Transiting Planets
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Radio cyclotron emission from extra-solar planets

Alexis Smith[1]† Andrew Cameron[1] Jane Greaves[1] Moira Jardine[1] Glen Langston[2] and Donald Backer[3]

[1]SUPA, School of Physics and Astronomy, University of St. Andrews
St. Andrews, Fife, KY16 9BX, UK

[2]National Radio Astronomy Observatory, Green Bank, WV 24944, USA

[3]Astronomy Department, University of California at Berkeley, Berkeley, CA 94720, USA

Abstract. We present results from an attempt to detect radio emission from the interaction between a transiting extra-solar planet and its host star. We determine a new upper limit of 47 mJy on the radio flux density from HD 189733b, in the frequency range 327–347 MHz.

1. Introduction

Five solar system planets have magnetic fields (Earth, Jupiter, Saturn, Uranus, Neptune). Fast moving electrons from the solar wind are accelerated along the planet's magnetic field lines, and radiate cyclotron emission. The frequency of this emission is dependent upon the magnetic field strength. Jupiter has the strongest planetary magnetic field in the solar system, and emits cyclotron radiation at a peak of about 40 MHz. Observations of Jupiter's radio emission tell us about Jupiter's magnetic field, composition, and rotation rate.

Extra-solar planets with magnetic fields are expected to interact with their host stars' stellar winds, emitting cyclotron radio emission. Most attempts to predict radio flux from extra-solar planets have been based on scaling solar system parameters (e.g. Lazio *et al.* 2004). Several previous attempts to detect radio emission from extra-solar planets have been made, none successful to date. Observations have been conducted using a variety of telescopes at a range of frequencies and sensitivities (see Grießmeier *et al.* 2006).

New predictions (Jardine & Cameron, *in prep.*) account for the small orbital separation of hot Jupiters, which means such planets may lie within the stellar magnetosphere. Cyclotron emission is predicted from the star as well as the planet. Assuming a stellar field strength of 40 G (Moutou *et al.* 2007), the transiting planet HD 189733b is predicted to have a flux density, $f \approx 2.8(\rho/\rho_{\odot})^2$ mJy where ρ denotes the stellar coronal density. If the coronal density is four times solar, for example, the predicted flux density is 45 mJy.

2. Observations of HD 189733b

Observations of the transiting planet HD 189733b were conducted in 2007 April using the NRAO Robert C. Byrd Green Bank Telescope (GBT). Spectra covering 1024 discrete frequencies in the range 307 to 347 MHz were taken with a time resolution of 1 second. Observations of the target ('ON') were interspersed with observations of a nearby

† email: `amss@st-and.ac.uk`

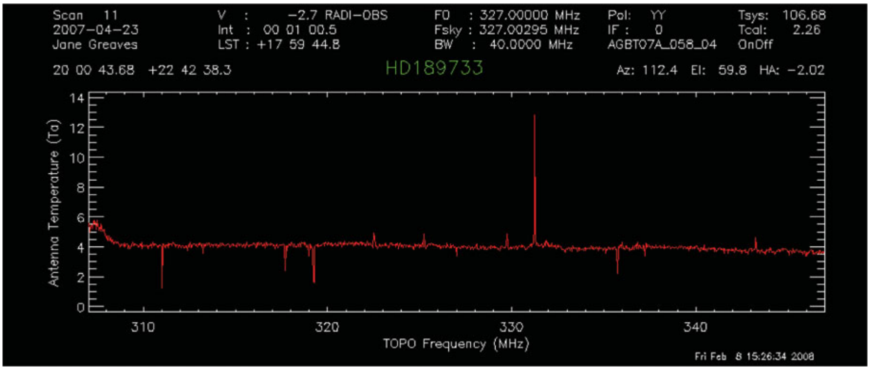

Figure 1. A typical GBT spectrum of HD 189733. The integration time is two minutes. The narrow 'spikes' (e.g. at ≈331 MHz) are caused by RFI.

(2 away) patch of sky ('OFF') for calibration purposes and to allow identification of radio-frequency interference (RFI).

Since the beam size is large (40 arcmin), we look for modulation of flux with the orbital period of the planetary system. The easiest way to do this is to observe a transiting planet during secondary eclipse, when radio emission should disappear as the planet moves behind the star.

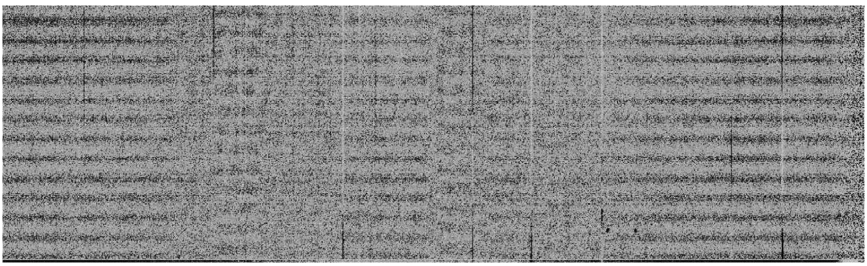

Figure 2. A series of time stacked spectra of HD 189733 spanning a total of five minutes. Frequency increases from right to left, time increases from top to bottom, while greyscale is indicative of flux (darker areas correspond to higher flux). The horizontal banding is caused by RFI from a military radar.

3. Analysis and conclusions

The observations were significantly affected by radio frequency interference (RFI) identified by presence in both ON and OFF scans. RFI was identified and removed in three stages:

(1) 7 pairs of scans contain obvious RFI across a range of frequencies. Probably caused by electrical interference in telescope control room. These scans were excluded from further analysis.

(2) Very narrow band (usually in just 1 or 2 frequency channels), short duration ($\sim$1 s) 'spikes' of high flux (see Fig. 1). 177 out of 1024 frequency channels were identified and excluded.

(3) Modulated RFI with a period of around 23 seconds, across all frequencies (see Fig. 2). Probably caused by a military radar system. A rectified sine wave was fitted to each 120 s block of data and subtracted.

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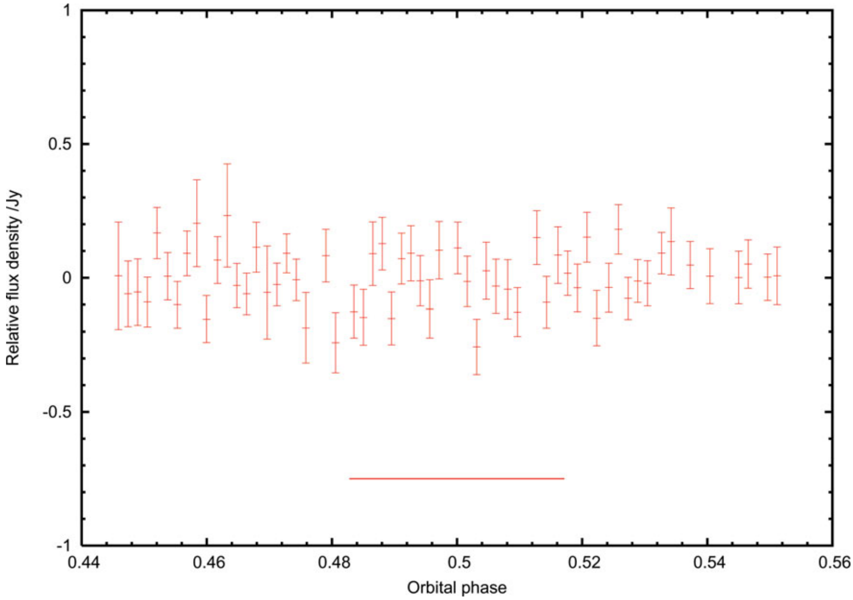

Figure 3. Radio (307 347 MHz) lightcurve of HD 189733b. The bar indicates the duration of secondary eclipse.

After removal of RFI, the data were binned and calibrated to produce a lightcurve (fig. 3). We fitted the lightcurve using a modified Box Least-Squares (BLS) algorithm (Collier Cameron *et al.* 2006), using the known time of secondary eclipse. Using the BLS algorithm, we determine the upper limit on the flux density of HD 189733 b in the 307 – 347 MHz regime to be 60 mJy, at the 3 sigma level. The equivalent limit for the 327 – 347 bandpass is 47 mJy.

These results suggest that the stellar corona may not be dense enough, or the planetary magnetic field not strong enough to produce detectable emission at the observed frequencies, but that our detection threshold is not far above plausible signal levels.

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