542.420	11.65	12.52	13.38	14.70	Sch
56 276.259         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	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         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	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
56 294.303 11.51 12.41 13.31 14.60 60-cm 56 578.482 11.60 12.46 13.31 14.68 60-cm	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

Table 1.	Continued.
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JD (24)	Ι	R	V	В	Tel	JD (24)	Ι	R	V	В	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

<sup>170</sup> instrumental errors of U band photometry are in the range <sup>171</sup> 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 bright-177 ness variability of GM Cep as the registered in the previ-178 ous studies Sicilia-Aguilar et al. (2008); Xiao et al. (2010); 179 Semkov & Peneva (2012); Chen et al. (2012). Out of deep 180 minimums GM Cep shows significant brightness variations 181 in the time scale of days and months. In our first paper 182 Semkov & Peneva (2012) we presented data about two ob-183 served deep minimums in brightness. During the period 2011 184 April-2014 August, three new well defined minimums in 185 brightness are observed. The third registered minimum is 186 very extended covering the period from the end of 2011 to 187 mid-2012. The fourth minimum has a duration of only 8-9 188 days and it is registered in 2013 August . A drop in brightness 189 with 0.74 mag (V) for a period of four days and a rise to the 190 maximum level for the same time was observed. The fifth 191 minimum is registered in the period from 2013 December 192 to 2014 June and it resembles in duration and amplitude the 193 minimum of 2011/2012. 194

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 200 duration at about half an year, and the fourth minimum (2013 201 August) has at one week duration (Figure 2). Other drops in 202 brightness with duration of about a week have not been surely 203 registered in our photometric study, but the occurrence of 204 such short events cannot be ruled out. Our photometric data 205 do not confirm the existence of a long-term periodicity, as 206 suggested by Chen & Hu (2014). Eclipses in the light curve 207 of the star are probably caused by objects of different sizes 208 and densities. Such objects could be massive dust clumps or-209 biting the star, inhomogeneous structures of the circumstellar 210 disk or planetesimals at different stages of formation. 211

Another important result of our study is the change in 212 colour of GM Cep at the deep minimums. Using data from 213 our UBVRI photometry the four colour-magnitude diagrams 214 (U - B/B, B - V/V, V - R/V and V - I/V) of the star are 215 constructed and displayed on Figure 3. The existence of a 216 turning point of each of the diagrams is seen on the figure. 217 In accordance with the model of dust-clump obscuration, the 218 observed colour reversal is caused by the scattered light from 219 small dust grains. Generally, the star becomes redder when 220 its light is covered by dust clumps on the line of sight. But 221 when the obscuration rises enough, the part of the scattered 222 light in the total observed light becomes significant and the 223 star colour gets bluer. For each colour, such a turning point 224 occurs at different stellar brightness, for example on V/B - V225 diagram the turning point occurs at V $\sim$ 14.0 mag, while on 226 V/V - I diagram at V~14.6 mag. As we mentioned in our 227 first paper Semkov & Peneva (2012), 'the observed change of 228 colour indices suggest for existence of a colour reversal in the 229



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'

<sup>232</sup> at minimum light and they are independent evidence that the

<sup>233</sup> variability of GM Cep is dominated by variable extinction

<sup>234</sup> 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 fea-<br/>tures of the circumstellar disk. Our photometric results for<br/>the period 2008 June-2014 August suggest that the variable<br/>extinction dominates the variability of GM Cep. In low ac-<br/>cretion rates both types of variability can act independently<br/>during different time periods and the result is the complicated<br/>light curve of GM Cep.239<br/>240241<br/>242<br/>243241<br/>244243<br/>244<br/>244243<br/>244244<br/>245244245<br/>246244

Due to the complex circumstellar environment around 246 PMS stars, such a mixture of different types of photometric 247

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

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**Table 2.** Data from U band observations of GM Cepduring 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 super-248 position of the both types of variability is seen on the long-249 term light curve of others PMS stars: V1184 Tau Semkov 250 et al. (2008); Barsunova, Grinin, & Sergeev (2006), V1647 251 Ori Aspin et al. (2009), V582 Aur Semkov et al. (2013) 252 and V2492 Cyg Hillenbrand et al. (2013). Recently, the re-253 sults of two long-term photometric studies in the field of 254 NGC 7000/IC 5070 Findeisen et al. (2013); Poljančić Beljan 255 et al. (2014) has shown that the eclipsing phenomena are 256 widespread type of variability in among the PMS stars. It 257 seems that the time variable extinction is characteristic not 258 only of HAEBE and early type CTT stars but is also a com-259 mon phenomenon during the evolution of all types of PMS 260 stars. 261

#### 262 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

	EW	FWHM	V <sub>rad</sub>
	[Å]	[Å]	[km s <sup>-1</sup> ]
Blue peak	$-1.09\pm0.02$	$3.00 \pm 0.02$	-392.3±0.1
Central dip	+0.23±0.02	$1.06 \pm 0.02$	-231.5±0.1
Red peak	-5.39±0.02	$5.05 \pm 0.02$	5.9±0.1

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 H $\alpha$  emission line. 271

The double-line profile of the H $\alpha$  line suggest that the 272 line is formed in a disk-like region Horne & Marsh (1986). 273 There are similarities between the profiles of the H $\alpha$  lines of 274 GM Cep and some Be/X-ray binary stars, e. g. LS I +61 303 275 Zamanov et al. (2013). The circumstellar disks in Be/X-ray 276 binaries are formed from the fast rotation of the Be star, non-277 radial pulsations and slow and dense equatorial wind. The 278 PMS stars are characterised with strong stellar winds. In case 279 of GM Cep, the wind probably form disk-like structure near 280 the surface of the star. The depth of the central absorption of 281  $H\alpha$  line suggest that the inclination of the star to the line of 282 sight is  $i \sim 75^{\circ}$  Hanuschik (1996). In Table 3, the measured 283 parameters of the H $\alpha$  line are given. 284

For rotationally dominated profiles, the peak separation  $_{285}$  can be regarded as a measure of the outer radius of the H $\alpha$   $_{286}$  emitting disk Huang (1972):  $_{287}$ 

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

297

From the spectrum we estimate  $\Delta V = 379.4 \pm 0.3 \text{ km s}^{-1}$  (the distance between the blue and red peaks of H $\alpha$ ). This velocity is connected with the outer edge of the disk. Using mass of the star  $M_* = 2.1 \text{ M}_{\odot}$  and inclination angel  $i = 75^{\circ}$ , 291 we calculate the outer radius of the H $\alpha$  emitting region to be 10.4 $\pm$ 0.5 R $_{\odot}$ .

Using the correlation between the H $\alpha$  velocity wings at 294 10% of the maximum ( $V_{H\alpha 10\%}$ ) and  $\dot{M}_{ac}$ , we can estimate the 295 accretion rate Natta et al. (2004): 296

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

where  $V_{H\alpha 10\%}$  is in km s<sup>-1</sup> and  $\dot{M}_{ac}$  is in M<sub> $\odot$ </sub> yr<sup>-1</sup>.

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

02



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

#### 302 4 CONCLUSION

Photometric and spectral data presented in this paper show 303 the usefulness of systematically monitoring of PMS stars 304 with large amplitude variability. On the basis of our photo-305 metric monitoring over the past six years, we have confirmed 306 that the variability of GM Cep is dominated by fading events 307 rather than by bursting events. The effect of a colour rever-308 sal at the minimum light is evidence of variable extinction 309 from the circumstellar environment. We plan to continue our 310 photometric monitoring of the star during the next years and 311 strongly encourage similar follow-up observations. 312

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8