EVLA OTF Interferometry and the VLASS

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- Simplified OTF imaging
- VLASS examples
- Computing performance issues

EVLA OTF Interferometry

- On-the-fly (OTF) interferometry observes with antennas in constant motion.
- Delay/phase tracking center periodically stepped.
- Effective observing mode when time per "pointing" not longer than move and settle time.
- "Quick and Dirty".
- Applying pointing corrections in imaging can be expensive, requires new software.

ftp://ftp.cv.nrao.edu/NRAO-staff/bcotton/Obit/EVLAOTF.pdf

Simplified ("Aussie") Mode

Visibility for n point sources

$$v_{k,t} = \sum_{i=0}^{n} b_{i,k,t}\ s_i\ e^{-2\pi j (u_k * x_i + v_k * y_i)}$$

where b is the antenna gain

Simplified ("Aussie") Mode

Visibility for n point sources

$$v_{k,t} = \sum_{i=0}^{n} b_{i,k,t} \; s_i \; e^{-2\pi j(u_k * x_i + v_k * y_i)}$$

where b is the antenna gain
For short enough observation

$$(u_k * x_i + v_k * y_i) \approx constant$$

and only b, the antenna gain is variable.
Integrating over time, each source imaged reduced by average beam.

Simplified (“Aussie”) Mode, continued

- If all antennas track the same position, the effective antenna pattern is the convolution of the instantaneous pattern and the trace on the sky.
- “Snapshot” imaging of delay center may ignore antenna motion
- Snapshots can be combined in a linear mosaic using the “effective” antenna pattern.
- Self cal as needed
- Need wideband, widefield imaging in I, Q & U
- Implemented in Obit

  http://www.cv.nrao.edu/~bcotton.html

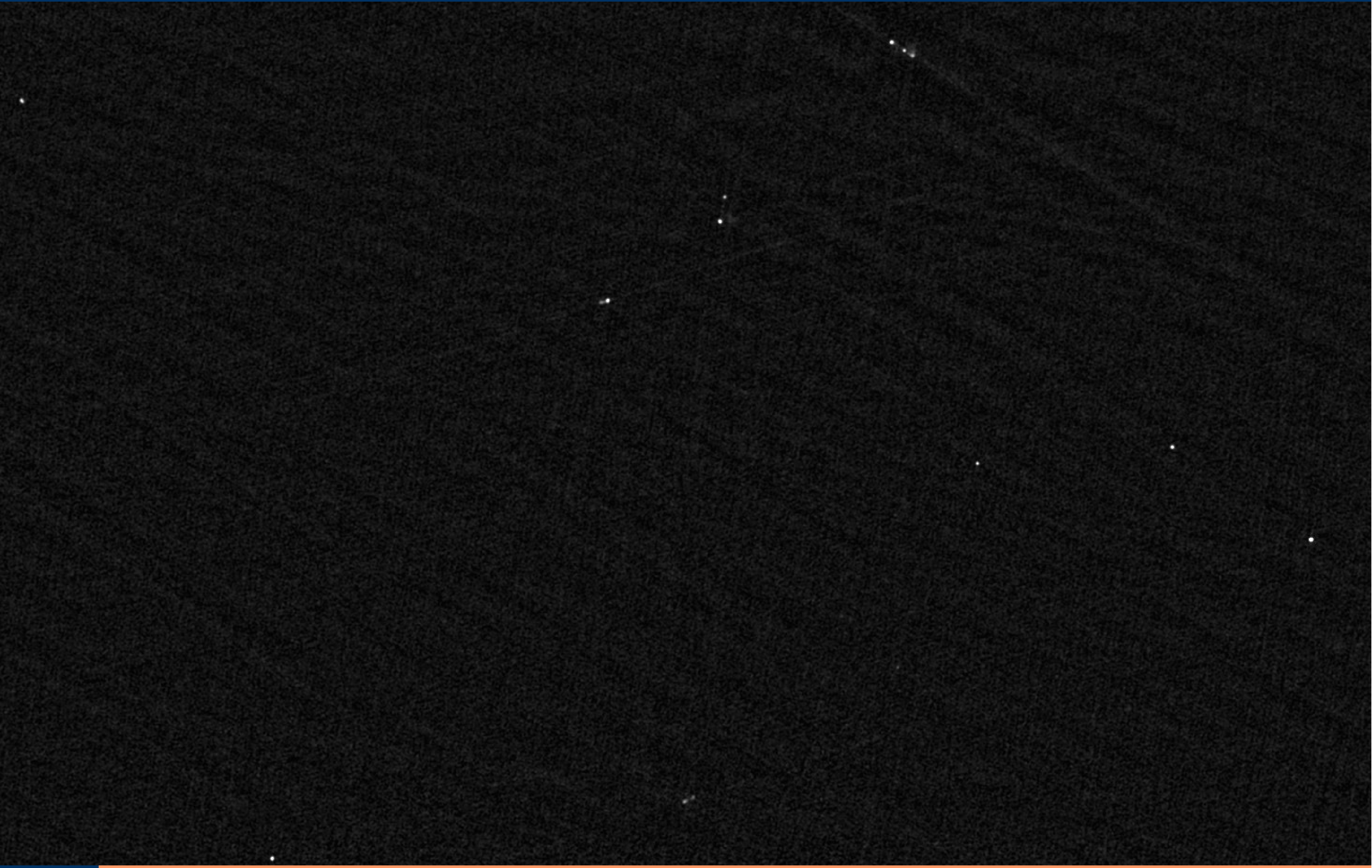
Simplified Mode Limitations

- Need fast delay center updates
- Need good antenna pointing/tracking
- Limited depth of CLEAN per delay center
  - Each position covered in many delay centers
  - VLASS coverage has weight ~5 in mosaicing
  - Noise in delay center CLEAN ~2x Mosaic
  - Dynamic range limit may be more important, many more pixels than visibilities.
- However, average over position dependent errors, e.g. off axis instrumental poln., asymmetries average out.

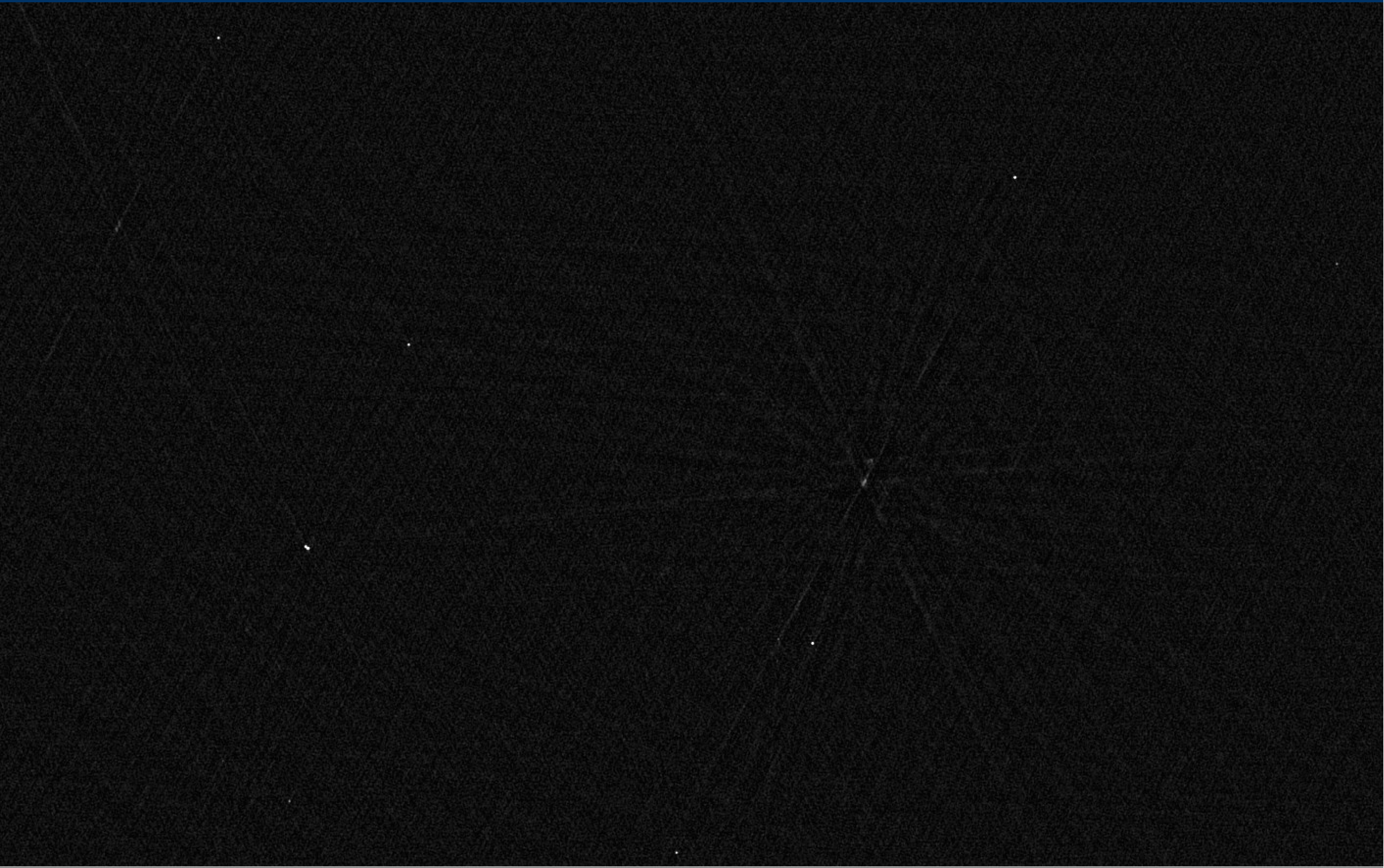
VLASS Examples

- Imaged VLASS test observations, I,Q,U
- Calibrated in Obit calibration pipeline
- Imaging using auto boxing, selfcalibration
- RMS ~150 μJy/bm @ 40°, ~180 @ 0°
- 120 deg^2 of sample images in
  ftp://ftp.cv.nrao.edu/NRAO-staff/bcotton/EVLAOTF/

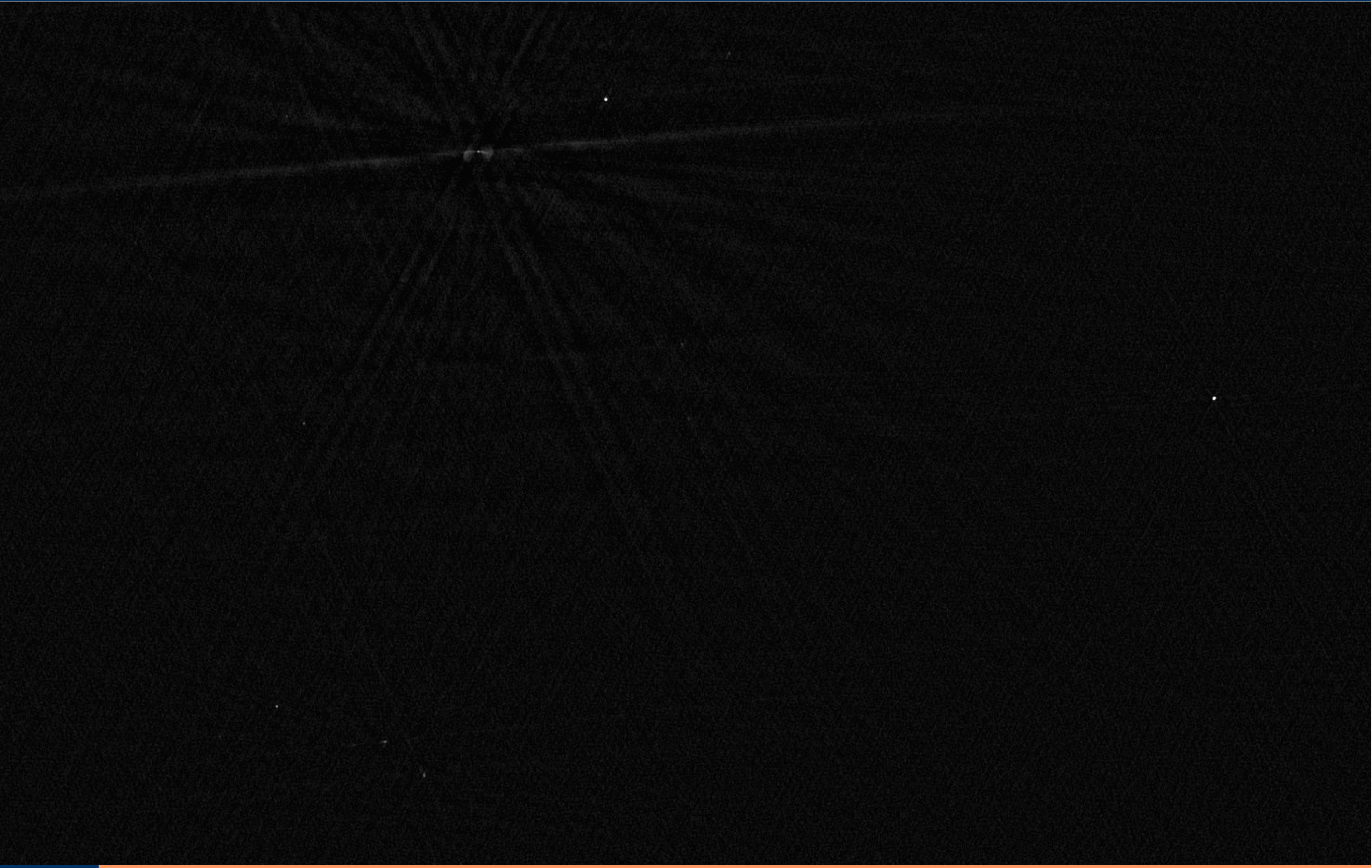
Example VLASS field 1



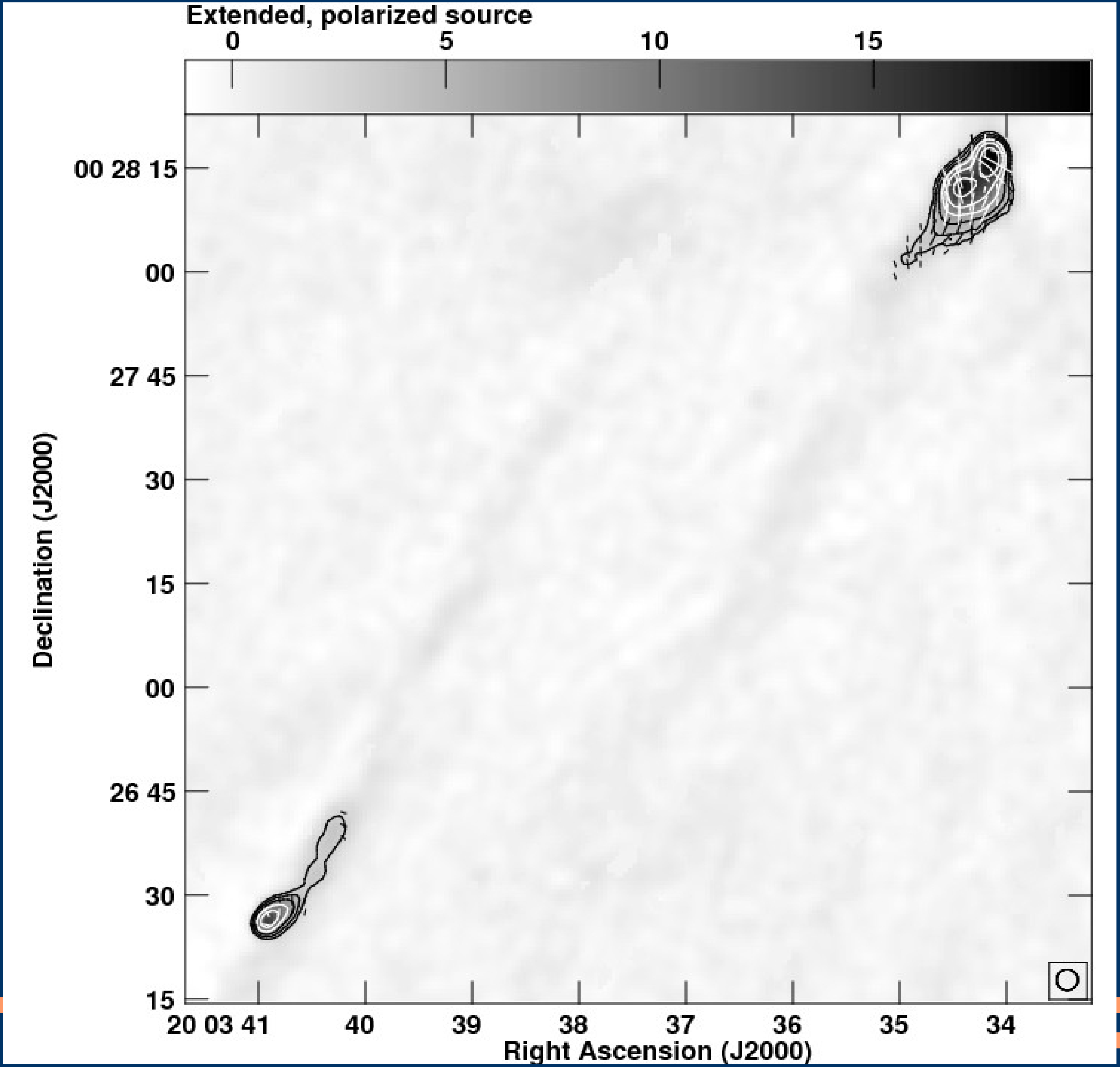
Example VLASS field 2



Example VLASS field 3

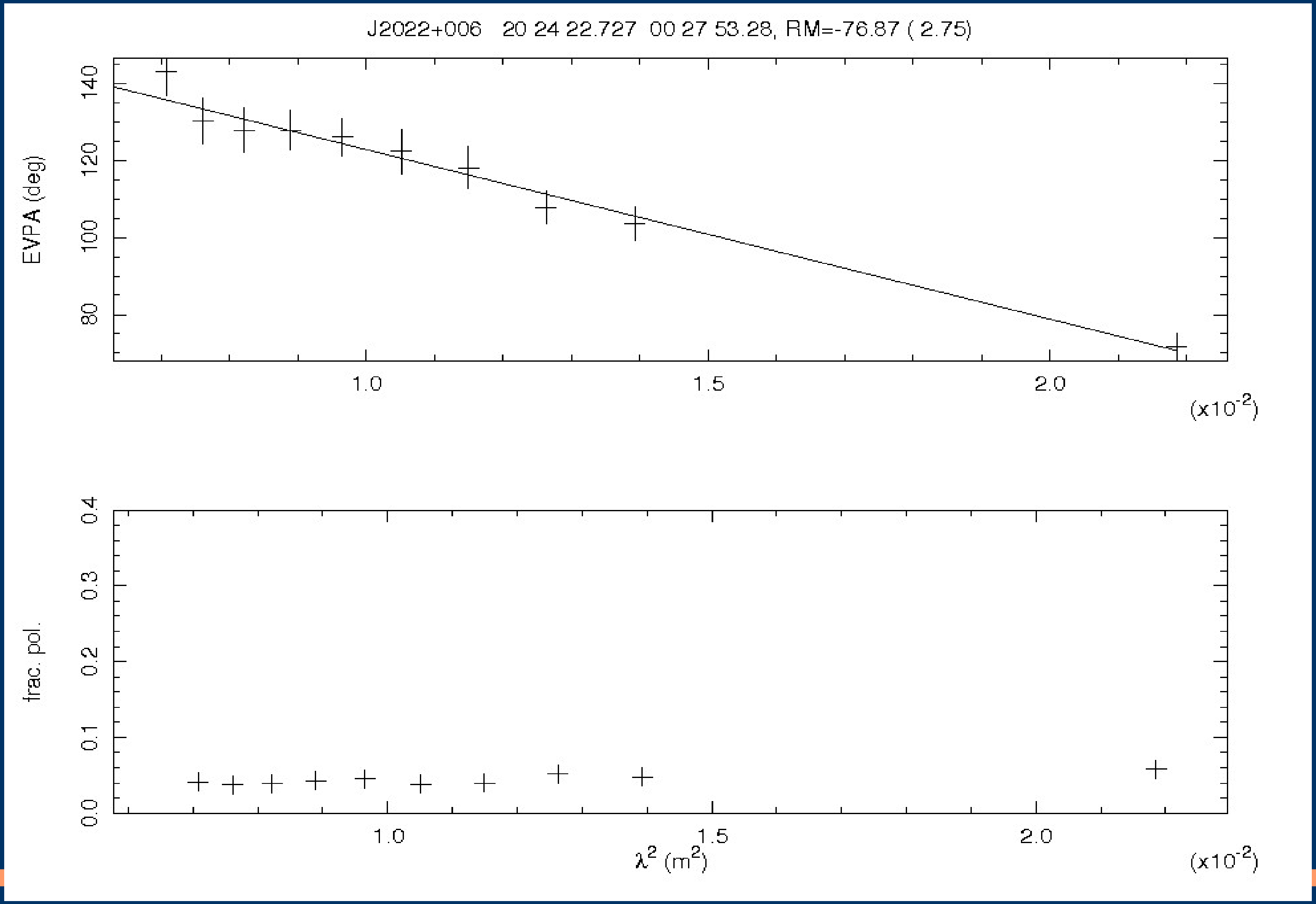


Polarized Source



Rotation measure

- Wide bandwidth of EVLA Sband system allows measuring rotation measure, ~ ½-1/deg^2



The Challenge: Processing in near real time

- Enormous potential for parallelization.
- Little data, many pixels per delay center
- Want to keep all cores fully occupied
- Tested several approaches in a single workstation.

Multiple streams using RAID, SSD disk

- Single stream makes inefficient use of cores
- Snapshot imaging then mosaic formation
- Snapshot images stored as gzipped FITS images
- Parallel independent processing streams
  - 4 imaging list of delay centers, 4/16 cores each
  - 2 mosaicing 4/16 cores each
- I,Q,U image+mosaic 200x observe time 😱
- I/O bottleneck, would not scale to a diskless cluster.

Must go faster: RAM disk

- Compare RAID, SSD, RAM disk
- Image/mosaic fraction of 4 hr VLASS session
- Parallel independent processing streams
  - 6 imaging, 4/16 cores each
  - 4 mosaicing 4/16 cores each
  - Scratch files in either RAID, SSD or RAM disk

RAID,SSD,RAM disk image comparison

TABLE I
IMAGING TIMING WITH 6 STREAMS

Disk	St. 1 hr	St. 2 hr	St. 3 hr	St. 4 hr	St. 5 hr	St. 6 hr	Avg hr
RAID	16.2	16.6	16.3	16.1	16.5	16.2	16.3
SSD	9.0	9.1	9.0	8.9	9.0	9.0	9.0
RAM	3.90	4.04	4.02	4.02	4.02	3.99	4.00

RAID,SSD,RAM disk mosaic comparison

TABLE II
MOSAIC TIMING WITH 4 STREAMS

Disk	St. 1 hr	St. 2 hr	St. 3 hr	St. 4 hr	Avg hr
RAID	24.5	24.5	24.7	24.8	24.6
SSD	18.5	18.6	18.9	18.9	18.7
RAM	2.98	3.03	3.28	3.30	3.15

Must go faster: RAM disk

- Compare, RAID, SSD, RAM disk
- Parallel independent processing streams
  - 6 imaging, 4/16 cores each
  - 4 mosaicing 4/16 cores each
  - Scratch files in either RAID, SSD or RAM disk
- RAM: I,Q,U image+mosaic 85x observe time
- I/O for RAID, even SSD falls apart
- Cores still not fully utilized

Must go even faster: 16 streams

- Upgrade workstation to 256 Gbyte RAM
- Parallel independent processing streams
  - 16 imaging, 1/16 cores each
  - 16 mosaicing, 1/16 cores each
- I,Q,U image+mosaic 35x observe time 😉
- Might scale to a cluster with distributed file system, limited I/O to long term storage.

Conclusions

- Simplified imaging can do I,Q,U OTF
- Stokes V might be interesting for transients
- Single workstation cannot keep up with VLASS
- Might be possible on modest diskless cluster, but
    - Cluster node performance not verified
    - I/O on distributed file system not verified

Thank You