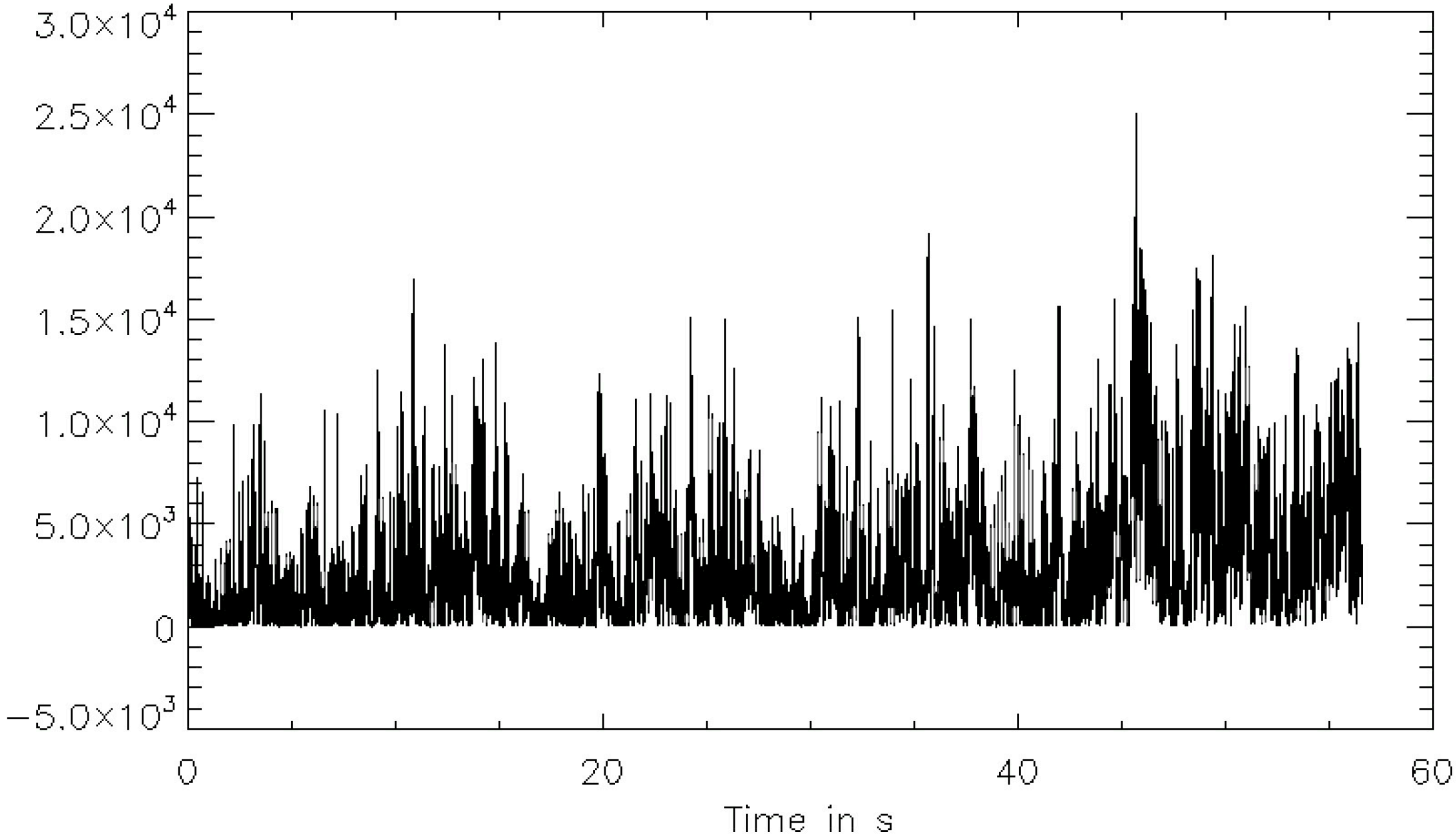
Nulling self calibration

D. Defrère and B. Mennesson

Hi-5 kickoff meeting -- Liège, Oct. 2-3

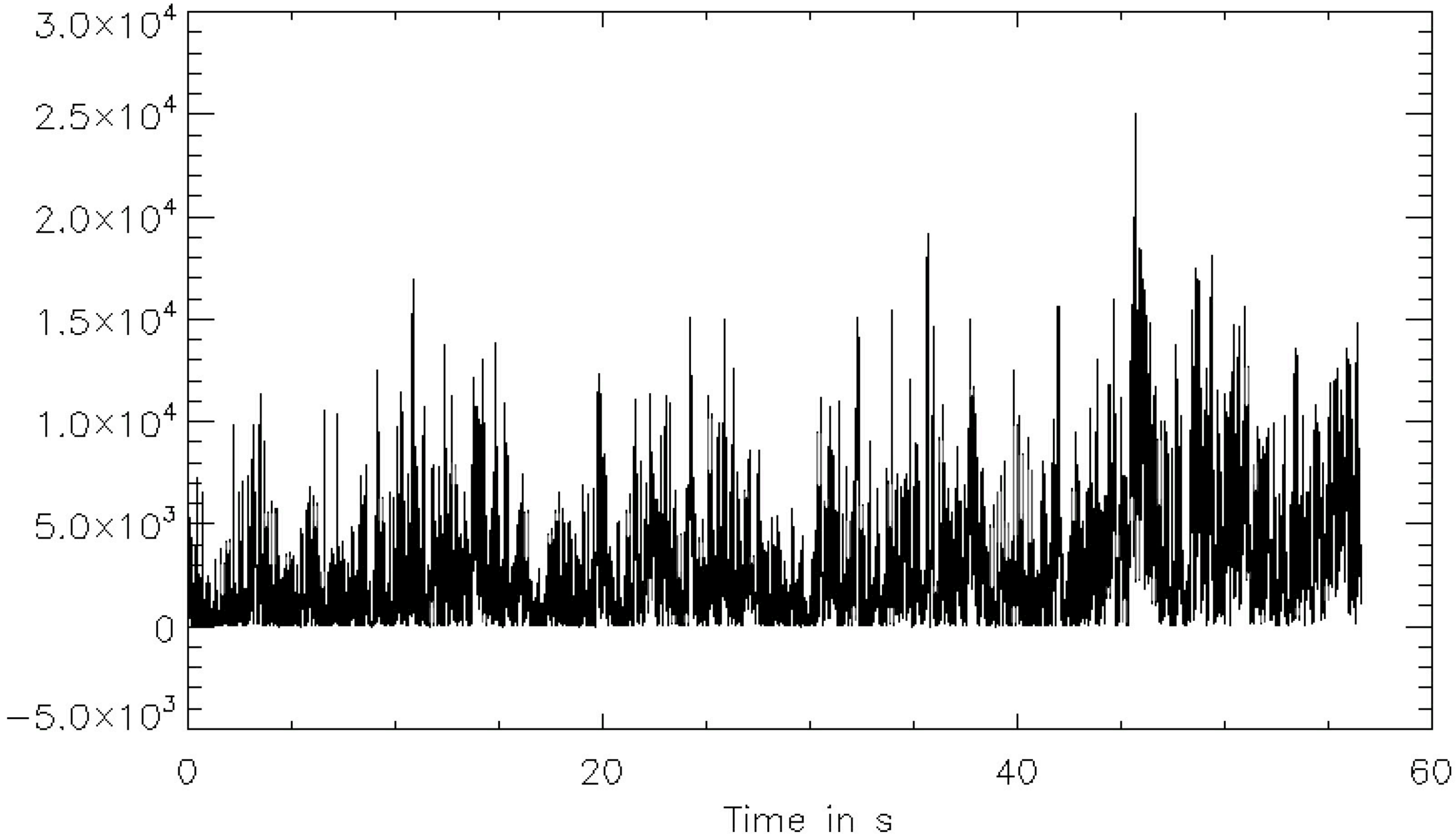
Example of nulling data



Given a time series of interferometric flux detected around the central dark fringe

“ WHAT IS THE NULL ?! ”

Example of nulling data



By "null", we actually mean the astrophysical quantity given by $N^{as} = (1- |V_B|) / (1 + |V_B|)$, which is a property of the target, not the instrument.

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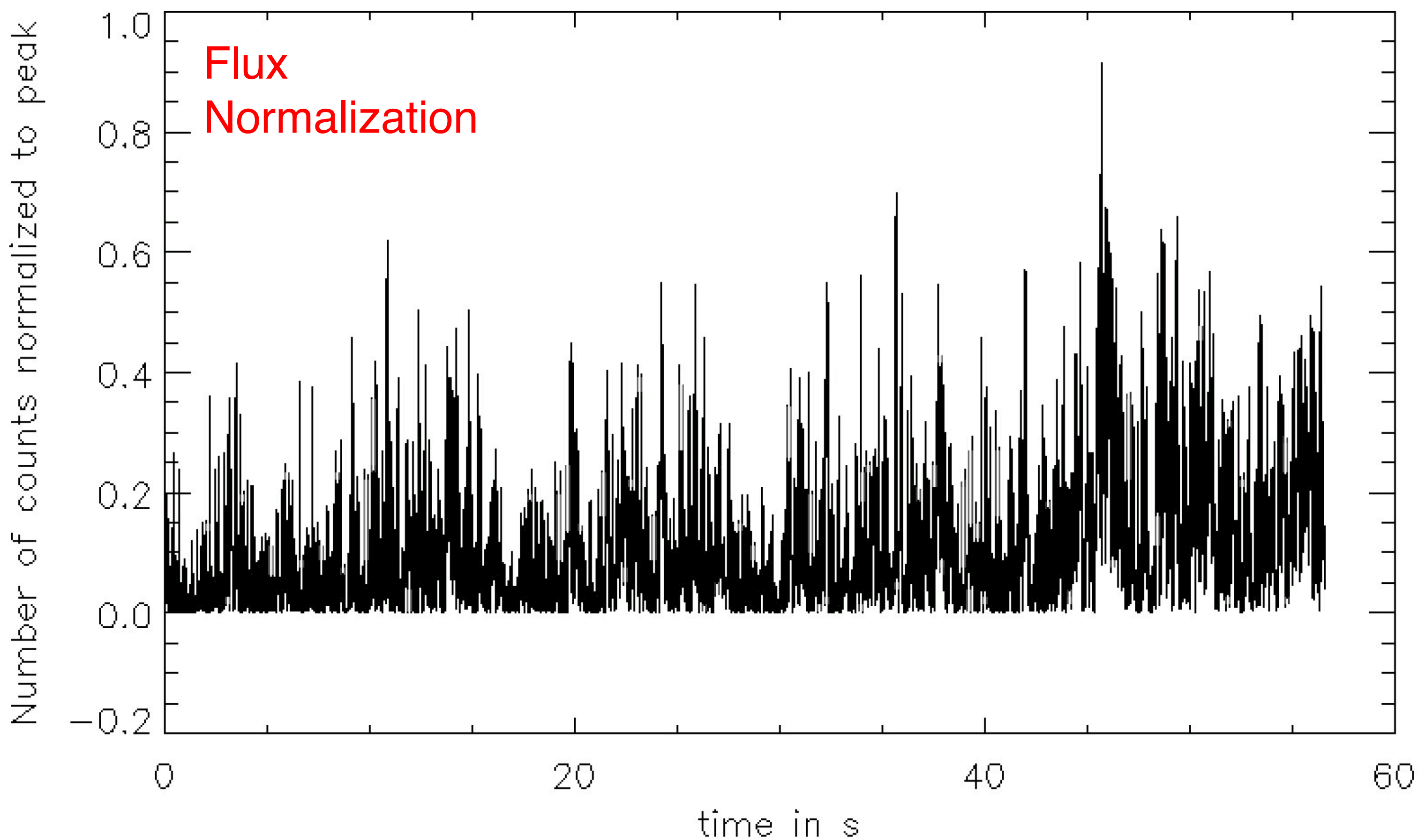

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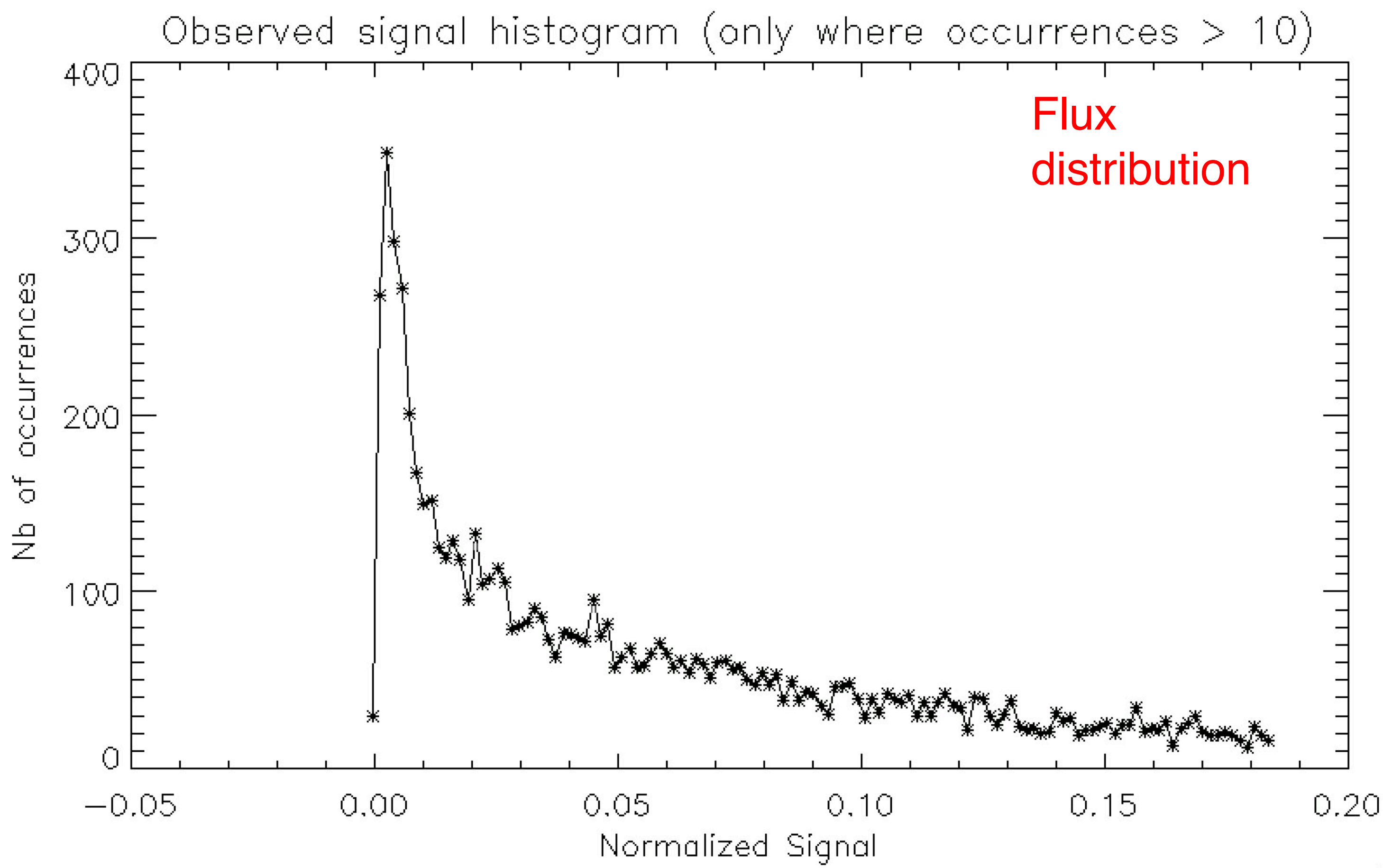
Hi-5



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Hi-5

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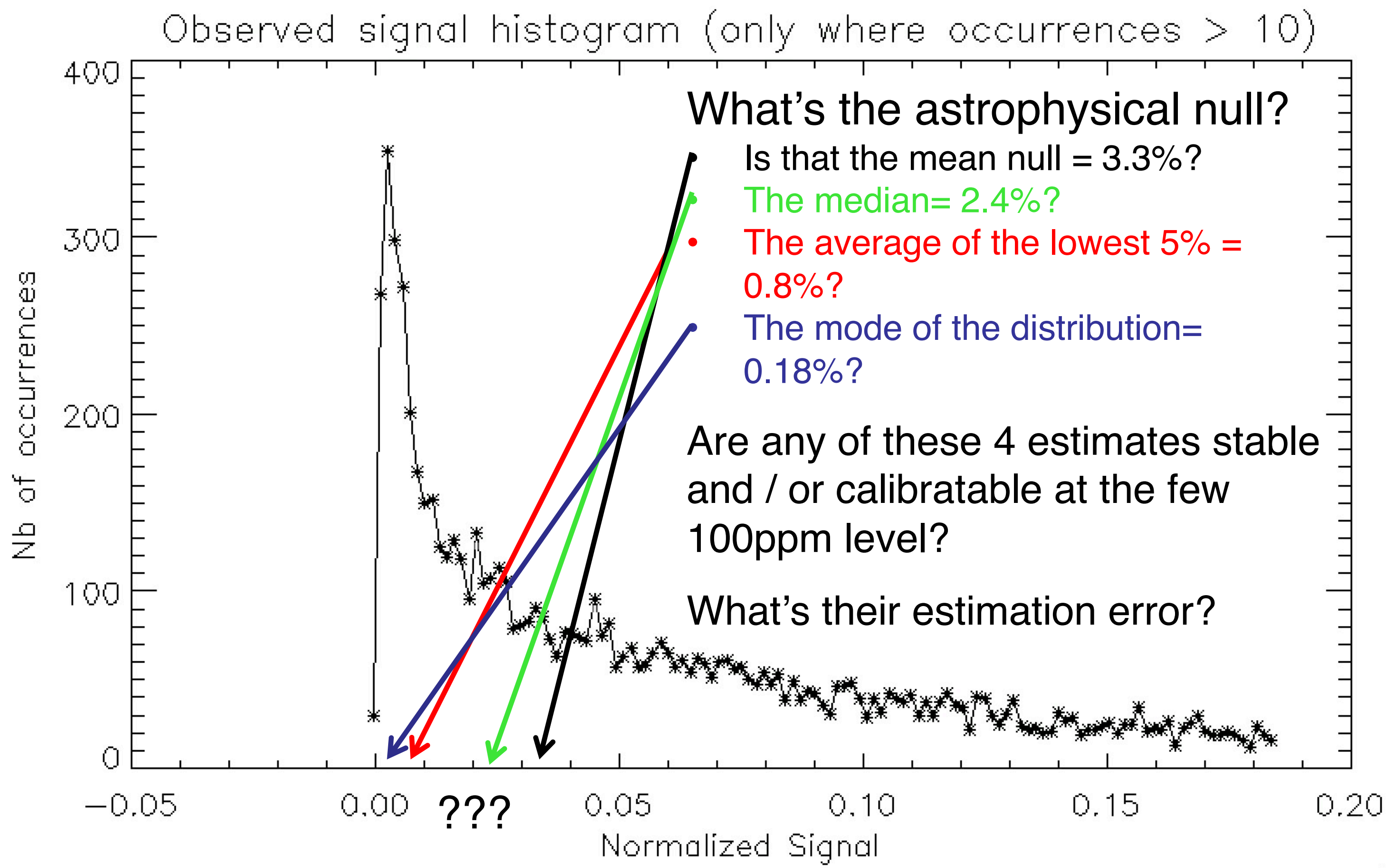

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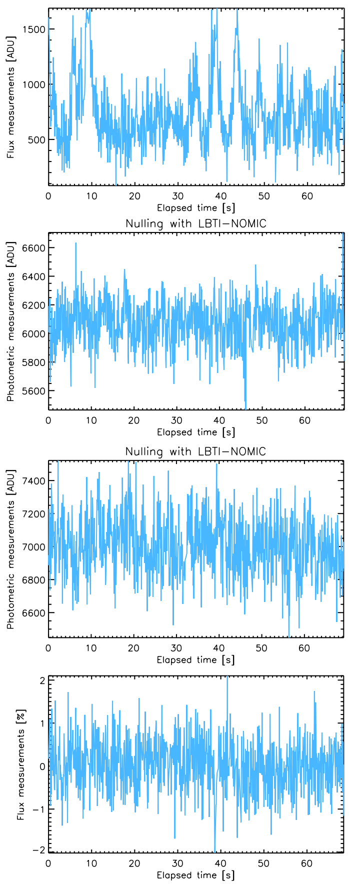
Nulling Self Calibration

$$
\begin{aligned}
\langle I_-(t)\rangle &= I_1 + I_2 + 2|V|\sqrt{I_1 I_2}\,\langle\cos(\Delta\phi(t))\rangle + B \\
&= I_1 + I_2 + 2|V|\sqrt{I_1 I_2}[\cos(\Delta\phi_0)\,\langle\cos\epsilon(t)\rangle \\
&\quad - \sin(\Delta\phi_0)\,\langle\sin\epsilon(t)\rangle] + B \\
&\simeq I_1 + I_2 + 2|V|\sqrt{I_1 I_2}\cos(\Delta\phi_0)(1 - 0.5\sigma_\epsilon^2) + B
\end{aligned}
$$



I_-

I_1

I_2

B

PHASECam OPD telemetry ε

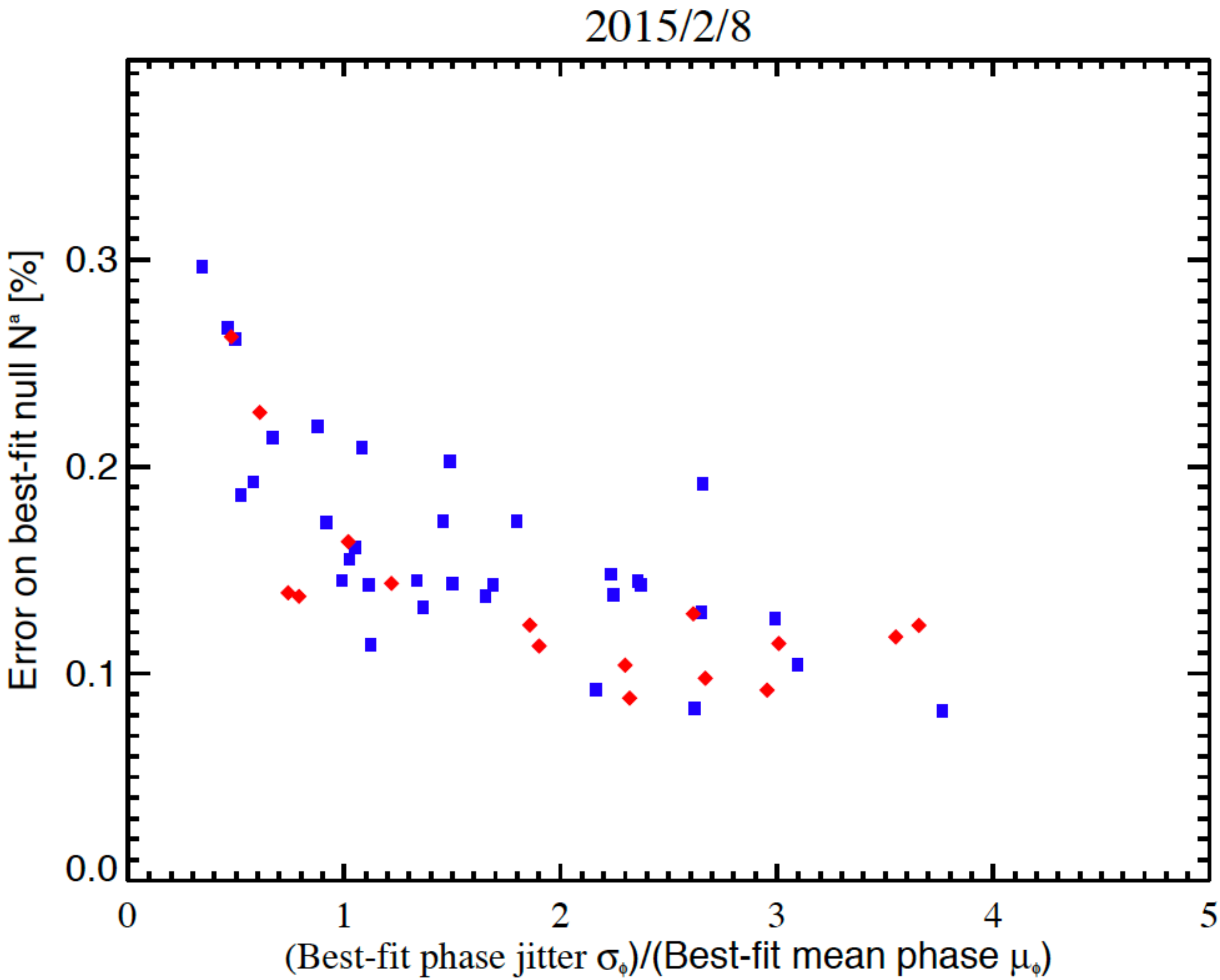
Nulling Self Calibration*
(NSC, Mennesson et al., ApJ 743, 2011)

Source null, phase setpoint, phase jitter

*improved and adapted for LBTI (Defrere et al. 2016):

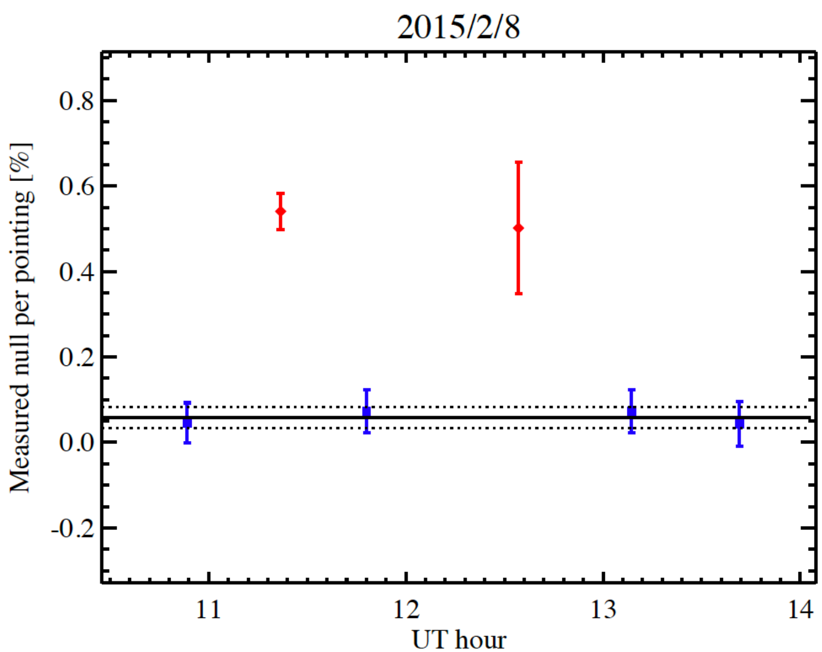
- 2D images (vs 1D);
- N band (vs K band);
- Account for high-frequency phase noise;
- Bayesian approach to compute error bars.

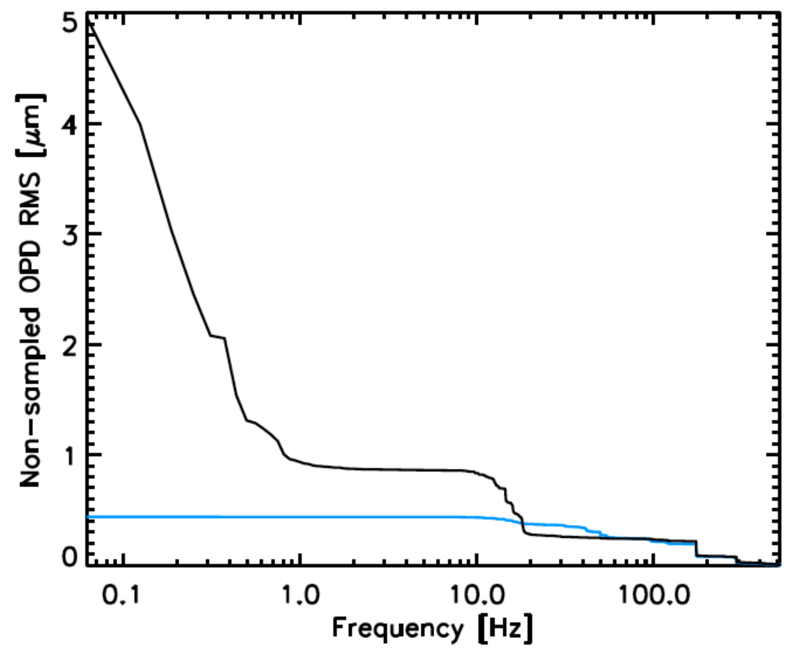
Limitations



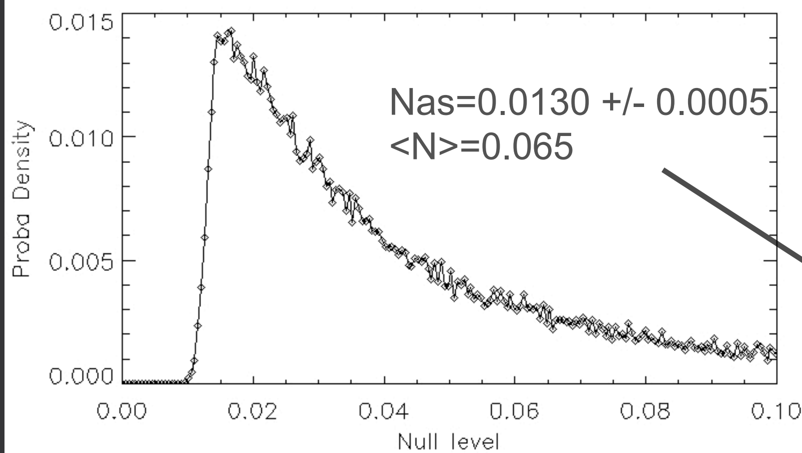
LBTI results

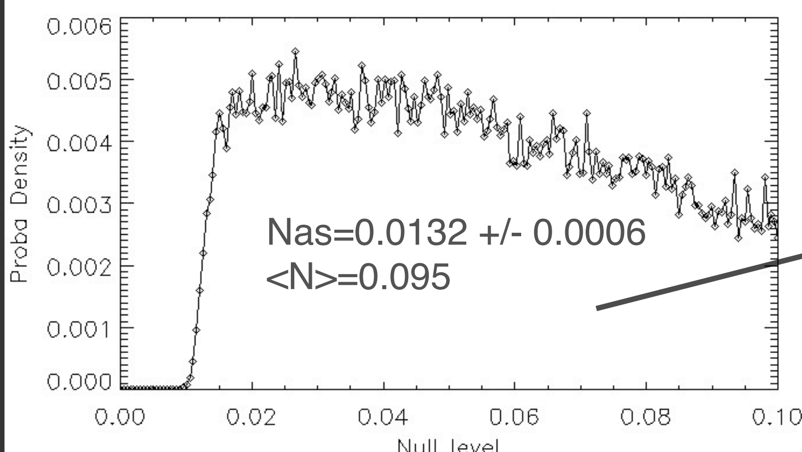
- Absolute calibration to 0.05% level (Defrère et al. 2016) despite ~350nm of fast-phase variations



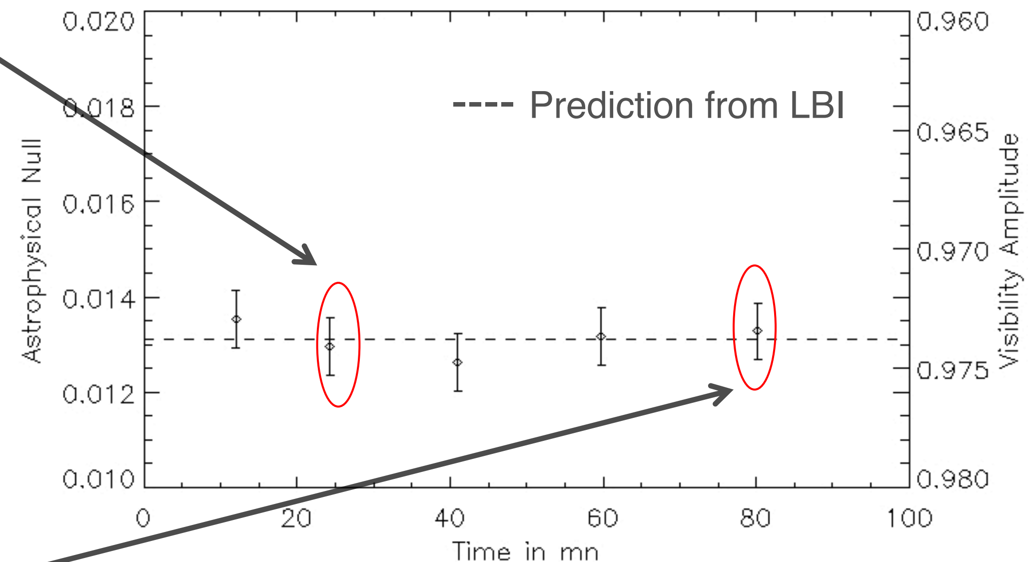


PFN results





Nastro = 0.0132 +/- 0.0003
i.e.Visibility = 0.9739 +/- 0.0006



Very different instrumental conditions, but same visibility measured within a few 10^{-4}
(PFN data)

Hi-5

NSC requirements

- Need single-mode fringe tracked data (< $\lambda/10$ rms) sampled faster than atm coherence time
- Need some photometric and background measurements close in time (within 1 min)
- Need dispersed data if long baselines used
- Perfect for Palomar Fiber Nuller - *and any fringe tracked fiber based dispersed LB interferometer!*
- *Does it work for the visibility? YES!*

PIONIER conceptual scheme

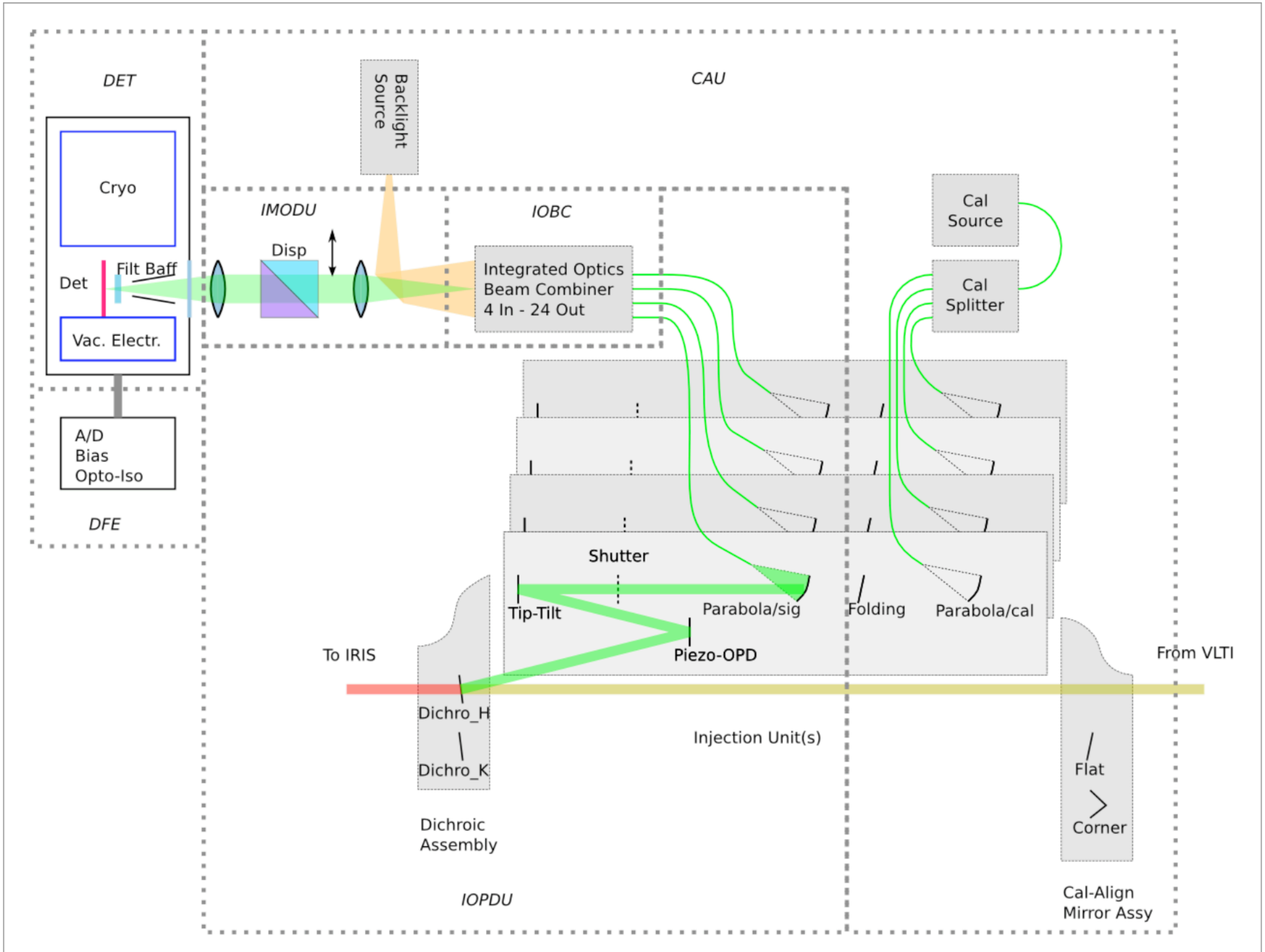


Figure 2. Pionier conceptual scheme

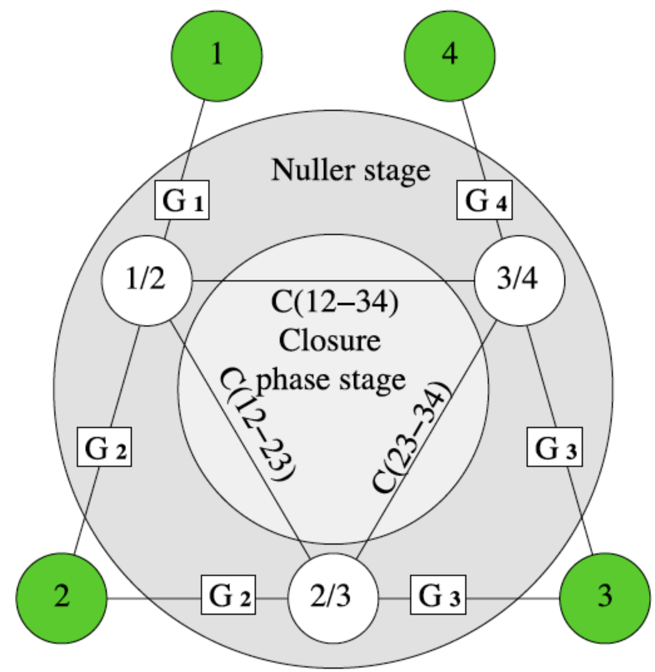
Beam combination scheme

- L- and M-band beam combiner
  - ✴ At least four beams
  - ✴ Single-mode fibers and/or integrated optics

- A few possible architectures
  - ✓ PIONIER-like 4T-ABCD combiner
  - ✓ Multi-telescope nulling interferometer
  - ✓ Combination of nulling + clossure phases

- Spectroscopic capabilities

Lacour et al. 2014



Guidelines for high-contrast interf.

- “Simple” instrument to minimize sources of systematic errors
- Single-mode fibers
- Fringe tracker
- Dispersed data
- Polarization control
- Fast data acquisition