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Observations of Particle Acceleration Associated with Small-Scale Magnetic Islands Downstream of Interplanetary Shocks

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We have recently shown both theoretically (Zank et al. 2014, 2015; le Roux et al. 2015) and observationally (Khabarova et al. 2015) that dynamical small-scale magnetic islands play a significant role in local particle acceleration in the supersonic solar wind. We discuss here observational evidence for particle acceleration at shock waves that is enhanced by the recently proposed mechanism of particle energization by both island contraction and the reconnection electric field generated in merging or contracting magnetic islands downstream of the shocks (Zank et al. 2014, 2015; le Roux et al. 2015). Both observations and simulations suppose formation of magnetic islands in the turbulent wake of heliospheric or interplanetary shocks (ISs) (Turner et al. 2013; Karimabadi et al. 2014; Chasapis et al. 2015). A combination of the DSA mechanism with acceleration by magnetic island dynamics explain why the spectra of energetic particles that are supposed to be accelerated at heliospheric shocks are sometimes harder than predicted by DSA theory (Zank et al. 2015). Moreover, such an approach allows us to explain and describe other unusual behaviour of accelerated particles, such as when energetic particle flux intensity peaks are observed downstream of heliospheric shocks instead of peaking directly at the shock according to DSA theory. Zank et al. (2015) predicted the peak location to be behind the heliospheric termination shock (HTS) and showed that the distance from the shock to the peak depends on particle energy, which is in agreement with Voyager 2 observations. Similar particle behaviour is observed near strong ISs in the outer heliosphere as observed by Voyager 2. Observations show that heliospheric shocks are accompanied by current sheets, and that IS crossings always coincide with sharp changes in the IMF azimuthal angle and the IMF strength, which is typical for strong current sheets. The presence of current sheets in the vicinity of ISs acts to magnetically confine magnetic islands and increases the effectiveness of the proposed acceleration mechanism. We show observations of unusual energetic particle flux increases near ISs associated with the occurrence of small-scale magnetic islands and discuss plasma configurations that are favourable for magnetic island formation and their confinement near ISs.