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Departamento de Fisica.
Facultad de ciencias
Fisicas y Matematicas,
Universidad de Chile.

Bouncing localized structures in a Liquid-Crystal -Light-Valve: an experimental evidence of non-variational dynamics

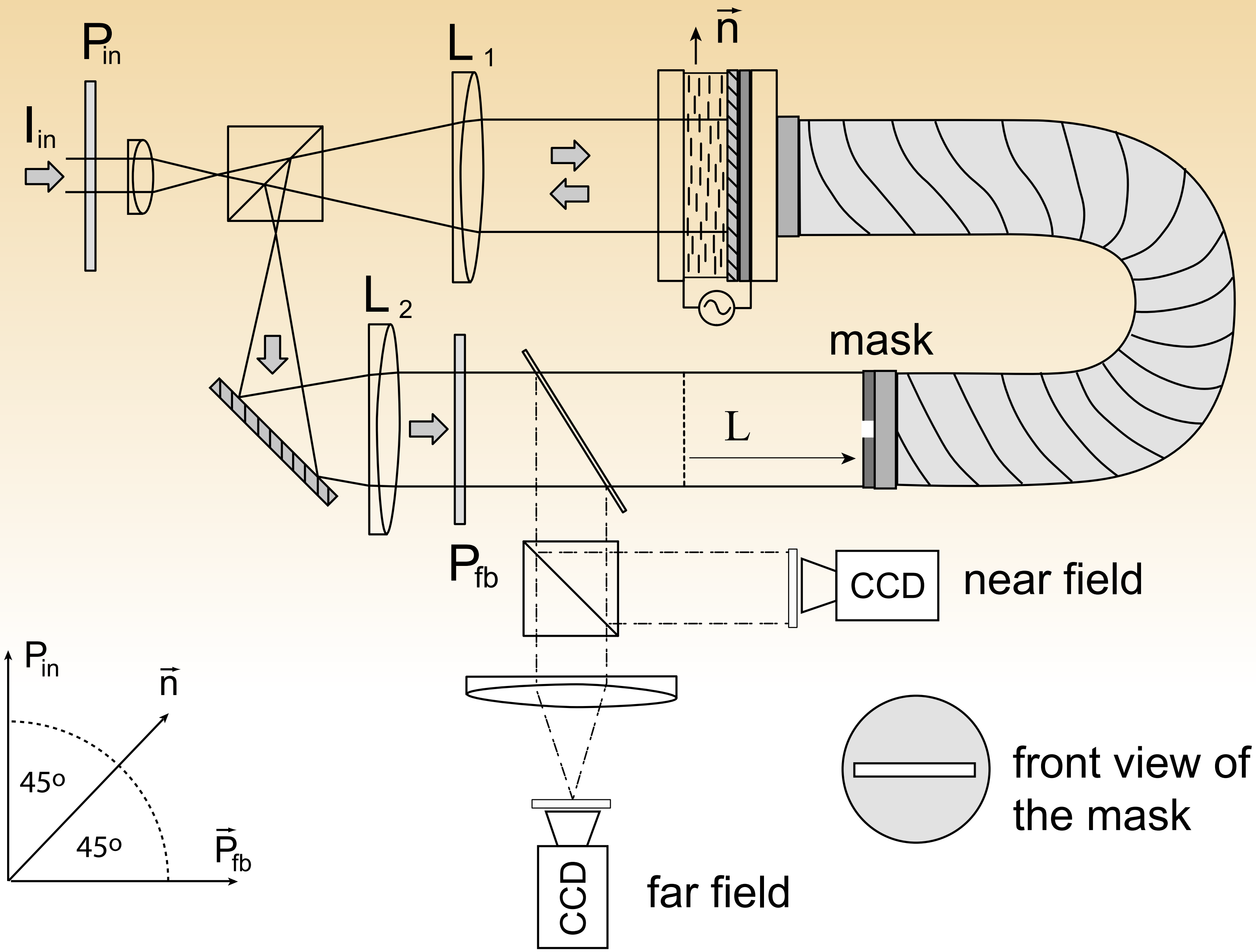
Marcel Clerc, Artem Petrossian and Stephania Residori

Ecos-Fondecyt and Fondap (CIMAT)

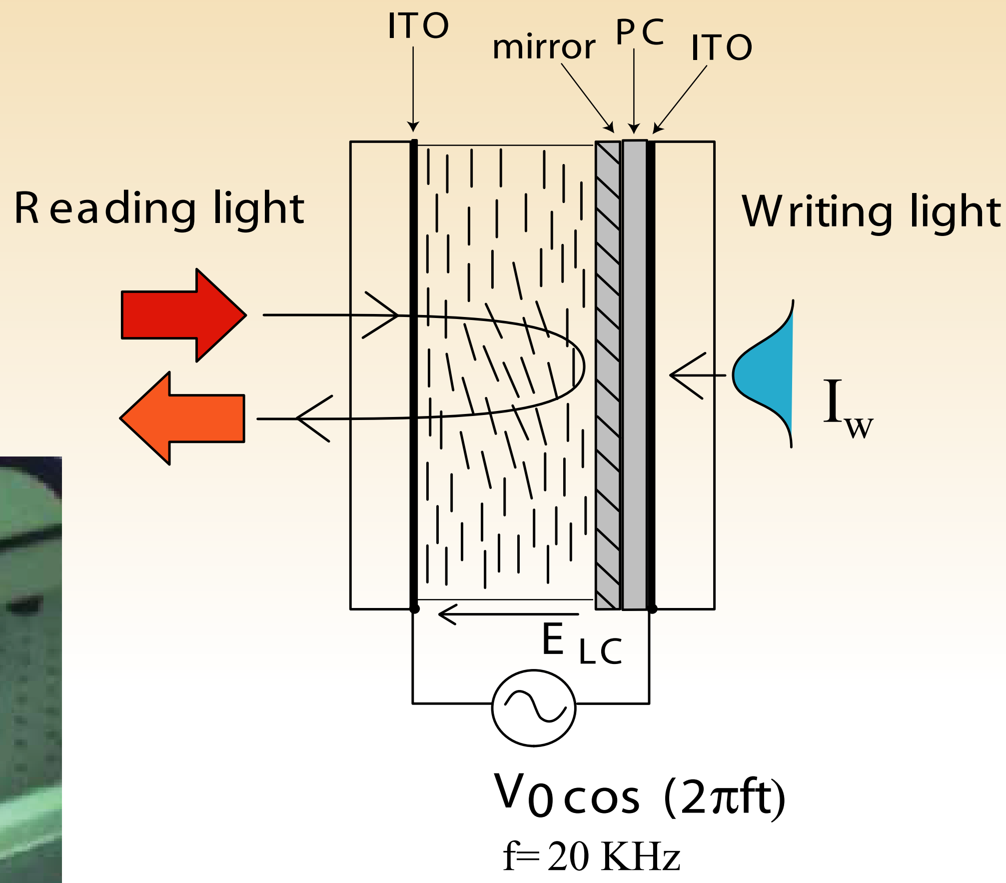
Outline

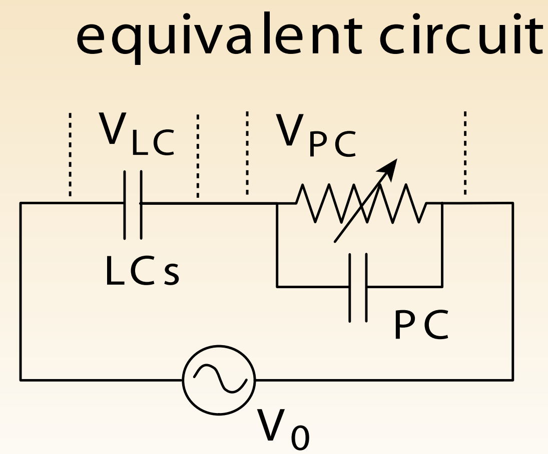
- Experimental setup (LCLV with optical feedback)
- Experimental observations of localized structures
- Characterization of the dynamics of localiaed structures
- Theoretical description
- Localized structures and robust phenomena
- Lifshitz point in the LCLV with feedback
- Non variational dynamicsl
- Conclusions
- Outlook

Experimental setup (LCLV)

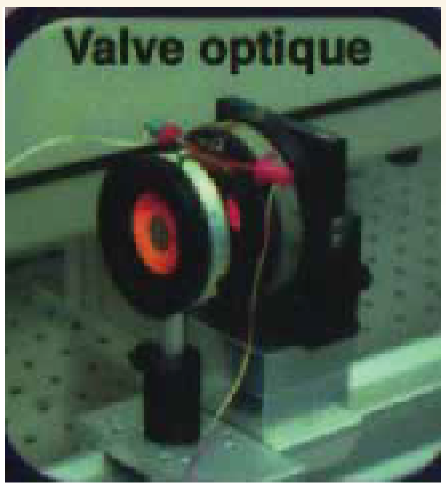


Liquid crystal light Valve (LCLV)





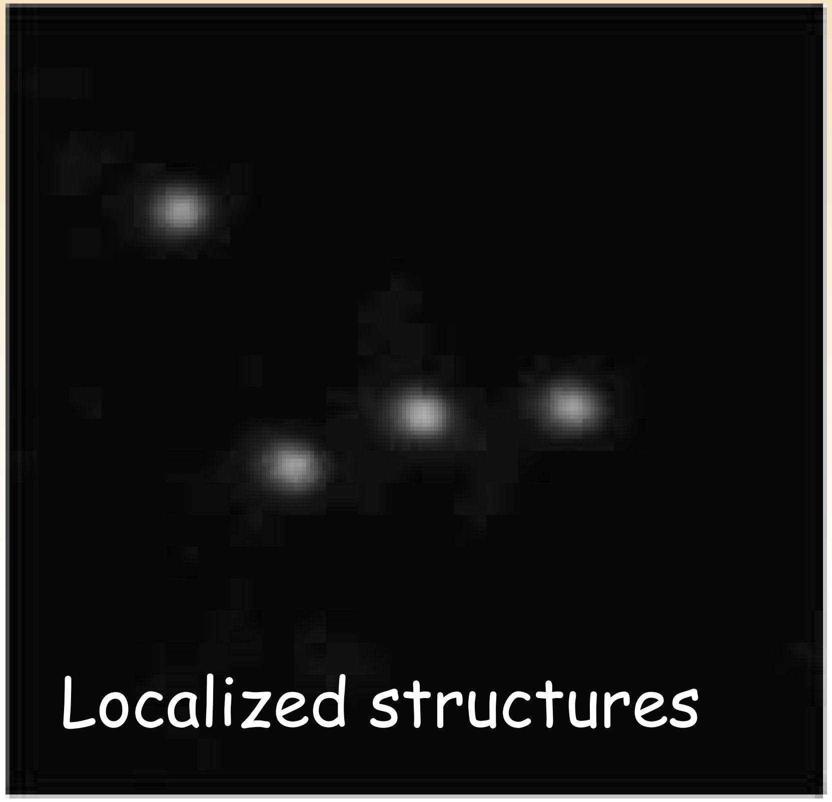
$$V_{LC} = V_0 \frac{1}{1 + Z_{PC} / Z_{LC}}$$



Experimental observation of Localized structures

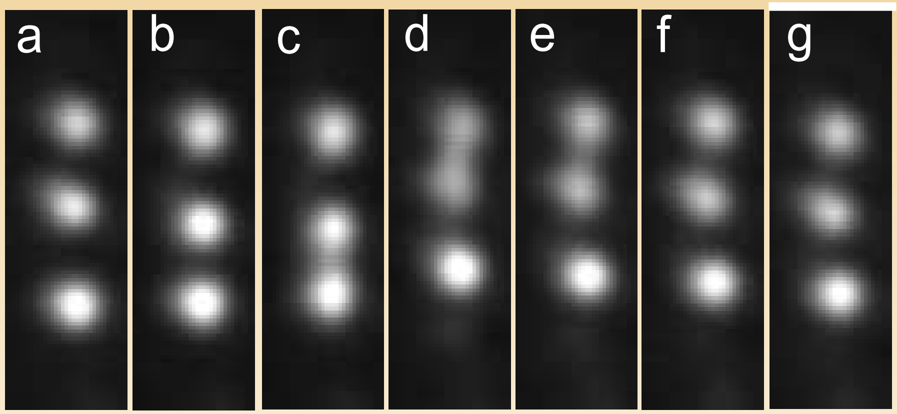
In the LCLV with optical feedback have been observed

- Coexistence between different Homogeneous states (Front dynamics)
- Pattern formation (roll, hexagon and quasi-crystal pattern)
- Coexistence between homogeneous and spatial periodic state
- Localized Structures

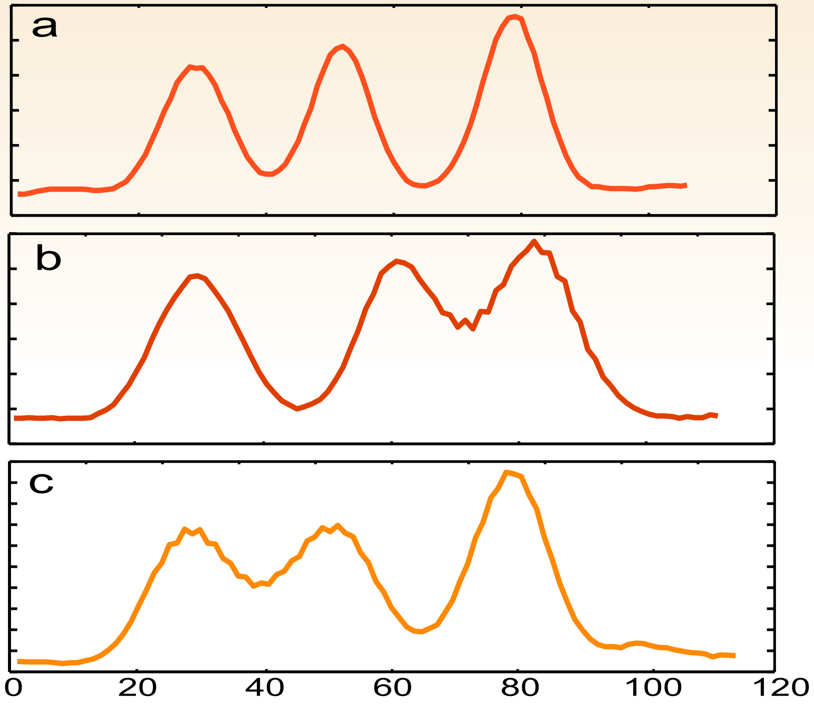


Experimental observation of Localized structures

Instantaneous snapshots showing three bouncing localized structures. Times a)0.0, b)1.0, c)1.3, d)17, e)2.1, f)2.4 g)2.8 s.

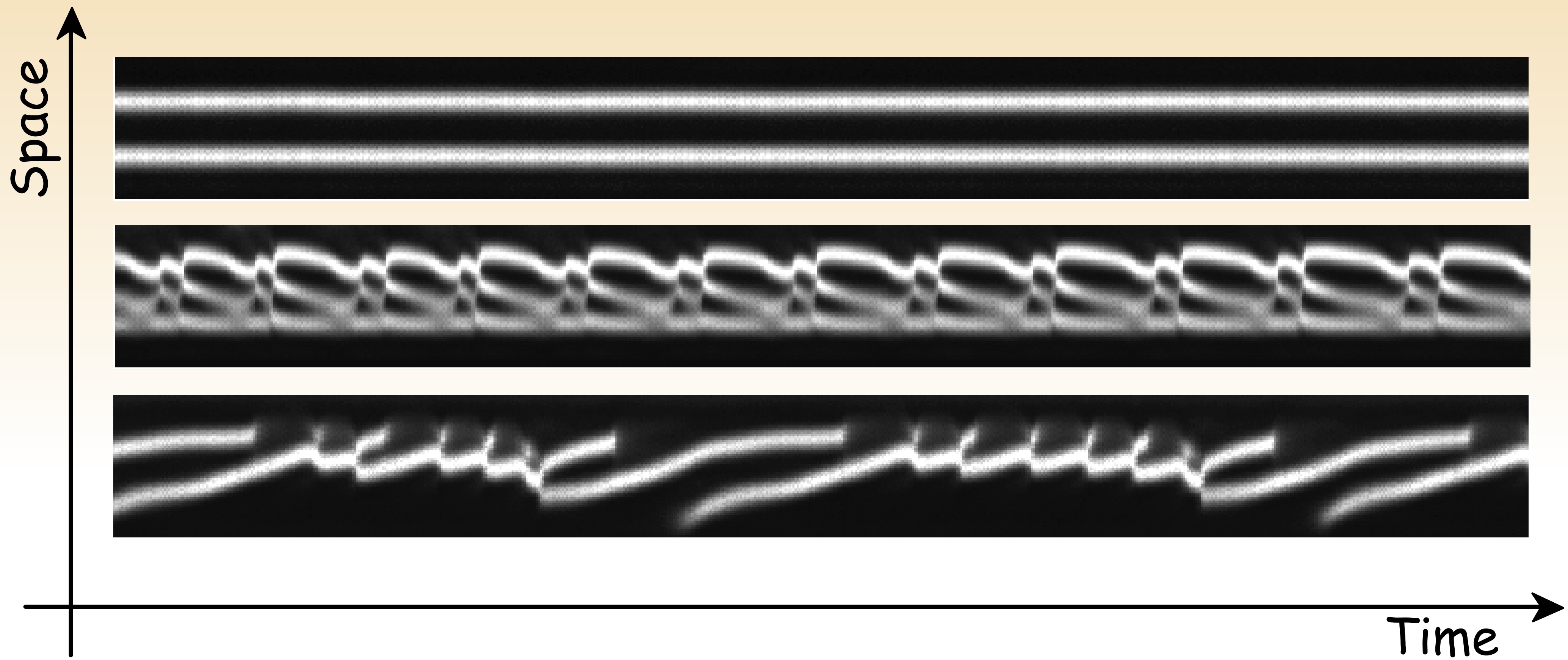


Spatial profile of the localized structures. Times a), b) and c)



Characterization of the dynamics of localiaed structures

Space-time diagrams for different V_0 showing: two stationary localized structures, periodic and aperiodic oscillations of the localized structures position.



Theoretical description

The light intensity I_W reaching the photoconductor is:

$$I_w(\theta, \partial_x) = I_{in} \left| e^{-\frac{L}{2k}\partial_{xx}} \left\{ \sin\psi_1 \sin\psi_2 + \cos\psi_1 \cos\psi_2 e^{-i2kd\Delta n \cos^2\theta} \right\} \right|^2$$

where x is the transverse direction of the liquid crystal layer, $2kd\Delta n \cos^2\theta$ is the overall phase shift experienced by the light traveling forth and back through liquid crystal layer, θ is the longitudinal average director tilt and L is the optical free propagation lenght.

As long as the I_{in} is small (mW/cm^2), the effective voltage applied to the liquid crystal layer cen be expressed as

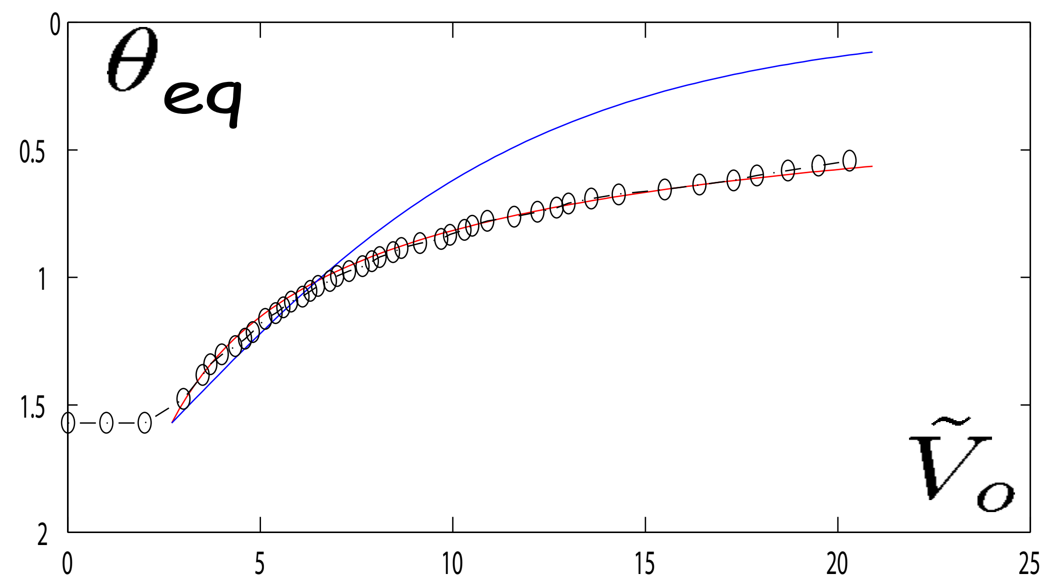
$$\tilde{V}_o + \alpha I_w(\theta, \partial_x)$$

Theoretical description

- The dynamic of θ is described by local relazation equation of the form (applied voltage larger than voltage of Freederickz transition)

$$\tau\partial_t\theta = l^2\partial^2_{xx}\theta - \theta + \frac{\pi}{2}\left(1 - \sqrt{\frac{V_{FT}}{\tilde{V}_o + \alpha I_w(\theta, \partial_x)}}\right)$$

- Experimental measurement of equilibruim average tilt as function of applied voltage without feedback.

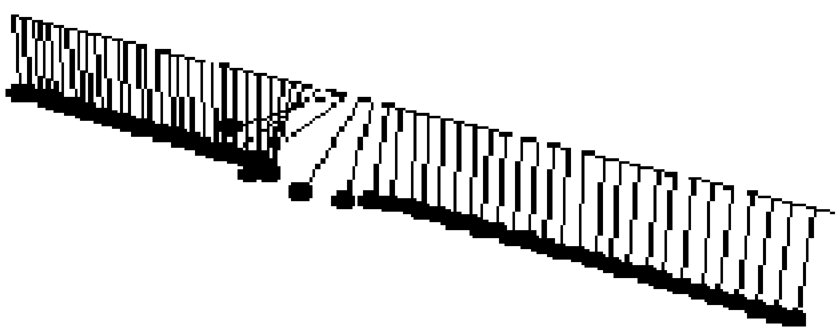


- The model is non-local in the space and non-variational

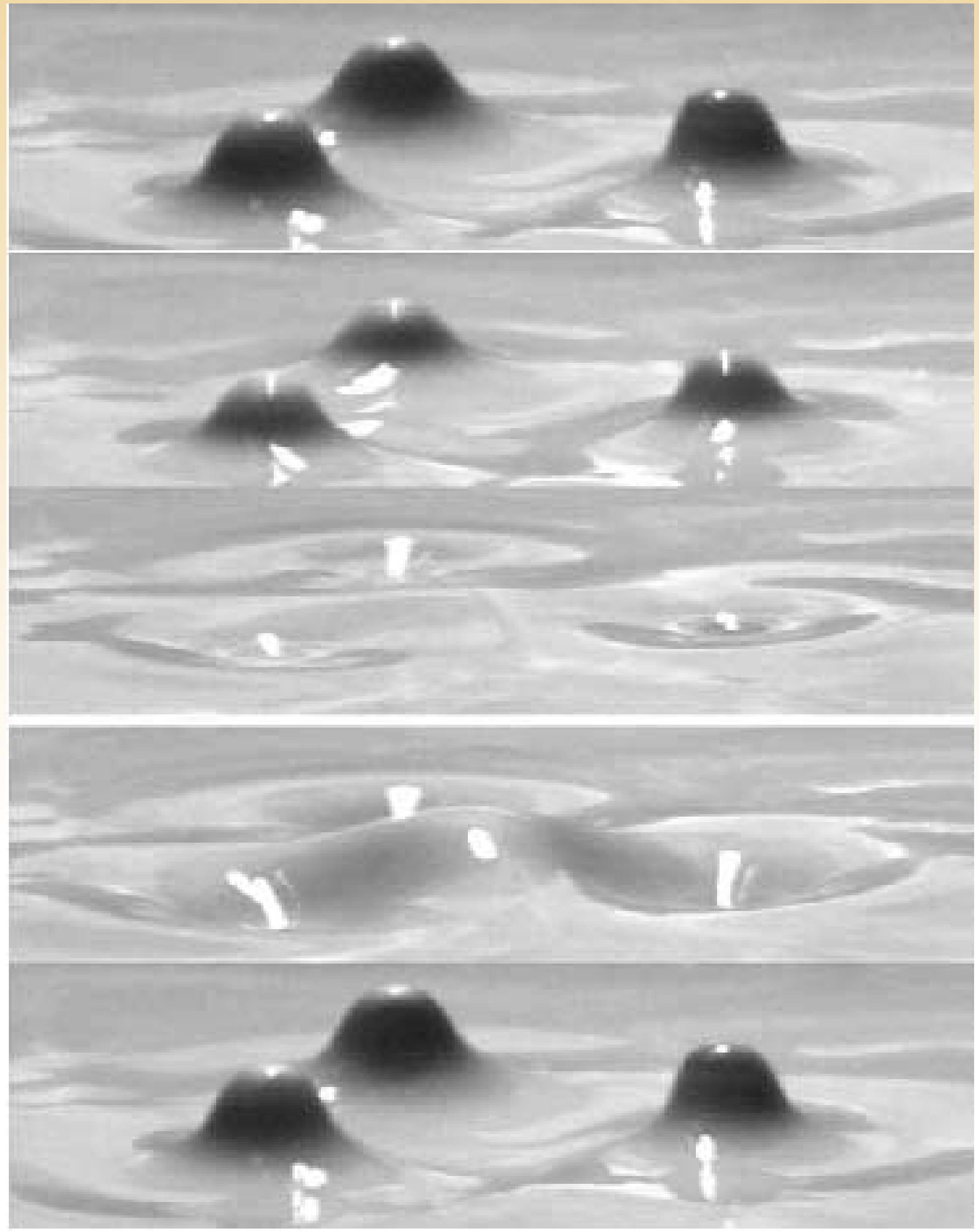
Localized structures and robust phenomena

Fluidized granular matter

Chain of pendula driven parametrically.



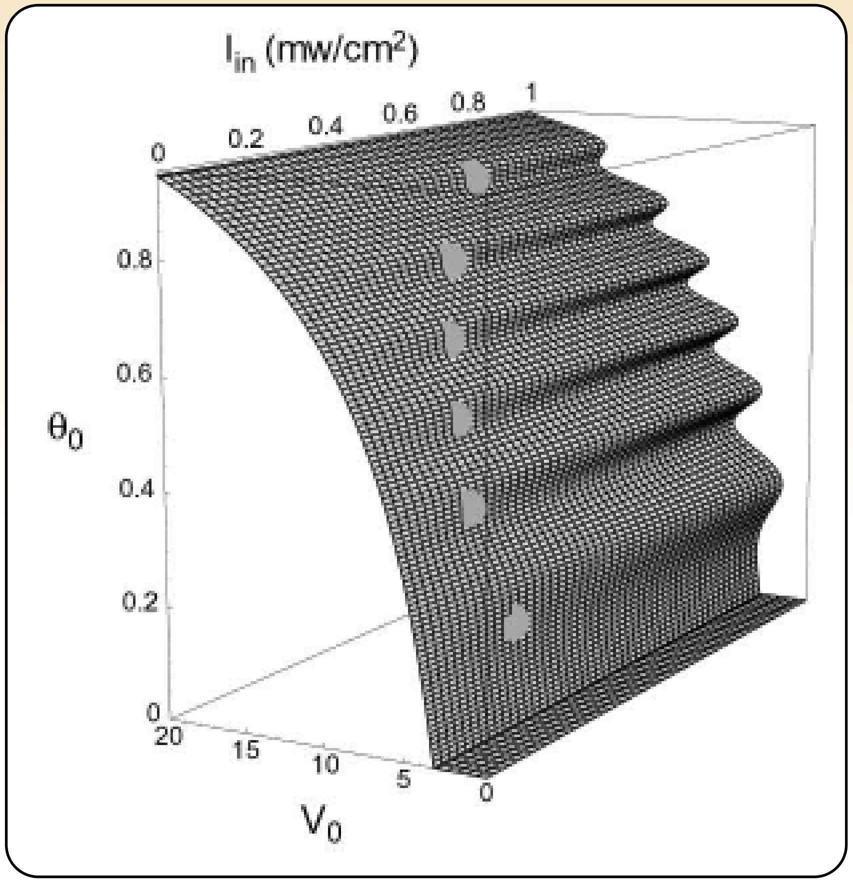
Colloidal Suspension

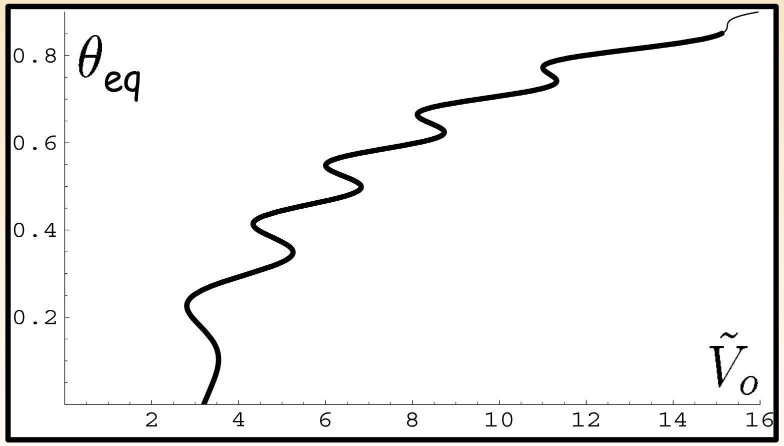


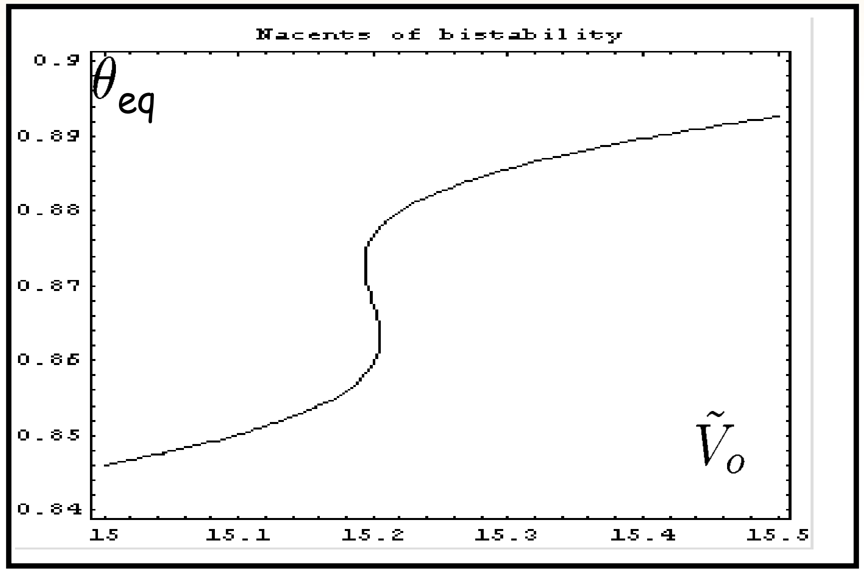
Lifshitz point in the LCLV with feedback

The confluence of the nascent bistability and the spatial bifurcation give rise a tricritical point (Lifshitz Point). Close to this point in the space of parameters the localized structures appear.

- Nascent of bistability for $V_{o,c}$ and $I_{in,c}$ (LCLV with feedback)







Lifshitz point in the LCLV with feedback

The normal form that describe the nascent of bystability is (imperfect pitchfork bifurcation)

$$\boxed{\partial_t u = \eta + \mu u - u^3}$$

The effective diffusion coefficient

$$\nu \propto l^2 + (\pi \beta L \cos^2(\beta/2 \cos^2\theta_o) \sin 2\theta_0)/4k((\Gamma V_o + \alpha I_{in}(1 + \cos(\beta \cos^2\theta_0)))$$

There is a critical L_c that effective diffusion coefficient becomes unstable. This L_c is for negative diffraction, that is, for the focusing case.

Lifshitz point in the LCLV with feedback

Normal form close to the lifshitz point

$$\partial_t u = \eta + \mu u - u^3 + \nu \partial_{xx} u - \partial_{xxxx} u + c\left(\partial_x u\right)^2 + D u \partial_{xx} u$$

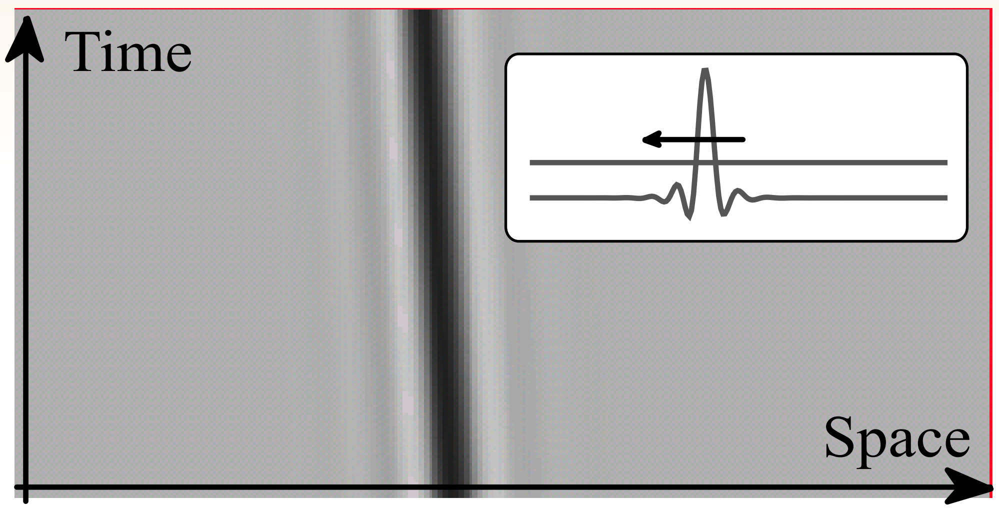
- This model is non-variational (D=2c)
- Swift-Hohenberg model (η=c=D=0)
- Generalized Swift-Hohenberg (c-D=0)
- Neglected the cubic term and D=0 the model becomes in Nikolaeski equation (Longitudinal Seismic wave)

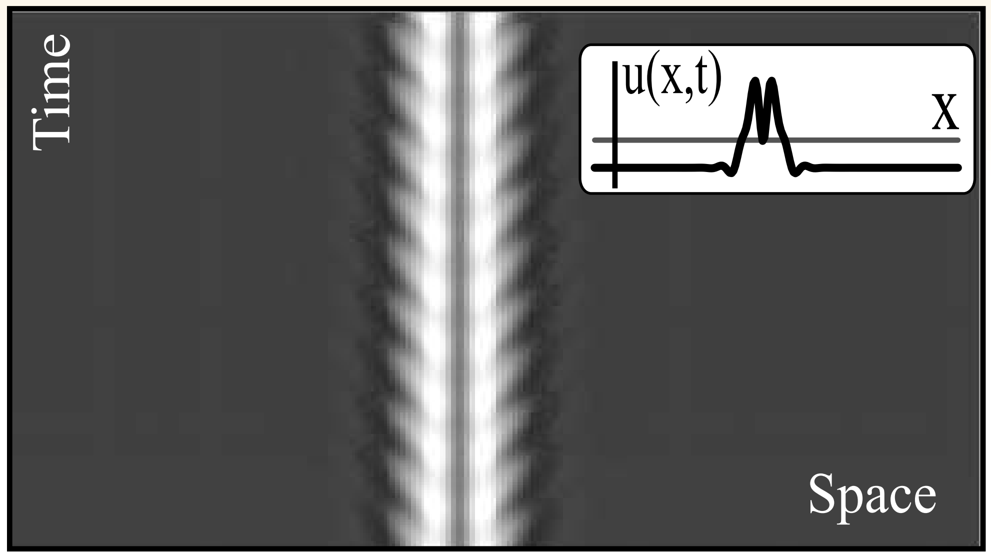
This model exhibits homogeous, spatial periodic state and Localized structures

Lifshitz point in the LCLV with feedback

Localized structures

Non-variational dynamics

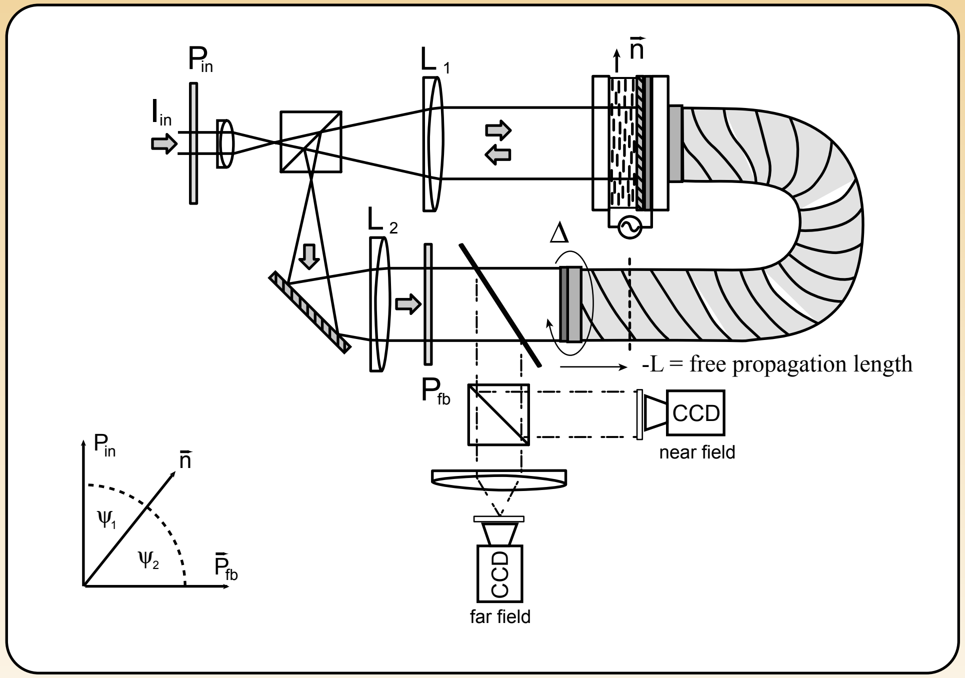




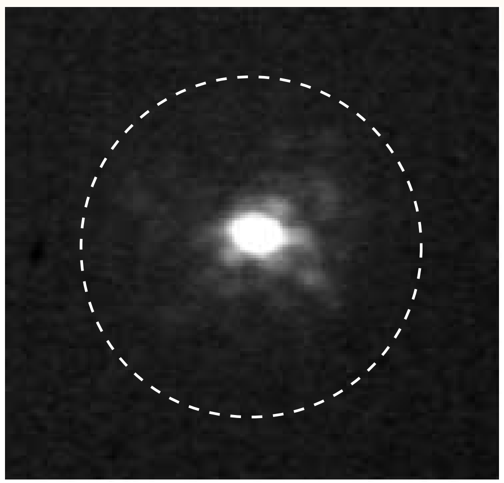
Conclusions

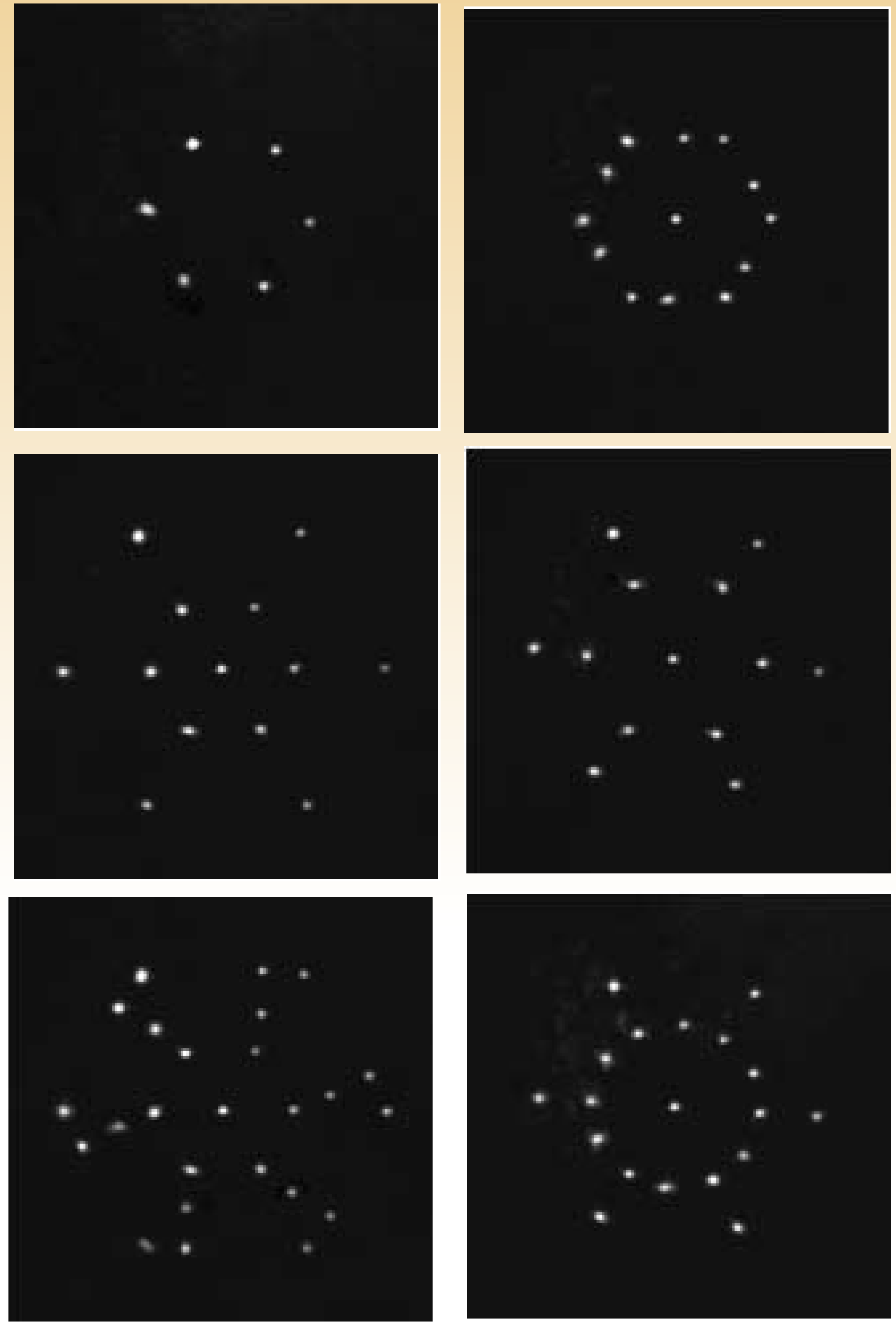
- We have shown a new kind of localized structure dynamics
- We have related it to the non-variational character of the system under study.
- We have derived an universal model, the Lifshitz normal form equation, that can be applied in many different physical systems.
- We have shown its application to the case of a LCLV with optical feedback.

Outlook



Far field





Outlook