PioNier Data Reduction Software

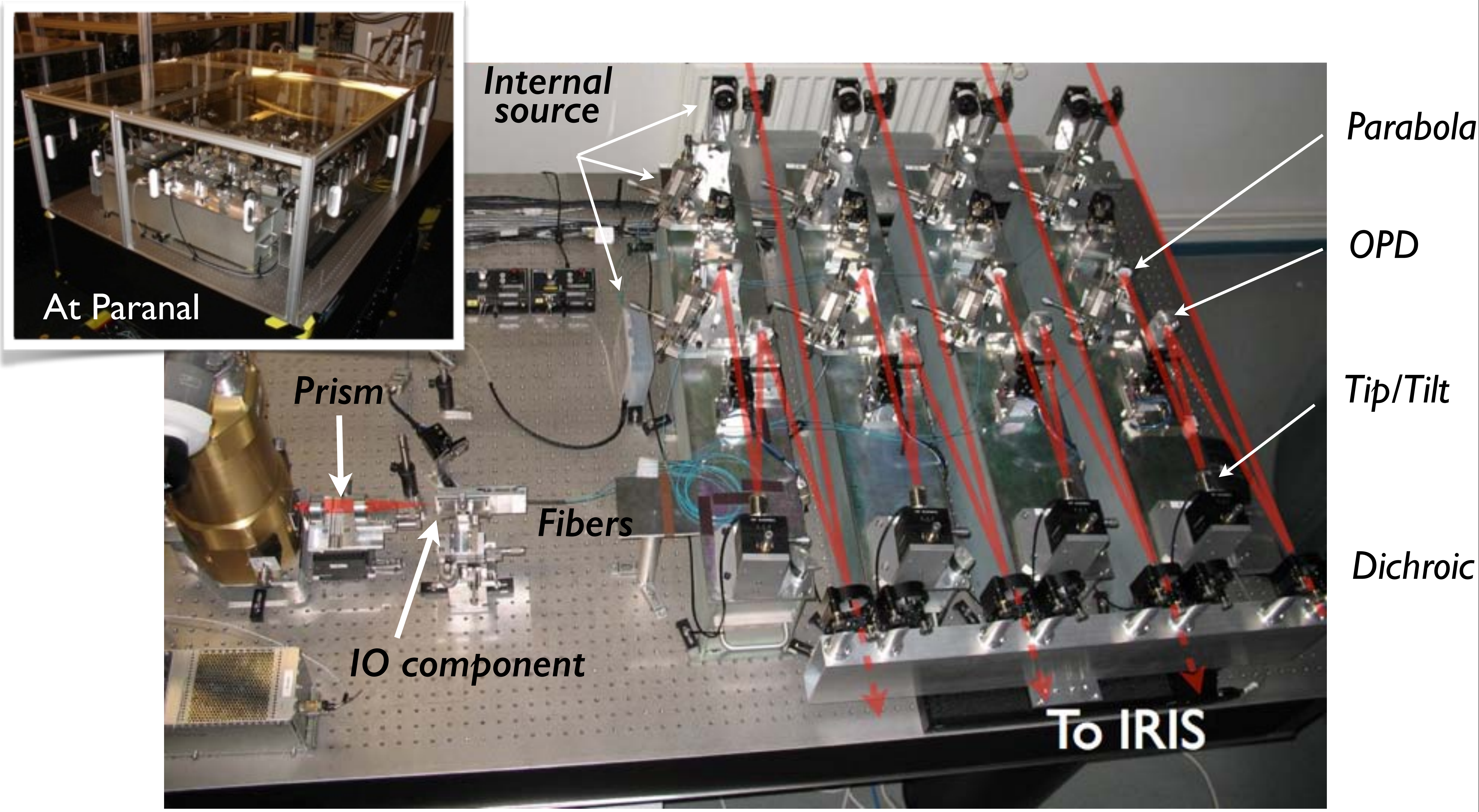
Le Bouquin et al.

ESO

IPAG
Institut de Planétologie et d'Astrophysique de Grenoble

JMMC

Top level description



The 4T IOBC

(where the interferometric combinations take place)

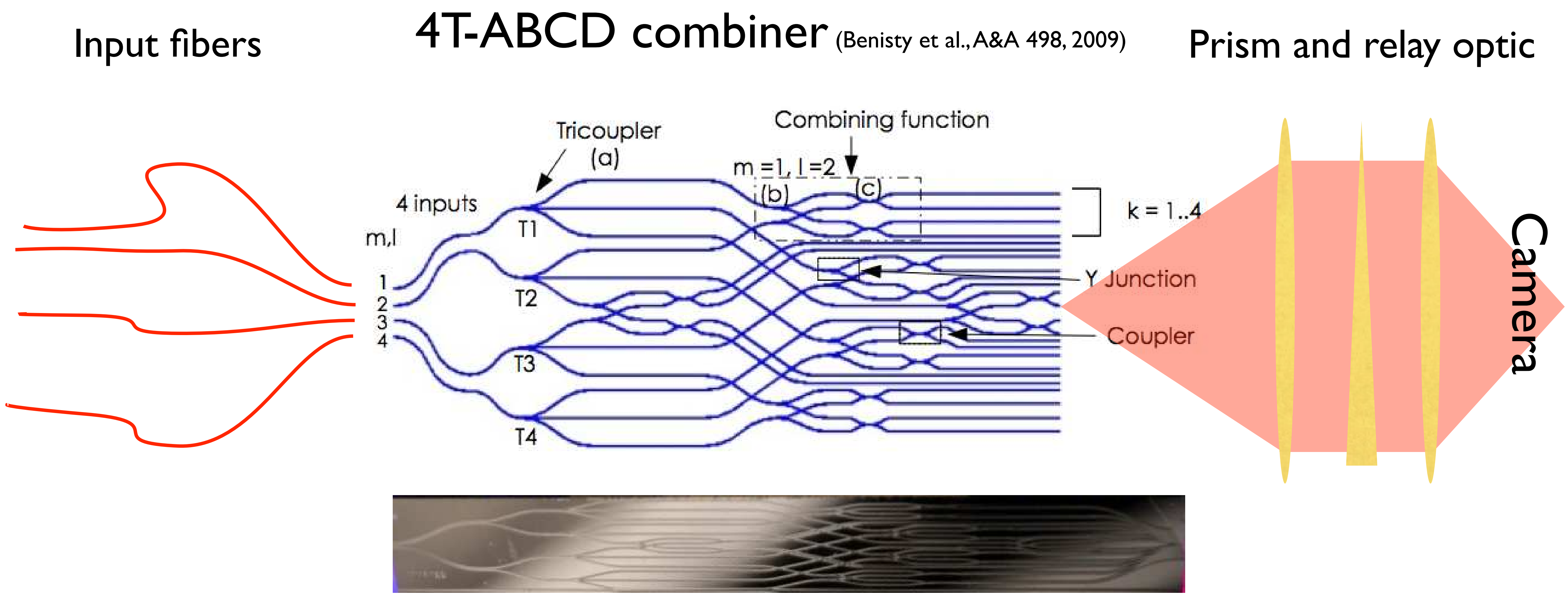
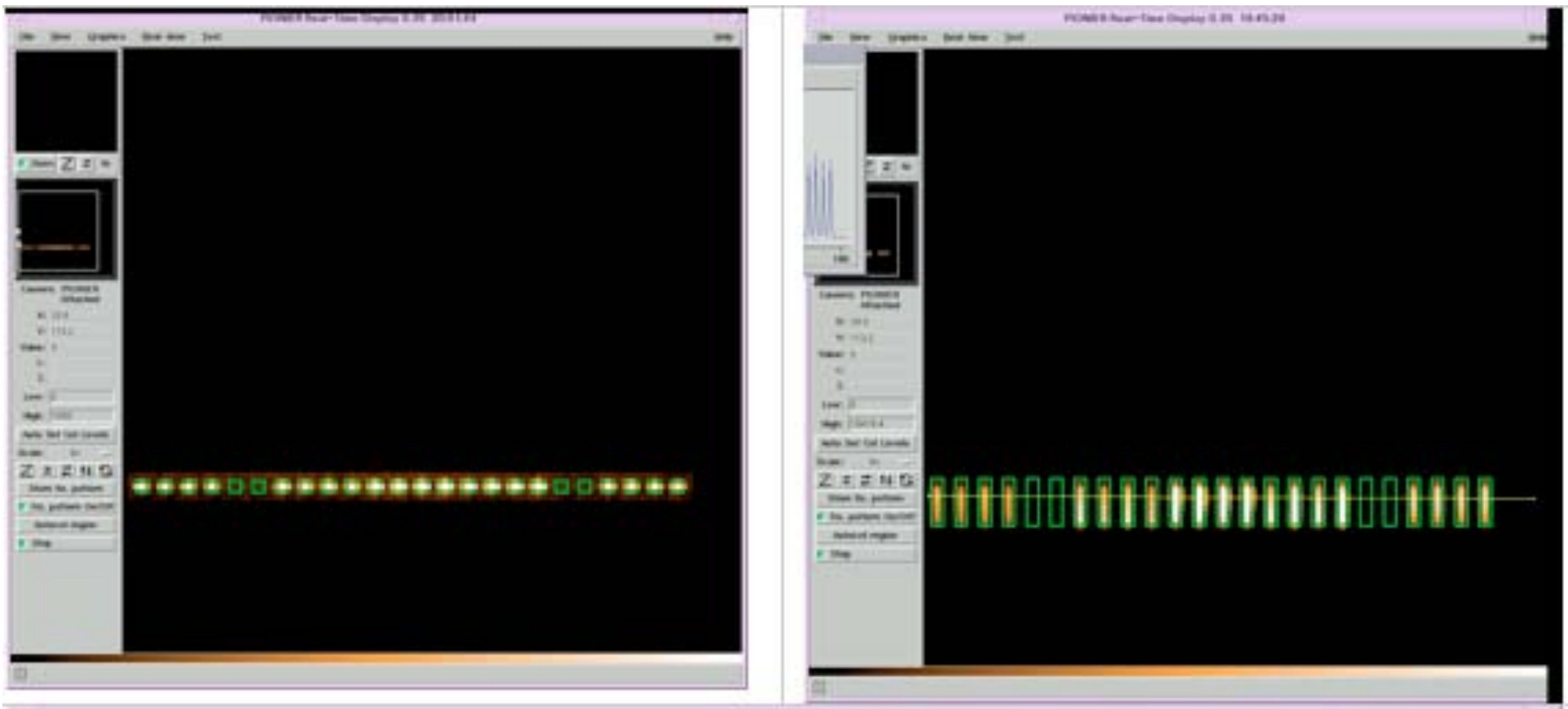
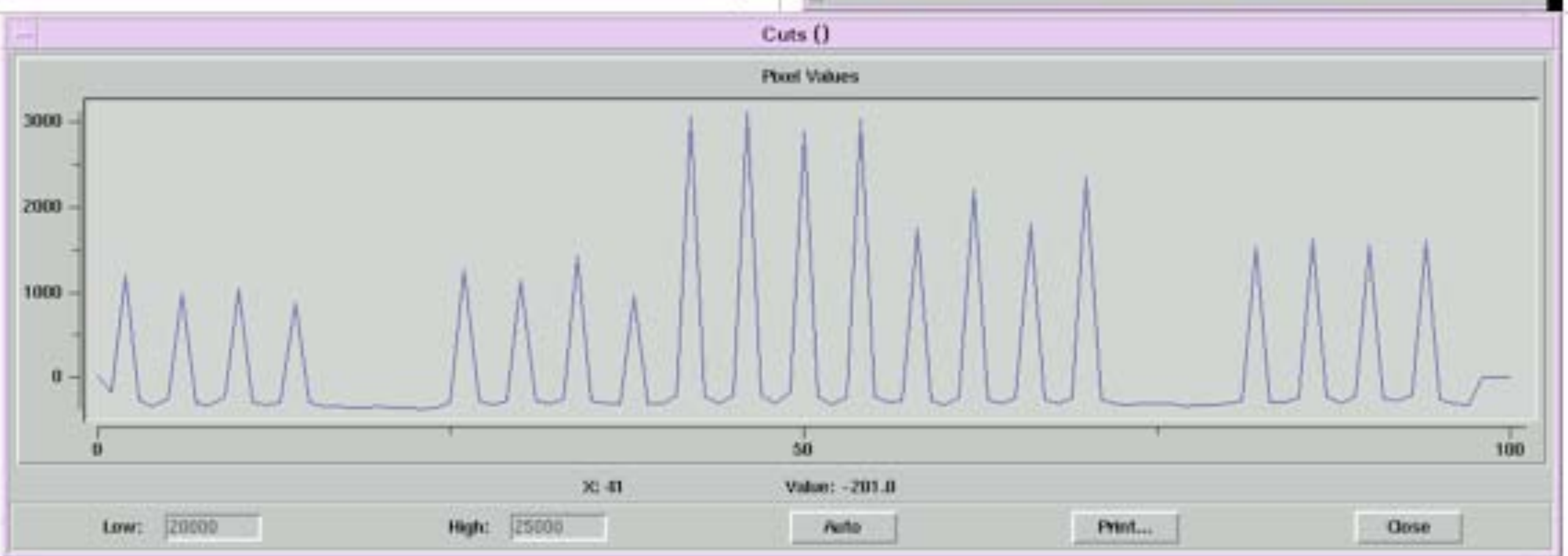


Image on the detector

BROAD-BAND

LARGE

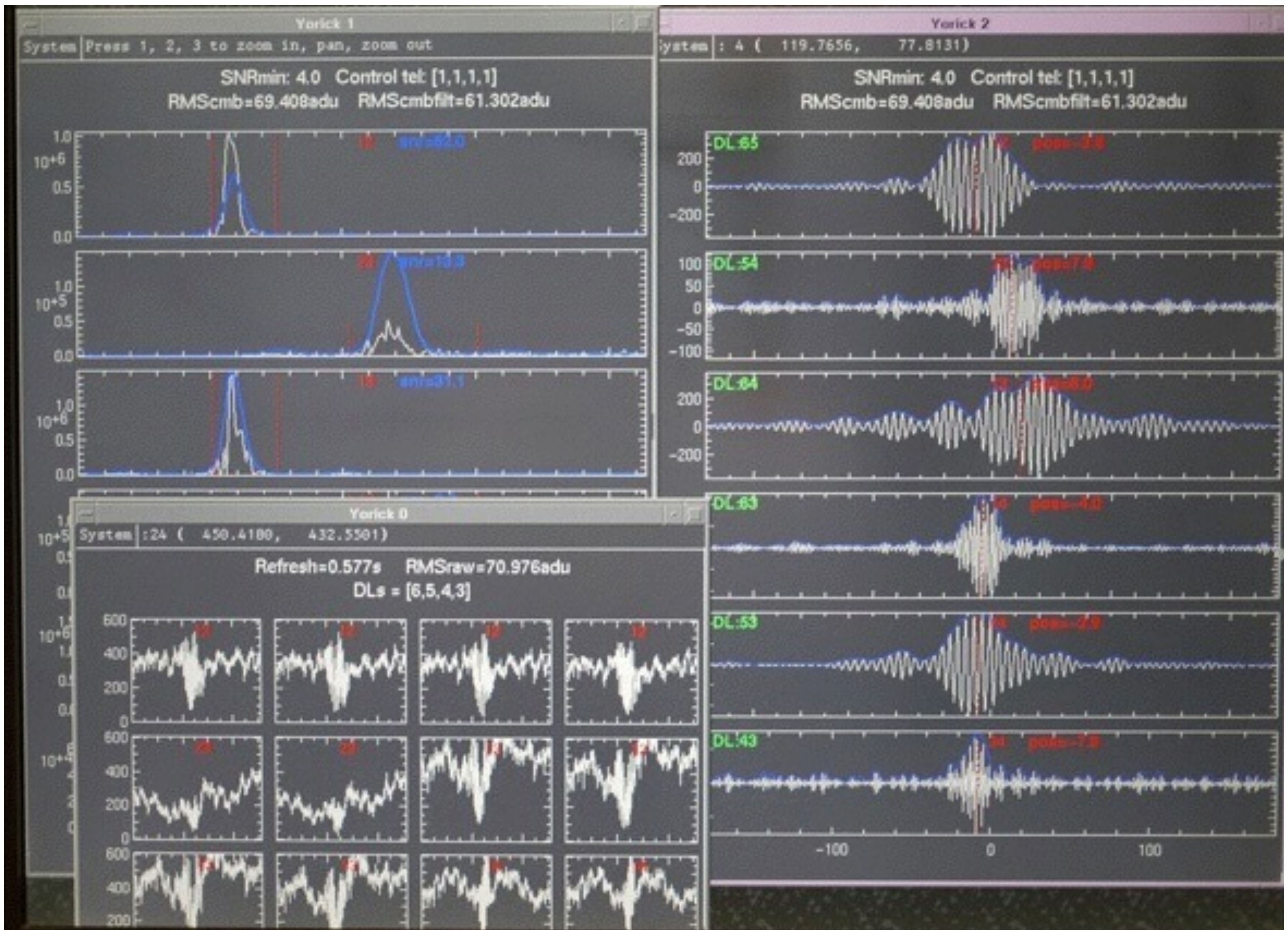




Temporal fringe coding

- Fringe position is corrected at the end of each scan
- One observation = 5 files of 100 scans
- Fringe visibility is computed as an energy in the PSD

Quicklook PSD



Quicklook interferograms

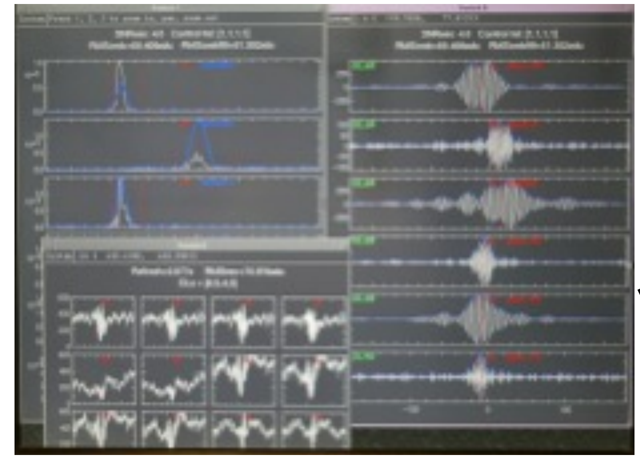
Raw Data

Existing pipeline "pndrs"

Data are transferred from *wpnr* to the ESO offline machine and the ESO main archive.

Step 1: Reduction (30min)

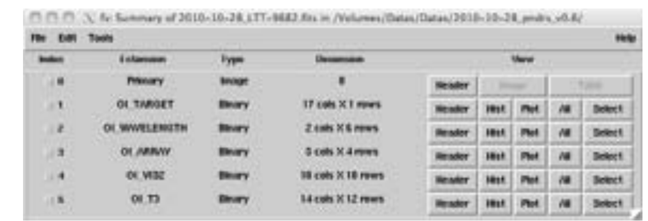
- Kappa-matrix and dark are associated automatically.
- The spectral calibration is implemented in the pipeline.



RAW data

Loop on fringe files

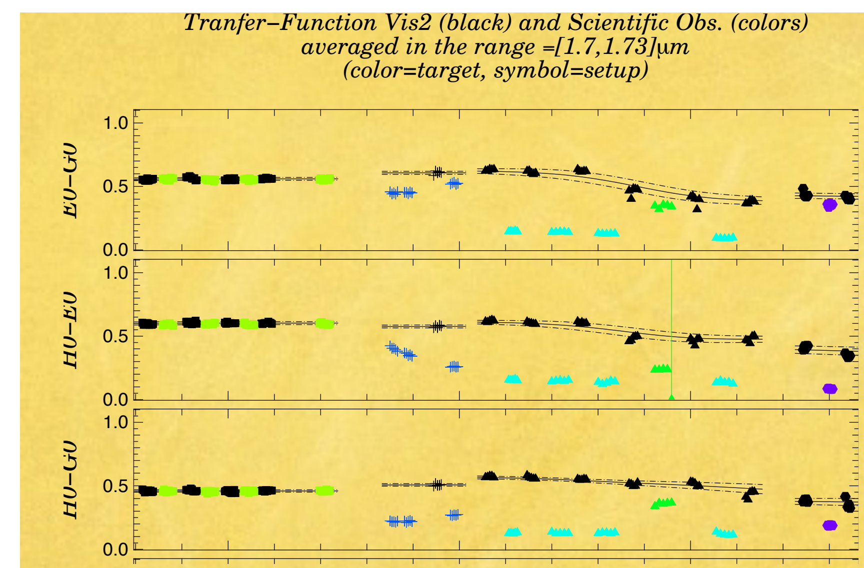
reduced data (OIFITS)



Step 2: Calibration (20s)

- Diameters of calibration stars are recovered automatically from the JMMC catalogue
- Run in real-time : science-ready data can be analyzed ~10min after observation => real-time decisions.

Build the transfer-function calibration of the entire night



Science-ready data (OIFITS)

Part 1 : Data reduction

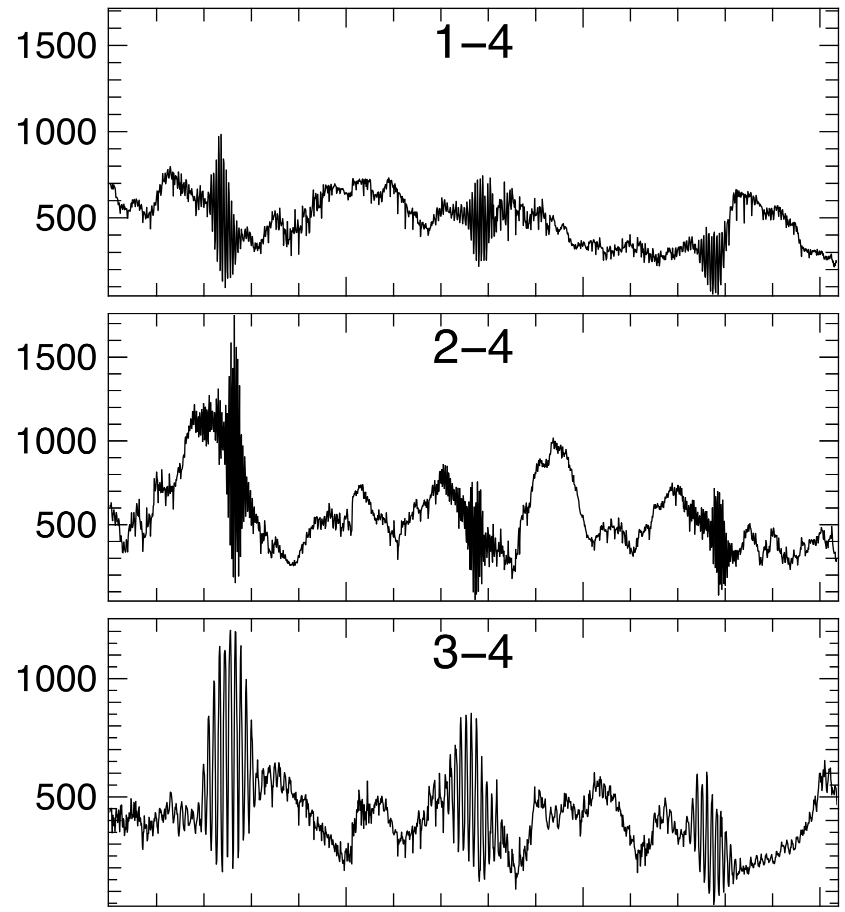
Interferometric equation

$$i^a = \kappa_i^a F_i + \kappa_j^a F_j + \sqrt{\kappa_i^a \kappa_j^a F_i F_j} V_{ij} \cos(\frac{2\pi\delta_{ij}}{\lambda} + \Phi_{ij})$$

Photometries Coherent fluxes F_{ij}

- Step 0 : detector cosmetic (dark)
- Step 1 : from 24 RAW data to 6_fringes and 4_photometry done with the P2VM formalism

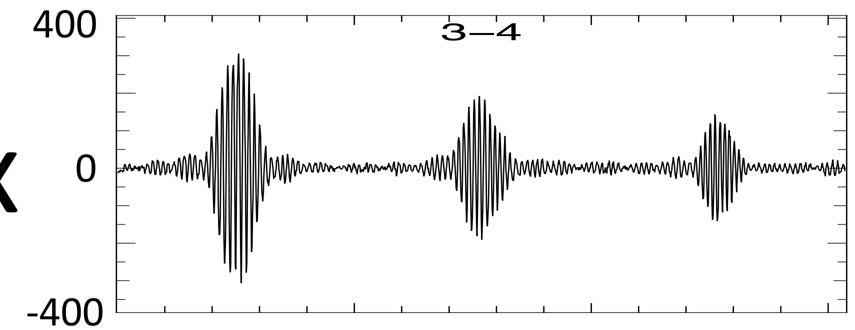
24 RAW scans



=>

Coherent flux F_{D0A1} , F_{D0G1} ...

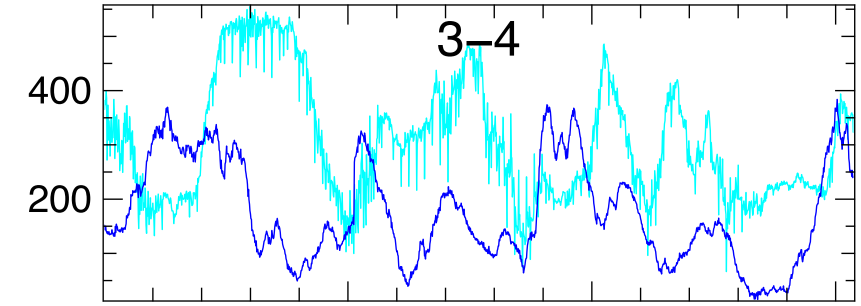
6 x



+

Photometries F_{D0} , F_{A1}

6 x



Data reduction

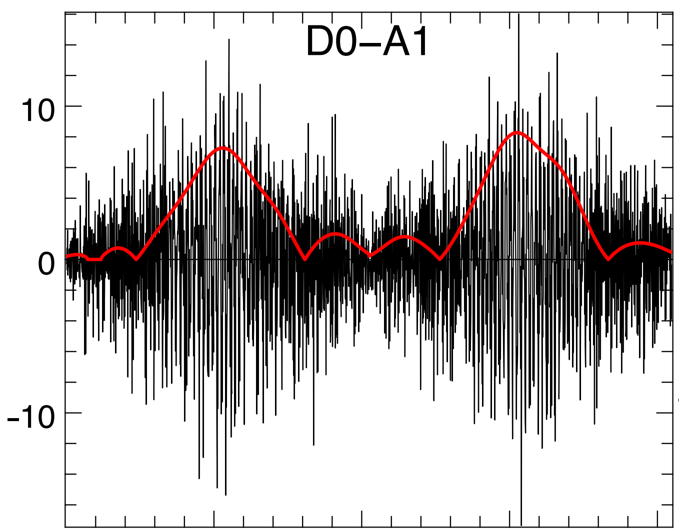
Interferometric equation

$$i^a = \kappa_i^a F_i + \kappa_j^a F_j + \sqrt{\kappa_i^a \kappa_j^a F_i F_j} V_{ij} \cos(\frac{2\pi\delta_{ij}}{\lambda} + \Phi_{ij})$$

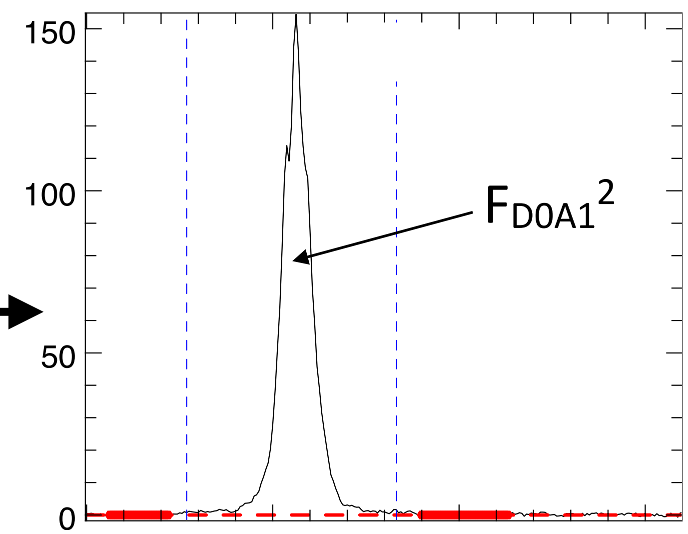
Photometries   Coherent fluxes

- Step 2 : E_HF and E_LF to get squared visibilities.

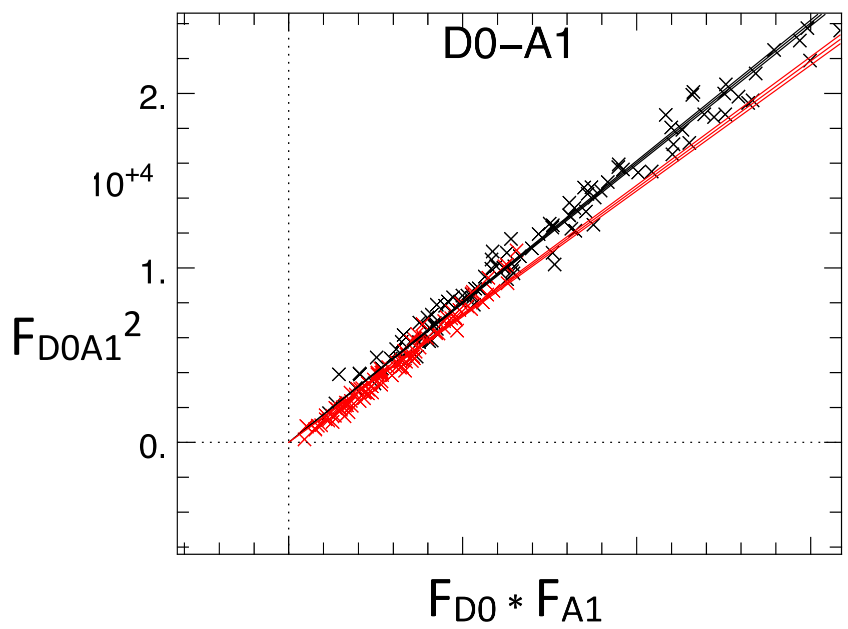
Coherent flux F_{D0A1}



PSD



Step 3 : Average the 100 scans



Photometries

F_{D0}

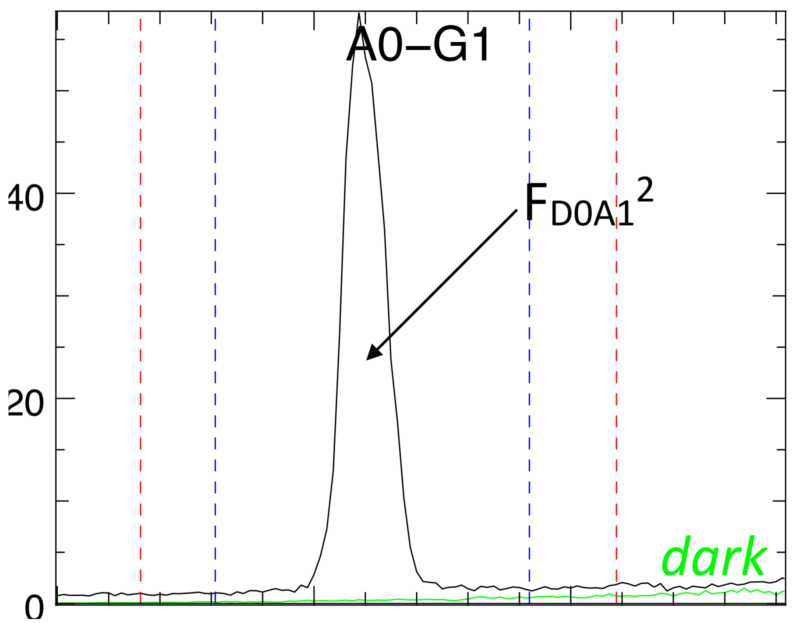
F_{A1}

Crop, filtering

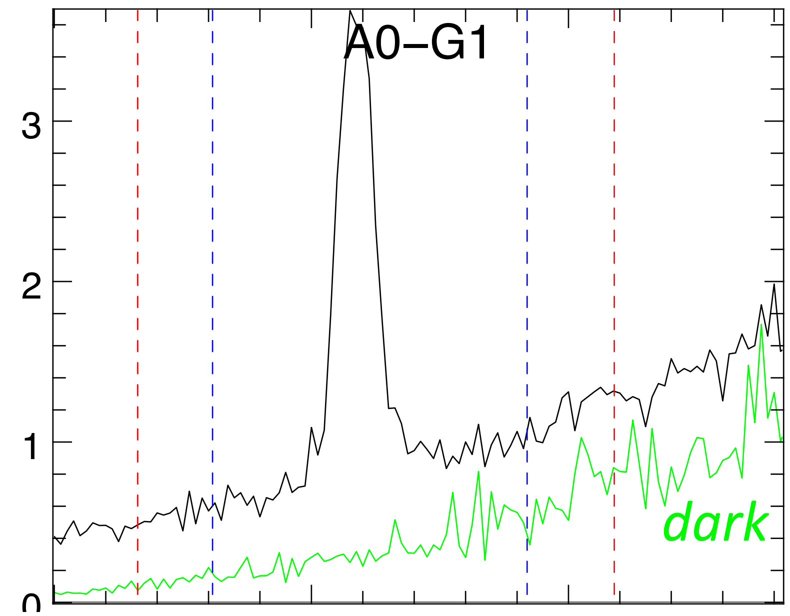
$F_{D0} * F_{A1}$

Data reduction : the trick of un-biasing

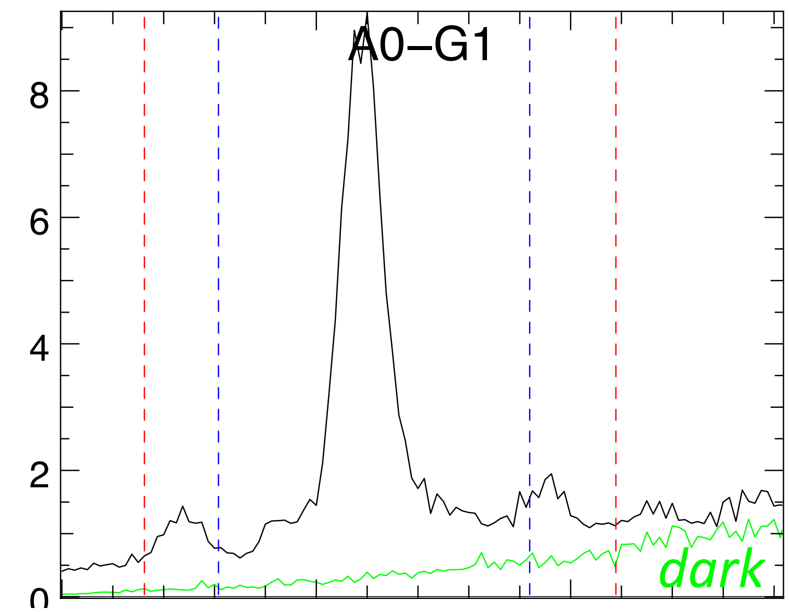
high SNR case



low SNR case

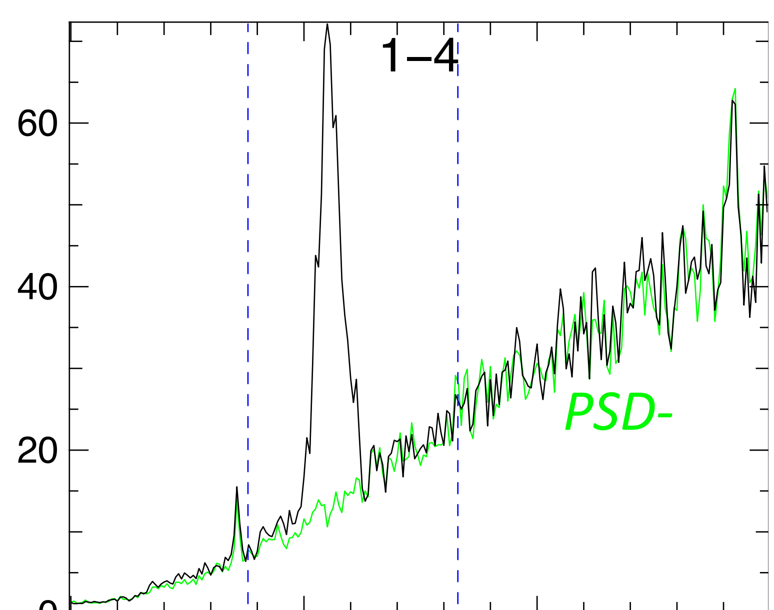


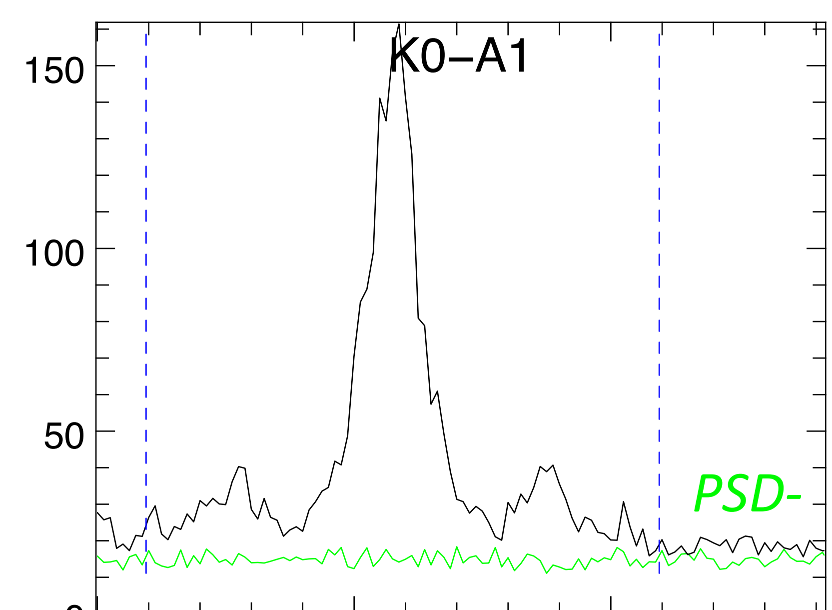
"Windy" case



Regions where one could estimate the bias

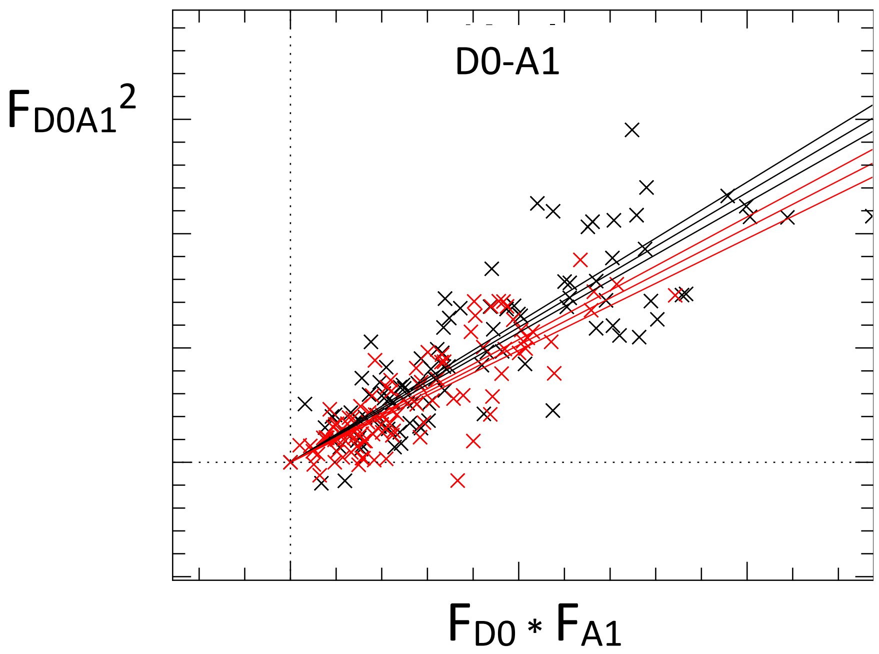
The ABCD + scanning methods allows to estimate the bias as the power at negative frequencies

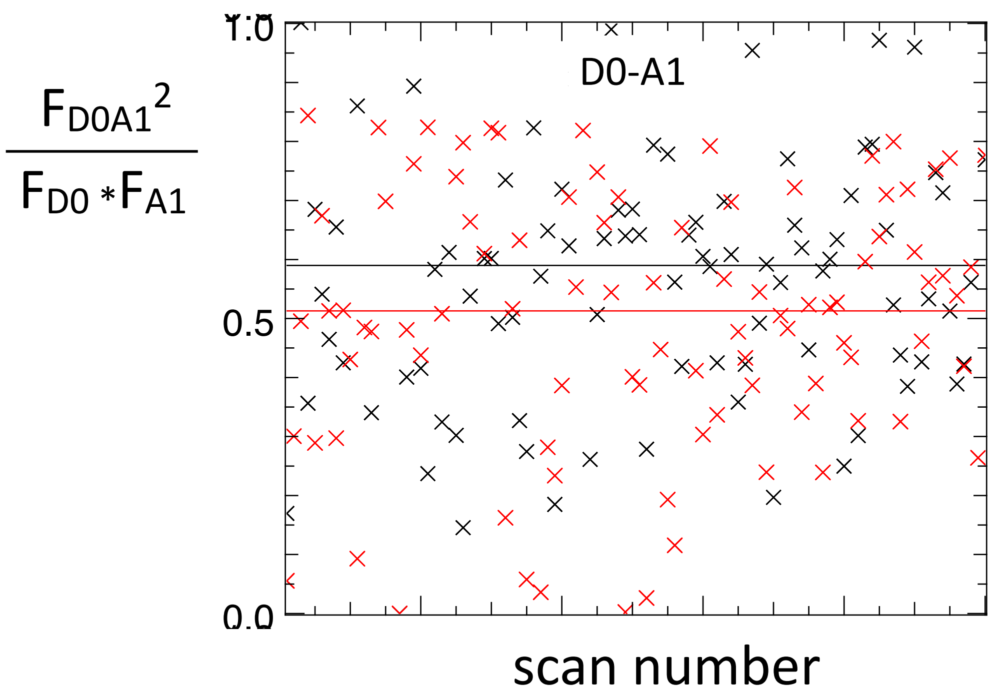




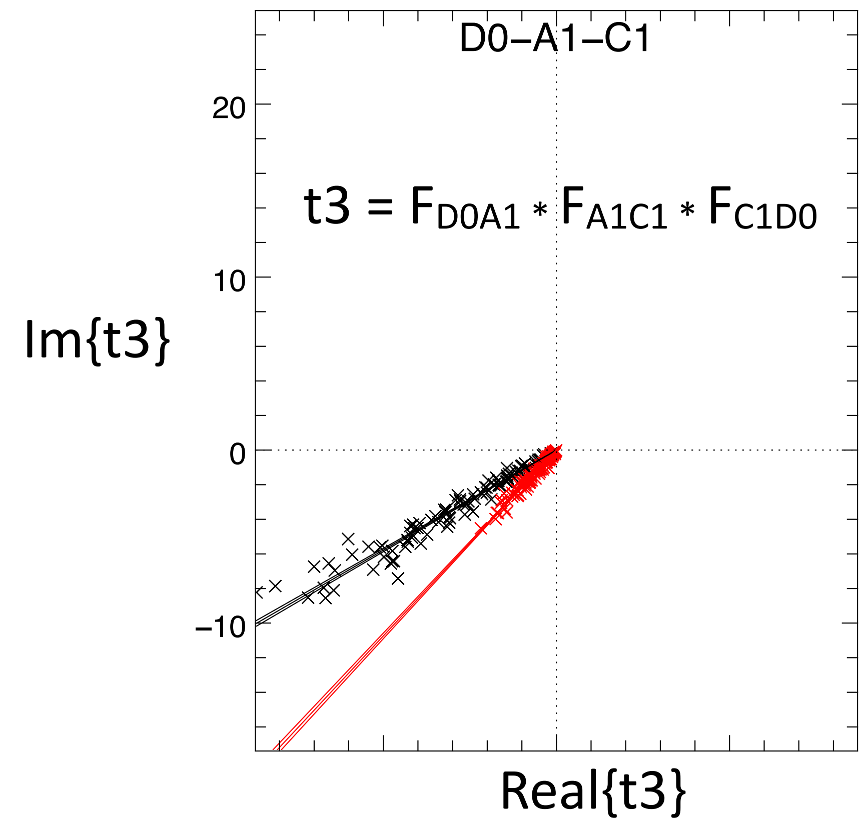
Statistical errors bars from the 100 scans

V2 (100 scans)



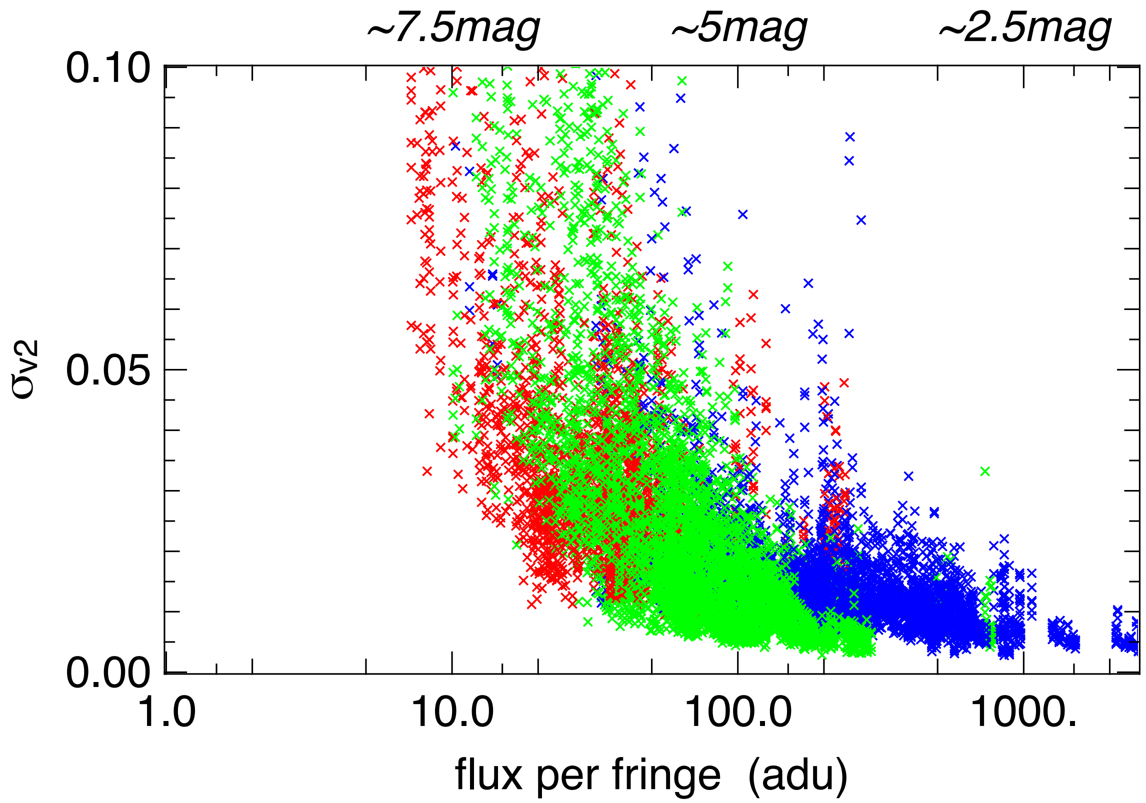


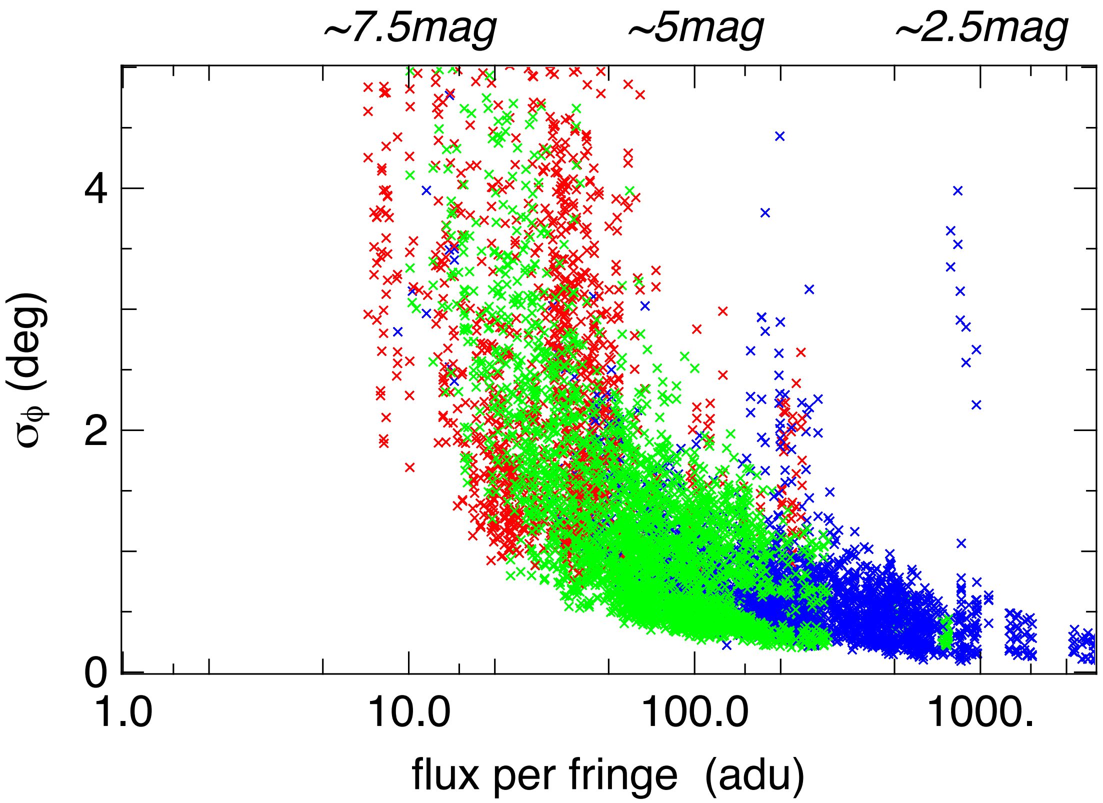
t3phi (100 scans)



- Statistical error bars well determined by bootstrapping technic over the 100 scans
- Indirect correlations between spectral channels (OPD estimation, turbulence...)

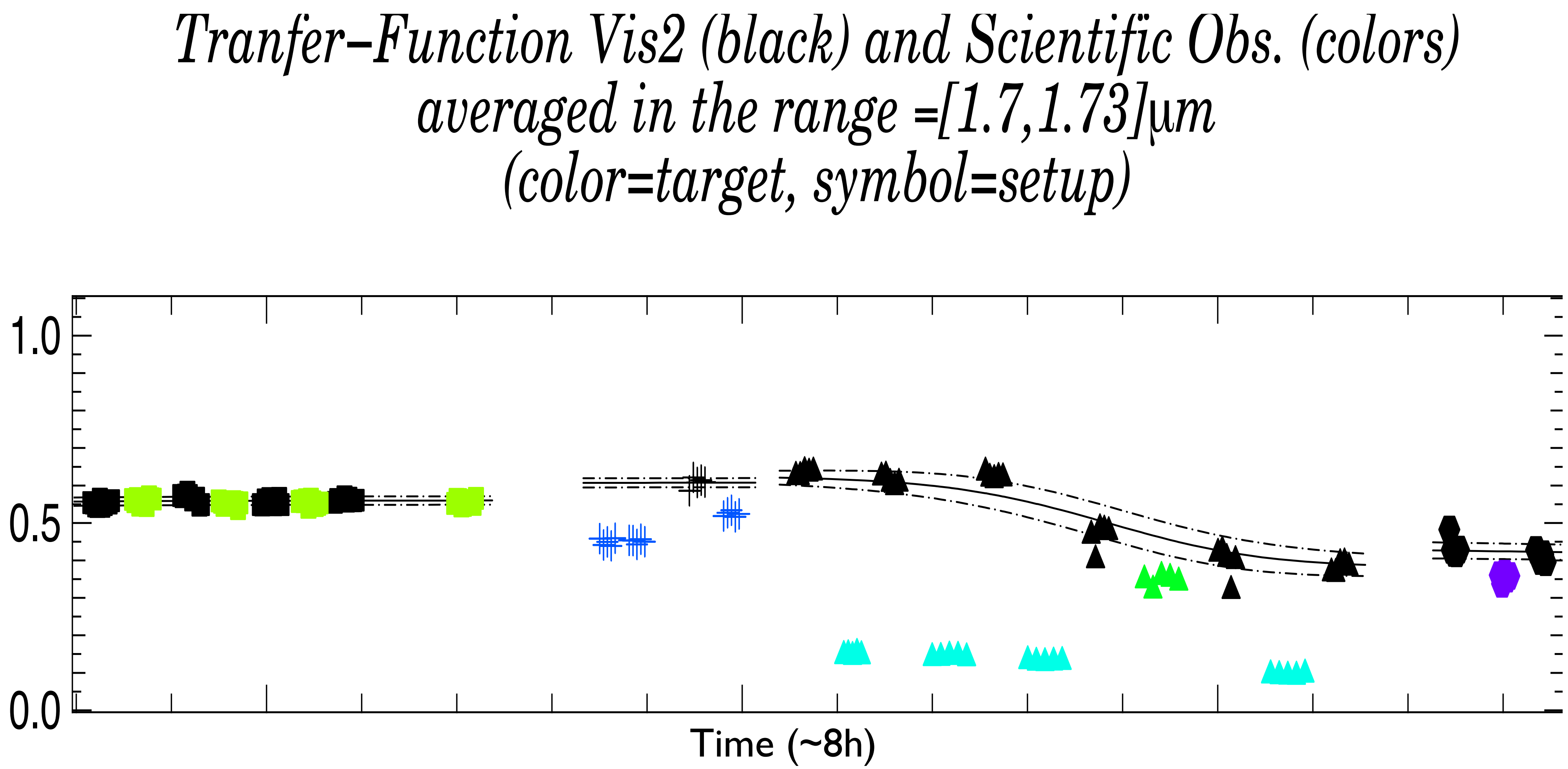
Statistical precision versus flux





Spectral dispersion: FREE (1 channel) SMALL (3 channels) LARGE (7 channels)

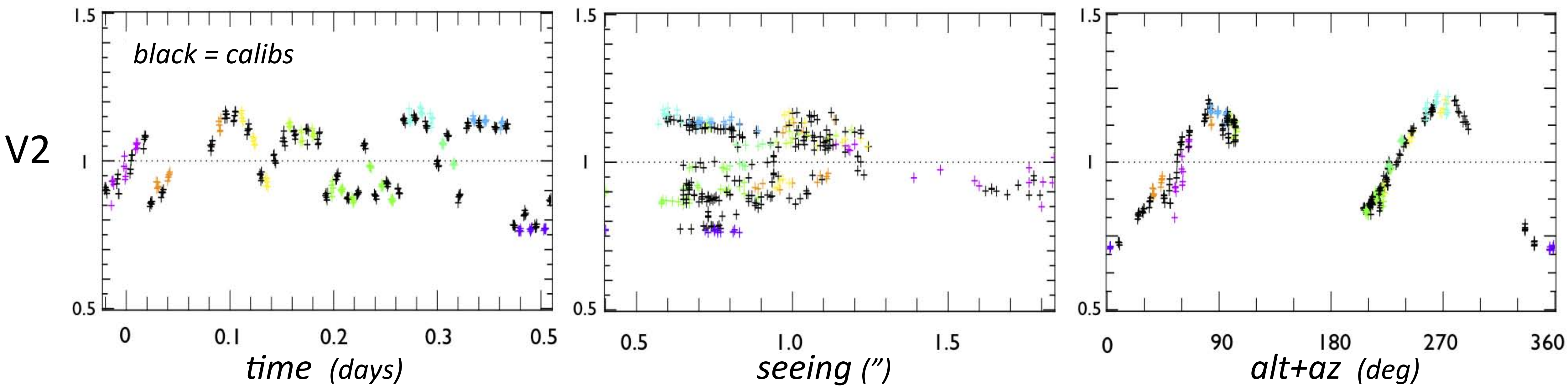
Part 2 : Calibration



- **PIONIER strategy: more than 1/2 of the time spend on calibrators**
- It confirms that statistical error bars well determined
- No direct correlations between spectral channels and baselines
- Strong correlations between consecutive files of a given baseline

Calibration

Stability of the transfer function versus various parameters

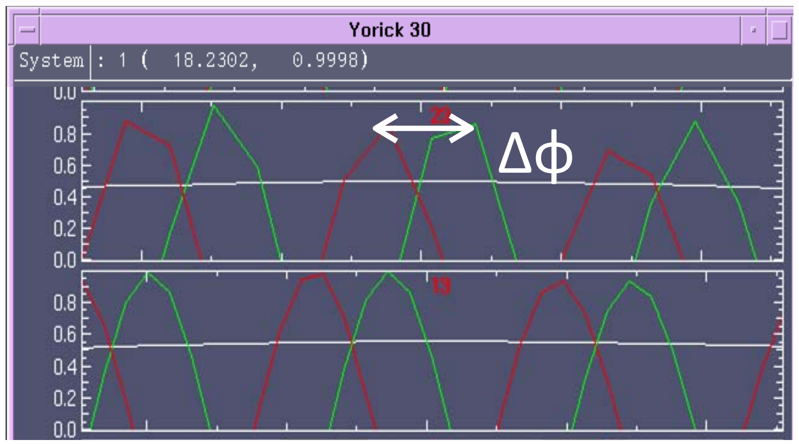


Strongest effet to be calibrated is the position on sky :

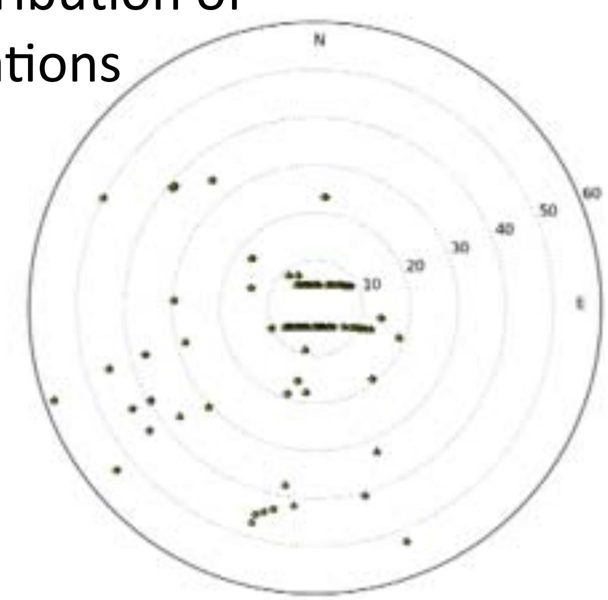
- Need calibration star <3deg for few percent accuracy
- Using several calibration stars mitigate the calibration error
- Split the night per region on the sky
- Large programs uses “all sky calibration” approach because they share the same setup for the entire night.

Calibration as a polarisation issue

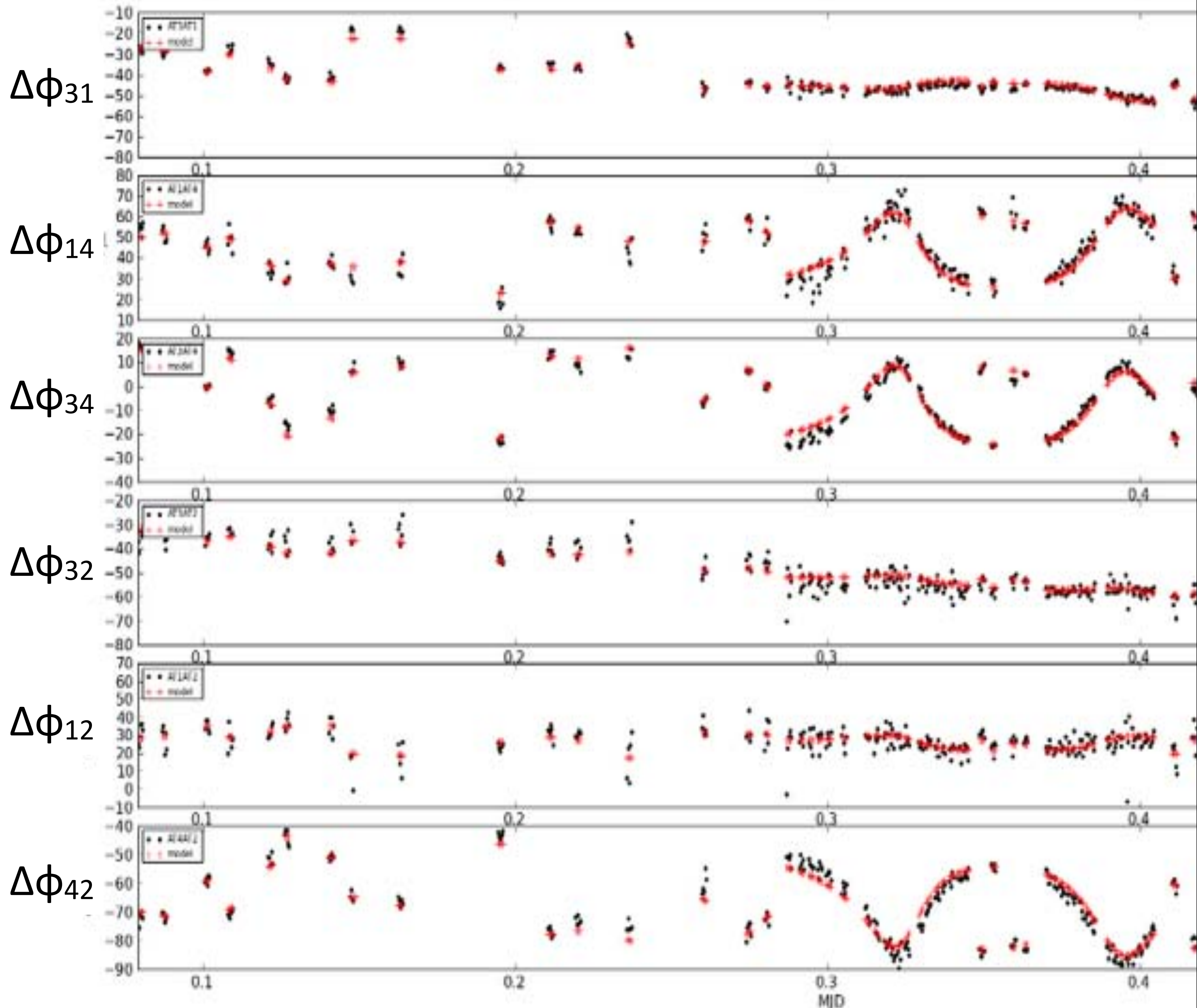
Measurement of the Δϕ between polarisation for various position on sky.



sky distribution of observations



+ measurements + Fitted polarisation model



time ~6h

courtesis: H.Sana who provide the observing time ; A.Merand for the model

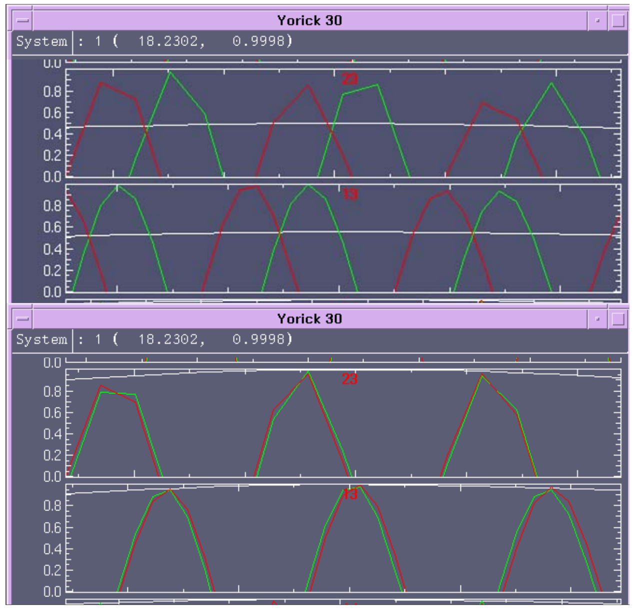
Calibration as a polarisation issue

PIONIER internal birefringence

Daily birefringence alignment with the Lithium Niobate

Before

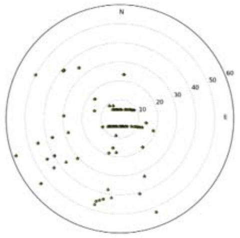
After

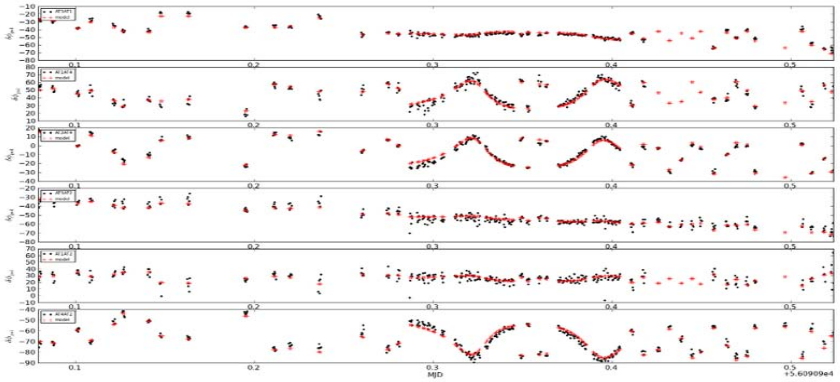


+

VLTI birefringence

VLTI birefringence depend on **pointing**.





- The observed effect changes on a daily basis due to PIONIER internal birefringence (fibers + plates).
- Should be able to reduce the effect by cancelling the sum of the PIONIER birefringence + average VLTI birefringence.
- Effect is more important toward shorter (H,J) wavelengths.

What to learn for the future ?

For GRAVITY (not talking about astrometry) :

- I expect the bias-removal to be the most delicate part of the GRAVITY pipeline.
- It may be possible to provide 5% and 2deg accuracy **without calibration.**
- Accordingly, it should be possible to have a fully automated pipeline that process all observation and deliver science-ready OIFITS with this level of accuracy.
- Statistical precision better than 0.2deg and 0.5% for bright targets with ATs, allowing a dynamic of $\Delta K>6.5$
- With VLTI as such, is may be possible to achieve a proper calibration at this level in K-band, but only with a dedicated and intensive calibration strategy.

For other aspects :

- We should work on VLTI polarisation to open the J band, which should otherwise suffer from strong TF instabilities.