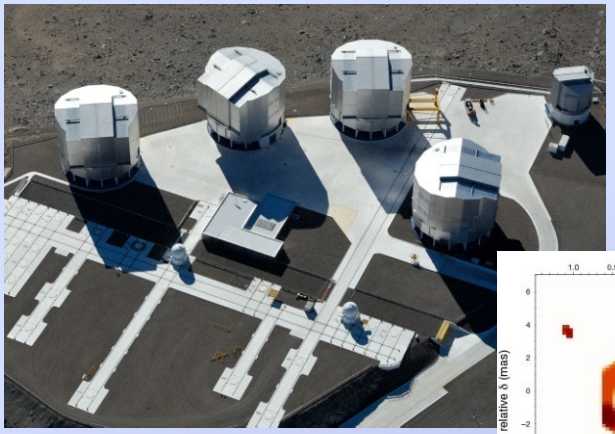
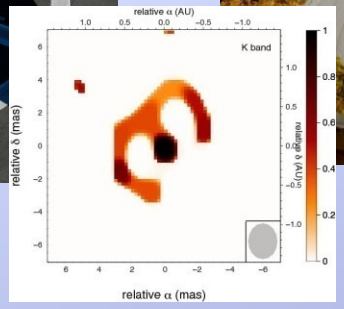
Optical Interferometry at the VLTI:

Italy's contribution and the latest advancements in understanding the circumstellar environment of young stars

In memory of S. Gennari





EWASS 2012, Symposium 10: "30 years of Italian participation to ESO"

Fabrizio Massi

INAF – Osservatorio Astrofisico di Arcetri

Optical interferometry at ESO

Birth and development of the ESO concept for a Very Large Telescope (VLT) - Milestones

December 1977, ESO Conference on the large Telescopes of future: first ideas on a 16-m Very Large Telescope

April 1983, Cargese Workshop: at the time a 16-m telescope seemed a bit out of technological capabilities; a multimirror telescope? An array of independent telescopes?

8 November 1983, ESO's Scientific and Technological meeting recommends an array of 8-10 m elements. It allows interferometry to be carried out. But big movable telescopes too expensive, so better fixed big telescopes and smaller movable ones.

June 1987, VLT Interferometry Working Group, Final Report n. 49: recommends that interferometry is implemented in the VLT

Optical interferometry at ESO

The Very Large Telescope turns interferometer (VLTI)

April 1984, IAU Colloquium n. 79 (Garching): linear array of 4 8-m elements concept presented!

1990, ESO VLT Interferometry Panel: recommends 1) a trapezium configuration for the array rather than a linear one, better for interferometry, 2) beam combination in air, less expensive, 3) a subarray of 2 smaller movable telescopes

4-5 October 1993: due to financial difficulties, the ESO Council decides to POSTONE the implementation of VLTI and VISA (VLTI Sub-Array)!

July 1994: the ESO Council approves a revised VLTI implementation plan to provide at least VISA (3 telescopes) by 2003 and UTs integration by 2006.

April 1995: a new Interferometry Science Advisory Committee (ISAC) is established

December 1995: new VLTI plan following ISAC recommendations.

1996: MPG, CNRS and ESO sign an agreement to resume development of VLTI by injecting additional resources

Optical interferometry at ESO

First fringes at the VLTI

June 1998: ESO and the Belgium firm AMOS for the delivery of 2 ATs

18 December 1992: CNRS-INSU, MPI and ESO sign agreement for the construction of a third Auxiliary Telescope.

25-26 May 1998: 1st light of UT1 (ANTU)!

4 September 2000: 1st light of UT4 (YEPUN).

17 March 2001: first interferometric fringes using 2 siderostats and VINCI!

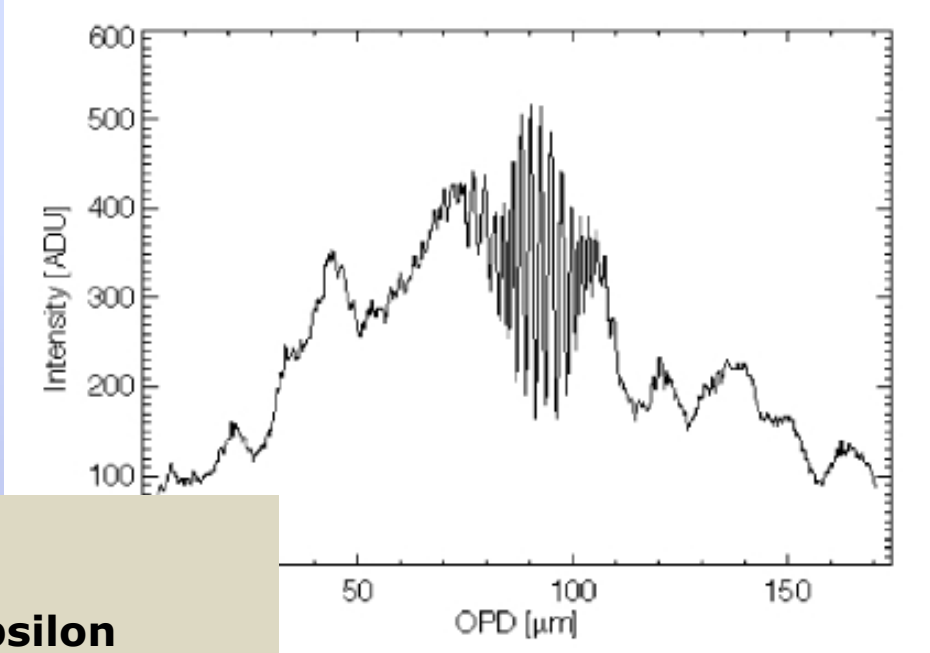
30 October 2001: first fringes with 2 UTs (ANTU & MELIPAL) in the K band (2.2 micron) on Achernar!

Optical interferometry at ESO

Current VLTI configuration (photo ESO)

Optical interferometry at ESO

First fringes at the VLTI



15 December 2002: first fringes with MIDI on Epsilon Carinae, combining
ANTU and MELIPAL

20-21 March 2002: first light AMBER using 2 siderostats and Theta Carinae.

30 January 2004: 1st light AT 1

15 December 2006: 1st light AT 4!

Italy becomes involved in the AMBER project for VLTI

Instrument development and construction

September 1996: meeting in Lyon of French interferometrists, first seeds

7 March 1997: first report on a concept study of a beam combiner for VLTI (only French institutes)

9 July 1997: new report, AMBER is defined, including other European institutes (Grenoble, Meudon, Nice, MPI Bonn; A. Richichi on behalf of Arcetri)

4/5 May 1999, 47th meeting of ESO Scientific and Technical Committee, AMBER is favourably supported

26 January 2001: ESO, UNSA, UJF, OCA, INSU, MPIfR and Arcetri sign an agreement to design and build AMBER, the consortium obtains guaranteed time observations (GTO)

July 2002 to July 2003: all subsystems made by different institutes are integrated in Grenoble

20/21 March 2004: AMBER first light on Theta Centauri with 2 beams from siderostats

May 2004: AMBER is shipped to Paranal

2nd semester 2005: AMBER open to observations

AMBER

The consortium

Involved Institutes:

Laboratoire d'Astrophysique de Grenoble (LAOG)
Laboratoire Universitaire d'Astrophysique de Nice (LUAN)
Max-Planck Institut fur Radioastronomie (MPIfR)
Osservatorio Astrofisico di Arcetri
Observatoire de la Cote d' Azur (OCA)

Investigators:
R. Petrov (LUAN, PI)
F. Lisi (Arcetri, coI)
F. Malbet (LAOG, coI)
D. Mourard (OCA, coI)
G. Weigelt (MPIfR, coI)

Arcetri (17 %) designing, construction and testing of the AMBER spectrograph

Other Italian contributes to VLTI:
OA Torino, fringe tracker FINITO (PI M. Gai)
Alenia, Fringe Sensor Unit for PRIMA

AMBER

The instrument

Technical characteristics:

First generation general-user focal instrument of VLTI

Fiber-fed beam combiner, it accepts 2 or 3 beams either from the UTs or from The ATs

Operating in the Near-Infared (JHK bands, 1-2.5 micron)

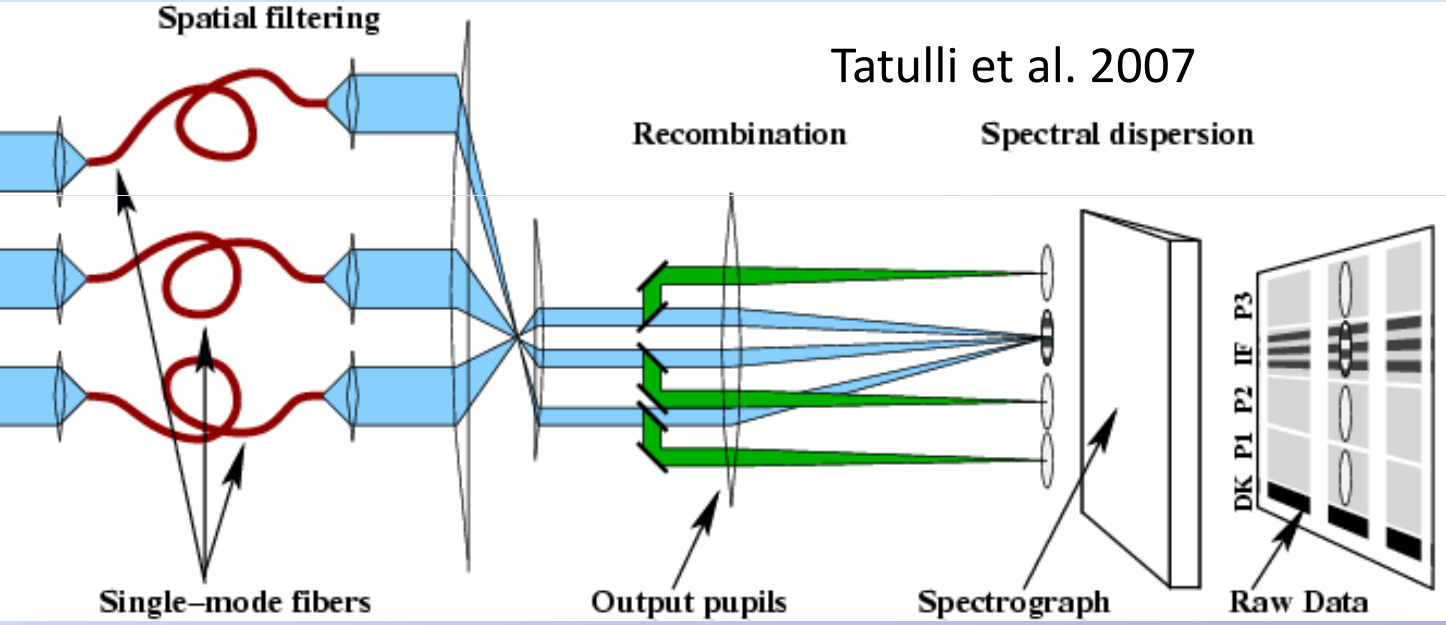
Spectrograph with low- (R=35), medium- (R=1200) or high-resolution (R=12000)

Available VLTI baselines (P90): UTs (47-130 m) ATs (11-140 m)

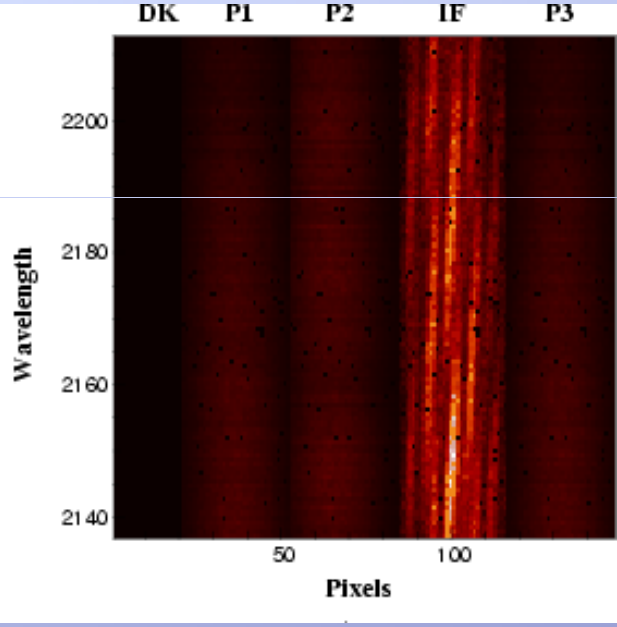
AMBER

The instrument

Technical characteristics:



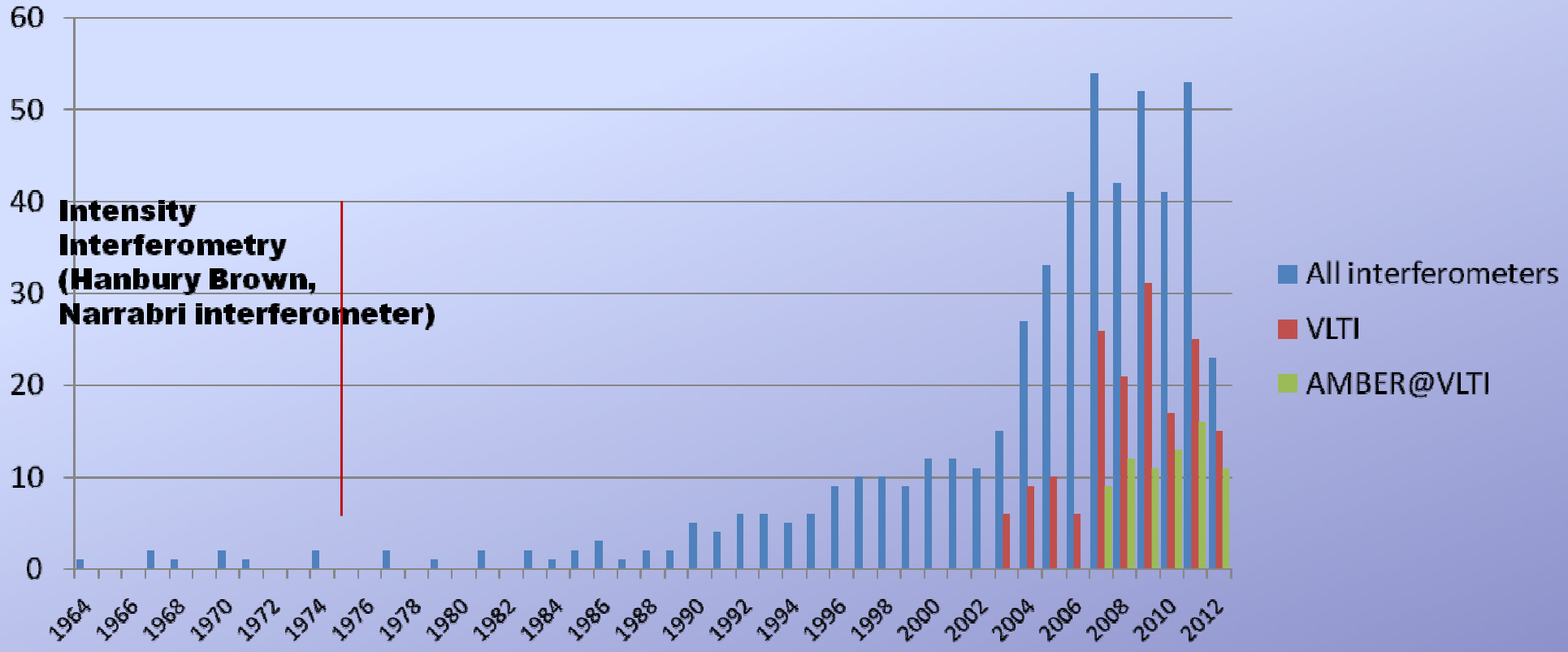
Tatulli et al. 2007



Publications in refereed journals

Only papers discussing results of interferometric observations

SOURCES: OLBIN (http://olbin.jpl.nasa.gov), NASA ADS



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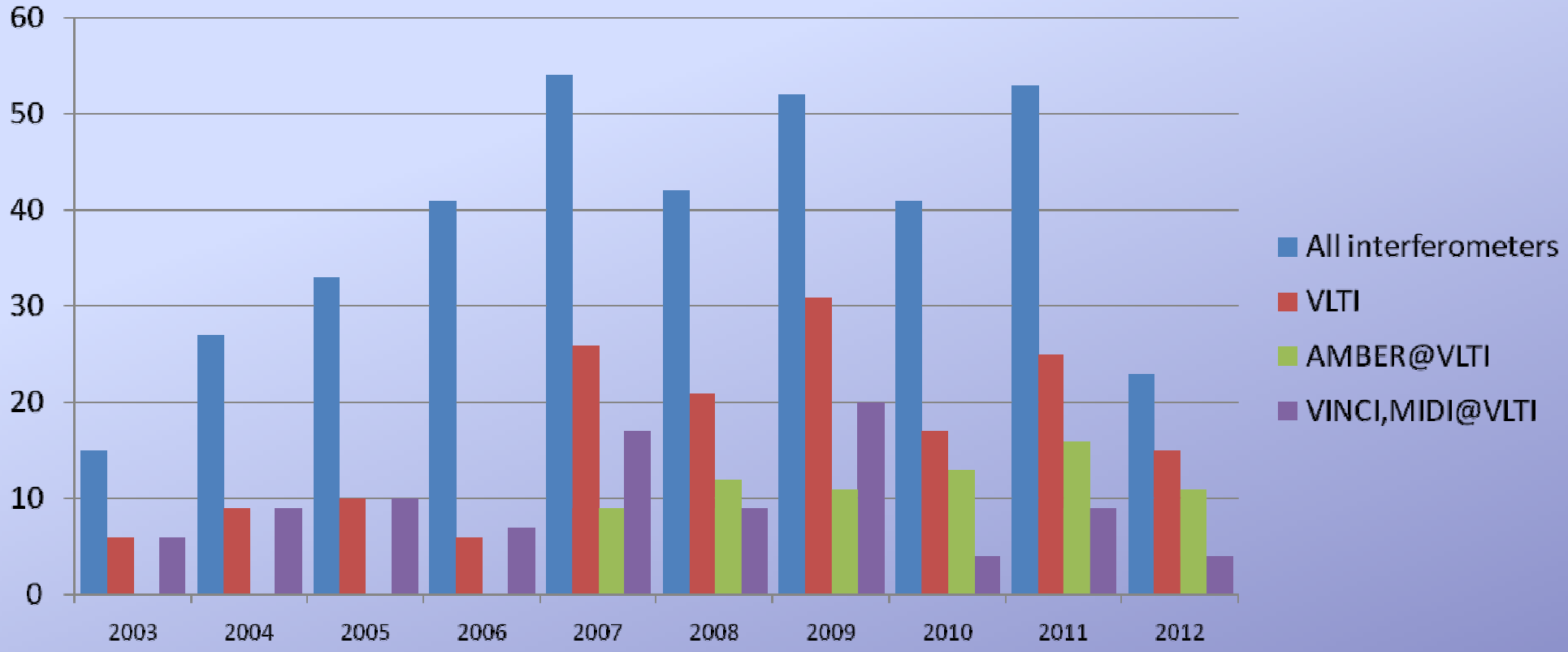

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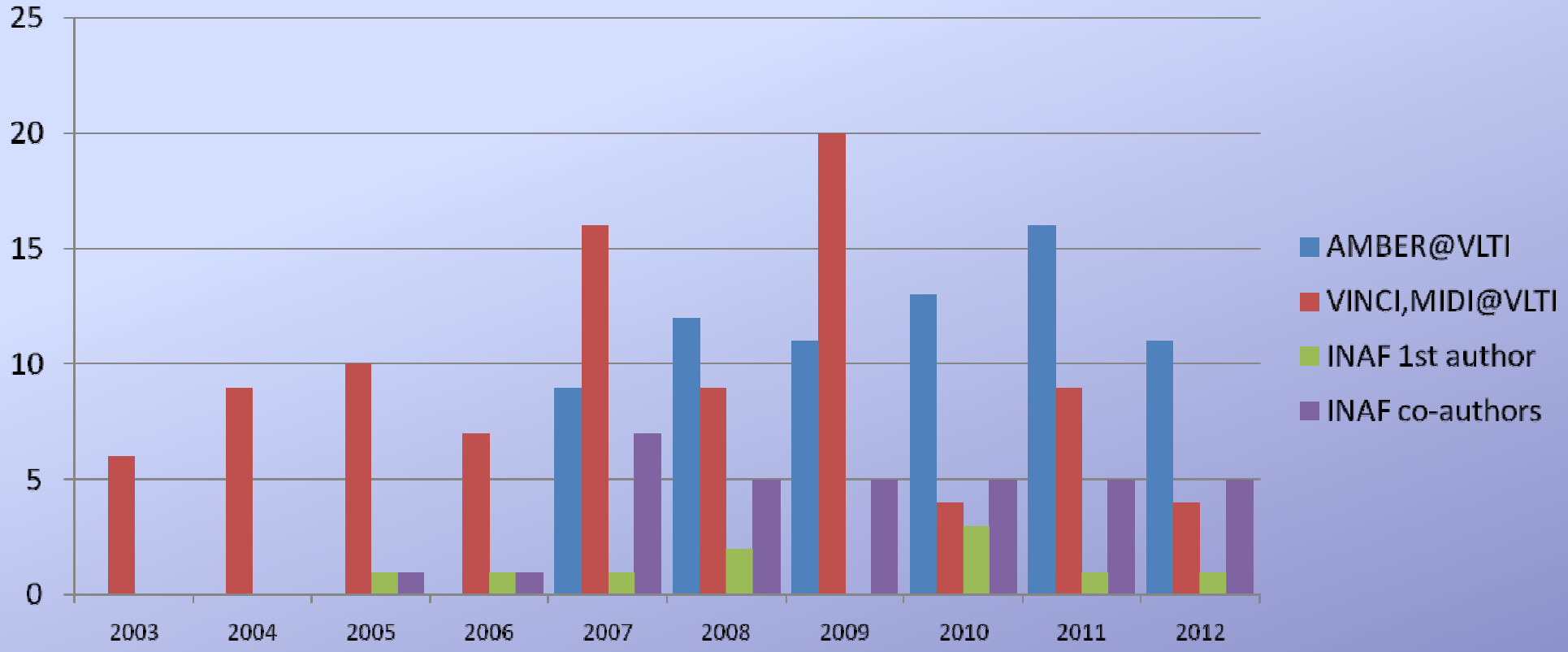

Publications in refereed journals

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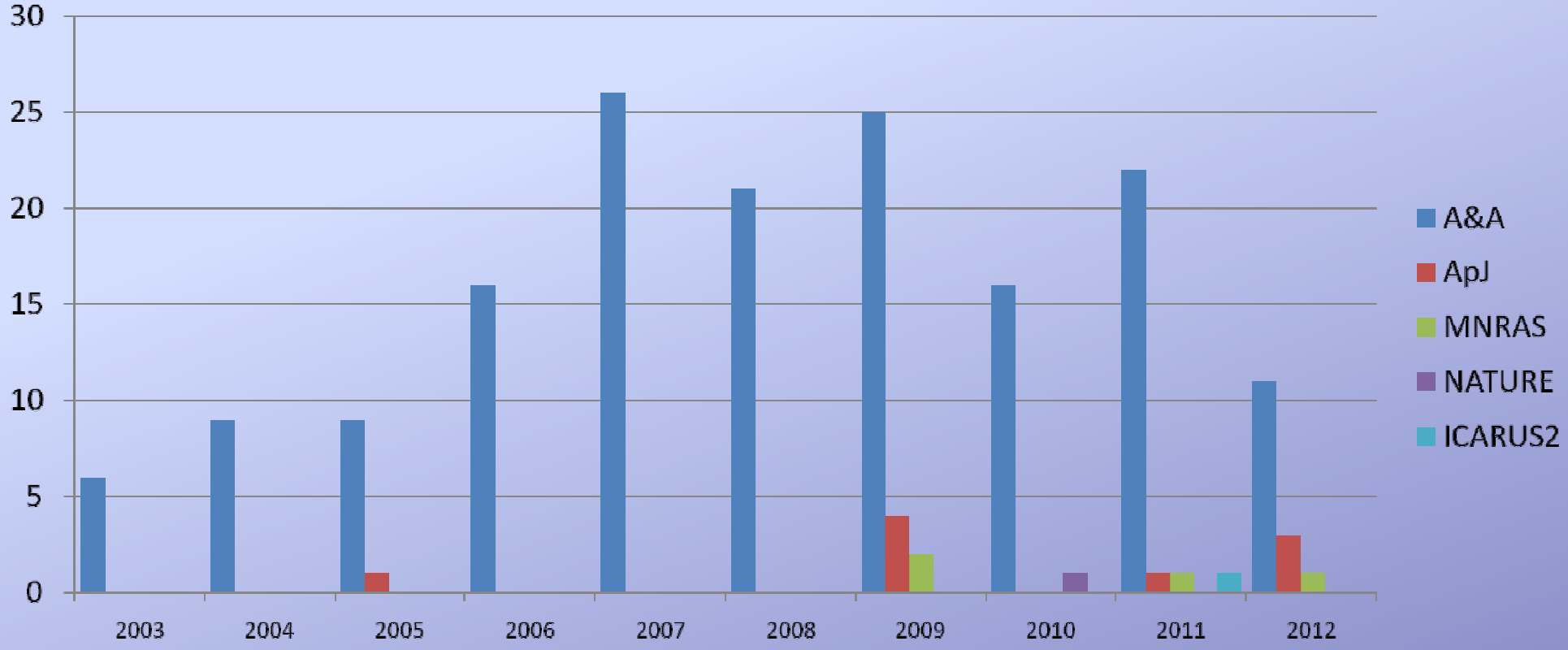


INAF authors and co-authors of papers on interferometric results in refereed journals

(not a comprehensive list)

M. Benisty (formerly INAF-Arcetri, now MPI Heidelberg)
E. Tatulli (formerly INAF-Arcetri)
S. Antoniucci (INAF-Roma)
F. Cusano (INAF-Bologna, formerly INAF-Napoli)
A. Isella (formerly INAF-Arcetri, now CalTech)
S. Ligori (INAF-Torino)
A. Marconi (INAF-Arcetri, Universitá di Firenze)
F. Massi (INAF-Arcetri)
A. Natta (INAF Arcetri)
L. Testi (INAF-Arcetri, ESO)

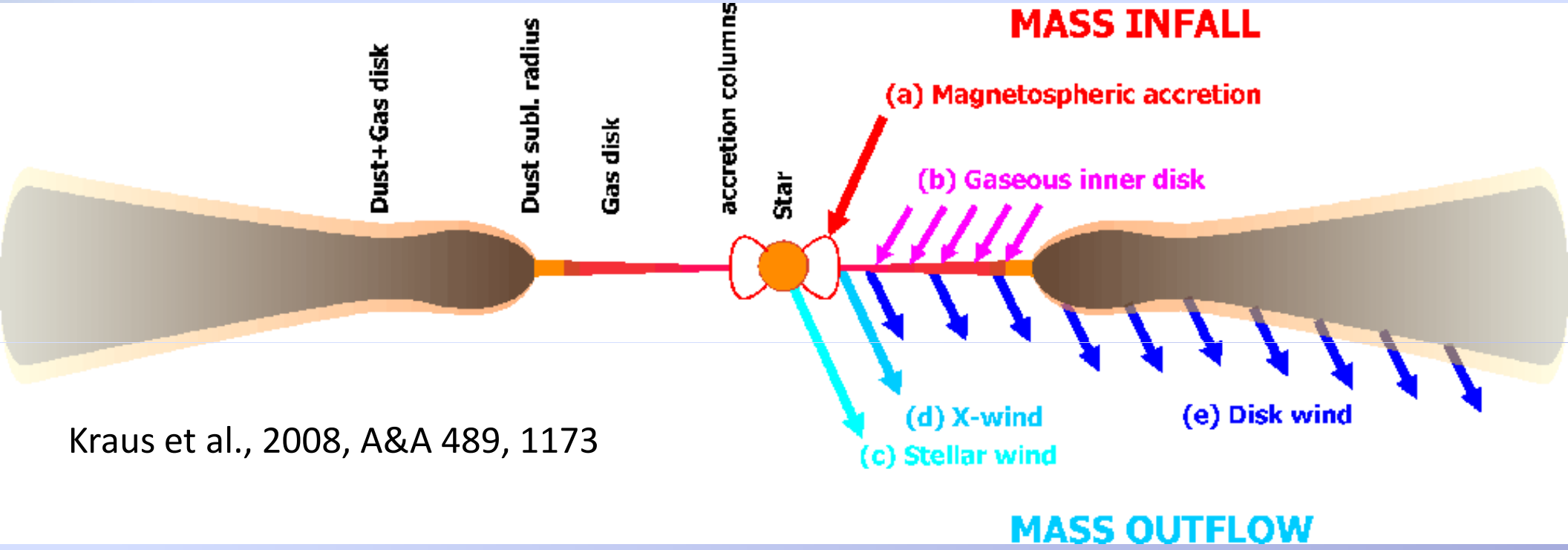
Time spent in interferometric observations with VLTI

AMBER GTO final amount : 1200 hrs ATs (Arcetri 218 hrs), 60 hrs per single UT (Arcetri 11 hrs)
Mainly for pms stars, some UT time on quasars

ITALY GTO (funding of ATs): time requested from P80 (2007) to P90 (last call) about 260 hrs
Mainly for pms stars, 93.5 hrs stellar evolution (AMBER, only 6 hrs on MIDI)

INAF-OATorino GTO (FINITO): 24 hrs requested in P90 (MIDI, stellar evolution)

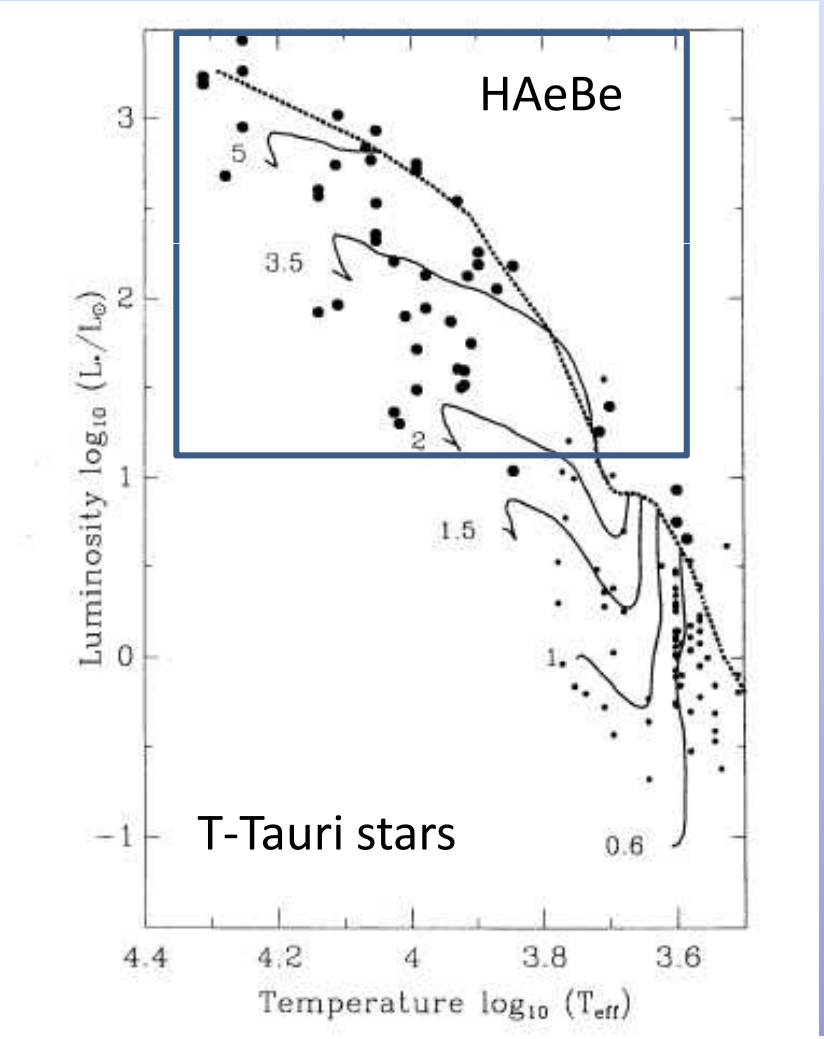
Arcetri's program on young stars with AMBER



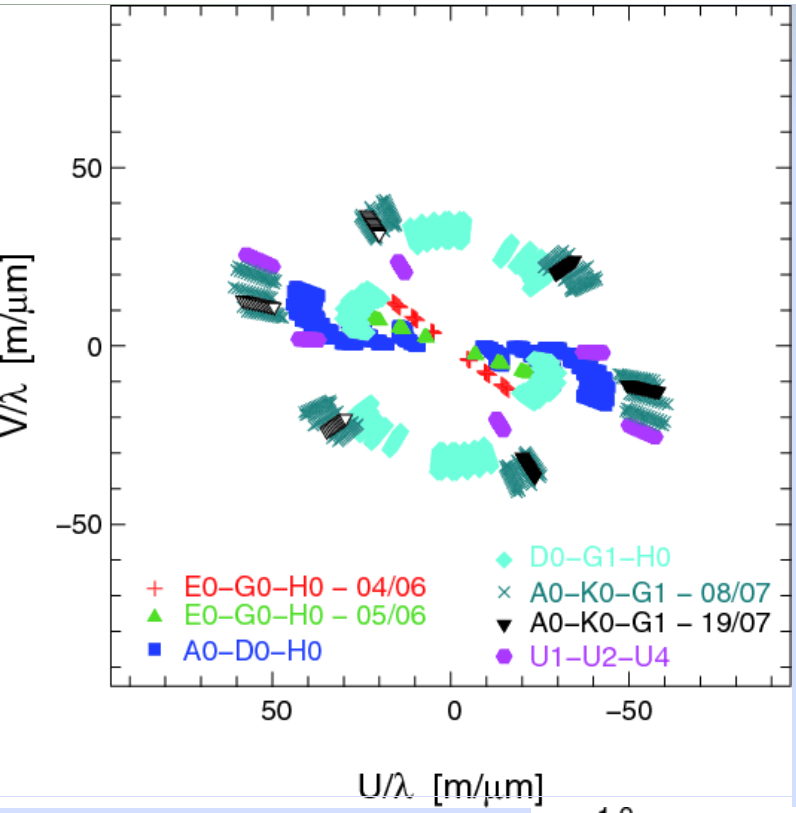
Kraus et al., 2008, A&A 489, 1173

Arcetri's program on young stars

Herbig AeBe: pre-main sequence stars of intermediate mass (2-10 Msun)



Palla & Stahler 1983



HD163296

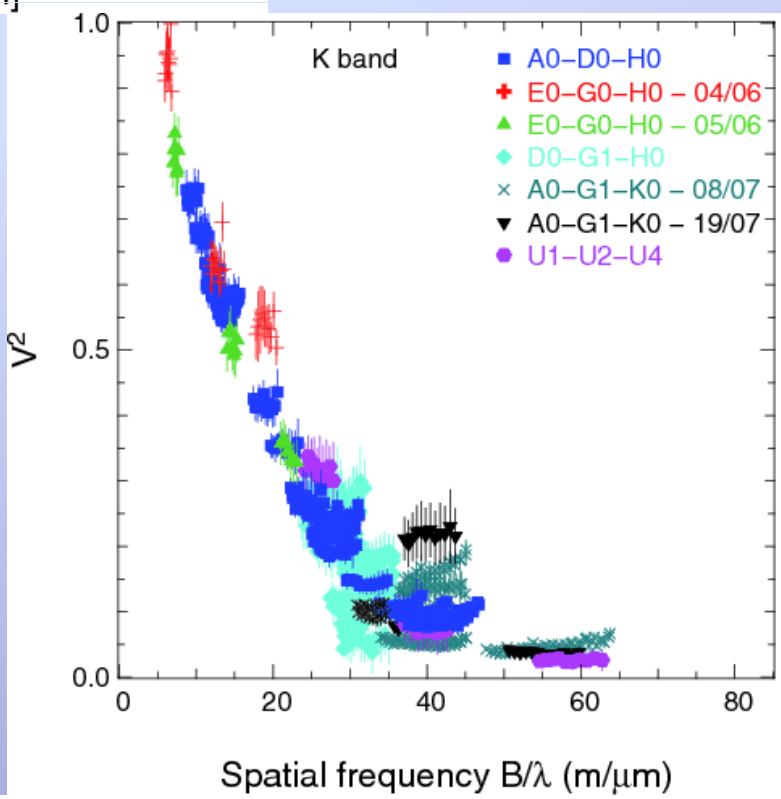
Herbig Ae star (A1)

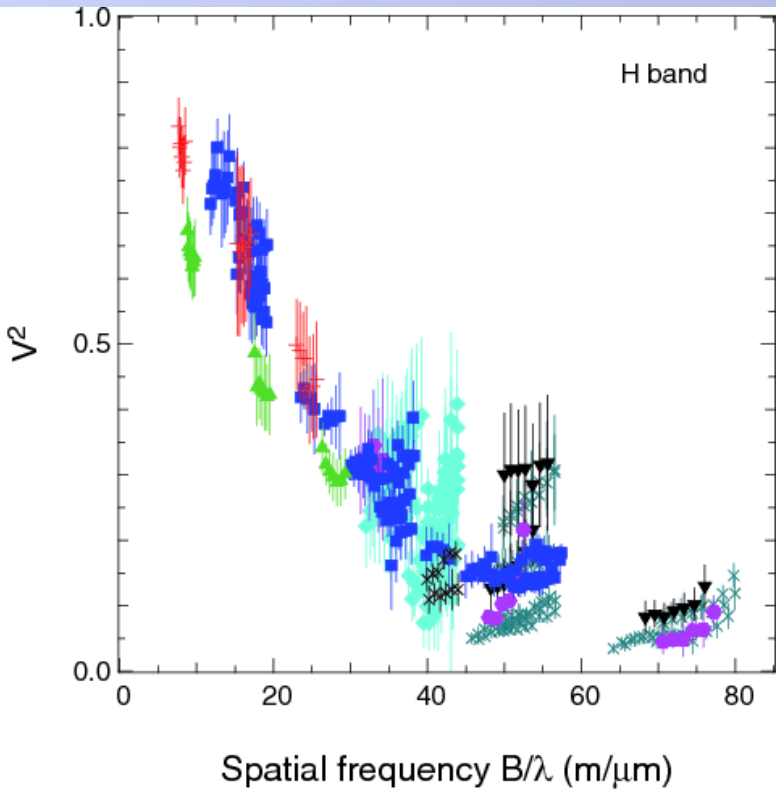
Mass = 2.3 Msun

Age = 4 Myr d=122 pc

Wide coverage of uv plane (ATs and UTs)
LR-HK

Benisty et al. 2010, A&A 511, 74

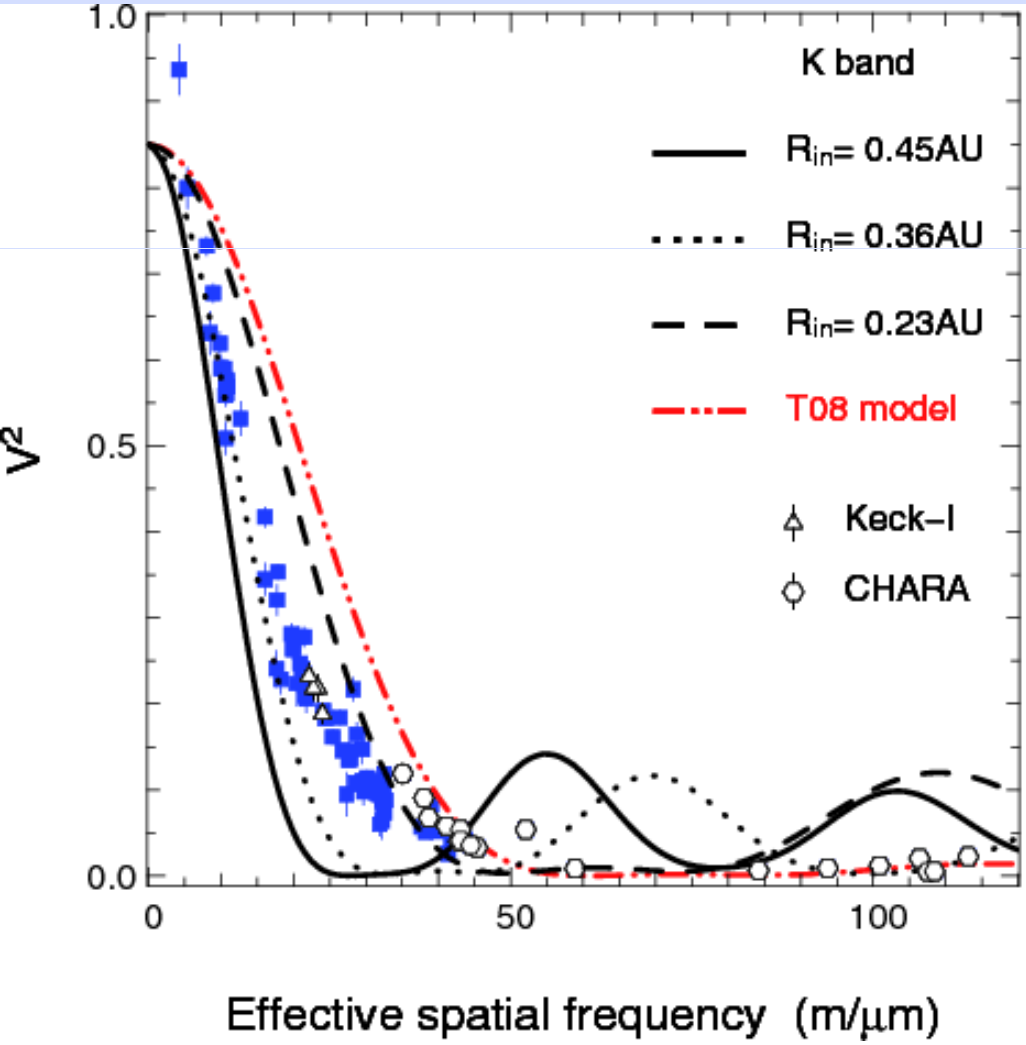


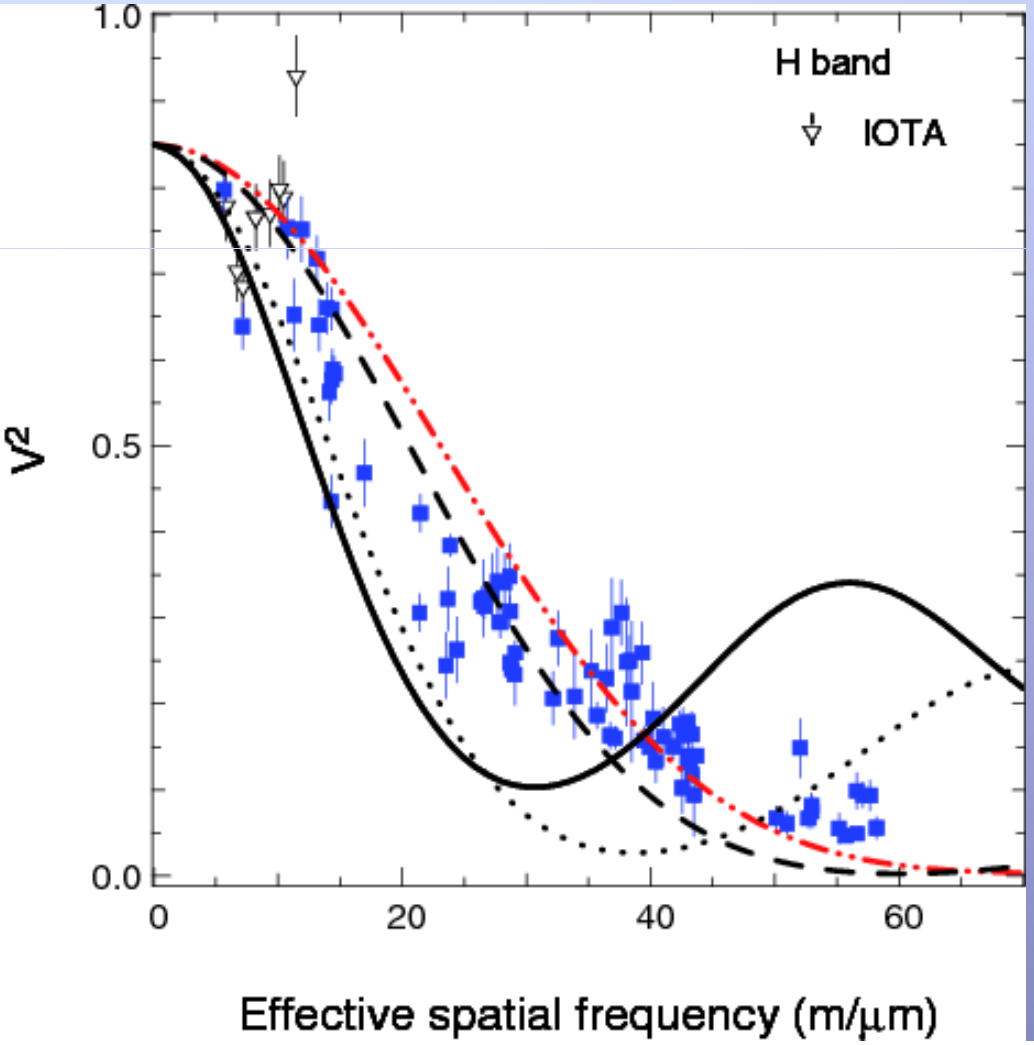


HD163296

Ring-like emission only does not fit the lobes at high spatial frequency, clearer in the H band!

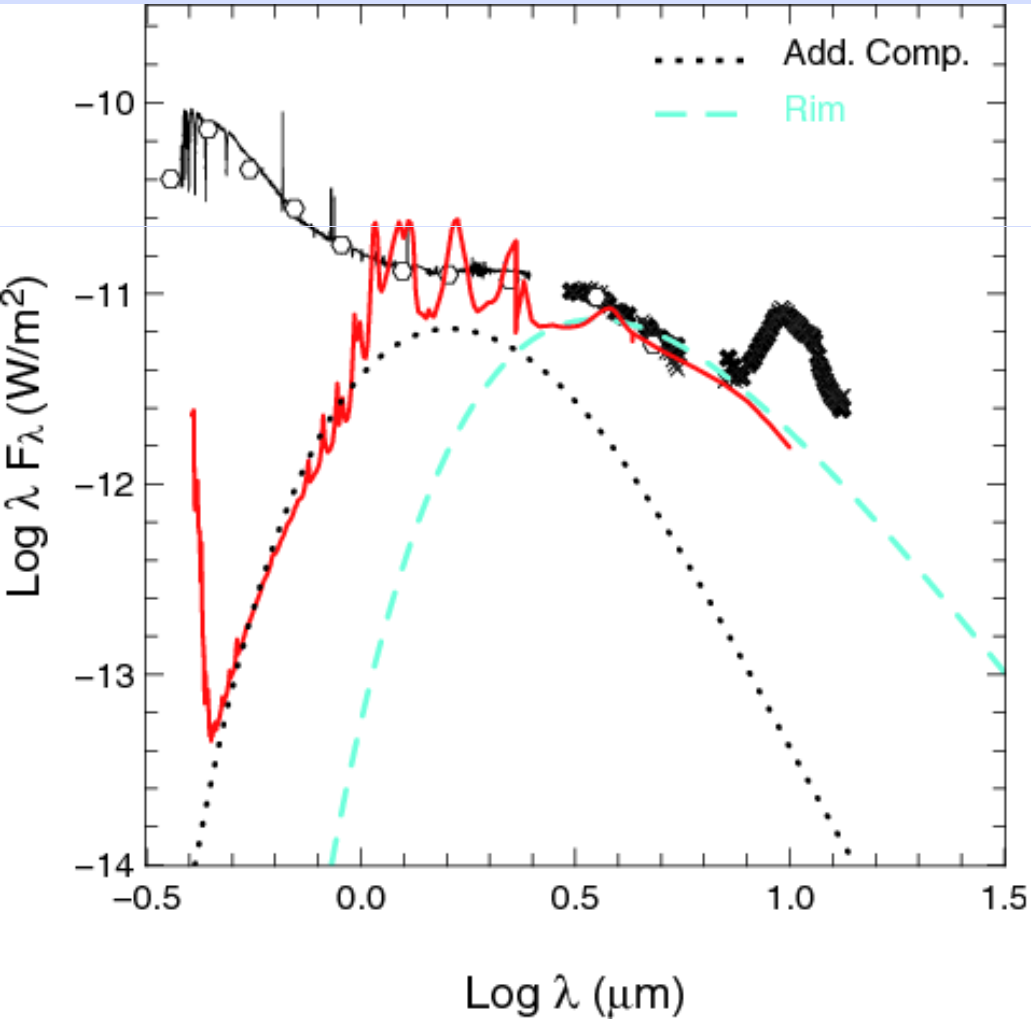
A more compact source of emission inside the inner dust rim is needed

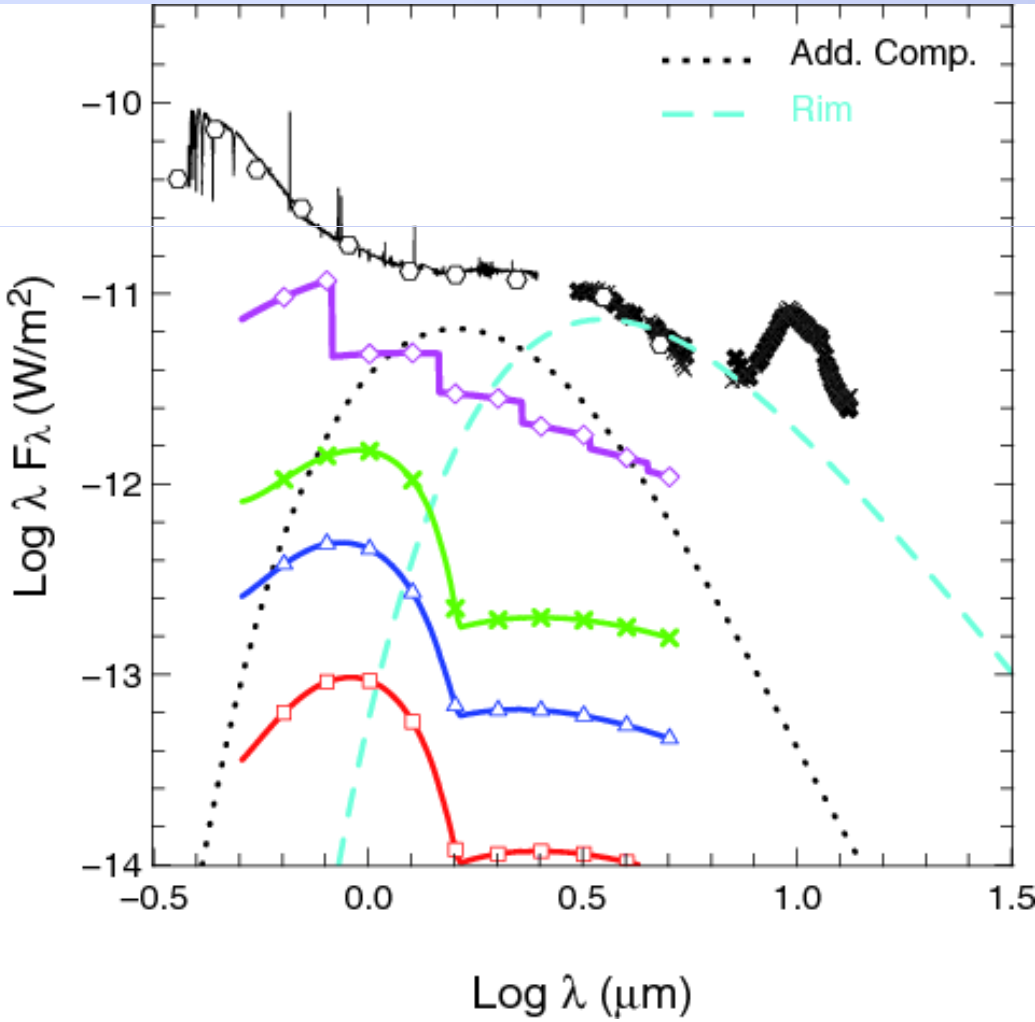




HD163296

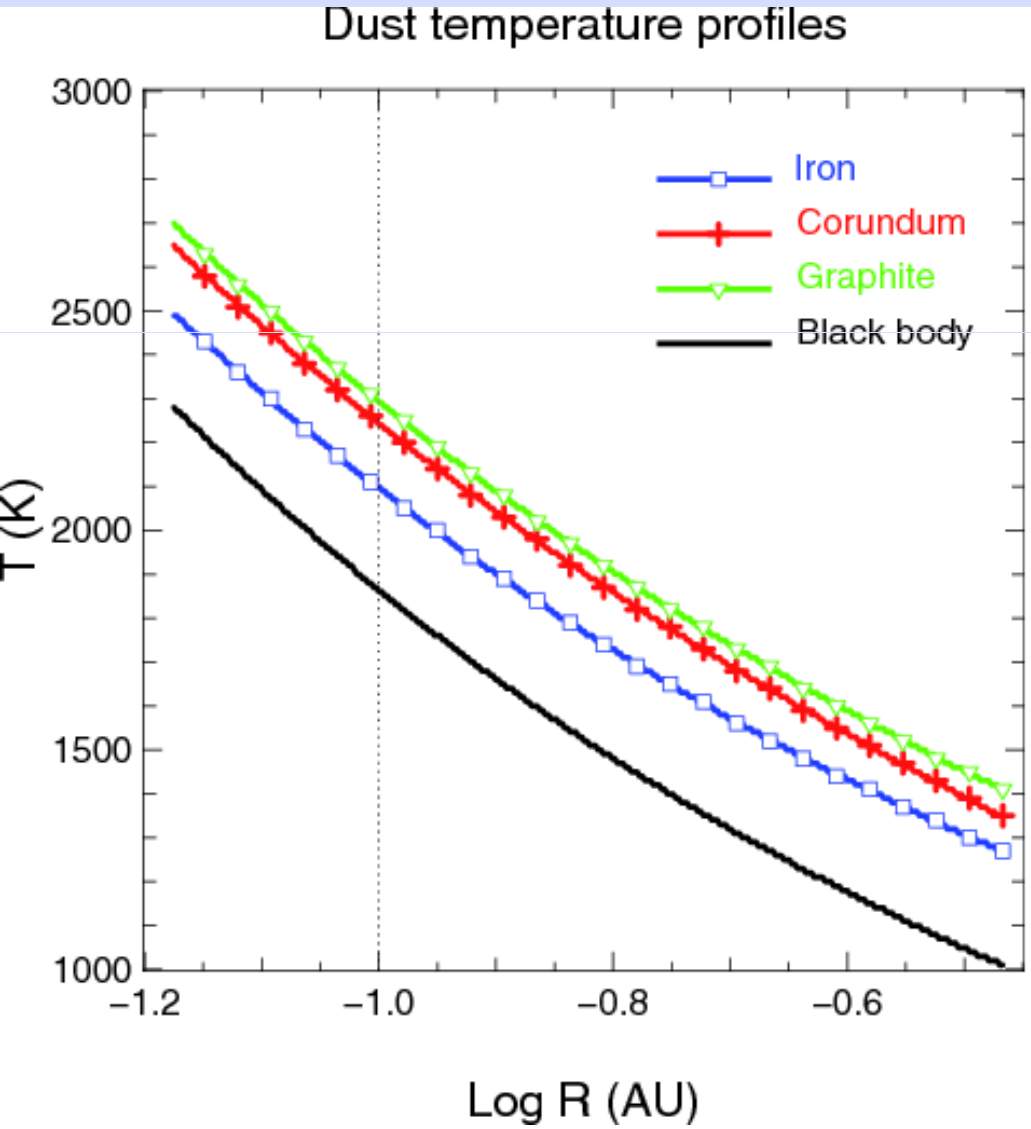
An inner gaseous disk? It does not fit well the SED …

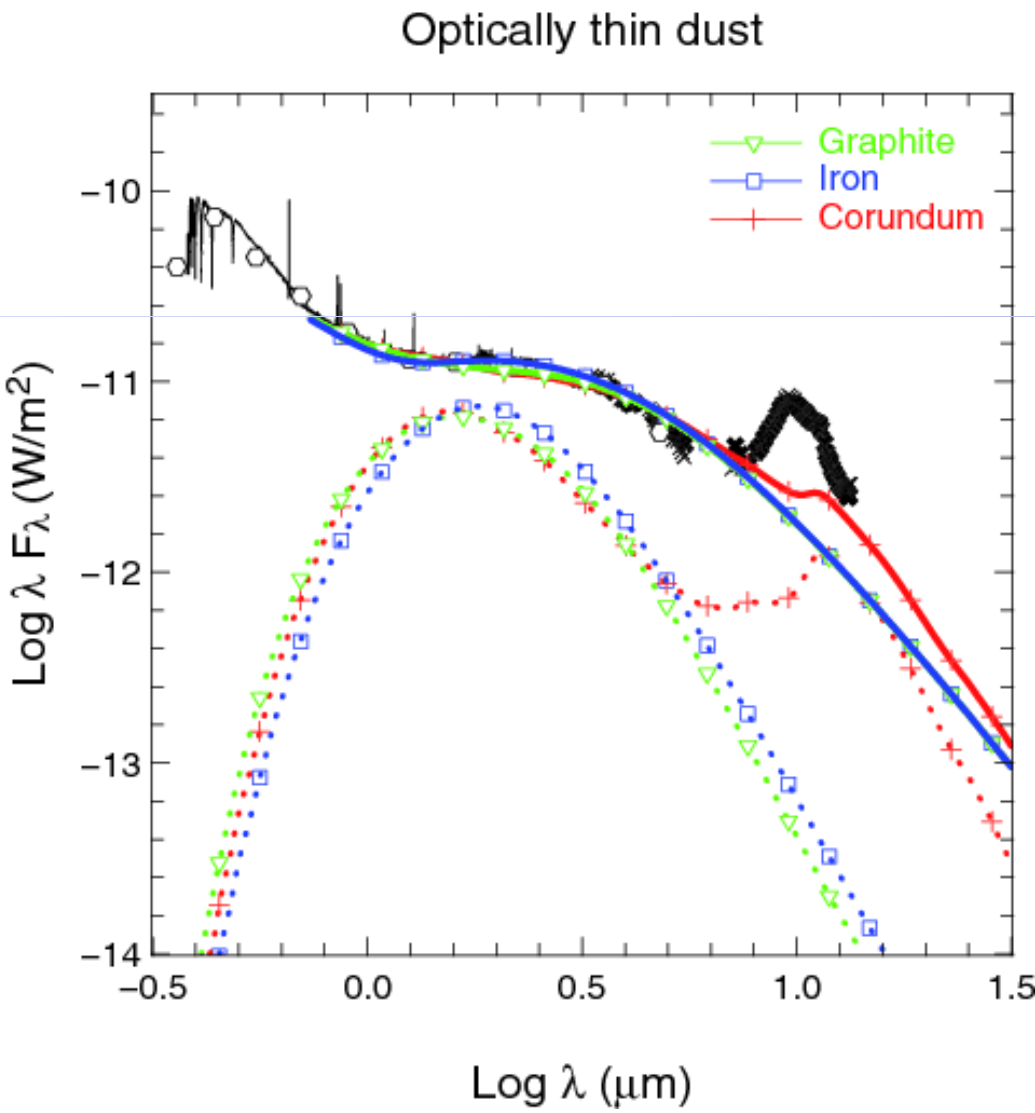




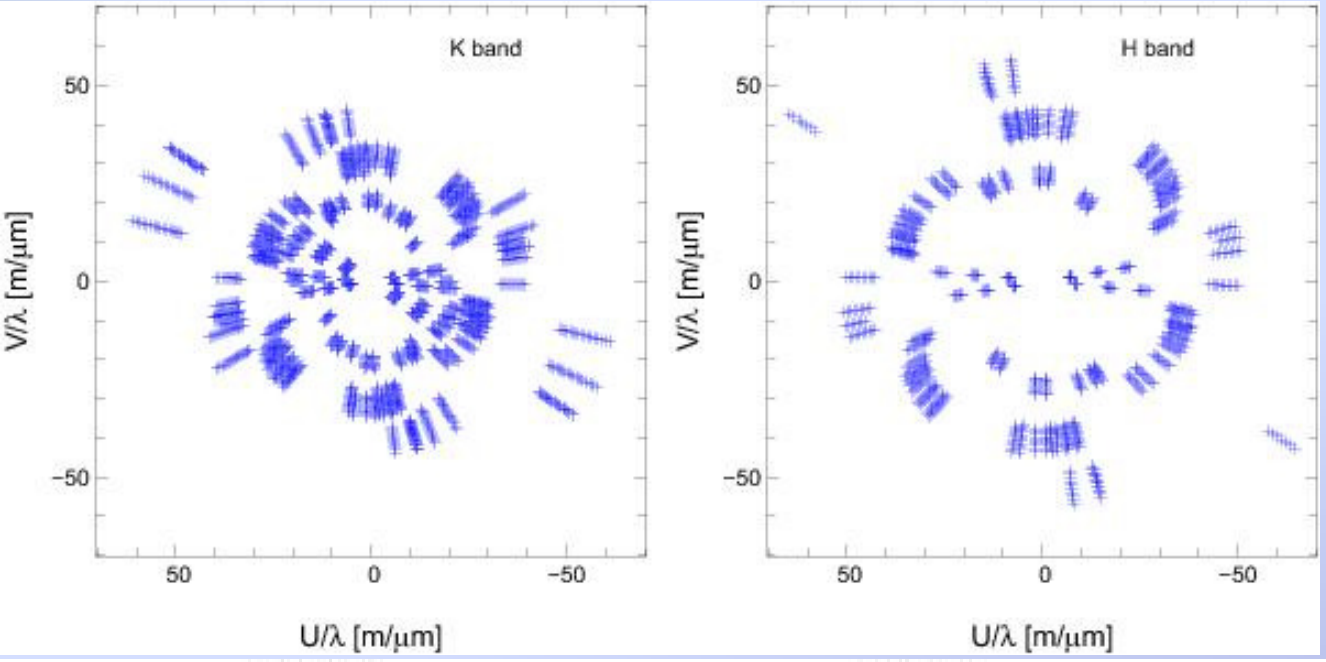
HD163296

Refractory dust grains inside the dust sublimation radius? A much better fit!





HR5999 Herbig Ae (A7 III-IV) star
Mass = 3-4 Msun Age =0.5 Myr d=210 pc

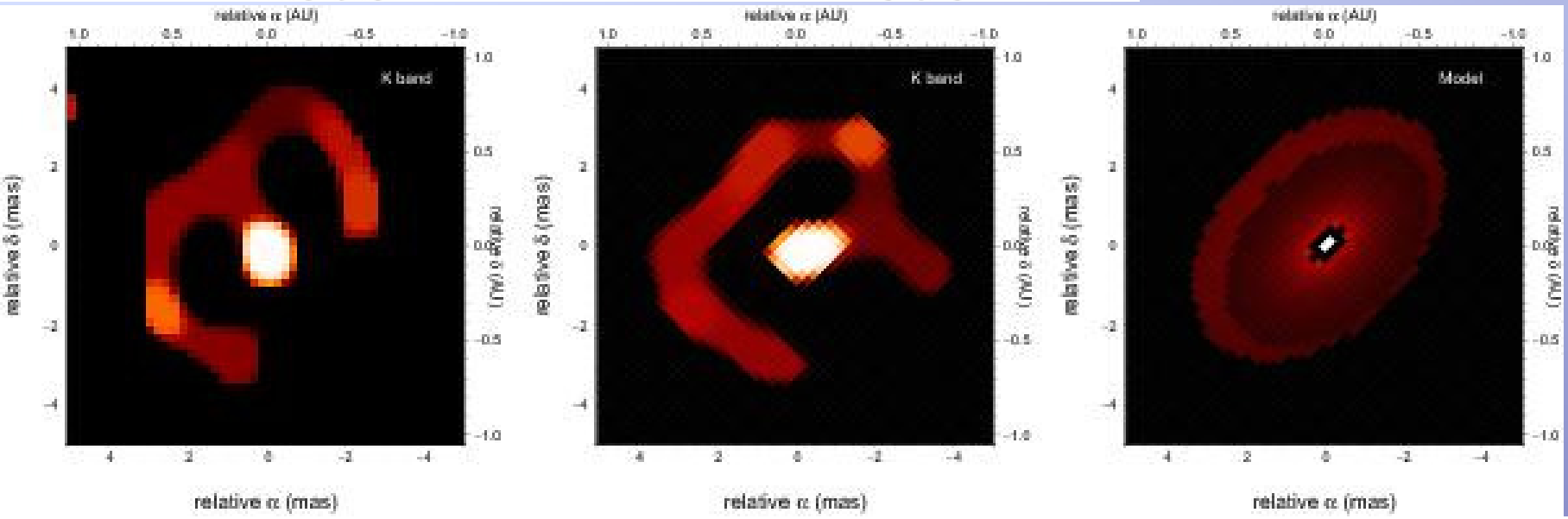


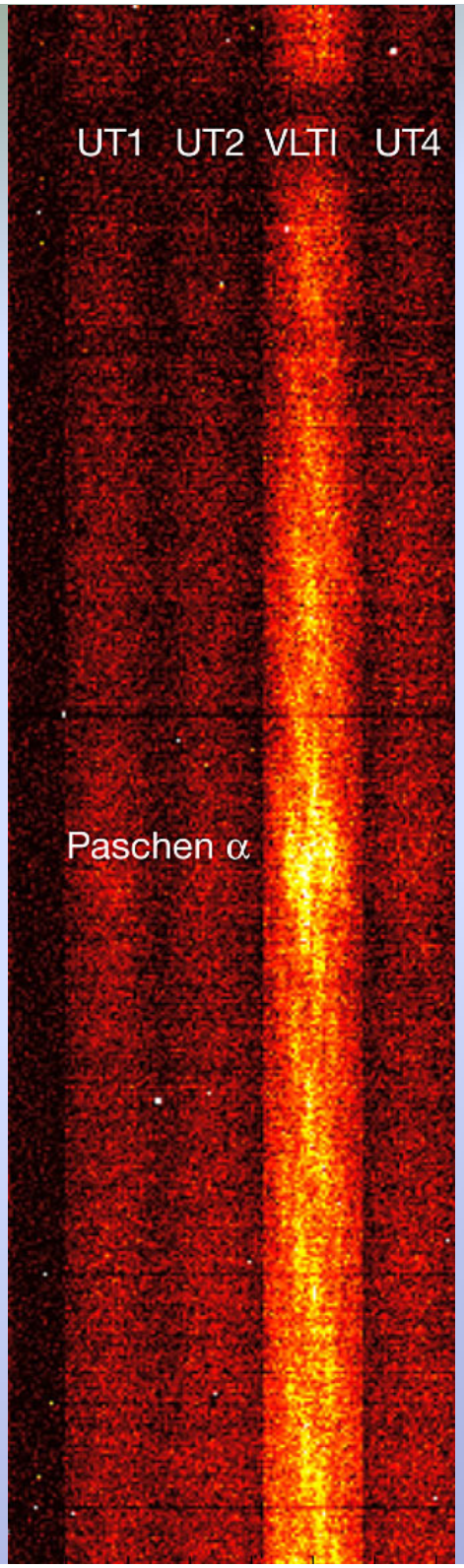
Observed with ATs at H,K
R=35 to 12000

Disk with i=48 deg
Dusty rim, radius = 0.65 AU
Inner disk of low surface brightness
image reconstruction!

INAF press release 17/06/2011

Benisty et al. 2011, A&A 531, 84





3C273: first fringes on an extragalactic source! 15-17 May 2011

Observed with UTs in AMBER GTO
K, MR

3C 273 K=9.5 !

Observed in BLIND OBSERVATION MODE:
1) Calibrate the interferometer on a nearby bright star, then switch to the fainter source
2) add together multiple apparently empty exposures

ESO announcement ann11031
INAF press release 06/06/2011

Conclusions

Optical interferometry is now mature for doing astronomy of bright objects and currently VLTI represents the major facility available to astronomers in the world

Italy had an important role in the development of the VLTI through its involvement in the AMBER consortium and the development of FINITO

As many as half of the papers on interferometric results have been based on VLTI observations in the last few years

A significant fraction of papers based on VLTI observations are co-authored by INAF astronomers

A few important milestone results in the field of young stellar objects were obtained by INAF astronomers through AMBER observations at the VLTI