Summarizing

(after the first week)

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

J.E.Noordam

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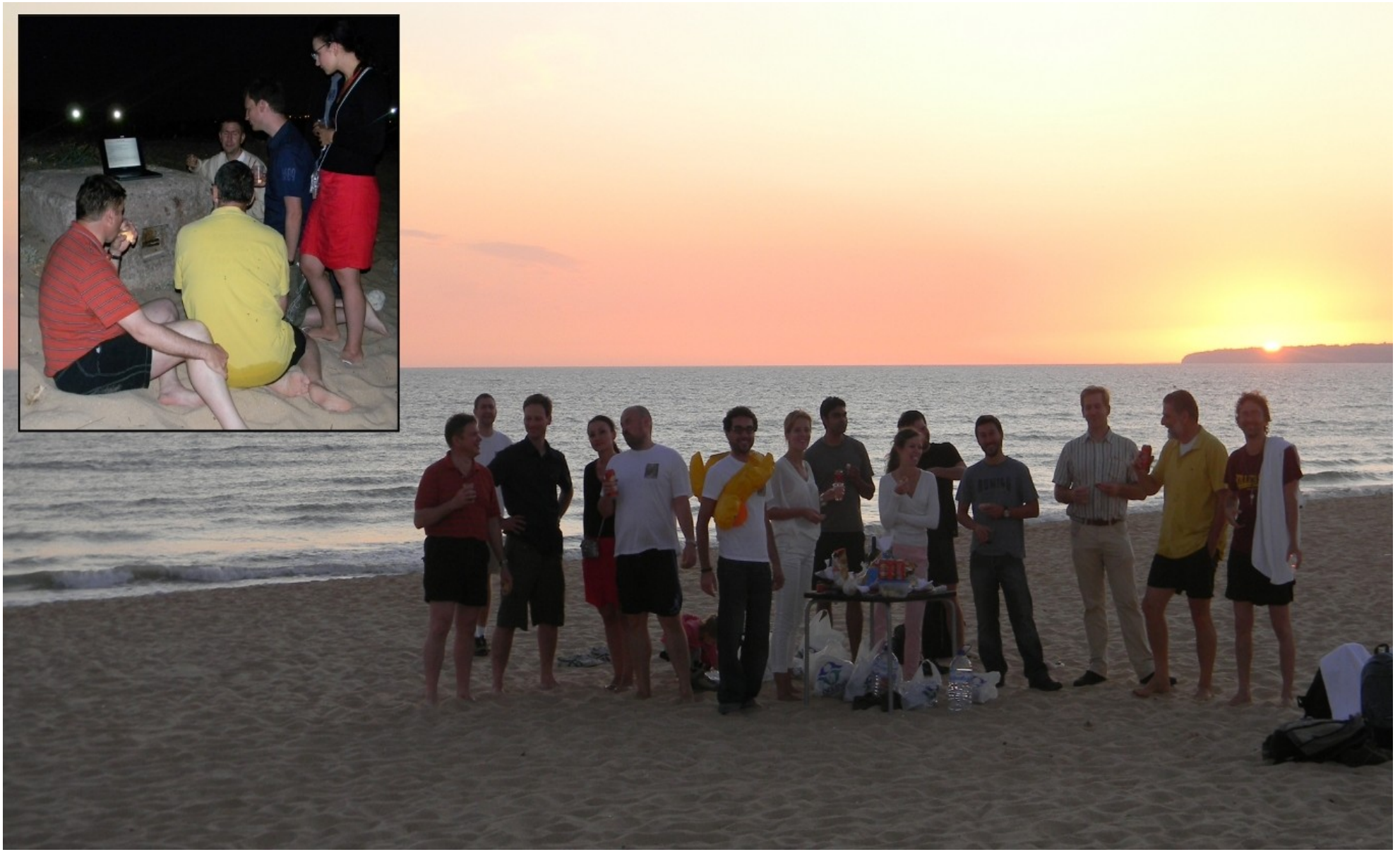
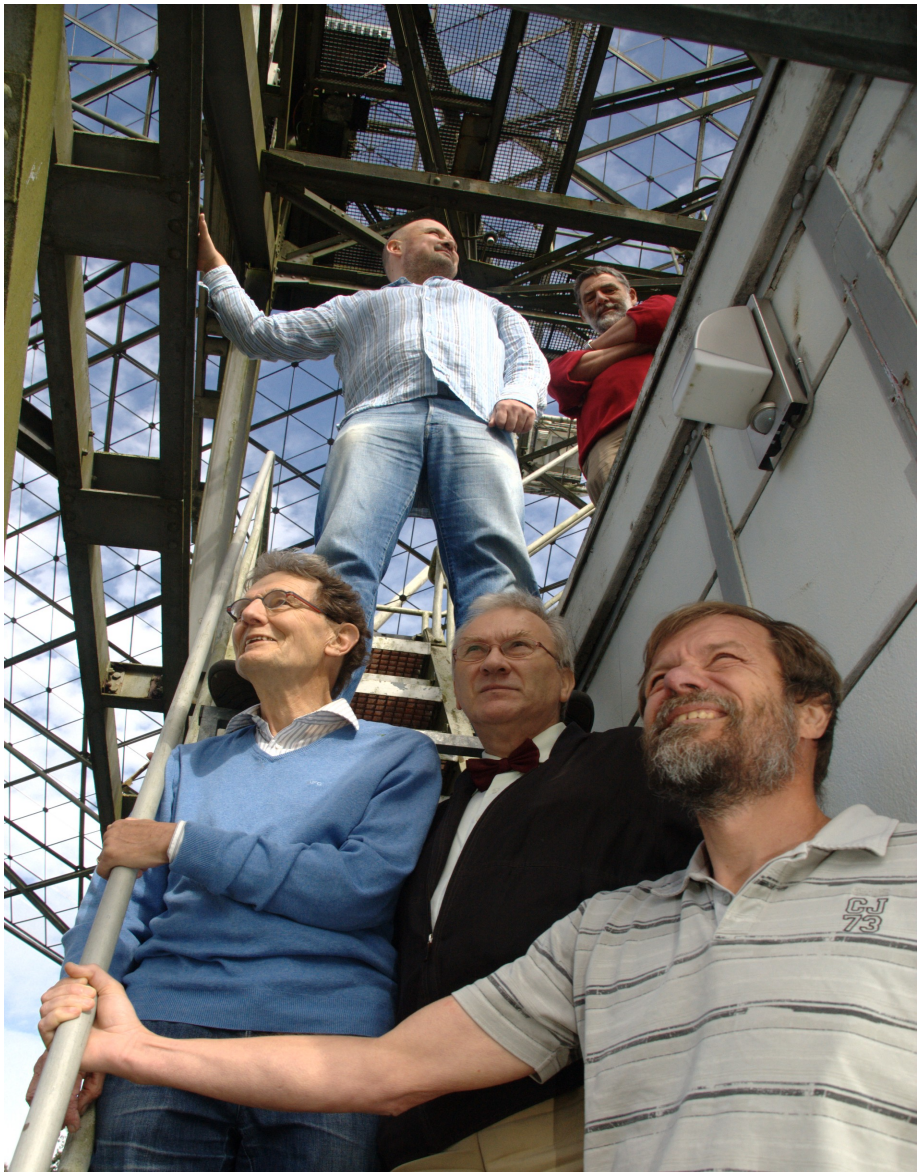
ASTRON/JIVE Image of the Day (AJDI) today



Setting the Scene (repeat)

Standing on the Shoulders of...



J.E.Noordam

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

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

Open-loop vs Closed-loop

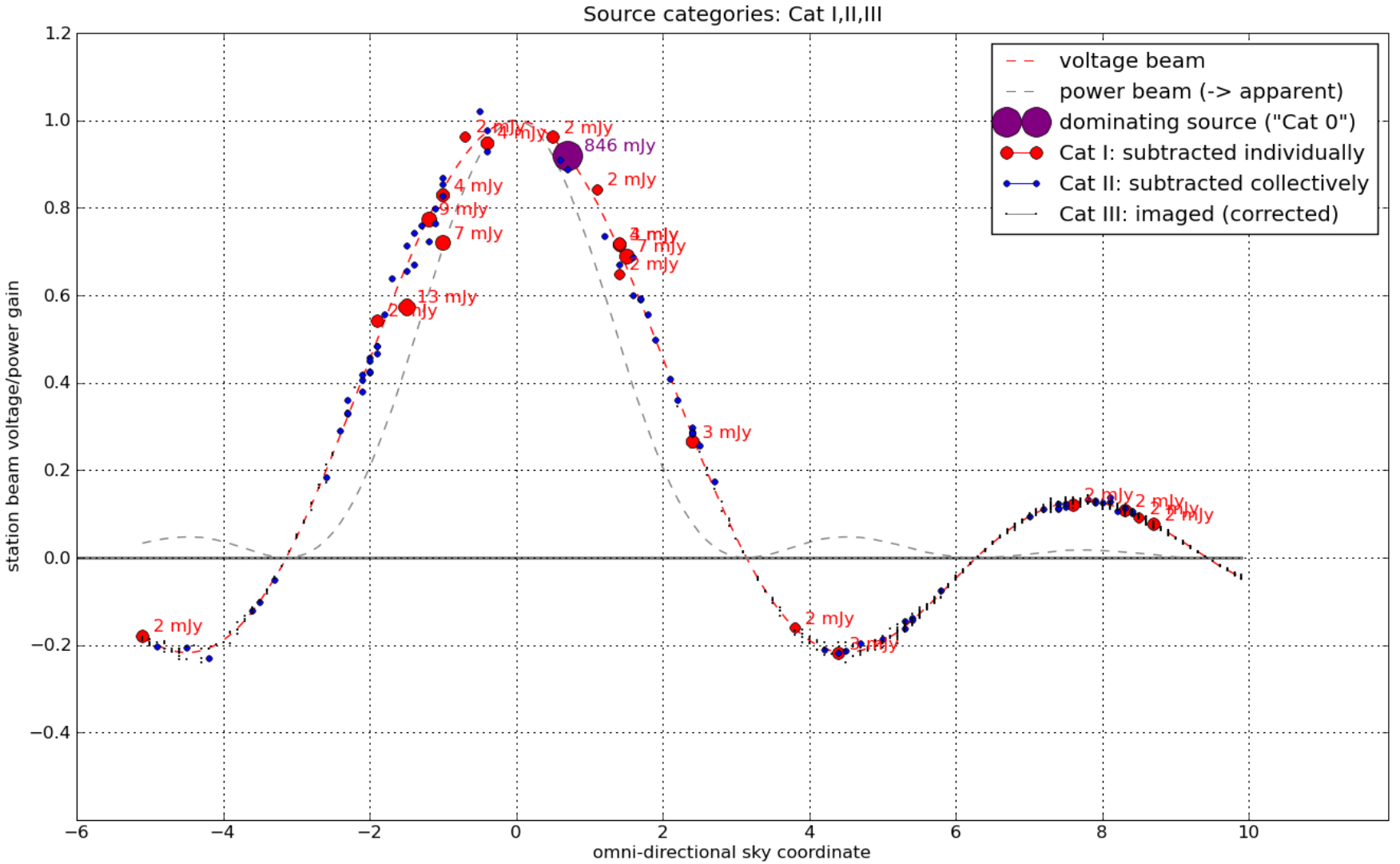
- Open-loop:
  - Use a theoretical beamshape model
  - Measure the beamshapes once and for all, e.g. by scanning through a bright source
- Closed-loop:
  - Continuous measurements during the observations
  - Using the “calibration beacons” (mJy sources) in the field
  - Time, frequency and polarization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

Source Categories

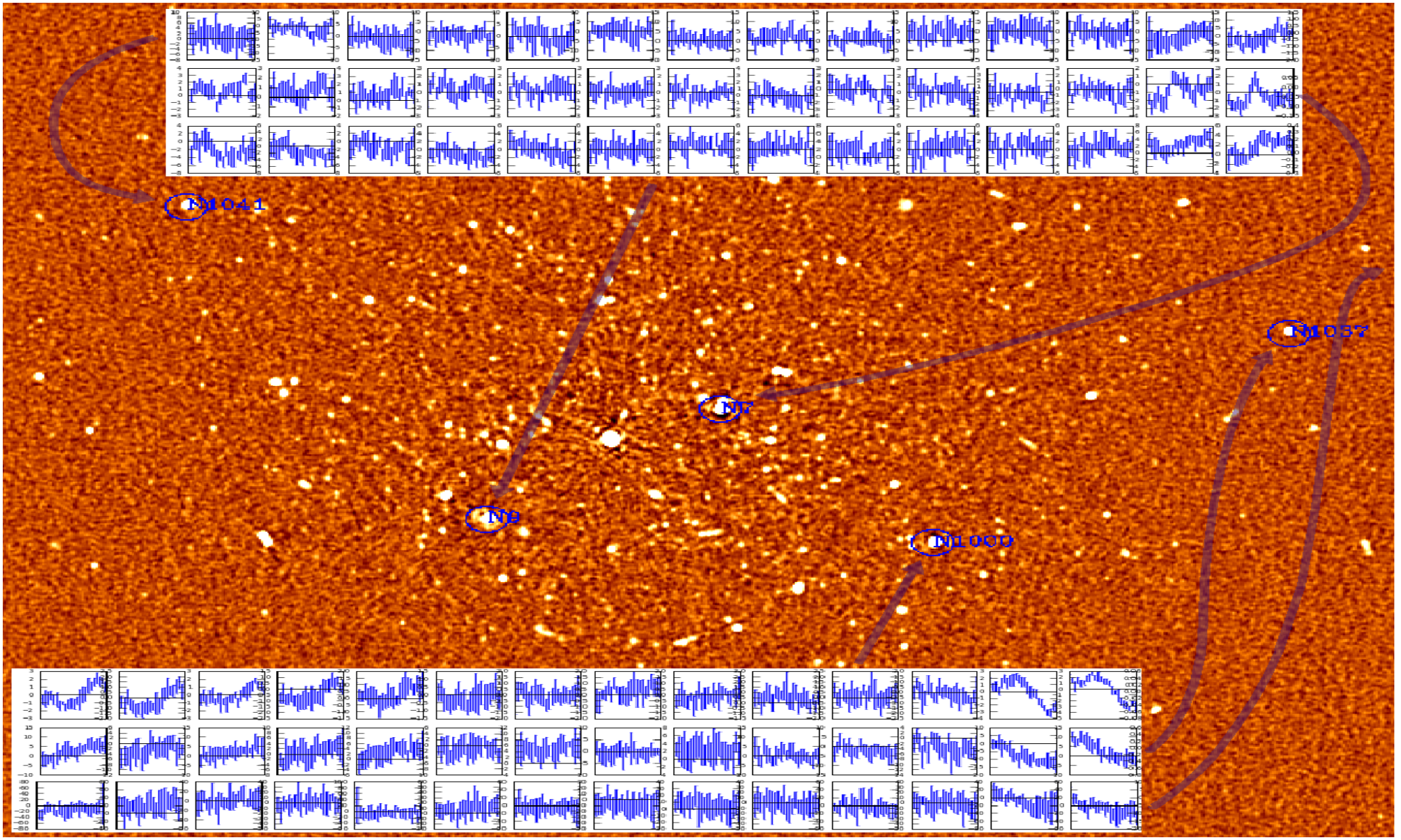
- Cat “0”: The dominating source (if any)
  - Used to calibrate rapidly varying errors
- Cat I: The 10-20 calibration beacons
  - Estimated and subtracted individually (from uv-data)
  - Used to estimate beamshapes
- Cat II: The 100-1000 fainter LSM sources
  - Subtracted collectively, from uv-data,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

How are Station Beamshapes used?

Source Categories (I,II,III)



The Differential Gains Method



Courtesy Oleg Smirnov

Summary of the Summary

Summary of the Summary

Beamshape Modeling

- Accuracy requirements (how and how much)
  - Stefan Wijnholds
  - 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
  - Walter Brisken

Summary of the Summary

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

Summary of the Summary

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)

Summary of the Summary

Miscellaneous

- RIME issues (Tobia)
- The limits of calibratability (Tobia)
- The propagation of beamshape errors (Stefan)
- The unitary ambiguity...?
- ...

Summary of the Summary

Reductions and Simulations

- Various exersizes (Oleg)
- EVLA differential gains (Ian)
- Looking forward to:
  - …
  - …
  - …
  - …
  - ...

The 3GC Community

- Jacques Anquetil won the Tour de France 5 times
  - ...but he did not do it alone...
- Heavy Lifters and Generalists
- Modular Specialists
- Testers and Critics (incl users and moaners)
- Tool Makers
- Communicators
- Visionary (one)

So, don't be intimidated

3GC is a new world for all of us

There is a place for everyone

Wherever you are

(peruse at leisure)

What follows is one slide per presentation

I have tried to do everyone justice...
… but of course I have failed

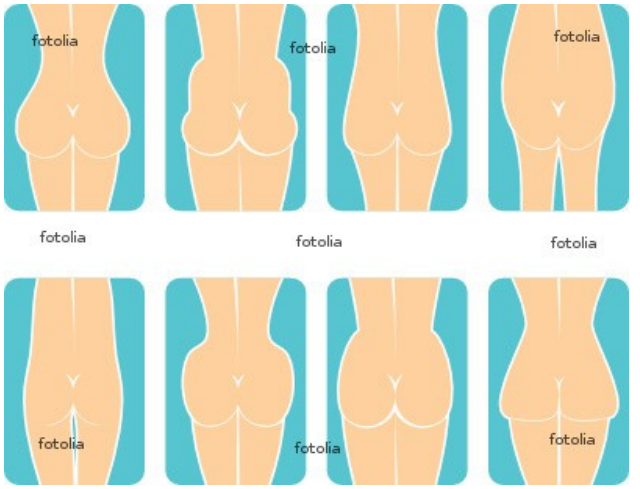
(on the other hand...
...those with an open mind rarely learn anything)

(one slide per presentation)

Beamshape Modeling

(one slide per presentation)

Beamshape Modeling



Requirements

- Accuracy:
  - At half-power
  - In the inner sidelobes
  - In the outer sidelobes
- As a function of time, freq, elevation...
- Open-loop vs closed-loop
- Polarization Purity....

OSKAR II

(Ben Mort, Oxford)

- Can handle BIG simulations
  - Complementary to MeqTrees
- Based on RIME
  - needs more of that
- Will be linked to MeqTrees
  - Other cross-overs too

Parametrized Expressions

(the heuristic approach)

- Voltage beams (i.e. not power beams)
- Smoothness “guaranteed” (l,m,t,f?)
- 2: one expression per dipole
- 4: one expression per Jones element
- Shared parameters between expressions
- Nr of terms (depends on size)
- Include physics knowledge (fewer parameters)?
- Or just functions (e.g. shapelets)

Suitable Base Functions

Marianna Ivashina (Chalmers)

- Analytic: Orthogonal, interpolatable, solvable
- Numeric: Based on physics
- Hybrid: Derive (parametrized) analytic functions from numeric results of E.M. Calculations etc
  - See next slide
- NB: What about parametrized analytic functions that are “inspired” by numerical models, and using physical knowledge to constrain the range of possible solutions?

AA and PAF Modeling

Marianna Ivashina (Chalmers)

- Assume that all elements have the same “embedded” beamshape
  - Ignoring edge effects (infinite, dipoles, PAFs)
- BeamForm with array factor, but taking the neighbouring elements into account
- This works well for Aperture Arrays (AA)
- For PAF's, use the AA beams in an E.M. simulator to account for the reflector (e.g. dish)

Suitable Base Functions

(smooth, multi-term)

- Polynomials: Easy but ill-behaved
- Zernike:
- Prolate Spheroids
- Karhunen-Loeve:
- Bessel:
- Elliptical Gaussian:
- Cos^3

The Role of E.M. Modeling

(Walter Brisken, NRAO)

- Various levels (WB, Bruce Veidt)
- Approximate (assumptions, cutting corners)
- More information than needed
- But: Rooted in physics
- Used as starting point of heuristic approach:
  - Identify suitable base functions
  - Estimate initial values for their parameters (I,m,f,t,..)

GRASP

(WB, Danish “Industry Standard”)

CASS (Cassegrain beam modeling)

(Walter Brisken, NRAO)

Off-axis Gregorians

- No central obstruction (low sidelobes)
  - However, there are still struts in the light-path
- Small focal area (problem for PAF's)
- Focussing problems for wide-band feeds
  - ATA “dog's eyes”
- Polarization issues
- A-symmetric beam, rotate or not

Instrumental Polarization

(Walter Brisken)

- Q and U clover-leaf patterns (same by 45deg)
  - NOT caused by dipole size!
  - Caused by slanted reflection
  - Same for WSRT and VLA, struts don't matter?
  - AA's (LOFAR) completely different
- Beam-squint (Stokes V)
  - Caused by off-axis feeds

(one slide per presentation)

Beamshape Measurement

Breaking The Degeneracy

- Stationary beam on the sky
  - Cannot separate instrumental and flux errors
  - But: We can divide the image by “the beam”
  - We know that source fluxes are constant in time
- How to break the degeneracy?
  - Drift scanning? now possible
  - Rotation of asymmetric beam?
  - Other?
- What is the price we pay?

Measuring the MWA beamshape

(Gianni Bernardi)

- Measured by scanning a bright source
  - Two polarizations, not tracking (yet)
- “Reasonably” close to predicted model
  - Dip in the zenith? For one frequency only....
- Closed-loop not easy
  - Not sensitive enough
  - Too much processing
  - What is the required accuracy

Measuring the EVLA beamshape

(Ian Heywood, Oxford)

- Differential gains
  - About 3 hours, @ 8 GHz, 4C source
  - Passes through 4-fold 1st sidelobe of rotating beam
- Surprising differences between stations
  - Pointing errors? Frequency dependence?
  - Oleg simulated on the spot → purr log
- Ian will make this an AJDI (plots with inset)
  - To stimulate an EVLA beam measuring program

Tony's Program

(Tony Willis, DRAO)

- Provide answers for SKA decisions
- Urgent! (why is it not done more vigorously?)
- People do not know what to do
  - We have to point the way (MeqTrees)
  - But insist that others do it
- Simulation and calibration
- The rapier versus the clamor

Formulating the Questions

- Can we calibrate?
  - Is there enough information?
  - Can we afford the processing?
- Allowable side-lobe levels
- Polarization effects
- Frequency dependency
- Mechanical stability
- Open-loop vs closed-loop (depends on requirements)
- Advantages of symmetry
- Sky (de-)rotation
- Breaking the degeneracy (between instrumental and flux parameters)

Answering the Questions

(one slide per presentation)

Beamshape Application

Correcting for DDE Jones (E,Z,F,..)

- Corrected uv-data do not exists (if DDE's)
- Facet Imaging
  - Many small images, uv-data corrected/integrated
  - Arbitrary accuracy (with more/smaller facets)
- AW-projection (forward, backward)
  - Convolution during (de-)gridding
  - Efficiency vs accuracy (size of convolution kernel)
  - Applicability (should Jones be unitary?)

(one slide per project)

Data Reduction and Simulations

(during the workshop)

The amazing TTU

- Oleg implemented variable pointing on the spot
  - Simulation
  - Calibration
- (One day, others will be able to do this too...)
- Conclusion (about breaking the degeneracy)
  - ....
  - ....

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

Apertif Beams

(one slide per issue)

Miscellaneous issues that we addressed in some way or another

(incomplete, of course)

RIME matters

- Z.E.dE vs Z.(E+dE)
  - The latter is better close to E~0 (dE very large)
  - However....
- A PAF is NOT a phased array (Isak Theron)
  - It is steered mostly by amplitude patterns

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|->0
- If the information is lost (e.g. gmin=0 or gmax=0), no amount of processing can retrieve it

Lowering the Threshold

The elusive MeqWizard

(encouraging you to share)