MILLIMETER ARRAY NEWSLETTER

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I. Millimeter Array Newsletter

This is the fifth issue of a newsletter intended to keep the astronomical community up to date on progress toward construction of a synthesis array for millimeter wavelengths in the U.S. The newsletter is edited jointly by F.N. Owen, P.C. Crane, and L.E. Snyder. Comments, requests, and/or contributions should be sent to

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We invite contributions in the forms of letters or articles. We also invite requests for additions to our mailing list.

II. Developments

During the past six months the most important development has been a decision inside NRAO to write a conceptual proposal for the millimeter array. This will be the starting point for obtaining funding for the project. We will write a document like the first volume of the VLBA proposal which will describe the general desire and requirements for the array. The proposal will be circulated in the community before it is submitted to the NSF. The decision on when and if we submit the proposal will depend on the reaction of the community and the funding situation at the NSF.

Funding is very tight at present. The VLBA project has been cut each year below NRAO's request, university grants seem more difficult to obtain, and the operating budgets of the national observatories are being reduced. Also the final effects of Gramm-Rudman are unclear. Thus the millimeter array seems further off than ever.

However, this is not the time to give up. The situation is in such a state of flux that it is difficult to predict where we will be in a few years. We have known for some time that the beginning of construction would probably not be until the 1990's; so how all the current situation affects us is unclear.

Our current plan is to proceed with site testing in order to find the best overall site. We have just finished automating (we think) the 230-GHz tipping device at the VLA, and it is beginning to take data in this mode. We are starting construction of at least three more of these devices for use on other sites, with the first one ready this fall. South Baldy, Grand Mesa, and Tucson are the sites currently planned for the devices. (The Tucson device will replace the device now being used at the VLA.)

If possible we would also like to test some sites on Mauna Kea. It seems clear that the sites on the top of the mountain are too small for even the smallest version of the array. Two possible sites exist at the 12000 ft level but these are not included in the current areas for astronomical use. One of the sites is near an area NRAO was considering for a VLBA antenna, which was not viewed favorably in Hawaii. Thus the current plan is to put the VLBA antenna on Mauna Loa with all the obvious problems associated with locating on an active volcano. As I understand it use of the sites on Mauna Kea for a millimeter array has not been ruled out but even testing the sites presents political difficulties. It is also far from clear that the 12000-ft sites will be very good. Crude extrapolation from the top of the mountain suggest that these sites might well not be very good, especially during the day. A guess might be that 2-5 millimeters of water vapor are present under typical clear conditions. Testing is clearly needed if we are going to consider Mauna Kea.

The scientific workshop held in October (discussed elsewhere in the newsletter) was quite exciting. Most of you should be getting the reports from the meeting over the next few months. We will use the results of the meeting as the basis for the scientific justification in the conceptual proposal. Although requirements for the array varied, most consistent, with the exception of the tradeoff between the transparency and the size of the site. A surprising number of experiments wanted long baselines, greater than 1 km. Many experiments require more than 10 km. This requirement seems to push one toward the VLA site or possibly the Aquarius plateau. On the other hand the dominant frequency band is clearly 200-300 GHz. This pushes one to higher sites with less water vapor. These sites will generally be smaller, more expensive and harder to staff and operate. Also we currently do not have any reliable data on the transparency (or phase stability) on any high site. We hope this conflict may be resolved by our site testing but we may well need to face reality and make a choice one day.

With the current budget situation we have some time to make these decisions. Nothing is ruled out at present but ideas are forming. Let's have some dialogue on these and any other questions.

F.N. Owen

III. Millimeter Array Science Workshop

The Millimeter Array Science Workshop, announced in the previous newsletter, was held in Green Bank on 30 September - 2 October 1985. The sixty astronomers present were charged with defining the scientific goals of the millimeter array. The discussions occurred within seven working groups: Chemistry (L. Snyder, chair), Solar System (I. de Pater), the Sun and the Stars (G. Dulk), Evolved Stars and Circumstellar Shells (P. Schwartz), Star

Formation and Molecular Clouds (N. Evans), Low-Z Extragalactic (L. BLitz), and High-Z Extragalactic (B. Partridge). Most groups found the benchmark array (see previous newsletter) well suited for doing the science they wanted to do. In the closing session of the workshop, the chairmen presented reports on the discussions in their groups, stressing the characteristics they deemed desirable for the array. The importance of dust-emission measurements was stressed by several groups, and such measurements (little explored by existing interferometers) were a goal which drove the frequency requirements of the array upward. Much of the discussion centered on tradeoffs between long baselines and high-frequency operation of the array.

The reports of the working groups will be issued as Millimeter Array Scientific Memomoranda, and the reports of the Solar System and the Sun and the Stars working groups have been issued as Memos 3 and 4, respectively. If you have not received copies, and would like to, please contact me. The remainder of the working group reports will be issued shortly. The reports will be collected, together with other relevant material such as the definition of the benchmark array, in a Green Bank Workshop Proceedings volume.

Some highlights of the working group reports:

1) Chemistry Working Group:

Interferometric maps of the OMC-1 cloud from Hat Creek have made it clear that abundances of interstellar molecules can vary substantially over very fine scales. The spatial-filtering properties of an interferometer can also be important in discerning small-scale fluctuations in the presence of a strong background, as might occur near embedded objects interacting with their surroundings. Chemical studies know no bounds on frequency, and broad coverage is important. High frequencies are important for the observation of light molecules, but resolutions provided by 1-km baselines seem adequate. Other strong demands on the array design are wide frequency coverage (several bands simultaneously), flexibility in frequency placement of correlator bands, and high frequency resolution.

2) Solar System Working Group:

Atmospheric and surface center-to-limb variations on the planets, satellites and comets could be made with <1% accuracy. Fast mapping, important due to rapid intrinsic variations, would be possible. Large planets could best be observed with only the inner parts of the 10m dishes illuminated, a capability which would be useful in the array. Imaging of the smaller objects (satellites, outer planets, asteroids) requires 0.1" resolution, corresponding to baselines >10 km at 30-50 GHz but only about 1 km at 1mm. Ideally, the frequency range of the instrument should extend from 30 GHz to 350 microns, but the 1, 2 and 3mm bands were judged most desirable. A higher, drier site no further north than the VLA site was recommended (specifically, the moon).

3) The Sun and the Stars Working Group:

Gamma ray-millimeter wave flares are probably the most important problems which the array could attack, and the taxing instrumental requirements for attacking this problem drive the design characteristics.

Flare observations require time resolution of <0.1 s and spatial resolution of <1" (about 1 km at 1mm), and very good uv coverage in snapshot mode owing to the complex and varying background. Rapid mosaicking is important, as exact flare locations cannot be anticipated. Simultaneous imaging at several wavelengths is important for definition of the changing energetic electron spectrum. Thermal photospheric or low-chromospheric radiation could be detected from about 600 stars, from the main sequence to giants. Canonical values for the stellar radii could be determined from the flux densities and effective temperatures. A direct check could be obtained through resolution of sixty nearby stars if 35-km baselines were available, about ten of which could be imaged.

4) Evolved Stars and Circumstellar Shells Working Group:

Both the Hat Creek and OVRO interferometers have produced impressive results. The isotopic composition of stellar envelopes, important observational data for studies of stellar and galactic evolution, needs to be studied at high resolutions. Photodissociation, for example, can introduce chemical gradients which confuse the interpretation of isotopic abundances in low-resolution observations. Dust observations are an important target for an array at the higher frequencies, to probe the region of its formation in evolved stars, and of its dissipation about main-sequence stars. Thermal emission from large circumstellar grains, as observed about Vega and Beta Pic, could be mapped with ten times the sensitivity of IRAS. Baselines as long as 10 km could be used to explore spatial scales down to 0.01" on some objects, and on SiO-maser stars. Such long baselines would be most useful for mapping dust emission, however, at high frequencies (1mm) where they may be difficult to obtain.

5) Star Formation and Molecular Clouds Working Group:

The power of interferometers has been amply demonstrated in this area by the OVRO and Hat Creek efforts. Most convincing evidence for the existence of protostellar disks derives from maps from these groups-the importance of spatial filtering for their detection and study is clear. On larger scales, the group found the central element very useful for rapid mapping of velocity fields over extended clouds. An important problem effectively addressed by the array is the identification and characterization of "protostellar" fragments. The brightness temperature of these cool fragments will be proportional to dust temperature and column density. In the absence of internal heating in a fragment, the interferometer will respond to the enhanced column density as the fragment contracts. A solar mass fragment would reach optical depth unity at a radius of 165 AU (1" in the nearest clouds). The group found that good performance at high frequencies was more important than baselines longer than 1 km. High spectral resolution (10 kHz) was recommended, as was the capability to observe several frequency bands with a flexible backend and IF system to measure many lines and continuum simultaneously.

6) Low-Z Extragalactic Working Group:

The OVRO maps of M51, IC342 and M82 have shown that the resolution afforded by interferometers is crucial to understanding the characteristics of molecular emission in galaxies. The benchmark array could map most of the CO emission from all the Shapley-Ames galaxies with 1" resolution-each galaxy would require a day or less of observation. Integrated emission from single galaxies might be detected to a z of 1. Using the diameters of tidally limited giant molecular clouds as standard rulers, one might usefully constrain the Hubble constant. Dust continuum emission at 1mm could be mapped in GMCs in nearby galaxies, and in nuclei out to 200 Mpc. Bandwidths of 10 GHz would be very important to maximize sensitivity. Most work discussed by this group is most effectively carried out at 1.3mm and shorter wavelengths, and the group found little need for baselines exceeding 3 km. Ideally, the J=2-1 and J=1-0, and 1mm and 3mm continuum emsission could be observed simultaneously.

7) High-Z Extragalactic Working Group:

The array could be important in determination of the small-scale structure of intrinsic temperature or intensity fluctuations of the background radiation when last it interacted with matter, and in observations of the Sunyaev-Zel'dovich effect. A large beam is important here, along with a stable atmosphere and wavelength short enough to avoid confusion by discrete sources, and these criteria are best met in the 30-50 GHz band. Even larger beams than provided by the benchmark array would be important, and very long baselines unnecessary. Redshifted infrared-bright primeval galaxies could be redshifted into the 1mm window at z>3, and may be detected with the array in its higher frequency bands. Some highly redshifted spectral lines (CI or CO) might be detected. The fine-scale mapping of inner radio jets and lobes, and the central engines, could be tied to VLBA maps if baselines of 3-30 km at the VLA site were available.

Al Wootten

IV. Millimeter Array Scientific Memorandum Series

As mentioned above, the reports of the scientific working groups at the Millimeter Array Science Workshop are being released as Millimeter Array Scientific Memoranda. The first two from the Solar System and the Sun and the Stars working groups are Memos 3 and 4, respectively.

We encourage the community to contribute to this series. Contributions should address specific scientific issues and their relation to the design of the array-for example, issues raised in the reports from the Science Workshop.

Contributions should be sent to

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We invite requests for additions to our mailing list, which is identical to the mailing list for the Millimeter Array Newsletter.

Two new memos have been released since the last newsletter:

3 Solar System Working Group Report — I. de Pater et al.
860201

4 Report of the Working Group on the Sun and the Stars G.A. Dulk et al.
860201

V. Millimeter Array Memorandum Series

Two Millimeter Array Memos (as of 31 March 1986) have been released since the last newsletter.

36 An Interim mm-Wavelength Astronomy Instrument R.M. Hjellming
851111

37 Atmospheric Opacity at the VLA J.M. Uson
860228

Copies of individual memos may be obtained by writing to

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VI. Future Developments for the Caltech Millimeter-Wave Interferometer

Within the next three years major expansion is planned for the Owens Valley three-element millimeter-wave interferometer: the addition of three more 10.4-meter antennas, the construction of an expanded and more flexible correlator, and the implementation of routine capability at 1.3 mm. The proposed six-element array, with the equivalent collecting area of a 24.5-meter telescope, will allow synthesis mapping with 2.5" resolution at 1.3 mm in an eight-hour observation. The greatly increased speed of the array will also make it a practical user facility, with up to fifity percent of the time available to the general astronomical community.

The present Owens Valley millimeter-wave interferometer has been operating in the three-element spectroscopic mode continuously (excluding summer shutdowns) for the past two years. Extensive mapping has now been done in the CO, 13CO, HC3N, CH3CN, and CS transitions in the 3-mm band. In addition to mapping molecules in local star-formation regions, the interferometer has also proven its ability to map nearby bright spiral galaxies. So far, the centers of five such galaxies have been mapped in CO, providing enexpected results in almost all cases.

In the present array the three antennas are equipped with SIS receivers and can be moved on a T-shaped track extending 100 meters east, west, and north from the center. The accuracies of the antennas are sufficiently high that they can be used for interferometry in both the 2.6- and 1.3-mm bands. One of the antennas has already been used extensively for single-antenna spectroscopy at 200-275 GHz.

The addition of three more antennas at Owens Valley in the next three years will greatly increase the sensitivity, the calibration accuracy (which limits the dynamic range), and, most importantly, the speed with which one can map a given source. One of the new antennas will have a multiple-feed system illuminating 4-meter patches of the primary to provide data on short u-v spacings. The effective field of view for mapping small-scale structure over regions larger than the primary beam can be expanded by tesselating multiple images. This approach has already been applied successfully to a 2' by 3' image of the CS emission in Orion (Mundy et al. 1986).

The new spectrometer will be of the hybrid filter-digital type providing flexible coverage within a total bandwidth of 500 MHz with 128 channels per baseline. The 128 channels can be divided among as many as four separate spectral lines.

Lastly, the 1.3mm band will open up new spectral lines for study and allow high-resolutution observations of the continuum emission from the dust in star-formation regions.

Full capability for data editing, calibration, and imaging (using AIPS) already exists on the VAX-11/750 at Owens Valley. Further expansion of the computer capability with the addition of an array processor and an image-processing terminal is also planned.

Besides the large increase in sensitivity, the expansion of the array will greatly facilitate its use by outside observers, since data collection will no longer need extend over a month. We expect fifty percent of the observing time to go to outside (non-Caltech) observers. The expanded array will provide a powerful interim instrument until the construction of the national millimeter array.

Nick Scoville

VII. Mosaicing?

From Barry Clark to Bill Cotton:

I tend to object to the verbing (hic) of nouns. Doesn't the existing verb tesselate really express what you mean? In any event, if mosaic is to become a verb, it should follow the examples of panic and picnic, and add a "k" in front of an "ing" ending.