Natural sonic crystal absorber constituted of Aegagropilae fiber network

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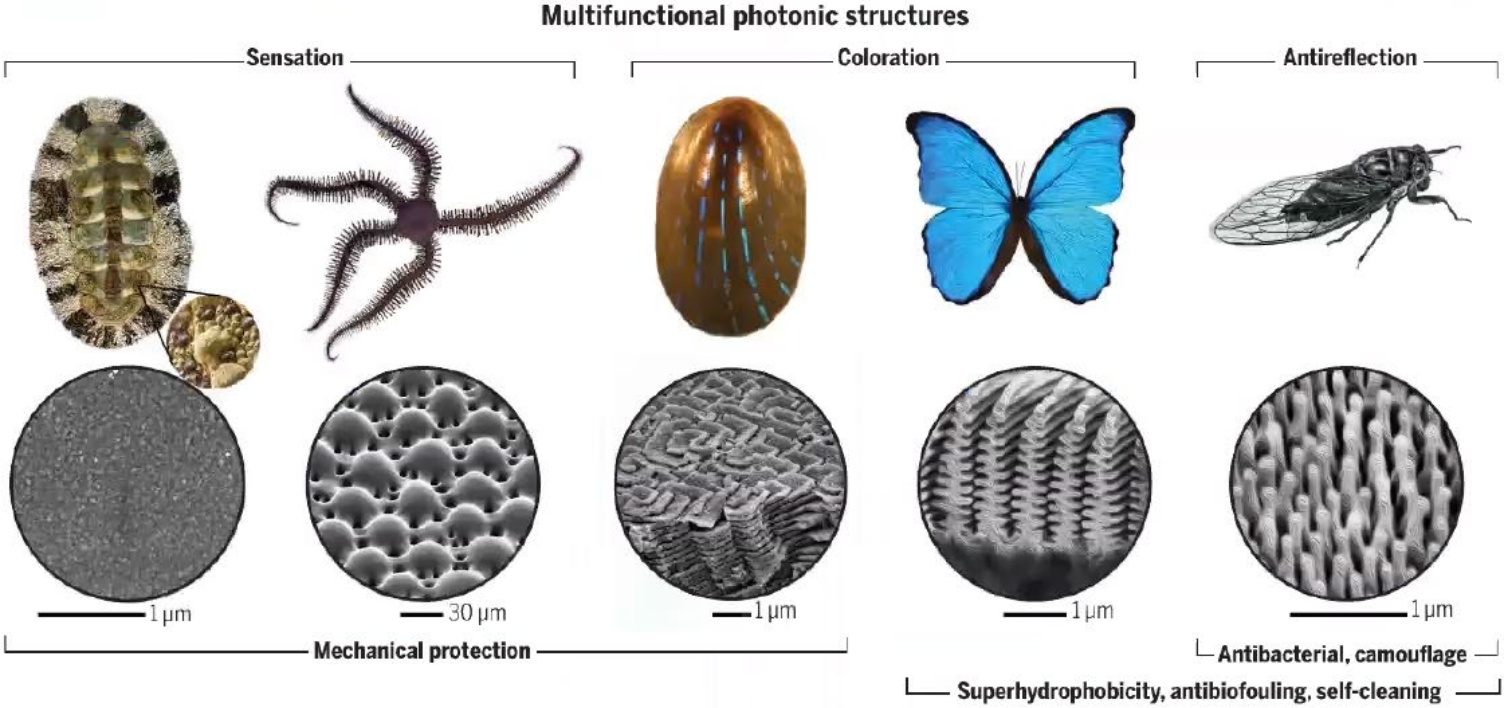


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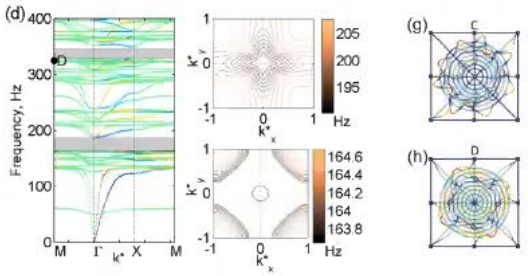
Symposium on Acoustics of Poro-Elastic Materials - 6th triennial
Remotely from Le Mans, 30th March 2021

Motivation

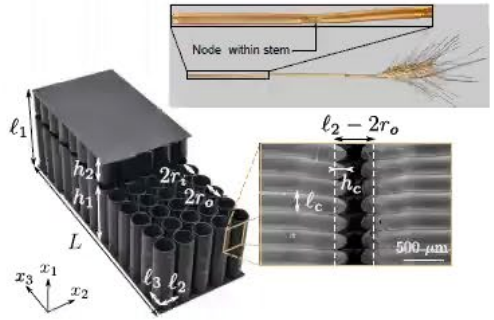
- Structured materials exist in Nature (Science, 362, 543-547, 2018;Nature, 424, 852-855, 2003)



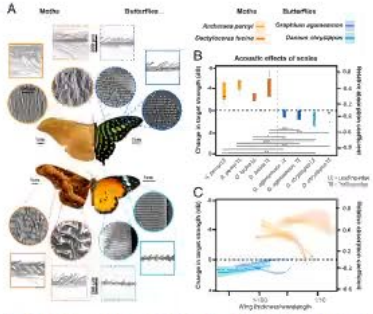
- In acoustics/elasticity structures are mostly bioinspired



Appl. Phys. Lett., 109, 071905, 2016



Sci. Rep., 9, 8496, 2019



PNAS, 117, 31134-31141, 2020

What about Aegagropilae, i.e., Posidonia balls?

- Endemic plant of Mediterranean Sea and southern coast of Australia



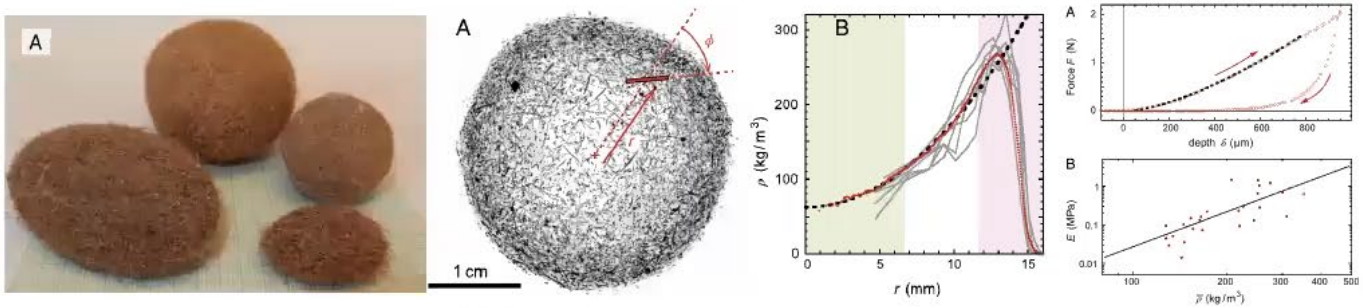
http://posimed.org/_movil/que-es-la-posidonia.html

https://en.wikipedia.org/wiki/Posidonia_oceanica



- Fully natural formation process of Aegagropilae in turbulent flow

(Aquatic Botany 6, 407, 1979; Phys. Rev. Lett. 112, 074501, 2014;Exp Fluids 57, 117, 2016)

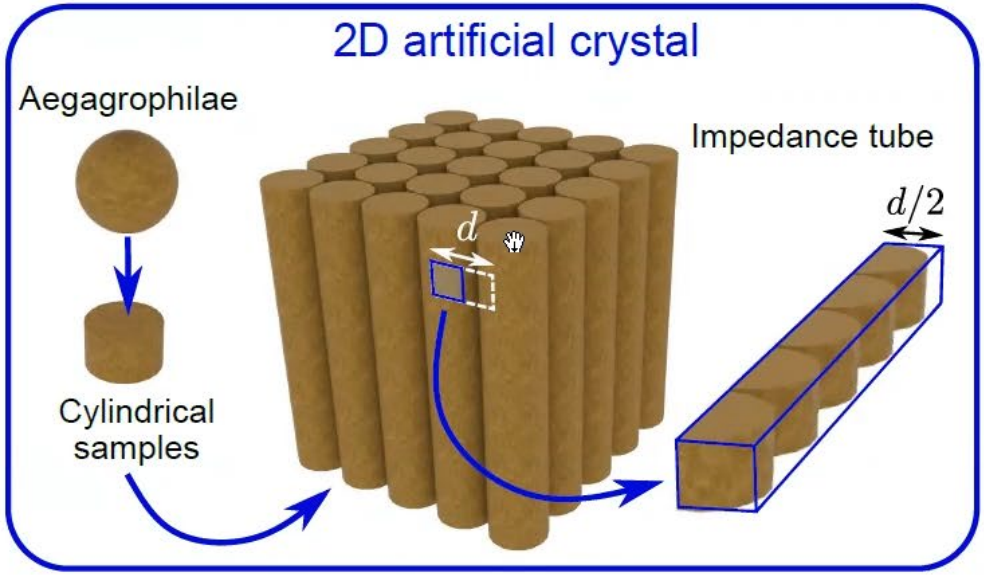


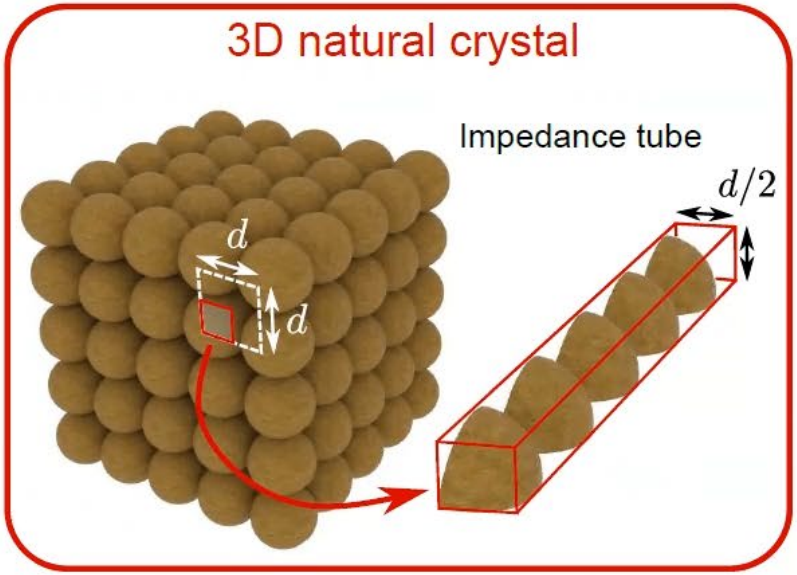
PNAS, 114 (18), 4607-4612, 2017

- Can we assess the Aegagropilae fiber network by acoustic means?
- Can we make use of Aegagropilae to design natural structures?

Description of the configurations



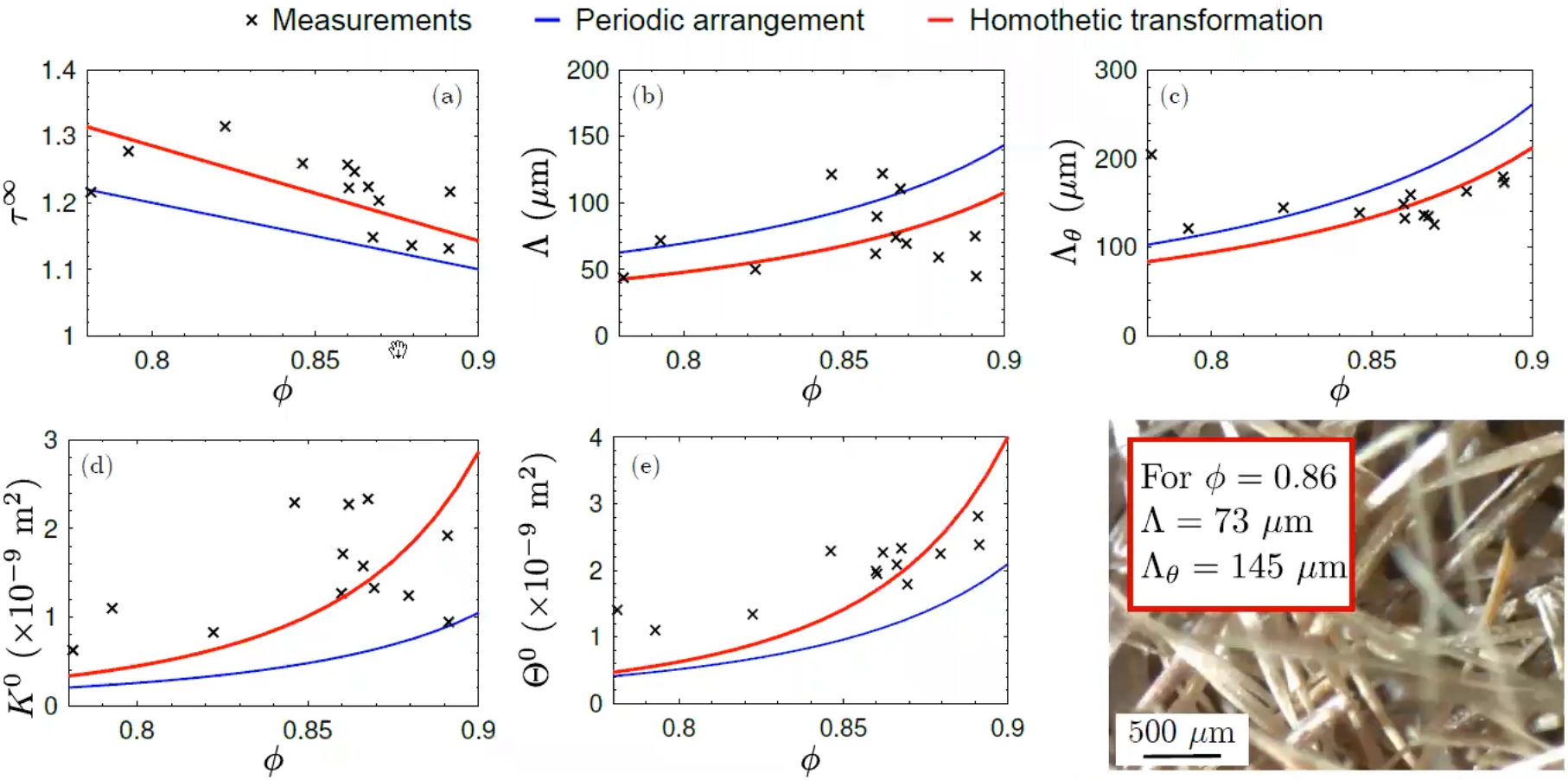




Scatterers are soft, lossy, and dispersive!

Characterization and analysis of the micro-structure

Johnson-Lafarge model is used (J. Fluid Mech., 1987; J. Acoust. Soc. Am., 1997).

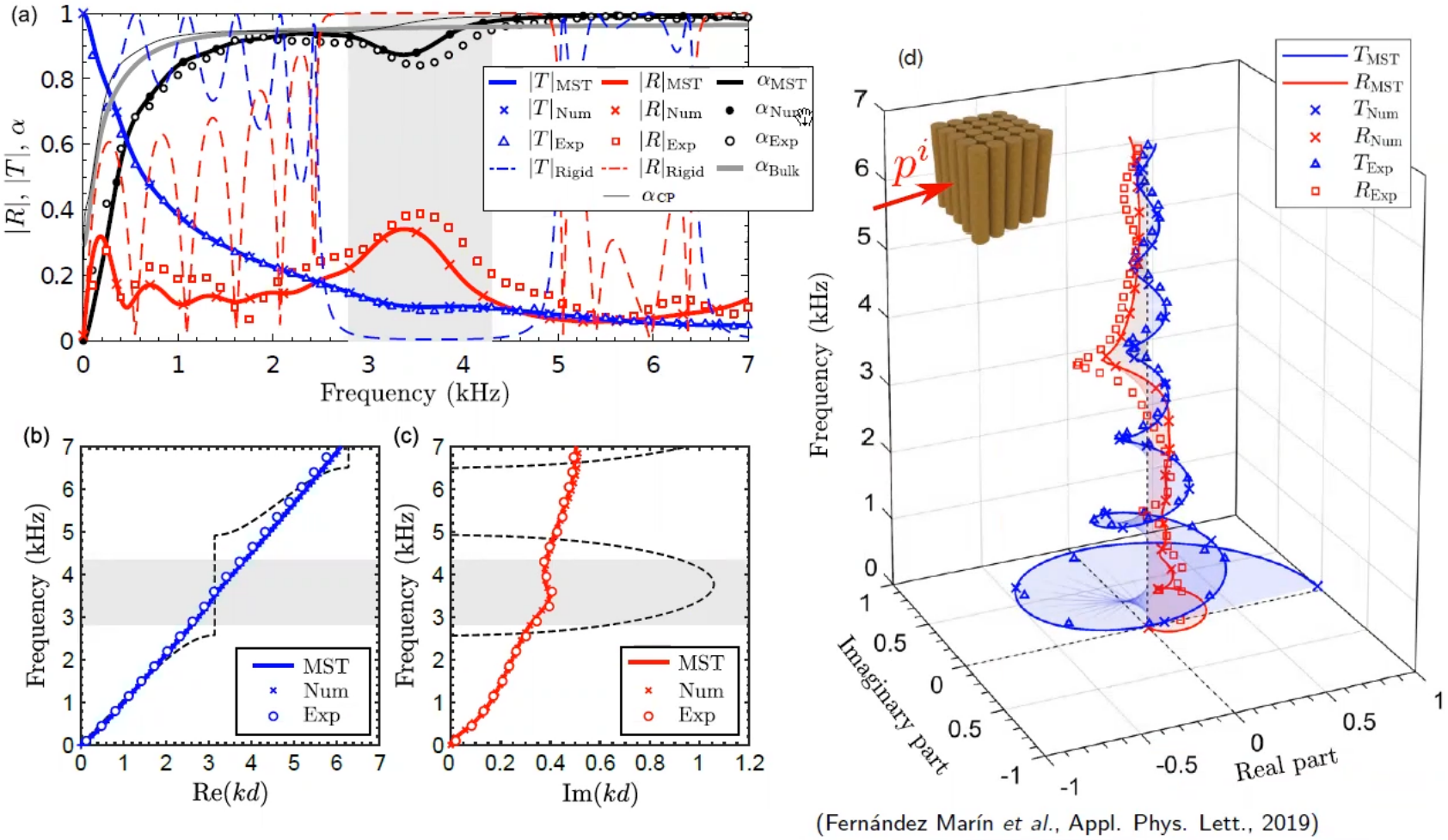


(Niskannen *et al.*, J. Acoust. Soc. Am., 142, 2407, 2017)

- Efficient tool to assess the micro-sctructure of Aegagropilae
- Parameters in accordance with those of fibrous materials

2D artificial sonic crystal

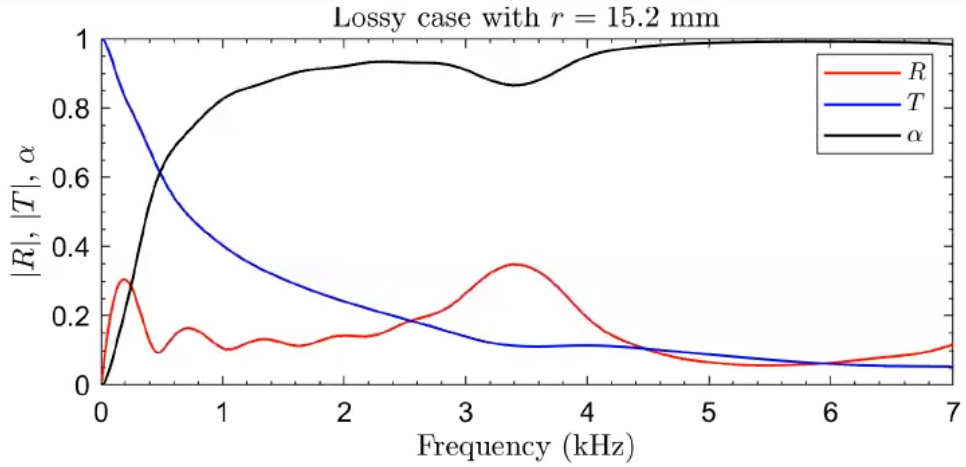
Square lattice $d = 43$ mm, $r = 15.5$ mm, $L = 6 \times d$.

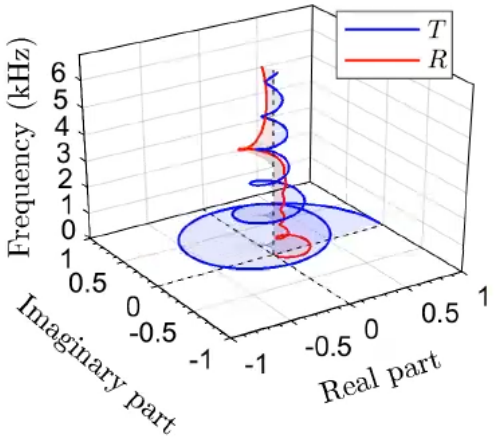


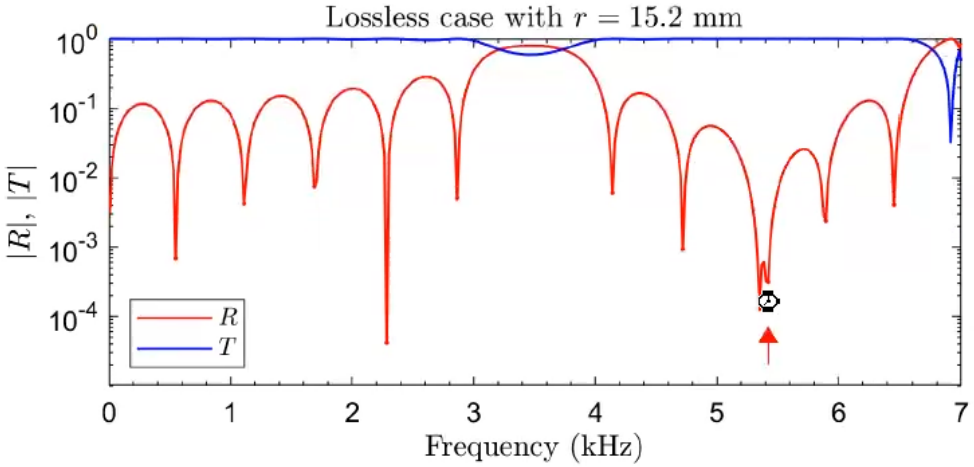
(Fernández Marín *et al.*, Appl. Phys. Lett., 2019)

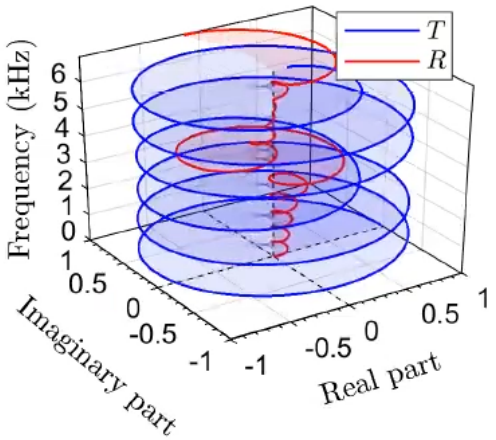
- Band gap mainly visible on the reflection; inflection point on $\mathrm{Im}\,(k_B)$
- More interesting for absorption than for pure insulation!

Topology of the sonic crystal







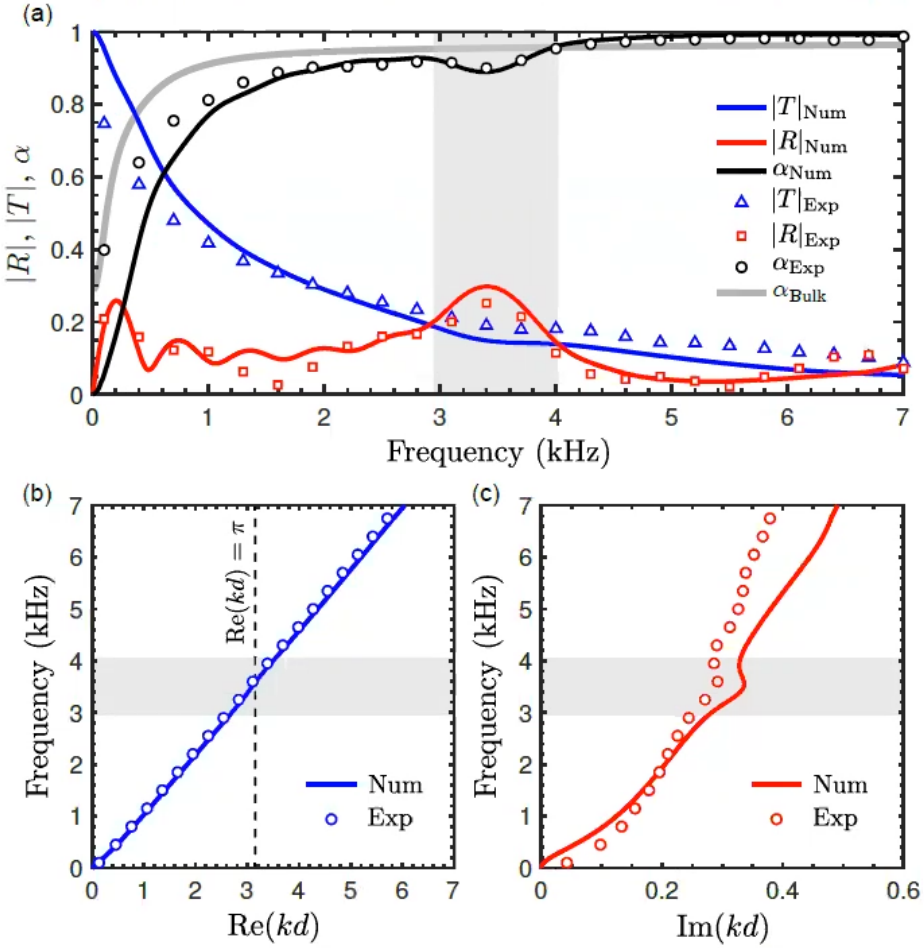


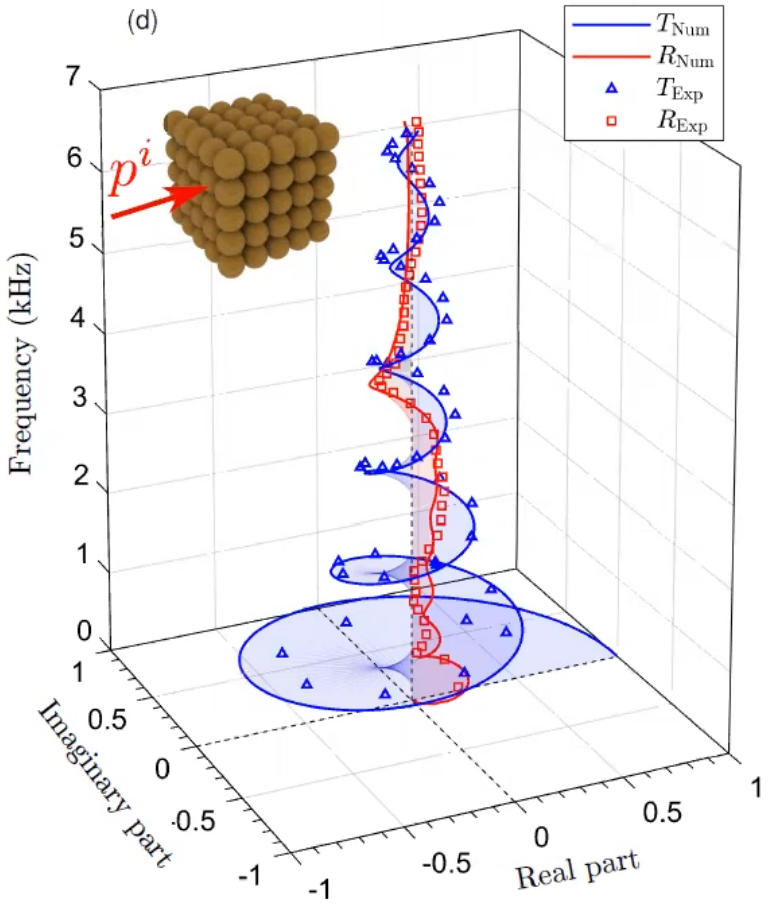


- Second pass band is a nontrivial bulk band
- Fabry-Perot peaks coalesce at the symmetry inversion frequency

3D natural sonic crystal

Primitive cubic lattice $d = 43$ mm, $r = 19.5$ mm, $L = 6 \times d$.





- Similar trend: symmetry inversion to achieve quasi-perfect absorption with symmetric structures in transmission problems
- Use of FCC may be more efficient at low frequencies!

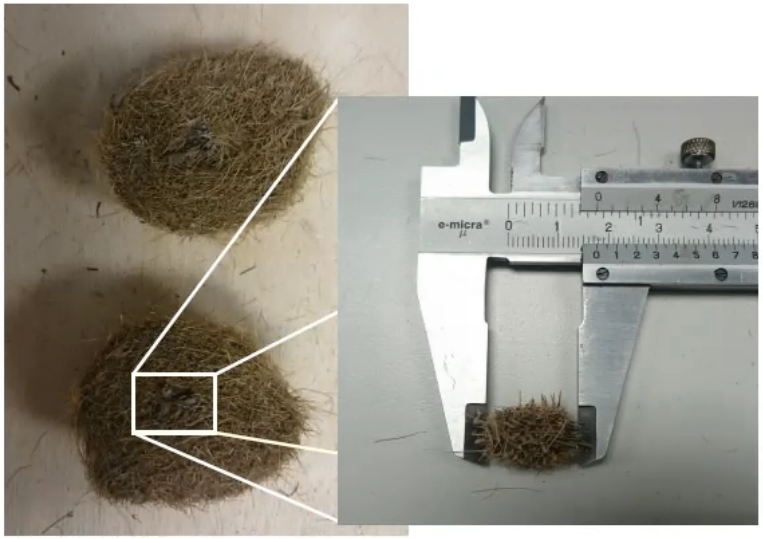
Conclusion and perspectives

- Acoustics: reliable tool to study the micro-structure and thus the formation of natural fiber networks like Aegagropilae
  $\Rightarrow$ greener manufacturing of usual fibrous materials
- Periodic arrangement of Posidonia balls proven to exhibit specific band structure and topology
  $\Rightarrow$ acoustic properties that are comparable and may overcome those of usual acoustic materials

Aegagropilae fiber network is probably one of the first fully natural building blocks of periodic sound structures and acoustic metamaterials.

Perspectives:

Some balls incorporate initiators!



Thank you for your attention!



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More information: L. Barguet, V. Romero-García, N. Jiménez, L.M. Garcia-Raffi, V. J. Sánchez-Morcillo, and J.-P. Groby, *Natural sonic crystal absorber constituted of seagrass (Posidonia Oceanica) fibrous spheres*, Sci. Rep., **11**: 711, 2021.