The case for imaging at the VLTI and the need to combine up to 6 to 8 telescopes

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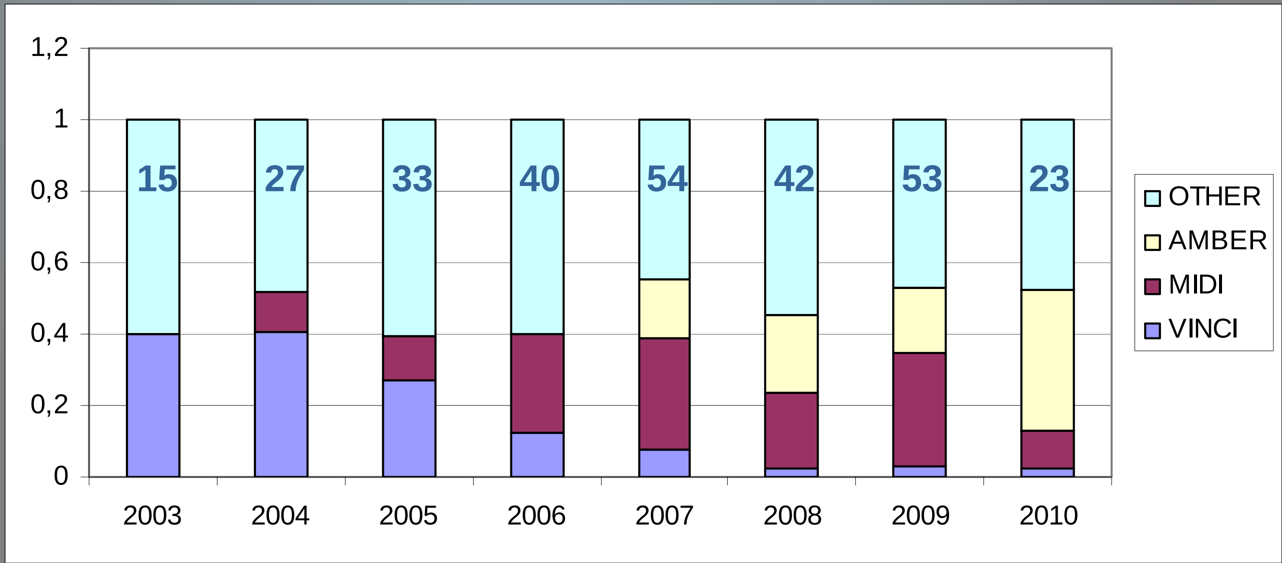
The case for imaging

- The VLTI is the most productive interferometer, with ~50% of all refereed astrophysical results

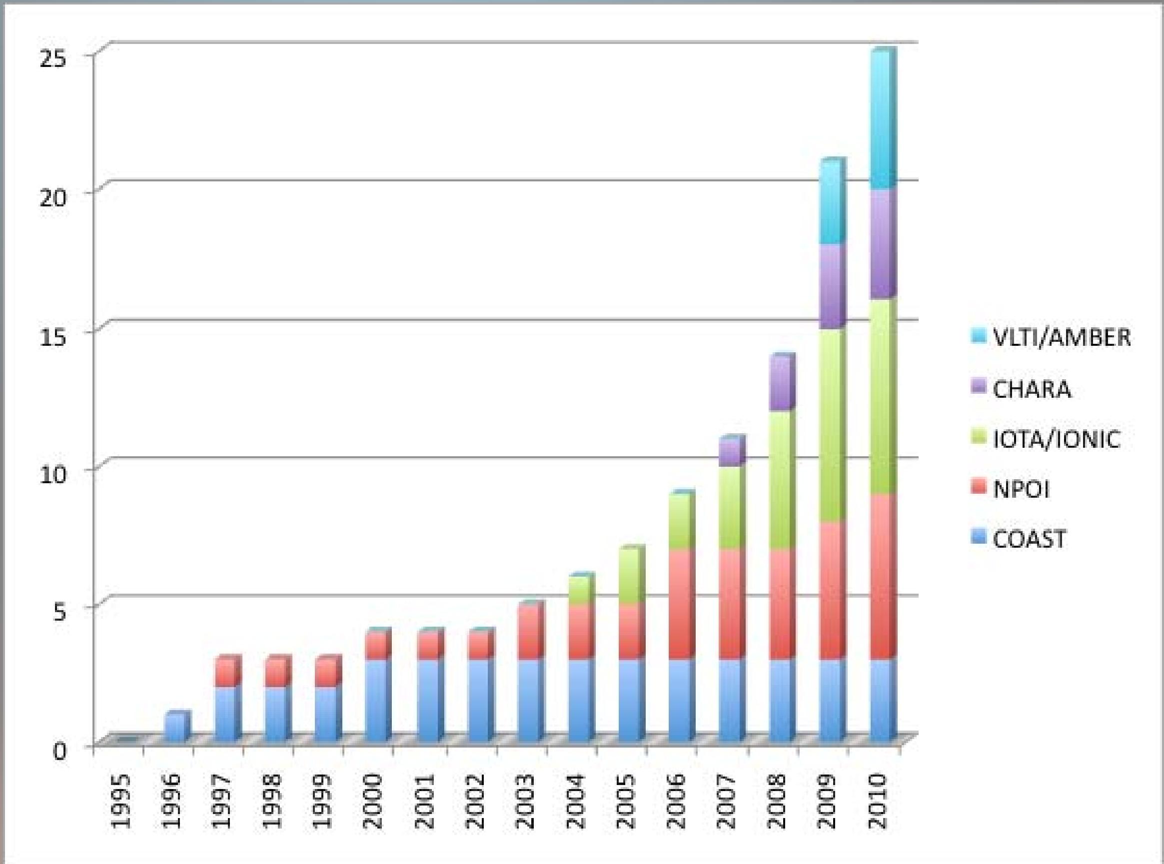


(OLBIN and ESO Library archive)

- Astrophysical productivity/output roughly stable since 2006.

The case for imaging

- The VLTI started imaging late, but now (2009-2010) produces the largest share of imaging papers
- But total number of imaging papers remains small



Cumulative refereed papers (OLBIN).

The case for imaging

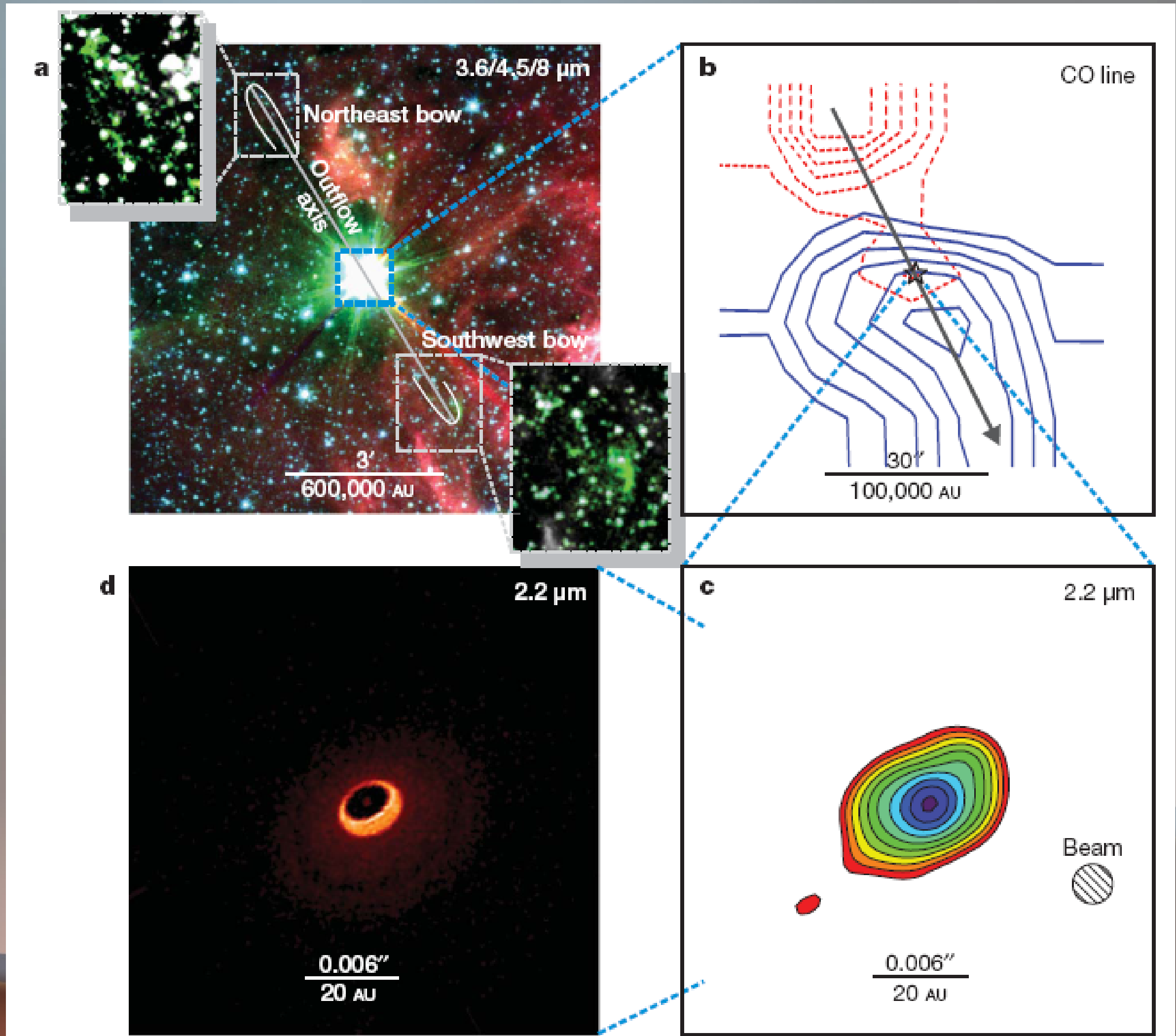
- Imaging is a high impact use on an optical interferometer

	2003	2004	2005	2006	2007	2008	2009	2010
Total Science/Nature papers		**3**		**1**	**2**			**2**
Imaging papers				**1**	**1**			**2**

- Cf. JENAM 2010 interferometry press release on MWC 275/HD 163296

The case for imaging

- Detection of a dusty disk in a massive young star (Kraus et al. 2010)



The case for imaging

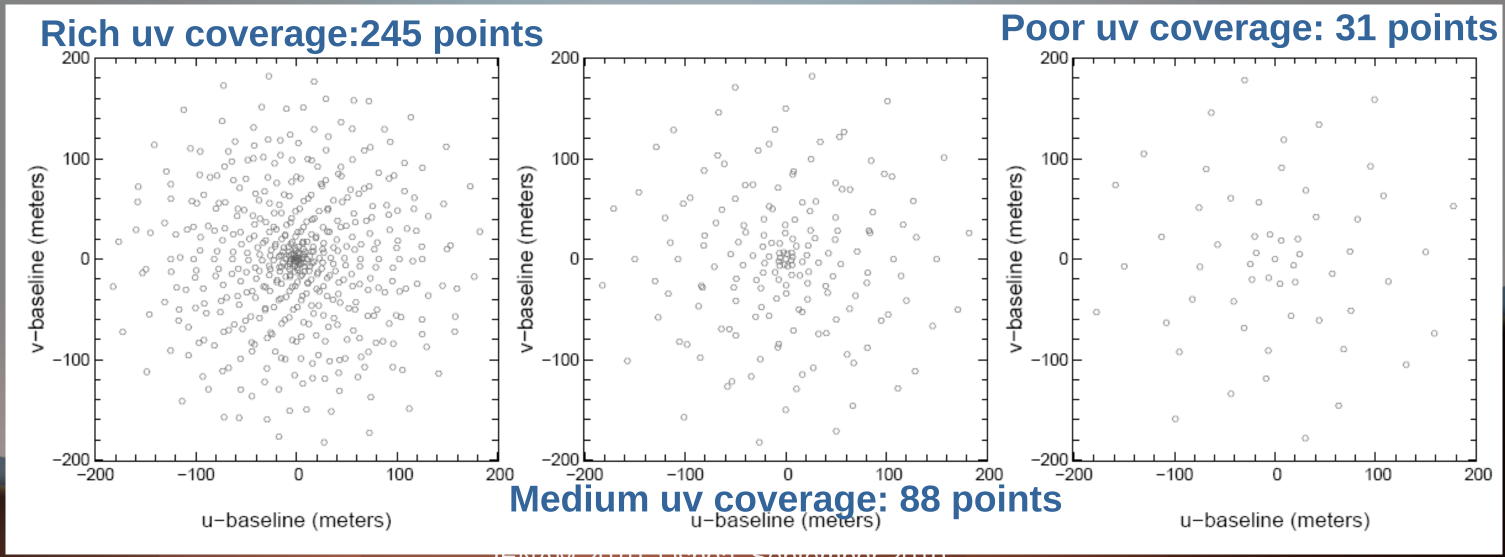
- More in Chesneau, Malbet, Pedretti, Wolf and ... talks

UV coverage is the critical variable

- Naively we would expect that imaging quality ***Q*** would scale as

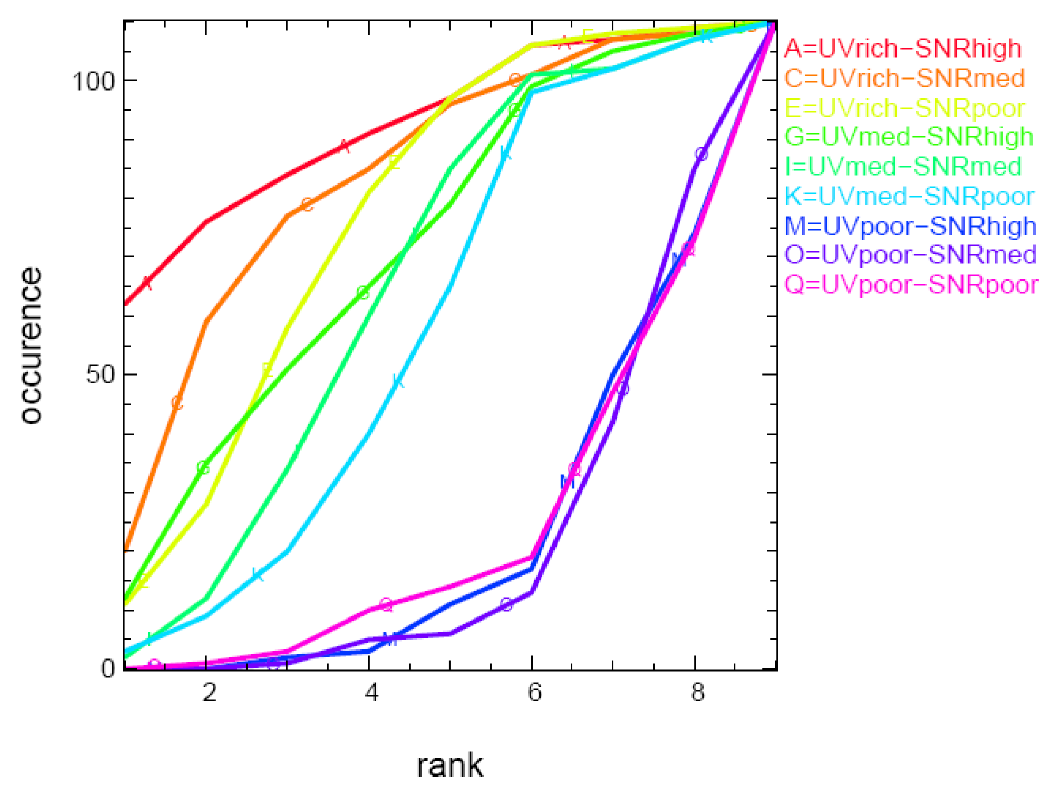
$$Q \propto \sqrt{N_{uv}} \times SNR(\vec{V}_{uv})$$

- Take three SNR cases: high (10%), medium (5%) and poor (1%)
- Take three uv coverage cases:



UV coverage is the critical variable

- Measure quality with $\text{MSE} = \frac{1}{N}\sum_n \left(x_n^{\text{rec}} - x_n^{\text{ref}}\right)^2$ and rank the reconstructed images



- uv coverage (i.e. number of telescopes) **is more important** than SNR in each point (Renard et al. 2010)

Sensitivity

- Sensitivity is critical as it drives the number of accessible objects
- In an optical interferometer, the fringe tracker defines the system sensitivity and limiting magnitude
- Standard combination of too many telescopes at the same time reduces available flux ($1/(N_{tel}-1)$) and therefore sensitivity (comment on Fizeau combination…)
- Sensitivity is critical for imaging ($F_c \sim F \times V^2$)

Sensitivity

- The trick is to **use many telescopes** but **combine minimum** number of telescopes
- Minimum number is not 3 but 4 (robustness and redundancy)

Blind et al. 2010

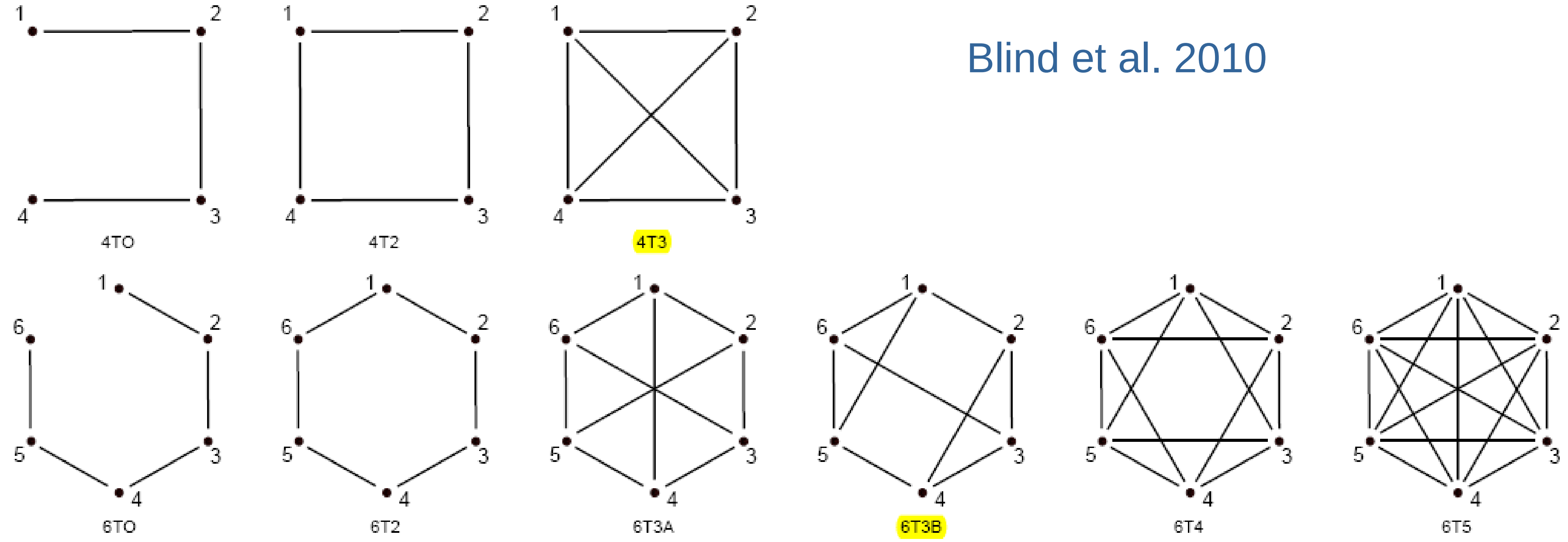
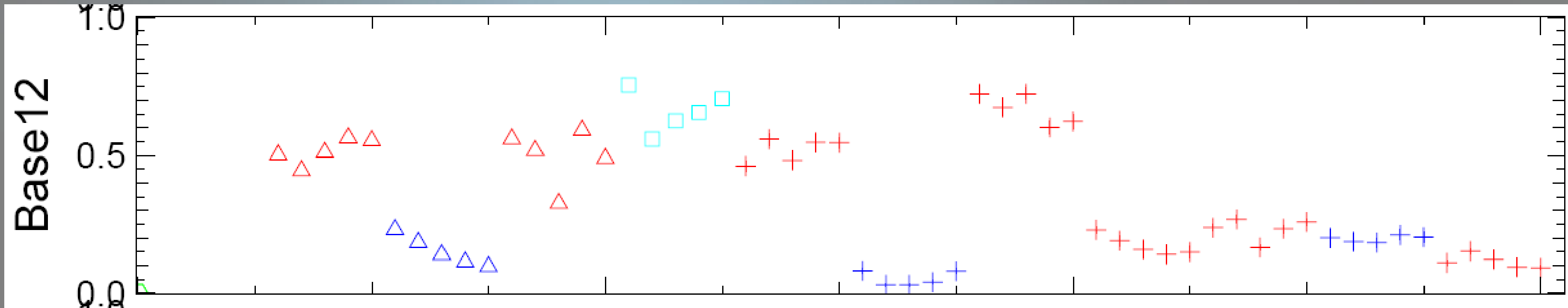


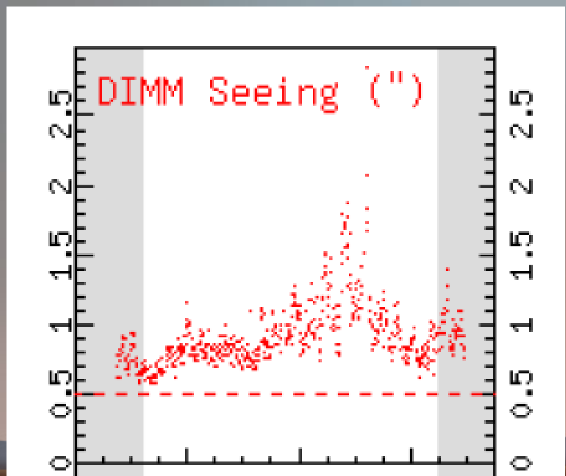
Figure 1. The conceptual combination schemes studied in the 4-telescope (top) and 6-telescope (bottom) cases, with the associated nomenclature below each one.

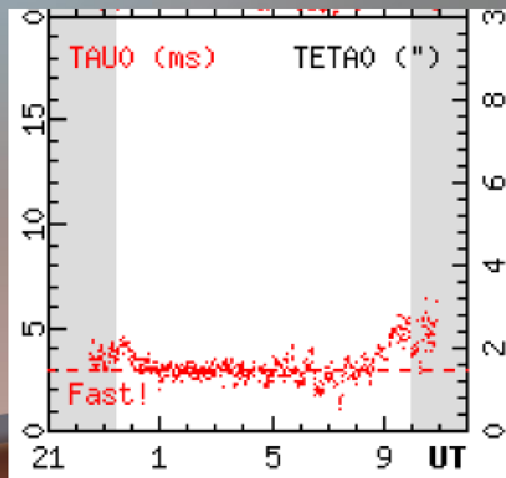
Operational issues and calibration

- Increase in uv coverage requires using earth rotation
- With 3 telescopes 9 nights are required for an image (e.g. MWC 275)
- But, 4 telescopes 3 nights, **6 telescopes 1 night.**
- Data calibration across the night and for many nights is an issue – will become the main limitation in imaging



Paranal, 6th June 2010

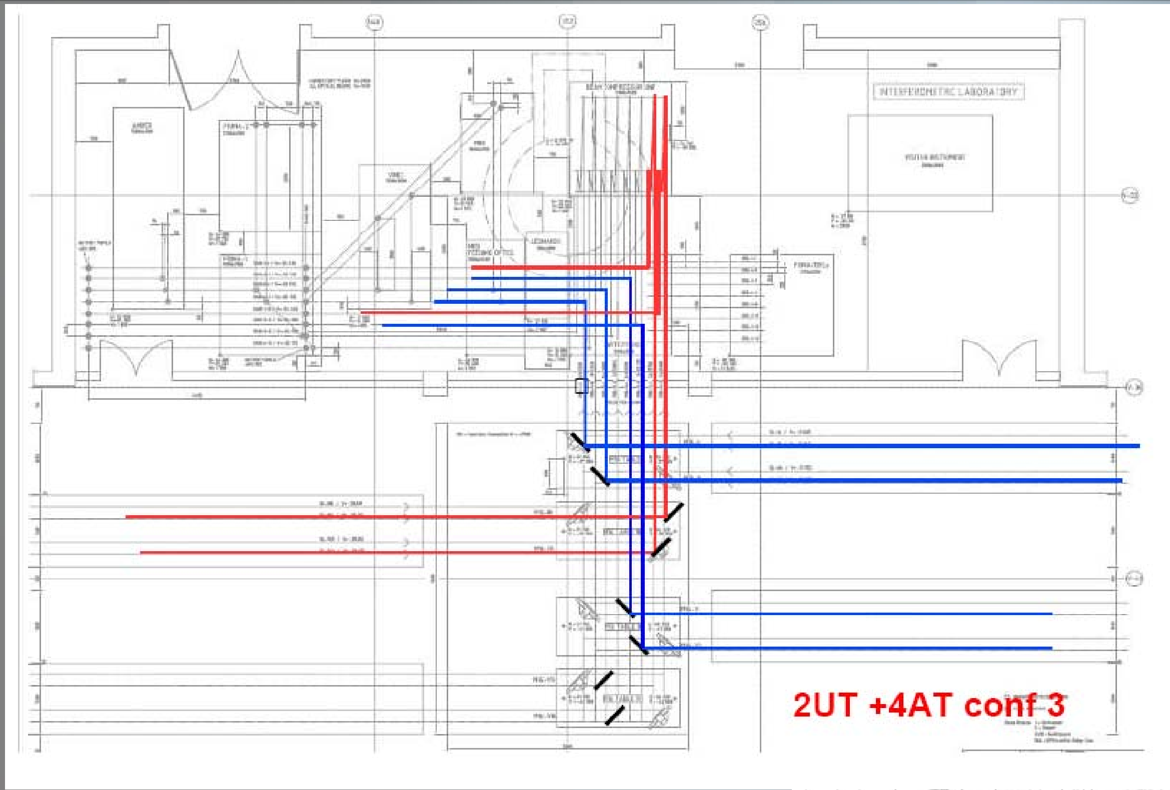


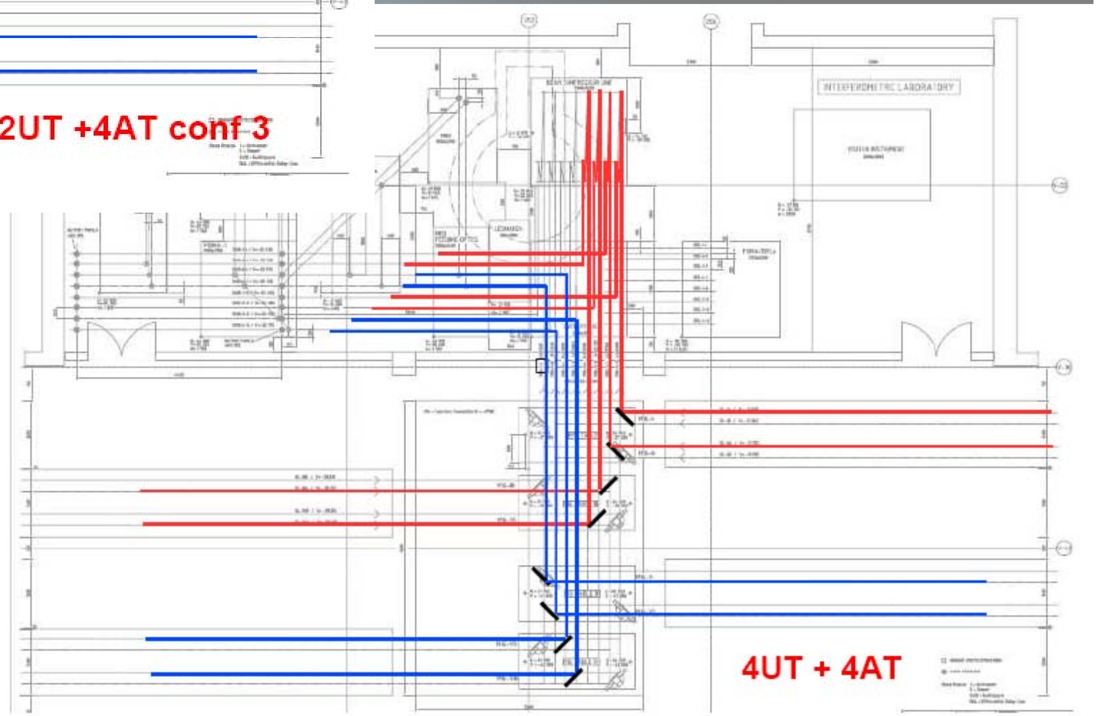


Non-imaging science

- Non-imaging optical interferometry mainly uses two methods
  - Diameter and size measurement
  - Differential phase across spectral lines
- Increase in number of telescopes → faster array
  - Higher data output and productivity
  - Survey science
  - Time-resolved observations (also applies to imaging)

Combining 6 and 8 telescopes





VSI Instrument analysis report

Combining 6 and 8 telescopes

VLTI config		Additional ATs	Additional DLs	Software update
4 UTs		No	No	No
4 ATs		No	No	No
4 ATs / 2 UTs		No	No	Yes
2 ATs / 4 UTs		No	No	Yes
6 ATs		2	No	Yes
4 ATs / 4 UTs		No	2	Yes
8 ATs		4	2	Yes

Summary

- Astrophysical productivity of optical interferometers is stable since 2006
- Imaging is a high impact use of an optical interferometer
- Imaging requires 6 telescopes (cf. radio experience)
- Increase in number of telescopes also allows V^2 and differential phase science ➔ surveys
- Sensitivity and robustness arguments ➔ combine the existing telescopes in sets of 4
- All VLTI telescopes could be combined or extra ATs could be available to use existing 6 delay lines