Test of the GG Index to Infer the IMF Polarities

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Abstract

The North-South cosmic-ray anisotropy (GG index), derived from the Nagoya multidirectional muon telescope data, is used to infer the interplanetary magnetic field (IMF) polarities, from January 1971 through December 1999. It turns out that the success rate (S) of the inferring method depends on the different solar wind regimes.

1. Introduction

The IMF polarity plays an important role in many phenomena occurring in the solar wind and the Earth's magnetosphere. As satellites and space probes do not monitor continuously the interplanetary space, the possibility of inferring the IMF polarity from ground measurements is attractive. It has been shown in the past that the North-South (N-S) cosmic ray (CR) anisotropy is a convenient proxy of the IMF polarity [2,3]. The suggested procedure may be summarized as follows. A daily index (GG) is derived from the observations performed at the Nagoya multidirectional muon telescope (geographic coordinates: 35° 09' N, 136° 58' E; altitude: 77 m a. s. l.). The average GG value over each Bartels rotation (GG_B) is then subtracted from the single GG values. The sign of the differences $\Delta GG = GG - GG_B$ allows to infer the IMF polarity. In general, $\Delta GG > 0$ should correspond to a negative and $\Delta GG < 0$ to a positive polarity, while $\Delta GG = 0$ to an undefined polarity (hereafter, it will be named *mixed polarity*: m). Recently, Laurenza et al. [1] performed a systematic comparison between the polarities derived with the above method and those simultaneously measured by magnetometers on board of Earth's satellites. They showed that the inferred polarities are affected by a bias when positive or negative sectors are dominant during a Bartels rotation. This bias cannot be removed, but the effect is reduced if one discards the polarities coming from the GG differences whose

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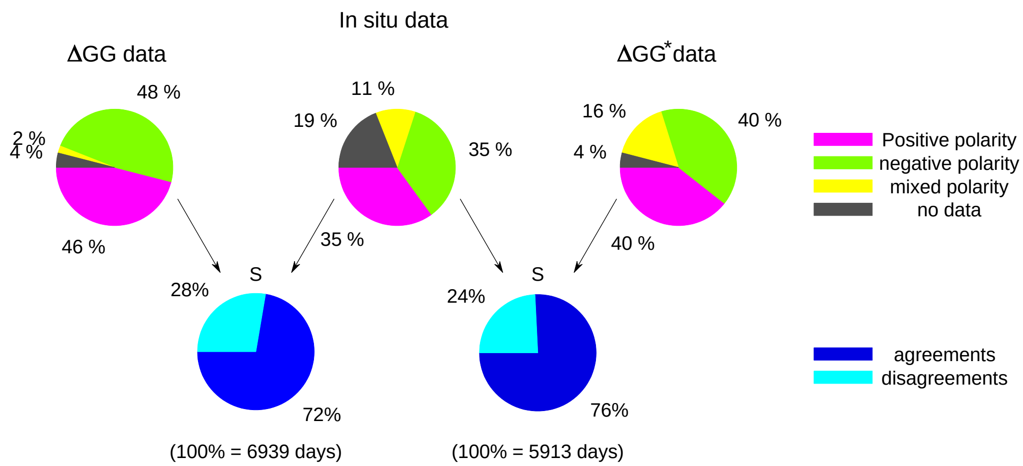

Fig. 1. Percentage of data used in the analysis (top) and Success rate (S, bottom) for the used data combination (see the text).

absolute values are smaller than σ_m (i.e the standard error of GG_B). Here we further investigate the reliability of the inferred polarities, using an extended data set from January 1, 1971 to December 31, 1999 (i.e. 10592 days). In particular, we will focus our attention on the role played by the basic interplanetary parameters on ΔGG values, in order to single out the solar wind regimes under which the inferred polarities may be used with the highest confidence.

2. Global comparison of inferred and measured polarities

In our study, we use the following data sets:
– daily values of the IMF polarity inferred from the GG indices with the procedure outlined in Sect. 1.
– daily values of the IMF polarity measured by a variety of Earth's satellites and made available as OMNI Database: http://nssdc.gsfc.nasa.gov/omniweb/ow.html.
The top of Fig. 1 shows the data distributions for the considered time period. However, a significant comparison can be performed only when both polarities are defined. We have thus removed the mixed polarities from our data to evaluate the success rate of the inferring method: $S = A/(A+D)$ (being A the number of *agreements*, i.e. the number of days for which the inferred and measured polarities were consistent with each other; D the number of *disagreements*, i. e. when they were inconsistent).

The results are shown in Fig. 1 (bottom) for the data set which considers as mixed only the inferred polarities with $\Delta GG = 0$ (left) and for the one (ΔGG^*) assuming mixed all the inferred polarities with $|\Delta GG| < \sigma_m$ (right). It was obtained S = 72 % and S = 76 %, respectively. Both these values are in close

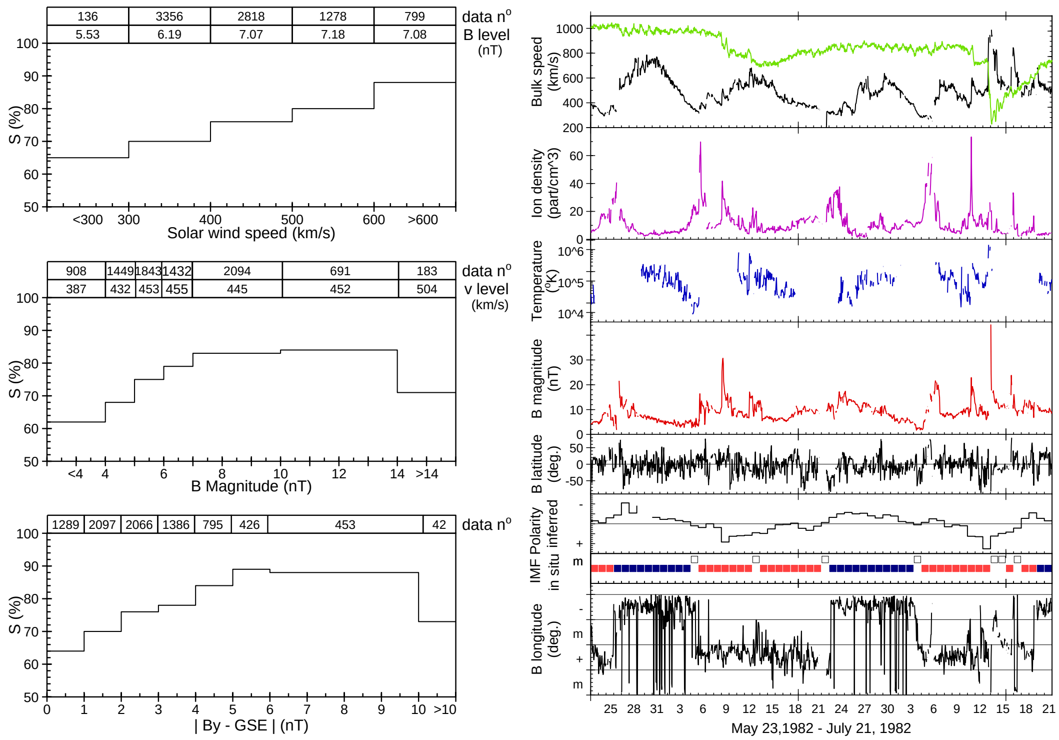

Fig. 2. Success rate (S) for different levels of the interplanetary parameters (left) and time history of several parameters (including Rome CR intensity from IFSI/La Sapienza Collaboration; see the upper panel) for the period May 23 - July 21, 1982 (right).

agreement with previous findings ([1] and references therein). The higher success rate obtained for the ΔGG^* set confirms that the inferred polarities become more reliable if the smallest absolute values of ΔGG are removed. Therefore, all the following analyses will be based on the ΔGG^* data set. We have also checked whether the reliability of the inferring method depends on the IMF polarity. The result S = 76 % for both polarities indicates that the method may be applied in either situations with the same confidence level.

3. Inferred/measured polarities for different solar wind regimes

We now turn to investigate the reliability of the inferred polarities under different interplanetary conditions. Daily averages of the solar wind velocity (v), the IMF GSE-component By and the IMF magnitude (B) derived from the OMNI Database were considered. For the investigated period the v values were available for 8387 days, while the B values for 8600 days. In the upper left panel of Fig. 2, the success rate of the inferring method is plotted as a function of v. It is seen that S steadily increases from a value as low as 65 % in the slow wind (v <300 km/s) up to 88 % in the fast wind (v >600 km/s). We then conclude that the inferring method can be applied with the best confidence in the fast solar wind (S>80 % for v >450 km/s), while its predictions should be taken with caution for v <300 km/s. The middle left panel of Fig. 2 shows results for the IMF intensity. S increases from 62 % (B <4 nT) to 84 % (10 nT< B <14 nT), but then decreases again to 71 % (B >14 nT). The increase of S could be partly related to the trend of the CR gyroradius (R_{CR}) which, for particles with an effective median rigidity of about 83 GV, decreases from 0.614 AU (B = 3 nT) to 0.131 AU (B = 14 nT). It is in fact expected that when particles come from the near-Earth space the inferred polarities better match with those measured by the satellites.

In the lower left panel of Fig. 2, S is plotted vs. the By absolute value. The S increase with $|By|$ can be explained by taking into account that larger absolute By values (positive or negative) better define the IMF polarities, thus strengthening the N-S CR anisotropy on which the inferring method is based. One notes, however, that S undergoes a net decrease towards the highest absolute values of By, as it happens for B. To interpret the described trends, one should keep in mind that relatively stable interplanetary conditions are often associated with corotating high speed streams. Thus, the GG values arising during these periods tend to have a regular time behaviour, leading to a better IMF polarity evaluation. On the other hand, the net S decrease towards the highest B and $|By|$ values (which also correspond to relatively high wind velocities, but it occurs for only the 2 % of the time) may be related to transient solar events associated with more variable interplanetary conditions. This hypothesis can be checked in the right panel of Fig. 2 where a two month period (from May 22, 1982 to July 21, 1982), characterized by both corotating and transient perturbations in the near-Earth space, is shown.

4. Conclusions

The interplanetary conditions occurring during the corotating high speed solar wind streams are ideal to infer the IMF polarity from the N-S CR anisotropy. On the contrary, the inferred polarities should be used with caution when v is low or the interplanetary medium is perturbed by transient solar phenomena.

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5. References

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