Independent analysis of Spitzer and HARPS : The still lonely and metal-rich GJ436b

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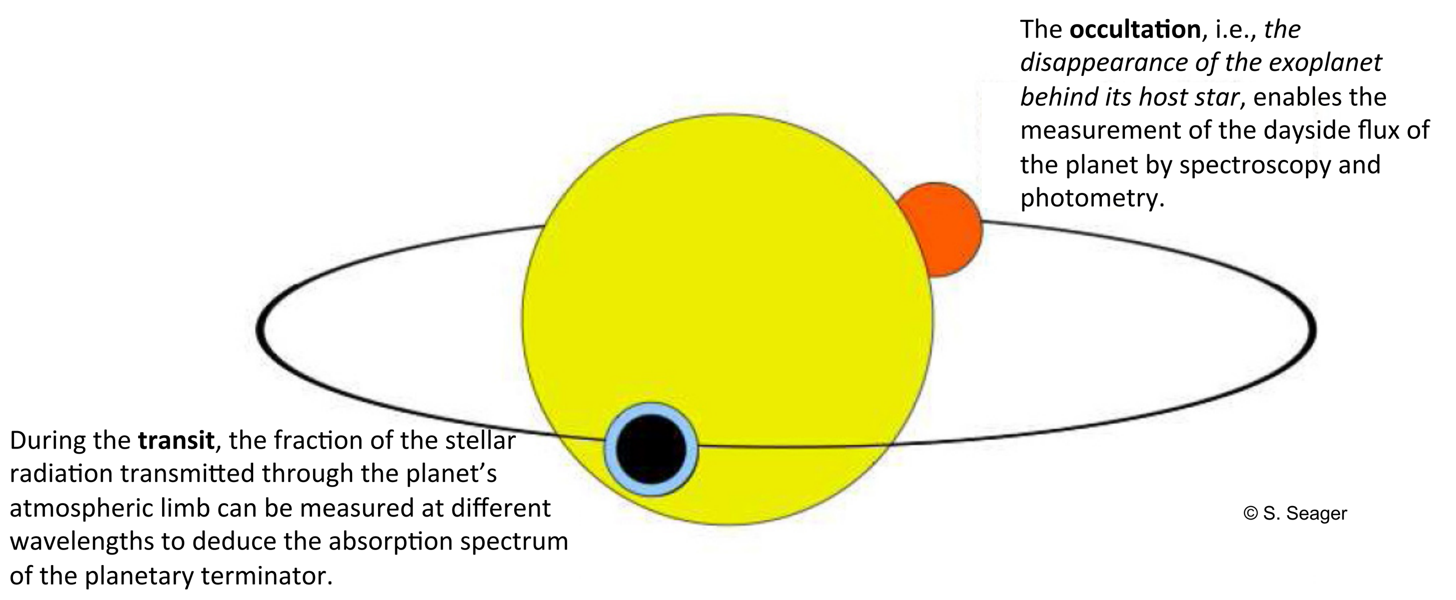
GJ 436b is a transiting hot Neptune showing an unexpected orbital eccentricity which is in contradiction with its loneliness and the old age of the system. Thanks to the infrared brightness and small size of its host M-dwarf, GJ 436b is at the heart of many surveys which probe its thermal emission and atmosphere. It is the most studied exoplanet in the Neptune-mass range. The Spitzer Space Telescope has gathered numerous observations of the planet in its 3.6, 4.5, 5.6, 8, 16, and 24 µm bands. However, independent analyses of several individual datasets of Spitzer have led to conflicting results attributed to different ways to treat the instrumental effects.

Transiting planets

Transiting planets give a wealth of information on their structure and atmospheric properties. Associated to radial velocity (RV) measurements and stellar parameters, the transit light curves provide the mass and the radius of the planet.



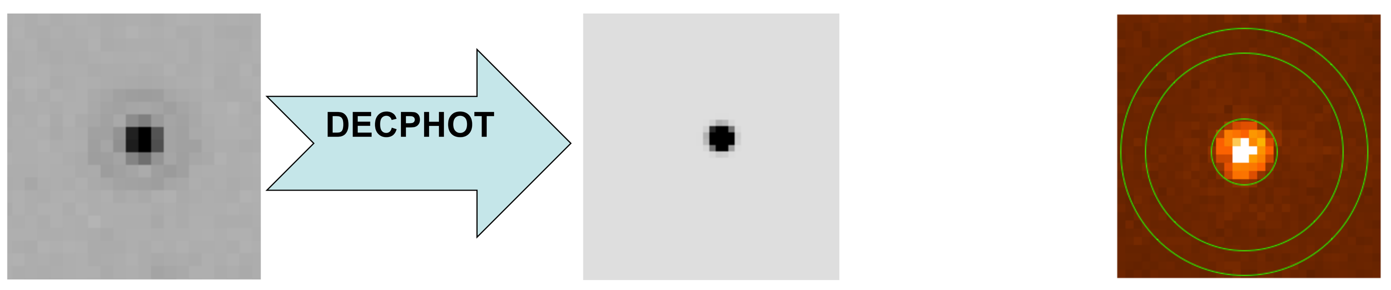
Spitzer data

The Spitzer Space Telescope has gather many invaluable measurements concerning exoplanetary atmospheres. It was equipped with three instruments to provide imaging and spectroscopic capabilities from 3.6 to 160 µm. It observed GJ 436 at 3.6 and 4.5 µm during 2 transits and 2 occultations, at 8 µm during 4 transits and 11 occultations, and at 5.6, 16, and 24 µm during an occultation.

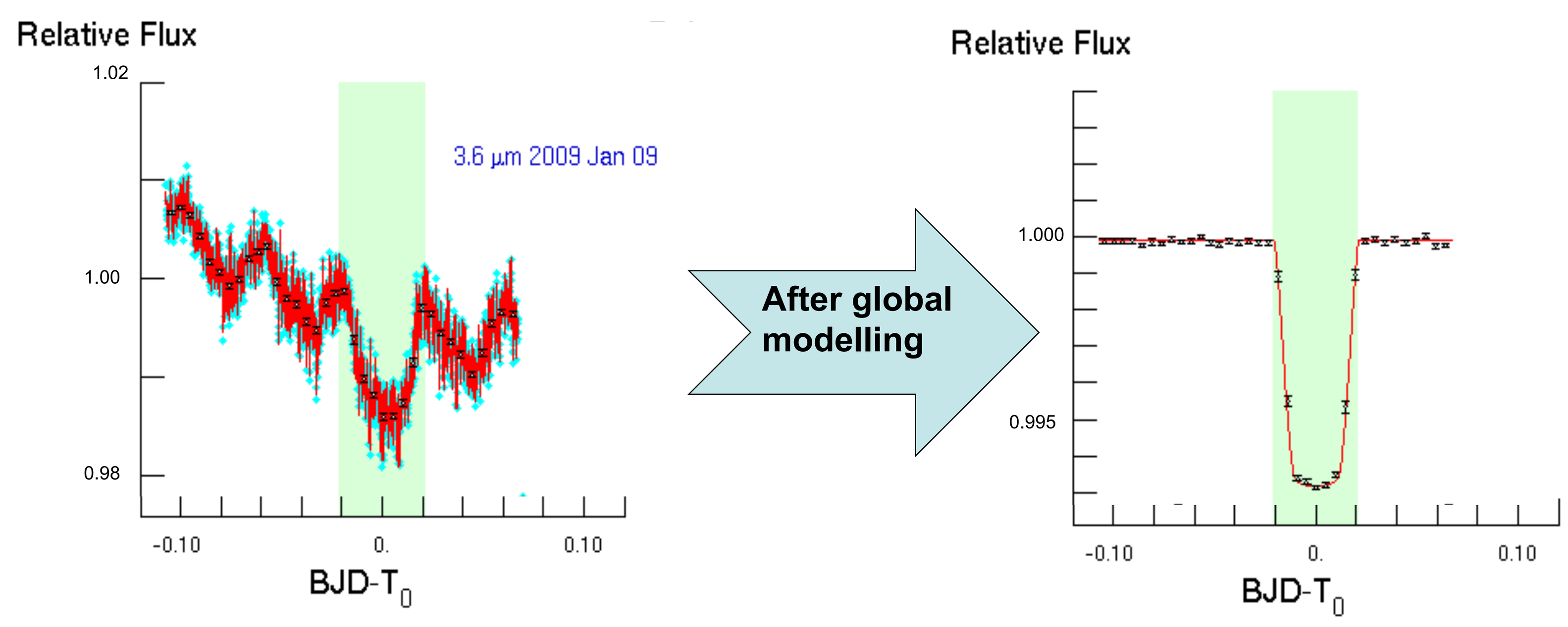
Data reduction and analysis

We optimise the photometric technique DECPHOT (Gillon et al. 2006), which is based on partial deconvolution, and apply it on the Spitzer data at 16 and 24 µm. The main advantage of DECPHOT is to optimally separate the light source from the complex background.

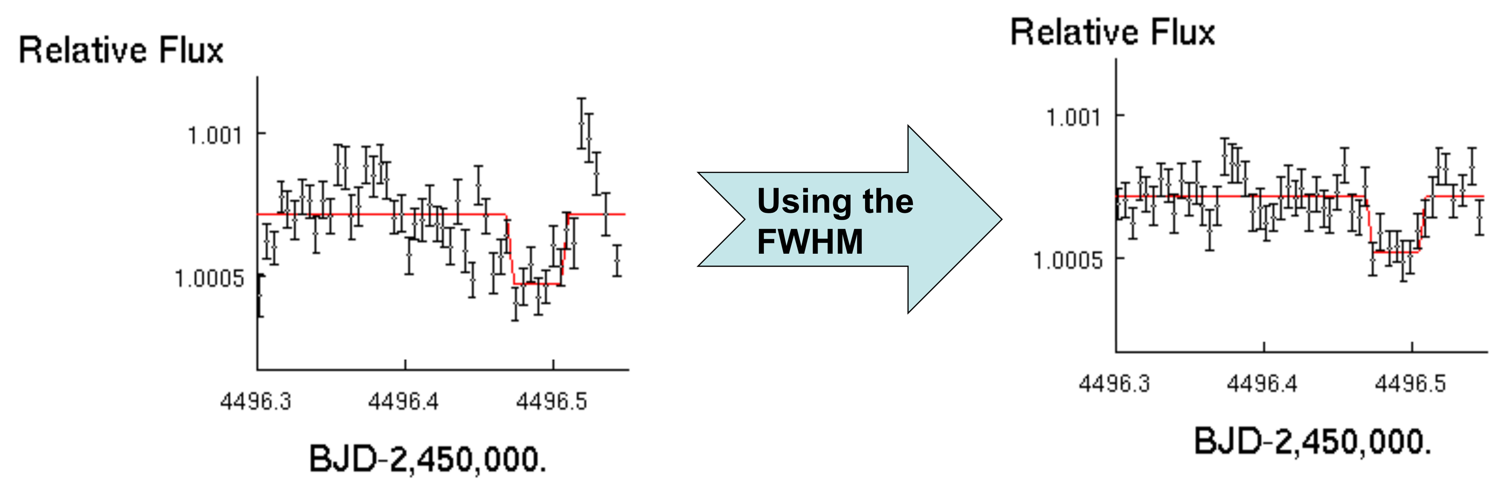
We also optimise the aperture photometry approaches for the other Spitzer data using DAOPHOT from Stetson (1987).



We perform a global analysis based on a Bayesian approach, using a Markov Chain Monte Carlo algorithm (Gillon et al 2012). It models the eclipse and the flux variations of instrumental and stellar origin at the same time.

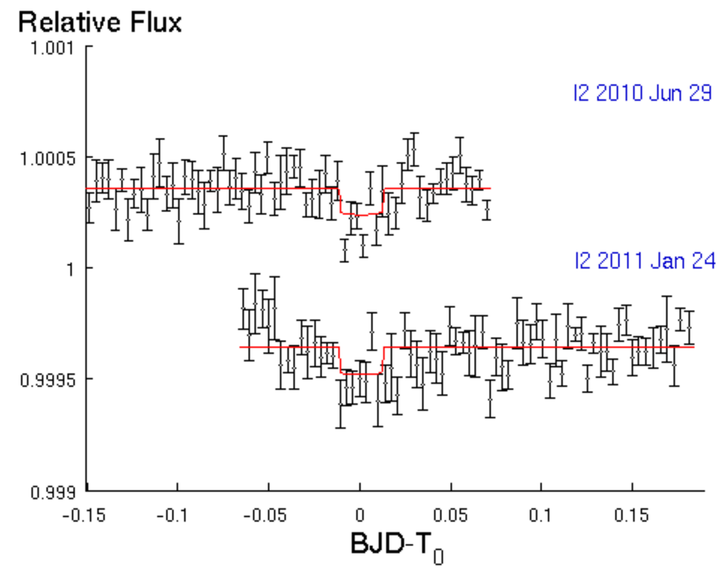


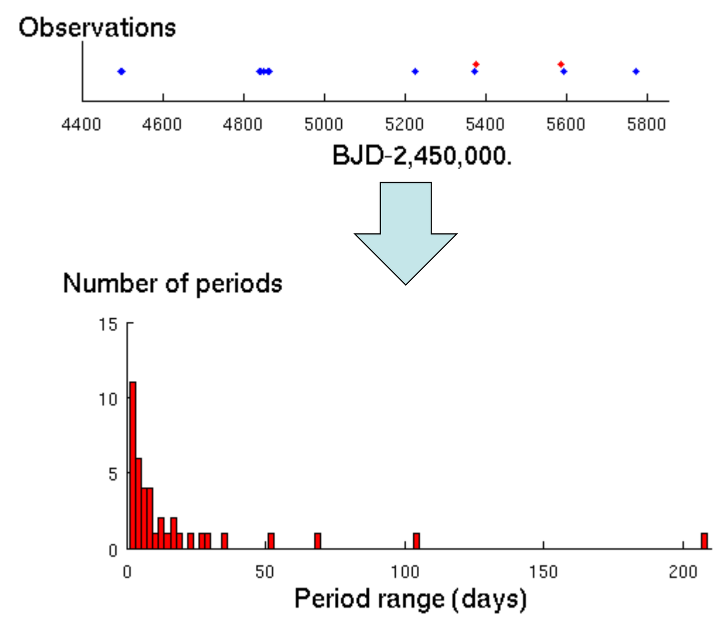
We include the dependence on the fluxes to the PSF FWHM in the global modelling process to correct for Spitzer instrumental systematics. We show it reduces considerably the noise level in some cases.



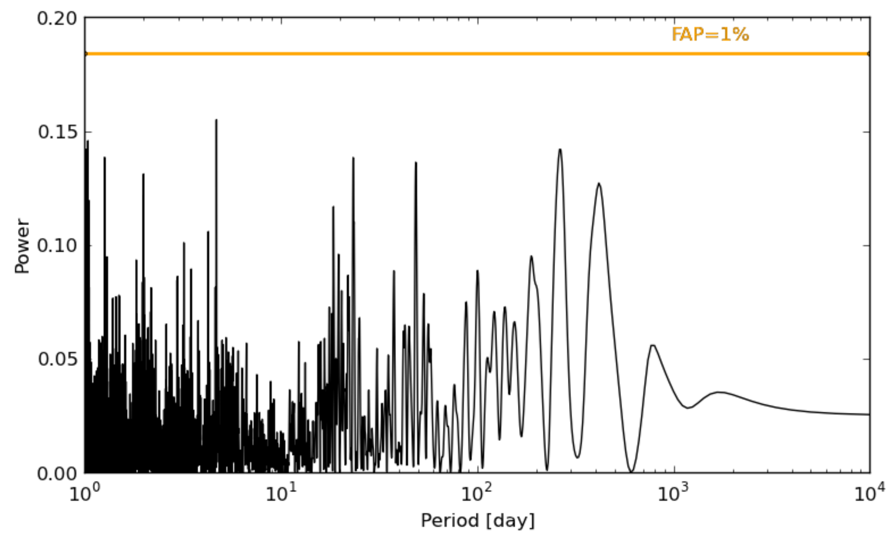
Looking for a planetary companion

We identify two potential transit-like events in the whole set of the Spitzer residual light curves although the actual significance of both structures is marginal when accounting for the correlated noise. The observations with lack of transit-like event help to constrain the possible periods of this potential planet.





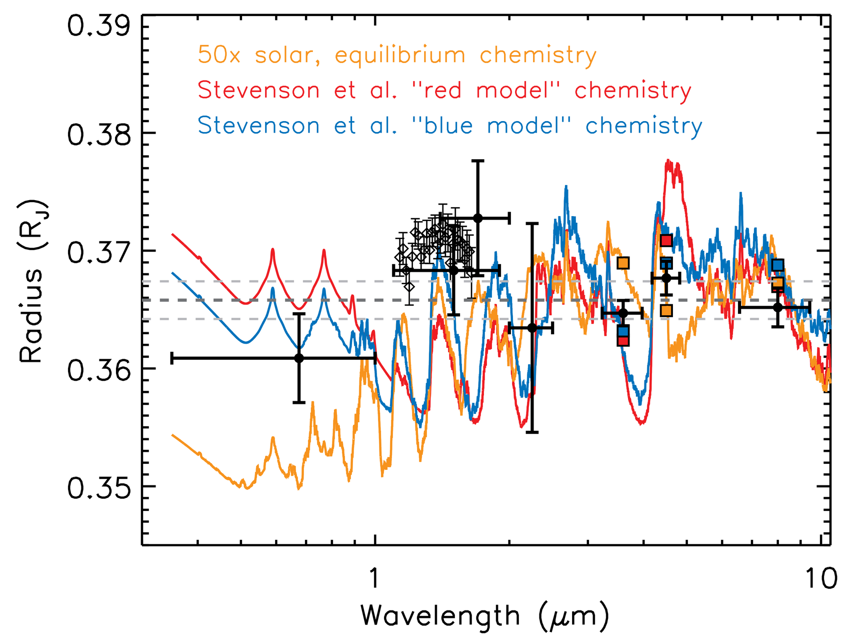
We also construct a periodogram of the HARPS residuals for a model composed of one planet on a Keplerian orbit plus one drift.

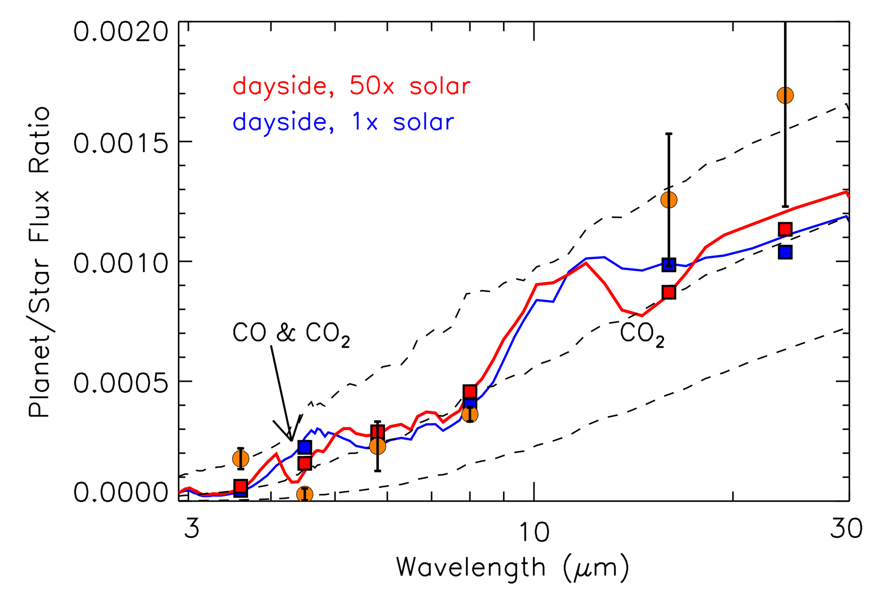


No confirmed planetary companion

Atmospheric modelling

The transit and occultation depth measurements allow us to derive transmission and emission models of the planet respectively. For this purpose we use the following atmospheric modelling tools: the 1D plane-parallel model atmosphere code from Fortney et al. (2008), the opacity database from Freedman et al. (2008), the equilibrium chemistry of Lodders & Fegley (2002), the solar abundances of Lodders (2003), and the transmission spectrum code described in Fortney et al (2010).





Our transit depth measurements are complemented with others found in the literature at different wavelengths (Ballard et al. 2010, Knutson et al. 2014, Pont et al. 2009, Alonso et al. 2008, Caceres et al. 2009).

Transmission and emission spectra disfavour equilibrium chemistry but support metal-rich atmosphere models with strongly enhanced CO and CO_2 and strongly depleted CH_4.

Conclusion

Our independent, homogeneous and global analysis permits to confirm and infirm former results based on data affected by systematics. We derive a planetary mass of 25.4 ± 2.0 $M_\oplus$ and a radius of 4.10 ± 0.16 $R_\oplus$. We can still not explain the eccentric orbit (e = 0.162 ± 0.004) and find no evidence for the presence of a planetary companion. We detect no stellar variability (no stellar flux variation on a large scale and no transit depth variation with time) in the whole set of Spitzer light curves and thus confirm GJ 436 weak activity. Our measurements are consistent with a very metal-rich atmosphere for the planet.

References :

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Acknowledgements :

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