ID: 1332 High-order coupling of shear and sonic continua in JET plasmas

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- •Toroidicity-induced AEs (TAEs), with frequency $\omega_{TAE}=v_A/(2qR_0)$, are one of the most extensively studied Alfvénic instabilities in tokamaks;
- •Here, we report and discuss Alfvénic activity observed on JET experiments, at about half the TAE frequency, in NBI/ICRH heated plasmas (Fig. 1);
- •The frequency of beta-induced acoustic AEs (BAAEs) due to lowest-order geodesic curvature terms, $\omega_{BAAE} \sim 2\beta^{1/2} \omega_{TAE}$, is too low (β ~10⁻²);
- •Higher-order geodesic curvature terms, due mainly to plasma elongation κ, open additional gaps of size $\sim \beta^{1/2}(\kappa^2-1)$ at higher frequencies [1]:

$$\omega = 2\beta^{\frac{1}{2}} \omega_{TAE} \left[3 - \beta^{\frac{1}{2}} \left(1 + \frac{3}{nq} \right) (8 - 2q^2)^{\frac{1}{2}} + \cdots \right]$$

•High-order geodesic AEs (or HOGAEs) inside these previously unexplored gaps are next employed to explain the experimental observations.



 ω_{BAAE}

0.4

EXPERIMENTAL OBSERVATIONS AND MHD ANALYSIS

•AE with frequency 83.2kHz and toroidal mode number n=2;

(a 0

MEASUREMENTS FOR JET #90198 AT 48 SECONDS:

(a) uncoupled

cylindrical limit (dots) 0.1

and lowest-order

circular eauilibria

IDEAL-MHD ANALYSIS:

(lines); (b) high-order

couplings enabled by

the elongation κ =1.3

FIG.1. Alfvénic activity observed in JET pulse #90198, with TAEs around 150kHz and lower-frequency AEs near 80kHz in the time interval between 47 and 48 seconds (40 seconds have been subtracted from the time base).

WGAM

0.6

 $\rho_{\rm pol}$

ES





FIG.4. Reflectometry data for JET pulse #90198: reference spectrogram of the magnetic signal (bottom); radial location (middle, bue) and safety factor (middle, green) at the cut-off layer; reflectometer spectrogram (KG8c, top).



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RESONANT INTERACTIONS WITH ENERGETIC IONS

- ENERGY EXCHANGE BY DRIFT-KINETIC CODE CASTOR-K:
 - Thermal D (after impurity-dilution correction): $\gamma_{thD}/\omega = -0.011$;
- NBI-heated D (distribution function by ASCOT): $\gamma_{\text{NBI-D}}/\omega = -0.001$;



• Equilibrium reconstructed by EFIT with Faraday-rotation constraints; • Continua by CSCAS: gaps open towards the axis for n=2 only (Fig. 3);

•n=2 NTM at 12.2kHz, whence the rotation frequency 6.1kHz at q=3/2;

•Electron density and temperature measured by HRTS and LIDAR;

•HOGAE computed by CASTOR: frequency 82.7 kHz (after Doppler-shift

0.6

 $\rho_{\rm pol}$

 ξ_m^S

0.8

BAAB

0.4

(b)

correction) agrees with measurements, AE located in the core (ρ_{pol} <0.44).



FIG. 3. JET #90198 continua at 48 s for n=1,3 (left) and n=2 (right); Vertical lines at the rational surfaces with lowest q for each n; Radial structure of the n=2 HOGAE (dominant harmonics only. in a.u.)



0.2

 P_{ϕ} (eV s)

0.1

•Alfvénic activity on JET plasmas, below but close to ω_{TAE} , was reported; •Its properties were explained using a model coupling shear-Alfvén and acoustic continua that depends strongly on the elongation of JET plasmas.

0.2 P_{ϕ} (eV s)

- •HOGAEs predicted frequencies/locations agree with measurements;
- •HOGAEs were found to be driven unstable by ICRH-heated ions (~300keV) if their distribution-function anisotropy is sufficiently high.

REFERENCES & ACKNOWLEDGEMENTS

0.3

[1] P. Rodrigues and F. Cella, "High-order geodesic coupling of shear-Alfvén and acoustic continua in tokamaks", https://arxiv.org/abs/2008.12753 This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and trai This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and trainin programme 2014-2018 and 2019-2020 under grant agreement No 633053. One of the authors (FC) was supported by FuseNet from the Eurator rch and training program me under Grant Agreement No. 633053. The views and opinions expressed herein do not the European Comr ion. IPFN activities were also supported by "Fundação para a Ciência e Tecnologia" (FCT) via project UID/FIS/50010/2013.

