LONG WAVELENGTH OBSERVATIONS OF SOLAR AND EXTRA SOLAR SYSTEM BODIES

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ABSTRACT

Very low frequency ($\lesssim$ 100 MHz) observations of planetary bodies hold the promise of probing regions which are extremely difficult to measure via any other remote sensing (or direct, for that matter) technique. We focus here on imaging of emission from Jupiter (current - from VLA observations at 74 MHz, and future) and possible future detection of emission from extrasolar giant planets.

INTRODUCTION

Very low frequency ($\lesssim$ 100 MHz) observations of planetary bodies hold the promise of probing regions which are extremely difficult to measure via any other remote sensing (or direct, for that matter) technique. At a frequency of 100 MHz, depths of 10's of meters are probed for the subsurfaces of the solid body planets, and 10's of bars (or deeper) for the atmospheres of the giant planets. In addition, a unique energy regime in the relativistic electrons in the magnetosphere of Jupiter is probed. Studies of the Sun at these frequencies could be carried out with low frequency radar (to probe CMEs), and by angular broadening observations. Finally, there is the possibility that extrasolar giant planets (EGPs) could be detected at these frequencies. We will focus here on the emission from Jupiter and EGPs.

JUPITER

Although the first observation of a solar system body (other than the Sun and Moon) at radio frequencies was at 22 MHz (Jupiter - [1]), nearly 50 years later we still have relatively little reliable data on solar system bodies (including the Sun and Moon) at these very long wavelengths. In order to make sensitive observations at these low frequencies, a combination of an instrument with enough raw sensitivity and resolution with an effective technique for rejection of confusing sources must exist. In the past, these two have not really existed together. With the current state-of-the-art (the VLA 74 MHz system), we are just beginning to reach the point in both of these two dimensions where observations of Jupiter are possible.

74 MHz Observations of Jupiter at the VLA

We have observed Jupiter with the 74 MHz system of the VLA (the VLA is operated by NRAO) twice in the last three years. The first observations were on September 19 and 20, 1998. These data sets proved extremely instructive in terms of learning how to do the background source subtraction, which is non-trivial. We had special problems subtracting the strong sources Cas-A and Cygnus-A, which were both in the sidelobes during our observations. After much effort, and using newly implemented techniques (which we helped in part to develop), we were able to satisfactorily subtract most of the background source emission in the end. The resultant images had a formal rms on each day of $\sim$110 mJy/bm. Combining the two days yielded the expected decrease in noise level, to $\sim$75 mJy/bm. Fig. 1 shows the images from the two days, with nearby background sources indicated. The motion of Jupiter (which presents other special problems) is obvious. Our result for the flux density of Jupiter at 74 MHz is 4.82 $\pm$ 0.14 Jy (normalized to a distance of 4.04 AU). When combined with simultaneous 330 MHz observations, where the measured flux density was 5.16 $\pm$ 0.10 Jy, we have observed reliably for the first time the low frequency turnover in the spectrum of Jupiter. This implies that the energy

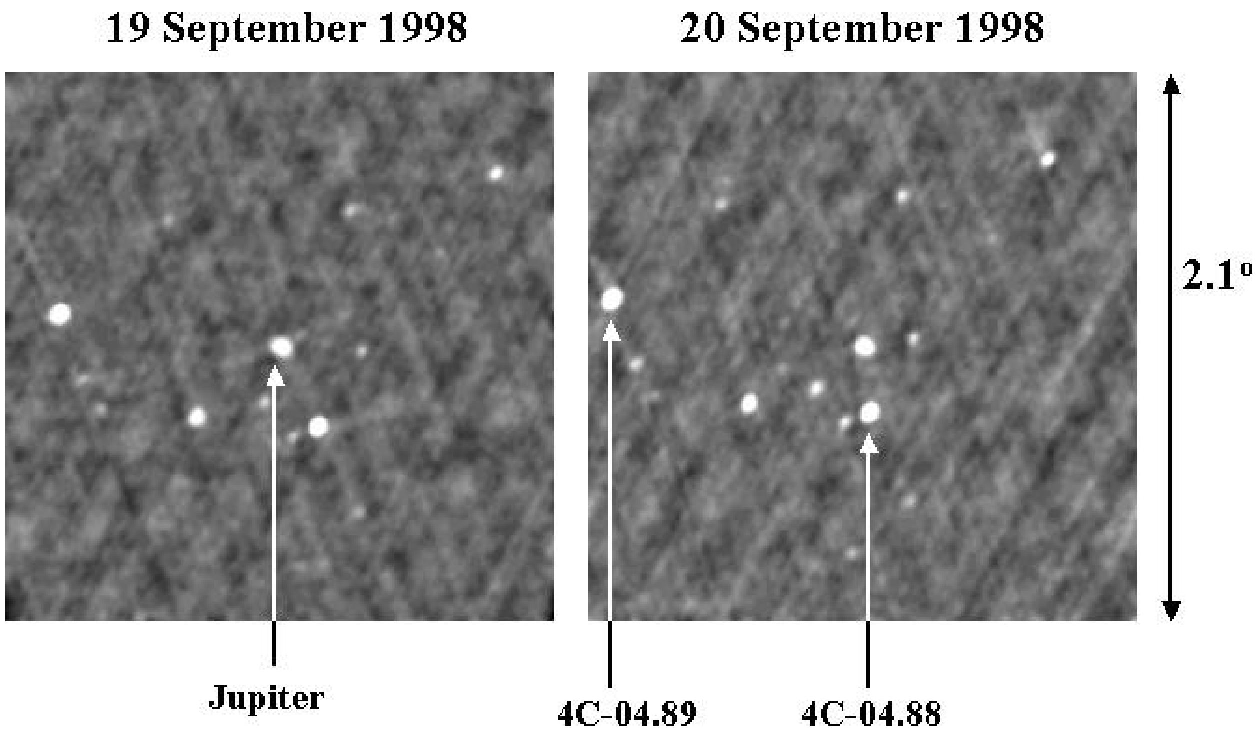

Figure 1: Radio images of Jupiter at 74 MHz taken on September 19 and 20, 1998. Jupiter is located at the center of the image, as indicated; the sources 4C-04.88 and 4C-04.89 are also indicated. Jupiter's motion with repect to the background sources can be seen clearly. From [2].

spectrum of electrons in the magnetosphere of Jupiter (which is where the emission arises from) consists of two power laws, consistent with in situ spacecraft data. Our second set of 74 MHz Jupiter observations were taken on six days in January and February, 2000. These data await full reduction, and should allow us to determine whether the emission at this long wavelength is variable.

With our current observations, the emission from Jupiter is barely resolved. In order to make much more definitive statements about the structure and energetics of the electrons in the magnetosphere (for the electrons with the appropriate energy range), images with much higher resolution are needed. If we could resolve, for instance, where the peak of emission was at the long wavelengths (relative to the shorter wavelengths), then conclusions regarding the importance of electron pitch angle scattering might be reached. This higher resolution must be accompanied by an increase in sensitivity, however, since as the resolution gets too fine, the emission begins to get resolved out completely.

EXTRASOLAR GIANT PLANETS

The emission from Jupiter at 74 MHz is dominated by emission from relativistic electrons in the magnetosphere. At lower frequencies, however, there is extremely strong emission from electrons in the auroral zones of the planet. This cyclotron maser emission occurs at frequencies $\lesssim 40$ MHz. The emission is very sporadic, but can reach magnitudes of 10^5 Jy. Could this emission be present at detectable levels on giant planets which have been discovered orbiting nearby stars (EGPs)? Current theory suggests that it is possible [3,4], though it may be that it is necessary to catch the planet in an outburst. Searches with the VLA at 74 and 330 MHz have been unsuccessful so far, however [5]. Added sensitivity and lower frequencies are what are needed for more conclusive searches for this emission.

THE FUTURE

There are currently two instruments being proposed to be built which would provide additional sensitivity and resolution at low frequencies - LOFAR and SKA. Prospects seem good that at least LOFAR may come on-line within the next decade or so. The techniques for confusing source rejection are currently being advanced significantly due to the work related to the 74 MHz system on the VLA. Although much remains to be done in this area, it seems reasonable to assume that by the time these new instruments become available, the techniques will be well enough developed to use effectively. With the added sensitivity, resolution, and reduction techniques, we expect that low frequency observations of planets will yield important and exciting results in the next decade.

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REFERENCES

[1] Burke, B.F., and K.L. Franklin, “Observations of a variable radio source associated with the planet Jupiter”, JGR, 60, 213, 1955.
[2] de Pater, I., and B.J. Butler, “Low Frequency VLA Observations of Jupiter”, Icarus, submitted.
[3] Farrell, W.M., M.D. Desch, and P. Zarka, “On the possibility of coherent cyclotron emission from extrasolar planets”, JGR, 104, 14025, 1999.
[4] Zarka, P., R.A. Treumann, B.P. Ryabov, and B. Vladimir, “Magnetically-Driven Planetary Radio Emissions and Application to Extrasolar Planets”, Ap&SS, 277, 293, 2001.
[5] Bastian, T.S., G.A. Dulk, and Y. LeBlanc, “A Search for Radio Emission from Extrasolar Planets”, ApJ, 545, 1058, 2000.