Simulations 101

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Up next:

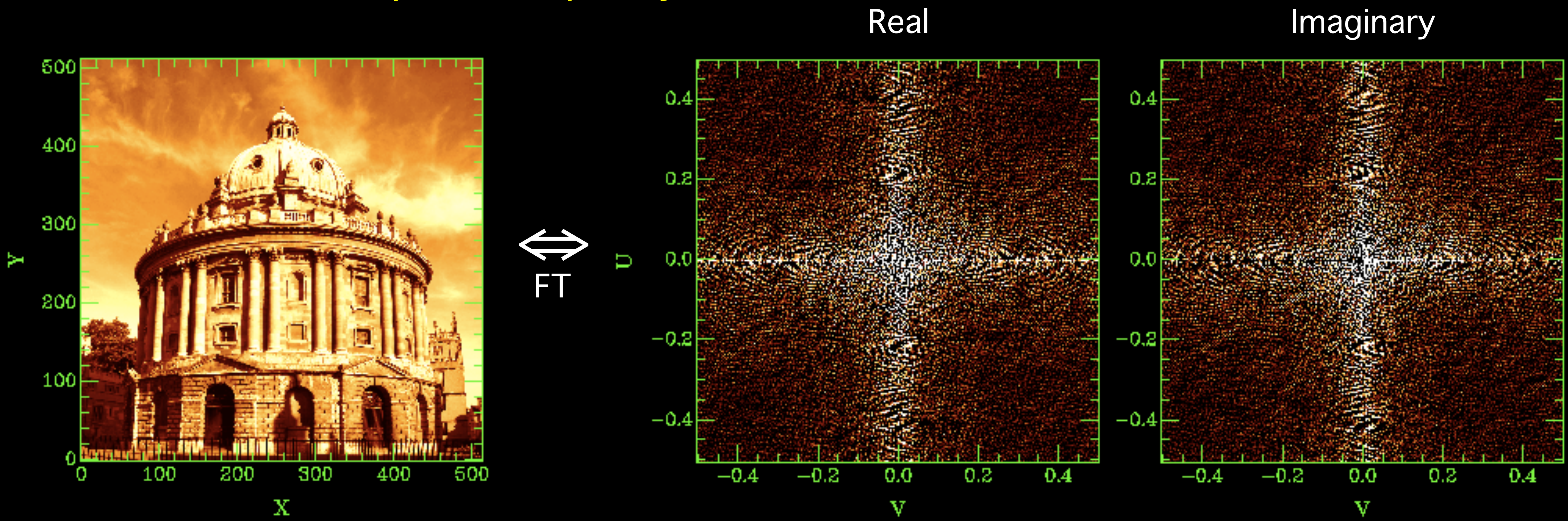
Simulations 1,000,000:1

(Oleg's talk)

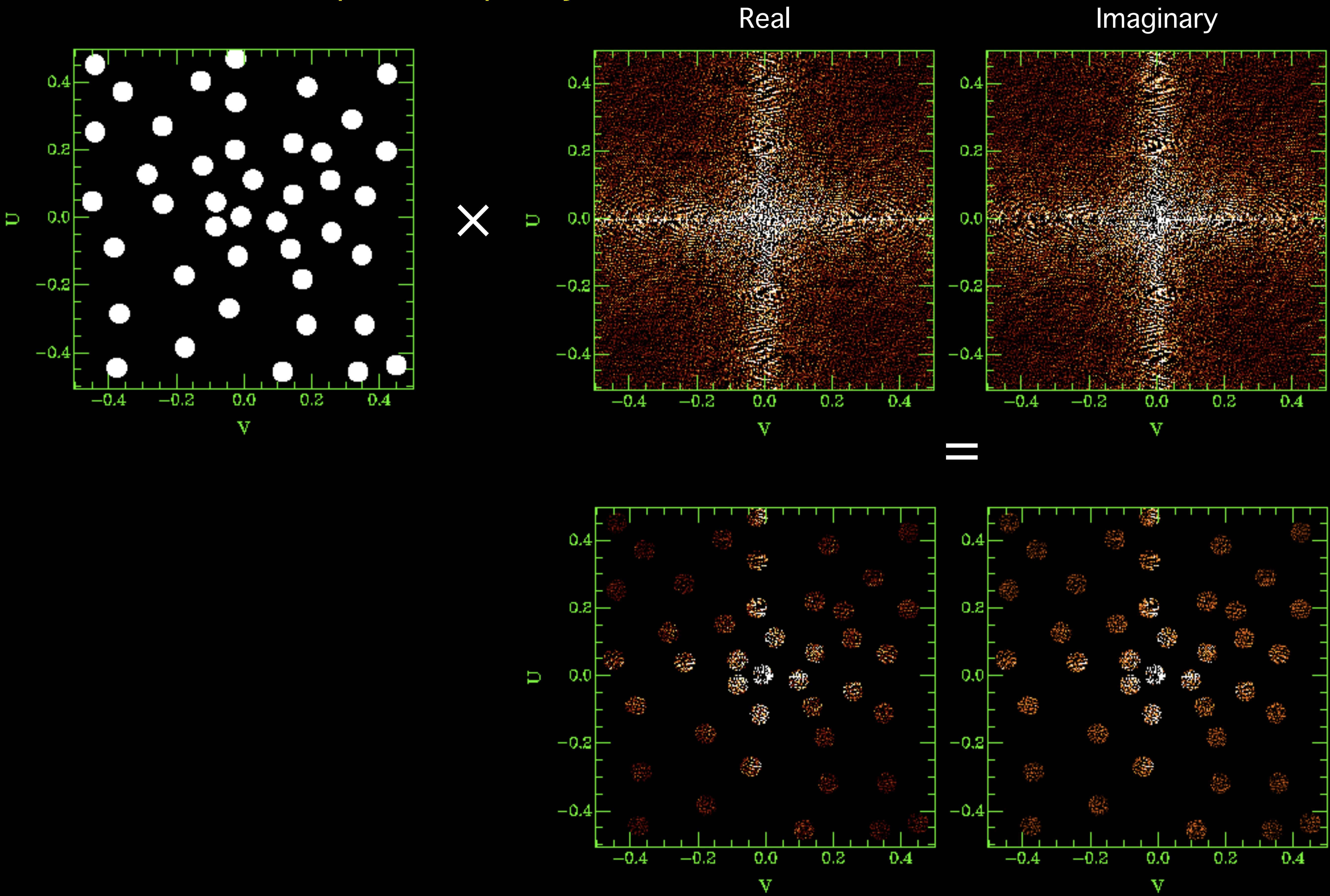
ALLERGY ADVICE

This talk may contain traces of opinion.
Produced in an envrionment handling opinion ingredients.

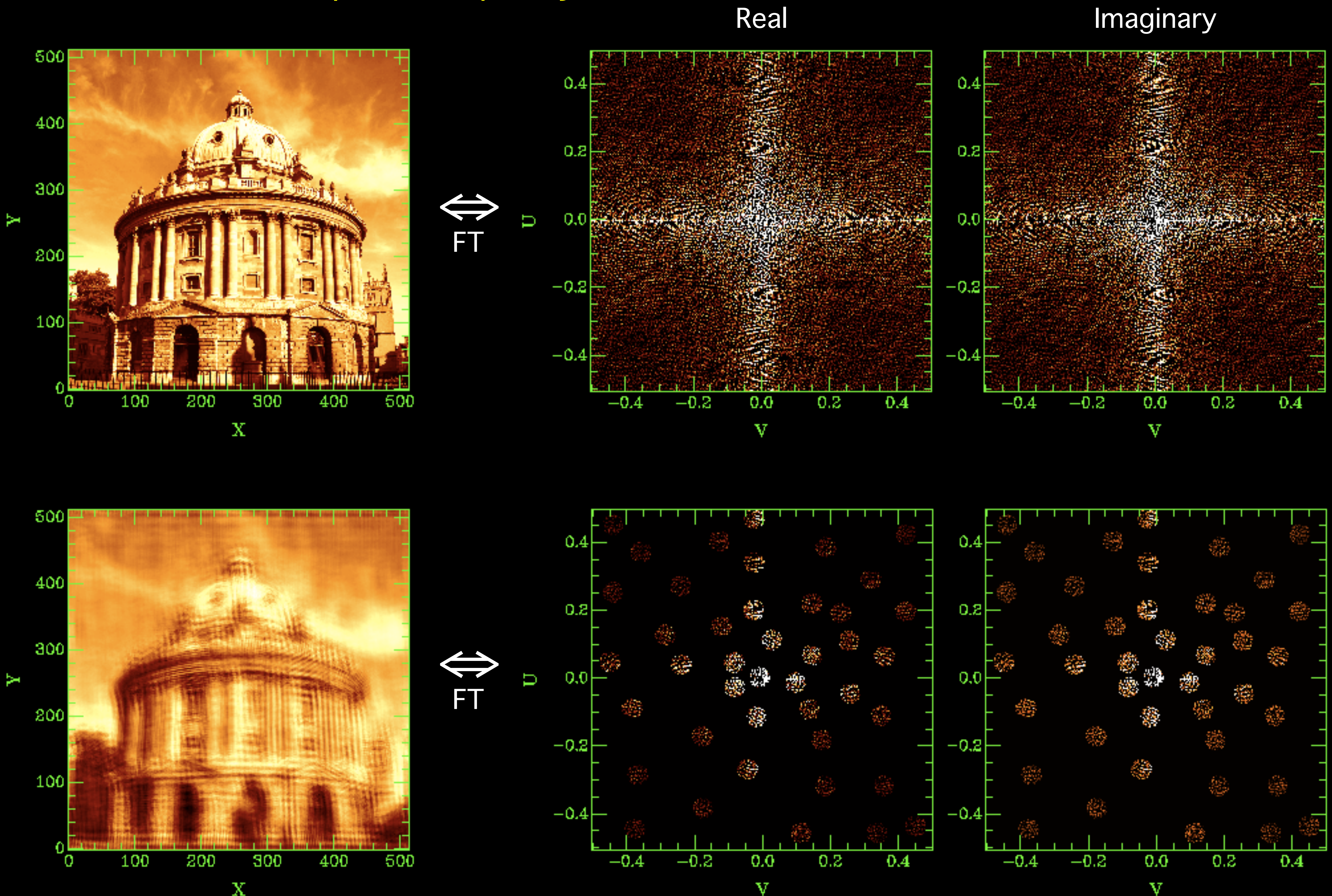
Interferometers as spatial frequency filters



Interferometers as spatial frequency filters



Interferometers as spatial frequency filters



The uv-plane sampling function

The recovered 'dirty' image

FT of the true sky brightness distribution (or your model of it)

$$I^D(x,y) \Leftrightarrow S(u,v) \times I(u,v)$$

Image plane

Fourier plane

A Fourier transform

Why bother?

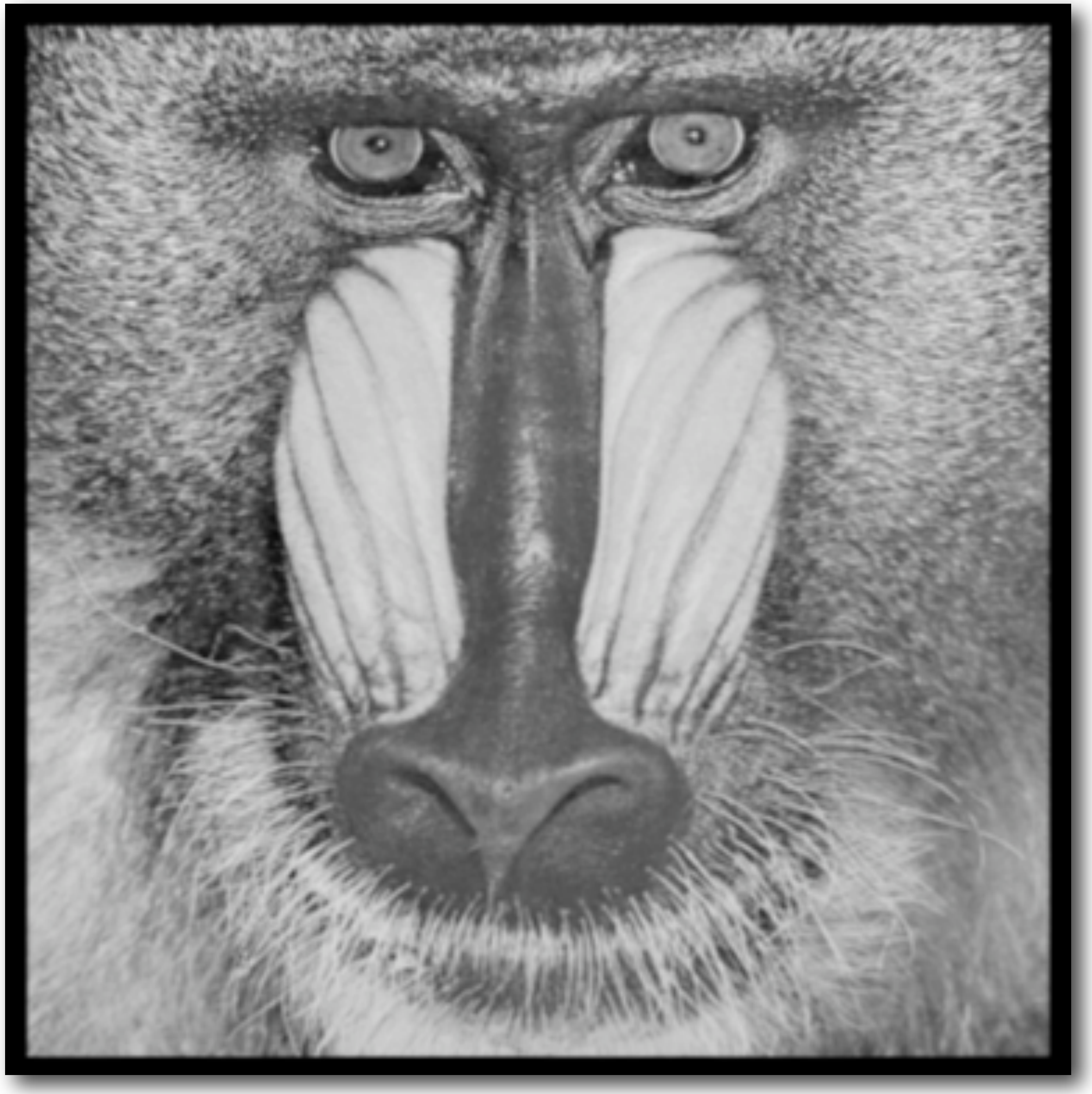
Feasibility studies / proposal writing

How dirty is your beam?

Optimising array design

Investigating how instrumental / atmospheric effects limit DR

Intuition!



AIPS

MeqTrees

CASA

Common Astronomy Software Applications

CASA

Image not found

Miriad

AIPS++

CASA

Common Astronomy Software Applications

The Measurement Equation

$$V_{pq} = M_{pq} B_{pq} G_{pq} D_{pq} \int E_{pq} P_{pq} T_{pq} F_{pq} \; S \; I_\nu(l,m) \; e^{-i2\pi(u_{pq} l + v_{pq} m)} \; dl \; dm + A_{pq}$$

The tetralogy of papers by Hamaker, Bregman & Sault

ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

MAY II **1996**, PAGE 137

Astron. Astrophys. Suppl. Ser. **117,** 137-147 (1996)

Understanding radio polarimetry. I. Mathematical foundations

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Received August 4; accepted October 22, 1995

Abstract. — The measurement of polarized radiation uses entirely different methods at optical and radio wavelengths. As a result, the algebraic analysis of polarimeter performance differs and, in the case of radio interferometry, is unnecessarily complicated. We demonstrate that the mathematical operation of outer matrix multiplication provides the missing link between the two approaches. Within one coherent framework, we then unite the concepts of Stokes parameters and Wolf coherency matrix, the Jones and Mueller calculi from optics, and the techniques of radio interferometry based on multiplying correlators. We relate the polarization performance of a complete radio interferometer to the (matrix) polarization properties of its successive signal processing stages, providing a clear view of how a radio polarimeter works. Our treatment also clarifies the nature of and the relations between the various types of transformations used in optical polarimetry. We develop the analysis from the radio interferometrist's point of view, but include enough background for a wider audience. In a companion paper, we discuss in more detail the application to the calibration of radio interferometer systems; in a third paper we investigate the IAU (1973) radio definition of the Stokes parameters and its precise translation into mathematical form.

Key words: methods: analytical — methods: data analysis — techniques: interferometers — techniques: polarimeters

Smirnov (2011) × 3

Astronomy & Astrophysics manuscript no. 16082
January 11, 2011

Revisiting the radio interferometer measurement equation. I. A full-sky Jones formalism

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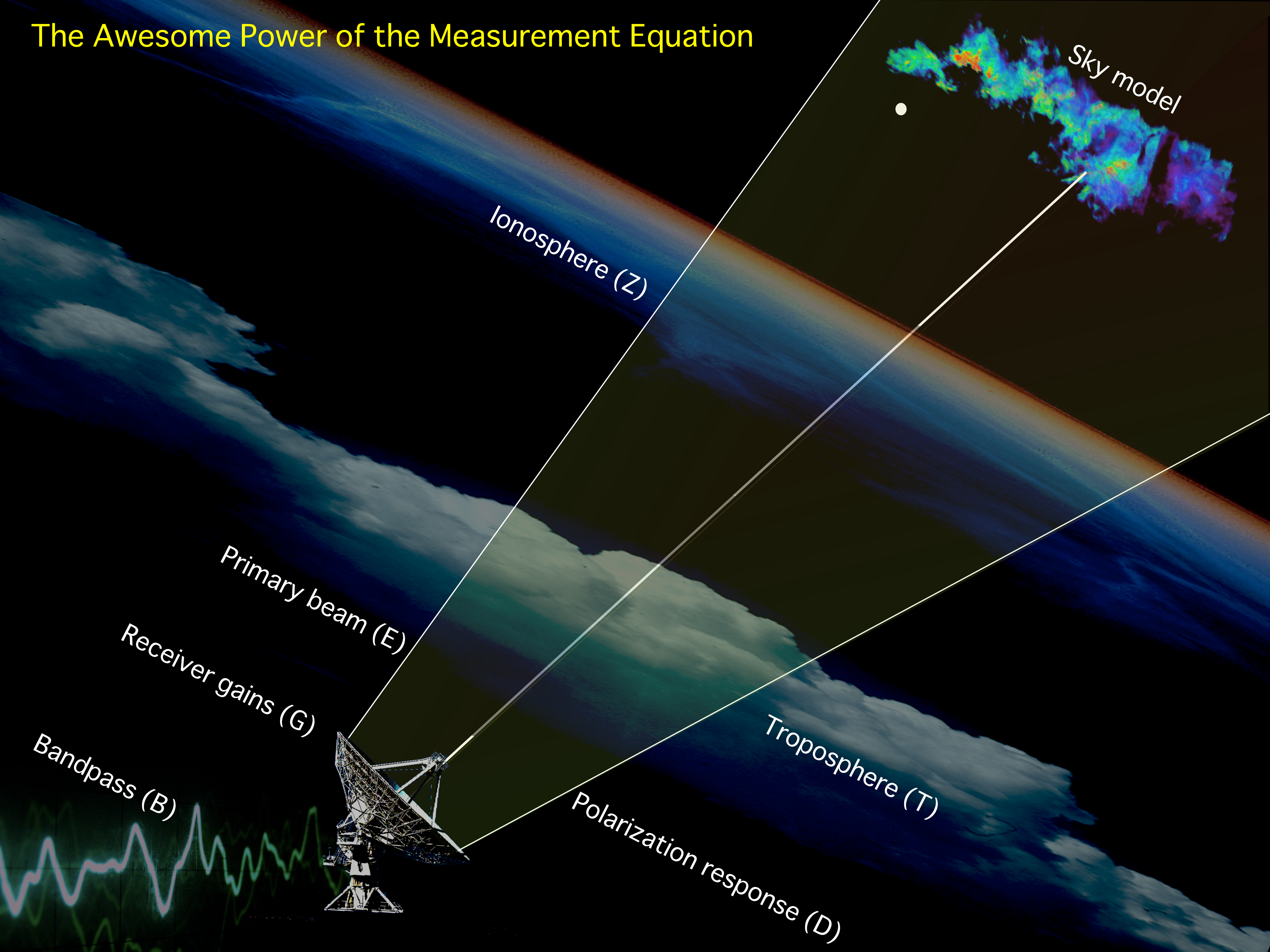
Received 5 Nov 2010 / Accepted 5 Jan 2011

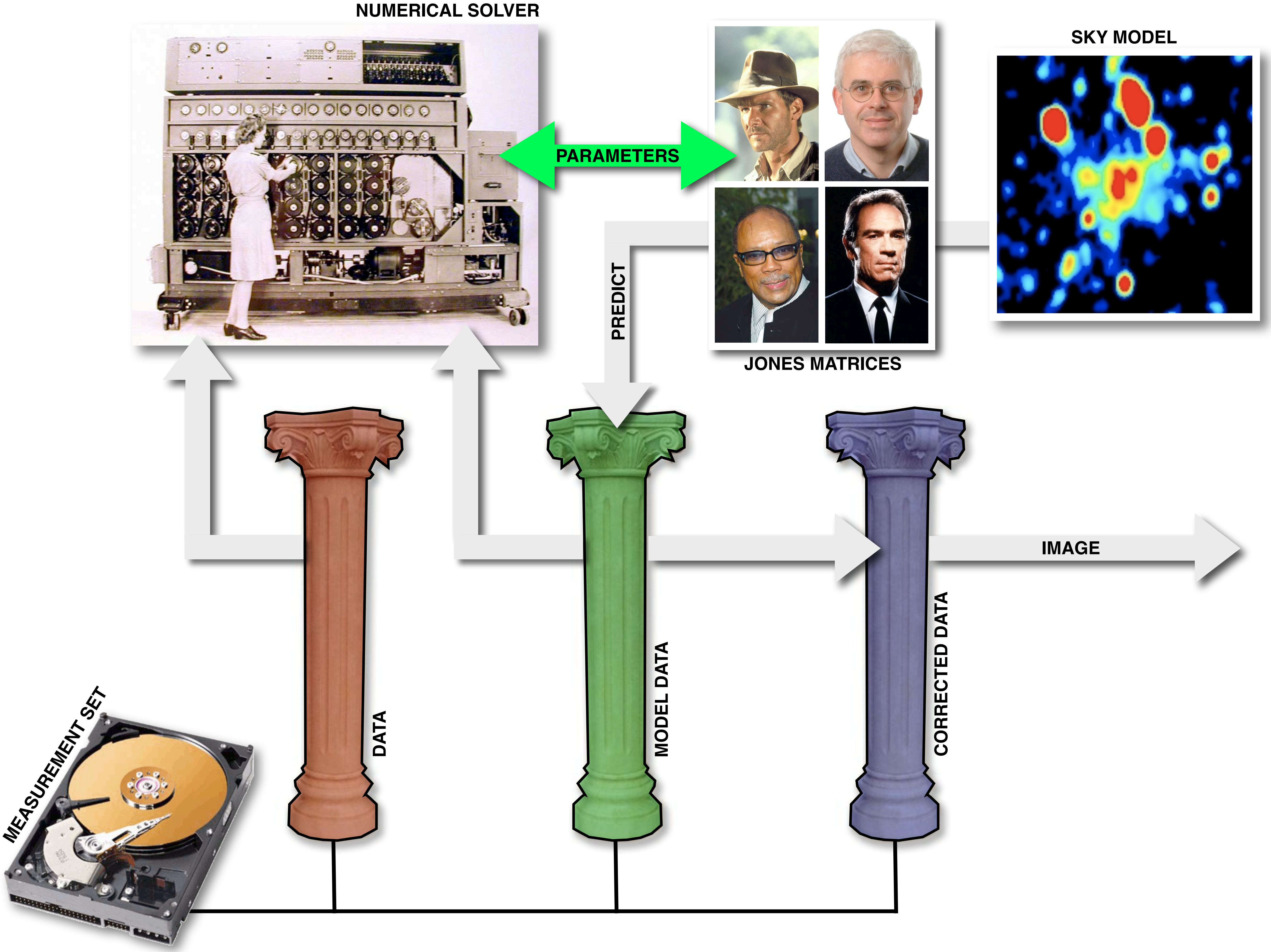
ABSTRACT

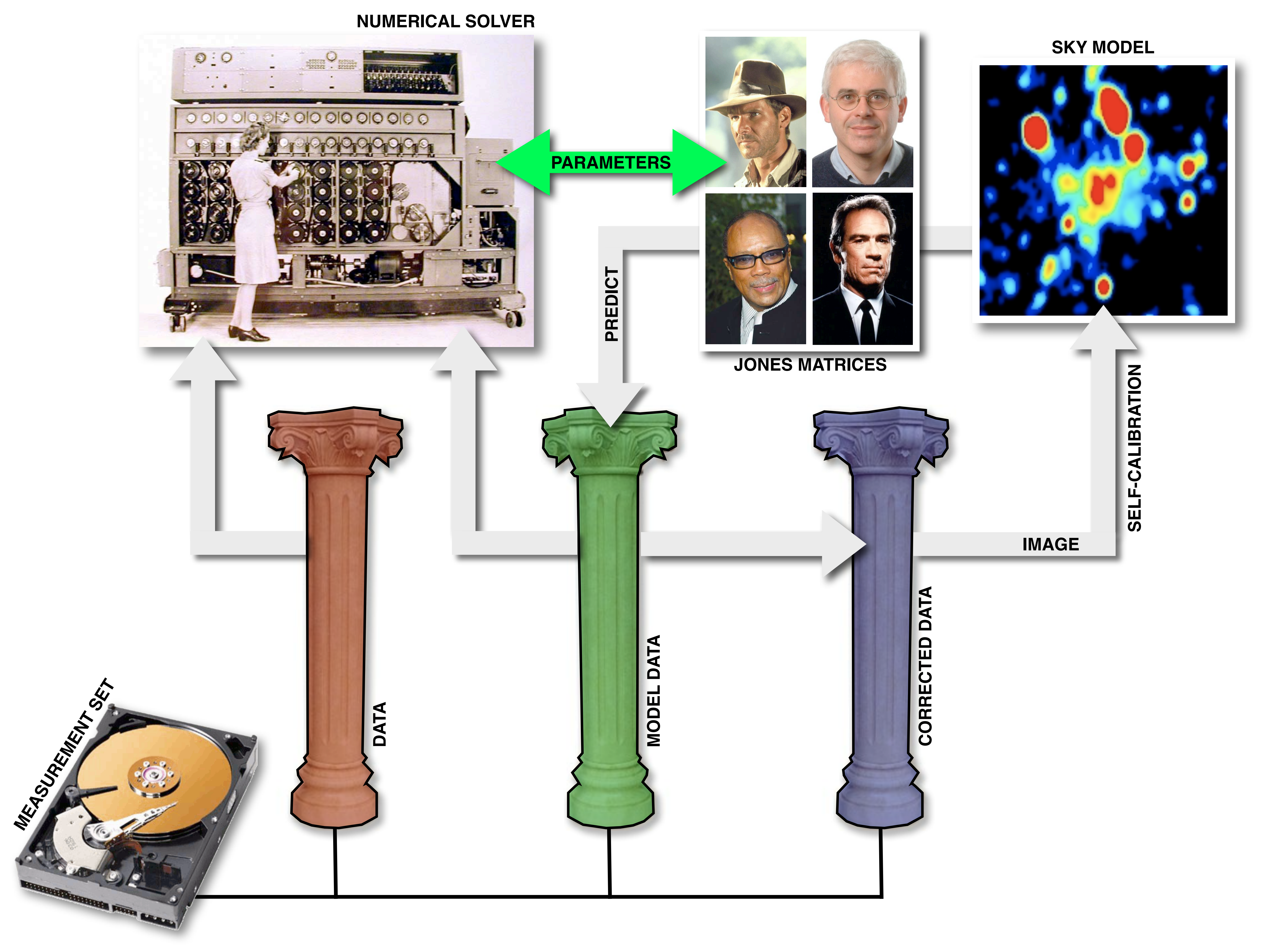
Context. Since its formulation by Hamaker et al., the radio interferometer measurement equation (RIME) has provided a rigorous mathematical basis for the development of novel calibration methods and techniques, including various approaches to the problem of direction-dependent effects (DDEs). However, acceptance of the RIME in the radioastronomical community at large has been slow, which is partially due to the limited availability of software to exploit its power, and the sparsity of practical results. This needs to change urgently.
Aims. This series of papers aims to place recent developments in the treatment of DDEs into one RIME-based mathematical framework, and to demonstrate the ease with which the various effects can be described and understood. It also aims to show the benefits of a RIME-based approach to calibration.
Methods. Paper I re-derives the RIME from first principles, extends the formalism to the full-sky case, and incorporates DDEs. Paper II then uses the formalism to describe self-calibration, both with a full RIME, and with the approximate equations of older software packages, and shows how this is affected by DDEs. It also gives an overview of real-life DDEs and proposed methods of dealing with them. Finally, in Paper III some of these methods are exercised to achieve an extremely high-dynamic range calibration of WSRT observations of 3C 147 at 21 cm, with full treatment of DDEs.
Results. The RIME formalism is extended to the full-sky case (Paper I), and is shown to be an elegant way of describing calibration and DDEs (Paper II). Applying this to WSRT data (Paper III) results in a noise-limited image of the field around 3C 147 with a very high dynamic range (1.6 million), and none of the off-axis artifacts that plague regular selfcal. The resulting differential gain solutions contain significant information on DDEs and errors in the sky model.
Conclusions. The RIME is a powerful formalism for describing radio interferometry, and underpins the development of novel calibration methods, in particular those dealing with DDEs. One of these is the differential gains approach used for the 3C 147 reduction. Differential gains can eliminate DDE-related artifacts, and provide information for iterative improvements of sky models. Perhaps most importantly, sources as faint as 2 mJy have been shown to yield meaningful differential gain solutions, and thus can be used as potential calibration beacons in other DDE-related schemes.

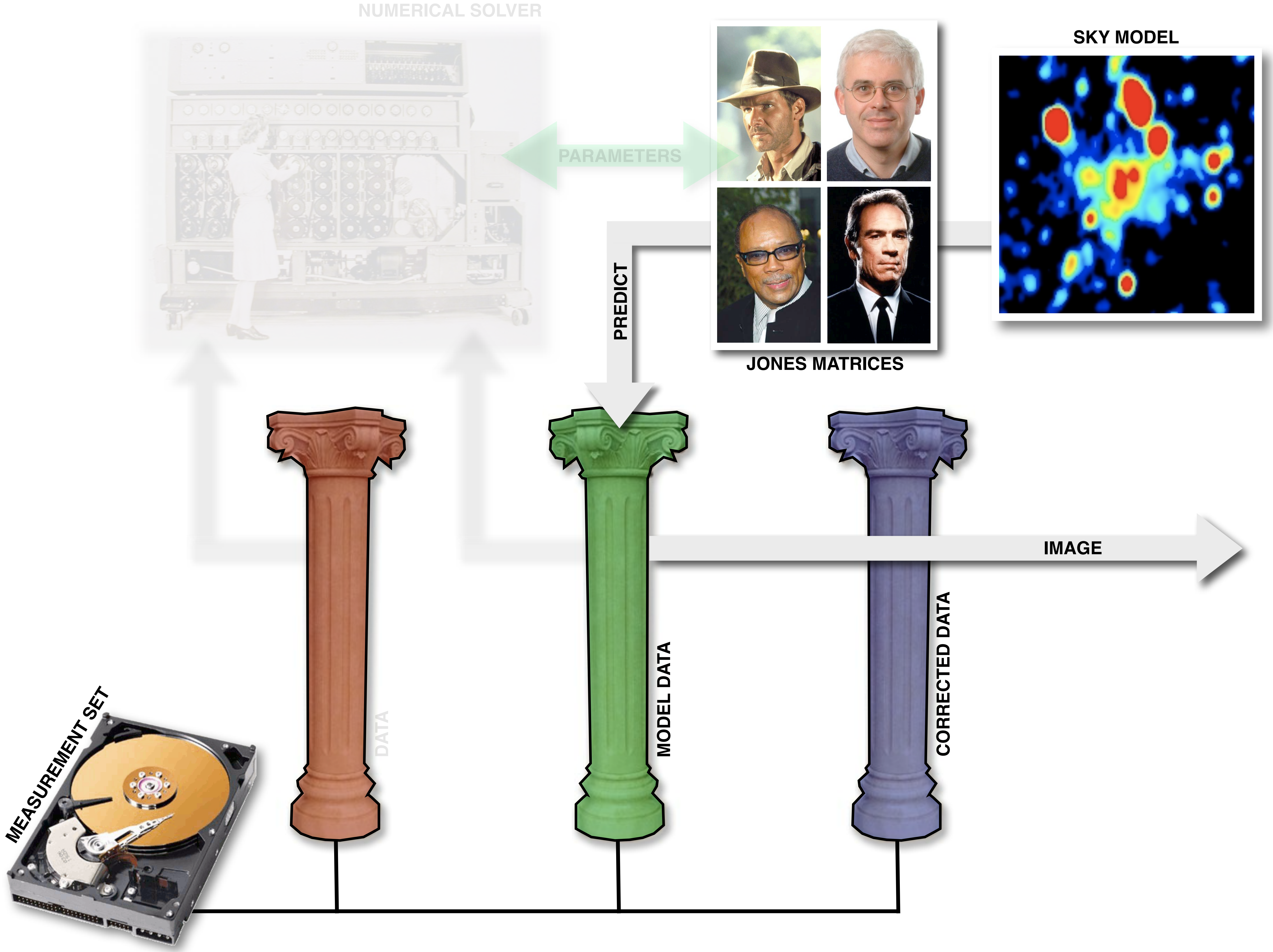
Key words. Methods: numerical - Methods: analytical - Methods: data analysis - Techniques: interferometric - Techniques: polarimetric


The Awesome Power of the Measurement Equation
Sky model
Ionosphere (Z)
Primary beam (E)
Receiver gains (G)
Bandpass (B)
Troposphere (T)
Polarization response (D)

Calibration


NUMERICAL SOLVER
PARAMETERS
SKY MODEL
PREDICT
JONES MATRICES
IMAGE
DATA
MODEL DATA
CORRECTED DATA
MEASUREMENT SET


NUMERICAL SOLVER
PARAMETERS
SKY MODEL
PREDICT
JONES MATRICES
SELF-CALIBRATION
IMAGE
DATA
MODEL DATA
CORRECTED DATA
MEASUREMENT SET



NUMERICAL SOLVER
PARAMETERS
SKY MODEL
PREDICT
JONES MATRICES
IMAGE
DATA
MODEL DATA
CORRECTED DATA
MEASUREMENT SET

A basic simulation setup

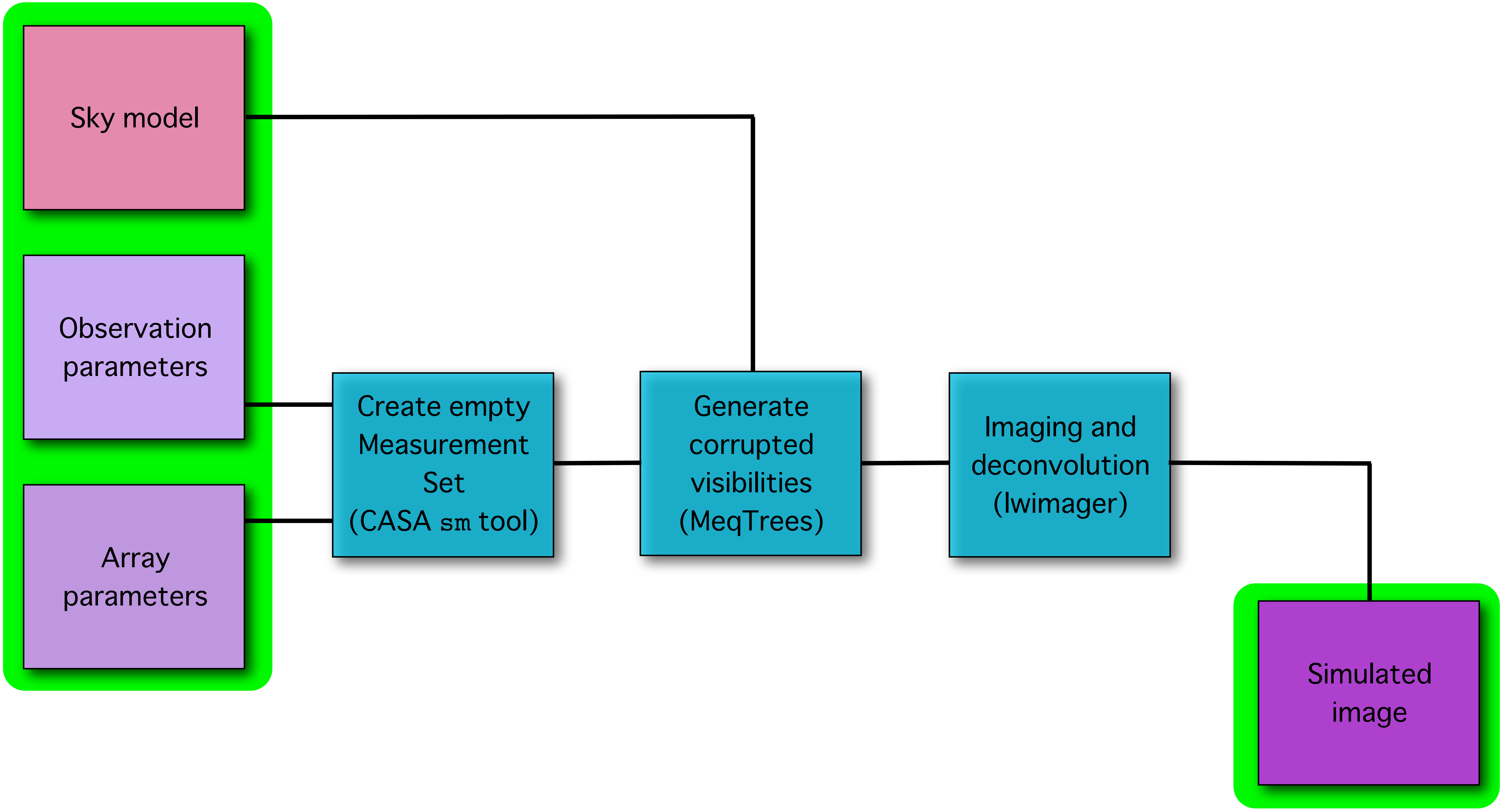
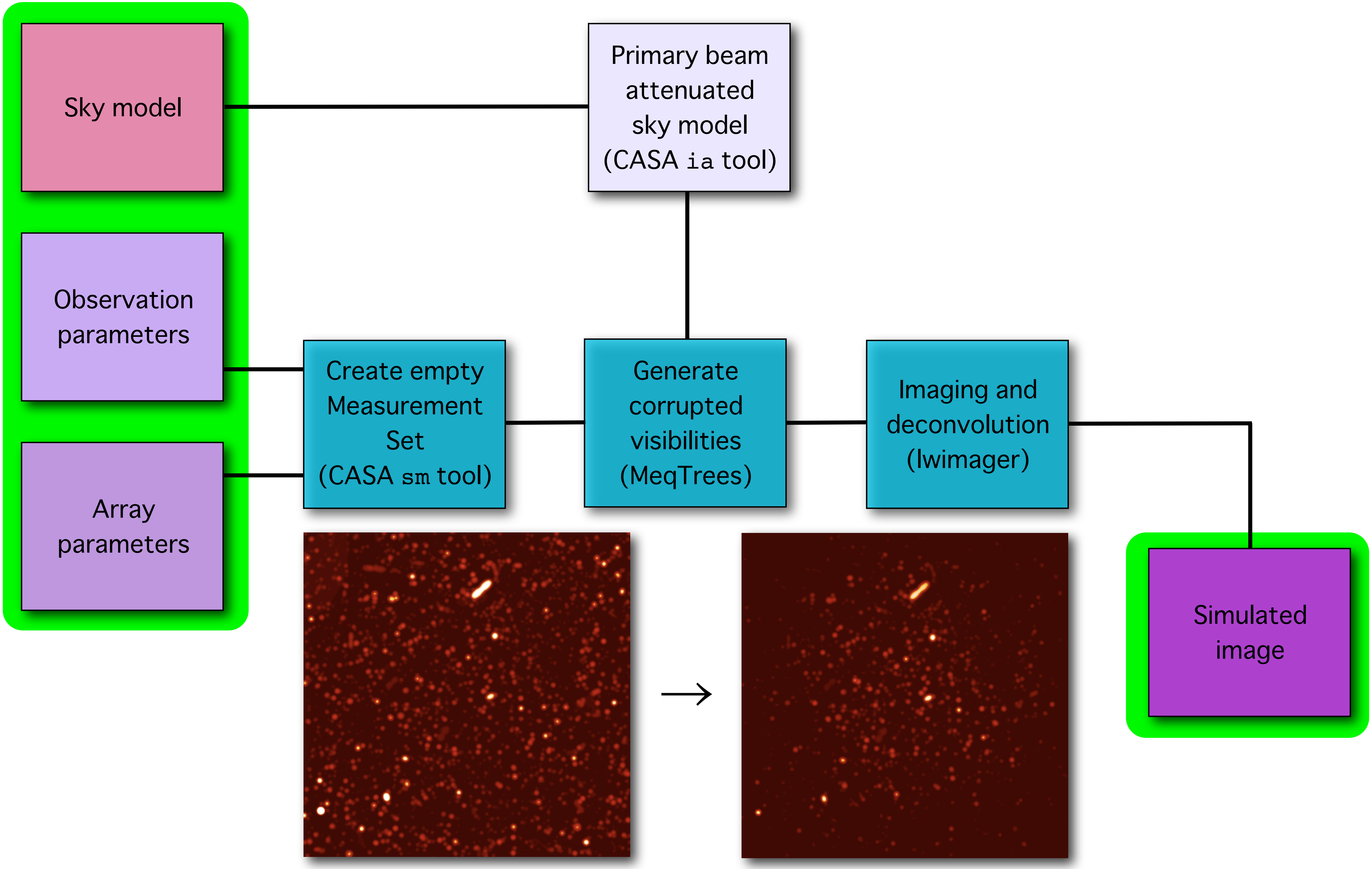
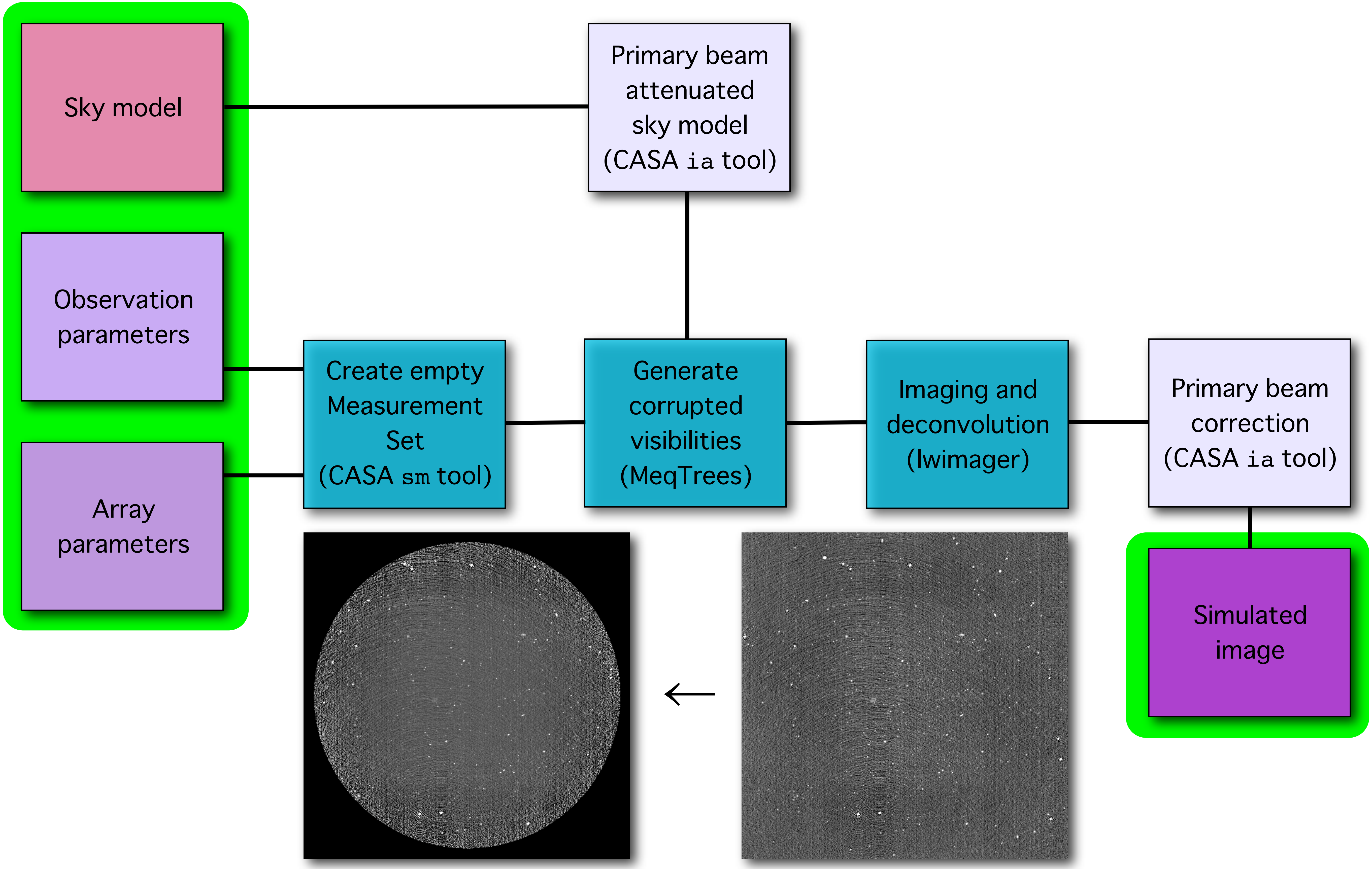


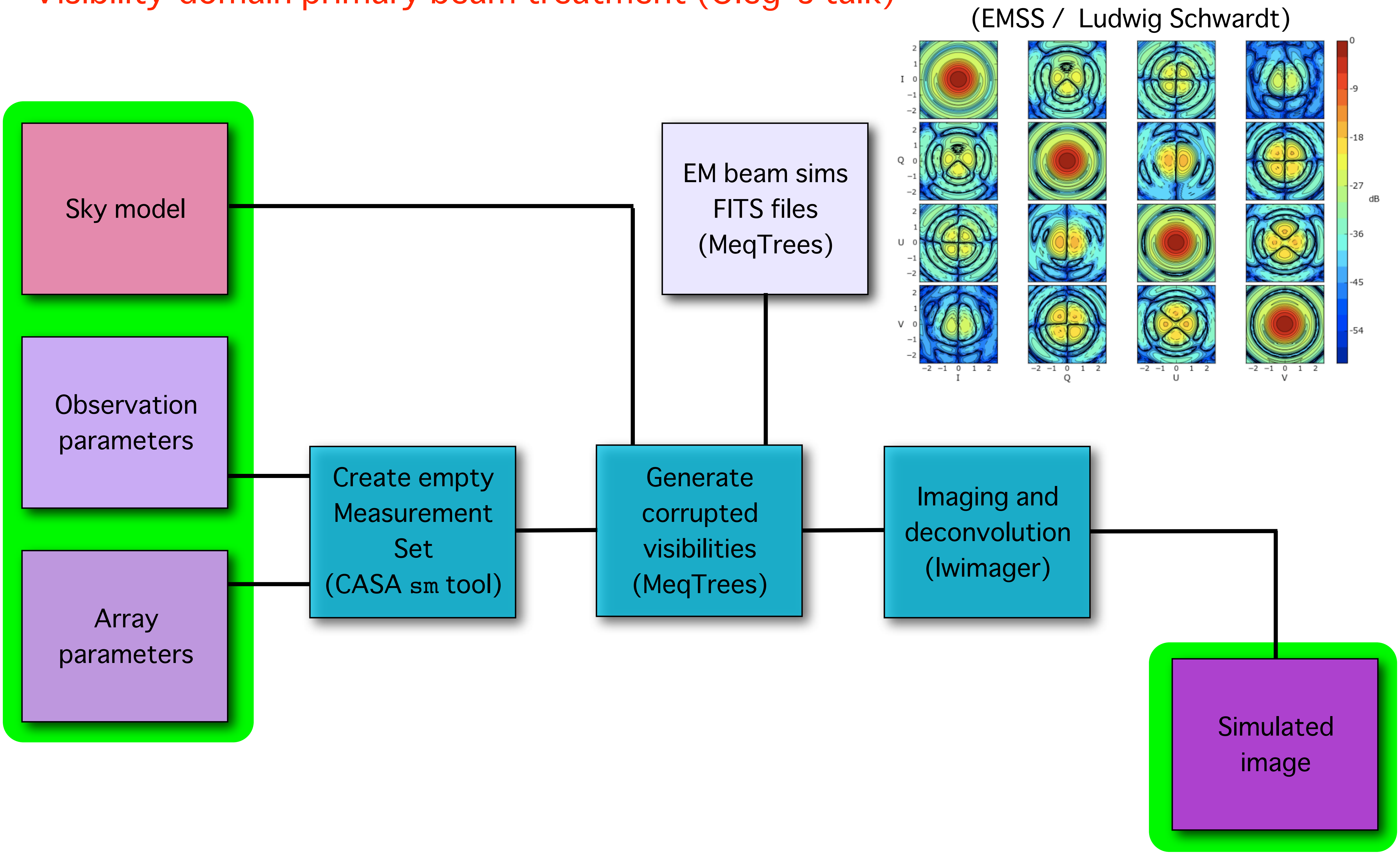
Image-plane primary beam treatment...



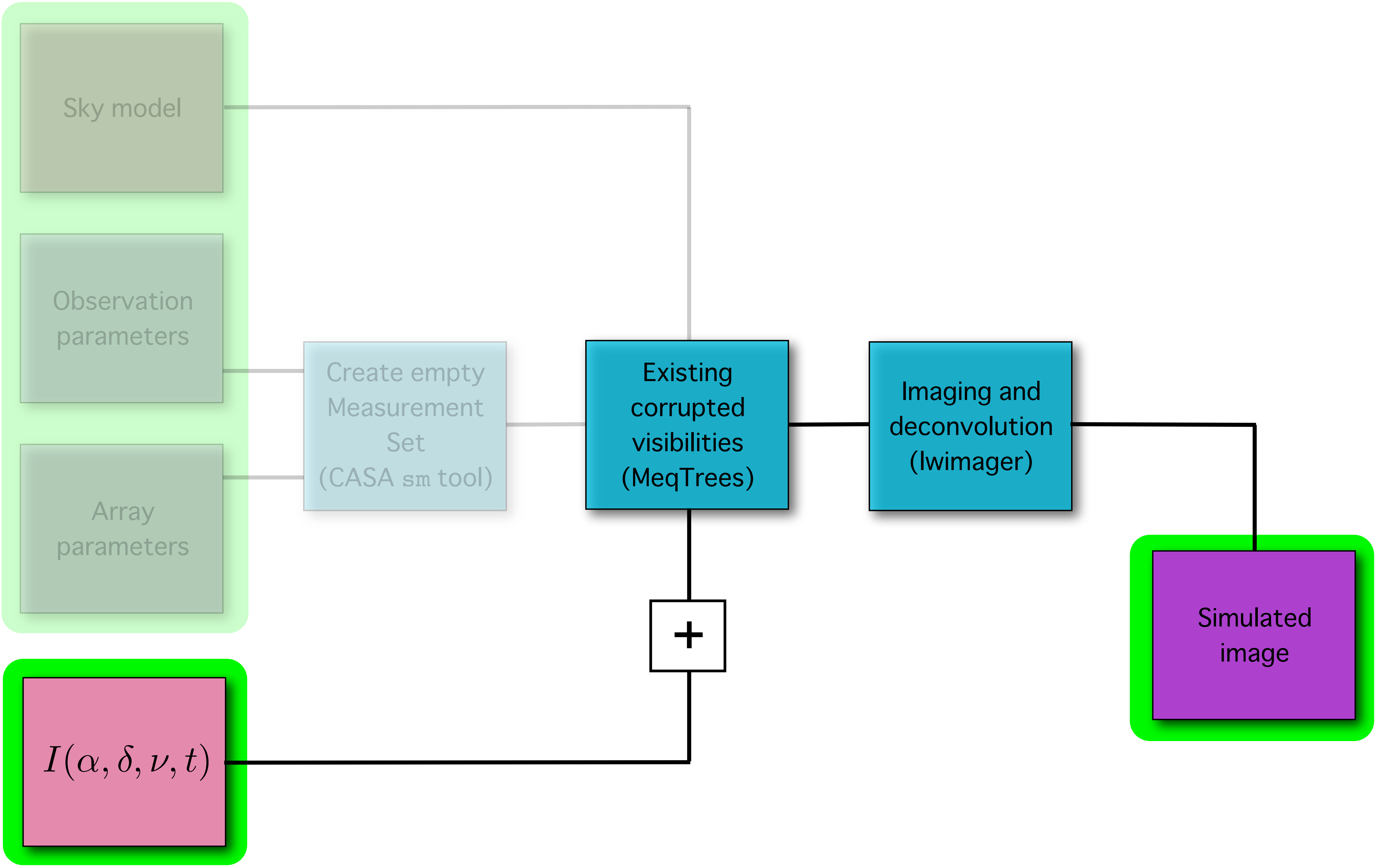
...with optional inversion



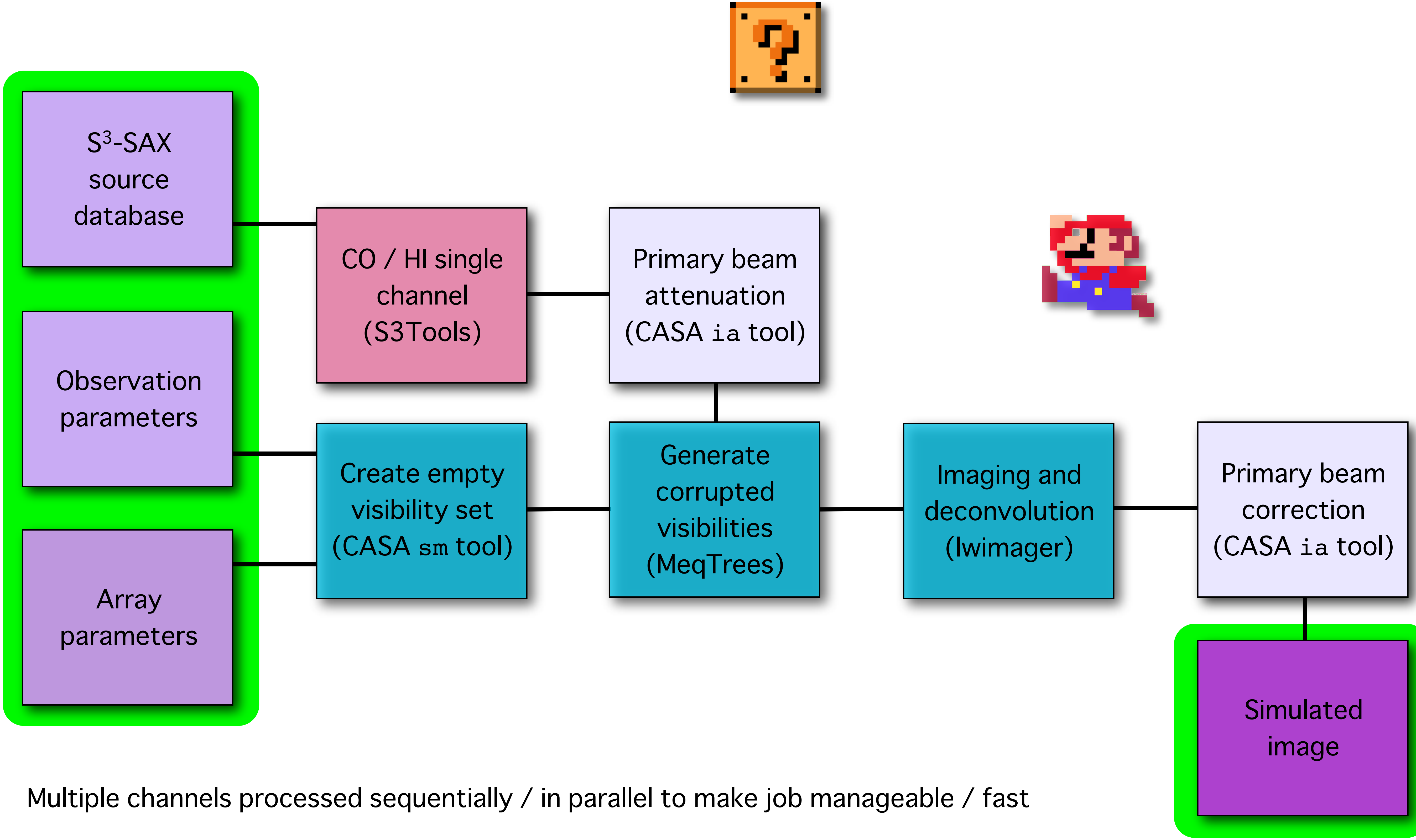
Visibility-domain primary beam treatment (Oleg's talk)



Iterative simulations



Setup for MESMER / LADUMA simulations

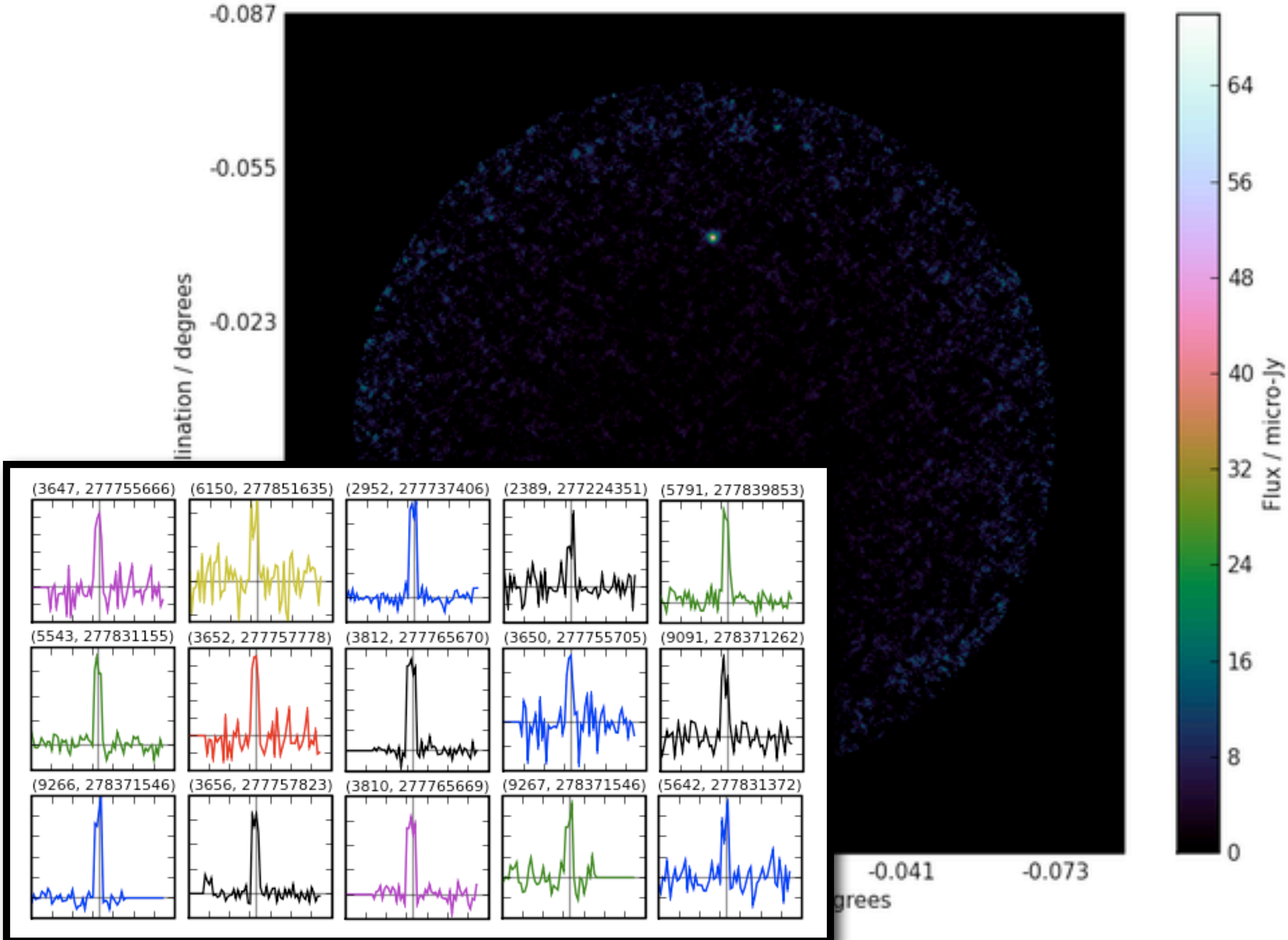


Multiple channels processed sequentially / in parallel to make job manageable / fast

http://s-cubed.physics.ox.ac.uk

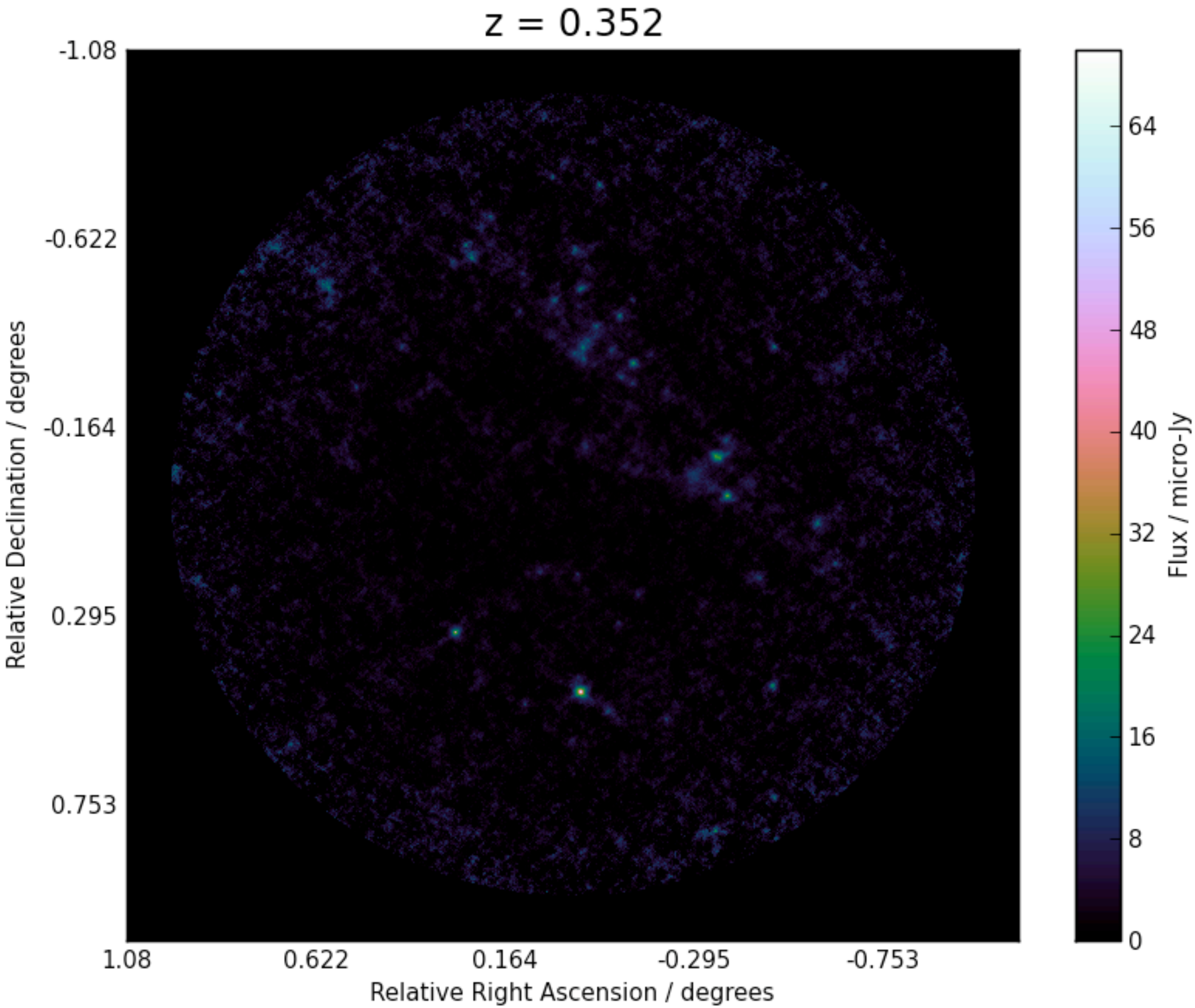
MESMER datacube: 4096 × 4096 × 256 / 6.95 ≤ z ≤ 8.22 / 2 GHz BW

0.3 TB visibility data / 17 GB image cube



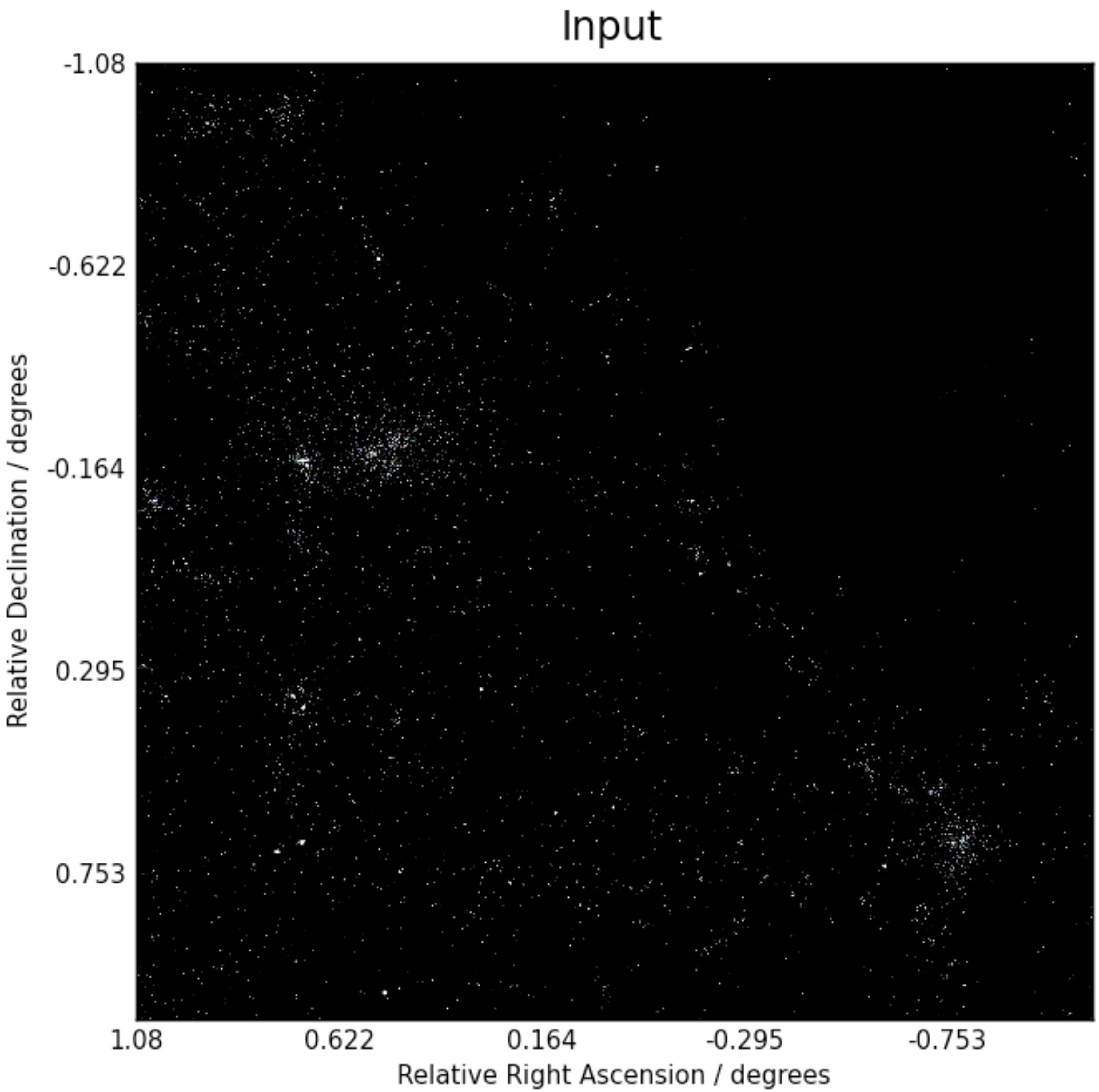
10,559

LADUMA datacube: 4096 × 4096 × 64 / 0.188 ≤ z ≤ 0.438 (not deconvolved)



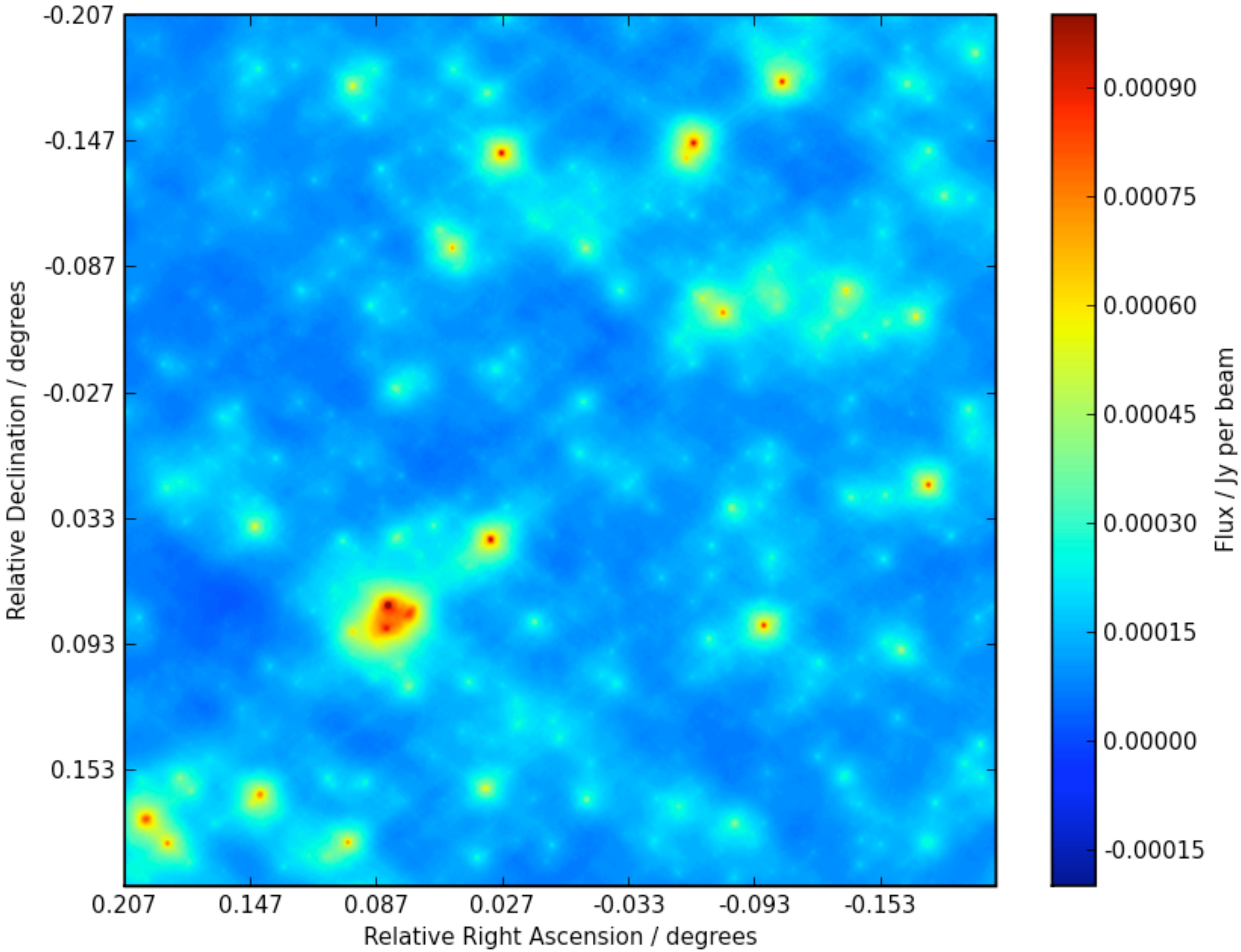
453,858

LADUMA datacube: 4096 × 4096 × 64 / 0.188 ≤ z ≤ 0.438 (sky model)

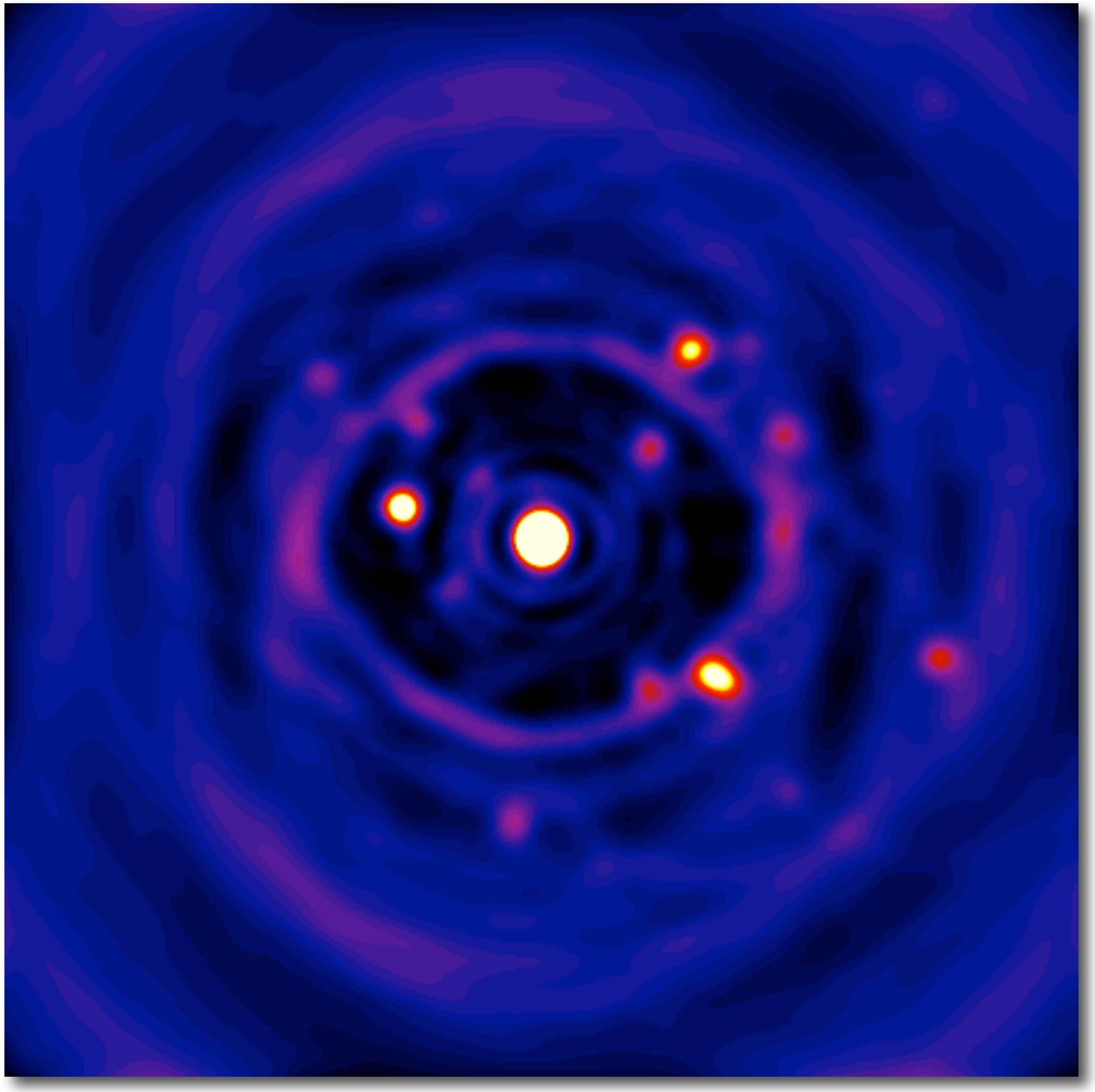


453,858

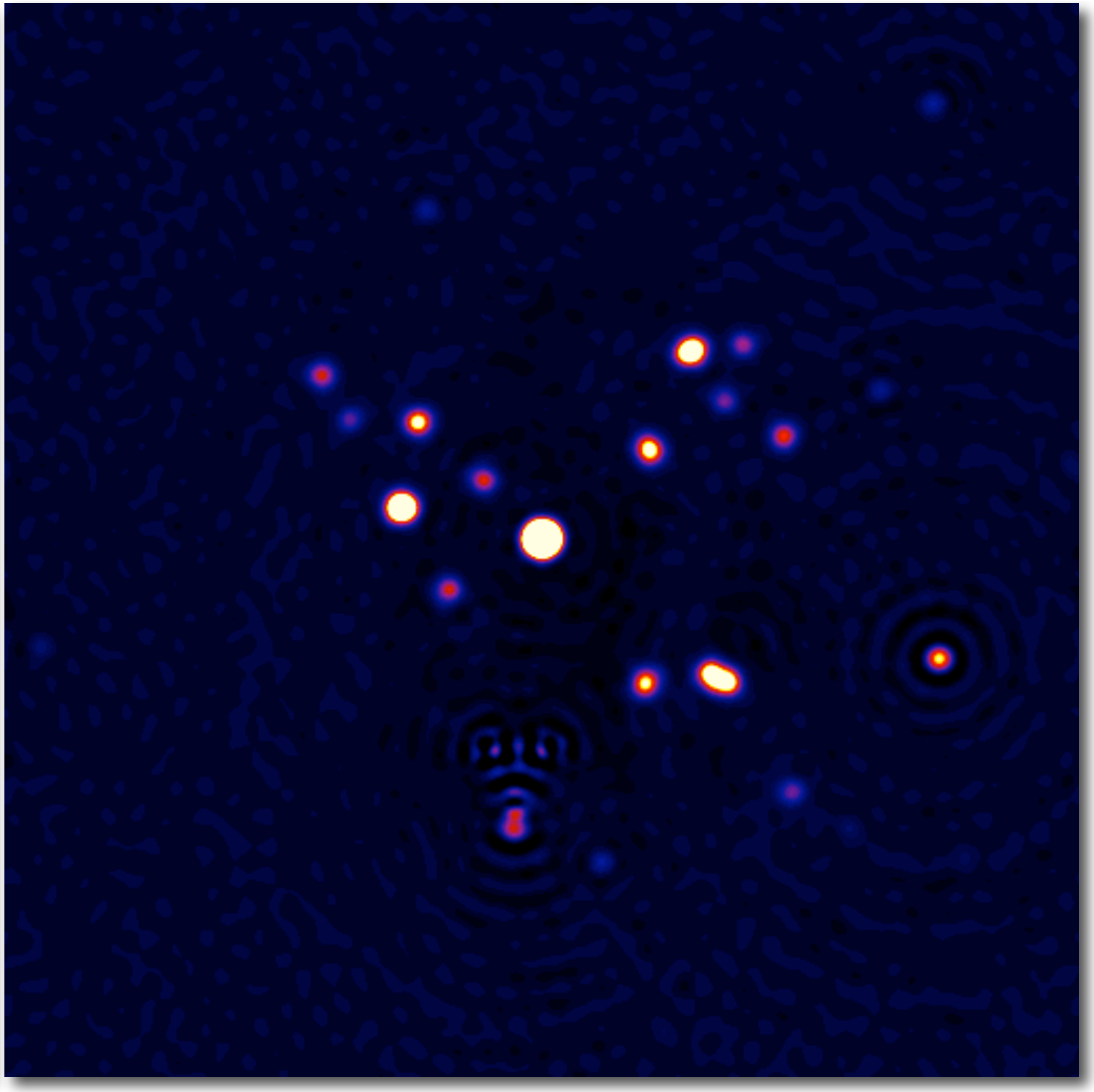
MIGHTEE image: 300-hour continuum field at 1.3 GHz



KAT-7 simulation / 24 hour track / 1.6 GHz / 2 degree field



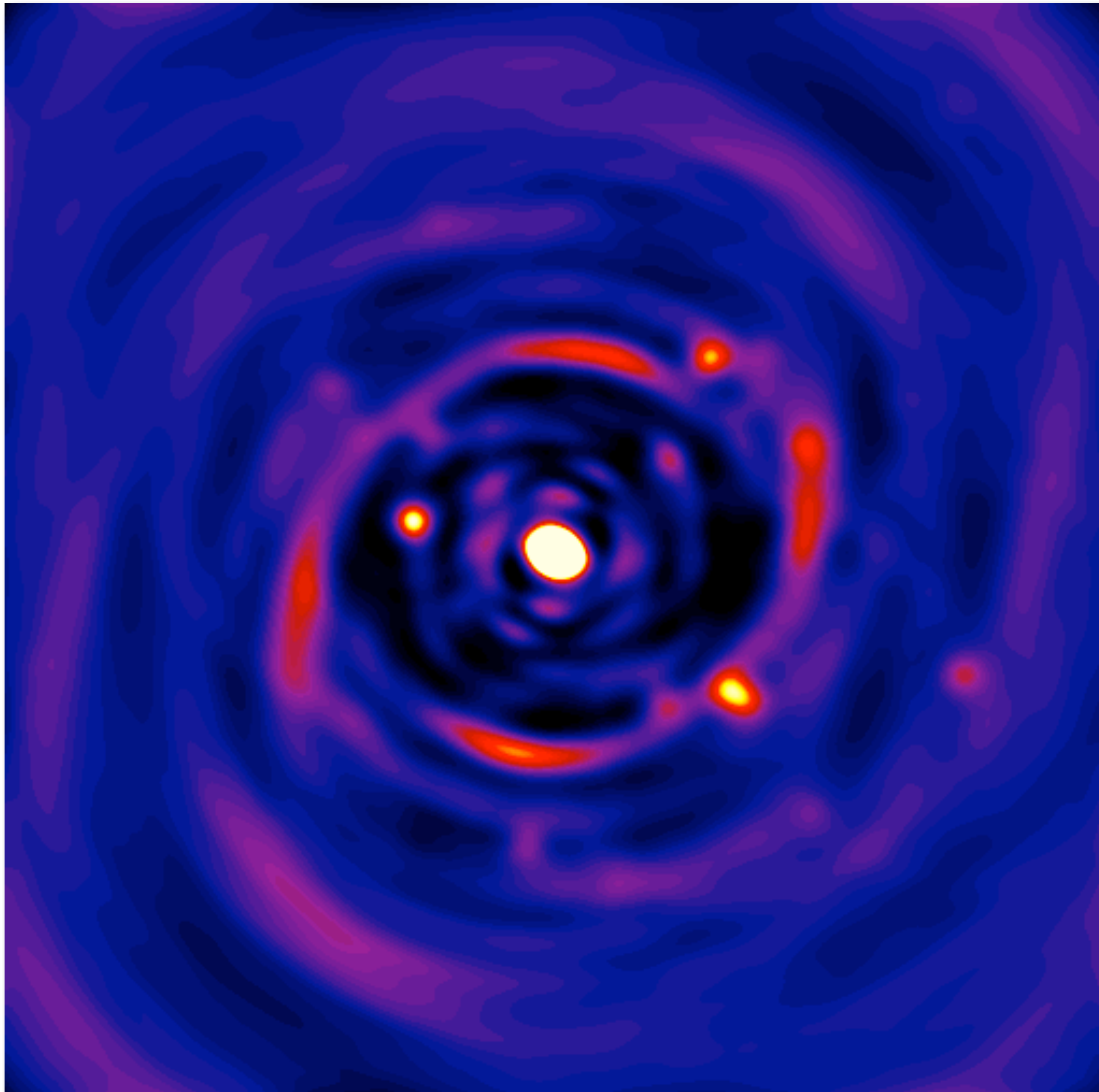
Dirty image, natural weighting



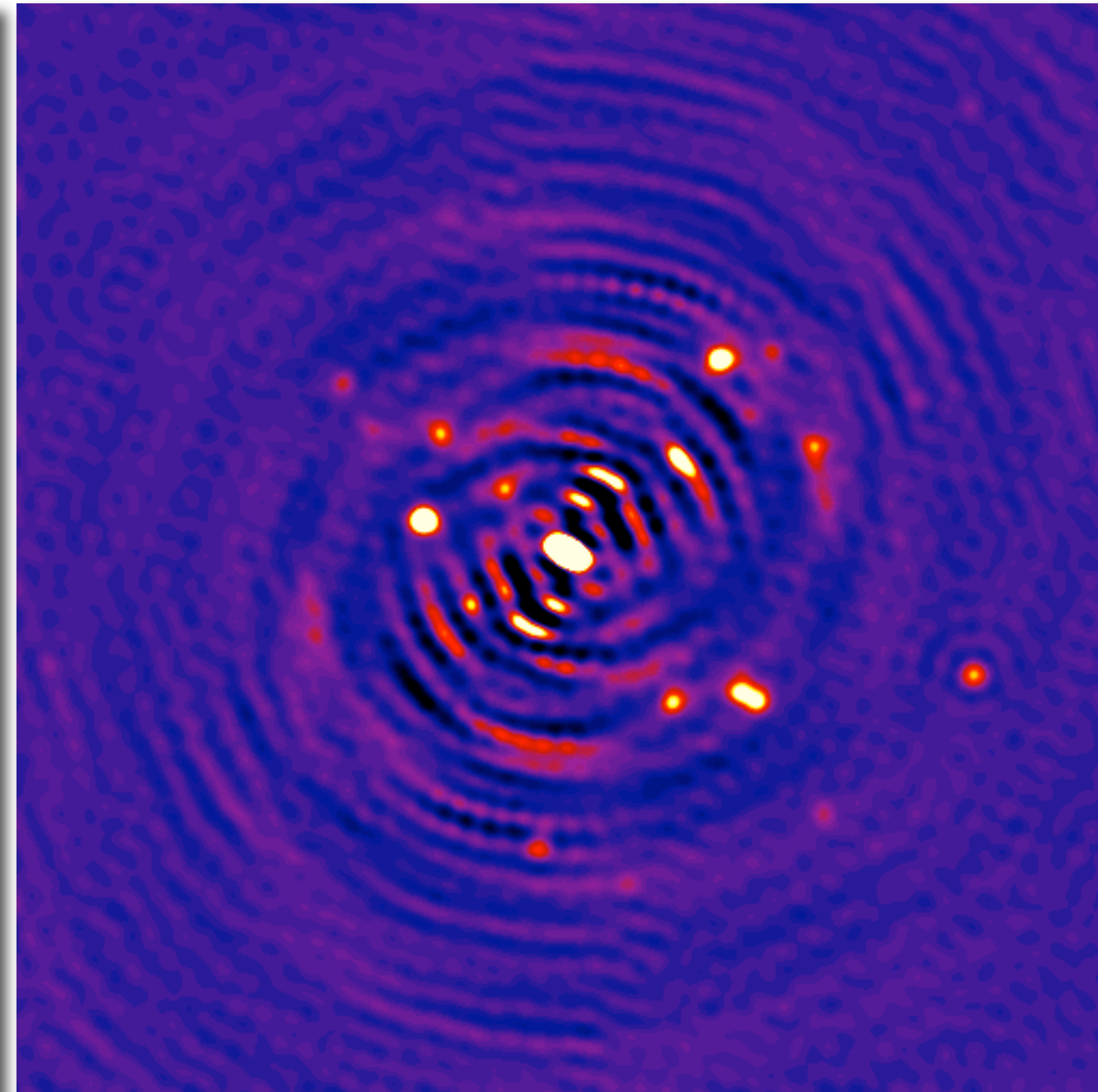
Blind clean, 12,000 components, Briggs weighting

KAT-7 simulation / 24 hour track / 1.6 GHz / 2 degree field

Central 1 Jy source flares to 3 Jy for about an hour

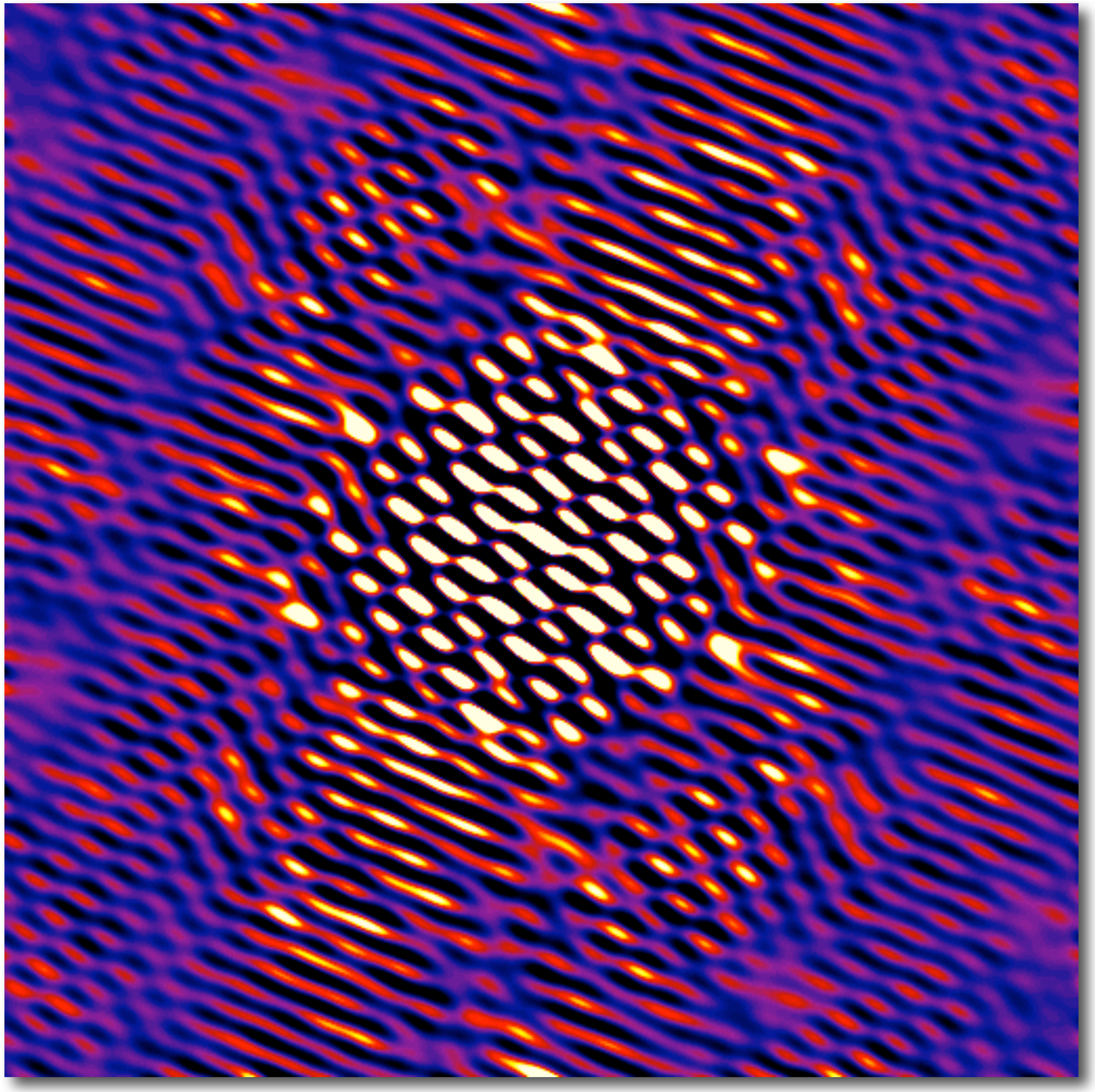


Dirty image, natural weighting

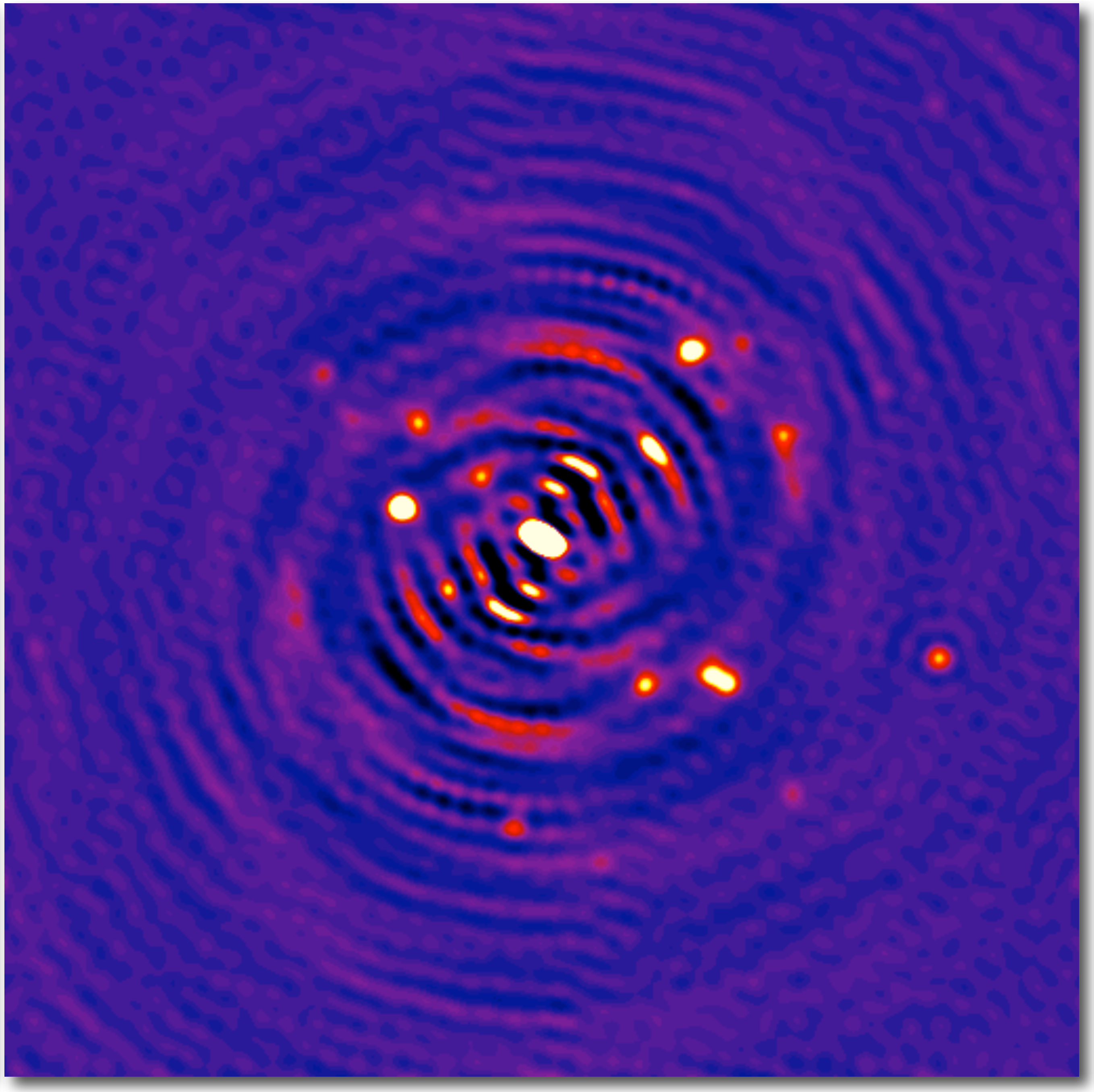


Blind clean, 12,000 components, Briggs weighting

KAT-7 simulation / 24 hour track / 1.6 GHz / 2 degree field



48 × 30-minute snapshot dirty images



Blind clean, 12,000 components, Briggs weighting