

LINC-NIRVANA: Achieving 10 mas Imagery on the Large Binocular Telescope

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ABSTRACT

LINC-NIRVANA is an innovative imaging interferometer fed by dedicated multi-conjugated adaptive optics systems. The instrument combines the light of the two, 8.4-meter primary mirrors of the Large Binocular Telescope (LBT) on a single focal plane, providing panoramic imagery with 23-meter spatial resolution. The instrument employs a number of innovative technologies, including multi-conjugated adaptive optics, state-of-the-art materials, low vibration mechanical coolers, active and passive control, and sophisticated software for data analysis. LINC-NIRVANA is entering its final integration phase, with the large adaptive-optics and imaging subsystems coming together in the clean room in Heidelberg. Here, we report on progress, including insights gained on integration of large instruments.

Keywords: near-infrared, imaging, interferometry, Fizeau, LBT

1. INTRODUCTION

LINC-NIRVANA (LN) is a near-infrared image-plane beam combiner, which will occupy one of the shared focal stations on the central platform of the Large Binocular Telescope (LBT). At this location, the instrument receives light from both 8.4-meter telescopes of the LBT (figure 1). By creating a scaled-down version of the telescope entrance pupil, LINC-NIRVANA permits Fizeau-type interferometric imaging over a panoramic field of view. The resulting images contain information at spatial frequencies up to that corresponding to the maximum baseline of the LBT (22.8 meters) along the direction connecting the primary mirrors, and up to 8.4 m spatial frequencies along the perpendicular direction. The Large Binocular Telescope has an alt-azimuth mount configuration, which means that the projected telescope pupil rotates with respect to the sky – so-called “earth rotation synthesis.” Combining multiple exposures taken at different projection angles allows the observer to synthesize panoramic images with full, 23-meter spatial resolution.

LINC-NIRVANA is being built by a consortium of four institutes: the Max Planck Institute for Astronomy (MPIA) in Heidelberg, INAF (including the observatories of Padova, Bologna, Arcetri, and Rome), the University of Köln, and the Max Planck Institute for Radioastronomy (MPIfR) in Bonn.

2. OPTO-MECHANICAL DESIGN

Figure 2 shows the LINC-NIRVANA optical path and major subsystems. Light from each of the two LBT tertiary mirrors enters the instrument enclosure and encounters an annular mirror near the location of the telescope focal plane. This mirror redirects the field from 2 to 6 arcminute diameter into the Ground-Layer Wavefront Sensor (GWS), which measures the atmospheric turbulence directly above the telescope enclosure. The GWS measures the wavefront using up to 12 natural guide stars and corrects this turbulence via the adaptive secondary mirrors, each of which has 672 voice coil actuators.

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Figure 1: The LBT nearing completion in January 2006. LINC-NIRVANA is the large, light gray box at the shared focal station closest to the viewer (installed courtesy of Photoshop). Note the human figure for scale.

Light from the central two arcminutes of the field passes through the hole in the annular mirror and enters the warm fore-optics of LINC-NIRVANA. These components produce a constant diameter “quasi-collimated” beam that is reflected twice before reaching the midline of the instrument. The first of the mirrors is a 349 actuator deformable piezo-electric device produced by Xinetics Inc. Conjugated to an altitude of 8-15 km, the Xinetics mirror corrects a second atmospheric layer, allowing multi-conjugated adaptive optics (MCAO).

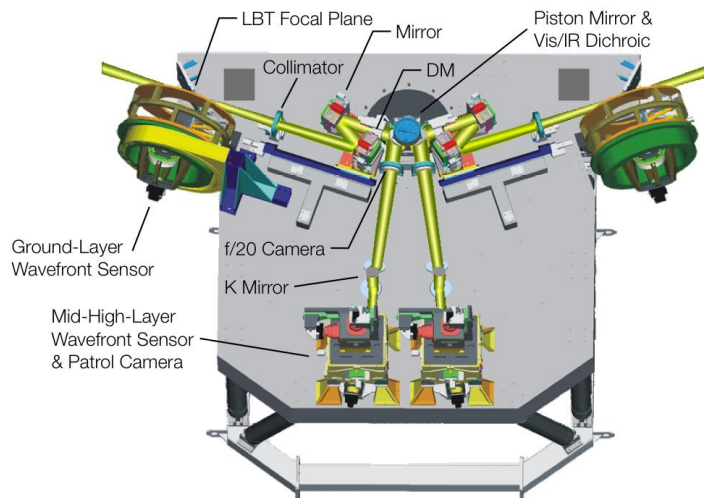


Figure 2: Warm optics and major subsystems of the LINC-NIRVANA instrument

Figure 3 shows the midline beam-combining area of LINC-NIRVANA. A pair of 45° mirrors directs the radiation downward into the cryostat below the optical bench. The down-folding mirrors for both arms of the instrument share a common mount, permitting differential optical path compensation via a piezo-electric actuator attached to this “piston mirror” assembly.

Immediately above the cryostat windows, a pair of visible / near-infrared dichroic mirrors reflect the visible light through a second set of warm optics and a K-mirror to remove field rotation. The resulting $f/20$ beams enter the Mid-High layer Wavefront Sensors (MHWS), which sense and correct higher altitude turbulence via the Xinetics deformable mirror. The

MHWS assemblies also include a CCD “patrol camera” which facilitates the placement of the eight MHWS probes on the natural guide stars.

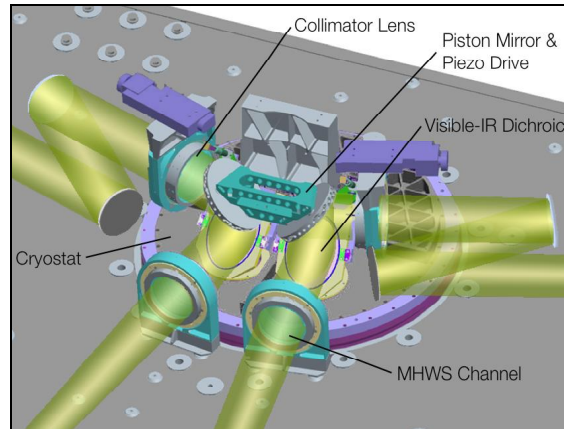


Figure 3: Beam combination area of LINC-NIRVANA

The near-infrared radiation passes through the visible / near-IR dichroic and enters the science channel cryostat, where a Cassegrain telescope images a 10x10 arcsecond field at 5 mas per pixel onto a Hawaii-2 detector (figure 4). Just before the science focal plane, an infrared-infrared dichroic separates one band for science and another for fringe tracking. The Fringe and Flexure Tracking System (FFTS) uses this light to remove differential phase via the piston mirror. To maximize sky coverage, the motorized head of the FFTS can explore a field of view of 60x90 arcseconds, and only looks through the IR-IR dichroic when the phase reference target shares the central 10 arcsecond field with the science detector.

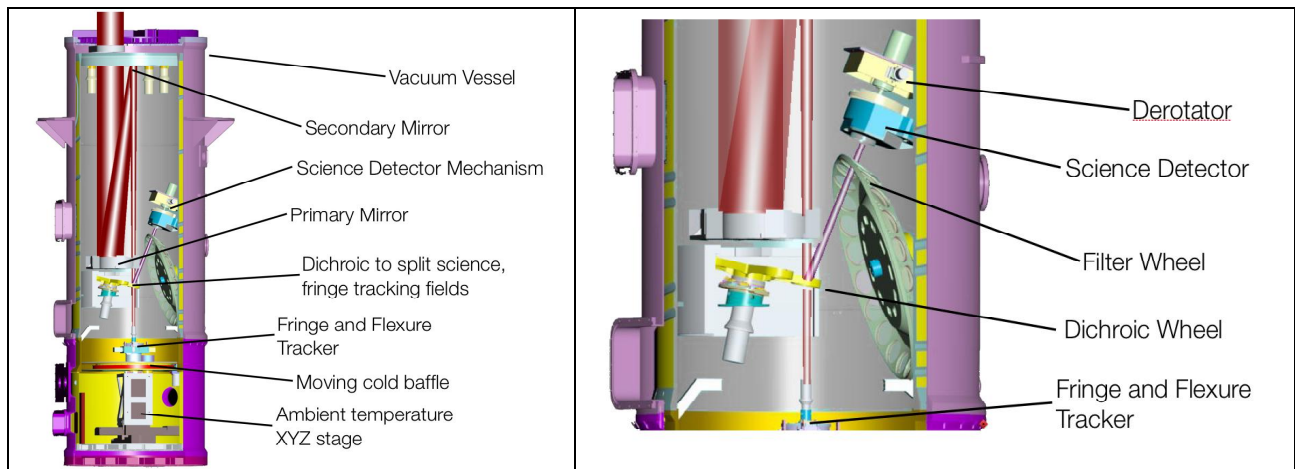


Figure 4: Vacuum cryostat (left), showing the Cassegrain optical system and separate science and fringe-tracking channels. A close-up (right) shows how the infrared-infrared dichroic divides the light.

3. THE LINC-NIRVANA SCIENCE PROGRAM

LINC-NIRVANA will be a sensitive, panoramic, high-resolution near-infrared imager. As such, its motivating science case involves a suite of relatively conventional programs brought to the next level by the combination of 12 meter

collecting area and 23 meter spatial resolution. As with all major instrument projects, however, time and the science context do not stand still during the construction phase.

The LINC-NIRVANA team is currently re-working its “Design Reference Mission” (DRM), a set of five key programs that will demonstrate that the instrument is capable of high-impact science soon after commissioning. The DRM serves the additional purpose of exercising most of LN’s observational modes, to ensure compliance of the hardware with the ultimate science program, and to provide the team with real-world information to aid in the development of observation preparation and data reduction software. Table 1 lists the five DRM programs.

Table 1: Programs of the LINC-NIRVANA Design Reference Mission

Program	Investigators
Host Galaxies at Redshift 1-2	Paolo Ciliegi (Bologna), Eva Schinnerer (MPIA)
Astrometric Follow-up of Radial Velocity Planets	Martin Kürster , Tom Herbst(MPIA)
Centers of Nearby Galaxies with Active Nuclei	Thomas Beckert, Gerd Weigelt (MPIfR)
Young Stellar Objects and their Environment	Dario Lorenzetti, Brunella Nisini (Roma)
Galactic Center Dynamics	Andreas Eckart, Thomas Bertram (Cologne)

4. INSTRUMENT ASSEMBLY AND INTEGRATION

LINC-NIRVANA is a very large instrument: *ca.* 6 meters wide by 4.5 meters deep by 4.5 meters high. In order to test for flexure, LN is bolted to a large tipping mechanism in the MPIA laboratory (figure 5). The large size and extra height of the tipping stage place the LINC-NIRVANA optical bench some four meters above the floor of the lab. This can make working on the individual components both difficult and dangerous. As a result, we have developed a hierarchical approach to instrument assembly and integration. In this scheme, individual components are verified and tested at the supplier then delivered to a traditional lab setting for integration into the appropriate subsystem. Finally, the working subsystems come together in the large, clean-room integration hall. Figure 6 explains the approach and gives examples of each phase of the process.

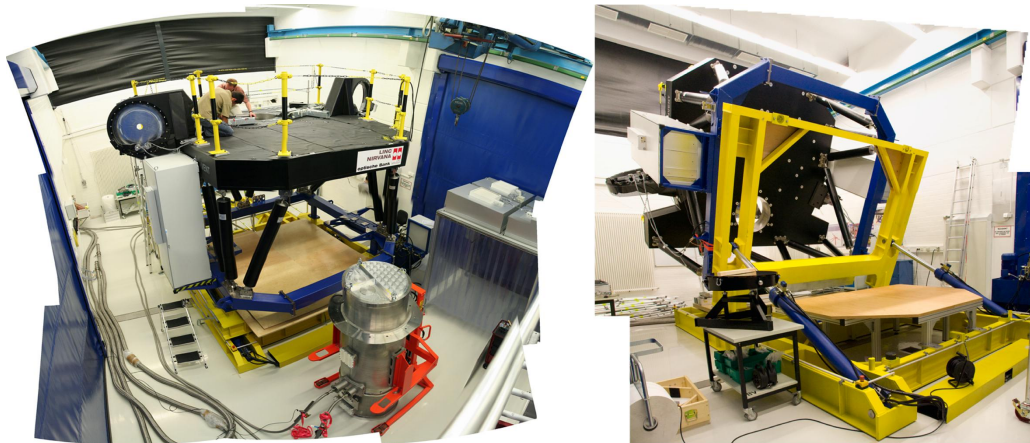


Figure 5: The LINC-NIRVANA bench in the MPIA clean room (left). Tilting the bench for flexure tests (right).

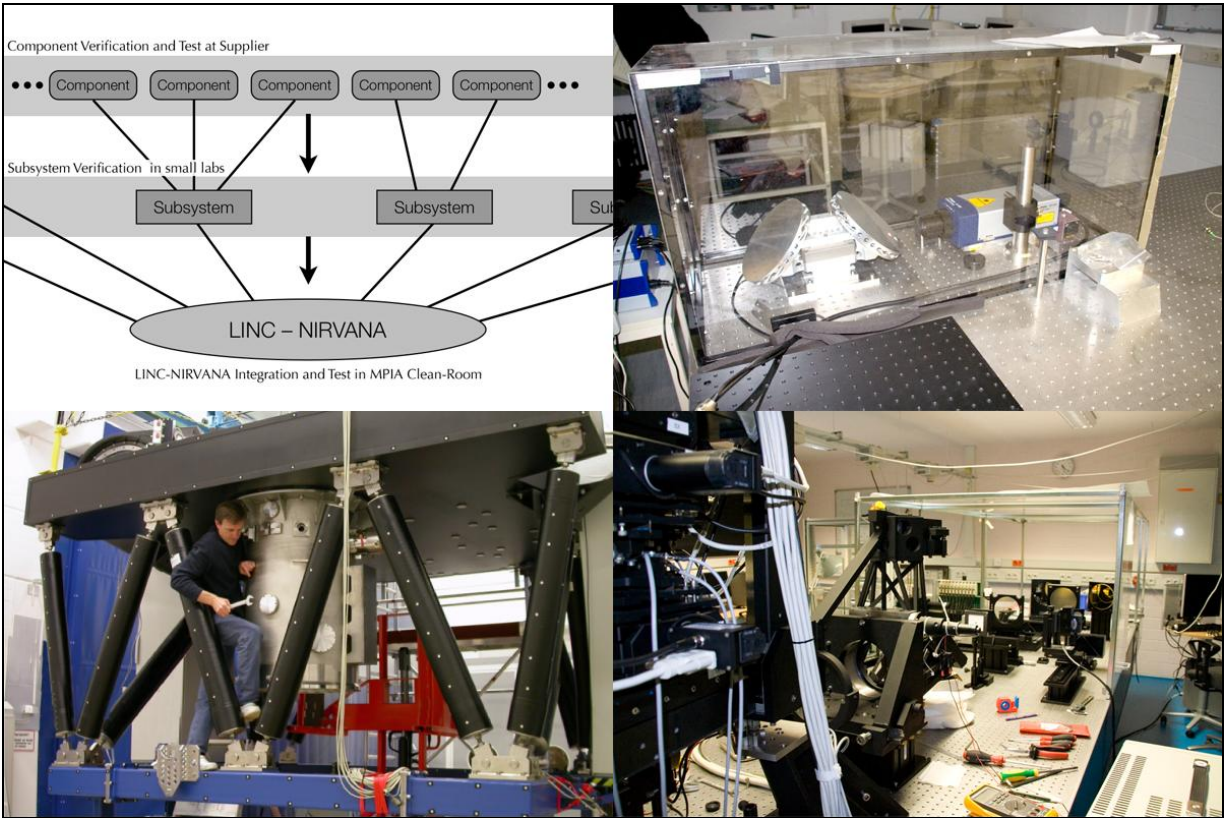


Figure 6: (*upper left*) The LINC-NIRVANA verification, test, and integration hierarchy. (*upper right*) The piston mirror, an example of an individual component, undergoing dynamical testing using a laser vibrometer. (*lower right*) The fully assembled warm optics subsystem of LINC-NIRVANA on a conventional laboratory bench. (*lower left*) Integration and flexure testing of the science channel cryostat on the LN bench in the clean-room.

5. UPGRADE PATH

Although LINC-NIRVANA will not appear at the LBT before the end of 2010, we are already examining upgrade paths to maintain the scientific relevance of the instrument through the next decade. Two design studies, carried out by the University of Cologne and the Max Planck Institute for Extraterrestrial Physics (MPE-Garching), examined ways of adding an integral field capability to LINC-NIRVANA without radically altering the instrument or influencing its implementation schedule. Two approaches seem promising: an anamorphic relay with a conventional small spectrograph and direct injection of the LBT PSF into monomode fibers.

6. LINC-NIRVANA AT THIS CONFERENCE

A single short paper cannot adequately capture an instrument of the complexity of LINC-NIRVANA. In fact, the instrument team produced a total of twenty presentations and posters for the Marseille SPIE conference. Table 2 lists the corresponding papers, organized by general subject area. Interested readers are encouraged to consult these other publications, and for the latest news on the progress of LINC-NIRVANA, point your web browser to:

<http://www.mpia.de/LINC>

Table 2: LINC-NIRVANA publications at this conference, organized by discipline

Discipline	Paper	Authors	Title
Science	7013-169	Eckart <i>et al.</i>	The Potential of Interferometric Observations of the Galactic Center: Combining LBT in the Near-Infrared with ALMA/CARMA in the mm/submm Wavelength Domain
	7013-115	Ciliegi <i>et al.</i>	Analysis of LINC-NIRVANA Simulated Images in Two Specific Scientific Cases
	7013-147	Desidera <i>et al.</i>	AIRY-LN: An ad-hoc Numerical Tool for Deconvolution of Images from the LBT Instrument LINC-NIRVANA
Fringe Tracking	7013-117	Lindhorst <i>et al.</i>	The LINC-NIRVANA Fringe and Flexure Tracking System: the Testbed Interferometer
	7013-78	Bertram <i>et al.</i>	The LINC-NIRVANA Fringe and Flexure Tracking System
	7013-118	Rost <i>et al.</i>	The LINC-NIRVANA Fringe and Flexure Tracker: Testing Piston Control Performance
Adaptive Optics	7015-202	Farinato <i>et al.</i>	The Multiple Field-of-View Layer-Oriented Wavefront Sensing System of LINC-NIRVANA: Two Arcminutes of Corrected Field using Solely Natural Guide Stars
	7015-192	Schreiber <i>et al.</i>	Integration of the Mid-High Wavefront Sensor to the LINC-NIRVANA Post-Focal Relay
Calibration & Control	7013-114	Labadie <i>et al.</i>	Calibration Procedures for Wide-Field Fizeau Interferometry on the LBT
	7012-92	Brix <i>et al.</i>	Vibration Measurements at the Large Binocular Telescope
Software	7019-71	Briegel <i>et al.</i>	A Component-Based Astronomical Visualization Tool for Instrument Control
	7013-116	Pavlov <i>et al.</i>	LINC-NIRVANA Observation Preparation Software: a Flexible Approach
	7019-56	Kittmann <i>et al.</i>	Design and Implementation of a Service-Oriented Driver Architecture for LINC-NIRVANA
	7019-70	Berwein <i>et al.</i>	A SOA Developer Framework for Astronomical Instrument Control Software
General	7013-122	Egner <i>et al.</i>	General Performance Analysis of a Fizeau Interferometer
	7014-8	Wagner <i>et al.</i>	An Overview of Instrumentation for the Large Binocular Telescope
	7013-77	Herbst <i>et al.</i>	LINC-NIRVANA, the Fizeau Interferometer for the LBT
Upgrades	7014-161	Müller-Sanchez <i>et al.</i>	Coupling LBT's Double Pupil into Optical Fibers
	7014-74	Müller-Sanchez <i>et al.</i>	SERPIL: A Design Study for Interferometric Imaging Spectroscopy at LBT
	7014-273	Gal <i>et al.</i>	LIINUS: A Design Study for Interferometric Imaging Spectroscopy at LBT