3rd (and 4th) Generation Calibration

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The structure of this talk

- Posted title: “The Minimum Ionospheric Model.”
- This will be discussed, but in a slightly wider context.
- The problem: The Telescope Bubble
  - The mismatch between the present glut of new and upgraded radio telescopes, and the available people and tools to operate and use them.
- A mild critique of how we do things
- Some suggestions

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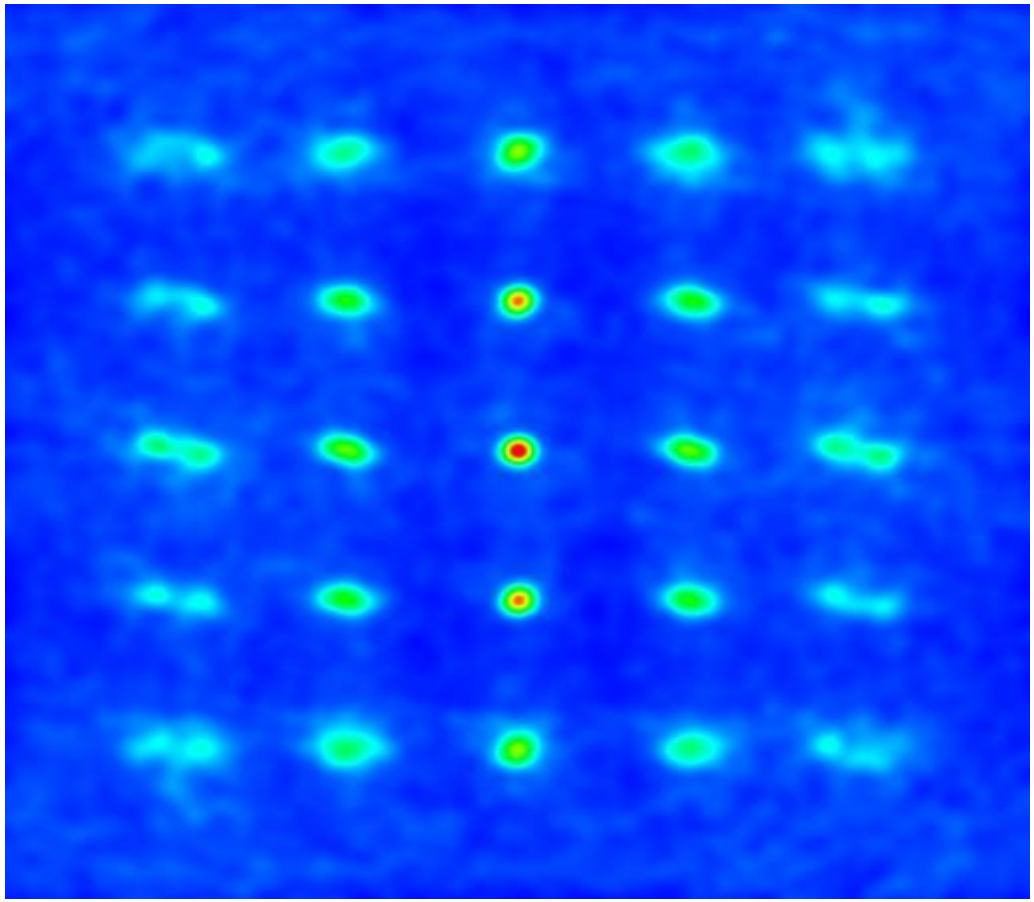
- As a reward for your indulgence, I will talk only 10-15 minutes, and give the rest of my time to Oleg, who will cheer you up again.

The Evolution of Ionospheric Calibration

- Simplest: Treat the ionospheric phase (and Faraday rotation) as uv-plane effects
  - Antenna-based, but constant over the FOV
- Improvement: Field-based calibration (Bill Cotton):
  - Uses source position variations in the image plane (snapshots). Operational (VLA 74 Mhz). Works for baselines < 10km
- Next step: SPAM (Huib Intema):
  - Solves for antenna phases in the uv-plane. Works for longer baselines.
- Next step: Minimum Ionospheric Model (MIM)
  - Fully general. Minimum nr of parameters, and minimum assumptions about the 3D ionosphere. Allows combination of astronomical and GPS data.

The ionosphere is an Image-Plane effect



You can only correct uv-data for a single point in the sky

3rd generation calibration

- Deals with image-plane effects (l,m,f,t)
  - Restless Ionosphere
  - Wobbly Station Beam Shapes
- It is needed for the new telescopes
  - And would be nice for the existing ones
- But: Many more parameters to be solved for
  - Large increase in processing
  - Is there sufficient information?
- Not easily implemented in the existing reduction packages
- It is more complex, and therefore (even) less flexible than existing software

4 generations of calibration

- 1st generation (<1980): Rely on instrumental stability over 12 hours
  - dynamic range 1:100
- 2nd generation (1980-): Selfcal, use bright source(s) in the field to solve for uv-plane effects
  - dynamic range: 1:5.000.000 (WSRT)
-
- 3rd generation (2010-): Image-plane effects
  - station beamshapes
  - ionosphere (phase and Faraday rotation)
- 4th generation (2012-): Statistical analysis of residuals
  - 3rd generation calibration creates the conditions

A glut of new radio telescopes

- 1956: Dwingeloo, Jodrell Bank
- 1960: Cambridge
- 1970: WSRT
- 1980: VLA, MERLIN
- 1990: ATCA, GMRT
- 2000: VLBA, GBT, EVN
- 2010: LOFAR, ALMA, eVLA, eMERLIN, ASKAP, MeerKat, ATA, MWA, LWA, WSRT/APERTIF, PAST, PAPER, FAST, ...
- 2020: SKA (the telescope to end all telescopes)

Available resources

- Money: OK, but underfunding is routine
- Hardware: OK, but cheap junk (necessarily)
  - (too?) many calibration parameters
- Software: A BIG problem
  - algorithms
  - processing power
  - calibration information
- Users: Too few, too spoiled, too distracted
- Developers: Too few, too scattered, not users
- The Way We Do Things: Subprime

Feet of Clay

- There are very few “gen 3” developers in the world
- Will there be enough of them?
- They are not active/experienced users
- They do not work together
- Active/experienced users are not involved
- Innovation (and debugging!) always takes forever
-
- As a community, we have feet of clay
-
- Can we afford that?

A Medieval System

- Master craftsmen (supervisors) and apprentices
- .. cranking the handle of AIPS, MIRIAD, NEWSTAR
- .. *all of which have been frozen for years*
- .. in which it is virtually impossible to implement new ideas
- .. let alone quickly
- Very few people know what these packages do exactly
- .. and how
- All are 2nd generation, without explicit M.E.
- A tribal system, with little interaction between “package-tribes”

Innovation Speed

- Jim Hacker (Yes Minister): “If you want change in British politics, you have to start a new party”
-
- In our little world: “If you have a new idea, you have to create a new reduction package to implement it”
  - I have done it twice (2.5?), and I am getting tired of it
-
- Even when the writers of AIPS, MIRIAD, NEWSTAR, DIFMAP were young and vigorous, it took forever to get your idea implemented
-

Ossified User Tribes

- The users are clustered in tribes, each cranking the handle of their favourite package, and accepting the result.
  - The AIPS tribe (80%, like Windows)
  - The MIRIAD tribe (20%, like MAC)
  - The DIFMAP tribe (?)
  - The NEWSTAR tribe (1 user)
  - The CASA tribe (?)
- These packages have been VERY successful!
- But new users are locked into these tribes
- The supervisors are beginning to realize that they are part of the problem....

As a result ...

The existing instruments (WSRT, VLA, VLBI, GMRT) are performing way below their real capabilities because there are too many obstacles to rapid experimentation

The Curse of Data Volume

- The data volume will be so large that it can only be processed once before it is thrown away
-
- Will that be the Standard Reduction?
-
- Or will it be possible to impose your own scheme?
  - If so, how do you develop (and test!) your scheme
  - And how does it get implemented on the Big Machine?
-
- Again: What is our track record here?

Some Points of Light

- AIPS is so widespread that it is virtually a common language
- It is possible to get Eric Greisen (63) or Wim Brouw (67) or Bob Sault (55) to implement new ideas in AIPS, NEWSTAR or MIRIAD respectively
- Most supervisors customize their favorite package by means of scripts
- Some modules and the MS (the uv-data file) of AIPS++/CASA are widely used as common tools
- There are data-converters between the packages
- We now interact at conferences and workshops
- We have the Measurement Equation

A Revolutionary Idea

-
- Let's work together
  - Let's try again, after learning from AIPS++
-
- But: Can we only change our ways after the shit hit the fan?
- And will we then get still the chance?
  - After all, we are not bankers
-
- How do we make people want to work together?
  - By making it worth their while

Get the Wave Functions to overlap

- a common language (M.E.)
- exchange of scripts
- exchange of tools/modules
- constructive competition
- get the maximum number of people involved in the thinking and tinkering
  - 500 BC: alphabet, cheap paper, leisure?
  - 1500 AD: reformation, reading, book printing
  - 1850 AD: machine operators, technical education
  - 2000 AD: internet...
-
- So: Get the wave-functions to overlap, but avoid Bose-Einstein condensate. Entanglement?

A 5-point Plan

- Adopt the Measurement Equation as a Common Language for all telescopes
- Adopt the MatLab/Python software model
  - A robust kernel, surrounded by user contributions
- Develop a Universal Processing Language (UPL)
  - Start from a combination of ParselTongue and TDL
- Require all (new) telescopes to accept UPL scripts for their processing
- Recognize that there a three pillars (calibration, imaging and data-handling), and act accordingly

Black-belt user-developers

- Liberate the user by reducing the size of the units he can manipulate with scripts
- Provide tools for generating complicated scripts
- Provide efficient uv-data handling tools
  - to reduce the size of experimentation data-sets
  - to combine data-sets, e.g. from different telescopes
  - to lessen the burden of pre-processing (e.g. flagging)
  - etc, etc
- visualization, visualization, visualization
- provide good simulation tools
- Set up an efficient script exchange mechanism
- *Ideally, a new idea should be implemented and tested the same day*

Conclusion

- We must recognize that, as a community, we have a bit of a problem
- .. and that we had better address it in some way
- .. before all these new telescopes overwhelm us

Thank You