PioNier Data Reduction Software

Le Bouquin et al.
Top level description

At Paranal

- Internal source
- Tip/Tilt
- Dichroic
- Parabola
- OPD
- Prism
- IO component
- Fibers
- To IRIS
The 4T IOBC

(where the interferometric combinations take place)

Input fibers

4T-ABCD combiner (Benisty et al., A&A 498, 2009)

Prism and relay optic

Camera

The 4T IOBC

(input fibers)

4T-ABCD combiner (Benisty et al., A&A 498, 2009)

Prism and relay optic

Camera
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
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.

**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.

RAW data

Loop on fringe files

Reduced data (OIFITS)

Transfer Function Vis2 (black) and Scientific Obs. (colors) averaged in the range = [1.7, 1.73] μm (color=target, symbol=setup)

Science-ready data (OIFITS)

Build the transfer-function calibration of the entire night
Part 1: Data reduction

Interferometric equation

\[ i^a = \kappa^a_i F_i + \kappa^a_j F_j + \sqrt{\kappa^a_i \kappa^a_j} F_i F_j V_{ij} \cos \left( \frac{2\pi \delta_{ij}}{\lambda} + \Phi_{ij} \right) \]

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

\[ 1-4 \]

\[ 2-4 \]

\[ 3-4 \]

\[ 6 \times \]

\[ + \]

6 x

Coherent flux \( F_{D0A1}, F_{D0G1} \ldots \)

Photometries \( F_{D0}, F_{A1} \)

\[ 6 \times \]
Data reduction

Interferometric equation

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

- Photometries
- Coherent fluxes

• Step 2: $E_{HF}$ and $E_{LF}$ to get squared visibilities.

Step 3: Average the 100 scans
Data reduction: the trick of un-biasing

The ABCD + scanning methods allows to estimate the bias as the power at negative frequencies.
Statistical errors bars from the 100 scans

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

\[ t_3 = F_{D0A1} * F_{A1C1} * F_{C1D0} \]
Statistical precision versus flux

Spectral dispersion: FREE (1 channel) SMALL (3 channels) LARGE (7 channels)
Part 2 : Calibration

Transfer-Function Vis2 (black) and Scientific Obs. (colors) averaged in the range $\mu m = [1.7, 1.73]$~
(color=target, symbol=setup)

- 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
The strongest effect to be calibrated is the position on sky:

- Need calibration star < 3 deg 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 $\Delta \phi$ between polarisation for various position on sky.

![Graph](image)

sky distribution of observations

$\Delta \phi$

+ measurements + Fitted polarisation model

$\Delta \phi_{31}$

$\Delta \phi_{14}$

$\Delta \phi_{34}$

$\Delta \phi_{32}$

$\Delta \phi_{12}$

$\Delta \phi_{42}$

time $\sim 6h$

courtesy: H.Sana who provide the observing time; A.Merand for the model
Calibration as a polarisation issue

- 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 ΔK>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.