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New Experimental Evidence in Support of the Accretion Theory for the Spontaneous Rotation Phenomenon and Relevant Developments*

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The "accretion" theory was proposed since the early experimental indications of this phenomenon and was inspired by the theory of millisecond pulsars. Accordingly, the explanation given was and is that angular momentum is transferred to the material wall surrounding the plasma by the effects of collective modes excited at the edge of the plasma column and that opposite angular momentum is carried toward the center of the plasma column by a different set of modes [1]. Then a series of predictions could be made that would prove the validity of the theory. (1)The toroidal velocity would have to invert its direction as the plasma column is taken from a regime with a high degree of confinement of the plasma thermal energy (so called H-regime) to a regime of low confinement (so called L-regime). In fact, the modes that, according to the theory, had to be excited at the edge of the plasma column would have opposite phase velocities in the two regimes. (2) Since the inward transport of angular momentum is considered to be at the edge of the plasma column, when the rotation starts it should be observed as localized in the outer part of the plasma column propagating toward the center. (3) Since the inward transport of angular momentum is attributed to plasma modes that are responsible for the outward transport of the nuclei thermal energy, according to the theory, the transport characteristic times for the angular momentum and for the nuclei thermal energy should be about equal. (4) The phase velocities of the plasma modes excited at the edge of the plasma column should be in a given characteristic direction (the so called electron diamagnetic velocity) in the H-confinement regime and in the opposite direction in the L-confinement regime. Conversely, the plasma column should rotate contrary to these directions. (5) The modes that can carry the angular momentum toward the center of the plasma column can be suppressed when a strong gradient of the particle density is produced. Therefore the rotation in the central part of the plasma column should disappear when a strong particle density gradient is produced.

A cycle of experiments carried out during the past year has confirmed all these points [2]. In particular, experiments were performed at MIT by the Alcator CMod machine where the transition from the L-regime to the H-regime was programmed so that a state of zero velocity could be reached as the velocity inverted its direction as predicted by the theory. Then as the plasma entered the H-regime, the rotation was seen to start from the outside. The time scales for the inward propagation of the angular momentum and the outward transport of thermal energy were found to be comparable. Moreover, when a strong density gradient was produced on a "shell" within the plasma column, the rotation was observed to disappear within the shell as predicted by the theory. The observation that the modes excited at the edge of the plasma column invert their phase velocities in the transition from the L-regime to the H-regime has been confirmed by further experiments carried out by the JET facility in England.

*Sponsored in part by the U.S. Department of Energy

[1] B. Coppi, *Nucl. Fus.*, **41**, 12, 1 (2002)
[2] B. Coppi, in Proceedings of the 2002 International Conference on Fusion Energy, paper TH/P1-02 (Publ. I.A.E.A., Vienna, 2002) to be published in *Nucl. Fusion*