Resonant control of Kelvin-Helmholtz modes of arbitrary wavenumber by rotating electric fields in magnetized nonneutral plasmas

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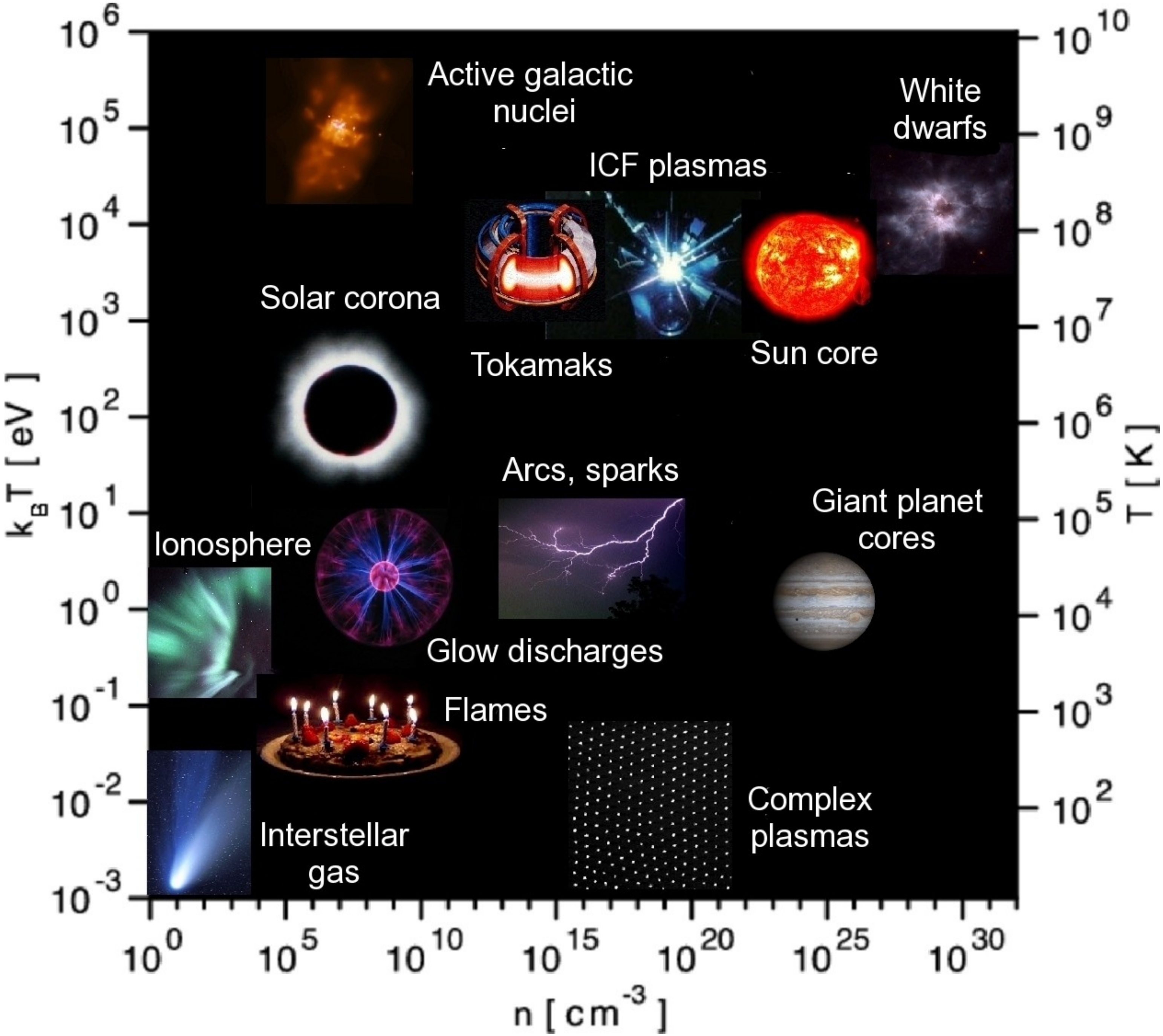
WHAT IS PLASMA?



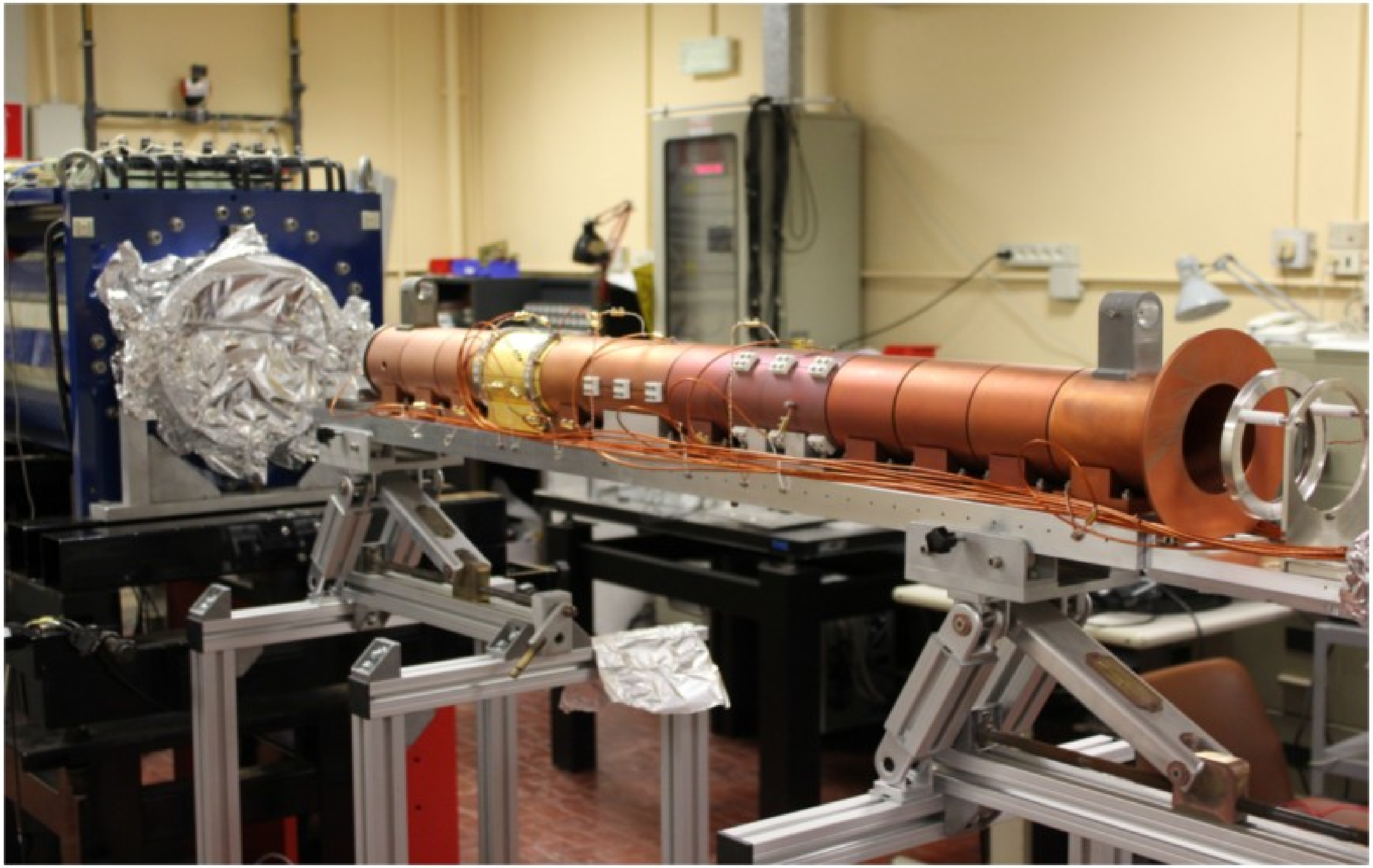
Neutral plasma:

$$\sum Q_i = 0$$

Nonneutral plasma:

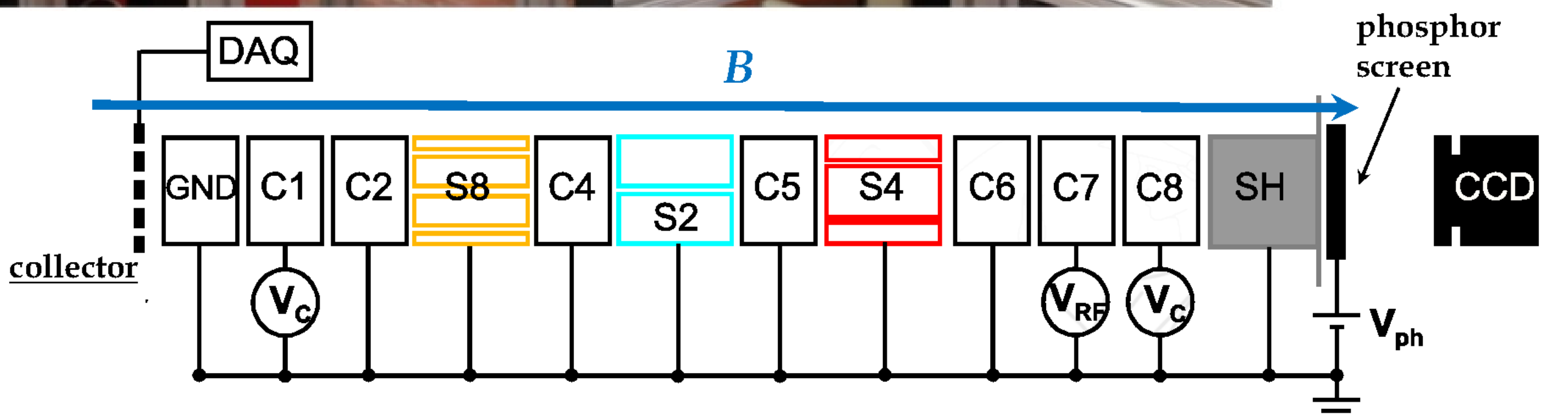
$$\sum Q_i \neq 0$$

ELTRAP



- $L<1$ m
- $\varnothing=90$ mm
- $B<0.2$ T
- $V_{con}=\pm100$ V
- $p\sim10^{-8}$ mbar

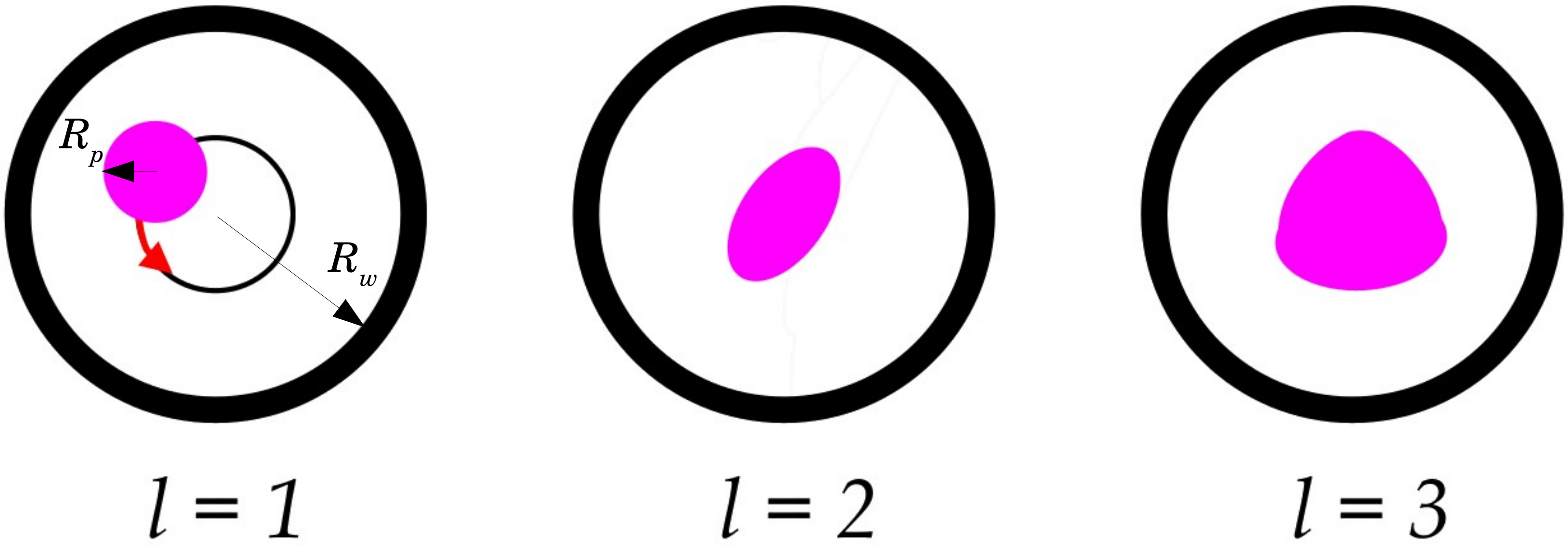
- $n_e\sim10^7 cm^{-3}$
- $\nu_{lon}\sim$ MHz
- $\nu_{E\times B}\sim$ kHz
- $T_e\sim10$ eV



FLUID ANALOGY

2D Ideal Fluid	2D Electron Plasma
$\frac{\partial \zeta}{\partial t} + \mathbf{v} \cdot \nabla \zeta = 0$	$\frac{\partial n}{\partial t} + \mathbf{v} \cdot \nabla n = 0$
$\nabla^2 \psi = \zeta$	$\nabla^2 \phi = 4\pi e n$
$\mathbf{v} = \mathbf{e}_z \times \nabla \psi$	$\mathbf{v} = \frac{\mathbf{e}_z \times \nabla \phi}{B} c$
$\zeta = (\nabla \times \mathbf{v}) \cdot \mathbf{e}_z$	$\zeta = \frac{c}{B} \nabla^2 \phi = \frac{4\pi e c}{B} n$
$\psi(\text{wall}) = \text{constant}$	$\phi(\text{wall}) = \text{constant}$

DIOCOTRON MODE

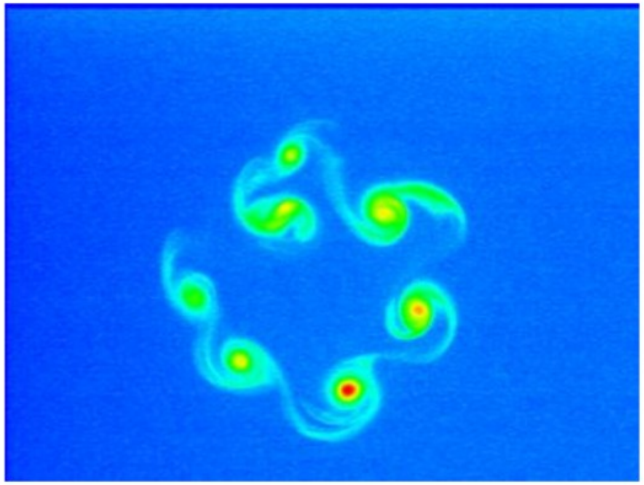


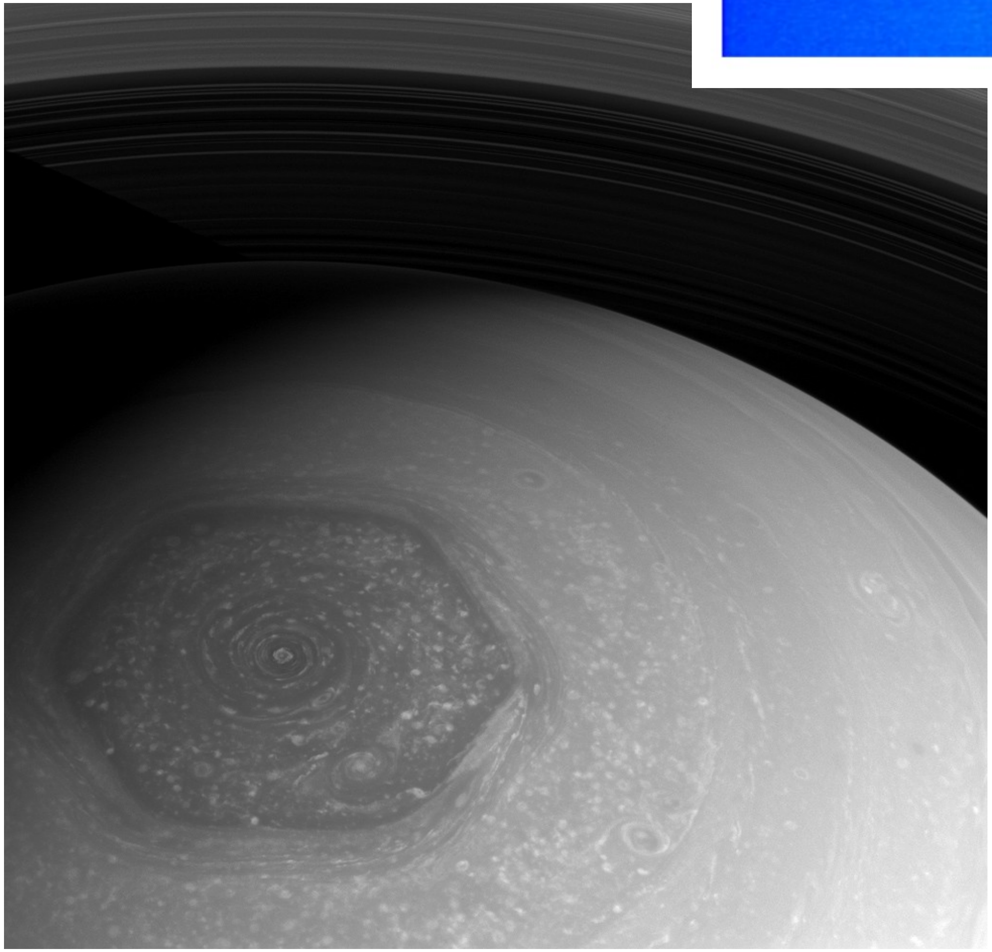
$$n_e(r,\theta,t) = n_e^0(r) + \sum_{l=-\infty}^{\infty} \delta n_e^l(r)\exp(il\theta - iwt)$$

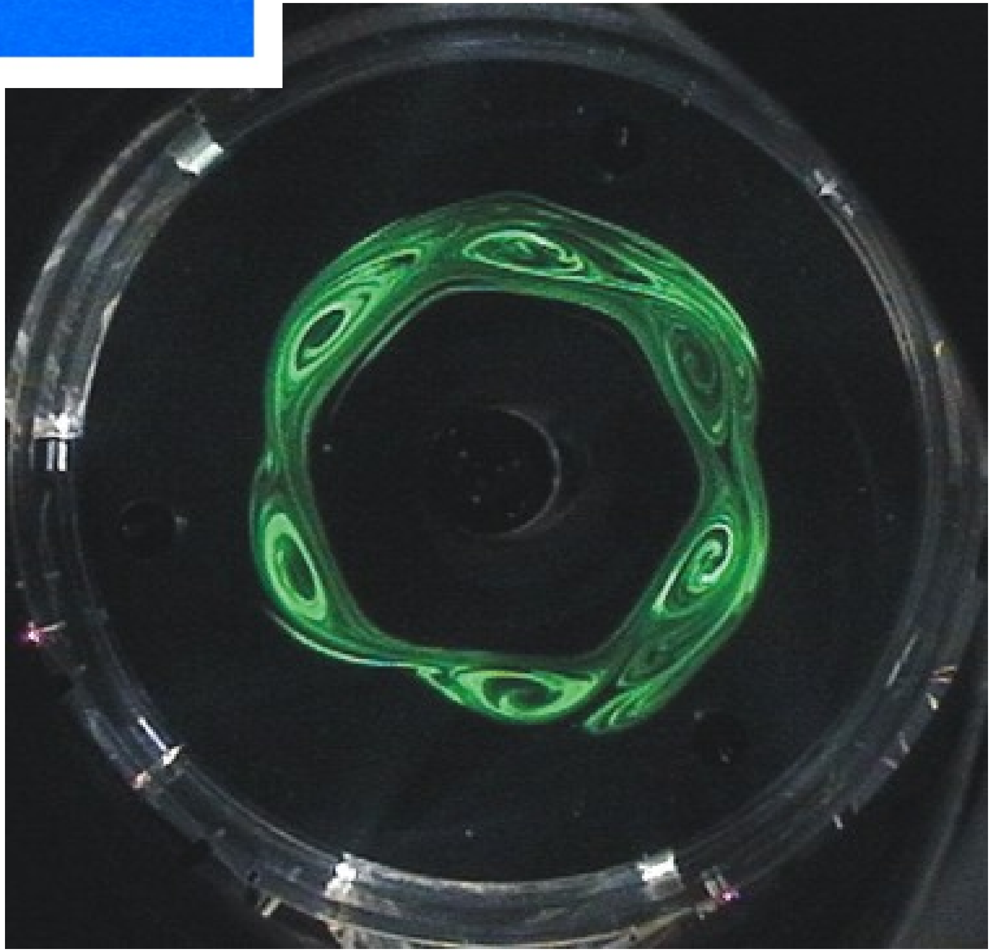
$$\phi(r,\theta,t) = \phi^0(r) + \sum_{l=-\infty}^{\infty} \delta \phi^l(r)\exp(il\theta - iwt)$$

$$\Omega_l = \frac{n_e e}{2\epsilon_0 B}\left(l - 1 + \left(\frac{R_p}{R_w}\right)^{2l}\right)$$

FLUID STRUCTURES IN NATURE AND IN LABORATORY







ROTATING ELECTRIC FIELD TECHNIQUE

$$\delta\phi(r=R_w,\theta,t)=\sum_{m=0}^{N_s-1}V_m(t)[H(\theta-2m\pi/N_s)-H(\theta-2(m+1)\pi/N_s)]$$

$$V_m=V_d\cos\left(\omega_d t+2\pi\sigma mj/N_s\right)$$

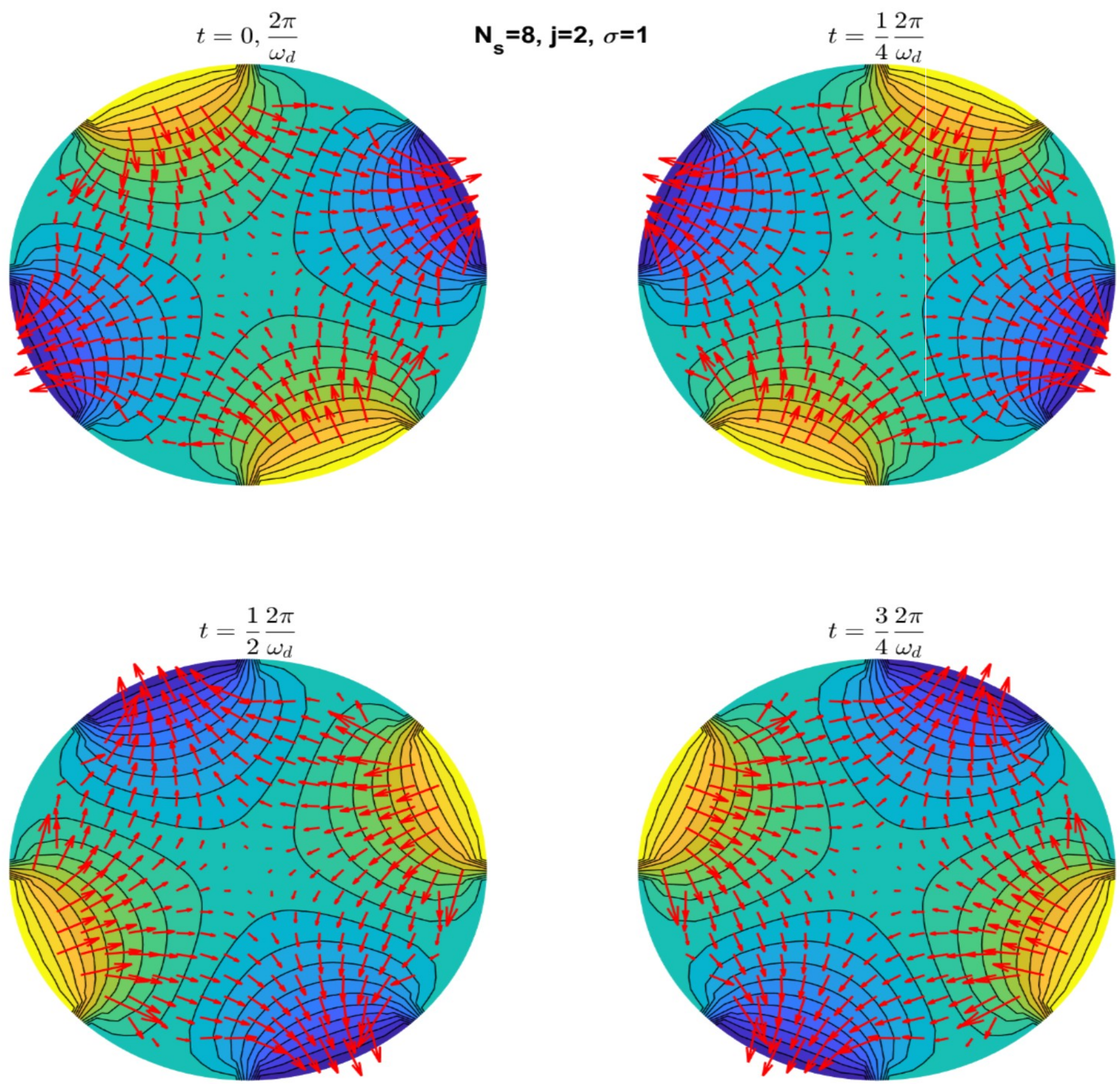
$$m=0,\ldots,N_s-1$$

$$j=1,\ldots,N_s/2$$

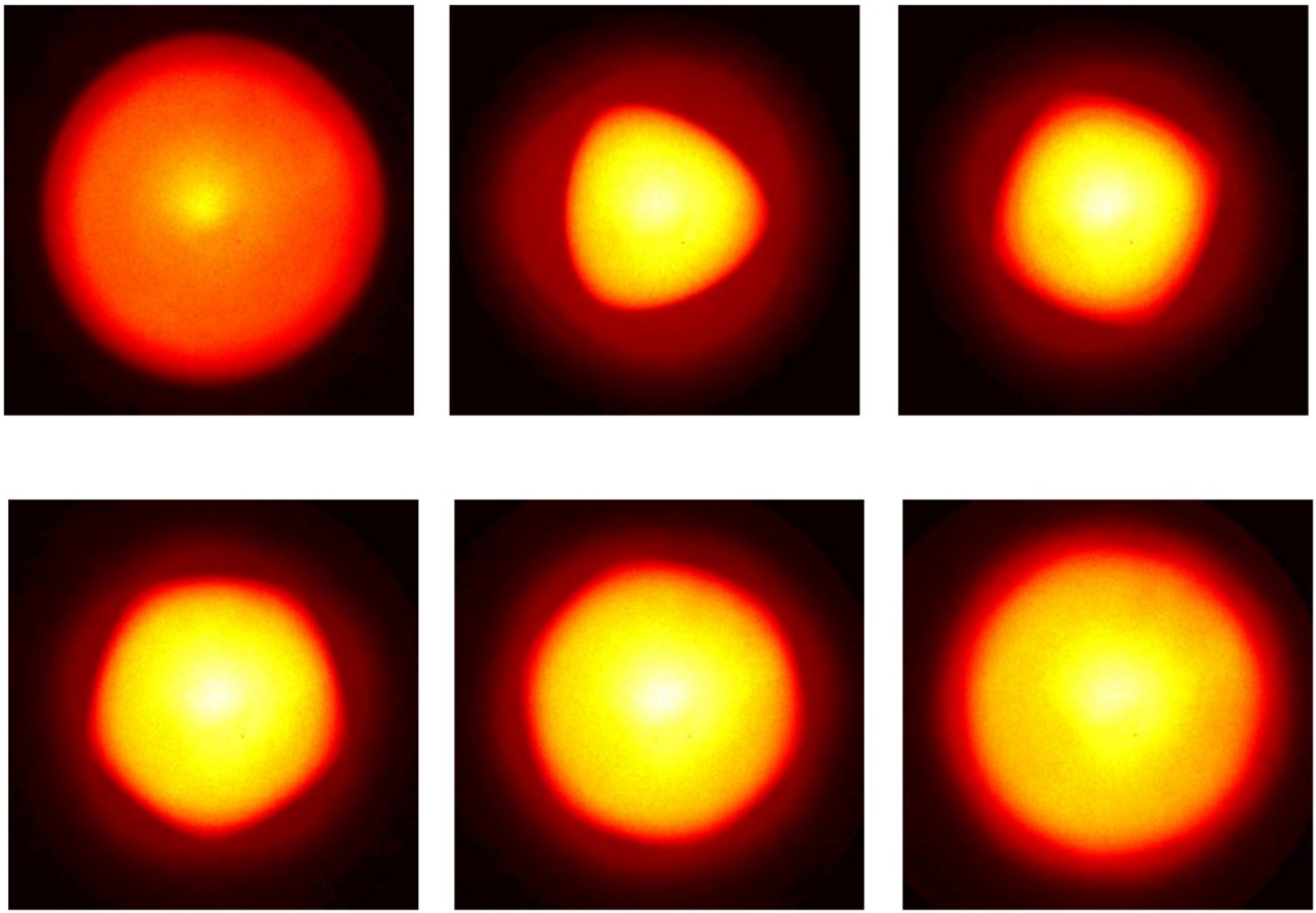
$$N_s=8$$

	excited modes		applied drive
j	σ=-1	σ=+1	
1	l=8k+1	l=8k+7	rotating dipole
2	l=8k+2	l=8k+6	rotating quadrupole
3	l=8k+3	l=8k+5	rotating sextupole
4	l=8k+4	l=8k+4	non-rotating octupole

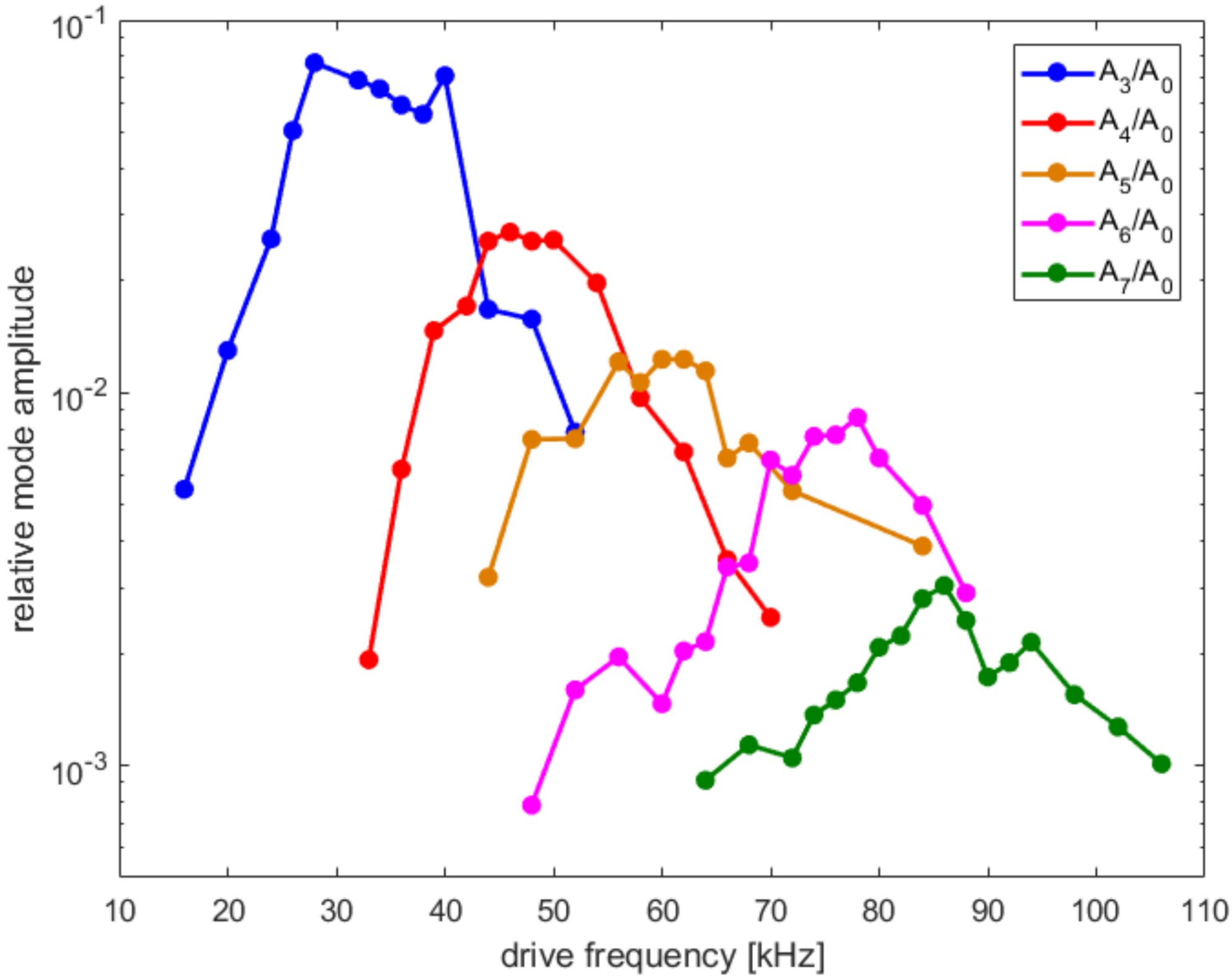
k=0,1,2,…



RESONANT DIOCOTRON MODE EXCITATION



RESONANT DIOCOTRON MODE EXCITATION



- t_{exc} ~ 100 ms
- Φ_{exc} ~ 3 V
- Φ_{plasma} ~ 20 V

In this work, we show an experimental technique to control Kelvin-Helmholtz modes of arbitrary wavenumber by rotating electric fields in magnetized nonneutral plasmas. The results are in good agreement with theoretical predictions, proving this technique to be a useful tool in the study and control of fluid instabilities. In the future we are going to

1) Study the nonlinear relationship between wave frequency and amplitude.
2) Provide a more thorough characterization of the cascade decay of the modes and their damping.
3) Observe nonlinear dynamics of the wave growth and accurately control the amplitude via autoresonant excitation.