SOLAR WIND VELOCITY NEAR THE SUN: RESULTS FROM INTERPLANETARY SCINTILLATION OBSERVATIONS IN 1989- 1992

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Abstract

The solar wind velocity near the sun has been derived from the interplanetary scintillation (IPS) observations at 2 and 8GHz, which have been carried out in 1989-1992 using two quasars; 3C279 and 3C273B. Results show clearly that the solar wind accelerates between 10 and 80Rs (solar radii), although the radial variation of velocities obtained from 3C273B observations is distorted significantly by the effect due to the coronal hole. It is also found that the high speed wind become dominant near the sun in recent years, and this fact is attributed to the development of the polar coronal hole in the descending phase of the solar cycle.

1. Introduction

Radio waves from a compact radio source are scattered with the density inhomogeneities in the solar wind plasma, and the diffraction phenomenon, so-called interplanetary scintillation (IPS), is observed on the ground. The IPS has been studied to obtain information on the solar wind as well as the radio source (Dennison and Hewish, 1967; Coles, 1978; Kojima and Kakinuma, 1990). Especially, the IPS measurement has a unique advantage in studying the solar wind formation, since it allow us to probe the solar wind motion in the region very close to the sun (< 0.3AU), where no direct measurement is available. Several researchers have investigated the radial variation of the solar wind velocity near the sun from IPS measurements using a short wavelength (Ekers and Little, 1971; Armstrong and Woo, 1978; Scott et

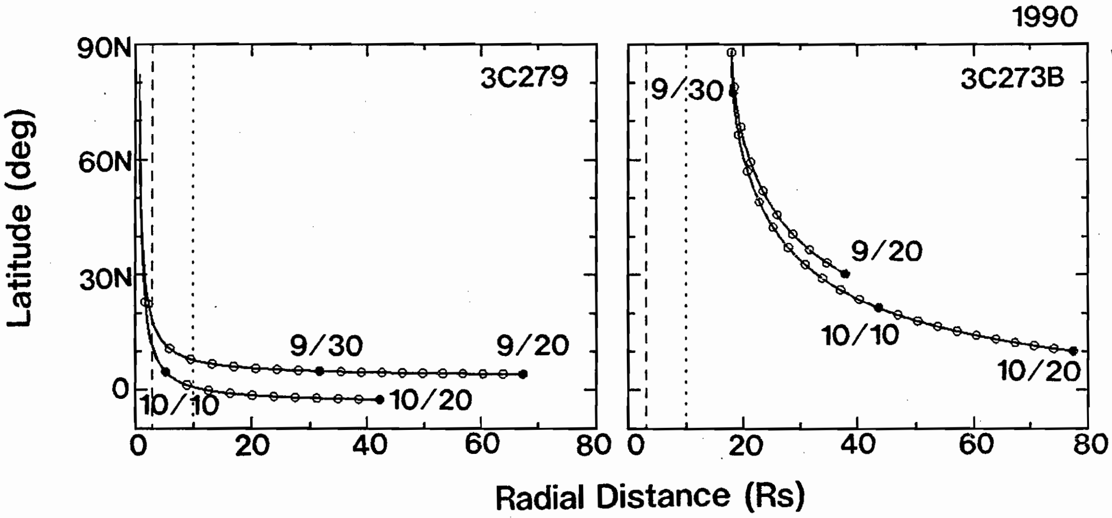

Fig. 1. Time variation of the heliographic coordinate of the point to be probed by IPS observation for 3C279(left) and 3C273B(right)

al.,1983b; Coles et al., 1991). However, observational facts, which have been clarified so far, is too limited to understand the solar wind acceleration fully, and further IPS studies are needed. The present paper describes briefly results of IPS velocity measurements of the near-sun solar wind, which we have carried out using 34m or 26m (after 1992) radio telescopes at Kashima Space Research Center of CRL (More detailed descriptions on our IPS studies are given in papers of Tokumaru et al.(1991,1993)). Here, we discuss the radial dependence of the solar wind velocity in the range from 10 to 80Rs, and its evolution during 1989-1992.

2. Observation

We have observed IPS phenomena of two quasars; 3C279 and 3C279, at 2 and 8GHz since 1989 (solar maximum) for the period from late September to mid October every year. The geometry of IPS observations changes slowly due to the annual motion, and figure 1 displays the time variation of the heliographic coordinate of the point to be probed by IPS for 3C273B and 3C279 during the observation period. As the figure shows, 3C279 approaches to the sun almost radially, keeping a constant latitude near the equator. Such trajectory is quite suitable to study the radial dependence of the solar wind velocity. In the case of 3C273B, which has more intense emission flux than 3C279, the observation point moves to high latitude simultaneously as the radial distance decreases. Therefore, the radial variation of the solar wind velocity derived from IPS observations for 3C273B could be distorted by the latitude variation. In other words, this means that IPS data of 3C273B allow us to discuss the velocity structure at high latitude.

To derive the solar wind velocities from IPS data in 1989, the spectral fitting method (Scott et al., 1983b; Manoharan and Ananthakrishnan, 1990; Tokumaru et al., 1991) has been employed. The solar wind velocities after 1990 have been derived by cross- correlating between IPS data at 2 and 8GHz (so-called "co- spectrum method"; Scott et al., 1983a; Tokumaru et al., 1993). Both of methods are based on the assumption of the weak scattering. This assumption becomes invalid in the vicinity of the sun where plasma turbulence scatters radio waves strongly. The scintillation index measurements indicate that the turnover from weak to strong scattering occurs at about 10 and about 3Rs (dotted and dashed lines in figure 1) for 2 and 8GHz, respectively. Therefore, IPS data obtained within these distances are considered to be less reliable.

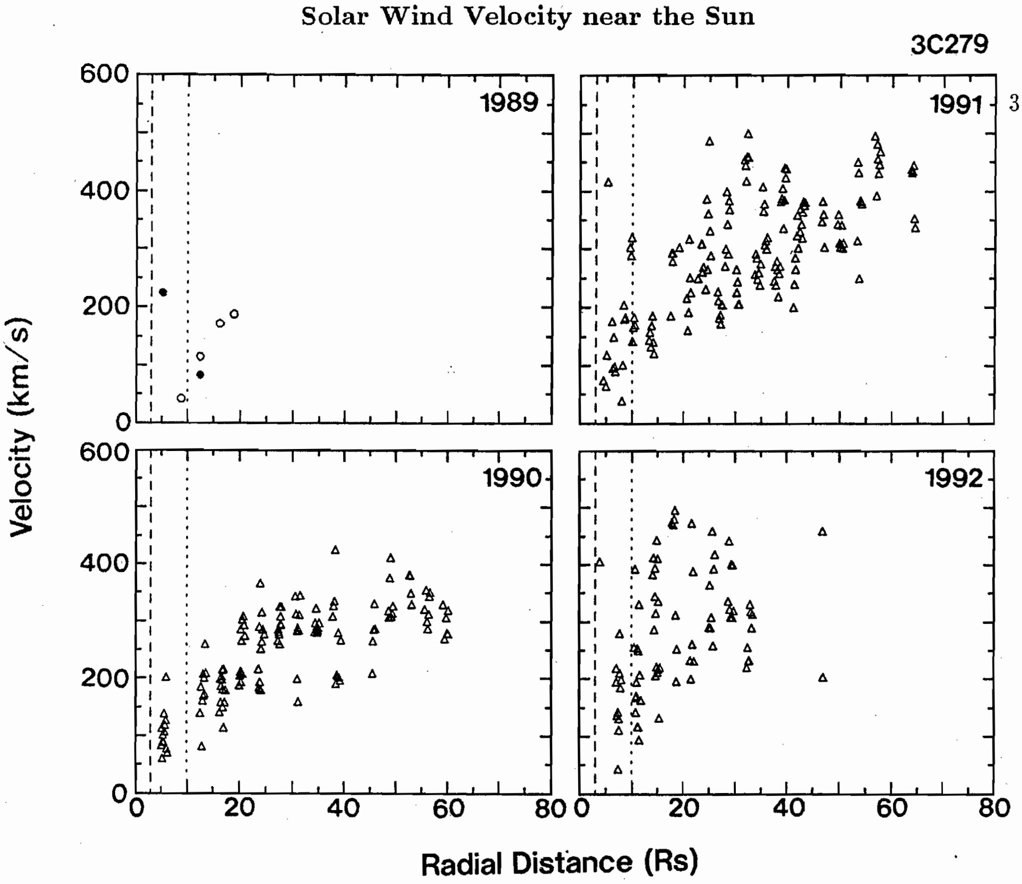

Fig. 2. Radial variations of solar wind velocities derived from IPS observations in 1989-1992 for 3C279. Open and solid circles correspond to velocities derived from IPS data at 2 and 8GHz, respectively. Triangles correspond to the velocity derived with the co-spectrum method.

3. Results

Results of IPS velocity measurements for 3C279 and 3C273B are presented in figures 2 and 3. Here, derived velocities are plotted as a function of the radial distance from the sun, being divided into four panels corresponding to each year. IPS data of 3C279 (figure 2) indicate clearly that the solar wind gains the velocity monotonously with increasing radial distance. Such feature is attributed to the intrinsic radial variation corresponding to the solar wind acceleration, since the trajectory of the 3C279's line-of-sight is oriented in the radial direction.

In the case of 3C273B (figure 3), the radial variation is rather complicated; That is, derived velocities increase near the sun, however they (except for data on 1989) reach a peak, and then decrease at large distance. From the comparison with He1083nm observations (Solar Geophys. Data), it is revealed that the velocity peaks are closely associated with the polar coronal hole or its extension to lower latitude. Therefore, the deceleration of the solar wind found in 3C273B data is ascribed to an apparent effect caused by the velocity structure on the solar surface and the azimuthal movement of the line-of-sight (see figure 1). On the other hand, an increase of derived velocities near the sun (< 40Rs) cannot be explained by such apparent effect, so that it is considered to be the effect due to the solar wind acceleration. Another important feature revealed in figure 3 is the evolution of the high speed wind near the sun in the period of 1989-1992. Such change is less pronounced in IPS data of 3C279, while the velocity gradient becomes somewhat steep. This fact suggests that the polar coronal hole

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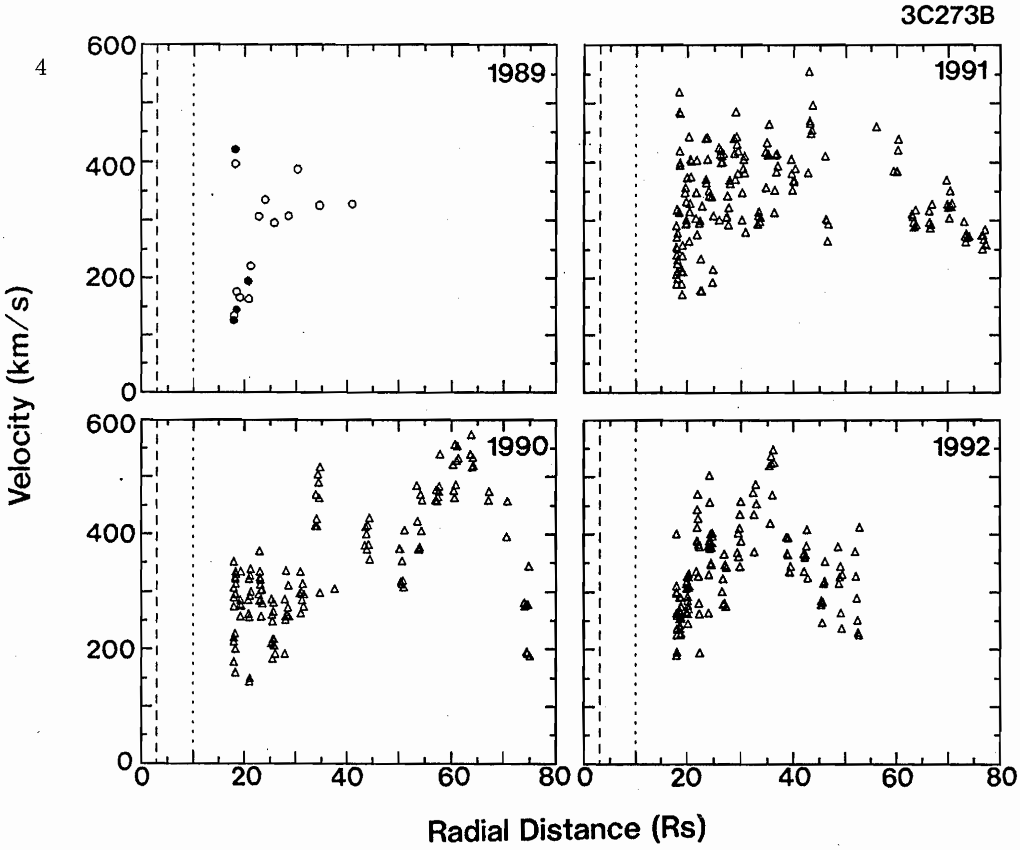

Fig. 3. Same as figure 2, but for 3C273B

develops as the solar activity declines, and shows a good agreement with the well-known solar cycle variation (Hundhausen et al., 1981; Rickett and Coles, 1991).

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