

Out-of-focus Holography Application at the Green Bank Telescope

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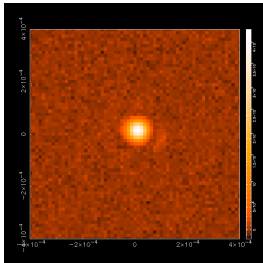
Green Bank, September 2007

Outline

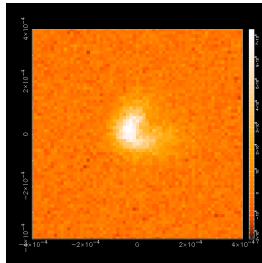
- 1 Introduction
- 2 GBT Specifics
- 3 Results

Simulated beams

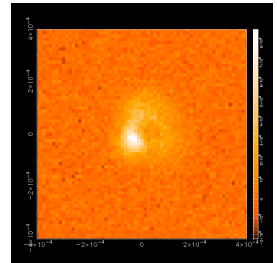
In-Focus



-ve De-Focus

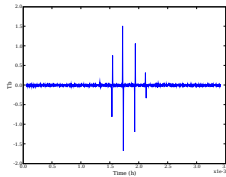


+ve De-Focus

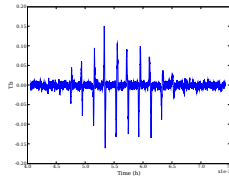


Observed (minimally processed) data

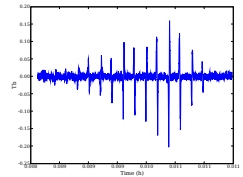
In-Focus



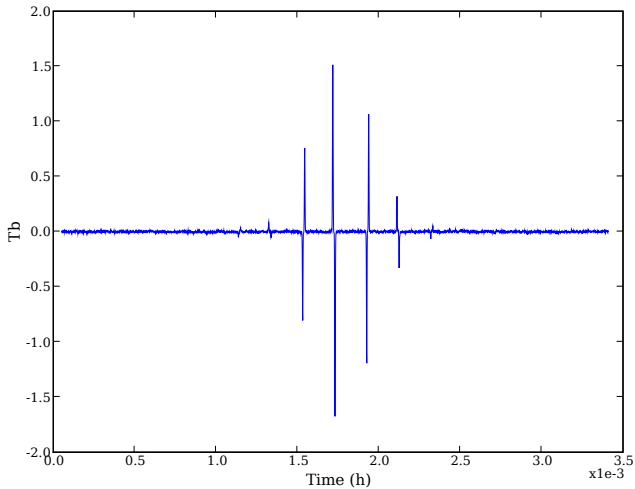
-ve De-Focus



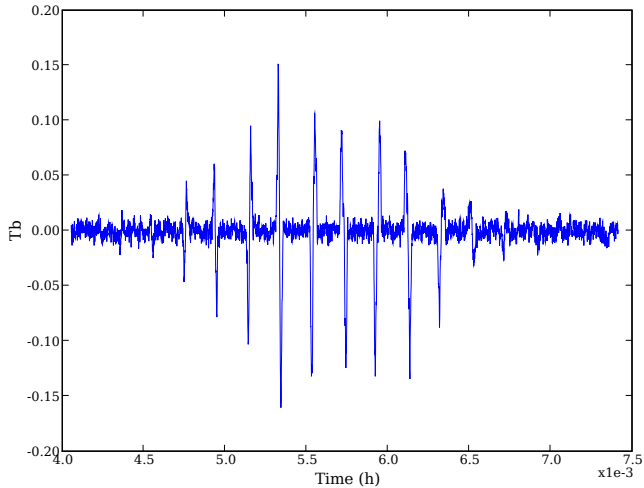
+ve De-Focus



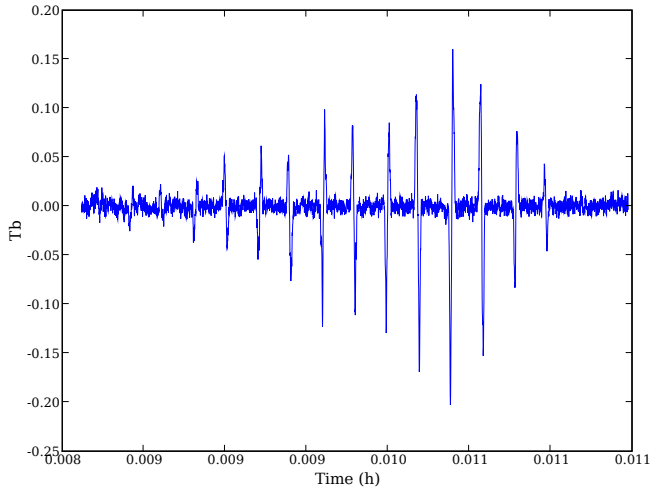
Observed (minimally processed) data: In-Focus



Observed (minimally processed) data: -ve Focus



Observed (minimally processed) data: +ve Focus



Why the GBT?

- The GBT is *not* exactly homologous:
 - The active surface can fully correct for non-homologous deformation (NHD) if it is known
 - Initially NHD estimated using a Finite-Element model
 - Gain-elevation curve is curved at high frequencies
 - Use OOF holography to compute an adjustment to the FEM model
- A fully active, continuously adjusted, primary surface
⇒ instant application of corrections
- Large collecting area ⇒ high signal to noise

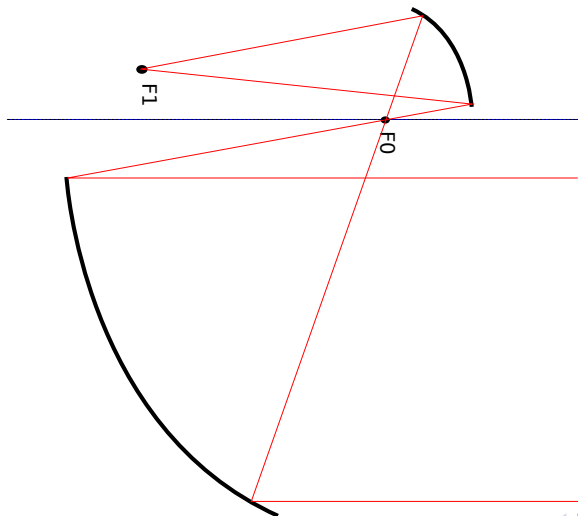
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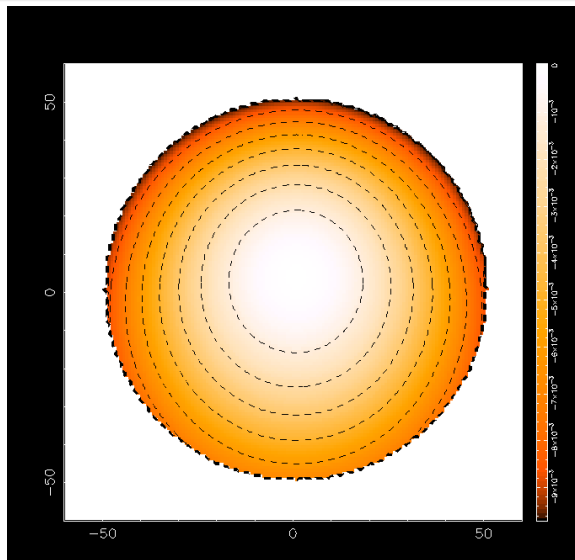
GBT-specific considerations

- Asymmetric off-axis design
 - Phase change of wavefront due to de-focus is asymmetric and a somewhat complex function of position in aperture
 - No aperture blockage to consider (although these are easily dealt with)
- Dual beam differencing scheme
- Expensive to fully sample the measured beams
 - Due to a combination of few pixels and relatively low telescope agility.
- Possibility of tracking/pointing errors
- Difficult to measure absolute and relative telescope efficiency

GBT Geometry

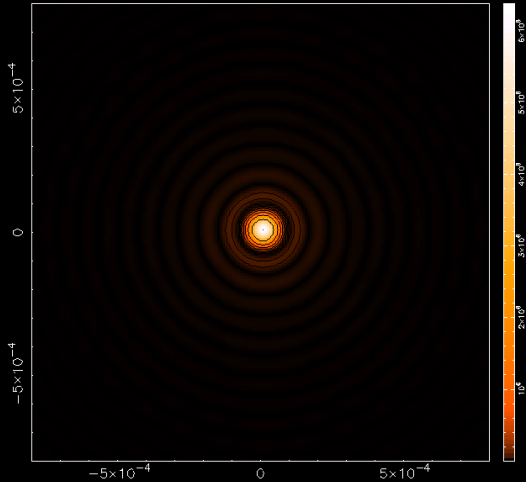


The wavefront phase due to de-focus

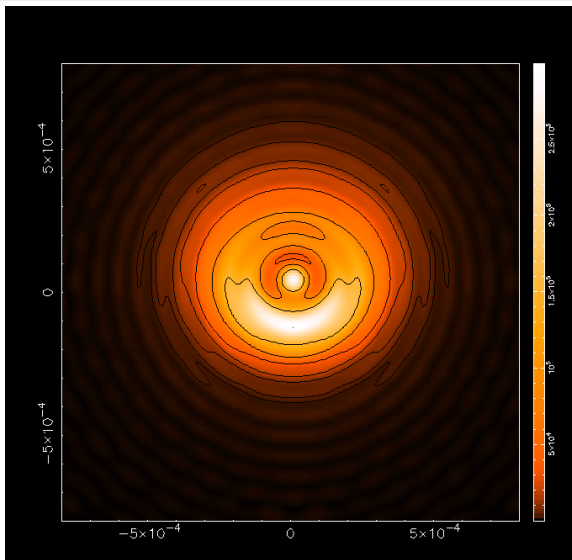


Calculated using
an analytical
approximation to
ray-tracing

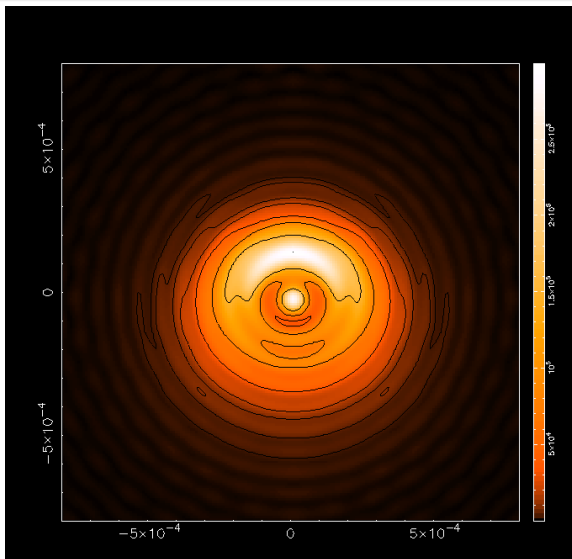
De-focused Beams (In-Focus)



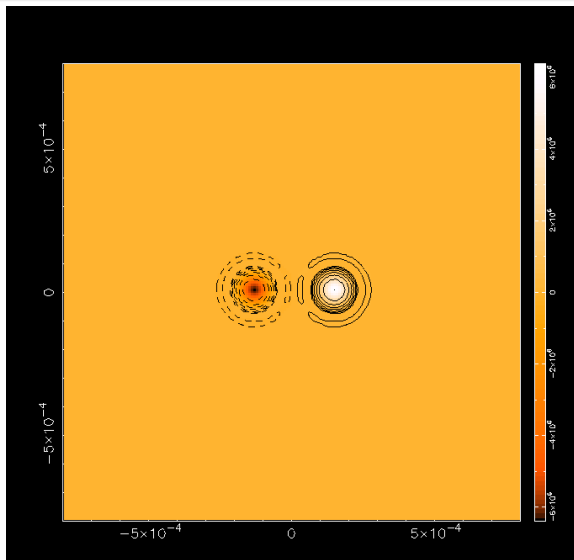
De-focused Beams (-35 mm De-Focus)



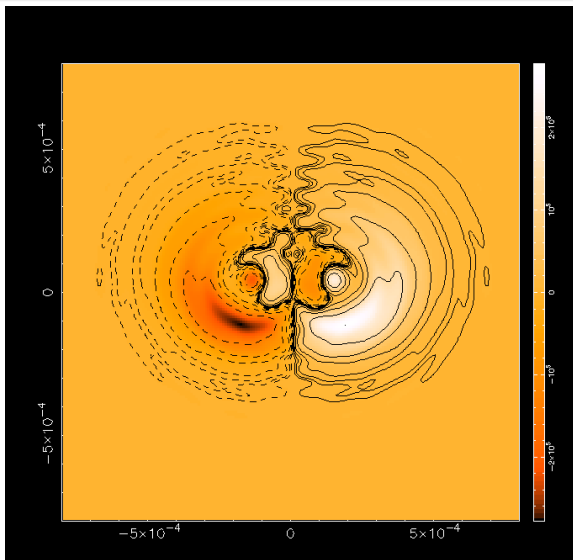
De-focused Beams (35 mm De-Focus)



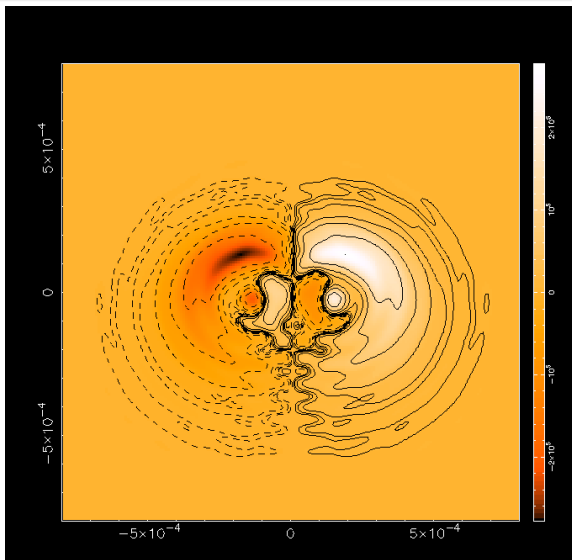
Differenced Beams (In-Focus)



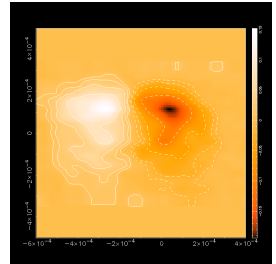
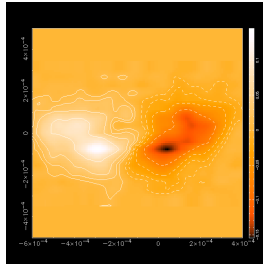
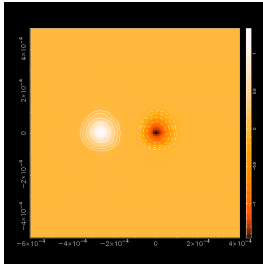
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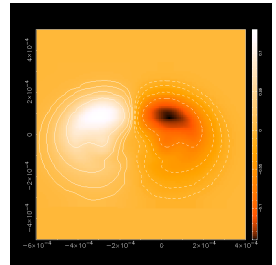
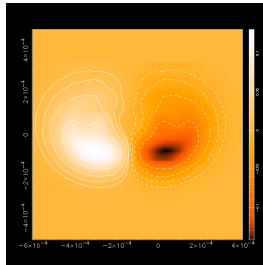
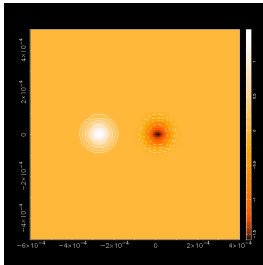
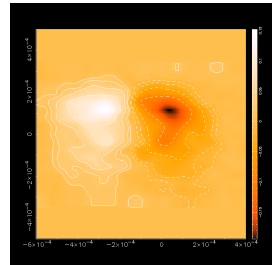
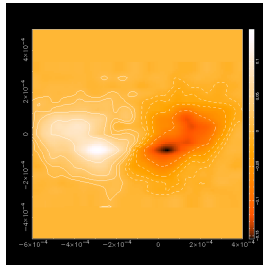
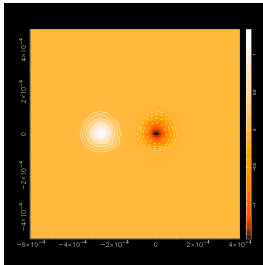
Differenced Beams (35 mm De-Focus)



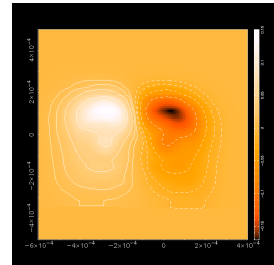
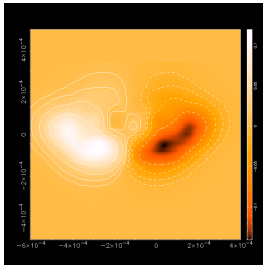
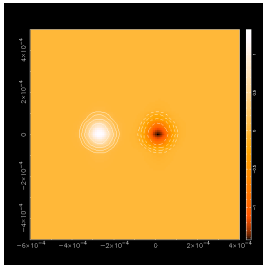
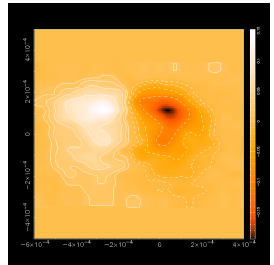
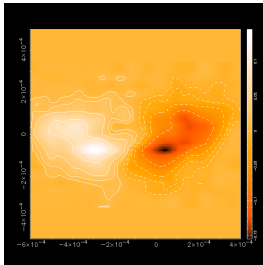
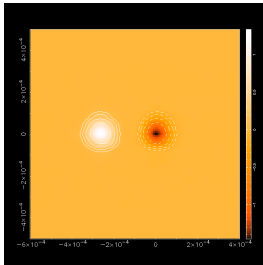
Sample GBT Observation



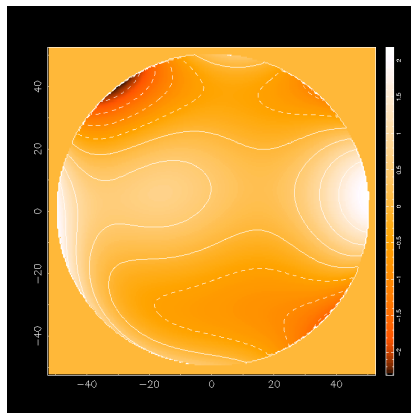
Sample GBT Observation



Sample GBT Observation



Sample GBT Observation: The Retrieved Surface



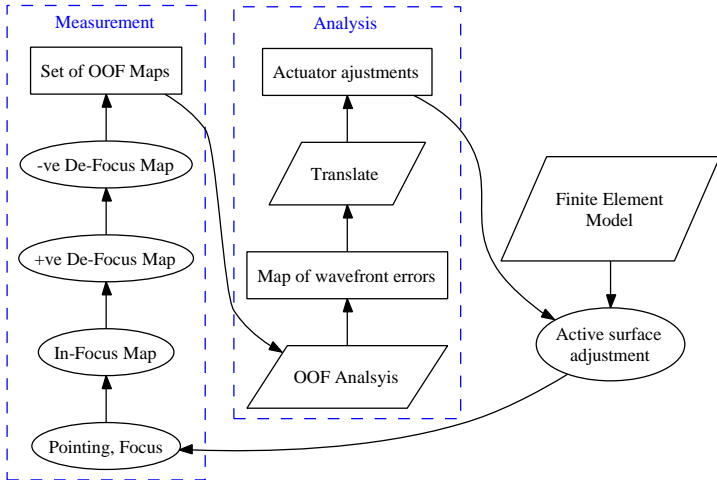
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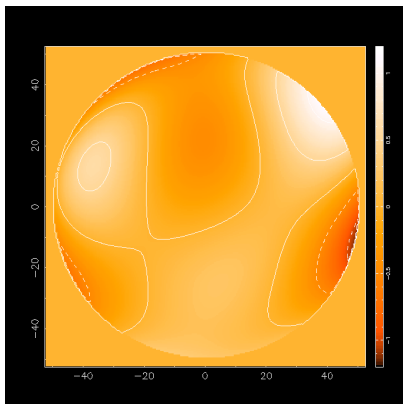
Experiments at the GBT

- Retrieval of known deformation (bump)
- Retrieval and correction of surface errors during both night-time and day-time conditions
- *Closure* – repeated measure-correct-measure cycles to measure consistency and random error of technique
- Derivation of a refinement for the gravitational deformation model

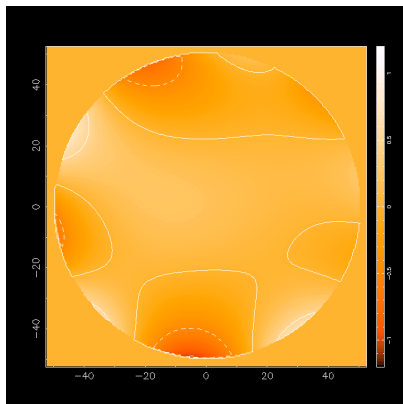
Closure



Closure: benign conditions

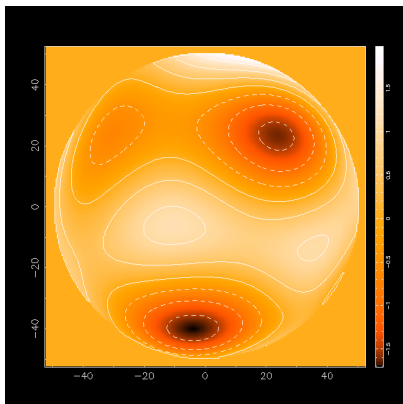


WRMS $\approx 150 \mu\text{m}$

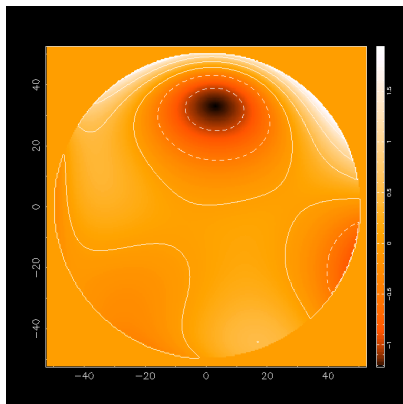


WRMS $\approx 100 \mu\text{m}$

Closure: Daytime

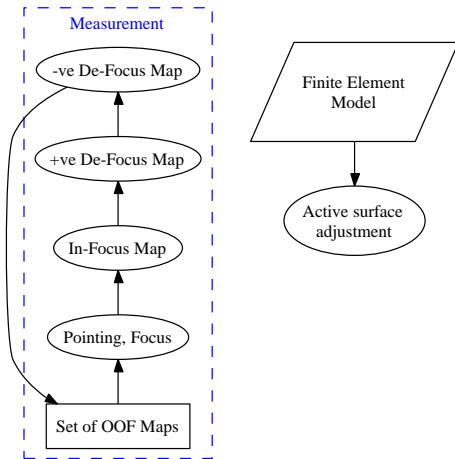


WRMS $\approx 340 \mu\text{m}$



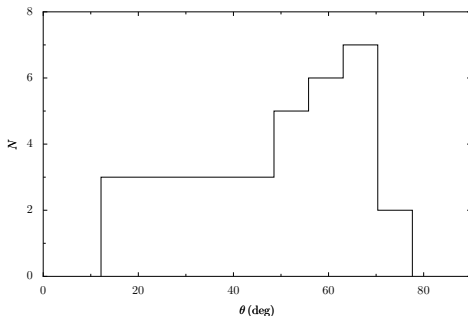
WRMS $\approx 210 \mu\text{m}$

Modelling Gravitational Deformation

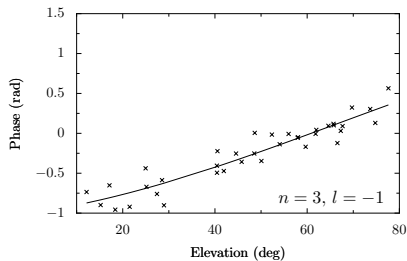
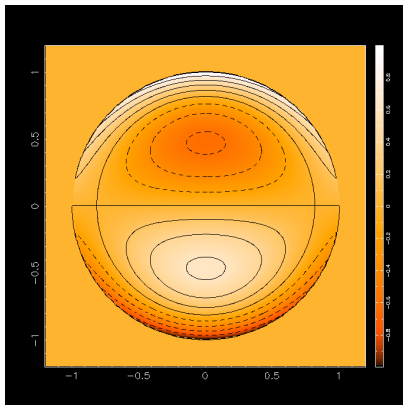


Modelling Gravitational Deformation

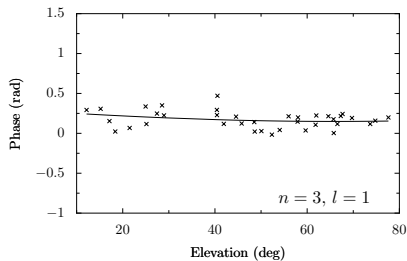
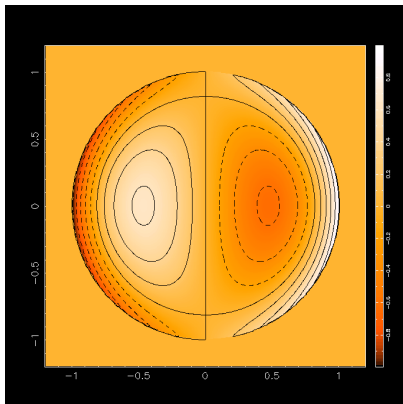
- Obtained 37 measurements over three sessions covering a range of elevations
- Fit $a \sin(\theta) + b \cos(\theta) + c$ to each Zernike coefficient individually



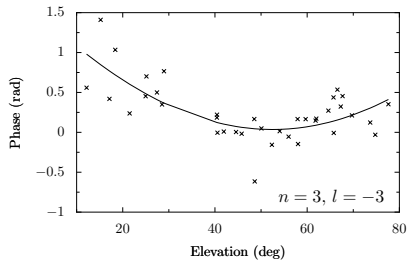
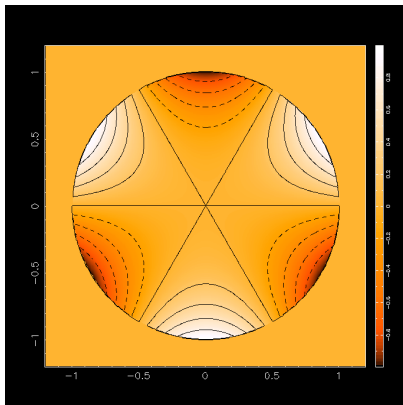
Gravitational Model: Vertical Coma



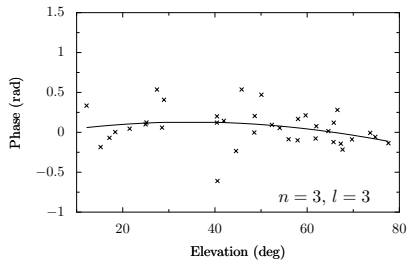
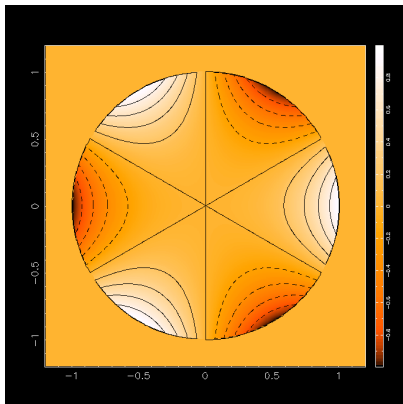
Gravitational Model: Horizontal Coma



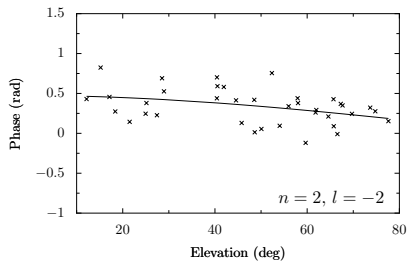
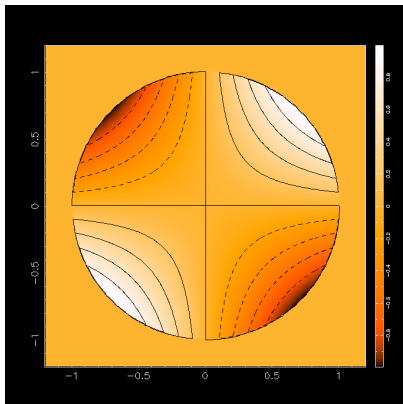
Gravitational Model: Trefoil



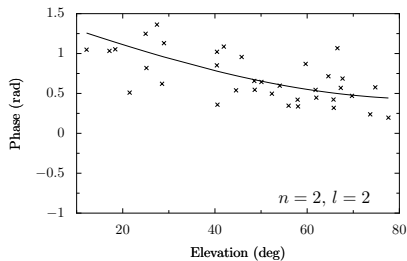
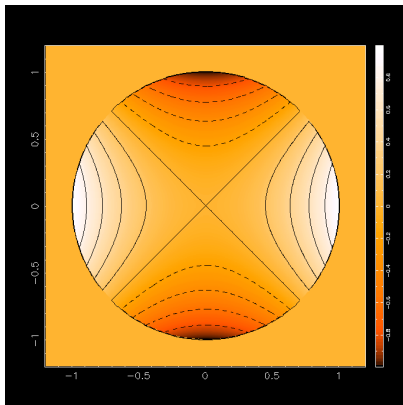
Gravitational Model: Trefoil



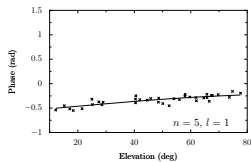
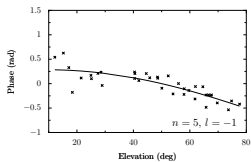
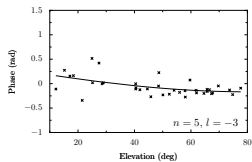
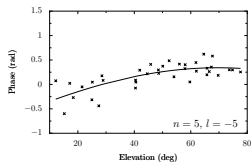
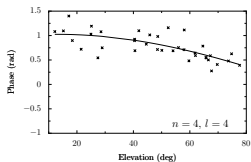
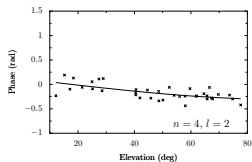
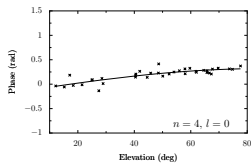
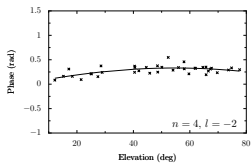
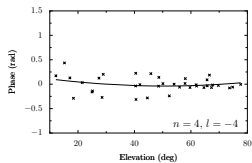
Gravitational Model: Astigmatism



Gravitational Model: Astigmatism

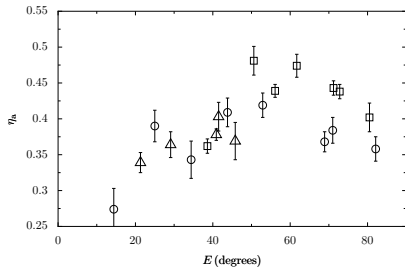


Gravitational Model



Gravitational Model: Efficiency

FEM Only



FEM and OOF gravitational model

