



WFC3: Precision Infrared Spectrophotometry with Spatial Scans of HD 189733b and Vega



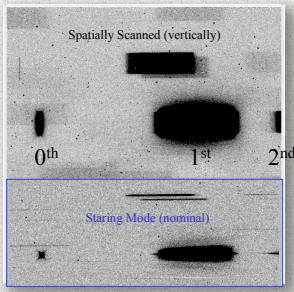
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Abstract

The Wide Field Camera 3 (WFC3) on the Hubble Space Telescope (HST) now routinely provides near-infrared spectroscopy of transiting extrasolar planet atmospheres with better than ~50 ppm precision per 0.05-micron resolution bin per transit, for sufficiently bright host stars. Two improvements of WFC3 (the detector) and HST (the spatial scanning technique) have made transiting planet spectra more sensitive and more repeatable than was feasible with NICMOS. In addition, the data analysis is much simpler with WFC3 than with NICMOS. We present time-series spectra of HD 189733b from 1.1 to 1.7 microns in transit and eclipse with fidelity similar to that of the WFC3 transit spectrum of HD 209458b (Deming et al. 2013). In a separate program, we obtained scanned infrared spectra of the bright star, Vega, thereby extending the dynamic range of WFC3 to ~26 magnitudes! Analysis of these data will affect the absolute spectrophotometric calibration of the WFC3, placing it on an SI traceable scale

Spatial Scans: How and Why

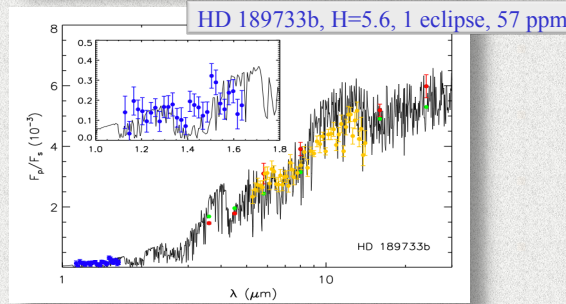
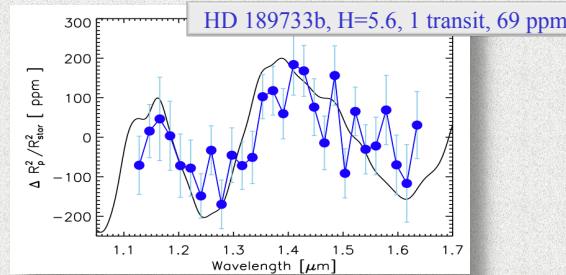
- ✓ Spatial scanning means moving the telescope (HST) during an exposure, in this case perpendicular to the dispersion of the spectrum.
- ✓ HST can scan at any rate from 0 to 7.8 arcsec s⁻¹. The scan rate determines the effective exposure time.
- ✓ Spatial scanning increases the number of photons recorded by a large factor because spatial scanning reduces overheads considerably. For each detector preparation-readout cycle, we obtain ~100 spectra (well-exposed rows on the detector) instead of just 1.
- ✓ Spatial scanning is most useful for bright stars (H < 10 mag).
- ✓ For very bright stars (H ~ 6 mag) such as HD 189733 and HD 209458, spatial scanning enables observations that otherwise would saturate the detector even before the exposure begins.
- ✓ Spatial scanning has enabled the “greatest hits” science in the sidebar (at far right) by increasing the S/N of exoplanet spectroscopy by factors of a few.



The spatially scanned spectrum of the star GJ1214 is labeled with its 0th, 1st, and 2nd order light and compared to a nominal staring-mode slitless spectrum of the same field (blue outlined inset). The images are 512 columns wide, of the detector's 1024. The scan was 40 pixels high. (4.8 arcsec).

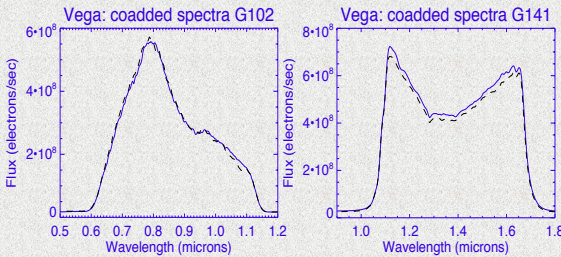
HD 189733b

We scanned the gas giant exoplanet HD 189733b with WFC3 in June, 2013. Its transit spectrum (blue data points, black model) shows water vapor features at 1.2 microns and 1.4 microns similar to those of HD 209458b as reported by Deming et al. (2013) and commensurate with a solar-abundance clear atmosphere (McCullough et al. 2014). Its eclipse spectrum (blue data points, black model) is flat and its molecular features are lower contrast than similar models predict (Crouzet et al. 2014).



Vega

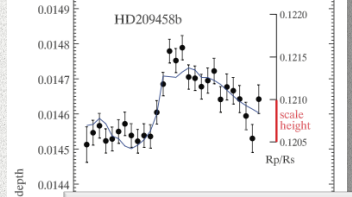
Spectra of Vega for the -1st orders of the two WFC3 IR grisms (Deustua et al. 2014). Solid lines represent “slower” scan rates (< 5 °s⁻¹); dashed lines represent faster scans (> 7 °s⁻¹). Left: at 24 Å/pix, Pa γ is just visible at 1.09 microns, and Pa δ at 1.05 microns. Right: at 46 Å/pix, Paschen β is the dip at 1.28 microns, and the series of features between 1.6 and 1.7 microns are Br 13,12, 11.



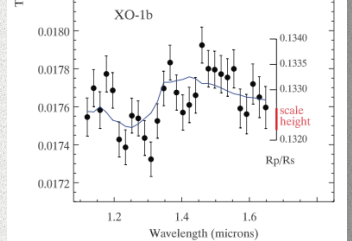
WFC3 Spatial Scans “Greatest Hits”

From top to bottom, transit spectra of HD 209458b and XO-1b (Deming et al. 2013), GJ436b (Knutson et al. 2013), and GJ 1214b (Kriedberg et al. 2014). The number of transits and estimated uncertainty in each R-70 spectral channel are listed.

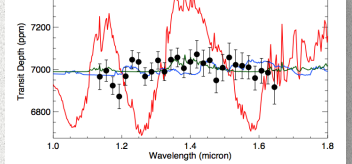
HD 209458b, H=6.4, 1 transit, 36 ppm



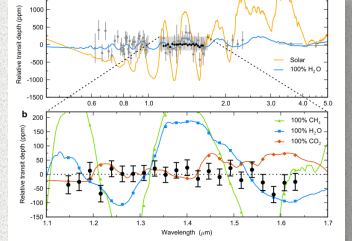
XO-1b, H=9.6, 1 transit, 96 ppm



GJ 436b, H=6.3, 4 transits, 40 ppm



GJ 1214b, H=9.1, 12 transits, 28 ppm



References

- Deming et al. 2013, ApJ, 774, 95
 Deustua et al. 2014, in prep.
 Crouzet et al. 2014, ApJ, in prep.
 Knutson et al. 2014, Nature, 505, 66
 Kriedberg et al. 2014, Nature, 505, 69
 McCullough et al. 2014, ApJ, in prep.