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Parker's Effect and its Relevance to Magnetic Confinement Fusion

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Over the past half-century of fusion research, much progress has been made in the understanding and design of fusion devices, yet there is no consensus over which technology may deliver electricity to the grid economically, while remaining of a practical size and cost to build and operate. This realization, strengthened by the urgency for securing reliable, environmentally benign energy, sufficient for current and future needs, has recently reinvigorated fusion research. This has encouraged some plasma physicists to investigate ideas for new devices, as well as to review some that were put aside in the early 1970s. A little-known electromagnetic effect discovered by the theoretical astrophysicist Eugene Parker and his collaborators in the late 1960s may offer such an alternative. The aims of this talk are to explain Parker's Effect, its possible relevance to fusion, how this can be verified, and to present the results of recent preliminary studies.

Parker investigated a simplified model of the flow of the solar wind around Earth's magnetic field, focussing on the strip where the flow is parallel to the field lines (Figure 1, red boxes). He discovered that, in the thin boundary layer between the plasma and the field, a secondary magnetic field would arise, stronger than the primary field in the ratio of the flow speed to the ion thermal speed. This effect causes the boundary layer to become unstable, under certain circumstances [1].

In 1979, Storey and Cairo suggested that Parker's Effect may have applications to fusion. Specifically, they showed that if the flowing plasma was confined by the magnetic field rather than the inverse, then the effect would reinforce the confinement [2]. In a simple current-carrying ring set up as shown in Figure 2, the secondary magnetic field created by the plasma flow strengthens the pressure confining the plasma at the throat.

This effect has never been observed experimentally or in simulation, mainly because it has not been sought. Our research group has designed a sequence of numerical simulations to confirm Parker's Effect and study its potential applications to fusion devices. If the effect is confirmed, the follow-up work would be to simulate a modular toroidal device to demonstrate the effective magnetic confinement of a flowing plasma, as illustrated by Figure 3. The work is ongoing, and preliminary results are encouraging. For instance, a simplistic kinetic simulation of such a system suggests that plasma confinement becomes excellent at flow velocity of about Mach 5 relative to the ion thermal speed (Figure 4).

Other figures of merit will be discussed, the current experiments described, and the latest results presented.

References

[1] E.N. Parker. "Dynamical properties of the magnetosphere" In *Physics of the Magnetosphere: Based upon the Proceedings of the Conference Held at Boston College June 19–28, 1967.* Springer Netherlands, 1968.

[2] L.R.O. Storey and L. Cairo. "Kinetic theory of the boundary layer between a flowing isotropic plasma and a magnetic field." *Magnetospheric Boundary Layers* 148 (1979)

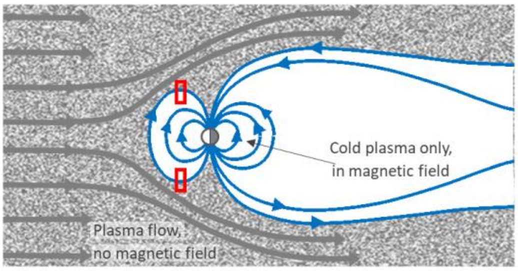

Figure 1. Simplifed model studied by E. Parker.

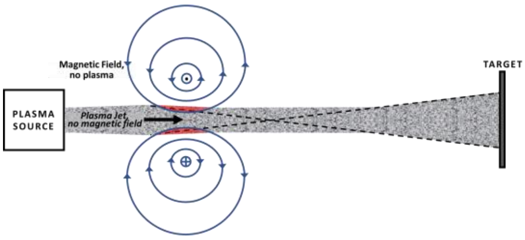

Figure 2. Main section of a system in which a magnetic field surrounds a flowing plasma.

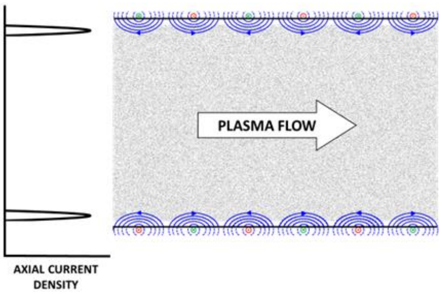

Figure 3. Simple system to evaluate the suggested method of plasma confinement.

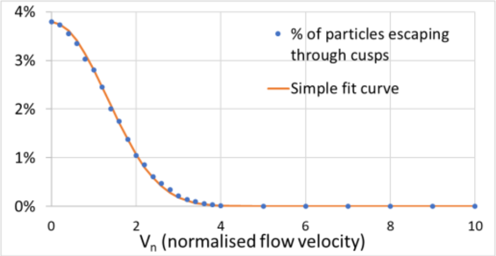

Figure 4. Numerical simulation of plasma loss rate vs. plasma flow speed in a setup similar to Figure 3.