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Ion distributions upstream of an interplanetary shock

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It is well known that supercritical collisionless shocks in the interplanetary (IP) space reflect part of the incoming particles (ions, electrons) in order to dissipate the kinetic energy of the upstream solar wind flow. When the conditions are right the reflected particles can escape far upstream from the shock. Their interaction with incoming ions and electrons results in the formation of the foreshock region which is populated by ultra-low frequency magnetic field fluctuations and different populations of reflected ions. Our knowledge on the latter comes mostly from observations of our planet's foreshock. However, the bow shock of the Earth typically has high Mach numbers, and the relatively small global curvature radius of the shock's shape affects the ion distribution characteristics. Interplanetary (IP) shocks, on the other hand, typically have lower Mach numbers and larger global curvature radii. In the past the majority of observed ion distributions detected upstream of IP shocks were diffuse. In only a couple of works the field-aligned ion beams were reported and even then the details of the ion distributions functions could not be determined. Here we present the first study showing clear observations of different types of ion distributions upstream of an interplanetary shock. The shock was observed on 8 October 2013 by several spacecraft, namely Wind, ACE, and the two ARTEMIS spacecraft P1 and P2. By using combined data from the Electrostatic Analyzer and the Solid State Telescope instruments onboard both ARTEMIS spacecraft we observed different types of ion distributions upstream of the shock: The distributions changed from field-aligned ion beams that were detected farthest from the shock, to intermediate and then to almost diffuse ion distributions near the shock transition. Furthermore, the observations at P1 and P2 locations also show spatial variability of the foreshock and the IP shock. The angle between the local shock normal and the upstream magnetic field, θ_{Bn}, was larger at P1 where the upstream ion fluxes were somewhat weaker than at P2 which observed the shock with smaller θ_{Bn}.