Non-diffusive cross-field plasma transport observations on START and MAST

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It has been reported that in tokamaks plasma originating from the core may recycle at the first wall rather than flow into the divertor [1,2]. Moreover, it appears that the wall recycling may not depend on how far the wall is from last closed flux surface which implies that this fast radial plasma transport exhibits convective features which can be associated with the motion of plasma filaments/blobs seen at the edge with fast cameras and other diagnostics [3].

There is evidence of non-diffusive cross-field plasma transport at the edge of spherical tokamaks (ST) plasma. Streamers, filaments, blobs and other visible light perturbations have been often seen at the edge of START and MAST [4] in double-null divertor (DND) plasmas and limiter plasmas, or "natural divertor" (ND) configurations [5], Fig.1, and also in NSTX plasmas [6]. Different types of filamentation (striation) at the plasma edge in and outside the SOL have been observed on START and MAST:

- "plume" or "pin-stripes" mainly in the divertor/exhaust region;
- long toroidal and poloidal filaments and arcs;
- edge localised "streamers".

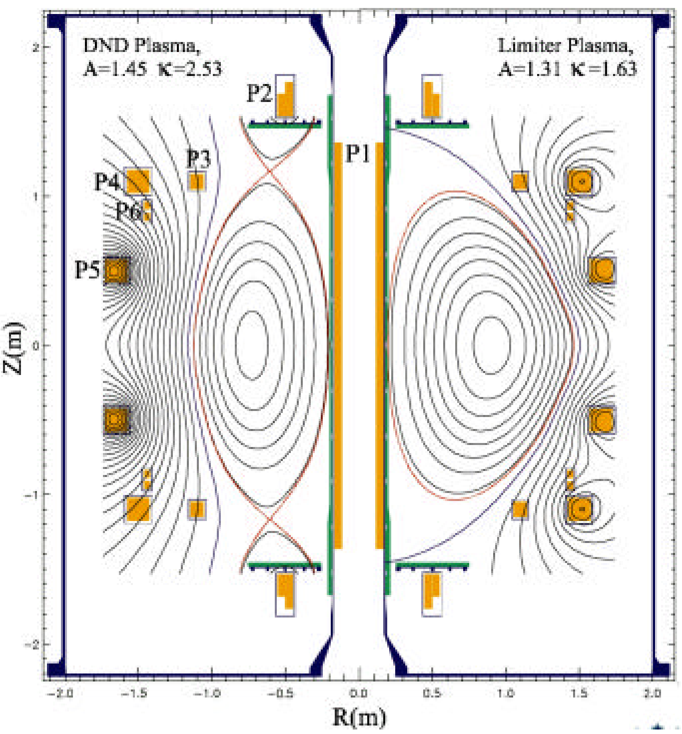

Fig.1. *Two of the possible divertor configurations on MAST: double-null (DND) and limiter, or "natural divertor" (ND) configuration*

They are clearly seen in CCD images, Fig.2, and in high-speed video film in visible light (the maximum framing speed on START and MAST can be up to 40000 frames/s). These streamers/filaments have helical structure with *n* ³ *1*, high *m* ³ *10* not necessarily coinciding with the vacuum flux structure after leaving the main plasma. They are usually better seen at higher densities ($n_e \geq 5\times10^{19}m^{-3}$). The radial extension of the filaments on START and MAST can be > 20cm. The toroidal extent can be at least one turn. The duration of a single streamer lifetime can be from tens of microseconds up to ~ 1 ms.

These events often correlate with MHD activity at the plasma periphery, they are sometimes suppressed in DND configuration and are significantly suppressed during ELM-free H-mode when the additional tenuous plasma outside the main SOL disappears, Fig.3.

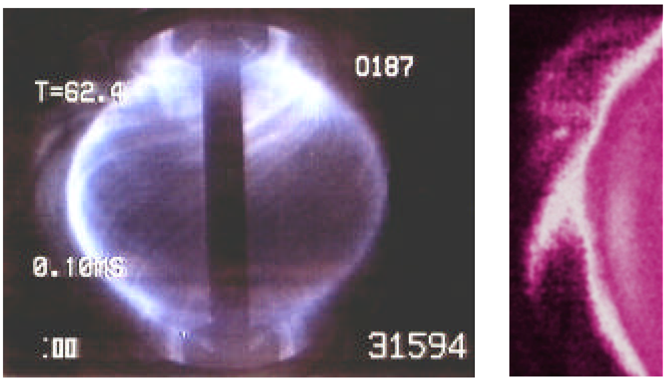

Fig.2. *Edge localised helical filaments and "streamers" seen in CCD images on START.*

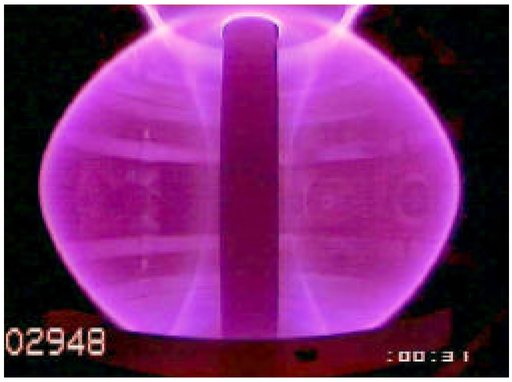

Fig.3. *MAST: The additional tenuous plasma outside the main SOL disappears during ELM-free H-mode*

The high measured cross-field diffusion through the last closed flux surface (LCFS) on START, $D_{\perp}\sim 2.7\ m^2s^{-1}$, which is higher than Bohm, together with the high density and density fluctuation level at the midplane suggest a macroscopic flow through LCFS [7].

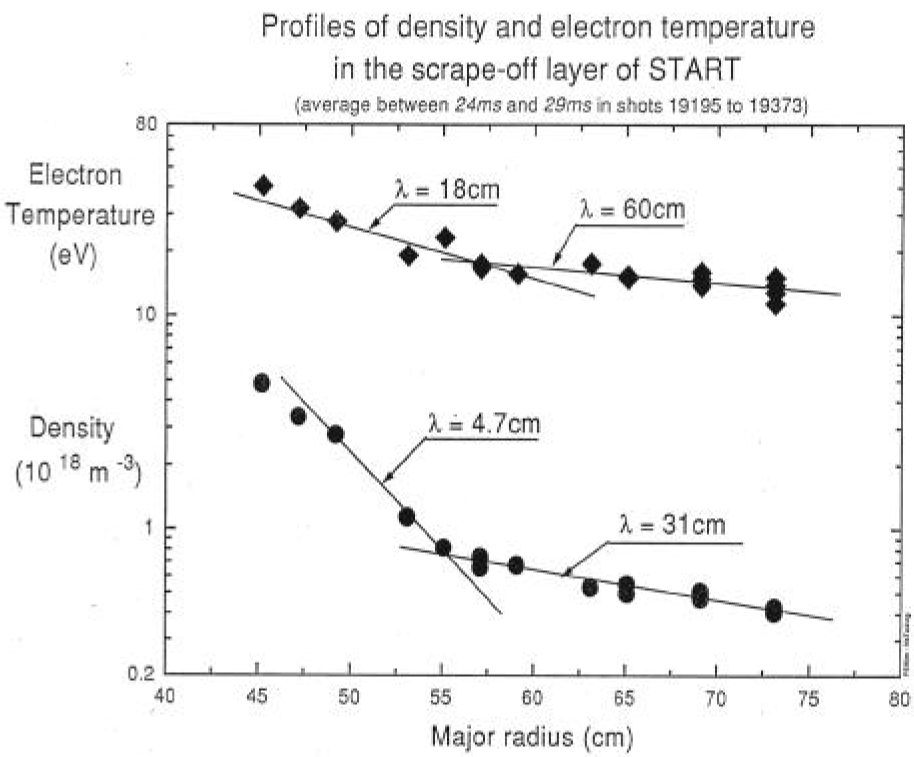

Fig.4. *SOL thickness for temperature and density measured with Langmuir probe at the midplane on START: the greater thickness observed at larger radius implies the existence of an additional "halo" tenuous plasma outside the main SOL*

These events may be connected with the non-diffusive cross-field transport through the SOL and LCFS, which feeds the “halo” tenuous plasma observed outside LCFS [8], Fig.4. The density fluctuation level can be reduced by biasing of the divertor target and by current ramp-down. This decrease is correlated with decrease in magnetic fluctuations in the core. Disappearance of the tenuous plasma also correlates with a decrease in magnetic and visible light fluctuations. These supports the suggestion that the outside “halo” plasma formation is mainly connected with non-diffusive cross-field transport across the LCFS and not with the ionisation outside the main plasma.

Bursts of a low-frequency mode are seen on some of the central column Mirnov coils. They usually last < 1ms and chirp down in frequency. These bursts correlate with the appearance of helical bright structures on the central rod seen on the HSV. A similar phenomenon has been observed on other tokamaks, for example, on DITE [9]. These "filamentary perturbations" were suggested to be connected with the existence of long, narrow filaments co-incident with magnetic surfaces and stretched along the field lines at the plasma periphery.

Cross-field transport plays an important role in divertor target power loading. In DND configuration only ~ 1/3 of the efflux power appeared at the targets on START and significant in/out divertor leg power asymmetry has been measured (~ 1/4 of the power going to the outboard side), implying significant losses across the SOL. A significant in/out divertor power asymmetry has been measured on MAST where the total outboard flow can be 10 times higher than at the inboard in L-mode (but less in H-mode). Divertor power loading is one of the key issues in STs due to potential high power load at the inner strike point. To predict the SOL performance in a next step ST it is important to investigate the role of non-diffusive cross-field plasma transport. These studies may influence the choice of the next step ST divertor design. The loss of power across the SOL, especially when combined with action to increase SOL/divertor radiation/detachment may be important to bring the inboard target loading in a burning plasma ST to an acceptable level.

Overall, we are dealing with robust phenomena, which are not only important for understanding of plasma transport, but can be crucial for power plant design.

Conclusions.

Streamers, filaments, blobs, pin-stripes and other visible light perturbations are often seen at the edge of ST as well as in conventional aspect ratio tokamak plasmas. These events often correlate with MHD activity at the plasma periphery, they are sometimes suppressed in DND configuration and are significantly suppressed during ELM-free H-mode. These events may be connected with the non-diffusive cross-field transport through the SOL and LCFS which feeds the “halo” tenuous plasma outside LCFS. Cross-field transport plays an important role in the divertor target power loading. In H-mode this transport mechanism is reduced. Additional measures to reduce the power loading in a burning plasma ST may be necessary (such as a natural divertor or divertor target biasing).

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