Advanced WVR Algorithms (AWA): Recent Progress

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Outline

Outline

Introduction/Scope

- Last meeting with TelCAL in June 07 – will briefly cover work since then
- The major focus has been a twin-track approach simulation:
  - Detailed simulation of radiometers (or pairs of radiometers) to analyse their performance
  - Simulations of ALMA as a system to connect:
    - atmospheric conditions
    - observing strategies
    - and WVR performance

  to metrics relevant for science observations.
- Minor work items: WVR CDR, article for Messenger, etc.

Twin track simulation approach (I)
Detailed radiometer modelling

Radiometer modelling
- Thermal noise, stability
- Calibration uncertainty
- Atmospheric conditions
- Unknown atmospheric parameters
- Retrieval algorithm

$\Rightarrow$

Results
- Residual phase fluctuation on baselines
- Phase transfer accuracy (i.e., correction of path change when slewing over significant distance on sky)

Use this to
- Design/investigate retrieval algorithm
- Initial optimisation of these algorithms

Twin track simulation approach (II)

System simulation

System simulation

- Results of radiometer modelling
- Atmospheric conditions
- Array configuration
- Phase calibration scheme (FS time cycle, distance to calibrator)

$\Rightarrow$

Results

- Point source sensitivity
- Resolution/image fidelity
- Astrometry and absolute flux calibration (especially for snapshots)

Use this to

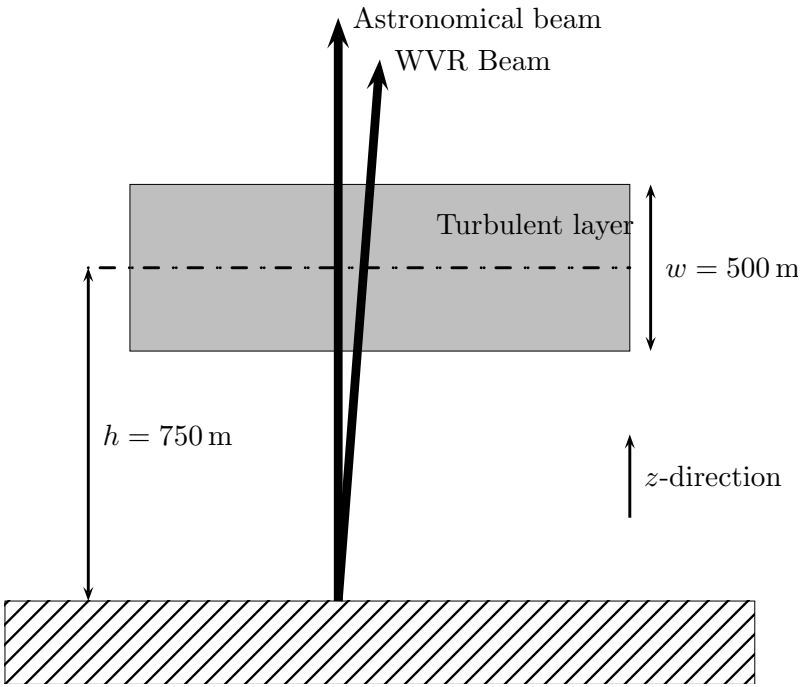
- Optimise phase correction/calibration techniques
- Understand impact on science
- Constraints on scheduling

Outline

Scope

Here I will show results published in ALMA memo 573, on the effect of beam mismatch between the radiometer and astronomical beams.

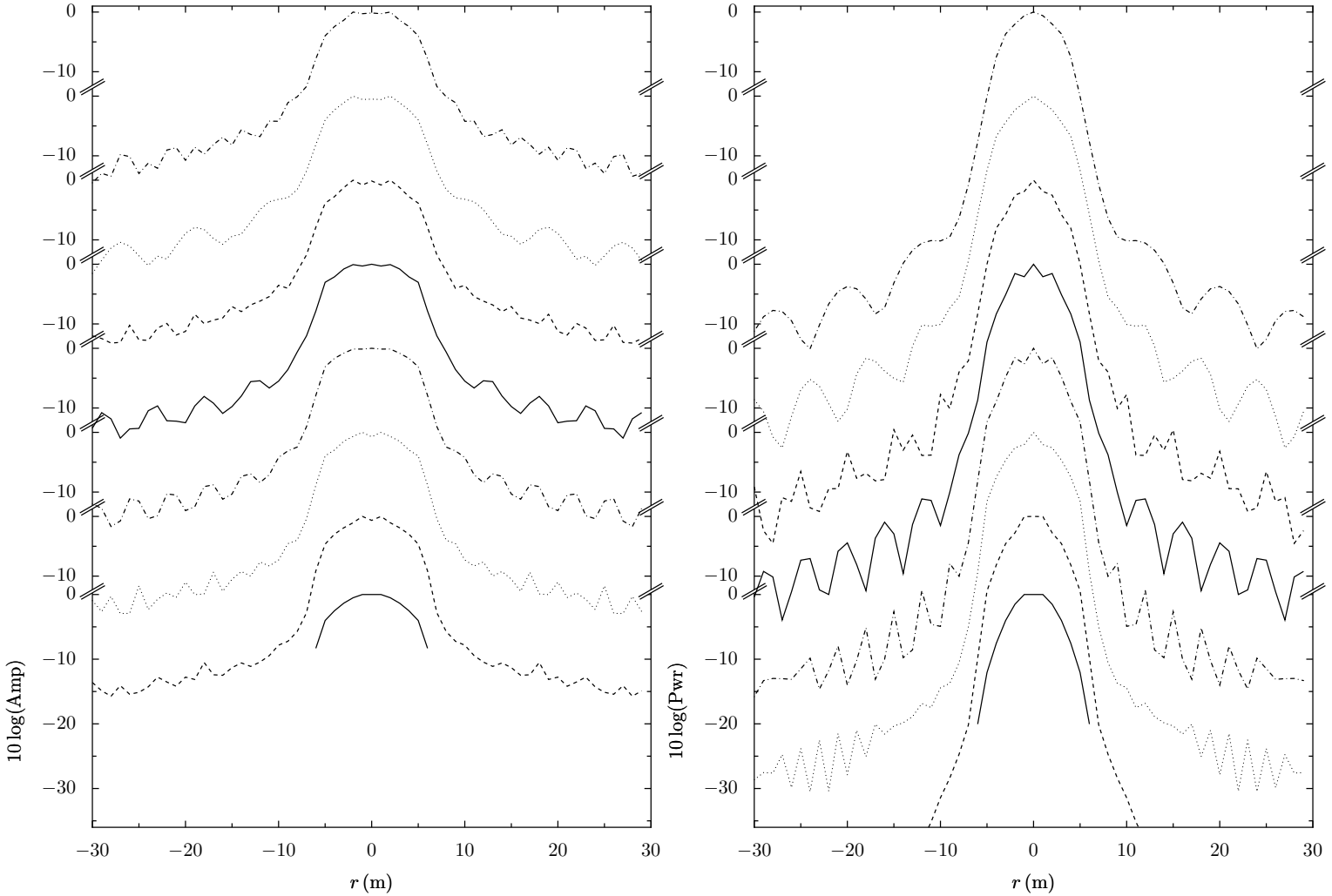
Effect of beam mis-match



Offset between astronomical beams and the radiometer beam for ALMA is between 4‘ (highest frequencies) and 9‘ (lowest frequencies).

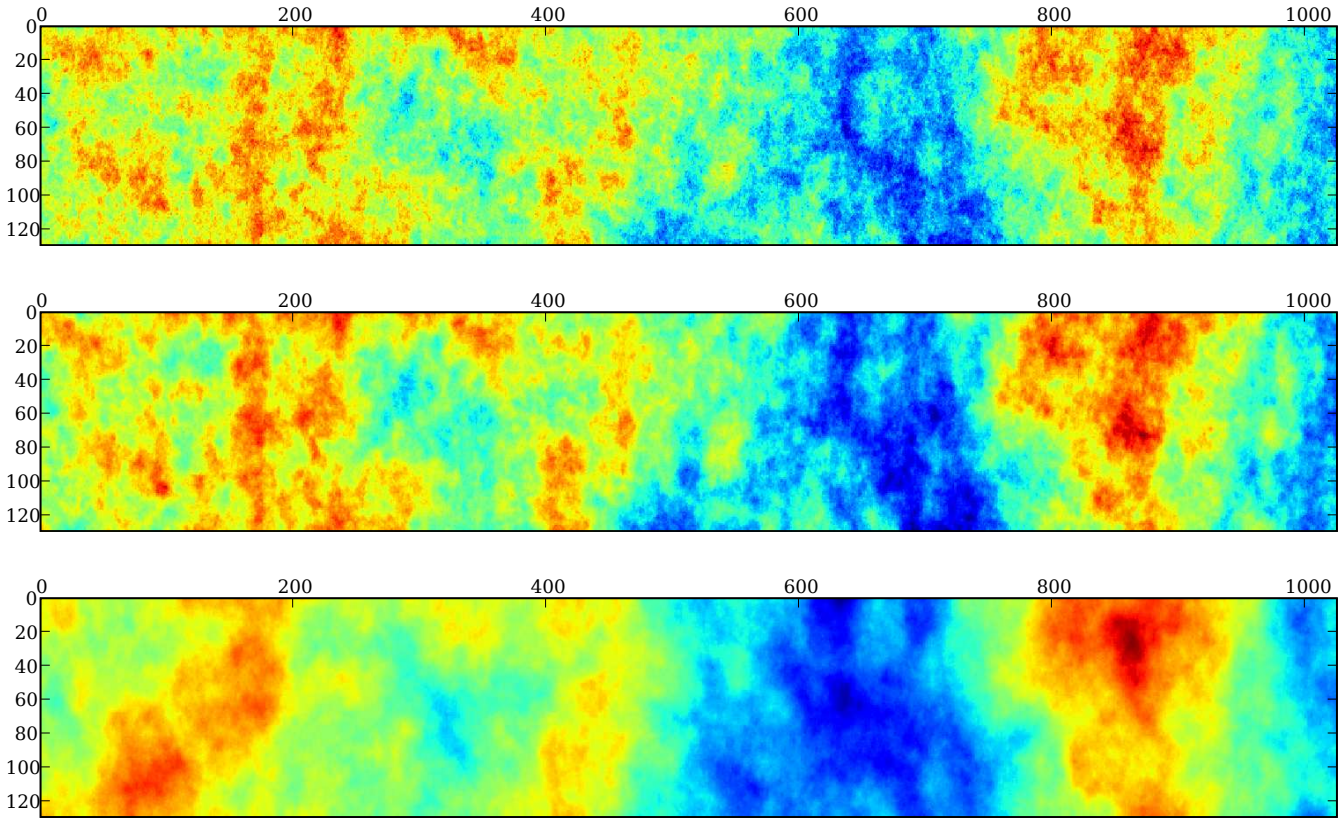
Beam shapes

Voltage response of astronomical beam Vs power response of radiometer beam

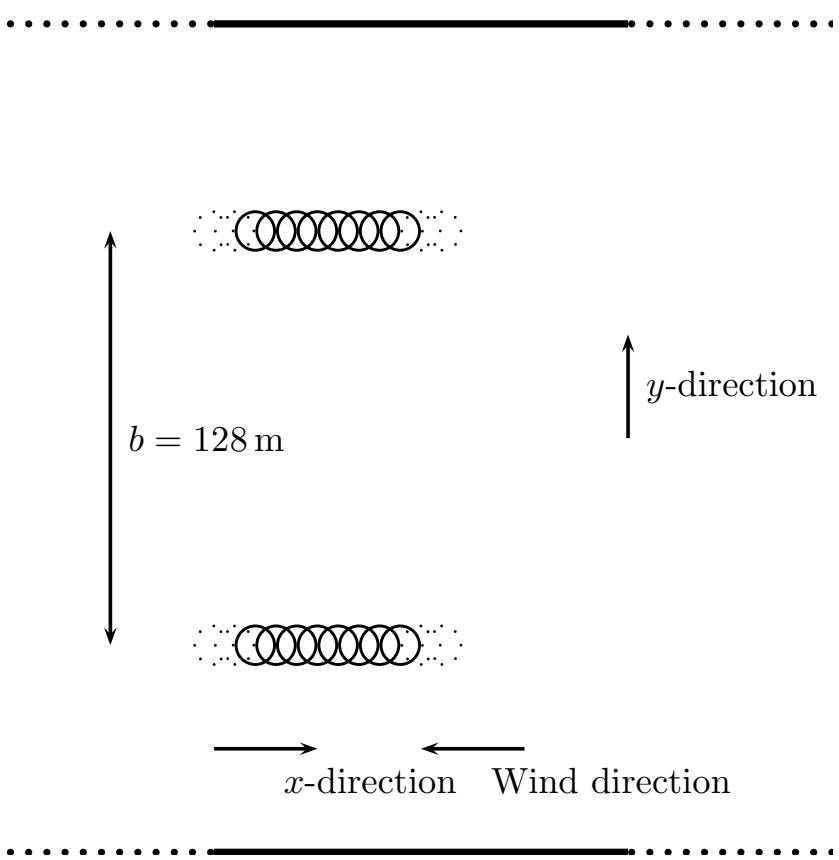


Statistical realisations of 3D turbulent screens

Illustration of sub-sections of 1 m, 10 m and 100 m thick screens



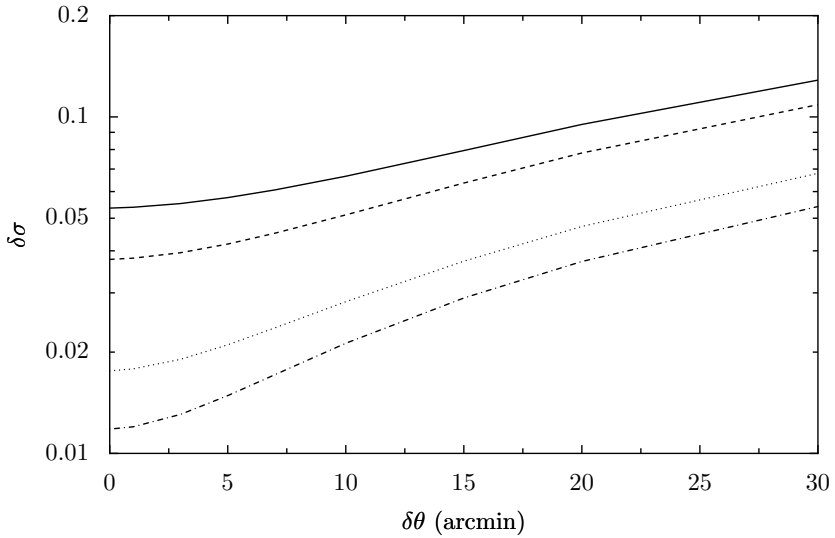
Beam mismatch simulations



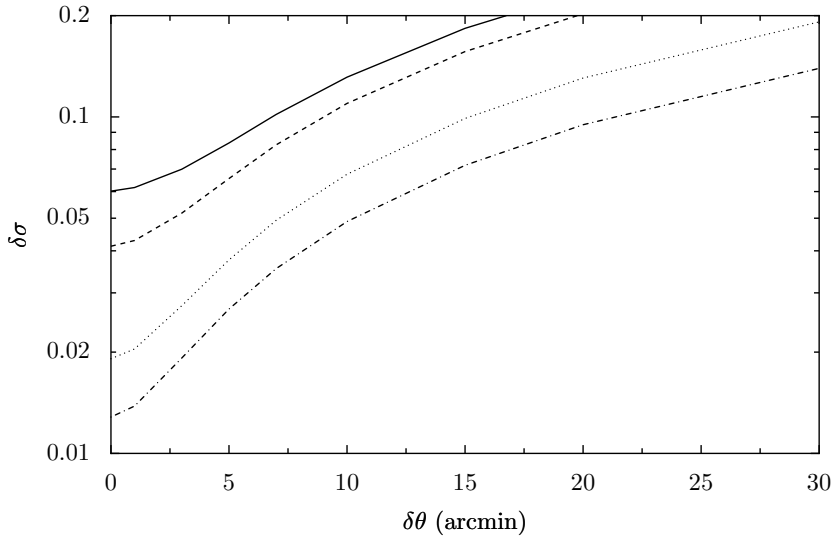
- Generate simulated time series of radiometer measurements using the power response pattern
- Compute phase fluctuation using the complex voltage response pattern of the antenna
- Find accuracy as function of beam offset, atmospheric properties, baseline length

Error due to beam mismatch

Turbulent layer at 250 m



Turbulent layer at 750 m



Fractional error due to the mismatch between the astronomical and water vapour radiometer beams. For each layer height, the error for four layer thickness have been calculated: thin-screen (solid line), 10 m thick layer (dashed line), 100 m thick layer (dotted line) and 500 m thick layer (dash-dot-dash line).

Outline

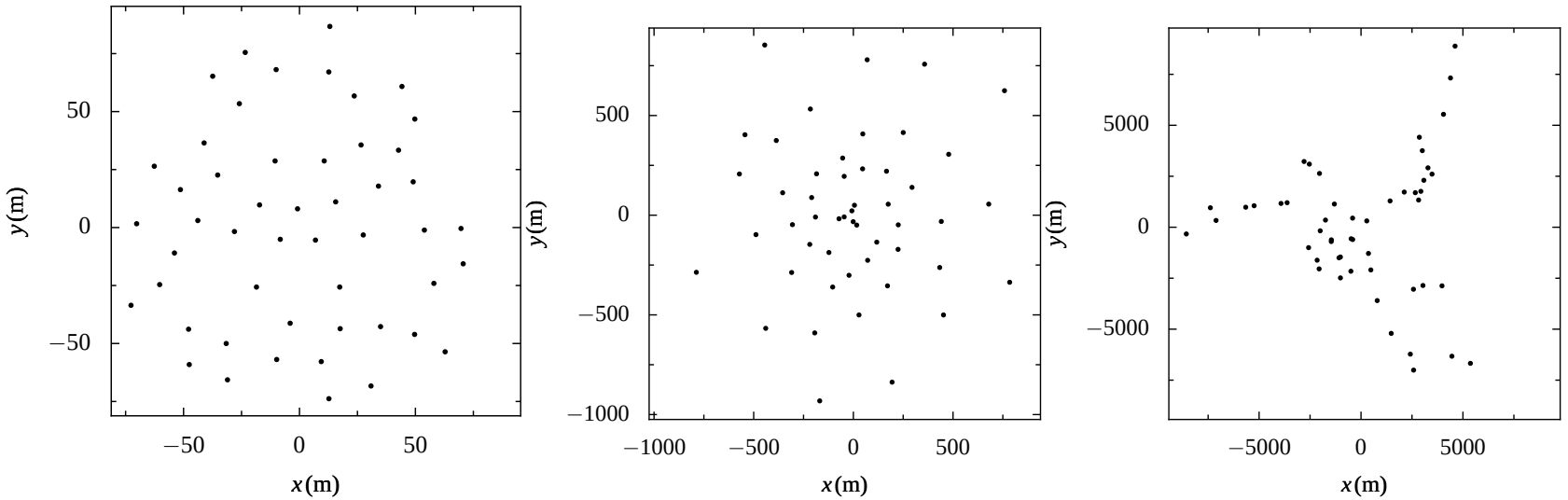
Simulation framework

1. Use `casa` to generate *uv* tracks and data
2. Simulate effects of the atmosphere:
   - Kolmogorov three-dimensional phase screens

   Produces corrupted *uv* data
3. A separate calibration stage
   - Fast switching calibration
   - WVR phase correction (in the future)

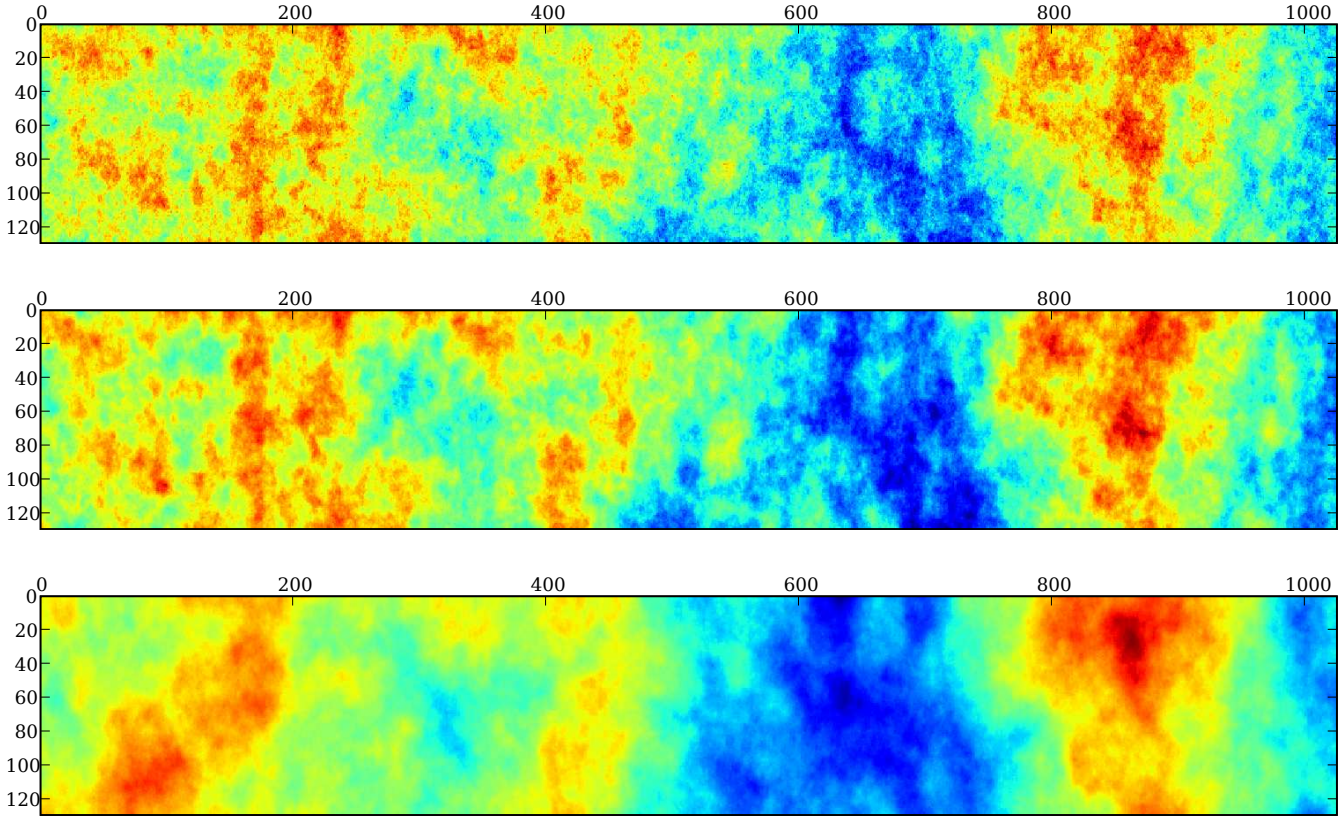
   Produces corrupted+calibrated *uv* data.
4. Finally use `casa` or `Obit` for imaging

Configurations

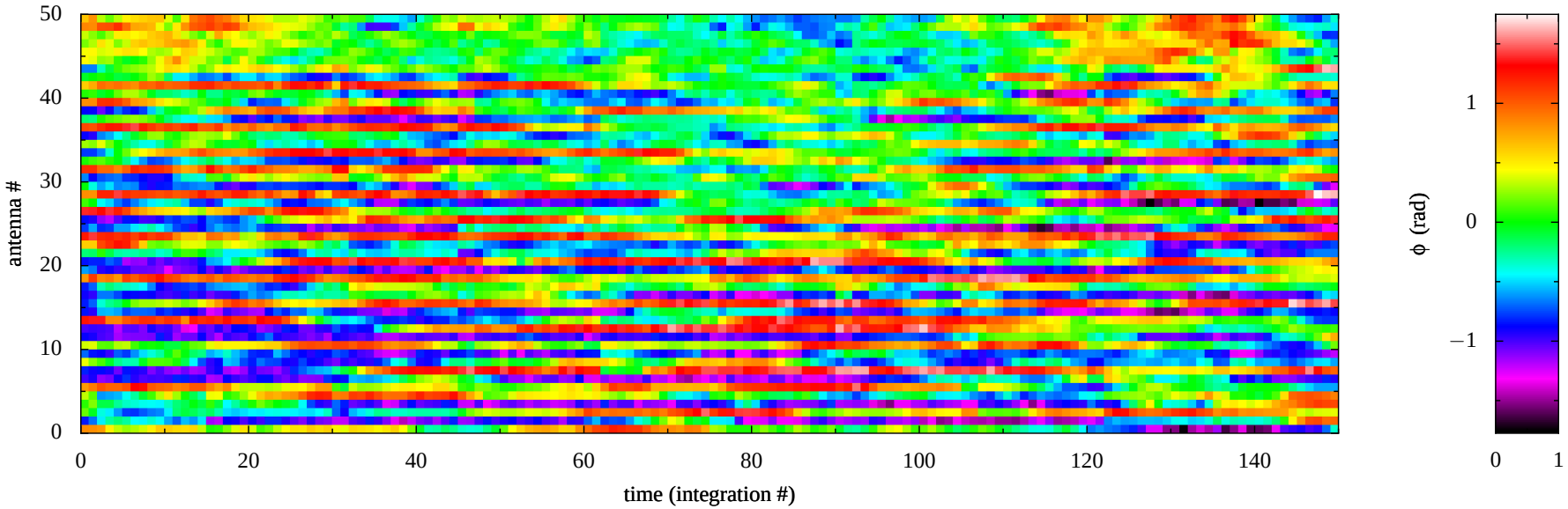


Statistical realisations of 3D turbulent screens

Illustration of sub-sections of 1 m, 10 m and 100 m thick screens

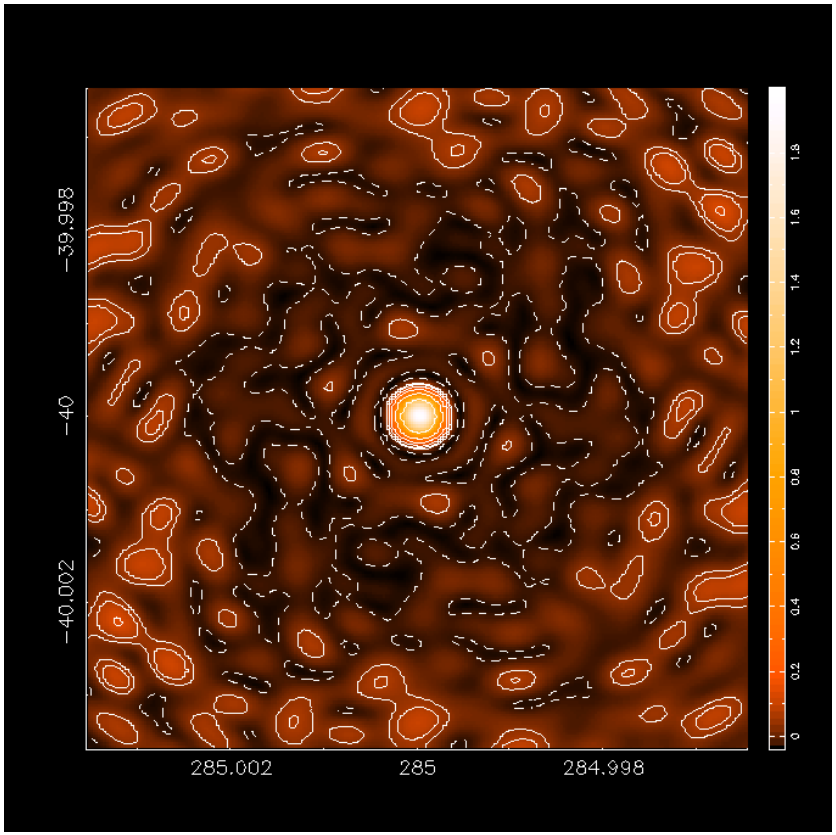


Corrupted UV phases

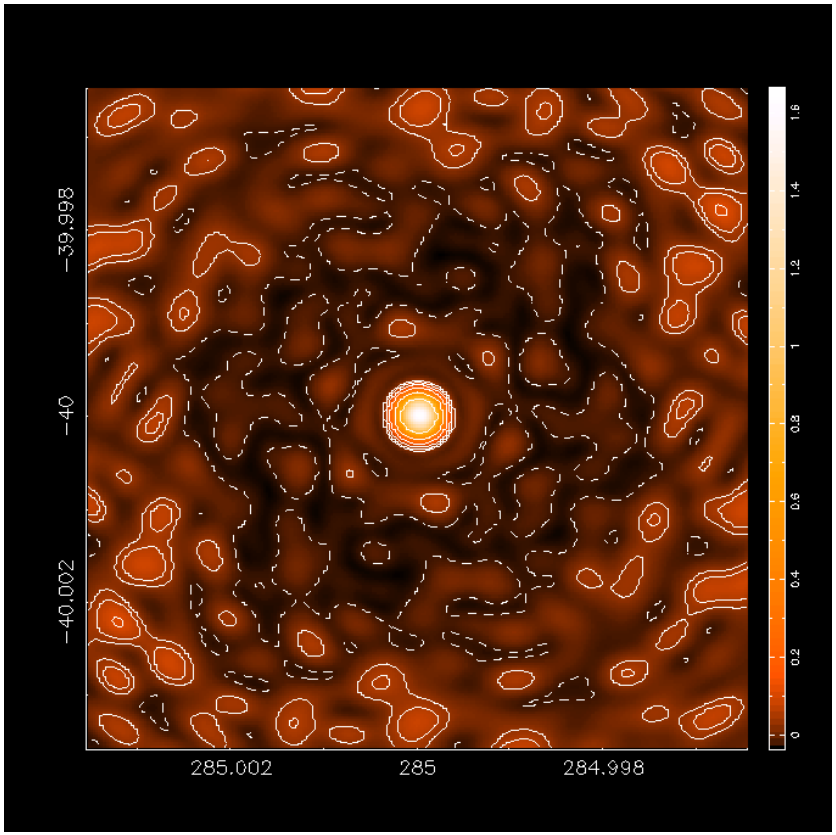


Simple results: no calibration, long integration

Peak: 2 Jy

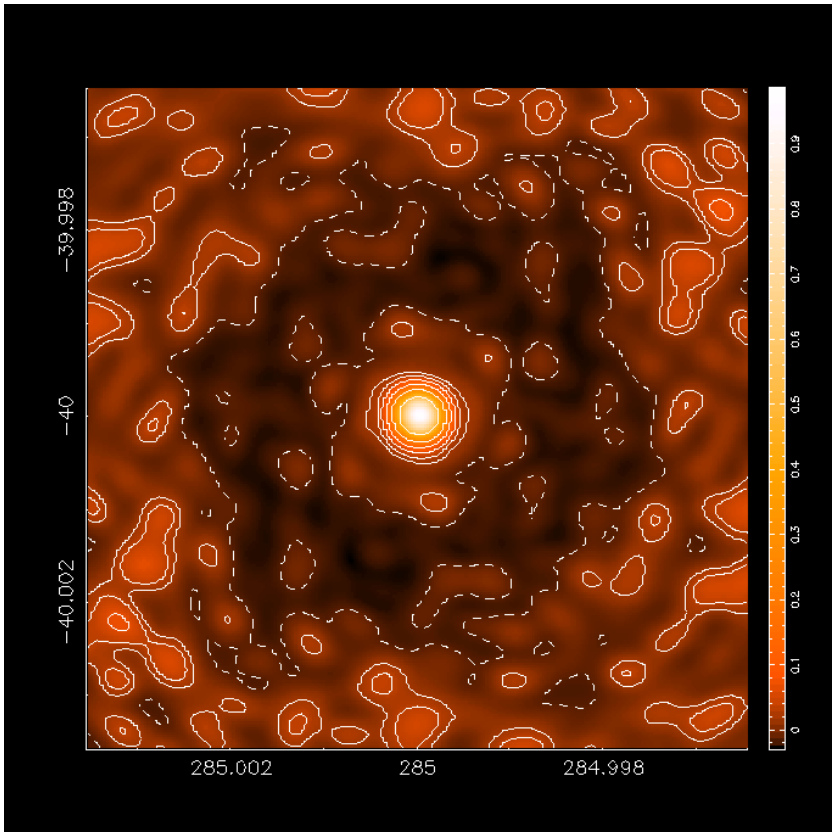


Peak: 1.66 Jy

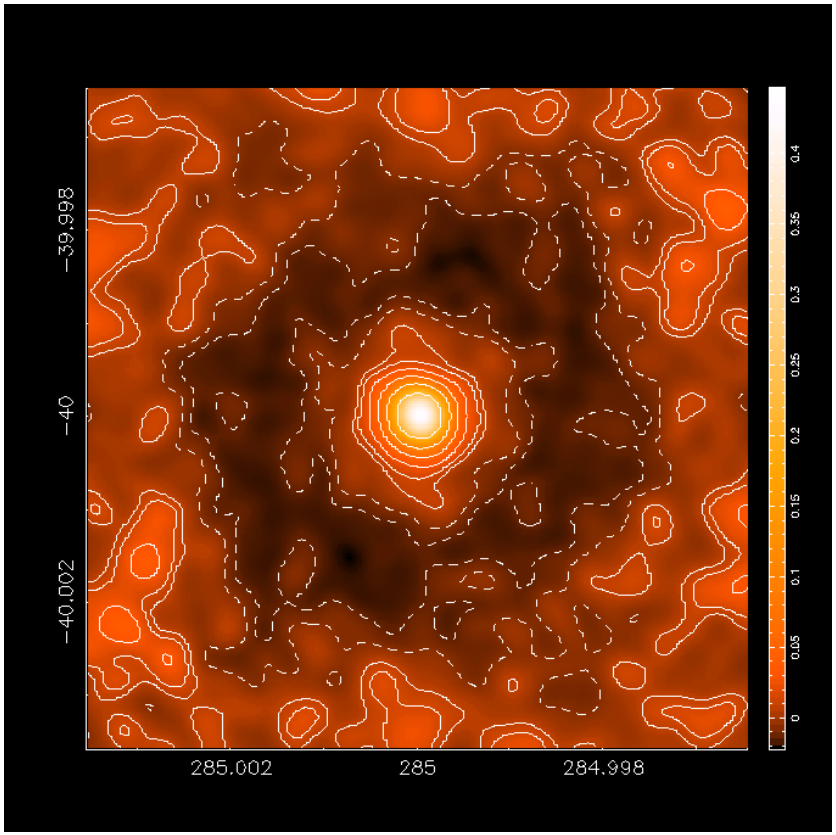


Simple results: no calibration, long integration

Peak: 0.98 Jy

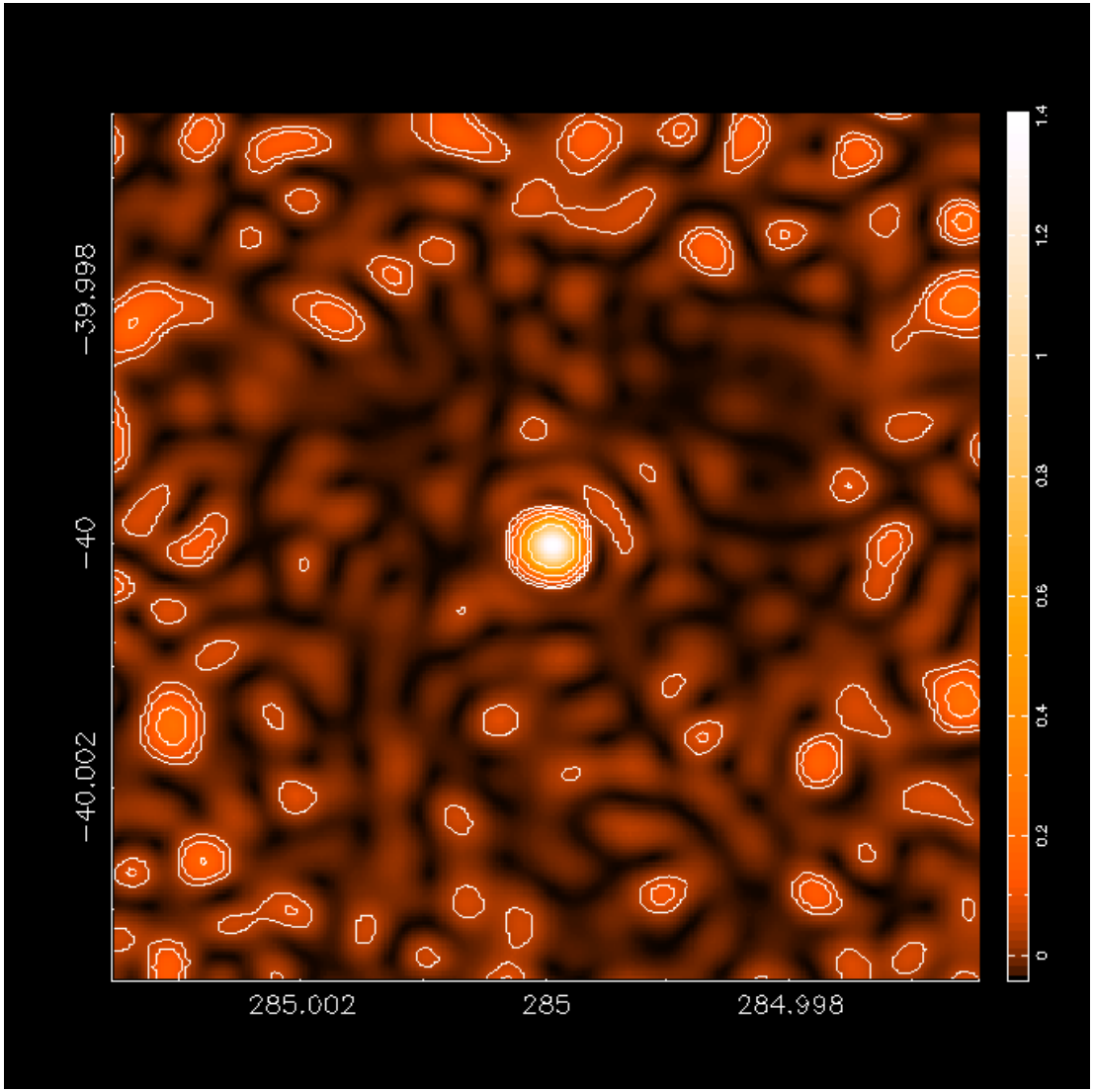


Peak: 0.45 Jy



Simple results: no calibration, snapshot

Sequence of snapshots separated by about 3 minutes in time



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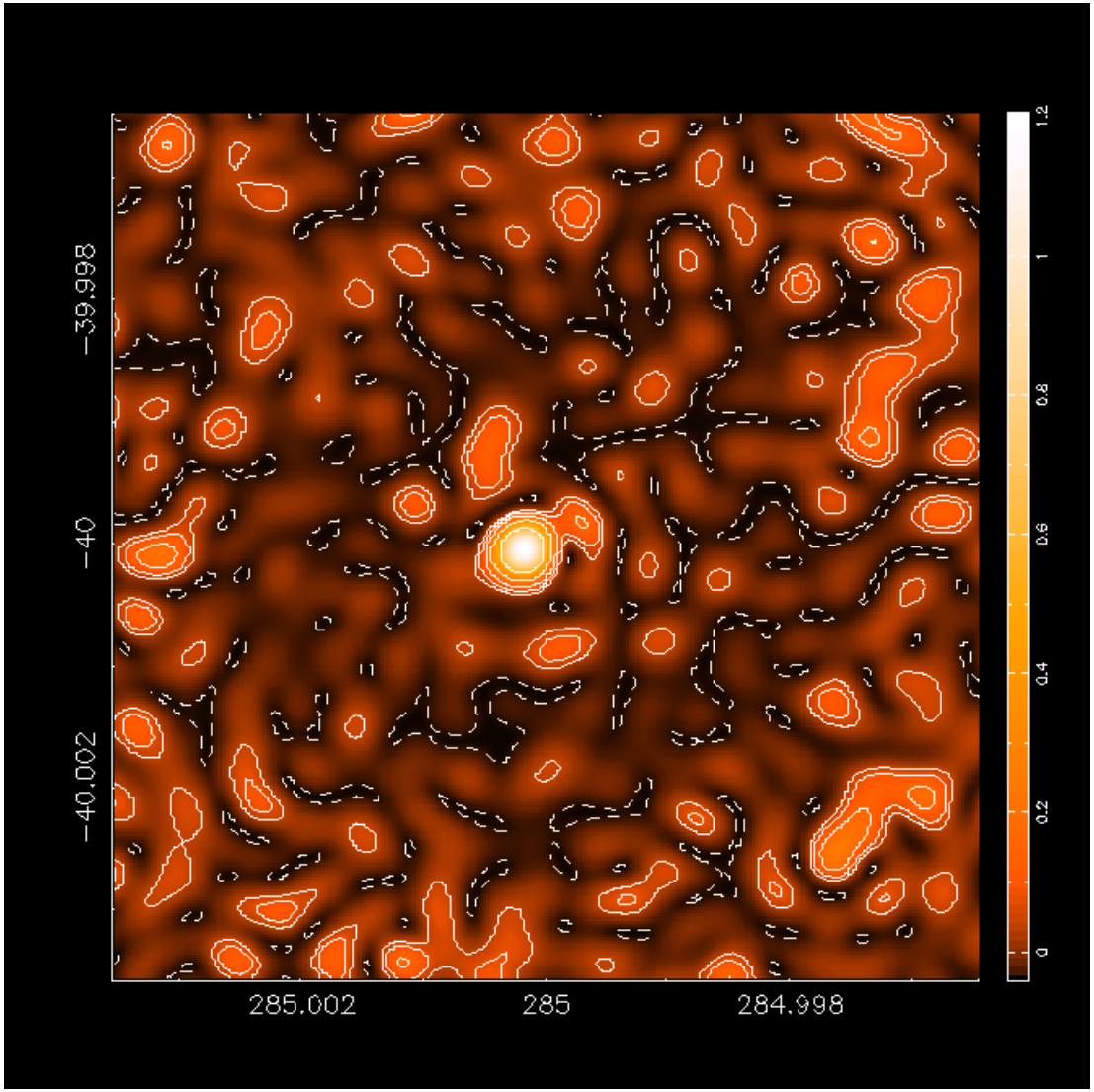

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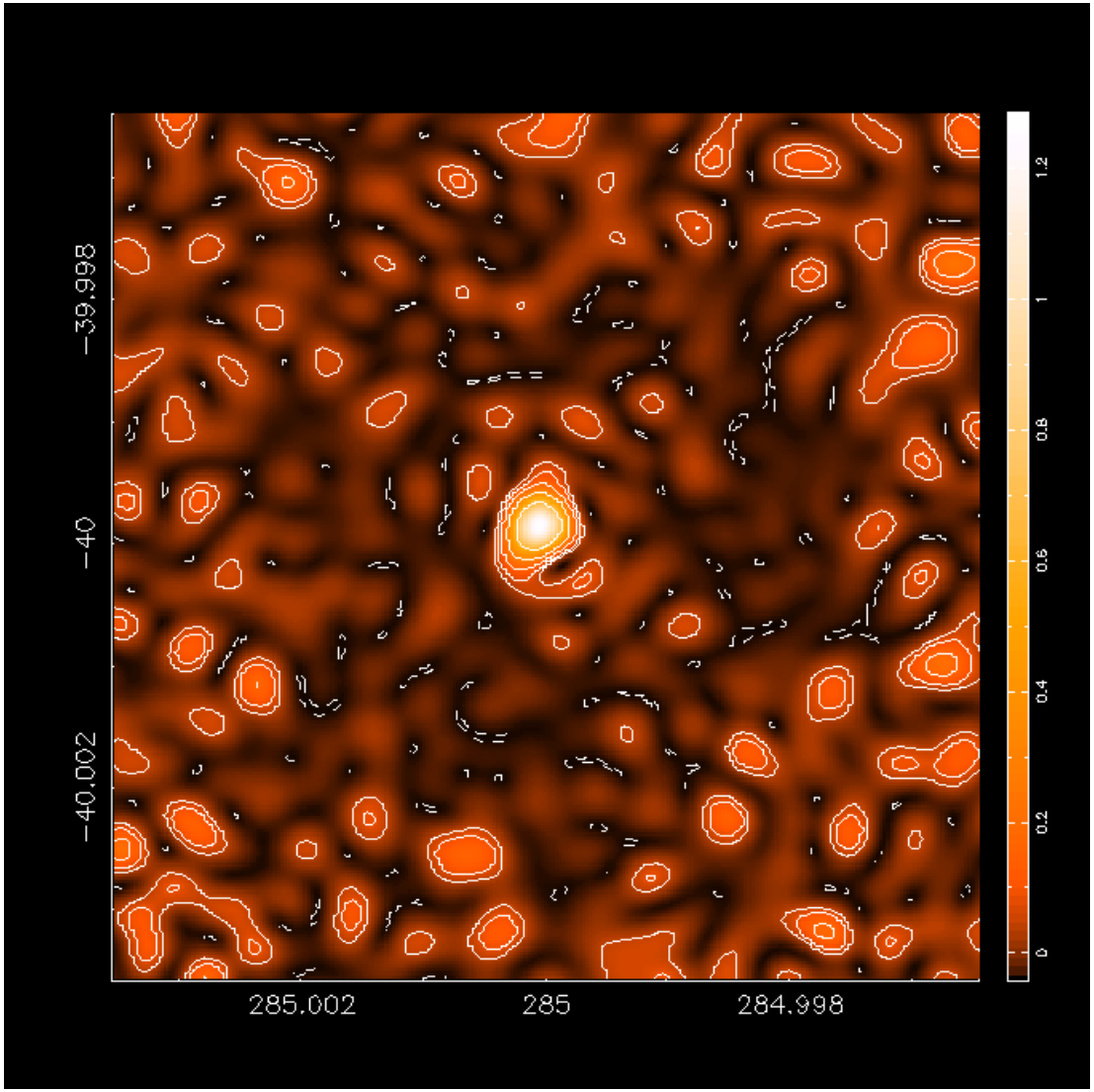

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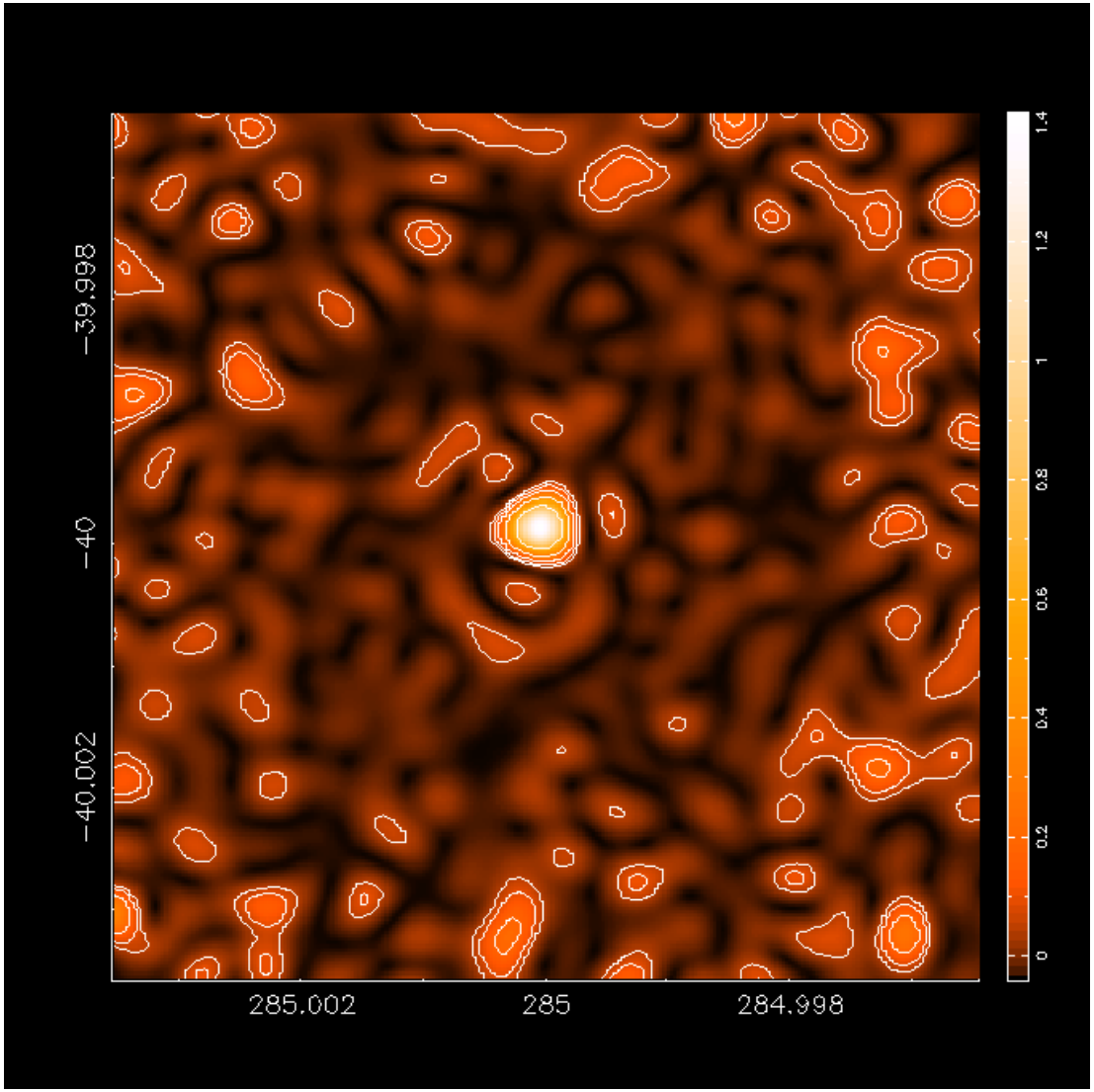

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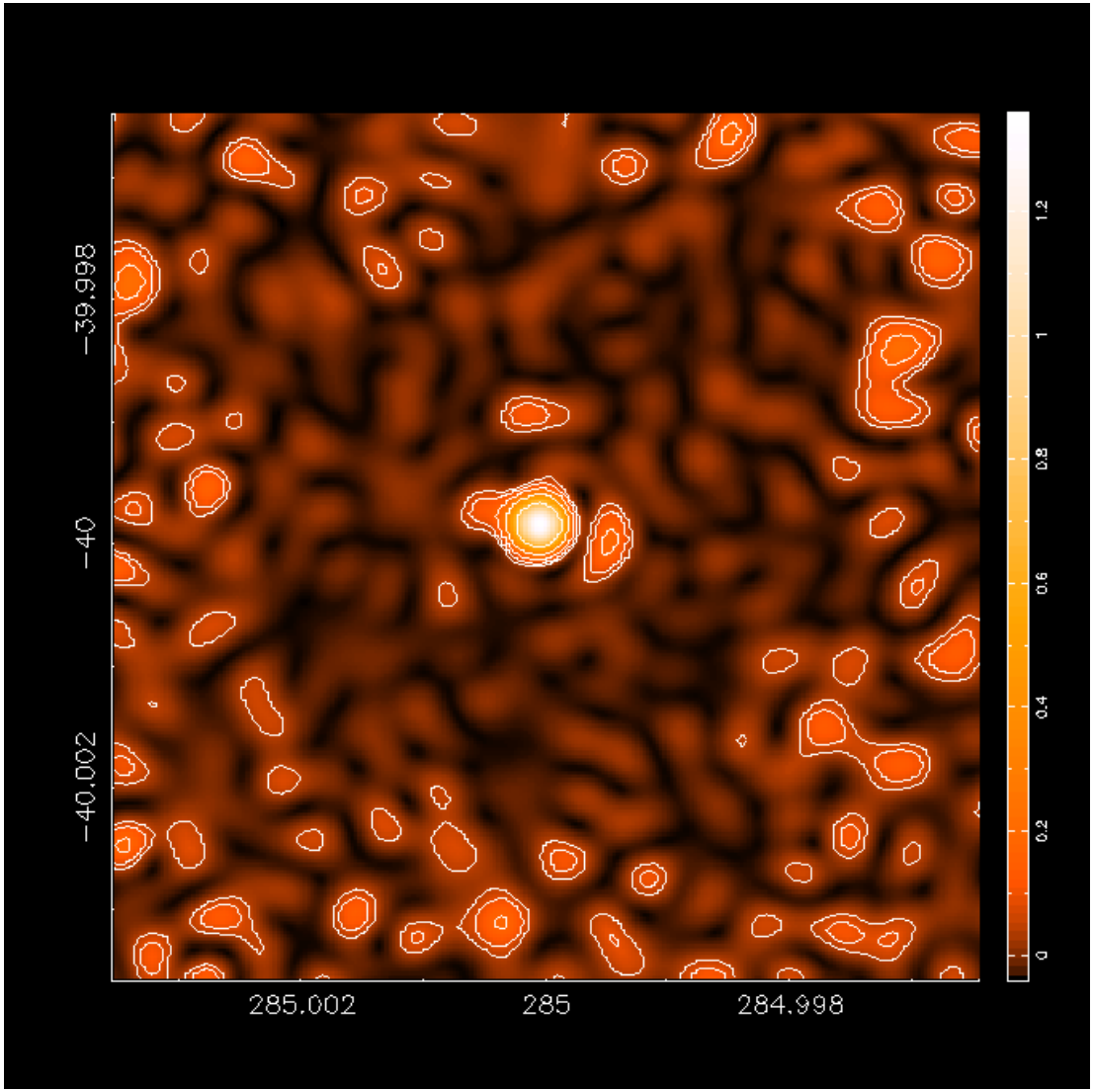

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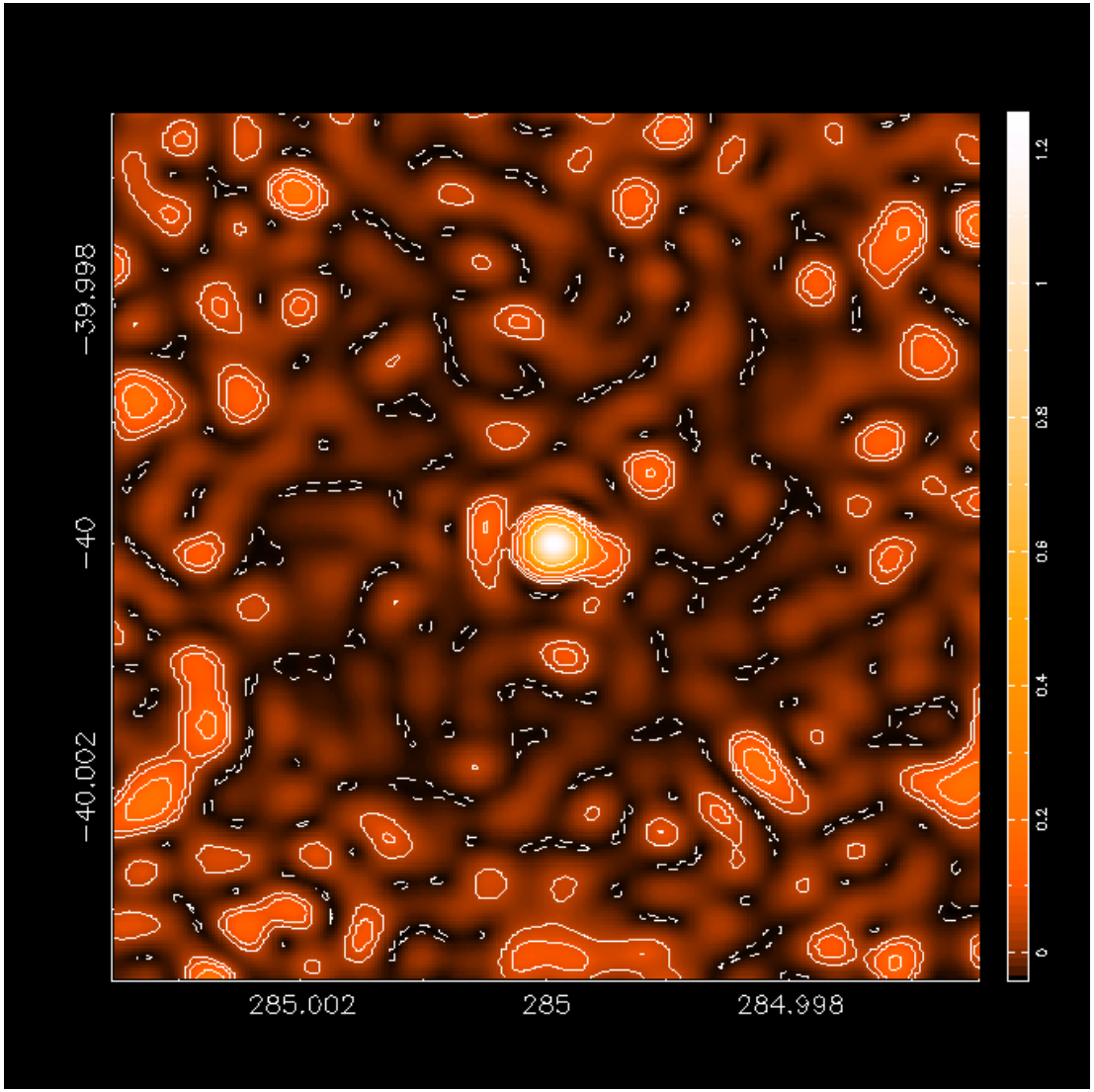
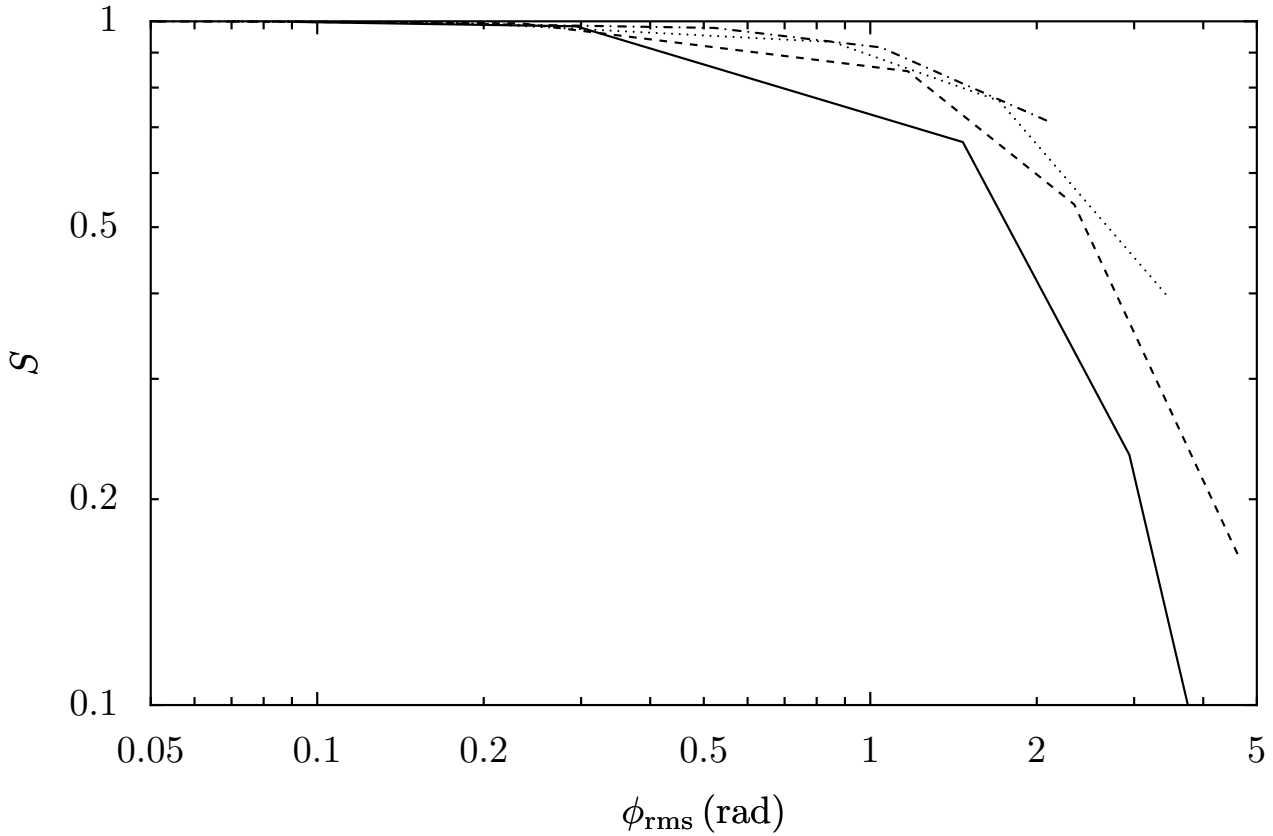


Uncalibrated: point source sensitivity

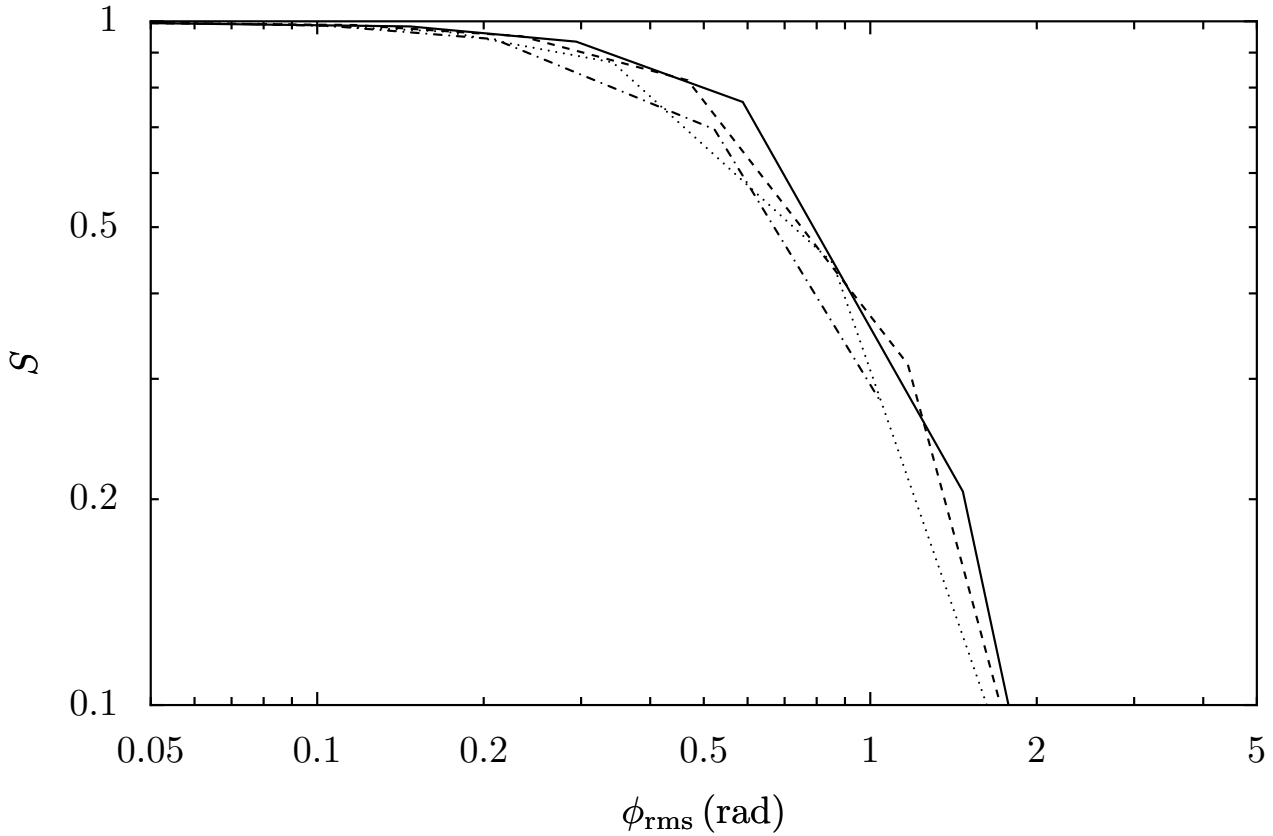
Compact configuration



Point source sensitivity (relative to no atmospheric phase fluctuations) as function of phase rms on a 300 m baseline, for four thicknesses of the turbulent layer and no phase correction.

Uncalibrated: point source sensitivity

Medium configuration



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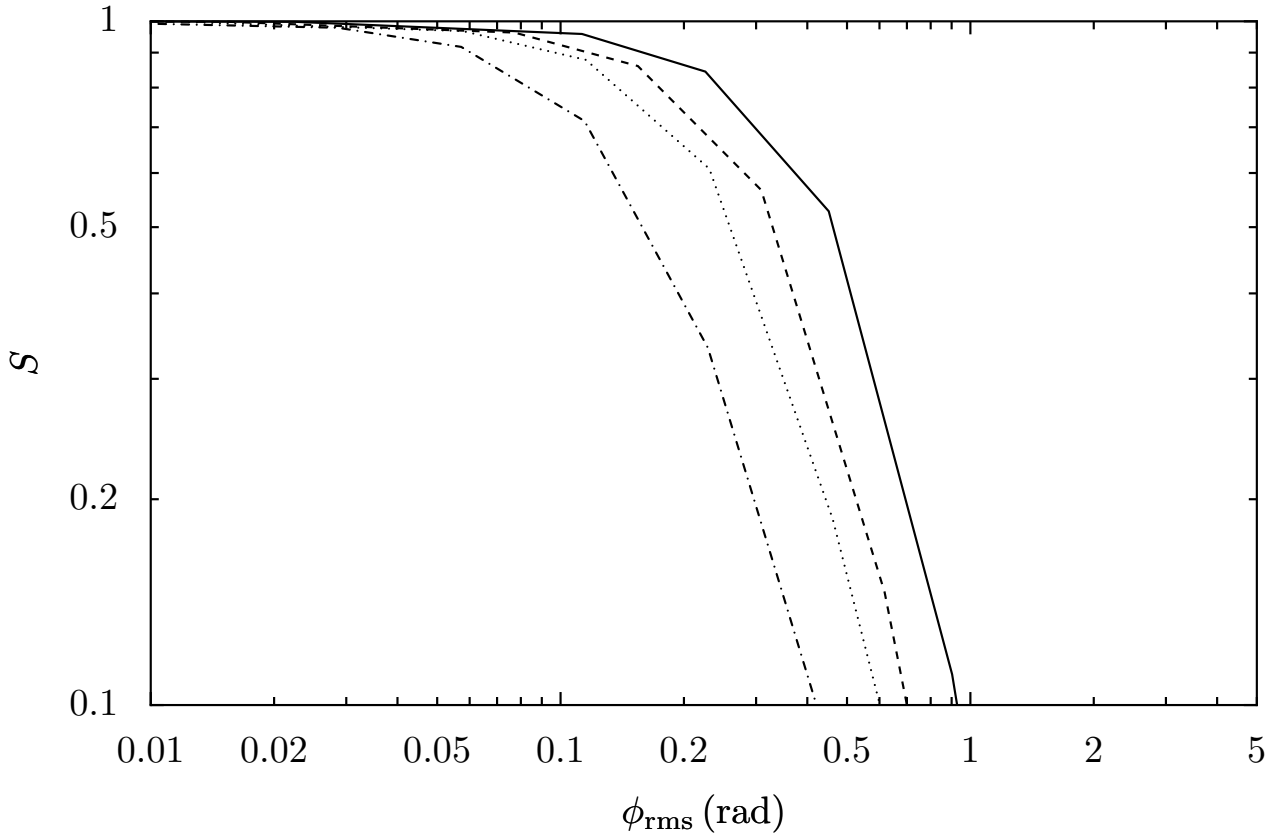
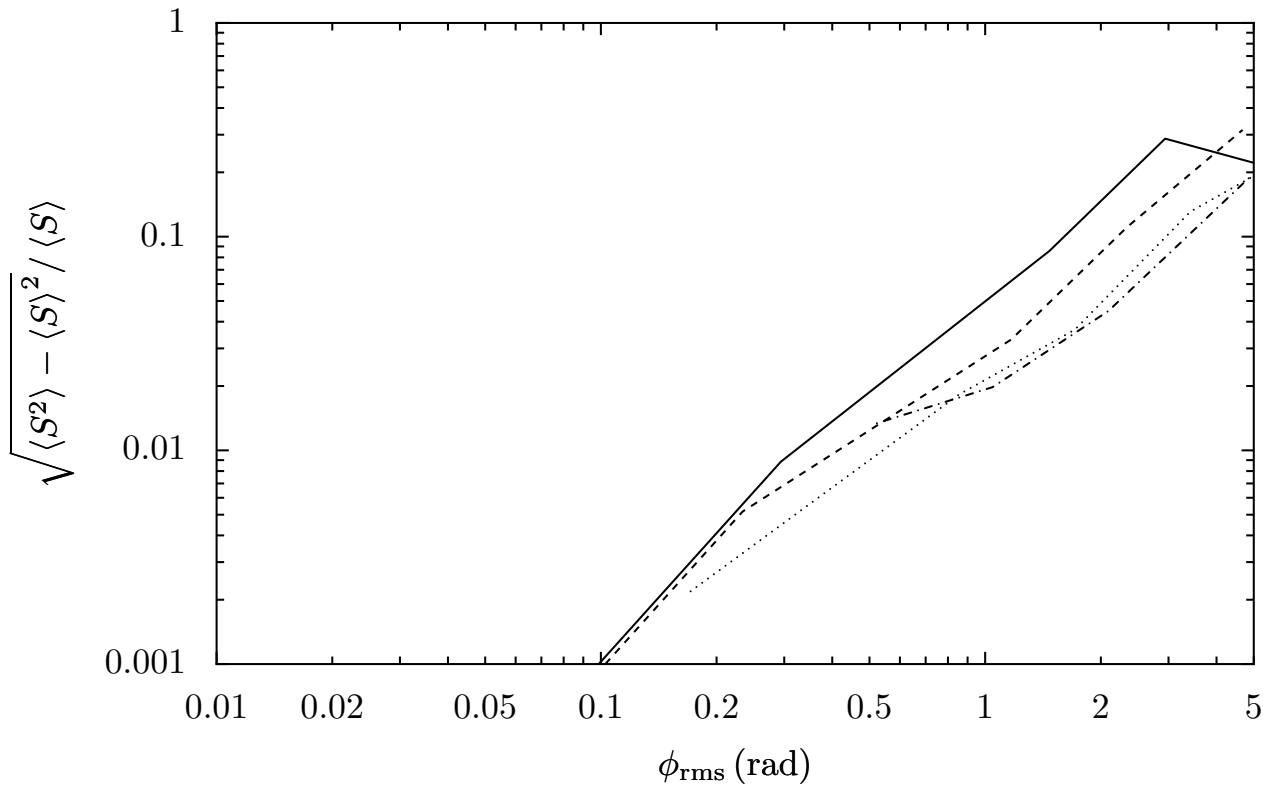
Uncalibrated: point source sensitivity

Extended configuration



Point source sensitivity (relative to no atmospheric phase fluctuations) as function of phase rms on a 300 m baseline, for four thicknesses of the turbulent layer and no phase correction.

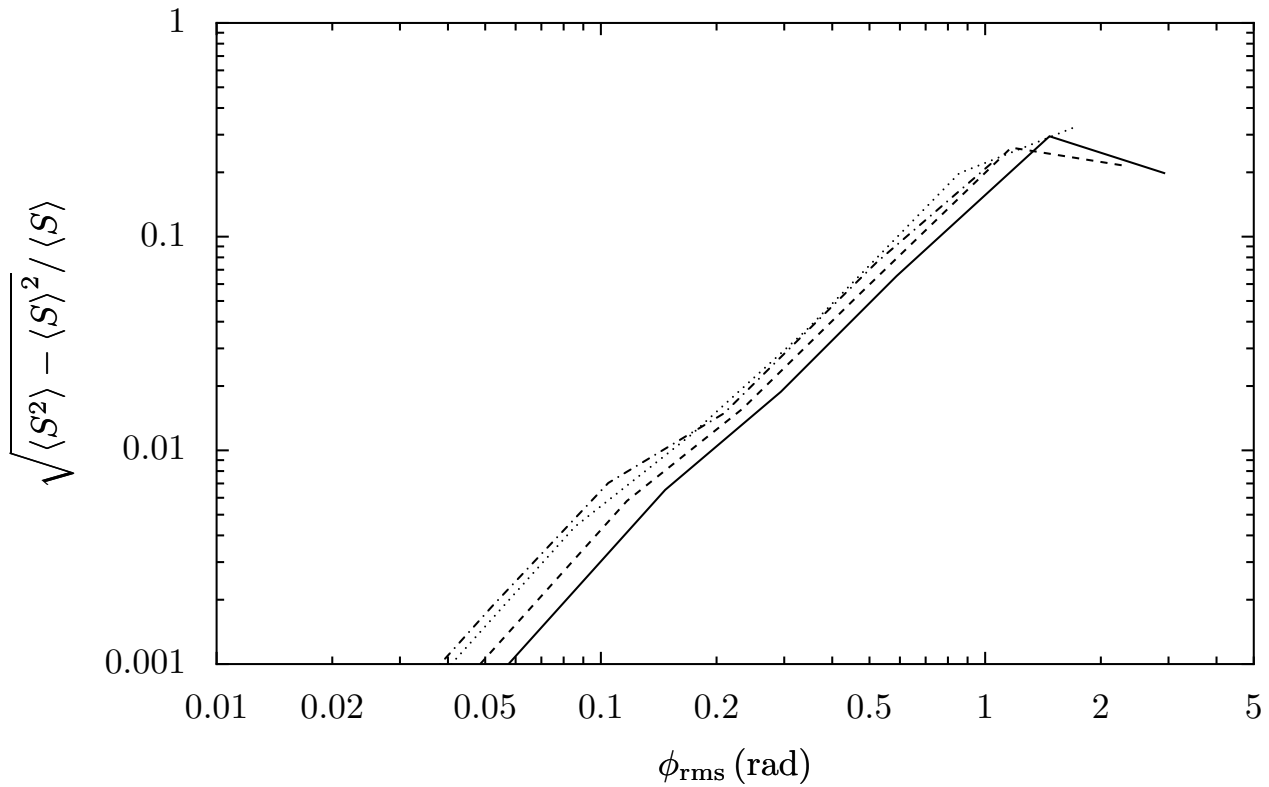
Snapshot observation sensitivity variance
Compact configuration



Standard deviation of relative point source sensitivity as function of phase rms on a 300 m baseline, for four thicknesses of the turbulent layer and no phase correction.

Snapshot observation sensitivity variance

Medium configuration



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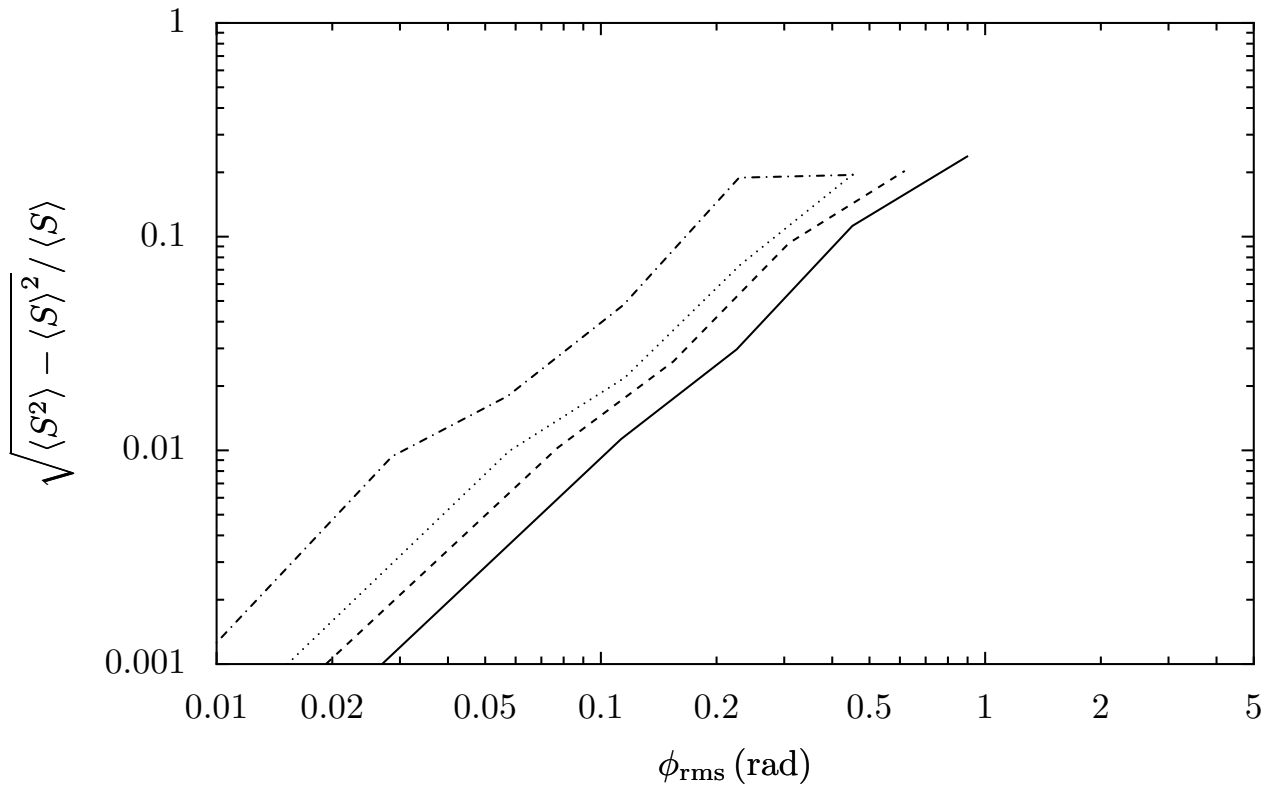

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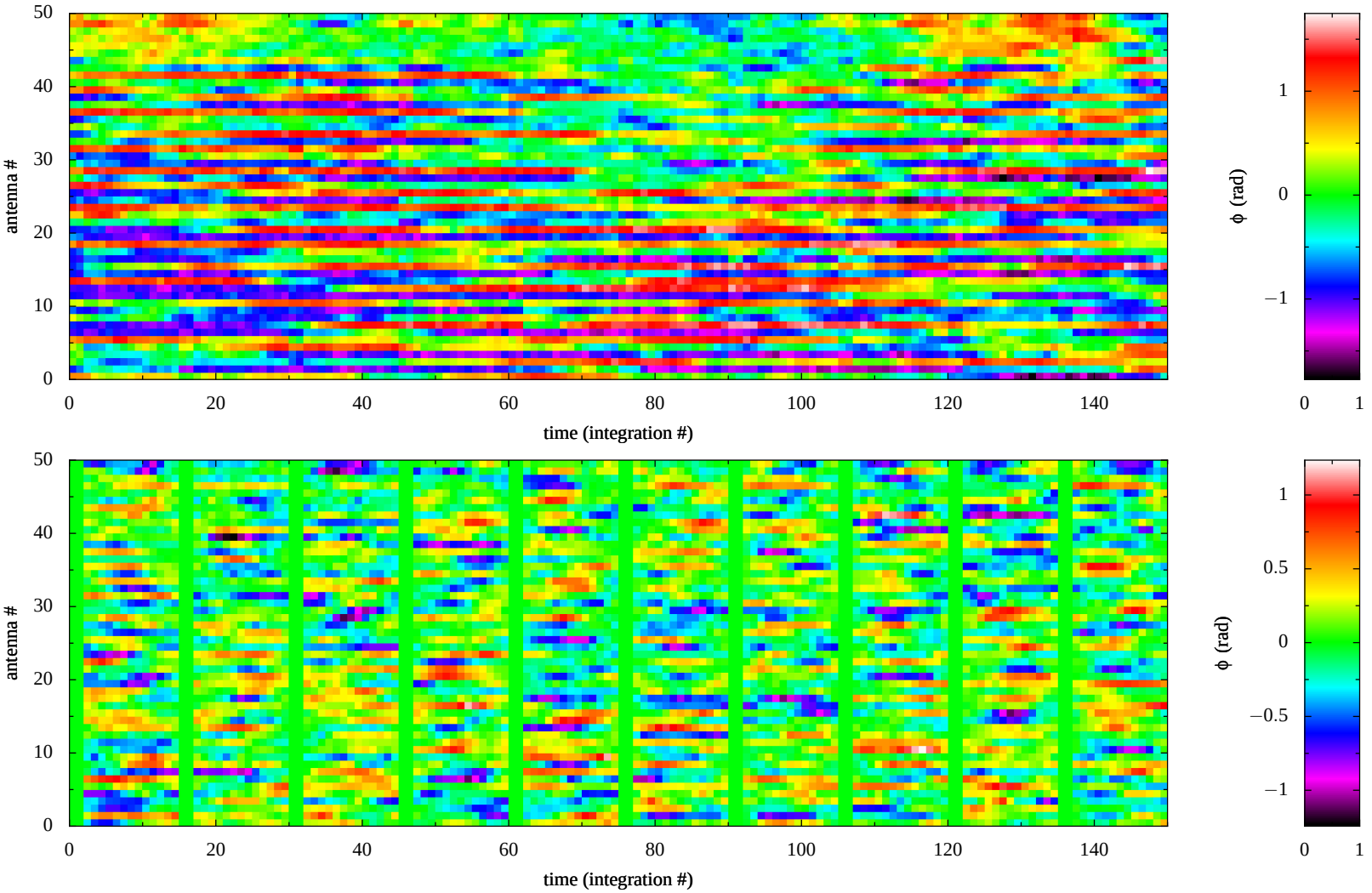
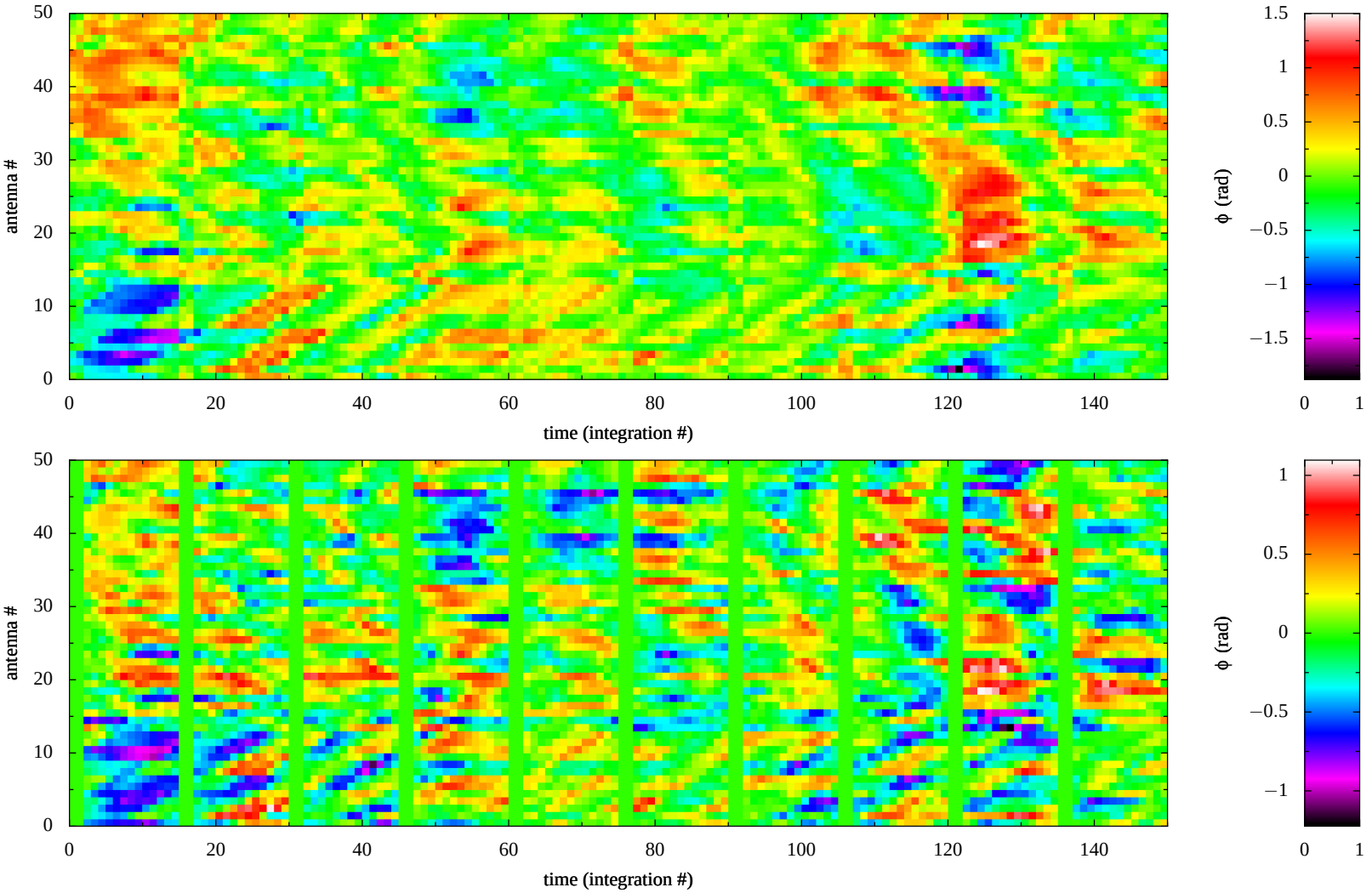
Fast switching phase calibration

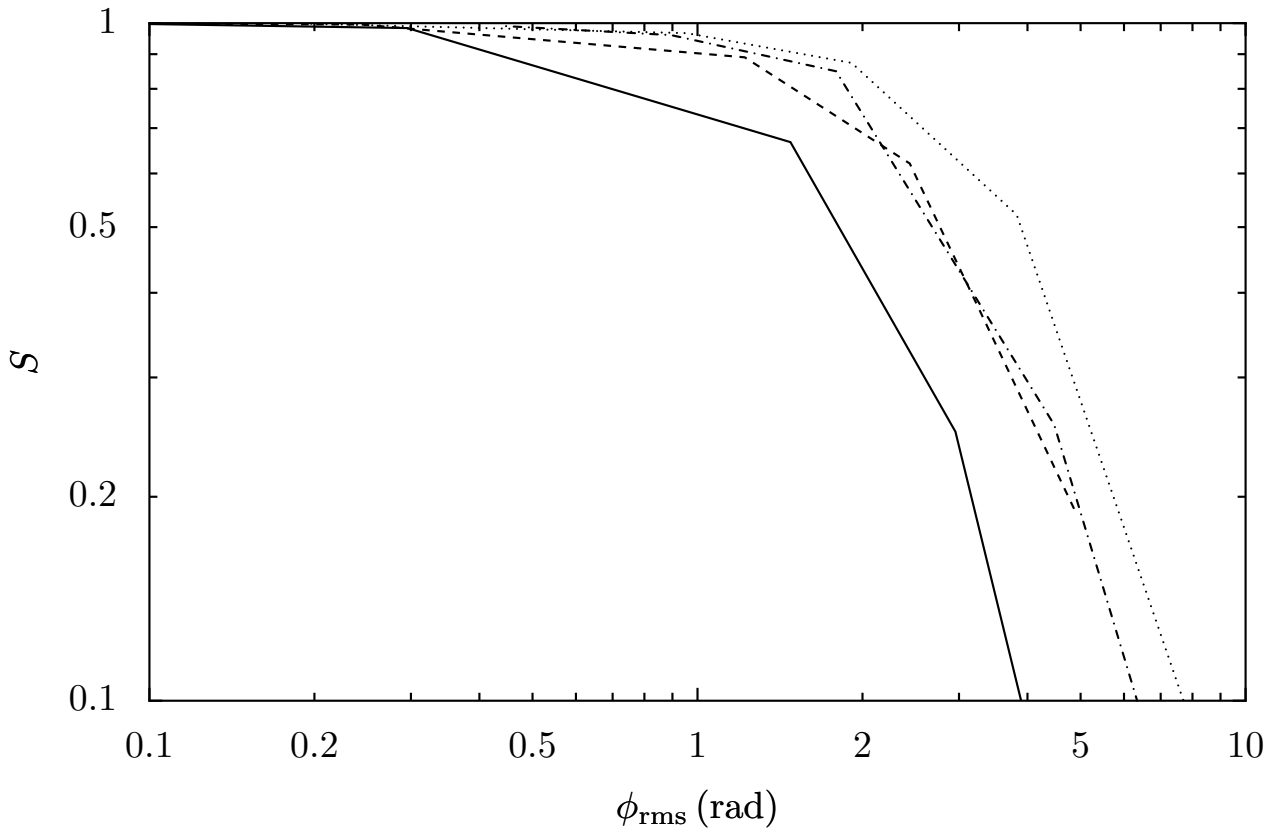


Fast switching phase calibration (compact conf.)



Fast-switching calibration: point source sensitivity

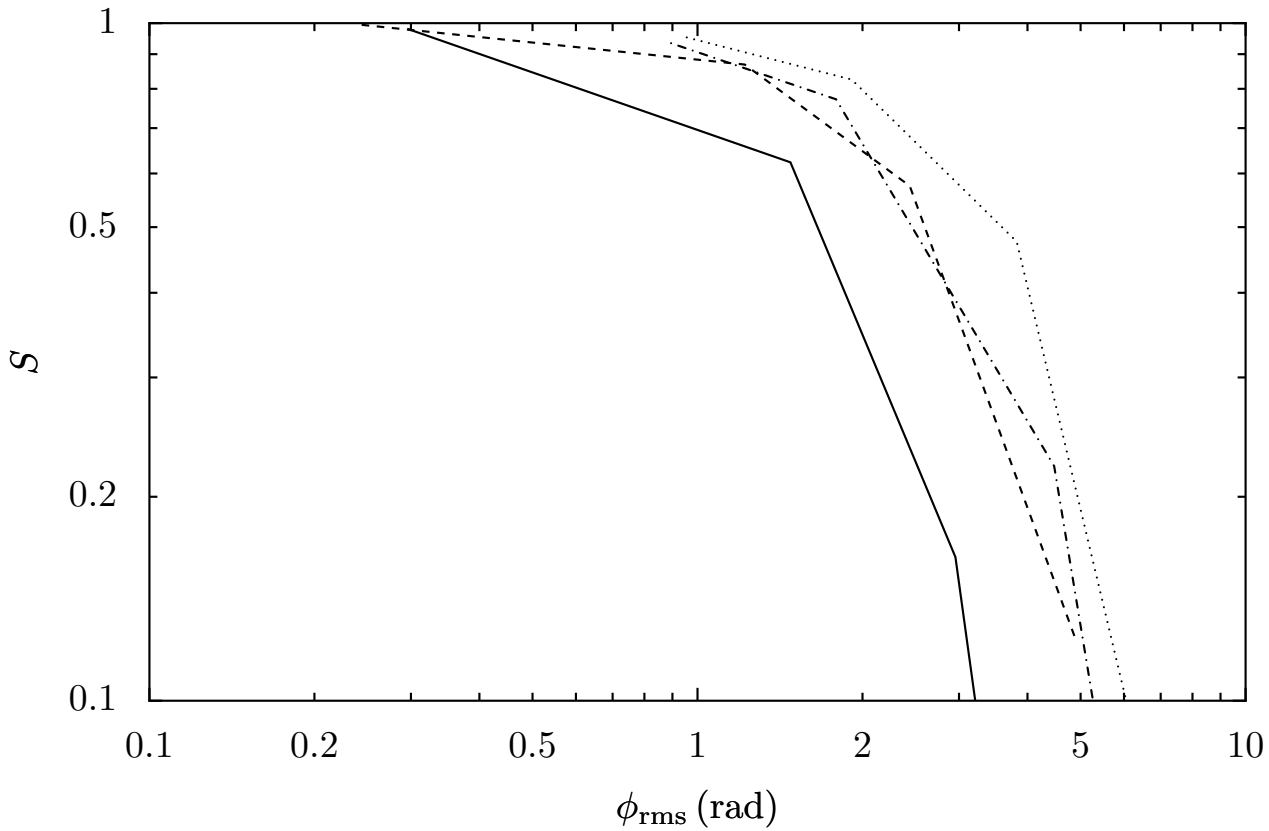
Compact configuration



Relative point source sensitivity, perfect fast-switching calibration with a 15 s duty cycle, 1.5 degree offset to calibrator, calibration transfer from lower frequency band.

Fast-switching calibration: point source sensitivity

Medium configuration



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Fast-switching calibration: point source sensitivity

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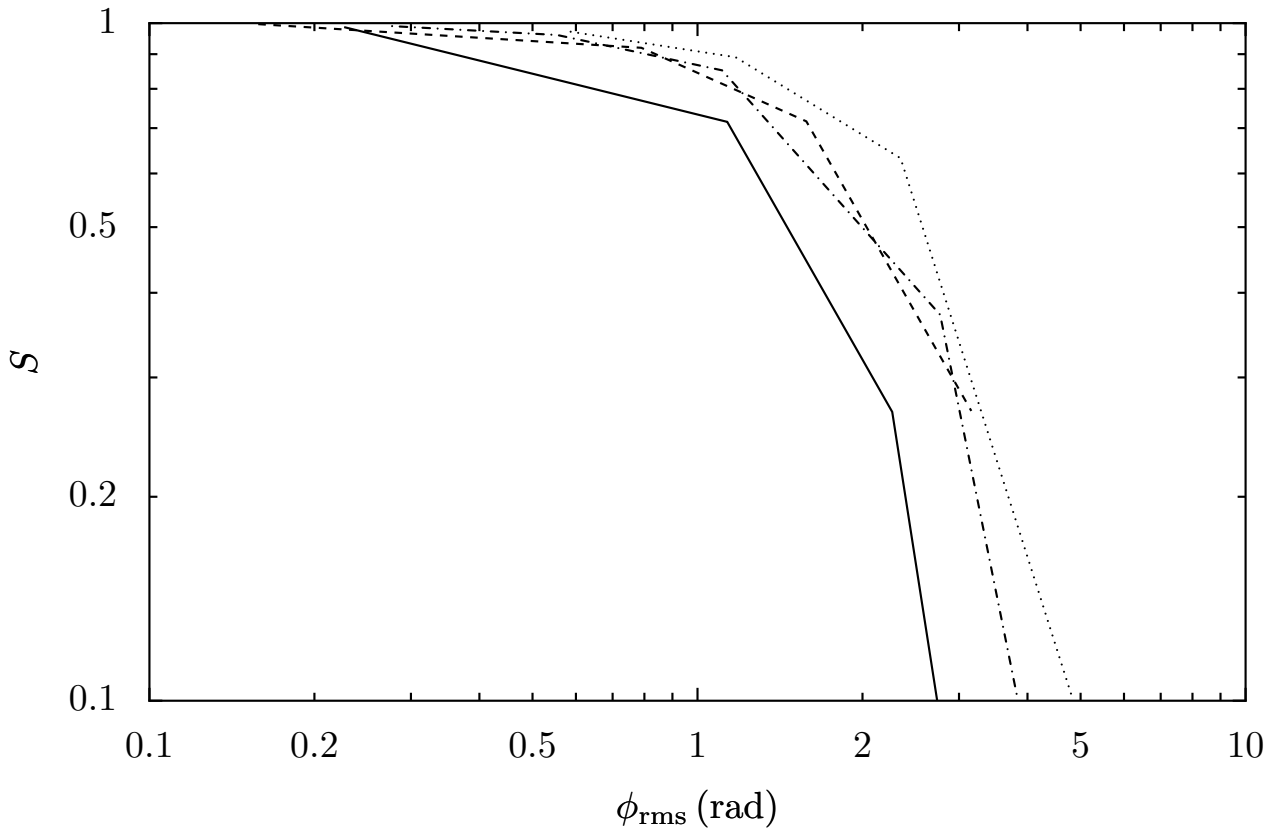

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