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EVLA Observations of Pluto, Charon, Makemake, Quaoar, and 2002 TC302 at 0.9 cm Wavelength

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Abstract

Observations of the Trans-Neptunian Objects (TNOs) Pluto, Charon, Makemake, Quaoar, and 2002 TC302 were made with the Expanded Very Large Array at a wavelength of 0.9 cm. These observations can be used to constrain the properties of the surfaces and subsurfaces (down to ~10 cm) of these bodies, including temperature, composition, and structure. We have detected Pluto and Charon, with the emission separated on the sky; the longest wavelength detection of either of these bodies to date. We have only upper limit non-detections for Makemake and 2002 TC302, but more data remain to be reduced, and we have not reduced any Quaoar data yet.

1. Introduction

Understanding the population of small bodies in the outer solar system is critical to understanding the formation of the solar system. There is abundant data on the orbits of these bodies, which has guided an understanding of the disparate populations present among the entire class (Centaurs, Kuiper Belt, scattered disk, and Oort cloud). Those which have satellites have relatively well determined masses. Almost all other physical properties (rotation rate, diameter, surface albedo, temperature, composition, etc.) are only poorly determined in most cases [1], [2]. Observations at long wavelengths (submm and longer) are valuable in determining the properties of these bodies. However, the sources are weak at those wavelengths and hence observations are difficult. Observations in the centimeter have simply not been possible previously, and those in the mm/submm are sparse [3]-[8]. The Expanded Very Large Array (EVLA) [9] has enough sensitivity to detect the largest of these bodies at centimeter wavelengths, and we have begun a program to do so, in order to try to constrain their temperatures and diameters.

1.1 Expected Emission

Given an equilibrium physical temperature T_e for a body, the expected flux density is the product of the Planck function (using a brightness temperature of $T_b = \varepsilon\, T_e$ for thermal emissivity ε), and the solid angle subtended by the source (equal to $\pi R^2/D^2$ for source radius R and distance D). The main uncertainties in the equilibrium temperature are the values of the optical albedo and the rotation state (which determines heat penetration into the subsurface). For the flux density, the diameter of the body is the main uncertainty. In addition, one must recall that we are sensitive only to the *difference* of emission between the body and the Cosmic Microwave Background (CMB). Using information on the physical properties of the larger TNOs [2], along with an estimate of the CMB emission at the location of the body during the observation (obtained from WMAP observations [10]), it is straightforward to calculate the predicted flux density from potential TNO targets, and this was done to determine which objects to include in our study. This exercise identified the brightest candidates, which are shown in Table 1, along with the range of expected flux densities (varying because of distance, CMB fluctuations, and uncertainties in physical quantities). Note that we would have also liked to observe Triton and Phoebe, which are potential TNOs, and were awarded time to do so, but observation of these bodies, which are so close to their bright primaries (Neptune and Saturn), is not possible currently with the EVLA.

Table 1: The brightest TNOs at 0.9 cm wavelength

Body	Expected Emission (μJy)
Pluto	150-220
Charon	60-90
Makemake	20-30
2002 TC302	20-30
Quaoar	15-25

2. Observations

All observations were carried out with the full continuum bandwidth currently available at the EVLA, almost 2 GHz, centered at 32.1 GHz. Calibration of pointing, delay, bandpass, flux density scale, and complex gain vs. time were done in the standard fashion. Data was reduced using the AIPS package, augmented with some of our own tasks that do planetary-specific operations on the data. We typically observed in 4-hour blocks, which counting calibration overhead yielded about 2.5 hours of on-source time. The noise in the resulting images is ~7 μJy for good atmospheric conditions, but can be up to a factor of two worse. We observed the targets on the following dates: Pluto/Charon - Jan05, Mar10, Mar13, Mar18, Mar29, May24, May26; Makemake - Dec21, Dec22, Dec29, Jan11, May08, May24, May26; 2002 TC302 – Jan02, Jan05; Quaoar – May03, May04, May05.

3. Results

Only a few of the datasets have been reduced to date, though the full complement will be presented at the meeting. For Makemake we have reduced the data from Dec21, Dec22, and Dec29 and have no detection, with an rms of 5.8 μJy (one-σ). For 2002 TC302 we have reduced the data from Jan02 and Jan04 and also have no detection, with an rms of 7.3 μJy (one-σ). We have not reduced any Quaoar data thus far.

3.1 Pluto and Charon

We first successfully observed the Pluto/Charon system on Jan05, but were in the C-configuration of the EVLA, where the two could not be resolved. The combined flux density was 244 μJy, consistent with a brightness temperature for Pluto of 37 K, and for Charon of 49 K, with a background temperature of 6 K. We subsequently successfully detected the two on Mar13 in the B-configuration, separating the two on the sky. On that date, Pluto had a measured flux density of ~160 μJy, while Charon was ~60 μJy. This is only consistent with the expected brightness temperatures (and those measured on Jan05) if the background temperature is ~10 K, which is too high for the position at the time. We stress that these flux densities are very preliminary, and further flux density scale refinement needs to be done. Figure 1 shows those two successful detections.

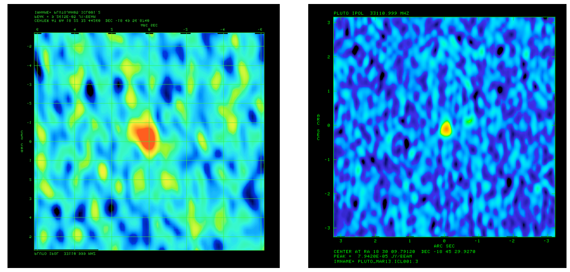

Figure 1: Pluto/Charon at 0.9 cm; left is Jan05 in the C-config, right is Mar13 in the B-config.

4. Summary and Conclusions

We have undertaken observations of the large TNOs Pluto, Charon, Makemake, Quaoar, and 2002 TC302 with the EVLA at a wavelength of 0.9 cm. We easily detect Pluto and Charon and separate the emission from the two. This is the longest wavelength detection of these two bodies to date. We have upper limits only for Makemake and 2002 TC302, but more data remains to be reduced for Makemake. We have not reduced the data for Quaoar yet.

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