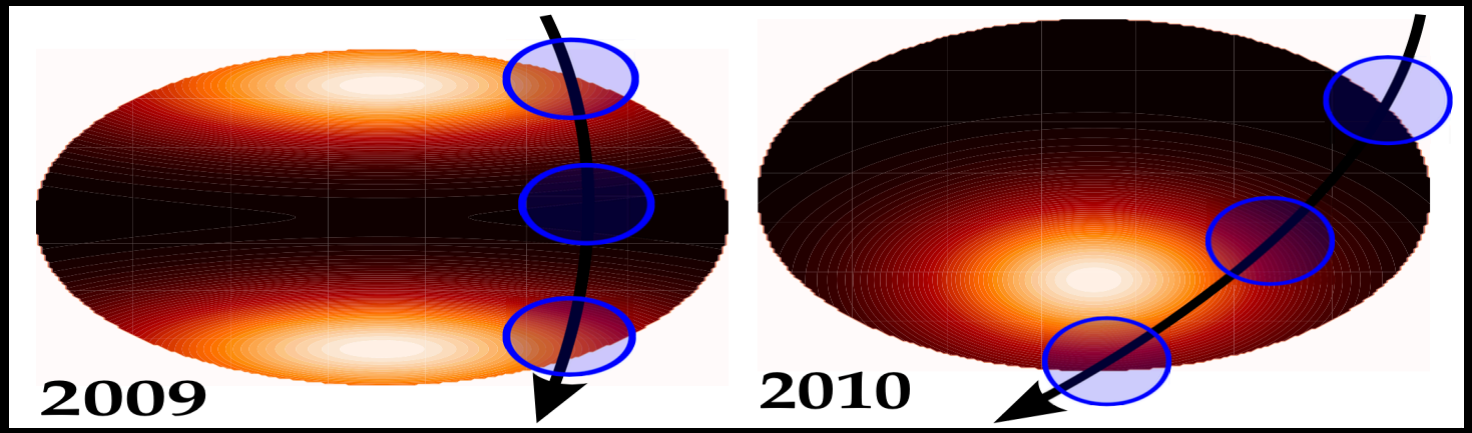
Re-characterization of a gravity-darkened and precessing planetary system PTFO 8-8695



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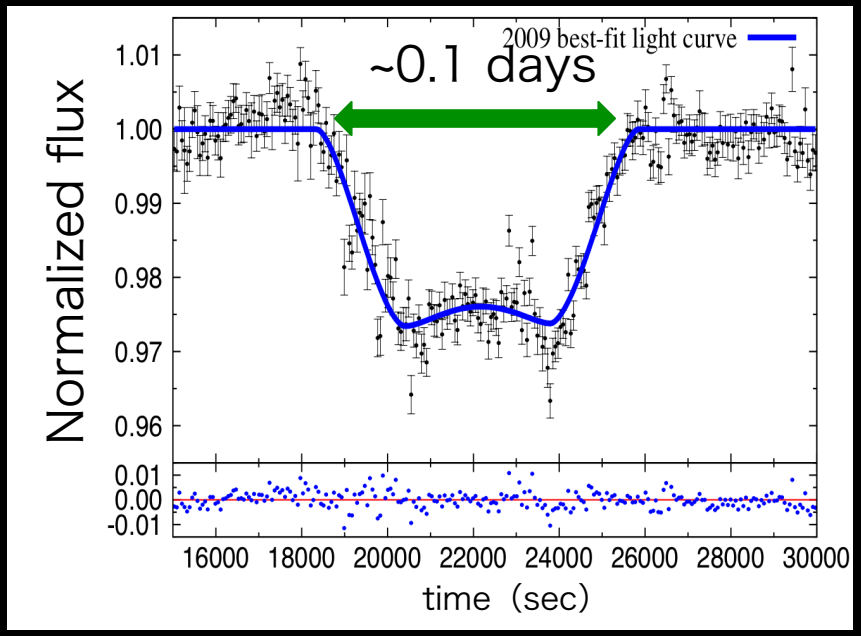
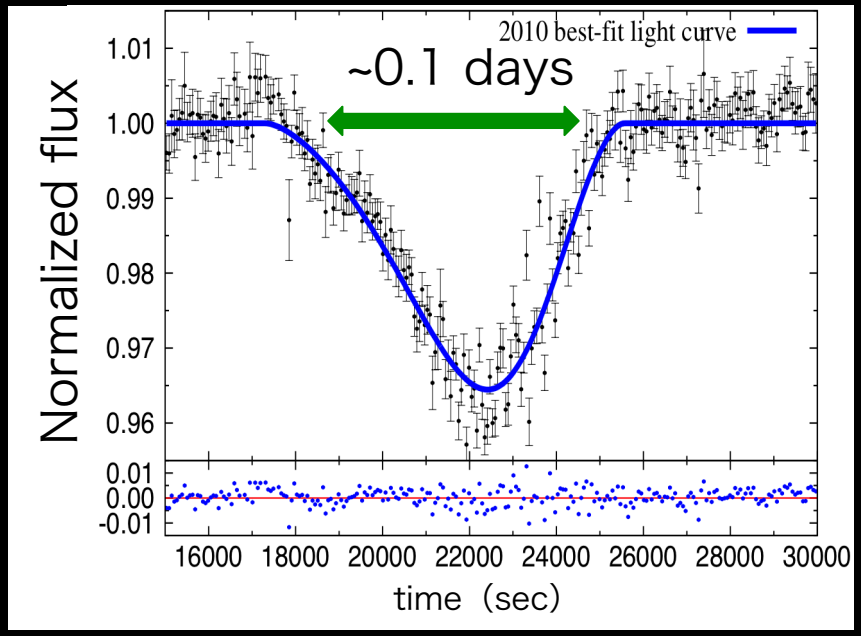
PTFO 8-8695 : unusual lightcurves

- T-Tauri star + hot Jupiter
- Transits were observed in 2009 and 2010.
  (van Eyken et al. 2012)

2009



2010

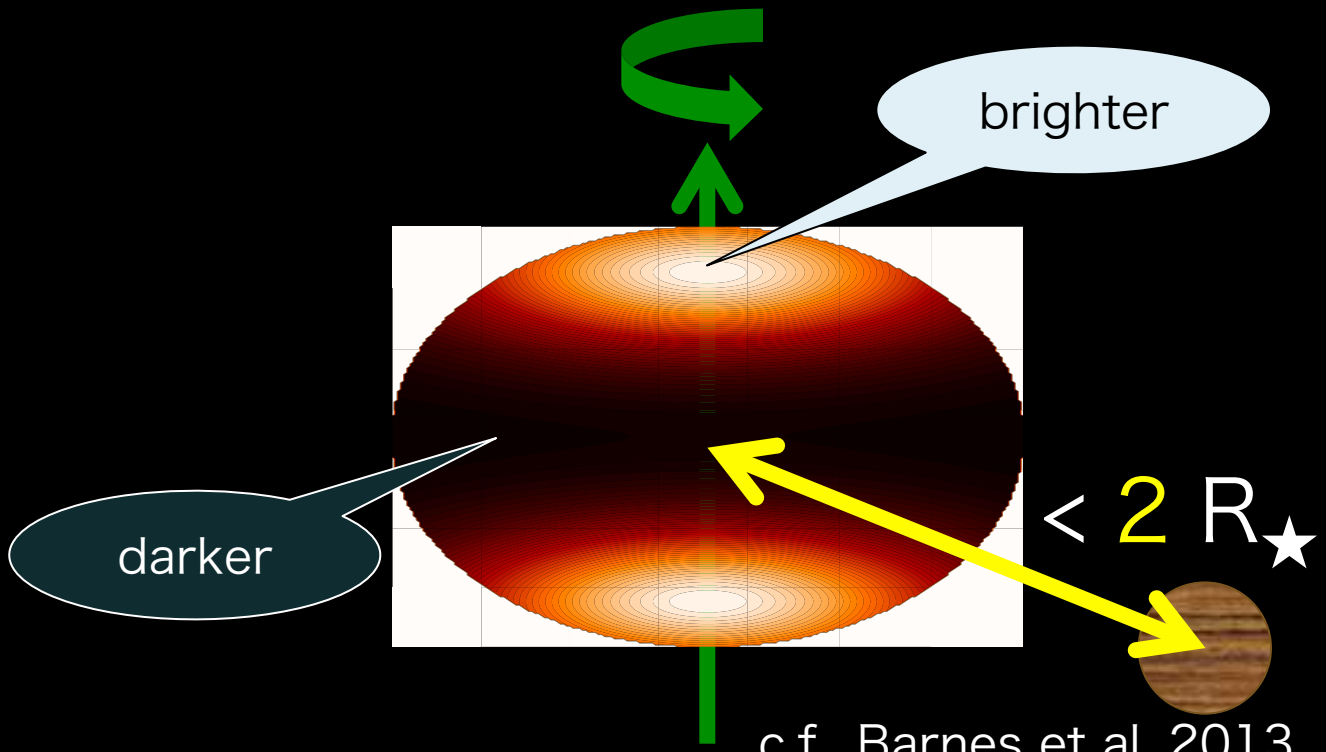


What makes such a difference？ (Barnes et al. 2013)

Photometric data by courtesy of Dr. Julian van Eyken and Prof. Masahiro Ikoma

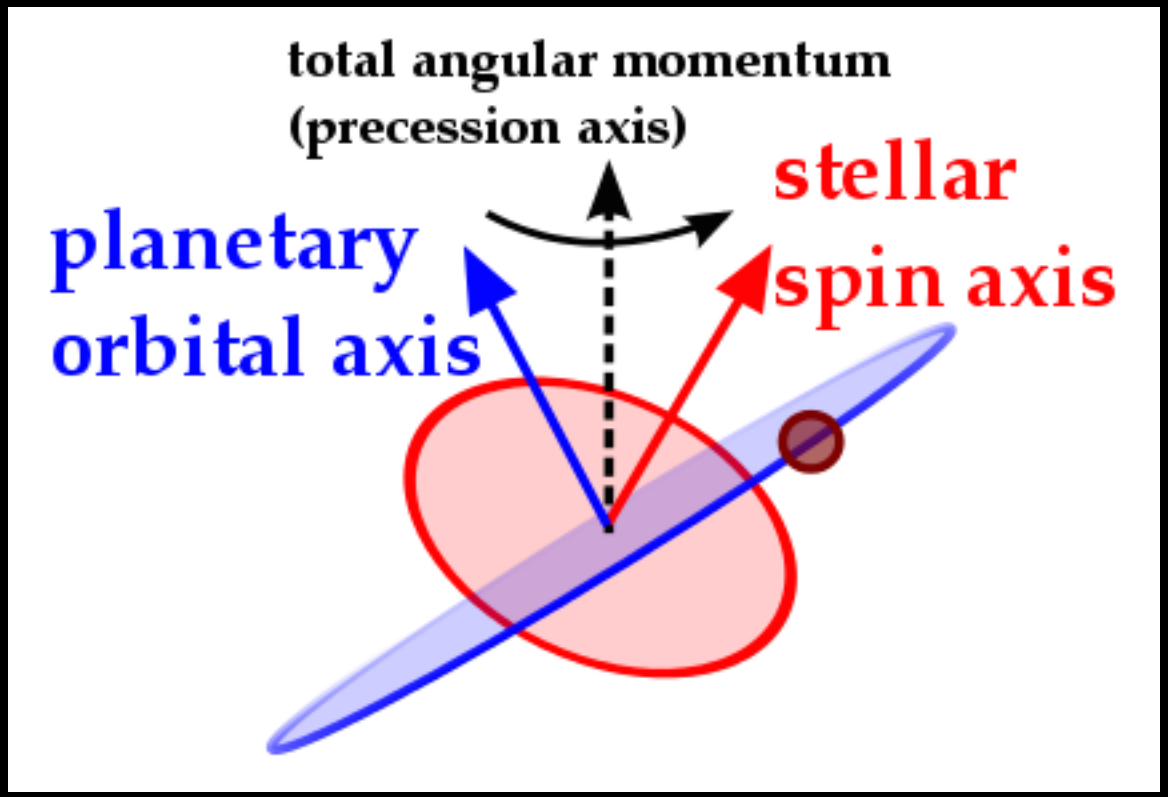
Rotationally-deformed star and close-in planet

- Rapid stellar rotation (period < 0.671days) induces gravity darkening.
- Planetary orbit is less than twice the stellar radius (orbital period = 0.448 days).



Spin-orbit nodal precession

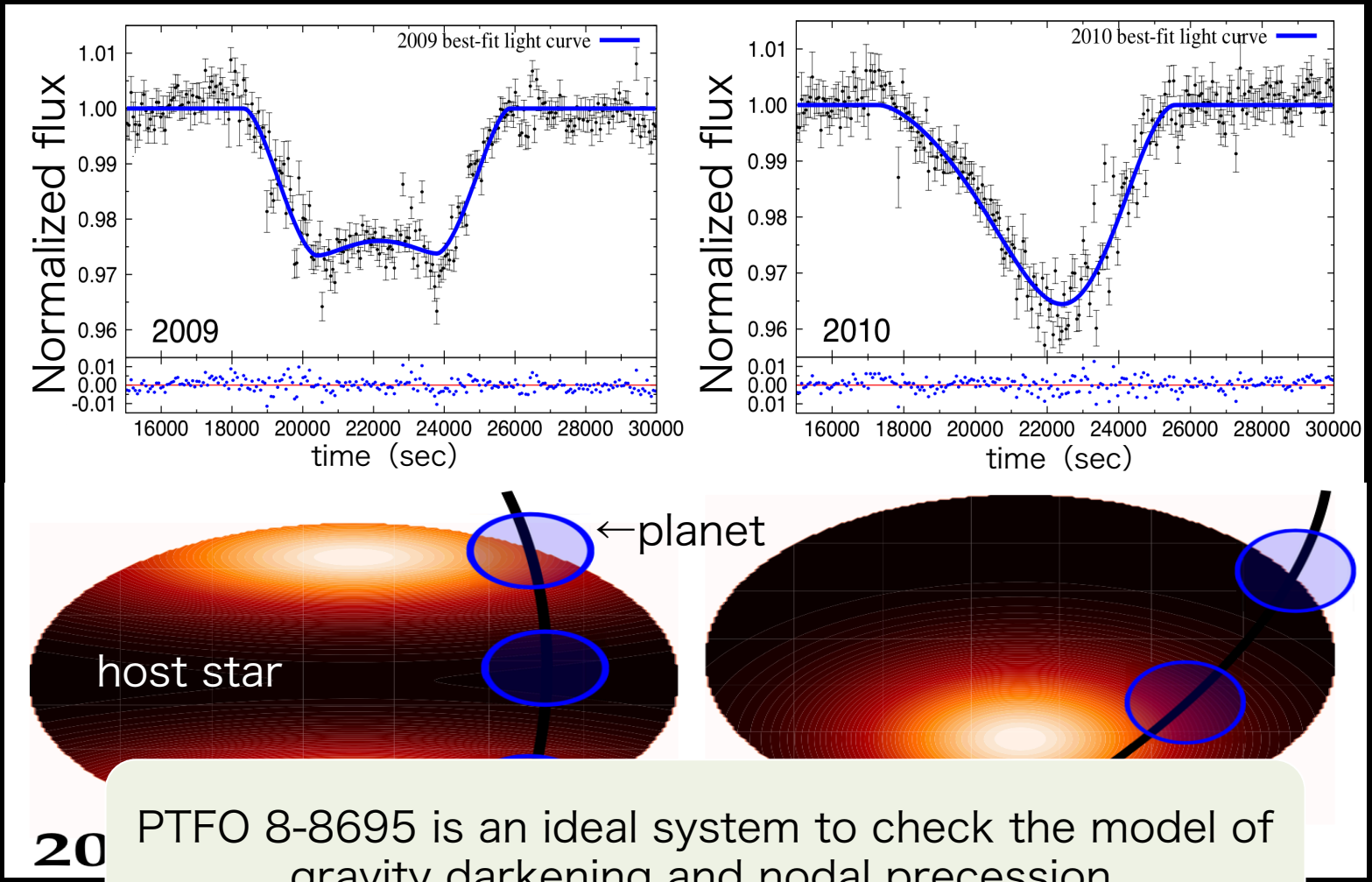
Stellar spin and planetary orbital axes precess with the period of ~ 1 yr.



c.f., Barnes et al. 2013

Gravity darkening + nodal precession → unusual and time-variable lightcurves!

2009 2010

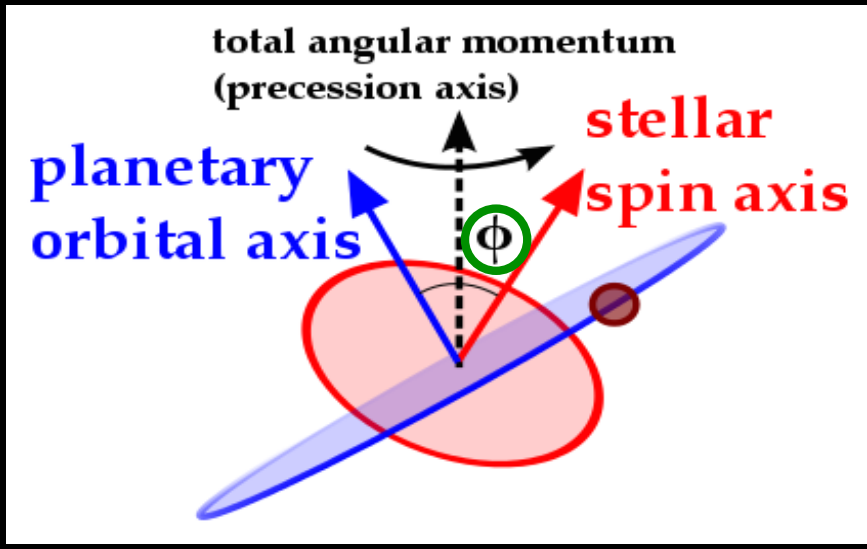


PTFO 8-8695 is an ideal system to check the model of gravity darkening and nodal precession.

20 ...l. 2013

Previous work：Barnes et al. (2013)

- Estimated system parameters that can satisfactory reproduce the observed feature (spin-orbit angle： ϕ=69°)



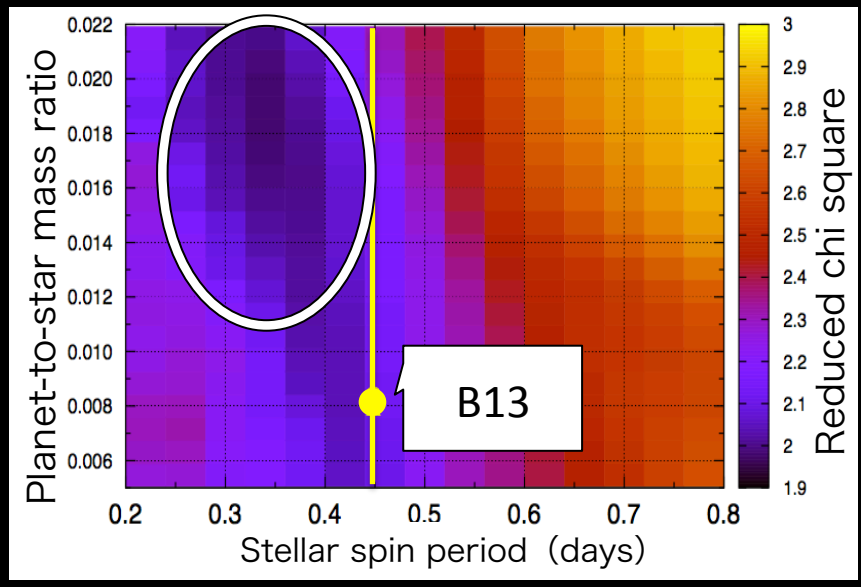
- adopted spin-orbit synchronous condition：

P_{spin} (< 0.671 days) = P_{orb} (0.448 days)

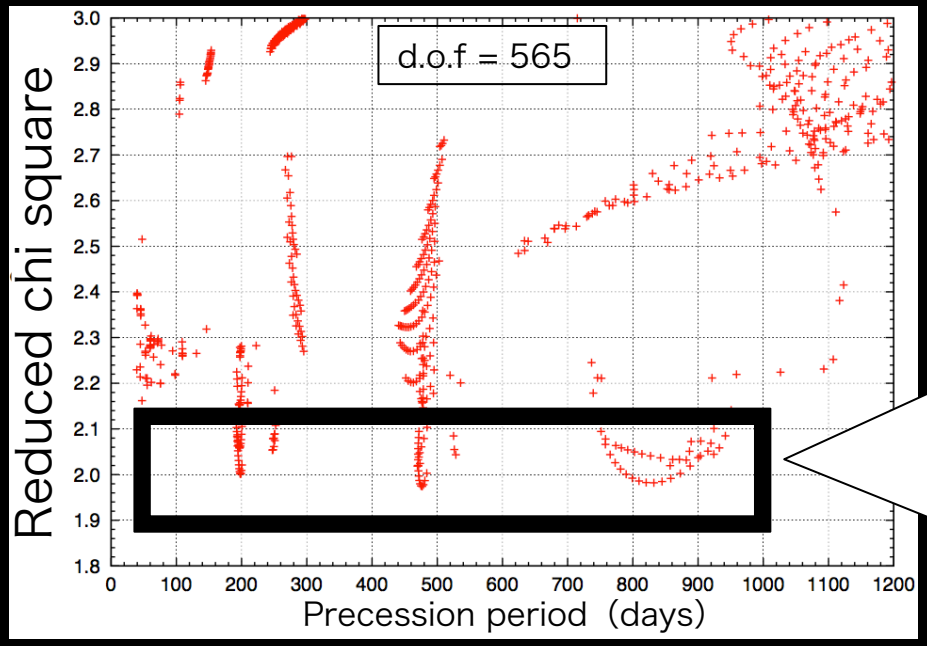
Standard tidal model does NOT favor such a synchronized state with significant misalignment.
→ need to extend the analysis to the case of $P_{spin} \neq P_{orb}$

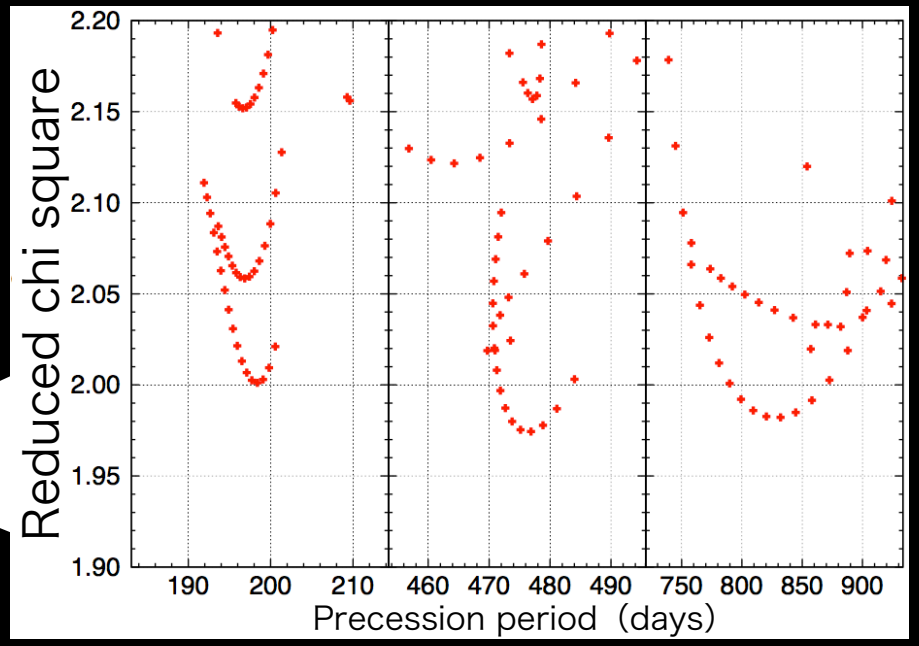
Three classes of solutions

- Slightly better solutions are obtained outside the synchronous condition.
- They are devided into three groups with different precession periods.



199 days 475 days 827 days

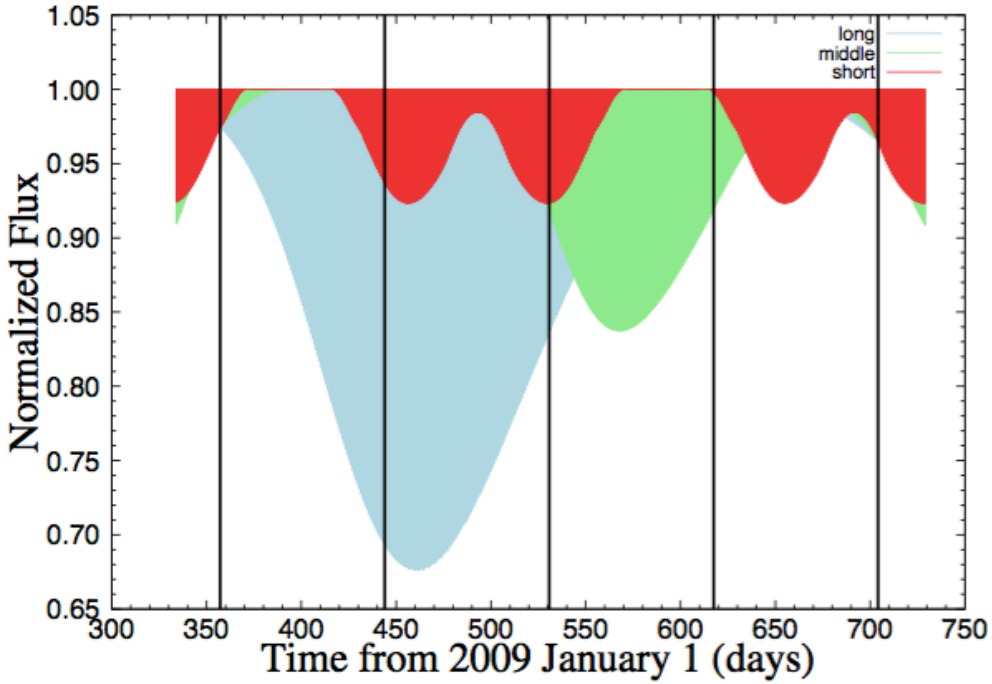


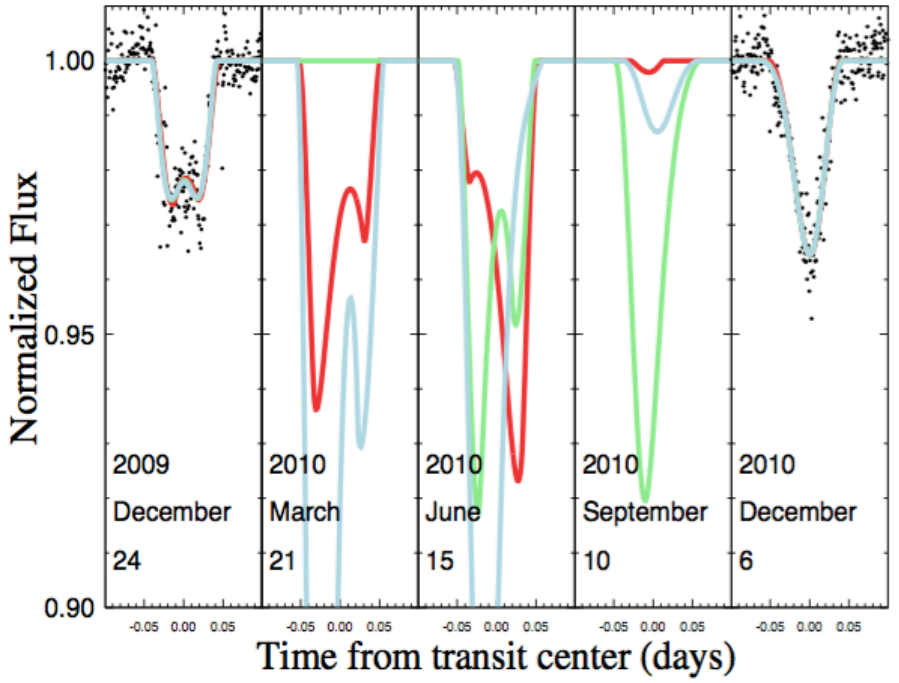


How to distinguish them?

- All the three solutions reproduce 09 and 10 data well.
- They are different during unobserved epochs.

09 obs | 10 obs | 09 data | 10 data



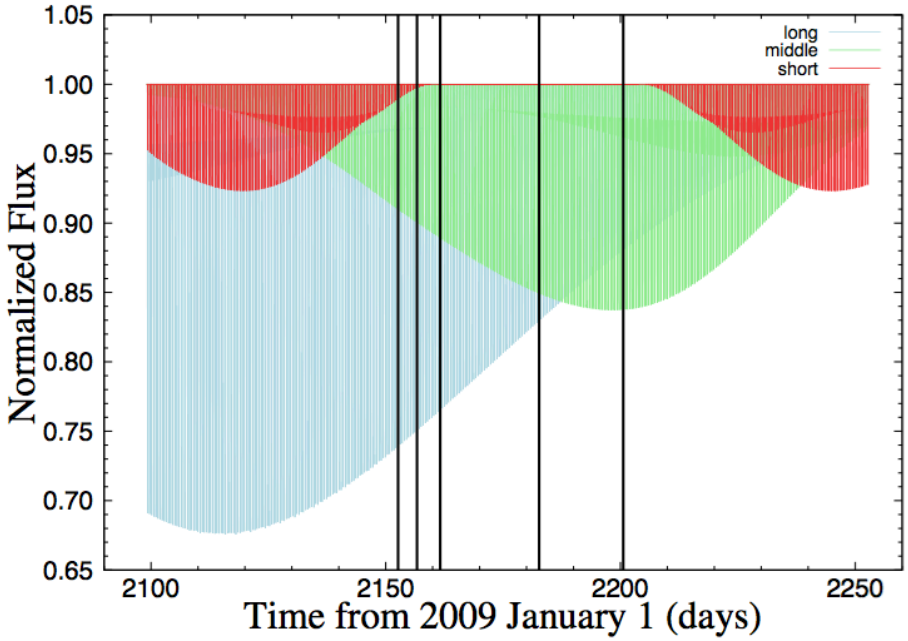


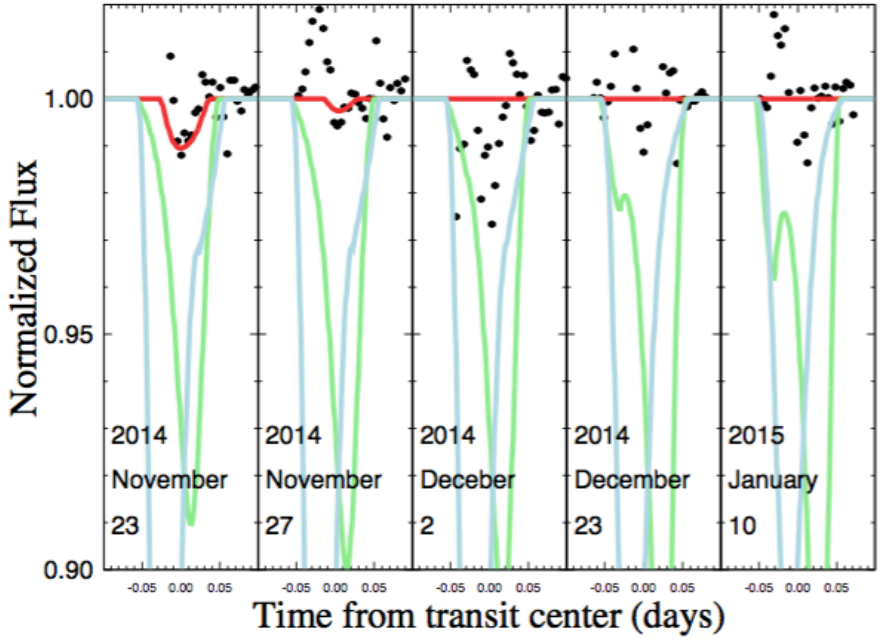
red, green, and blue : 199, 475, and 827 days solutions

Preliminary comparison with photometry at Koyama Astronomical Observatory

- Predicted transit depth is ~1% for 199 days solution, while over 10% for 475 and 827 solutions.
- No clear transit signal beyond the noise level of data

→ Data seems to prefer the 199 days solution.





red, green, and blue : 199, 475, and 827 days solutions

Summary

- PTFO 8-8695 is an ideal system to check the models of gravity darkening and nodal precession, which account for the time-variable transit lightcurves.

- Analysis discarding synchronous condition reveals that three different solutions reproduce the observed data, whose precession periods are 199, 475, and 827 days.

- Difference in transit depth is particularly useful to distinguish them with the frequent monitoring of the system.

Discussion

- The stellar gravity darkening serves as the methodology to characterize the exoplanetary systems which consist of rapid rotators (Barnes et al. 2011, Zhou and Huang 2013, Philippov and Rafikov 2013, Ahlers et al. 2014, Masuda 2015).

- This method is expected to unveil the properties of younger or hotter stars, which are known to be rotating more rapidly than older or cooler ones.