Collaboration with China and Korea on Theory and Simulation*

Fulvio Zonca[1,2], Matteo V. Falessi[1] and Yueyan Li[1,3]

[1]Center for Nonlinear Plasma Science and ENEA C.R. Frascati, 00044 Frascati, Italy
[2]IFTS and Dept. Physics, Zhejiang University, Hangzhou, 310027 P.R. China
[3]Consorzio CREATE, Via Claudio 21, 80125 Napoli, Italy

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General framework

- ☐ Center for Nonlinear Plasma Scinece (CNPS):
  - https://www.afs.enea.it/zonca/CNPS/
  - Established in 2020 as "Virtual Center" based on two hubs, one located at the ENEA Frascati Research Center and another at the University of Science and Technology of China, Hefei, to promote a joint research and collaboration network.

- ☐ International collaboration network
  - Institute for Fusion Theory and Simulation, ZJU
  - ASIPP, Hefei (EAST/BEST/CFETR)
  - SWIP, Chengdu (HL-2A/2M)
  - NFRI, Daejeon (KSTAR)

CNPS mission

❑ CNPS mission:

- The main scope of CNPS is the proposal of joint research projects, exchange of faculty members, researchers and students, and organization of workshops and schools.
- Topics of interest cover nonlinear plasma science in a broad sense, including laboratory and space environments.
- In particular, the magnetic fusion research activities and joint projects of CNPS are collocated under the umbrella of the CFETR-DTT collaboration agreement on science and technology (MoU) between China and Italy (to be renewed).

CNPS structure and plans I

- CNPS structure and plans:
  - CNPS-ENEA: Coordinator (FZ) + 7 associates (incl. M.V. Falessi, Y. Li) + collaborators on various ongoing research projects (ENR, TSVV …).
  - CNPS-USTC: Director (Ge Zhuang), 2 Deputy Directors (Zhiyong Qiu, IFTS + Quanmin Lu, USTC-Space plasmas) + associates and collaborators
  - Kick-off meeting planned in 2022 (2021, postponed due to Covid-19)
  - Focus on physics of burning plasmas:
    - Foundations of plasma science: thinking out of the box
    - Target challenging problems on mid-long term
    - Train next generation of plasma researchers
    - Applications to present devices: EAST, HL-2A, KSTAR, …
    - Applications to CFETR, BEST, DTT…

CNPS structure and plans II

- ☐ CNPS structure and plans:
  - From Bi- to Tri-lateral collaboration: CHI-KOR-ITA
    - **First ENEA-IFTS Workshop** on Fusion Theory and Simulation, Taormina, October 2-4, 2013
    - **First Trilateral International Workshop** on Energetic Particle Physics, Hangzhou, November 9-12, 2017
    - **Second Trilateral International Workshop** on Energetic Particle Physics, Seoul, November 10-12, 2019
    - **Third Trilateral International Workshop** on Energetic Particle Physics, Frascati, 2021 → 2022
  - Extended from the very beginning to all interested Italian Research Labs and Universities

CNPS structure and plans III

- More on Trilateral collaboration: CHI-KOR-ITA
  - Memorandum of Understanding: 3.rd Mtg. Seoul Nov2019
    - i. RMP-induced fast ion losses due to nonlinear wave particle resonances: K. Kim (NFRI), Z.W. Ma (IFTS)
    - ii. Observations of energetic circulating particle-driven fishbone/EPMs: H. Jhang (NFRI), G. Fu (IFTS), F. Zonca (ENEA)
    - iii. Zonal cross-scale coupling between EP and turbulence: M.V. Falessi (ENEA), Y. Li (IFTS/CREATE)
    - iv. Validation of MHD model in experiments: Z.W. Ma (IFTS), H. Park (NFRI)

- CNPS focus on Burning Plasmas (ENEA/USTC):
  - Key role of CFETR and Burning Experimental Superconducting Tokamak (BEST: EAST follow up)
  - Possible applications to DTT

CNPS research/training

☐ Publication summary (2020/21):

- 14 Journal papers: 2 Rev. Mod. Plasma Physics, 1 New J. Phys., 1 Science China, 1 Phys Rev Lett.
- 9 Conference presentations: Invited @ Varenna 2020, @ APPS 2020, 2021

☐ Education/Training:

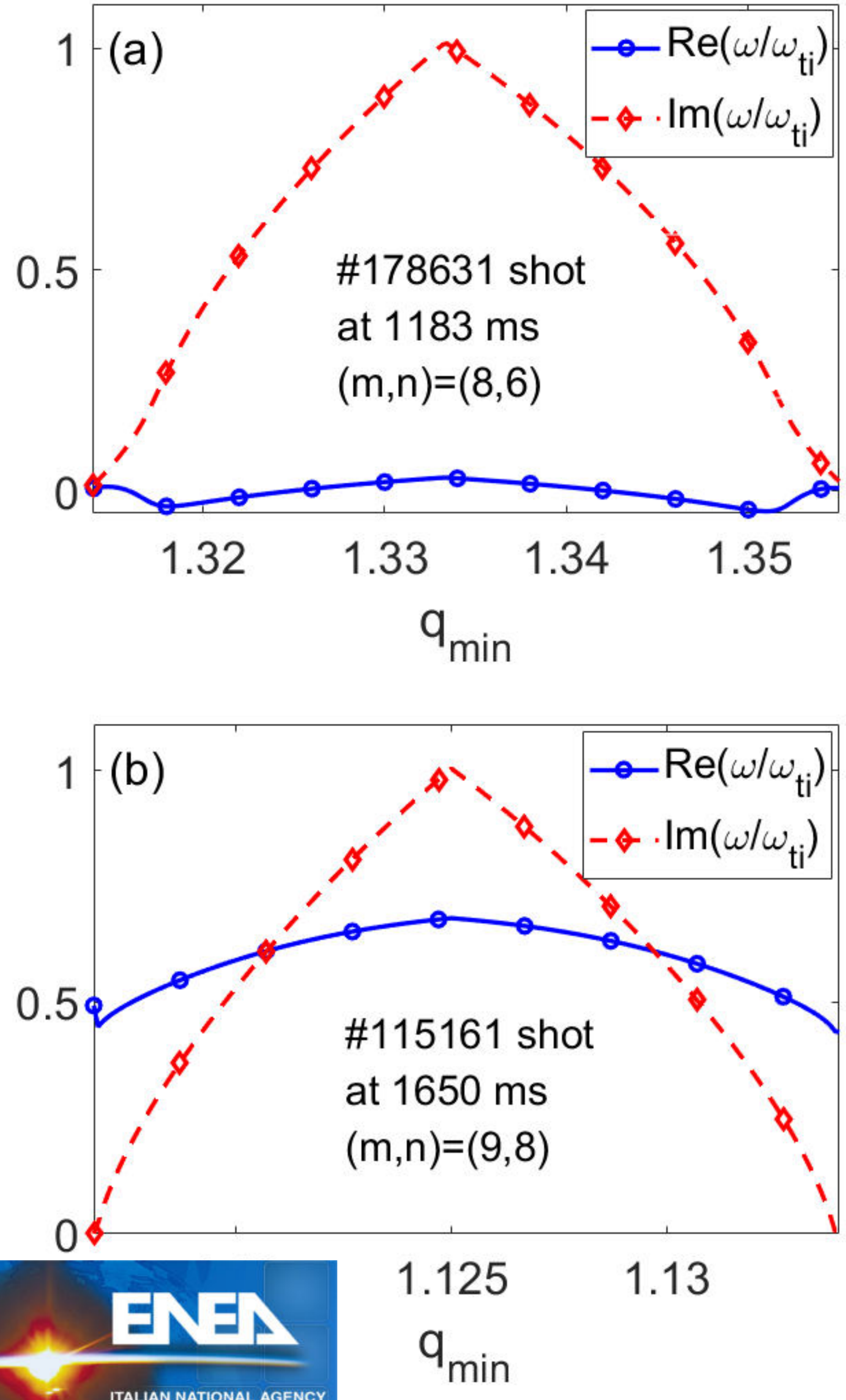
- **Nonlinear kinetic theory and simulation of toroidal fusion plasmas** (Livio De Fabrizio - Ph.D. Student XXXV Ciclo, RomaTre University of Rome)
- **Test particle transport in tokamak divertor magnetic field geometry** (Leonardo Corsaro - Master Student, University College London)
- **Investigation of Negative Neutral Beam Injection profiles in DTT** (Simone Vitale - Master Student, Université Libre de Bruxelles)

☐ Joint CNPS-DTT MHD&Theory Seminars

CNPS results I

- Drift Alfvén instabilities with s=0

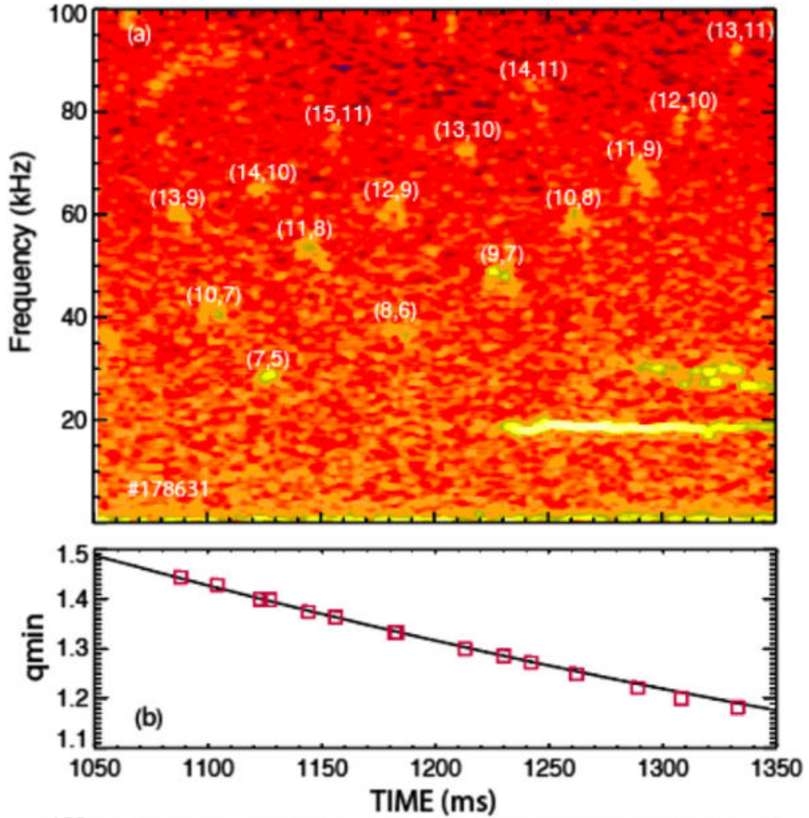
[Ma21PPCFaccepted, Fig. 6]

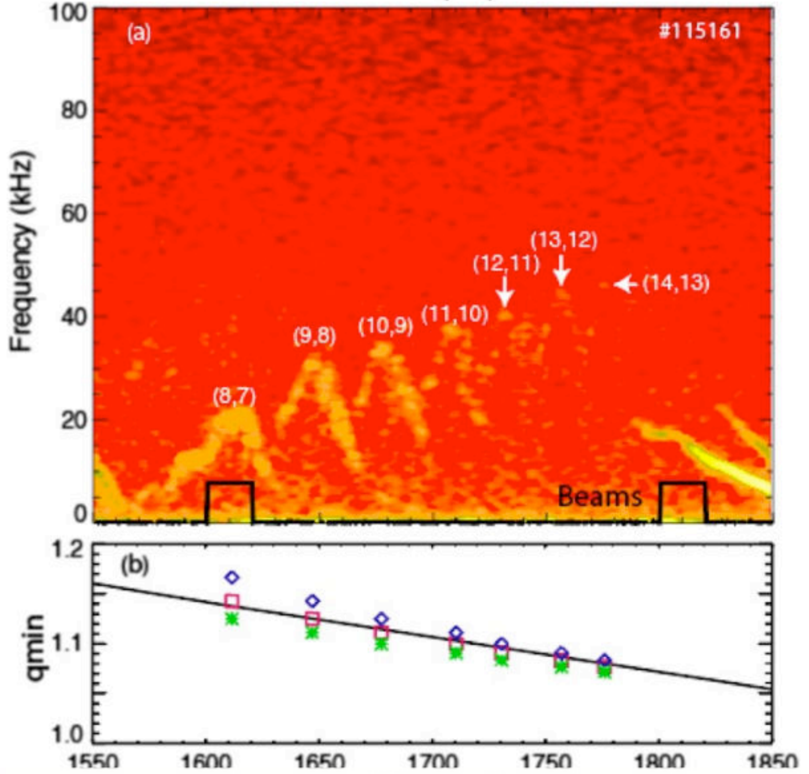


General fisbone like dispersion relation

Christmas lights/trees in DIIID explained

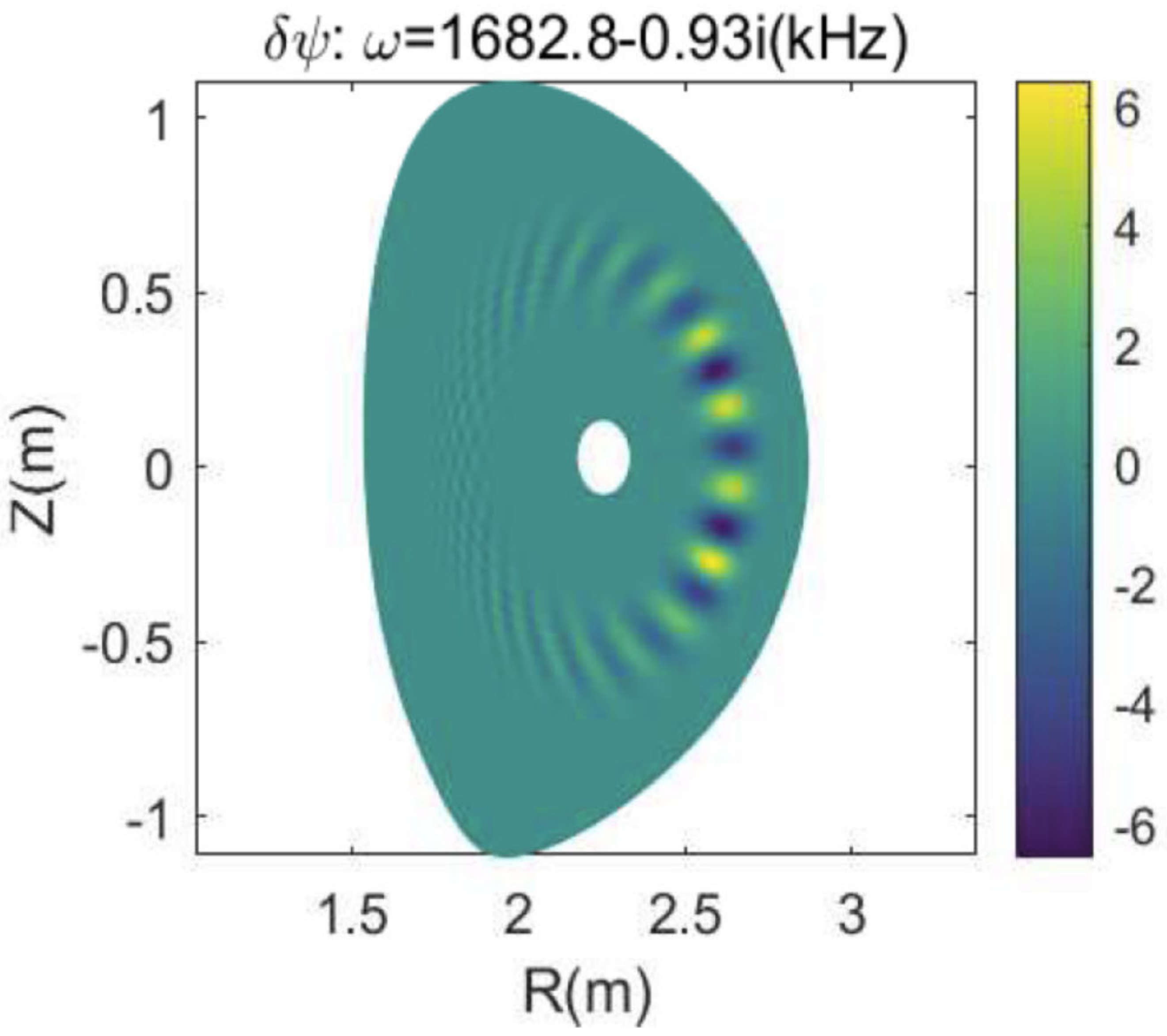
[Heidbrink21NF, Fig. 6(a), Fig. 14(a)]

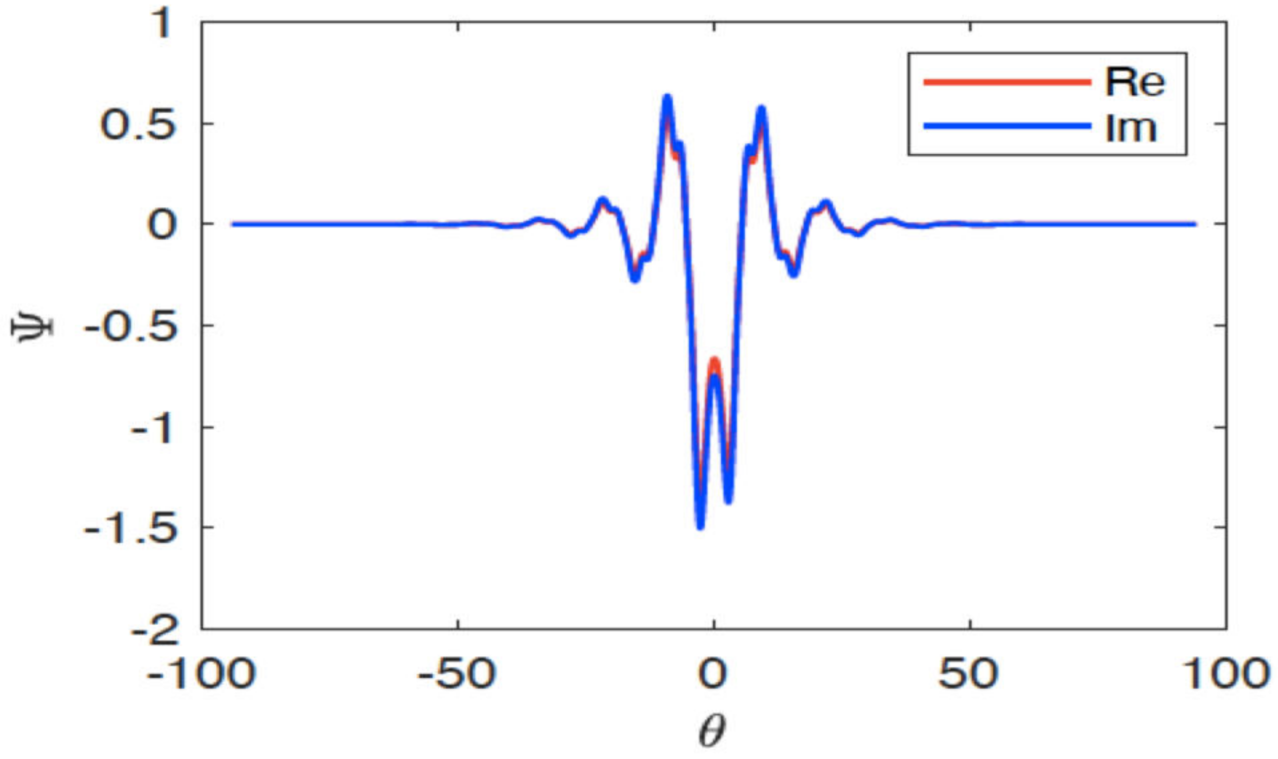


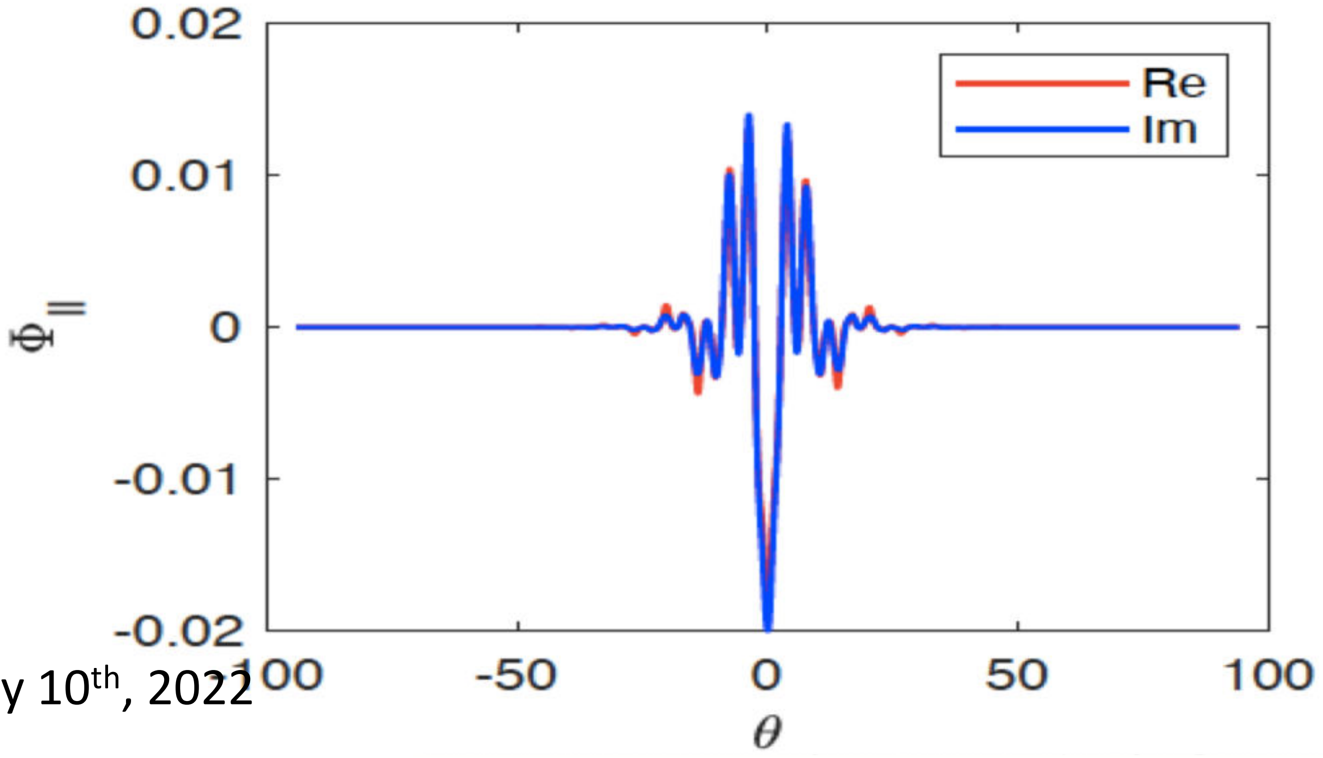


CNPS results II

- Prediction of drift Alfvén fluctuation spectrum in DTT: n=20 Toroidal Alfvén Eigenmode (DAEPS code)







Advanced theory & simulation

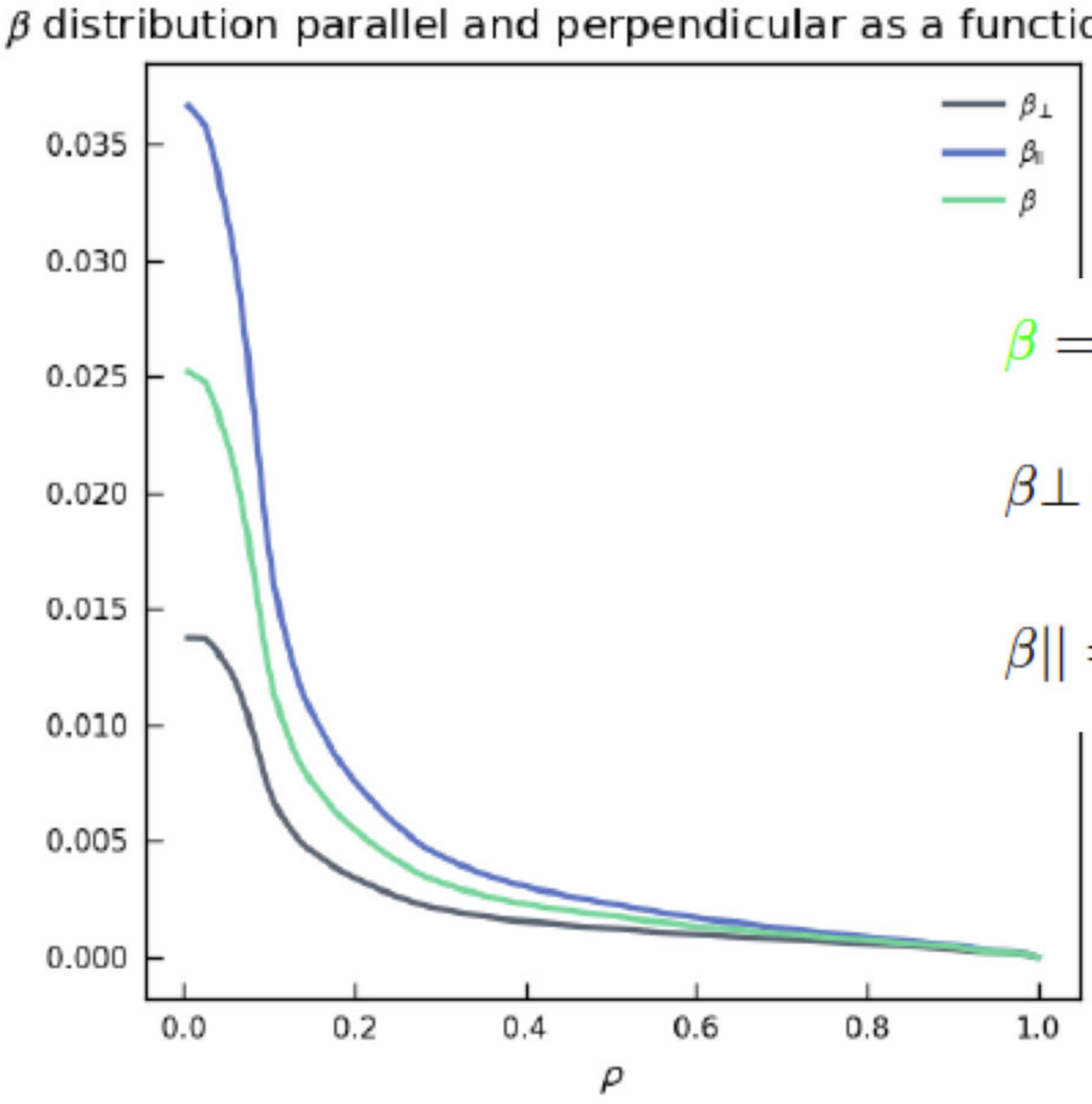
- ☐ Development of the E&B scheme for gyrokinetics (L. Chen, H. Chen, Y.Lin, Z. Qiu, FZ):
  - ➢ Solve fundamental issues with Vlasov-Maxwell GK (joint CNPS-DTT MHD&Theory Seminar this Friday)
  - ➢ Based on moment approach
  - ➢ Suitable for analyzing global transport on long time scales

- ☐ Extension of the E&B scheme to high frequency (L. Chen, H. Chen, Y.Lin, Z. Qiu, FZ):
  - ➢ Gyrokinetic electrons and Fully kinetic ions (GeFi) (Y. Lin)
  - ➢ Based on moment approach and E&B (and potentials)
  - ➢ Suitable for analyzing global stability and transport in a wide frequency range

PhD XXXV Ciclo Roma Tre: Livio De Fabrizio

Beam deposition effects on AE

- **Strong excitation of core localized modes/EPM**



$$\beta = \frac{1}{2}(\beta_\perp + \beta_\parallel)$$

$$\beta\perp = \frac{2\mu_0}{B_0^2} 2\pi \int_{-1}^{+1} d\zeta (1-\zeta^2) \int_0^\infty dx v_c^3 x^2 m \frac{x^2 v_c^2}{2} f(x,\zeta)$$

$$\beta|| = \frac{2\mu_0}{B_0^2} 2\pi \int_{-1}^{+1} d\zeta \zeta^2 \int_0^\infty dx v_c^3 x^2 m x^2 v_c^2 f(x,\zeta)$$

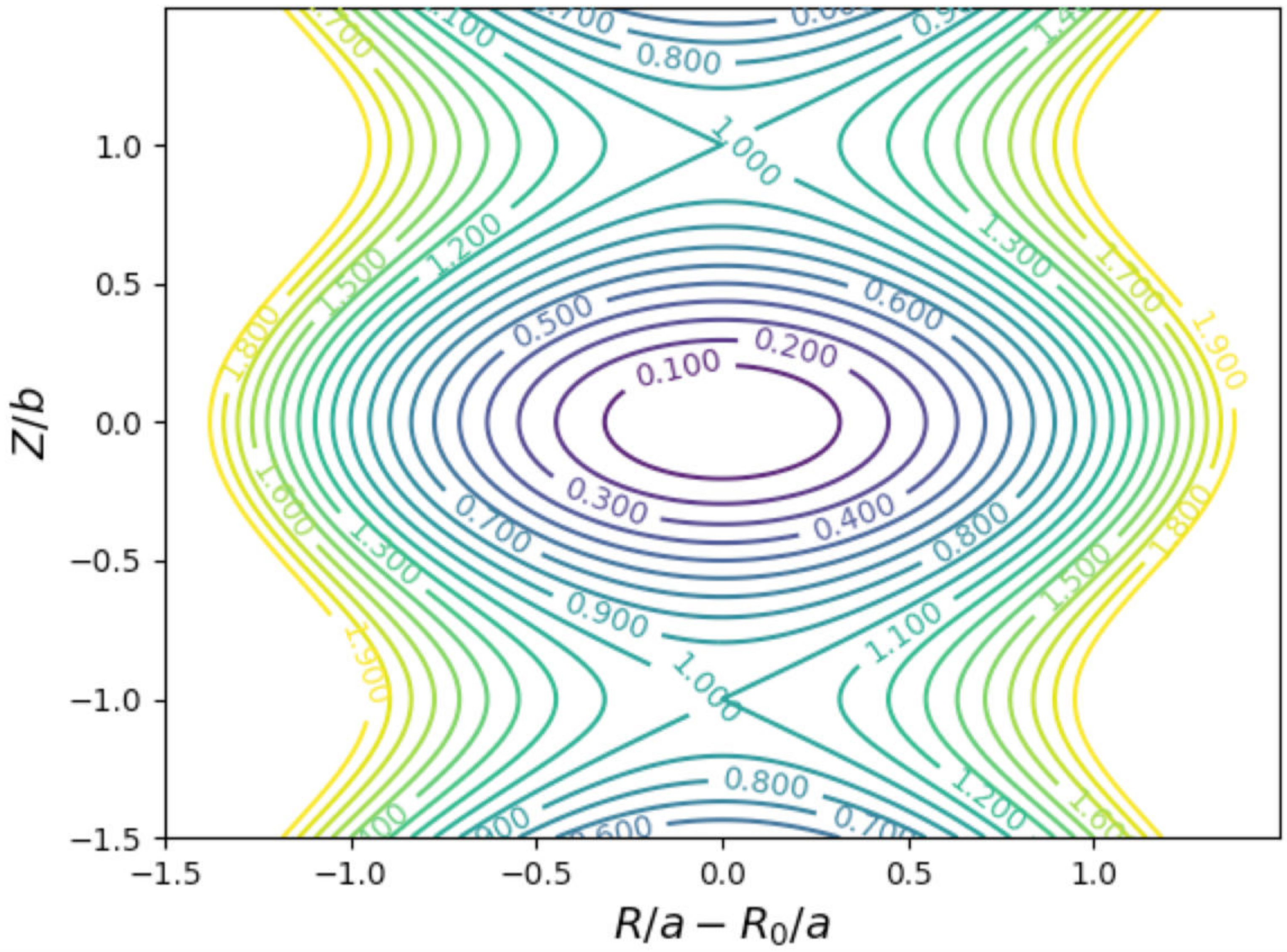
Internship training: Simone Vitale ULB

Boozer coordinates outside SX

- **Breaking myths in plasma physics**

➔ Application to test particle transport

➔ ORBIT



Model equilibrium
with double X-point

Flux surfaces

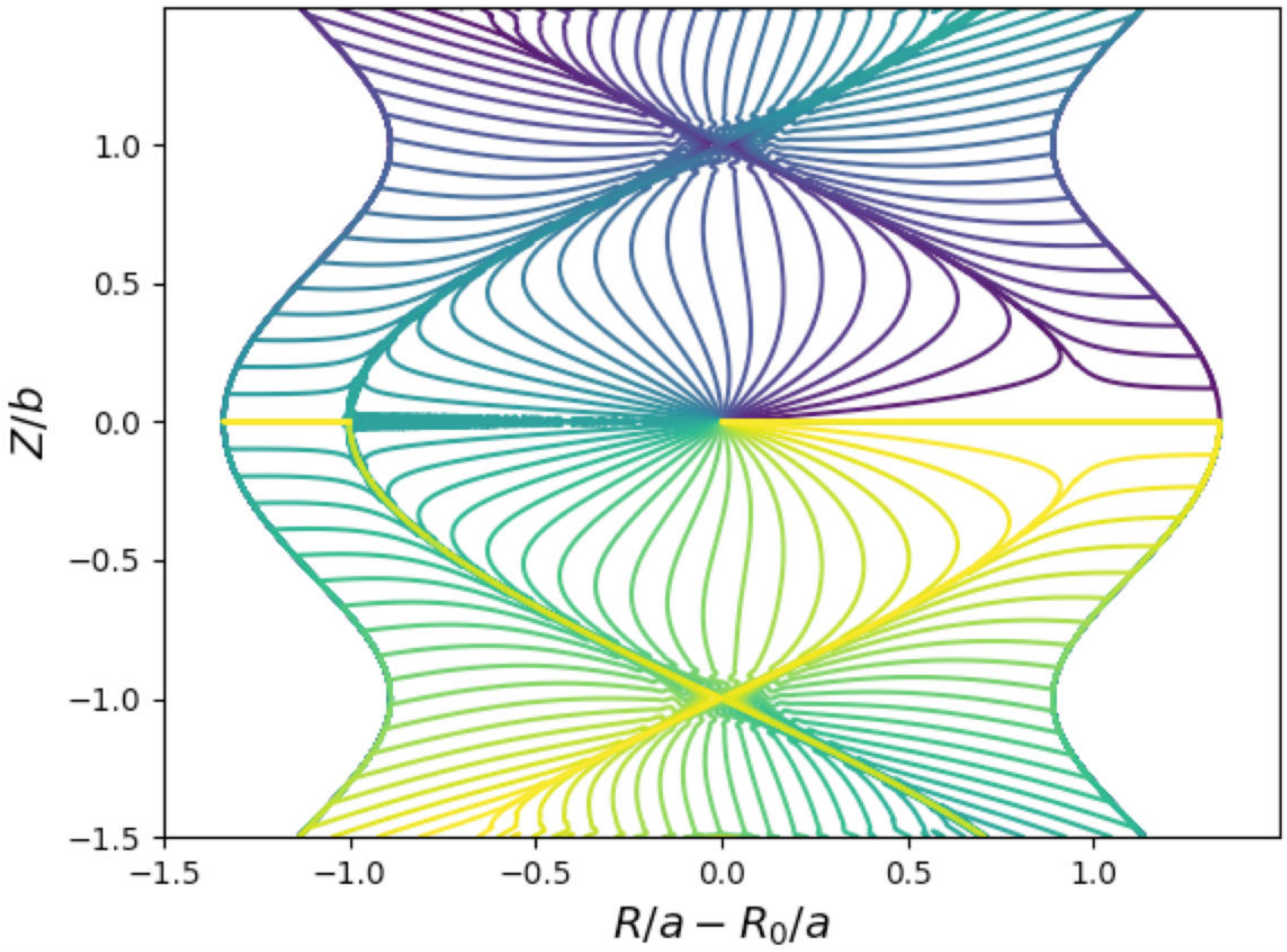
Master Thesis: Leonardo Corsaro UCL

Boozer coordinates outside SX

- **Breaking myths in plasma physics**

➔ **Application to test particle transport**

➔ **ORBIT**



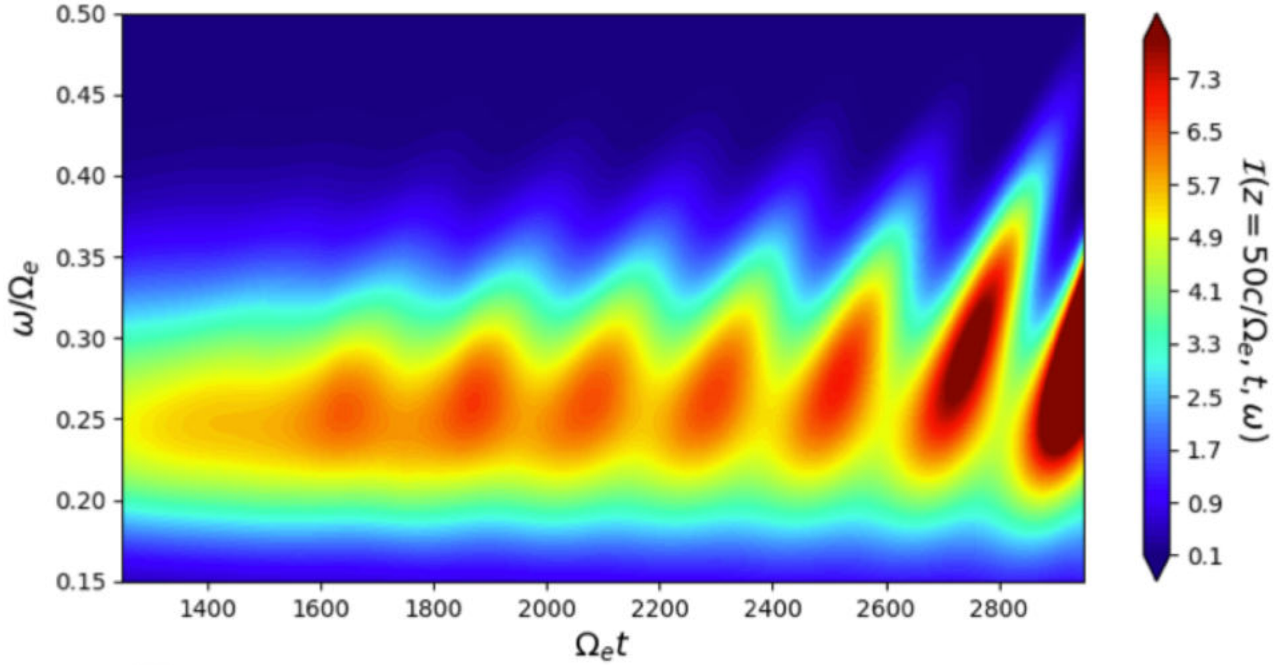
Model equilibrium with double X-point

Boozer isolines

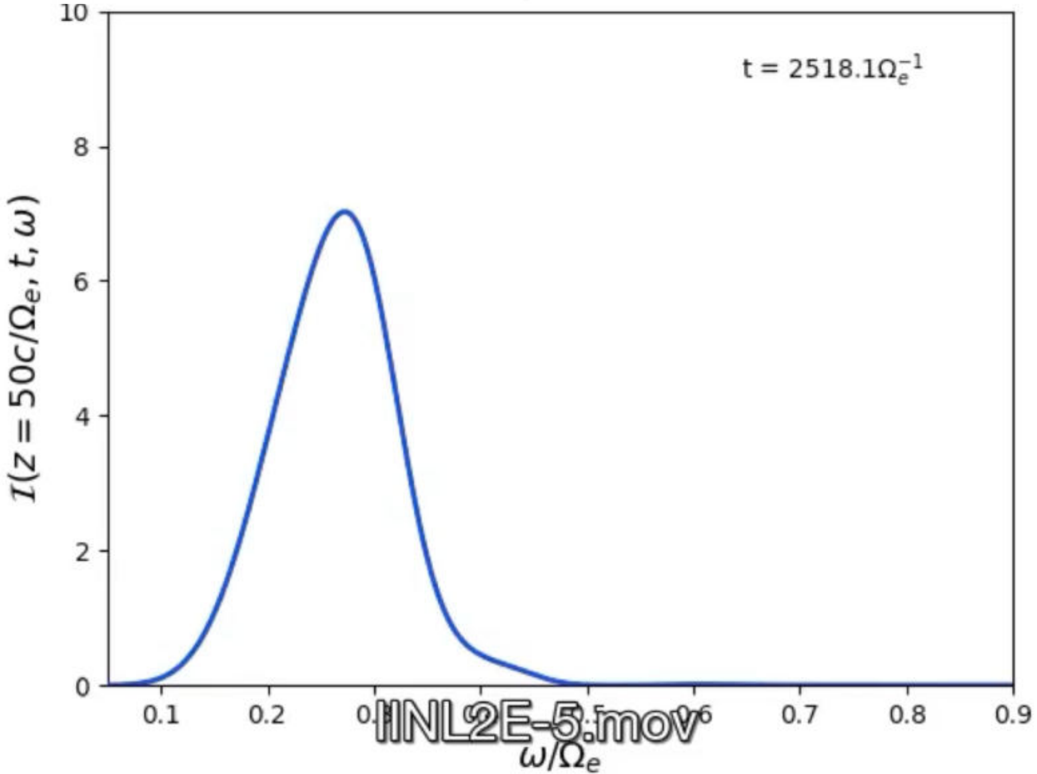
Master Thesis: Leonardo Corsaro UCL

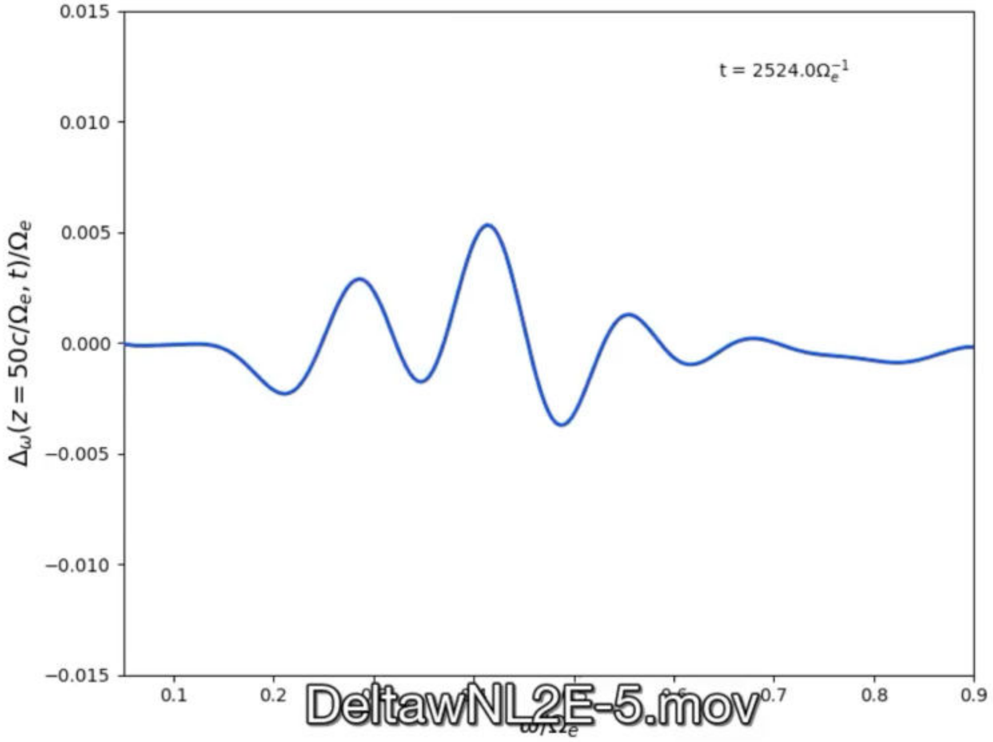
Chorus chirping

- **Theory and simulation of whistler chorus (ENEA/USTC):**



Solution of the Dyson Schrödinger Model (DSM) for space plasmas





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ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

ifts 浙江大學聚變理論與模擬中心 潘雲鶴

Institute for Fusion Theory and Simulation, Zhejiang University

Questions/Comments

- ☐ Questions/comments are welcome