BeamSims:

Are Unstable Primary Beams Going To Bite Us In The *X*?

(And what is *X*, anyway?)

(And should you be worried?)

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Project Overview

- Characterize the impact of primary beams (PB) on a number of upcoming telescopes
  - MeerKAT, APERTIF, ASKAP, SKI-hi
  - LOFAR & EMBRACE
- Develop simulations framework and figure out some figures of merit (FoM)
  - different depending on science
  - Imaging DR, spectral DR, polarization purity, etc.
- CASA: setup of measurement sets, imaging
- MeqTrees: simulation & calibration

Why Beams?

- Selfcal deals with direction-independent effects (DIEs), as we go deeper we need to deal with DDEs.

- Of these, PB variation is the "scariest"
  - at low frequencies: ionosphere

- PBs vary in time and between antennas
  - Az/el: rotating sky
  - Pointing error
  - Wind/gravity/thermal deformations
 - PAFs: element LNA gains

Why worry?

- PB variation translates into time-variable DDE (different towards each source)
    - imaging artefacts: DR limit
    - DD bandpass: spectral DR
    - DD (and time-dependent) instrumental polarisation
- Implication for transients?
    - Overall quality of calibration
    - Sources rotating through nulls (or steep parts of the PB)
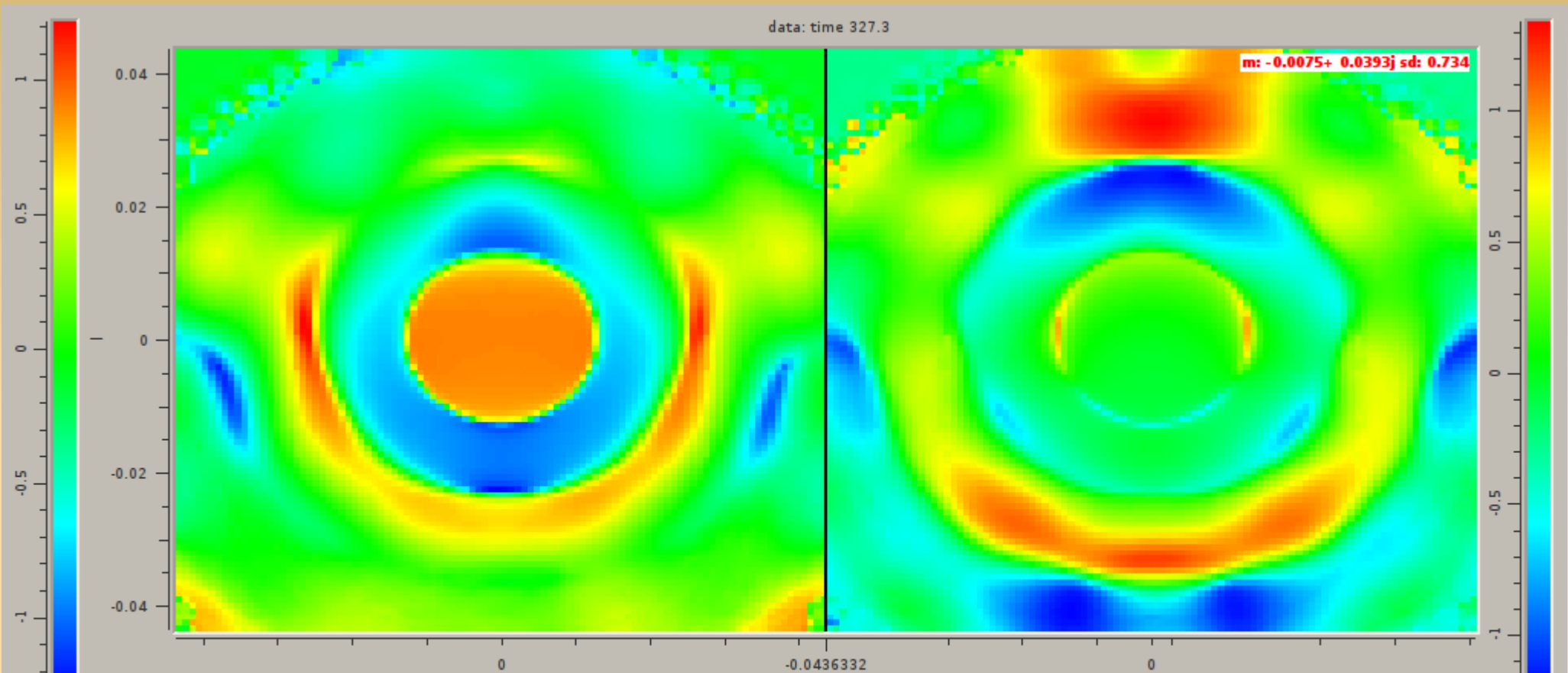
MeerKAT Beams
prime-focus vs. gregorian
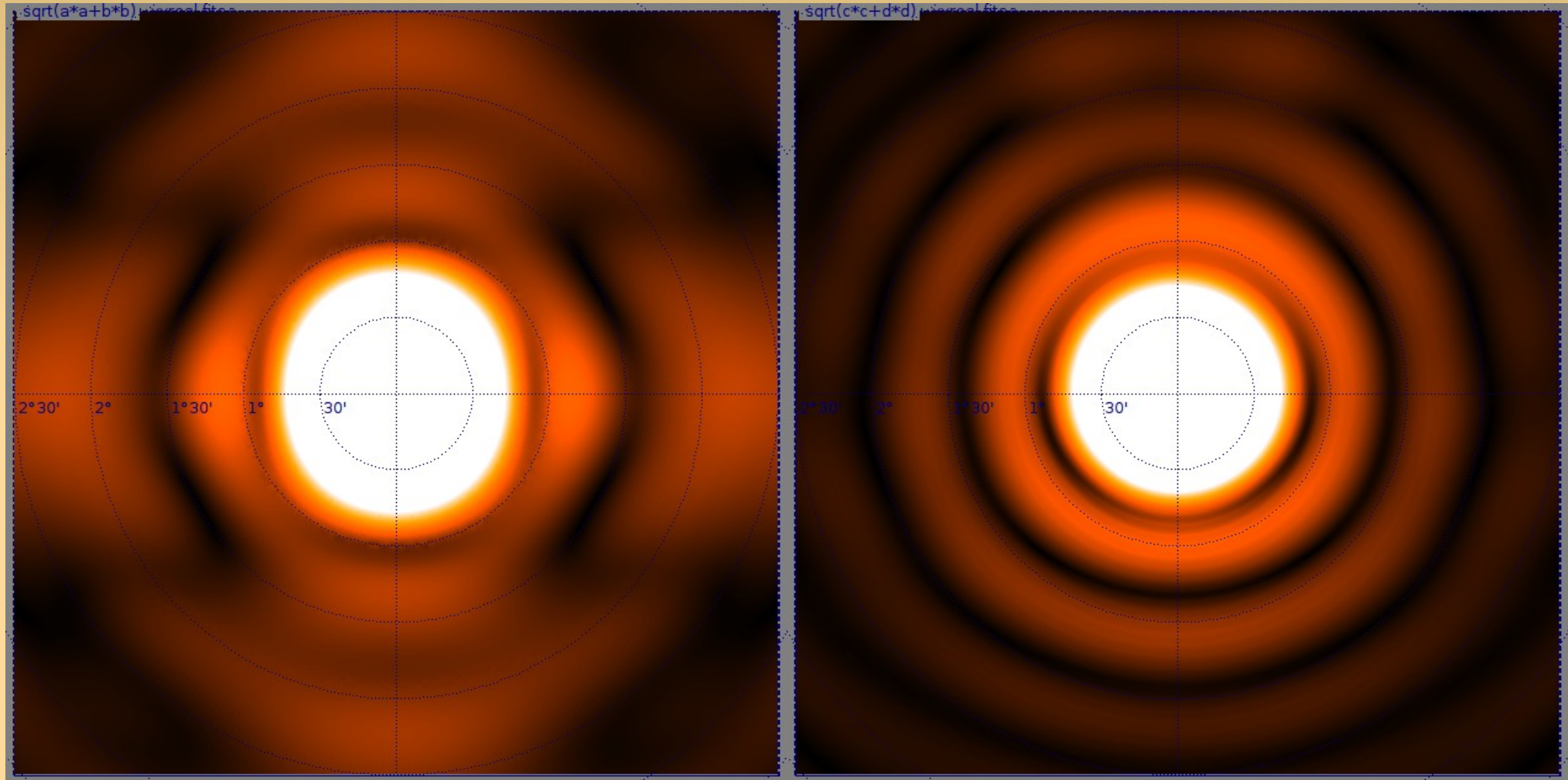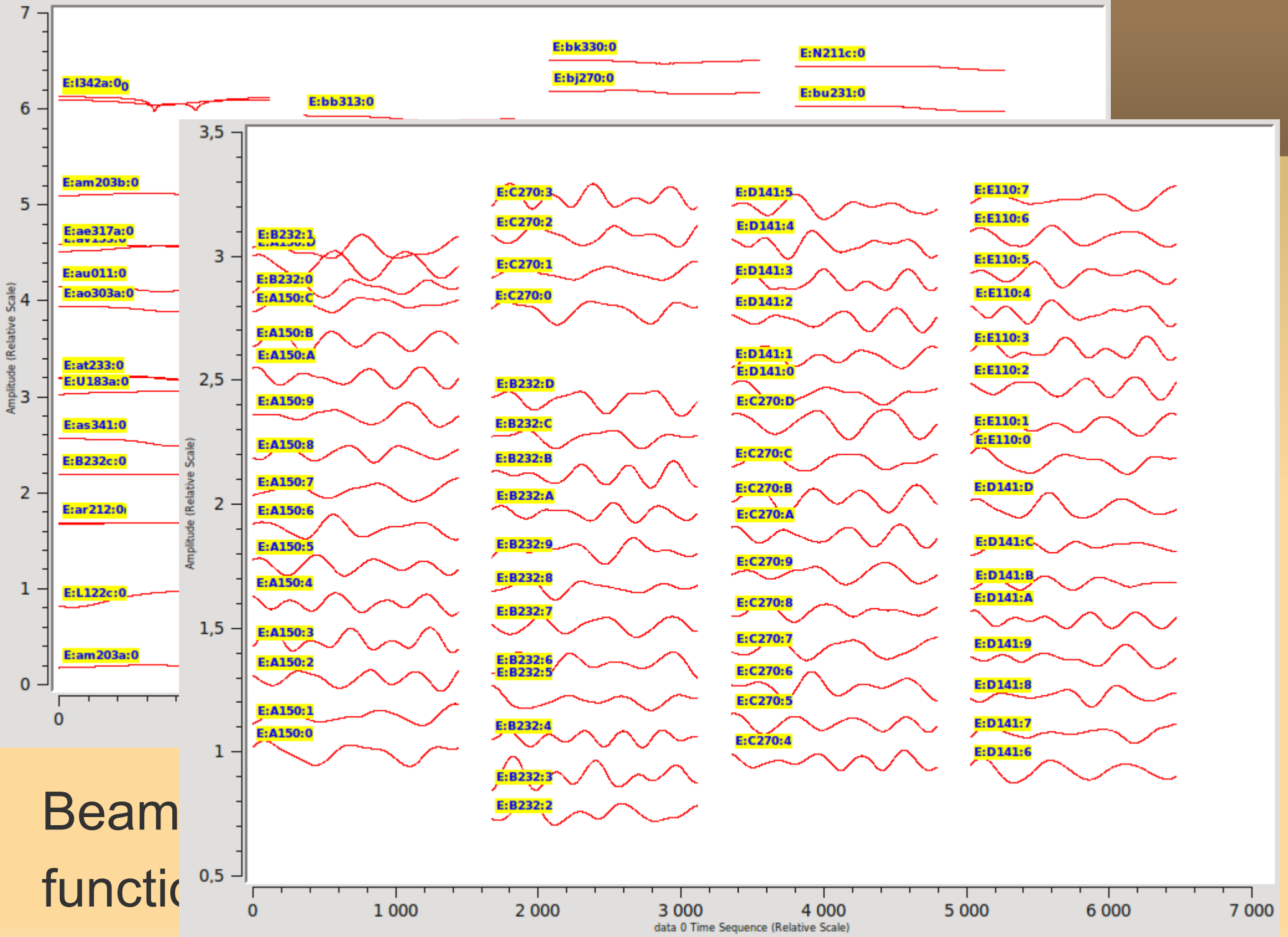
Beam functic

(Very preliminary) APERTIF beams

data: time 327.3

m: -0.0075+ 0.0393j sd: 0.734

Off-axis compound beam, simple max-SNR weighting. LOTS of room for improvement here, so do not be alarmed.

What Can Be Simulated Today

- Beam patterns specified via FITS files
  - e.g. MeerKAT, APERTIF, ASKAP etc. beams from EM simulations
- Full Jones formalism (incl. cross-terms)
- Sky rotation (w.r.t. beam pattern)
- Pointing error, thinking about deformation
- PAF beam forming
  - Including element gain drifts
- Sky: images, point sources, Gaussian components
  - including transients
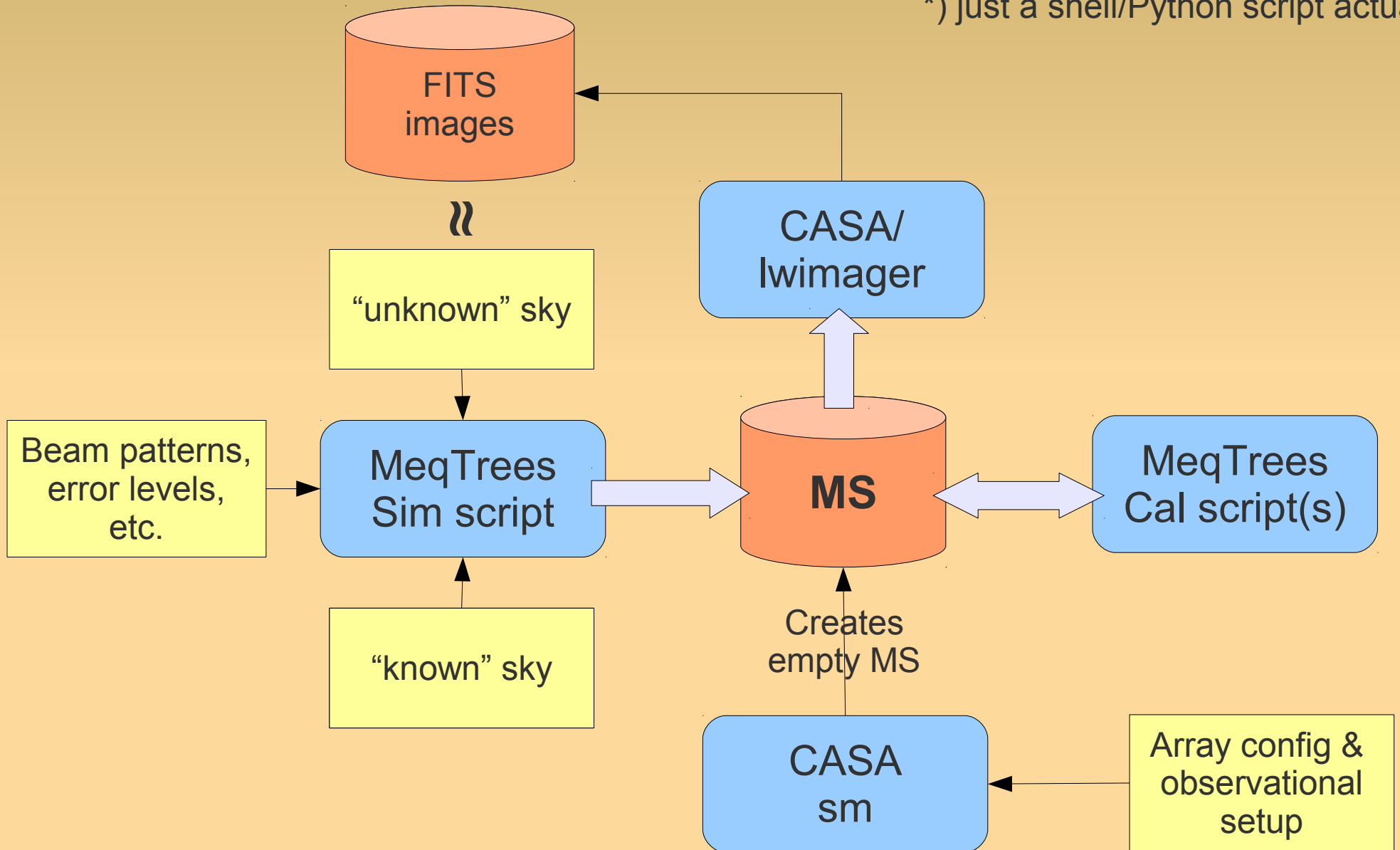
What Can't Be Simulated (For Now)

- Cannot apply pointing error (& other image-plane effects) to images

  - A-deprojection required (hopefully UCT will help)

- For now, done on a per-source basis, expense (CPU, RAM) scales as $N_{src} \times N_{baselines}$

- For MeerKAT, can reasonably do 20~100 sources

Simulation Strategy

- Simulated sky split into
  - "bright" vs. "faint"
  - "known" ("calibration model") vs. "unknown"
- "Faint" sky simulated w/o errors for performance reasons
- "Bright" sky simulated with full errors
- Perform calibration using the known calibration model
- Evaluate our ability to recover the "unknown" sky properly

BeamSim Simulation Pipeline*

*) just a shell/Python script actually

FITS images

"unknown" sky

Beam patterns, error levels, etc.

MeqTrees Sim script

"known" sky

CASA/ lwimager

MS

MeqTrees Cal script(s)

Creates empty MS

CASA sm

Array config & observational setup

BeamSim Results

- ## No hard answers yet
  - GIGO syndrome: need real numbers for errors such as pointing, etc.

- ## Differential sims already meaningful
  - How does setup A differ from setup B, assuming everything else is identical?
  - What's the difference with and without effect X?

- ## Very early result (from this Monday)

MeerKAT vs. WesterKAT

- WesterKAT: WSRT with MeerKAT gregorian offset dishes
  - 14 antennas, 12 hour synthesis
  - sky rotation and 40" pointing error
- 64-dish MeerKAT, same dishes
  - 2 hour synthesis
  - sky rotation and 40" pointing error
- 3C147 field
  - Sky models readily available
  - Everyone knows & loves 3C147
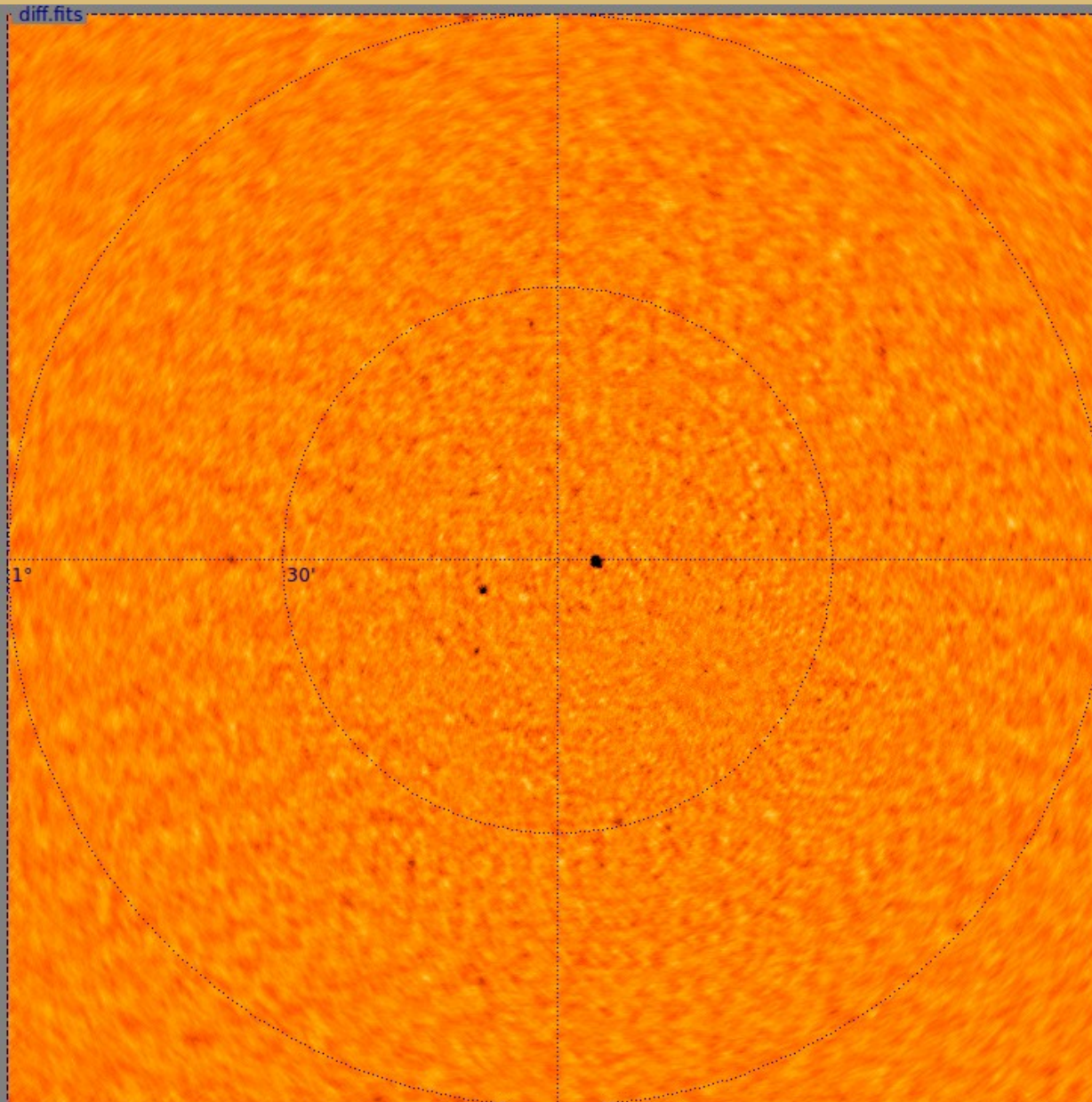
WesterKAT
off-axis imaging artefacts
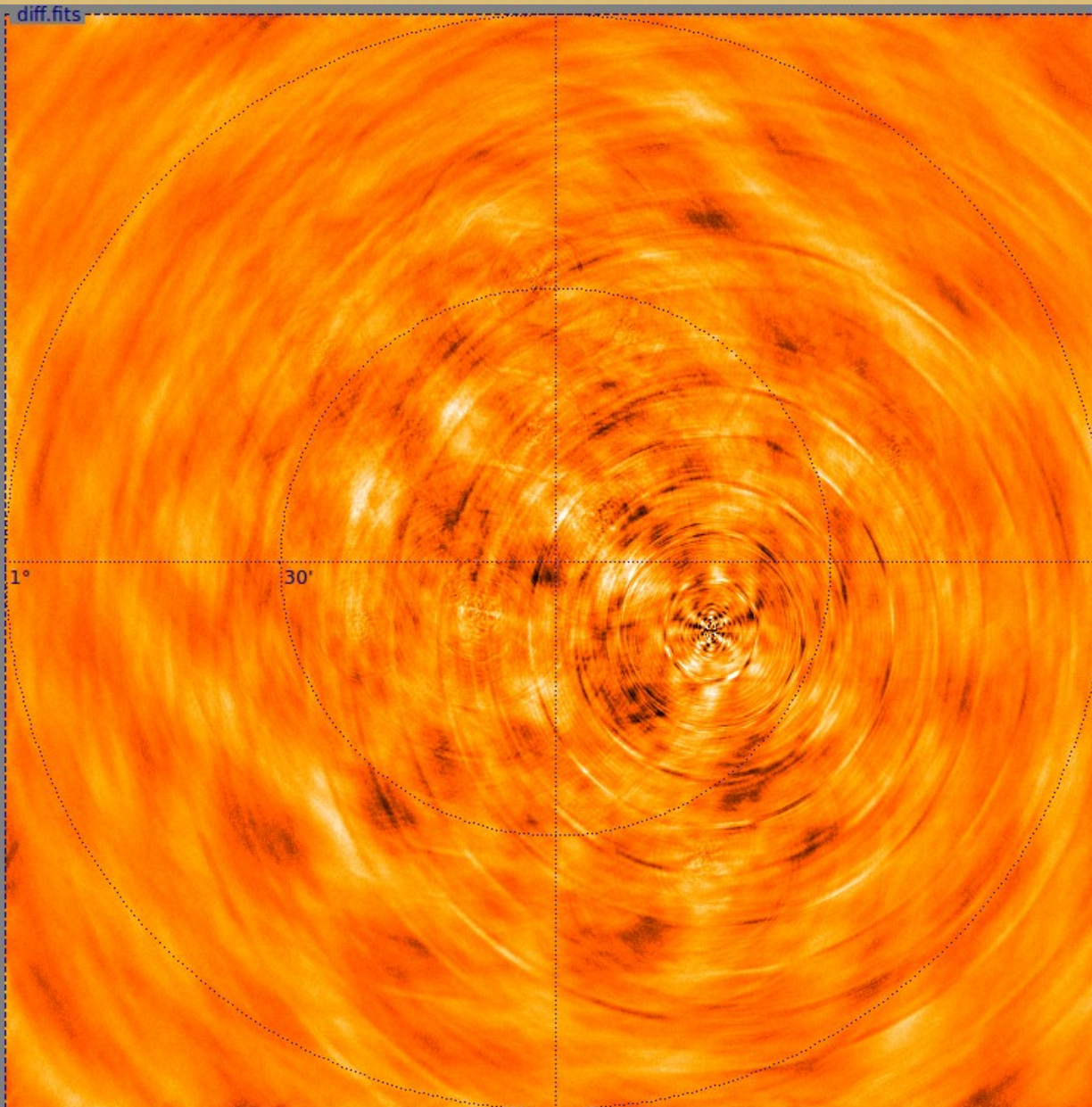
limits
±75 μJy
$\sigma = 15\ \mu$Jy

MeerKAT
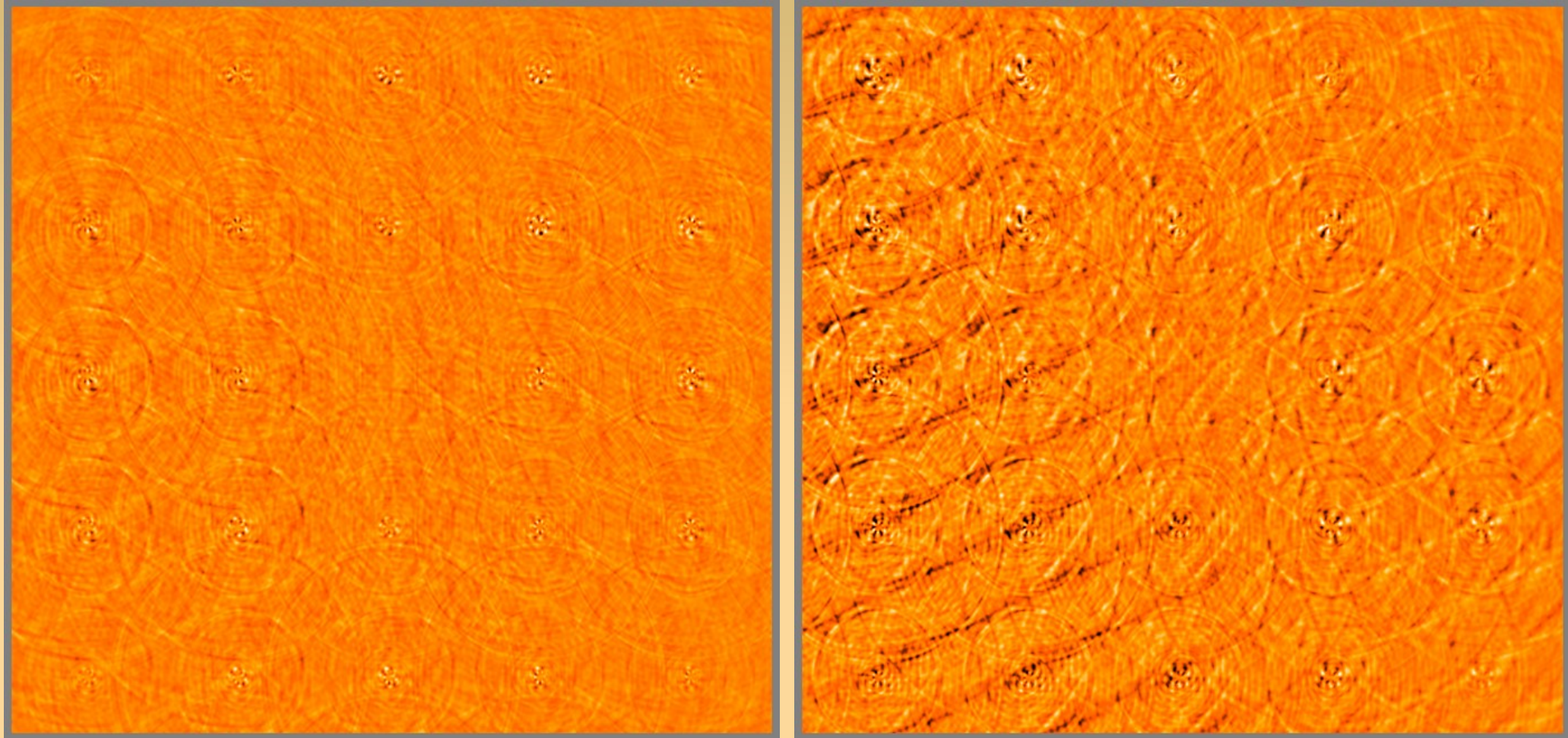## off-axis imaging artefacts
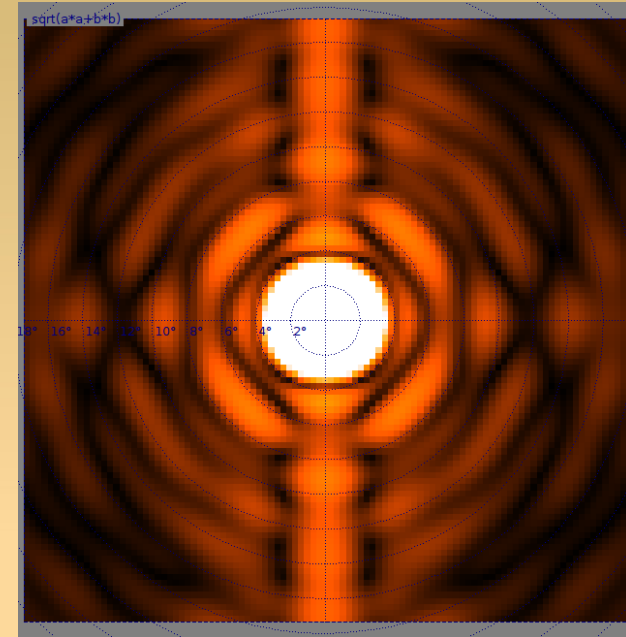

limits
±75 μJy
σ =10 μJy

APERTIF

"Gridded skies" showing calibration residuals as a function of position for an on-axis and an off-axis compound beam.
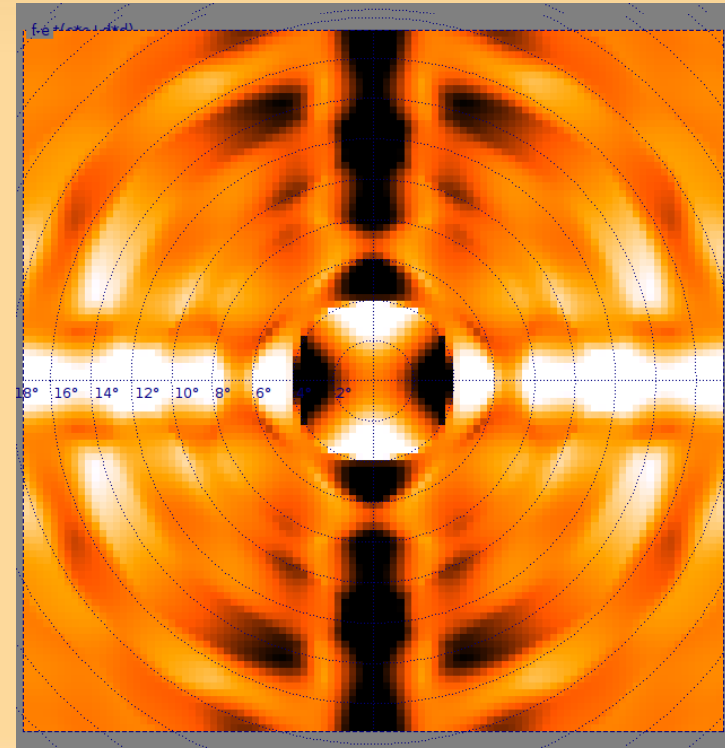
ASKAP Beams

- Lead: Tony Willis, DRAO

Tony concentrating on a particularly difficult point of Oleg's MeqTrees talk.

Puschino, Russia (AJDI 05/08/2007)

ASKAP Issues

- POSSUM (Polarisation Sky Survey of the Universe's Magnetism)

  - Co-PI: Russ Taylor, U. of Calgary

  - Instrumental polarization (and its stability) critical

- The Willis simulations:

  - ASKAP project provides the PB patterns

  - UC provides polarized skies

  - Tony develops MeqTrees scripts & runs simulations

ASKAP Exx & Eyy-Exx

ASKASS Strikes

- In an audacious raid, the Australian SKA Secret Service descends on the Willis residence and confiscates the top-secret ASKAP beam patterns.

NASKAP

- Despite this setback, answers still needed, not (currently) provided by ASKAPsoft

- Tony & Bruce Veidt to simulate from scratch an instrument that is NOT ASKAP, but acts just like one

What We Can Do For You

- Brad has a working MeerKAT sim pipeline

- Some scaling issues, but simple stuff readily available

  - Sky images + a few point sources

- Want a snapshot or a transient sim?

  - Give us a sky image and a source list (can even do transient sources, light curves etc.)

  - Bribe Brad