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save

COMMENTS ON A VERY LARGE ANTENNA

I. Problems of Major Interest in Radio Astronomy During the Coming Years: There are, of course, a large number of known specific problems which could be listed. In addition, however, many more will arise which cannot now be anticipated in any specific sense. It is as much for the latter as the former that improved instrumentation in radio astronomy is required. I list below a number of general areas in which advances may be expected.

1. Sun and Solar System

2. Statistics of Discrete Sources: Because of the potential value to cosmology of information concerning the distribution of distant sources, a great deal of effort is now going into this particular subject. Almost all of the very large antennas now in operation or under construction, including those at Cambridge, University of Illinois, and Ohio State, are principally for this purpose.

3. Properties of Discrete Sources: Many of the problems of discrete sources properly fall in some of the other areas listed below, since once a source is identified, its radio characteristics then give information of interest in various other astronomical problems. However, the identification of sources is still a major problem, and in this and other connections, source positions, spectra, brightness distribution, etc., form a class of their own. In addition, from the standpoint of cosmology and the statistics of sources, it is essential that positive evidence be obtained as to whether or not the majority of faint discrete sources are very distant extragalactic objects.

4. Star-Gas Interactions: This encompasses a very wide variety of problems,

including stellar formation and evolution. The radio observations that can be of value in this field are extremely varied, and include 21-cm line studies of particular regions and objects in the galaxy, studies of the thermal emission from various objects, studies of the nonthermal emission from the galactic radio sources, and possibly studies of radio emission from objects such as flare stars and T Tauri stars which have not yet been detected at radio wavelengths.

5. <u>The Structure and Evolution of Galaxies:</u> Here there are a large class of problems involving observations of both 21-cm line emission, and continuous emission from galaxies and clusters of galaxies.

6. <u>Structure and Dynamics of our Galaxy:</u> This problem has, of course, already been intensively studied by radio means, but there is a great deal more to be learned. In particular, the role of galactic magnetic fields is not well understood, and radio observations may offer one way to study this.

This brief listing is not meant to be all-inclusive, or very comprehensive. Each topic could, of course, be expanded on to considerable length. Nor are the topics distinct from one another - many specific investigations would provide information on several of the broader problems. However, if interpreted broadly enough, the list includes almost all radio astronomy investigations, in a delineation I think is amenable to what follows.

II. <u>What Programs Should the NRAO Instrument For:</u>

I believe that the NRAO should aim to provide instrumentation principally for items 4 and 5 in Section I. There are two reasons for this choice.

a) Radio astronomy has tended in the past to be a rather distinct field, with problems of its own and relatively few connections with other astronomical problems. I do not believe that this situation should or will continue, and that radio astronomy will more and more become an additional tool for studying the usual astronomical problems. In the general areas 4 and 5 above, radio astronomy is potentially capable of providing a very great deal of information which, when used in conjunction with optical observations, should contribute immensely to these problems. This potential value of radio astronomy is largely unexploited thus far.

b) The other problems, 1, 2, 3 and 6, are in general being heavily concentrated on at other institutions.

The only properties of a source of continuous emission which are, in principal, directly observable are:

a) the position of the source;

b) the brightness distribution across the source;

c) the spectrum - intensity as a function of wavelength;

d) any time variations of the above parameters.

polarization

Certain specific problems might best be done with antennas specifically designed for the problem. However, if the NRAO is to aim towards the general problems suggested above, we should acquire an instrument which is as versatile as possible, in terms of the above observable quantities.

The first listed parameter - position - requires, for precise determinations, specialized equipment. As long as our telescope has accurate relative settability, most problems can be pursued without precise knowledge or determination of absolute positions. In addition, several other instruments will be capable of precise position determination. I do not think accurate measurement of absolute positions should be a requirement of our telescope.

The last parameter - time variations - may come to be extremely important. However, this imposes requirements on observing techniques and calibration procedures more than on the nature of the telescope.

The middle two quantities - brightness distribution and spectrum - are the controlling factors in determining many of the telescope characteristics. The general telescope characteristics indicated are:

1) The telescope should not be a single frequency instrument, but must have wide frequency coverage. Spectral information is of major interest in almost all of the problems we may be concerned with. Furthermore, recognition and separation of thermal and non-thermal components of radiation requires observations at more than one frequency.

2) The telescope should have high resolution. Many of the problems of interest will involve objects or regions of sky which have complex fine structure in the brightness distribution.

3) The telescope should have high gain, since many of the problems will involve the study of weak signals. The existence of radio emission from certain objects can today be inferred from other

known properties of these objects, but the radio emission is too weak for existing equipment.

4) The telescope must have compatible gain and resolution. This essentially means that the telescope should have a filled aperture, so that both gain and resolution are set by the same linear dimensions. Gain and resolution can be increased independently of one another in various ways. Interferometric techniques increase resolution without corresponding gain increase, and cause serious problems of confusion which make interpretation of observations of individual objects or small regions of the sky difficult. An increase in system gain by increasing receiver sensitivity is, of course, always desirable. However, the ratio of side lobe to main lobe gain is set solely by the antenna system, and can be a limiting factor in many problems. It may very well be desirable, on occasion, to use the large antenna in an interferometer, for special problems, and we will certainly take advantage of every increase in receiver sensitivity, but the basic instrument should have compatible gain and resolution.

5) The telescope must have some degree of sky coverage. There must be sky coverage in declination to allow observations of as large a portion of the sky as possible. In addition, the instrument should not be solely a transit instrument, but should have some sky coverage in hour angle. This is necessary to provide reasonable integrating times for weak sources, and also, because so many of the problems will involve intense study of

particular objects or small regions of the sky, to allow observations of a particular object or region for as long a period of time as possible in a given day.

6) Telescope should not differentiate between orthogonal modes of polarization.

There are additional factors which govern the choice of frequency range to be covered. They are:

a) The telescope should operate at 21-cm wavelength. Hydrogen line studies are of great importance in both of the major fields suggested. In addition, to observe the red-shifted line, the telescope should go to longer wavelengths. It is difficult to set a long wavelength limit on this basis.

b) Several other factors should be considered in setting the long wavelength limit. The flux from nonthermal sources increases rapidly with wavelength, thus giving stronger signals to work with. The brightness of the background and the relative effects of the sun and other strong sources also increases with wavelength. For spectral information, a range of at least 2 or 3 to 1 is desirable. If a source emits both thermal and nonthermal radiation, as may frequently be the case, a still greater spectral range is desirable.

c) Observations at wavelengths shorter than 21-cm are also very desirable. Many thermal sources of radio emission become optically thick at wavelengths longer than 21-cm. With a given antenna, therefore, where the gain increases with decreasing wavelength, thermal sources of small angular extent can best be observed at shorter wavelengths. Another factor favoring shorter wavelengths is receiver sensitivity. The sensitivity obtainable today at centimeter wavelengths is comparable to that at longer wavelengths. There is every expectation of considerable improvement in sensitivity at all wavelengths. At the longer wavelengths, however, sensitivity is now, or soon will be, set by background noise, spillover, etc. This is not the case at centimeter wavelengths, where improved receiver sensitivity leads immediately to improved system sensitivity.

In view of these qualitative considerations, I believe that a wavelength of 60 to 75-cm is the longest that should be considered, if it is necessary that the antenna have a long wavelength limit. The operable wavelength range should extend to 21-cm, and as far beyond as is economically possible.

The exact degree of sky coverage that may be achieved, and upper limit to operating frequency, are largely economic problems that should be settled in the course of the feasibility study. Some compromise between sky coverage, high frequency limit, and other characteristics of the antenna will undoubtedly have to be made, but I don't think they can be intelligently made until some engineering and cost studies have been done, and an overall dollar figure has been set.

I personally feel that a large spherical reflector probably best fits the requirements discussed above. A fixed spherical reflector has, to my mind, two great advantages:

1) The size of the reflector can be fairly easily increased simply by adding another ring around the outside.

2) Various different combinations of illuminated aperture and sky coverage can be obtained with different feed combinations.

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