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PROTO-SPHERA, a MHD configuration formed and sustained by magnetic reconnections

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The PROTO-SPHERA experiment [1,2] is based upon a new magnetic confinement scheme, which aims at producing – in its Phase-2 – a Spherical Torus (with $I_{ST} \leq 300$ kA) around a Plasma Centerpost (a Screw Pinch with $I_e = 70$ kA) fed by electrodes of annular shape. The torus current is sustained through Helicity Injection from the centerpost; phenomelogical evidences suggest the presence of an MHD dynamo field lasting for periods far greater than the resistive relaxation time.
In particular, 3D tomographic reconstructions of the visible light emitted by the plasma highlight the presence of a quasi-static closed magnetic domain, which is originated and sustained as a result of the onset of resistive MHD instabilities. These events are not axisymmetric neither in the topology nor in the spatial distribution; moreover, they correlate with saw teeth recorded on the axial/poloidal flux probes and corresponding to magnetic reconnections, in this context known as dynamo relaxation events.
PROTO-SPHERA experiment was inspired by jet-torus configurations which are common around compact objects in astrophysics (i.e. the Pulsar Wind Nebulae) and are described by force-free equilibria. It is worth noting that, unlike other self-organized laboratory plasmas like Spheromaks and RFPs, PROTO-SPHERA lacks a flux conserver and is therefore a better candidate for laboratory astrophysics activity.
Despite the lack of a flux conserver, PROTO-SPHERA displays ideal MHD stability; furthermore, a significant rotation of plasma in toroidal direction around the centerpost acts as a further stabilizing feature.
The dynamics of radial helicity transport in an open system is nonetheless not fully understood; in fact, in this operational phase (i.e. $I_e \leq 10$ kA), there is evidence of an axial current flowing outside the torus, the origin and impact of which is still to be addressed.
PROTO-SPHERA experiment is currently undergoing a major upgrade, with the aim of installing a more complete diagnostic set and of addressing the presence of spurious current loops. An improved diagnostics coverage will be required for kinetic measurements and for magnetic topology reconstruction during Phase-2 (with full currents); in this phase, energy confinement quality inside the torus will be addressed, in view of a possible application of this new configuration to magnetic fusion.

References:

[1] Franco Alladio et al, 2024 *Plasma Phys. Control. Fusion* **66** 035011
[2] Micozzi P et al 2024 *Plasma Sci. Technol.* **26** 005100