Mapping Exoplanet Atmospheres with Direct Ground-Based Observations

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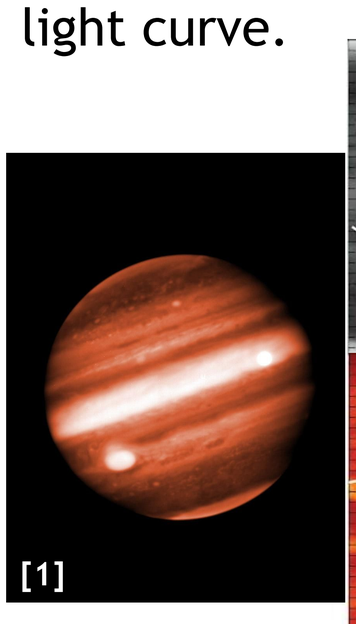
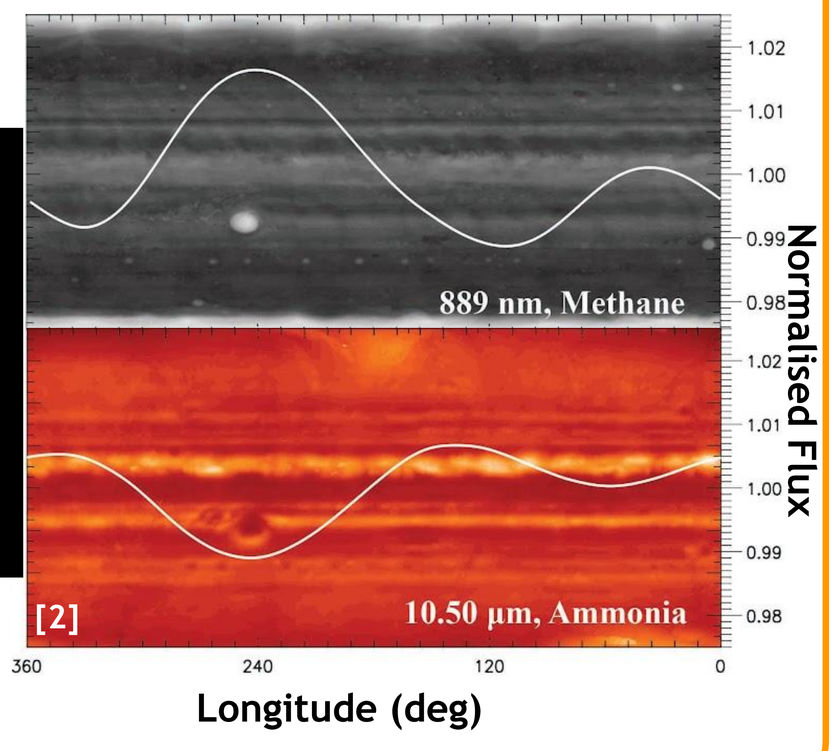
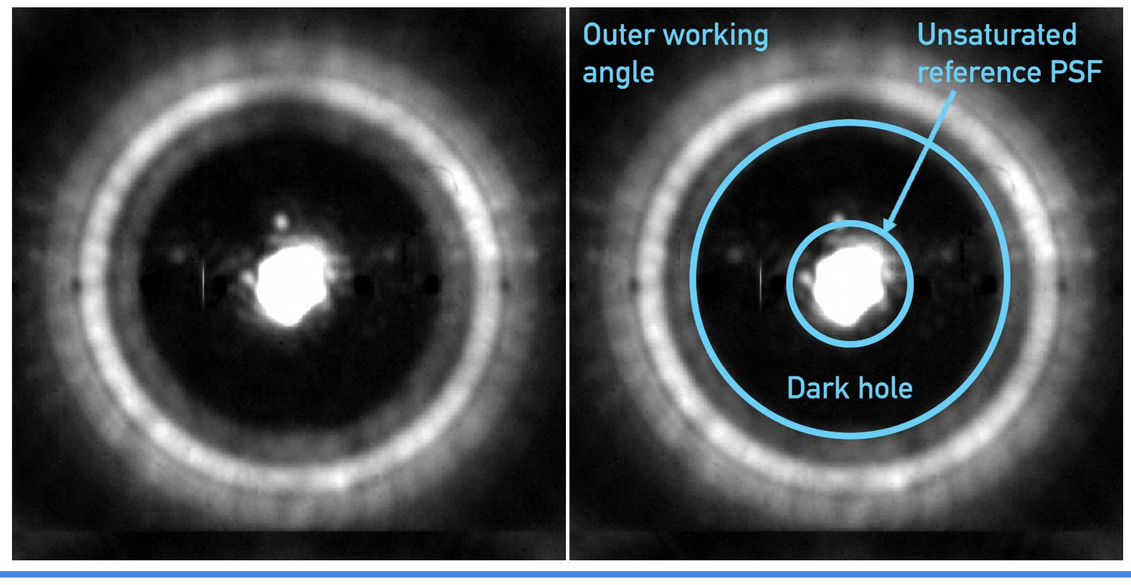
1. Goal: We aim to make light curves of directly-imaged exoplanet and brown dwarf companions to search for variability due to clouds, storms, and other effects cf. Jupiter light curve.

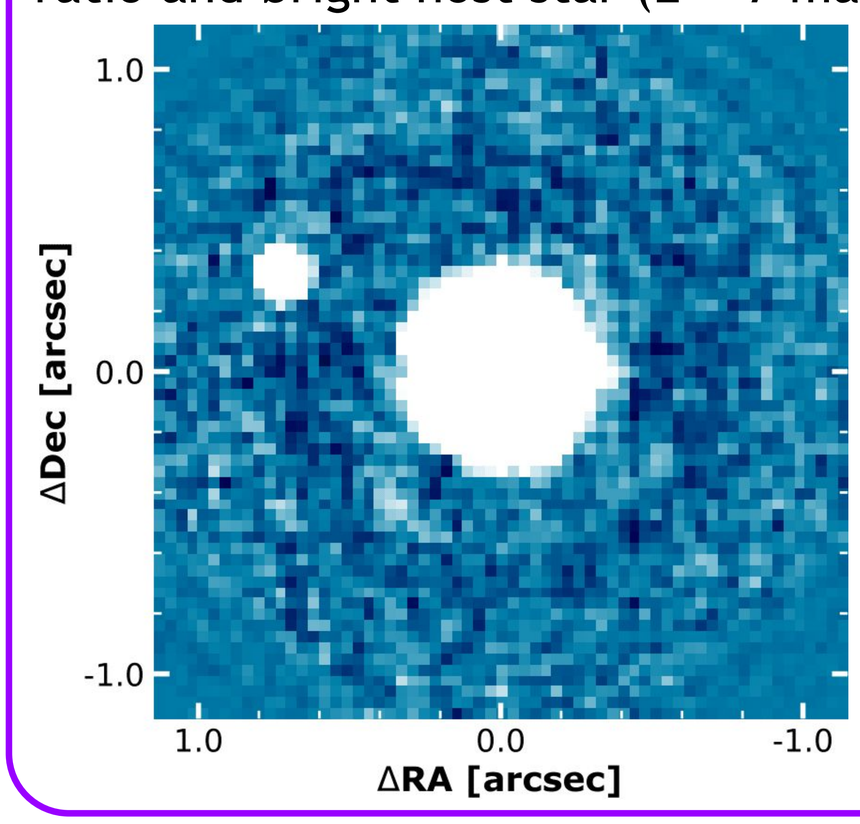




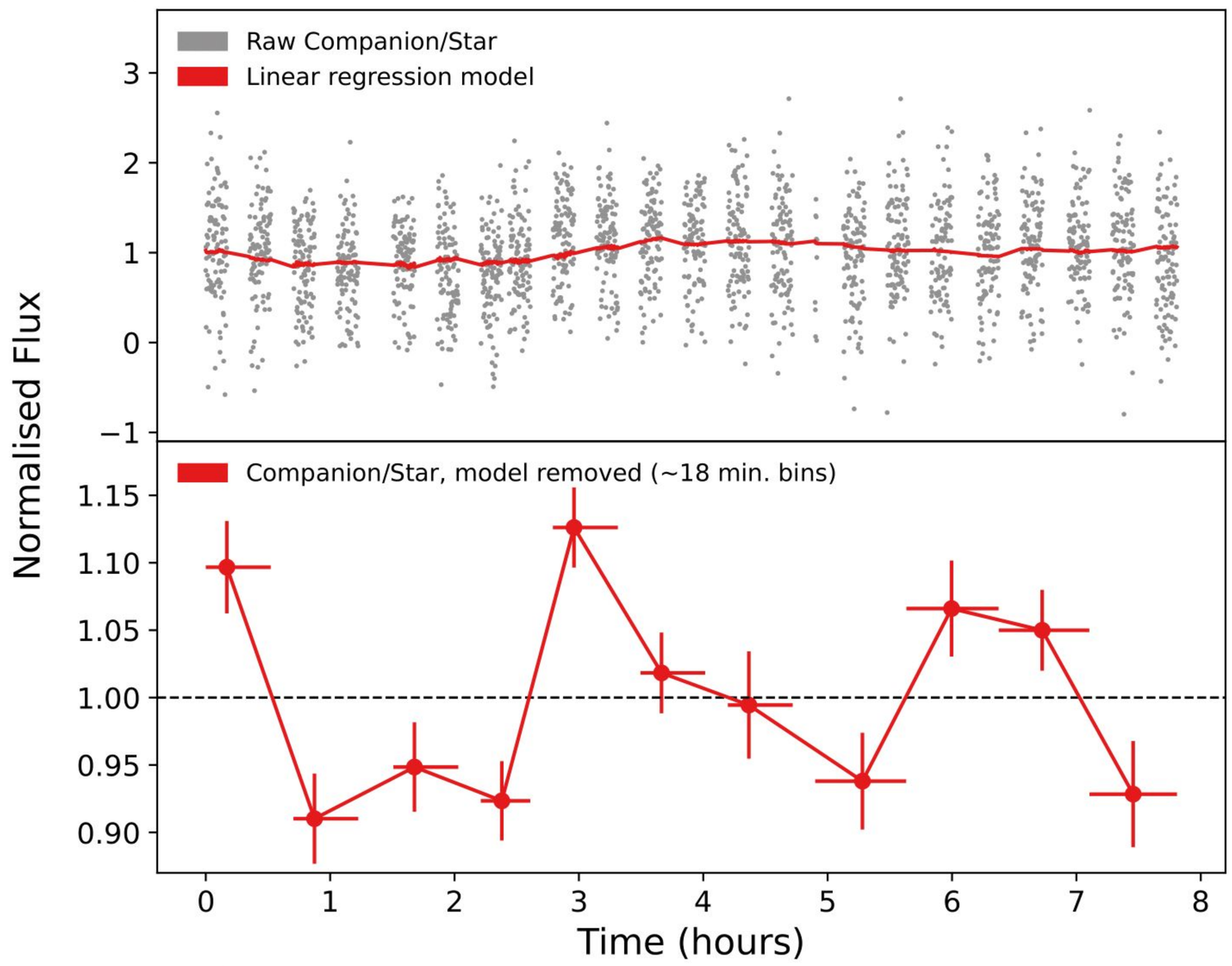
2. Such objects have been shown to vary (e.g. Zhou et al. 2020, Vos et al. 2022). We want to use the greater spatial resolution of ground-based telescopes, but a lack of simultaneous photometric reference makes ground-based measurements difficult. The 360vAPP coronagraph enables simultaneous imaging of high-contrast companions and their host star, so the host star can act as a reference to remove systematics.



3. We combined the 360vAPP with the LBT/NALES IFS (λ = 2.8-4.2 µm) to perform differential spectrophotometry: incoming light is dispersed into individual spectra, and then recombined into 'white-light' data. This smooths out flat-fielding errors and allows wavelength regions with instrumental absorption or variable telluric bands to be left out, therefore reducing systematic effects and improving precision. We tested this on red companion HD 1160 B, which has a ΔL′ = 6.4 mag contrast ratio and bright host star (L′ = 7 mag).



4. We simultaneously extracted photometry of the star and the companion in each wavelength channel, before recombining to produce white-light photometry. We divided the companion by the star to remove most systematic trends common to both light curves. We removed further residual trends due to e.g. airmass using a linear regression model on the differential light curve (Sutlieff et al. 2023, Sutlieff et al. submitted).



Key result: HD 1160 B varies at 8.8% level with ~3.24 hour period, 4% uncertainties achieved in 18 min. bins.

References: [1] Gemini Observatory/NIRI at 1.69 microns, [2] Ge et al., 2019 The Astronomical Journal 157:I2 15pp., [3] Zhou et al., 2020, The Astronomical Journal, Volume 159, Issue 4, id.140, 13 pp., [4] Vos et al., 2022, The Astrophysical Journal, Volume 924, Issue 2, id. 68, 24pp., [5] Sutlieff et al., 2023, MNRAS, Volume 520, Issue 3, pp.4235-4257, [6] Sutlieff et al., 2024, MNRAS, submitted.