

**THE 2014 ECLIPSE OF EE Cep: ANNOUNCEMENT  
 FOR A THIRD INTERNATIONAL OBSERVATIONAL CAMPAIGN**

GALAN, C.<sup>1</sup>; WYCHUDZKI, P.<sup>2</sup>; MIKOŁAJEWSKI, M.<sup>2</sup>; TOMOV, T.<sup>2</sup>; DIMITROV, D.<sup>3</sup>

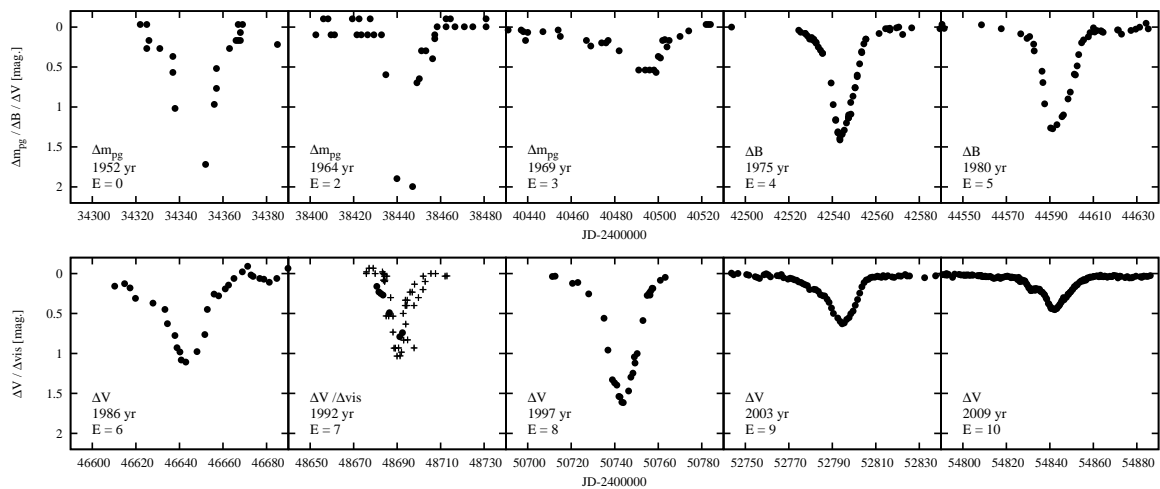
<sup>1</sup> Nicolaus Copernicus Astronomical Center, Bartycka 18, PL-00-716 Warsaw, Poland;  
 e-mail: cgalan@astri.uni.torun.pl (CG)

<sup>2</sup> Nicolaus Copernicus University, Centre for Astronomy, Gagarina 11, PL-87-100 Toruń, Poland;  
 e-mail: adyrbyh@gmail.com (PW); mamiko@astri.uni.torun.pl (MM); tomtom@astri.uni.torun.pl (TT)

<sup>3</sup> Institute of Astronomy and NAO, Bulg. Acad. Sc., 72 Tsarigradsko Chaussee Blvd., 1784 Sofia, Bulgaria  
 e-mail: dinko@astro.bas.bg (DD)

**1 Introduction**

The variability of the 11th magnitude star EE Cep was discovered in 1952 ( $E = 0$ ) by Romano (1956) and soon confirmed by Weber (1956), who reported observations obtained during a previous eclipse in 1947 ( $E = -1$ ). Thereafter all consecutive eclipses were observed with an orbital period of 5.6 yr. The eclipses vary in an unusual way changing their shape, duration and depth across a wide range of about 0.5 to 2.0 magnitudes (Fig. 1) and simultaneously with very small color variations.



**Figure 1.** The light curves of ten among the eleven eclipses of EE Cep observed since 1952 are shown. The mean values of Halbach's (1992) visual observations of the 1992 eclipse are marked with crosses.

To explain this unusual behavior Mikolajewski & Graczyk (1999) suggested that the eclipses of the B5 III primary are caused by an invisible secondary component that consists of a dark, opaque, relatively thick disk around a low luminosity central object: a low-mass single star or a close binary. In such a model, the differences between the particular eclipses could be explained by precession, which changes the inclination of the disk to the line of sight and the tilt of its cross-section to the direction of motion. Most of the eclipses have a similar, asymmetrical shape, in which it is possible to distinguish repeatable phases of atmospheric ingress followed by a real ingress, sloped-bottom transit during the central part of the eclipse, and real egress followed by atmospheric eclipse (see for details Fig. 2 in Gałan et al. 2012). The unique flat bottom eclipse, observed in 1969 ( $E=3$ ), can be explained by a nearly edge-on and non-tilted projection of the disk.

The last two eclipses, in 2003 ( $E=9$ ) and 2008/9 ( $E=10$ ) were studied in the framework of wide international campaigns (Mikołajewski et al. 2005ab; Gałan et al. 2010). The results of these campaigns complemented by the historical light curves (Graczyk et al. 2003), enabled us to create a model of the eclipses. According to this model, the eclipses are caused by a dark, geometrically thin disk precessing with period  $P_{\text{prec}} \approx 11 - 12P_{\text{orb}}$  (Gałan et al. 2012). The model is based on the observations, obtained in an interval of time, almost exactly equal to the predicted precession period. Additional photometric and spectroscopic observations are needed for the model verification.

## 2 EE Cep – still a unique system

EE Cep is a member of the very rare class of binary systems in which the eclipses are caused by a dark, dusty disk surrounding the orbiting companion. The precursor of this group is the extremely long-period ( $\sim 27$  yr)  $\varepsilon$  Aur (see Guinan & Dewarf 2002), extensively studied during its last 2009–2011 eclipse, by the use of photometric, spectroscopic, interferometric, astrometric, and polarimetric observations (Stencel 2013 and references therein). Our photometric and spectroscopic observations are published in Tomov et al. (2012) and Hkiewicz et al. (2013). During the last eclipse, the disk in  $\varepsilon$  Aurigae, was revealed directly by infrared interferometric imaging (Kloppenborg et al. 2010) for the first time. The mechanisms of disk formation in EE Cep and  $\varepsilon$  Aur seems to be radically different. Containing a B5-type star EE Cep has to be a very young system while  $\varepsilon$  Aur with an F-type supergiant is significantly evolutionarily advanced. The observations of the eclipses provided indications for a complex structure formed in the  $\varepsilon$  Aur (Ferluga 1990) and EE Cep (Gałan et al. 2008) disks. The true nature of these structures is not known. In the case of  $\varepsilon$  Aur a multi-ring structure (Ferluga 1990, Leadbeater & Stencel 2010) was suggested but other corotating inhomogeneities cannot be excluded (Harmanec et al. 2013). The light curve and color variations observed during the last two EE Cep eclipses we interpreted in terms of a multi-ring structure too and speculated that possible planets could be responsible for their formation (Gałan et al. 2010).

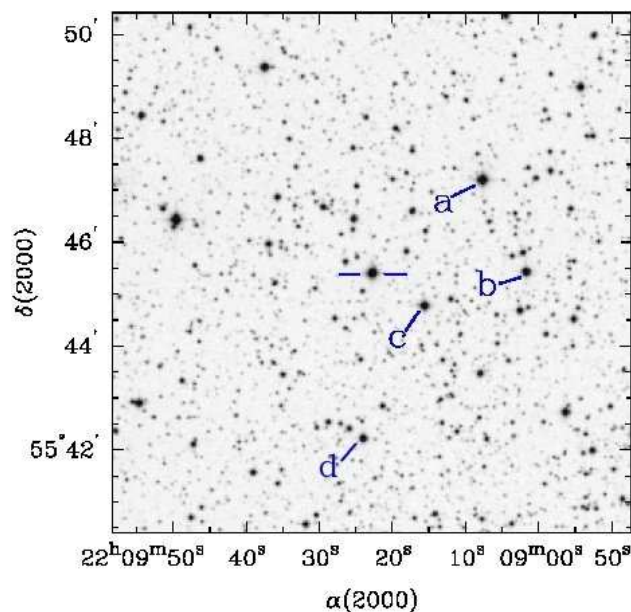
For a long time  $\varepsilon$  Aur and EE Cep remained the only two known systems with dark, dusty disks as obscuring objects. Recently however, new cases of similar systems, with circumstellar or circumbinary disks responsible for obscurations, emerged:

1SWASP J140747.93394542.6 (Mamajek et al. 2012), OGLE-LMC-ECL-11893 (Dong et al. 2014), OGLE-LMC-ECL-17782 (Graczyk et al. 2011), M2-29 (Hajduk et al. 2008), KH 15D (Winn et al. 2006, Herbst et al. 2008). This opens perspectives for studying the dusty disk phenomenon in binary and/or multiple systems and can be helpful to understand the origin of such disks, how they form and evolve in various environments

and on various time scales. EE Cep still remains a unique case of great importance among this small sample, because of its well-documented disk precession history during one, approximately full, precession period (see for details Gałan et al. 2012).

### 3 Call for observations

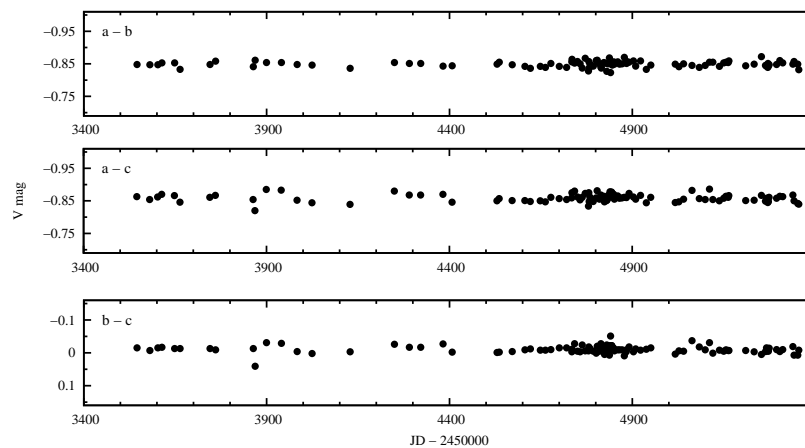
The next eclipse ( $E=11$ ) approaches and we announce a third observational campaign. According to the ephemeris by Mikolajewski & Graczyk (1999) the minimum should take place on Aug 23, 2014 ( $JD_{\text{mid-ecl}} = 2456893.44$ ). Based on our model of the disk precession (Gałan et al. 2012) we can predict that it should belong to the deepest ones reaching about 2 mag (from 10.8 mag outside of eclipse to  $\sim 13$  mag during the minimum in  $V$  photometric band). The longest duration eclipses observed so far occurred in 1969 ( $\sim 60$  days), and 2003 and 2008/9 ( $\sim 90$  days). So, we propose to conduct systematic photometric monitoring in at least three months time interval (July, August, September) centred on the mid-eclipse moment. During the previous two eclipses the blue maxima in the colors were observed about nine days before and after the mid-eclipse. Therefore, special attention should be paid on precise measurements, covering about one week time intervals around  $\sim JD$  2456884 (Aug 14) and  $\sim JD$  2456902 (Sep 1). However, these moments are subject to change slightly due to changes in the orientation of the disk.



**Figure 2.** The sky area ( $10' \times 10'$ ) around EE Cep (reprinted from Mikolajewski et al. 2003). The blue color marks the comparison and the check stars recommended for the CCD photometry.

We recommend photometric observations in the standard Johnson-Cousins  $UBV(RI)_C$  system. At least one measurement per night with an accuracy possibly close to  $\sim 0^m01$  or better is needed. Some multicolour observations, far from the eclipse, should be obtained in order to calibrate systematic differences between the observatories. We propose to use the four brightest objects from the Meinunger's (1975) sequence as comparison stars. This sequence recommended by Mikolajewski et al. (2003) has been used in the observational campaigns during the recent eclipses. These stars are very close in the sky, within  $\sim 3'$ ,

around EE Cep. In the finding chart shown in Figure 2 the sequence stars are marked with Meinunger’s designations: “*a*”, “*b*”, “*c*”, and “*d*” for BD+55°2690, GSC-3973 2150, BD+55°2691, and GSC-3973 1261, respectively. Stars “*b*” and “*c*” are designated as New Suspected Variables in the General Catalog of Variable Stars (Samus et al. 2009) – NSV 25842, and NSV 25843, respectively. Baldinelli & Ghedini (1976) were the first who noted  $\sim 0^m.5$  amplitude variations of star “*c*” based on photographic photometry. But they stressed the absolute necessity to confirm this result by photoelectric method. Mikołajewski et al. (2003) used an one channel diaphragm photometer with a cooled photomultiplier to observe the stars “*a*”, “*b*”, and “*c*” during the EE Cep eclipse in 2003 and found no significant light variations in these stars. Star “*b*” was suggested to be variable on the basis of photographic photometry by Baldinelli & Ghedini (1977), Baldinelli et al. (1981). However, these variations were not discussed and there was no light curve presented.

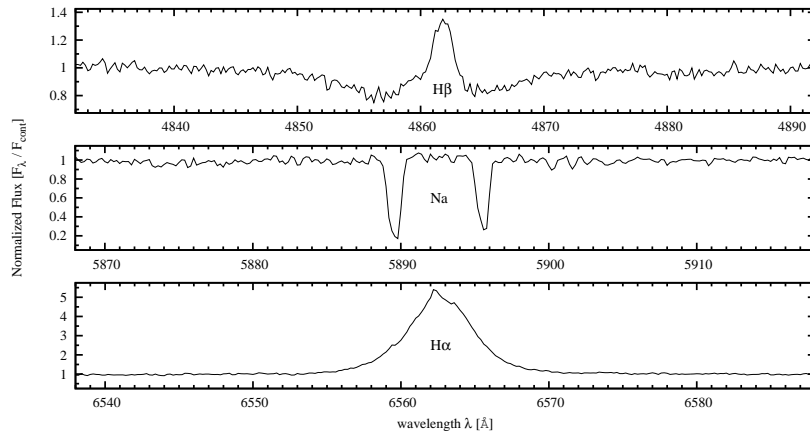


**Figure 3.** Differential  $V$  magnitudes ( $a - b$ ,  $a - c$ , and  $b - c$ ) of the stars BD+55°2690 (*a*), GSC-3973 2150 (*b*), and BD+55°2691 (*c*) obtained in  $\sim 5$  years time interval during and around the 2008/9 eclipse.

We performed  $UBV(RI)_C$  CCD photometry of these stars during the last eclipse in 2008/9. The CCD photometry is less weather dependent than the one channel diaphragm photometry and thus offers better accuracy for the  $BV(RI)_C$  bands. The differential  $V$  magnitudes for stars “*a*”, “*b*” and “*c*” obtained during and around the last eclipse are shown in Figure 3. The observed light variations in  $a - b$  differential magnitudes are insignificant and the brightness of the stars “*a*” and “*b*” can be recognized as a constant within the accuracy of our photometry, which in the photometric bands  $BV(RI)_C$  is typically  $\sim 0^m.01 - 0^m.02$  (depending on weather conditions during the observations). The differential magnitudes with respect of star *c* ( $a - c$  and  $b - c$ ) demonstrate somewhat larger scatter, in which small changes with a similar pattern can be seen. Small variations of star “*c*” with an amplitude of a few hundredths of a magnitude cannot be excluded. Therefore, we recommend to use “*a*” and “*b*” as comparison stars and “*c*” and “*d*” as check stars.

Any optical and infrared photometric as well as spectroscopic observations obtained before, during and after the EE Cep eclipse could turn out to be very important. They could make it possible to detect the mysterious companion (disk and/or its central star/stars) in the EE Cep system. During the last three orbital epochs we observed about  $0^m.2$  vari-

ations in the  $I$  passband, before and after the eclipses, which may prove a significant contribution of a dark body in this band. In the  $JHK$  passbands, the cool component can dominate the observed fluxes. Moreover, these variations can reflect in some way the changes in the spatial orientation of the disk.



**Figure 4.** Spectra of EE Cep obtained on April 8, 2014 in the  $H\alpha$ ,  $H\beta$  and NaI regions ( $R \sim 16000$ ) using the Coudé spectrograph on the 2m Ritchey–Chrétien telescope at Rozhen Observatory.

The deep EE Cep eclipses have never been well covered with spectroscopic observations. Thus, it will be important to carry out systematic, high and low resolution spectroscopic monitoring of the star during the forthcoming eclipse. Our spectra obtained on April 8, 2014 in the regions of  $H\alpha$ ,  $H\beta$ , and NaI doublet lines (Fig. 4) do not show changes caused by eclipse in the profiles of these lines (compare with the profiles in Mikołajewski et al. 2005b). Spectroscopic observations obtained during the two previous eclipses in 2003 and 2008/9 show, that the absorption lines, caused by the circumstellar matter were visible up to about 2.5 – 3 months before and after the mid-eclipse. Thus, it is advisable to cover with spectroscopic observations the period from May to November 2014, with increased frequency of observations during the photometric eclipse (July – September), when we can expect significant night to night changes in the profiles of the absorption and the emission lines. At least  $S/N \sim 30$  is recommended. In the case of low ( $R \sim 1000$ ) resolution observations, it would be advisable to focus mainly on the Balmer lines evolution. Observations of spectrophotometric standard stars are encouraged, because they will permit us to reduce the spectra in fluxes and to study the spectral energy distribution changes during the eclipse.

The observers can use a special web page, prepared to support the campaign coordination <https://sites.google.com/site/eecep2014campaign/>. All interested to participate in collecting of photometric, spectroscopic or any other observations of the forthcoming event are encouraged to contact Piotr Wychudzki at [adyrbyh@gmail.com](mailto:adyrbyh@gmail.com).

**Acknowledgements:** This study is partly supported by the Polish National Science Centre grant No DEC-2013/08/S/ST9/00581. This paper is partly a result of the exchange and joint research project Spectral and photometric studies of variable stars between Polish and Bulgarian Academies of Sciences. We gratefully acknowledge A. Smith for careful reading of the manuscript.

## References:

- Baldinelli, L., & Ghedini, S., 1976, *IBVS*, No. 1225
- Baldinelli, L., & Ghedini, S., 1977, *MmSAI*, **48**, 91
- Baldinelli, L., Ferri, A., Ghedini, S., 1981, *IBVS*, No. 1939
- Dong, S., Katz, B., Prieto, J. L., et al. 2014, *arXiv:1401.1195v1*
- Ferluga, S., 1990, *A&A*, **238**, 278
- Gałań, C., Mikołajewski, M., Tomov, T., Cikała, M., 2008, *IBVS*, No. 5866
- Gałań, C., Mikołajewski, M., Tomov, T., et al. 2010, *ASPC*, **435**, 423
- Gałań, C., Mikołajewski, M., Tomov, T., et al. 2012, *A&A*, **544**, A53
- Graczyk, D., Mikołajewski, M., Tomov, T., et al. 2003, *A&A*, **403**, 1089
- Graczyk, D., Soszyński, I, Poleski, R., et al. 2011, *Acta Astronomica*, **61**, 103
- Guinan, E. F. & Dewarf, L. E., 2002, *ASP Conf. Ser.*, **279**, 121
- Hajduk, M., Zijlstra, A. A., Gęsicki, K., 2008, *A&A*, **490**, 7
- Halbach, E. A., 1992, *JAAVSO*, **21**, 129
- Harmanec, P., Božić, H., Korčáková, D., et al. 2013, *CEAB*, **37**, 99
- Herbst, W., Hamilton, C. M., LeDuc, K., et al. 2008, *Nature*, **452**, 194
- Ikiewicz, K., Wychudzki, P., Gałań, C., et al. 2013, *AASP*, **3**, 23
- Kloppenborg, B., Stencel, R., Monnier, J. D., et al. 2010, *Nature*, **464**, 870
- Leadbeater, R., & Stencel, R., 2010, *arXiv:1003.3617*
- Mamajek, E. E., Quillen, A. C., Pecaut, M. J., et al. 2012, *AJ*, **143**, 72
- Meinunger, L., 1975, *IBVS*, No. 965
- Mikołajewski, M. & Graczyk, D., 1999, *MNRAS*, **303**, 521
- Mikołajewski, M., Tomov, T., Graczyk, D., et al. 2003, *IBVS*, No. 5412
- Mikołajewski, M., Gałań, C., Gazeas, K., et al. 2005a, *Ap&SS*, **296**, 445  
(<http://www.springerlink.com/content/v6t4630310j26300/fulltext.pdf>)
- Mikołajewski, M., Tomov, T., Hajduk, M., et al. 2005b, *Ap&SS*, **296**, 451  
(<http://www.springerlink.com/content/w28t429p3446p615/fulltext.pdf>)
- Romano, G. 1956, *Coelum*, **24**, 135
- Samus, N.N., Durevich O.V., Goranskij V.P., et al. 2009, *General Catalogue of Variable Stars (Samus+ 2007-2013)*
- Stencel, R. E., 2013, *CEAB*, **37**, 85
- Tomov, T., Wychudzki, P., Mikołajewski, M., et al. 2012, *BlgAJ*, **18**, a3
- Weber, R. 1956, *Doc. des Obs. Circ.*, **No. 9**
- Winn, J. N., Hamilton, C. M., Herbst, W. J., et al. 2006, *ApJ*, **644**, 510