Imaging and Calibration Algorithms for EVLA, e-MERLIN and ALMA

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Why do we need a workshop?

- EVLA, e-MERLIN, ALMA and wide-band VLBI will produce their first science data very soon.
- They all provide large improvements in continuum sensitivity and spectral coverage/flexibility.
- These advances require new software, particularly:
  - Automated removal of bad data
  - Calibration of ionospheric and tropospheric effects
  - Wide-field, wide-band imaging
- Data volumes are large and algorithms are more complex, so we need higher processing speeds.
- (New) users must be able to do science efficiently.

What are we trying to do?

- List the problems we need to solve.
- Make an inventory of the software already available and identify what is missing.
- Compare approaches.
- Promote discussion between different groups.
- Work out how to implement new and existing algorithms in a framework which allows astronomers to make best use of the new instruments.
- Encourage new talent to work on the problems.
- Provide a resource for development of PhD projects, and proposals to observatory management, national and cross-border funding agencies.

Outputs

- Presentations and a record of the discussion (wiki + Radionet archive).
- A document describing:
  - Problems to be solved
  - Available software
  - Work in progress
  - What else is needed
  - Proposed solutions

Write down a consensus and use the result to focus existing efforts and make the case for better funding.

Low-frequency instruments and SKA

- This workshop is focused on urgent issues for cm and mm-wave arrays – new or upgraded – which will start operation over the next 1 – 5 years.
- We are not trying to solve problems specific to very low frequencies or to SKA.
- Nevertheless, we recognise that there are common problems and welcome two-way interaction.

Dialogue is important, but solutions may be different

What are we trying not to do?

- Argue about which package is “best”
- Discuss how we got to where we are now
- Design ambitious new software not driven by current requirements

Focus on adapting existing software to meet imminent new requirements

Issues for discussion

Examples, not exhaustive
Incremental on existing software

Data editing

- Much larger data volumes → automation essential
- Interference: especially an issue in the extended L-band (1-2 GHz) and at lower frequencies
- Atmospheric effects (e.g. decorrelation) at (sub-)mm wavelengths
- Automatic flagging algorithms must be reliable for a wide variety of spectral configurations

Not many talks on this: encourage discussion, especially after the session on pipelines

Calibration

- Instrumental, troposphere and ionosphere
- Stability: timescales of various effects
- Anisoplanatism: how serious at $\nu > 1$ GHz?
- Robust self-calibration
- Correction for residual closure errors
- Transfer of calibration across different spectral configurations (e.g. wide/narrow bands) and between receiver bands
- Measuring and correcting for the primary beam: how accurate and stable?
- Correcting for pointing errors

Wide-band imaging

- EVLA, e-MERLIN and e-VLBI achieve gains in continuum sensitivity mostly by increasing bandwidth
- ALMA will also have large fractional bandwidths
- Effective uv coverage is improved
- Source structure changes with frequency
- High dynamic range required (at least 10^5; up to 10^7).

→ Develop multi-frequency synthesis and related algorithms.

Wide-field, wide-band imaging

- Imaging over the full primary beam
- Facets versus w-projection
- Variation of primary beam across the observing band
- IQUV across the beam
- Elevation effects, beam squint
- Heterogeneous arrays (ALMA+ACA; e-MERLIN; VLBI; combinations of different arrays and configurations)
- Combination with single-dish data
- Mosaics

Polarization

- On-axis calibration: improved methods, use of resolved standard sources
- Imaging in linear and circular polarization over the entire primary beam
- Requires measurement/correction of leakage beams
- Stability
- Variation of polarization structure across the observing band (e.g. Faraday rotation).
- RM synthesis and related techniques

A lot of interest expressed, but few presentations

Deconvolution

- Improve image fidelity
- Reduce interactive and subjective elements (automatic boxing for CLEAN ....)
- Mosaics
- Multi-scale CLEAN implementations
- Maximum entropy: improved convergence and dealing with point sources
- Other methods?

Pipelines and interoperability

- Existing algorithms are distributed amongst different packages: how can these be made interoperable?
- Experience from existing pipeline projects
- How do we turn the existing collection of software plus new algorithms into a practical data-reduction path for (potentially inexperienced) users?
- Who does what? Data provider (observatory) or user?
- Ease of installation
- How is support provided?

Data Volume and Processing Speed

- This workshop is focused on algorithms rather than their implementation, so we have not scheduled presentations on processing speed
- Nevertheless, dealing efficiently with the large volumes of data from the new instruments is a critical problem:
  - What limits processing speed: CPU, memory, I/O?
  - Effective parallelization
  - What computing resources will be required?

We expect this to be both a major discussion point at this meeting and a key issue for follow-up