REVIEW OF LINKED ARRAY INSTRUMENTS

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At cm wavelengths aperture synthesis radio-telescopes (arrays of linked antennas which synthesize an image of the sky with high angular resolution) are now becoming the dominant astronomical research tool. Major new facilities such as the VLA are in full operation, others such as the Australia Telescope are nearing completion and a number of telescopes designed to form images in real time have been converted to operate in the aperture synthesis mode (e.g. MOST, Bologna Cross). See Napier et al. (1983) for a review of modern synthesis telescopes. The high resolution, sensitivity and freedom from confusion have led the aperture synthesis telescopes into very diverse astronomical applications.

In addition to the obvious advantages of high angular resolution for increased detail in an image and avoiding confusion, there are a number of other less obvious advantages. Deconvolution algorithms take advantage of the precision with which the beam of a linked array is known to correct for sidelobes. New algorithms, such as those described in a previous lecture by Cornwell, which can factor out antenna dependant errors, now enable imaging with extremely high dynamic range. The highest dynamic range images which have been made have a ratio of more than a million between the brightest feature and the faintest believable feature. There may also be dynamic range advantages for spectral line observations. Errors which modulate the gain of an antenna, and hence its system temperature, as a function of frequency do not normally affect the output of the interferometer since the receiver noise is uncorrelated. This has been particularly advantageous in imaging spectral lines which are a very small fraction of the continuum signal.

The ability of an array to filter out extended emission, corresponding to Fourier components with spacing less than the minimum spacing in the array, can be both an advantage and disadvantage. It is an obvious advantage to filter out atmospheric emission and its variability with time. In more specialised cases, for example to measure the Crab Pulsar in the presence of the extended emission from the Crab Nebula, the signal to noise can be improved with an array which resolves out the extended emission causing an increase in the system temperature. However it is a disadvantage when this filter distorts the structure (causing a bowl) and decreases the sensitivity to low brightness objects.

The computations required to form an image using observations from different spacings and different days must be done with considerable precision to avoid degradation of the beam quality. As a result astrometric accuracy is an automatic by-product of any synthesis observation.

In many cases where it is necessary to map an area of the sky the synthesis telescope has a considerable advantage because of the number of simultaneous beams which can be

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formed. In general, the speed of a synthesis telescope to map an area of sky is only matched by a single dish of the same total collecting area if it has an array of feeds equal to the number of elements in the synthesis telescope array.

A synthesis telescope measures the low spatial frequencies with less weight (and for very low spatial frequencies zero weight) so it is always relatively less sensitive than a single dish of the same total area for large diffuse objects.

Because of the large number of receivers required it is far more expensive to obtain frequency agility with an array than with a single dish.

An array generates its synthesized beam by manipulating the phase of the received signals instead of the delay. As a result it suffers from severe chromatic aberration and wide-bandwidth imaging is only possible when the band is divided into many small pieces. This adds to the complexity of the back end and the imaging process and will limit the total bandwidth to that available in the correlator. An instrument which forms its image in the focal plane is not affected by this form of aberration and much wider bandwidths may be employed.

To optimize the quality and quantity of science done with a linked array radio-telescope a balance must be found between two opposing factors. On one hand it is necessary to make the instrument readily available to users with interesting astrophysical problems but who are not "black belt interferometerists". On the other hand the most demanding observations and the unexpected discoveries are most likely to be made by astronomers with a clear understanding of the property of the instrument they are using (eg Harwit 1981). Both of these goals can be satisfied by providing interface between the user and the instrument which is as far as possible free from the use of technical jargon and other factors which obscure the underlying principles of operation. As systems become more complex and flexible the use of expert systems may be the best way to provide a suitable user interface.

The development of low noise solid state receivers has greatly simplified and improved reliability of arrays requiring large numbers of low noise front-ends. The limiting factor in the design of arrays with a large number of elements is now becoming the correlator since its complexity scales as the square of the number of elements. Here also large scale integration is making it possible to design even larger correlators. The use of fibre optic cables for IF transmission pioneered in the Australia Telescope will make wider bandwidths available and again the limitation will depend on the maximum bandwidth achievable in the next generation of correlator.

Some of the most dramatic changes have come from the developments of new algorithms of the type discussed in a previous lecture by Cornwell. Deconvolution algorithms are becoming more robust and the implementations more efficient. The cost for given computing capacity continues to decrease making increasingly complex imaging problems accessible. Forefront research in this area includes the deconvolution of data combining multiple instruments or multiple fields on the sky (mosaicing). Another development enables us to take advantage of the better spatial frequency coverage obtained through bandwidth synthesis by allowing for variations in both intensity and spectral index across the image.

In the area of self calibration current research involves questions of uniqueness, application of additional constraints based on physical models of the atmosphere and, in the case of low frequencies, solving the self calibration problem in the non-isoplanatic case.

References

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