300 MHz Survey of Cyclotron Emission from known Extra-Solar Planets

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ABSTRACT

All magnetized planets in our solar system emit intense cyclotron maser radiation. Like Jupiter, the recently discovered extra-solar planets are probably magnetized. If in addition, there is a source of energetic (keV) electrons in their magnetospheres, it is likely that extra-solar planets are also cyclotron-maser emitters.

We present a progress report on a survey of 16 Extra-solar planets around nearby stars. This survey used the Robert C Byrd Green Bank Telescope (GBT) for dual circularly polarized observations at 285 to 335 MHz. Using the GBT spectrometer, we produced high time and frequency resolution observations, searching for flaring events. To date, only upper limits can be placed on the flaring emission from these planets. Since cyclotron maser emission from Jupiter is episodic, long observations may be required to detect Extra-solar planets. Detection of Faint Radio Sources by Spectral Variation is Difficult!

Models for Extra-Solar Planets based on Jupiter Data

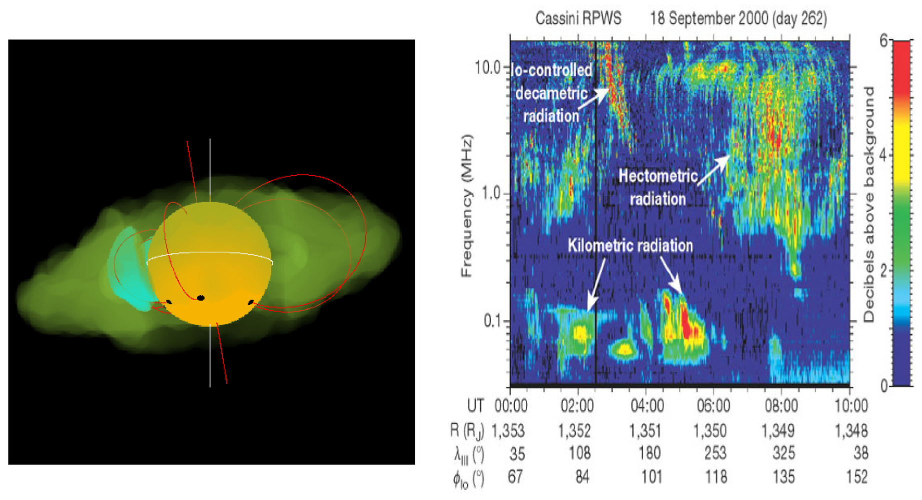

Figure 1a (left). Graphical Representation of Jupiter's Magnetic fields (from R. Sault 2002). Figure 1b (right). Dynamic spectra for Jupiter, illustrating the type of events expected for the extra solar planets (from D. Gurnett 2002).

Introduction

Like Jupiter (Burke and Franklin 1955), the recently discovered extra-solar planets are probably magnetized. We present a survey of nearby planets, in which the GBT was used to observe known systems over the frequency range 285 to 335 MHz.

The data reduction is not yet complete, as Radio Frequency Interference (RFI) has made confirming detections difficult. Here we present the observing techniques and an example of the data obtained. Figure 1 shows the type of emission expected, based on models for Jupiter. (In order for these systems to be detected by our observations, the extra-solar planets must be more strongly magnetized and have higher particle densities than Jupiter.)

The visible and infrared emission from planets is much weaker than the parent stars, but radio emission need not be (see Farrell, W. M., Desch, M. D. & Zarka, P. (1999), and Bastian, Dulk and Leblanc (2000)). Extreamly intense radio emission can be generated by the electron-cyclotron maser instability. The requirements for the instability are simple: a magnetic field and a source of energetic (Kev) electrons. The emission frequency is typically the electron gyro-frequency, f(MHz) = 2.8 B (Gauss) and is therefore proportional to the magnetic field strength B. The maximum frequency is the gyro-frequency near the planets surface. For Jupiter, $f_{max} = 39.5$ MHz, so $B_{max} = 14.5$ Gauss. For extra-solar planets to be detected with the GBT, the planets must have stronger magnetic fields, of order 110 Gauss.

Why search for radio emission from extra-solar planets? The radio emission is a means of detecting a planet directly. Once detected the magnetic field and rotation properties of the planets can be measured. Since cyclotron maser emission from Jupiter is episodic, long observations toward the planets may be required to detect cyclotron maser emission from extra-solar planets.

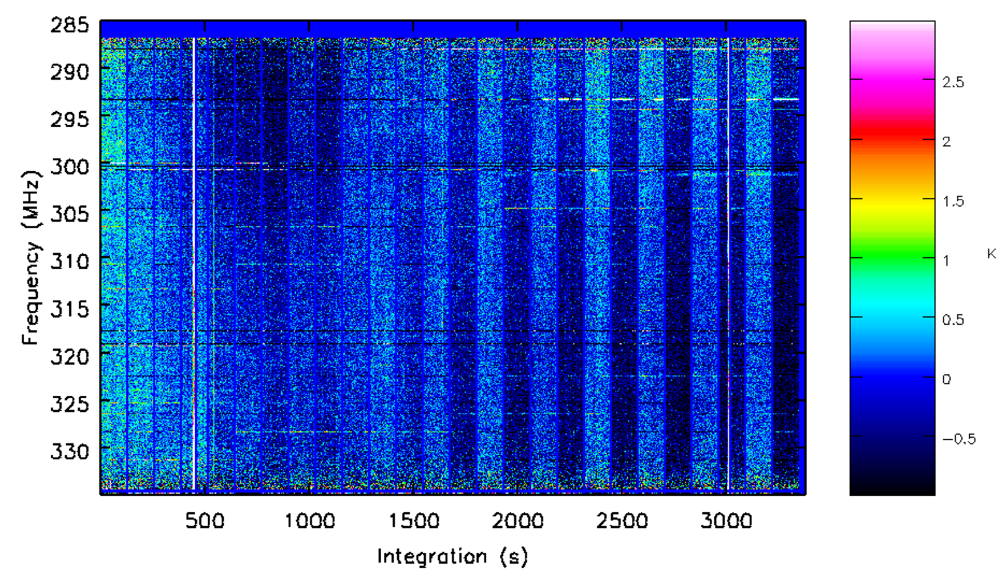

Figure 2. Graphical Display of a time series of integrations on the *Upsilon Andromedae (Ups And)* system. The plot shows time on the horizontal axis and frequency (335 to 285 MHz) on the vertical axis. The Off/On scans are in pairs, with Off preceding On source scans.

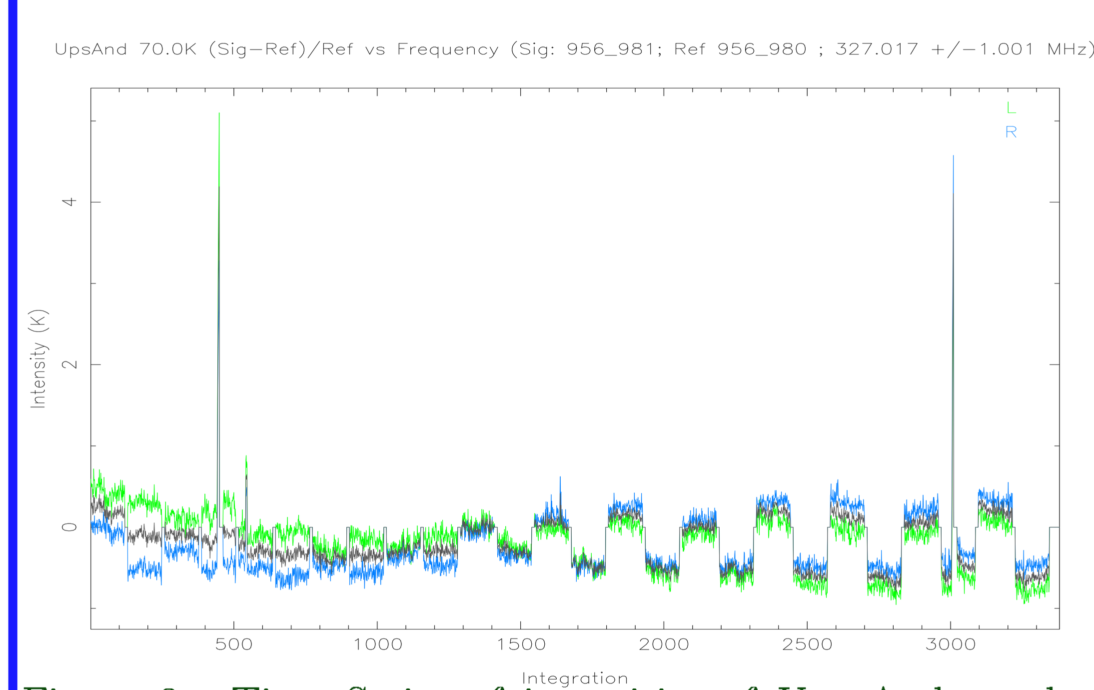

Figure 3. Time Series of intensities of Ups Andromeda, showing 26 scans, each of 2 minute duration. The scans are in Off Source, On source pairs. The spikes in emission in the 4th and 26 scans are while observing *Ups And*, but are probably due to RFI. There are no significant medium term events indicating maser emission. The long term variations are due to the On and Off source locations having slightly different elevations causing changes in the system temperature.

Conclusions

We have made observations towards extra-solar planet systems and place limits on medium term ($\sim$ 2 minute) variability. These sources do not show flaring emission greater than 0.5 Jy over a single 2 minute scan. These limits will be improved after more careful examination of the spectra and rejection of data corrupted by RFI. Data reduction algorithms must be carefully designed to reject RFI, especially burst of emission, strong enough to corrupt observations over the entire observing band.

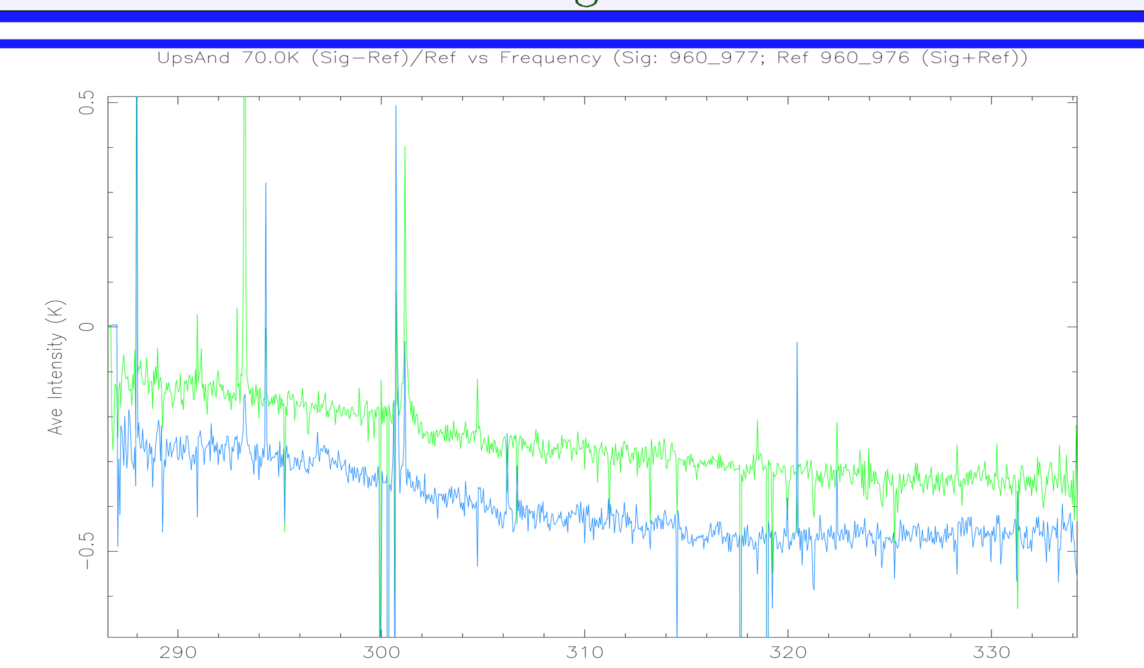

Figure 4. Dual polarization spectral of *Ups. And.*, showing the RFI present in this band. X axis is frequency in MHz and Y axis is Intensity (K). The spectral intensities are negative because the off-source position contains a background radio source.

Observations

The observations were performed on 2002 August 28, 29 and 30 using the GBT and prime focus 1 (PF1) receiver with the 280 to 350 MHz feed. The observations used the dual left and right circular polarization of the PF1 receiver. The calibration noise diode was continuously fired at a 5 Hz rate. The observations were obtained in 2 minutes scans, each consisting of 119 one second integrations.

The scans were obtained in Off/On Source pairs, to allow calibration of the observations by:

$$T_{sys} \times (On_{source} - Off_{source})/Off_{source}$$

Fifteen pairs of scans were obtained for each source, yielding 30 minutes On source and 30 minutes Off source for each candidate. The Off source observations were also used as a check for RFI.

The time variability of these source is over three intervals: *1)* short, less than a few seconds, *2)* medium, variations over the two minute scan, and *3)* slow variations over the hour of observations.

Star Name	M *sin* i M_{jup}	Period (days)	Semimajor Axis (AU)	Eccentricity	K (m/s)
HD46375	0.25	3.024	0.041	0.02	35.2
HD187123	0.54	3.097	0.042	0.01	72.0
HD209458	0.63	3.524	0.046	0.02	82.0
51Peg	0.46	4.231	0.052	0.01	55.2
UpsAndb	0.68	4.617	0.059	0.02	70.2
HD168746	0.24	6.400	0.066	0.00	28.0
HD217107	1.29	7.130	0.072	0.14	139.7
HD38529	0.77	14.31	0.129	0.27	53.6
HD195019	3.55	18.20	0.136	0.01	271.0
HD168443	7.18	58.10	0.29	0.53	470.0
GJ876	2.07	60.90	0.207	0.24	235.0
HD37124	1.13	154.8	0.547	0.31	48.0
UpsAndc	2.05	241.3	0.828	0.24	58.0
HD12661	2.83	250.2	0.799	0.20	89.3
HD222582	5.18	576.0	1.35	0.71	179.6
16CygB	1.68	796.7	1.69	0.68	50.0

Measured properties of Extra solar planets observed The planets are listed in order of increasing orbital period. Parameter K is the measured velocity perturbation of the star due to the planet.

Discussion

A large number of short term events are seen, but these are probably due to RFI sources passing momentarily into one of the sidelobes of the main beam. The most promising detections are those of high RMS variations in the individual 2 minute scans. The long term variations appear in both the off-source and on-source spectra, suggest other effects are contributing to the brightness variations.

References

Burke, B. F. and Franklin, K. L. 1955, "Observations of a variable radio source associated with the planet Jupiter", *J. Geophys. Res.*, **60**, 213

Bastian, T.S., Dulk, G.A., and Leblanc, Y (2000), **Ap. J**, **545**, 1058.

Gurnett, D. A. *et al.*2002, *Nature*, **415**, 985.

R. Sault 2002, web site `http://www.atnf.csiro.au/people/rsault/jupiter`

Farrell, W. M., Desch, M. D. & Zarka, P. 1999, *Journal of Geophysical Research*, **104**, pg. 14025,