YETI – search for young transiting planets

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YETI Observers, all over the world

Mercury transit
8. Nov. 06 (SOHO)

Hot Planets and Cool Stars

Garching

12. November 2012

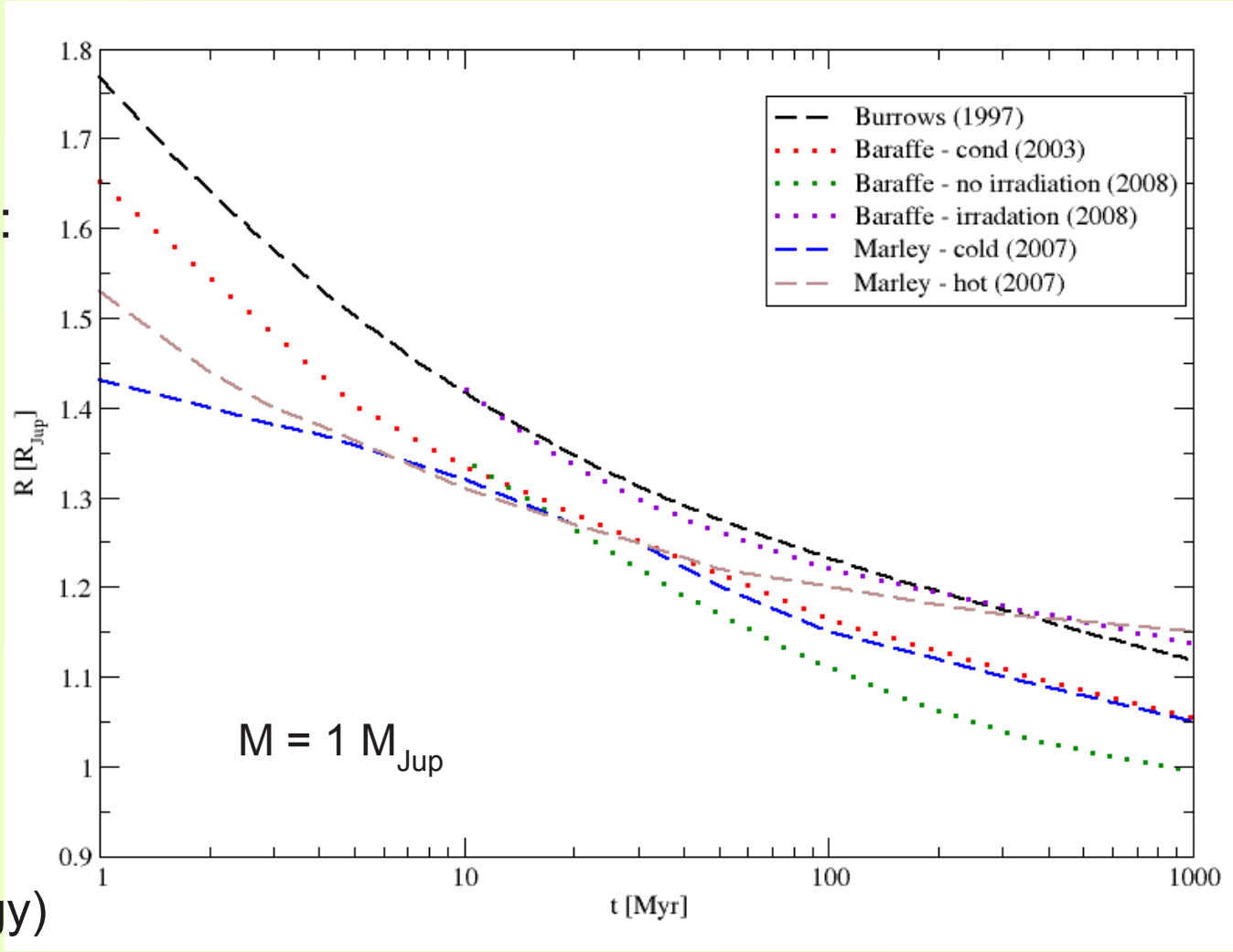
Venus transit 6. June 12

- The First 10 Million Years of the Solar System - a Planetary Materials Approach -
SPP 1385
DFG

Motivation

youngest transiting planets:

- Corot 2:
  - 130 – 500 Myr
    - (from star spots)
  - 30 – 40 Myr
    - (from planet radius)
- Corot 20:
  - 100 – 800 Myr
    - (from Li-abundance)
- Wasp 10:
  - 200 – 350 Myr
    - (from gyro-chronology)



→ younger transiting planets (Radius+true Mass) needed, to test models, and planet formation scenarios

Observation strategies

increase probability for transiting planet: monitoring of many young stars

-> Young open clusters

orbital periods: ~1 to ~10 days
transit duration: ~1 to few hours
→ 1 to 5% of orbit in transit phase

observation with single telescope:
data gaps because of daytime, weather, ...

increase probability for observing transit signal: long continuous observation

-> YETI

YETI-network (Young Exoplanet Transit Initiative)

Tenagra II

0.8-m telescope

Llano del Hato Observatory

1-m Schmidt telescope

Gettysburg

Collage Observatory 0.4-m telescope

Sierra Nevada

1.5-m telescope

Jena

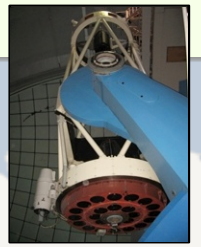
Astrophysical Institute 0.9/0.6-m telescope

Stara Lesna

Astronomical Institute 0.6-m telescope

Byurakan

1.0 and 2.6 telescopes

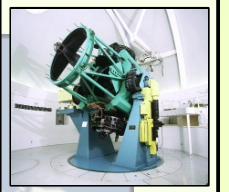


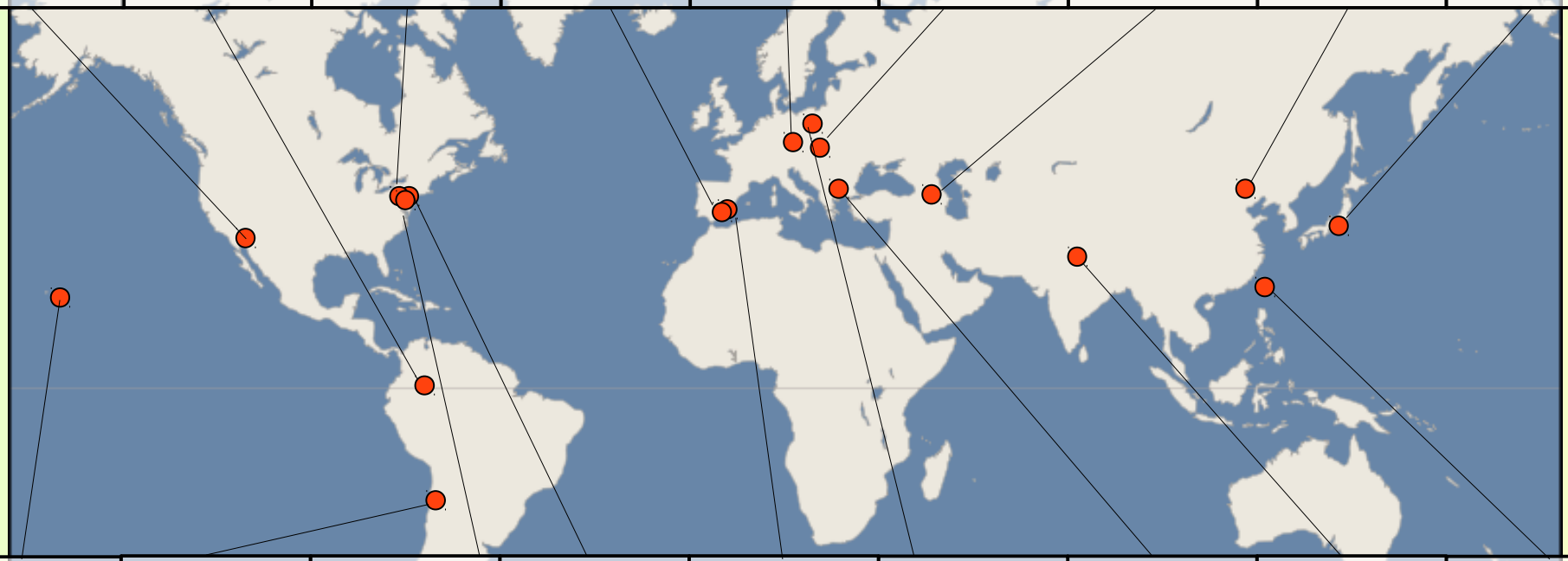
Xinglong

Observatory 90/60 cm

Gunma

Astronomical Observatory 1.5-m telescope





Mauna Kea

Univ. of Hawaii 2.2m telescope

Observatorio Cerro Armazones

two 5.9" telescopes

Stony Brook

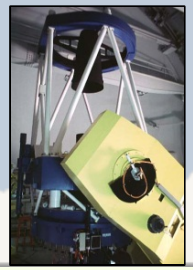
14"" telescope

Swarthmore

0.6-m telescope

Calar Alto

2.2-m telescope

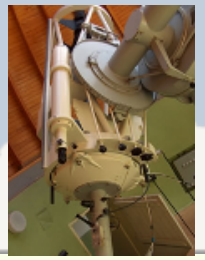


Torun

60 cm telescope

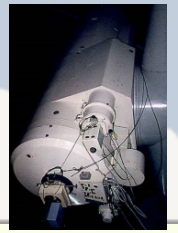
Rozhen

0.6 and 2-m telescopes



Nainital

State Observatory 1-m telescope



Lulin

Lulin Observatory 1m Telescope

YETI-network (Young Exoplanet Transit Initiative)

Astron. Nachr. / AN **332**, No. 6, 547 – 561 (2011) / **DOI** 10.1002/asna.201111573

The Young Exoplanet Transit Initiative (YETI)

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Received 2011 Apr 20, accepted 2011 Jun 15
Published online 2011 Jul 11

Trumpler 37

part of H-II region IC 1396

distance: 870 pc (*)

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

Diameter: 1.5°

Extinction:
A_V = 1.5 mag

Cluster radial velocity
v = -15.0 ± 3.6 km/s (*)

18000 stars,
500 known members(*)

*Sicilia-Aguilar et al. (2004-2007),
Marschall and van Altena (1987)
Contreras et al. (2002)

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

Observations

Jena (Großschwabhausen)

2009: 36 nights, 5515 data points
2010: 37 nights, 1800 data points
2011: 98 nights, 5600 data points
→ **12 900** data points in R filter in each exposure time

B,V,I filter: 1300 data points

YETI campaign runs

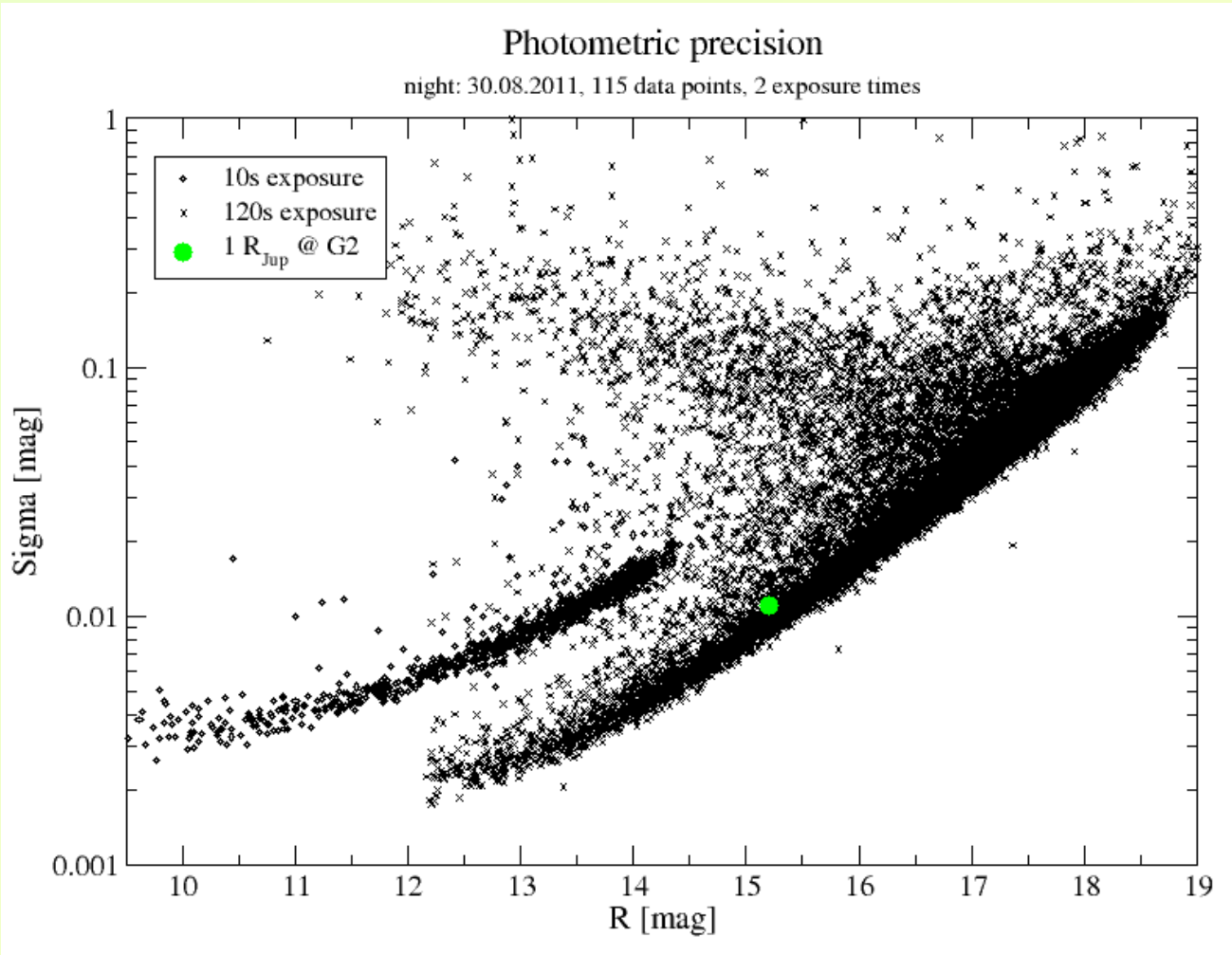
2010:
3. - 12. Aug.
26. - 12. Sept.
24. - 30. Sept.
→ **27500** images from **11** telescopes

2011:
11. - 22. July
10. - 22. Aug.
9. - 20. Sept.
→ **21000** images from **9** telescopes

Photometric precision

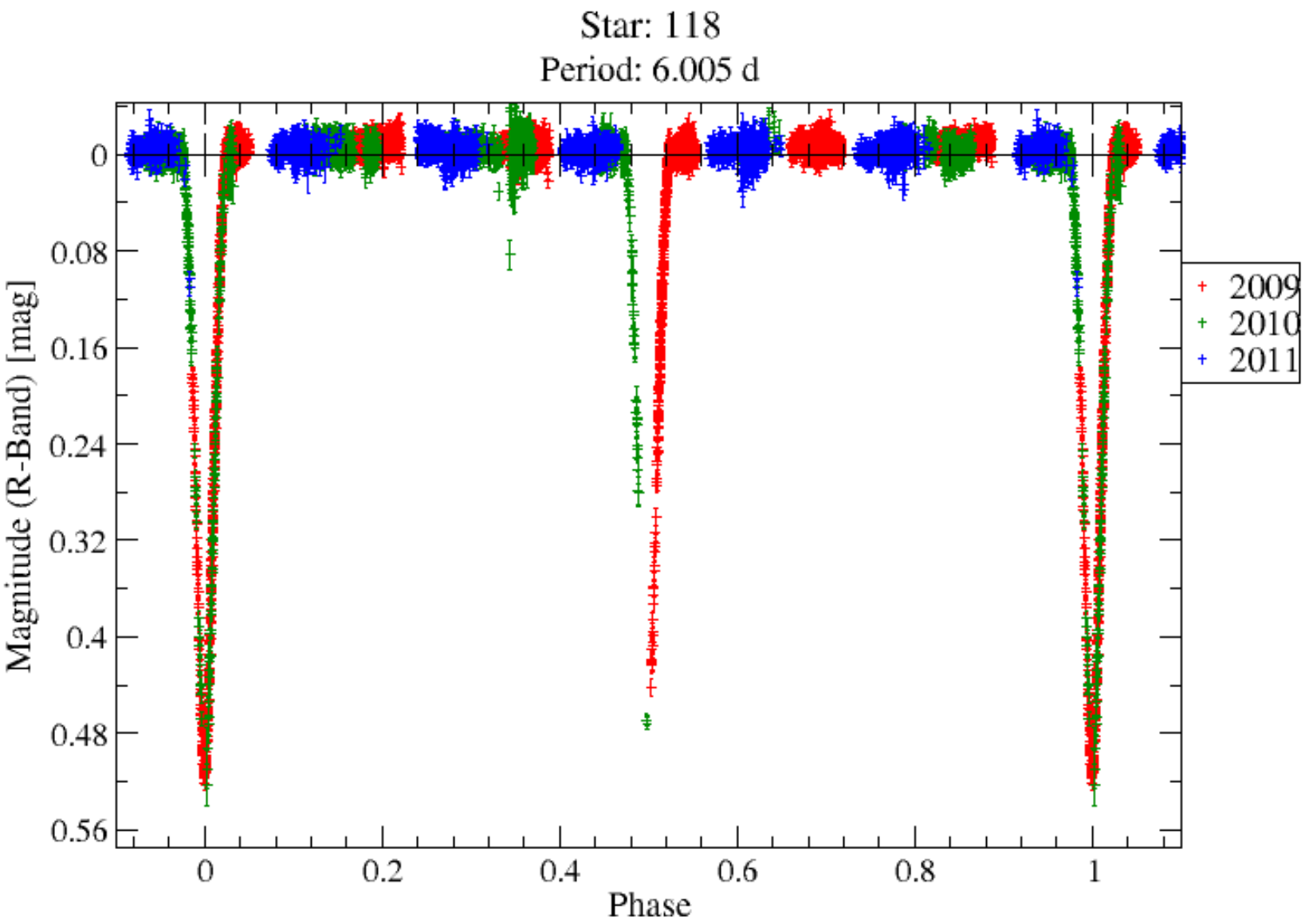
for 10s exposure time:
163 stars: σ < 5 milli-mag
for 120s exposure time:
690 stars: σ < 5 mmag
5351 stars: σ < 30 mmag

Most cluster members have brightness:
R = 11.0 to 17.0 mag



Multi-site campaign on Trumpler 37

10 000 data points, but still gaps in the phase folded light curve

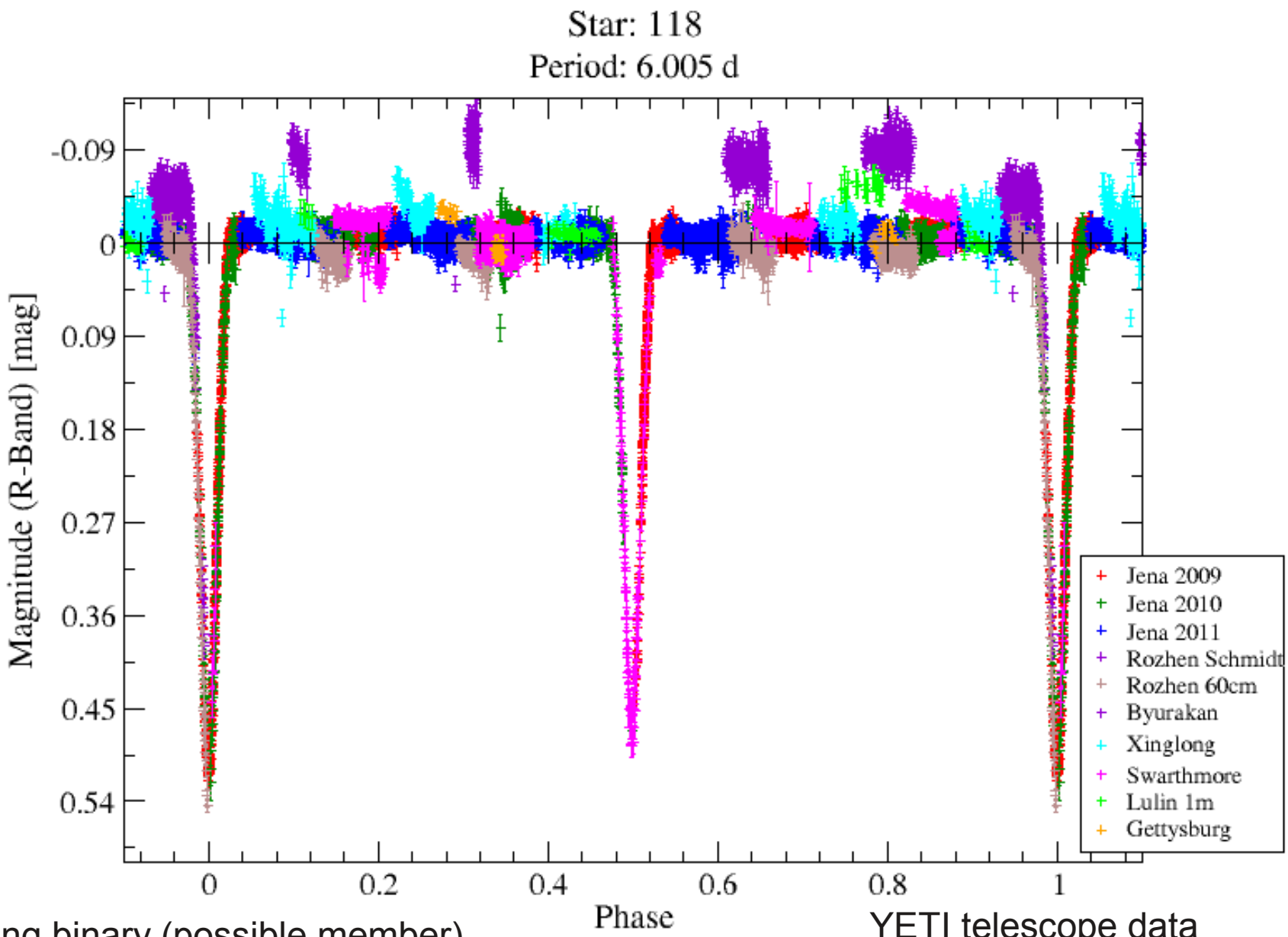


only Jena data

Multi-site campaign on Trumpler 37

no gaps

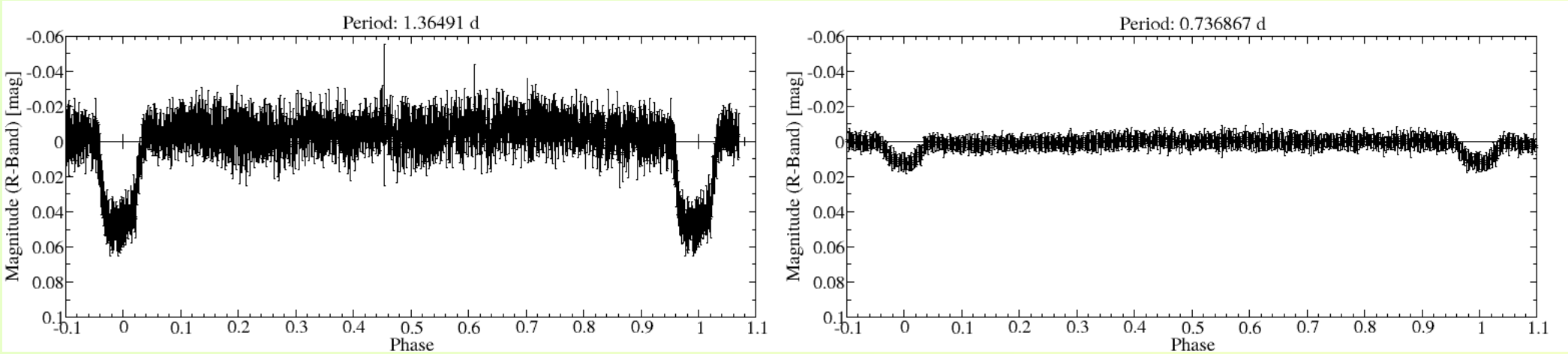
but need for some improve-ments in combining data from different telescopes



Star 118: eclipsing binary (possible member)

YETI telescope data

Transit-candidates

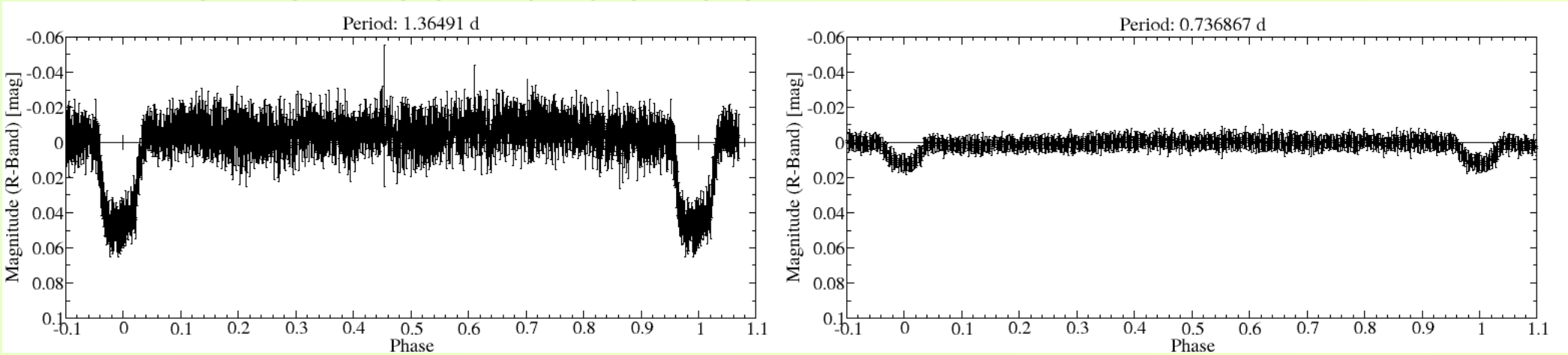


phase folded and binned R-band lightcurve of the Jena data (10 000 data points)

R	= 15.1 mag	13.4 mag
P	= 1.36491 d	0.736867 d
SpT:	G2	G4
	fit with EDT:	
ΔR_{trans}	= 54 milli-mag	10.6 milli-mag
t_{trans}	= 172 min	79 min
	fit with IDL-TAP:	
I	= 86.5°	71.2°
R_P/R_*	= 0.1965 → ≈ 2 R_{Jup}	0.1084 → ≈ 1 R_{Jup}

star is active over several days with
$\Delta m \approx 15$ milli-mag

Transit-candidates



phase folded and binned R-band lightcurve of the Jena data (10 000 data points)

R = 15.1 mag

P = 1.36491 d

SpT: G2

ΔR_{trans} = 54 milli-mag

t_{trans} = 172 min

I = 86.5°

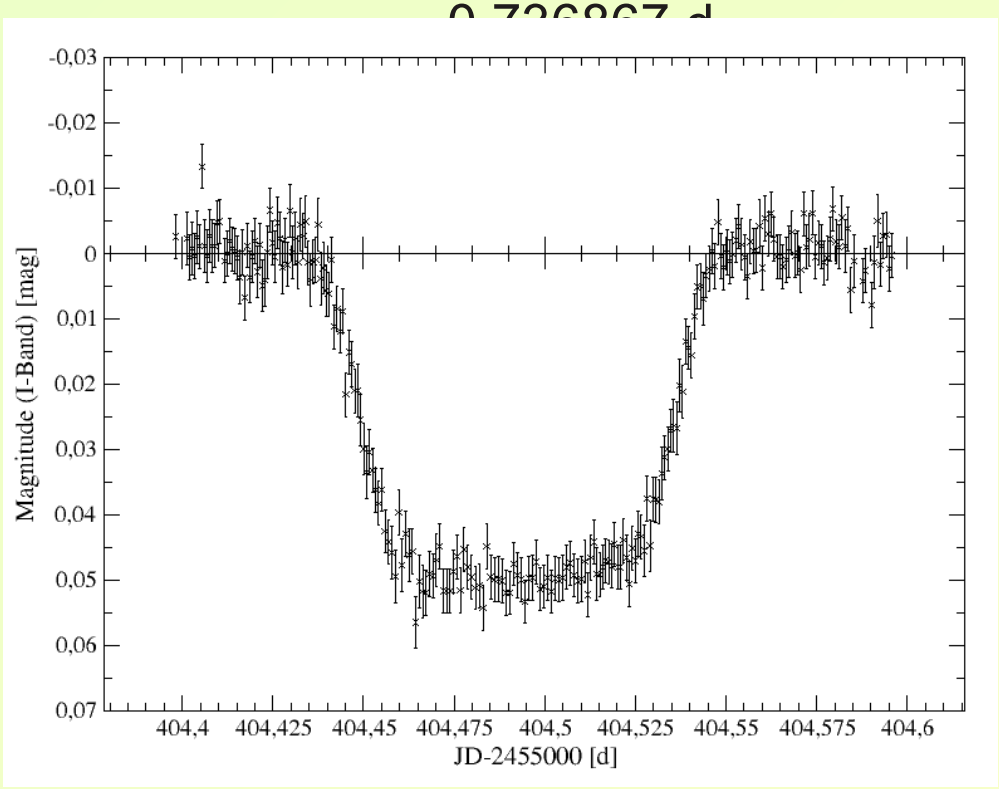
R_P/R_* = 0.1965 → ≈ 2 R_{Jup}

Calar Alto 2.2m:

ΔI_{trans} = 51.8 milli-mag

t_{trans} = 160 min

13.4 mag



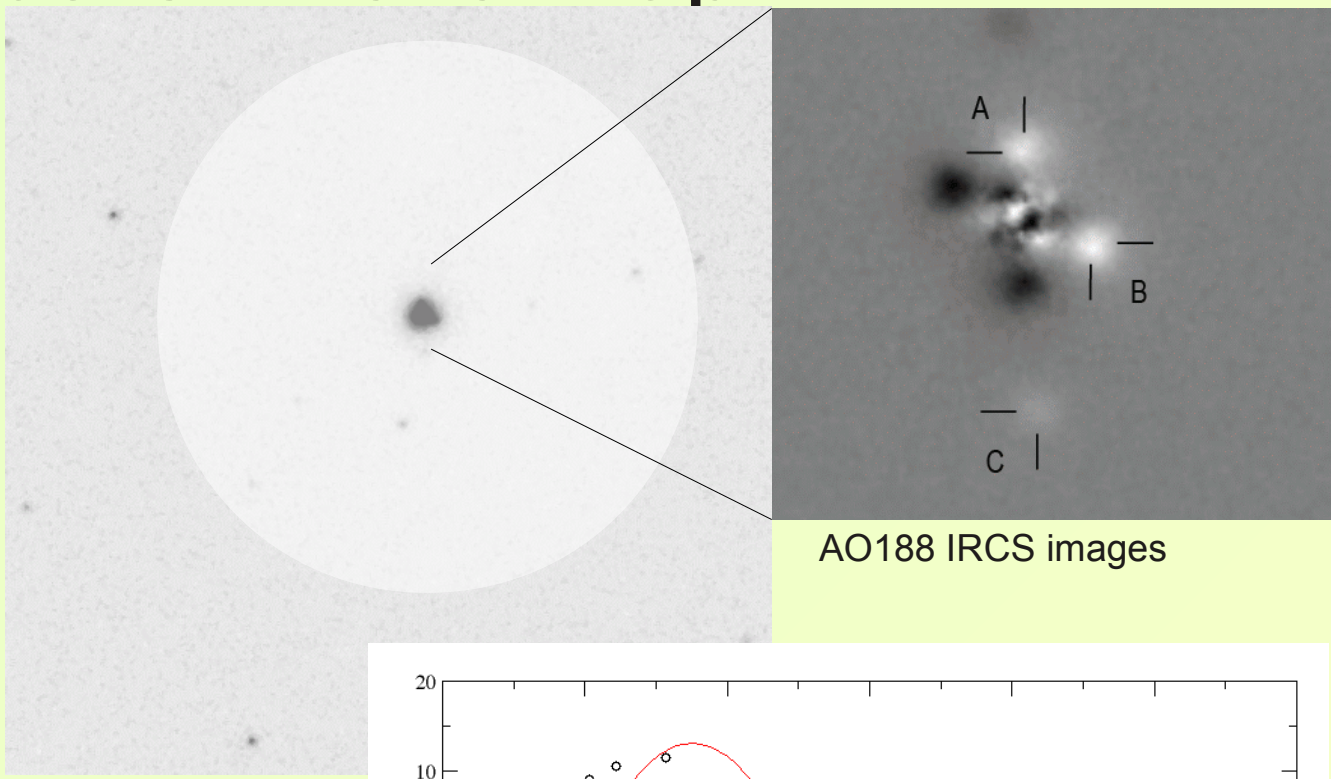
l days with

Transit-candidate 1 follow-up

- High resolution infrared imaging to check, whether there are other (eclipsing?) stars nearby (in the optical PSF)

  → 8m Subaru AO imaging

  => all too faint

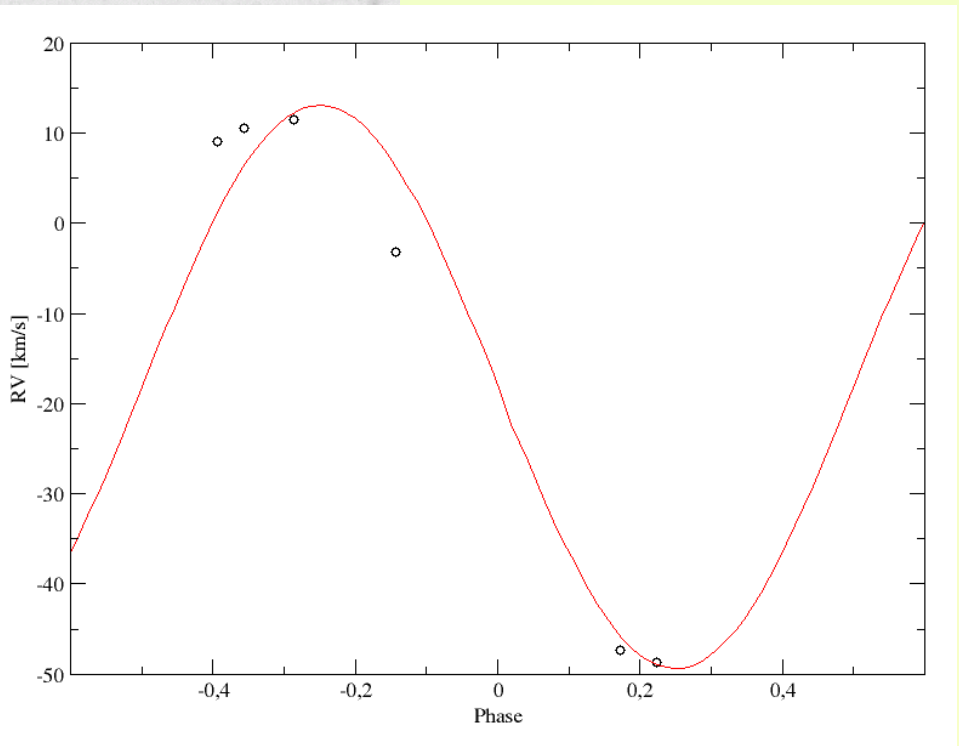


AO188 IRCS images

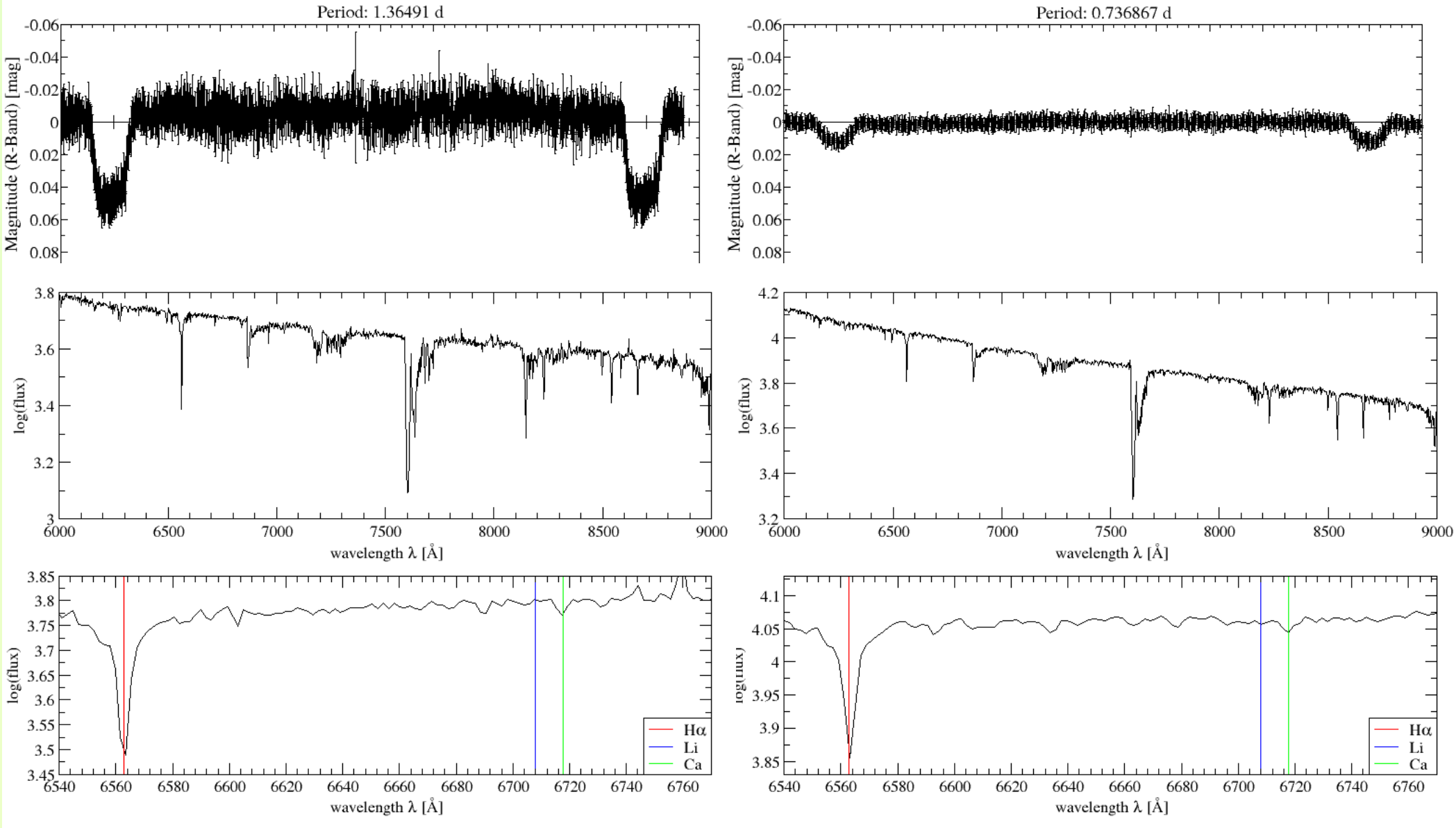
- High resolution spectra to measure line shift and radial velocity

  → 10m-Keck-I: HIRES spectrograph

  RV-Amplitude: 30 km/s
  => Mass of the small component:
  M_B=0.16±0.02 M_{sun}
  (M6 V)



Follow-up – Lithium: with Calar Alto 2.2m



weak Lithium line, EW = 0.1 Å

no Lithium visible

→ no members in the young cluster

Transiting candidate in 25 Ori

The PTF Orion Project: a Possible Planet Transiting a T-Tauri Star

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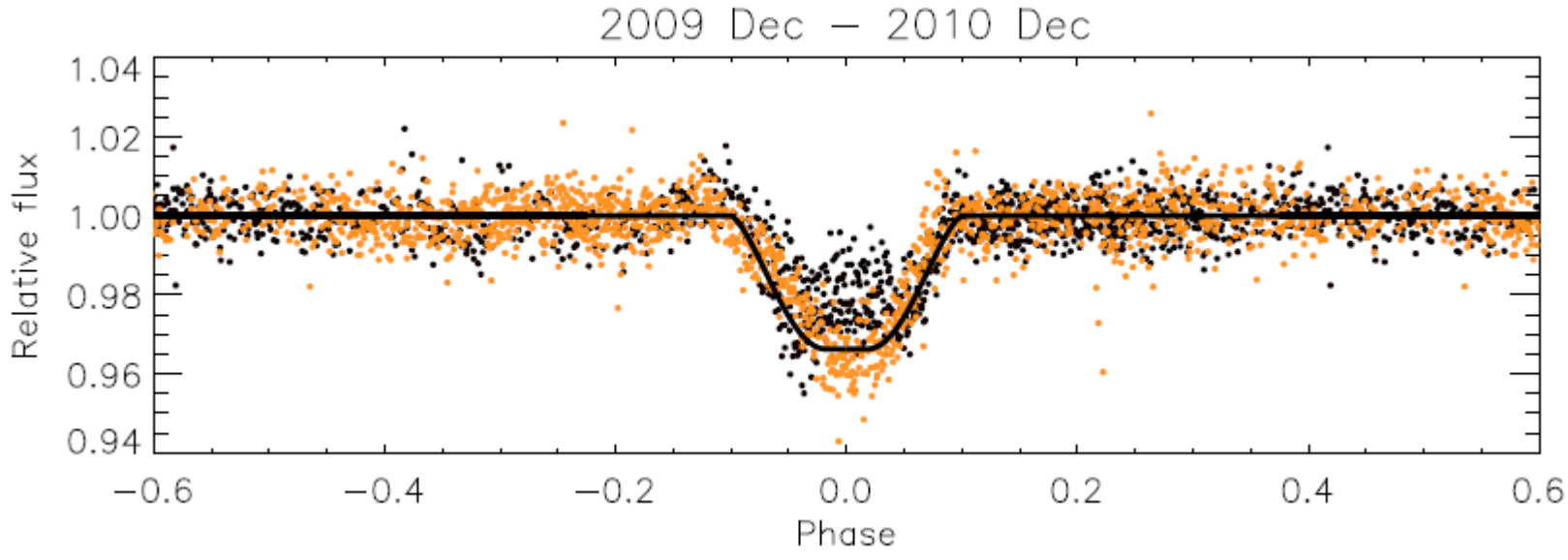
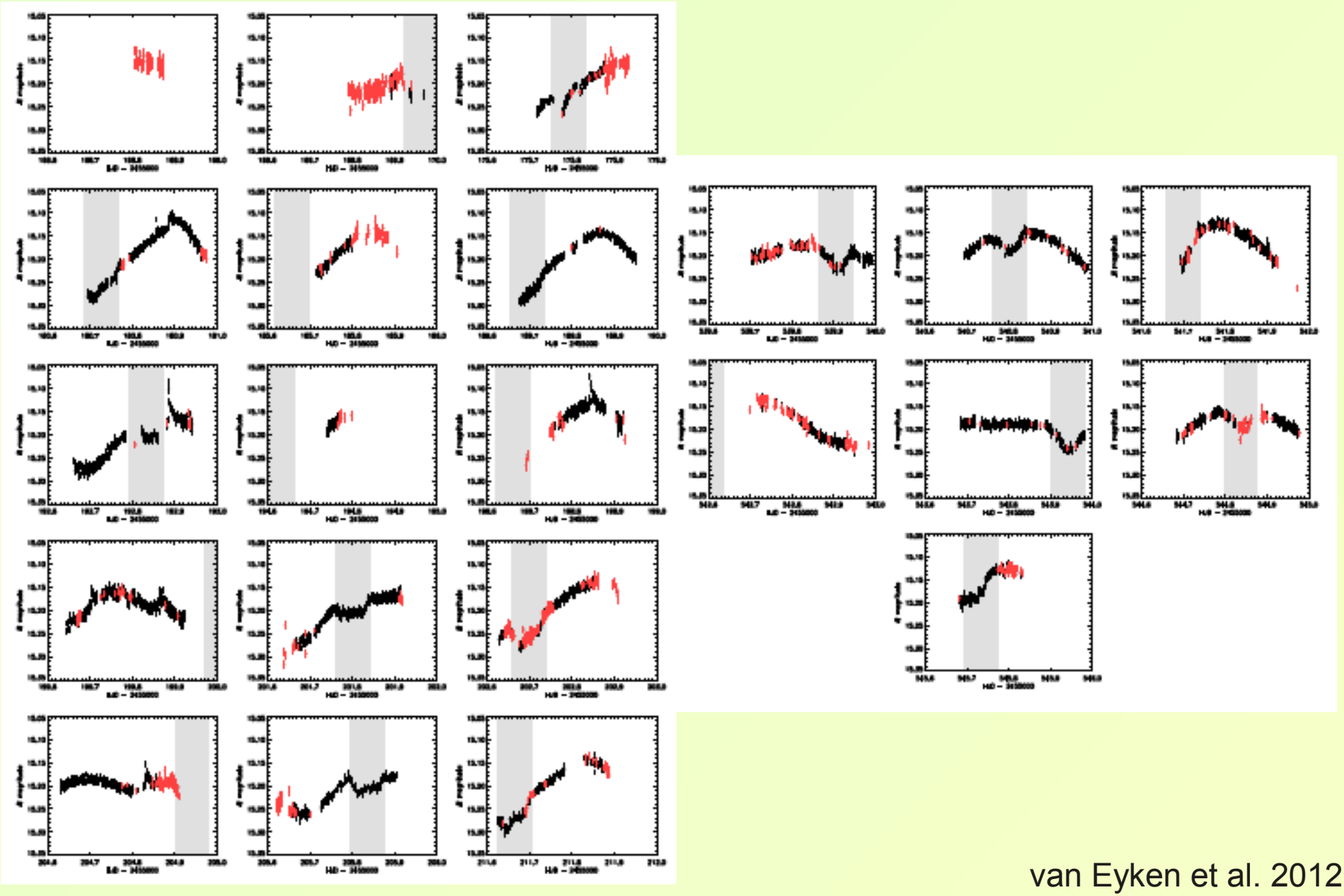
and

Jason A. Surace[10]

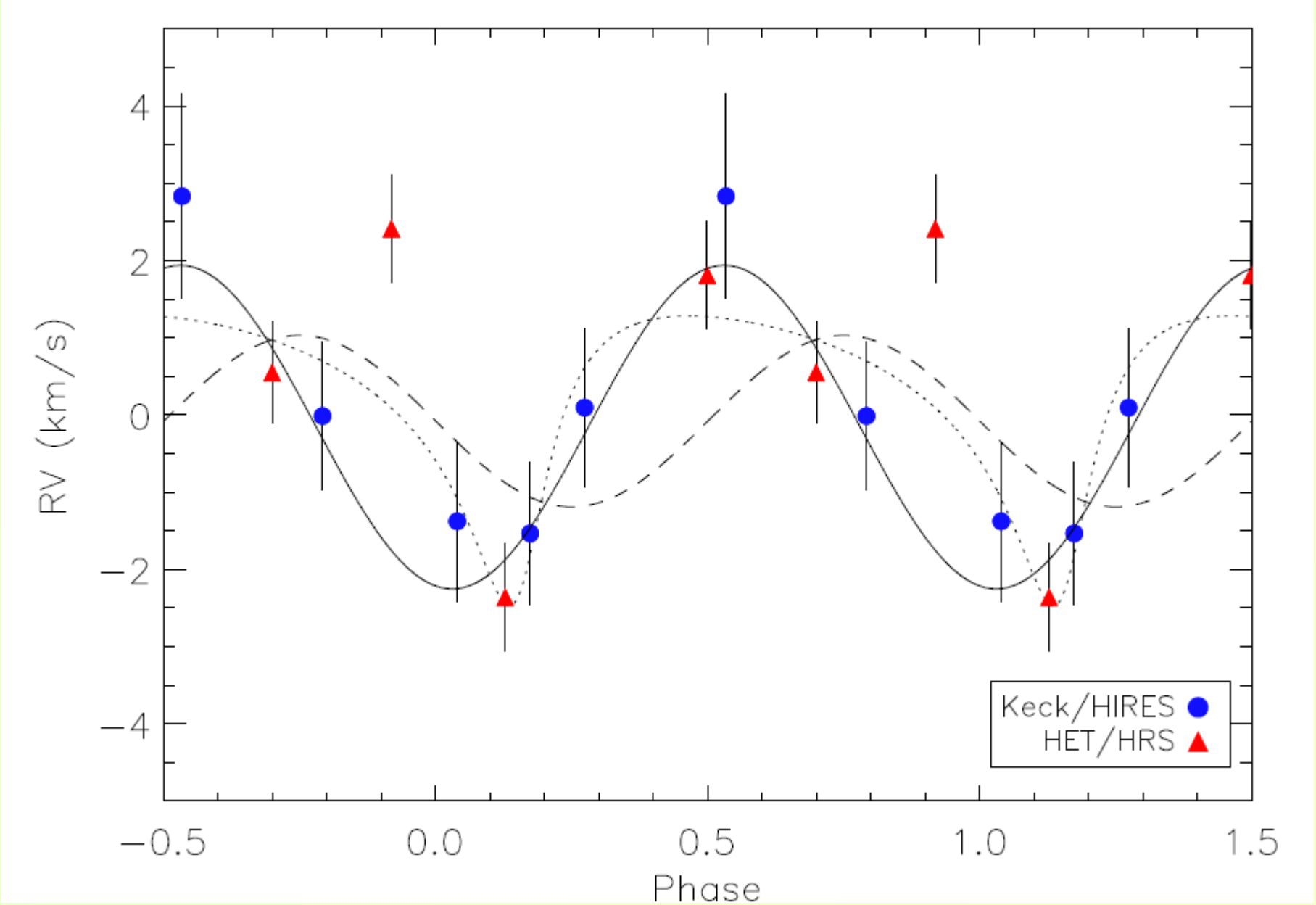


Transiting candidate in 25 Ori



van Eyken et al. 2012

Transiting candidate – Radial velocity



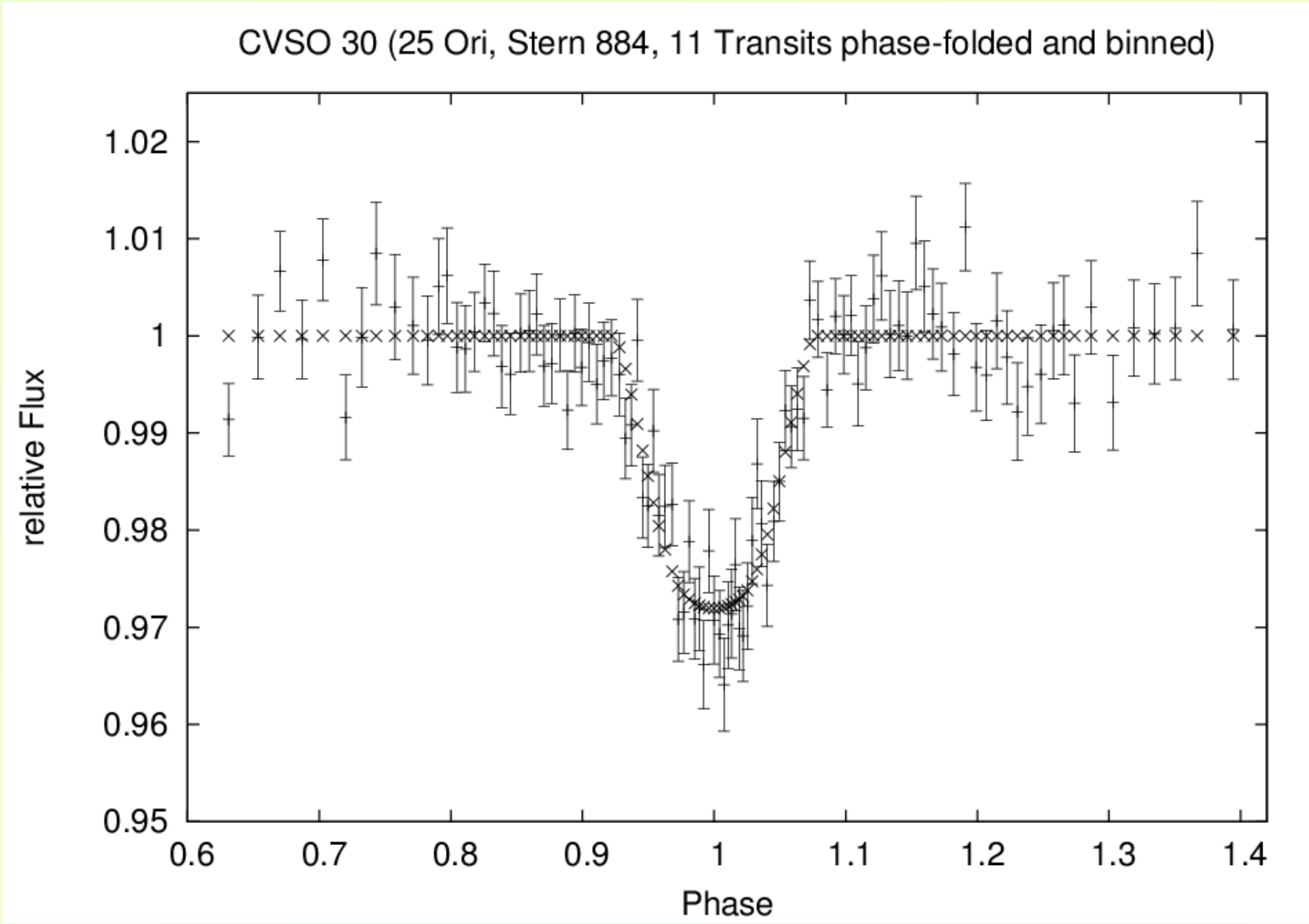
van Eyken et al. 2012

Property	Value
Alternative designations	CVSO 30
	2MASS J05250755+0134243
	PTF1 J052507.55+013424.3
α (J2000)	$05^{h}25^{m}07^{s}.55$
δ (J2000)	$+01°34'24.3''$
V	16.26 mag[a]
2MASS J	12.232 ± 0.028 mag[b]
2MASS H	11.559 ± 0.026 mag[b]
2MASS K_S	11.357 ± 0.021 mag[b]
Median R	15.19 mag[c]
R range	0.17 mag (min to max)[c]
H_α equiv. width	-11.40Å[a]
LiI equiv. width	0.40 Å[a]
Sp. Type	M3 (PMS weak-lined T-Tauri)[a]
$T_{\rm eff}$	3470 K[a]
A_V	0.12 mag[a]
Luminosity	$0.25\,L_\odot$[a]
Radius	$1.39\,R_\odot$[a,d]
Mass (Baraffe/Siess)	$0.44\,M_\odot/0.34\,M_\odot$[a,e]
Age (Baraffe/Siess)	2.63 Myr/2.68 Myr[a,e]
Distance	~ 330 pc (mean dist. to OB1a/25 Ori assoc.)[a,f]

Parameter	Value
Measured	
P	0.448413 ± 0.000040 d
$i_{\rm orb}$	$61.8 \pm 3.7°$
a/R_*	1.685 ± 0.064
$R_{\rm p}/R_*$	0.1838 ± 0.0097
T_0 (HJD)	2455543.9402 ± 0.0008
$v_{\rm r} \sin i_*$	80.6 ± 8.1 km s^{-1}
Derived	
a	0.00838 ± 0.00072 AU
	$= 1.80 \pm 0.15\,R_\odot$[a]
R_*	$1.07 \pm 0.10\,R_\odot$
$R_{\rm p}$	$1.91 \pm 0.21\,R_{\rm Jup}$
$M_{\rm p} \sin i_{\rm orb}$	$\leq 4.8 \pm 1.2\,M_{\rm Jup}$[b]
$M_{\rm p}$	$\leq 5.5 \pm 1.4\,M_{\rm Jup}$

van Eyken et al. 2012

Transiting candidate – Jena data



Conclusions and further investigations

We are able to find transit signals of Jupiter sized planets and do follow up

YETI-network closes observational gaps

Monitoring for more young clusters: 25 Ori (8 Myr, 6 YETI-campaigns already done), IC 348 (2 Myr, second campaign in progress), and Collinder 69 (1-6 Myr, first campaign End of Nov.)

Improved transit search (Bayesian approach for change point detection and fit with trapeze instead of a box), adding up images

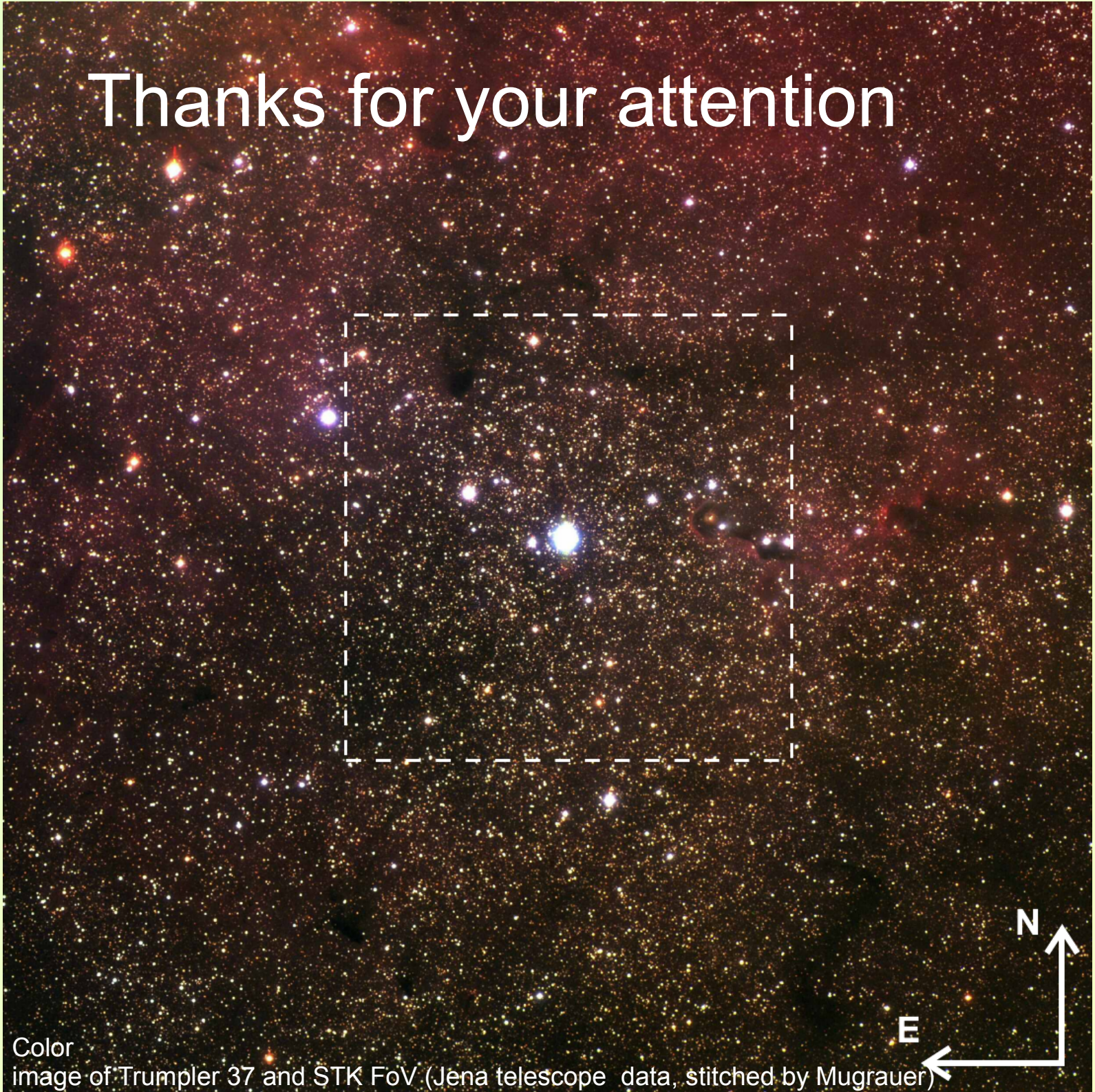
→ more transit candidates expected (especially at late type stars)

→ Additional follow-up observations (membership, orbits, masses, …)

Investigations in variability, young eclipsing binaries, membership, and cluster properties

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

Thanks for your attention



Color
image of Trumpler 37 and STK FoV (Jena telescope data, stitched by Mugrauer)

Additional Slides

Table 1. Target clusters

Cluster name (c)	age [Myr]	distance [pc]	number of stars with R$\leq$ 16.50 mag: members in total	members in Jena FoV	stars in Jena FoV (b)	expected no. of transit planets in the Jena FoV (a) (and among members)
Trumpler 37	~ 4	870	614	≥ 469	6762	$\sim 8.1 \pm 2.8$ ($\geq 1.1 \pm 1.1$)
h and χ Per	2-10	2000	488	≥ 488	3490	$\sim 4.2 \pm 2.0$ ($\geq 1.1 \pm 1.1$)
Collinder 69	1-6	438	167	≥ 162	1089	$\sim 1.3 \pm 1.1$ ($\geq 0.4 \pm 0.6$)
total numbers:			1269	≥ 1119	11341	$\sim 13.6 \pm 3.6$ ($\geq 2.6 \pm 1.7$)

Table 2. Telescope network (1) (sorted by longitude)

Observatory	Long. [deg]	Lat. [deg]	Mirror diameter [m]	CCD type (camera)	no. of pixels	size of field [min x min]	Ref.
Gunma/Japan	139.0 E	36.6 N	1.50	Andor DW432	1250 x 1152	12.5 x 12.5	(2)
Lulin/Taiwan	120.5 E	23.3 N	1.00	Marconi CCD36-40 PI1300B	1340 x 1300	22 x 22	
			0.41	E2V 42-40 (U42)	2048 x 2048	28 x 28	
Xinglong/China	117.6 E	40.4 N	0.90 (3)	E2V CCD203-82	4096 x 4096	94 x 94	Wu07
Nainital/India	79.5 E	29.4 N	1.04	TK2048E	2000 x 2000	13 x 13	
Byurakan/Armenia	44.3 E	40.3 N	2.60	SCORPIO Loral	2058 x 2063	14 x 14	
Rozhen/Bulgaria	24.7 E	41.7 N	0.60	FLI ProLine 09000	3056 x 3056	17 x 17	(4)
			0.60 (5)	FLI ProLine 09000	3056 x 3056	27 x 27	(4)
			0.70 (6)	FLI ProLine 16803	4096 x 4096	73 x 73	(4)
			2.00	Princ. Instr. VersArray:1300B	1340 x 1300	6 x 6	(4)
Stará Lesná	20.3 E	49.2 N	0.50	SBIG ST10 MXE	2184 x 1472	20 x 14	
(Slovak Rep.)			0.60	SITe TK1024	1024 x 1024	11 x 11	
			0.25	SBIG ST10 MXE	2184 x 1472	43 x 29	
Toruń/Poland	18.6 E	53.1 N	0.90 (3)	SBIG STL-11000	4008 x 2672	48 x 72	
Jena/Germany	11.5 E	50.9 N	0.90 (3)	E2V CCD42-10 (STK)	2048 x 2048	53 x 53	Mug10
			0.25 (7)	SITe TK1024 (CTK)	1024 x 1024	38 x 38	Mug09
			0.25 (8)	E2V CCD47-10 (CTK-II)	1056 x 1027	21 x 20	Mug11a
			0.20	Kodak KAF-0402ME (RTK)	765 x 510	8 x 5	Mug11b
S. Nevada/Spain	3.4 W	37.1 N	1.50	EEV VersArray:2048B	2048 x 2048	8 x 8	
Calar Alto/Spain	2.5 W	37.2 N	2.20 (9)	SITe1d (CAFOS)	2048 x 2048	16 x 16	(10)
Armazones/Chile	70.2 W	24.6 S	0.15	Apogee U16M KAF-16803	4096 x 4096	162 x 162	(11)
CIDA/Venezuela	70.9 W	8.8 N	1.00	Quest-I CCD Mosaic	8000 x 8000	138 x 138	Ba02
			1.00 (5)	FLI Proline E2V42-40	2048 x 2048	19 x 19	
Stony Brook/USA	73.1 W	40.9 N	0.37	SBIG ST1001E KAF-1001E	1024 x 1024	17 x 17	
Swarthmore/USA	75.4 W	39.9 N	0.62	Apogee U16M KAF-16803	4096 x 4096	26 x 26	
Gettysburg/USA	77.2 W	39.8 N	0.40	SITe 003B	1024 x 1024	18 x 18	(12)
Tenagra II/USA	110.5 W	31.3 N	0.81	SITe SI003 AP8p	1024 x 1024	15 x 15	
Mauna Kea/Hawaii	155.5 W	19.8 N	2.20	8 CCD chips for mosaic	8 x 2048 x 4096	33 x 33	

Remarks: (1) Listed are only those, from which we have obtained (or proposed) photometric monitoring data so far; (2) www.astron.pref.gunma.jp/e/inst_ldsi.html; (3) 0.60m in Schmidt mode; (4) www.nao-rozhen.org/telescopes.fr_en.htm; (5) with focal reducer; (6) 0.50m in Schmidt mode; (7) until July 2010; (8) since August 2010; (9) by open time observing proposals; (10) w3.caha.es/CAHA/Instruments/CAFOS/cafos_overview.html; (11) www.astro.ruhr-uni-bochum.de/astro/oca/vysos6.html; (12) www3.gettysburg.edu/$\sim$marschal/clea/obshome.html.

Ref.: Mug09 - Mugrauer 2009; Mug10 - Mugrauer & Berthold 2010; Mug11a,b - Mugrauer 2011a,b (in prep); Wu07 - Wu et al. 2007; Ba02 - Baltay et al. 2002.

Cluster name	Age [Myr]	Distance [pc]	Number of stars with R < 16.5 mag			Expected number of transiting plane	
			Members in total	Members in FoV	Stars in FoV	In FoV	Among members
Trumpler 37	4	870	614	≥ 469	6762	8.1 ± 2.8	≥ 1.1 ± 1.1
25 Ori	7-10	323	179	≥ 108	1045	1.3	≥ 0.3
h and χ Pers	2-10	2000	488	≥ 488	3490	4.2 ± 2.0	≥ 1.1 ± 1.1
Collinder 69	1-6	438	162	≥ 162	1089	1.3 ± 1.1	≥ 0.4 ± 0.6
total			1448	≥ 1227	12386	14.9 ± 3.6	≥ 2.9 ± 1.7

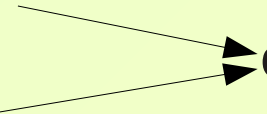
Observations

Work flow:

- data reduction partly done
- identify stars in the images (adding to list / using part of list)
- finding optimal aperture for one night
- aperture photometry on star list
- differential photometry (Broeg et al. 2005)

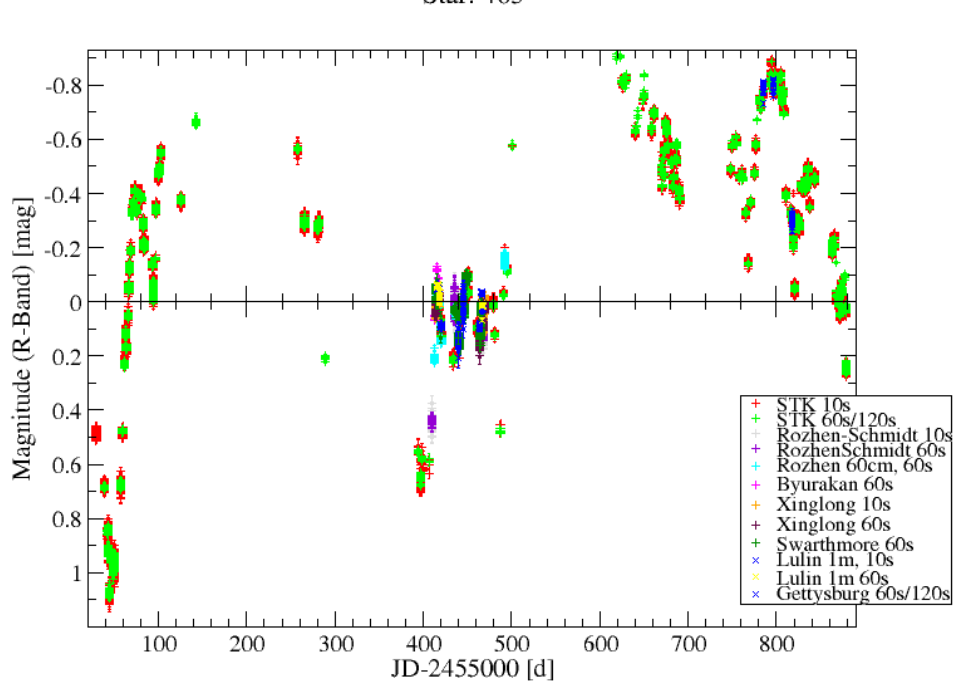
combining nights of one telescope

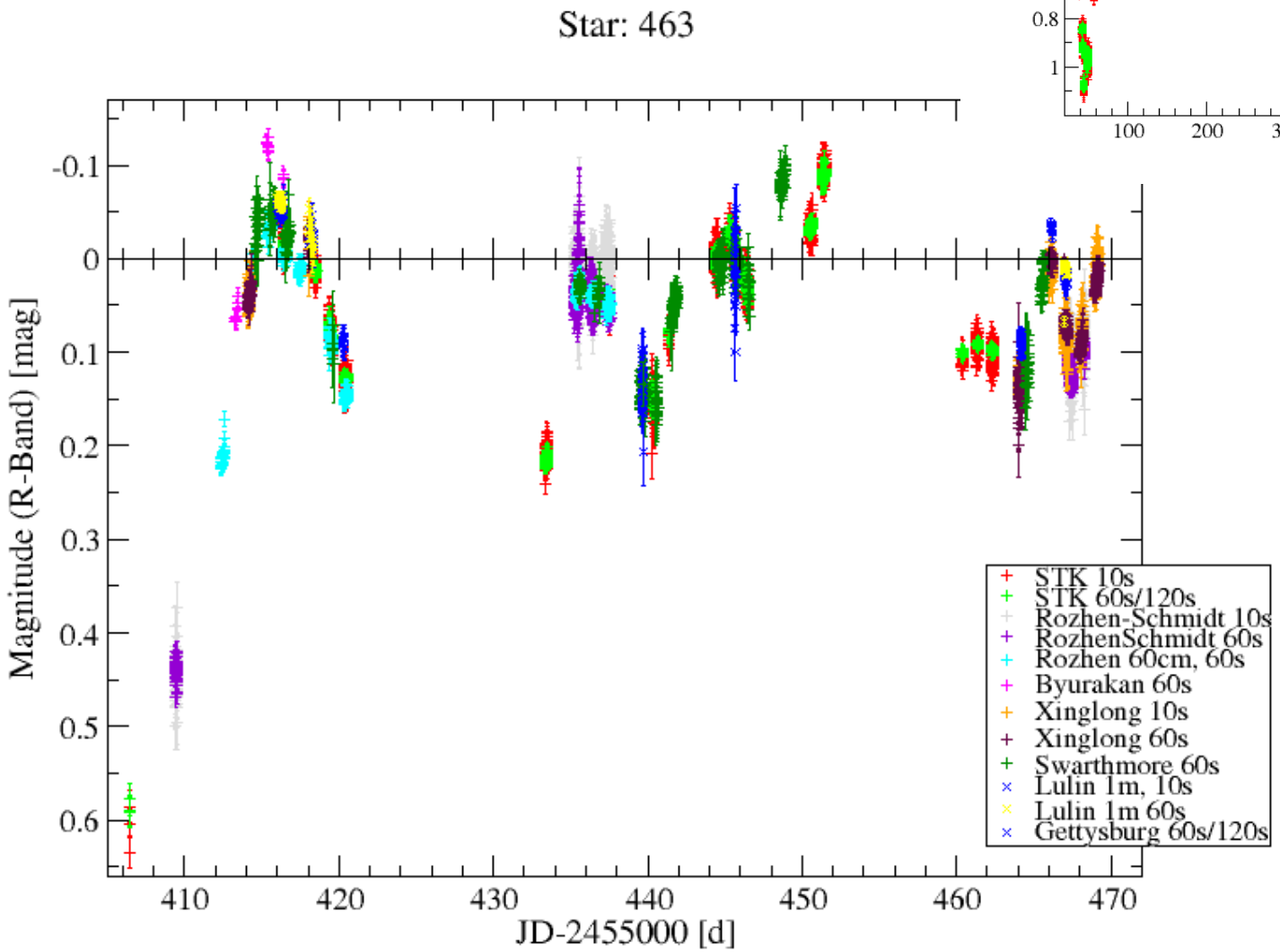
combining data of all telescopes



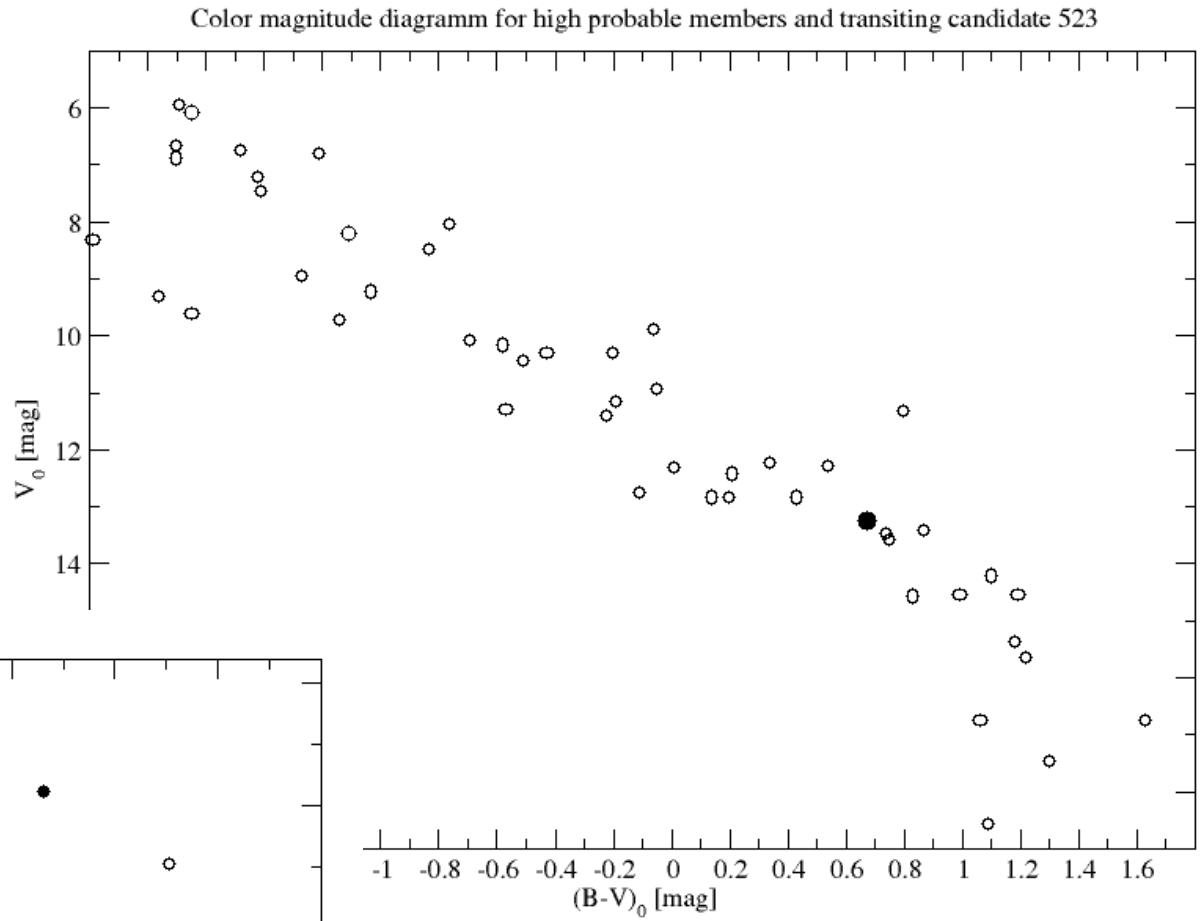
comparing constant stars (similar color, small distance to target)

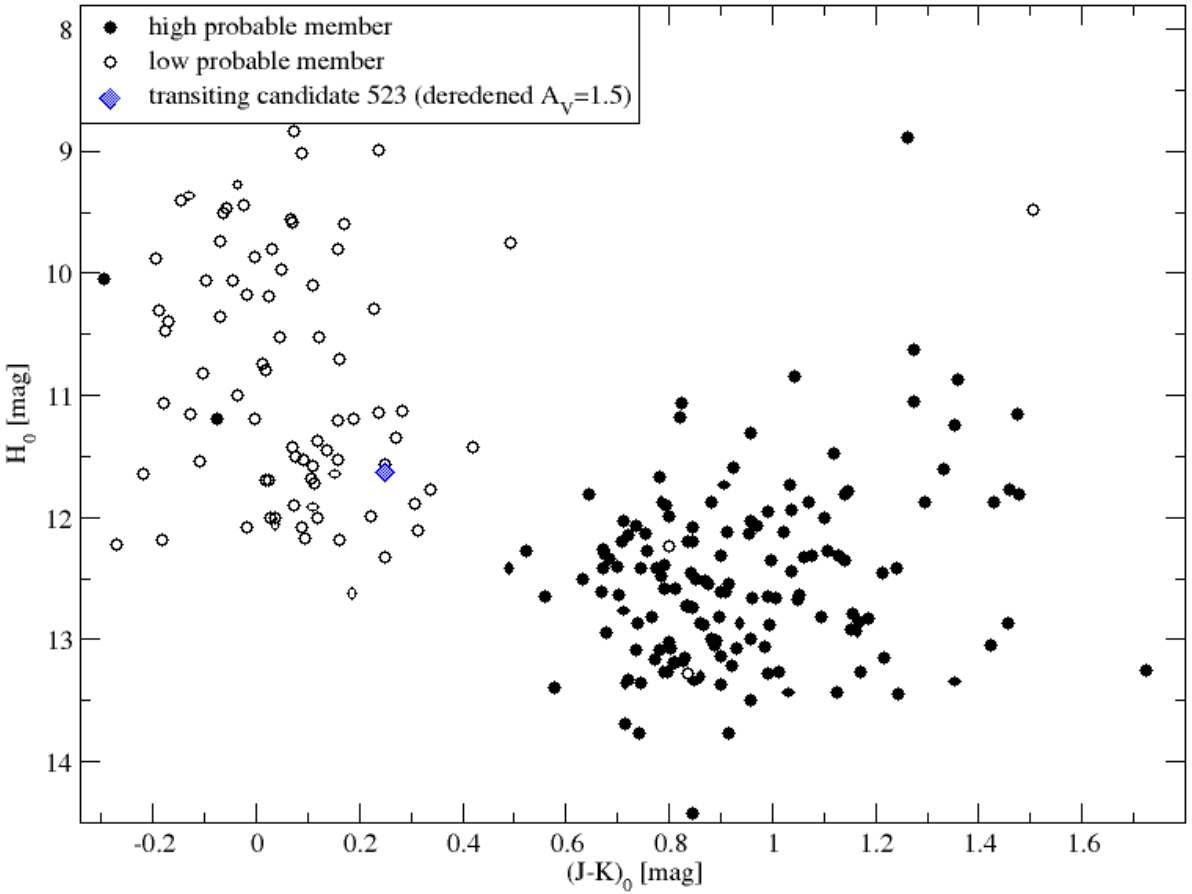
GM Cep


-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Magnitude (R-Band) [mag]
100
200
300
400
500
600
700
800
JD-2455000 [d]
STK 10s
STK 60s/120s
Rozhen-Schmidt 10s
RozhenSchmidt 60s
Rozhen 60cm, 60s
Byurakan 60s
Xinglong 10s
Xinglong 60s
Swarthmore 60s
Lulin 1m, 10s
Lulin 1m 60s
Gettysburg 60s/120s

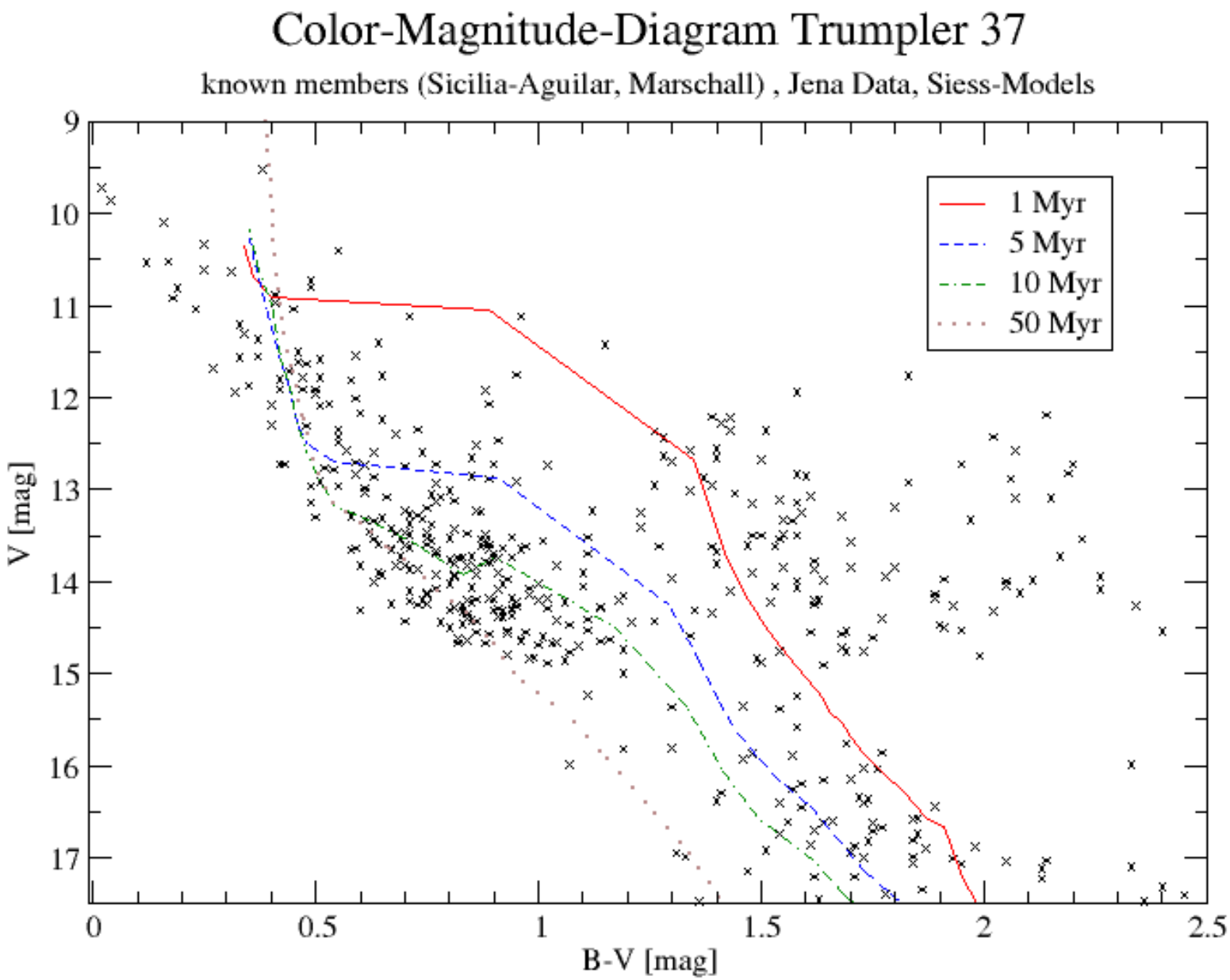

Star: 463
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
Magnitude (R-Band) [mag]
410
420
430
440
450
460
470
JD-2455000 [d]
STK 10s
STK 60s/120s
Rozhen-Schmidt 10s
RozhenSchmidt 60s
Rozhen 60cm, 60s
Byurakan 60s
Xinglong 10s
Xinglong 60s
Swarthmore 60s
Lulin 1m, 10s
Lulin 1m 60s
Gettysburg 60s/120s

CMD for Tr 37


Color magnitude diagramm for high probable members and transiting candidate 523
V_0 [mag]
$(B-V)_0$ [mag]


high probable member
low probable member
transiting candidate 523 (deredened A_V=1.5)
H_0 [mag]
$(J-K)_0$ [mag]

Trumpler 37 – Color-Magnitude-Diagram



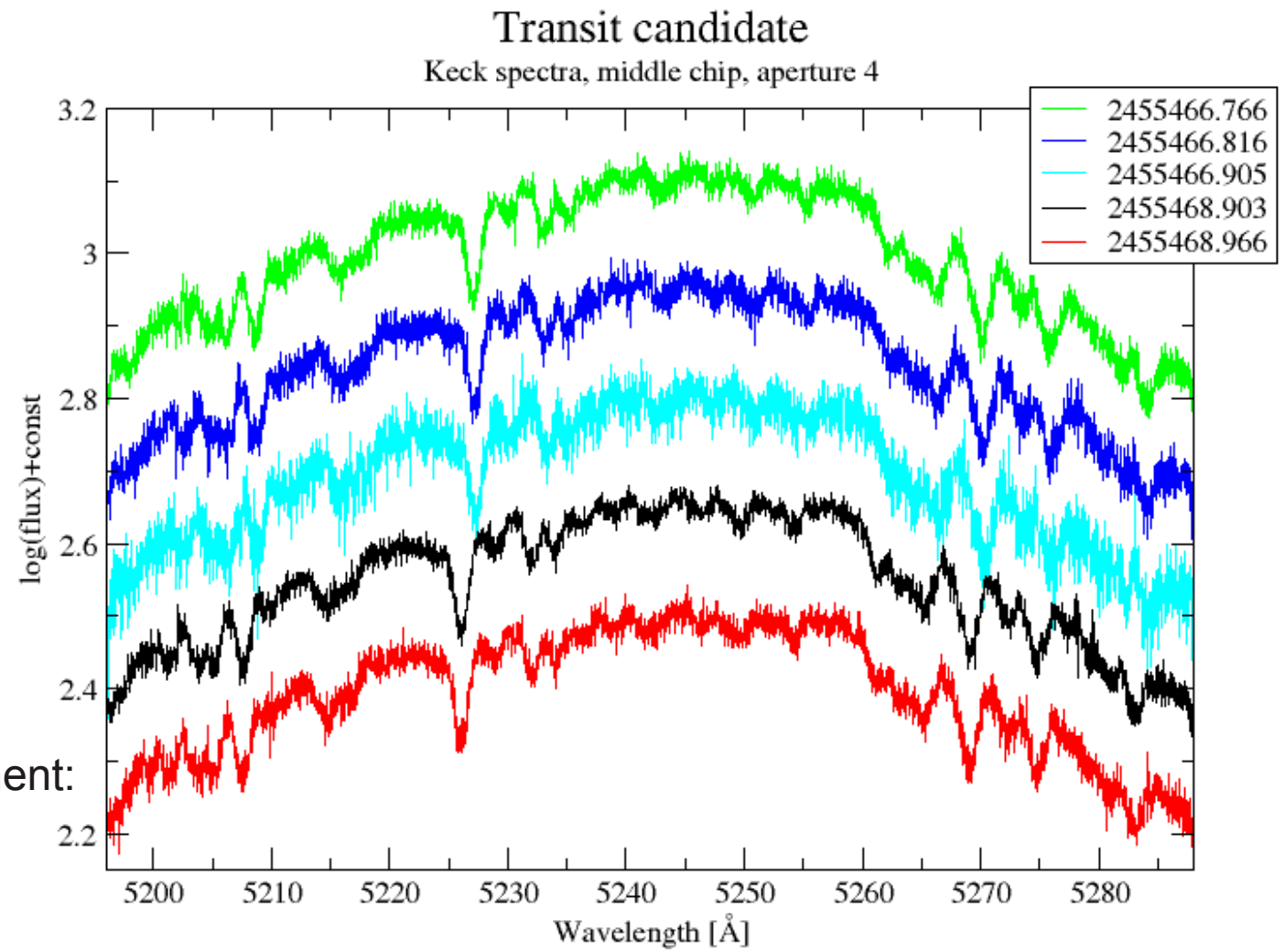
Follow-up - Keck

Radial velocity orbit for transit candidate:
HIRES spectrograph at 10m-Keck-I telescope

Cross correlation with artificial spectra:

HJD-2455000	RV [km/s]
466.74372	9.071
466.79397	10.548
466.88945	11.482
468.88121	-47.398
468.94959	-48.682
521.68193	-3.242

Mass of the small component:
M_B=0.16±0.02 M_{sun}
(M6 V)



New transiting candidate

R = 13.4 mag
V = 14.1 mag
B-V= 0.8 mag
≈ G4

proper motion and color magnitude diagram → probable member

star is active over several days with $\Delta m \approx$ 15 milli-mag

$P_{transit} \approx 0.7367$ d