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Modeling cross magnetic field suprathermal ion transport with a persistent random walk

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In TORPEX [1], a toroidal basic plasma physics device located at the Swiss Plasma Center in Lausanne, Switzerland, we study cross magnetic field ion transport by injecting suprathermal lithium-6 ions into a turbulent hydrogen plasma and observing their poloidal distribution as it evolves with toroidal distance. Extensive experimental studies and simulations have shown that, in general, transport of the lithium-6 ions is non-diffusive. Different transport regimes, including sub-diffusive, quasi-diffusive and super-diffusive, can be observed depending on injection energy and evolution time [2].

Although models based on fractional Levy-motion have successfully been used to describe the suprathermal ions [3], they have been unable to capture the observation that the transport regime may change as the ions propagate. Furthermore, they allow extremely large motion steps that can be difficult to justify in spatially bounded systems like TORPEX.

Here, we discuss a different modeling approach using persistent random walks (PRW) [4, 5], where the motion of particles is affected by instantaneous random changes of the velocity instead of the position. Using simple Poisson-distributed collisions and well-behaved velocity distributions, we obtain models of transport with time-changing properties.

A comparison with TORPEX experimental data and simulations [5] shows that this approach can capture the main features (Fig. 1) of the suprathermal ion transport at different injection energies and toroidal distances, including transitions between transport regimes.

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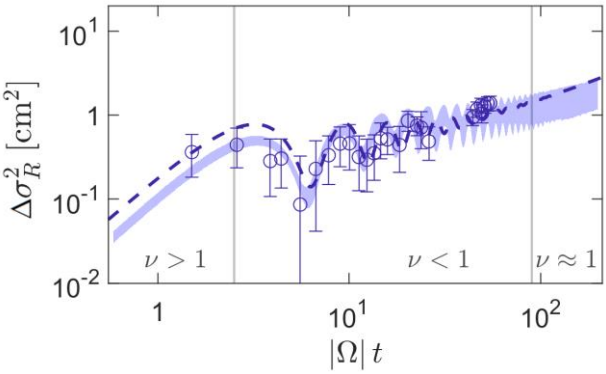

Fig. 1: Experimental data (circles), simulations (colored band) and PRW model (dashed lines) for the radial width change of 70eV lithium-6 ions injected in a turbulent hydrogen plasma in TORPEX, as described in Ref. [5]. *The horizontal axis is the time evolution in units of the ion cyclotron frequency, and is directly related to the toroidal propagation distance. The model follows the different cross magnetic field transport regimes observed in the experiments and simulations, including super-diffusive ($\upsilon>1$), sub-diffusive ($\upsilon<1$) and quasi-diffusive ($\upsilon\approx1$).*

References

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