SINGLE PARTICLE APPROXIMATION FOR THE INNER COMA OF COMET HALLEY

P. L. ISRAELEVICH and A. I. ERSHKOVICH

Department of Geophysics and Planetary Sciences, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Ramat Aviv 69978, Israel

(Received in final form 15 July, 1993)

Abstract. Parameters of the plasma in the inner coma of comet Halley are derived from the magnetic field measurements by using single particle approximation. Both the plasma velocity and the temperature obtained by using this approach are self-consistent and happen to be in good agreement with in situ measurements whereas the neutral gas production rate happens to be 2–3 times higher than the conventionally cited value $6.9 \times 10^{29} \text{s}^{-1}$.

1. Introduction

According to results of magnetic field measurements aboard the Giotto spacecraft, the nucleus of comet Halley is surrounded by a magnetic field free cavity with radius of $\sim 4000 \text{km}$ (Neubauer et al., 1986). A magnetic barrier exists upstream of the cavity, and the magnetic pressure near the barrier maximum approximately equals the dynamic pressure of the solar wind. The diamagnetic cavity and the magnetic barrier are separated by a rather thin ($\sim 20 \text{km}$) transition layer, or the ‘ionopause’ (Neubauer, 1988) where the magnetic field jumps from zero up to $\sim 20 \text{nT}$.

In order to explain the magnetic barrier existence Cravens (1986) and Ip and Axford (1987) suggested that the dominant force supporting the barrier is the friction between outflowing cometary neutrals and nearly stagnating plasma. They succeeded, basing on this assumption, to reproduce approximately the observed profile of the magnetic field. However, with conventional parameters of the neutral gas production rate $Q = 6.9 \times 10^{29} \text{s}^{-1}$ (Krankowsky et al., 1986) and neutral/ion momentum exchange rate $k_{\text{in}} = 1.1 \times 10^{-9} \text{cm}^3\text{s}^{-1}$ (Cravens and Korosmezey, 1986) only 40% the observed magnetic field pressure can be explained. Even after including into consideration the plasma velocity in the barrier (Haerendel, 1987, Israelevich et al., 1992a), $Q$ and/or $k_{\text{in}}$ happen to be significantly larger in order to obtain the required magnetic field profile.

This fact is not unexpected, since magnetic field measurements are significantly more accurate than those of the plasma and neutrals. The latter are affected by restriction of fields of view of instruments, windows transparencies, changes of detectors sensitivities during the flight, etc. Thus the claimed accuracy of the neutral production rate was only $\sim 50\%$ (Krankowsky et al., 1986).

However, the magnetic field is closely related with plasma parameters via well
known equations. Thus, applying the momentum balance to different regions of the cometary ionosphere one can derive plasma and neutrals parameters from magnetic field measurements. Using this procedure in the magnetic barrier we conclude (Israelevich et al., 1992a) that $Q = 1.9 \times 10^{30} \text{ s}^{-1}$, if $k_{\text{in}} = 1.1 \times 10^{-9} \text{ cm}^3 \text{ s}^{-1}$. Here, we will derive $Q$ from the magnetic field measurements at the ionopause itself, basing on a simple model of the ionopause and without using the $k_{\text{in}}$-value (which is also poorly known).

2. The Pressure Balance at the Ionopause and the Neutral Gas Production Rate

Let us estimate the cometary ion outflow and the neutral gas production rate by using a simple model of the cometary ionopause suggested by Ip and Axford (1990) (see Figure 1). The ionopause is a transition layer of thickness $\Delta$ separating regions where the magnetic field equals zero and $B_1$, respectively. The magnetic field grows linearly in this layer. Cometary ions moving inside the diamagnetic cavity with the velocity $V_0$ enter the magnetic field and deviate under the action of the Lorentz force. The final result is the reflection of ions back to the cavity.