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Abstract. The magnetic field observed by the VEGA spacecraft seems to be disturbed by the comet over a wide frequency band, and over an extended range surrounding the comet. The level of magnetic fluctuations seems higher than that of the solar wind at least as low as - 0.3 mHz and as far as - 10 Mkm. The observed fluctuation level near water group ion cyclotron frequency does not show a clear dependence on the distance from the comet when the spacecraft is far from the comet, but in the cometary magnetosheath the fluctuation level decreases with the decreasing distance from the comet near both proton and water group ion cyclotron frequency.

Introduction

The interaction of the solar wind with a comet is characterized by enhanced magnetic field fluctuations near the cyclotron frequency of the newborn cometary ions, and by the extended region of the fluctuations surrounding the comet. The basic physical process which causes this fluctuation is the pick-up of the newborn cometary ions by the electromagnetic fields of the solar wind flow. During the encounter with the comet Giacobini-Zinner, the ICE spacecraft observed magnetic fluctuations with characteristic frequency corresponding to the water group ion cyclotron frequency [Smith et al., 1986; Gosling et al., 1986; Tsurutani and Smith, 1986a, b; Tsurutani et al., 1987], and the discrete wave packets associated with the leading edge of the steepened low-frequency waves [Smith et al., 1986; Tsurutani et al., 1987; Le et al., 1989a]. The radial variation of the fluctuation level is an increase with decreasing distance from comet G-Z for both low-frequency waves near the proton and water group ion cyclotron frequency band and discrete wave packets [Le et al., 1989a, b]. The observations at comet Halley also show strong MHD turbulence surrounding the comet [Riedler et al., 1986; Glassmeier et al., 1987, 1989; Saito et al., 1986; Yumoto et al., 1986]. The fluctuations corresponding to the MHD mirror mode instability have been observed within the induced magnetosphere of comet Halley [Russell et al., 1987], but the similar waves were not seen at comet G-Z. No evidence of steepened low-frequency waves and discrete wave packets have been reported at comet Halley. In this paper, we will present results of an examination of the VEGA 1 and 2 magnetic measurements at comet Halley during their flights by Halley on March 6 and March 9, 1986. The highest time

resolution data (0.1 s) are available from three hours before until one hour after the closest approach. Occasional periods of 6 sec resolution data, which are averaged on board the spacecraft, are also available within two days from the closest approach.

Observations

In this study, the fluctuation level of the magnetic field is represented by the normalized wave amplitude or the normalized wave energy. The wave amplitude and wave energy within a specific frequency band are derived from the power spectra, and contain both transverse and compressional components. Then we normalized them by the average magnetic field strength and energy, respectively.

We have looked at the magnetic fluctuations at low frequencies and large encounter distances. Figure 1 shows 40 hours of magnetic field data observed simultaneously by VEGA 1 and 2. The time resolution of the data is 2.5 minutes. During this interval, VEGA 1 is traveling along the outbound trajectory from 5.9 Mkm to 17.3 Mkm from the comet nucleus, and VEGA 2 along the inbound trajectory from 14.2 Mkm to 3.1 Mkm. The magnetic fluctuations at both spacecraft seems more turbulent than those in the undisturbed solar wind. The power spectra from VEGA 1 and 2 during this interval (Figure 2) are very similar in the frequency range 0.1 to 3 mHz. Comparing to undisturbed solar wind, Figure 2 shows that the fluctuation level is even higher than that of active solar wind discussed by Siscoe et al. [1968] down to frequencies at least as low as 0.3 mHz. Figure 3 presents the variation of the amplitude of the fluctuation in the frequency range 0.1 to 3 mHz as a function of distance from the comet, where the solid lines are VEGA 1 data and dotted lines VEGA 2 data. The fluctuation level during the outbound pass is higher than that of inbound pass, on average. This may be caused by the facts that the inbound and outbound trajectories are not symmetric, and that the outbound trajectory is more upstream from the comet than the inbound trajectory. The upstream region may be more unstable because the solar wind and cometary ion distributions are more narrow here. Downstream the anisotropies should be weaker and the waves, which grow upstream, damped by the warm plasma.

From the 6 sec resolution data available we have calculated the wave energy near the water group ion cyclotron frequency ($.75f_{H, O^+}$ to $1.25f_{H, O^+}$) at large distances from the comet as shown in Figure 4. We have used the local average magnetic field strength to calculate the ion cyclotron frequency. The energy of fluctuations near the water

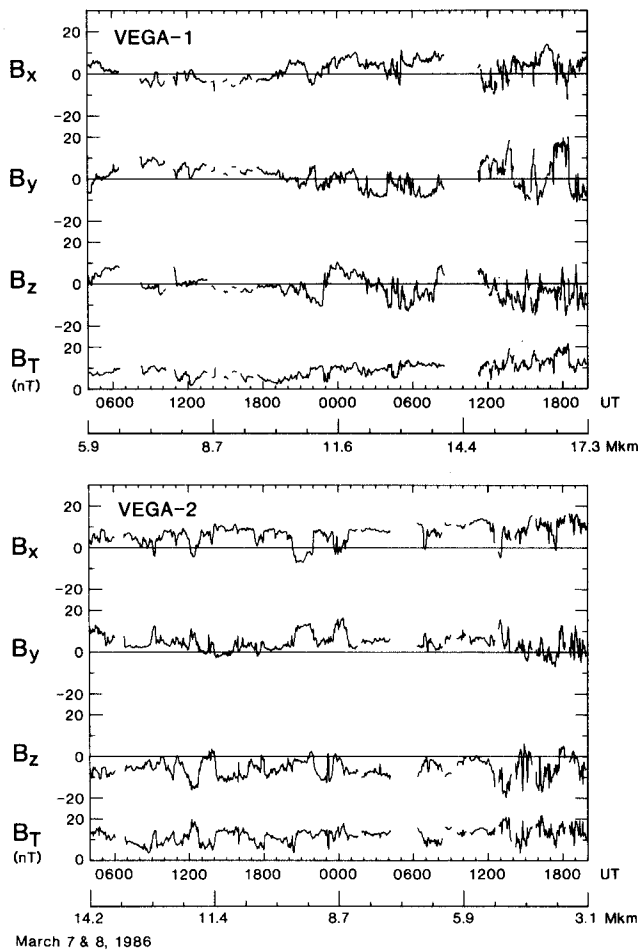


Fig. 1. Low time resolution (2.5 min) magnetic field data observed simultaneously by VEGA 1 and 2. The coordinate system is cometary solar ecliptic with x directed toward the sun.

group ion cyclotron frequency is quite variable. We can not see any clear dependence of the wave energy on the distance from the comet. But we notice that the fluctuation level seems higher for smaller background magnetic fields. Figure 5 shows the wave amplitudes vs. background magnetic field magnitudes. We can see that both absolute wave amplitudes (upper panel) and normalized amplitudes (lower panel) are anticorrelated with the magnitude of the background magnetic field. Because of the lack of higher resolution data, the wave amplitudes near proton cyclotron frequency are not available at large distance from the comet.

Three hours before until one hour after the closest approach, the magnetometer was switched to the direct transmission mode with 10 vectors per sec [Riedler et al., 1986]. From these highest resolution data, we can study the fluctuations near the water group ion and proton cyclotron frequency very close to comet Halley, i.e., in the cometary magnetosheath. The magnetic field data within the magnetosheath show that the level of fluctuation appears more and more quiet when we get closer to the comet. This is true for both proton and water group ion cyclotron frequency band. Figure 6 shows the wave energy near the proton cyclotron frequency ($.75f_{H^+}$ to $1.25f_{H^+}$) vs. distance from the comet. The wave energy drops when the distance becomes smaller. The wave energy

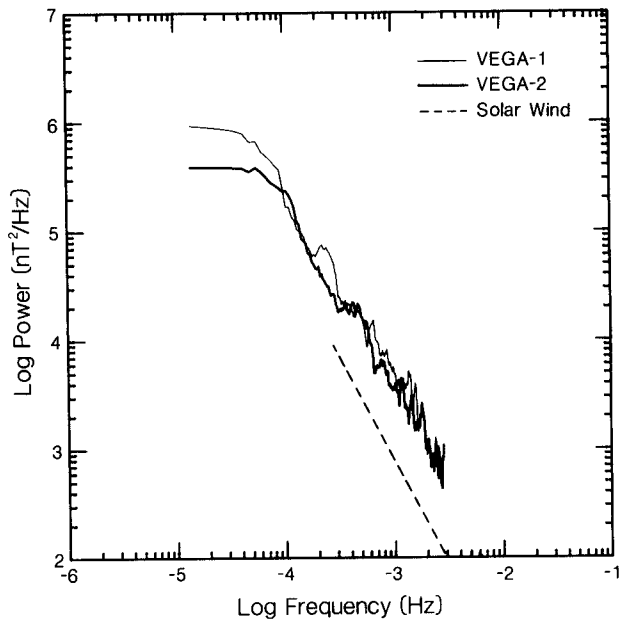


Fig. 2. The power spectra of the magnetic field in the time interval corresponding to Figure 1. The lighter trace is the total power of three magnetic field components measured by VEGA 1, and the heavier one by VEGA 2.

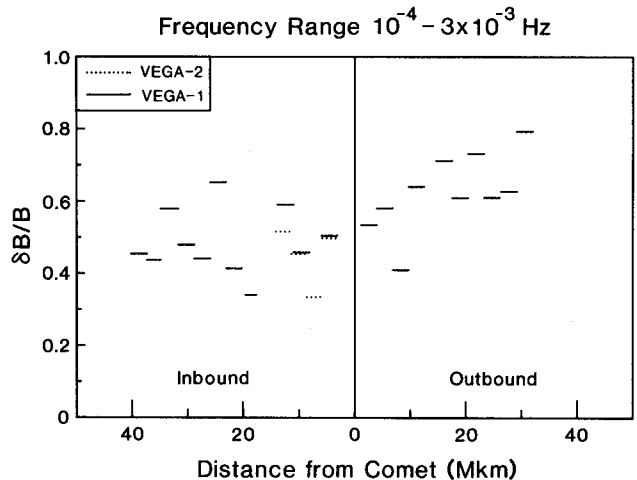


Fig. 3. The amplitude of fluctuations in the frequency range from 0.1 to 3 mHz vs. distances from the comet.

near the water group ion cyclotron frequency has a similar variation, as shown in Figure 7.

Discussion and Summary

The magnetic field observed by VEGA 1 and 2 seems to be disturbed over a wide frequency band and an extended range surrounding the comet by the cometary new born ions. The fluctuation level is even higher than that of active solar wind [Siscoe et al., 1968] at least as low as 0.3 mHz, and as far as 17 Mkm from the nucleus (cf. Figure 2). We don't see any evidence of steepened low frequency waves and the discrete wave

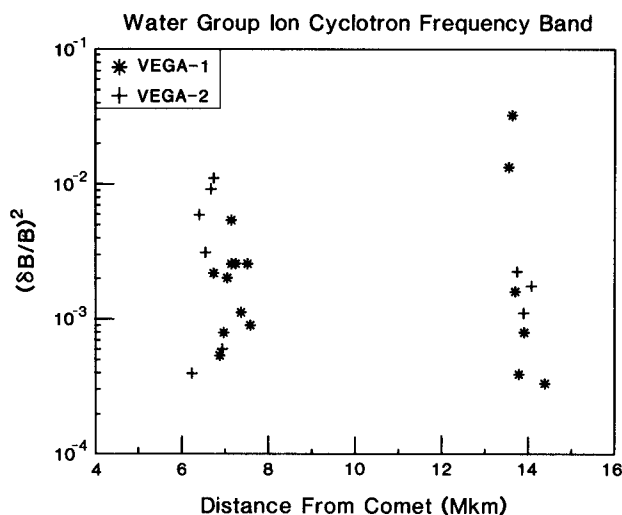


Fig. 4. The wave power near the water group ion cyclotron frequency at large distances from the comet.

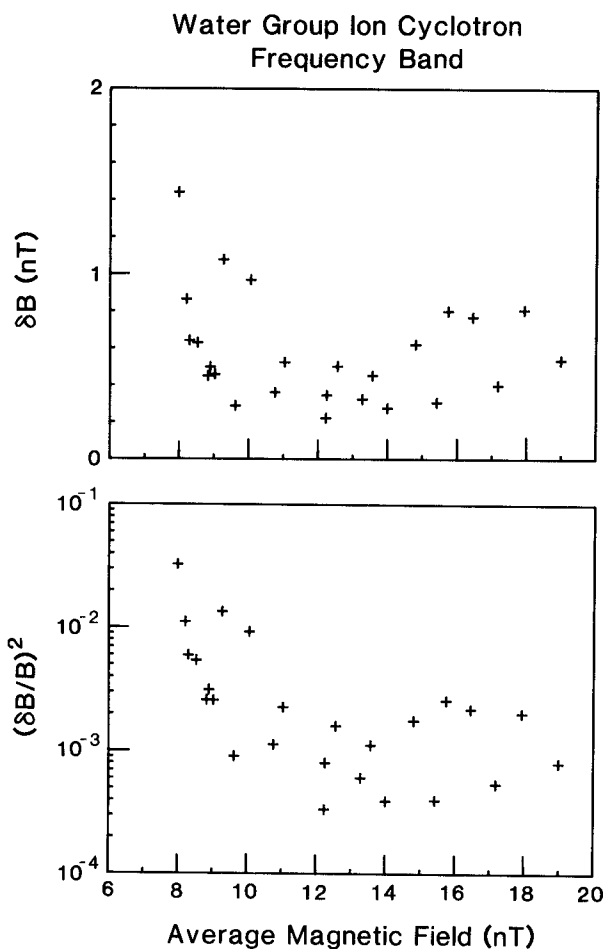


Fig. 5. The wave amplitude (upper panel) and power (lower panel) vs. background average magnetic field at large distances from the comet.

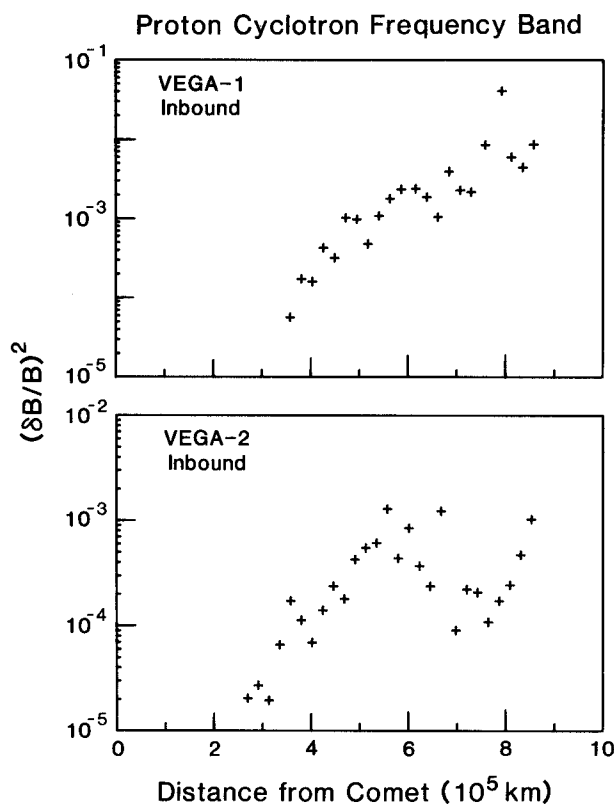


Fig. 6. The wave power near the proton cyclotron frequency as a function of distance from the comet in the cometary magnetosheath.

packets, as observed upstream from the comet Giacobini-Zinner. The Giotto observation at comet Halley also shows the lack of steepened waves [Glassmeier et al, 1987]. This may be due to the lack of high resolution magnetic field data in the upstream region, too. The fluctuation level near the water group ion cyclotron frequency does not show the increase with decreasing distance from the comet, expected from quasilinear theory [Sagdeev et al., 1986] and computer simulations [Gary et al., 1988, 1989]. This is in contrast to the results of Galeev [1986], who found a clear increase of magnetic field energy density with decreasing distance from the comet, although the same data set has been used. We are unable to determine how Galeev's results were derived. The values reported herein are correct as can be verified by visual inspection of the data.

The fluctuation level in the cometary magnetosheath and magnetosphere decreases with decreasing distance from the comet at both the proton and water group ion cyclotron frequencies, while the magnitude of the magnetic field increases to a peak of 70–80 nT due to the field pile-up. The reason for the decrease in wave power may be that the free energy of the instabilities becomes smaller closer to the comet. When cometary ions become the dominant species in the plasma, the solar wind ions will provide the free energy to the instabilities. As the solar wind becomes heavily mass loaded with cometary ions, it moves more slowly as it approaches the nucleus. As a result, the fluctuation level will decrease as we get closer to the comet. The situation is different at large distance from the comet, where the solar wind ion is dominant in the plasma, and the cometary pick-up ions will provide the free energy. In this case, an increase of the pick-up ion density will enhance the fluctuation level.

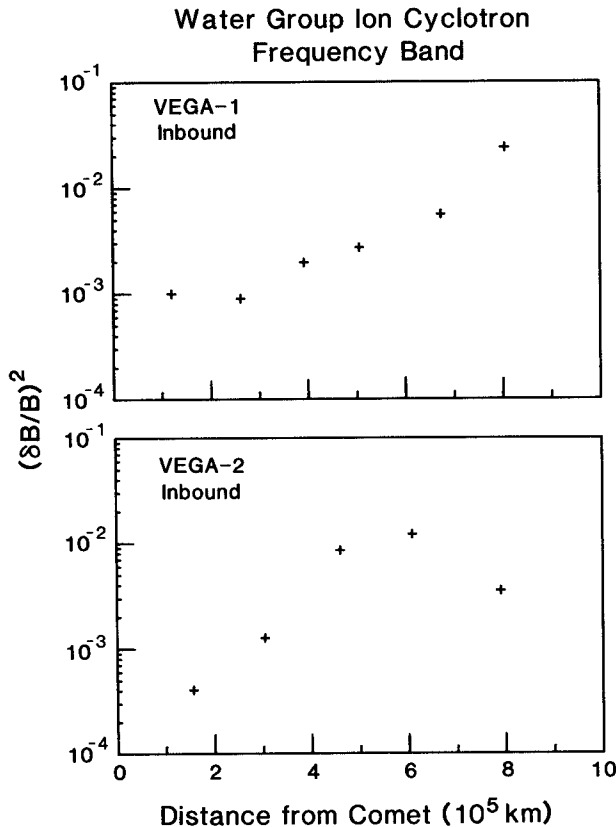


Fig. 7. The wave power near the water group ion cyclotron frequency as a function of distance from the comet in the cometary magnetosheath.

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