Analysis of the solar wind at 1 AU from ACE data

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Abstract

The study of the solar wind has improved thanks to the data taken from spacecraft which are placed in different locations out of the magnetosphere. There are many measurements close to L1 point, mainly from ACE spacecraft. We focus this work on the analysis of the level 2 data from ACE of different solar wind magnitudes such as the magnetic field, speed, density and temperature taken from 1998 to 2017. The goal of this work is to separate the behavior of the quiet solar wind, formed by the slow and fast wind, from the extreme solar wind and the structures that appears in it. Our starting point has been the fitting of the distribution functions of the magnitudes by using gaussian distributions functions. Then we have analysed the parameters coming from the fitting and the relationship among them.

1.- Introduction

Solar wind distribution function can help to understand the population of the solar wind and the physical mechanisms involved in the transport of this plasma away from the Sun. In previous works we found that:

- Burlaga and King (1979) proposed the use of the **lognormal distribution function** for the interplanetary magnetic field
- The lognormal function has been used also for the density, speed or temperature (Burlaga, 2001; Veselovsky et al., 2010)
- Based on the values of the skewness and the kurtosis of the magnetic field distribution, Feynman and Ruzmaikin (1994) shows that it is **not distributed normally or lognormally**
- Vörös et al. (2015) shows that **Kappa-like distributions**, with fat tails, can be obtained as a superposition of random uncorrelated, normally or lognormally distributed processes
- Venzmer and Bothmer (2018) used a **bi-component lognormal** approach for the speed

Our aim is to analize the solar wind data through different magnitudes **to separate the different contributions of the quiet sun, i.e., slow and fast wind**

2.- Data

- Level 2 data from ACE spacecraft
- Measurements from instruments SWEPAM and MAG, onboard ACE
- Hourly average ×Twenty years ⇒≃ 175000 data per magnitude

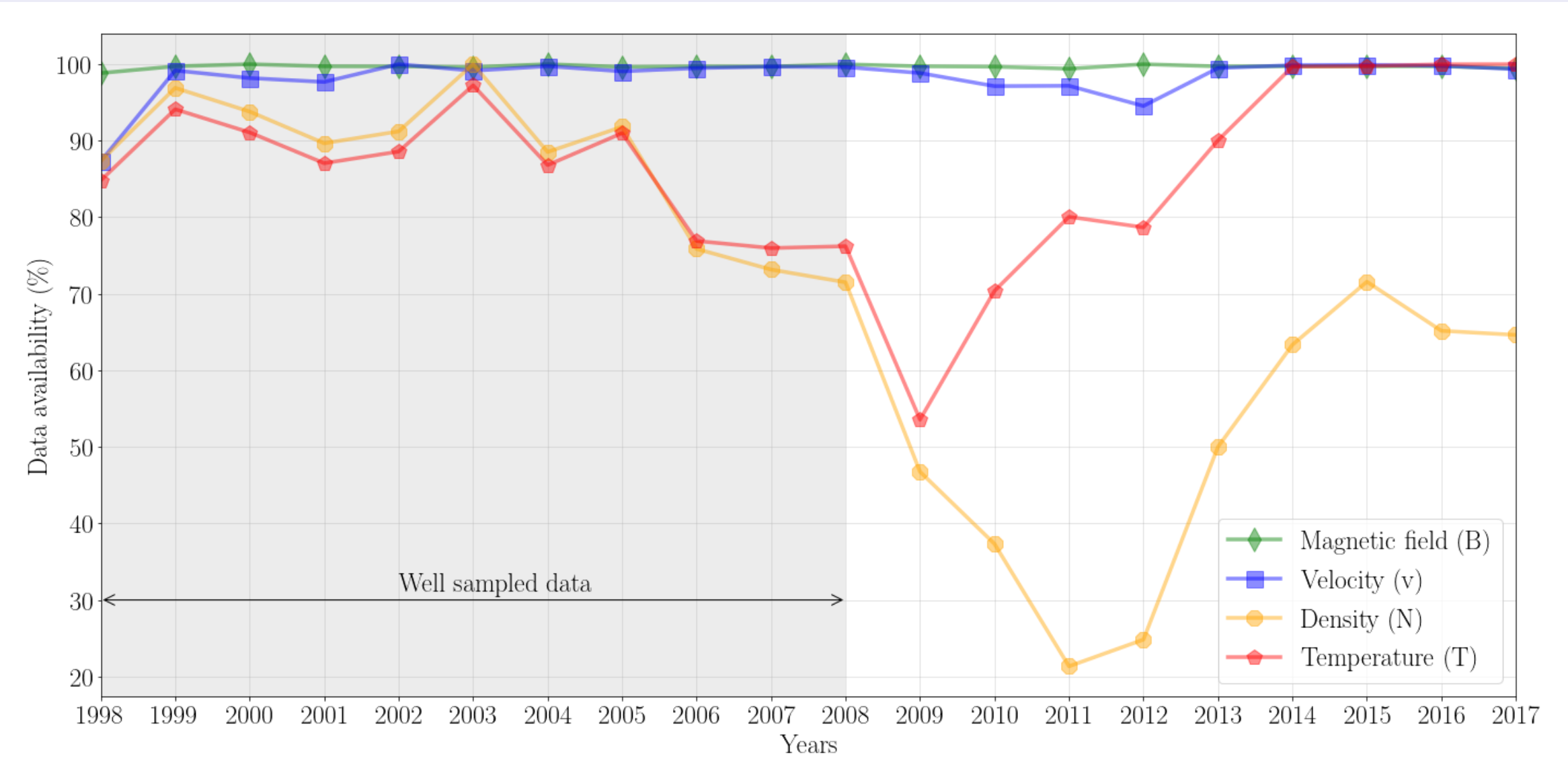

Figure 1: *Data availability. Percentage of available data for proton speed, magnetic field, proton temperature and speed for each year. The shaded region represents the years with data availability over 70% for all magnitudes*

3.- Our approach

- The solar wind is classified in 3 types: **slow, fast and transients**
- Fast and slow wind, could be represented using **gaussian distribution functions?**
- The addition of two gaussian distribution functions ⇒ **Bimodal distribution function (BM)**
- Bi-gaussian fit will provide **six parameters** $(h_1, p_1, w_1, h_2, p_2, w_2)$

$$\boxed{BM = h_1 \cdot \exp\left(\frac{-z_1^2}{2}\right) + h_2 \cdot \exp\left(\frac{-z_2^2}{2}\right);\ z_1 = \frac{x-p_1}{w_1};\ z_2 = \frac{x-p_2}{w_2}}$$

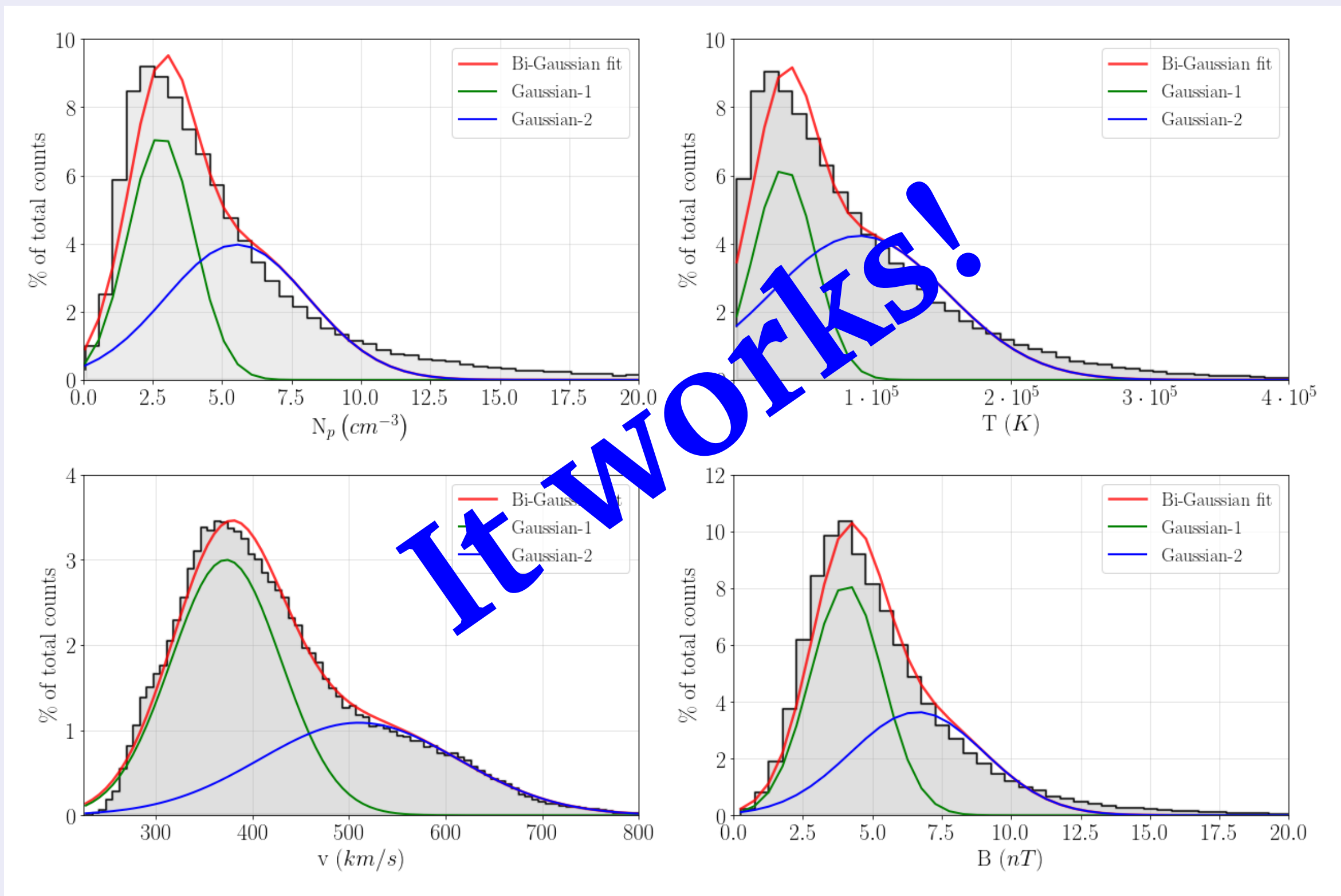

Figure 2: *Bi-gaussian fits. Red line is the bimodal distribution. The green and blue lines are the first and second gaussian distribution functions*

4.- Our results: Yearly bi-gaussian fit

- We have made a **bi-gaussian fit for each year**
- As expected, the **speed of the solar wind has a bimodal distribution**
- Temperature, density and magnetic field also show **two types of wind**
- The position of the center of the peak of every gaussian (p_1, p_2) of the analyzed years shows **clear separation**

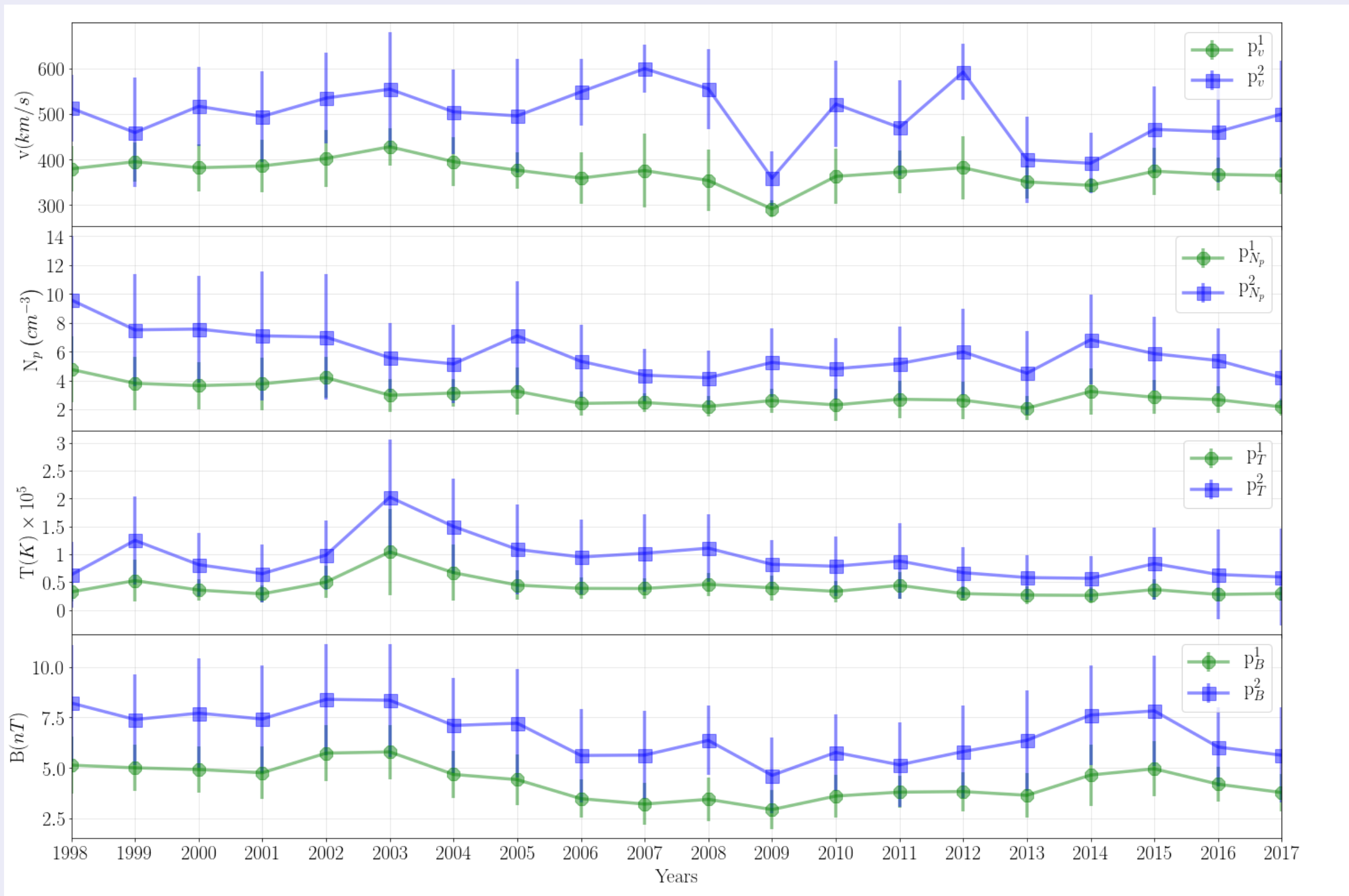

Figure 3: *Temporal evolution of positions. From top to bottom: Speed, density, temperature and magnetic field.The error bars correspond to the width of each gaussian distribution function.*

5.- Fitting parameters relevance

- We define the bi-gaussian fractional height $F\left(h_p^s\right)$ like

$$\boxed{F\left(h_p^s\right) = \frac{h_p^s}{S}}$$

$$\boxed{S = \sum_{\eta=v,N,B,T} \sum_{\alpha=I,II} h_\eta^\alpha}$$

  - For one year⇒ $\sum F\left(h_p^s\right) = 1$
  - η represents the magnitude and α the first (I) or second (II) gaussian
  - Fractional heights shows the contribution of each population and solar wind magnitude to the overall solar wind

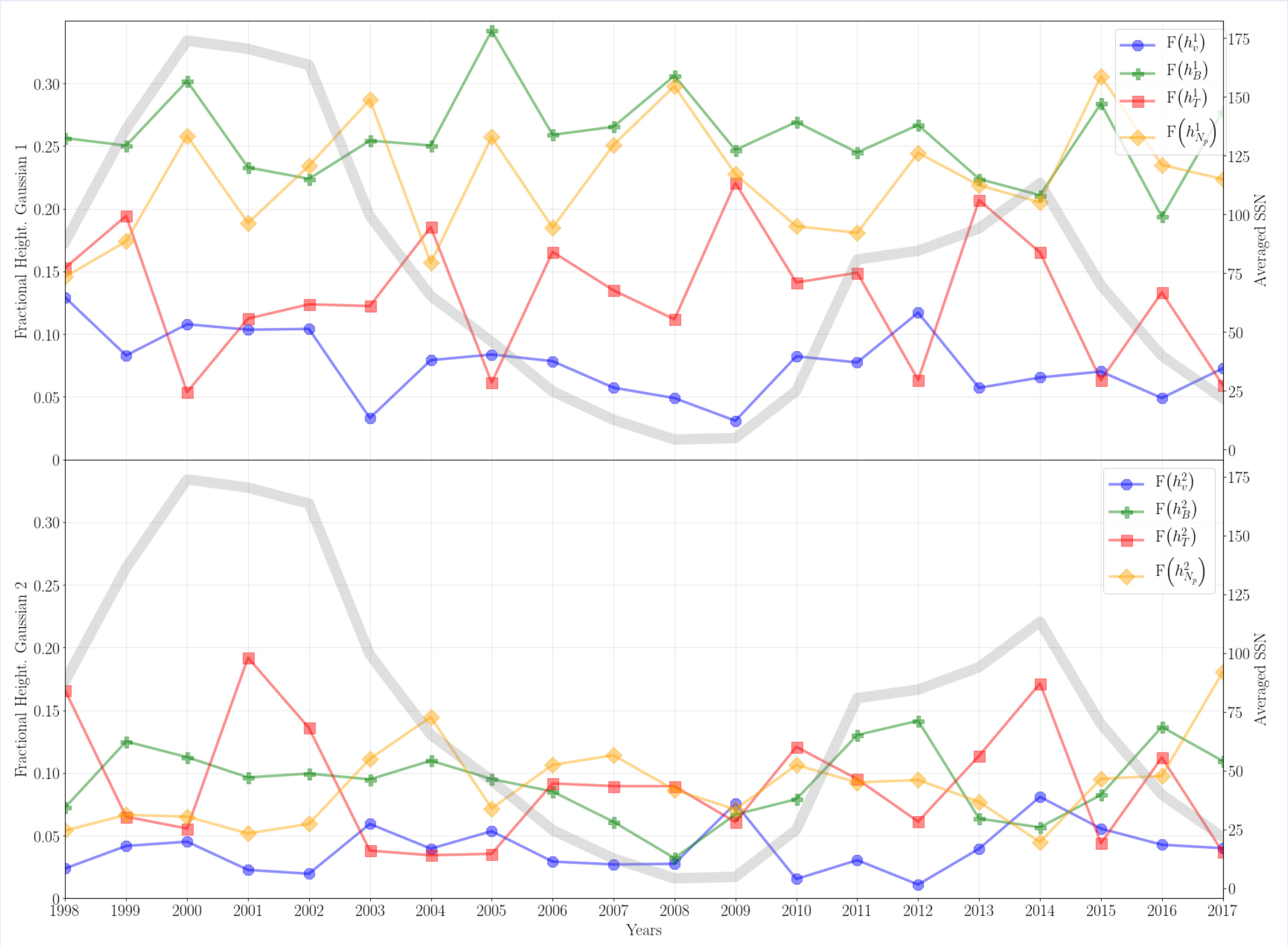

Figure 4: *Fractional heights of speed (v), magnetic field (B), density (N) and temperature (T). The grey line is the yearly sunspot number*

6.- Plasma β and Alfven speed

- The plasma β allows us to know the **relevance between the magnetic pressure over the plasma pressure**
- Alfven speed will show the importance of the magnetic field related with the density

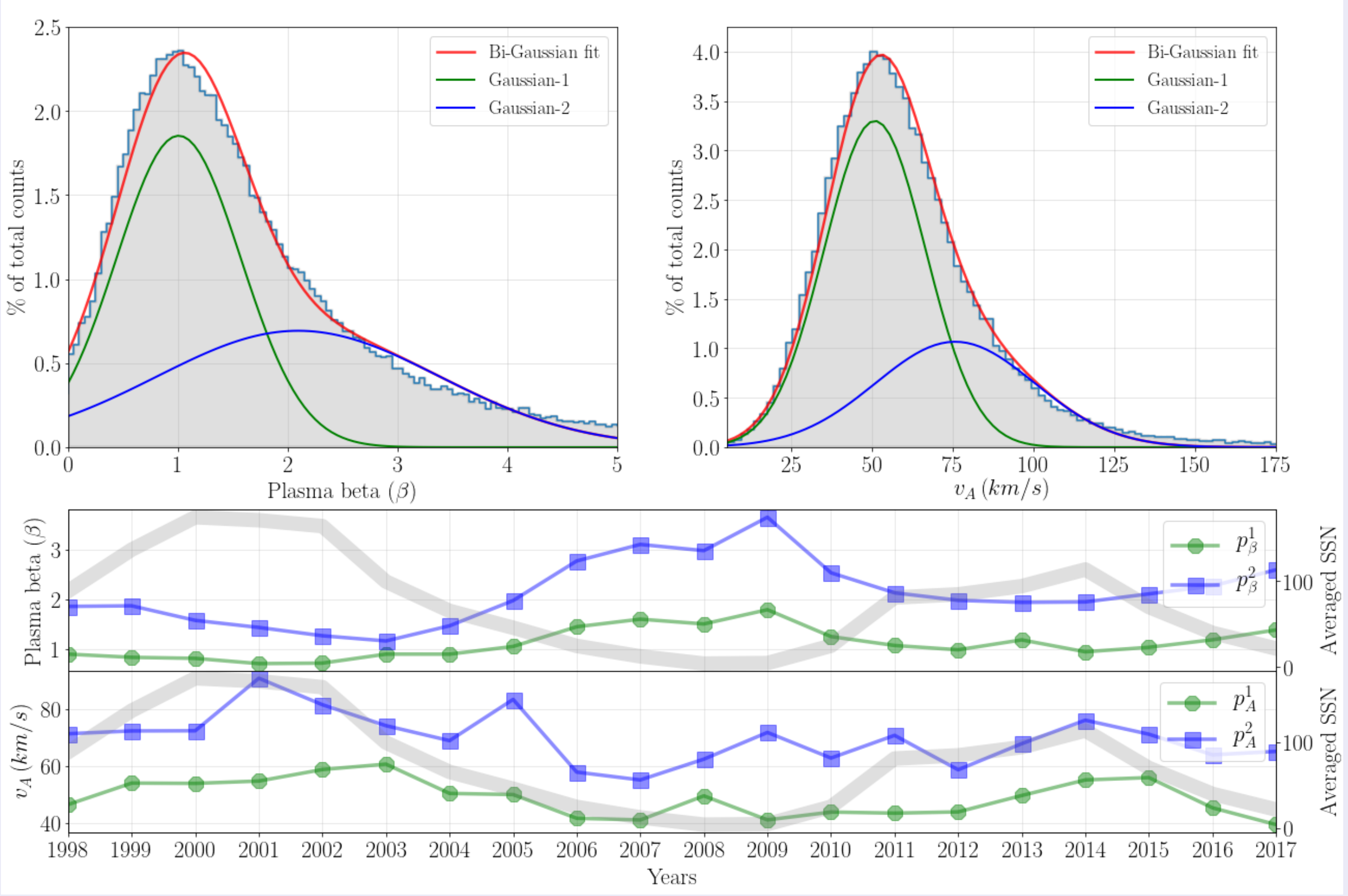

Figure 5: *Bi-gaussian fit for plasma β and Alfven speed. Temporal evolution of position*

7.- Conclusions

- The **bimodal distribution function** properly reproduce the distribution of speed, density, temperature and magnetic field
- The **density and magnetic field** play a major role in the solar wind physics when compared with the speed and temperature
- There is **no correlation between the fractional heights and the solar cycle**
- The Alfven speed and plasma β also exhibit a **bimodal distribution function**
- The **plasma** β shows an **anticorrelation** with the **solar cycle**
- The **Alfven speed** shows a **correlation** with the **solar cycle**

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