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Studying multi-beam ion temperature inside a collisionless reconnection plasmoid by means of Gaussian Mixture Model

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Being ubiquitous energy converter is space plasmas, magnetic reconnection releases stored magnetic energy into kinetic energy of particles. Magnetic reconnection involves several particle acceleration mechanisms which form beams directed parallel to the magnetic field. It was recently demonstrated analytically that in the presence of complicated velocity space structures, the definition of higher moments (like thermal pressure) should be extended to cover such multibeam distributions. In practice, the number of beams at each spatial point of interest is not know a priori. With the aim to automatically reveal the information about the beams generated in the reconnection process, we applied an unsupervised machine learning algorithm (Gaussian Mixture Model, GMM) to the 2.5D Particle-in-Cell simulations of collisionless magnetic reconnection. We studied the ion distributions inside a plasmoid and found that the multibeam ion temperature within the reconnected outflow deviates significantly from the standard ion temperature (calculated as the 2nd moment of the ion distribution function). In particular, the regions of the strong parallel heating contain in fact relatively cold counterstreaming beams and the overestimation of parallel temperature in this case could be as high as 10. In the current study, we make an attempt to figure out how long the multi-beam regime exists without significant thermalization inside a plasmoid formed by two adjacent X-lines.