Interplanetary scintillation observations of the solar wind disappearance event of May 1999

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[1] We report extensive interplanetary scintillation (IPS) observations of the solar wind during the period centered around 11 May 1999, when the Earth was engulfed by a region of solar wind with unusually low densities (<1 cm^{-3}) and velocities (<350 km s^{-1}). IPS observations with the Ooty Radio Telescope (ORT), operating at 327 MHz, probe the inner heliosphere along a large number of closely spaced lines of sight over the heliocentric distance range of 0.2 to 1.0 AU, daily, at the rate of about 150 sources in the course of 10 hours. Using these observations, the southern half of the inner heliosphere was monitored everyday between 3 and 16 May 1999. The data show that the solar wind densities were globally subdued, having started subsiding from 3 May 1999, itself at different parts of the heliosphere. This was accompanied by a noticeable decrease in the velocity of the general solar wind also. The IPS data also reveal a small subset of closely spaced sources lying to the west of the Sun that show a steep drop in inferred densities to immeasurably low amounts on and around the 11th May. The actual morphology of the subsidence event, from our observations, is shown to be that of a "void-within-a-void". The role of the polar magnetic field reversal that was taking place between Carrington rotations 1947–1954, which may have played a key role in generating the subsidence event, is also examined. To the best of our knowledge this is the first time that sustained levels of low densities and velocities have been recorded for such a long period over a large part of the inner heliosphere. Some possible signatures of high energy "strahl" electrons were also recorded in this period. *INDEX TERMS:* 2164 Interplanetary Physics: Solar wind plasma; 2169 Interplanetary Physics: Sources of the solar wind; 2118 Interplanetary Physics: Energetic particles, solar; 2134 Interplanetary Physics: Interplanetary magnetic fields; *KEYWORDS:* solar wind, density depletion, IPS, strahl, magnetic-field-reversal

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1. Introduction

[2] Interplanetary scintillation (IPS) observations of compact extragalactic radio sources provide one with an effective and economical ground based method for studying the large scale properties of the solar wind plasma. The main parameters measurable by IPS are the root-mean-square deviation in electron density, the scale size distribution of the density irregularities and the velocity of the solar wind. They are derived from the power spectrum of the observed intensity fluctuations of compact extragalactic radio sources. The Ooty Radio Telescope (ORT), with an effective collecting area of about 8500 m^2 and a declination (δ) coverage of $-60° \leq \delta \leq +60°$, can observe 150–200 scintillating sources in the course of 10 hours yielding high signal to noise ratio (S/N) power spectra with data stretches as short as two minutes. The spectra can be used to estimate the electron density fluctuations (ΔN_{rms}) in the solar wind and to derive the velocity of the solar wind across the line of sight (LOS) to the source [*Balasubramanian et al.*, 1995; *Janardhan et al.*, 1996].

[3] Figure 1 shows a schematic of the observing geometry for a typical IPS observation. The ecliptic plane is shown by the lightly shaded semi ellipse with the letters "S" and "E" denoting the Sun and Earth respectively. The line from the Earth through point "P" represents the LOS to a compact extragalactic radio source, with the point "P" being the foot point of the perpendicular from the Sun to the LOS. The line from the Sun through "P" represents the radially directed solar wind flow across the LOS to the radio source. The point "A" is the foot point of the perpendicular from "P" to the ecliptic plane. The lines SE and SA in Figure 1 lie in the ecliptic plane while the other lines lie outside the ecliptic plane. The angles ϵ and γ are respectively, the solar elongation and heliographic latitude of the radio source. The scattering power in the interplanetary medium is a function of the distance "r" from the Sun to the LOS and is given by $\beta \propto r^{-4}$. It is therefore obvious that in any IPS observation, most of the contribution to scintillation will come from a small region around the point "P" on the LOS.

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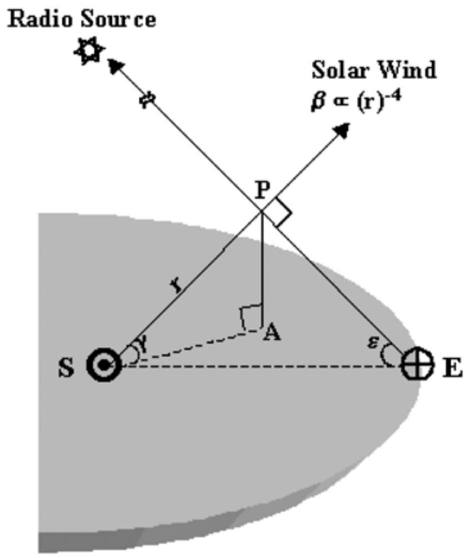

Figure 1. Shows a schematic of the observing geometry for a typical IPS observation. The ecliptic plane is shown by the lightly shaded semi ellipse with the letters "S" and "E" denoting the Sun and Earth respectively. The line from the Earth through point "P" represents the LOS to a compact extragalactic radio source, where the point "P" is the foot point of the perpendicular from the Sun to the LOS. The line from the Sun through "P" represents the radially directed solar wind flow across the LOS to the radio source. The point "A" is the foot point of the perpendicular from "P" to the ecliptic plane. The lines SE and SA lie in the ecliptic plane while all other lines lie outside the ecliptic plane. The angles ϵ and γ are respectively, the solar elongation and heliographic latitude of the radio source.

[4] At 327 MHz, the coverage in ϵ, the angle between the LOS to the source and the Sun-Earth line, is $15° \leq \epsilon \leq 60°$. This corresponds to $\sim 55\ R_\odot \leq r \leq 190\ R_\odot$ where r is the distance between the Sun and the LOS to the source and $R_\odot$ is the solar radius. Regular observations of a large number of compact, spatially well-distributed radio sources can yield a large-scale picture of the density fluctuations and velocities prevailing in the solar wind, in addition to tracking traveling interplanetary disturbances (IPD) on a day-to-day basis [*Janardhan et al.*, 1996; *Balasubramanian et al.*, 1996]. With the advent of spacecraft, however, it is possible to investigate the solar wind much closer to the Sun using radio links between deep space probes and the Earth [*Woo and Armstrong*, 1981; *Woo et al.*, 1982; *Janardhan et al.*, 1999; *Lotova et al.*, 2002]. Such observations are however rare as they require the fortuitous placement of a spacecraft in superior conjunction and are generally confined to the ecliptic plane.

[5] Deviations from "normally expected IPS behavior" can be quantified in terms of the value of a normalized scintillation index (m) defined as, $g = m(\epsilon)_{obs}/m(\epsilon)_{exp}$. Here m is the ratio of the root-mean-square deviation of the signal intensity to the mean signal intensity, while $m(\epsilon)_{obs}$ is the observed m at a given ϵ and $m(\epsilon)_{exp}$ is the expected long-term average m of the source at the same ϵ [*Hewish and Bravo*, 1986]. Using over 2 years of data around solar maximum in 1978–1979 *Hewish et al.* [1985] showed that there was no evidence for enhanced or decreased scintillation that was not associated with corresponding variations in density. IPS can therefore be used with confidence to monitor plasma density along the LOS to a source even though it measures only the fluctuation in density and not the density itself.

[6] The reliable determination of solar wind velocity from single station IPS data requires that the S/N of the power spectra are more than 10 db above the background noise level [*Tyler et al.*, 1981; *Scott et al.*, 1983; *Manoharan and Ananthakrishnan*, 1990]. This implies that while g can be estimated for a large number of scintillating sources, the velocity can be derived only for a lesser number of sources which scintillate well.

2. Observations

[7] From 3 May 1999 to 16 May 1999 a large portion of the southern part of the inner heliosphere was monitored, by IPS observations with the ORT, on a daily basis. The data were unusual since the scintillation levels for all the sources were much below normal whereas one would expect the general scatter in the g-plots to be around a mean g of unity under normal conditions, as is implied by the definition of g. The data are shown in Figures 2a and 2b which we refer to as "g-plots." Each panel of the g-plots show a polar plot of g-values for one day of observations. The finely dotted circles are circles of equal ϵ with the Sun at the center. The various ranges of g-values are shown by different symbols with open five-pointed stars indicating $g = 0$; filled gray dots indicating $0.0 < g \leq 0.6$; open circles indicating $0.6 < g \leq 1.0$; and open squares indicating $g > 1.0$. It may be noted that $g = 1$ implies that the solar wind densities are normal, while $g < 1$ and $g > 1$ imply depleted and enhanced densities respectively. The plots indicate that the entire interplanetary medium (IPM) was experiencing lower than normal densities. The data also show that microturbulence [*Ananthakrishnan et al.*, 1980] in the IPM remained low for a prolonged duration of several days over a large part of the inner heliosphere.

[8] Although other instances of low densities in the IPM have been reported earlier [*Schwenn*, 1982; *Gosling et al.*, 1982; *Phillips et al.*, 1989] these were of much shorter duration. Figure 3 compares the IPS data of May 1999 with that of August 1998 and May 1995, during the approach to solar maximum and during the solar minimum respectively. During both these periods a stretch of one month of data has been shown when the solar wind was monitored with the ORT in a manner similar to that of the May 1999 period under discussion. The three panels on the left in Figure 3 show respectively the solar wind velocity plotted against g for the period May 1999 (upper panel), May 1995 (middle panel), and August 1998 (lower panel), while the panel on the right shows the sunspot number progression of solar cycle 23 from 1994 onward. Dashed vertical lines in the right hand panel indicate the periods May 1995, August 1998, and May 1999 during the current solar cycle for which IPS data are shown in the left hand panels. The data of August 1998, during the approach to maximum, show the normally expected scatter around a g-value of unity, whereas in the May 1999 data g-values are seen to be even lower than that during the solar minimum in May 1995. It is seen further from the three left hand

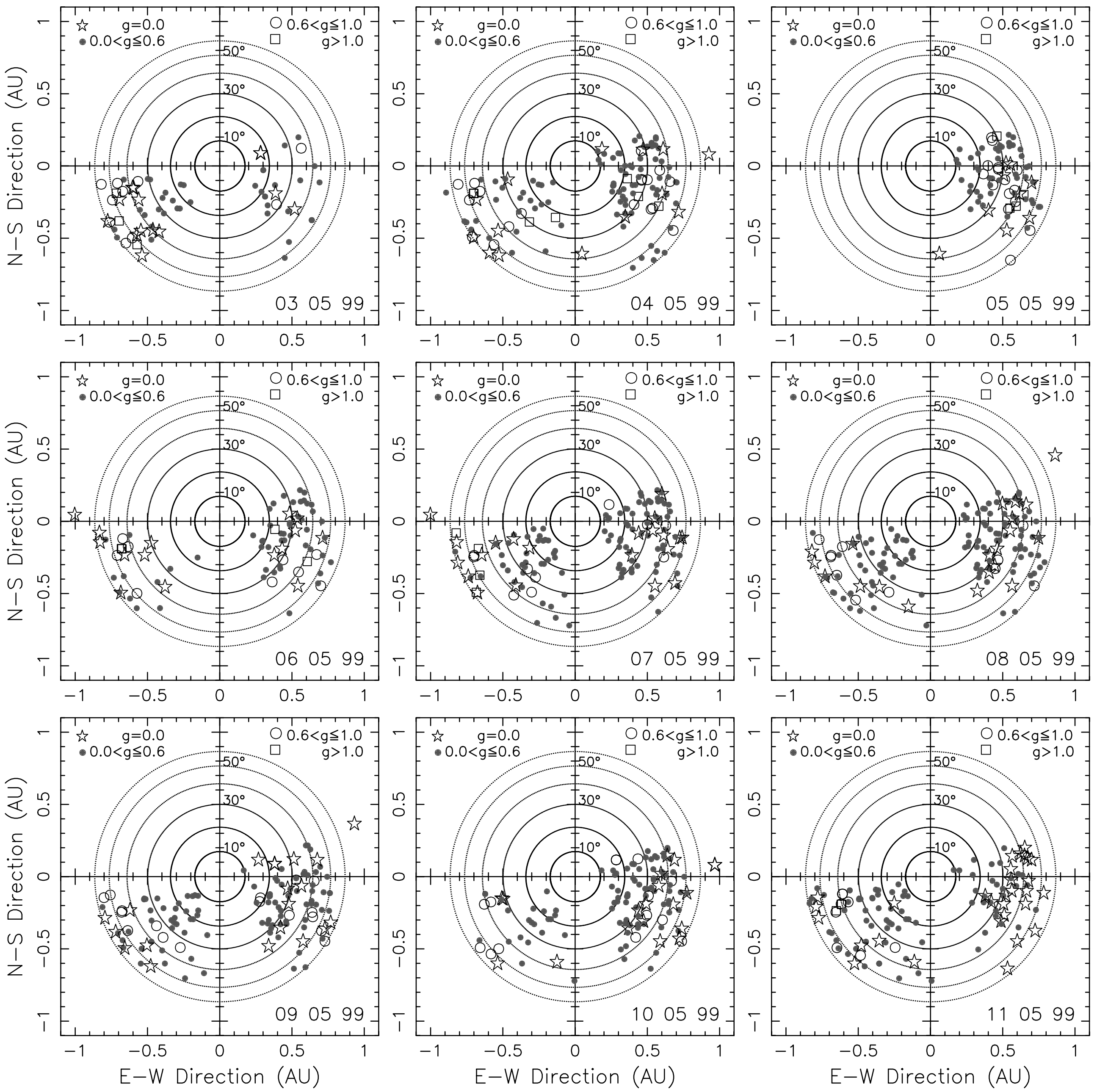

Figure 2a. Shows polar plots of g-values for each day of observations. The finely dotted circles are circles of equal elongation with the Sun at the center. The various ranges of g-values are shown by different symbols. It may be noted that g = 1 implies that the solar wind densities are normal, while g < 1 and g > 1 imply depleted and enhanced densities respectively.

panels of Figure 3 that the mean of the velocity values for May 1999 tends to be significantly lower than for the data of May 1995 and August 1998; the mean velocities are about 350 km s^{-1} for May 1999, as compared with 500 km s^{-1} in the other two cases.

3. Distribution of Low g Values

[9] Figure 4 shows the distribution of g-values plotted as histograms on each day of observations. In the distribution, with the exception of 11 May 1999, ∼60% of the sources have g-values ≤ 0.3 and ∼80% have g-values ≤ 0.6. On 11 May, out of a total of 120 observations, around 80% have g-values ≤ 0.3 while 95% have g-values ≤ 0.6. This distribution of g-values may be contrasted with in situ spacecraft measurements of density. During the interval from about 00 UT 10 May to ∼18 UT 11 May, the density of protons in the solar wind, as recorded by the Wind spacecraft, started decreasing, dropped to below 1 cm^{-3} and went down to values as low as ∼0.2 cm^{-3} [*Farrugia et al.*, 2000; *Richardson et al.*, 2000]. Similar data from ACE SWEPAM showed that the proton density started decreasing from a few particles cm^{-3} at about 06 UT on 10 May to values less than 1 cm^{-3} by about 18 UT on 10 May, and continued to

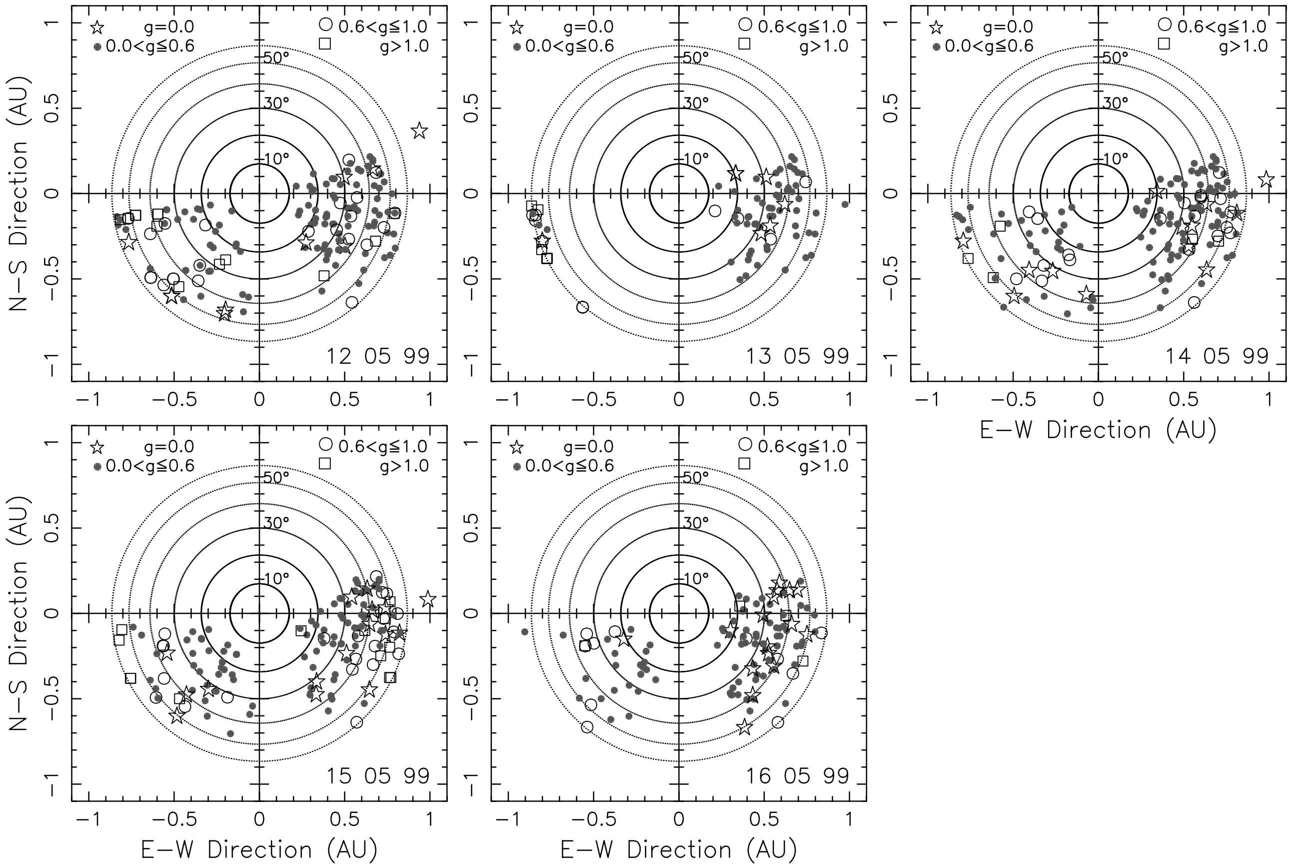

Figure 2b. (continued)

decrease further. By about 00 UT on 12 May it was immeasurably low. The densities started increasing on 12 May from about 02 UT and built up to the level of a few tens of protons cm^{-3} by about 16 UT on the same day. Figure 5 reproduces the hourly averaged proton densities recorded by ACE SWEPAM between 1 and 17 May 1999 (data available at http://www.srl.caltech.edu/ACE/ASC/level2/lvl2DATA_SWEPAM.html). The important point to bear in mind is that the in situ measurements indicate normal density levels before and after the steep dip on 11 May 1999. Our measurements on the other hand, cover extensive regions of the inner heliosphere and clearly indicate that the entire inner heliosphere had less than normal densities well before 11 May and the densities had not returned to normal values even by 16 May 1999. Further, of the approximately 285 radio sources observed during the period 3–16 May 1999 a small subset of sources showed a steep fall in g-values on and around 11 May 1999, in a manner similar to that observed by spacecraft.

[10] Figures 6a and 6b plot g as a function of date for this small subset of sources. Also indicated in each plot are the source names, the helio latitudes and longitudes and the distance in AU from the Sun of the point along the LOS to the source that is closest to the Sun. Figure 7 is a polar plot of the g-values for the sources in Figures 6a and 6b. Note however, that the g-values for each of the sources have been plotted for all the observations. The finely dotted circles in Figure 7 are circles of equal ϵ with the Sun at the center. The various ranges of g-values are shown by different symbols with filled dots indicating g = 0.0; gray crosses indicating $0.0 < g \leq 0.6$; thick dashes indicating $0.6 < g \leq 1.0$; and open circles indicating $g > 1.0$. All the sources are located west of the Sun-Earth line and occupy a region between ~0.5 AU and ~0.8 AU. From the values of latitude, longitude and distance for these sources in Figures 6a and 6b we may note that the LOS to these sources probe a localized region of the IPM. We believe that the scenario in the IPM in this period was that of a "void-within-a-void," with a small region of the IPM showing a near absence of particles (indicated by the sources for which g's drop to zero) while the rest of the IPM had lower than normal densities (indicated by the majority of observed sources for which g's are well below normal). The fact that a few sources recorded the dip before 11 May and a few, after, imply that the exact morphology of the void was spherically asymmetric, as is to be expected. In a recent paper *Vats et al.* [2001] discuss the same event of May 1999 and, based on very scanty data they conclude that the event represents a nearly "normal plasma flow in most of the medium." This is clearly not the case as can be seen from our extensive data set.

4. Solar Polar Field Reversal and Coronal Magnetic Field

4.1. Field Reversal

[11] The periodic 22 year solar magnetic cycle starts with the rapid poleward extension of the heliospheric current sheet (HCS). The existing magnetic fields at the poles of the Sun are thus carried to the opposite poles in approximately 6 to 8 solar rotations, thereby causing a polar field reversal.

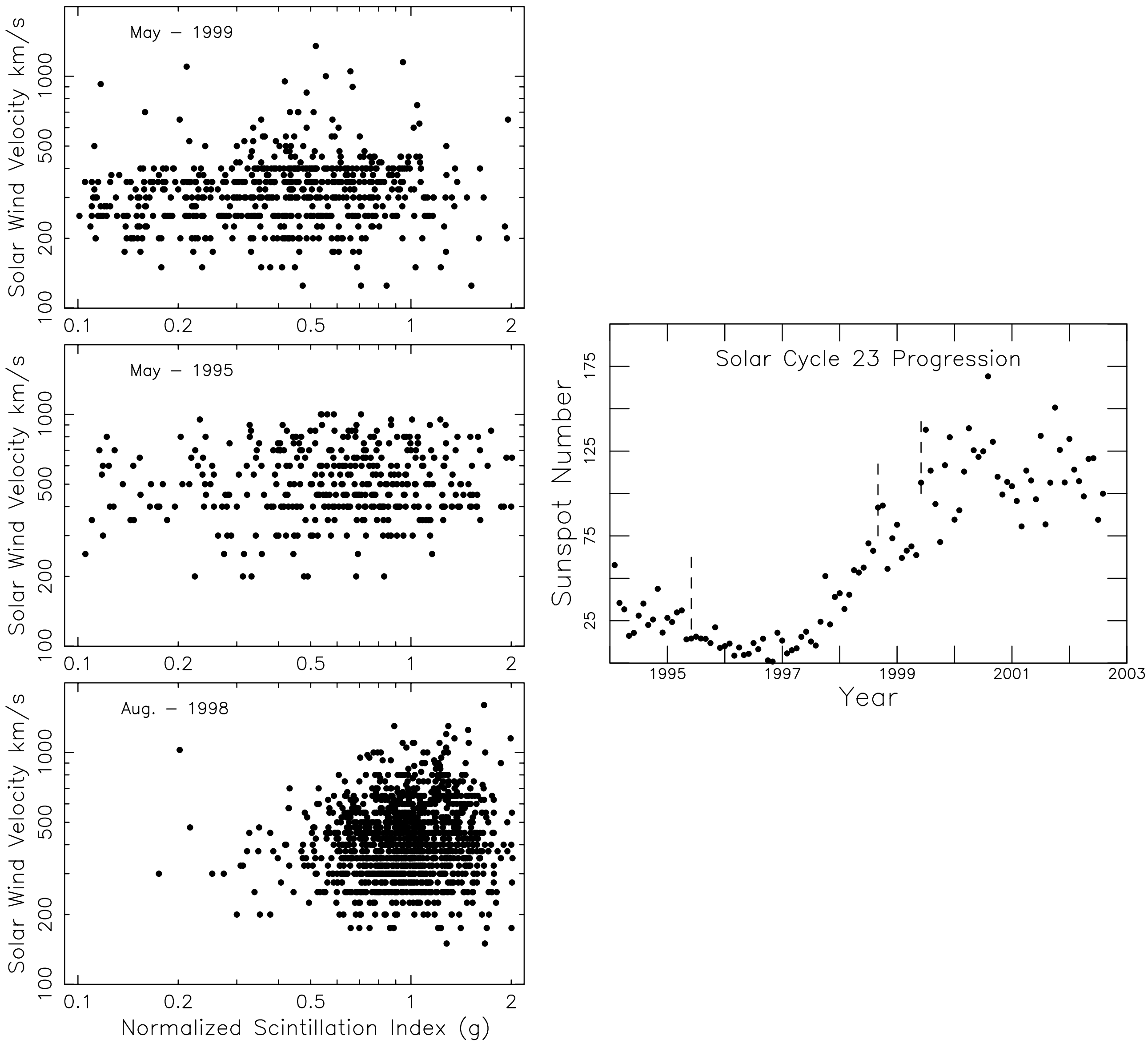

Figure 3. Shows, in the left-hand panels, velocity values versus g during the subsidence event in May 1999 (top panel), around the solar minimum in May 1995 (middle panel), and August 1998 (bottom panel). The data of May 1995 and August 1998 show normal expected distribution of g-values during minimum and maximum years. However, the data of May 1999 are clearly abnormal, resembling the distribution during solar minimum conditions with only a few g-values greater than unity. The panel on the right shows the sunspot number progression of solar cycle 23 from 1994 onward. Dashed vertical lines in the right-hand panel indicate the periods May 1995, August 1998 and May 1999, in the current solar cycle for which IPS data are shown in the left-hand panels.

The rapid poleward extension, at the start of the new magnetic cycle, began in CR1947 [*Usmanov et al.*, 2000] and the polar field had reversed by CR1954 [*Asaoka et al.*, 2002]. It may be noted that the period May 1999 corresponds to CR 1949. *Usmanov et al.* [2000] have concluded that the deformation of the HCS that takes place during such field reversals, at the beginning of any solar activity cycle, is likely to be associated with density anomalies.

4.2. Coronal Magnetic Field

[12] The coronal magnetic field cannot be measured directly, but can be computed, [*Hakamada and Kojima*, 1999], using measured values of the photospheric magnetic field coupled with a potential field extrapolation. Figure 8 shows the computed three-dimensional structure of the coronal magnetic fields for Carrington rotation 1949 (M. Kojima, private communication). The solid line marks the location of the HCS. The magnetic field lines, shaded differently to distinguish the two polarities, are shown projected on to a source surface at 2.5 $R_{\odot}$ beyond which the potential field lines are assumed to be radial.

[13] In Figure 8 the midlatitudes in both hemispheres are almost entirely dominated by closed loop structures. The only exception is the large open field structure on the west

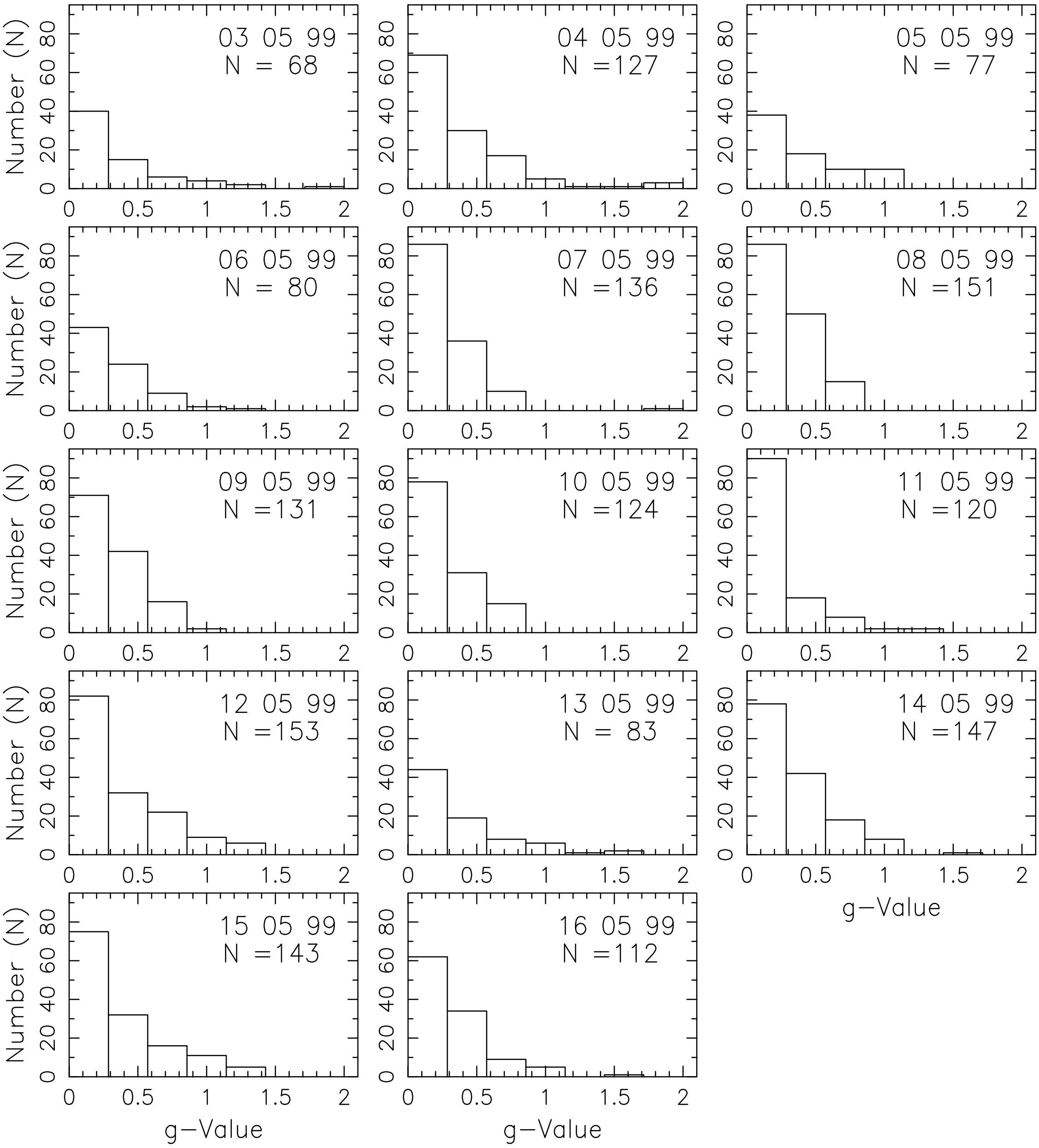

Figure 4. Shows histograms of g-values for each day of observation. The histogram for 11 May 1999 clearly shows a much steeper drop in densities with around ~95% of the sources being observed with g-values less than 0.6. The value N, below the date in each panel, gives the number of sources observed on that day.

limb originating at the boundary of the HCS. This open field region fans out into interplanetary space from a small region of the photosphere, otherwise dominated by closed loops. However, the sharp localized decrease in the densities observed to the west of the Sun (Figures 5, 6a, 6b, and 7) may imply that the field lines beyond the source surface remained non-radial during 3–16 May 1999 and possibly even more non-radial a few days prior to 11 May 1999 thereby creating the void-in-void morphology that we see. Another candidate for creating the above morphology is a classical CME moving through an already depleted medium. However, in the list of events recorded by the LASCO coronagraph we found no appropriately located CMEs during this period. We, therefore, believe that the former scenario is more likely since large-scale realignments in magnetic field structure take place during a solar polar field reversal.

[14] Corroboration for this view comes from *Schwenn* [1982], who reported "strange though rare excursions from the average solar wind" that occurred in November 1979, and June 1980. The data were from HELIOS 2 and 1 spacecraft respectively when they were 0.3 or 0.37 AU from the Sun. The data from HELIOS 1 during 6–8 June 1980 were dramatic because the proton densities decreased steadily over an entire day from the normal value of ~100 cm^{-3} to less than 1 cm^{-3}, while the velocity and the magnetic field remained constant at ~300 km s^{-1} and ~35 nT, respectively. *Schwenn* [1982] has noted that there

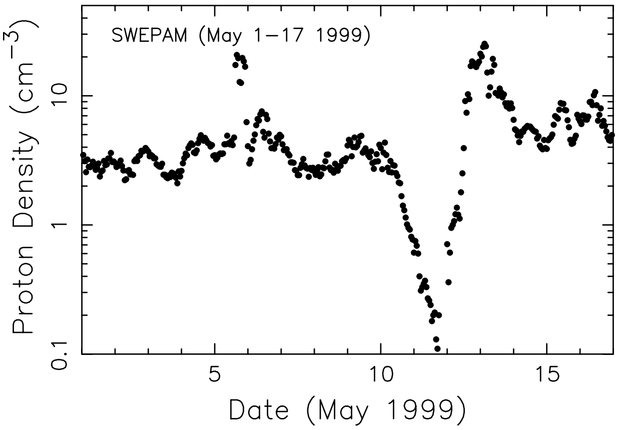

Figure 5. Shows the hourly averaged proton densities recorded by ACE SWEPAM between 1 and 17 May 1999 (data available at http://www.srl.caltech.edu/ACE/ASC/level2/lvl2DATA_SWEPAM.html). The proton density starts decreasing from a few particles cm^{-3} at about 06 UT on 10 May to values less than 1 cm^{-3} by about 18 UT on 10 May, and continues to decrease further. By about 00 UT on 12 May it is immeasurably low. The densities started increasing on 12 May from about 02 UT and built up to the level of a few tens of protons cm^{-3} by about 16 UT on the same day.

was no disturbance in the interplanetary medium for several days ahead of the density drop, nor was there any associable solar surface feature. Solar Geophysical Data reports during the period December 1979–July 1980 show that a field reversal had taken place.

5. Stray High Velocities

[15] During 3–16 May 1999, the solar wind was generally subdued. However, a few stray high velocity streams (~1000 km s^{-1}) were recorded. These high speed components were due to "two-stream" IPS power spectra which had two components–one, a normal low speed solar wind, and the other, a high speed one [*Moran et al.*, 2000]. It was noted further that whenever such a high velocity stream occurred at any ϵ it was not accompanied by high velocities at adjacent elongations, thereby ruling out traveling IPD [*Ananthakrishnan et al.*, 1999].

[16] Table 1 summarizes the occurrence of the few stray high speed solar wind streams crossing the LOS to the scintillating sources, as detected by our IPS observations on 8, 9, 10, 12 and 13 May 1999. The columns in Table 1 list respectively, the date of observation in May 1999, the time of observation in UT, the ϵ of the source, the S/N of the observed IPS spectra, and the derived two-stream (low and high) solar wind velocities. Such two-stream IPS spectra are abnormal and can be identified and model-fitted to yield the velocities of both the high velocity stream crossing the LOS and the background low speed solar wind [*Moran et al.*, 2000].

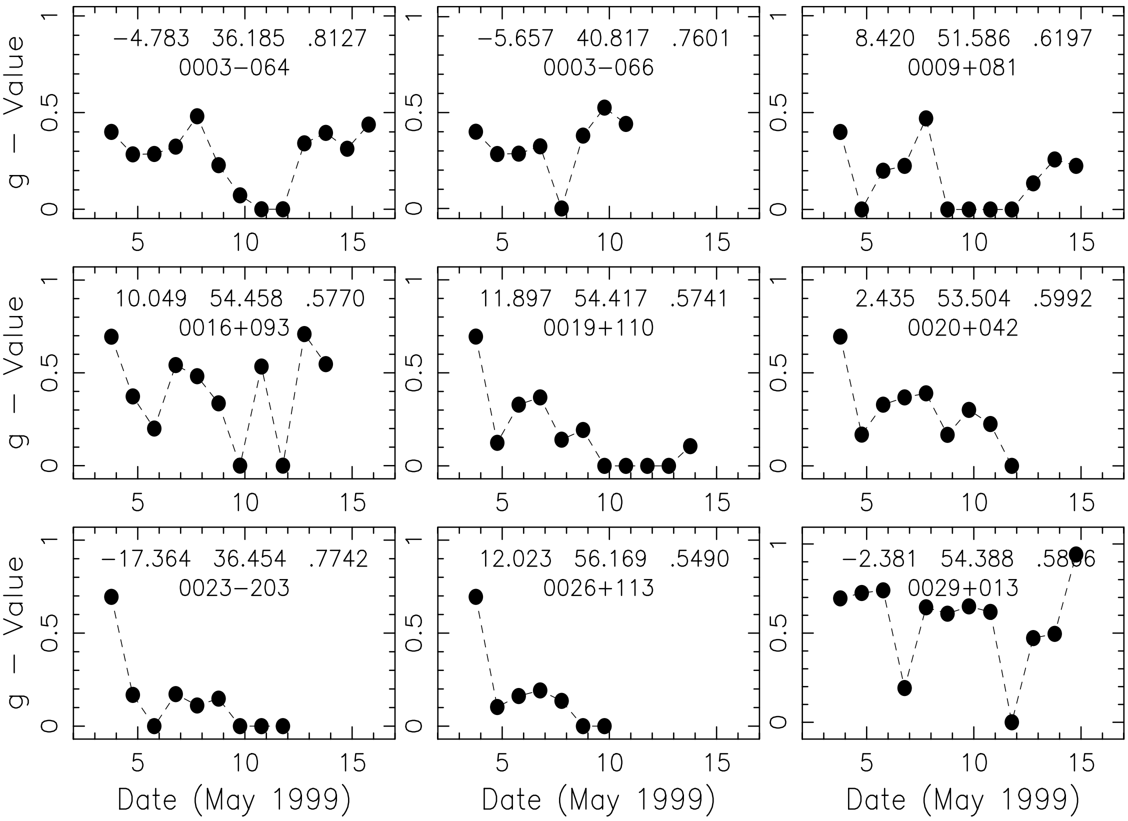

Figure 6a. Shows plots of g-values versus date of observation for sources that showed a clear dip in g-values on and around the 11th May 1999. The helio latitude, helio longitude, distance from the Sun in AU and source name are shown at the top of each panel. See the text for details.

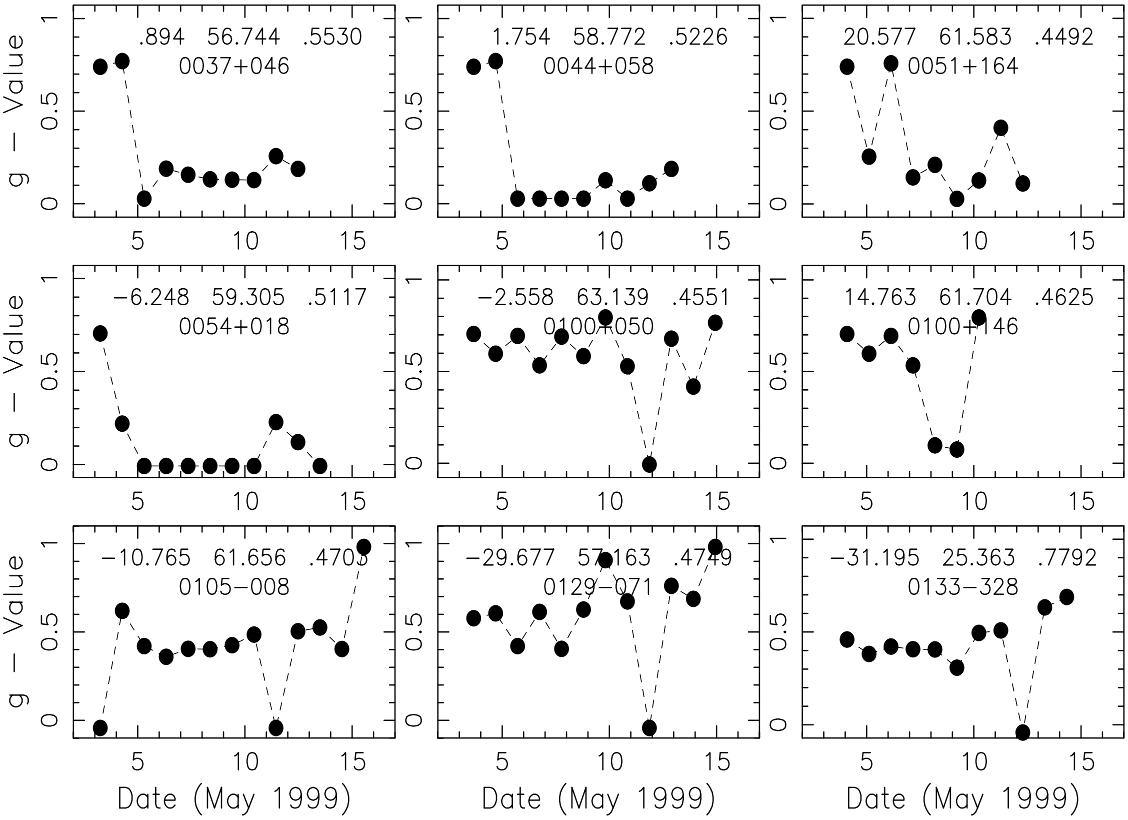

Figure 6b. (continued)

[17] It is important to understand the occurrence of such high velocities along isolated, stray lines of sight. On each of these days, i.e., when such high velocities were observed at stray ϵ, there are measurements of velocities at several closely spaced LOS at adjacent ϵ which showed "normal" velocities only. These stray high velocities imply that the microturbulence along the LOS to the particular source was dominated by isolated, collimated, high velocity streams. High time resolution observations of IPS, obtained by continuous monitoring of a single strong IPS source over periods of about 10 hours, have shown that the scintillation index [*Gothoskar and Rao*, 1999] can change substantially over a few minutes of time depending on the location of the IPS disturbance along the LOS. Even small disturbances cutting across the LOS at the point "P" (ref. Figure 1) can cause large variations in scintillation index as compared to larger disturbances crossing the LOS at points other than "P."

[18] A probable explanation for the stray, high speed streams that we have observed is that they are the highly collimated "strahl" electrons proposed by *Fairfield and Scudder* [1985]. These streams represent electrons streaming away from the Sun along directly connected magnetic field lines to the Earth. During 9–13 May 1999, an intense polar rain of "strahl" electrons on to the northern polar cusp region and a dipolarization of the geomagnetic field, extending as far as six Earth radii has been reported [*Farrugia et al.*, 2000]. These authors find that whereas during the normal polar rain, electron number fluxes are measured in the few hundred eV range, the number fluxes measured up to ~15 keV energy around 11 May 1999. We speculate that these high energy electron beams as also the narrow high speed streams, originate from the same open field region referred to in section 4.2. If so, they could give rise to microturbulence and abnormal temporal spectra, as they interact with the ambient slow solar wind. If these streams cut the LOS at or near the point "P" (ref. Figure 1) then the scattering power β will increase dramatically due to the r^{-4} dependence of β, thereby giving rise to the two-stream spectra that we observe. It is important to keep in mind the fact that the solar wind densities around 11 May 1999 were greatly depleted, implying that contributions to IPS from parts of the LOS other than around the "P" point would be negligible.

[19] From Table 1, it is seen that we have detected the two-stream velocity structures at various elongations, mostly, in the weak IPS scattering regimes. These cover a large spatial extent of the inner heliosphere, whereas the in situ spacecraft which are confined within the magnetosphere can monitor only narrow regions of the Earth's proximal space, around the polar regions, for strahl. More studies are required to confirm our conjectures so that such IPS observations could be possibly used as a diagnostic for detecting "strahl" in the inner heliosphere.

6. Discussion

[20] While near-earth spacecraft observed the solar wind densities and velocities drop to unusually low values

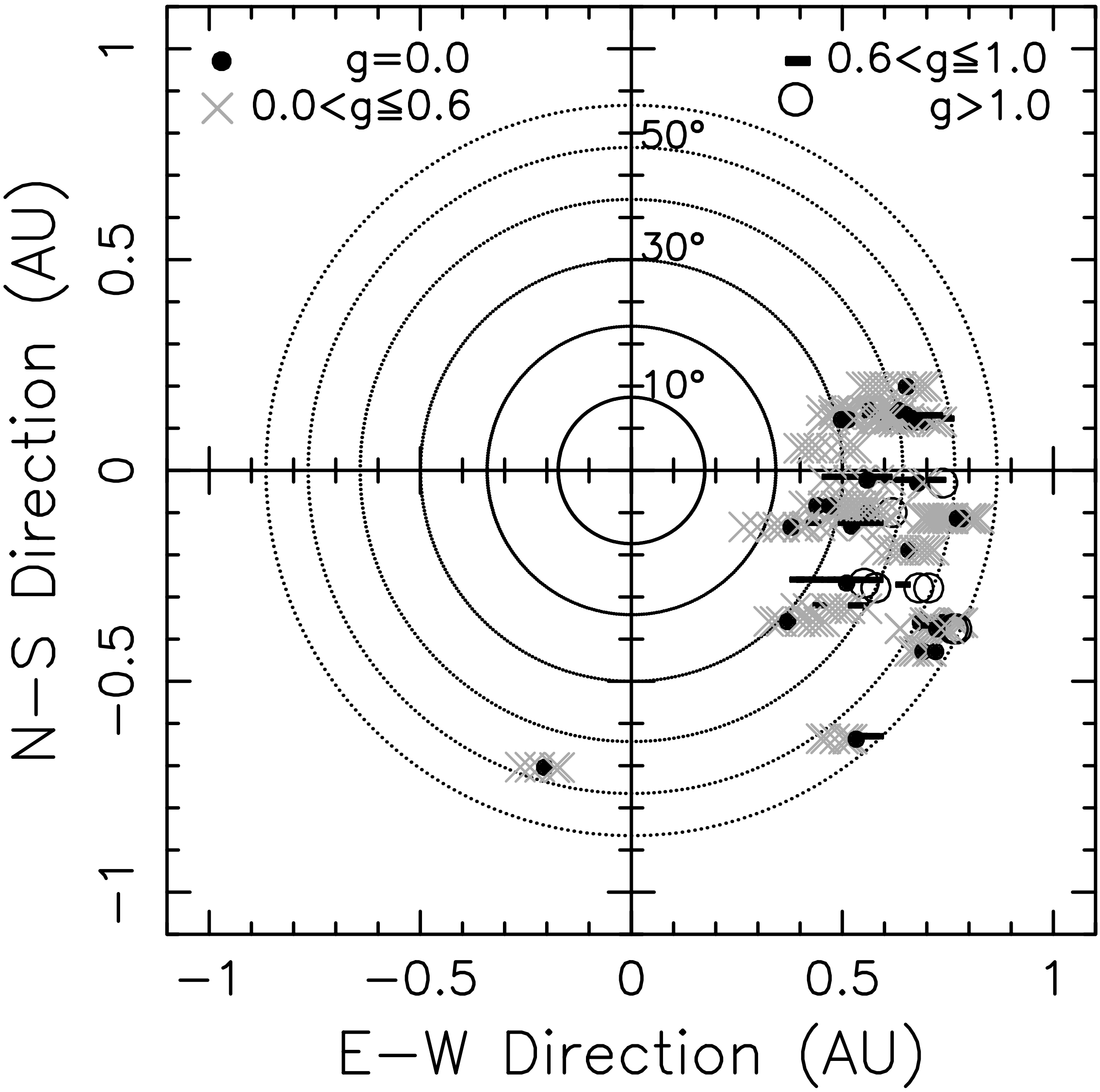

Figure 7. Polar plot of g-values for sources that show a steep drop in g-values on and around 11 May 1999. The g-values for each of the sources have been plotted for all of the days it was observed. The finely dotted circles are circles of equal elongation with the Sun at the center. The various ranges of g-values are shown by different symbols, with the filled dots indicating g-values that became immeasurably low on or around 11 May 1999. The gray crosses indicate $0.0 < g \leq 0.6$; thick dashes indicate $0.6 < g \leq 1.0$; and open circles indicate $g > 1.0$. It may be noted that g-values of sources adjacent to those represented by filled dots (indicating $g = 0$) are by and large very low ($g \leq 0.6$).

between 10–12 May 1999, IPS observations of a large part of the southern heliosphere have shown that the decrease in electron density fluctuations began right from 3 May 1999. Such subsidence was accompanied by a perceptible decrease in the speed of the solar wind from 7 May 1999. We infer from our extensive data that the microturbulence in the solar wind becomes low during such prolonged intervals of subsidence in solar wind parameters. Since the observations were available only in the period 3–16 May, it is difficult to say when exactly the densities and velocities began to decrease and when it recovered to normal solar wind values. However, our data indicate that the restoration of normal conditions began by the latter half of 12 May though it was not completed till 16 May 1999. Apart from the general decrease in densities over a large portion of the IPM it was seen that there was a localized region within the large void where there was further depletion of electron densities-i.e., a void within a void was observed.

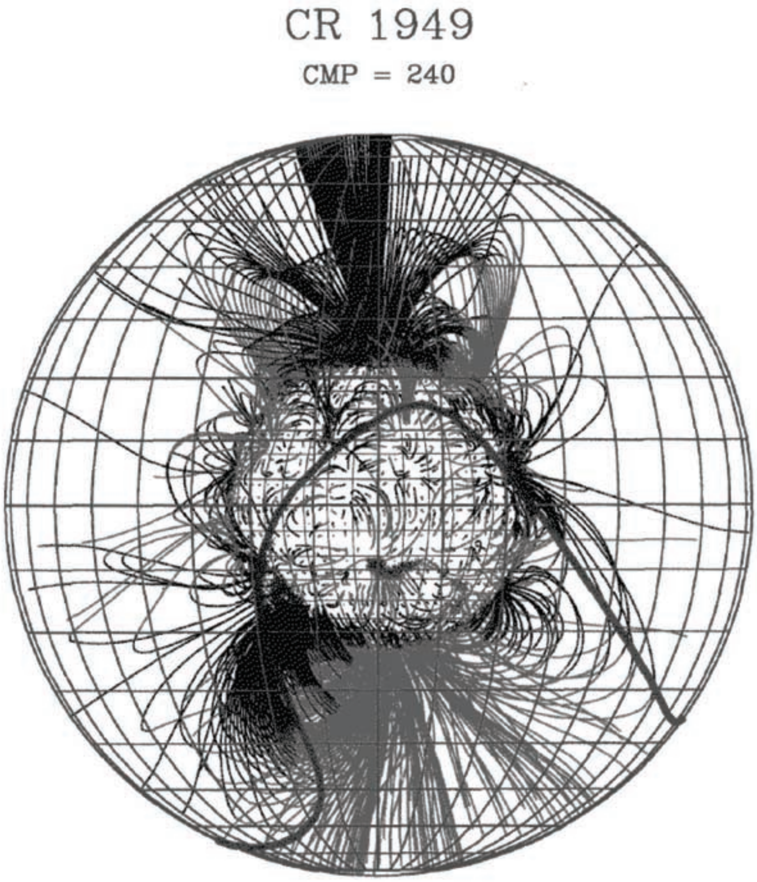

Figure 8. Shows the computed three-dimensional structure of the coronal magnetic fields for Carrington rotation 1949. The solid line marks the location of the HCS. The magnetic field lines, shaded differently to distinguish the two polarities, are shown projected on to a source surface at 2.5 $R_\odot$ beyond which the potential field lines are supposed to be radial. In order not to clutter the figure with too many lines, only fields between 5 G and 250 G on the photosphere are plotted. Heliographic longitudes and latitudes at intervals of 10° are indicated by the graticule superposed on the solar surface at 2.5 $R_\odot$. The plot is viewed from 240° in Carrington longitude and 30° in heliographic latitude.

[21] The subsidence in electron density fluctuations was also accompanied by the detection of high speed streams along a few trajectories in the IPM. These were probably due to the highly collimated, and closely field-aligned beams of strahl electrons due to polar field lines connecting back to the Sun [*Fairfield and Scudder*, 1985]. The occurrences of strahl electrons were found during 8–13 May 1999.

[22] As stated earlier, this period was the longest observed with solar wind densities below 1 particle cm^{-3}. However, it is not known now as to why such periods of low density occur and what its solar origin is. It is possible that changes taking place in the coronal magnetic field configurations, as during a polar magnetic field reversal on the Sun, resulted in a low velocity, low density heliospheric environment [see also *Usmanov et al.*, 2000]. As a consequence, a long stretch of low density microturbulence ensued in the IPM. This was sensitively measured by our IPS observations.

[23] Since the near-earth environment frequently encounters phenomena whose solar origins are unclear, IPS monitoring of the solar wind, which provides an overall view of the inner heliosphere, is an important tool in studying the solar wind and the Sun-Earth connection. Global coverage using an international network of IPS stations is however required to provide continuous monitoring.

Table 1. Location and Velocities Derived From Two-Stream IPS Spectra Between 8 and 13 May 1999[a]

Date, May 1999	Time, UT	Elongation, °E or °W	S/N, db	Velocity, $km\ s^{-1}$ Low	High
8	0715	14 E	25	200	950
8	0840	30 E	20	350	1350
9	0133	17 W	31	300	1050
9	0625	23 W	22	350	1200
10	0129	18 W	31	200	1050
10	0947	39 E	22	250	1000
10	2314	75 W	18	400	1500
12	0450	15 W	19	250	1100
13	0118	20 W	24	300	1250

[a]Columns list, respectively, the date of observation in May 1999, the time of observation in UT, the ϵ of the source, the S/N of the observed IPS spectra, and the derived two-stream (low and high) solar wind velocities.

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