

# The preferential orientation of magnetic switchbacks, implications for solar magnetic flux transport



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## ABSTRACT

**Context.** Magnetic switchbacks in the solar wind are large deflections of the magnetic field vector, often reversing its radial component, and associated with a velocity spike consistent with their Alfvénic nature. The Parker Solar Probe (PSP) mission revealed that they were a dominant feature of the near-Sun solar wind. Where and how they are formed remains unclear and subject to discussion.

**Aims.** We investigate the orientation of the magnetic field deflections in switchbacks to determine if they are characterised by a possible preferential orientation

**Methods.** We compute the deflection angles  $\psi = [\phi, \theta]^T$  of the magnetic field relative to the theoretical Parker spiral direction for encounters 1 to 9 of the PSP mission. We first characterize the distribution of these deflection angles for calm solar wind intervals, and assess the precision of the Parker model as a function of distance from the Sun. We then assume that the solar wind is composed of two populations, the background calm solar wind and the population of switchbacks, characterized by larger fluctuations. We model the total distribution of deflection angles we observe in the solar wind as a weighed sum of two distinct normal distributions, each corresponding to one of the population. We fit the observed data with our model using a Monte-Carlo Markov Chain algorithm and retrieve the most probable mean vector and covariance matrix coefficients of the two Gaussian functions, as well as the population proportion.

**Results.** We first confirm that the Parker spiral is a valid model for calm solar wind intervals at PSP distances. We observe that the accuracy of the spiral direction in the ecliptic is a function of radial distance, in a manner that is consistent with PSP being near the solar wind acceleration region. We then find that the fitted switchback population presents a systematic bias in its deflections, with a mean vector consistently shifted towards lower values of  $\phi$  ( $-5.52^\circ$  on average) and  $\theta$  ( $-2.15^\circ$  on average) compared to the calm solar wind population. This results holds for all encounters but E6, and regardless of the magnetic field main polarity. This implies a marked preferential orientation of switchbacks in the clockwise direction in the ecliptic plane, and we discuss this result and its implications in the context of the existing switchback formation theories. Finally, we report the observation of a 12-hour patch of switchbacks that systematically deflect in the same direction, so that the magnetic field vector tip within the patch deflects and returns to the Parker spiral within a given plane.

**Key words.** Solar Wind – Magnetic Switchbacks – Interchange Reconnection – Data analysis –