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Reflected light from exoplanets via high resolution spectroscopy

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Introduction

Why detect reflected light in the visible?

- In the optical, an exoplanet's signal is essentially reflected light
- It is essentially a copy of the star's spectrum
- It represents a direct detection of an exoplanet

Why detect reflected light in the visible?

Permits a direct characterisation of the planet

- Dynamics

- Interiors

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  - inclination and real mass *(e.g. Rodler et al. 2012)*
  - rotation *(e.g. Kawahara 2012)*
  - atmosphere physics *(winds, e.g. Snellen et al. 2010)*
- Interiors

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  - composition (H_2O, CH_4, *e.g. Swain et al. 2008)*
  - geometric albedo *(e.g. Demory 2014)*

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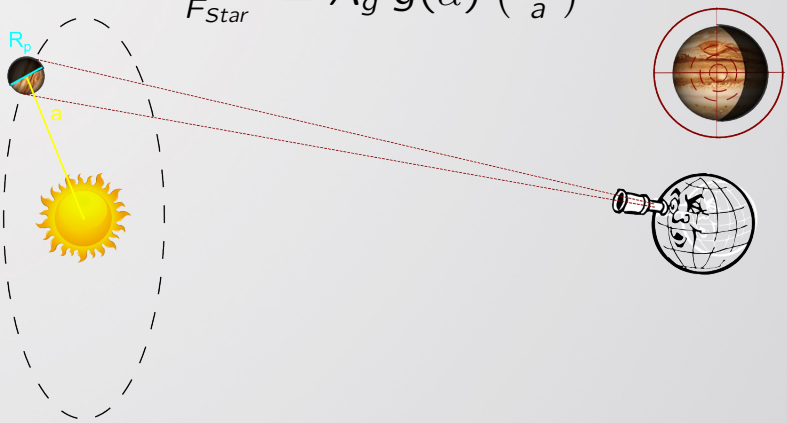
- Low albedos are caused by strong atomic/molecular gas absorption in cloud-poor atmospheres.

Problem

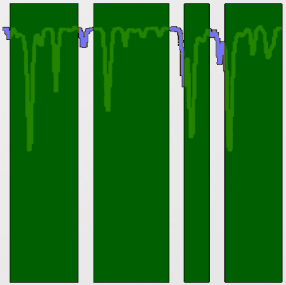
$$\frac{F_{Planet}}{F_{Star}} = A_g \; g(\alpha) \; \left(\frac{R_P}{a}\right)^2$$



$R = R_{Jup},\ P = 2days,\ A_g = 0.3$: $\frac{F_{Planet}}{F_{Star}} \approx 6.8 \times 10^{-5}$

The Method

The Cross Correlation Function



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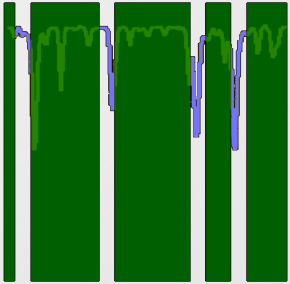

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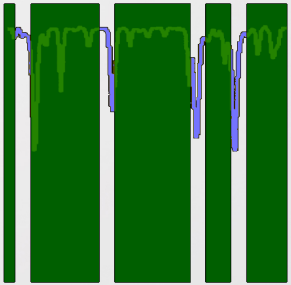

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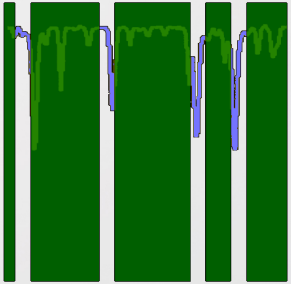

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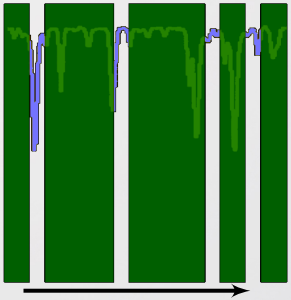
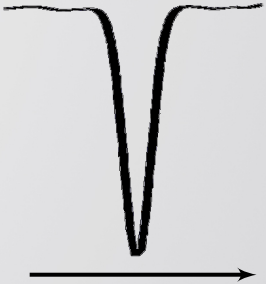
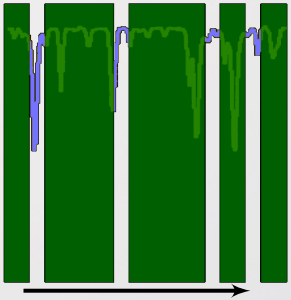


Wavelenght



Radial Velocity

The Cross Correlation Function



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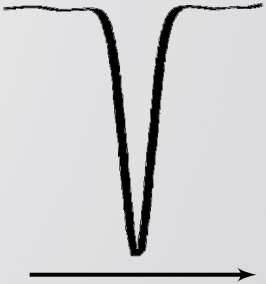

Radial Velocity

$$S/N_{CCF} = \sqrt{n}\, S/N_{spectrum}$$

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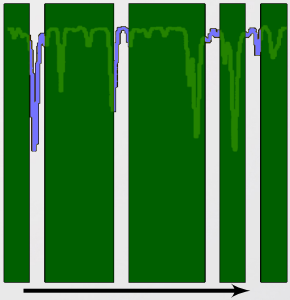

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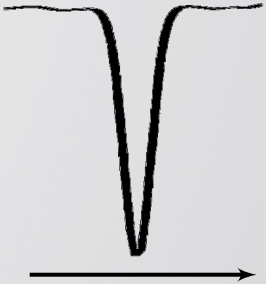

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for a binary mask with 3600 lines, the S/N increases 60 times!!!

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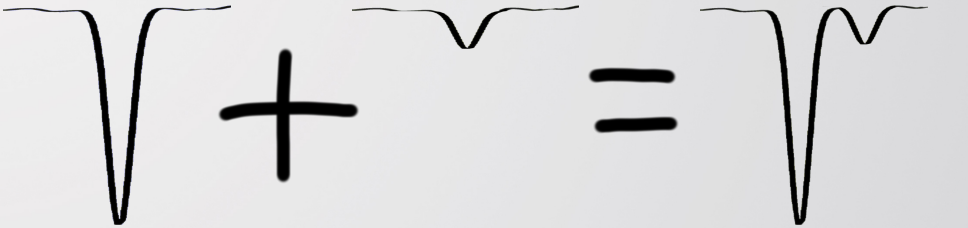
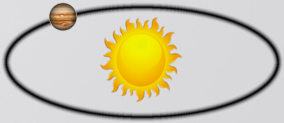
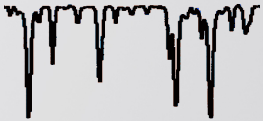




Detecting the planetary signal

Planet+Star Observations



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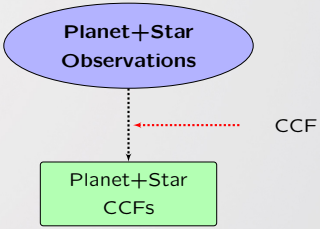

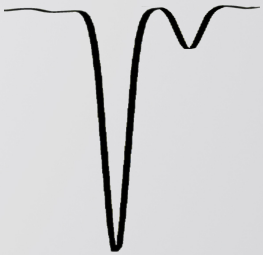

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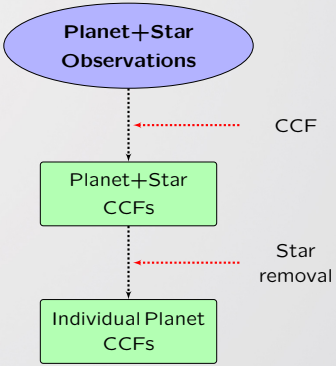

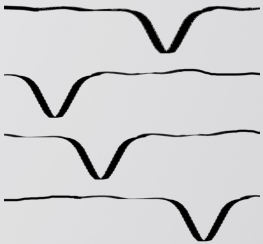

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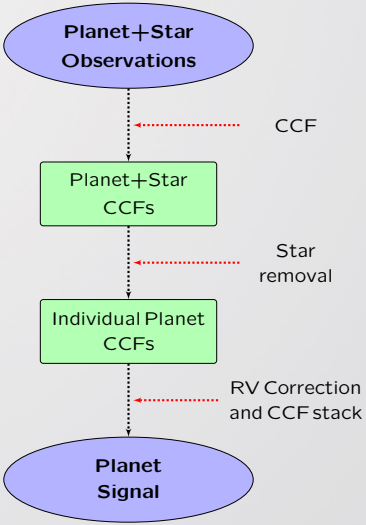
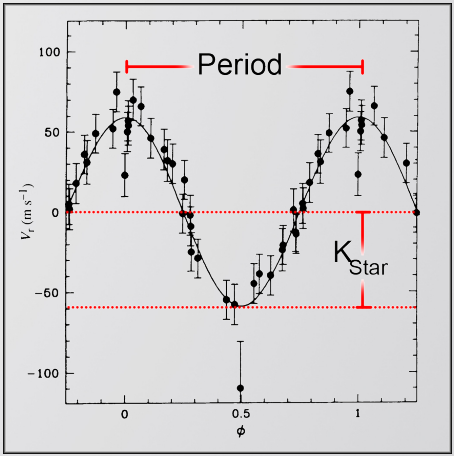


What can be done with this?

The Data

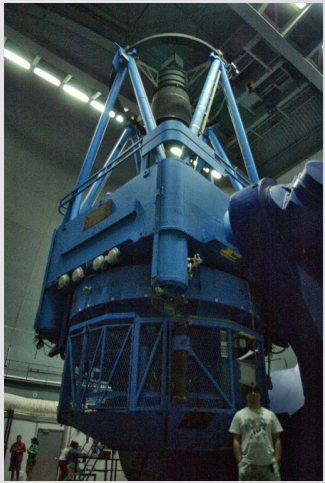
- 51 Peg b;



(Mayor & Queloz 1995)

The Data

- 51 Peg b;
- HARPS@ESO's 3.6m;



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- 51 Peg b;
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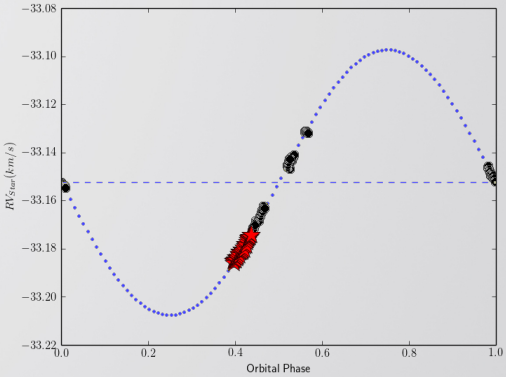
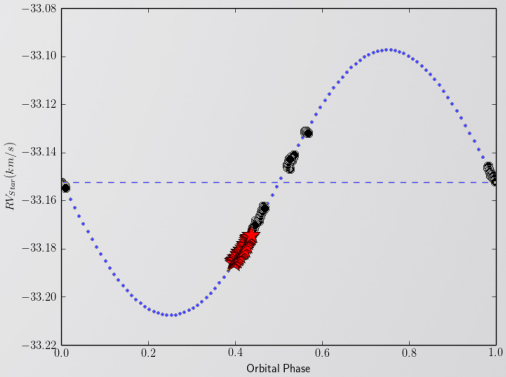
- 90 spectra / ∼12.5h ;



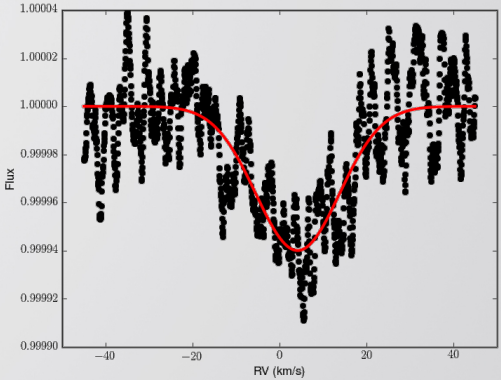
The Data

- 51 Peg b;
- HARPS@ESO's 3.6m;
- 90 spectra / ∼12.5h ;
- ∼ 20 spectra



What we found:

Amplitude	$6.0 \pm 0.4 \times 10^{-5}$
Significance	$3.7 \pm 0.2 \sigma_{\rm noise}$
FWHM	$22.6 \pm 3.6 \, {\rm km \ s^{-1}}$



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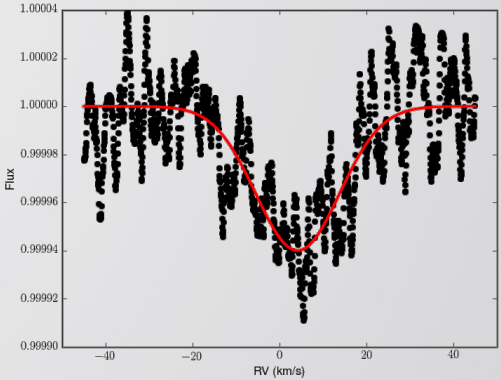
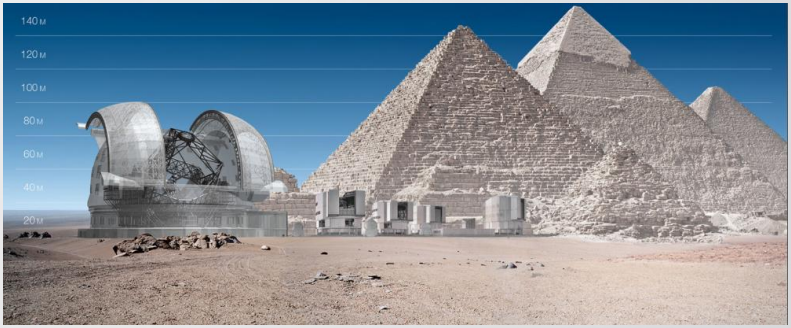
$\Downarrow$

Inflated hot Jupiter with high albedo!



The Future

Next generation of Observing Facilities



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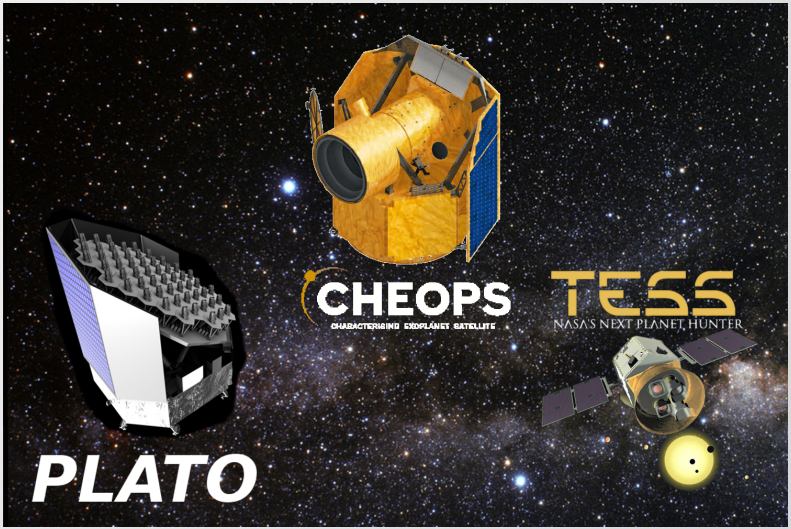
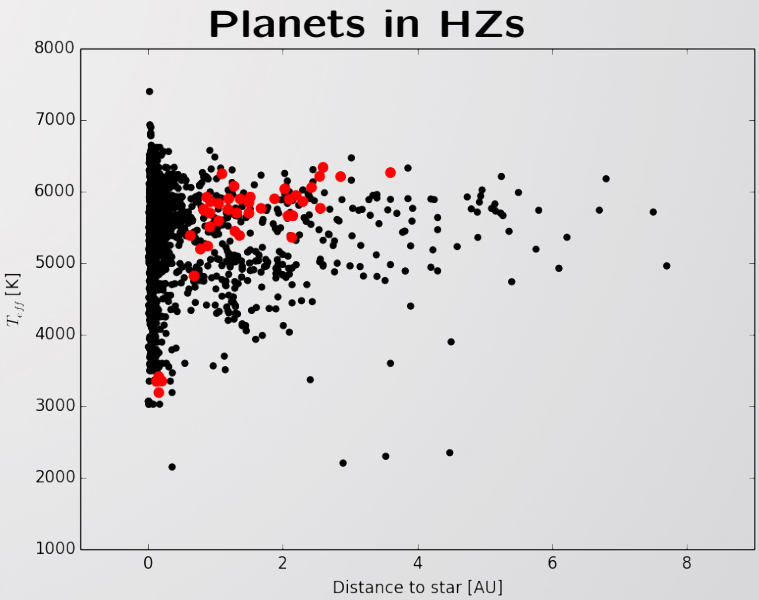
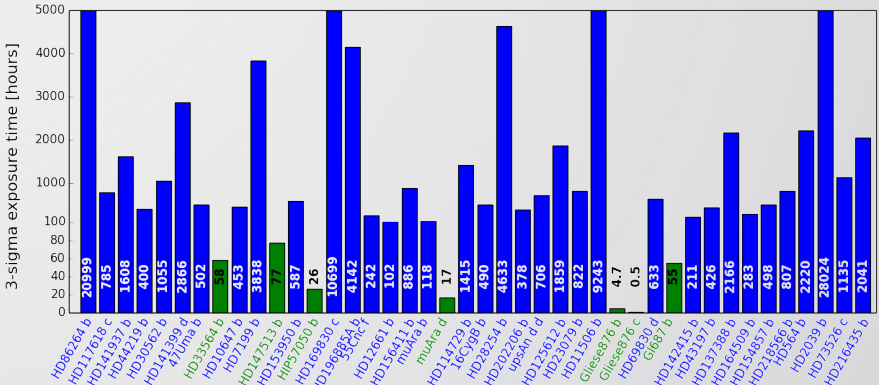




from exoplanet.eu - Schneider et al. (2011)

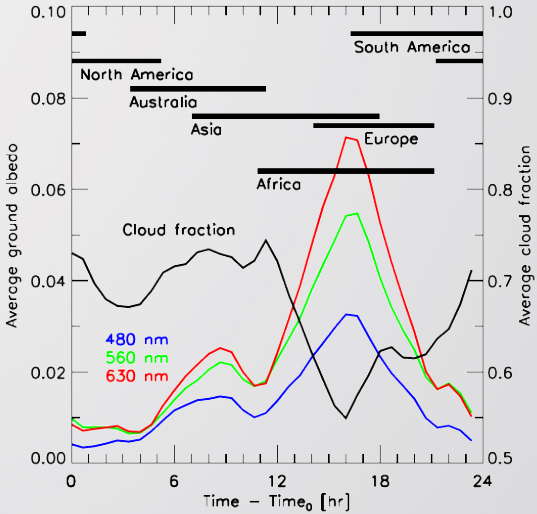
Planets in HZs



Martins et al 2015 - submitted to

Proceedings of "Habitability in the Universe: From the Early Earth to Exoplanets"

Ultimate goal



Variation of Earth's ground albedo over 24h

(from Garcìa Muñoz 2014)

Main ideas:

- The detection of reflected light at optical wavelengths from other planets is already possible
- We were able to recover the reflected visible light spectrum of 51Peg on its orbiting planet
- 51 Peg b is most likely an inflated hot Jupiter with a high albedo
- Next generation observing facilities should allow us to peek at habitable zones
- Missions like CHEOPS, TESS, PLATO should enable us to increase the number of available candidates.


Questions?