The Pre-GENIE experiment:

I. Thermal background fluctuations
II. Water vapor dispersion fluctuations

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Outline

- Objectives of experiments
- Thermal background experiment
- Sensor characterization
- Temperature and humidity characterization of the VLTI infrastructure
- Road ahead

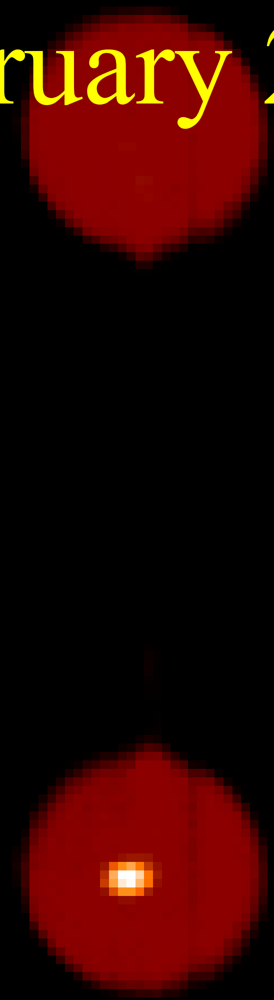
Objectives of experiments

- How it started:
  - GENIE L' versus N band.
    - Need to understand the photometric variations of (thermal) background, frequency response of system
    - Need to understand the stability of longitudinal dispersion effects (mainly water vapor)
- Implementation:
  - MIDI
    - Build on MIDI experience and use this as sensor
    - Install temperature and humidity sensors in the delay line tunnel

Phased approach

Experiment			
1 Single UT, long time series		February 2003	done
		October 2003	done
2 Two telescope, fringe tracking for an hour with MIDI		Spring 2004	anticipated
3 Fringe tracking with FINITO, fringe detection with MIDI		Spring 2004	anticipated
3 Installation of 4 humidity sensors			
	1 Purchased by ESO	February 2003	done
	2 Calibrated by Leiden	November 2003	done
	3 Installation at Paranal	January 2004	planned

February 2003



- Some results

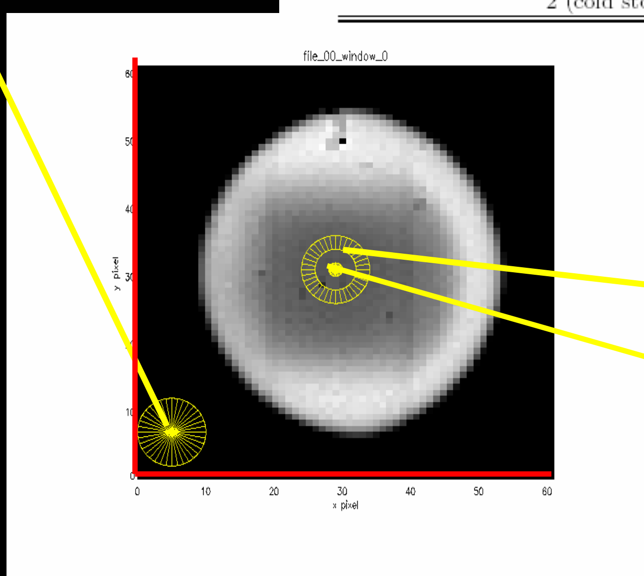
Selected regions

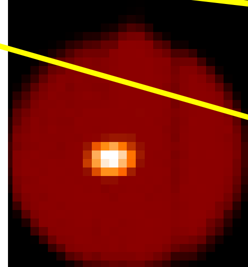
Table 1: Windows and regions selected.

MIDI Beam	Window	Region	Absolute central pixel x	Absolute central pixel y	Radius inner	Radius outer	No. of pixels
B	0 (UT3)	0 (source)	189	162	0	1	5
		1 (background)	189	162	3	5	56
		2 (cold stop)	165	138	0	5	81
A	1 (UT1)	0 (source)	190	76	0	1	5
		1 (background)	190	76	3	5	56
		2 (cold stop)	165	138	0	5	81

Window 0: UT3
Window 1: UT1
Region 0: central pixels
Region 1: background circle
Region 2: dark detector pixels

Region 2: Detector





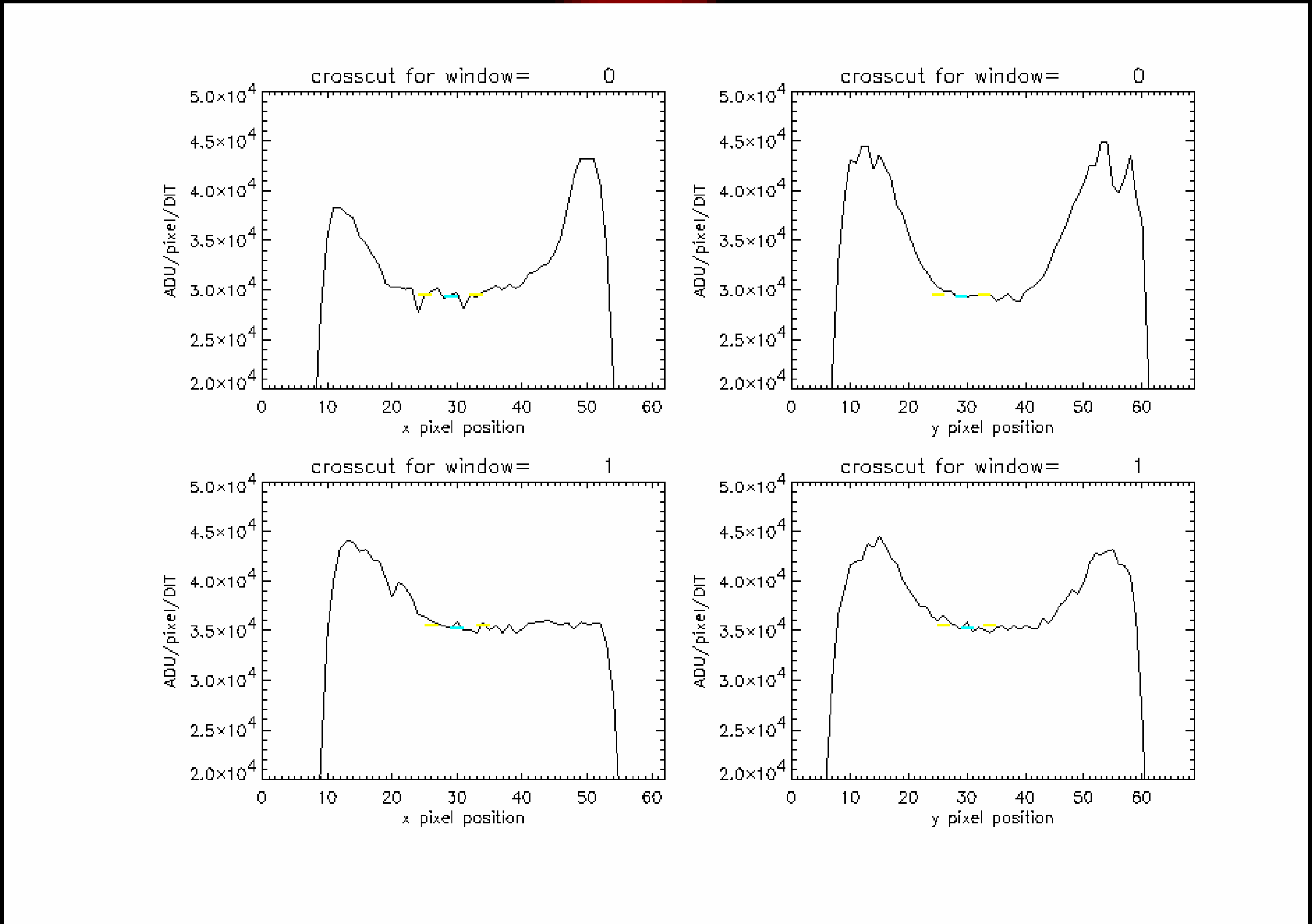
Region 1: Background

Region 0: Source

Cross-cuts

UT3

UT1



X-crosscut

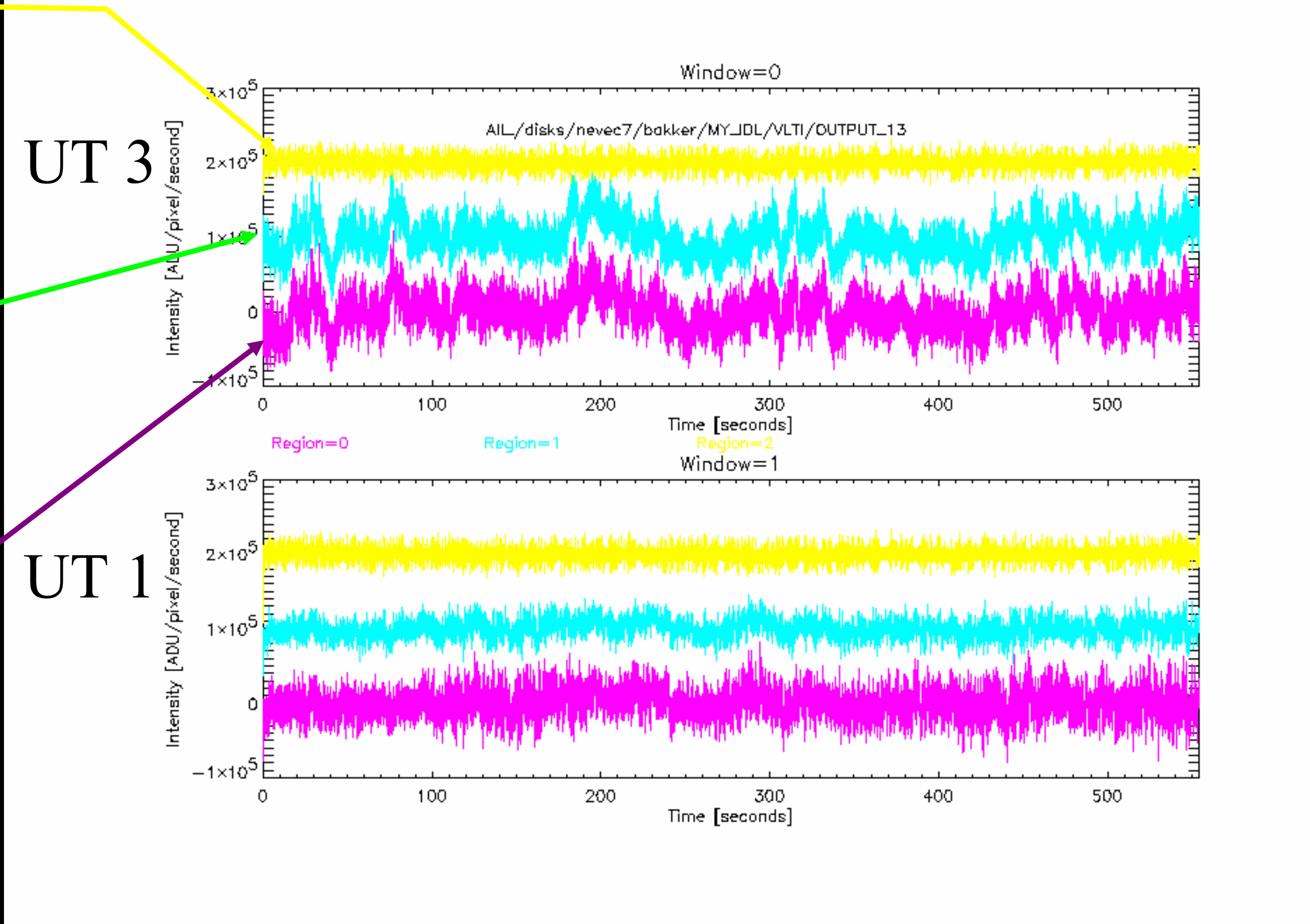
Y-crosscut

Time series
(relative photometry)

Yellow:
Region 2: dark pixels (mean value subtracted and offset by 2e5)

Green:
Region 1: background pixels (mean value subtracted and offset by 1e5)

Red:
Region 2: source pixels (mean value subtracted)



Relative photometry

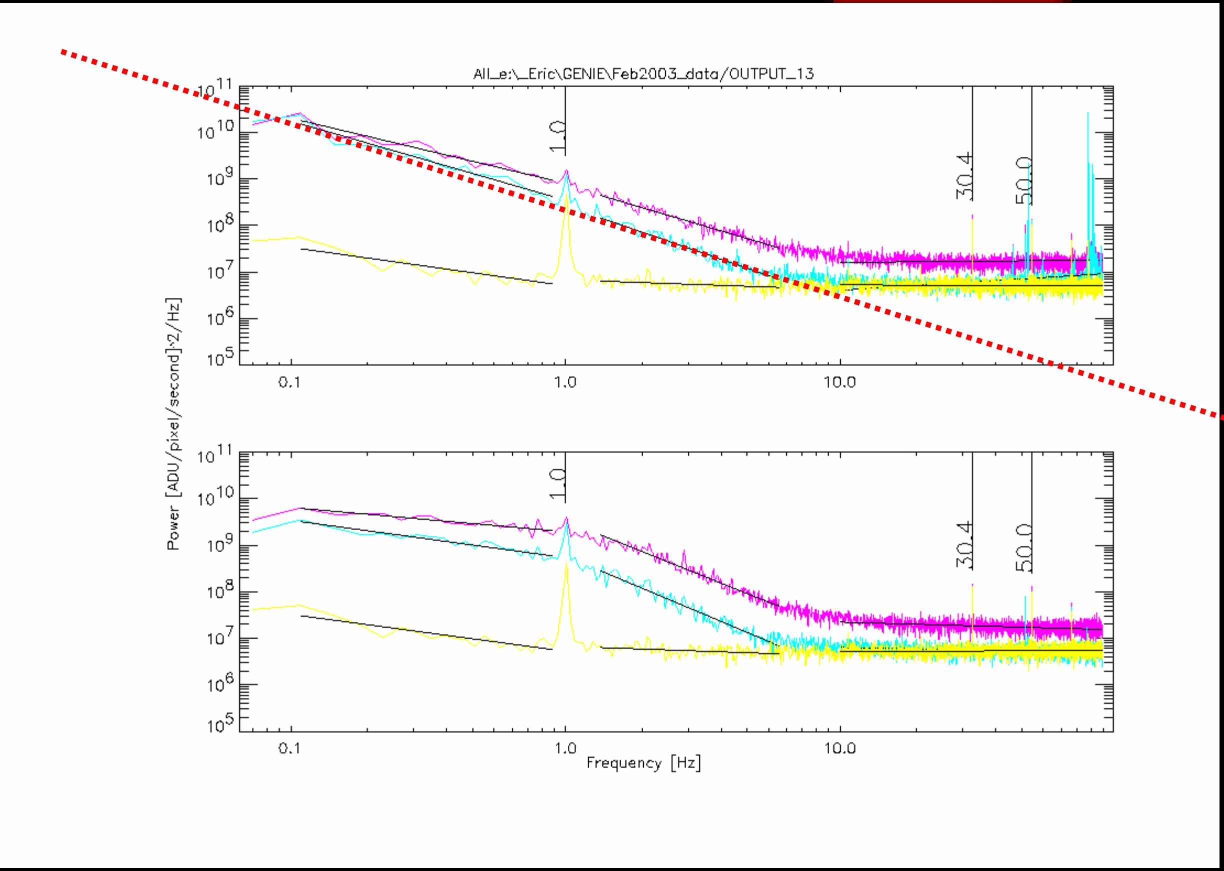
Table 4: Raw intensity, slope and standard deviation per data set.

No.	Window	Region	Mean	Slope	Standard Deviation	Comment
13	0	0	2.45247	23.55966	0.00230	
13	0	1	2.45681	17.39459	0.00222	
13	0	2	0.20782	-5.60590	0.00045	
13	1	0	2.93945	62.04174	0.00169	
13	1	1	2.96813	50.81066	0.00102	
13	1	2	0.22124	-11.23346	0.00046	

1. Mean [10^7 counts/pixel/second] is the mean of the whole dataset
2. Slope [counts/pixel/second^2] determined after subtraction of mean
3. Standard deviation [10^7 counts/pixel/second] determined after removing mean and slope

These number relate to the graphs displayed on the previous and next page

Power Spectral Density



Slope: -2.02
(averaged over 5 pixels)
UT3, 1.3-6 Hz

Slope: -1.73
(averaged over 56 pixels)
UT3, 1.3-6 Hz

This slope is consistent with a random walk
(slope of -2.03)

Slope of power spectrum

Table 5: Slope of power spectrum for different frequency bins.

Experiment Number	Window	Region	0.10-0.90 Hz Offset	Slope	1.30-6.00 Hz Offset	Slope	10.00-90.23 Hz Offset	Slope	Comment
13	0	0	8.90	-1.40	8.86	-1.73	7.15	0.05	
13	0	1	8.54	-1.70	8.42	-2.02	6.23	0.37	
13	0	2	6.70	-0.80	6.83	-0.21	6.75	-0.03	
13	1	0	9.29	-0.52	9.52	-2.36	7.51	-0.17	
13	1	1	8.73	-0.80	8.77	-2.48	6.90	-0.10	
13	1	2	6.72	-0.79	6.83	-0.21	6.68	0.03	

Frequency analysis

MIDI closed cycle cooler

Power line

Table 6: Frequencies identified in power spectra.

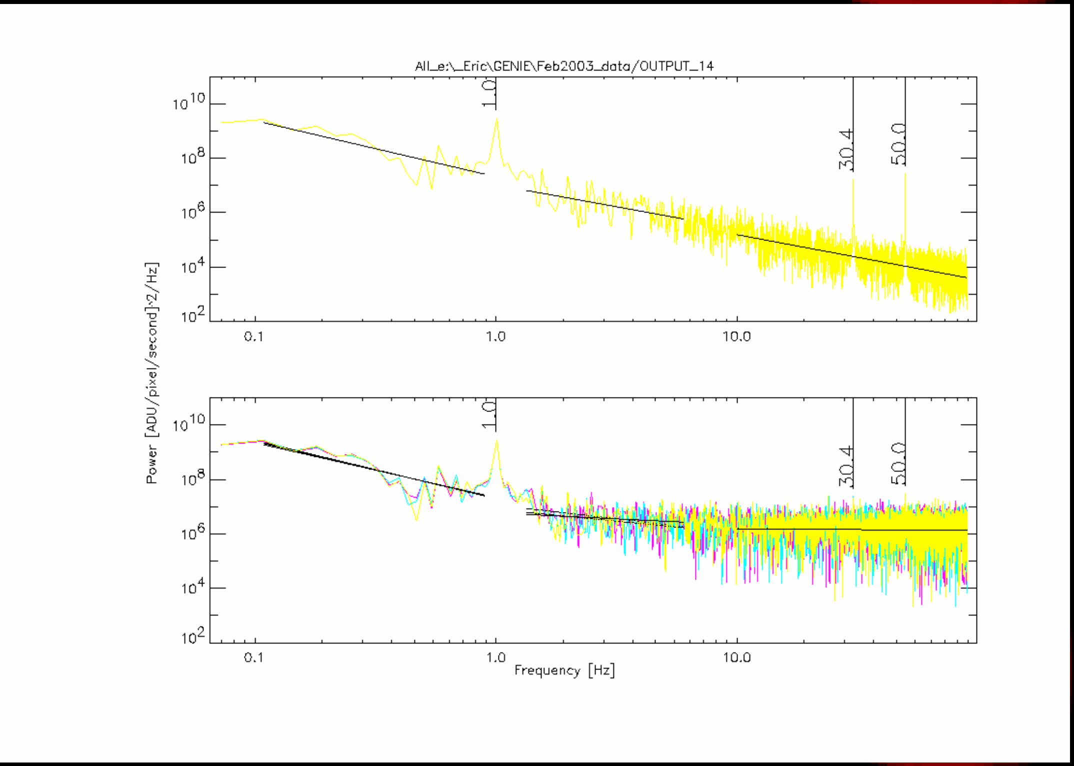
Experiment Number											Frequencies in PSD [Hz]											
0	1.0			10.5	19.8						30.1					50.1						
5	1.0										30.4		42.6		48.2	50.0					80.5	83.5
6	1.0										30.1					50.1						
7	1.0	2.0		10.2	19.8						30.1					49.7						
8	1.0	2.0	3.0								30.4				48.2	50.0			69.5		80.6	
9	1.0	2.0									30.4					50.0			69.7		80.6	83.5
10	1.0	2.0									30.4					50.0			69.2			
11	1.0										30.4			47.4	48.6	50.0					80.5	
12	1.0	2.0		10.0	16.0	16.9	18.0	24.2	26.0	27.0	30.4	36.0	42.5	47.2	48.6	50.4	53.5	55.2	69.2	71.6	79.7	83.6
13	1.0										30.4		42.5	47.4	48.6	50.0		55.0	69.8		80.5	83.6

Unknown source, MIDI specific

Expected peaks in PSD

Frequency	Source
0.6 Hz	Main delay line shift for these tests
1.0	**MIDI closed cycle cooler**
2.0	2*f1.0
3.0	3*f1.0
3.79	MIDI piezo stroke f3=f145/48 for these tests
24	Liquid cooling pump of UT (Di Folio)
45	UT Fans for electronics (Di Folio)
50	**Power lines**
58	Optical Table modes (for VINCI)
71	Modulation of fringes by MIDI for science source
72	Nyquest sampling interval of time series
100	2*f50
145	Sampling window f145=1/0.00688

Simulated PSD



The simulated data is build on one of the real datasets (time sampling). 1 Hz, 30 Hz and 50 Hz sinus signals have been added for the MIDI closed cycle cooler (1 Hz), and the power line frequency (50 Hz), and one for a yet unknown source (30 Hz).

In the lower panel photon noise is added which gives a flat spectrum at high frequencies (> 10 Hz).

Peaks in PSD

Each time series has a peak in the power spectrum at 1 Hz (and possible the overtones 2 and 3 Hz), and at 50 Hz due to the power line frequency.

A 30.4 Hz MIDI specific peak of unknown origin is also consistently present.

Additional peaks are present, but do not consistently occur in all dataset.

Slopes of PSD

We identify three regions in the PSD:

- 0 to 1 Hz (random walk noise)
- 1 to 10 Hz (random walk noise)
- 10 Hz and beyond (photon noise)

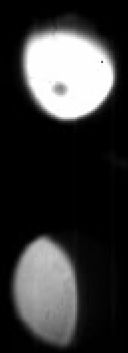
The power for UT1 is lower than for UT3:
UT1 was vignetted, and the sky contribution was lower.

Hence most power comes from the sky background contribution and not from the VLTI infrastructure (airflows, mirrors, moving/vibrating parts).

Pupil Vignetting

Status February 2003

Status October 2003
(only UT3, MIDI beam B)



UT3, MIDI beam B

UT1, MIDI beam A

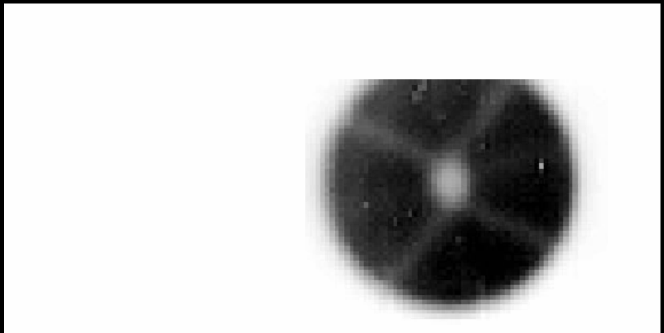
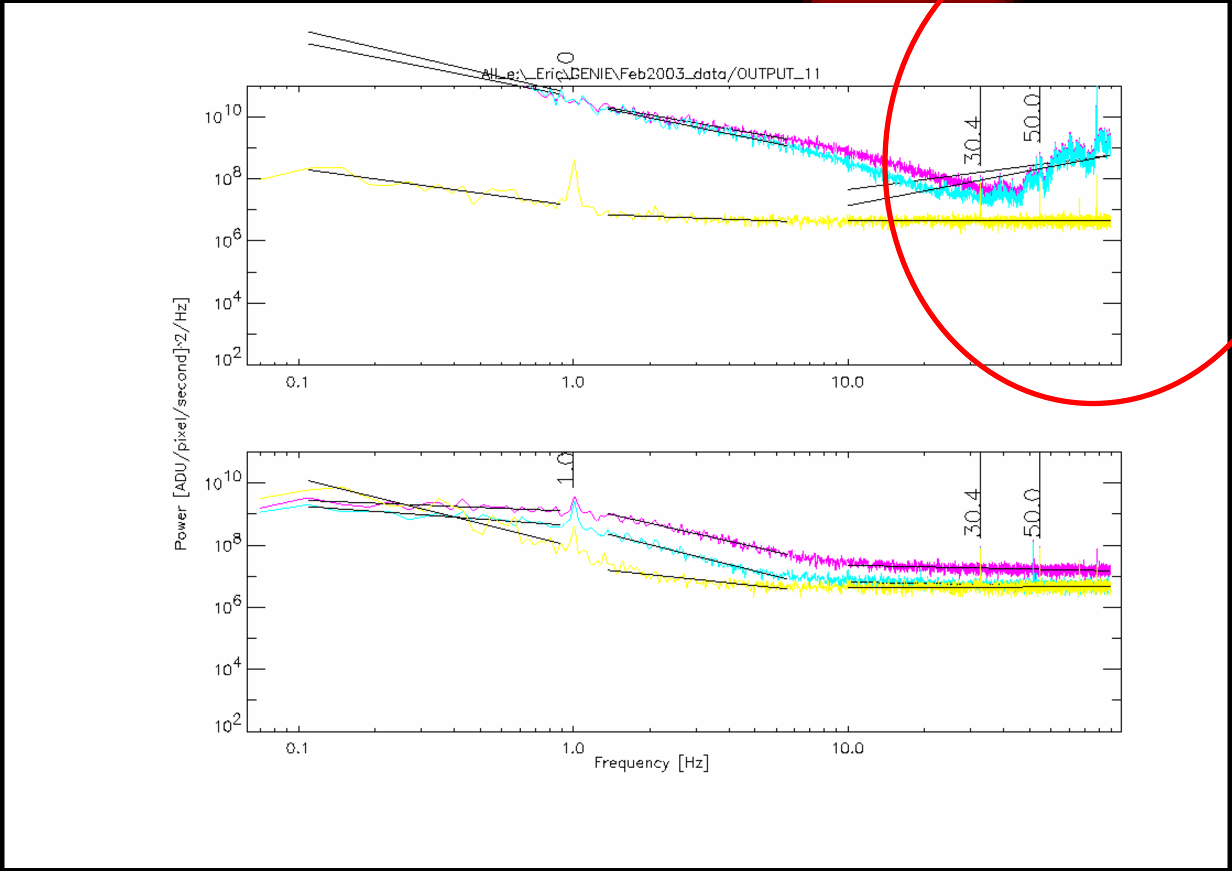


Figure 3: pupil plane image on the sky (07T01:43).

UT 1 is more vignetted than UT 3

The central bright spot is the M2 mirror of UT3. Note the four spider arms which are brighter than the surrounding sky.

People at Coude focus



During experiment exp11, engineers were working at UT3 to fix technical problems with the Coude optics. This has apparently introduced significant power above 50 Hz, and an overall increase of the power for low frequencies (0 to 10 Hz).

Power in PSD

For experiment exp13, both telescopes looked at the sky, but with different elevations angles and hence different air-masses. Unfortunately other effects, e.g. vignetting, makes the interpretation difficult.

When opening the dome (exp11, exp12, and exp13) the power short-wards of 10 Hz increased by 2 orders of magnitude, while the count-rate decrease slightly (the sky is colder than the VLTI infrastructure) w.r.t. exp10 (black-plate in delay line tunnel) and exp09 (dome closed).

Clearly a large fraction of the fluctuations below 10 Hz are due to the atmosphere, and not to the VLTI infrastructure.

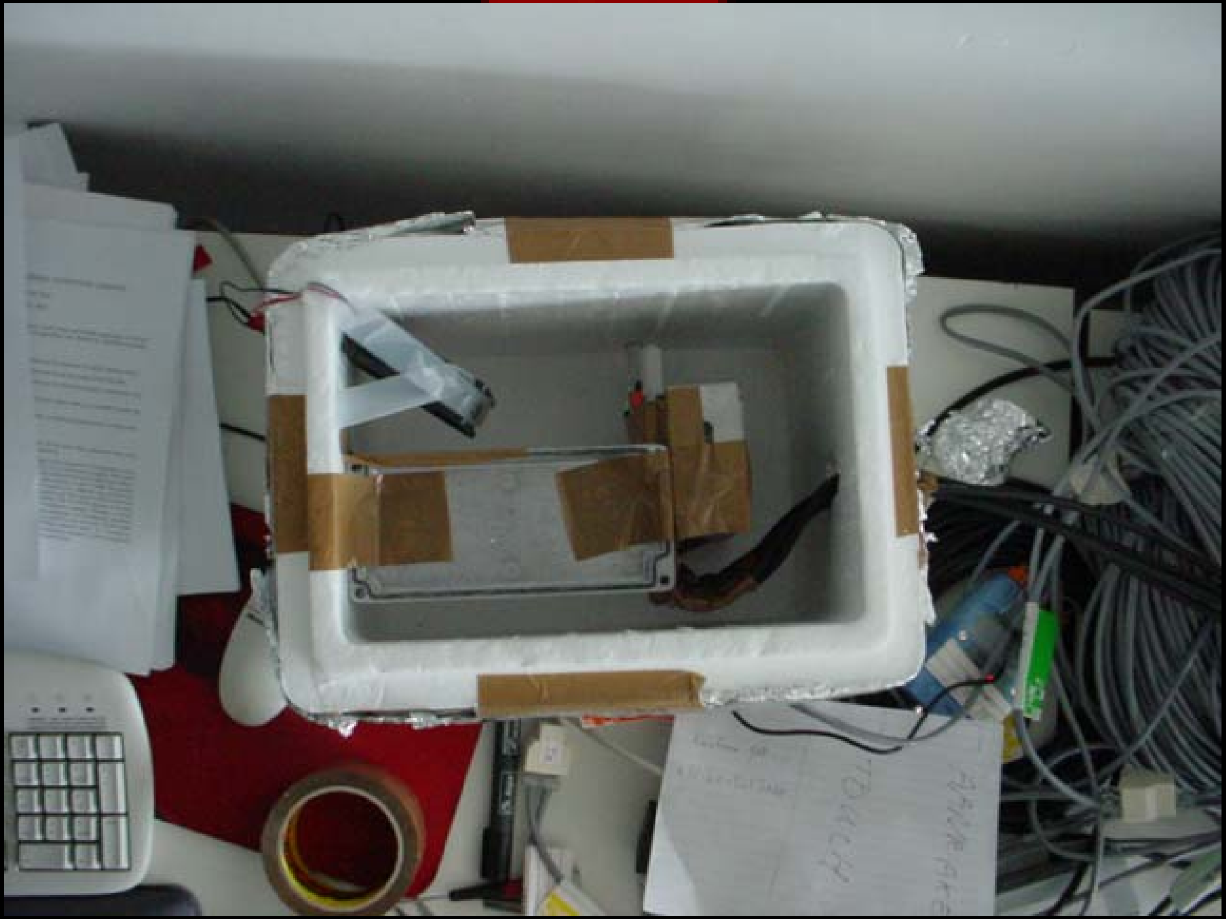
Temperature/humidity sensors

With external fringe tracking (at another wavelength then the science band), fluctuations in dispersion may lead to phase fluctuations in the science channel.

To characterize the fluctuations in the temperature and humidity of the VLTI infrastructure, sensors will be installed.

Isolating box

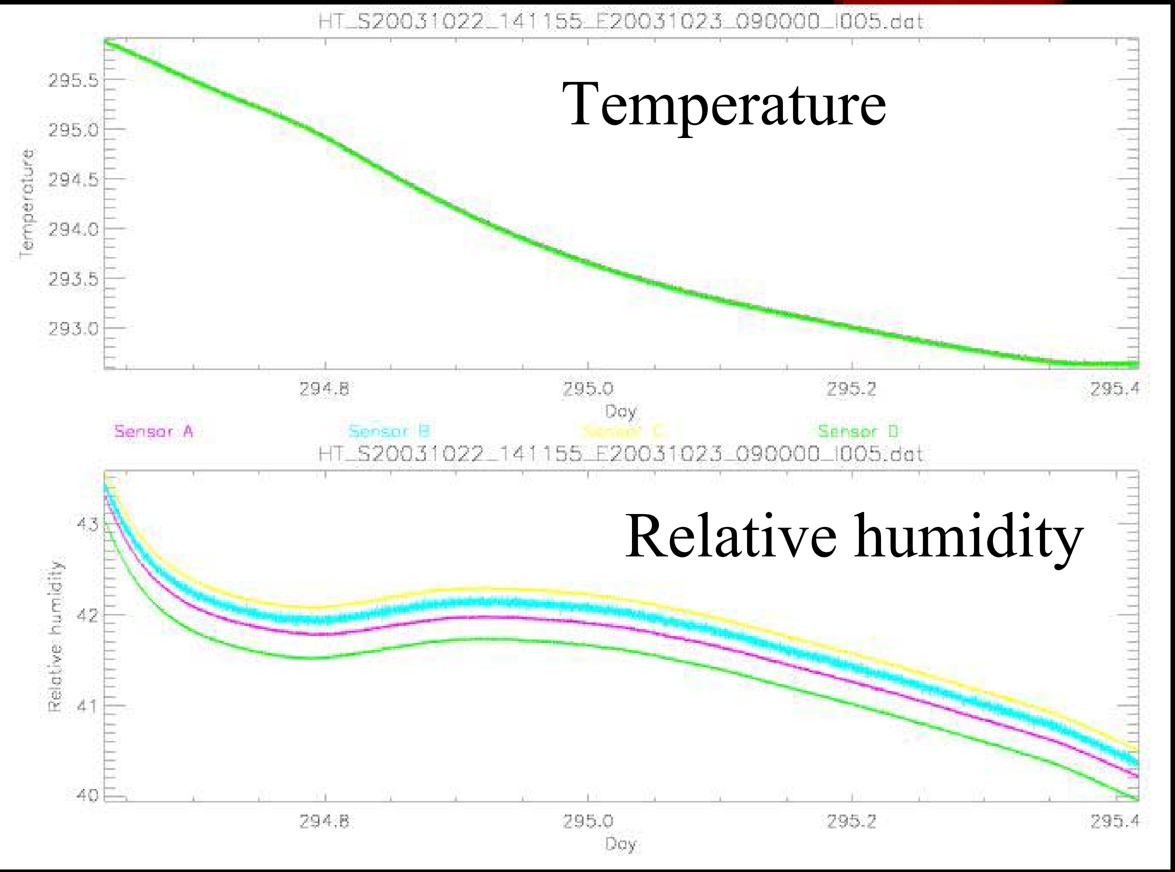
Isolating box



Electronics

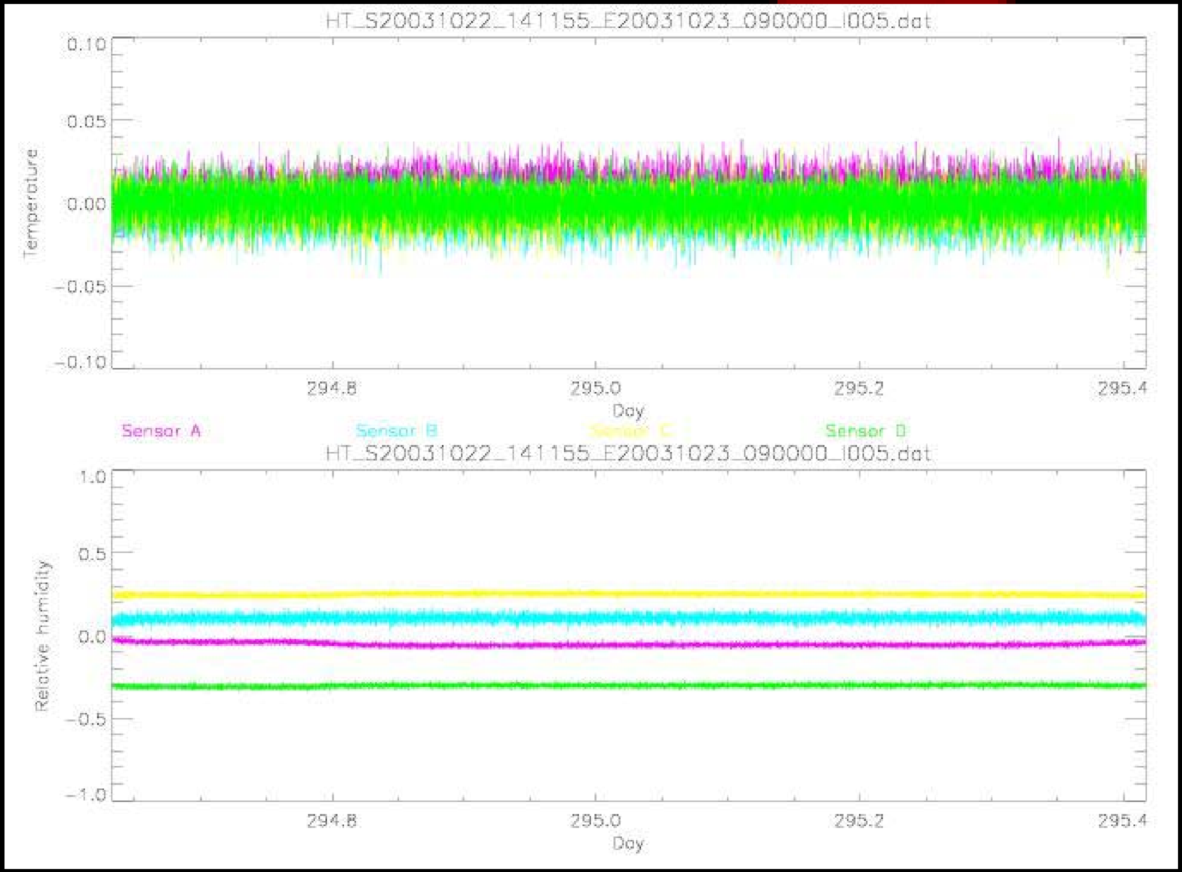
Sensor heads

Absolute sensor readings



Four sensors have been positioned in a box. Temperature and humidity readings for all 4 sensors are presented below for a test environment at Leiden. Note that the four temperature readings fall on top of each other. For humidity there is a small spread, a consistent off-set between the four sensors. The drop in temperature is due to cooling over night. The graph starts at 2 pm until 10 am the next day

Relative sensor readings



Same as previous plot, but the average temperature and relative humidity (of the four sensors at any given time) has been subtracted.
Top panel is the temperature, lower panel the relative humidity for the duration of one night.

Preliminary results

- Biggest problem:
  - Temperature gradient in box: solution to build a custom made box and position the sensors at the same horizontal position within the box
- Statistics:
  - Temperature reading have sigma of 0.03 K
  - Different sensor reading vary by at most 0.1 K
  - Humidity reading have a sigma of 0.1 %
  - Different sensor reading vary by 2 %

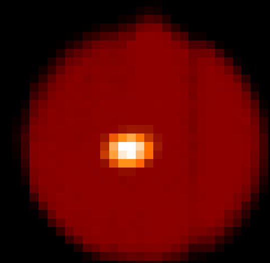
Road Ahead 1/3

Background experiment no. 1:
Observations of the thermal background with one telescope (photometric observations) using a dispersive element will allow to characterize the thermal stability of the VLTI infrastructure and the atmosphere as function of wavelength (done in October 2003).

Background experiment no. 2:
To identify air flows in the atmosphere by tracing emission patterns in the pupil-plane. For this purpose we propose to insert the pupil camera of MIDI in the optical path and obtain an exposure on the sky of an hour (done in October 2003).

Road Ahead 2/3

Background experiment no. 3:
The final objective is to track a fringe with FINITO for at least an hour, and follow any additional Optical Path Length Changes at 10 micron with MIDI. This will provide information on the fluctuations of the index of refraction of air due to water vapor fluctuations.



Road ahead 3/3

Sensor experiment no. 1:

Sensors: East, Center, West in VLTI delay line tunnel

Sensor experiment no. 2:

vertical aligned near VLTI interferometric lab

Sensor experiment no. 3:

horizontally aligned near interferometric lab