Blobs and drift wave dynamics

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Blobs, high plasma density coherent filamentary structures, propagating in tokamak edge toward outer wall with speed ~1 km/s, play an important role in the scrape-off layer plasma transport in both L-mode and H-mode in between ELMs [1]. Although the blobs are studied for about 15 years, the mechanism(-s) of blob formation is still under debates. Meanwhile blobs are often observed inside the separatrix where they move mainly in poloidal direction and once in a while cross the separatrix and appear in the SOL (e.g. see Ref. 2) Recently [3], the Hasegawa-Mima equation [4] was generalized by considering Boltzmann electrons and keeping all nonlinearities, which gives:

$$\frac{d\phi}{dt} - \rho_s^2\left(\frac{1}{2}\frac{d(\nabla\phi)^2}{dt} + \frac{d\nabla^2\phi}{dt}\right) - \Lambda\vec{e}_x\cdot(\vec{V}_0 - \rho_s^2\frac{d\nabla\phi}{dt}) = 0, \qquad (1)$$

here we are using a standard notation while x and y are radial and poloidal coordinates. This equation has two integrals:

$$I_1 = \left\langle \exp(\phi - \Lambda x)\right\rangle_{xy}, \qquad I_2 = \left\langle \phi - \rho_s^2(\nabla\phi)^2/2\right\rangle_{xy}. \qquad (2)$$

In Ref.2 it was shown that Eq.(1) has traveling wave solution F(x,y,t)=F(y-Ut), which at large amplitude resembles blob-like structure. Moreover, from the conservation of the first integral in Eq.(2) it fallows that in the amplitude of wave-packet propagating in the direction of decreasing background plasma density will increase exponentially with the distance travelled until nonlinear effects become important. The results of our 1D and 2D numerical solutions of Eq.(1) support our analytic results. In 1D case (neglecting x-dependence) the amplitude of normalized electrostatic potential is limited by the second integral, while in 2D case it growing exponentially and then saturates at the level ~1 by nonlinear effects. At this stage, normalized density bursts reaching factor ~3, which is close to experimental observations of blob plasma density in the vicinity of the separatrix.

References

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