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On the profile of energetic particles close upstream of interplanetary shocks: an easy task for THOR

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Collisionless shock waves are considered to be one of the main acceleration mechanisms for energetic particles in space and astrophysical plasmas. The most popular shock acceleration mechanisms, diffusive shock acceleration, is based on diffusive motion of energetic particles, but anomalous transport regimes, including subdiffusion and superdiffusion, are also possible. Here we present the extension of the well known Parker equation for the transport and acceleration of energetic particles and cosmic rays to the case of superdiffusion. The latter is modelled by means of fractional order derivatives of the particle distribution function, instead of the second order derivatives, on the spatial diffusion term. It is shown that the upstream steady state solution of the fractional Parker equation can be written in terms of the Mittag-Leffler functions, which generalize the standard exponential function, and correspond to stretched exponentials close to the shock, and to power laws far from the shock. Comparison of these solutions with available spacecraft data on interplanetary shocks shows that a much higher temporal resolution of energetic particle measurements is required, in order to be able to resolve the steep profile close upstream of the shock. Therefore, THOR high resolution measurements of energetic particle fluxes will allow a breakthrough in the understanding of energetic particle transport and acceleration.