Variable stars in Trumpler 37 and follow-up of the first transit candidate

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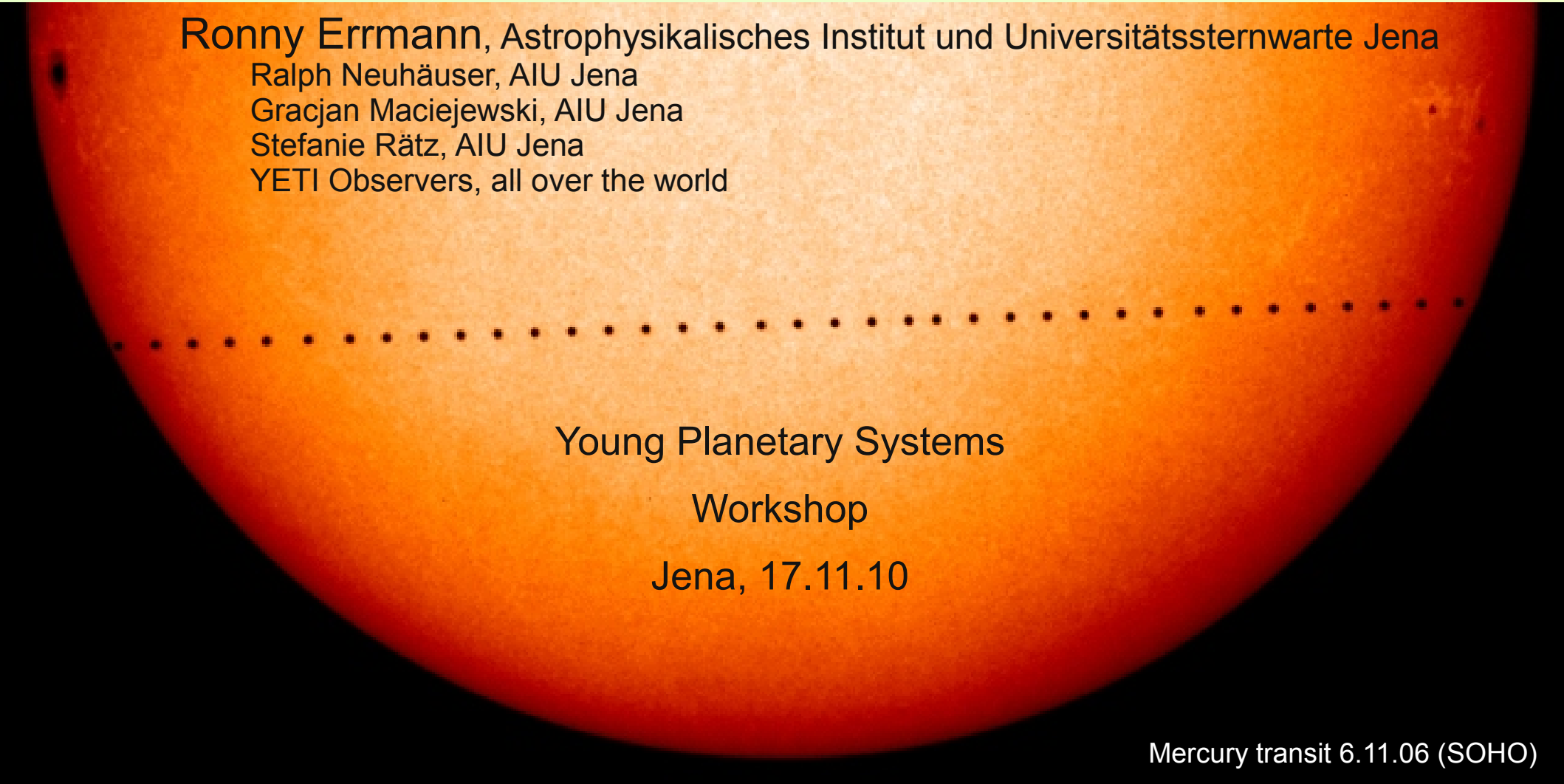
YETI Observers, all over the world

Young Planetary Systems

Workshop

Jena, 17.11.10



Mercury transit 6.11.06 (SOHO)

Trumpler 37

part of H-II region IC 1396 in Cepheus

distance: 800-900 pc (*)

age: 4 to 10 Mio years (*)
→ formation of planets

Diameter: 1.5°

A_V = 1.5 mag

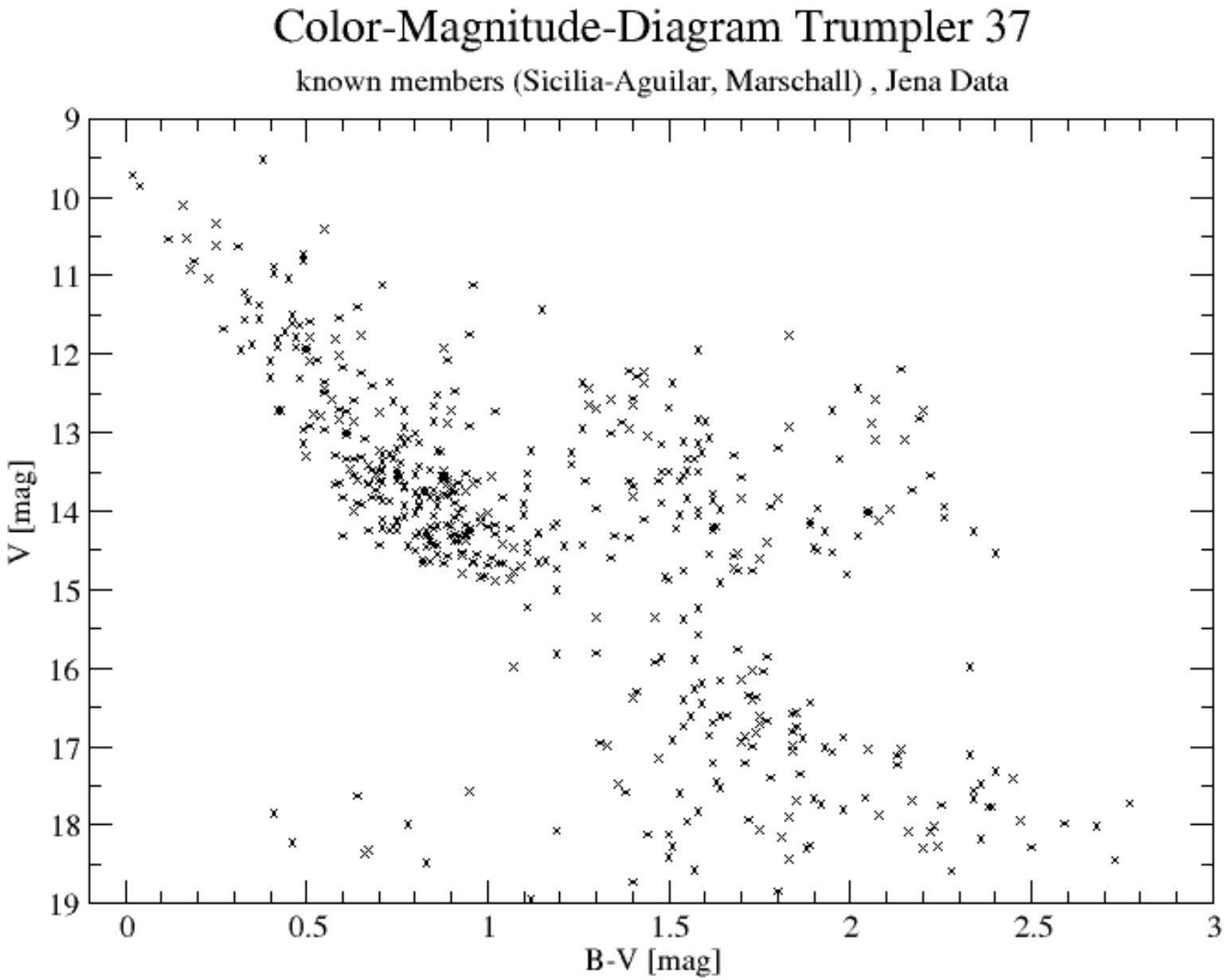
cz = -15.0 ± 3.6 km/s (*)

17000 stars
know members of the cluster: 500 stars

*Sicilia-Aguilar et al. (2007), Marschall and van Altena (1987) Contreras et al. (2002)

central part of Trumpler 37 from 90/60cm Telescope Jena, R-Band 60s
FOV: 53' x 53'

Trumpler 37 – Color-Magnitude-Diagram



Jena telescope

Number of observation nights:

2009:

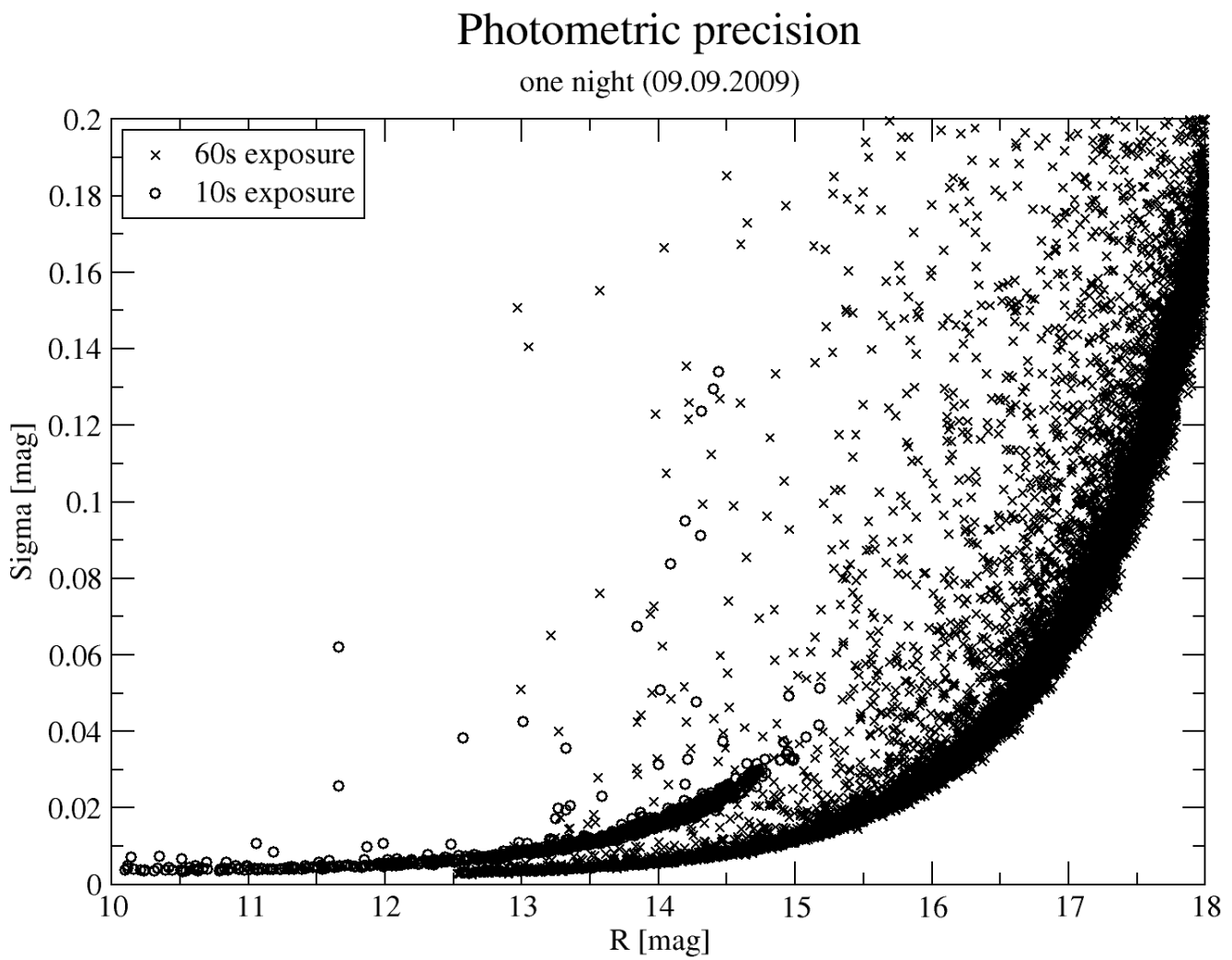
July:	2
August:	18
Sept:	11
Oct./Nov:	2

2010:

March:	7
July:	9
August:	8
Sept:	9
Oct./Nov:	7

6600 data points

5000 stars have precision better than 50 mmag



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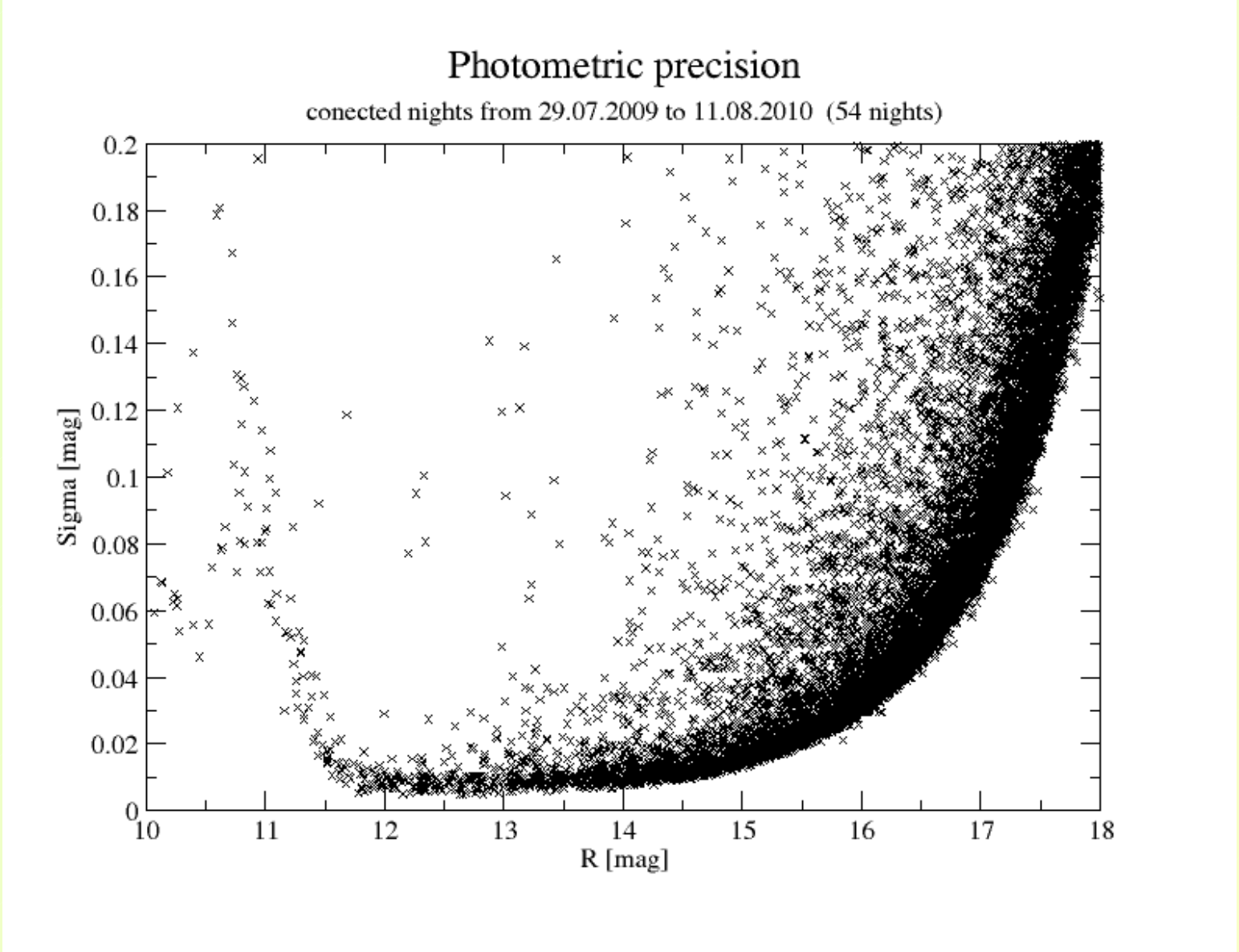


Photometric analysation

- aperture photometry

- differential photometry (Broeg et al. 2005)

Results Jena data

more than 300 variable stars (status: July 2010)

mostly T Tauri stars (periodic and non periodic stars)

50 eclipsing binaries

30 Flares

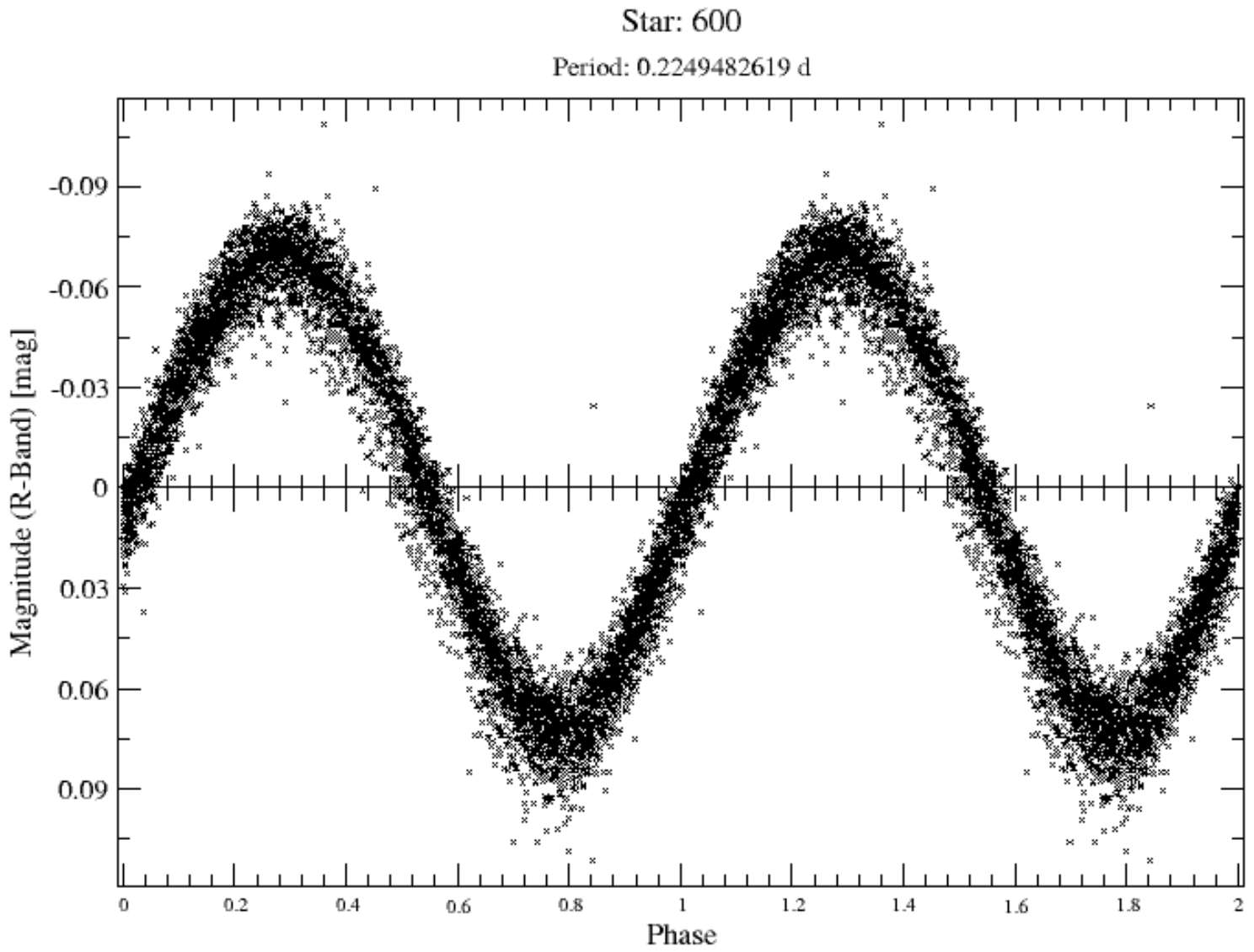
5 short periodic Pulsations

1 transit candidate

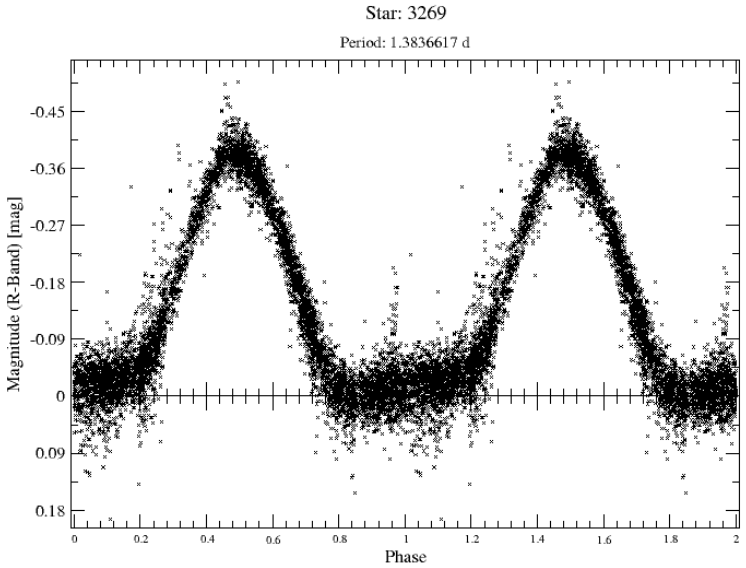
Pulsation / Rotation Periods (130 Stars)

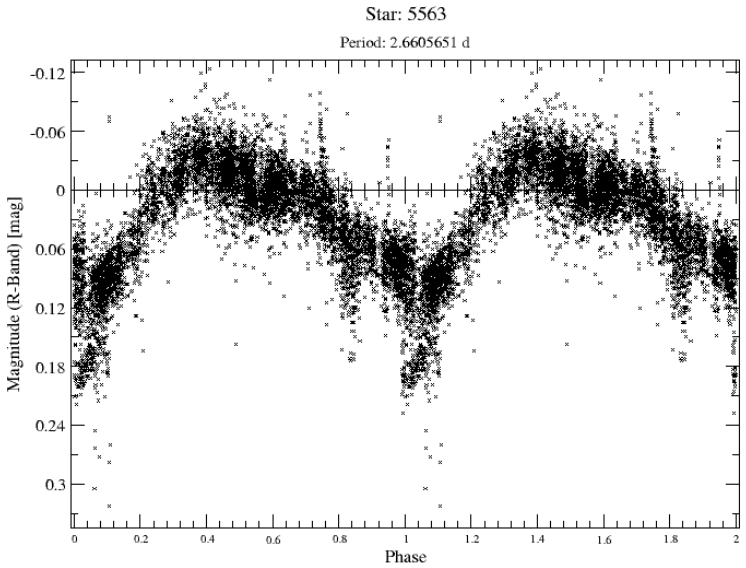
V = 14.3 mag
G8

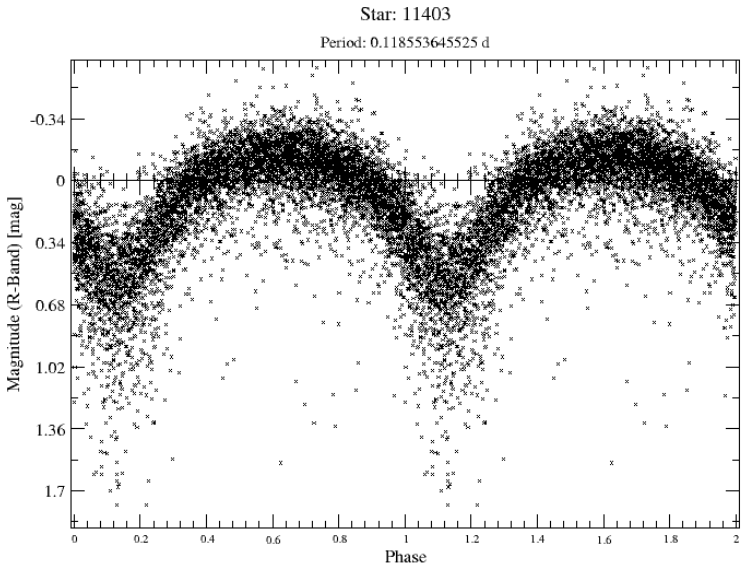
P = 5.4 h
ΔR = 0.14 mag

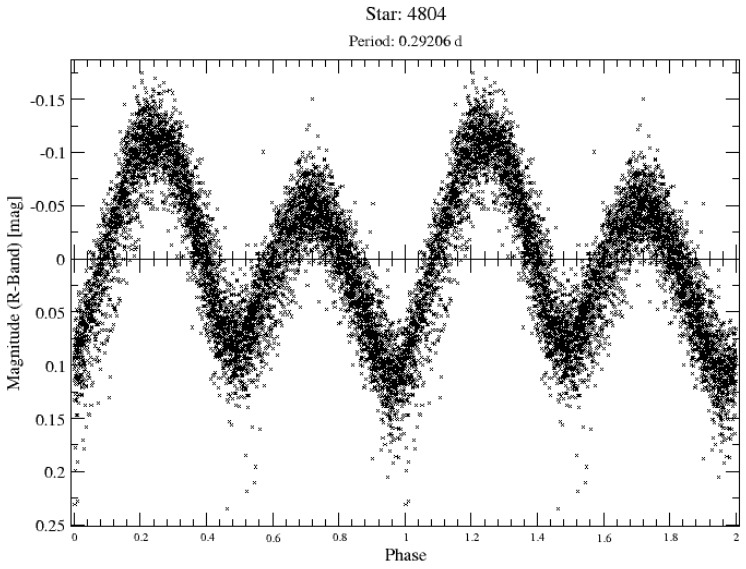


Pulsation / Rotation Periods (130 Stars)









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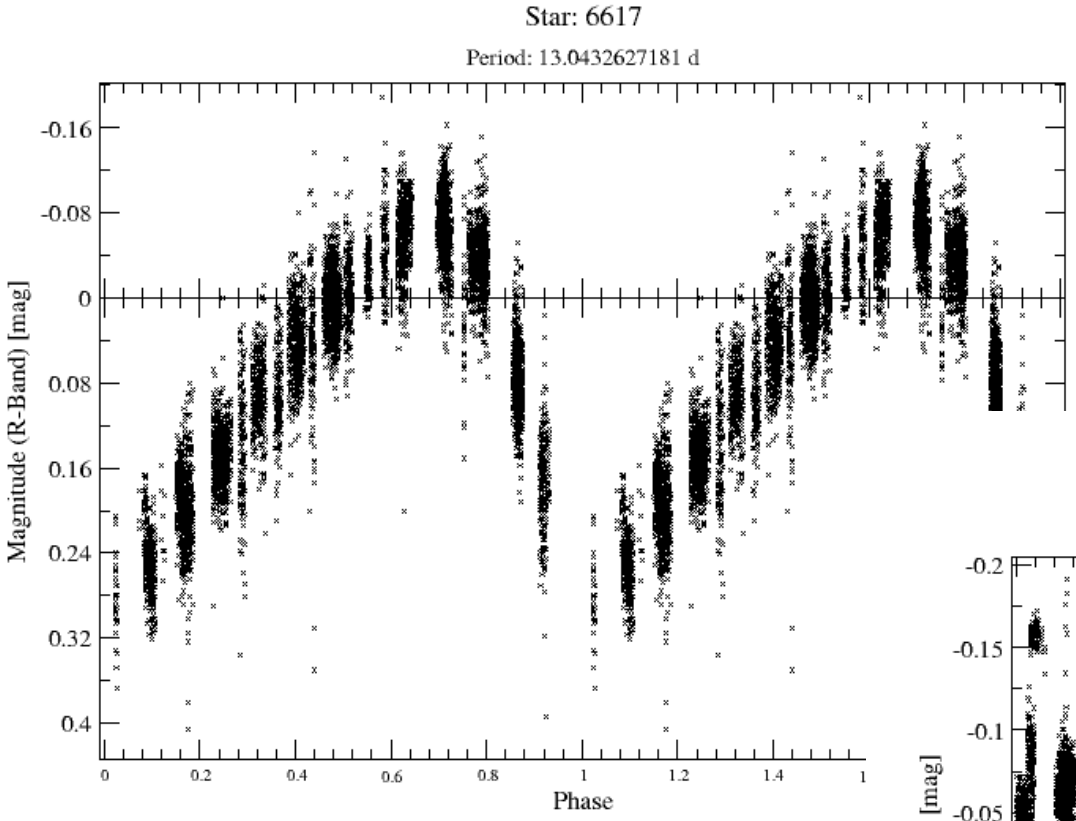
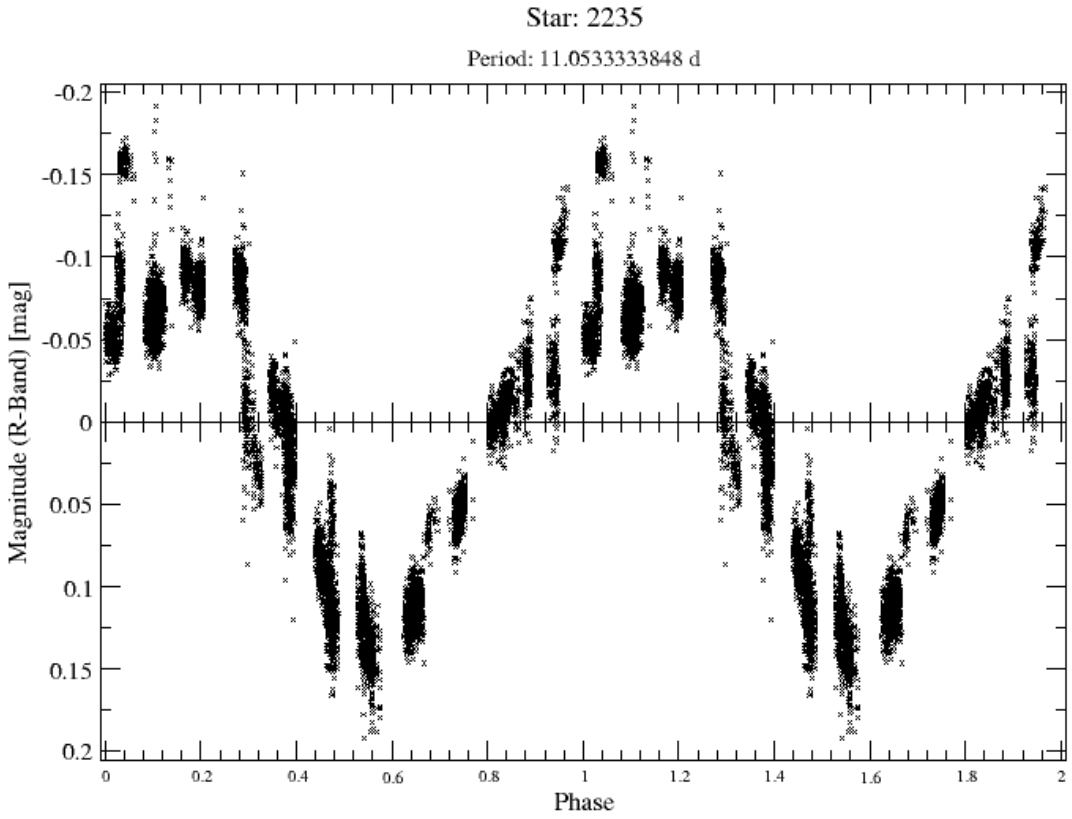
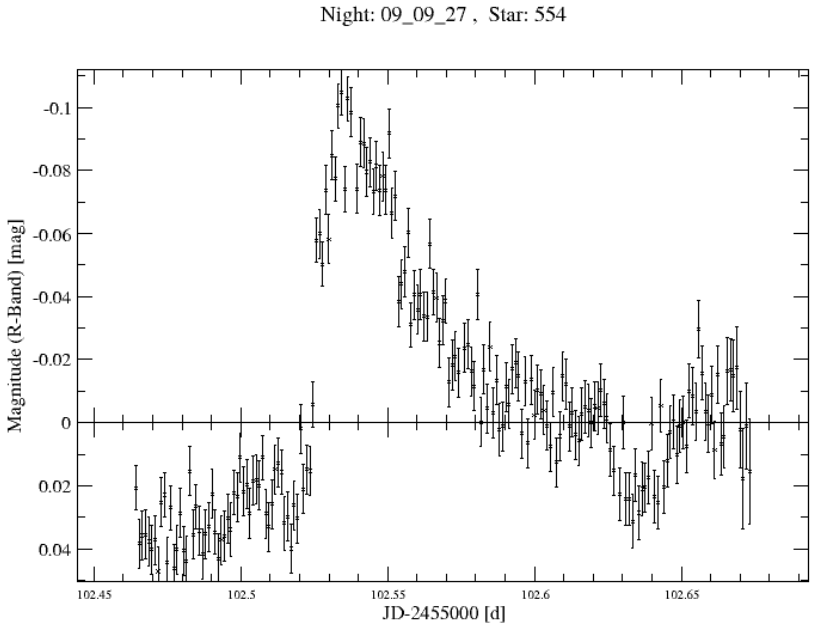
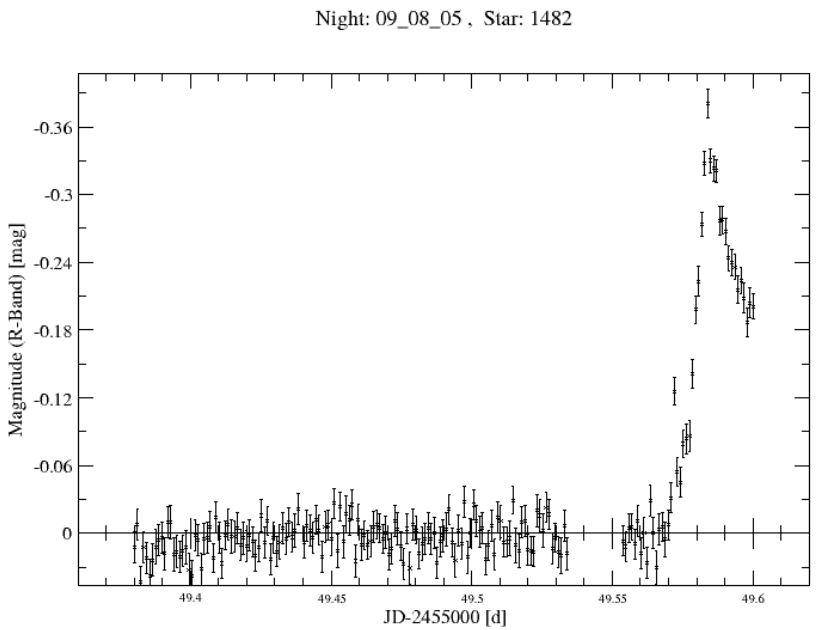
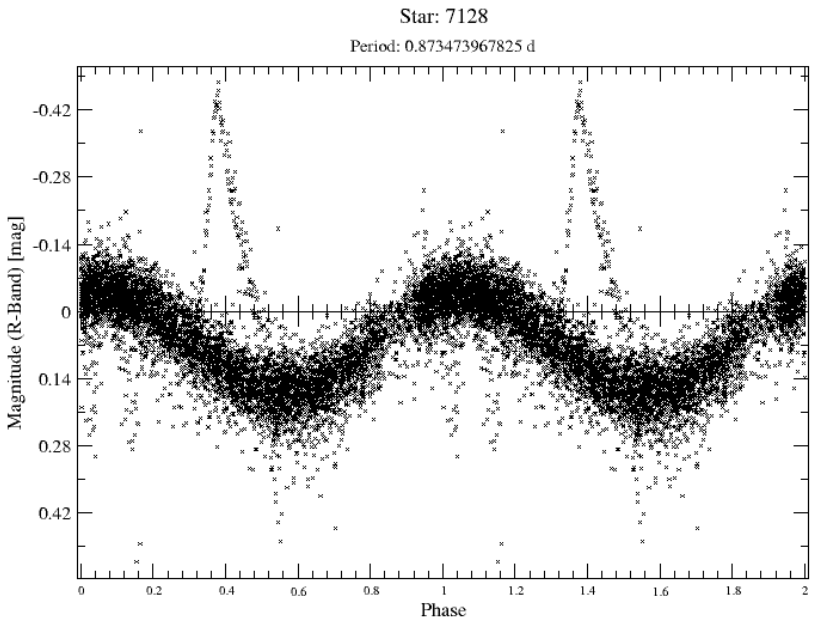


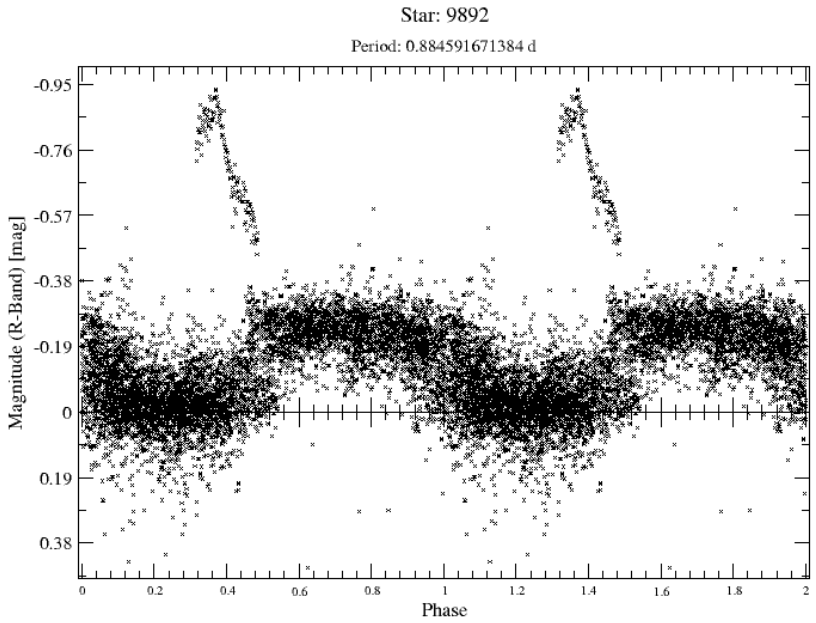


Flares (30 Stars)







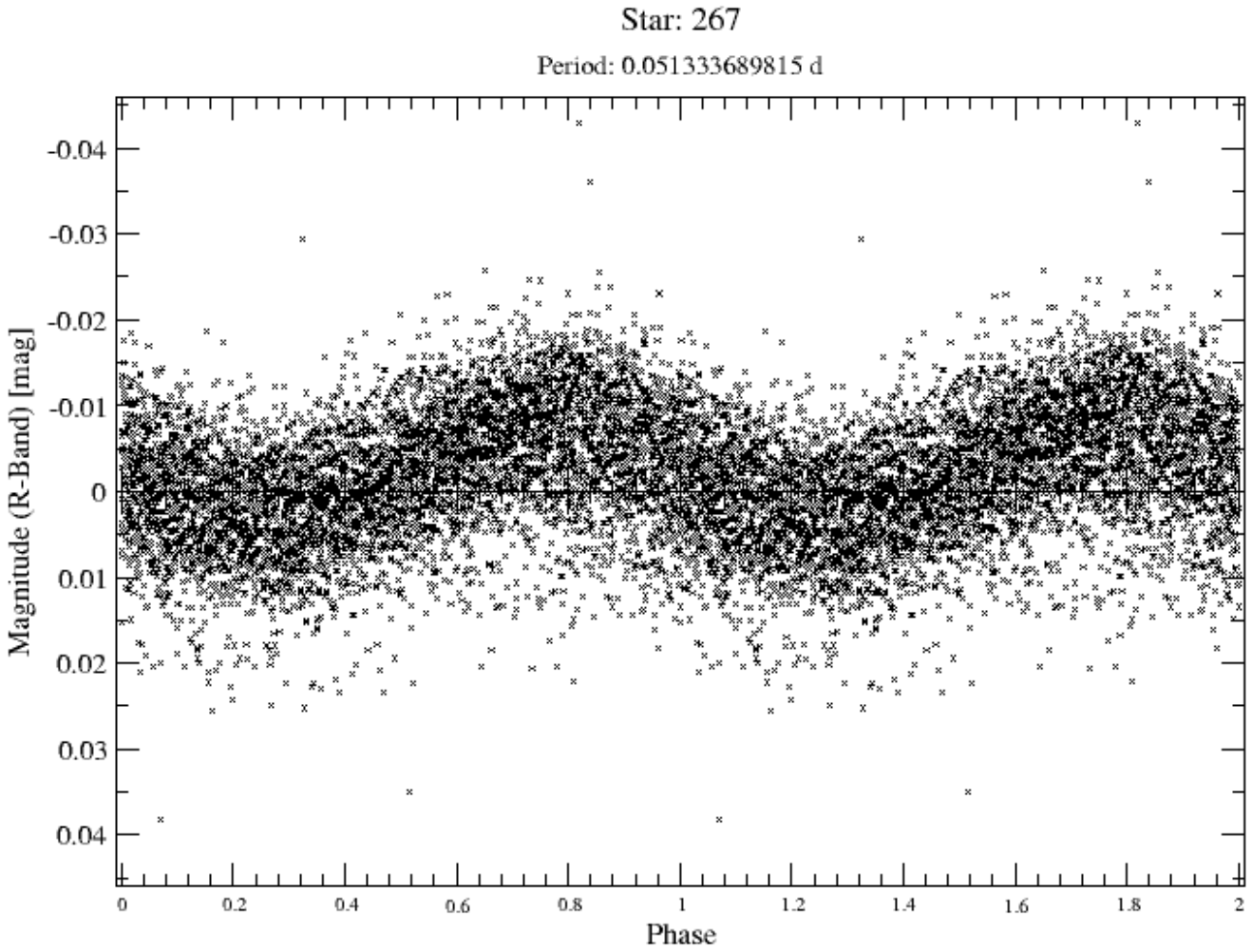


Pulsations (5 Stars)

V = 13.05 mag

photometric
spectral type: F9

P = 1.23 h
ΔR = 11 mmag

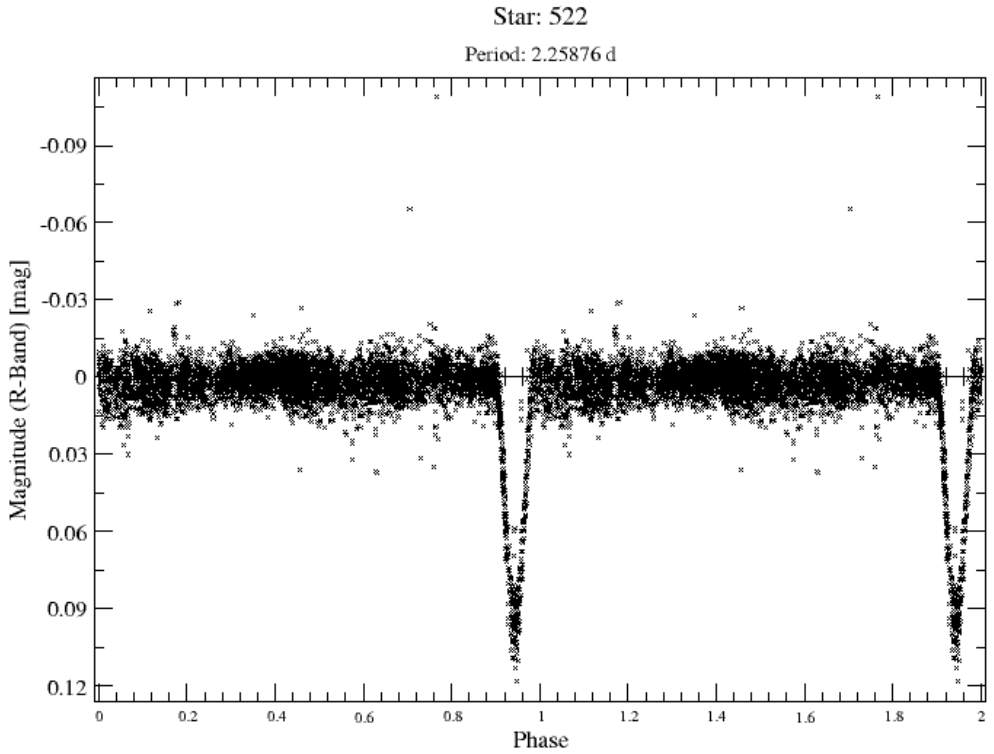


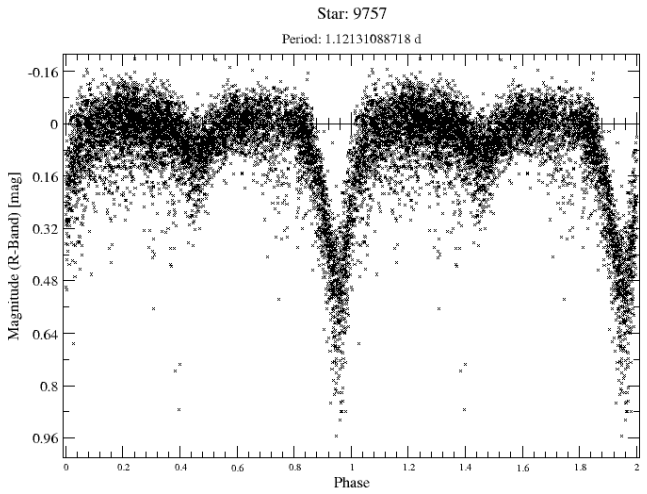
Eclipsing Binaries

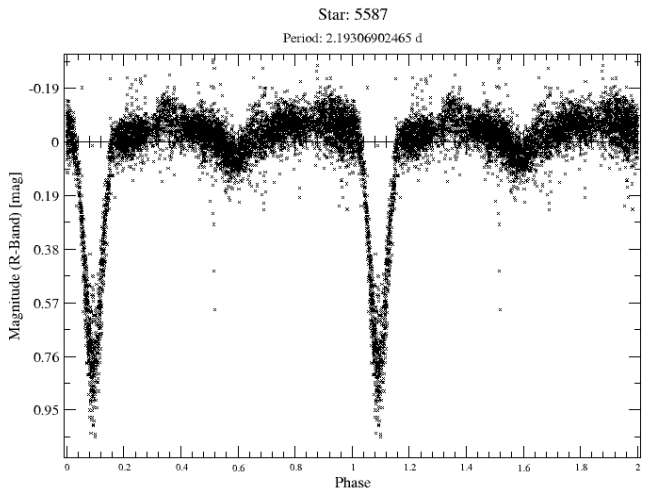
Algol type:

23 Stars

P = 1...8 d







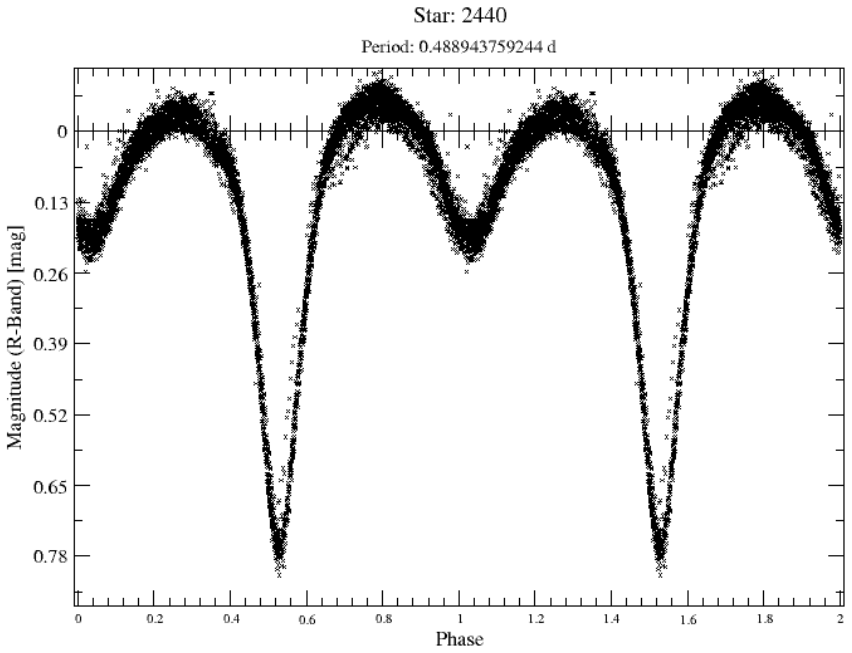
Eclipsing Binaries

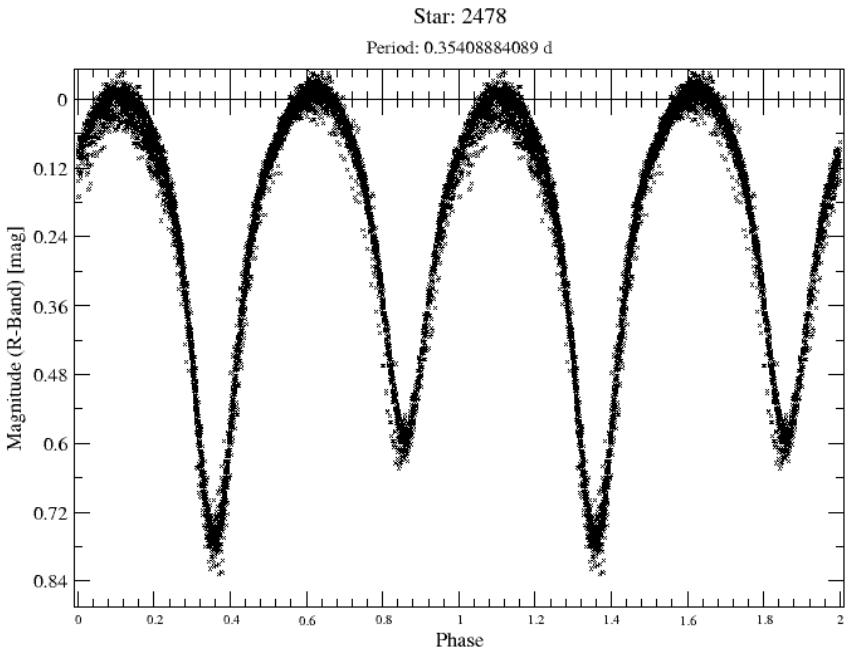
Algol type

β Lyrae:

9 Stars

P = 0.5 ...2.5 d



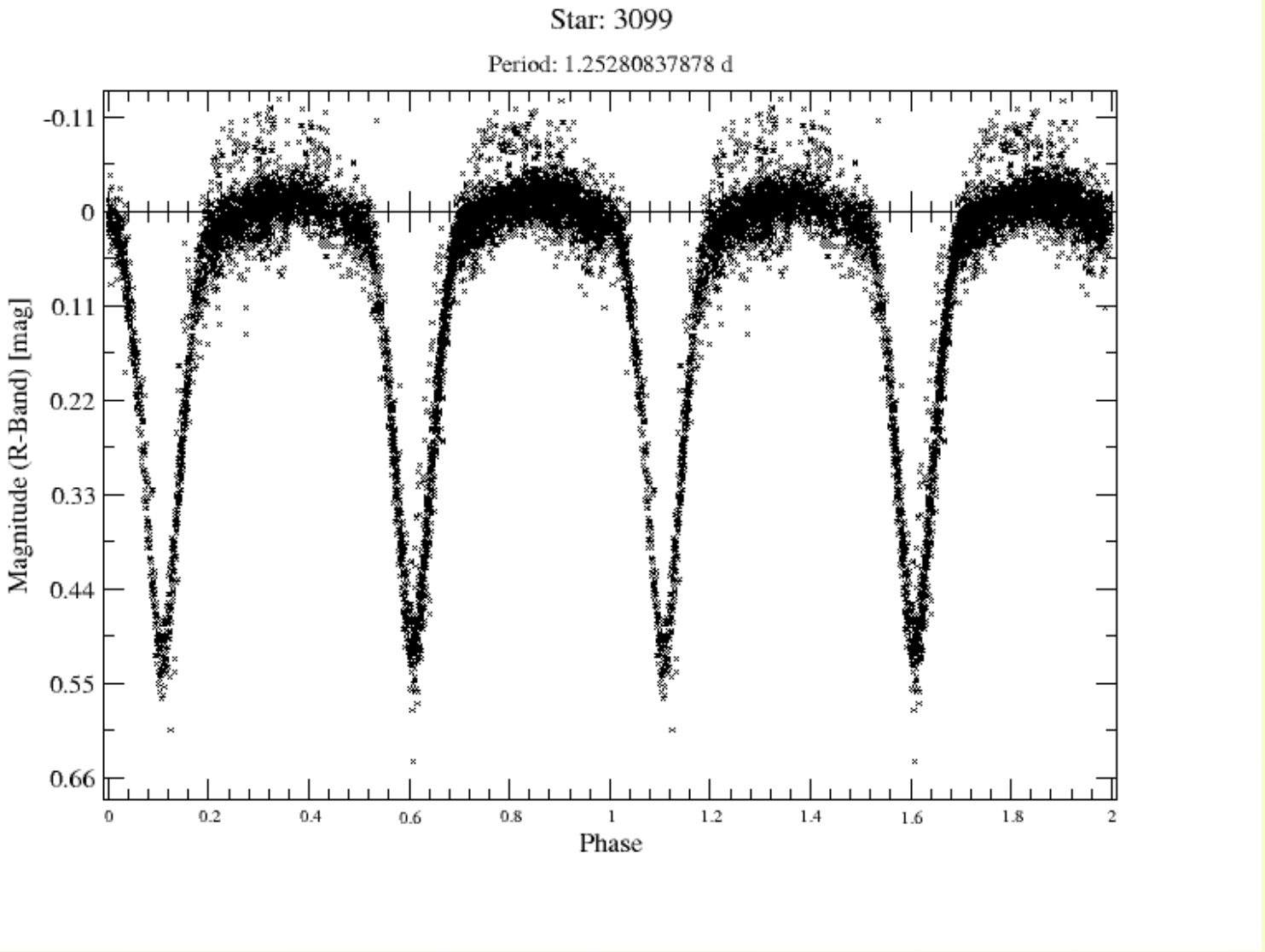


Eclipsing Binaries

Algol type

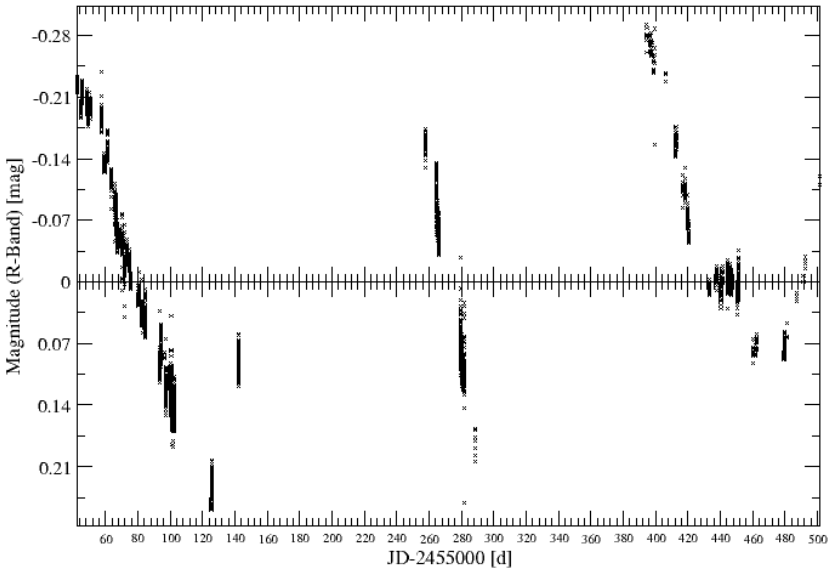
β Lyrae

W Ursa Majoris:
12 Stars
P = 0.3 ...1 d

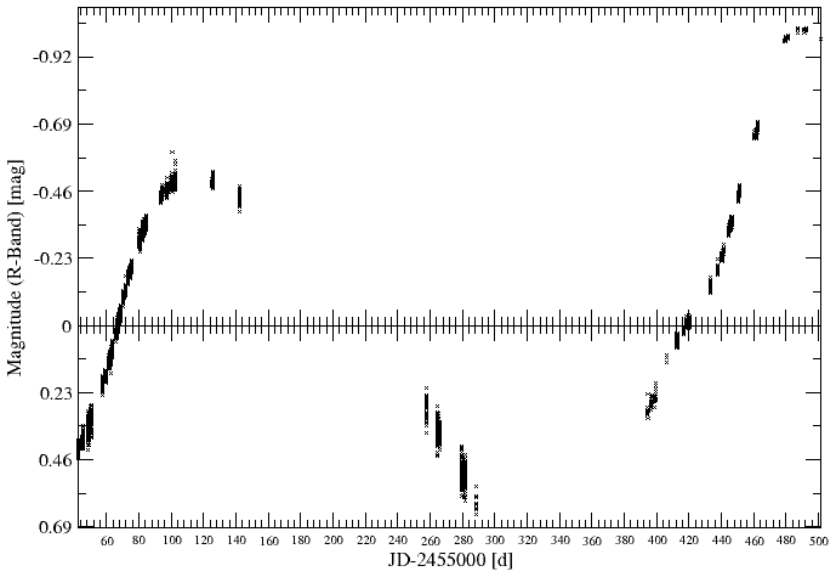


Longterm Variable (30 Stars)

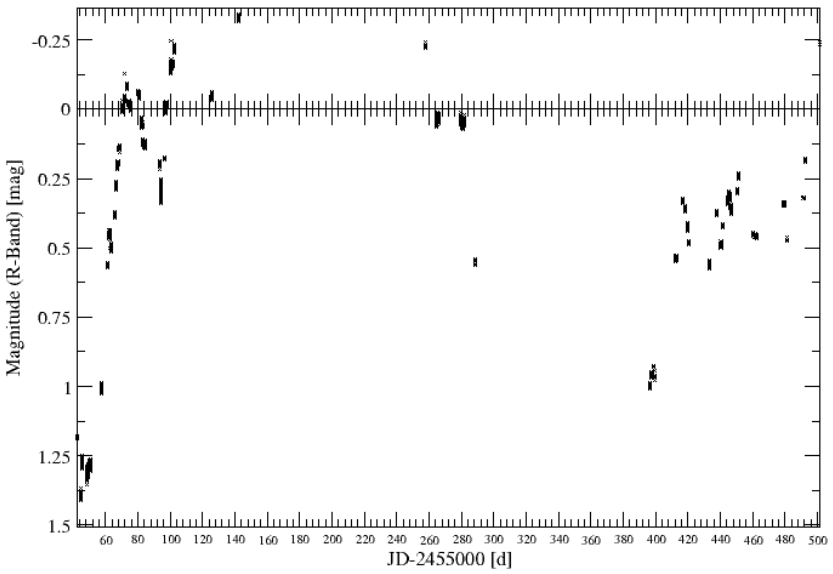
Star: 324



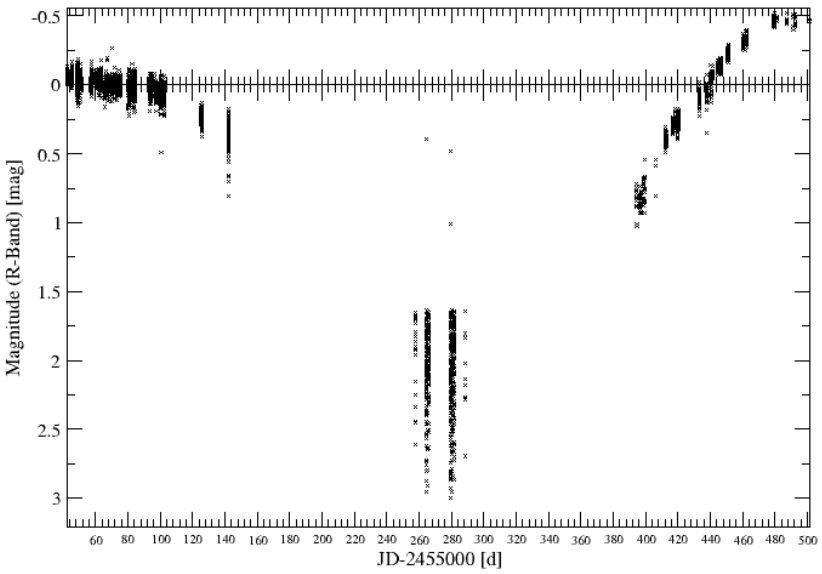
Star: 3034



Star: 463 (GM Cep)



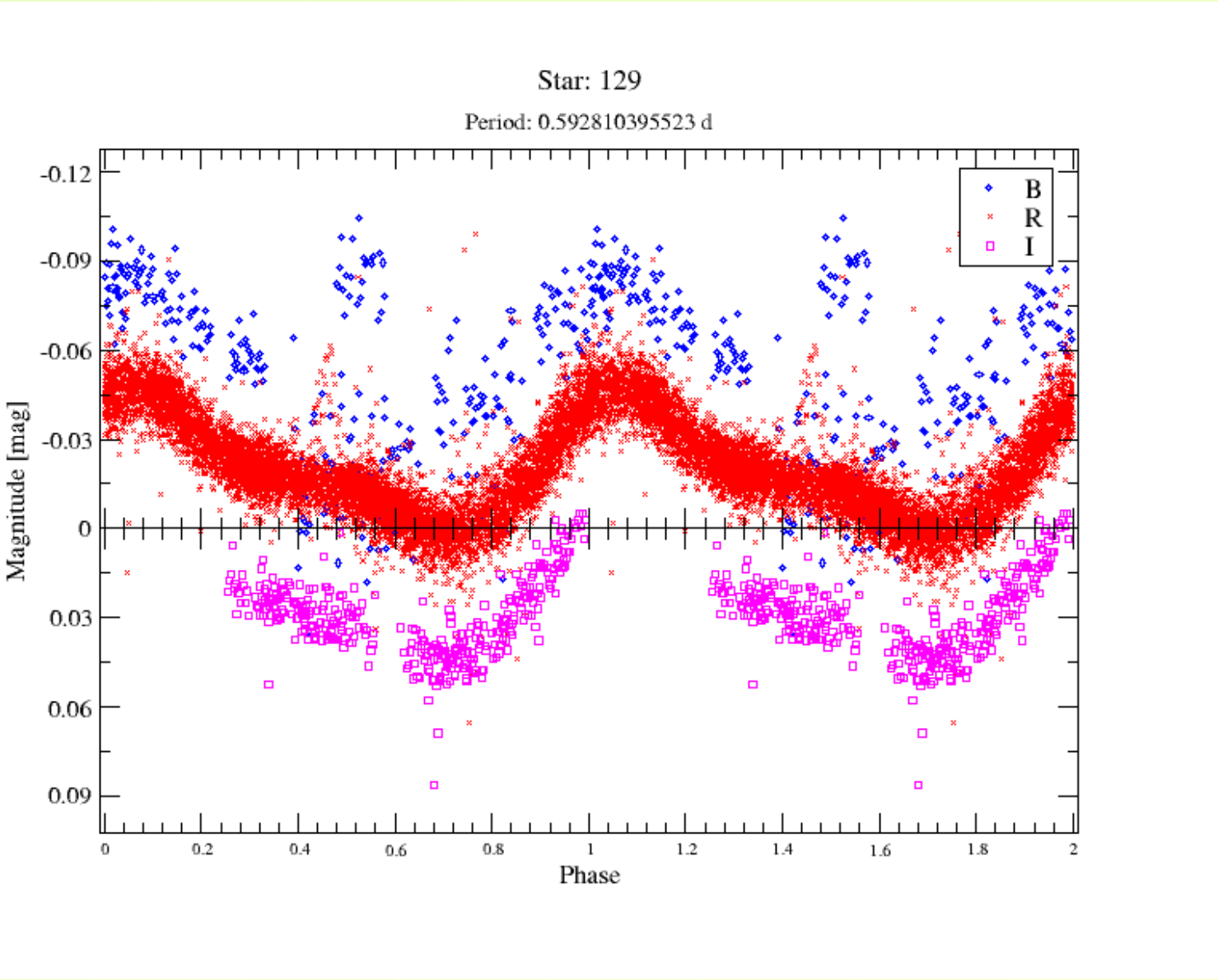
Star: 9875



Color Informations

Number of data points in the filters:

B	270
V	315
R	6680
I	340



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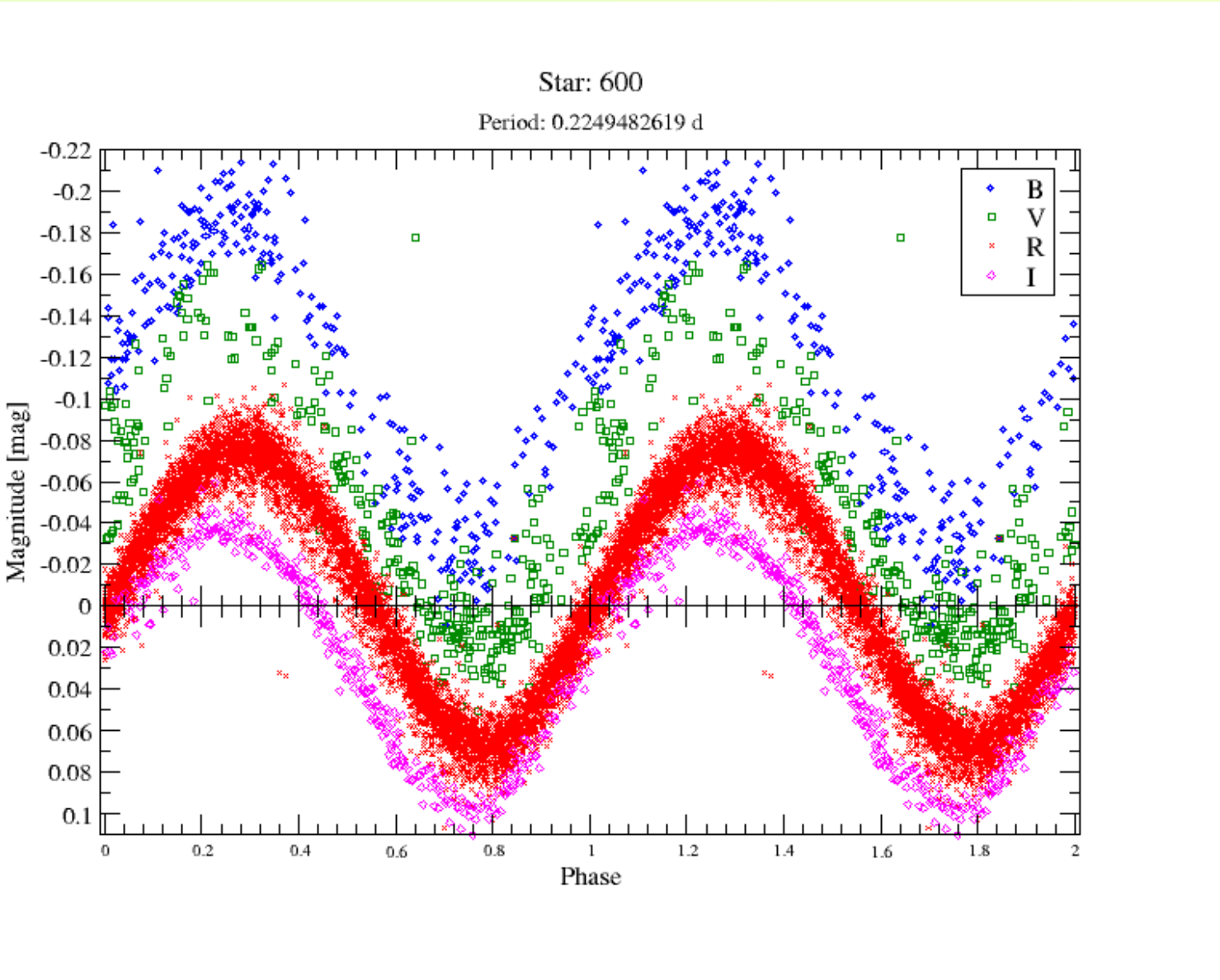


Transit-candidate

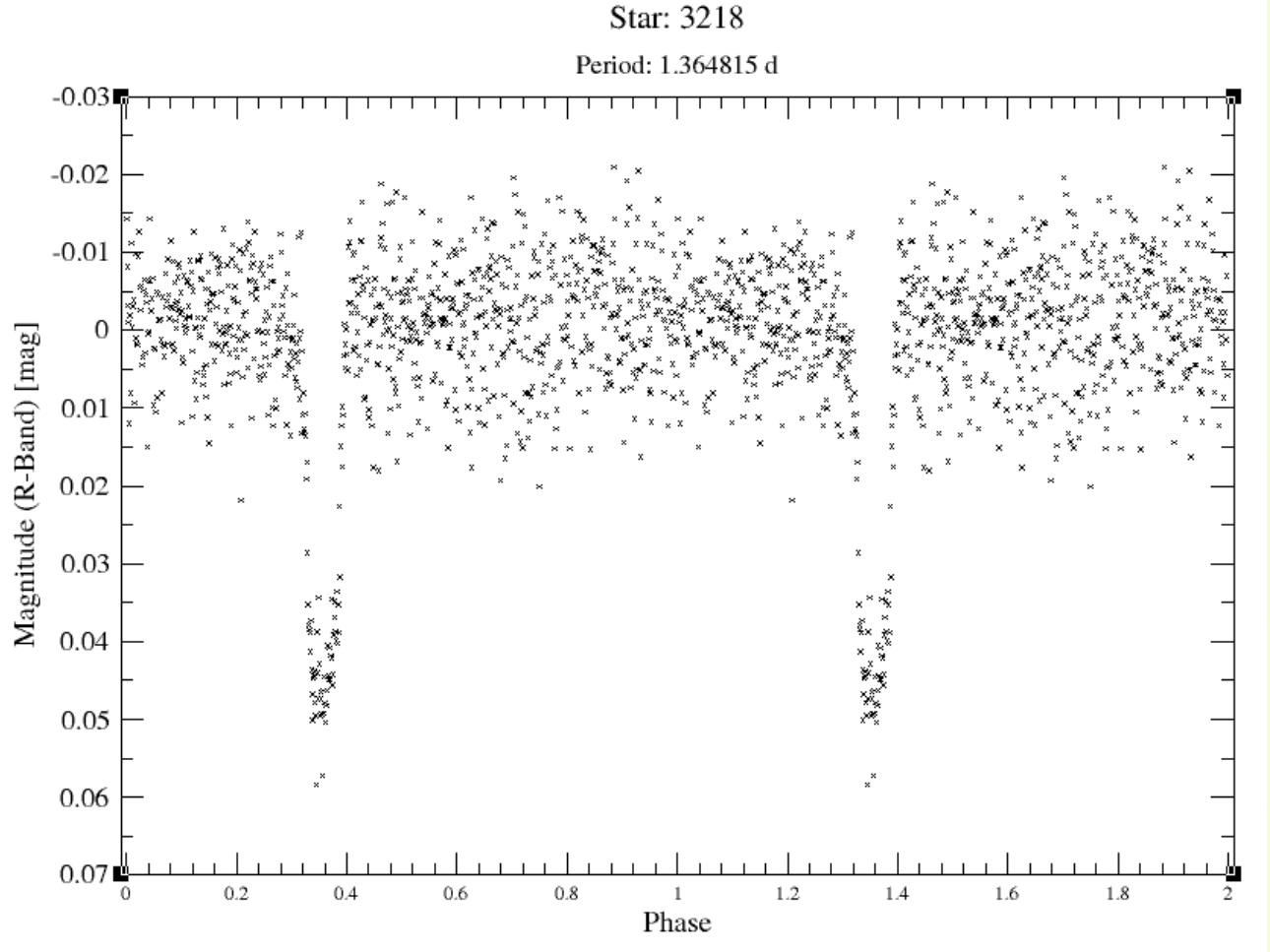
V = 15.55 mag
B-V = 1.02 mag
ΔR ≈ 0.045 mag

probable member in the cluster from:

- color-magnitude-diagram
- radial velocity
- proper motion

photometric spectral type:

G8-K5



phase folded and binned R-band lightcurve of the Jena data

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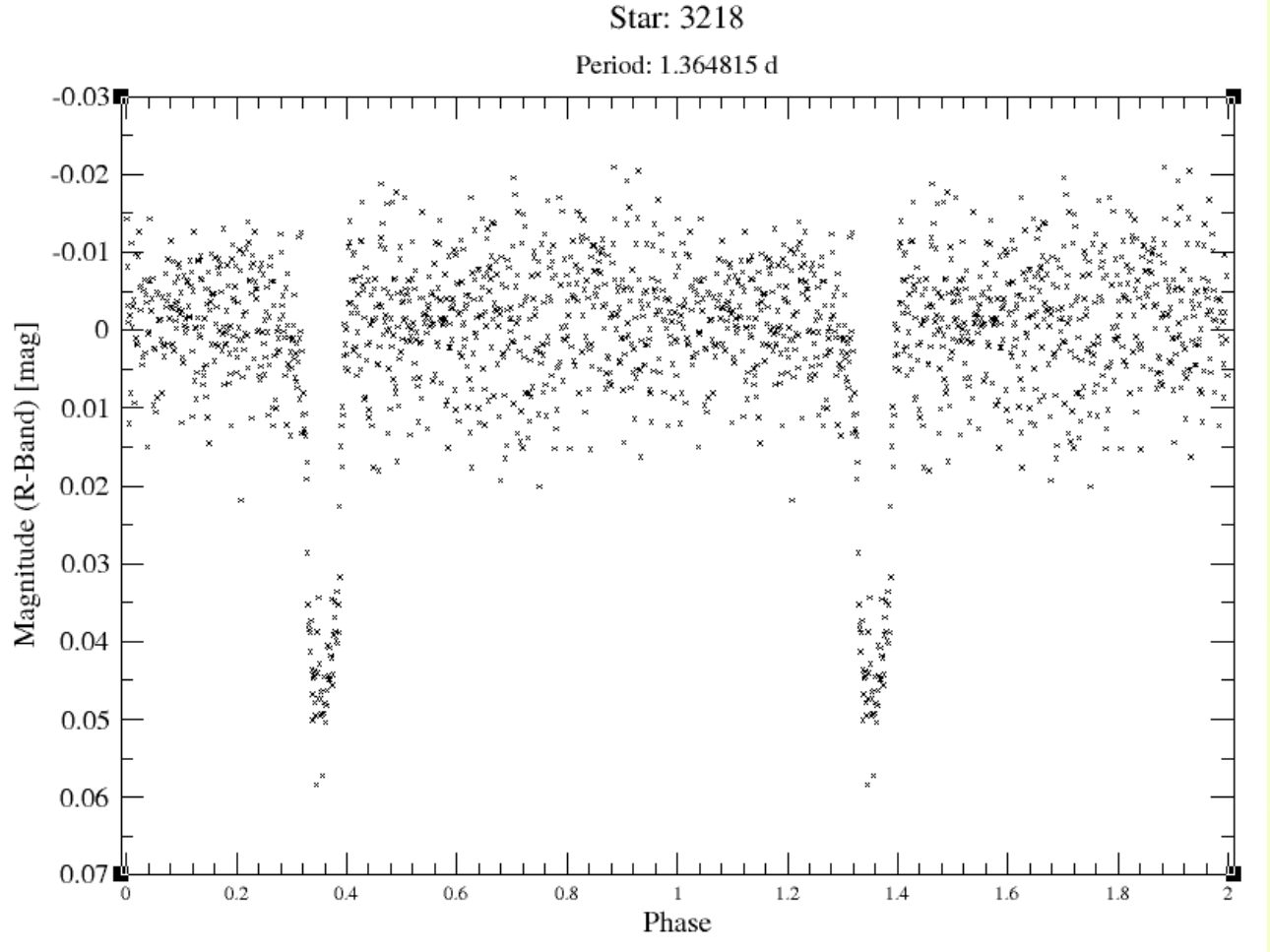
deep transit could be from young planet with ongoing contraction (R ≈ 1.7 R_{Jup})



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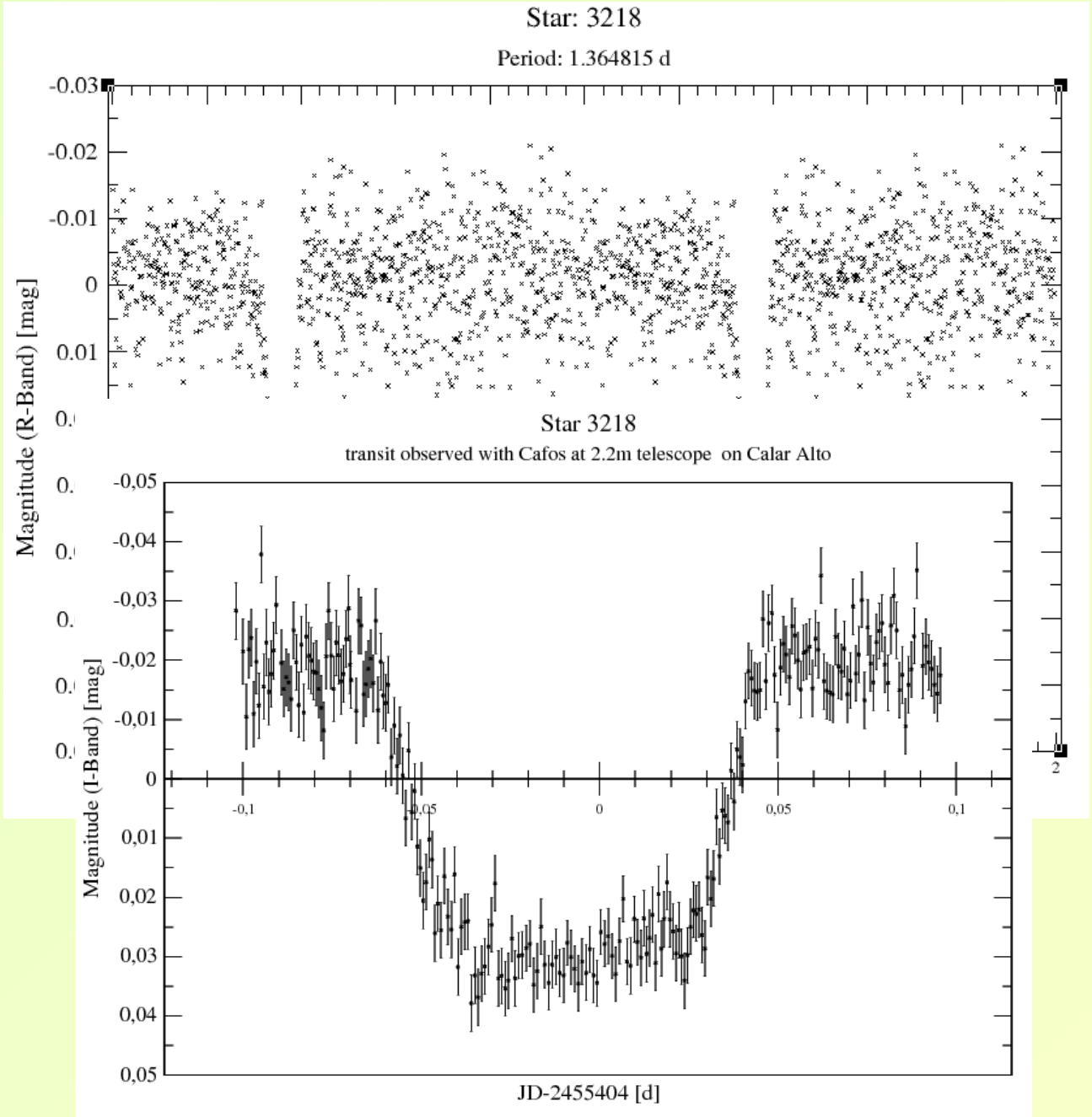
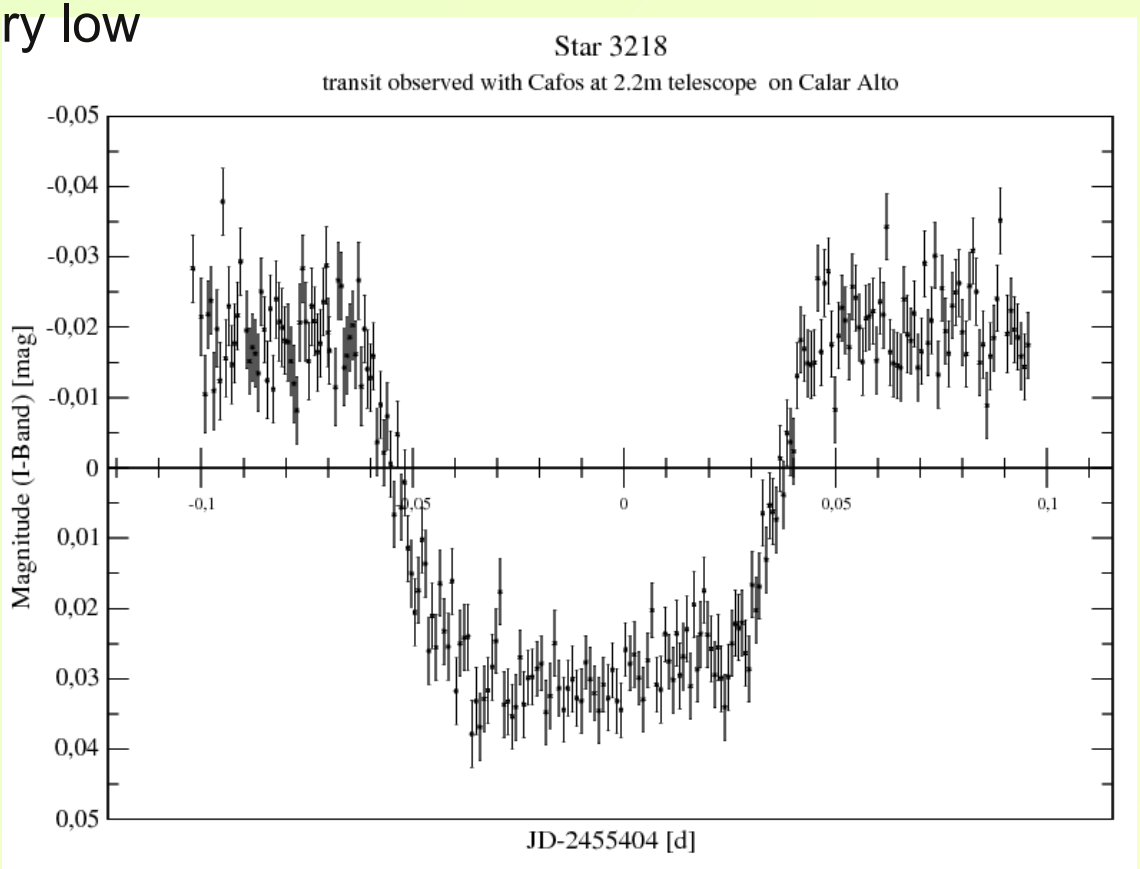
Photometry 2.2m Calar Alto:
ΔI ≈ 0.05 mag



Transit-candidate

Transit like light curve with flat-bottom dip can be due to either

- real planet transit
- or eclipsing background star in PSF
- or grazing eclipse of two stars
- or transiting brown dwarf or very low mass star



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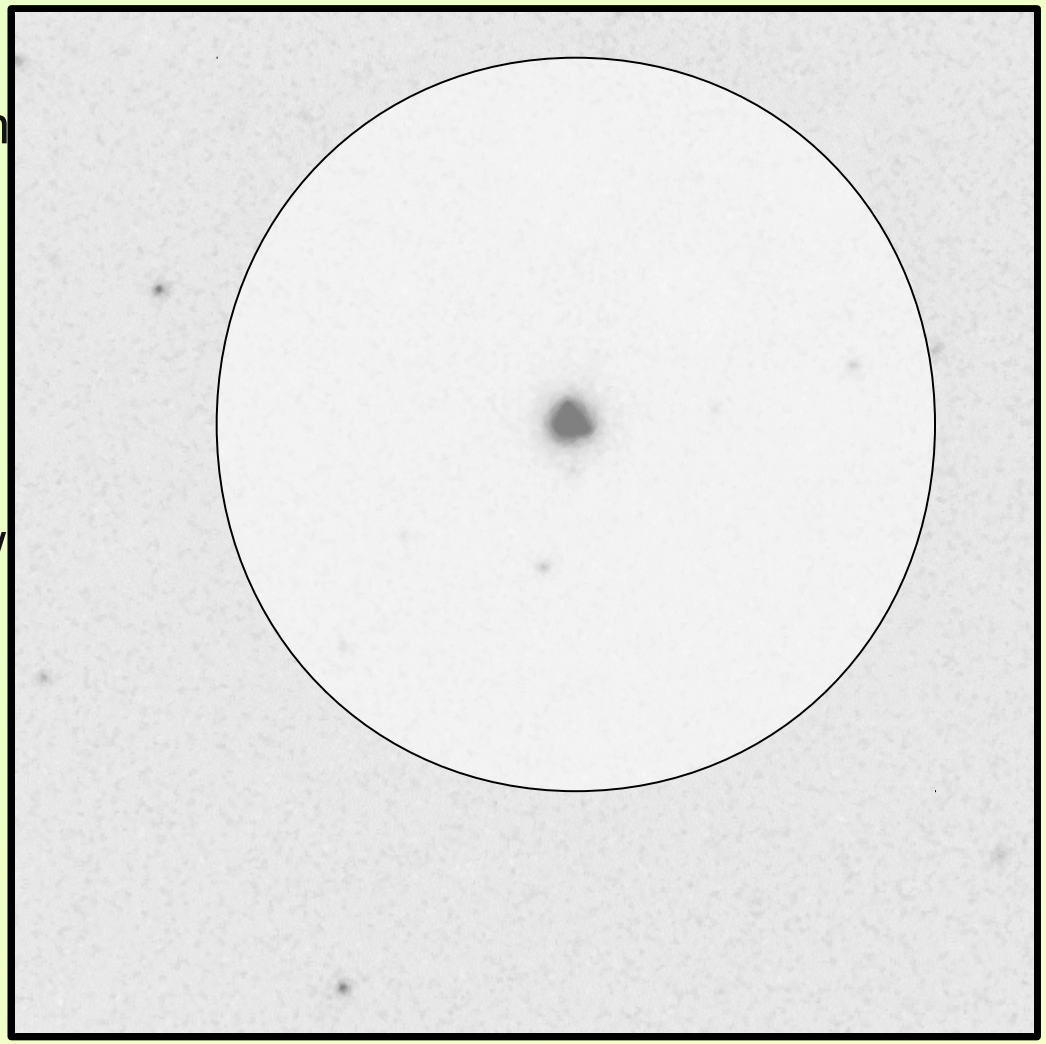
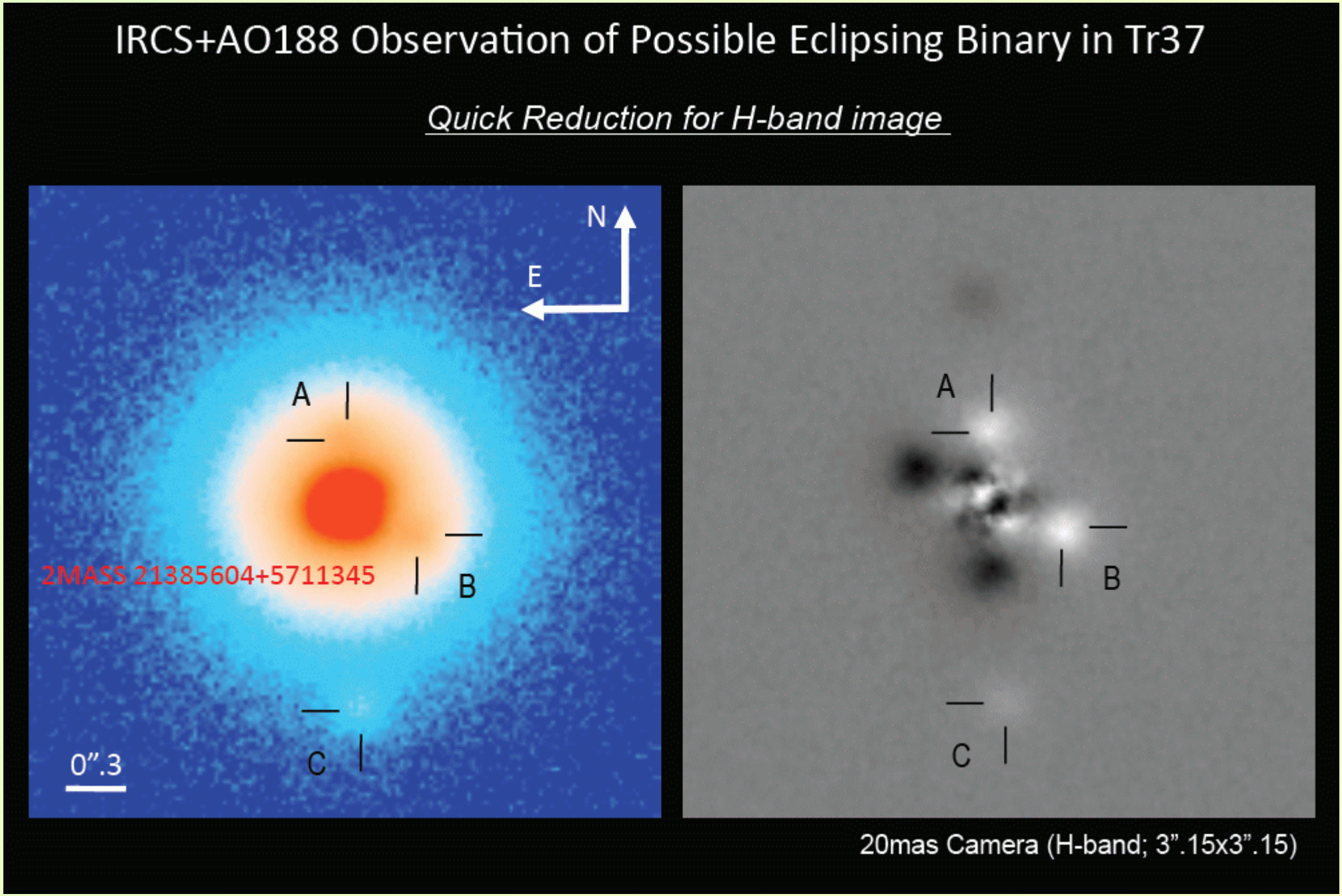
High resolution infrared imaging to check, whether there are other (eclipsing?) stars nearby (in the optical PSF)
→ 8m Subaru AO imaging



Transit-candidate - Subaru



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High resolution spectra yield radial velocity variation of host star and hence mass (M sin i) of companion
→ 10m Keck spectra

Follow up - Keck

Radial velocity orbit for transit candidate:
HIRES spectrograph at Keck telescope

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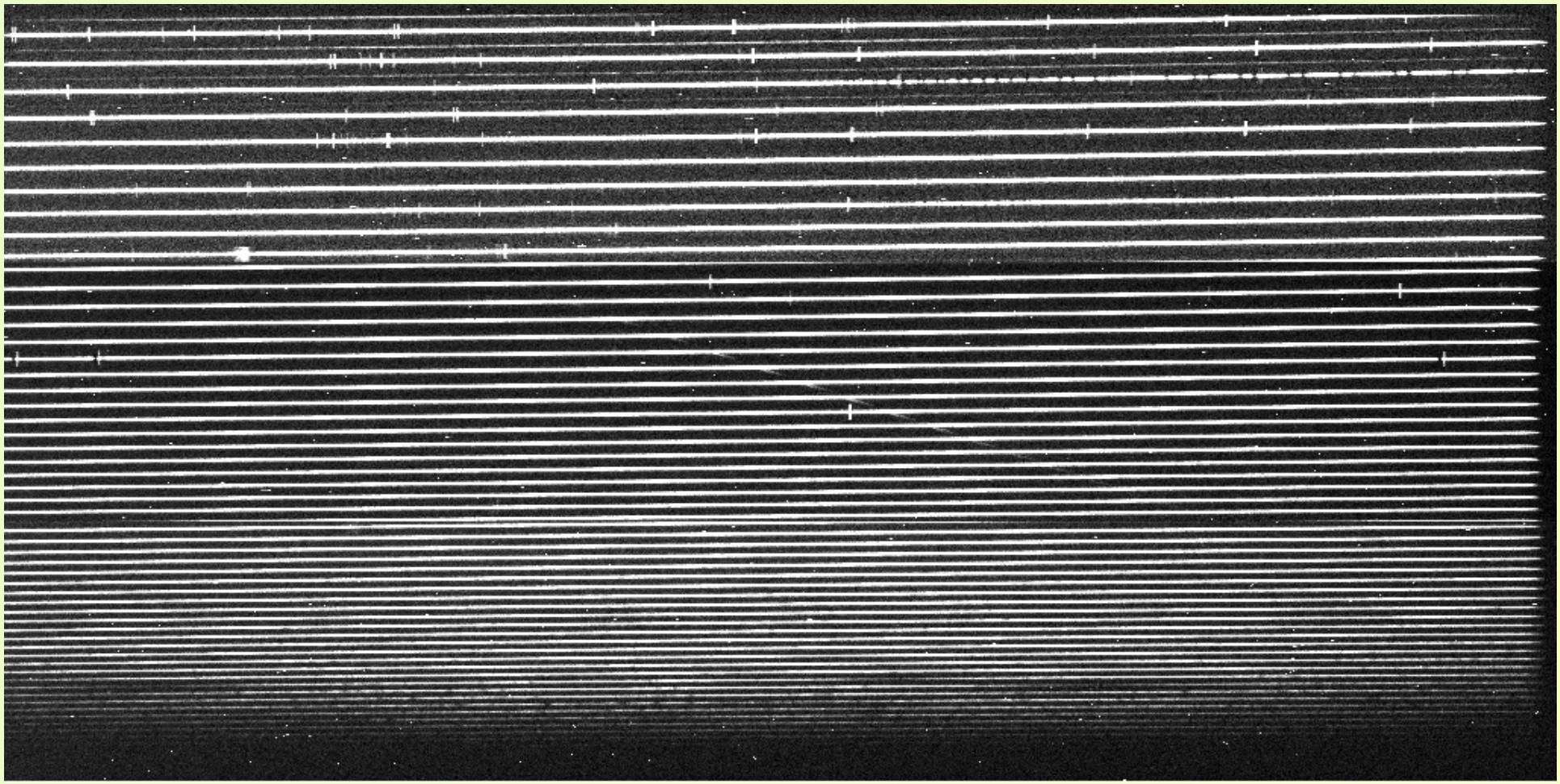
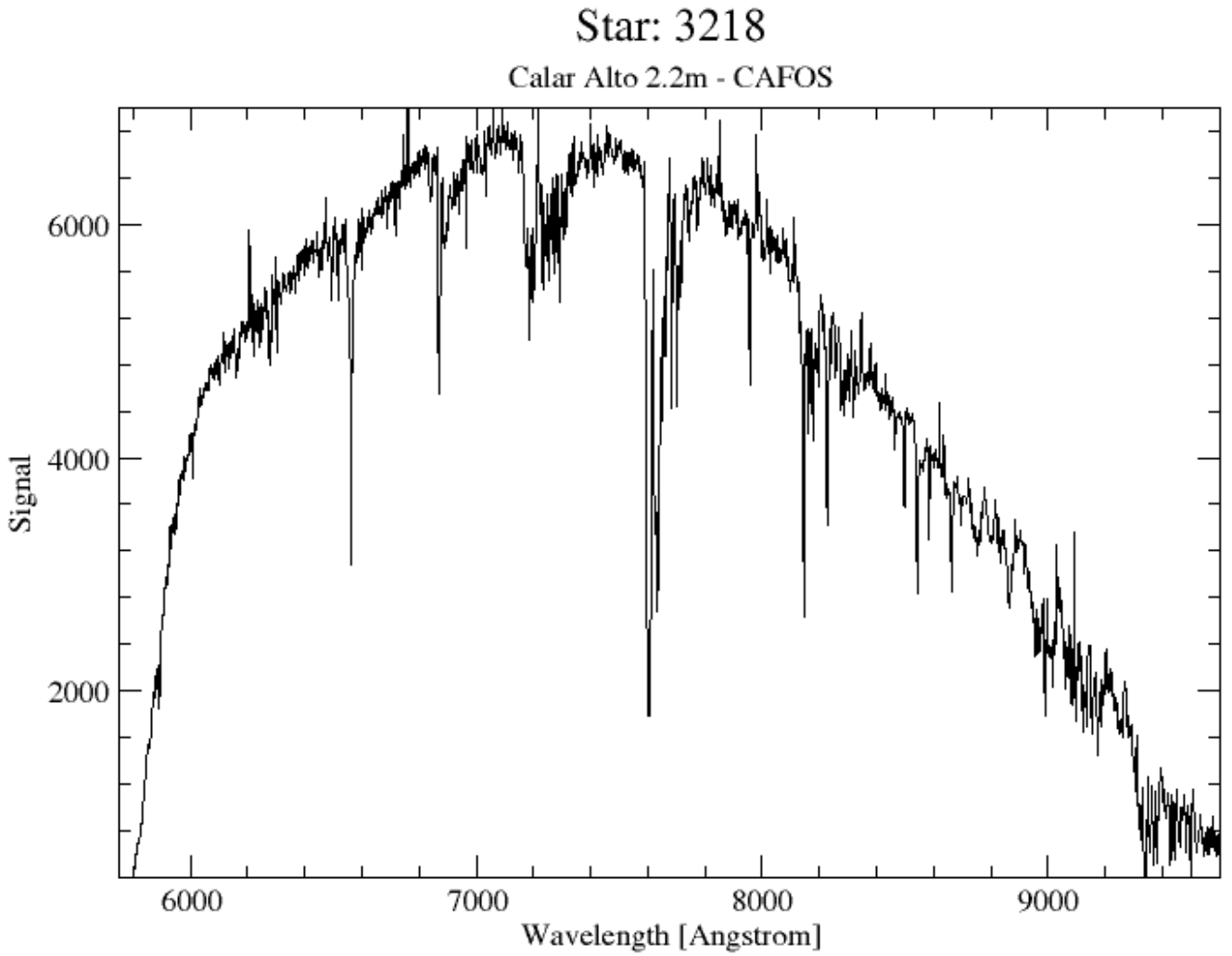


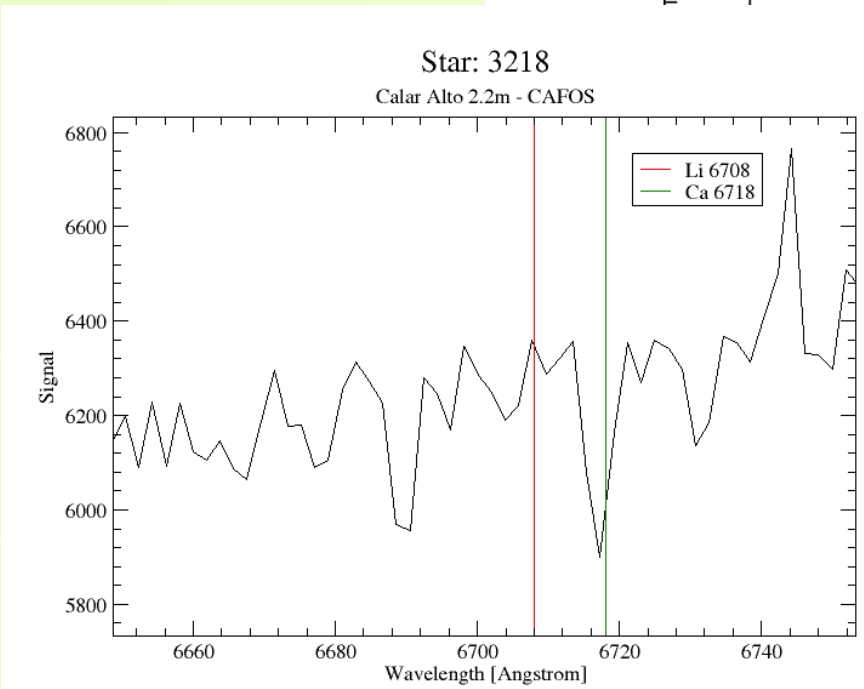
4950-9700Å
→ Reduction still ongoing

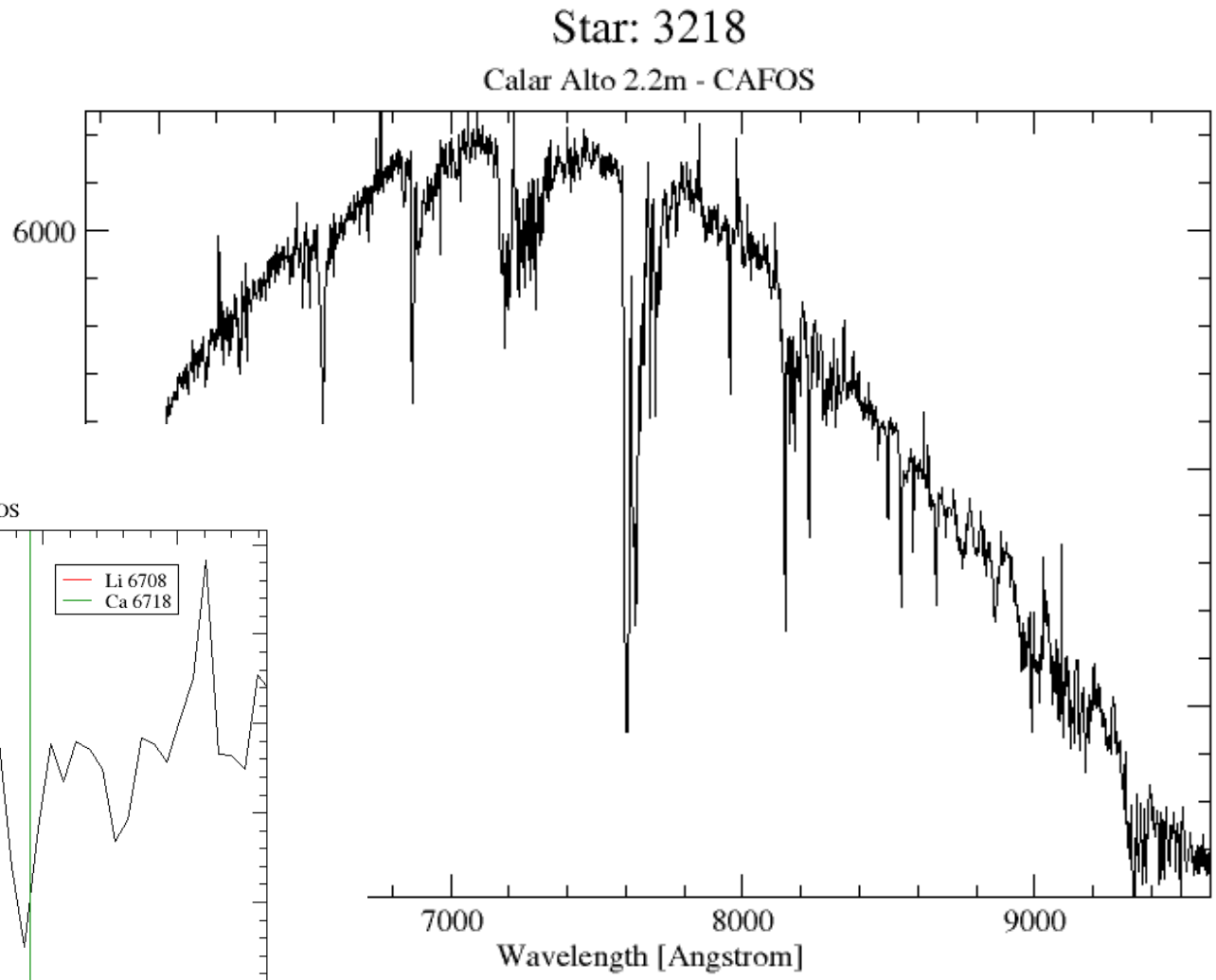
Follow up for eclipsing stars – CAFOS



Follow up for eclipsing stars – CAFOS

too less Li for
10 Myr old star
of spectral
type G-K





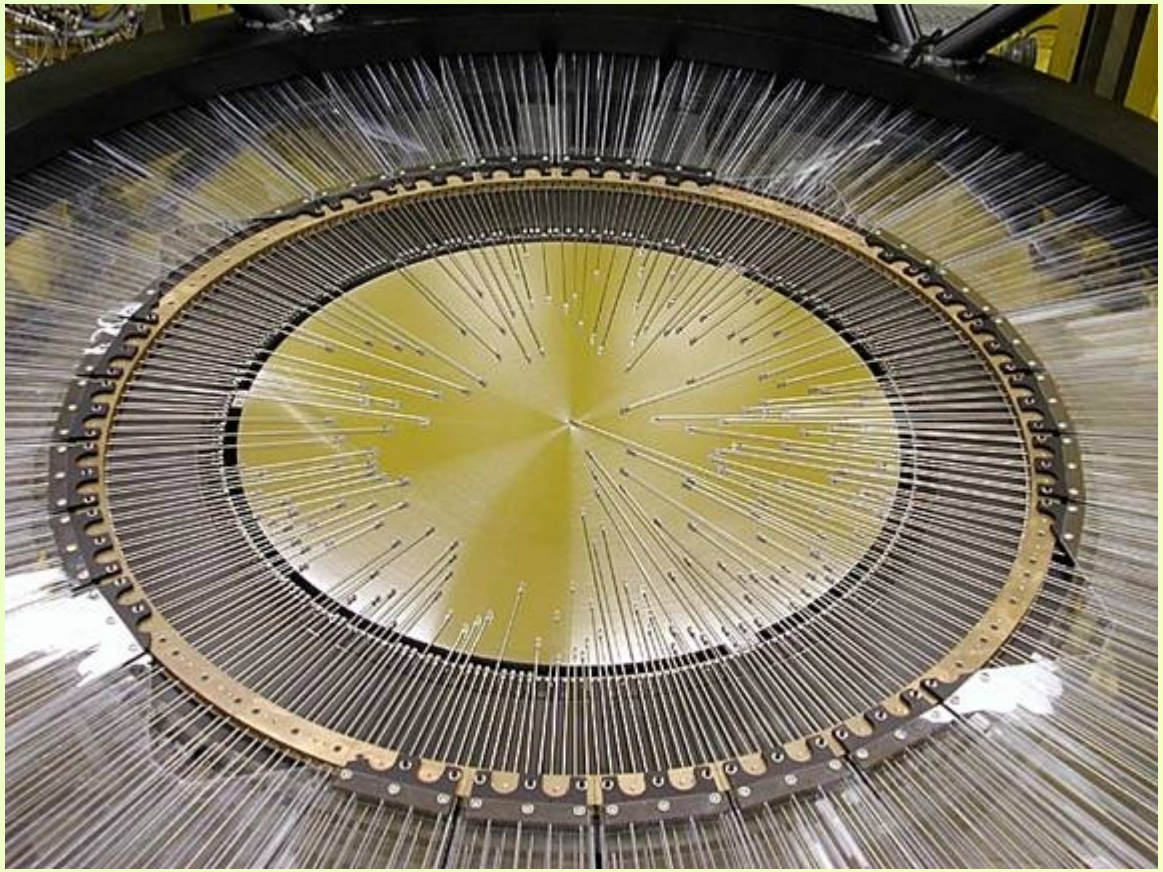
Follow up for Variable Stars – Hectochelle

(at MMT on Mount Hopkins/Arizona)

Membership in Cluster from:

- Radial velocity
- Spectral type

Cluster properties



Follow up for Variable Stars – Hectochelle

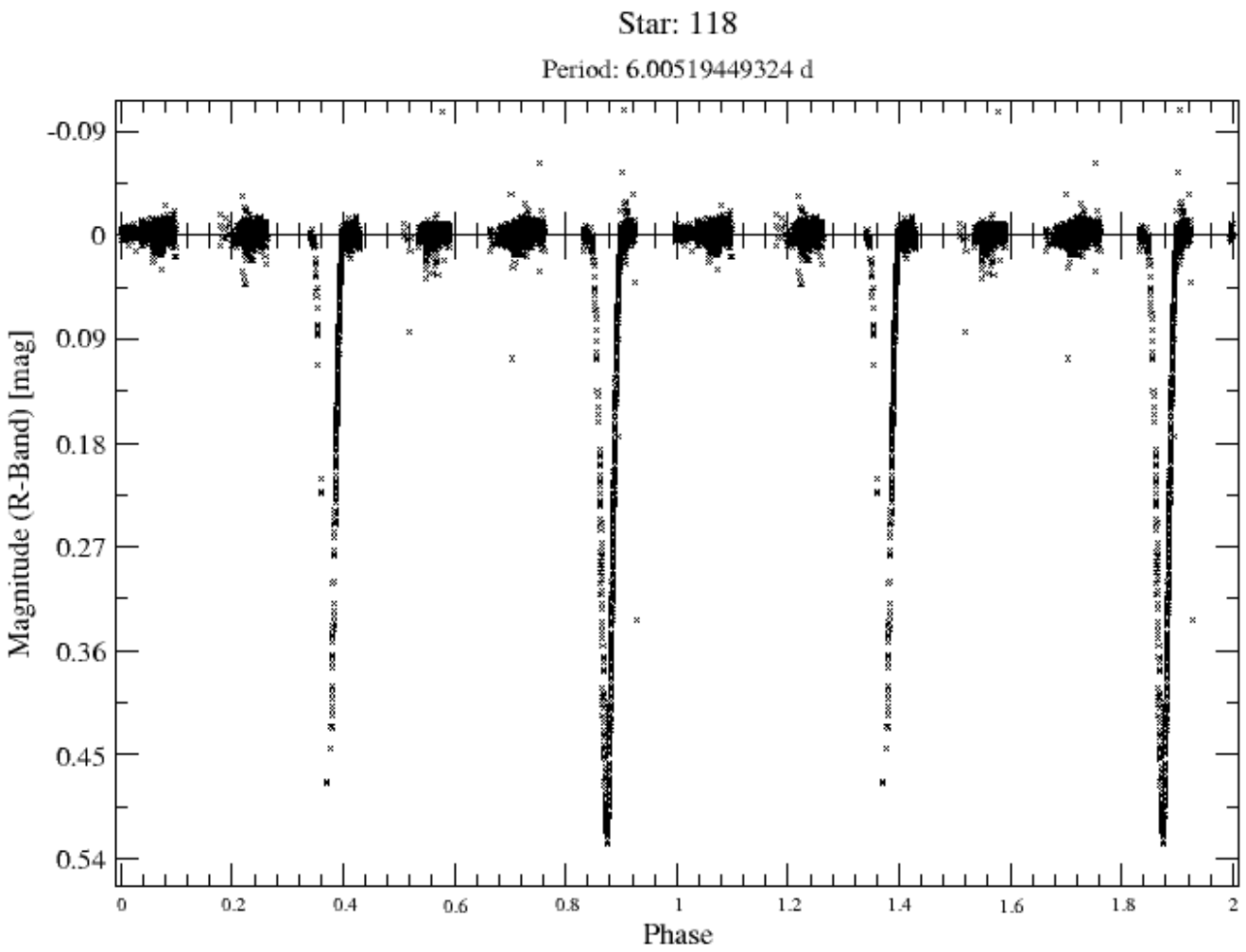
V =11.94 mag
B-V = 0.76 mag

photometric
spectral type: F9

P = 6.0052 d

ΔR_1 = 0.52 mag
ΔR_2 = 0.47 mag

CAFOS Spectra:
too less Li



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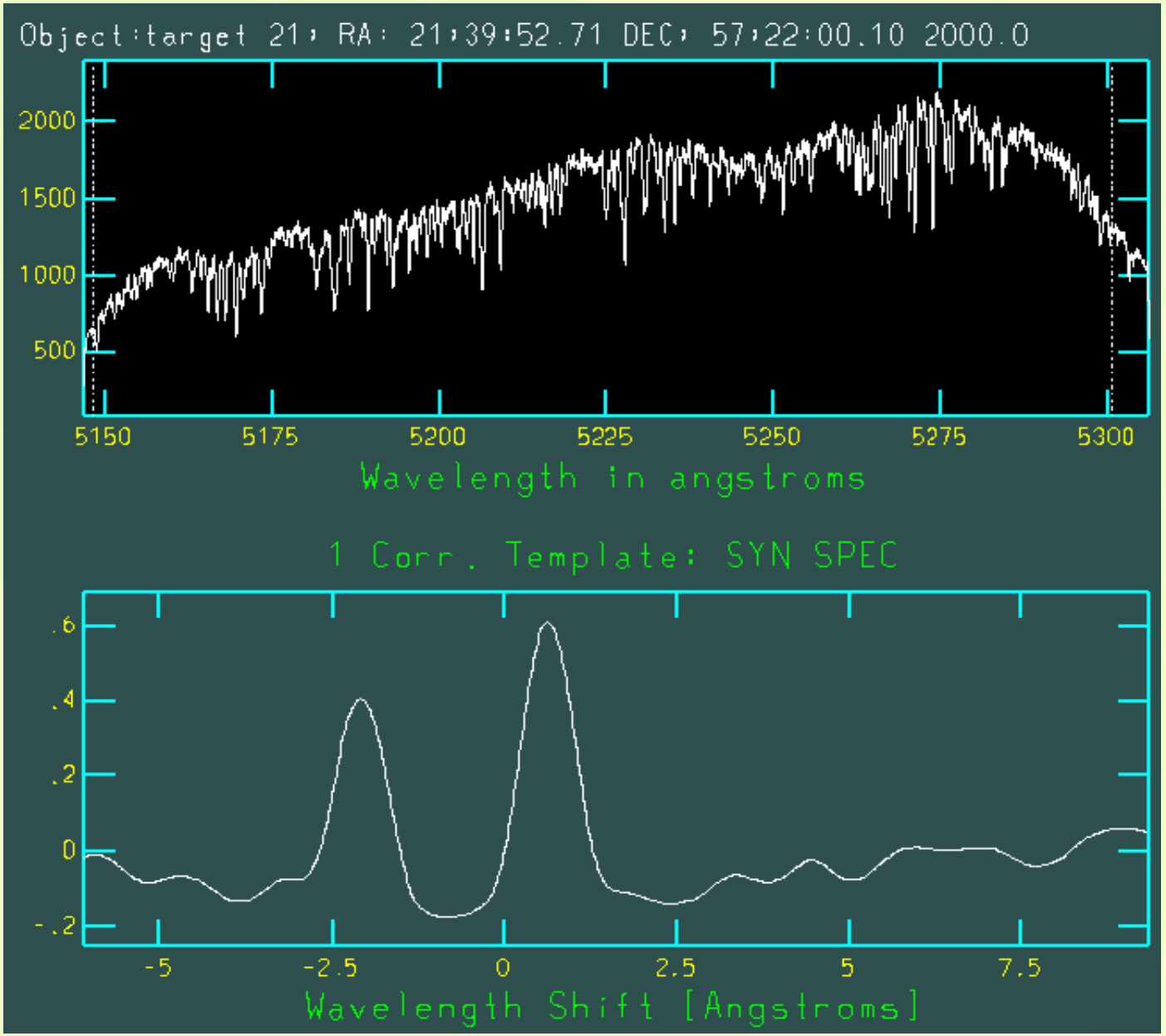
V =11.94 mag
B-V = 0.76 mag

photometric
spectral type: F9

P = 6.0052 d

ΔR_1 = 0.52 mag
ΔR_2 = 0.47 mag

Brighter:
T_{eff} = 6250 K
log g = 4.0
[m/H] = 0
v sin i =12 km/s



Follow up for Star 118 – TRES

From Dave Latham & Sam Quinn (only for this single star)

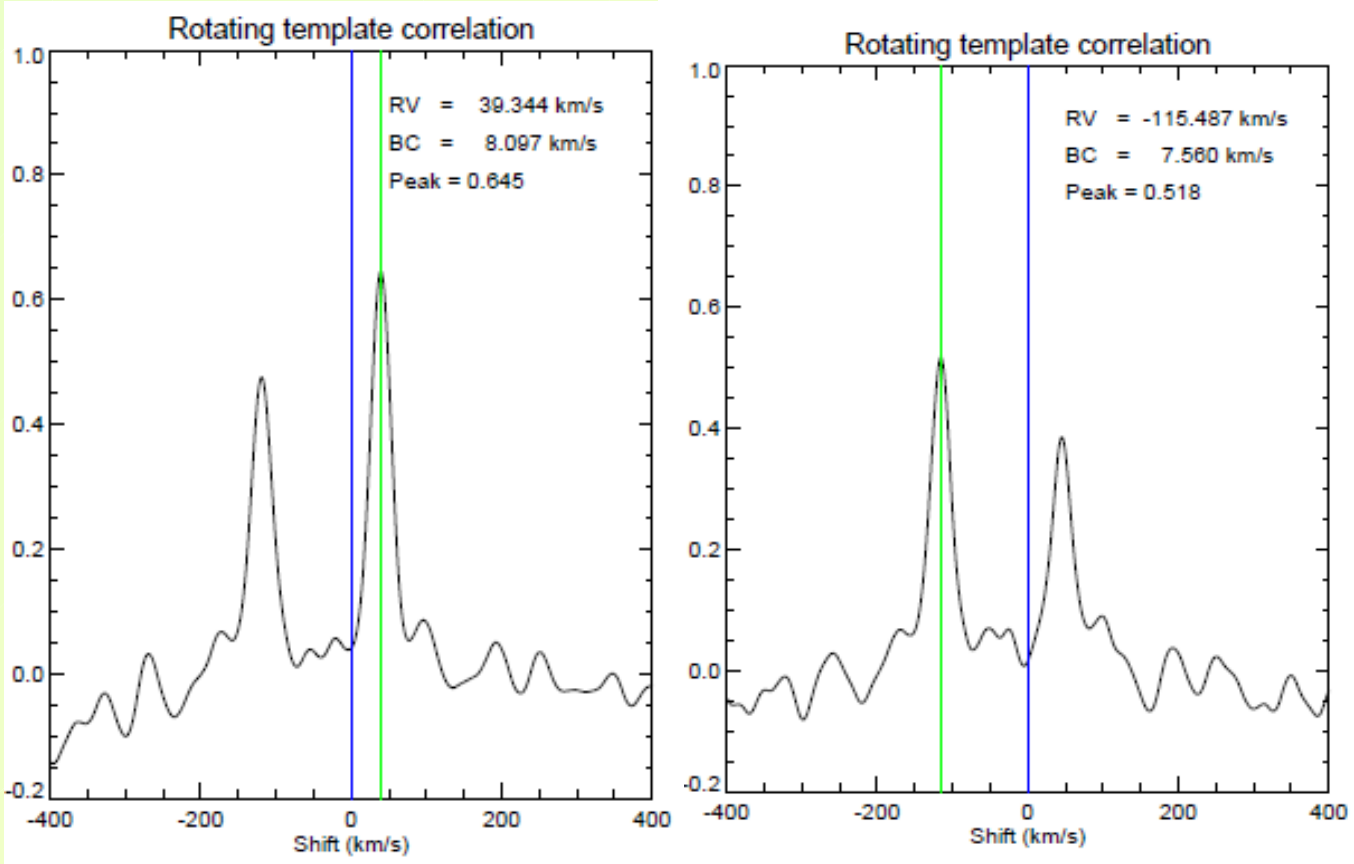
2 Spectra near quadratures

cz = -15.9 km/s

M_1 = 1.32 M_{sun}
M_2 = 1.25 M_{sun}

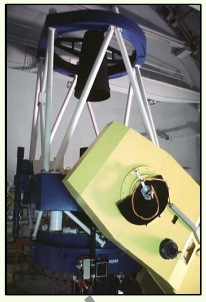
→ 2 G-type stars orbiting each other

no member of cluster due to Li equivalent width



Multi-site campaign on Trumpler 37

Calar Alto
Astronomical Observatory
2.2-m telescope

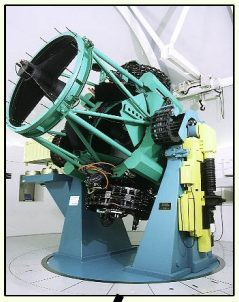


Jena
Astrophysical Institute
0.9/0.6-m telescope

Stará Lesna
Astronomical Institute
0.6-m telescope

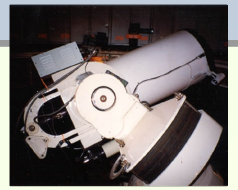
Byurakan
Astrophysical Observatory
1.0- and 2.3-m telescopes

Gunma
Astronomical Observatory
1.5-m telescope



Tenagra II
Observatory
0.8-m telescope

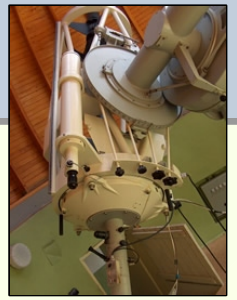
Gettysburg
Gettysburg College
0.4-m telescope



Swarthmore
Peter van de Kamp Observ.
0.6-m telescope

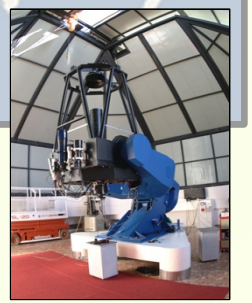
Toruń
Centre for Astronomy
0.6-m telescope

Rozhen
Astronomical Observatory
0.6- and 2.0-m telescopes



Xinglong
National Astronomical O.
0.9/0.6-m telescope

Lulin
Lulin Observatory
1.0-m telescope



Multi-site campaign on Trumpler 37

Dates of the 3 runs:

3.8. - 12.8.2010
26.8. - 12.9.2010
24.9. - 30.9.2010

	3.8	4.8	5.8	6.8	7.8	8.8	9.8	10.8	11.8	12.8
Gunma	-	-	-	-	122	-	-	-	-	-
Lulin	-	-	-	560	704	-	688	432	-	768
Xinglong	-	-	140	82	-	-	29	10	-	-
Byurakan	-	37	-	44	27	-	-	-	-	-
Stara Lesna	-	-	-	-	79	-	-	301	175	214
Rohzen	232+380	-	82	362	362	370	66	400	-	-
Jena	208	244	-	-	92	-	106	232	188	-
Calar Alto	?	-	?	?	-	-	-	-	-	-
Swarthmore	-	-	508	416	552	-	-	100	-	-
Gettysburg	-	-	-	-	-	-	-	32	-	-
Tenagra	-	-	-	-	-	-	-	-	-	-

Number of Pictures taken with the different telescopes

Multi-site campaign on Trumpler 37

Dates of the 3 runs:
3.8. - 12.8.2010
26.8. - 12.9.2010
24.9. - 30.9.2010

	26.8	27.8	28.8	29.8	30.8	31.8	1.9	2.9	3.9	4.9	5.9	6.9	7.9	8.9	9.9	10.9	11.9	12.9
Gunma	-	-	-	-	-	-	-	-	150	36	-	-	-	-	-	-	-	-
Lulin	120	-	-	32	-	-	-	-	-	-	188	-	126	-	-	320	290	224
Xinglong	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Byurakan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stara Lesna	-	-	-	-	-	-	-	-	-	-	-	180	280	-	-	-	-	-
Rohzen	380+496	436+520	478+520	-	-	-	404	426	-	-	-	-	-	-	-	-	-	-
Jena	-	-	74	-	-	90	46	-	-	274	304	288	-	-	-	358	200	-
Calar Alto	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swarthmore	257	252	-	-	-	-	704	-	-	744	576	170	-	656	-	-	-	-
Gettysburg	-	-	-	-	48	-	-	-	-	-	56	-	-	-	-	-	-	-
Tenagra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Number of Pictures taken with the different telescopes

Multi-site campaign on Trumpler 37

Dates of the 3 runs:

3.8. - 12.8.2010

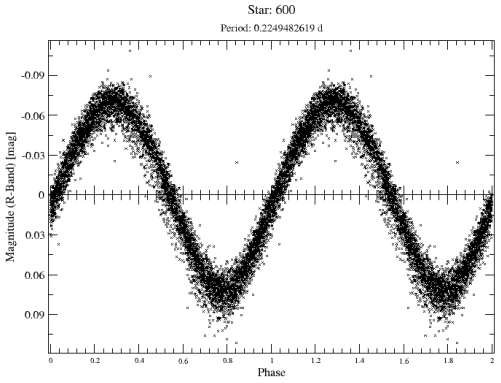
26.8. - 12.9.2010

24.9. - 30.9.2010

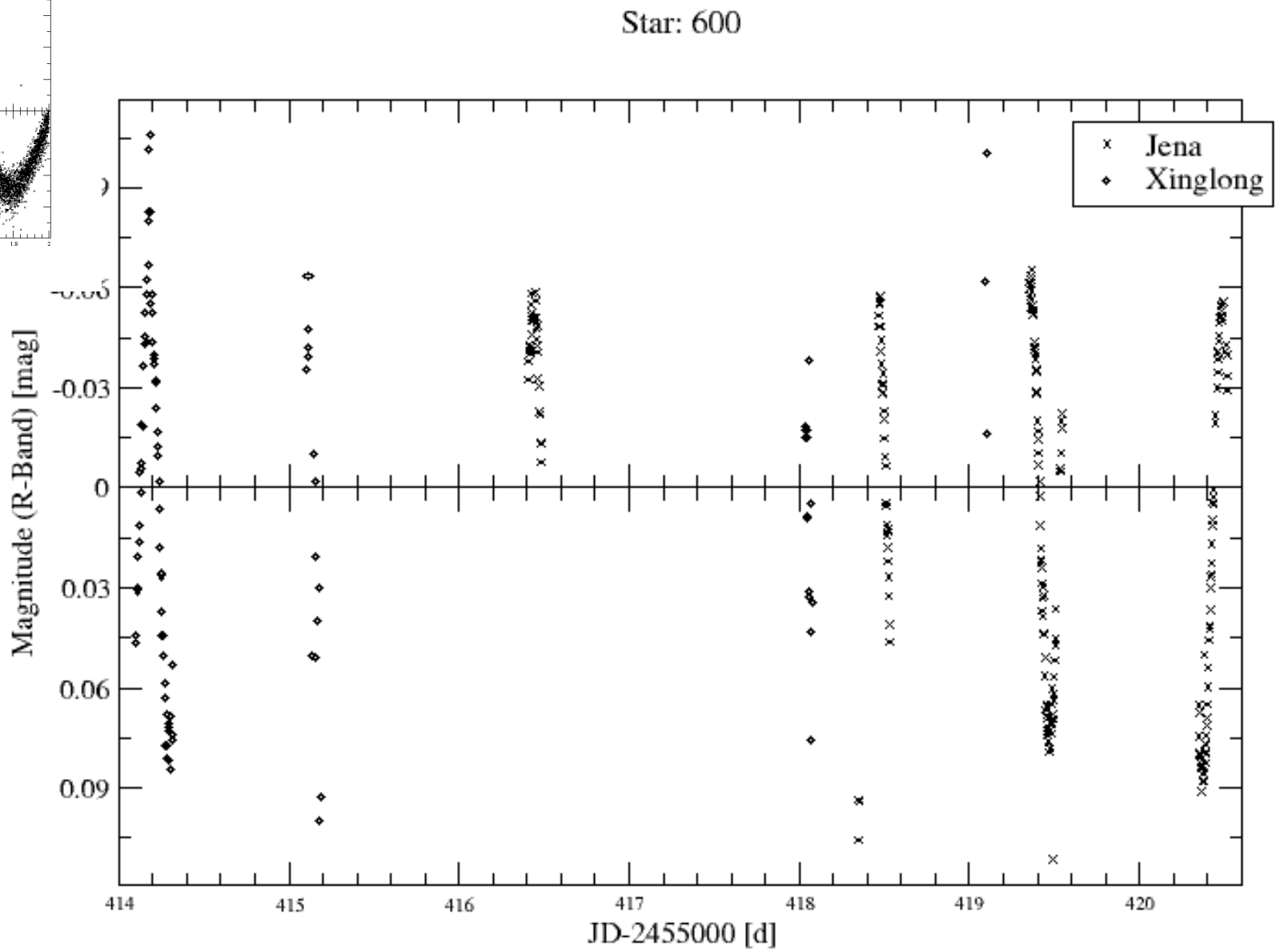
	24.9	25.9	26.9	27.9	28.9	29.9	30.9
Gunma	-	129	171	-	150	-	-
Lulin	152	12	96	200	236	256	220
Xinglong	162	-	175	162	159	161	155
Byurakan	-	-	-	-	-	-	-
Stara Lesna	311	-	-	-	-	-	-
Rohzen			195+310	292+542	172+212	-	-
Jena	-	-				-	-
Calar Alto	-	-	-	-	-	-	-
Swarthmore	232	313	-	-	-	-	-
Gettysburg	-	-	-	-	-	-	-
Tenagra	319	344	316	339	298	335	300

Number of Pictures taken with the different telescopes

Results of Xinglong and Jena

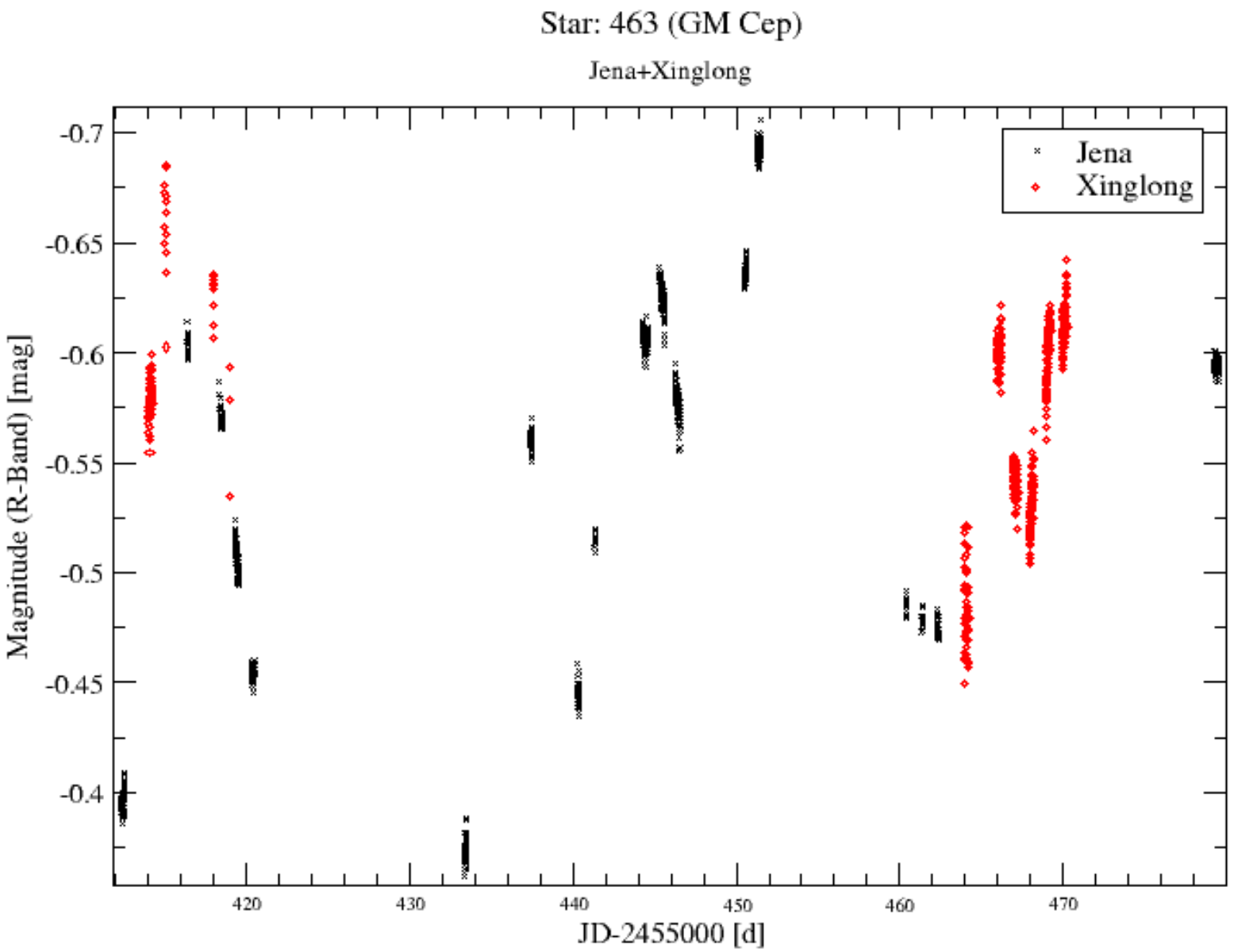


Data from first run



Results of Xinglong and Jena

Star: GM Cep:
Flare Star



Data
from all 3
runs

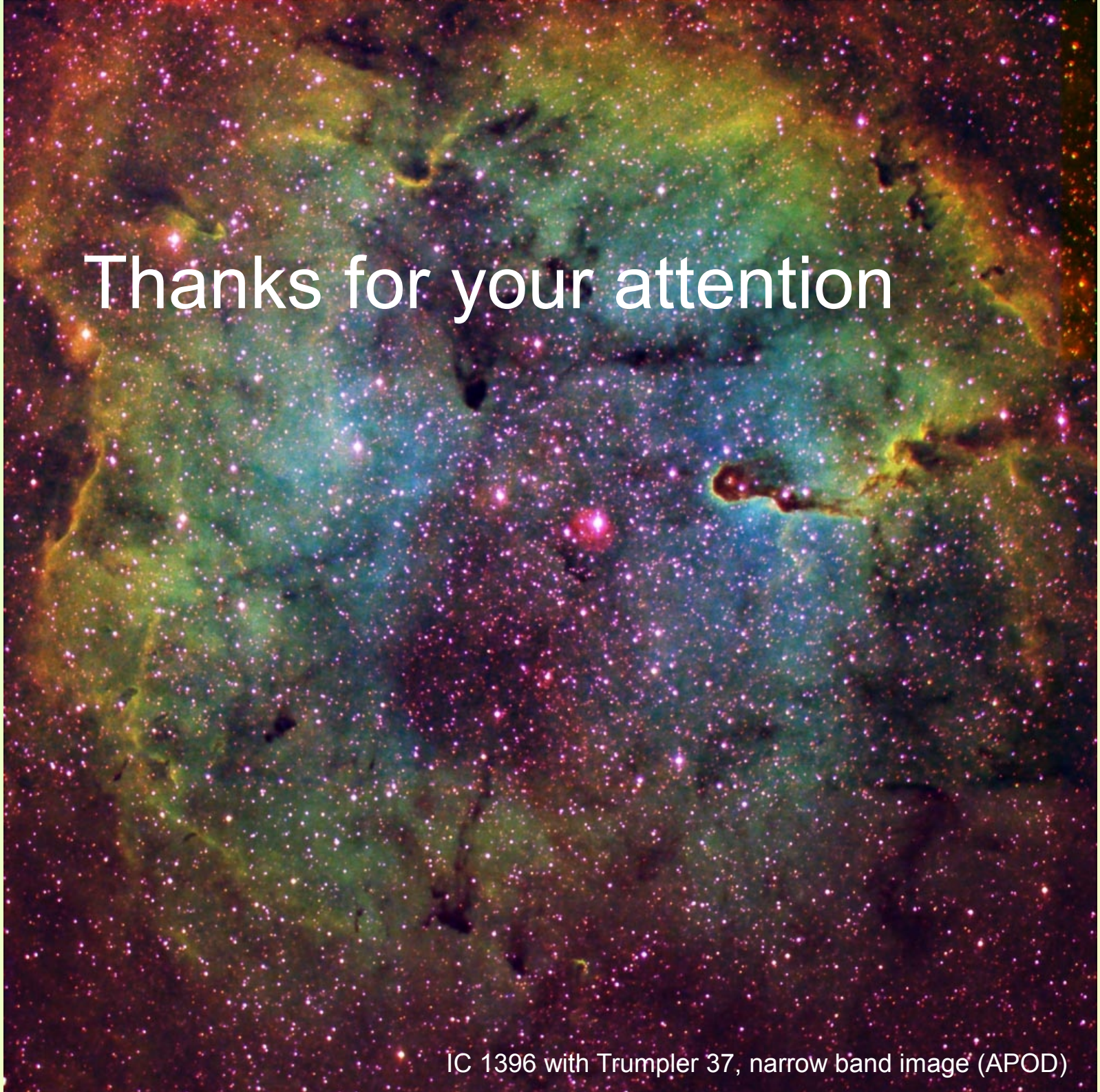
Further investigations

Reducing Trumpler 37 data from summer 2010
→ some more transit candidates and variable stars expected

Adding up pictures → for fainter stars better precision
→ new transit candidates

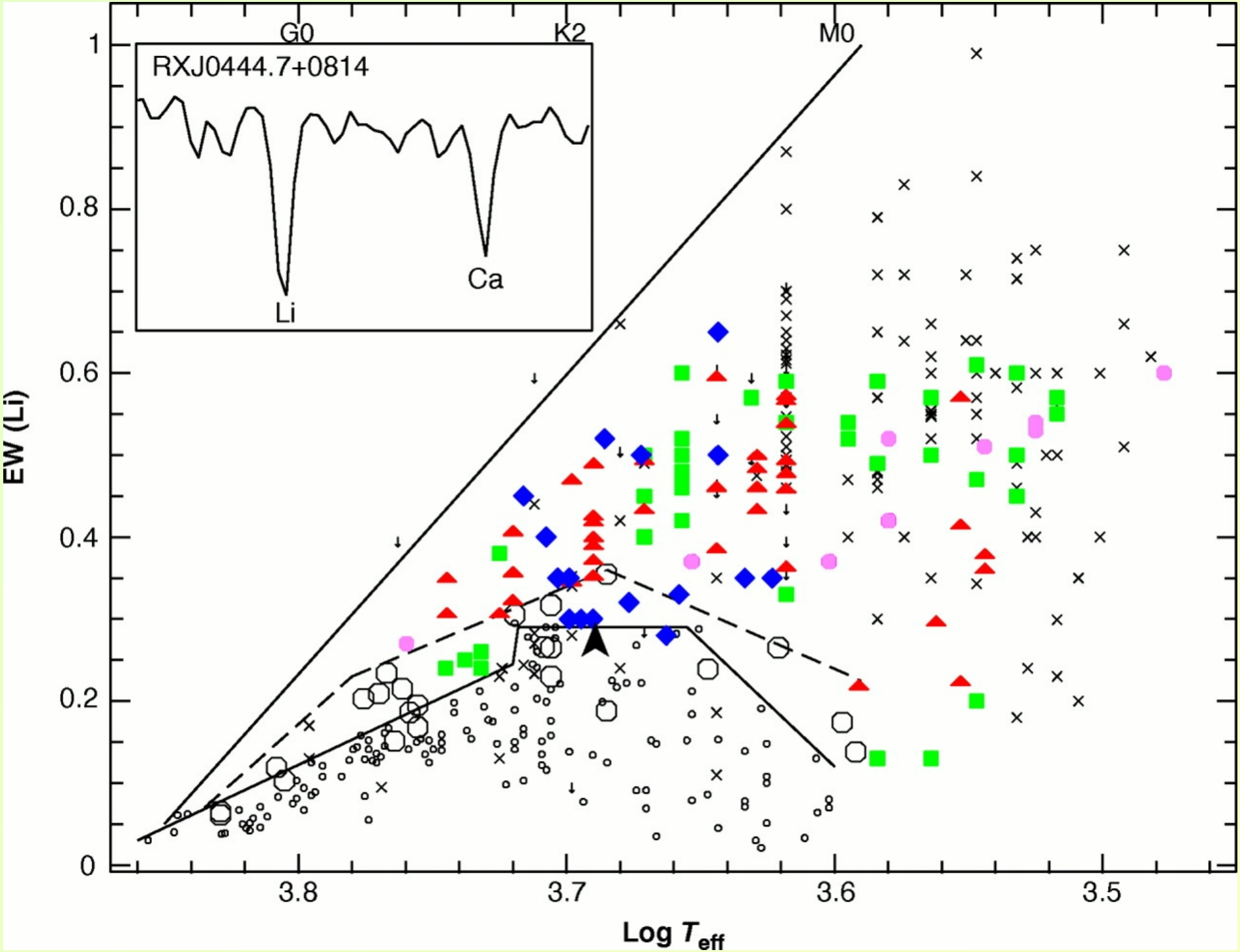
Additional Follow up observations (membership, orbits, ...)

Goal: young stars and planets to constrain formation models, to study planetary interior, and to compare with solar system planets

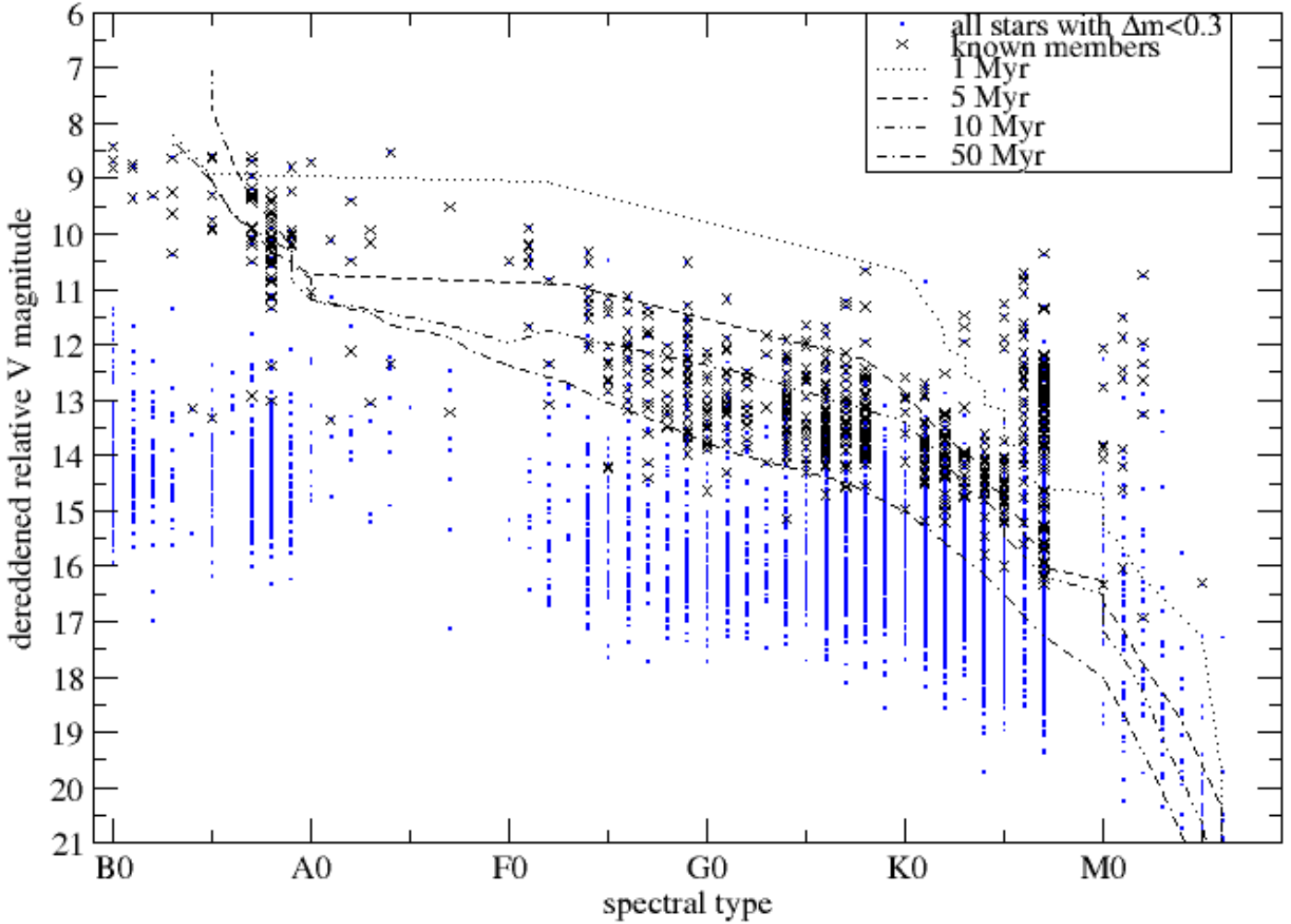


IC 1396 with Trumpler 37, narrow band image (APOD)

Additional Slides


G0
K2
M0
RXJ0444.7+0814
Li
Ca
EW (Li)
Log T_{eff}
1
0.8
0.6
0.4
0.2
0
3.8
3.7
3.6
3.5

Trumpler 37


Hertzsprung-Russell-Diagram for Trumpler 37
all stars with Δm<0.3
known members
1 Myr
5 Myr
10 Myr
50 Myr
dereddened relative V magnitude
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
B0
A0
F0
G0
K0
M0
spectral type

Follow up for eclipsing stars – CAFOS

(on Calar Alto 2.2 m/Spain)

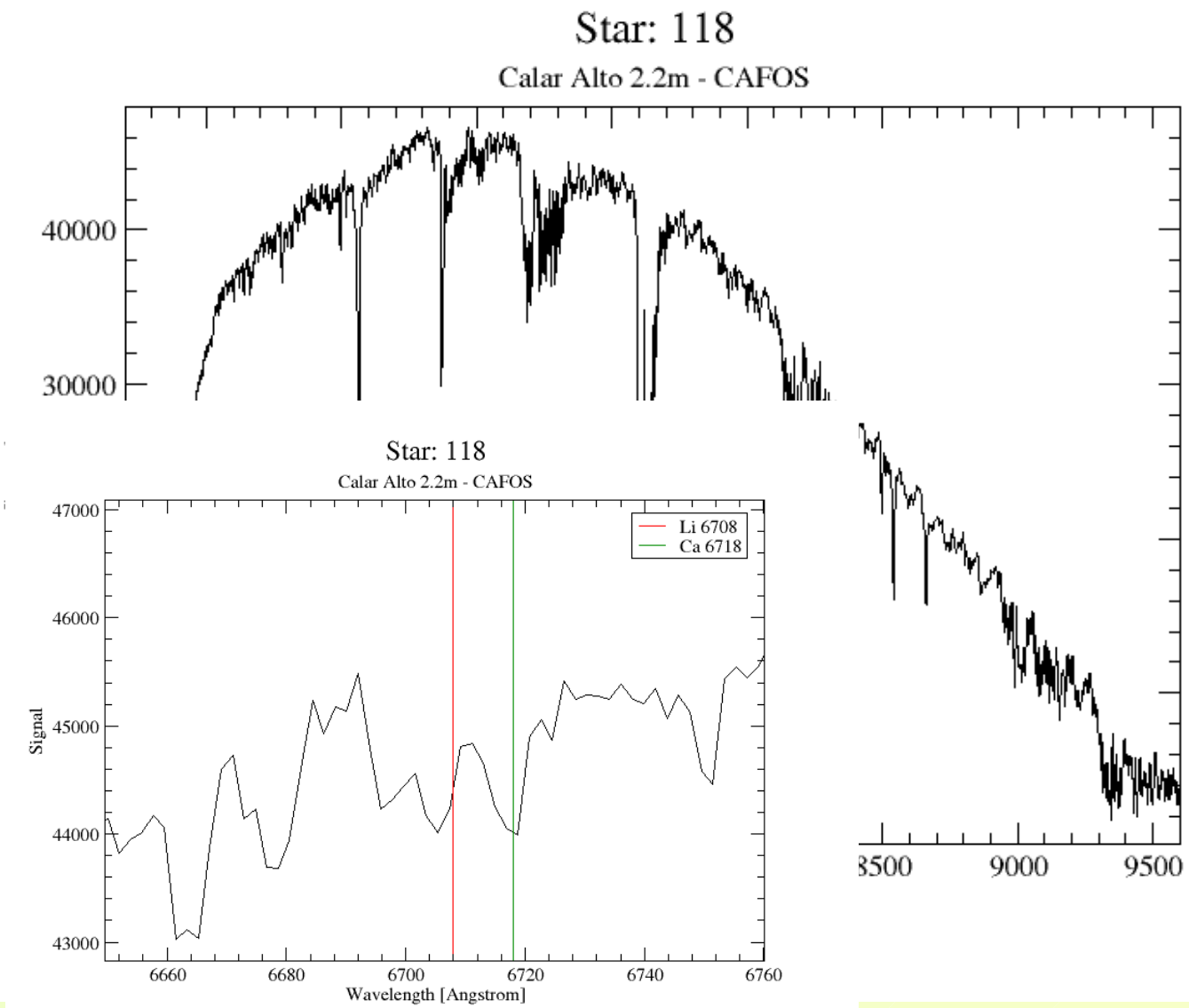
V =11.94 mag
B-V = 0.76 mag

photometric
spectral type: F9

P = 6.0052 d

ΔR_1 = 0.52 mag
ΔR_2 = 0.47 mag

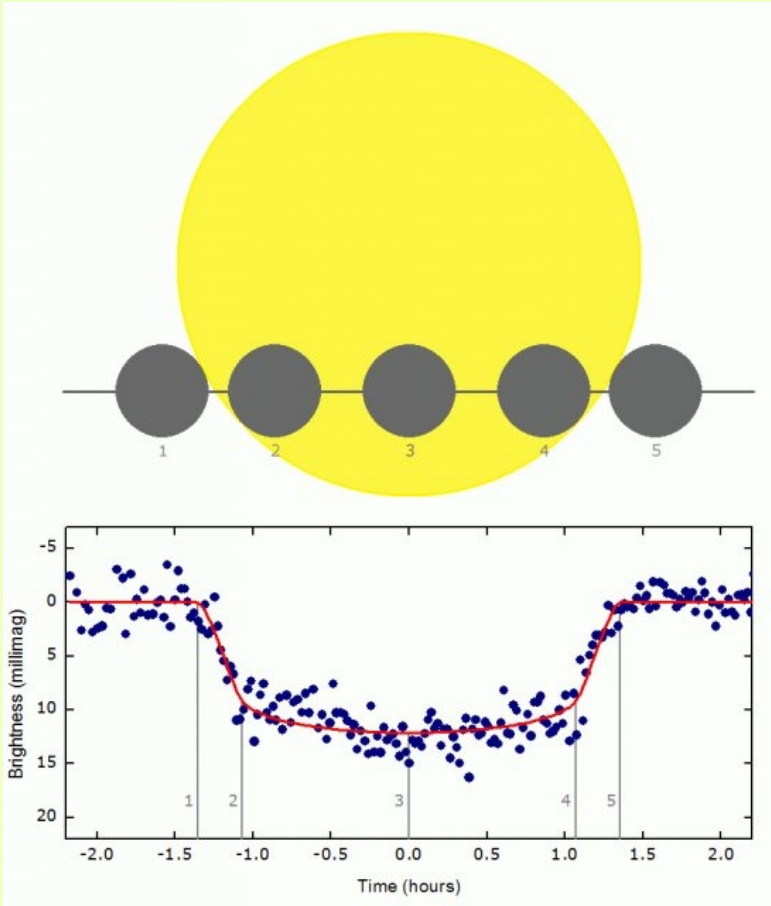
EW(Li) = 0.12 Å



Transit search technique

Planet blocks light from star

→ gives typical shape in lightcurve



Jupiter in front of sun:

11 milli-mag or

1 %

Information from transit

from depth:

$$\Delta m = -2.5 \log \frac{R_S^2 - R_P^2}{R_S^2}$$

from differences between first to last and second to third contact:

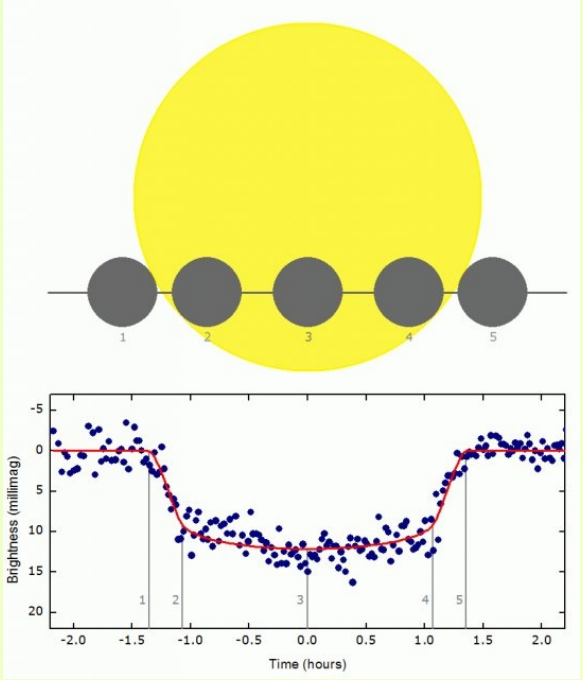
$$\left(\frac{t_{2-4}}{t_{1-5}} \right)^2 = \frac{(R_S - R_P)^2 - a^2 \cos^2 i}{(R_S + R_P)^2 - a^2 \cos^2 i}$$

from 3. Kepler law:

$$a^3 = P^2 \frac{G M_S}{4 \pi^2}$$

from follow up radial velocity measurements:

→ $M_P \sin i$



m: brightness
R_S: Star radius
R_P: Planet radius
t: duration
a: semi major axis
i: Inclination
P: Orbit period
M_S: Star mass
M_P: Planet mass
G: Gravitational constant

Transit method is only method to measure radius of planet and inclination of the orbit

→ together with M_P: density, surface gravity, escape velocity, modeling the inner structure (Ulrike Kramm)

Probability of detecting a transiting planet

ratio between star and planet radius (see the transit)

$$\Delta m > error$$

planet in line of sight

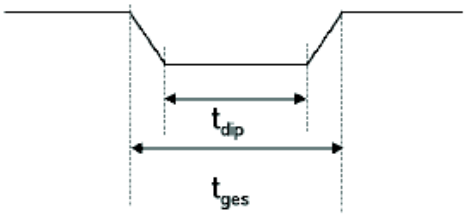
$$probability_{transit} = \frac{R_S}{a}$$

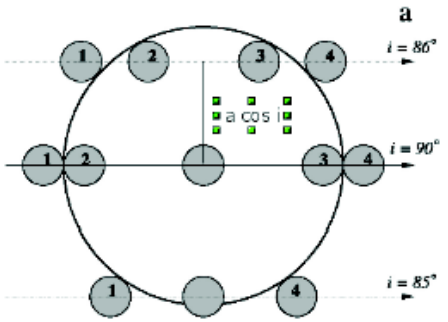
→ detection of transit most probable for close-in planets

Increase probability:

- high number of observed stars
- long continuous observation
- young planets

Duration of a transit





For $i = 90°$:

$$\frac{t_{dip}}{t_{ges}} = \frac{2(R\star - R_P)}{2(R_\star + R_P)}$$

otherwise:

$$\left(\frac{t_{dip}}{t_{ges}}\right)^2 = \frac{(R\star - R_P)^2 - a^2\cos^2 i}{(R_\star + R_P)^2 - a^2\cos^2 i}$$