National Aeronautics and Space Administration

Spectropolarimetric modeling of brown dwarfs (BDs) and extrasolar giant planets (EGPs)

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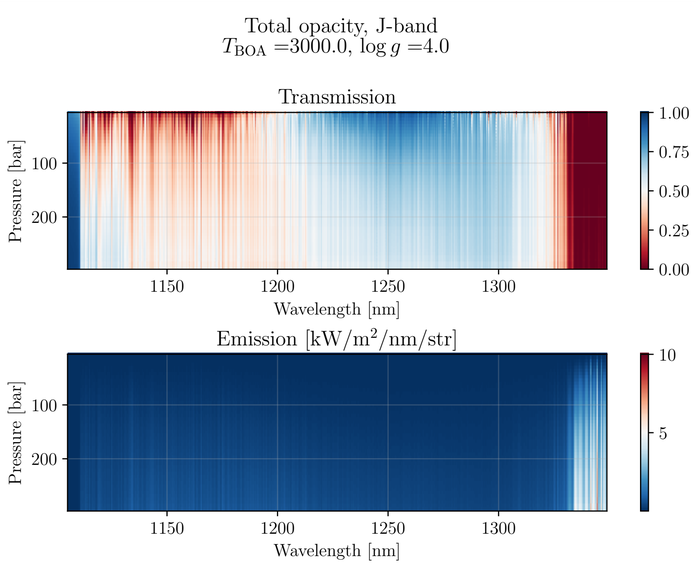
Program: Innovative Spontaneous Concepts

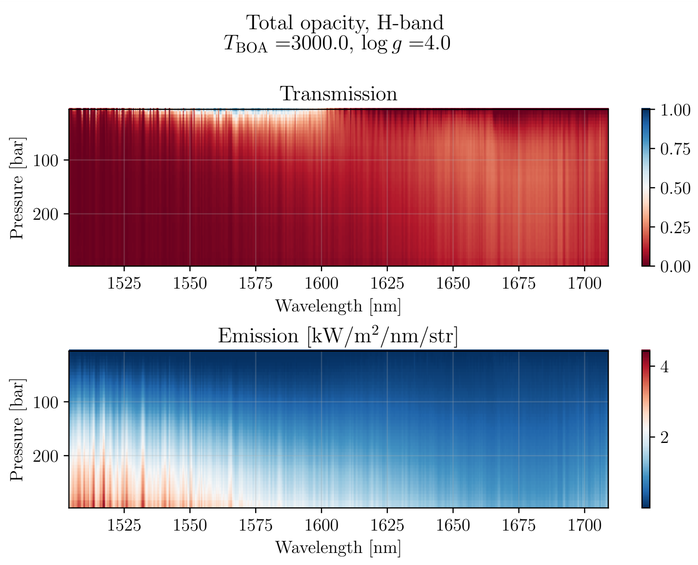
Project Objective:

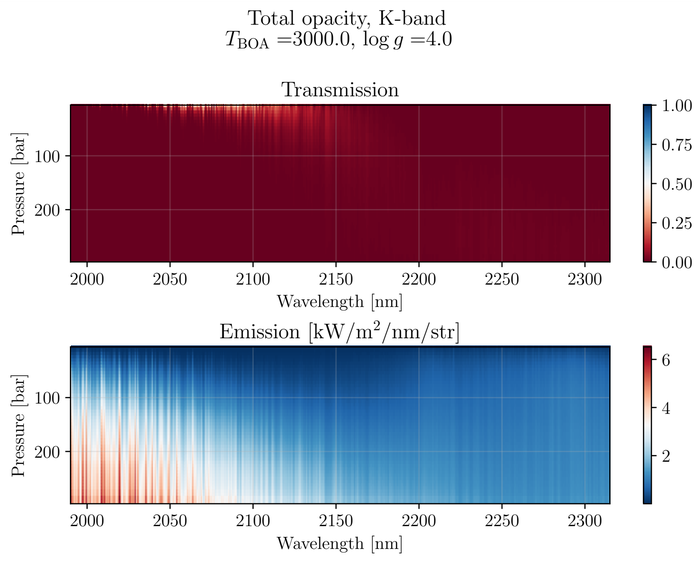
Our objective was to achieve the ability to simulate spectropolarimetric direct-imaging observations of BDs/EGPs (from the JPL-funded WIRC+Pol at Mt. Palomar as well as those expected from future platforms like JWST and WFIRST) by incorporating realistic opacities due to molecular absorption in our radiative transfer model. This forward modeling capability is indispensable for the meaningful science interpretation of measured (polarized) spectra.

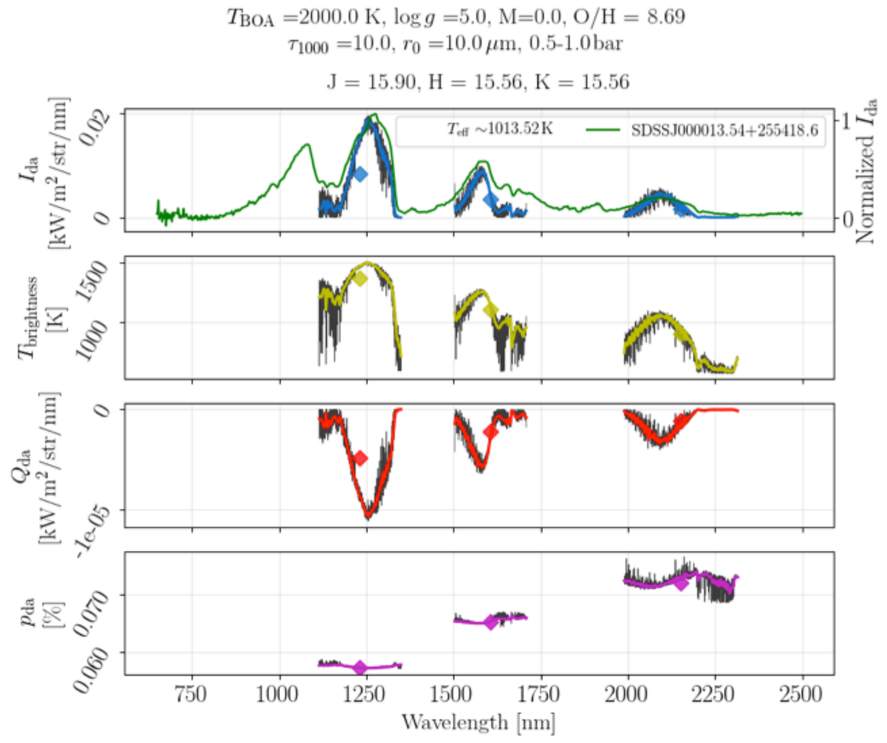
FY18/19 Results:

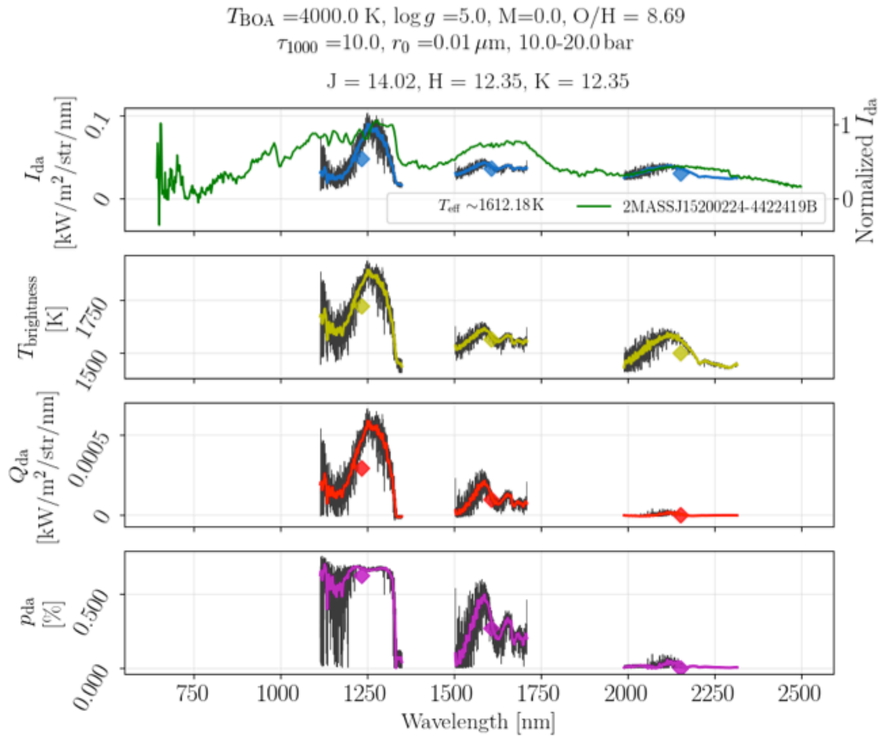
For spectropolarimetric analyses, we implemented opacities due to molecular absorption using high temperature line lists (Exomol, Tennyson and Yurchenko (2012), Tennyson et al. 2016), HITEMP and HITRAN to generate a database of cross-sections for important absorbers (CH_4, H_2O, NH_3, CO, CO_2, CIA due to H_2) in the NIR spectrum due to BD/EGP atmospheres. This database was used with 1D vertical profiles generated using the thermochemical equilibrium abundances (TEA) model developed by Blecic et al. (2017) to generate detailed opacities. We used the 3D RT model framework of Sanghavi & Shporer (2018) to simulate spectropolarimetric measurements for different parameters like effective temperature, surface gravity and metallicity, and different cloud properties. Our work resulted in a publication entitled "Spectropolarimetric Characteristics of Brown Dwarfs. II. Uniform Clouds" (Sanghavi & West, 2019) which details the extension of the photopolarimetric capability of Sanghavi & Shporer (2018) to spectropolarimetric analyses to support synergistic scientific interpretations of EGP/BD atmospheres observed by different past, present and future instruments.











Benefits to NASA and JPL (or significance of results):

This work resulted in an extension the photopolarimetric capability of SS18 to detailed spectropolarimetric analyses to support synergistic scientific interpretations of EGP/BD atmospheres observed by different past, present and future instruments. This capability will be useful for the wider JPL community to interpret spectropolarimetric observations in a rigorous scientific fashion. The physical presence of the model developer at JPL will allow it to be readily tailored to different studies being carried out here. The model can motivate and justify future innovation in instrumental development and design at JPL. This work will enable us to write compelling proposals to NASA's Exoplanet Research Program (XRP) as the focus of the community moves increasingly from detection towards scientific interpretation of observed BDs and EGPs.

Publications:

- Sanghavi, Suniti, and Avi Shporer. "Photopolarimetric Characteristics of Brown Dwarfs. I. Uniform Cloud Decks." *The Astrophysical Journal* 866.1 (2018): 28.
- Sanghavi, Suniti, and Robert West. "Spectropolarimetric Characteristics of Brown Dwarfs. II. Uniform Clouds." *The Astrophysical Journal* 877.2 (2019): 134.
- Tennyson, Jonathan, and Sergei N. Yurchenko. "ExoMol: molecular line lists for exoplanet and other atmospheres." *Monthly Notices of the Royal Astronomical Society* 425.1 (2012): 21-33.
- Tennyson, Jonathan, et al. "The ExoMol database: molecular line lists for exoplanet and other hot atmospheres." *Journal of Molecular Spectroscopy* 327 (2016): 73-94.
- Blecic, Jasmina, Joseph Harrington, and M. Oliver Bowman. "TEA: a code calculating thermochemical equilibrium abundances." *The Astrophysical Journal Supplement Series* 225.1 (2016): 4.

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