RADAR IMAGING OF THE ICE DEPOSITS ON MERCURY'S POLES, D.O. Muhleman, B.J. Butler, Caltech, M.A. Slade, Jet Propulsion Laboratory

Anomalously strong radar echoes were detected from the north pole of Mercury and interpreted as ice deposits by Slade, Butler and Muhleman, *Science*, **258**, 635-640, 1992. Subsequently, a very similar anomaly was found on the south pole and the north pole anomaly was confirmed by Harmon and Slade, *Science*, **258**, 640-643, 1992. A full discussion of the observations and compelling arguments for the ice determination and stability on Mercury appears in Butler, Muhleman and Slade, *J. Geophys. Res.*, **98**, 15,003-15,023, 1993. At the time of this writing, our group is scheduled in Feb. 1994, to carry out synthetic aperture radar imaging of the Mercury south polar region with the Very Large Array (VLA)/Goldstone Radar. Currently, our group with others is active in the formulation of a Discovery Mission plan (called the Mercury Polar Flyby) to fly a complement of instruments, including a Synthetic Aperture Radar, over the north and south poles of Mercury and over the equatorial region.

Ice deposits in the Mercury polar regions are likely to be relatively old structures residing in the permanently shadowed regions within 100 to 200 kilometers from the poles. These structures may be unique to Mercury because of the essentially zero obliquity of that planet and the stability of that parameter. Ice on Mercury at temperatures less than, say, 120 K is stable against sublimation for millions of years. This is a time scale which, according to Butler, *et al* (1993), is sufficient for the buildup of ice from meteoritic and cometary impacts, and from the cold-trapping of water vapor outgassed from the planet to explain our observations. The measurements made at the VLA at a wavelength of 3.5 cm and those at Arecibo at 13 cm require an ice thickness of no less than a couple of meters and the deposits could very well be covered up with up to several 10's of centimeters of Mercury dust. Such dust, which must be present in some amount "protects" the ice from high-energy particles and would make the ice invisible to active probing at visible and IR wavelengths. It is obvious, of course, that the ice in permanently shadowed regions can never be visible in reflected sunlight, *e.g.*, in Mariner 10 imaging or any future passive imaging. We believe that the only remote sensing technique which could have discovered the putative ice deposits or can study them further is radar sounding. The remote possibility remains that the ice is magically clean and uncovered, and it is not impossible to image it with visible-light, laser sounding. (Radar is "laser" sounding).

The argument for the identification of the radar anomalies as ice is complex and will be reviewed in detail in the oral presentation. The essential ideas are the following: The anomalies are very tightly confined to polar regions in areas that are reasonably expected to be populated with permanently shadowed structures such as craters, cracks, *etc.* That circumstance strongly suggests that the material in the deposits is a volatile that is only stable, or condenses out in very cold regions on the planet. Planetologically, water ice is the most likely volatile. (Other ices such as CO_2, NH_3, CO, etc. could also reside there if the temperatures are very cold. These ices would have similar centimeter-wave radar signatures). Secondly, the polarization properties of the radar echoes at both wavelengths are completely consistent with those of radar echoes from the Residual South Polar Ice Cap on Mars and echoes from the icy surfaces of the Galilean satellites. At both observatories, the transmitted signals were circularly polarized in one sense and the echoes were measured in both circular

senses. The reflectivities were not only strong but the circularly polarized reflectivity ratios are the same as that from the icy surfaces listed
above. In our experience, such polarization properties of natural surfaces are limited to icy surfaces. Our theoretical understanding of the reflection phenomena is incomplete but it does seem nearly certain that a required physical characteristic of such a substance is high transparency of the material at the specific wavelength, creating relatively long path-lengths through the deposit, probably with strong forward scattering. Ice is the only likely such substance on Mercury's surface!

Results of the Feb, 1994 VLA/Goldstone Mercury south polar imaging will be presented. In addition, a brief discussion of the SAR radar experiment on the proposed Mercury Polar Flyby will be presented. The design goals are 1 kilometer imaging in both modes of circular polarization in the region within 300 km of both poles. In addition, we expect to radar image most of the planet to a resolution of order 10 km with 1-2 km resolution over a significant fraction of the equatorial region of at least one hemisphere. Mercury Polar Flyby will also have a Neutron spectrometer to certify that the polar volatiles are indeed water ice, if that be the case.