The Spatiotemporal Structure of Geodesic Acoustic Modes in the Edge Plasma of TEXTOR

S. Zoletnik[1], L. Bardoczi[1], G. Anda[1], D. Dunai[1], G. Petravich[1], D. Réfy[4], A. Krämer-Flecken[2], I. Shesterikov[5], S. Soldatov[3], Y. Xu[5] and the TEXTOR Team[2]

1 KFKI RMKI, Association EURATOM, Budapest, Hungary
2 Institut für Energieforschung – Plasmaphysik, Forschungszentrum Jülich GmbH, Association EURATOM, Trilateral Euregio Cluster, Jülich, Germany
3 Department of Applied Physics, Ghent University, Rozier 44, 9000 Gent Belgium
4 Budapest University of Technology and Economics, Association EURATOM, Hungary
5 Laboratory for Plasma Physics, Ecole Royale Militaire /Koninklijke Militaire School, Brussels, Belgium

Abstract

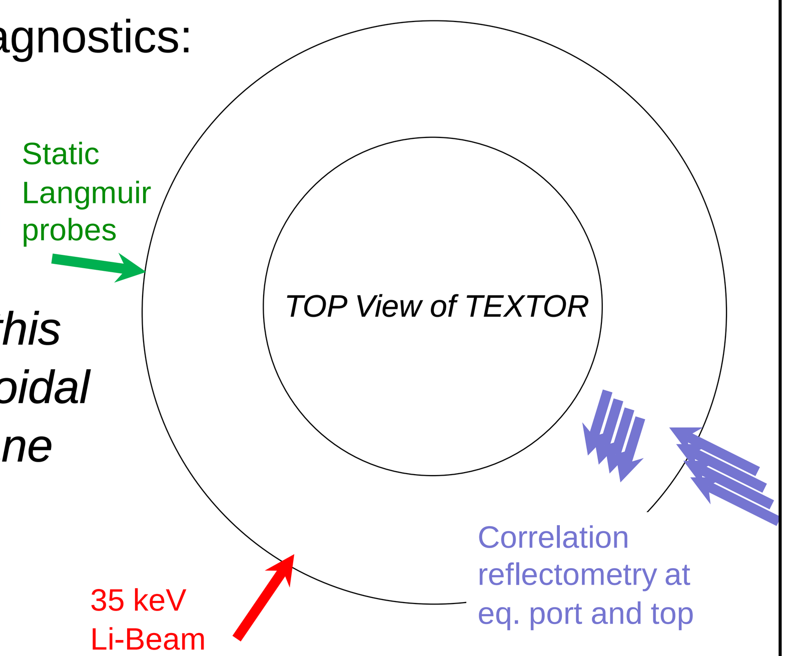
The spatial and temporal structure of Geodesic Acoustic Modes (GAMs) in the r/a=0.9...1 radial range of Ohmically heated TEXTOR plasmas is studied via spectral and correlation analysis involving 3 independent diagnostics: reflectometry, probes and Li-beam. The GAM frequency changes continuously as a function of radius. The long-range correlation of the velocity modulations clearly obeys to m=0, n=0. Similarly to other experiments the radial phase structure shows liner phase shift, but correlation analysis reveals a more complicated structure. Empirical modelling of the correlations indicates that radially extended GAM excitations are needed to explain the results.

Diagnostics

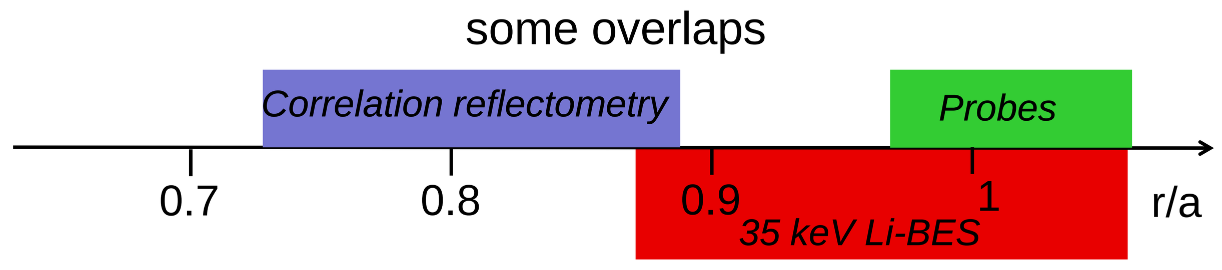
GAMs are detected with 3 diagnostics:

- Static probes [1]
- 35 keV Li-BES [2]
- Correlation reflectometry [3]

Measurements presented in this poster are performed at 3 toroidal locations in the equatorial plane + top of plasma



Radially these diagnostics cover the r/a=0.75...1.1 range with some overlaps



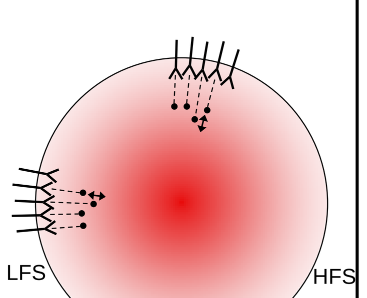
GAMs are measured through different effects:

- Potential modulation measured by floating potential probes[1]
- GAM density component is seen by reflectometry at θ≈100º[2]
- Through the movement of ambient turbulence in all 3 diagnostics

The poloidal-radial resolution of diagnostics as used in this analysis:

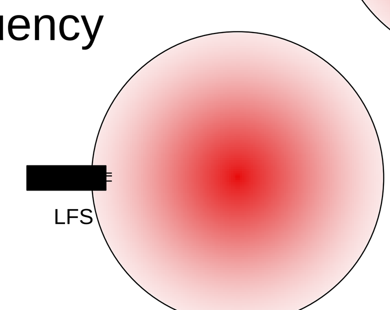
Reflectometry:

- 5 poloidally displaced antennas each in
- 2 cross-sections
- 1 antenna with step-tunable frequency



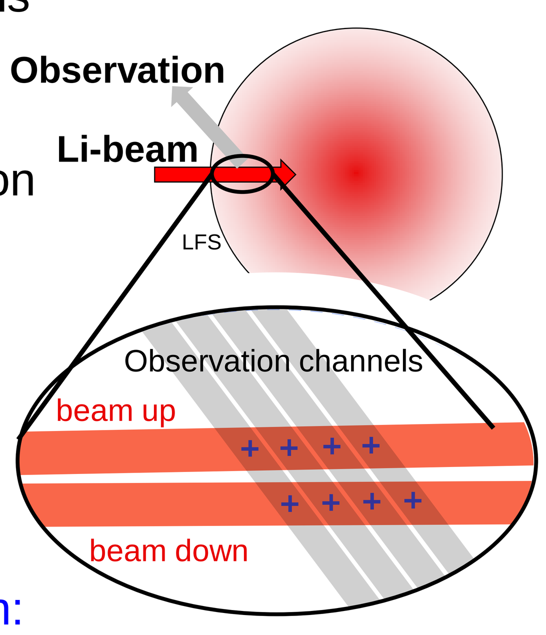
Probes:

- Multi-pin head at fixed position
- Ion saturation and floating probe signals



Li-beam[4]:

- 14 channels with 1 cm radial separation
- 2.5 MHz sampling, SNR: ~50
- Beam hopping for quasi-poloidal resolution at 417 kHz



Studies:

Poloidal-toroidal structure determination:

Coherency/crossphase analysis of all 3 diagnostics

Radial structure in r/a=0.9-1.0:

Li-beam using other diagnostics as reference.

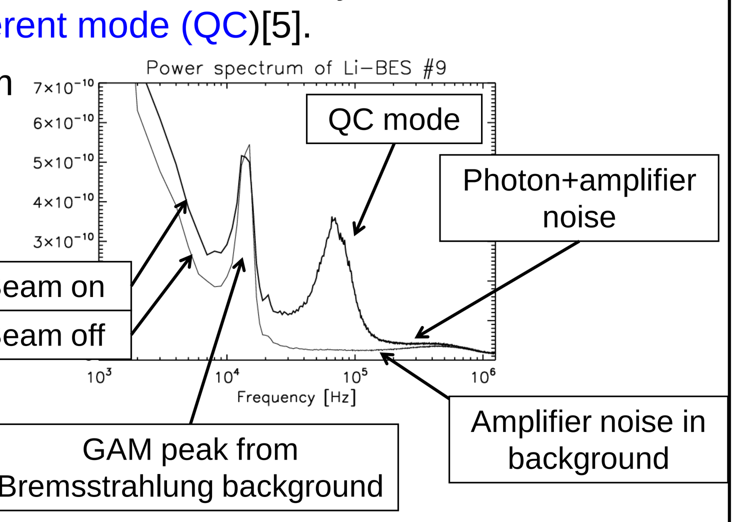
References

[1] Y. Xu , *et al., 36th EPS Conference on Plasma Phys. Sofia,* **ECA Vol.33E**, P-1.191 (2009)
[2] A. Krämer-Flecken, *et al. Plasma Phys. Control Fusion* **51** 015001 (2009)
[3] S. Zoletnik, *et al., 36th EPS Conference on Plasma Phys. Sofia,* **ECA Vol.33E**, P-1.192 (2009)
[4] G. Petravich, *et al. to be submitted to Rev. Sci. Instrum*
[5] A. Krämer-Flecken, *et al. Nucl. Fusion* **44** 1143 (2004)
[6] T. Ido, *et al., Nucl. Fusion* **46** 512 (2006)
[7] G. McKee, *et al., Phys. Plasmas* **10** 1712 (2002)

Turbulence properties at the edge of TEXTOR

Edge plasma turbulence is dominated by a broadband mode, also called quasi-coherent mode (QC)[5].

Typical power spectrum of Li-BES channel Shows QC mode and GAM signal from Bremsstrahlung background



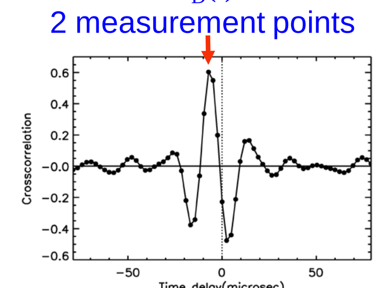
The QC mode is absent in the SOL.

Velocity calculation

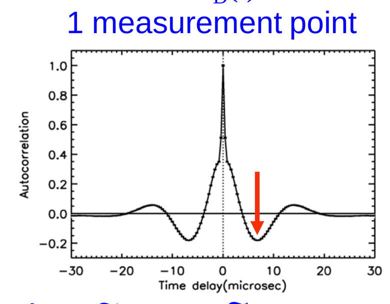
A time delay signal $\tau_D(t)$ is calculated from various diagnostic signals using different algorithms:

- Where two poloidally displaced measurement points are available TDE is used.
- Where only 1 signal is available TDE is used on the minimum of the autocorrelation function (ACFM). This method relies on the QC nature of edge turbulence and assumes constant poloidal wavelength.

TDE: $\tau_D(t)$ from 2 measurement points



ACFM: $\tau_D(t)$ from 1 measurement point



Assuming small velocity modulation: $\tilde{\tau}_D(t) \sim -\tilde{v}_p$

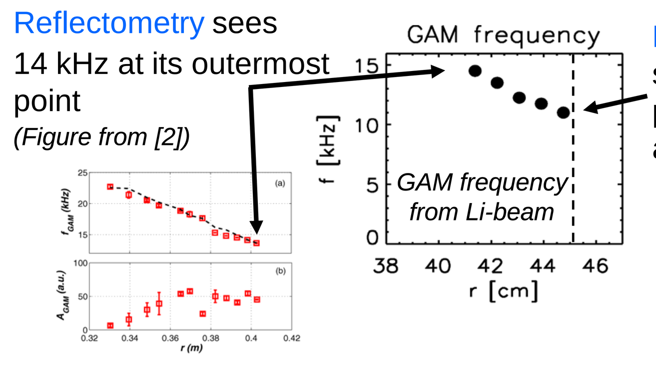
Signals are always filtered for QC band before processing to ensure removal of GAM frequencies from Li-BES background.

TDE and ACFM time delay signals were cross-checked where possible. ACFM has proven to be a suitable method in the TEXTOR edge plasma

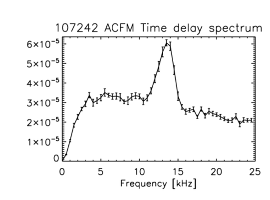
GAM frequency

In the r/a=0.85...1.0 range GAM frequency increases continuously from 8-10 kHz at the LCFS to 15-17 kHz at r/a~0.85.

Reflectometry sees 14 kHz at its outermost point *(Figure from [2])*



Langmuir probe sees 10 kHz floating potential modulation around LCFS[1]



A typical spectrum of $\tau_D(t)$ signal from Li-beam

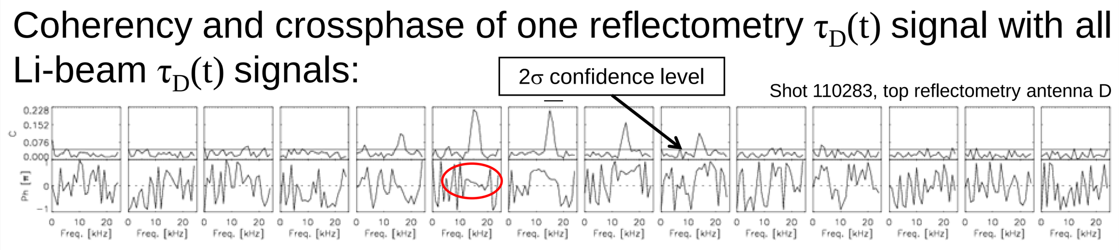
Deeper in the plasma reflectometry indicates co-existence of multiple GAM rings.

Long-range correlation of poloidal velocity modulations (poloidal-toroidal GAM structure)

Coherency between Li-beam and reflectometry $\tau_D(t)$ signals

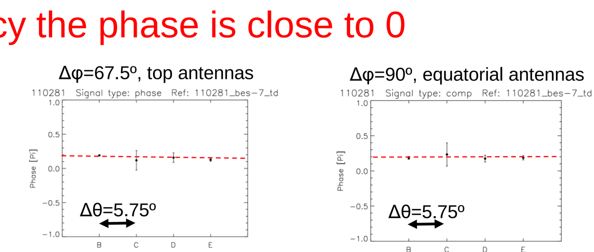
$\tau_D(t)$ signals are calculated from reflectometry phase signals and Li-beam signals.

Coherency and crossphase of one reflectometry $\tau_D(t)$ signal with all Li-beam $\tau_D(t)$ signals:



At the highest coherency the phase is close to 0

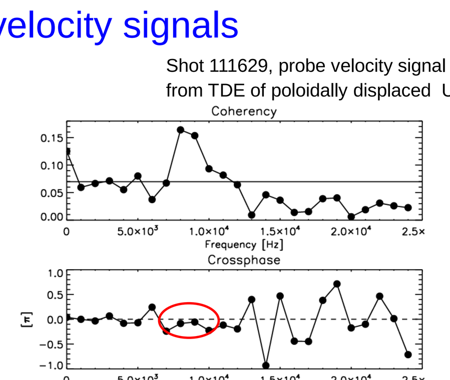
The crossphase between the Li-beam $\tau_D(t)$ signal at the highest coherency and all reflectometry $\tau_D(t)$ signals.



Crossphase is independent of both poloidal and toroidal angles.

Coreherency with probe velocity signals

Coherency and crossphase between probe time delay signal (two-point TDE) and Li-beam time delay signal at LCFS.



Crossphase is 0 at GAM frequency

Velocity modulations have clear m=0, n=0 structure

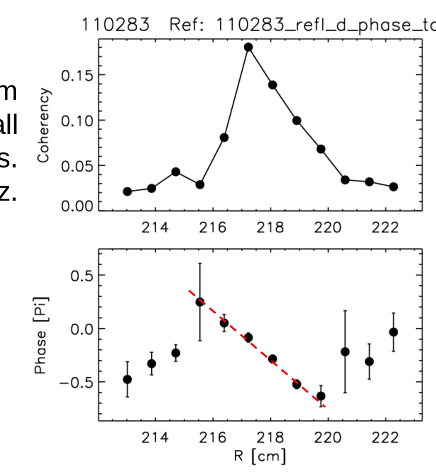
Radial structure

The time delay signals contain inevitable broadband noise originating from the calculation method. This noise is radially correlated due to the radial correlation of turbulence and Li-beam atomic physics.

To avoid the effect of noise time delay functions from different diagnostics are used: measurement points are not in the same flux tube → noise effect of turbulence is uncorrelated, correlation functions and crossphase indicate radial structure of global velocity modulations.

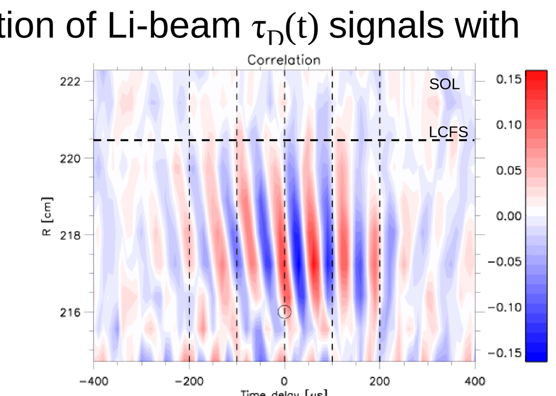
r/a~0.9-0.95

Crossphase of $\tau_D(t)$ from reflectometry antenna D and all $\tau_D(t)$ from Li-beam signals. Frequency range is 13.5-17 kHz.



A linear phase shift is seen as a function of radius: similar to other measurements e.g. [6,7].

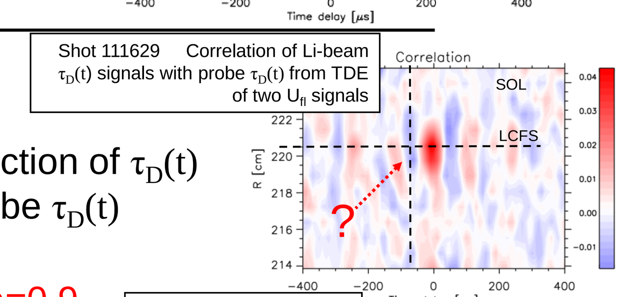
Spatiotemporal correlation function of Li-beam $\tau_D(t)$ signals with reflectometry $\tau_D(t)$ as reference.



Complicated structure, correlation exists between radial locations with different GAM frequency.

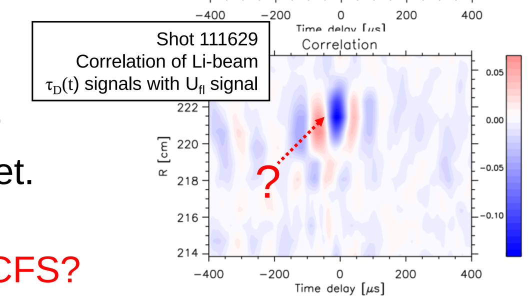
r/a~1

Spatiotemporal correlation function of $\tau_D(t)$ signals from Li-beam, with probe $\tau_D(t)$ (TDE) as reference.



Correlation is different from r/a=0.9.

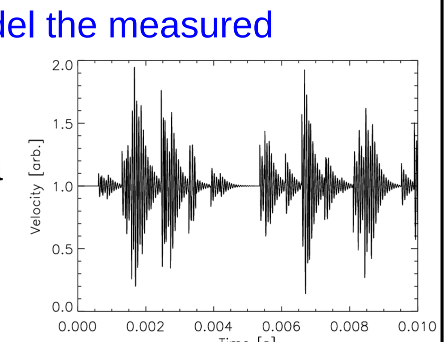
Correlation with probe U_{fl} has better statistics but more difficult to interpret.



Signature of GAM propagation to LCFS?

Empirical modelling of radial structure

An attempt was made to qualitatively model the measured correlation function at r/a=0.9-0.95:



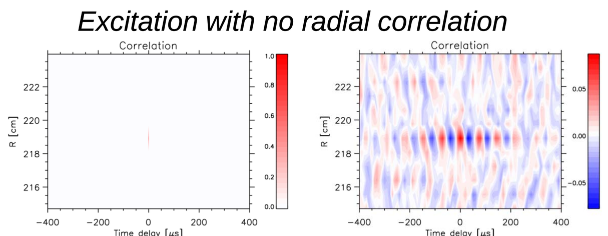
- Random GAM excitation at each radius, radial correlation length of excitation is a free parameter
- Velocity signal generated by convolving excitation with local kernel function (modulated sinusoidal)
- GAM frequency is linear function of radius
- Infinite lifetime spatial (poloidal) turbulence structure is moved with modeled local GAM velocity. Broadband detector noise added.
- $\tau_D(t)$ and correlation calculated from simulated signals using the same procedure as for the experiment

Conclusions:

Few cm radial correlation is needed in excitation to reproduce correlation between different frequency GAMs.

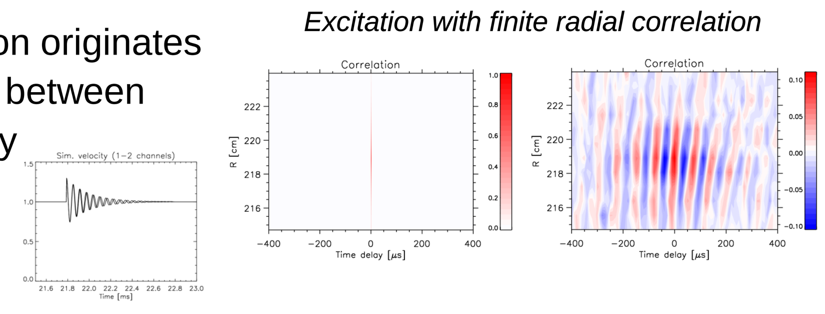
Excitation | Modeled experiment

Excitation with no radial correlation



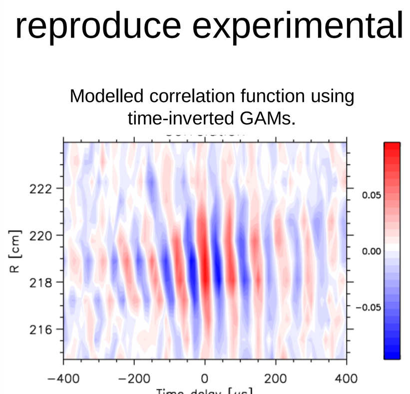
Slope of correlation originates from phase delay between different frequency GAM layers.

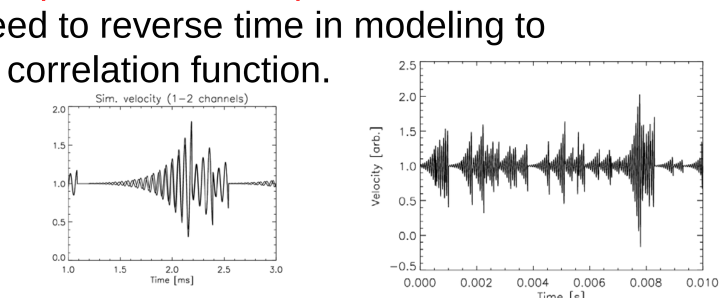
Excitation with finite radial correlation



Apparent GAM propagation is consequence of GAM frequency scaling and radially correlated excitation. An apparent GAM k_r can also be calculated.

Decaying GAMs cannot reproduce the slope of the measured correlation functions. Need to reverse time in modeling to reproduce experimental correlation function.





These growing GAMs can reproduce the correct phase structure of measurement.