

Towards Fusion Energy for Space Propulsion : The Interaction between Magnetic Topology and Plasma Flows

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Abstract: In the USA and Japan, an "innovative confinement concepts" program investigates alternatives to the large and expensive "tokamak" device for fusion energy. Compact toroids like spheromaks or FRCs are smaller and simpler, hence potentially more economical. Their study is uncovering some complex interaction between plasma flows and magnetic topology: e.g. flared magnetic flux tubes collimate into astrophysical jets and magnetic helical shapes annihilate, generating substantial plasma flows. The spheromak, however, is limited by low beta (ratio of plasma pressure to magnetic pressure), and the high-beta FRC exhibits poor confinement. Because new favourable compact toroid states could be attained with sufficient understanding of the interaction between plasma flows and magnetic topology, full 3D diagnostics and interpretations are being developed. This interaction also plays a major role in the physics of electromagnetic thrusters. Hall thrusters are considered mature for low-power space propulsion, and magnetoplasma-dynamic thrusters are attractive solutions for high-power applications. However, they both present significant limitations in the intermediate power range. A "variable geometry" plasma gun could improve on both concepts while allowing variable thrust and specific impulse. Ultimately, compact toroid concepts with magnetic nozzles could enable future human spaceflight throughout the Solar System.