Bimodal distribution of the solar wind using data from ACE spacecraft

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Presentation based on the article Astronomy & Astrophysics Larrodera and Cid (2020)

Introduction

- Different probability distribution functions has been used to represent the solar wind:
  - Burlaga and King (1979) were the first suggest that lognormal distribution function represents the distribution of B
  - Lognormal distribution functions has been also used for solar wind speed, density or temperature (Veselovsky et al., 2010)
  - The lognormal distribution has been used extensively to describe not only B, but also solar wind speed, density and temperature Venzmer and Bothmer (2018)
- Our study uses data from ACE spacecraft from 1998 to 2017. The dataset includes:
  - Proton density (n_p)
  - Proton temperature (T_p)
  - Proton speed (V_p)
  - Magnetic field (B)

The bi-Gaussian approach

- We use a bi-Gaussian approach as the probability distribution function (PDF) of the two main components of the solar wind.
- It is defined as the addition of two Gaussian distribution functions.
- h_i is the height of the peak, p_i the position of the peak, w_i the Gaussian RMS width. The subindex i represents the first or second Gaussian distribution function.

Bi-Gaussian PDF

$$bG(x) = h_1 \cdot \exp\left[\frac{-(x-p_1)^2}{2w_1^2}\right] + h_2 \cdot \exp\left[\frac{-(x-p_2)^2}{2w_2^2}\right]$$

The bi-Gaussian approach

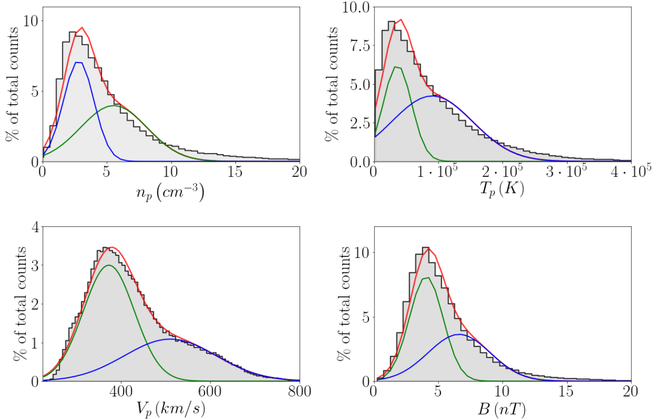

Figure 1: *Empirical distribution functions of the main solar wind parameters, n_p, T_p, V_p, and B, for the whole data available from ACE and the fitting to a bi-Gaussian (red). Green and blue lines correspond to the single Gaussian curves. Larrodera and Cid (2020)*

Dataset and solar cycle dependence

- We check if the values obtained from the yearly bi-Gaussian fitting change over time.
- Indeed, we compare for the solar wind parameters the position of the peaks from the yearly bi-Gaussian fitting with the sunspot number.
- The Pearson's correlation coefficient for p_B^1, p_B^2,p_N^1 and p_N^2 are around 0.7
- For p_V^1, the correlation coefficient is 0.5, indicating a weak correlation and no correlation appears in other cases.

Dataset and solar cycle dependence

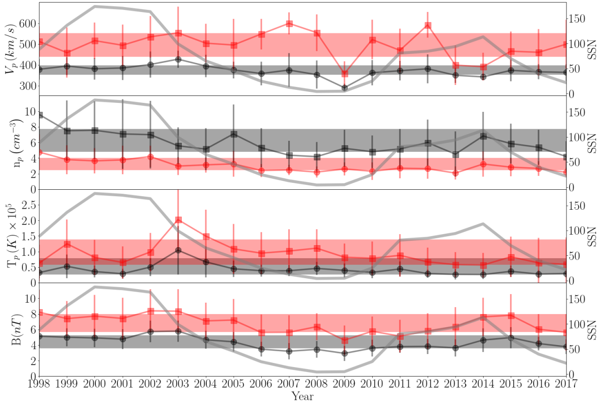

Figure 2: *From top to bottom: Yearly position of the centre of the peak of every single Gaussian curve, p, for V_p, n_p, T_p, and B PDFs. black (red) points correspond to slow (fast) wind. Uncertainty has been estimated using the Gaussian RMS width of the corresponding single curve, w. The grey line in the four plots represents the sunspot number, with the corresponding y-axis on the right of every plot. Larrodera and Cid (2020)*

Conclusions

- The bi-Gaussian function reproduces the bulk solar wind at 1AU not only for proton speed, also for proton density, proton temperature and magnetic field.
- Our result suggest that the bulk solar wind at 1 AU is bimodal.
- Table 1 summarised the values for the parameters from the bi-Gaussian fitting.
- The magnetic field strength and the proton density are strongly related to the solar cycle.

Conclusions

	$V_p(km/s)$	$B(nT)$	$n_p(cm^{-3})$	$T_p(\times 10^5 K)$
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: *Typical values for the main parameters of the slow and fast component of the solar wind according to the results from this study. The years included as the solar maximum (minimum) period are from 1998 to 2003 and from 2011 to 2016 (from 2006 to 2010) Larrodera and Cid (2020)*

References

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