Chaos in the Electric Curtain

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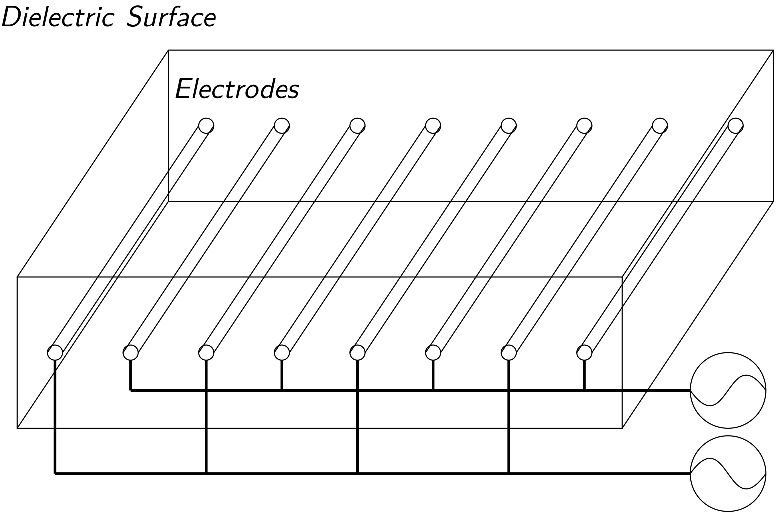
The Electric Curtain



Why Study the Electric Curtain's Chaotic Dynamics

A better understanding of the sensitivity of particle motion to physical parameters will improve applications such as:

- Dust mitigation in extraterrestrial envirionments (Mazumder et al., 2007)
- Separation of cells in solution (Masuda et al., 1988)
- Separation of by-products from agricultural processes (Weiss et al., 1984)
- Separation of particles with different charge to mass ratios (Kawamoto, 2008)

Simplifications

1. Primarily investigated single particle motion on the surface of the EC (1D) model.
2. Only preliminary work on particle motion above the surface.
3. In both cases dissipative forces are considered.
   - 1D Dissipative forces: Rolling resistance and viscous fluid force. Both are proportional to velocity (Brillianttov and Poschell, 1999).
   - 2D: Viscous fluid force (non-dissipative collisions)
4. For the center line charge approximation the electrodes are considered as one dimensional wires. To make this approximation valid we need the surface to be an adequate distance above the plane of electrodes.

Center Line Charge Approximation

Approximate electric field equations (Masuda and Kamimura, 1975):

$$E_x = \frac{kQ}{4\pi\epsilon_0} \sum_{n=0}^{1} \frac{\sin(kx - n\pi)\cos(\omega t - n\pi)}{\cosh(ky) - \cos(kx - n\pi)}$$

$$E_y = \frac{kQ}{4\pi\epsilon_0} \sum_{n=0}^{1} \frac{\sinh(ky)\cos(\omega t - n\pi)}{\cosh(ky) - \cos(kx - n\pi)}$$

Non-Dimensionalized Parameters

$$t' = \omega t$$
$$x' = kx$$
$$y' = ky$$

$$j = \frac{k^2 qQ}{4\pi\epsilon_0 m^2 \omega^2}$$
$$g' = \frac{gk}{\omega^2}$$
$$\beta' = \frac{\beta}{m\omega}$$

j is the dimensionless interaction amplitude.
Dimensionless Equations of Motion:

$$\frac{d^2x'}{dt'^2} + \beta' \frac{dx'}{dt'} = \sum_{n=0}^{1} j \frac{\sin(x' - n\pi)\cos(t' - n\pi)}{\cosh(y') - \cos(x' - n\pi)}$$

$$\frac{d^2y'}{dt'^2} + \beta' \frac{dy'}{dt'} = \sum_{n=0}^{1} j \frac{\sinh(y')\cos(t' - n\pi)}{\cosh(y') - \cos(x' - n\pi)} - g'$$

Interaction Amplitude Regimes

Place particle directly above electrode to solve for when the electrostatic force equals the gravitational force.

$$\sum_{n=0}^{1} j \frac{\sinh(y') \cos(t' - n\pi)}{\cosh(y') - \cos(x' - n\pi)} = g'$$

The inequality:

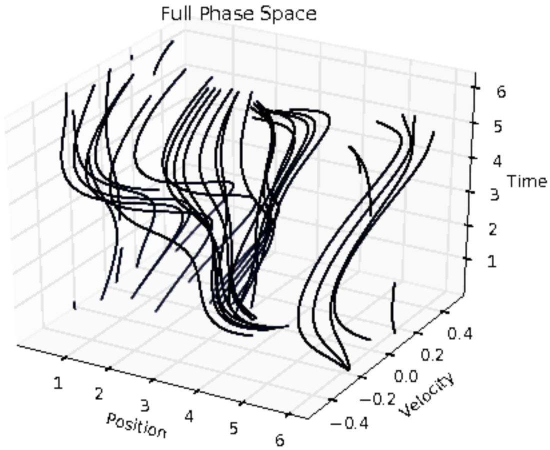
$$\frac{j}{g'} \leq \frac{\cosh^2(y') - 1}{2 \cos(t') \cosh(y')}$$

needs to be satisfied for the particle to remain on the surface. When we make $\cos(t')$ one and put it $y' = 1$ we find that:

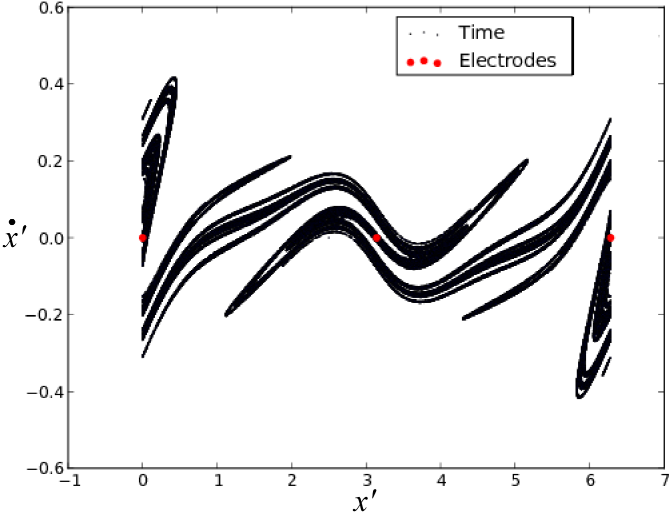
$$\frac{j}{g'} \approx .448$$

is the critical ratio that needs to be considered.

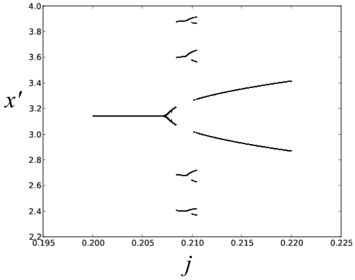
The full periodic phase space



Full phase space time sliced



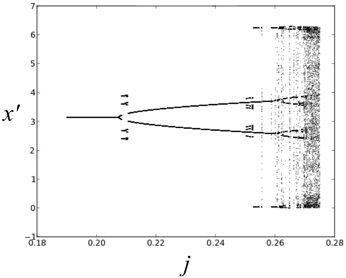
Period doubling?



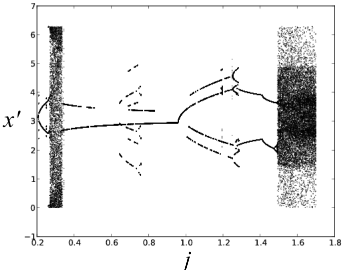
Period 2 Orbit

Period 4 Orbit

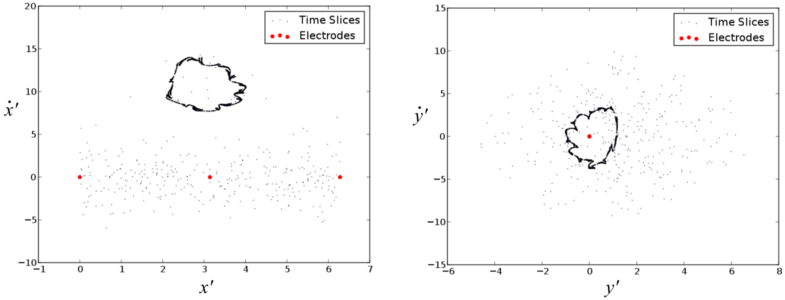
A unique period doubling rout to chaos



Chaotic Orbit



Preliminarly 2D Work



Conclusion

- We have analyzed a simplified model of the electric curtain by using Poincaré sections and bifurcation diagrams.
- Particle trajectories in a real Electric curtain have the potential to be chaotic but may also exhibit order. Understanding the chaotic dynamics may help improve the electric curtain for its current applications and may suggest the possibility of new applications.
- **Future work:**
  - Improve our computational model and start to include particle-particle interactions.
  - Experimentally verify our computational findings.
  - Quantify the strength of chaos (find the Lyapunove spectrum)

Bibliography

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