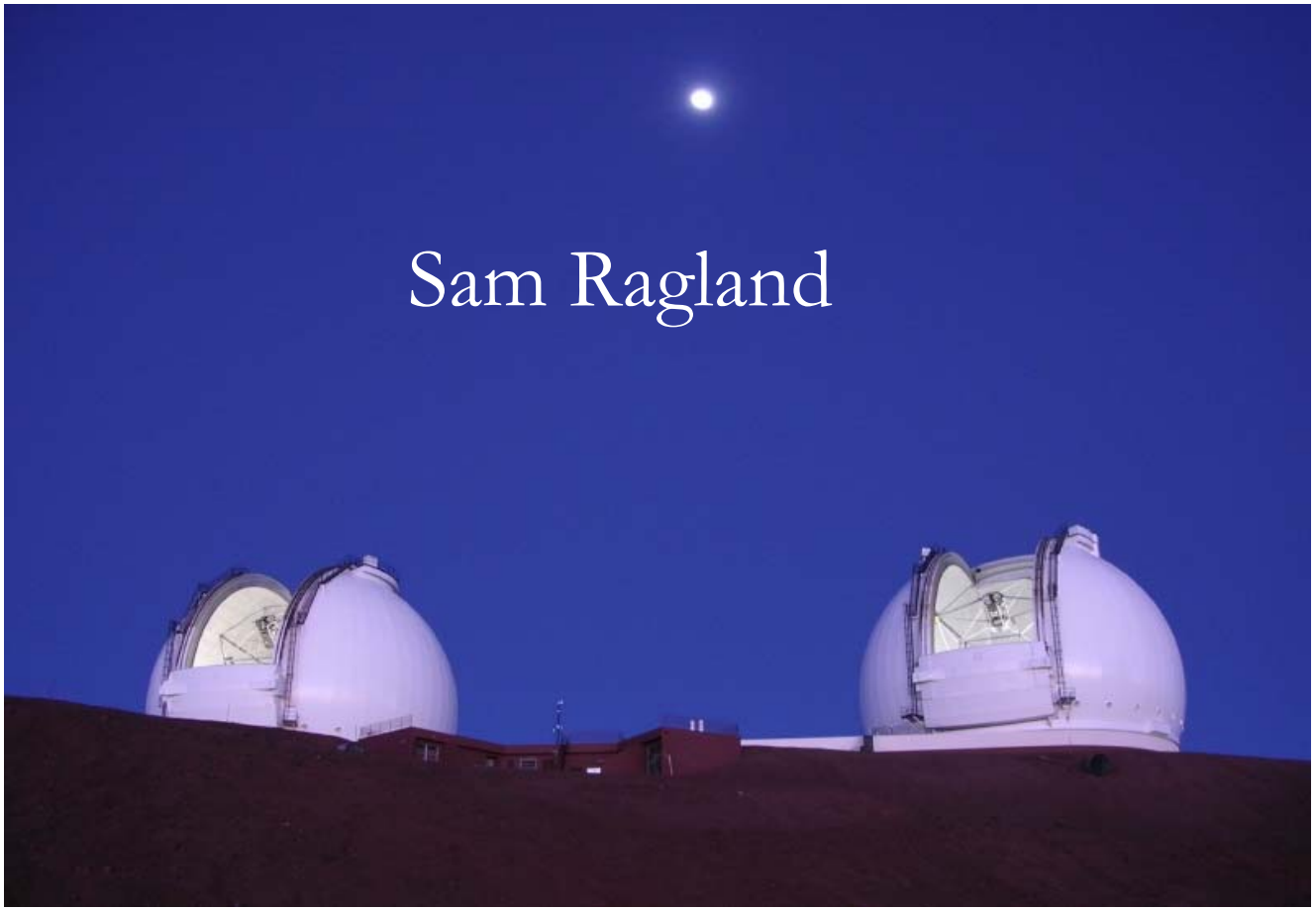
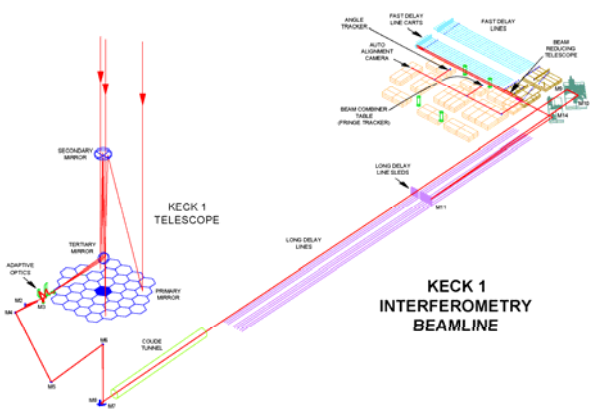
Keck Interferometer: A status Update



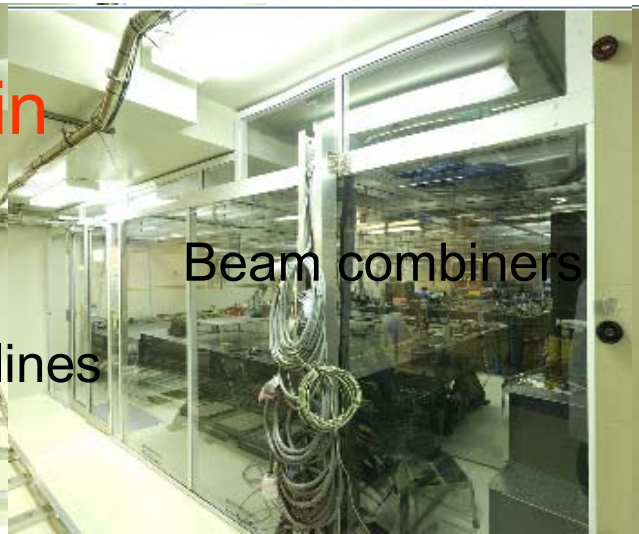
Presentation sequence

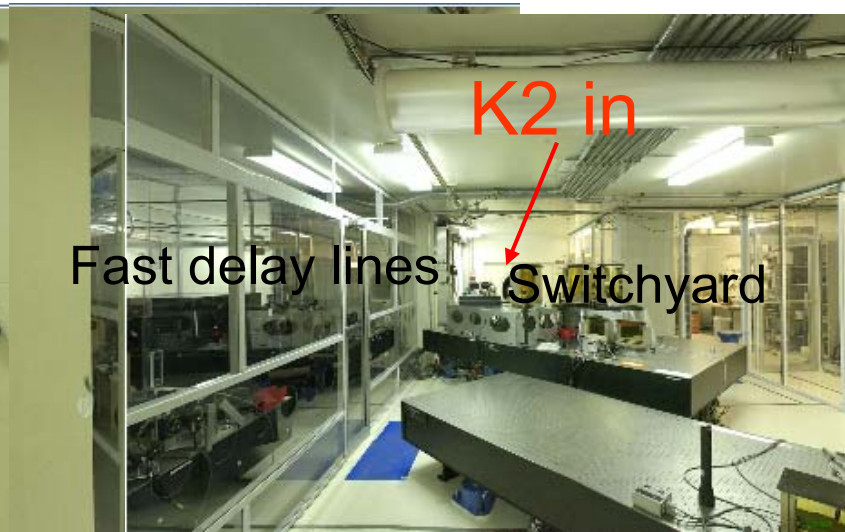
1. Introduction
2. Operational capabilities
3. Science operations
4. Science highlight
5. Future Plans

1. Introduction



- Two Keck 10m telescopes w/ 85m baseline
- Visibility-square (1.65, 2.2 & 3.8 μm) & Nulling (10 μm) measurements
- Keck Interferometer (KI) is funded by NASA Joint development among JPL, WMKO, and NExScI
- Demonstrated good reliability of the instrument (> 90% uptime)
- NSF-funded ASTRA project in process of delivering new capabilities





2. Operational Capabilities (Slide 1 of 4)

• KI is the most sensitive IR interferometer on the planet with unique operational capabilities, but limited in terms of uv coverage

	KI Capabilities	Current performance
1	Nulling mode	N-band flux > 1.7 Jy
2	V^2- K5 ; R~27	K' < 10.3
3	V^2- K10 ; R~54	K' < 9.5
4	V^2- K42; R~230	K' < 7.6
5	V^2-SPR; R~1700	K' < 7
6	V^2- H4; R~22	H < 9
7	V^2- L10; R~63	L' < 6
8	V^2- K/L	K' < 8.7 & L' < 4.8
9	V2-DFPR	K < 12.3 for 5-15" field; K < 11.3 for 15-25" field

Adaptive optics and Angle tracking limit

- AO sensitivity: R < 12
- KAT sensitivity: J/H < 10.5 (H < 9 for SPR & H < 13 for DFPR)

Modes offered for shared-risk science are highlighted in red

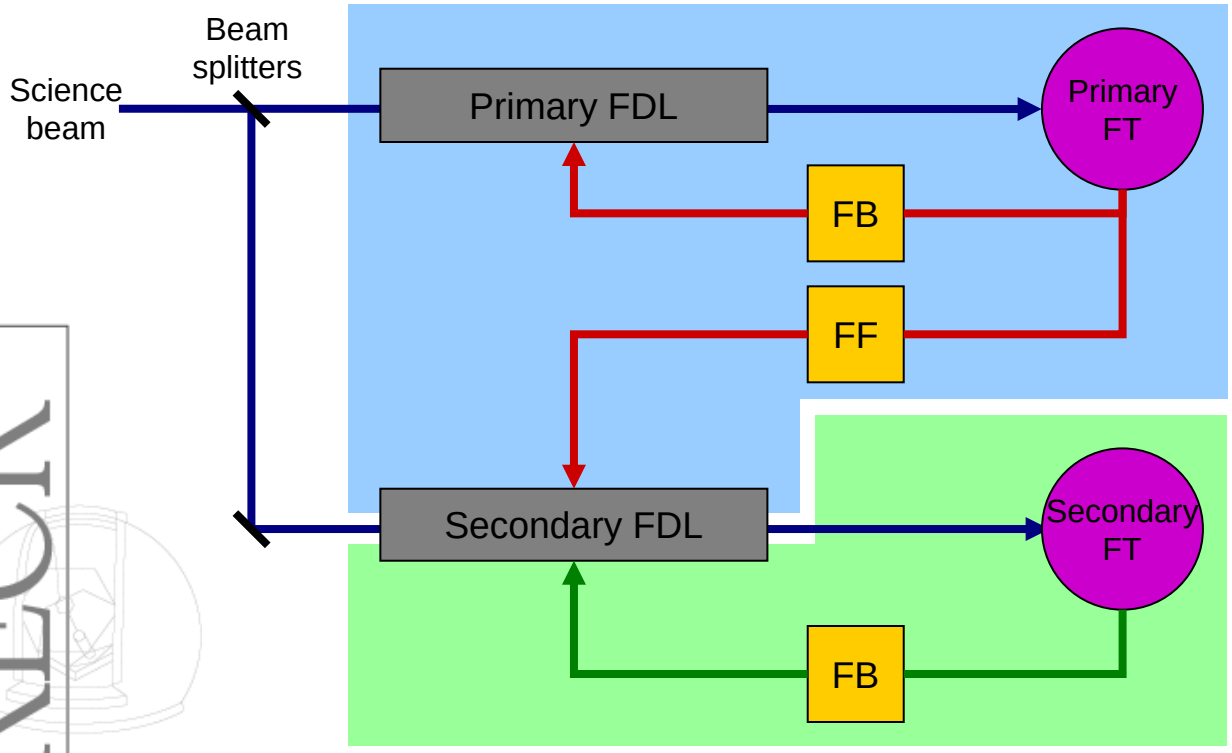
Interferometer

KECK

2. Operational Capabilities (Slide 2 of 4)

Self-Phase Referencing (SPR) mode

- Spectral resolution of ~ 1700 in K-band for K' < 7
- Commissioned ASTRA Self-phase referencing mode and offered as a fully operational science instrument for semester 2010B



- Fast Servo
- Closed loop feed-back
- Open loop feed-forward

- Slow Servo
- Limited feed-back
- Long integration times
- High Spectral Resolution

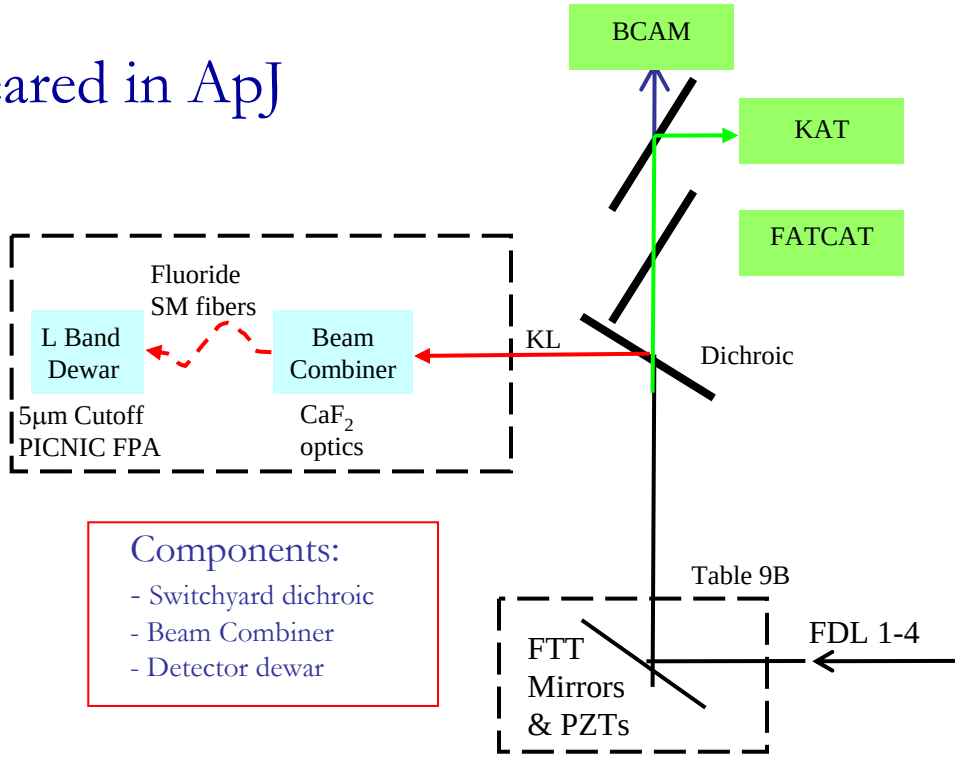
Interferometer

KECK

2. Operational Capabilities (Slide 3 of 4)

L-band & Simultaneous K/L Modes

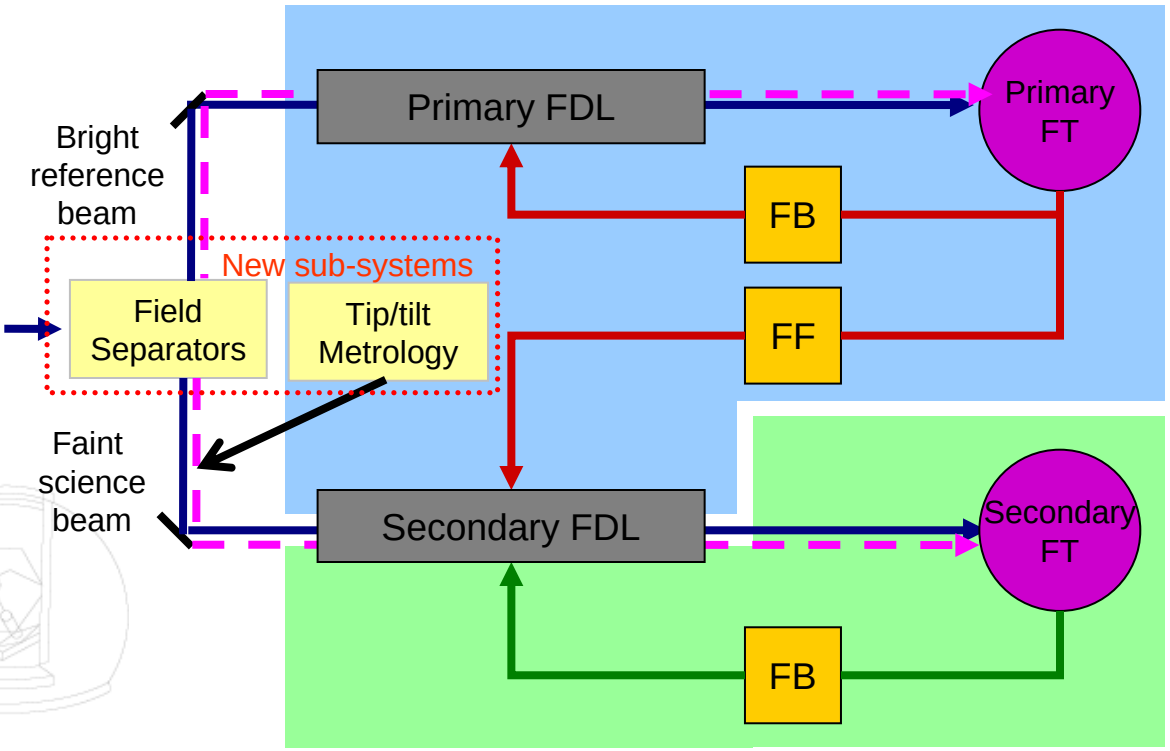
- L-band instrument is an unique capability
- In the process of commissioning these two modes
- Offering these modes for shared-risk science in semester 2010B
- 1st science paper appeared in ApJ



2. Operational Capabilities (Slide 4 of 4)

Dual Field Phase Referencing (DFPR) mode

- Measurements up to K ~ 12 (ultimately to K ~ 14) when suitable nearby reference star is available within 25" field
- Offering ASTRA Dual-field Phase Referencing (DFPR) mode for shared-risk science in 2010B



- Fast Servo
- Closed loop feed-back
- Open loop feed-forward

- Slow Servo
- Limited feed-back
- Long integration times
- Fainter magnitude limits

3. Science Operations: KI usage (slide 1 of 2)

- Observations with KI are supported with service observing and pipeline data reduction through all phases of the project
- Demand for KI remains high with 6-8 (2 telescope) nights allocated per semester from TACs with oversubscriptions rates from as high as 5 (NASA) to 8 (NOAO/TSIP)
- 2 year statistics: lost ~ 1/4th of sky time to bad weather
- Science topics in last 2 years
  - Young stellar objects
    - T Tauri, Herbig, FU Oris and massive YSO disks
    - Stellar mass
  - Circumstellar material around Cepheids
  - Circumstellar material around main sequence stars
  - Dust in AGNs

3. Science Operations: KI usage (slide 2 of 2)

Observing run schedule

Past Runs

Future Runs

Aug 28	0.5 night ASTRA eng.
Oct 24-27	2.5 nights Nuller & L-band Science
Nov 6-8	2 nights V2 science
Nov 23-26	2 nights V2 science
Dec 13	0.5 night ASTRA eng.
Dec 29	1 night ASTRA eng.
Feb 24-26	2 nights V2 science
Mar 29-30	1.25 nights ASTRA eng.
Apr 23	0.5 night V2-DFPR sci. + ASTRA eng
Apr 28-May 1	2 nights V2 science
May 29-Jun 1	3 nights Nuller & L-band Science
19-20 July	0.5 night V2-DFPR sci. + ASTRA eng.

V^2 (H, K, L, SPR, DPFR), V^2-K/L and Nulling modes are offered in semester 2010B

3. Science Operations: Nulling Key Science Update

- After completion of the data taking phase for the Nulling Key Science project (Feb 2009), the KI team did a comprehensive analysis to derive the final uncertainties and systematics
  - Detailed description of data collection and analysis published in Colavita et al (2009), PASP, 121, 884
- 8 runs Feb 2008 – Jan 2009: 32 interferometer nights
- Completed the observational phase of the Nuller Key Science exo-zodiacal survey
  - 44 unique targets observed out of 46 submitted
  - 40 targets have no detectable exo-zodiacal dust at limits of several hundred zodi and remain viable candidates for terrestrial planet searches
  - Some data already public and all data will be public in July, 2010
  - Papers in preparation by Key Science team

4. Science Highlight (slide 1 of 4)

7 refereed publications since start of 2009

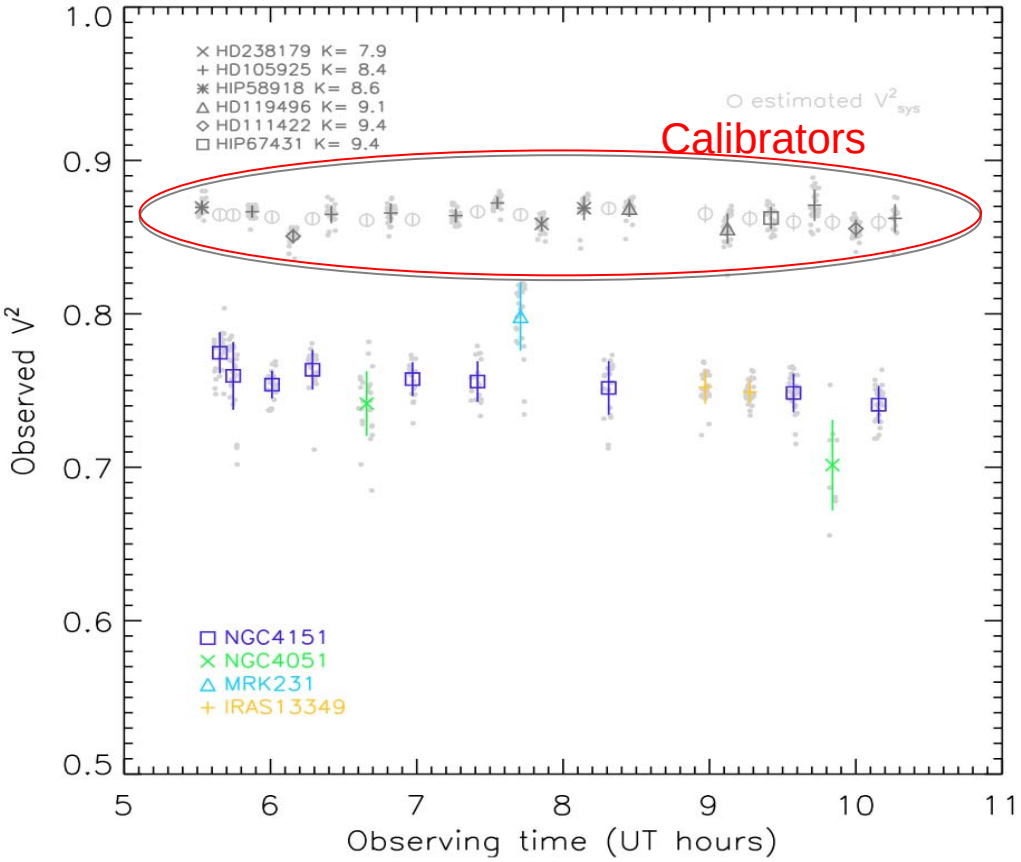
- Spatially resolved spectroscopic observations of 15 young stars in the K-band (Eisner et al. 2009)
  - Detect hot hydrogen gas through Br γ emission line
  - Observations suggest the presence of water vapor and CO gas in the inner disk of several objects
- Interferometric evidence for resolved warm dust in the DQ Tau system (Boden et al. 2009)
  - Suggests the IR excess from this PMS binary system is distributed on the physical scale of the binary orbit (0.1-0.2 AU)

4. Science Highlight (slide 2 of 4)

- First L-band observations of a YSO disk (Ragland et al. 2009)
  - Studied the temperature structures of the inner disks a Herbig AeBe star though simultaneous K & L measurements
  - Press release in Dec 2009: http://www.keckobskeck_telescopes_take_deeper_look_at_planetary_nurseries; http://www.nasa.gov/topics/universe/features/keck-life-zone.html
- 51 Oph: A possible Beta Pictoris analog measured with the Keck Interferometer Nuller (Stark et al. 2009)
  - A two component model: inner disk of blackbody grains and outer disk of small grains was essential to explain the observed KI measurements in conjunction with VLTI-MIDI & Spitzer observations
- Transitional Disks with KI (Pott et al. 2010)
  - Searching for close companions as the reason for dust depletion
  - No companions found
    - Rule out binary companions within specific parameter range
    - All but one target spatially resolved and consistent with hot dust at 0.1 AU inside nominal hole

4. Science Highlight (slide 3 of 4)

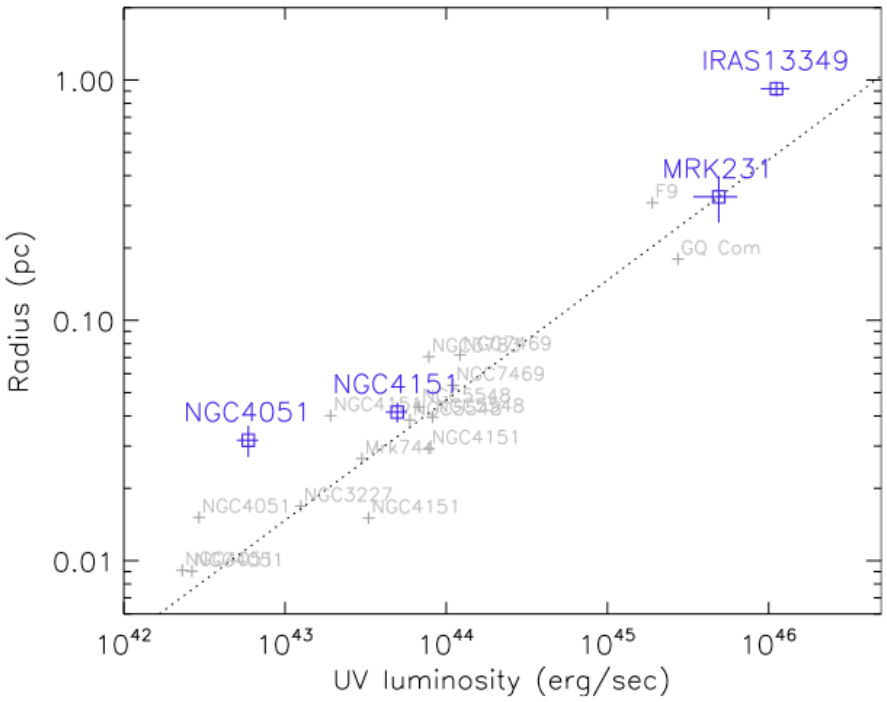
- Exploring the inner region of type 1 AGNs with the KI (Kishimoto et al. 2009)
  - Four Type I AGNs – thanks to the recent angle tracking improvements
  - These observations partially resolved the dust sublimation region; fit ring radii range from 0.04 to 0.9 parsecs
  - Press release in Dec 2009:
    http://keckobservatorkeck_observatorys_interferometer_takes_closer_look_at_supermassive_black_ho/



4. Science Highlight (slide 4 of 4)

Kishimoto et al results (Kishimoto et al. 2009)

- The effective radius of these four AGNs, obtained from ring model, is comparable to the light travelling distance for the time lag of the K-band flux variation from the U/V optical variation.
- This is suggest that these interferometric observations probe the dust sublimation region.



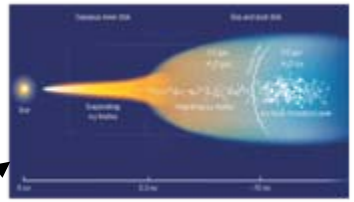
Corrected ring radius derived for each KI target (squares), plot- ted against UV luminosity. Radii from reverberation mapping shown in grey.

5. Future plans

- Complete commissioning of L-band & ASTRA-DFPR modes
  - 1.5 engineering nights to complete DFPR commissioning (March & April) with July night as backup
- Implement ASTRA astrometry mode
  - First astrometric tests starting in July 2010
  - Qualification campaign through 10B

ASTRA Overview

A $2M NSF MRI grant
Performance: July 2006 - July 2010

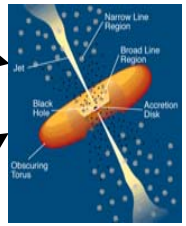


Young Stellar Objects
Chemical Composition at R~1800

1 **Self Phase Referencing**
K<8 limit
R~1800

2 **Dual Field Phase Referencing**
K<8.5 reference
K<15 science

3 **Astrometry**
30μarcsec for 10" separation



Active Galactic Nuclei
Chemical Composition
Increased Sample

Galactic Center
Stellar Populations
Black Hole Mass
General Relativity Effects

Exoplanets
Mass of Known Planets
Reflex Motion of Multiple Planet Systems

Summary

- Keck Interferometer (KI) is a high sensitivity IR interferometer with unique operational capabilities
- KI operates for ~ 15 nights per year
  - Demonstrated good reliability of the instrument & operational efficiency is high
- ASTRA-SPR mode has transitioned to facility class instrument
- Commissioning ASTRA-DFPR, L-band & K/L modes
- ASTRA-astrometry mode is under development