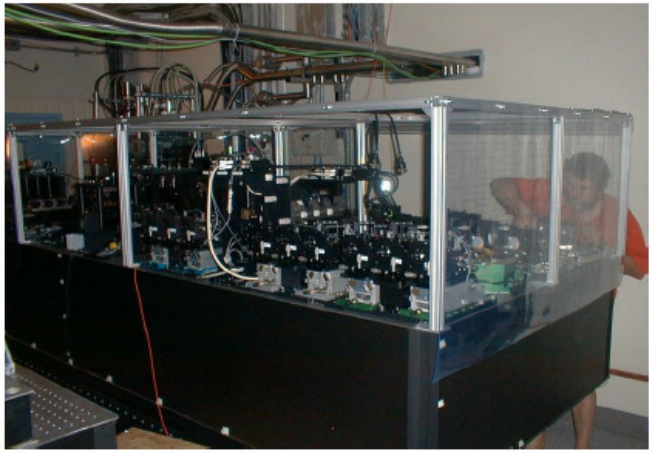
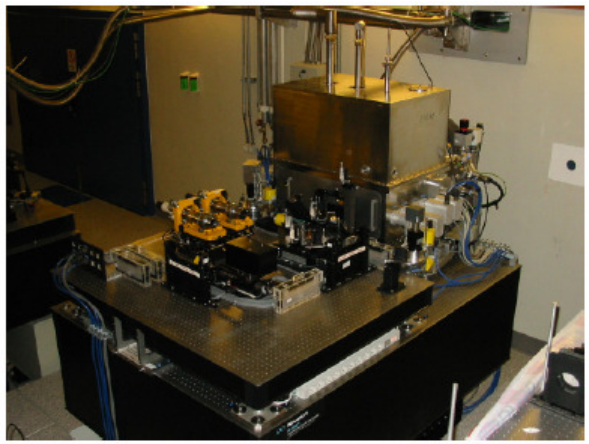
The AMBER & MIDI instruments of the VLTI

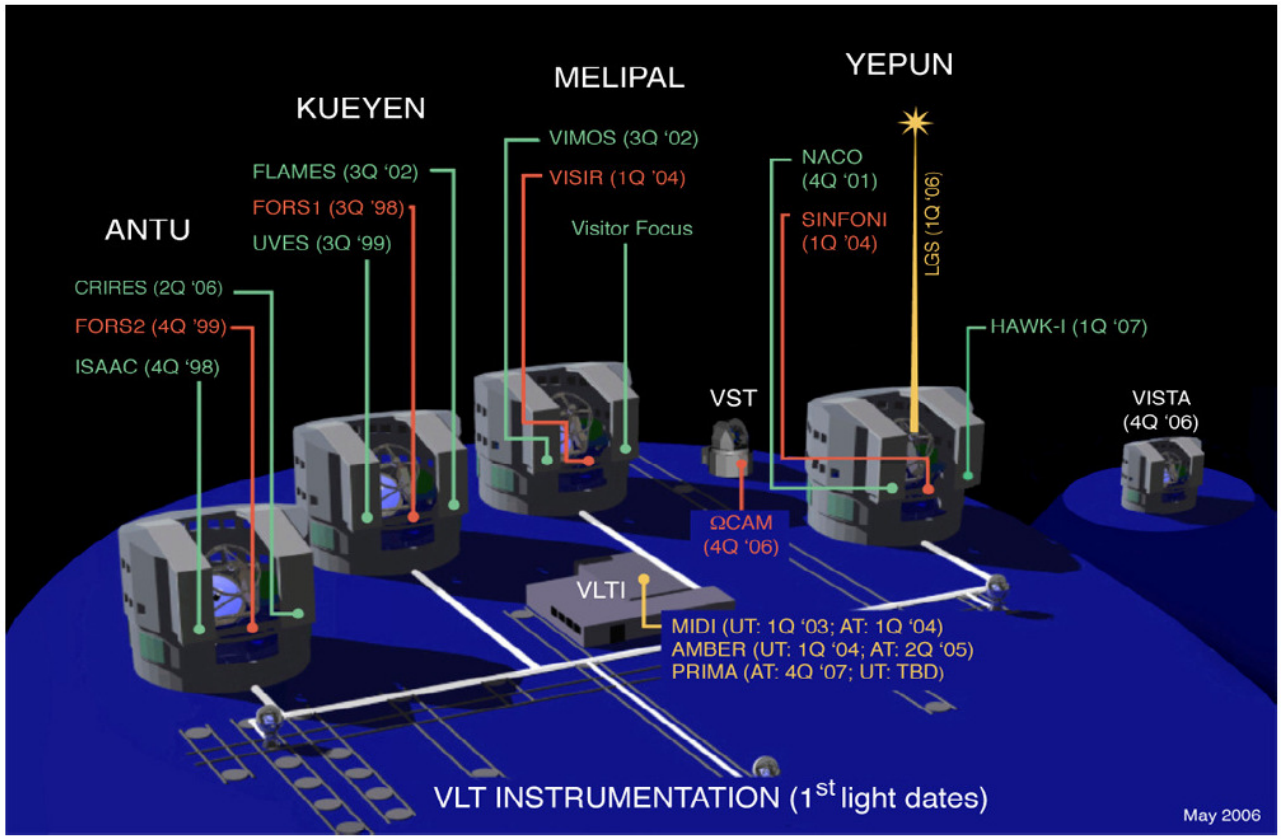




(Observationnal Astronomy II)

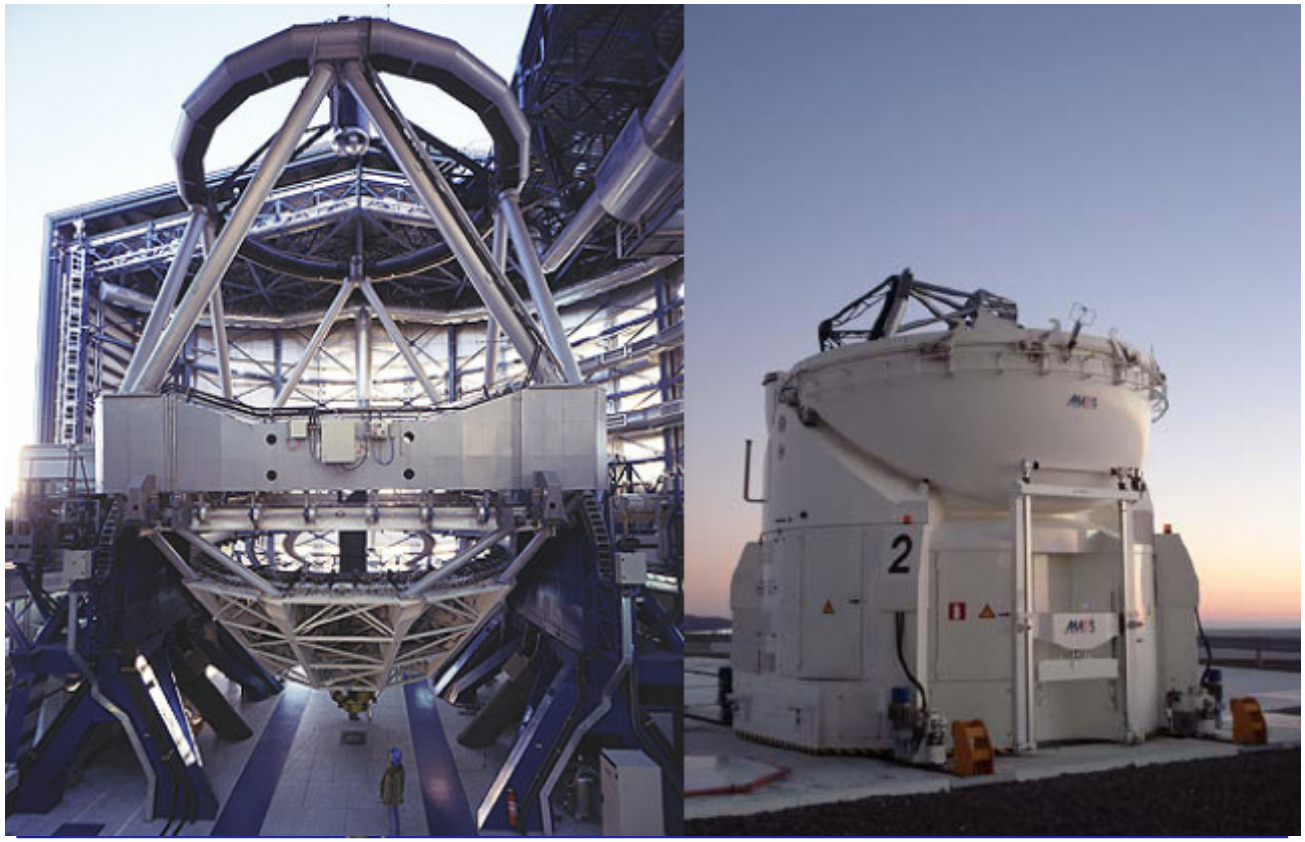
Lecture by Stéphane Sacuto

The VLT/VLTI telescopes



- 4 Unit Telescopes (UTs) with main mirrors of 8.2m diameter (Six Baselines 47m-130m)
- 4 movable 1.8m diameter Auxiliary Telescopes (30 stations with Baselines 8m-202m)
- in the middle is the location of the recombine light coming from the pairs or triplet of telescopes. In this room are installed the focal instruments of the VLTI : AMBER and MIDI.

The VLT/VLTI telescopes



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One word about the delay lines

- VLTI has OPD_{max}~120m
- The OPD correction varies roughly as B.cos(θ) dθ/dt, with θ the zenith angle
- The correction has to be better than $\lambda_{coh} \sim \lambda^2/\Delta\lambda$.

The VLTI focal instruments

- AMBER : Near-Infrared (**J**/**H**/**K-bands** 1-2.5µm) 3-way beam combiner.
  Spectral resolution: R=30 (low), 1500 (medium), 12000 (high)
  Result: 3 photometric spectra per observation
  3 spectrally-dispersed visibilities per observation.
  3 spectrally-dispersed differential phases per observation
  1 spectrally-dispersed closure phase per observation.

- MIDI : Mid-Infrared (**N-band**: 8-13 µm) 2-way beam combiner.
  Spectral resolution: R=30 (prism), R=230 (grism).
  Result: 2 photometric spectra per observation
  1 spectrally-dispersed visibility per observation.
  1 spectrally-dispersed differential phase per observation

Documentation

Regularly updated ESO sites:

- MIDI : http://www.eso.org/intruments/midi
  MIDI user manual, MIDI template manual

Scientific observations with MIDI on the VLTI: present and future,
Leinert 2004, SPIE, 5491, 19

- AMBER : http://www.eso.org/instruments/amber
  AMBER user manual, AMBER template manual

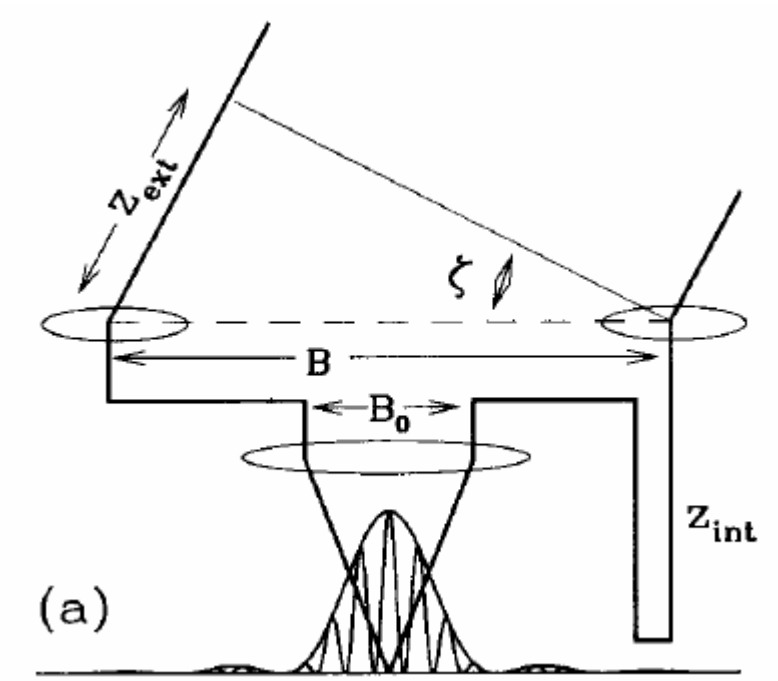
AMBER, the near-infrared spectro-interferometric three telescope VLTI instrument,
Petrov et al. 2007, A&A, 464, 1-12

Technical description of MIDI and AMBER

Beam combination :

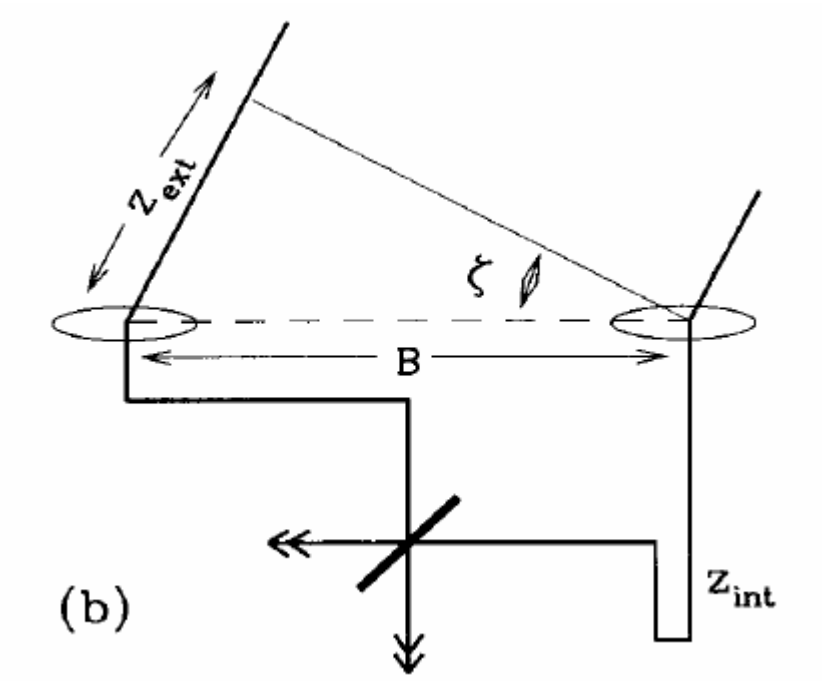
AMBER

Fizeau recombiner (image plane)



MIDI

Michelson recombiner (pupil plane)

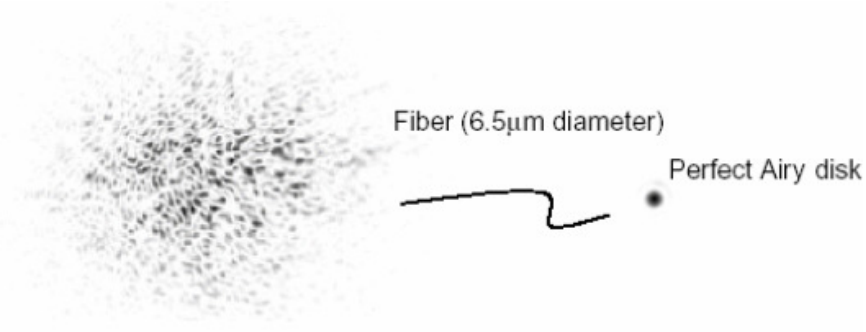


Spatial filtering :

AMBER

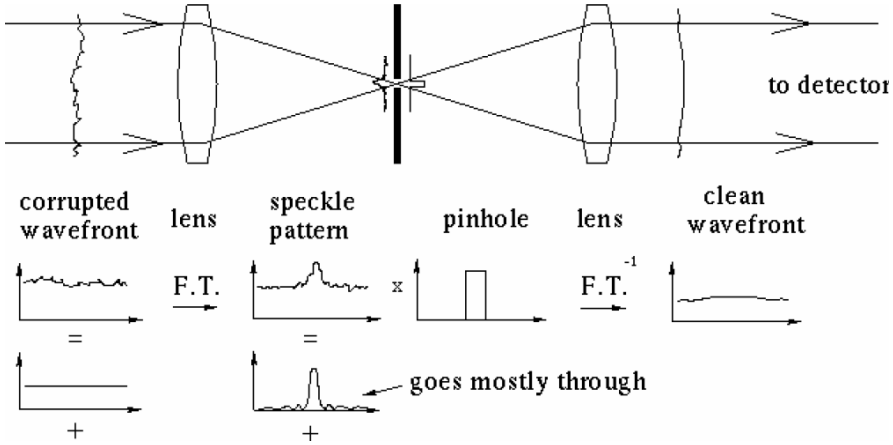
Single-mode optical fibers

Separator for J, H, K



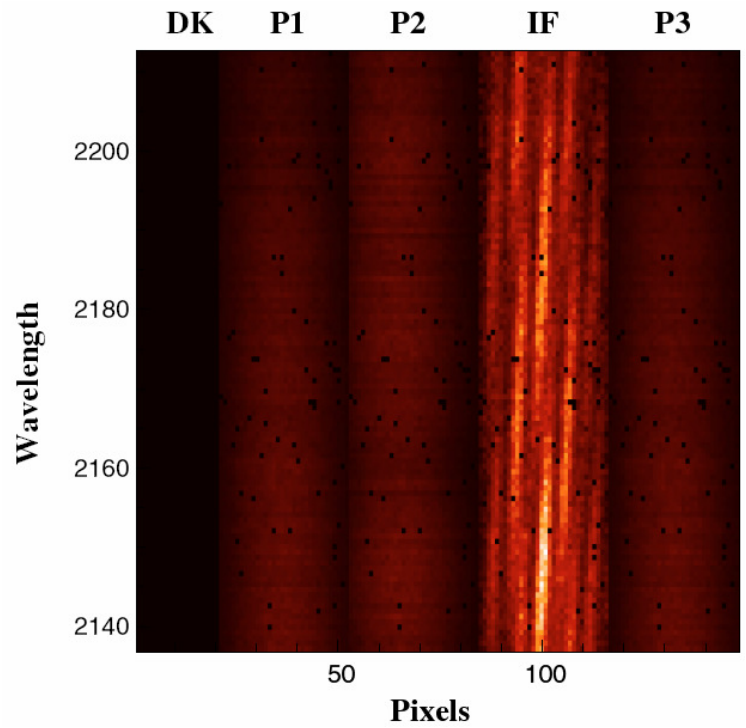
MIDI

Pinhole, slits



Photometric calibration :

AMBER



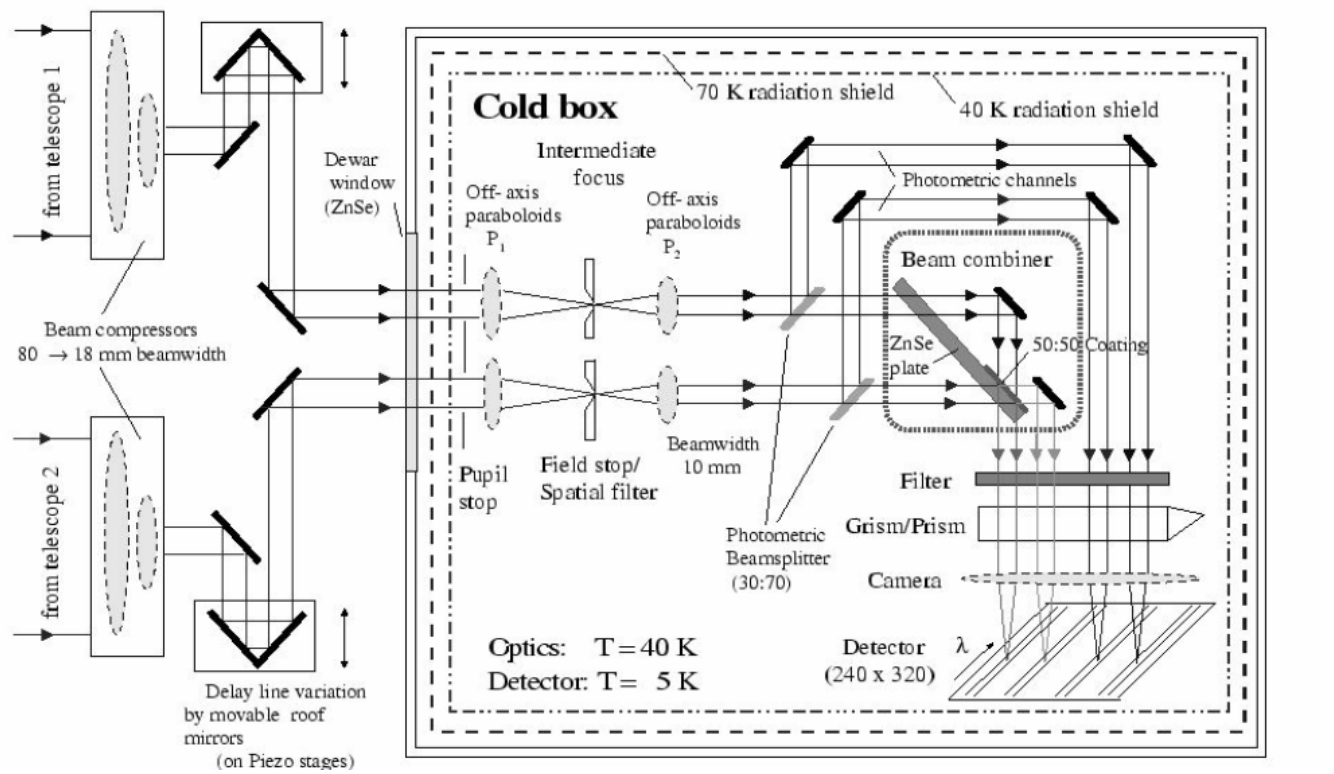
The photometric signals corresponding to the three incoming beams (P1, P2,P3) and the interferometric signal (IF) are alway taken simultaneously

MIDI

HIGH_SENS mode:
First, only the interferometric signal is recorded. Then, the beam combiner is moved out and the photometric signal is recorded sequentially.

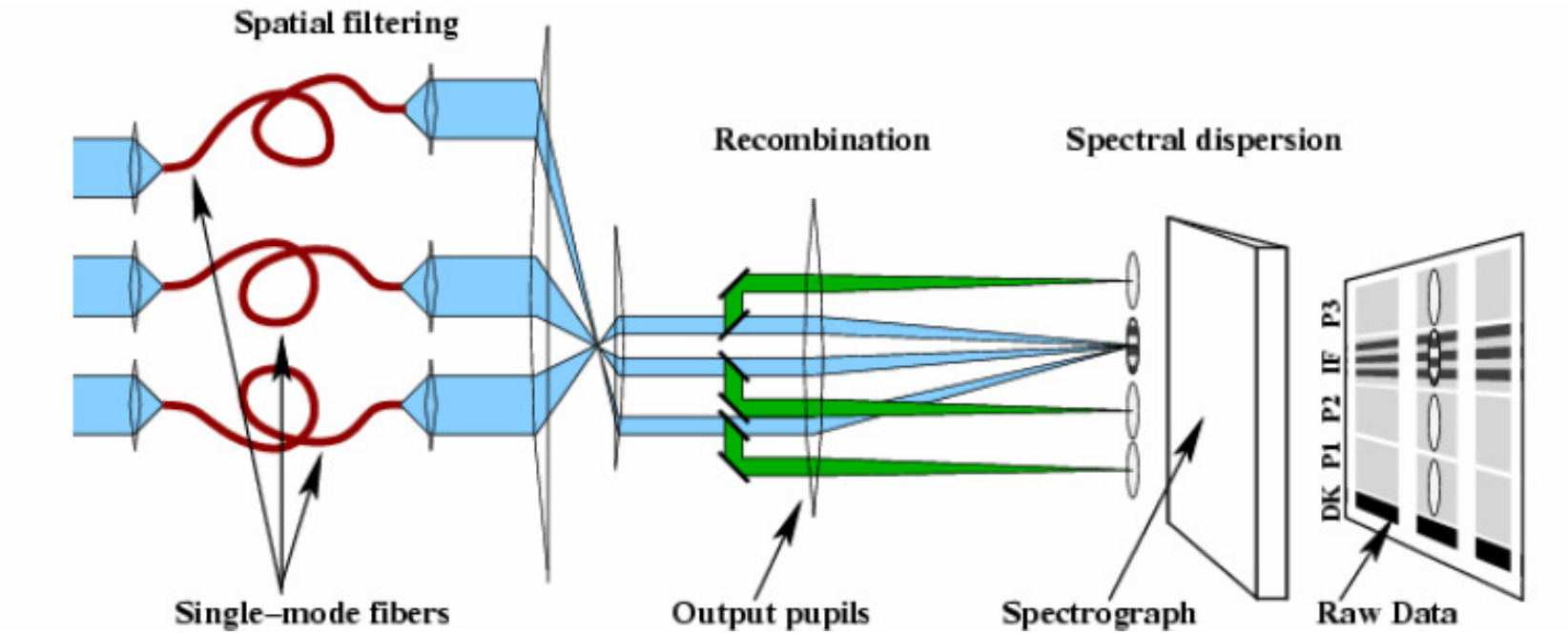
SCI_PHOT mode:
Beamsplitters are used to record the interferometric signal and the photometric signal simultaneously.

Principle of MIDI (Michelson recombiner):



- Light arriving from 2 UTs or 2 ATs, corrected by AO: MACAO or STRAPS, IRIS (laboratory tip-tilt), FINITO (fringe tracking system),
- Time-modulated OPD variations to generate interferogram (Piezo mirrors),
- Pupil stops to reduce background and stray-light,
- Optional 30/70 beam-splitters to obtain simultaneously photometry and interferometry,
- Beam-combination by 50:50 beam-splitters,
- Spectral filter. Dispersion by PRISM (R=30) or GRISM (R=230),
- Focused onto the detector.

Principle of AMBER (Fizeau recombiner):



- Warm optics : Dichroid plates separates the J,H,K bands, light is injected into single-mode fibers for spatial filtering,
- The three beams are focused into a common Airy Disk that contains the fringes,
- Spectrograph: Dispersion by a standard long-slit spectrograph, (3 different spectral resolutions of R=30, 1500, 12000),
- The photometric signals corresponding to the three incoming beams (P1,P2,P3) and the interferometric signal (IF).

What measures :

AMBER

- ✓ **Spectrum**
  (in J,H,K)

- ✓ **Absolute visibility**
  (in each spectral channel: 3% accuracy)

- ✓ **Relative visibility**
  (ratio of the visibility in each spectral channel **over** the visibility in a reference spectral channel: 1% accuracy)

- ✓ **Differential phase**
  (phase in each spectral channel **minus** the phase in a reference spectral channel)

- ✓ **Closure phase** ($\Phi=\Phi_{12}+\Phi_{23}+\Phi_{31}$)

MIDI

- ✓ **Spectrum**
  (in the N-band)

- ✓ **Absolute visibility**
  (in each spectral channel:
  5-10% accuracy)

- ✓ **Differential phase**
  (phase in each spectral channel **minus** the mean phase determined in the full N-band region)

Overview of MIDI and AMBER

	MIDI	AMBER
Beams	2	3
Beam combination	Pupil plane	Image plane
Wavelength	8-13 μm	1-2.5 μm
Spectral resolution	30 (Prism); 230 (Grism)	30 (LR); 1500 (MR); 12000 (HR)
Limiting magnitude UT	*N*=4 (current) *N*~9 (FSU in K)	*K*=7 (current) *K*~10 (FSU), *K*~18 (PRIMA)
Limiting magnitude AT	*N*=0.74 (current), *N*~5-6 (FSU in K)	*K*=5 (in all modes with FINITO) *K*~8 (FSU), *K*~15 (PRIMA)
Visibility accuracy	<10-20% (1-5%)	1% (diff.), 3% (abs.), current 2-10%
Airy disk FOV	0.26'' (UT), 1.14'' (AT)	60 mas (UT), 250 mas (AT) in *K*
Spatial resolution, 200m	10 mas	1 mas (*J*), 2 mas (*K*)
UT First Fringes	December 2002	March 2004
Regular observations	Since April 2004	Since October 2005
Consortium	D/F/NL (PI Ch. Leinert)	F/D/I (PI R. Petrov)

Observing Proposal
Rules of the game

- Preparation of an observing proposal in interferometry based on ESO Press-Release topics or a source of your choice.

- Teams of 2 students

- Present it “live”
  - **maximum** 8/10 slides & 10/15 min of presentation + 5 min of comments and questions

Kind of target / instrument

- Target:
  - From ESO Press-Releases (simple choice)
    (*i.e. Additional observations to confirm a prediction*)
  - Any kind of new sources of your choice
- Instruments:
  - AMBER (Near-Infrared VLTI instrument)
  - MIDI (Mid-Infrared VLTI instrument)

What do we expect? (part I)

- What ?
  - which object (http://simbad.u-strasbg.fr/simbad/)
  - general astrophysical context
  - which results are expected

- Why ?
  - scientific justification
  - why the use of interferometry with the VLTI?

- Observability ?
  - declination (*observable from paranal?*)
  - period of observation (ASPRO : http://www.jmmc.fr/aspro_page.htm)

What do we expect? (part II)

❑How ?

- which instrument (MIDI/AMBER), and why?
- which telescope UT/AT, and why?
- number of telescopes “if AMBER (2-3)“, and why?
- which configuration(s), and why?
- number of hours you request (single point confirmation, model-fitting, image reconstruction), and why?
- which epoch (*i.e. to constrain a variability effect*), and why?
- which spectral mode (LR-MR-HR AMBER; LR-HR MIDI), and why?

❑Realization ?

- delay line
- brightness of the source compared to the sensitivity of the instrument (http://www.eso.org/sci/facilities/paranal/instruments/)
- is the length of the projected baseline sufficient to resolve the structure? is the structure over-resolved? (*) (*simulations with ASPRO*)
- is the angle of the projected baseline suitable to constrain the object morphology? (*simulations with ASPRO*)

(*) *http://www.jmmc.fr/aspro_page.htm*

What do we expect? (part III)

- Calibrators (ASPRO : http://www.jmmc.fr/searchcal_page.htm)

  - find the best calibrator for you observations

- Restrictions

  - see ESO/VLTI baseline configurations at disposal (http://www.eso.org/sci/facilities/paranal/telescopes/vlti/configuration/index.html)

ESO Press-Releases

ESO Press-Release / Related paper	Topic
PR 06/09 **Le Bouquin et al., 2009, A&A 496, L1**	**Imaging the close environment of an AGB Star**
PR 15/08 **Ohnaka et al., 2008 A&A 484, 371**	**Resolving the central dust torus toward a Supergiant**
PR 42/07 **Chesneau et al., 2007** **A&A 473, L29**	**Resolving a central disk** **toward a Planetary Nebulae**
PR 10/04 **Jaffe et al., 2004 Nature 429, 47**	**Resolving the central dusty torus of an Actic Galactic Nuclei**
PR 22/08 **Cheneau et al., 2008** **A&A 487, 223**	**Dust formation event of a Nova**
PR 43/07 **Deroo et al., A&A 474, L45**	**Resolving the circumbinary disc of a post-AGB binary**
PR 34/07 **Leao et al., A&A 466, L1**	**Inner dusty region of a** **R CrB-type variable**

Some Material

- **Simbad database** : http://simbad.u-strasbg.fr/simbad/
  to choose your favorite object
- **ASPRO** : http://www.jmmc.fr/aspro_page.htm
  software to prepare observations
- **VLTI instruments** : http://www.eso.org/sci/facilities/paranal/instruments/
  instrumental constraints (sensitivity, resolution, …)
- **Base** : http://www.eso.org/sci/facilities/paranal/telescopes/vlti/configuration/index.html
  configurations available

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GOOD LUCK!

Reports and discussion on the ASPRO/SearchCal home works