Analysis of the solar wind distribution functions at 1AU

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Introduction

- The solar wind is classified in slow and fast wind (bulk solar wind) and transient events
- Different distribution functions have been proposed to characterize the solar wind distribution, e.g. Burlaga and King (1979); Li et al. (2016)
- Solar wind magnitudes, like proton speed, evolve dynamically between Sun and Earth. Nevertheless, no major changes are expected in the composition
- Solar wind composition is used as a signature of interplanetary coronal mass ejection (Heidrich-Meisner et al., 2016)
- Average iron charge state ($\langle Q_{Fe} \rangle$) values above 12 show the presence of ICMEs (Lepri et al., 2001; Lepri, 2004)

Data set

- We use data from the Advanced Composition Explorer (ACE) at the L1 point
- The data range is from 1998 to 2017
- The sources of the data are the instruments
  - Magnetic Field Experiment (MAG)
  - Solar Wind Ion Composition Spectrometer (SWICS)
  - Solar Wind Electron, Proton and Alpha Monitor (SWEPAM)

Bi-Gaussian approach

- We propose a bi-Gaussian distribution function to characterize the solar wind distribution

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

- h is the height of the peak, p the position of the center and w the Gaussian RMS

Bi-Gaussian approach. Dynamic magnitudes

- We have applied the bi-Gaussian distribution function to the whole data set of:
  - Proton speed
  - Proton temperature
  - Proton density
  - Magnetic field magnitude

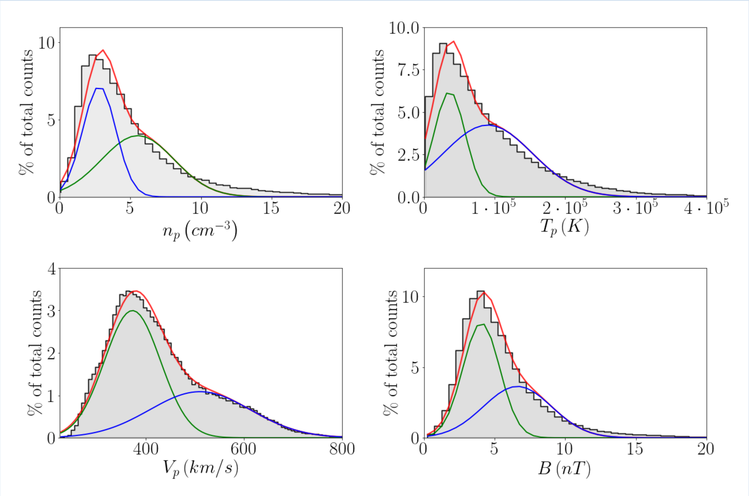

Figure 1: Solar wind distribution for different magnitudes, n_p, T_p, V_p and B for the whole ACE data set (Larrodera and Cid, 2020a)

Bi-Gaussian approach. Composition

- We have also applied it to the whole data set of the average iron charge state $\langle Q_{Fe} \rangle$

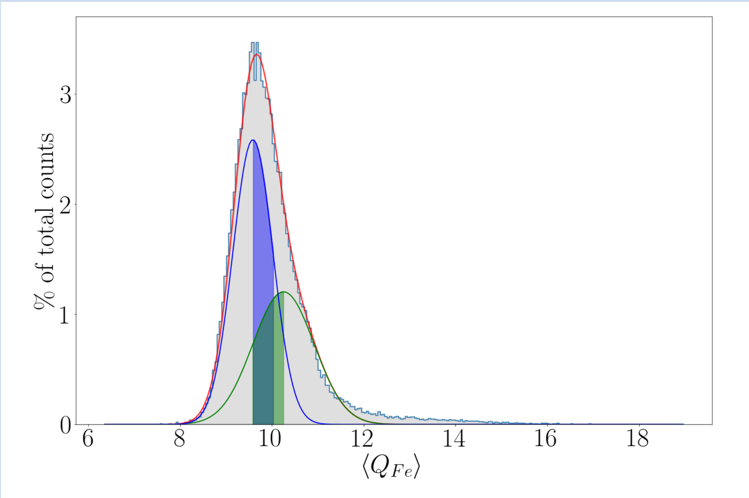

Figure 2: Solar wind distribution for $\langle Q_{Fe} \rangle$ for the whole ACE data set (Larrodera and Cid, 2020b)

Solar Cycle evolution

- We have applied the bi-Gaussian approach also to the yearly data set
- We are able to study how the position of the peaks of the Gaussian PDF evolves
- We compare the position of the peaks with the Sunspot Number in order to study the correlation with the Solar Cycle

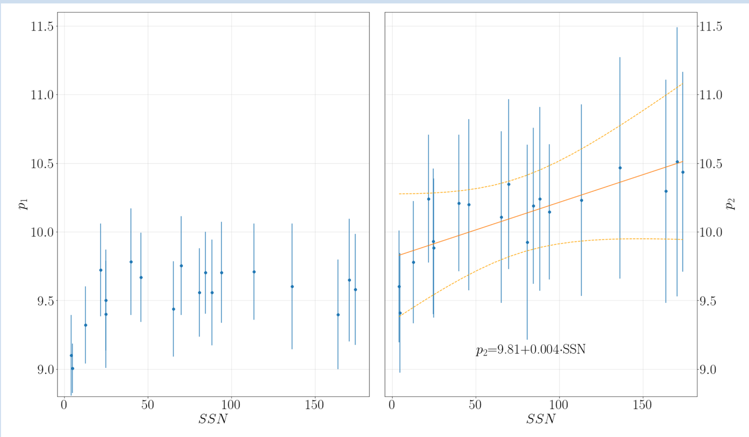

Figure 3: Scatter plots for $\langle Q_{Fe} \rangle$ against the sunspot number. (Larrodera and Cid, 2020b)

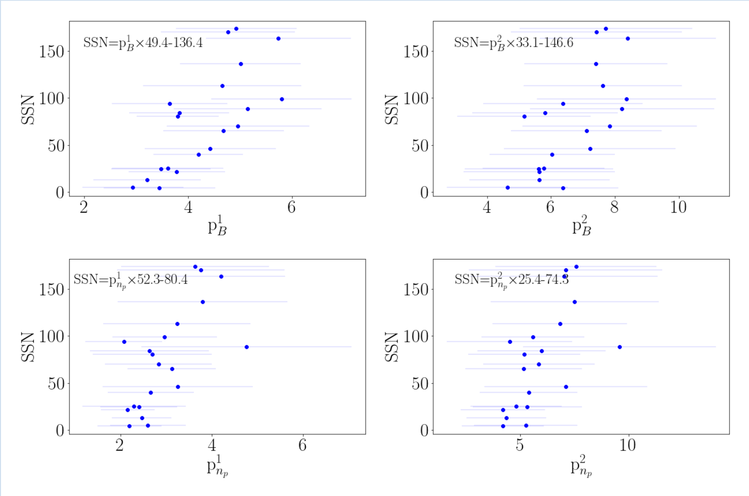

Figure 4: Scatter plot of n_p , T_p , v_p and B against the sunspot number. (Larrodera and Cid, 2020a)

ICMEs identification

- Large deviation from typical values of $\langle Q_{Fe} \rangle$ are related with ICMEs
- Considering $\langle Q_{Fe} \rangle > 12$ at least for 10 hours we found 27 events:
  - 'Extended': Events where an extension of catalogued ICMEs will covered them
  - 'New': Events not previously catalogued

Conclusions

- The bi-Gaussian function properly reproduces the bulk solar wind
- The five magnitudes analyzed show a bimodal distribution
- These results suggest that the bulk solar wind at 1 AU is bi-modal
- Some fitting parameters show a strong correlation with the solar cycle
- $\langle Q_{Fe} \rangle$ allow us to locate ICMEs previously not cataloged
- $\langle Q_{Fe} \rangle > 12$ is a sufficient signature to identify ICMEs and its boundaries

Complete information

- A complete description of our research can be found in the publisehd papers:
  - **https://www.aanda.org/articles/aa/abs/2020/03/aa37307-19/aa37307-19.html**
  - **https://link.springer.com/article/10.1007/s11207-020-01727-8**
- For further questions, please contact me at: **carlos.larrodera@edu.uah.es**