Improving **Null Depth** Measurement with **statistics** : theory and first results with the Palomar Fiber Nuller

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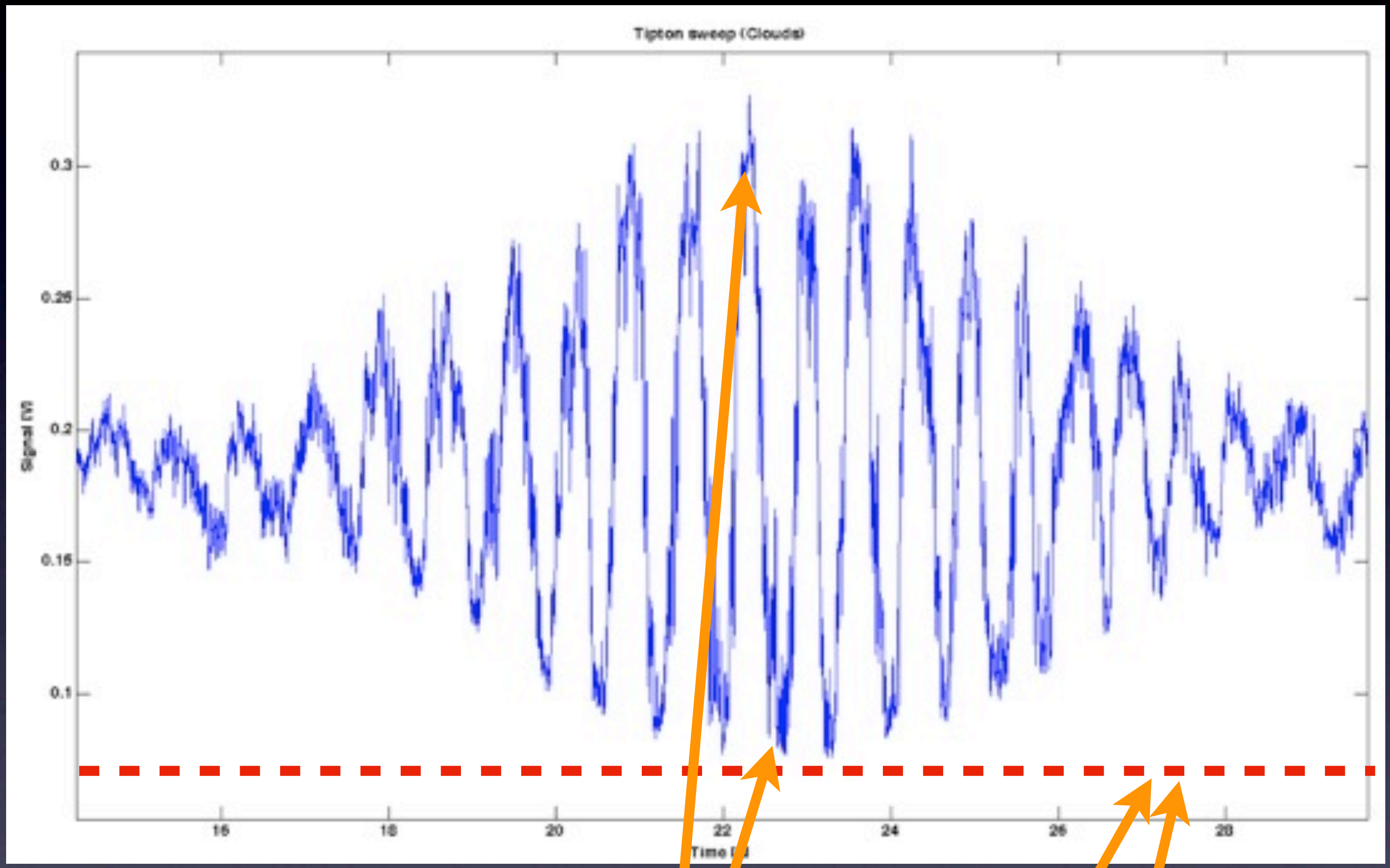
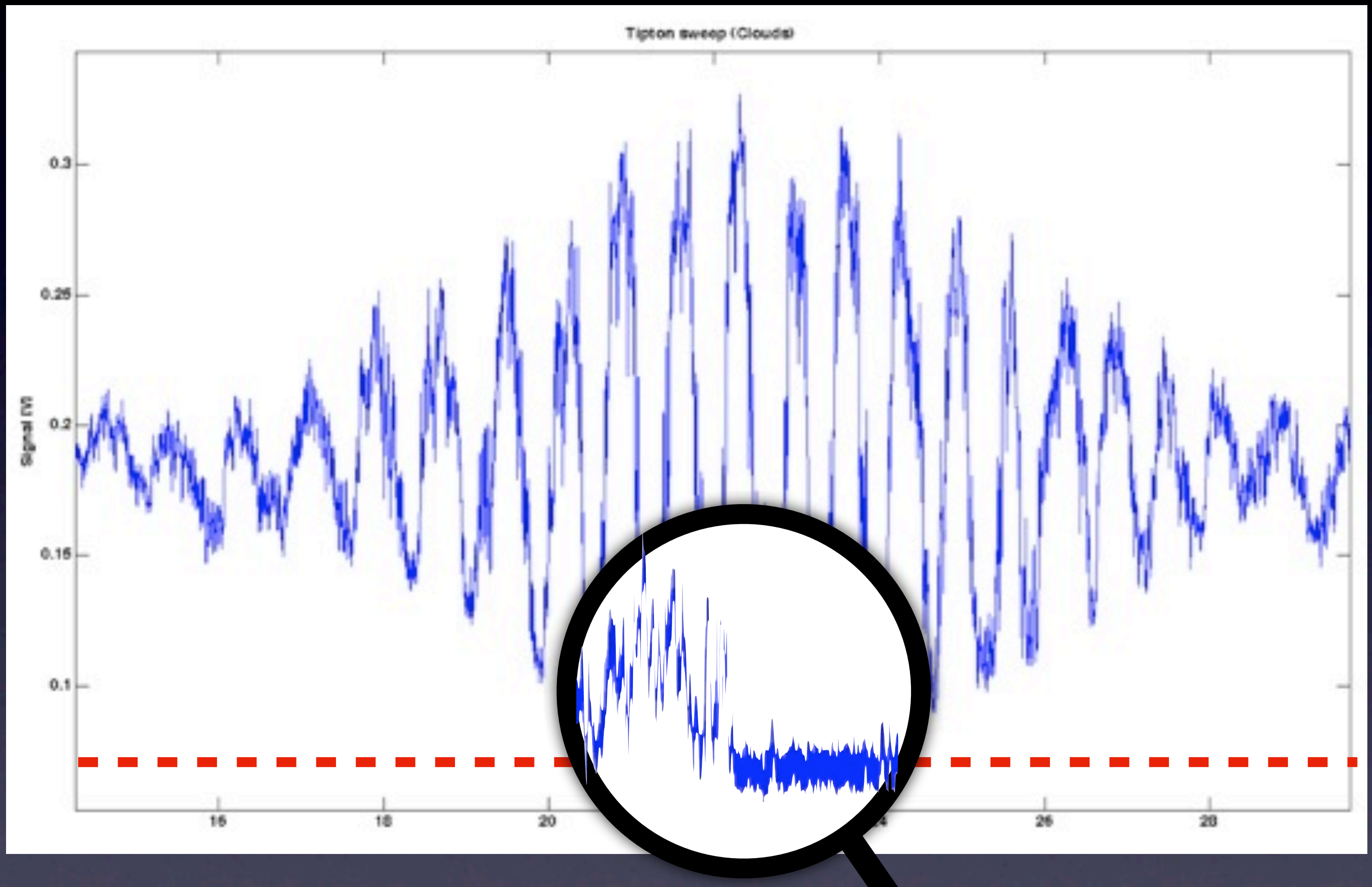
What is the Null Depth ?



$$ND = \frac{I_{min} - Bkg}{I_{max} - Bkg}$$

Problem : How to measure Null Depths ?



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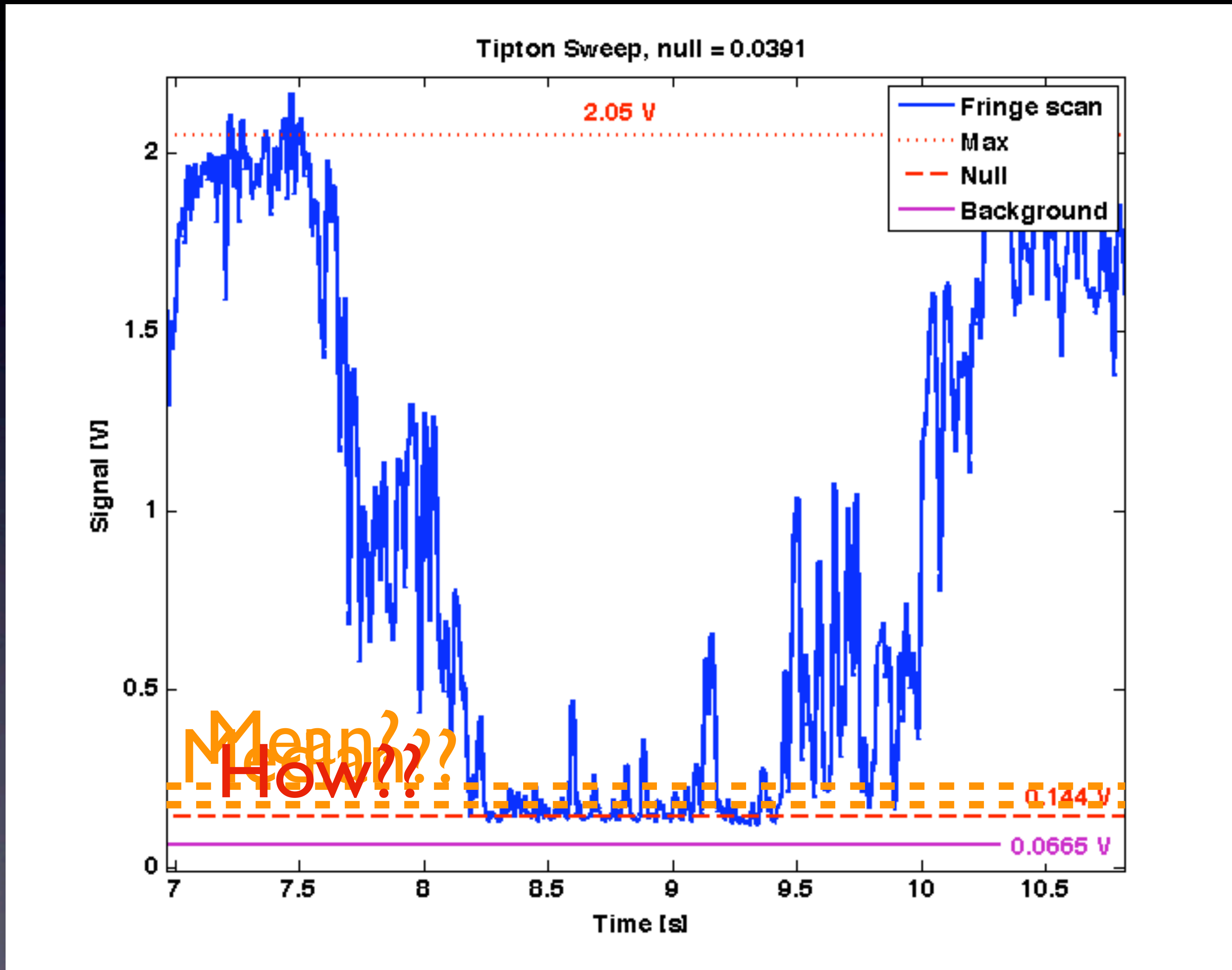

Classical method

- Non-calibrated ND

$$\langle N(t)\rangle = N_a + \langle N_{Instr}(t)\rangle \longrightarrow \text{Science target}$$

$$\langle N_{cal}(t)\rangle = N_{a,cal} + \langle N_{Instr}(t)\rangle \longrightarrow \text{Calibrator star}$$

- Calibrated ND

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

Classical method

Advantages

- Easy to process
- Used for centuries

Drawbacks

- Duty cycle
- Require lots of observations
- Limited by fluctuations
- $N_{a,cal}$ dependent

Statistical Method

$$N(t) = I_N(t)\left(\frac{\Delta\phi_d(t)^2}{4} + \frac{\delta I(t)^2}{16} + \alpha_{rot}^2\right) + N_a$$

Normalized intensity

Phase error

Intensity mismatch

Polarization

Astrophysical leakage

Statistical Method

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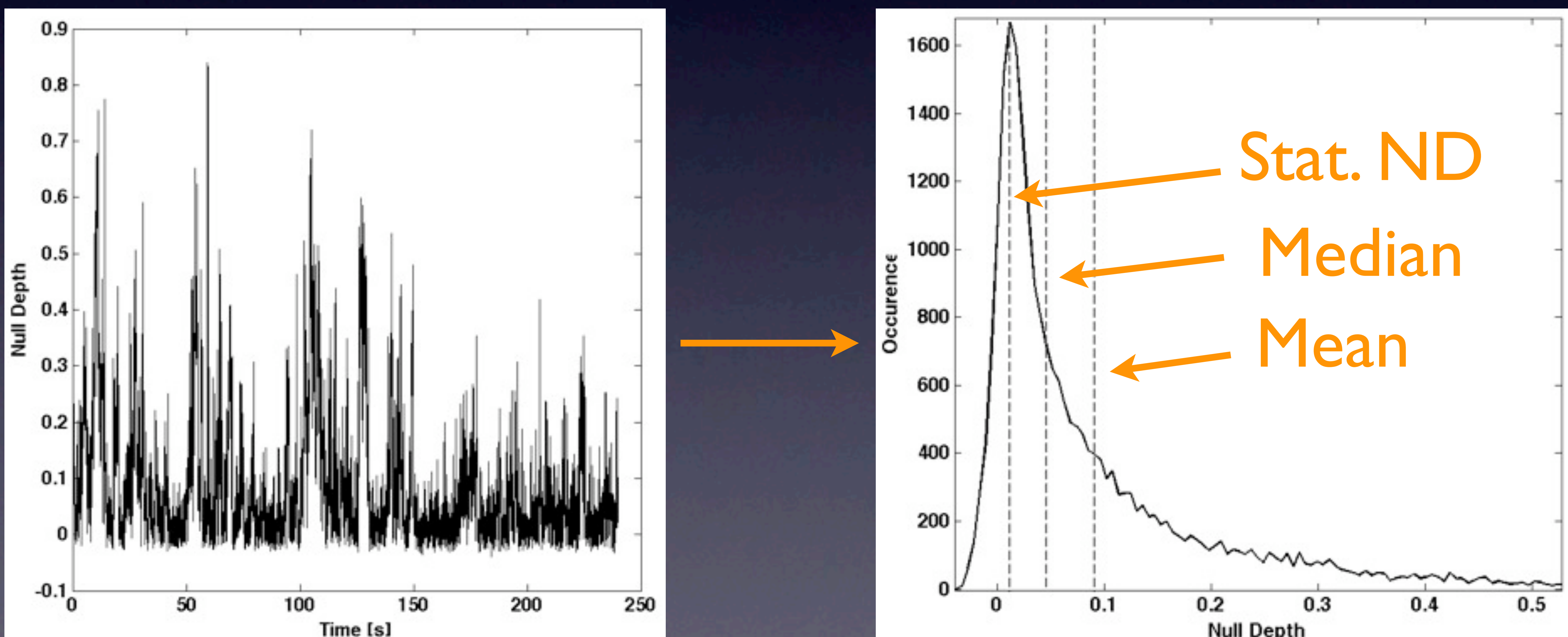


Statistical Method

$$N(t) = I_N(t)(\frac{\Delta\phi_d(t)^2}{4} + \frac{\delta I(t)^2}{16} + \alpha_{rot}^2) + N_a$$

If:

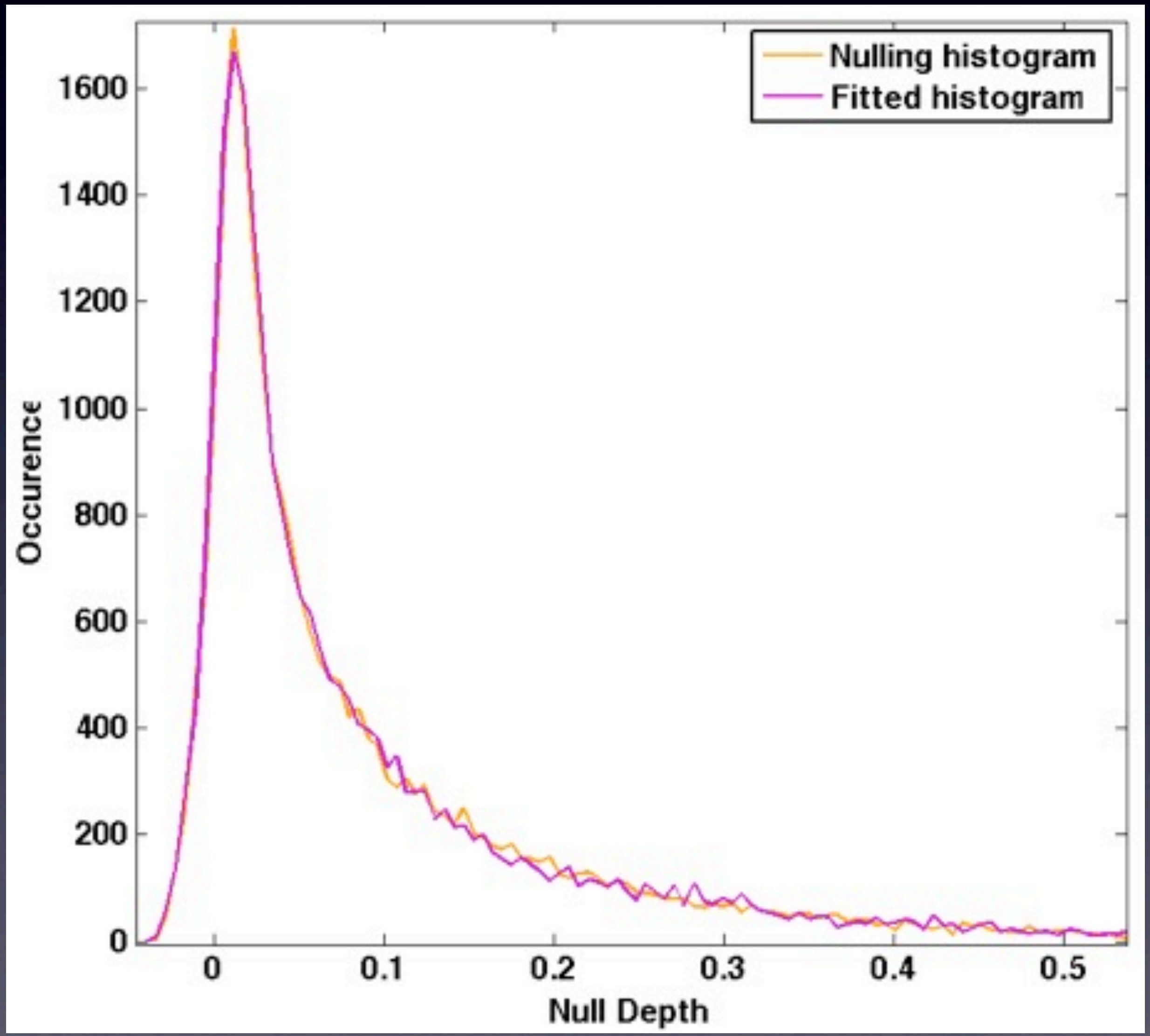
- Random fluctuations are Normal distribussion
- Random fluctuations are uncorrelated

Then:

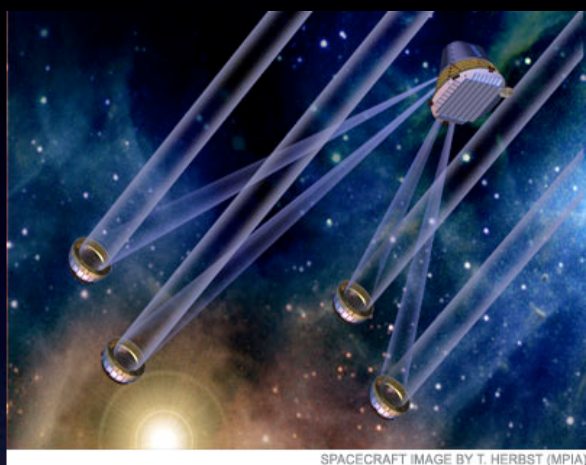
- N(t) has an analytical expression

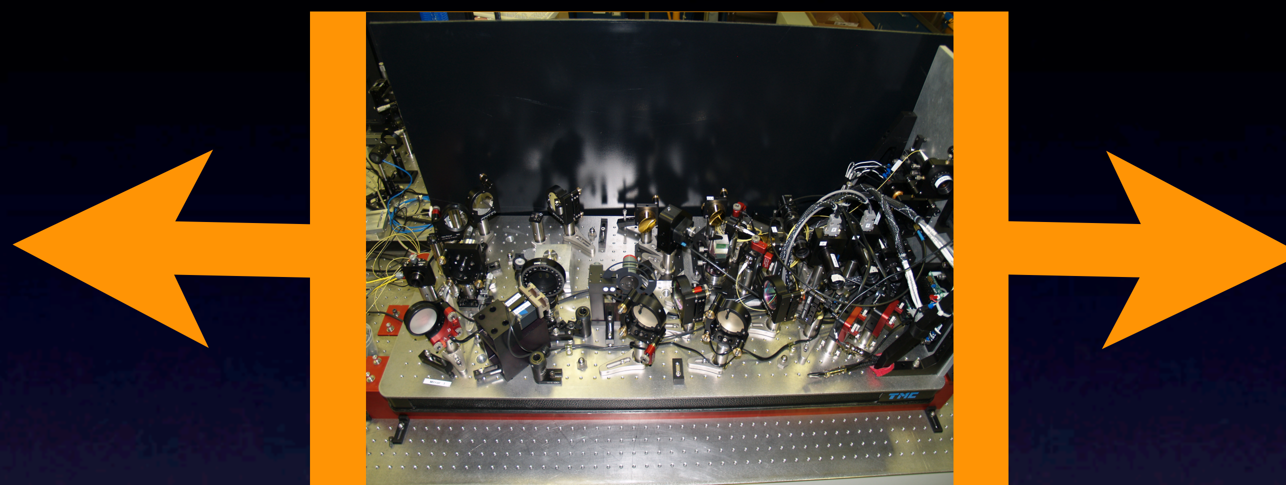
Statistical Method

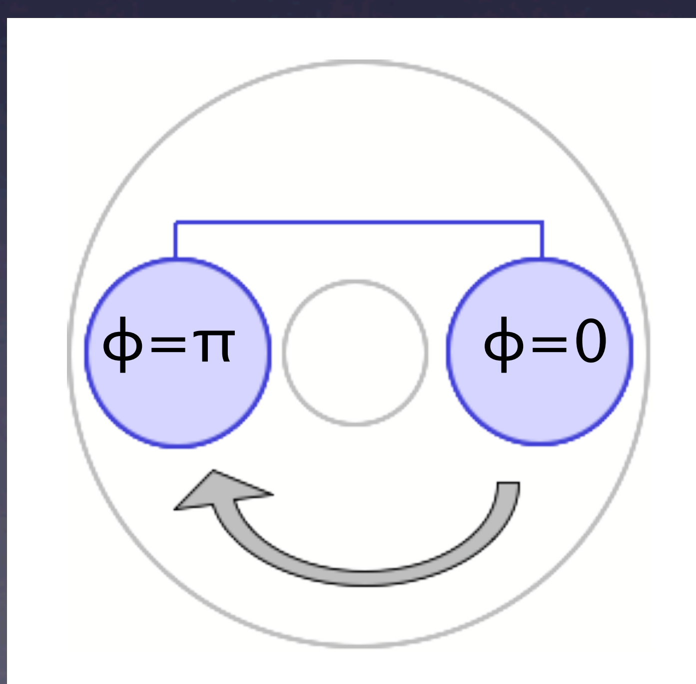
- $N_a = 1 \times 10^{-3}$
- Phase = 0.2 rad
- $\delta I = 2.37\%$

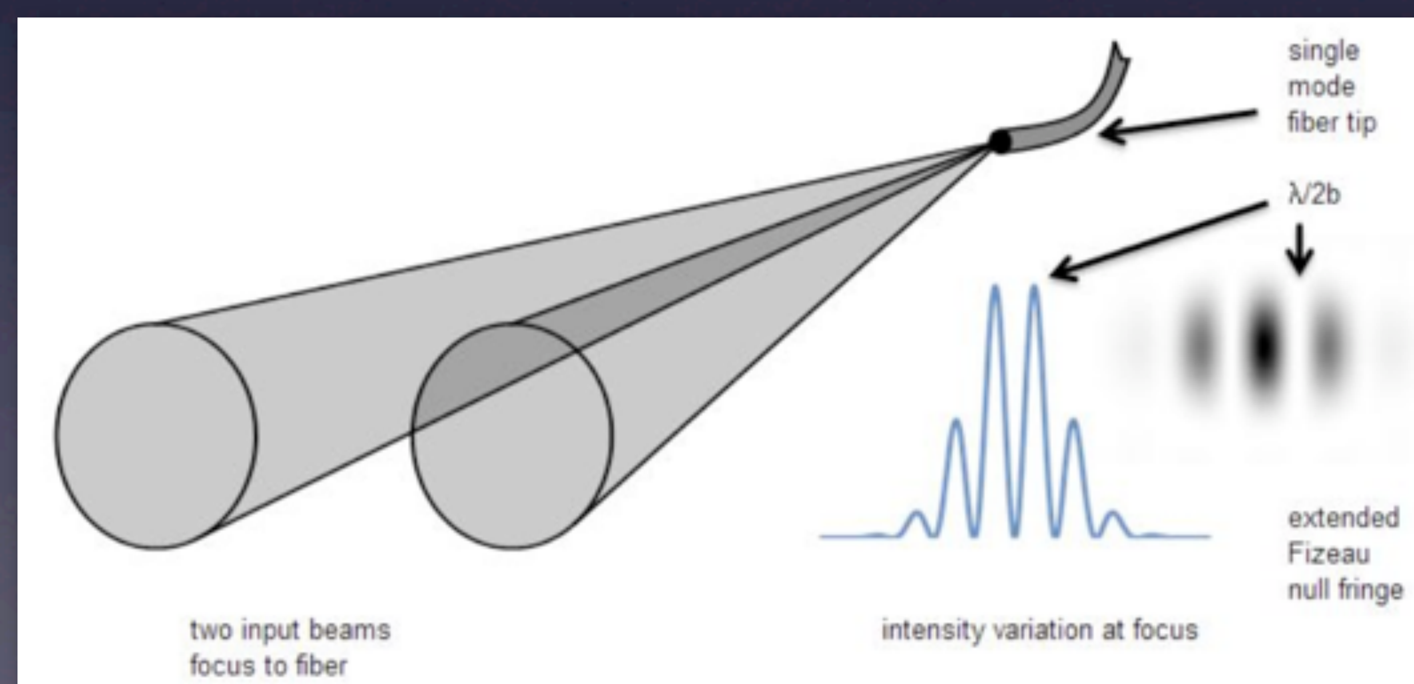


Palomar Fiber Nuller



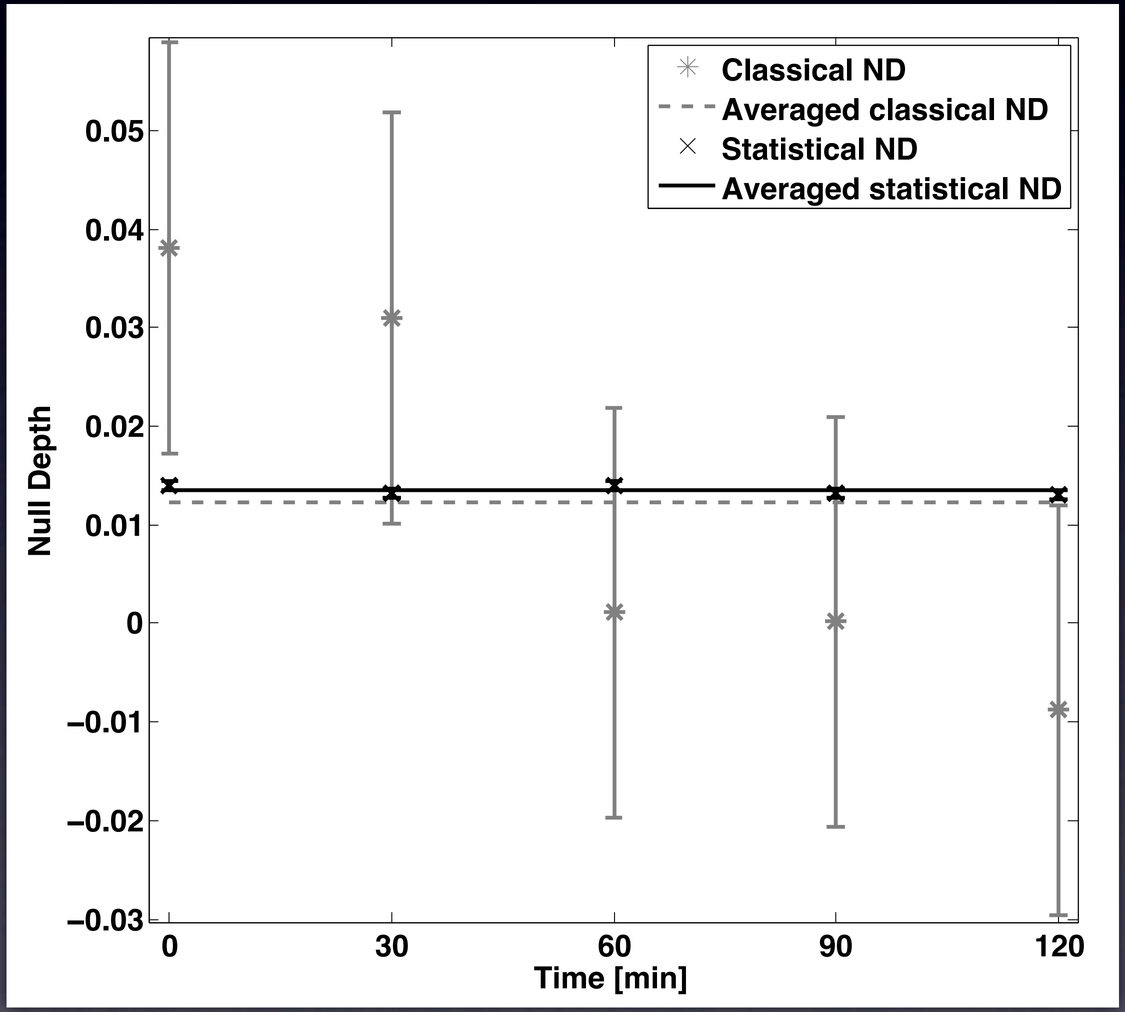




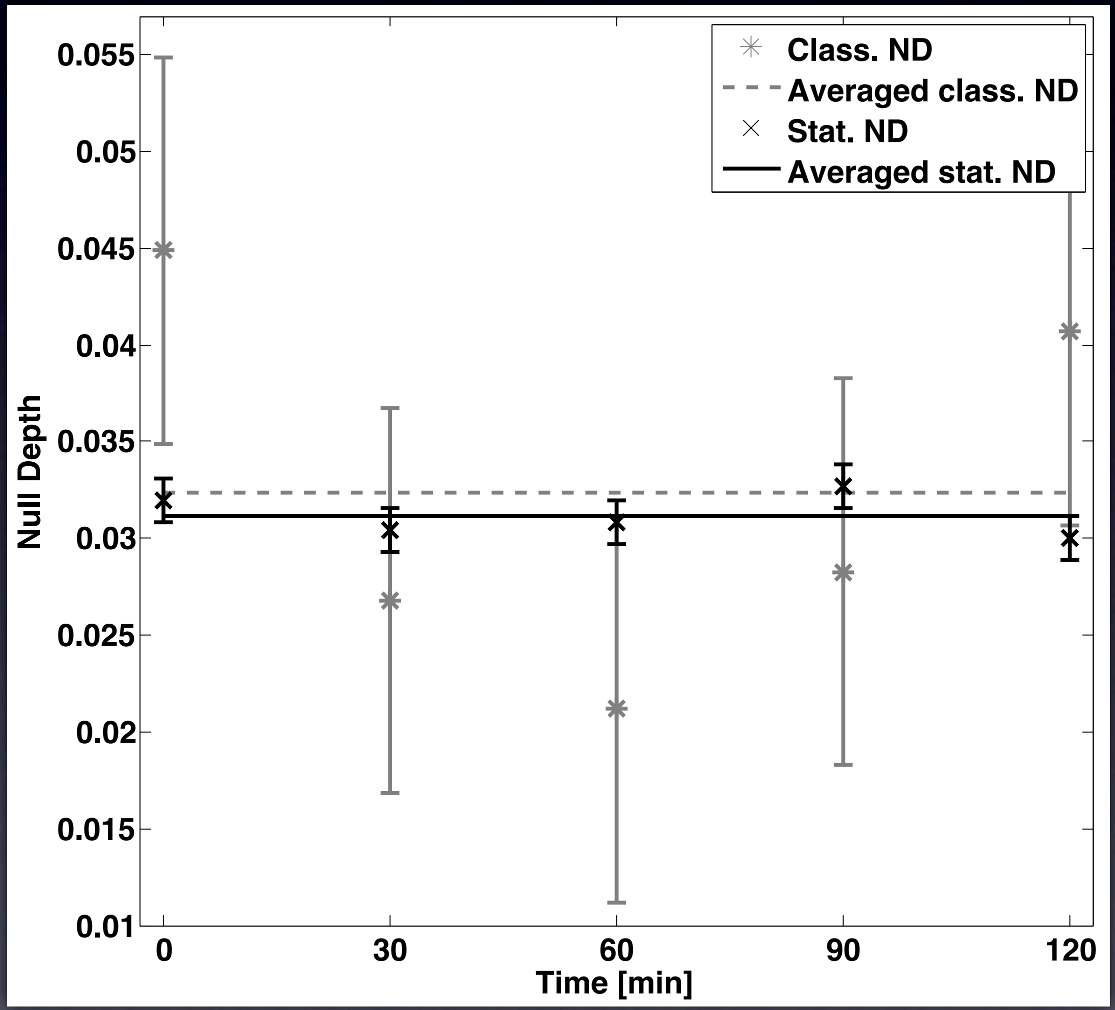


Comparison classical vs statistical

Alpha Boo



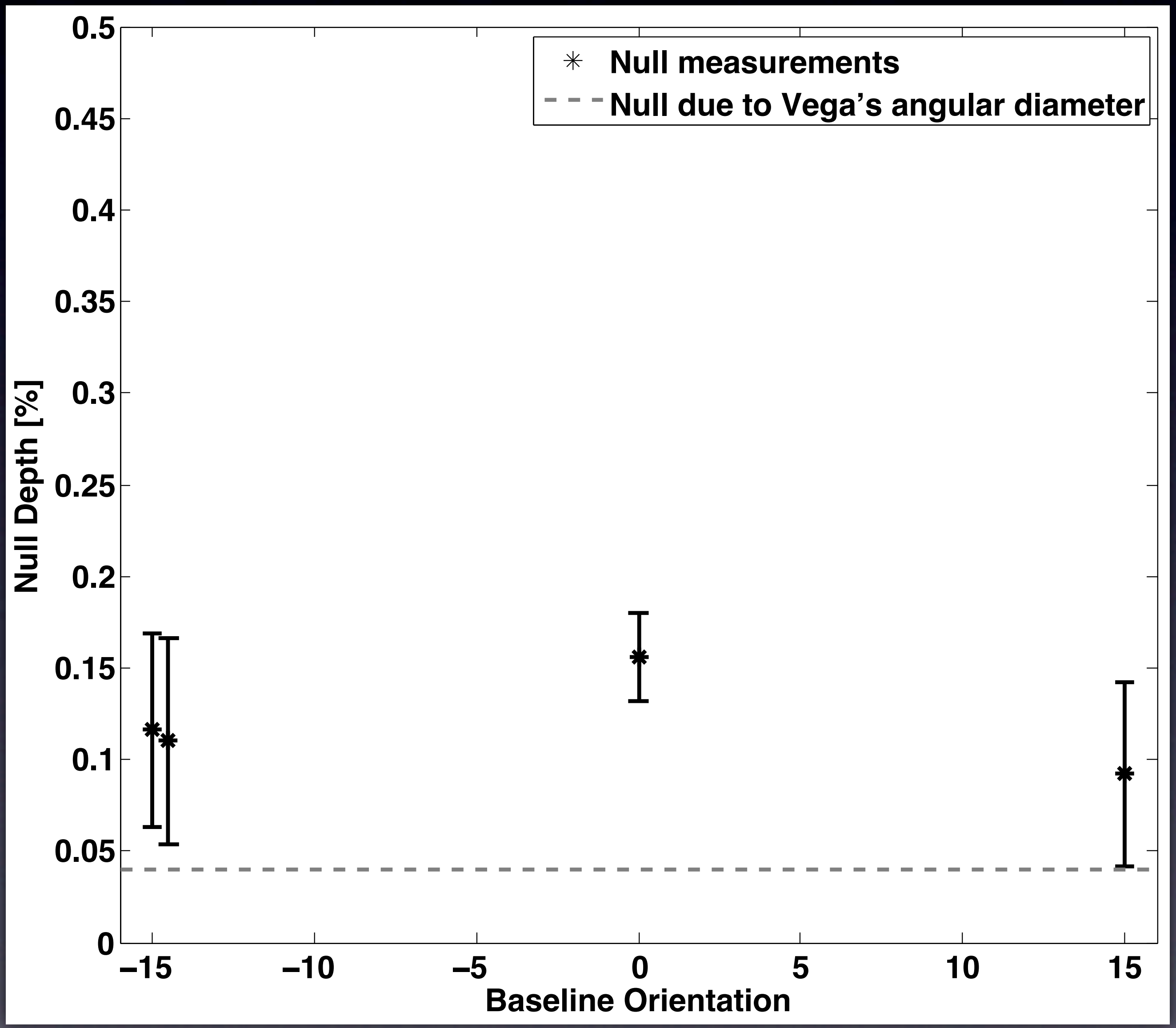
Alpha Her



Results

- ND excess : 0.6×10^{-3}
- Symmetric
- Constrain the model

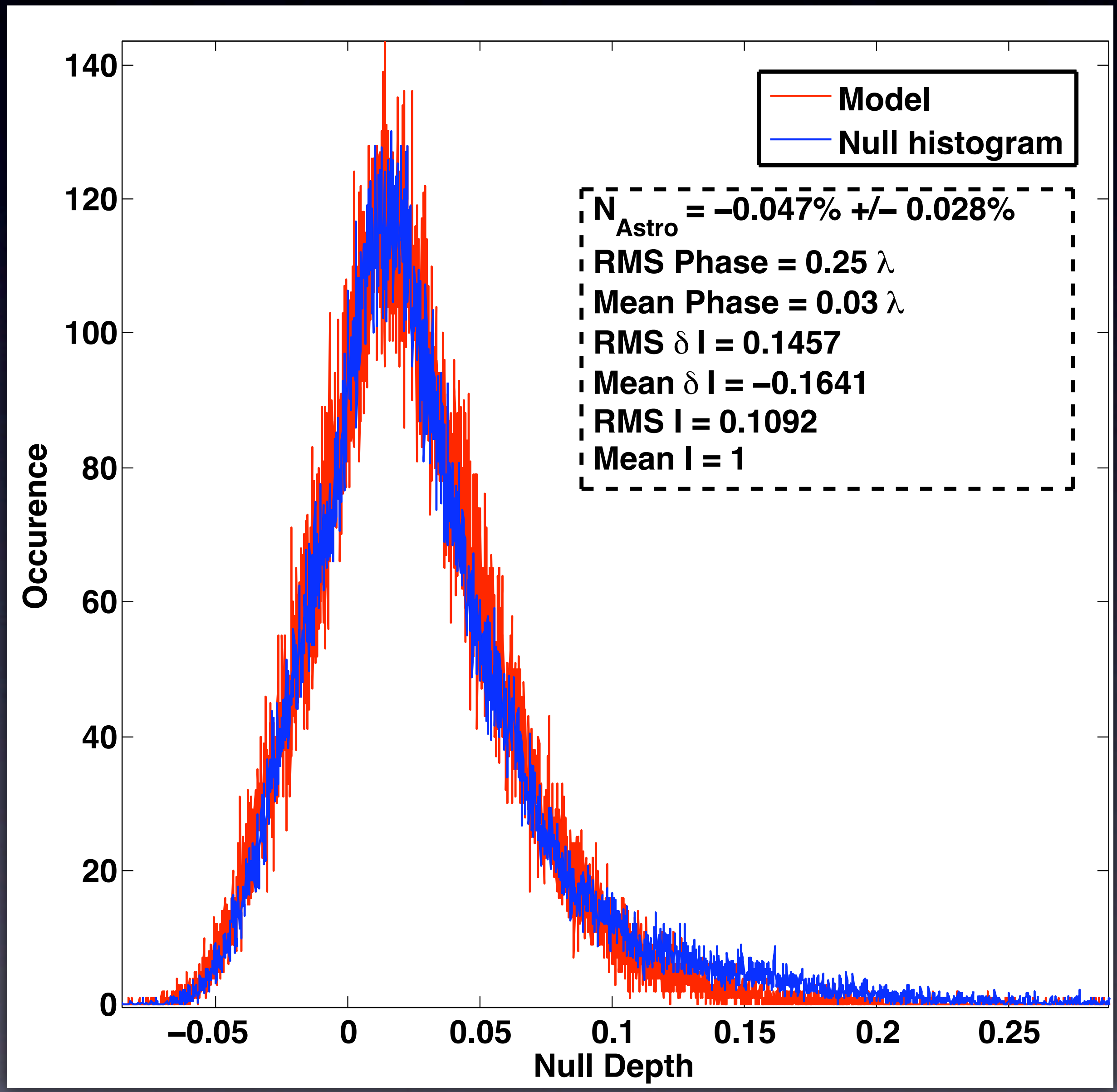
Vega



Results

Eta Peg

- ND excess : 4.7×10^{-4}
- Theo. excess : 3.5×10^{-4}
- Bias : 1.2×10^{-4}



Conclusion

- A new data reduction method for interferometry
- Better stability and accuracy of the measurements
- Better sensitivity
- Best ND ever achieved on the sky