

Tree architecture and tree multi-modal response to wind

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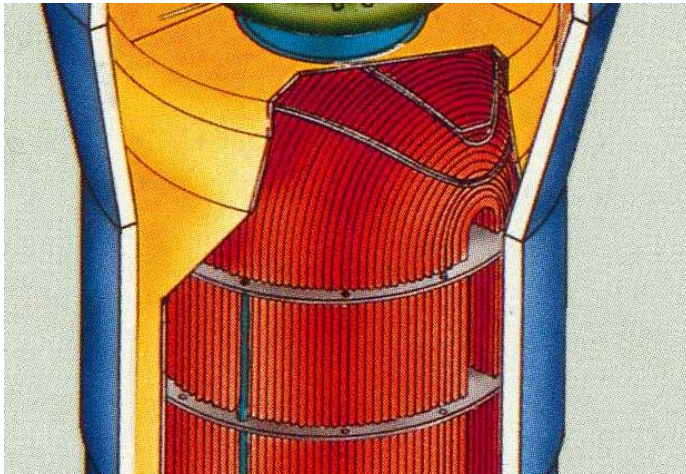
INRA, France

Ecole polytechnique, France

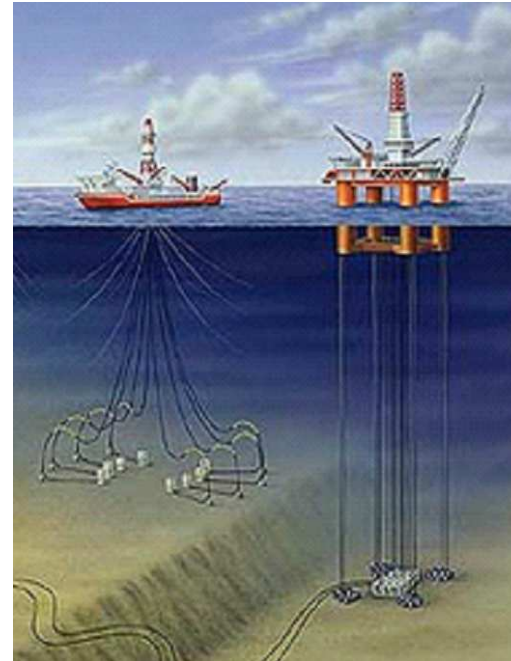
Focus on relation between numerical models and physical models

Point of view : Mechanical engineering

Flow-induced vibration in Nuclear engineering

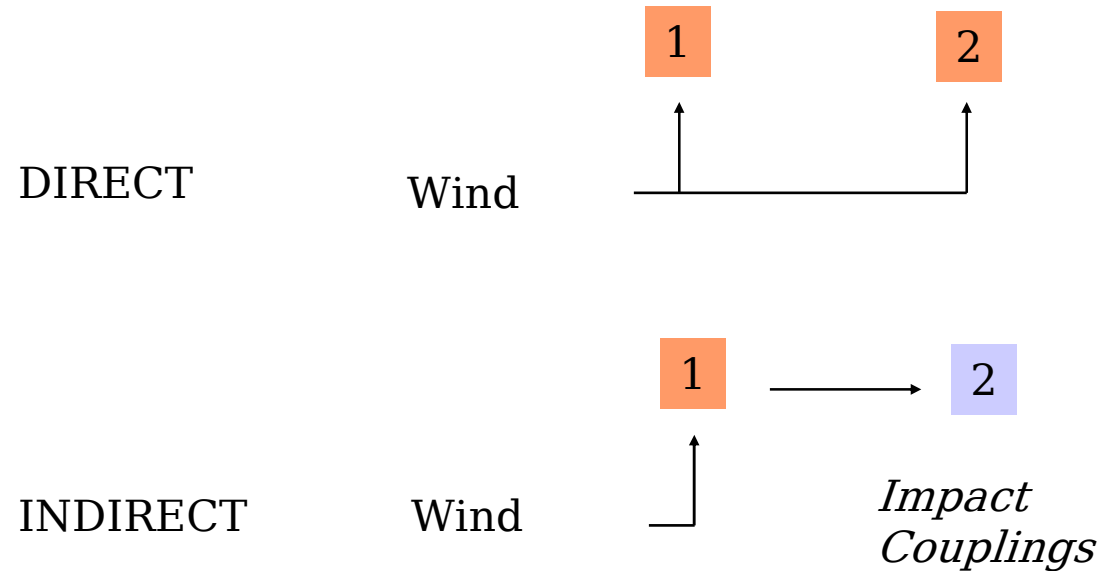


Flow-induced vibration in Petroleum engineering



Tree multimodal dynamics

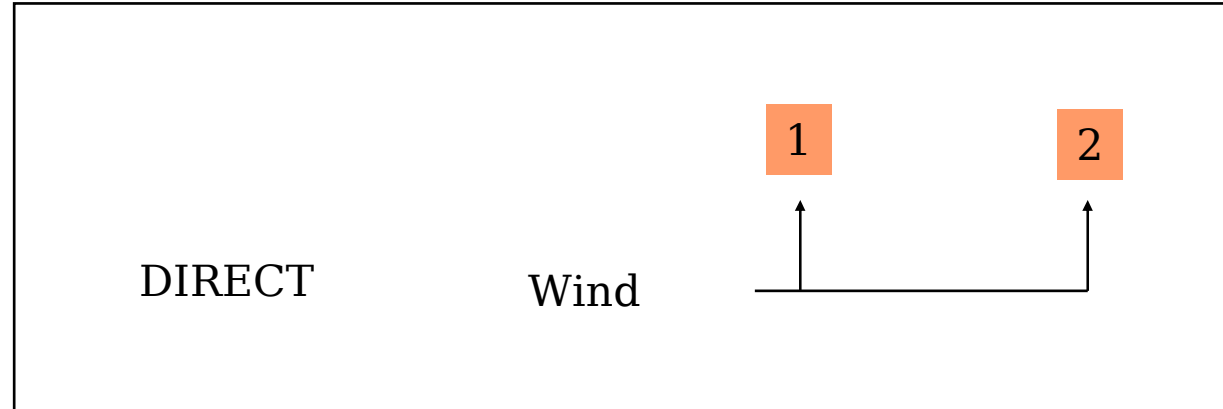
Causes



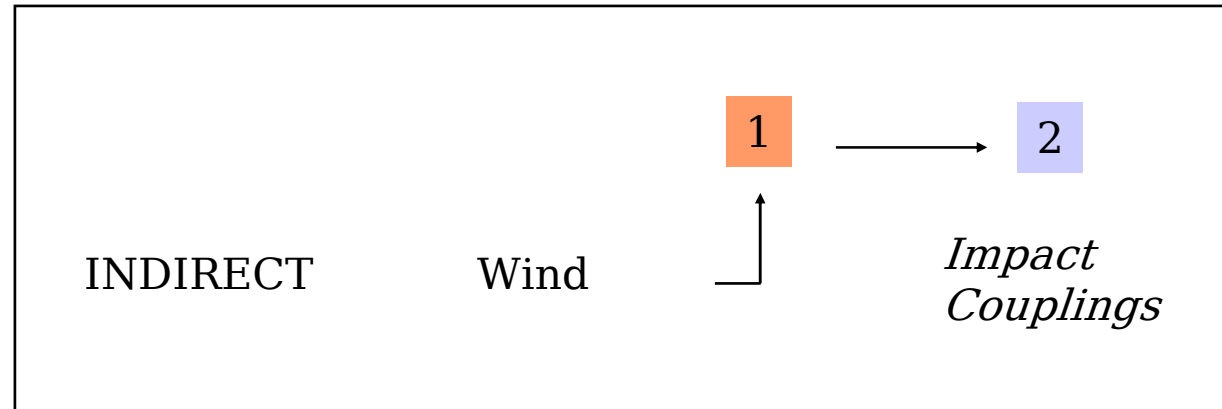
Moore & Maguire (2005) - Sellier et al. (2006)
James et al. (2006) - Spatz et al. (2006)

Consequences

COMPLEX
MOTION



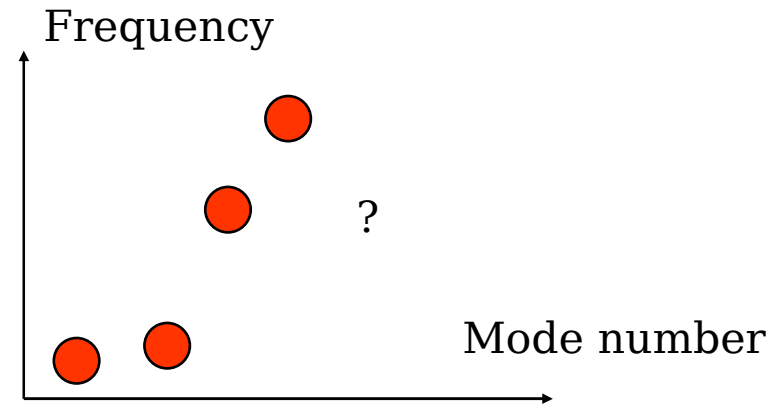
ENHANCED
DISSIPATION



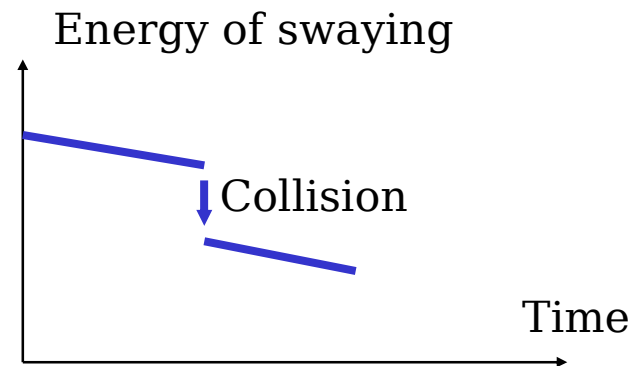
Depends on mode density

Modal organization

[Paper in Freiburg 09]



Damping by crown collision



Modal organization

1. Test
2. Numerical prediction of frequencies
3. Prediction using allometry

Related previous work

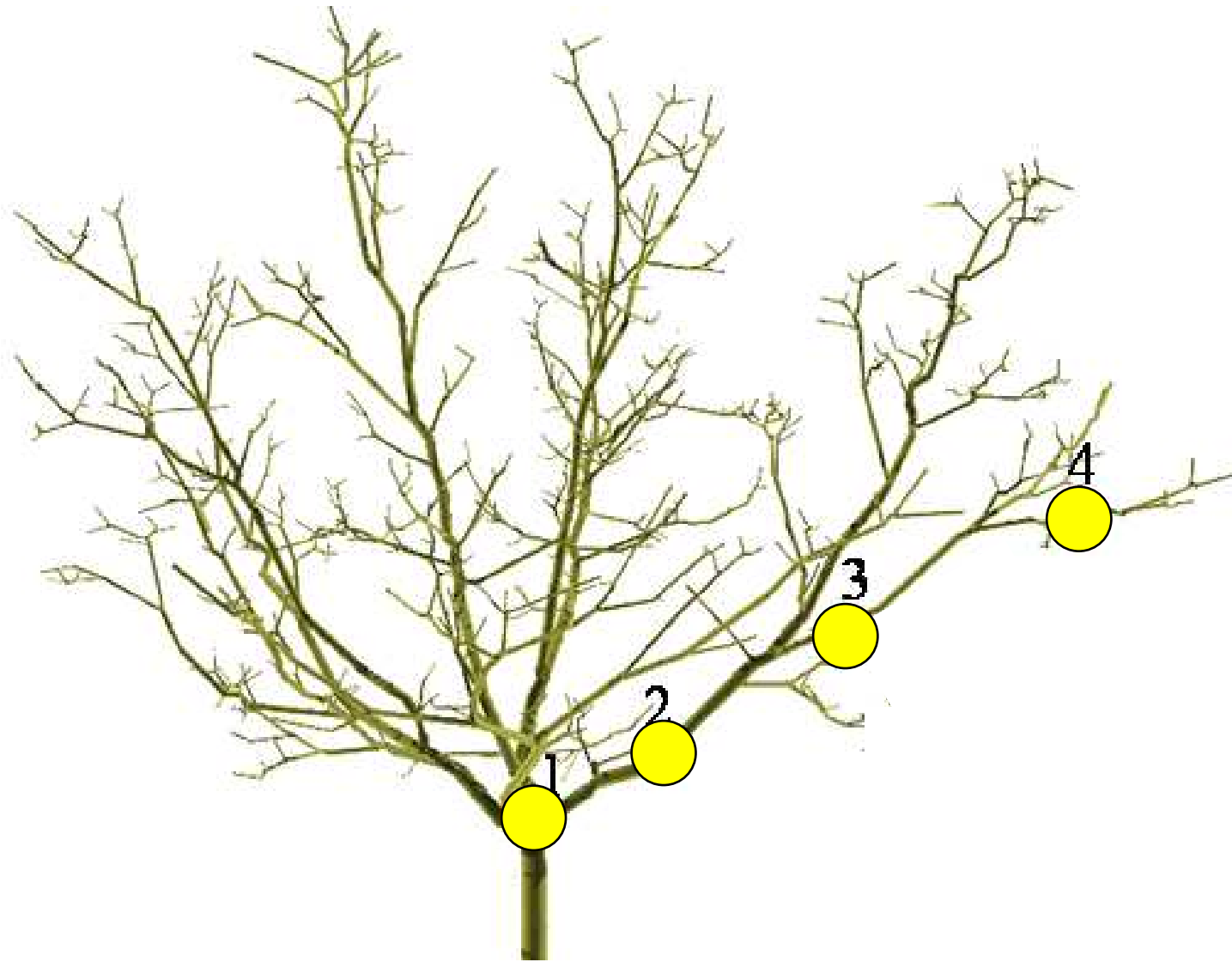
Rodriguez Moulia de Langre *Vancouver 2007* and *American Journal of Botany (2008)*

Walnut tree

4.2m

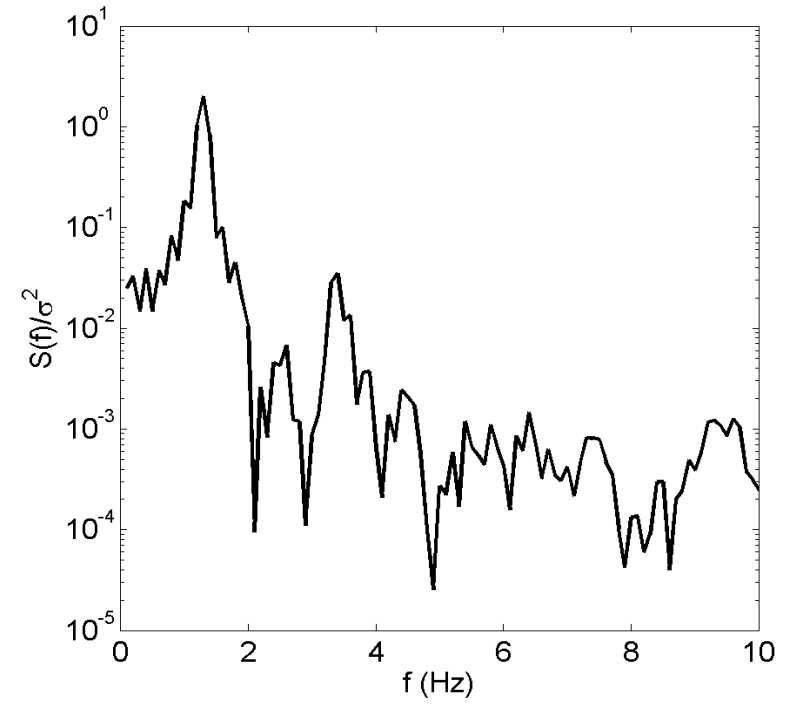
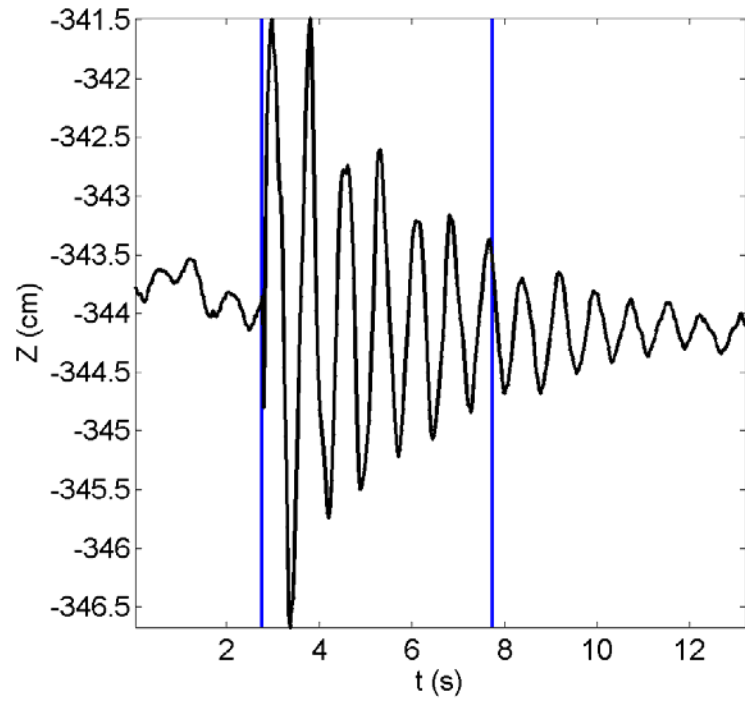
INRA-PIAF, Clermont-Ferrand

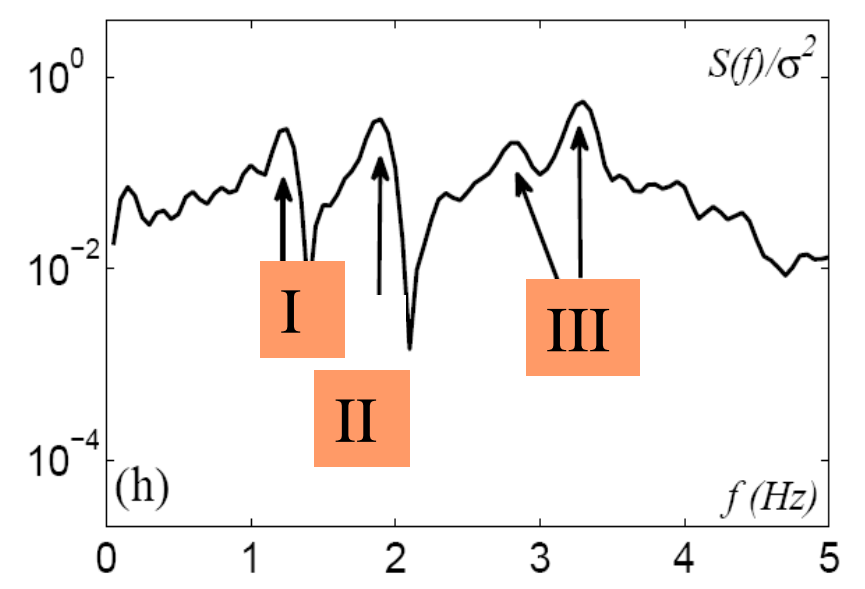
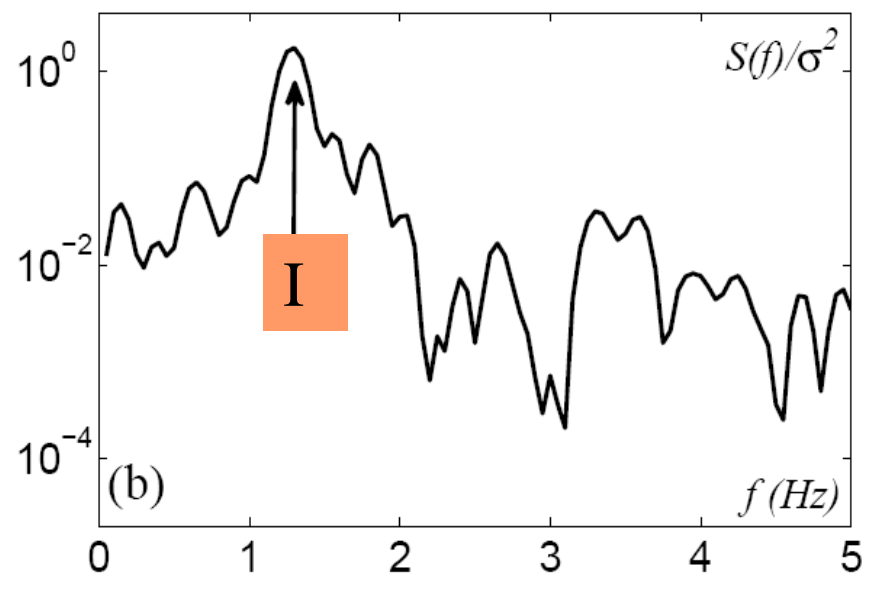
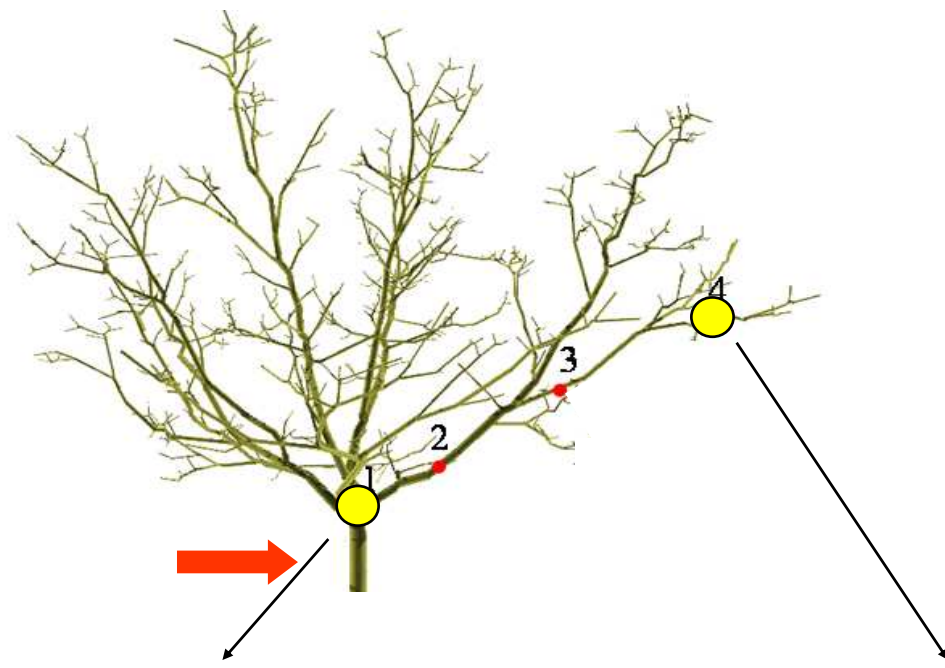






Hammer impact





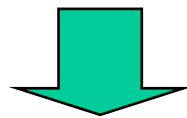
Finite element model

3D magnetic recording
(positions of segments, diameters)

Mesh generation
(2271 nodes)

Euler beam model
for transverse displacements

FEM modelling
(Cast3M)

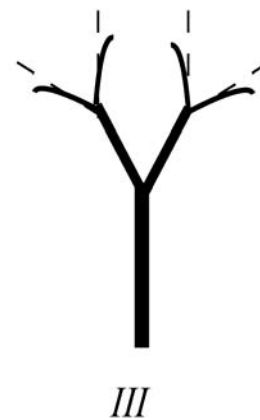
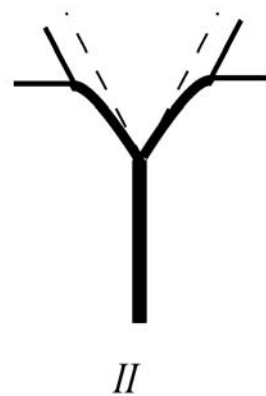
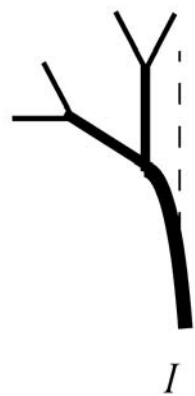
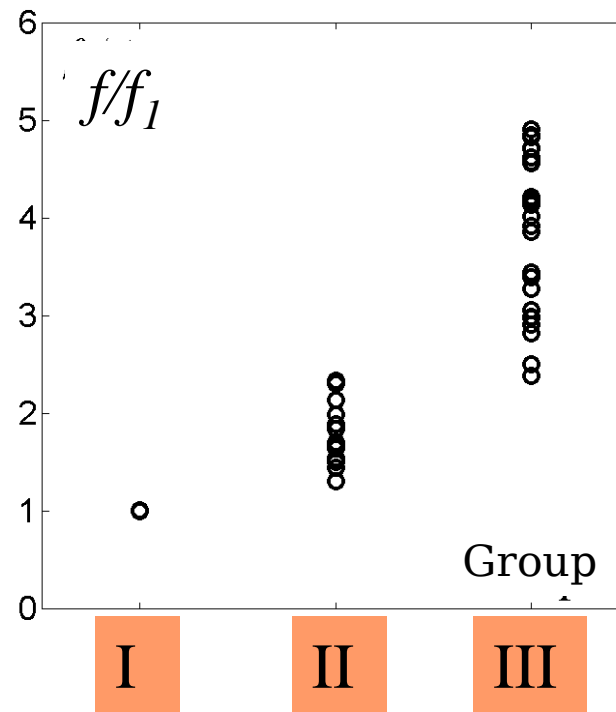
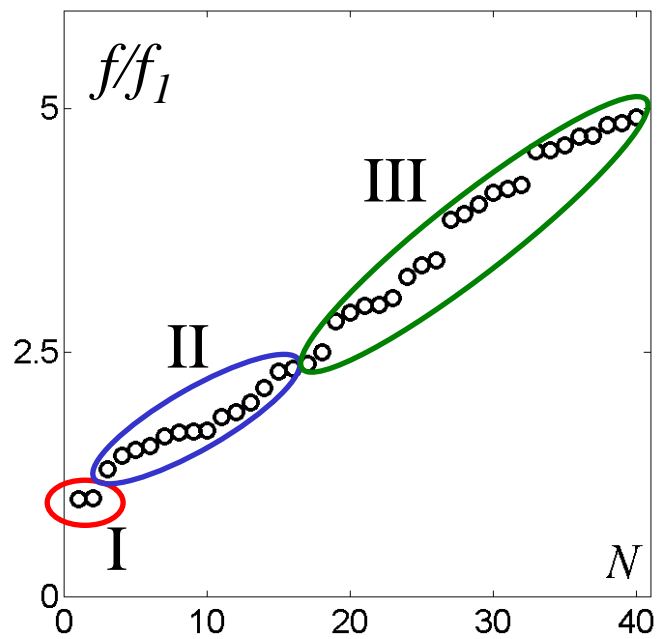


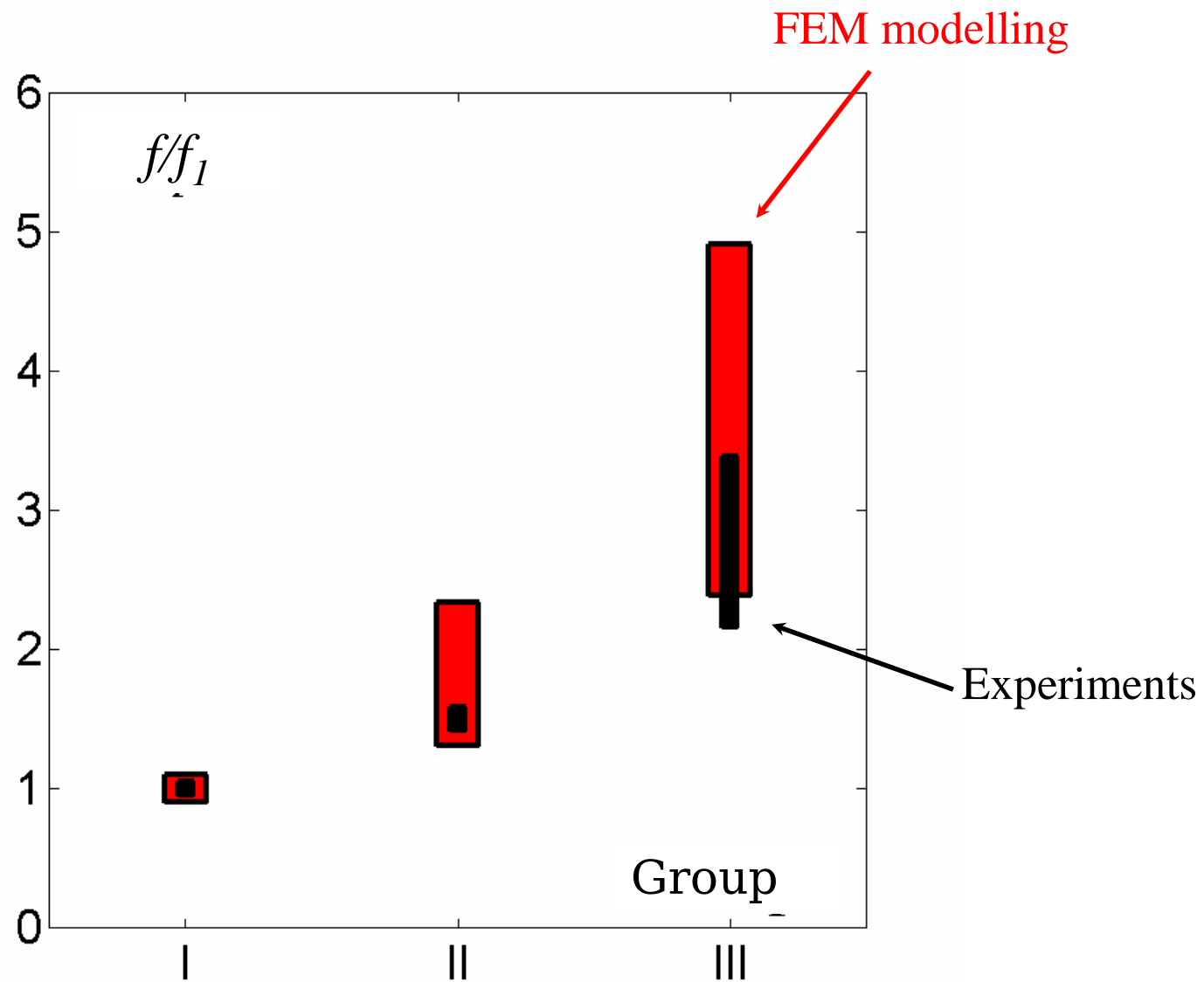
Modes





Frequencies



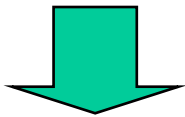


Scaling law using allometry

[see Rodriguez, Moulia, de Langre, AJB 2008]

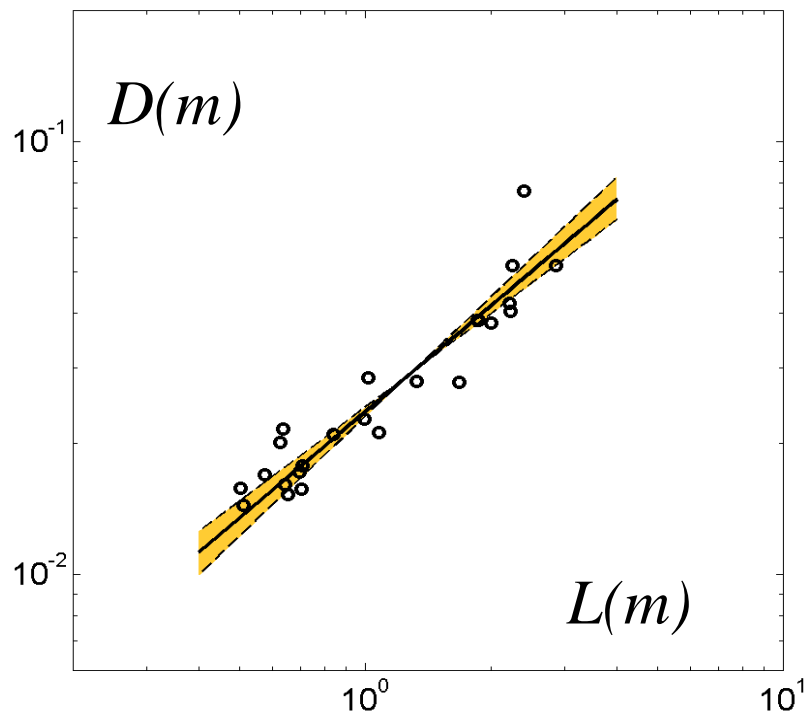
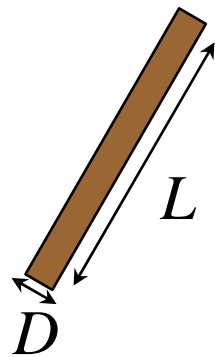
3D magnetic recording
(positions of segments, diameters)

Allometry



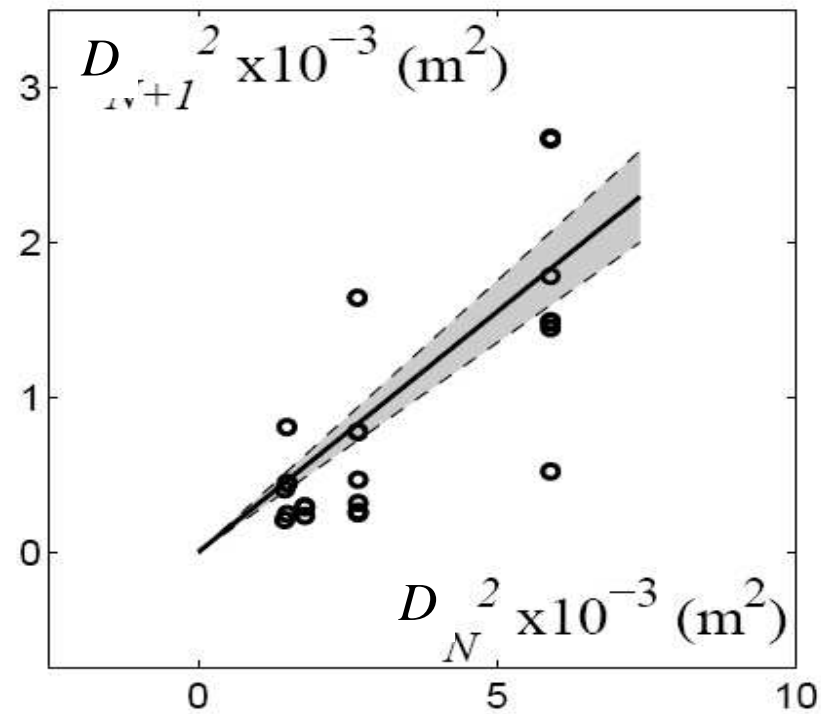
Scaling of frequencies





$$D \approx L^\beta$$

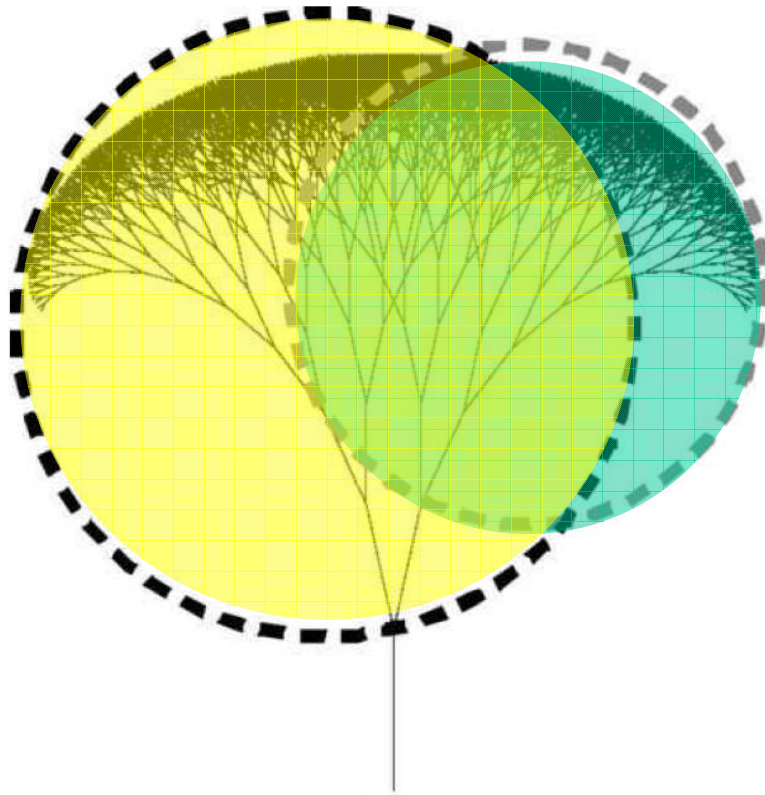
$$\beta = 0.82$$



$$D_{N+1}^2 = \lambda D_N^2$$

$$\lambda = 0.31$$

$$D \approx L^\beta$$



Subsystems

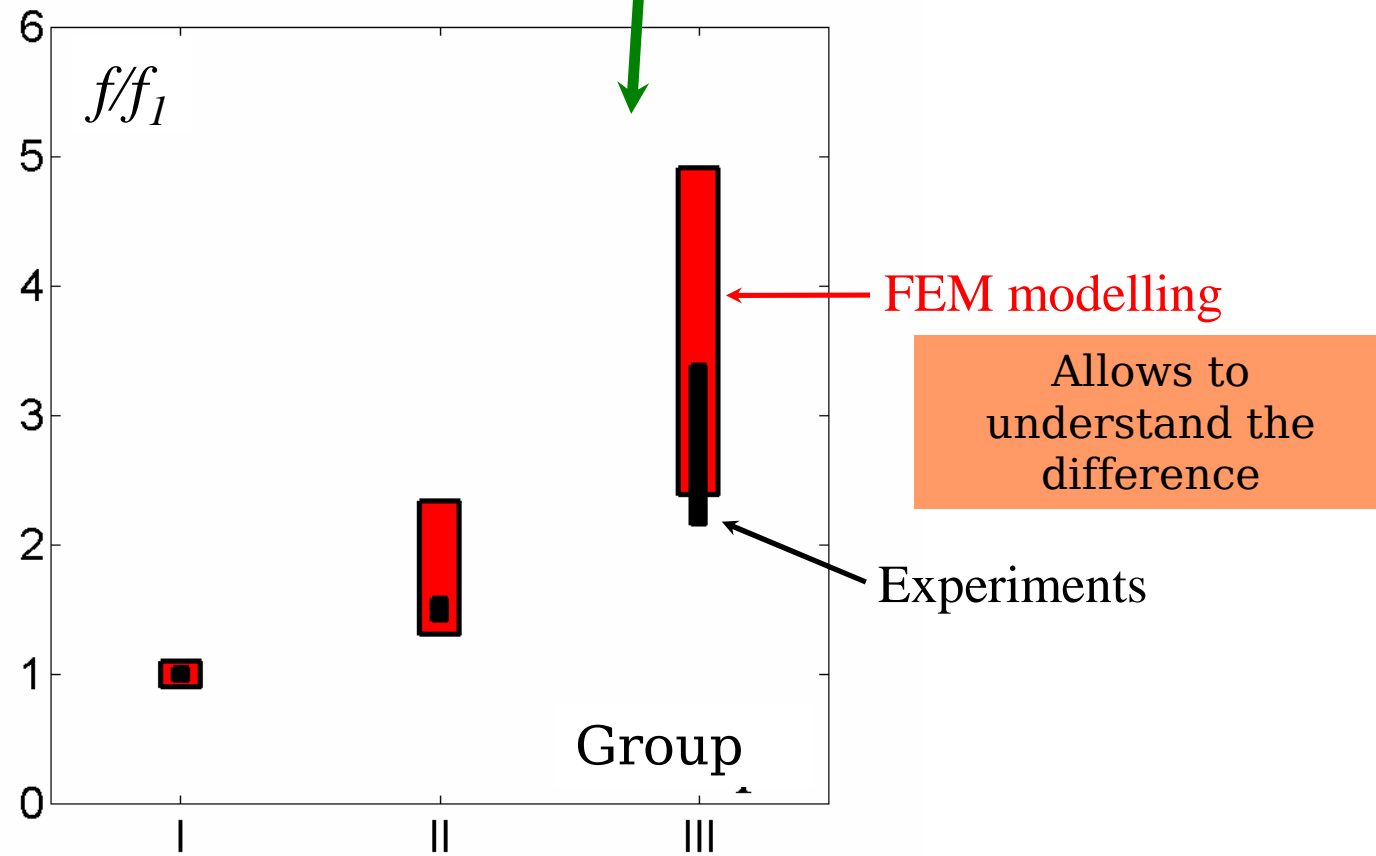
$$D_{N+1}^2 = \lambda D_N^2$$

$$f \approx DL^{-2}$$



$$\frac{f_{II}}{f_I} = \lambda^{(\beta-2)/2\beta}$$

$$\frac{f_N}{f_1} = \lambda^{(N-1)(\beta-2)/2\beta}$$



Response to wind using scaling laws

Modal frequency $f \approx DL^{-2}$

Modal damping $\xi \approx DL^{-2}$

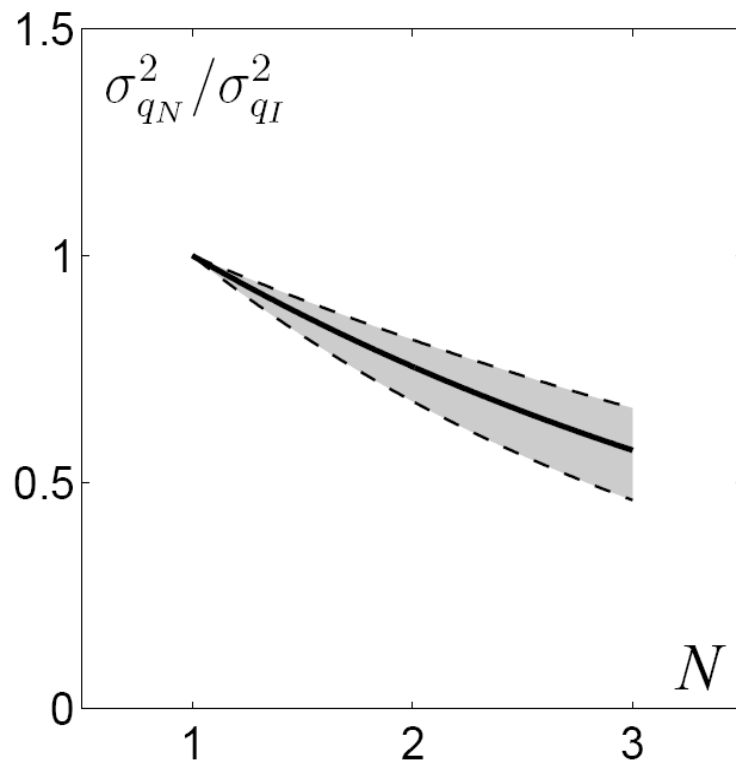
Velocity spectrum $S \approx f^{-5/3}$

Modal amplitudes $\sigma^2 \approx D^{-1/3} L^{2/3}$

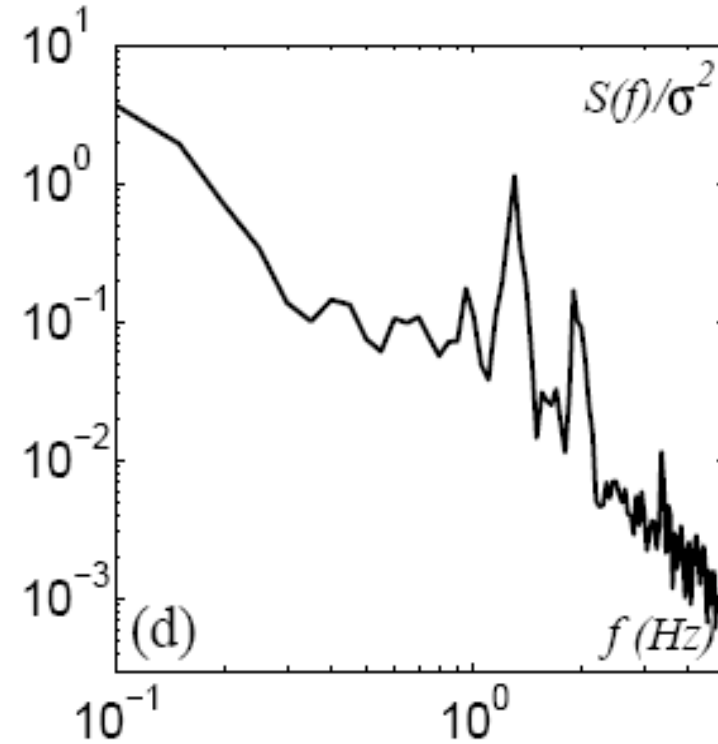
$$\frac{\sigma_{II}^2}{\sigma_I^2} = \lambda^{(2-\beta)/6\beta}$$

Comparative contribution of modal groups

Prediction by scaling



Experiment



Strong contribution
of all groups by direct excitation

Conclusions

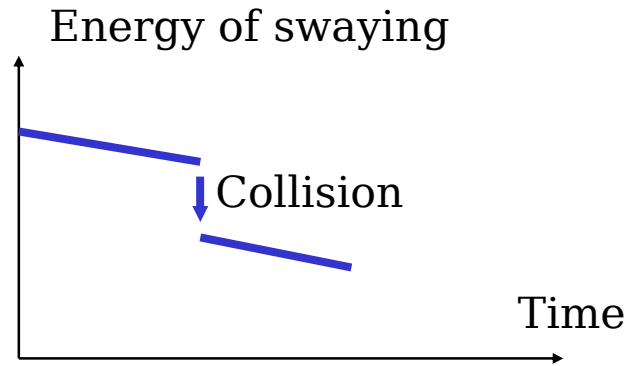
Detailed data on tree multimodal dynamics

Finite element modelling

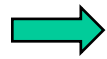
Scaling laws much simpler

Multimodal contributions to wind

Damping by impact

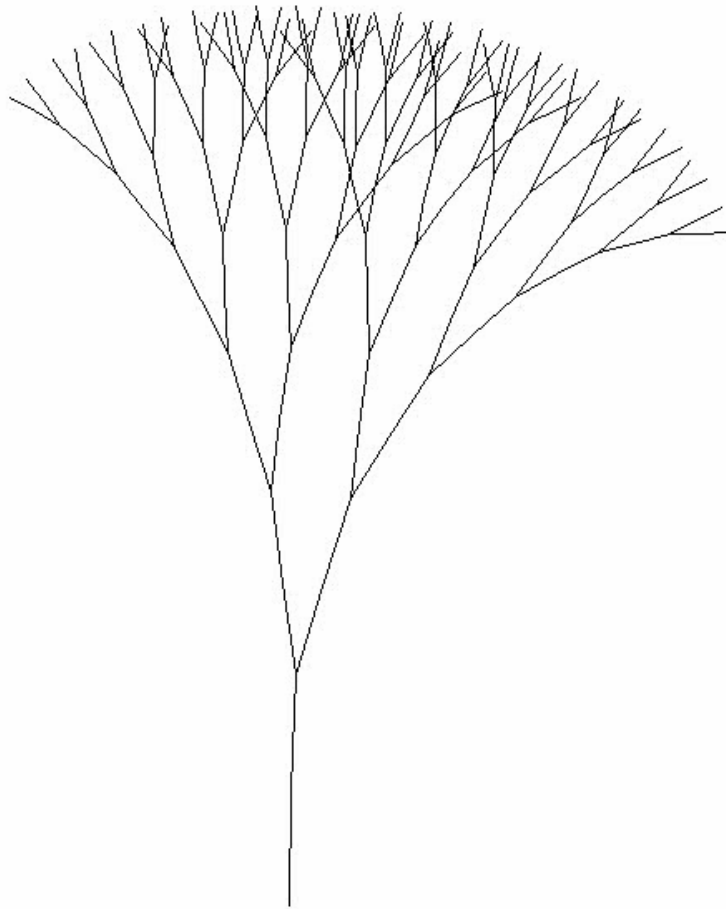


Effect of parameters ?

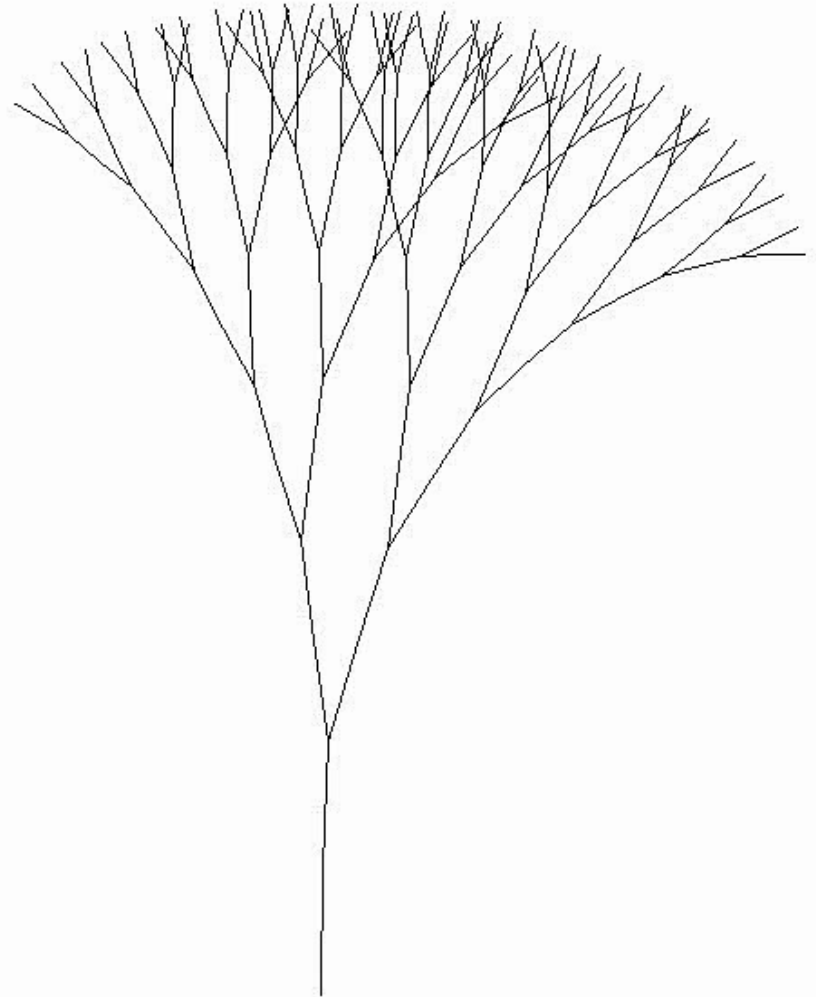


Numerical simulation needed

I

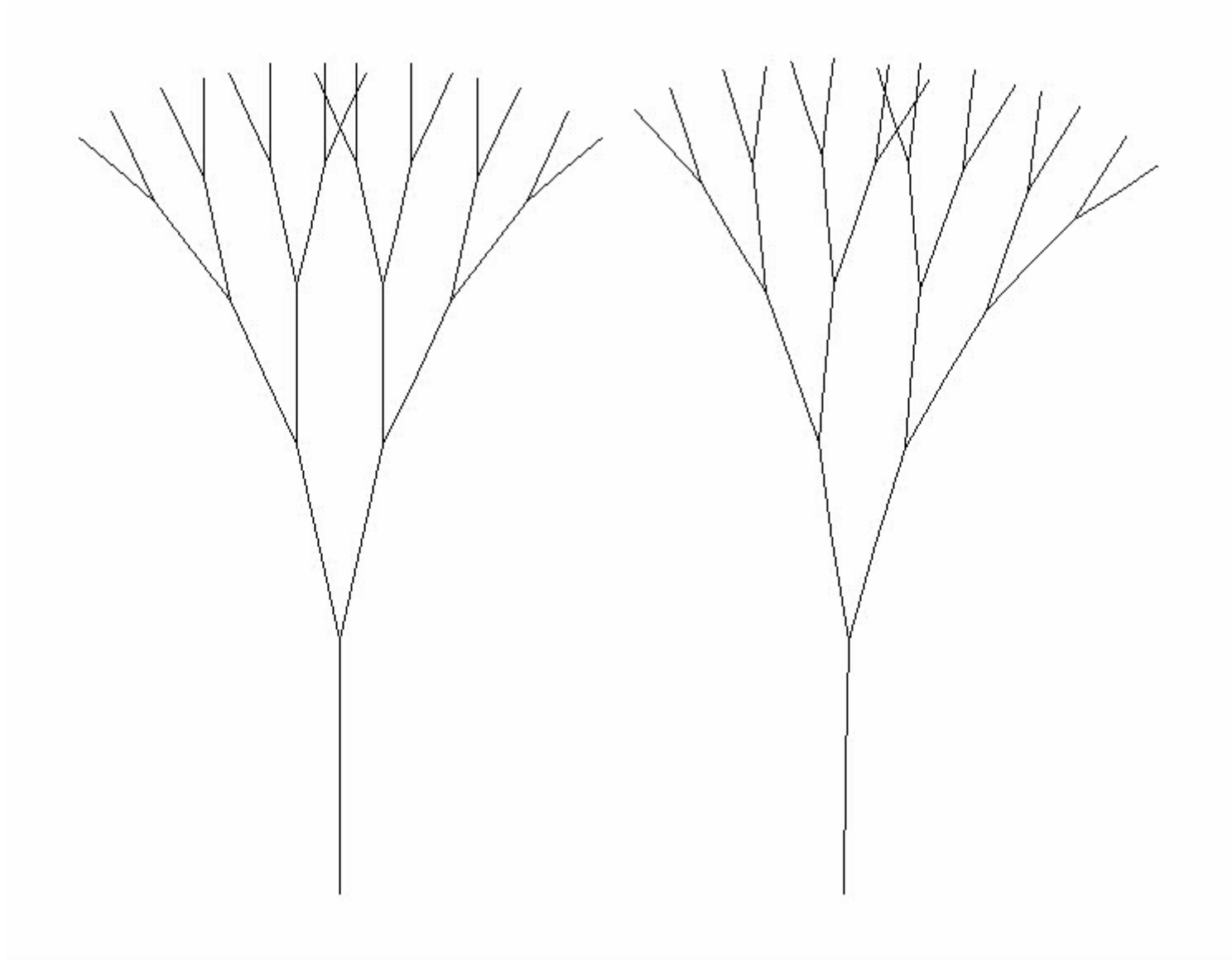


No impact



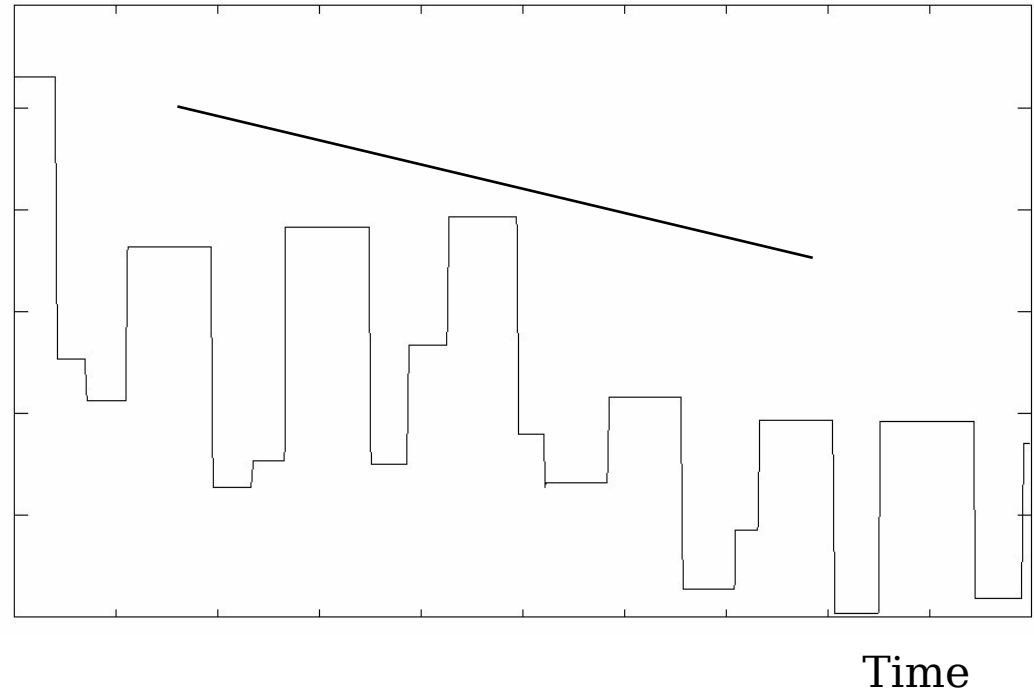
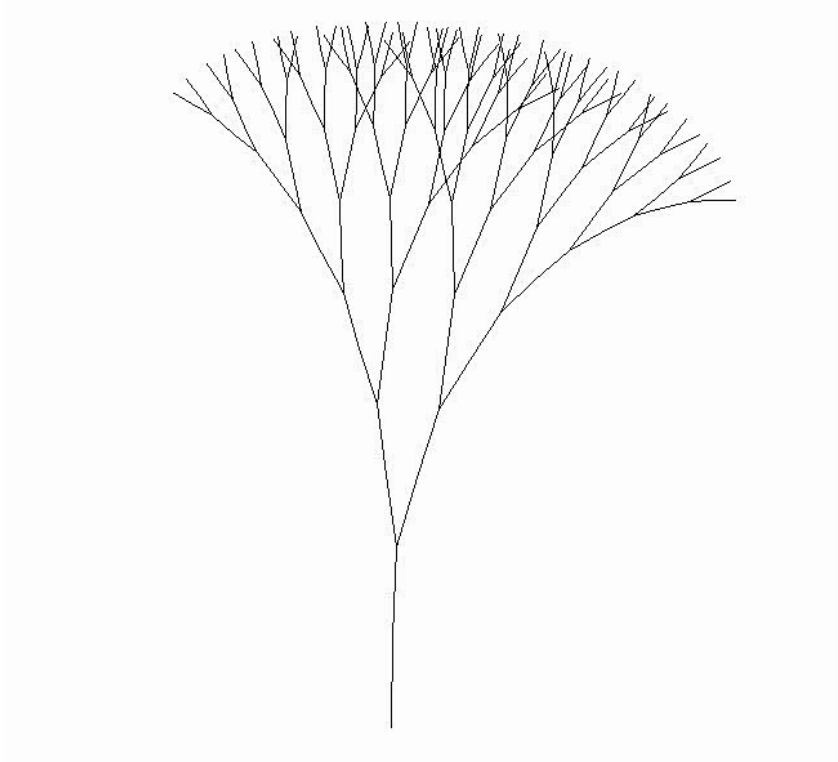
Impact condition on left

Collision

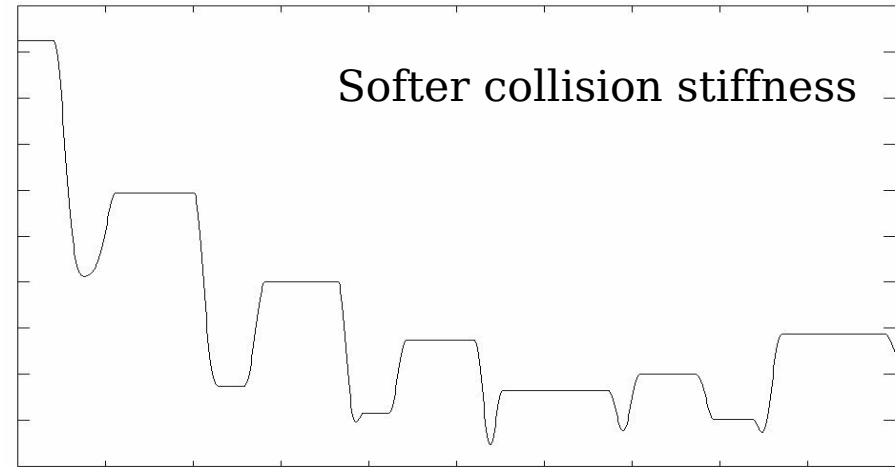
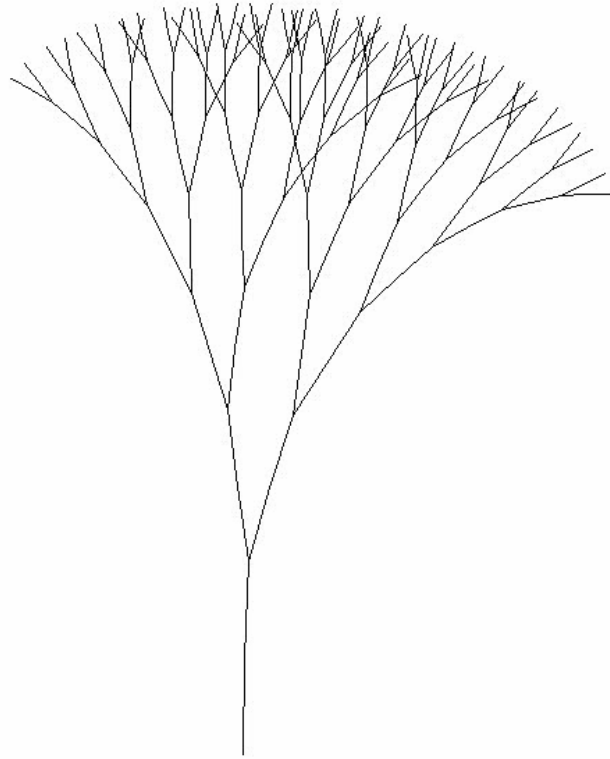


Energetics

Energy of swaying (mode 1)



Energy of swaying (mode 1)



Time

Use of Finite element code Cast3M

Linear and Non-linear statics and dynamics

Freeware for academic purpose

Now used in all 4 groups of the French program on wind and trees



Common language

Different use in each group

Conclusions

Numerical tool to help understand physical process

Then build simpler model to incorporate in higher level tool

Avoid increasing complexity

Common tools allows common language

This is not standardisation