Astronomical Data Analysis Software and Systems XIII
ASP Conference Series, Vol. 314, 2004
F. Ochsenbein, M. Allen, and D. Egret, eds.

VO Access to Complex Data - MERLIN and Other Interferometry Archives

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Abstract. Radio interferometry data should be as accessible as any other part of the electromagnetic spectrum in the form of images, spectra or whatever the astronomer requires, without laborious massive dataset transport or esoteric software at the user end. Many existing facilities are developing on-line access to archive and current data, incorporating VO compatibility. The next generation of interferometers will have data access for non-experts designed into their archives.

1. Introduction

Until recently, many astronomers regarded reducing radio astronomy data as an unnatural art. Yet pipelines and other user-friendly tools are now common. Most astronomers make some use of radio data such as in identifying galaxy types from the spectral energy distribution or probing obscured star-forming regions. Public access data are at last becoming accessible, albeit usually via the individual observatory web sites. The next step for VOs and data providers is to supply final data products from any registered archive via a single interface. The responses to our questionnaire to interferometry observatories show that

[1]The Astrophysical Virtual Observatory

[2]AstroGrid

pipelined data reduction up to the production of images is possible for fixed-element cm-wave telescopes such as

- ATCA (Australia Telescope Compact Array);
- MERLIN (Multi-Element-Radio-Linked-Interferometer-Network, UK);
- VLA (Very Large Array, USA);

and is becoming possible, for the calibration stages at least, of VLBI networks like the EVN (European VLBI Network) and the US VLBA. Calibration pipelines and on-line access are also in use at mm wavelengths although data acess is more restricted e.g.

- The US BIMA and OVRO, being combined as CARMA;
- IRAM (France).

In the next decade more arrays will come on line, first the wide-bandwidth upgrades e-MERLIN and eVLA, then the LOFAR low frequency array and ALMA (Atacama Large MM Array) and finally the SKA (Square Kilometre Array).

The data models and tools required are being developed in the context of setting international standards for VOs, to provide a basis for the next generation of interferometers. The IVOA hosts the radiovo@ivoa.net mailing list (open to anyone interested) and the radiovo archive[1].

2. Interferometry Data

Raw interferometry data consists of a series of complex visibilties which need to be calibrated and Fourier transformed to produce an image. A single observation can produce a range of resolutions (obtained by weighting the data or combining data from different arrays); minimum beam size and maximum sensitivity to extended emission are mutually incompatible. Moreover, the potential field of view is typically $30'$ or 2×10^9 $0''.04$ pixels. The best way to meet user requirements is to extract tailor-made products on demand from calibrated visibility data. Even so, the data volume and visualisation can be daunting, for example multi-epoch 3D monitoring of SiO masers in 512 spectral channels, two transitions and full polarization (Diamond & Kemball 2003). The product may not even be a image, but extracted spectra, a radio light curve of an X-ray binary, or the more specialised time series required for pulsar astrophysics. Calibrated visibility data is the prime product for some applications such as gravitational lens modelling. It may be the only product for interferometers with a small number of elements such as in the optical and IR (see e.g. Monnier 2003).

3. VO Access to Interferometry Products

The questionnaire identified a range of user requirements. Astronomers want a full data processing history but only a small minority want to do it themselves (however this possibility should always be open). Most astronomers want a final product, commonly but not exclusively an image. On-the-fly imaging will allow the full extent of archives to be used such as the MERLIN prototype (Fig. 1).

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[1] `http://www.ivoa.net/forum/radiovo/`

Interferometry is by definition a high-resolution science but two surveys covering substantial fractions of the sky, WENSS and NVSS are already available via their host observatories and Aladin. The first substantial multi-wavelength spectral data-cube survey to become accessible via Aladin will be the CGPS. The complementary and more traditional approach is to provide catalogues of pointings and source properties. Almost all open-access interferometers now provide on-line lists of observations. However there are two significant obstacles:

1. Archives often list observations by proposal code or non-standard source name. The named source may not be in the centre of the field. Considerable cross-referencing can be required to establish the spatial, spectral and temporal extent and the resolution and sensitivity of an observation.
2. Catalogue entries are often non-trivial to identify with SIMBAD sources. For example, how do you identify radio lobes tens of arcsec apart with the optical core of a QSO? Or distinguish between masers arising from an even larger star-forming region and those associated with a Mira variable along the same line of sight?

The first problem will be solved as observatories beome more aware of the benefits from serendipitous use of their data and as data access and VO use even in calibration is developed from the planning stage of new instruments, e.g. LOFAR: Smirnov (2004), ALMA: Schwarz (2004), CARMA: Scott (2004). The second is being tackled at CDS using iteratively refined astronomical knowledge (e.g. spectral index properties) to find counterparts to catalogue radio sources. In the long term more sophisticated methods will be needed to locate data related to complex objects using astrophysical templates and pattern recognition, investigating techniques already developed by planetary scientists.

At present, the MERLIN archive can be accessed by three routes; the MERLIN web page, via Vizier/Aladin and via the prototype AstroGrid registry. VO searches and automatic updating (harvesting) will be implimented. This relies on accurate metadata consistent with global standards. An IVOA[2] working group is developing a radio interferometry data model. It is likely that most data providers will need a specialised data model for internal use. This should provide parameters needed by a generalised model (such as IDHA or the SIAP and SSA protocols) for providing data for users. For example, the factors determining the field of view (integration time, channel width, primary beam etc.) may have observatory-specific names and algorithms but the VO just needs to know the availability and quality of data in a given region.

4. Conclusions

Virtual observatories provide a great opportunity to open up all types of observation. Tools as well as data are needed to enable this in the case of complex interferometry data. Current experience suggests that observatories (real and virtual) should prioritise providing FITS images, calibrated visibility data and other products, in that order. Archive access is being retro-fitted to most existing radio observatories which is vital not only to provide a service to the

[2]`http://www.ivoa.net/twiki/bin/view/IVOA/IVOADMInterferometryWP`

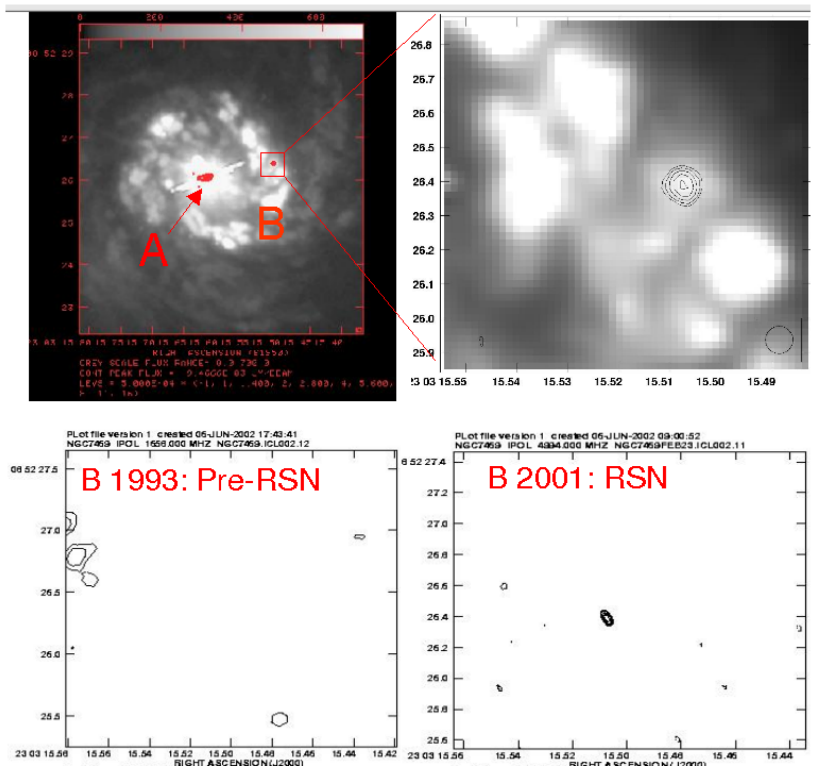

Figure 1. The top images (HST overlaid with MERLIN contours) show a radio supernova (B) in NGC 7469 discovered by Colina (2001). The MERLIN archive revealed that HI absorption against the core A had been observed in 1993 and on-the-fly imaging of the calibrated visibilities showed that the RSN was not then detectable (lower left).

astronomers of today but to act as testbeds to ensure that the next generation of telescopes meet the demands of all potential users.

References

Colina, L., Alberdi, A., Torrelles, J. M., Panagia, N., & Wilson, A. S. 2001, ApJ, 553, L19

Diamond, P. J. & Kemball, A. J. 2003, ApJ, 599, 1372

Monnier, J. D. 2003, Reports of Progress in Physics, 66, 789

Richards A. M. S., Garrington S. T. G., Reynolds C. & Allen M. G. 2003 in The Scientific Promise of the SKA, Oxford, 2002, ed. Kramer M. & Rawlings S. `http://www.jb.man.ac.uk/ska/oxfordfull.pdf`

Schwarz, J. 2004, this volume, 643

Scott, S. L. 2004, this volume, 768

Smirnov, O. 2004, this volume, 18