AO with LBTI

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LBTI is a versatile instrument which can combine light from both LBT apertures and image on science detectors sensitive to 1.5-5 microns (LMIRcam) and 8-13 microns (NOMIC) (e.g., Hinz et al. 2016). The instrument is optimized for infrared high-contrast imaging, which means that the instrument virtually always uses LBT's AO system. The world-class LBTAO system, together with LBTI's wavefront sensors, can produce 4 micron Strehls of ~90% in 1.5-2" seeing (Bailey et al. 2014).

LBTI's wavefront sensors work by dividing the pupil into base subapertures small enough to stretch ~30 across the diameter (Fig. 4). However, these can be binned for dimmer targets to collect more photons in each. As they are binned, the control radius r_c within which the correction is active shrinks. We tend to use N_{bin} = 1 for $m_R < 9$; N_{bin} = 2 for $9 < m_R < 11$; N_{bin} = 3 for $11 < m_R < 14.5$; N_{bin} = 4 for $m_R > 14.5$. The control radius is approx. $\lambda/2d$, where d is the interaperture spacing.

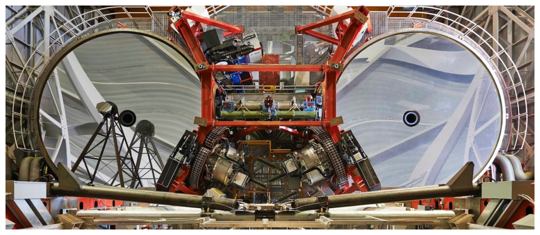


Fig. 1: View of the LBT primary mirrors, with LBTI inside the rectangle formed by the red trusses between the two apertures. (Credit: LBTO, Enrico Sacchetti)

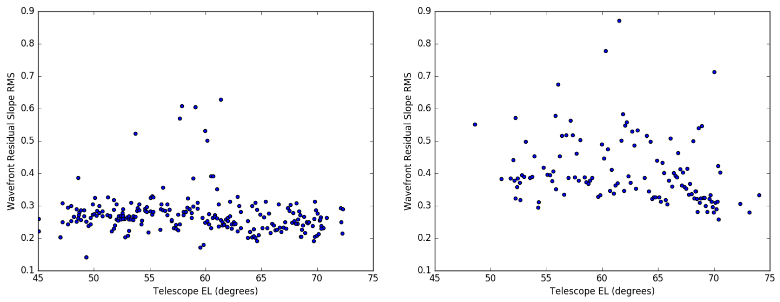


Fig. 5: Wavefront slope RMS residuals at different elevations during the night of April 5, 2017. Lower elevations produce poorer correction, and there are clear personality differences between the two sides.

Targets are usually observed at >40 degrees EL, though under circumstances it is also possible to observe down to 30 degrees. A number of other considerations are made during queue mode observing: if wind (generally from the southwest) is high, AO performance is generally better directly out of the wind; seeing towards the target has also been seen to loosely vary with telescope azimuth due to apparent wind effects.

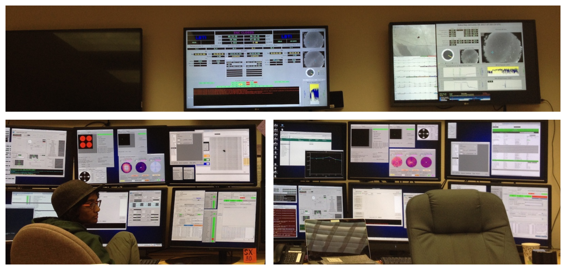


Fig. 6: The AO operational setup in the remote room in Tucson, AZ. This image is split into parts to indicate telescope and weather telemetry (top), left aperture AO operations (bottom left) and its right aperture counterpart (bottom right). All three parts are required to produce a double-sided AO correction, and require a two-person team.

AO science cases in …

Mediocre conditions (generally seeing >1.2")

- Snapshots of binaries
- Possible angular-differential-imaging-oriented PSF imaging of bright stars at reduced contrast sensitivity

Good conditions (generally seeing <1.2"):

- Interferometry (Fizeau or nulling; e.g., Hinz et al. 2012)
- Optimal ADI-oriented PSF imaging
- Dim stars or galaxies with extended structure

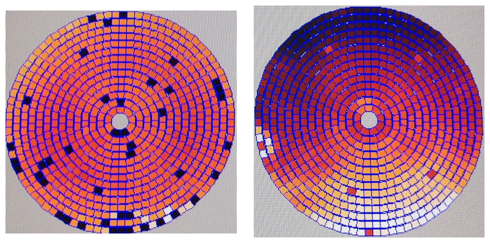


Fig. 2: Left: Example of current actuator positions with relative position color coding. Right: Actuator commands in terms of position, which qualitatively shows what the wavefront aberration looks like. Note the sprinkling of deactivated actuators in both images.

Hints for PIs to help the observing team:

- Have accurate *r* and *i* target magnitudes. Otherwise, more time may be lost to manual changes to the AO correction, and some dim targets may actually turn out to be too dim for the wavefront sensors.
- Have accurate finder charts. The fields-of-view of the finding cameras are ~20x20 square arcseconds, and it is difficult to find the right star in a crowded field.
- Factor into observing design the fact that (as of now) a new AO setup is required at each new target, even if a new target is a nearby calibrator. Each new setup requires at least 5 minutes.

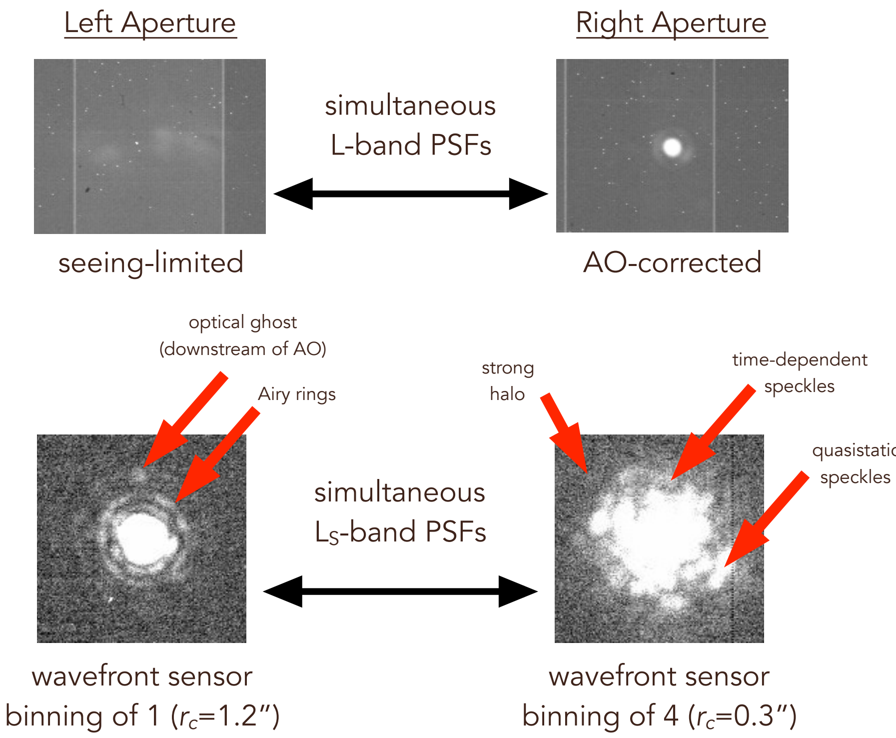


Fig. 3 (left): Top row: LMIRcam readouts showing the effect of AO. Bottom row: Variation in PSF quality depending on wavefront subaperture binning, with shade scaling to show the area outside the PSF cores.

Fig. 4 (below): An image of a wavefront sensor pupil with N_{bin} = 1.

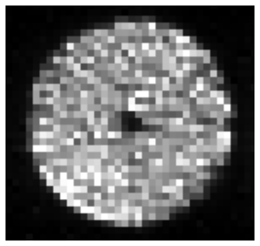
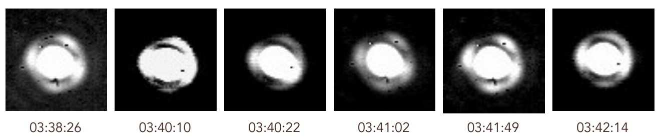
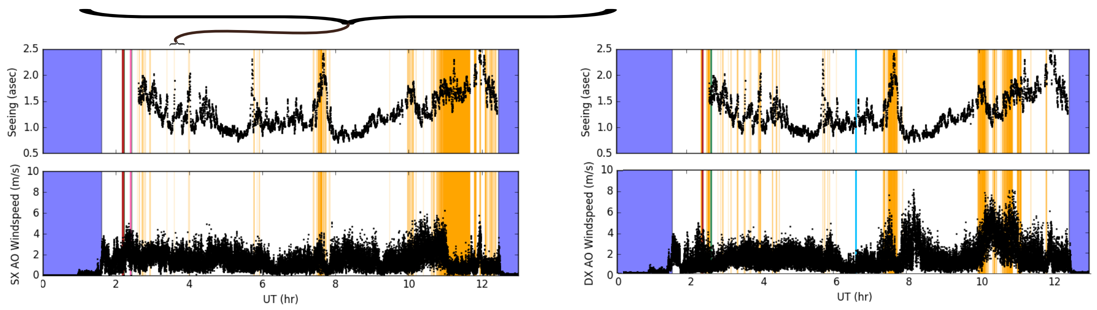


Fig. 7: Diagrams of AO events during the night of April 3, 2017. Left-hand diagrams refer to the left side AO system, right-hand diagrams to the right side. Blue shaded areas indicate closed dome. Orange vertical stripes indicate momentary 'safety' pauses in the AO loop, which will result in degraded PSF correction. These events can be triggered by seeing spikes or strong winds on the adaptive secondary mirrors. Other vertical lines indicate software hiccups that will temporarily halt operation and decrease observing efficiency. Images of PSFs show changes in PSF shape in unstable seeing.





References: **Hinz et al. 2012**. "First AO-corrected interferometry with LBTI: steps towards routine coherent imaging observations" *Proc SPIE*; **Hinz et al. 2016**. "Overview of LBTI: a multipurpose facility for high spatial resolution observations" *Proc SPIE*; **Bailey et al. 2014**. "Large Binocular Telescope Interferometer Adaptive Optics: On-sky performance and lessons learned" *Proc SPIE*.