

Disk Variability: Challenges to High Resolution Studies of Disks

New (and Old) Adventures in Synoptic SED Studies

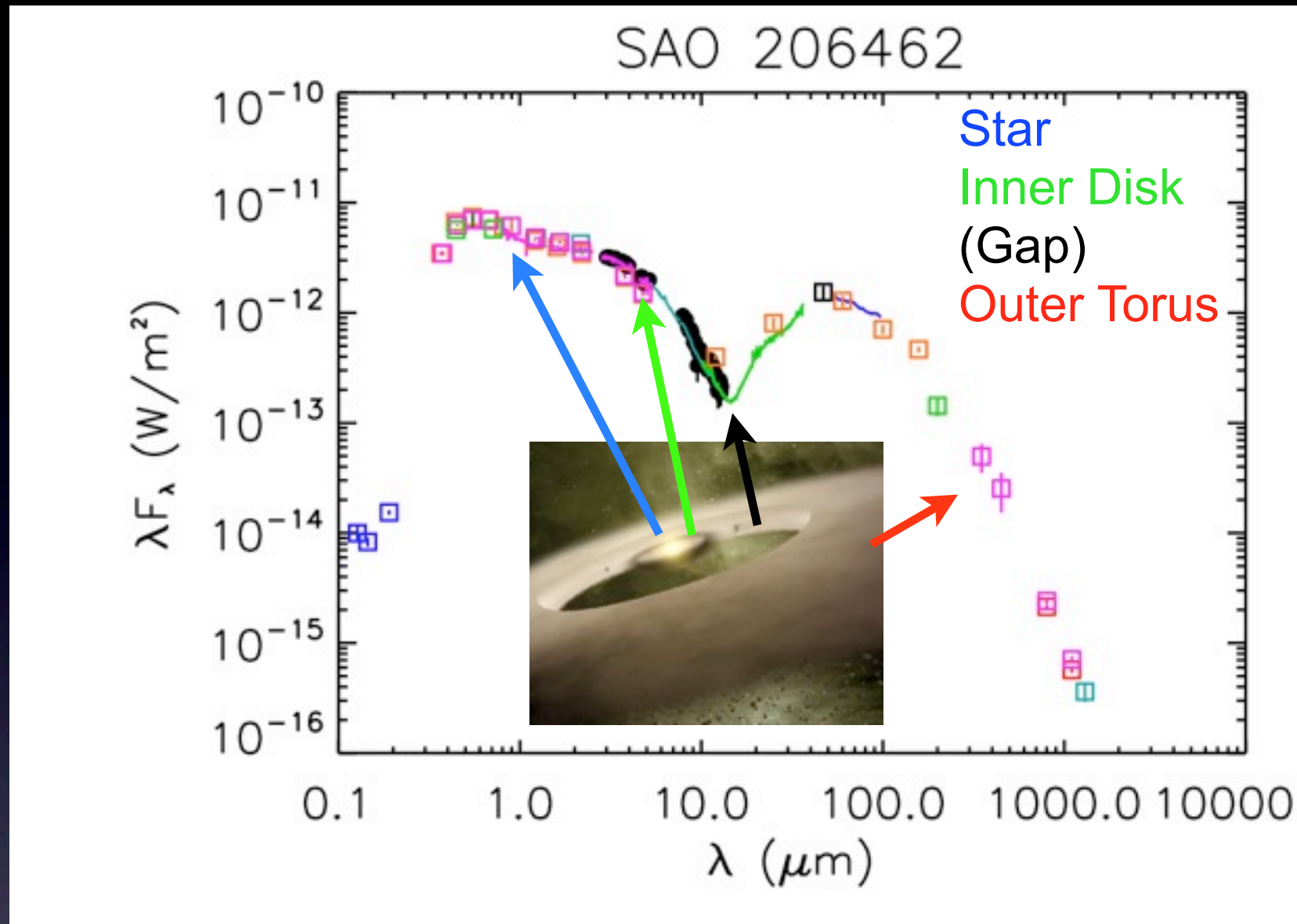
M.L. Sitko

Space Science Institute &
University of Cincinnati



NCAD 2012



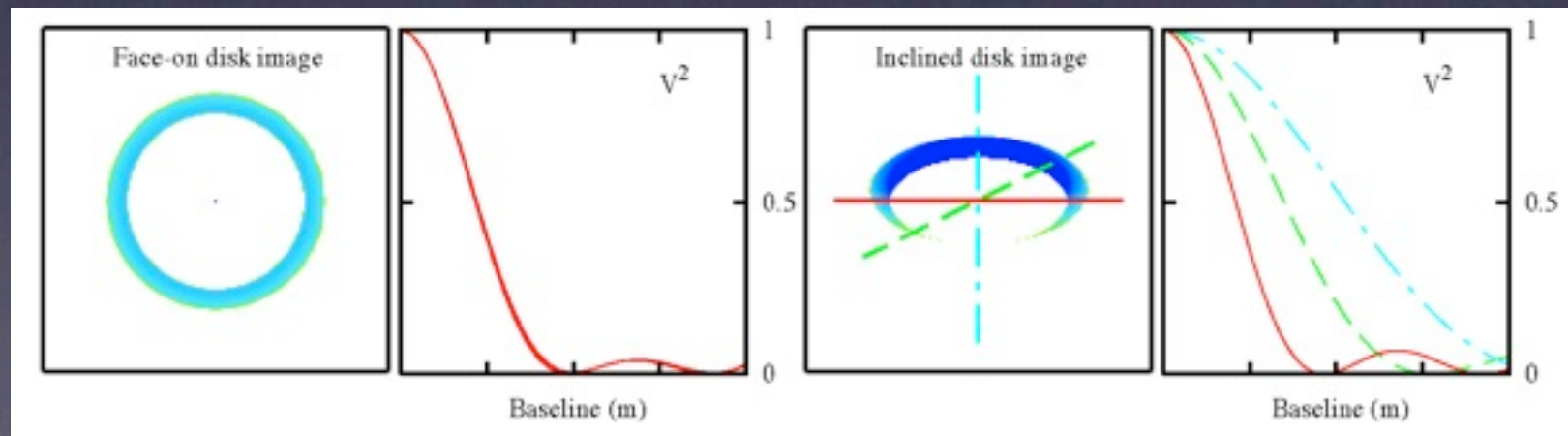
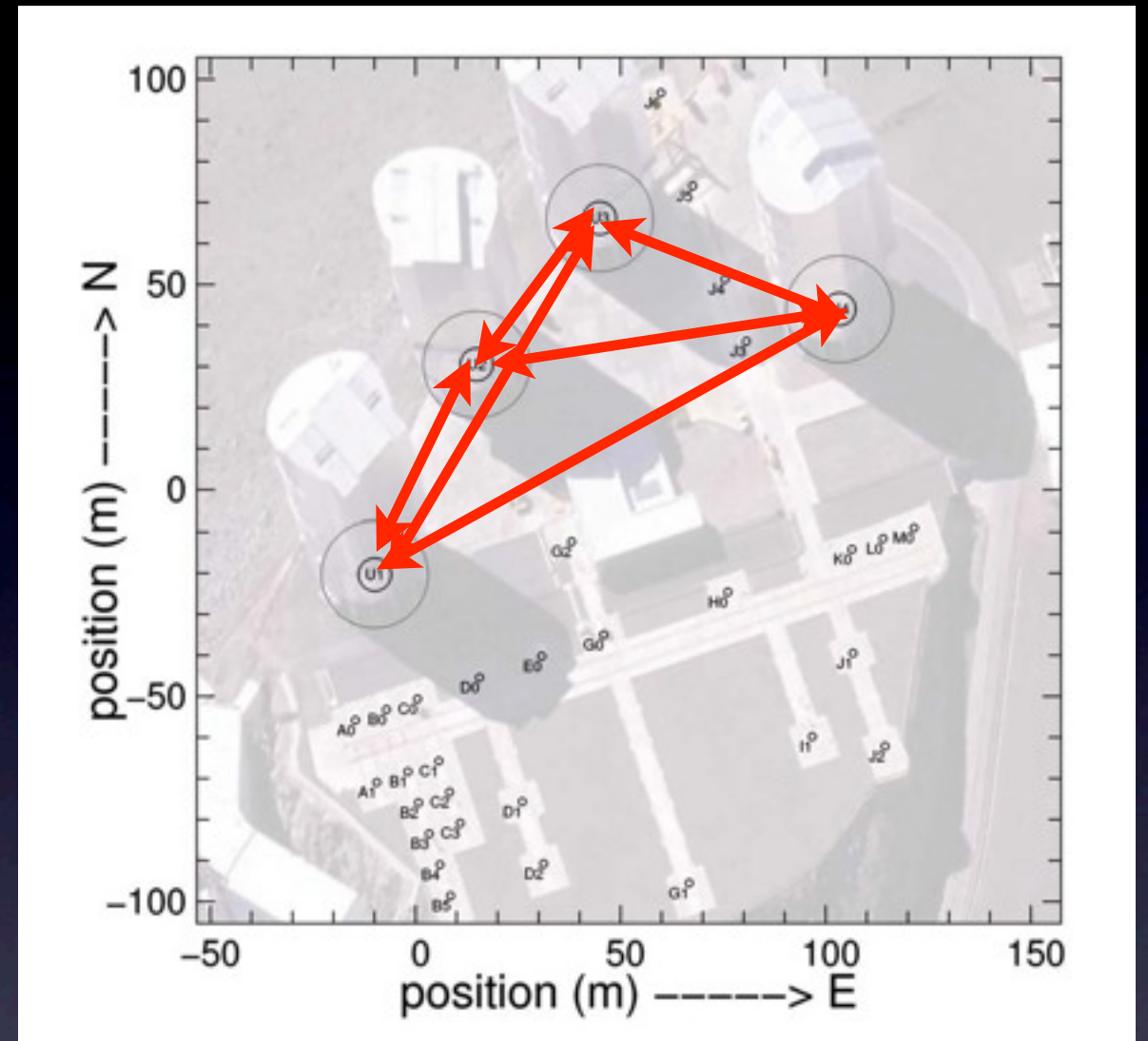
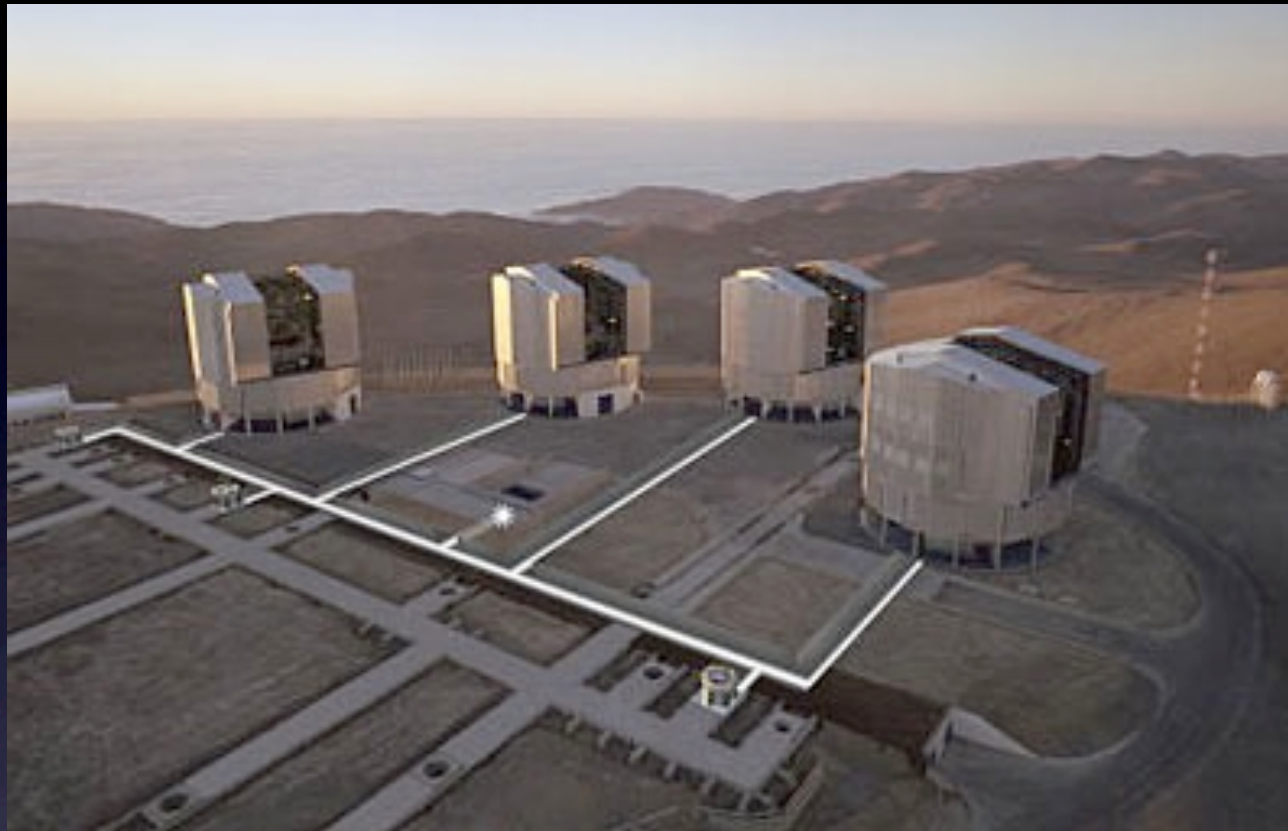


Imaging \longleftrightarrow SED \longleftrightarrow Interferometry

Each relies on information gleaned from other techniques

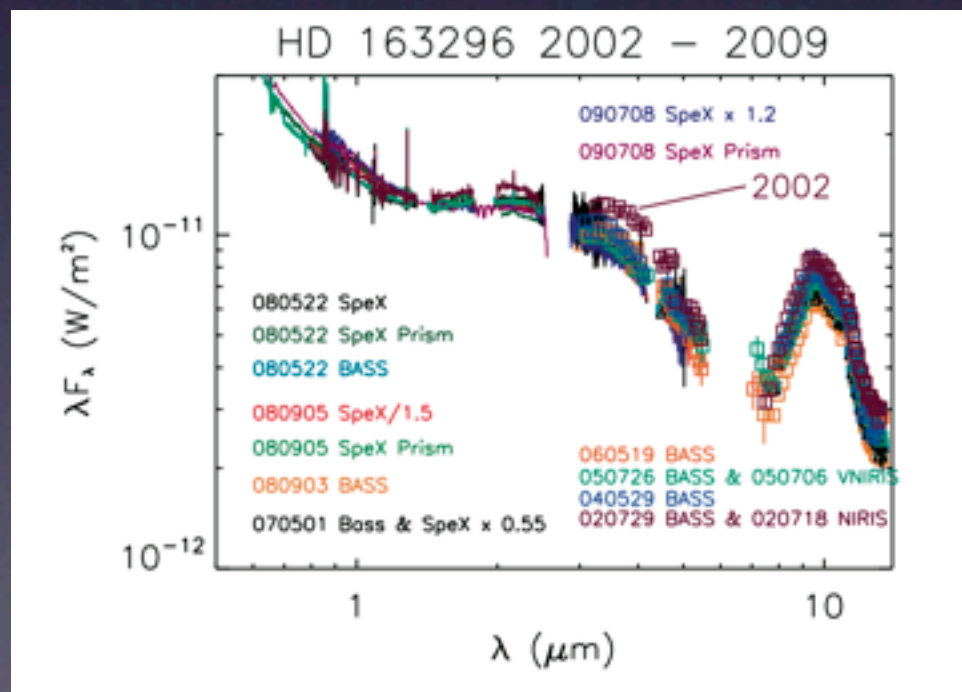
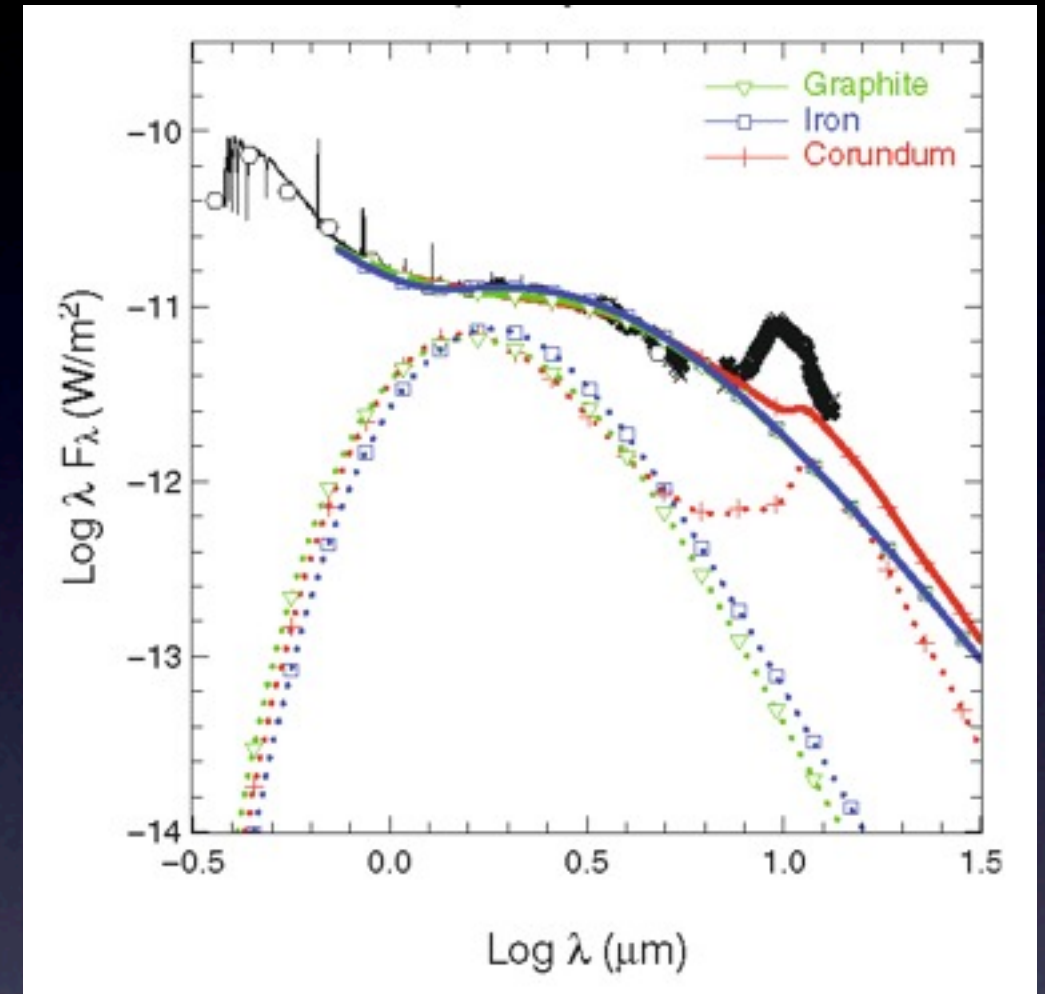
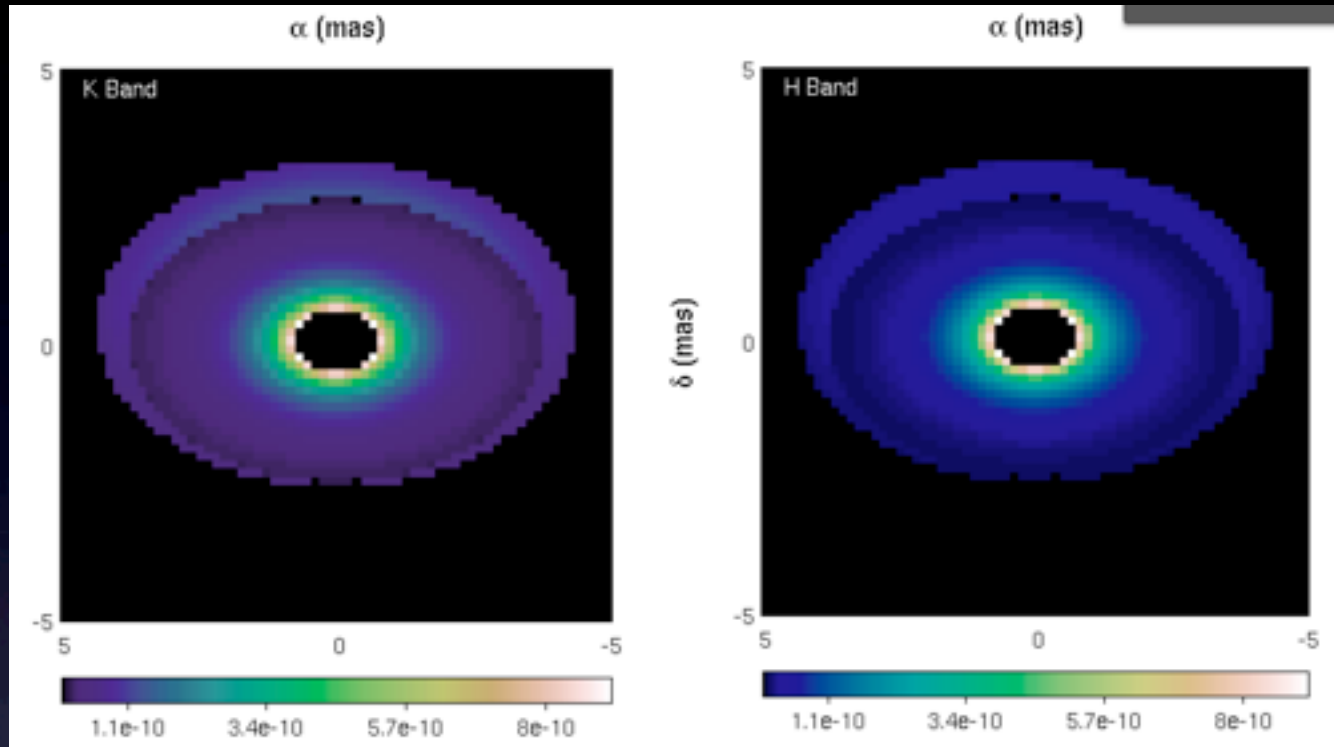
Example: Inner Disk Structure from Interferometry

VLTI



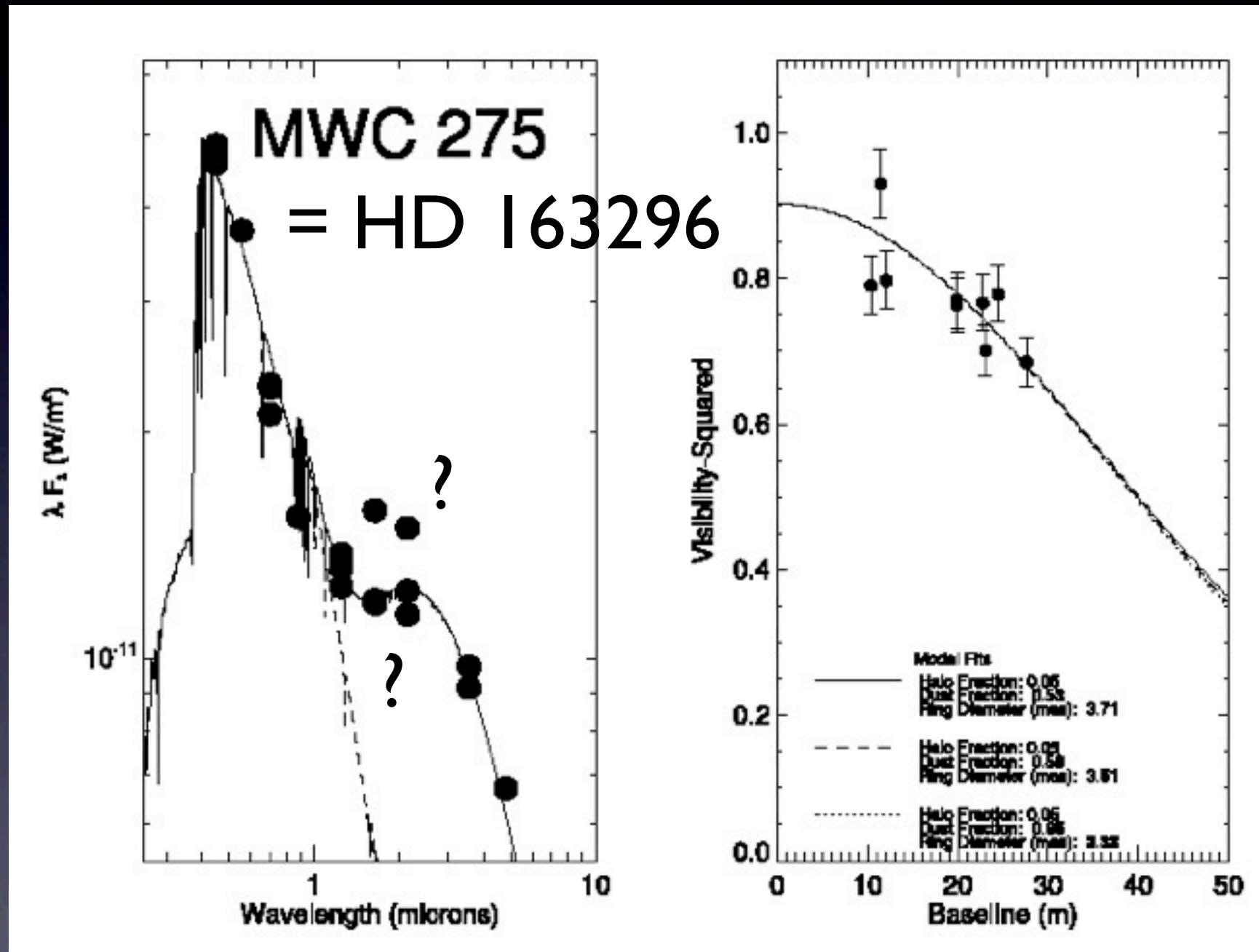
Inner “hole” and inclination from fringe visibilities

Combined VLT/AMBER & SED (BASS & VNIRIS) - Super-refractories in HD 163296 (Benisty et al. 2010)



In this case during relative stability (2007-2008)

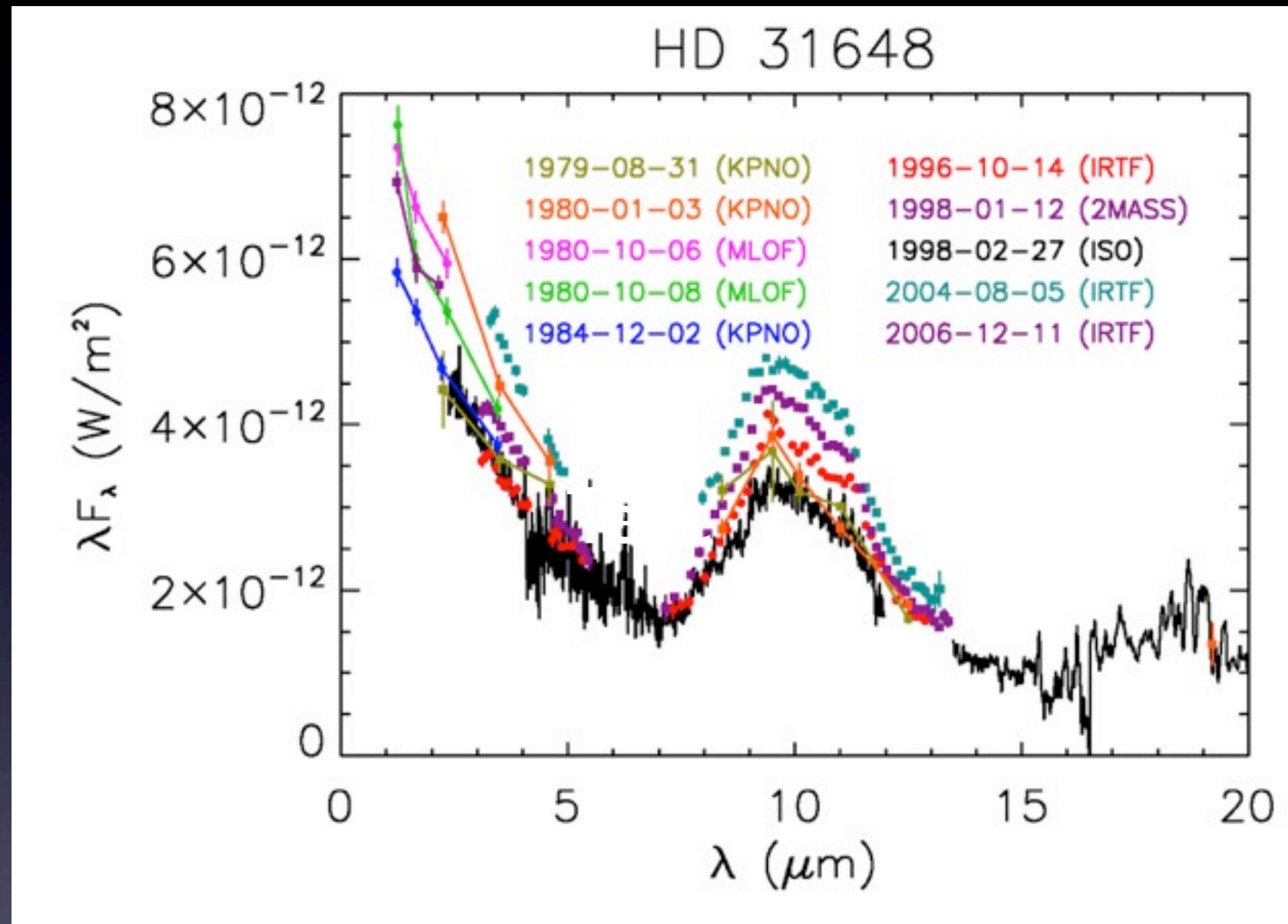
More generally - comparing interferometrically-derived disk models to archival SEDs leads to ambiguities. Which observations to use?



Monnier et al. 2006

Example: HD 31648 = MWC 480

“The IR emission for this star may be variable.” - Sitko (1981)

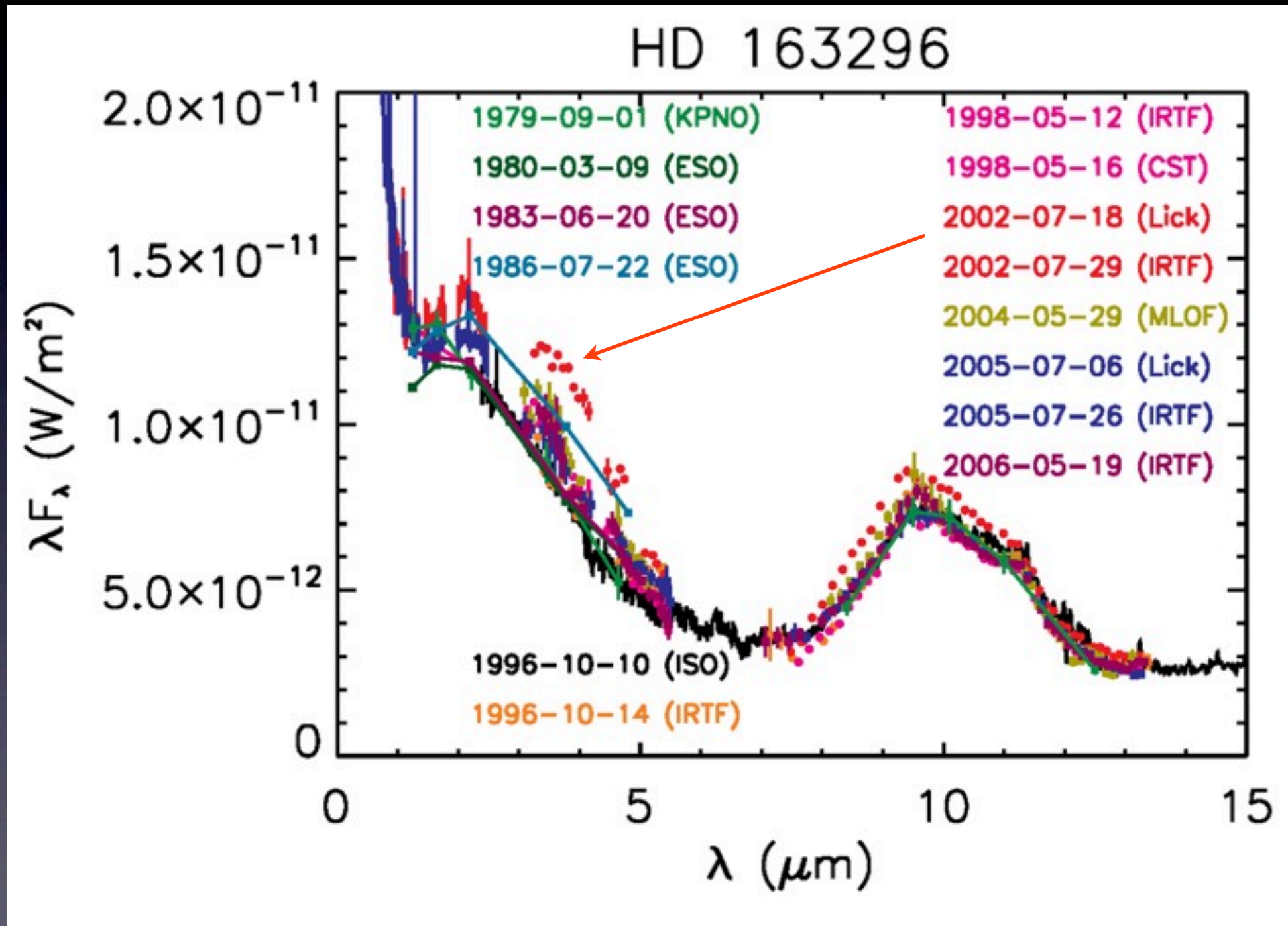


The inner regions of the disk are intrinsically variable
(Sitko et al. 2008)

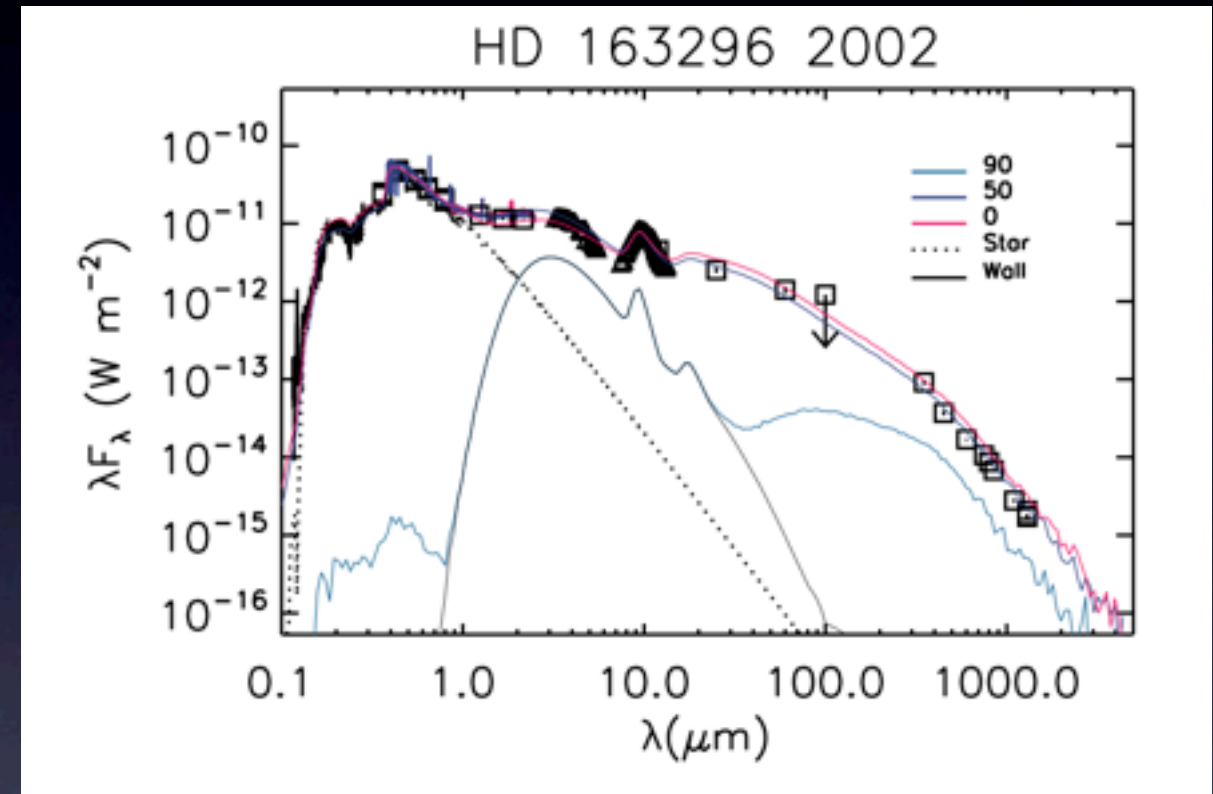
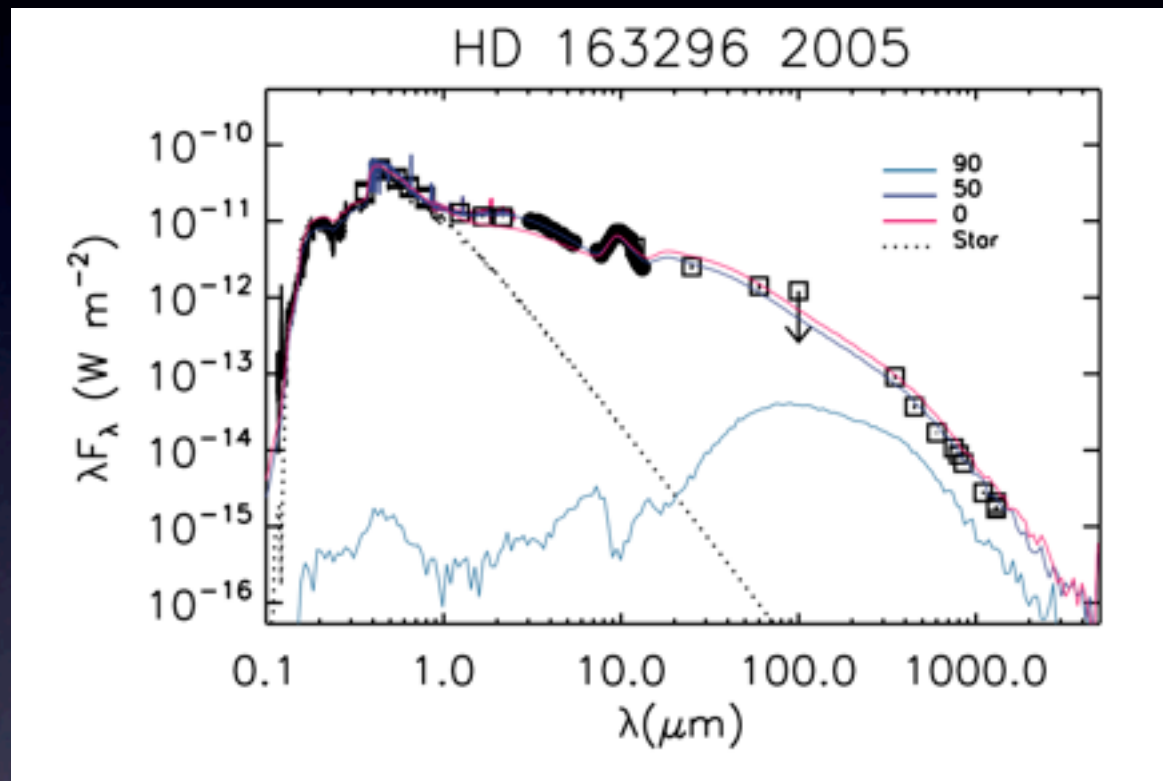
How the 1-5 Micron Variability Affects the Interpretation of the Interferometry and the Imaging

MWC 275 = HD 163296 - 10 Epochs

Major “outburst” in 2002

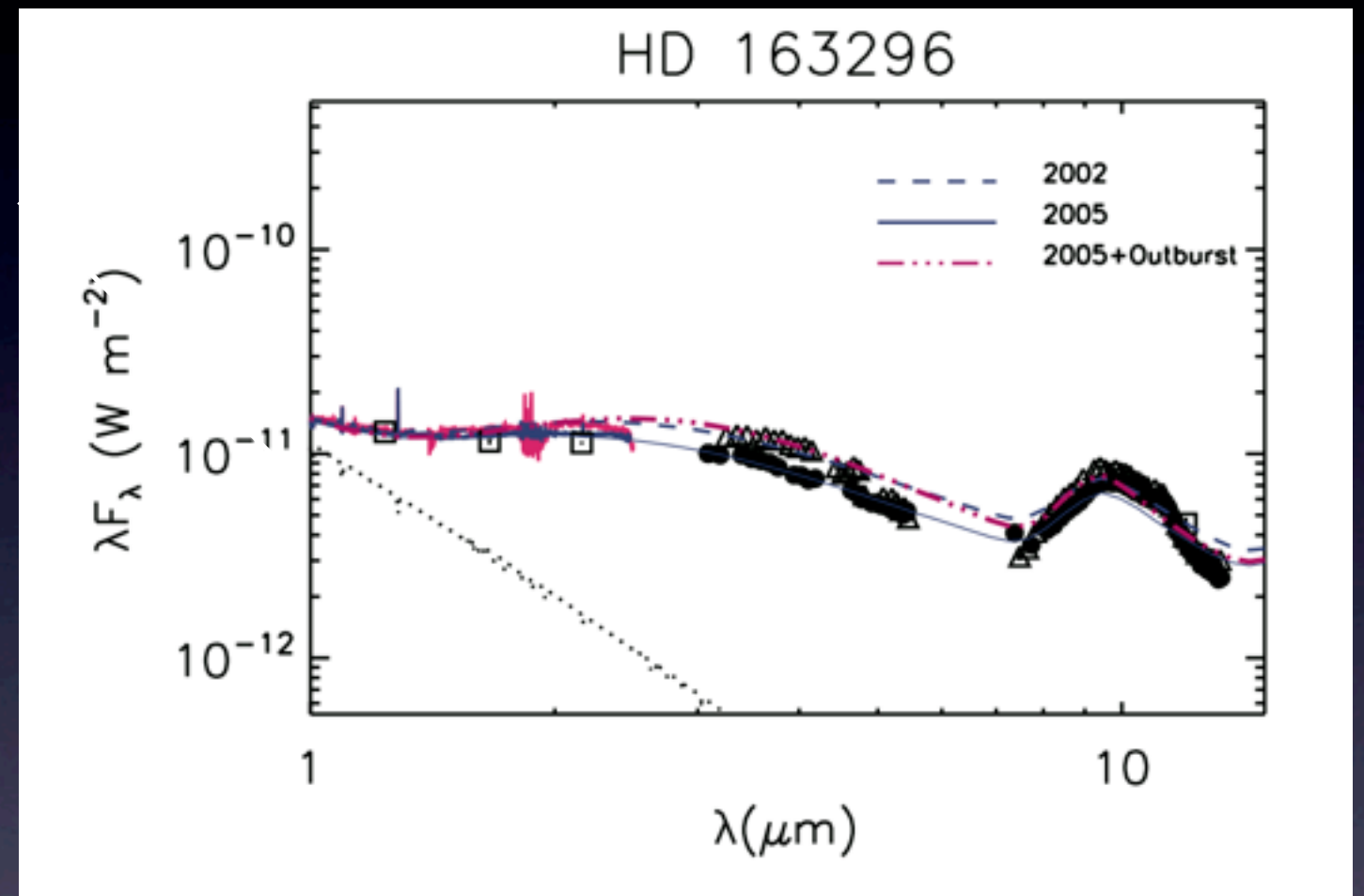
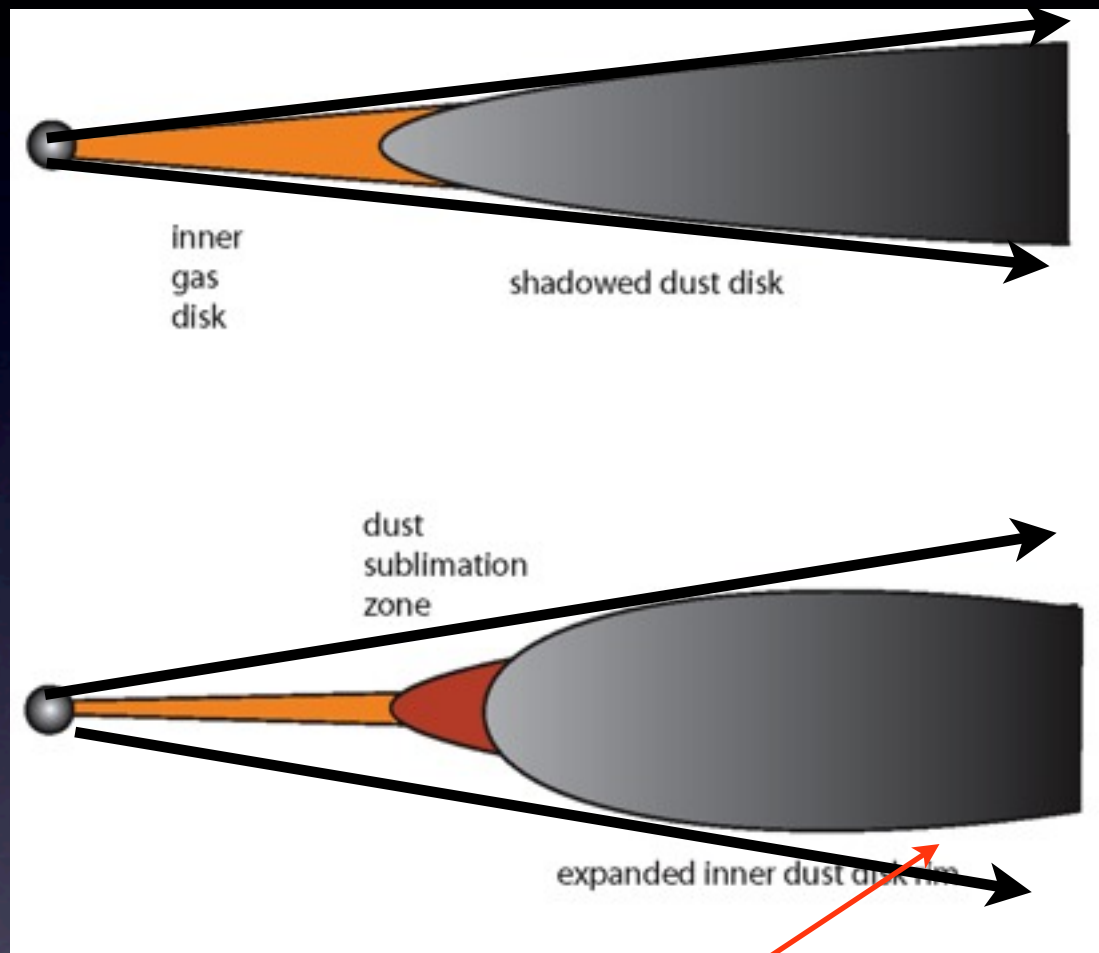


Simplistic Approach to Model the Changes (add simple halo using DUSTY)



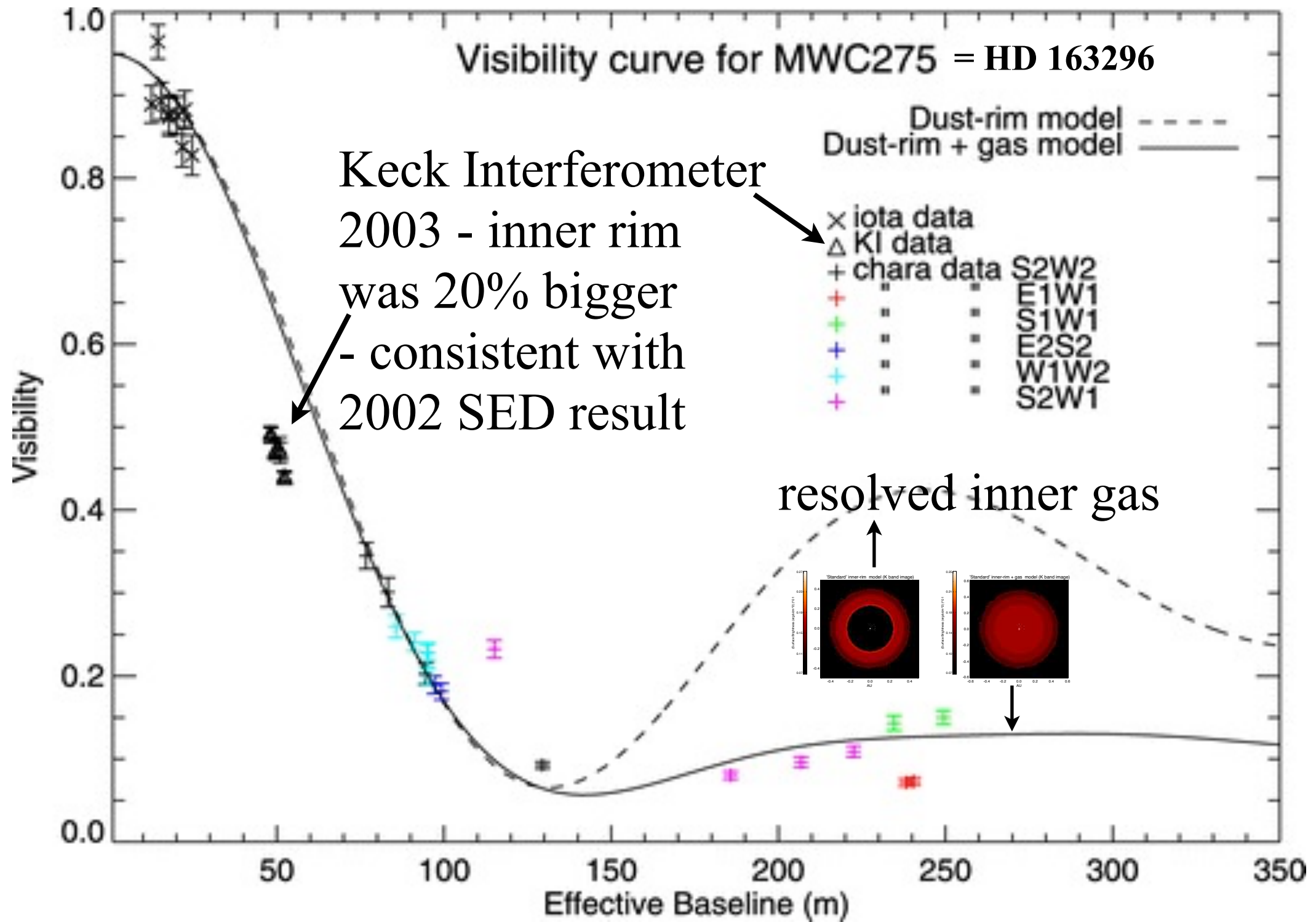
Change the Disk Structure in a Full Radiative Transfer Treatment (Whitney code)

Sitko et al. 2008



Raise inner rim height from 0.12 AU to 0.18 AU
and inner rim radius from 0.29 AU to 0.35 AU
(note that this changes the degree of shadowing of the outer disk)

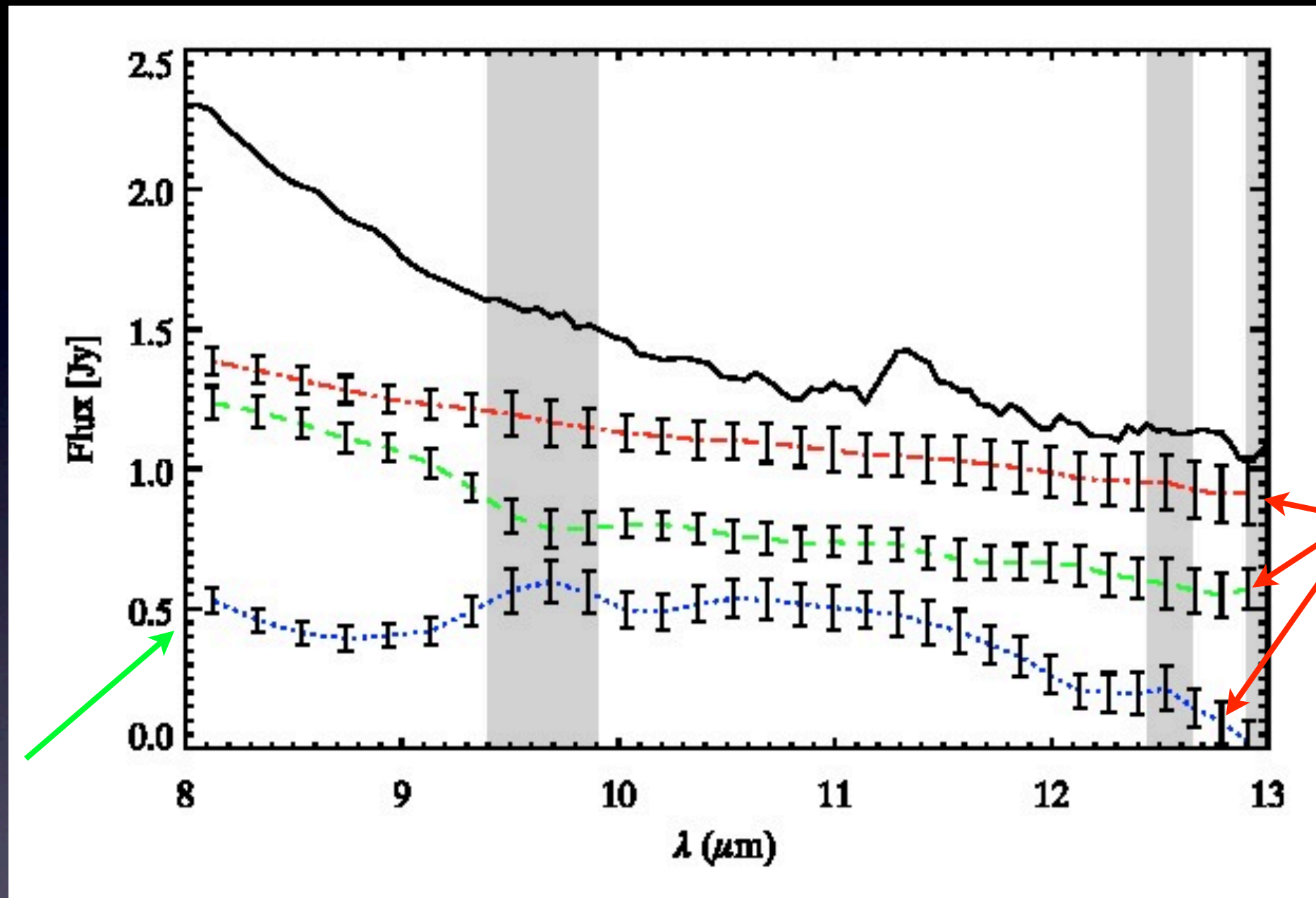
HERE IS HOW IT AFFECTS THE INTERFEROMETRY



Tannirkulam et al. 2008

SAO 206462 - VLTI

Spatially-resolved interferometry (Fedele et al. 2008)



different
baseline

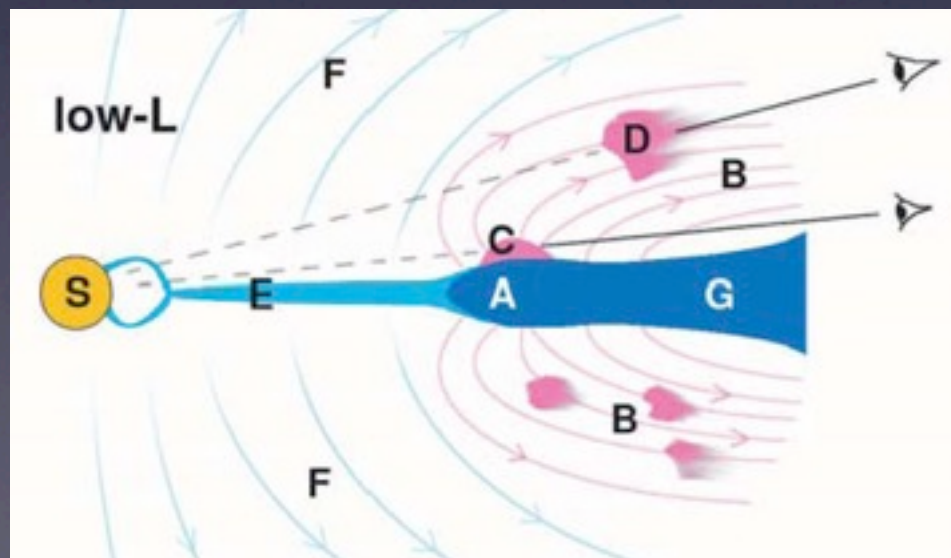
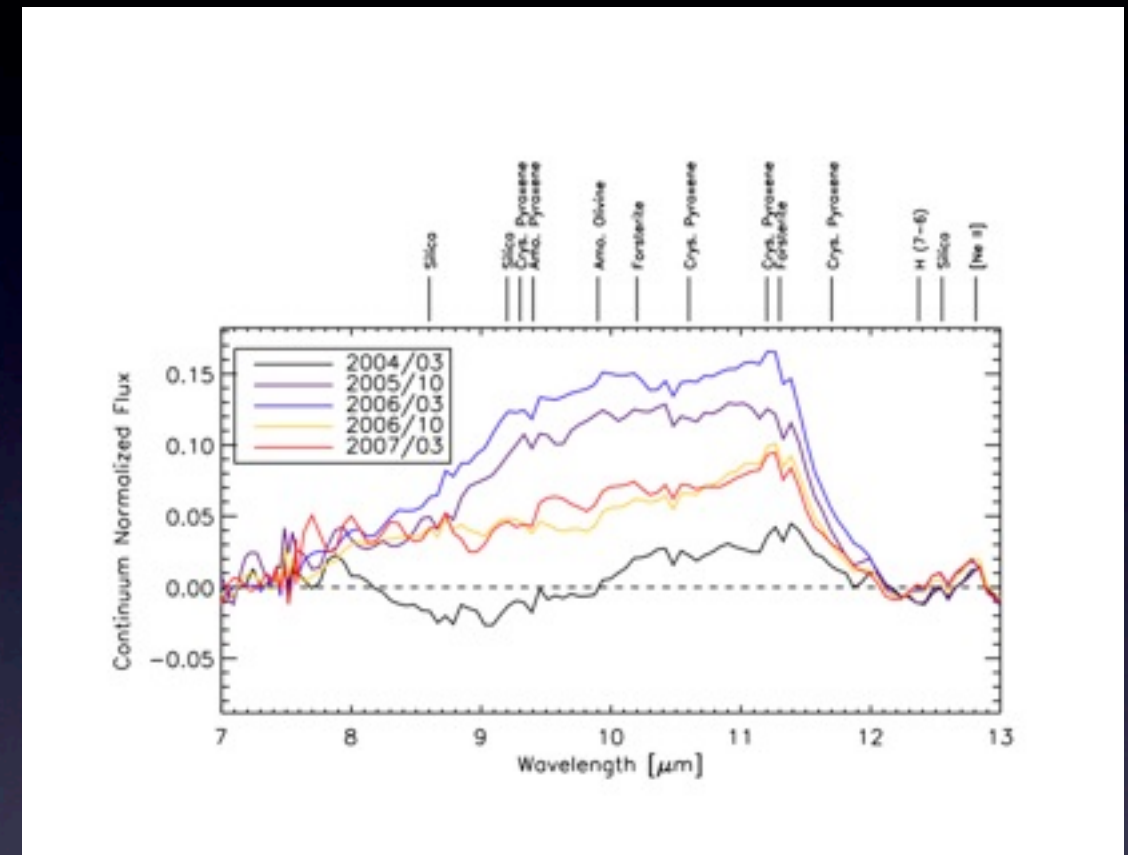
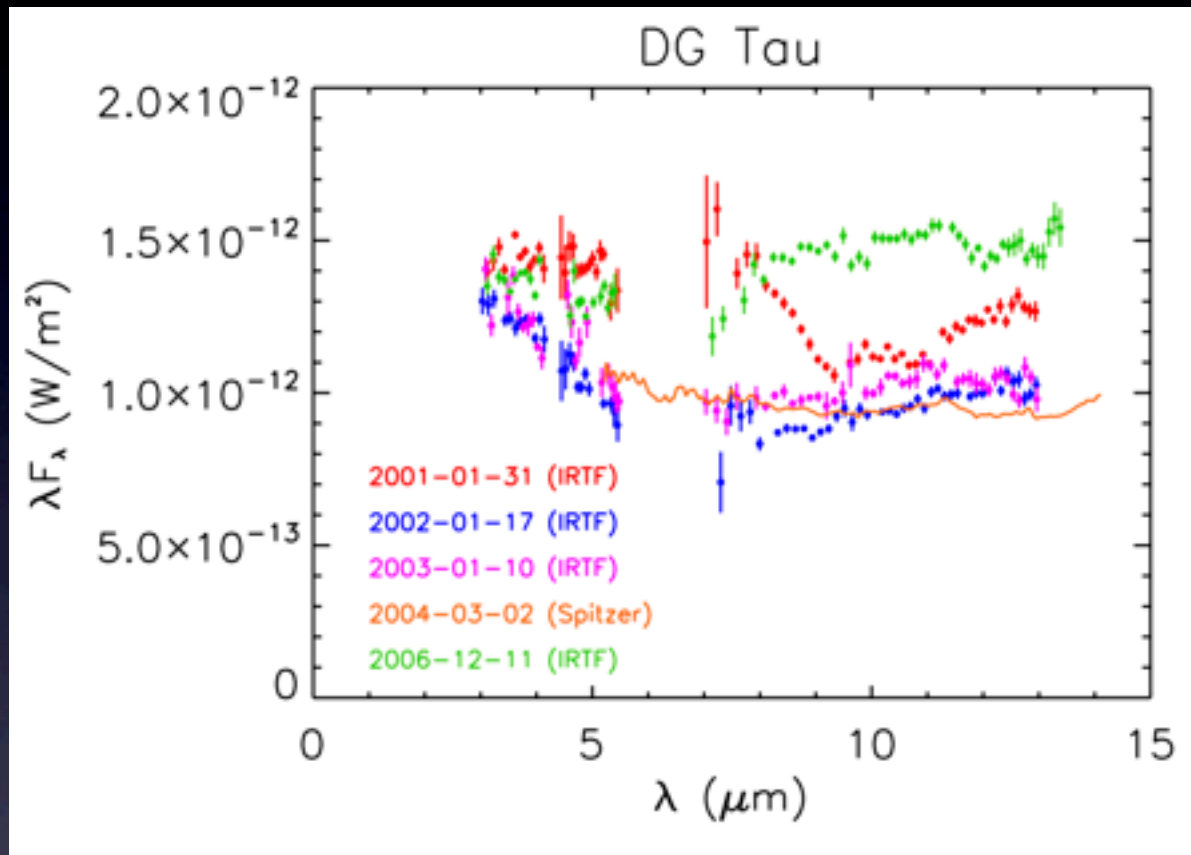
different
dates

...affects spatially resolved spectral features, too??
Silicate band variability?

We already know the silicate band changes in PMS stars - DG Tau

Sitko et al. 2008

Bary et al. 2009



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Vinković & Jurić 2007

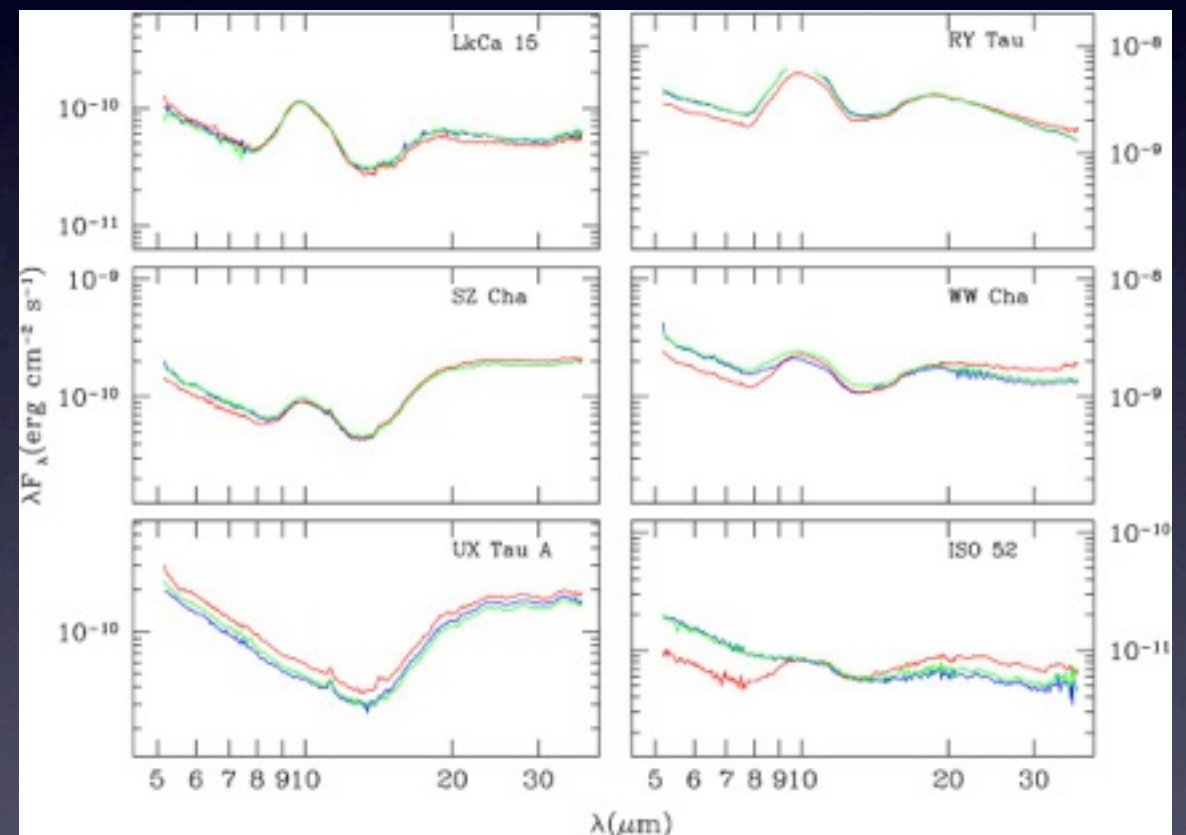
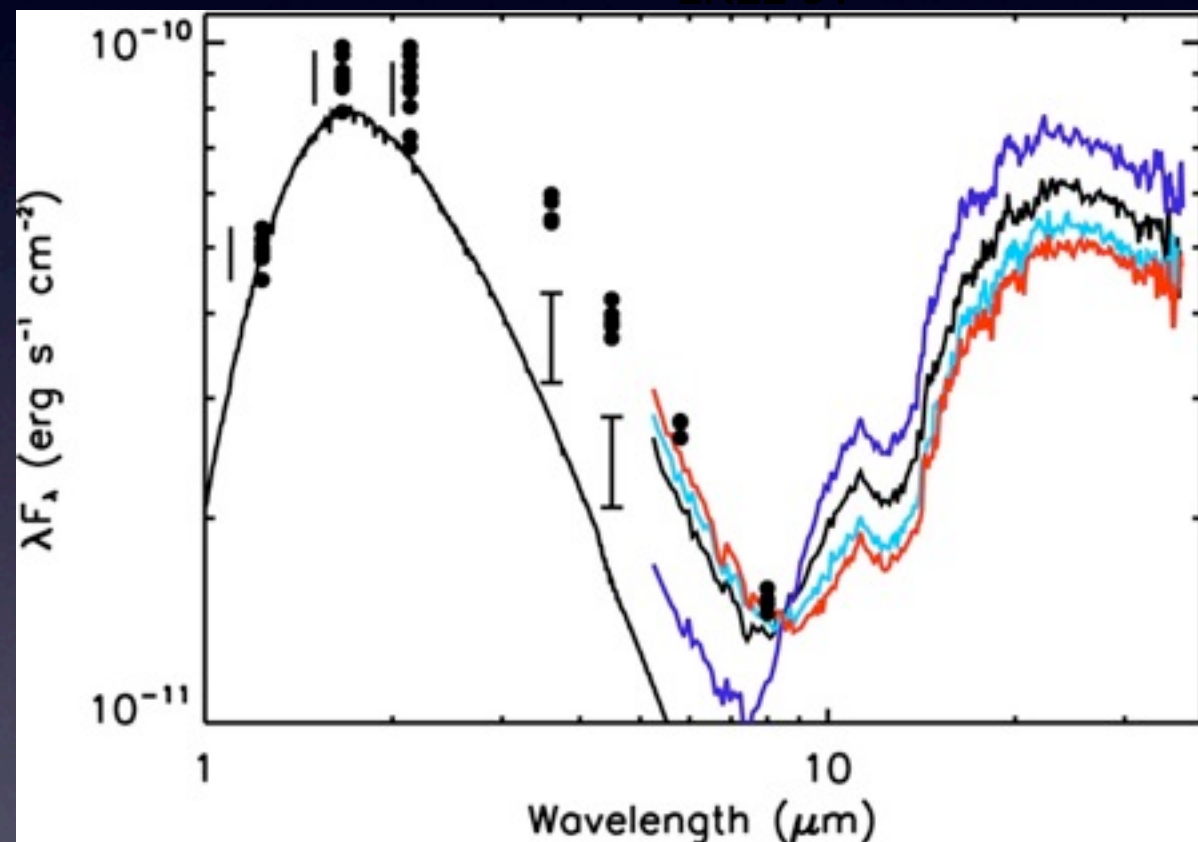
The View from Spitzer: “See-saw” Variability

Raising inner rim height increases near-IR emission but decreases irradiation of the outer disk.

Muzerolle et al. 2009
Flaherty et al. 2011

Espaillet et al. 2011

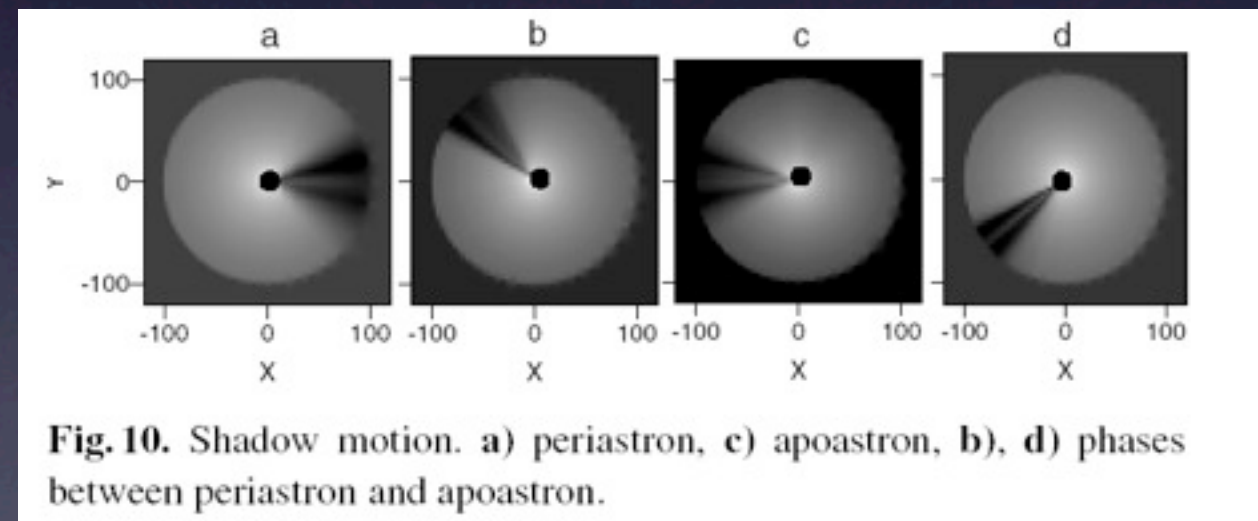
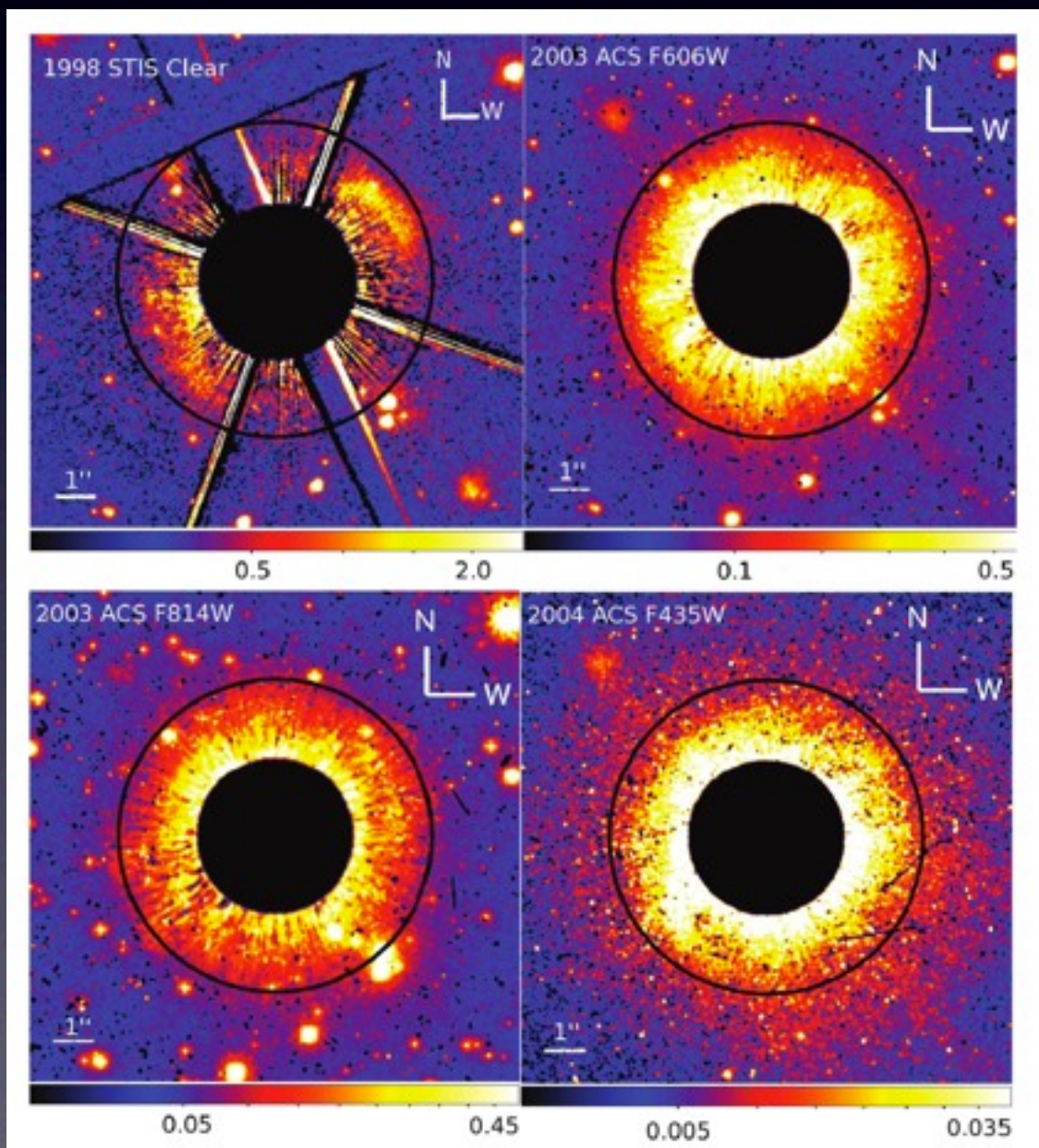
LRL 31



Changing inner rim geometry will change the heating of the outer disk, AND THE SCATTERED LIGHT COMPONENT

Variations in Disk Shadowing
 (Wisniewski et al. 2008
 Fukagawa et al. 2010)
 MWC 275 = HD 163296

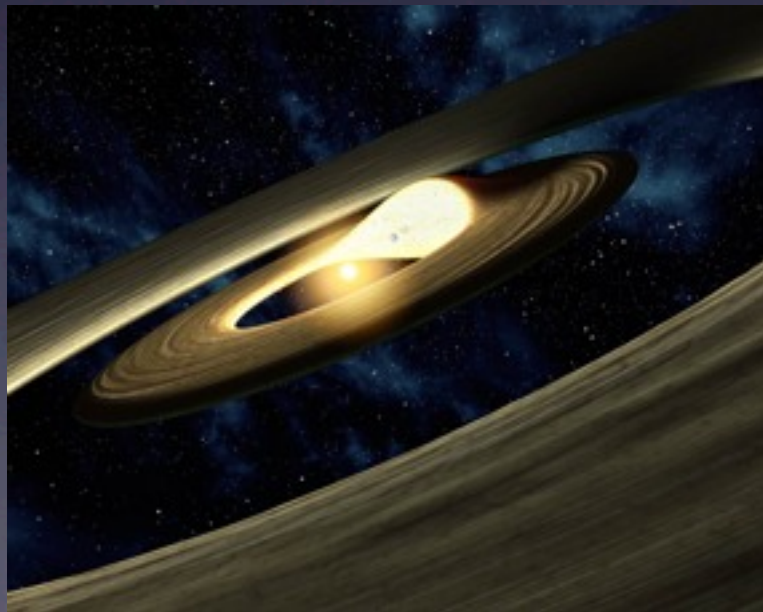
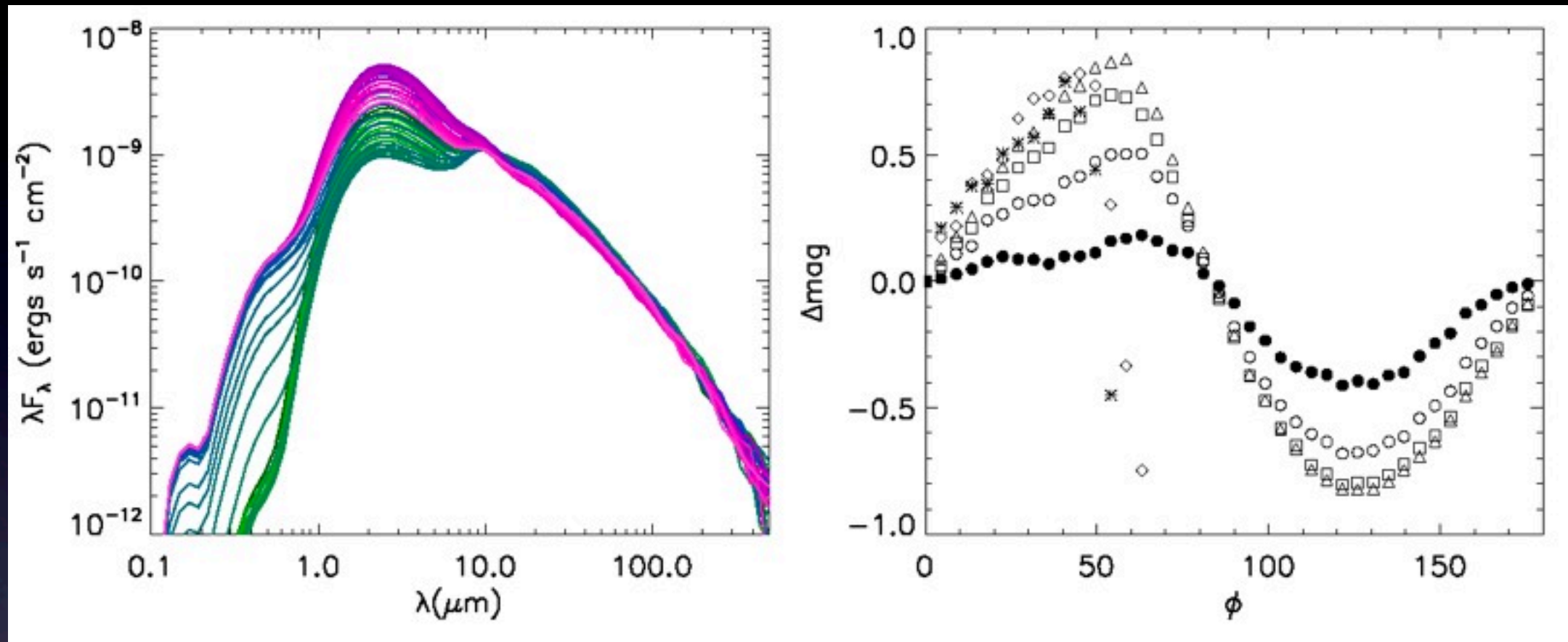
Actually an “old” idea:
 “The alterations in the
 appearance of the nebula
 NGC 6729 are apparently
 caused by the shadowing
 effects of clouds which are
 very close to the star...” -
 Graham & Phillips 1987



Moving shadows -
 Tambotsvena et al. 2006

Precessing Inner Disk Warp

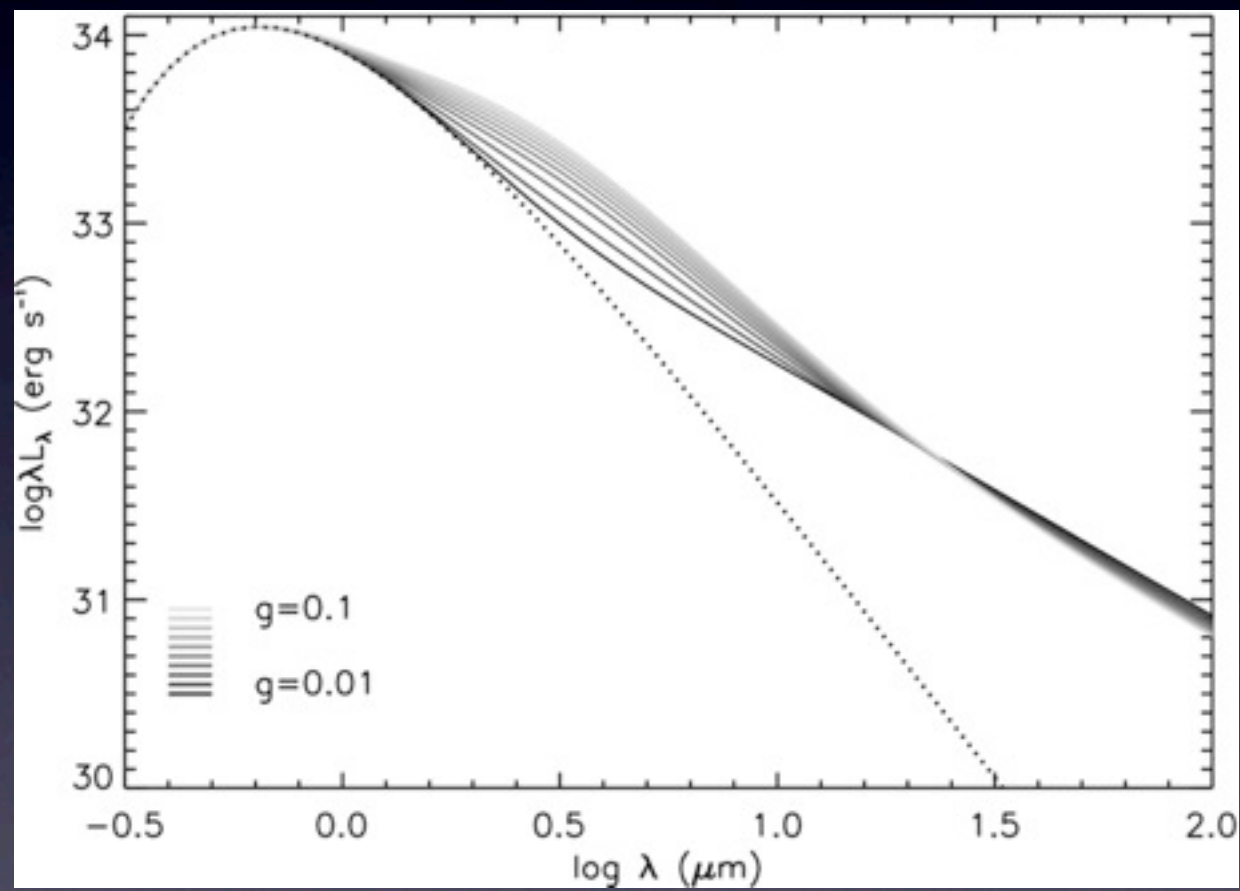
(Morales-Calderon et al. 2009 but see a pre-print version!)



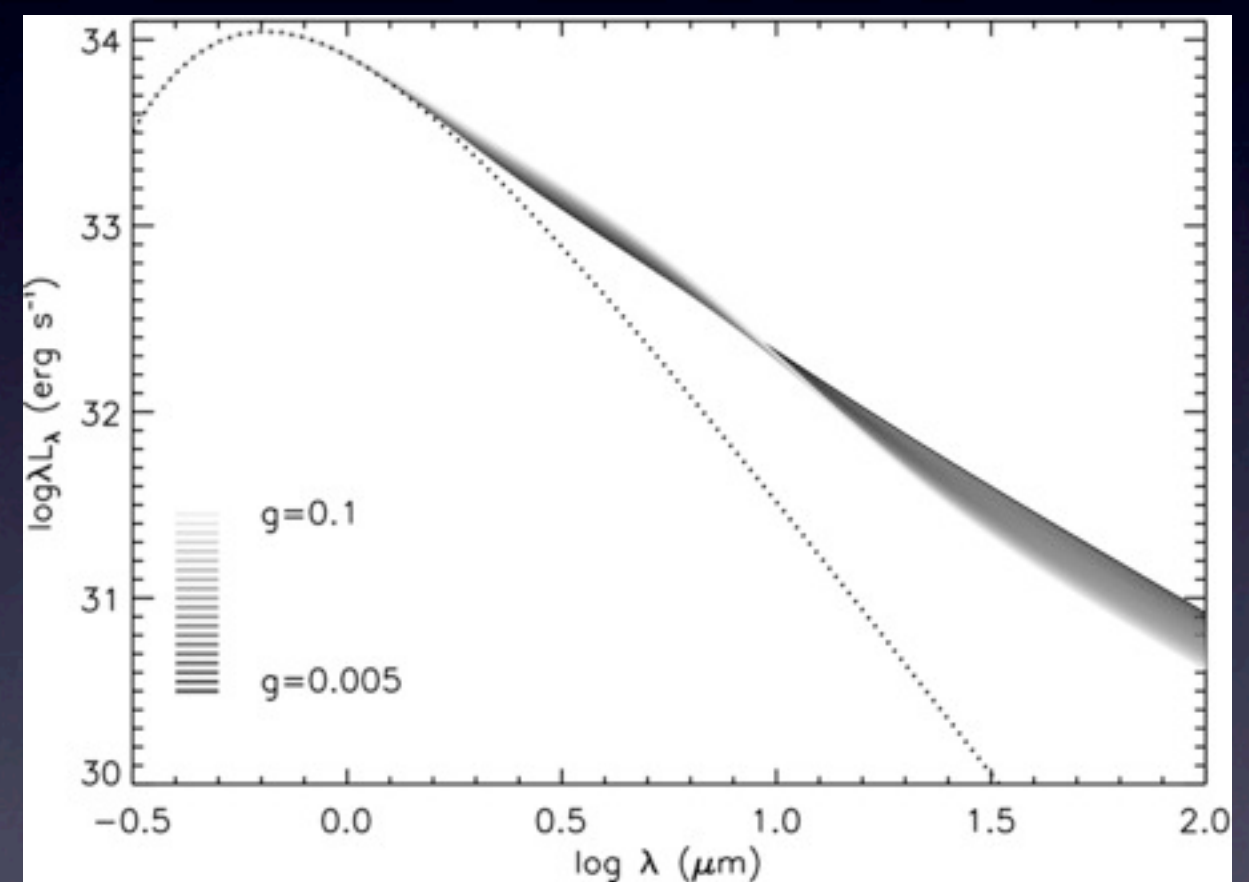
Planet-disk warps
Will they shadow the
outer disk sufficiently?

Flaherty & Muzerolle 2010

Growing Inner Disk Warp



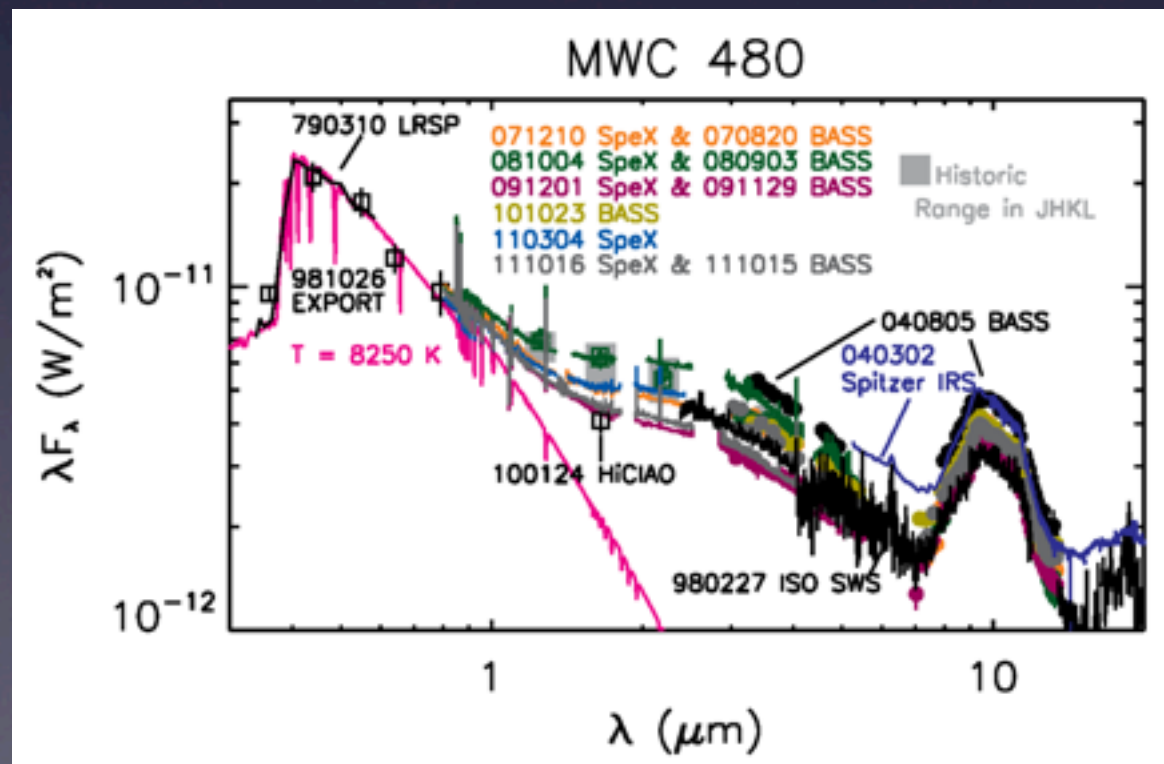
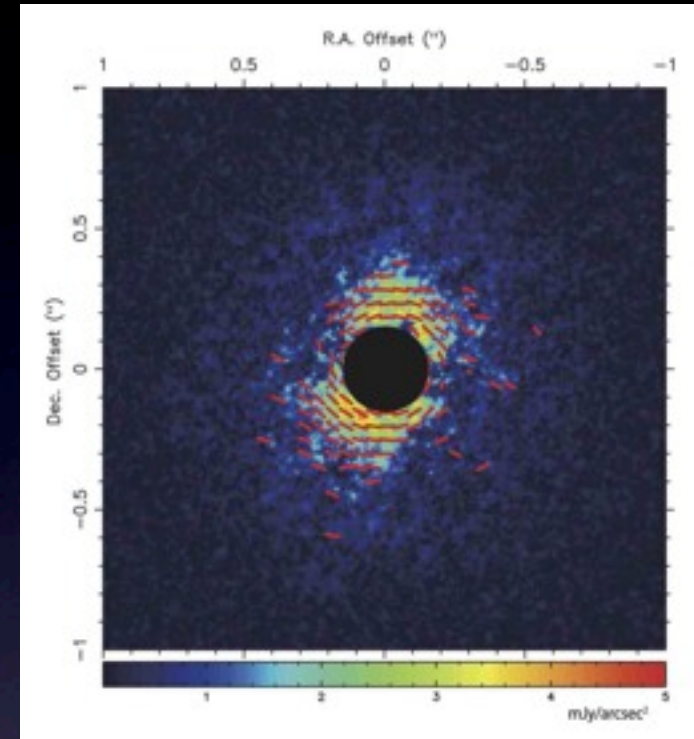
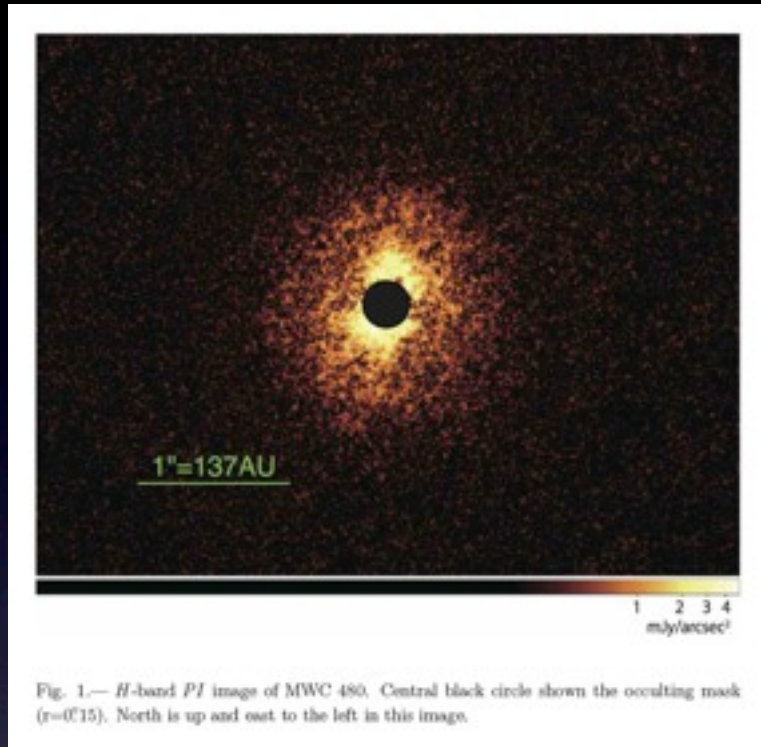
Growing Spiral Arm



Coordinating SED Observations with High Contrast High Spatial Resolution Imaging (adaptive optics coronagraphic observations)

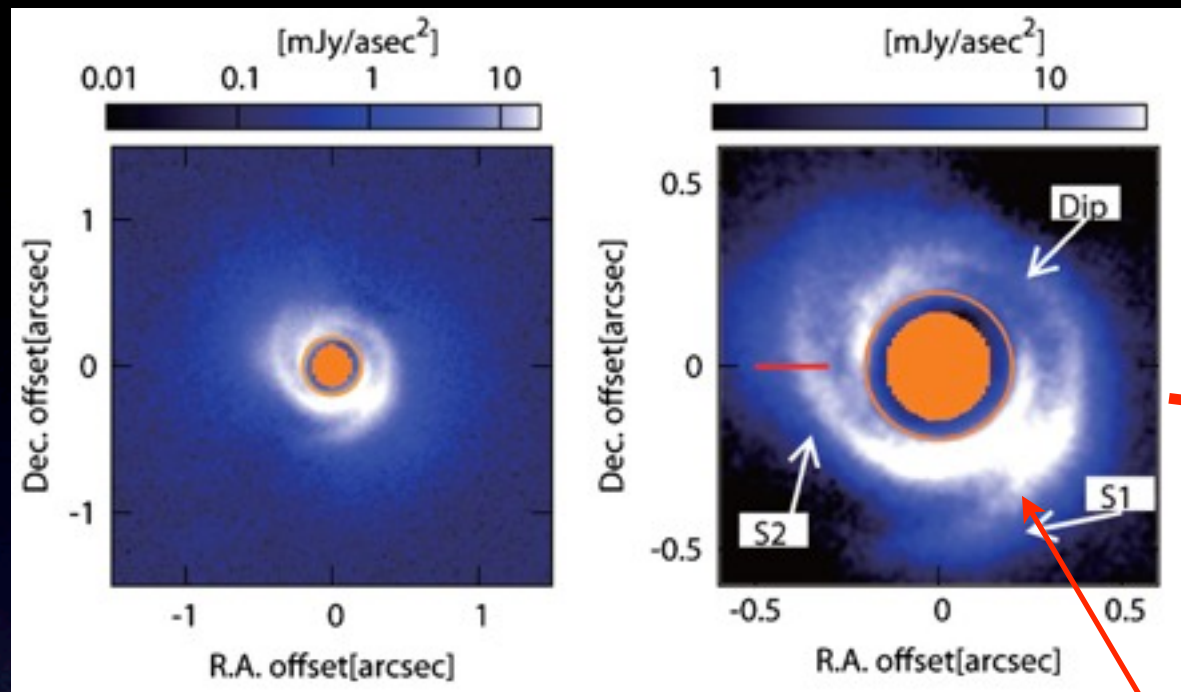
Subaru/HiCIAO and IRTF/SpeX & BASS

MWC 480 - Kusakabe et al. 2012

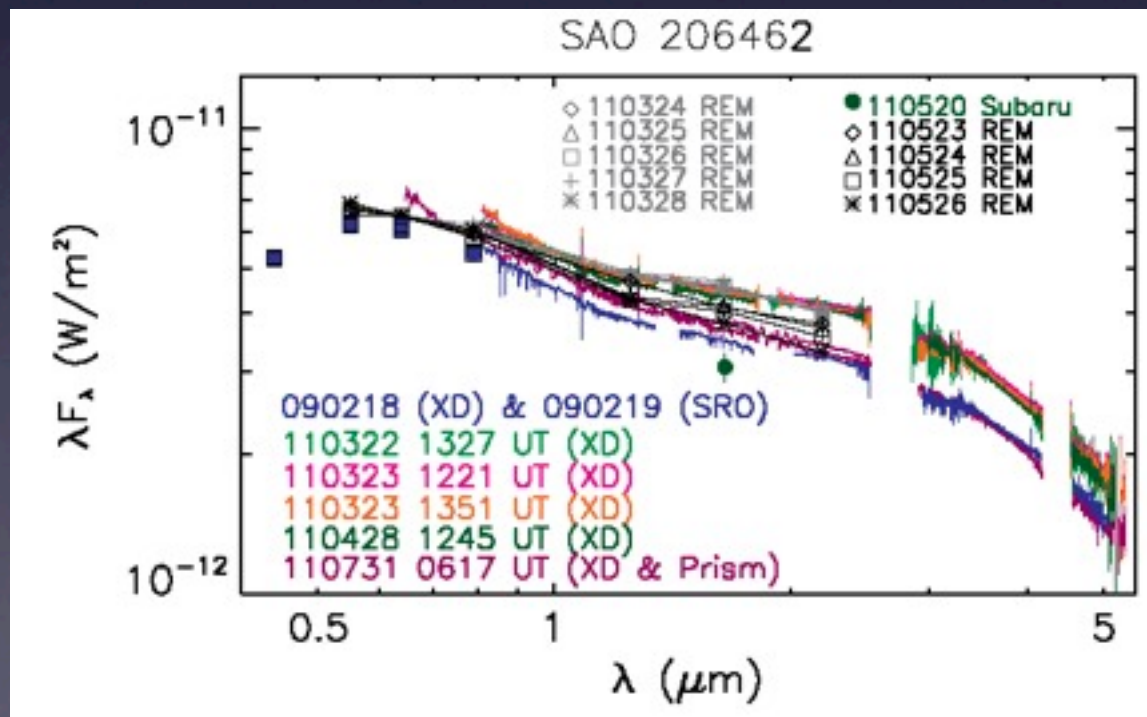


Subaru/HiCIAO observations were made when MWC 480 was at or below historic minimum! This maximized outer disk scattered light. Important to know!

SAO 206462 (HD 135344B) - Muto et al. 2012



20 May 2011



Inner wall height determines scale height that spiral arm material must reach to be illuminated

Coordinated Observations with Interferometers - Keck and VLT

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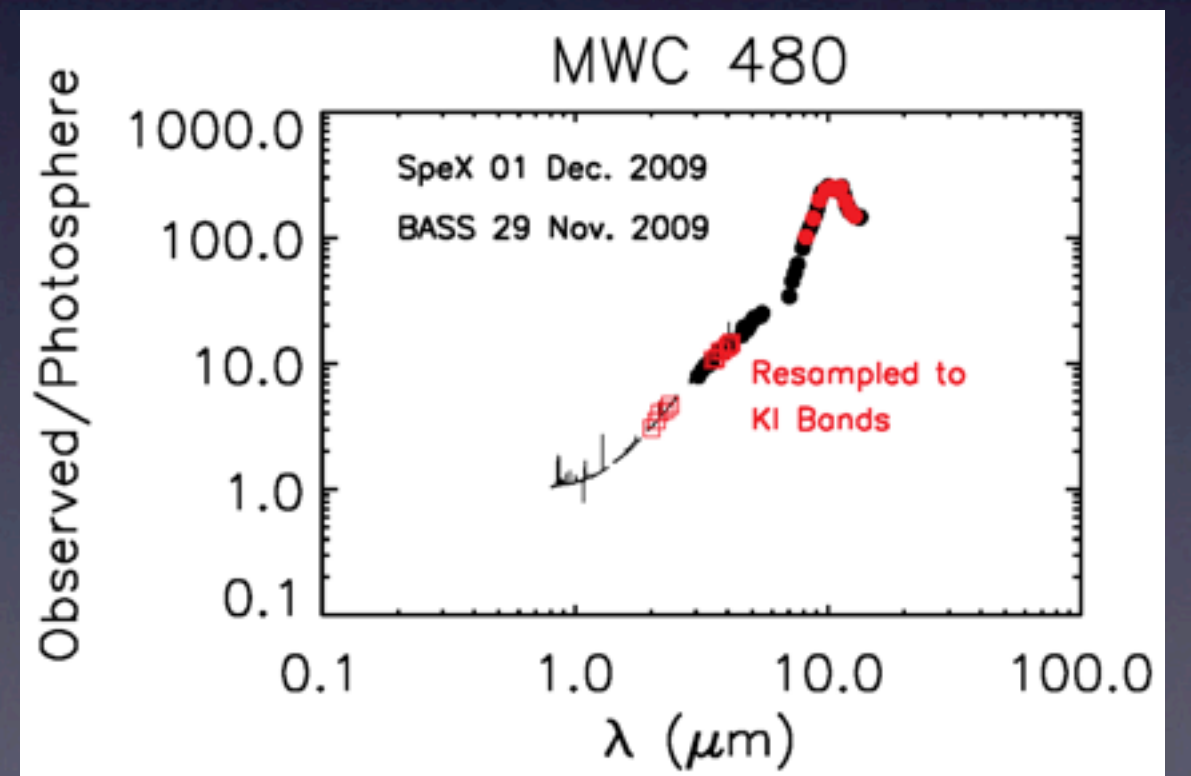
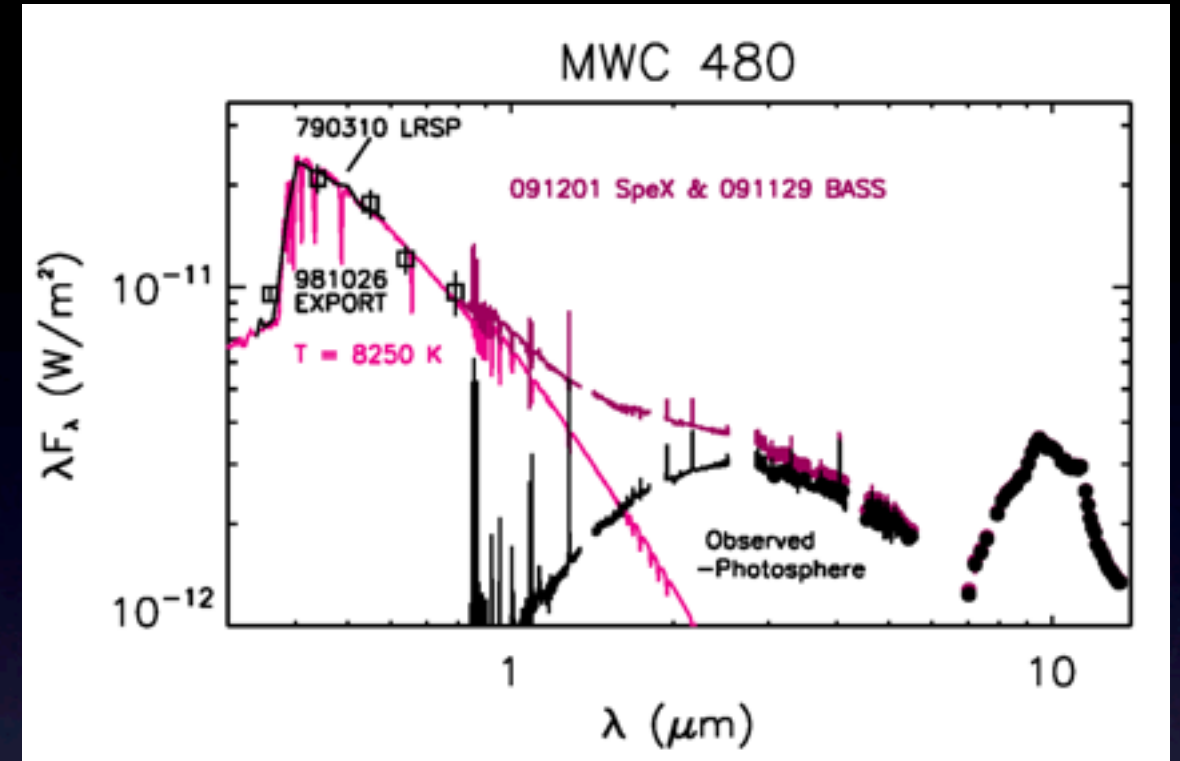
Che et al. (in preparation)

	Keck Interferometer:	IRTF SpeX: $0.8 - 5 \mu m$	IRTF BASS: $3 - 13 \mu m$
MWC 275	2009-07-07 2011-03-22	2009-07-08 2011-03-23	2009-07-14&16
MWC 480	2009-10-26 2012-03-02	2009-12-01	2009-11-29
AB Aur	2009-10-26	2009-12-01	2009-11-29
V1057 Cyg	2009-07-07 2010-09-21	2009-07-10	2009-07-16 2010-10-23
SU Aur	2010-09-21		2010-10-23
MWC 758	2010-09-21		2010-10-24

SED “Product”

SAO 206462

VLT: 2012-02-23 : IRTF 2012-02-24
 2012-03-01
 2012-03-02 ↔ 2012-03-02
 2012-03-27
 2012-03-28 ↔ 2012-03-28
 2012-03-29 ↗ 2012-03-30



Scheduled Subaru AO Imaging

Scheduled IRTF

2012-09-10

2012-09-11

2012-09-12

2012-09-13

2012-11-03

2012-11-04

2012-11-05

2012-22-06

2012-11-18

2012-12-31

2013-01-01

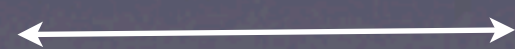
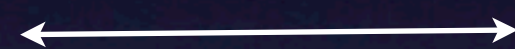
2013-01-02

2012-09-12

2012-11-04

2012-11-17

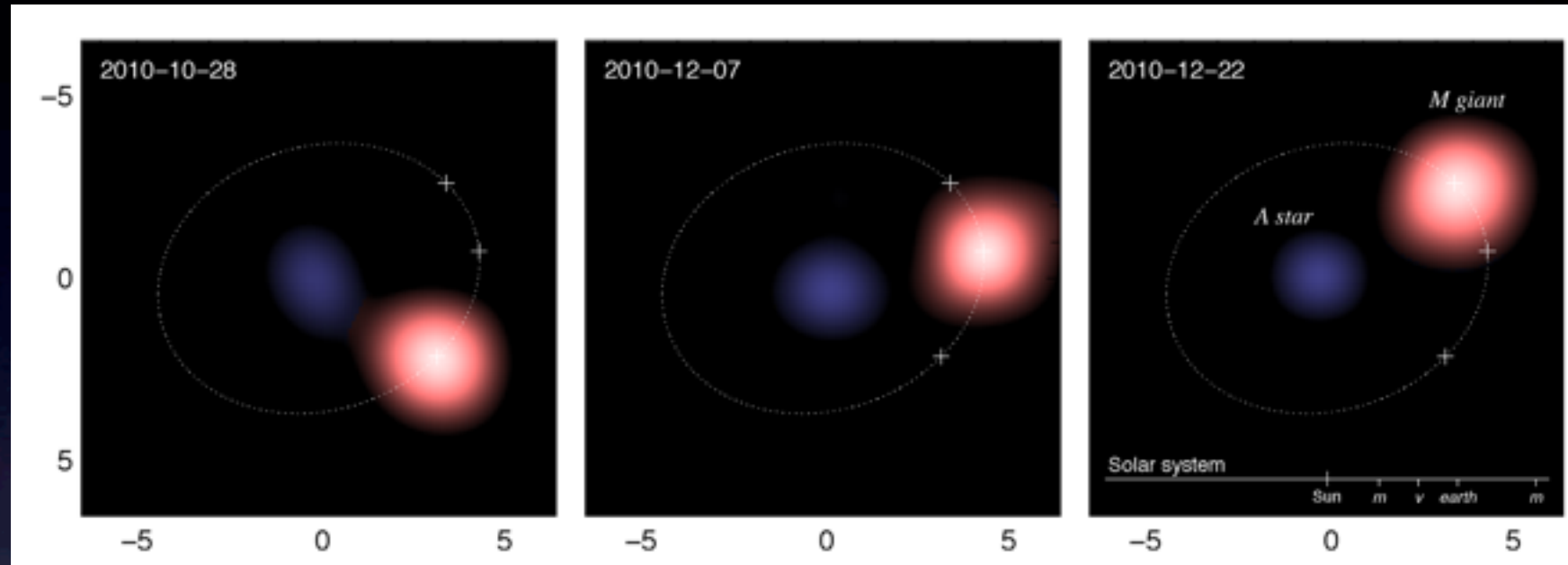
2013-01-02



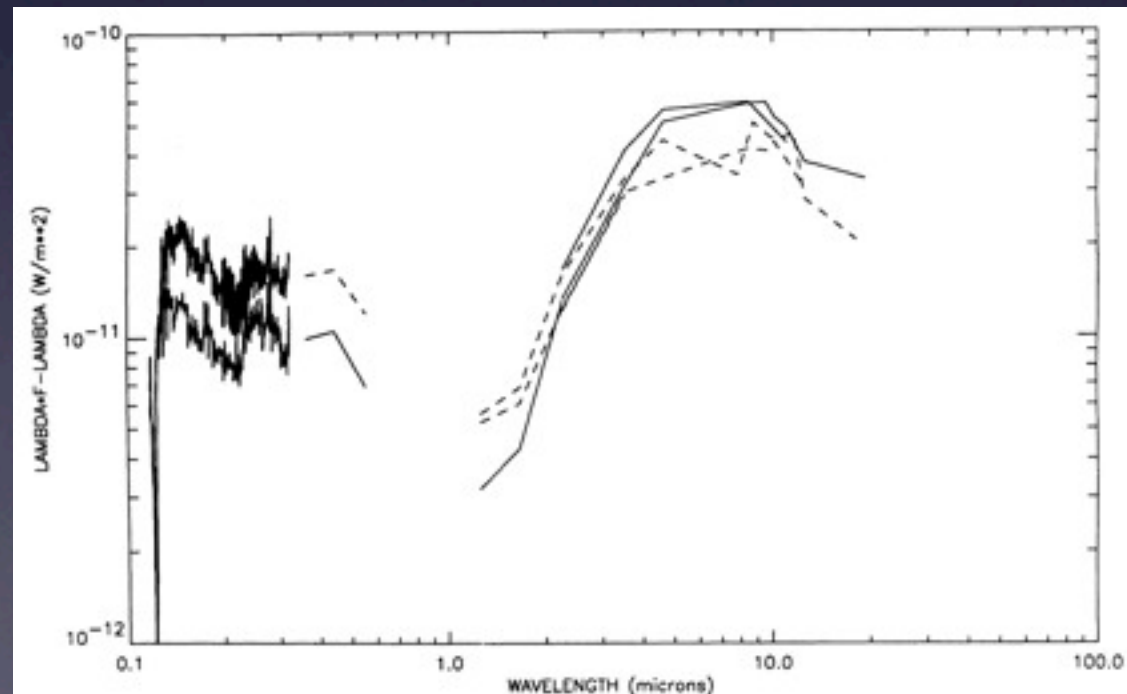
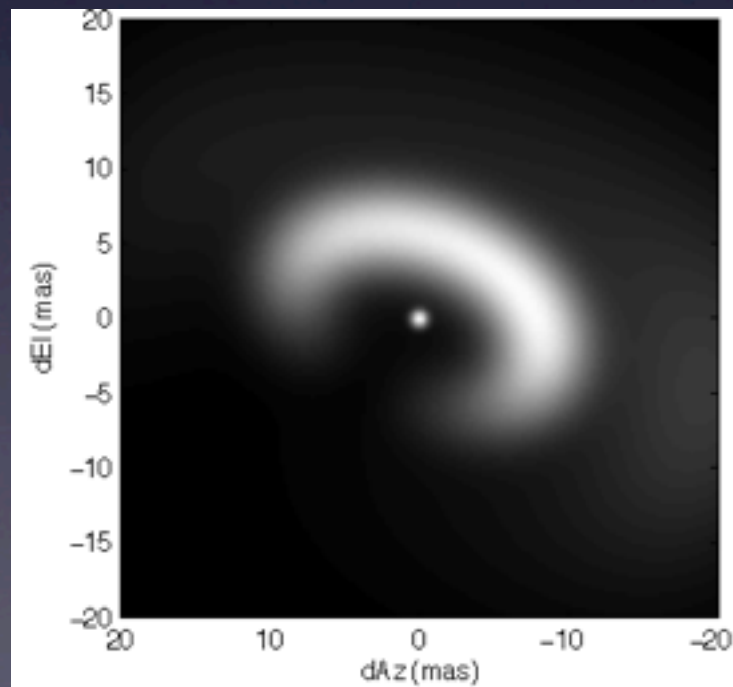
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What's "next"?

VLTI - PIONIER & GRAVITY & MATISSE



SS Lep



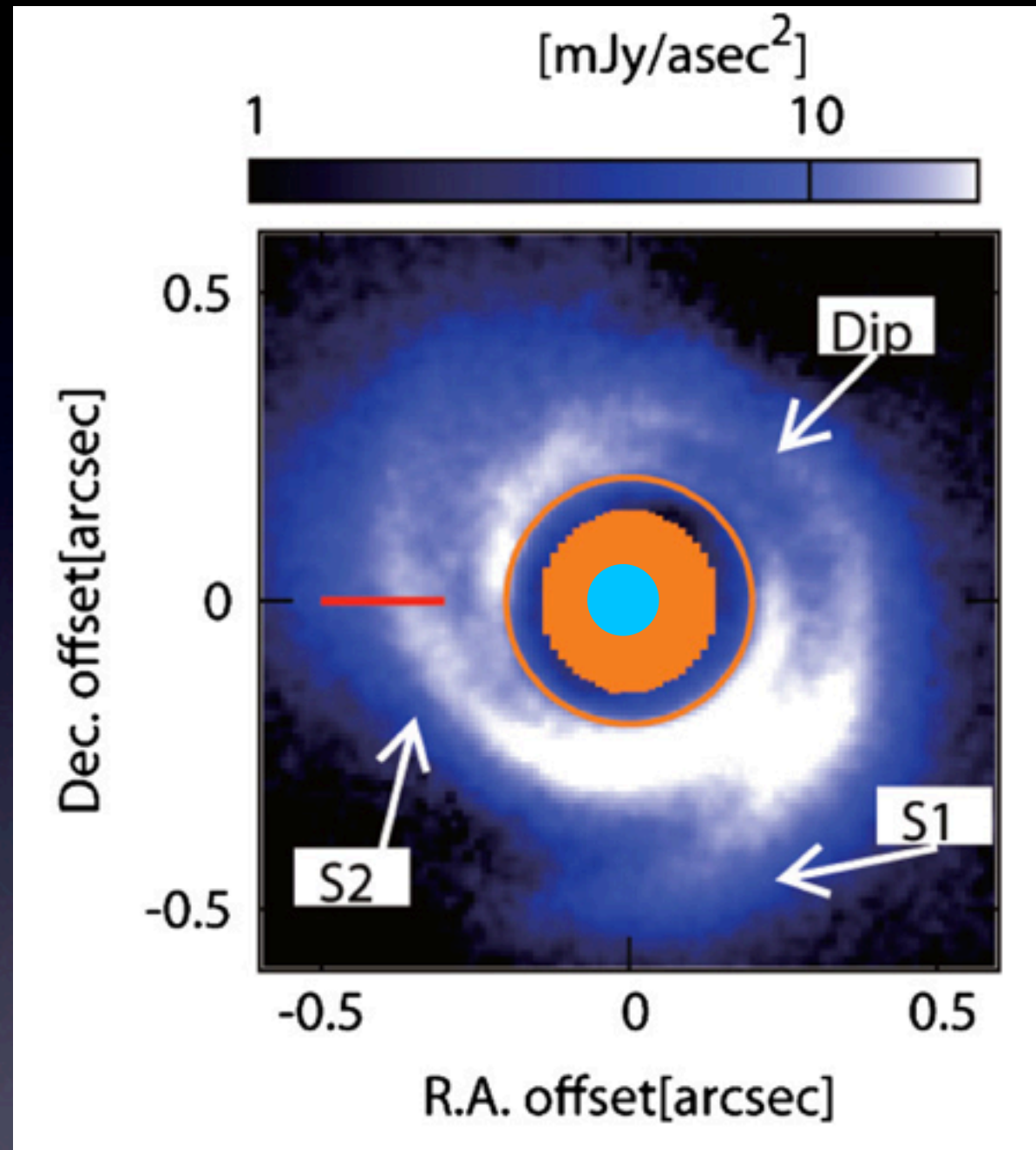
HD 45677

Subaru SCExAO

Inner Working
Angle:

Old

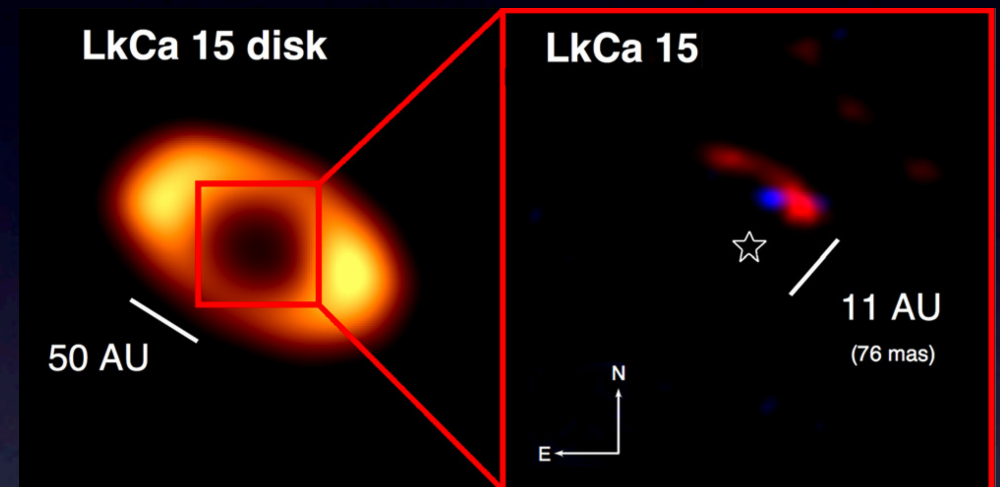
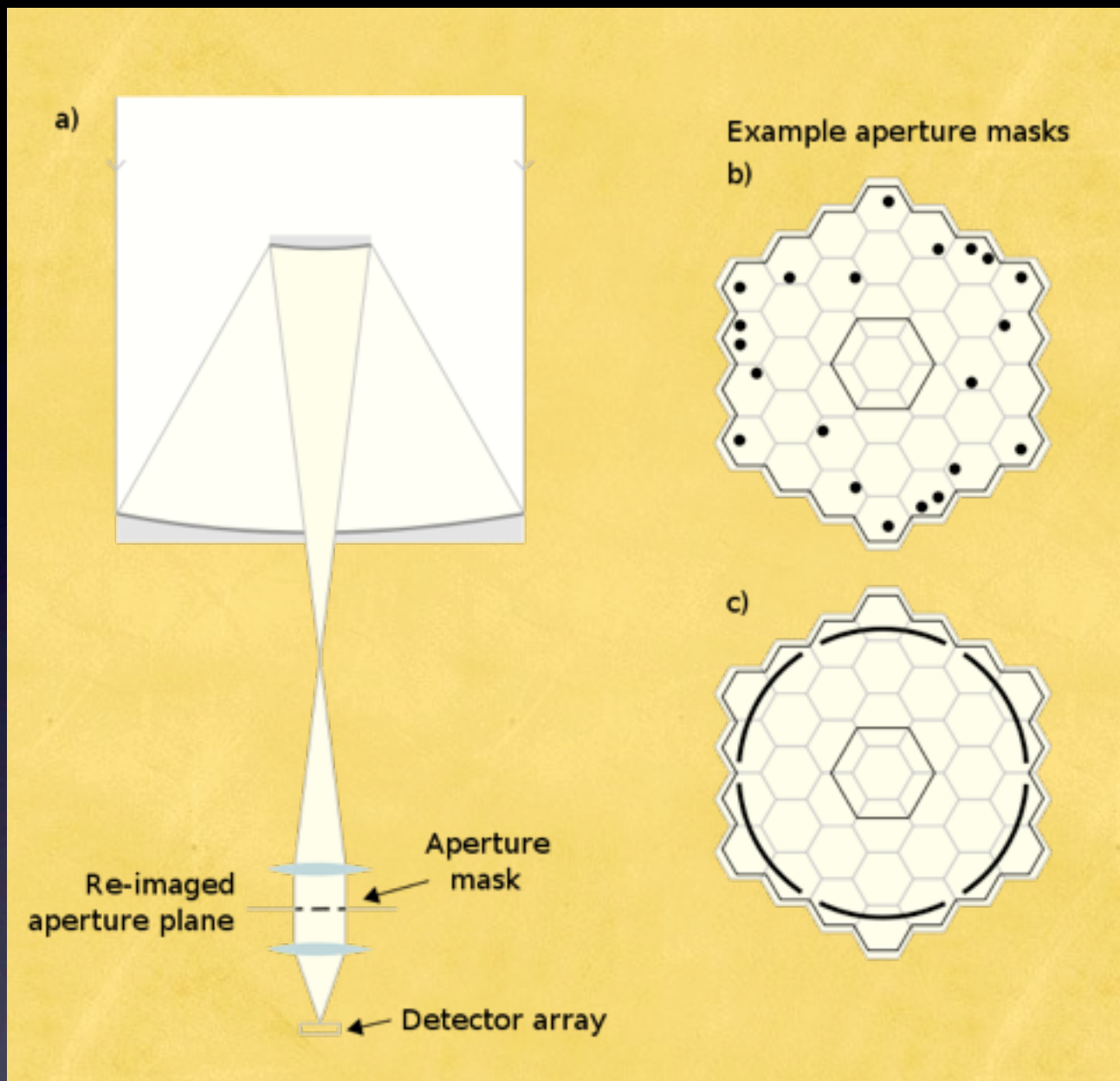
New



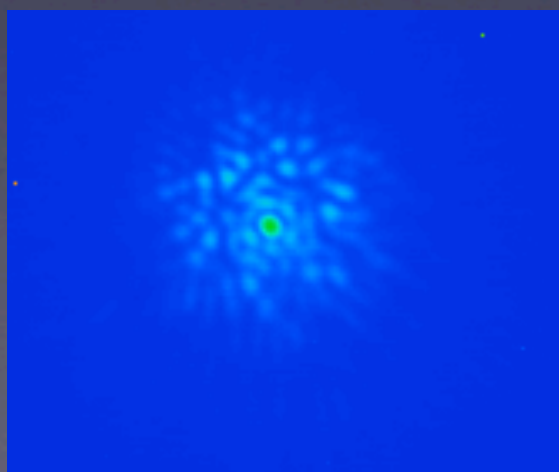
SPHERE, etc.

Non-Redundant Sparse Aperture Mask Interferometry (continued)

Kraus & Ireland 2011



Protoplanet candidate in a disk



Also - ALMA, LBT, etc. will help revolutionize our knowledge of these systems

Extra Thanks to:

Carol Grady, Stefan Kraus,
John Monnier, Misato Fukagawa, Ray Russell

and an army of undergraduate students:
Lori Beerman, Kwassi Ablordeppey, Robin Kimes,
Amanda Day, Chelsea Werren, Alexa Stefanko

This work was supported by NASA ADP grants
NNH06CC28C and NNX09AC73G, *Hubble Space Telescope*
grants HST-GO-10764 and HST-GO-10864, Chilean National
TAC grants CNTAC-010A-064 and CNTAC-011A-050, and the
IR&D program at The Aerospace Corporation.