WAVEFRONT SENSING IN SPACE FROM THE PICTURE-B SOUNDING ROCKET

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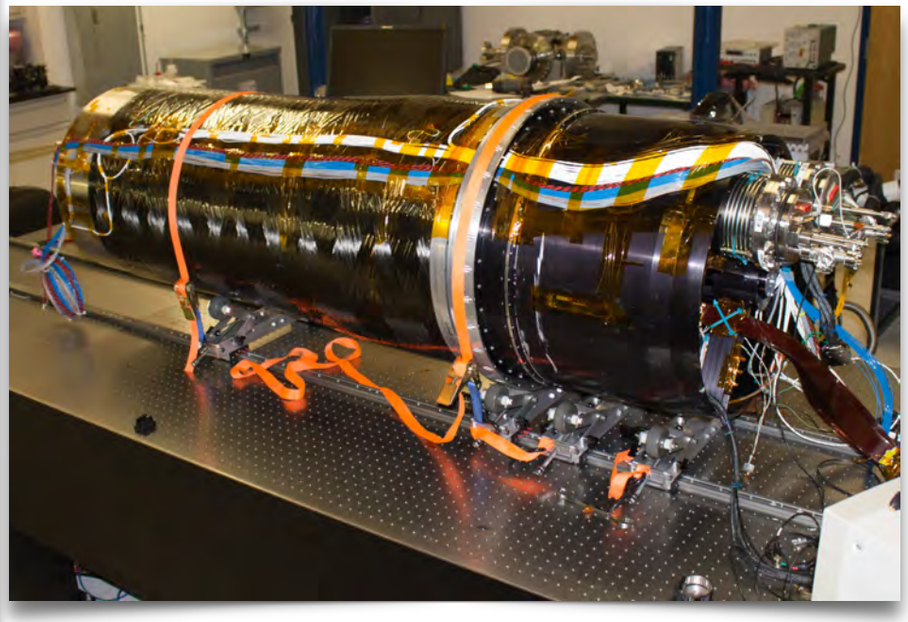

Acknowledgements:
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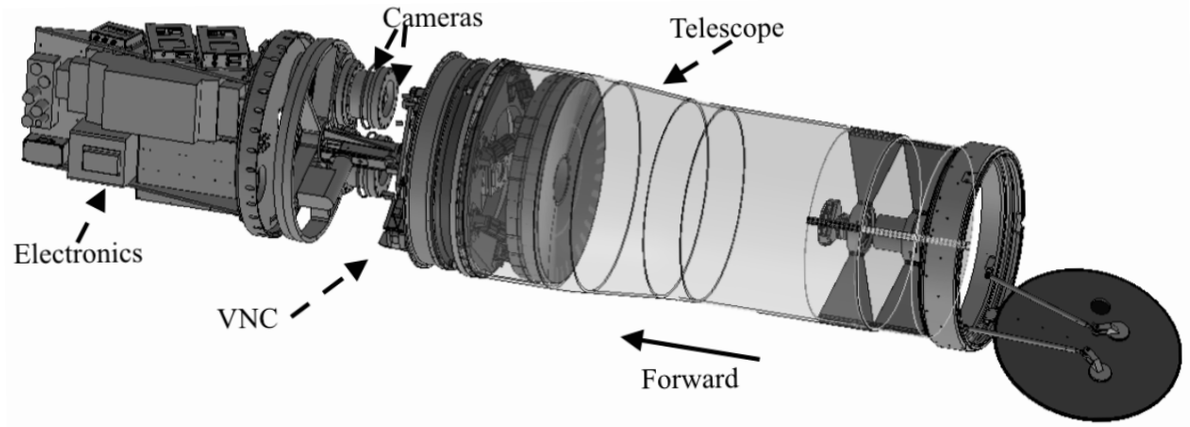
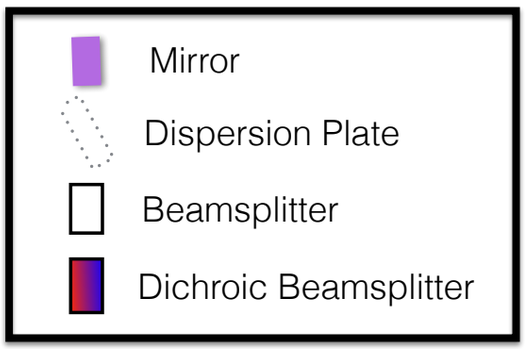
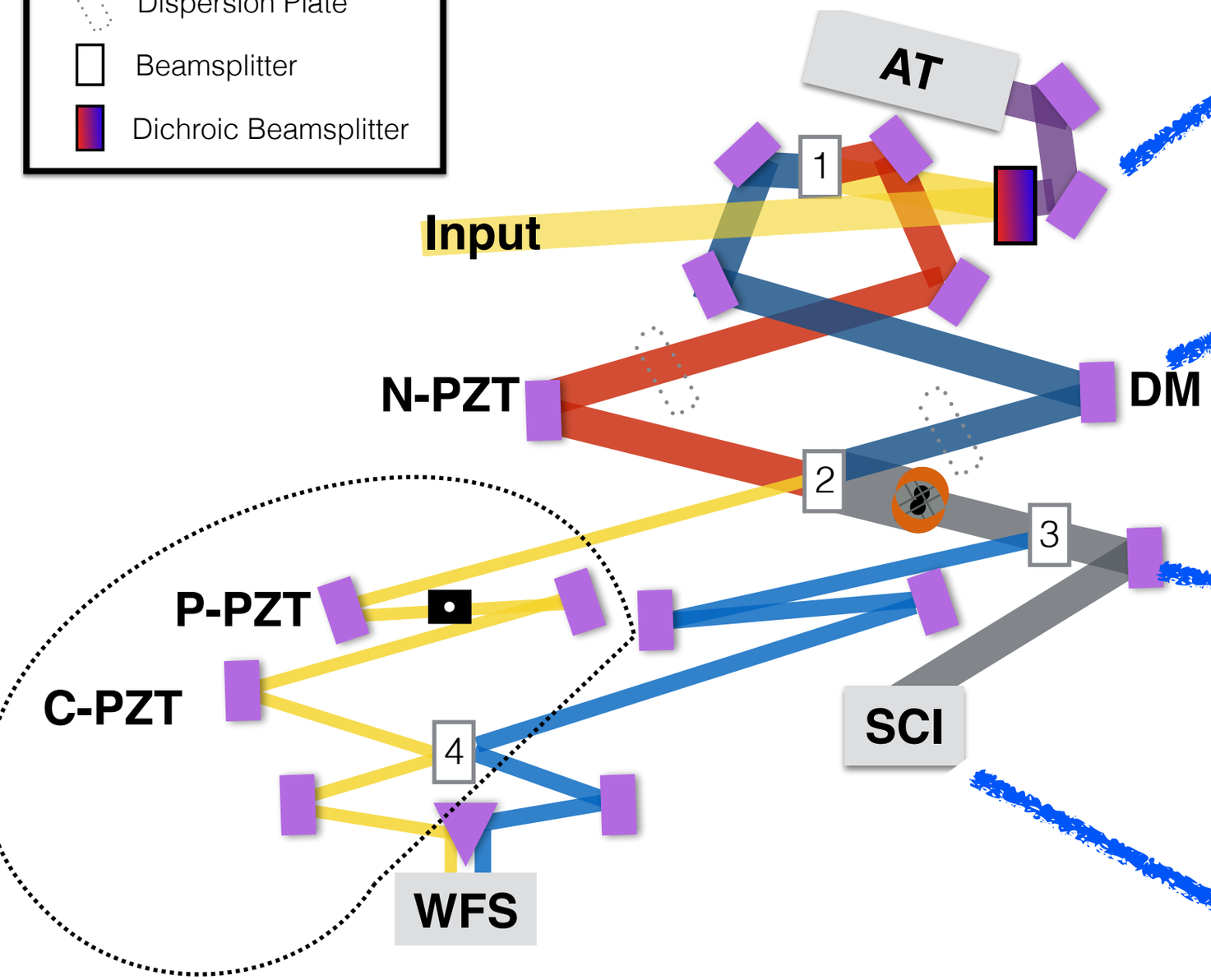
Planet Imaging Coronagraphic Technology Using a Reconfigurable Experimental Base

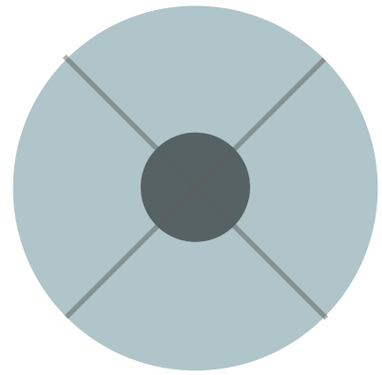


VISIBLE NULLING CORONAGRAPH

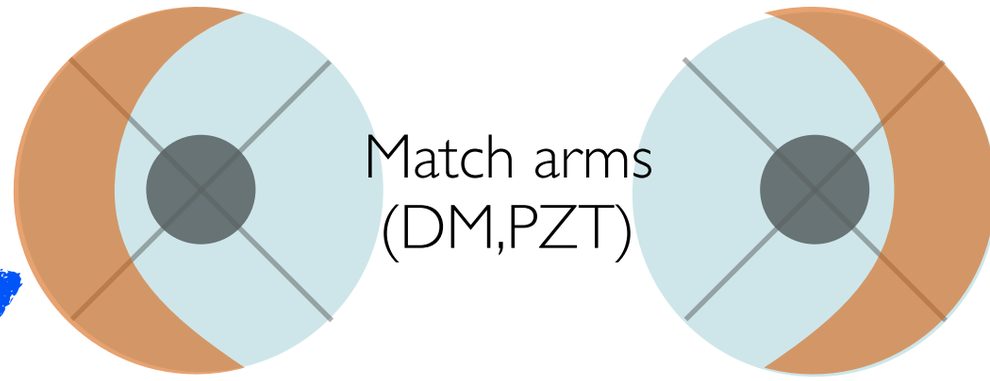
A lateral shearing interferometer
built for PICTURE at JPL





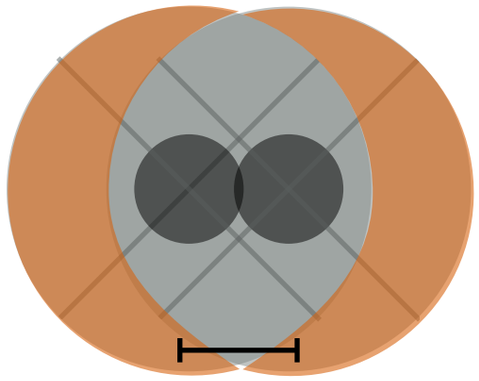


Split and shear beam:

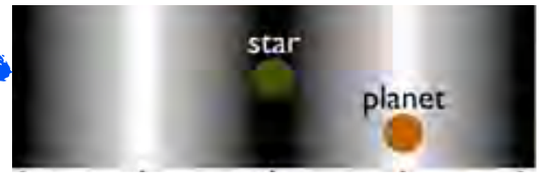


Match arms
(DM,PZT)

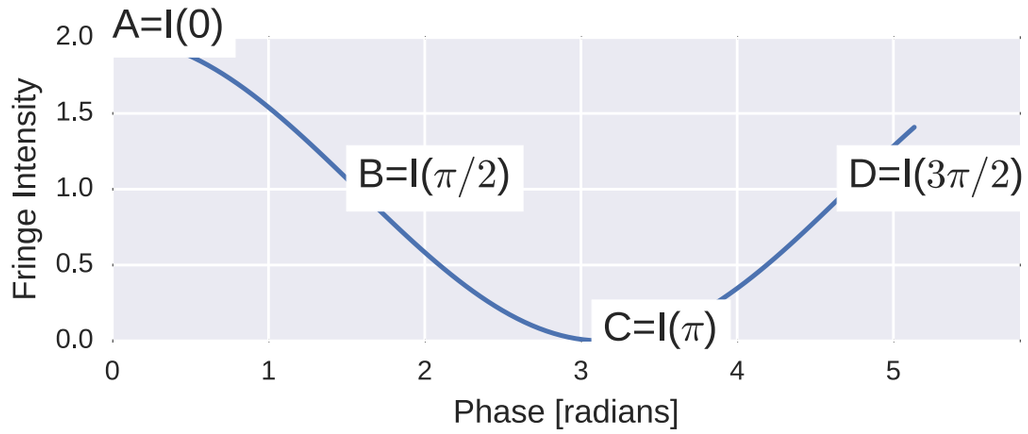
Recombine and mask:



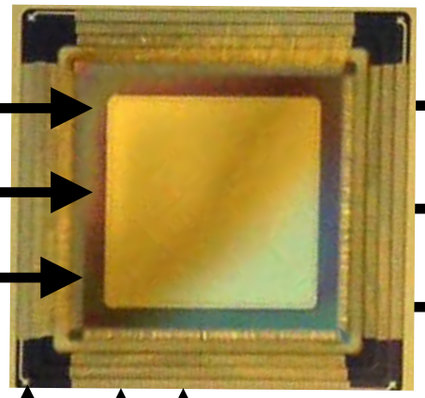
baseline=0.15m



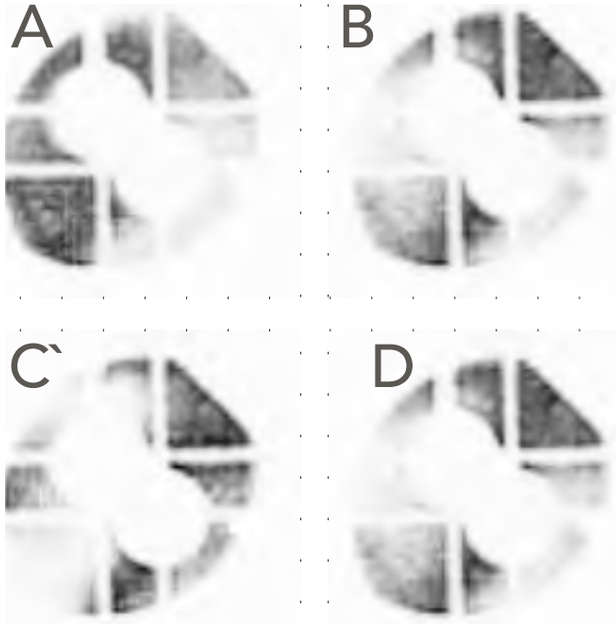
CONCEPT OF WAVEFRONT SENSING OPERATION: NULLER STEPPING MEASURES MISMATCH BETWEEN ARMS



Tip/Tilt/Piston
& MEMS Kilo-DM Deformable Mirror
Correction

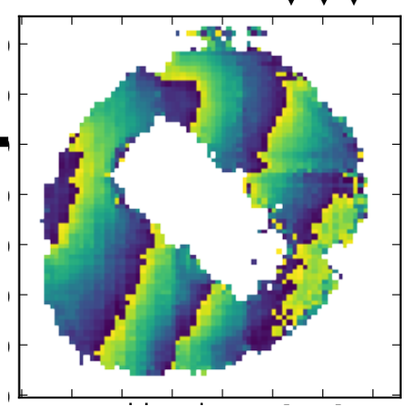


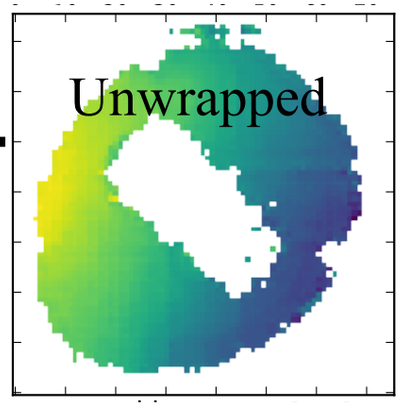
Sheared
Wavefront



(Science
Camera
Saturated)

Wrapped
Phase Error



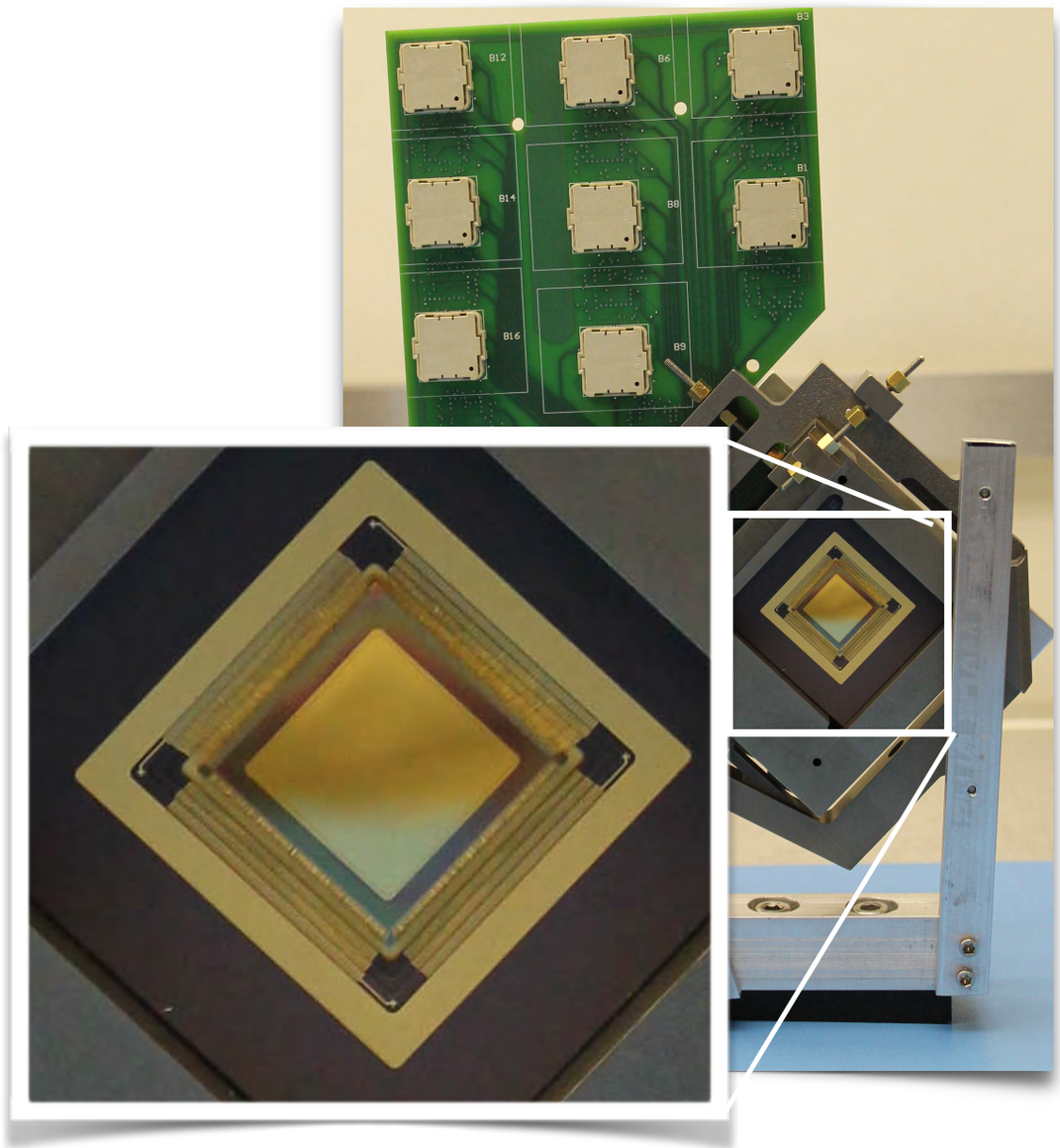


DM actuators
+ PZT TTP

PAYLOAD REFURBISHING

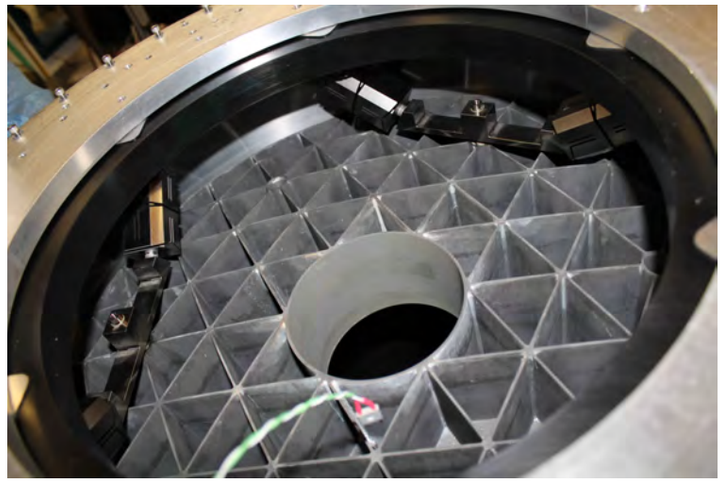
NEW DEFORMABLE MIRROR ASSEMBLY

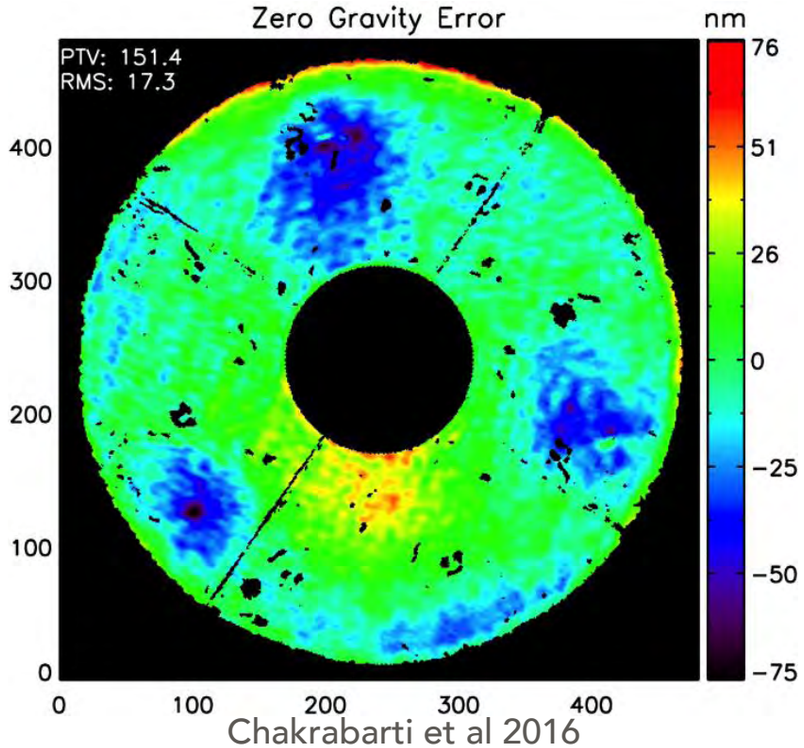
- Replacement MEMS deformable Mirror (Boston Micromachines Inc. Kilo-DM)
- Reinforce Polyimide Cables



NEW LIGHTWEIGHT PRIMARY MIRROR

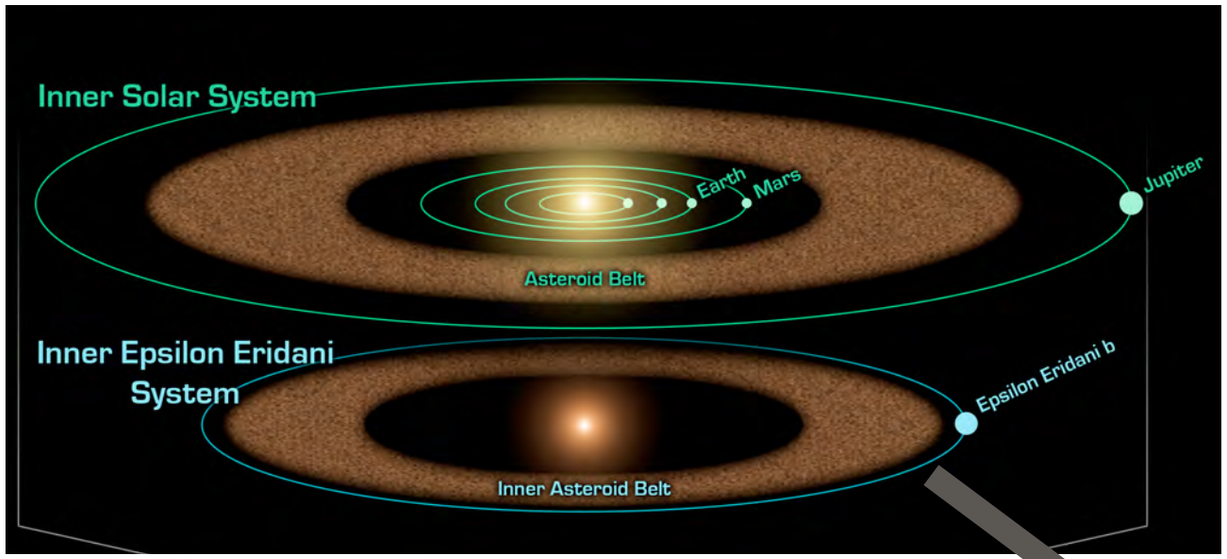
- Built by AOA Xinetics (Northrop Grumman)
- SiC Substrate with a Si cladding.
- Lambda/4 surface at low spatial frequencies





Chakrabarti et al 2016

MODEL DISK + LAB CONTRAST



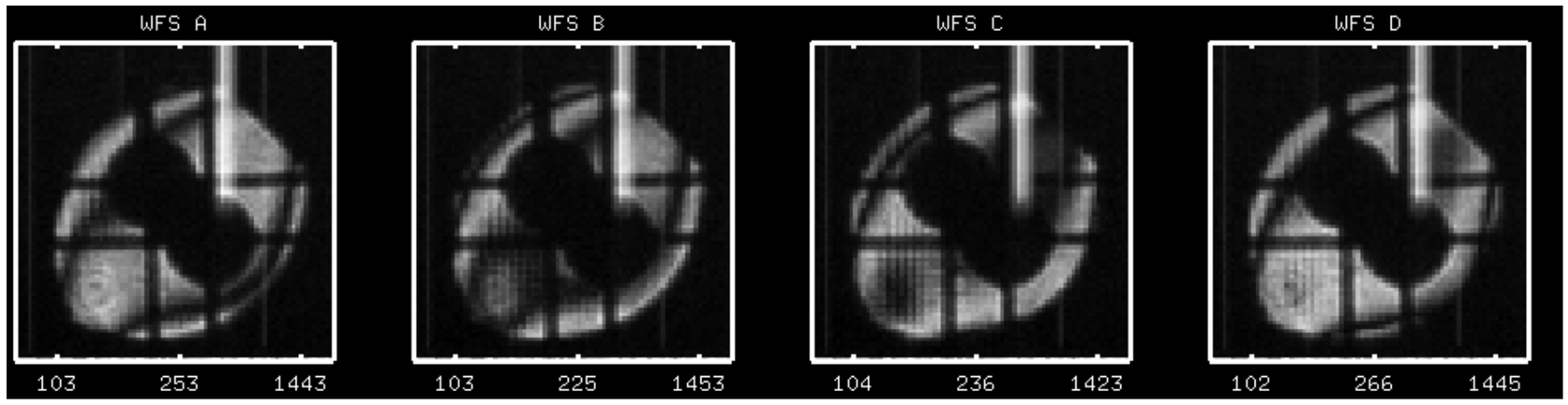
(http://www.jpl.nasa.gov, after Backman et al 2009)

The flight payload's lab performance was sufficient for testing the 3AU dust ring prediction.

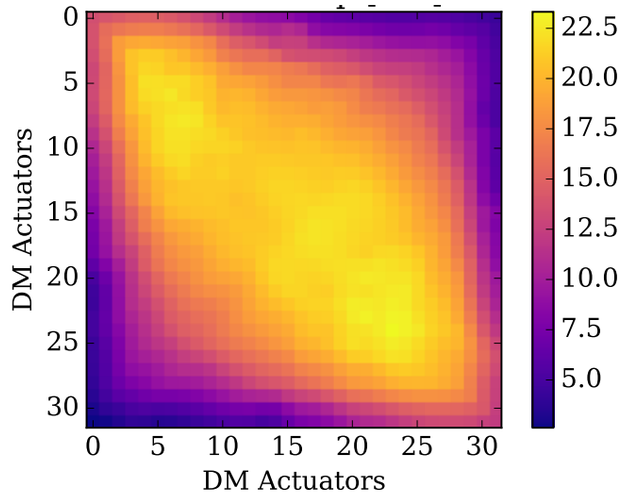
Courtesy WSMR/ NASA WFF

DEFORMABLE MIRROR ACTUATED IN FLIGHT

Unpowered deformable mirror fringes show residual curvature (*Laboratory*):



Pre-recorded deformable mirror flat map applied in flight to remove curvature:



Flat *Flight* Wavefront Sensor Measurements of Pupil Plane Fringes:

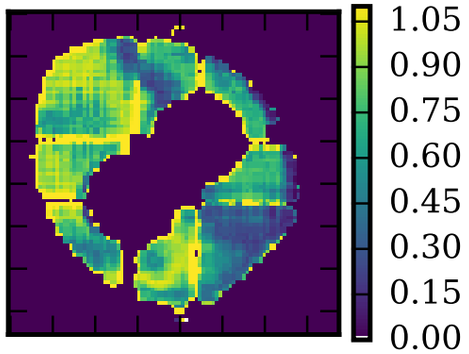
A, PZT: 10,8.77,8.92μm

B, PZT: 10,8.87,9.01μm

C, PZT: 10,8.97,9.11μm

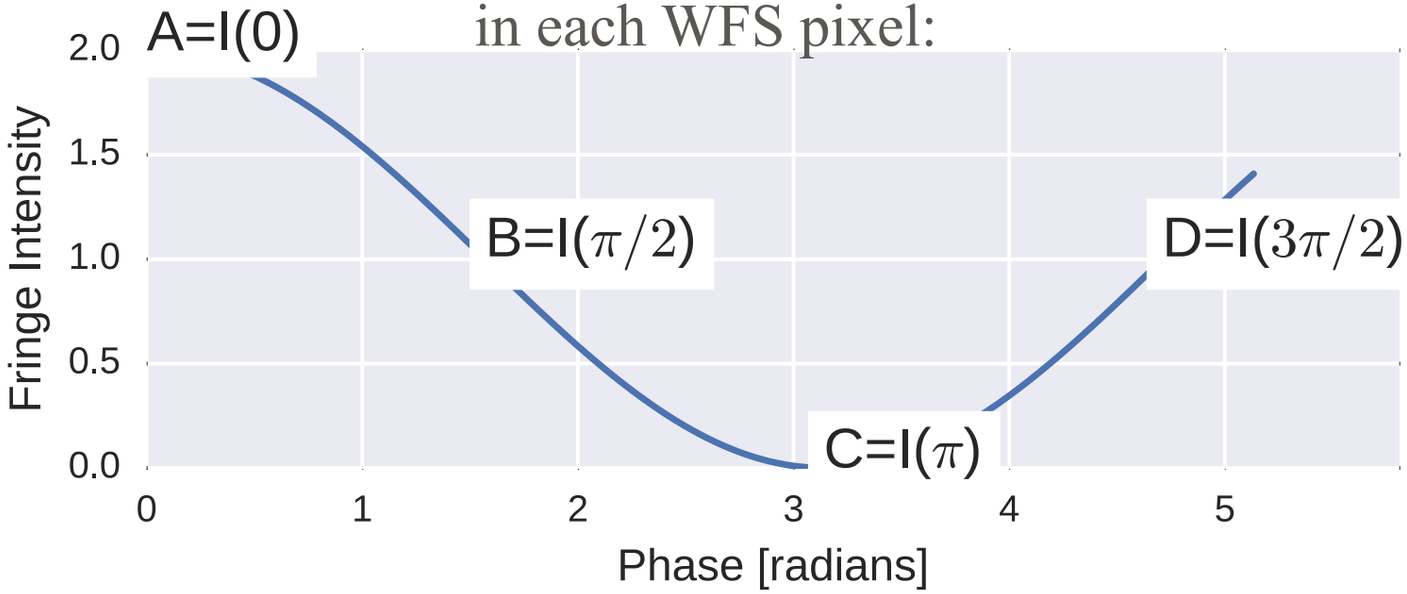
D, PZT: 10,9.07,9.21μm

Visibility

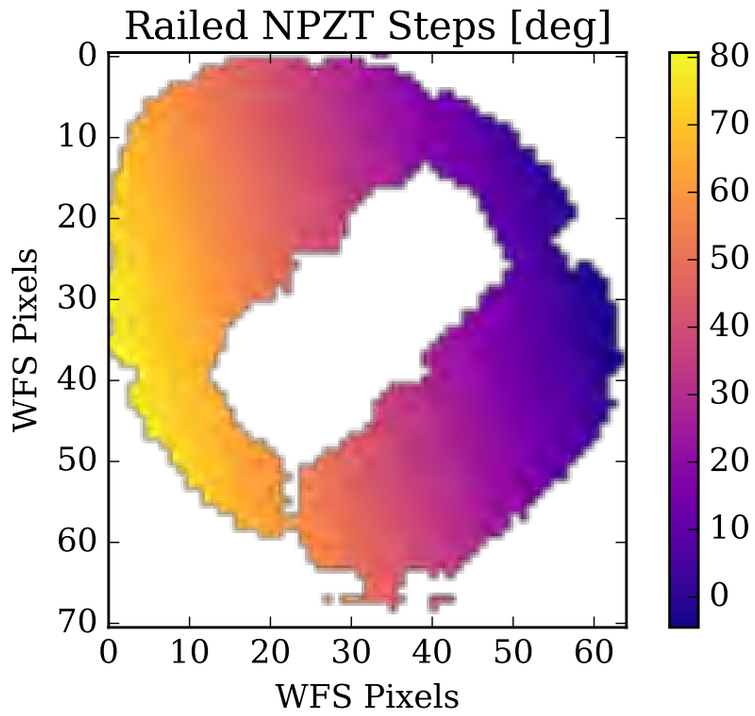


STEPPING N-PZT RAILED IN FLIGHT

Design, 90 degree phase steps in each WFS pixel:



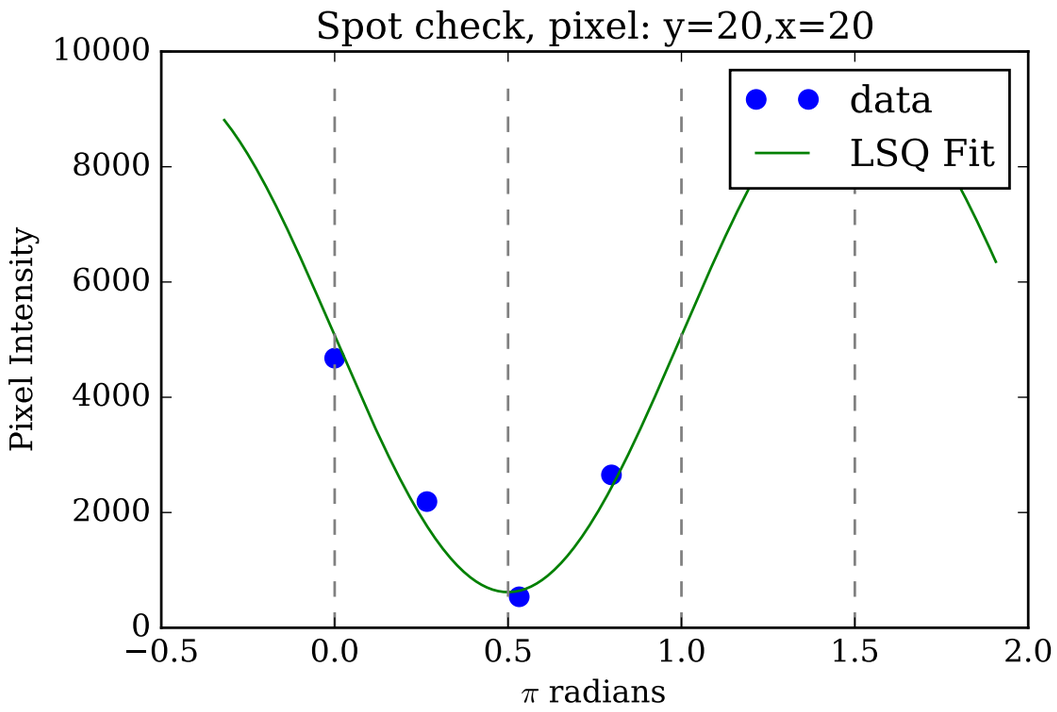
Reality, Gradient in step size:



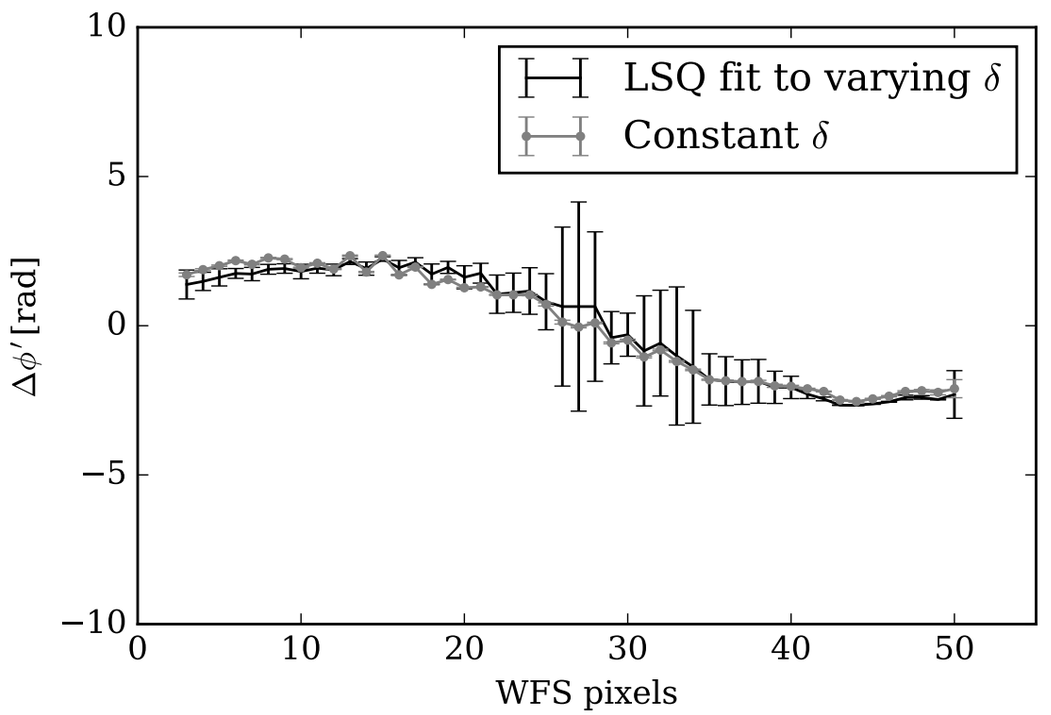
- Full range of PZT is 10 microns.
- One actuator railed at 10 microns and the other two stepped.
- Post-flight laboratory testing found the optimal NPZT position has shifted several microns compared to the prelaunch alignment.
- This shift is likely due to motion of the 6-degree-of-freedom DM mount.
- Whether this shift occurred prior to the payload acquiring the target or upon reentry and impact cannot be definitively determined since flight motion of NPZT could also have been due to a large temperature gradient within the payload.

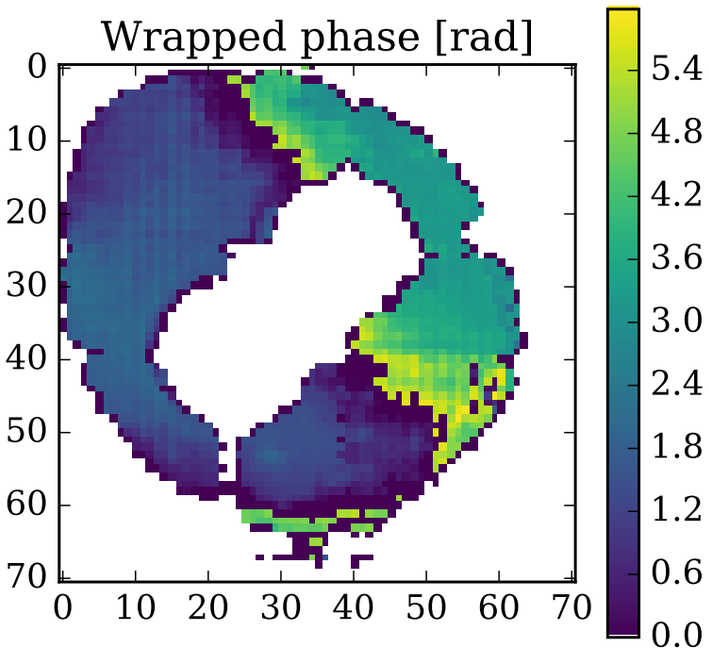
SIMPLE PHASE ERROR MEASUREMENT DOESN'T APPLY

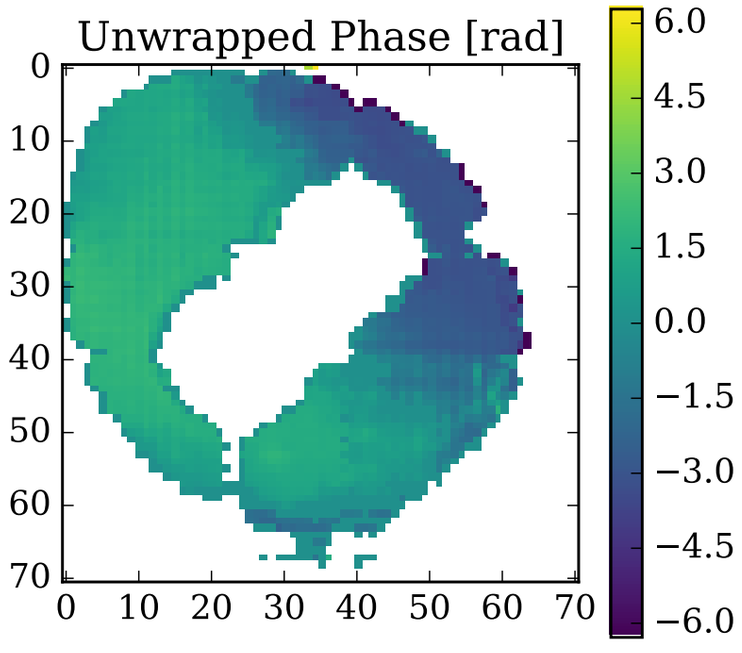
ALTERNATIVE, LEAST SQUARES FIT TO A PIXEL:

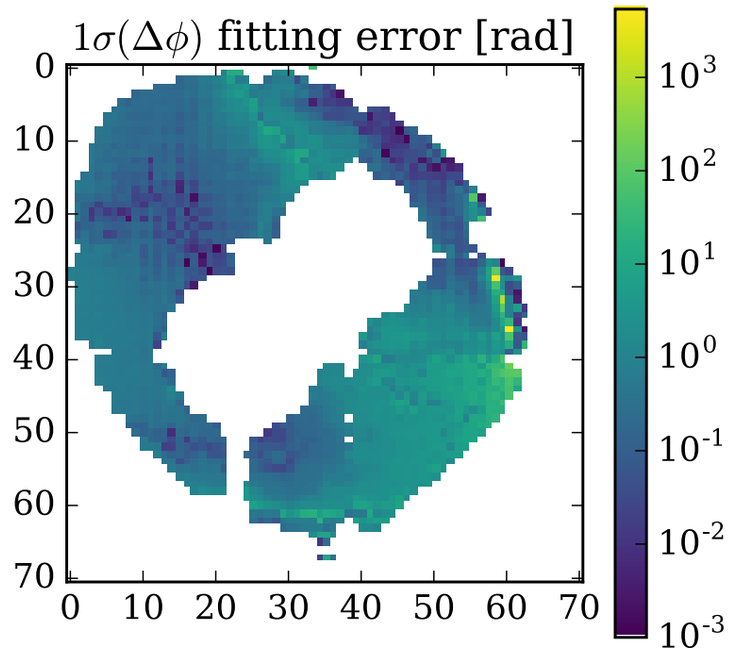


BUT ASSUMING 90 DEGREE STEPS GIVES A COMPARABLE RESULT:



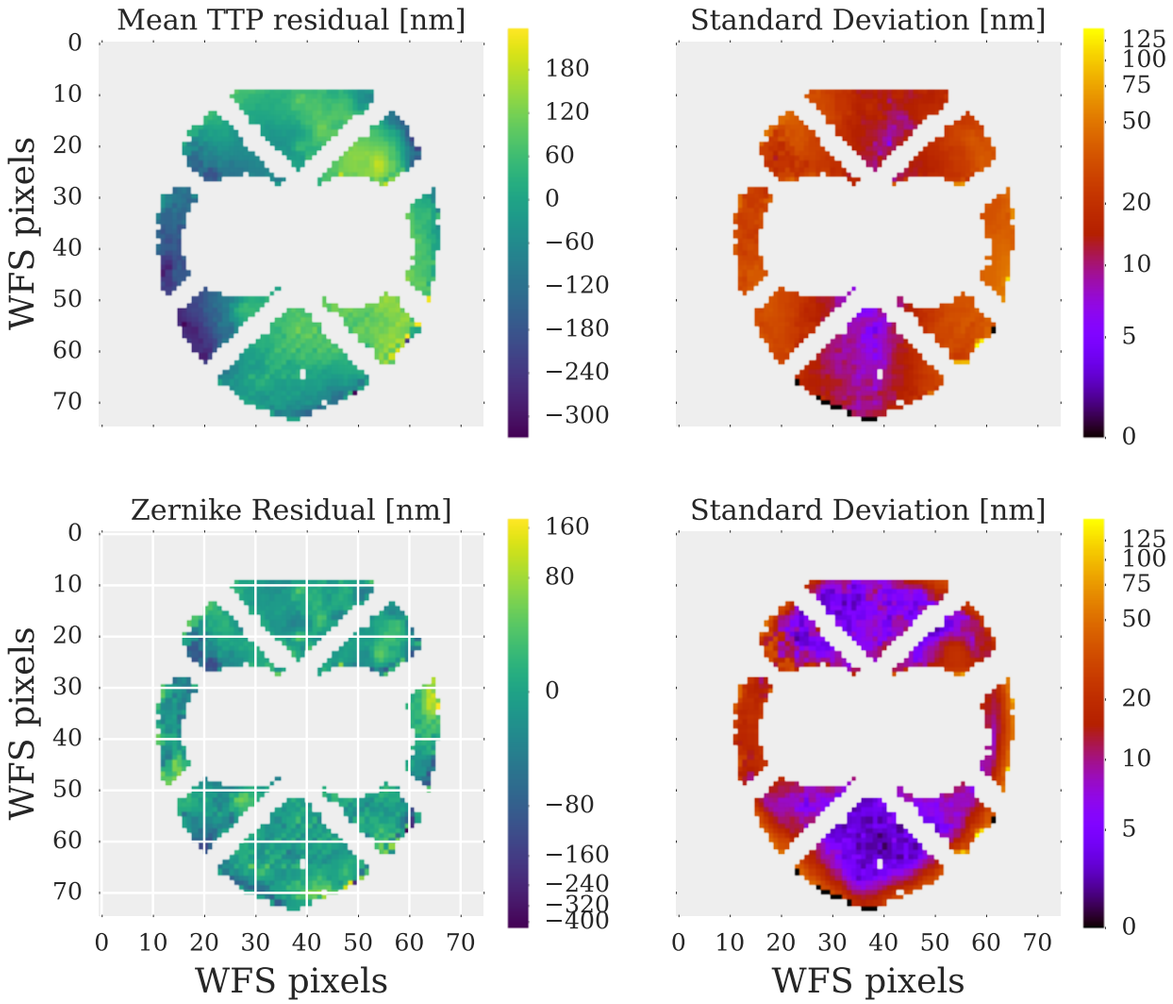




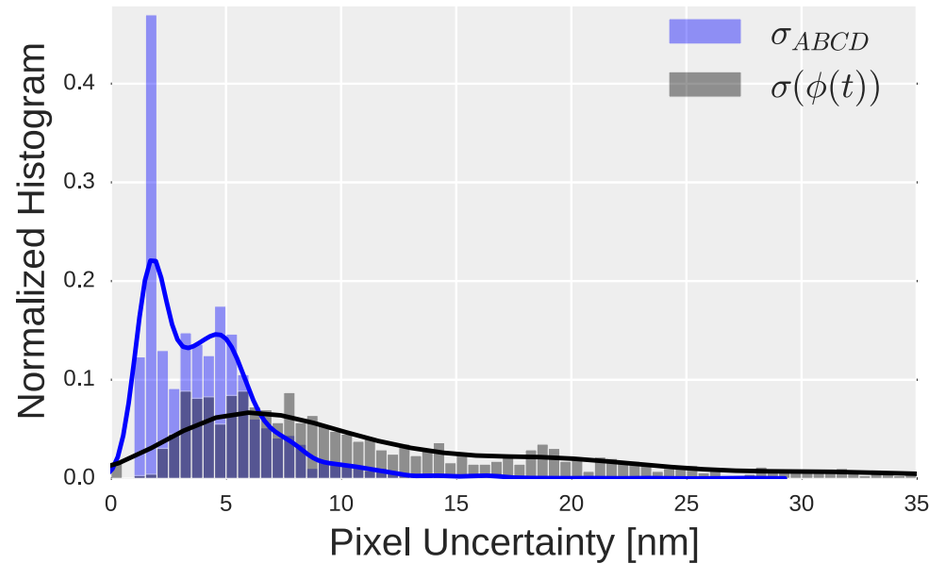


RESIDUAL ERROR AND ZERNIKE EVOLUTION

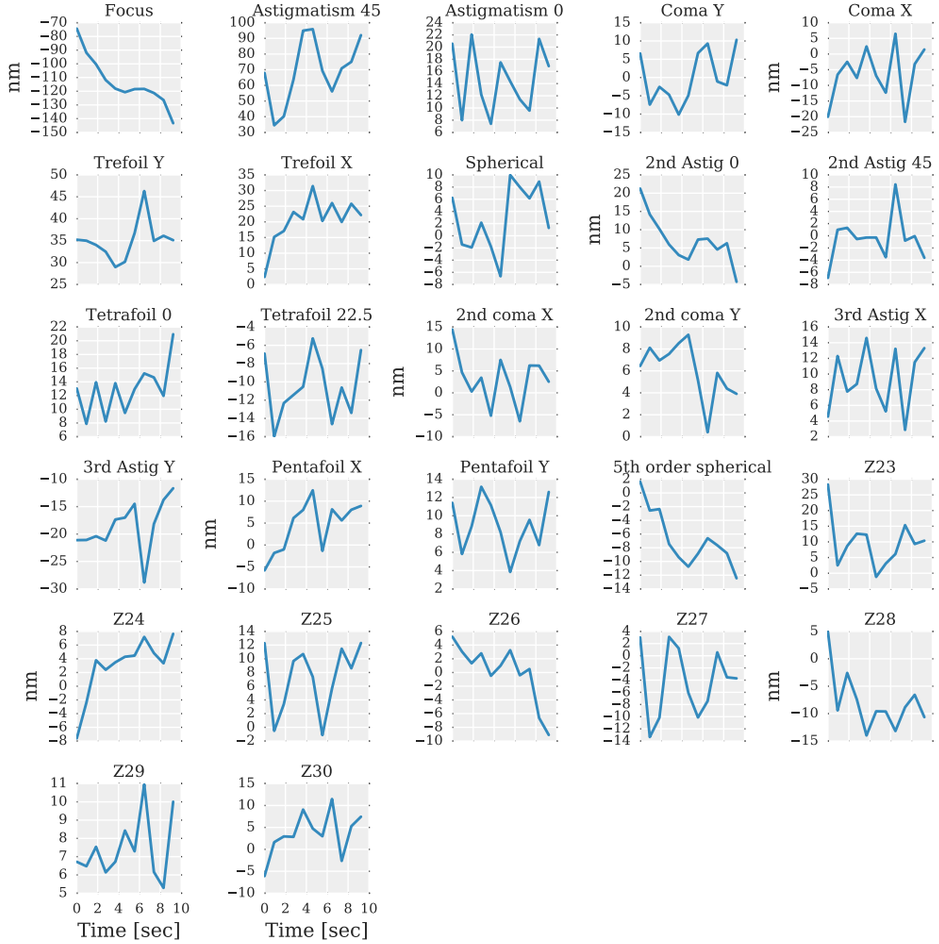
First 11 frames



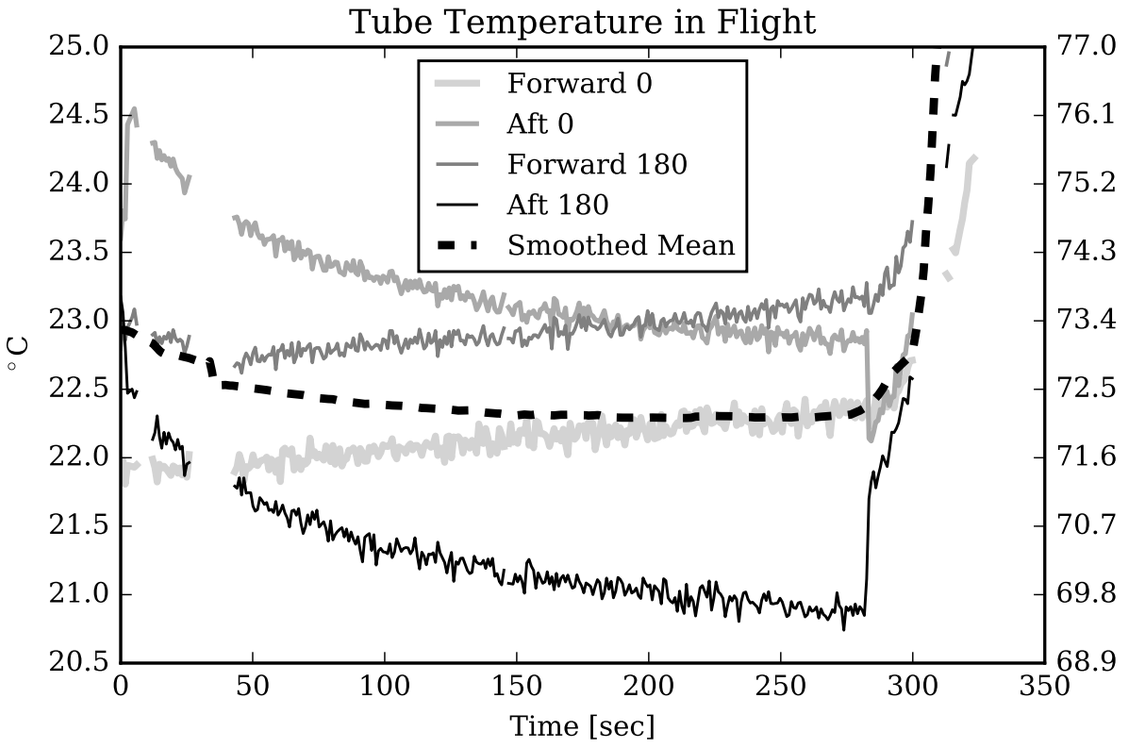
MEASUREMENT TO MEASUREMENT STANDARD DEVIATION



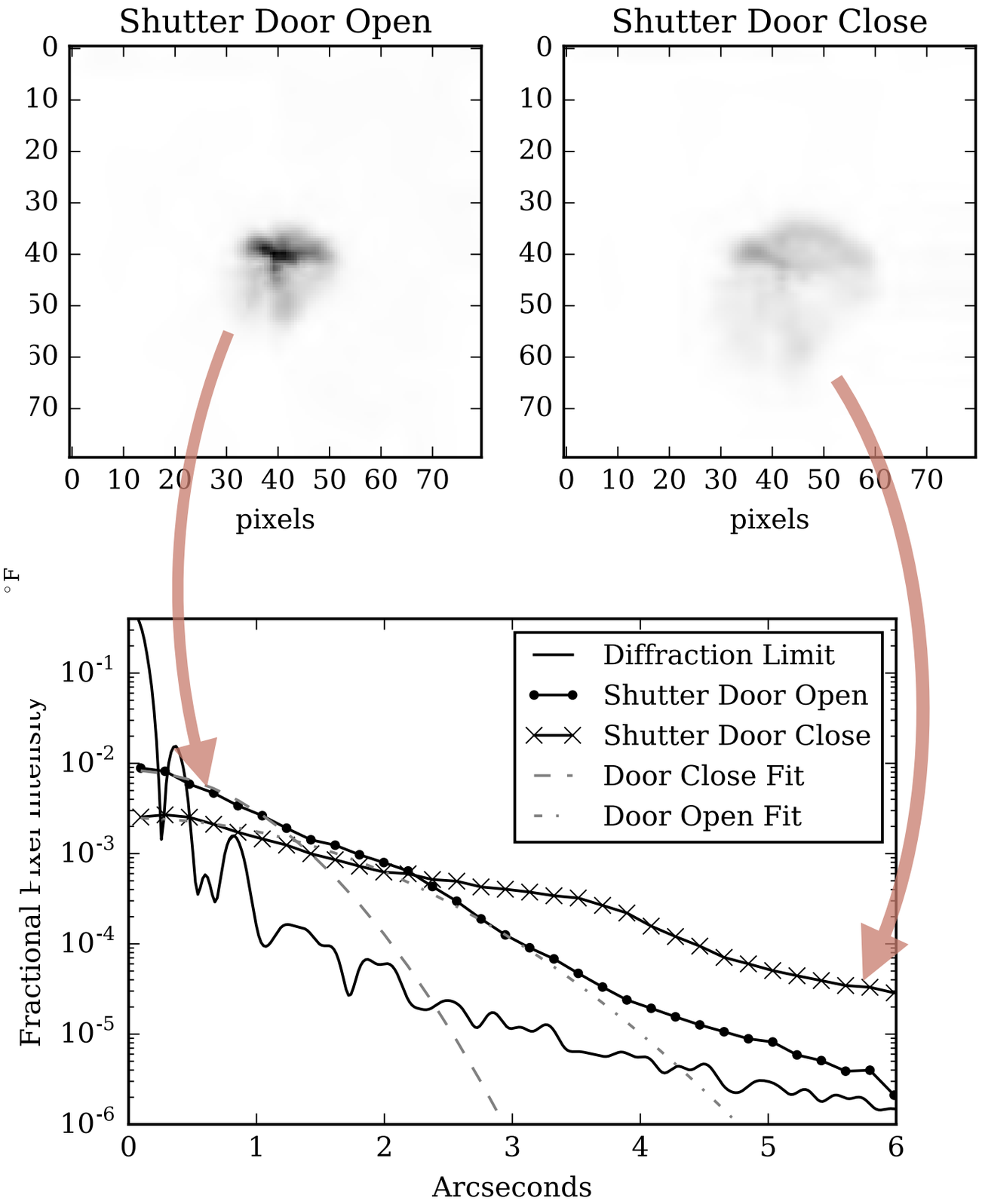
TIME EVOLUTION OF ZERNIKE TERMS



EVOLUTION OF FOCUS IN FLIGHT



This spot size would have prevented testing for the 3AU (1”) radius ring.



PAYLOAD
RECOVERED INTACT

Courtesy WSMR/ NASA WFF

TIMELINE

Year

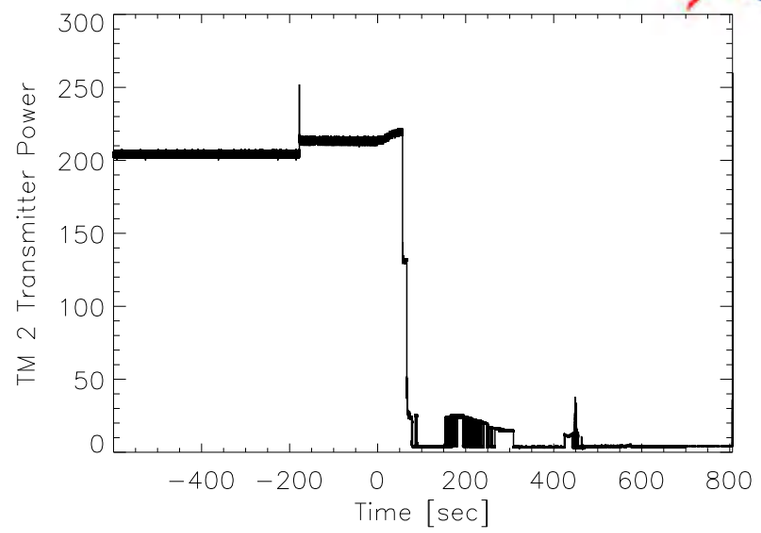
2005

PICTURE

Planet Imaging Concept Testbed Using a Rocket Experiment

2011

~5 min Sounding Rocket Flight of
Visible Nulling Coronagraph
to image epsilon Eridani.
2011 Launch:
Fine Pointing Success and Telemetry Failure (Mendillo et al 2012a,b)



2012

PICTURE (-B) " "

+ SiC Primary Mirror

Launched November 2015

2015

PICTURE-C

Planetary Imaging Concept Testbed Using a Recoverable Experiment - Coronagraph

Cook et al. 2015

2018

Two Short Duration Balloon flights
One VNC and
one Vector Vortex Coronagraph+MKID
Expected Launches 2017 & 2019.