Magnetosheath kinetic structure: Mirror mode and jets during southward IP magnetic field

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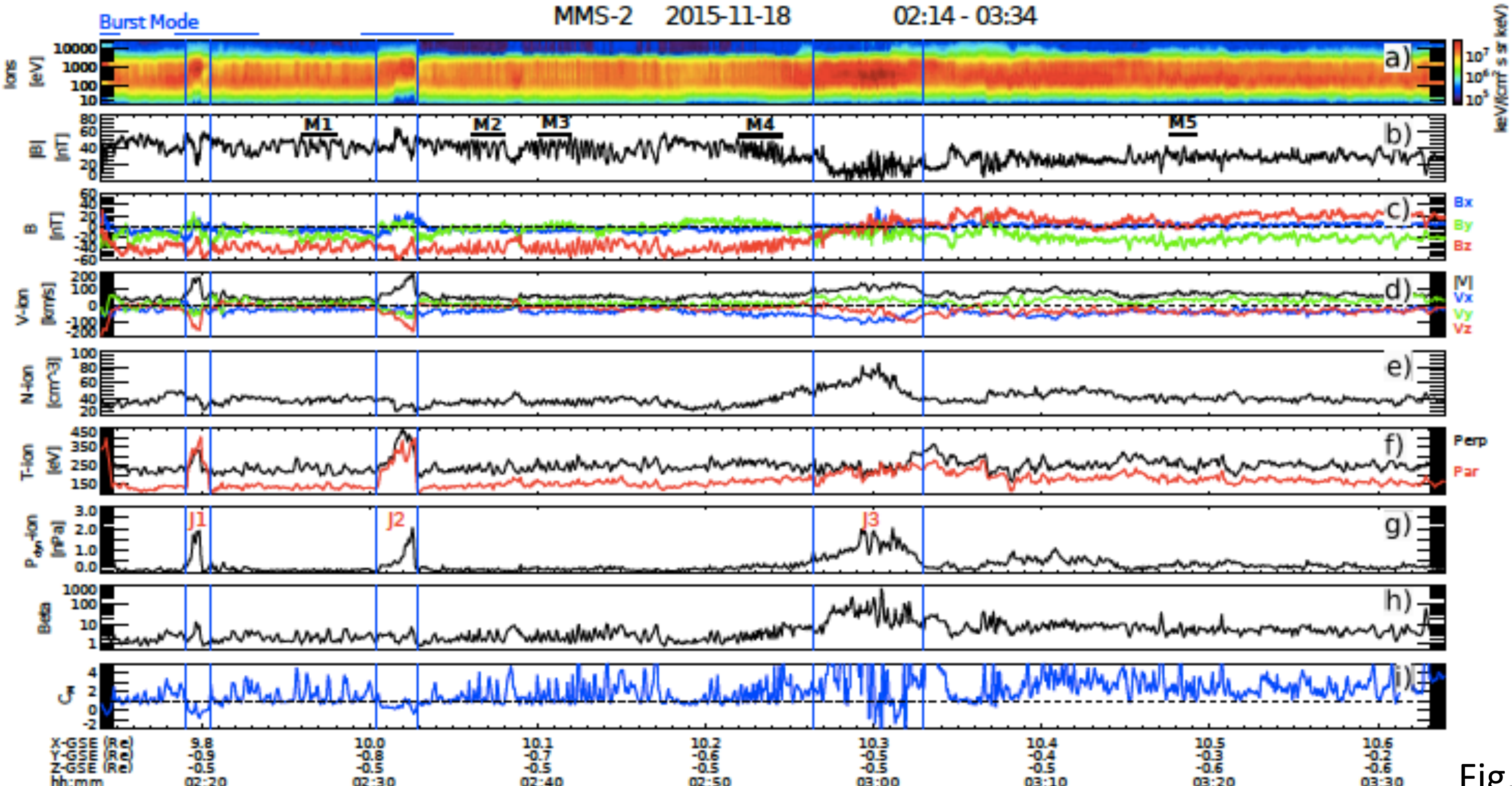

Fig. 1

On November 18, 2015 MMS observed an extended interval with southward Bz (02:14:00-02:59:46 UT). This period was chosen by the GEM "Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction" focus group to examine different aspects of the SW interaction with Earth's magnetosphere under negative Bz. The horizontal blue segments on top of the panels indicate periods with burst mode data. During the shown interval the magnetosheath plasma is clearly not homogeneous with interesting microstructure which includes well defined transients and waves.

We identify three magnetosheath jets (J1, J2, and J3) and various intervals with mirror mode waves (M1 to M5). Jets were identified using the criteria of Archer & Horbury (2013), which states that the dynamic pressure inside the jets has to reach values of at least twice the background dynamic pressure. Due to the limited time interval that the MMS spacecraft spent on this occasion in the magnetosheath, we average the P_{dyn} over 2.5 minutes instead of the 20 minutes. The horizontal line in Fig. 2d and 3d indicates the value of $2 < P_{dyn} >$.

Mirror mode waves and waves inside jets

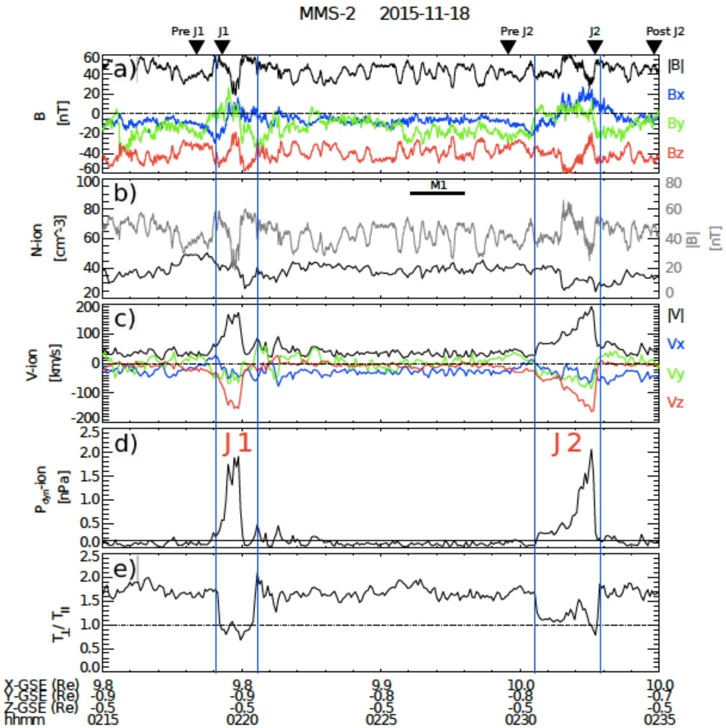

Figure 2

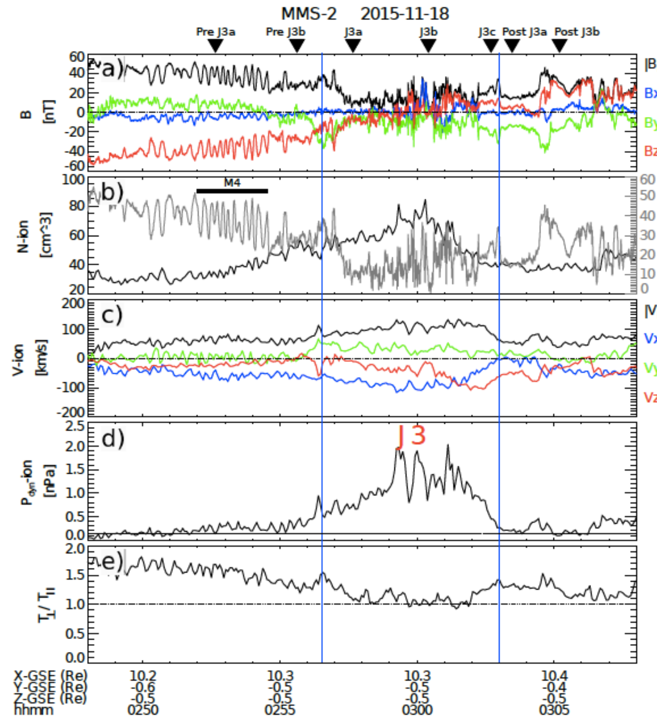

Figure 3

- J1 and J2 are different from J3. Their duration in the data is 54 s and 70 s, respectively. Through them the speed increases more than 100 km/s, mostly due to enhanced Vz . In contrast, J3 lasts 6 minutes and the velocity increment is 50 km/s, with almost no change in the plasma flow direction.

- J1 and J2 show temperature enhancements within them, while the total temperature drops in J3 as can be observed in Figure 1f. These differences in jet characteristics suggest that J1 and J2 share a common origin, which seems to be different from the origin of J3.

- It is possible to see that the interjet regions are permeated by compressive waves which show an anti-correlation between B and N. The shape of these waves is variable, with larger periods observed between J1 and J2, and shorter ones just before J3. The waves between J1 and J2 also show superposed higher frequency small amplitude fluctuations.

Inside Jets

Outside Jets

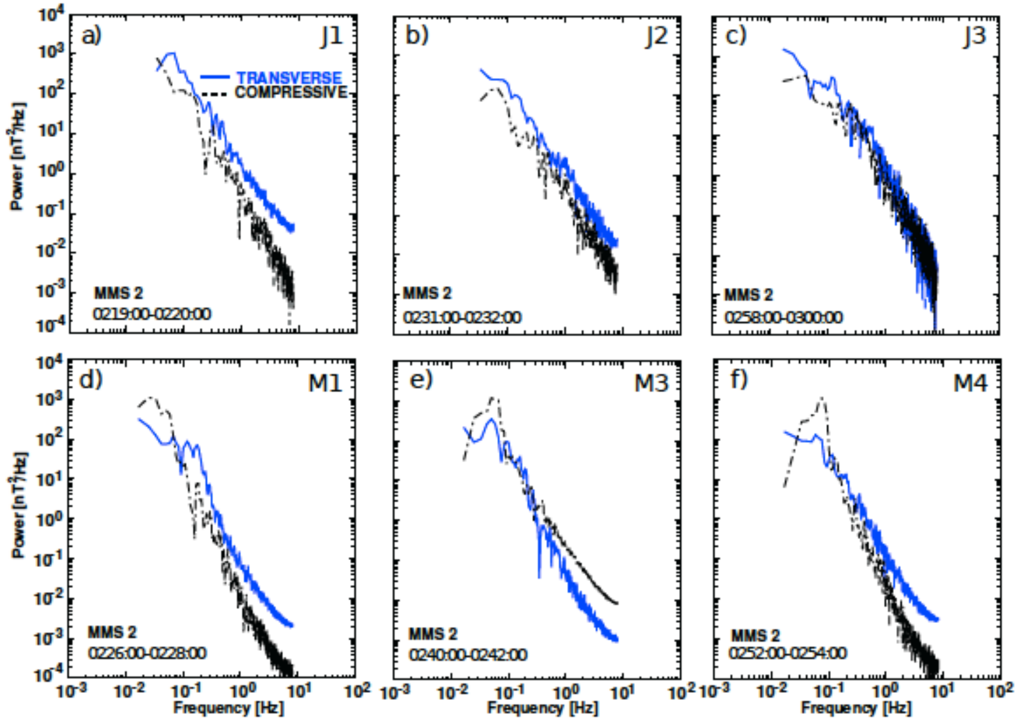

Figure 4

•The top panels show B -feld spectra inside J1, J2 and J3. The bottom panels are for the inter-jet mirror mode intervals M1, M3 and M4.

•Inside the jets the transverse component is the dominant one, however the fluctuations also have a strong compressive component. In contrast, the waves in the inter-jet regions clearly contain more compressive power at low frequencies, $f < 10^{-1}$ Hz. For the waves observed during 02:26:00-02:28:00 (panel 4d), there is also a peak in transverse power corresponding to very small amplitude waves that can be seen in Figure 2.

•To strengthen our argument in favour of mirror mode waves, we use minimun variance analysis and apply the criteria of Genot et al. (2001). According to these authors, mirror mode waves should satisfy $\lambda_{max} >> \lambda_{int}$ and $\theta_{Boi} < 20$, where λ_{max}, λi_{nt} , and θ_{Boi} are the maximum and intermediate eigenvalues, and the angle between the ambient magnetic field and the maximum direction of fluctuation, respectively. Mirror mode waves are linearly polarized when $\lambda_{int}/\lambda_{max} \leq 0.2$, and $\lambda_{min}/\lambda_{int} \geq 0.3$. If the last two criteria are not satisfied, mirror-mode waves are considered to be elliptically polarized. All mirror mode waves identified in this study show elliptical polarization.

Ion distributions, J1 and J2 region

- The VDFs in the interjet regions (02:18:24, 02:29:34, 02:34:54) are bi-Maxwellian with a $T_{perp} > T_{par}$, typical of the Qperp magnetosheath. In contrast, the VDFs inside J1 and J2 show two populations, with the secondary (less dense) beam drifting along **B**.

- The temperature inside J1 and J2 increases. These properties and distributions are very different from those reported in the past (Shue et al., 2009; Archer et al., 2012; Archer & Horbury, 2013; Plaschke et al., 2013; Karlsson et al., 2018) whose jets usually exhibit diminished temperature, and exhibit only one ion population.

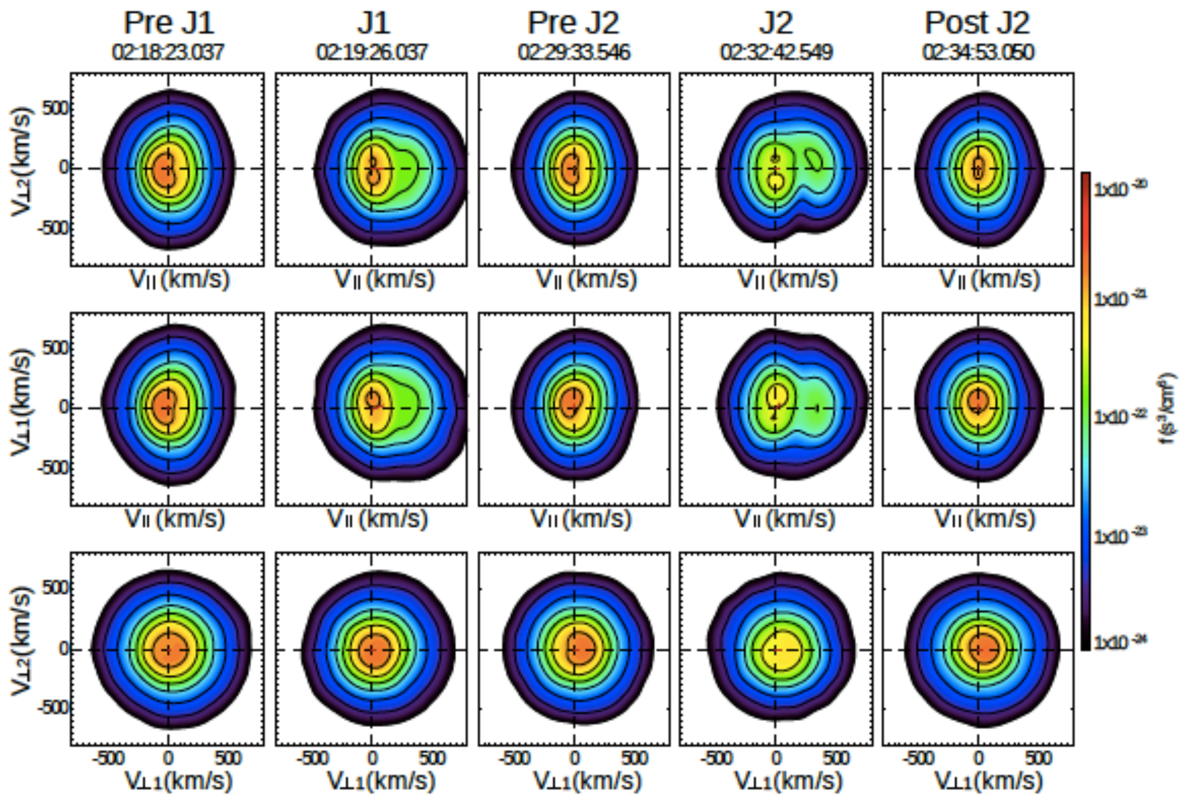

Figure 5. Ion distributions associated with J1, J2 and their surrounding regions. Distributions are given for three planes, where $V_{\perp 1}$, $V_{\perp 2}$, and $V_{\|}$ indicate directions perpendicular and parallel to the B-field.

Ion distributions, J3 region

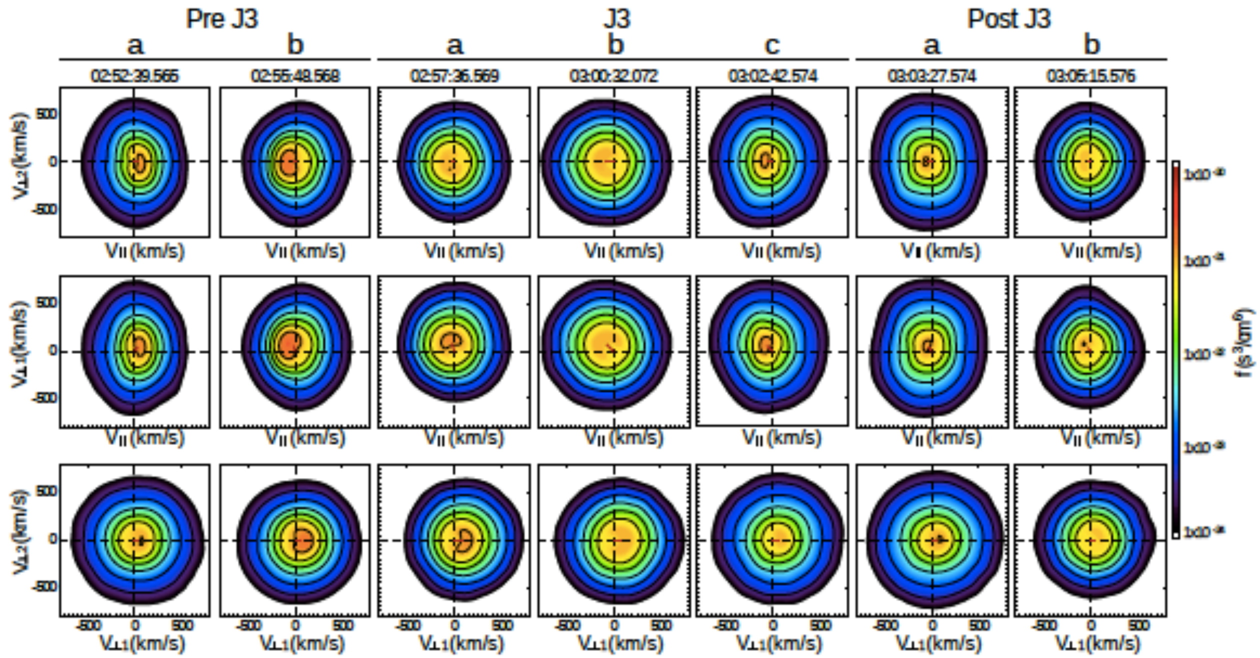

Figure 6. Ion distributions associated with J3 and their surrounding regions. In the same format as Figure 5

- The ion distribution at 02:52:39 UT is associated with mirror mode waves and exhibits $T_{perp} > T_{par}$. The ion distribution observed at 02:55:48 UT is not associated with mirror mode waves, and is less anisotropic (see also Fig 3e) .
- Two of the ion distributions inside the jet are isotropic (at 02:57:36 UT, 03:00:32 UT), while the VDF at the rear part of the jet at 03:02:42 UT shows anisotropic ion VDF.
- At the times of the first two VDFs inside J3 there are clear B-field fluctuations (see Fig. 3a) which are mostly transverse but also contain a strong compressive component and their frequencies range is between 0.05-0.10 Hz (see also Figure 4c). At the rear part of J3 there are no such fluctuations.
- The VDF in the post-J3 region resembles those in the pre-J3 region.

Various features of J1 and J2, such as their enhanced and dominant V_z, and the ion distributions observed inside them suggest that they could have been produced by magnetic reconnection.

In contrast, the origin of J3 seems to be related to a magnetic field rotation crossing the bow shock.

Electron pitch angle distributions inside the jets support the fact that J1 and J2 share a common origin distinct to J3.

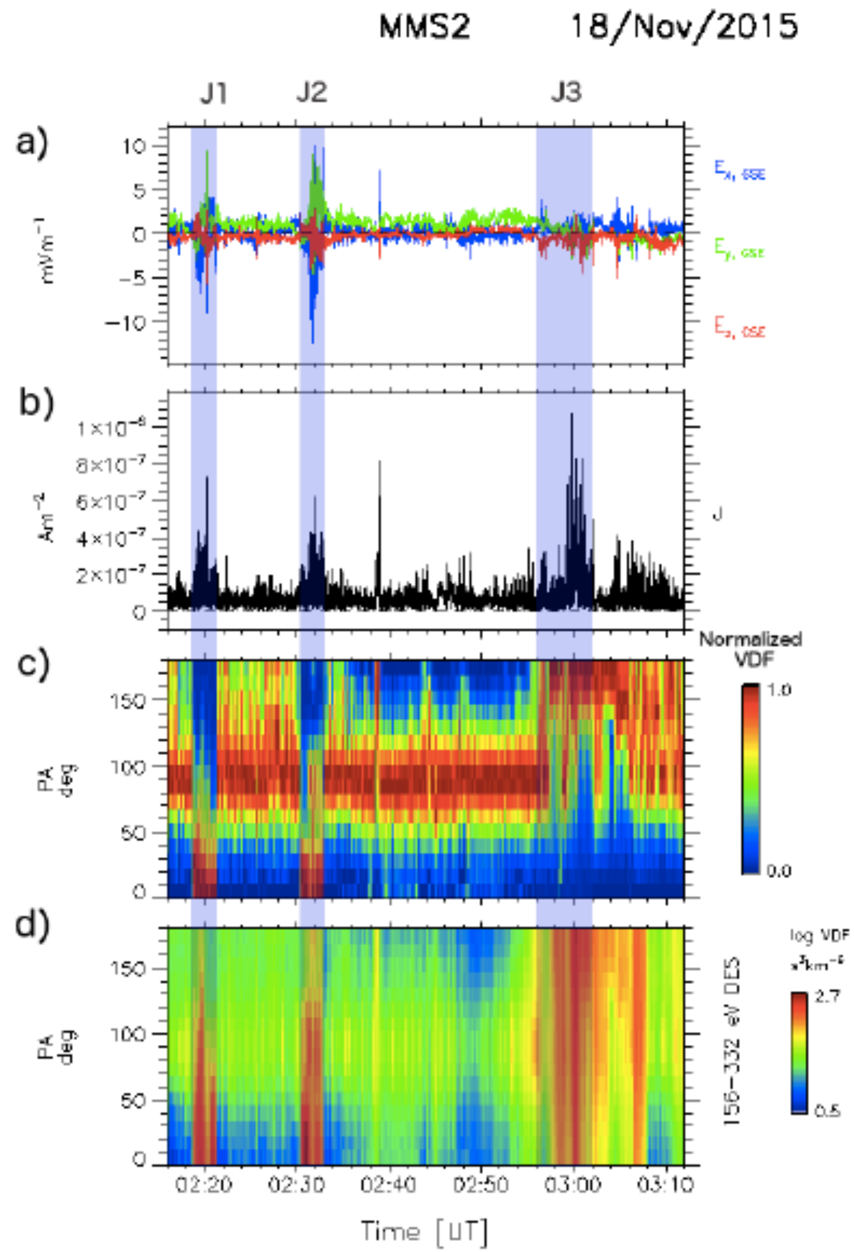

Figure 7. a) electric field components, b) electric current calculated with the curlometer method (Robert et al., 1998), c) and d) suprathermal electron pitch angle distributions which are normalized on panel c).

Conclusions

•Jets and mirror mode waves can coexist in the dayside magnetosheath.

•We have shown that a variety of plasma structures can be identified as jets using statistical identification criteria. However, the structures can be very different between them which suggests different generation mechanisms.

•The temperature increased inside J1 and J2 which is in contrast to reported examples (Karlsson et al., 2018), where the decrement in temperature has been explained in terms of plasma that has been less processed than in their surroundings. J3 has a total temperature slightly above the background value.

•Waves inside and outside of the jets were different, inside the jets waves are mainly transverse and propagate off angle. It is possible that inside J3 the waves arise from a combination of modes, as $C_B > 1$, The inter-jet regions showed the existence of mirror mode waves, and no ion cyclotron waves were identified. Because mirror mode waves are compressive structures, it is possible that their arrival to the magnetopause in combination with the jet arrival can have an impact on the magnetopause.

•We found clear differences on VDF's in/out side jets. In the interjet regions the VDF's are anisotropic with Tperp/Tpar > 1. In contrast, J1 and J2 show values close to 1 and even below 1. J3 shows more isotropic distributions, which could result from wave interaction.

•The charactristics of J1 and J2 suggest that they were produced by magnetic reconnection. The origin of J3 is explained in terms of a field rotation discontinuity crossing the bow shock.

•It remains as part of future work to study wave-particle interaction inside magnetosheath jets.

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