Spatiotemporal structure of Geodesic Acoustic Modes in the edge plasma of TEXTOR

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Introduction and Diagnostic Setup

The spatiotemporal structure of Geodesic Acoustic Modes (GAMs) was investigated in the r/a=0.85-1 radial range of Ohmically heated TEXTOR limiter plasmas. Three diagnostics are capable of measuring GAMs in TEXTOR: reflectometry in the inner region in the equatorial plane and at the top of the plasma, Langmuir probes at the very edge, and a 14-channel Lithium Beam Emission Spectroscopy (Li-BES) diagnostic in the whole r/a=0.85-1.0 radial range, with a radial resolution of about 1 cm. This range overlaps with both the range of reflectometry and probe at its two edges. The Langmuir probes and the Li-BES make measurements in the equatorial plane. The location of the diagnostics is presented on *Fig.1*.

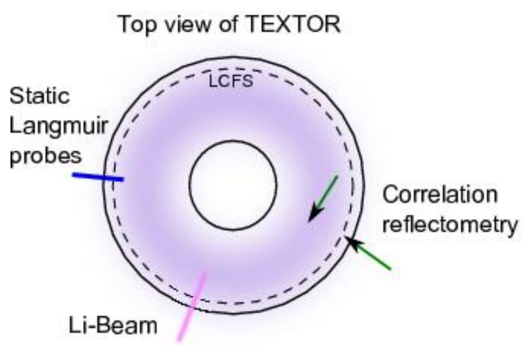

Fig.1. Location of diagnostics used for GAM measurements at TEXTOR.

Plasma and turbulence signal

Only Ohmic plasmas (R=173 cm, a=46 cm) were studied now, where the plasma current was varied between 250-350 kA, the toroidal magnetic field was 1.9-2.25 T. Long time averages (1-3 s) were computed during the stationary regime. The edge turbulence is dominated by a quasi-coherent (QC) mode [1] which has a broad spectral peak typically in the 30-130 kHz range (see *Fig.2.(a)*). The peak around 15 kHz originates from modulation of the background light in the Li-Beam observation system. As it is highly coherent with GAM velocity modulations it is believed to be a result of Bremsstrahlung modulation by the GAM-related density oscillations at the bottom of the plasma. The presence of the QC mode is localized in the edge plasma R=216-221 cm, see *Fig.2. (b)*.

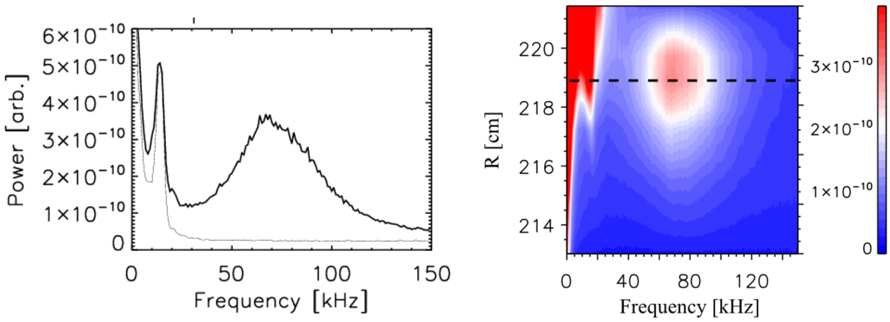

Fig.2.(a) Power spectrum of Li-BES signal at R=219 cm, shot 110281. The thin line shows the spectrum when the beam is off; (b) Contour plot of power spectra of all 14 Li-BES signals. The dashed line refers to the position where Fig.2.(a) was computed. The estimated position of the LCFS is at R=221-222 cm.

Velocity calculation and other GAM-related signals

The poloidal velocity fluctuations were determined from the motion of the QC turbulence structures using both one point and two point Time Delay Estimation (TDE) methods [2] and the obtained results were cross-checked. The power of the QC mode drops significantly inside R=216 cm, therefore the sensitivity of the TDE methods is limited to R>216. Power spectra of time delay signals show a peak with mean frequency in the 10-20 kHz range. The modulation in the peak is highly correlated across all diagnostics and shows all properties of GAMs [3,4]. Additionally to the velocity, the potential fluctuations related to GAM activity were also studied with probes. The density component of the GAM can be seen at the top and bottom of the plasma with reflectometry and in the background light of the Li-BES diagnostic optics (see *Fig.2.(a)*)

GAM properties

On the spatial resolution of the Li-BES diagnostic a single peak is observed in the spectra of velocity (time delay) modulations at all radii where GAMs are detected. An example is presented on *Fig.3.(a)*.

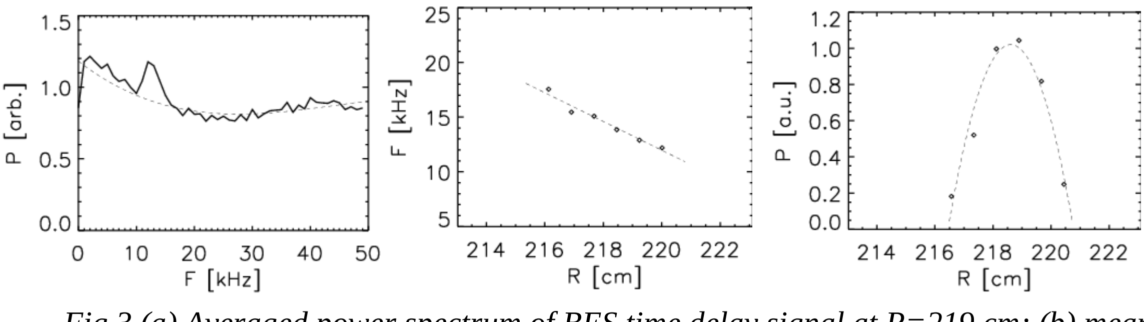

Fig.3.(a) Averaged power spectrum of BES time delay signal at R=219 cm; (b) mean frequency of GAM peak versus radius; (c) power vs. radius. (Shots: 110281, 110283, 110287.)

The mean frequency of the peak is calculated after subtracting a fitted background. Its dependency on the minor radius is shown in *Fig.3(b)*: a linear dependence is found in the r/a=0.9-1 radial range. The FWHM of the peak in the frequency spectra is about 3 kHz indicating a few hundred microsecond lifetime of the velocity oscillations.

Long-range correlation

As the three diagnostics are located at different toroidal and poloidal positions of the tokamak, it is possible to study the poloidal and toroidal symmetry properties. The radial structure was studied using the radially resolved Li-BES data.

A significant coherency with 0 phase shift was found in the GAM frequency domain between velocity modulations calculated from different diagnostics when measuring at the same radius. This clearly indicates the expected m=n=0 structure.

For the study of the radial structure spatiotemporal correlation functions of time delay signals from Li-BES data are used. As reference a time delay signal from either reflectometry or probe is taken, this way keeping only the long-range correlation in the signals. The radial and temporal structure of the GAMs is significantly different at r/a=0.9 (*Fig.4.(a)* and *(b)*), where a clear radial phase shift is observed, and at r/a=0.98 (*Fig.4.(c)*), where this is much less pronounced.

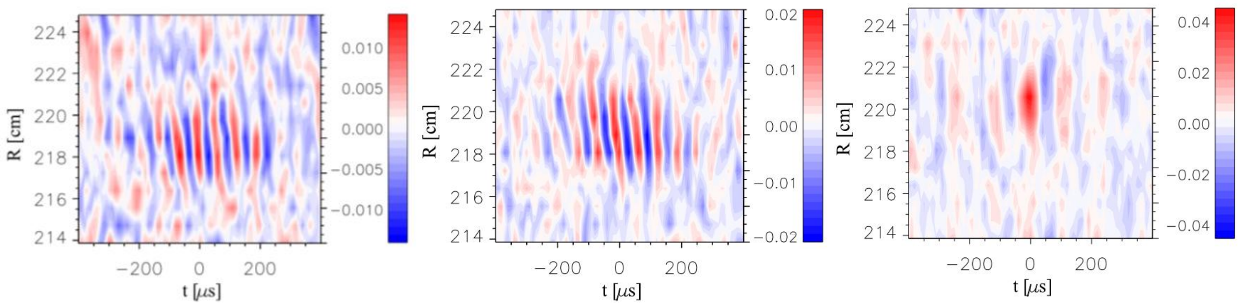

Fig.4. Spatiotemporal structure of GAMs. Reference signal is (a) TD from phase of reflectometry top antenna (shot 110281), (b) TD from phase of reflectometry equatorial plane antenna (shot 110283) and (c) TD from floating potential signal of Langmuir-probe located in the equatorial plane (shot 111629).

Attempt for interpretation

Empirical simulations were carried out to understand the observed spatiotemporal structures at r/a~0.85. A GAM was modeled by a decaying oscillation (see *Fig.5.(a)*). This was convolved with a random excitation function that had zero correlation time and finite radial correlation width. The excitation was poloidally and toroidally symmetric, resulting the m=n=0 mode structure. The frequency was a linear function of the radius. This model velocity field was used to move modeled turbulence with parameters fitted to the QC mode in the experiment. Finally the detector noise was modeled by adding uncorrelated, normally distributed noise. The velocity field was determined from this modeled turbulence data using the same on point TDE program used in the experiment. The spatiotemporal correlation function of the computed velocity signals are presented on *Fig.5.(b)*, which is similar to *Fig.4.(a)* and *(b)*. The best results were obtained when a radial inward propagation of the velocity oscillation was assumed with about 1 km/s velocity.

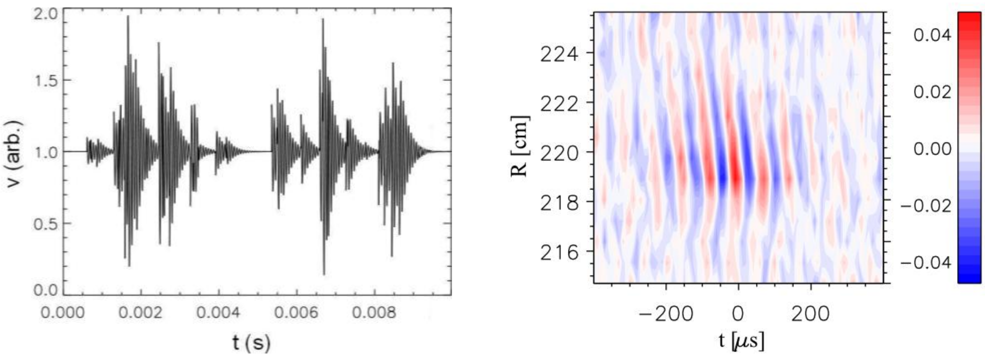

Fig.5.(a) Model velocity signal with decaying oscillations. (b) Spatiotemporal correlation function computed from the model turbulence signals.

Conclusions

GAMs are seen at TEXTOR from in the radial range R=216-220 cm consistently by three diagnostics at different toroidal and poloidal locations. The temperature dependence of the frequency scaling was checked previously [3]. The frequency changes linearly vs. radius, which is in good agreement with theoretical expectations. The phase between the velocity signals at the GAM frequency is zero at toroidally and poloidally shifted measurement points, which corresponds to the m=n=0 structure. The radial-temporal correlation functions show various properties of the GAMs: the typical lifetime is 150 μs, the radial correlation length is 1-2 cm. At r/a~0.85 the radial structure can empirically be modeled by assuming radially extended excitation and inward GAM propagation.

References

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