Abstract. Between 1965 and 1975, our knowledge of Mercury and its physical characteristics improved dramatically. Radar studies of the planetary orbit and rotation rate and Mariner 10 spacecraft studies of its surface, atmosphere, magnetic field and plasma environment provided startling new results on what had been the least understood member of the terrestrial planets. With a highly cratered surface and a modest magnetic field, Mercury is a differentiated planet with fractionally the largest iron core of all.

1. Introduction

Until quite recently, the planet Mercury was considered to be one of the least understood principal objects in the solar system, except for Pluto and the satellites of Mars and the giant planets. However, in the decade from 1965 to 1975, two extremely important experiments were conducted by the U.S.A. which have led to significant scientific discoveries regarding the physical characteristics of its surface, its interior and its evolution as a planet.

The two experiments which have dramatically altered our knowledge of Mercury were radar studies of the planetary rotation rate, conducted in 1965, and the three flybys by the Mariner 10 spacecraft in 1974 and 1975. In addition, these results have also contributed immeasurably to the general study of the other terrestrial planets in the framework of comparative planetology. For example, the surface of Mercury has been found to be heavily cratered, like the Moon and Mars, and the planet has been found to possess a modest but significant global dipole magnetic field (1% of Earth), whose existence implies a differentiated core-mantle interior. The planet also possesses a magnetosphere and magnetic tail, like Earth, but no radiation belts. The purpose of this review is to summarize what is now known about the planetary magnetic field and interior of Mercury.

Mercury has always been a difficult object to study with ground based optical facilities, both because of its small size (radius = \( R_M = 2439 \pm 1 \) km, so that the disk subtends only 7–11 min of arc) and especially its closeness to the Sun (the maximum elongation is 27°). In spite of this, classical astronomical observations of the orbit of Mercury long ago revealed the planet as an enigmatic object because it has such a large eccentricity \( (e = 0.206) \) and inclination relative to the ecliptic \( (i = 7°) \). With a semi-major axis of 0.387 AU, Mercury's perihelion and aphelion are 0.307 and 0.467 AU so that the solar insolation varies by more than a factor of 2. Mercury is among the most dense of planets, its 5.44 g cm\(^{-3}\) being nearly equal to that of Earth, 5.41 g cm\(^{-3}\) but this has only been known relatively recently, since the 1950s.
One of the great accomplishments of the general theory of relativity was the explanation of the discrepancy observed in the precession of the perihelion of Mercury from that predicted by classical celestial mechanics. The orbital period of Mercury is 87.969 Earth days and until 1965 it was the consensus that the rotation period was also the same, i.e. synchronous with the orbit. Thus, like the special relationship between the Moon and Earth, the same hemisphere of Mercury would always face the Sun. However, the radar results showed that the rotation period was actually $59 \pm 5$ days.

Shortly after the first encounter by Mariner 10 with Mercury, scientific results of all the investigations carried out on the spacecraft were briefly reported upon in 1974 in *Science* **185**. More comprehensive and thorough discussions of these initial results were subsequently published in 1975 in *J. Geophys. Res.* **80**. The first International Colloquium on Mercury was held at the California Institute of Technology in June 1975. Most of the research reports which were presented at this meeting were subsequently published as a collected work in 1976 in *Icarus* **28**. Reviews of the Mariner 10 results have appeared and discuss the entire planet (Gault *et al.*, 1977) or were restricted to a discussion of its magnetic field (Ness, 1977a) or the atmosphere or magnetosphere of Mercury (Kumar, 1976; Ness, 1977b).

Unfortunately, there are as yet no definite plans for future spacecraft missions to return to the planet Mercury and so in view of the increasing time scales necessary to implement such activities, it shall surely be another decade or two before additional data become available in connection with the topics of this review.

This paper is organized into four sections. The first deals briefly with the 1965 radar observations, which delineated the correct rotation rate of Mercury as being $\frac{3}{2}$ of the previously assumed value. The second section treats the Mariner 10 magnetic field observations during the first and third encounters with the planet in 1974 and 1975 and the analysis of that data. The third section summarizes studies of the interior of the planet Mercury beginning in 1975 and including those recent ones stimulated by the Mariner 10 magnetic field results. These have consisted of both steady-state models and those describing the thermal evolution of the planet. The last section discusses and evaluates the two possible source mechanisms for the observed intrinsic planetary magnetic field; an active dynamo or a passive paleomagnetic field frozen in to the planet's outer layers at an earlier epoch.

### 2. 1965 Radar Observations and Spin Orbit Coupling

As the power in ground based radar systems increased and receiver sensitivity was improved, Mercury became a prime target for study. During the short span of 10 days in April 1965, Pettingill and Dye (1965) investigated the rotation rate of Mercury, using techniques based upon the careful analysis of doppler shifted and time delayed radar reflections from the surface of the planet. The results were startling in that they were grossly inconsistent with the conventional wisdom that