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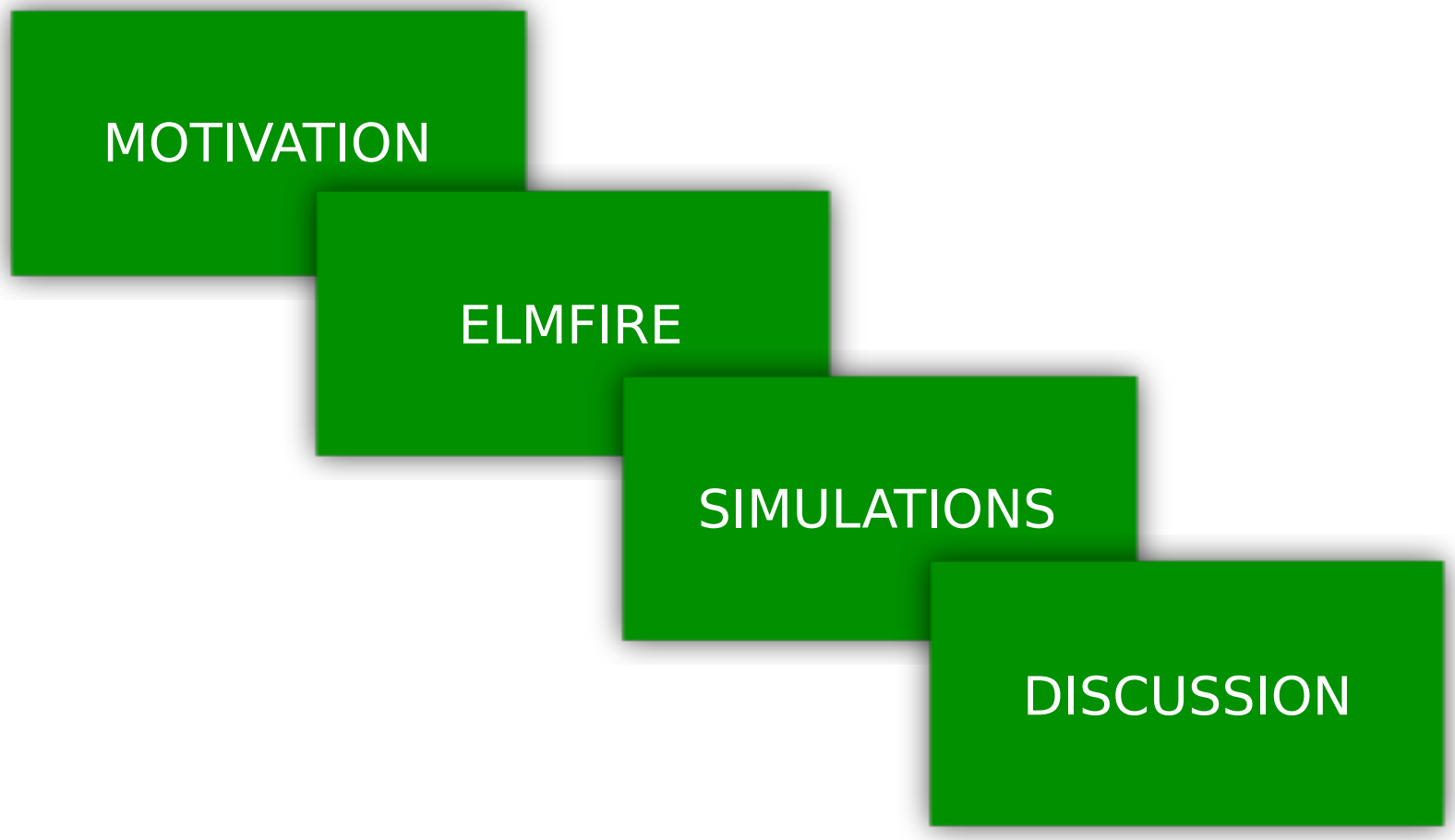
Gyrokinetic investigation of isotope effect on flow oscillations in ohmic tokamak discharges

P. Niskala, T.P. Kiviniemi, S. Leerink, T. Korpilo

Department of Applied Physics
Aalto University, School of Science
paavo.niskala@aalto.fi
Twitter @Paavi

EFTSOMP Workshop 2015

Outline



Geodesic acoustic mode could play a role in the isotope effect

Isotope effect

- Confinement improves with increasing isotope mass.
- Gyro-Bohm scaling would predict the opposite.
- Zonal flow amplitude increases with A. (Xu PRL 2013)

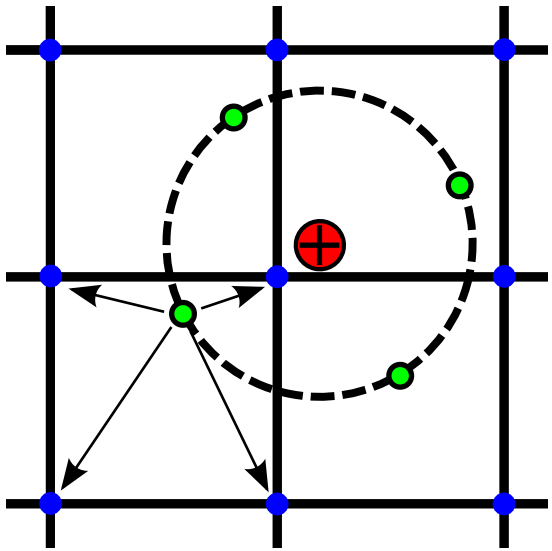
Geodesic acoustic mode

- A branch of the zonal flows with finite k_r and f.
- Participate in shearing of turbulence along with the mean flow in the L-I-H transition (Conway PRL 2011)

ELMFIRE applies gyrokinetics and particle-in-cell method in full-f simulations

ELMFIRE

- Kinetic electrons and ions (2 ion species).
- Momentum and energy conserving binary collision operator.
- Self-consistent electric field.
- Electrostatic turbulence and neoclassical dynamics.

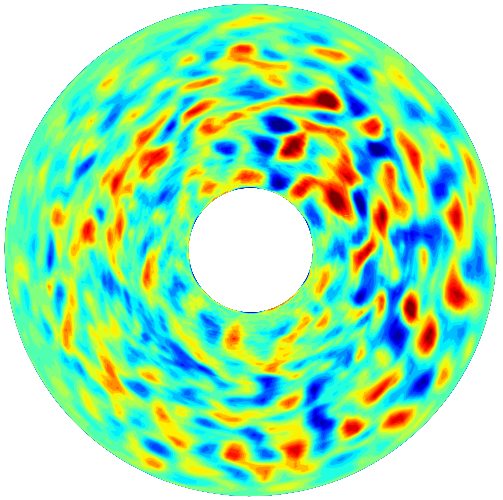


Gyrokinetic & Particle-in-Cell

Global simulations on a toroidal grid with circular cross section

ELMFIRE

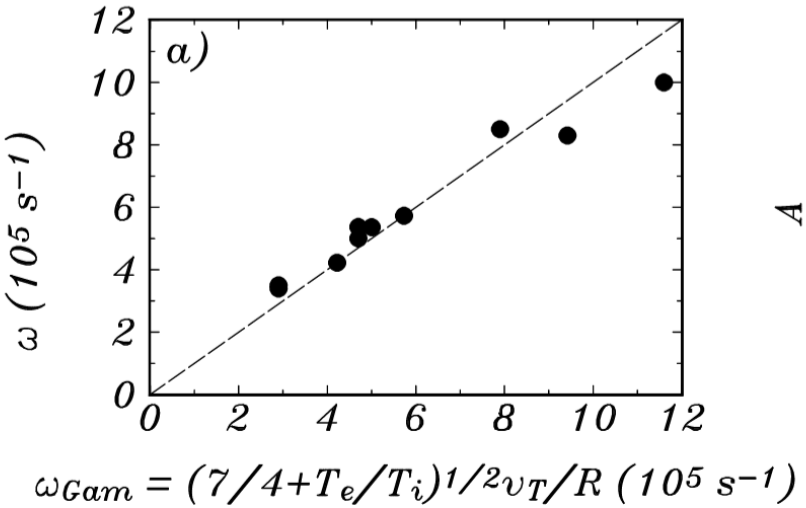
- Input profiles for temperature, density and radiation losses.
- Input current defines q profile and grid.
- Grid has a circular cross section with no shift.

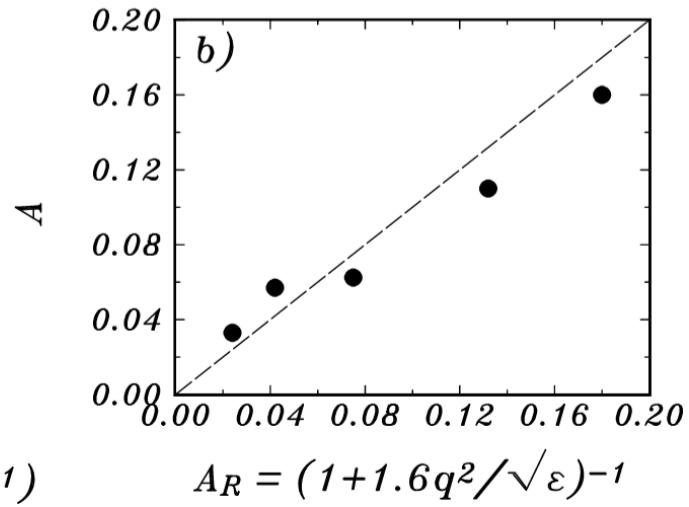


Turbulent δn on poloidal cross section.

Properties of GAMs match theoretical predictions in ELMFIRE simulations

Homogeneous plasmas with flat *q* profiles and no collisions produce GAM frequencies and Rosenbluth residuals predicted by theory (Heikkinen JCP 2008).





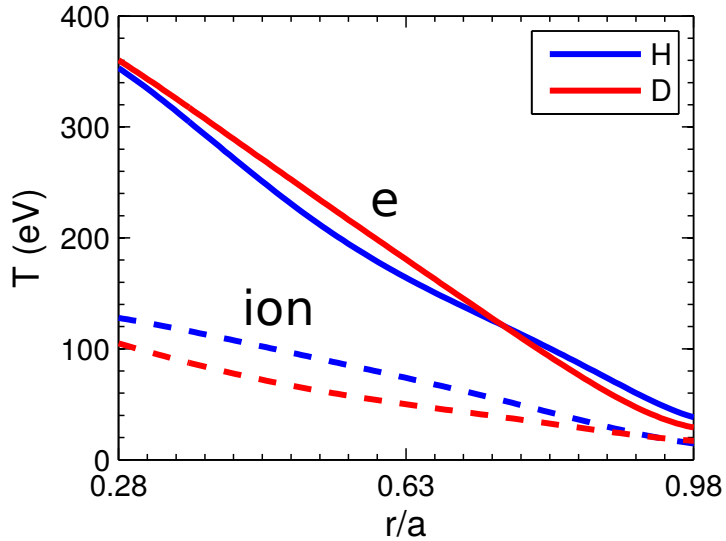
Parameters and input profiles from FT-2 tokamak were used to initialise simulations

Simulating two FT-2 ($a = 0.08$ m, $R_0 = 0.55$ m) discharges (H and D).

Isotope	H	D
B_ϕ (T)	2.27	2.22
I_0 (kA)	20.5	19.4
T_e (eV)	416	435
T_i (eV)	147	151
n_e (10^{19} m^{-3})	2.68	2.48
Z_{eff}	2.3	2.8

Values at magnetic axis.

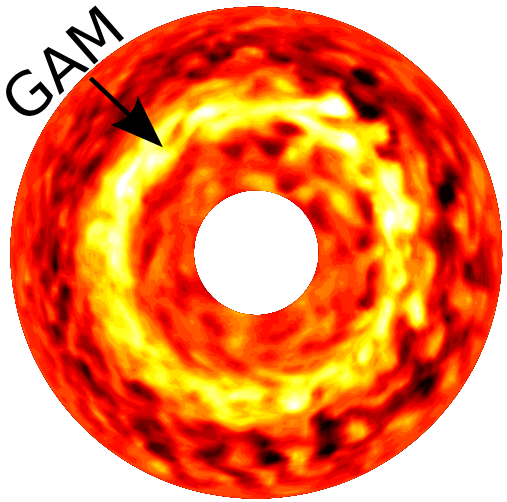
Low-β plasmas with TEM turbulence.



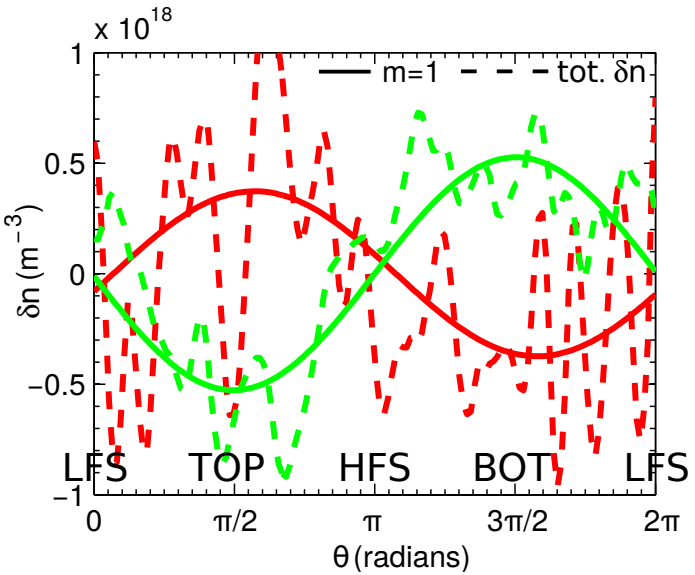
Simulating plasma within $r = 0.02 - 0.08$ m for 180 μs.

Simulations capture essential GAM characteristics in potential and density

Poloidal snapshot shows the radial potential fluctuation.



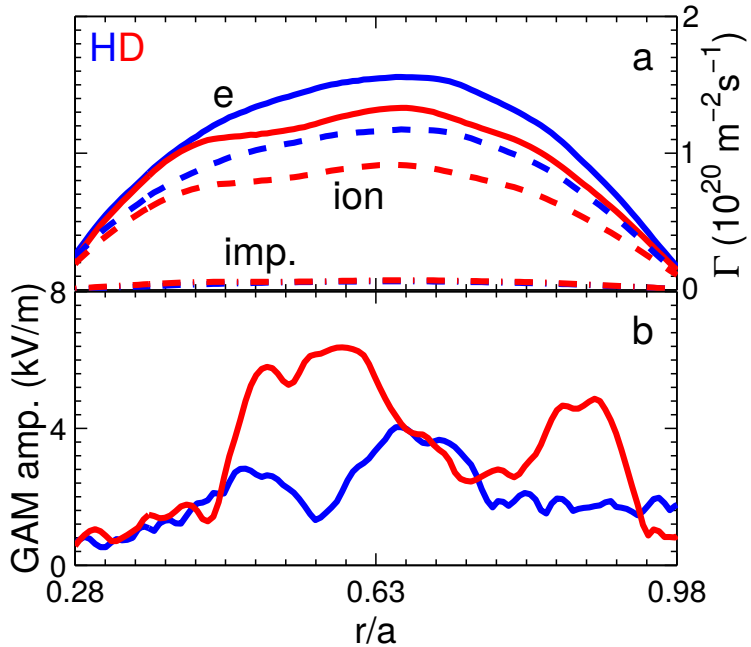
Temporal oscillations of density at top and bottom of the tokamak.



Deuterium case has larger GAM amplitude, hydrogen has stronger particle flux

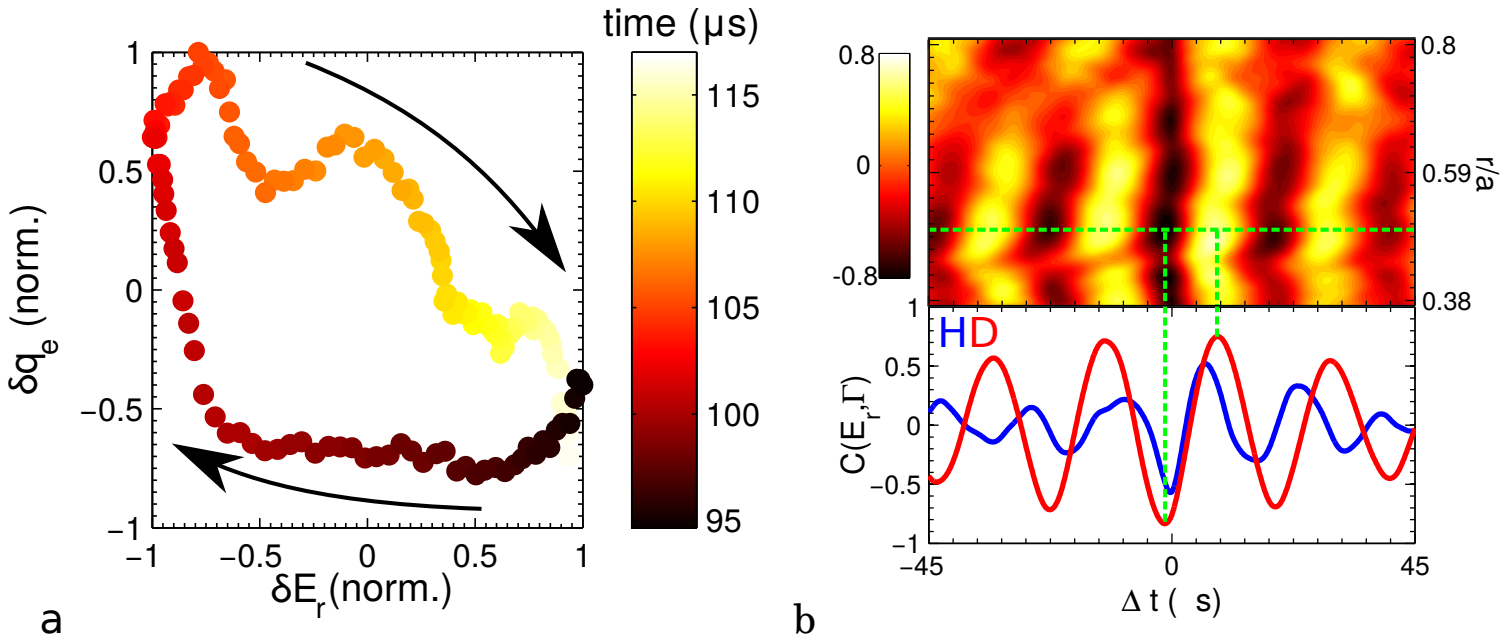
Deuterium has

- Lower GAM frequency and longer wavelength (as in Gurchenko EPS 2015).
- Larger GAM amplitude (as in Gurchenko EPS 2015).
- Lower particle and energy flux.
- Comparable conductive q_e, smaller q_i.



Deuterium exhibits stronger correlation between E_r and transport oscillations

Limit cycle like oscillations visible for electric field and transport. Correlation is overall weaker for hydrogen.



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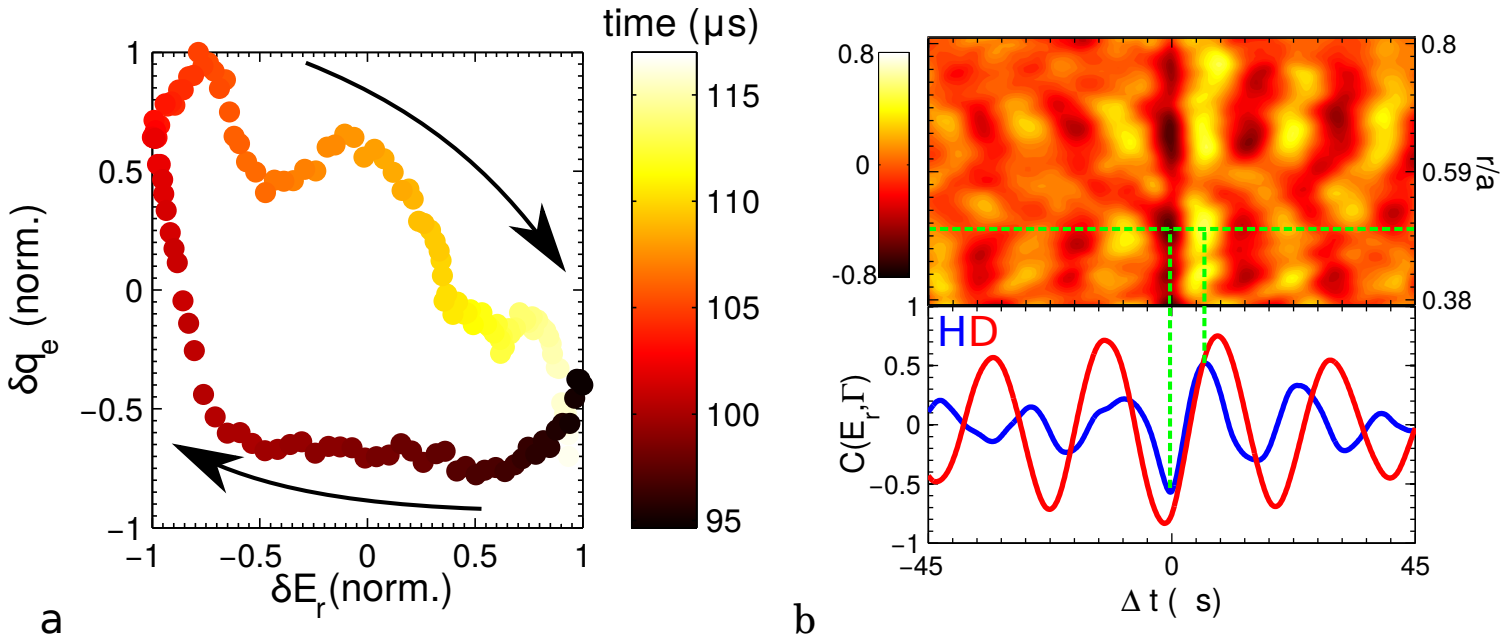

Conclusions and discussion

Simulations show stronger GAM activity and correlation with transport for increased isotope mass.

Experimental results follow similar trends (Gurchenko EPS & EFTSOMP 2015).

Lower frequency and higher amplitude for deuterium could lead to stronger effective shearing (Hahm PoP 1999).

Thank you for your attention

http://www.elmfire.eu

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