The Very Large Telescope Interferometer

EuroSummer School

Active Galactic Nuclei at the highest angular resolution: theory and observations

Torun, Poland
August 27-September 07, 2007

Markus Schöller
European Southern Observatory
September 01, 2007

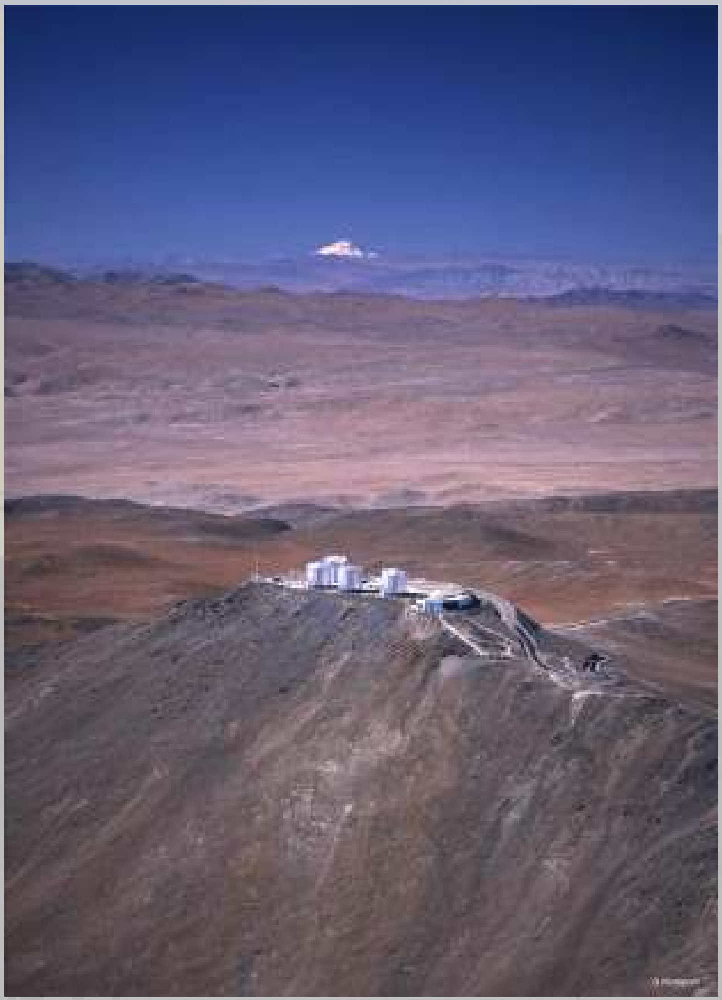
ESO - The “European Southern Observatory”

European Organisation for Astronomical Research in the Southern Hemisphere

A brief history of VLTI

- 1980s - Interferometry integral part of the VLT project, early linear array design for UTs goes to trapezium structure
- Early 1990s - engineering of the general layout
- 1993 - council stalls the VLTI, infrastructure implementation (light ducts, tunnel, lab) continues
- 1996 - MPG/CNRS/ESO tri-partite agreement for third AT
- 1997 - MIDI and AMBER proposed by community
- 1998 - contracts for ATs and Delay Lines awarded, MIDI and AMBER instruments started
- 2000 - start of implementation on Paranal (siderostats and delay lines)
- March 2001 - first fringes with VINCI on siderostats

VLTI

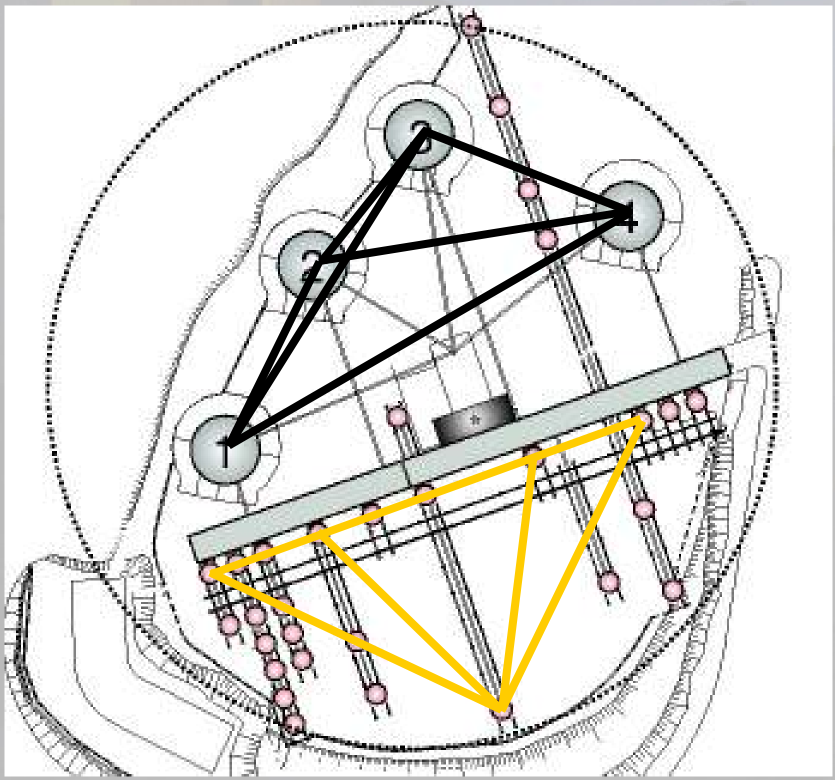


Four 8.2m telescopes (UTs)
All equipped with AO (MACAO)
Six Baselines 47m-130m

Four 1.8m telescopes (ATs)
Movable to 30 stations
Baselines 8m-202m

Six delay lines
PRIMA dual feed facility
FINITO fringe tracker
IRIS lab tip/tilt tracker
MIDI/AMBER/VINCI

Status



All UTs operational with full AO, all six baselines and all four baseline closures used for science

AT1-4 in operations on four baseline triples

4 Delay Lines in operations for UTs, 3 Delay Lines for ATs (with VCM)

MIDI offered since April 2004 on UTs and October 2005 on ATs

AMBER offered on UTs since October 2005 and ATs since April 2007

~50% of nights used for VLTI science operations

Five operations astronomers, three fellows, numerous TIOs to run VLTI

60+ refereed papers

What does the VLTI infrastructure do?

Put the light in the one place at the one time.

- Inject the image plane into the lab
- Make the pupils coincide
- OPD variations should only be atmospheric or their residuals

How does VLTI do it?

Each UT has a MACAO system that concentrates the bulk of the photons within the Airy ring.

The beam is propagated via the relay optics to the delay lines

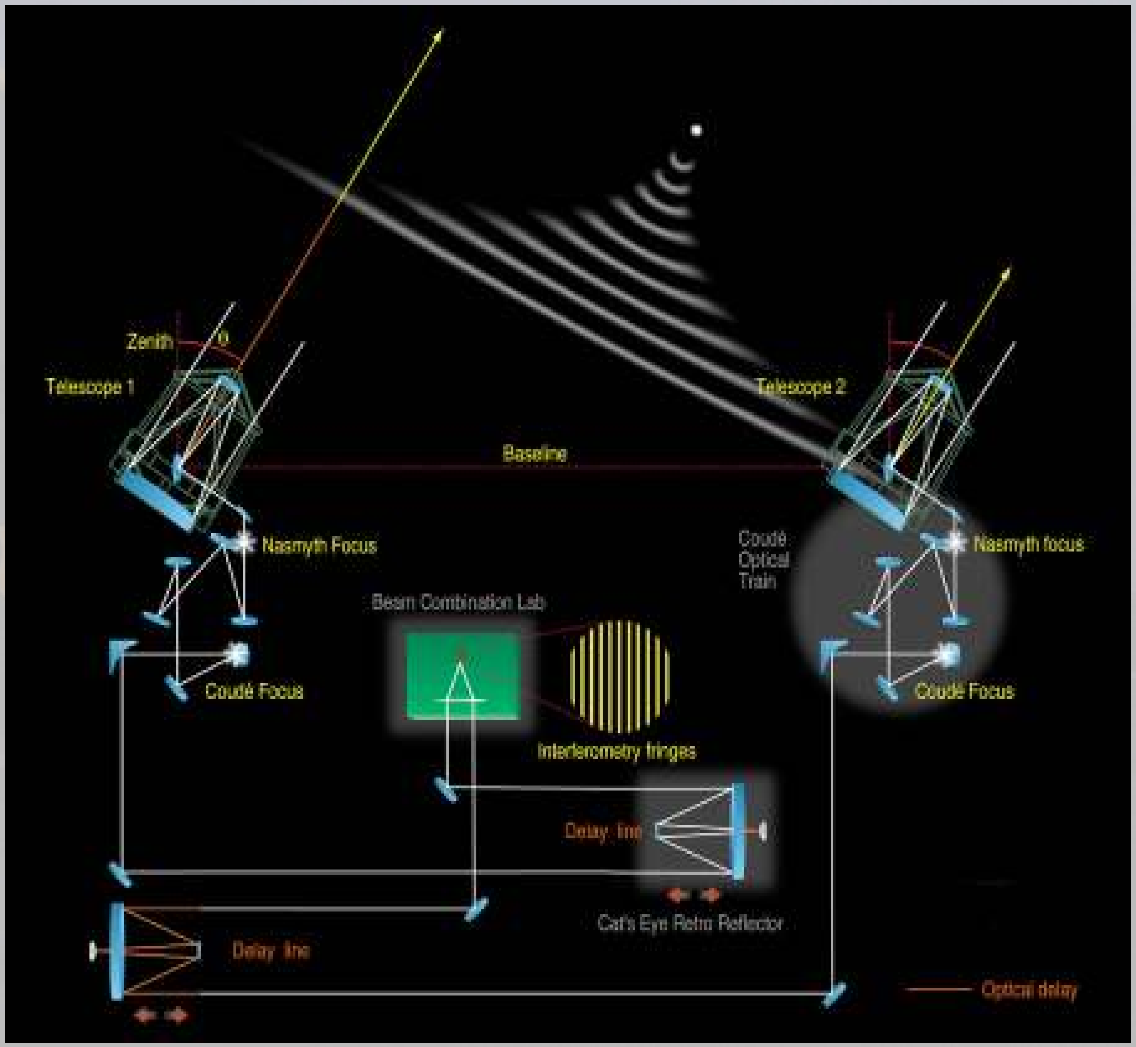
The delay lines correct in ‘open loop’ geometric OPD (telescope and star locations)

The VCMs on the delay lines move the pupil in the ‘axial’ direction.

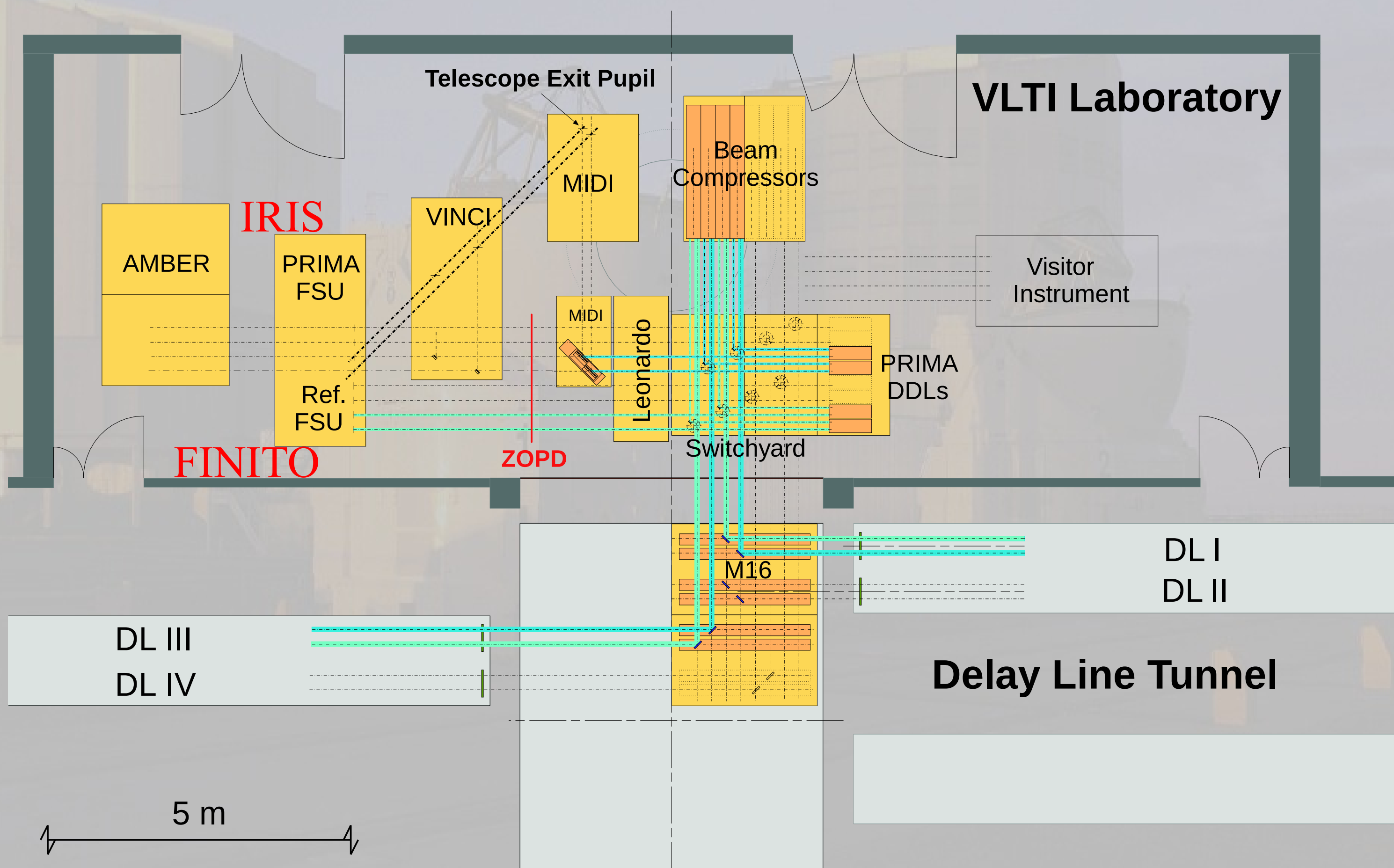
IRIS corrects for drifts in the conjugation between the MACAO reference and the lab reference

FINITO corrects for atmospheric OPD variations through the delay lines

VLTI Scheme

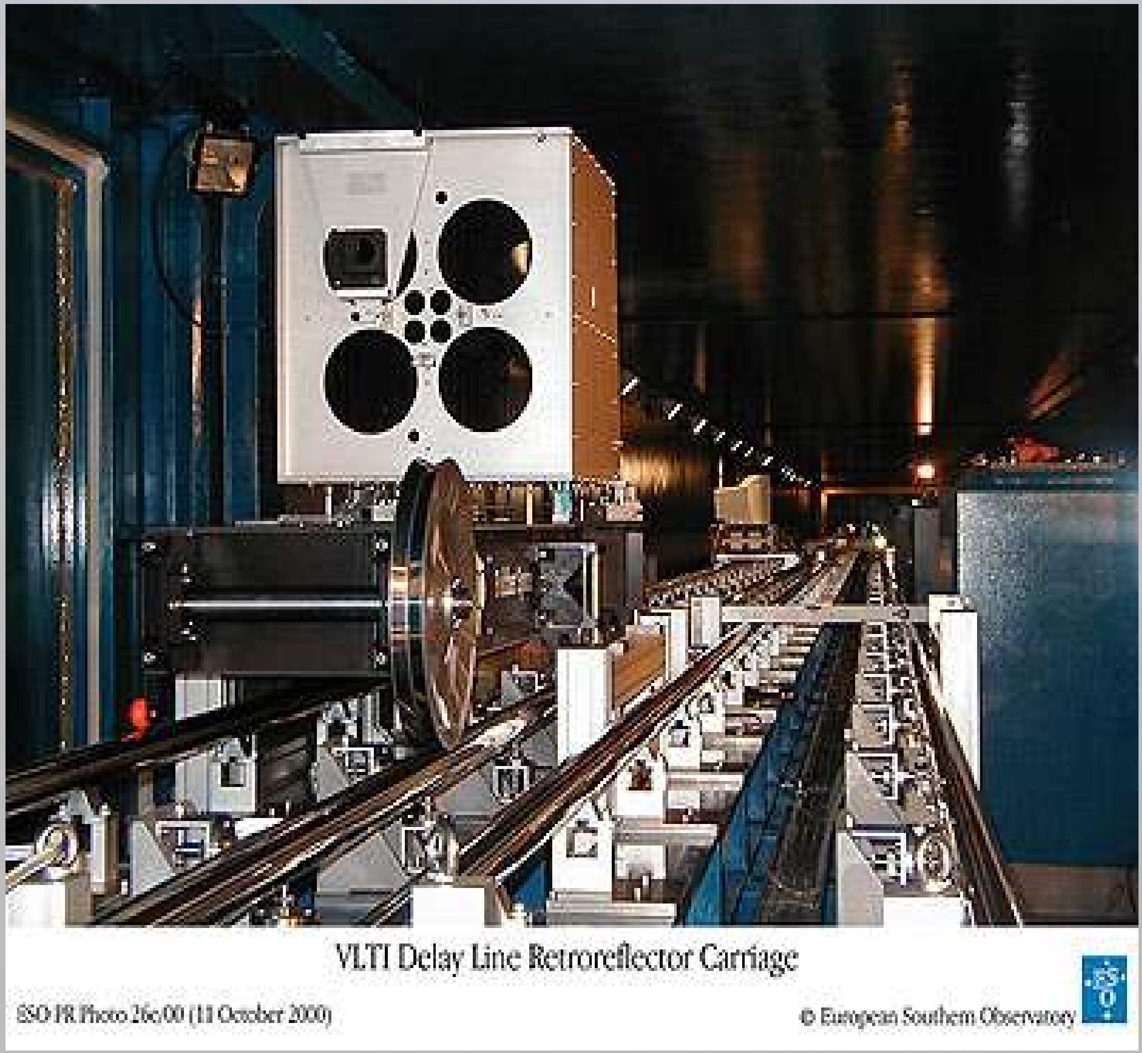

Zenith
Telescope 1
Telescope 2
Baseline
Nasmyth Focus
Nasmyth focus
Coudé Optical Train
Beam Combination Lab
Coudé Focus
Coudé Focus
Interferometry fringes
Delay line
Cat's Eye Retro Reflector
Delay line
Optical delay

The interferometric laboratory



The VLTI Telescopes

Delay Lines


VLTI Delay Line Retroreflector Carriage
ESO PR Photo 26c/00 (11 October 2000)
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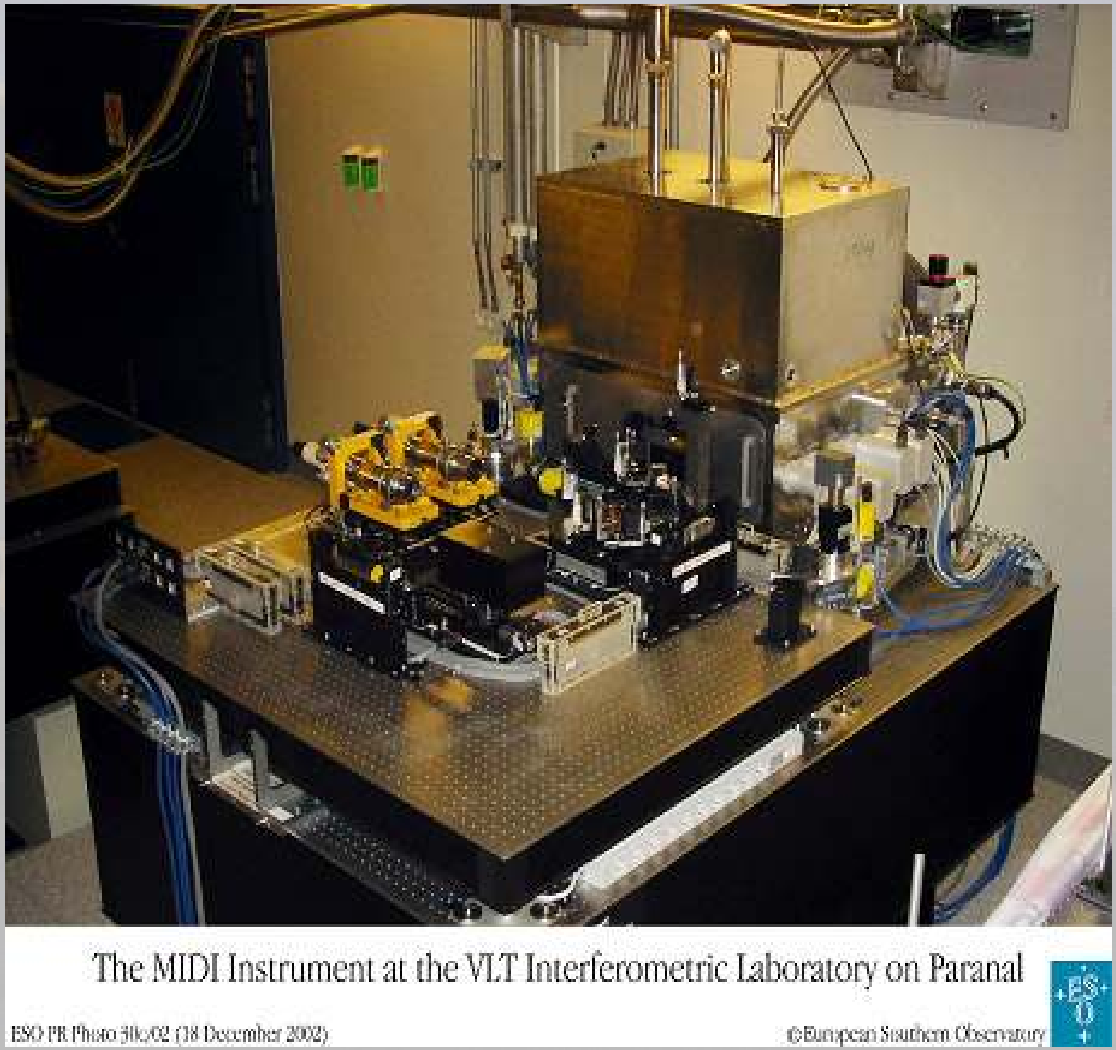
MIDI in the VLTI lab



AMBER in the VLTI Lab

VLTI Science Instrumentation

	Bands	# telescopes	spectral resolution	limiting magnitude (UTs/ATs/ ATs+FINITO)
AMBER	J,H,K	3	35, 1500, 12,000	7,4,1.5/ 3.6,0.6,-/ 3,3,3
MIDI	N	2	30, 230	4 (1Jy), 2.8/ 0.7,0.3

Beam injection

Beacon from Nasmyth A to IRIS

QuickTime™ and a
decompressor
are needed to see this picture.

Beam injection

Star to IRIS

QuickTime™ and a
decompressor
are needed to see this picture.

ATs

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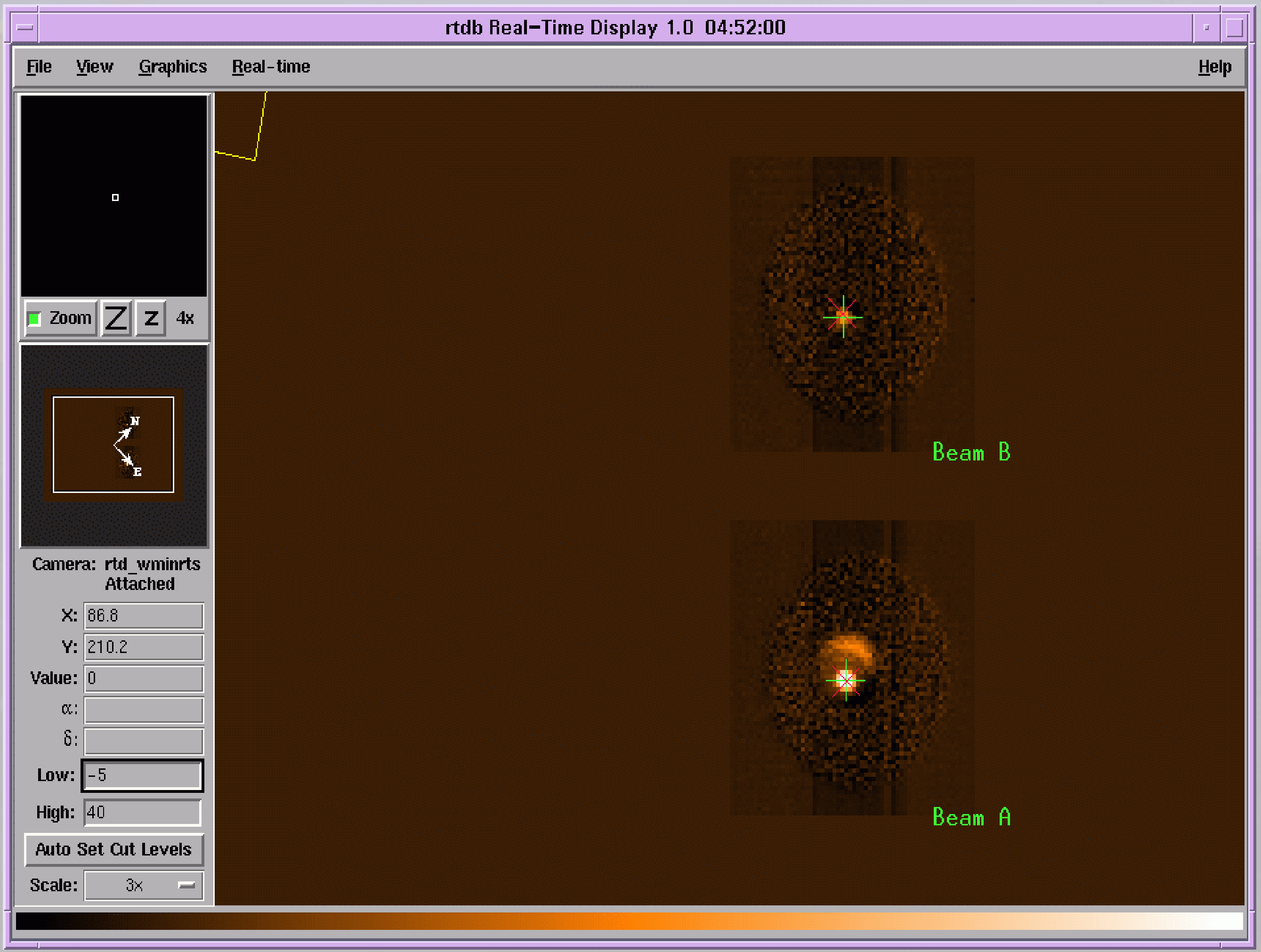
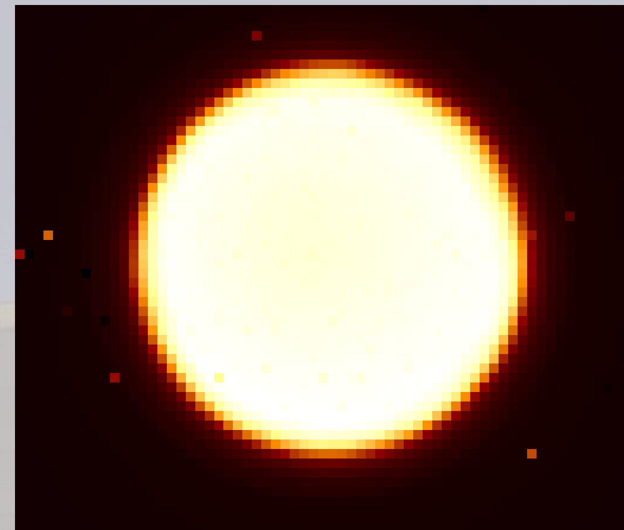
Figure 2: front view of the STRAP head. The 4 lenses are clearly visible. The dimension of the central white square is ~ 0.7mm. The picture was taken with a digital camera and flash.

AT field of view on MIDI

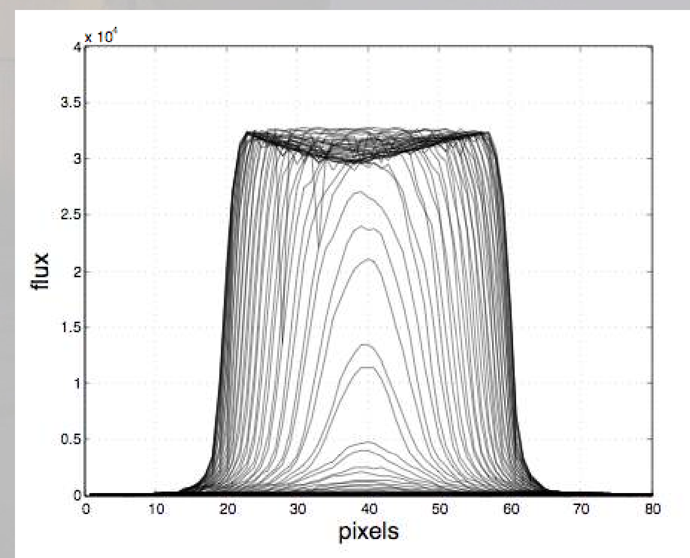


VCMs

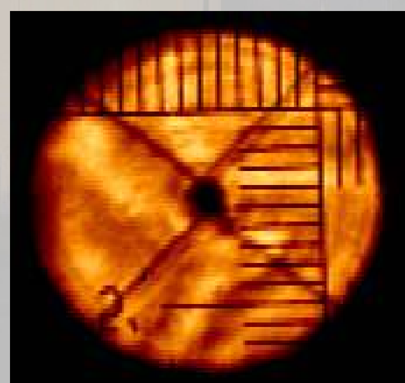
Without the VCMs functioning the field of view of the ATs is limited to about an arcsecond (approx the diffraction limit of a 1.8-m telescope at 10 microns).



J moon in IRIS



Fwhm = 7.6 arcsec

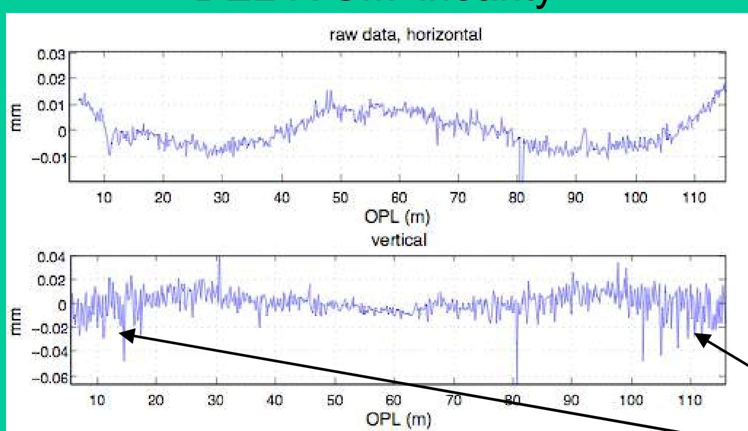


AT2 pupil on ARAL through DL6

Delay Lines : DELIRIUM

- two 2D capacitive sensors *(+water pots for earth horizon referencing)*
- One inclinometer for roll measurement
- Metrology (laser or coarse)
- Complete trajectory reconstruction

DELIRIUM linearity

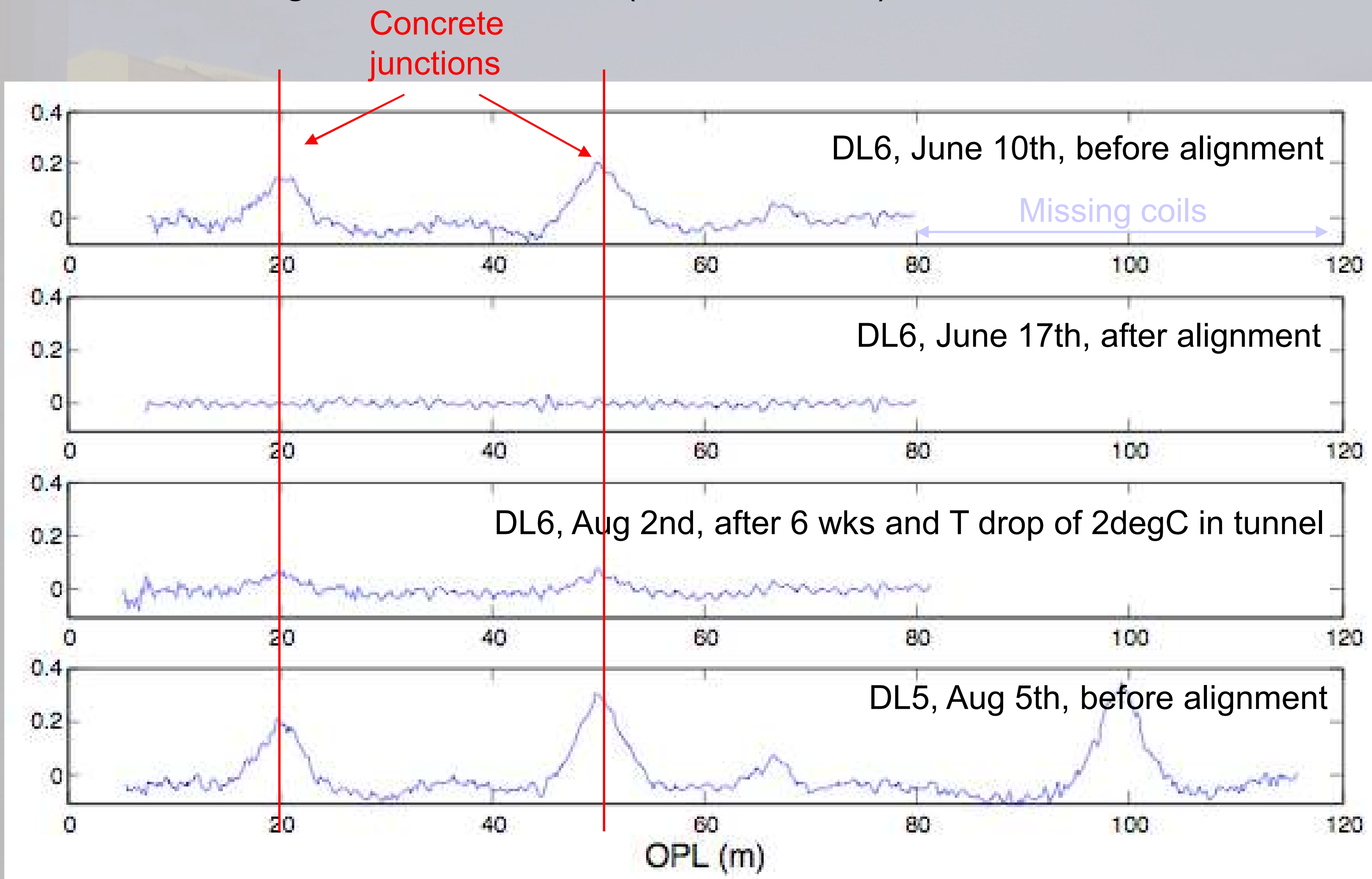


DELIRIUM raw data (DL5).
Diff between 2 scans with wire sags of resp. 9 and 6 mm

Weird, but goes away with laser metrology (TBC)

DL rail drift

DL6 was aligned in Dec 2004 (summer time)



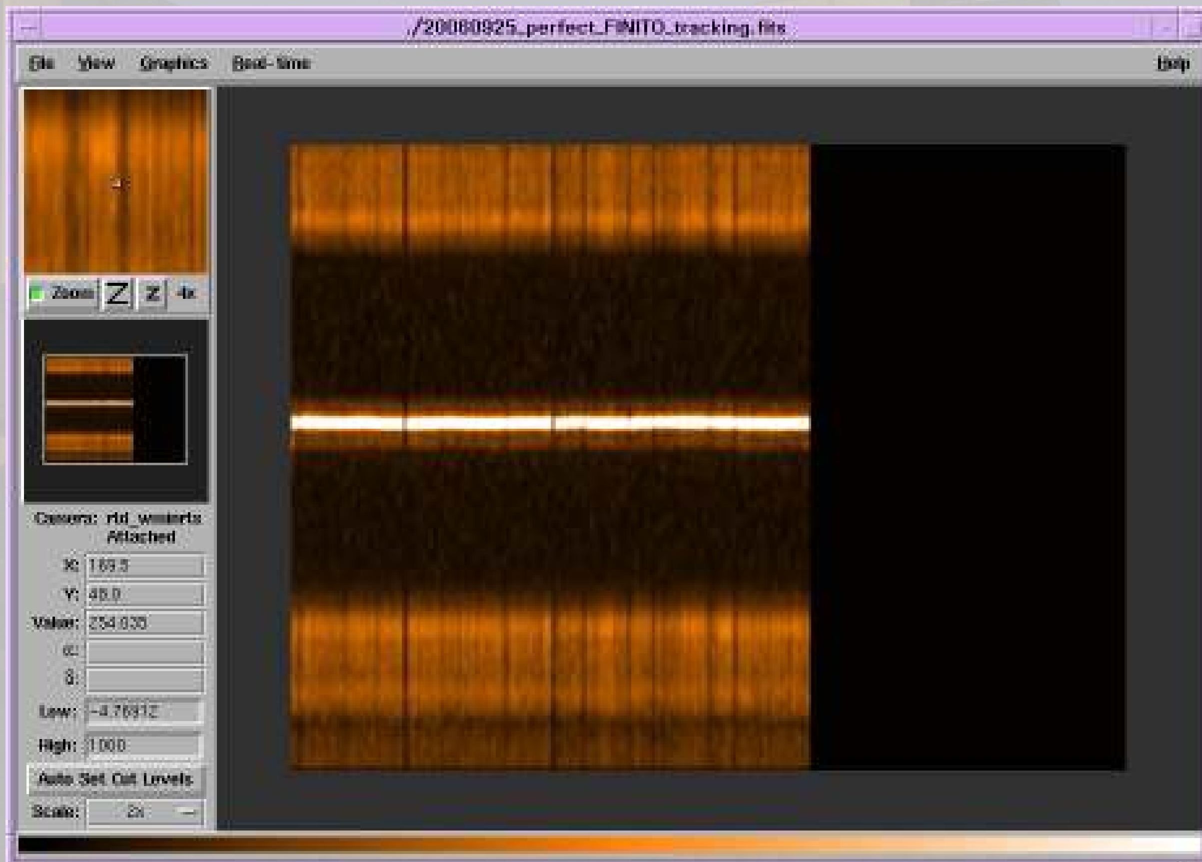
Where should the IRIS signal be sent?

The ACU actuators directly in front of the fiber, normally used only to align the fiber, were retuned from a few Hz bandwidth to a few 100 Hz bandwidth and IRIS now drives them open loop (signal from IRIS feeds ACU but there is no feedback)

Immediate improvement installation - ATs

- Installation of the variable curvature mirror (VCM) in all six Delay Lines
- Get FINITO operational on the ATs for three beams
- Allow AMBER fringe tracking on three ATs: dichroics, injection stabilization

Stabilized fringes on MIDI (Sep 06) - Running from template



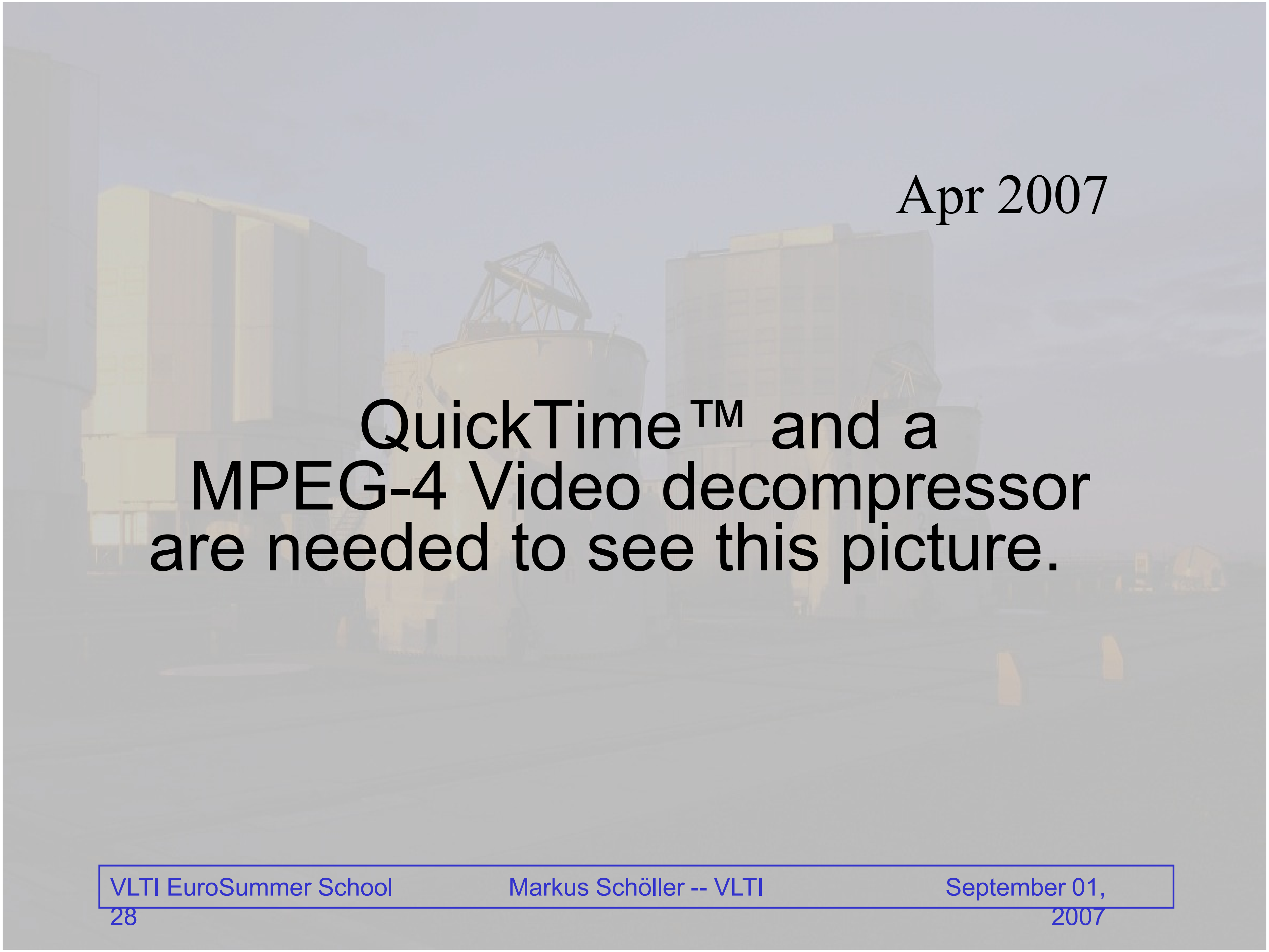

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Nov 06


QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Jan 07

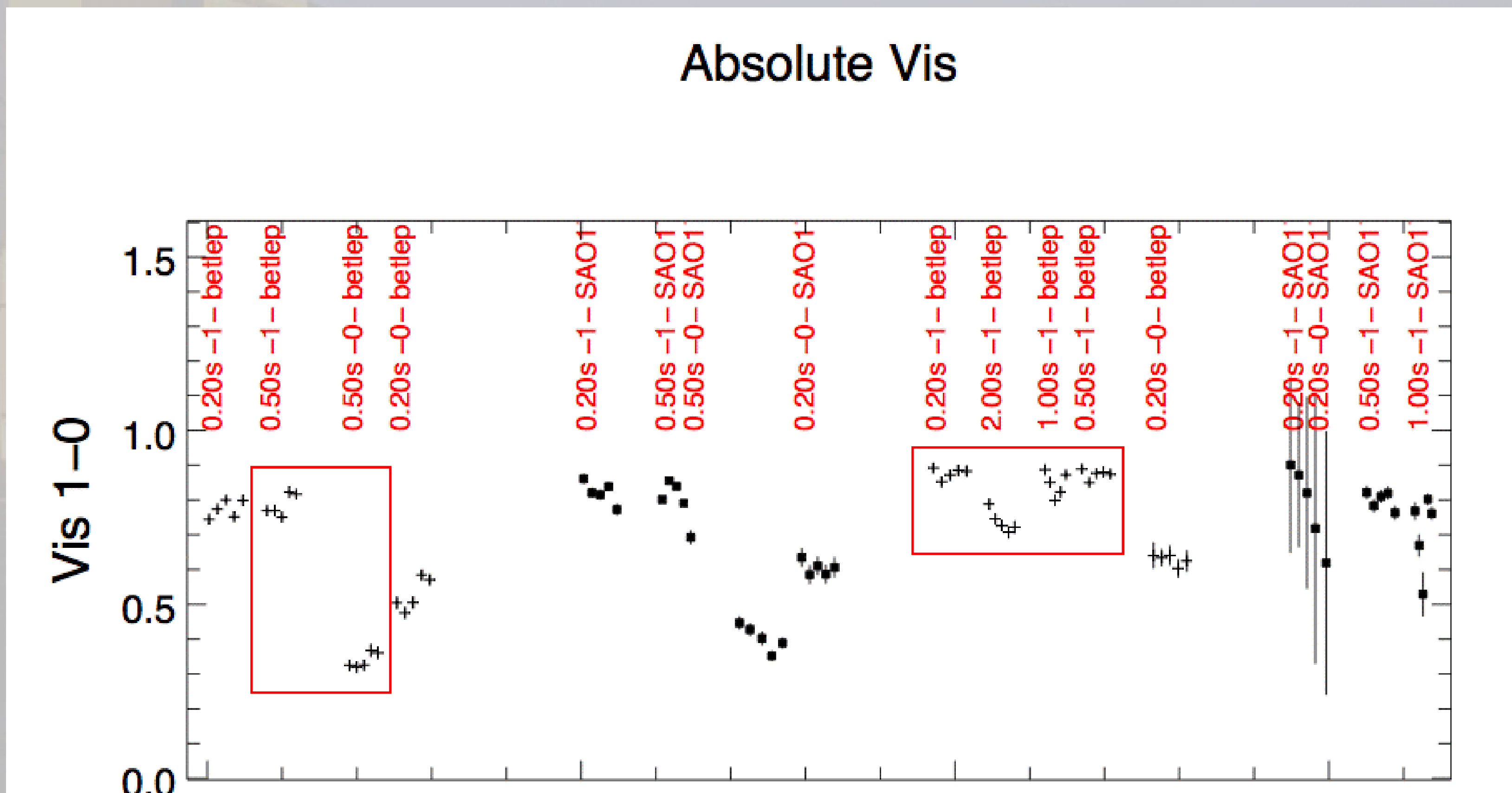
AMBER MRK



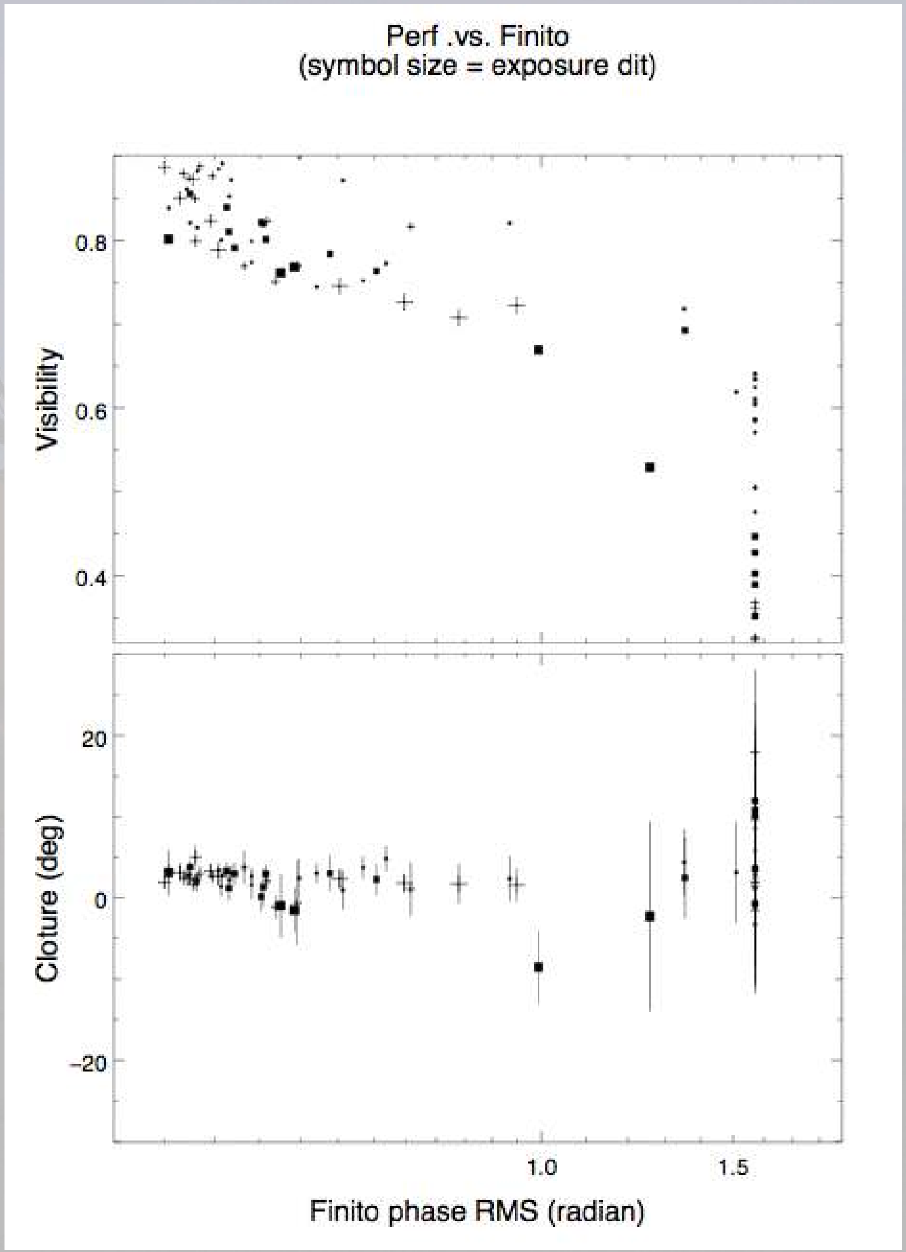
Apr 2007

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.

AMBER visibilities improved by FINITO



FINITO performance



The stable beam challenge on the UTs

MACAO although meeting specs for long term Strehl performance did suffer from saturation of the mirror creating PSF explosions and flux dropouts.

Long and frequent flux Dropouts are FINITO killers.

The ITF developed the SMA (saturation management) and AW (anti-windup) algorithms and deployed them in the RTC of MACAO

- SMA manages the expensive aberrations without loss of Strehl.

OPD variations

Vibrations coming from:
- MACAO cabinets (50Hz)
- acoustic waves from pumps through cooling circuits (96Hz)
- M1 cell Eigenmodes
- M3 tower Eigenmodes
- UT instrument cryocooling systems (e.g. CRIRES on UT1)
- …

Possible solutions:
- damp vibrations
- determine vibrations with accelerometers
- determine vibrations with other sensors, ie MACAO and FINITO

Goals of iiip - phase 2/1

- Offer AMBER+FINITO on three UTs for the P81 call (Aug 15 - date missed; now: Feb 15)

- Implement the MACAO SW CRE (SMA/AW)
- Removal of MACAO cabinets from UT 4/3/2 - DONE
- Implement Manhattan2 (Accelerometers on UTs) on UT1, upgrade systems on UT3/4, later install on UT2 (~DONE)
- Implement VTK (FINITO/MACAO vibration tracking)

May/June/July/August: about 80% of technical nights lost due to weather

Goals of iiip - phase 2/2

- MACAO2 DM recalibration or exchange
- implement MACAO calibration plan
- install VCM on DLs 1/2/3 (DONE)
- redesign the DL communication box to allow its alignment
- use two channel laser communication on the DLs
- fix all remaining open DL issues: parking, safety, communication, ...
- improve the guiding, focusing and relocation situation on the ATs
- implement AMBER IFG mode (~DONE - needs testing)
- implement a high level VLTI observation software panel
- implement open loop pupil control

Further prospects

- **Installation of PRIMA starting in early 2008**
- **2nd gen instrumentation phase A studies are finishing**

Some acronyms

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- OPL - optical path length
- OPD - optical path difference
- ZOPD - zero optical path difference
- UT - Unit Telescope (8.2m)
- AT - Auxiliary Telescope (1.8m)
- MACAO - Multi Application Curvature Adaptive Optics
- STRAP - System for Tip-tilt Removal with Avalanche Photo diodes
- VINCI - VLT INterferometer Commissioning Instrument
- AMBER - Astronomical Multiple BEam Recombiner
- MIDI - MID Infrared interferometric instrument
- FINITO - Fringe sensing Instrument NIce TOrino
- IRIS - InfraRed Image Sensor
- ISS - Interferometer Supervisor Software