Hands-on Session: Detection and Spectroscopic Characterization of Transiting Exoplanets with the James Webb Space Telescope

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Monday, November 16, 2015
8:00 - 9:00
REGISTRATION and COFFEE
STScI Rear Lobby

SESSION 1: Laying the Groundwork
Chair: Nikole Lewis

9:00 - 9:10
Welcome from the Director’s Office
& JWST
Ken Sembach, Director, STScI

9:10 - 9:20
Goals/Overview of the Meeting
Nikole Lewis

9:20 - 10:00
Transiting Exoplanet Science Overview
Mercedes Lopez-Morales
Harvard-Smithsonian CfA

10:00 - 10:30
Status of JWST and Operations for Transiting Exoplanet Observations
Mark Clampin
NASA GSFC

10:30 - 11:00
COFFEE BREAK
Café Azafran

SESSION 2
Chair: Knicole Colon
NASA Ames

11:00 - 11:40
Giant Exoplanet Science with JWST
Adam Burrows
Princeton University

11:40 - 12:20
Terrestrial Exoplanet Science with JWST
Victoria Meadows
University of Washington

12:20 - 1:30
LUNCH

SESSION 3
Chair: Everett Schlawin
University of Arizona

1:30 - 1:50
Comparing and Contrasting Detectors: JWST NIR vs. HST WFC3
Bernard Rauscher
NASA Goddard

1:50 - 2:10
Transiting Exoplanets with NIRISS
Loic Albert
Université de Montréal

2:10 - 2:30
Transiting Exoplanets with NIRCam
Jonathan Fraine
University of Arizona

2:30 - 2:50
Transiting Exoplanets with NIRSpec
Stephan Birkmann
ESA

2:50 - 3:10
Transiting Exoplanets with MIRI
Pierre-Olivier Lagage
CEA Saclay

3:10 - 3:40
COFFEE BREAK
Café Azafran

SESSION 4
Chair: Natasha Batalha
Pennsylvania State University

3:40 - 4:10
JWST Instrument Synergies
Tom Greene
NASA Ames

4:10 - 5:00
Discussion: Sample Science Programs and Current Capabilities
Moderator: Jonathan Fortney
UC, Santa Cruz

5:00 - 6:30
POSTER SESSION
Café Azafran

Sagan Summer Work 2016
Is There a Planet in My Data?
Why Transiting Extrasolar Planets?

- See cyclical variations in brightness of planet
- See radiation from star transmitted through the planet’s atmosphere
- See thermal radiation and reflected light from planet disappear and reappear

Currently more than 3000 confirmed transiting extrasolar planets!
A continuum from clear to cloudy hot Jupiter exoplanets without primordial water depletion.

Figure 1 | HST/Spitzer transmission spectral sequence of hot Jupiter survey targets. Solid coloured lines show fitted atmospheric models with prominent spectral features indicated. The spectra have been offset, ordered by values of $\Delta Z_{UB}$ (the altitude difference between the blue-optical and mid-infrared, Table 1). Horizontal and vertical error bars indicate the wavelength spectral bin and $1\sigma$ measurement uncertainties, respectively. Planets with predominantly clear atmospheres (top) show prominent alkali and H$_2$O absorption, with infrared radii values commensurate or higher than the

\[ \frac{R_p^2}{R_*^2} \sim 0.01\% \text{ to } 1\% \]

Probes Pressures 100-1 mbar Near Planetary Limb

Sing et al. (2016)
In the Era of Webb....

Greene et al. (2016)
In the Era of Webb….

Greene et al. (2016) compared with those derived from the molecular abundances in our baseline free retrievals (i.e., Figure 8, top row). The C/O histograms are qualitatively similar; both suggest a weak constraint of the C-to-O ratio. Perhaps more interesting is the comparison of the metallicity histograms. The chemically consistent approach provides a metallically constraint that is several orders of magnitude better than that derived from retrieving the molecular mixing ratios freely. This is because the chemically consistent approach rules out combinations of molecular abundances that do not abide by thermochemical equilibrium. Effectively, more prior information is being added to the chemically consistent retrieval system in the form of a more sophisticated parameterization with more assumptions but with fewer free parameters. More generally, it would be possible to apply chemically consistent models on all posterior "free" retrieval histograms (Figures 6–9) to rule out non-physical parameter spaces within the equilibrium framework. This would be an intermediate step between the classic retrieval and forced self-consistency, but we do not implement it here.

Given a high enough signal-to-noise ratio and sufficient spectral resolution along with correct physics and chemistry constraints, one would expect the two approaches to produce the same distributions of the retrieved quantities. That would suggest true independence from any prior assumptions, and this would be the ideal regime for learning more about these atmospheres.

5.2. T–P Profiles and Parameter Uncertainties
Figure 11 shows the range of T–P profiles retrieved from the simulated emission spectra over the three different wavelength ranges. Figure 12 shows normalized thermal emission contribution functions for the solar-composition hot Jupiter and warm sub-Neptune planets to illustrate where their thermal emissions originate. The contribution function for the solar-composition warm Neptune is very similar to that for the warm sub-Neptune.

Table 5 lists the 68% confidence intervals of the retrieved parameters of the transmission and emission scenarios (see Section 3, Table 1). For cases in which a molecule is not particularly abundant (e.g., CH₄ in the hot Jupiter and CO or CO₂ in the cooler objects), only upper limits could be obtained. We quote the 3σ upper limits instead of confidence widths in these cases. We caution, however, that many of these upper limits are relatively soft and that one should really look at the histograms to get a sense of the distribution. These numbers are meant to be a guide to illustrate how the constraints change from one object to the next. We also note that there is typically a ∼10% uncertainty on these uncertainty numbers.
The Near Infrared Imager and Slitless Spectrograph
Single Object Slitless Spectroscopy mode:
NIRISS SOSS

Fig. 18.—Simulated traces for the SOSS mode with NIRISS in Orders-1 to 3. The zeroth Order is the detector on the right side. The magenta rectangles represent the 2048×256 (top - standard mode) and 2048×80 (bottom - bright mode) detector sub-arrays read-out for those modes. The standard mode covers from 600 nm to 2800 nm (850 nm to 2800 nm in Order-1, 600 nm to 1350 nm in Order-2) while the bright mode covers from 1000 nm to 2800 nm (in Order-1 only). The Order-3 trace has very low throughput and is unlikely to be of any use. Note that these sub-array are along the edge of the detector to make use of the reference pixels and that they are along the amplifier long-axis direction, meaning that the readout can not be multiplexed using 4 amplifiers. The abrupt cut at 2700 nm is an artifact of the simulation.

7.2.5. Operational Limitations & Efficiency
Wheel repeatability will be the main limitation on the spectral traces position. The encoder precision is equivalent to $0.15^\circ$ on the wheel which results in a rotation of $\pm 4^\circ$ pixels at each end of the Order-1 trace. Contamination by the Order-2 trace increases.

Fig. 19.—(Left) A cut through the spectral trace along the spatial direction near 1.5 microns as measured at cryo vacuum 1 in 2013. The trace is approximately 20 pixels wide with the brightest pixel receiving about 7% of the monochromatic light flux. The trace width does not vary significantly across the wavelength range of 0.6-2.8 microns. (Right) Monochromatic PSF of NIRISS in the SOSS mode at 0.64 microns. A slight tilt of approximately 2 degrees was dialed in so that a given spectroscopic feature is sampled at different intra pixel positions.

Beichman et al. (2015)
The participants in this hands-on exercise will complete a three-step process to detect and characterize the planet in their JWST NIRISS SOSS data.

1. Work with high-level data products from the JWST pipeline to find the planetary transit as a function of wavelength.

2. Use MCMC-based fitting tools to measure changes in the planetary radius with wavelength to find the planetary spectrum from 0.6 to 2.5 microns.

3. Determine the atmospheric composition of the planet using spectroscopic retrieval tools.
Work with high-level data products from the JWST pipeline to find the planetary transit as a function of wavelength.
Use MCMC-based fitting tools to measure changes in the planetary radius with wavelength to find the planetary spectrum from 0.6 to 2.5 microns.

batman: BAsic Transit Model cAlculatioN in Python
© Laura Kreidberg, Kreidberg (2015)
Determine the atmospheric composition of the planet using spectroscopic retrieval tools.
Goals of Transit Hands-on Session

- Get participants familiar with the types of data products that will be produced by JWST pipeline and delivered to MAST archive.

- Help participants understand the basics of transit data and how to extract a planetary spectrum given spectroscopic time-series observations.

- Guide participants through a robust process for determining exoplanet atmospheric composition.

- Introduce participants to python, which will be the language in which all JWST pipeline modules, tools, etc. will be built.

Questions?

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Is There a Planet in My Data?