Identification of Electron Diffusion Regions with an AI approach

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Introduction

- Training of a **Neural Network** on the **32 reported EDRs** from phase 1 **listed in Webster et al. (2018)** to study and understand complex relationships between several physical parameters in the case of EDRs.
- **Predictions** of the algorithm **on magnetopause crossings intervals** (listed in the ISSI team's magnetopause crossings database) **from phase 1a**
- Use of an artificial scalar parameter we called **MeanRL** to identify electron Velocity Distribution Functions (eVDFs) crescents on MMS data time series
- Production of a **list of 18 possible EDR candidates** with both **INNER and OUTER electron diffusion regions**, the distinction being the sign of the energy dissipation **J.E'** [Cozzani et al. (2019)] :
  - **J.E'** > 0 + other EDR characteristics → Inner EDR
  - **J.E'** < 0 + other EDR characteristics → Outer EDR
- Paper : Lenouvel et al. (2020) "**Identification of Electron Diffusion Regions with a Machine Learning approach on MMS data at the Earth's magnetopause**" submitted to "JGR:Space Physics" last week

Computation of the MeanRL parameter

Source : Lenouvel et al. (2020) [submitted]

- The MeanRL parameter is an **adimensional scalar** created from the eVDF to **help identifying potential crescents** in time series of MMS data
- High value = high probability to find a crescent
- <u>First step</u> : Normalization of each bin of (f) by the mean

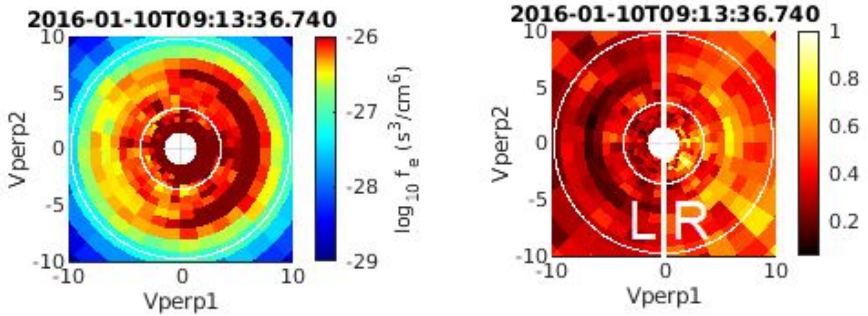
of the bins at the same energy [$\varepsilon_\perp = ½ \, m_e(V_{\perp,1}^2 + V_{\perp,2}^2)$] :

$$f'(\mathcal{E}_\perp) = \frac{f(\mathcal{E}_\perp)}{\sum_i f_i(\mathcal{E}_i = \mathcal{E}_\perp)}$$

- <u>Second step</u> : Computation of the MeanRL with the

following formula [ε_1=40 eV, ε_2=275 eV] :

$$MeanRL = \frac{\sum_i f'_i(V_{\perp,1} > 0, \mathcal{E}_1 < \mathcal{E}_\perp < \mathcal{E}_2)}{\sum_i f'_i(V_{\perp,1} < 0, \mathcal{E}_1 < \mathcal{E}_\perp < \mathcal{E}_2)}$$



f : eVDF of an EDR presenting a crescent on the positive $V_{\perp,1}$ side in the ($V_{\perp,1}$,$V_{\perp,2}$) plane	f' : Normalization by ring of the eVDF on the left to compute the MeanRL scalar
Here, $V_{\perp,1}$ and $V_{\perp,2}$ are in 10^3 km/s and the two white circles delimit the range of energy [40 eV, 275 eV]	

List of EDR candidates

Source : Lenouvel et al. (2020) [submitted]

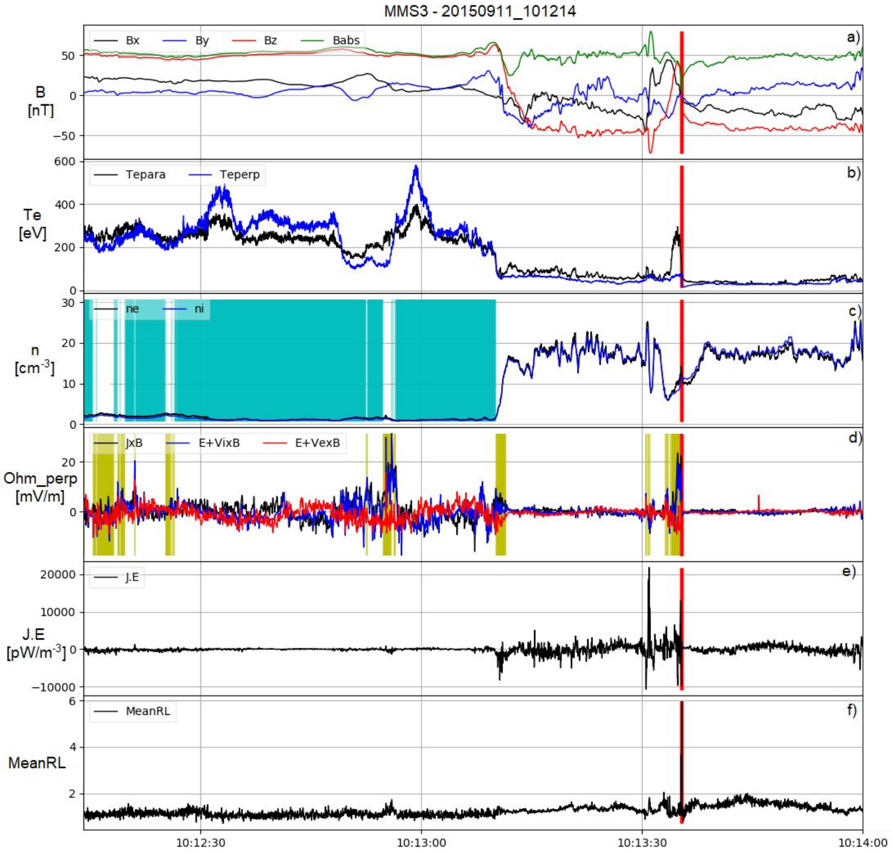
- Table of the 18 inner and outer EDR candidates found using our algorithm in the data of the phase 1a of MMS

ID	EDR Time	MMS	Mean SC Separation (km)	J.E (nW/m3)	MeanRL	Label
20150909_084324	08:43:58	3	200	5	3	EDR
20150909_125814	13:00:22	4	154	1	3.5	EDR
20150909_142734	14:28:51	3	145	1	2.6	EDR
20150911_101214	10:13:35	3	178	-10/+2	5	EDR
20150914_161634	16:17:50	2	139	-10	3.5 / 2.75	OEDR
20150919_092544	09:26:27	3	62	7.5/4	3/1.8 ; 2.5	EDR
20150922_134024	13:41:31	3	51	-6	3.5	OEDR
20150923_090914	09:09:38	4	62	-6	4	OEDR
20151001_065214	06:53:43	2	51	-5	5	EDR
20151006_141714	14:17:54	1	26	1.8	3	EDR
20151202_011514	01:17:02	1	18	-4	3.2	OEDR
20160102_234614	23:46:17	4	41	-2.1	2.75	OEDR
20160107_221104(2)	22:12:20 ; 22:11:37	3,4	44	5 ; -10/+20	2.5 ; 2.75	EDR
20160205_221924	22:19:46	1	14	3	2.25	EDR
20160211_015924(2)	02:01:04	1,3	14	1.2 ; 1	6 ; 4.8	EDR
20160214_204124(3)	20:41:56	2,3,4	15	-4/+5 ; -1/+1 ; 10	4.75 ; 4.3 ; 5	EDR
20160219_183904(2)	18:42:38-39 ; 18:42:38-40	1,3	15	1.2/2.75 ; 1.1/1.5	3.1/2.5 ; 3/2.5	EDR
20160228_010604(2)	01:07:33	1,3	16	4 ; 7.5	5 ; 2.4	EDR

Event illustration : 20150911_101214

Source : Lenouvel et al. (2020) [submitted]

- This is an **event illustration of one of the 18 new EDR candidates** found by our algorithm
- EDR candidate found on **2015-09-11 at 10:13:35 UTC** in MMS3 data
- Detections in blue, yellow and red are done by the algorithm **for each time step** and correspond respectively to **Magnetosphere**, **IDR** and **EDR** detections, the rest is considered as **Boundary Layer**
- The **EDR candidate is located near an IDR** and close to a **magnetopause crossing** (with visible transition from Magnetosphere side to Magnetosheath side)
- Visible high values for **J.E and MeanRL**



Event illustration : 20150911_101214

Source : Lenouvel et al. (2020) [submitted]

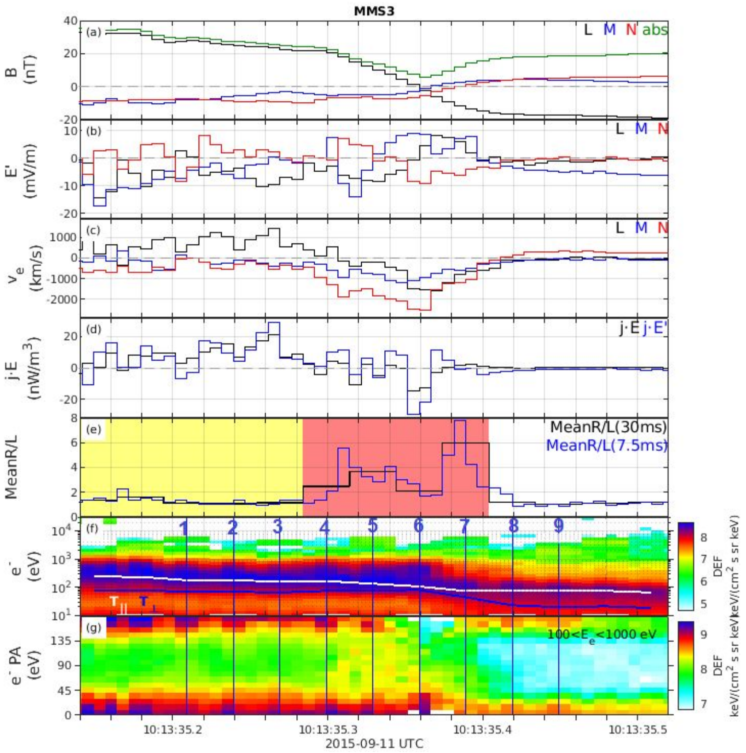
At the EDR time :

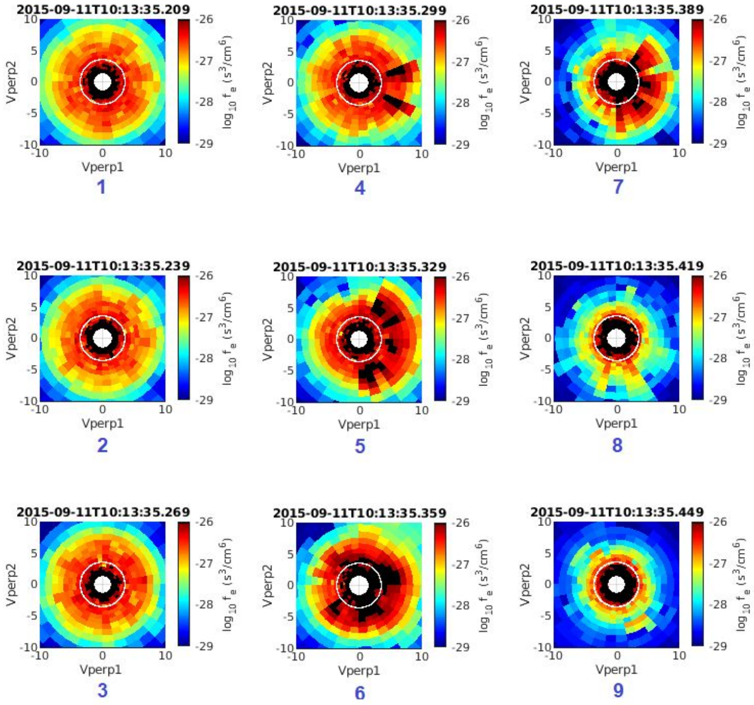
- B < 6 nT
- E' > 10 mV/m
- e⁻ outflow in -N
- J.E'<0 at lowest B

but J.E'>0 overall

- High MeanRL for eVDFs n°4, 5 & 7
- Temperature anisotropy

⇒ EDR candidate





End

Thank you for your attention !

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