Direction dependent calibration

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2.2.1

12+15

- Ionosphere, (Troposphere)
- Antenna/Station beams

Use cases

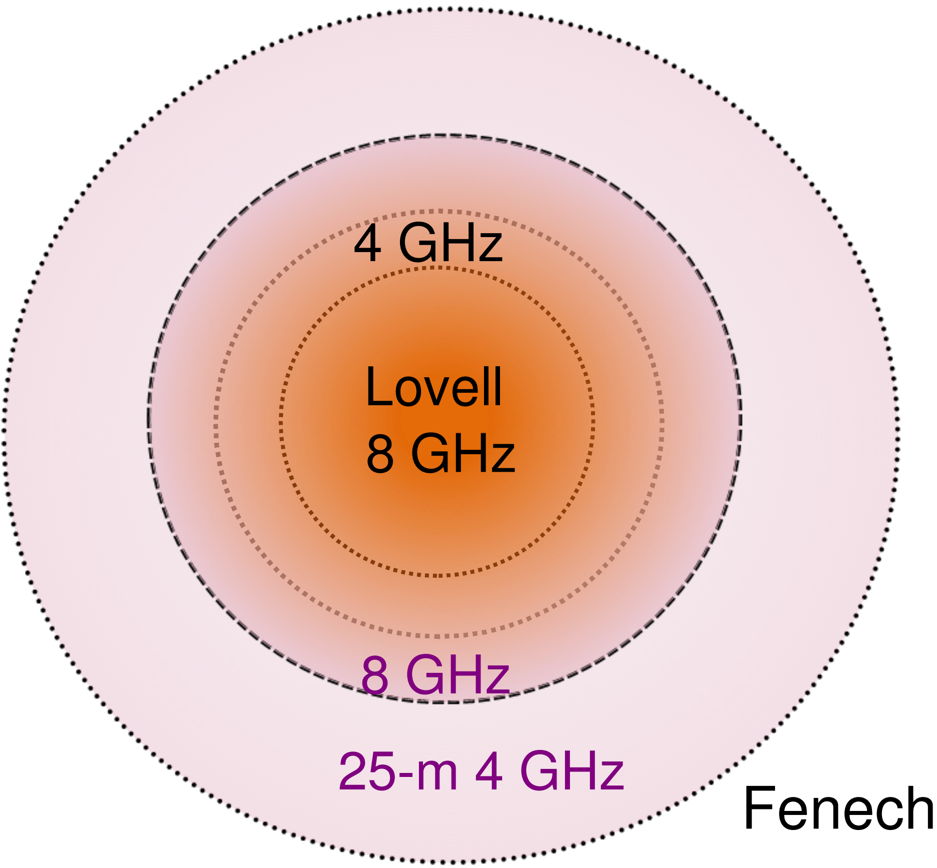
- cm-wave imaging of full primary beam
  – objects of interest
  – confusion
- Mosaicing and array combination
- Science requirement to what accuracy level?
  – imaging fidelity
  – flux scale accuracy, astrometry, polarisation
- Not our problems (directly)?
  – all-sky survey instruments
  – mm/sub-mm wave and single dissues
  – rapidly-moving solar-system objects?

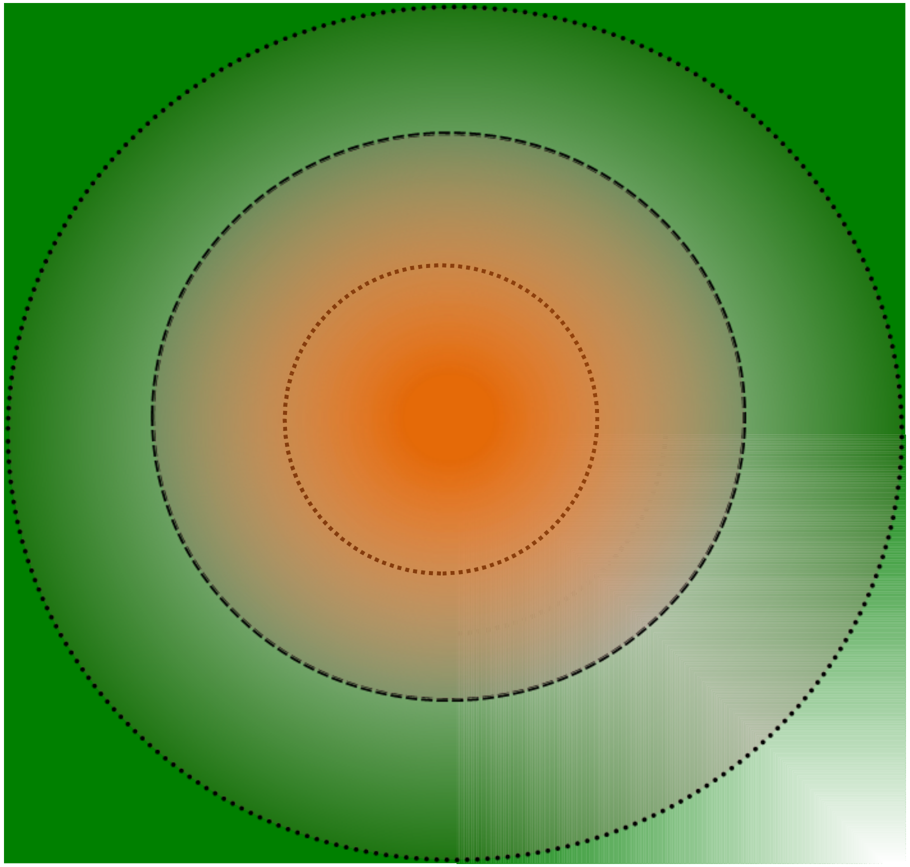
Objectives

- Calibration strategies for practical implementation
  - remove atmospheric and instrumental corruption variations on arcmin/sub-degree scales
  - by corrections for direction- and antenna-dependent, time-varying complex gains
- Decompose instrument- and target-dependent considerations into a range of approaches
  - standard observatory pipelines, customised scripts, interactive/user calibration/imaging
- Allow for flexible/modular implementation
  - combine with VLBI methods
  - support different imaging strategies
  - interoperability between packages where needed

Heterogenous beams

- From 25 to 75 m
  - and then add a phase screen...





Visibility-plane approaches

- Direction dependent matrix solution in *uv* plane
  - using predicted beams (Bhatnagar)
    - 'aw' projection
    - first order or higher gradients?
    - *efficient* ME parameterization
- Differential gains at source positions (Smirnov)
  - concerns over no. of degrees of freedom
- Direct correction using measured beams
  - Reid et al for DRAO ST polarisation

Ionosphere cont.

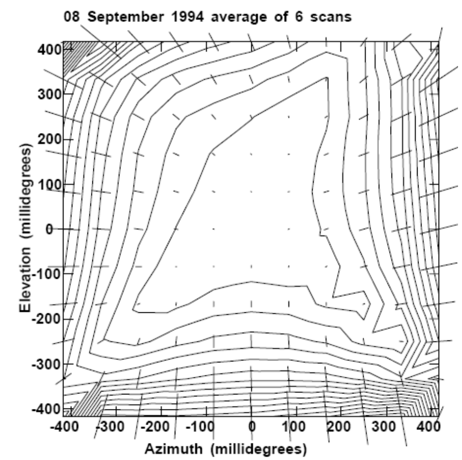
- For ionosphere
  - fitting Zernicke polynomials (Cotton)
  - ionospheric parametrisation (MIM, Noordam)
    - work from large to small-scale structure
  - external information eg GPS (Anderson)
    - geographical limitations to applicability

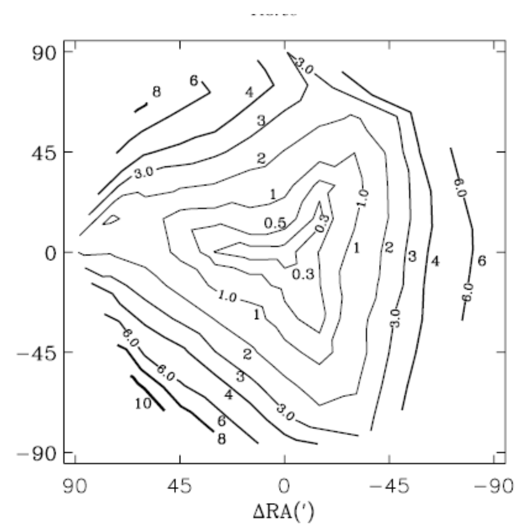
Image plane

- Peeling (Osterloo, Cotton,...)
  - works for general direction-dependent effects
  - pragmatic
  - isolating sources
    - identify scales of isoplanatic regions for self-cal

Wide-field polarimetry

- Leakage & gains vary across PB
  - Rotates on sky for alt-az
  - Pointing errors, elevation, thermal effects
  - Scales with frequency
- Image plane approaches (for points):
  - Cotton(1994): VLA
  - measure apparent (Q,U)/I using coarse beam raster (~4% at 3dB)
  - scale by I, subtract rotated pattern
  - average over all antennas, same parallactic angle (snapshots)
- Peracaula, Taylor et al (2003) DRAO
  - similar approach; non-rotating beam
- Both work to <1% over full field

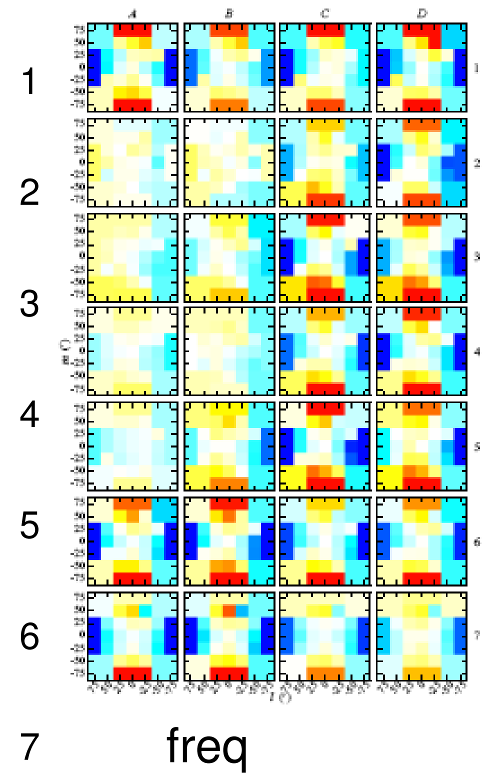




Empirical or analytic

- Integrate & FT Jones matrices
  - Directional antenna voltage patterns, ν dependence
  - Reid et al (2009) DRAO: Measure
    - correct Stokes Q,U using linear combinations of d-terms, model *I* cc
  - Bhatnagar et al (2008) VLA: Predict
    - full direction dependent matrix
    - incorporate FT of Mueller matrix for baseline *ij* ,calculate residual image
    - tested for I & V incl. beam squint
  - Smirnov (2008) solve for differential gains (leakages) at source positions

$$V_{ij}=\int M_{ij}(\mathbf{r})I(\mathbf{r})e^{2\pi i\mathbf{r}\mathbf{B}_{ij}}d\mathbf{r}$$



DRAO Pol. beam variations between 'identical' dishes

Plans

- Review approaches
- Assess suitability for different arrays, ν's etc.
- Science goals: flexible images/other products
  – ensure consistent calibration across fields
    - optimise weighting for specific targets
- Consider stages of user interaction
- Review tools required and platforms available
- Select test data sets
- Initial implementations
  – Parseltongue/AIPS, CASA
- Further developments

Issues

- Variety of techniques in variety of environments
- Differing use/applicability of external cal info
- Ranges over which specific solutions applicable
  - don't record everything at the highest granularity
    - gradients/vectorise where possible
  - different requirements for cal models/science?
- Requirements for sky models/catalogues
  - bright sources, flux standards backgrounds
  - w-projection v. faceting for field-based calibration
- Storing image information for iterative calibration
  - ν and PB-dependent information

More issues

- Instrumental polarization variations across field
  - heterogenous arrays
  - ν-dependence
- Pointing and elevation-dependent effects
  - deformation, opacity
- Transient sources
- Performance, data bulk, parallelization
- Accuracy estimates/stopping criteria
- Differing degrees of user interaction
  - Implementation platform(s)
  - Pipelines
  - Interoperability

Starting from here

- Contributed effort Garrington, Richards, Muxlow, Beswick
  - assess/test what's already available
  - obtain test data
  - with Eyres' summer student, prepare source catalogue using MERLIN phase-ref archive
- New hire
  - implementation
  - acceptance tests
- All: reports

Milestones

- Month 10 reports
  - relevant instruments/science requirements
  - available algorithms and strategies
- Month 16 experimental implementations
- Month 21
  - final test results
  - final report