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Painless Access to Interferometry Images Comes Closer

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Abstract. Ready-made radio interferometry archive images usually only cover a few percent of the potential field of view in the visibility data. The next generation of instruments will achieve orders of magnitude increases in sensitivity, giving many detectable sources in any one observation. The most economical (and user-friendly) solution is to provide images or other data products on-demand at the chosen positions and resolutions. This can be driven remotely using a Virtual Observatory interface. Radio observatories are also providing software to automate most stages of data processing and form the basis of tools for specialist users. Recording and supplying metadata is vital to these processes.

1. Introduction

The maximum field of view of a radio synthesis observation is determined by the primary beam of the individual telescopes but the resolution is determined by the maximum baseline length. MERLIN[1] could potentially produce Gpixel images up to half a degree in diameter at λ=21 cm and 150-mas resolution. The field of view is also limited by the integration time and frequency resolution. The recent JIVE[2] correlator upgrade (van Langevelde et al., 2005) allows 20-arcmin Very Long Baseline Interferometry fields to be imaged at 20-mas resolution.

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[2]Joint Institute for VLBI in Europe

Gpixel images are unwieldy to produce and to process and traditionally only a small fraction of the area covered by a dataset was ever imaged. This made sense when the surface brightness sensitivity was typically $> 10^4$ K for high resolution observations, making it rare to find many detectable sources in the same field. The *e*-MERLIN project is connecting the telescopes of MERLIN with optical fibres, along with other upgrades, which will increase the sensitivity 10–30-fold. *e*-MERLIN will reveal tens of μJy sources in a single run, whether very distant non-thermal emission from active galaxies, or thermal emission within the Milky Way; extended observations will push this to hundreds of sources. A similar upgrade is planned for the VLA[3].

The goals for the next generation of interferometers are to provide managable images anywhere in the field of view, to the specification of the user (trading off resolution against sensitivity) or to supply other data products such as time-series derived from visibility amplitudes for a variable source. Again traditionally, this has involved downloading Gb (now almost Tb) visibility datasets and using specialised software (dedicated to one or a few arrays). Alongside the hardware and correlator upgrades, data access is being revolutionised to free the user from as much data processing as possible (or as they want) and to deliver only the data needed for a given scientific purpose. In Europe, RadioNet is coordinating best practices between observatories.

The instrumental upgrades are incremental, as are the improvements in access, so that some facilities described here are already available and will be developed further in response to user feedback.

2. MERLIN data delivery

1. **Raw data** Data are correlated in real time and stored on disc and backup tape. Metadata descibing observational parameters (array properties, pointing positions, observing frequencies and times etc.) are extracted.
2. **Data archiving** A short series of Perl scripts drive dedicated software needed to convert the visibility data to FITS, scaled in physical units. Next, an AIPS runfile is used to continue data reduction including applying calibration derived from the phase-reference source to the target and making sample images of the inner few tens of arcsec. The data are stored in AIPS with reversible calibration in extension tables. More detailed metadata are recorded as logfiles and summarised in a database.
3. **Data delivery** The details of the archived data are accessible via a web form, including diagnostic plots and FITS images. The full data and its history are supplied in response to email requests. The visibility data for a target and its reference souces, their calibration and history are extracted from datasets stored AIPS in response to email requests or via a trial web interface and downloaded over the internet or supplied by post (tape).
4. **User Processing** The visibility data can be further processed in AIPS using the MERLIN procedure which provides defaults or extracts parameters from the data, reducing tenfold the number of user commands required.

[3]Very Large Array, USA

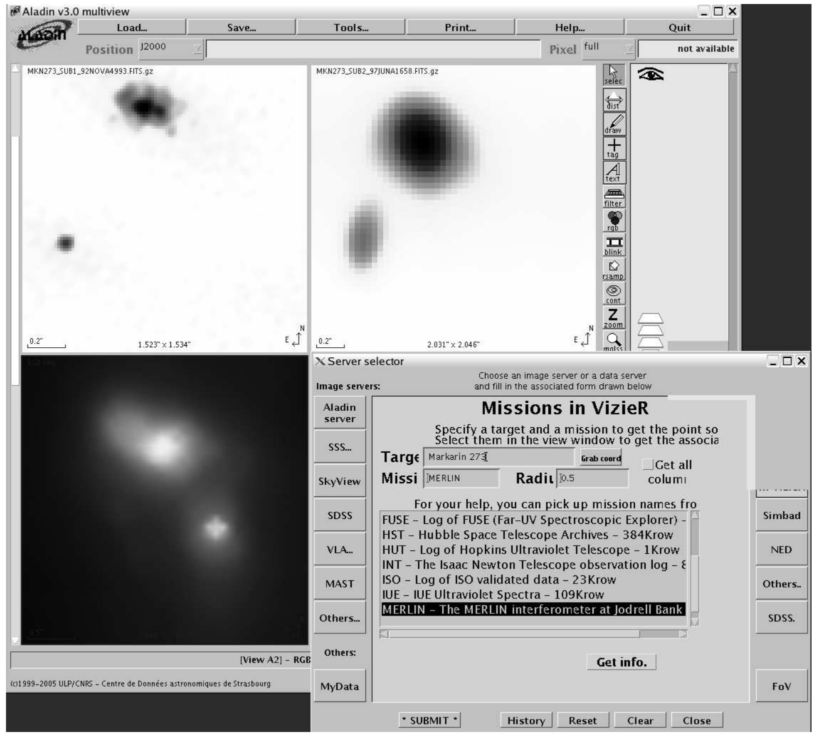

Figure 1. MERLIN archive images of Markarian 273 at 6- and 18-cm wavelength, and an aligned HST image, displayed using Aladin.

Stages **1.** and **2.** are normally carried out by MERLIN staff but the archive runfile is available for users who want to modify it. The most labour-intensive operation is usually editing; Renting et al. (2005) report an automated procedure in use at the WSRT[4] which may provide the basis for automatic flagging of MERLIN data. Stages **3.** and **4.** use the AIPS scripting language (POPS), Perl, shell scripts and CGI at present. We intend to replace much of this using ParcelTongue (Kettenis, van Langevelde & Cotton 2005), which is a python-based scripting interface to AIPS or, potentially, other software packages. It offers a more direct route to on-demand data processing from web-based (including VO) input and is likely to be more accessible for power-users who want to modify scripts themselves. In the longer term, *b2e* systems will describe and deduce specifications from the initial proposal through archiving to legacy-mode retrieval. The RadioNet Common Proposal Tool (Holties et al. 2005) is tacking this problem from one end, whilst other stages are covered by software development for *e*-MERLIN, NRAO[5] and ALMA (Viallefond 2005).

[4]Westerbork Synthesis Radio Telescope

[5]National Radio Astronomy Observatory, US

3. Virtual Observatory interfaces

Ready-made images from the MERLIN archive can already be accessed via Vizier and Aladin and the related AVO prototype. Figure 1. shows a radio-optical comparison using Aladin. Major imaging surveys such as NVSS and WENSS are available by this route or services provided by other VOs such as the NVO. Technical issues which affect using generic software to interpret radio images include the units (usually Jy/beam) and the importance of polarization. On the plus side, the units are usually physical and the astrometry is usually very good. In the near future, tools which will be accessible via AstroGrid include:

- A parameterized workflow for extracting MERLIN images at a given position, wavelength band, field size and resolution. This will establish whether the image would fall within the field of view of the calibrated visibility held on-line in AIPS and if so, use ParselTongue to mediate its processing and delivery to MySpace for passing to other VO tools.
- Modification of the Solar Movie Maker to handle frequency- or velocity-channel series and make fly-through's of spectral data cubes.

Such developments are only possible using IVOA standards such as data models to define the image properties a user may seek for interpretation by a data server. These have to be well-defined enough to be unambiguous for software but flexible enough to describe the *potential* products which can be extracted from a visibility data set using available VO tools – and intelligible to the user. Thus, spatial resolution should be characterised in terms of a range from the smallest restoring beam to the largest scale structure detectable, rather than in terms of baseline lengths.

4. Conclusions

Radio data providers are developing software to automate the early stages of interferometry data reduction (removing instrumental characteristics, transfering calibration from reference sources etc.), which are the most intimidating for non-specialist astronomers. This will allow flexible access to images using Virtual Observatory interfaces and open up the radio sky to all astronomers. Disentangling the starburst and AGN contributions to galactic activity, or estimating the lifetimes of YSOs in crowded regions, are just two of the science cases which will benefit from the inclusion of radio data in multi-wavelength comparisons.

References

Holties, H., Vermuelen, R., Smit, A., Vermaas, N., Verhoef, B. & Bokhorst 2005, this volume, [P.25]

Renting, A., Mellema, G., Oosterloo, T., Schoenmakers, A. & Holties, H. 2005, this volume, [P.97]

van Langevelde, H. J., Anderson, J., Kettenis, M., Olnon, F., Szomoru, A. & Verkouter, H. 2005, this volume, [O10.4]

Viallefond, F. 2005, this volume, [O10.1]