**LGS AO Imaging Polarimetry of Herbig Ae/Be Stars
Supporting Online Material**

Methods and Materials

The Lick Adaptive Optics system was developed at Lawrence Livermore National Laboratory, and can operate in both natural and laser guide star modes (*1, 2*). In the laser guide star mode, the atmospheric wavefront reference is created by a laser tuned to the sodium D2 line at 589 nm, which excites mesospheric sodium at roughly 90 km altitude. The 589 nm light is generated by a tunable dye laser pumped by a set of frequency-doubled solid-state (Nd:YAG) lasers. Typically, 11-14 W of average laser power is projected into the sky with a pulse width of 150 ns and a pulse repetition rate of 13 kHz. Laser guide star systems are insensitive to tip and tilt, requiring a separate tip/tilt sensor using a natural guide star. For the observations presented here, the science targets served as their own tip/tilt references.

The sodium guide star has an apparent size of 2 arcseconds in 1 arcsecond seeing and a magnitude which depends on the atmospheric sodium density, which varies on all timescales from hourly to seasonally. The sodium level was low during July 2003, decreasing the magnitude of the guide star, and forcing the adaptive optics system to operate at its lowest frame rate of 55 Hz. As a result, the Strehl ratios achieved were modest (S 0.05-0.1) despite the good atmospheric seeing. Correspondingly the full-width at half-maximum (FWHM) of the point spread function was larger than the FWHM of a diffraction limited beam, 0.27 arcseconds versus 0.15 arcseconds respectively at 2.1 microns.

The science camera used with the Lick AO system is IRCAL (*3*), which has as its detector a 256^2 pixel HgCdTe PICNIC array manufactured by Rockwell. The observations presented in this paper used the standard astronomical J (1.24 micron), H (1.65 micron), and K_s (2.15 micron) broad-band filters. IRCAL's plate scale, 0.0754 arcsec/pixel, was chosen to Nyquist sample the diffraction-limited beam at K_s. The imaging polarimetry mode of IRCAL utilizes a cryogenic $LiYF_4$ (frequently called "YLF") Wollaston prism to produce simultaneous images of orthogonal polarizations. YLF was chosen for its excellent achromaticity throughout the near infrared. A rotating achromatic half-wave plate mounted immediately before the camera entrance window modulates the polarization, allowing measurement of both Stokes parameters Q and U.

Each target was observed for the same amount of time in J, H, and K_s, divided equally between Stokes Q and U observations. Typical exposures were 30-90 s in duration, with small dithers performed every few exposures. Total integration time was 1440 s per band for LkHα 233, and 960 s per band for LkHα 198. The data were flat-fielded and bias-subtracted in the standard manner for near infrared astronomical data. Sky background frames were obtained in polarimetric mode and subtracted from the data. However, the near infrared sky is nearly unpolarized so this step is not essential. The data from different dither positions were registered together via a Fourier transform cross-correlation code and stacked to produce mosaic Stokes I, Q, and U images. These observing techniques and data reduction methods are based on (*4*).

The instrumental polarization bias was established through observations of standard stars known to be unpolarized; From the derived bias (2% at a position angle of -85°) we calculate the effective Mueller polarization matrix for the instrument and apply the inverse of this matrix to the Stokes mosaics to remove the bias.

Table S1: Target Summary

Object	V (magnitudes)	Distance (parsec)	Spectral Type	Luminosity $(L_\odot)$	Mass $(M_\odot)$	Time per band (s)
LkHα 198	14.3	600	A5e-A7e	5.6	1.2	960
LkHα 233	13.6	880	A5e	28.2	2.6	1440

V magnitude, distance, luminosity, and mass are from (*5*).

Figure S1: The Lick Observatory LGS AO system in operation on 2003 July 22. The laser beam is visible in Rayleigh scattered light for several kilometers. The faint cirrus clouds illuminated by the Moon remained outside our pointing direction and did not interfere with the observations. The yellowish cast of the dome is due to the street lights of nearby San Jose.
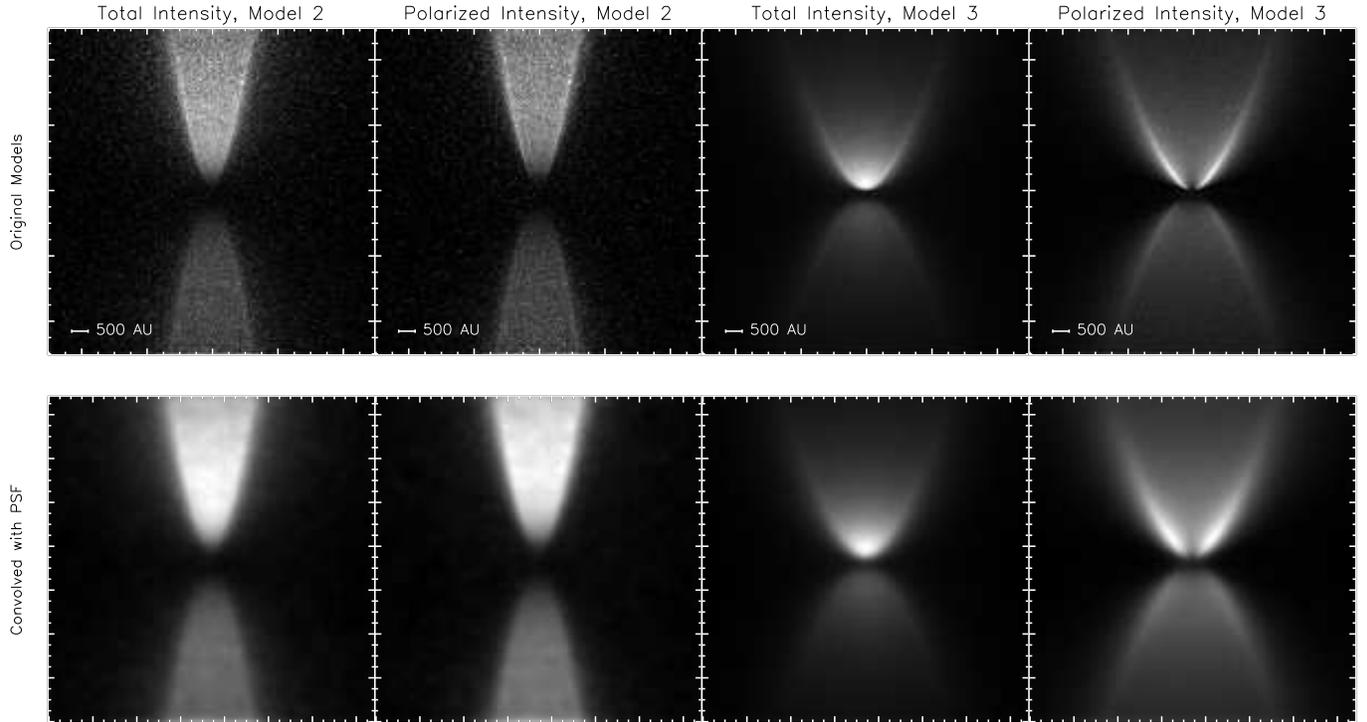
Figure S2: Example radiative transfer models of envelopes around class I T Tauri stars. These are models 2 and 3 from (*6*) at H band (1.6 microns), which were computed for rotationally supported envelopes with bipolar outflow cavities with 10 and 20 opening angles, respectively. For each model we display both total intensity I and polarized i intensity P, on the left in original form from the Monte Carlo simulation output as provided to us by B. Whitney, and on the right convolved to match the angular resolution of our LGS observations. For model 2, with a 10 degree opening angle, there is no limb brightening. Limb brightening for model 3 (with a 20 degree opening angle) is visible in the original total intensity image but only extremely marginally in the reduced resolution version. However, model 3 is strongly limb brightened in both polarized intensity images. Models with larger opening angles display increasingly more pronounced limb brightening. The morphology of Model 3 here is similar to that we observe around LkHα 233.

References

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