SCExAO/CHARIS Astrometric and Atmospheric Characterization of Planet HIP 99770 b

Danielle Bovie (danielle.bovie@my.utsa.edu)[1], Thayne Currie[1,2], Mona El Morsy[1], Timothy Brandt[3], Julien Lozi[2], Jeff Chilcote[4], Kyohoon Ahn[2], Brianna Lacy[5], Taylor Tobin[6]

[1] *University of Texas at San Antonio, San Antonio, TX* [2] *Subaru Telescope, Hilo, HI* [3] *UCSB, Santa Barbara, CA*

[4] *University of Notre Dame, South Bend, IN* [5] *UCSC, Santa Cruz, CA* , [6] *University of Michigan, Ann Arbor, MI*

Abstract

We present preliminary results for the SCExAO/CHARIS follow-up characterization of the directly-imaged superjovian exoplanets HIP 99770 b. SCExAO/CHARIS data provide high-contrast detections, astrometry, and 1.1–2.4 micron spectra of the faint companion. HIP 99770 b was originally detected in the low resolution (R∼20) broadband mode, while this follow-up revisited the planet in higher resolution H and K-bands (R∼80). These new observations allow us to put further constraints on the planet's atmosphere, orbit, and dynamical mass.

HIP 99770 b Detection

Our survey combines direct imaging with astrometry from Hipparcos and Gaia to detect superjovian planets and low mass brown dwarfs around nearby young accelerating stars. The direct imaging data is taken with the high contrast imaging instrument SCExAO and integral field spectroscopy CHARIS on the Subaru Telescope. The low resolution broadband mode (R∼20) is used for initial discovery.

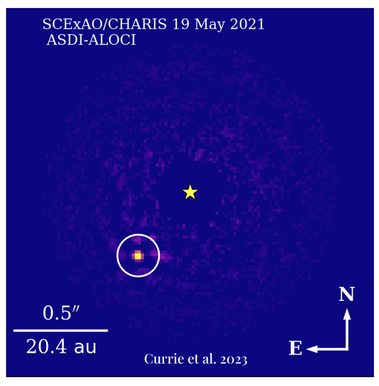

Figure 1. Initial detection of HIP 99770 b

Direct imaging alone, spectra and relative astrometry of the companion, does not directly constrain the dynamical mass and provides poor orbital constraints. But direct imaging with astrometry, which identifies acceleration from the dynamical pull of companions, allows us to simultaneously put constraints on the dynamical mass, orbit, and atmosphere of the companion.

Follow-up

HIP 99770 b was selected to be a target for follow-up characterization. Follow-up data was taken in the higher resolution H and K-bands (R∼80).

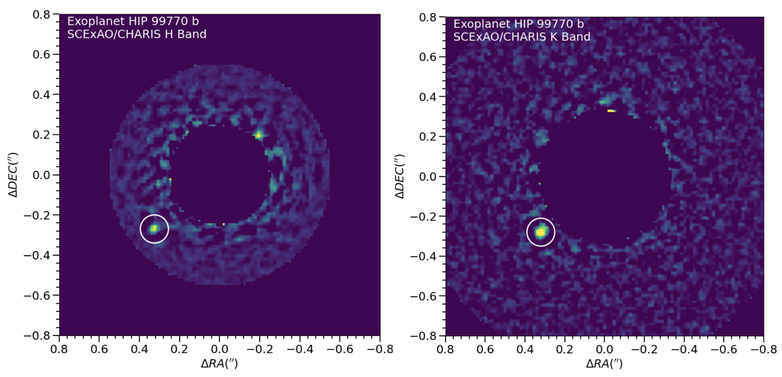

Figure 2. Follow-up images of of HIP 99770 b in H and K band

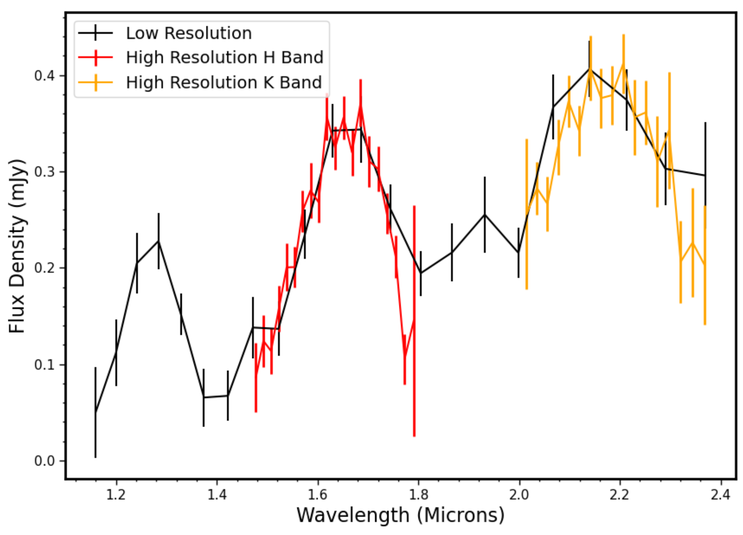

Figure 3. H and K band spectra overlaid on top of the low resolution spectrum

Follow-up characterization allows us to further constrain HIP 99770 b's dynamical mass, orbit, and atmosphere.

Astrometric Characterization

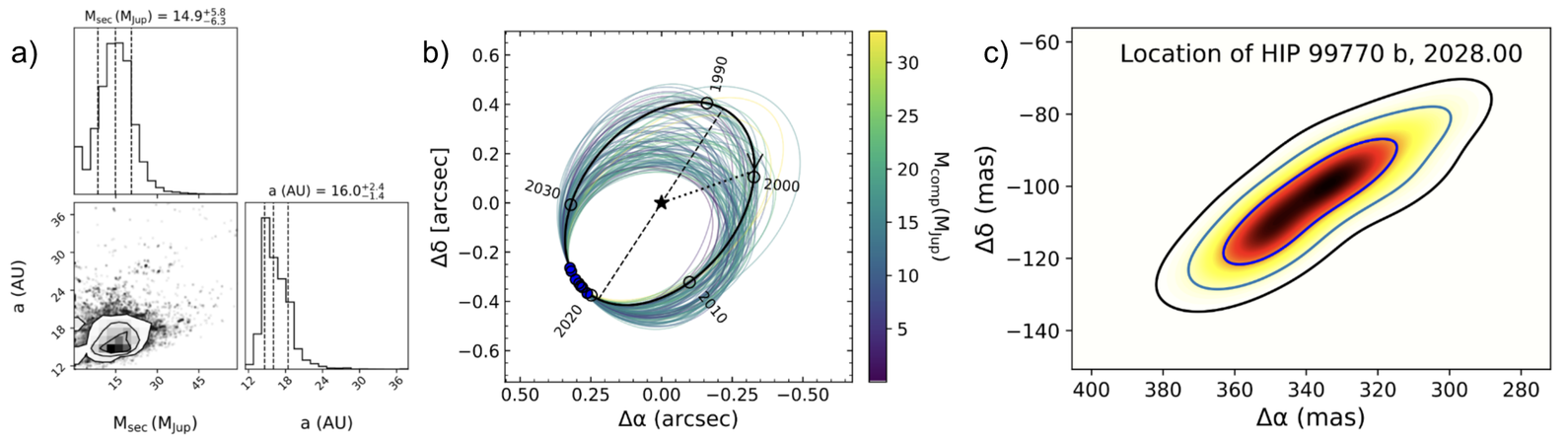

Figure 4. a) Corner plot of semi-major axis vs planet mass b) Predicted orbit c) Predicted location in 2028

With orvara we are able to determine HIP 99770 b's orbital parameters:

$$M_{pri}(M_\odot) = 1.74^{+0.21}_{-0.18} \qquad M_{sec}(M_{Jup}) = 14.9^{+5.8}_{-6.3} \qquad a(AU) = 16.0^{+2.4}_{-1.4} \qquad e = 0.29^{+0.18}_{-0.20} \qquad i(^\circ) = 138^{+11}_{-7.3}$$

The corner plot for the semi-major axis vs planet mass is shown in Figure 4 a). We are also able to predict HIP 99770 b's orbit based on what has been observed so far, which allows us to predict the planets most likely future location. The predicted location of the planet in 2028 is shown in Figure 4 c). This year was selected to help determine if HIP 99770 b is a potential candidate for the Roman CGI tech demo.

Atmospheric Characterization

By comparing HIP 99770 b's spectra to modeled spectra we are able to put empirical constraints on the planet's atmospheric properties. Figure 5 shows how well HIP 99770 b's spectra fits to other spectra in the Montreal Spectral Library. The best-fitting spectra range from L5 to L9.5, which is most consistent with a temperature of $T_{eff} \sim$ 1300-1500 K.

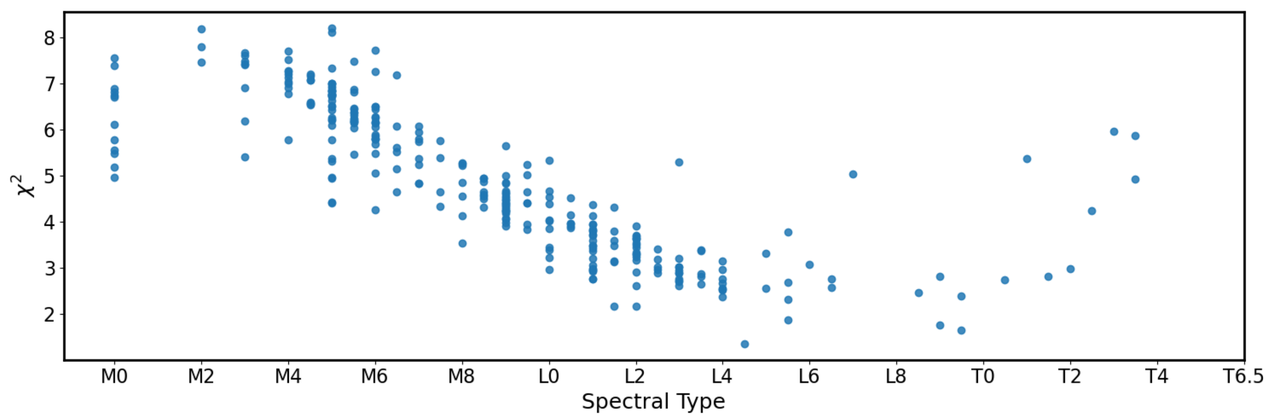

Figure 5. Comparison of HIP 99770 b's spectra to others in the Montreal Spectral Library

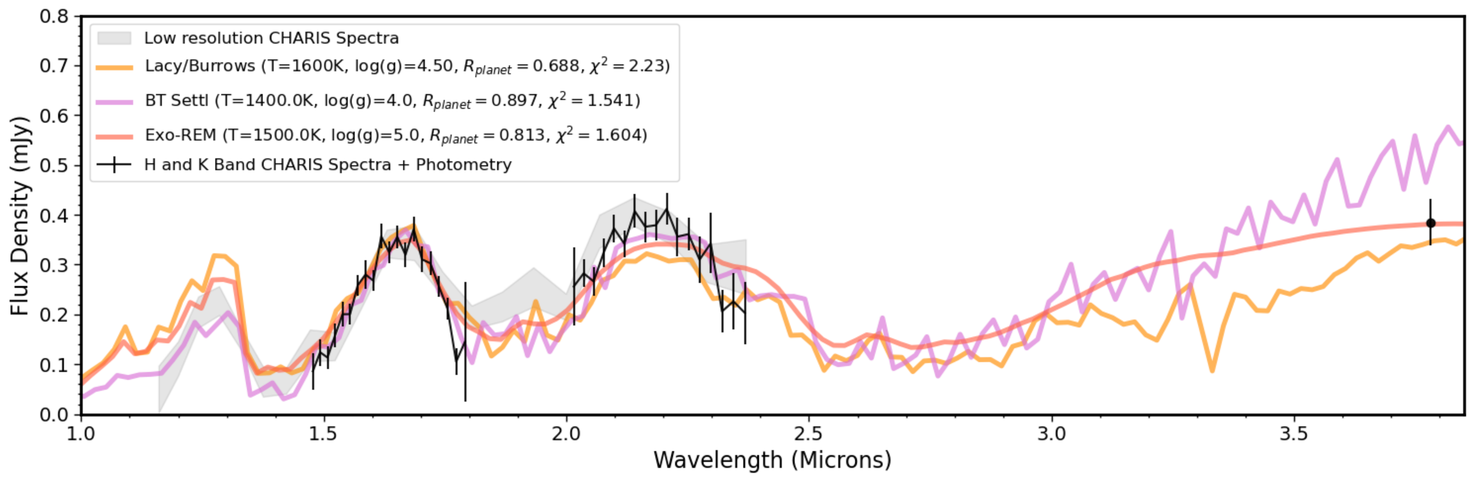

Figure 6. Comparison of HIP 99770 b's spectra to Lacy/Burrows, BT Settl, and Exo-REM

Similarly, HIP 99770 b's spectra is compared to modeled spectra from Lacy/Burrows, BT Settl, and Exo-REM, shown in Figure 6, to constrain temperature, gravity, C/O, and metallicity; parameters that are varied in the models. From the best fit models, the temperature is most likely in the range $T_{eff} \sim$ 1400-1600 K.

Conclusion

High resolution follow-up characterization of HIP 99770 b puts new constraints on the planet's atmosphere and orbit. Our ability to predict the future location of the planet makes it an excellent follow-up target at other wavelengths, such as for Roman CGI in the optical. HIP 99770 b's spectra is best matched by a mid/late L dwarf. From comparison to modeled spectra from Lacy/Burrows, BT Settl, and Exo-REM; its temperature is most likely in the range $T_{eff} \sim$ 1400-1600 K.