Extreme events in the solar wind

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» Introduction

- Extreme solar wind events can cause geomagnetic storms seriously damaging infrastructures
- The understanding of these events is nowadays crucial
- We use data from the ACE spacecraft from 1998 to 2017 of the interplanetary magnetic field and the proton speed
- We estimate the return value for twice and four times the data set range, i.e., 40 and 80 years

» Extreme value theory

- We group the data set into two-day blocks size and calculate the maximum value
- We use the generalized extreme value (GEV) distribution to fit the maximum values
- Depending on the sign of the shape parameter (ξ) we will have 3 different probability functions

Frechet ($\xi > 0$), Weibull ($\xi < 0$) probability distribution function

$$G(z) = \exp\left(-\left[1 + \xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-1/\xi}\right)$$

Gumbel ($\xi = 0$) probability distribution function

$$G(z) = \exp\left[-\exp\left(-\left(\frac{z-\mu}{\sigma}\right)\right)\right]$$

- We use coordinate $-\log(-\log(p))$ vs $\log(z)$ and z to choose between Fréchet or Gumbel distribution respectively
- The plot with higher correlation coefficient show the distribution function
- In both cases, the Fréchet distribution is more appropriate
- We can apply the extreme value analysis to the interplanetary magnetic field and proton speed data set
- The threshold for the extreme events is set in the percentile 99

* The threshold is between 26 and 35 nT, with 99% confidence interval
* The return values for 40 and 80 years is around 100 nT

40 years	80 years
81-107 nT	97-131 nT

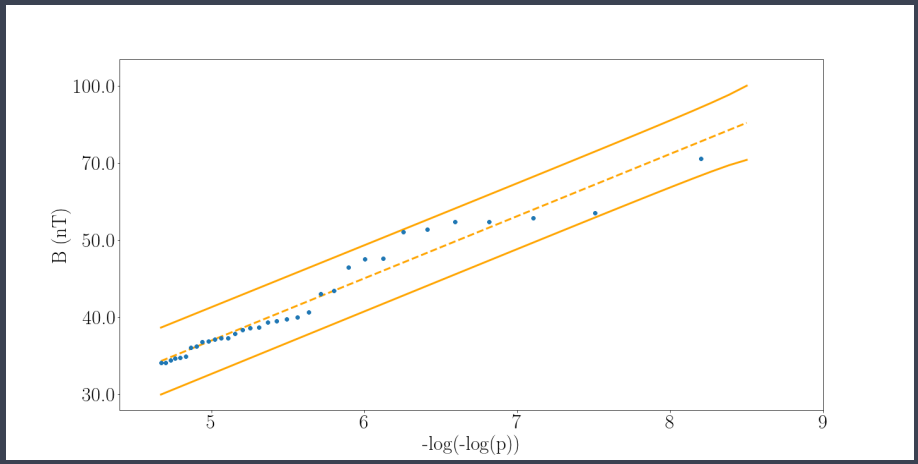

Figure 1: **Extreme values for the interplanetary magnetic field**

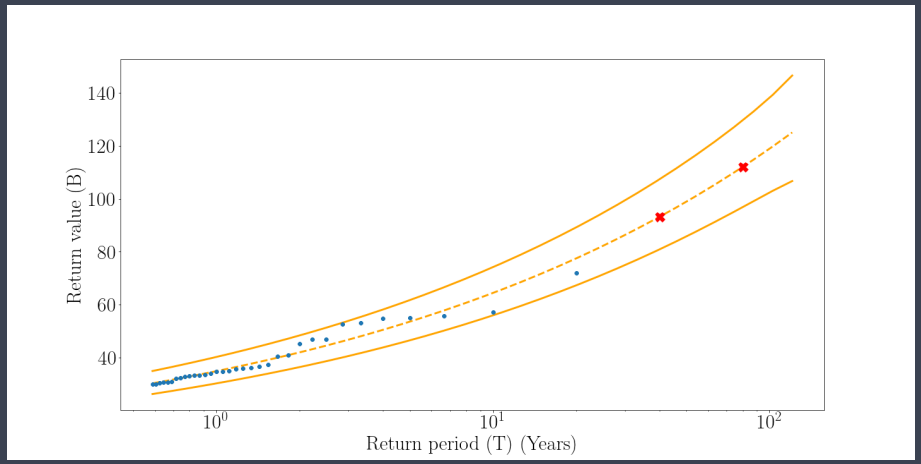

Figure 2: **Return plot for interplanetary magnetic field**

* The threshold is between 650 and 1230 km/s, with 99% confidence interval
* We develop a procedure to estimate the speed of the data gaps
* It is based on the time difference between the departure and the arrival to Earth

40 years	80 years
2990-5550 km/s	4000-7670 km/s

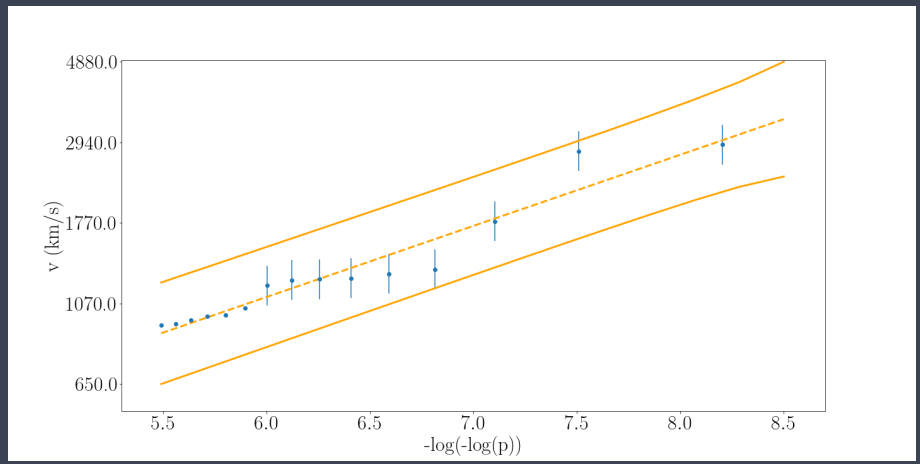

Figure 3: Extreme values for the proton speed. The highest points are gap estimations

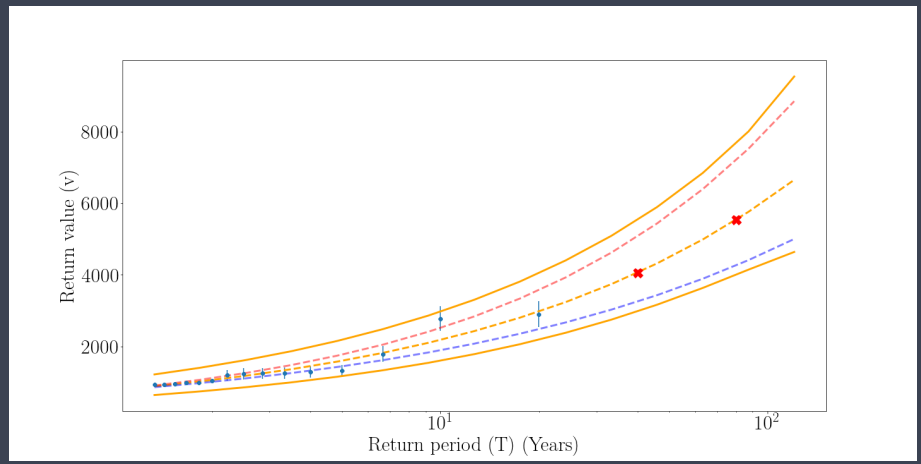

Figure 4: Return plot for proton speed. Red (blue) lines are regression with the points plus(minus) the error

» Conclusions & Future work

- The Fréchet distribution is more appropriate to analyze the extreme events of the interplanetary magnetic field and the proton speed
- We have been able to filled the gaps produced by the most extreme events
- All this work will be detailed in a scientific paper currently under preparation
- Could be a physical limit for the upper boundary of the proton speed?
- The return values of the proton speed are too high.
- We need to analyze these results carefully