Antonio Castellanos
Prof. of Electromagnetism
1947 – 2016
A great scientist and a great man

by F. Pontiga, A. Ramos and E.F. Grekova

The roots

Antonio Castellanos was born in Antoñanes del Páramo, a small village near León, on 7th of March of 1947.

The roots

He was the third (and last) child of a modest family.

His father, Manuel Castellanos Berjón, was a talented teacher. He was a "republican teacher", persecuted by Franco's regime. He taught children during all his life, though for many years he was prohibited to do it.

Manuel Castellanos Berjón, Antonio's father

The roots

Antonio's mother, Fidela Mata Sarmiento, was also a woman of exceptional intelligence, strong personality and a passionate reader.

Antonio's parents separated in his early childhood, but his father continued to be in touch with the children, and taught Antonio mathematics.

Fidela Mata Sarmiento, Antonio's mother

The roots

Close family ties with his mother and his siblings, Domingo José and Aurora, were very important for Antonio during all his life.

Antonio with his sister, mother and brother in Gijón (Spain) 1997.

The child

Antonio and his family moved to León when he was six years old.

He decided to entered the seminary to become a priest, which gives him the possibility of pursuing his undergraduate studies.

However, during his adolescence, he started questioning the religious philosophy he had to study, and he left the seminary.

The child

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León Cathedral, also called *The House of Light*

The university student

He enters the Faculty of Physical Sciences of the University of Valladolid in 1963, and graduated in 1969.

In 1972 he got his PhD in Nuclear Physics.

Later, he will spend the next academic year in Ohio University (USA), with a Fulbright scholarship.

Antonio (right), with some classmates, during a travel to Madrid.

The traveler

Before returning to Spain, Antonio, with his friend Sergio, embarked on a journey through almost all of Latin America, following the trail of the Pan American Highway.

This was a journey no exempt of risk and real danger, which marked his whole life.

The husband and father

Antonio met his first wife, María Elena Navarrete Sandoval, while he was staying in USA. They had two children: Antonio and Dayeli Anahí.

Antonio and María Elena.

The husband and father

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Antonio Junior with his father

Dayeli

The husband and father

During a conference in St. Petersburg, Antonio met his second wife, Elena Grekova, with whom he had two children: León and Iván.

Elena and Antonio

The husband and father

During a conference in St. Petersburg, Antonio met his second wife, Elena Grekova, with whom he had two children: León and Iván.

Iván, León and Antonio

The Professor

After coming back from the USA, he started to work at the University of Valladolid, and later at the University of País Vasco.

In 1978 he joined the group of Prof. Manuel García Velarde, at the Universidad Autónoma (Madrid).

In 1983 he obtained the position of full professor, at the University of Seville, where he worked until the end of his life.

Giving a seminar…

The Scientist

He worked in closed collaboration with top researchers from around the world: *Pierre Atten* (Grenoble, France), *Keith Watson* (Xerox Corp., Rochester, USA), *J. S. Chang* (Hamilton, Canada), *Hywel Morgan* (Glasgow, UK), *Anton M. Krivtsov* (St. Petersburg, Russia) and many others.

He co-authored more than 350 papers with more than 7800 citations (after Google Scholar).

Antonio, K. Urashima, J. Yagoobi and P. Atten

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Antonio at K. Watson's home.

The Scientist

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Antonio at Mc Master, with J.S. Chang, G. Touchard, K. Asano, T. Lee, O. Lesaint, and others.

Antonio and Advanced Problems in Mechanics

Pavel Zhilin, Iliya Blekhman, Vladimir Palmov, Anton Krivtsov, Dave Harris and Antonio Castellanos at APM 2004.

Antonio and his group participated in APM conferences starting from 1998, when it still had another name: “Nonlinear Oscillations in Mechanical Systems”. He was one of first foreign participants of APM, a permanent member of its Scientific Committee, and organized various minisymposia. Antonio always was very keen to discuss with his Russian colleagues, among them especially with Pavel Zhilin, Dmitri Indeitsev and young scientists, who always were attracted by his passion for science, bright ideas, his open, friendly personality and fine sense of humour.

Antonio and Advanced Problems in Mechanics

These scientific discussions continued even at the banquet…

First plan: Irina Goryacheva, Elena Grekova, Antonio Castellanos, Anton Krivtsov at APM2005

The Head of EHD&CGM Group

Antonio founded the EHD&CGM Group of the University of Seville, which encompasses three major research lines:

-Electrohydrodynamics,
-Gas discharges,
-Cohesive granular materials.

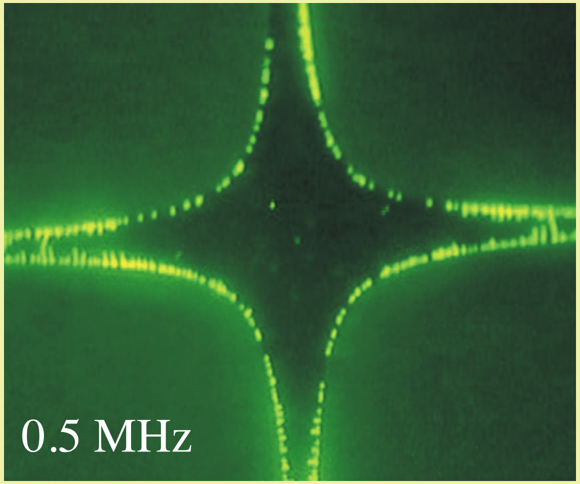
His exceptional leadership allowed him to found two excellent laboratories.

Two outstanding contributions:

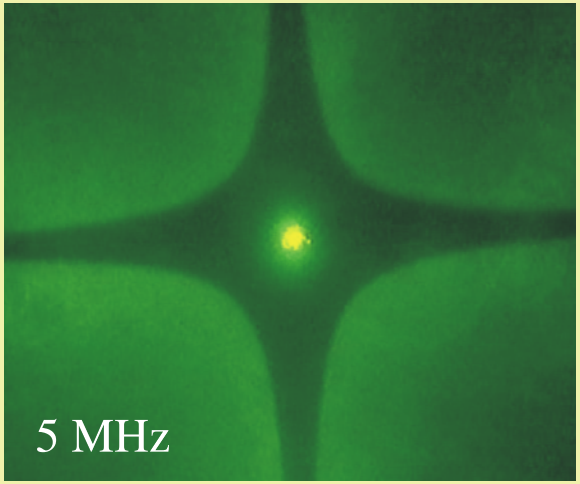
- *Flow of electrolytes driven by AC electric fields on microelectrode structures: AC Electroosmosis*

- *Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient*

Flow of electrolytes driven by AC electric fields on microelectrode structures: AC Electroosmosis



Positive DEP



Negative DEP

During dielectrophoretic manipulation of particles suspended in electrolytes…

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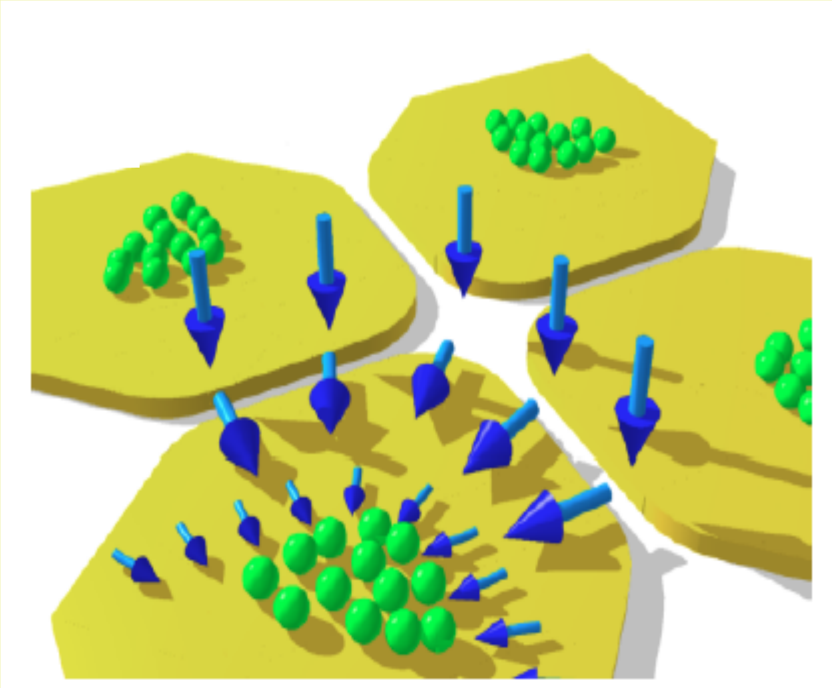
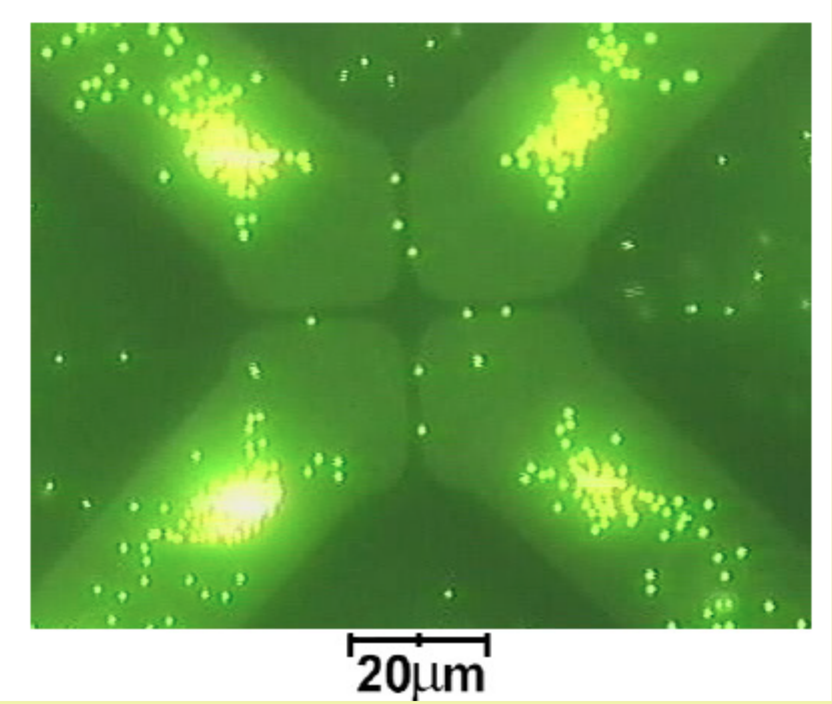
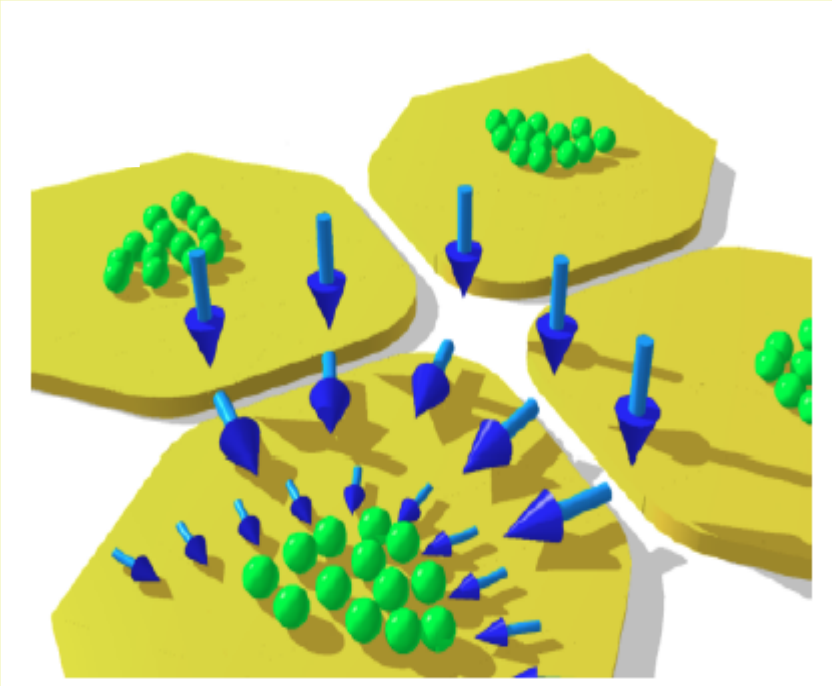
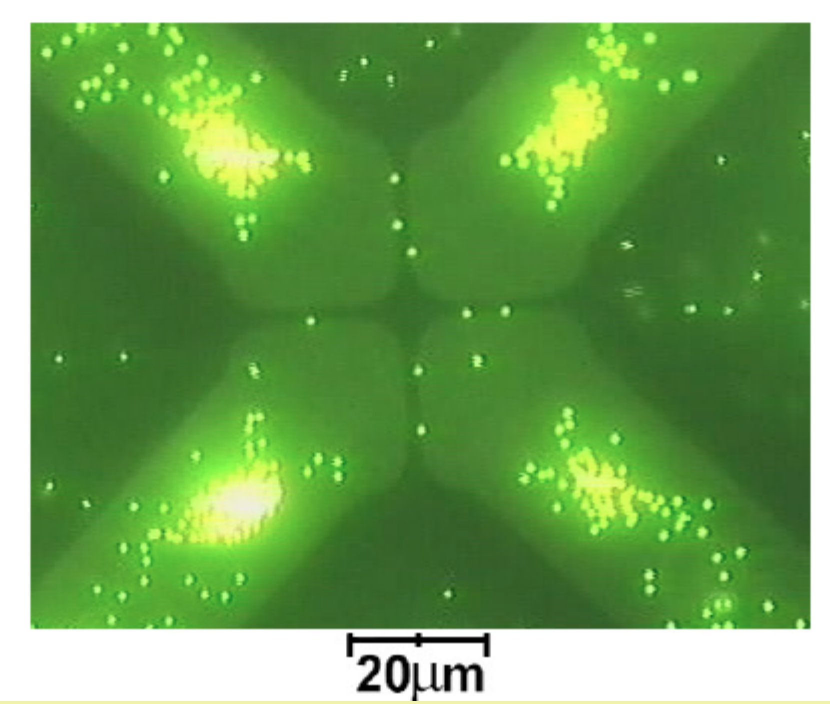




…strong frequency-dependent fluid flow is observed, predominantly at low frequencies.





The flow occurs due to the action of the applied electric field on the charge which is induced in the electrical double layer on the electrodes.

AC Electric-Field-Induced Fluid Flow in Microelectrodes

Journal of Colloid and Interface Science **217**, 420–422 (1999)
Article ID jcis.1999.6346, available online at http://www.idealibrary.com on IDEAL®

LETTER TO THE EDITOR

AC Electric-Field-Induced Fluid Flow in Microelectrodes

Antonio Ramos,*
Hywel Morgan,†,1
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Antonio Castellanos*

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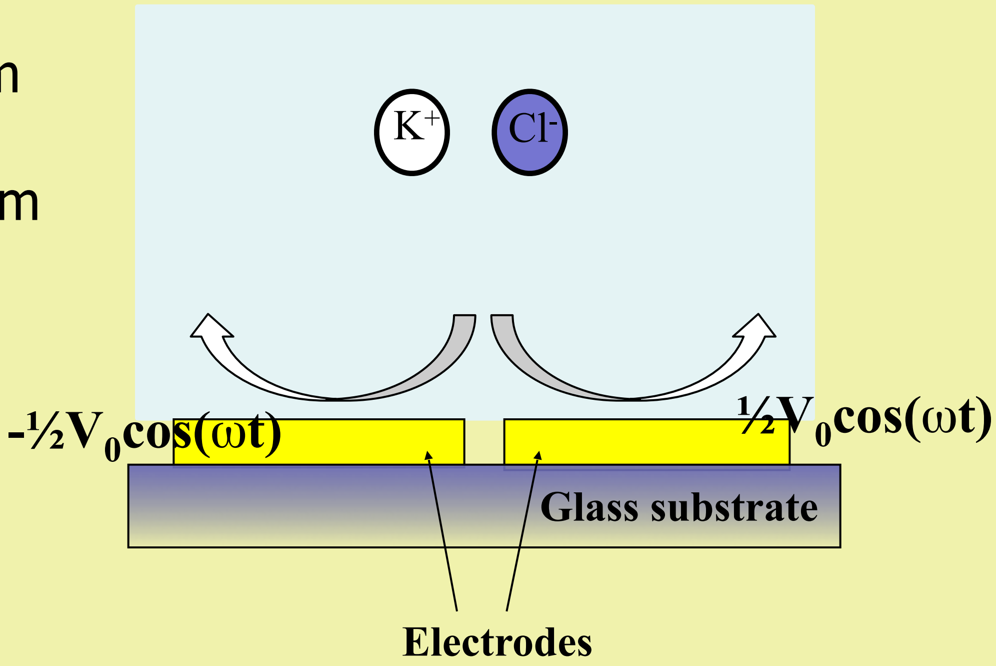
Department of Electronics and Electrical Engineering
University of Glasgow
Glasgow G12 8LT
United Kingdom

Citations 488 (28 in 2016)

Fluid flow at low voltage and frequencies is induced on microelectrode surface

- **Saline solutions in water:**
  $c < 0.1$ M
- **Typical length** $L \sim 1$ to 100 μm
- **Debye length** $\lambda_D \sim 5$ nm to 50 nm
- **Signals from** 0 to 5 Volts
  $E \sim 10^4 - 10^5$ V/m
- **Frequency range:**
  $f = 10^2$ to 10^5 Hz
  $T = 1/f >> \varepsilon / \sigma$



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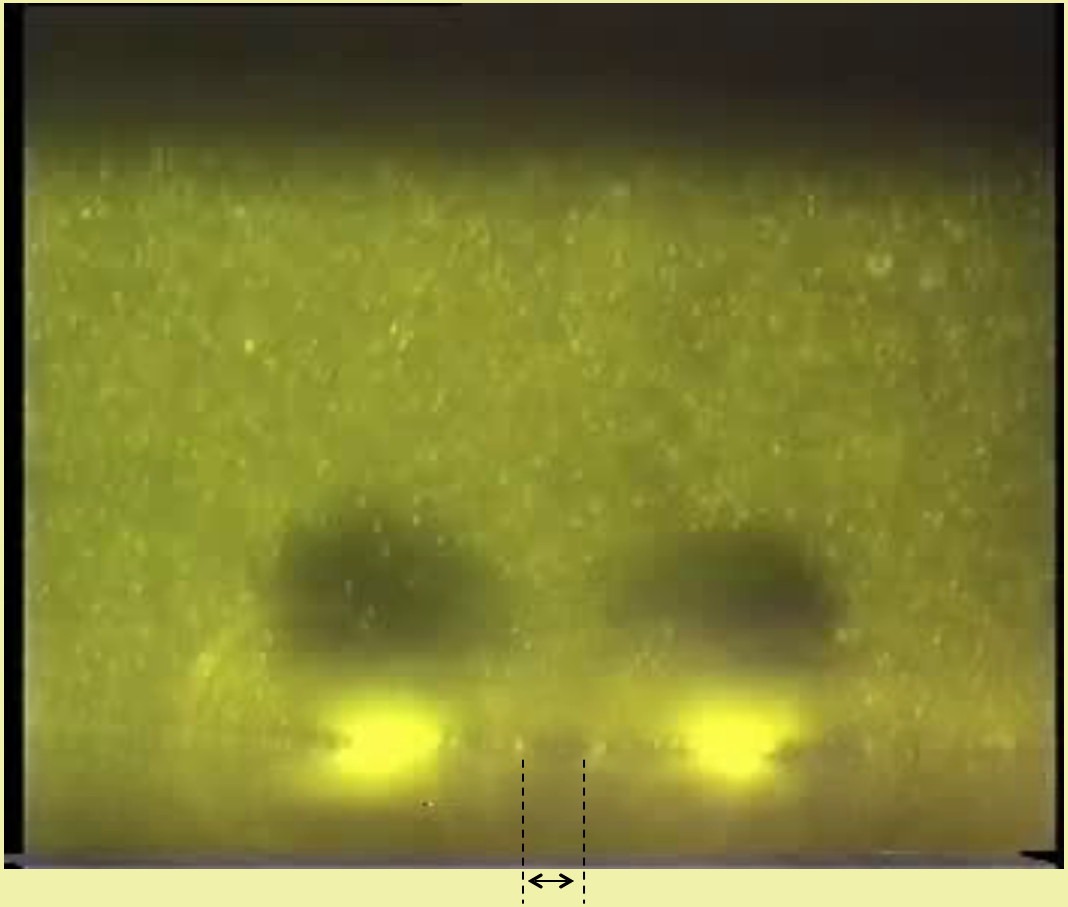
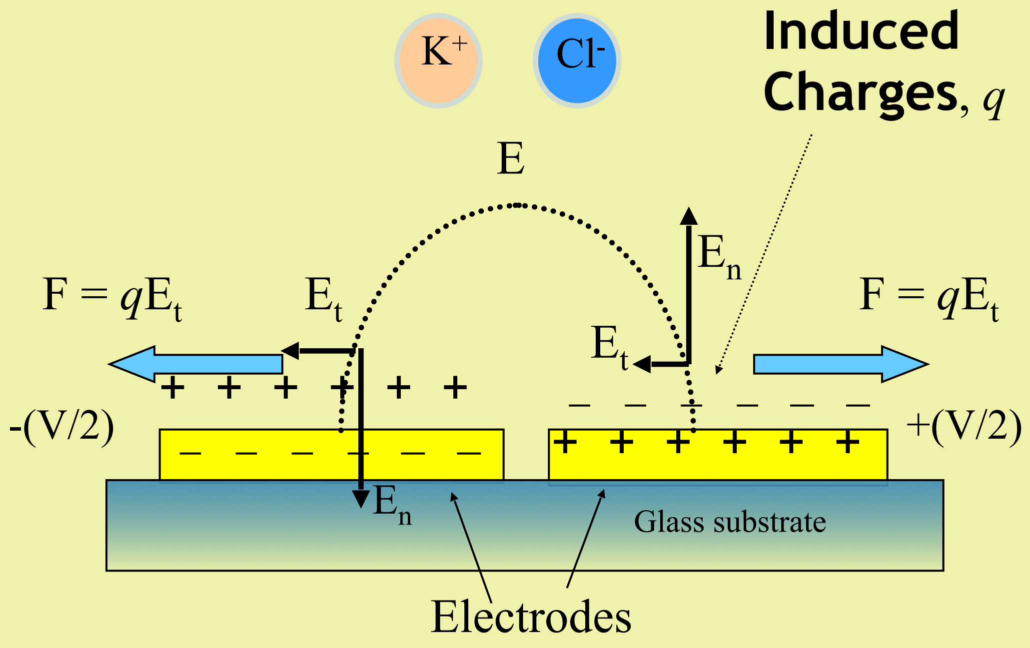
4 Vpp, 1 kHz



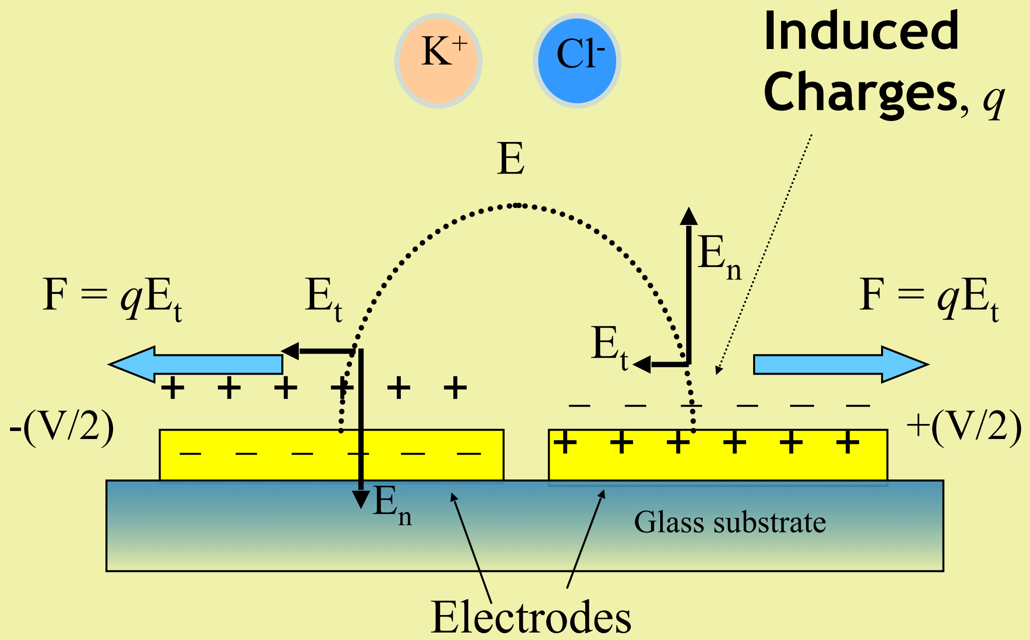
Charge induced in the double-layer leads to the appearance of electrokinetic slip velocity



$$\sigma E_n = C_{DL} \frac{\partial \zeta}{\partial t}$$

Double layer charging from electric current

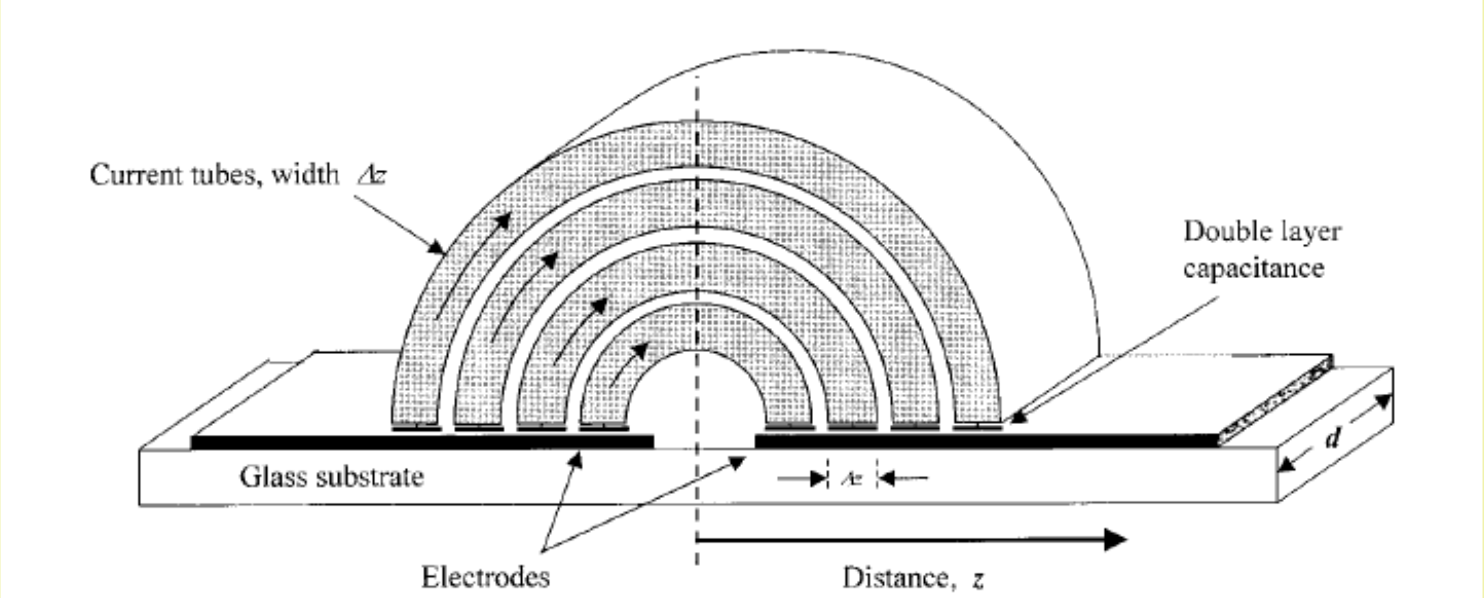
Charge induced in the double-layer leads to the appearance of electrokinetic slip velocity



$$u_{slip} = \frac{\varepsilon \langle \zeta(t) E_t(t) \rangle}{\eta}$$

Helmholtz-Smoluchowski equation

A simplified model reveals the important length and time scales



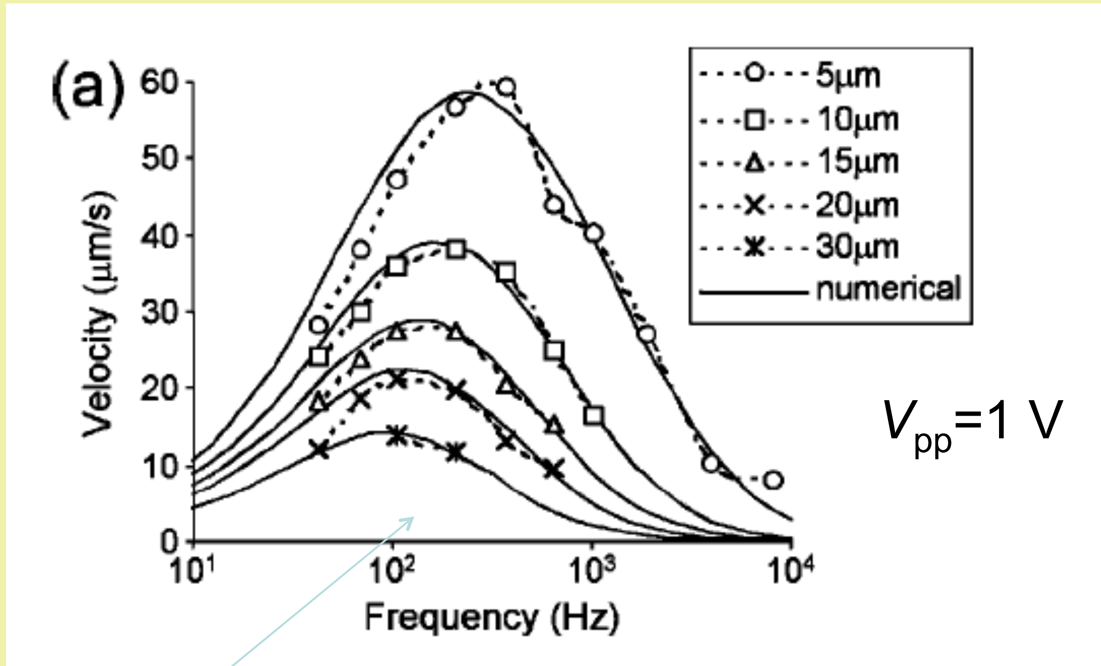
The voltage across the double layer is

$$V_d(z) = \frac{V_0}{2 + j\omega\pi z \frac{\varepsilon}{\sigma} k}$$

And the slip velocity is

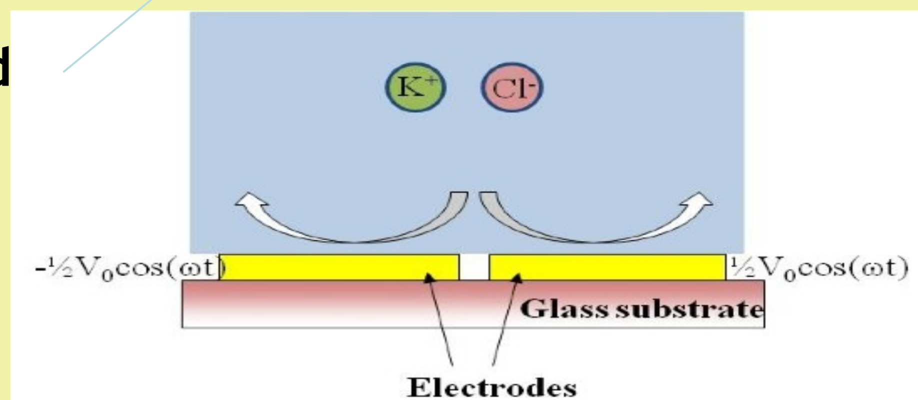
$$< v >= \frac{1}{2}\mathrm{Re}\left\{\frac{\Delta\sigma_q E_t^*}{\eta k}\right\} = \frac{1}{8}\frac{\varepsilon V_0^2 \Omega^2}{\eta z (1+\Omega^2)^2}$$

Comparisons theory and experiments



V_{pp}=1 V

characteristic frequency around $1/R_{bulk}C_{DL}$



A detail experimental and theoretical study was published

Fluid flow induced by nonuniform ac electric fields in electrolytes on microelectrodes. I. Experimental measurements
Physical Review E, vol. 61, no. 4, pp. 4011-4018 (2000) **(citations 509)**

Fluid flow induced by nonuniform ac electric fields in electrolytes on microelectrodes. II. A linear double-layer analysis
Physical Review E, vol. 61, no. 4, pp. 4011-4018 (2000) **(citations 385)**

Fluid flow induced by nonuniform ac electric fields in electrolytes on microelectrodes. III. Observation of streamlines and numerical simulation
Physical Review E, vol. 66, no. 2, pp. 26305 (2002) **(citations: 427)**

INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS D: APPLIED PHYSICS
J. Phys. D: Appl. Phys. 36 (2003) 2584–2597 PII: S0022-3727(03)63619-3

Electrohydrodynamics and dielectrophoresis in microsystems: scaling laws

A Castellanos[1], A Ramos[1], A González[1,2], N G Green[3] and H Morgan[3,4]

[1] Dpto. Electrónica y Electromagnetismo, Facultad de Física, Universidad de Sevilla, Reina Mercedes s/n, 41012 Sevilla, Spain
[2] Dpto. de Física Aplicada III, E.S.I. Universidad de Sevilla, Camino de los Descubrimientos s/n 41092 Sevilla, Spain
[3] Bioelectronics Research Centre, Dept. Electronics and Electrical Engineering, University of Glasgow, Oakfield Avenue, Glasgow G12 8LT, UK

This paper is one of 12 papers chosen from *Journal of Physics D: Applied Physics* for a book containing 50 highly influential papers published in the *Journal of Physics* series during the last 50 years.

Two outstanding contributions:

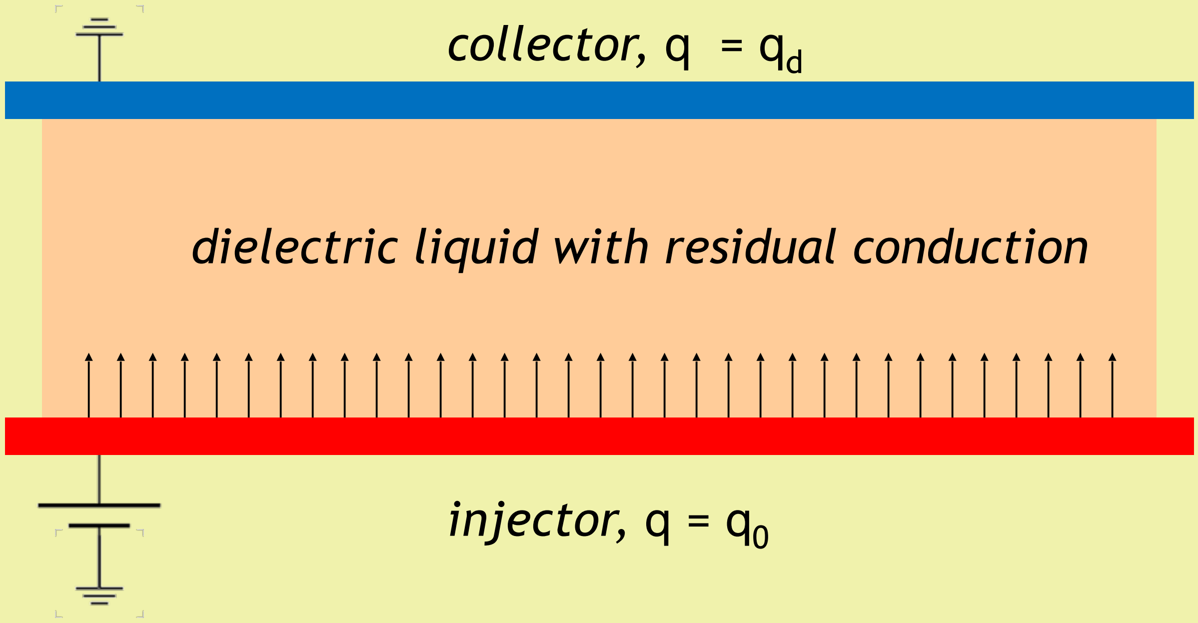
- *Flow of electrolytes driven by AC electric fields on microelectrode structures: AC Electroosmosis*
- *Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient*

Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

F. Pontiga
Departamento de Electrónica y Electromagnetismo, Facultad de Fisica, Avda. Reina Mercedes s/n, 41012 Sevilla, Spain and Departamento de Fisica Aplicada. E. U. A. T. Avda. Reina Mercedes s/n, 41012 Sevilla, Spain

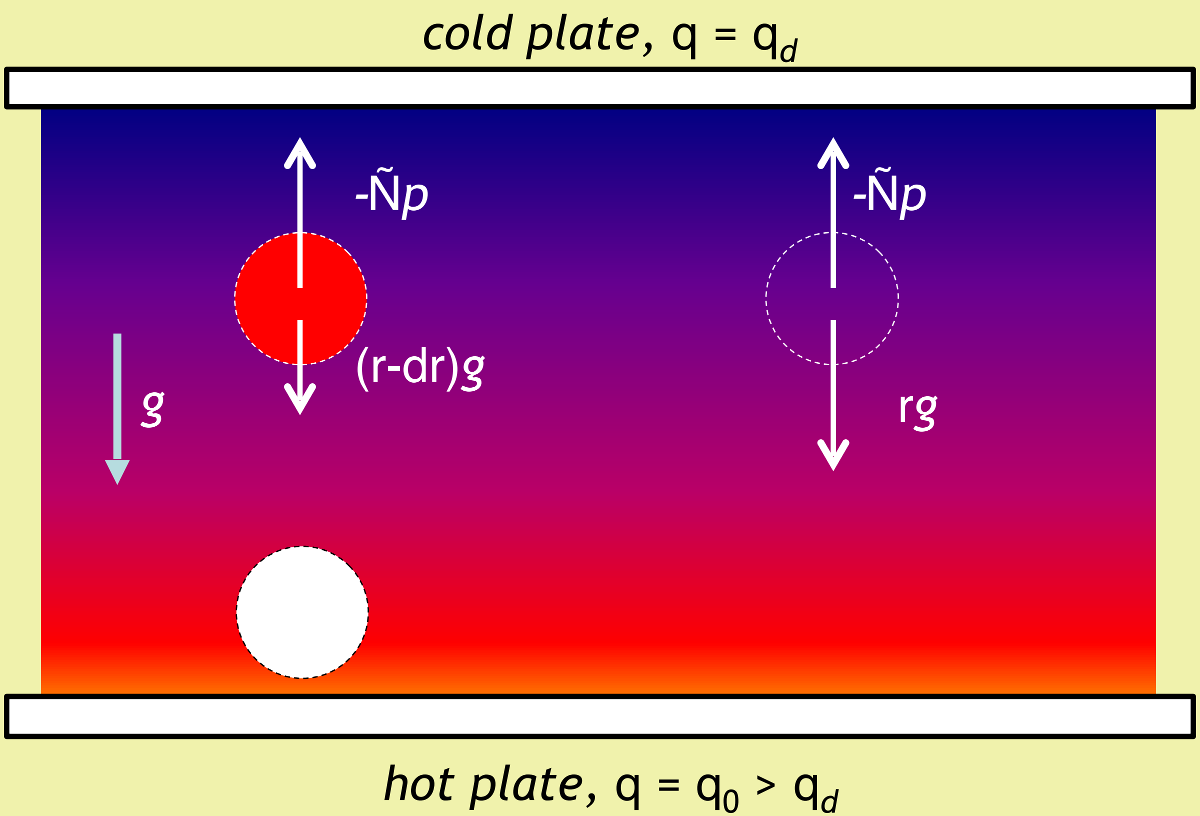
A. Castellanos
Departamento de Electrónica y Electromagnetismo, Facultad de Física, Avda. Reina Mercedes s/n, 41012 Sevilla, Spain

Physics of Fluids **27**, 1607 (1984); doi: http://dx.doi.org/10.1063/1.864816



Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

Rayleigh-Bénard convection



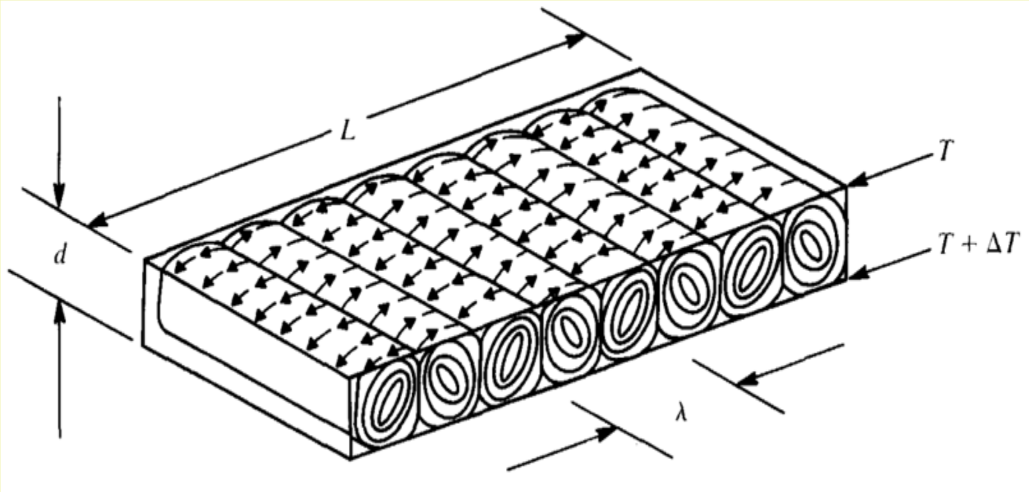
$$\frac{\text{buoyancy force}}{\text{viscous force}} \approx$$

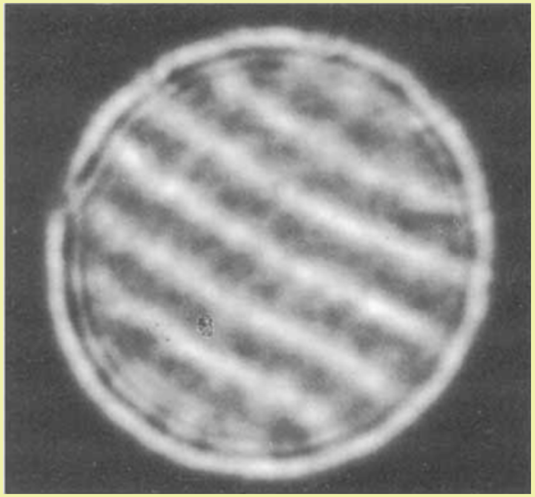
$$\approx \frac{\rho_0 \alpha g (\theta_0 - \theta_d) d^3}{\kappa \eta} = Ra$$

$$Ra_c = 1708$$

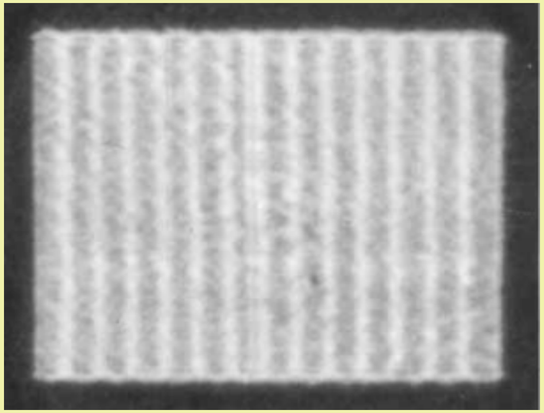
Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

Rayleigh-Bénard convection





$\mathrm{Ra} = 1.05 \times \mathrm{Ra_c}$



$\mathrm{Ra} = 1.23 \times \mathrm{Ra_c}$

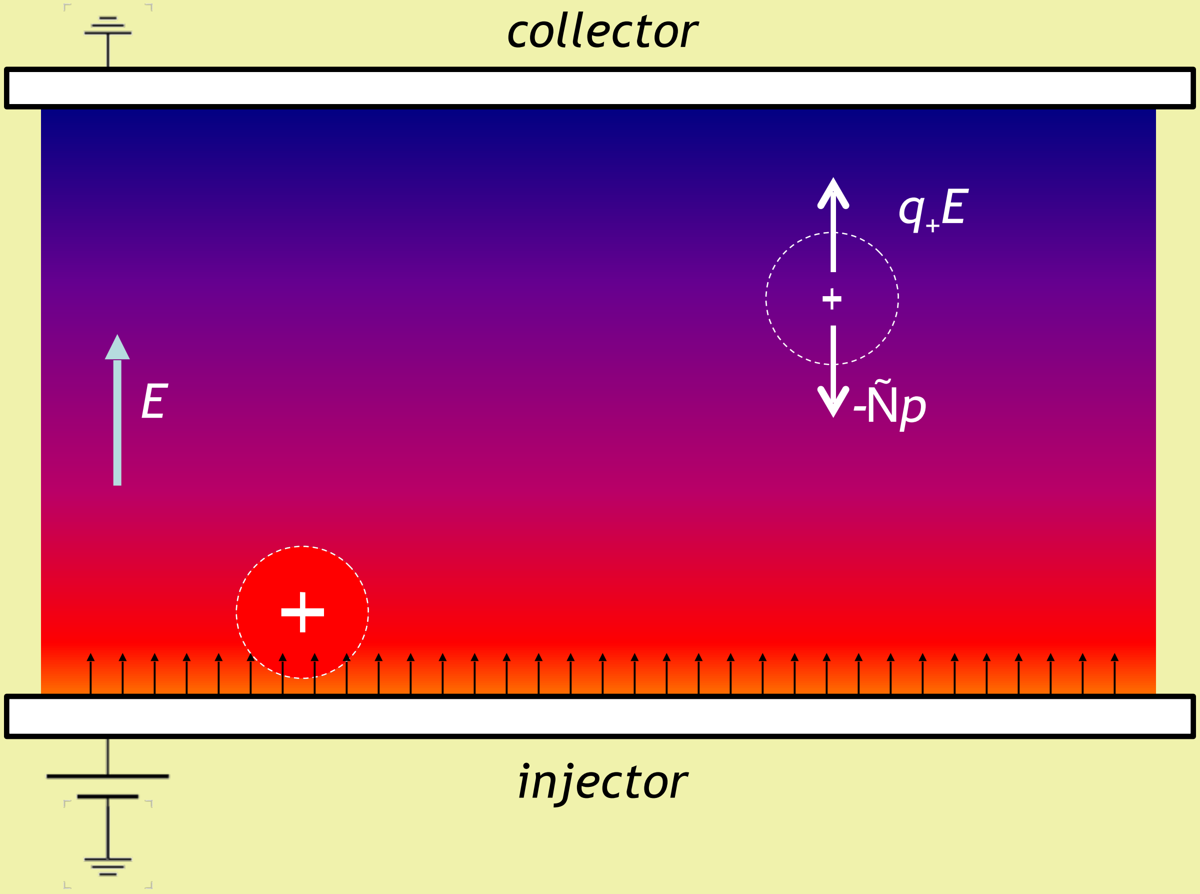
Source:

Vincent Croquette (1989) Convective pattern dynamics at low Prandtl number: Part I, *Contemporary Physics*, **30**:2, 113-133

Vincent Croquette (1989): Convective pattern dynamics at low Prandtl number: Part II, *Contemporary Physics*, **30**:3, 153-171

Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

Charge injection

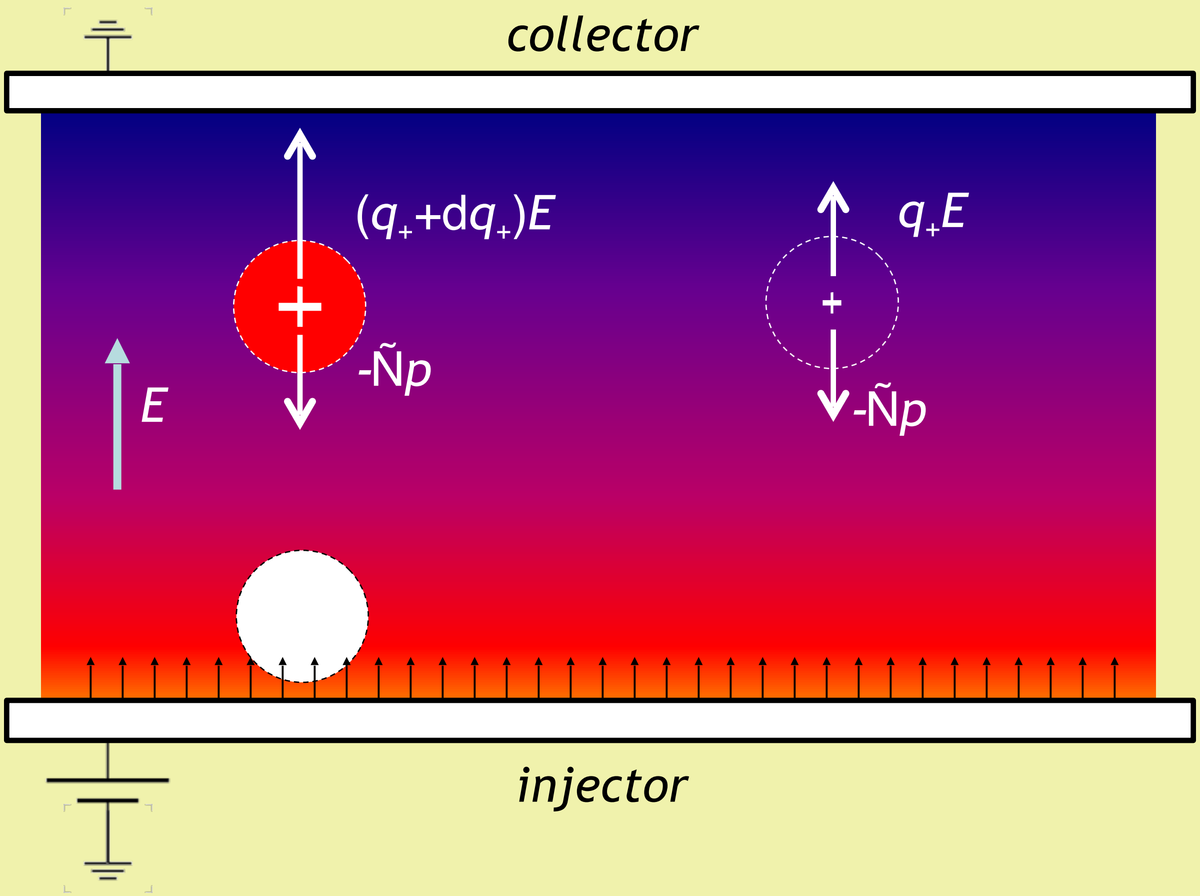


$$\frac{\text{space charge}}{\text{electrode charge}} \approx$$

$$\approx \frac{q_i d^2}{\epsilon V} = C$$

Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

Charge injection



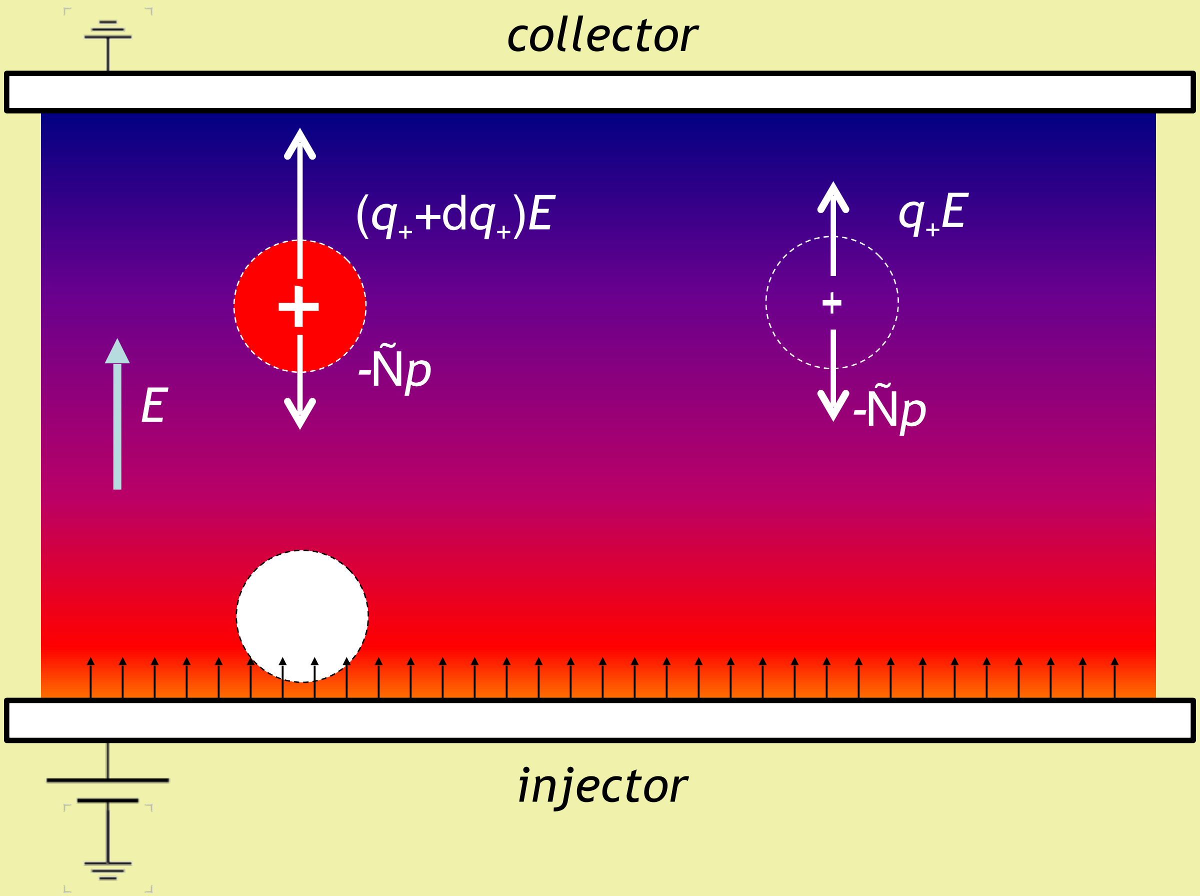
$$\frac{\text{electric force}}{\text{viscous force}} \approx \frac{\epsilon V}{K\eta} = T$$

$$T_{\text{c}} = 161$$

(strong injection)

Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

Charge injection



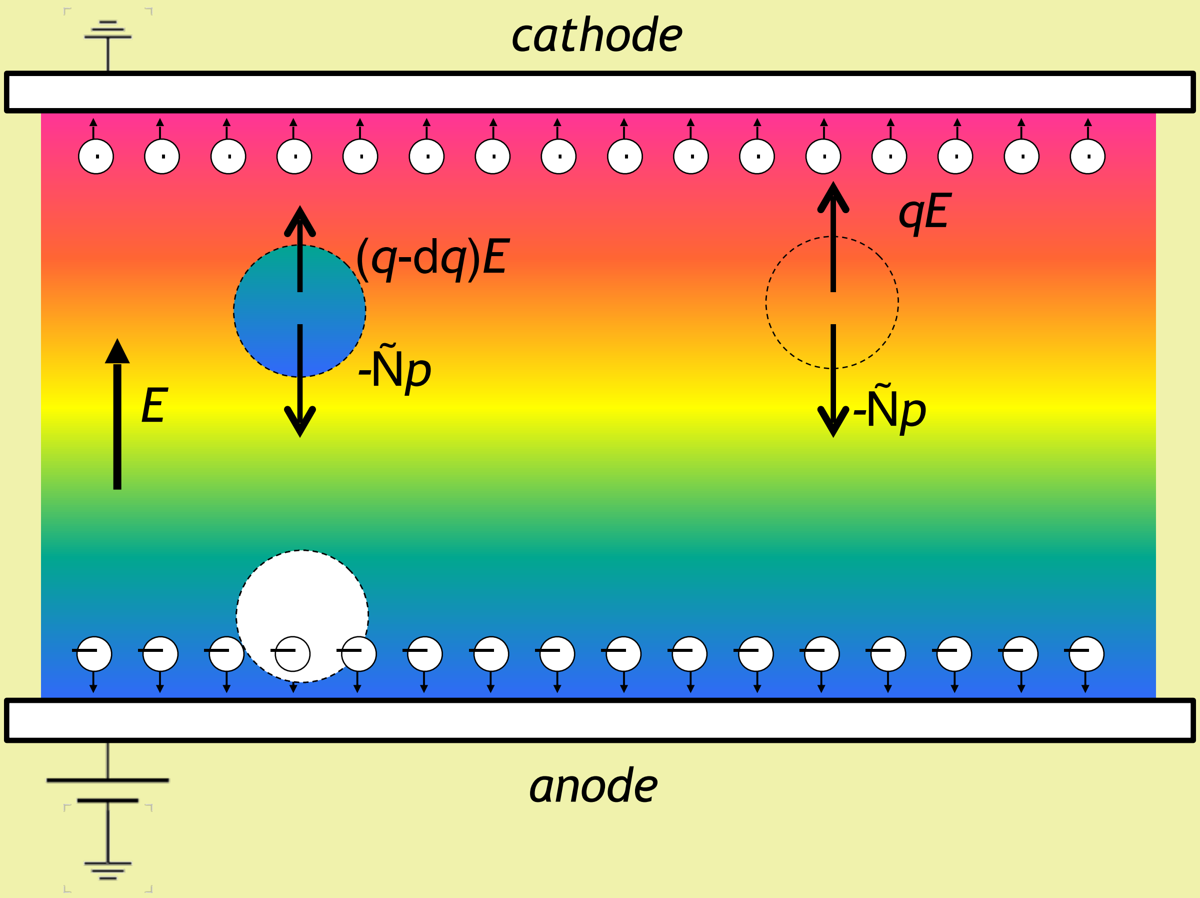
$$\frac{\text{electric force}}{\text{viscous force}} \approx TC^2$$

$$T_c C^2 = 221$$

(weak injection)

Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

Residual conduction

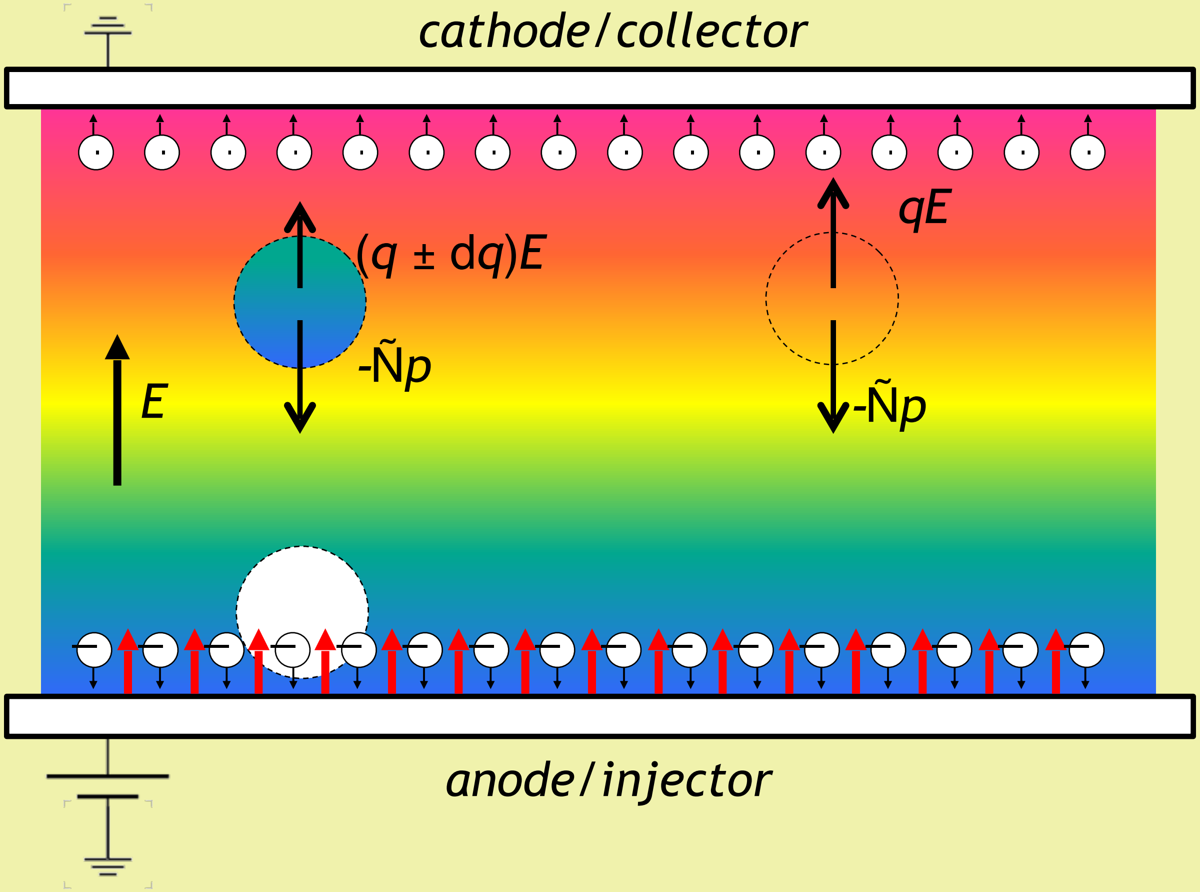


$$\frac{\text{space charge}}{\text{electrode charge}} \approx$$

$$\approx \frac{q_0 d^2}{\epsilon V} = C_0$$

Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

Injection + residual conduction



$$\frac{\text{electric force}}{\text{viscous force}} \approx$$

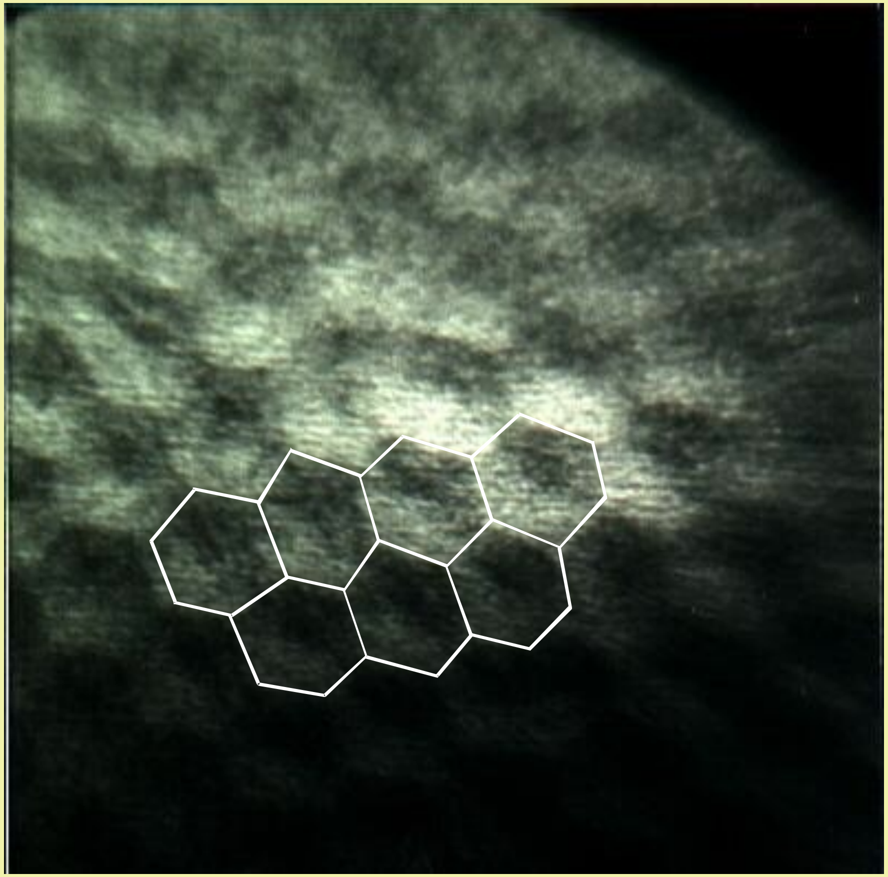
$$\approx T(C^2 - 8C_0^2)$$

$$T_c(C^2 - 8C_0^2) = 221$$

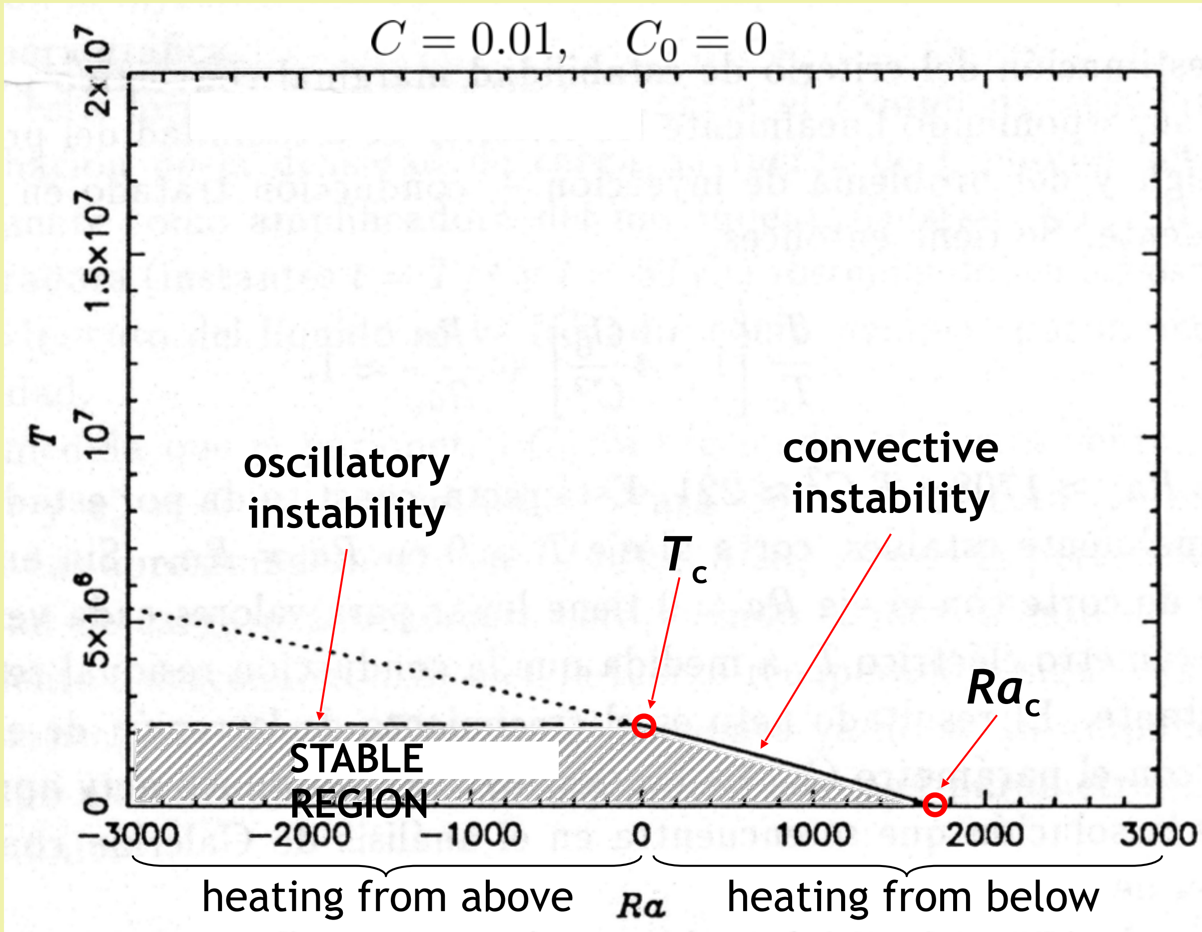
(weak injection)

Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient

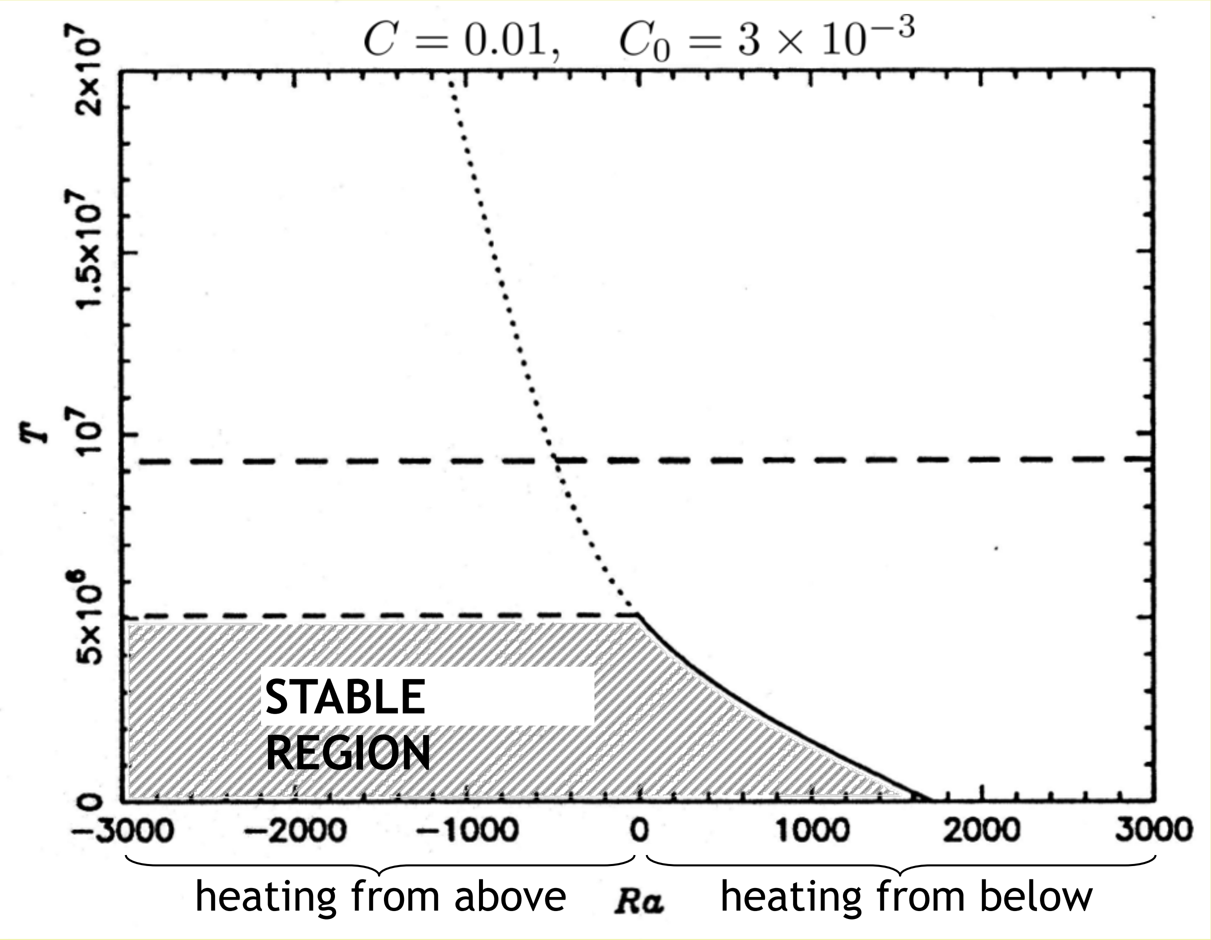
Injection + residual conduction



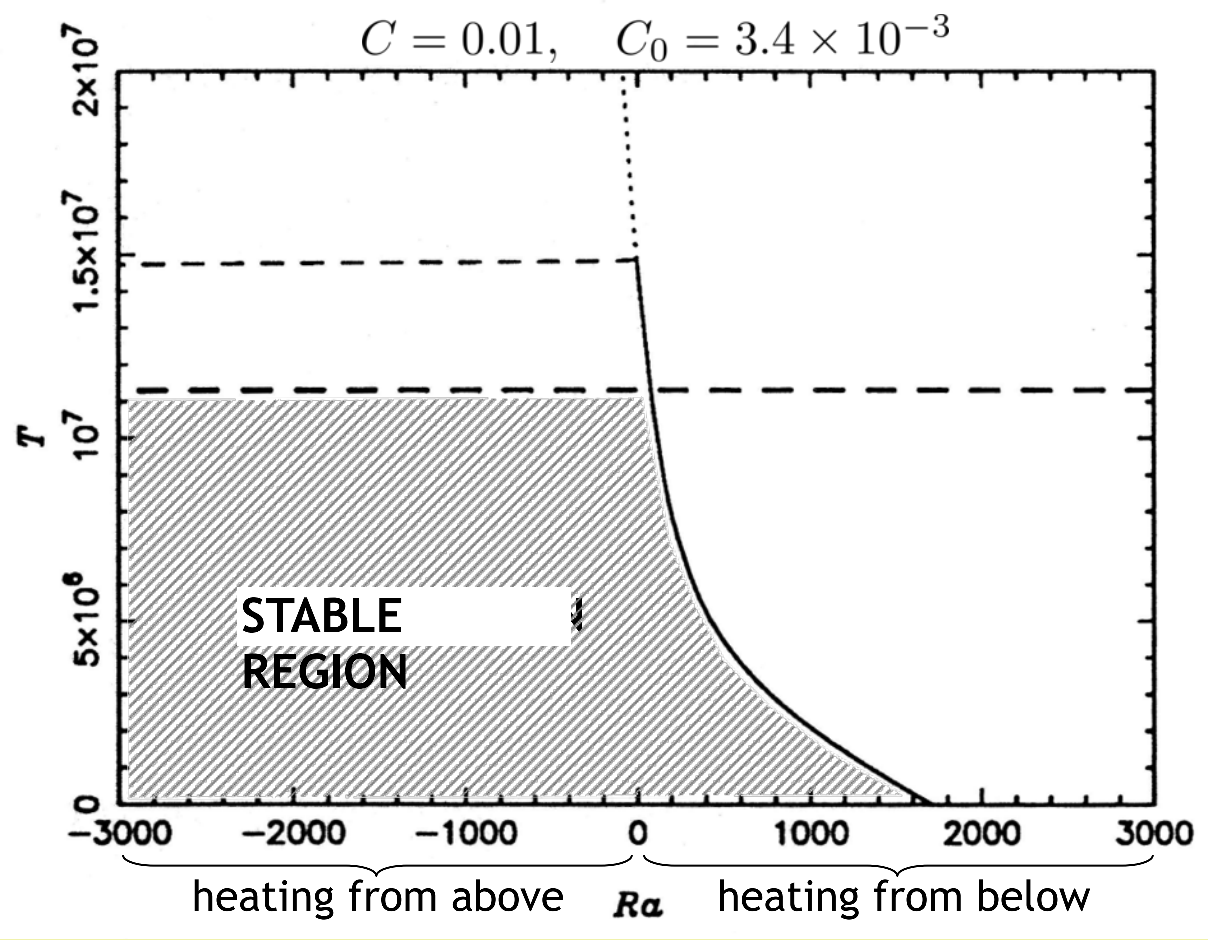
Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient



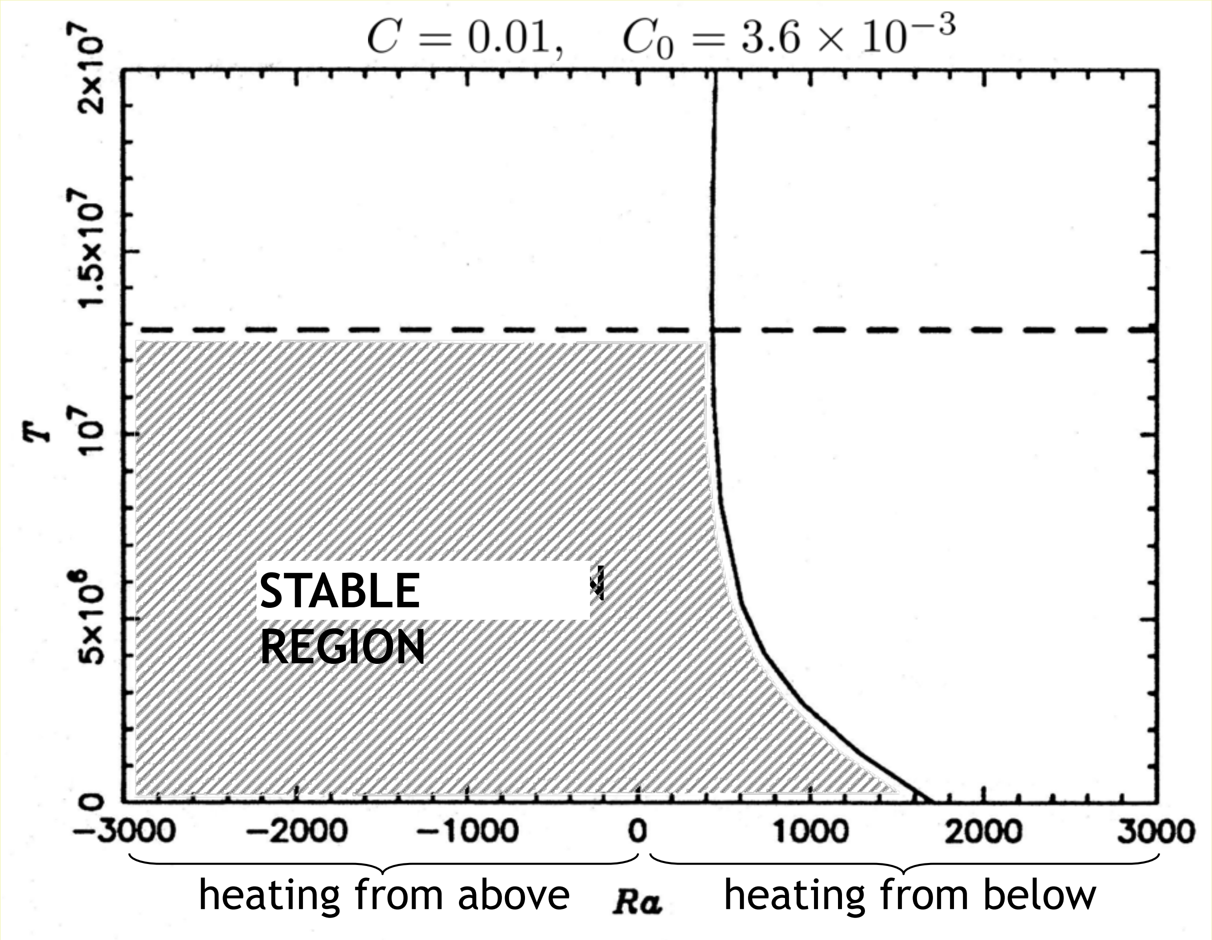
Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient



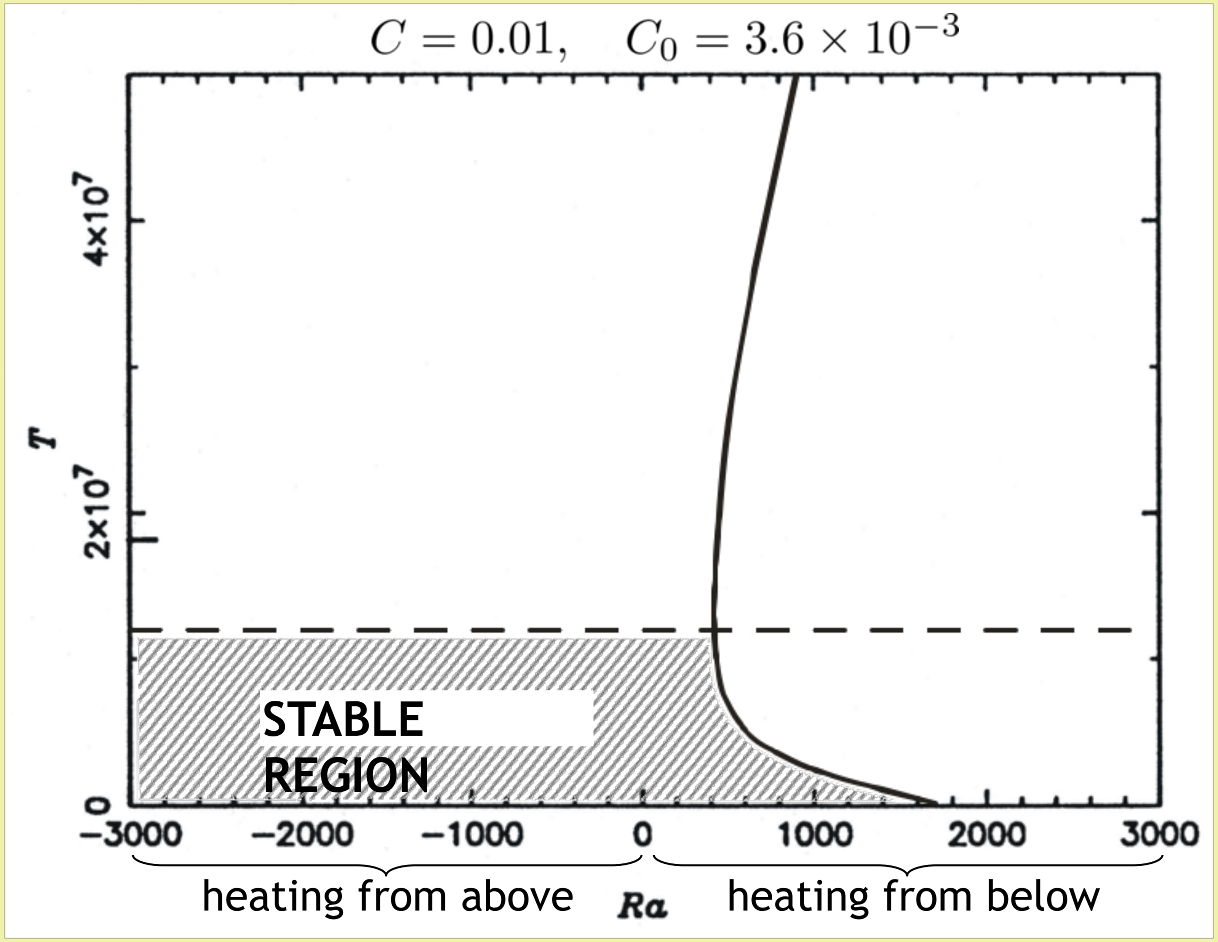
Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient



Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient



Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient



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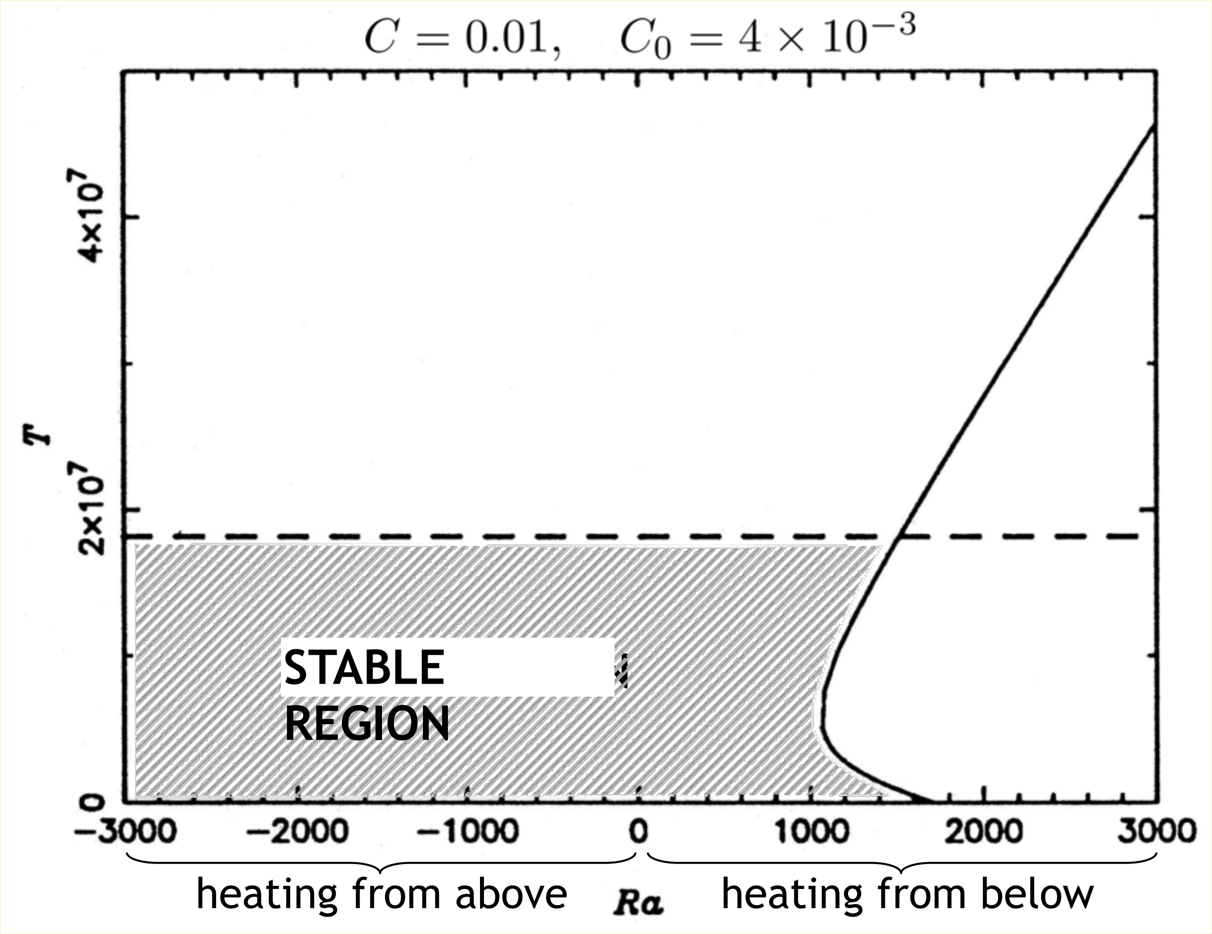
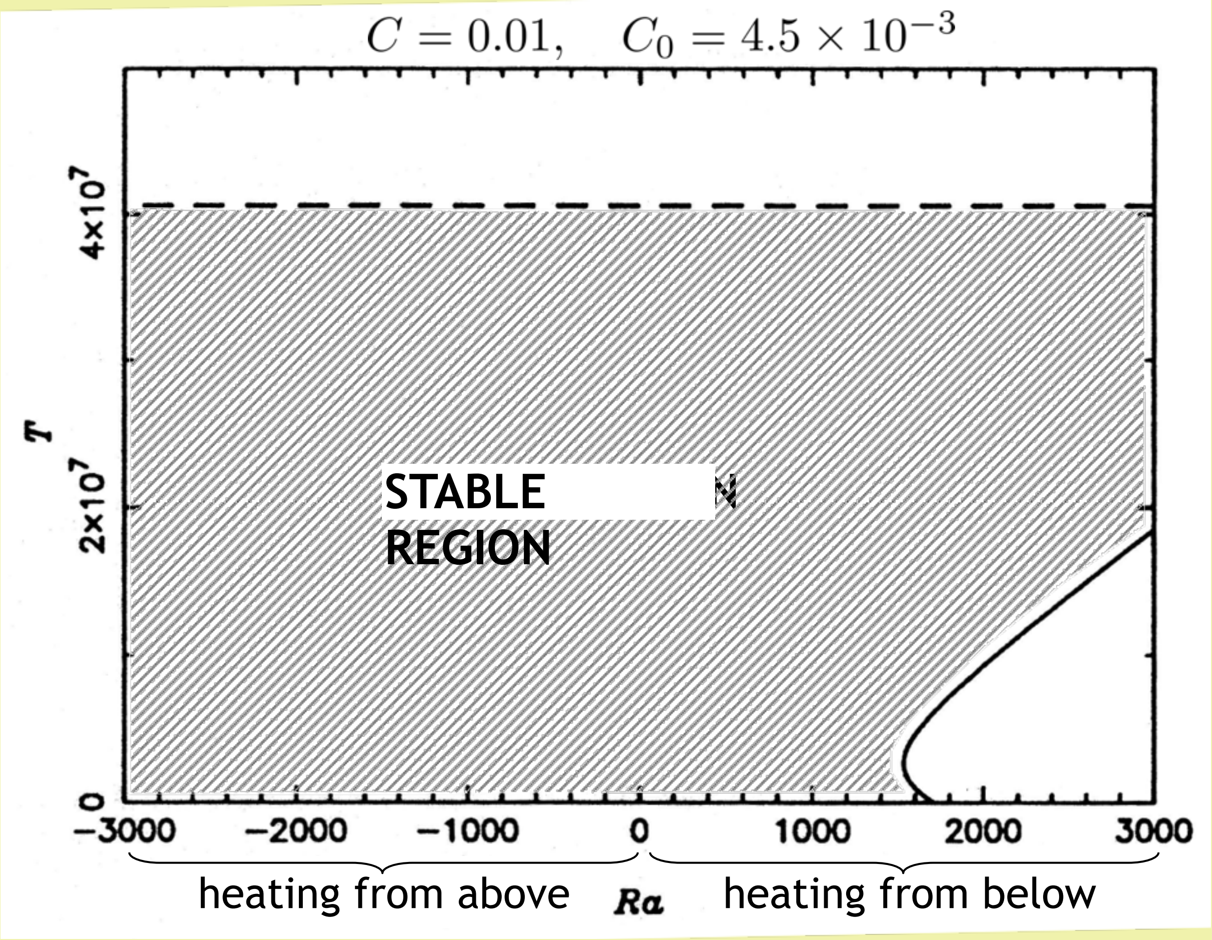
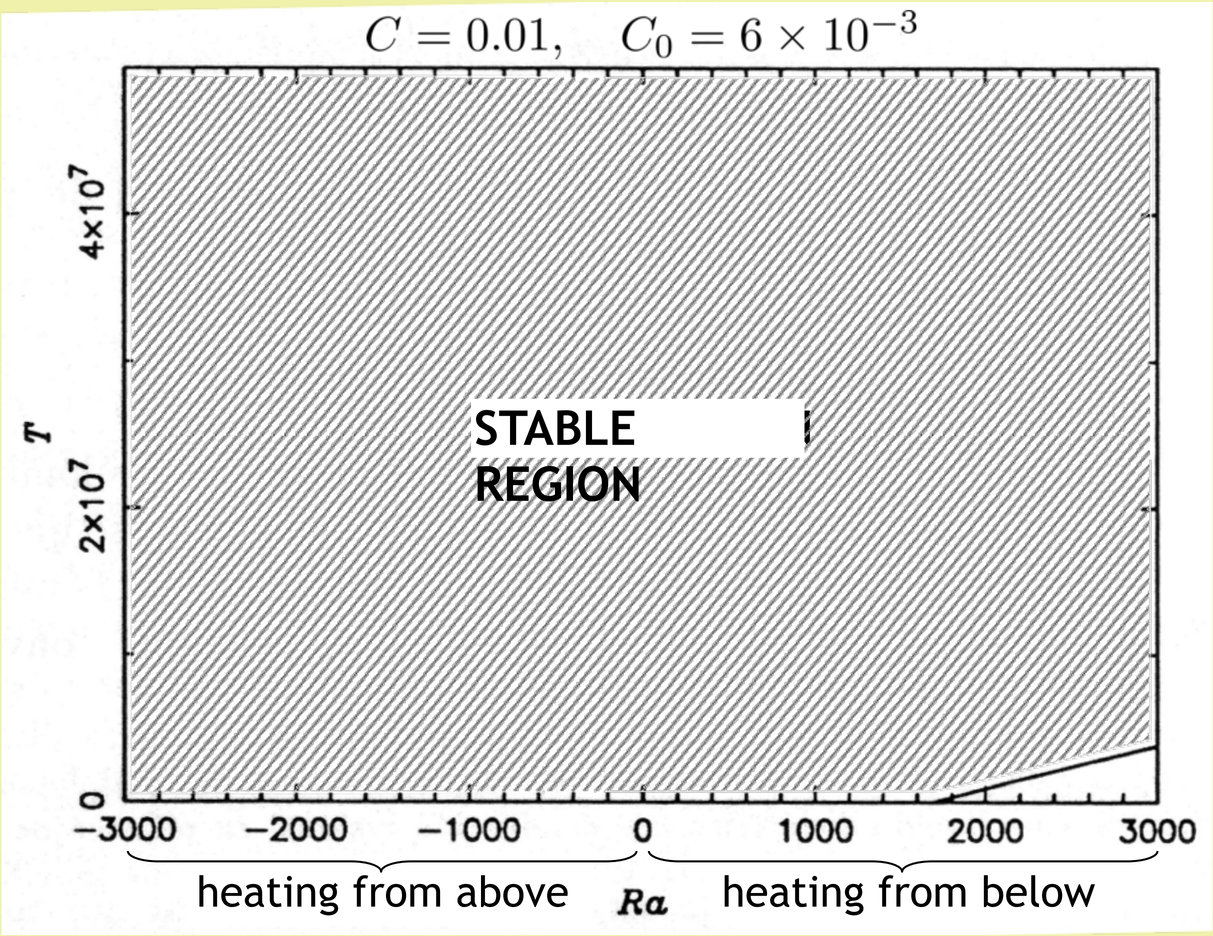
Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient



Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient



Physical mechanisms of instability in a liquid layer subjected to an electric field and a thermal gradient



Epilogue

- Antonio always looked for the basic understanding and modeling of the physical phenomena.
- He made important contributions to the progress of science in many different areas, and particularly in electrohydrodynamics and electrokinetics, plasma chemistry of gas discharges, and physics and mechanics of cohesive granular materials.
- He took care of and trained numerous doctoral students who today are relevant researchers in their respective fields.
- He was appreciated by all who knew him. We will remember him forever, with affection and admiration.

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