PUSHING EXOPLANET DETECTION CAPABILITY USING
TUNABLE KERNEL-NULLING

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NULLING & KERNEL-NULLING

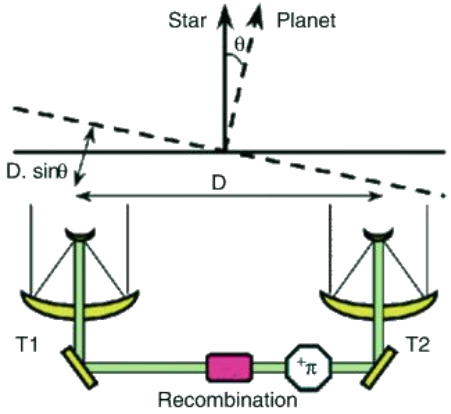
Bracewell et al. (1978) *Martinache & Ireland (2018)*

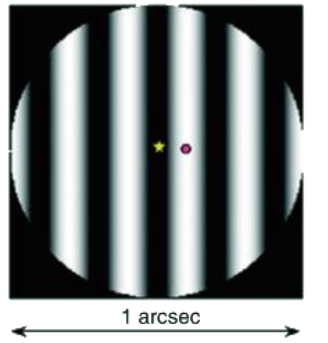
Null Depth:

$$d = \frac{I_-}{I_+}$$

Require extreme phase stability

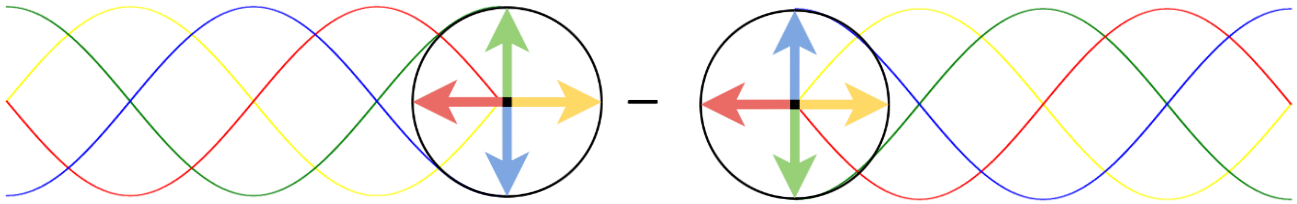
Intensity difference between two symetric phase quadrature combinations

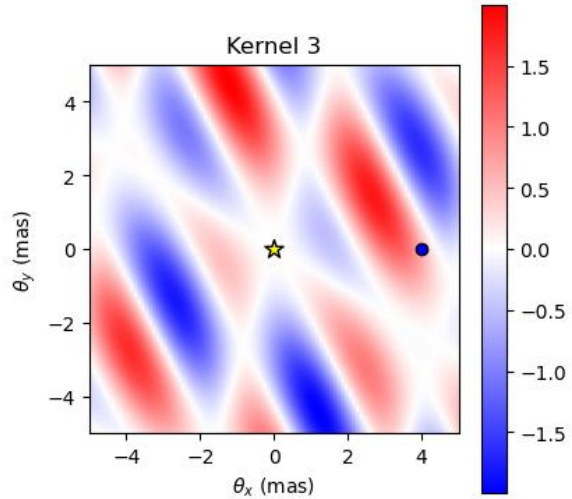




λ = 10 µm, D = 10 m, θ = 0.1 arcsec

D. Rouan (2022)

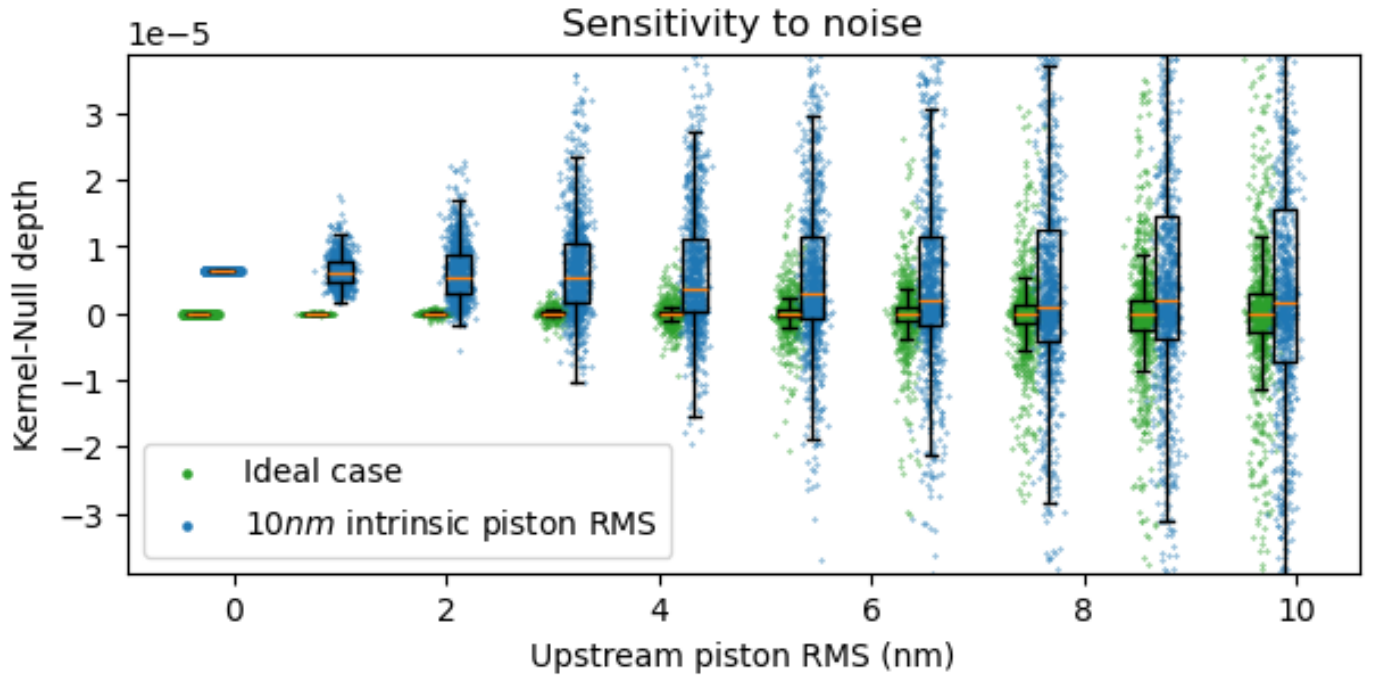




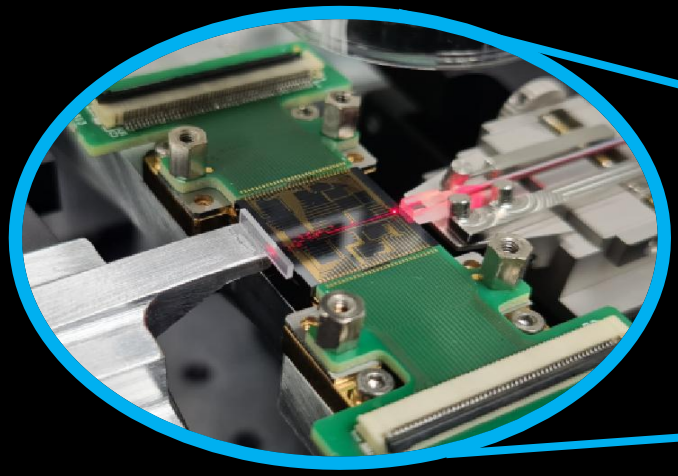
PHASE ABERRATION SOURCES

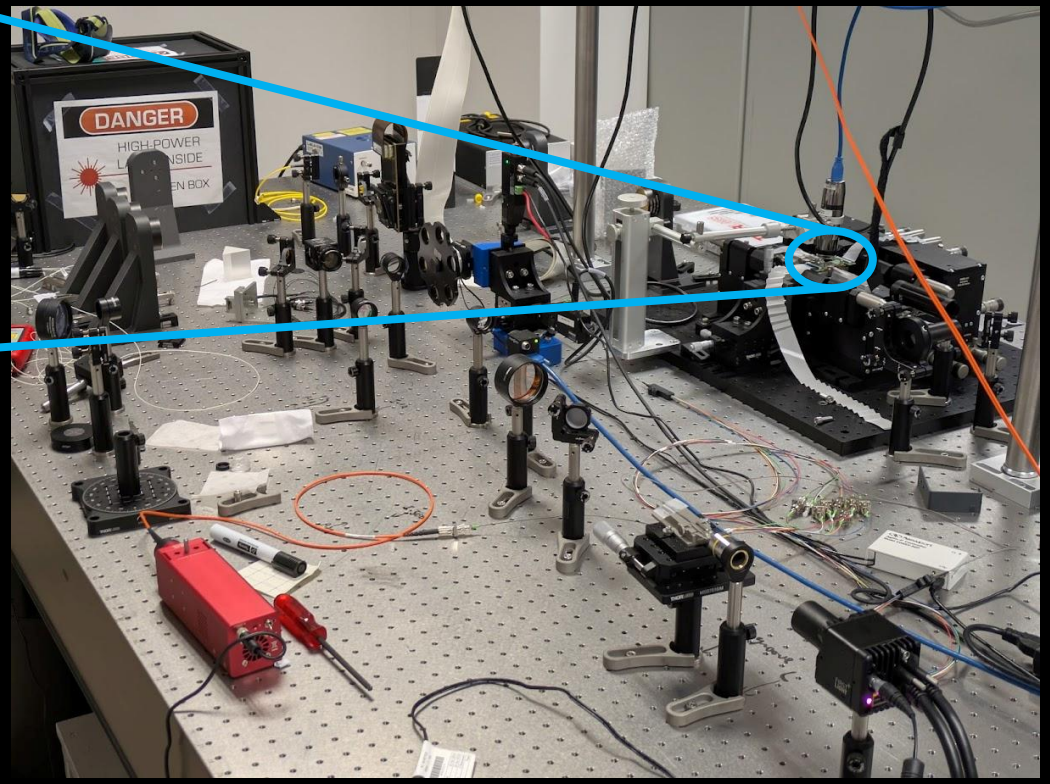
- Upstream → AO, fringe tracking
- Intrinsic → **calibration**

→ **statistical analysis**



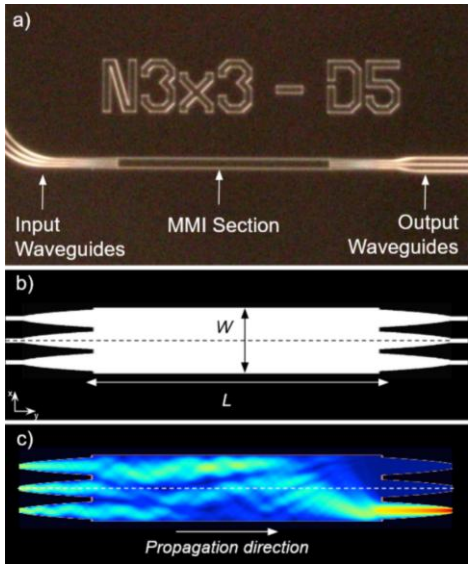
PHOTONIC TECHNOLOGY





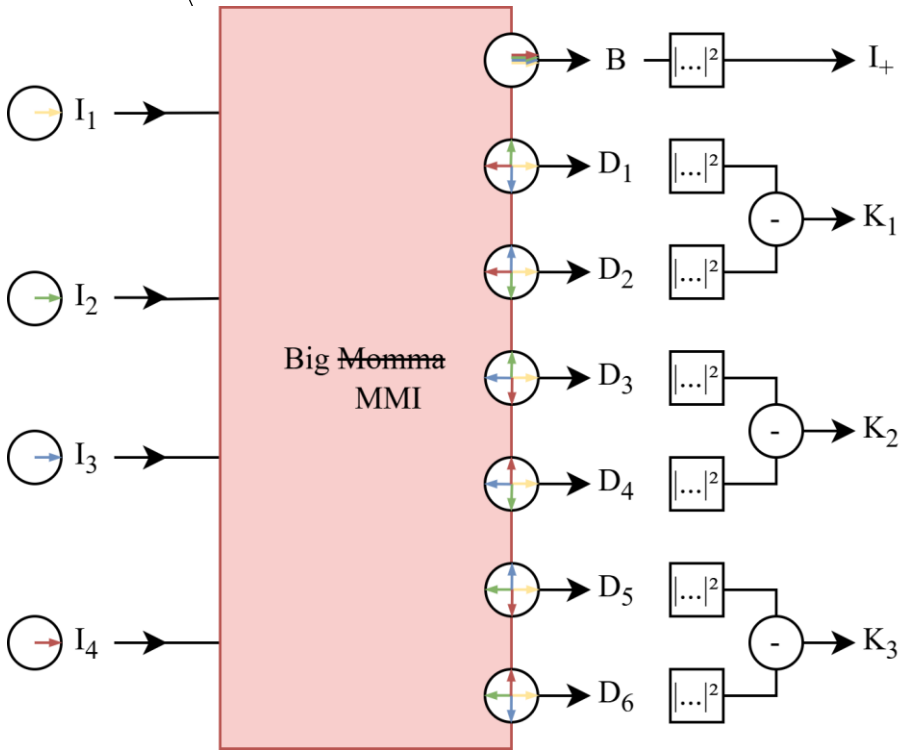
- Photonic chip made of SiN ($16mm$ large)
- H band ($\lambda_0 = 1.55\mu m$)

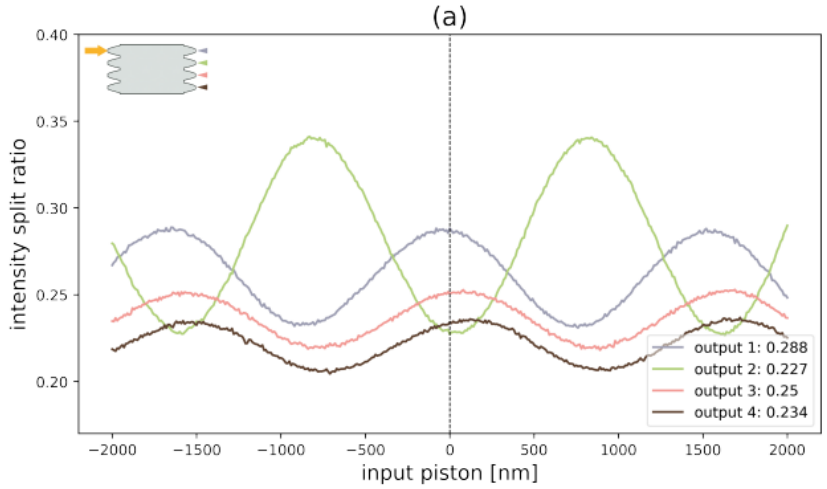
MULTI MODE INTERFEROMETER (MMI)



Wave propagation simulation in a MMI (Multi Mode Interferometer)

N. Cvetojevic et al. (2022)

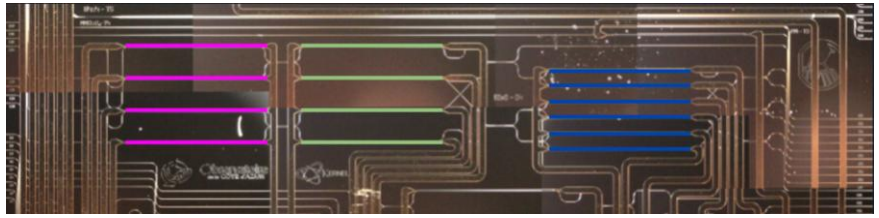


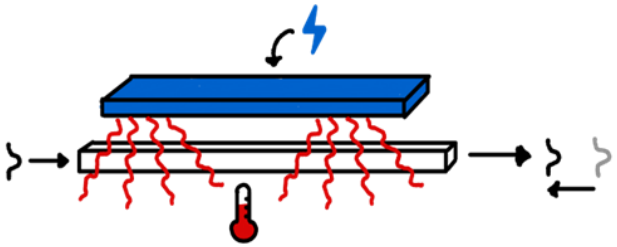


Variation of the beam splitting ratio at the outputs of the 4x4 MMI

P. Chingaipe (2024)

TUNABLE ARCHITECTURE

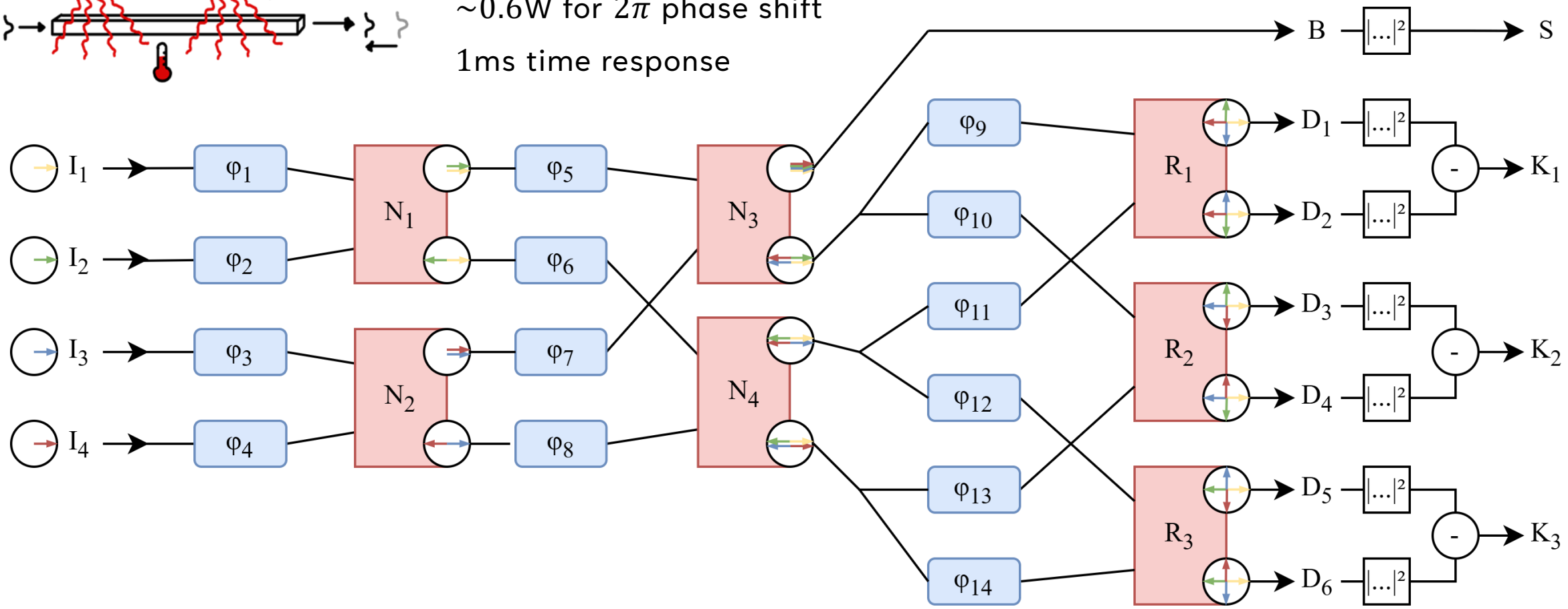




Thermo-optic phase shifters

~0.6W for 2π phase shift

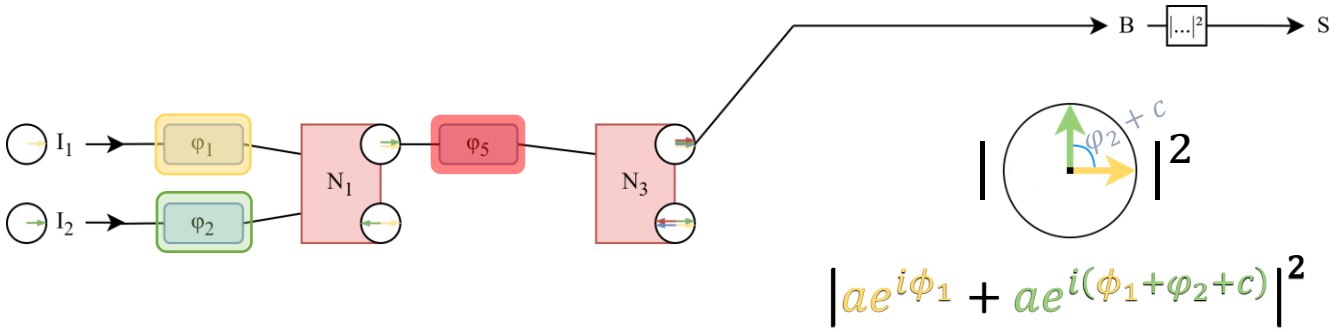
1ms time response



TWO CALIBRATION APPROACHES

Obstruction

Isolate one MMI

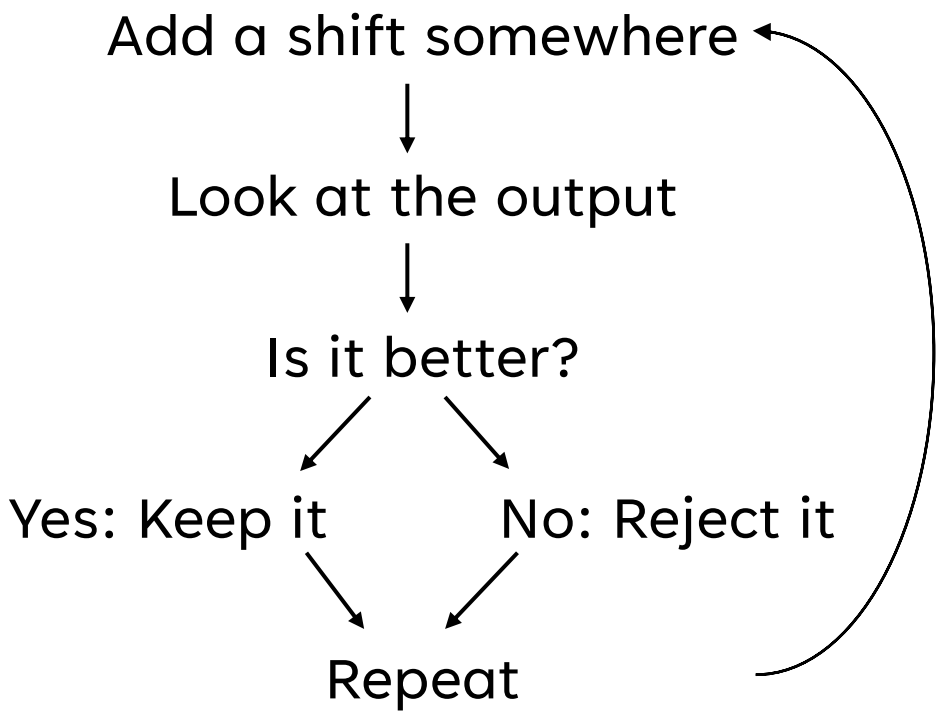


Tweak input relative phase

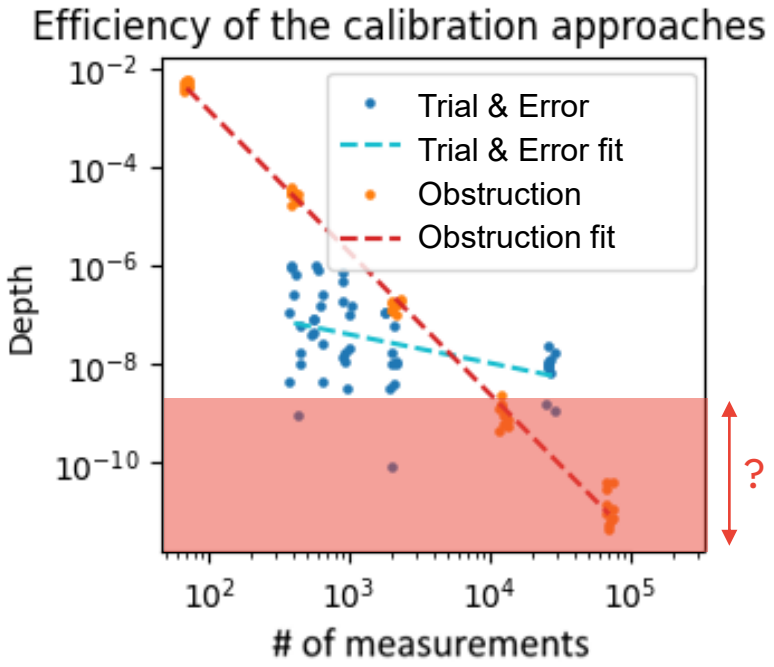
Deduce right shift to inject from output response

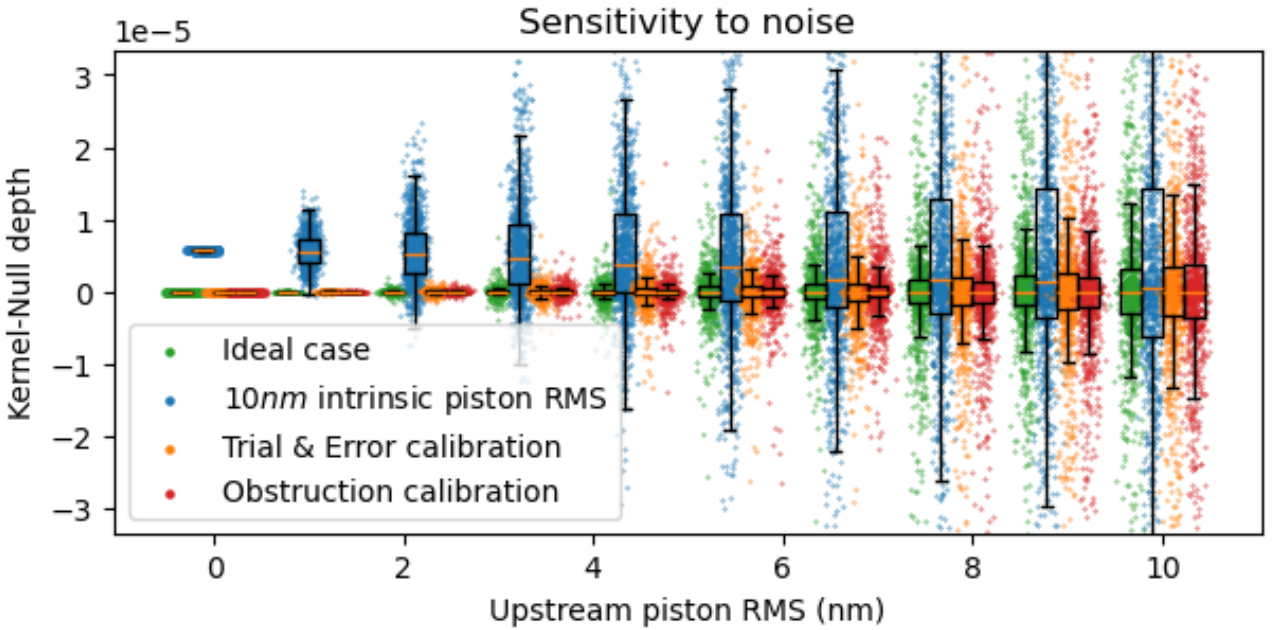
Do it for all MMI

Trial & Error



COMPARISON

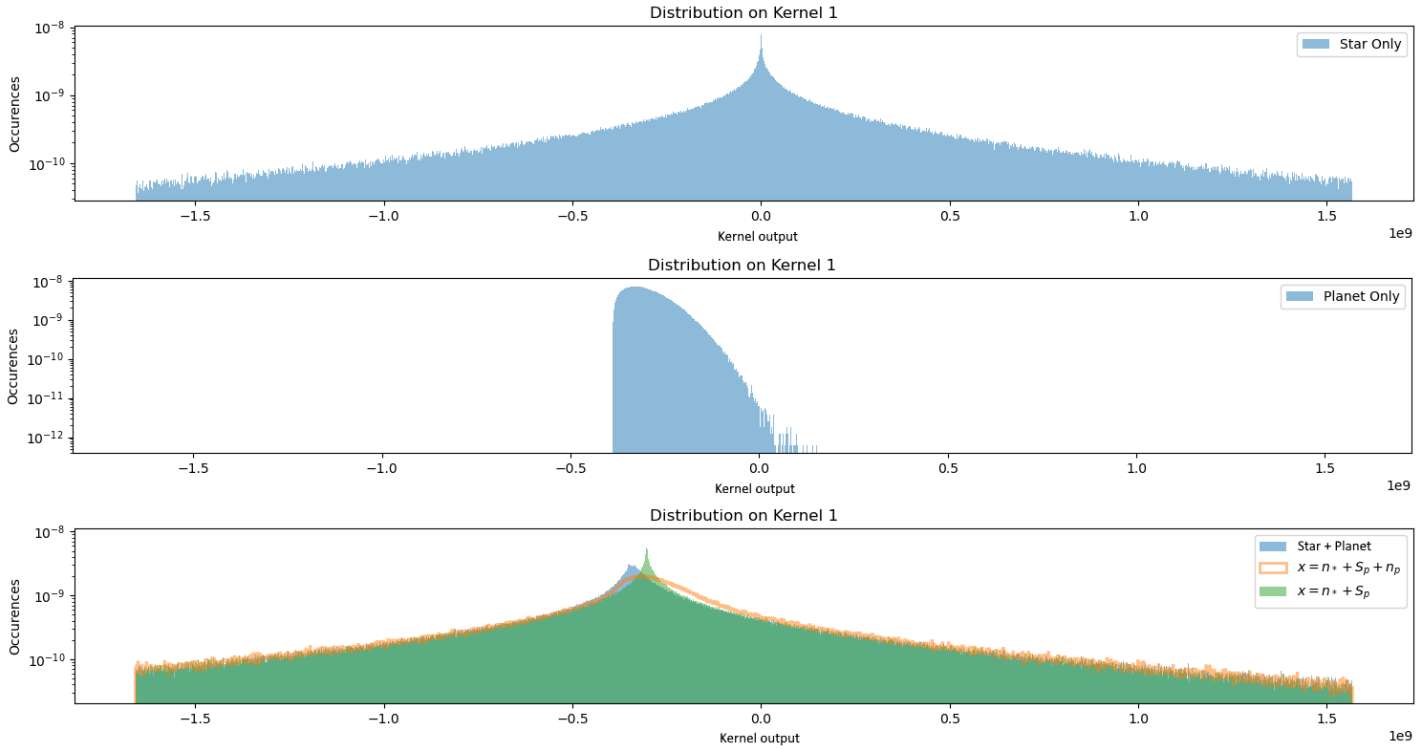

Efficiency of the calibration approaches
Trial & Error
Trial & Error fit
Obstruction
Obstruction fit
Depth
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{2}
10^{3}
10^{4}
10^{5}
# of measurements
?

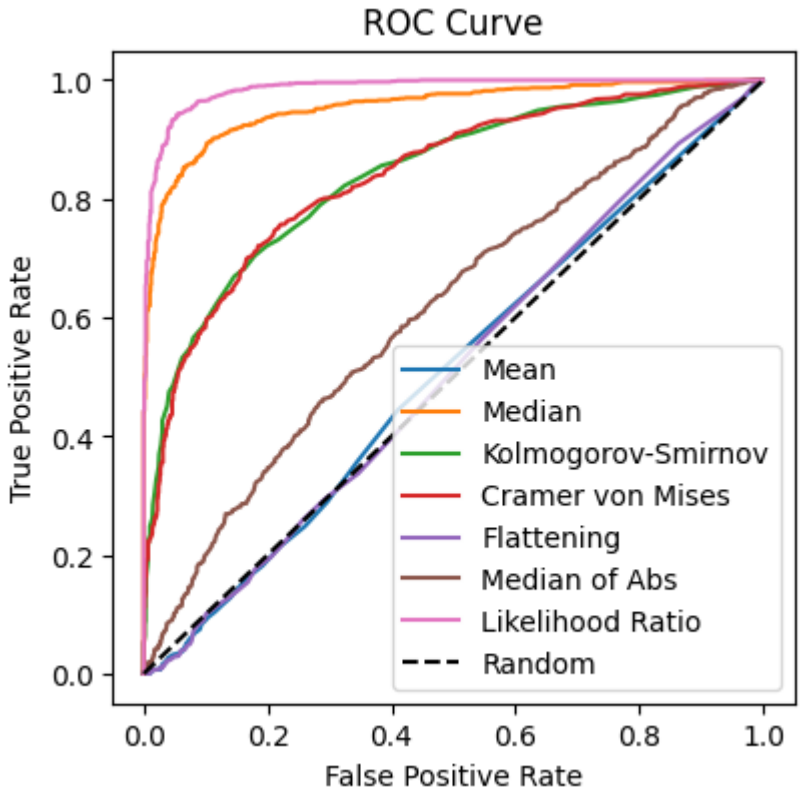

Sensitivity to noise
1e−5
Kernel-Null depth
3
2
1
0
−1
−2
−3
Ideal case
10nm intrinsic piston RMS
Trial & Error calibration
Obstruction calibration
0
2
4
6
8
10
Upstream piston RMS (nm)

OUTPUT DATA ANALYSIS

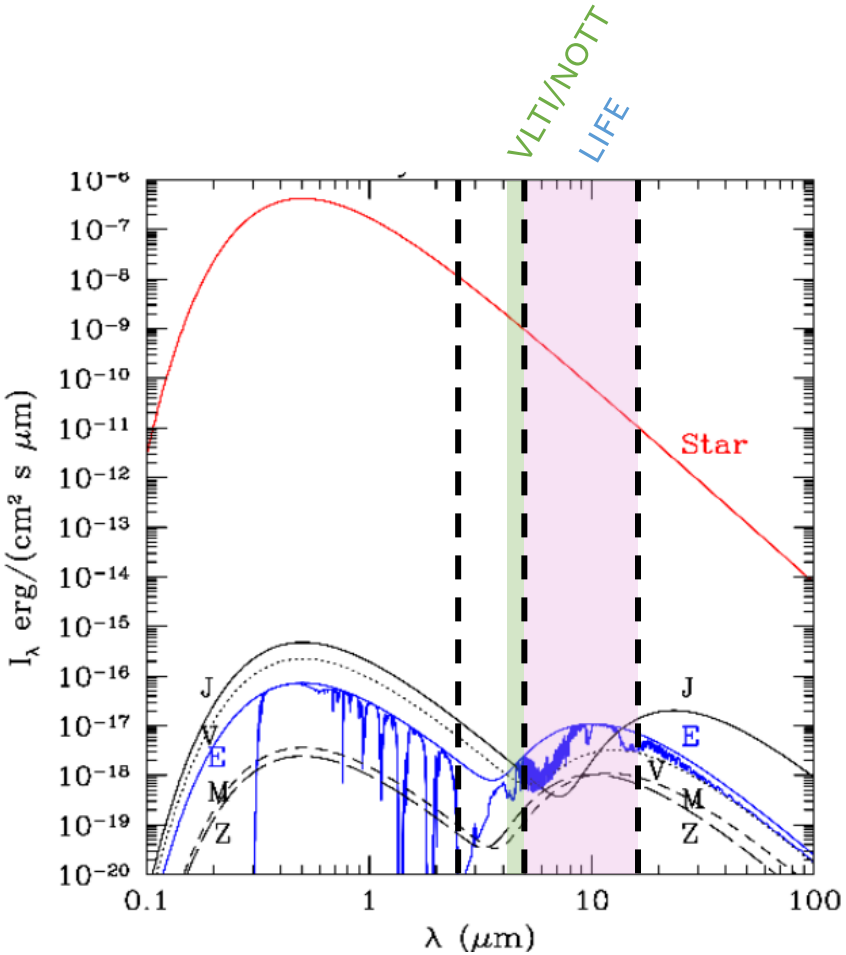
Kernel outputs follows an **unknown distribution**

Companion effect is not yet clearly understood





DETECTION CAPABILITY



SAO model of our solar system
Kaltenegger et al. (2010)

	VLTI/NOTT	LIFE
$1.55\ \mu m$ Current component	$10^{-3} \rightarrow 10^{-4}$ $2.5\ mas$	$10^{-6} \rightarrow 10^{-9}$ $0.5\ mas$
$4\ \mu m$ VLTI/NOTT & LIFE	$10^{-5} \rightarrow 10^{-5}$ $6.3\ mas$	$10^{-8} \rightarrow 10^{-11}$ $1.4\ mas$
$18\ \mu m$ Upper limit of LIFE	$10^{-6} \rightarrow 10^{-7}$ $28.5\ mas$	$10^{-9} \rightarrow 10^{-12}$ $6.2\ mas$

⚠ Numerical simulations

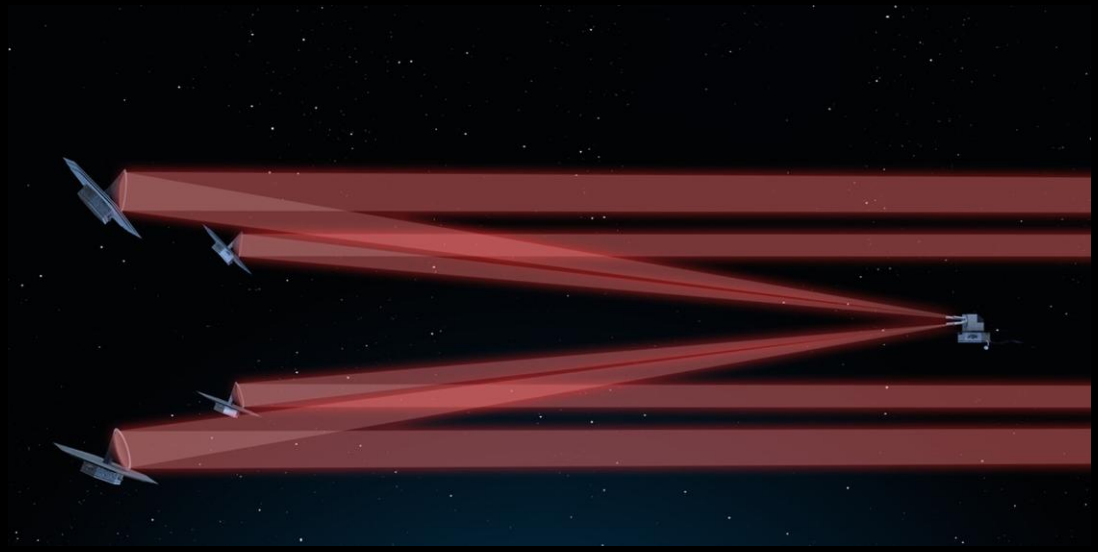
→ Soon to be validated in lab

CONCLUSION

- Compact, stable, light
- Possibility to make it almost ideal!
- According to the intrinsic aberrations,
  we can win up to a factor 10 in contrast

FUTURE PROSPECTS

- VLTI/NOTT
- LIFE



THANK YOU!

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