

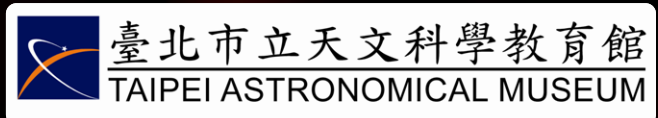
Abruptive Variability of Young Stars: A Case Study of GM Cep

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Taiwan



17th Nov, 2010

Young Planetary Systems Workshop

@ Jena, Germany

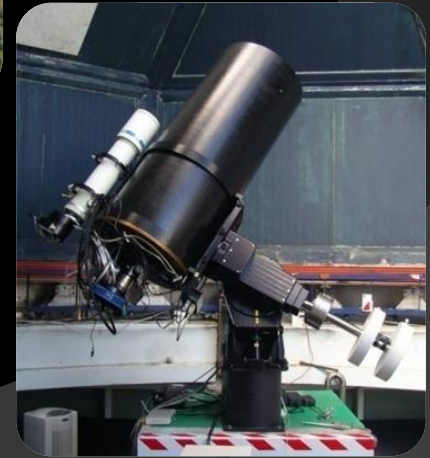
YETI- Summary of Tr 37 Campaigns



LOT
1-m



SLT
0.4-m



Lulin Observatory, Taiwan
120.873 +23.467 [2862m]



Tenagra Observatory, Arizona
W110.88 +31.46 [1312m]



Tenagra II
0.81-m

1st Campaign: Aug 3 - Aug 11/12 (9 nights)

- ⦿ Aug 06 LOT 6 hr
- ⦿ Aug 07 LOT 8 hr
- ⦿ Aug 08 LOT 0 hr
- ⦿ Aug 09 LOT 8 hr
- ⦿ Aug 10 LOT 5.5 hr
- ⦿ Aug 11 LOT 7 hr

TOTAL 34.5 hr



2nd Campaign: Aug 26 - Sep 11/12 (17 nights)

- ⦿ Aug 26 SLT 3.5 hr
- ⦿ Aug 27 SLT 0 hr
- ⦿ Aug 28 SLT 0 hr
- ⦿ Aug 29 SLT 0.5 hr
- ⦿ Aug 30 SLT 0 hr
- ⦿ Aug 31 SLT 0 hr
- ⦿ Sep 01 SLT 0 hr
- ⦿ Sep 02 SLT 0 hr
- ⦿ Sep 03 SLT 0 hr
- ⦿ Sep 04 SLT 0 hr
- ⦿ Sep 05 SLT 2.5 hr
- ⦿ Sep 06 SLT 0 hr
- ⦿ Sep 07 SLT 5 hr
- ⦿ Sep 08 SLT 0 hr
- ⦿ Sep 09 SLT 0 hr
- ⦿ Sep 10 SLT 4.5 hr
- ⦿ Sep 11 SLT 2.5 hr
- ⦿ Sep 12 SLT 4 hr

TOTAL 17.5 hr

3rd Campaign: Sep 24 - Sep 29/30 (6 nights)

| | | | | | |
|----------|---------|--------|----------|---------|--------|
| ⦿ Sep 24 | LOT | 4 hr | ⦿ Sep 28 | SLT | 4.5 hr |
| | Tenagra | 7 hr | | Tenagra | 5.5 hr |
| ⦿ Sep 25 | LOT | 0.1 hr | ⦿ Sep 29 | SLT | 4 hr |
| | Tenagra | 7 hr | | Tenagra | 6 hr |
| ⦿ Sep 26 | LOT | 2.5 hr | ⦿ Sep 30 | SLT | 3 hr |
| | Tenagra | 7 hr | | Tenagra | 6.5 hr |
| ⦿ Sep 27 | LOT | 4.5 hr | ⦿ Oct 01 | SLT | 0.3 hr |
| | Tenagra | 7 hr | | | |

TOTAL 69 hr

Summary of Tr 37 Campaigns

1st campaign: 34.5 hr

2nd campaign: 17.5 hr

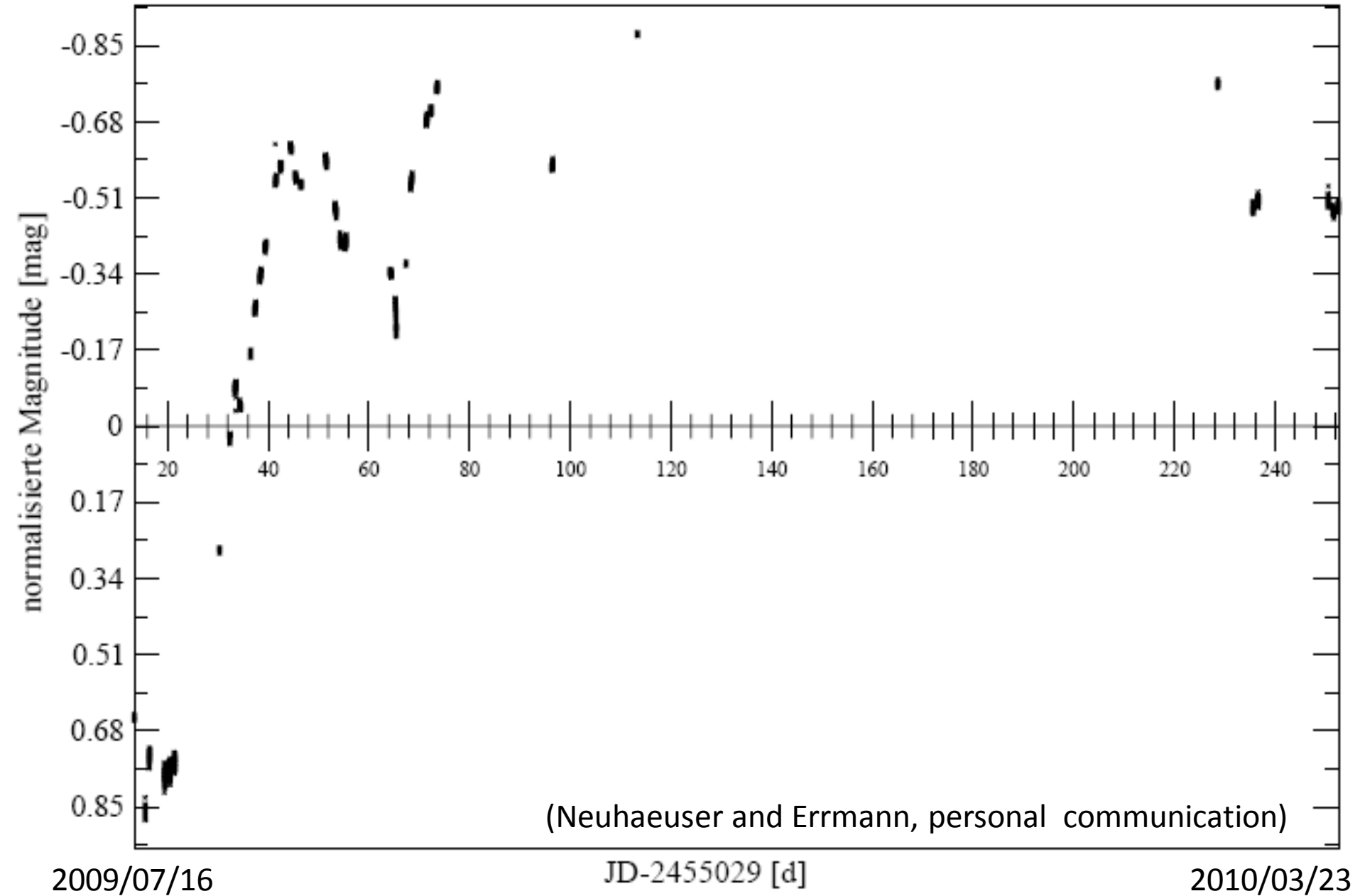
3rd campaign: 69 hr

TOTAL

121 hr

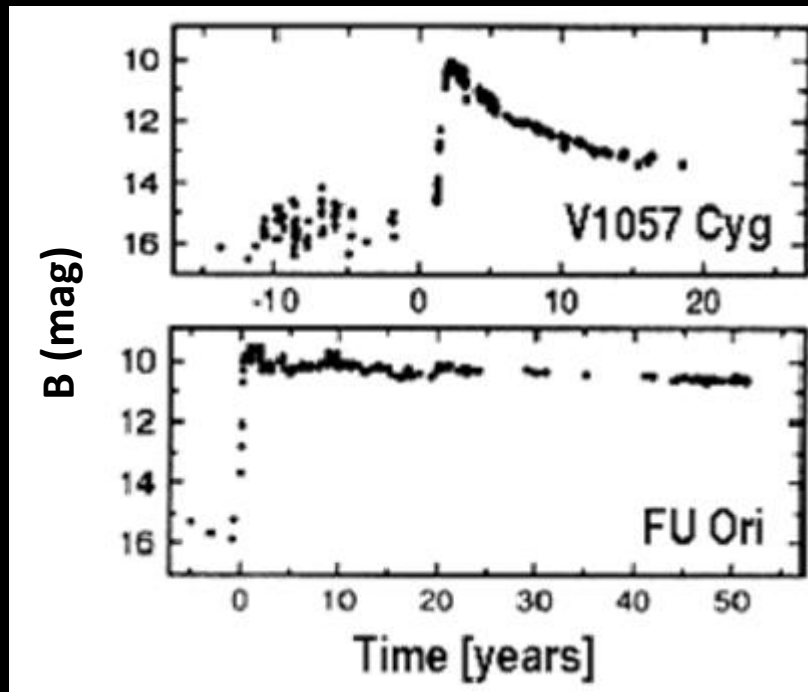
**Abruptive Variability of
Young Stars:
A Case Study of GM Cep**

R band light curve of GM Cep



FUors

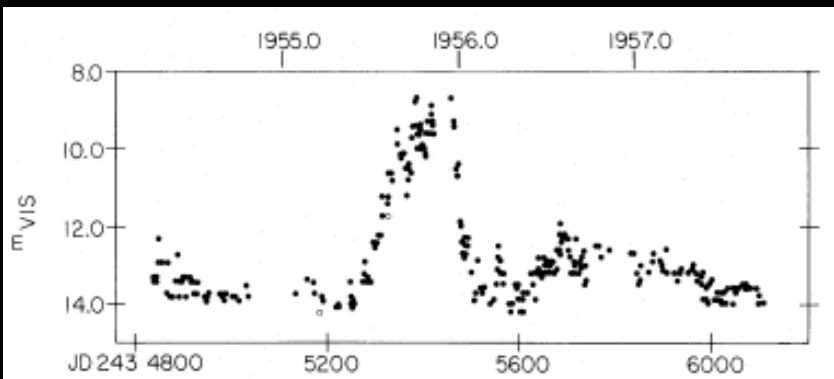
- Strong increase by up to 6 mag within a few months
- A slow decline on time scales of years to decades



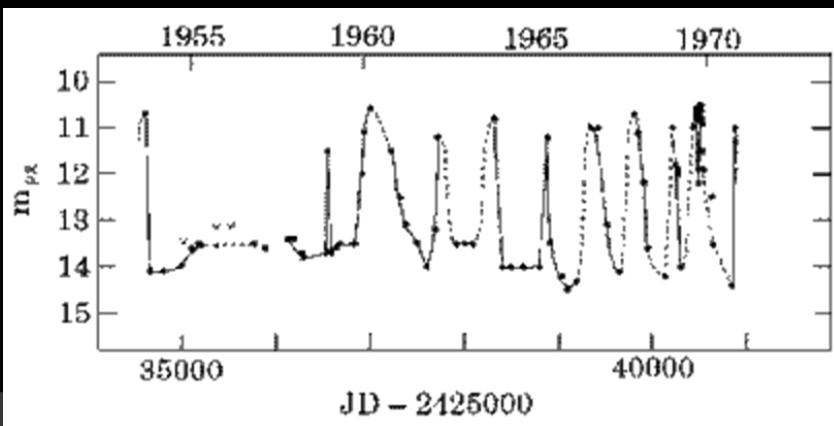
(Hartmann and Kenyon, 1996)

EXors

- Strong increase by up to 5 mag within a few months
- Decrease on about the same time scale



Light curve of EX Lupi
(Herbig, 1977)



Light curve of VY Tau
(Herbig, 1977)

Previous studies are controversial...

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THE RAPID OUTBURSTING STAR GM CEP: AN EXor IN Tr 37?

AURORA SICILIA-AGUILAR,¹ BRUNO MERÍN,² FELIX HORMUTH,¹ PÉTER ÁBRAHÁM,³ THOMAS HENNING,¹
MÁRIA KUN,³ NIMESH PATEL,⁴ ATTILA JUHÁSZ,¹ WOLFGANG BRANDNER,¹
LEE W. HARTMANN,⁵ SZILÁRD CSIZMADIA,³ AND ATTILA MOÓR³

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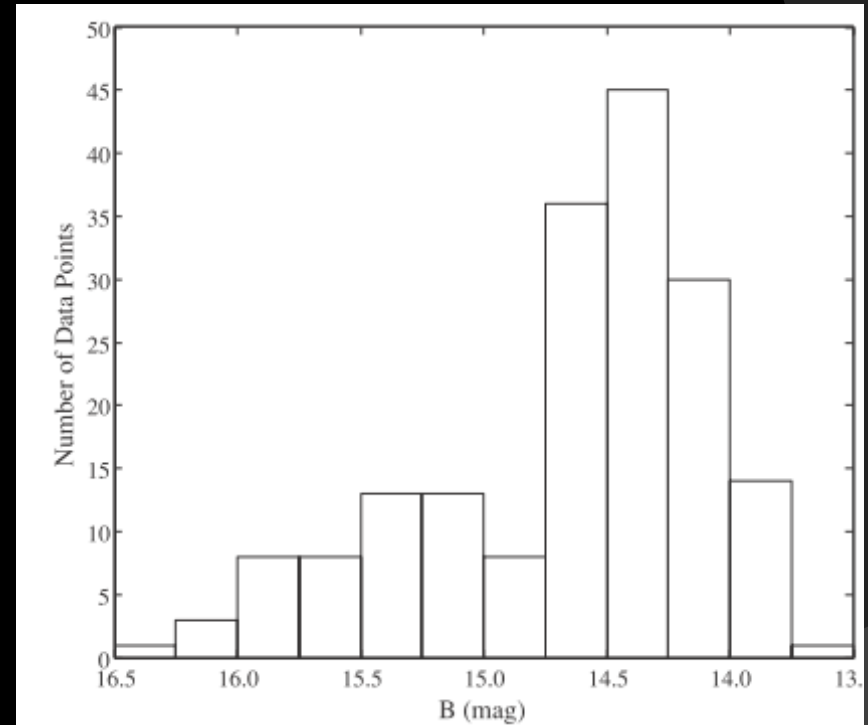
◎ Sicilia-Aguilar et. al., 2008

- Data from the literature and multi-wavelength observation
- Variability dominated by **strong increases in accretion**, similar to **EXor** episodes

Previous studies are controversial...

◎ Xiao et al., 2010

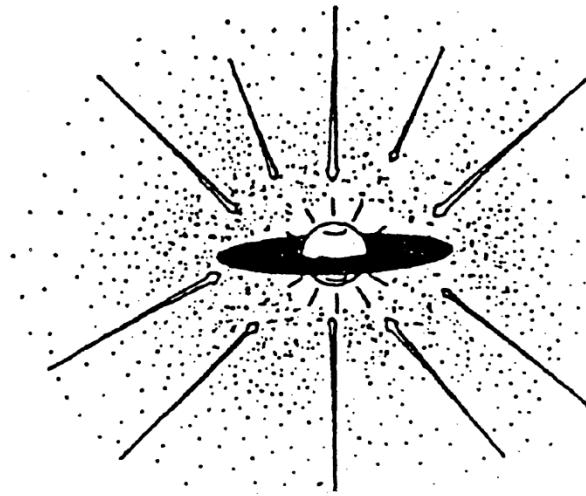
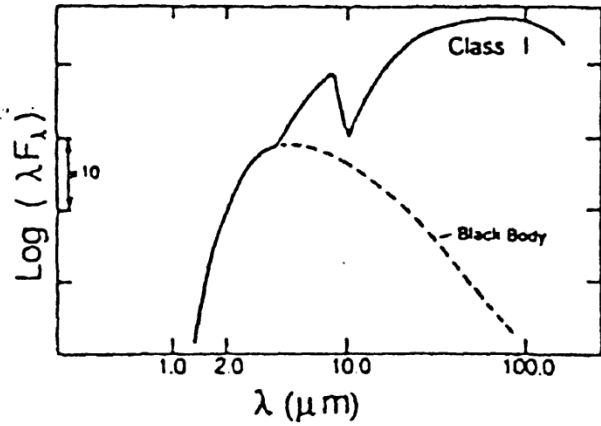
- Long-term lights curve from archival plate at Sonneberg and Harvard observatories
- Light curves dominated by **dips (possibly from extinction)** superposed on some quiescence state, instead of outburst caused by accretion flares



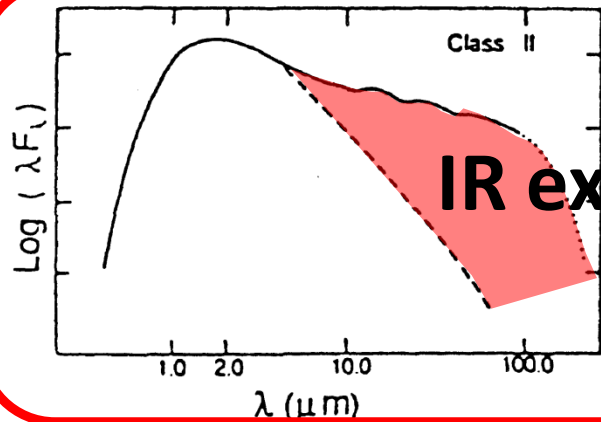
GM Cep

- ⊙ A solar type variable in the ~ 4 Myr old open cluster Tr 37
- ⊙ Spectral type: G7-K0
- ⊙ High accretion rate
 - $\dot{M} \sim 10^{-7}$ to $5 \times 10^{-6} M_{\odot} \text{ yr}^{-1}$
- ⊙ A very fast rotator
 - $V \sin i \sim 43 \text{ km s}^{-1}$

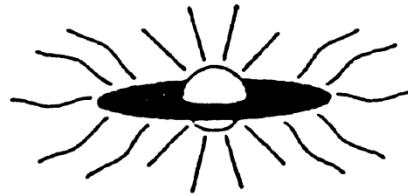
Class I



Class II

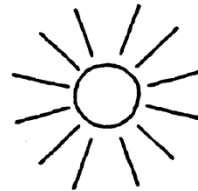
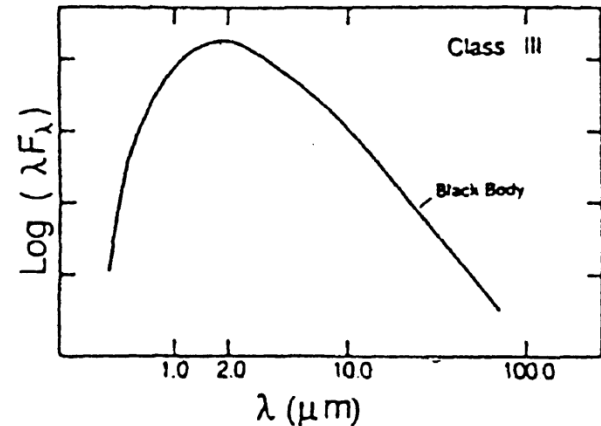


IR excess



W of H α = 5-20 Å

**Disk-bearing
CTTSs (Classical T
Tauri Stars)**



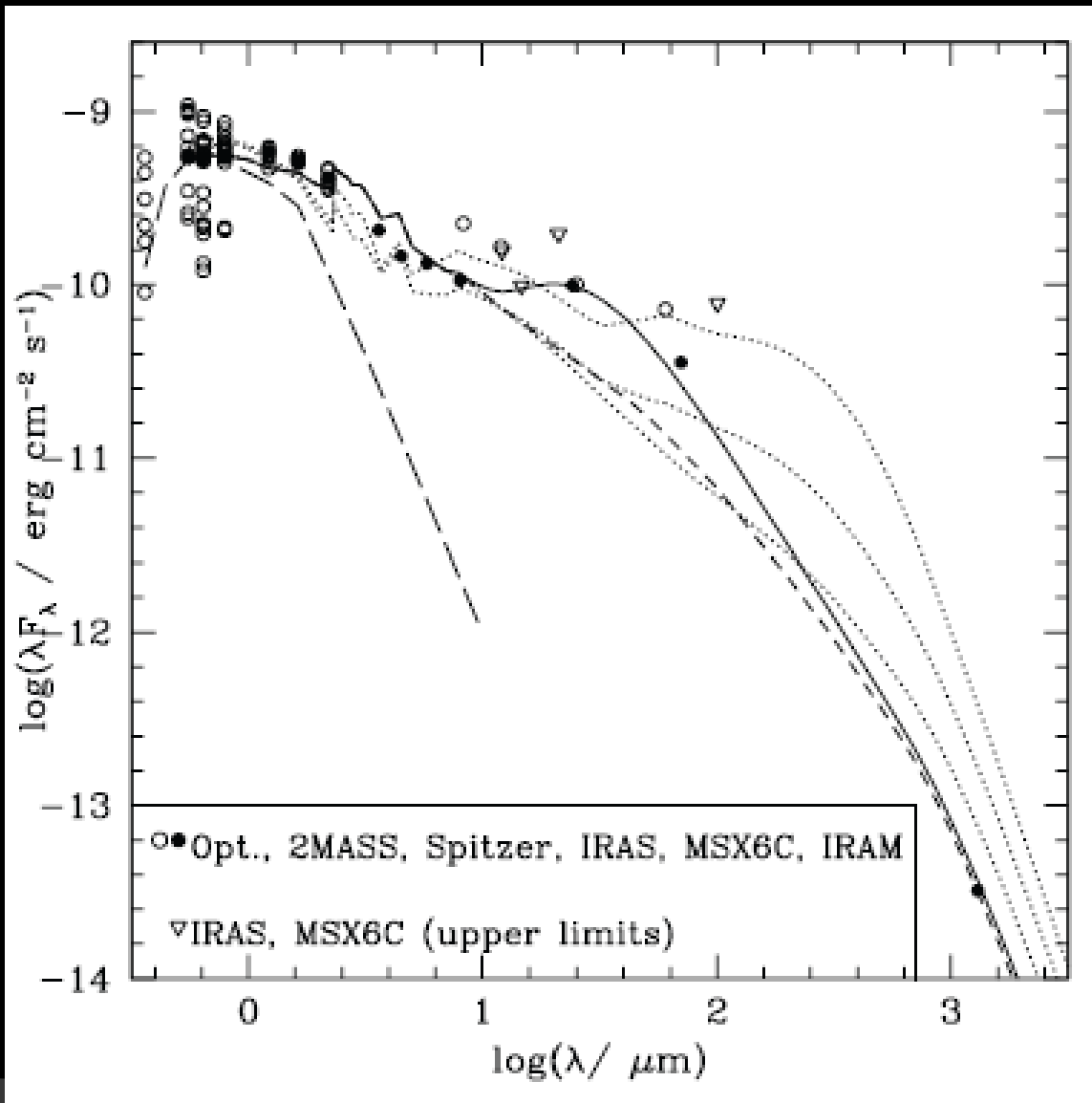
W of H α < 5 Å

Class III

**Diskless
WTTSs (Weak-
lined T Tauri Stars)**

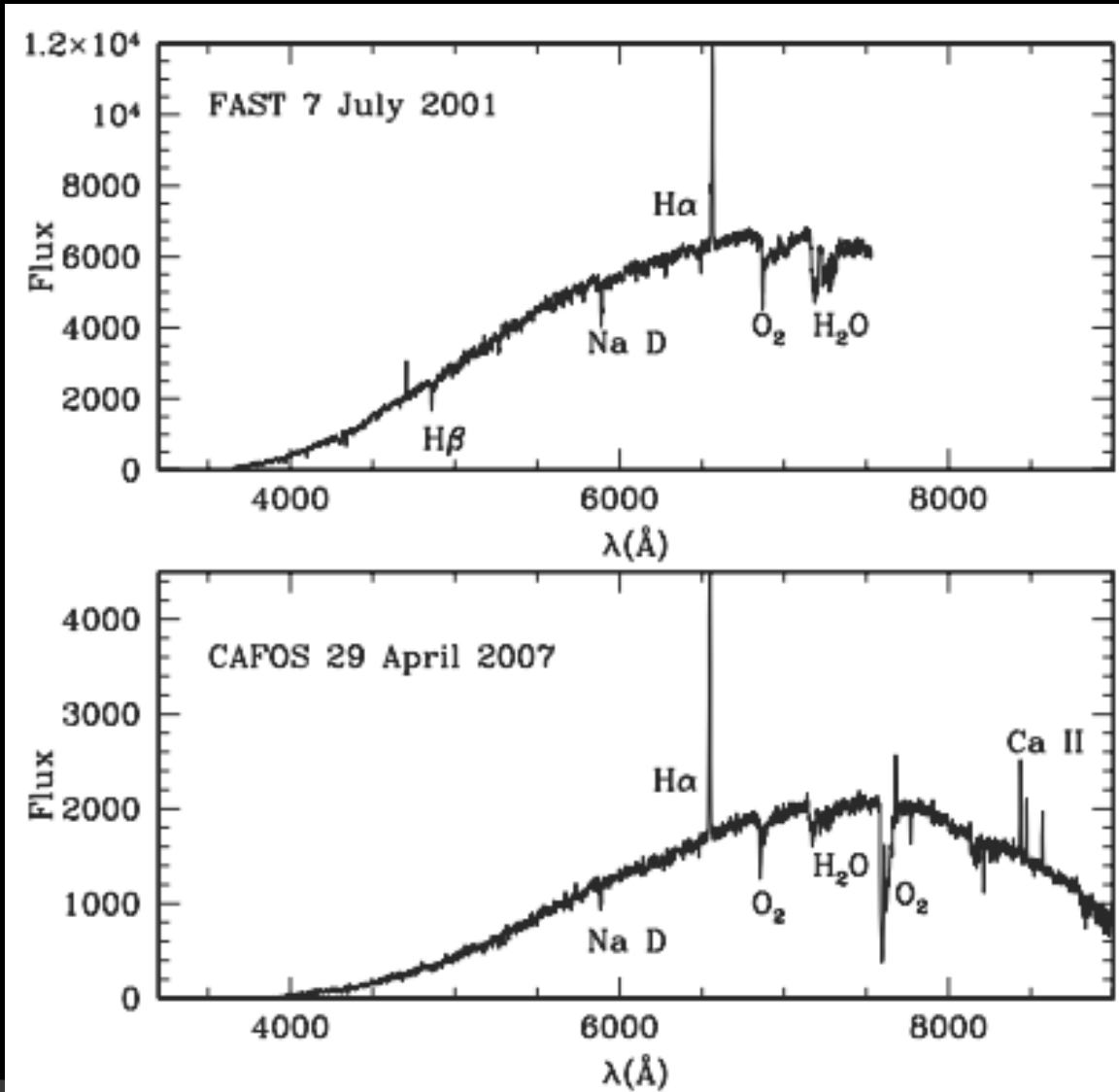
(Palla, 1993)

SED data for GM Cep



(Sicilia-Aguilar et al., 2008)

Low resolution spectra of GM Cep



(Sicilia-Aguilar et al., 2008)

GM Cep

Magn: 13.5 - 16.4 p
Period:
Type: INS
Spec: G1e

GM CEP
(2000) 21:38:17.32 +57:31:22.0

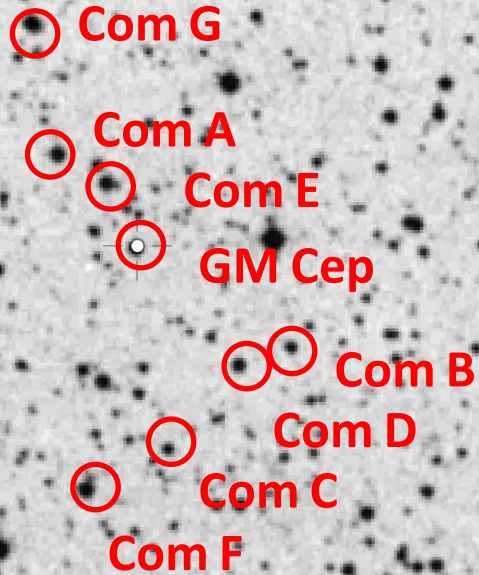
AAVSO

Chart

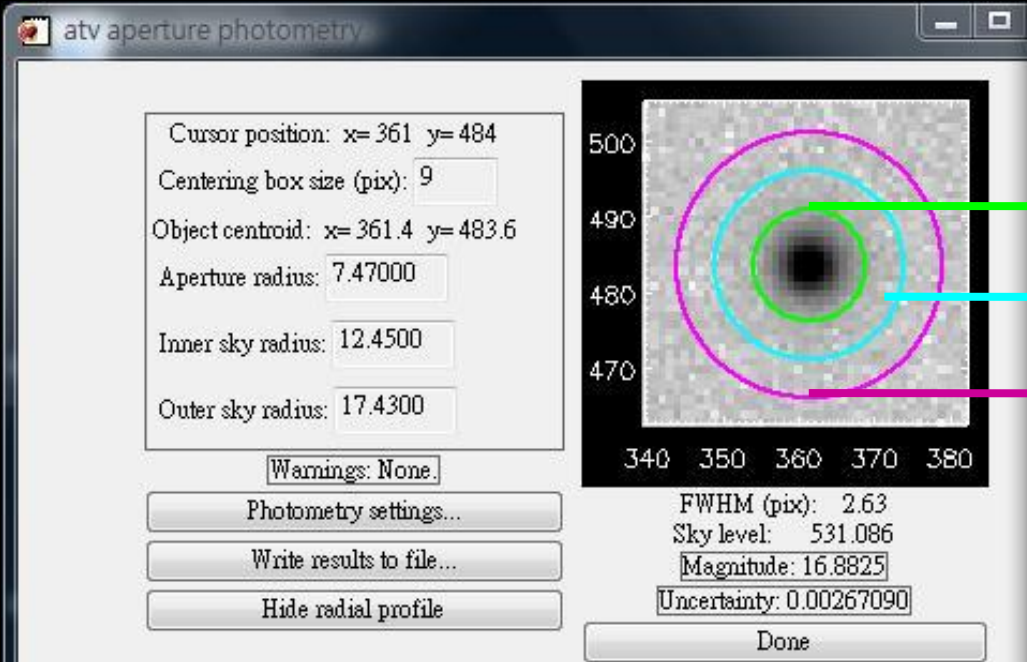
3325sya

Comparison Stars

| Star | B | V | R |
|------|--------|--------|--------|
| A | 16.313 | 14.213 | 12.984 |
| B | 16.015 | 14.961 | 14.364 |
| C | 15.445 | 14.837 | 14.455 |
| D | 15.333 | 14.357 | 13.770 |
| E | 14.628 | 13.601 | 13.187 |
| F | 14.389 | 13.358 | 12.770 |
| G | 13.374 | 12.829 | 12.513 |



(Xiao et al., 2010)

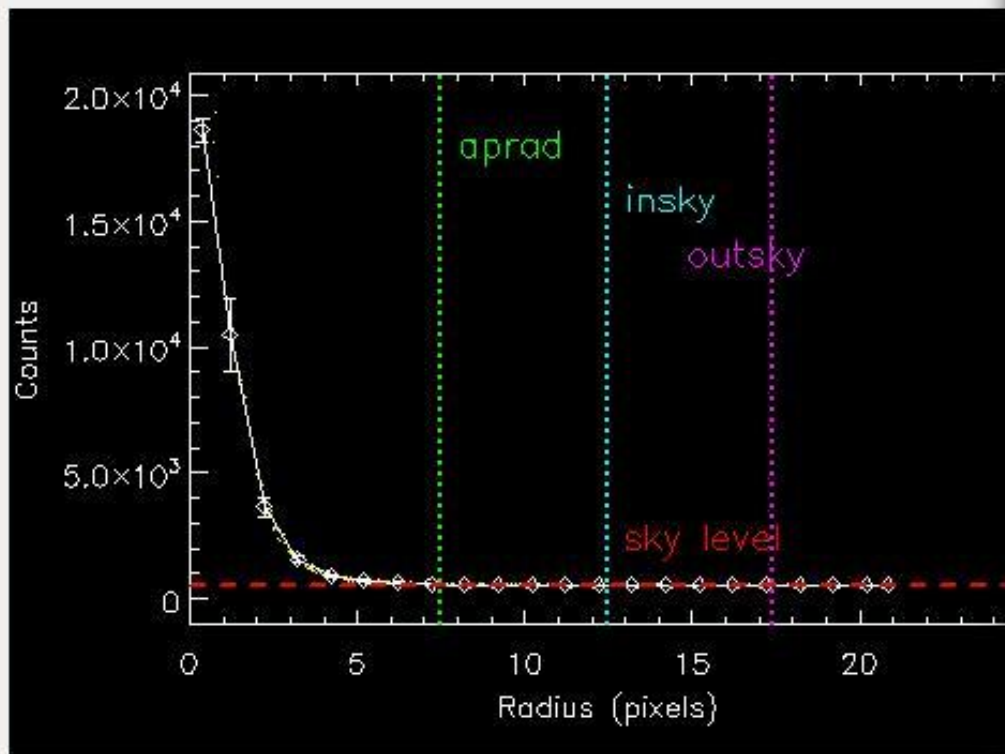


Aperture photometry

Aperture radius = 3 x FWHM

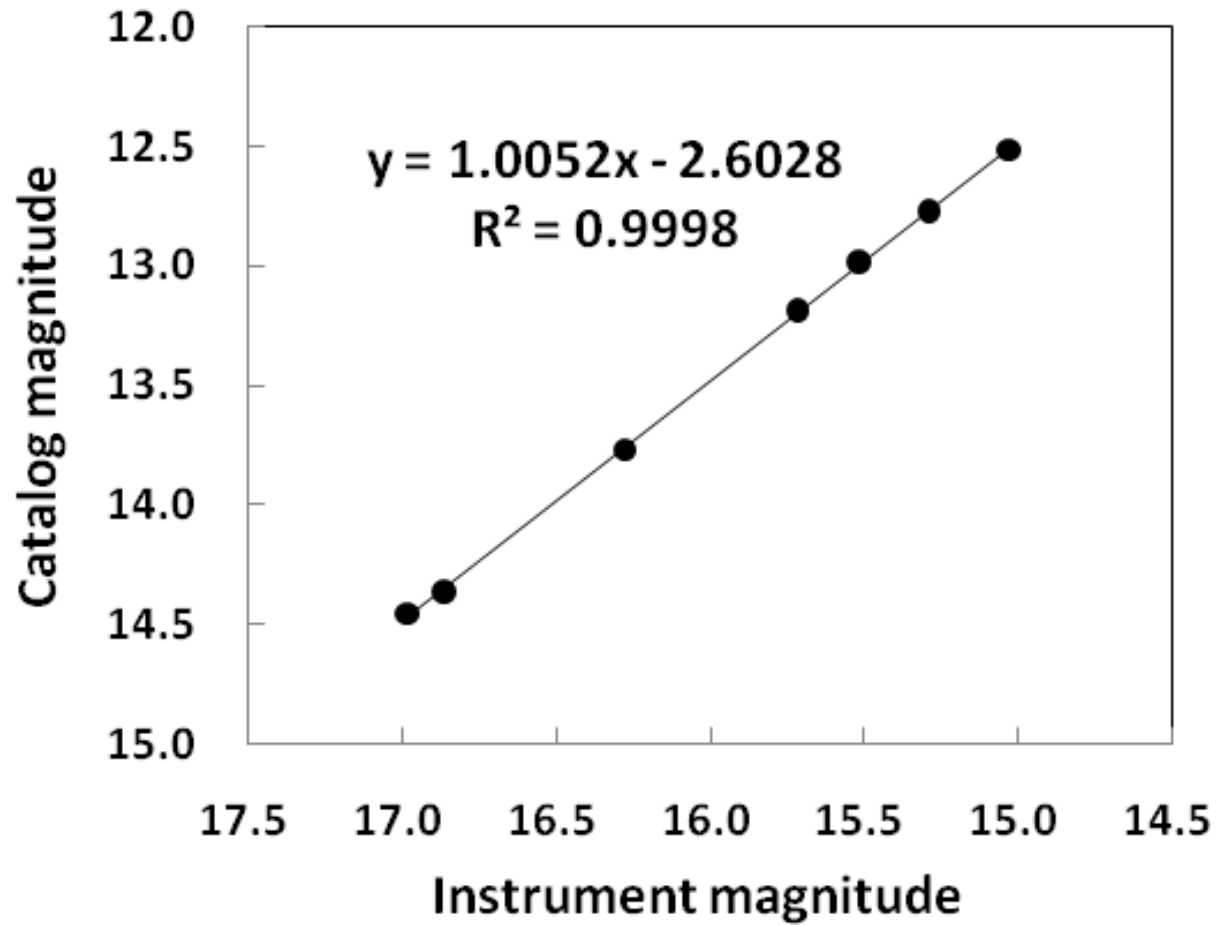
Inner sky radius = 5 x FWHM

Outer sky radius = 7 x FWHM

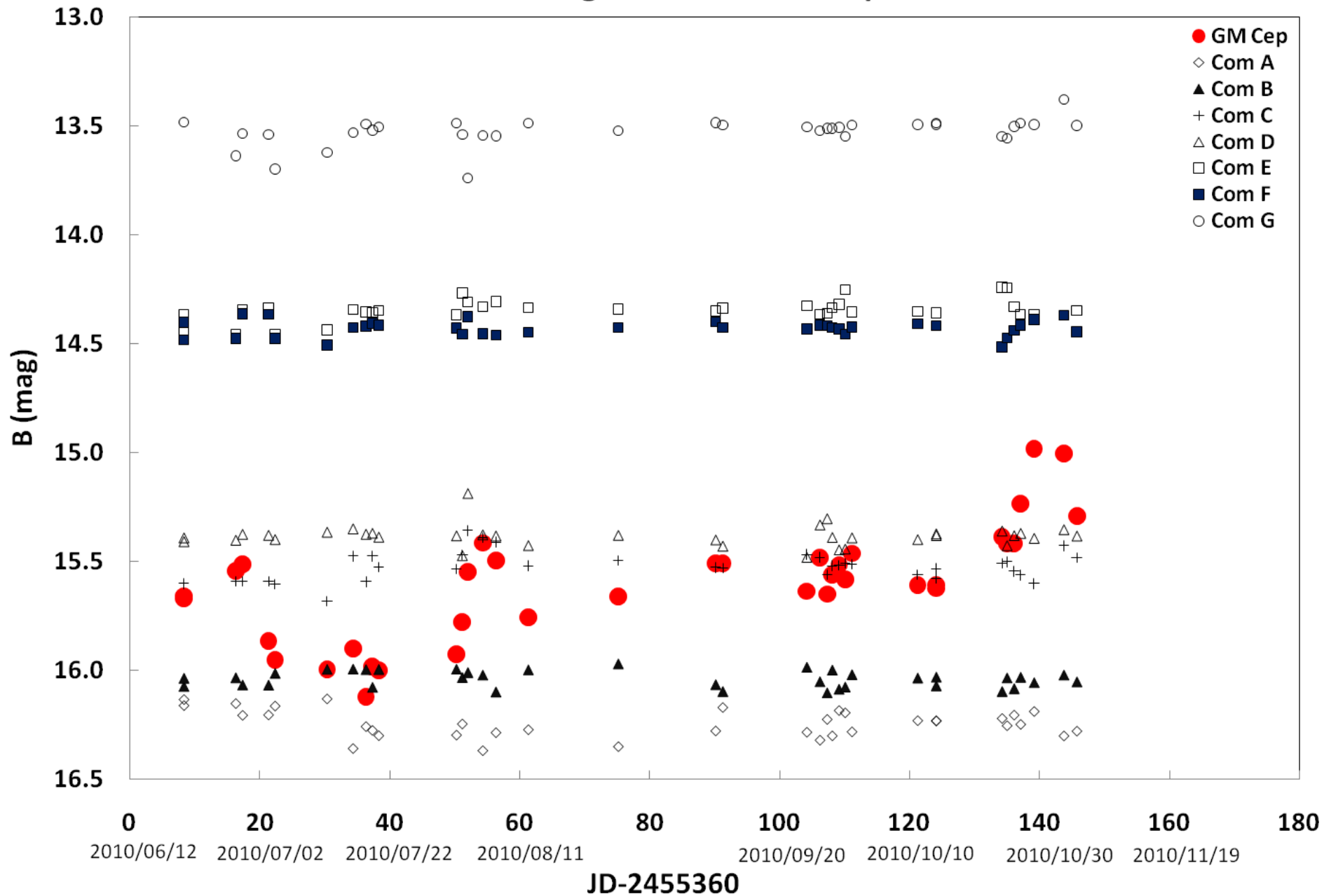


Radial profile

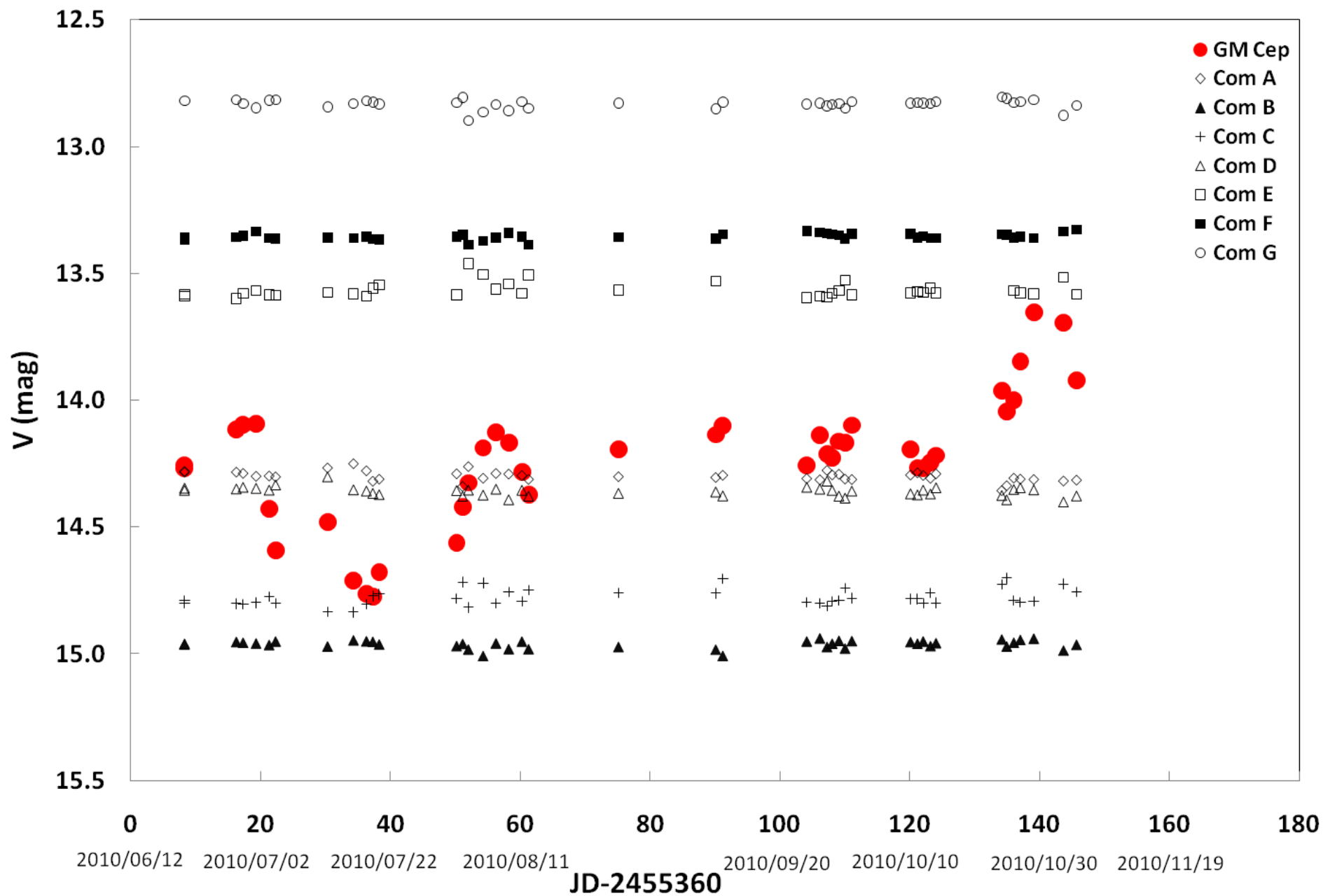
Magnitude conversion



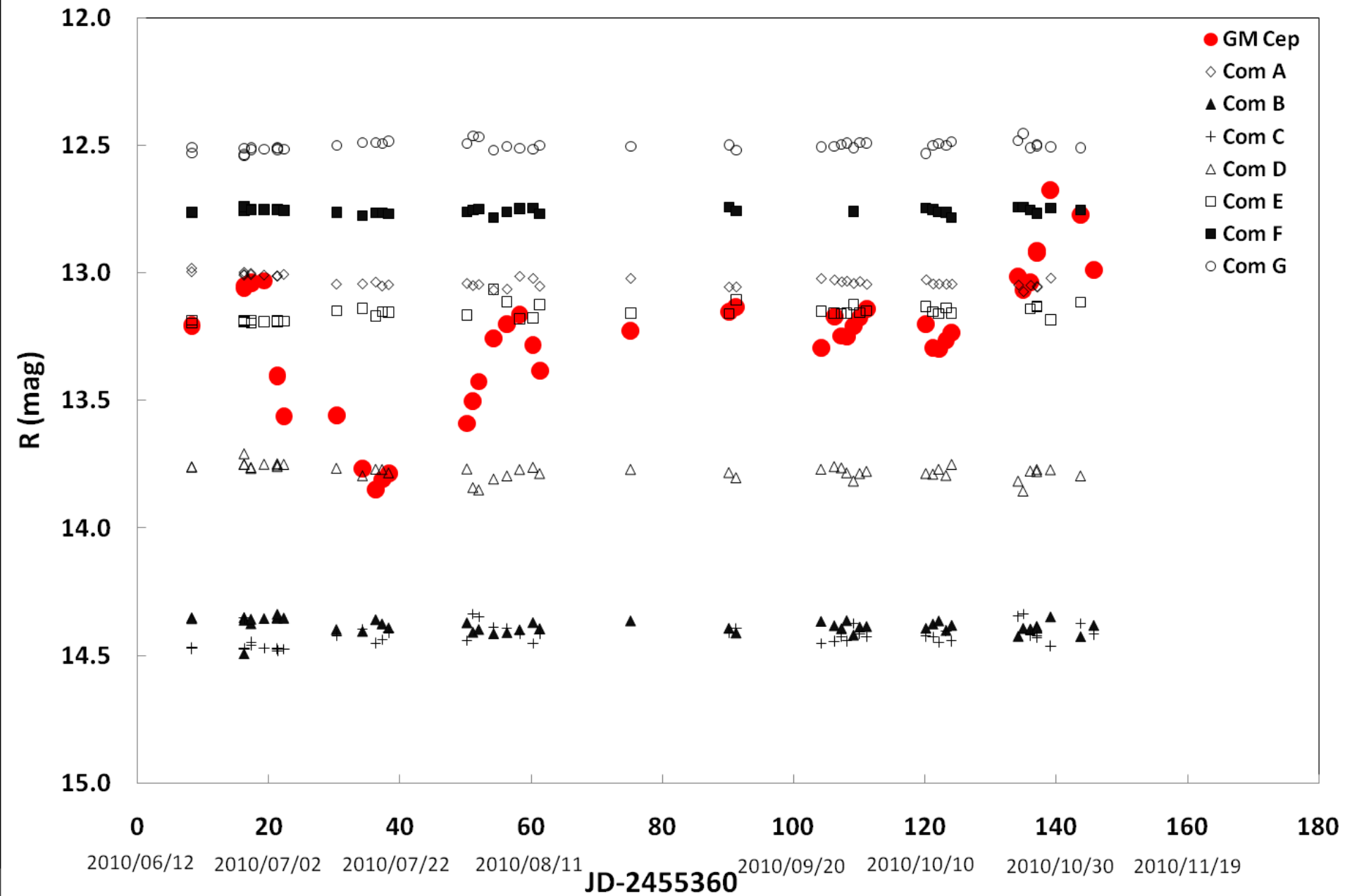
B band light curve of GM Cep



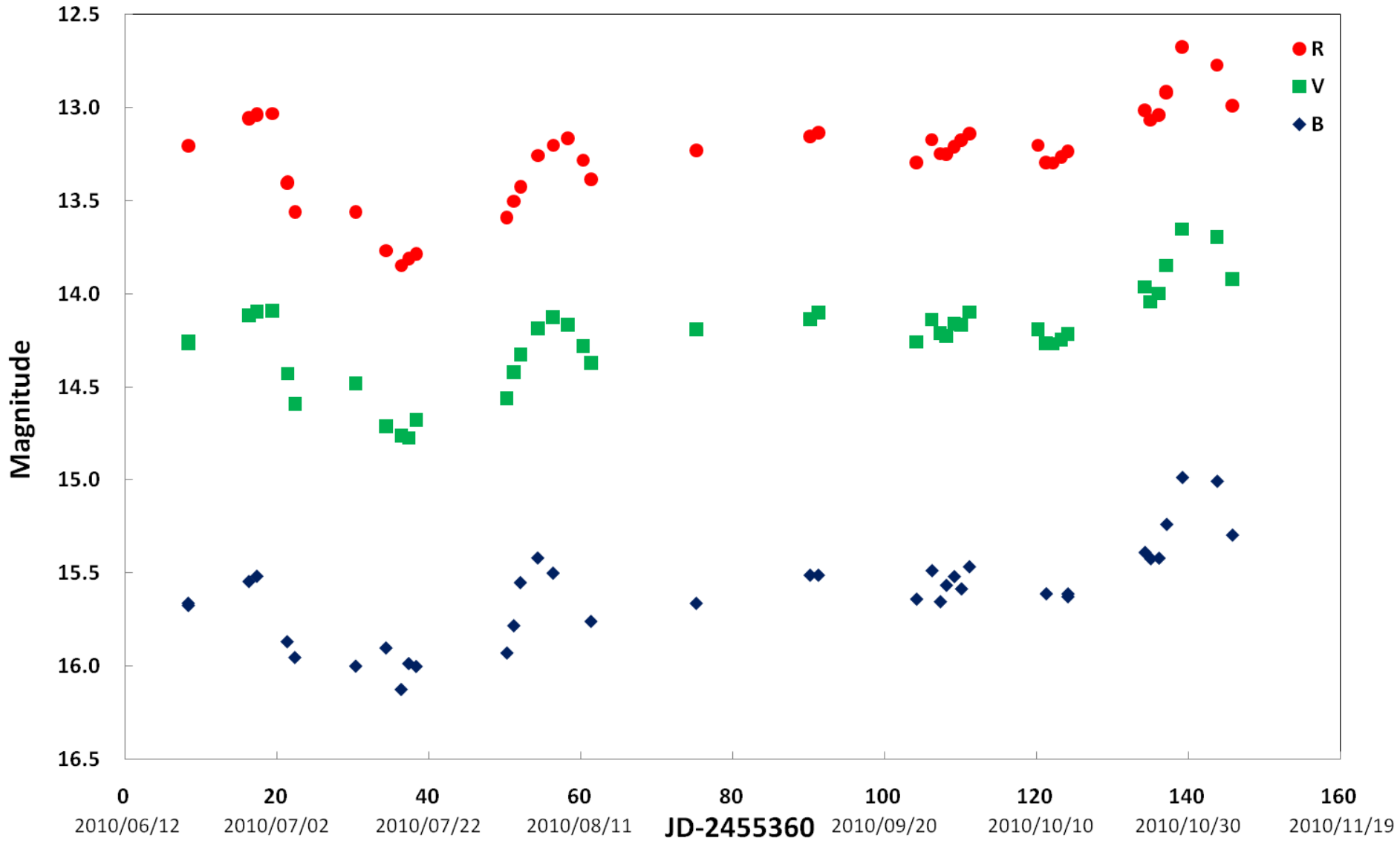
V band light curve of GM Cep



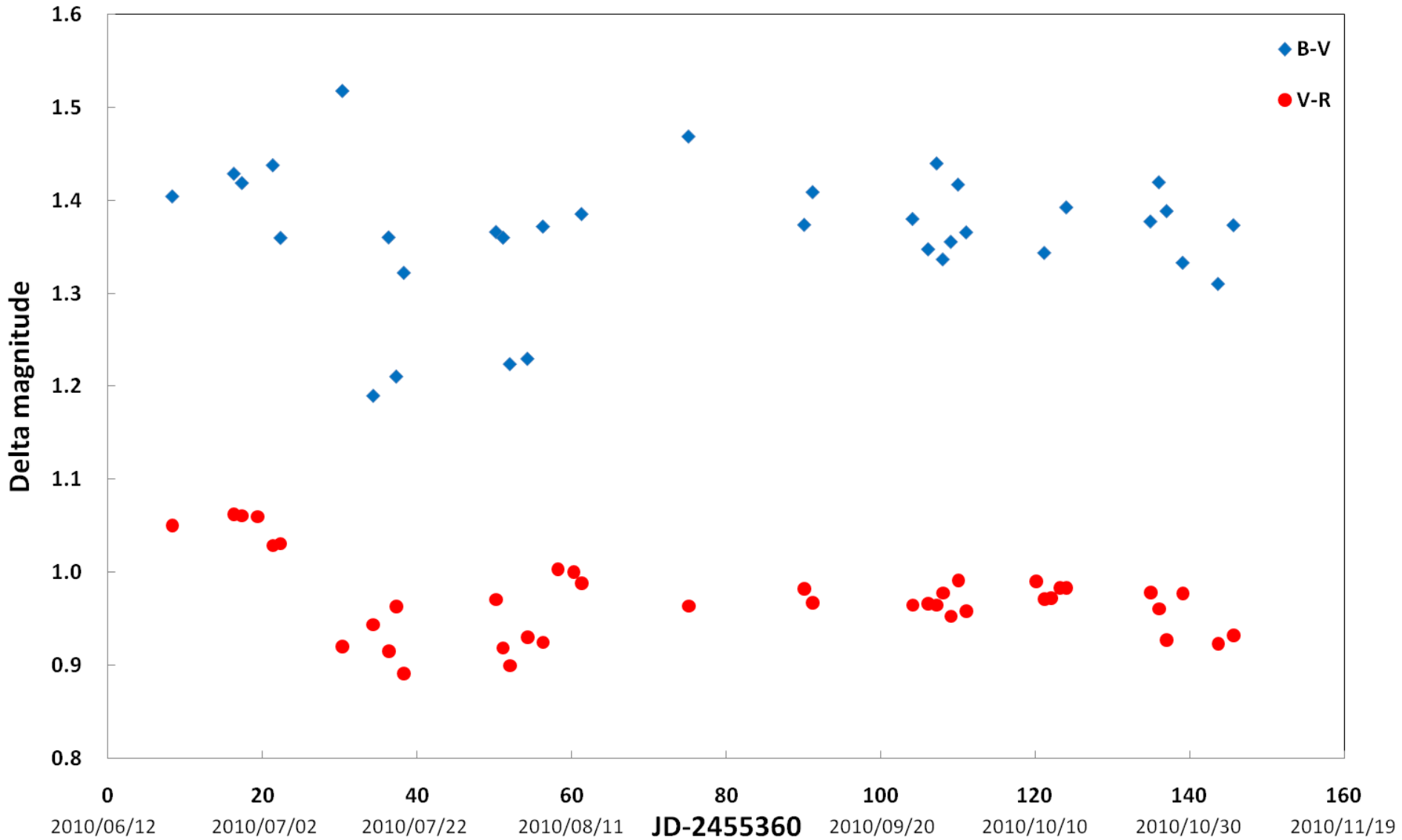
R band light curve of GM Cep



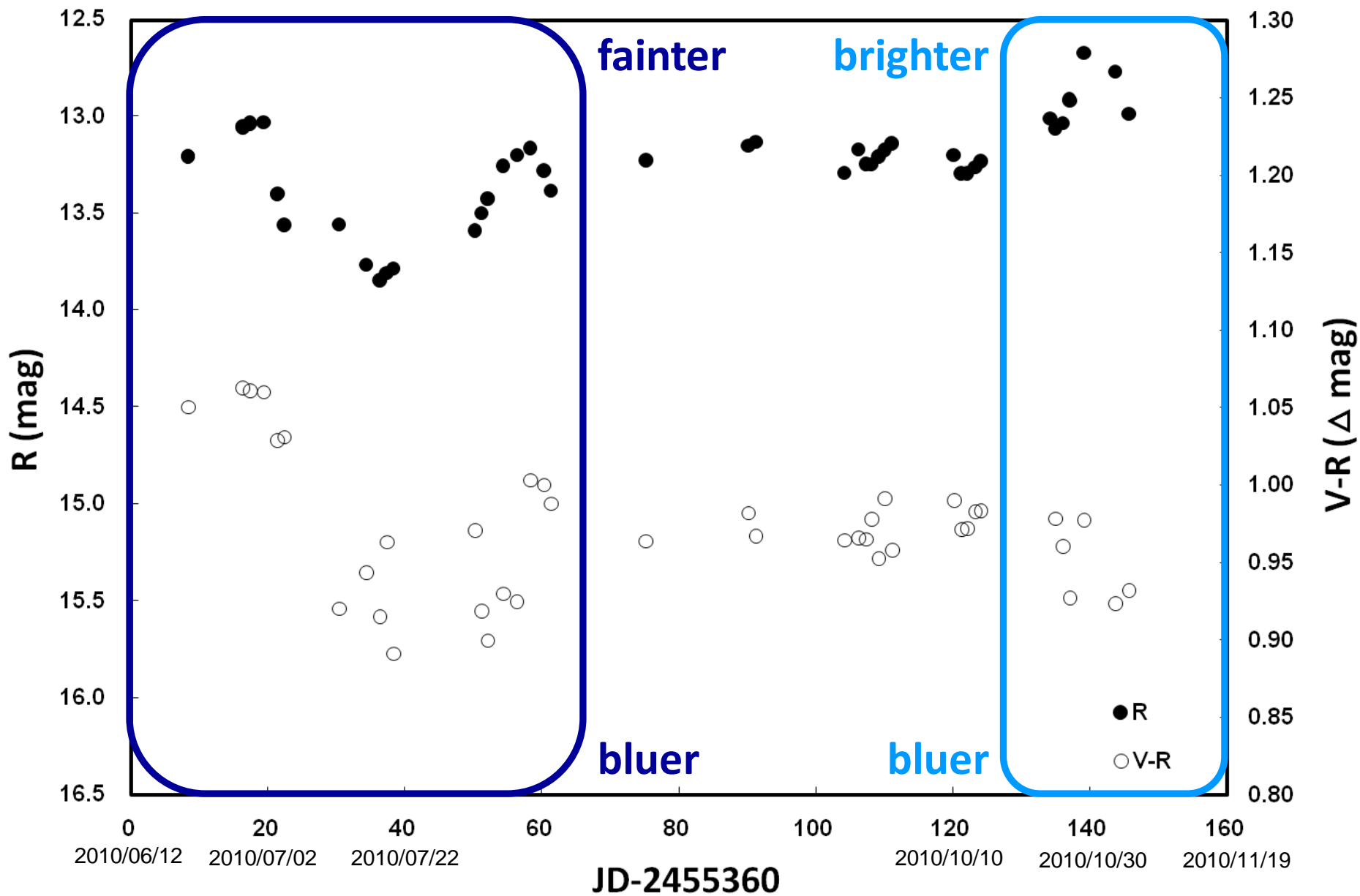
Light curves of GM Cep

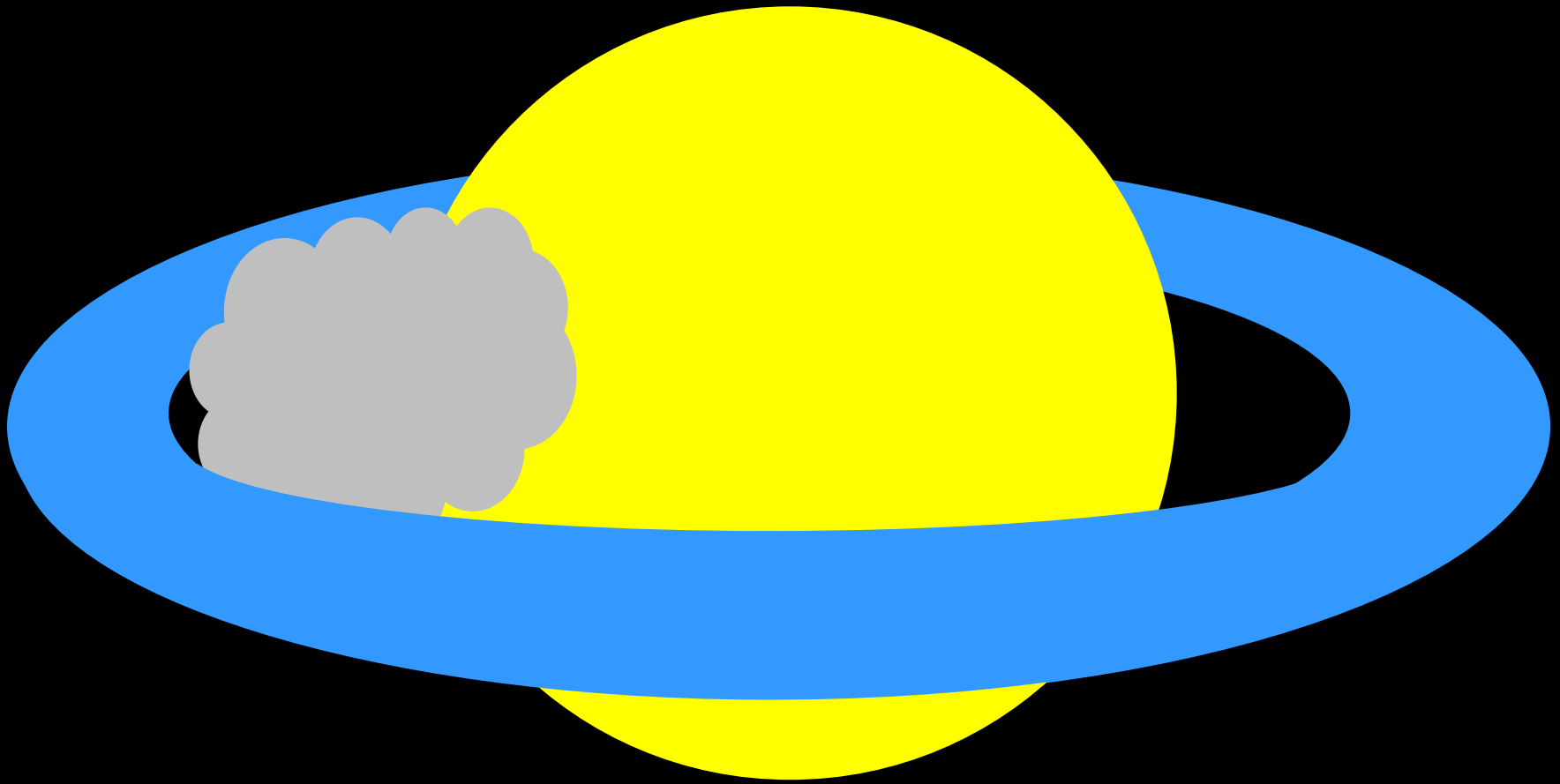


Color curves of GM Cep



R band light curve and V-R color curve of GM Cep





Estimation of clump size & distance

$$\frac{t}{P} = \frac{2R_C}{2\pi \times a}$$

$$t \sim 30 \text{ days}$$

$$P \sim 318 \text{ days}$$

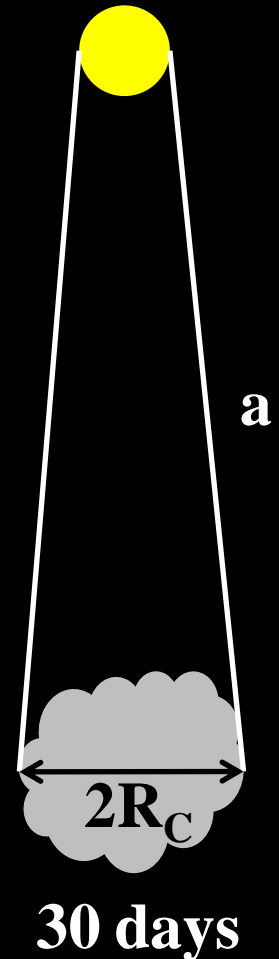
$$M_* \times P^2 = a^3$$

$$P \sim 318 \text{ days}$$

$$M_* \sim 2 M_\odot$$

$$\Rightarrow a \sim 1.16 \text{ AU}$$

$$\Rightarrow R_C \sim 73 R_\odot$$



Conclusions

- A ~ 0.5 mag rise/fall within 10 days, with bluer color at brighter epoch
 - ⇒ an increasing accretion episode?
- A ~ 1 mag brightness fall/rise within 30 days, with bluer color at fainter epoch
 - ⇒ obscuration by a clump of dust around the star
- Combining literature, AAVSO, and our data
 - ⇒ a quasi-cyclic fading episodes?
- GM Cep is not a flaring star, but rather a UXor variable.

Thank You for Your Attention

