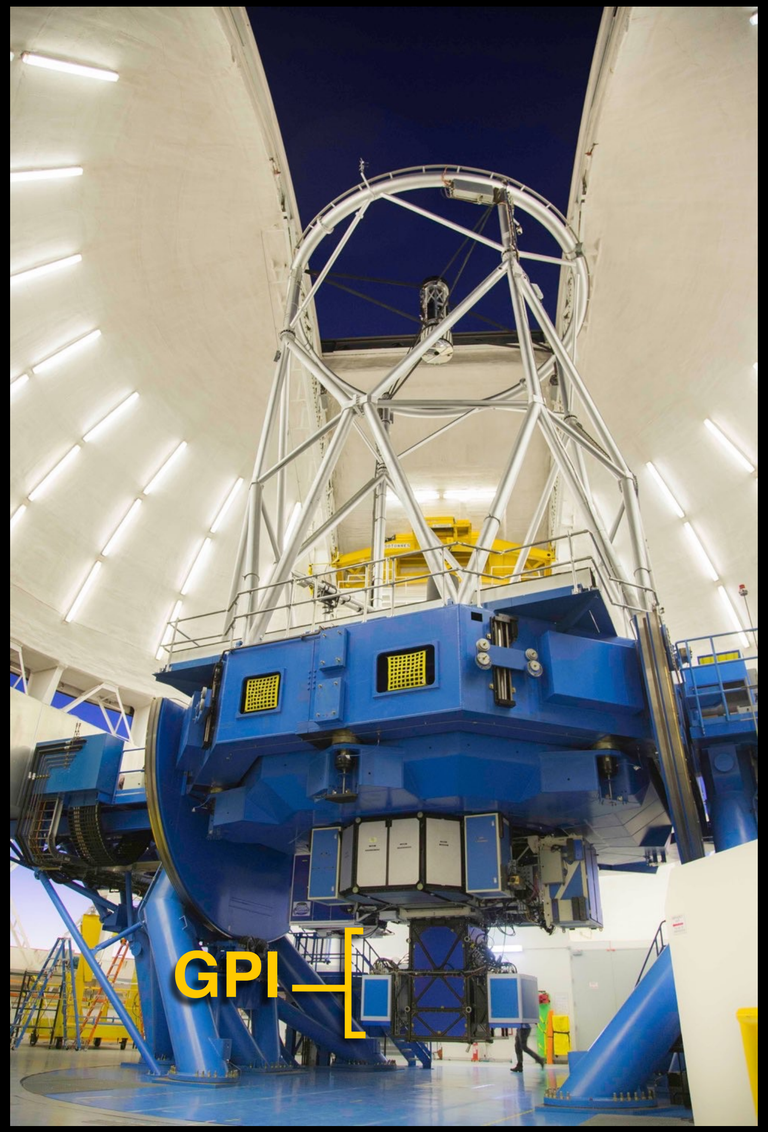
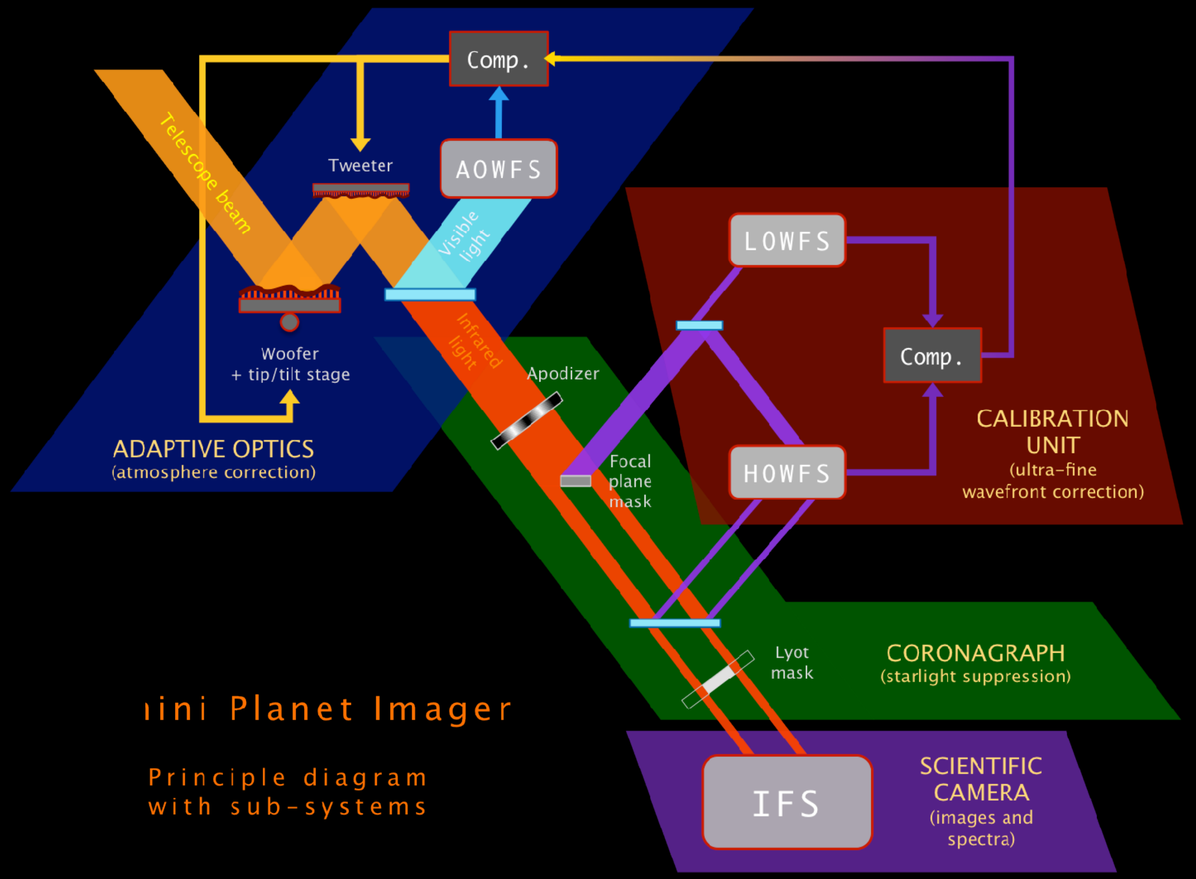
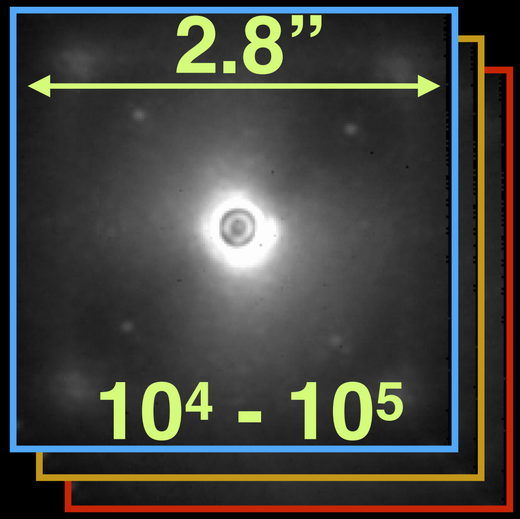
Instrument characterization from metadata & telemetry

Vanessa Bailey
Jet Propulsion Laboratory, California Institute of Technology

Gemini Planet Imager

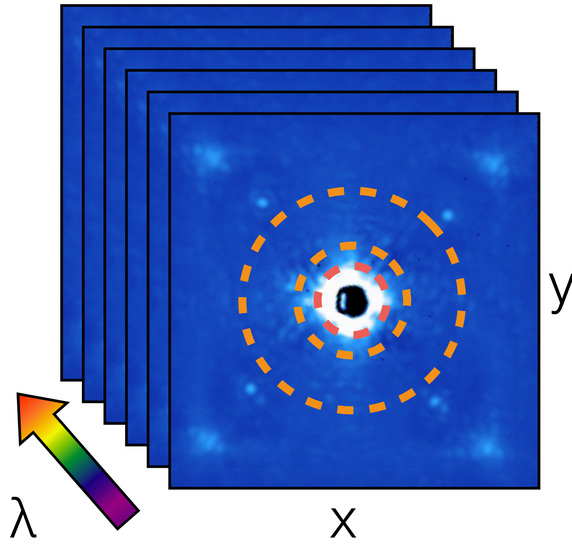






Credit - Paul Langlois

Every GPI image has environment & performance data



Bailey+ 2016

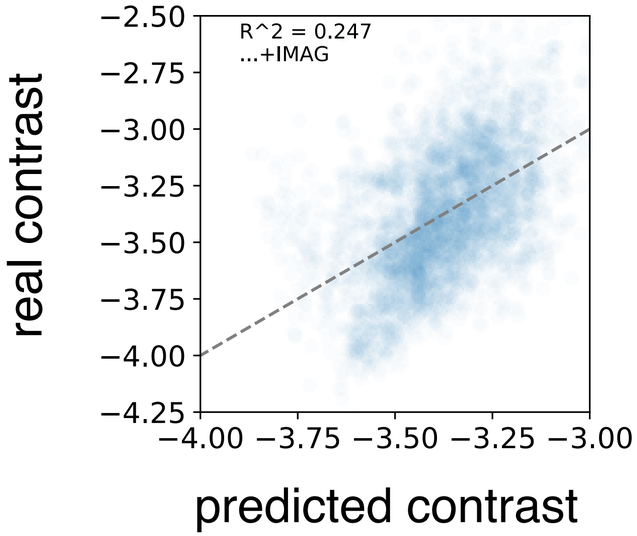
- raw image contrast @ 0.25”, 0.4”, 0.8”
- ~ WFE
- ~ AO tip/tilt & focus vibration
- environment:
  - seeing (Gemini MASS* & DIMM)
  - wind, temperature

* MASS quit working April 2016

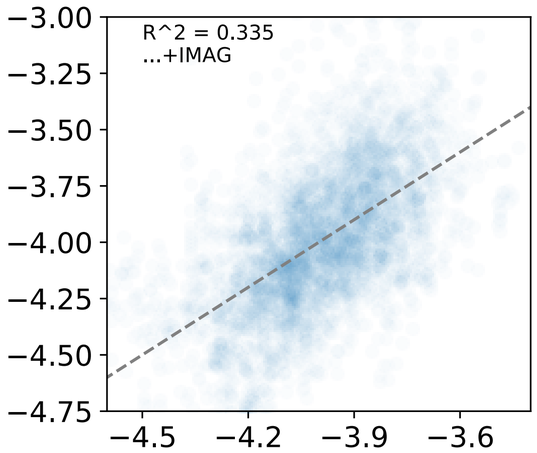
Environment parameters alone explain 25-40% of GPI raw contrast variation

- Tau
- DIMM seeing
- dT = abs(AO - amb)
- I mag

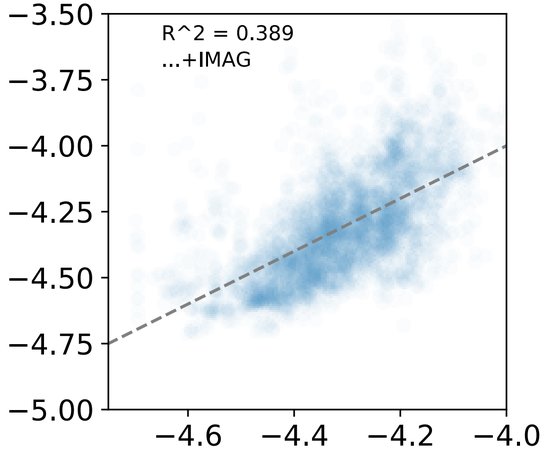
0.25” R^2=0.25



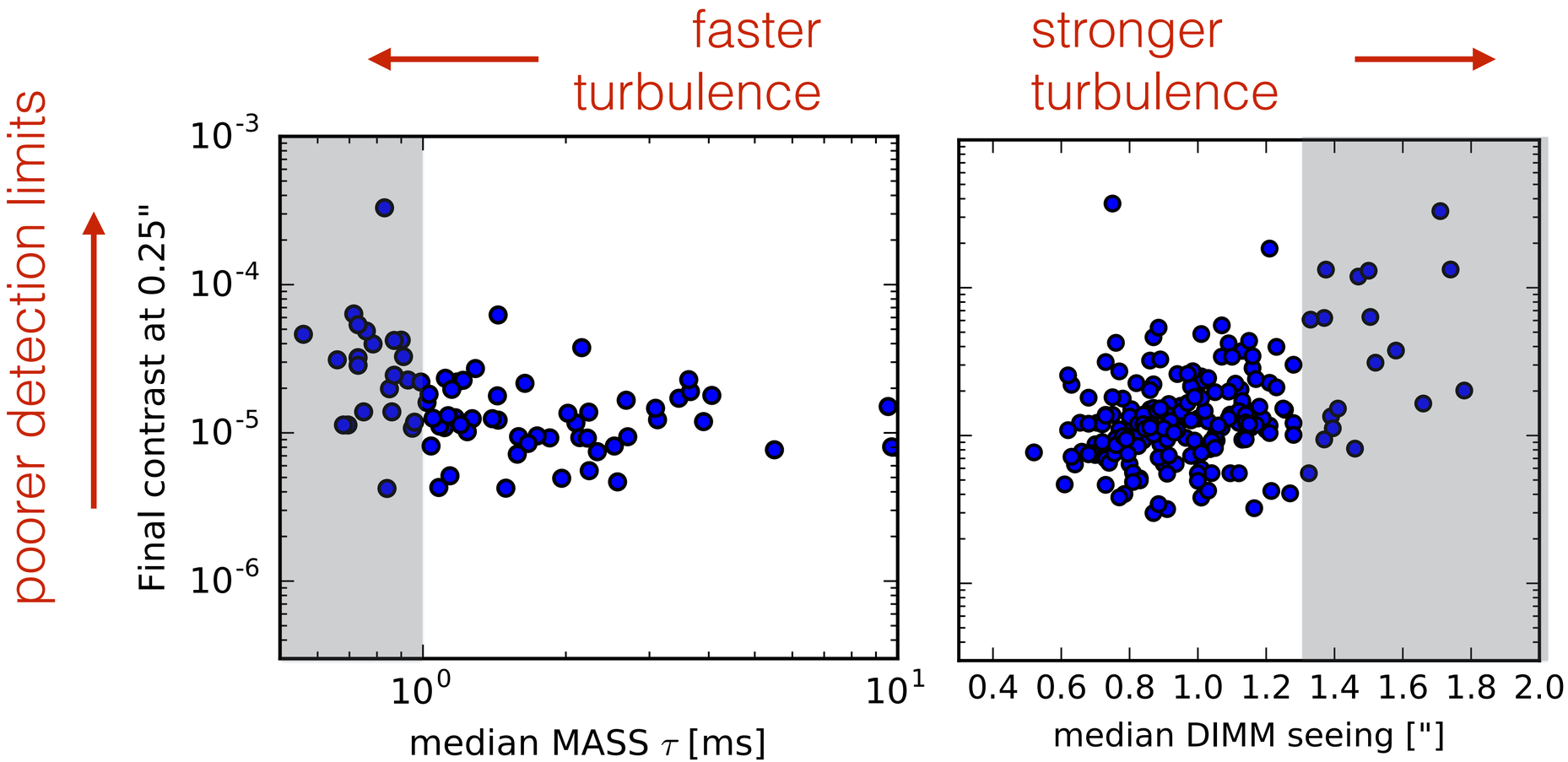
0.4” R^2=0.33



0.8” R^2=0.38

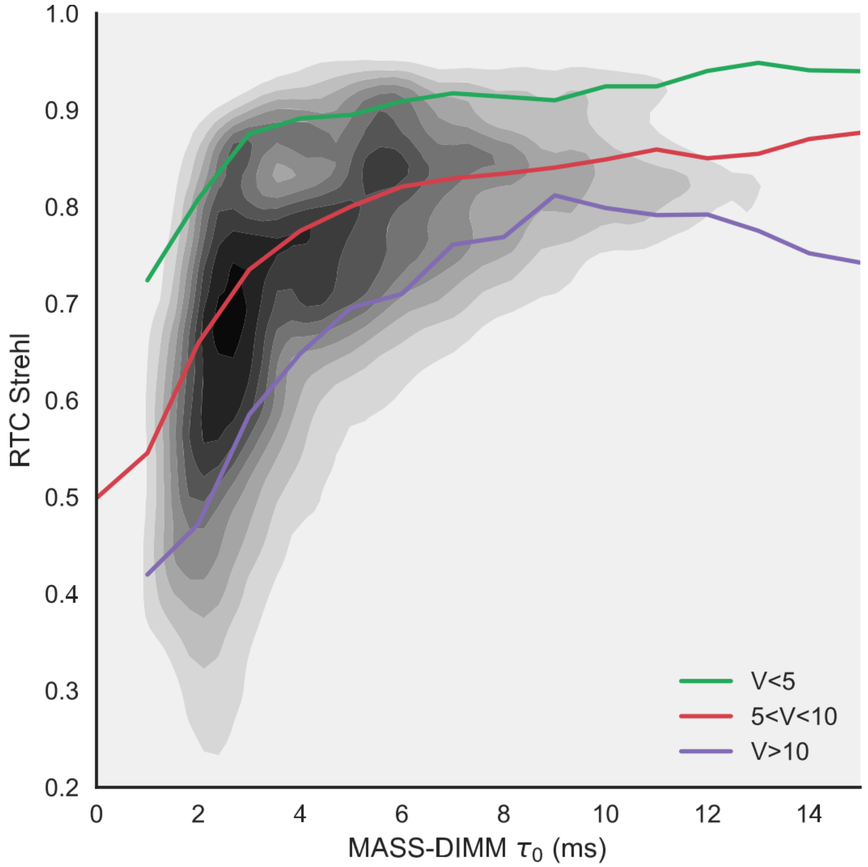


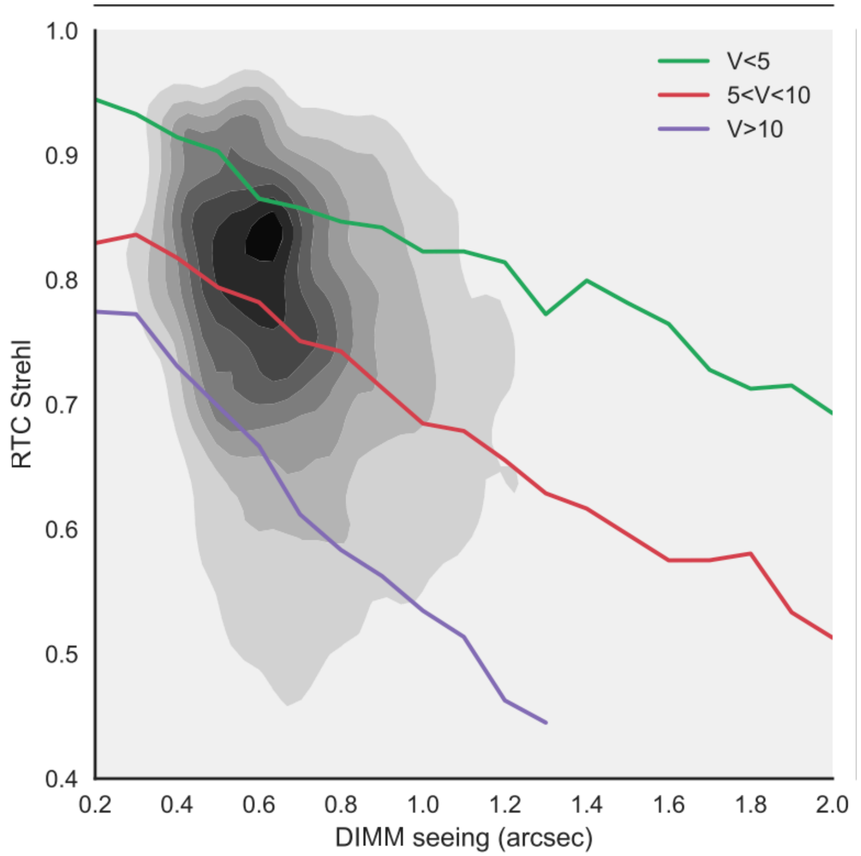
Tau governs final GPI contrast more often than raw seeing does

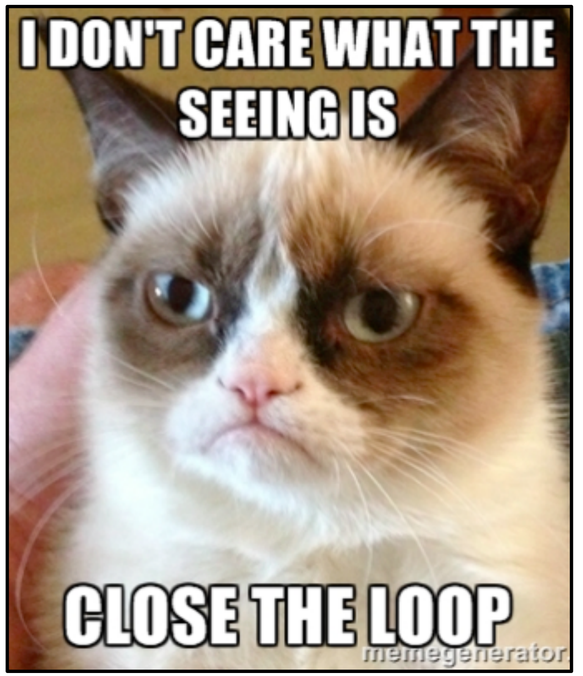


Similar effects seen in other instruments

Milli+ 2017



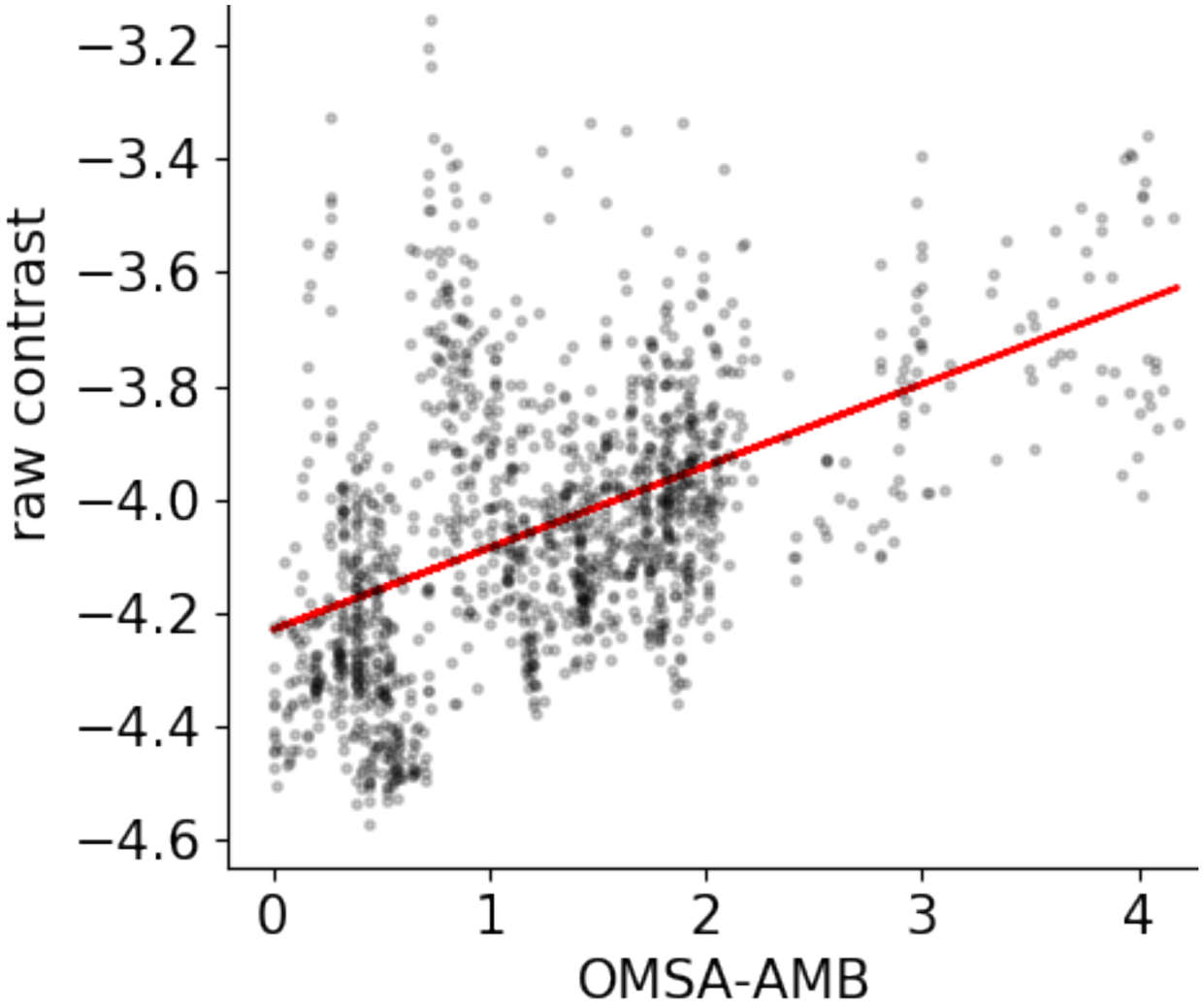




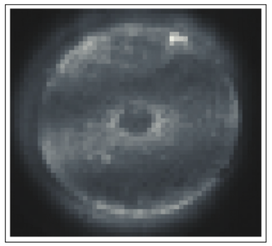
Similar analysis for NIRC2 by Jerry Xuan (Pamona) ongoing

Temperature disequilibrium degrades GPI performance

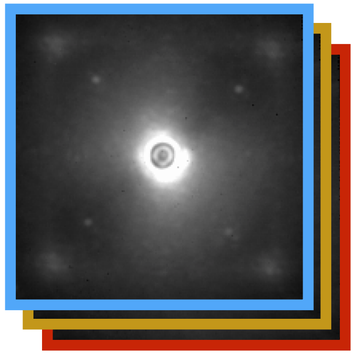
Melisa Tallis
in prep



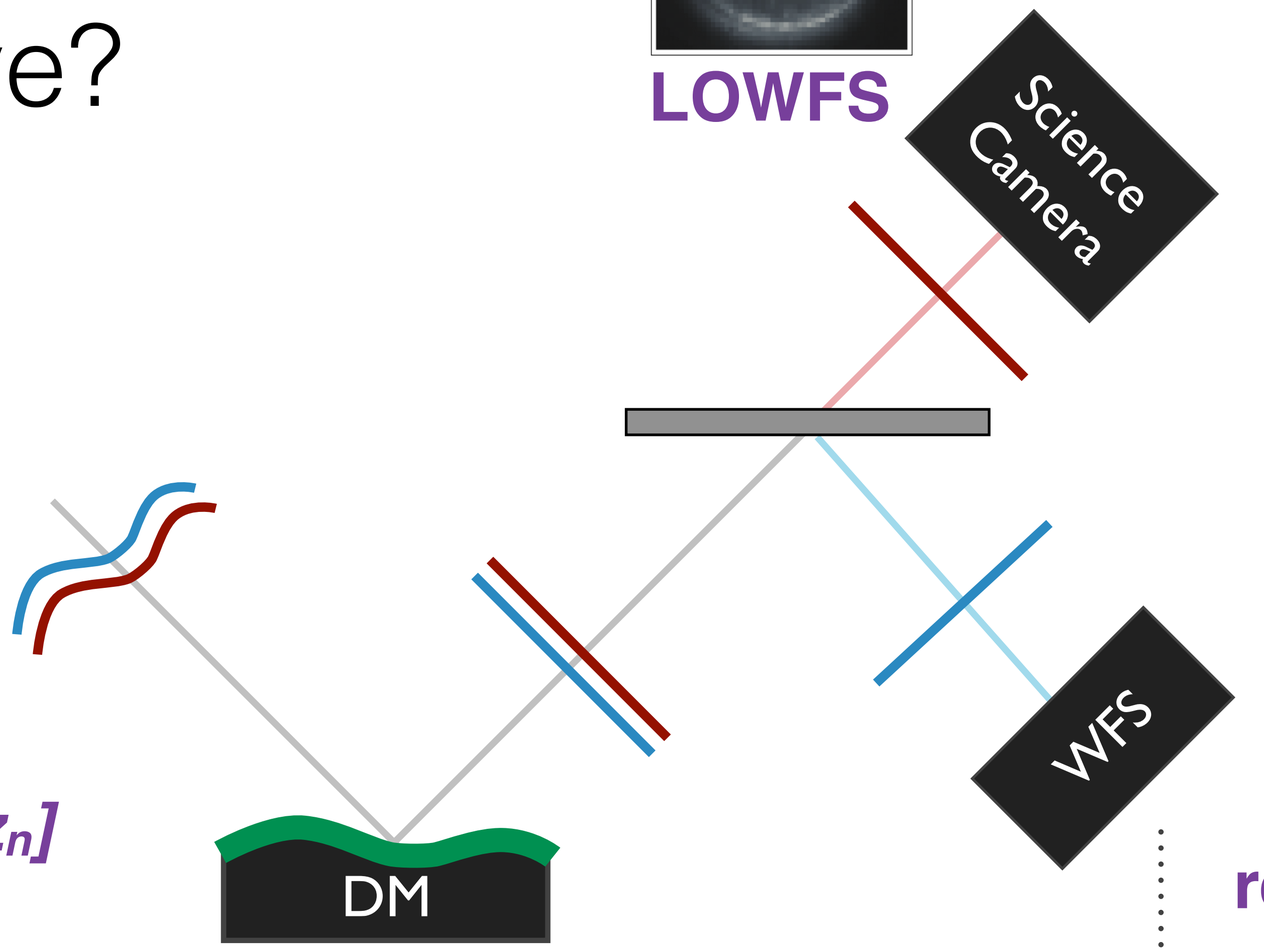
What telemetry can we save?

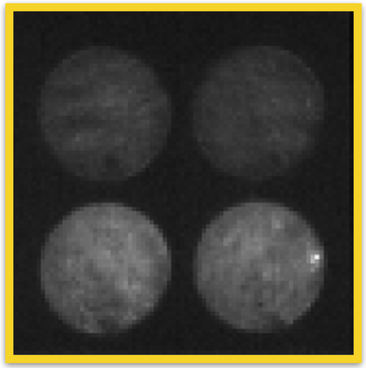


LOWFS



accelerometers
temperatures
pointing





positions: [$z_1 \ldots z_n$]

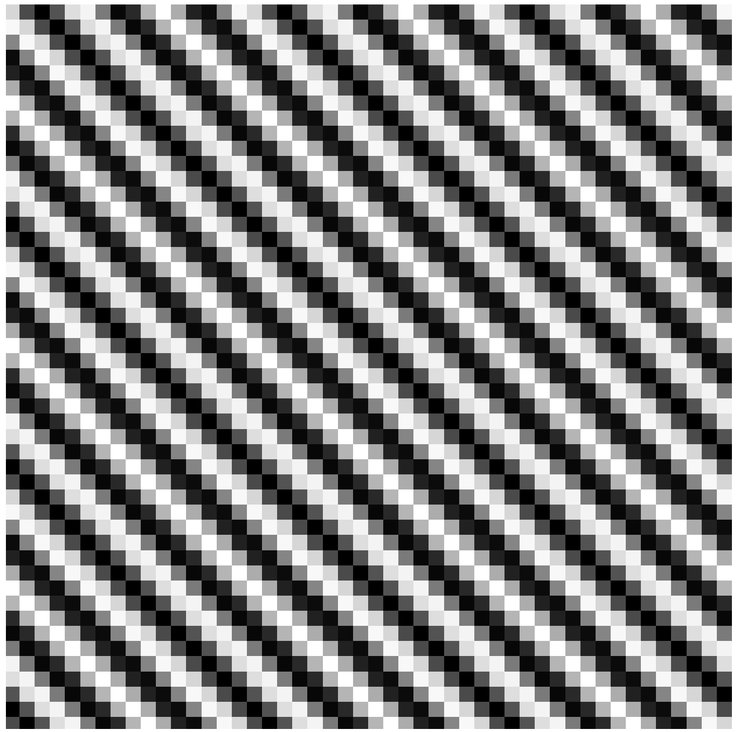
residual slopes:
[$x_1, y_1 \ldots x_n, y_n$]

commands:
[$z_1 \ldots z_n$] or [$m_1 \ldots m_n$]

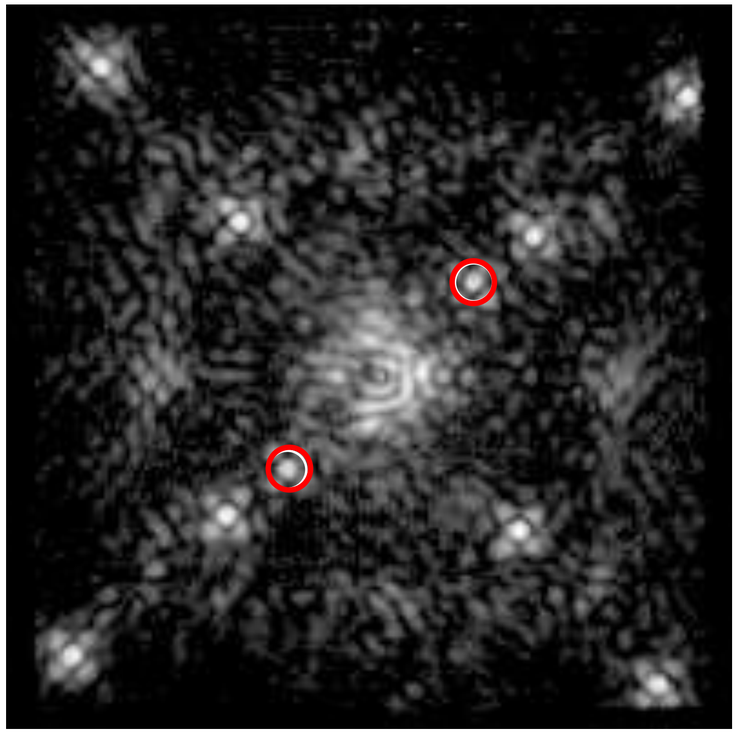
modal gains

GPI uses a Fourier modal basis set with individually controlled gains

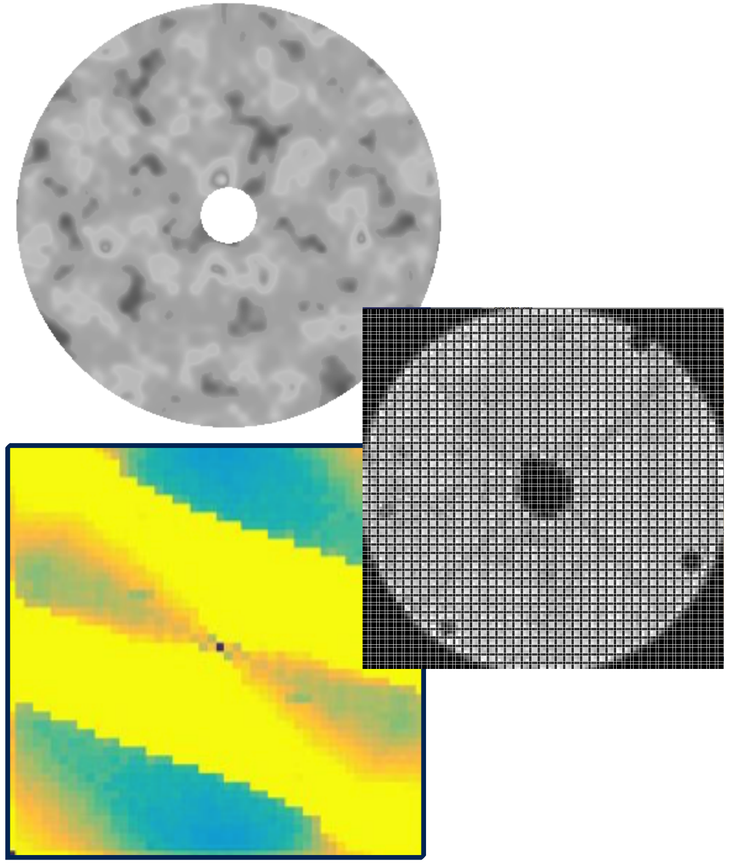
(spatial) mode



PSF



5 - 60sec

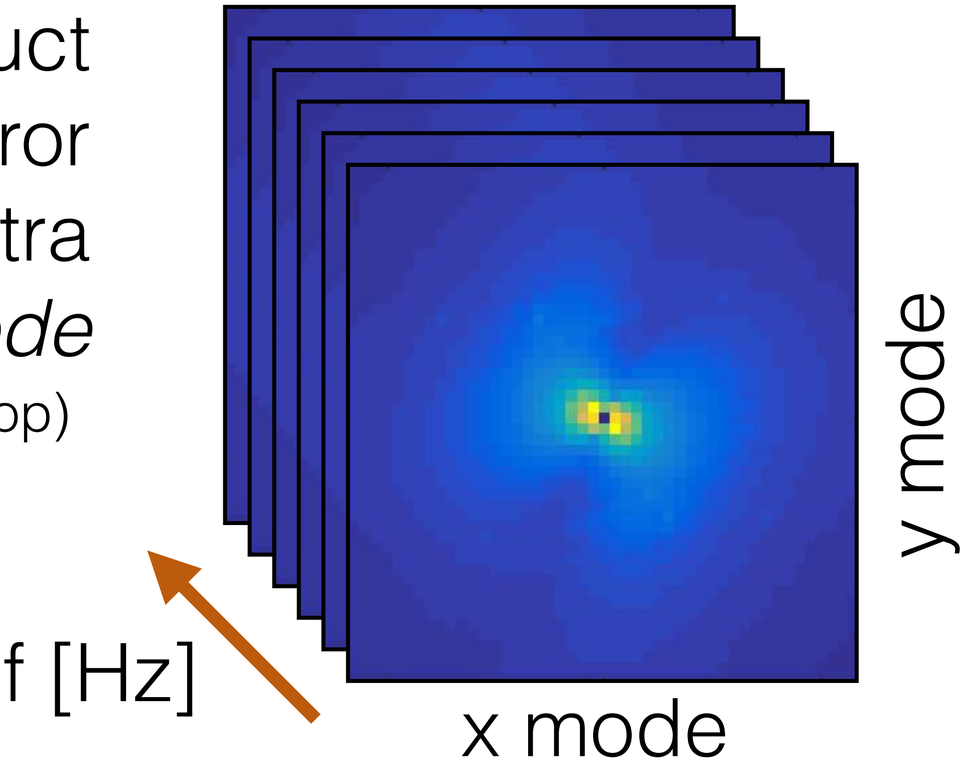


Full data rate
>1GB / min

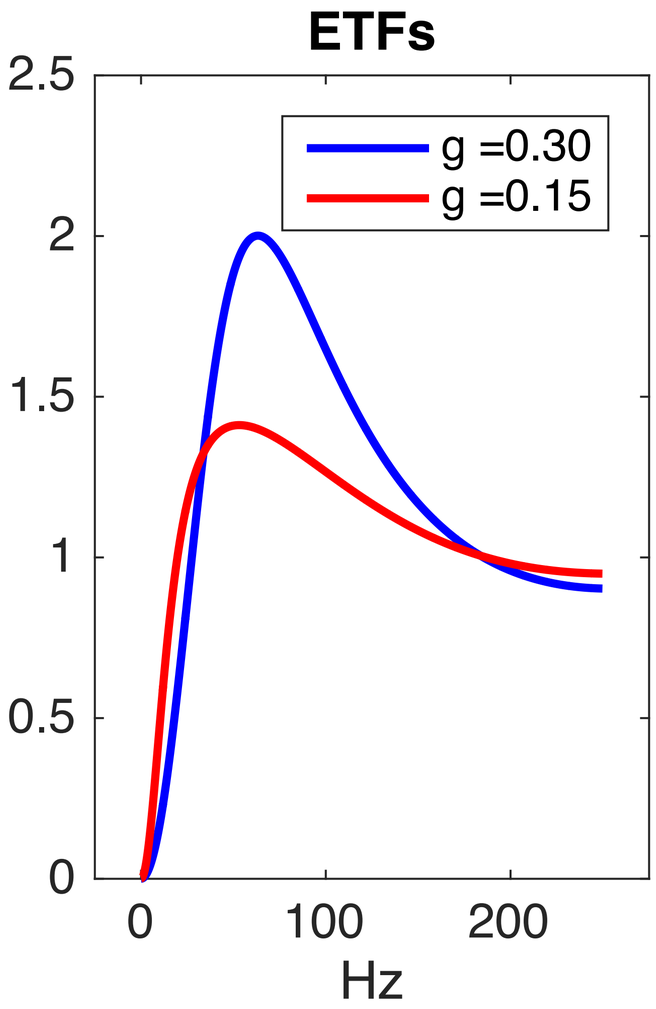
Manual AO telemetry sets record detailed information

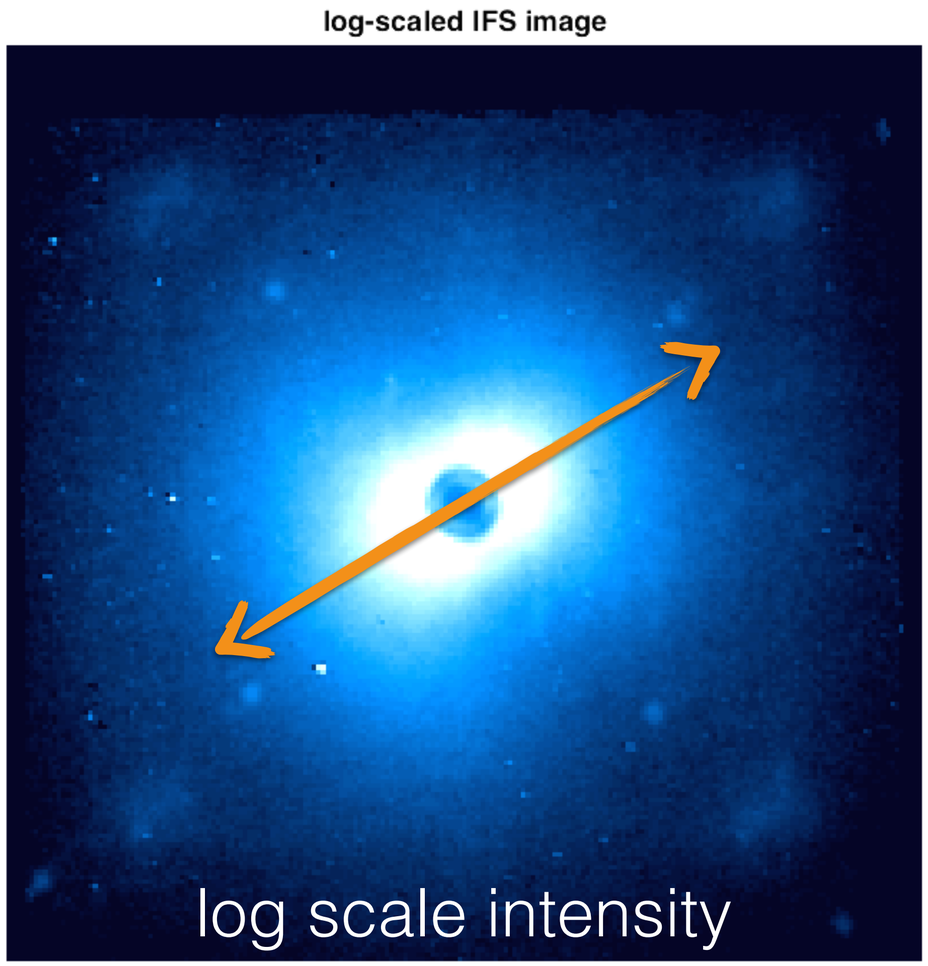
Lisa Poyneer, Dimitry Savransky, Bruce Macintosh

reconstruct
wavefront error
power spectra
for *each mode*
(closed & open loop)

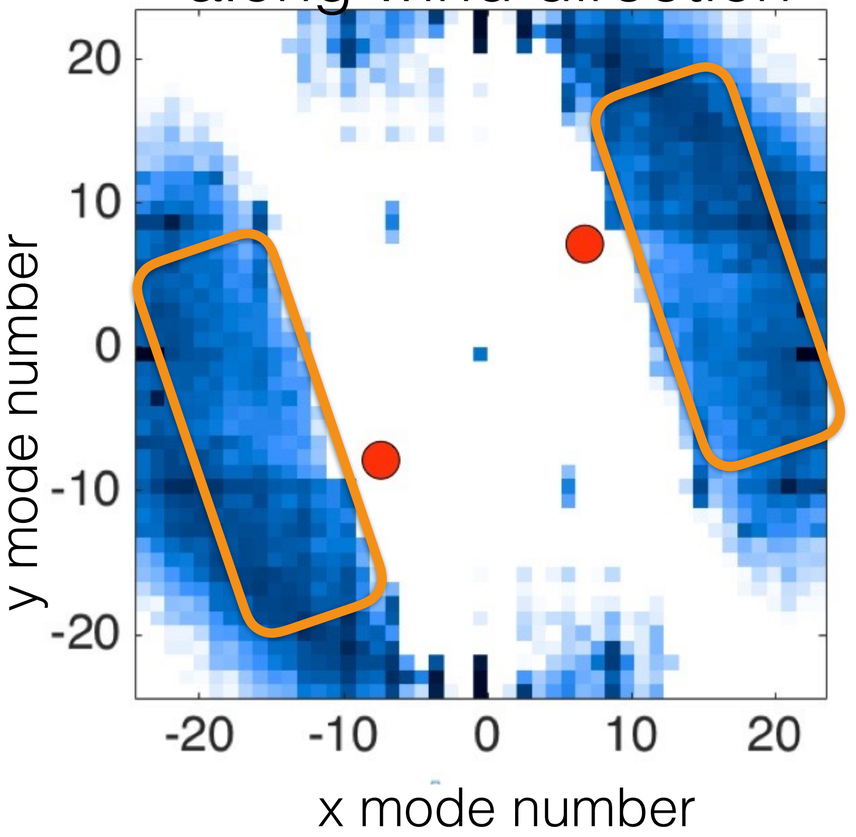


Gains optimized every 8 sec

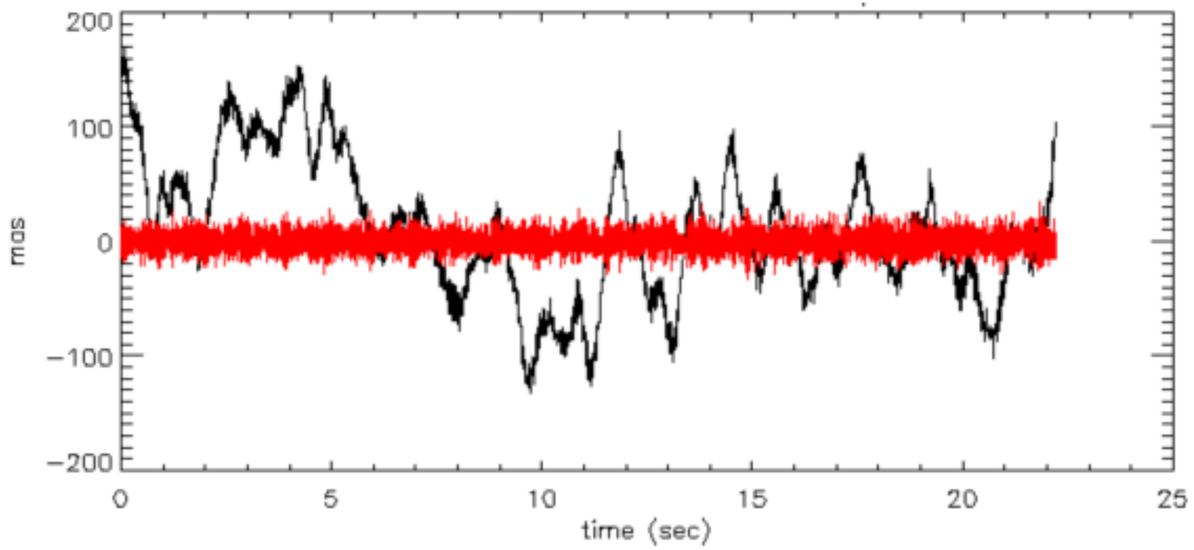


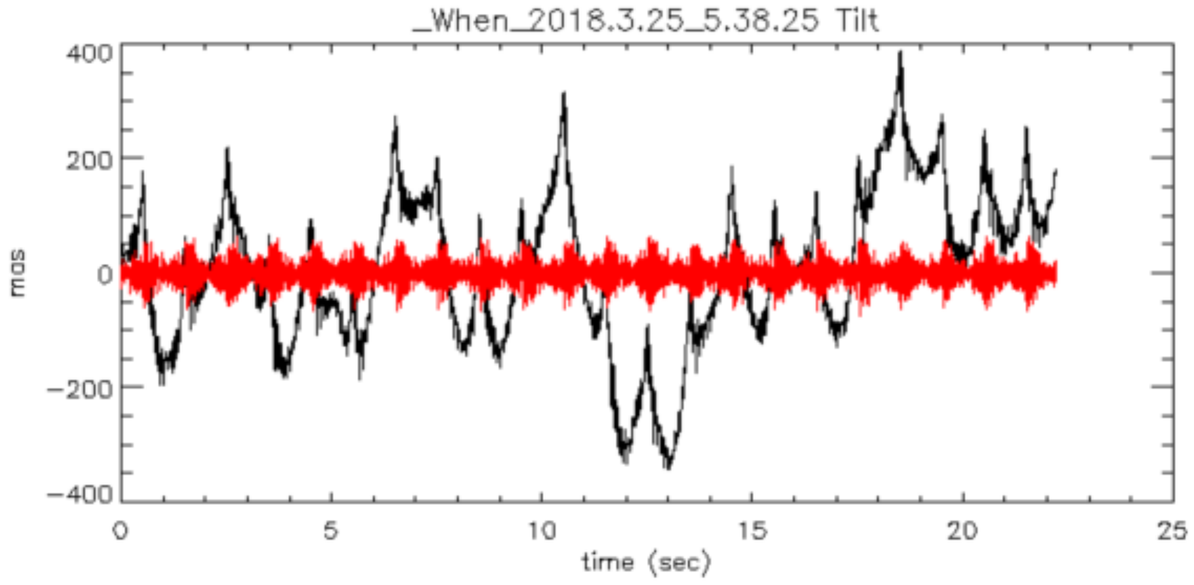


lag errors -> gains lower along wind direction

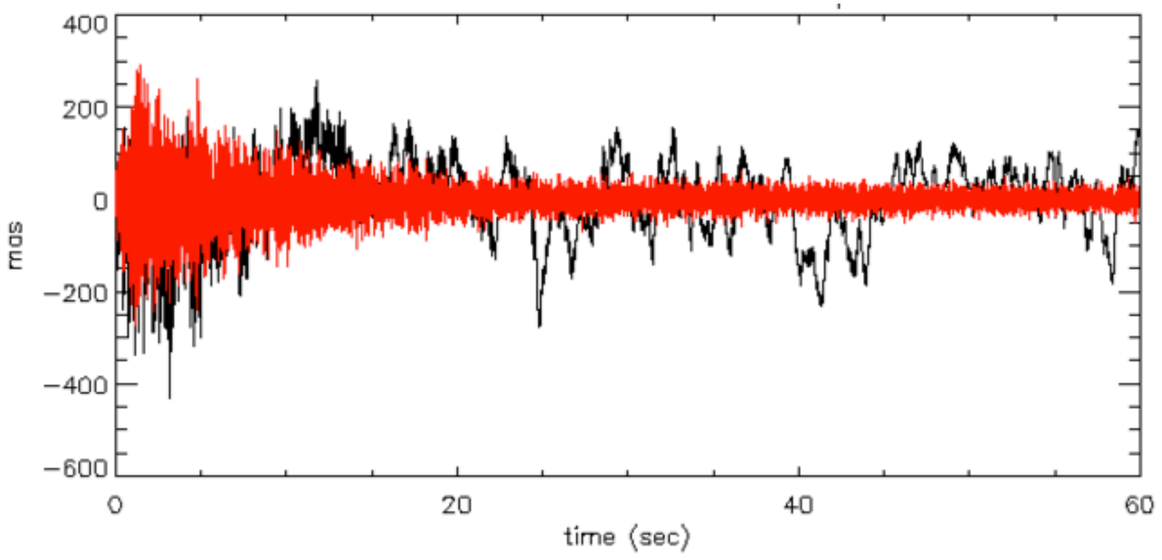


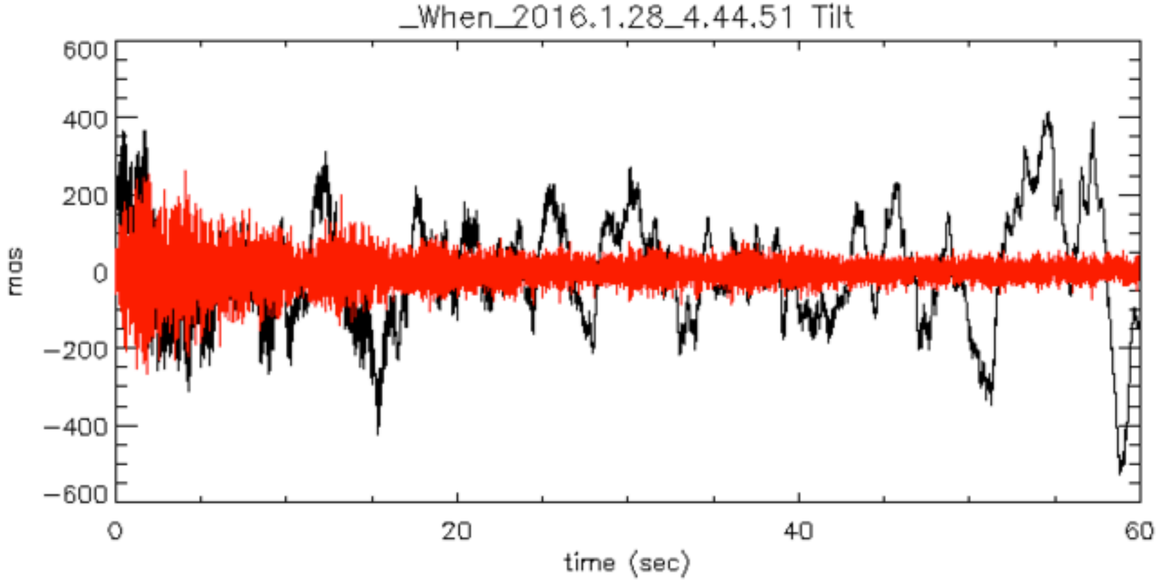
Telescope tracking



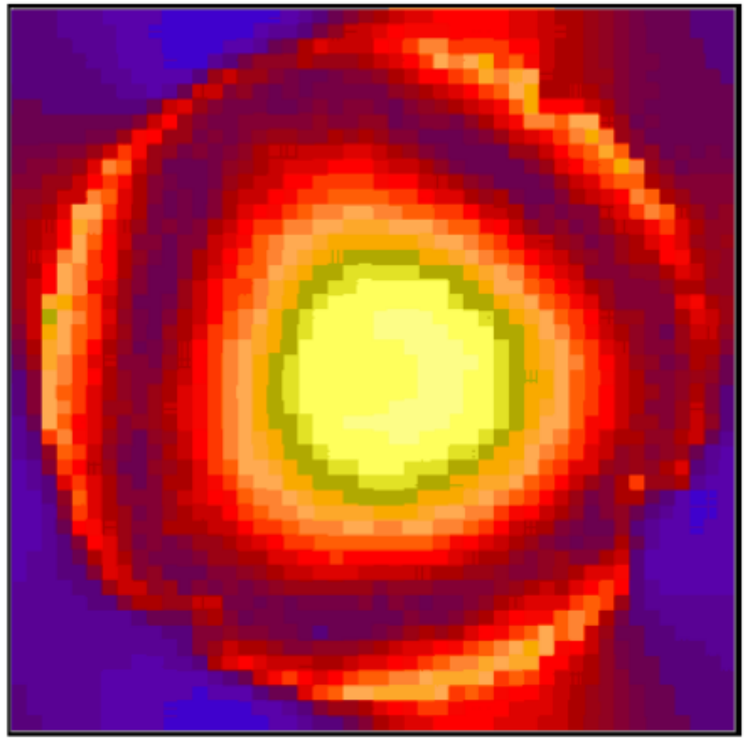


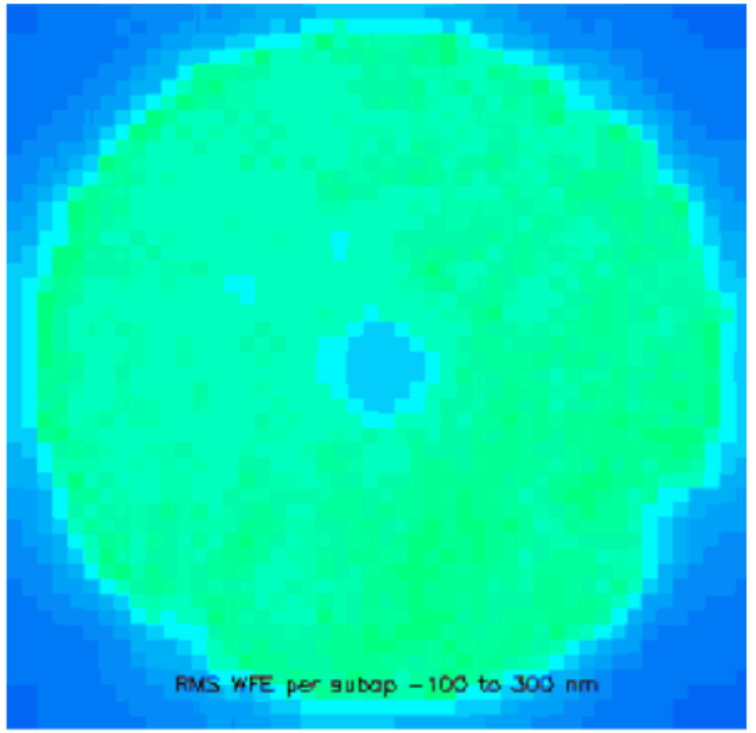
Earthquake





Example: cryocooler controller replace to mitigate M1 60Hz coupling



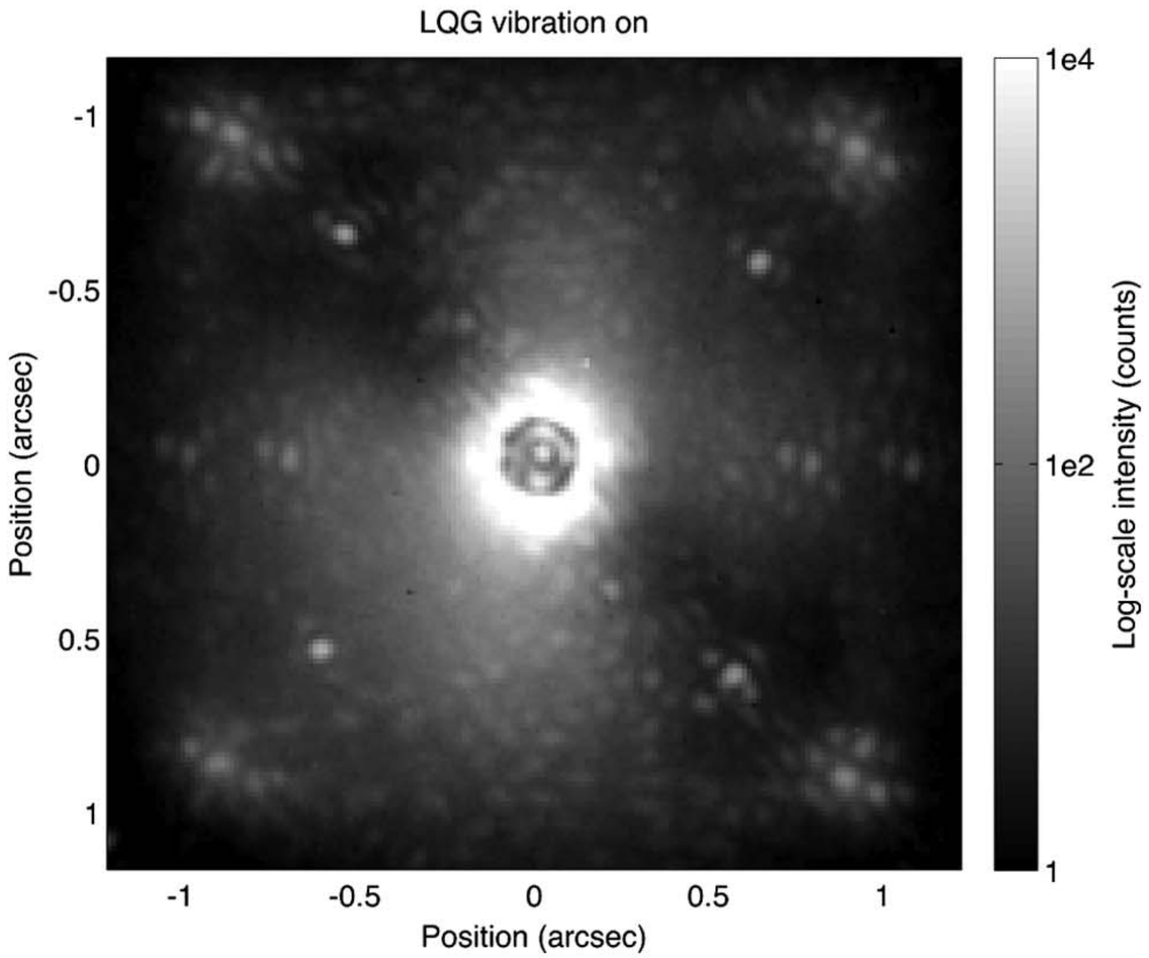


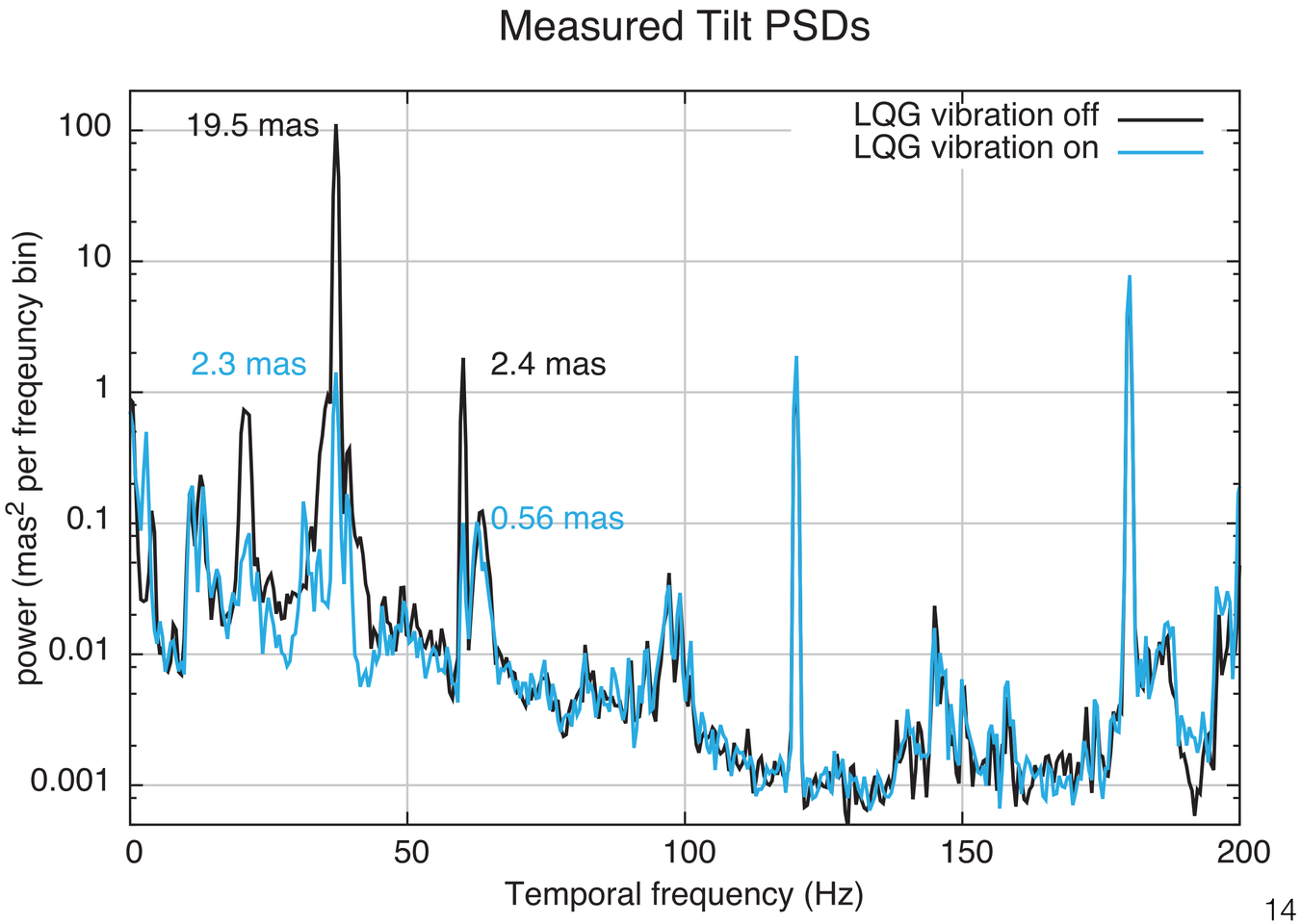
Hartung+, SPIE, 2014

Vibration analysis example: faulty fan

Poyneer+, Appl Opt, 2016

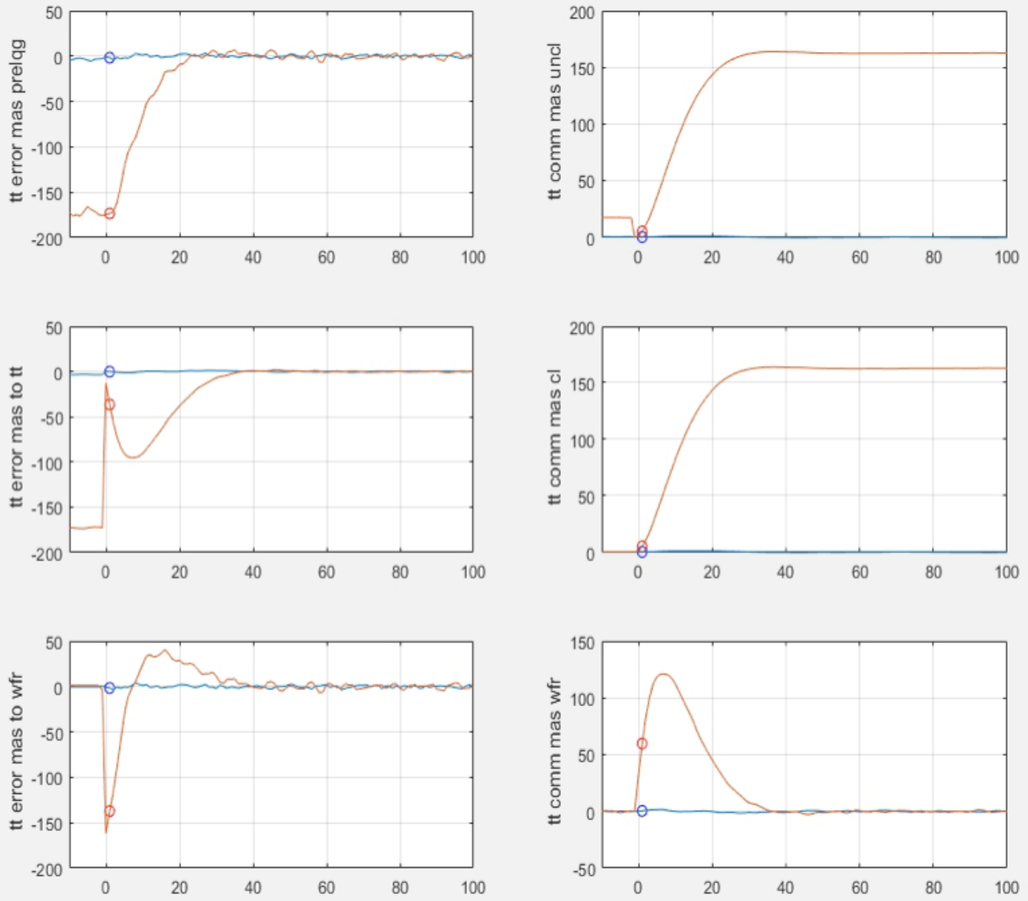
Also LBTI, GEMS, SPHERE

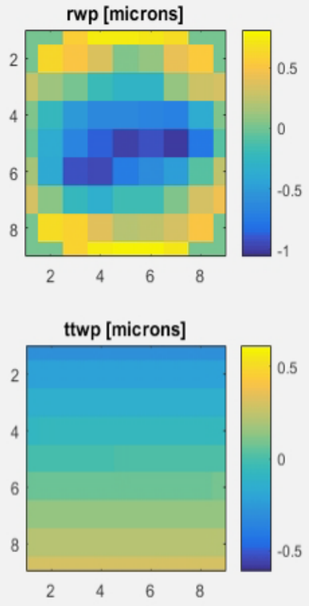


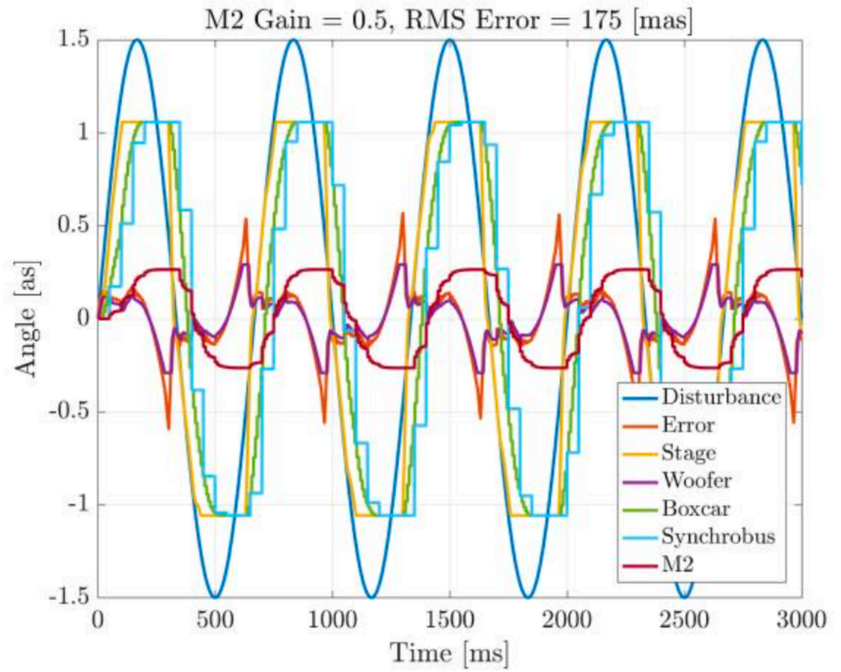


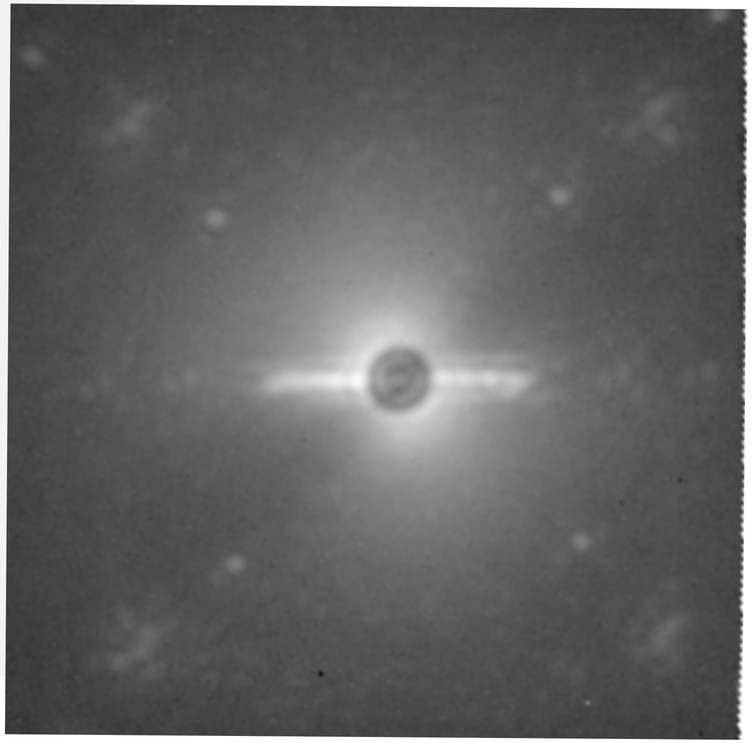
telescope windshake

Connor Beierle in prep



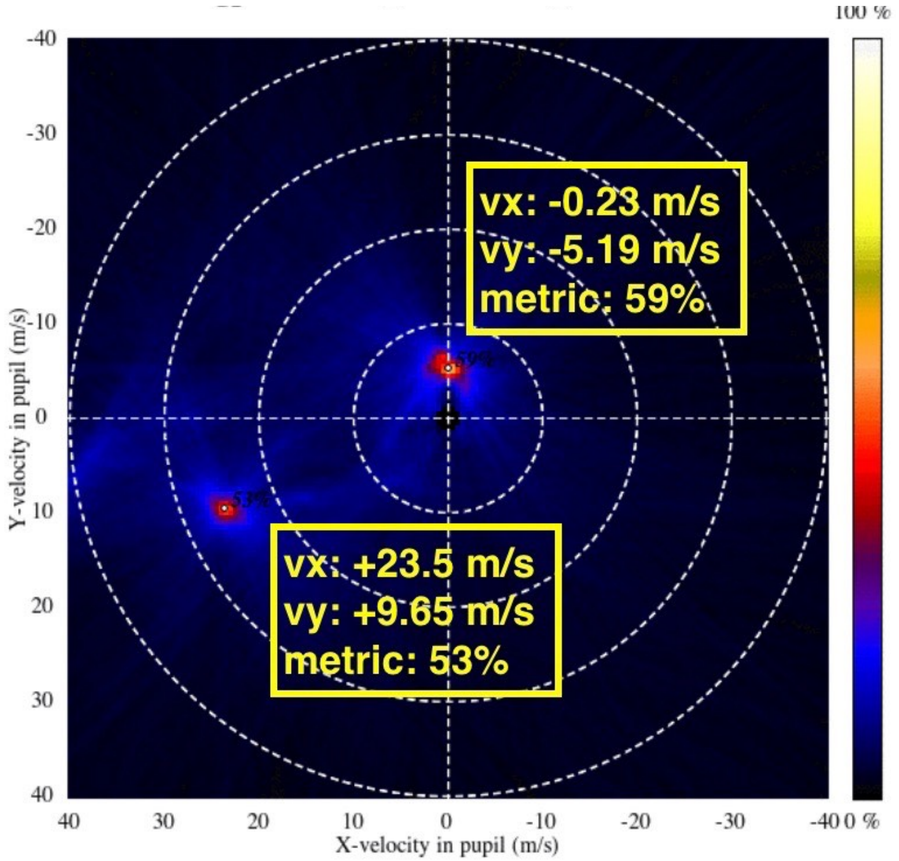






Tangent: site characterization

- **Regular AO telemetry = regular site monitoring** (postprocessing required!!)
- Compare to observatory MASS, DIMM, etc.
- planning upgrades &/or new instruments (AO and seeing-limited)

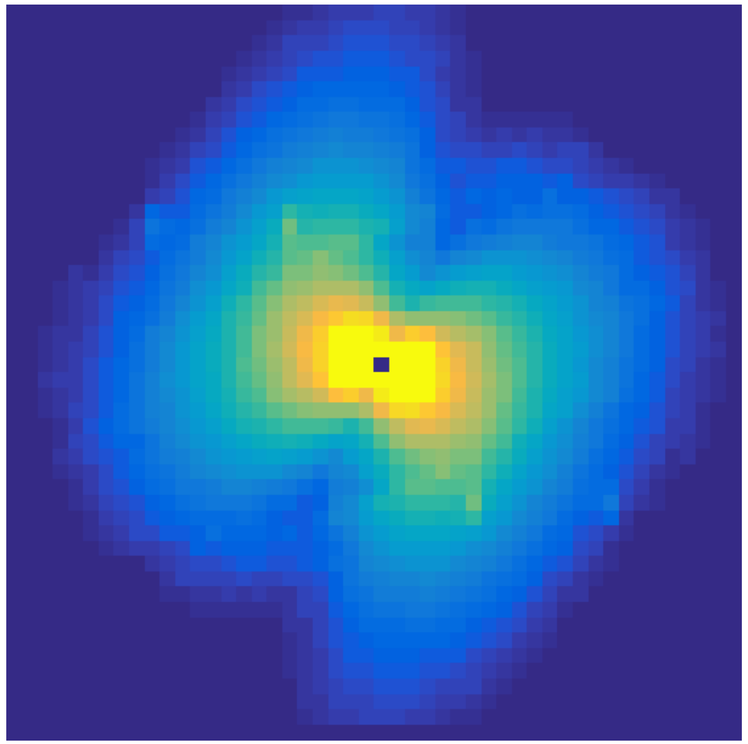


Sri Srinath - SPIE 2016
Adam Snyder - SPIE 2016

Reconstructed WFE ~ GPI IFS frames

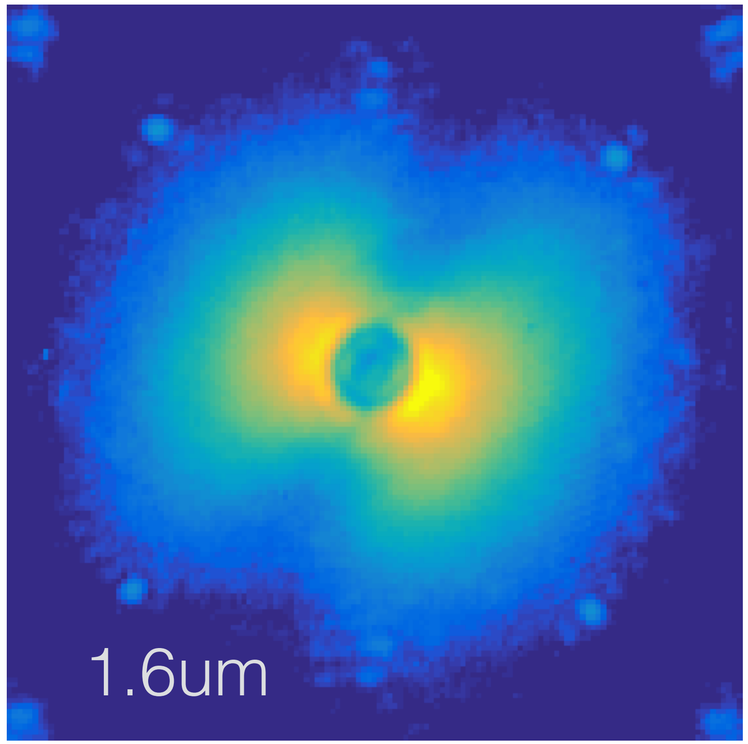
other PSF reconstruction:
Veran+1997,
Jolissaint+2012, …

pseudo-closed loop
WFE^2 [nm^2]



2016.2.29_22.52.44

IFS img



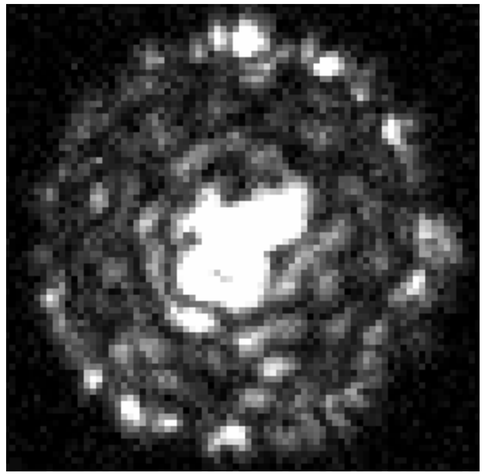
S20160301S0059_spdc

WFIRST HOWFS

HCIT: Eric Cady, Brian Kern

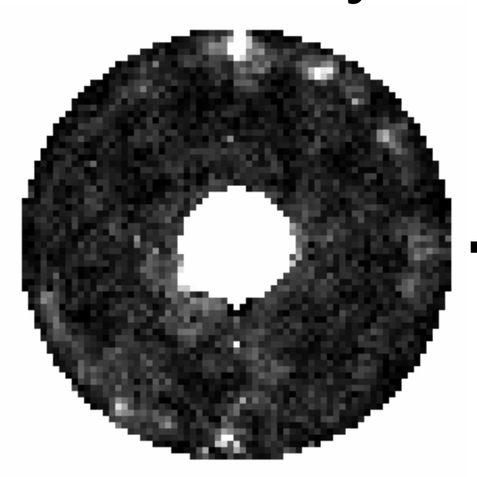
- HOWFS uses science camera images themselves

measured intensity



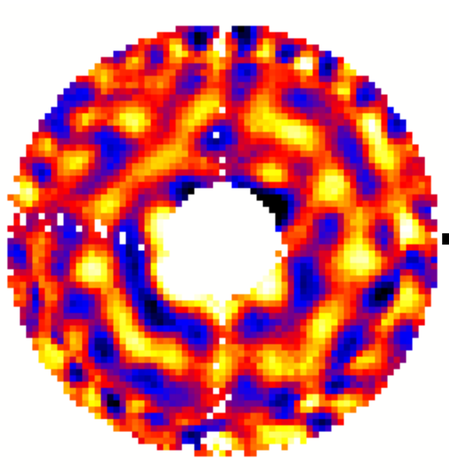
=

incoherent intensity



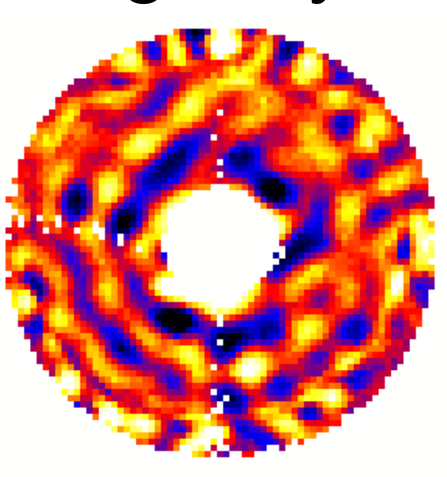
+

coherent real E



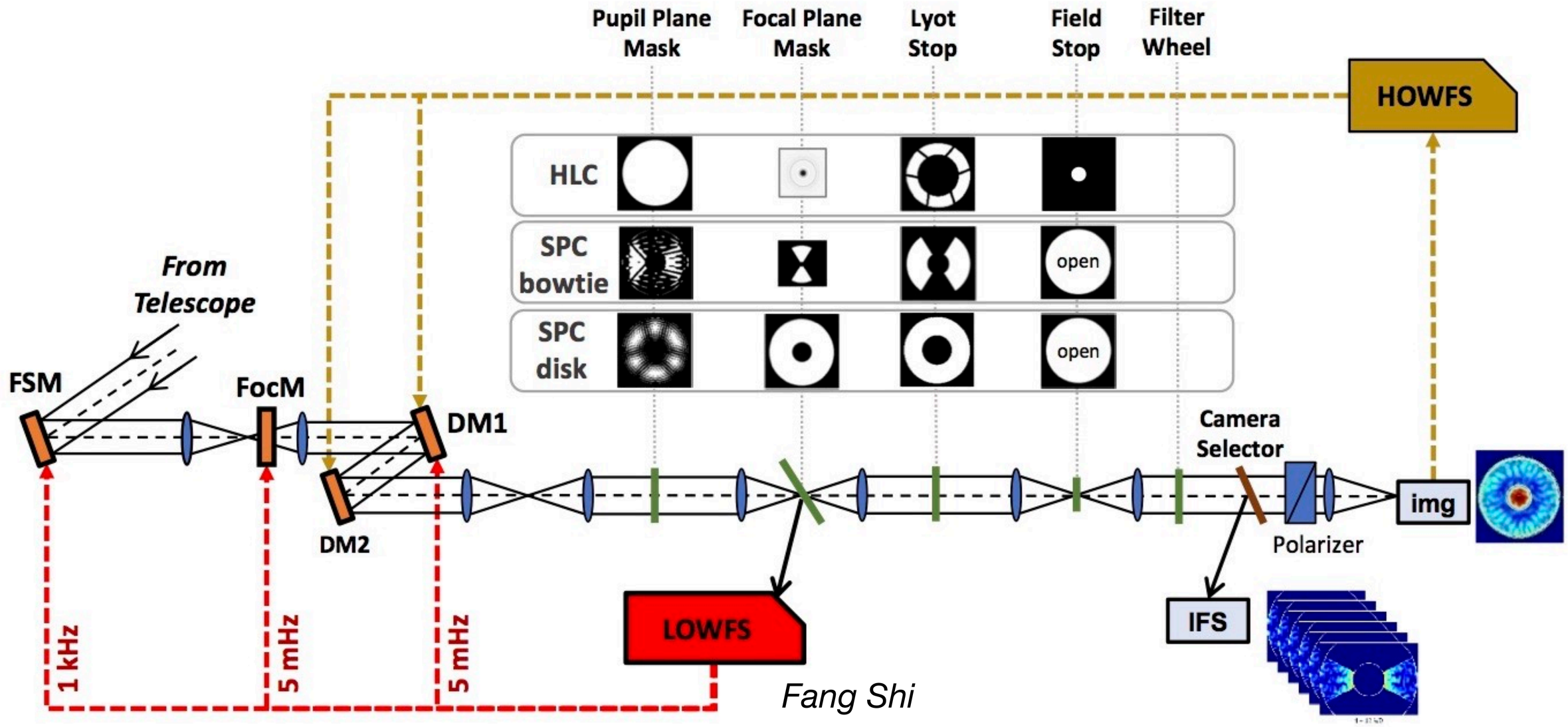
+ i

coherent imaginary E



$|\ \ |^2$

- realtime x/y centering location of star in every science frame
- contribution from Z2-Z11 = input to PCA?



Fang Shi

What is the minimal AO data we need to save?

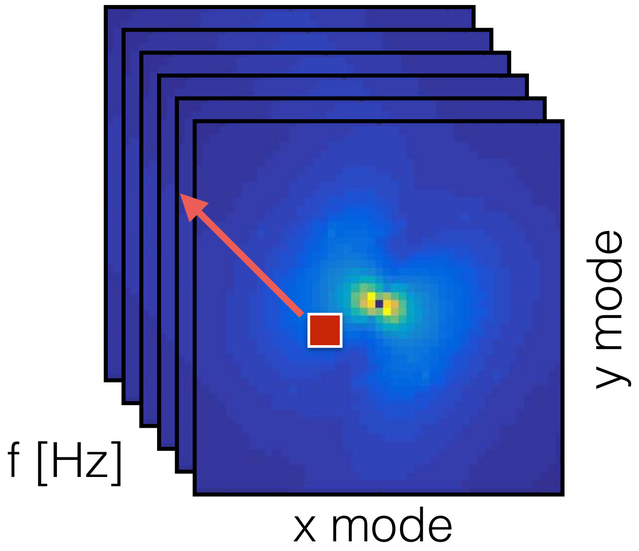
- Analyze system performance?
- Complement focal plane WFS?
- Complement data reduction?
- What cadence?
- Save everything? Realtime process?
- S/N & error tolerance?
- ?

ground vs. space?

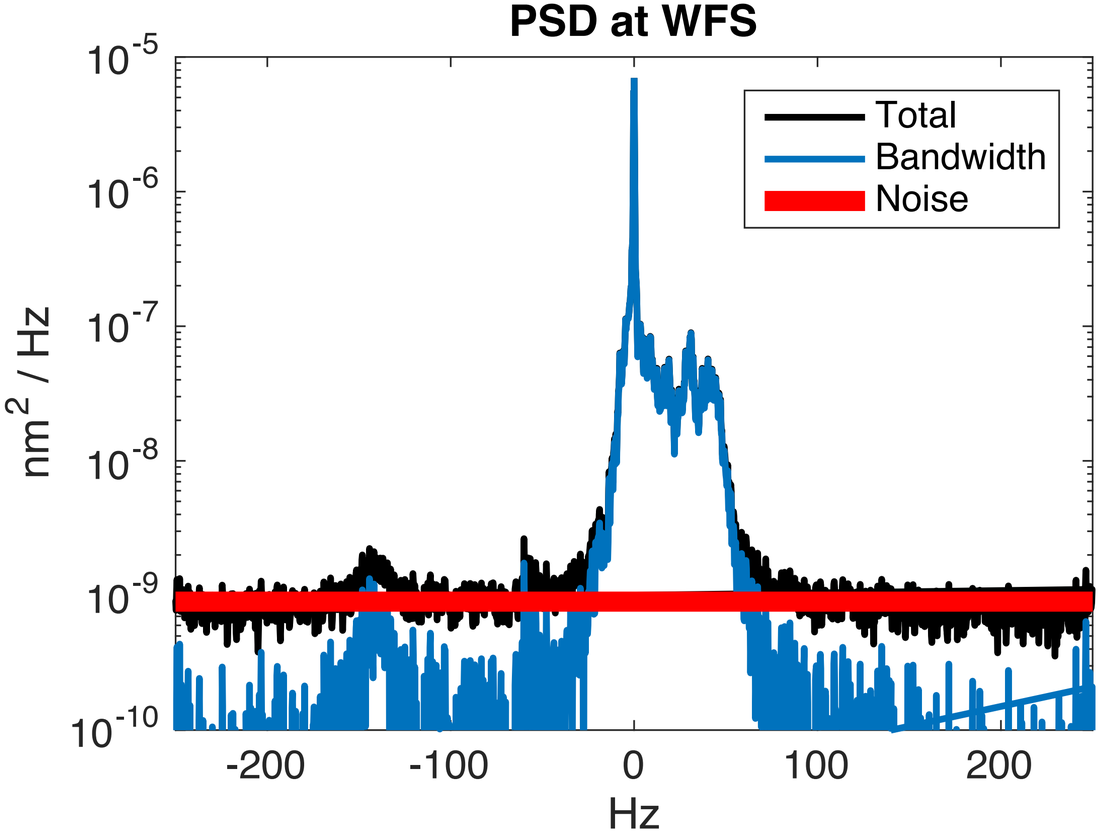
Summary

- Reach specs on *current* systems
  - Develop AO telem pipelines & infrastructure
  - Identify factors limiting *astrophysics*, not WFE
- Enable post-processing on *future* systems
  - Include telemetry in design
  - Save as much data as we can

AO WFE : bandwidth & noise



PSD for mode
$[x_i, y_i]$



atmosphere errors
"bandwidth WFE"

photon/read noise
"noise WFE"