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INTERFEROMETRY AT THE LBT

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Abstract. The Large Binocular Telescope, resulting from a US/Germany/Italy partnership, is designed to be a multi-purpose observatory with single-dish and interferometric capabilities in the optical, near and mid infrared. The LBT is partially operational for science observations, and the interferometric instruments LINC-NIRVANA and LBTI will become available in 2010. I will summarize the current status of the LBT, focusing more particularly on the Fizeau interferometric wide-field imager LINC-Nirvana.

1 Introduction

The Large Binocular Telescope (LBT) installed on Mount Graham, Arizona, is a unique facility supporting two 8.4-m primary mirrors jointly moved by an alt-azimuth mount (see Fig. 1). The LBT will offer, at time of full operation, eight “single-eye” instruments and two interferometers. For comparison, The Paranal Observatory runs thirteen instruments including the three interferometers AMBER, MIDI and PRIMA, this last one being presently commissioned. The LBT is a gregorian telescope, which means that the primary focus lies between the primary and the secondary mirror. This offers the opportunity to exploit the prime focus for wide-field imaging over several arcminutes. The telescope appears as a compact ensemble of circa $25\,\mathrm{m}^3$ and is installed under a cubic dome that opens horizontally a further 20 m in observing mode (see white arrows in Fig 1). The two interferometers, LINC-Nirvana and LBTI, are installed on the interferometric platform between the two primaries, and therefore bounded to the telescope structure. This solution certainly means that LBTI and LINC-Nirvana will have to support additional flexure during operation, unlike traditional interferometers installed at the Coudé focus. However, this configuration will allow us to perform Fizeau interferometry with LINC-Nirvana for the first time on large telescopes, and in addition is very favorable to nulling interferometry performed by the LBTI since it reduces the number of warm reflections and consequent background contamination. The LINC-Nirvana instrument is currently under integration at the MPIA of Heidelberg. In its coherent combination configuration, LINC-Nirvana will offer the equivalent of a 23-m telescope, which is among the largest telescopes in the world and naturally appearing as a pre-ELT facility. To exploit the full potential of the telescope, adaptive optics is installed to allow reaching diffraction-limited images. At LBT, the secondary mirror is adaptive to correct for the ground layer turbulence.

2 Overview of LBT instrumentation

Eight single-aperture instruments equip the LBT. These are the two LUCIFER near-infrared spectro-imagers, the two prime focus cameras LBC-Blue and LBC-Red operating in the visible and in binocular mode, the two MODS and the two PEPSI spectrographs, one on each eye of the telescope.
LUCIFER : This is the *LBT Near Infrared Spectroscopic Utility with Camera and Integral Field Unit for Extragalactic Research* (Mandel et al. 2006), the near-infrared instrument built by a German consortium. LUCIFER operates in the 0.9 - 2.5 m spectral range and provides imaging and spectroscopic capabilities in seeing and diffraction limited modes. LUCIFER can reach a spectral resolution up to R$\sim$30000 and covers a field-of-view of 30”$\times$30” in the diffraction-limited mode.
LBC : The LBT is equipped with two prime focus camera covering the visible range thanks to several broad-band and narrow-band visible filters. The mosaic of CCD detectors gives access to a large field-of-view of 27

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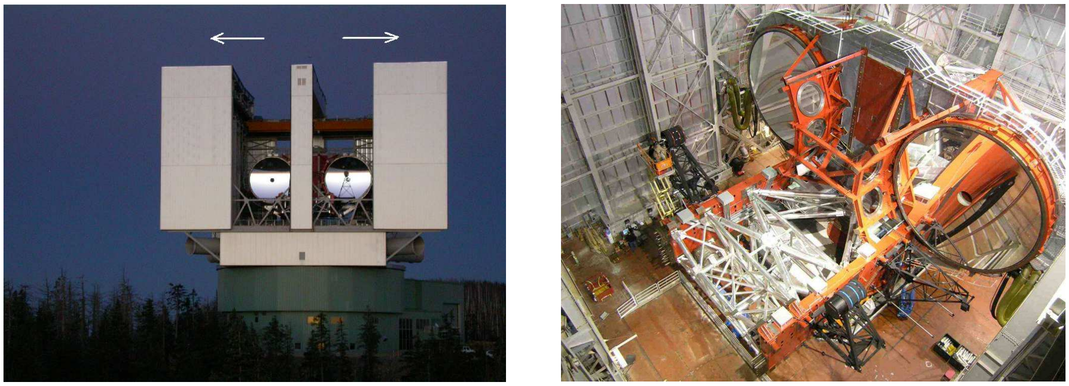

Fig. 1. *Left*: general view of the LBT dome on Mount Graham, Arizona. The enclosure has a cubic shape. On this image, only the blue prime focus camera is installed on the left eye. The *Right*: the binocular telescope inside the dome. The two 8.4-m mirrors are 14.4-m center-to-center and supported by an alt-azimuth mount.

arcmin square with 0.23" pixel scale. The two camera are in operation at the moment at LBT delivering science data.

MODS and PEPSI : MODS 1 and 2 – blue and red – are the two visible imagers and medium-resolution spectrographs placed directly at the F/15 focus of the telescope. The accessible field-of-view is 6'×6' with 125 mas pixel scale. PEPSI is a fiber-feed high-resolution Echelle spectrograph – up to R$\sim$300000 – designed to use the two apertures in spectropolarimetric mode.

3 Interferometric capabilities at the LBT

3.1 Nulling interferometry with LBTI

The two primary mirrors are located 14.4 meters apart center-to-center, which is a moderate baseline compared to classical long-baseline interferometers like MIDI or Keck. However, this is particularly adapted for nulling interferometry since a short baseline will minimize the leakage from the cancelled star. The LBT-Interferometer – LBTI – is the nulling interferometry instrument devoted to the search for exo-zodiacal dust around solar-type stars (Hinz et al. 2004). In addition to the various noises from astrophysical origin, the thermal background is a strong limitation for the detection of exo-zodiacal light. With only three warm reflexions prior to entering the cryostat, LBTI is able to keep this level of instrumental contamination at a very low level. Combined to the relatively short baseline, the detection capabilities of the LBTI are clearly improved in comparison to the Keck nuller (see Table 1).

Wavelength (μm)	ratio ρ=EZE/star at LBT	ratio ρ=EZE/star at Keck
8 μm	0.14	0.012
10 μm	0.45	0.031
10 μm	1.07	0.067

Table 1. expected ratios between the exo-zodiacal emission (EZE) and stellar leakage expected in the N band at the LBT and Keck interferometer. The short-baseline configuration of the LBT is very advantageous because of its broad null across the stellar disk.

3.2 Fizeau interferometry with LINC-Nirvana

LINC-Nirvana is a Fizeau interferometer that coherently combines on the detector the images from each aperture. If the condition of homotheticity between the input and output pupils is respected (Angel et al. 1998), every point-like source produces a interferometric fringe pattern at the spatial frequency B/λ modulated by the 8.4-m PSF, where B=22.8 m and λ is the wavelength. This combination scheme permits to access a wide

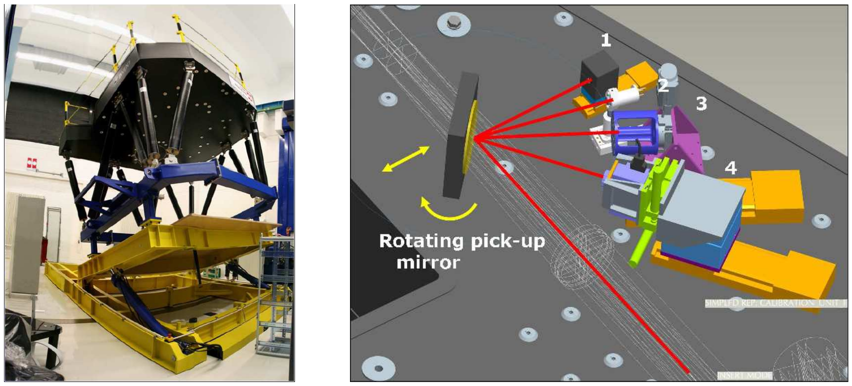

Fig. 2. *Left*: The LINC-Nirvana bench tilted to simulate the behavior on the telescope. *Right*: Design of the calibration unit with the pick-up mirror that feeds the instrument with the sources 1, 2, 3 and 4 alternatively.

field-of-view at high angular resolution, unlike other classical pupil-plane interferometers. LINC-Nirvana operates as a true imager delivering the angular resolution of a 23-m telescope over a 10"×10" field-of-view. The angular resolution is, respectively, 10, 15 and 20 mas in the J, H and K bands. As for any large telescope, diffraction-limited observations require a performing adaptive optics system to compensate for the atmospheric turbulence. Conventional adaptive optics systems are able to correct the wavefront corrugations with a good Strehl ratio only over a small field-of-view of a few arcseconds. This is a limiting factor for science programs that aim at studying large scale structures. The alternative is to implement multi-conjugated adaptive optics (MCAO), which makes use of several guide stars, and possibly several deformable mirrors, to analyze the atmospheric turbulence over a larger field-of-view. Several approaches are possible for implementing MCAO (Ground Layer AO, Layer-Oriented AO etc...) and a starting point on this technique can be found in Beckers (1993) or Ragazzoni et al. (2002). This technique is obviously more complex than single AO systems, but in the case of LINC-Nirvana using MCAO is clearly mandatory to obtain a good fringe contrast over a larger field-of-view. The MCAO system on LINC-Nirvana is based on eight pyramid wavefront sensors operating in the visible (Ragazzoni et al. 2003). The correction of the ground layer turbulence can be achieved over a 6 arcminutes field-of-view by coupling the wavefront sensor to the deformable secondary mirror. The internal 2 arcminutes field-of-view that is used for interferometry is also corrected for higher atmospheric turbulence at 4 and 10 km, by conjugating the deformable mirror to the appropriate altitude. Such an adaptive optics system for wide-field correction will clearly be a major step towards large telescope operation. Meanwhile, the technique was demonstrated on-sky recently with the first spectacular K-band images from MAD at the VLT which delivered a high Strehl correction over a 2'×2' field-of-view (ESO press release).

3.3 Status of LINC-Nirvana

LINC-Nirvana is currently under integration at the MPIA. The optical bench can be tilted as a whole in order to reproduce the configuration at the telescope (see Fig. 2). This will permit to investigate the impact of flexure on the optical alignment and the stability of the fringes. This is also an essential aspect to estimate the operability of the fringe tracking system, which is responsible for detecting and correcting the effects of flexure on the PSF overlap.

The MCAO has been delivered for integration at the MPIA and is currently undergoing functional tests. Other key sub-systems are following a test phase prior to integration on the bench. This concerns the piston mirror unit that corrects for the residual optical path difference (OPD) in conjunction with the FFTS[1], the cryostat and the infrared detector and the calibration unit. Concerning this last sub-system, we have developed a design that can ensure a good stability for the reference sources (see Fig. 2). The purpose of the calibration unit is to give absolute references to the piston mirror for the zero-OPD position, to check for simultaneous zero-OPD on-axis and off-axis for pupil homotheticity, to provide reference sources for the MCAO unit and flat-fielding for

[1]FFTS: Fringe and Flexure Tracking System

the detector (Labadie et al. 2008). Tests are in progress, in particular for the zero-OPD unit which represents the most critical part in terms of calibration of systematic errors due to telescope flexure.

3.4 Scientific programs with LINC-Nirvana and installation schedule

LINC-Nirvana, as a high-resolution and wide-field imager, will permit to study a large variety of science cases in the field of galactic and extragalactic astronomy. They are:

- YSOs environment, circumstellar disks, outflows, formation of binary stars.
- Stellar clusters and compact HII regions.
- Astrometry for extrasolar planets.
- Solar systems minor bodies.
- The Galactic Center.
- Host galaxies at z$\sim$1-2.

The main constraints for these different science cases are on the availability of reference stars for the MCAO, the quality of the PSF and the astrometric and photometric capabilities of the instrument.

The integration phase at the LBT has started in 2005 with the installation of LBC-Red and will go on until the installation of the interferometric *strategic* instruments. The two prime focus cameras are in place and performing science observations. LUCIFER 1 has passed the acceptance test and is currently being commissioned on Mount Graham. The two interferometers LBTI and LINC-Nirvana are following the integration phase and are expected to be on sky on 2010.

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