GOLDSTONE/VLA RADAR RESULTS

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ABSTRACT

Since 1987, it has been possible to use the VLA to image the radar reflections from planetary bodies illuminated at X-band. The joint Goldstone/VLA radar instrument has been used to image Mercury, Venus, Mars, Ganymede, and Callisto, and to detect Titan and several asteroids. We will discuss the Goldstone/VLA radar instrument, and summarize some of its past observations.

INTRODUCTION

In preparation for the Voyager encounter of Neptune, NASA funded the installation of X-band (3.5 cm) receivers on the antennas of the Very Large Array in New Mexico (the VLA is operated by NRAO). Since that time, joint radar experiments using the Goldstone 70-m antenna (operated by JPL) to transmit, and the VLA to receive, have been possible. This joint Goldstone/VLA radar has been extremely successful, providing important results from experiments involving many solar system bodies.

Observations with the joint Goldstone/VLA radar allow for completely unambiguous mapping of the facing hemisphere of the body, an advantage over traditional delay/doppler mapping, especially in equatorial regions. Mapping of polar regions is generally at a disadvantage when compared to CLP delay/doppler in terms of resolution [1,2], but interesting results may still be obtained.

INSTRUMENTAL DETAILS

A nearly monochromatic, circularly polarized, 3.5 cm wave is transmitted from the 70-m Goldstone antenna, with nearly 500 kW of power (increased from 350 kW in the earlier observations). After reflection from the planetary surface, the radiation is received at the 27 25-m antennas of the VLA. Dual circular polarization is almost always recorded, and full Stokes can be recorded if desired, at the cost of frequency resolution. The frequency resolution of the receiving system is relatively coarse: ~760 Hz in dual polarization mode. The spatial resolution varies as the VLA antennas are moved about, with finest resolution ~0.25°. Data are reduced in the normal way for radioastronomical observations at the VLA.

MERCURY

Observations of Mercury in 1991-1995 showed very bright (and previously unknown) reflectors in the polar regions, in addition to many other surface features [3]. Fig. 1 shows an image of the SC radar echo mapped with the Goldstone/VLA radar on August 23, 1991. The bright reflector at the north pole is obvious. In addition to being very bright, this feature also displays a polarization inversion. Higher resolution radar images show that the feature is made up of a number of smaller regions, contained in the permanently shadowed equatorward portions of polar craters [2]. Similar features exist in south polar regions [4,5]. The favored explanation is that it is caused by volume scattering from within relatively clean (and possibly thinly buried) water ice deposits [2-8]. Other bright reflective regions are in the unphotographed hemisphere of Mercury, but higher resolution delay/doppler radar indicates that they are young, bright rayed craters, similar to Tycho on the Moon, which is also a bright radar reflector [5,9].
Figure 1: SC Radar reflectivity of Mercury as mapped with the combined Goldstone/VLA radar on August 23, 1991. Sub-Earth latitude and longitude were +11.0° and 353.5°. Red colors are brightest reflection (brightest reflectivity is ~15%), with yellow, then green, light blue, dark blue and finally black, representing successively dimmer reflections.

VENUS

Observations of Venus in 1990 and 1993 allowed for multi-polarization mapping of several bright volcanic regions [10]. Fig. 2 shows an image of the SC radar echo mapped with the Goldstone/VLA radar on August 23, 1991.

Figure 2: Radar reflectivity of Venus as mapped with the combined Goldstone/VLA radar on March 4, 1993. Sub-Earth latitude and longitude were -7.3° and 302.5°. Actual SC reflectivity is shown on left, topography and feature names are shown on the right. From [10].

MARS

Observations of Mars in 1988, 1992/93, and 1999 revealed very bright reflectors related to the residual polar ice caps, bright reflections associated with the Tharsis and Elysium volcanic regions, and a curious radar-dark region (dubbed “Stealth”), in addition to a large number of other surface features [4,11,12]. Fig. 3 shows an image of the SC radar echo mapped with the Goldstone/VLA radar on October 22, 1988. The bright reflector caused by the residual south polar ice cap is obvious. Other bright reflecting regions are mostly the younger lava flows associated with the Tharsis and Elysium (just on the limb in Fig. 3) volcanic complexes. Fig. 4 shows a model reconstruction using all of the data taken in
1988, 1992, and 1993. The large extent of the Stealth feature is obvious. The current favored explanation is that this is wind-blown ash from massive eruptions of the Tharsis volcanoes [13], although recent imaging indicates a much more complicated story [14].

Figure 3: SC Radar reflectivity of Mars as mapped with the combined Goldstone/VLA radar on October 22, 1988. Sub-Earth latitude and longitude were -23.7° and 122.9°. Red colors are brightest reflection (brightest reflectivity is ~70%), with yellow, then green, light blue, dark blue and finally black, representing successively dimmer reflections.

Figure 4: This triptych shows a model reconstruction of the radar reflectivity of the surface of Mars from data taken in 1988, 1992, and 1993 with the combined Goldstone/VLA radar instrument. The subearth longitudes for the 3 panels are: 0, 120, and 240 degrees, and the subearth latitude is -24 deg (close to that observed in 1988). The mottled appearance of some locations is due to poor coverage of those areas. Red is brighter reflection.

TITAN

Prior to 1990, the prevailing wisdom was that the surface of Titan was covered by a deep (up to 1 kilometer) ethane/methane ocean [15]. This was thought to be required to continually replenish the methane in the thick atmosphere. Goldstone/VLA observations of Titan in 1990-1995 disproved this theory, and showed that the surface of Titan is most likely similar to the Galilean satellites (although the presence of local “seas” cannot be discounted) [16,17].
OTHER EXPERIMENTS

Observations of the Galilean satellites occurred during the winters of 2000 and 2002 [18]. Observations of asteroids 1991EE, Toutatis, Bamberga, Iris, and Golevka in 1991, 1992, and 1995 allowed for constraints on their surface compositions and spin orientations [19]. Observations of comet Hale-Bopp were attempted in 1997, but were unsuccessful due to transmitter problems. Other comet observations will certainly be attempted in the future.

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REFERENCES