Murchison Widefield Array (MWA) Update

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Outline

- Quick review of the MWA
- MWA imaging approach
- MWA buildout
- Some 32T results

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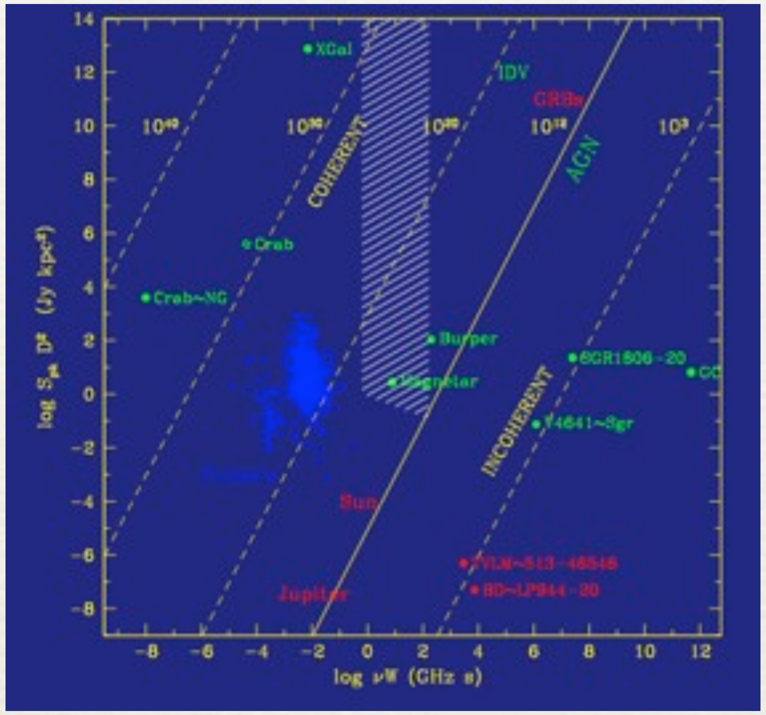
MWA

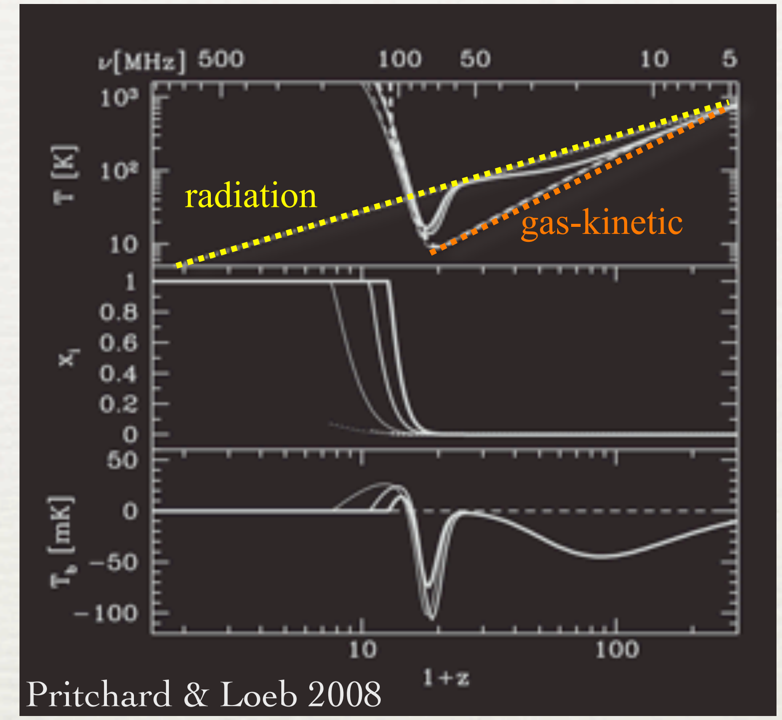
Wide-field radio interferometer covering 80-300 MHz

Transients



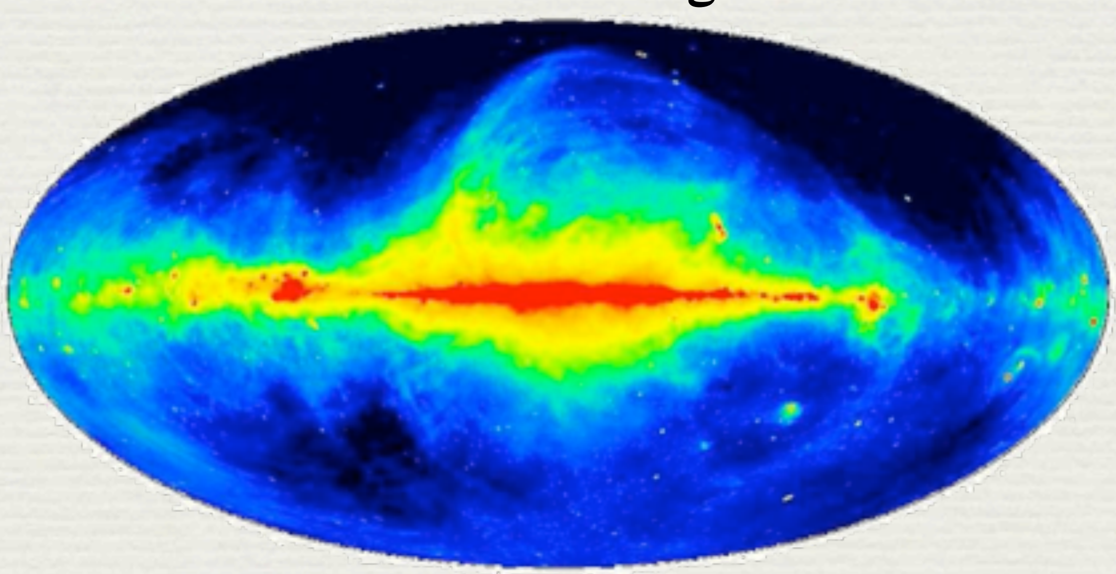
Chatterjee & Murphy
(adapted from Cordes et al. 2003)

EoR via redshifted HI



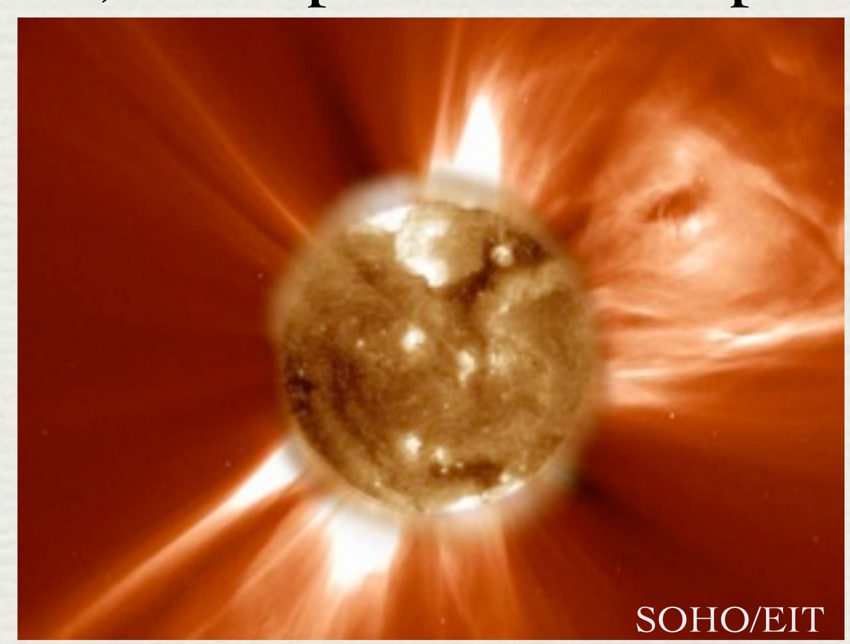
Pritchard & Loeb 2008

Galactic & Extragalactic



Testori et al. (2001, 2004) / Wooleben et al. (2005)

Solar, Heleospherical & Ionospheric



SOHO/EIT

The MWA Consortium

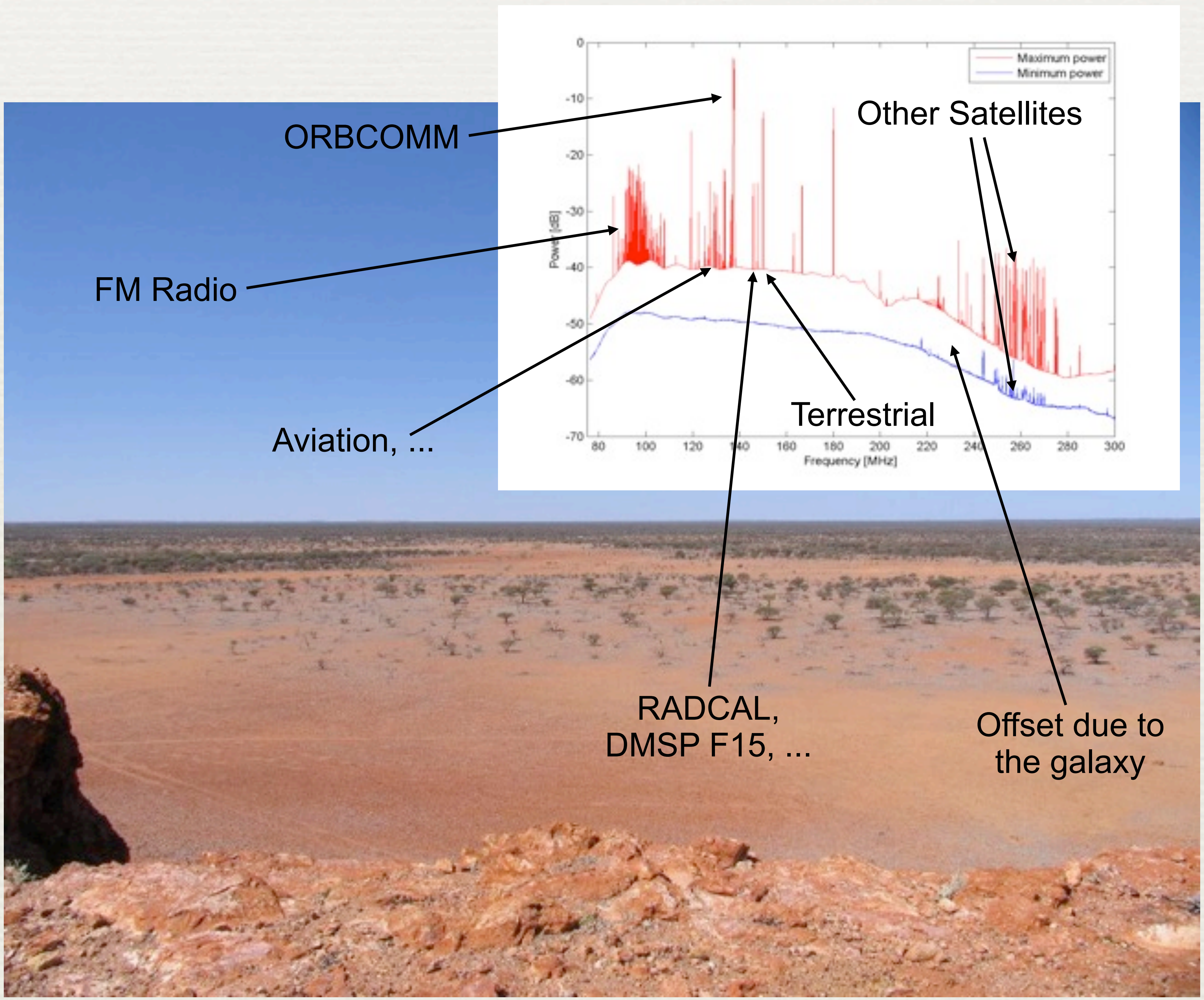
- MIT Haystack Obs.
- MIT campus (MKI)
- Smithsonian Inst.
- Harvard U.
- U. Melbourne
- Curtin U. of Tech.
- U. WA
- U. Tasmania
- U. Sydney
- ANU
- Raman Research Inst.
- CSIRO

Also U. Wisc, U. Wash, ASU, and Victoria U. Wellington

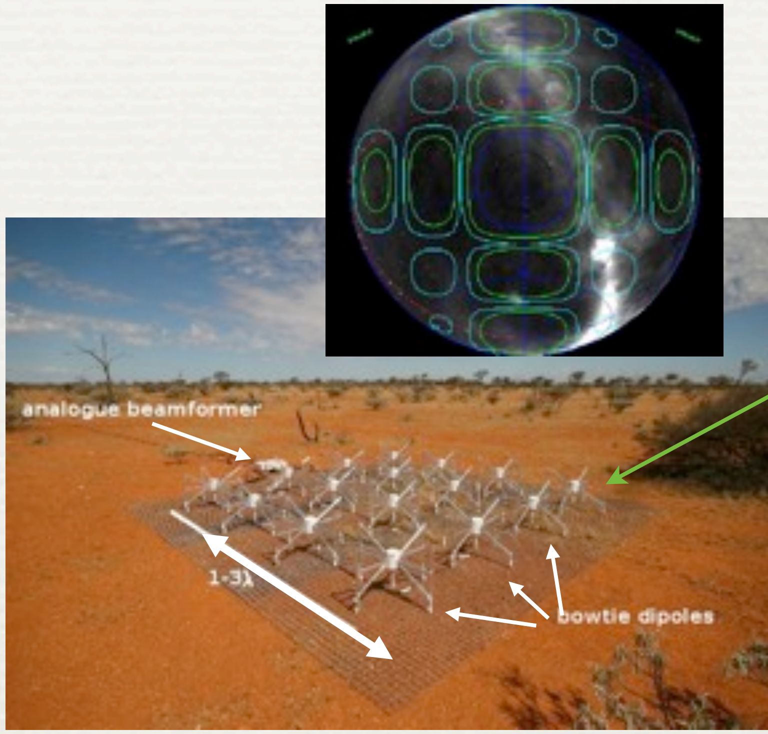
MWA Specifications

- Snapshot imaging (0.5 - 8 sec)
- Lots of "cheap" antennas
  - excellent instantaneous uv coverage
  - well constrained calibration problem
- Fully-polarised (Stokes images)
- Wide frequency range (31 MHz from 80–300 MHz)
  - frequency resolution of 40 kHz (768 channels)
- Wide, steerable field of view (10-50 degrees)
- A few arc-minute resolution (1.5 km: ~ 2.3' - 8.6')
  - plus a 3 km ring of outriggers (~ 1.1' - 4.3')
  - ~ km baselines → ~ 2D ionospheric models

Murchison Radio Observatory

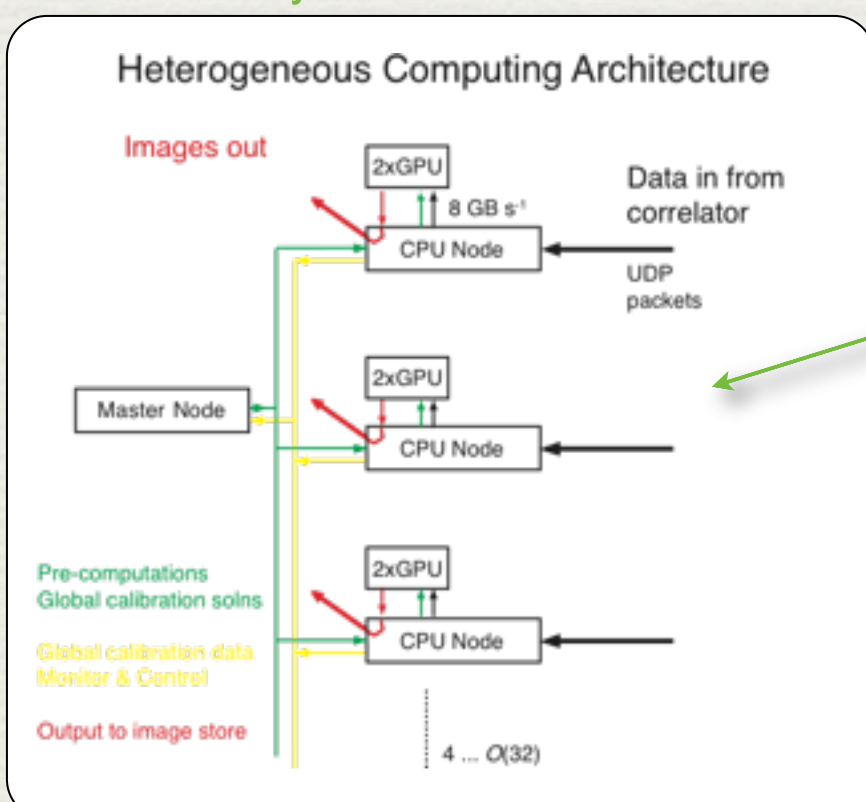


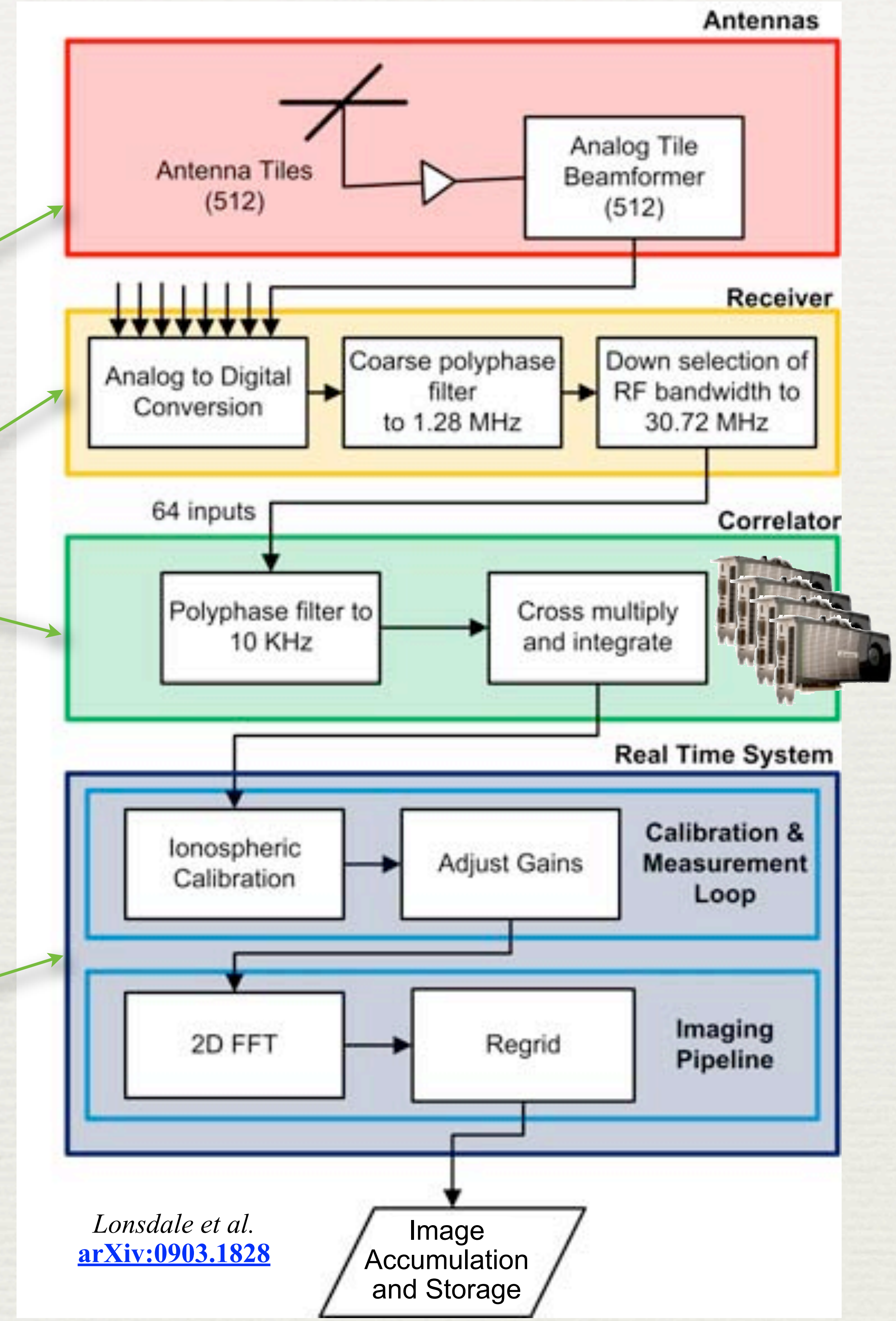
MWA analysis pipeline



FPGAs

Real-Time System: CPUs/MPI + GPUs





Lonsdale et al.
arXiv:0903.1828

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Wide-field Approaches

- c.f., Cornwell et al., arXiv:0807.4161
- 3D transform
  - FFT (sparse volume)
  - DFTs (expensive)
- 2D transforms
  - image-plane facets
  - uvw-space facets
  - **warped snapshots** →
  - w-projection
- Combinations (e.g., peeling and segmenting)

Good fit for MWA

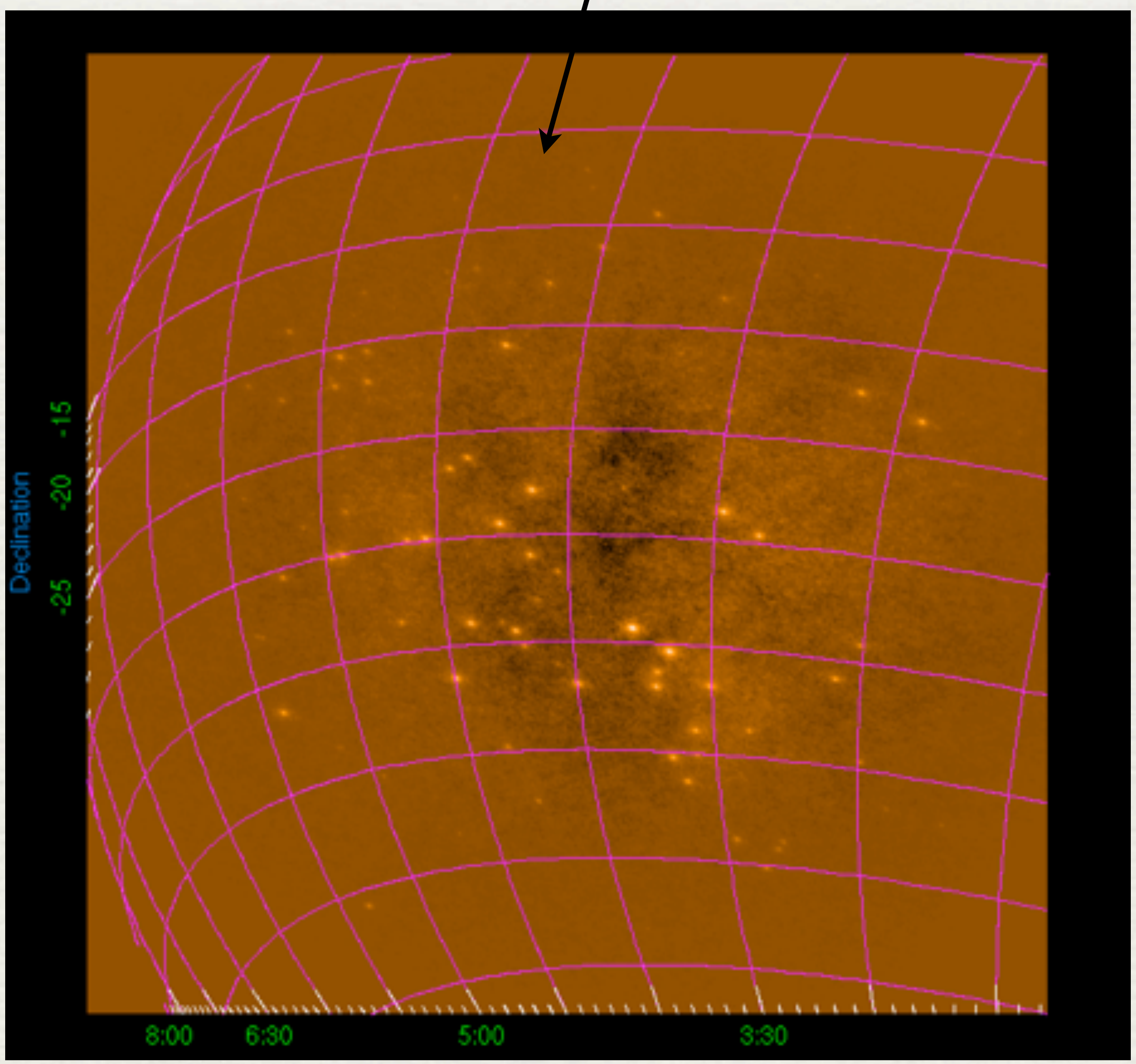
- snapshot imaging with image resampling for time-dependent ionospheric corrections (in image plane).
- snapshot imaging for transient detection.
- good snapshot beam.

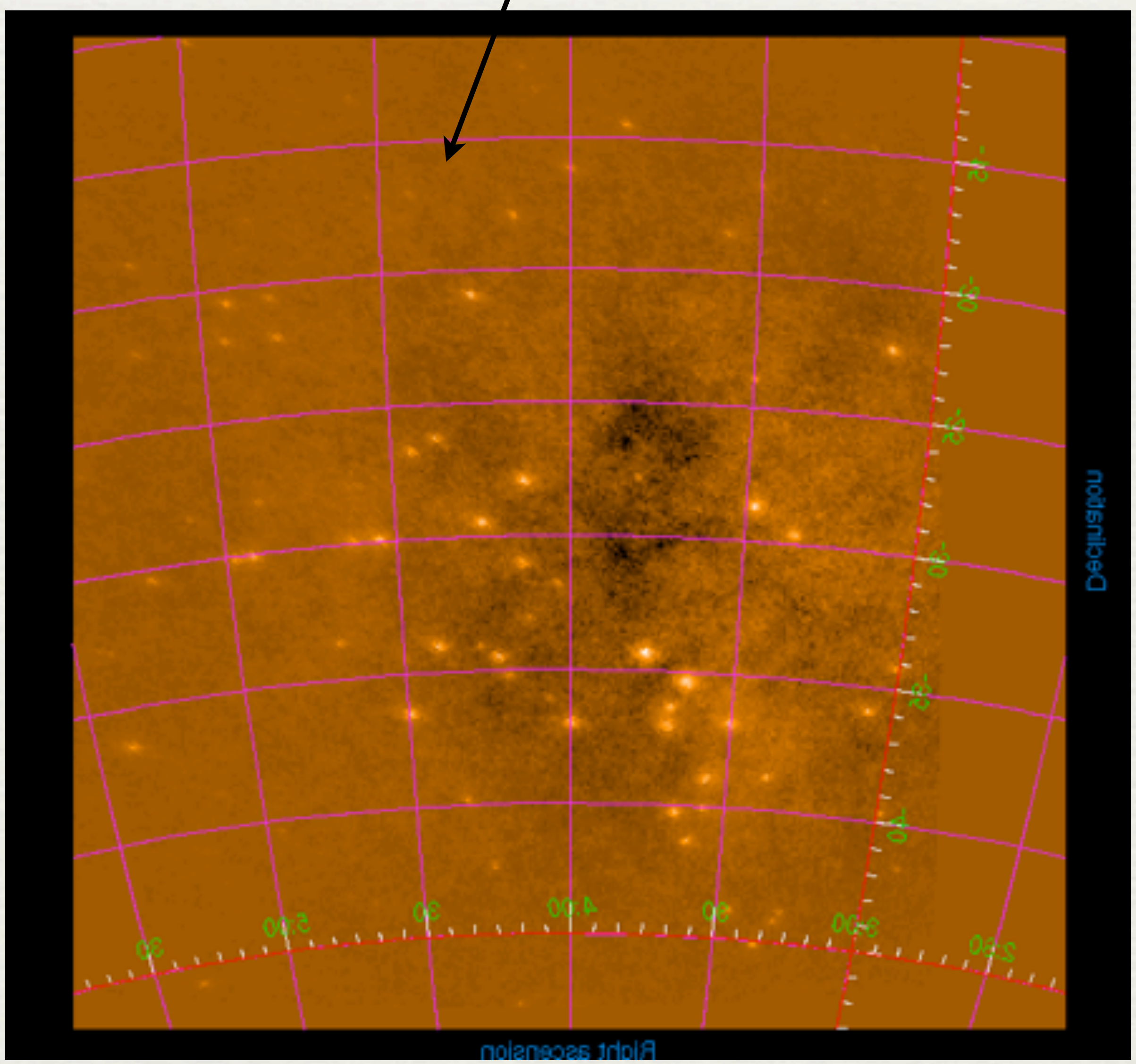
Warped Snapshots

Simulated data, centred at HA = -3.5 to +3.5 hrs

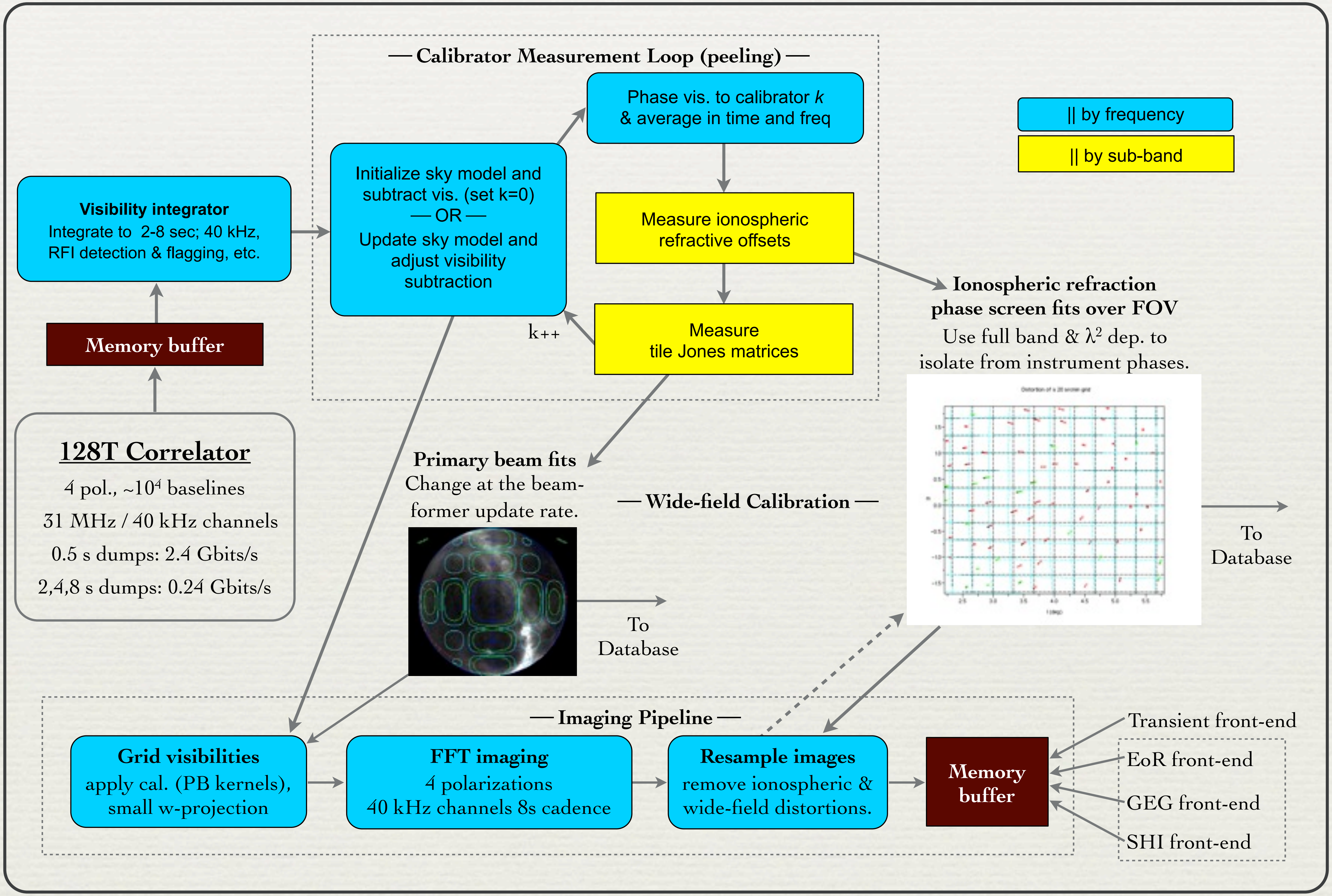
Determine grid (wide-field effects & ionosphere) and weights (primary beams & potentially FR) for snapshots

Re-sample to a constant frame for integration

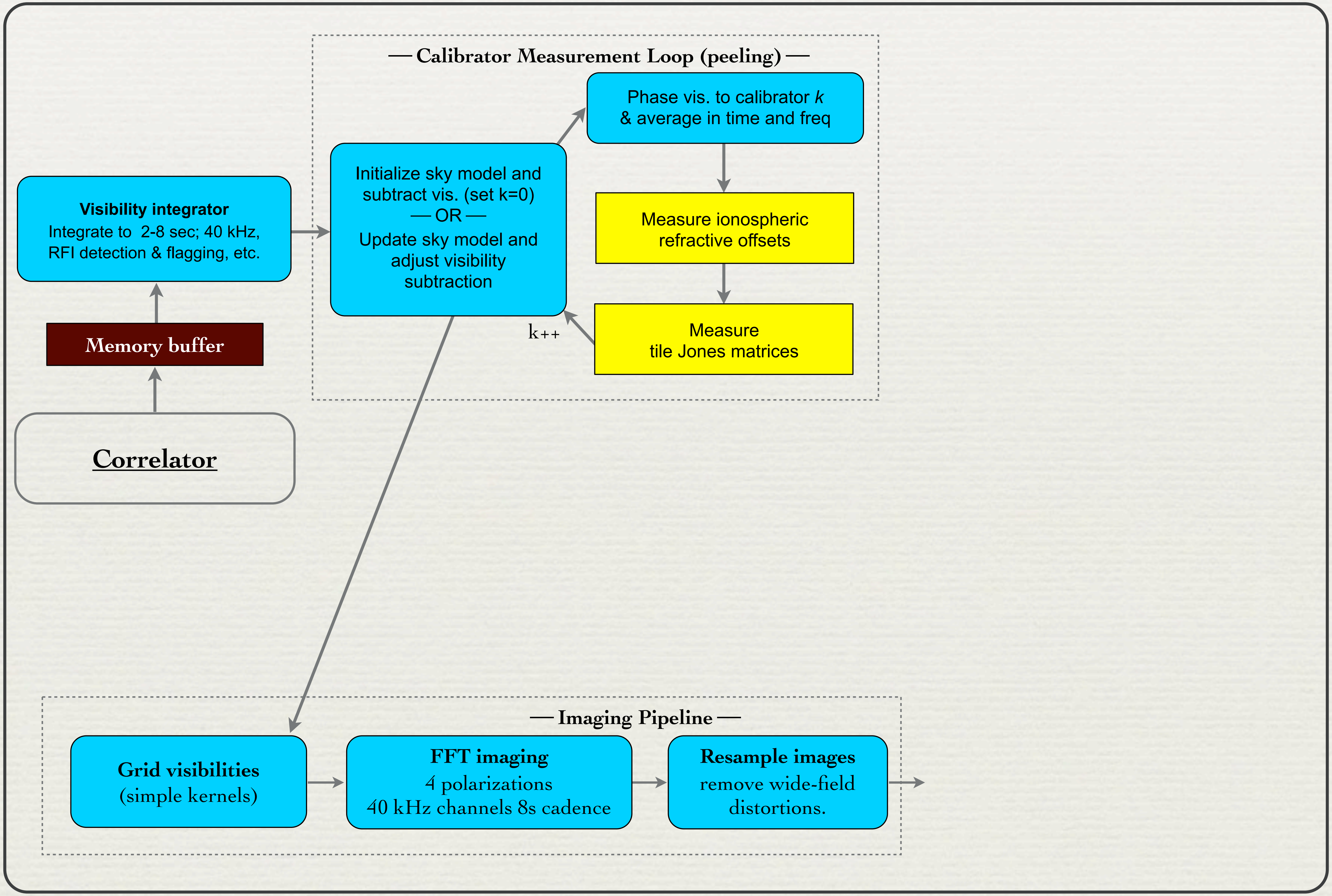




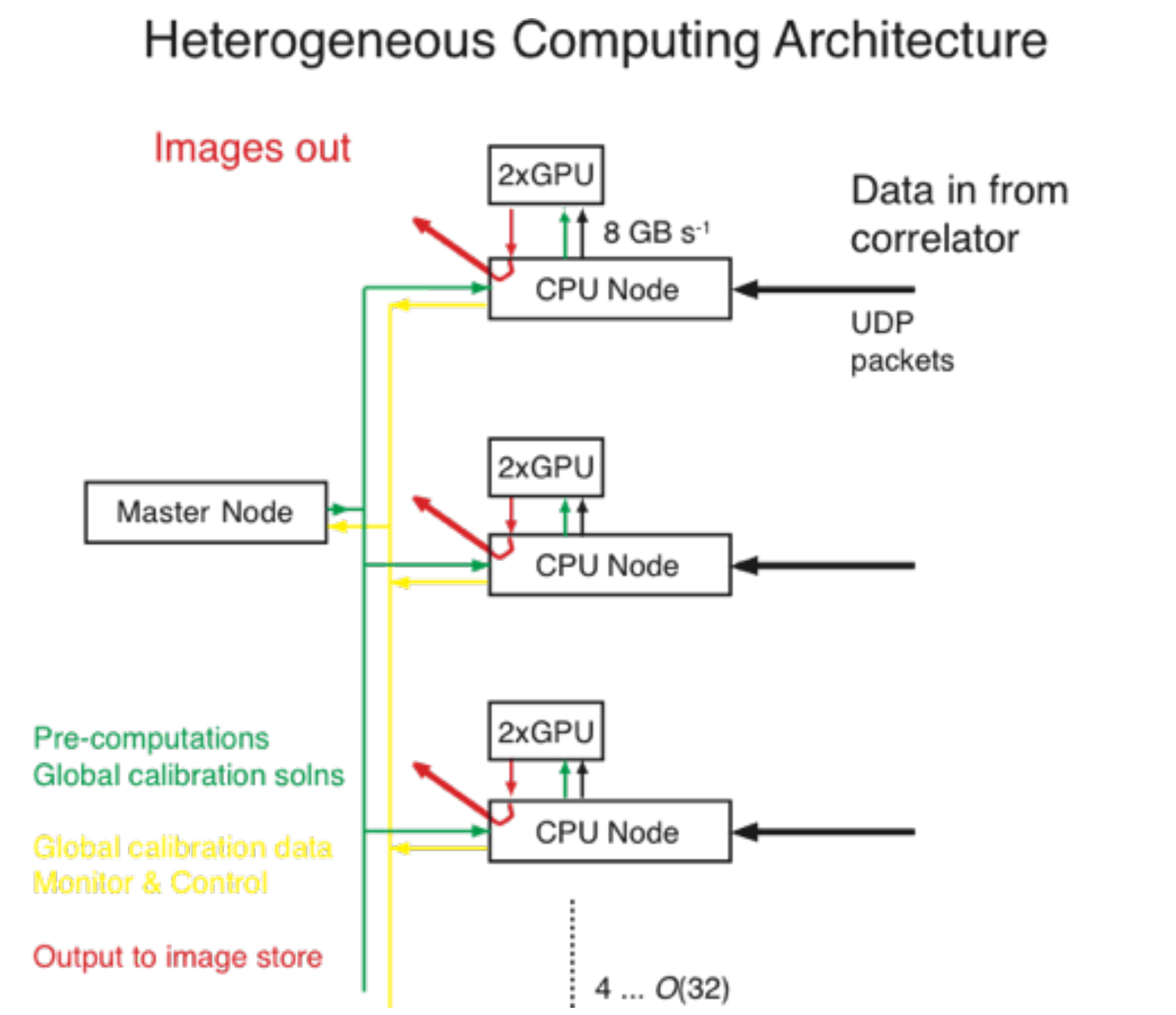
Real-Time System



CPU+GPU Status



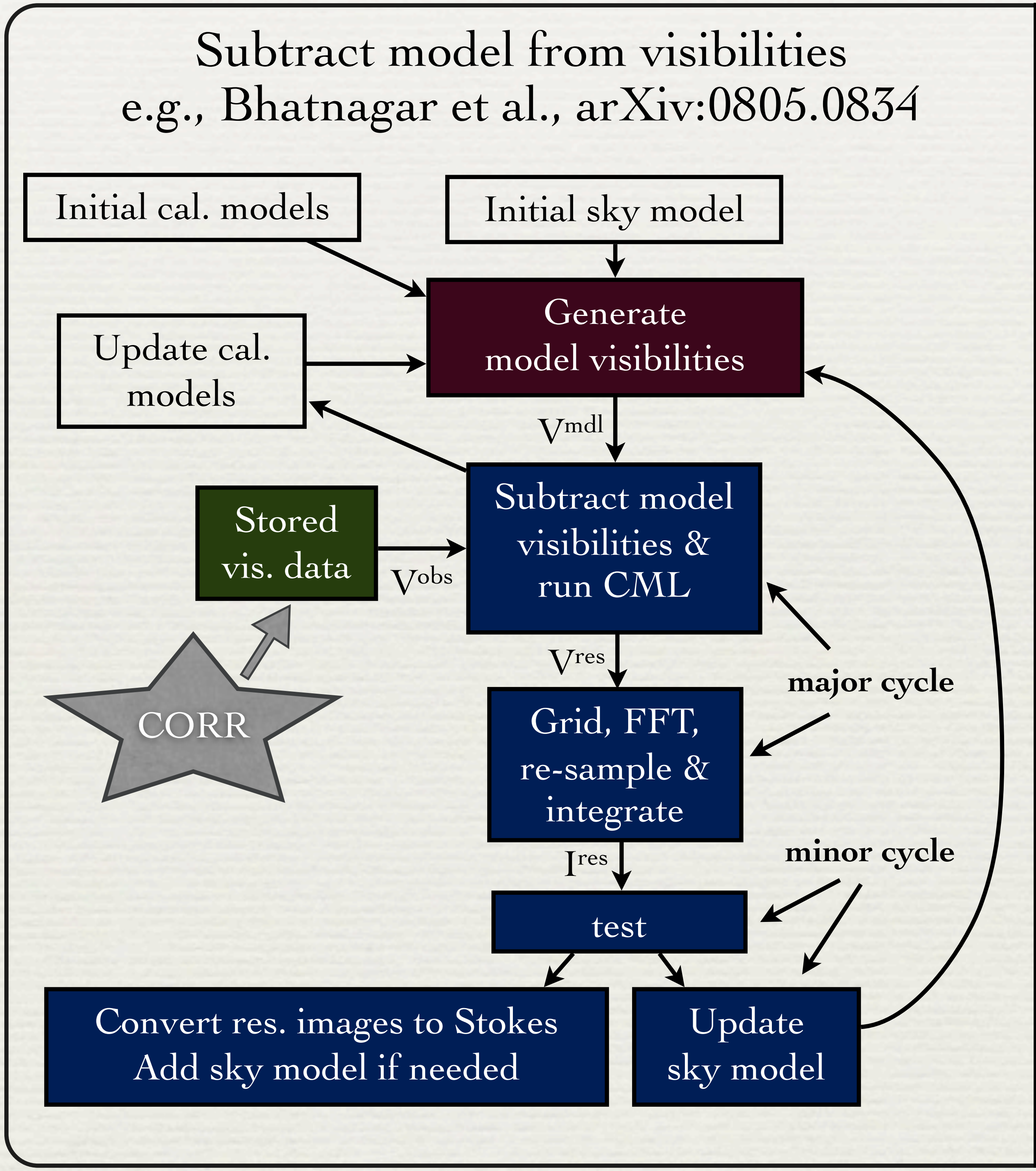
Real-Time Computer

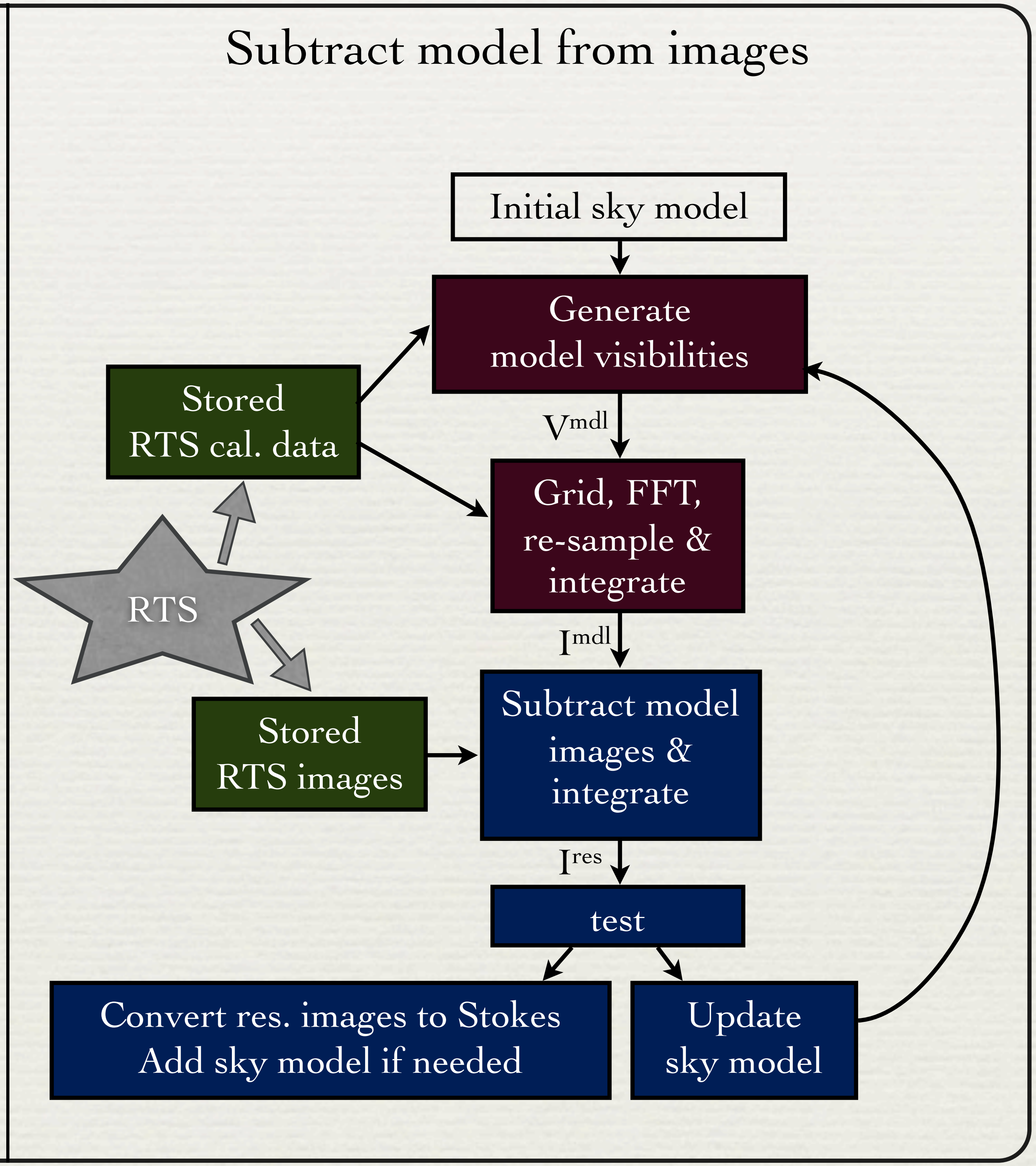


Greenhill et al.

- Parallel over frequency
  - MPI
- 32 servers
  - 2 × Xeon X5650, 6 core, 2.66 GHz
  - 2 × nVIDIA Tesla M2070
  - 2 × 300GB SAS RAID (6Gbps)
  - Have ~ 1/3 in Perth now
- 512T tests
  - 12 freq. channels per GPU
  - 21 degree FoV
  - 50 sources calibrated & peeled
  - Does not include all-sky primary beam and ionospheric phase fits
  - 2.66 GHz quad core Nehalem + NVIDIA C1060 Tesla GPU
  - completed in < 8 seconds

Iterative Deconvolution





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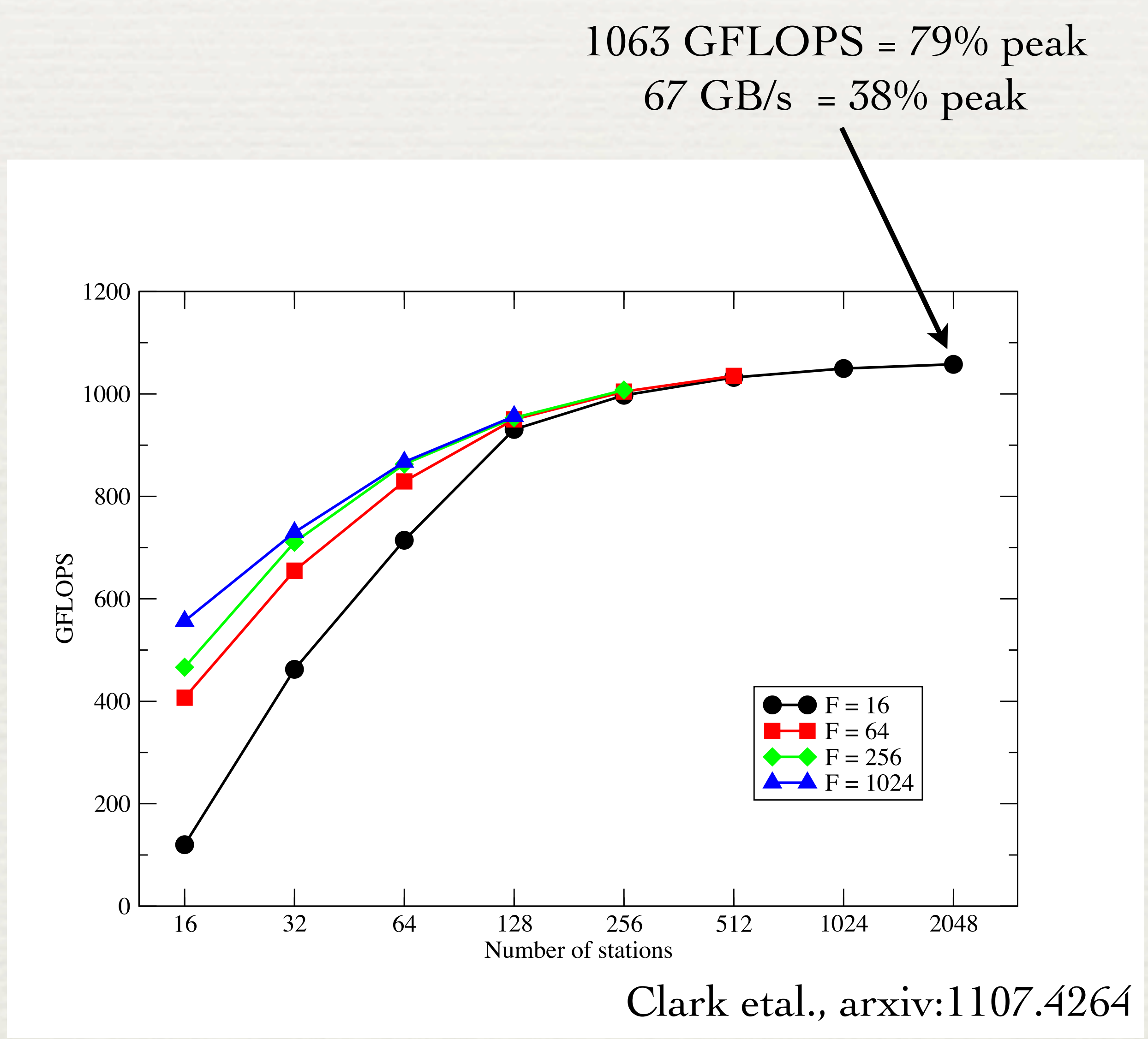
Project Status

- Focused on building a fully-operational 128-tile array (current funding limit). Infrastructure designed with expansion in mind.
- Currently working through the details of the infrastructure tender process.
- Running a 32-tile array in expedition mode (several expeditions per year).

128T Correlator

- For 128T, the "X" part of the planned 512T correlator will be replaced with GPUs.
  - F-engines: 2-stage FPGA PFBs
  - X-engines: RTC hardware
- All x-engines can fit on ~11 NVIDIA M2070s
  - leaving ~ 53 for the RTS
- An alternative is to split the x-engines over all 64 GPUs and combine them with the RTS



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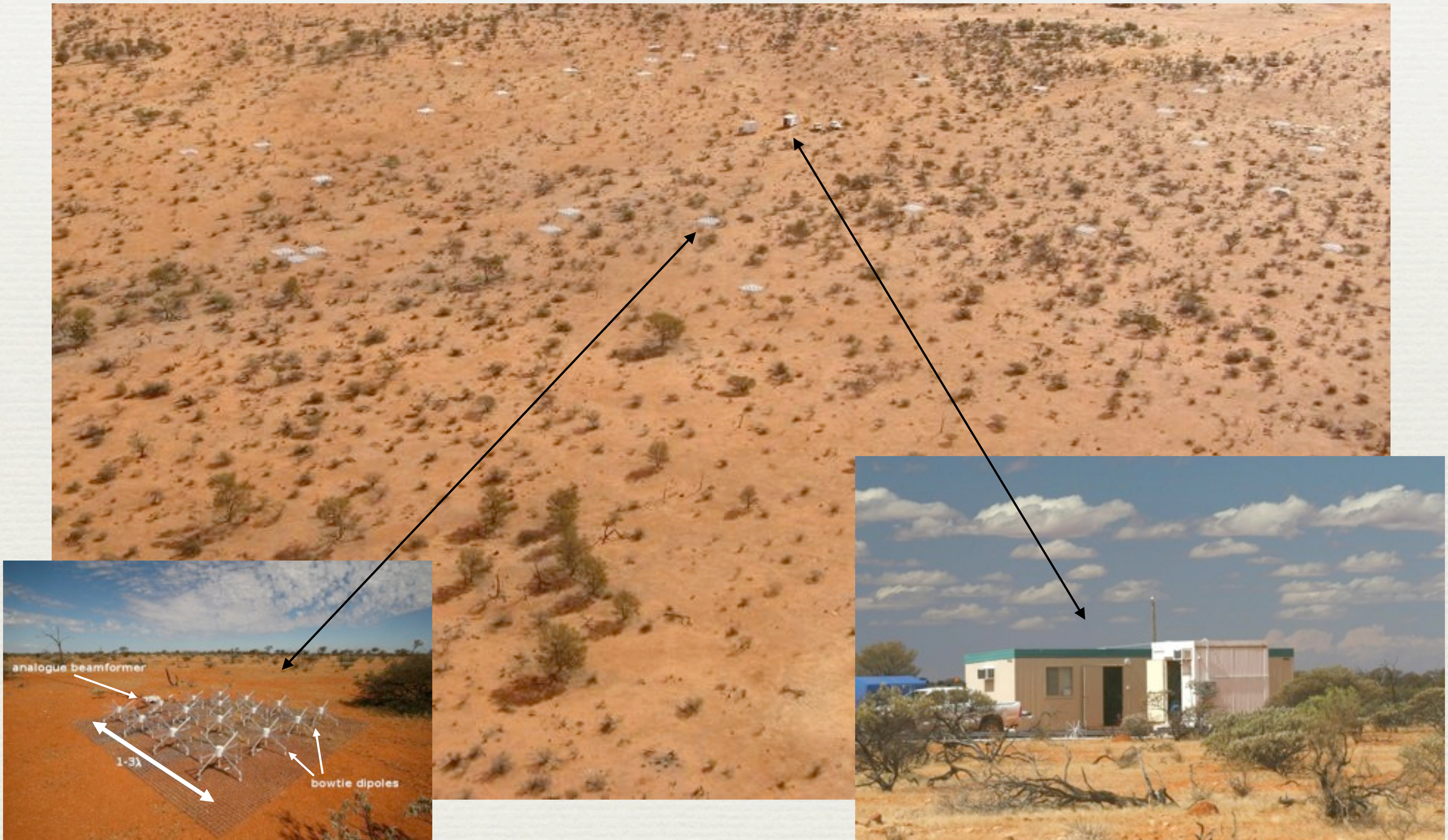
MWA 32-tile Prototype

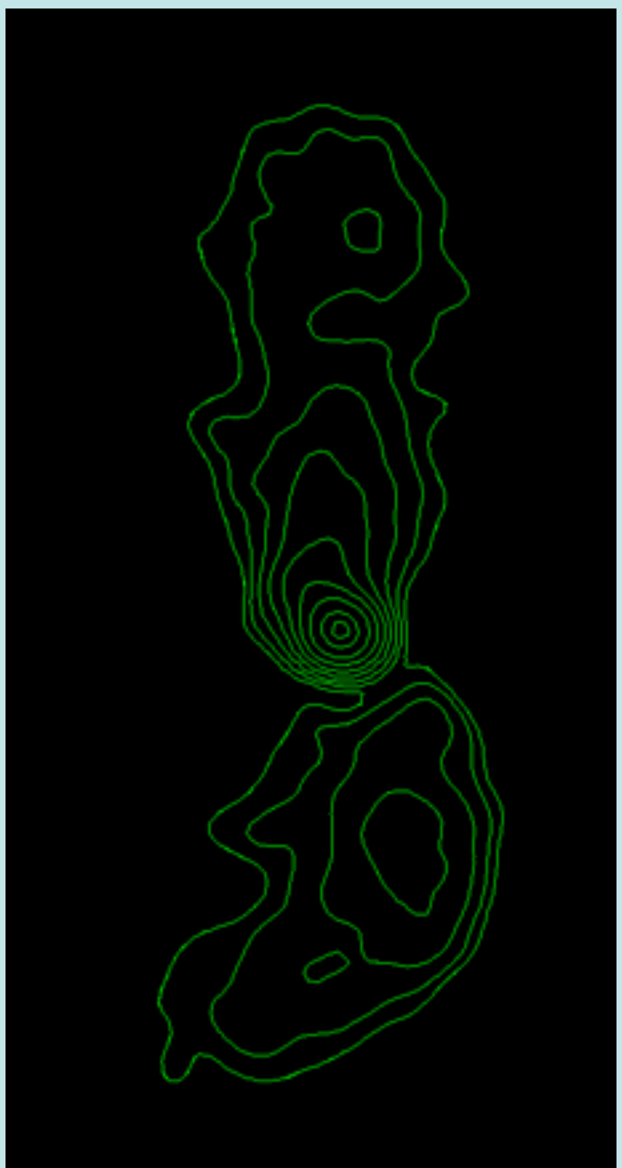


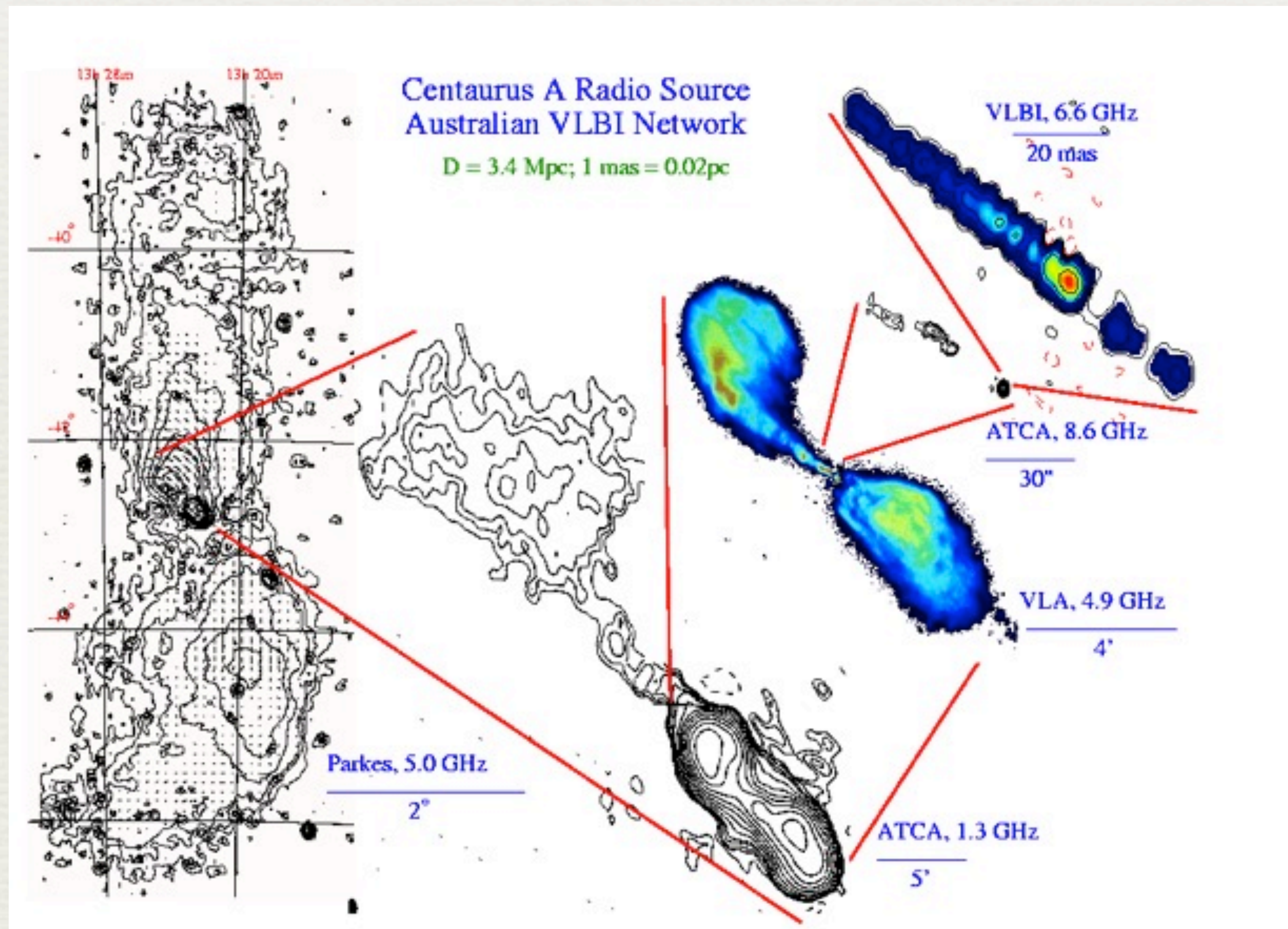
Optical

Centaurus A

MWA @2.6m wavelength.

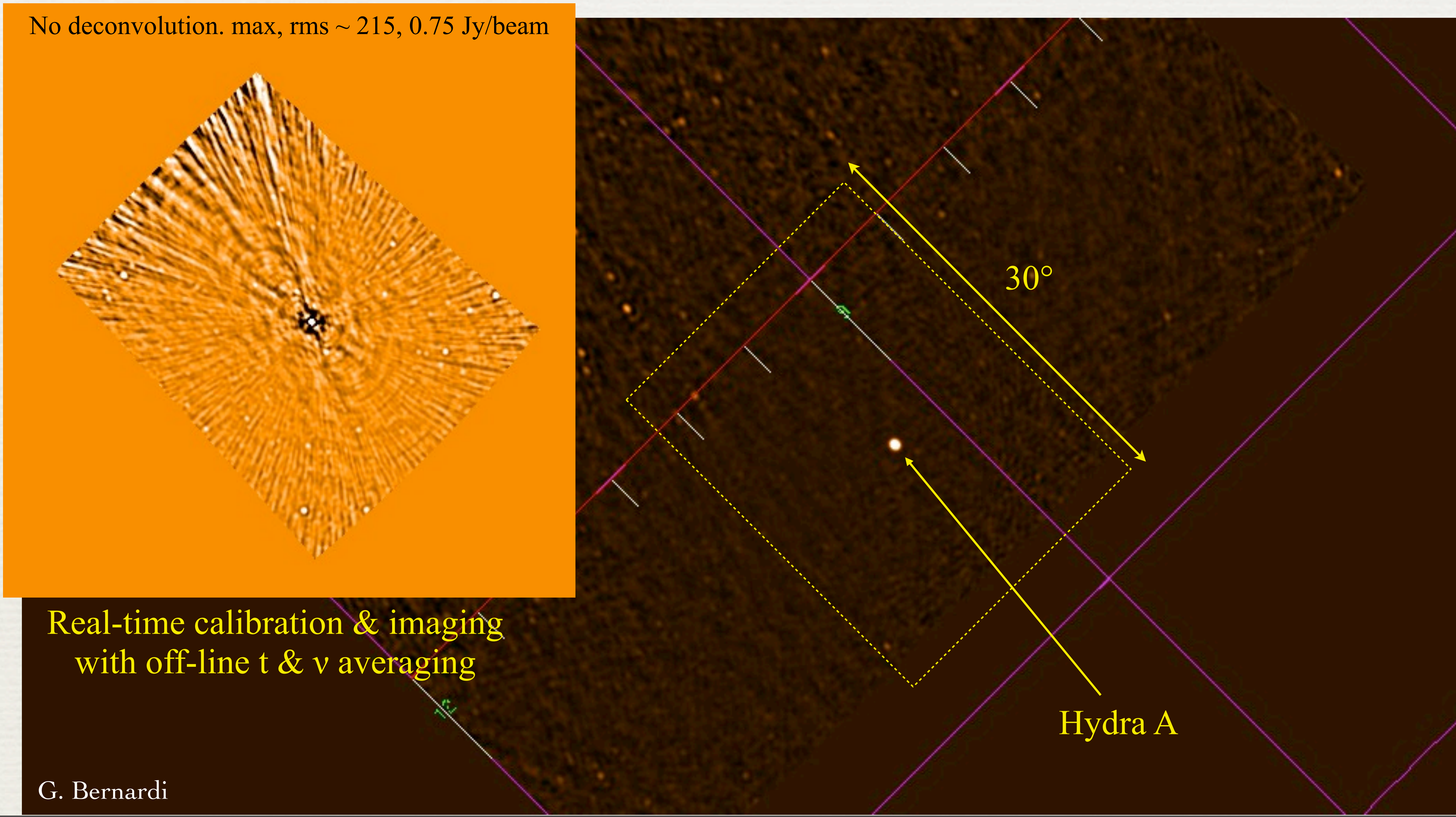
30’ resolution



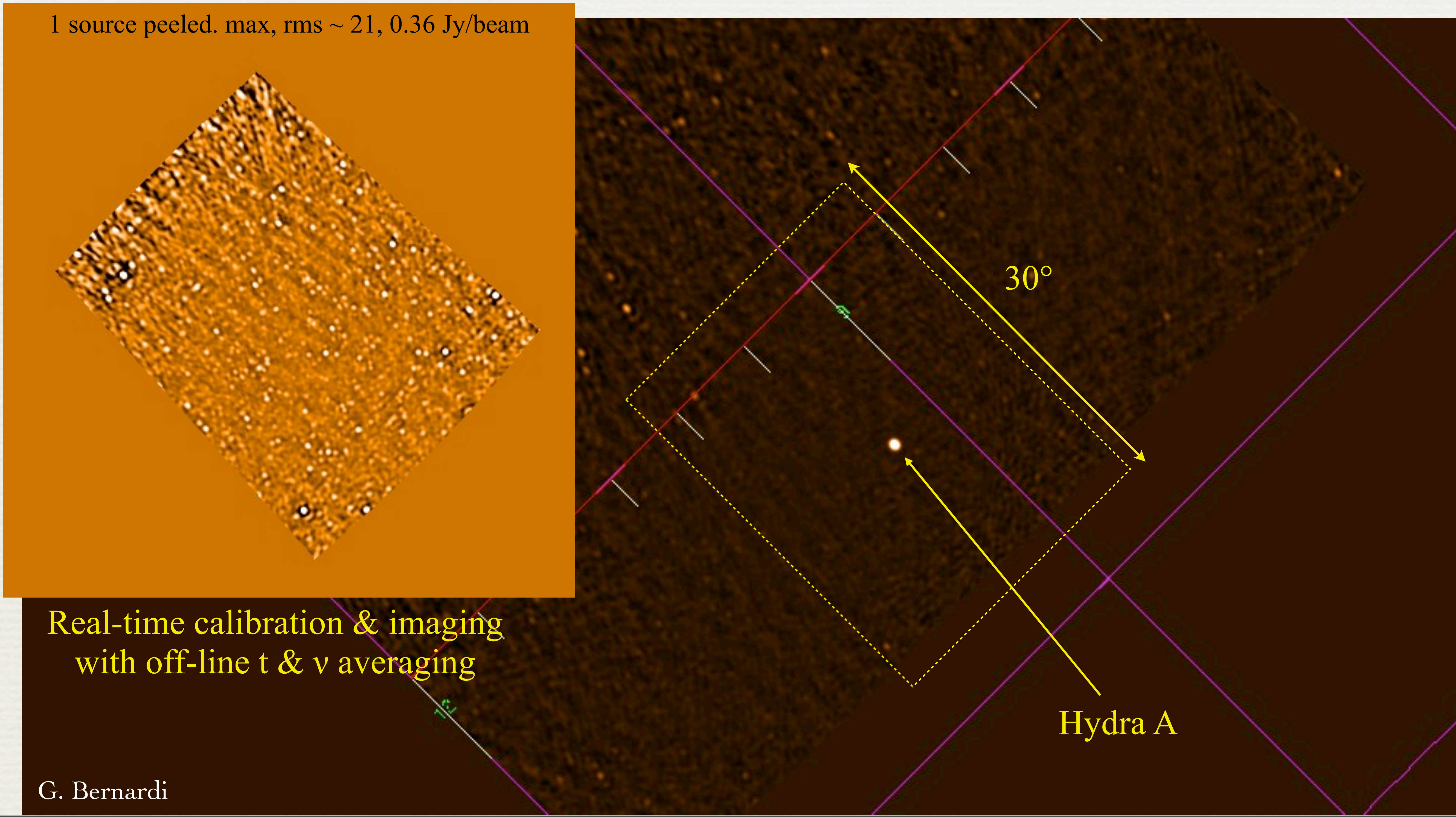


F. Briggs & S. Tingay

FM-band Sky Survey



FM-band Sky Survey



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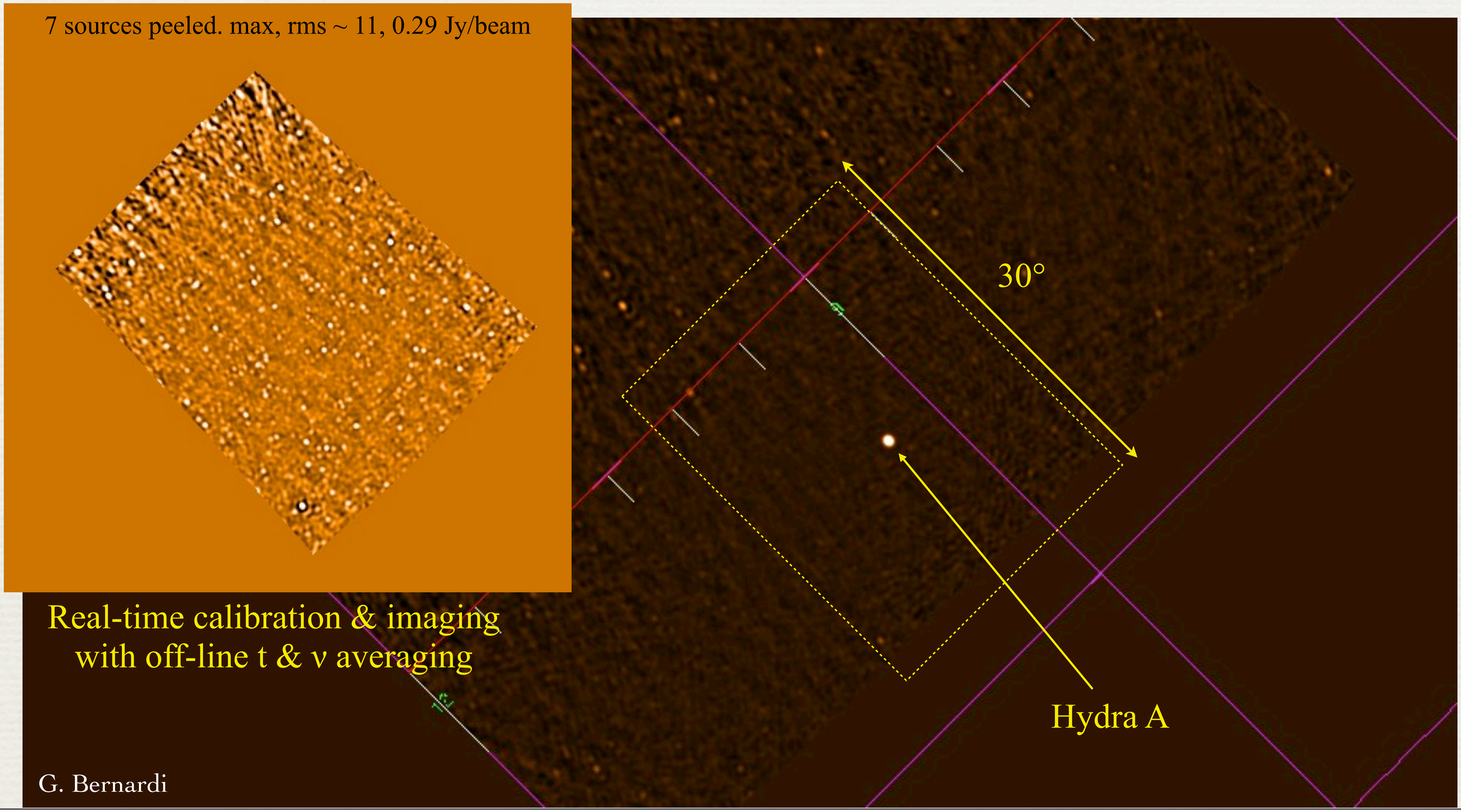
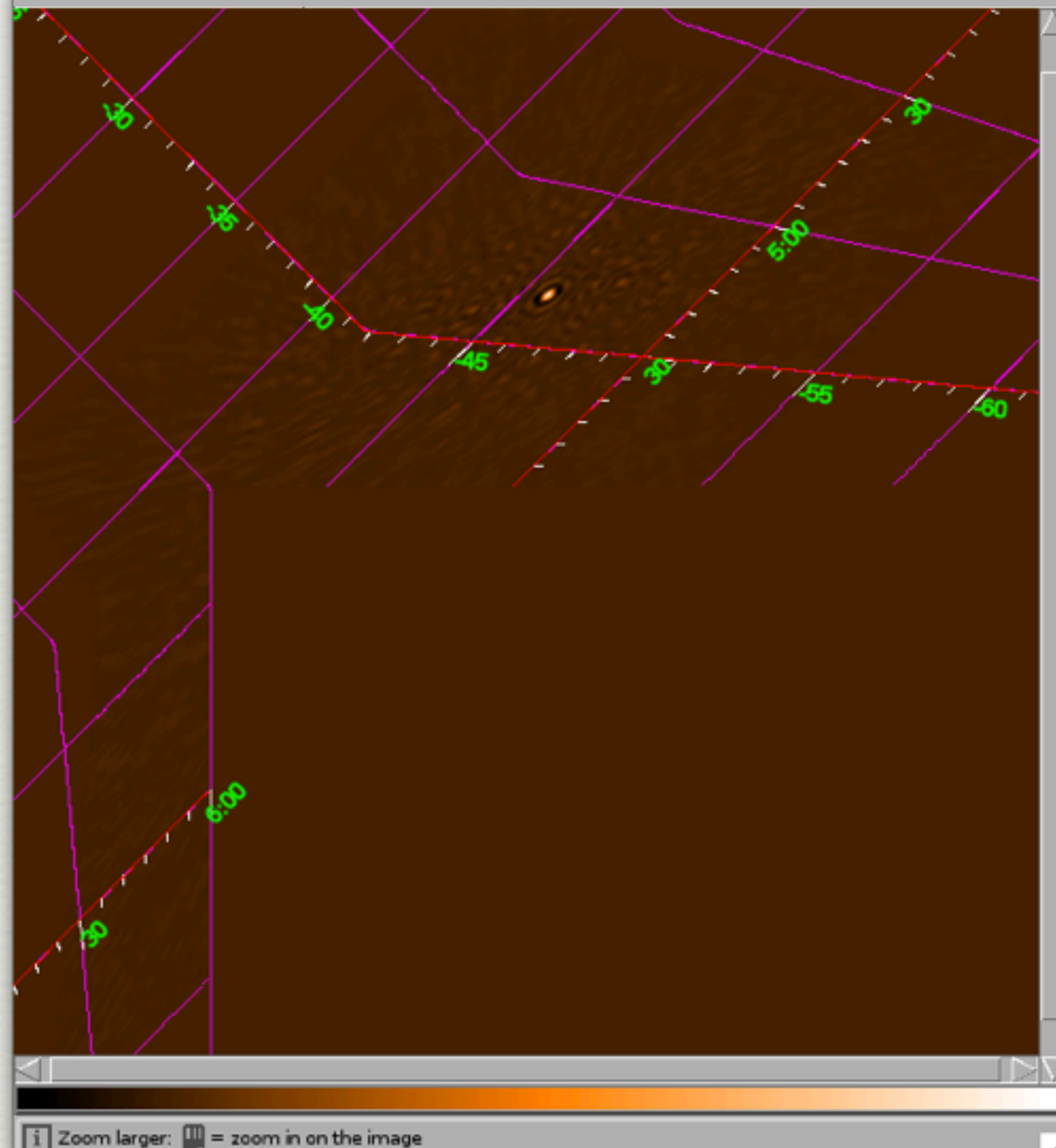


Pictor A field



G. Bernardi

Pictor A field

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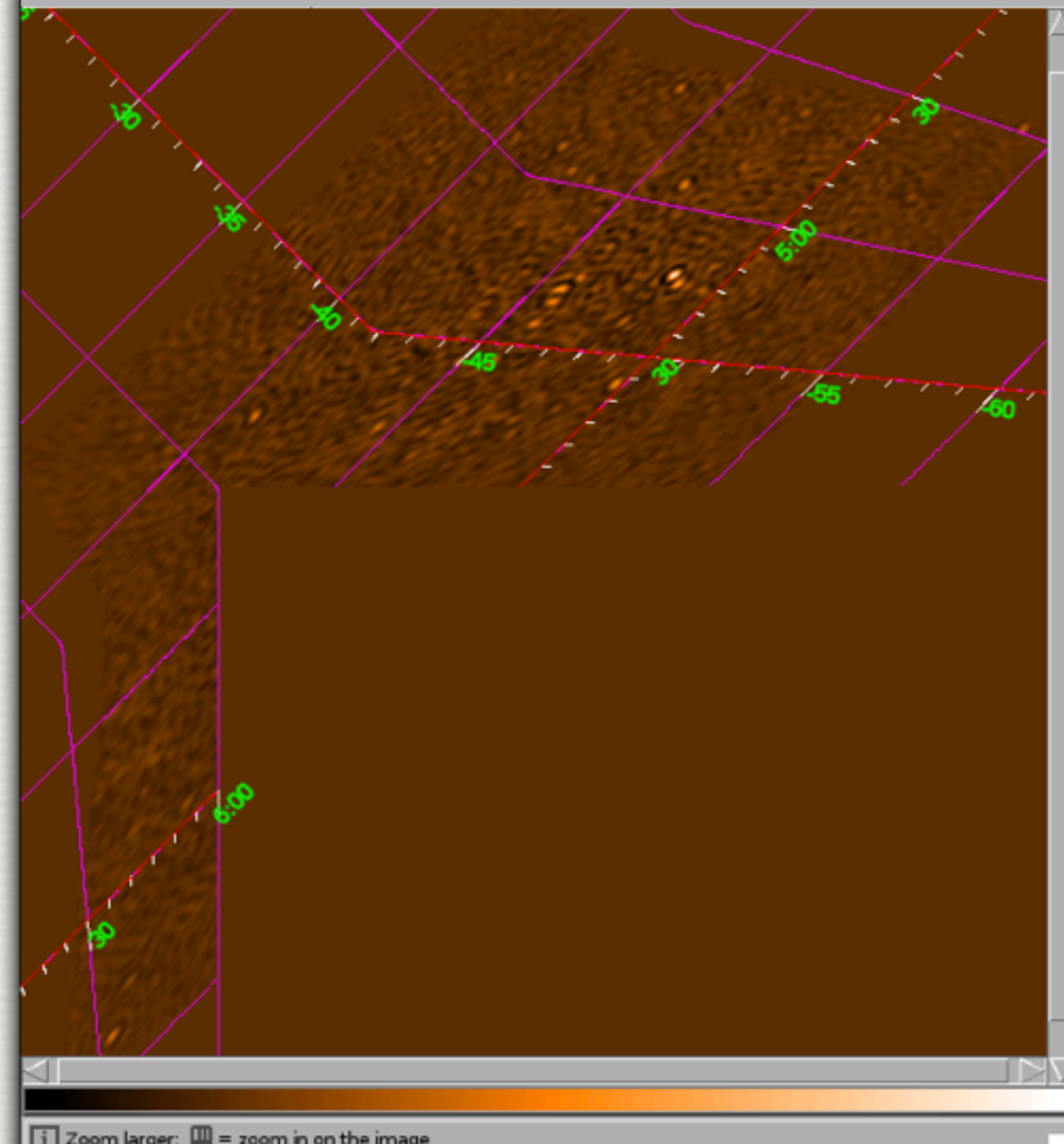

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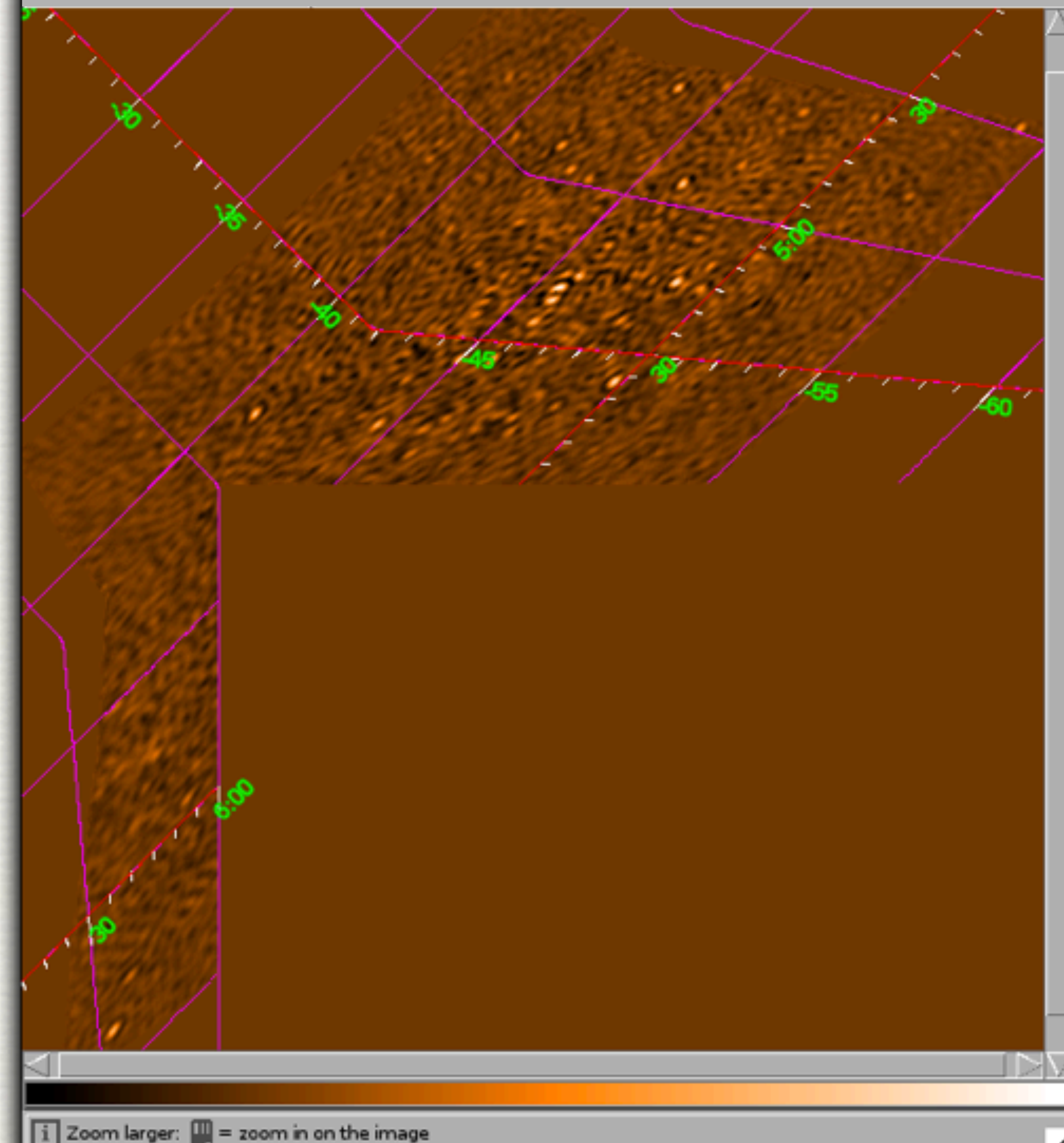

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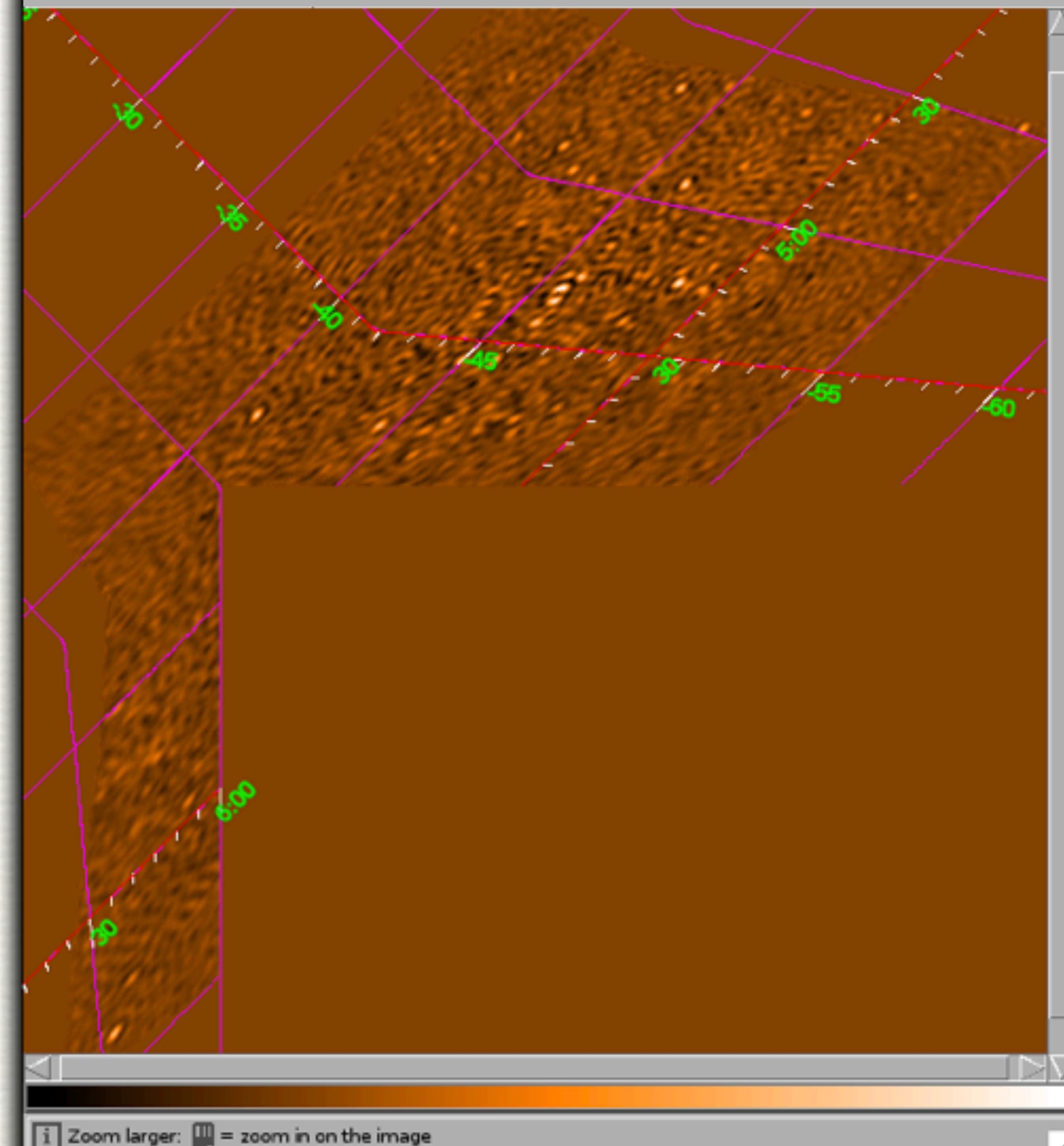

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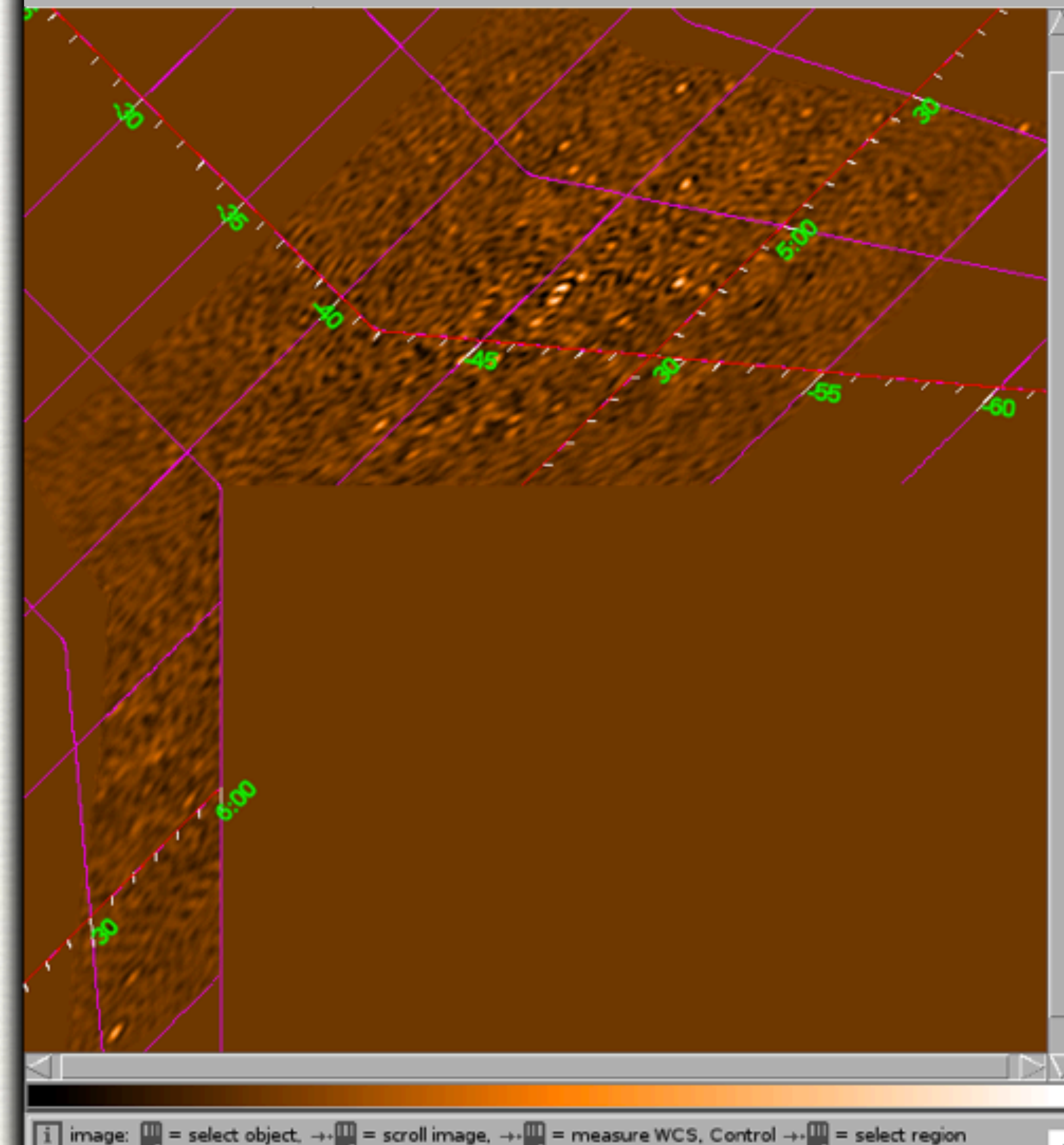

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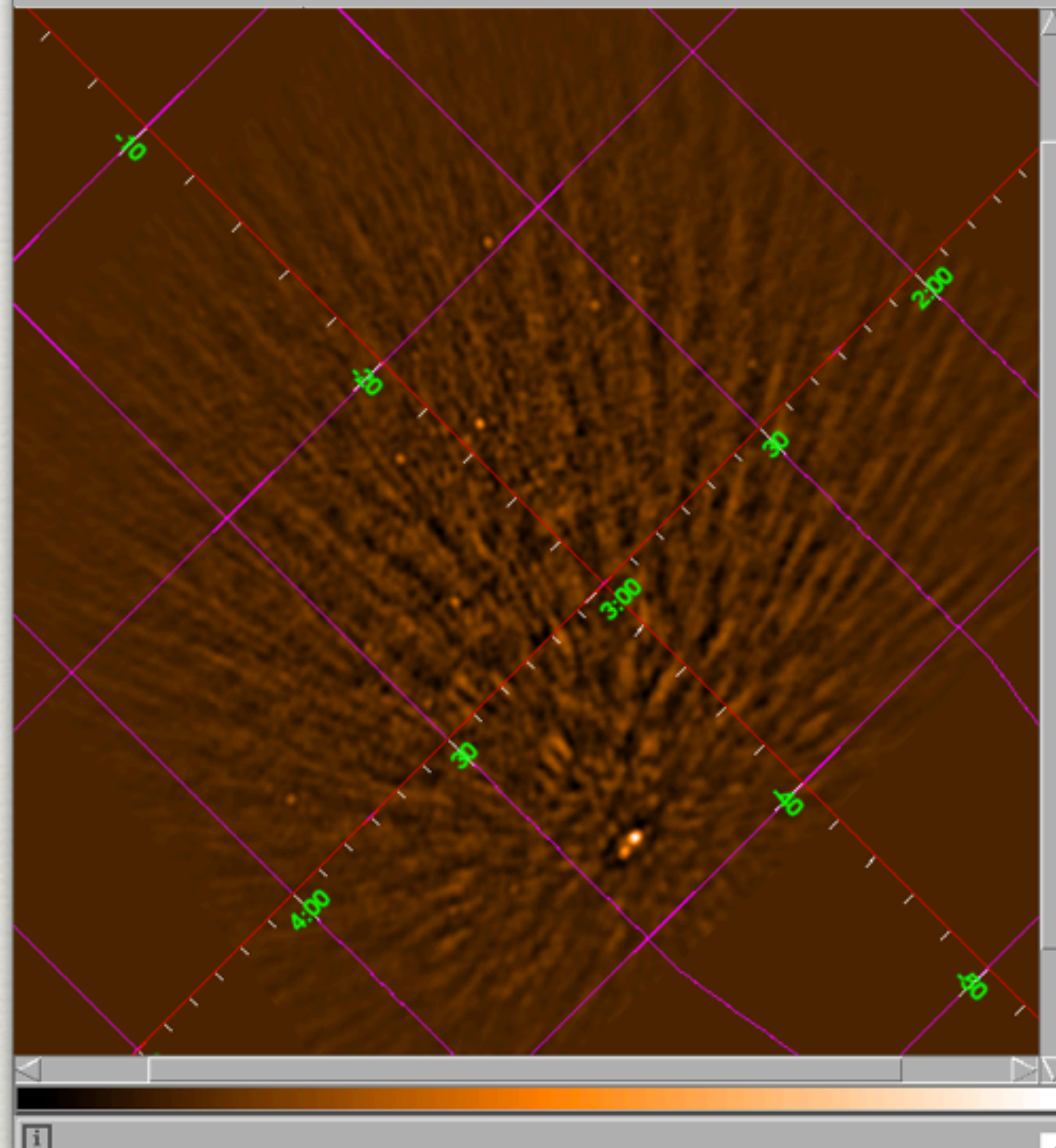
Fornax A



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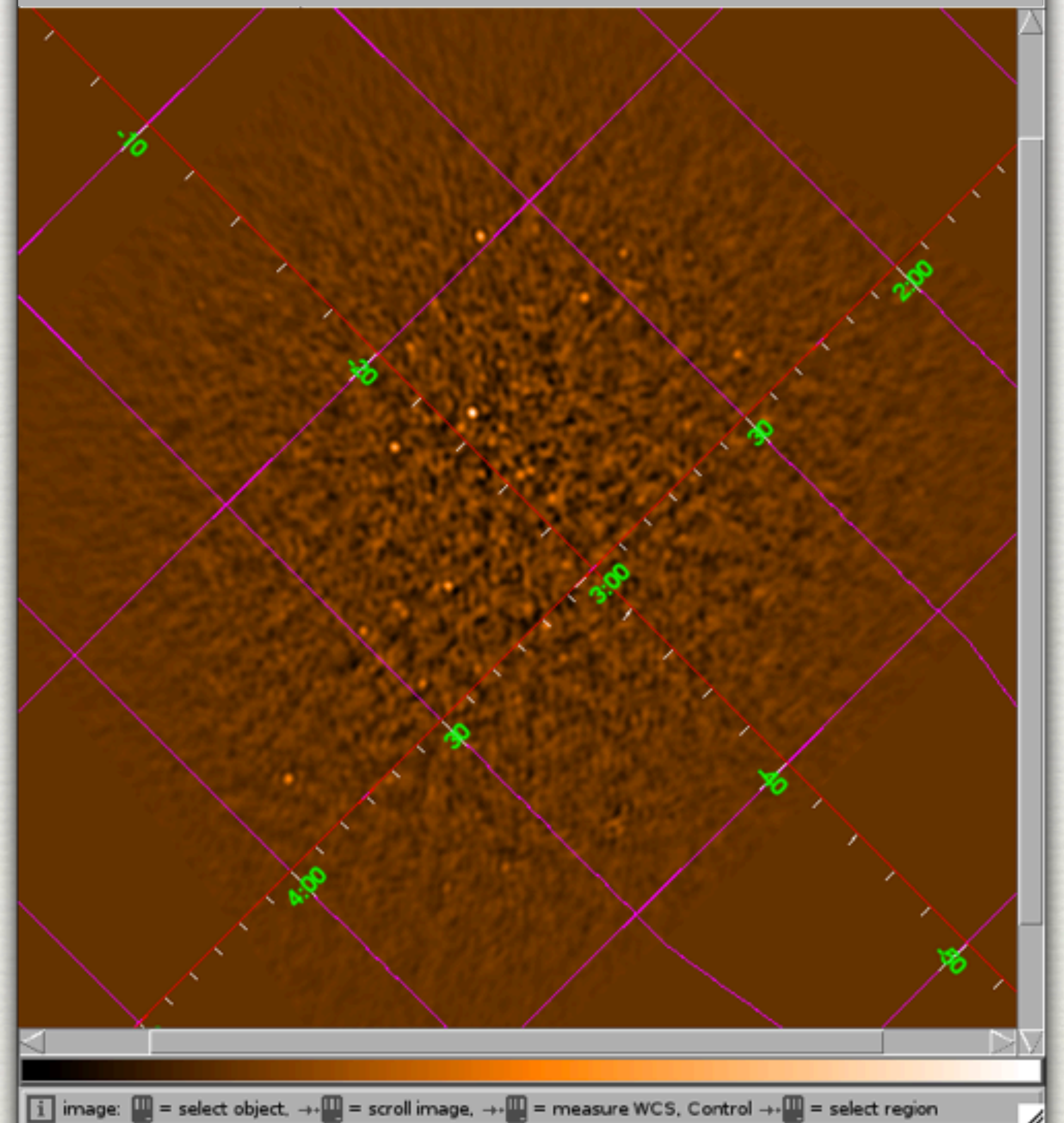
Fornax A



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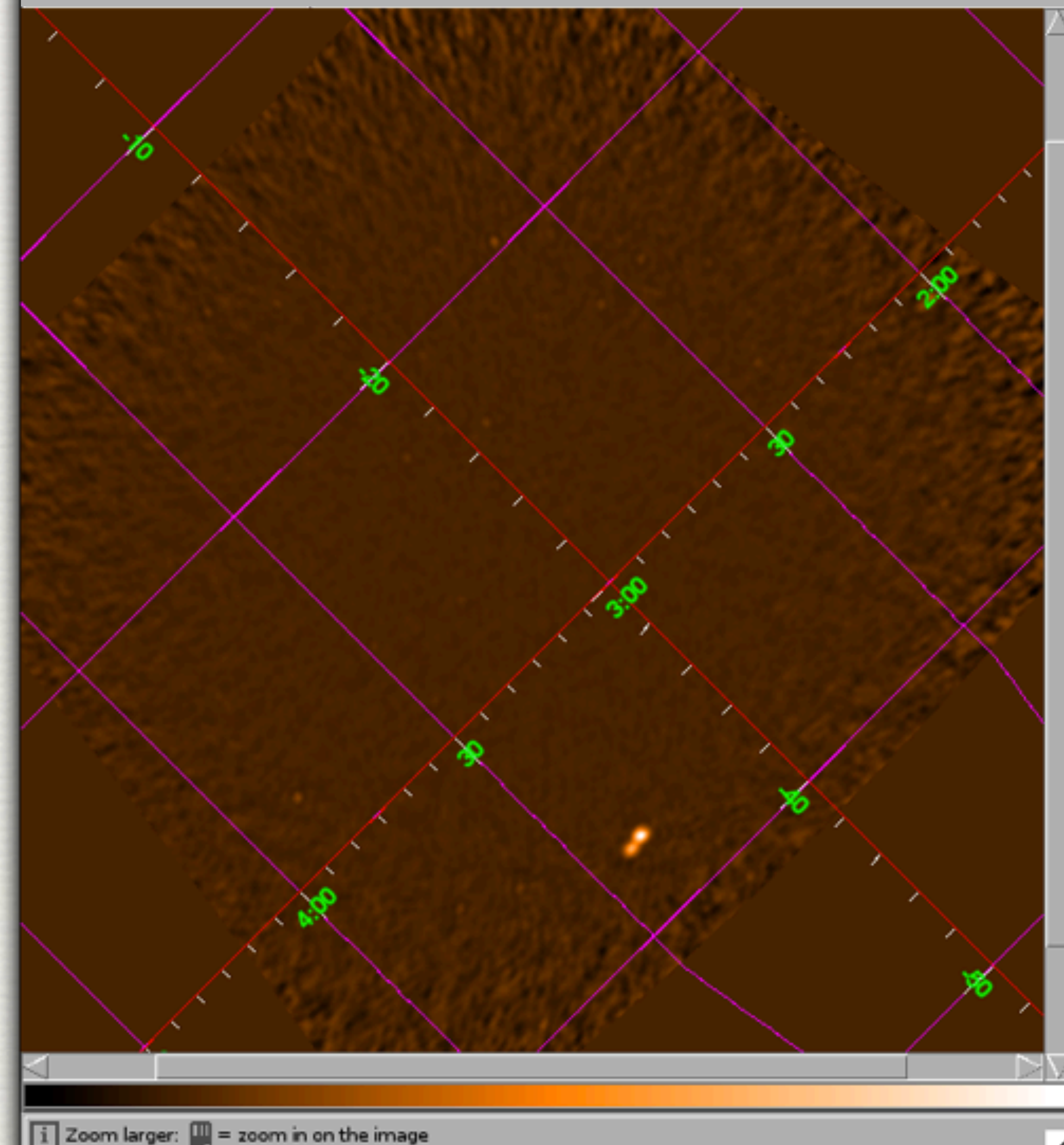
Fornax A



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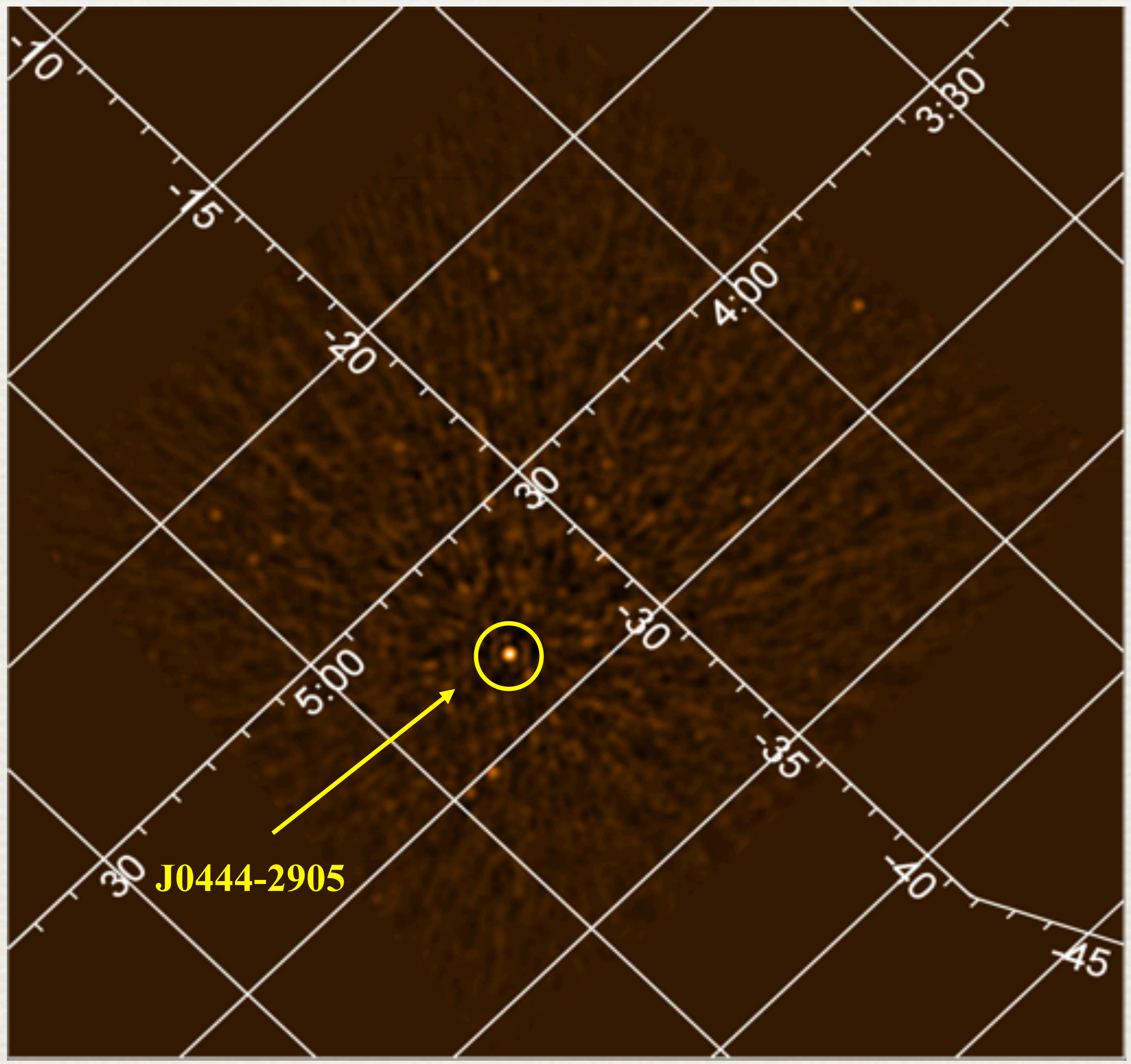
Primary Beam Measurements



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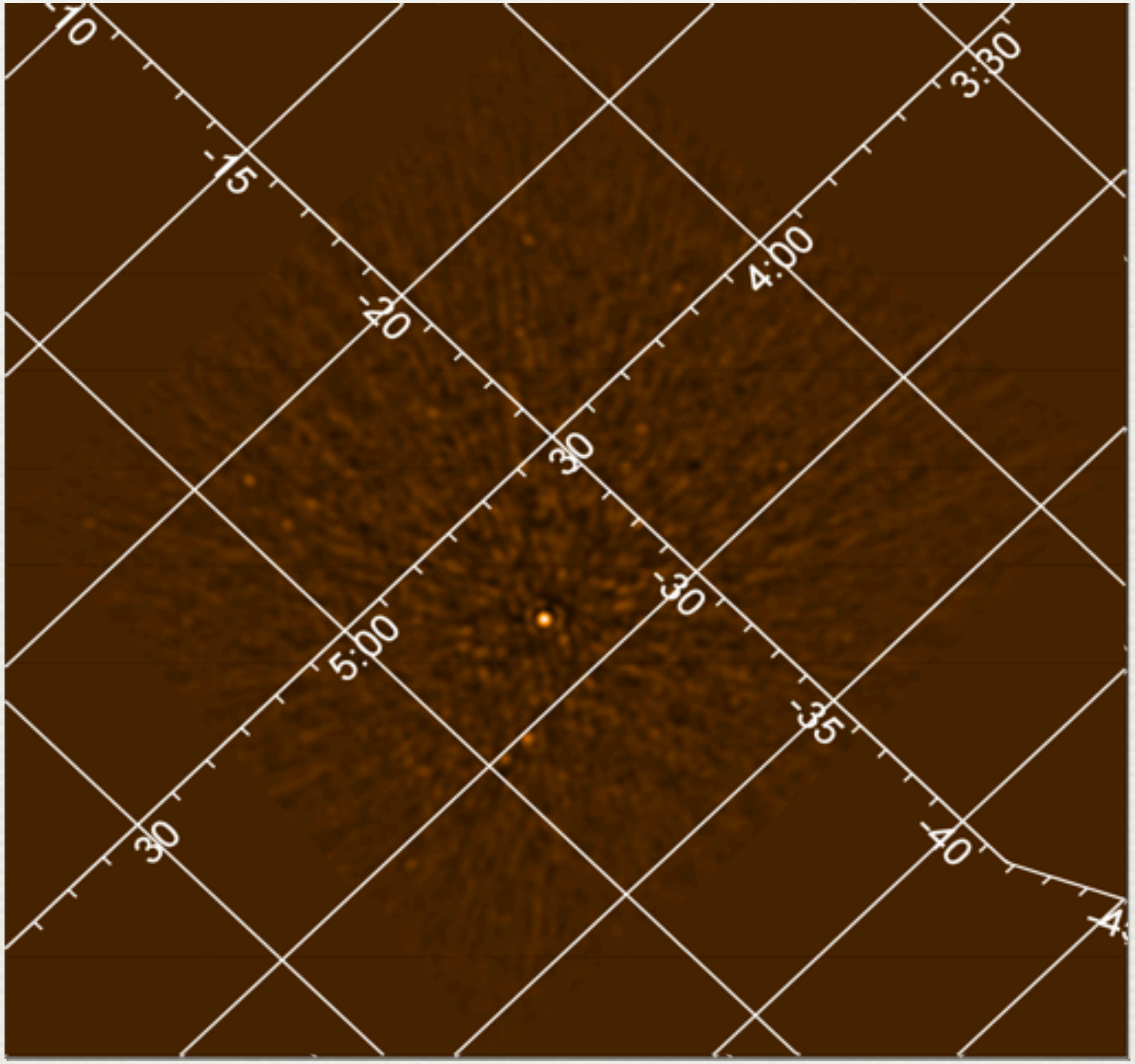

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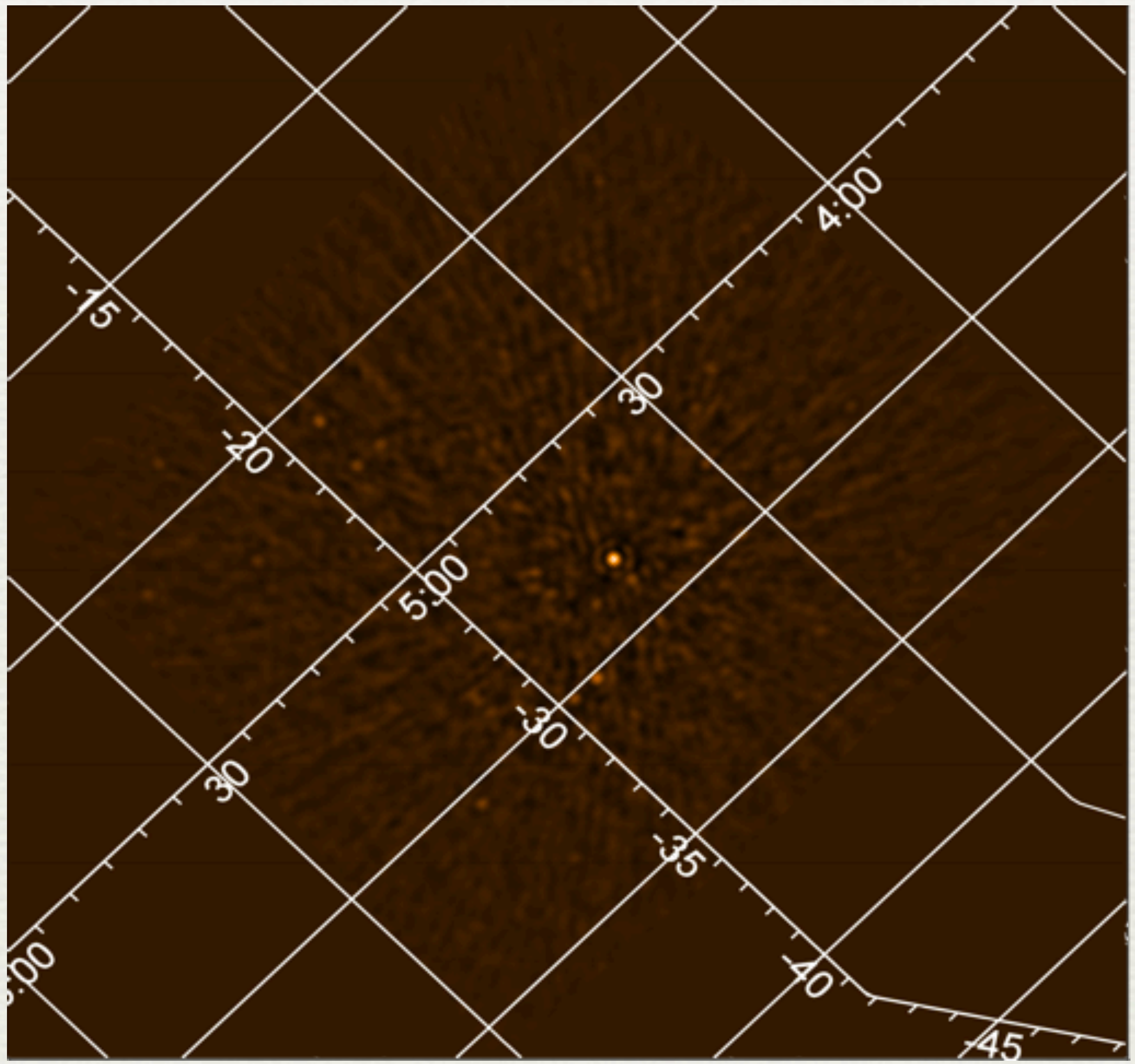

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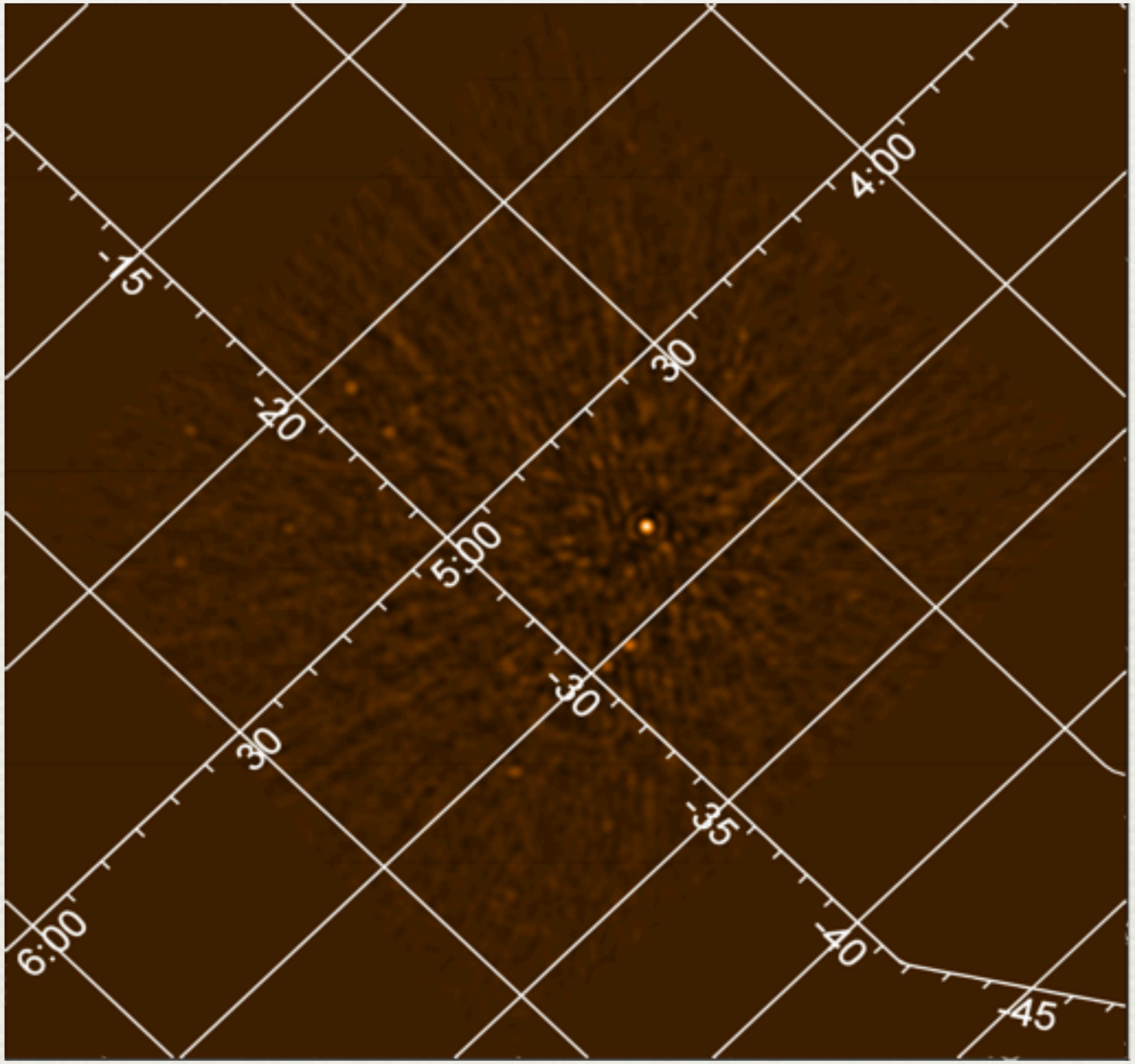

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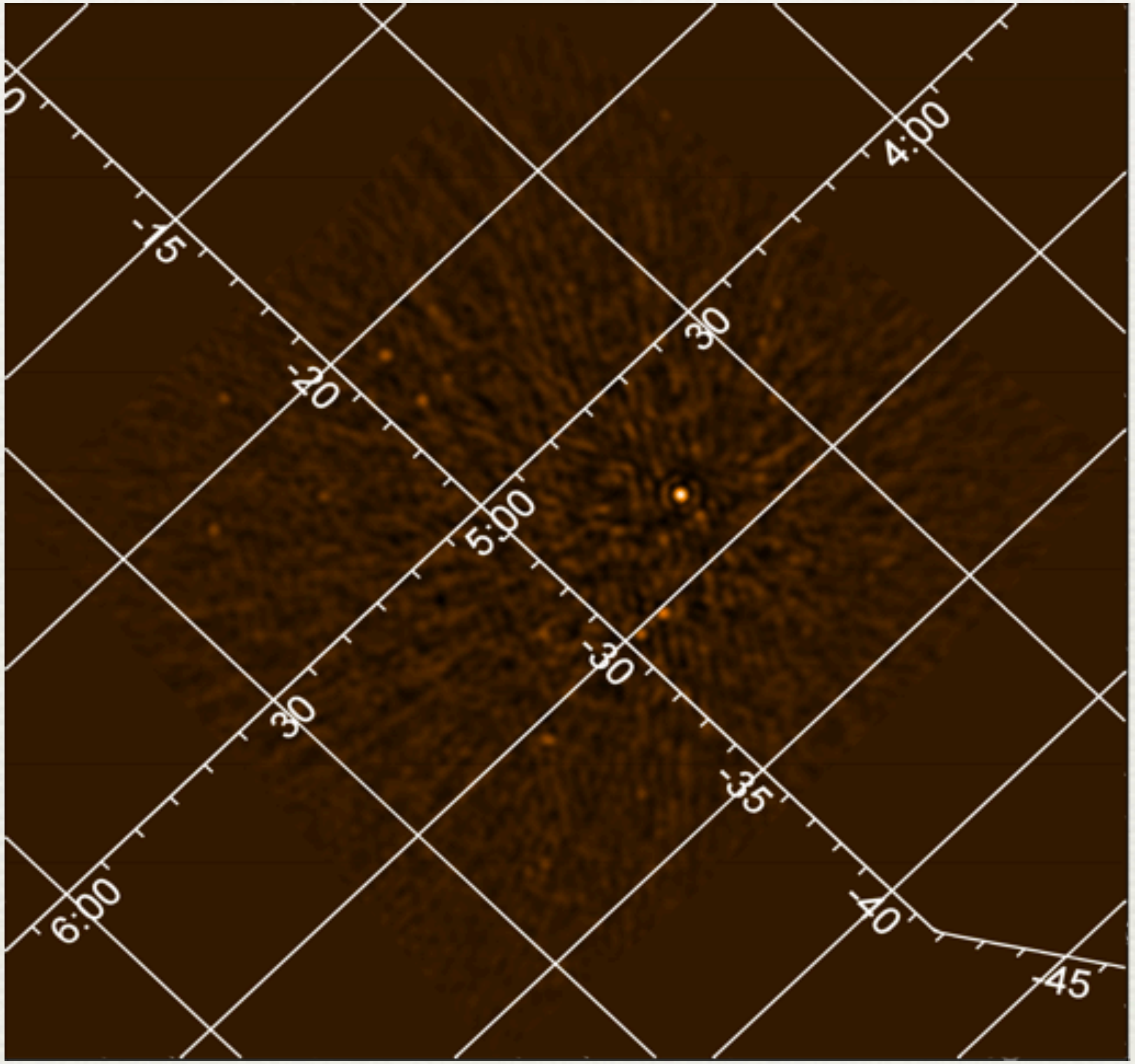

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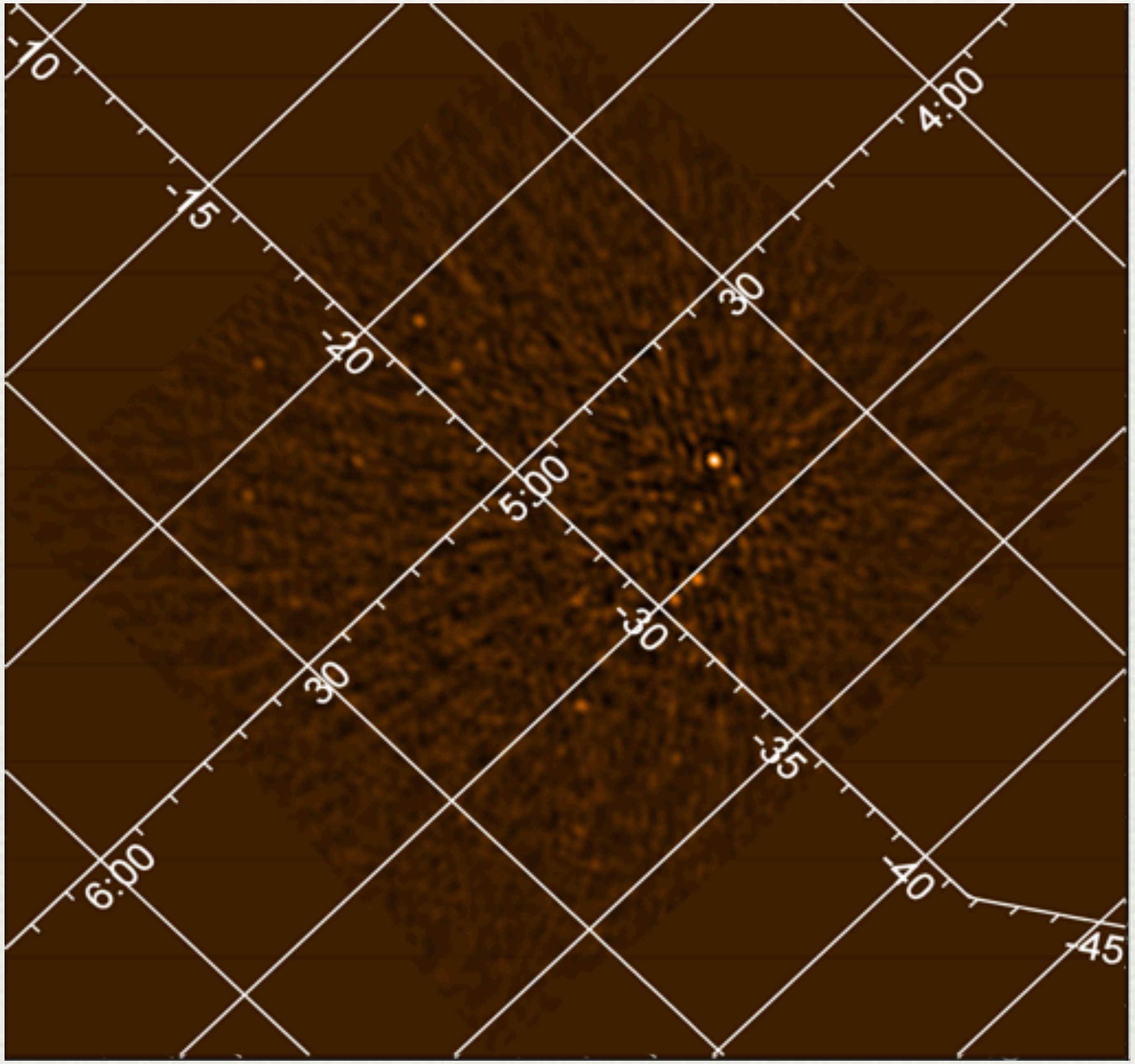

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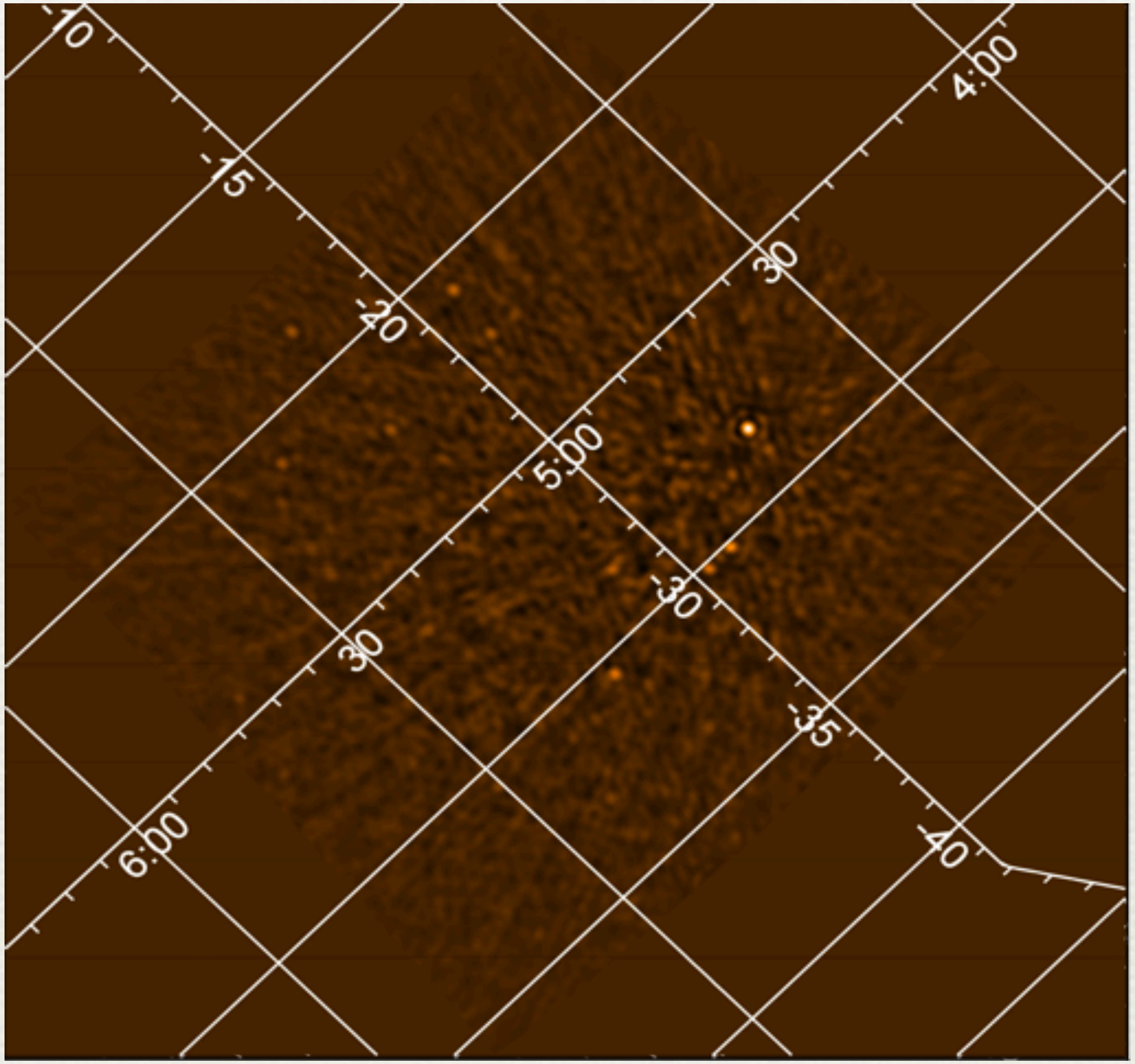

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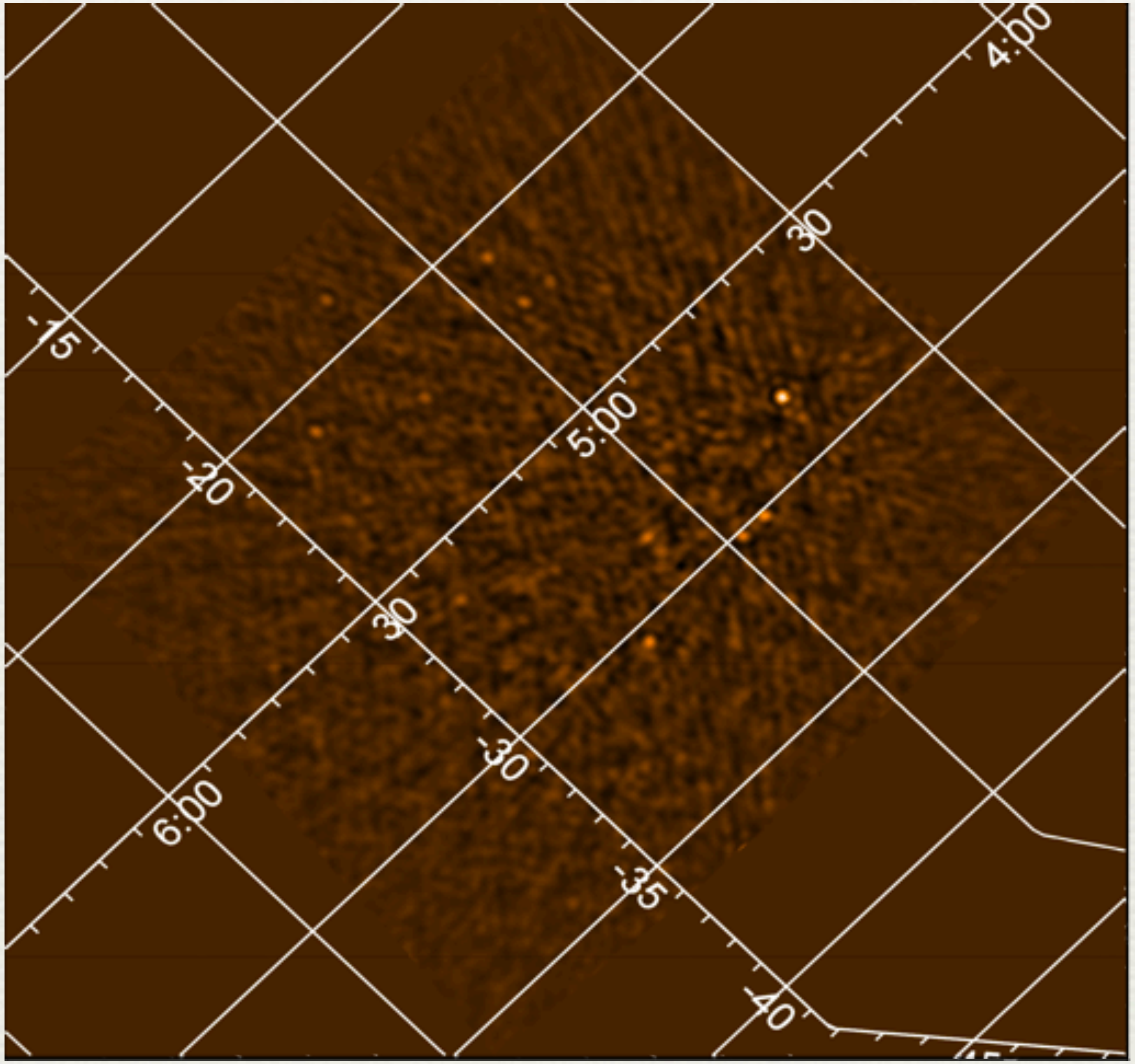

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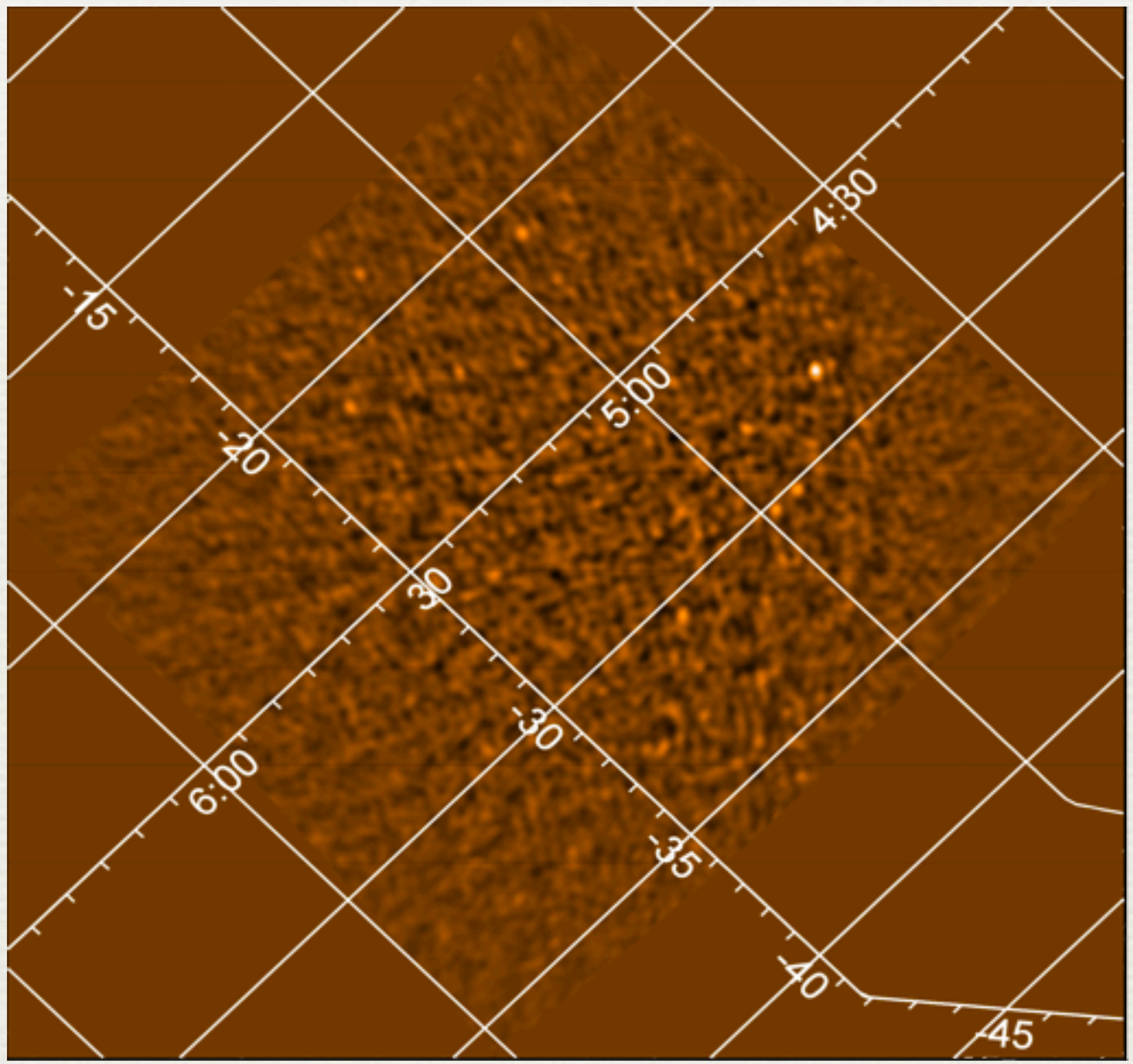

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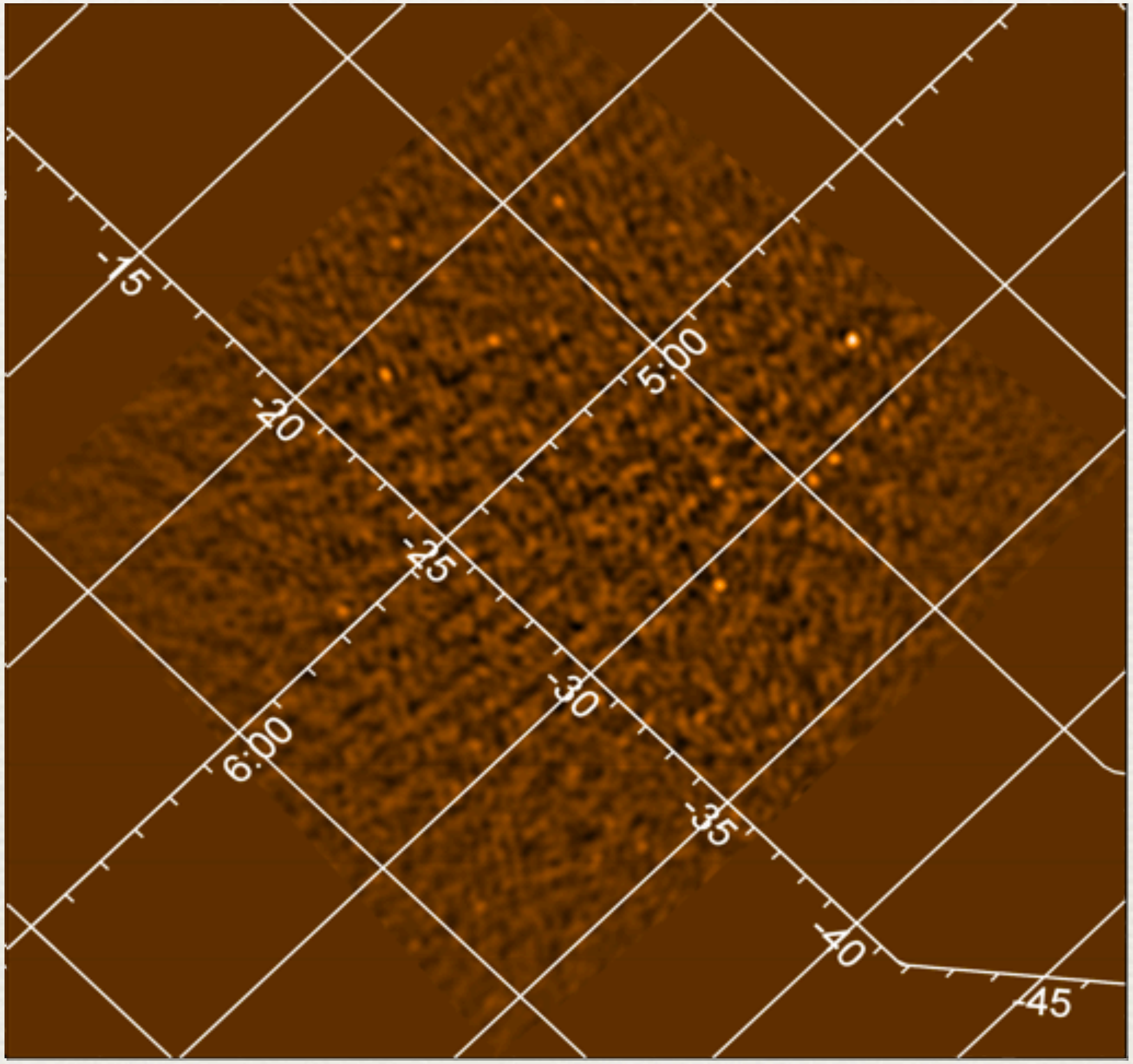

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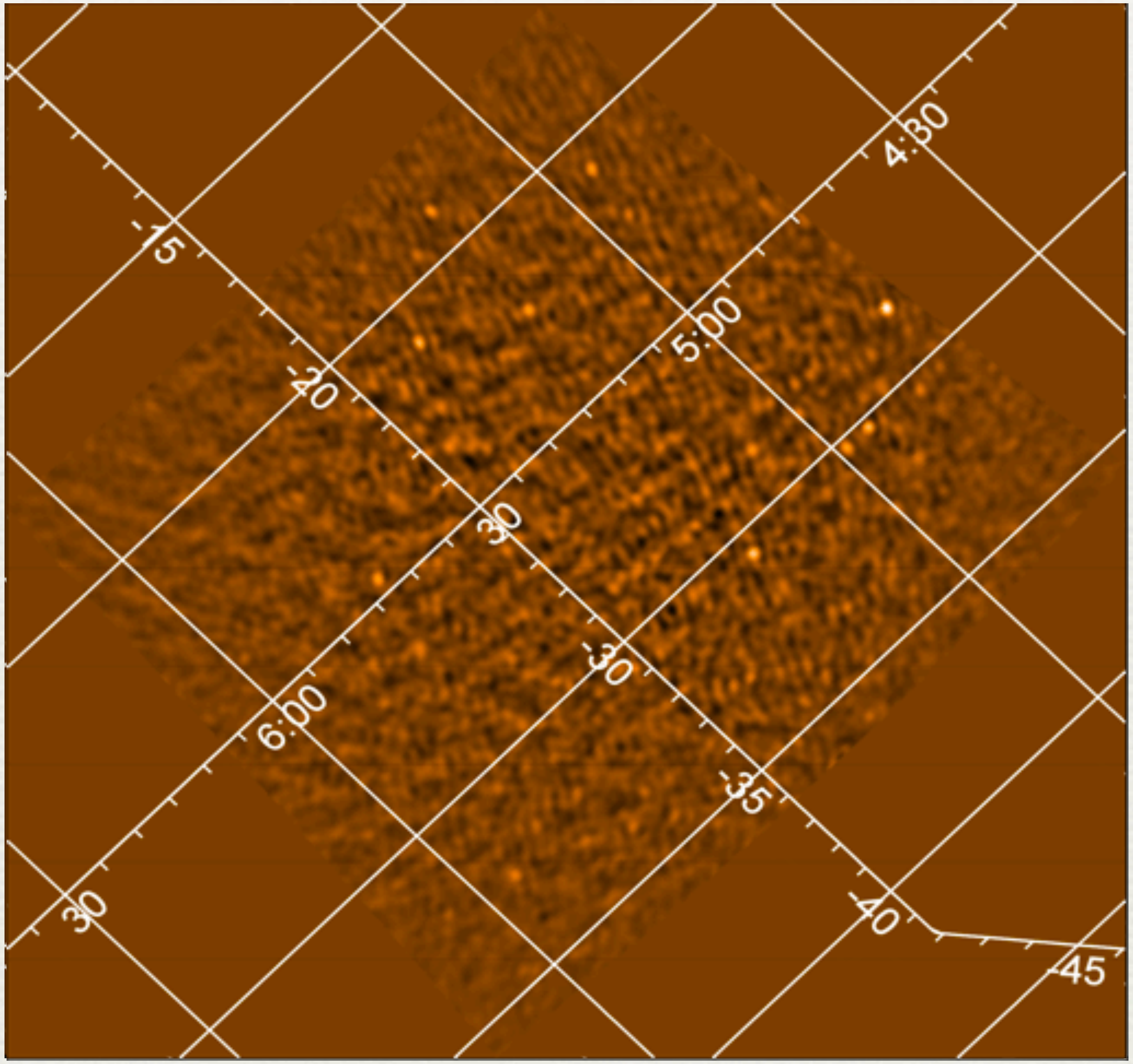

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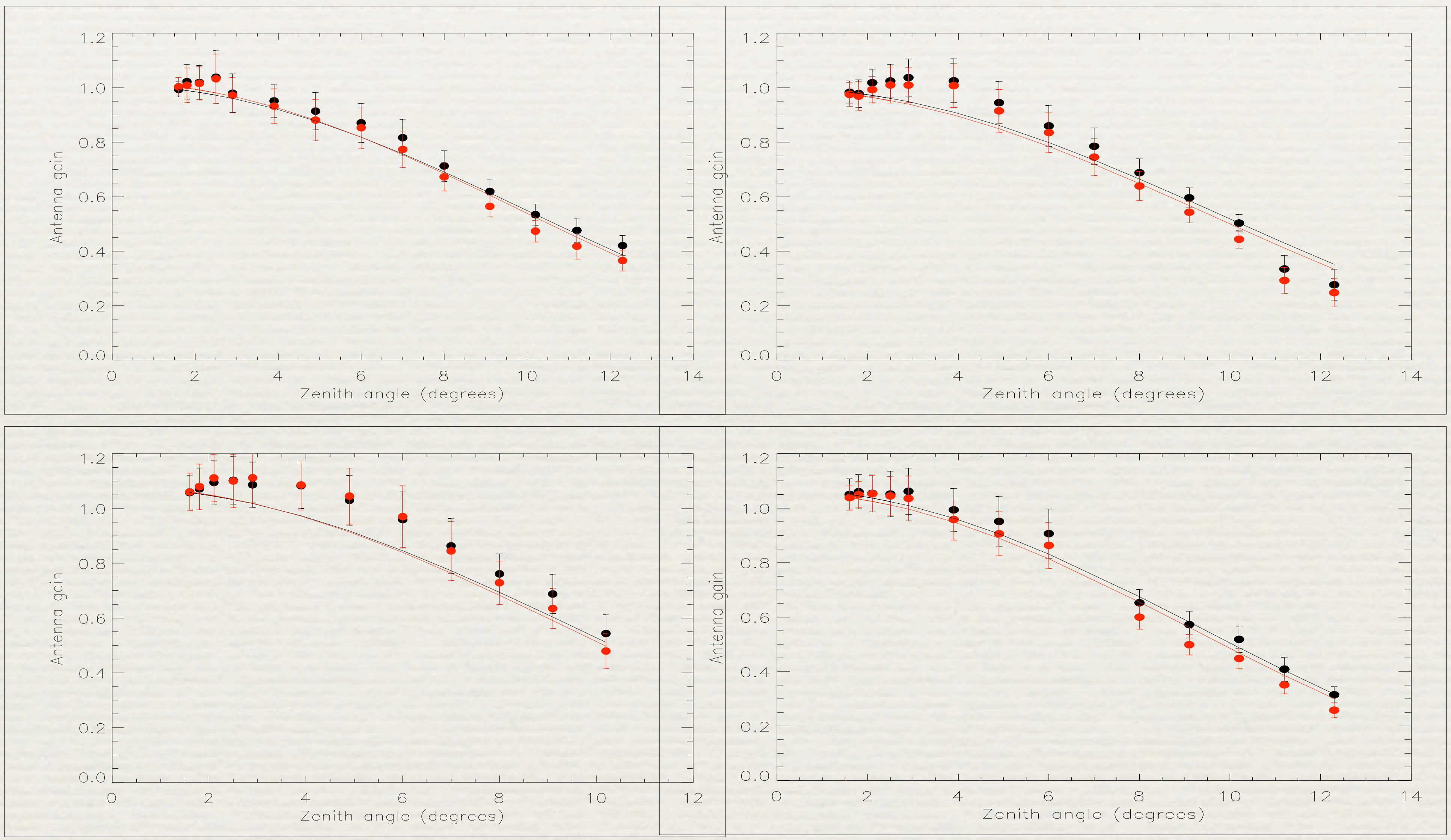
Simple Beam Model



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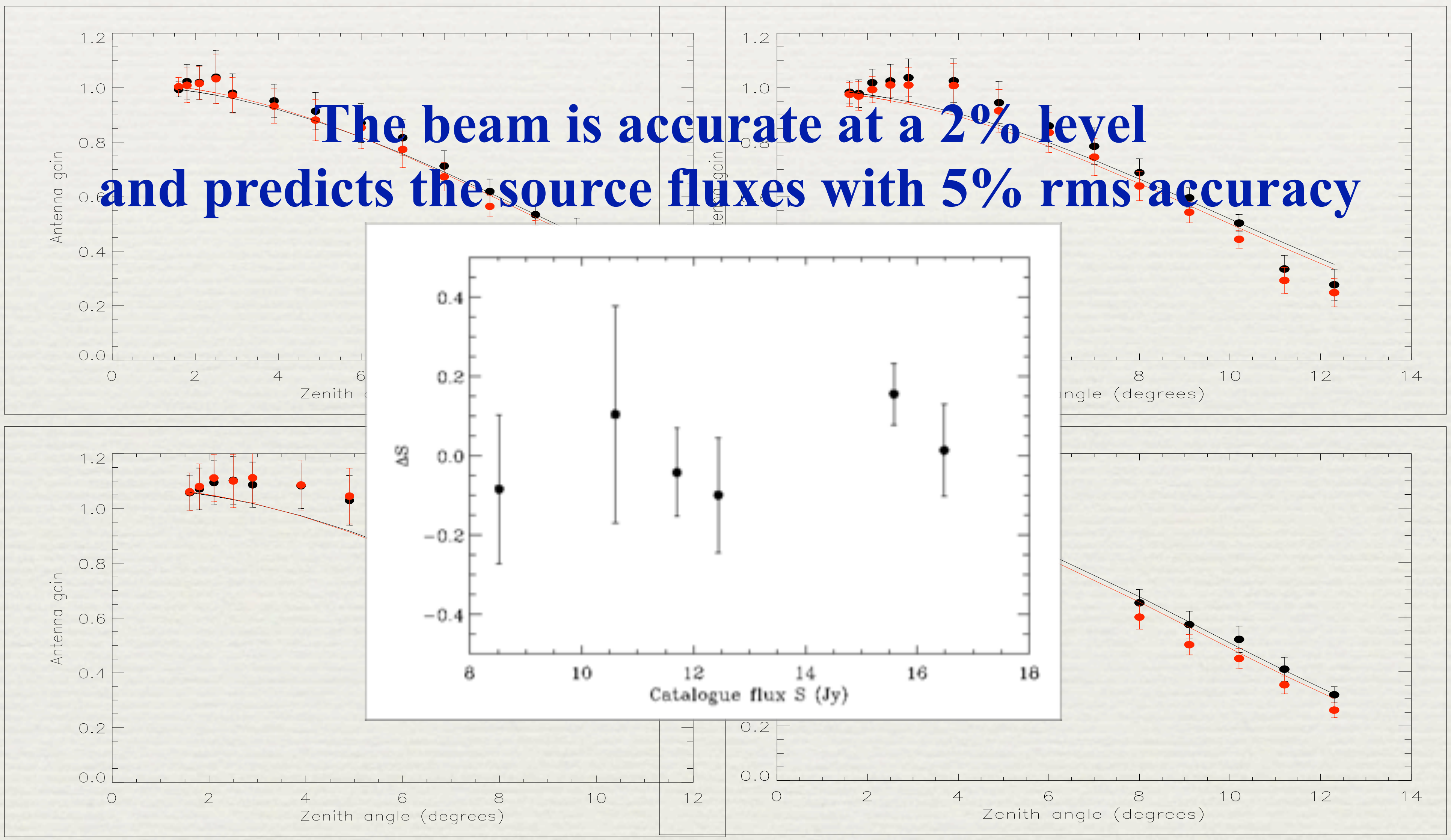
Simple Beam Model

The beam is accurate at a 2% level
and predicts the source fluxes with 5% rms accuracy



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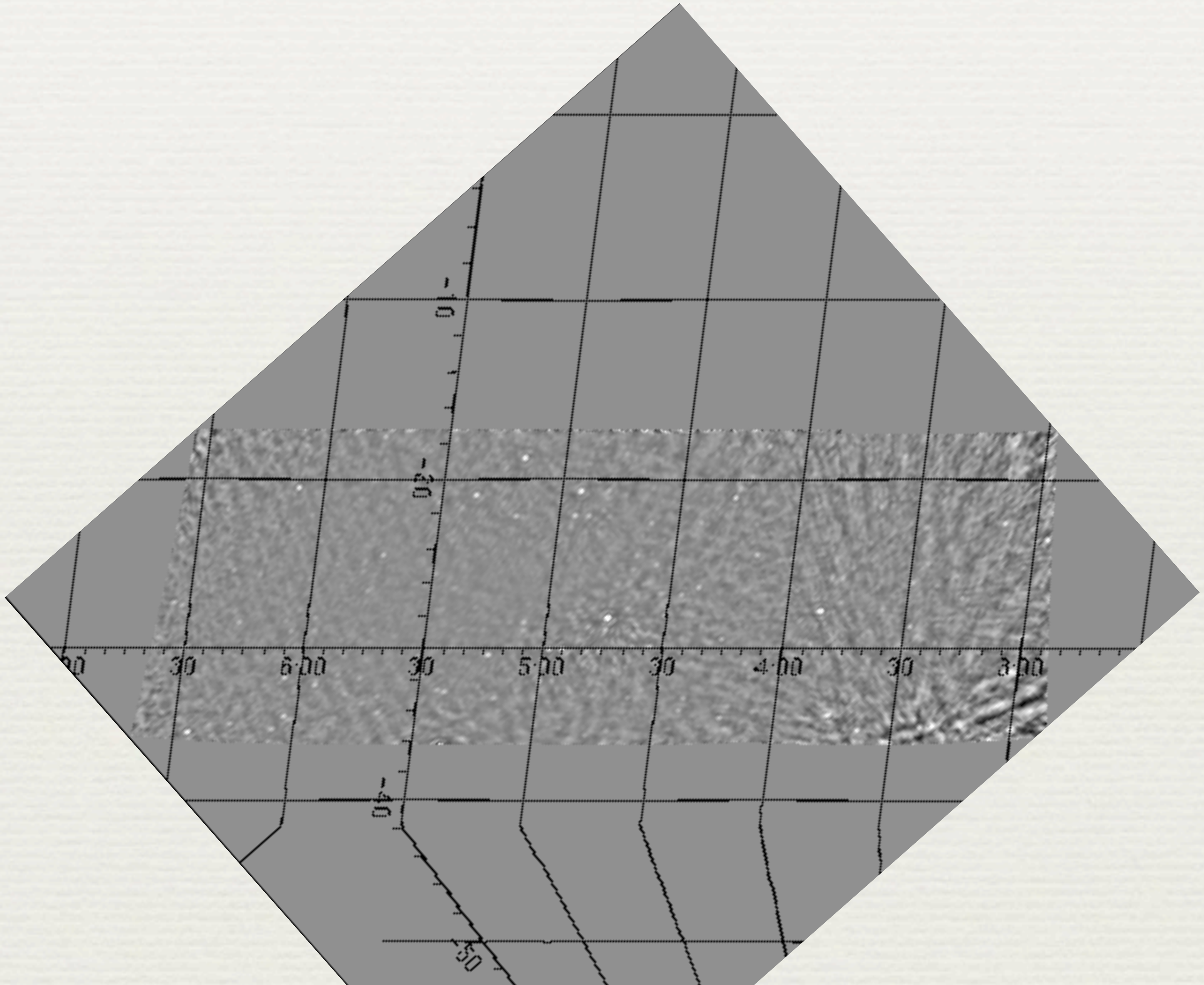
Calibrated Zenith Strip



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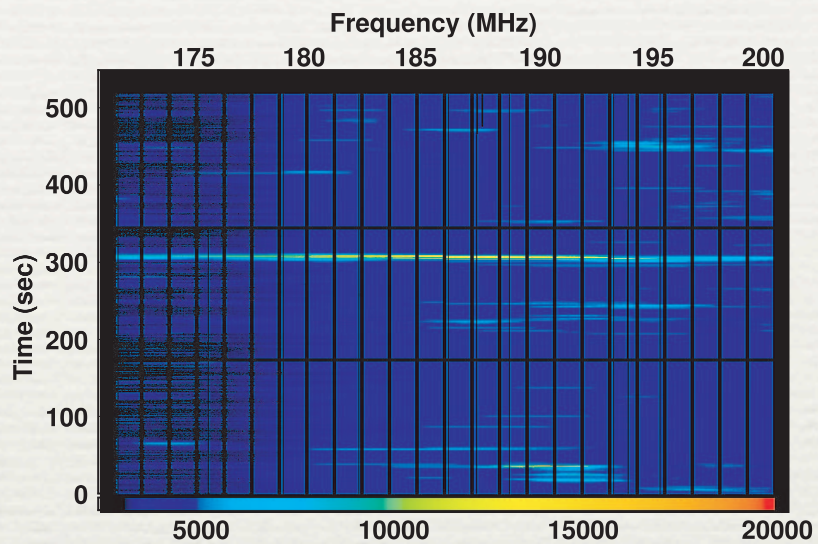
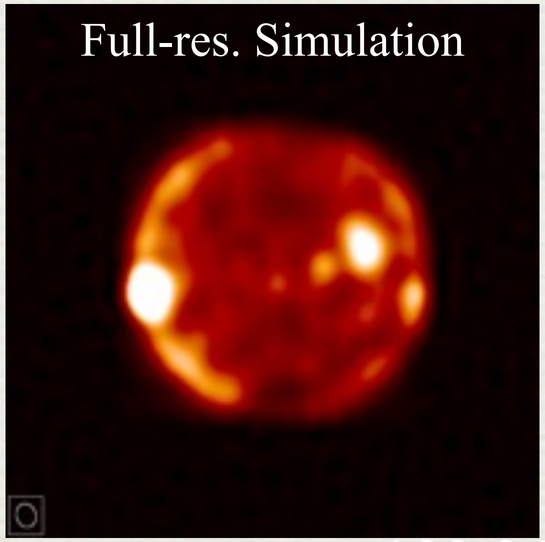
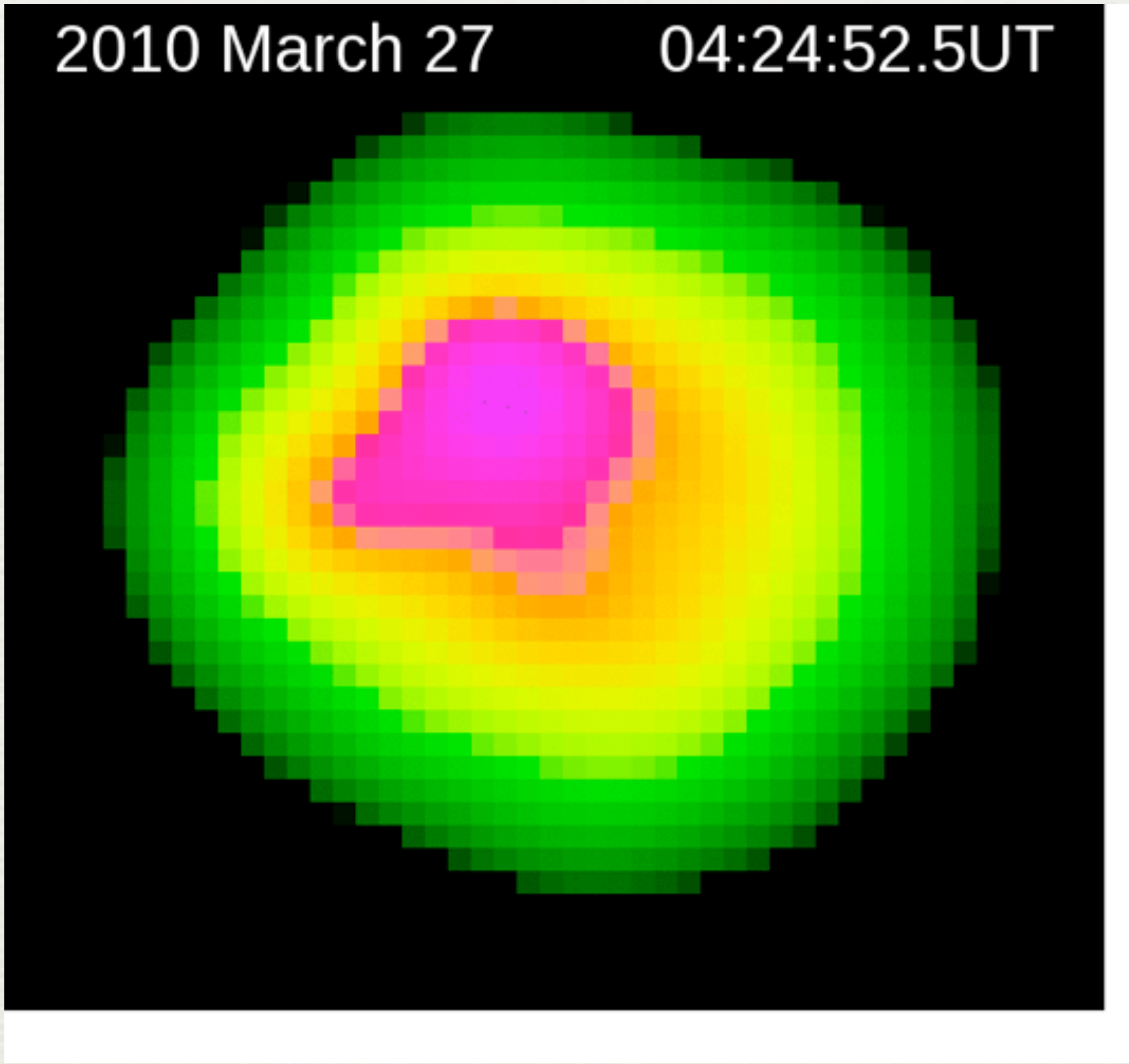
32T Solar Imaging



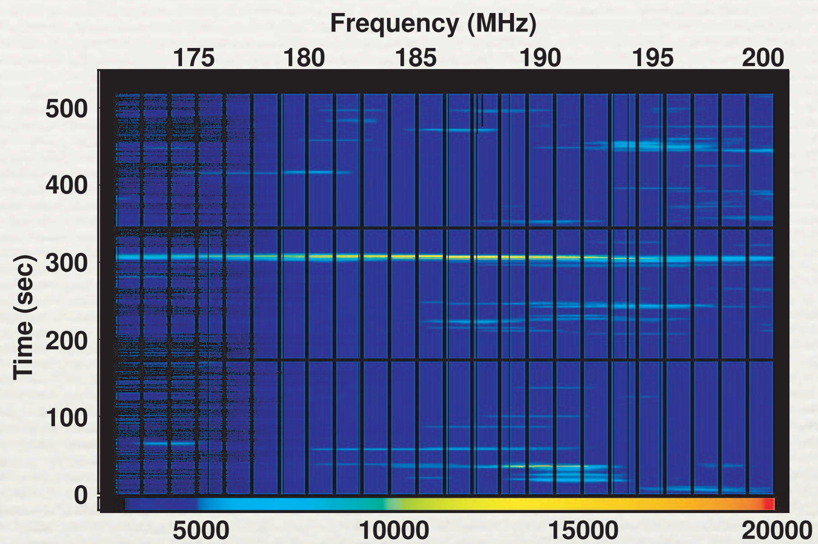


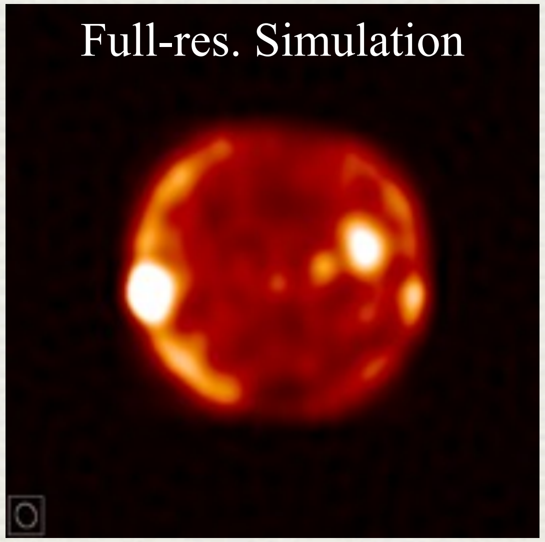
193.3 MHz

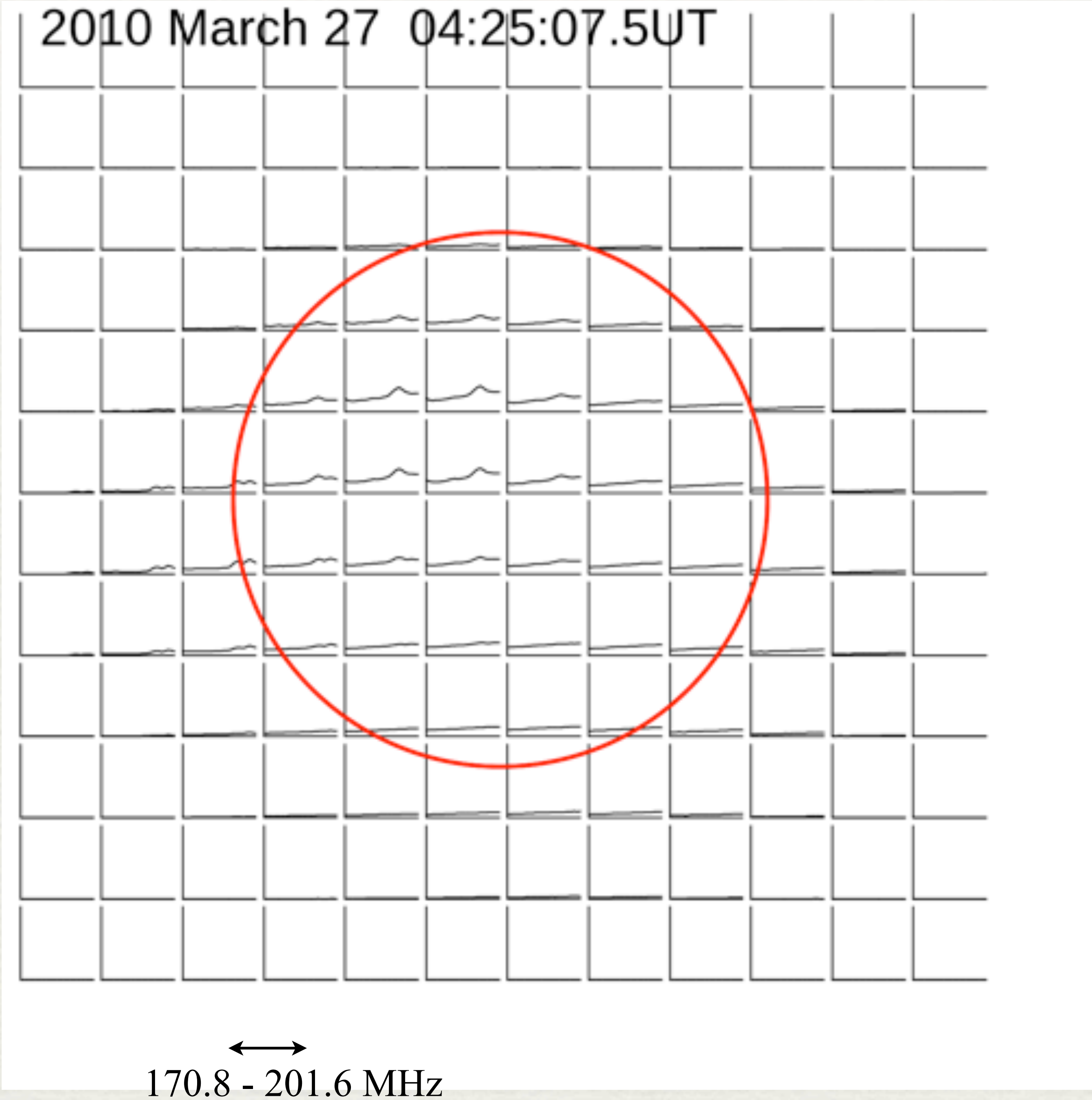


Oberoi et al., 2011, ApJL, 728:L27

32T Solar Spectra







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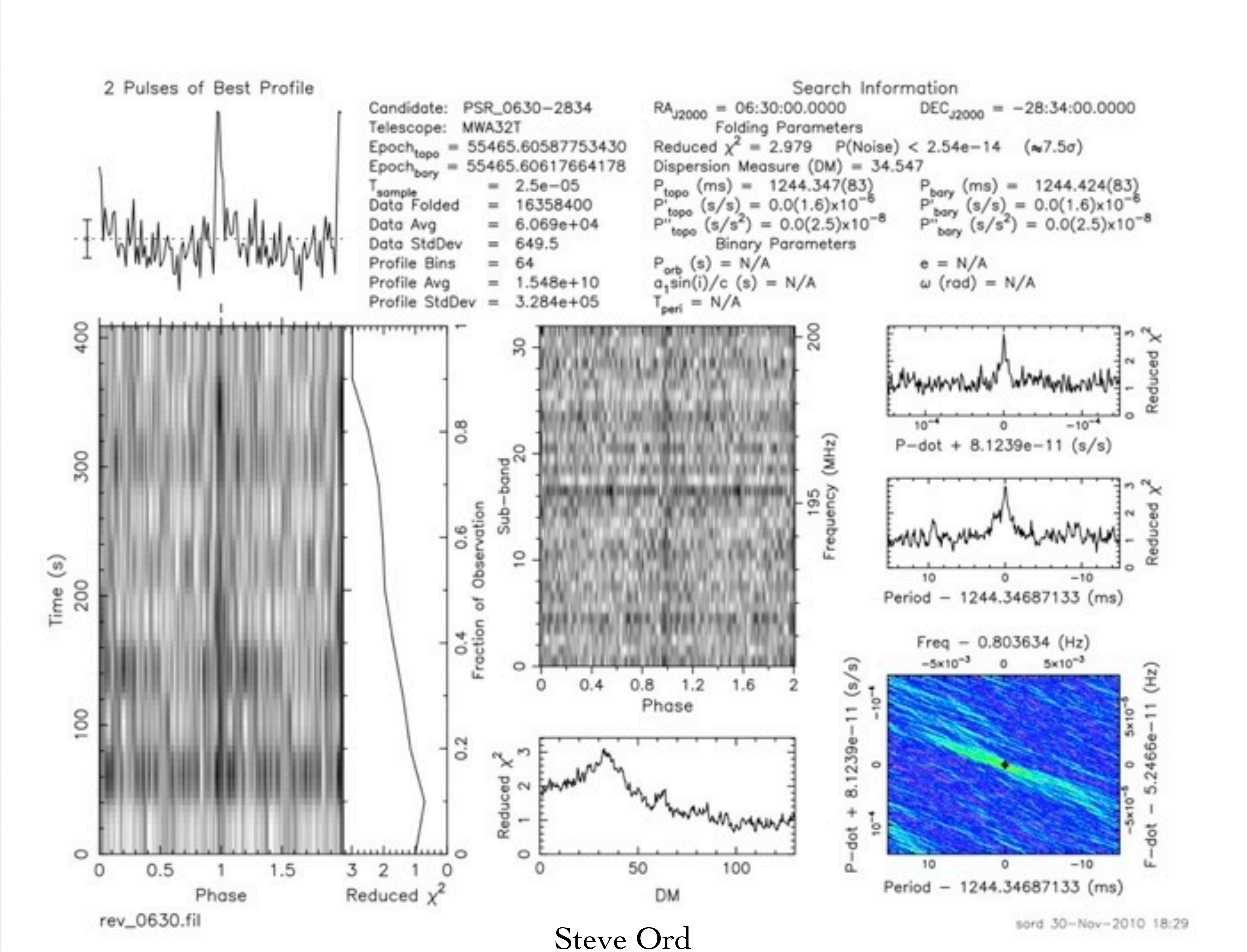
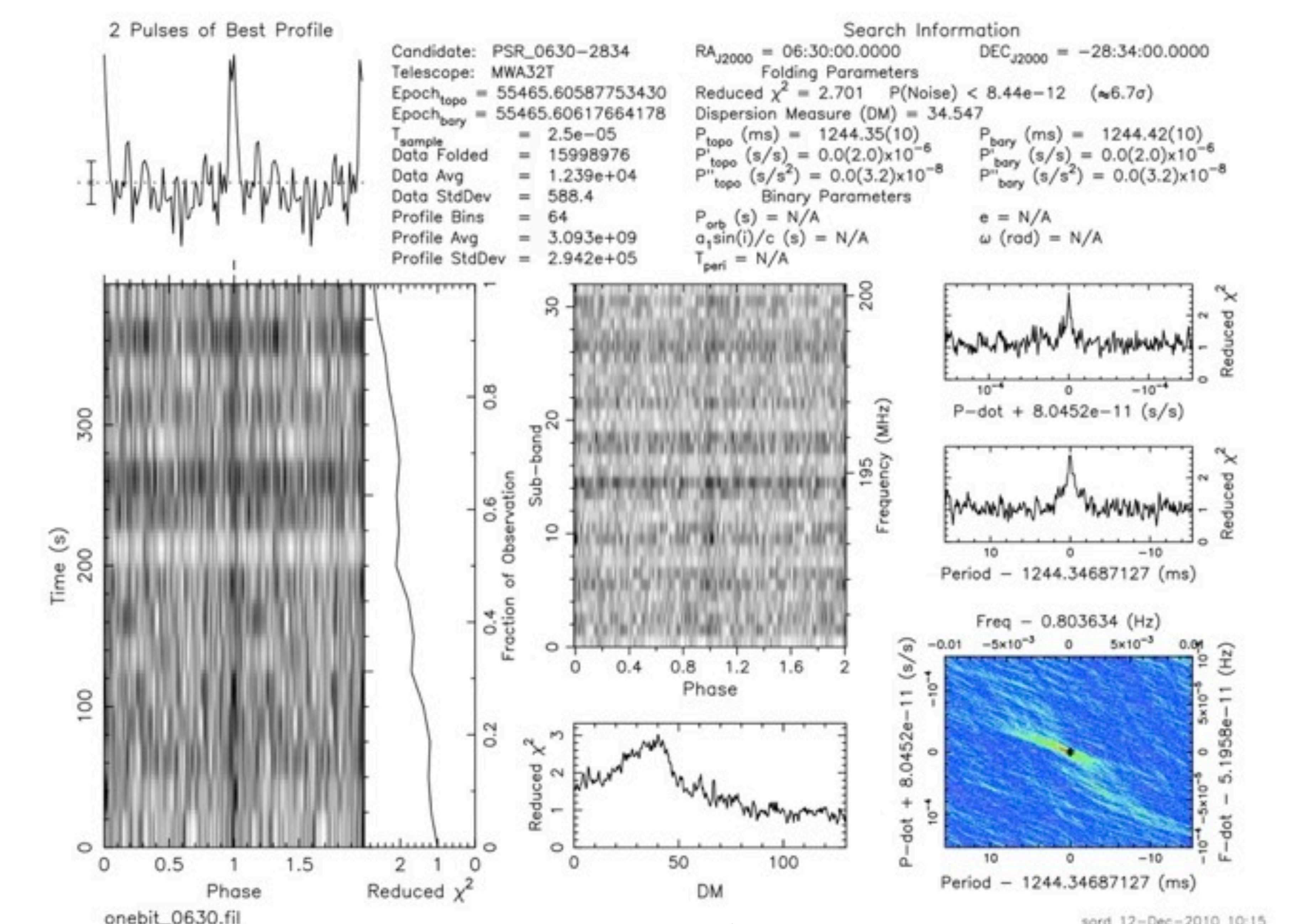
5-bit pulsar detections



Steve Ord

1-bit pulsar detections



Steve Ord

Summary

- The current focus is a fully operational 128-tile array.
- Infrastructure tender process is underway, with array expansion part of the design.
- Approximately 1/3 of the RTC hardware is in Perth, and we will have a CDR very soon.