The LOFAR Multifrequency Snapshot Sky Survey (MSSS)

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Outline

- Standard imaging pipeline: *short* overview
- Why MSSS?
- Survey strategy
- Test observations
- Progress, outlook, and timeline

Standard Imaging Pipeline not covered in much detail...


and also the Imaging Cookbook!
LOFAR standard imaging pipeline
LOFAR standard imaging pipeline

Observatory

Data processing

OLAP → Temp UV Storage → DP3 → BBS → Imager → Source Extraction → Image Storage

Control

UV Storage

Initial LSM

Calibration Parameters

LSM

Initial GSM

GSM
LOFAR standard imaging pipeline

Observatory to Data processing

Kickoff
LOFAR standard imaging pipeline

- Flagging
- (Demixing/src subtr)
- Averaging
LOFAR standard imaging pipeline

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Observatory

Data processing

Calibration

Kickoff initially from MSSS
LOFAR standard imaging pipeline

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 Initially from MSSS
LOFAR standard imaging pipeline

- Observatory
- Data processing
- Kickoff

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Initially from MSSS
LOFAR standard imaging pipeline

- Flagging
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Initially from MSSS
Demixed CygA, CasA, VirA (latter not necessary in hindsight)
3C196 LBA_INNER: images

- **no demixing** (but using gains obtained post-demixing)
- **no cleaning**
- **image rms 122 mJy**

- **with demixing** (using gains obtained post-demixing)
- **no cleaning**
- **image rms 66 mJy**

- **with demixing** (using gains obtained post-demixing)
- **(unguided) cleaning**
- **image rms 40 mJy**
3C196 LBA_INNER: images

Each image (single beam!) has size: 100 square degrees
Following demixing, ~thermal noise is reached
(6h observation, 0.2 MHz bandwidth)

Required MSSS depth is not much beyond this
(but note that uv coverage will be different)

<table>
<thead>
<tr>
<th></th>
<th>image rms</th>
<th></th>
<th>image rms</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>122 mJy</td>
<td></td>
<td>66 mJy</td>
<td></td>
<td>40 mJy</td>
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</tbody>
</table>
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  - Self-calibration does not work (properly) at this stage due to lack of beam correction in the imaging stage (see talk by Tasse about the new imager).
- Matching resolution in the model is crucial to jumpstarting the calibration cycle on remote baselines.
MSSS fundamentally a commissioning survey

Key roles:

- Fill the initial GSM for calibration of arbitrary fields at arbitrary frequency in LOFAR bands

Multifrequency - need fluxes over wide LOFAR bands

Snapshot - spend little time to image the sky

Sky - cover the full LOFAR sky (dec \geq 0 \text{ degrees})

Survey - provides output catalog of sources in the sky

- Guide development of, and exercise observatory operations, processing software, imaging pipeline, (and commensal applications?)
MSSS Strategy

- Processing of data on baselines ≤3km in HBA; 10km in LBA, which would yield similar characteristic beamsizes in both bands, of ~1.5-2 arcmin (@ 60,150 MHz)
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- Key reasons:
  - Beam information is not available (yet) in the imager, so differing HBA station sizes could not be taken into account (this may be a moot point in the near future...)
  - Processing time increases with baseline length, so using a compact array makes ~real-time processing more realistic
## MSSS Specifications

<table>
<thead>
<tr>
<th></th>
<th>MSSS-LBA</th>
<th>MSSS-HBA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Array configuration (observed)</strong></td>
<td>full</td>
<td>full</td>
</tr>
<tr>
<td><strong>Array configuration (processed)</strong></td>
<td>≤10km baselines</td>
<td>core baselines</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>16 MHz/beam</td>
<td>16 MHz/beam</td>
</tr>
<tr>
<td><strong>Number of beams</strong></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Time per field</strong></td>
<td>9x10 min</td>
<td>2x7 min</td>
</tr>
<tr>
<td><strong>Final sensitivity</strong></td>
<td>15 mJy/beam</td>
<td>5 mJy/beam</td>
</tr>
<tr>
<td><strong>Number of fields</strong></td>
<td>619</td>
<td>3522</td>
</tr>
<tr>
<td><strong>On-source time</strong></td>
<td>309.5 hr</td>
<td>293.5</td>
</tr>
<tr>
<td><strong>Total time (with overheads)</strong></td>
<td>6 weekends</td>
<td>6 weekends</td>
</tr>
</tbody>
</table>
Declination of 3C196 = 48 deg
MSSS Calibration Strategy

- Determination of instrumental gain solutions from known calibrator field, and transfer those to target MSSS fields
- Individual fields observed in $\geq 1$ snapshots, primarily for uv-coverage (but maximizing usefulness for transient searches...)
- Broad frequency span in both LBA and HBA (Low)
- Self-calibration loop (to be specified once awimager is available)

See talk by David Mulcahy
LOFAR SIP: MSSS implementation

Calibrator part

Target part
Comparison of relevant surveys

Table 2: Parameters of default MSSS and comparison with other surveys

<table>
<thead>
<tr>
<th>Survey</th>
<th>Frequency</th>
<th>Sensitivity</th>
<th>Resolution</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSSS-LBA</td>
<td>30 – 78 MHz</td>
<td>$\leq 15$ mJy beam$^{-1}$</td>
<td>$\leq 100''$</td>
<td>20,000 $\arcmin^2$ ($\delta &gt; 0^\circ$)</td>
</tr>
<tr>
<td>VLSS</td>
<td>74 MHz</td>
<td>100 mJy beam$^{-1}$</td>
<td>80''</td>
<td>30,000 $\arcmin^2$ ($\delta &gt; -30^\circ$)</td>
</tr>
<tr>
<td>MSSS-HBA</td>
<td>120 – 170 MHz</td>
<td>$\leq 5$ mJy beam$^{-1}$</td>
<td>$\leq 120''$</td>
<td>20,000 $\arcmin^2$ ($\delta &gt; 0^\circ$)</td>
</tr>
<tr>
<td>TGSS</td>
<td>140 – 156 MHz</td>
<td>7 – 9 mJy beam$^{-1}$</td>
<td>20''</td>
<td>32,000 $\arcmin^2$ ($\delta &gt; -30^\circ$)</td>
</tr>
<tr>
<td>WENSS</td>
<td>330 MHz</td>
<td>3.6 mJy beam$^{-1}$</td>
<td>54''</td>
<td>10,000 $\arcmin^2$ ($\delta &gt; +30^\circ$)</td>
</tr>
<tr>
<td>NVSS</td>
<td>1400 MHz</td>
<td>0.45 mJy beam$^{-1}$</td>
<td>45''</td>
<td>35,000 $\arcmin^2$ ($\delta &gt; -40^\circ$)</td>
</tr>
</tbody>
</table>

Note. Sensitivity and resolution values for the MSSS surveys are upper limits corresponding to core-only (HBA) and 10-km (LBA) surveys. Full array observations will be taken; final sensitivity and resolution values are likely to improve (provided that the new imager is fully functional, and that sufficient compute resources are available).
First MSSS test pointings

- Each set of pointings covers approx 200 square degrees
- Key is to make these as realistic as possible
  - test, understand, and optimize: data taking, handling, processing, major cycle algorithm, pipeline runtime, catalog creation, etc etc etc
Tracking MSSS observations

8hr of MSSS-test observations: 1% of MSSS sky
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M81/82

California Nebula

M31
Tracking MSSS observations

8hr of MSSS-test observations: 1% of MSSS sky
MSSS scheduling

- MSSS observations can be specified semi-automatically but with no dynamic re-shuffling of snapshots for maximum efficiency (This is coming with the observatory’s new scheduler...)

- Observatory measurement management system is being updated to include all of the metadata needed for processing

George Heald / First Science with LOFAR / 14-09-2011
Science applications

- Science teams are defining projects that can run in parallel with MSSS, or use its data products to generate additional output:
  - Cosmic ray triggering
  - International-baseline observations
    - finding compact calibrators for future long baseline observations
    - first high-resolution images of bright sources
  - Search for polarization calibrators
  - Search for (slow) transient sources on hour - week(?) timescales
    - intelligent scheduling of individual snapshots....
MSSS test data

- MSSS test data are being run through the preliminary pipeline (starting last week, proceeding now.....!)
- The calibration part seems to be functioning properly but there are still some problems to be sorted out
- The next step is applying solutions to the target fields (well understood from the procedural perspective), and then imaging the data and combing the MSSS desert!
- So, test data are in hand and we have done some first processing, but there are no results from the test fields yet
- We will be tabulating statistics as the analysis proceeds
MSSS Timeline

- Now - Sept 2011: test observations and pipeline runthroughs
  - First test (observed, in processing): 200 sq deg near 3C196
  - Second: 3C465 - including piggybacking applications
  - Third: a “blank field” (TBD)

- Oct 2011: begin MSSS
  - Start with LBA part, during HBA tile repair process
  - continue to HBA when possible

- Priority:
  - A-team
  - 3C catalog
  - Rest of northern (dec>=0) sky
  - Southern sky as time/resource allocation permits
Playing a role in MSSS

- We will be seeking out assistance in running (and inspecting the output of!) MSSS via the KSPs ... including things like:
  - Source detection in MSSS test fields
  - Algorithm for major cycle stop criteria
  - Identification of final survey pointing grids in LBA and HBA
  - Identification of calibration (& astrometric) reference grid(s)
  - Assistance to Radio Observatory in setting up and performing observations
  - Assistance in data handling
  - Inspection of pipeline output and identification of fields that require follow-up post-processing
  - ...!