Imaging with the SKA core

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Introduction

Least squares image estimation (OMM):

- can handle **arbitrary image plane effects**
- can handle **arbitrary visibility plane effects**
- can handle **non-sparse fields**
- is **statistically efficient on actual data**
- becomes **computationally feasible** in SKA era
- can be **easily integrated with calibration**

Applications: confusion limited imaging, Galactic polarimetry, Galactic HI

Data model

Snapshot array covariance matrix (visibility matrix):

$$\mathbf{R}_m = \mathbf{A}_m \, \Sigma \, \mathbf{A}_m^H + \Sigma_m$$

Σ — $N_{im} \times N_{im}$ image parameter coherency matrix

Σ_m — $N_{rec} \times N_{rec}$ noise covariance matrix

$\mathbf{A}_m$ — $N_{rec} \times N_{im}$ instrument and environment model

- one complex factor per receiver per image param.
- arbitrary visibility plane corrections
- arbitrary image plane corrections

Least squares imaging

S.J. Wijnholds & A.J. van der Veen, IEEE JSTSP, Oct 2008

After a little mathematics:

snapshot: $\sigma_{m} = \mathbf{M}_{dm}^{-1}\ \sigma_{dm}$

After a little more mathematics:

synthesis: $\sigma = (\sum \mathbf{M}_{dm})^{-1}\ (\sum \sigma_{dm}) = \mathbf{M}_{d}^{-1}\ \sigma_{d}$

deconvolution matrix properties:

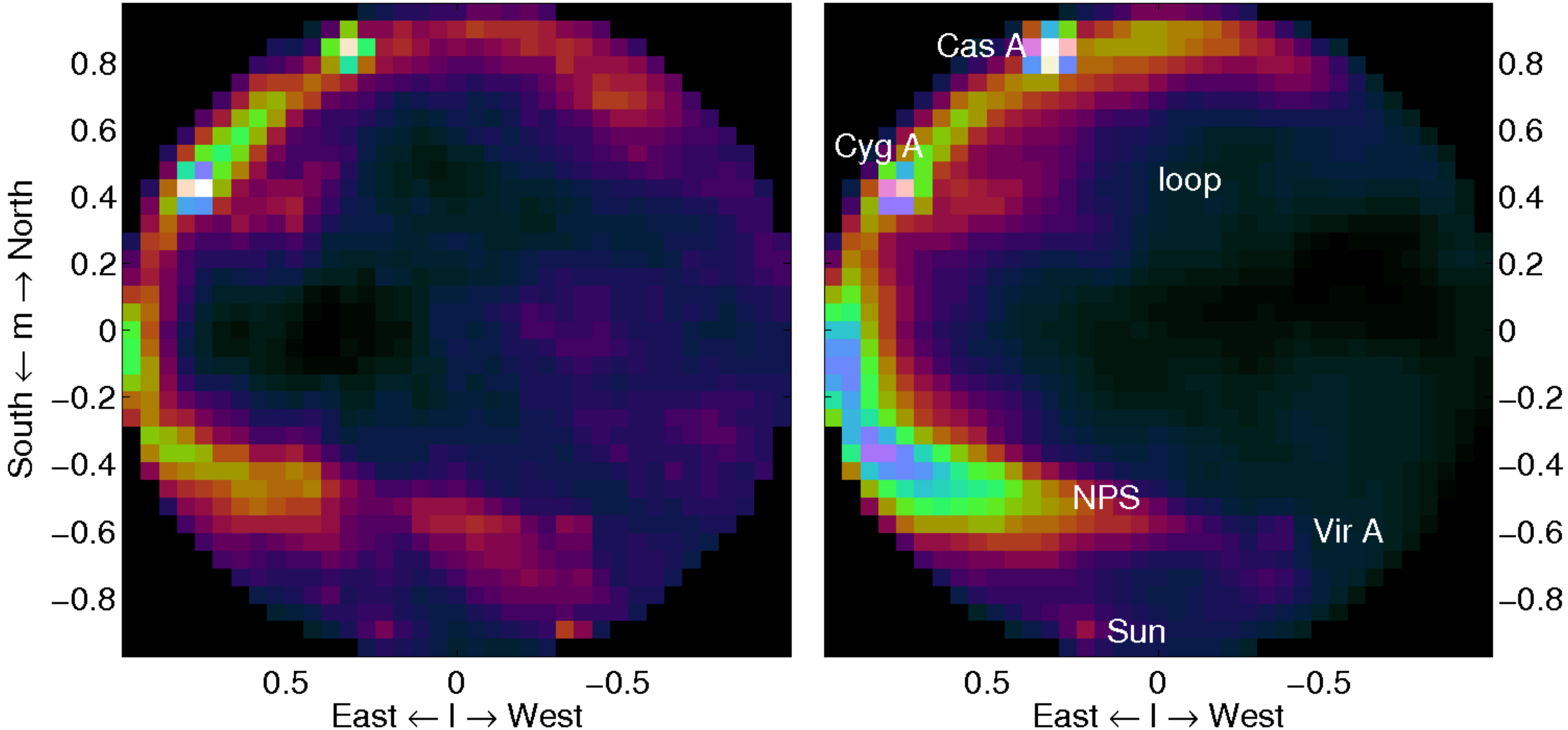
- max size N_{im} x N_{im}
- arbitrary time varying visibility and image plane effects
- no explicit inversion required
- condition number determines resolution

DFT imaging versus LS imaging

Stefan J. Wijnholds, URSI Benelux Forum, 8 June 2009

8 Nov. 2008, 10:21:59 – 10:26:45 UTC, 10 s integration

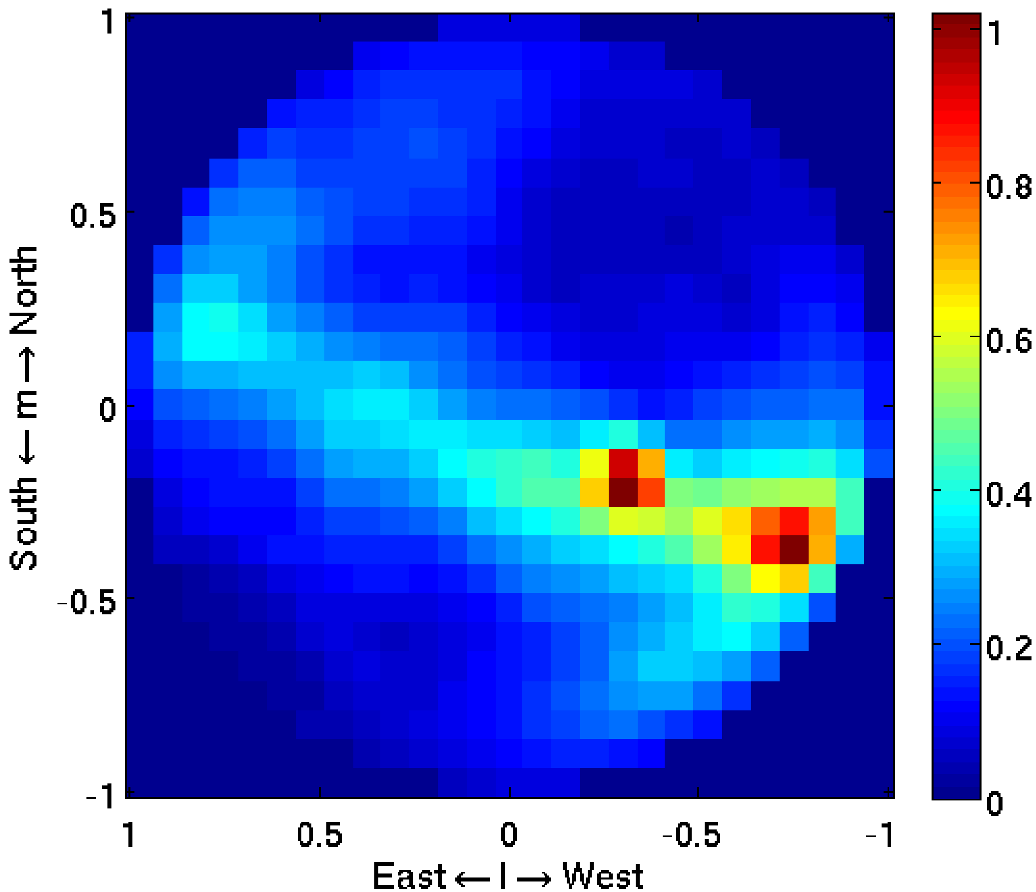
27 156 kHz subbands between 45.3 and 67.3 MHz



Noise in the image

Observation summary

- start: 14 Feb 2008, 15:46:44 UTC
- duration: 300 s
- 10 – 90 MHz
- 298 snapshots
- 1 s integration
- 195 kHz @ 50 MHz
- RT station correlator



Statistically efficient?

Stefan J. Wijnholds, CalIm, 30 March – 3 April, 2009
Stefan J. Wijnholds, Ph.D. thesis, 2 March 2010

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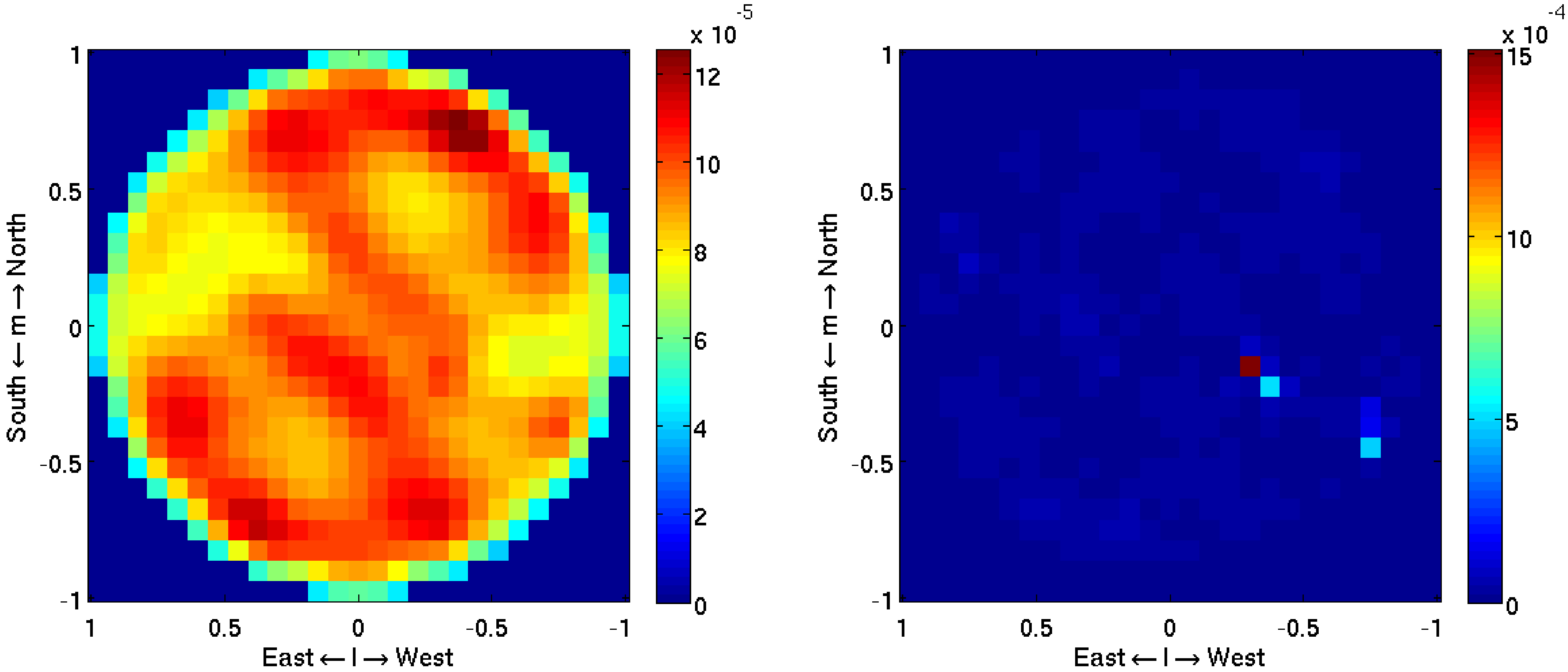
Left: image variance based on CRB

Right: image variance over 298 snapshot images

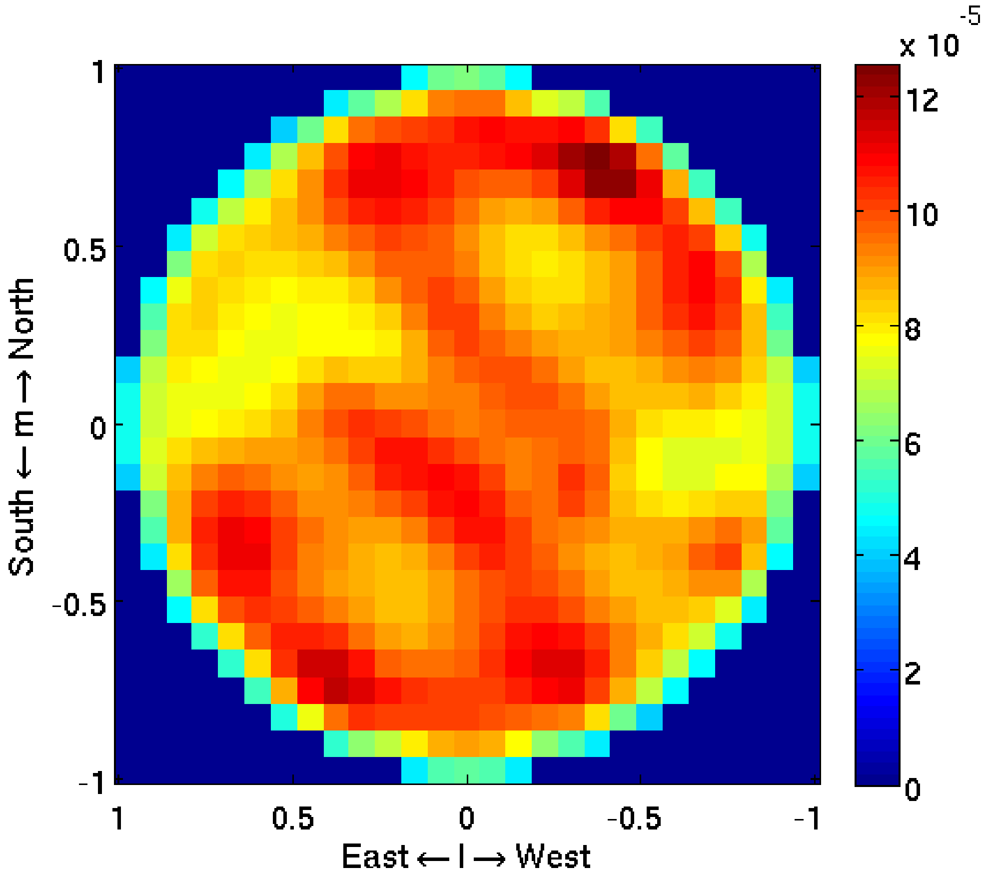


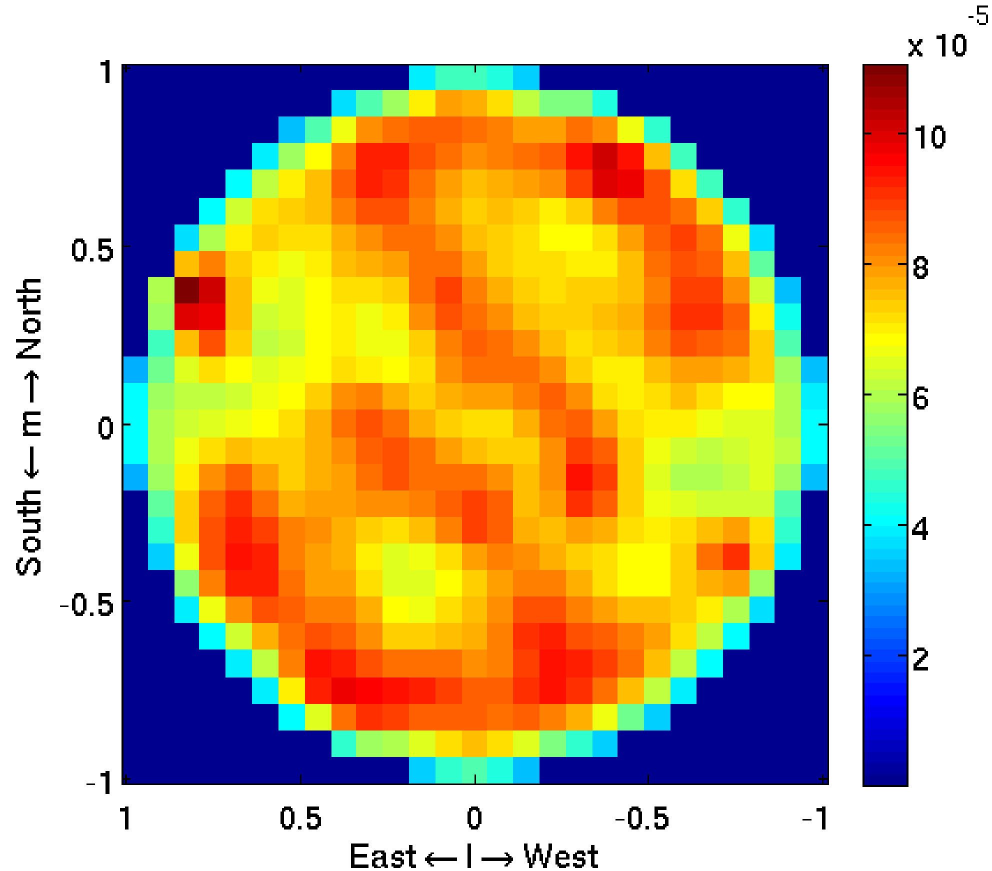
After Earth rotation correction: YES!

Stefan J. Wijnholds, CalIm, 30 March – 3 April, 2009
Stefan J. Wijnholds, Ph.D. thesis, 2 March 2010

Left: variance based on CRB

Right: variance over 298 snapshots (moving average)





Processing and memory requirements

Memory: $N_{im} \times N_{im} \times 8$ byte (in place processing)

Processing: $\sim N_{im}^{3}$ flop (**not flops**)

Numerical example: scalar imaging with the SKA core

- $D_{core} = 5$ km, $D_{dish} = 15$ m (AA stations are larger)
- $N_{im} = ((D_{core} / D_{station}) / 0.7)^2 = 2.27 \times 10^5$;
- memory: 411.4 GB
- processing: ~11.7 Pflop
- to compute in 4h: 809.7 Gflops

Range of applicability

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scalar size	memory	processing	flops in 4h
128x128	2.15 GB	~4.40 Tflop	306 Mflops
256x256	34.4 GB	~281 Tflop	19.5 Gflops
512x512	550 GB	~18.0 Pflop	1.25 Tflops
1024x1024	8.80 TB	~1.15 Eflop	79.9 Tflops
2048x2048	141 TB	~73.8 Eflop	5.13 Pflops
4096x4096	2.05 PB	~4.72 Zflop	328 Pflops

Conclusions

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