Resilience, robustness and viability

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Are resilience and robustness the same?

For Anderies, Folke, Walker, Oström 2013:

Robustness = Ability to keep some properties despite shocks

Resilience = Robustness + adaptability, transformability

Since adaptability and transformability are particular dynamics then:

Resilience = Robustness

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This is true but it's a pity!

- Indeed, resilience is most of the time considered as the same as robustness

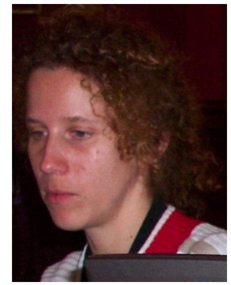
But:

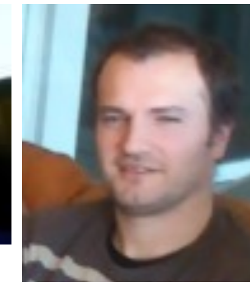
- If the concepts are the same why using resilience and not robustness?
- This view misses an important part of the intuitive concept of resilience : the ability to recover properties after having lost them

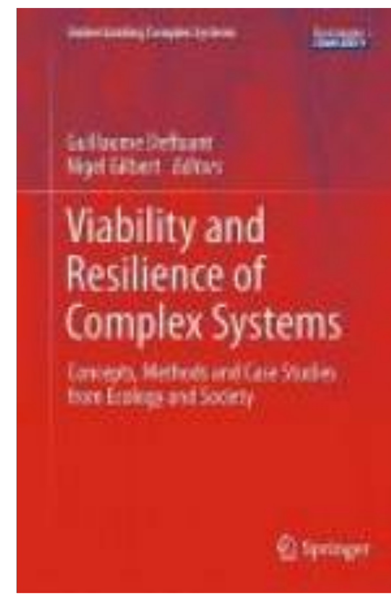
Formalising resilience with viability theory

Using viability theory (Aubin 1991, 2011)

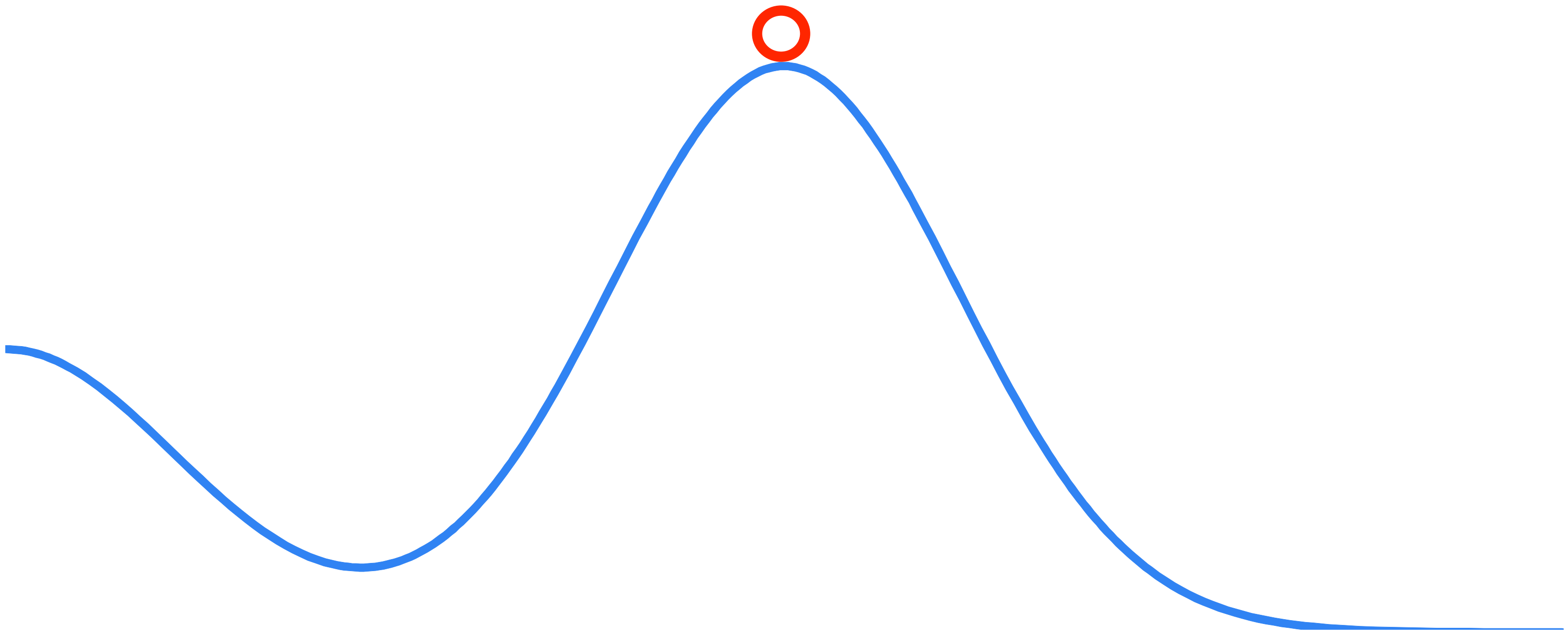
- Béné, Doyen, Garbay 2001
- Martin 2004
- Deffuant & Gilbert 2011
- Rougé, Mathias, Deffuant 2013, 2014



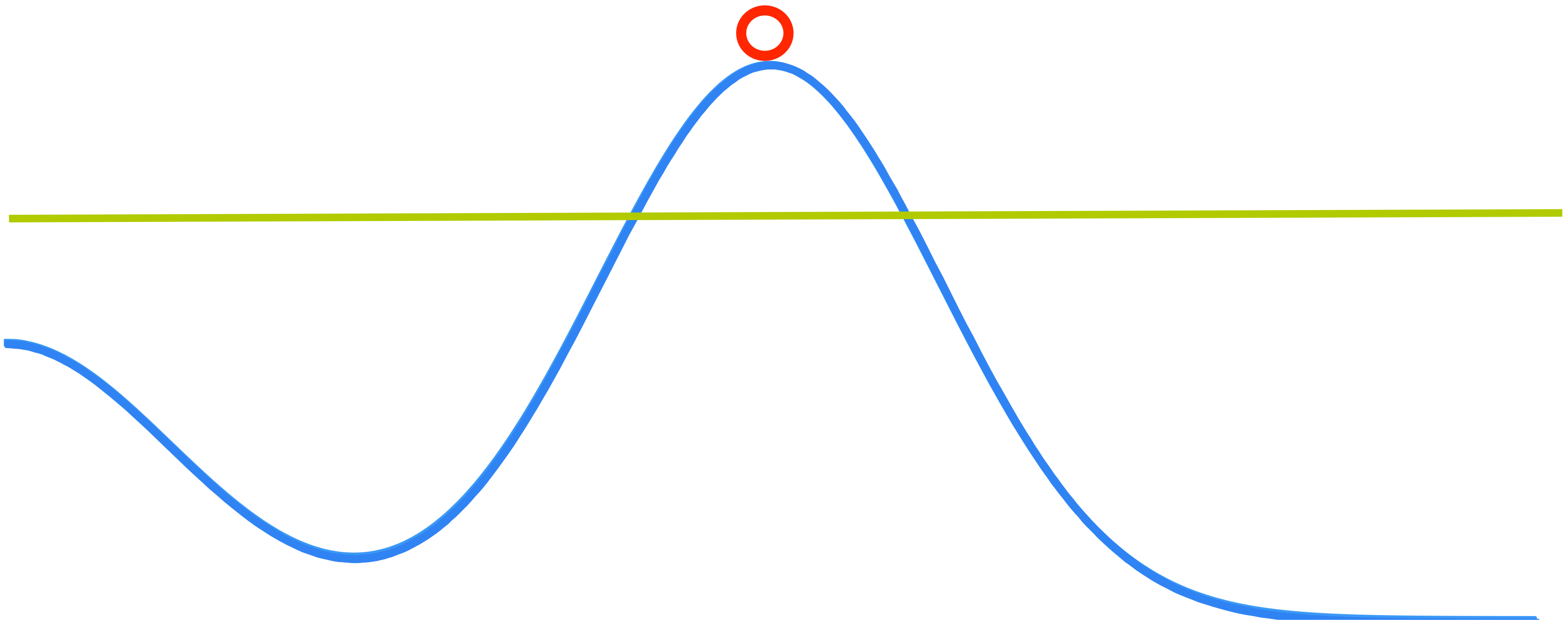




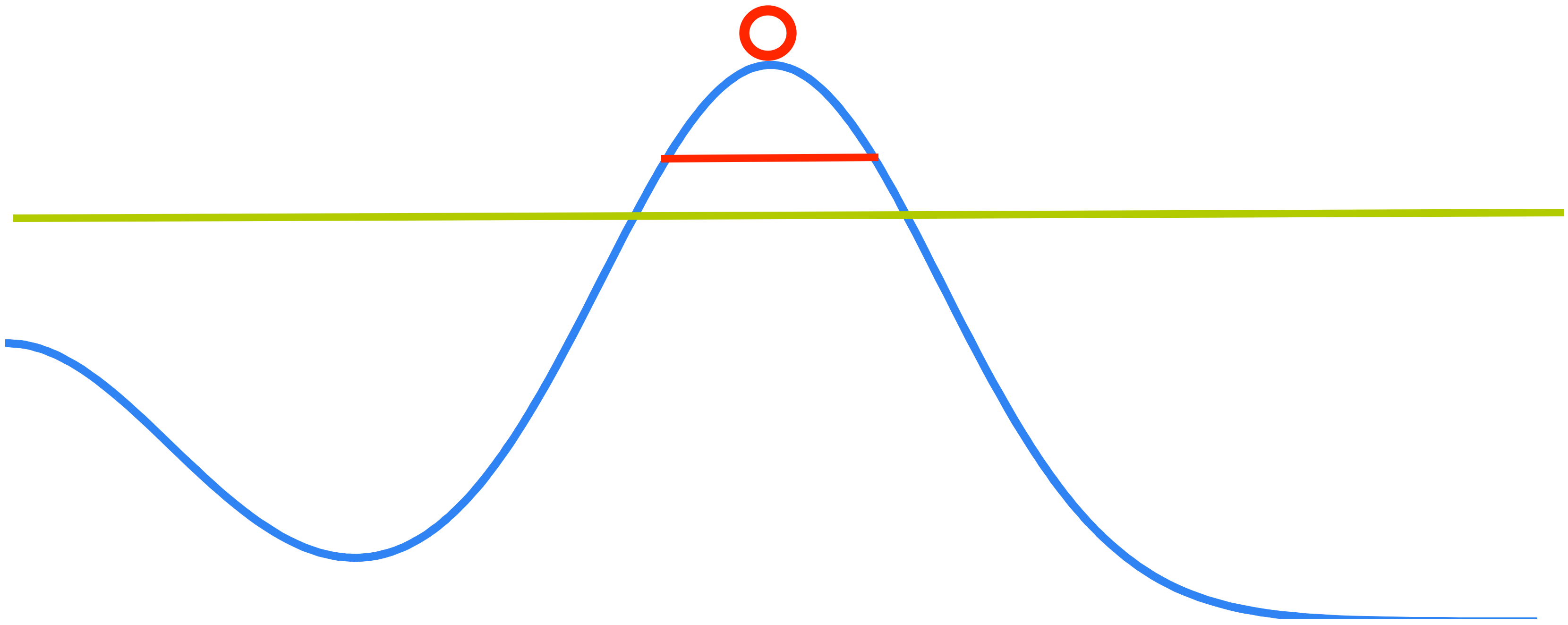
Toy example 2: mobile ball on hills



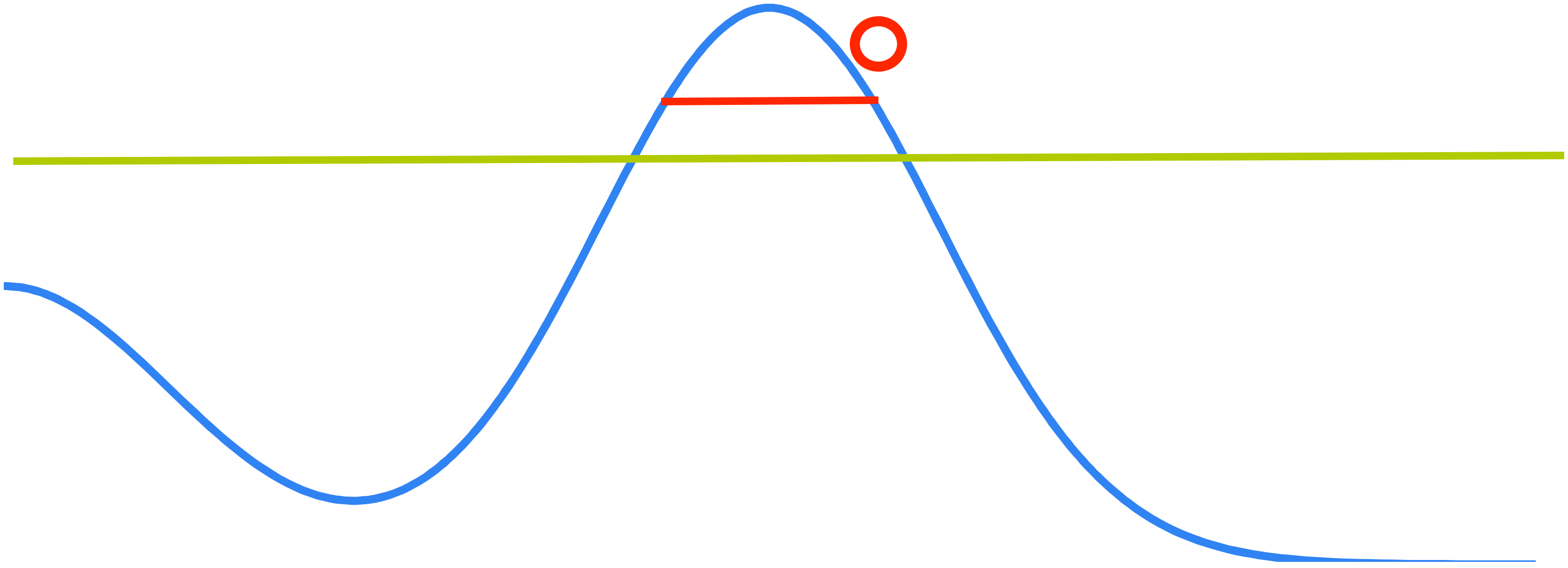
Property: the ball is above the green line



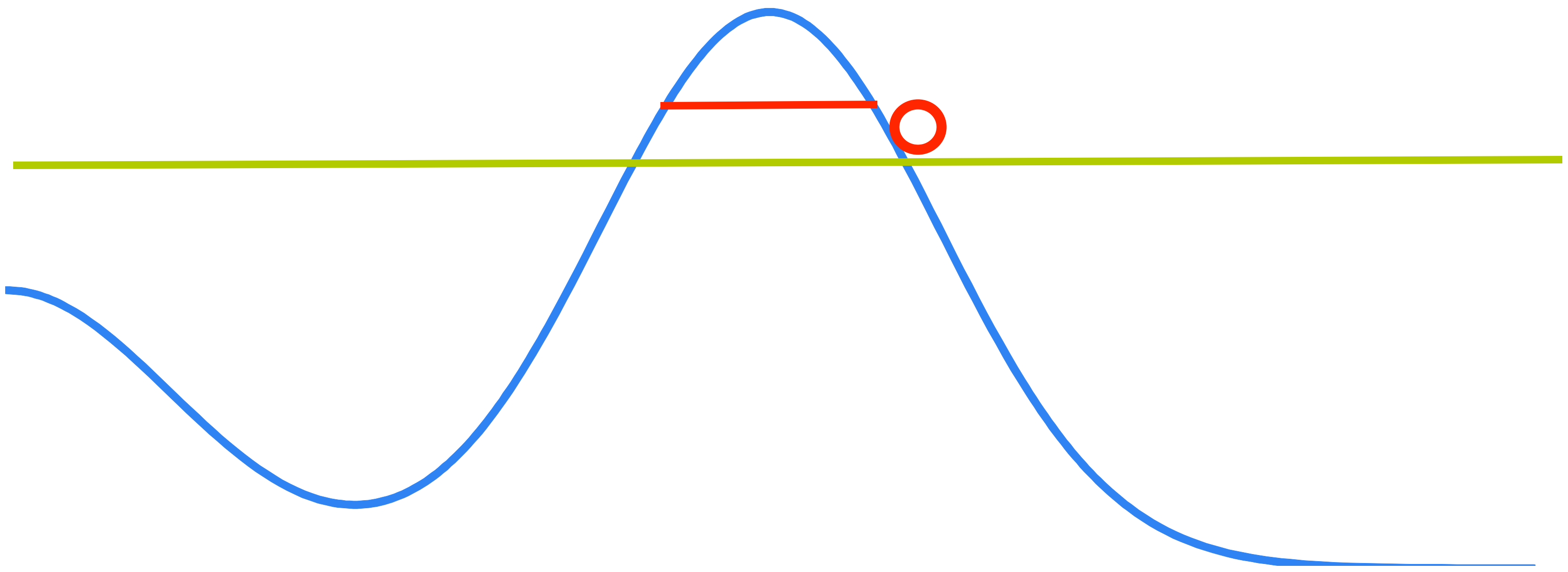
Limit perturbations for robustness (ball with engine inside)



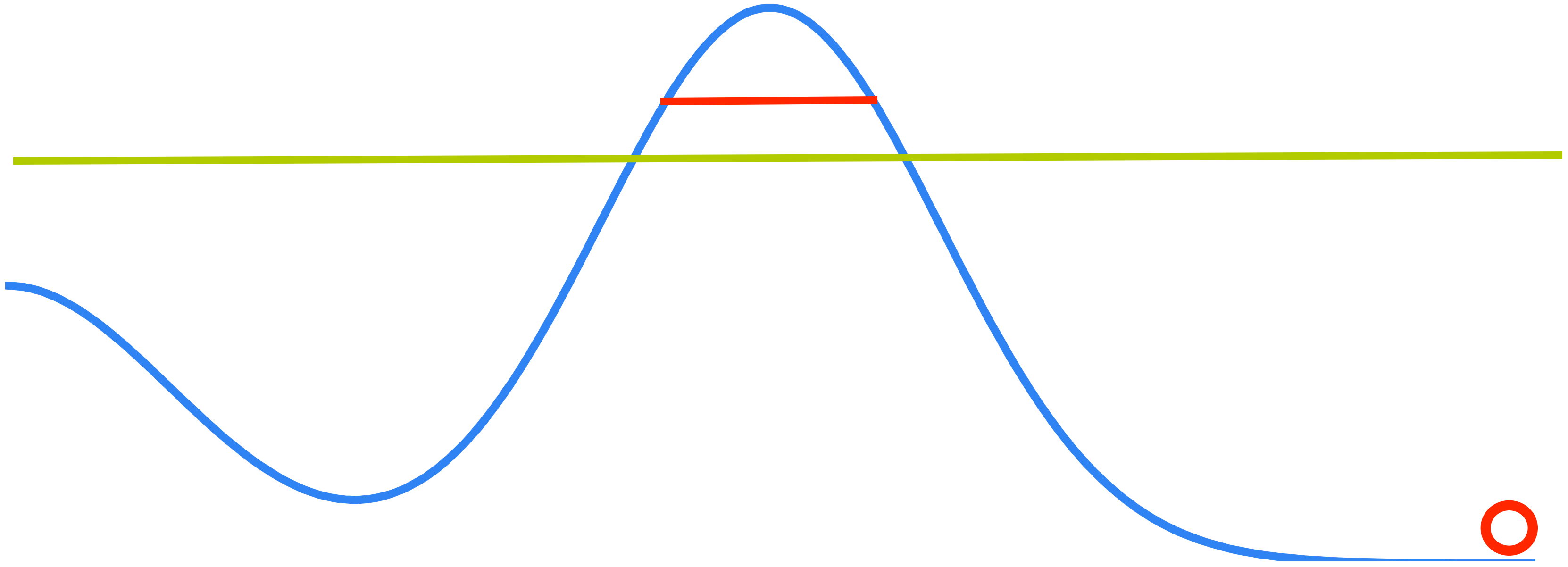
Limit perturbations for robustness



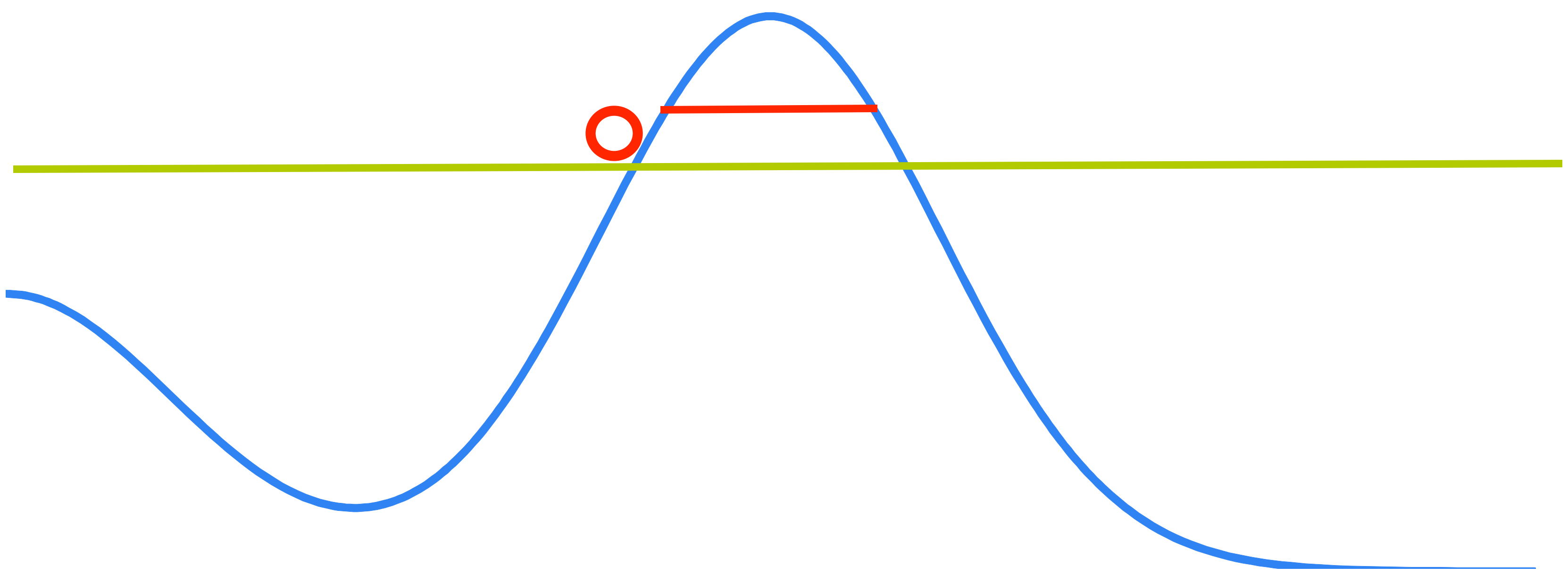
Limit perturbations for robustness



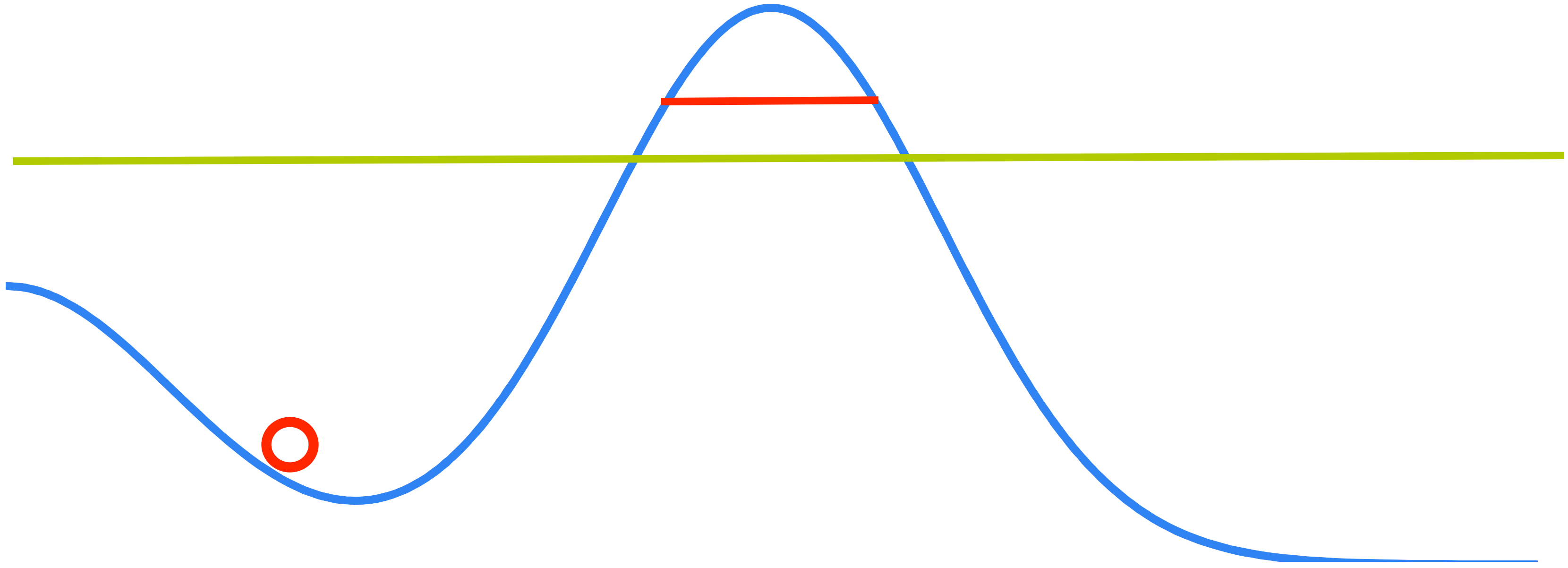
Cannot recover the property



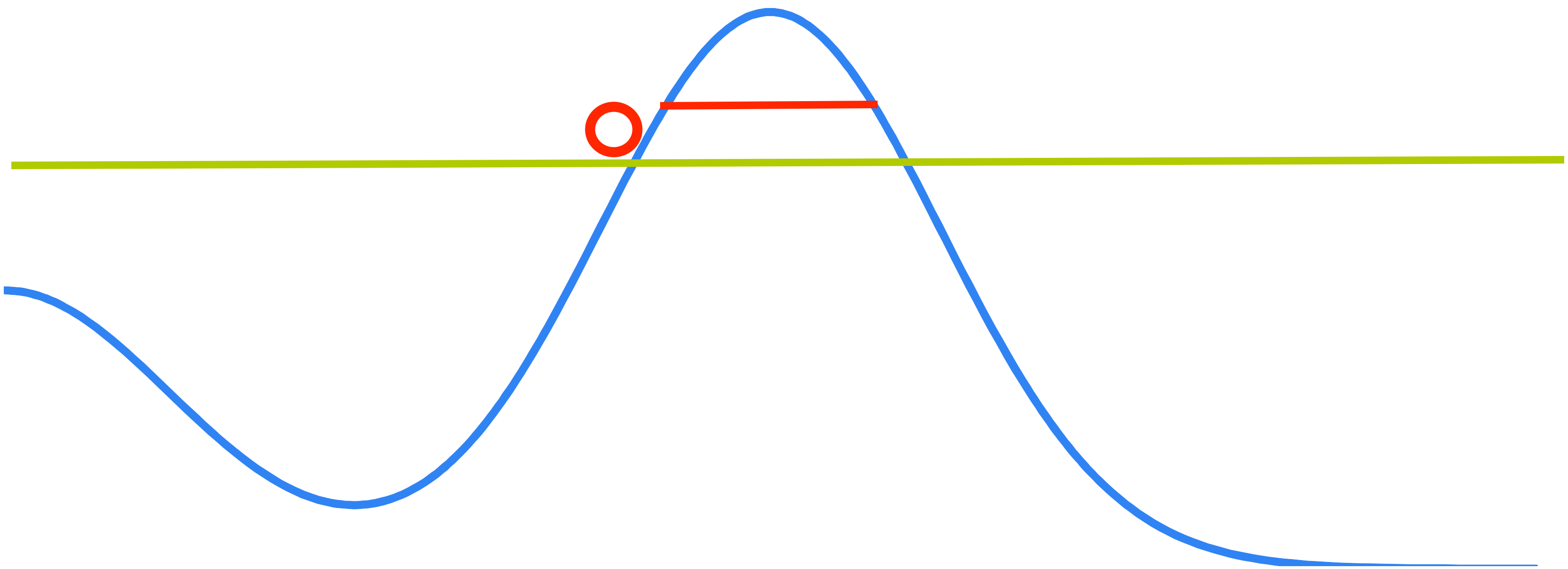
Trajectory when braking all the way



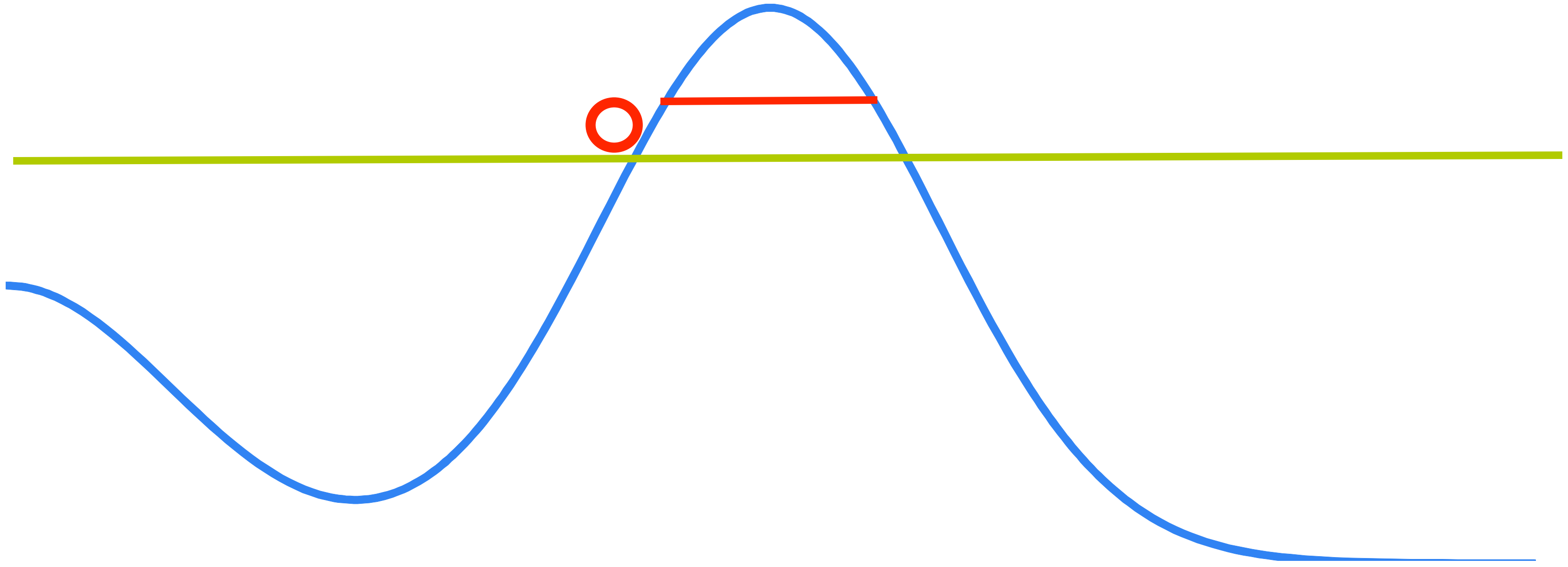
Can recover the property but cannot keep it



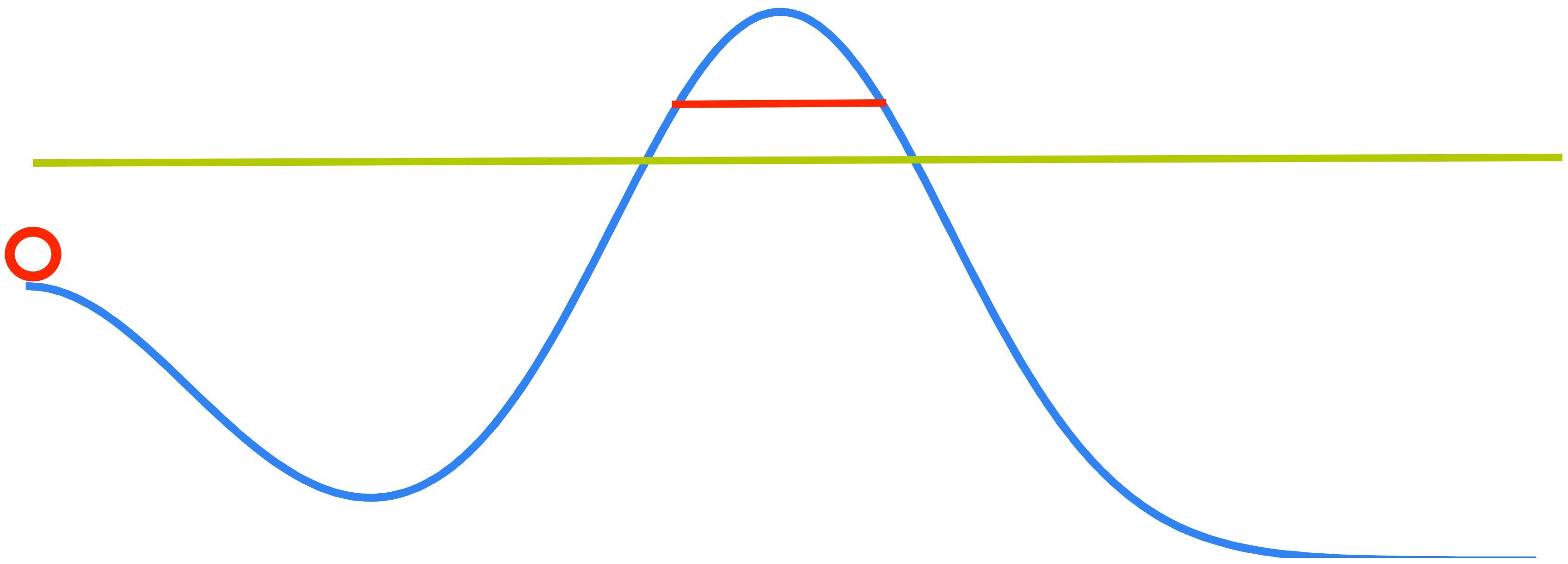
The ball falls again



Trajectory without slowing down



The mobile can then recover the property and keep it



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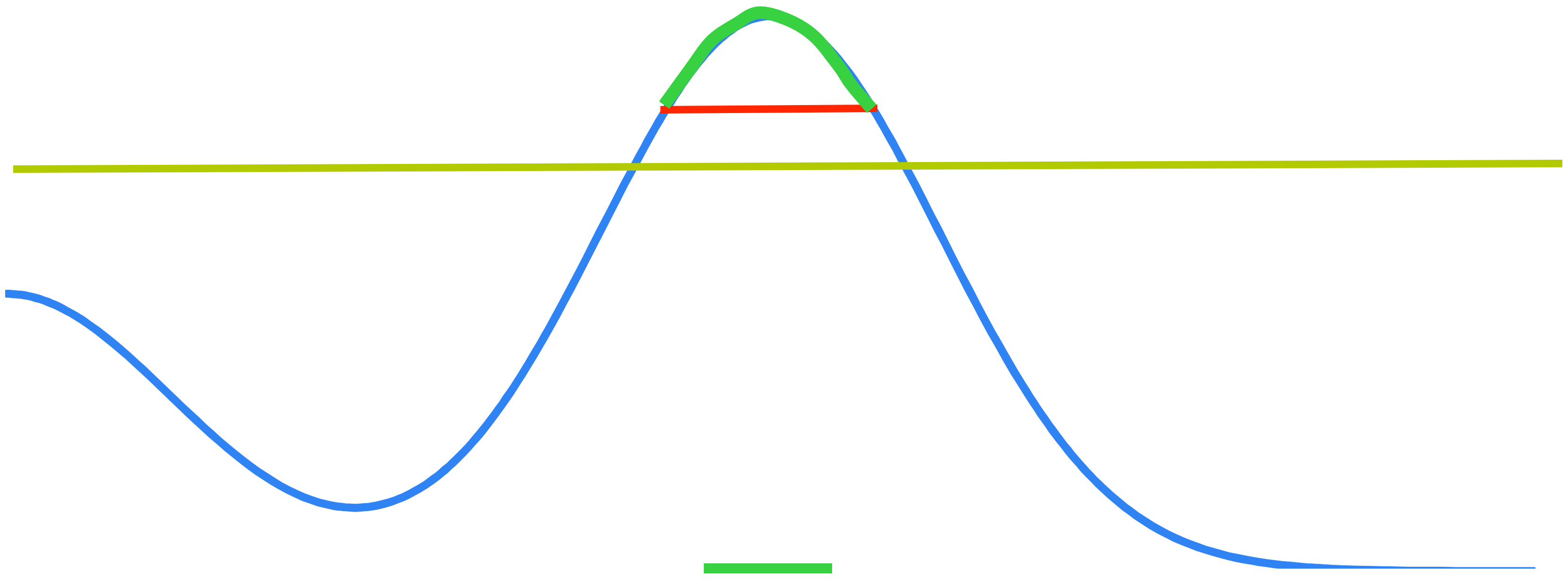
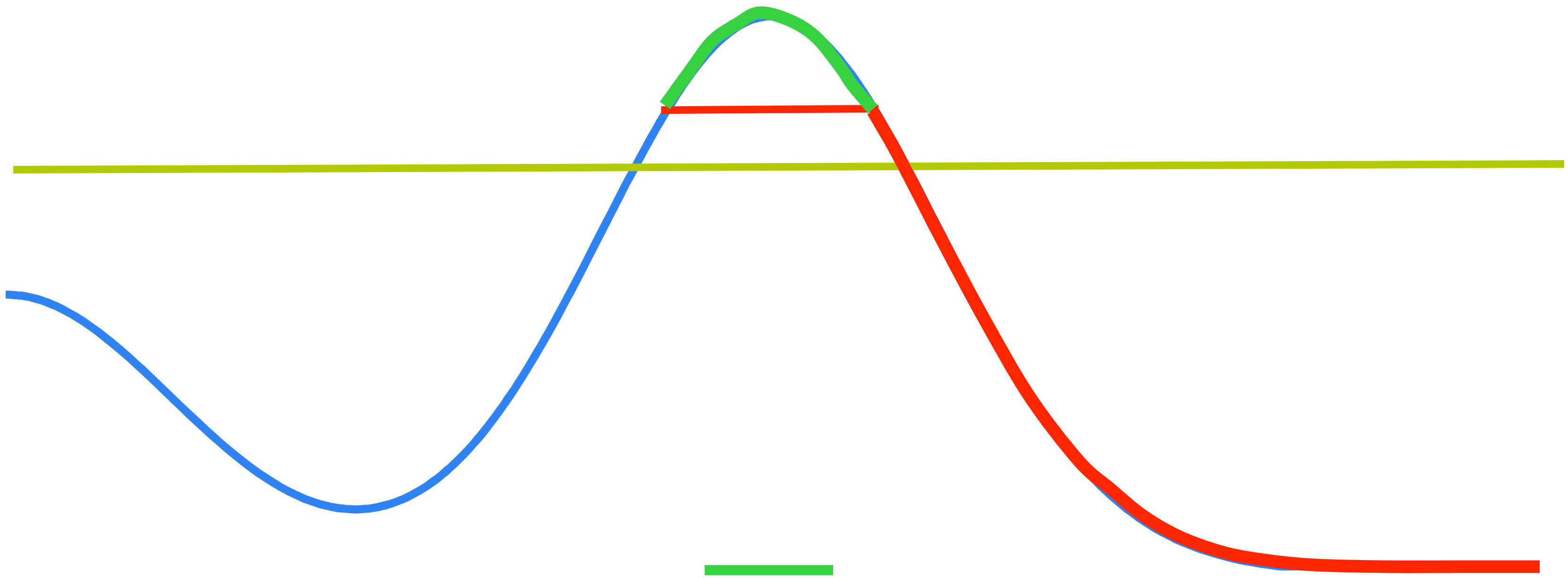
Robustness and viability



The property is robust to the perturbations

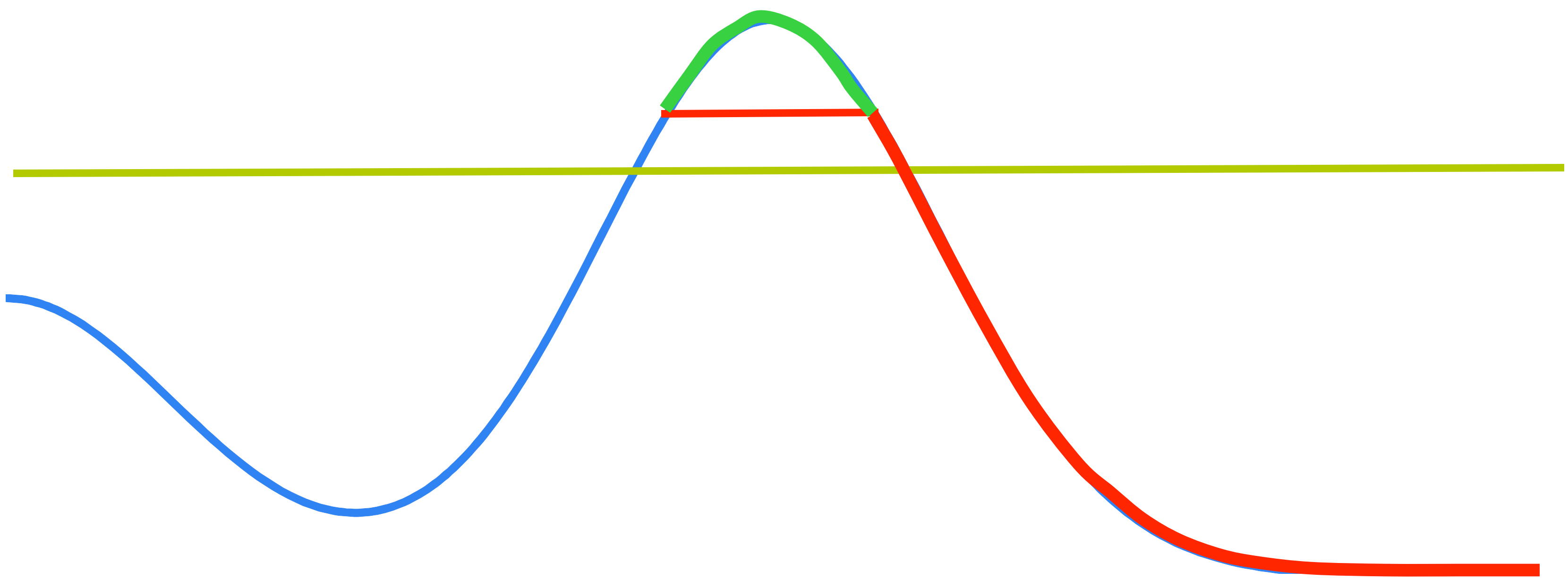
Property is not resilient



The property can be kept (robust)

The property cannot be recovered : it is non resilient

Property is resilient

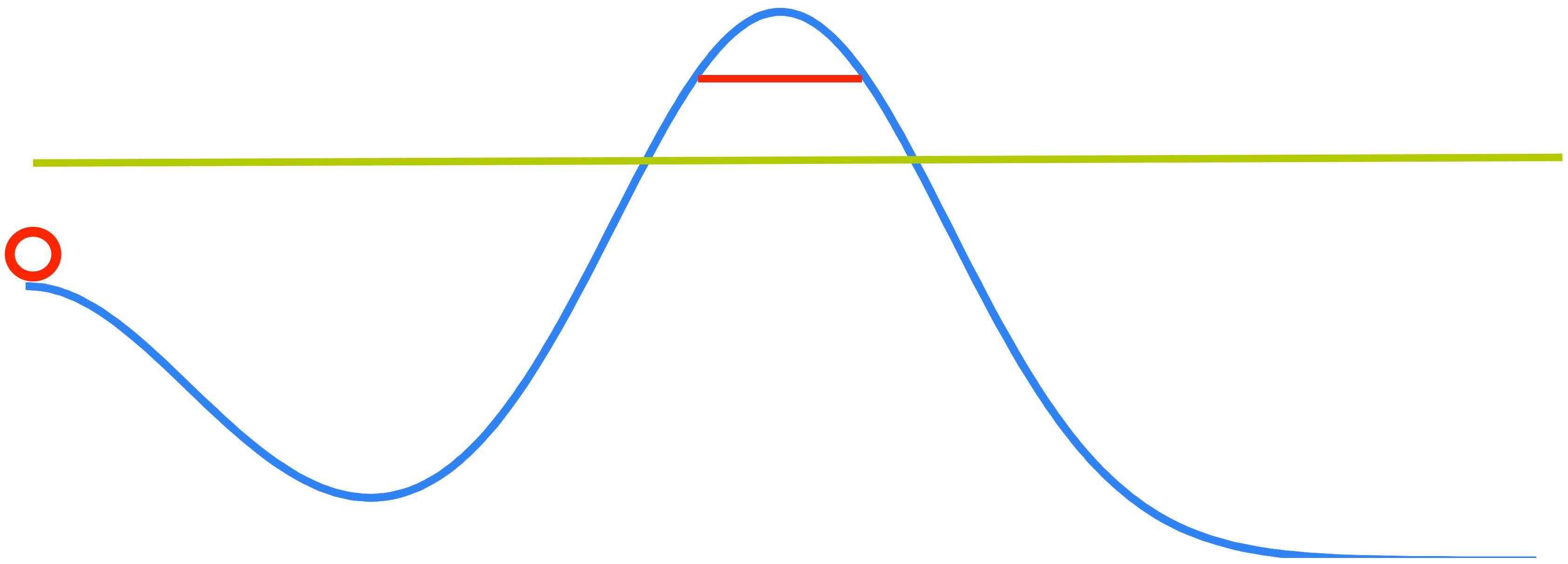


The property can be recovered and kept: it is resilient

The property is kept (robust)

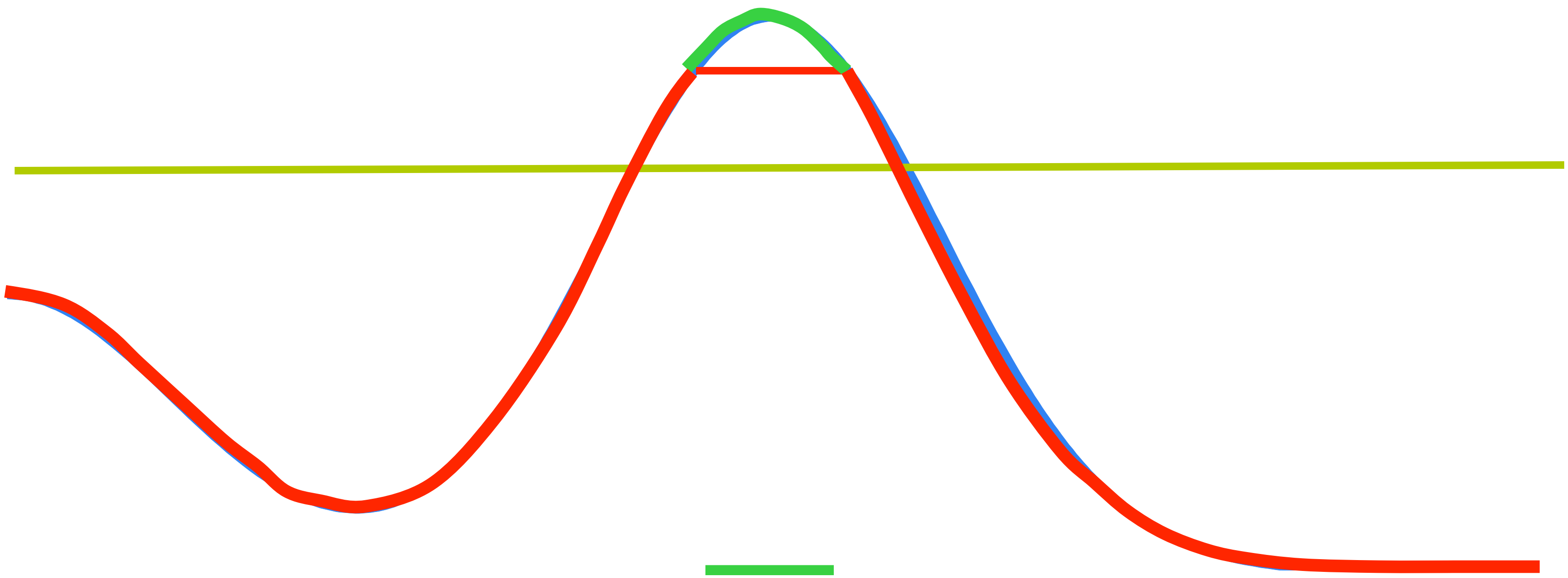
The property cannot be recovered : it is non resilient

The engine is a bit less powerful



The system gets the property back but cannot keep it.
It is not resilient.

Property is not resilient

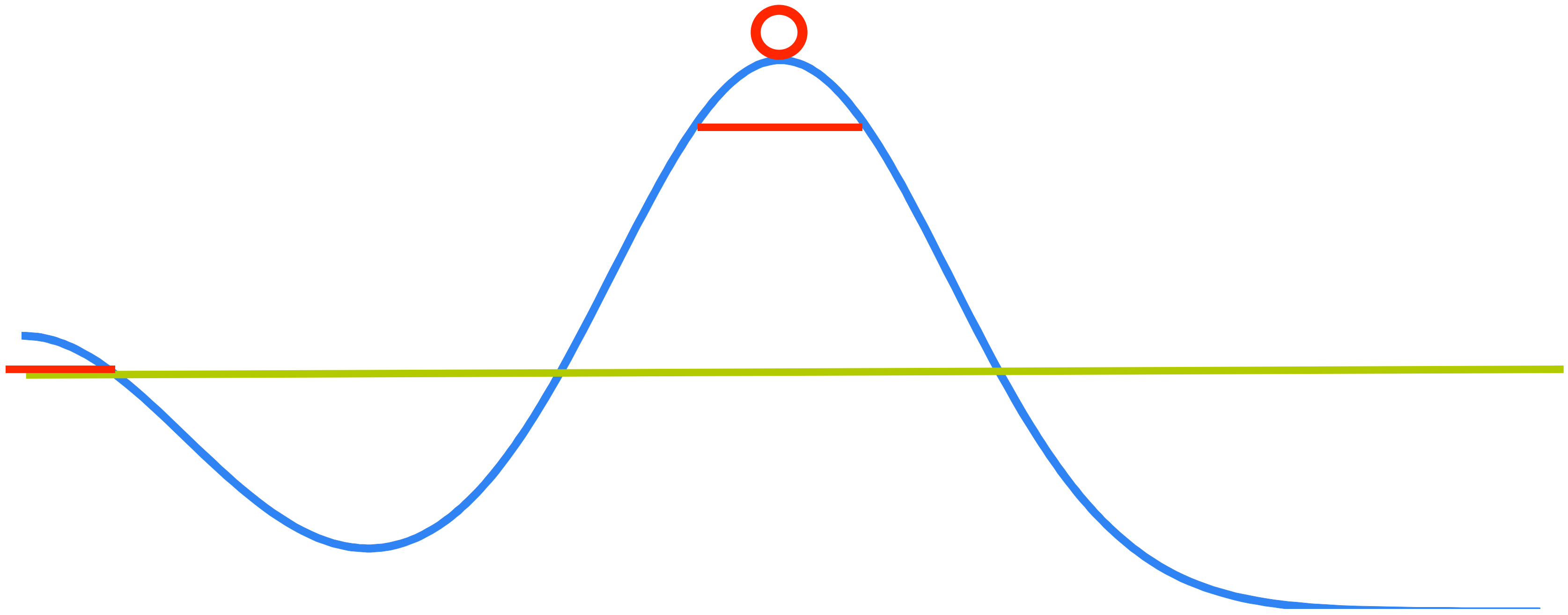


The property can come back to a robust stare: it is resilient

The property is robust to the perturbations

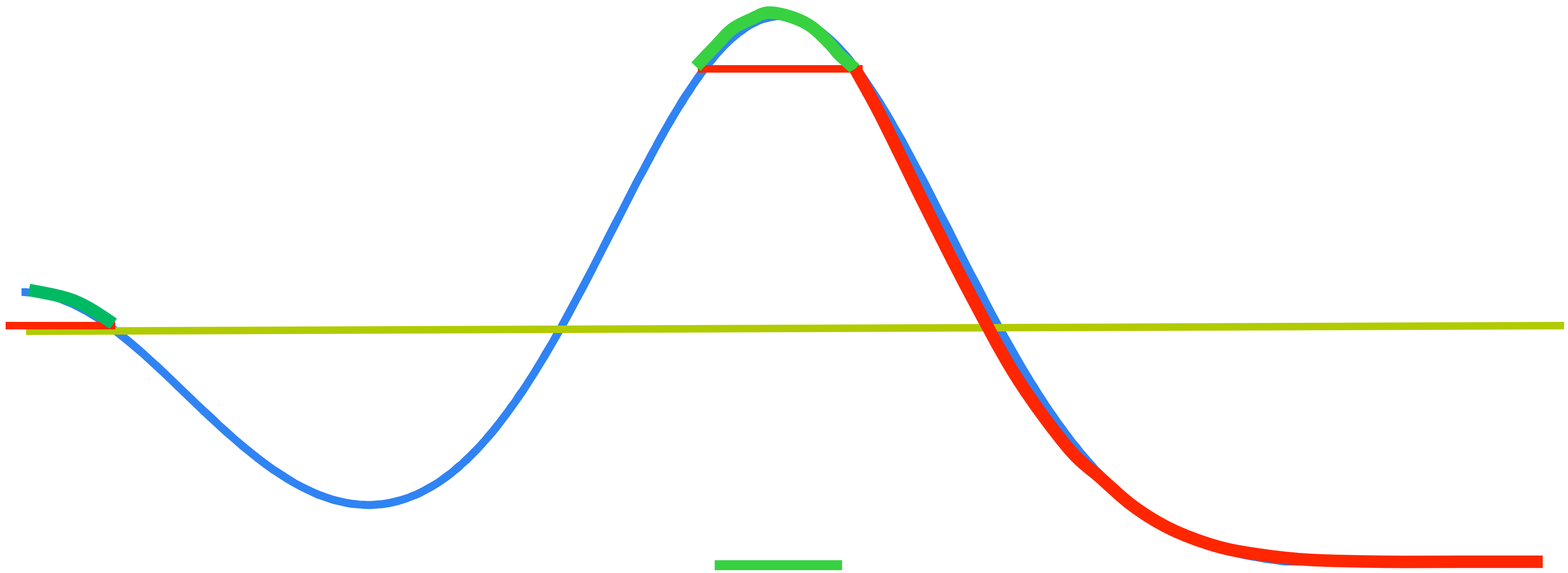
The property cannot be recovered : it is non resilient

Changing the property



The system gets the property back but in an other state
and it cannot get back to its initial point

A part of the space becomes resilient again



The property is kept (robust)

The property can be recovered and kept: it is resilient

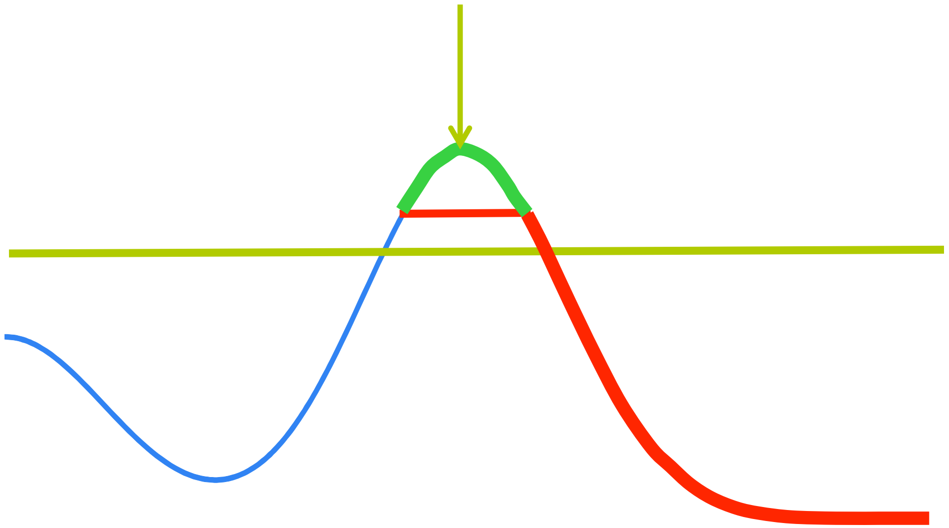
The property cannot be recovered : it is non resilient

Viability kernel (of a property)

- The states of the system from which it can keep the property forever (without perturbations)

=

- The post-perturbation states from which the property can be kept forever



Resilience basin (of a property)

- The states of the system from which the viability kernel can be reached (without perturbations)

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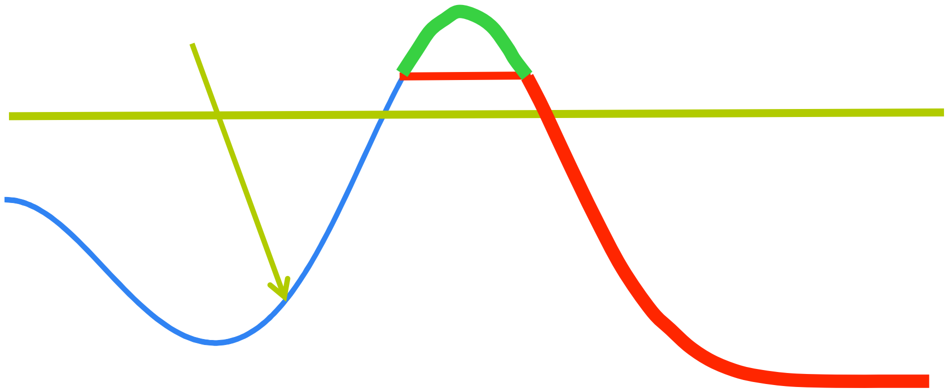
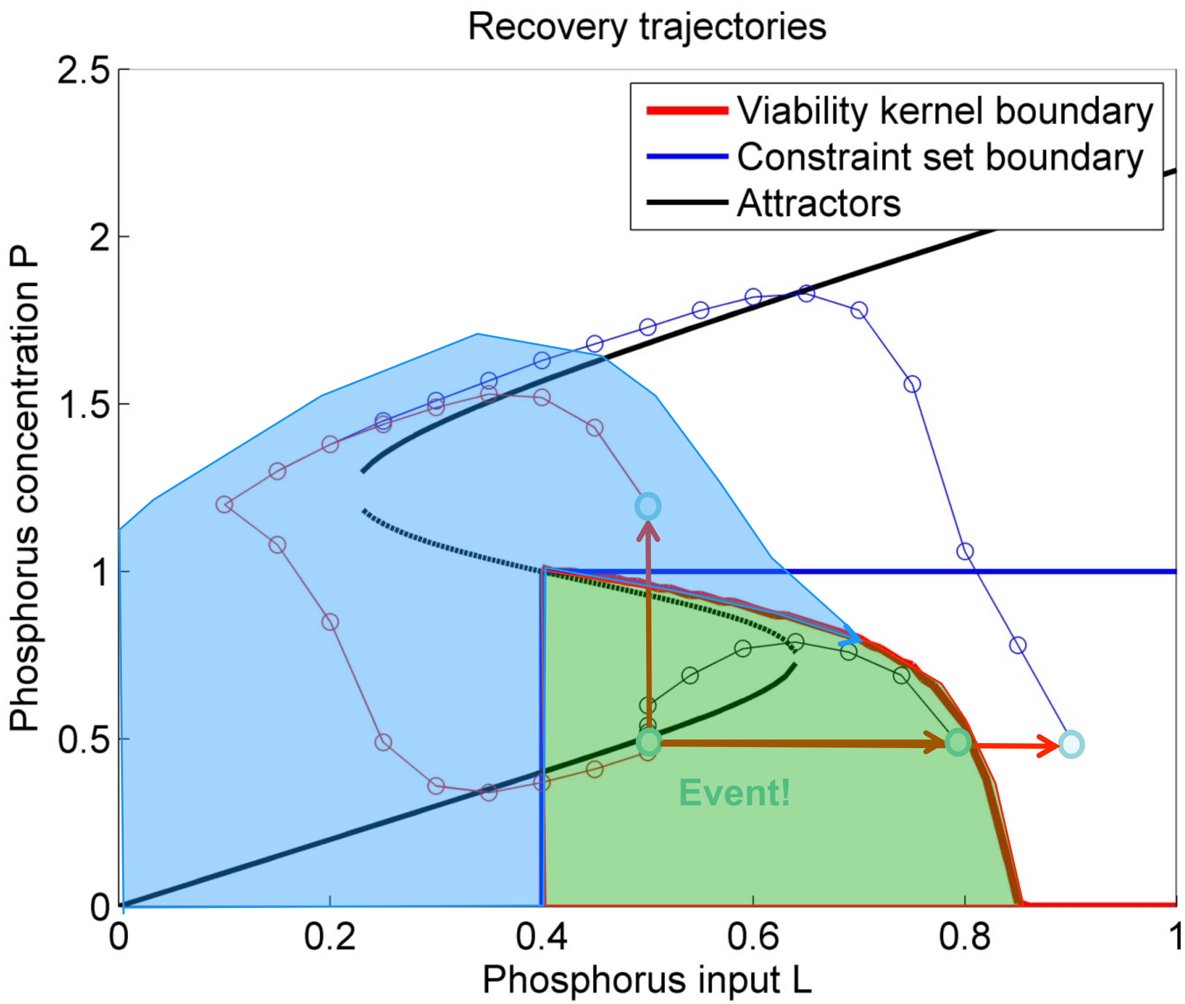
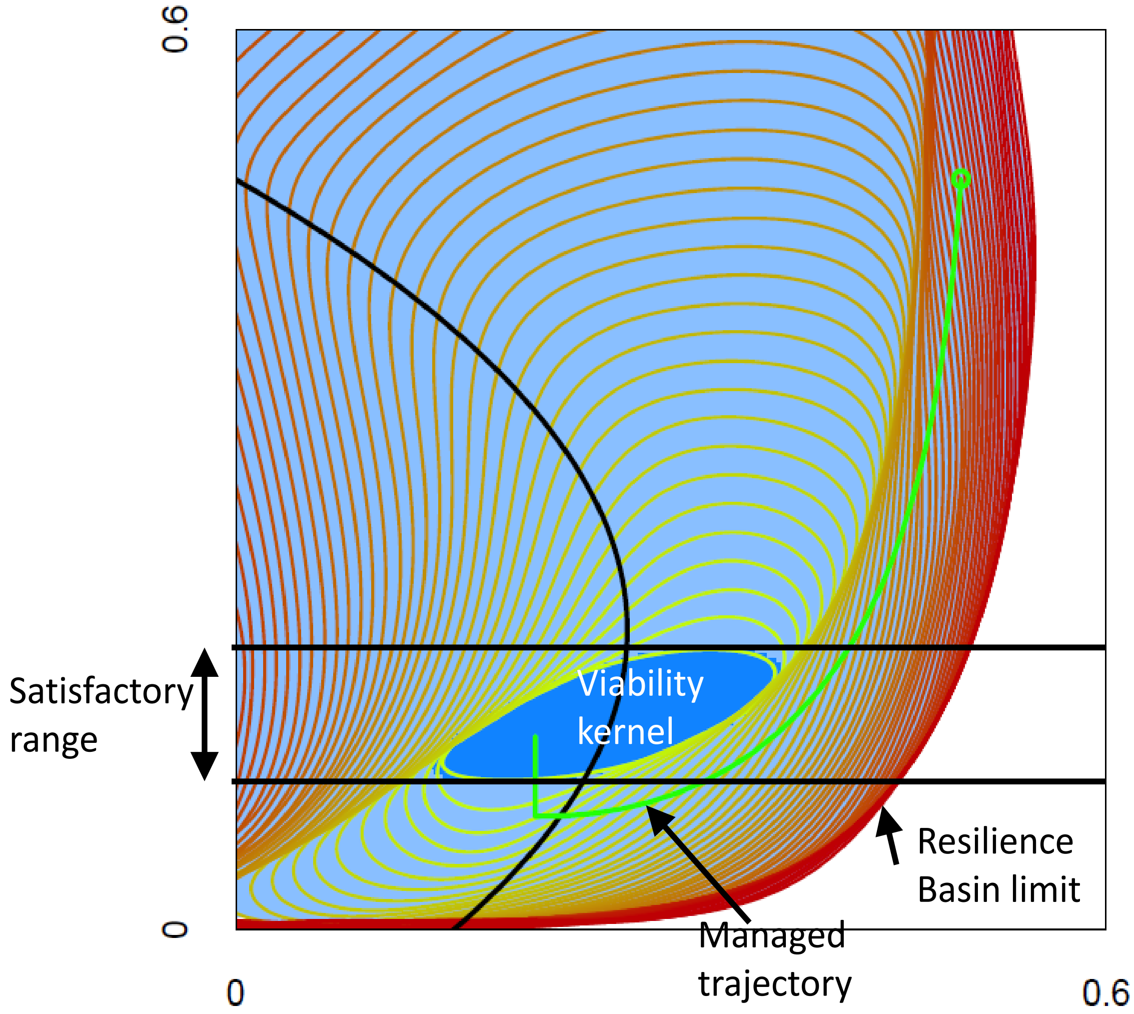
- The post-perturbation states from which the property recovered and kept forever (without perturbations)



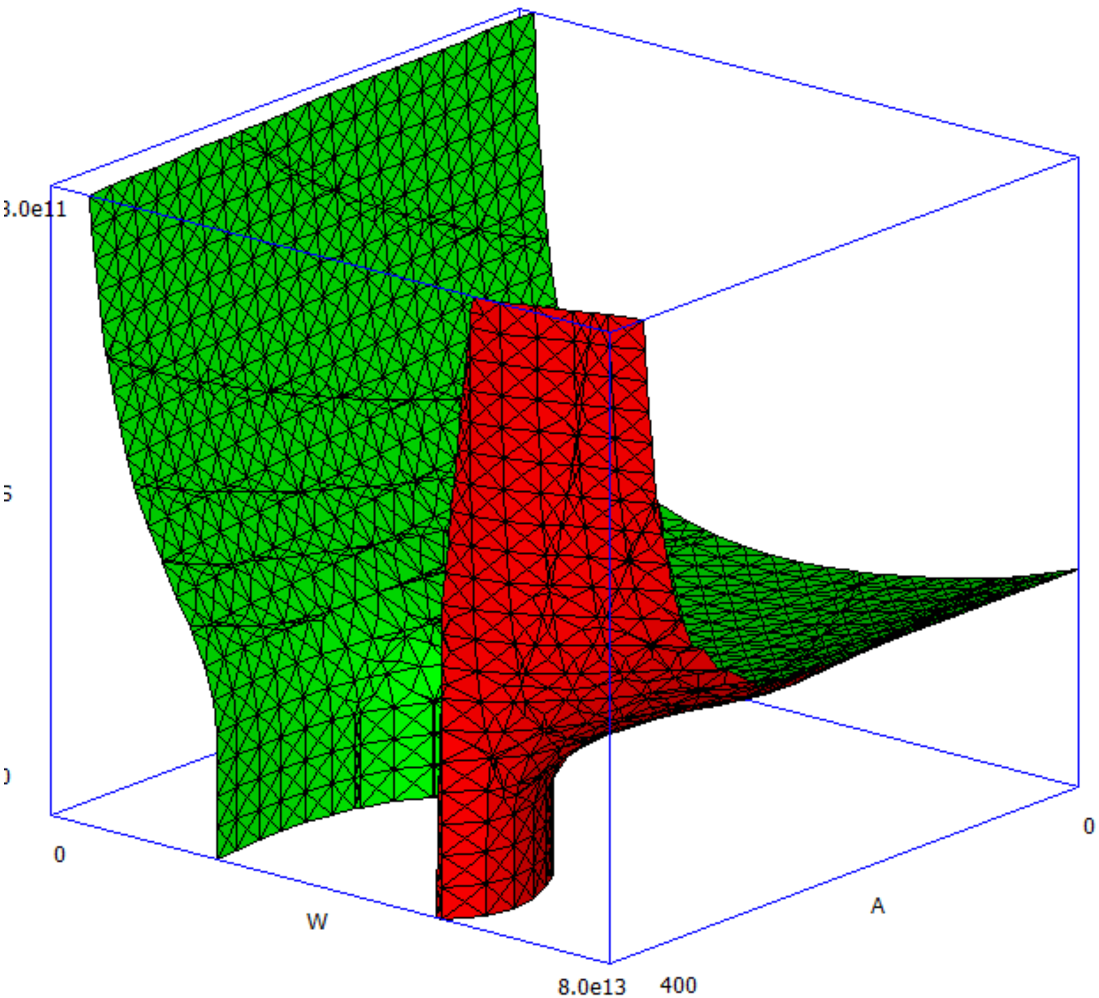
Example based on lake dynamics model



Example based on savannah dynamics model



Example C02 in atmoshpere (Viability kernel for 3D simple model)



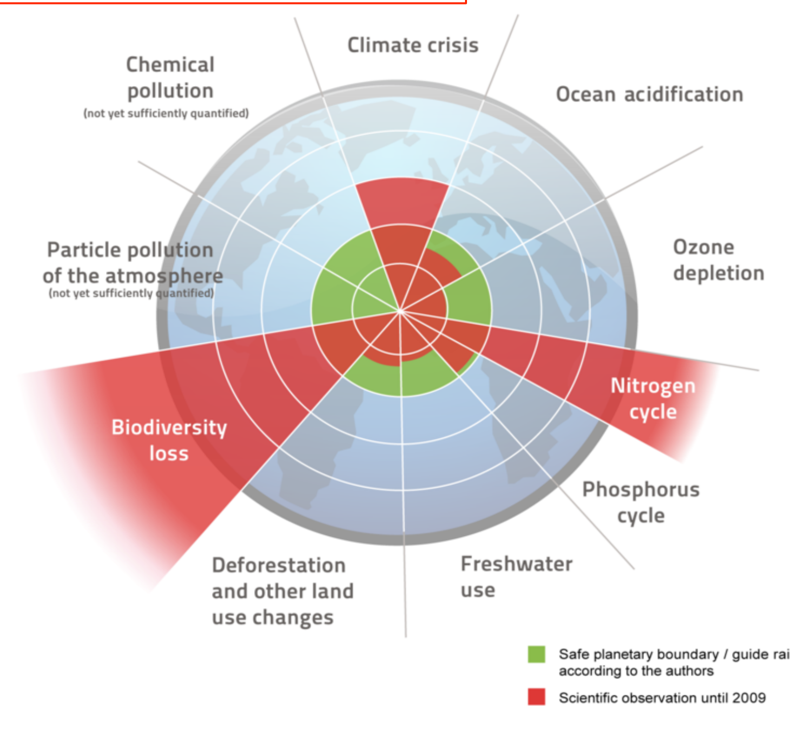
Different problems to be addressed

- Defining the property to be kept (political & scientific problem)
- Defining the envisaged actions on the system (political & scientific problem)
- Defining the state space of the model and the dynamics when applying the different actions over time (scientific problem: modelling)
- Determining the sequences of actions to apply in order to keep or recover the property (scientific problem: control theory)

Same distinctions in control theory approach, but

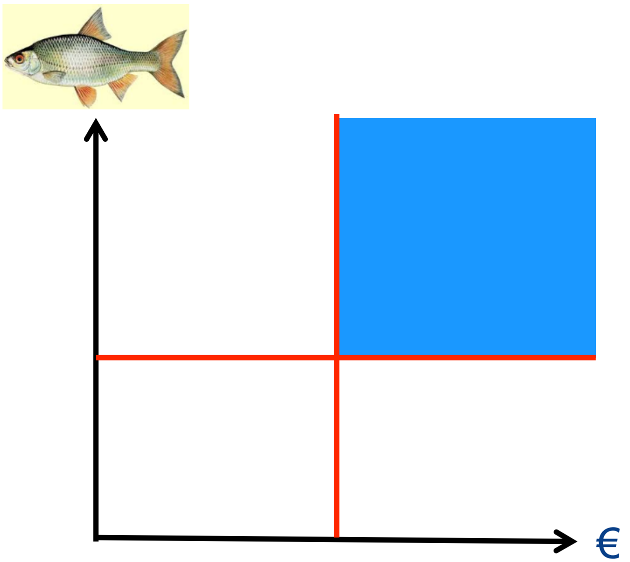
The property is defined by constraints in state space

- Maastrich criteria: (3% GDP deficit, 60% GDP debt). Political choice; Submitted to referendum in several member states in 1992.
- Planetary boundaries (Rockstöm et al): based on evaluation by scientists of risk of shift to dangerous regime. Are planetary boundaries the property to be kept or an estimation of the viability kernel ?



Multi-criteria without aggregation

- In usual control theory when the goal is multi-criteria, then need to aggregate using weights
- The property to be kept in viability approach can be defined as the intersection of different constraints e.g. economic and environmental



No discount rate over time

- In usual control theory the goal is to the sum of future gains:

$$G = \sum_{1}^{\infty} g(t)\, e^{-\delta t}$$

- Depending on this discount rate, it can be rational to over-exploit and destroy a resource
- There is no necessity of such a discount rate in viability theory: keeping the property can be as important in the future as it is now

Current developments

- Including uncertainties into the framework
- Connecting the framework with socio-ecological and coupled infrastructure systems
- Including the possibility of different control regimes (no control, standard and emergency for instance). See Heitzig et al. 2016