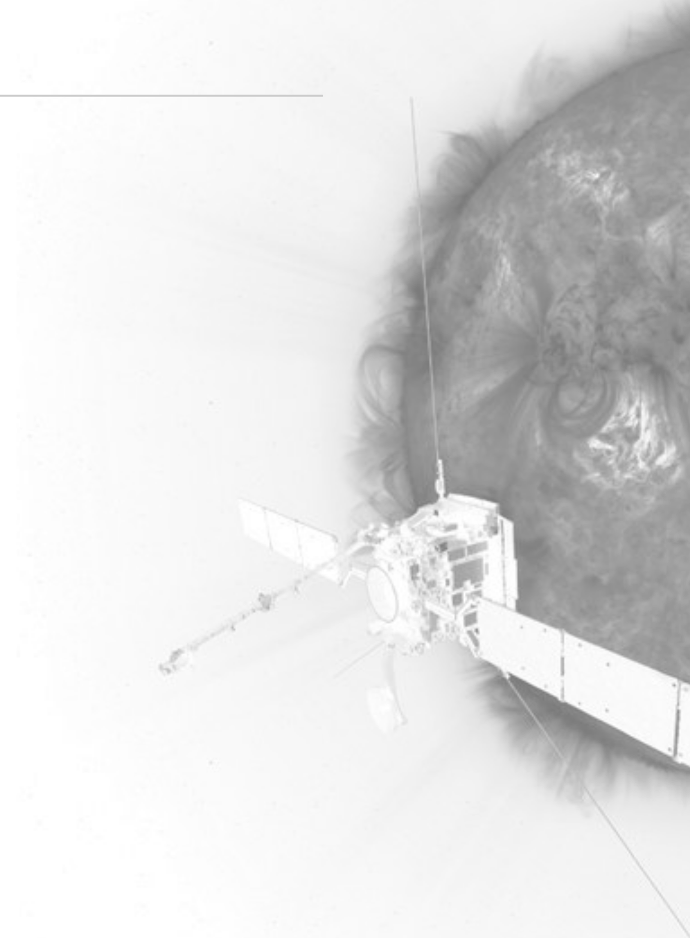
Reconnection identification

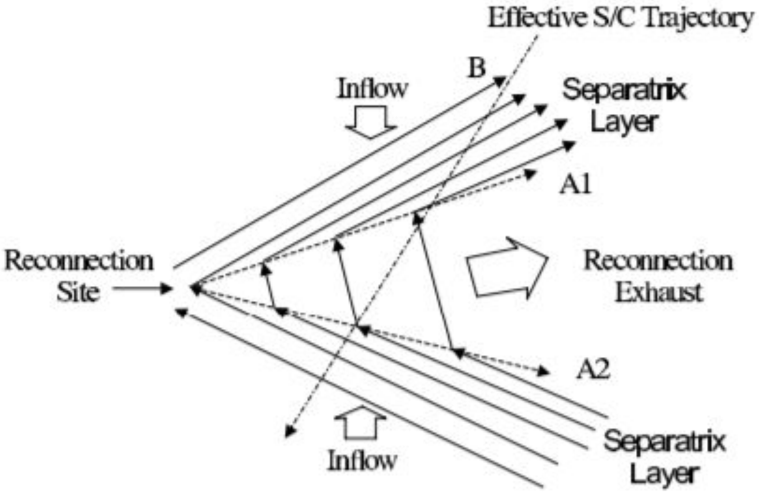
December 2021 | Naïs Fargette, Benoit Lavraud, Alexis Rouillard

Table of contents



Magnetic reconnection signature

- ❑ **B shear**
- ❑ **V jet**

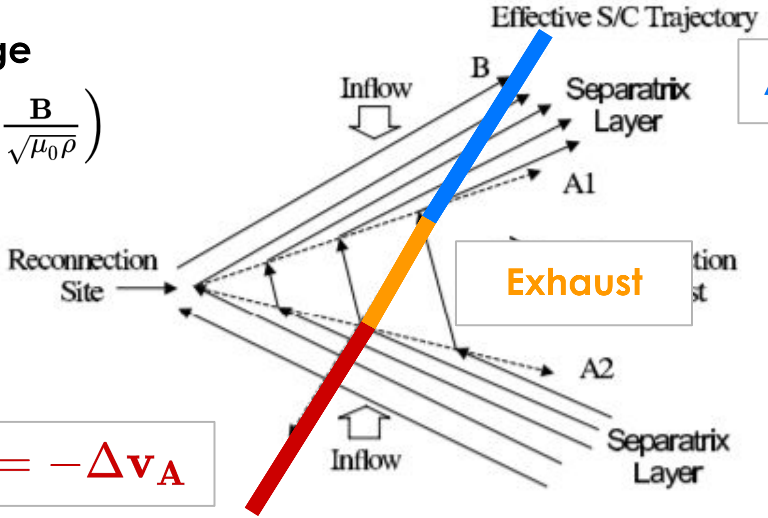


Gosling et Al. 2005

The Walen relation

- B shear
- V jet
- Correlation change

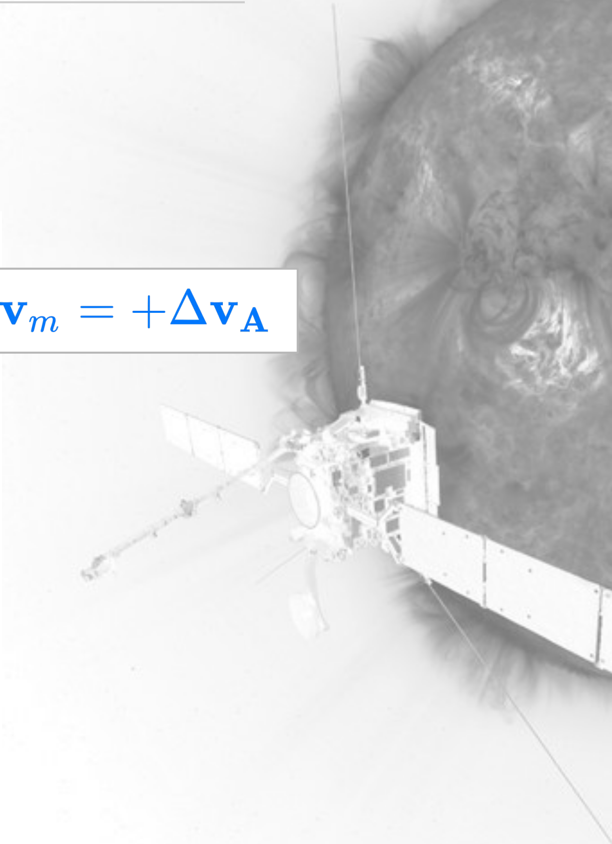
$$\Delta \mathbf{v}_m = \pm \Delta \mathbf{v}_\mathbf{A} = \pm \Delta \left(\frac{\mathbf{B}}{\sqrt{\mu_0 \rho}} \right)$$



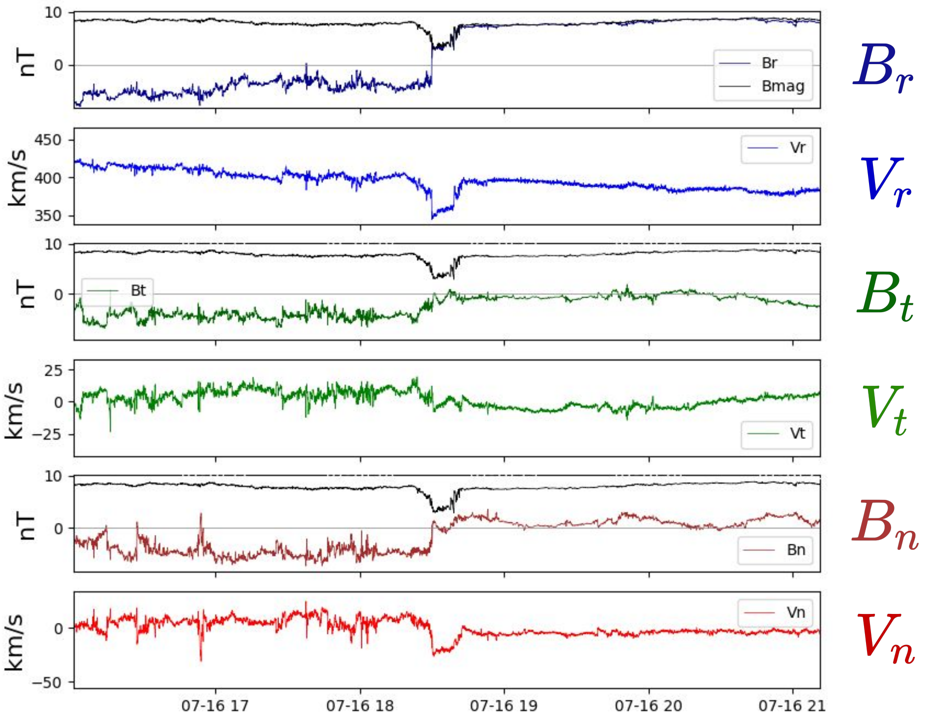
$$\Delta \mathbf{v}_m = +\Delta \mathbf{v}_\mathbf{A}$$

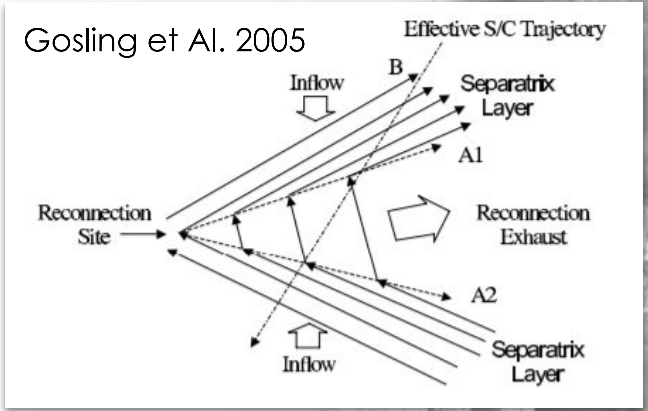
$$\Delta \mathbf{v}_m = -\Delta \mathbf{v}_\mathbf{A}$$

Gosling et Al. 2005



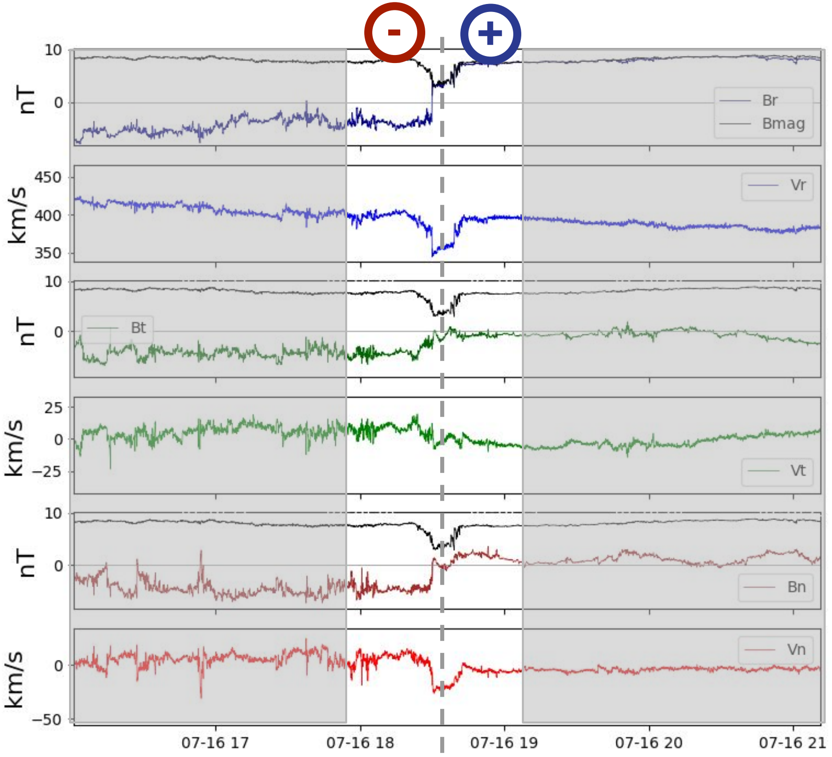
Reconnection jet





- ❑ **B shear**
- ❑ **V jet**

Reconnection jet



B_r

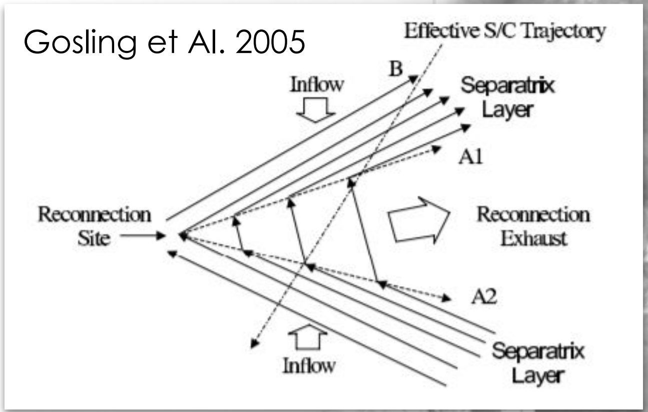
V_r

B_t

V_t

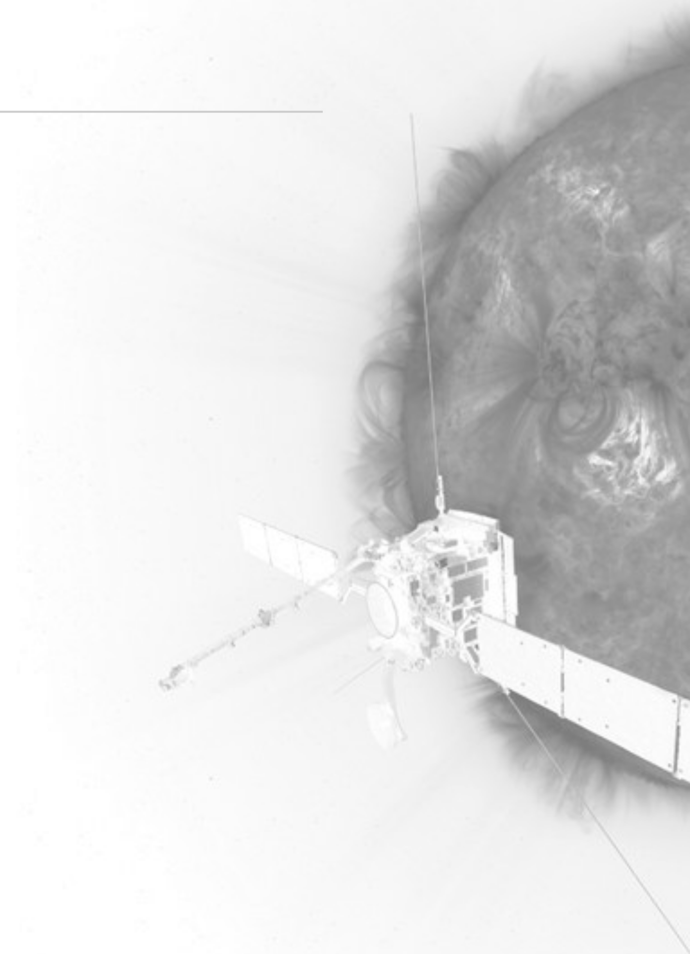
B_n

V_n



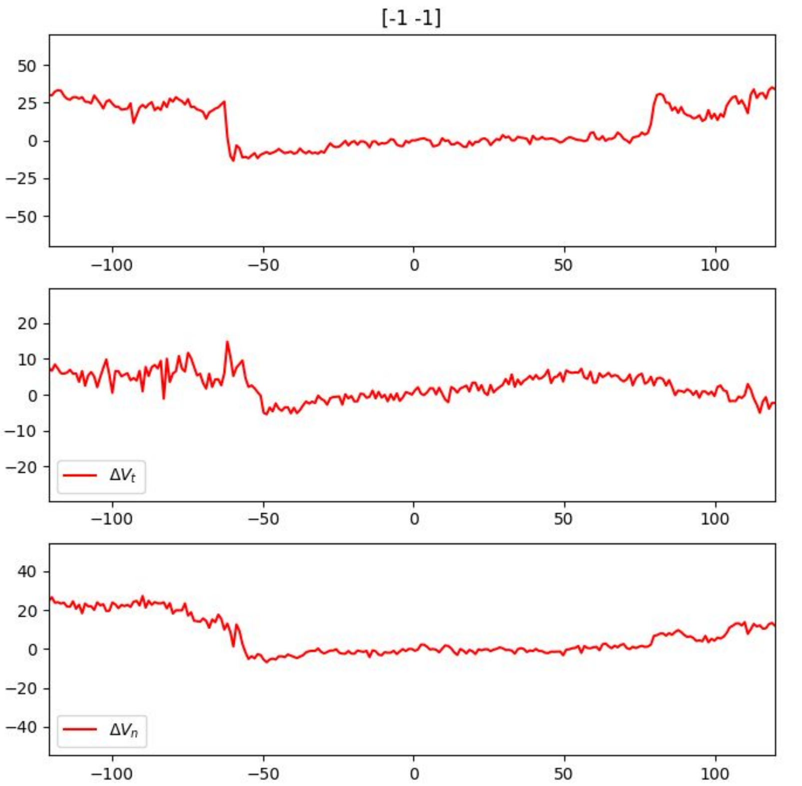
- ❑ **B shear**
- ❑ **V jet**
- ❑ **Correlation change**

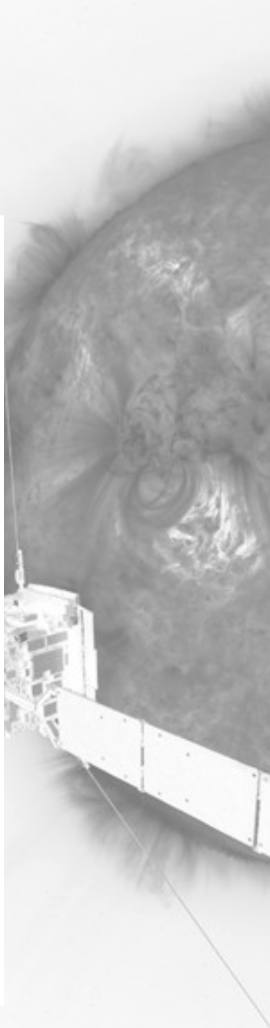
Table of contents



The Walen relation

Data : $\Delta \mathbf{v} = \mathbf{v}(t) - \mathbf{v}(t0)$





The Walen relation

Data : $\Delta\mathbf{v} = \mathbf{v}(t) - \mathbf{v}(t0)$

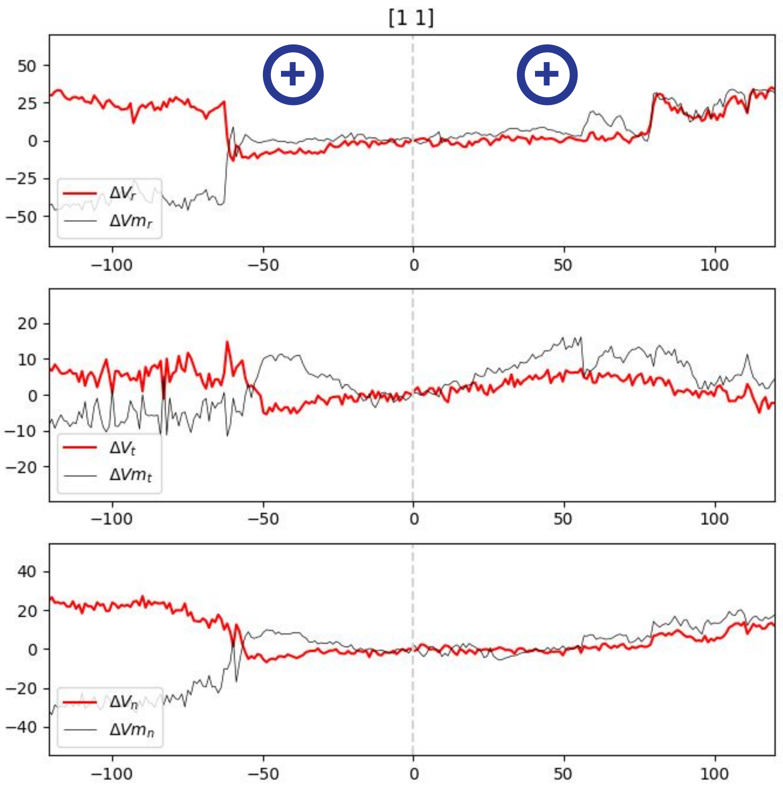
Model : $\Delta\mathbf{v}_m = \pm\Delta\mathbf{v}_\mathbf{A}$

1 - Correlated + / +

2 - Anticorrelated - / -

3 - Jet + / -

4 - Jet - / +



The Walen relation

Data : $\Delta \mathbf{v} = \mathbf{v}(t) - \mathbf{v}(t0)$

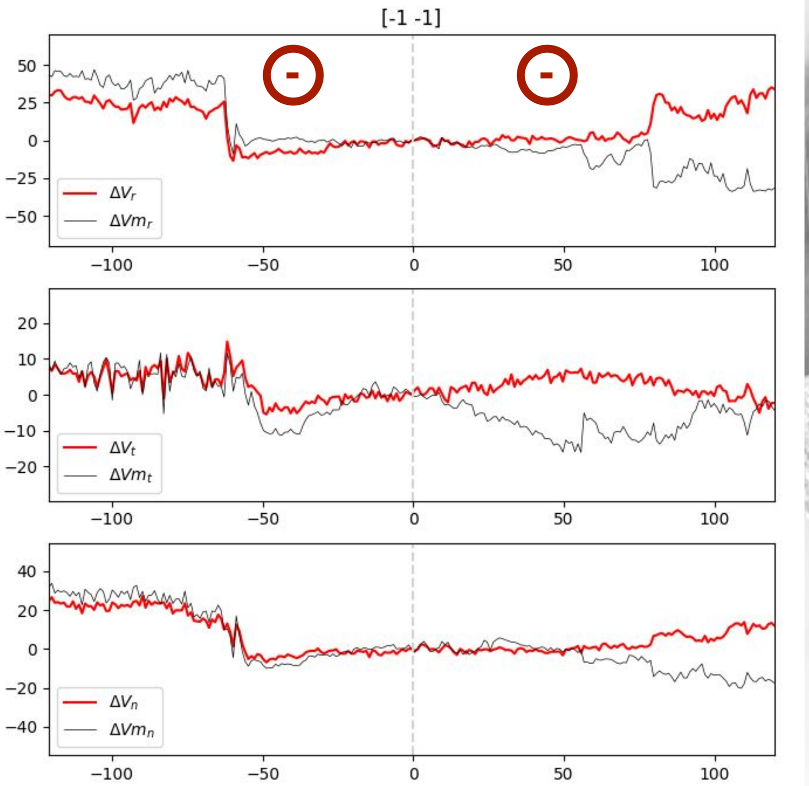
Model : $\Delta \mathbf{v}_m = \pm \Delta \mathbf{v_A}$

1 - Correlated + / +

2 - Anticorrelated - / -

3 - Jet + / -

4 - Jet - / +



The Walen relation

Data : $\Delta\mathbf{v} = \mathbf{v}(t) - \mathbf{v}(t0)$

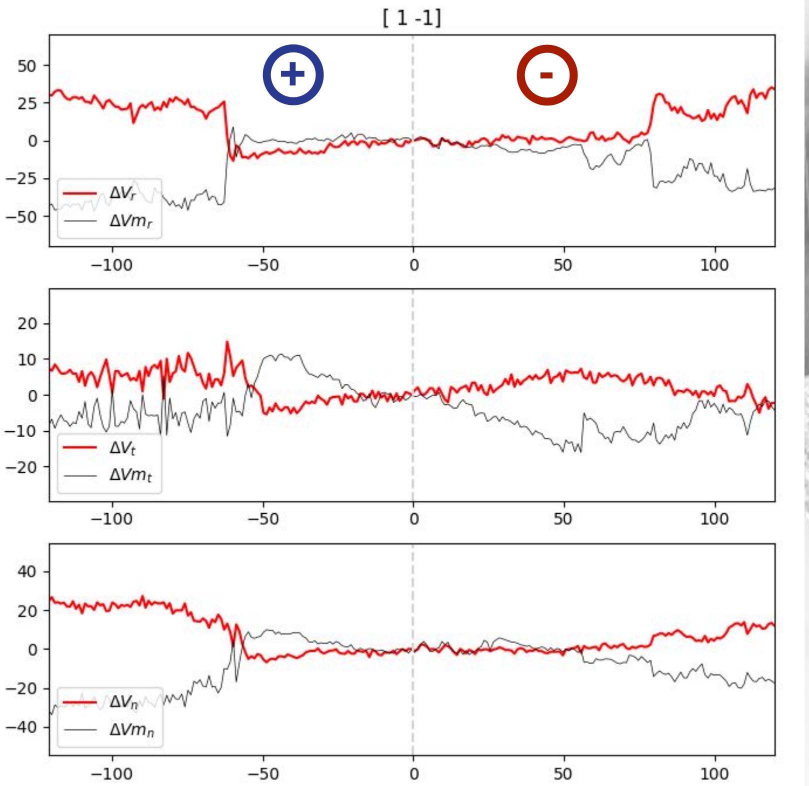
Model : $\Delta\mathbf{v}_m = \pm\Delta\mathbf{v_A}$

1 - Correlated + / +

2 - Anticorrelated - / -

3 - Jet + / -

4 - Jet - / +



The Walen relation

Data : $\Delta \mathbf{v} = \mathbf{v}(t) - \mathbf{v}(t0)$

Model : $\Delta \mathbf{v}_m = \pm \Delta \mathbf{v}_\mathbf{A}$

1 - Correlated + / +

2 - Anticorrelated - / -

3 - Jet + / -

4 - Jet - / +

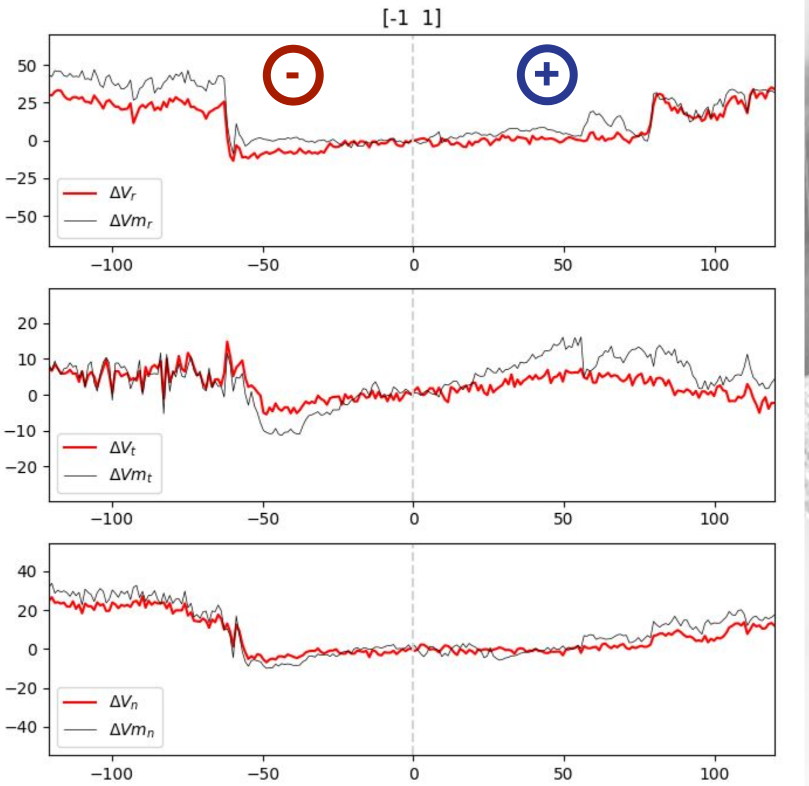
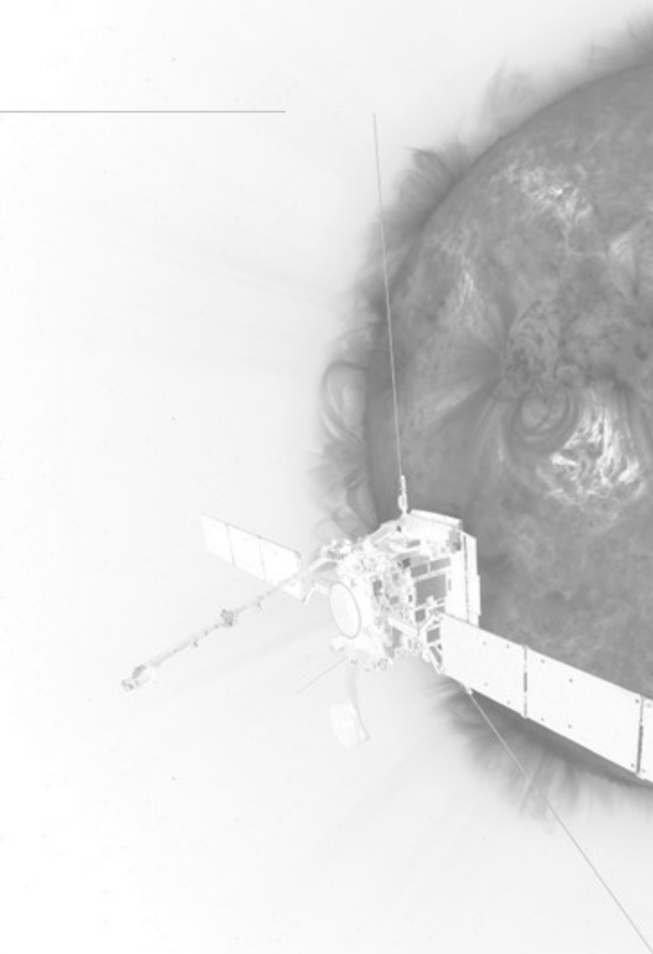


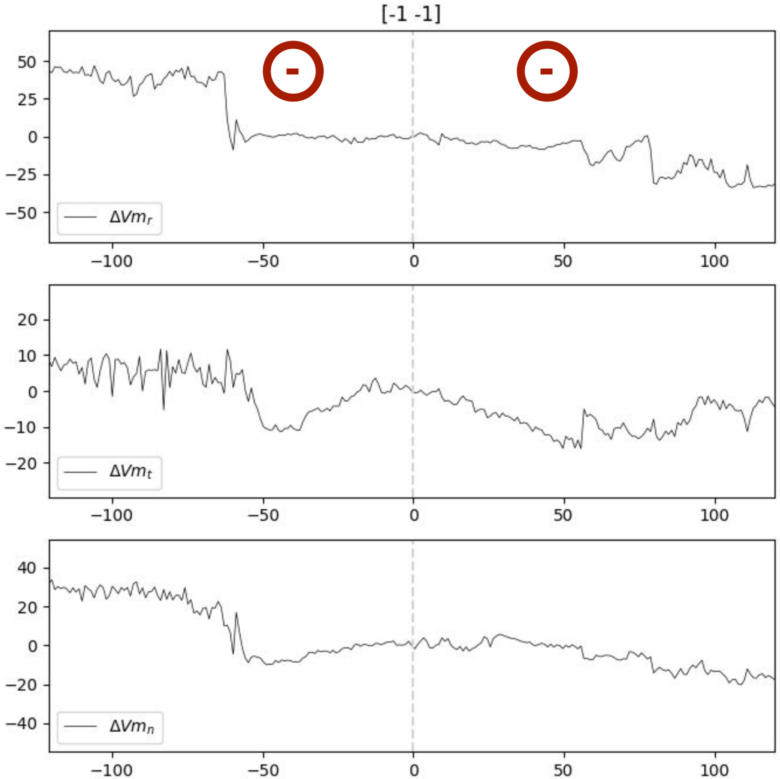
Table of contents



Anticorrelated model

Model : $\Delta \mathbf{v}_m = -\Delta \mathbf{v}_\mathbf{A}$ ——

- Let's assume a **normal distribution** of the data around the model with **dispersion = 10 km/s**

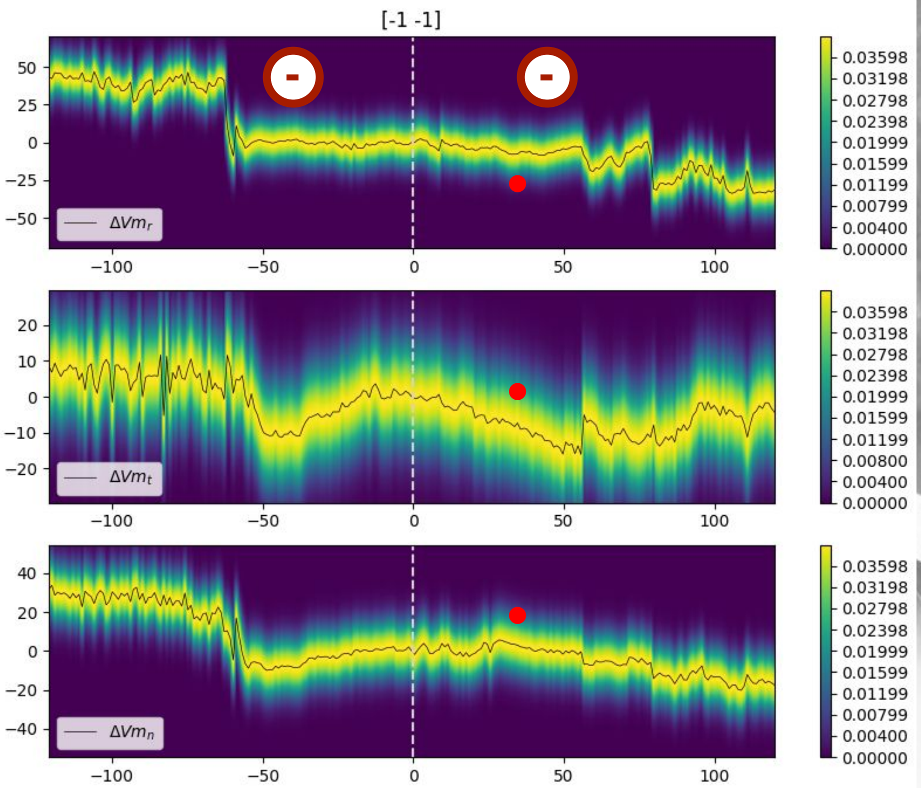


Anticorrelated model

Model : $\Delta \mathbf{v}_m = -\Delta \mathbf{v}_\mathbf{A}$

- ❑ Let's assume a **normal distribution** of the data around the model with **dispersion = 10 km/s**
- ❑ For each data point **the likelihood writes**

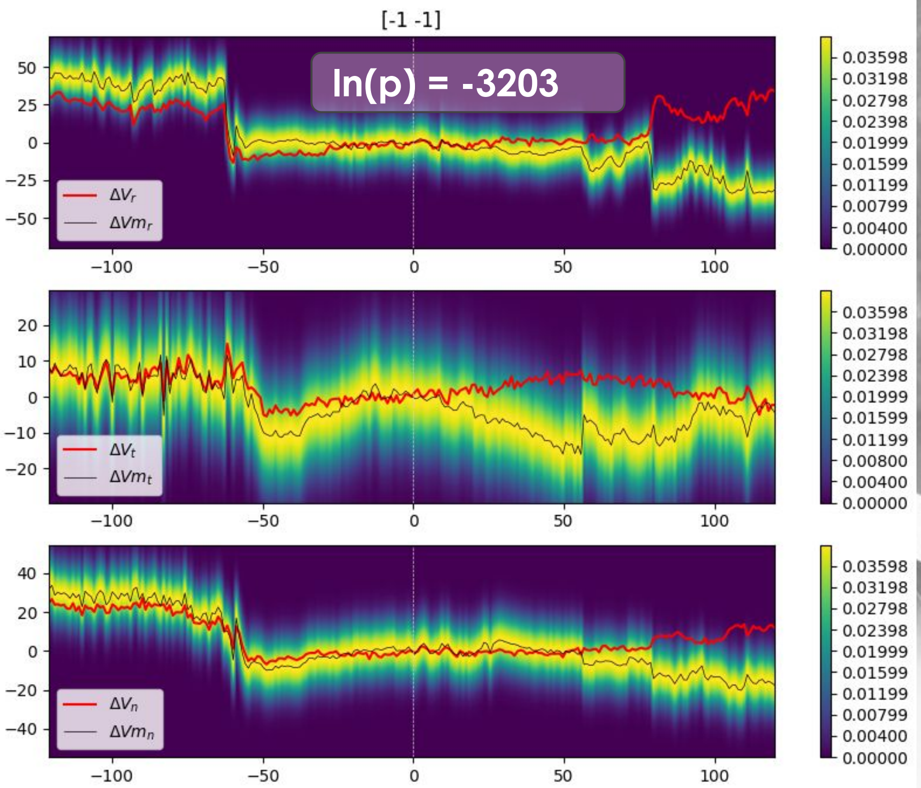
$$p(\Delta \mathbf{V}_i|\mathcal{M}_j) = \frac{1}{(2\pi\sigma^2)^{3/2}} \exp \frac{-||\Delta \mathbf{V}_i - \Delta \mathbf{V}_{\mathcal{M}_j,i}||^2}{2\sigma^2}$$



Anticorrelated model

Model : $\Delta \mathbf{v}_m = -\Delta \mathbf{v}_{\mathbf{A}}$

- Let's assume a **normal distribution** of the data around the model with **dispersion = 10 km/s**



- For each data point **the likelihood writes**

$$p(\Delta \mathbf{V}_i|\mathcal{M}_j) = \frac{1}{(2\pi\sigma^2)^{3/2}} \exp\frac{-||\Delta \mathbf{V}_i - \Delta \mathbf{V}_{\mathcal{M}_j,i}||^2}{2\sigma^2}$$

- For the complete vector :

$$\ln p(\Delta \mathbf{V}|\mathcal{M}_j) = \sum_{i=1}^{n} \ln p(\Delta \mathbf{V}_i|\mathcal{M}_j)$$

Jet -/+ model

Model : $\Delta \mathbf{v}_m = -\Delta \mathbf{v_A}$ ——

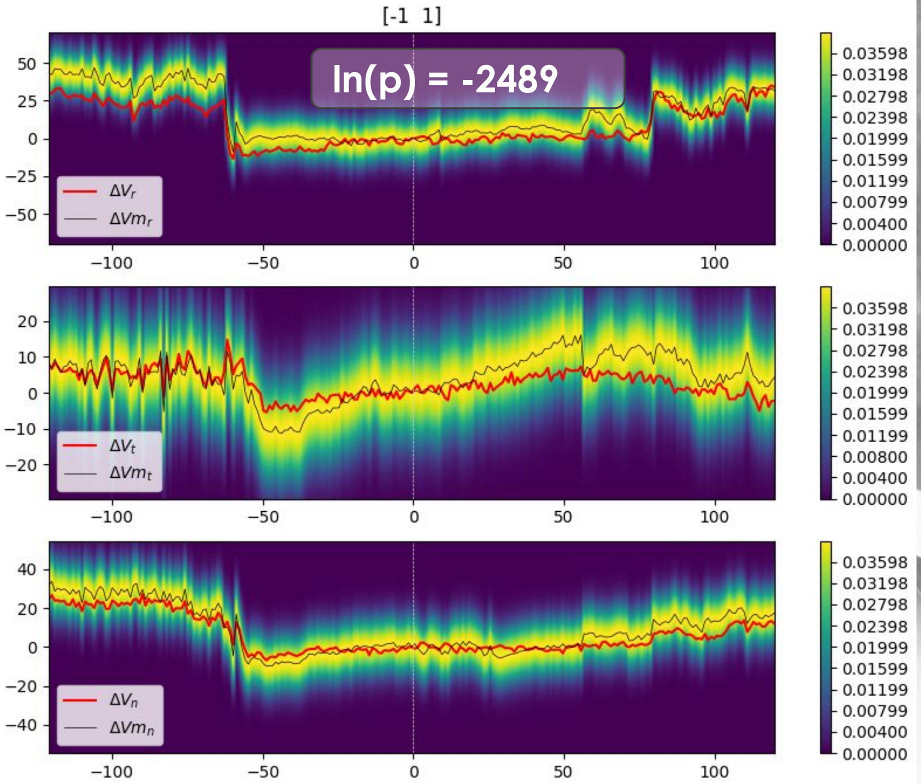
- Let's assume a **normal distribution** of the data around the model with **dispersion = 10 km/s**

- For each data point **the likelihood writes**

$$p(\Delta \mathbf{V}_i|\mathcal{M}_j) = \frac{1}{(2\pi\sigma^2)^{3/2}} \exp \frac{-||\Delta \mathbf{V}_i - \Delta \mathbf{V}_{\mathcal{M}_j,i}||^2}{2\sigma^2}$$

- For the complete vector :

$$\ln p(\Delta \mathbf{V}|\mathcal{M}_j) = \sum_{i-1}^{n} \ln p(\Delta \mathbf{V}_i|\mathcal{M}_j)$$



Comparing likelihood overtime

$$\ln\left(\frac{p(\Delta\mathbf{V}|M_{-/+})}{p(\Delta\mathbf{V}|M_{-/-})}\right) > n$$

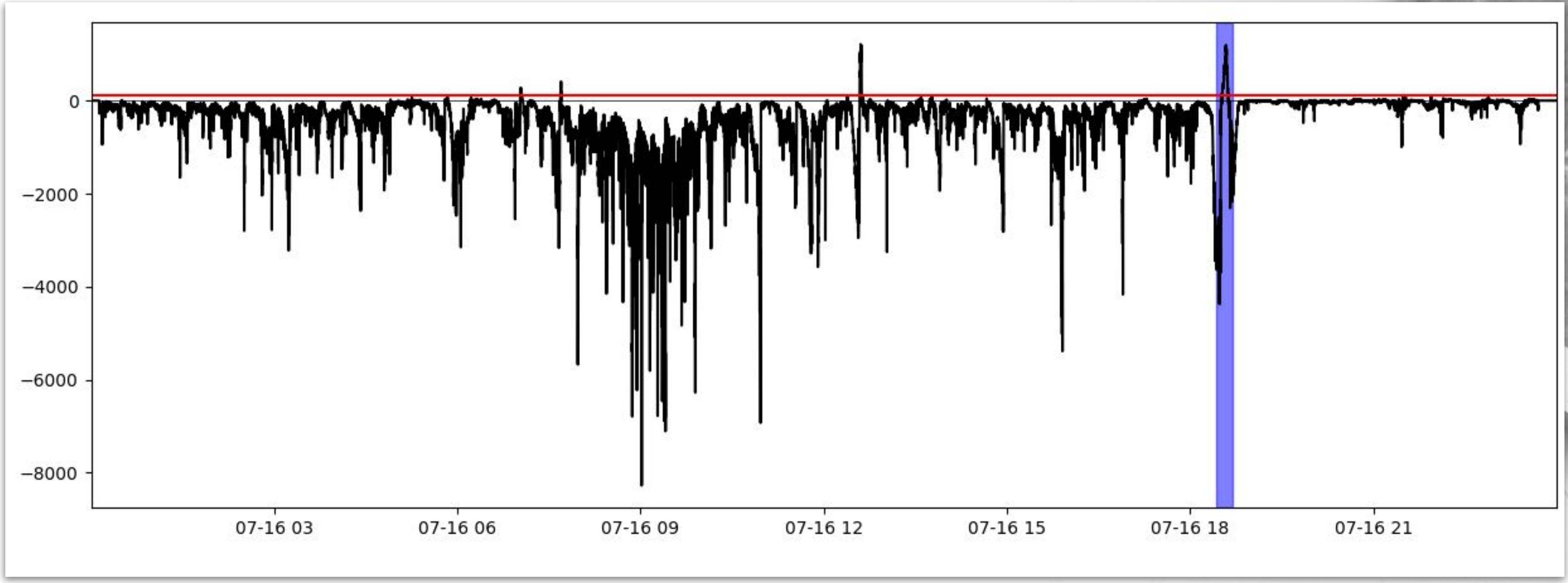
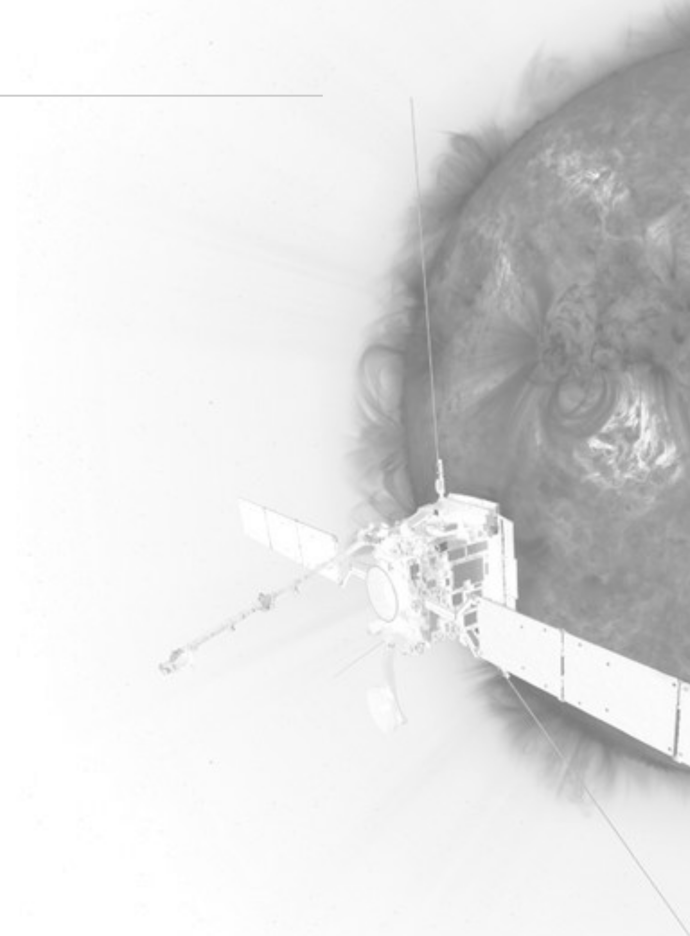


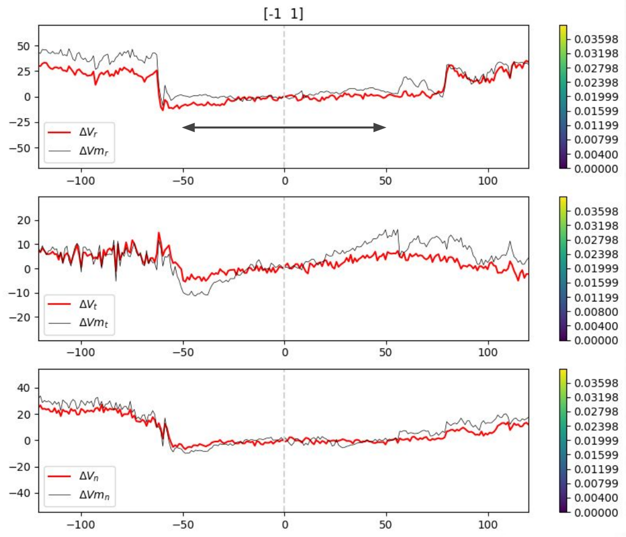
Table of contents

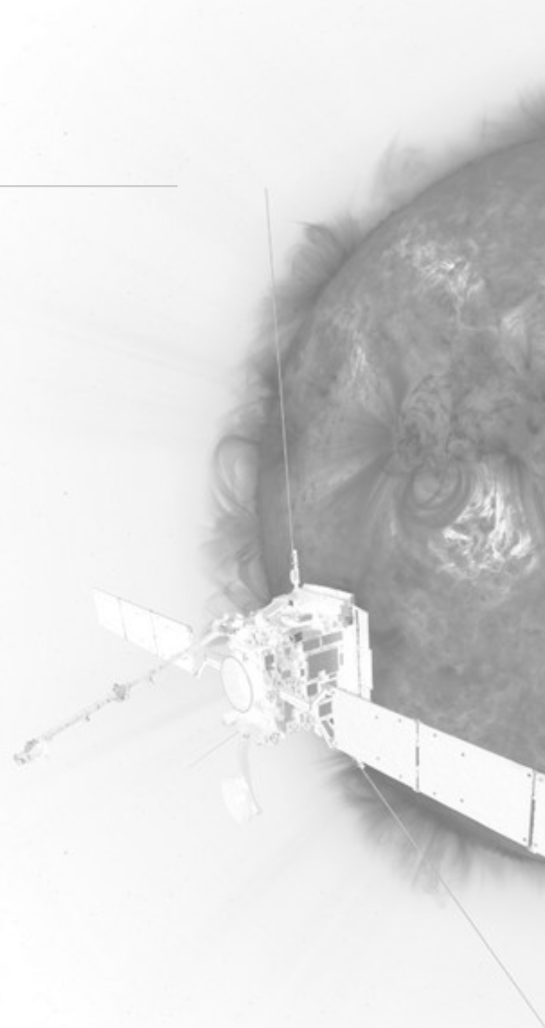


2 detection criteria

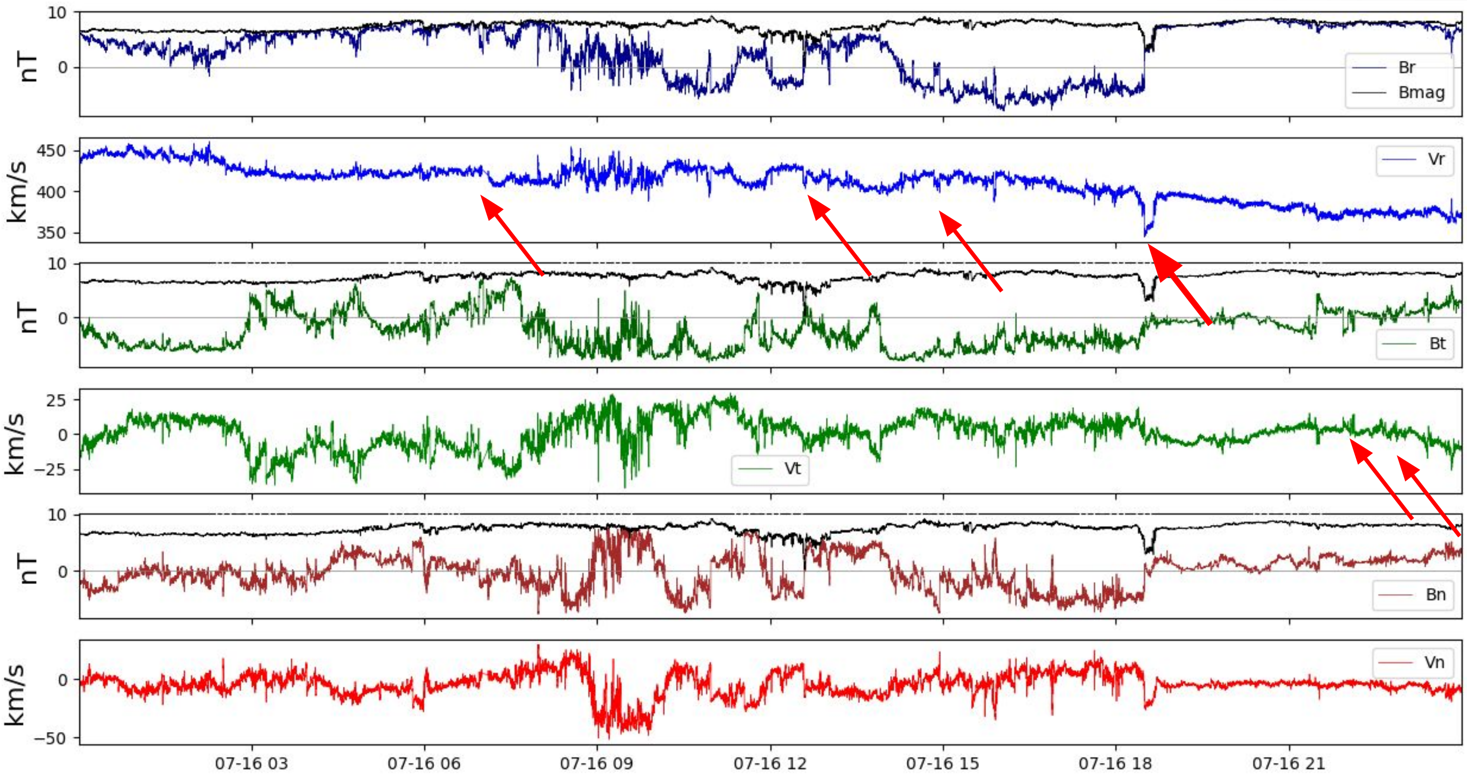
- ❑ $$\ln\left(\frac{p(\Delta\mathbf{V}|M_{-/+})}{\max(p(\Delta\mathbf{V}|M_{+/+}),p(\Delta\mathbf{V}|M_{-/-}))}\right) > n$$

- ❑ Detection persistent
  for at least 10% of n points





Case study : Lavraud + 2021



B_r

V_r

B_t

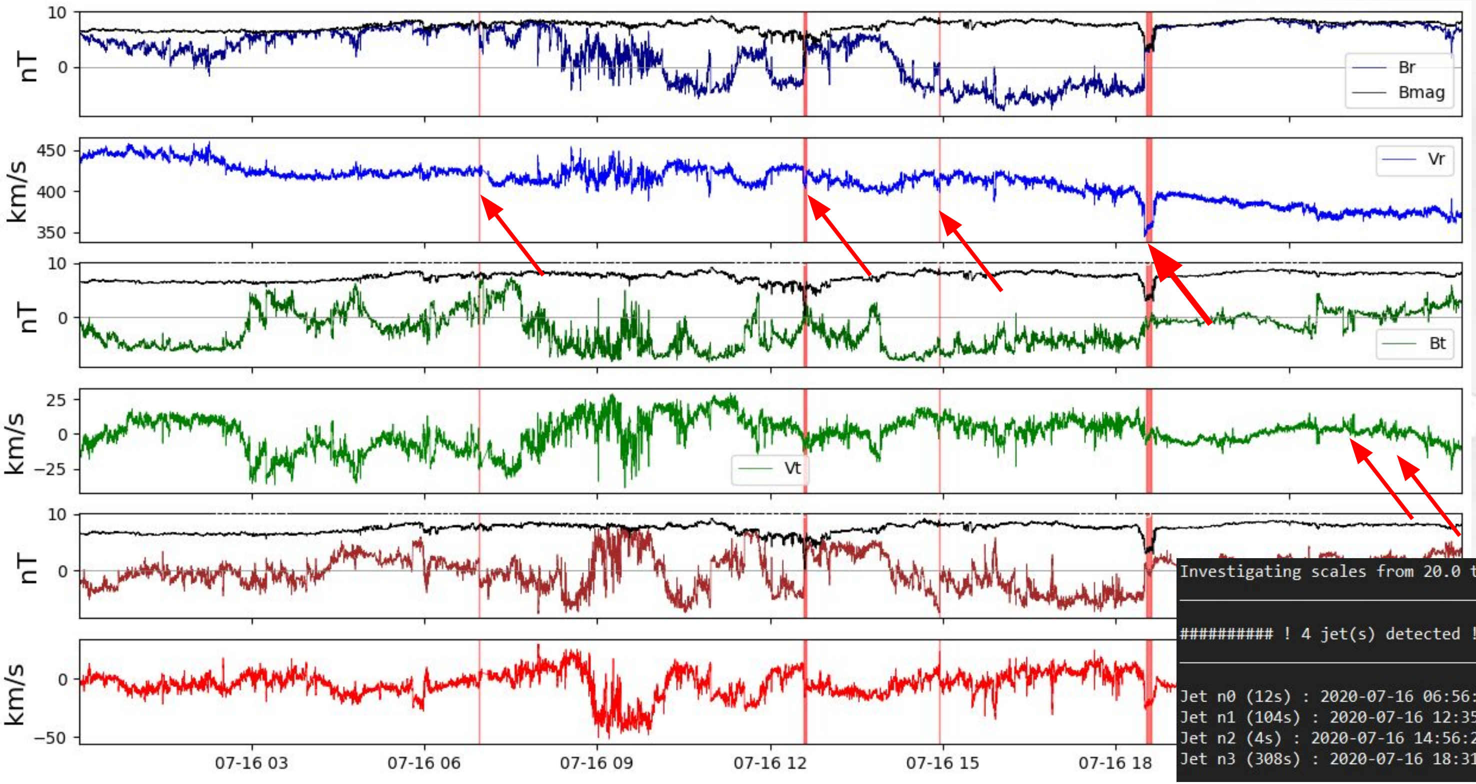
V_t

B_n

V_n

16th of July 2020

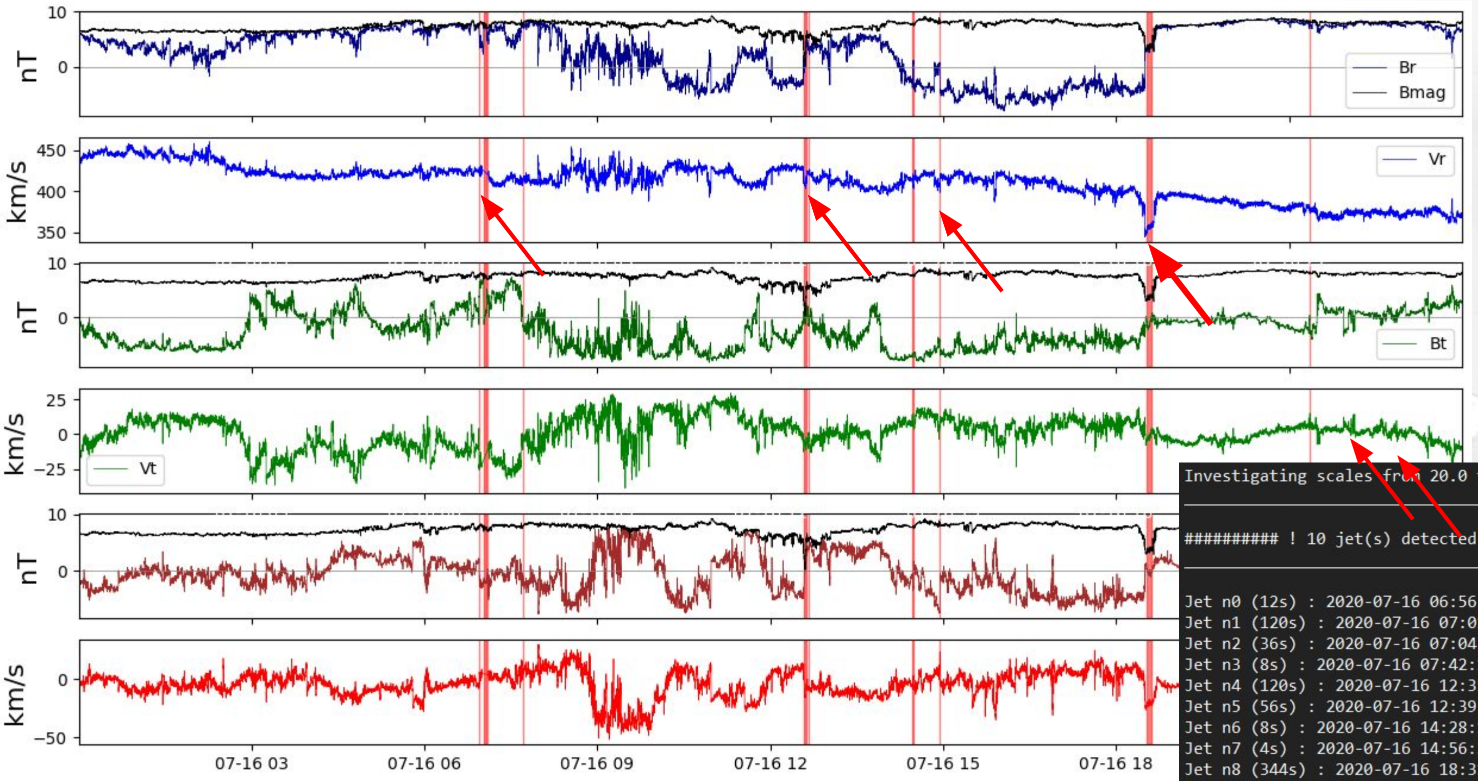
$$\ln\left(\frac{p(\mathbf{\Delta V}|M_{-/+})}{\max(p(\mathbf{\Delta V}|M_{+/+}),p(\mathbf{\Delta V}|M_{-/-}))}\right) > n$$




```
Investigating scales from 20.0 to 961.192 seconds
__________________________________________________________

########## ! 4 jet(s) detected ! ##########
__________________________________________________________

Jet n0 (12s) : 2020-07-16 06:56:51.803 - 2020-07-16 06:57:03.803
Jet n1 (104s) : 2020-07-16 12:35:23.897 - 2020-07-16 12:37:07.898
Jet n2 (4s) : 2020-07-16 14:56:27.936 - 2020-07-16 14:56:31.936
Jet n3 (308s) : 2020-07-16 18:31:43.996 - 2020-07-16 18:36:51.998
```

16th of July 2020

$$\ln\left(\frac{p(\mathbf{\Delta V}|M_{-/+})}{\max(p(\mathbf{\Delta V}|M_{+/+}),p(\mathbf{\Delta V}|M_{-/-}))}\right) > n/2$$

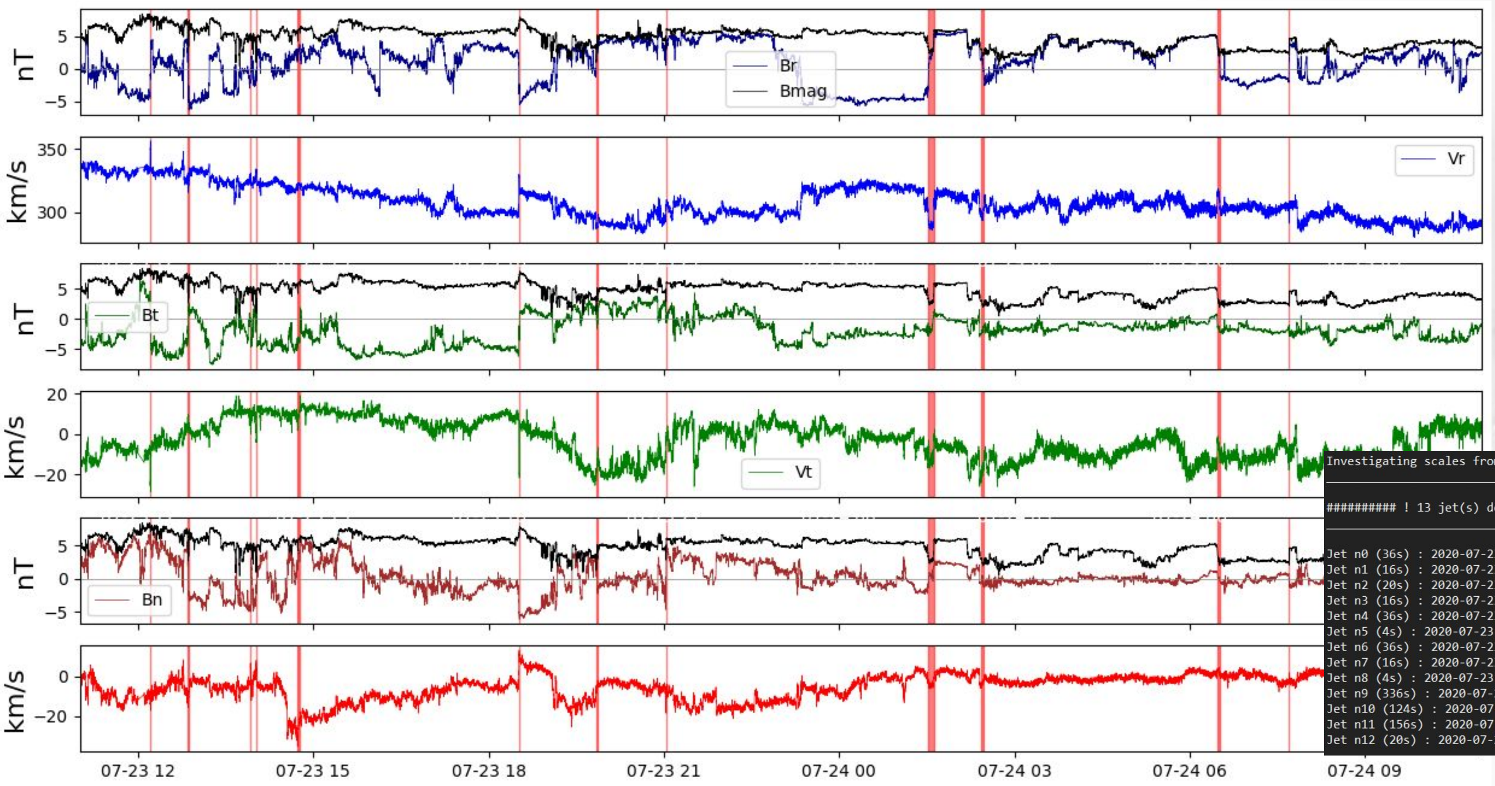



```
Investigating scales from 20.0 to 961.192 seconds
________________________________________________

########## ! 10 jet(s) detected ! ##########
________________________________________________

Jet n0 (12s) : 2020-07-16 06:56:51.803 - 2020-07-16 06:57:03.803
Jet n1 (120s) : 2020-07-16 07:01:47.804 - 2020-07-16 07:03:47.805
Jet n2 (36s) : 2020-07-16 07:04:55.805 - 2020-07-16 07:05:31.805
Jet n3 (8s) : 2020-07-16 07:42:15.816 - 2020-07-16 07:42:23.816
Jet n4 (120s) : 2020-07-16 12:35:19.897 - 2020-07-16 12:37:19.898
Jet n5 (56s) : 2020-07-16 12:39:27.898 - 2020-07-16 12:40:23.898
Jet n6 (8s) : 2020-07-16 14:28:11.928 - 2020-07-16 14:28:19.928
Jet n7 (4s) : 2020-07-16 14:56:27.936 - 2020-07-16 14:56:31.936
Jet n8 (344s) : 2020-07-16 18:31:31.996 - 2020-07-16 18:37:15.998
Jet n9 (4s) : 2020-07-16 21:21:28.043 - 2020-07-16 21:21:32.043
```

23/24th of July 2020

Kieokaew + 2021

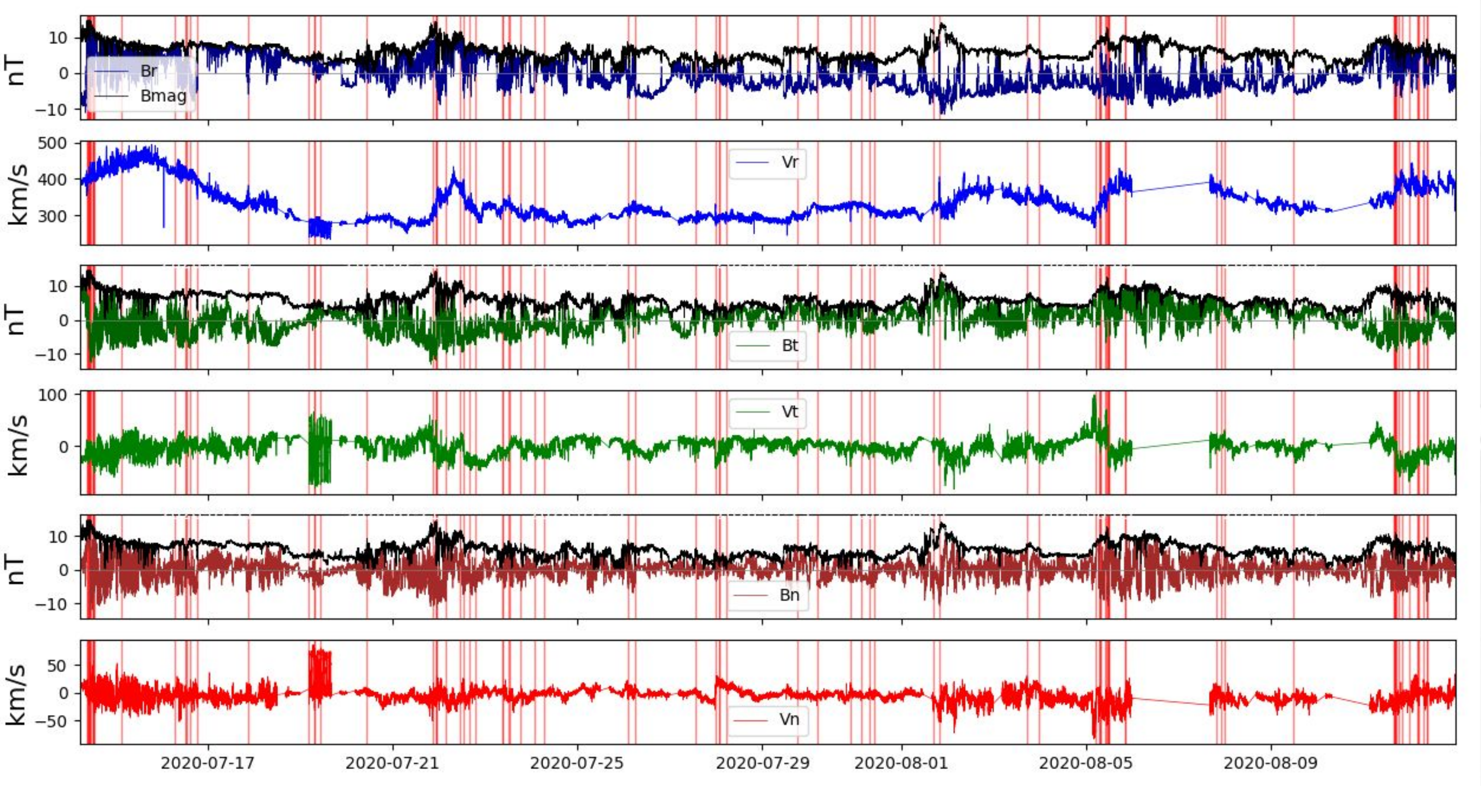
$$\ln\left(\frac{p(\Delta\mathbf{V}|M_{-/+})}{\max(p(\Delta\mathbf{V}|M_{+/+}),p(\Delta\mathbf{V}|M_{-/-})}\right) > n/2$$

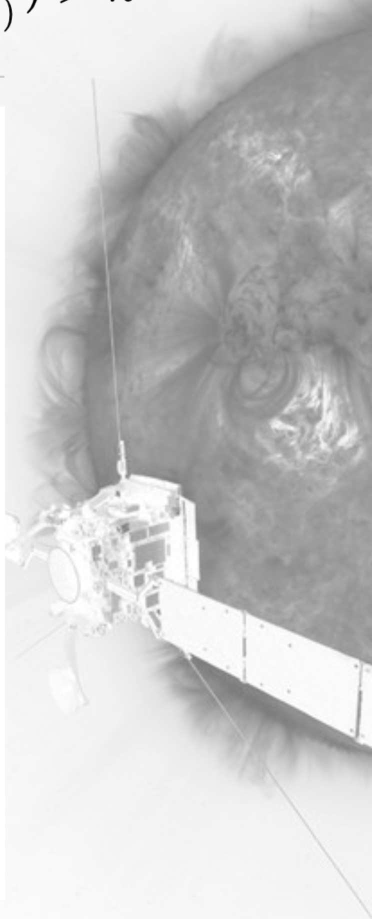



```
Investigating scales from 20.0 to 961.192 seconds

########## ! 13 jet(s) detected ! ##########

Jet n0 (36s) : 2020-07-23 12:12:28.902 - 2020-07-23 12:13:04.903
Jet n1 (16s) : 2020-07-23 12:51:29.014 - 2020-07-23 12:51:45.015
Jet n2 (20s) : 2020-07-23 13:55:29.198 - 2020-07-23 13:55:49.199
Jet n3 (16s) : 2020-07-23 14:01:13.214 - 2020-07-23 14:01:29.215
Jet n4 (36s) : 2020-07-23 14:43:49.337 - 2020-07-23 14:44:25.339
Jet n5 (4s) : 2020-07-23 14:46:21.344 - 2020-07-23 14:46:25.344
Jet n6 (36s) : 2020-07-23 18:31:09.991 - 2020-07-23 18:31:45.993
Jet n7 (16s) : 2020-07-23 19:51:18.222 - 2020-07-23 19:51:34.222
Jet n8 (4s) : 2020-07-23 21:02:22.426 - 2020-07-23 21:02:26.426
Jet n9 (336s) : 2020-07-24 01:31:39.201 - 2020-07-24 01:37:15.217
Jet n10 (124s) : 2020-07-24 02:26:03.357 - 2020-07-24 02:28:07.363
Jet n11 (156s) : 2020-07-24 06:28:24.055 - 2020-07-24 06:31:00.062
Jet n12 (20s) : 2020-07-24 07:42:00.266 - 2020-07-24 07:42:20.267
```

July / August 2020 - ~100 jets

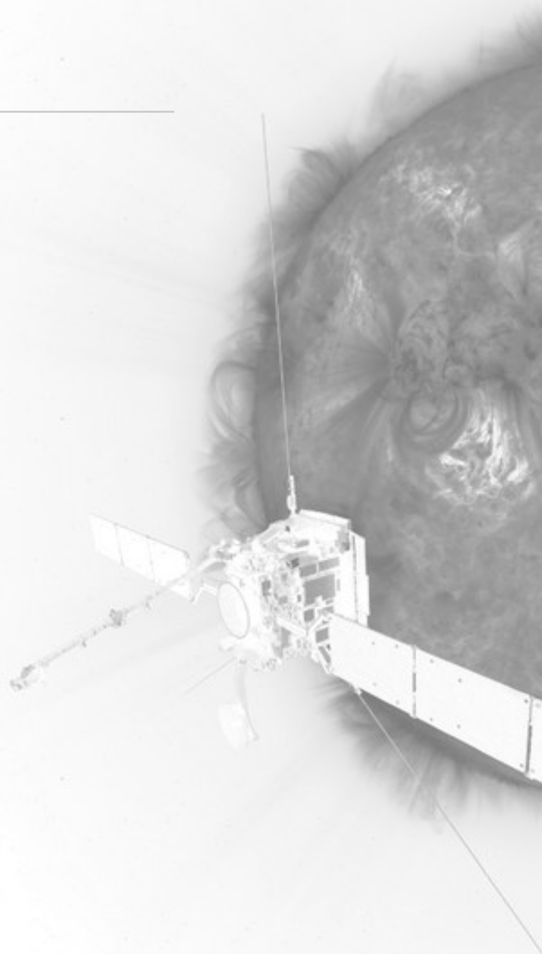
$$\ln\left(\frac{p(\mathbf{\Delta V}|M_{-/+})}{\max(p(\mathbf{\Delta V}|M_{+/+}),p(\mathbf{\Delta V}|M_{-/-})}\right) > n$$

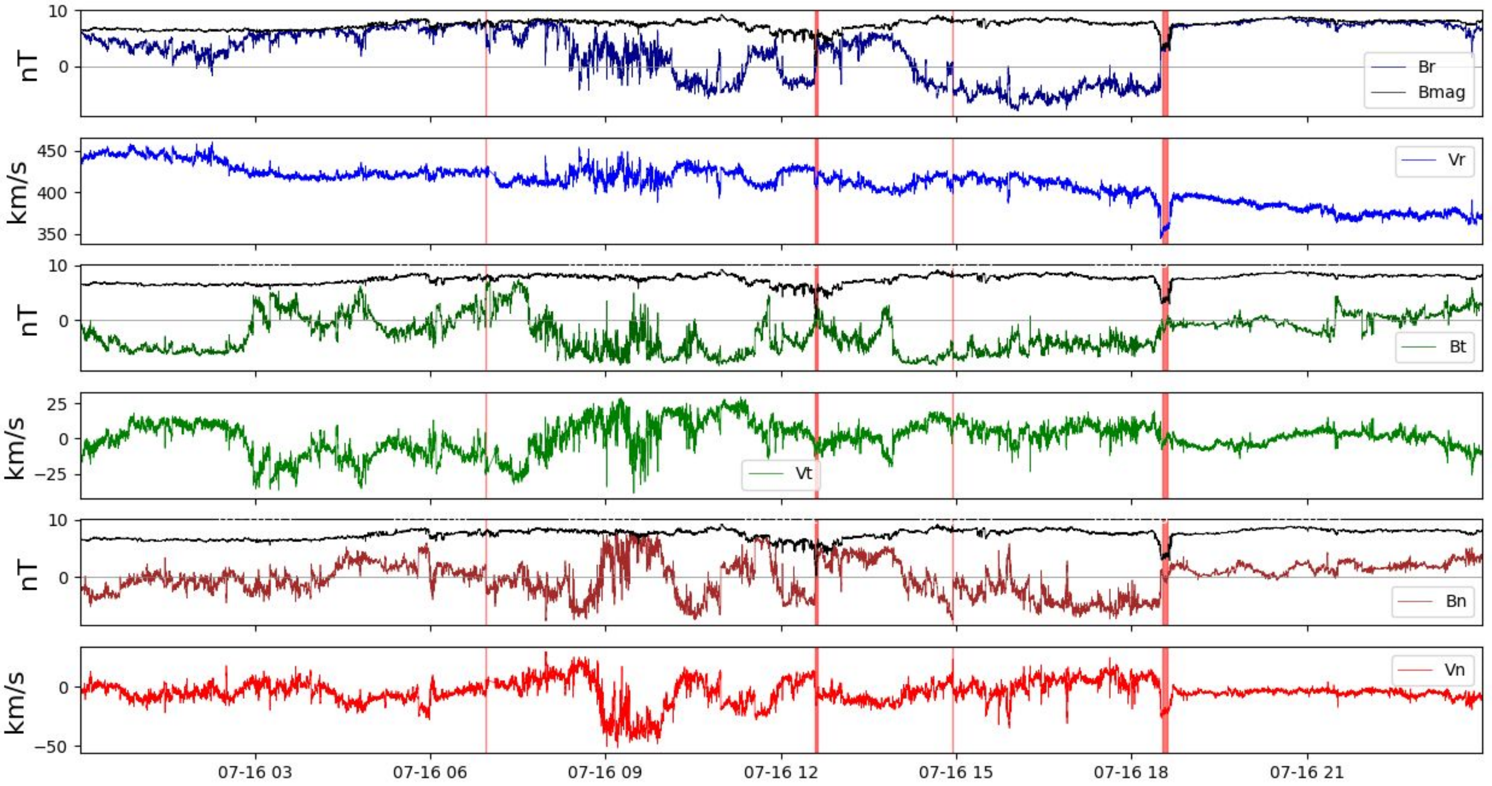




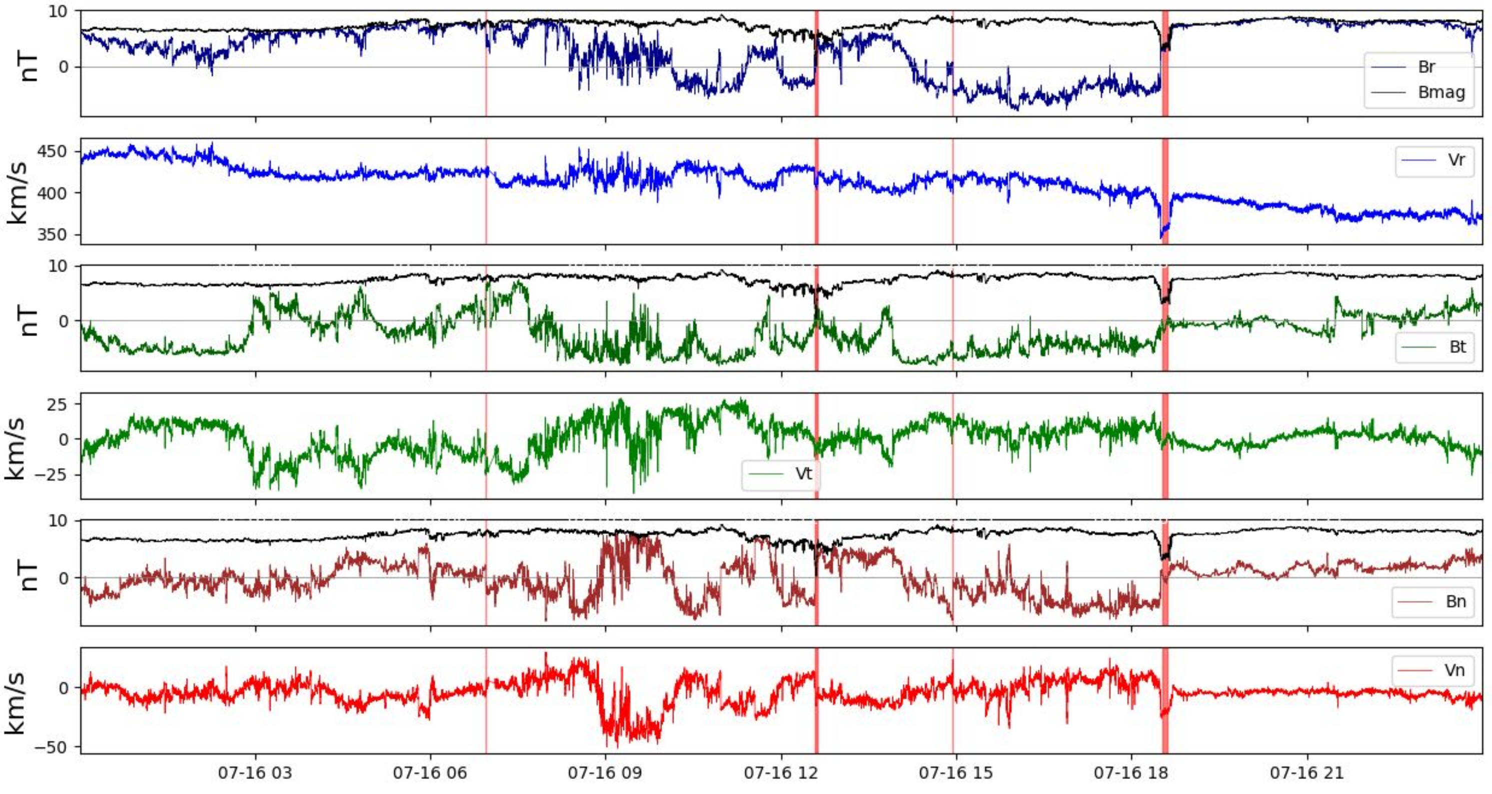
Conclusions & next steps

- ❑ Detection algorithm based on the Walen relation
- ❑ Could include some priors on the different models
- ❑ Check for coincidental burst mode data
- ❑ Check the potential detections and do some science :)

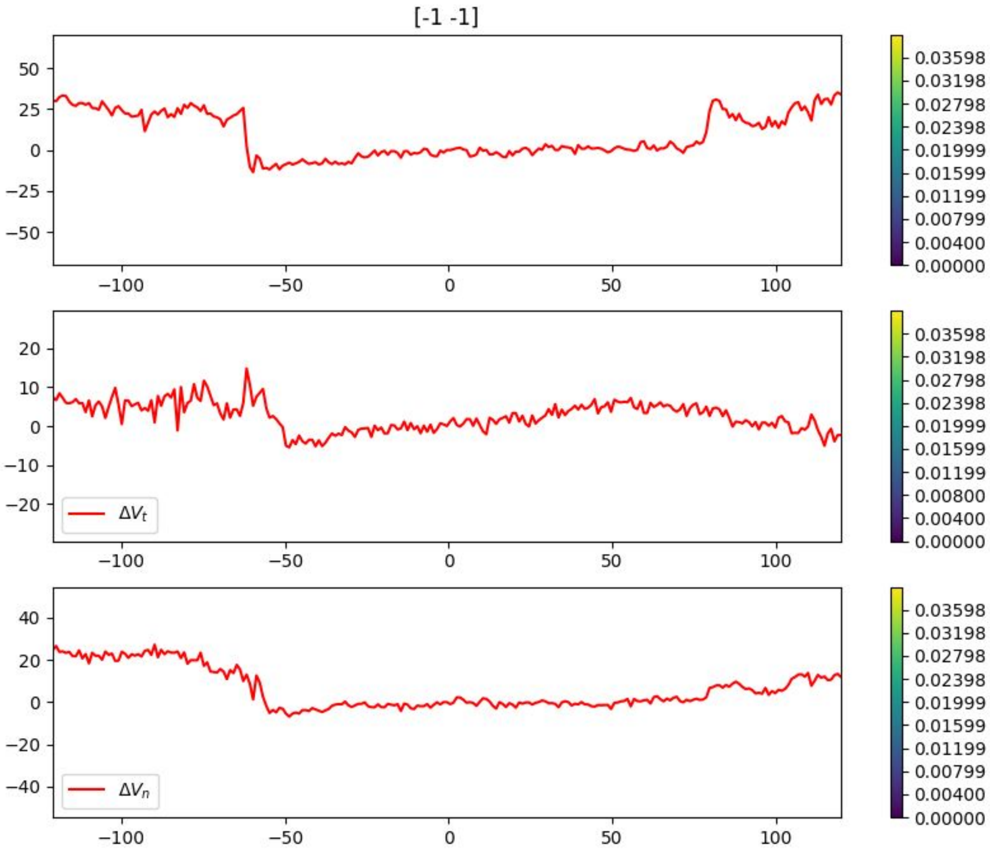


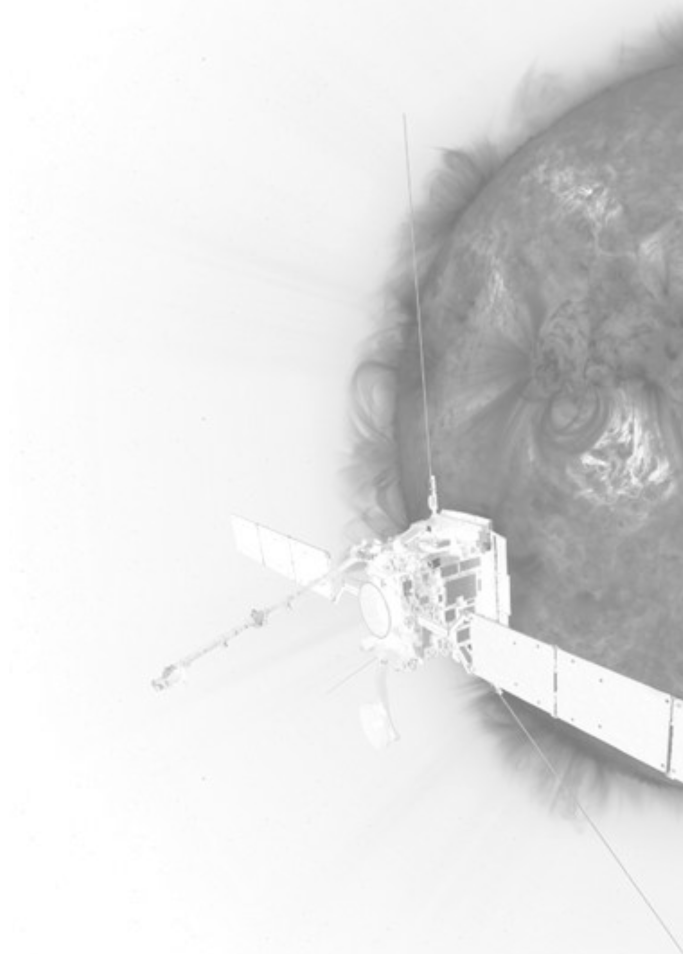


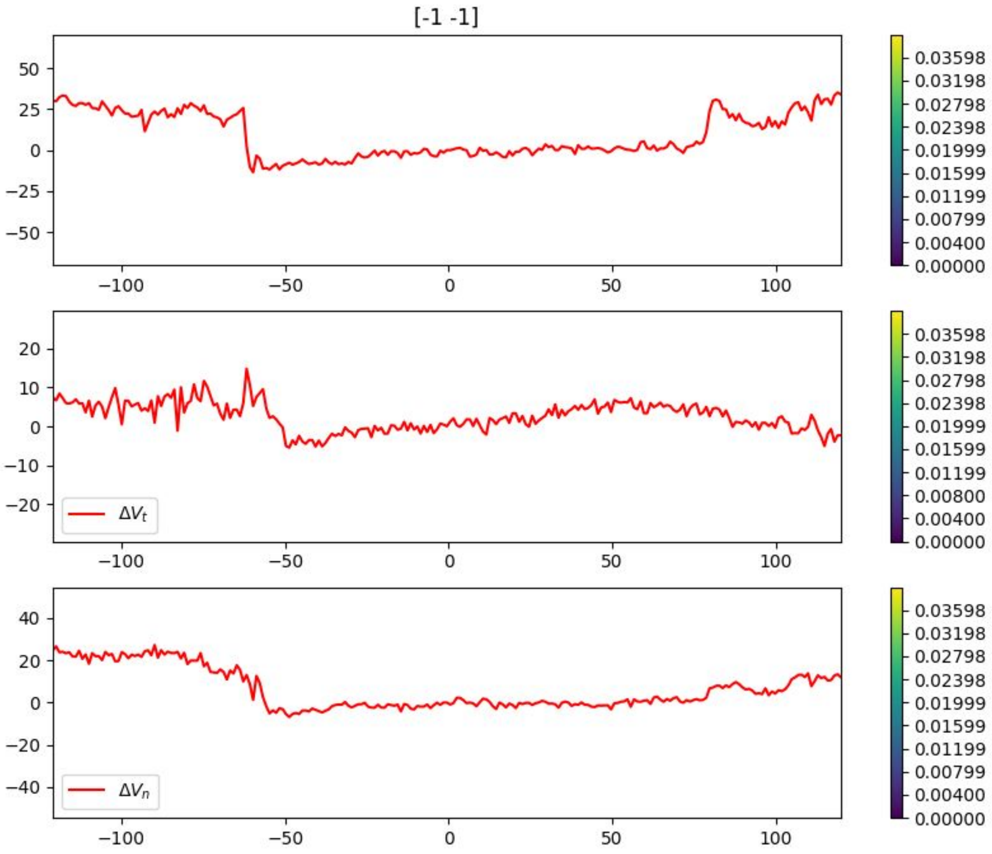
10
0
nT
Br
Bmag
450
400
350
km/s
Vr
10
0
nT
Bt
25
0
−25
km/s
Vt
10
0
nT
Bn
0
−50
km/s
Vn
07-16 03
07-16 06
07-16 09
07-16 12
07-16 15
07-16 18
07-16 21



10
0
nT
Br
Bmag
450
400
350
km/s
Vr
10
0
nT
Bt
25
0
−25
km/s
Vt
10
0
nT
Bn
0
−50
km/s
Vn
07-16 03
07-16 06
07-16 09
07-16 12
07-16 15
07-16 18
07-16 21


[-1 -1]
50
25
0
−25
−50
−100
−50
0
50
100
0.03598
0.03198
0.02798
0.02398
0.01999
0.01599
0.01199
0.00799
0.00400
0.00000
20
10
0
−10
−20
ΔV_t
0.00800
40
20
0
−20
−40
ΔV_n




[-1 -1]
50
25
0
−25
−50
−100
−50
0
50
100
0.03598
0.03198
0.02798
0.02398
0.01999
0.01599
0.01199
0.00799
0.00400
0.00000
20
10
0
−10
−20
ΔV_t
0.00800
40
20
0
−20
−40
ΔV_n