Personal Research Interest of Dr. Vianello

N. Vianello

Dr. Vianello's research activity has been devoted to the analysis, interpretation and modeling of experimental and numerical results obtained in the framework of high temperature plasmas, with emphasis on magnetically confined plasmas. More in details Dr. Vianello focused his attention on the electromagnetic fluctuations induced transport phenomena occurring in the edge region of confined plasmas, with interpretation in the wider framework of turbulence theory.

It is well known that transport phenomena in thermonuclear plasmas are governed by electromagnetic turbulence, which represents the main cause of the so-called *anomalous transport*. Scientific interest is further enhanced by the consideration that magnetically confined plasmas are a complex and self-organized system, which thus represents an ideal environment for non-linear dynamics studies.

During his research activity Dr. Vianello has collected a large experience on electromagnetic transport analysis, working on different magnetic configurations, from Reversed Field Pinches (working on RFX-mod operating in Padova, Extrap-T2R operating in Stockholm and TPE-1RM20 which was in operation in Japan), stellarators (with experimental activity on TJ-II heliac type operating in Spain) and Tokamaks (ASDEX-Upgrade and JET). In the following a brief overview of the principal results obtained during his research activity is reported.

Electrostatic turbulence induced transport and sheared flow interaction

At the beginning of his career Dr. Vianello studied the effect of active modification of flow shear, obtained through edge biasing experiment performed on RFX Reversed Field Pinch, on electrostatic turbulence induced particle transport [1]. Indeed Dr. Vianello has experimentally proved that flow shear enhancement causes a reduction of particle losses due to the electrostatic turbulence obtained through a modification of the phase difference between density and potential fluctuations. This reduction is not homogeneous in k-space but concentrated around wavenumber where restitive g-modes are expected to be unstable [2].

Intermittency and self-similarity studies

Strong effort has been devoted to the studies of the statistical properties of electromagnetic turbulence as measured at the edge of fusion relevant plasmas. It has been proved that magnetically confined turbulence exhibits an high degree of intermittency: this phenomenon is actually responsible for the lack of self-similarity which causes the breaking of Kolmogorow paradigm of turbulence energy cascade with the existence of localized (in time and space) stronger fluctuations which can be better described as *coherent structure* observed in various devices [3–5]. The experimental verification of this lack of self-similarity has been made possible through a multi-scale analysis, realized through the application of advanced analysis technique borrowed from fluid dynamics such as *Continuos Wavelet Transform* and *Local Intermittency Measurements*. The observations done by Dr. Vianello and co-authors allowed also to discriminate the applicability of the so-called *Self Organized Criticality* paradigm to fusion plasma turbulence: indeed it has been proved that this dynamical model does not apply to fusion plasmas [6, 7] as SOC models are inherently self-similar (apart models where characteristics scales, which are in open contradiction with the original SOC paradigm, are *ad hoc* introduced). Interestingly similar observations have been compared with solar wind and hydrodynamical turbulence[8] showing remarkable similarities.

Coherent structures and filaments

As aforementioned intermittent character of electromagnetic turbulence is caused by the presence of strong localized fluctuations often referred as *blobs* or *coherent structure*. Extensive experimental and interpretative work has been done by Dr. Vianello in order to characterize completely these fluctuations. These structure exhibit an higher pressure than the surrounding plasma, with a vortex-like velocity pattern resembling monopolar or dipolar vortices [9, 10]. They have been found to strongly contribute to particle and energy transport through their radial convective motion and also through an enhancement of particle and heat diffusivity through their merging and coalescence [3, 11]. These structures have also been electromagnetically characterized, providing the first direct measurements of the parallel current associated to a plasma blob in a thermonuclear relevant plasma [12, 13]. An accurate interpretation of the measurements proved also that these blobs, as detected in the edge region of an RFP plasma are actually *drift-kinetic alfvén vortices* [14] resulting from the non-linear coupling of drift and kinetic alfvén waves. Indeed pioneering studies of current filaments associated to plasma blobs have been extended during the research activity of Dr.Vianello with measurements performed in stellarators [15], in simple magnetized torus [16, 17] and in low current ohmic tokamak [15]. Expertise in current filaments studies has been extended to the studies of ELM filaments providing for the first time an experimental direct estimation of the current density associated to a type-I filament [18–20].

Momentum transport studies

Deepening the subject of interaction between turbulence and flow, Dr. Vianello focused on the turbulence flow generation processes [21, 22] through Reynolds and Maxwell stresses. Providing pioneering measurements on Reversed Field Pinches of both the quantities, and actually first measurements of Maxwell stress in a fusion relevant plasma, Dr. Vianello proved that, despite the high level of magnetic fluctuation characterizing the RFP configuration, perpendicular flow is still driven by electrostatic turbulence. The analysis has been further extended considering the whole energy transfer process between fluctuations and mean fields, including Kinetic and Magnetic energies [23], trying to establish the whole scheme of relationship between energetic basins and sinks. Interestingly those analysis have drained attention very recently as they are suspected to have a role in driving H mode in tokamak plasmas as shown for example in [24, 25], through the so-called Limit Cycle Oscillations.

3D Physics

In present fusion research a strong effort is devoted to the comprehension of the effects of a 3D magnetic field on the plasma. Indeed, apart from the research line devoted to strongly 3D shaped plasmas as stellarators [26], non-axysimmetric magnetic fields are now considered as fundamental also for configurations long considered as toroidally symmetric, or inherently 2D. In fact, 3D fields are considered for example as a viable technique for momentum variation in torqueless tokamak plasmas [27, 28] or for mitigation of power loads on the divertor [29]. Among all of these tools, it is worth mentioning Resonant and Non Resonant Magnetic perturbations for ELM control, which are presently installed in all of the major tokamaks [29–32], and foreseen also for next generation devices [33]. These experiments share the rationale of the edge ergodization obtained for example in the DED experiment at TEXTOR [34], and more generally to the island divertor concept developed for present and future stellarators [35].

The edge physics of the improved confinement regime observed in high current operations in Reversed Field Pinch (RFP) configuration [36], whose discovery and characterization Dr. Vianello has actively contributed, exhibits strong analogies with physical phenomena observed in 3D magnetic configurations.

In particular in recent years Dr. Vianello focused his attention on the interaction between non-axysimmetric magnetic field and flow. It has contributed to the observation of the role of magnetic islands in determining the flow pattern associated to the MARFE phenomenon [37, 38] occurring in high density regime in an RFP and more recently to the existence of an helical flow pattern velocity, as the result of an ambipolar electric field response to a magnetic perturbation in helical Reversed Field Pinches [39]. The provided experimental evidences exhibit analogies with the RMP experiments, suggesting the necessity to correctly consider the spatial phase relation between experimental observations and magnetic perturbations also in the case of non-axysimmetric tokamak plasmas. Magnetic perturbation causes also the modification of pressure profiles, with different behavior of density and temperature: as a consequence high-k turbulence has been found to be profoundly influenced [40] and this phenomenon represents the present subject of investigation of Dr. Vianello.

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