

Interaction of Moving Discrete Breathers with Impurities

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Background and objective

- Interaction kink–impurity in continuous systems (Arbitrary nonlinearity):
 - Z Fei, YuS Kivshar, L Vázquez: PRA 45 (1992) 6019; PRA 46 (1992) 5214
 - OM Braun, YuS Kivshar: Phys. Rep. 306 (1998) 1
- Interaction of a moving discrete breather with an impurity (Low nonlinearity):
 - K Forinash, M Peyrard, BA Malomed: PRE 49 (1994) 3400
- Objective:
 - Study of moving discrete breather–impurity interaction with arbitrary nonlinearity

Hamiltonian

$$H = \sum_n \left(\frac{1}{2} m_n \dot{u}_n^2 + V_n(u_n) + \frac{1}{4} C_n [(u_n - u_{n-1})^2 + (u_n - u_{n+1})^2] \right)$$

$$V_n(u_n) = D_n (e^{-u} - 1)^2$$

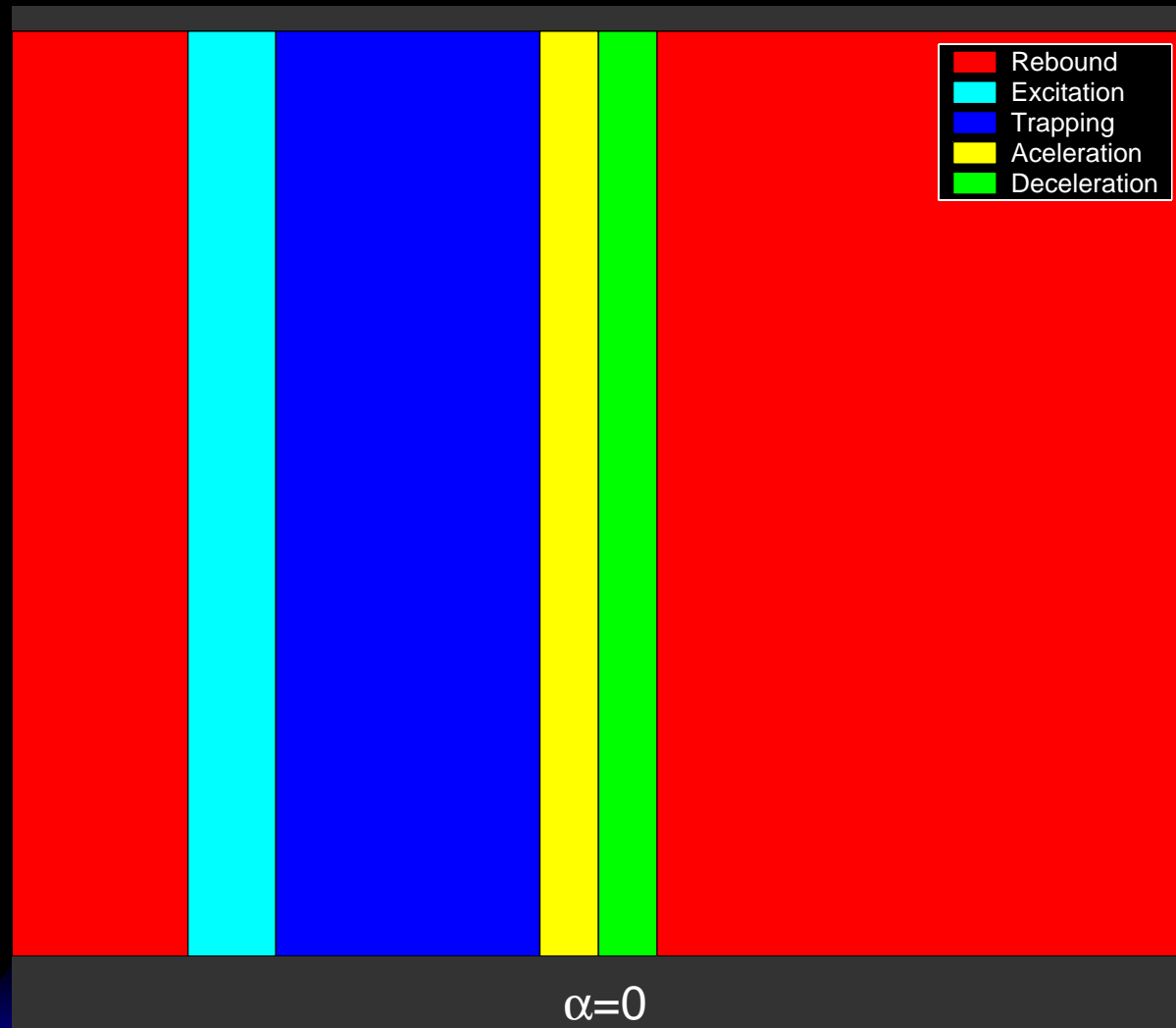
$$D_n = D(1 + \alpha \delta_{n,0})$$

$$C_n = C(1 + \beta \delta_{n,0})$$

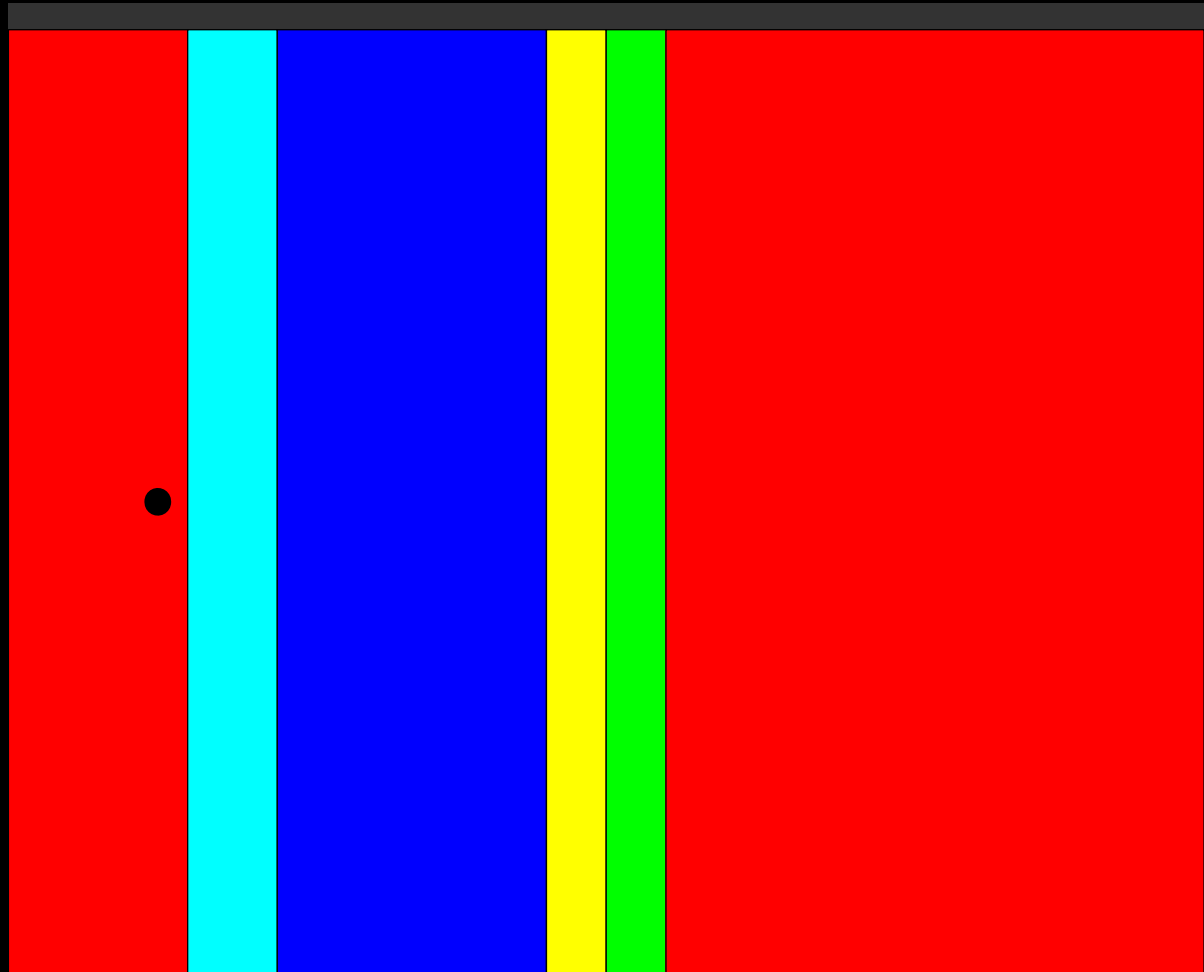
$$m_n = m(1 + \gamma \delta_{n,0})$$

$$m = 1, D = 1/2, \omega_b = 0.8, C = 0.13$$

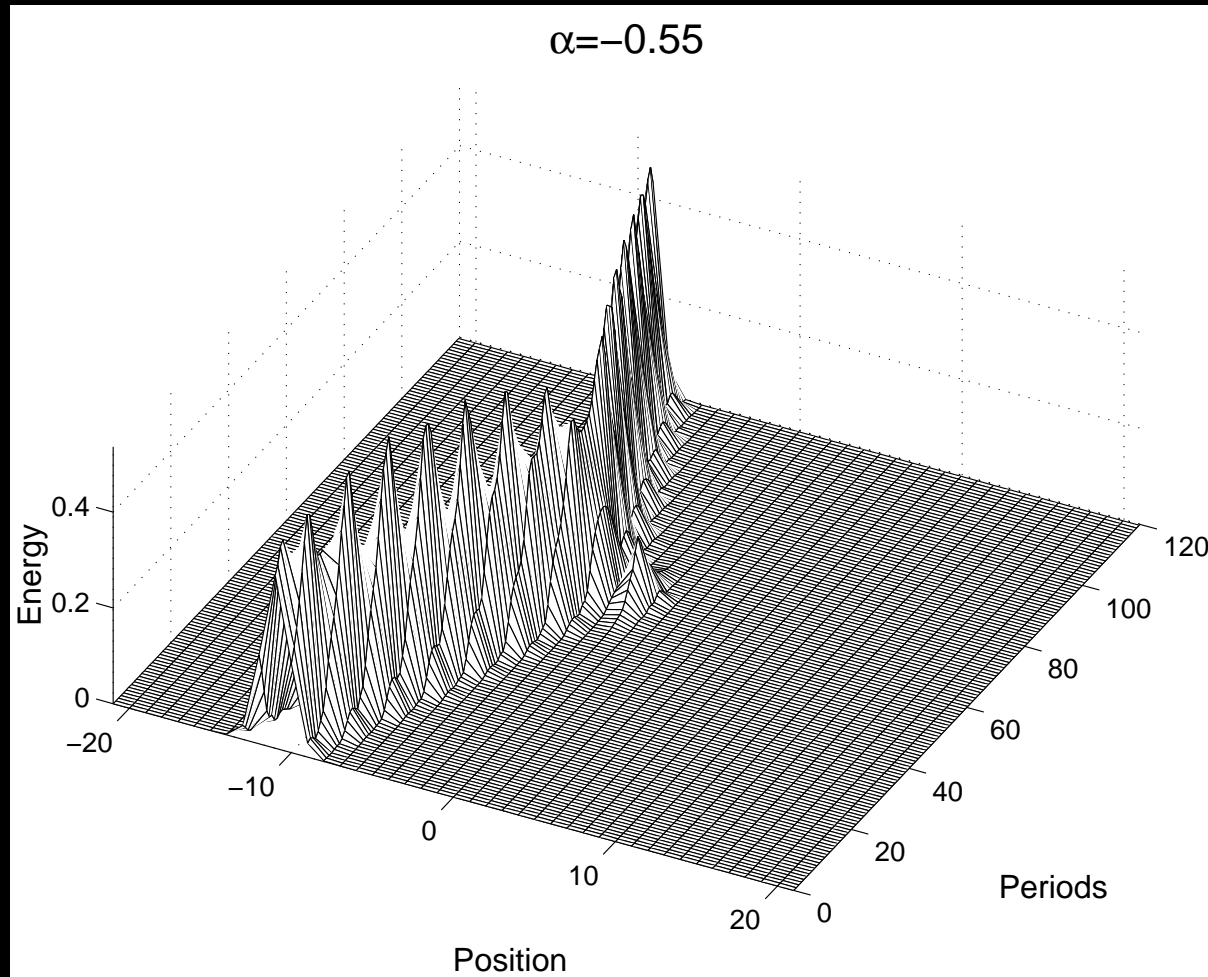
Observed behaviour



Rebound



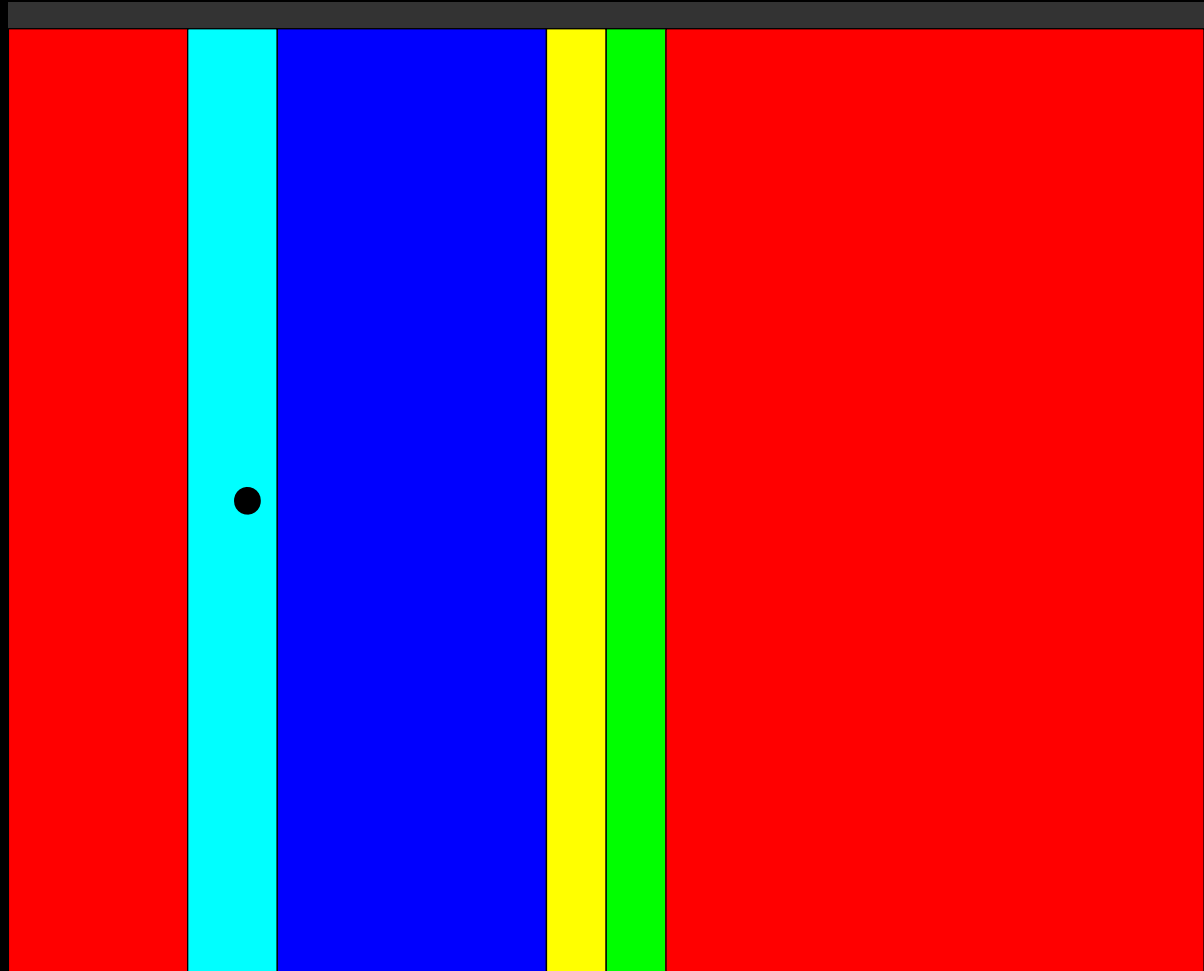
Rebound



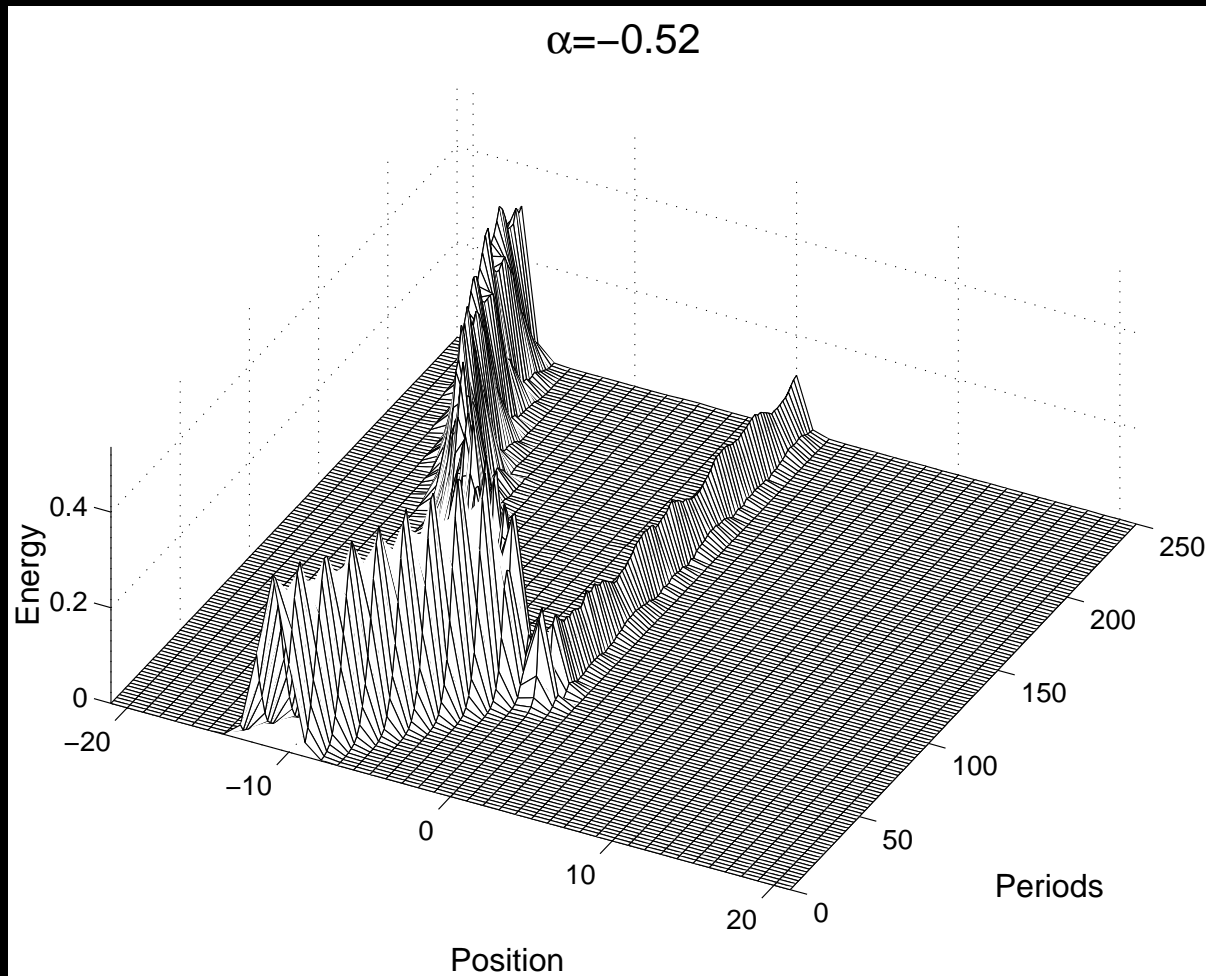
Rebound

MOVIE

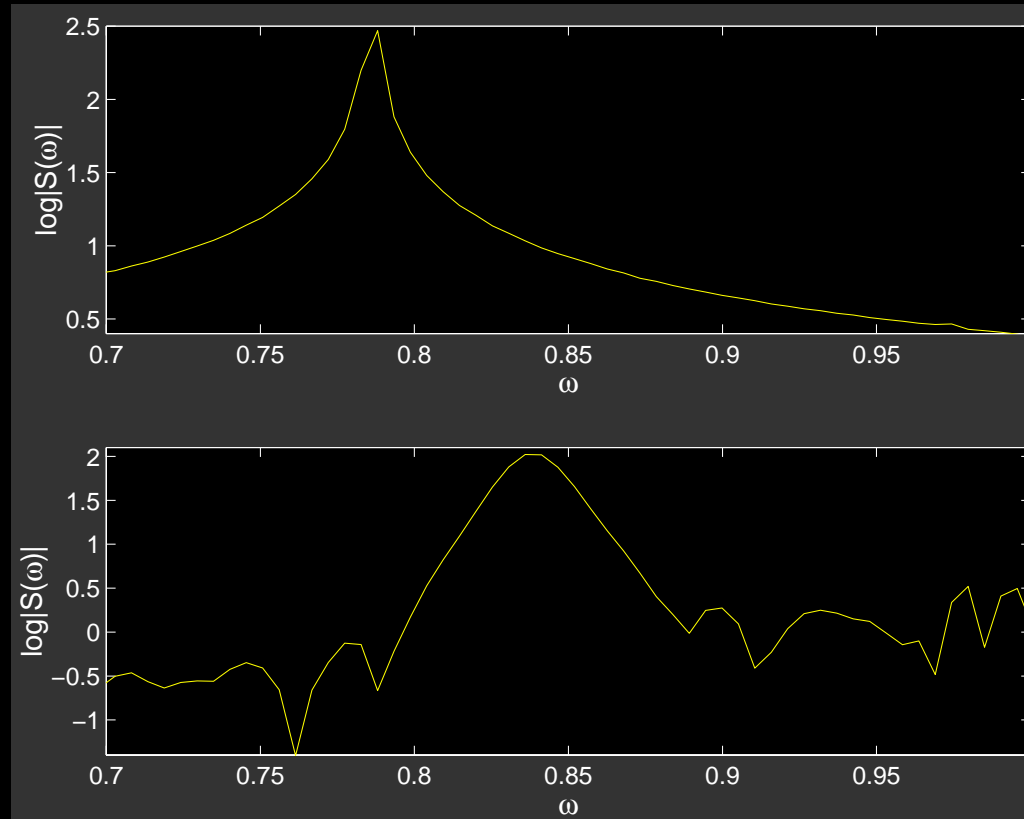
Impurity Excitation



Impurity Excitation



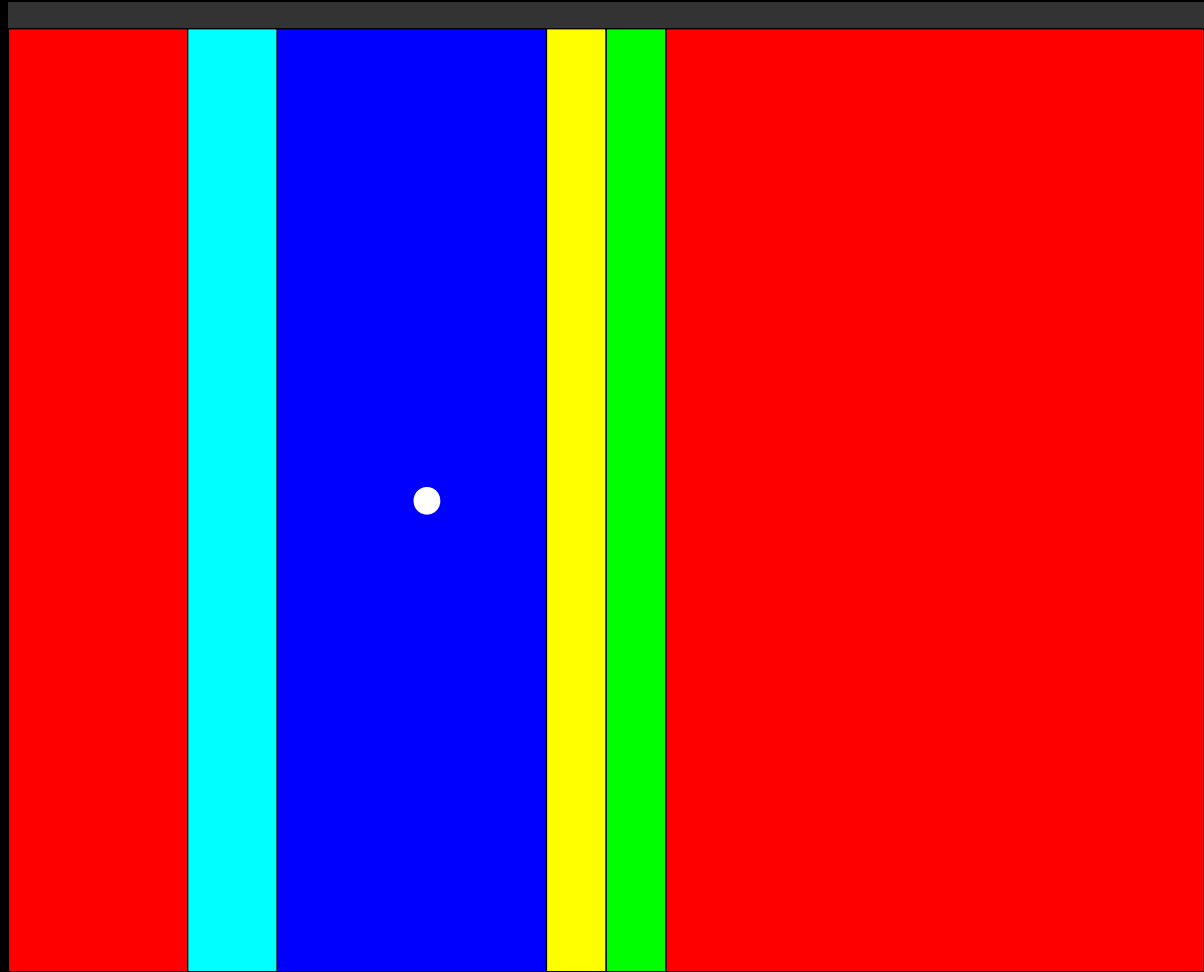
Impurity Excitation



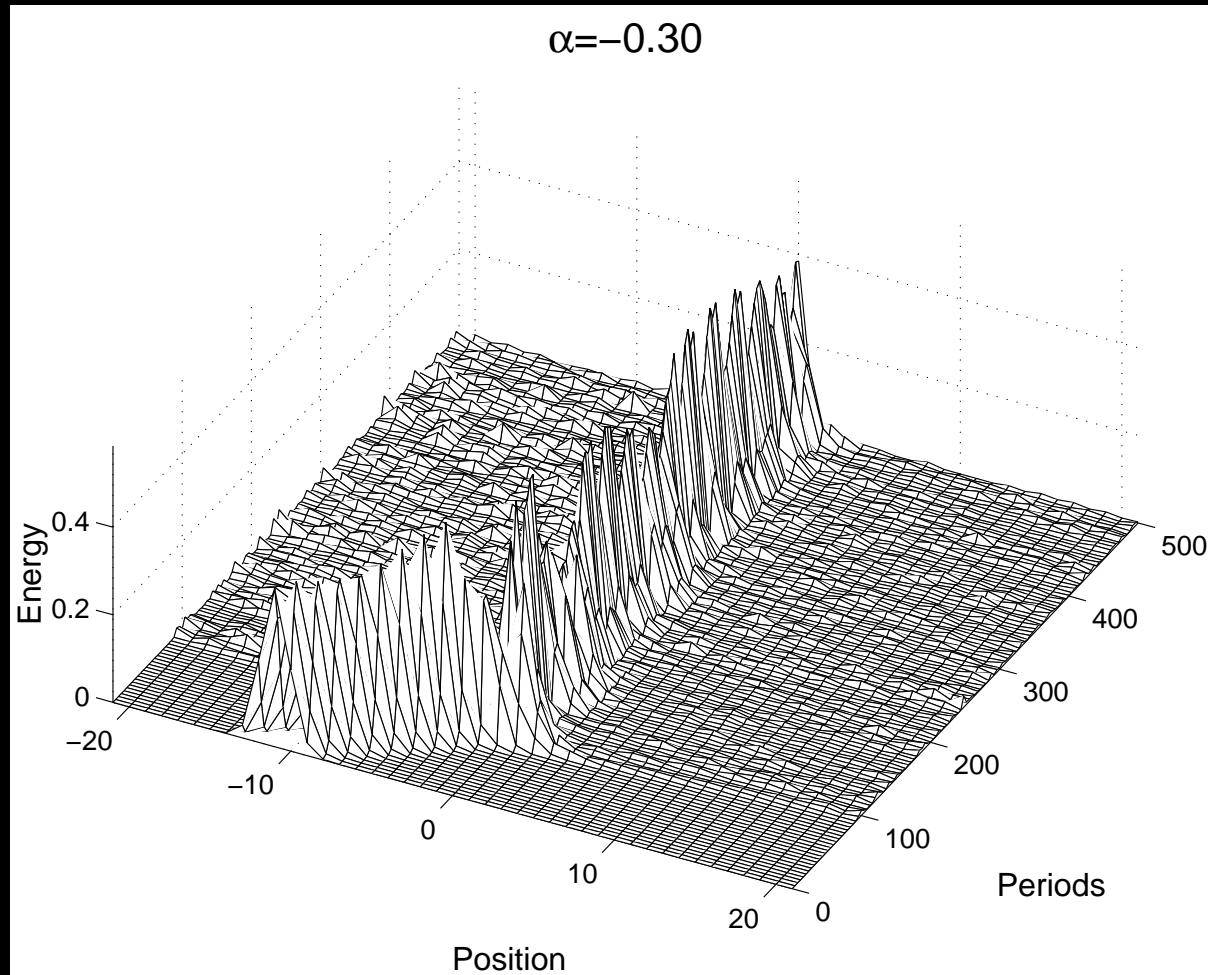
Impurity Excitation

MOVIE

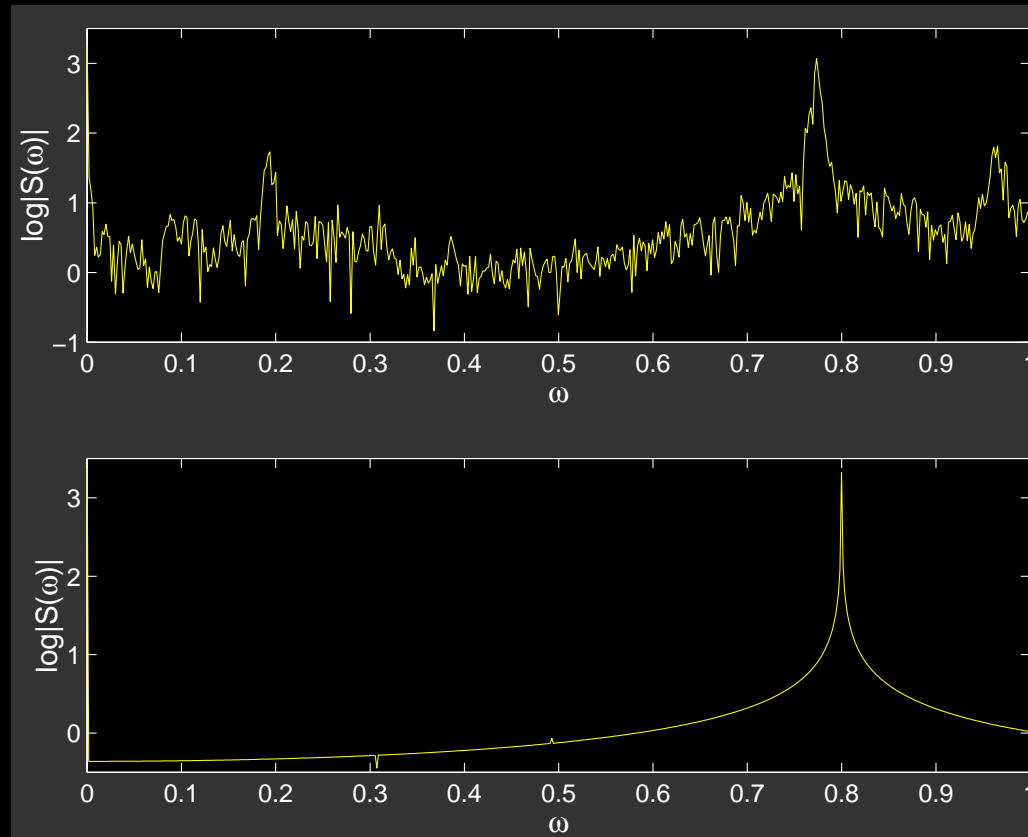
Trapping



Trapping



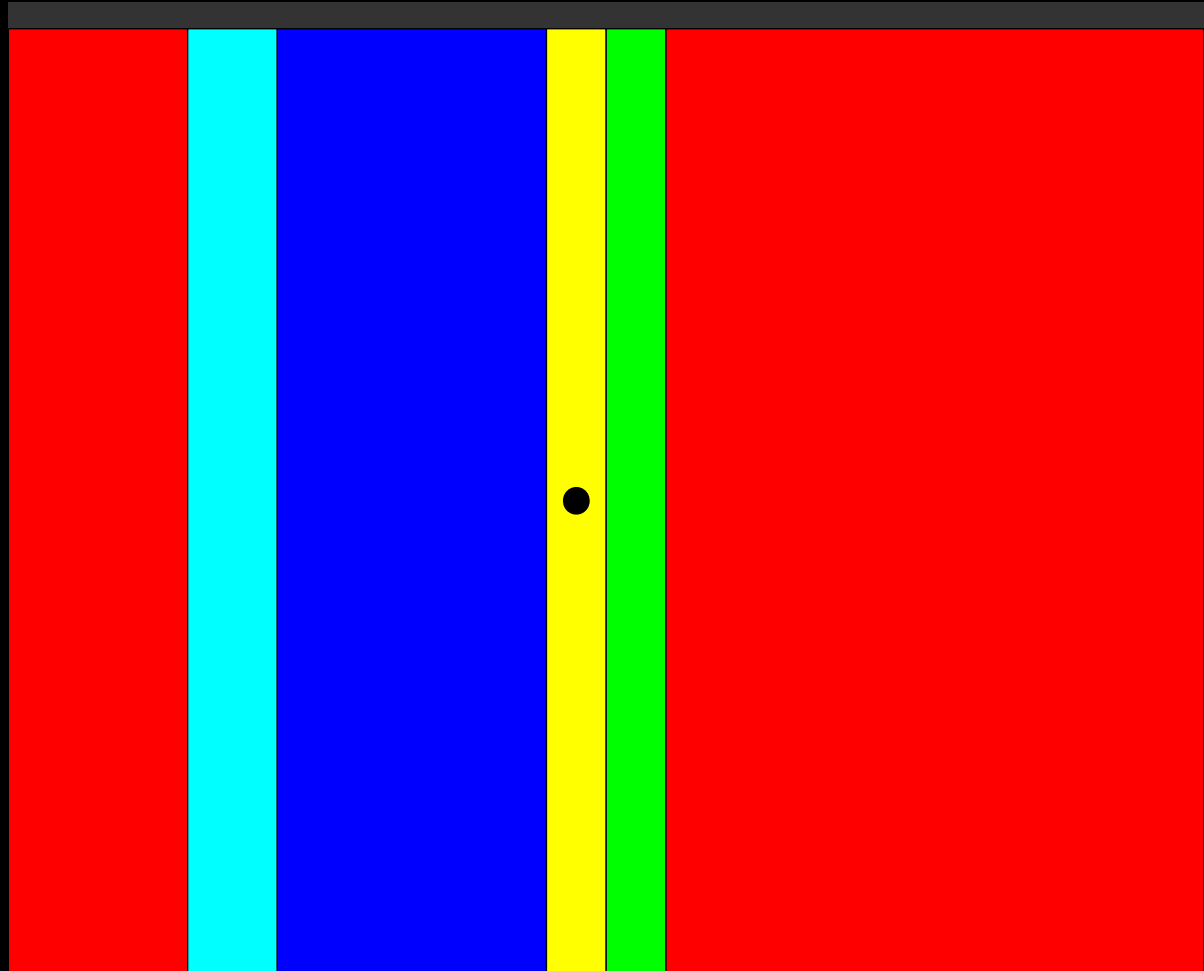
Trapping



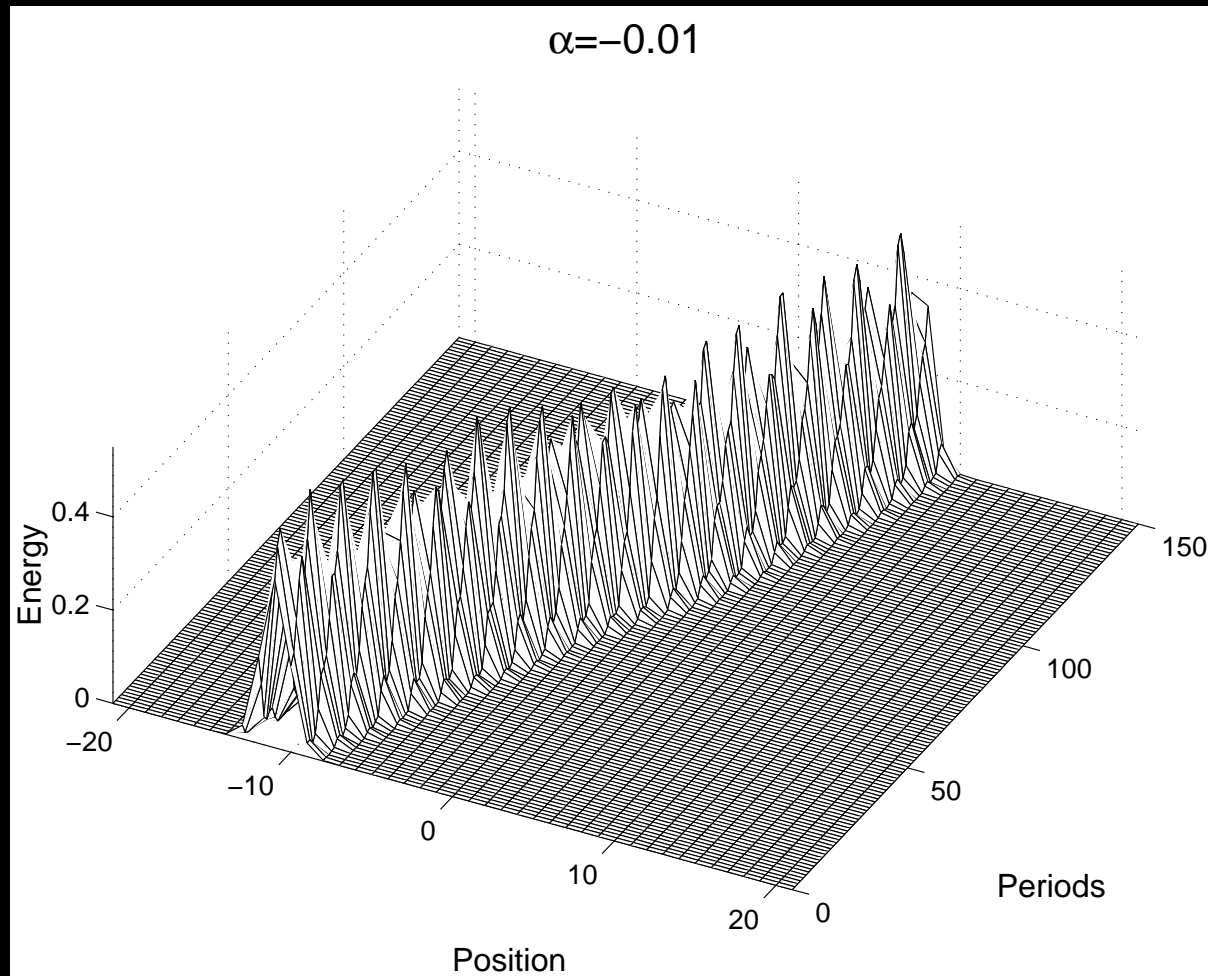
Trapping

MOVIE

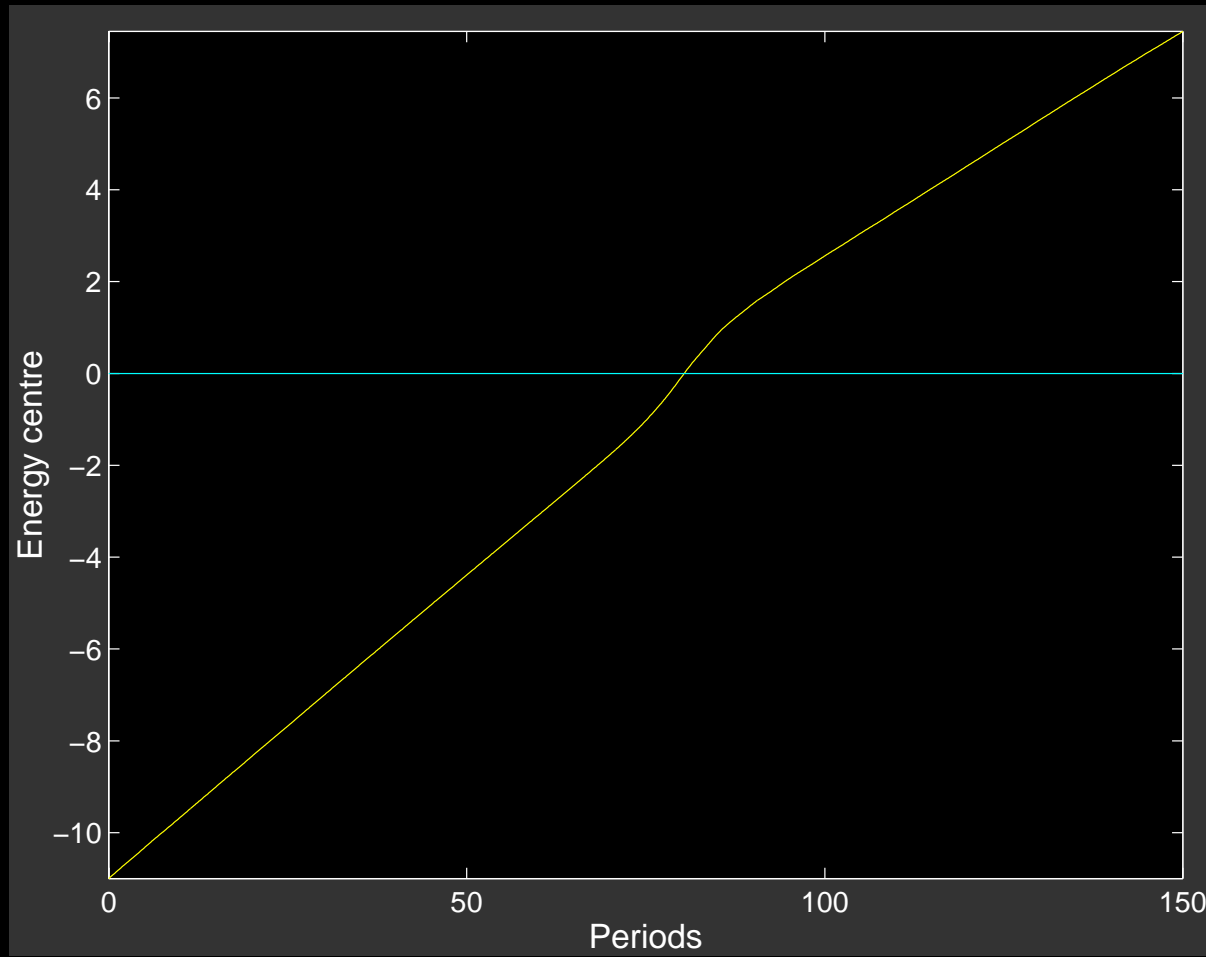
Acceleration



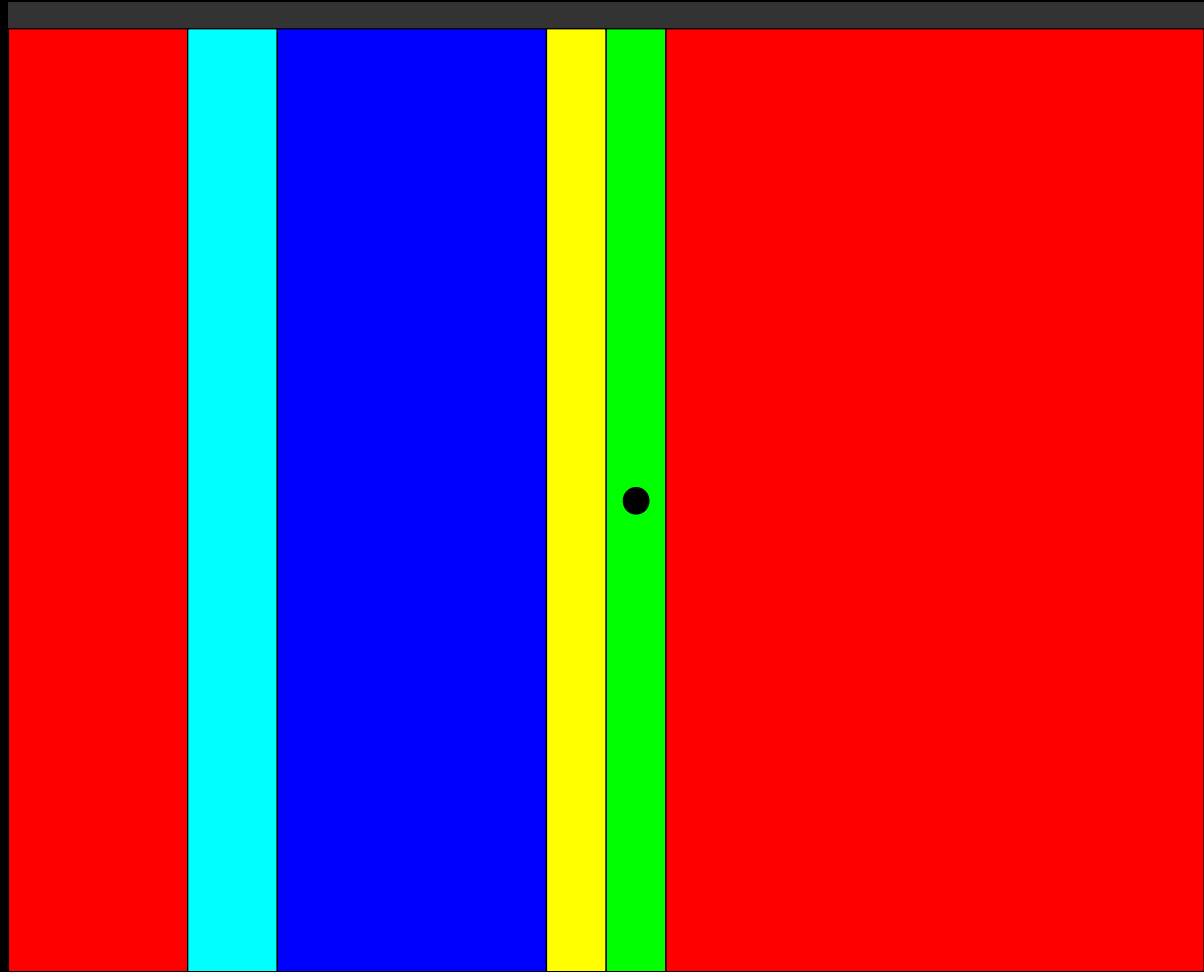
Acceleration



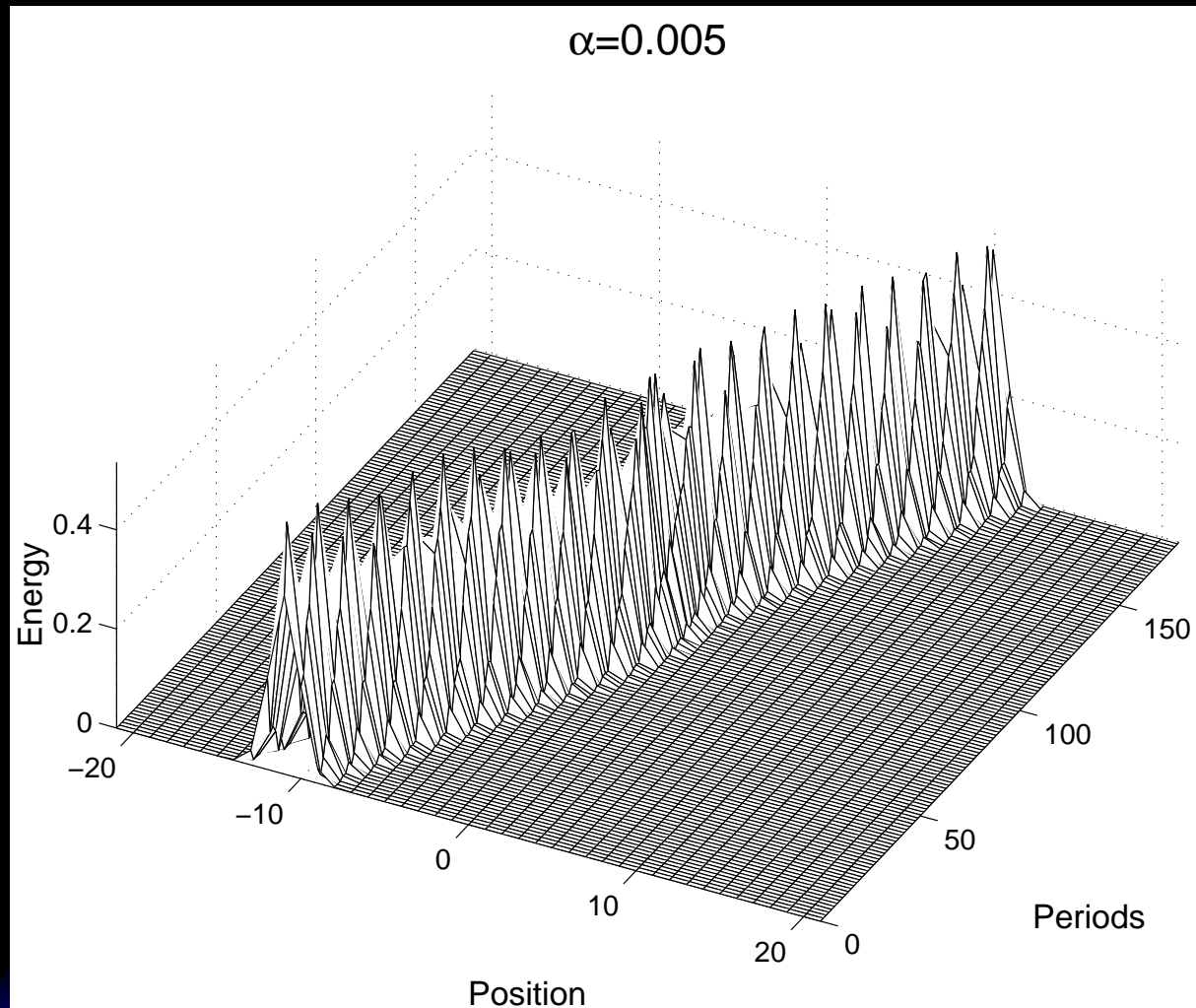
Acceleration



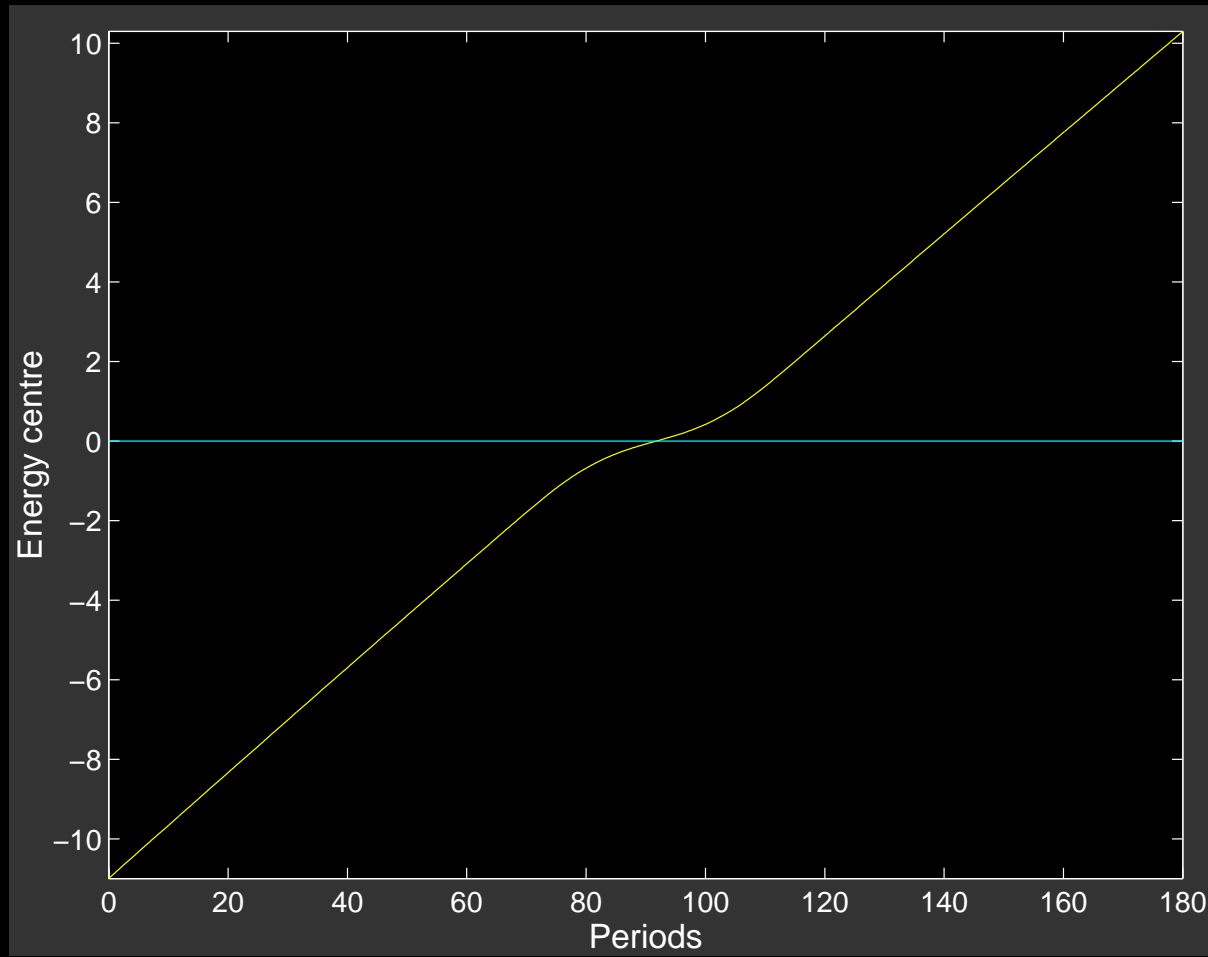
Deceleration



Deceleration



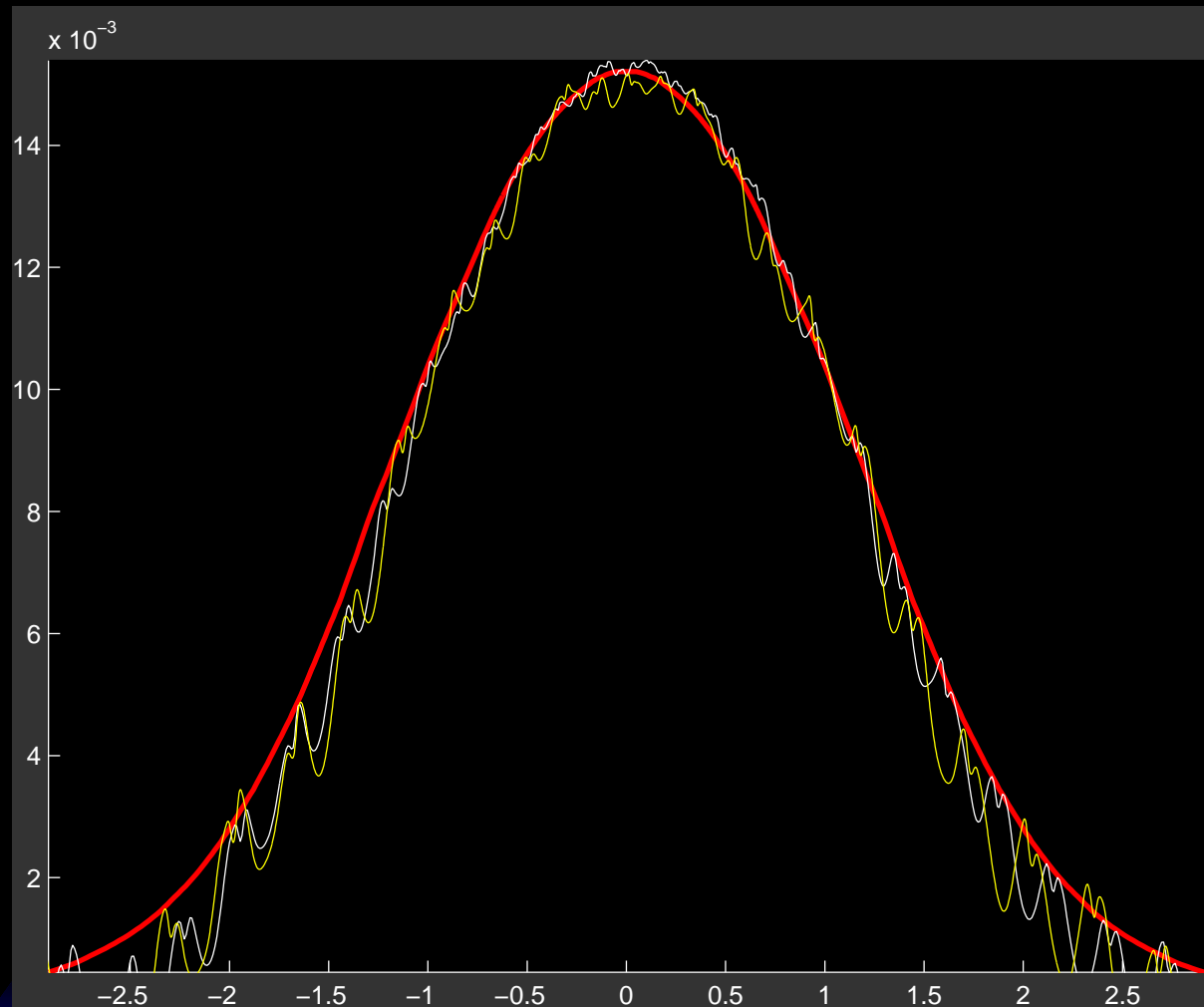
Deceleration



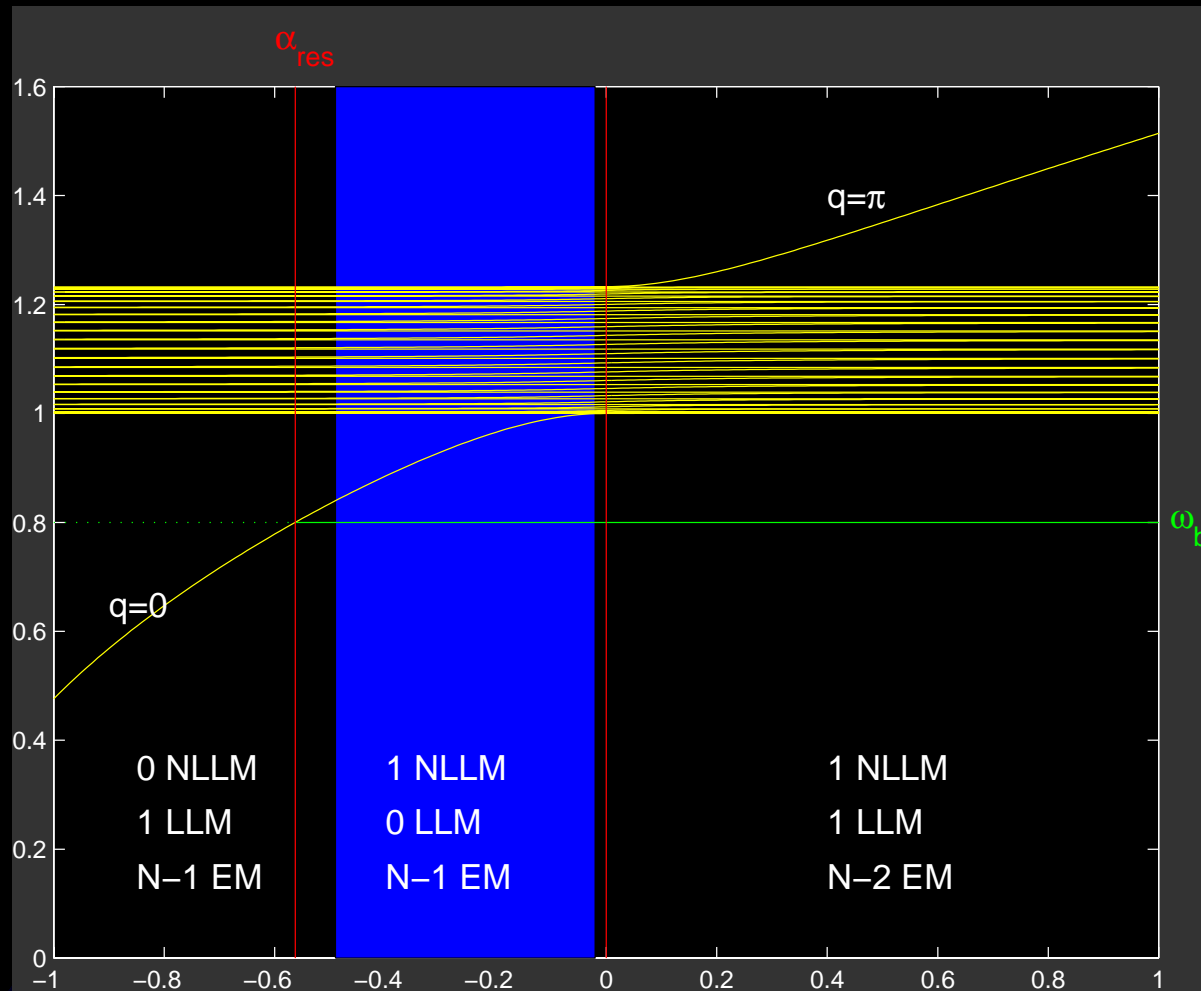
Potential barrier

- For $\alpha \gtrsim 0$, the moving breather–impurity entity can be considered as a particle with constant energy E within a potential barrier (E : translational energy of moving breather).
- E_o : Maximum of the barrier. This behaviour occur for all the range $\alpha > 0$. The maximum of the barrier increase with α .
- The potential barrier can be calculated following two methods:
 1. Fixing $E < E_o$, the barrier is giving by (x, E) , being x the turning point of the moving breather.
 2. Fixing $E > E_o$. The barrier is giving by $E_b(x) = E(1 - (v(x)/v_o)^2)$, being v the translational velocity of the moving breather.

Potential barrier



Stationary solutions



The NLLM hypothesis

Necessary condition for the existence of trapping:

1. There must exist a NLLM with the same parameters of the moving breathers.
2. There must not exist a LLM with a wave vector different to the NLLM's.

Justification of the hypothesis

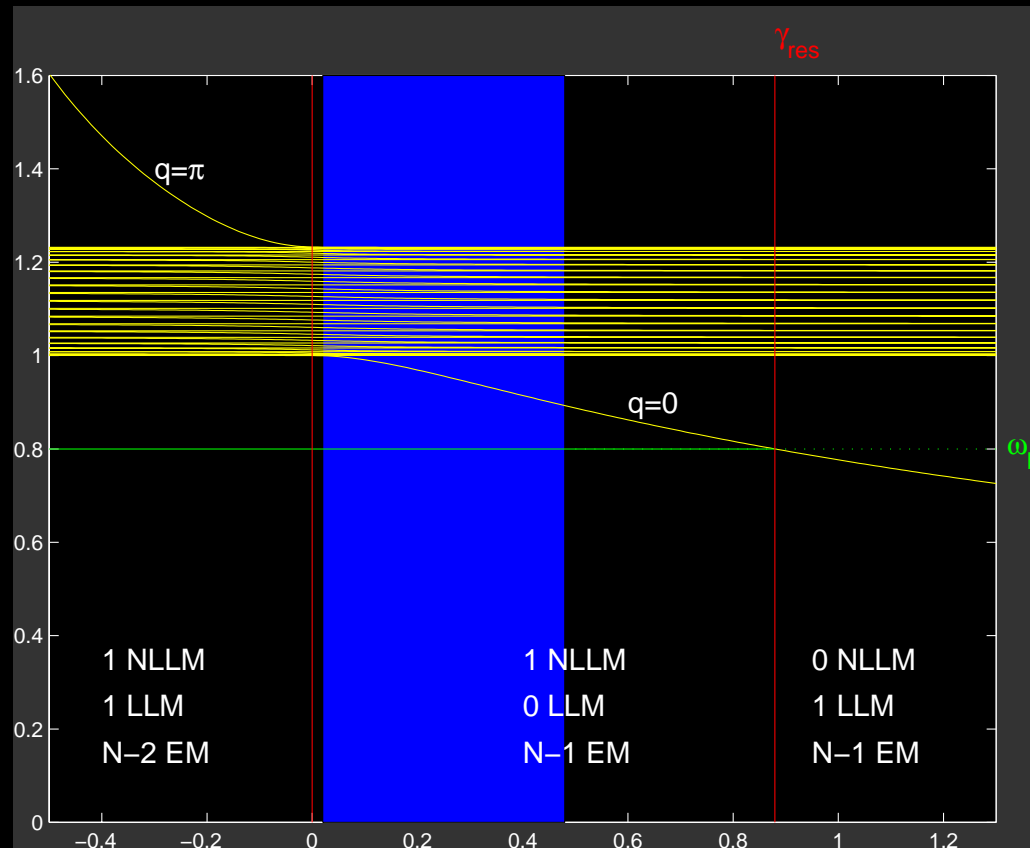
- The moving breather must excite the NLLM when it reaches the impurity in order to be trapped.
- If it would exist a LLM with different wave vector, the moving breather excites the NLLM and the tails of the LLM. The tails of the NLLM and LLM have different vibration patterns and enter into conflict.

Checking the hypothesis

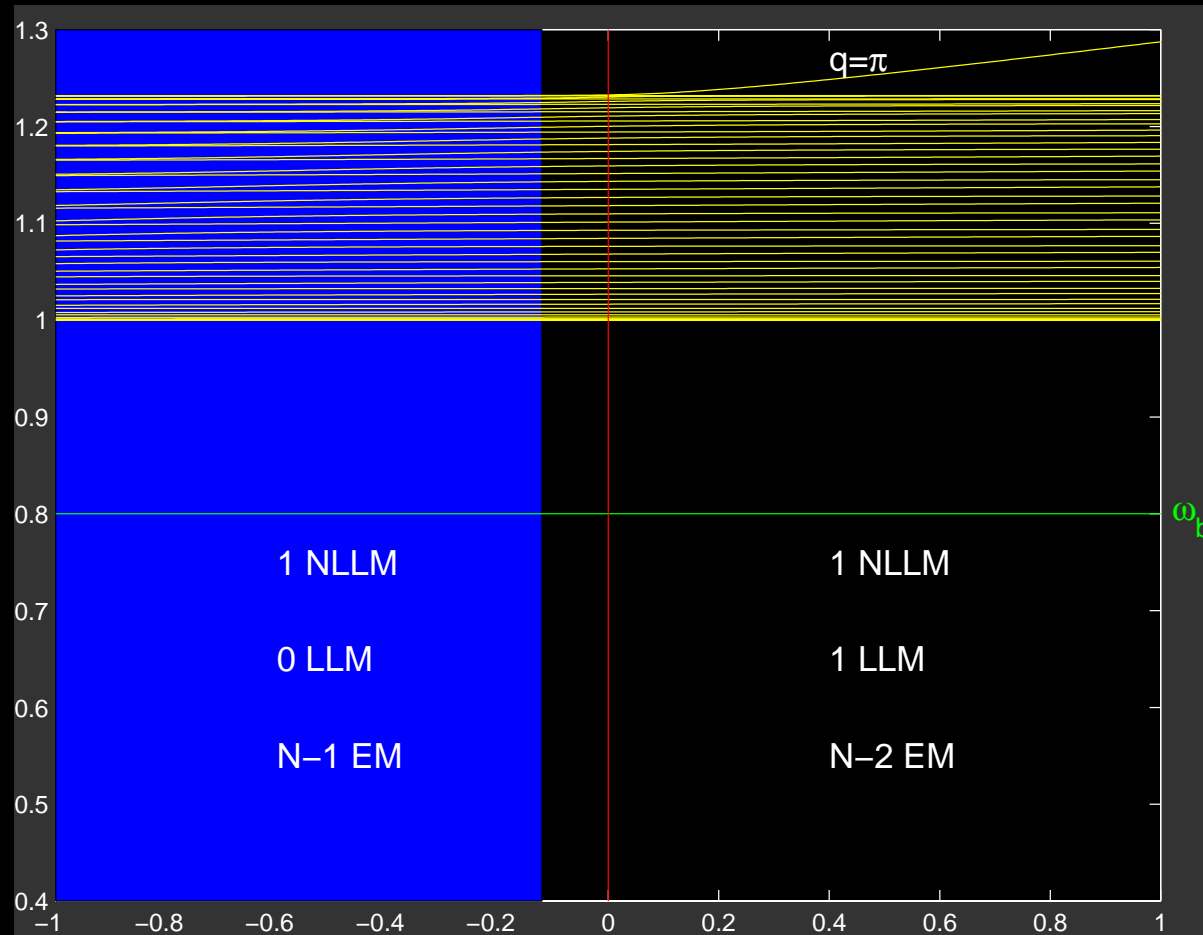
We have checked that the NLLM hypothesis holds making the following changes:

- Hard potential
- Impurity in the mass
- Impurity in coupling

Impurity in mass



Impurity in coupling



Conclusions

- The breather traps for a wide range of parameters, provided the impurity is heavier or the potential is less deep. It can be due to the resonance with a nonlinear local mode originated by the impurity.
- The occurrence of trapping is independent on the velocity of the moving breather.
- The breather can cross the impurity as long as the system is not very inhomogeneous.

Comparison with other works

Interaction kink–impurity: The kink rebound, is trapped or cross the impurity depending on the velocity.

Interaction breather–impurity with low nonlinearity:
The trapping is due to the resonance with a linear local mode.