LUCI & ARGOS

This short document provides selected information about the LUCI instrument and the expected performances upgrade that ARGOS will bring by early 2015.

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LBT

The Large Binocular Telescope is a two 8.4 mirrors telescope on a single mount.

Latitude: 32°42’04.71”N   Longitude: 109°53’20.63”W

Binocular mode: will be available for LUCI observation. The observation will be essentially of the same field, within a few arcseconds degree of freedom.

LUCI

LUCI is a near-infrared wide field imager, a long slit spectrograph (LSS) and a multi-object spectrograph (MOS) for each LBT eye. The full field-of-view (FoV) is 4’x4’, the useful FoV for MOS is 4’x2.8’.

The MOS makes use of pre-cut mask and as such allows for virtually any useful sizes and shapes. There are two LUCI, -1 and -2, one for each LBT side.

LUCI-1 is installed at LBT and operational. LUCI-2 is being commissioned and will be available in 2014.

Natural guide star single conjugated adaptive optics (SCAO) will be available for both LUCI, providing diffraction limit resolution over a small FoV of 30’’x30’’ (N30 camera).

Instrument characteristics

The general characteristics of the instrument are summarized here, see also [1] for more details (in particular Chap.1 and Chap. 5).

Table 1General LUCI characteristics.

Camera Scale [”/px]	N1.8 0.25	N3.75 0.12	N30 0.015
Imaging			
FoV	4x4 (center)	4x4 (full detector)	0.5x0.5
Spectroscopy			
FoV **Resolution** **Modes**	4x2.8 1900 … 8500 LSS & MOS Full coverage of z, J, H, K, H+K band	4x2.8 3800 … 17000 LSS & MOS Limited band coverage	0.5x0.5 10000 … 40000 LSS (& MOS) Only narrow band useable

The likely workhorse grating (grating 2) configuration for LUCI with ARGOS will be (see also Tab. 4.4 [1]):

Table 2 Grating 2 with camera N3.75.

Camera	N3.75
[”/pixel]	0.12
Nyquist (2px) slit	0.25’’
Resolution @ λ_c	3700 (@1.65µm), 5100(@2.2µm)
R over spec. range	3100-4300, 4400-5700
Spectral range [µm]	1.40-1.89, 1.95-2.44
Observable bands	H or K (full if slit in the center of the FoV)

Another grating is available providing higher resolution (~10000) in the different bands for the same camera. The LUCI’s also provide a set of narrow filters.

The current LUCI detectors are Hawaii-2. The one in LUCI-1 has a QE of z=0.37, J=0.48, H=0.55, K=0.57.

The detectors will be upgraded by Hawaii-2RG detectors in 2014. LUCI-2, that is being commissioned, has this detector with a measured QE>80 from 800-2000nm [3].

S/N example and other considerations

Currently, for a 4hrs integration on point-like target (distant galaxies),

- In H-band, a 2.5e-17 erg/s/cm^2 line was detected with a S/N of 7.5.
- In K-band, a 3.8e-17 erg/s/cm^2 line was detected with a S/N of 6.2.

Detector upgrade

The current detector in LUCI-1 has many bad pixels which affect data reduction and the effective usage of the FoV. This is expected to improve with the upcoming new detectors.

The current efficiency of LUCI is ~25%, with the upcoming Hawaii-2RG it will be ~35-40%.

Comparison to SINFONI IFU observation

Comparison with SINFONI for an extended object shows that the S/N characteristics are very similar, with a factor 1.1 higher S/N in SINFONI, due to slit-losses with LUCI. See also section 5.2 of [1].

Comparison of LUCI with other near-infrared multi-object spectrometers can also be found in Chap. 5 of [1].

ARGOS

ARGOS is a multi-laser guide star adaptive optics for the LBT, and for both LUCI in particular. It features three Rayleigh laser guide stars per LBT eye used to measure the ground layer turbulence. In other words, ARGOS is intended to be a wide field "seeing enhancer".

Most of the commissioning will happen in 2014, and ARGOS could be available with LUCI as early as (end of 2014) beginning of 2015.

More advanced discussion on the gain in science capabilities and specific science cases can be found in [2].

Improvement brought by ARGOS

ARGOS will provide a gain of 1.5-3 in FWHM (in the J to K-band) over the 4'x4' LUCI FoV (4'x2.8' in MOS mode).

Fig. 1 presents seeing statistics for a neighbor telescope (MMT). The bottom line is that 1) observations can be done much faster, 2) science programs that would require the best seeing conditions could instead be performed most of the time.

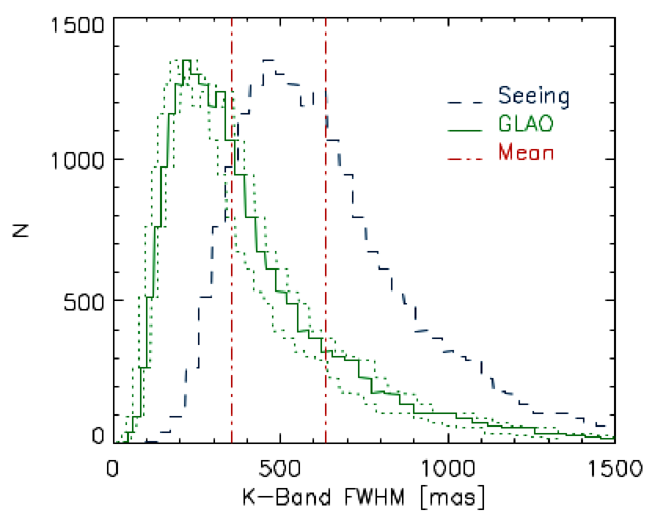

Figure 1 Predicted reduction of the PSF size in the K-band to a seeing statistics as derived at the MMT in Arizona. The mean of the distribution before 0.63'' and after GLAO, 0.34'', correction are indicated in red. This is consistent with the median seeing observed at LBT including dome seeing of 0.75-0.8 FWHM in visible band.

The gain brought by ARGOS can be described in a number of ways (a more details description can be found in [2]),

- *Point source sensitivity*
  For point source, the improvement in the PSF FWHM allows one to reduce the aperture size and hence reduce the background noise contribution. The S/N in background limited regime scales as:

$$\frac{S}{N} \propto \frac{f_{aper} t}{\sqrt{d_{aper}^2 t}}$$

$$t \propto \left(\frac{d_{aper}}{f_{aper}}\right)^2 \qquad \text{at constant S/N}$$

where f_{aper} is the fraction of the point source flux within the aperture, d_{aper} is the aperture diameter, and t the integration time.
We can readily see that for a constant f_{aper} the aperture diameter can be reduced by a factor 2-3, hence the integration time by 4-9 times.

- *Slit coupling efficiency*
  For a fixed spectral resolution, compact sources will be better couple to the slits. This effect will be particularly important at small slit width (hence high resolution) and the gain in integration time would be similar, i.e. estimated to ~5.

- *Crowding noise*
  Wide field correction is especially interesting for crowded field that can be larger than the isoplanatic patch of a SCAO system. ARGOS will improve the depth of dense star cluster fields with a gain in magnitude of a few.

- *Spatial resolution*
  For extended source, the gain does not reside in SNR (as one uses smaller pixels), but as a gain in morphological and kinematical information. Galaxy structures and their rotation curves may be acquired in greater details and this over the large FoV of 4' of LUCI.

ARGOS requirements

A number of conditions are required for ARGOS to be operational

- **NGS tip-tilt star**: magnitude limit *R*~18.5. The available FoV is equivalent to LUCI, hence 4'x4'. Tip-tilt star in the center of the FoV will be preferred for better performances (better PSF uniformity).
- **Maximum telescope elevation** : ~45 degree (laser propagation regulation limitation)
- In very bad seeing condition, the gain (or even the operability) could degrade due to limitations of the Adaptive Secondary (force limits). This is experienced by the SCAO which cannot operate >~1 arcsec seeing. This will be much more relaxed for ARGOS (lower order correction compared to SCAO and hence less constraints on the Adaptive Secondary).

S/N example and other considerations

For the same example as before (point source, *H* and *K* bands separately, 8hrs integration), for the same S/N, the exposure time will be reduced by

- 4-9 times (ARGOS),
- 2 times in Binocular mode (*H* and *K* simultaneously)
- Some additional gain from the future new detector (increase in efficiency of 40-60%)

Hence, instead of 8hrs, the same observation could be done in <1hr. (Here disregarding instrument overheads considerations). Another alternative is a gain of >~3 in S/N for an exposure time of 4hrs (Binocular mode) instead of 8hrs.

Slit choice

We will certainly want to use narrower slits to obtain higher S/N (to reduce the background contribution) and higher spectral resolution (less OH contamination by line-blending). Blind spectroscopy (i.e. of objects without known spectroscopic redshifts), will be less affected by OH, hence will get better. In that respect, the configuration presented Tab.2 is likely to fulfill our needs.

Field Density

Fainter targets will get reachable, hence the density of possible targets will increase in the LUCI FoV.

Imaging

Imaging at higher resolution over a large 4'x4' FoV, in particular K-band (for which e.g. WFC3 cannot observe).

Other facilities

There is no other wide field GLAO system in operation (in GLAO, currently only SAM at SOAR 4.1m with 1LGS). GeMS at Gemini South provides a 85''x85'' diffraction limit FoV and up to 2'x2' corrected field for which their have both a NIR camera with 85''x85'' (GSAOI) and a MOS NIR FLAMINGOS-2. In that respect LUCI with ARGOS will provides a unique wide FoV.

References

[1] Buschkamp P., PhD thesis, 2012

[2] ARGOS Science Case Study, ARGOS-PDR-001, 2008

[3] "LUCIFER-2 acceptance test report", LBT-LUCIFER-TRE-025, 28.06.2013