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The tokamak density limit: A thermo-resistive disruption mechanism[1]

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A magnetic island growth mechanism based on radiative cooling of the internal island flux surfaces [1] is shown to produce the correct physical scaling [2] to explain one of the long standing mysteries of tokamak physics - the empirical Greenwald density limit [3]. In this presentation we will review the phenomenology of the density limit and the correlation between the Greenwald limit and the onset threshold for radiation-driven tearing modes. The behavior of magnetic islands with a 3D electron temperature distribution which is consistent with a large ratio of radial to parallel heat conductivity - and a corresponding 3D resistivity profile - is examined for islands with near-zero net heating in the island interior. The effect of varying impurity mix on the local island onset threshold is consistent with the established experimental scalings for tokamaks at the density limit. A simple analytic theory [4] is developed which reveals the effect of heating and cooling in the island interior as well as the effect of island asymmetry. It is shown that a new term accounting for the thermal effects of island asymmetry is a crucial addition to the Modified Rutherford Equation. The resultant model exhibits a robust onset of a rapidly growing tearing mode - consistent with the disruption mechanism observed at the density limit in tokamaks. Additionally, a fully non-linear 3D cylindrical calculation is performed that simulates the effect of net island heating / cooling by raising / suppressing the temperature in the core of the island. In both the analytic theory and the numerical simulation a sudden threshold for explosive growth is found to be due to the interaction between three distinct thermal non-linearities, which affect the island resistivity, thereby modifying the growth dynamics. Expanding on the model presented, we speculate that the mechanism described may be applicable to a much wider range of tokamak disruptions than just those near the Greenwald limit.

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[4] R. B. White et al, Phys. Plasmas **22** (2015) 022514.

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