



Update on KI and LBTI

*Rafael Millan-Gabet
Caltech/NExScI*

Feb 29 – Mar 2, 2012





Keck Interferometer

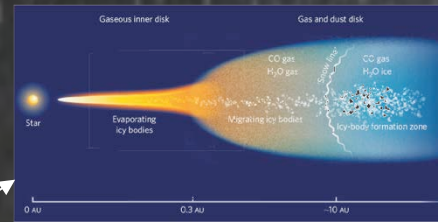




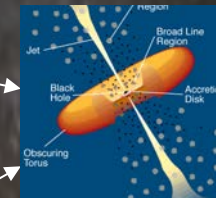
KI Timeline

- **First fringes: March 2001.**
- Original plan for modes and NASA science drivers:
 - 2 x D = 10m Kecks + 4 x D = 1.8m outriggers.
 - Exoplanet differential phase.
 - Exoplanet astrometry.
 - Exozodi nulling.
 - V^2 science, not required, a bonus.
- Reality following elimination of outriggers, DP and Astrometry:
 - Single Keck-Keck baseline (85m).
 - High sensitivity ($K \sim 11$, >3 mags improvement since 2004).
 - Spectral coverage: H ($1.6 \mu\text{m}$), K ($2.1 \mu\text{m}$), L ($3.8 \mu\text{m}$), N ($10 \mu\text{m}$).
 - Spectral resolution: up to K330 ($R=2000$).
 - Nulling at N band (unique worldwide), or equivalently MIR visibility with 0.6% precision.
 - NSF-funded new modes: SPR, DFPR, Astrometry (ASTRA project).
- **Current semester (2012A, ends in July 2012) is the last one.**

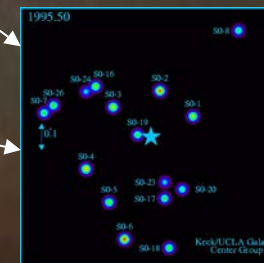
ASTRA: (NSF funded KI Upgrades, PI: J. Woillez, KO) ASTrometry and phase-Referencing Astronomy



Young Stellar Objects
Chemical Composition at R~2000



Active Galactic Nuclei
Chemical Composition
Increased Sample



Galactic Center
Stellar Population
BH mass
and GR effects



Exoplanets
Reflex Motion of
Multiple Planet
Systems



1 Self
Phase Referencing

K<8 limit
R~2000

2 Dual Field
Phase Referencing

K<8.5 reference
K<15 science

3 Astrometry

30μ" for
10" separation

Interferometer





ASTRA status

- **Self-phase referencing (SPR) mode fully operational.**
 - Sensitivity upgrade: Replacement for K/N dichroics → Hope to reach NGC 4151 ($K_{\text{mag}} = 9-10$).
 - Sensitive H band angle tracking (for red objects).
 - Science papers published, instrument paper accepted.
- **Dual-field phase referencing mode in shared risk operation.**
 - Routine Bright/Faint observations at $K \sim 12.5$ (extrapolates to $K=14-15$)
- **Astrometry mode also offered as shared-risk.**
 - Demonstrated 100nm rms correlation between primary and secondary on bright-bright pair → very good starting point for astrometry.
- Only a few more nights left in 2012A, strategic choices:
 - Focus on Dual Field demonstration on galactic center.
 - Make LGS-IF a top priority.



KI Demand & Usage

- About 6-9 KI nights per semester allocated.
- Over-subscription: 5-8 (TACs NASA, NOAO/TSIP).
- 23 distinct PIs since 2003.





Refereed Publications

http://nexsci.caltech.edu/software/KISupport/KI_biblio.shtml

- 38 papers since 2003.
- Main science themes:
 - Preplanetary disks around young stars of all types (dust and gas).
 - Transition disks.
 - Young stars dynamical masses.
 - Novae.
 - Evolved stars (dust & molecular layers).
 - Be stars (gas disk spectro-interferometry).
 - Exozodi levels, and detailed debris disks studies.
 - AGNs (dust tori size measurements).
- Instrument papers:
 - Nulling theory & practice, fringe measurement & tracking, water vapor compensation, self-phase referencing.



Papers since last CHARA meeting

2011

[First Keck Nulling Observations of a Young Stellar Object: Probing the Circumstellar Environment of the Herbig Ae star MWC 325](#), S. Ragland, K. Ohnaka, L. Hillenbrand, S. T. Ridgway, M. M. Colavita, R. L. Akeson, W. Cotton, W. C. Danchi, M. Hrynevych, R. Millan-Gabet, W. A. Traub, 2011, A&A accepted for publication

[Mapping the radial structure of AGN tori](#), M. Kishimoto, S. F. Hoenig, R. Antonucci, F. Millour, K. R. W. Tristram, G. Weigelt, 2011, A&A accepted for publication

[Resolving the Sub-AU-scale Gas and Dust Distribution in FU Orionis Sources](#), J. A. Eisner, L. A. Hillenbrand, 2011, ApJ, 738, 9

[Exo--Zodiacal Dust Levels for Nearby Main Sequence Stars](#), R. Millan-Gabet, E. Serabyn, B. Mennesson, W. A. Traub, R. K. Barry, W. C. Danchi, M. Kuchner, S. Ragland, M. Hrynevych, J. Woillez, K. Stapelfeldt, G. Bryden, M. M. Colavita, A. J. Booth, 2011, ApJ, 734, 67

[The innermost Dusty Structure in Active Galactic Nuclei as Probed by the Keck Interferometer](#), M. Kishimoto, S. F. Hoenig, R. Antonucci, R. Barvainis, T. Kotani, K. R. W. Tristram, G. Weigelt, K. Levin, 2011, A&A, 527, A121

[Radial Structure in the TW Hya Circumstellar Disk](#), R. L. Akeson, R. Millan-Gabet, D. R. Ciardi, A. F. Boden, A. I. Sargent, J. D. Monnier, H. McAlister, T. ten Brummelaar, J. Sturmman, L. Sturmman, and N. Turner, 2011, ApJ, 728, 96



LESIA



Observatoire de la CÔTE d'AZUR

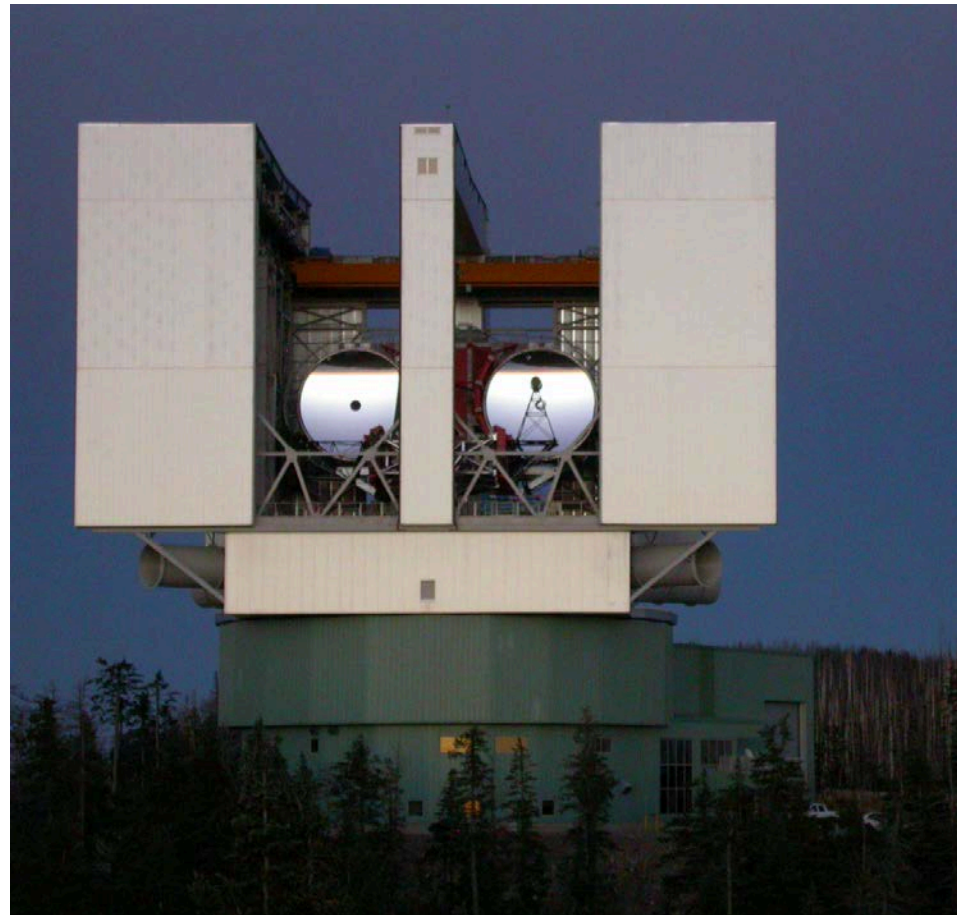


KI close out

- 2 more observing runs:
 - Apr 29 – May 3 (V^2 -SPR, V^2 -K, V^2 -L & V^2 -DFPR)
 - Jul 27-29 (V^2 -DFPR & V^2 -L)
- Close-out starts in May 2012, starting with sub-systems not needed for the last runs.
- But, maintain the KI functionalities for an additional year, in case there is a restart of operation.
- KI data will be transferred from the KI-specific archive to KOA (Keck Observatory Archive) during 2012 for long-term access.



Large Binocular Telescope Interferometer

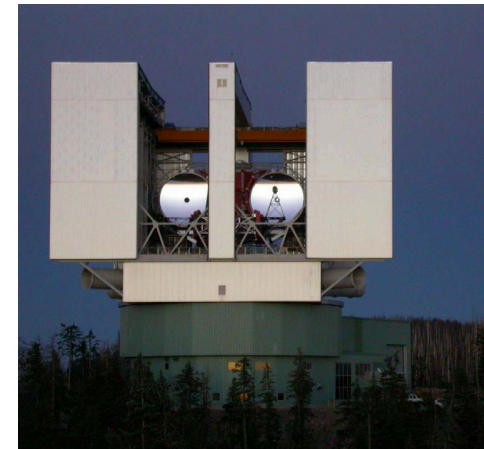




LBTO & LBTI

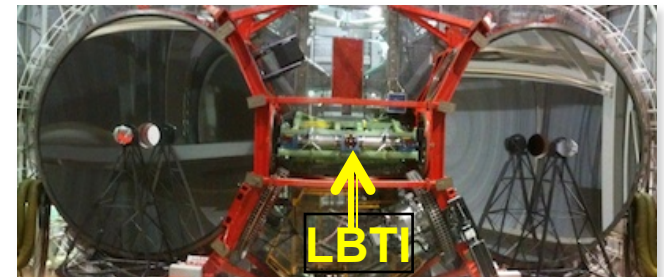
- **LBTO (Mt Graham, AZ)**

- First light: 2005, 2008
- Partners: UA, Italy, Germany, Research Corporation, Ohio State U.
- Instruments for Vis-IR imaging, photometry & spectroscopy
- AO on each telescope (deformable secs, pyramid wavefront sensor).



- **LBTI:**

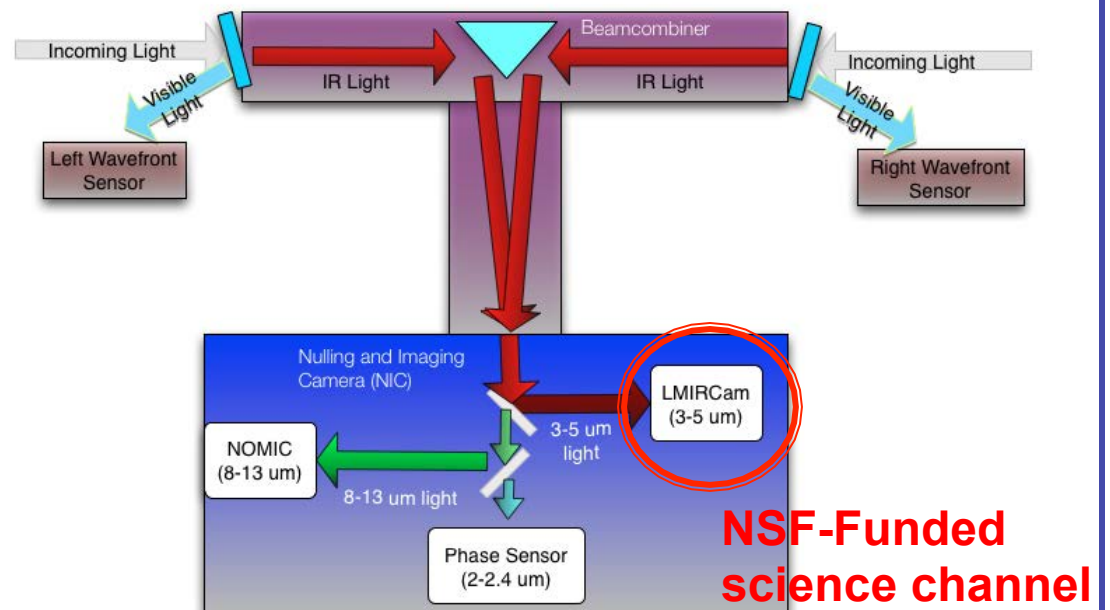
- UA instrument, funded by NASA. PI: Phil Hinz.
- Installed Sep 2010. First fringes Oct 2010.
- NASA science drivers: sensitive exozodi survey, exoplanet imaging.





Instrument Overview

- **Sensitivity:**
 - 2 x D = 8.4m telescopes on a single mount.
 - Simple optical path and cooled optics combiner.
- **Resolution:**
 - 22.7 m max. baseline.
- **High contrast:**
 - AO delivers e.g. Strehl >95% at 3.8um.





Expected Performance

	LMIRcam	NOMIC
Wavelength Coverage (μm)	2.9-5.1(1.5-5.1 capable)	8-14 (8-25 goal)
Throughput	>30%	>20%
Pixel Size	0.011"	0.018"
FOV	20"	12"
minimum Strehl	90% (3.8 μm)	98% (11 μm)
Spectral Resolution	350	100
5 sigma detection, 1 hour	19.8 (3.4 μJy) @ L'	14.3 (70 μJy) @ N'
Spatial Resolution	40 mas @ L'	100 mas @ N'

2 M_J planet
at 1 Gyr

0.4 AU
at 10 pc

1/3 zodi
debris disk

1 AU at
10 pc

**Expected
calibration:
3 – 6 zodis (1 σ)**



LESIA



Observatoire
de la CÔTE d'AZUR

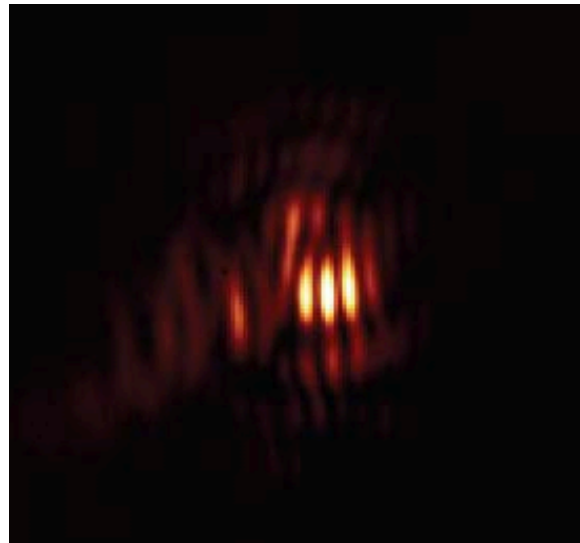


Instrument Status & Plans

- Both AO systems have been commissioned.
 - Observatory is ready for interferometry!
- LBTI is installed at the telescope.
- LBTI commissioning under-way, until Fall 2012.
- On-sky tests done thus far (& shared-risk science):
 - Single telescope imaging with the LBTI cameras.
 - Seeing limited interferometry.
 - Aperture masking (Tuthill & Eisner).
- Nulling tests will follow, starting in Winter-Spring 2012 ...

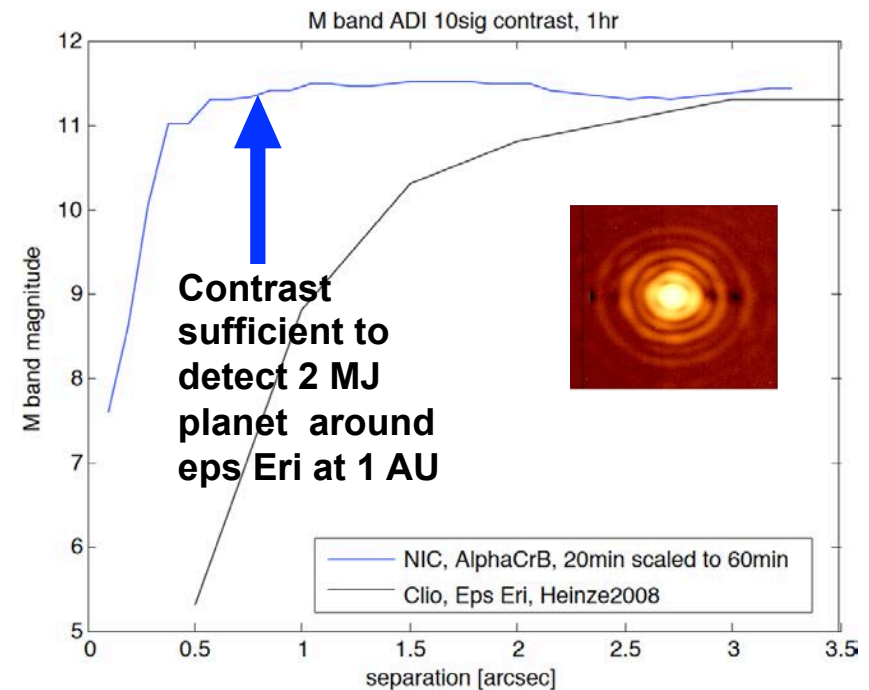


Demo Science



First 10 μm fringes.
 β Peg. Seeing limited under poor weather (~1.2 arcsec seeing).

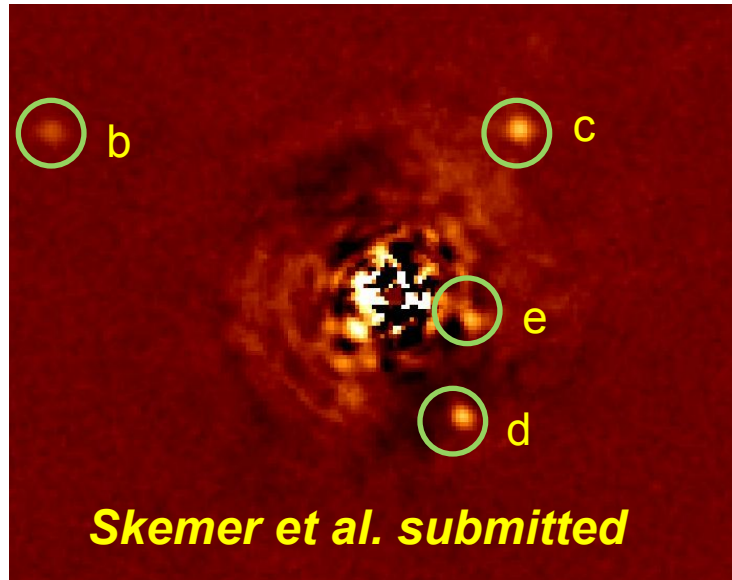
- **AO tests in May 2011 demonstrated 95% Strehl at M (4.8 μm , top right).**
- **Very stable PSF allows subtraction to the background limit outside of 0.3 arcsec.**



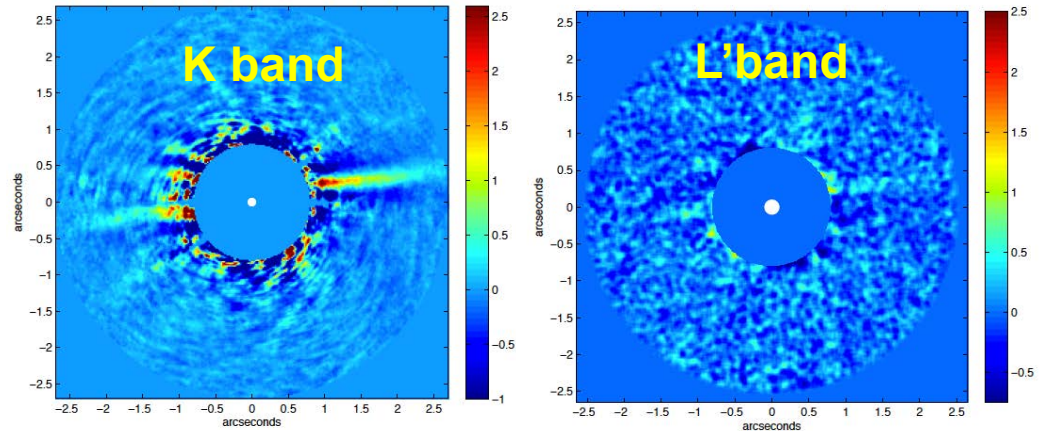


Demo Science (cont.)

First Detection of 4 planets around HR 8799 in methane absorption ($3.3 \mu\text{m}$)



Scattered light from young edge-on debris disk



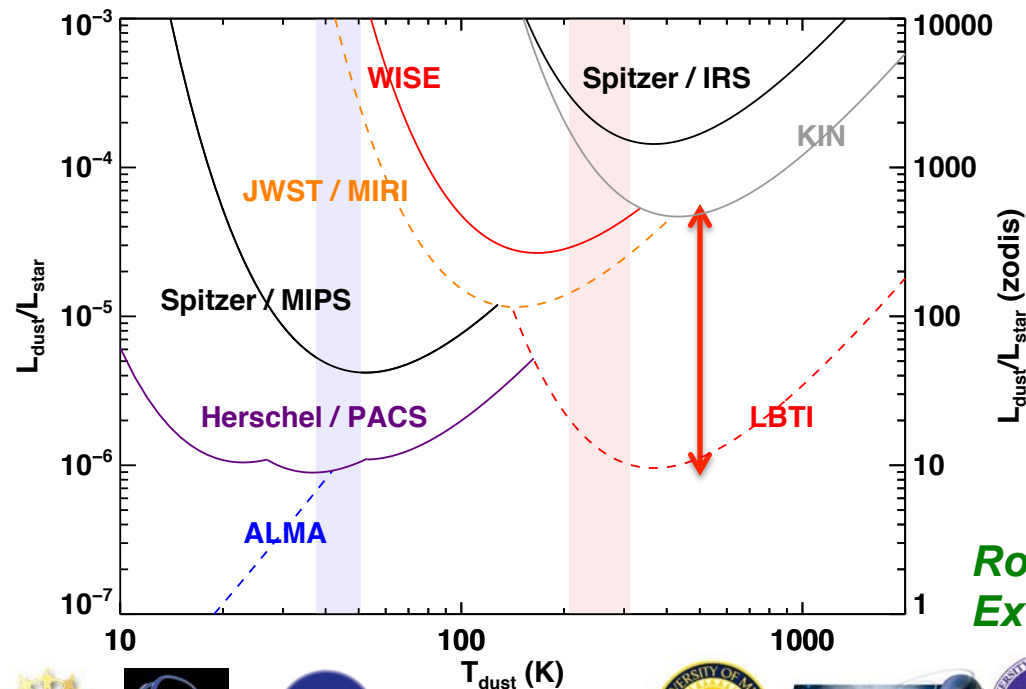
Rodrigas et al. submitted



NASA-LBTI Key Science

Decadal Survey ASTRO2010:

“... need to characterize the level of zodiacal light present so as to determine, in a statistical sense if not for individual prime targets, at what level starlight scattered from dust will hamper planet detection”.



*Roberge et al. 2012
ExoPAG report*



LESIA



Observatoire de la CÔTE d'AZUR



THE NASA / LBTI Survey

- Survey of 60-100 FGKM nearby stars for exozodi levels with 3-6 zodi expected sensitivity (1σ).
- PI: Phil Hinz (UA).
- 60 nights dedicated to this project (80-100 stars).
- Observations start after commissioning i.e. Fall 2012. Most observing to be completed by Fall 2015.
- Data archiving and public distribution at NExSci.
- **NASA solicits members of the community to join the key science team.**
- Expected selection and funding of 3-4 external team members; which will contribute critical expertise needed for the optimum execution of the key science exozodi survey (target selection, observing strategies, data analysis, and interpretation).
- **Application deadline: April 27, 2012.**
- **http://nexsci.caltech.edu/missions/LBTI/cfp_keysci.shtml**