

In Summary

Workshop 3GC-II (Portugal)
On Station Beamshapes
Modeling, Measurement and Application

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A Rough Draft Of History

Will be completed with
the slides of the topic chairs
And the comments made

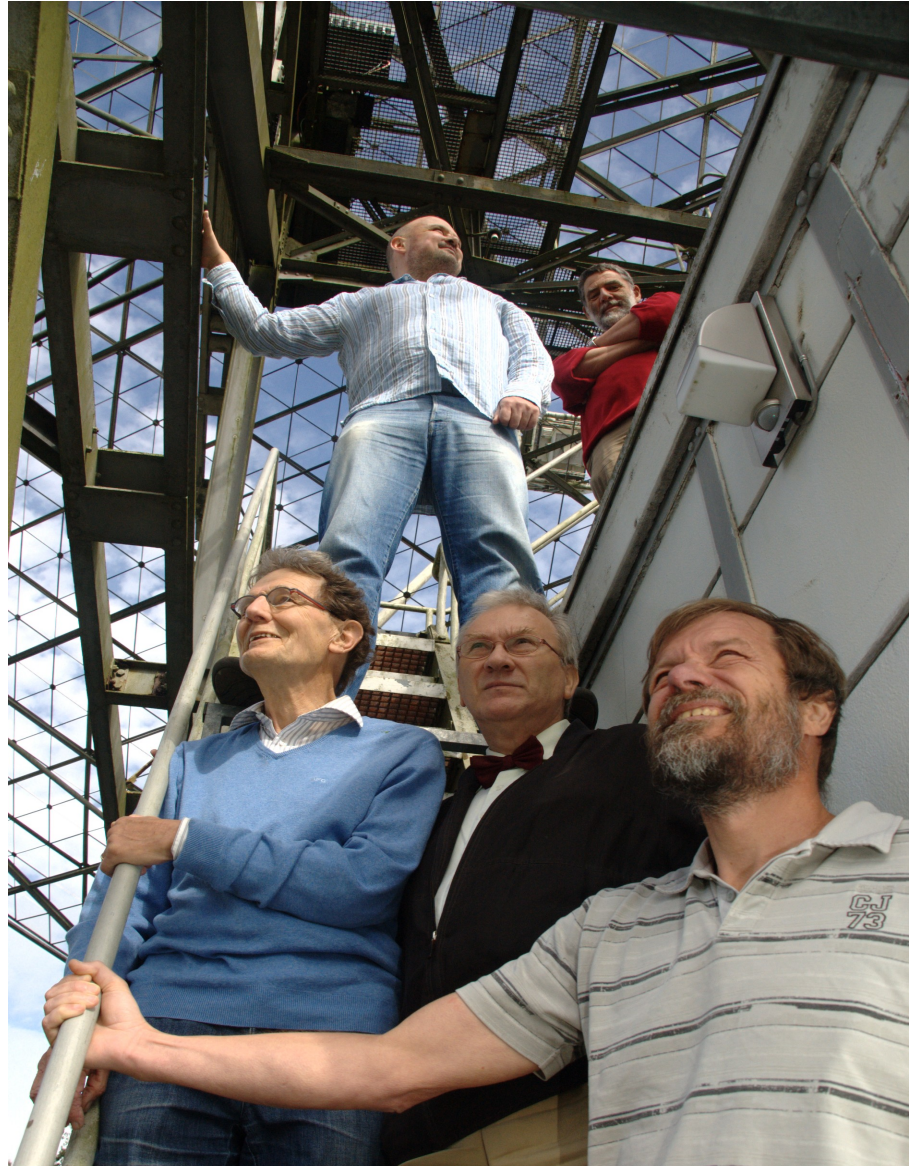
And perhaps turned into a paper

ASTRON/JIVE Image of the Day (AJDI) today



Setting the Scene

The Radio Interferometric Measurement Equation (RIME)



3rd Generation Calibration (3GC)

- 1GC: Rely on instrumental stability (1:100)
 - Enough for the great discoveries of the 70's
- 2GC: Selfcal (2 parameters per antenna)
 - >1:1.000.000 (WSRT/NEWSTAR)
 - The easiest telescope to calibrate (36 years)
- 3GC: Direction-Dependent Effects (DDE)
 - More parameters, more processing, more equations
- 4GC: Statistical analysis of the residuals

3GC-I (Nancay, 2009)

- Delightfully primitive and isolated
- First of a new style of workshops
 - Preparation/selection, 2 full weeks, continue afterwards
 - Encouraged by SKADS and RadioNet
- The concept still needs to be tweaked:
 - Narrowed scope (just beamshapes, no ionosphere)
 - Proven software now exists (OMS, WSRT)
 - The world is more aware of the 3GC problem
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 - Proven software now exists (OMS, WSRT)
 - The world is more aware of the 3GC problem
- **So what about 3GC-III (next year? in ZA?)**

The Topic of 3GC-II: Station Beamshapes

- **Modeling** (2x2 parametrized expressions)
 - Topic chair: Isak Theron
- **Measurement** (open-loop vs closed-loop)
 - Topic chair: Stephen Bourke
- **Application** (aw-projection vs facet imaging)
 - Topic Chair: Cyril Tasse

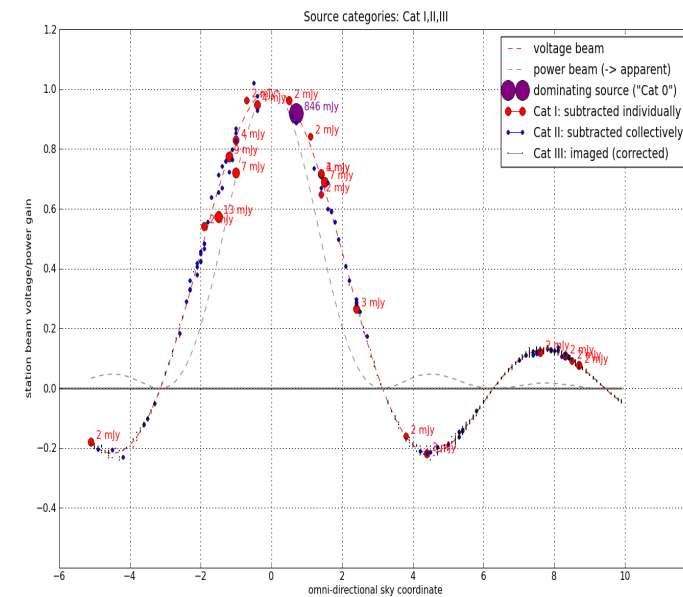
The summaries of the 3 topic chairs are attached

Open-loop vs Closed-loop

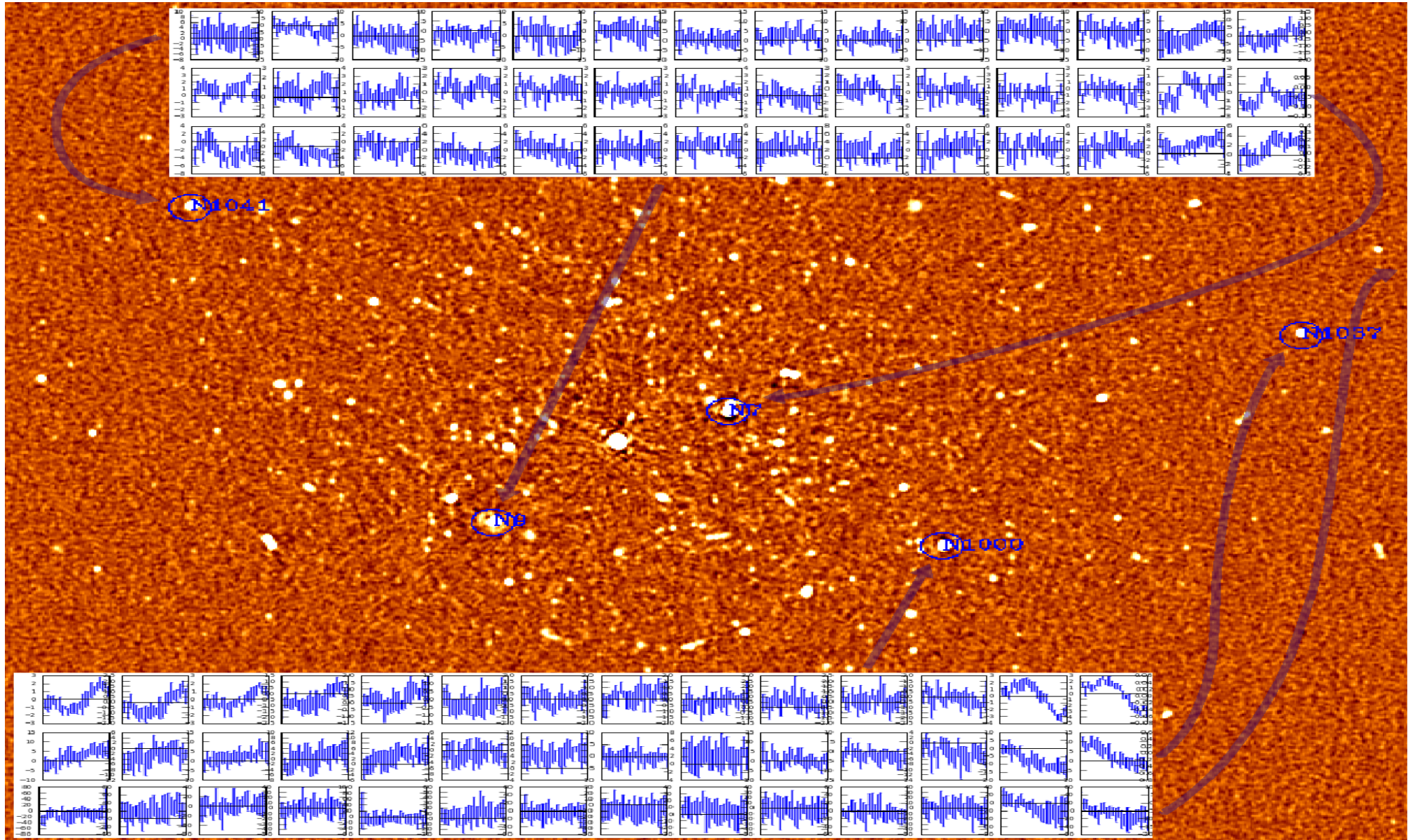
- Open-loop:
 - Use a theoretical beamshape model
 - Measure the beamshapes **separately**, e.g. by scanning through a bright source
- Closed-loop:
 - Beamshape measurements **during the observations**
 - Using the “calibration beacons” (mJy sources) in the field
 - Function of time, frequency and polarization
 - Generalized selfcal (i.e. more than N parameters)

Source Categories

- **Cat “0”**: The dominating source (if any)
 - Used to calibrate rapidly varying errors
- **Cat I**: The 10-20 calibration beacons
 - Estimated and subtracted individually (from uv-data)
 - **Used to estimate beamshapes and other instrumental effects**
- **Cat II**: The 100-1000 fainter LSM sources
 - Subtracted collectively, from uv-data, using interpolated DDEs
- **Cat III**: The many “one-sigma” sources
 - Imaged after correcting the uv-residuals for DDEs (!)
 - Difficult to deconvolve, because PSF varies over the field



The Differential Gains Method



Courtesy Oleg Smirnov

So what happened
in these 2 weeks
of 3GC-II?

After the 1st week

Beamshape Modeling

- Accuracy requirements (how and how much)
 - The pros and cons of open-loop estimation
- People are proposing suitable base functions
 - Parametrized, multi-term, physics constraints
 - The role of theoretical/numerical models
- Understanding instrumental polarisation
- **For a summary of the full 2 weeks, see the separate contribution of topic chair Isak Theron**

After the 1st week

Beamshape Measurement

- The WSRT experience (tricky)
 - Now followed up for the EVLA (Ian)
- Hot topic: Breaking the degeneracy (!)
- These are urgent questions, because their answers drive the choice of SKA stations
 - Dishes or Aperture Arrays
 - Symmetric beams vs low sidelobes
 - Sky rotation or not
- For a summary of the full two weeks, see the separate contribution of topic chair Stephen Bourke

After the 1st week

Beamshape (DDE) Application

- We are beginning to understand the problem
 - Corrected uv-data do not exist (with DDE's)
 - Forward and backward application
 - Unitarity of DDE Jones matrices?
- Now we must understand (and implement, and test, and make available) the solutions
 - AW-projection (gridding convolution schemes)
 - Facet imaging (expensive fallback position)
- **For a summary of the full two weeks, see the separate contribution of topic chair Cyril Tasse**

Data Reduction and Simulations

The amazing TTU (~45 min)

- Oleg implemented many things on the spot
 - Simulation, calibration, visualization, analysis
 - Visible progress (e.g. on off-axis Gregorions)
- His scripts and tools allow him to do this
 - In a whirl of voracious clicking
- One day, (many) others will also be able to do this. But until then ...

EVLA beams

- Explanation of Ian Heywood's differential gains
- They can be accounted for by typical pointing variations
- These are amplified since the 4C source is close to the first null
 - Tobia Carozzi has something to say about that
- The “purr log” is available

Off-axis Gregorians

- Complex voltage beams (polar form) provided by Isak Theron
- Phase gradient over the main lobe
- Pointing errors can cause source shifts
- But selfcal can solve for this
- Conclusion: ...not a show-stopper, as long as the proper RIME is used (properly)

(one slide per issue)

Miscellaneous issues
that we addressed
in some way
or another

(incomplete, of course)

RIME matters

- $Z \cdot E \cdot dE$ vs $Z \cdot (E + dE)$
 - The latter is better close to $E \sim 0$ (dE very large)
 - However....
- A PAF is NOT a phased array (Isak Theron)
 - It is steered mostly by amplitude patterns
- Does the Jones matrix have to be unitary for A-projection? (pretty fundamental)

How DDE errors propagate

(Stefan Wijnholds, ASTRON)

- How do we specify DDE accuracy?
- What accuracy is needed?
- For the first time ever: A beamshape spec!
 - <1% of the peak value, @half-power
 - The assumption is that the brightest source in a typical field is 50 mJy, and that the errors change every 5 minutes, in a random way (...?)
 - This is achieved by selfcal, every minute
 - But the errors of open-loop calibration are systematic (“constant”) over the entire observation

Limits of Calibratability

(Tobia Carozzi, Chalmers)

- A full measurement of the E.M. Field requires 4 complex numbers
- Sensitivity to 2 polarizations can be expressed by two gain factors (“gmin” and “gmax”).
- The IXR has (gmin-gmax) in its denominator. Ideally, gmin=gmax, i.e. $|gmin-gmax| \rightarrow 0$
- If the information is lost (e.g. gmin=0 or gmax=0), no amount of processing can retrieve it

Future Data Reduction Systems

- Since this was a gathering of people with a wide range of backgrounds and experience...
- ... we had a free-roaming discussion about the way astronomers would reduce data in future
- ... with (obscenely) huge data volumes
- ... and the extra processing of 3GC (and 4GC)
- **See the separate contribution by discussion leader Peter Williams**

MeqTrees Batch Mode

- Much faster than MeqBrowser
- Preferred for serious data processing
- Simple yet effective

So, how did we do
this time?

Absolute Highlights

- **Modeling:** Parametrized (multi-term) beam models
 - Including physics constraints
- **Measurement:** EVLA Differential Gains
 - Including simulation and analysis
- **DDE Application:** Clarification of A-projection
- Ger's talk: The Voice of Experience
- Greater awareness of 3GC and its issues
 - Even for those that did not exercise very much
- The state of Oleg's scripts and tools

The Good

(collected at the bitching session)

- Isolated venue, lunches, picnics on the beach
- Diversity of participants, exchange of ideas
 - Remote participation
- Informality, flexibility in schedule
- Powerful server for hands-on work
- Training sessions
- Rapid experimentation with new ideas

The Not So Good

(bitching session, cont'd)

- Too little (time-)overlap between participants
- Practicals were sometimes difficult to follow
 - Too fast (voracious clicking by Oleg)
 - Too few “black-belt” assistants
 - Participants should perhaps be paired
- Horse-shoe layout of the tables
- Intermittent bandwidth, no internet in rooms

Let's revisit the (optimistic) dreams of Workshops Past

(they might still be relevant
For workshops to Come)

Finally,
I cannot resist
to end with
a little exhortation

The 3GC Community

- Jacques Anquetil won the Tour de France 5 times
 - ...but he did not do it alone...
- We need: Heavy Lifters and Generalists
- And Modular Specialists
- And Testers and Critics (incl users and other moaners)
- And Tool Makers and Distributors
- And Communicators (smiles, football, picnics, ...)
- And (one) Visionary

So, don't be intimidated

3GC is a new world for all of us

There is a place for everyone

Wherever you are

However...

We must lower the threshold

(for using MeqTrees, the tool of 3GC)

...somehow...

e.g.: The MeqWizard

(promises, promises...)



- 3-click automatic TDL code generation
 - Detailed access to the TDL code (TDLHFs)
 - For an “infinite” wide range of application
 - Levels of tweaking and freezing/setting of options
 - Lots of help and documentation where and when
- A system of MeqTrees Project Control
 - Export and import of tar balls (easy sharing by email)
 - Gently enforcing the use of purr logs
 - One-click access to relevant tools
 - Help with MeqParm (.mep/.mfp) file management

So, goodbye for now

But we hope to hear from you...

...in the coming months...

...and at 3GC-III next year