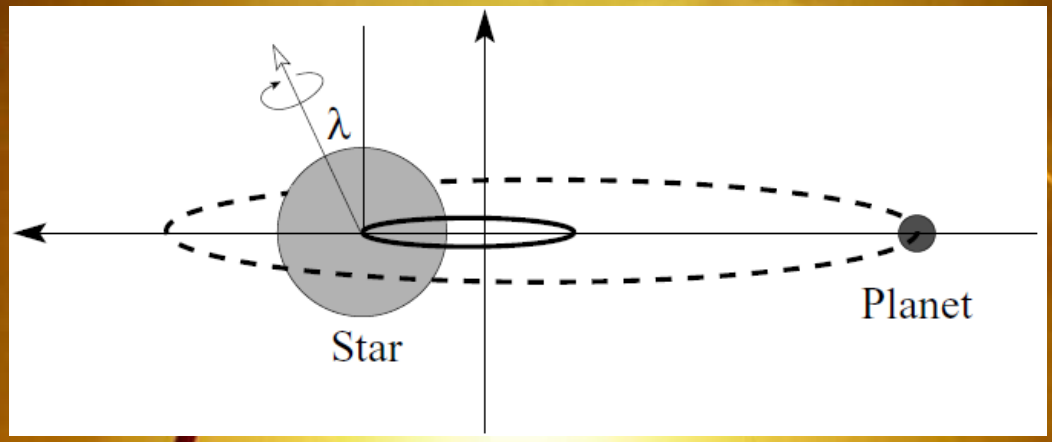
The Rossiter-McLaughlin effect of transiting extrasolar planetary systems



IAU
The International Astronomical Union

9th ASIAN-PACIFIC REGIONAL MEETING
July 26-29, 2005
Bali-Indonesia

$$\lambda = -4^\circ.4 \pm 1^\circ.4$$

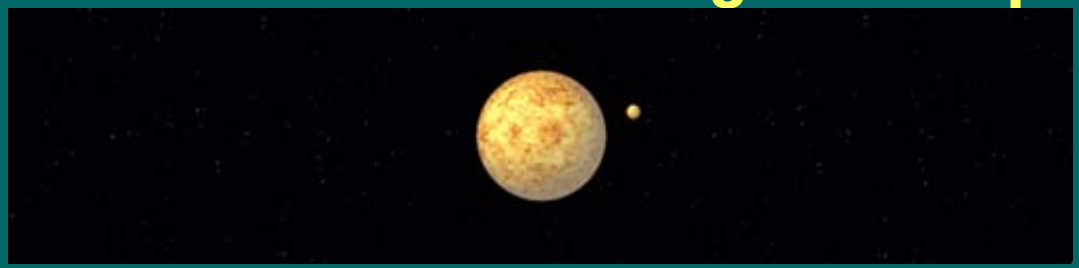
a transiting planetary system HD209458b

Yasushi Suto, Y.Ohta & A.Taruya

Department of Physics, The University of Tokyo

Extrasolar planet projects at Univ. of Tokyo

- **Search for the planetary atmosphere (HD209458) from the ground observation with Subaru HDS**
  - the most stringent upper limits from ground ～0.1%
  - Winn et al. PASJ 56(2004) 655 (astro-ph/0404469)
  - Narita et al. PASJ 57(2005) 471 (astro-ph/0504450)
- **Constraining the stellar spin and the planetary orbital axes from the Rossiter-McLaughlin effect**
  - New analytic formulae (Ohta, Taruya & Suto 2005, ApJ, 622, 1118)
  - First detection (Winn et al. 2005 ApJ in press, astro-ph/0504555)
  - Search for rings around extrasolar planets (Ohta et al. 2005)
- **Search for reflected light from planets in progress**



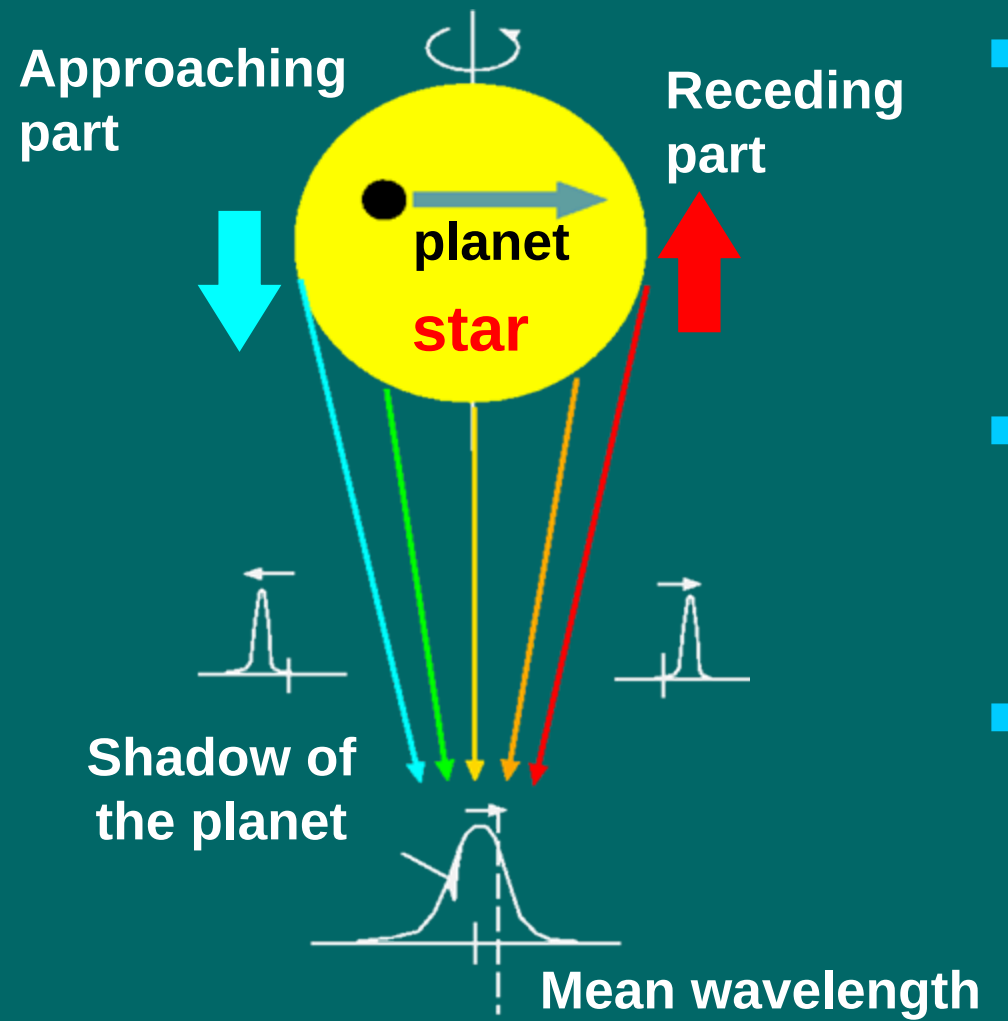
transiting extrasolar planets !

Measurement of Spin-Orbit Alignment in an Extrasolar Planetary System

- Joshua N. Winn (CfA→MIT), Robert W. Noyes, Matthew J. Holman, David B. Charbonneau, *Yasuhiro Ohta, Atsushi Taruya, Yasushi Suto, Norio Narita, Edwin L. Turner (Univ. of Tokyo),* John A. Johnson, Geoffrey W. Marcy, R. Paul Butler, & Steven S. Vogt

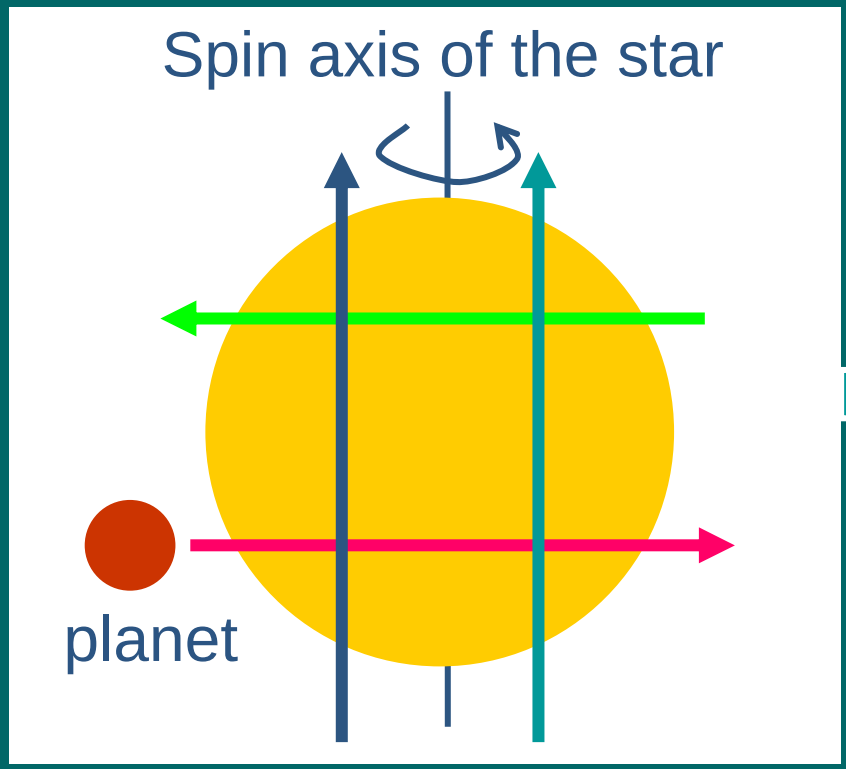
- astro-ph/0504555 (ApJ 2005, in press)

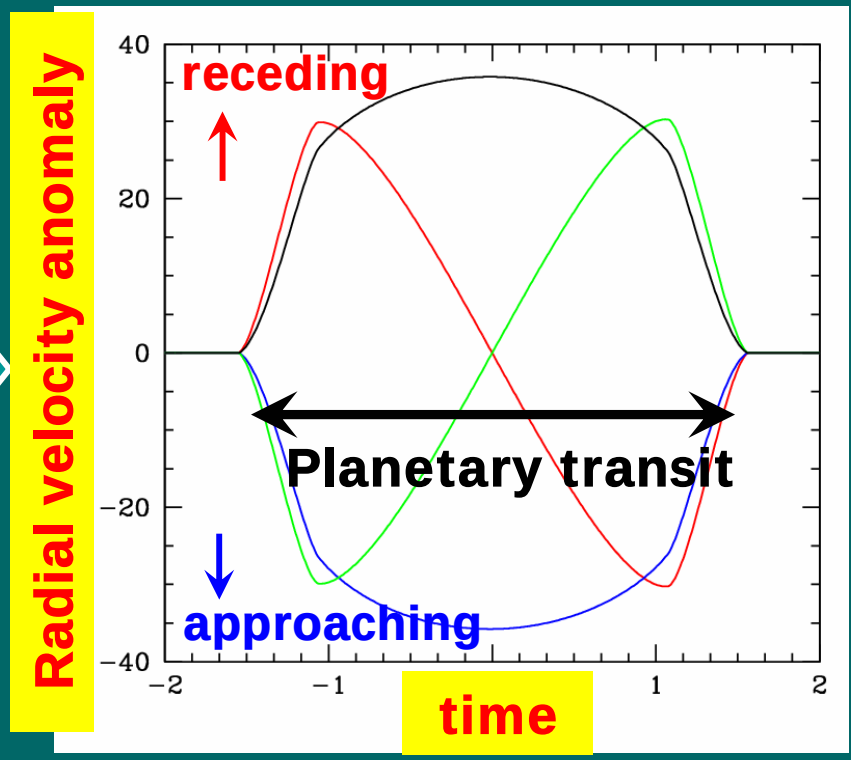
Spectroscopic transit signature: the Rossiter-McLaughlin effect



- Time-dependent asymmetry in the stellar Doppler broadened line profile
- an apparent anomaly of the stellar radial velocity.
- originally discussed in eclipsing binary systems long time ago
  - Rossiter (1924)
  - McLaughlin (1924)

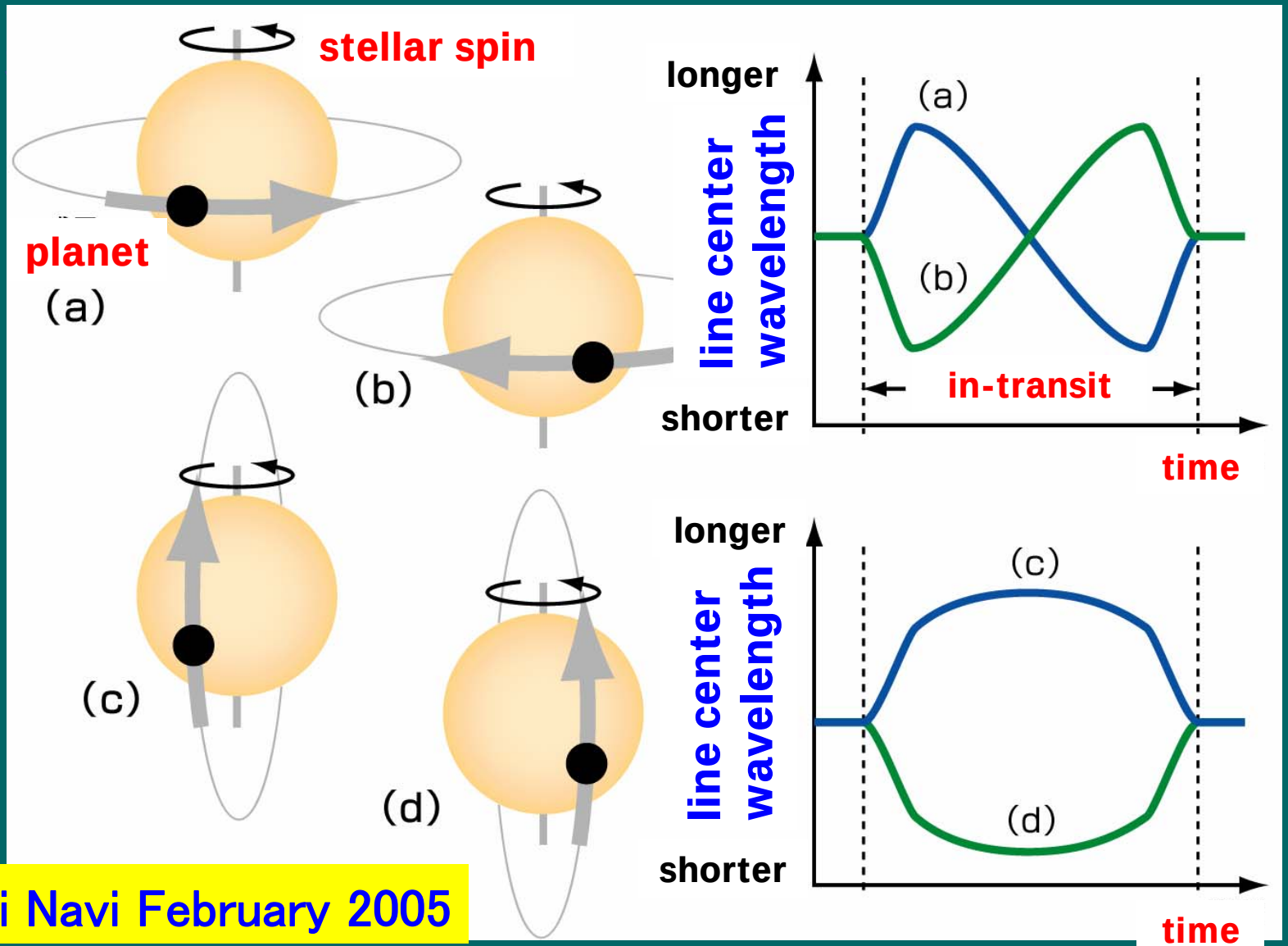
Radial velocity anomaly due to the Rossiter-McLaughlin effect I





- **Planetary orbital axis with respect to the stellar spin axis**
  - **origin of planets and of the angular momentum**

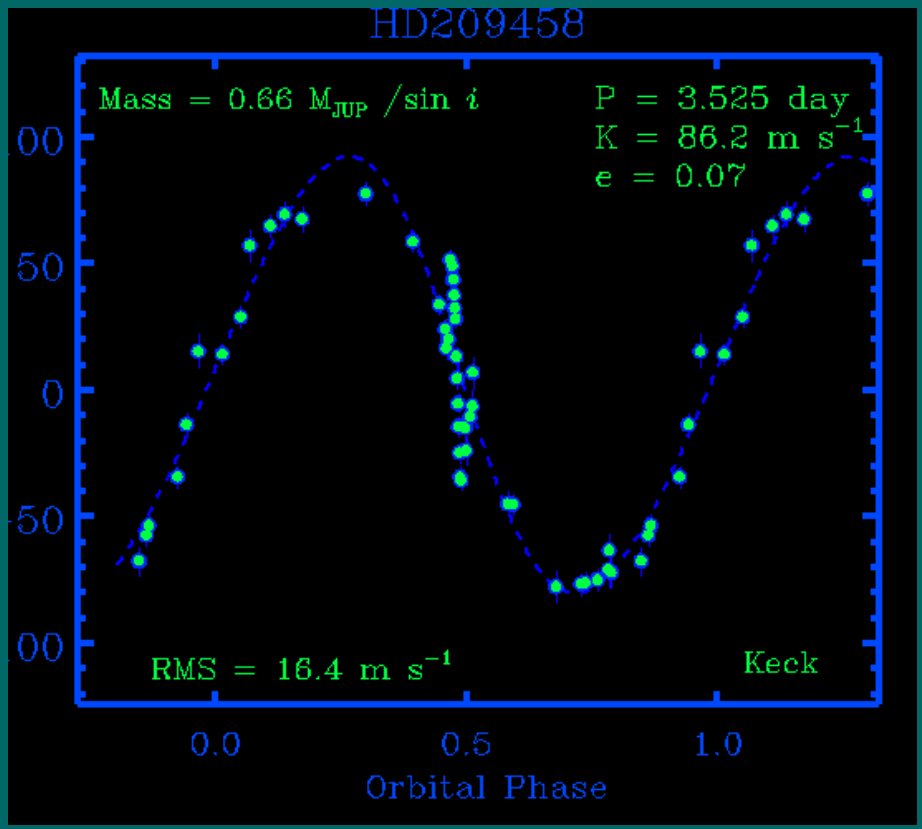
Radial velocity anomaly due to the Rossiter-McLaughlin effect II

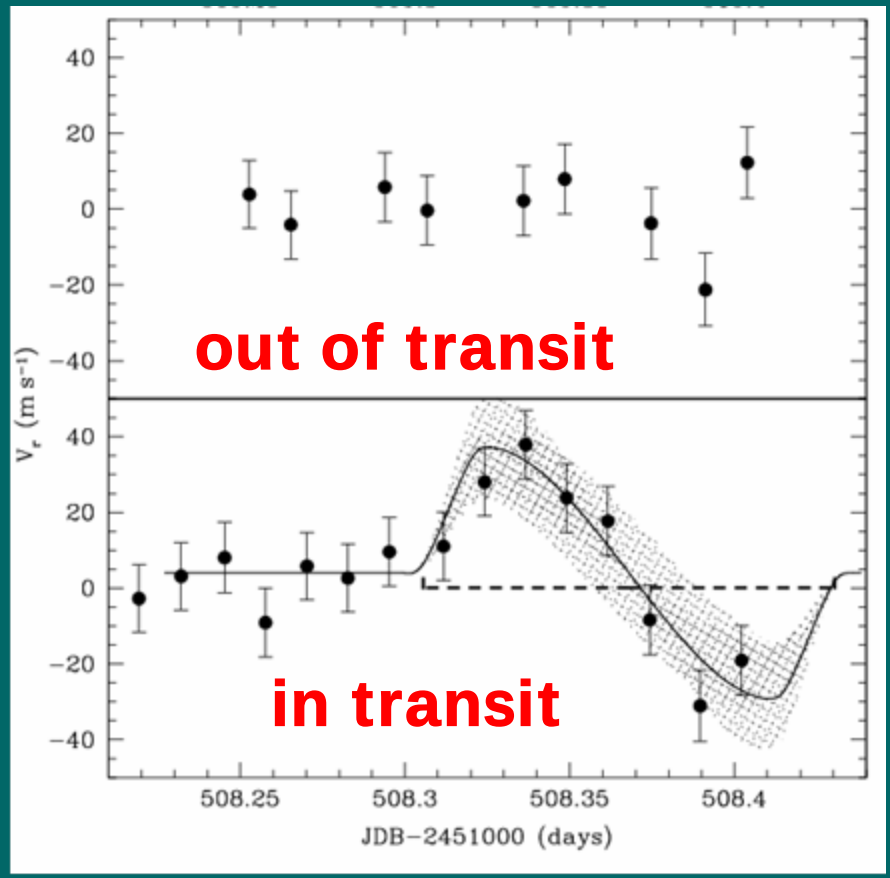


Hoshi Navi February 2005

Previous result of the Rossiter-McLaughlin effect for an extrasolar transit planetary system HD209458

Origin of angular momentum





HD209458 radial velocity data
http://exoplanets.org/

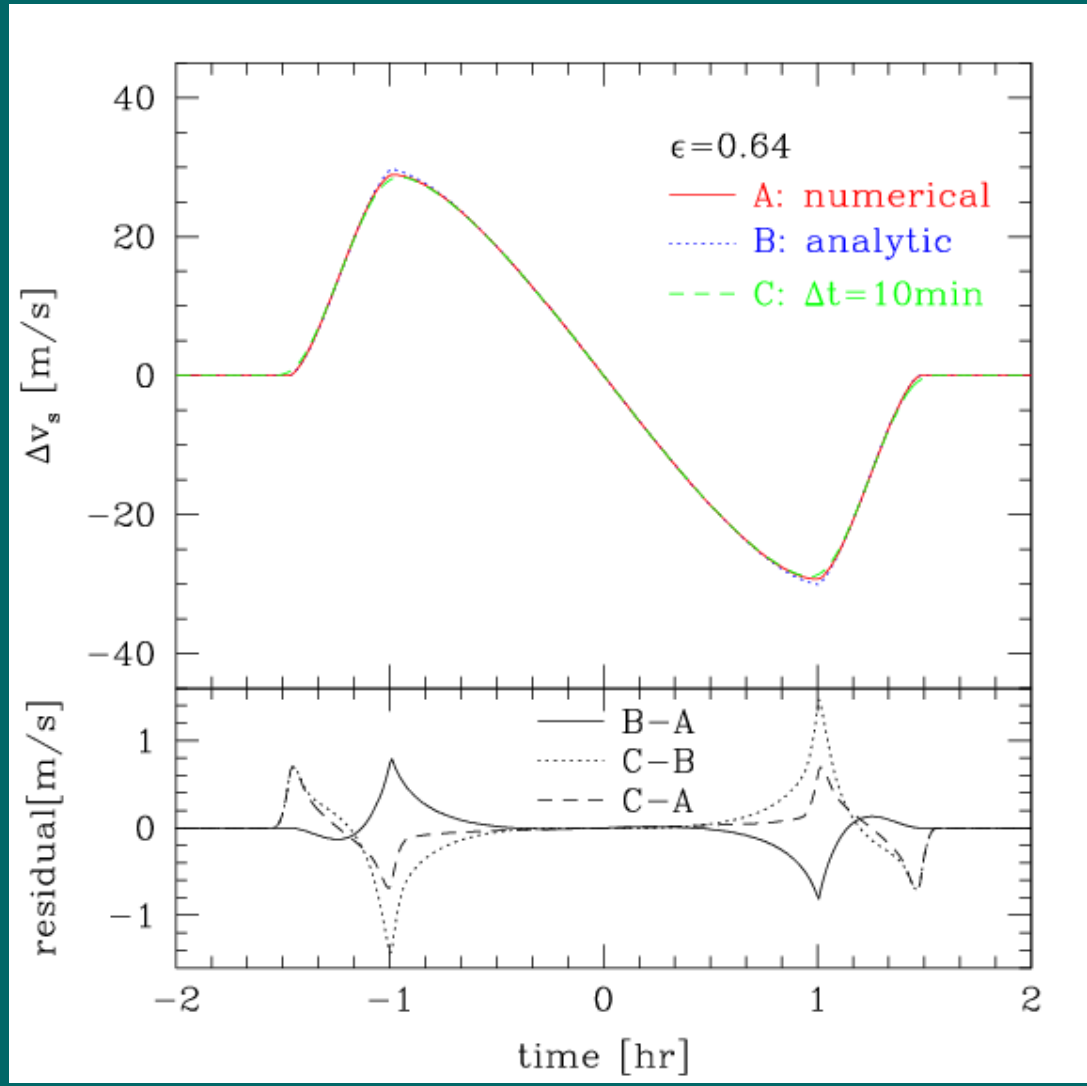
Stellar rotation and planetary orbit
Queloz et al. (2000) A&A 359, L13
ELODIE on 193cm telescope

Analytic templates for the velocity anomaly due to the Rossiter -McLaughlin effect

Limb darkening:
$B = 1 - \varepsilon (1 - \cos\theta)$

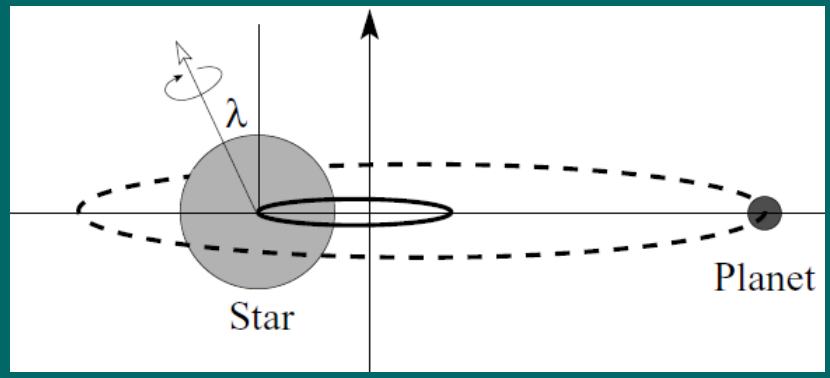
First analytic formula using perturbation theory

Ohta, Taruya & Suto
(astro-ph/0410499
ApJ 2005, 622, 1118)



Precision analysis of the Rossiter-McLaughlin effect for HD209458

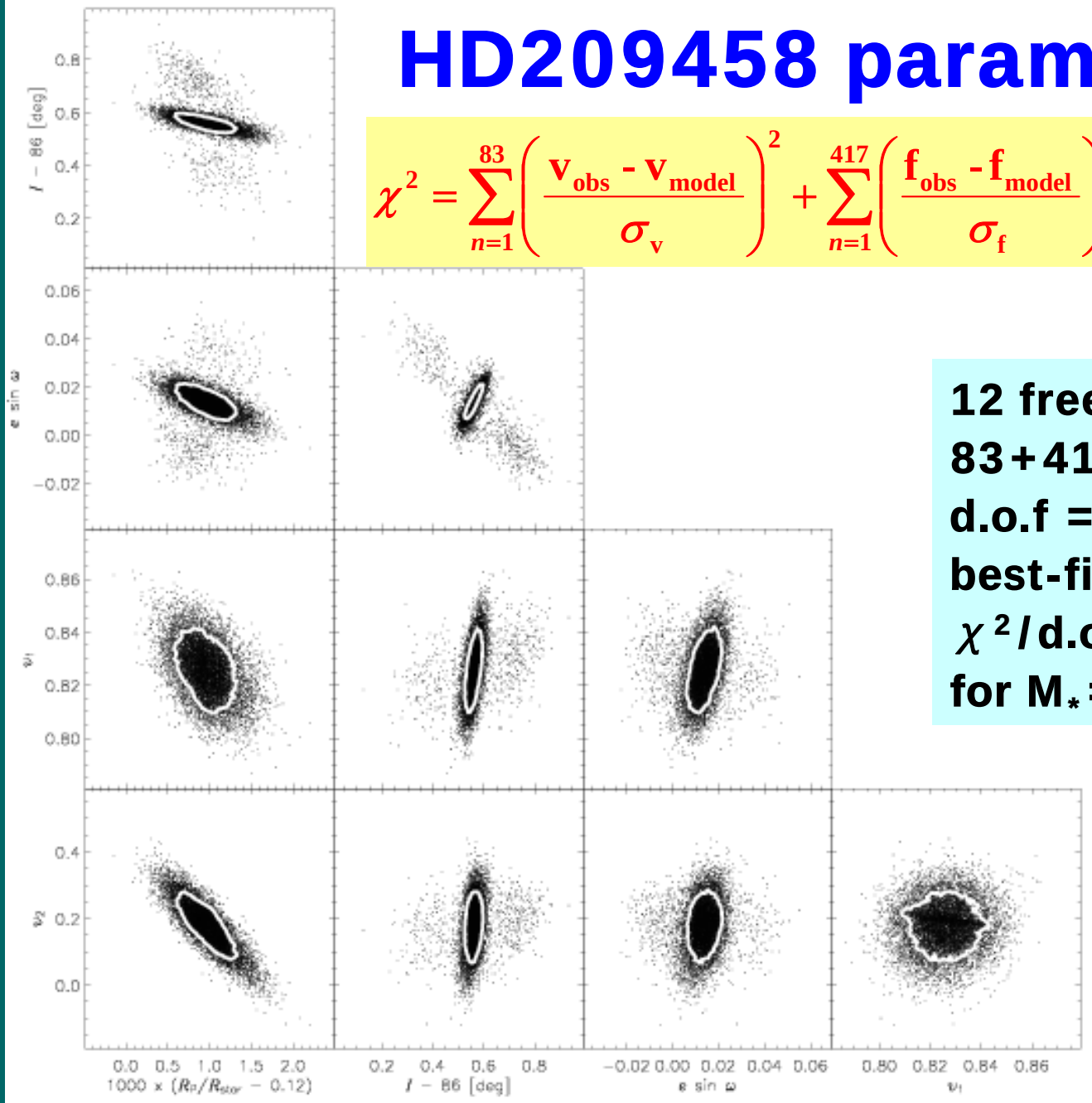
- the precision fitting of HD209458 with the best data available
  - radial velocity data (Keck)
  - optical photometry (HST)
  - infrared photometry (Spitzer)



- ***the first detection of the misalignment between stellar spin and the planetary orbital axes by (−4.4±1.4)deg***
  - more than an order-of-magnitude improvement of the previous error-bar
  - c.f., 7 degree misalignment known for the Solar system
- ***confirms the basic picture, but yet another λ ≠0 problem other than in cosmology !***

HD209458 parameter fit

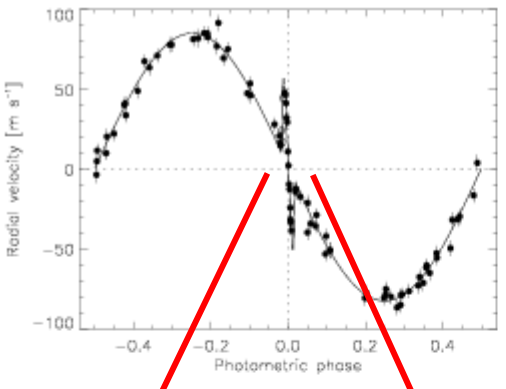
$$\chi^2 = \sum_{n=1}^{83}\left(\frac{v_{obs} - v_{model}}{\sigma_v}\right)^2 + \sum_{n=1}^{417}\left(\frac{f_{obs} - f_{model}}{\sigma_f}\right)^2 + \left(\frac{t_{2nd,obs} - t_{2nd,model}}{\sigma_t}\right)^2$$

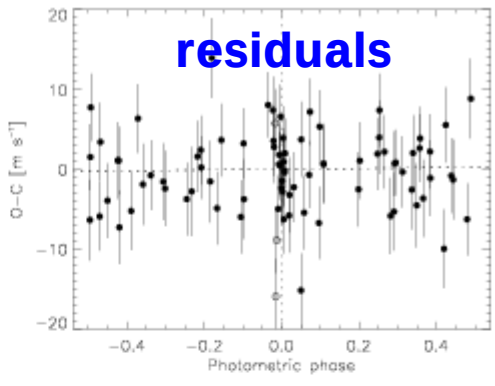


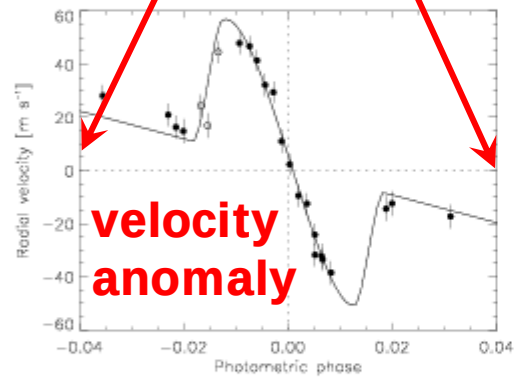
12 free parameters
83+417 data points
d.o.f = 83+417-12=489
best-fit :
χ^2/d.o.f=528/489=1.08
for $M_* = 1.06 M_{sun}$

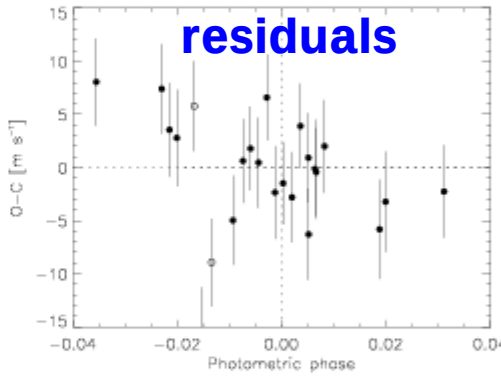
Winn et al.
astro-ph/0504555
ApJ 2005, in press

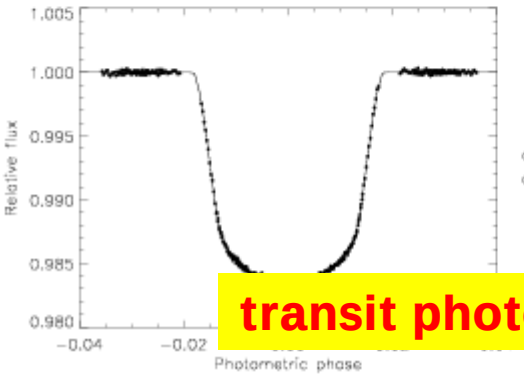
radial velocity (Keck)

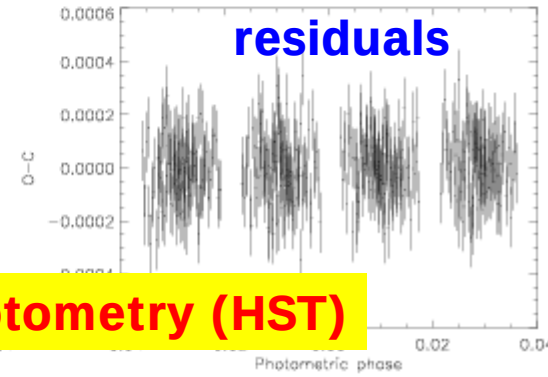






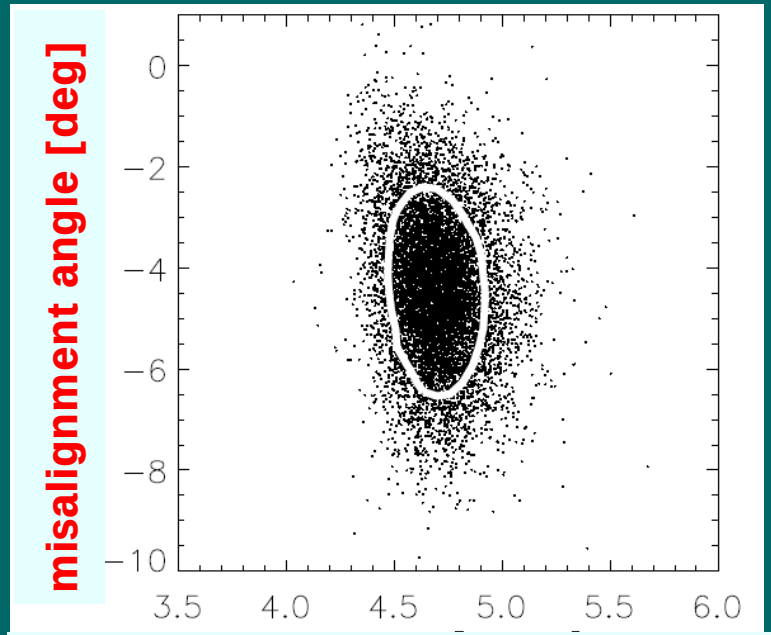






transit photometry (HST)

first detection of non-zero λ !

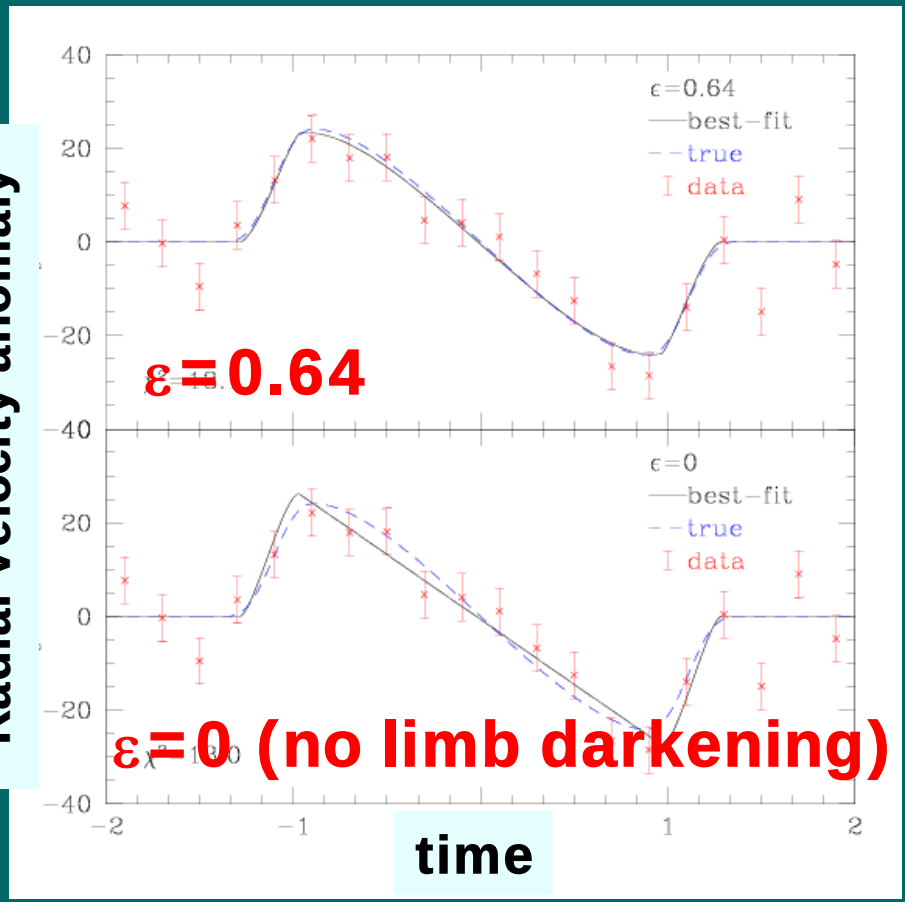


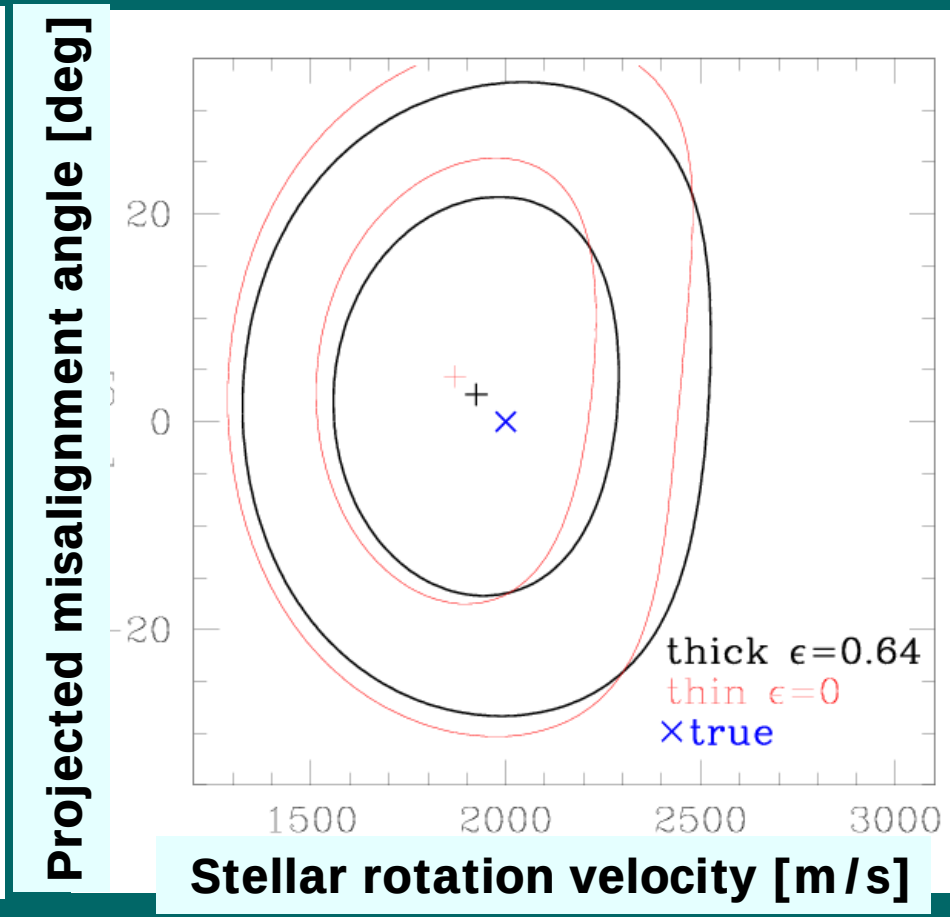
$$\lambda = -4^{\circ}.4 \pm 1^{\circ}.4$$

3σ detection !

Winn et al. astro-ph/0504555 ApJ 2005, in press

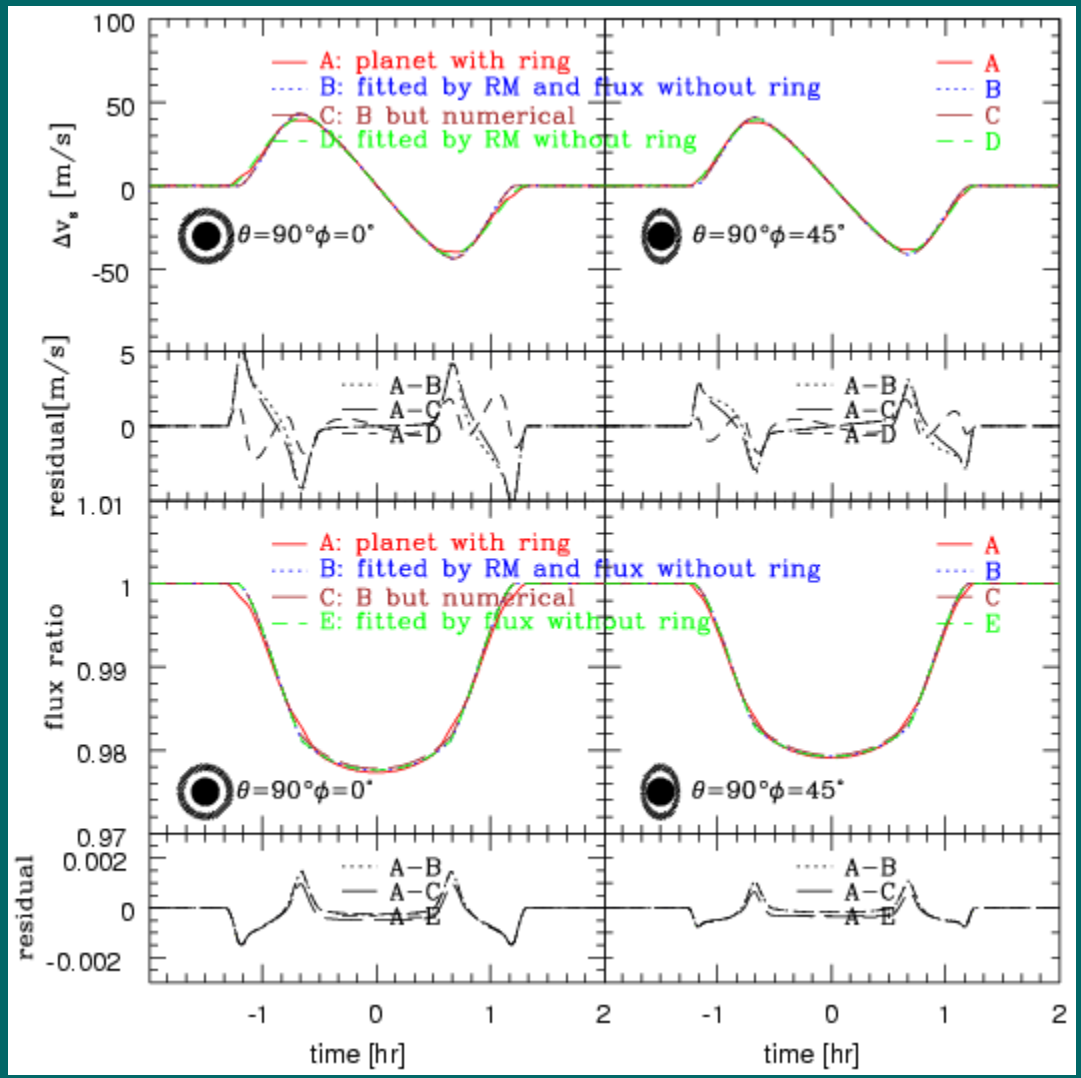
Feasibility to constrain TrES-1 system





- Mock data analysis using the parameters estimated by Alonso et al. (2004) and the analytic templates by Ohta, Taruya and Suto (2005)

Detectability of a ring around an extrasolar transiting planetary system using the Rossiter-McLaughlin effect



- **Search for characteristic anomaly due to a planetary ring in photometric and spectroscopic data during transit**
- **$\delta v \sim$ a few m/s**
- **$\delta F/F \sim$ 0.1%**

Ohta (2005, ph.D. thesis)
Ohta, Taruya & Suto (in prep.)

Summary: from mere discovery to characterization of extrasolar planets

- **Transiting extrasolar planets !**
  - planetary atmospheric signature (Charbonneau et al. 2001; Winn et al. 2004; Narita et al. 2005)
  - spin-orbit misalignment via the Rossiter effect (Winn et al. 2005)
  - ring systems around extrasolar planets (Ohta, Taruya & Suto 2005)
  - terrestrial planets (Kepler mission 2008 ?)
- **Ultra-precise photometry and spectroscopy are the key !**