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MILLIMETRE WAVE CAPABILITY FOR THE AUSTRALIA TELESCOPE: A DISCUSSION DOCUMENT FOR USERS

Peter Hall, July 1990

1. Introduction

In this submission I suggest that the remaining Australia Telescope construction funds be used to complete the Mopra antenna to the point where it is useful as a 3 mm (100 GHz) instrument, to equip (or partially equip) the Compact Array with 7 and/or 3 mm receivers, and to investigate the feasibility of a millimetre wave long baseline array. I believe that this course is more sound than either building the long baseline array as originally envisaged or funding a centimetre wavelength VLBI network.

At present Australia has no operational radio telescope capable of being used above 43 GHz. Apart from a program of 115 GHz observations conducted some years ago at Epping, one early trial 43 GHz program, and my own recent 43 GHz Parkes studies, the millimetre region of the spectrum has been ignored in Australia. This is surprising given the new science generated by overseas millimetre wave astronomy programs and the potential contribution of small telescopes equipped with modest instrumentation: the type that might be operated by a university (Thaddeus 1989).

I state at the outset my view that astronomy remains a technology-driven science: new instrumentation, used by people willing to branch into areas outside their traditional interests, produces demonstrably good results. We in Australia can seize an important technological and scientific opportunity. For our own benefit, as well as the benefit of the next generation of astronomers and engineers, we should do so.

2. Millimetre Wave Astronomy

Recent published results and compilations such as those edited by Wolstencroft & Burton (1988) and Winnewisser & Armstrong (1989) contain ample evidence of the scientific contribution of millimetre wave astronomy. In addition, Payne (1989) offers an excellent overview of the current state-of-the-art in antenna, receiver, spectrometer and interferometer technology. Planetary and cometary astronomy, molecular cloud studies, the physics and chemistry of evolved stars, studies of the galactic nucleus, studies of the interstellar medium and star formation regions (and associated bipolar flows), the dynamics of external galaxies, and the nature of active galactic nuclei (AGN) are some fields in which millimetre wave work has been crucial.

The last field is one which is topical in centimetre VLBI proposals and which attracts some Australian workers at the moment. It is worth mentioning that millimetre waves allow the innermost parts of AGN to be probed. These radio cores (possibly the beginning of jets) become optically thin at millimetre wavelengths and the outburst activity apparently peaks in this region. Centimetre wave VLBI shows only the evolved structures (e.g. old ejected knots); Voltaoja (1989) notes that millimetre wave studies give clues to energy generation and channelling and notes that the millimetre regime is "where the action is". He also comments that the new Swedish-ESO Submillimetre Telescope (SEST)

4. Millimetre Wave Engineering

Millimetre wave engineering has been identified as an area of national priority by bodies such as the Australian Telecommunications and Electronics Research Board. This is no doubt due to the boom in overseas telecommunications research and development in areas such as point-to-point and inter-office links. While there is relevant engineering expertise within CSIRO, there is essentially no Australian commercial or industrial base in the millimetre wave telecommunications field. CSIRO therefore has a special responsibility in helping to build a national capability.

Very few Australian tertiary institutions have millimetre wave teaching or research facilities at the moment. This in itself hinders development of a national capability. Through our staff/student exchange schemes and joint research funding, CSIRO has a unique opportunity to help rectify the deficiency. Institutions such as the Universities of Sydney and Tasmania with a strong existing radio engineering and astronomy groups would benefit enormously from such input. Universities such as Western Australia and Adelaide with established physics and astronomy bases have the potential to contribute greatly to device and system design, fabrication and testing.

Programs involving millimetre wave technology offer significantly greater educational benefits and thence commercial opportunity than, say, the installation and maintenance of off-the-shelf centimetre VLBI systems.

5. Justification of the Millimetre Proposal

While the initial AT plan called for the construction of a three-element long baseline array, most of us recognize the scientific limitations of such an instrument, particularly if it is operated at centimetre wavelengths. I believe that millimetre wave programs of the types outlined have such clear benefits from the astronomical, imaging science, engineering, educational and technology transfer viewpoints that the ATNF is justified in re-casting the remaining construction plan.

My hope is that the university astronomers and educators who sit on our AT Users' Group will recognize the national advantages to be gained from embarking on what is a fairly modest millimetre wave program. We should however be wary of "in principle" endorsements which do not provide for immediate action. Although we are behind in this field, a well-directed program started soon could take us from an inferior to a leading position.

6. Summary of Proposal

I suggest the following steps in the development of an AT millimetre wave capability:

(i) completion of the Mopra telescope to the point where 7 and/or 3 mm receivers and appropriate back-ends are provided;

(ii) completion of two experimental 7 or 3 mm receivers for two elements of the Compact Array;

(ii) characterization of the CA antennas and Narrabri atmospheric conditions;

(iv) characterization of the Culgoora-Mopra baseline (or possibly the Culgoora-Mopra-Parkes baseline at 7 mm since we already have a 7 mm receiver at Parkes);

(v) provision of further CA receivers if the results of (ii) are favourable;

in Chile is in need of help from other southern telescopes in order to get the best out of AGN and other extragalactic observations.

Much millimetre wave work is done with 15-20 m single dishes operating below 120 GHz and situated at sites near 1000m elevation: instruments comparable with our Mopra telescope. One often hears comments in Australia that our atmospheric conditions are unsuitable for millimetre wave work. Indeed, this was a prime objection when my colleagues and I made the Parkes time request for our first 43 GHz program. In fact, our spectral line studies over several years have been virtually unhindered by weather. Most studies have been done in average winter conditions and some were done in fog or drizzle. Continuum programs are more vulnerable but the opinion of the experienced millimetre wave astronomers I have spoken to leads me to believe that we Australians take the weather too seriously. My own experience is certainly in line with Payne's (1989) results and interpretations of atmospheric effects. In any case, the Parkes 7 mm spectral line work is entirely viable; a 3 mm receiver at Mopra would quickly establish the merits of that site.

3. Millimetre Wave Interferometry

Little serious imaging has been done to date because the first millimetre arrays at Hat Creek and Owens Valley have only three antennas. Welch (1989) points out that with the expansion of these arrays, the commissioning of a five-element Nobeyama array and the completion of the European IRAM array, the techniques pioneered at longer wavelengths for making high quality images will become viable. He also gives an overview of current millimetre wave interferometric techniques, special problems encountered, topical astronomy (much of it relating to areas mentioned in the previous section) and potential development paths. In addition, the Australia Telescope director has summarised many of the scientific reasons for adding a millimetre wave capability to the instrument (Ekers 1989). Finally, the NRAO leaflet describing their proposed Millimeter Array (MMA) promises 350 GHz sub-arcsecond synthesis and describes many scientific objectives.

The AT Compact Array has six high quality antennas capable of operating to at least 115 GHz. At this frequency the instrument would yield a theoretical resolution of about 0.11 arcsec. although based on overseas experience poorer median values of "seeing" may be expected. Our signal processing and local oscillator systems have been designed with high frequency operation in mind. What we need to appreciate is that we have a unique window of opportunity available to us: the provision and operation of a millimetre wave imaging array in the south. The receiver technology needed is advanced, but not impossibly so. For example, I am convinced that our AT engineering groups are capable of building a 3 mm receiver equal to (or better than) the SEST unit.

My proposal is that we assess immediately the viability of high frequency operation of the Compact Array. To do this we need to characterize the antennas and the site atmospheric conditions. We should provide initially two 7 mm or 3 mm receivers, undertake holographic antenna meaurements and conduct atmospheric phase monitoring. The reasons I mention a possible 7 mm trial are that front-ends based on high electron mobility transistors (HEMTs) are likely available soon from the US or Europe (at least on loan) and very strong astrophysical SiO masers at 43 GHz may provide suitable holography test sources.

We should also recognize that millimetre wavelength VLBI observations experiments are already being carried out overseas. For example, a recent program involved SEST, Nobeyama, and antennas in Hawaii and North America. The observations were conducted at both 3 mm and 1 mm and, based on early processing, it appears that at least the 3 mm study was successful. Clearly, an AT millimetre wave capability would allow us to fill a void in the Pacific array.

(vi) extension to a millimetre LBA or VLBI network.

I estimate that with the remaining funds we could proceed to step (iv).

7. References

1. Ekers, R. D.: Development of the Australia Telescope. Presented to symposium "Future of Astronomy in Australia" Canberra, June 1989. AT35.4/003.

2. Payne, J. M.: Millimeter and Submillimeter Wavelength Radio Astronomy. *Proc. IEEE,* 77, July 1989, pp. 993-1017.

3. Thaddeus, P.: Galactic Molecular Surveys: The Role of Small Telescopes. In *The Physics and Chemistry of Interstellar Molecular Clouds,* Springer-Verlag, 1989, pp. 14 - 21. See ref. 7 below.

4. Voltaoja, E.: Extragalactic continuum sources. In *ESO Messenger,* 57, Sept. 1989. (A special edition marking the first anniversary of the SEST).

5. Welch, W. J.: Techniques and Results of Millimetre Wave Interferometry. In *Millimetre and Submillimetre Astronomy,* Kluwer, 1989, pp. 95-116. See ref. 6 below.

6. Wolstencroft, R. D. & Burton, W. B. (eds.): *Millimetre and Submillimetre Astronomy,* Kluwer Academic Publishers, Dordrecht, 1989.

7. Winnewisser, G. & Armstrong, J. T. (eds.): *The Physics and Chemistry of Interstellar Molecular Clouds (mm and Sub-mm Observations in Astrophysics),* Springer-Verlag, 1989.