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Millimeter-wave Imaging of the Pluto/Charon System

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Abstract

We present further analysis of all high-resolution observations of the Pluto/Charon system obtained with the Submillimeter Array in order to determine best values of the mean millimeter-band brightness temperatures of each object. The best imaging is still obtained from our May 2005 observations, which find mean brightness temperatures of 37±2 K for Pluto and 49±8 K for Charon. Observations in 2009 were significantly degraded due to weather. Observations in 2010 were of high quality but provide unrealistically low temperatures, and were likely negatively impacted by the presence of background emission near the galactic plane. We will discuss possible methods for retrieving better values from the 2010 observations using WMAP and Planck results. We will also discuss limits on the CO abundance of the atmosphere obtained from a subset of the data.

1. Introduction

Determining the surface temperatures of Pluto and Charon places strong constraints on the types of ices stable on their surfaces. This in turn yields information on the composition of these bodies, and constrains models of solar system formation. For a distance of 30.03 AU and an albedo of 0.4, the equillibrium temperature of Pluto is ~53 K. IRAS observations of 55-60 K at 60 and 100 μm ([11], [2]) initially supported the conclusion that the surface was at this equillibrium. However, millimeter band observations found temperatures near 40 K ([1], [9], [5]), and near-IR spectroscopy of N_2 [12] showed the ice temperature was 40±2 K. The current model is that the low mean temperature of the surface is controlled by sublimation of nitrogen (see review [3]). The surface is not isothermal, inferred from the large scale optical albedo variations (e.g. [10]), and ISO observations showing maximum dayside temperatures of 54-63 K [6]. Pluto's IR spectrum is dominated by N_2, CO, and CH_4 ices, while Charon's by water ice, suggesting the latter has a substantially warmer surface (e.g. [8], [4]).

Prior to 2005, no thermal imaging had spatially resolved the pair. Their close proximity (maximum 0.9" separation) make resolving the pair at thermal wavelengths a challenge. Only in the past few years have millimetre-wave interferometers become sensitive enough while providing sufficient resolution to resolve the system.

2. Observations

Observations of the Pluto/Charon system were performed using the Submillimeter Array (SMA, located near the summit of Mauna Kea, HI) in its most extended configuration, with baselines to just over 500 m, for three observing periods: 4 dates in late May 2005 (at 1.4 mm), 3 dates in July 2009 (at 1.4 mm) , and 4 dates in July 2010 (2 each at 1.1 mm and 1.4 mm). In the majority of observations, weather (particularly atmospheric stability) degraded the observations beyond usability.

Observations from 21 May 2005, were undertaken in particularly good conditions for both atmospheric transmission and stability. Calibration and image construction (see Fig 1) provided the first ever map of the resolved flux densities of the pair at a thermal wavelength. The flux densities lead to disk average brightness temperatures 37±2 K for Pluto and 49±8 K for Charon. Assuming mean surface emissivities of 0.9±0.1, these imply mean physical surface temperatures of 41±5 K for Pluto and 54±11 for Charon, consistent with the standard model of Charon in equilibrium with solar radiation and Pluto in vapor pressure equilibrium with atmosphere.

Observations in 2009 were significantly affected by weather, but one date may provide a usable measurement of the resolved flux densities (and from them brightness temperatures) and will be discussed.

Observations in 2010 were mostly of good quality due to fairly stable weather. However, the data obtained at both 1.1 mm and 1.4 mm show anomalously low brightness temperatures for both objects (Pluto mean temperatures between 26 and 31 K, and Charon between 33 and 35 K). Such temperatures are likely too low to support the current atmosphere (most recently measured in methane and carbon monoxide, see [7]) and are inconsistent with the direct measurements of N_2 ice spectroscopy.

During 2010, the Plutonian system crossed over the galactic plane. We hypothesize that large scale thermal emission near the galactic plane may be present. An interferometer is sensitive only to the contrast of an object above any larger scale background. We estimate that if the system passed in front of galactic emission ranging from 11 to 16 K at millimeter wavelengths then the 2010 observations would be consistent with our 2005 'best' result. We can begin to assess this possibility by comparison of Pluto's position at the time vs maps of the large scale background available from WMAP (wavelengths longer than 3mm)

3. First Resolved Thermal Image

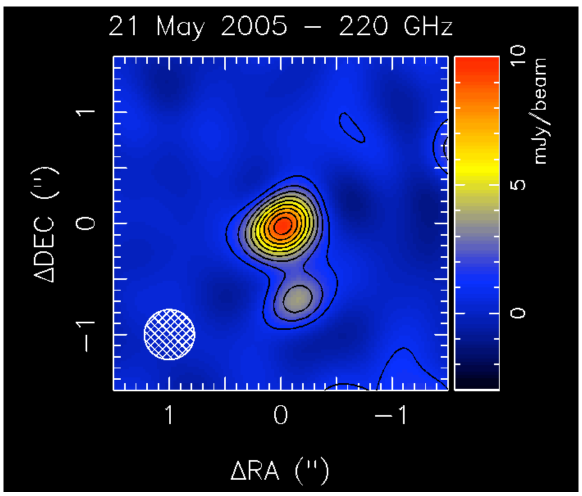

Figure 1: Submillimeter Array continuum band observations of the Pluto/Charon system obtained 21 May 2005 at 220 GHz (1.4 mm). The measured flux densities lead to disk average brightness temperatures of 37±2 K for Pluto and 49±8 K for Charon.

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