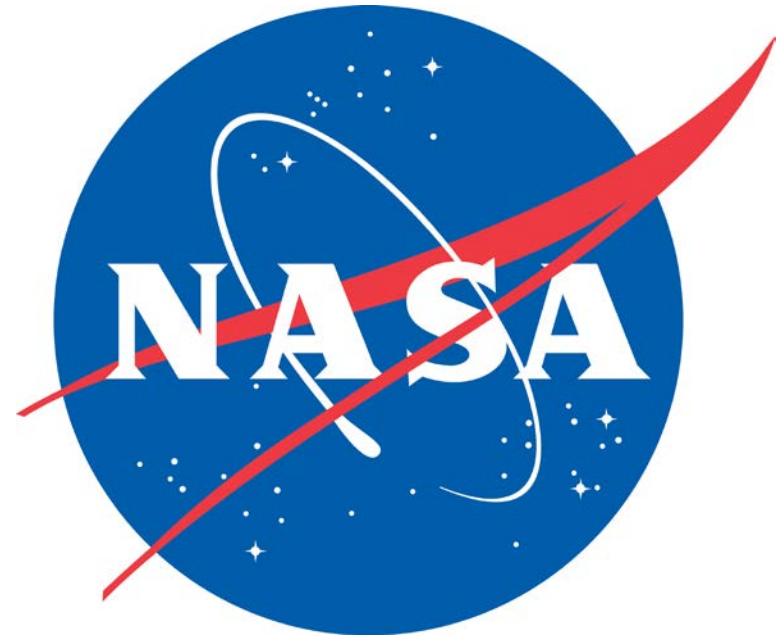


# Analysis of the NGXO telescope x-ray Hartmann data

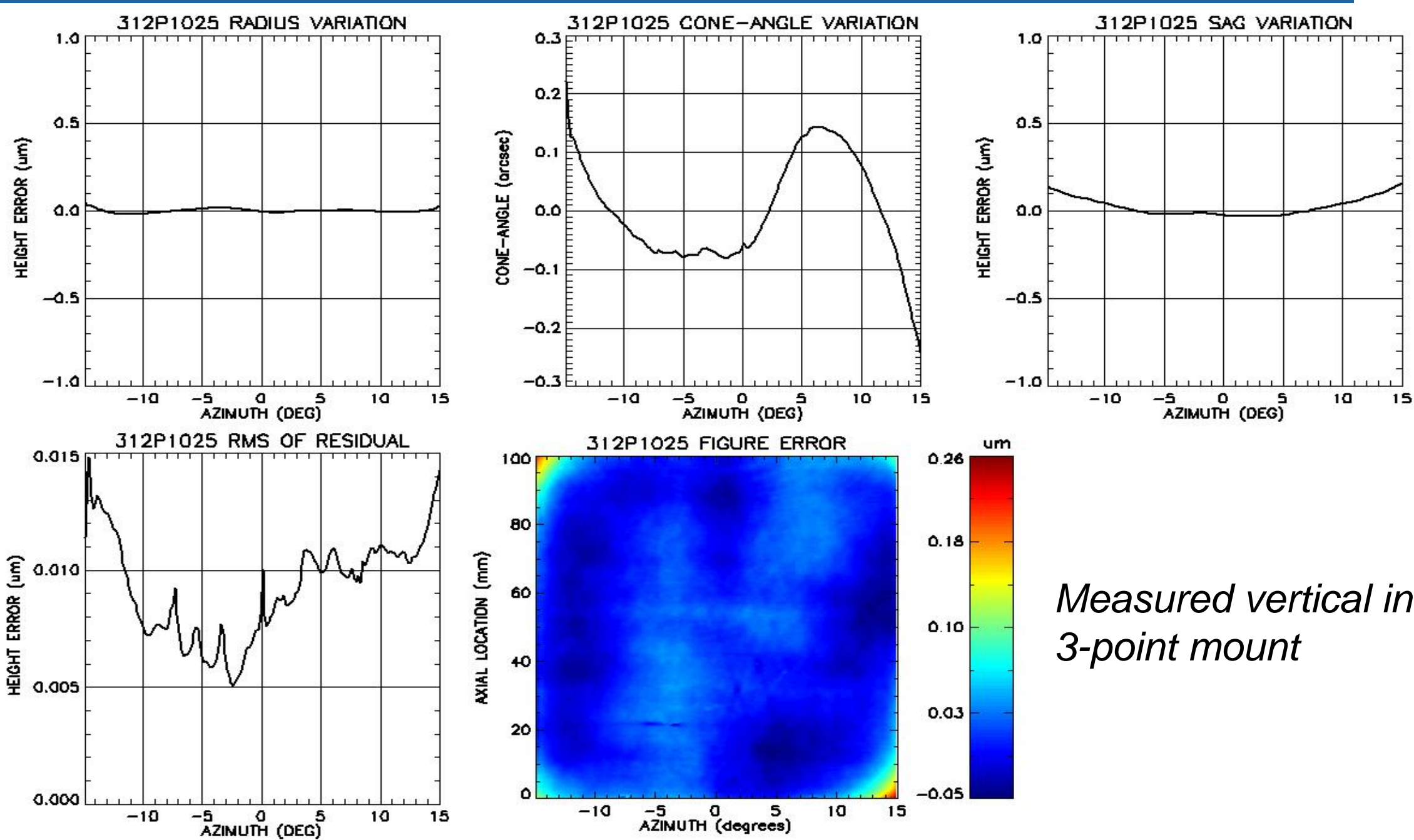
Timo Saha<sup>a</sup>, Vadim Burwitz<sup>b</sup>, Kai-wing Chan<sup>c</sup>, Gisela Hartner<sup>b</sup>, Marlis-Madeleine La Caria<sup>b</sup>, Ryan McClelland<sup>a</sup>, Carlo Pelliciani<sup>b</sup>, Peter Solly<sup>d</sup>, and William Zhang<sup>a</sup>  
NASA-GSFC-USA, MPE-Germany, CRESST-USA, STG Inc-USA



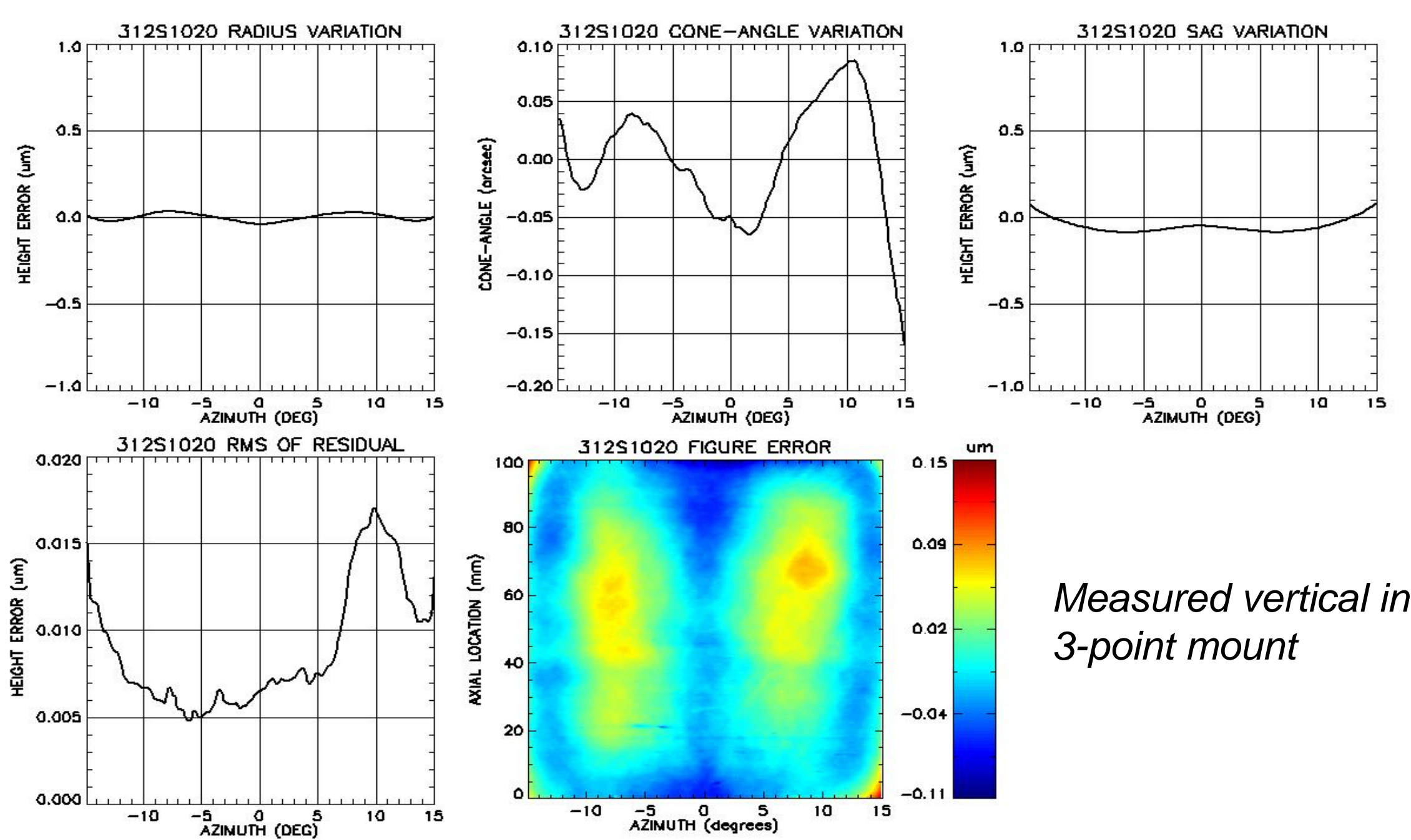
## ABSTRACT

Next Generation X-Ray Optics (NGXO) team at the Goddard Space Flight Center (GSFC) has been developing a new silicon-based grazing incidence mirror technology for future high resolution x-ray astronomical missions. Recently, the GSFC team completed the construction of first few mirror modules that contain one pair of mirrors. One of the mirror pairs was tested in GSFC 600-m long beamline facility and PANTER (Neuried, Germany) 120-m long x-ray beamline facility. Both full aperture x-ray tests, Hartmann tests, and focal plane sweeps were completed. In this paper we present the data analysis process and compare the results from our models to measured x-ray centroid data, x-ray performance data, and out of focus images of the mirror pair.

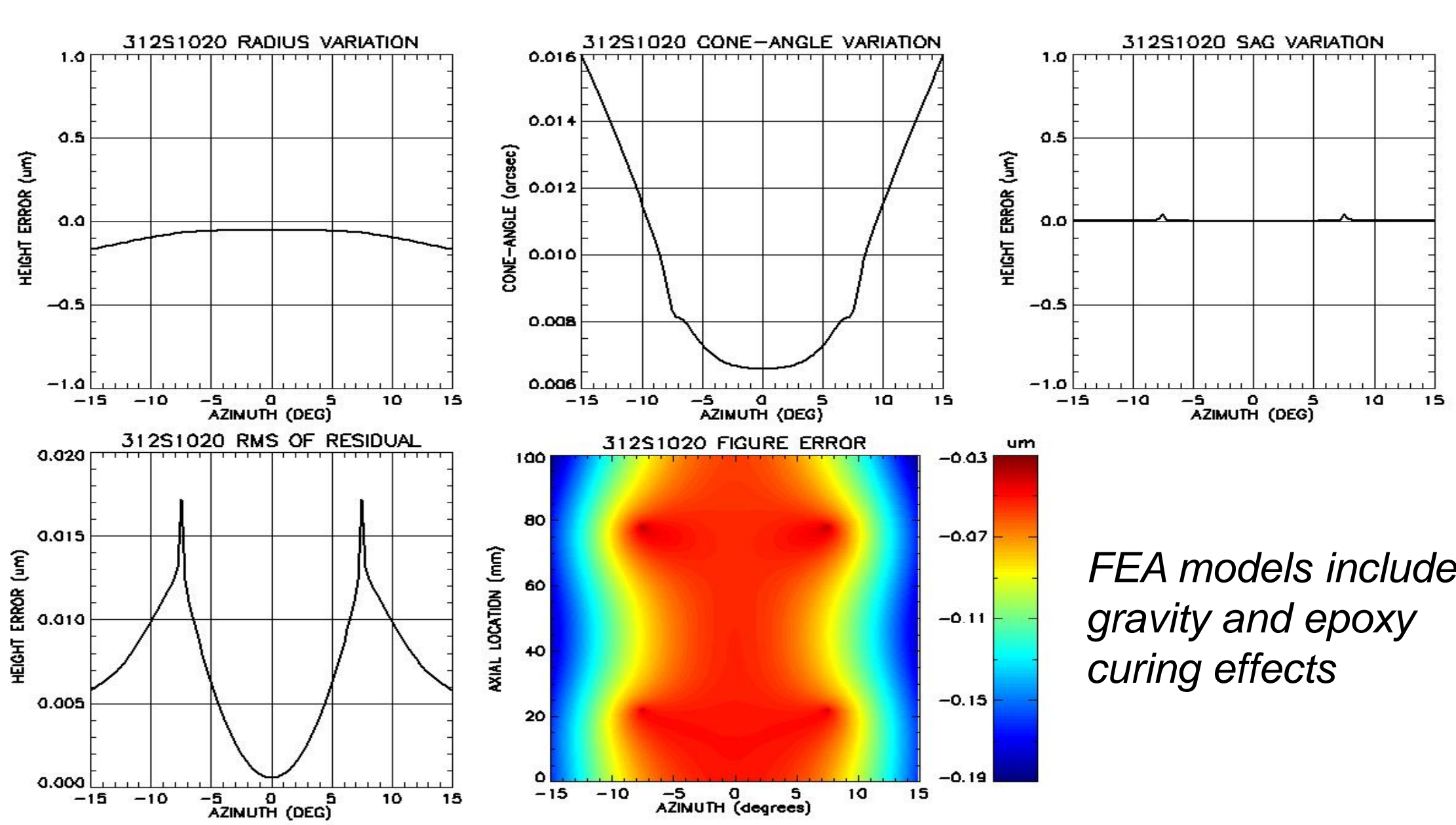
## Primary mirror errors



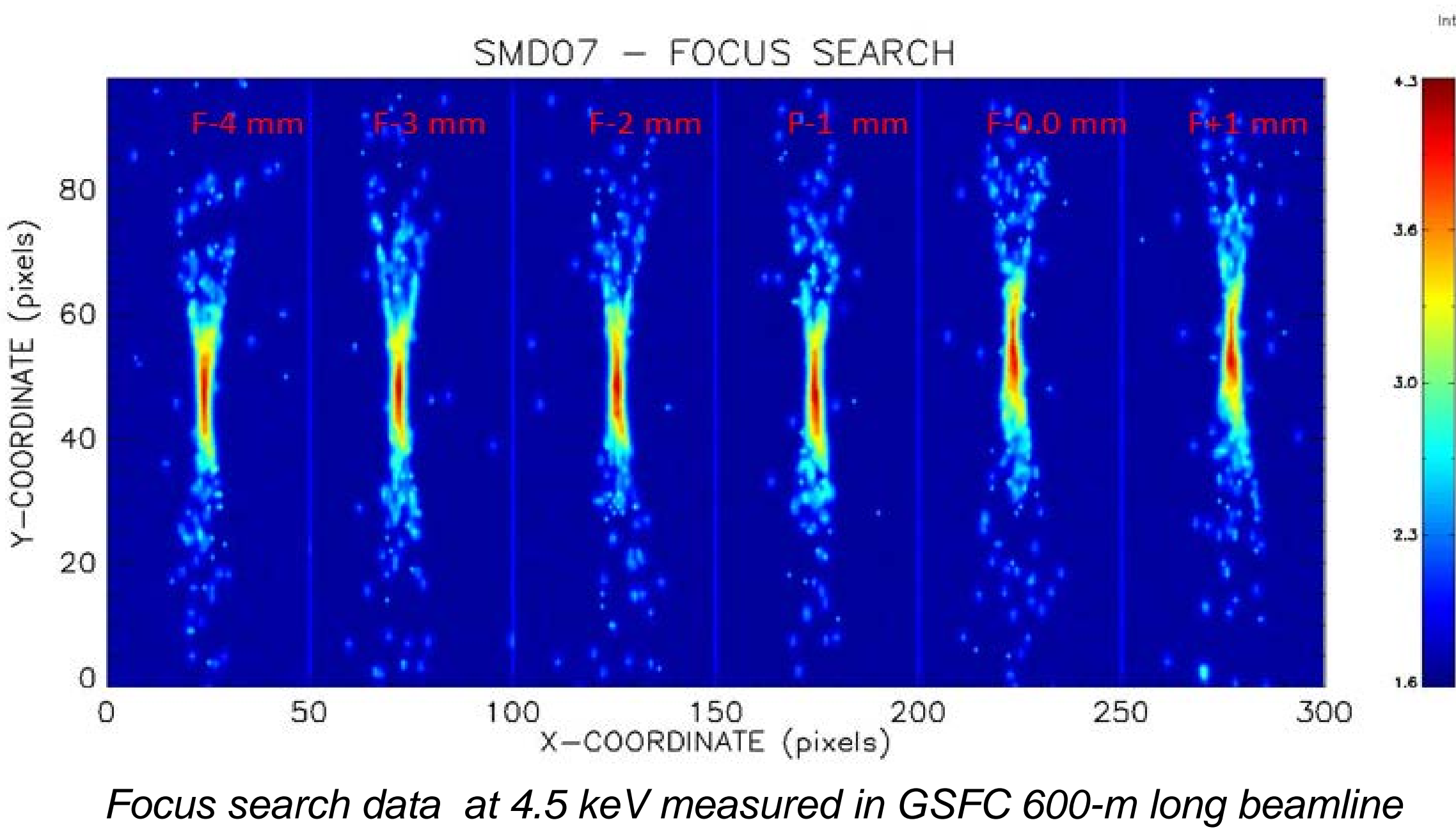
## Secondary mirror errors



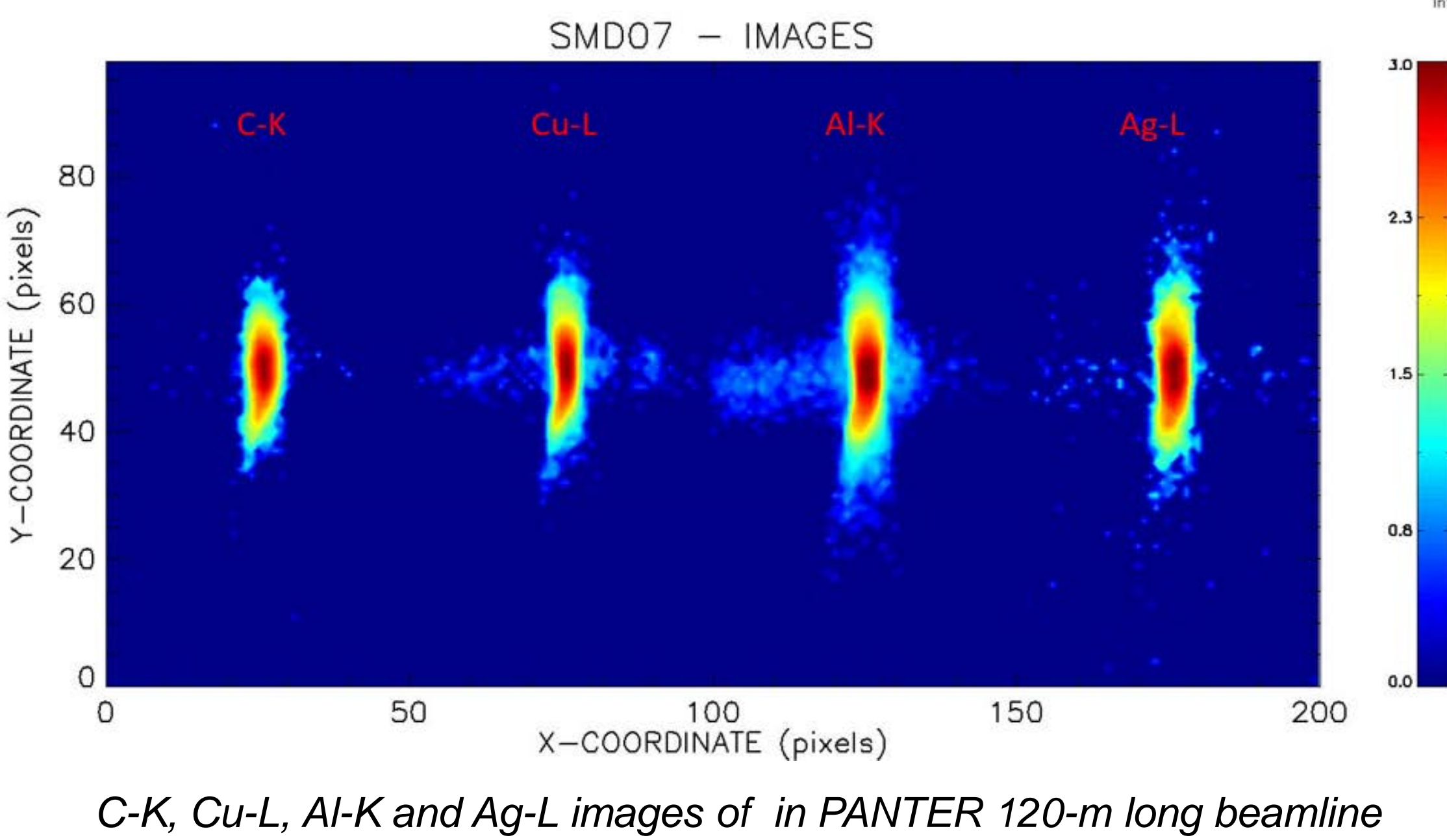
## FEA models of mirrors



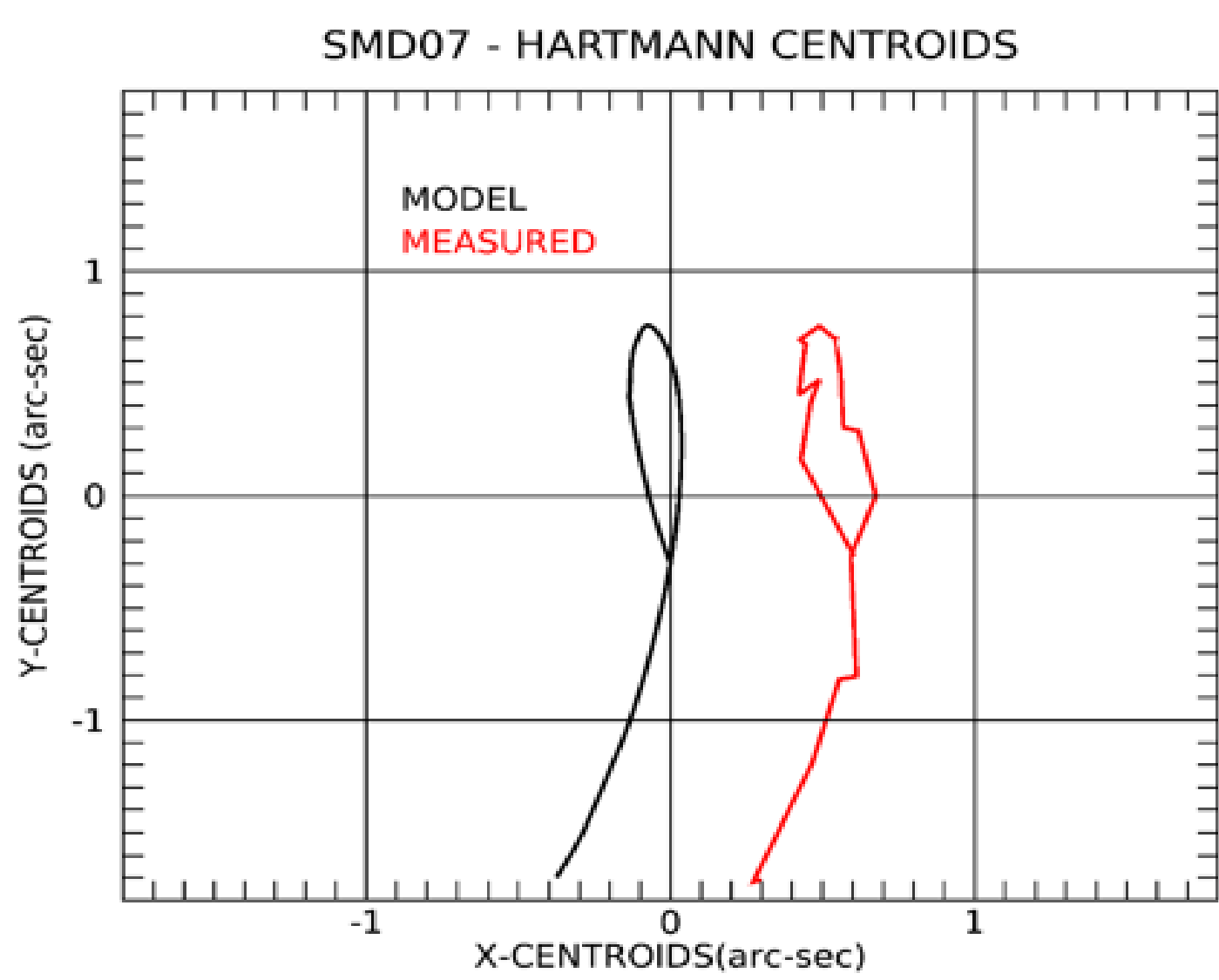
## Images measured at GSFC



## Images measured at Panter

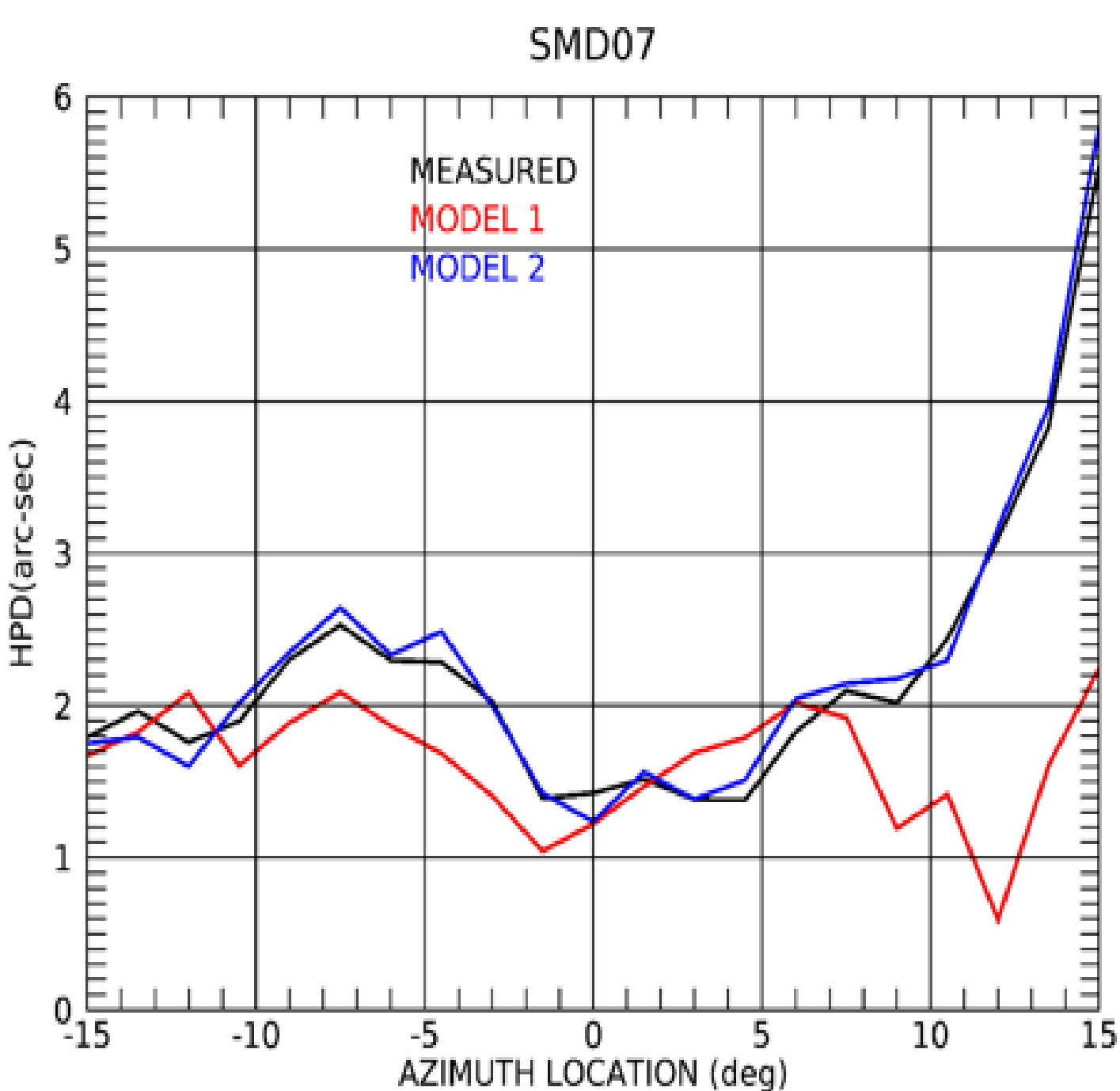


## Hartmann scan centroid data



Plot shows measured centroids calculated from PANTER x-ray data and model centroids calculated from low order surface models. Model includes cone-angle, yaw, pitch, and de-focus errors

## HPD variation

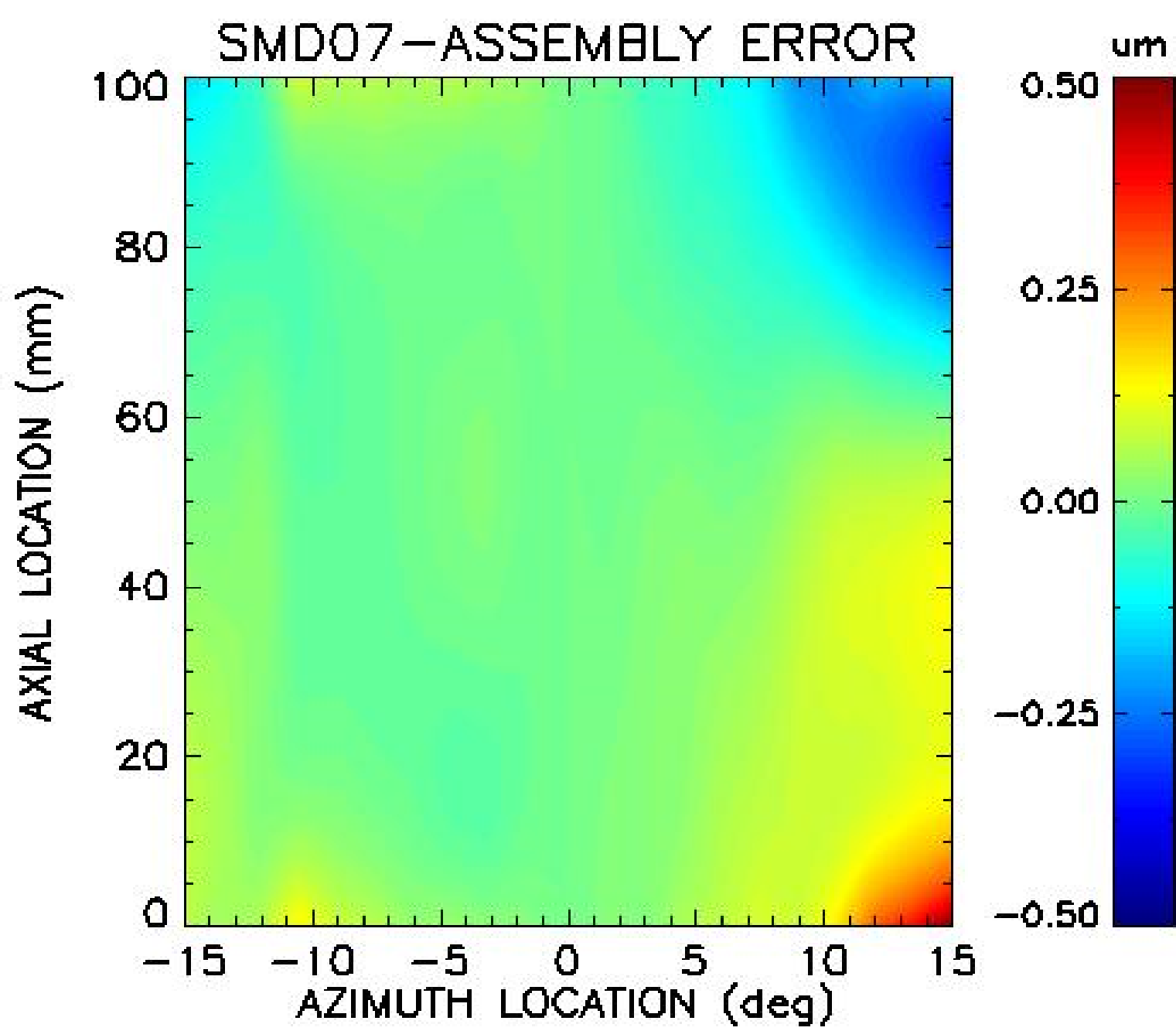


Graph compares HPD variations calculated from measured data and models 1 and 2

Model 1 includes measured errors and FEA models of the mirrors

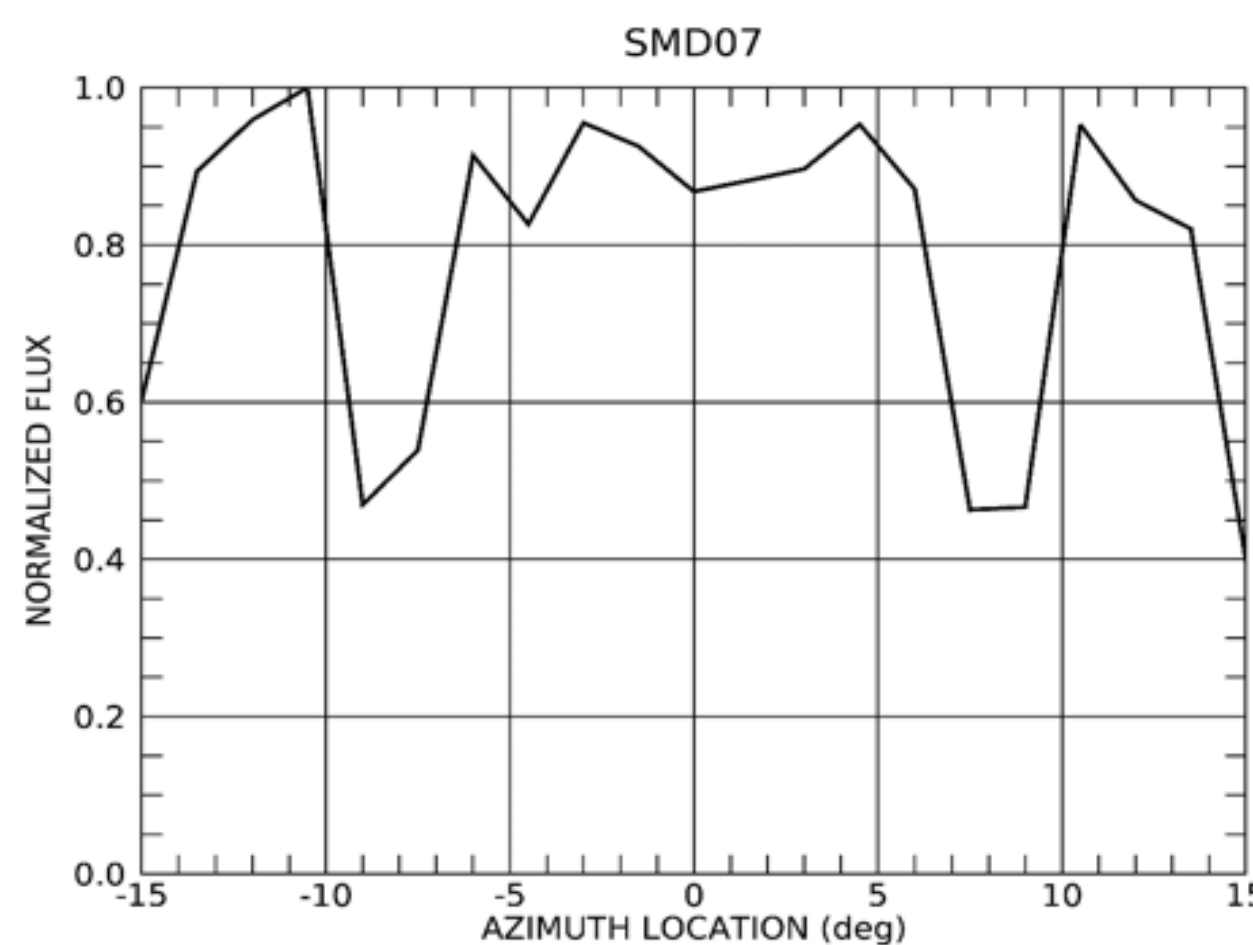
Model 2 includes measured errors, FEA models of the mirrors, and centroid and sag errors of the mirrors

## HPD variation



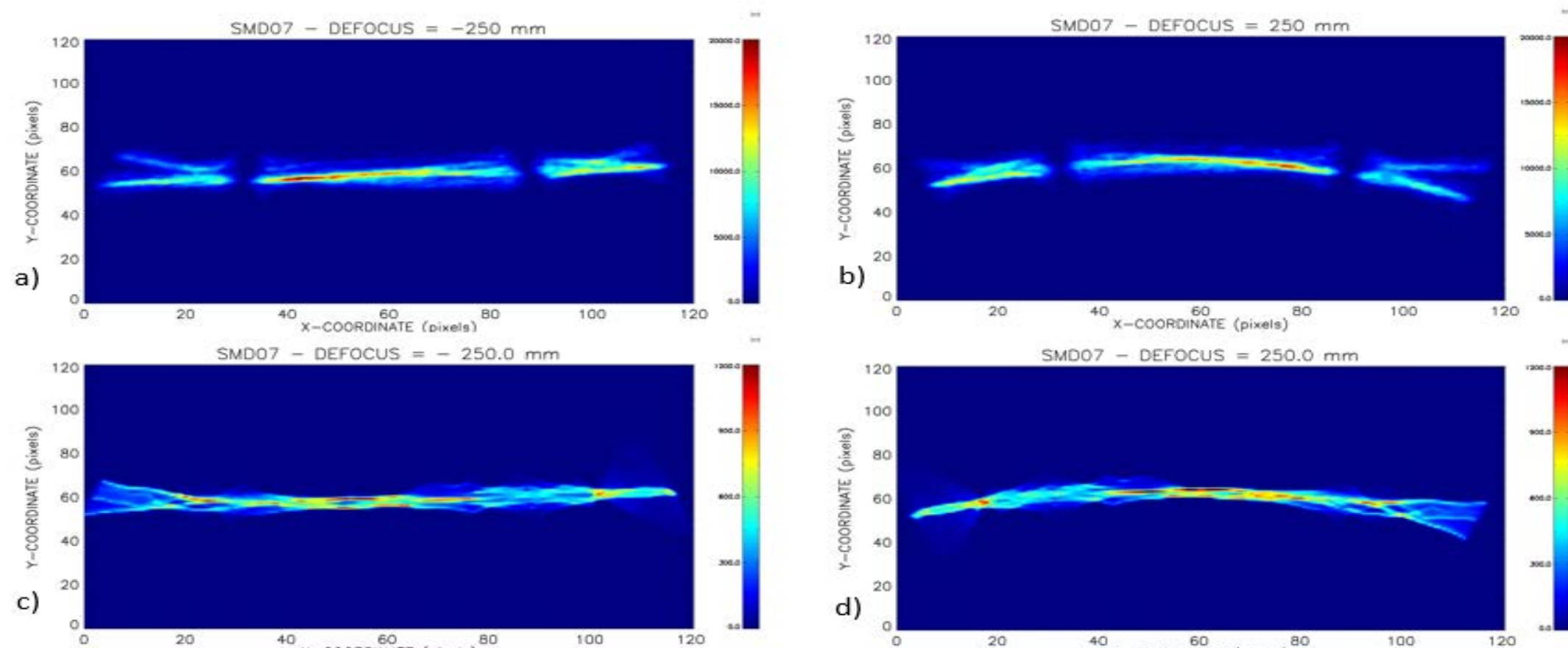
Assembly errors needed to match ray traced centroid and HPD variation of the model to measured centroid and HPD variation data

## Flux variation



Flux variation measured across the azimuth of the mirrors. Mirror spacers block the x-rays at ~7 degrees from the edges and the edge points cover only half of the surface area

## Extra- and intra-focal images



Panels a) and b) depicts intra-focal images measured  $\pm 250$  mm from the focus of the telescope. Panels c) and d) show simulated intra- and extra-focal images generated at  $\pm 250$  mm from the focus of the telescope. Obscurations of the spaces are not included in the simulated images

## X-ray performance

|  | Half power diameter (HPD) (arc-sec) |
|--|-------------------------------------|
| HPD of full aperture image at 1.49 keV (PANTER data) | 2.7                                 |
| HPD of model 2 at 1.49 keV                           | 2.1                                 |
| HPD of model 1 at 1.49 keV                           | 1.8                                 |
| HPD of full aperture image at 4.5 keV (GSFC data)    | 2.9                                 |
| HPD of model 2 at 4.5 keV                            | 3.0                                 |
| HPD of model 1 at 4.5 keV                            | 2.5                                 |

## ACKNOWLEDGEMENTS

This work has been financially supported by NASA through its ROSES/SAT and APRA programs.