Observing solar-mass stars with the VLTI

Evolution of Solar-mass Stars, March 5, 2010 — A. Richichi (ESO)

ESO Chile

Chajnantor, 5000m

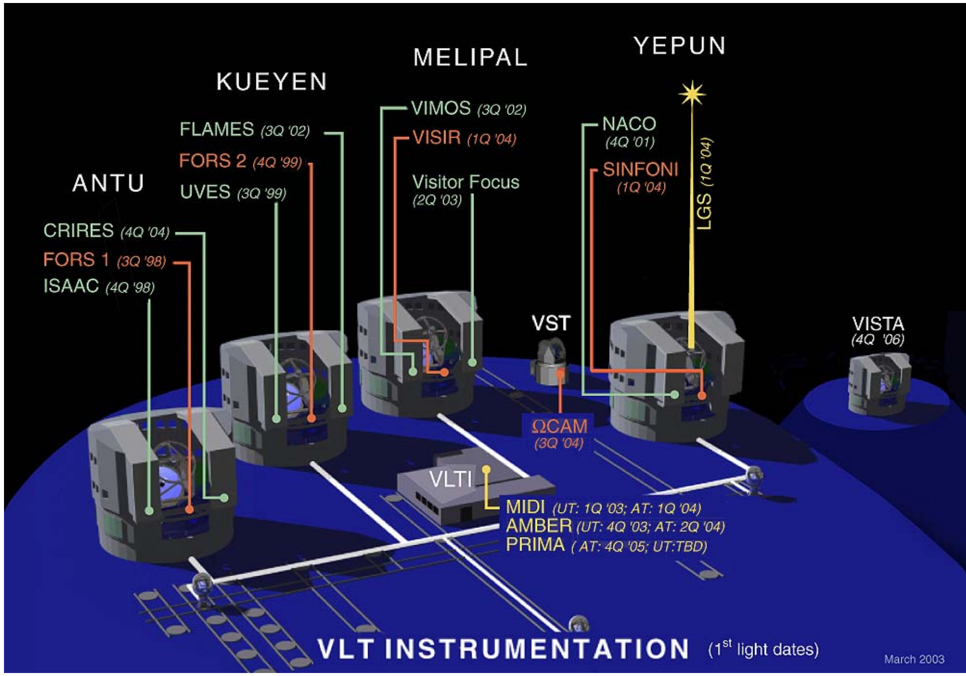
Paranal, 2600m

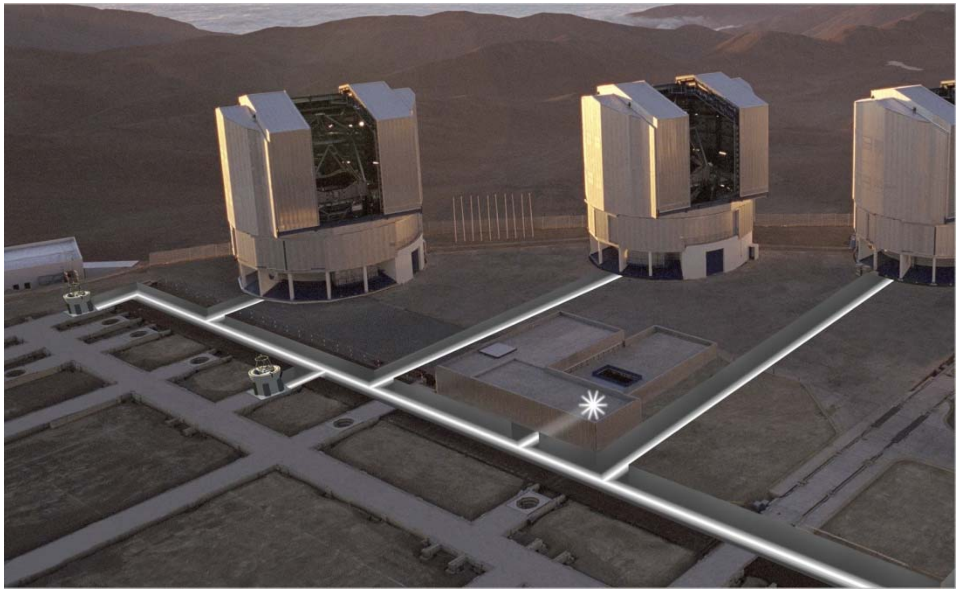
La Silla, 2400m

Santiago Office


Paranal

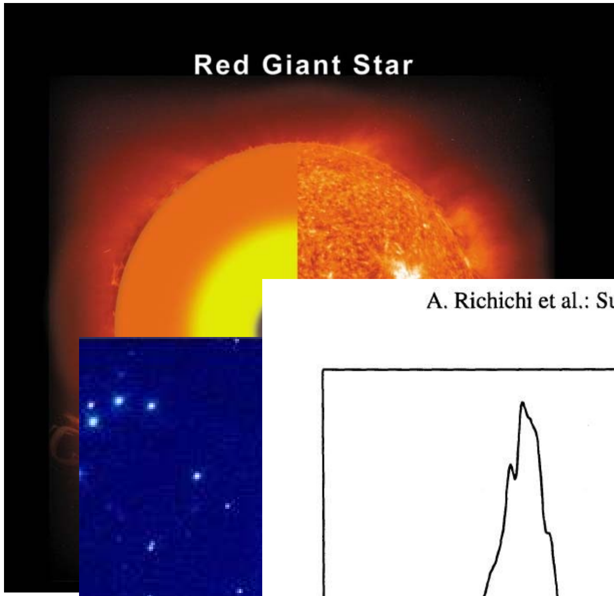
Paranal and its Instruments

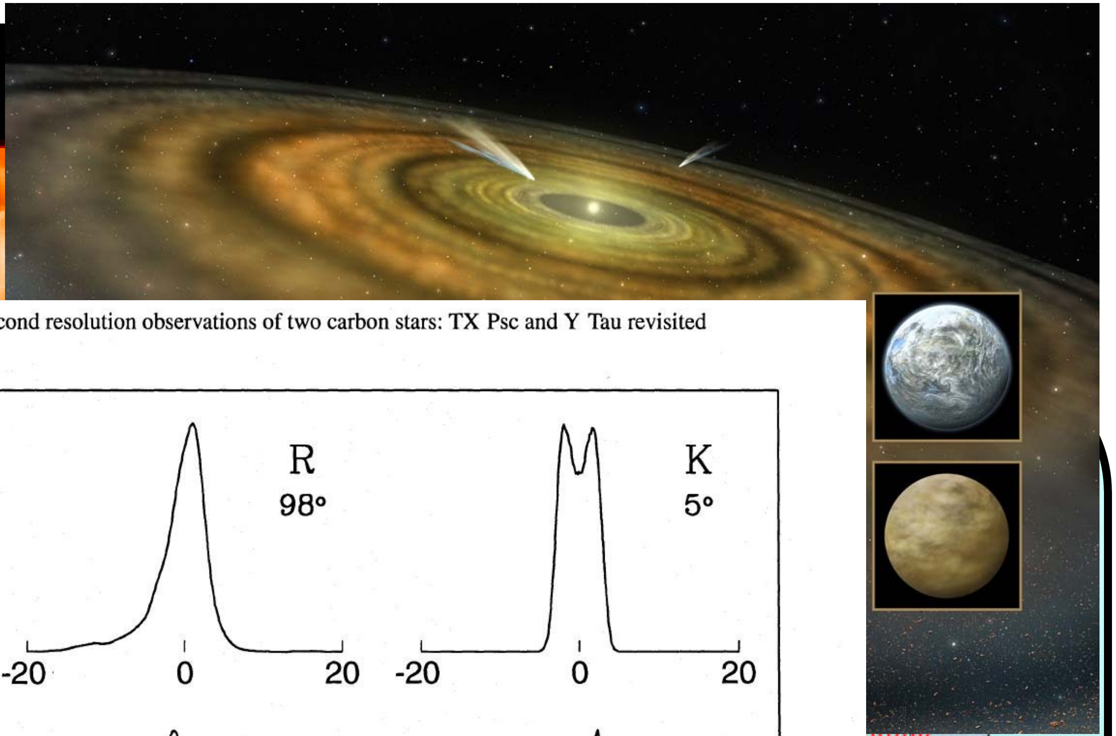


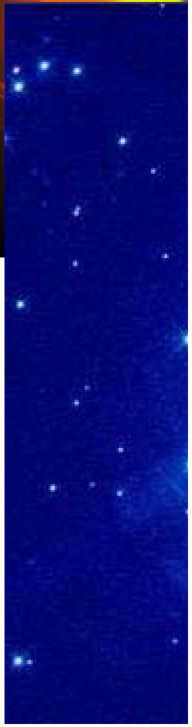


Lots of videos and pictures available from the ESO Web site...

The quest for high angular resolution of solar-mass stars







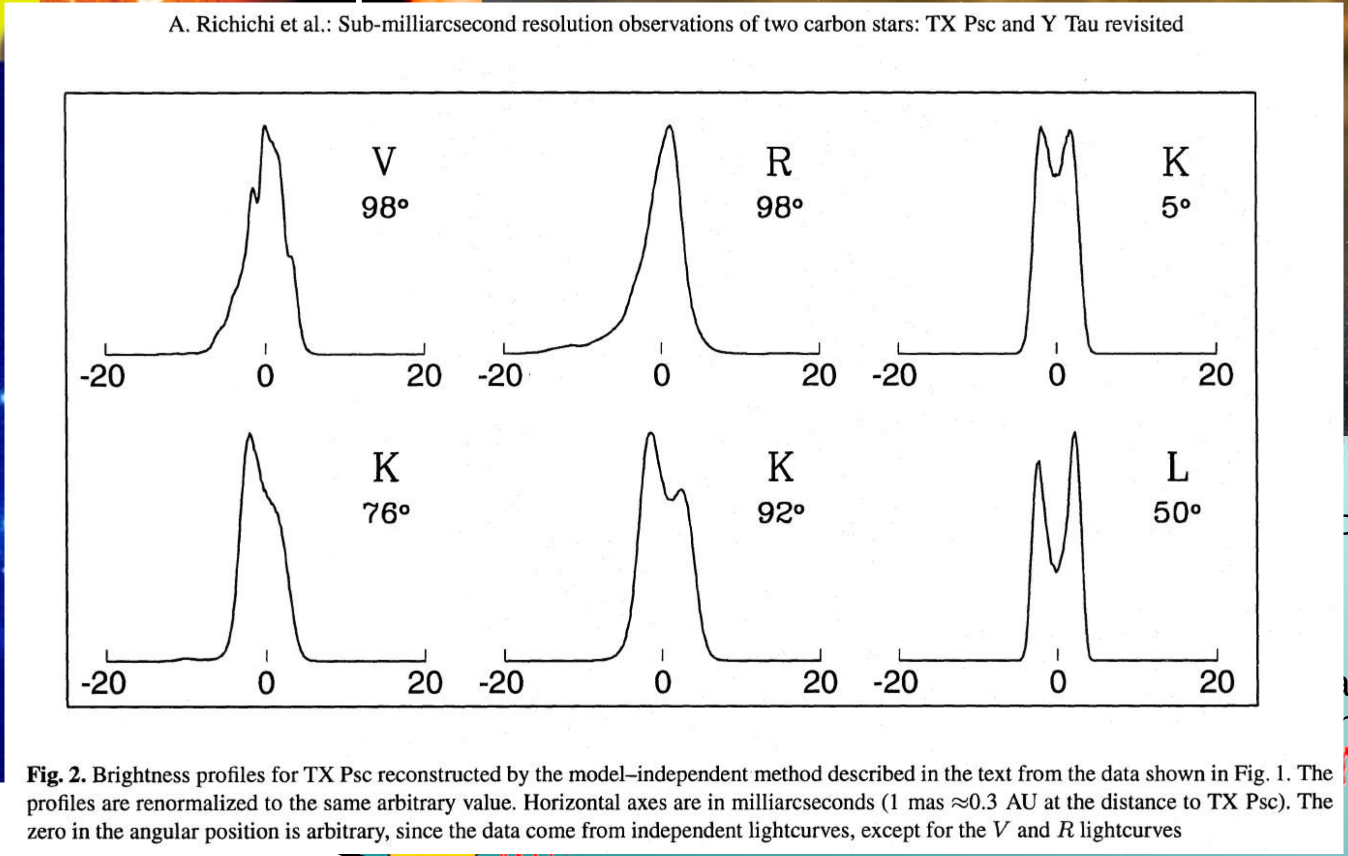

A. Richichi et al.: Sub-milliarcsecond resolution observations of two carbon stars: TX Psc and Y Tau revisited

Fig. 2. Brightness profiles for TX Psc reconstructed by the model–independent method described in the text from the data shown in Fig. 1. The profiles are renormalized to the same arbitrary value. Horizontal axes are in milliarcseconds (1 mas ≈0.3 AU at the distance to TX Psc). The zero in the angular position is arbitrary, since the data come from independent lightcurves, except for the V and R lightcurves

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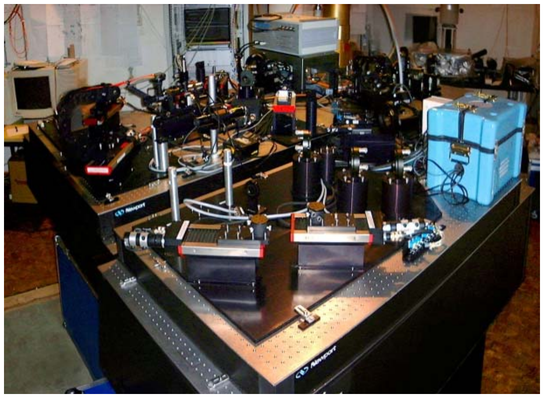
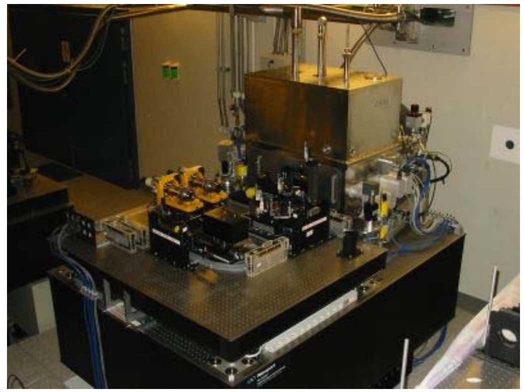
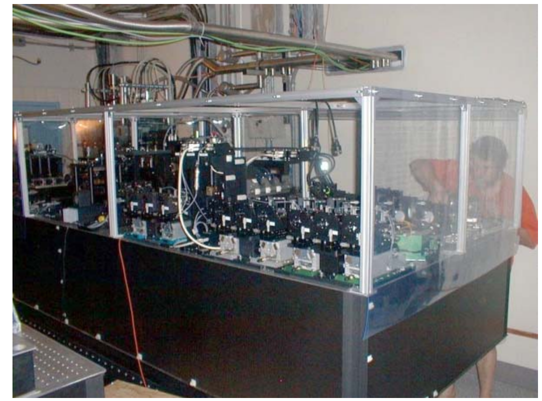
VLTI 1st Gen Instrumentation



VINCI



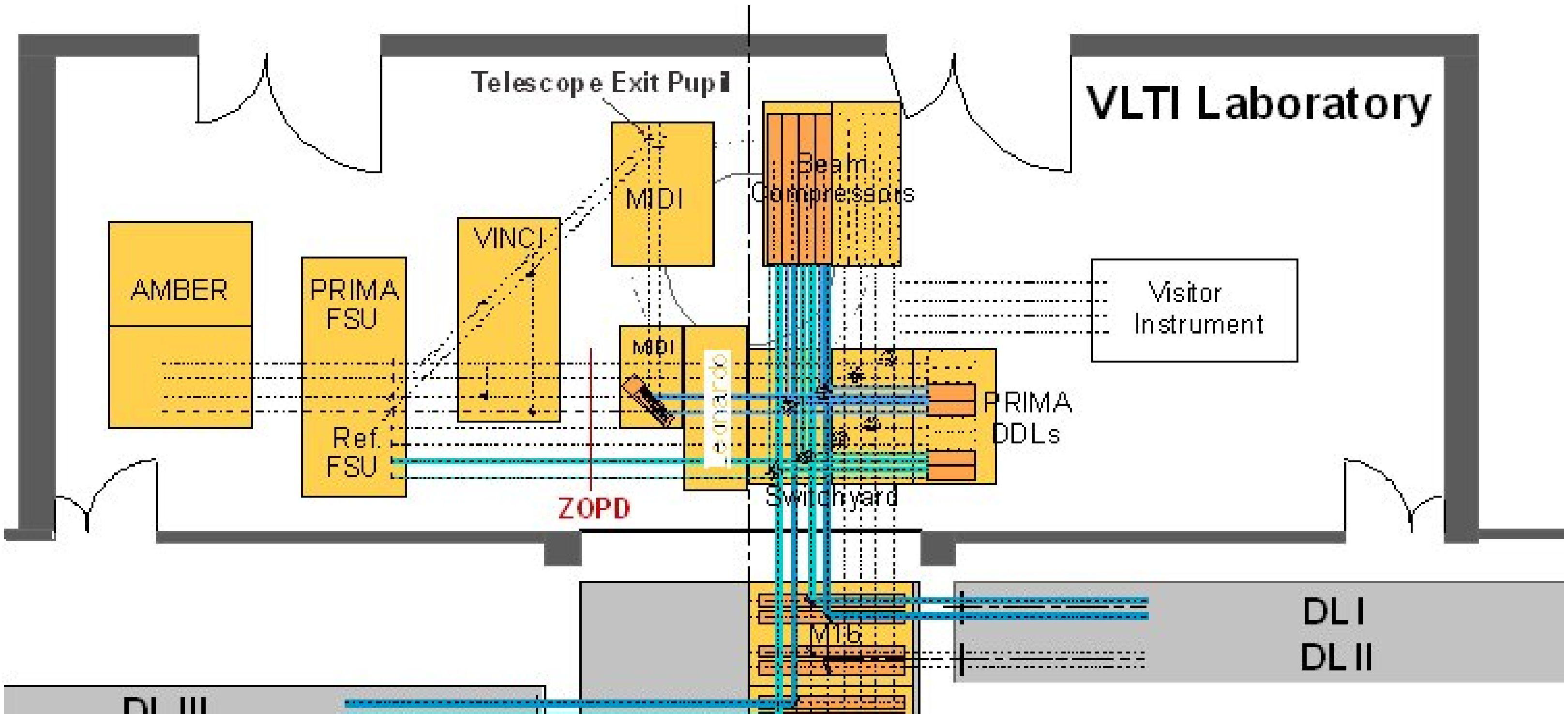
MIDI

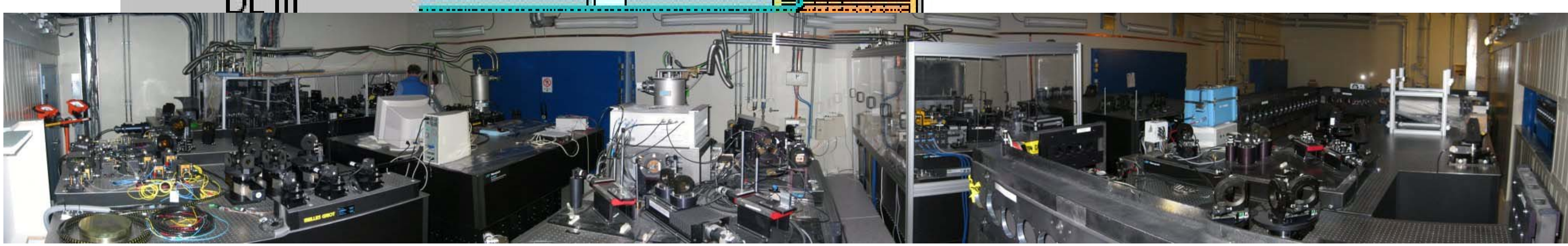


AMBER

PRIMA
VLTI - Phase-Referenced Imaging and Micro-arcsecond Astrometry -
ESO

VLTI Laboratory





MIDI Overview

D/F/NL; PI: C. Leinert (MPIA Heidelberg)

offered since P73 (Apr 2004)

Paranal: November 2002

First Fringes with UTs: December 2002

Mid IR instrument (8–13 μm) , 2-beam, Spectral Resolution: 30-260

Limiting Magnitude N ~ 4 (1.0Jy, UT with tip/tilt, no fringe-tracker) (0.8 AT)

N ~ 9 (10mJ, with fringe-tracker) (5.8 AT)

Visibility Accuracy 5%

Airy Disk FOV 0.26” (UT), 1.14” (AT)

Diffraction Limit [200m] 0.01”

AMBER Overview

F/D/I; PI: R. Petrov (Nice)

offered since P76 (Oct 2005)

Paranal: February 2004

First Fringes with SIDs: March 2004; with UTs: May 2004

Near IR Instrument (1–2.5 μm) , 3-beam combination (closure phase)

Spectral Resolution: 35-14000 (prism, 2 gratings)

Limiting Magnitude K =11 (specification, 5 σ, 100ms self-tracking)

J=19.5, H=20.2, K=20 (goal, FT, AO, PRIMA, 4 hours)

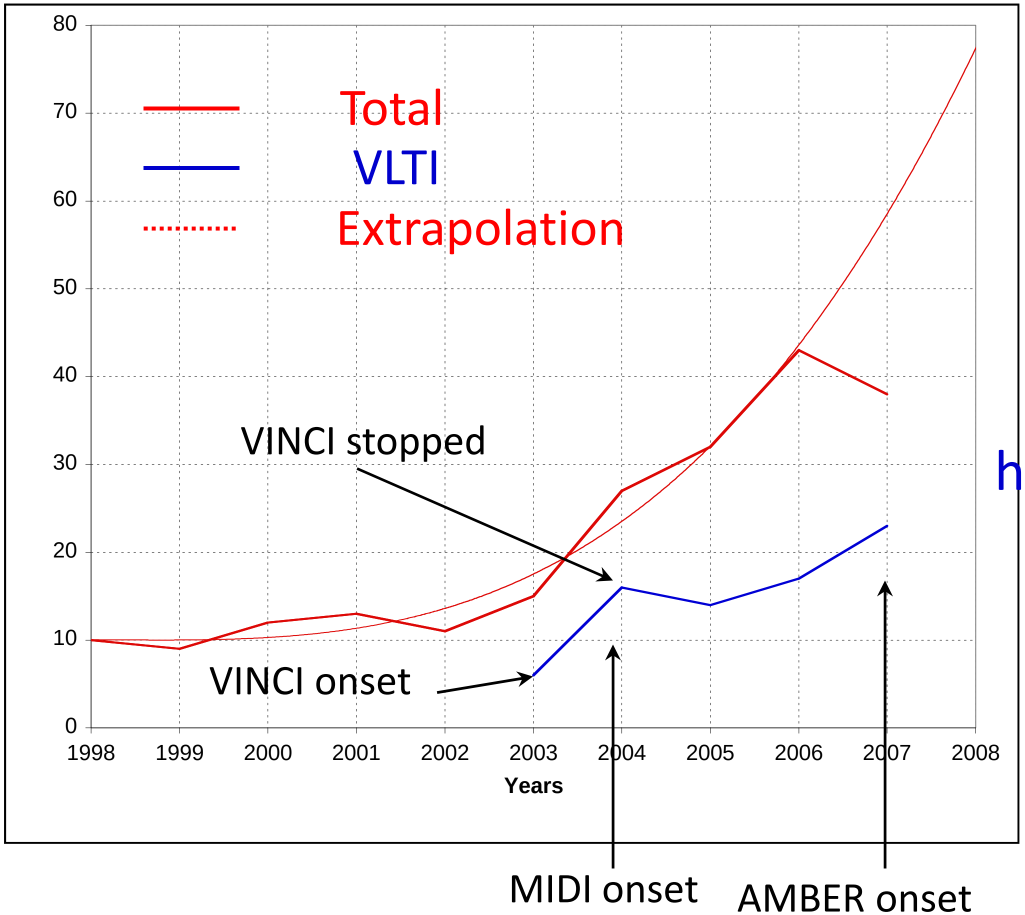
Visibility Accuracy 1% (specification)

Airy Disk FOV 0.03"/0.06" (UT), 0.14"/0.25" (AT) [J/K band respectively]

Diffraction Limit [200m] 0.001" J, 0.002" K"

VLTI science statistics (1)

Interferometers refereed science papers



Instruments	Refereed science papers	Citations
VINCI	33	527
MIDI	36	321
AMBER	8	50

http://olbin.jpl.nasa.gov/iau/briefs/

ESO telescope library:
44 different first authors

(courtesy of G. Perrin/ M. Schoeller)

VLTI science statistics (2)

As of 26 Feb June 2010:

- 46 publications based on VINCI data
- 67 publications based on MIDI data
- 36 publications based on AMBER data

- 136 publications based on VLTI data
- 71 different first authors (23 with more than 1 first-author VLTI publication)

(from M.Wittkowski)

From the ESO database

From OLBIN (science only, refereed)

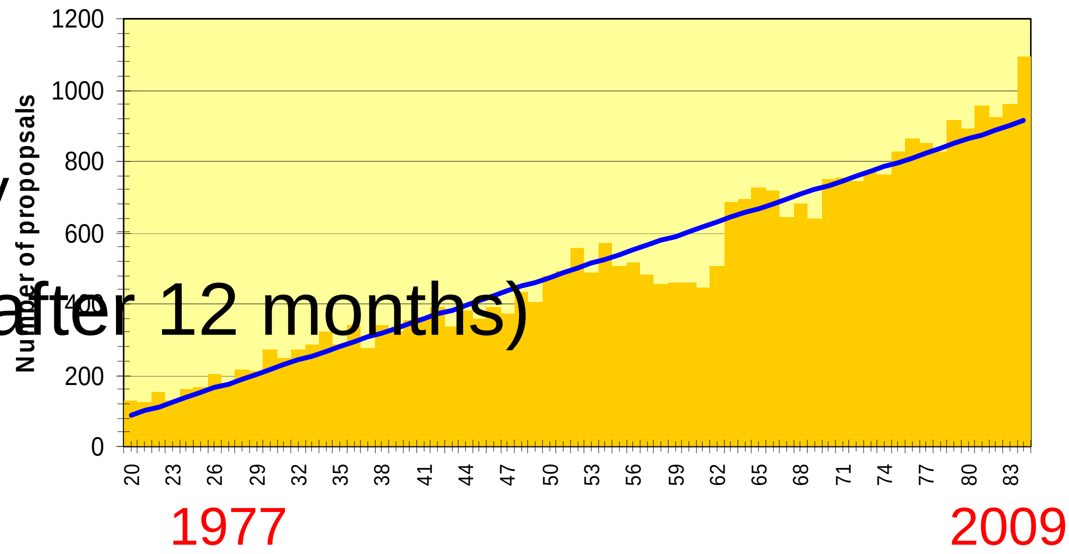
	CHARA	Keck	VLTI	Others	SUSI	IOTA	NPOI	Total	VLTI %
2010	1	1	1	-	-	-	-	3	33%
2009	3	1	15	23	1	1	-	44	34%
2008	4	1	8	26	-	-	1	40	20%
2007	4	1	13	33	1	-	-	52	25%

From ADS:
VLTI, refereed, no articles only

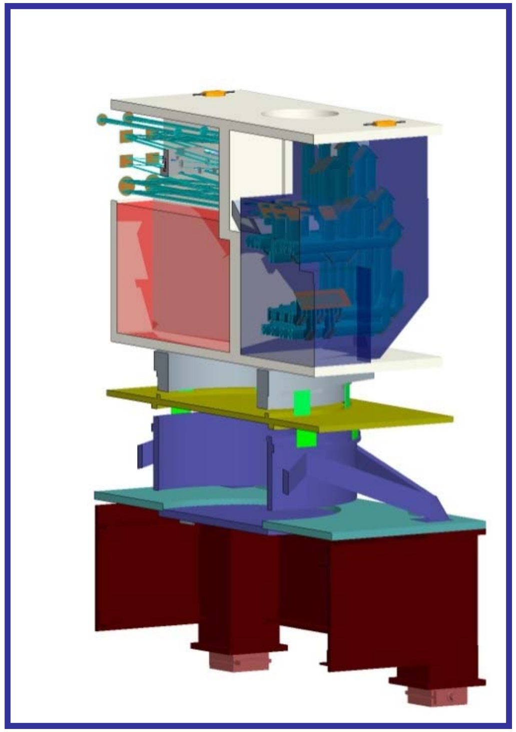
2002	2003	2004	2005	2006	2007	2008	2009	2010
3	25	10	25	12	26	11	20	1

Observing at ESO (incl. VLTI)

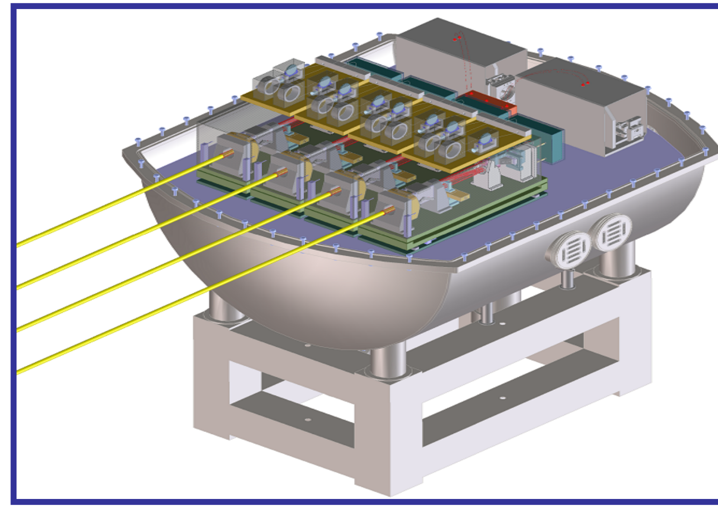
- Observing proposals
  - ~1000 proposals per semester (and growing)
  - La Silla, Paranal, APEX
  - Over-subscription factor ~5-8 on VLT
- Observing Programs Committee
  - Twice per year,12 sub-panels
  - Time allocated on scientific merit
  - no limits on nationality
- Data Archive (public after 12 months)
- Data Pipelines



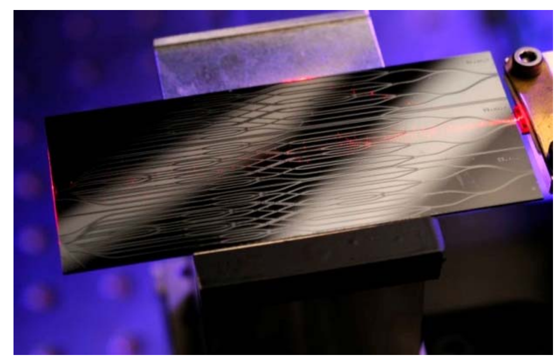
VLTI 2nd Gen Instrumentation



MATISSE



GRAVITY



PIONIER

PIONIER Overview

Precision Integrated Optics Near-infrared Imaging ExpeRiment

Visitor Instrument

F + USA, Others; PI: J.-P.Berger, J.-B. Le Bouquin

Paranal: September 2010?

First Fringes with ATs: Q4 October 2010

Near IR instrument (1.5-2.2μm) , 4-beam, No Spectral Resolution

Limiting Magnitude K ~ 8.5 (AT, no fringe-tracker, self OPD mod)

H ~ 7.5

Visibility Accuracy <1%

Airy Disk FOV 0.2” (AT)

Diffraction Limit [200m] 0.01”

PIONIER Science Drivers

The study of young stars environments at the AU scale

1. Direct imaging of the inner boundaries of disks around Herbig AeBe stars;
2. Solving the T Tauri size/luminosity enigma;
3. Revealing the structure of debris-disk hot dust component
4. Detecting and characterizing two hot Jupiter

request: 12 nights/semester over 2 years on ATs
(4. requires 3 UT nights)

Imaging the inner boundaries of protoplanetary disks

SCIENTIFIC GOALS:

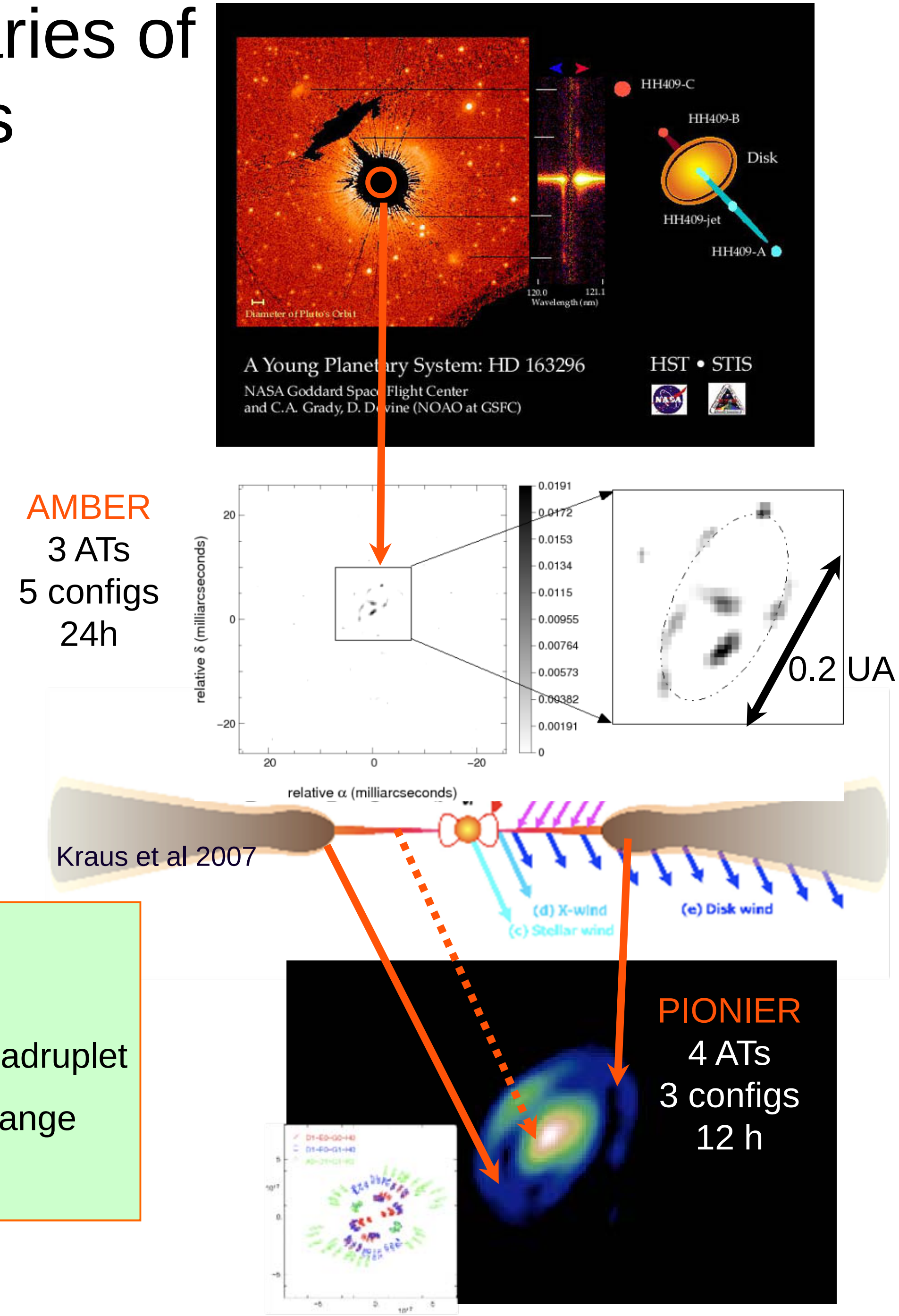
- Characterizing the inner astronomical unit of protoplanetary environments through aperture synthesis imaging.
- Morphology studies: inner disk vertical structure, dust grain size, hot inner emission linked to accretion and/or ejection

THE CHALLENGE:

- Obtaining a decently covered (u,v) plane
- AMBER effort very time consuming and affected by intrinsic variability
- Clumpy image

PIONIER strengths:

- Provides 6 visibilities and 4 closure phases
- It takes 4 AMBER triplets to get one PIONIER quadruplet
- Visibility precision 5 x AMBER: higher dynamic range



MATISSE Overview

Multi-AperTure mid-Infrared SpectroScopic Experiment

F, D, NL, Others; PI: B. Lopez

Paranal: 2014?

Cost: 133FTE, 3.4MEUR, +ESO contributions

Mid IR instrument (L,M,N) , 2-bands, 4-beam, Spectral Resolution 10^1-10^3

Limiting Magnitude N ~ similar to MIDI

L ~ 8.7, 10.2, 15.1 (UT; w/o, FT on-, FT off-axis)

Visibility Accuracy ~ AMBER, MIDI

Airy Disk FOV 0.09”-0.26” (UT), 0.38”-1.14” (AT)

Diffraction Limit [200m] 0.003 ” to 0.01”

MATISSE Science Cases

Science Case	L&M band ATs/UTs	N band ATs/UTs
Star and Planet Formation		
- Low-mass Stars and Planet Formation	~ 100 / >100 [a]	~ 100 / >100 [b]
- Young low-mass Binary Stars	>25 / >60	>15 / >30
- FU Orionis Stars	6 / 9	5 / 13
- Debris Disks	250 / 320	70 / 180
- Massive Star Formation	~ 50 [c] / ~ 50	~ 50 [c] / ~ 60
Active Galactic Nuclei	0 / 47	0 / 17
Evolved Stars		
- Low-mass stars [d] : a) O	~ 30 / 30	~ 90 / 90
b) C	~ 6 / 6	~ 15 / 15
c) S	~ 2 / 2	~ 5 / 5
- R CrB	3 / 10	3 / 10
- PNs	3 / 10	3 / 10
- Cepheids	6 / 6	6 / 6
- High-mass stars: a) B[e] stars	15 / 7	15 / 3
b) WR stars	10 / 25	10 / 15
c) LBV stars	3 / 5	1 / 5
d) Be stars	30 / 30	0 / 0
Solar System Minor Bodies	0 / ~ 30	$\sim 10^3$ / $\sim 6\times10^3$
Extrasolar Planets	3 / 25	0 / 1
Galactic Center	0 / 1	0 / 1

Tracing proto-planets with MATISSE

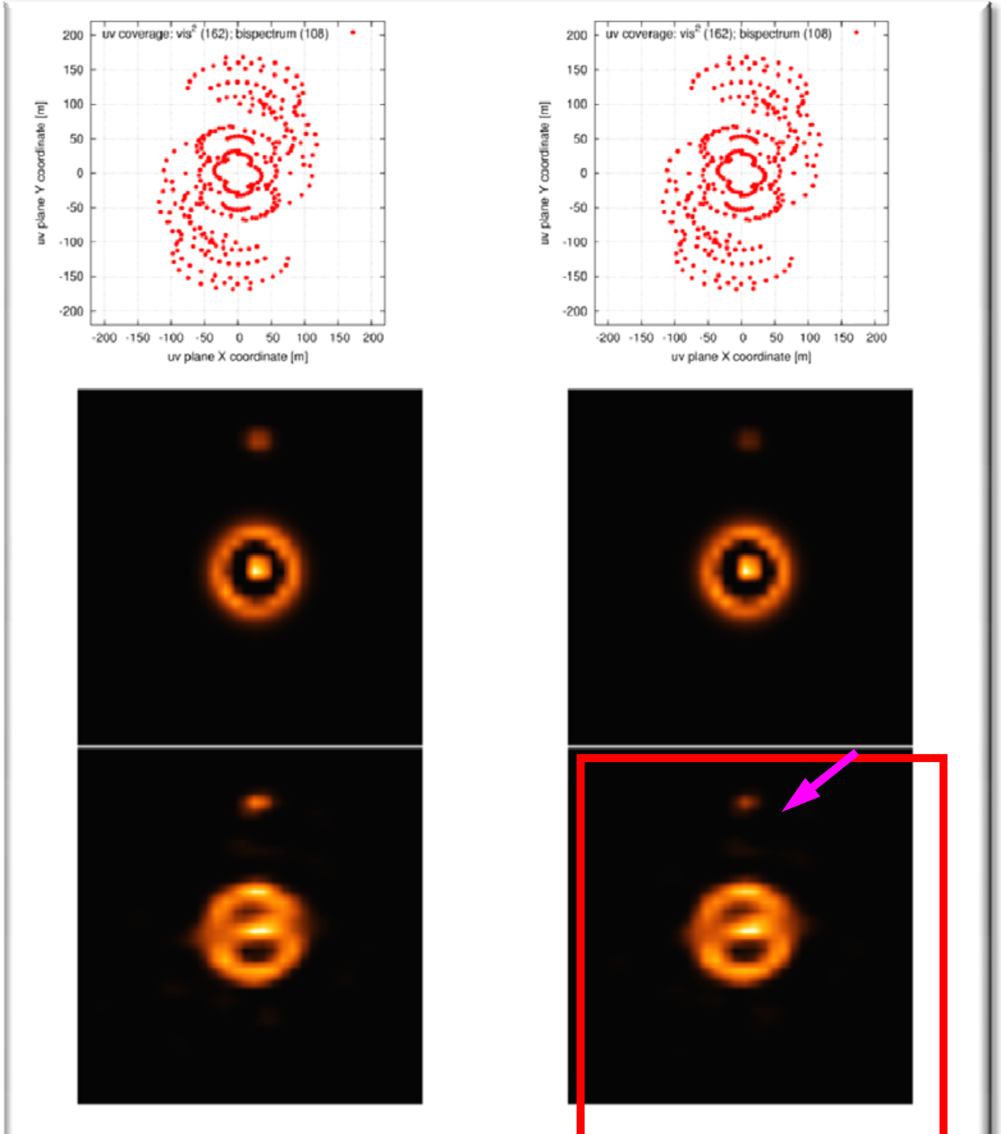
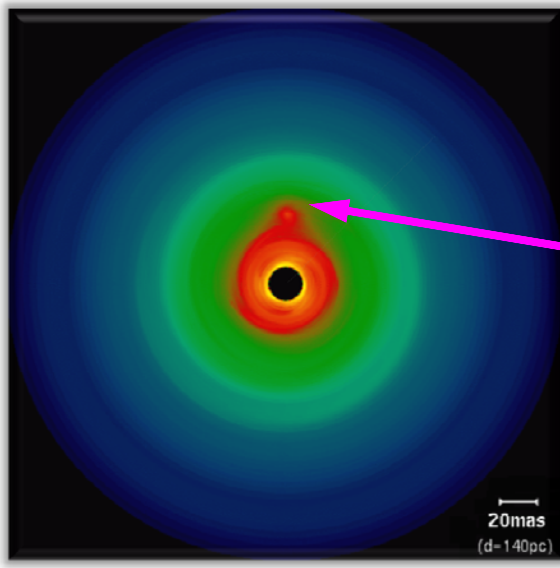
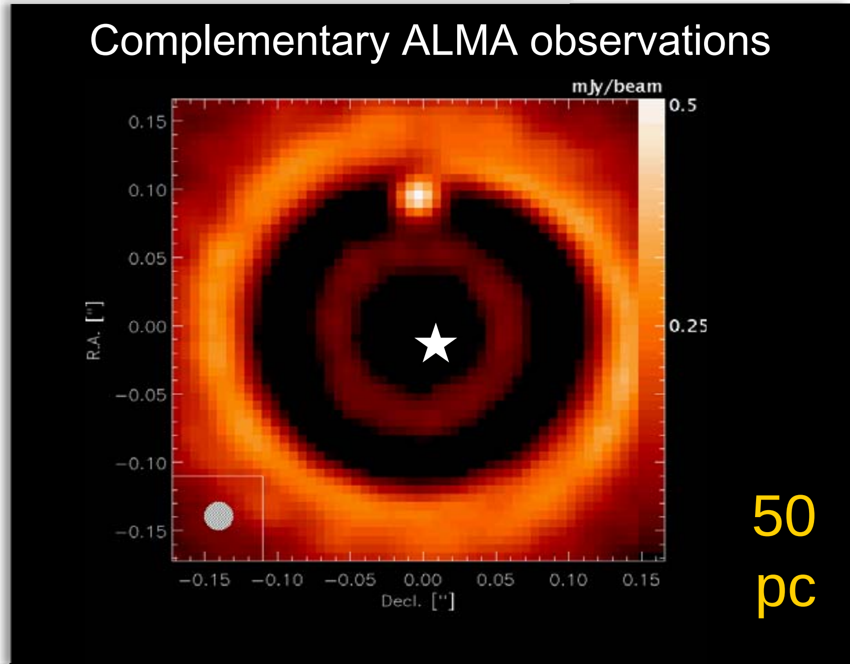


Figure 6: Reconstructed N band images (3x4ATs; ∼ 150 m) of a protoplanetary disk with an embedded planet (see Fig. 5[right]). Left: Brighter planet: intensity ratio star/planet=100/1; Right: Fainter planet: intensity ratio star/planet=200/1. First row: uv coverages Second and third row: originals and reconstructions, respectively. The images are not convolved (2x super resolution). Simulation parameter: modelled YSO with planet (declination -30°; observing wavelength 9.5 μm; FOV = 104 mas; 1000 simulated interferograms per snap shot with photon and 10 μm sky background noise (average SNR of visibilities: 20). See Doc. No. VLT-TRE-MAT-15860-5001 for details.



Mid-infrared-bright planetary accretion region



GRAVITY Overview

D,F, P; PI: F. Eisenhauer

Paranal: 2013?

Cost: 148FTE, 7.6MEUR -ESO contributions

Near IR instrument (2.2μm) , 4-beam, Spectral Resolution ~20-4000

within VLTI beam FOV: internal FT and dual-feed

own IR AO (Strehl 10% @ K=10)

Limiting Magnitude K ~ 19? (UT, fringe-tracker)

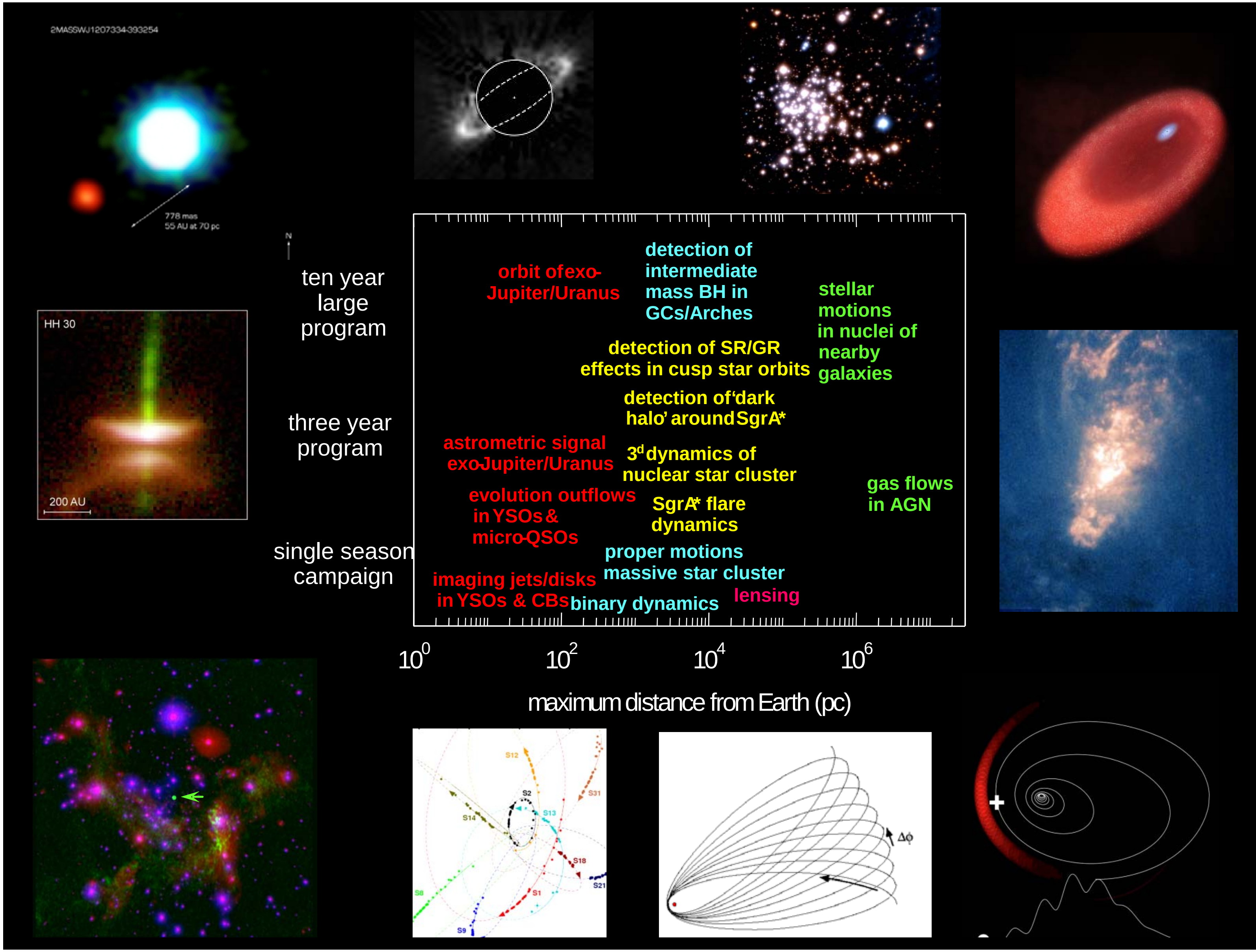
astrom. prec. 30μ" (*10*) for K=10+15 in 5 min

Visibility Accuracy <1%

FOV ~2" (UT) ~4" (AT)

Diffraction Limit [200m] 0.002"

GRAVITY Science Cases



The next frontier in interferometry:

Imaging!

http://www.eso.org/sci/facilities/paranal/telescopes/vlti