Bimodal distribution of the solar wind at 1 AU

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The main goal of this work is to separate the behavior of the two types of quiet solar wind at 1 AU: fast and slow. Our approach is a bi-Gaussian distribution function, formed by the addition of two Gaussian distribution functions, where each one represents one type of wind. We check this approach by fitting the bi-Gaussian to data from ACE spacecraft. We use level 2 data measured during solar cycles 23 and 24 of different solar wind parameters, including proton speed, proton temperature among others. Our results show that the approach is fine and only transient events departs from the proposed function. Moreover, we can show bimodal behavior of the solar wind at 1 AU, not only for the proton speed, but also for the other analyzed parameters. We also check the solar cycle dependence of the different fitting parameters.

Context of the research

- *Burlaga & King (1979) were the first to suggest that lognormal distribution function might represent the distribution of the interplanetary magnetic field (B)*
- *The lognormal distribution has been used extensively to describe not only B, but also solar wind speed, density and temperature (Burlaga & Szabo 1999, Veselovsky et al. 2010))*
- *Venzmer & Bothmer (2018) noted that the lognormal did not describe appropriately the solar wind speed, therefore they considered a bi-component lognormal for the velocity distribution*
- *Within the years, more complex mathematical functions have being implemented assuming the mixing and dynamical interaction of the components of the solar wind*
- *In this work, we propose the use of the bi-gaussian probability distribution function (PDF) to describe the distribution of different solar wind magnitudes at 1 AU like proton speed, proton temperature, proton density and magnetic field*

Description of the work

- ***We use data from the ACE spacecraft with a time range from 1998-2017 with a resolution of 1 hour***
- ***The data are measured using the instruments SWEPAM and MAG on board ACE***
- ***The data set includes proton density (n_p), proton temperature (T_p), proton speed (V_p), and magnetic field (B)***
- ***We use the bi-Gaussian probability distribution function (PDF) to fit the empirical distribution of each magnitude***
- ***We use two different data sets for the fittings***
  - ***Whole data set***
  - ***Yearly dataset***

Results

- We represent first the result for the analysis of the whole dataset
- The fitting of a bi-Gaussian is appropriate for the PDF of all the solar wind magnitudes analyzed
- Two solar wind types can be distinguished, not only in V_p, but also in n_p, T_p and B
- The tails are expected to be related with transient events and compression of solar wind regions of different speeds

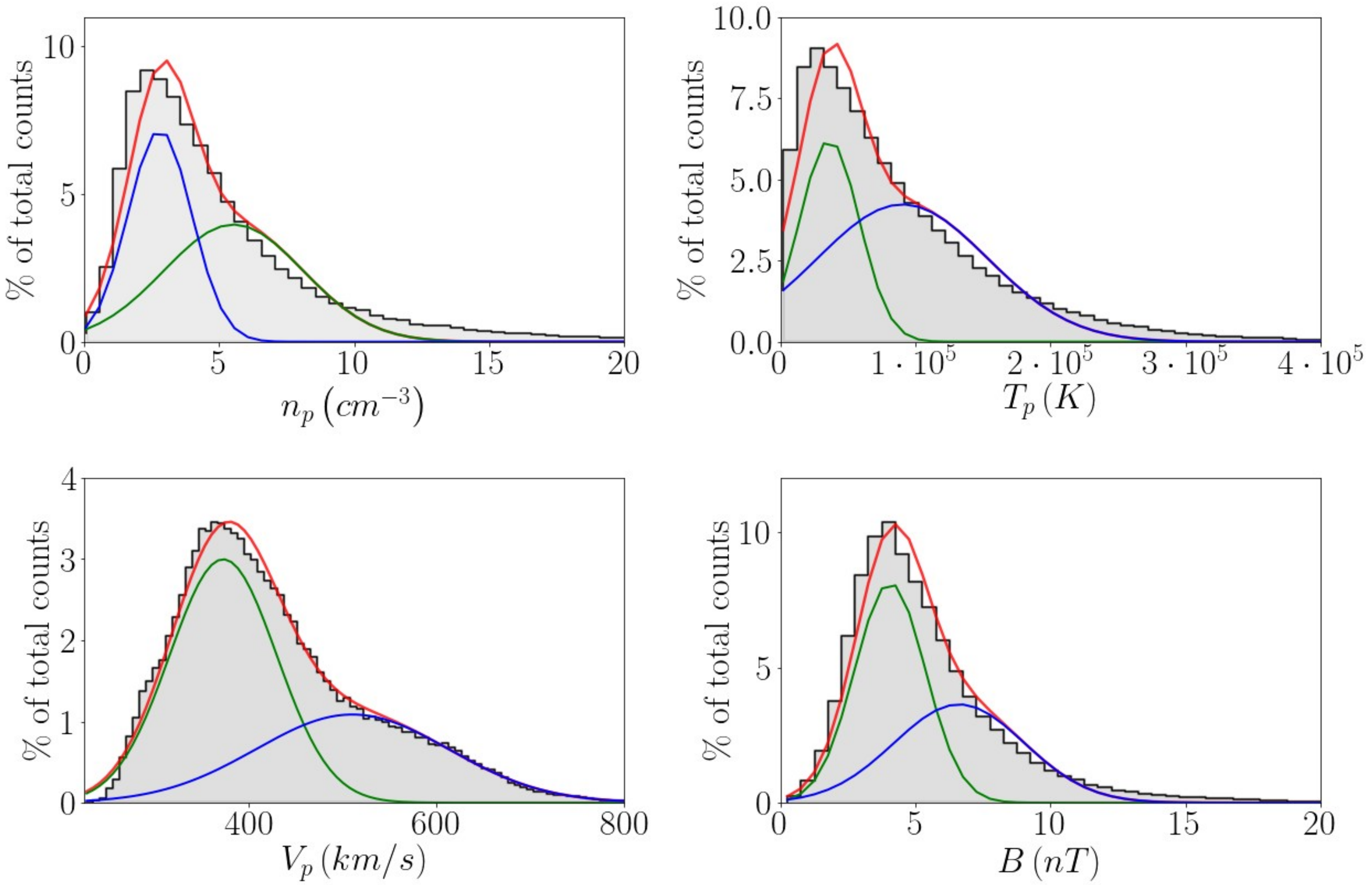

Figure 1: Empirical distribution function of proton density (n_p), proton temperature (T_p), proton speed (V_p), magnetic field (B). Red line represents bi-Gaussian fitting. Green and blue lines correspond to the single Gaussian curves (Larrodera & Cid 2020)

Results

- *Each solar wind type is described by the position of the peak and the RMS width of each single curve*
- *The analysis of the yearly data set shows correlation between the position of the peaks and the solar cycle for magnetic field and proton density*
- *Correlation coefficient in the position of the peak of the proton density is above 0.65. The correlation with the position of the peak of the magnetic field is above 0.7*
- *We propose new values for each type of solar wind (see Table 1)*

	$V_p(km/s)$	$B(nT)$	$n_p(cm^{-3})$	$T_p(\times 10^5 K)$
Slow wind	380 ± 40	4.8 ± 0.7^M	7 ± 1^M	0.5 ± 0.6
		3.3 ± 0.3^m	4.8 ± 0.5^m	
Fast wind	500 ± 100	7 ± 1^M	3.5 ± 0.8^M	1.0 ± 0.8
		5.6 ± 0.6^m	2.4 ± 0.2^m	

$^{(M)}$ Maximum solar cycle $^{(m)}$ Minimum solar cycle

Table 1: Values for the main parameters of slow and fast wind from the study. The years included as the solar maximum (minimum) period are from 1998 to 2003and from 2011 to 2016 (from 2006 to 2010) (Larrodera & Cid 2020)

Impact and prospects for the future

- *This work shows that the bi-Gaussian function reproduces the bulk solar wind at 1 AU not only for proton speed, but also for proton density, proton temperature and magnetic field*
- *We suggest that the bulk solar wind is bimodal not only for proton speed, with a fast and slow component*
- *Some magnitudes like magnetic field or proton speed are strongly related with the solar cycle*
- *Future work is been done applying the bi-Gaussian function to the average iron charge state at 1 AU (Article under revision)*

References

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