Characteristic Fluctuations in solar Wind structures

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Outline

1 The Method

2 Statistical results (MC and EJ)

3 Some examples

MAIN OBJECTIVE:

We want to study the evolution of ICMEs from the low corona to 1 AU.

We are going to used STEREO, LASCO, WIND and ACE data.

LASCO and SECHI for the inner corona and STEREO, WIND and ACE at 1 AU. Four different points of view of the same event.

Partial OBJECTIVE:

Find out an automatic recognition method to find ICMEs by using fluctuations in the most relevant parameters (a method independent of the observer).

With this method we will be able to identify and determine systematically the ICMEs structures: shock, sheath and ejecta.

We explain the ICME interaction with the interplanetary medium as two different fluids interacting,

During this interaction, two regions are formed, where the conditions are relatively stable (at least different) and between these two systems there is a region where the gas acts disorderly.

This intermediate region is known as sheath, and is characterized by high density, increased pressure, strong Magnetic Field and high variability of these parameters.

If an ICME moves faster than the characteristic speed of the ambient medium, It also can drive a shock.

Therefore, the arrival of shocks at the spacecraft is a good indicator of the impending ICME arrival.

In practice, it is pretty hard to recognize and characterize ICMEs due to their interaction with other structures in the solar wind.

Theoretically we know that when an ICME is passing through the spacecraft, the magnitude of the SW parameters change considerable.

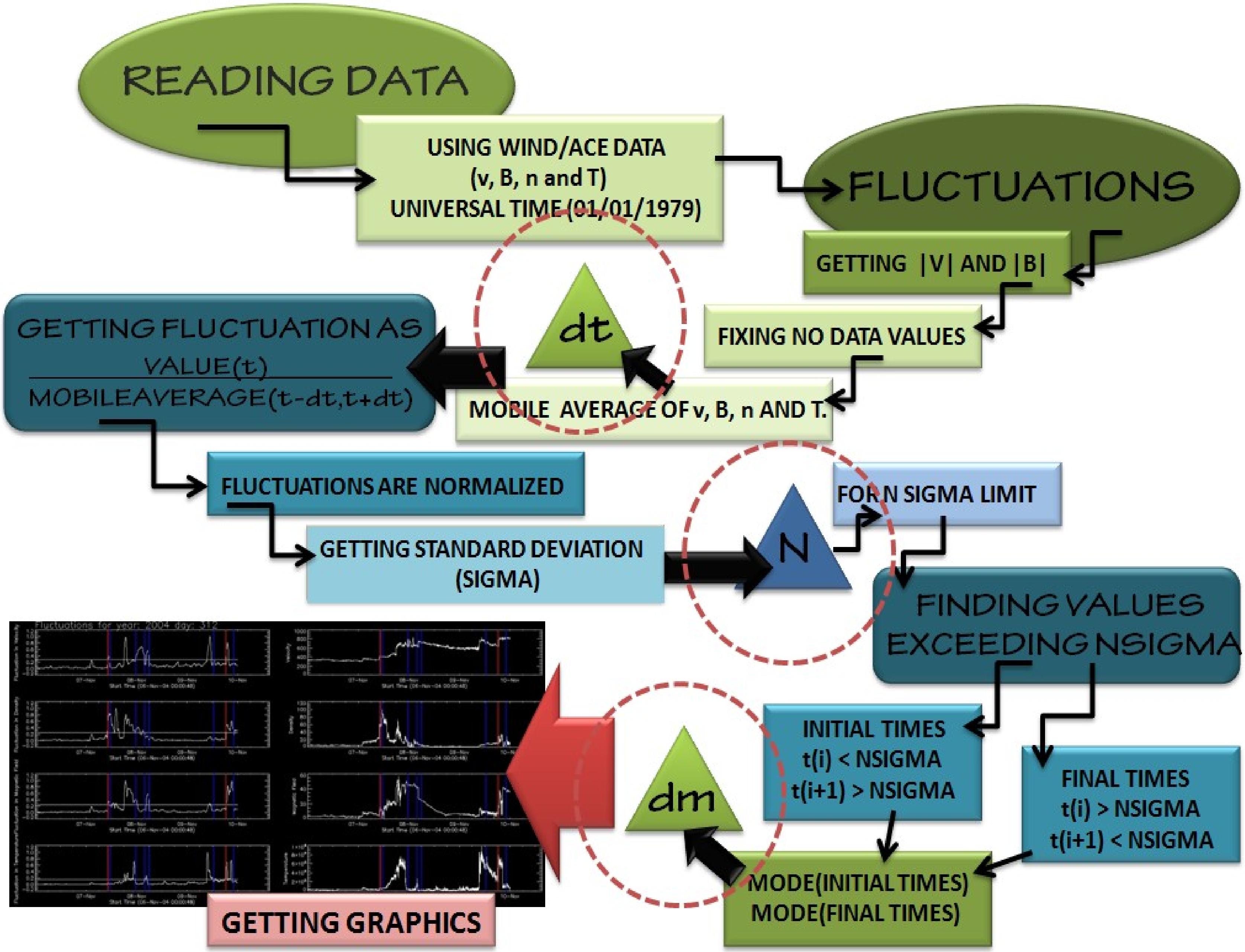
The shock and the sheath are related to unstable conditions, which will be characterized by high fluctuations in the measurements.

Our method uses the fluctuations of 5 different parameters, these are: velocity, density, temperature, magnetic field and beta

We are able to estimate the time of the different structures (sheath and ejecta) of an ICME by using these fluctuations.

FIRST STEP:

Defining a fluctuation


READING DATA
USING WIND/ACE DATA
(v, B, n and T)
UNIVERSAL TIME (01/01/1979)
FLUCTUATIONS
GETTING |V| AND |B|
FIXING NO DATA VALUES
MOBILE AVERAGE OF v, B, n AND T.
dt
GETTING FLUCTUATION AS
VALUE(t)
MOBILEAVERAGE(t-dt,t+dt)
FLUCTUATIONS ARE NORMALIZED
GETTING STANDARD DEVIATION
(SIGMA)
N
FOR N SIGMA LIMIT
FINDING VALUES
EXCEEDING NSIGMA
INITIAL TIMES
t(i) < NSIGMA
t(i+1) > NSIGMA
FINAL TIMES
t(i) > NSIGMA
t(i+1) < NSIGMA
MODE(INITIAL TIMES)
MODE(FINAL TIMES)
dm
GETTING GRAPHICS

To find the best bin sizes of the moving averages we analyzed data from a complex event (November 4th, 2006).

Then, we used data (from WIND and ACE) from 27 ICMEs which occurred in 2000 to 2005. The selection was made based on publications were the events were considered ICMEs. These events have been studied by different authors, all of them have corroborated that these are ICMEs moving in the IPM.

We started by imposing:

1) An ICME must have a SHEATH. The sheath can be found using the fluctuations.

2) At least THREE of FOUR parameters (velocity, density, magnetic field and temperature) needed to have a fluctuation almost at the same time.

We could have fluctuations in the parameters for different reasons. To consider that the fluctuations were due to an ICME we decided to look for those fluctuations that were N times higher than the standard deviation.

We wrote an IDL routine in order to estimate the fluctuations and to find the time where the fluctuations occur almost simultaneously, in order to consider these fluctuations due to an ICME.

We estimated the fluctuation of each parameter. We compared the magnitude of [v], [B], [n] and [T] at certain time with the average of the parameter in a time range of minutes before till minutes after (Moving Average).

In order to ignore noise and background effects we chose N times SIGMA value as a limit to find fluctuations related to ICMEs.

As a result we have three parameters to determine:

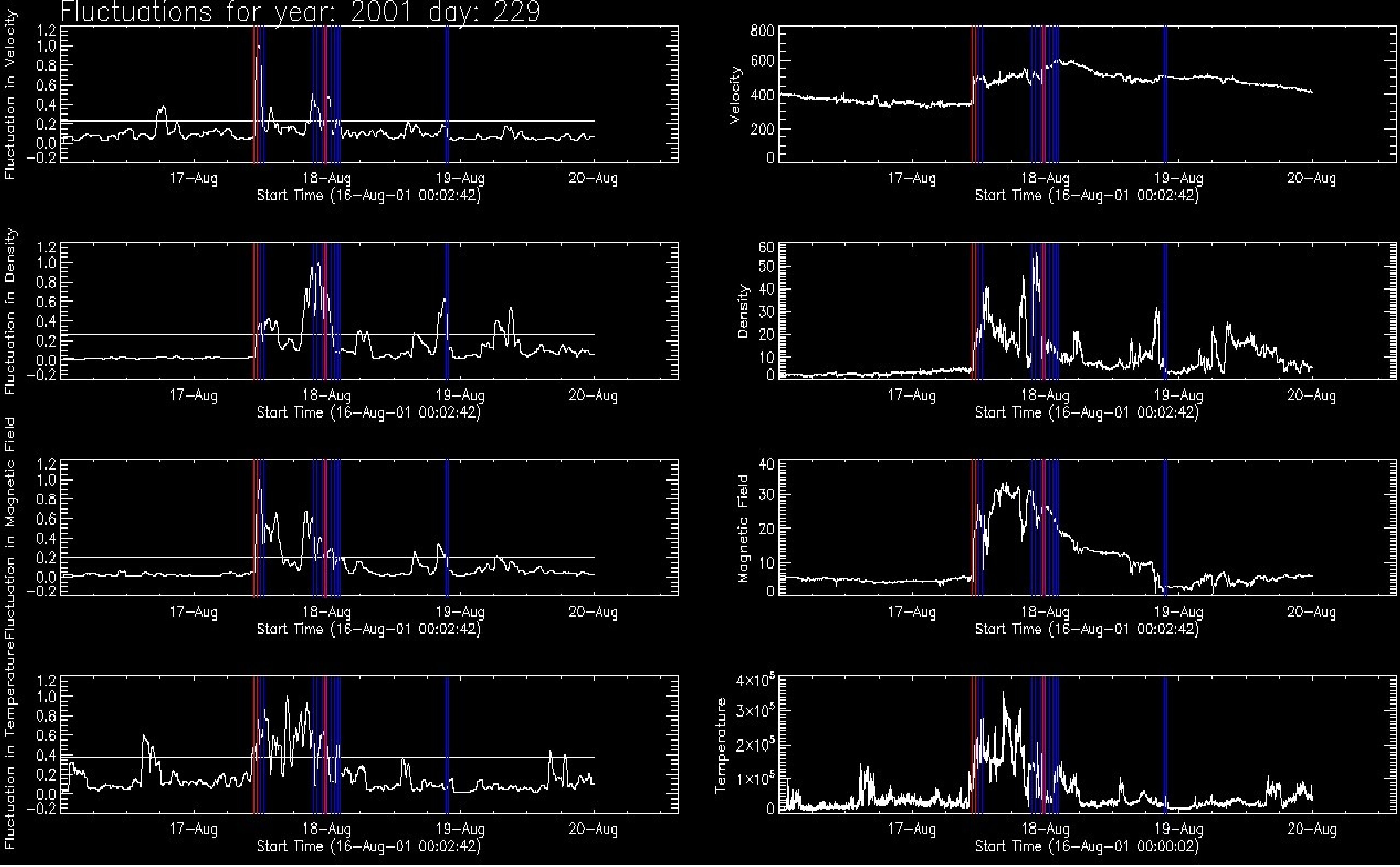
1) Window SIZE (***dt***) for the Moving Average of the Fluctuations.

2) The **N** times of the standard deviation (SIGMA).

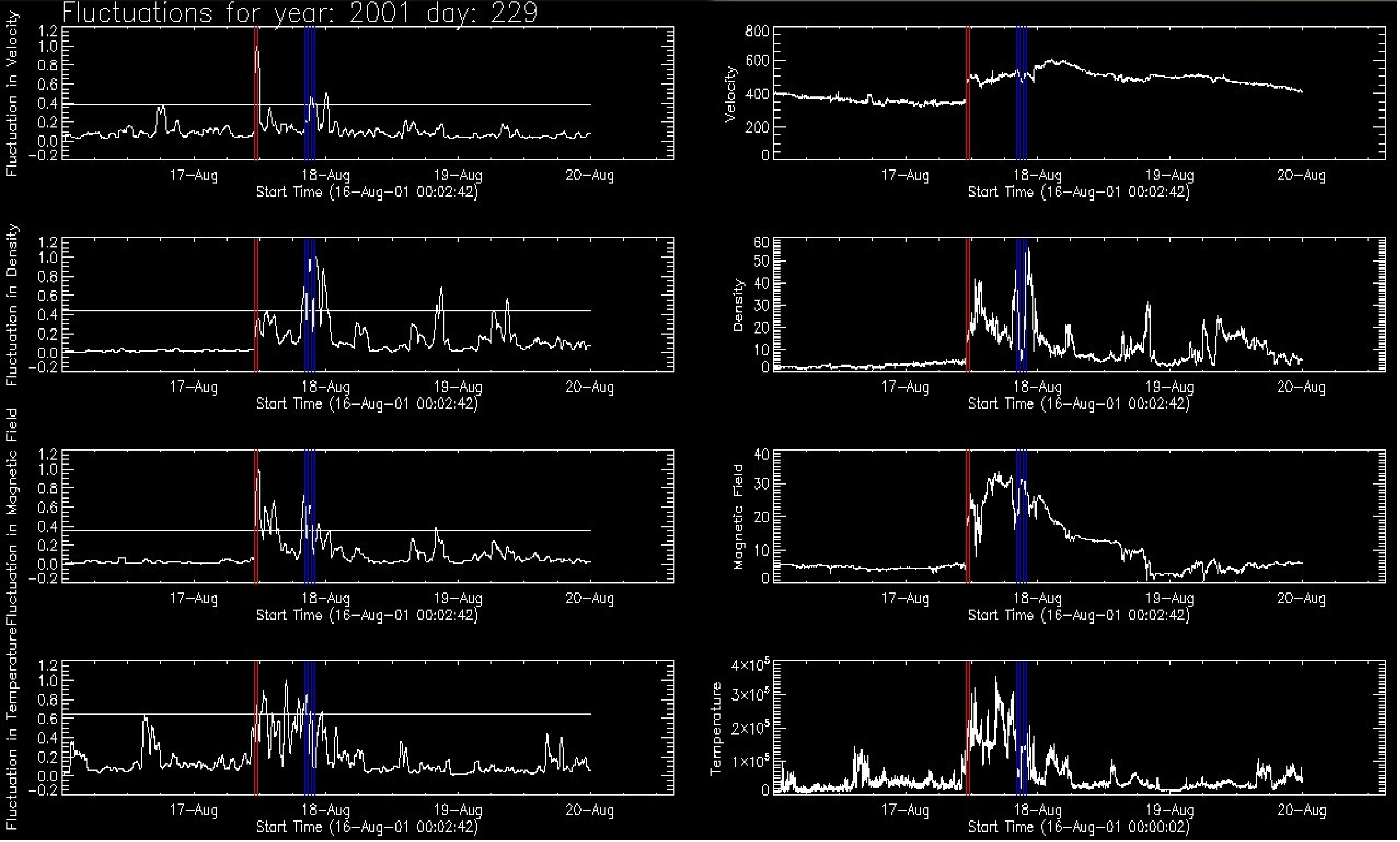
3) The BIN SIZE (***dm***) for the Histogram to decide were the fluctuations occur almost at the same time.

As example we present the same event but having different values of ***dt***, ***dm*** and ***N***.

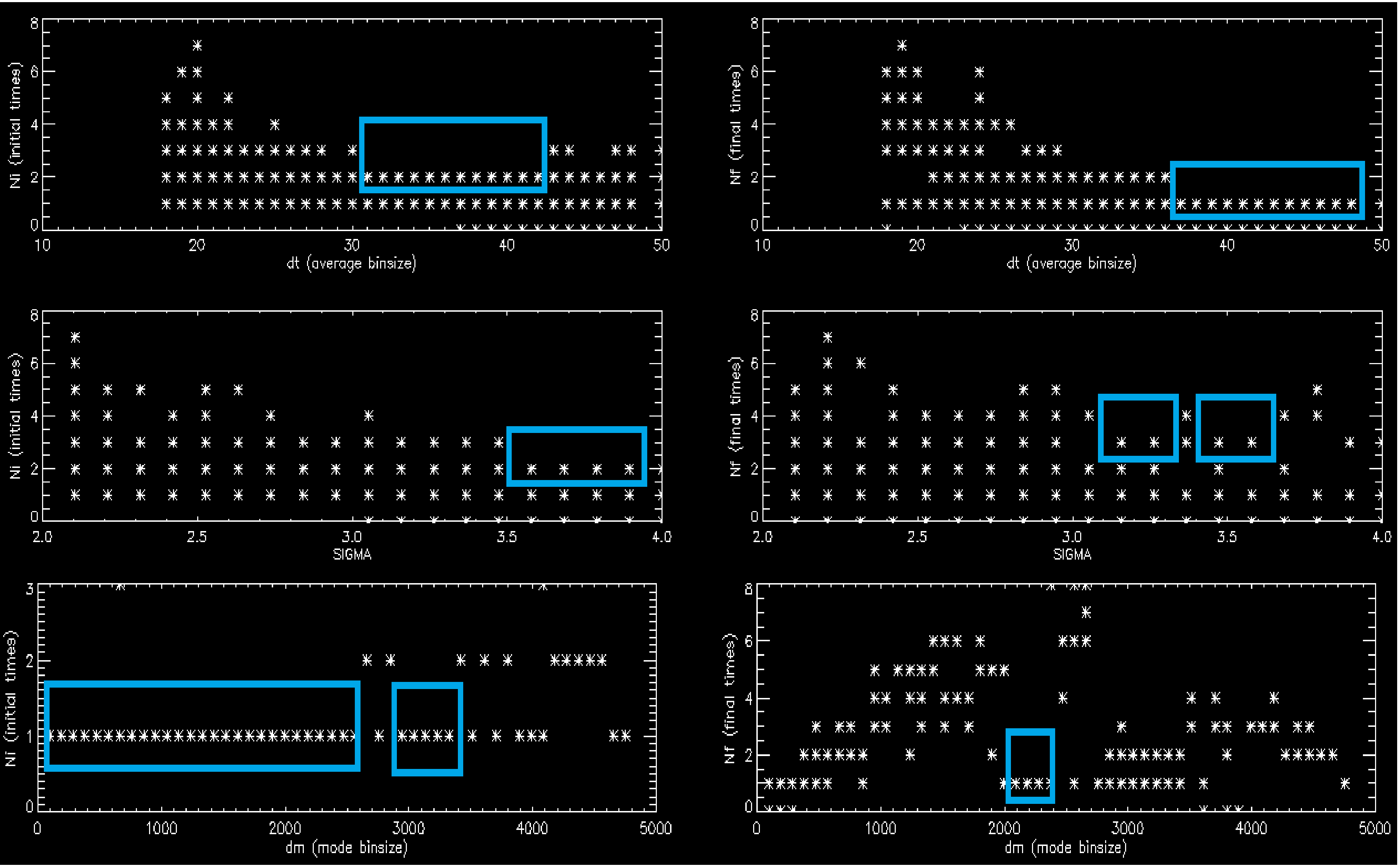
The red lines correspond to the possible initial times of the sheath.
The blue lines to the final times.



In the right side you can see the velocity, density, magnetic field and temperature in terms of time. The highest values correspond to the pass of the ICME. In the left side you can see the fluctuations obtain by the method we are proposing. You can see that the method is finding times where fluctuations exceed the NSIGMA (red bins) and where the fluctuations go below NSIGMA (blue). To do the fluctuations we tried *N=2*, *dt=50* and *dm=1900*.



The same event but changing values as *N=3.6*, *dt=40* and *dm=2200*. We improved the location for the initial and final times consistent to what we could see happening with the parameters as the ICME passed through the instruments. This method can identify the first increase of the parameters but if we change *dt*, *dm* and *N* to something more similar to the FIG. then you can observed that even with those trial values we were able to see the second structure.



Number of possible initial (left) and final (right) times of the sheath for different values of *dm* inside the ranges chosen for *dt* and the selected value of . We chose the values of *dm* that showed less number of possible initial (red bins) and final (blue bins) times. The light blue squares shows the ranges for *dm*.

We looked for those ranges where the number of possible initial and final times were the minima.

dt We found two possible ranges at the initials and finals: 38 – 42.

dm The possible range for the initial and final times is

2000 – 2400.

N For the initials the range is: 3.5 – 4.0 and for the finals: 3.4 – 3.7.

Only one value could be in both ranges: 3.6

The value just in the middle of each range was chosen as follows:

dt = 40 ***dm = 2200*** ***N = 3.6***

Considering ***dt = 40***, ***dm = 2200*** and ***N = 3.6***

- We could find automatically 18 out of 27t ICMEs in a testing set. The rest were not so clear. Those events are not simple structures.

With the aim to compare our results with our proposed method we reviewed the details from each event. From daily graphics we looked for the Shock time and the initial time of the ICME. The difference between these times is considered the sheath duration.

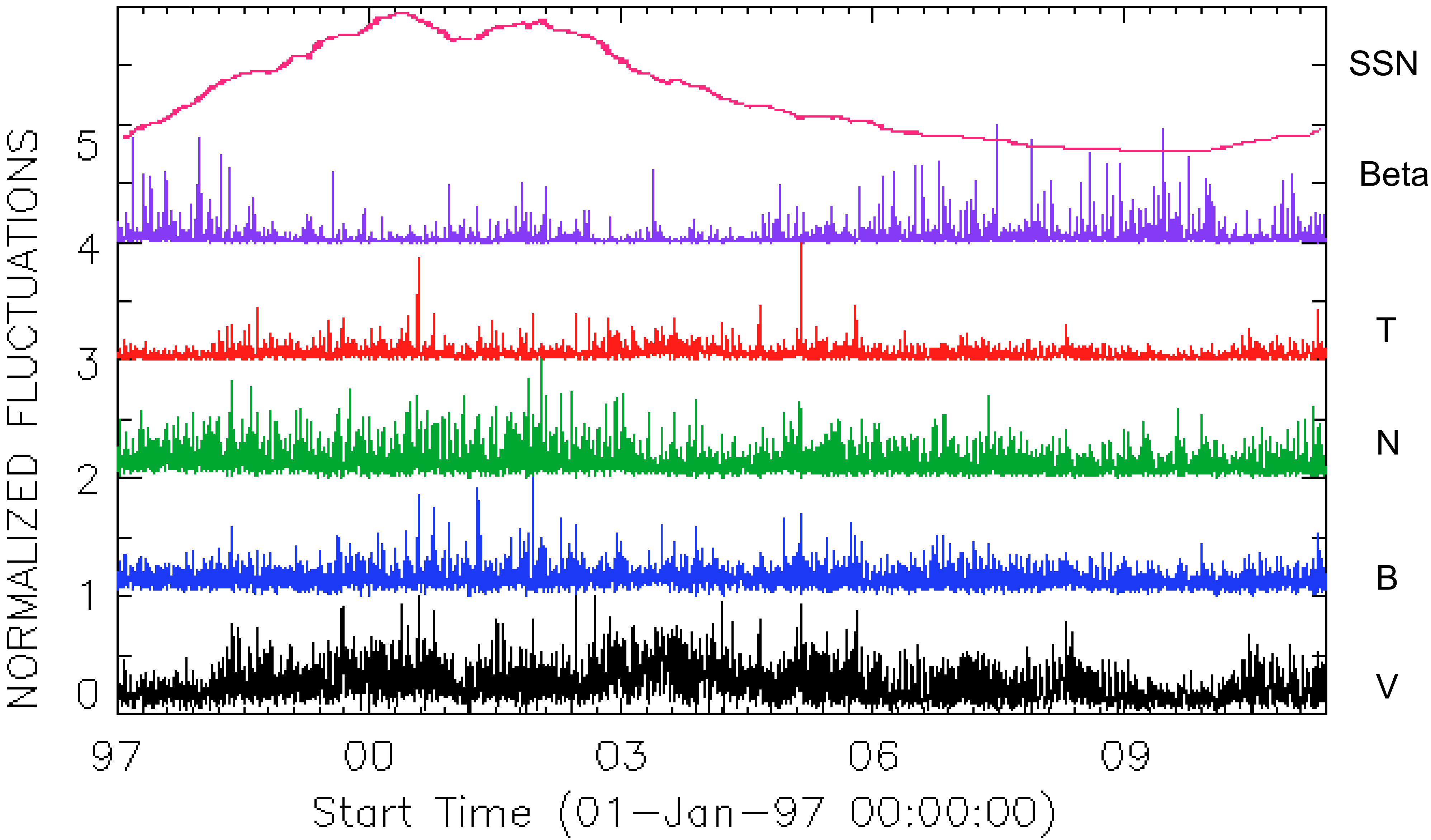
ANALYZING THE FLUCTUATIONS

We estimated the fluctuations of five different parameters.

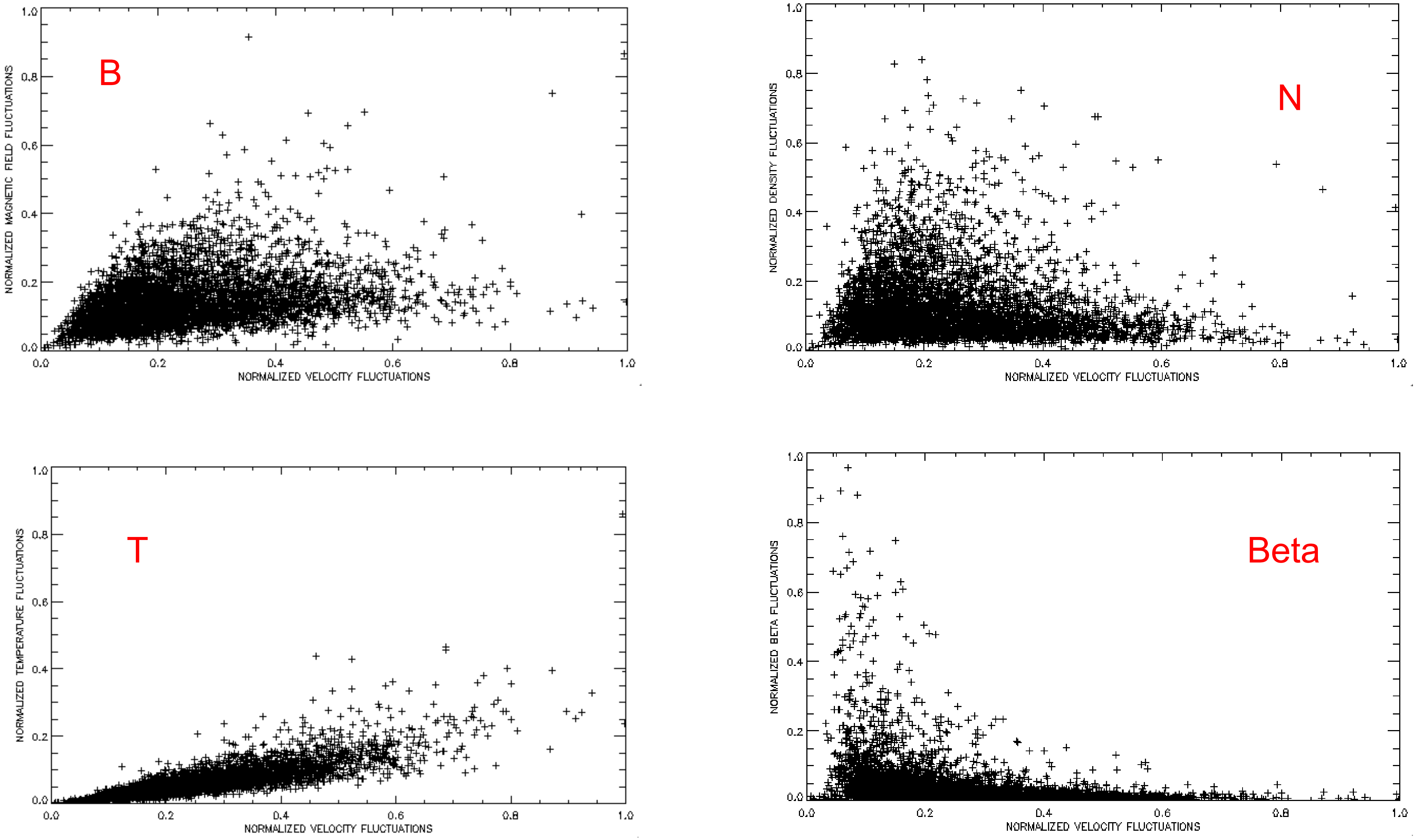
ARE THE FLUCTUATIONS TELLING US SOMETHING?

This is a STEP BACK in the pursuit of the identification of ICMEs at 1 AU.

But It is necessary to understand what the fluctuations are giving us of information.

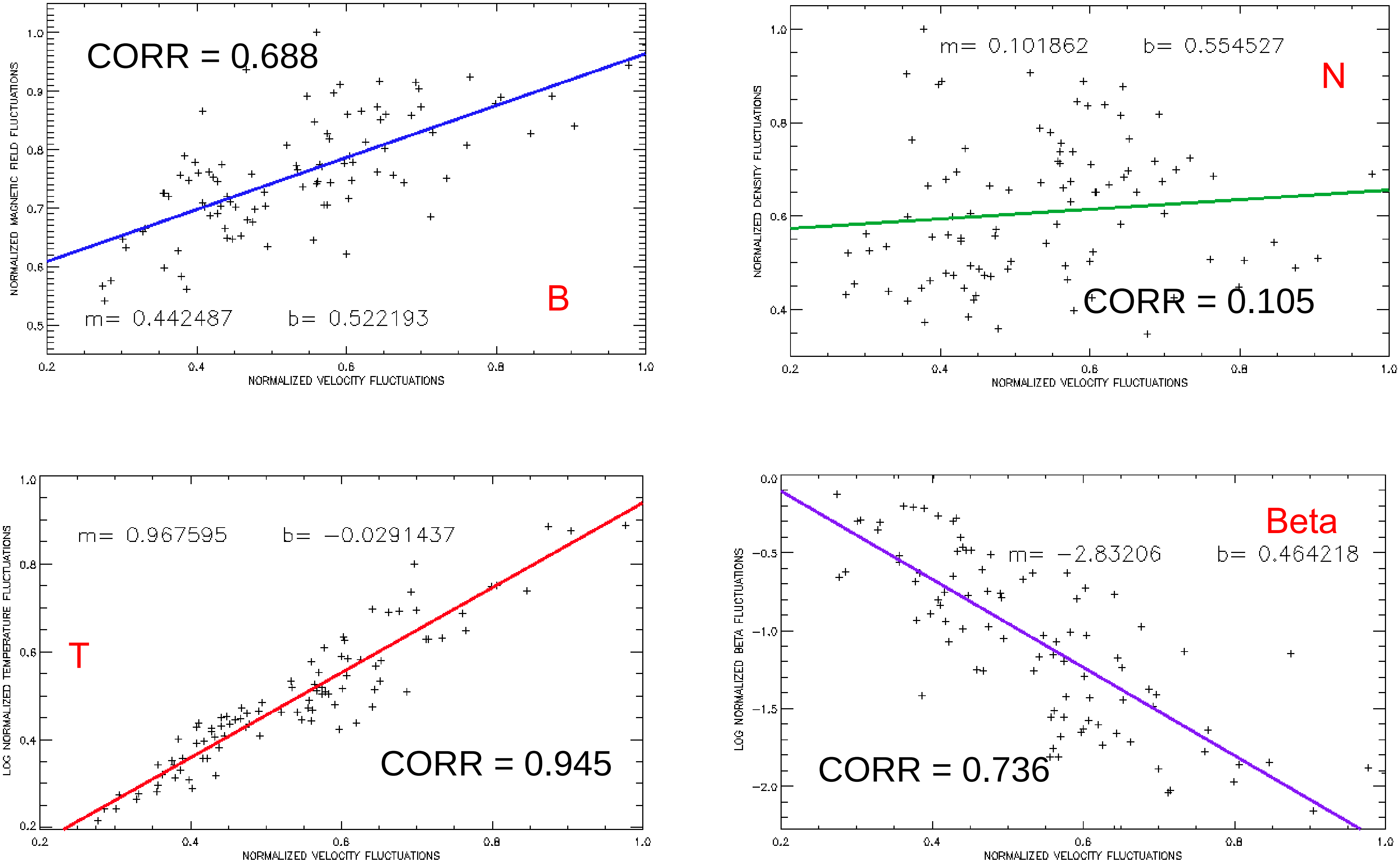


Normalized Fluctuations of different parameters: velocity (black), magnetic field (+1, blue), density (+2, green), temperature (+3, red) and beta (+4, purple) from January 1997 to April 2011. Beta parameter shows fluctuations that could be correlated with the solar activity cycle. In pink normalized number of sunspots (+5).



Velocity

Normalized fluctuations of the velocity with the normalized fluctuations of: magnetic field, density, temperature and beta parameters. It’s clear the dependency of the temperature with the velocity. This dependency is not due to the instruments.



Velocity

Monthly average of the velocity normalized fluctuations with the monthly average of the normalized fluctuations of magnetic field, density temperature and beta parameters. We include the linear functions that better adjust the values. For the beta we used a *1/x*, and for the rest a linear function of the form: *y=mx+b*.

- There is a tendency of the fluctuations to follow the solar activity cycle.

- There is a direct relation between the velocity and the temperature. It is independently of the way these are measured. The correlation is not due an instrumental bias. We found that the slope of the temperature is the value obtained by Borovsky in 2006 by using other statistical approach.

- The density fluctuations depend on how fast the arcade is arriving to the instrument. The faster the arcade goes less time it takes to the arcade to pass through. An instrumental limitation that can be solved with higher time resolution.

- The magnetic field fluctuations increase as the fluctuations of velocity do too. The slope of the function can be attribute to the idea that the plasma is frozen in the magnetic field.

- The fluctuations of beta decrease as the fluctuations in the velocity increase.

- We can get better identification and characterization of structures if we can determine the dependency of these parameters.

SISTEMATICALLY

We tried our method to find its own structures.

The conditions that we imposed to consider a fluctuation as a **structure of interest** were:

- The fluctuation needed to exceed 3.6 times the standard deviation and it occurred in 3 of 4 of the analyzed parameters. And we continue using dt = 40 and dm = 2200.

Now we are using data from January 1997 to April 2011 obtained at CDAWeb.

We found 997 structures of interest.

TWO QUESTIONS:

1. What are these 997 structures?
2. Can the fluctuations give us new information?

1. WHAT ARE THESE 997 STRUCTURES?

R = They could be any kind of structure, not only ICMEs. They could be CIRs, RS, MC, changes of magnetic field sectors, etc.

In order to characterize them (identify the type of structure), we compared the velocity of the structure with the characteristic velocity of the IPM (Alfven velocity).

We present you an example of an structure.

The green line indicates the time where the Shock happened.

The blue line indicates at what time we are taking a 10 minute average of the different parameters to estimate de Alven velocity.

The red line the time we are taking a 10 minute average of the velocity to be compared with the Alven velocity.

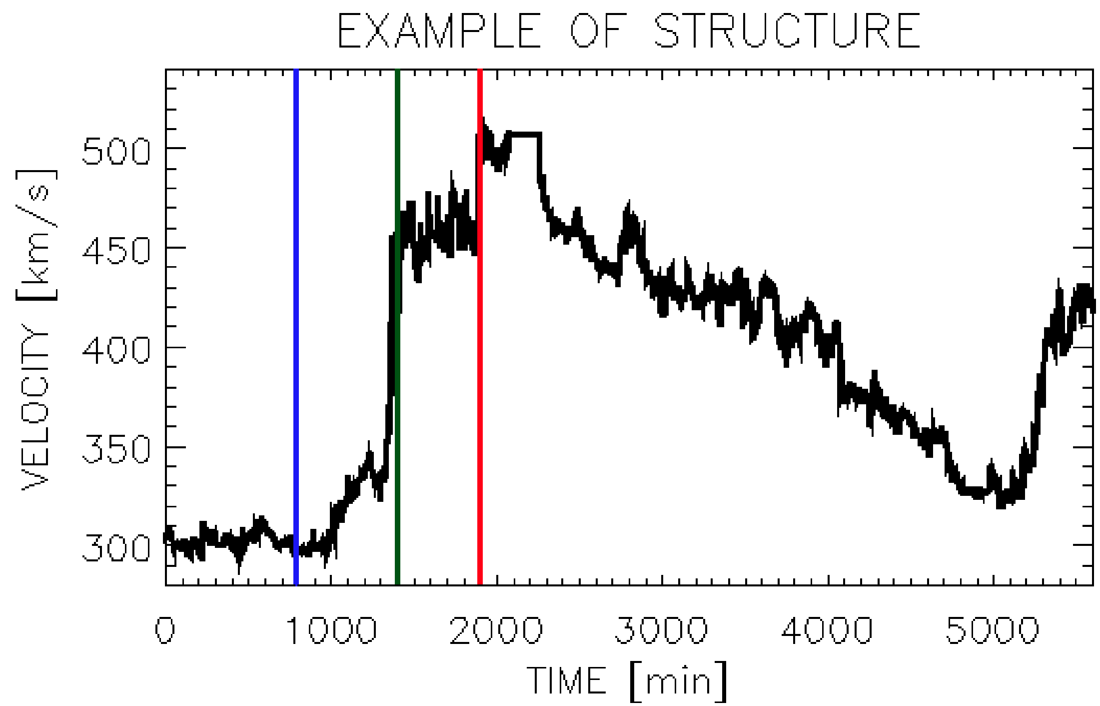
Characterizing Structures of Interest

Alfven Velocity

$$v_A = \frac{B}{\sqrt{\mu_0 n_i m_i}}$$

$$\Delta v = v_{MAX} - v_{MIN}$$

FAST WINDS	SHOCKS
$v_A < \Delta v < 2v_A$	$\Delta v \geq 2v_A$

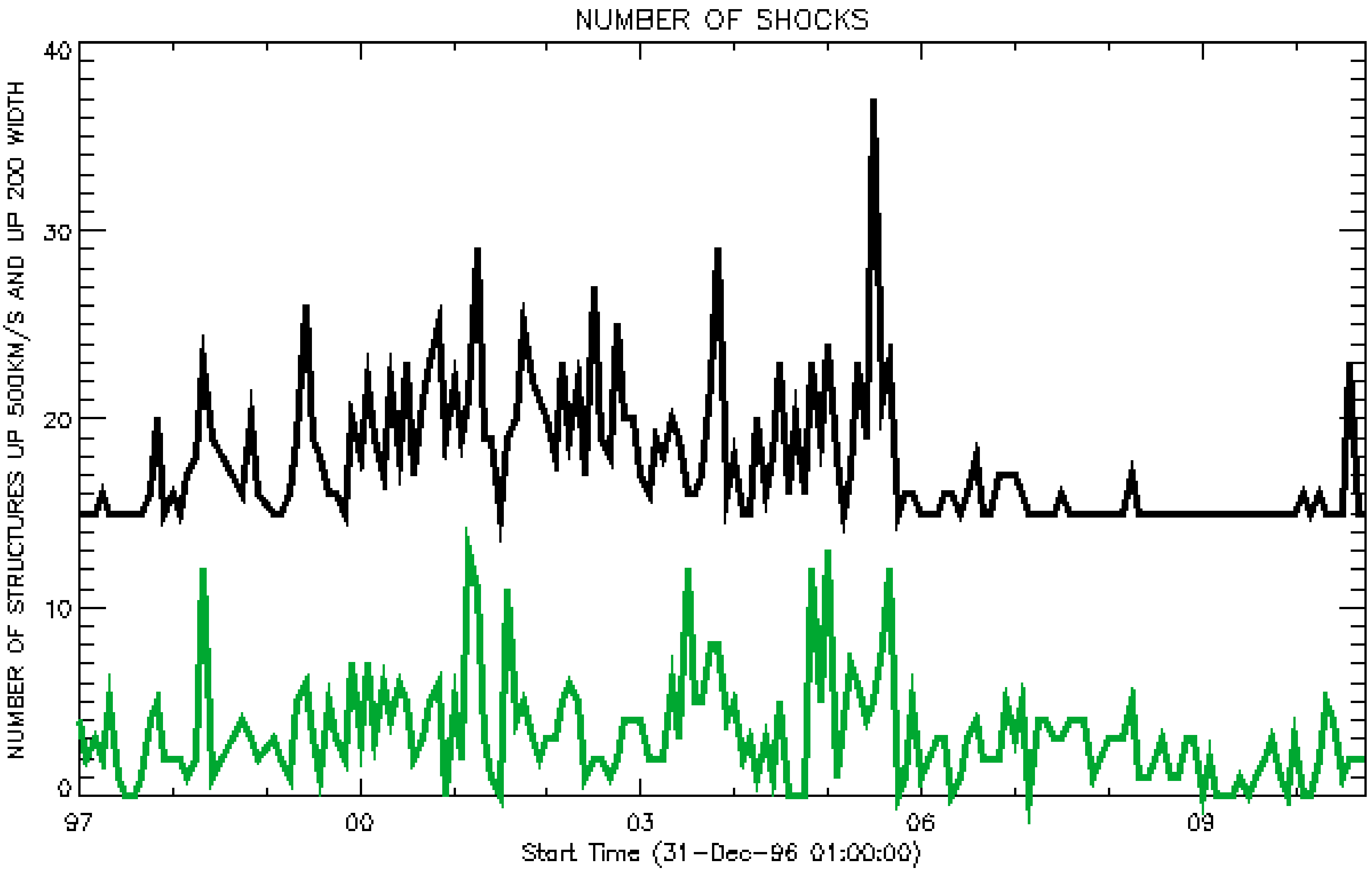


NUMBER OF STRUCTURES	NUMBER OF SHOCKS
997	563

NUMBER OF FAST WINDS
227

We can´t compare directly the number of structures found with our method with the total number of CMEs register by LASCO, this is because not all of the CMEs observed in the inner corona reached the instruments at 1 AU.

But we present the comparison of events with the LASCO CME LIST.



Number of CMEs that exceeded 500 km/s and 200 width in LASCO (+15, black line) compared with the number of shocks we found per month (green line).

CAN THE FLUCTUATIONS GIVE US NEW INFORMATION?

It has being observed that the fluctuations can help us to identify whenever a different structure has reached an ICME.

We have been trying to determine if this method can determine when an MC is passing through and we are trying to identify at 1 AU if MCs lead ICMEs.

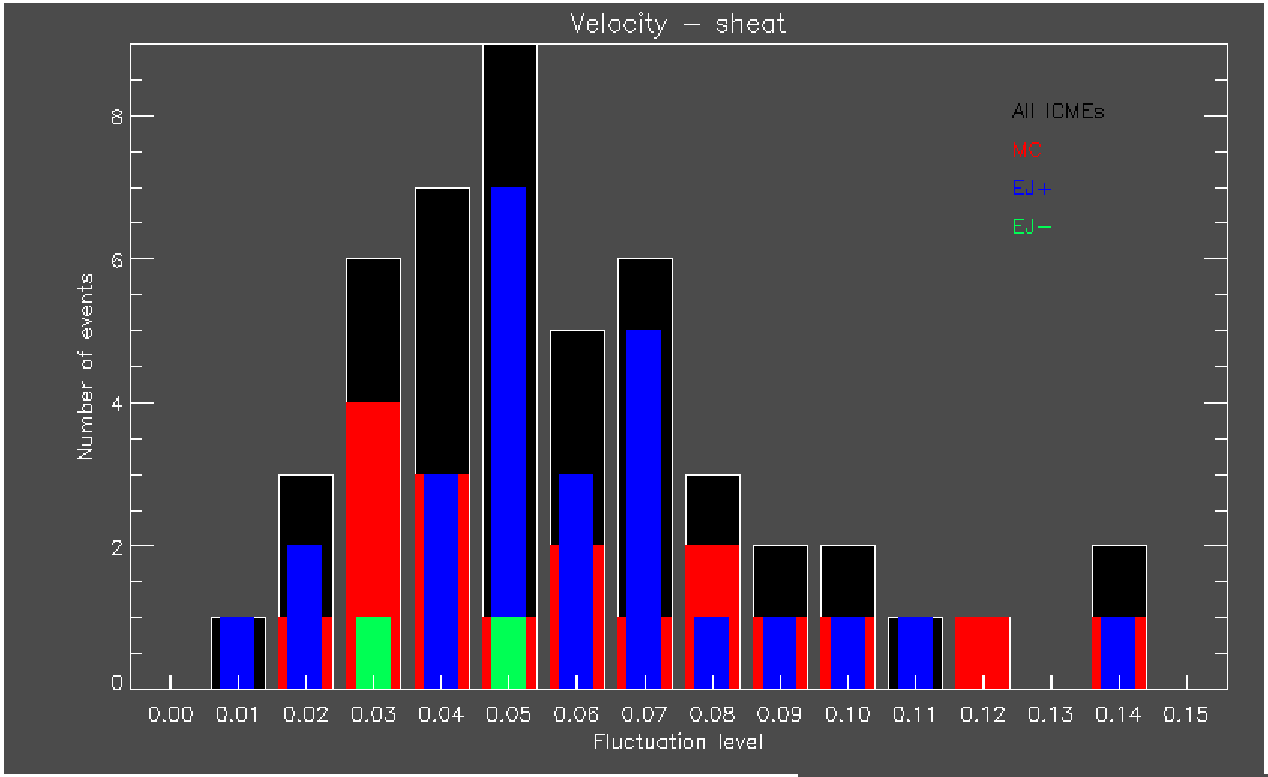
It is possible that our method can help us to study the temporal evolution of interactions of different kind of structures with ICMEs.

We still need to work on the identification of different kind of structures and what kind of fluctuations can lead each type.

2 Statistical Results of CDAW events

(There are differences in the fluctuations between MC and ejecta?)

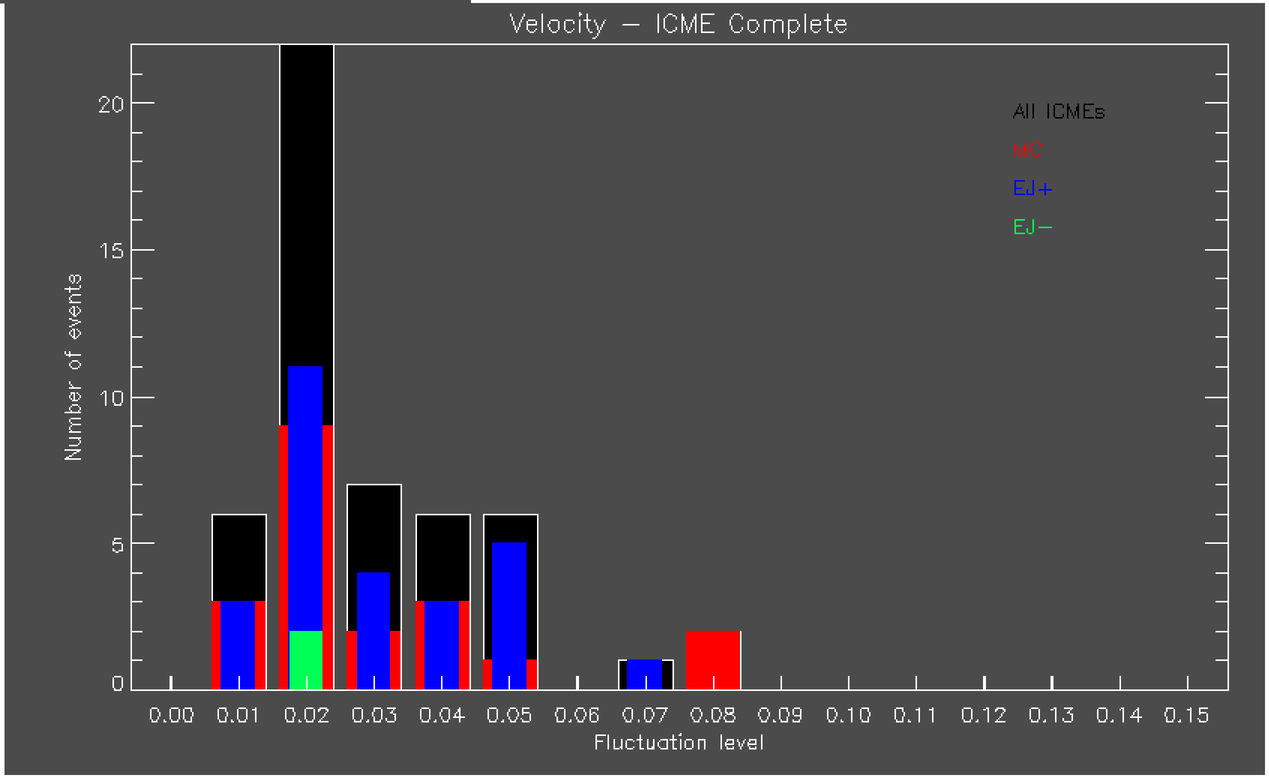
Speed Fluctuations



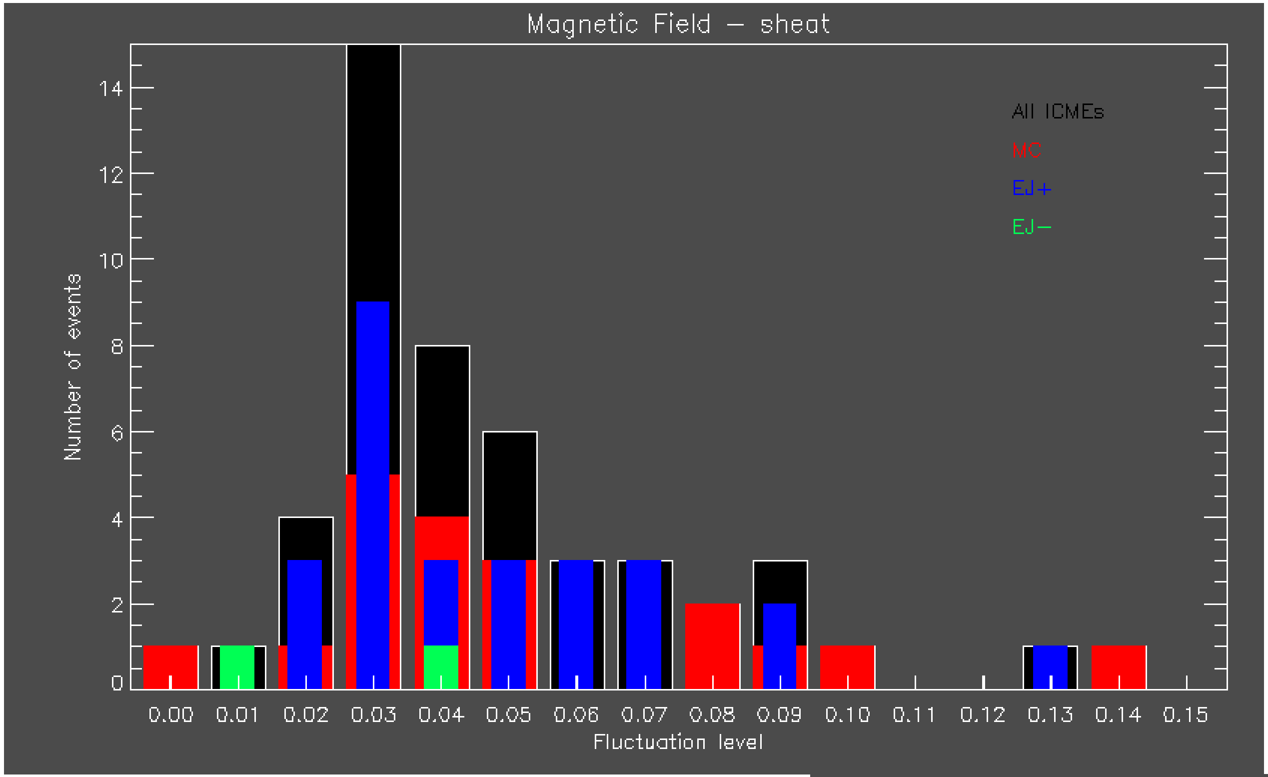
Sheath

There is a small difference in the sheath distributions.

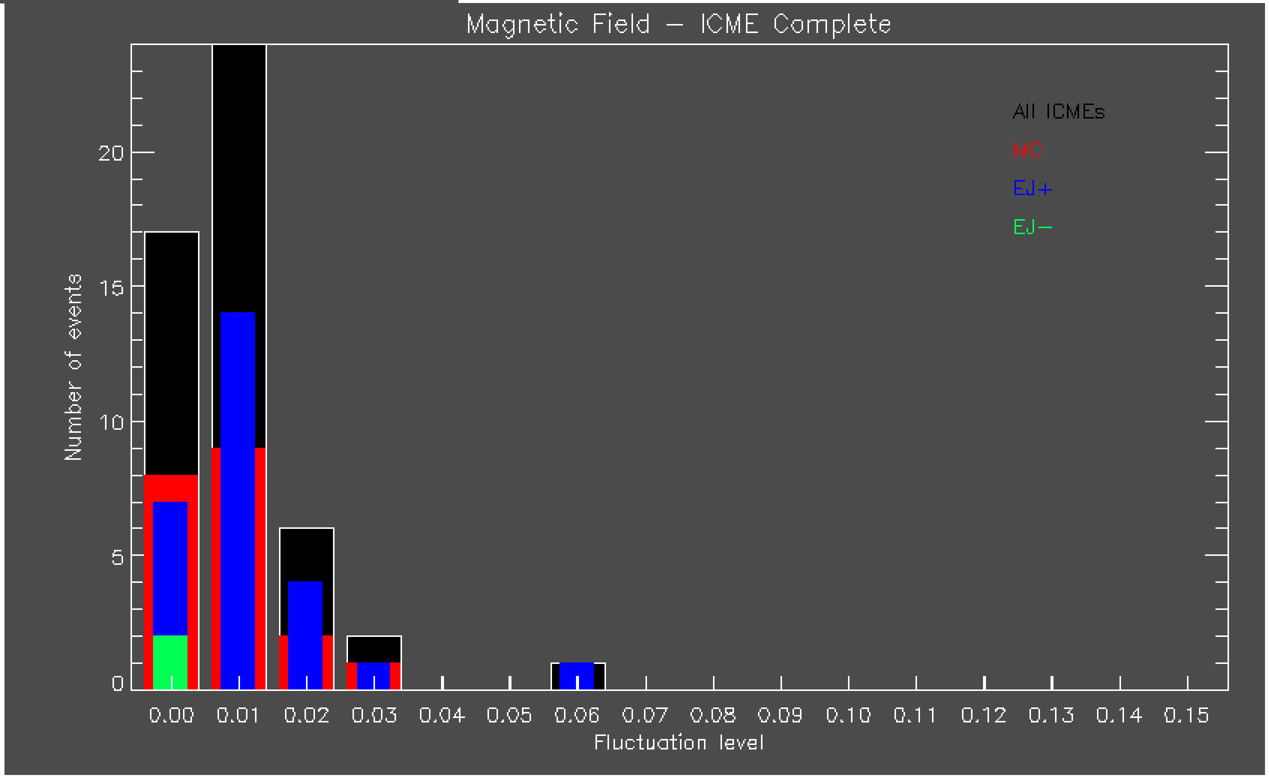
ICME



Magnetic Field Fluctuations

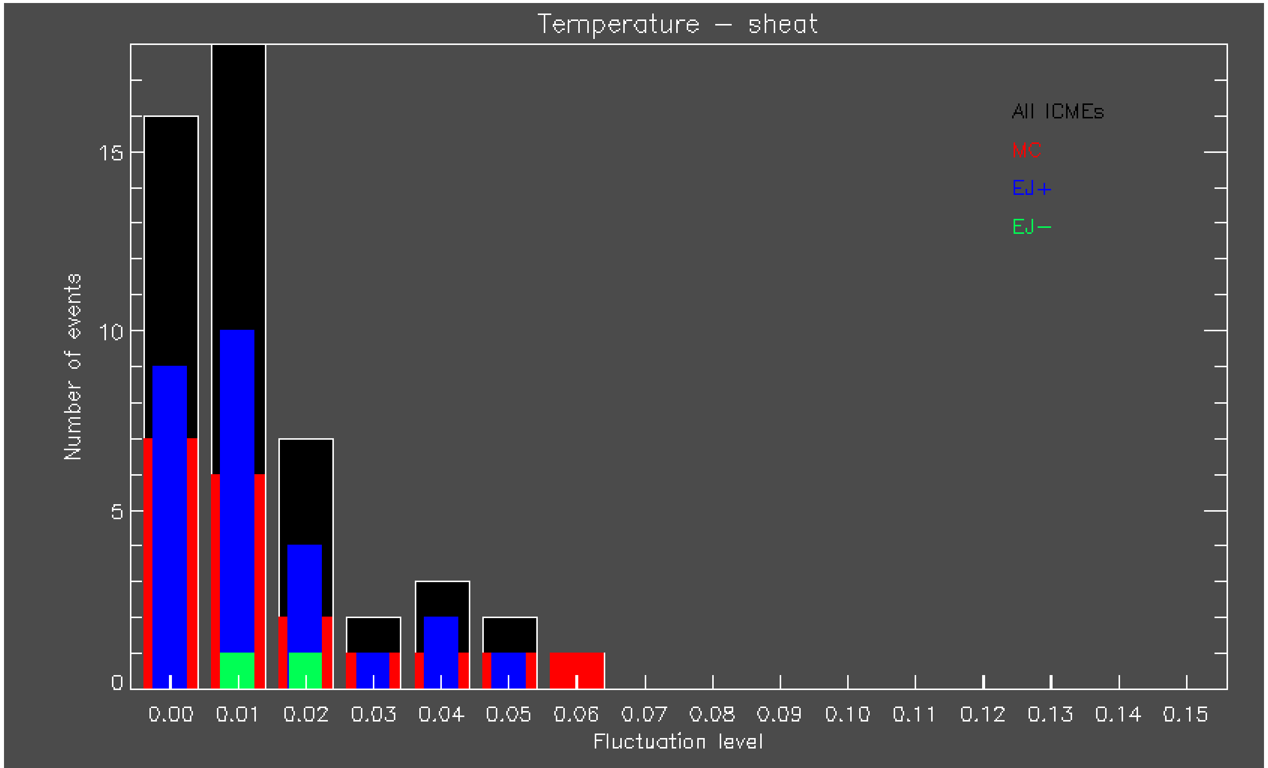


Sheath



ICME

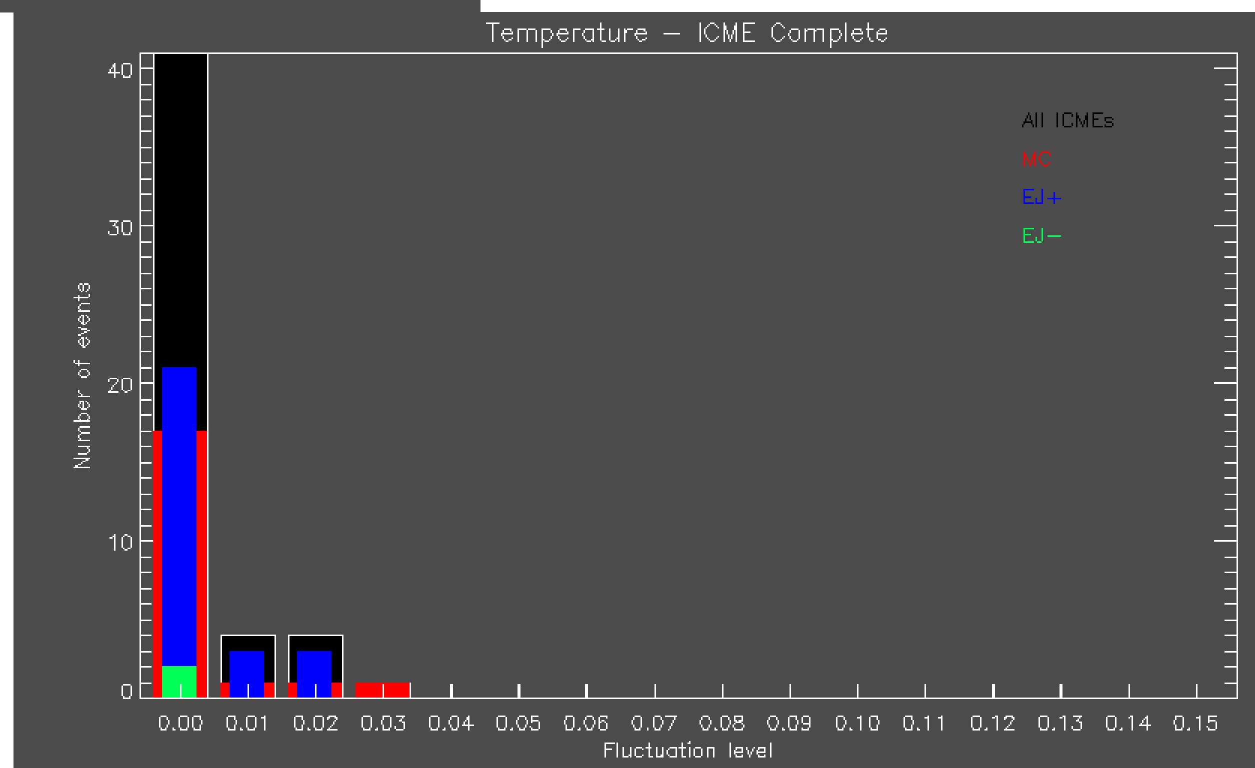
Temperature Fluctuations



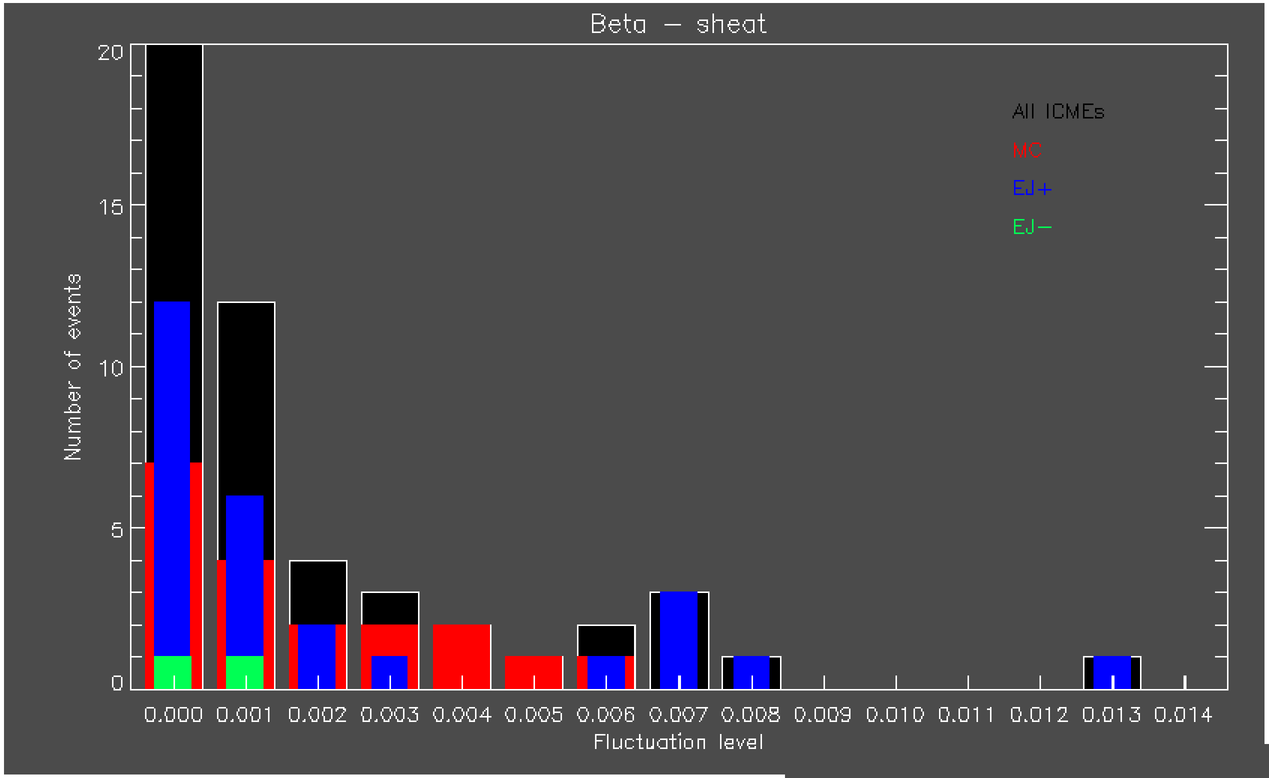
Sheath

There is a small difference in the sheath distributions.

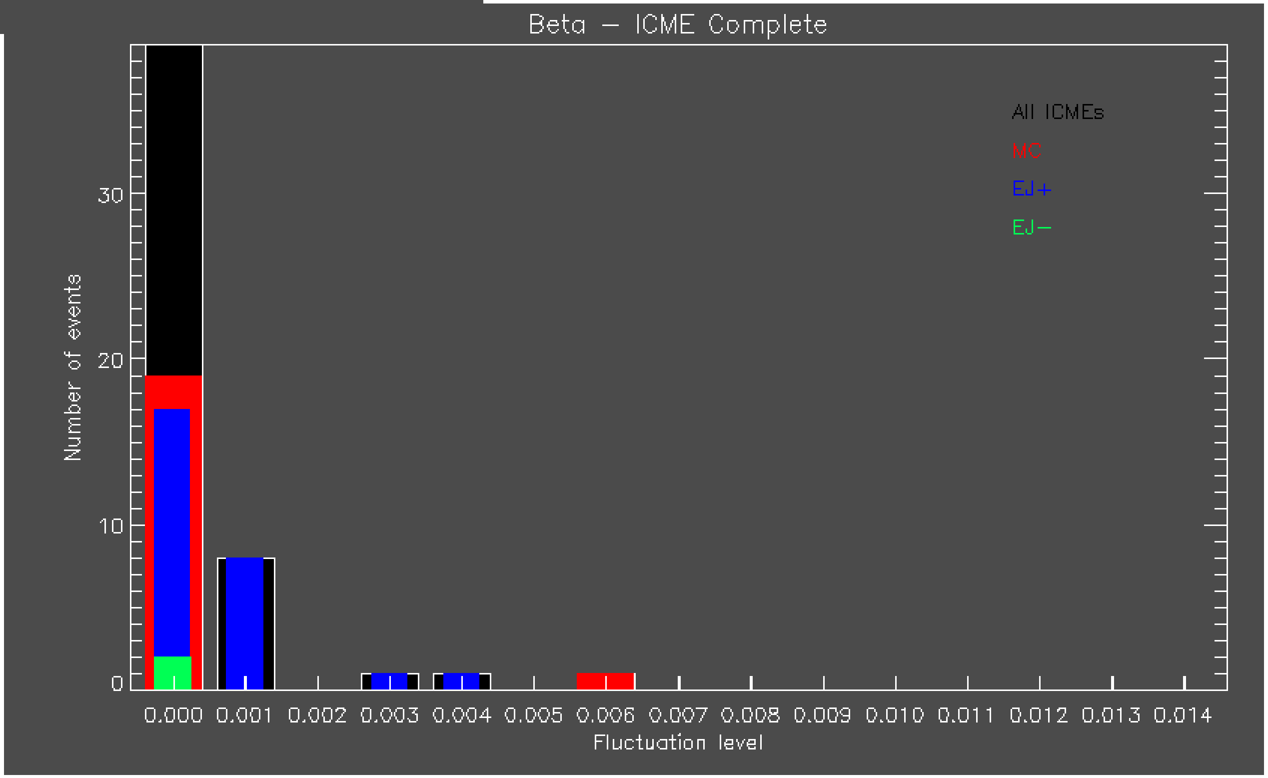
ICME



Beta Fluctuations

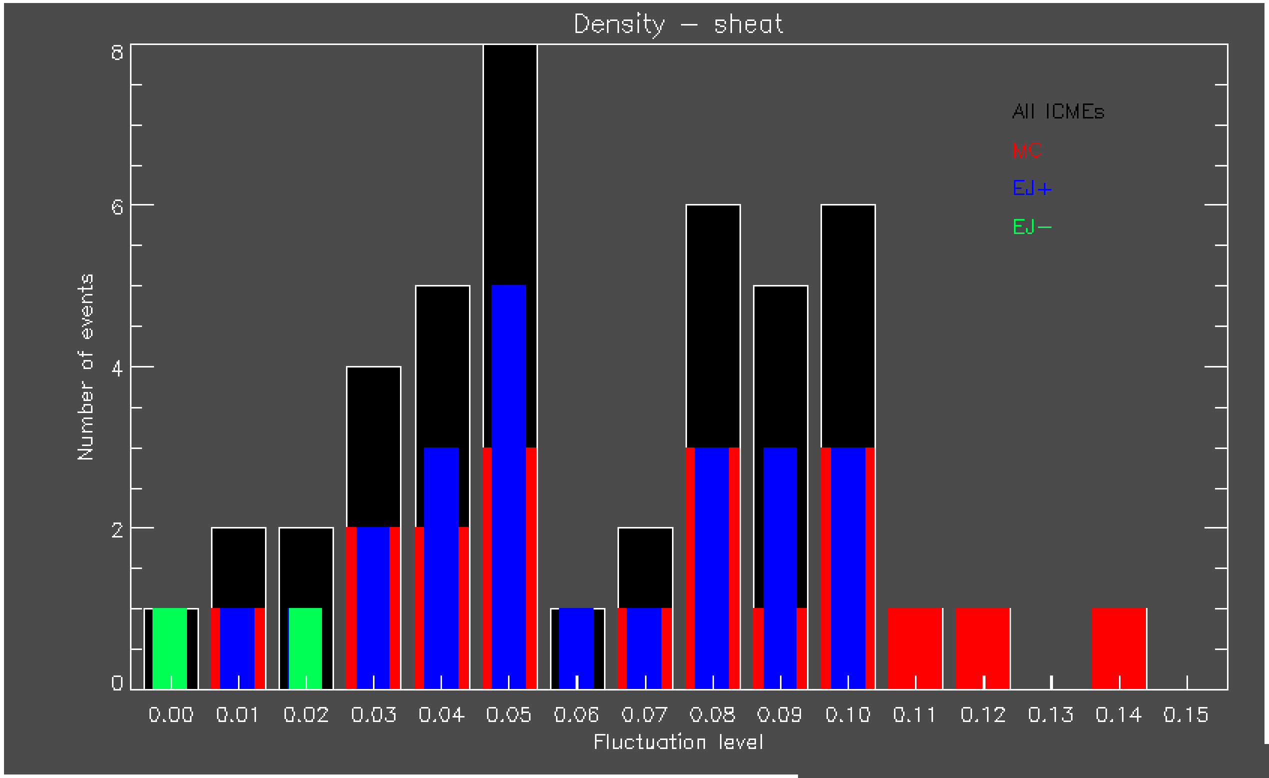


Sheath



ICME

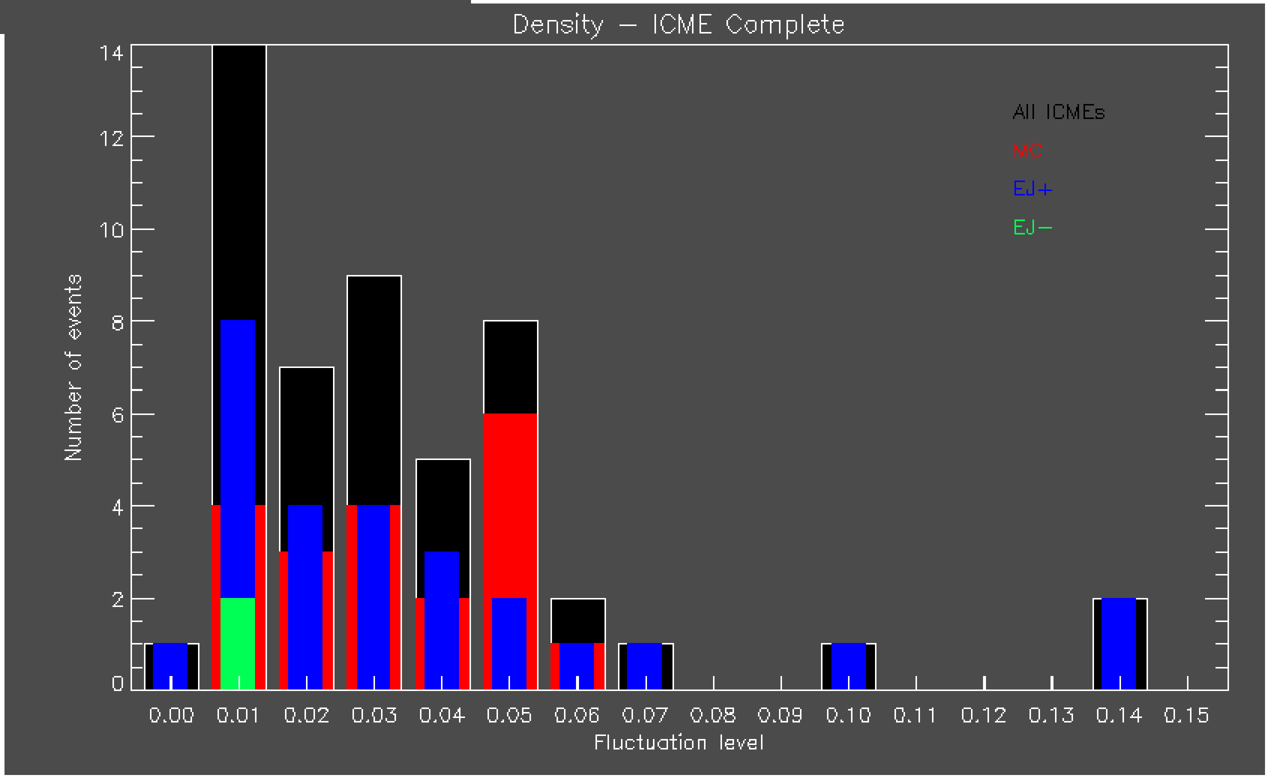
Density Fluctuations



Sheath

The density fluctuations are not useful for the identification!

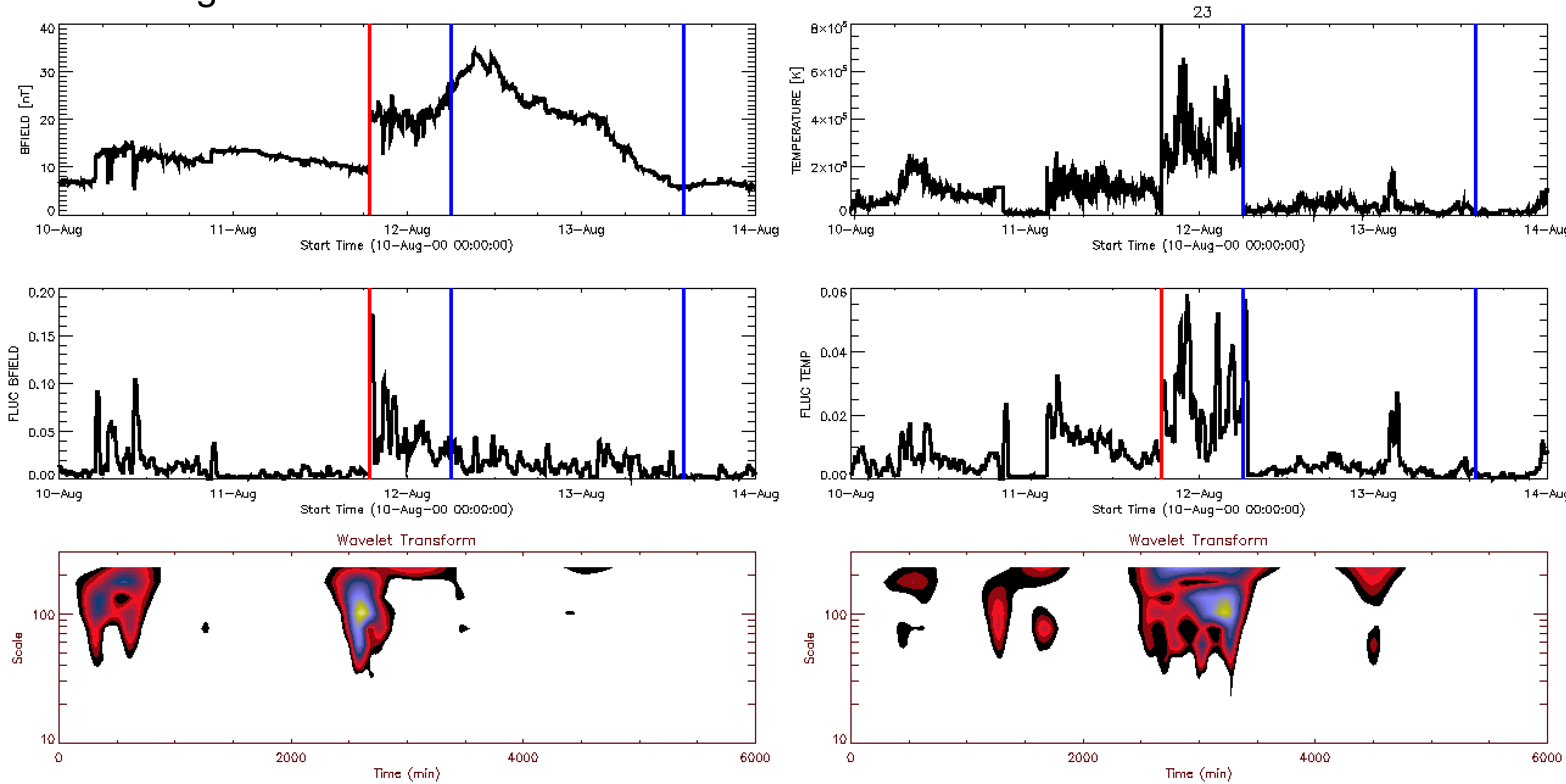
ICME



3 Examples

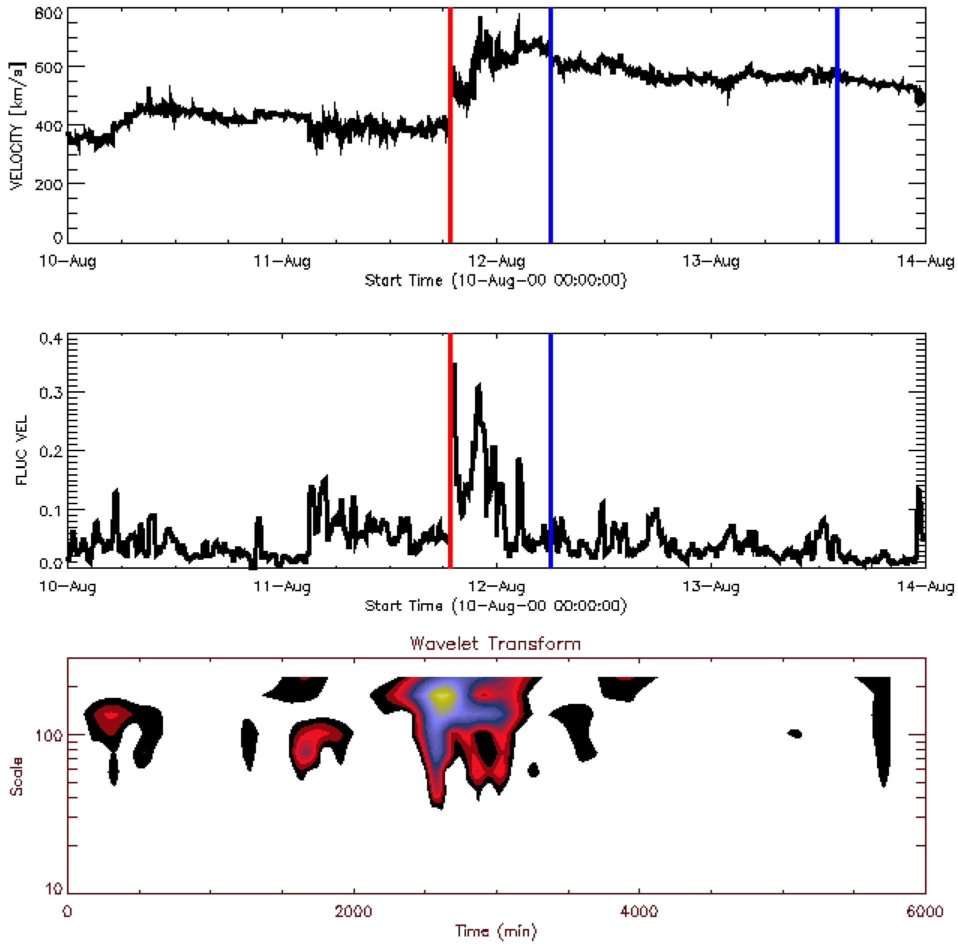
Magnetic Field

Temperature

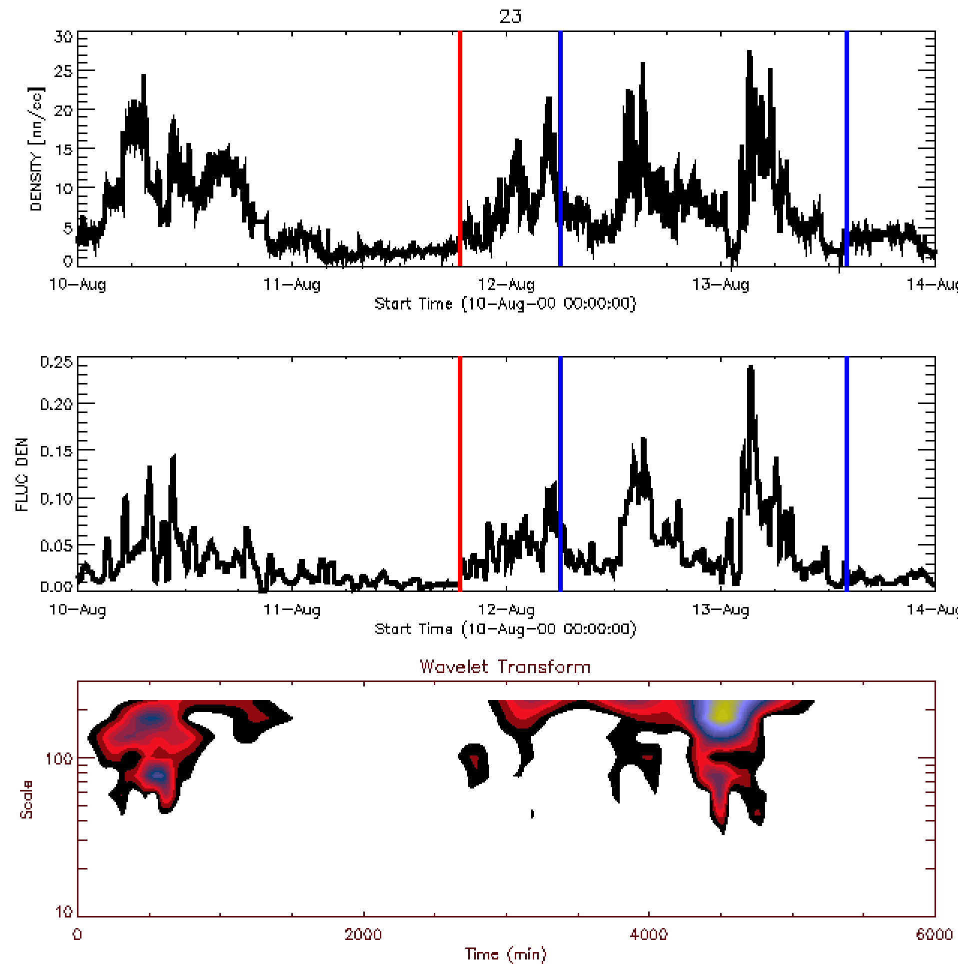


Magnetic Cloud # 23

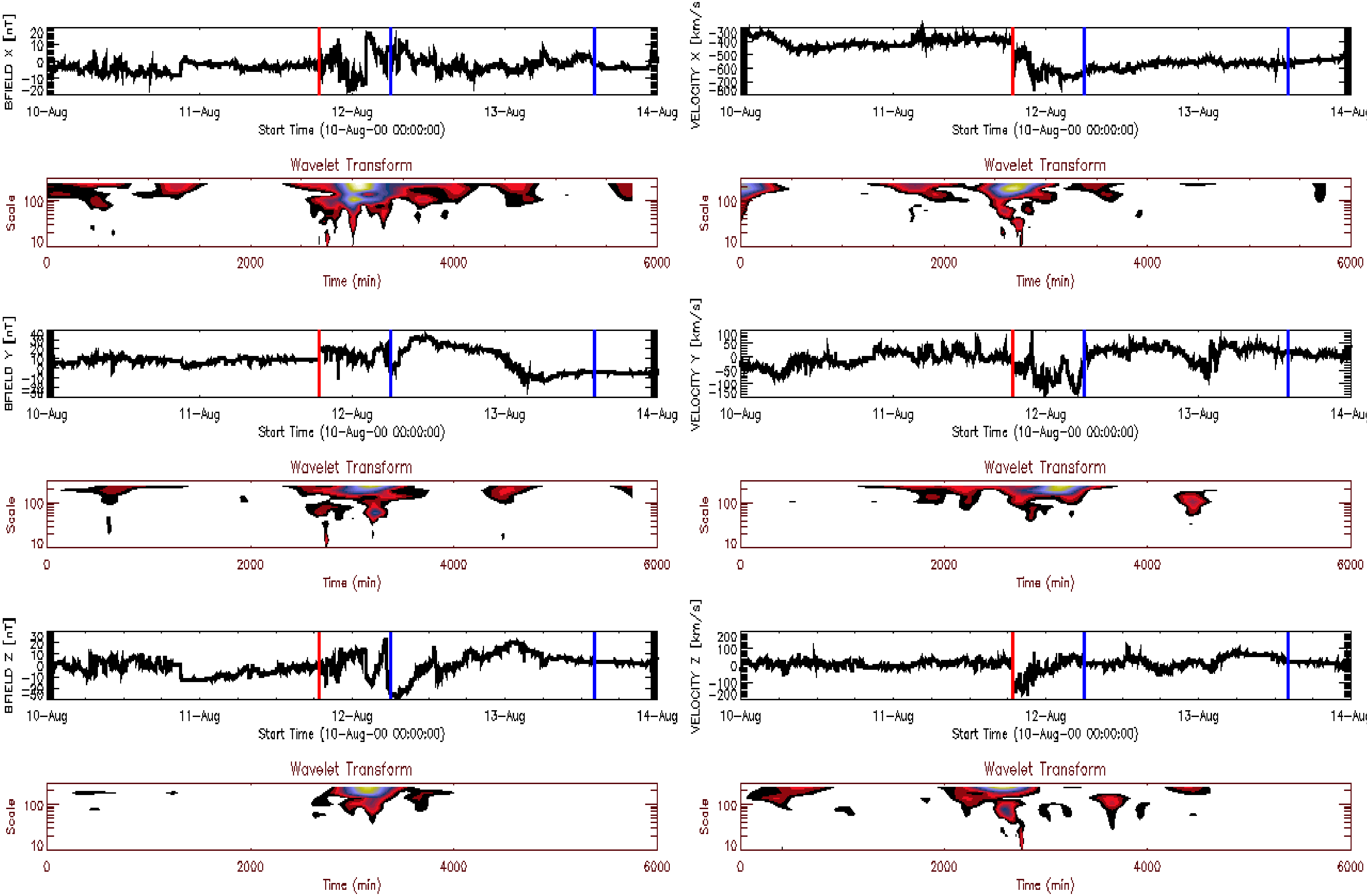
Velocity



Density



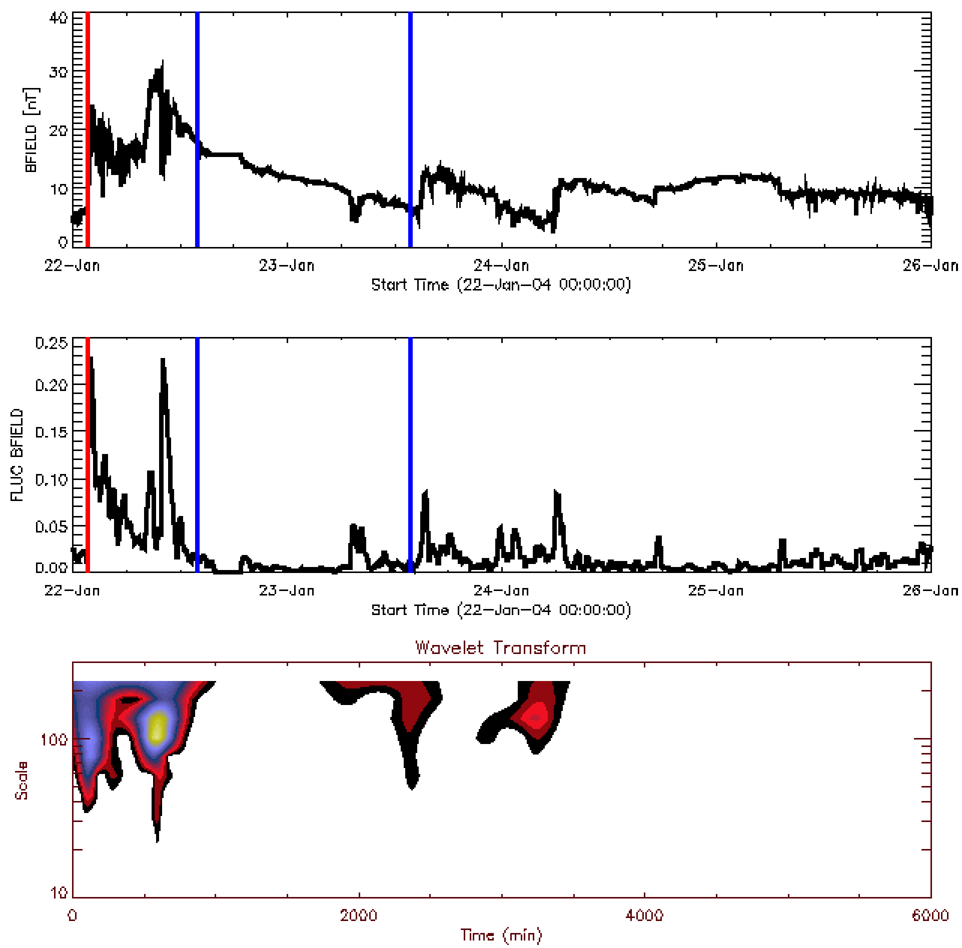
Magnetic Cloud # 23



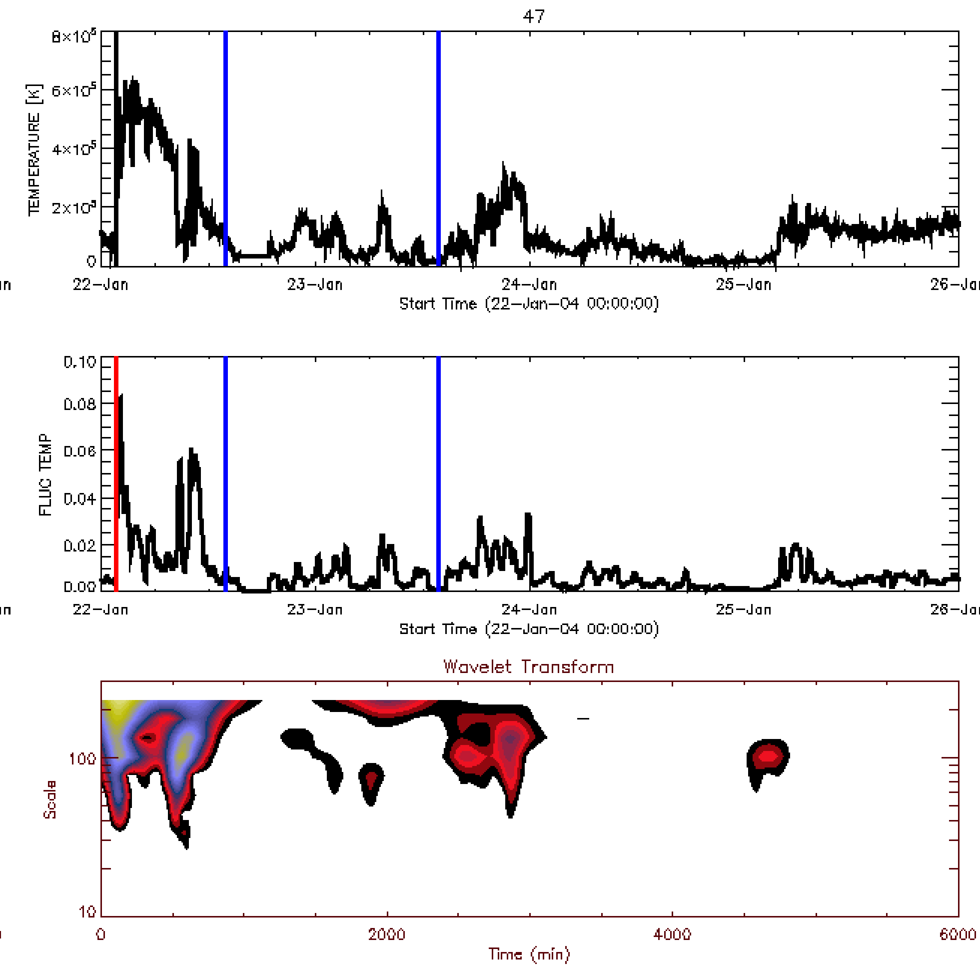
Magnetic Cloud # 23

V and B components

Magnetic Field

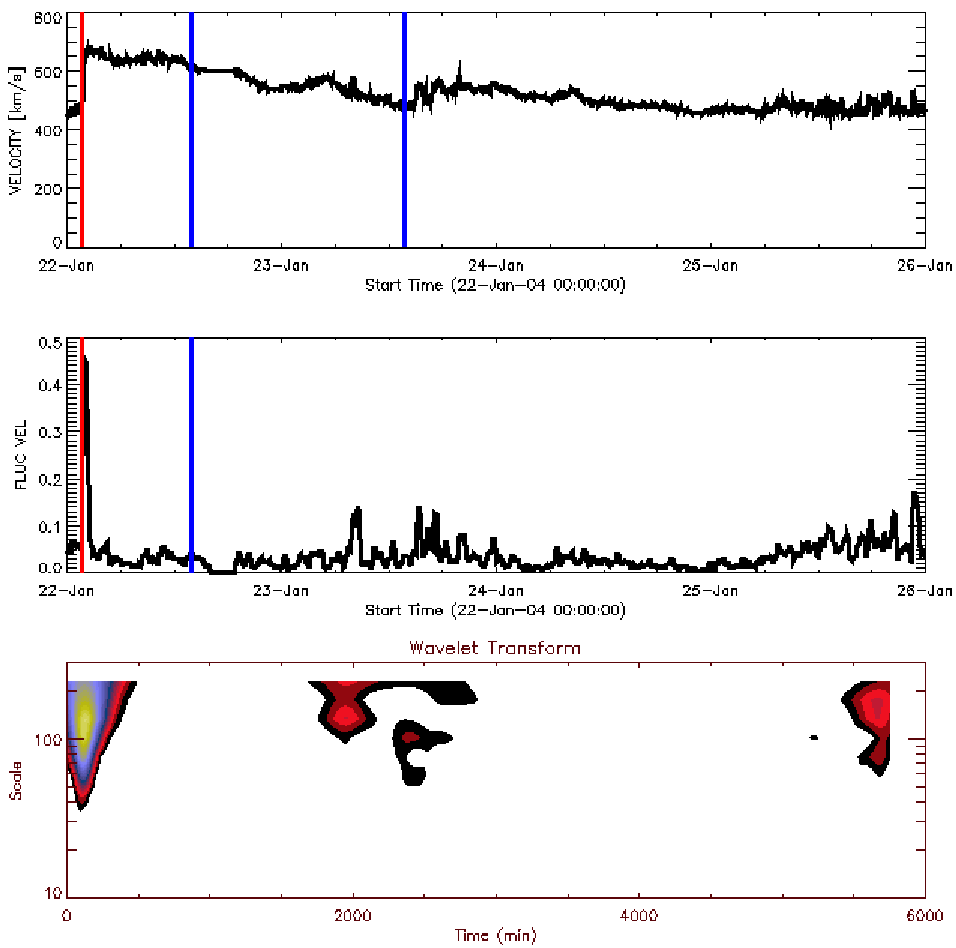


Temperature

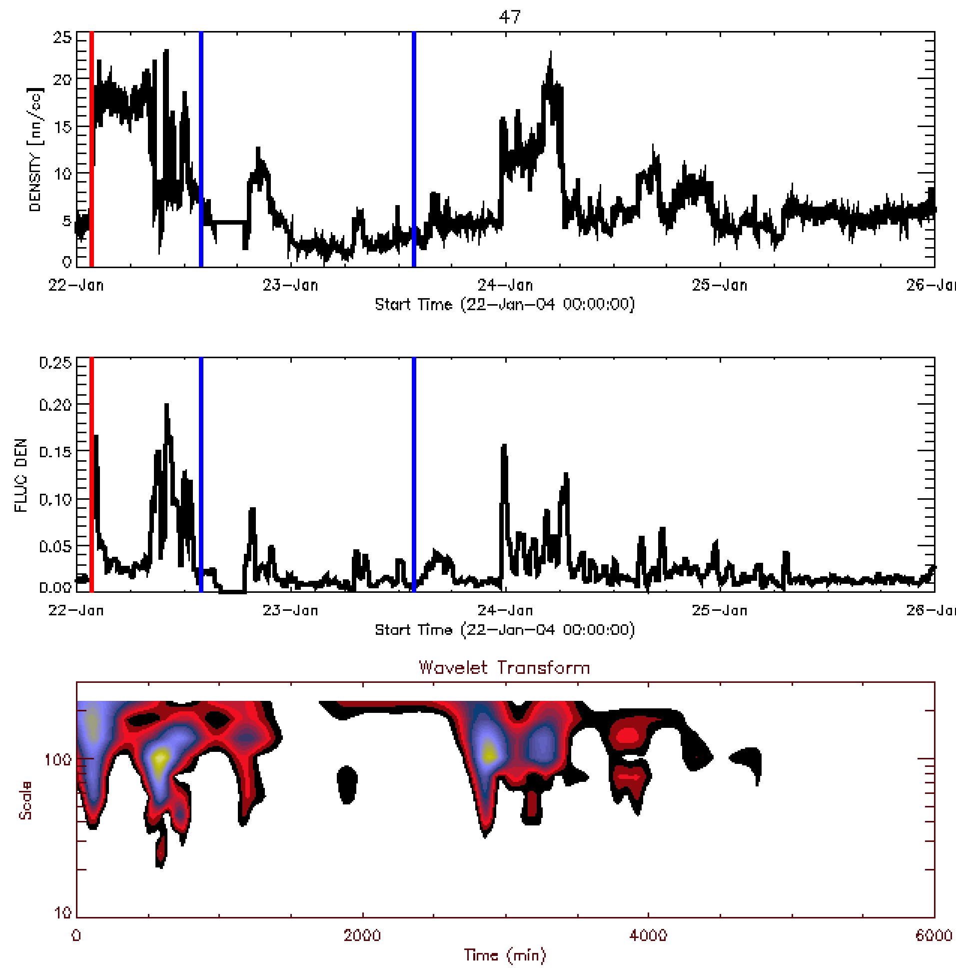


Ejecta + # 47

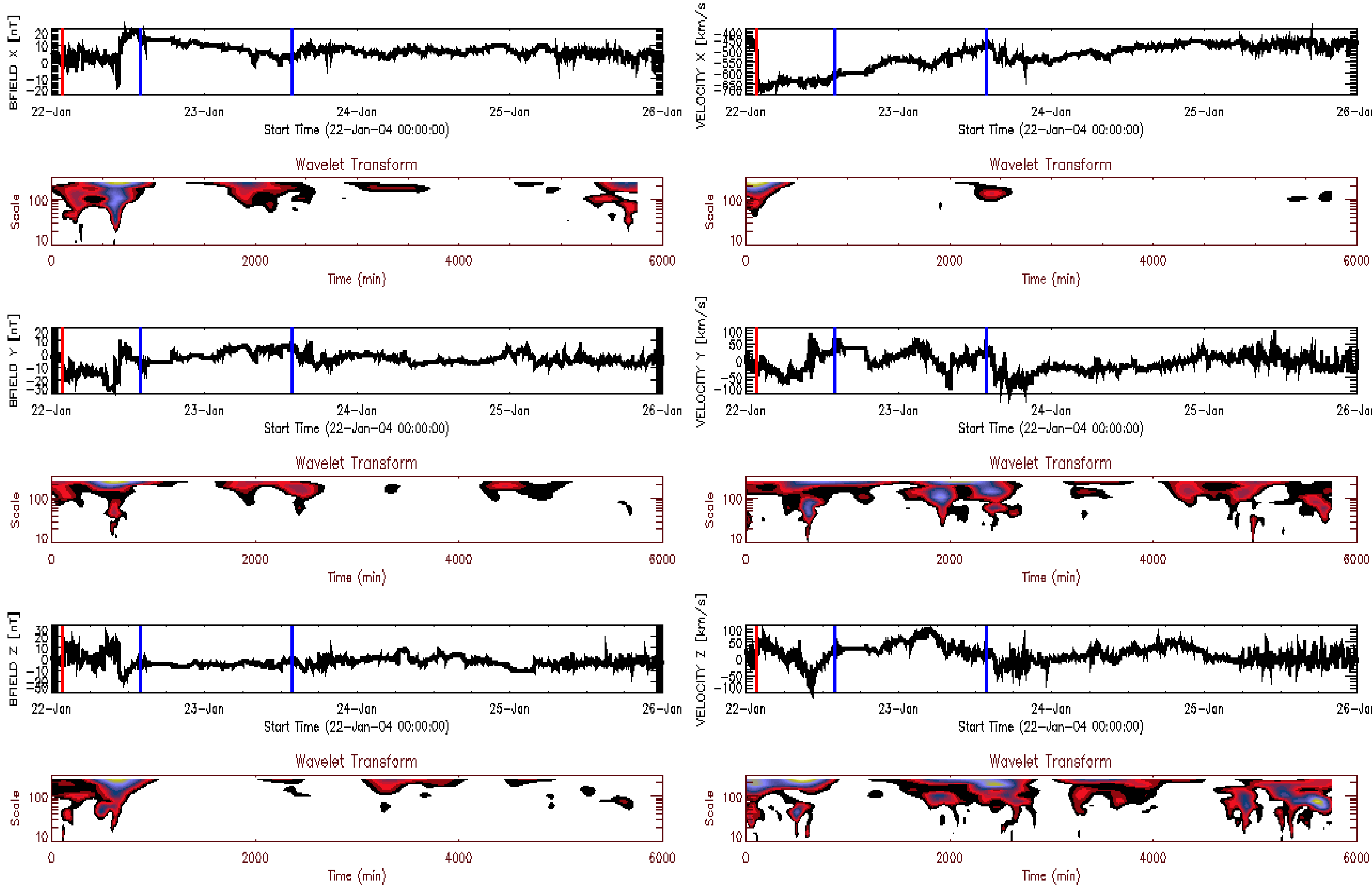
Velocity



Density



Ejecta + # 47



Ejecta + # 47

V and B components

Thanks!