Making the most of LBTI nulling interferometry observations using a statistical data reduction method

Lindsay Marion (Université de Liège, marion@astro.ulg.ac.be), Bertrand Mennesson (Jet Propulsion Laboratory), Denis Defrère (University of Arizona), Philip Hinz (University of Arizona), Olivier Absil (Université de Liège)

1. The statistical data reduction method

Classical method

- Mean of the **fluctuations** of individual null measurements:

$$\langle N(t)\rangle = N_a + \langle N_{inst}(t)\rangle$$
$$\langle N_{cal}(t)\rangle = N_{a,cal} + \langle N_{inst,cal}(t)\rangle$$

\+ Intuitive
\+ Easy and fast
− Need for a **calibration star**
− Does **not use the entire information** in the signal

Statistical method
(Mennesson, Hanot, et al.)

- Use known distributions (I, bkg)
- Assume Gaussian phase distrib.
- **3 free parameters left**: N_a , $\mu_{\Delta\phi}$, $\sigma_{\Delta\phi}$ → 3D grid
- Build theoritical histograms
- **Minimize χ^2** on the 3D grid

\+ **Self calibrated method**
\+ **Use the entire information** in the signal

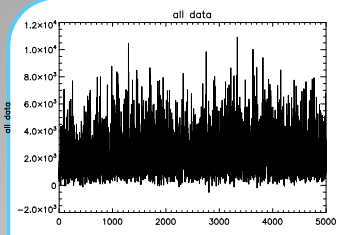


Fig. 1 Flux measurements at null for HD104979

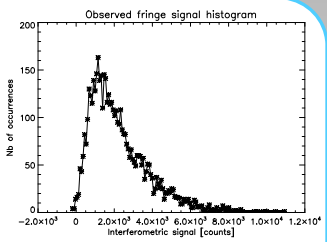


Fig. 2 Resulting observed histogram

All the statistical information is used!

2. Demonstration on Palomar Fiber Nuller data

Method improved in 2013 during the master's thesis of L. Marion:

- Automatic truncation of the histogram (avoid additional bias due to the histogram tail—useless in the determination of astrophysical null),
- More robust,
- Improve computation time,
- Test correlation between free parameters

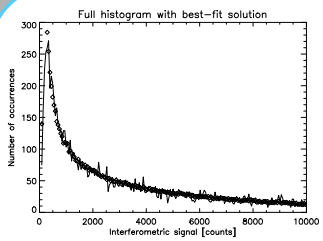


Fig. 3 Observed histogram (solid line, in terms of interferometric signal) and modeled histogram (diamonds)

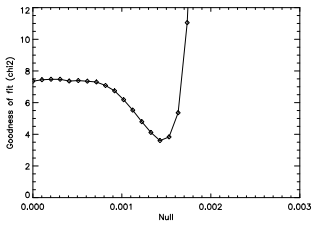


Fig. 4 Associated χ^2 as a function of the astrophysical null, corresponding to the best fit histogram giving the best estimators for the 3 parameters

Move from PFN to LBTI data is not easy because:
- Higher thermal background
- No single mode fibers ➔ good histogram fits?

Vega:
Na = 0.00145 ± 0.00005
X^2 = 2.23 ± 0.09

Beta Leo:
Na = 0.016 ± 0.002
X^2 = 1.95 ± 0.35

3. Adaptation to LBTI data

Preliminary results

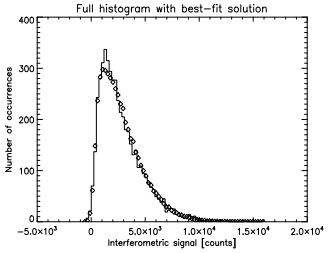


Fig. 5 Observed histogram (solid line, in terms of interferometric signal) and modeled histogram (diamonds)

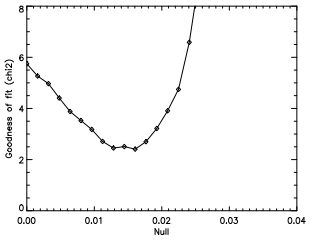
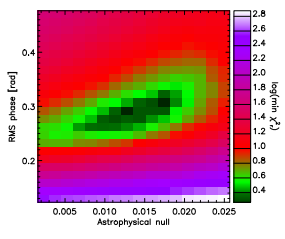
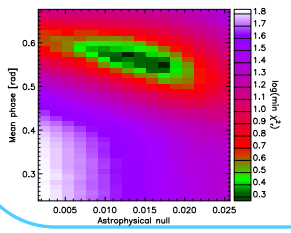


Fig.6 Associated χ^2 as a function of the astrophysical null, corresponding to the best fit histogram giving the best estimators for the 3 parameters





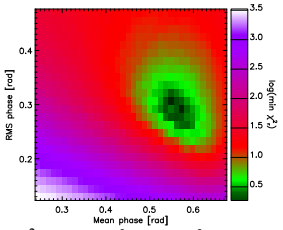


Fig.7 χ^2 maps as a function of, respectively, rms phase and astrophysical null, rms phase and mean phase, mean phase and astrophysical null, in order to determine the correlations between the 3 parameters

4. Comparison between the classical and the statistical data reduction methods

- Error bars are **twice smaller** for the statistical method!
- BUT: **very** preliminary results because:
  - ➢ Still need to remove open-loop frames
  - ➢ Still need to improve fringe tracking

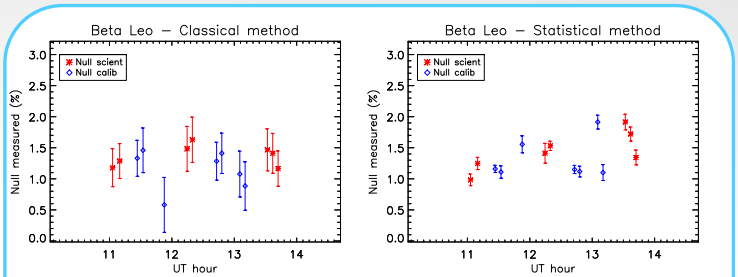


Fig.8 Comparison between the classical and the statistical methods in terms of measured nulls for Beta Leo

5. Conclusion

- Well tested and improved method
- Statistical data reduction method gives more accurate results
- Adaption of the method to N-band LBTI data still on-going (improved background handling, non single-mode treatment, …)
- Going further: improve the method to use 2D images from the LBTI and use the phase information from the fringe sensor