Progress in understanding quasi-coherent modes through gyrokinetic simulation

J. Citrin[1] (J.Citrin@differ.nl)[1,2], H. Arnichand[2], J. Bernardo[3], C. Bourdelle[1], X. Garbet[2], S. Hacquin[2], R. Sabot[2]

[1]FOM Institute DIFFER – Dutch Institute for Fundamental Energy Research, Association EURATOM-FOM, Partner in the Trilateral Euregio Cluster, The Netherlands, www.differ.nl,
[2]CEA, IRFM, F-13108 Saint Paul Lez Durance, France, [3]5 Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade Técnica de Lisboa, 1049-001 Lisboa, Portugal

1. Quasi-coherent modes in Tore-Supra

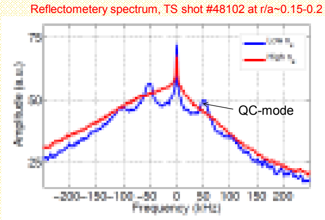
Reflectometer spectra of ion-scale turbulence can have several characteristics [1,2]

- Coherent modes ($\Delta f \sim 1$ -10kHz). Related to e.g.,GAMs
- Broadband fluctuations ($\Delta f \sim 100$s kHz). Associated with turbulence
- Quasi-coherent (QC) modes. ($\Delta f \sim 10$s kHz). Appear in specific regimes in multiple machines. Their origin is yet to be determined

We focus on QC-mode observations In an Tore-Supra Ohmic plasma #48102 [3]
Shot has density ramp, and passes through an LOC-SOC transition.

QC-modes observed in LOC phase. Low density - $\bar{n} \approx 2.4 \cdot 10^{19}$ [m^{-3}]
QC-modes disappear in SOC phase. High density - $\bar{n} \approx 4.6 \cdot 10^{19}$ [m^{-3}]

Reflectometery spectrum, TS shot #48102 at r/a~0.15-0.2



Simulate turbulence in these phases with the nonlinear gyrokinetic code GENE [4].
Analyze simulated nonlinear frequency spectra for qualitative differences

Questions: LOC-SOC transitions proposed to be related to a turbulence regime transition from TEM-ITG [5]. Do we observe this transition? Are the characteristics of each regime related to the appearance or nonappearance of QC-modes?

See talk of H. Arnichand (this conference) for further details

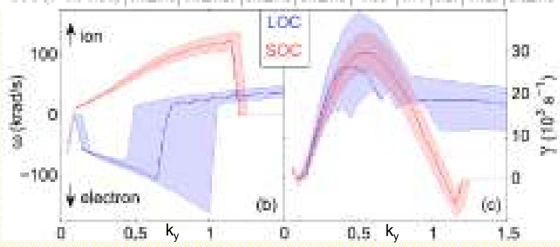
2. Linear calculations

Initial value linear GENE simulations for #48102 parameters at r/a=0.37

Outside reflectometry measurement location due to better profile diagnostics.
Still relevant since reflectometry measurements typically show QC-modes signals persist over a wide radial extent

Linear-GENE input (from a CRONOS [6] interpretative simulation) and results.
Growth rate uncertainties found by propagating the logarithmic gradient uncertainties.

Phase	R/L_{Ti}	R/L_{Te}	R/L_{ne}	T_e/T_i	f_c [%]	ϵ	q	ν^*	Z_{eff}
LOC (t=3.0-3.4 s)	4.7±0.5	9.2±0.35	2.8±0.1	1.8±0.1	0.13	0.7	1.3	0.012	3.0±0.1
SOC (t=5.8-6.4 s)	5.0±0.4	8.0±0.25	1.8±0.1	1.0±0.1	0.14	0.75	1.25	0.029	1.4±0.1



LOC phase dominated by TEM modes
SOC phase dominated by ITG modes

- LOC→SOC transition here is indeed related to TEM→ITG transition
- Dedicated tests show that dilution and R/L_n are the strongest players in this transition, followed by collisionality.

References

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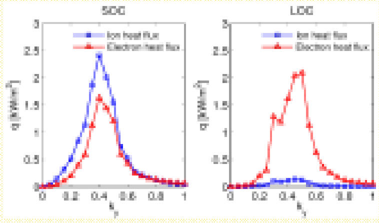
4. Nonlinear simulations – close to experiment?



Comparison of simulated and experimental fluxes. All values in kW/m²

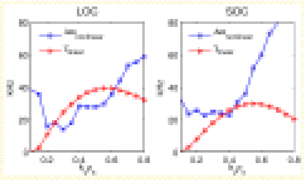
	Power balance		GENE	
	q_i	q_e	q_i	q_e
LOC	4.5 ± 1	6.7 ± 1	1 ± 1	12 ± 3
SOC	14 ± 3	-1 ± 3	14 ± 2	9 ± 2

- Convergence of GENE simulations carefully verified
- GENE uncertainties from simulation intermittency.
- Power balance uncertainties from propagation of T_i and T_e errors in collisional heat transfer
- Agreement with nominal parameters apart from SOC q_e.
- Error bars to be further improved by propagating driving gradient errors in GENE simulations, and assessment of potential Ti-Te systematic errors

Bottom line: justified to relate the simulation frequency spectra to the experiment

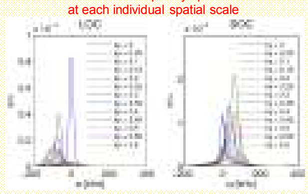
5. Nonlinear frequency spectra

Comparison of linear growth rates and nonlinear frequency broadening

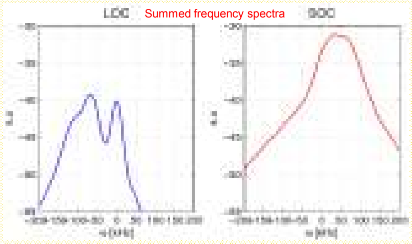


- $\Delta\omega_{nl}$ comparable to γ_{lin} where linear drive is strong
- Justifies assumption in quaslinear models [7,8]
- LOC nonlinear broadening less than SOC
- Related to dissipation mechanisms?

Nonlinear frequency spectra at each individual spatial scale



- Difference in broadening has major ramifications
- LOC narrow broadening leads to separation between the drift-wave $k_y > 0$ and the zonal $k_y = 0$ spectra
- SOC spectra all overlap



Summed spectra qualitatively show same characteristics as the reflectometry measurements. QH-modes as a marker for TEM?

6. Conclusions

- QC-modes measured in LOC phase and disappear in SOC phase. Linear simulations relate LOC→SOC to TEM→ITG
- Non-linear simulations show that TEM frequency broadening is narrower than the ITG case
- TEM frequency spectra thus shows double peak between drift wave and zonal flow components. ITG is broadband. Qualitatively similar to measurements. Are QC-modes an experimental signature of TEM?

Next steps

1. Synthetic diagnostic for more quantitative comparison
2. Test modelling sensitivities to improve comparison with power balance
3. Theoretical understanding of frequency broadening differences

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