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# Prospects for the characterization of exoplanet atmospheres

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Spectra of the giant planets of our own solar system have provided important constraints on the origin of these bodies (1). Spectra of extrasolar giant planets potentially can do likewise, provided the spectral resolution is sufficiently high. For terrestrial planets, spectra will provide the primary—or even the only—way to gauge habitability of these objects (2). Currently extrasolar giant planets around solar-type stars are examined spectroscopically during both primary eclipses of the parent star ("transits") and secondary eclipses. Of the 235 extrasolar planets known at the time of writing of this abstract, not much more than a dozen have been examined in primary eclipse, and only a handful in secondary eclipse. The latter provides an opportunity to detect the infrared emission from the planet with the Spitzer Space Telescope in the 7 to 13 micron region, which is key for close-in giant planets because their flux peaks in this spectral region (3).

When Spitzer's supply of cryogen is depleted, the ability to utilize the mid-infrared will be lost until the launch of the James Webb Space Telescope (JWST) early in the next decade (4). The James Webb Space Telescope (JWST) is a large (6.6 m), cold ($<$50 K), infrared (IR)-optimized space observatory that will be launched early in the next decade into orbit around the second Earth Sun Lagrange point. The observatory will have four instruments: a near-IR camera, a near-IR multi-object spectrograph, and a tunable filter imager will cover the wavelength range, 0.6 - 5.0 $\mu$ m, while the mid-IR instrument will do both imaging and spectroscopy from 5.0 - 29 $\mu$ m. The extraordinary sensitivity of this device will be unparalleled even from 30-meter ground based telescopes beyond 3 microns wavelength. Direct detection of objects twice the mass of Jupiter and direct R$>$1000 spectroscopy of objects in excess of 7 Jupiter masses at the age of the Sun, 10 parsecs from Earth, will be possible. (The masses translate into infrared brightnesses and assume large separation from the parent, Sun-like star). This will allow study of massive giant planets in some ways akin to the studies of our own giant planets undertaken today by ground-based telescopes. JWST will be able to conduct a program of spectroscopy, in emission and transmission, of a variety of extrasolar giant planets including those that may be discovered by Kepler and Corot.

The unique piece of planetary parameter space that JWST may be able to open up is transit spectroscopy of near-Earth-sized planets orbiting M-dwarf stars. The smaller size of M-dwarfs relative to sun-like stars makes possible the detection of planets approaching the size of Earth with transits, and the mass of Earth with the Doppler spectroscopic technique, as demonstrated recently in the discovery of a body with M sin i (i the inclination of the orbit to the star-observer line of sight) of 5.1 Earth masses (5). The mirror size and instrument sensitivities of JWST make it conceivable that transit spectroscopy of putative Earth-sized planets around solar neighborhood M dwarfs could detect major atmospheric or oceanic features if such planets exist with the right orbit inclinations (6). Detection of subtler but also more diagnostic clues to habitability (7) will require something more on the scale of ESA's planned Darwin mission. Meanwhile Corot, already in space, and Kepler, planned for launch in 2008, will provide a transit-based census of the occurrence of planets from Jovian down to terrestrial in size, allowing a better constrained strategy for extending spectroscopy to the numerous planetary systems in our cosmic neighborhood.

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