SEARCH FOR RADIO EMISSIONS FROM EXTRASOLAR PLANETS:
ANALYSES OF RADIO DATA TARGETED AT UPSAND

Daniel Winterhalter, Thomas Kuiper, Walid Majid, Joseph Lazio, and Geoffrey Bryden
Jet Propulsion Laboratory, California Institute of Technology

Introduction & Objective:

Non-thermal, low-frequency radio emissions have been observed for decades from planets in our solar system, and they are also expected from the magnetospheres of extrasolar planets. Particularly from "Hot Jupiters", extrasolar planets of Jupiter size that orbit their primary at very close range (< 0.1 AU in some cases), we expect the radiated power to be strong enough to allow detection from Earth. This is because the energy input into a magnetosphere so close to a star is orders of magnitude larger than that experienced by our own Jupiter.

Using the new 150 MHz receivers of the Giant Metrewave Radiotelescope (GMRT) in India, we have searched for radio emissions from a sub-set of known "hot Jupiters". We have observed several extrasolar planetary systems (see “selection of targets” table below). No observation of these targets has been attempted previously at these frequencies with the sensitivity and aperture offered by GMRT. Calibrations with GMRT at 150 MHz have confirmed the noise floor to be 2 mJy over a 5 MHz bandwidth. The noise floor is well below the expected flux levels from the targets.

Because of early promising observations, we have concentrated in the current effort on the Upsilon Andromeda planetary system.

Objective of the Study::

With The GMRT radio telescope, search for low frequency radio emissions from the Upsilon Andromeda planetary system. Analyze the data with AIPS and other CLEANing software to reduce the noise level due to interference.

Benefits to NASA and JPL

The proposed experiment is highly relevant to long-wavelength astrophysics, fundamental space physics, the formation & evolution of planetary systems, and the interior structure and thermal evolution of extrasolar planets. Furthermore, the proposed project will supply information on the interaction of planetary magnetospheres with stellar winds, potentially covering a wider range of parameters than present in our solar system.

The discovery and characterization of extrasolar planets is an important aspect of NASA's Origins Program. Here, we investigate the possibility of planetary searches around variable stars, which are eliminated from the traditional radial velocity surveys and from SIM's and TPF's target lists. Applying this method to stars of low variability will augment information gained from SIM and TPF. Discovery of the radio emissions will prompt spacecraft missions to exploit lower noise regions away from Earth (e.g., Moon), and to access lower frequencies (= higher flux density) above the ionospheric cut-off altitude.

Publications:

Kuiper, T., et al., American Geophysical Union, 2005.

Majid, W., et al., American Geophysical Union, 2005.

Majid, M., et al., European Geophysical Union, 2005.

Majid, W., et al., in “6th International Workshop on Planeterary Radio Emissions”, 2005 (submitted).

Winterhalter, D., et al., American Geophysical Union, 2005.

Winterhalter, D., et al.,American Geophysical Union, 2005.

Winterhalter, D., et al., Search for Radio Emissions from extrasolar planets: The observation campaign, in “Planetary Radio Emissions 6”, ed. Rucker, H.O., W.S Kurth, and G. Mann, Östreichische Akademie der Wissenschaften, Wien, 2006.

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We conducted a series of observations at the GMRT (Giant Meterwave Radio Telescope, Pune, India) during the observatory's Cycle 7 observing period, with a center radio frequency near 150 MHz. We collected both interferometric as well as pulsar mode (phased array mode) data on a number of sources simultaneously. In interferometric mode, we used 22 of the 30 antennas, excluding one or two extreme antennas in each arm as well as four antennas that were not operating at 150 MHz. On March 16, we recorded exclusively in pulsar mode. In pulsar mode, we only used the central square array (CSQ) because of their phase stability over long durations and the nature of the pulsar mode data stream, which unlike interferometric mode, rules out post-correlation phase corrections. The analyses of the Upsilon Andromeda data brought the following results.

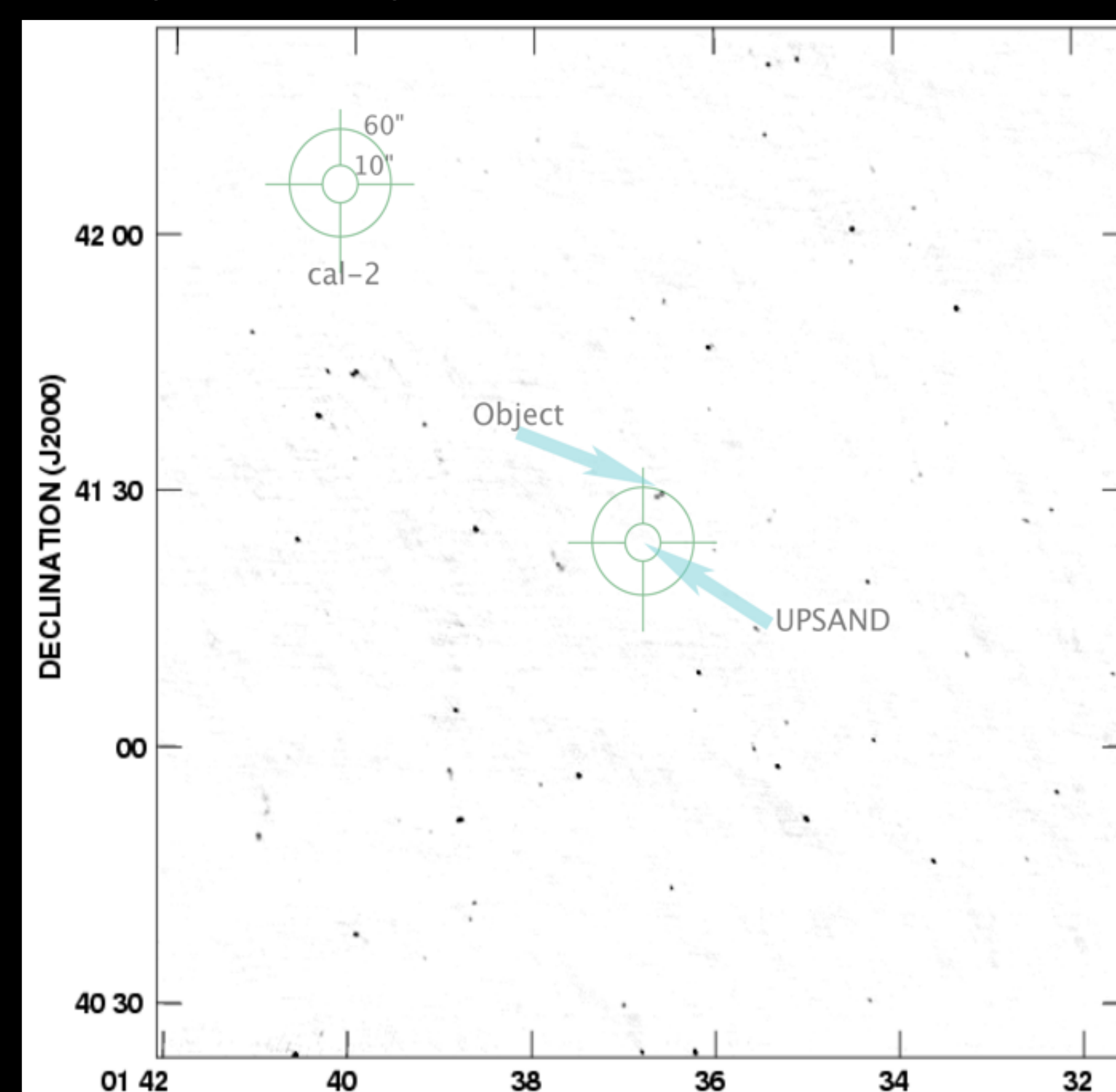
RESULT 1: Radio Map

A radio map of the Upsilon Andromeda region. It is the most sensitive map ever in this frequency regime (153 MHz):

- **Beam size ≈ 60 arcseconds.**
- **1 hr integration, 5 MHz bandwidth.**
- **RMS Noise: 3 mJy (expected signal 147 mJy)**
- **Nothing is seen at the location of UpsAnd.**

The negative result can have one (or all) of at least three reasons:

1. The emissions are much lower in power than the estimates indicate.
2. The cut-off frequency for the emissions (determined by the largest B-Field, i.e., those close to UpsAndb) is below 154 MHz.
3. The emissions are strongly beamed

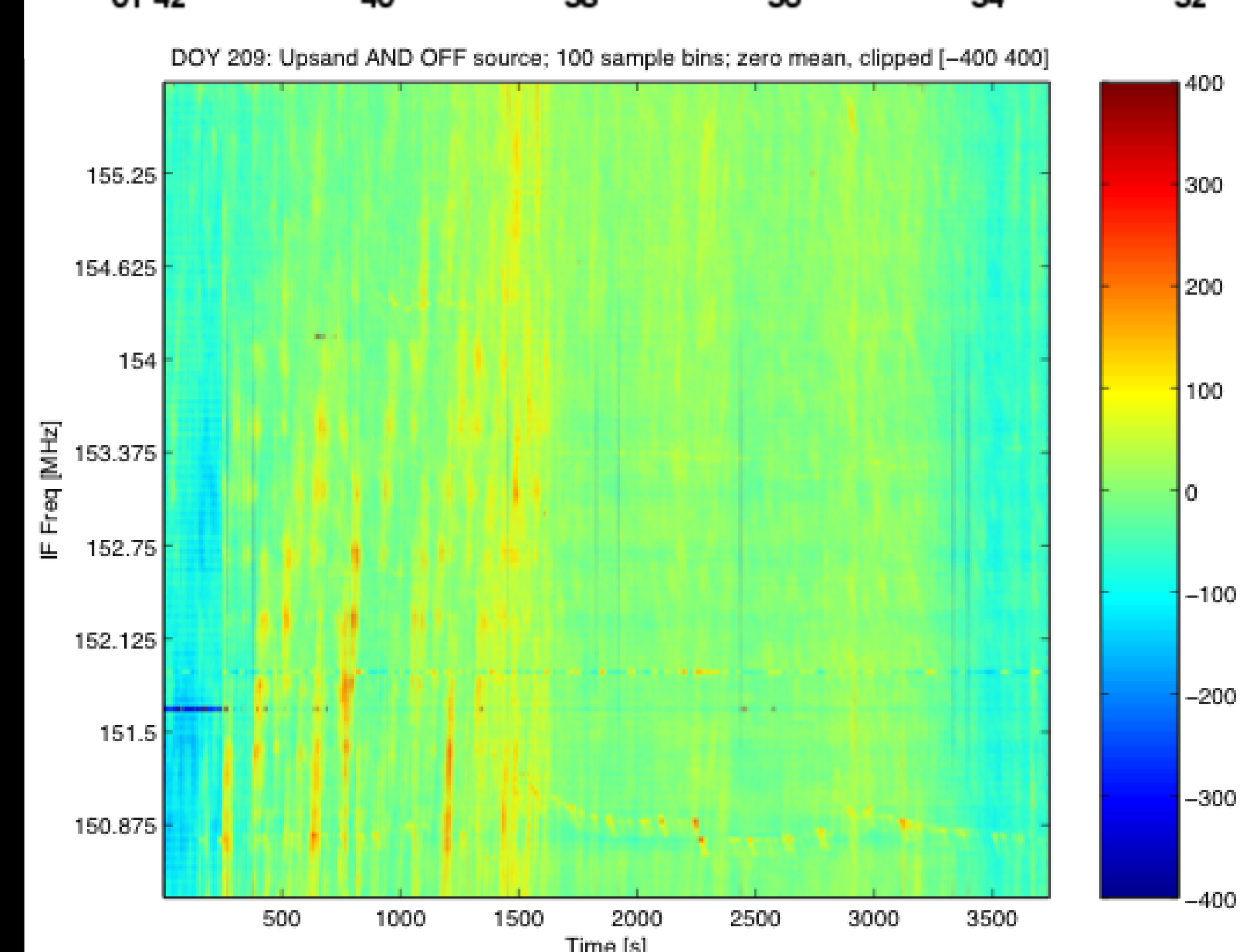


RESULT 2: Spectrum

A radio spectrum from the Upsilon Andromeda region, and OFF Source (for calibration). There are 100 sample bins; Zero mean; Clipped [-400, 400].

- **The off-source shows no signal (at the beginning and at end of the plotted interval)**
- **On-source, however, intriguing signals are seen (yellow and red striations) that appear to have a slope (dispersion?).**

While intriguing, the “signals” are likely NOT from UpsAnd emissions, as further analyses show. More probable, they are caused by Earth’ rotation which changes the path lengths to the compact object at the edge of the beam (labeled “Object” in above map), generating “interference fringes”. This is a common, if not well-understood occurrence in this kind of observation, and is called “confusion”.



THE OBSERVATORY: The Giant Meterwave Radio Telescope (GMRT) is the largest fully steerable telescope operating at meter wavelengths. Currently, its lowest operating frequency is 150 MHz. The facility, located near Pune, India, consists of 30 individual 45 meter dishes.

SELECTION OF TARGETS

Theoretical studies have proposed scaling “laws” to estimate the radio power (P_r) emitted from solar (stellar) wind driven cyclotron emissions*:

$$P_r \propto \left(\frac{m}{m_j}\right)^{1.33}\left(\frac{d}{d_j}\right)^{-1.60}\left(4x10^{11}\right)W$$

name	M (Jup)	a (AU)	dist (pc)	Flux1 (mJy)	Gal Lat
tauboo	***5.2***	0.05	15.6	***717.8***	***-73.9***
HD162020	2.4	0.21	***4.7***	43.6	59.6
HD179949	1.2	0.04	27.0	211.1	15.8
70vir	9.3	0.48	18.1	1.6	-74.1
Upsandb	0.9	***0.06***	13.5	147.3	20.7

*Desh. M. D., and M. L. Kaiser, Nature, 310, 755, 1984;
Farell, W. M., et al., Geophys. Res. Lett., (in press), 2003;
Zarka, P., R. A. Treumann, B. P. Ryabov, and V. B. Ryabov, Astrophys. and Space Science, 277, 293, 2001.