The VLTI now and in the future

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VLTI-School, Barcelonette
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Outline

1 VLTI status

2 VLTI: instrument status

3 Comments on the scientific use of VLTI

4 Preparing for the next generation instruments

5 Medium and Longer term view on VLTI

VLTI the visible

As a service mode user you get to know:

- User support department: C. Hummel, M. Wittkowski

As visitor you get to know:

- User support department: C. Hummel, M. Wittkowski
- The Paranal science operations group (astronomers): W.-J. de Wit, R. Grellman A. Mérand, , A. Mueller, S. Rengaswamy, T. Rivinius;
- The Paranal science operations group (TIOs): S. Cerda, C. Cid, L. Faundez, P. Guajardo, C. Herrera, M. Lopes, A. Pino, L. Rivas;

VLTI the invisible

Those you almost never get to know:

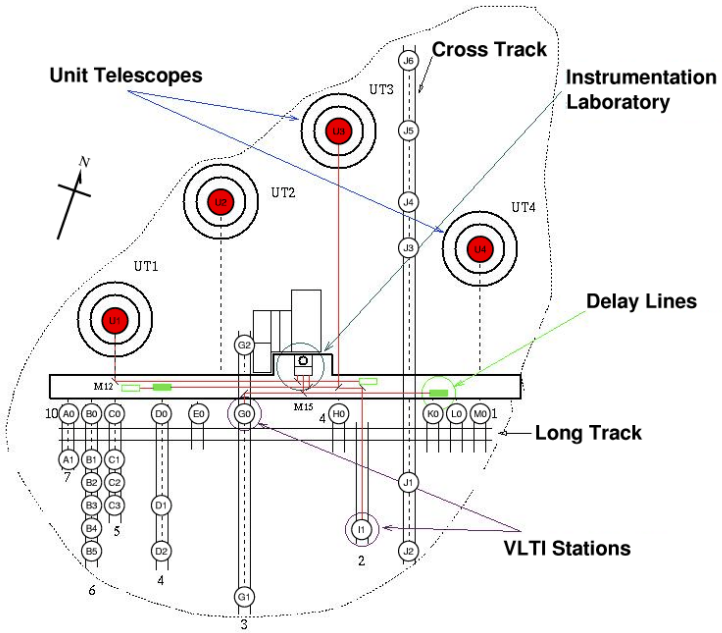
- Paranal System Engineering: J. Alonso, P. Gitton, P. Haguenauer, S. Morel, S. Poupar N. Schuler;
- Paranal Instrumentation: P. Bourget, P. Mardones
- Paranal Software: D. del Valle, A. Ramires, A. Segovia;
- Paranal Engineering (more) : Electronics, Mechanics, Optics + Maintenance;
- Quality control: I. Percheron
- Instrument scientists: M. Schoeller (GRAVITY, MATISSE), J. Woillez (VLTI)
- Garching Software: R. Abuter, L. Andolfato, A. Gabash, T. Phan Duc,
- Garching Engineering: F. Delplancke, F. Derie, N. di Lieto S. Guniat, C. Schmid;

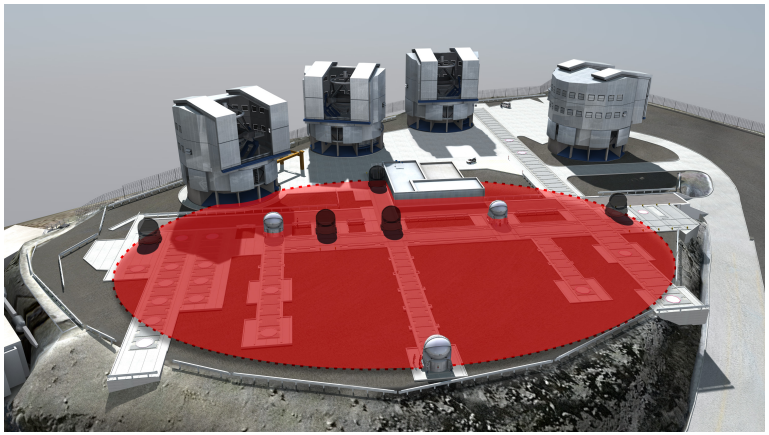
VLTI status

VLTI in a nutshell

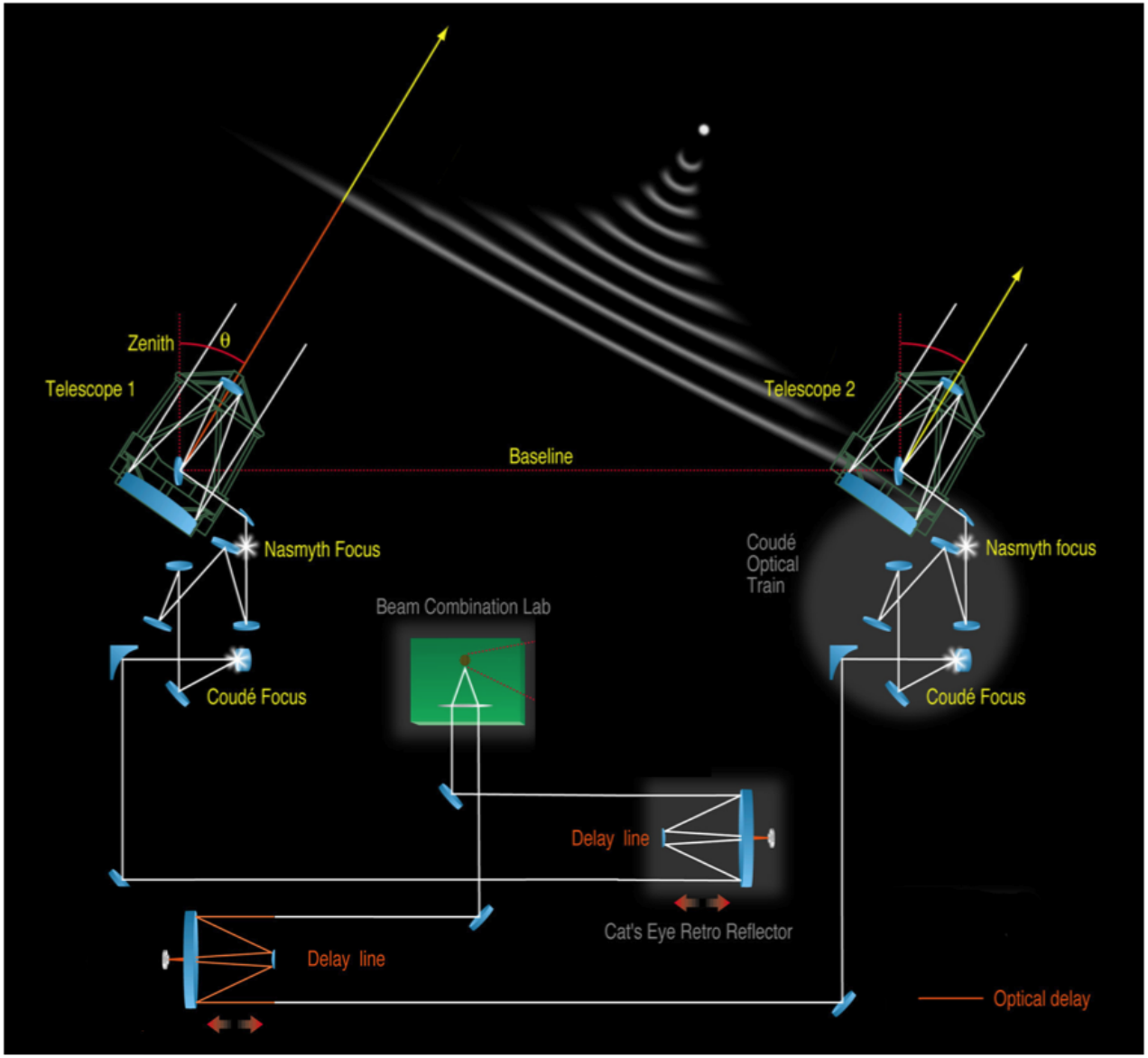
- Array of 4 ATs (1.8m) or 4 UT (8m);
- Four telescope configurations offered;
- Two official instruments: AMBER (H,K) , MIDI (N);
- Visitor instrument: PIONIER (H);
- Visitor, Service, Delegated visitor modes;
- P90: Science time 80%;

VLTI: site layout





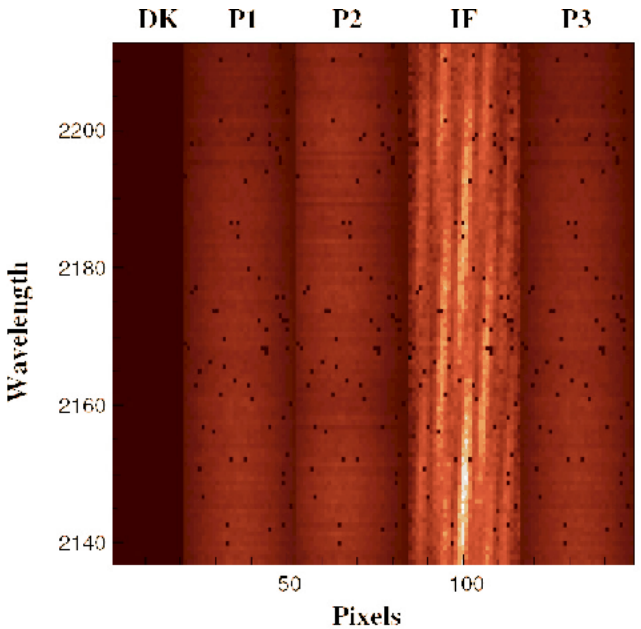
VLTI: behind the scenes



Fringe tracking

- *A* Fringe tracker: provides stable fringes by actively correcting optical path differences;

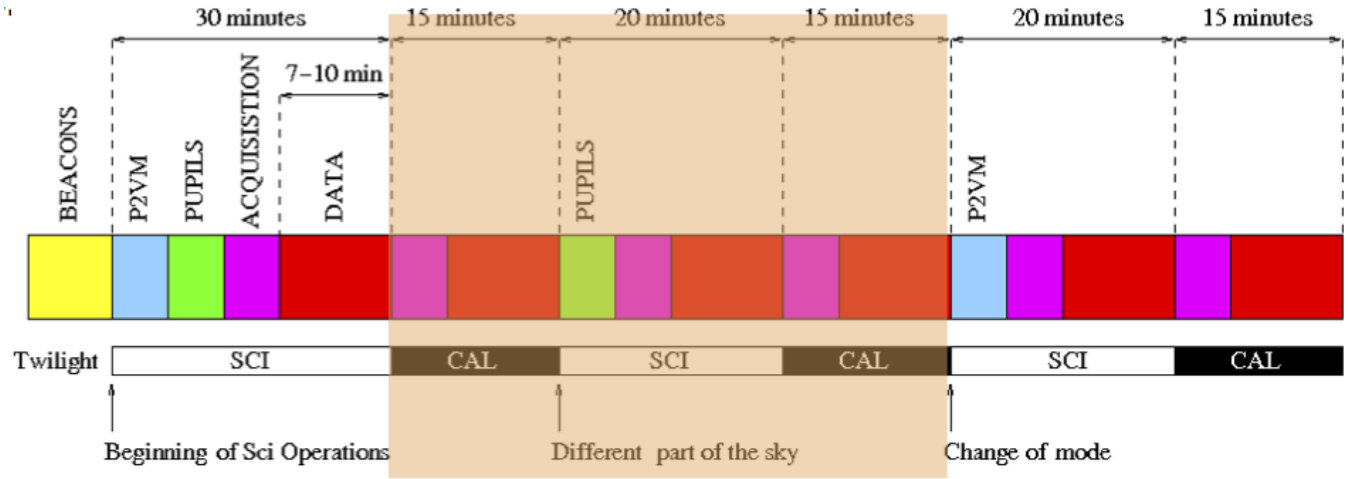
- FINITO: H band 3T fringe tracker (AMBER);
- PRIMA-FSU: K band 2T fringe tracker (MIDI);
- FT benefits:
  - Integration;
  - Coherent integration;
  - Better data calibration.



VLTI operation

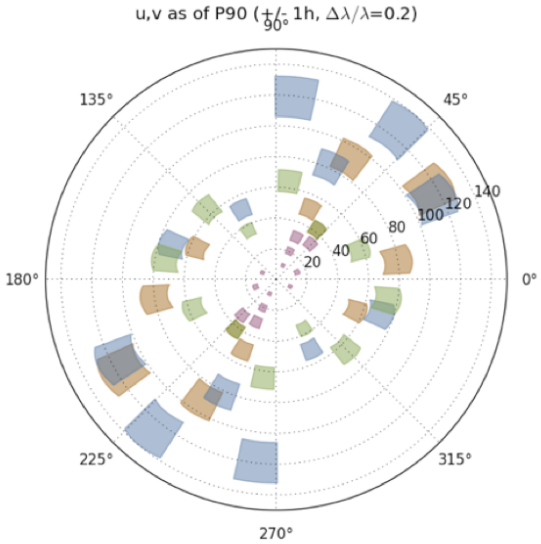
- VLTI fully integrated into the VLT operations scheme;
  - VLTI operations profit from the established VLT infrastructure (unified tools);
  - VLTI observations can easily be combined with other techniques in the same observing program;
  - VLT tools adapted to include VLTI specific requirements (baseline, LST);
- VLTI operations included in new generation operation tools (concatenation of OBs, filtering, ranking).

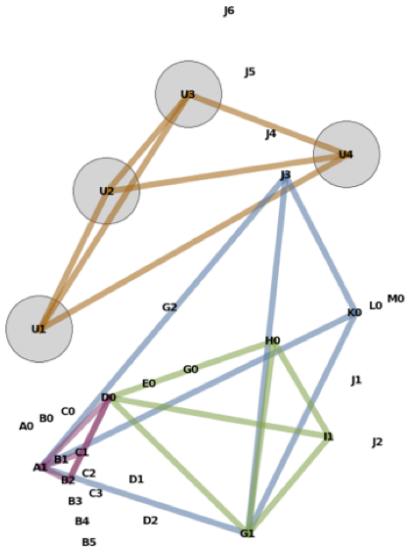
Preparing observations



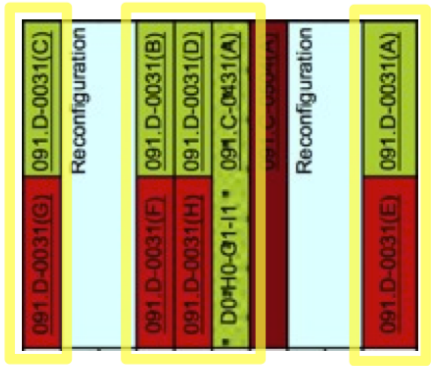
- The basic building block is a CAL-SCI-CAL (or CAL-SCI) sequence;
- Concatenations of sequences available
- Aperture synthesis: needs OBs at different LST and telescope configurations
- Observations are conducted in
  - service: observations repeated until quality control says ok, better chance of good seeing;
  - visitor: one-shot, more flexibility, only technical loss in GTO ”reimbursed”;
- ESO provides preparation tools (VISCALC/ CALVIN)
- JMMC provides preparation tools (Aspro2/ SearchCal)

AT configurations



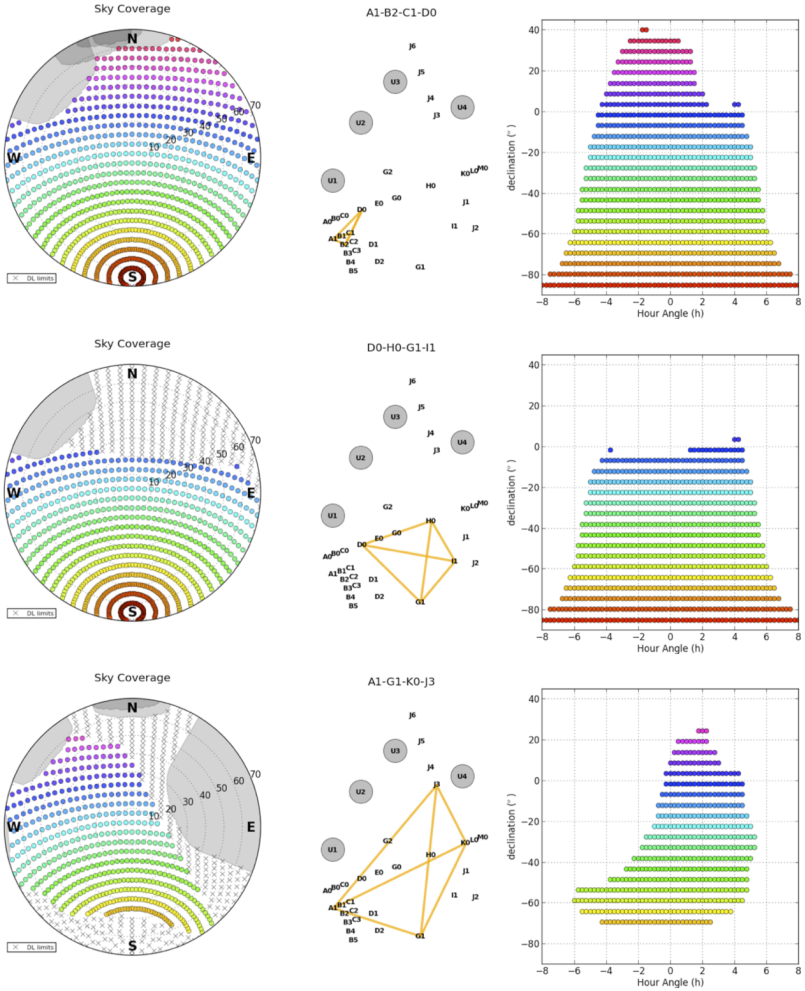


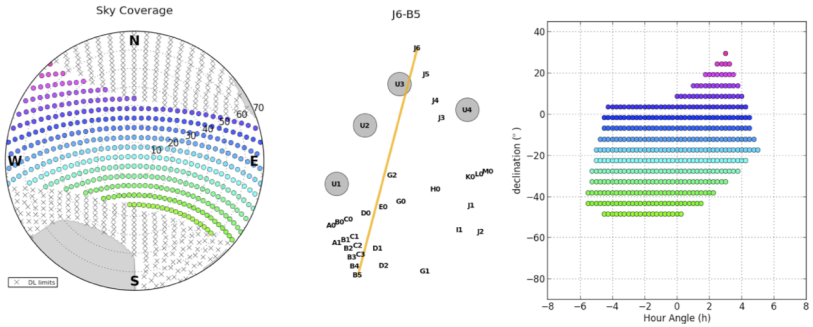
- relocation: 15 to 34 nights/period;
- 2 ATs per day;
- 1/2 test night after relocation;
- intermediate configs not used;
- user request based schedule;



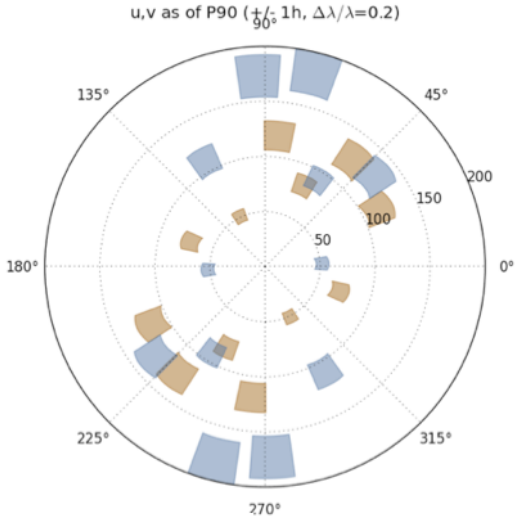
April 2013: **4n** relocation for **5n** VM program

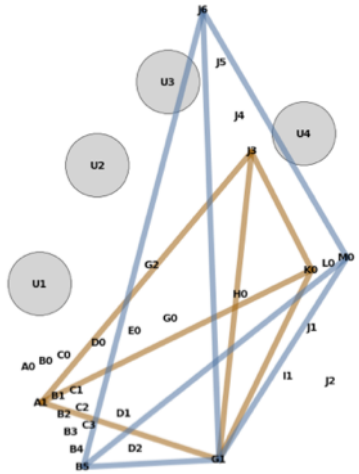
Sky coverage (1)

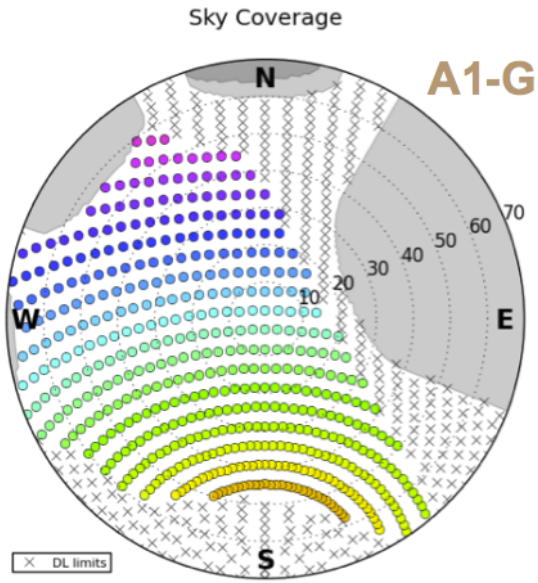




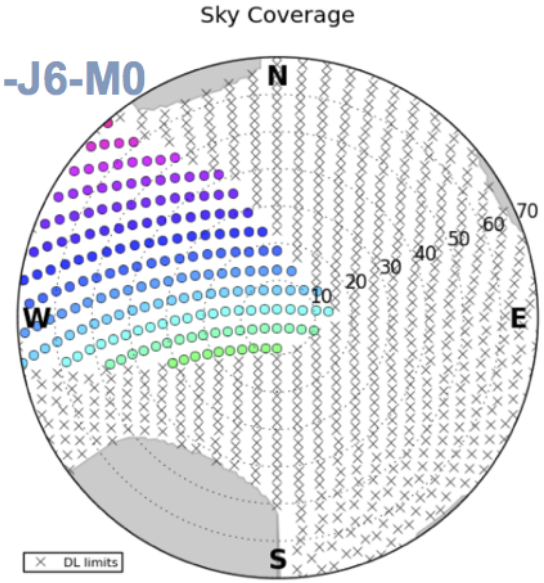
Sky coverage (2)







max B ×= ~1.4



Data reduction

- ESO/VLTI does not provide reduced data;
- ESO/VLTI does not provide calibrated data;
- AMBER:
  - Library amdlib, version 3.0.4 publicly available from http://www.jmmc.fr/data_processing_amber.htm;
  - ESO pipeline based on amdlib is available;
  - Reflex workflow discussed;
- MIDI
  - MIA & EWS software (Jaffe, Koehler, et al.), publicly available from http://www.strw.leidenuniv.nl/~nevec/MIDI/index.html;
  - Independant ESO pipeline available;

Good points

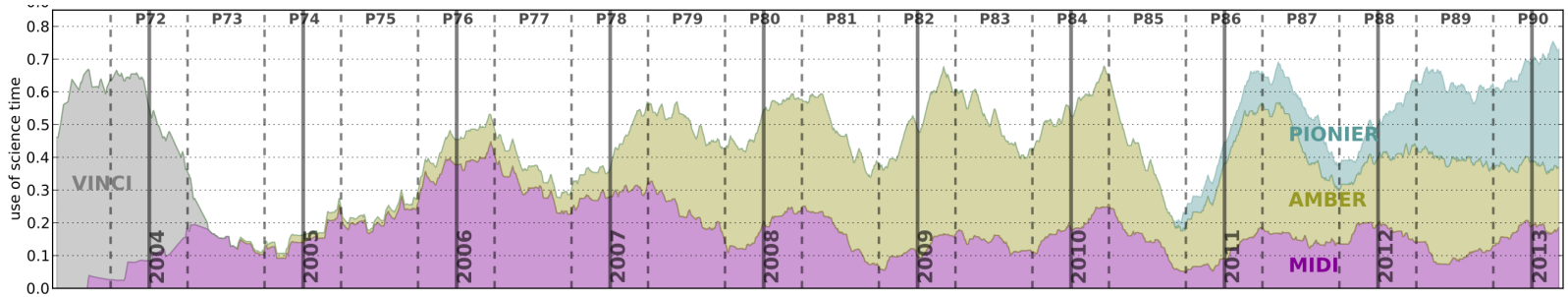
- Time dedicated to science has increased ($\approx$ UTs);
- Less technical dowtime;
- reasonable sky coverage (3 quadrants);
- 4T configs offered with choice between all 2T/3T possible;
- User has total control of uv coverage (LST & configs);
- User can specify time constraints.

Areas of improvement

- Too many proposals requesting good seeing conditions (AMBER 80% s$\leq$ 0.8" ;
- Low number of Service Mode Nights, low requests, visitor instruments;
- almost no filler programs;
- rationalisation of the scheduling.

VLTI: Instrument status

VLTI usage: instruments



- AMBER had a slow start, Medium resolution K a hit;
- PIONIER (visitor instrument) currently 40% of scheduled time
- MIDI proposals + 25% since P90 because PRIMA-FSU (AT sensitivity $\approx \times 10$)

MIDI

- Proposals raised by 30% with new PRIMA-FSU + MIDI mode;
- Critical wavelength window that will disappear until MATISSE;
- Extended in P93 (GRAVITY delay)
- Fate: To be removed at the start of lab work.

AMBER

- (J) H and K, R 35, 1500, 12000
- Good data reduction support (JMMC);
- Suffered from FINITO degraded performances;
- Strong competition from PIONIER in low resolution;
- Medium/High spectral resolution is AMBER's strength;
- Existence of an AMBER++ alternative to amdlib (fainter,F. Millour);
- frontal competition when GRAVITY arrives
- High spectral resolution very interesting but limited by lack of FT;
- Fate: Will remain on the mountain until GRAVITY is fully operational.

PIONIER

- Visitor instrument, 4 telescope, H band R $\approx$ 5,40;
- Accounts for $\approx$ 40% of scheduled time;
- New potential ”game-changing” camera end of 2013;
- LSP(STC) recommended to study its extension on the mountain;
- Discussion with PI-institute on the conditions of transfer to ESO;
- Demonstrator for future phase 3 products delivery (calibrated data);
- offered in visitor mode for P93;
- Fate: Leaves when Gravity arrives. Will be prolongated if proper technical solution can be found;

PRIMA

Goals:

- fringe tracking for MIDI and AMBER;
- 2 telescope astrometry in K band ($\approx 20 - 50\mu$as).

a Commissioning process interrupted;

b Major system issues identified;

c Switched to “engineering mode” to enable experimental astrometry;

d Principle of a *G*ate Review examined by management;

- Assesment of the current/expected PRIMA performances;
- Establishing a recovery plan;

e Establish a go/no go pathway based on technical, scientific, operational and managerial assessment.

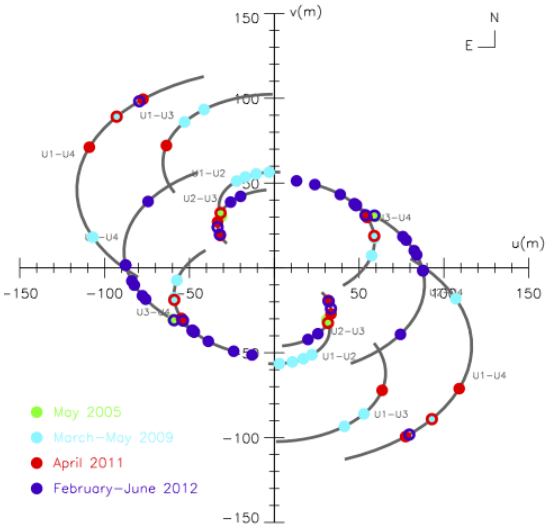
VLTI scientific use

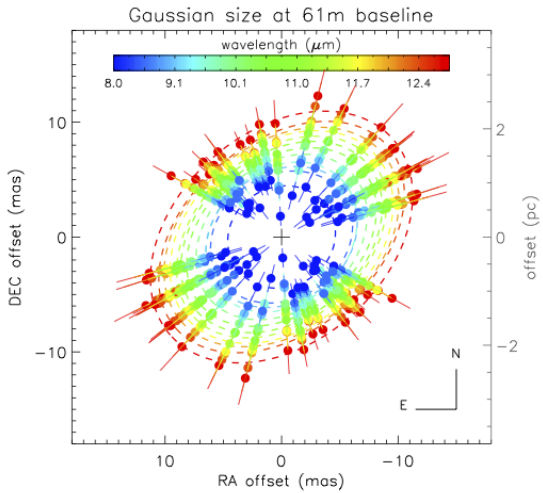
VLTI: hunting terrain

- **Stars from birth to death**;
- **Binary stars: from birth to death**;
- **Active galactic nuclei**;
- Minor bodies;
- Exoplanet (direct detection, astrometry);
- Black hole dynamics;
- Lensing;
- Cosmology;

Plan your uv coverage

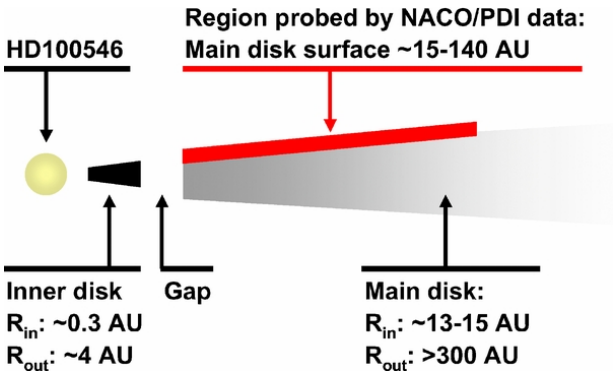
- Marginally vs. fully resolved ?
- Imaging vs. Model fitting
- Optimum uv coverage for the science ?



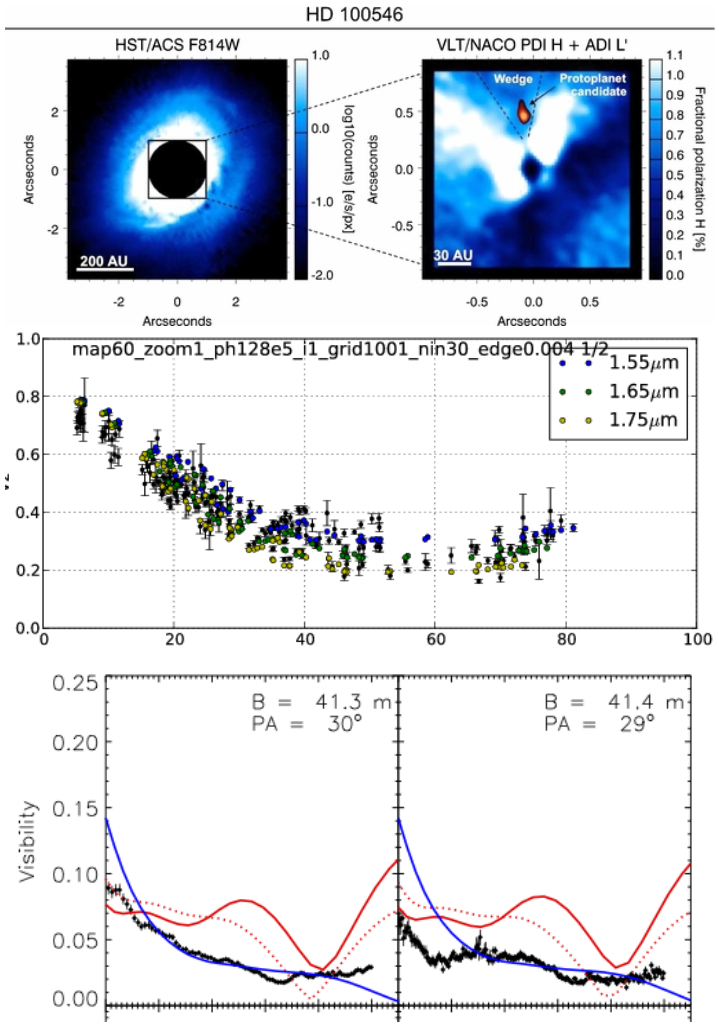


Hoenig et al. 2013

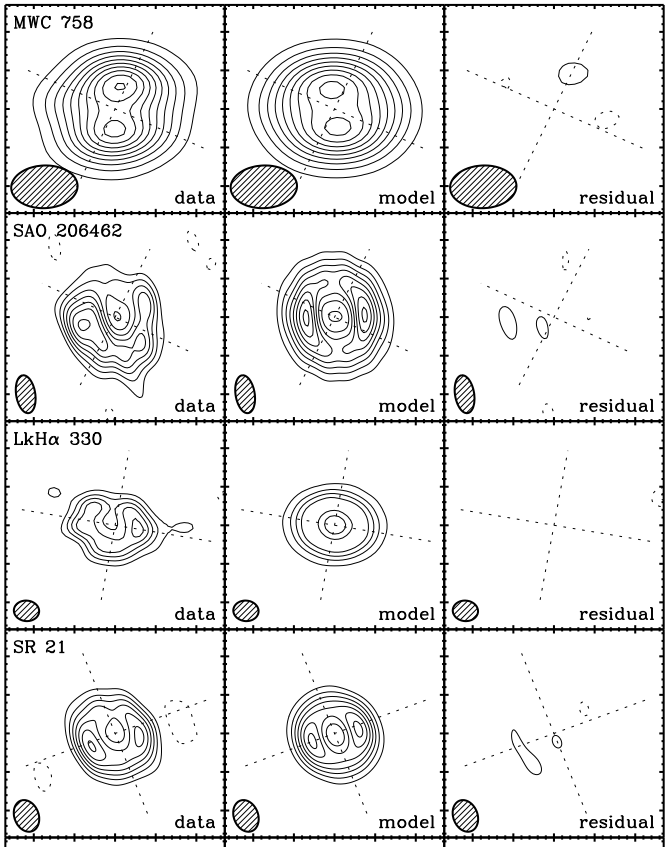
VLTI: multiwavelength, multitechnique

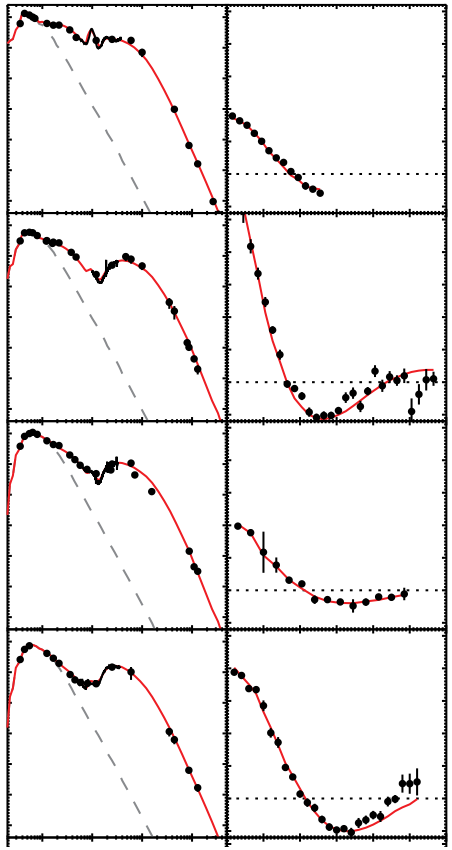


- Multiwavelength use of VLTI not widespread;
- Multitechnique use of VLTI is not widespread (e.g ALMA)



The use of large programs (1)

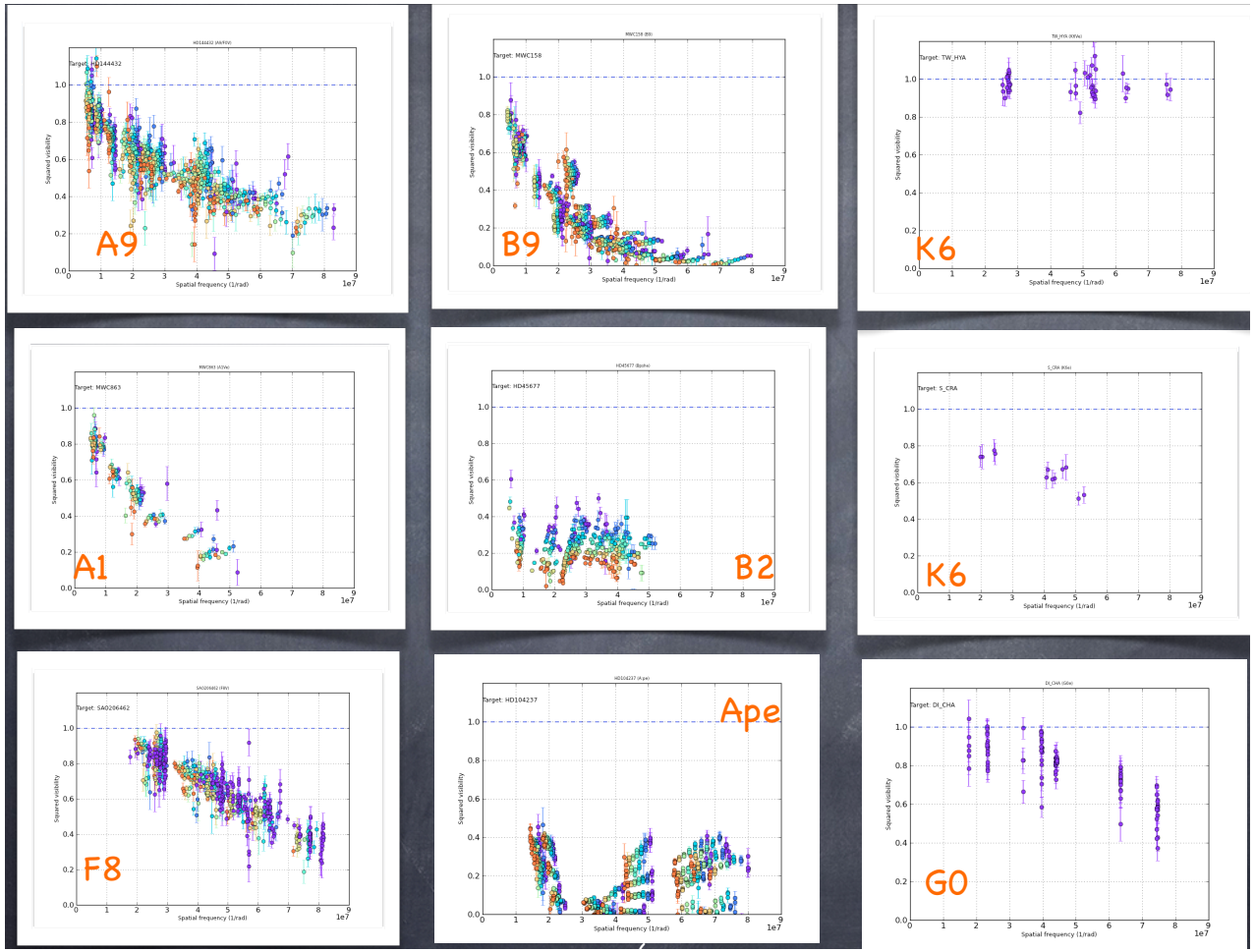




Andrews et al. 2011.

The use of large programs (2)

Herbig AeBe survey to match ALMA targets



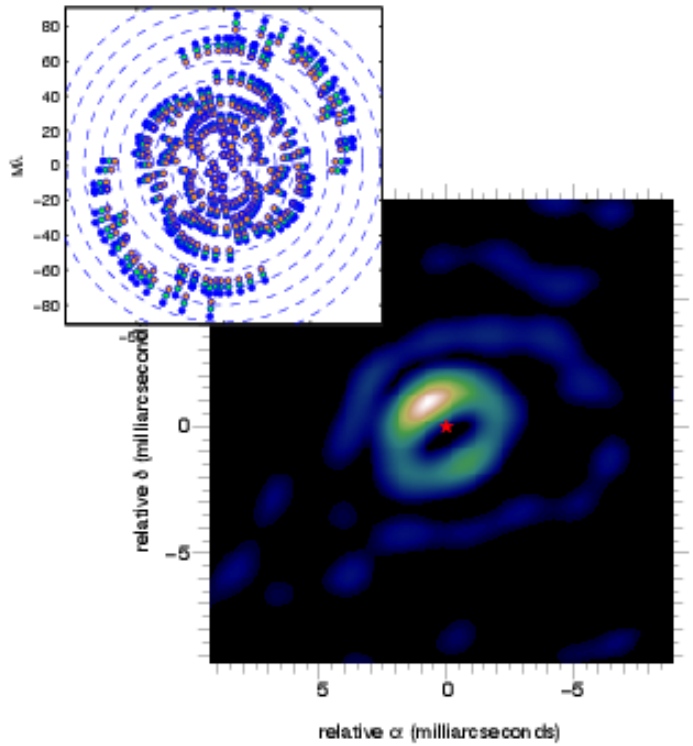
- Make use of large program !

The filler program

- Flag your program as filler if suited;
- Needs to be robust to seeing conditions;
- A fraction of completion is sufficient to extract scientific results;
- Probability of execution very high;

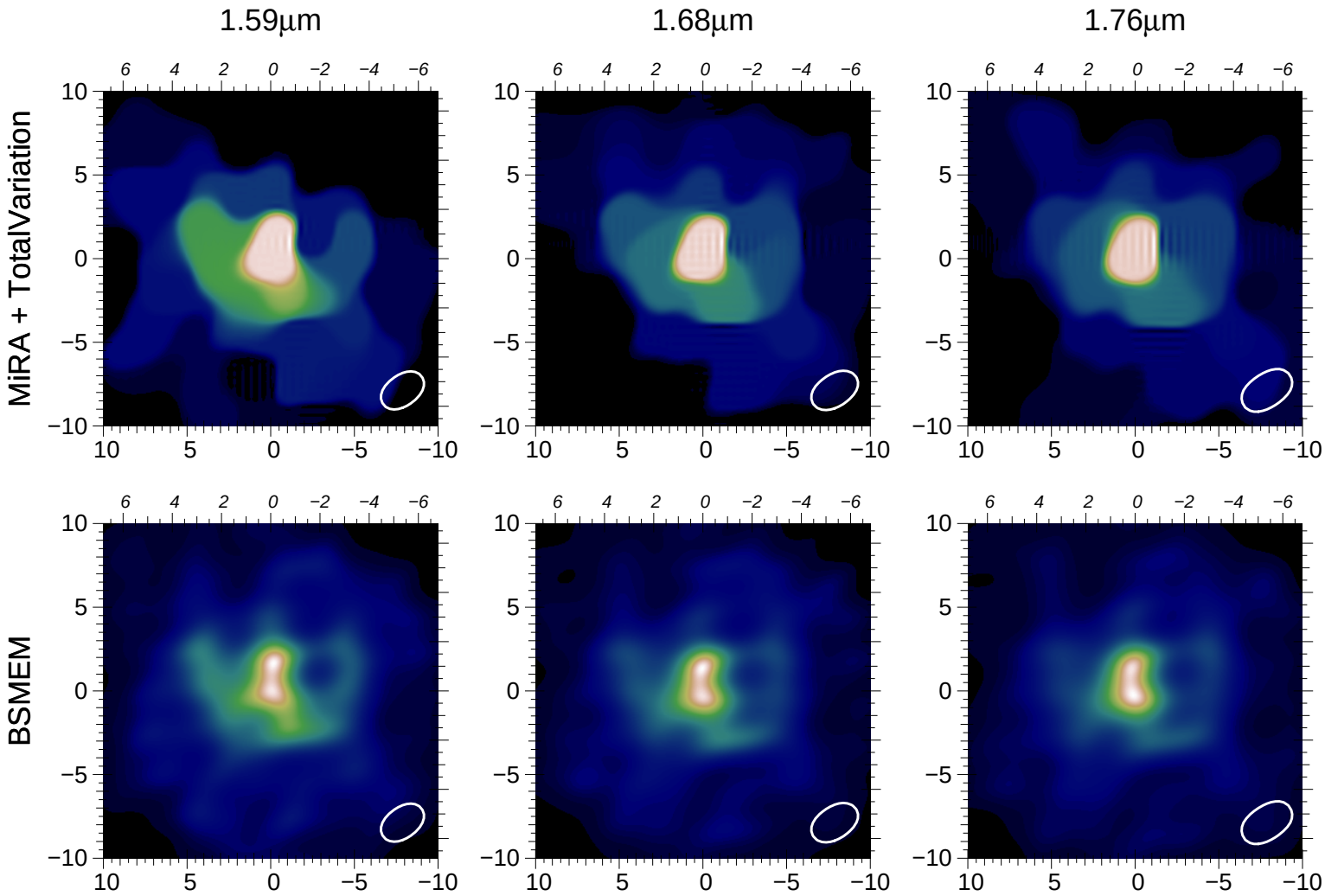
4T imaging

- VLTI functionally operated as an ”imaging” interferometer
- All three AT configuration can be offered in ≈ 10 days
- Typical imaging programs: 3 half nights;
- 4T clearly more efficient than 3;
- UT array not ideal
- Should improve with second generation;
- but ...



J. Kluska et al.

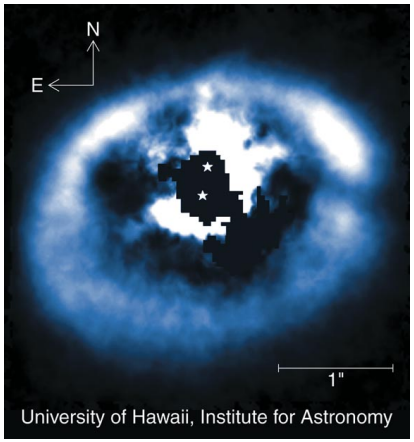
4T imaging limitations

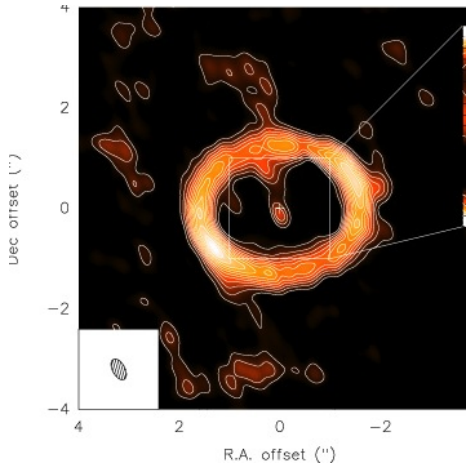


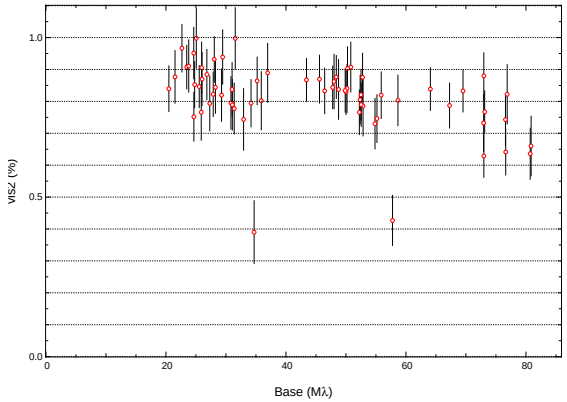
Paladini et al. in prep.

- Be realistic on the level of complexity that can be retrieved with 4 T combination. Use several IR codes when possible.

VLTI: the central engine revelator







Di

Folco et al.

- Use VLTI UT adaptive optics potential

Preparing for the next generation instruments

VLTI: the wish list

Request	Action
Increase sensitivity	Vibrations, Detect.,2GFT, NAOMI, off-axis
Provide astrometric stability	System engineering
Increase baseline length	currently stalled
Increase accessibility of VLTI	ESO/community effort
Increase reliability/efficiency	Considerably improved (System eng. monitor)
Increase uv plane mapping	relocations nights, more configs conflicting
Increase wavelength coverage	H,K,L,N,M shorter would require new instrument
Increase temporal coverage	conflicting with ”imaging”
Provide polarimetric capability	not considered

Gravity and Matisse in a nutshell

GRAVITY

- K band 4T “imaging” and “astrometric” machine;
- Spectral resolution 22, 500, 4000
- internal fringes tracker ($K \approx 7$ ATs, $K \approx 11$ UTs);
- UT sensitivity if off axis reference target within FOV (2”): $K \approx 15$
- astrometry 10 μ as in 5 mn on

MATISSE

- L, M, N band 4T imaging;
- L&M Spectral resolution ($\approx$) 30, 500, 950
- N Spectral resolution ($\approx$) 30, 220
- requires external fringe tracker;
- Sensitivity: L (ATs) $\approx$ 0.1 Jy (UTs) $\approx$0.01 Jy
- Sensitivity: N (ATs) $\approx$ 1.5 Jy (UTs) $\approx$0.1 Jy

Instrumentation and facility upgrade agenda

- Gravity: PAE fall 2014, shipment Oct 2014, Installation: March 2015
- Matisse: Gravity + 1 year
- ATs dual feed preparation (UTs, ATs) completed mid-2016;
- NAOMI (ATs adaptive optics): Call for Tender on corrective optics
- 2GFT (2nd generation fringe tracker): Technical specifications done but approval for CfT pending ESO's restructuration outcome
- PIONIER and MIDI: out starting period 94 (october 2014);
- PIONIER back in period 95 (?) ... if technical solution.

Sensitivity

	H (ATs)	K (ATs)	K (UTs)
AMBER	6.0	6.0	8.5
PIONIER	7.5 (9.0)		
GRAVITY		>8	>10

Table 2 : Comparison of MIDI (offered) and MATISSE expected performances.

	MIDI		MIDI + FSU		MATISSE +2GFT	
ATs	20Jy (@12 mic)	N = 0.9	1Jy(@12mic)	N =4.1	1.6Jy(@12mic)	N=3.4
UTs	1Jy (@12 mic)	N = 4.2	50mJy(@12mic)	N = 7.4	0.125Jy(@12mic)	N=6.2

Aperture synthesis: new operation model ?

How to operate the VLTI in the “imaging” - “astrometric” era ?

- What telescopes configurations will be offered ?
- What flexibility can we offer ?
- 4T out of 6;
- Adapt preparation and OT tools to imaging and astrometric programs;
- Implement the delivery of final reduced and calibrated products;
- Dedicated workshops to prepare users to the exploitation of PIONIER, GRAVITY and MATISSE;
- Keep in mind: ultimate performances of GRAVITY might not be the standard service mode performance.

Medium and Longer term view on VLTI

ESO: Medium and Longer term

WARNING: from now on pure speculation

Projects not funded and strongly linked to the ELT decision. To be included in the global ‘’VLT in the ELT era” context.

Two timescales:

- medium (until 2020): likely hampered by current project delays
- longer (2020 . . .), the “ELT era”

Possible projects:

a 3rd generation instrument at VLTI very competitive (financially speaking), don’t necessarily need 10 Meuros to open new scientific avenues;

b Unexplored bands: J (very interesting lines) angular resolution improved by $\times$ 2 with respect to K band.

c Unexplored bands: Visible: strong interest to enable fundamental stellar parameters estimation at VLTI.

d Extension of VLTI to 6 telescopes ? :first 2UTs/4ATs then array extension

e Open a visitor focus to test new ideas (6T nullers, visible combiners, direct imagers);

PIONIER science meeting
&
VLTI Community day

Likely: January 13-15th 2014 (Grenoble, France)