Understanding ion and impurity flows in the Wendelstein 7-X stellarator

J.A. Alonso[1], J. Baldzuhn[2], C. Brandt[2], C.D. Beidler[2], S. Bozehnkov[2], K. J. Brunner[2], R. Burhenn[2], I. Calvo[1], D. Carralero[1], N. Chaudhary[2], H. Damm[2], A. Dinklage[2], T. Estrada[1], O. Ford[2], T. Fornal[3], G. Fuchert[2], J. M. García-Regaña[1], J. Geiger[2], M. Hirsch[2], U. Höfel[2], J. Knauer[2], M. Kubkowska[3], A. Langenberg[2], A. Mollén[2], U. Neuner[2], J. W. Oosterbeek[2], N.A. Pablant[4], E. Pasch[2], K. Rahbarnia[2], E. Sánchez[1], J. Schilling[2], H. M. Smith[2], H. Thomsen[2], Y. Turkin[2], L. Vanó[2], J. L. Velasco[1], T. Windisch[2] and the W7-X team.

[1]*Laboratorio Nacional de Fusión, CIEMAT, 28040 Madrid, Spain*
[2]*Max-Planck-Institut für Plasmaphysik, IPP, 85748 Garching, Germany*
[3]*Institute of Plasma Physics and Laser Microfusion, 01-497 Warsaw, Poland*
[4]*Princeton Plasma Physics Laboratory, 08543-0451 Princeton, NJ, USA*

Two of the highest priorities in stellarator research are to verify the effects of orbit drift-optimization on the energy core confinement and to learn to prevent the accumulation of impurities in high-density plasmas. The basic framework for understanding energy and particle transport in these devices is neoclassical theory and plasma *flows* is one of its most fundamental predictions, upon which further transport modeling relies.

In this talk we will present an integral interpretation of flow measurements, in terms of the neoclassical ambipolar radial electric field and the Pfirsch-Schlüter and net parallel velocities, to test our understanding of plasma flows in high-density, low-collisionality (i.e. optimization-relevant) plasmas. Furthermore, the deviation of impurity flow fields from an incompressible spatial variation has been linked to significant inhomogeneities of impurity density on flux surfaces (see e.g. [1] and references), which, in turn, give rise to a damped low-frequency oscillation in the radiation traces after sudden profile changes such as those caused by pellet injections [1]. The observation of a similar oscillation in W7-X plasmas [2] has sparked the question whether such impurity density variations can also be observed in W7-X and whether or not they are important in determining the radial impurity fluxes. In the talk, fluid and kinetic modeling of the density variation and radial fluxes will be presented and confronted with the observed X-ray oscillations as well as with the stationary radial fluxes calculated with the three-charge-states technique [3] to provide an up-to-date status of our understanding of these questions.

[1] J A Alonso, J L Velasco, I Calvo *et al.* 2016 *Plasmas Phys. Control. Fus.* **58** 074009.
[2] C. Brandt, H. Thomsen, T. Andreeva *et al.* 2018 *EPS Plasma Phys. Conference*, P4.1056.
[3] A. Langenberg, N. Pablant, O. Marchuk *et al.* 2017 *Nucl. Fusion* **57** 086013.