

PROTO-SPHERA: a “bridge” between laboratory and astrophysical plasmas

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The PROTO-SPHERA experiment 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 $I_c = 70$ kA) fed by electrodes of annular shape. The torus current is sustained through Helicity Injection from the centerpost; phenomenological evidences suggest the presence of a 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. $I_c \leq 10$ kA), there is evidence – when the torus is formed and sustained – of an axial current flowing outside the torus itself, still to be fully investigated, that seems to allow for the correct helicity flow from the external region with open field lines to the nested flux surfaces of the torus also at low I_c level.

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.

In fact, if the energy confinement shall be of good quality many problems that affect the standard Tokamak configuration could be solved. In particular this kind of magnetic configuration is intrinsically stationary (due to the Helicity Injection from the screw pinch to the torus), does not need any additional heating system and is disruption free.