DSN AND GAVRT OBSERVATIONS OF JUPITER AT 13 GHZ

AND THE CALIBRATION OF THE

CASSINI RADAR INSTRUMENT FOR PASSIVE RADIOMETERY

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ABSTRACT

The flyby of the Cassini-Huygens spacecraft past Jupiter in December 2000 provided an opportunity to perform in-flight calibrations of the passive microwave radiometer subsystem that is part of the Radar Instrument on the spacecraft. To support these in-flight calibrations, a coordinated series of ground-based observations named the Cassini-Jupiter Microwave Observing Campaign (Cassini-JMOC) was carried out from November 2000 through March 2001. One objective of the Cassini-JMOC observations was to measure Jupiter's average disk temperature with high accuracy at 13.78 GHz, which is the frequency of the radar receiver on the spacecraft. Preliminary results of the ground-based observations are reported. A second objective of the Cassini-JMOC project included an educational component that allowed middle- and high school students to participate directly in the ground-based observations and data analysis.

INTRODUCTION

The flyby of the Cassini-Huygens spacecraft past Jupiter in December 2000 provided an opportunity to perform in-flight calibrations of the passive microwave radiometer subsystem that is part of the Radar Instrument on the spacecraft. The objectives of the Radar Instrument are to map the surface of Titan and to measure properties of Saturn's rings and atmosphere. The in-flight calibrations (see companion paper by Janssen et al.) were supported by a coordinated series of ground-based observations named the Cassini-Jupiter Microwave Observing Campaign (Cassini-JMOC). One objective of the Cassini-JMOC program was to support the in-flight calibrations by measuring the flux density of Jupiter at 13.78 GHz with a 1-sigma accuracy of two percent. The accuracy of the ground-based calibrations can be transferred to the spacecraft radiometer because it was used during the flyby to map Jupiter [1] at the same microwave frequency .

A second objective of the project included an educational component that allowed students to participate directly in the ground-based observations and data analysis. A large percentage of the Goldstone observations were conducted by middle- and high-school students from classrooms across the nation. The students and their teachers are participants in the Goldstone-Apple Valley Radio Telescope (GAVRT) science education project, which is a partnership involving NASA, the Jet Propulsion Laboratory and the Lewis Center for Educational Research (LCER) in Apple Valley, CA. Working with the Lewis Center over the Internet, GAVRT students conduct remotely controlled radio astronomy observations using 34-m antennas at Goldstone. Approximately 2300 GAVRT students and their teachers from 26 schools across the United States were part of the ground-based research team that supported the Cassini-JMOC program. The GAVRT team supported a total of 167 observing sessions of Jupiter and calibration radio sources during the campaign that lasted from November 2000 through March 2001.

OBSERVATIONS

The 34-m GAVRT antenna was used to participate in a multi-frequency campaign to study Jupiter's synchrotron radiation [1]. A 34-m antenna used for research and development at Goldstone was instrumented with a 2.2 cm receiving system to support the Cassini-JMOC observations at 13.78 GHz. GAVRT students and teachers teamed with professional scientists and engineers to measure the ratio of Jupiter relative to six calibration sources that were selected to mitigate different sources of random and systematic errors. The calibration source selection criteria included the following:

- Flux density greater than 2 Jy to ensure high signal-to-noise (5<SNR<10) for individual measurements.
- Spectral Index is *known* with sufficient accuracy to interpolate the flux density at 13.8 GHz
- Angular size should be small compared to 0.039 degree (the 3-dB width of the 34-m antenna beam at 13.8 GHz). The source 3C405 (Cygnus A) was *exempted* from this selection criteria because it is one of the sources that is also being measured directly from Cassini during special calibration sequences in the fall of 2000 and other times during the mission.
- There is evidence that the source does not vary with time
- Circular polarization is small (<2%)
- Proximity with Jupiter's location on the sky (right ascension and declination)

All measurements of Jupiter and calibration sources were calibrated to remove sources of error caused by changes in system performance with antenna tracking in azimuth and elevation. System "minical" sequences were performed about three times per hour to monitor subtle changes in receiving system gain, stability and linearity.

RESULTS

The observed ratios of Jupiter to the six calibration sources were used to calculate the effective disk temperature of Jupiter for each calibrator. The results are shown in Figure 1. The average disk temperature is 165.3 +/- 7.2 K.

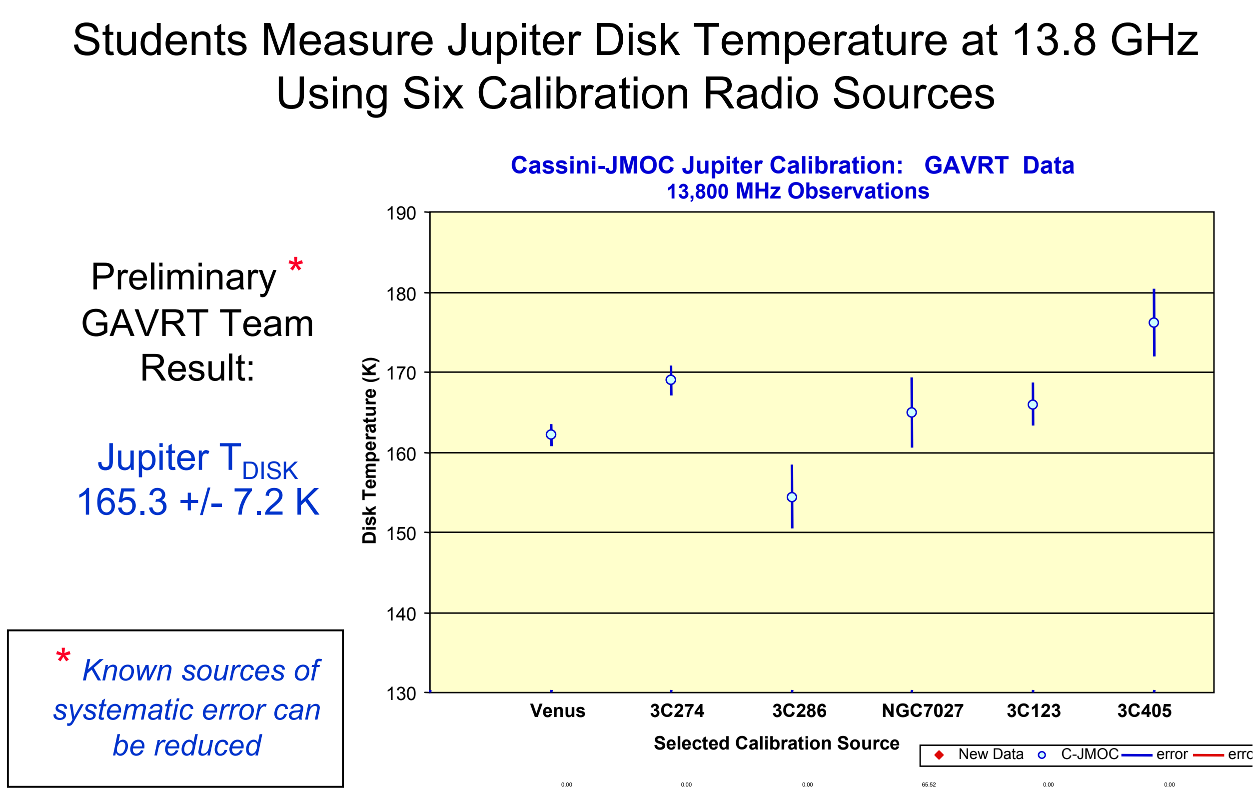

Figure 1. Preliminary results of the calibration of Jupiter at 13.78 GHz by the GAVRT Team

The average disk temperature reported here is a preliminary result that is currently being refined as the results of continuing calibration work are applied to the data to reduce the systematic error "budget". Most notable of these refinements will be the results of a new set of observations being carried out at Goldstone to map the brightness distribution of 3C405 and 3C274 using a "raster scan" technique developed by Richter and Rochblatt [2]. The raster scan technique reduces the uncertainty in the total flux density measurement that arises when the antenna beam partially resolves the spatial dimensions of an extended radio source. The spectral indices of Venus and the sources 3C286, 3C123 and NGC 7027 will also be updated with new results from the National Radio Astronomy Observatory (NRAO). The anticipated result of these updates will be to reduce the formal error from 7.2 K (~4%) to approach our goal of two percent (1-σ) error.

GAVRT teachers are reporting that their students are motivated when they realize that their contributions to the science team are valued by the scientists and that their data are being reported at international conferences and published in professional journals. This result is consistent with the goals of the GAVRT project to engage students in the real world of scientific investigation and to include them as valued members of the science team.

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