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Exoplanetary atmospheres and WFC3

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Abstract

Spectroscopic observations of transiting exoplanets are providing an unprecedented view of the atmospheres of planets around nearby stars. With the high stability of Spitzer, Hubble, and large ground-based telescopes the spectra of bright close-in massive planets can be obtained and ionic, atomic and molecular species have been detected.

Explanatory spectroscopy typically requires a photometric precision of 1 part in 10000, a level that current generic instruments were not designed for and cannot be achieved without de-trending and noise reduction techniques. Since the demise of Hubble-NICMOS the replacement WFC3 has taken the stage and is still to prove itself in this manner.

In this conference I will present data from both NICMOS and WFC3 comparing the systematics in both cameras in the different modes used and discuss spectral reduction methods.

1. Introduction

The field of transiting extrasolar planets and especially the study of their atmospheres is one of the youngest and most dynamic subjects in current astrophysics. Permanently at the edge of technical feasibility, we are successfully discovering and characterising smaller and smaller planets. To study exoplanetary atmospheres, we typically require a 10^{-4} to 10^{-5} level of accuracy in flux. Achieving such a precision has become the central challenge to exoplanetary research and is often impeded by systematic (non-Gaussian) noise from either the instrument, stellar activity or both. Dedicated missions, such as Kepler, feature an a priori instrument calibration plan to the required accuracy but nonetheless remain limited by stellar systematics. More generic instruments (like NICMOS and WFC3) often lack a sufficiently defined instrument response function, making it very hard to calibrate. Different camera modes produce differences in the systematics which need to be removed. Many observers often handle systematics differently leading to different results at this high level of precision.

2. NICMOS

NICMOS was sensitive to positional changes both in the x and y direction, the rotational angle of the spectrum on the chip, FWHM of the spectrum (focus breathing), see figure 1. These were extractable parametrically first shown by Swain (2008) and the spectral result later verified by Gibson (2012) using Gaussian processes and Waldmann (2013) via ICA, both non-parametric methods. Our own analyses using the Swain (2008) method reached similar conclusions to both - (figure 2) but the difference demonstrates the problem with this technique. This level of spectral agreement has yet to be reached with WFC3.

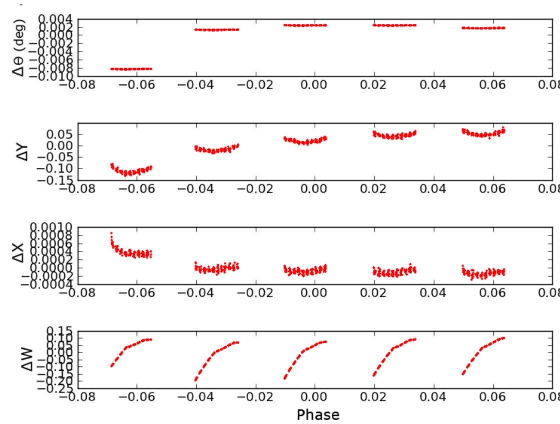

Figure 1: Our extraction of NICMOS parameters showing the variation in Angle (θ), X and Y position on the detector and FWHM of the spectrum (W).

3. WFC3

WFC3, the latest addition to Hubble, has started to produce results of varying quality resulting in a large amount of unpublished data in the archive. The new scanning mode is still a newcomer with few published

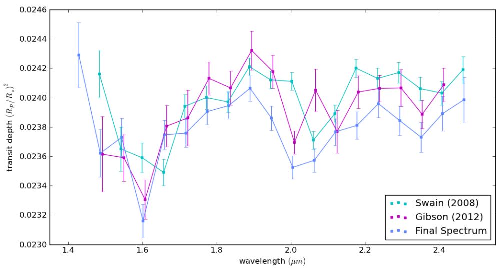

Figure 2: Our spectrum of HD 189733b (final spectrum) compared with Swain (2008) and Gibson (2012) all using the same data but with different extraction methods.

targets and no extensive tests of the instrument response function (IRF). The most significant systematics in WFC3 data is 'ramping' or 'hooks' probably caused by 'charge trapping' within the detector pixels. Whilst some groups have claimed its reproducibility this has yet to be proven. We also found significant variation in the sky, making background subtraction a necessity not just a formality.

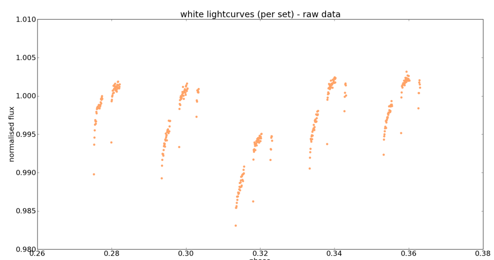

Figure 3: WFC3 data of GJ-3470 showing the 'ramp' or 'hook' systematic in WFC3

4 Summary and Conclusions

In this conference I will present old and new WFC3 data of exoplanet atmospheres, comparing the response functions for various instrument set-ups used – e.g. scanning and staring mode, comparing these to the systematics of NICMOS and discussing ways to separate the signal from the systematics.

References

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