New Measurements of Spin-Orbit Angles in Planetary and Binary Star Systems

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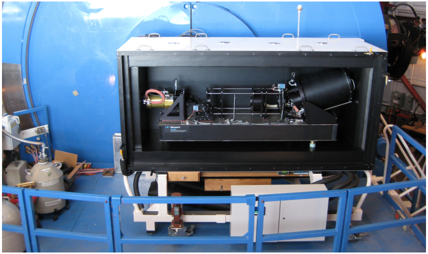
The Planet Finder Spectrograph

Magellan Clay 6.5 m Telescope

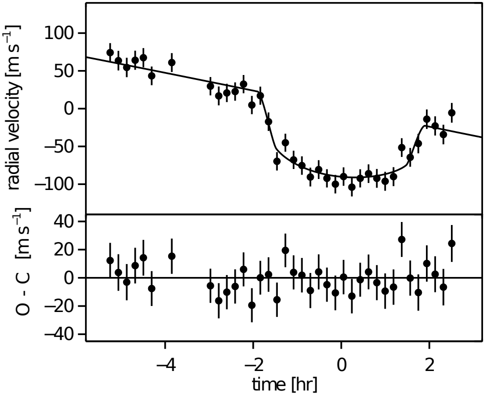
Planet **F**inder **S**pectrograph

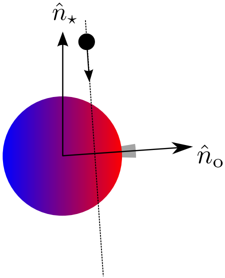


PFS team:
Paul Butler, Jeff Crane, Steve Shectman, Ian Thompson

WASP-7: hot misaligned

- Period = 4.9 days;
- $M_{Planet} = 0.9\,M_{Jupiter}$



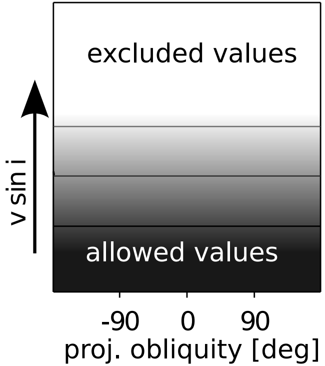


Challenges: Low SNR

What we would expect if $v \sin i_\star \approx 0\,\mathrm{km\,s^{-1}}$?

$\Rightarrow$ no RM signal

$\Rightarrow$ no proj. obliquity preferred



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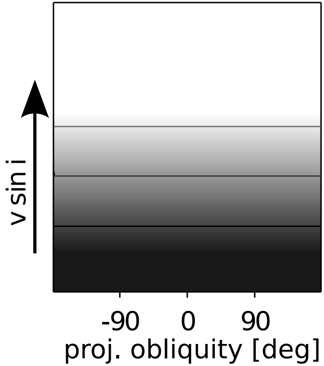
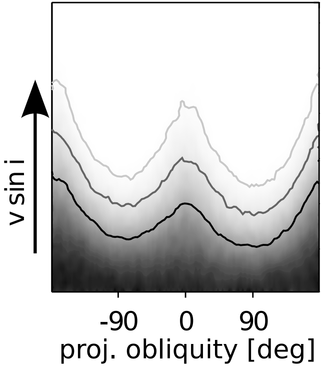


Mock data
without RM signal



Challenges: Low SNR

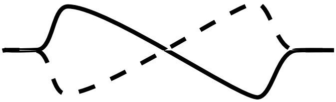
Need to isolate RM signal

- subtract systemic velocity $\rightarrow$ **offset**
- subtract orbital RVs $(K_\star)$ $\rightarrow$ **slope**

$\Rightarrow$ high-pass filter

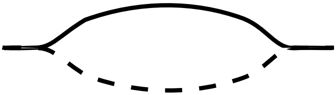
and

0° or 180°



high frequency

90° or -90°



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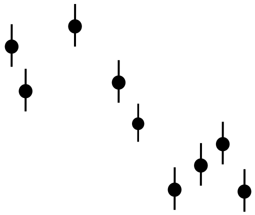

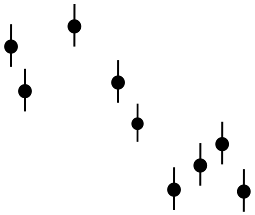

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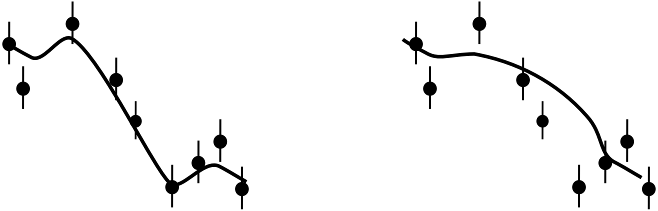
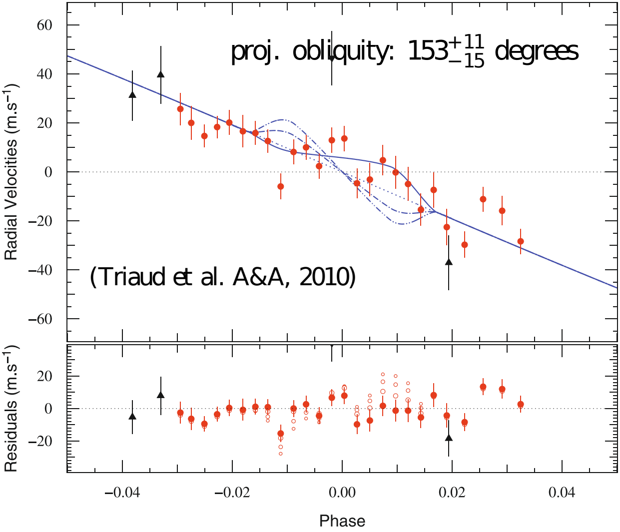


WASP-2: misaligned?



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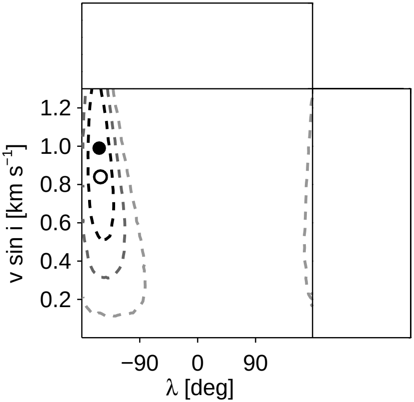
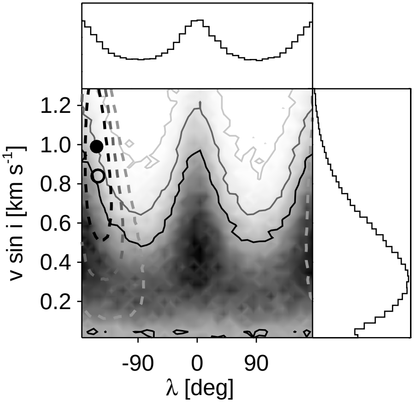
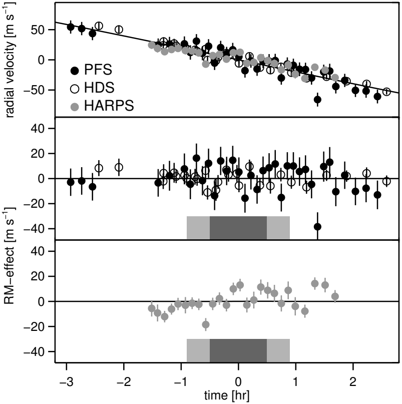


WASP-2: fit to mock data without RM effect



WASP-2: new observations



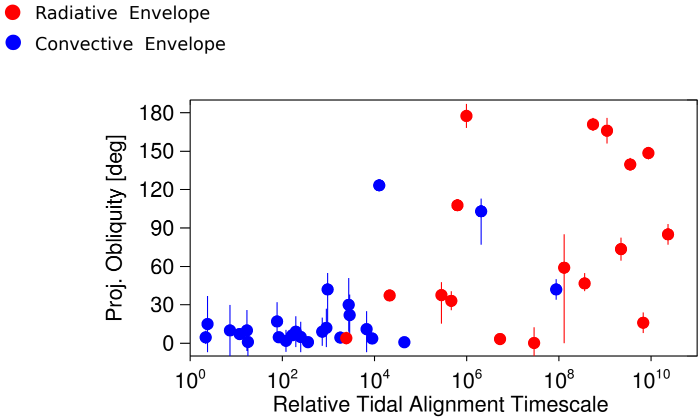
RV scatter during transit and out of transit similar

⇒ no RM effect measured

⇒ obliquity is undetermined

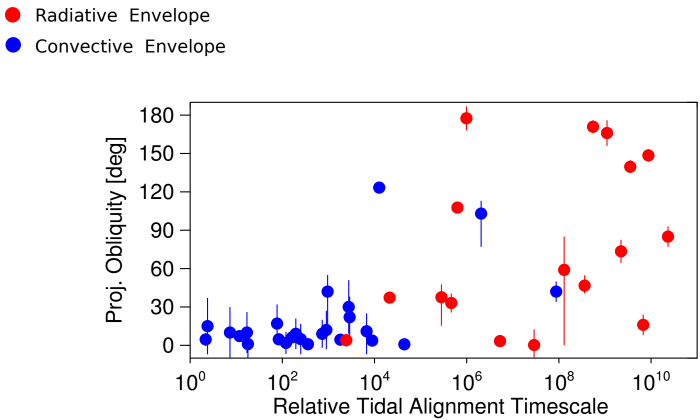
(Albrecht et al. ApJ, 2011)

Projected Obliquity: new measurements added



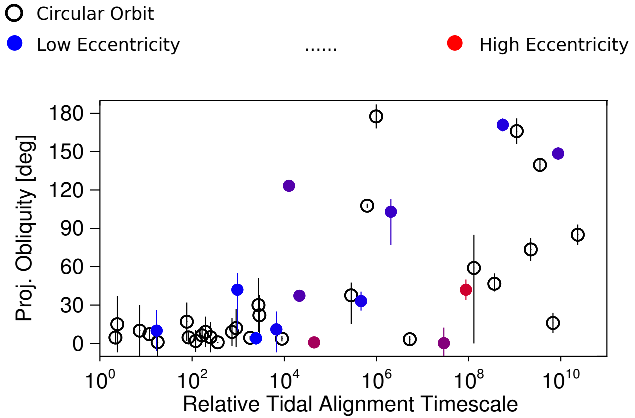
Tidal forces seem to be important

Projected Obliquity



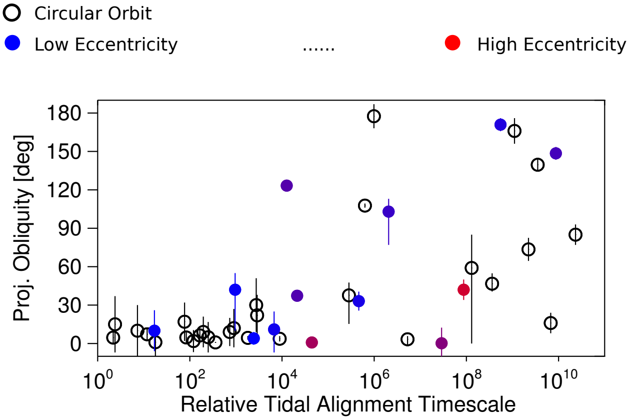
Tidal forces $\Rightarrow$ also the eccentricity should be affected

Orbital Eccentricity



systems with **low eccentricities** can have **high obliquities**

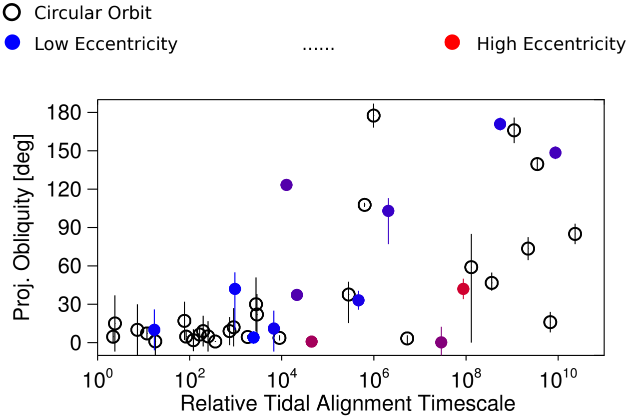
Orbital Eccentricity



exoplanet systems: $\tau_{\rm circ} < \tau_{\rm align}$

double star systems: $\tau_{\rm circ} > \tau_{\rm sync}$

Orbital Eccentricity

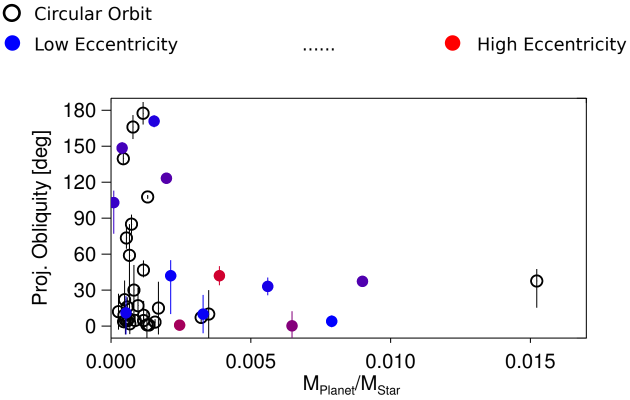


Mass of the secondary

exoplanet systems: $L_{\mathrm{rotation}}{:}L_{\mathrm{orbit}} \approx$ 1:1

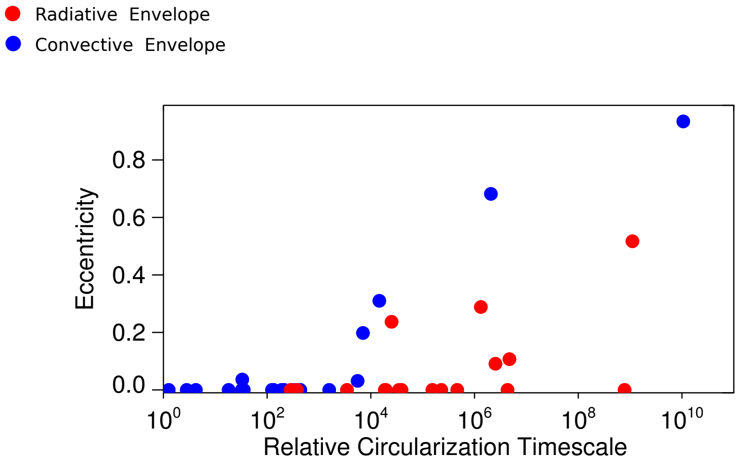
double star systems: $L_{\mathrm{rotation}}{:}L_{\mathrm{orbit}} \approx$ 1:1000

Obliquity and eccentricity function of mass ratio?



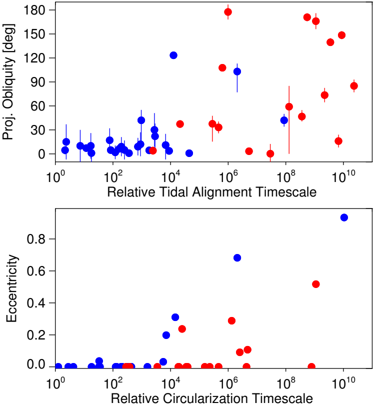
see also Johnson et al. (2009), Hébrard et al. (2010, 2011)

Orbital eccentricity



formulas from Zahn (1977)

Evidence for tidal forces



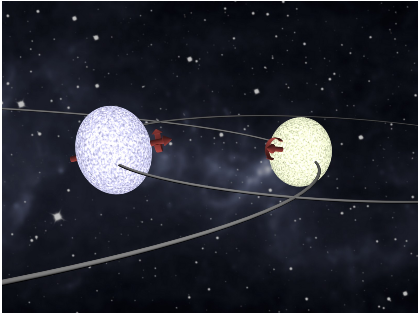
$\Downarrow$

1) tidal forces are important

2) originally wide distribution in obliquity and eccentricity

What about close binary stars?

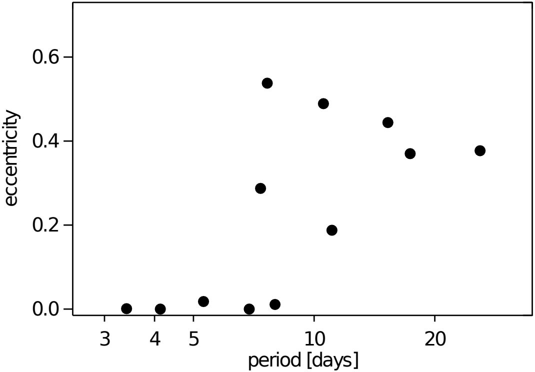
- The RM effect was first measured in binary systems (1924), but only a few quantitative RM results
- Formation of close binaries still not completely understood



Let's take the Rossiter-McLaughlin effect back to its roots

BANANA Survey

Binaries **A**re **N**ot **A**lways **N**eatly **A**ligned



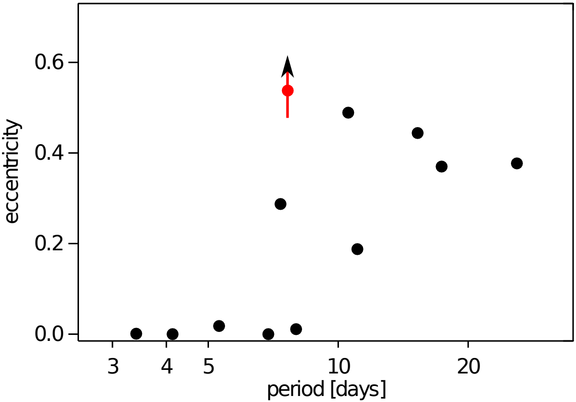
Early type stars (young & radiative envelope)

$\Downarrow$

"primordial" obliquities

BANANA Survey

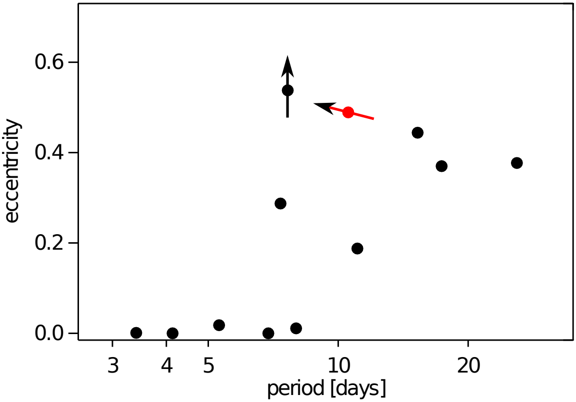
- V1143 Cyg: aligned (Albrecht et al. A&A 2007)



(Hamilton spectrograph 0.6 m)

BANANA Survey

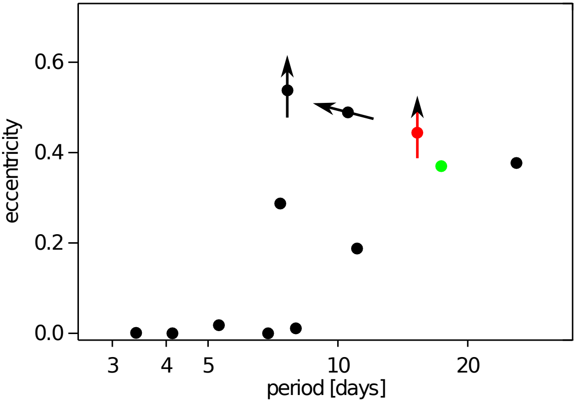
- DI Her: strongly misaligned (Albrecht et al. Nature, 2009)



(SOPHIE OHP)

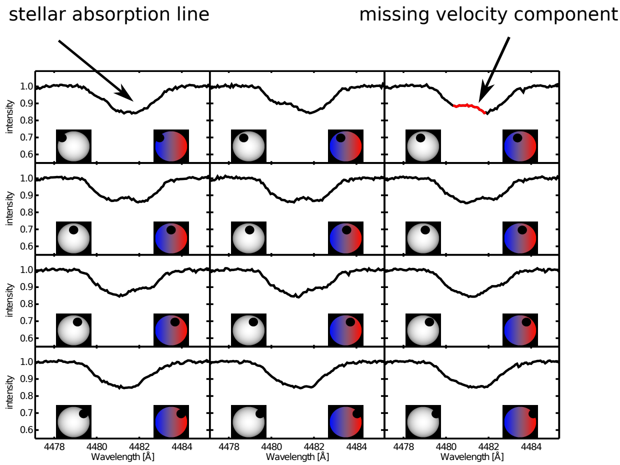
BANANA Survey

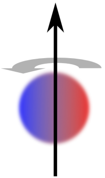
- NY Cep: aligned (Albrecht et al. ApJ, 2011b)



(SOPHIE OHP)

α CrB: primary aligned $\beta_\mathrm{p} = 2 \pm 4^\circ$

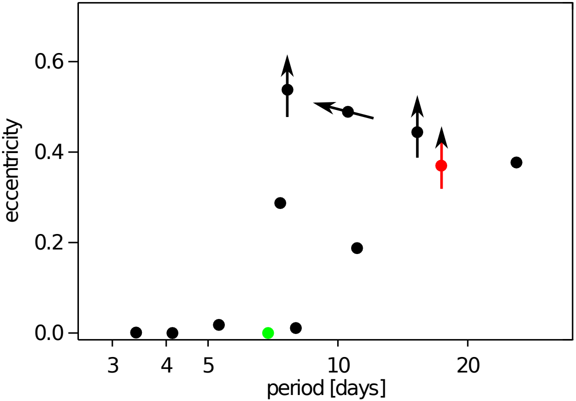




(Hamilton spectrograph 0.6 m)

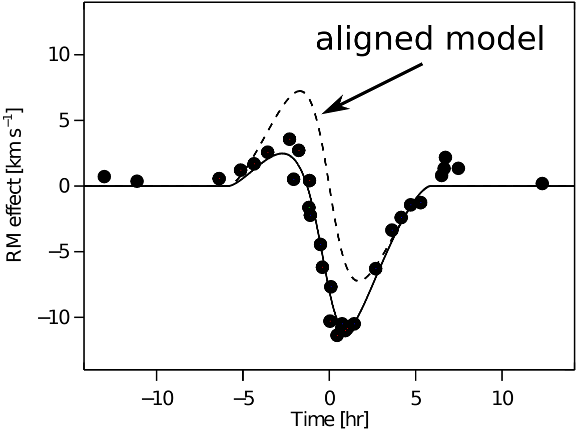
BANANA Survey

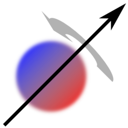
- α CrB: aligned – Maybe short period, circular systems?



CV Velorum: primary misaligned $\beta_{\mathrm{p}} = -42 \pm 10^\circ$

- Short period (6.9 days);
- circular orbit ($e = 0$)



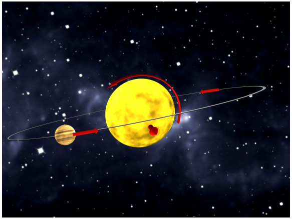


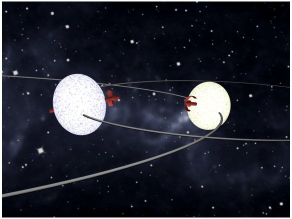
(FEROS 2,2 m)

Conclusions

exoplanets:

- Tidal forces are important
- Wide distribution in obliquities and eccentricities





stellar binaries:

- Misalignment might be common
- Alignment seems not to be a simple function of period or eccentricity