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Using the James Webb Space Telescope to Study Ice Giant Atmospheres

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Abstract

We present preliminary estimates of the James Webb Space Telescope (JWST) instrument sensitivities, exposure times, and SNR calculations with respect to ice giant atmospheric observations. We describe the benefits and limitations of each spectroscopic and imaging observing mode, along with alternative observing methods for instances of predicted detector saturation.

1. Introduction

The James Webb Space Telescope (JWST) will provide the astronomical community with a 6.5 meter infrared space-based observatory. Although extragalactic and cosmological science objectives provided the initial motivation for the telescope, JWST is equipped with moving-target capabilities that will enable Solar System body observations. The ice giant planets (Uranus and Neptune) are particularly well-suited for JWST to observe due to their relatively low surface brightness, in contrast with the gas giant planets (Jupiter and Saturn). The focus of this study is to determine the strengths and limitations of JWST with regard to observations of the ice giant planets.

Based on sensitivity and SNR calculations, both Uranus and Neptune can be observed with JWST at high spectral and spatial resolution without the risk of detector saturation. JWST will provide some of the first high spatial and continuous spectral resolution (R=3000) IR ($0.5 - 27\ \mu$m) space-based observations of the ice giant planets. Spatially resolved measurements of methane and ethane emission features in the upper atmospheres of Uranus and Neptune will help constrain the abundances of these compounds and the photochemistry involved in their formation. The abundances and variability of chemical species, as well as the confirmation of radicals thought to be involved in the photolysis process, may be observed with JWST to more accurately characterize the atmospheric processes and formation of these planets. We present instrument sensitivity and saturation limits, exposure time estimates, and SNR calculations for the ice giant atmospheric emission features.

2. Proposed Observations

The Near-Infrared Camera (NIRCam) and the Mid-Infrared Instrument (MIRI) will be capable of spatially resolving methane and ethane emission and absorption features within the ice giant atmospheres. The large field of view (FOV) of the imagers allows for complete planetary coverage, and will help identify atmospheric emission feature candidates for spectroscopic observations.

Near-infrared spectroscopic observations of the ice giant planets using fixed-slit spectroscopy may be performed with the Near-Infrared Spectrograph (NIRSpec). NIRSpec is also equipped with an integral field unit (IFU) ($3'' \times 3''$), which may be better suited for Uranus observations in cases where the angular diameter of the planet exceeds the length of the fixed slits.

The Medium Resolution Spectrograph (MRS) on MIRI contains four IFUs for observations in the $5-27$ μm range. The IFUs range in size from $3.0'' \times 3.87''$ at the shortest wavelengths, to $6.7'' \times 7.73''$ at the longest, and will provide spatial and spectral (R=3000) data on selected regions of the planetary disk [4]. Due to the wavelength dependence of the IFUs and the similarity of the size of the IFU FOVs and the angular diameter of the ice giants, a dither pattern will ensure adequate spatial and spectral sampling across the planet [1]. Figure 1 shows Uranus at opposition with the fields of view of all four MRS IFUs for comparison.

Saturation limits for NIRCam, the MIRI Imager, NIRSpec, and MRS and their implications on ice giant observations were calculated [2],[3]. Alternative methods of observations, including use of the IFUs on NIRSpec, and the sub-array mode implemented on NIRSpec and MRS detectors, are presented for cases

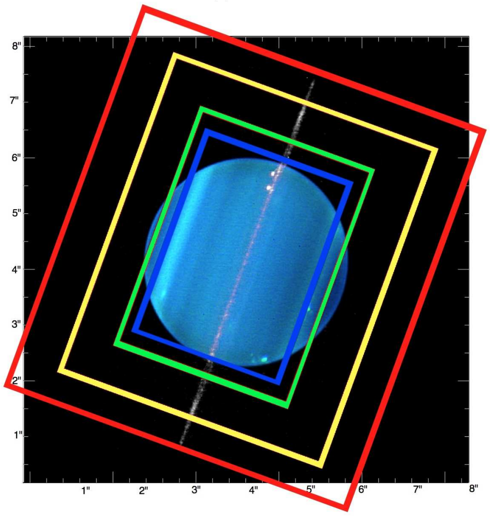

Figure 1: The MRS will allow for spatially resolved mid-IR spectroscopy of the ice giants. [Uranus image provided by: W. M. Keck Observatory (http://keckobservatory.org/gallery/detail/40/)].

that saturate in standard observing modes. We used the JWST exposure time calculator to estimate exposure times of Uranus and Neptune in each observing mode based on flux values derived from existing IR spectra of both planets. We compared the exposure time estimates for individual spectroscopic measurements and narrow-band imaging with the planetary rotation speeds to determine the number of imaging filters and spectral resolution elements that may be sampled before significant planetary rotation occurs.

3. Summary

JWST will provide many opportunities for Solar System observations, and will be particularly useful for observing the ice giant planets. We present our calculations for exposure times and SNRs of ice giant planets in various observing modes as well as potential atmospheric emission feature candidates based on detector saturation limits, planetary characteristics, and instrument capabilities.

Acknowledgments

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