EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Faculty of Science
Institute for Astronomy and Astrophysics

Updates on the story of the young transiting planet candidate CVSO 30 b

St. Raetz

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And YETI-team all over the world

Credit: Maciej Szyszko

The 25 Ori Project

- Detection and study of <u>complete</u> planetary systems at young ages below 10 Myrs

→ <u>complete</u>:

- inner planets (< 1 AU) with the transit method
- intermediate separation planets (1-80 AU) with astrometry
- wide planets (> 80 AU) with adaptive optics (AO) imaging

- Goal:

  comparison of solar system with young extrasolar planetary systems, e.g. test of migration theories (young systems should be different)

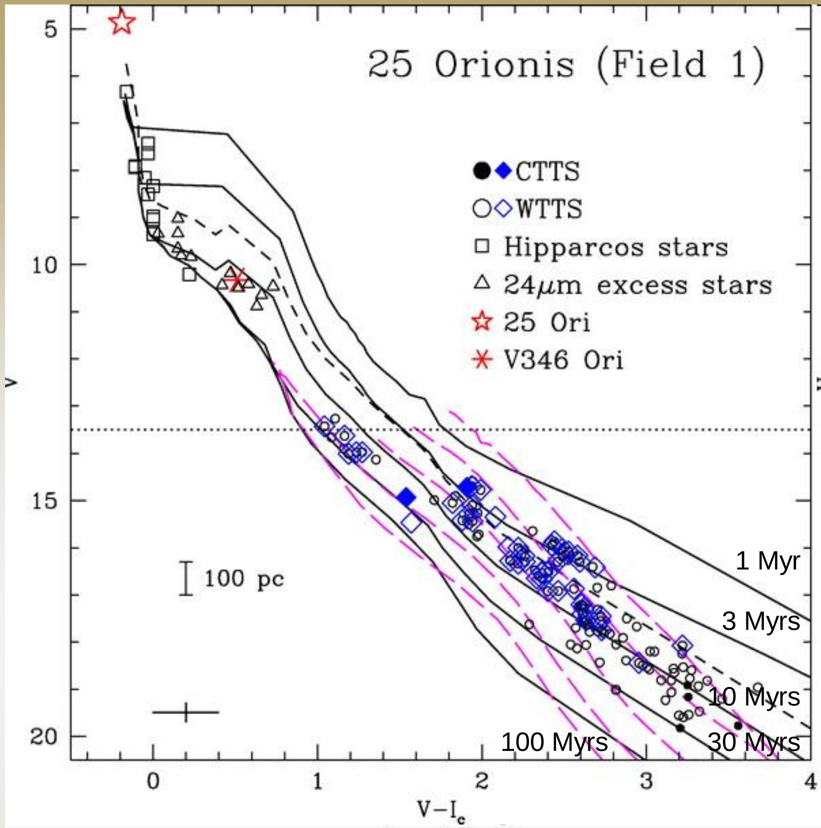
- Target selection: why 25 Ori?

  – Young (below 10 Myrs)
  – Near-by
  – Many cluster members with intermediate magnitudes
  – Location near the celestial equator

25 Ori cluster

(Briceño et al. 2007)

- Well defined group of at least 200 low-mass pre-main-sequence stars
- The parallaxes of the Hipparcos stars yield a mean distance of 323 pc
- Low mass members follow a well-defined band in the color-magnitude Diagram → isochronal age ~7-10 Myrs



- Most populated cluster in this age range known within 500 pc

Observations

- Start of the monitoring of 25 Ori: January 2010
  - Observations from three Observatories beginning of 2010
- Season 1 (winter 2010/2011):
  - 3 runs: 2010 Dec., 2011 Jan., 2011 Feb. (13 Observatories)
- Season 2 (winter 2011/2012):
  - 3 runs: 2011 Dec., 2012 Jan., 2012 Jan./Feb. (12 Observatories)
- Season 3 (winter 2011/2012):
  - 3 runs: 2012 Dec., 2013 Jan., 2013 Feb. (7 Observatories)

Direct Imaging

NaCo VLT

- 2010 December 22-24 (3 nights)
- 2012 December 2-4 (3 nights)

→ See Tobi‘s talk

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

Astrophysikal. Institut
0.9/0.6-m telescope

Stara Lesna

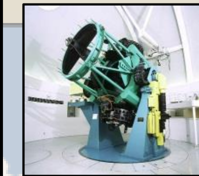
Astronomical Institute
0.6-m telescope

Xinglong

Observatory
0.9/0.6-m telescope

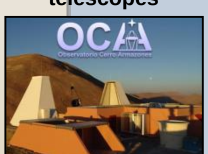
Gunma

Astronomical Observatory
1.5-m telescope



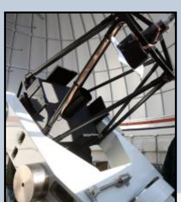
Observatorio Cerro Armazones

two 5.9'' telescopes



Swarthmore

0.6-m telescope

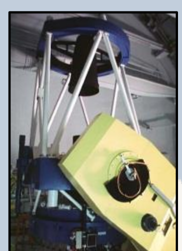


La Palma

0.5-m robotic telescope PT5M

Calar Alto

2.2-m telescope



Rozhen

0.6 and 2-m telescopes

Nainital

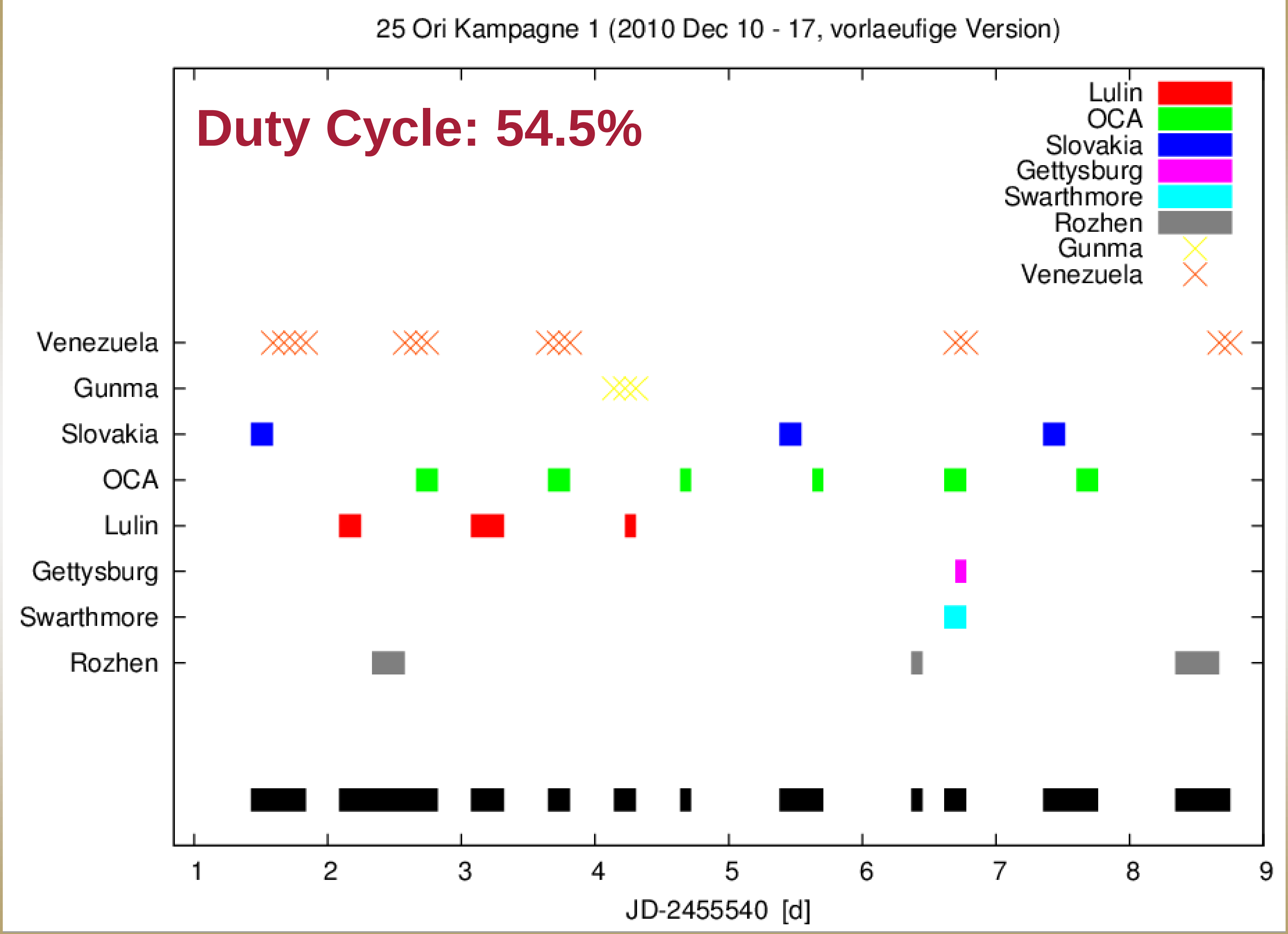
State Observatory
1-m telescope

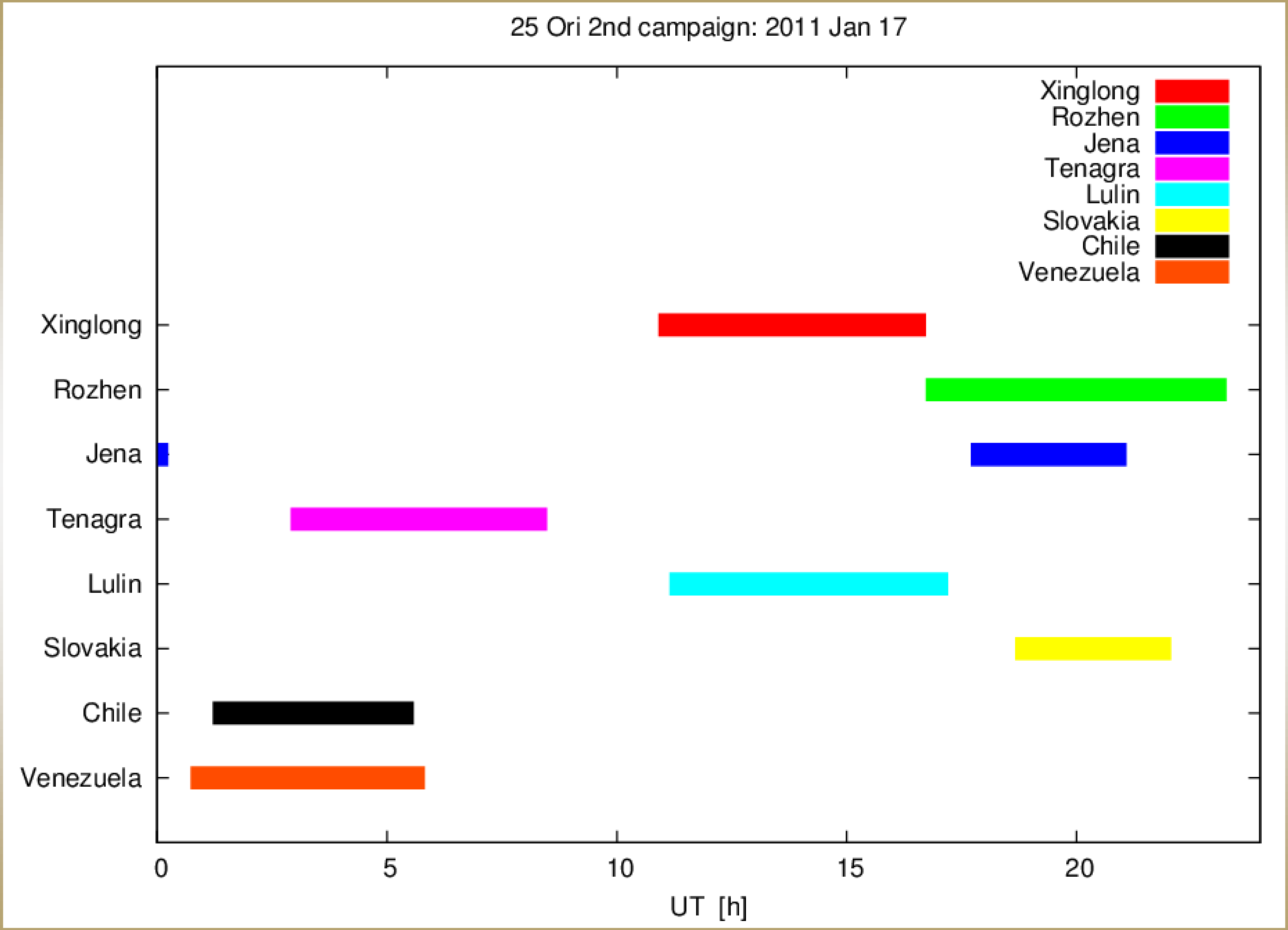
Lulin

Lulin Observatory
1-m telescope

Saitama

Dodaira Observatory
0.91-m telescope

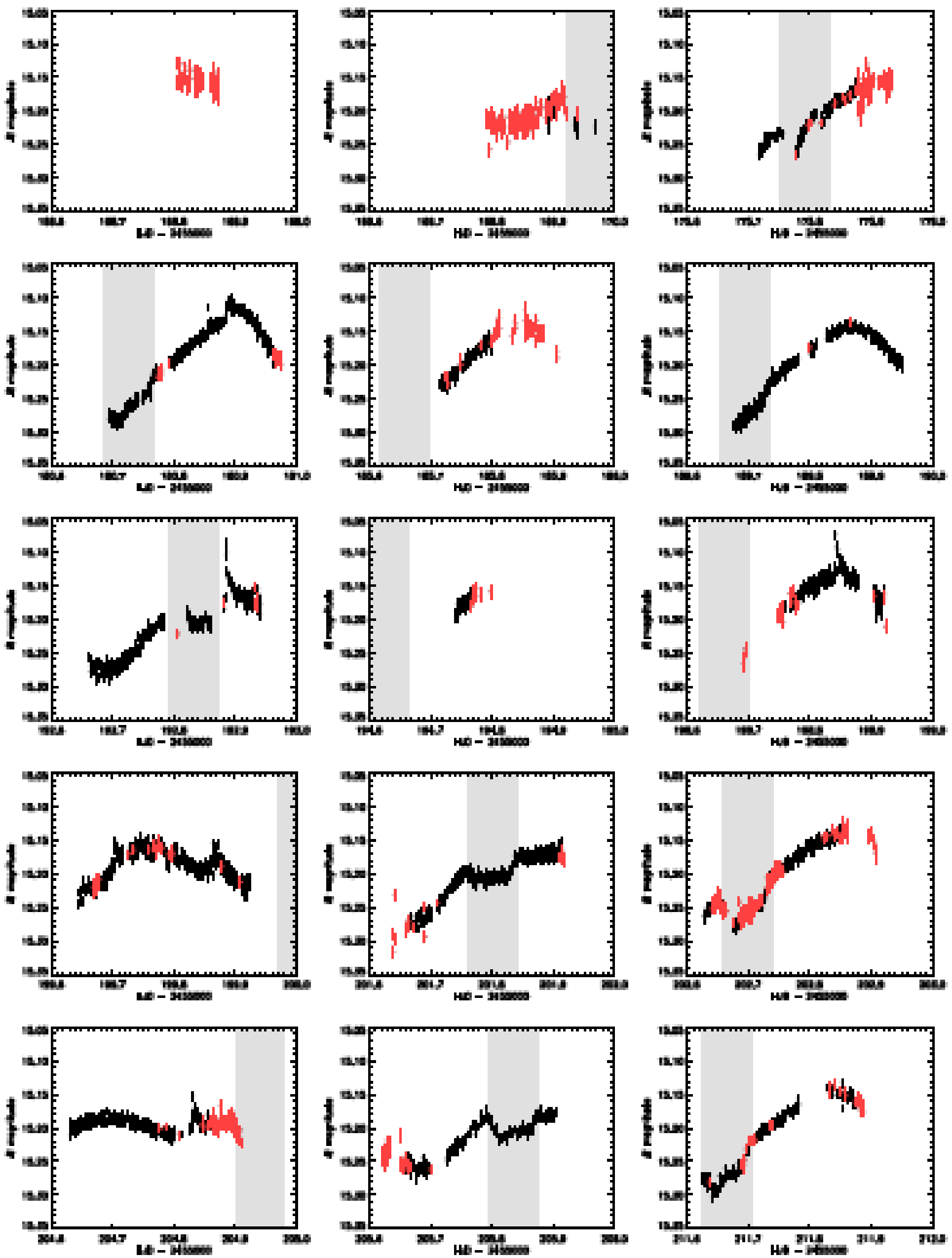

25 Ori Kampagne 1 (2010 Dec 10 - 17, vorlaeufige Version)
Duty Cycle: 54.5%
Lulin
OCA
Slovakia
Gettysburg
Swarthmore
Rozhen
Gunma
Venezuela
1
2
3
4
5
6
7
8
9
JD-2455540 [d]



25 Ori 2nd campaign: 2011 Jan 17
Xinglong
Rozhen
Jena
Tenagra
Lulin
Slovakia
Chile
Venezuela
0
5
10
15
20
UT [h]

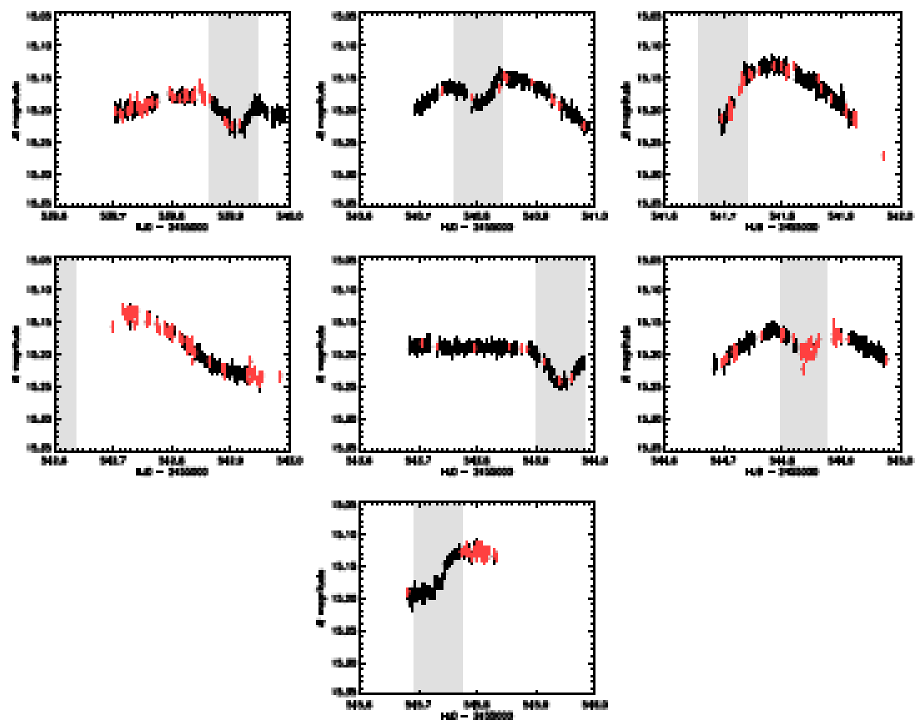
First Transit candidate

(van Eyken et al. 2012)



CVSO-30 or PTFO 8-8695

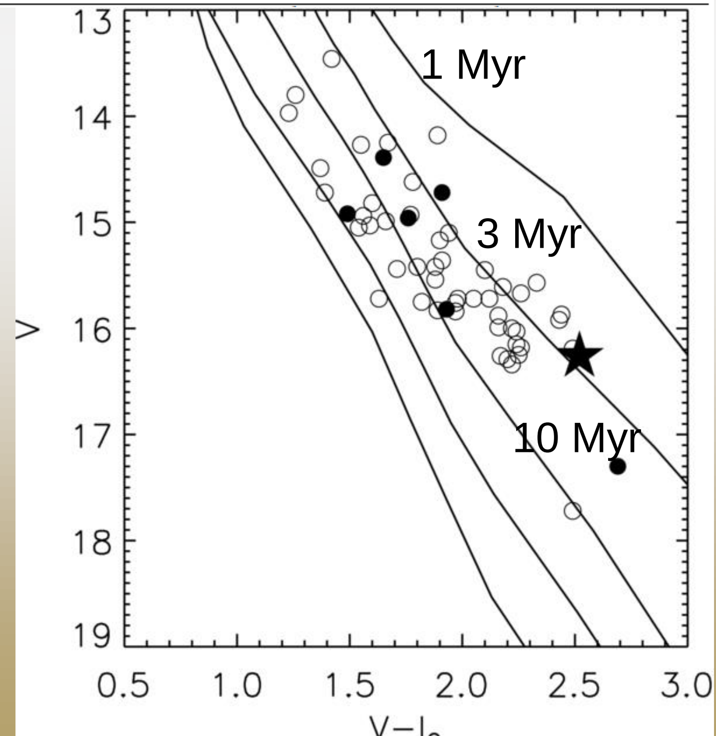
(Palomar Transient Factory, PTF)



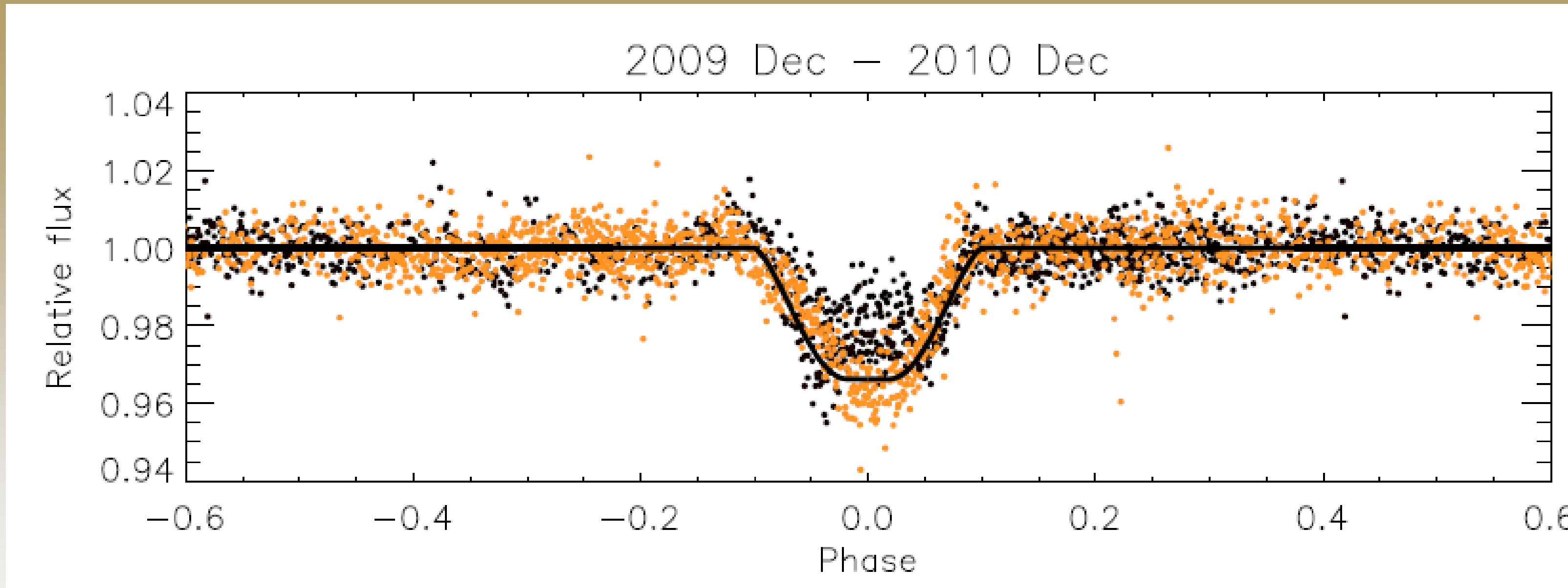
CVSO-30 in 25 Ori

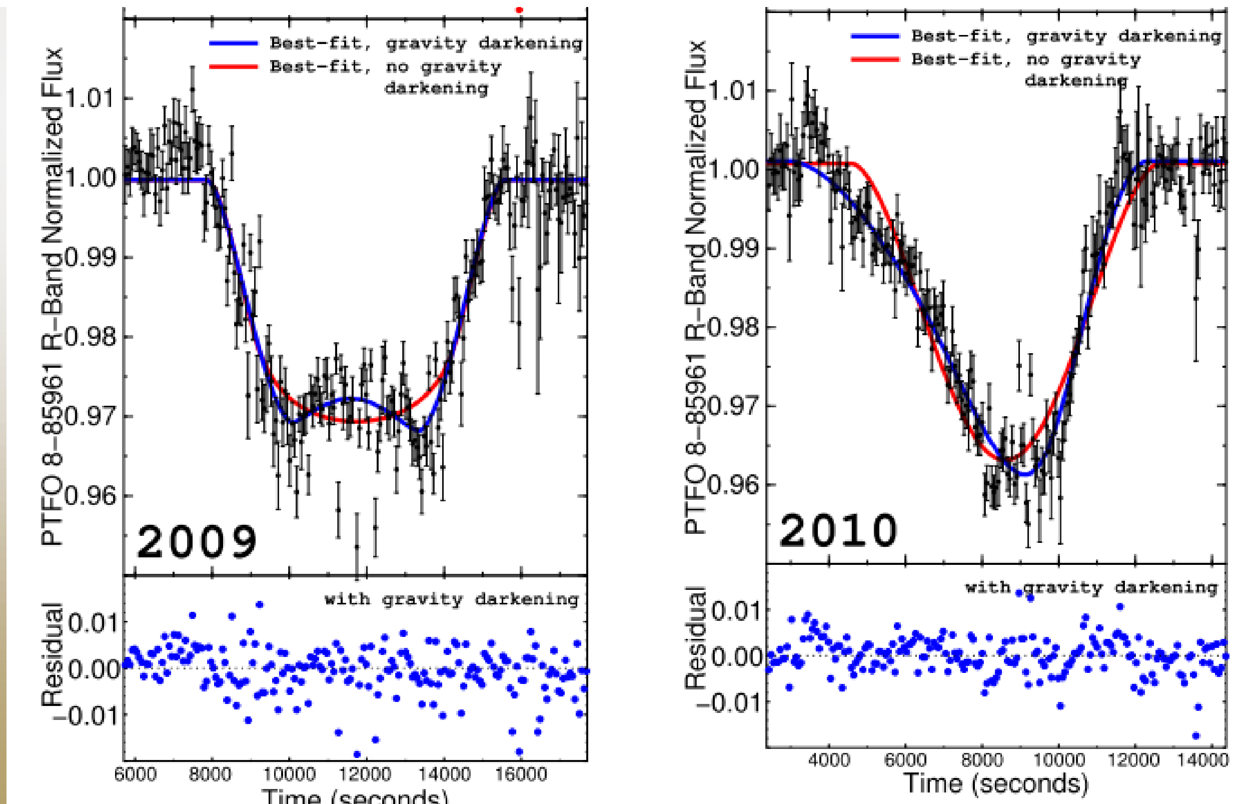
	CVSO 30
Altern. designations	2MASS J05250755+0134243, PTF1 J052507.55+013424.3
Location	25 Ori / Orion OB 1a
RA, Dec	05h 25m 07.57s, +01° 34′ 24.5″
Spectral type	M3 (weak-line T-Tauri, WTTS)
Mass	0.34 / 0.44 $M_\odot$
Luminosity	0.25 $L_\odot$
Radius	1.39 $R_\odot$ / 1.07 ± 0.10 $R_\odot$ / [1.03 / 1.04 ± 0.01 $R_\odot$]
Temperature	3470 K
Opt. extinction	0.12 mag
Distance	[323^{+233}_{-96}, 322^{+504}_{-122}] pc / 357 ± 52 pc
Age	$2.39^{+3.41}_{-2.05}$ Myr
H_α equivalent width	-11.40 Å
LiI equivalent width	0.40 Å
v sin(i)$_*$	80.6 ± 8.1 km s^{-1}
Proper Motion [E,N]	[-0.1 ± 5.3, 0.9 ± 5.5] mas/yr
B, V, R photometry	[18.35, 16.26, 15.19] mag
J, H, K photometry	[12.232 ± 0.028, 11.559 ± 0.026, 11.357 ± 0.021] mag

Briceño et al.
2005
&
2007



CVSO = CIDA Variability Survey in Ori
CIDA= Centro de Investigaciones de Astronomía (Venezuela)

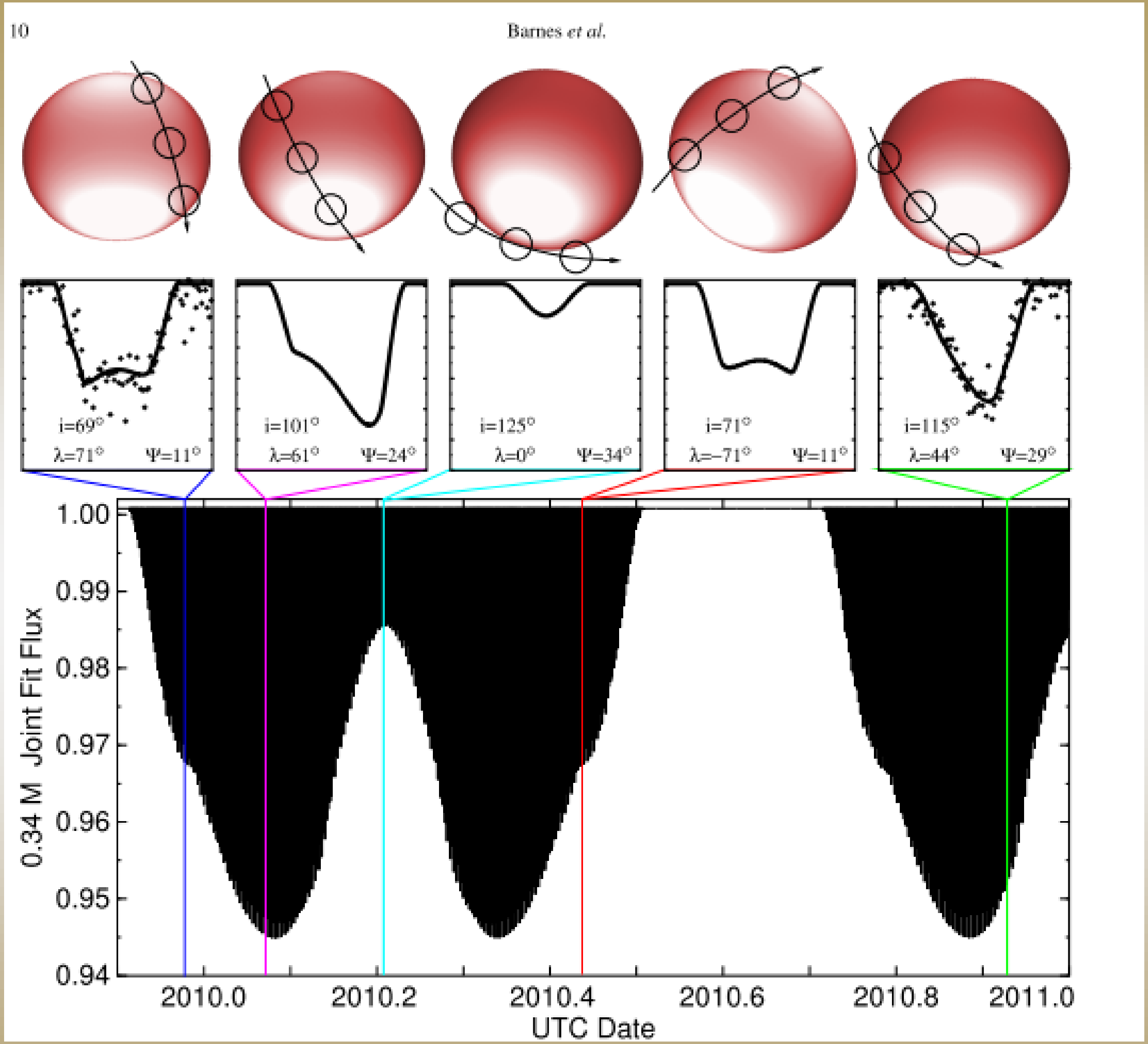




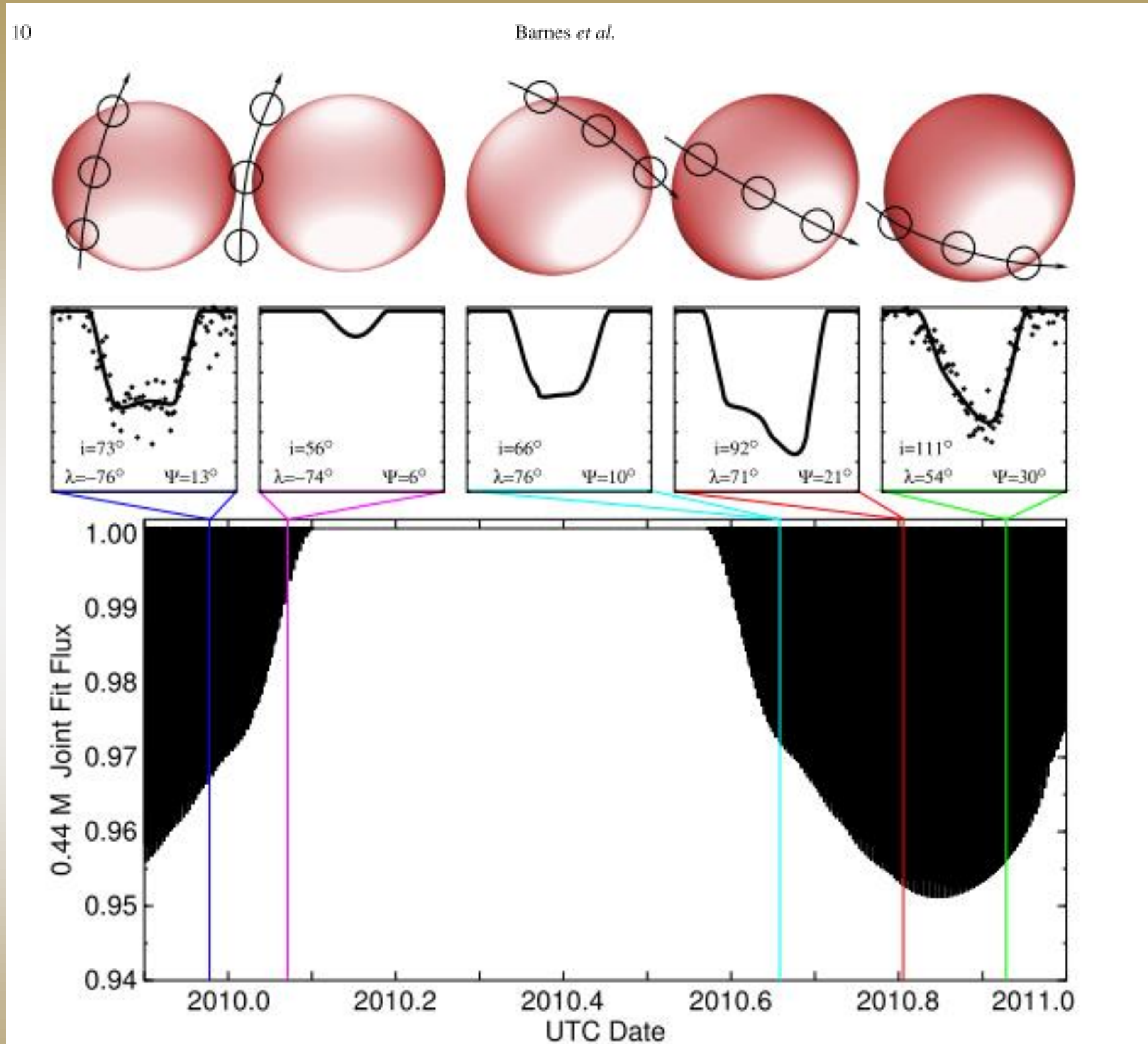
a precessing planet transiting a gravity-darkened star

Barnes et al. 2013

Gravity Darkening



Fast rotation → star is oblate (larger radius at the equator than at the poles)
→ poles have a higher surface gravity, and thus, higher temperature and brightness



Gravity Darkening

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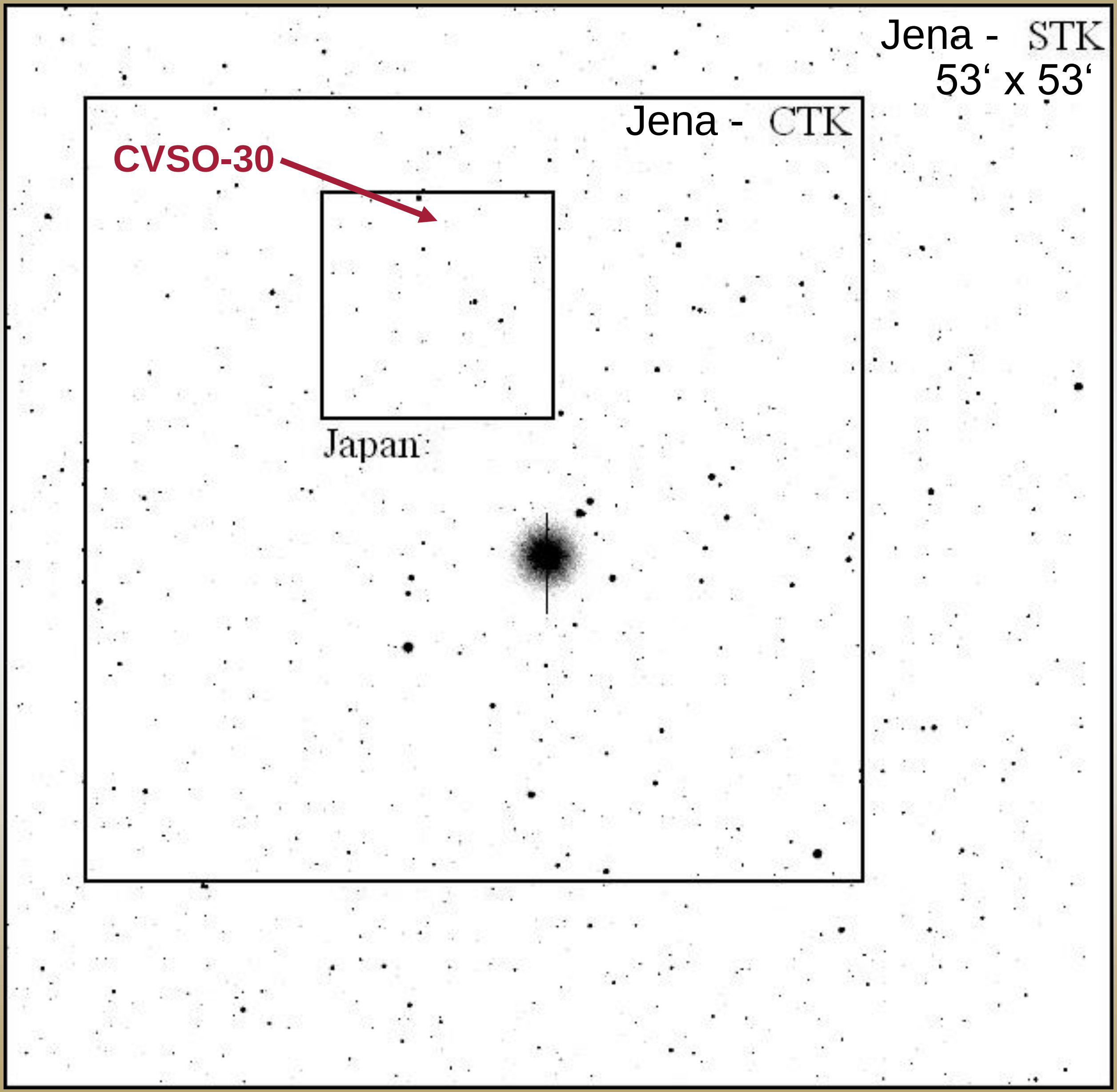
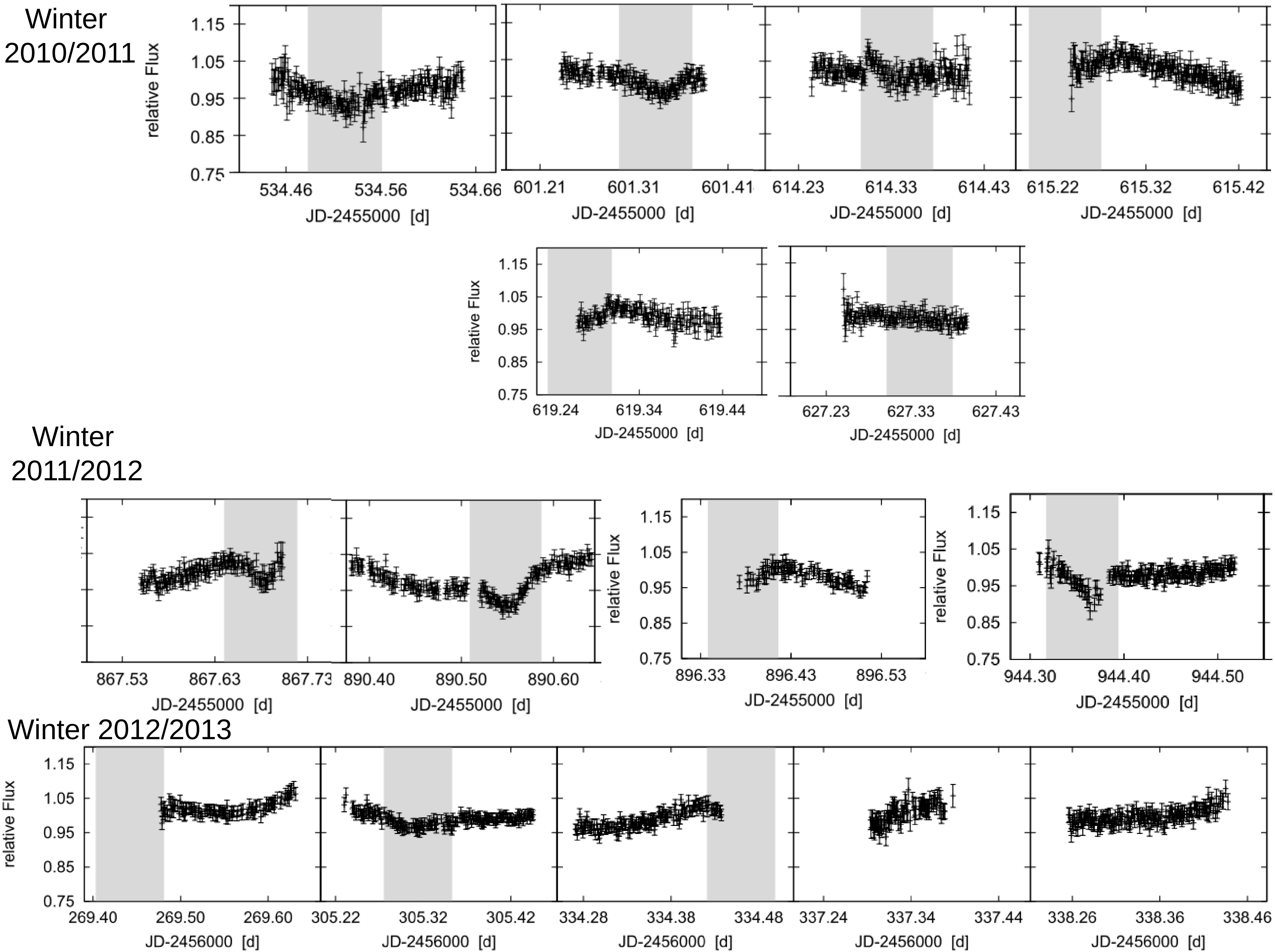
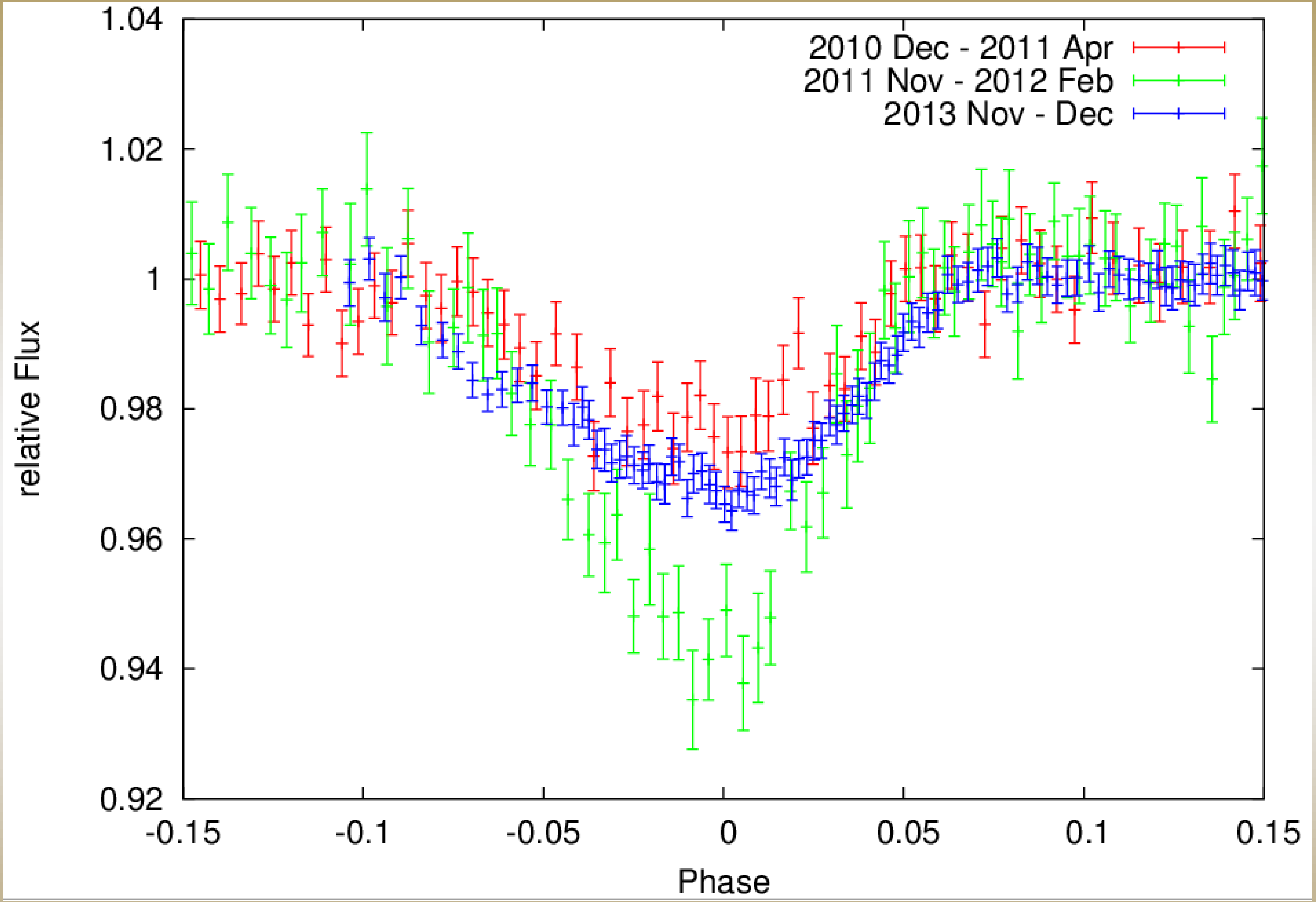
25 Ori – Field of View of the YETI Monitoring

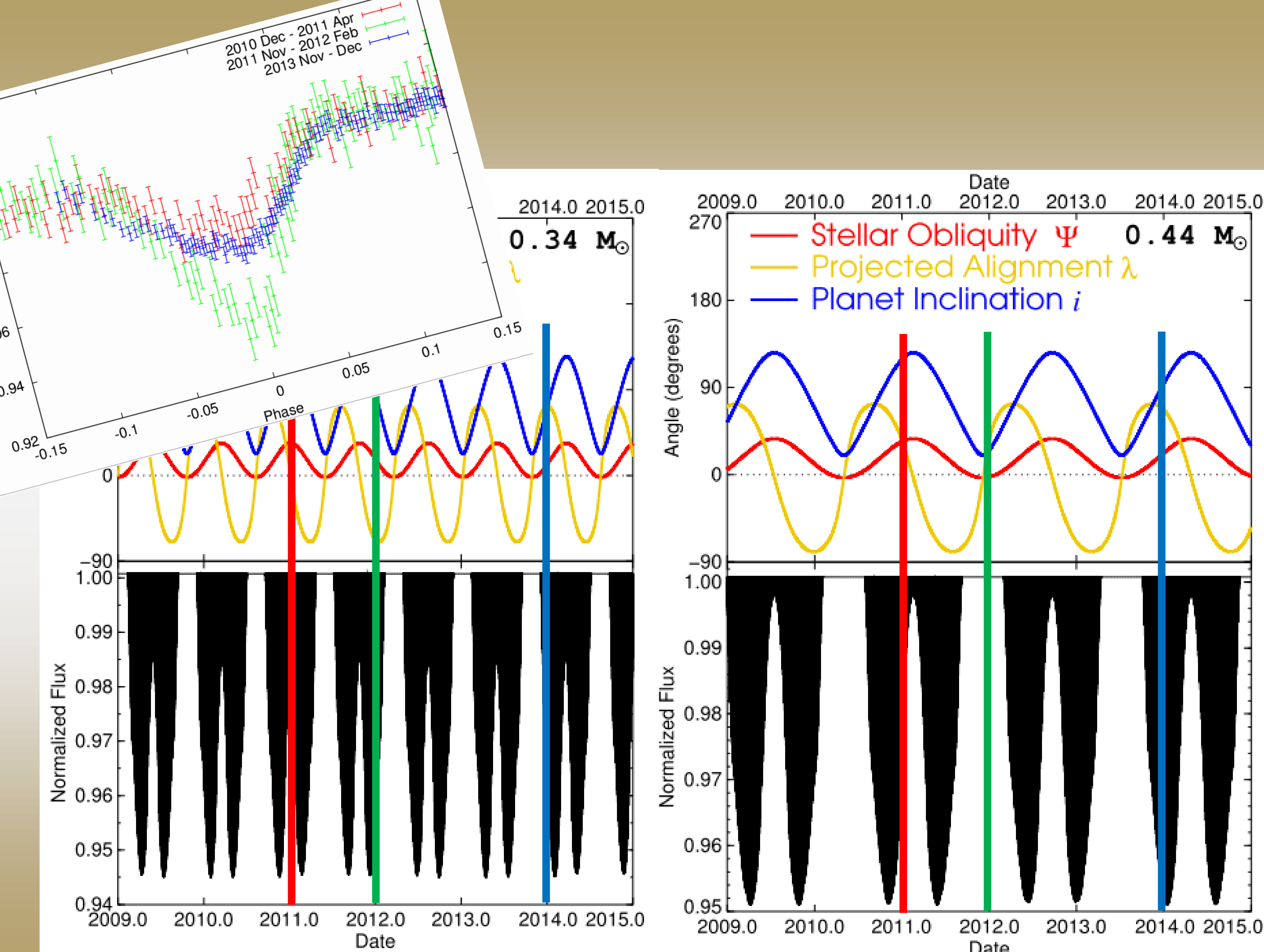



Winter 2010/2011
relative Flux
1.15
1.05
0.95
0.85
0.75
534.46
534.56
534.66
601.21
601.31
601.41
614.23
614.33
614.43
615.22
615.32
615.42
JD-2455000 [d]
619.24
619.34
619.44
627.23
627.33
627.43
Winter 2011/2012
867.53
867.63
867.73
890.40
890.50
890.60
896.33
896.43
896.53
944.30
944.40
944.50
Winter 2012/2013
269.40
269.50
269.60
305.22
305.32
305.42
334.28
334.38
334.48
337.24
337.34
337.44
338.26
338.36
338.46
JD-2456000 [d]

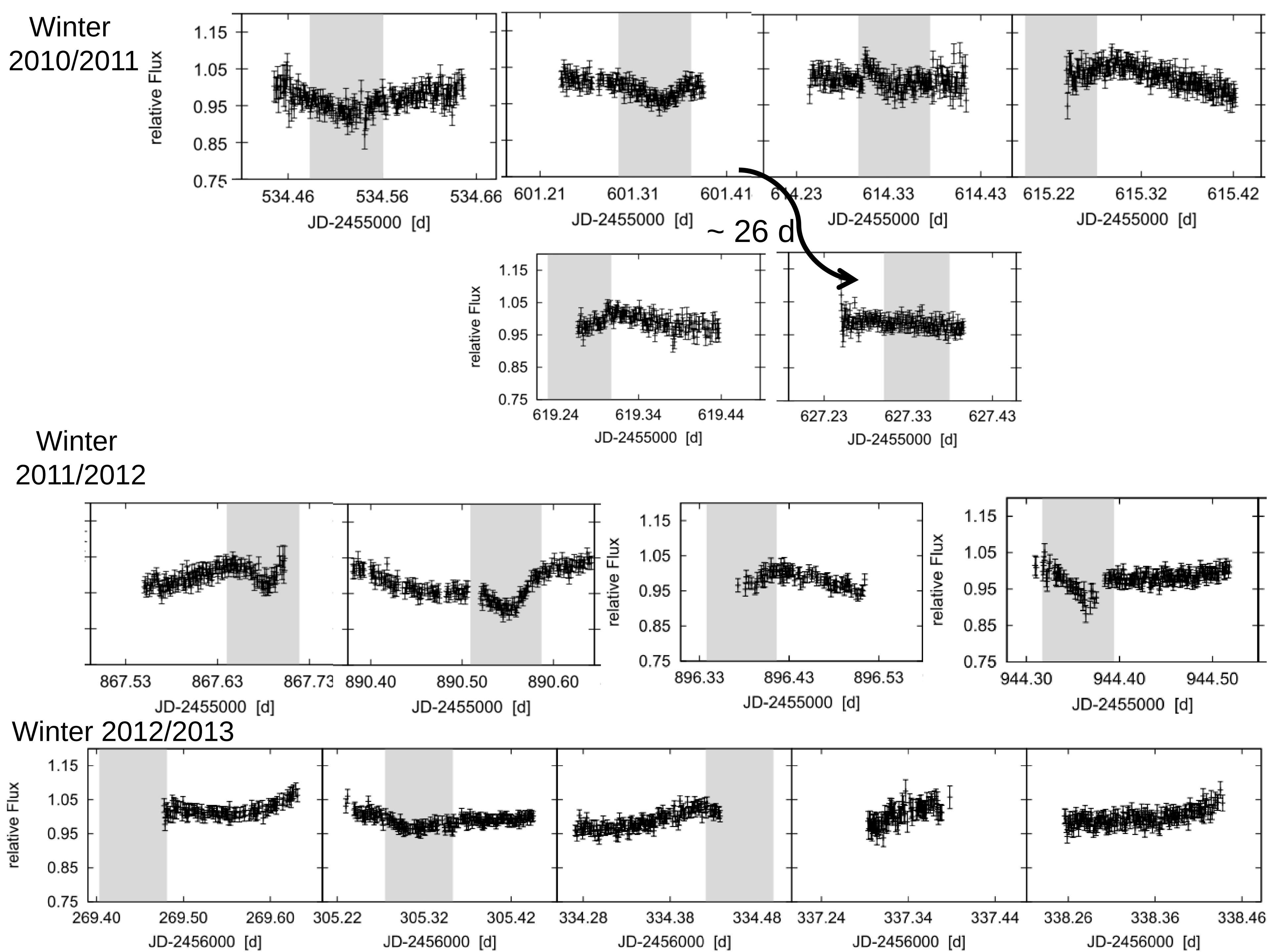


Barnes et al. 2013:

a precessing planet transiting a gravity-darkened star



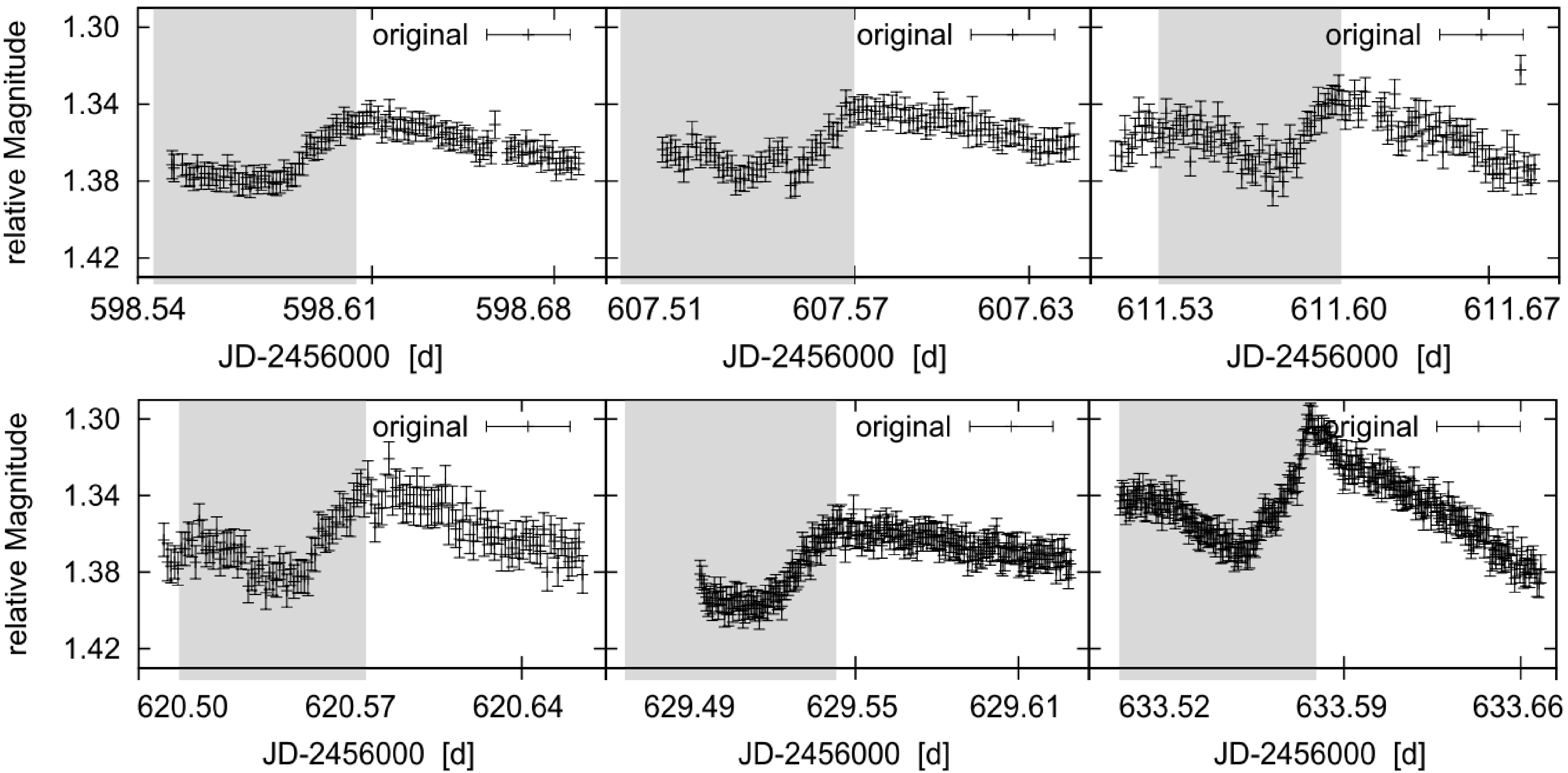
2010 Dec - 2011 Apr
2011 Nov - 2012 Feb
2013 Nov - Dec
Phase
0.34 M☉
Normalized Flux
Date
Stellar Obliquity Ψ
Projected Alignment λ
Planet Inclination i
0.44 M☉
Angle (degrees)
Normalized Flux
Date



Winter 2010/2011
Winter 2011/2012
Winter 2012/2013
~ 26 d
relative Flux
JD-2455000 [d]
JD-2456000 [d]

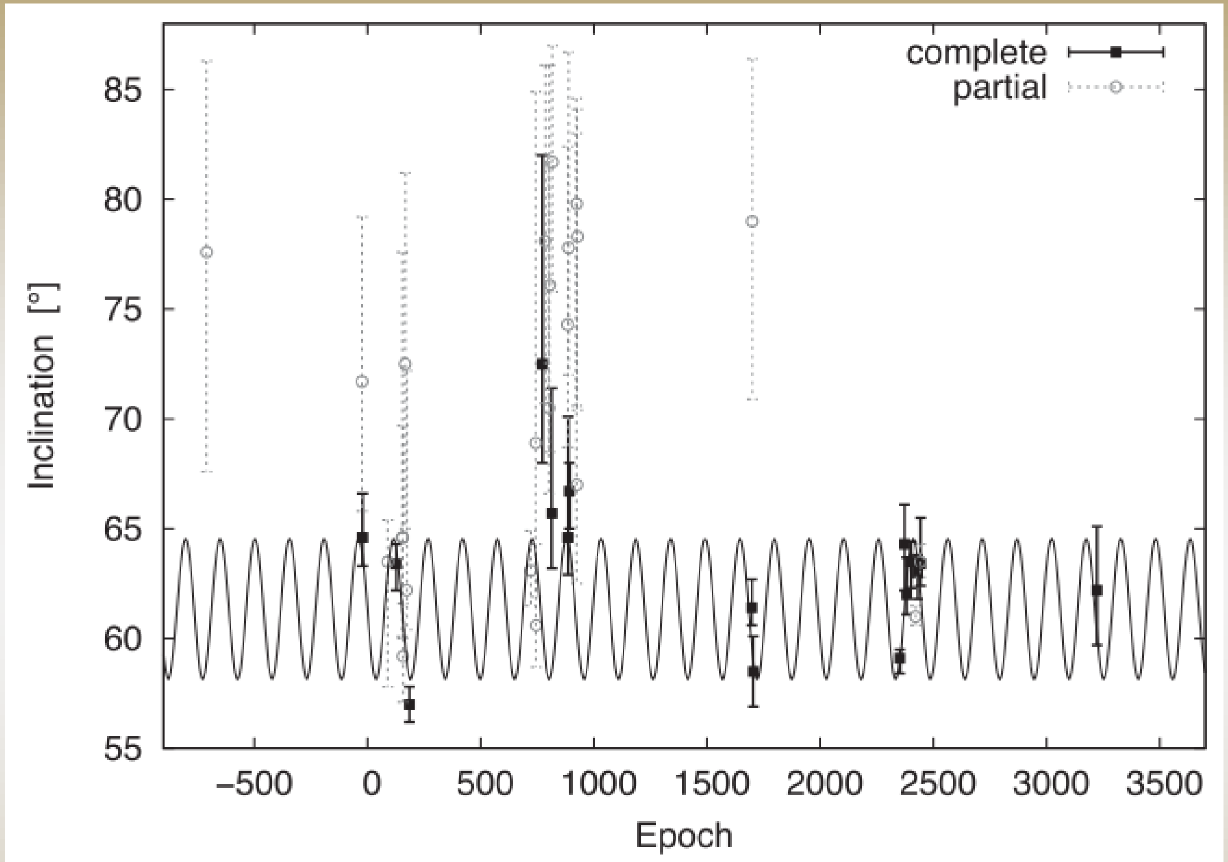
Photometric Follow-up

Season 2013/2014, OSN



Raetz et al., (2016)

Assumption for transit modelling: precessing planetary orbit
→ account for the changing shape by fitting an individual inclination



Best fitting period P_{Incl} ~ 153 epochs (~ 68.5 d)
smaller than the previously published values derived from numerical models

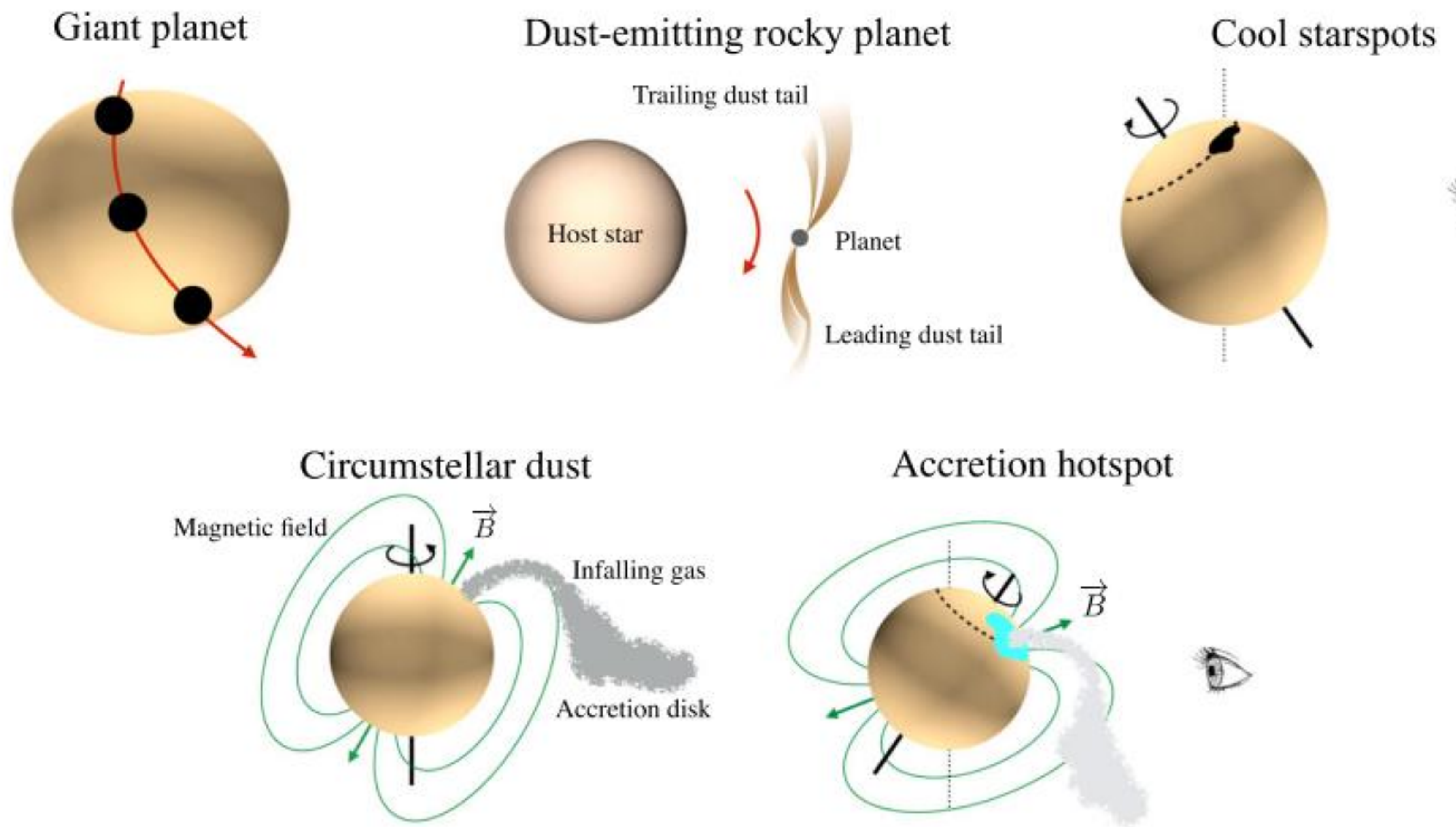
Time between a clear and a non-detection

→lower precession period seems to be plausible

Raetz et al. (2016)

TESTS OF THE PLANETARY HYPOTHESIS FOR PTFO 8-8695b

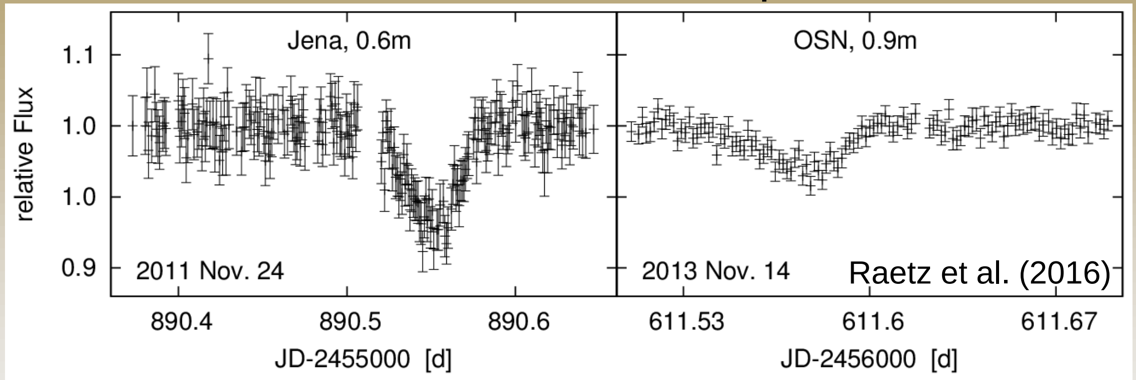
Yu et al. (2015)



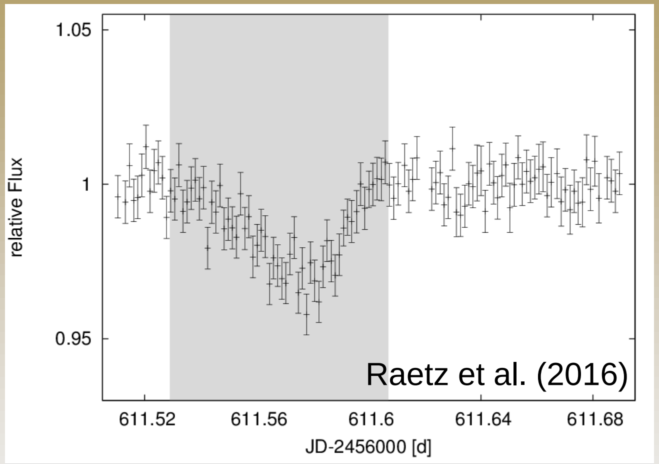
Disintegrating planet?

Disintegrating planet?

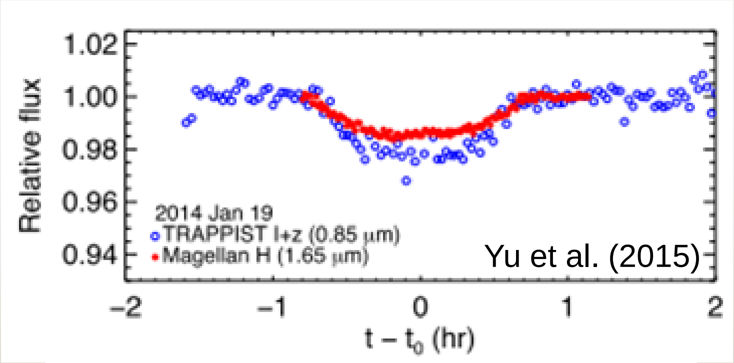
variable transit depth

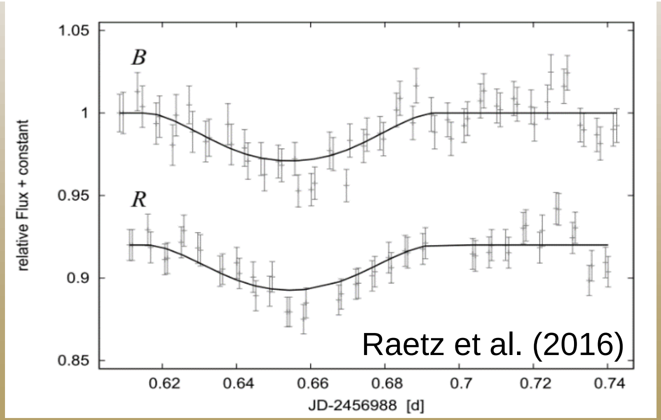


asymmetric transit shape

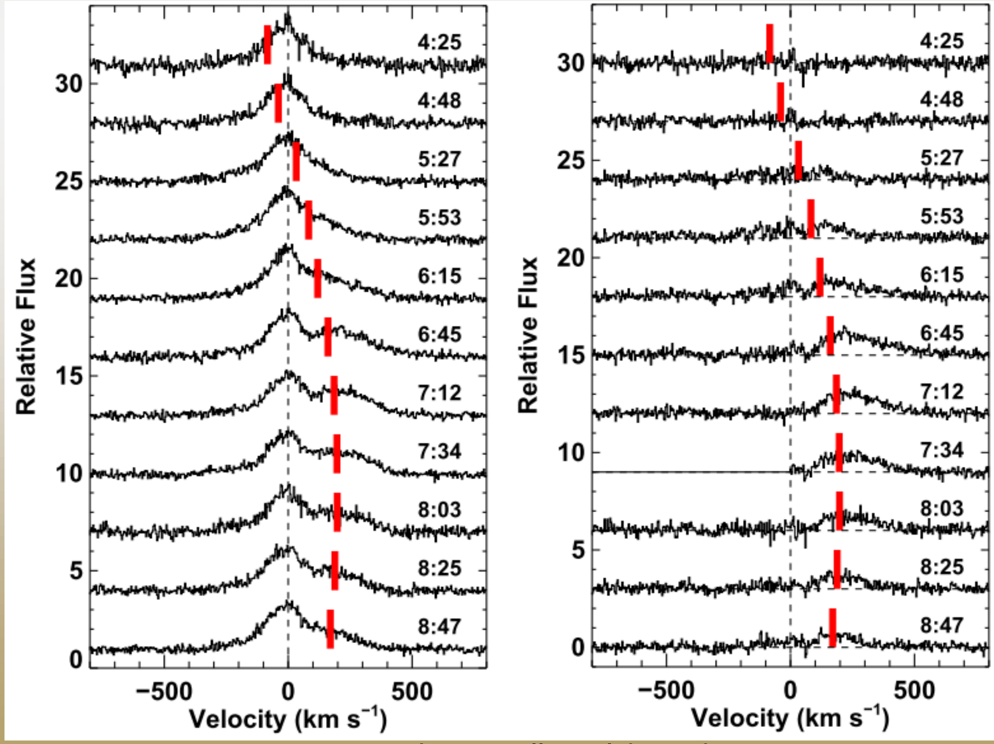


Transit depth occasionally depends on wavelength





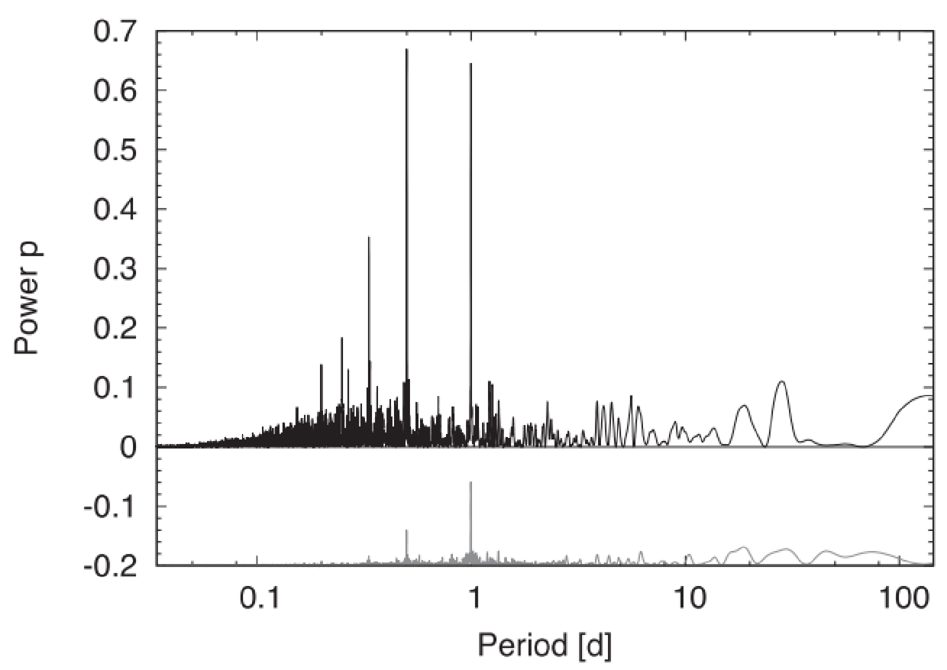
Hα excess moving in velocity as expected if planetary companion exists



Johns-Krull et al (2016)

Rotation period vs. transit period

Previous studies claimed: orbital period of planet is locked to rotation period of star



Highe
No pe

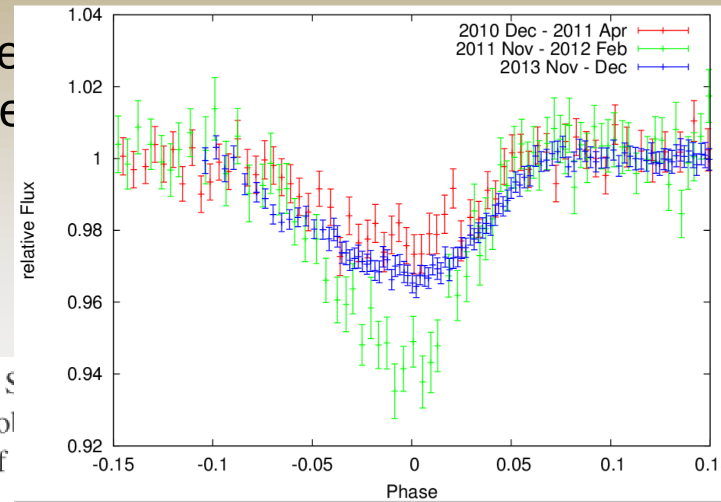


Table 6. S... ogram that was o... combi- nations of ...

Season	Observatory[a]	Period (d)	Amplitude (mmag)
S00	Jena, Gunma	0.499 32 ± 0.000 07	52.7 ± 1.8
S01	Jena	0.499 36 ± 0.000 01	41.0 ± 0.8
S02	Jena	0.499 45 ± 0.000 01	55.3 ± 0.5
S02	Jena, CIDA, Rozhen	0.499 27 ± 0.000 01	78.6 ± 0.6
S03	Jena	0.498 99 ± 0.000 05	38.0 ± 1.0
S03	Xinglong	0.499 28 ± 0.000 22	28.9 ± 1.8
S03	Jena, Xinglong	0.498 96 ± 0.000 05	37.3 ± 1.0
2455941	Jena, CIDA, Rozhen	0.538 34 ± 0.006 52	99.3 ± 2.1
2455958 2455967	Jena, CIDA	0.497 45 ± 0.000 36	72.7 ± 1.8

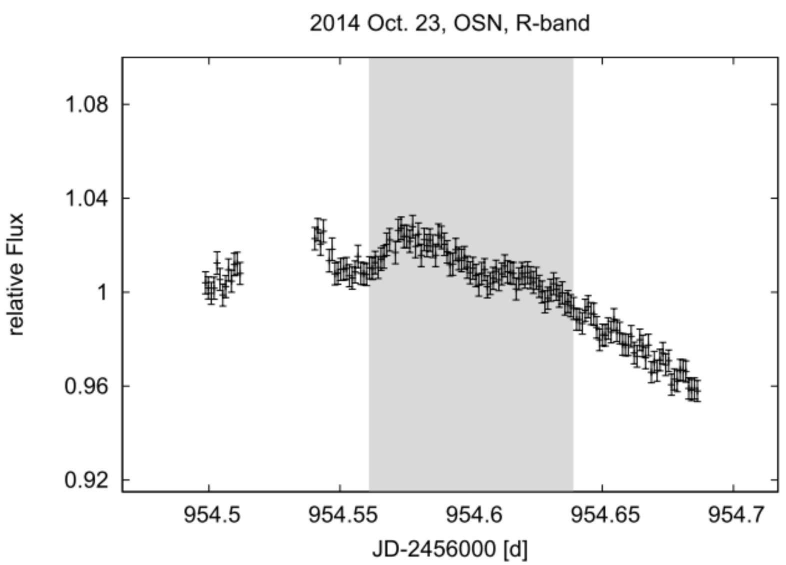
→ amplitude of variability seem to be correlated with the transit depth

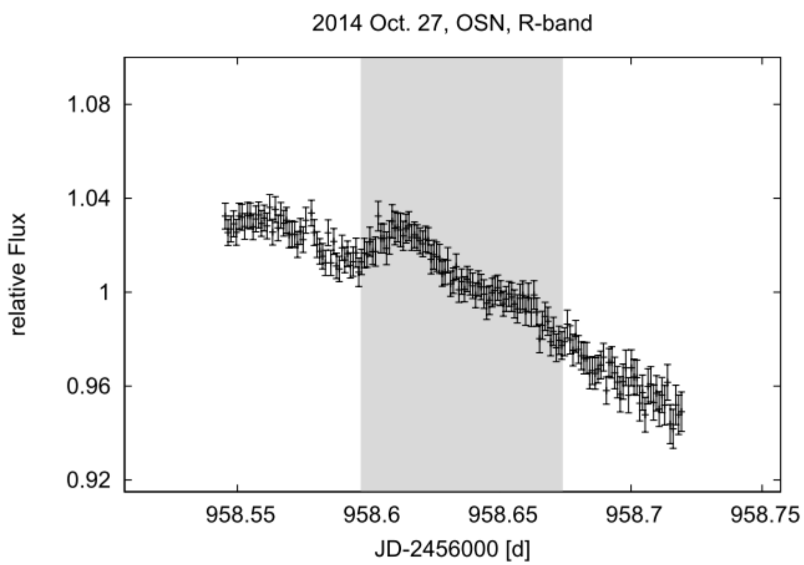
→ higher stellar activity: more material is ‘blown’ away from the planet through higher levels of stellar high-energy irradiation.

Raetz et al., (2016)

Light curves of CVSO 30

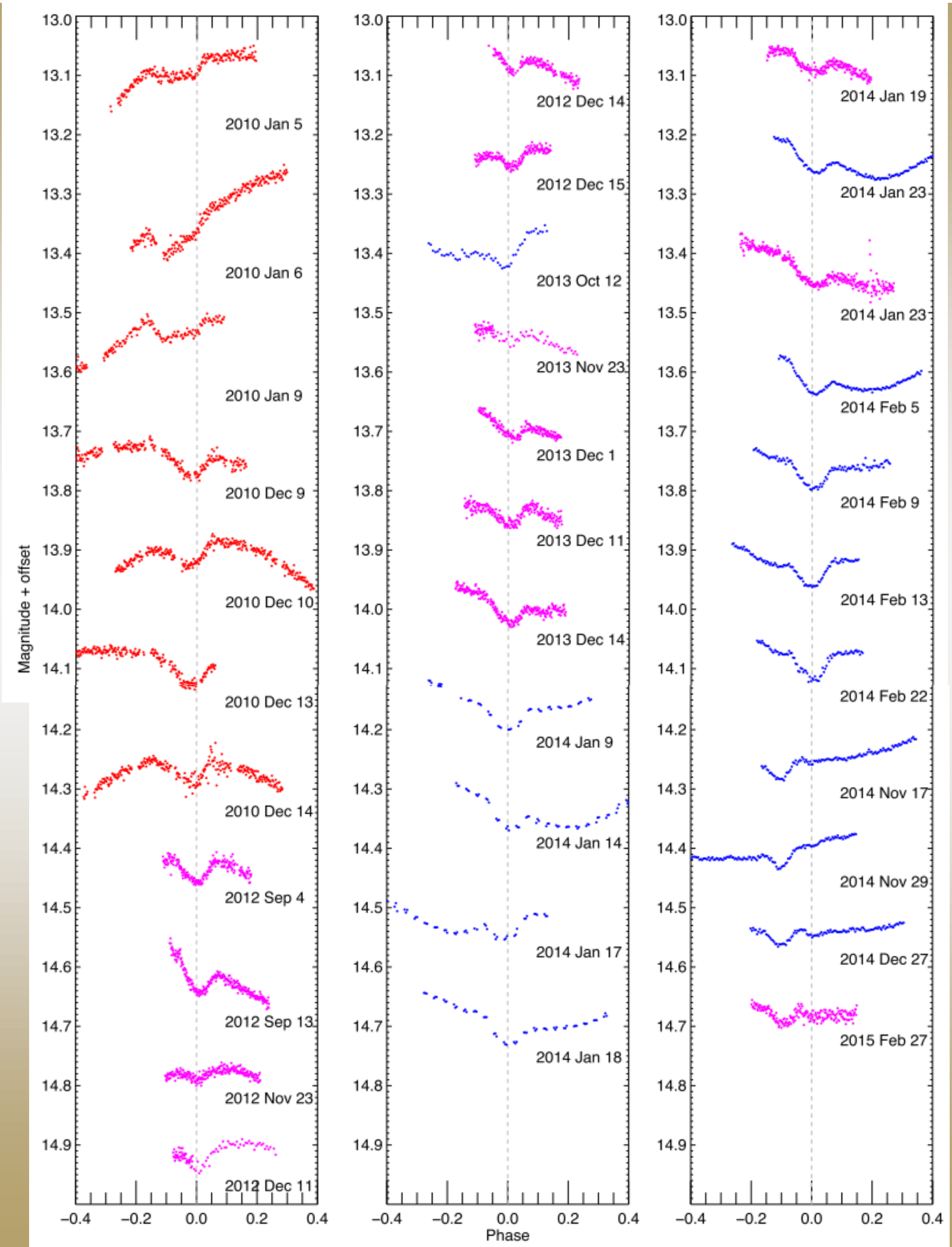
Season 2014/2015





TESTS OF THE PLANETARY HYPOTHESIS FOR PTFO 8-8695b

Yu et al. (2015)



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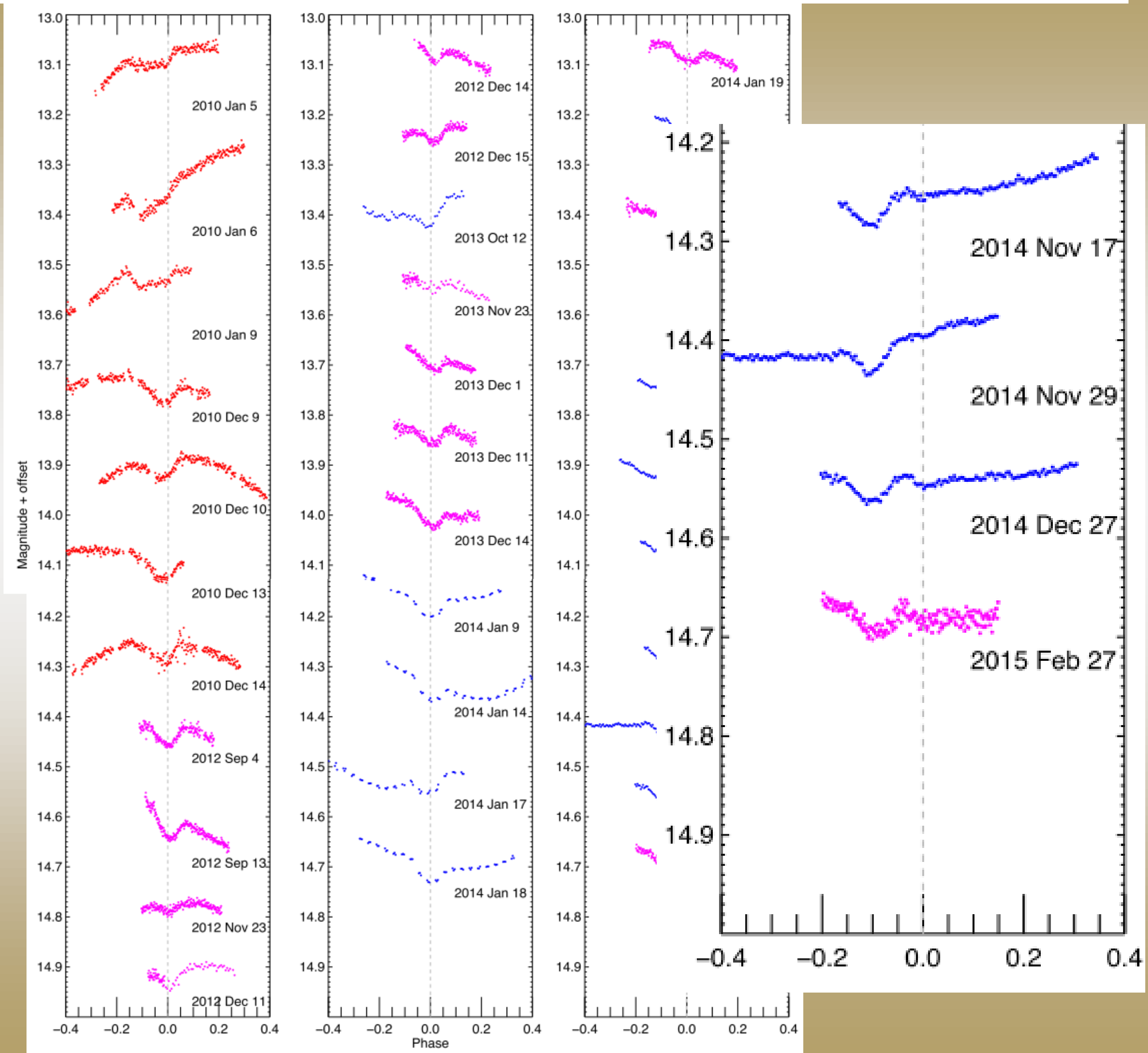
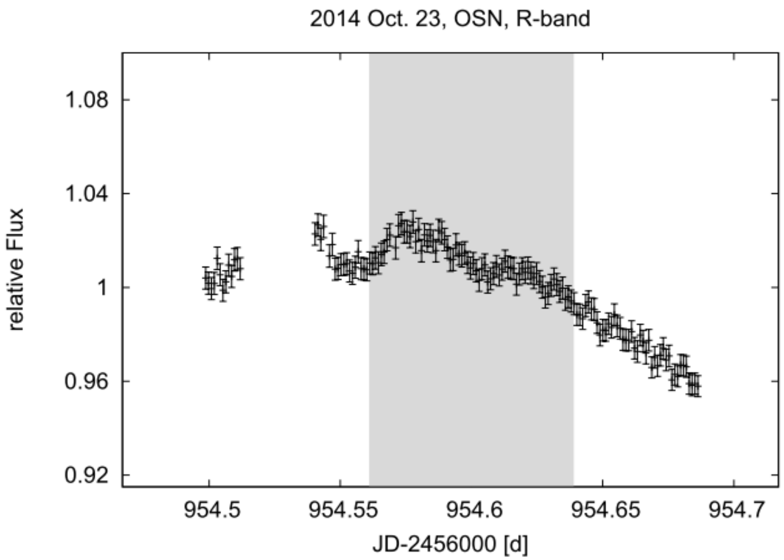
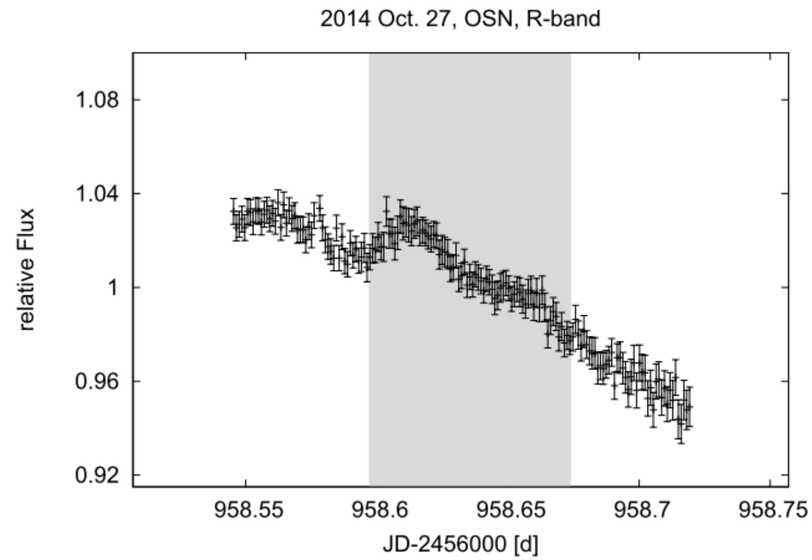


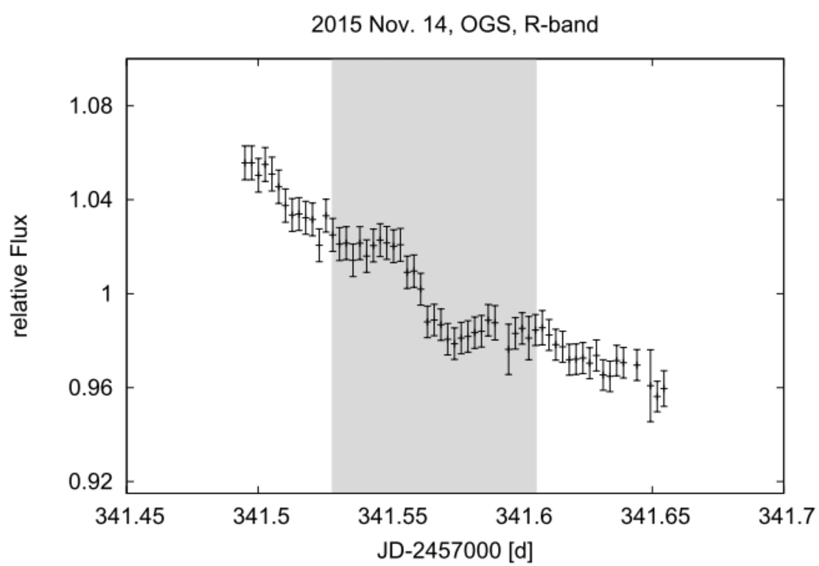
Light curves of CVSO 30

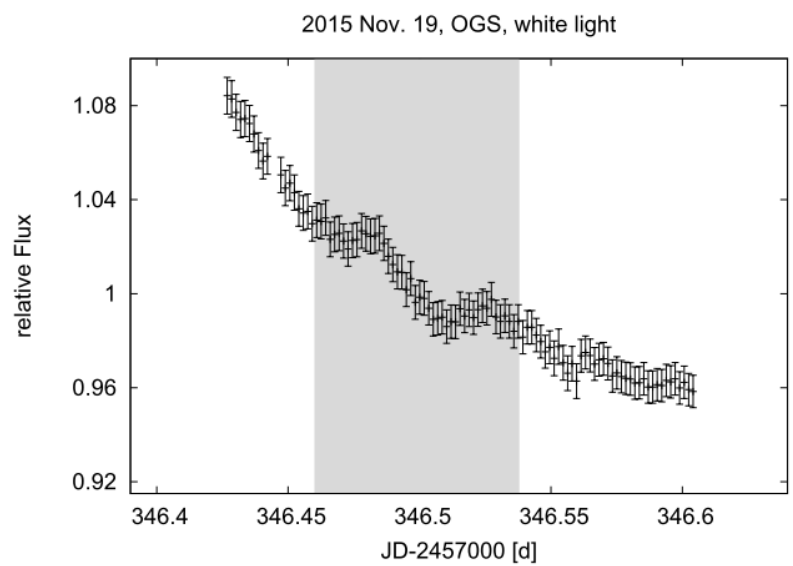
Season 2014/2015



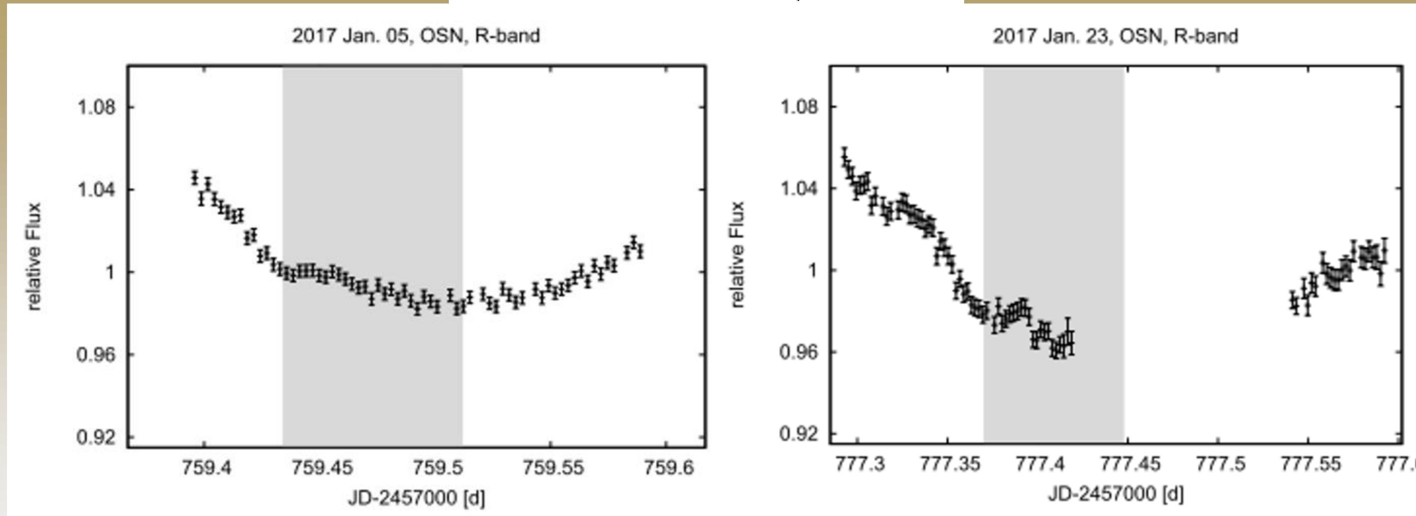


Season 2015/2016

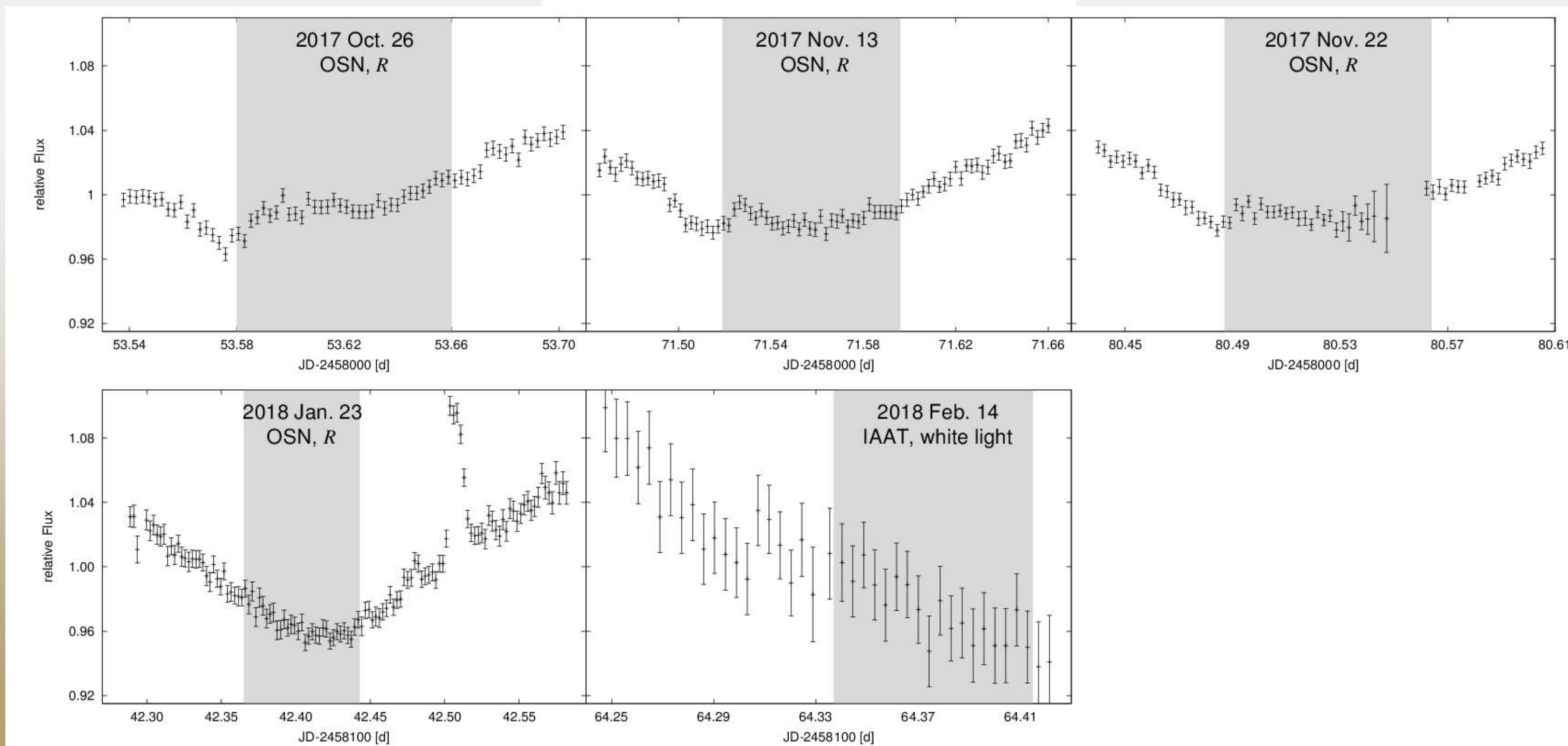


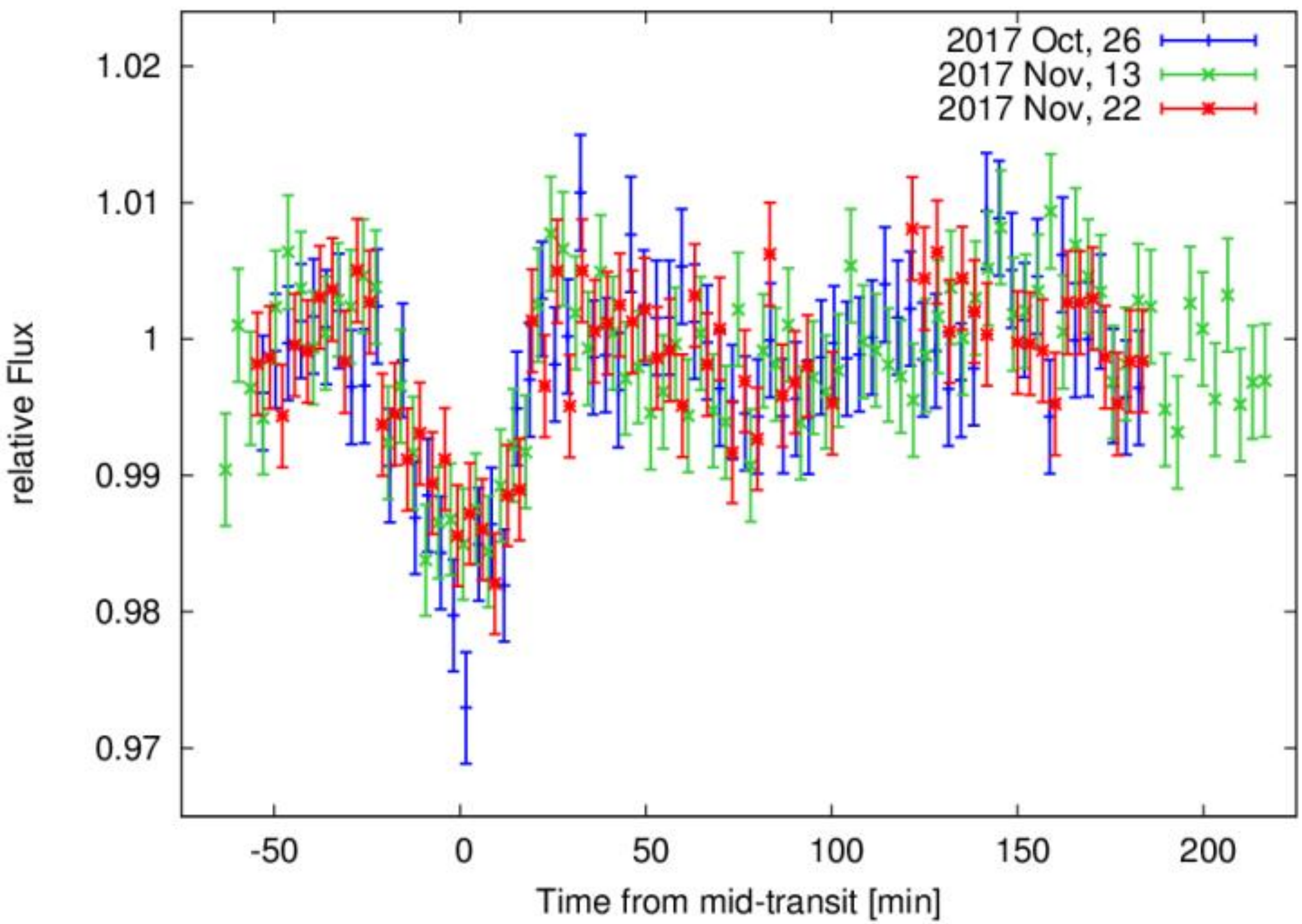


Season 2016/2017

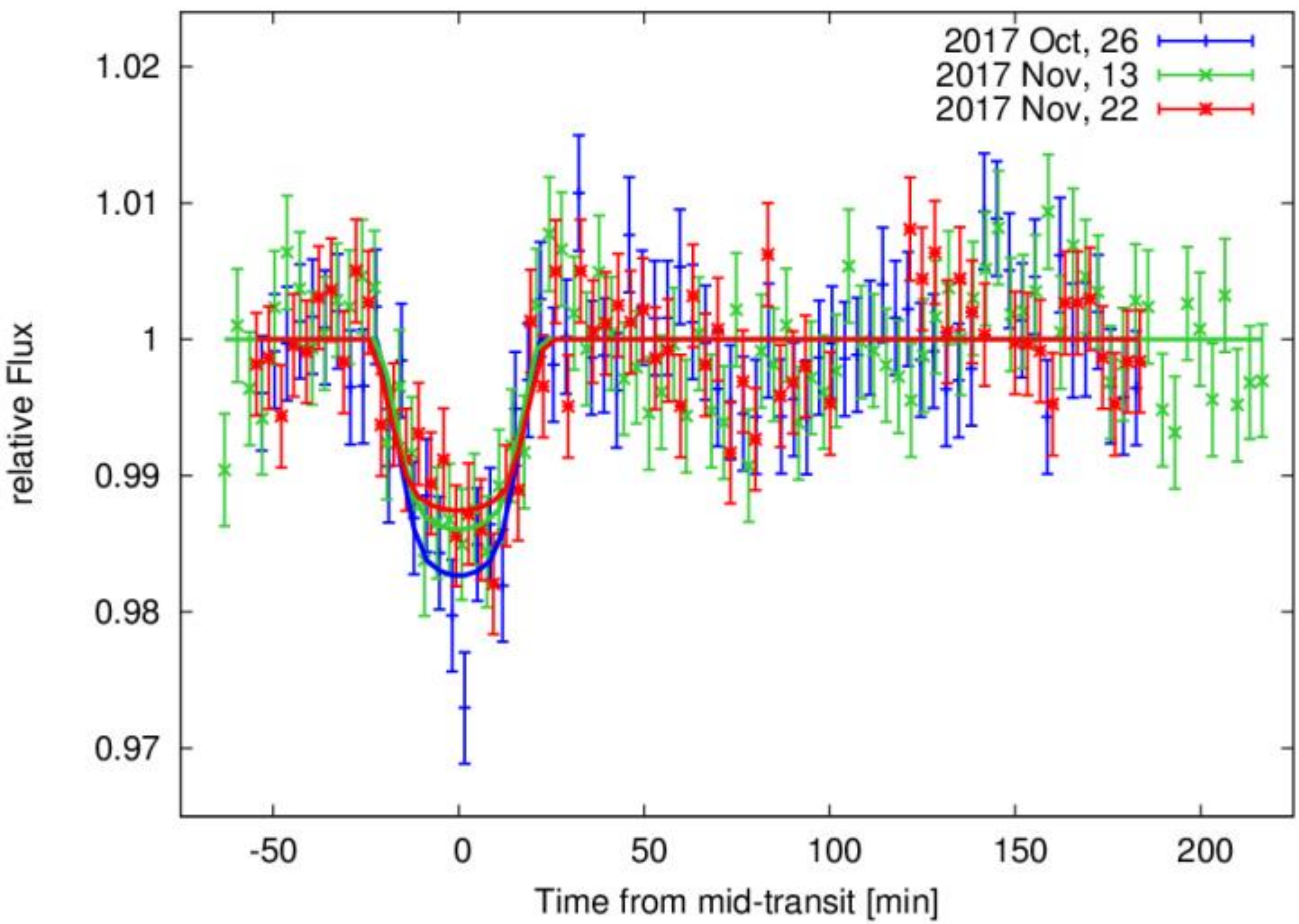


Season 2017/2018

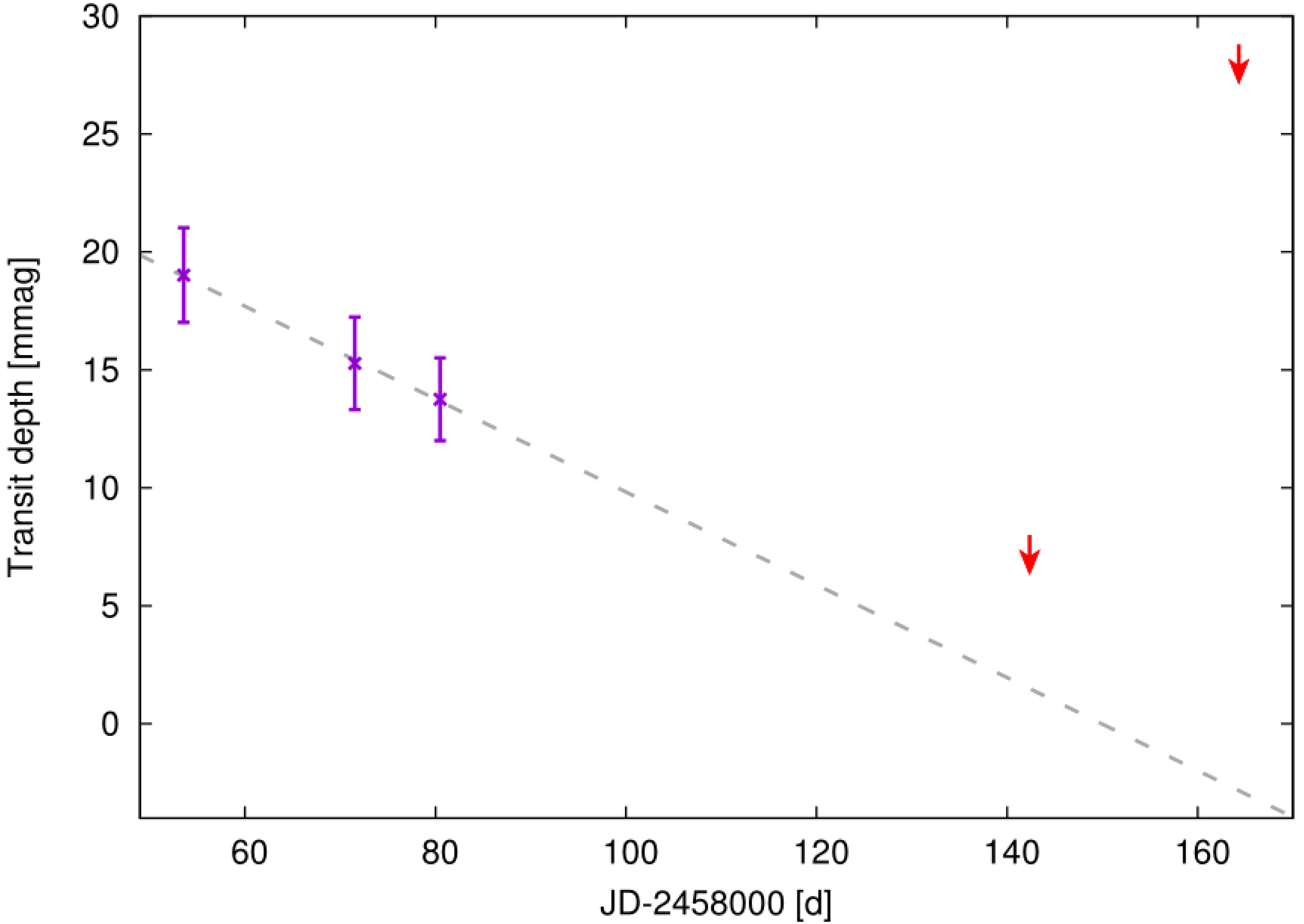




2017 Oct, 26
2017 Nov, 13
2017 Nov, 22
relative Flux
1.02
1.01
1
0.99
0.98
0.97
-50
0
50
100
150
200
Time from mid-transit [min]



2017 Oct, 26
2017 Nov, 13
2017 Nov, 22
1.02
1.01
1
0.99
0.98
0.97
relative Flux
-50
0
50
100
150
200
Time from mid-transit [min]



30
25
20
15
10
5
0
Transit depth [mmag]
60
80
100
120
140
160
JD-2458000 [d]

Conclusion

- the system is too complex to confirm the planetary nature of CVSO 30 b, yet
- If it is indeed a giant planet on a precessing orbit the period may be shorter than previously thought
- Our most favoured solution: disintegrating planet (or planetesimals)

Outlook

- continuing the process of analysing the full data set obtained with all 13 telescopes during the three years of YETI monitoring.
- obtaining further follow-up observations of this unique and fascinating system
- **TESS observation of the system with a 2min cadence was granted to us**
  → ~27d of continuous 2min observations will be collected next year

If it is indeed confirmed as a planet, it will provide important constraints on planet formation and migration time-scales, and their relation to protoplanetary disc lifetimes.

Thank you
for your attention!