Multi-color Interferometric Investigations of YSO disks

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Presentation sequence

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2. Observations
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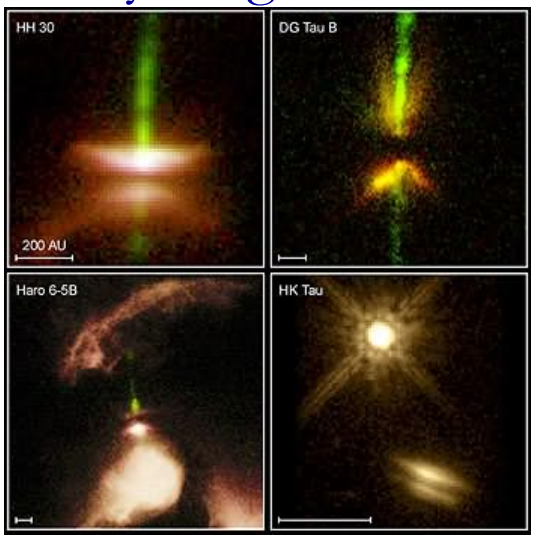
2. Introduction (slide 1 of 2)

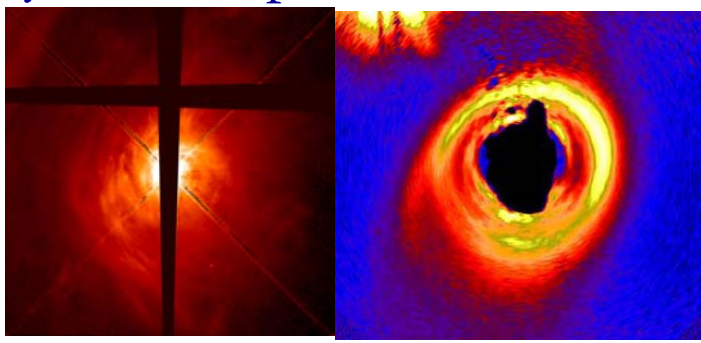
- Pre-main sequence (PMS) stars are surrounded by a disk of gas and dust during the first several million years.
- These circumstellar disks provide the raw material for planet formation. Thus, understanding the evolution of a disk helps us to understand planet formation.
- Clues to the physical conditions of planet formation and hence future suitability for life on planets other than Earth potentially can be inferred from a detailed characterization of inner young stellar object (YSO) disks.
- Long-baseline interferometric observations provide the milliarcsecond angular resolution required to resolve the planet-forming structures immediately surrounding PMS stars.
- A large number of YSOs have now been spatially resolved in the infrared wavelengths.



Credit: NASA/HST

2. Introduction (slide 2 of 2)

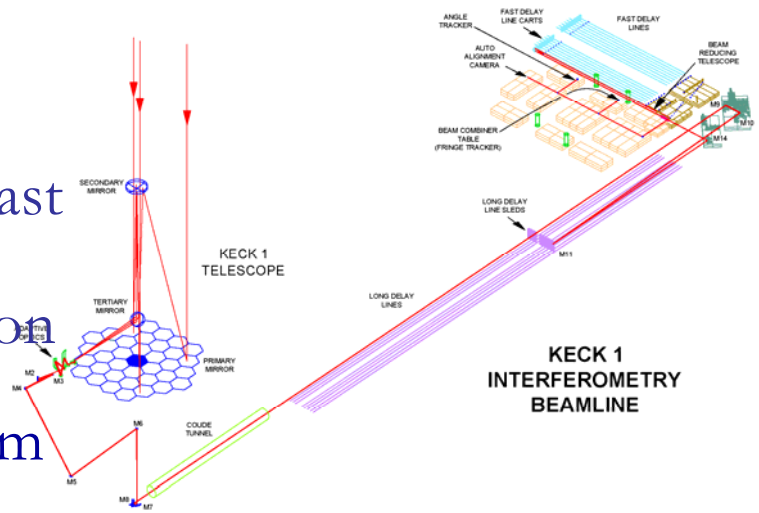
- We have initiated a systematic investigation of YSO disks of different luminosity types through a new instrumental approach, namely, multi-color interferometry at well-separated wavelengths using the Keck Interferometer (KI).
- Multi-wavelength observational capability is well suited to probing the temperature distribution in the inner regions of YSO disks.
- Our primary objective is to resolve and characterize the inner dust and gas disks in order to test disk models of Pre-Main Sequence (PMS) stars, and establish density and temperature profiles of relatively cooler zones of the disk that are not measured by the previous H and/or K band interferometric observations.



Credit: NASA/HST

2. Observations (slide 1 of 2)

- KI combines the two 10 m Keck telescopes as a long baseline interferometer.
- Baseline: 85 m; Position angle: 38° east of north.
- High-order adaptive optics systems on both telescopes.
- Resolution ($\lambda/2B$): ~ 3 mas at 2.2 μm & 12 mas at 10μm.
  - A factor of ~ 20 finer resolution than that of single 10 m telescope diffraction limit along the direction of baseline.
- KI is funded by NASA.
- Joint development among the Jet Propulsion Laboratory, the W. M. Kec Observatory, and the NASA Exoplane Science Institute.



2. Observations (slide 2 of 2)

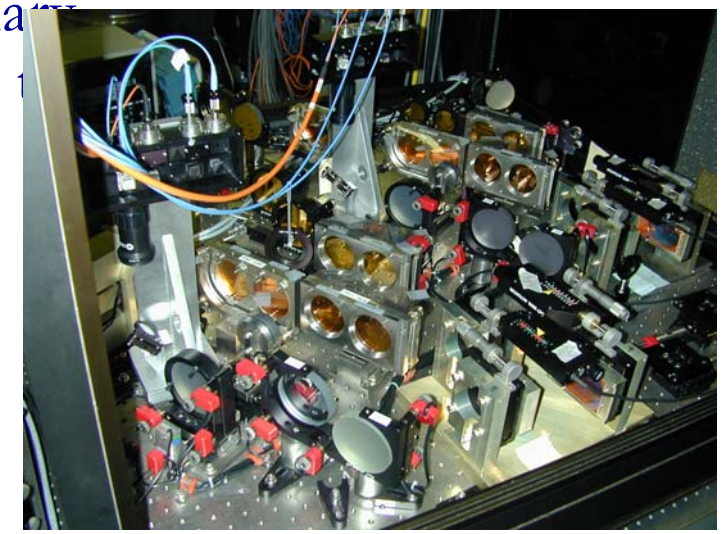
- Goal is to observe in the K, L & N bands.
- 2 observing modes:

(1) Simultaneous K/L Mode

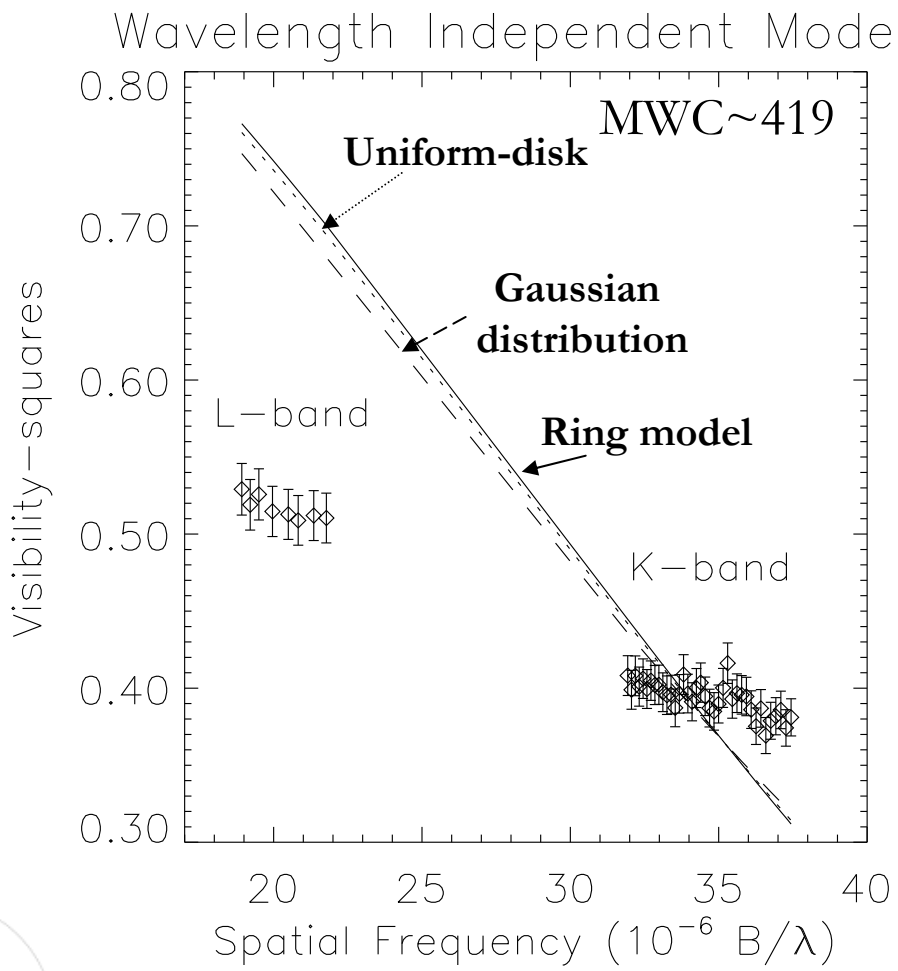
- A new mode offered for shared-risk science in semester 2010A
- Operates in split-pupil configuration
- K-band beam-combiner uses the prima beams & L-band beam-combiner uses t secondary beams
- Sensitivity, L ~ 5 & K ~ 9

(2) Simultaneous K/N Mode

- Standard N-band nulling mode with K-band fringer tracker data



3. Geometrical model fits (slide 1 of 2)



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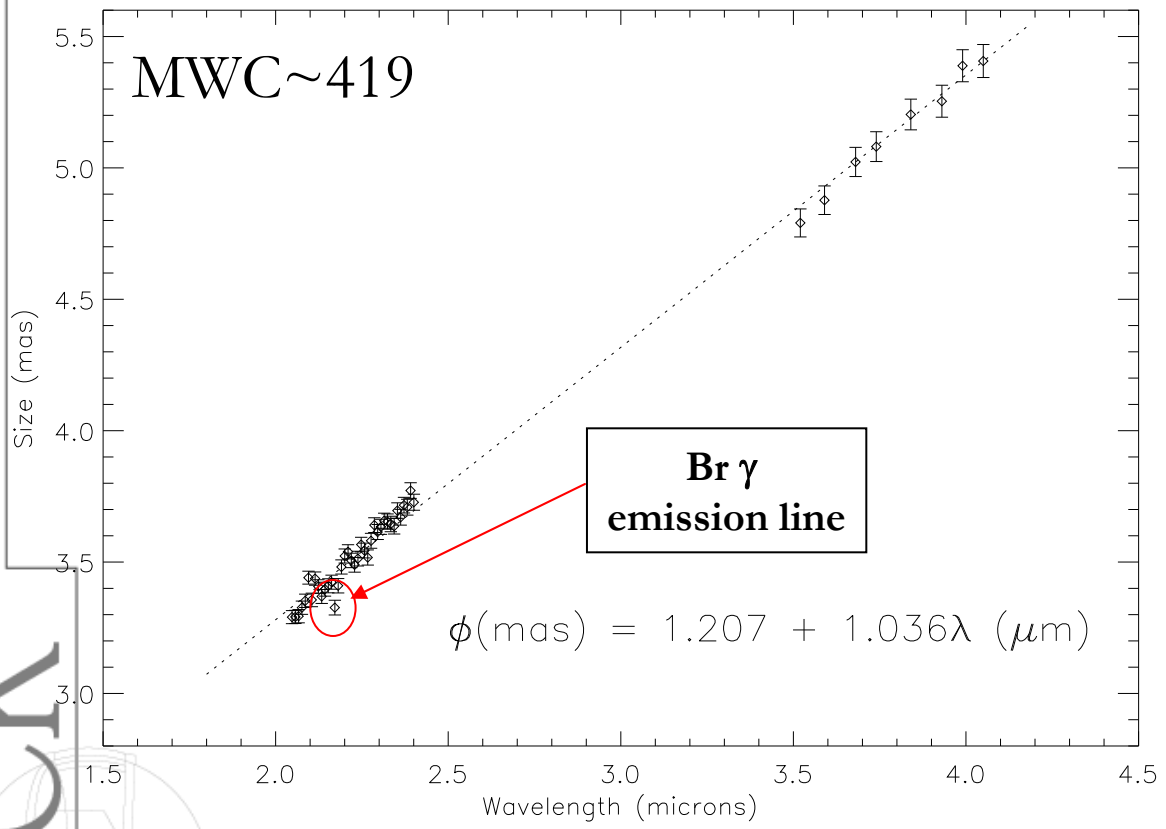
- Simple wavelength independent geometric models fail to fit our measurements.
- Sizes: 3.6 mas, 2.2 mas & 3.9 mas for Uniform-disk, Gaussian (FWHM) & ring models respectively.
- Reduced Chi-squares: ~ 40.

3. Geometrical model fits (slide 1 of 2)

Wavelength-dependent linear fit



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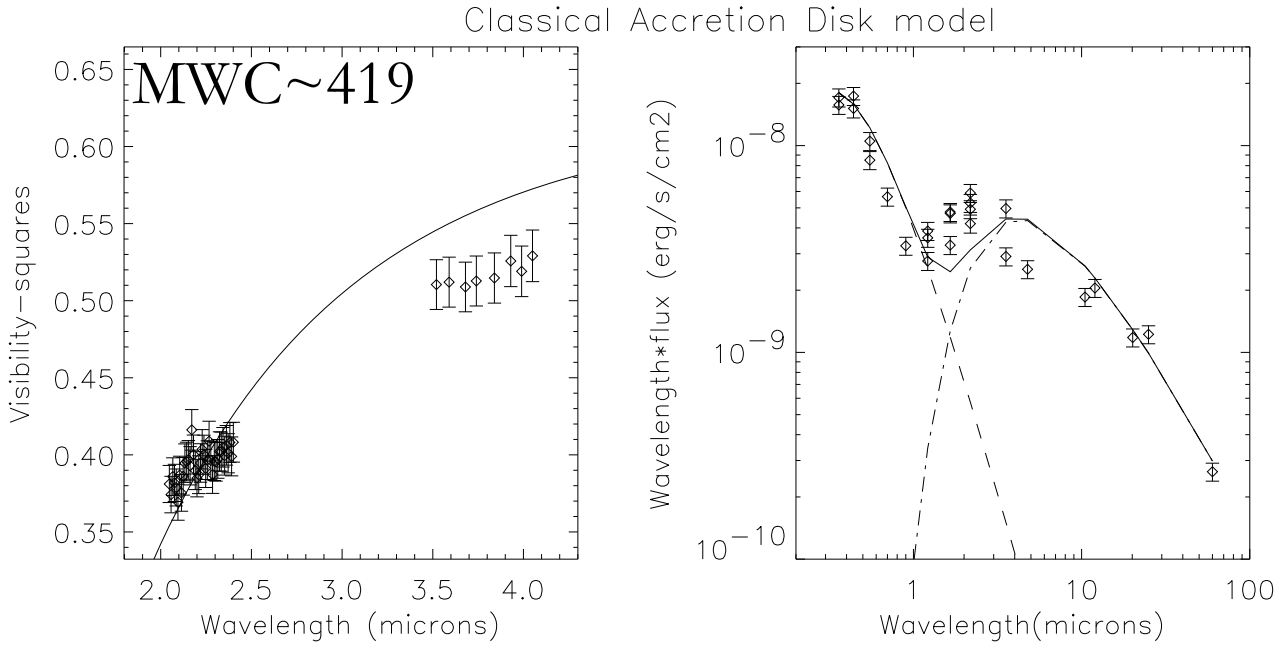
- The mean UD size of the disk in the L-band is ~ 44% larger than that in the K-band.
- The wavelength dependent size suggests that the disk is extended with strong radial temperature gradient.
- We detect a compact Br γ emitting region from spatially resolved K-band spectra.

Interferometer

KECK

4. Disk Models: Classical accretion disk



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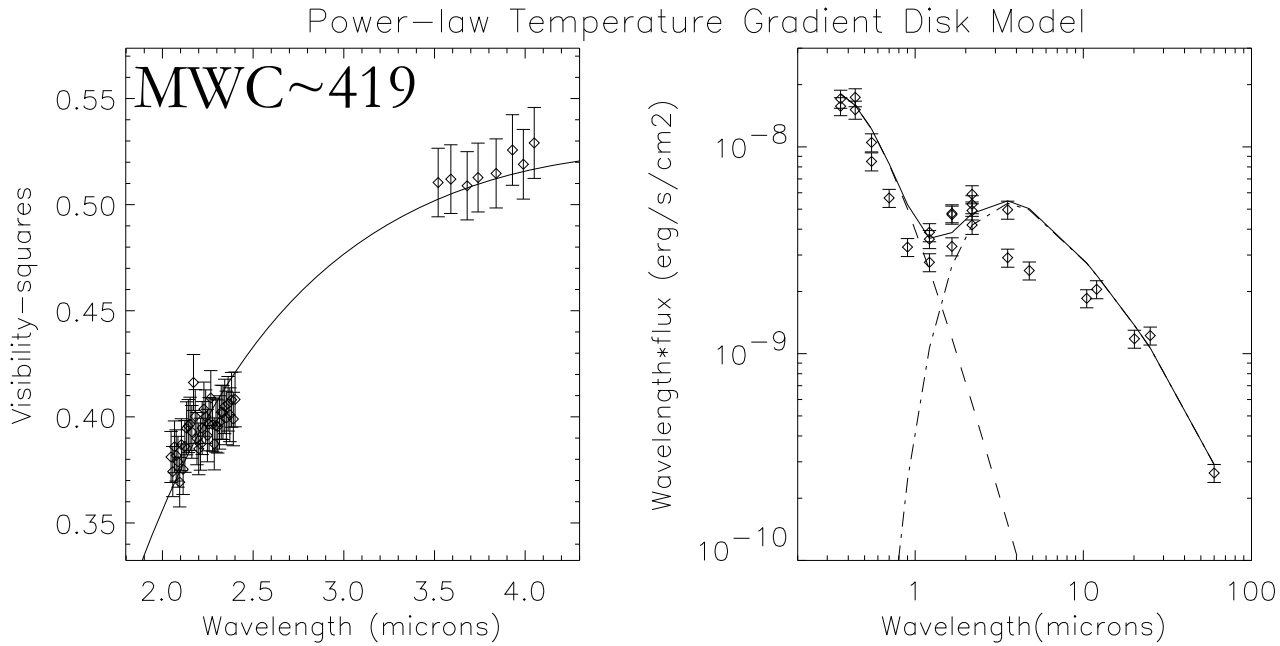
- Accretion disk mode of Hillenbrand et al. (1992)
  - Inner hole size treated as free parameter – 0.54 AU (T_{in} = 1457K)
  - Mass loss rate fixed at unrealistically large value of ~ 3 x 10^{-5} M_{Sun}/yr to satisfy SED
- Fit to V^2 data is not satisfactory; reduced Chi-square is ~ 3

4. Disk Models: Power-law distribution



- T(r) a $r^{-\alpha}$

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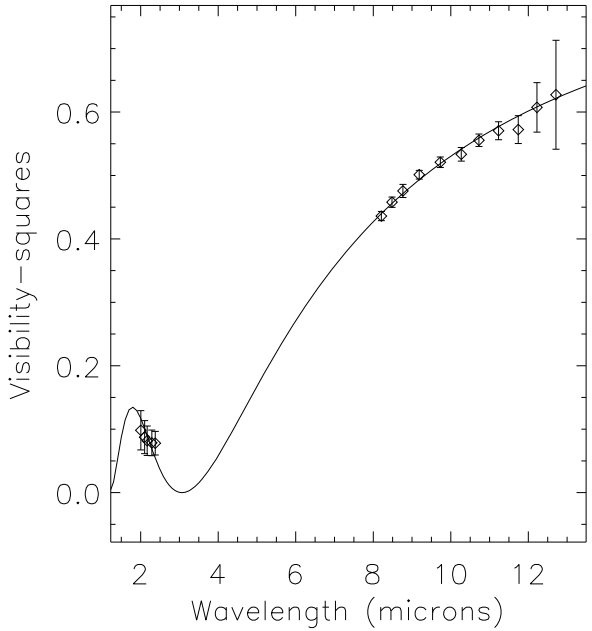
- Temperature of the inner hole fixed at 1800K to satisfy SED
- Inner hole size & α are treated as free parameter
  - hole size: 0.48 AU at 1800K; α = 0.71
- Fixed the outer radius of the disk at 20 AU (~125K)
- Reduced Chi-square for visibility-squares fit ~ 1

4. Disk Models: Power-law distribution

MWC 325

- Temperature of the inner hole fixed at 1500K.
- Inner hole size: 0.77 AU.
- $\alpha = 1.35$ (not consistent with flaring or flat disk geometry).
- Exploring more complex disk models to explain the measurements.
- Observations of a sample of YSO disks in the K-, L- & N-bands is underway to test more complex disk models.



Ragland et al. 2009 (in preparation)

Summary

- Multi-color interferometry at well separated wavelengths have the potential to constrain the YSO disk models.
- Initiated a systematic K, L & N-band observing program to investigate the temperature and density distributions of dust and gas at the inner regions of YSO disks (< 1AU).
- So far, 4 observing runs for this study.
  - 3 half-nights (Team Keck) and one full-night (NASA).
  - Observed 3 targets in the K, L & N bands; 12 targets in the K and L bands; 3 targets in the K and N bands and 1 target in the K band.
- Currently, modeling YSO disks to interpret the results.

Collaborators

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