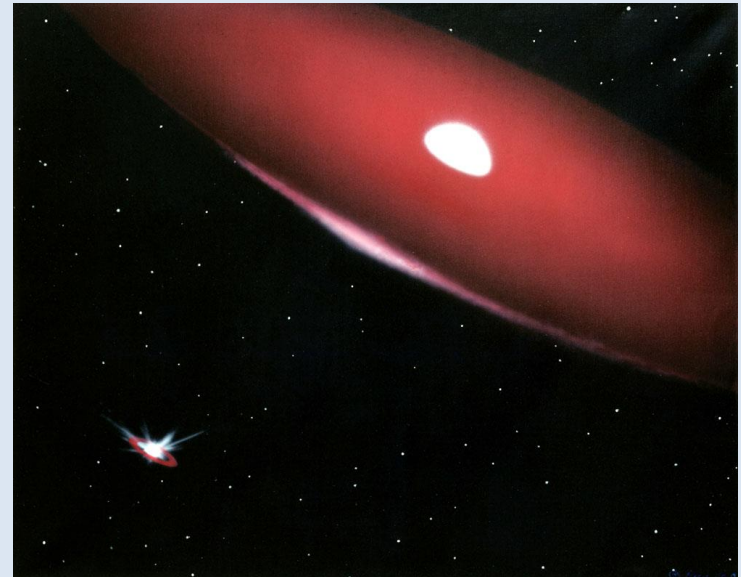


Be Sterne: Variabilität auf verschiedenen Zeitskalen

Klaus Bernhard
Hartha, Mai 2017

Dank an:
Stefan Hümmerich
Ernst Pollmann
Erik Wischnewski

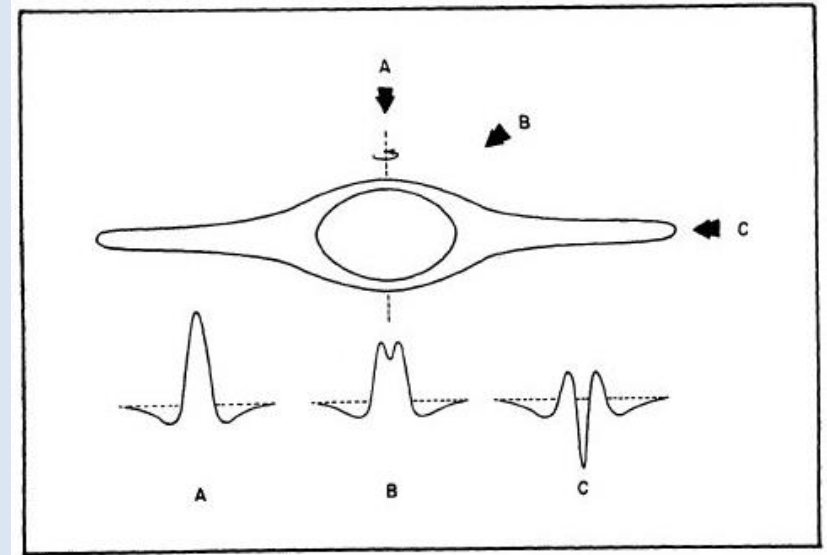


Was sind Be Sterne?

- Während ‚normale‘ B Sterne nur Absorptionslinien zeigen, zeigen Be Sterne zumindest zeitweise Balmer-Emissionslinien.
- Jaschek et al. (1981): „**A non-supergiant B star whose spectrum has, or had at some time, one or more Balmer lines in emission.**“ (klassische, weit verbreitete Definition)
- Das Be Phänomen ist schon seit langem bekannt. So berichtete Pater A. Secchi bereits 1866 bei einer Beobachtung von γ Cas über das Vorhandensein einer hellen (Emissions)Linie an der Stelle von H β :
„[...] une particularité curieuse ... une ligne lumineuse très-belle et bien plus brillante que toute le reste du spectre.“
(verfasst in Französisch von einem italienischen Astronomen, der im Vatikan arbeitete, und erschienen in einem deutschen Journal [AN]; vgl. Rivinius et al. 2013)

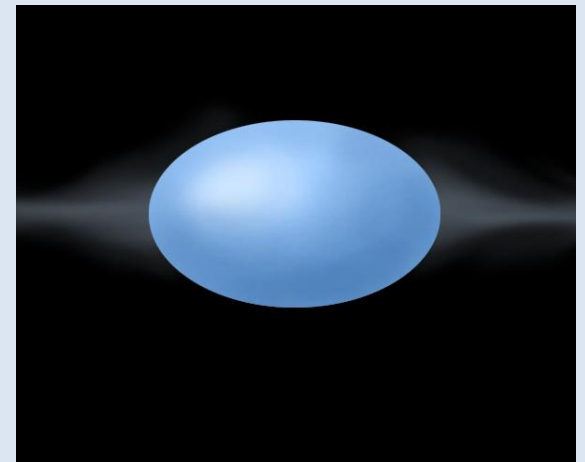
Was sind Be Sterne (Fortsetzung)?

- OeBeAe-Sterne: frühe Sterne der Leuchtkraftklasse V, IV, oder III (also keine Überriesen)
- zeigen mindestens zeitweise Balmer-Emissionslinien
- Emissionslinien entstehen in optisch dünnen Hüllen entlang des Äquators = Dekretionsscheibe



Einige Eigenschaften

- Be Sterne rotieren sehr schnell ($\sim 75\%$ der kritischen Rotationsgeschwindigkeit oder mehr)
- Neuere Beobachtungen mit Weltraumteleskopen legen nahe, dass alle Be Sterne non-radiale Pulsationen aufweisen (z.B. Baade et al. 2016).
- Mechanismen, die zur Ausbildung der Scheibe führen, sind nicht abschließend geklärt, jedoch wird vermutet, dass Pulsationen eine entscheidende Rolle spielen.
- Scheibenbildung auch durch den Einfluss eines Begleitsterns möglich.
- Beispiel Achernar (Alpha Eri) einer der 10 hellsten Sterne; bei uns unbeobachtbar



Be Sterne und der GCVS

BE

GCVS-type for Be stars that show variability but no light outbursts (GCAS variables). Most of them may be **LERI** variables.

GCAS

Eruptive irregular variables of the γ Cassiopeiae type. These are rapidly rotating O9-A0 III-Ve stars with mass outflow from their equatorial zones. The formation of equatorial rings or disks is accompanied by a temporary brightening (pole-on stars like ω CMa) or fading (equator-on stars like Pleione). Light amplitudes may reach 1.5 mag. in V.

LERI

λ Eri type variables. Be stars with the light variation caused by rotational modulation or non-radial pulsations. Their light curves are usually double-waved and with changing amplitude. Periods in the order of 0.3 - 3 d.

B[e] Sterne vs. Be Sterne

- **FSCMa**

B[e]-type stars that exhibit much stronger Hydrogen emission lines than those seen in classical Be stars and also exhibit forbidden (low excitation) lines of FeII, [FeII], [NII], [OI] and strong IR excesses, which are indicative of compact dust envelopes. They are also not fast rotators like the Be stars. They are most likely binary systems that currently undergo or have recently undergone a phase of a rapid mass exchange, associated with dust formation. The secondaries are typically 2-3 magnitudes fainter than their primaries. Complex structure of the circumstellar environments significantly veils the underlying stars and requires multitechnique investigation. They are located outside star formation regions and they probably main sequence stars (not supergiants). Their light curves show irregular long-term variations with long term (years) mean magnitude changes up to 2 magnitudes in V. Most of the stars in this group were previously considered as Unclassified B[e] stars. Examples: FS CMa, V0743 Mon.

Helle Be Sterne

| Name | AUID | Coords (J2000) | Const. | Var. type | Period (d) | Mag. range |
|--------------------|-------------|-------------------------|--------|-----------|------------|----------------|
| S NSV 15249 | -- | 01 09 30.10 +47 14 31.0 | And | BE: | -- | 4.25 - 4.5 l |
| V psi 2 Aqr | 000-BCR-365 | 23 17 54.22 -09 10 57.0 | Aqr | BE: | 1.073 | 4.40 V (0.06b) |
| V V0862 Ara | 000-BDG-752 | 17 31 23.28 -56 55 15.5 | Ara | BE: | -- | 5.92 - 6.04 Hp |
| V iot Ara | 000-BDG-766 | 17 23 16.08 -47 28 05.5 | Ara | BE | 0.5565 | 5.18 - 5.26 V |
| V NO CMa | 000-BDH-928 | 07 23 00.70 -31 55 25.6 | CMa | BE: | -- | 5.33 - 5.38 Hp |
| V V0382 Cep | 000-BCN-716 | 21 19 22.22 +64 52 18.7 | Cep | BE | -- | 5.08 - 5.23 V |
| V CO Cir | 000-BDM-097 | 14 48 44.55 -66 35 36.8 | Cir | BE | -- | 5.79 - 5.92 Hp |
| V tet CrB | 000-BBW-269 | 15 32 55.78 +31 21 32.9 | CrB | BE | -- | 4.06 - 4.33 V |
| V V2119 Cyg | 000-BCL-442 | 20 23 44.37 +37 28 35.2 | Cyg | BE | -- | 5.74 - 5.85 Hp |
| V lam Cyg | 000-BCM-508 | 20 47 24.54 +36 29 26.6 | Cyg | BE | -- | 4.47 - 4.54 Hp |
| V alf Eri | 000-BFQ-084 | 01 37 42.85 -57 14 12.3 | Eri | BE | 1.263 | 0.40 - 0.46 Hp |
| V KT Lup | 000-BDT-404 | 15 35 53.25 -44 57 30.2 | Lup | BE | 2.0894 | 4.48 - 4.5 Hp |
| V iot Lyr | 000-BCW-362 | 19 07 18.13 +36 06 00.6 | Lyr | BE | -- | 5.2 - 5.27 Hp |
| V bet Mon | 000-BBL-376 | 06 28 49.07 -07 01 59.0 | Mon | BE | -- | 3.77 - 3.84 Hp |
| V LS Mus | 000-BDW-064 | 13 03 05.34 -71 28 32.6 | Mus | BE | -- | 5.9 - 6.01 Hp |
| V zet Oph | 000-BBX-821 | 16 37 09.54 -10 34 01.5 | Oph | BE | 0.193 | 2.56 - 2.58 V |
| V OQ Peg | 000-BFS-647 | 21 53 03.77 +25 55 30.5 | Peg | BE | -- | 5.02 - 5.06 Hp |
| V UU PsA | 000-BFC-760 | 22 04 36.77 -26 49 20.5 | PsA | BE | -- | 5.86 - 5.91 b |
| V V1075 Sco | 000-BCX-176 | 17 15 19.25 -33 32 54.3 | Sco | BE: | -- | 5.50 - 5.64 V |
| V V0481 Sct | 000-BFR-380 | 18 33 55.29 -06 58 38.7 | Sct | BE: | -- | 5.85 - 6.23 K |
| V NW Ser | 000-BCC-113 | 18 21 28.40 +05 26 08.6 | Ser | BE | -- | 5.39 - 5.59 U |
| V V1155 Tau | 000-BFN-189 | 05 07 55.44 +21 42 17.4 | Tau | BE | -- | 5.82 - 5.96 Hp |
| V QV Tel | 000-BFN-545 | 18 17 07.53 -56 01 24.1 | Tel | BE | -- | 5.31 - 5.38 Hp |
| V MV Vel | 000-BBR-386 | 10 20 54.80 -56 02 35.6 | Vel | BE | -- | 4.49 (0.06) V |
| Name | AUID | Coords (J2000) | Const. | Var. type | Period | Mag. range |
| V V0395 Vul | 000-BCJ-273 | 19 51 04.11 +22 36 36.2 | Vul | BE | -- | 4.78 - 4.97 V |

Beobachtung heller Be Sterne in der BAV

<https://www.bav-astro.eu/rb/rb2016-3/26.pdf>

Delta Scorpii (δ Sco) - B-Stern im Helligkeitsausbruch

Wolfgang Vollmann

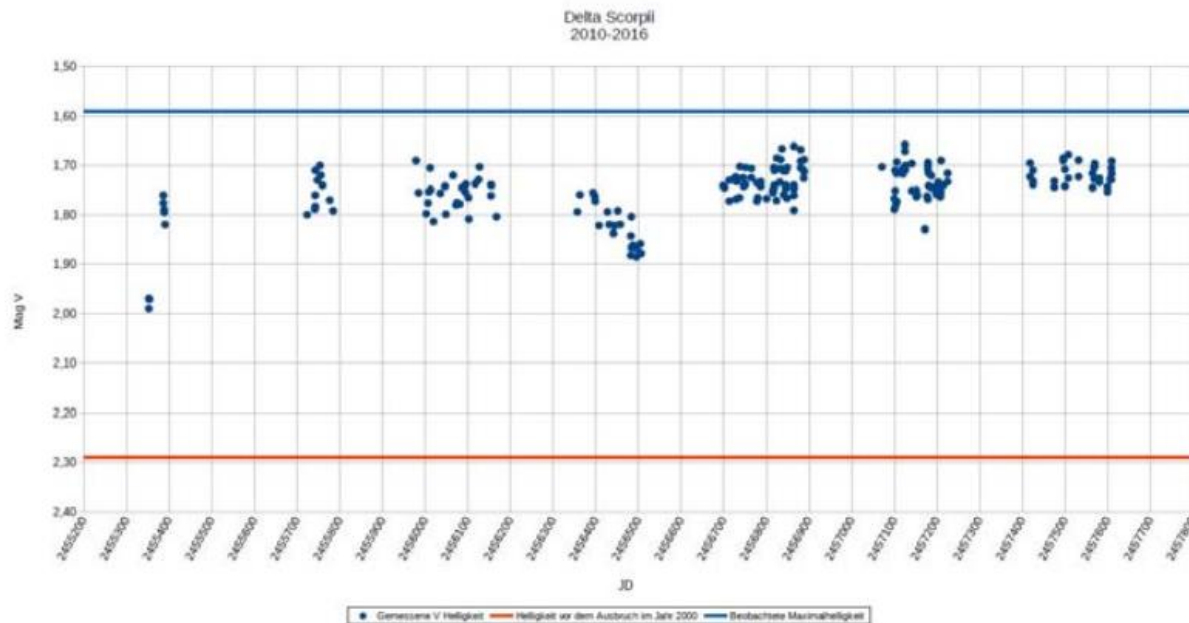


Abb. 2: Lichtkurve von Delta Scorpii in den Jahren 2010 bis 2016, beobachtet mit der Digitalkamera. Jeder Messpunkt ist der Mittelwert aus 10 Einzelfotos. Die blaue Linie zeigt die bisher erreichte Maximalhelligkeit des Sterns in den Jahren 2003/2004. Die rote Linie zeigt die Sternhelligkeit vor dem Helligkeitsanstieg im Jahr 2000. Die beobachteten Helligkeitsänderungen in den sieben Jahren sind gering, zwischen 1,7 und 2,0 mag.

Zeitskalen der Veränderlichkeit

Astron. Astrophys. Suppl. Ser. **108**, 237-250 (1994)

Long-term photometry of Be stars.

I. Fading events and variations on time scales of years*

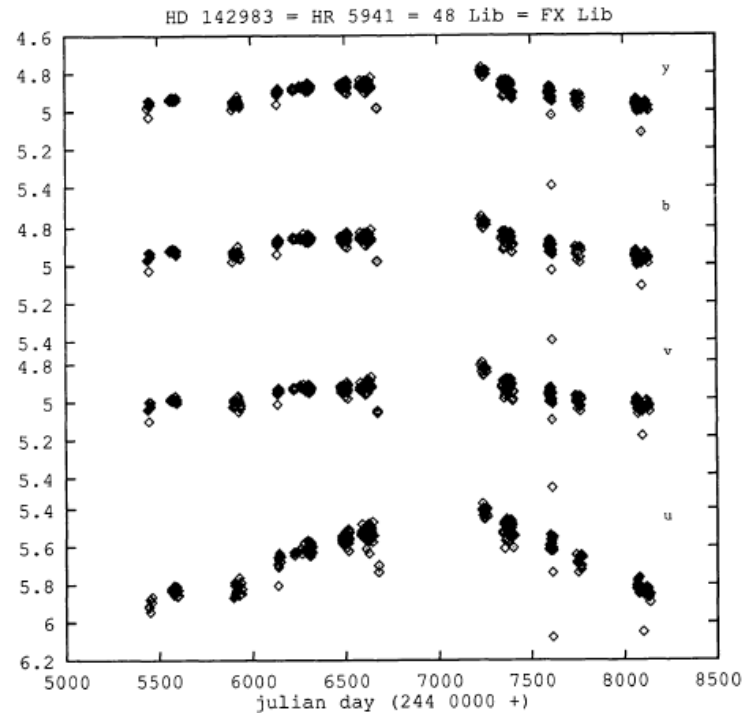


Fig. 8. General light curve of 48 Lib. From top to bottom:
y, *b*, *v* and *u* band pass

Zeitskalen der Veränderlichkeit

Long-term photometry of Be stars

II. Periodic variations on time scales of days to months*

C. Sterken^{1,**}, N. Vogt^{2,***}, and R.E. Mennickent³

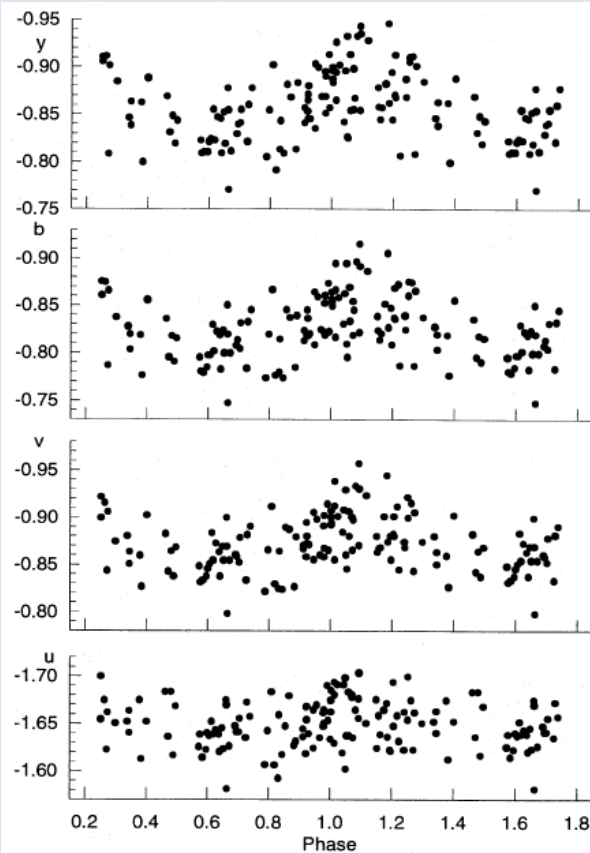


Fig. 2. HR 2492 *uvby* phase diagrams for the period $P = 87^d.9$ (epoch JD 2445000, System 7 data only)

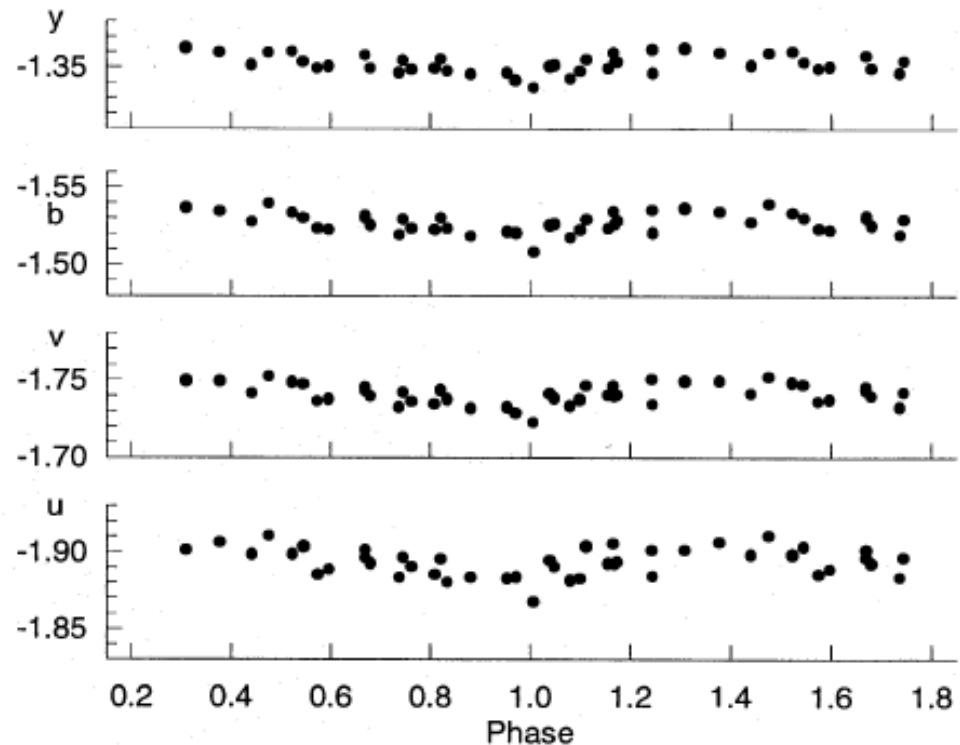


Fig. 6. HR 4074 *uvby* phase diagrams for $P = 4^d.656$ (epoch JD 2445000, System 7 data in the time interval JD 2446412–6608 only; same magnitude scale as in Figs. 2 and 4)

Animation von Zeta Tau

Dr. Pollmann aus Daten von G. H. Schaefer et al. 2010

Cartoon depiction of ζ Tauri's disk precession variations
as seen at the sky.

It shows the change in the precession of the disk tilt and the
„one-armed“ spiral density maximum (small gray dot).



$$\tau = 0.000$$

$$P = 1429 \text{ d}$$

Pleione (Dr. Pollmann)

<http://astrospectroscopy.de/media/files/bu-tau-dateien/28-Tau.pdf>

Spektroskopischer Doppelstern
mit Periode von 218 Tagen und
großer Exzentrizität

100 Jahre Beobachtungen:
Zyklische Veränderungen
Periode 35-36 Jahre

Begleiter verursacht im Periastron
Massenverlust des Primärsterns:
Neue Scheibe entsteht
(Envelope-Spektrum)
Alte Scheibe durch Präzession schon
außerhalb Äquatoralebene

→ transformiert zurück zur Be-Phase

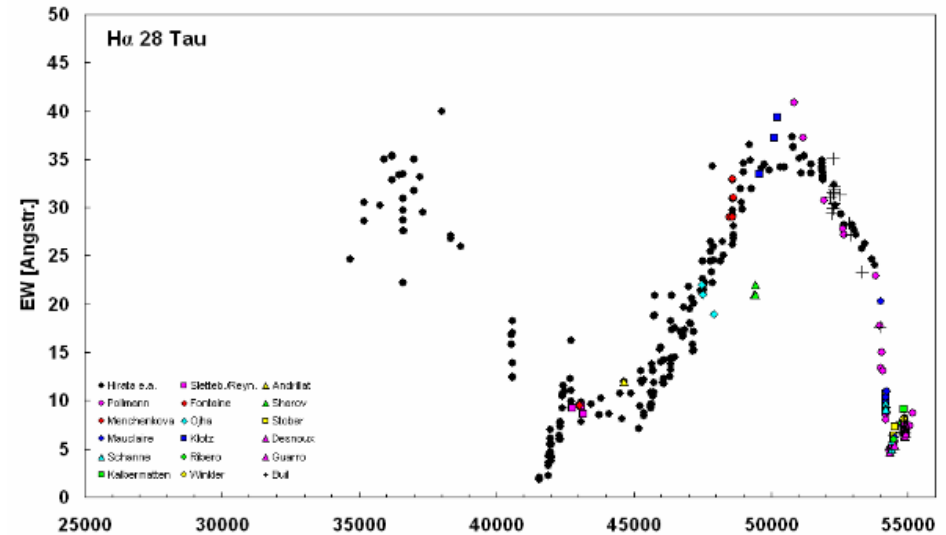


Fig. 3a: Time behaviour of H α equivalent width from professional and amateur observations

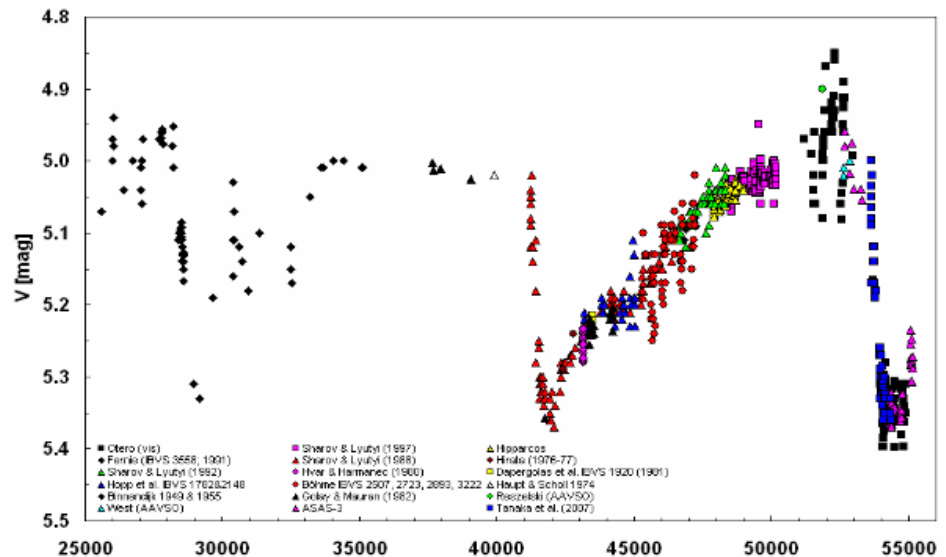


Fig. 3b: Historic V light curve from various sources

Korrelation H alpha line flux vs V

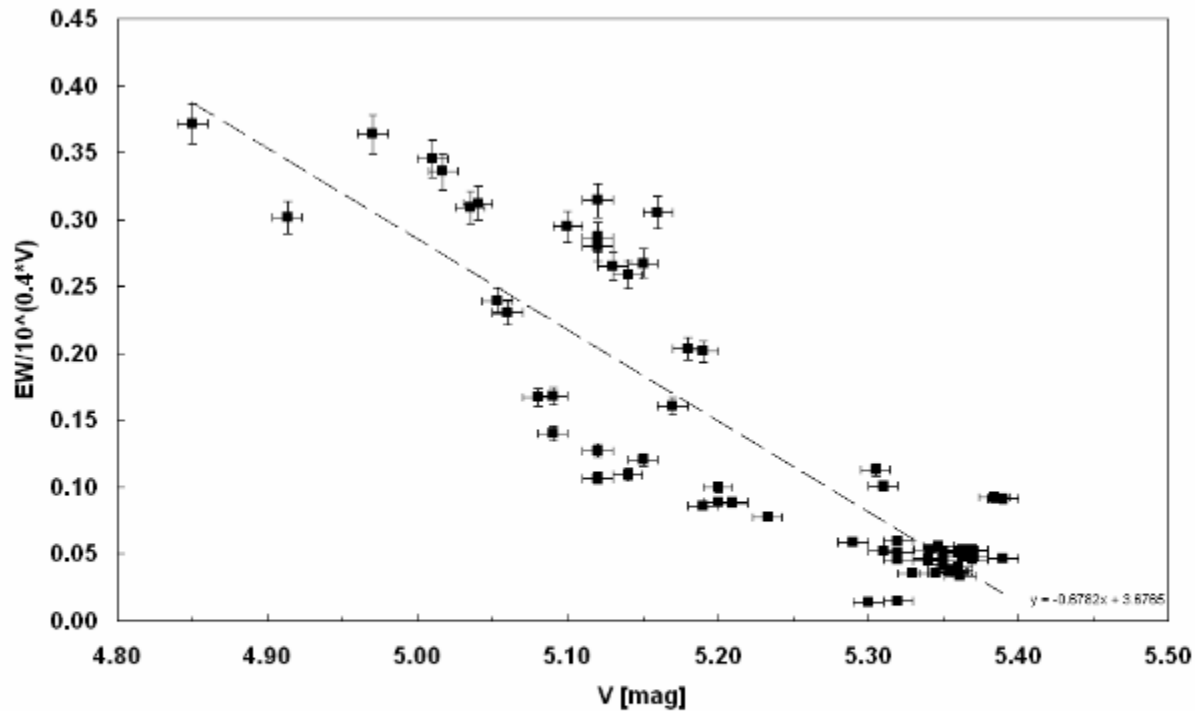


Fig. 3c: Correlation of intrinsic H α line flux versus V brightness from 74 simultaneous measurements

H α -Spectroscopy and V-Variations of Be star 28 Tauri (Pleione)

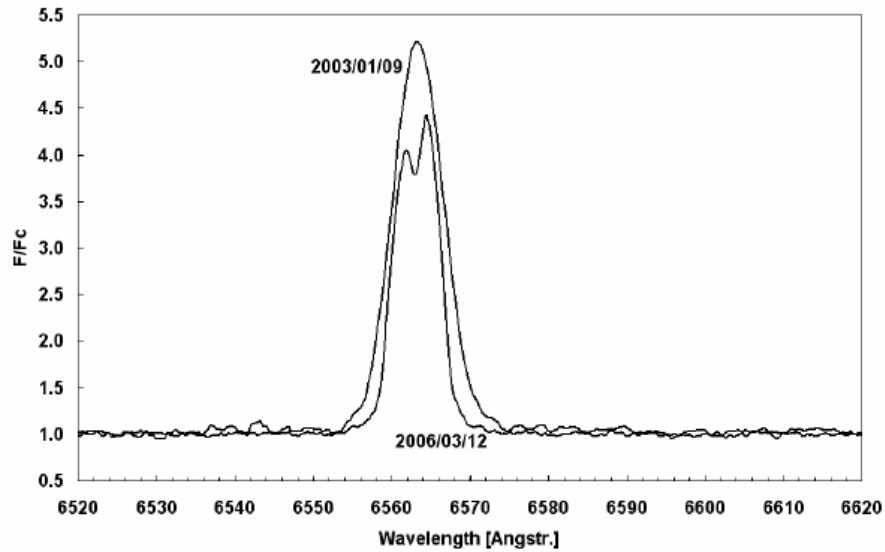


Fig. 1: Own prism spectra of 28 Tau during Be phase (1989 until approx. end of 2005)

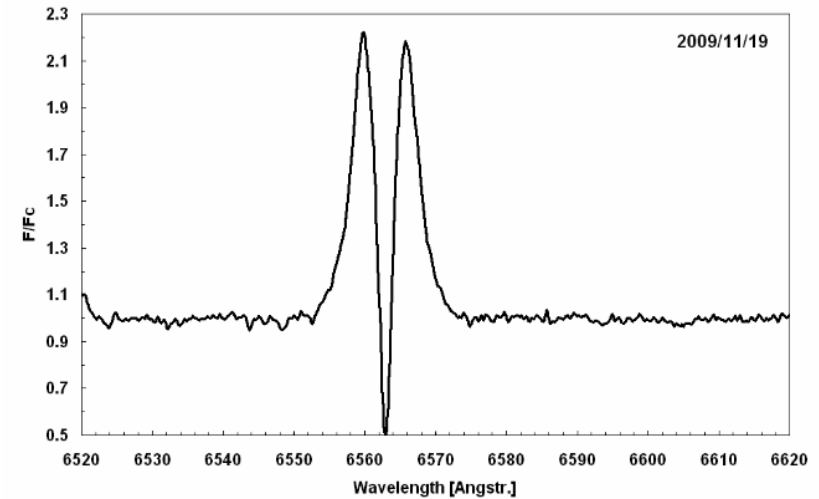
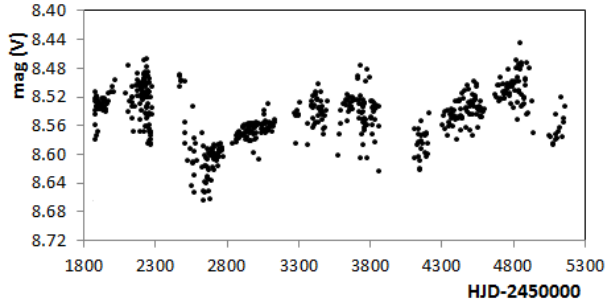


Fig. 2: High-resolution grating spectrum of 28 Tau (2009/11/19) in its current Be shell phase

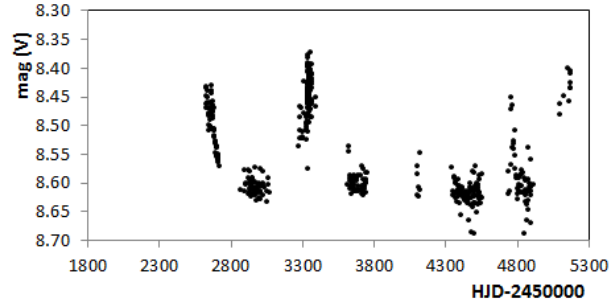
296 neue Be Sterne in der ASAS Datenbank

Otero/Hümmerich/Bernhard – langperiodische Variationen

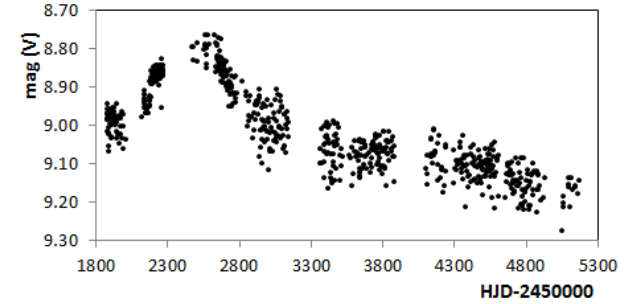
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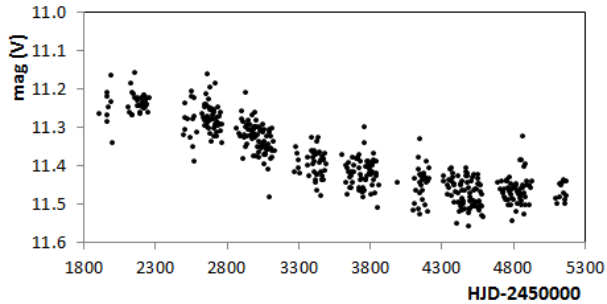
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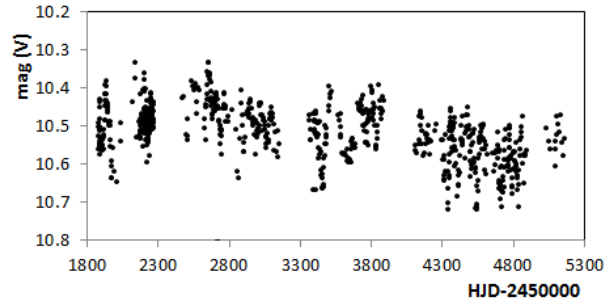
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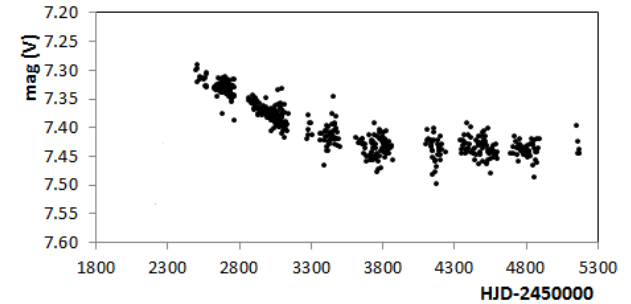
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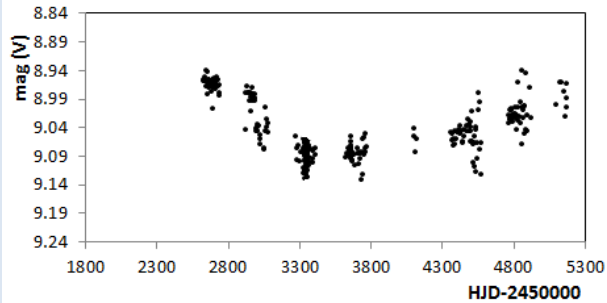
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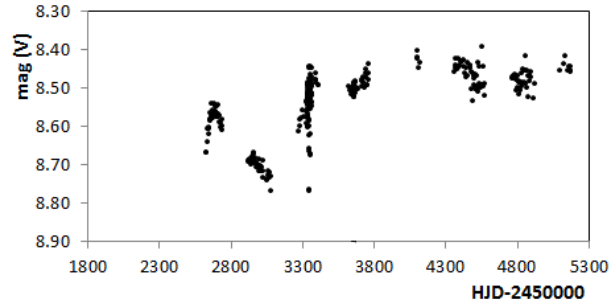
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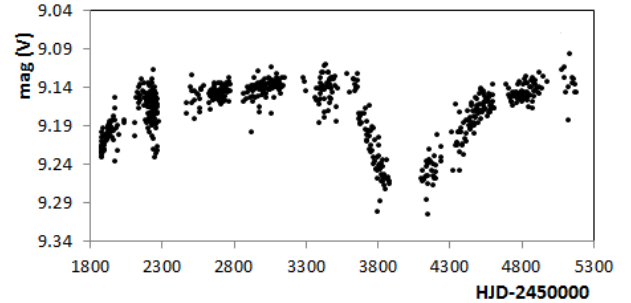
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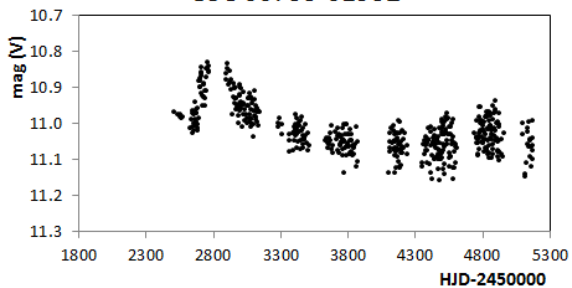
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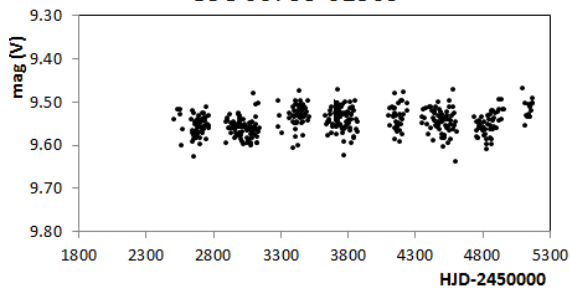
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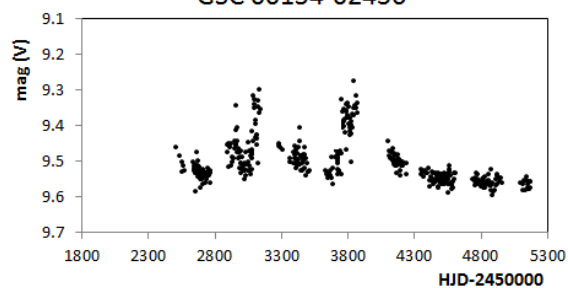
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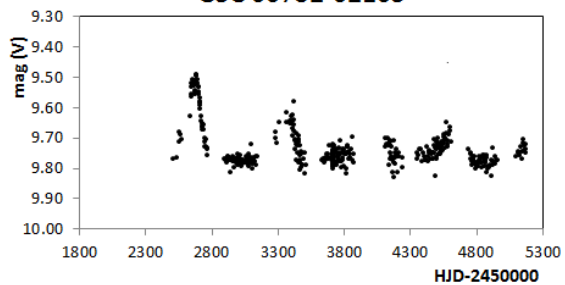
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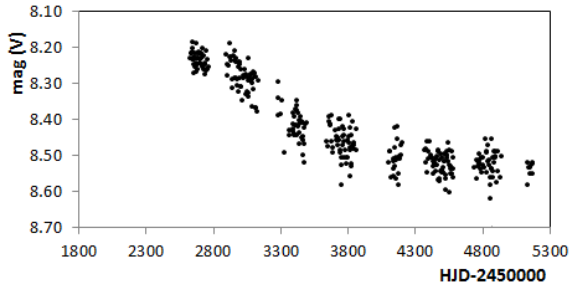
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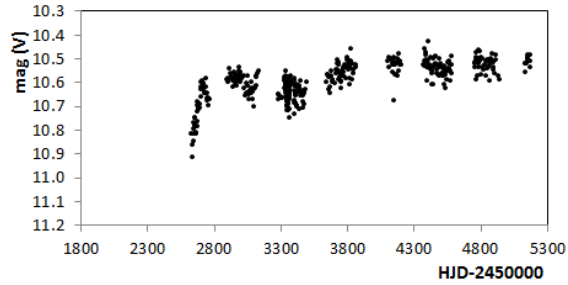
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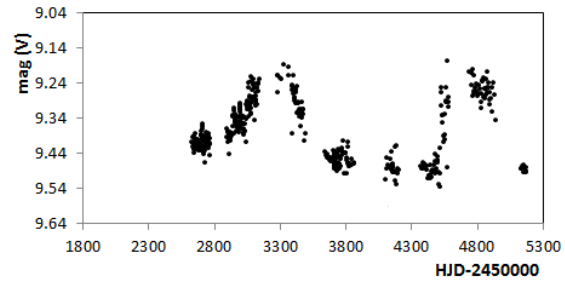
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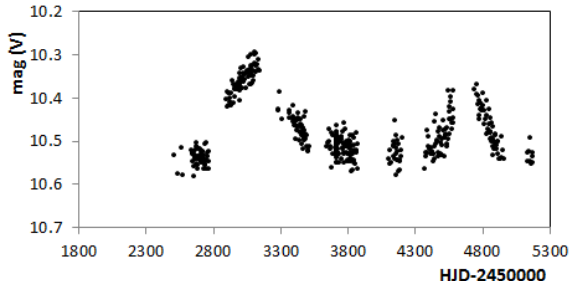
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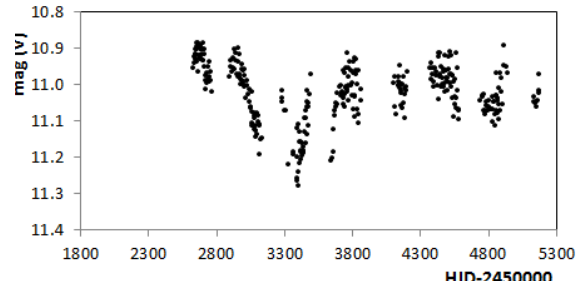
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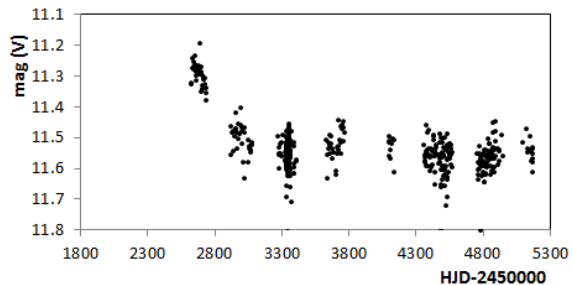
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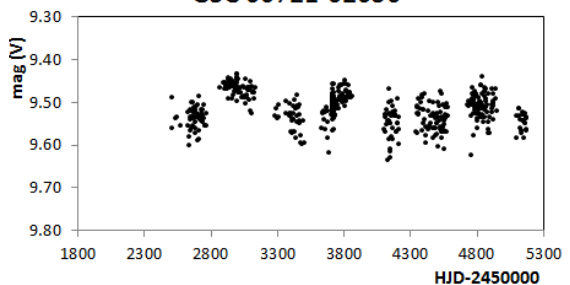
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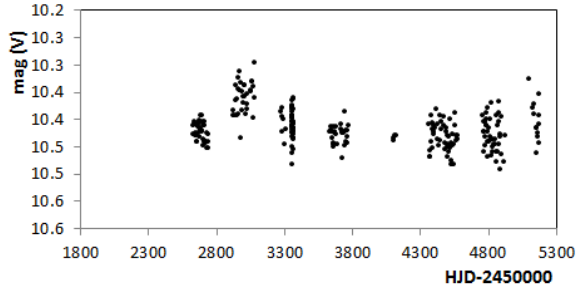
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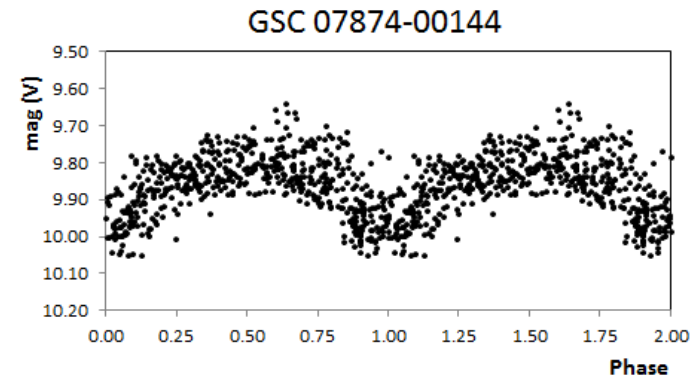
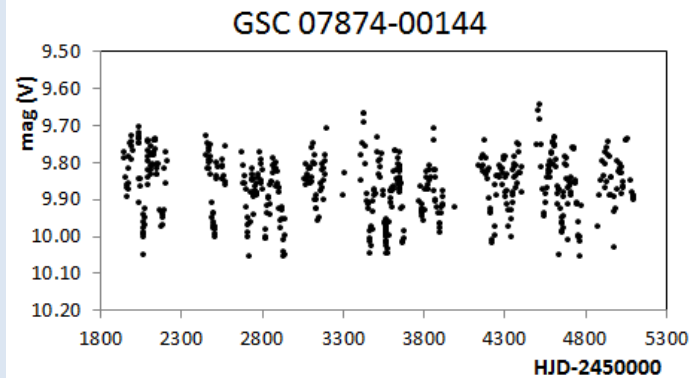
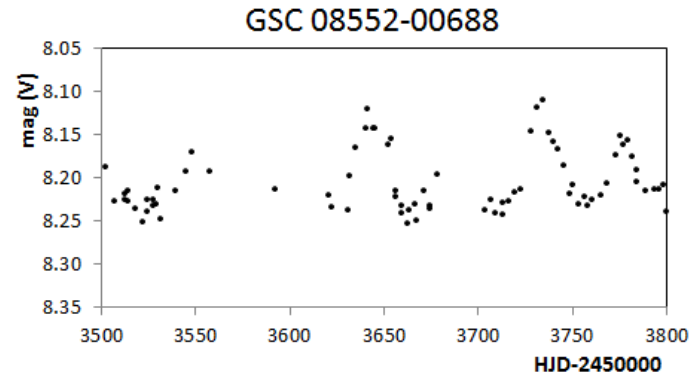
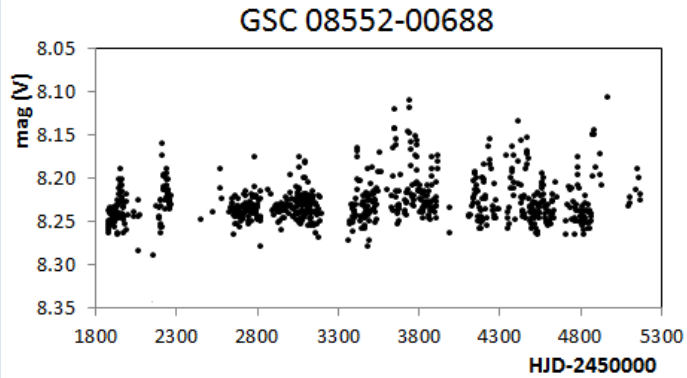
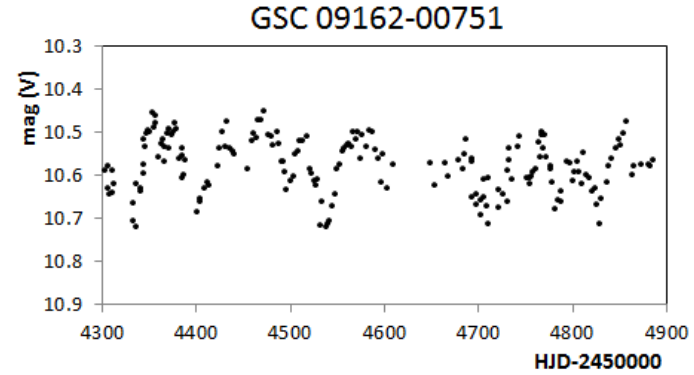
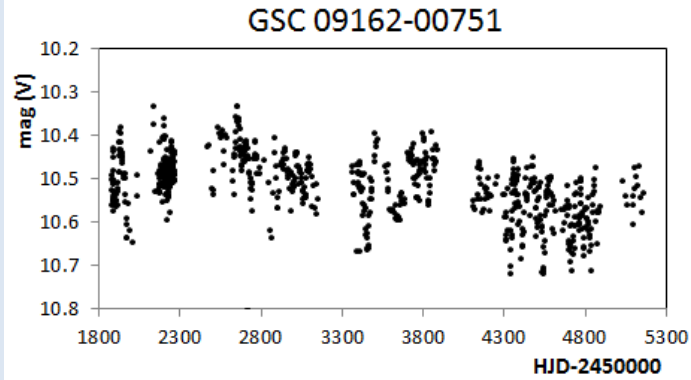
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"Medium" Variationen



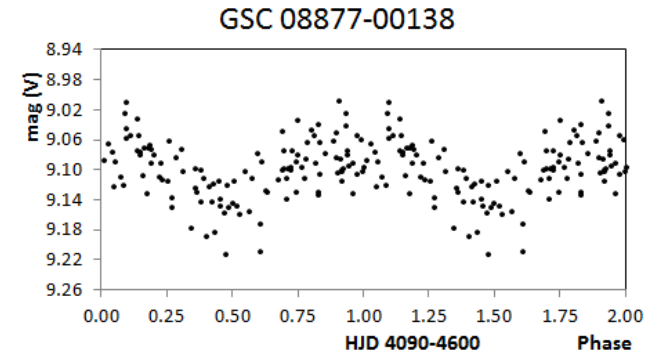
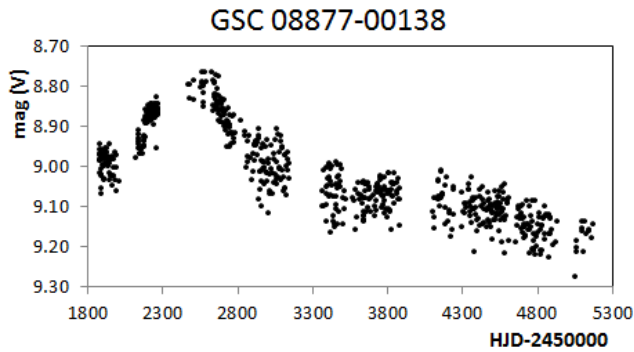
Ausreißer!

108.56d

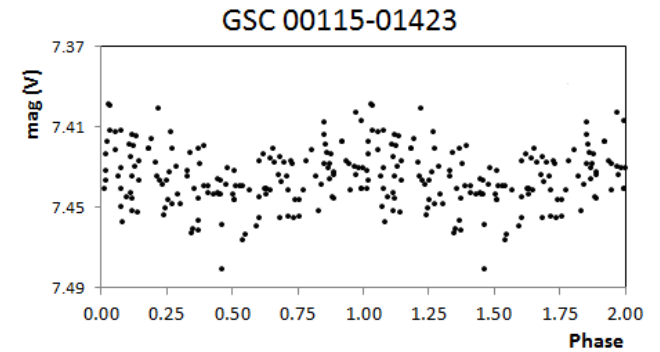
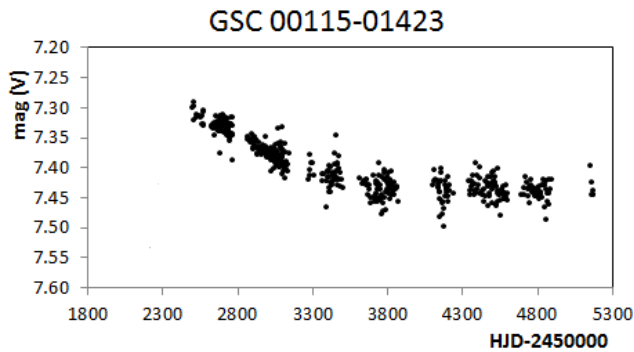
B2:[e] + F

Kurzperiodische Variabilität

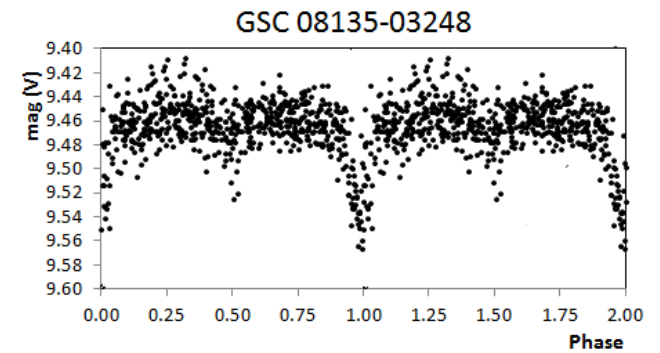
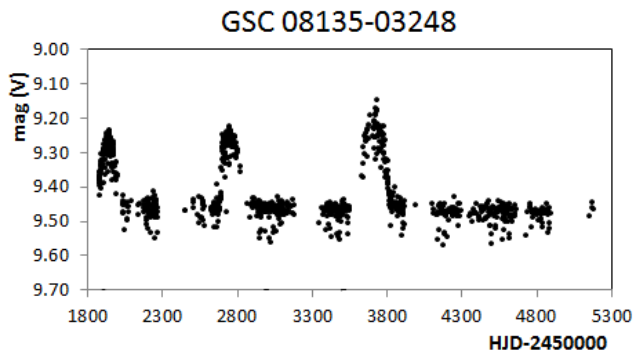
1.10487 d



0.77143 d



1.28209 d
(eclipsing)



Abschlußbemerkung: "Gut Ding braucht Weile"

Peremennye Zvezdy Variable Stars

Founded in 1928 by B.V. Kukarkin.

"Peremennye Zvezdy",
Prilozhenie,
vol. 17, N 1 (2017)

Light Curves of Variable Active Galactic Nuclei from the Catalina Sky Survey

[K. Bernhard](#)^{#1,2}, [S. Huemmerich](#)^{#1,3}

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Received: 9.05.2014; accepted: 26.01.2017

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| # | Name | Other | Coord (J2000) | Type | Max | Min | System | Period | Epoch (JD) | type | Sp | Comment | L.Curve | Find.Chart | Data |
|---|------|------------------------|----------------------------|------|------|------|--------|--------|------------|-------|----|-------------------------|--------------------------|-----------------------------|----------------------------|
| 1 | | 2MASS 00185977+0619319 | 00 18 59.776, +06 19 31.99 | AGN | 16.9 | 17.9 | CV | | | other | | Comm. 1 | lc01.jpg | chart01.png | data01.txt |
| 2 | | 2MASS 00305804-1153059 | 00 30 58.043, -11 53 05.90 | AGN | 16.8 | 17.3 | CV | | | other | | Comm. 2 | lc02.jpg | chart02.png | data02.txt |