NONLINEAR DYNAMICS OF NONNEUTRAL PLASMAS

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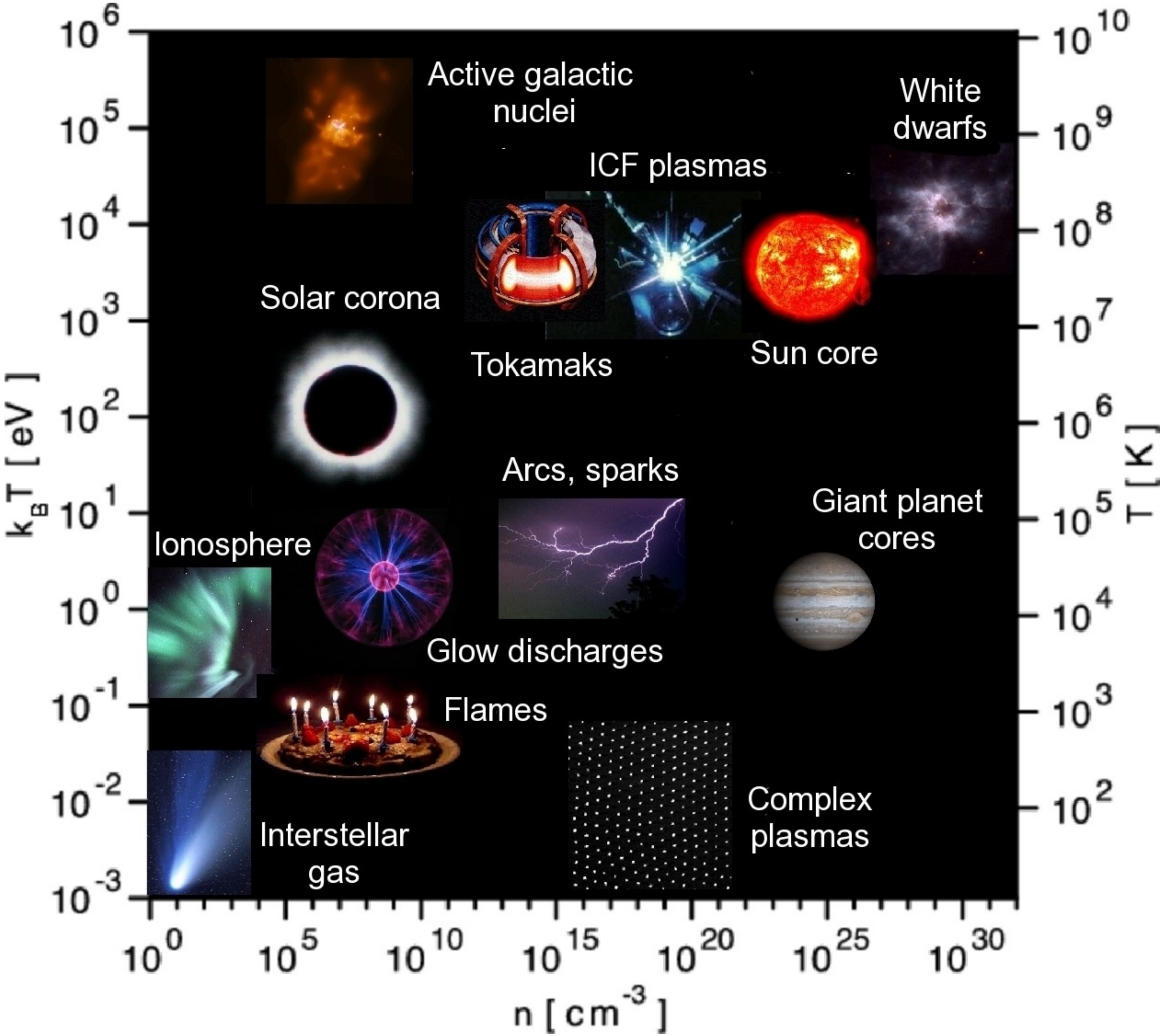
WHAT IS PLASMA?



Neutral plasma:

$$\sum Q_i = 0$$

Nonneutral plasma:

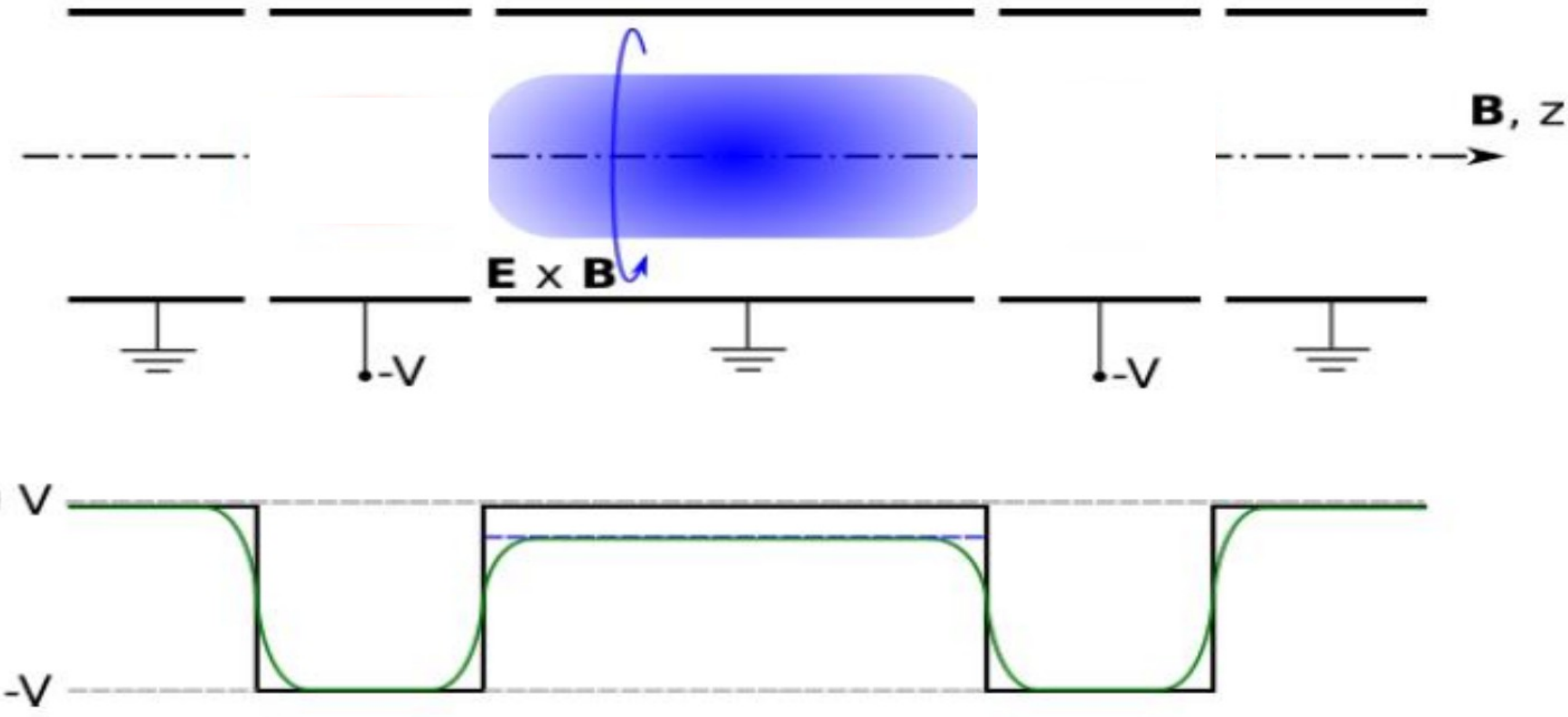
$$\sum Q_i \neq 0$$

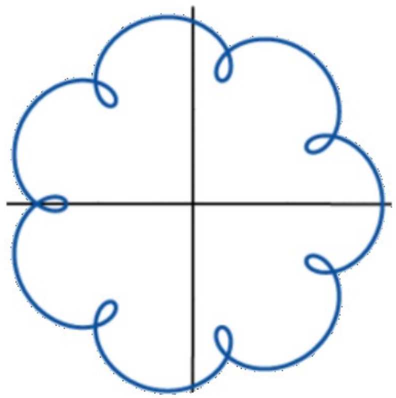
MAIN TOPICS OF MY RESEARCH ACTIVITY

1) EXPERIMENTS AND THEORETICAL MODELIZATION OF RADIOFREQUENCY GENERATION TECHNIQUE AND PLASMA DYNAMICS UNDER RF EXCITATION

2) FLUID INSTABILITIES AND COHERENT STRUCTURES IN NONNEUTRAL PLASMAS (E.G. DIOCOTRON WAVES AND THEIR DECAY)

PLASMA CONFINEMENT PRINCIPLE

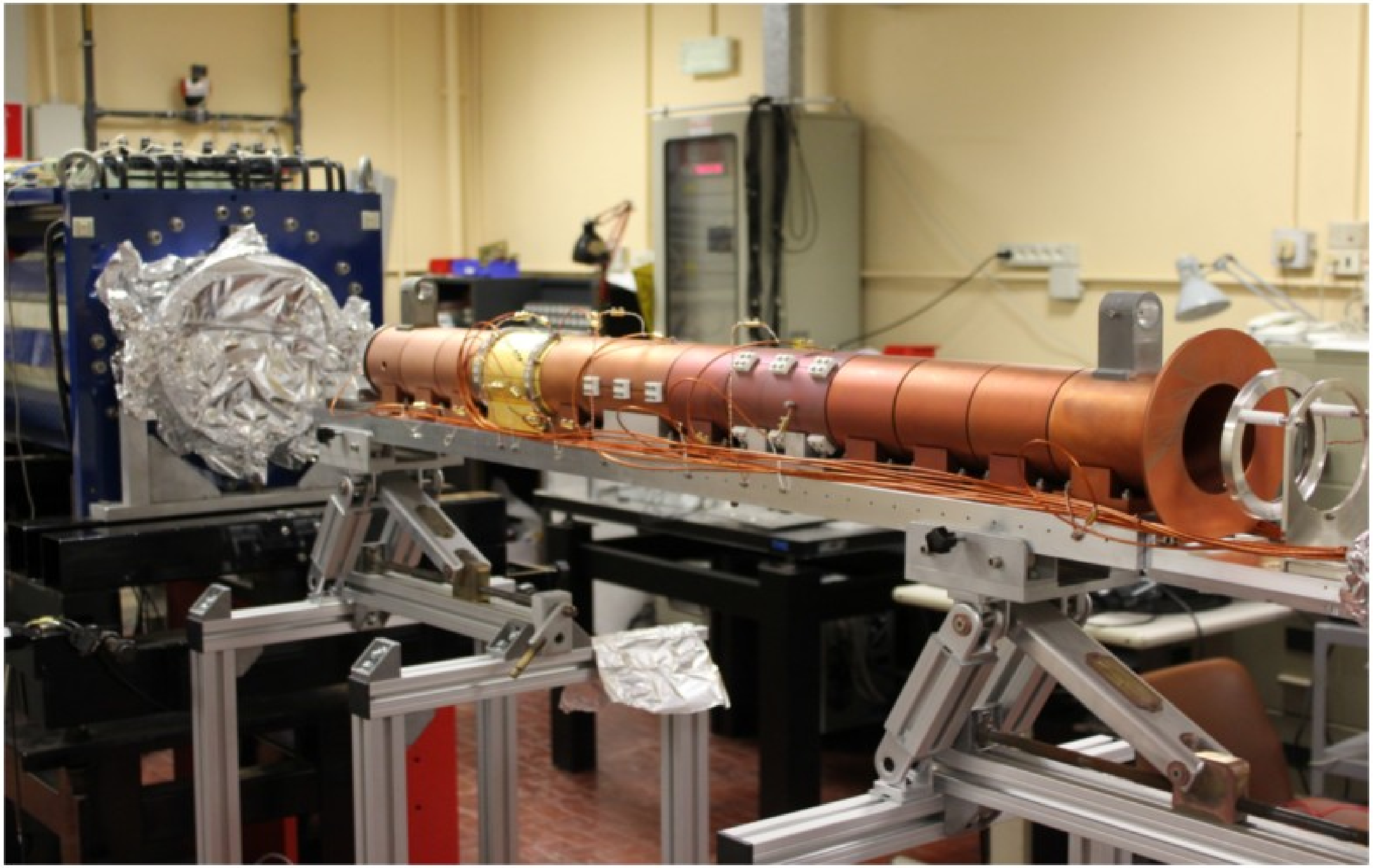




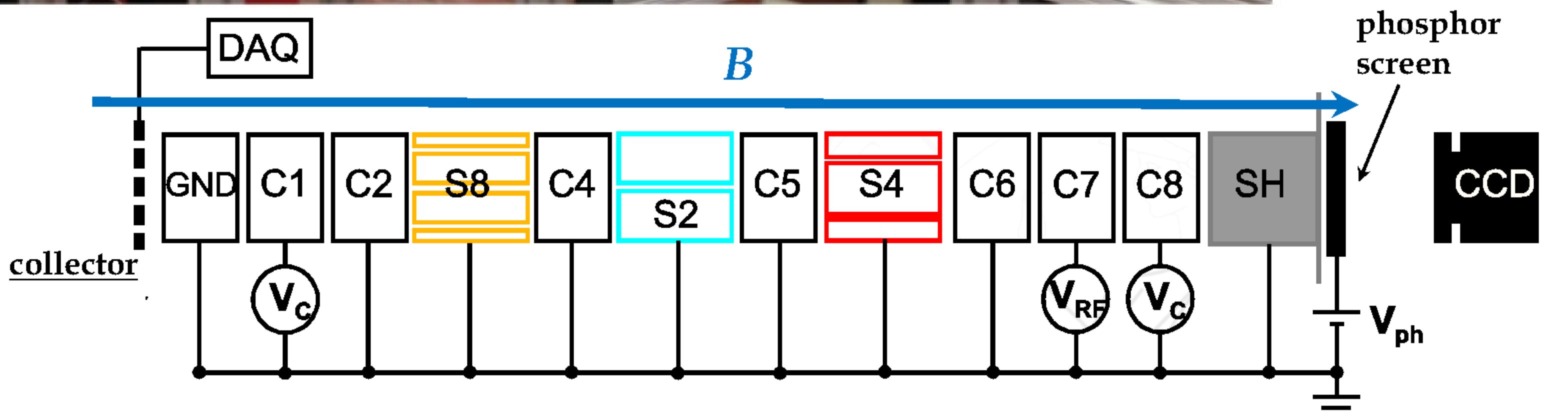
→ Cyclotron and E×B drift single particle orbit

$\nu_{ExB} << \nu_{lon} << \nu_{cyc}$

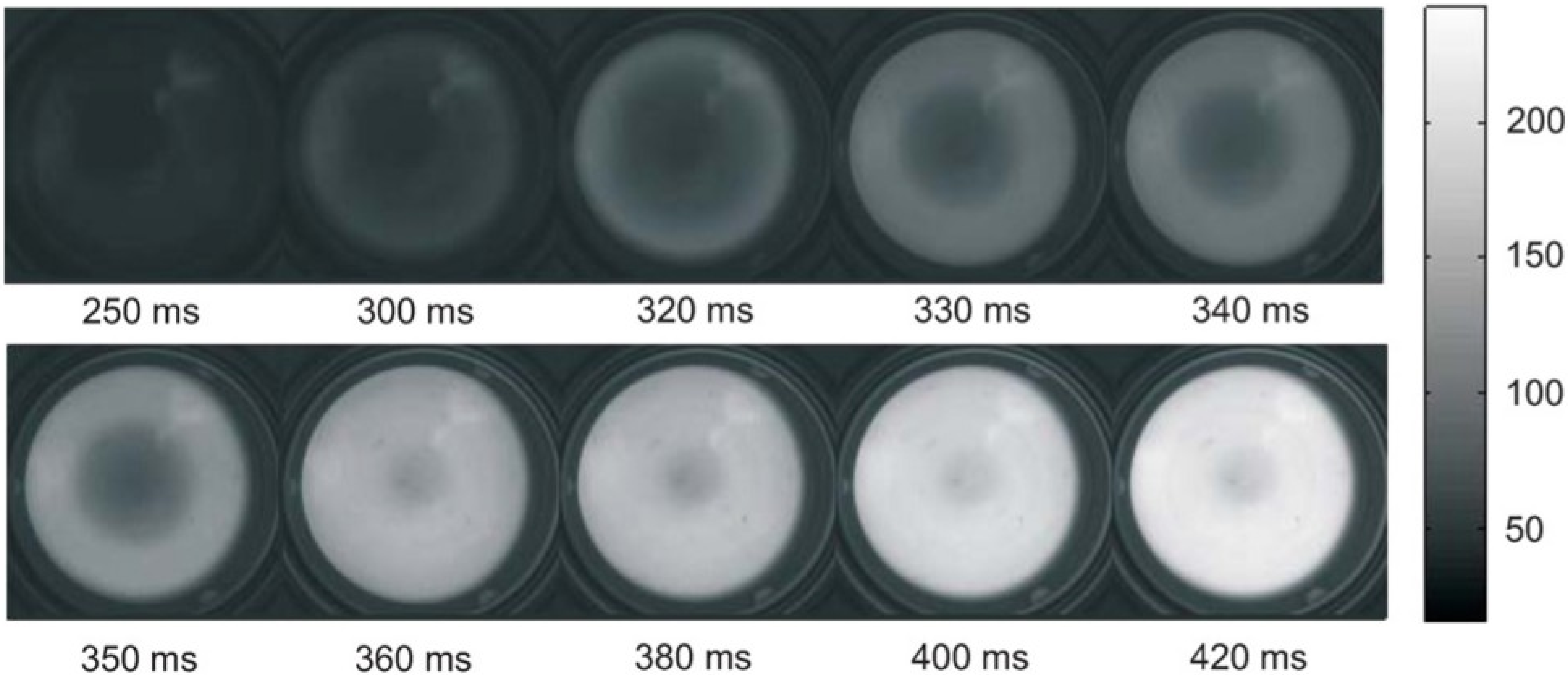
ELTRAP



- L<1 m
- ∅=90 mm
- B<0.2 T
- V_{con}=±100 V
- p~10^{-8} mbar
- T~300K



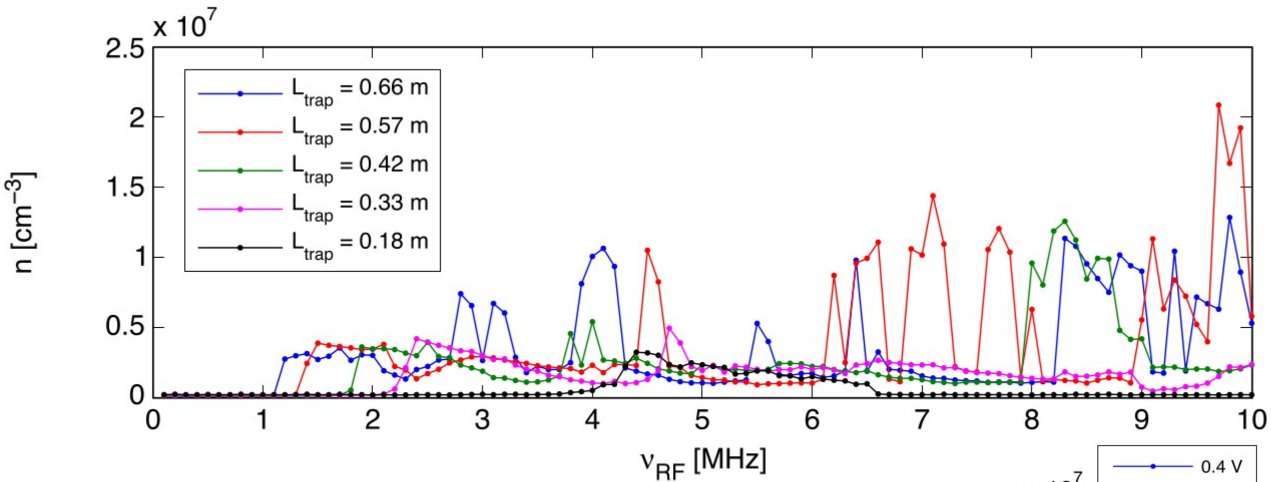
PLASMA FORMATION

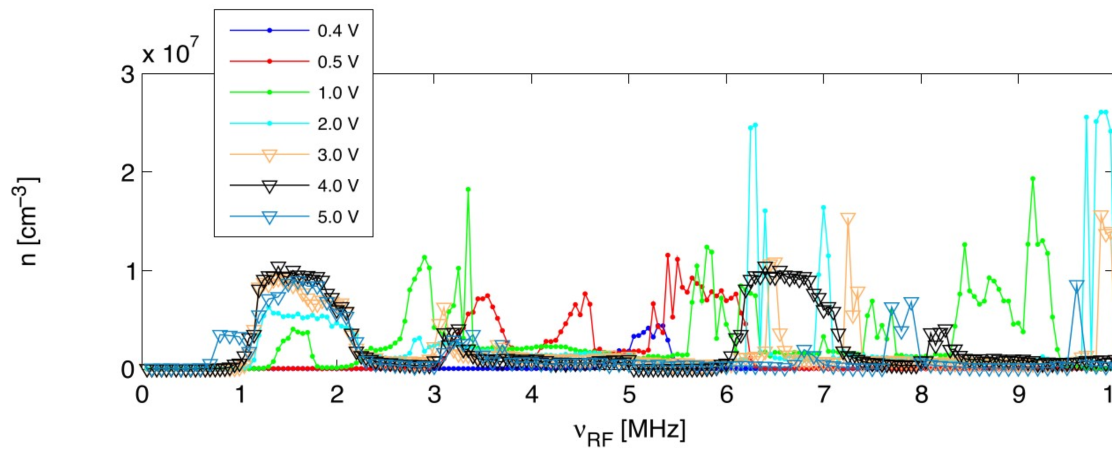


Radiofrequency excitation
- ν_{RF}~ MHz
- V_{pp}~ V
- Excitation time ~ s

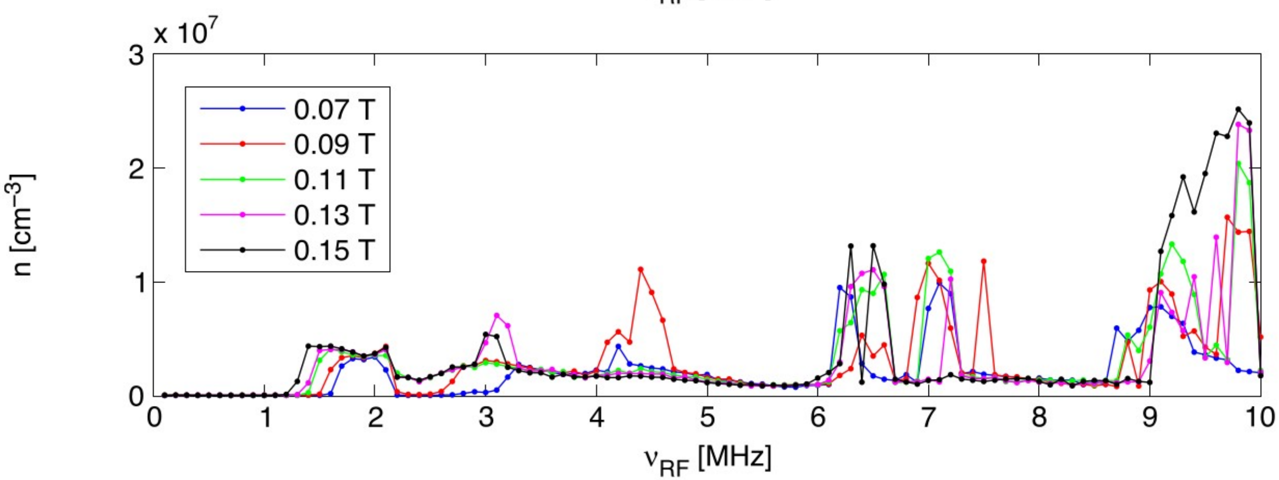
Electron plasma
- n_e~10^6 cm^{-3}
- Q~ 10^2 pC
- $T_{\parallel}$~ eV
- N_i/N_e<0,1

RF GENERATION SYSTEMATIC ANALYSIS

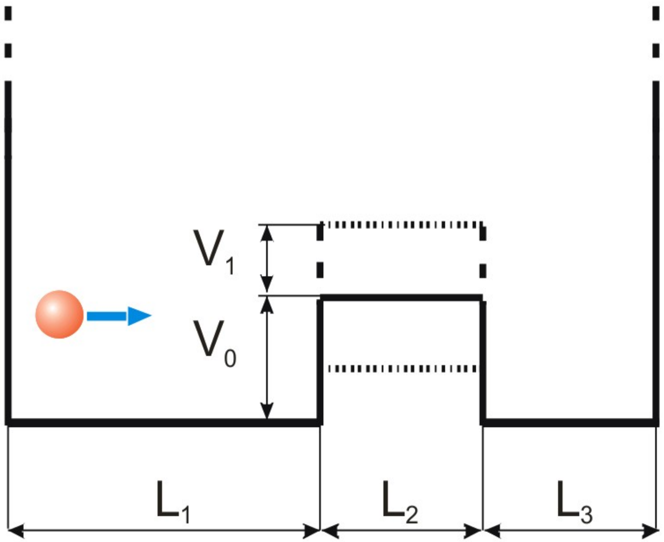


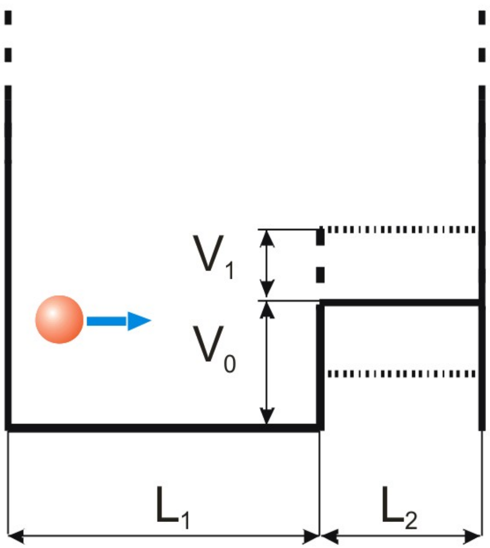


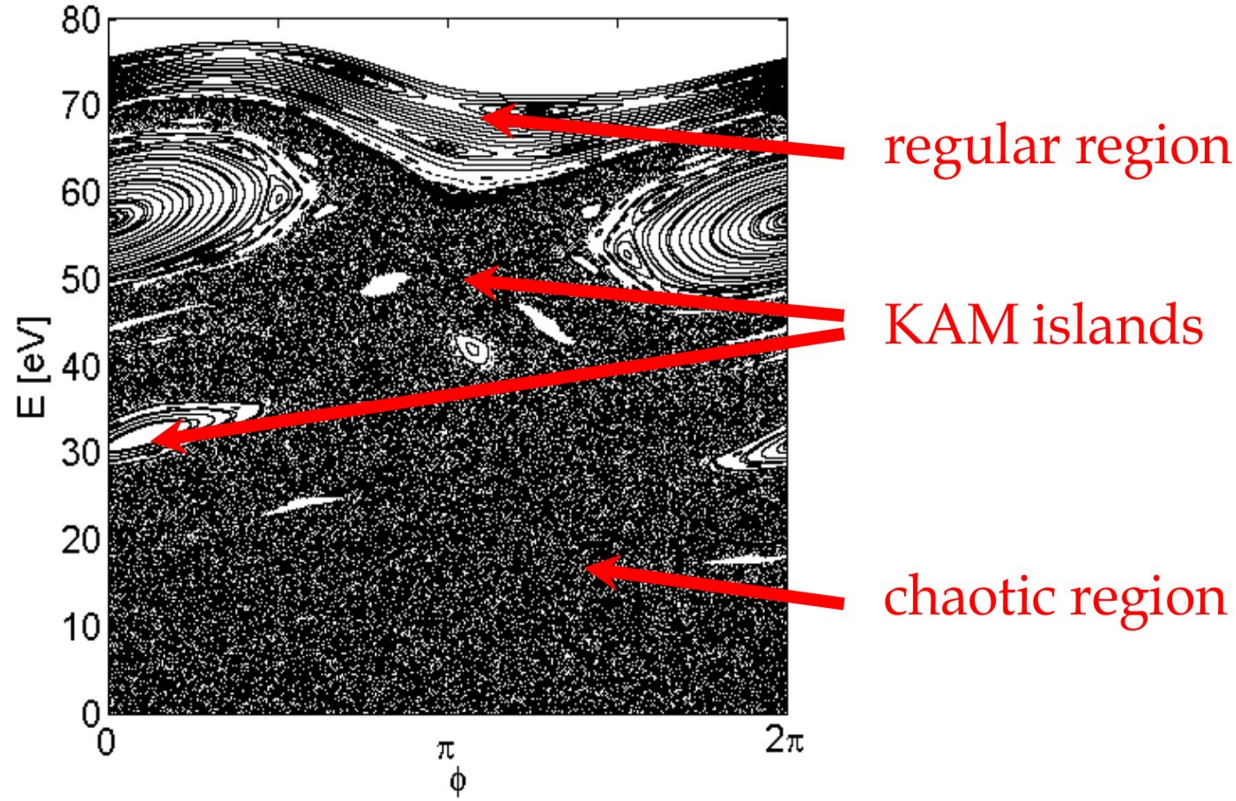
ν_{RF} [MHz]



1D SINGLE PARTICLE HEATING MODEL





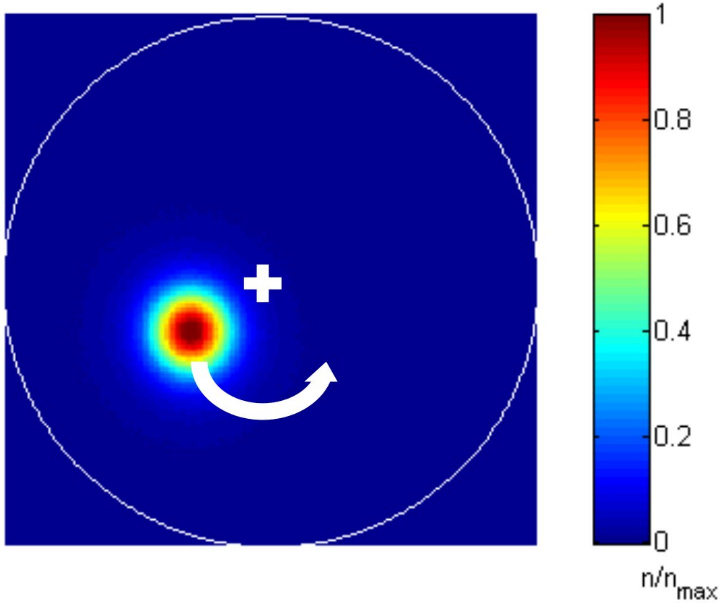


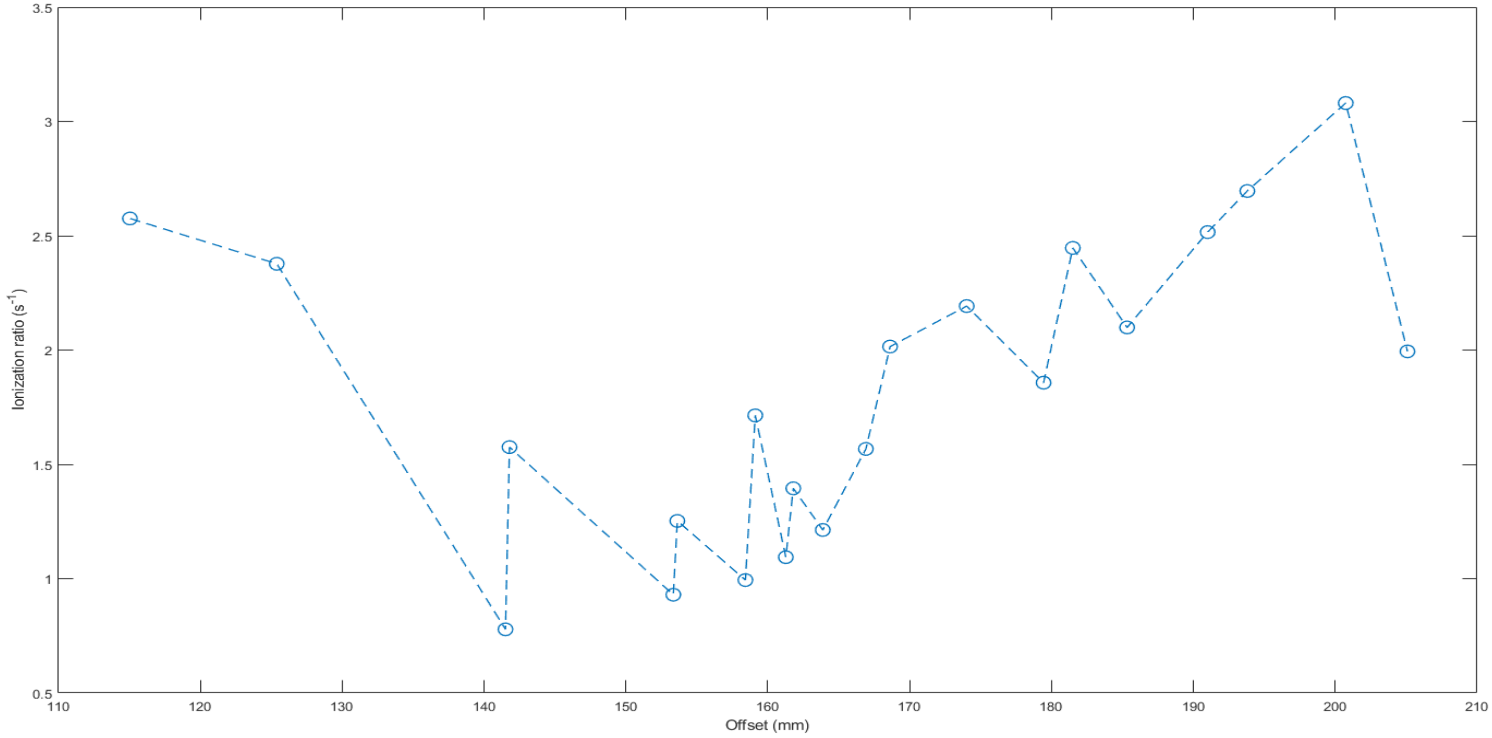
$$T_A \begin{cases} e_{n+1} = e_n \\ \phi_{n+1} = \phi_n + 4M / e_{n+1}^{1/2} \bmod (2\pi) \end{cases}$$

$$T_B \begin{cases} e_{n+1} = e_n - \sin\left(\phi_n + \phi_n^{'}\right) + \sin\left(\phi_n + \phi_n^{'} + 2i\phi_n^{''}\right) \\ \phi_{n+1} = \phi_n + \phi_n^{'} + 2i\phi_n^{''} + 2M / e_{n+1}^{1/2} \bmod (2\pi) \end{cases}$$

$$\text{with} \quad e_n = E_n / V_1, \quad M = L_1 \nu \Big/ \sqrt{2V_1/m}$$

RF SPATIAL CHARACTERIZATION

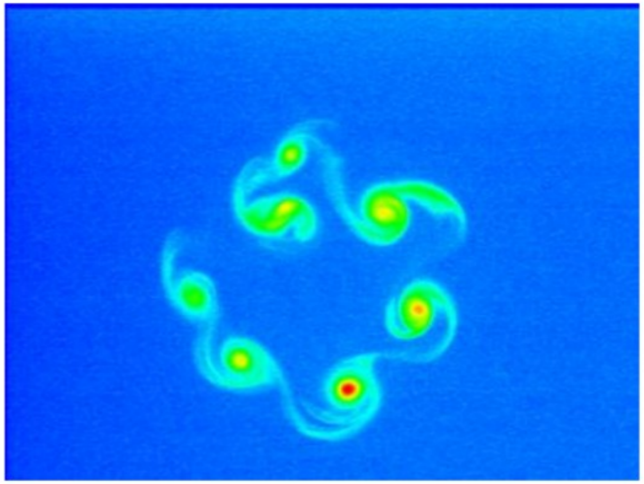


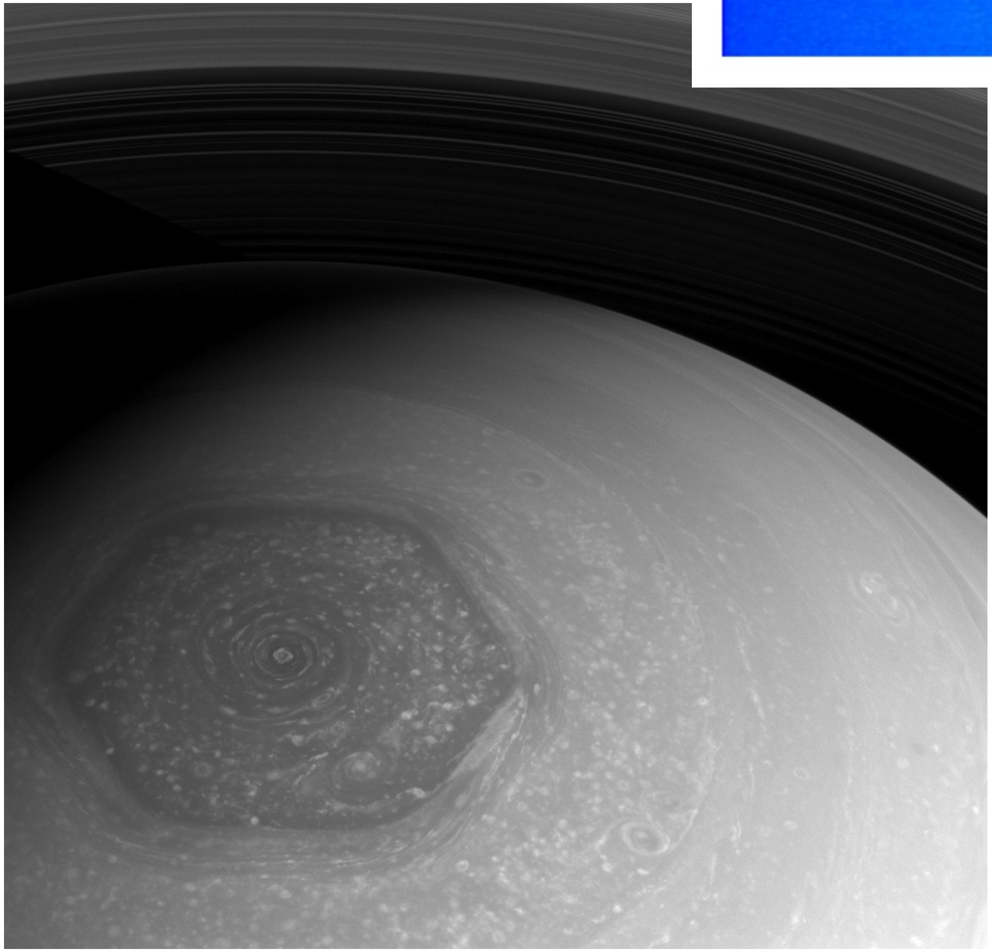


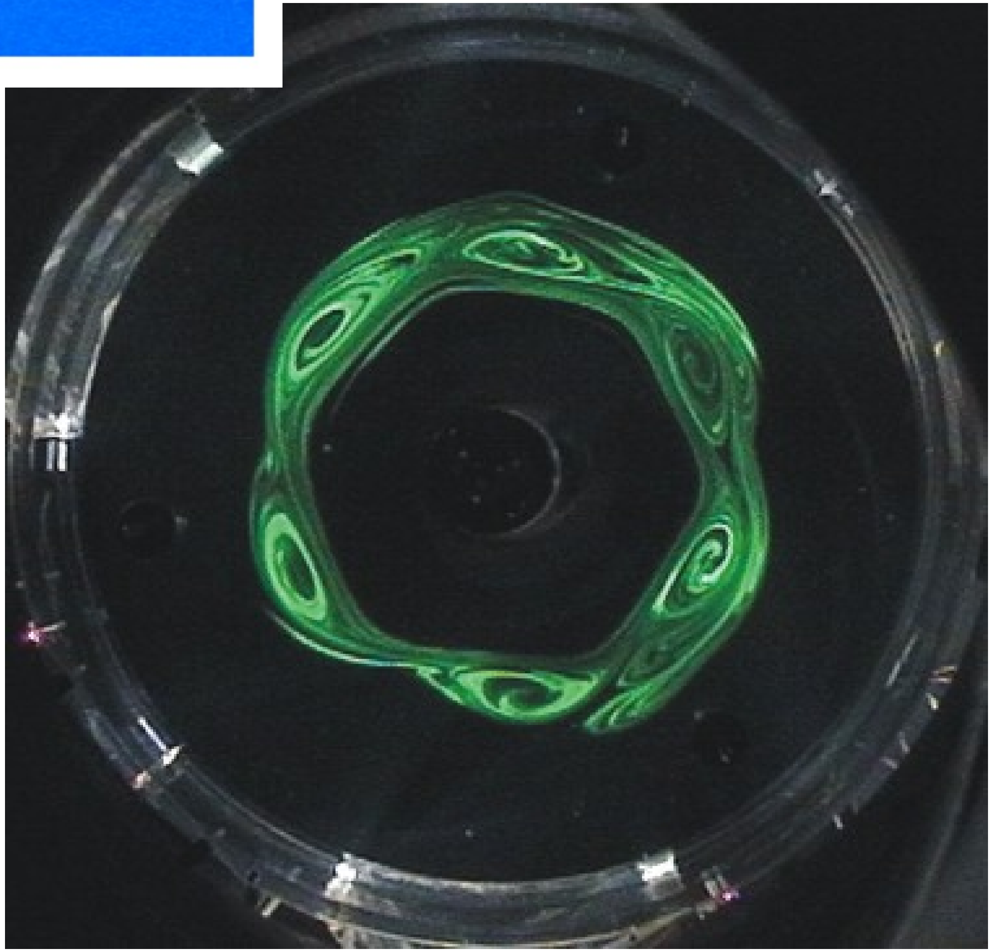
FLUID ANALOGY

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

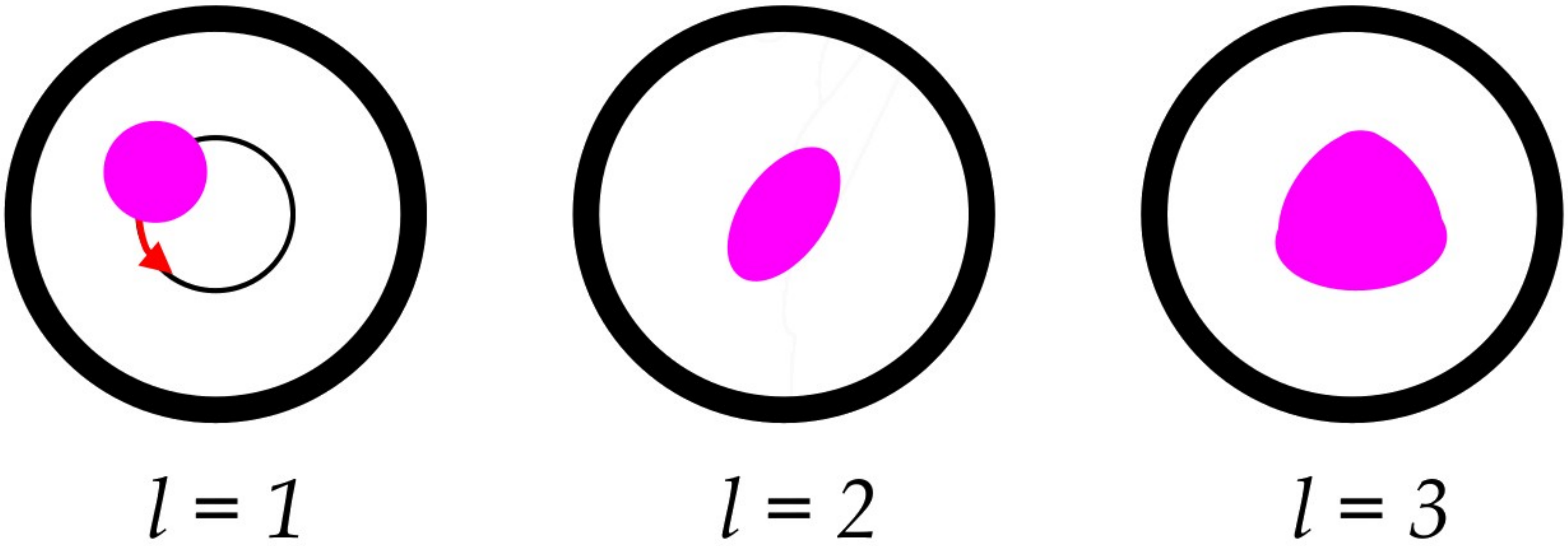
FLUID STRUCTURES IN NATURE AND IN LABORATORY







DIOCOTRON MODE



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

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

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

ROTATING ELECTRIC FIELD TECHNIQUE

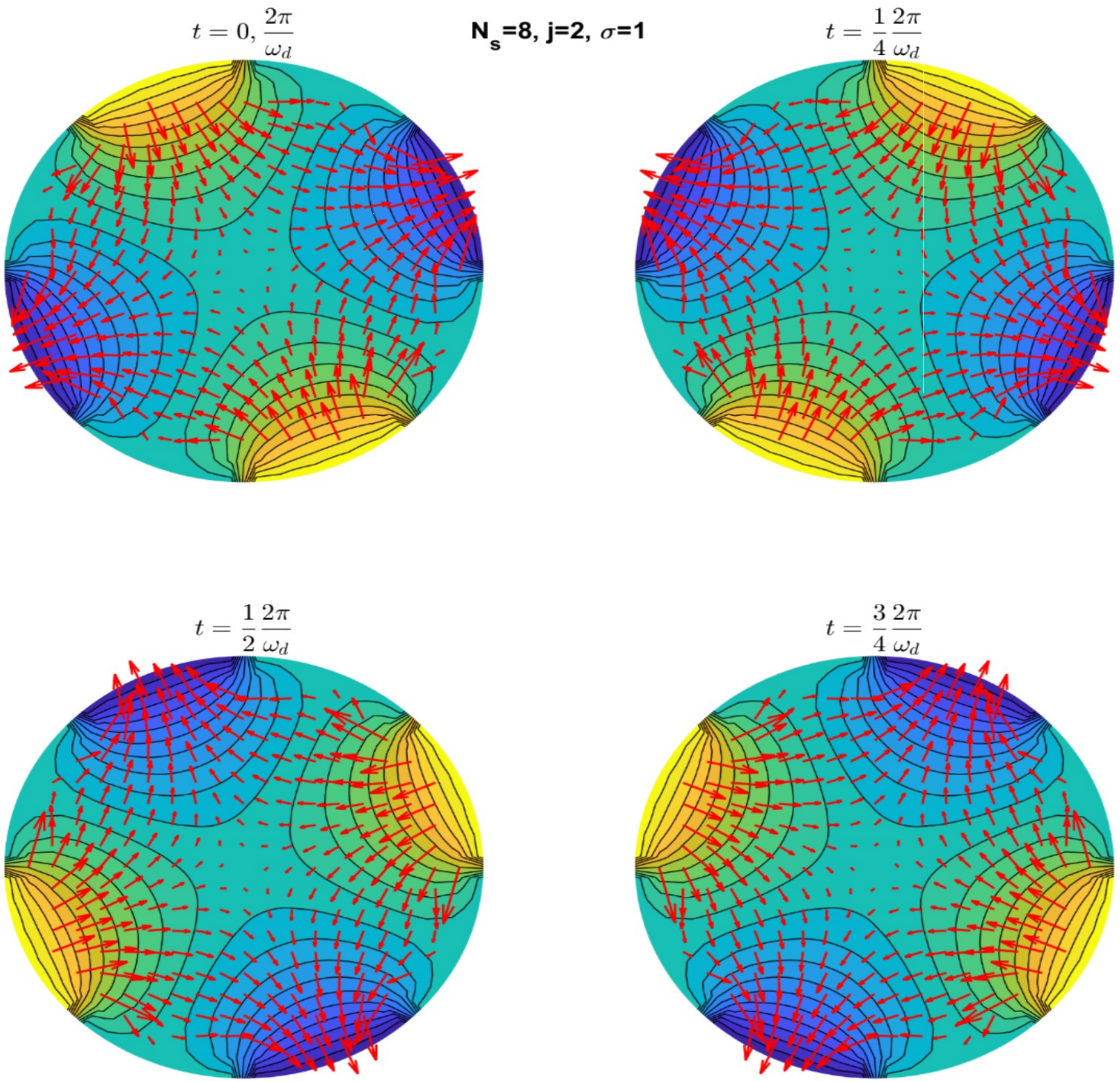
$$\delta\phi(r = R_w, \theta, t) = \sum_{m=0}^{N_s - 1} V_m(t)[H(\theta - 2m\pi / N_s) - H(\theta - 2(m+1)\pi / N_s)]$$

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

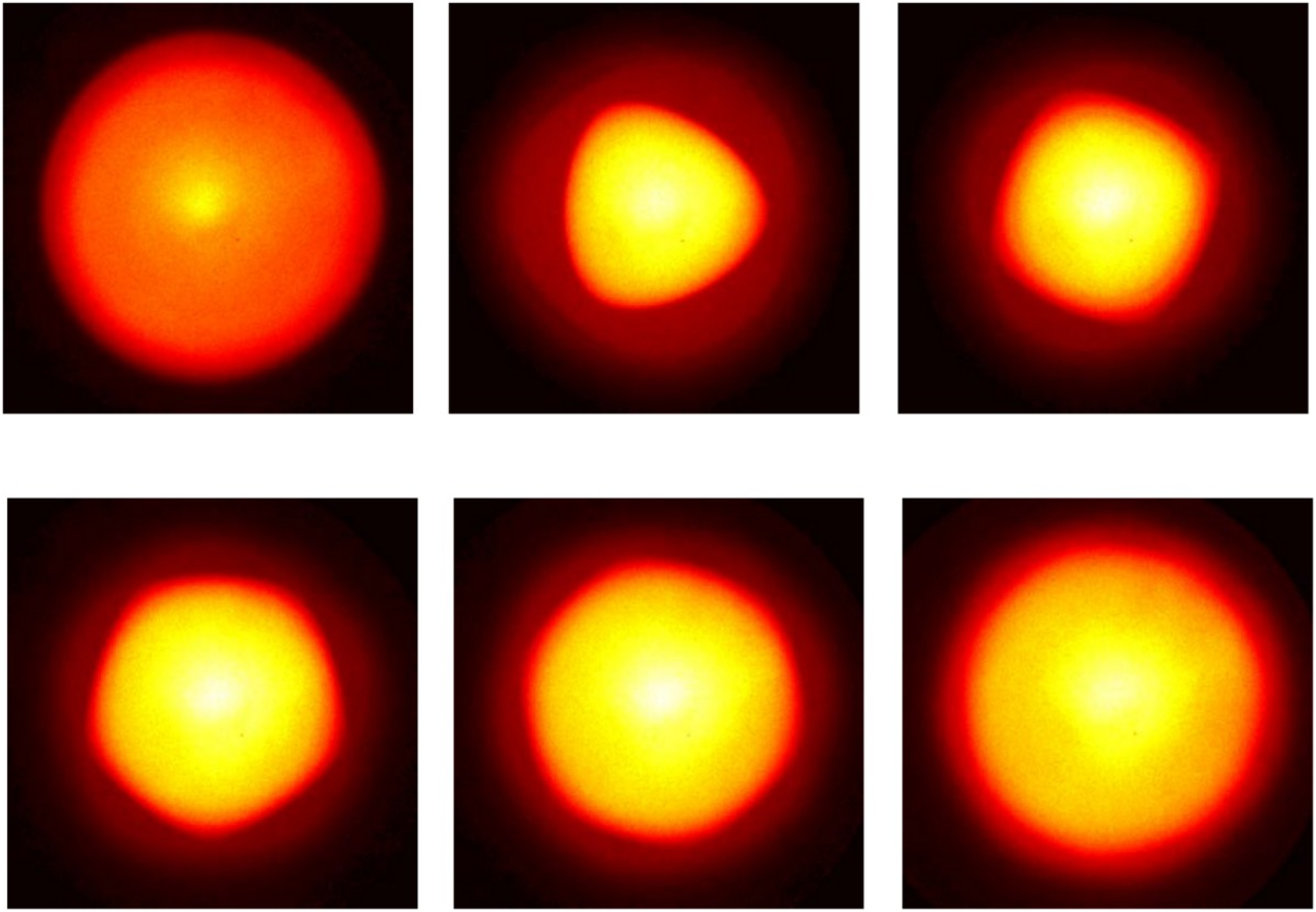
$$m = 0, \ldots, N_s - 1$$

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

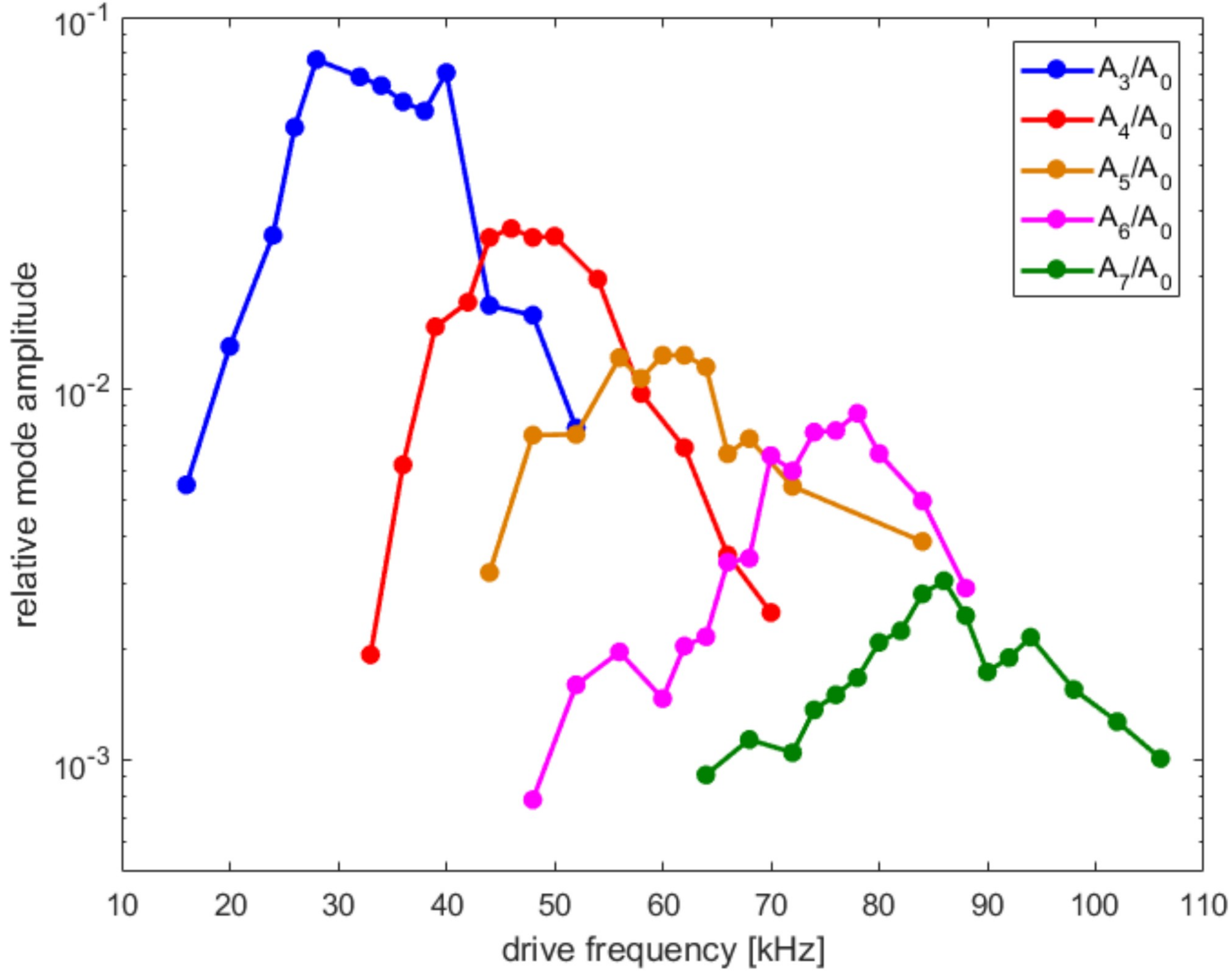
$$N_s = 8$$



RESONANT DIOCOTRON MODE EXCITATION



RESONANT DIOCOTRON MODE EXCITATION



FUTURE PERSPECTIVES

- Complete theoretical modelization and experimental characterization of RF-generation technique and plasma dynamics (formation, stationary states, modulation, bifurcation) under RF excitation.
- Systematic studies on higher diocotron mode excitation and waves decay, corroborated by pic 2D simulations, and theory development for linear and nonlinear case.
- Improvement of manipulation techniques of RF generated plasma for a better control of the quantities in interest (e.g. charge and density profile) in order to have a better shot-to-shot repeatability (feedback damping technique, plasma longitudinal squeezing).
- 2nd year PhD at UCSD