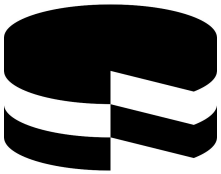
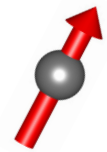
Dielectric properties

impedance spectroscopy



water and ice

Lorentz and Lorenz



by Alexander Tsirlin, Leipzig University

Lecture 10: November 9, 2023

Dielectric losses at 50 Hz

	ε	$10^4 \operatorname{tg} \delta$
Air	1	0
Polyethylene	2	0
Teflon	2	0
Nylon	5	15
Glasses	2–20	1–200
Water	80	>100
$BaTiO_3$	1500	15

Image credits: Simon Koopmann and CMBJ (CC-BY-SA)

Polarizability

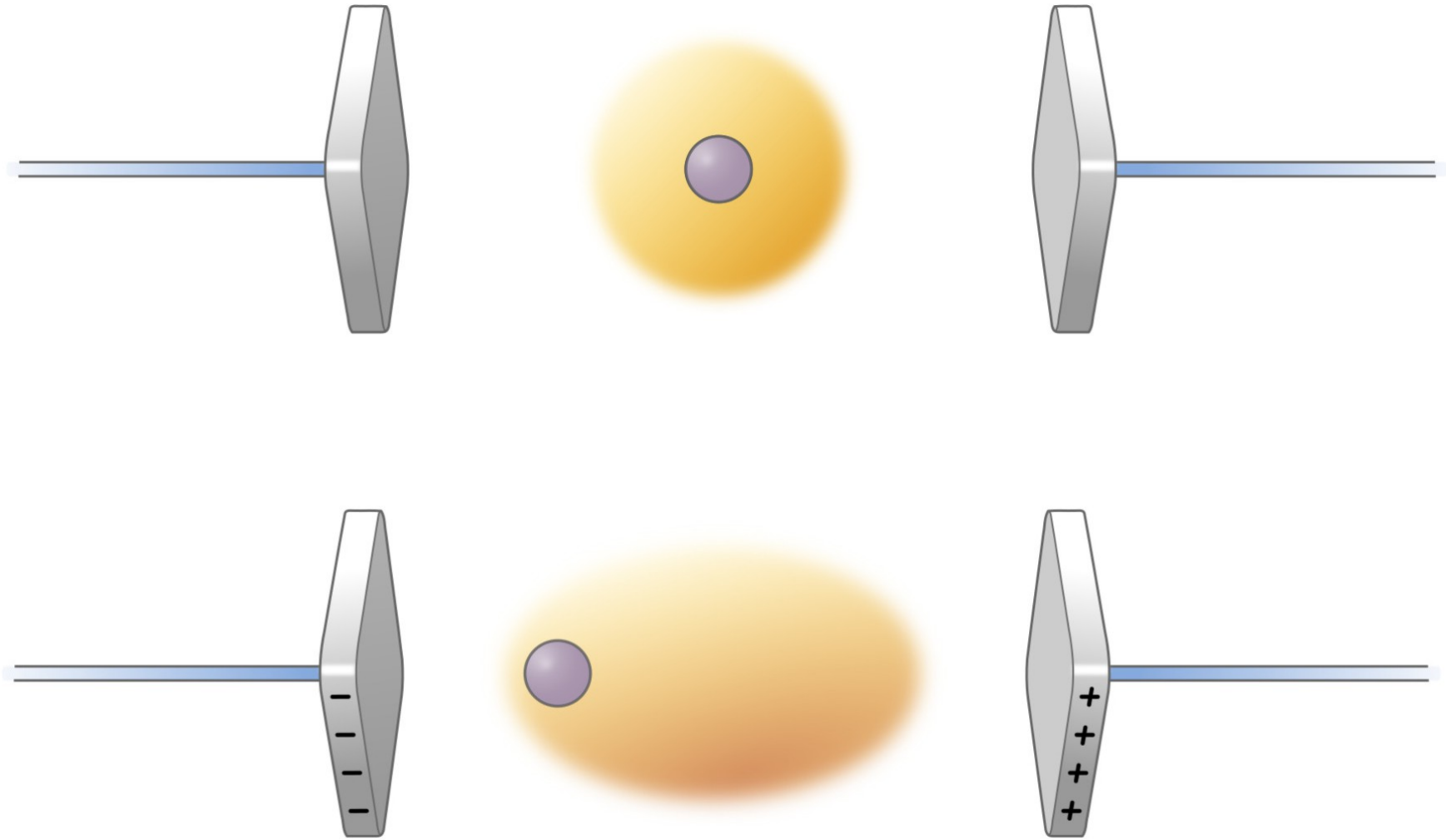


Image credit: LibreTexts (CC-BY-NC)

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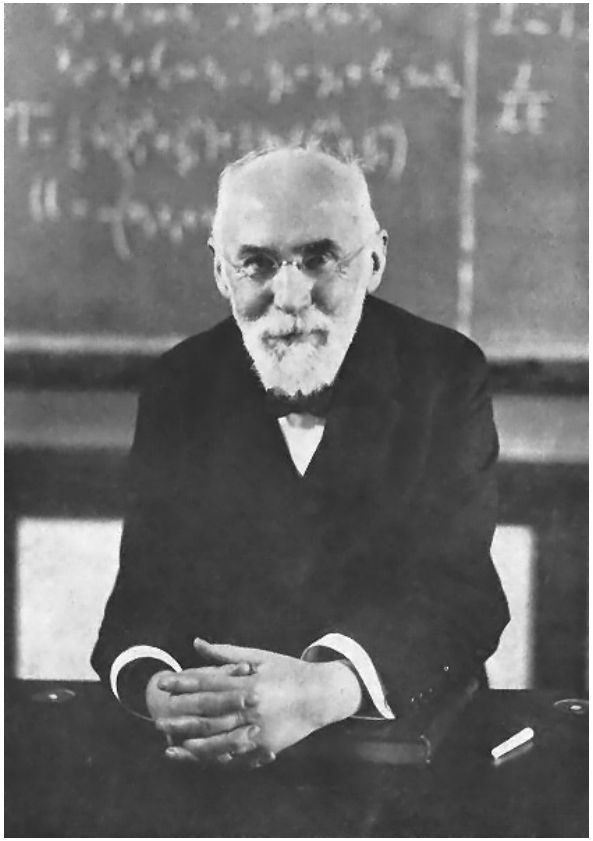
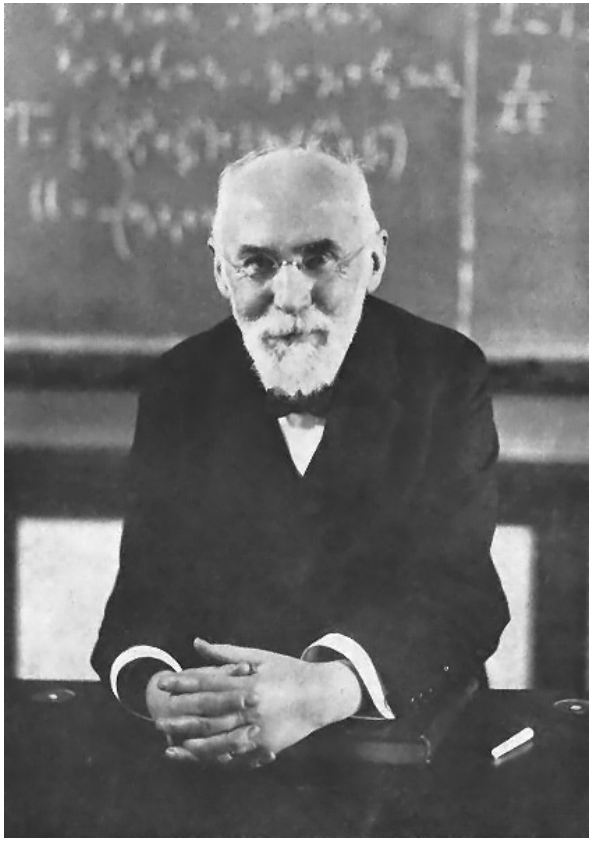
Person

Lorentz and Lorenz



Hendrik Antoon Lorentz
1853 – 1928



Hendrik Antoon Lorentz
1853 – 1928

electrodynamics, special relativity

1902 Nobel Prize in Physics

It may well be said that Lorentz was regarded by all theoretical physicists as the world's leading spirit, who **completed what was left unfinished by his predecessors** and prepared the ground for the fruitful reception of the new ideas based on the quantum theory.

Nobel Foundation

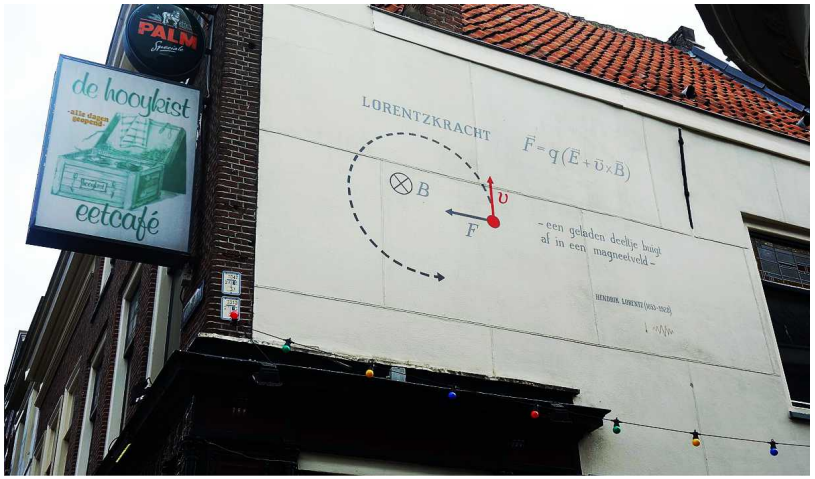
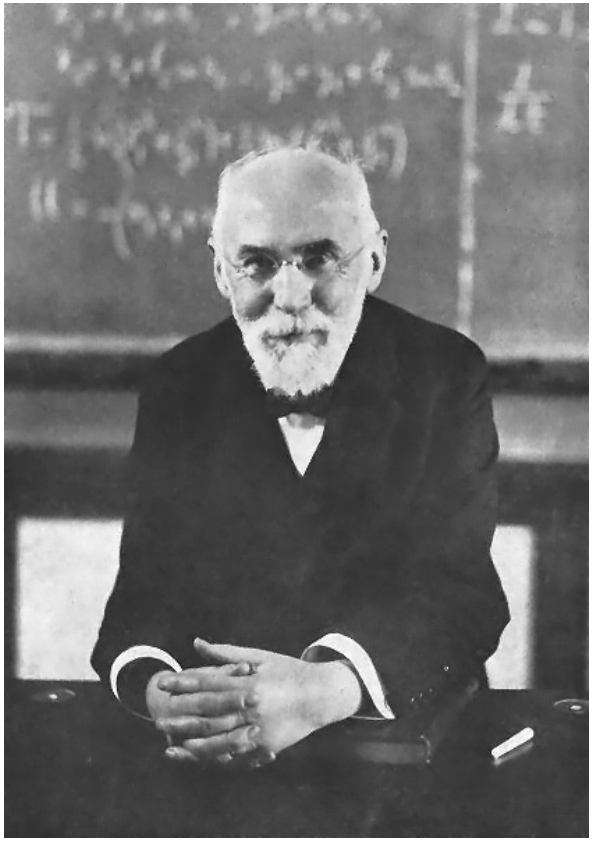


Image credit: Vysotsky (CC-BY-SA)

Lorentz or Lorenz?

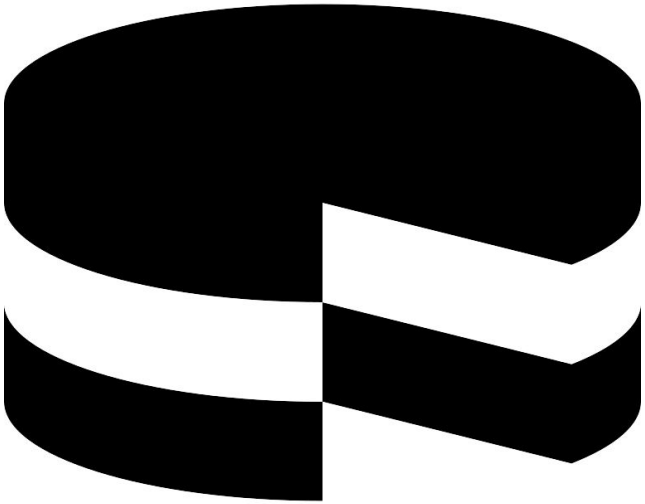


Hendrik Antoon Lorentz
1853 – 1928

derived the equation in 1878
"a curious case of coincidence"

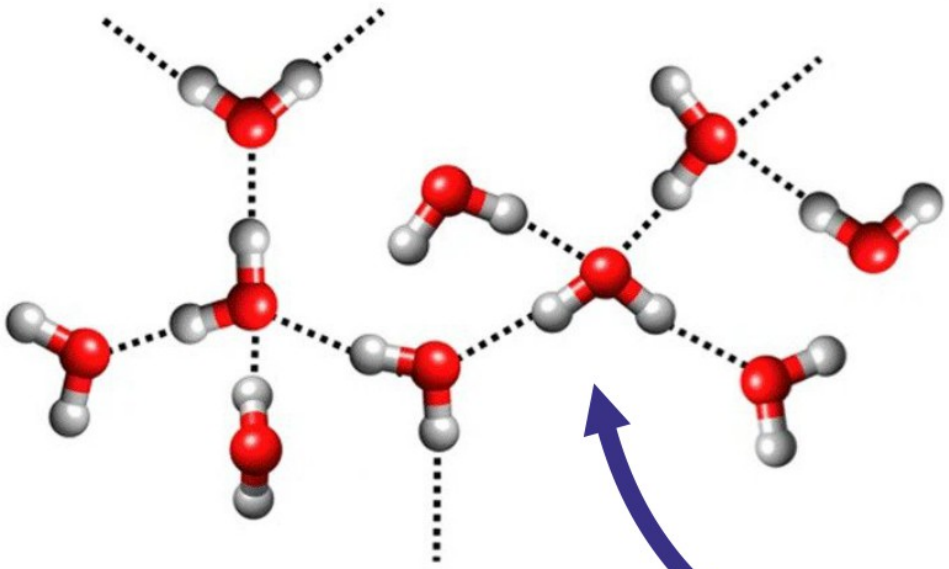
Ludvig Lorenz
1829 – 1891

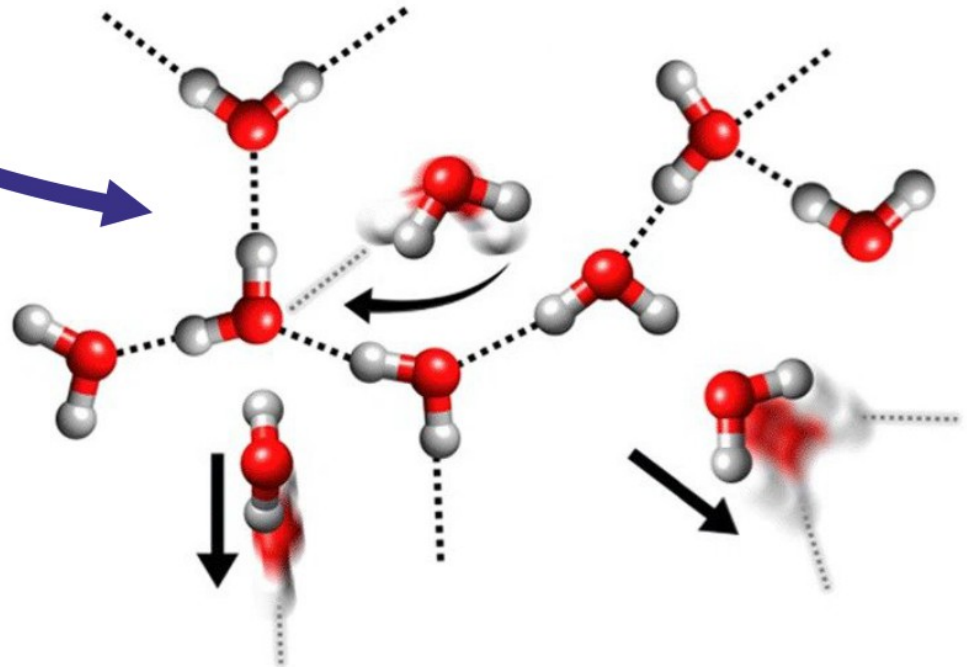
derived the equation in 1869



Material

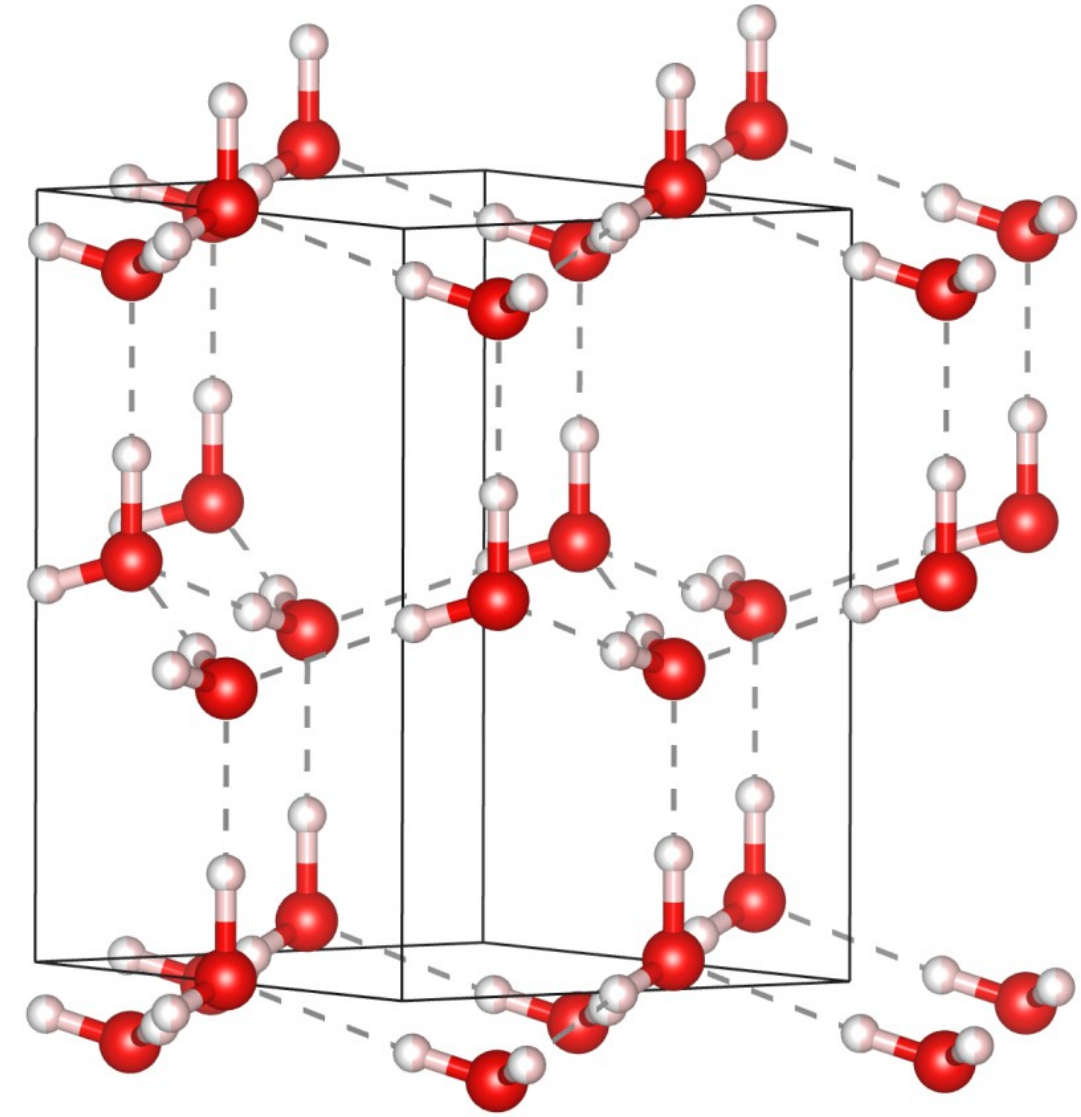
water and ice

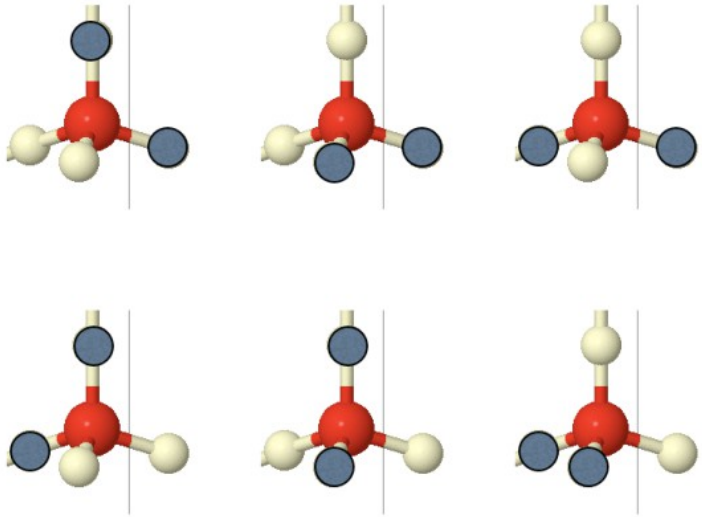




At least 80% water molecules
in the Ocean are hydrogen-bonded

Image credits: DevizK (CC-BY-SA) and J. Biosciences 43, 499 (2018)



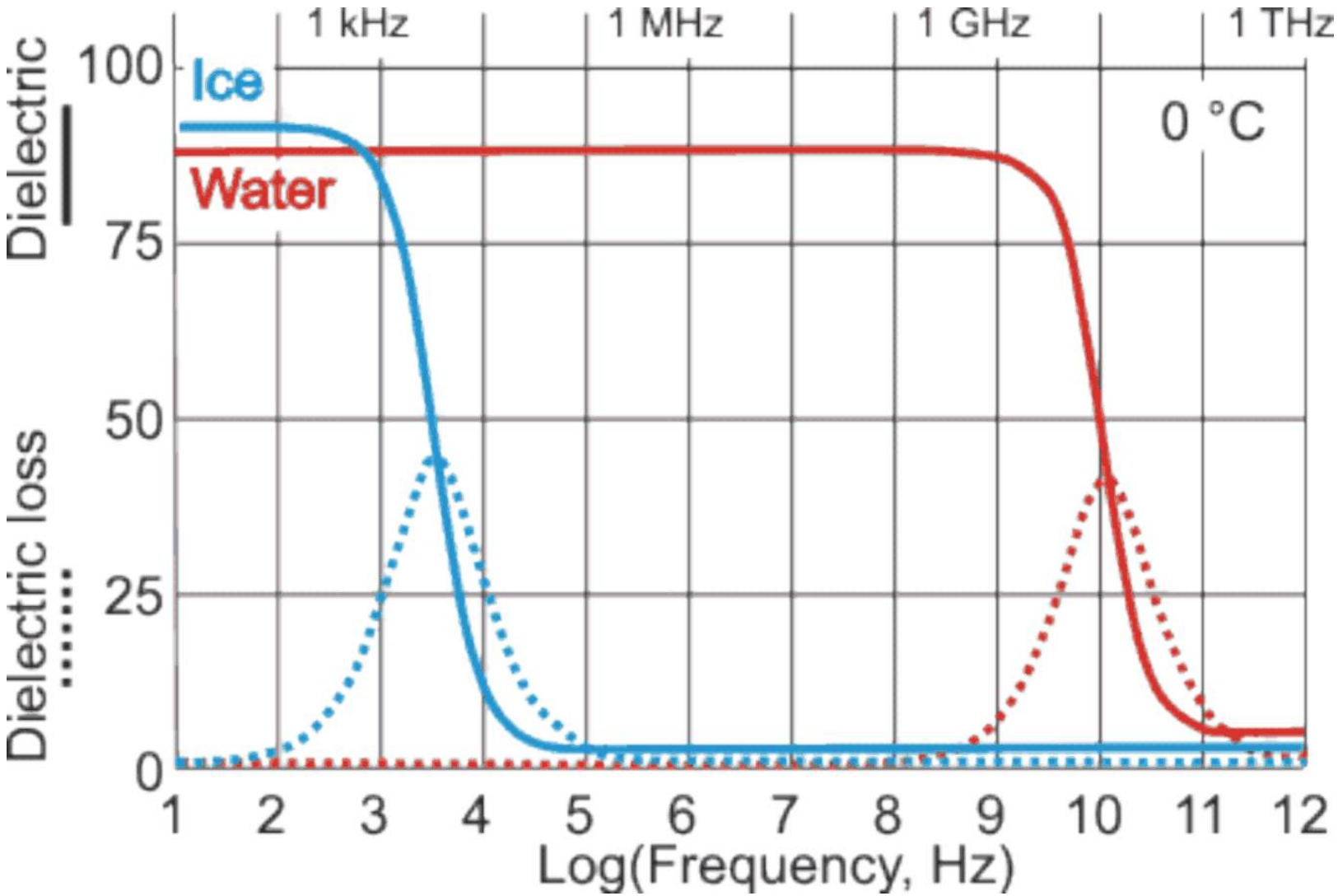


2-in-2-out (**ice rule**)

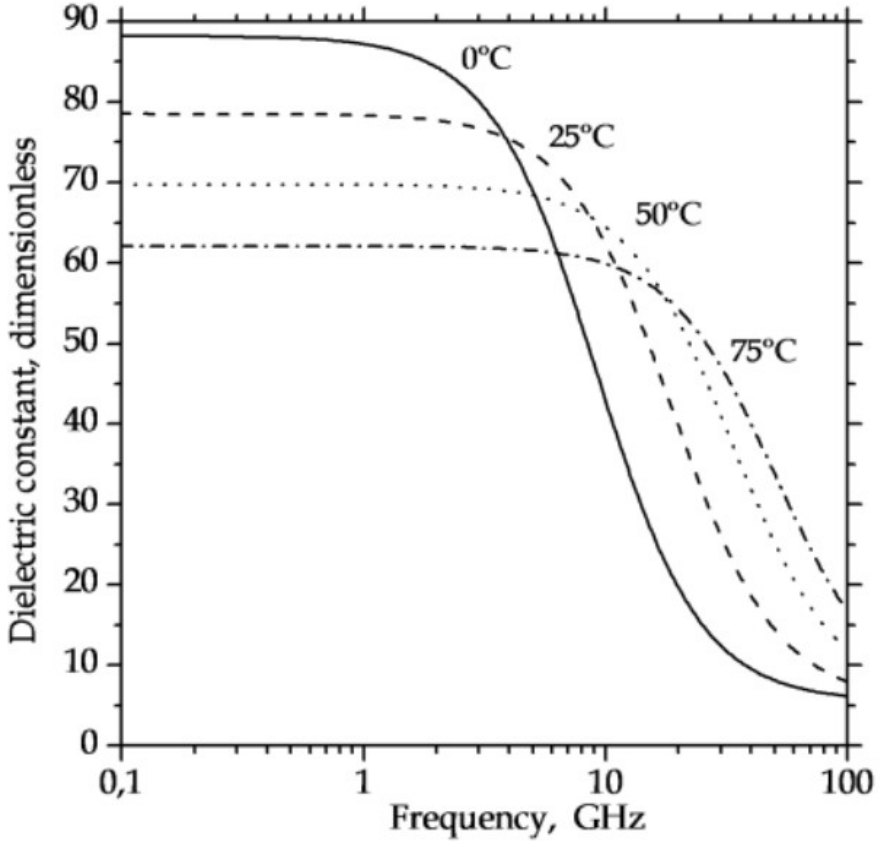
Conventional ice (I_h) features residual entropy of $R \ln \frac{3}{2}$ due to random positions of hydrogens

Image credit: Mystery of water (CC-BY-SA)

Water vs. ice



Water again



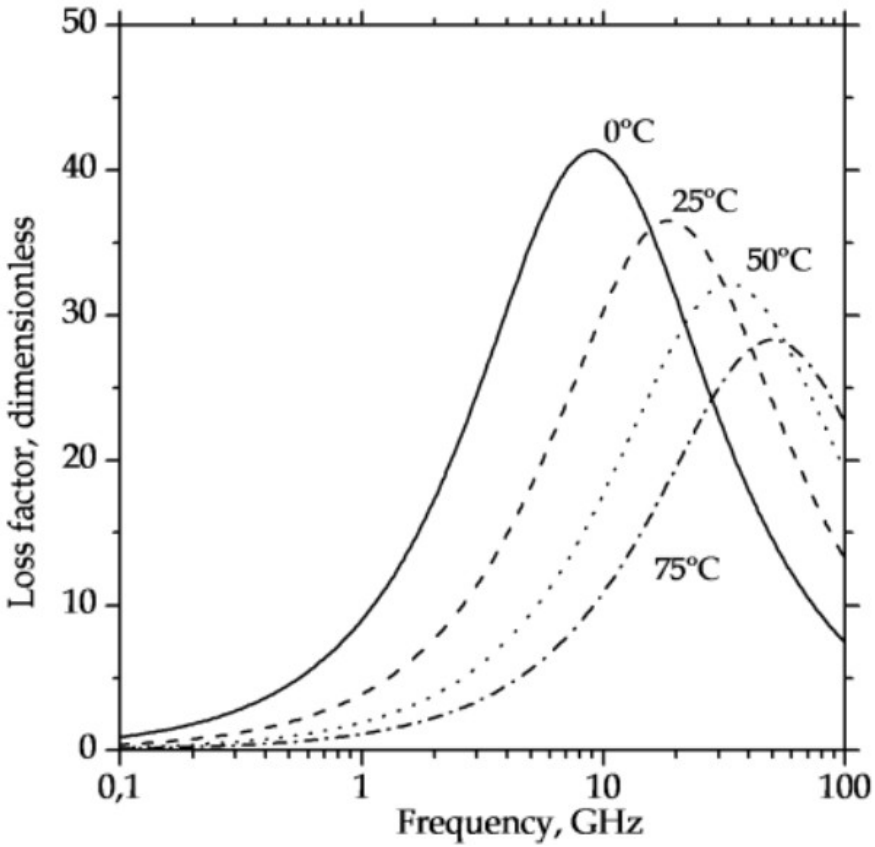
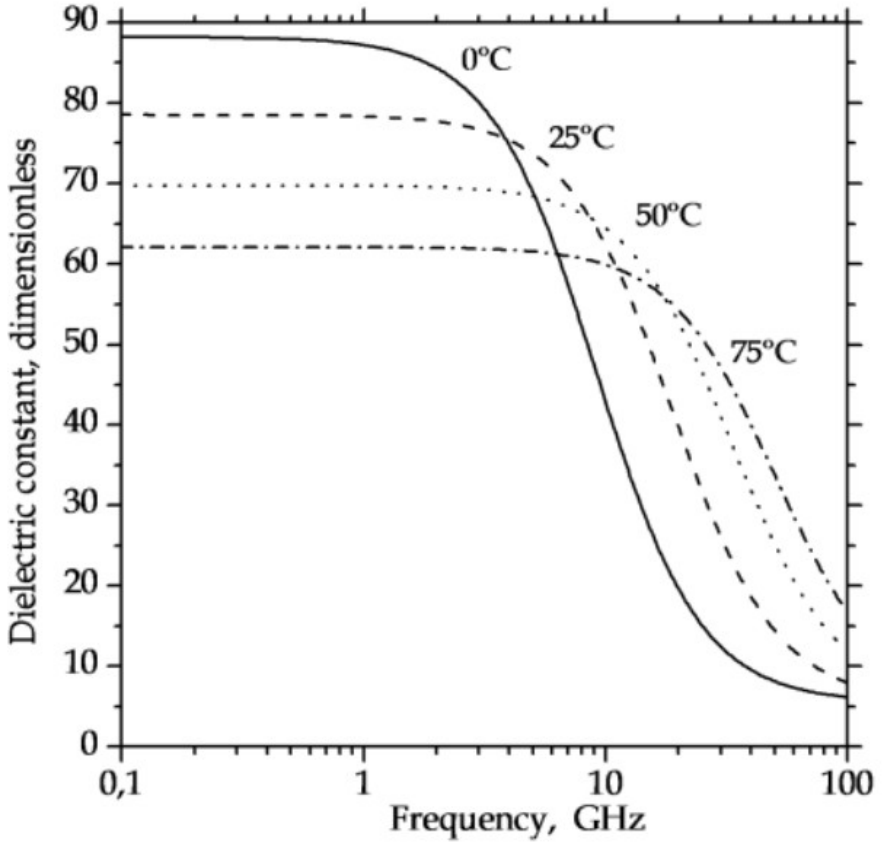


Image credit: Microwve Materials Characterization

Water again



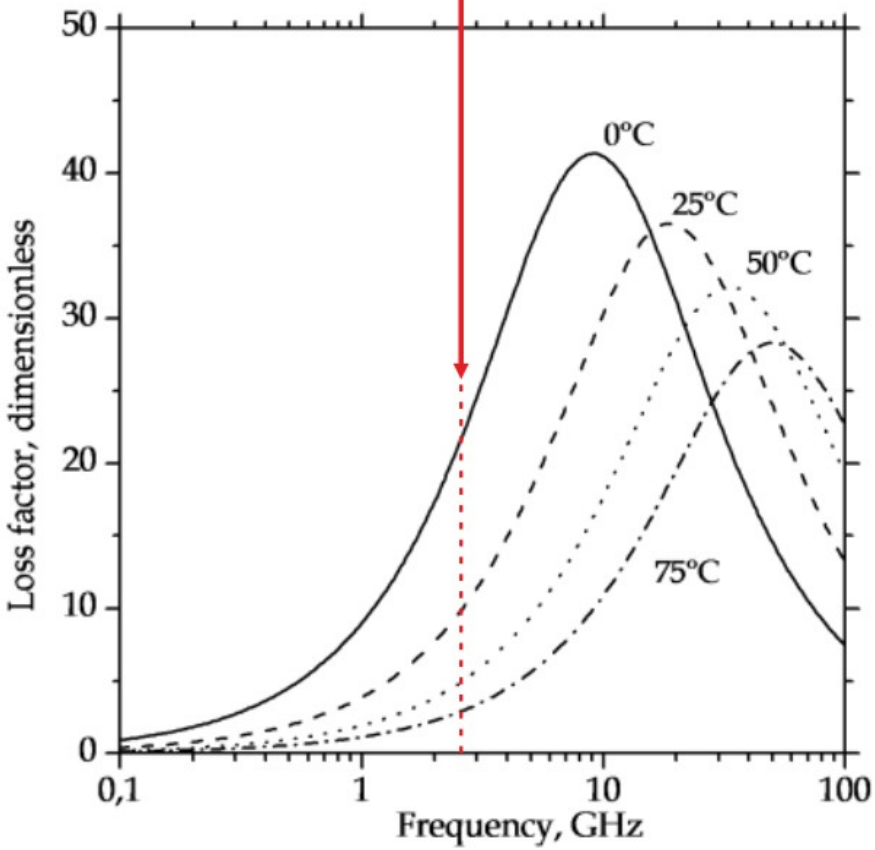


Image credit: Microwve Materials Characterization and Eric Fischer (CC-BY-SA)

Standing wave

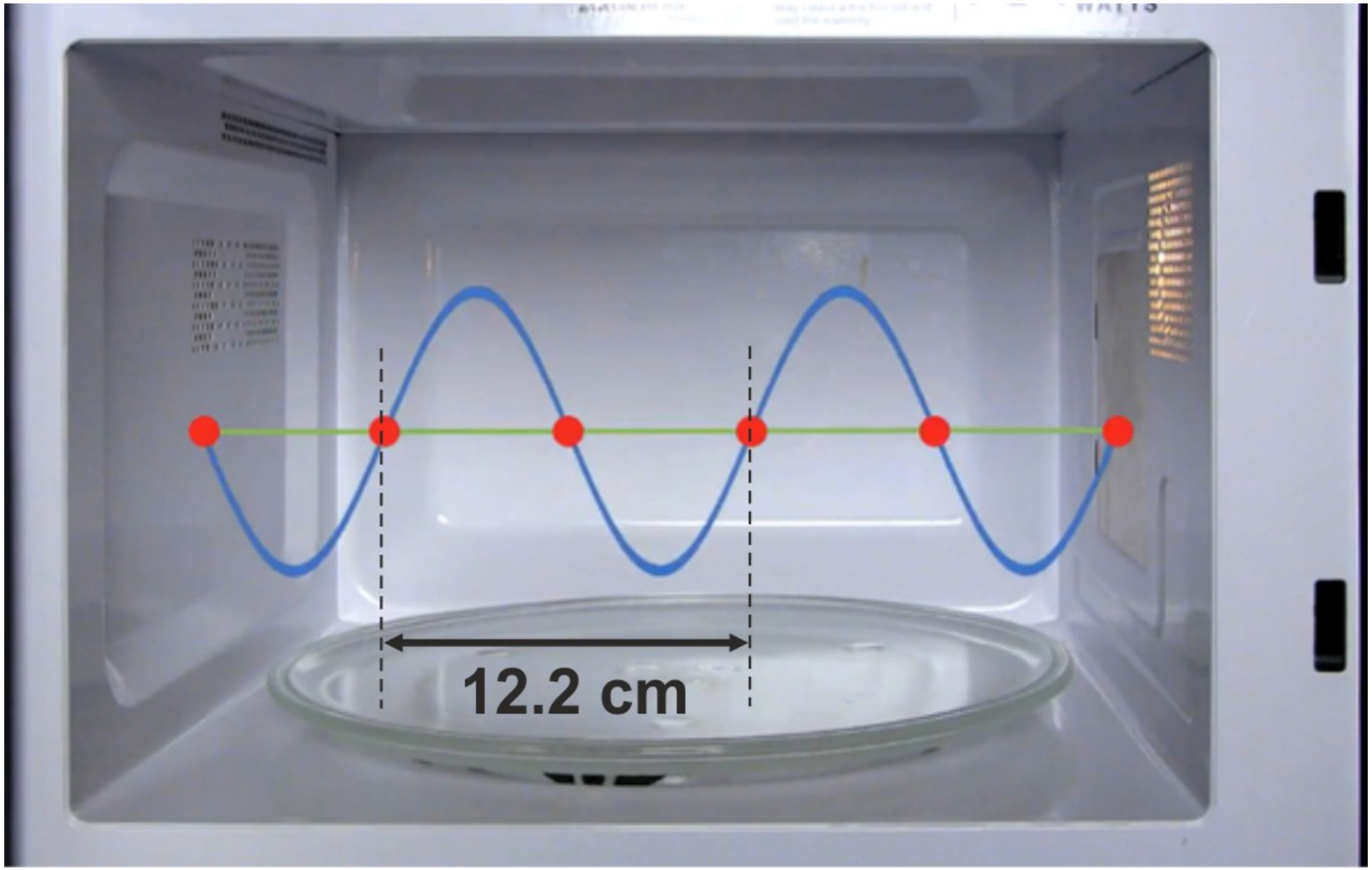


Image credit: Scientific Finger Food

Microwave oven: operation manual

- At **2.45 GHz**,
  large dielectric loss for water
- Microwaves reflected by the conducting walls (*Faraday cage*)
- With the wavelength $\lambda \simeq 12\,\mathrm{cm}$, metal grid on the door prevents microwaves from going out

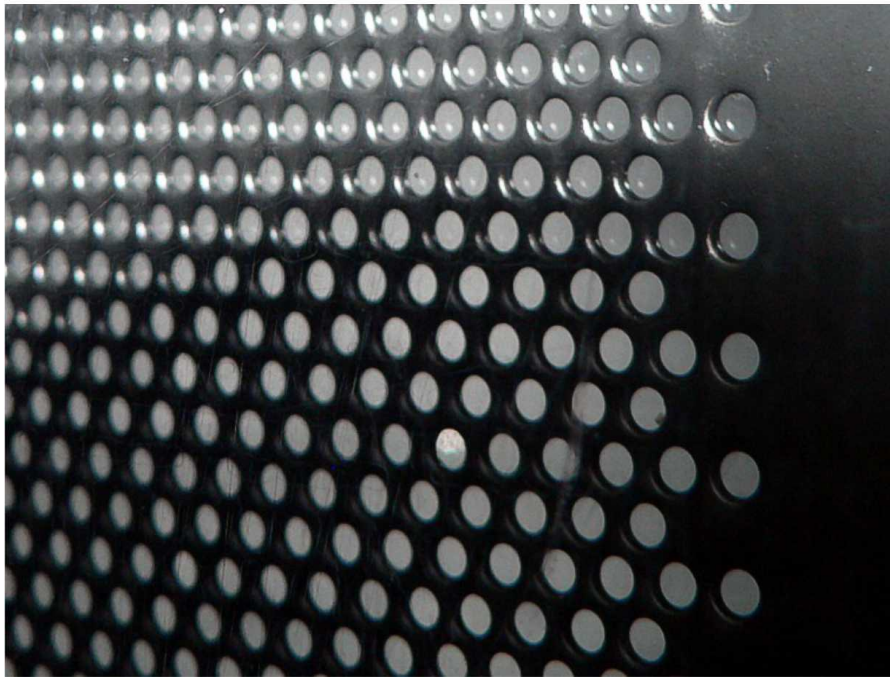


Image credits: DromoTetteh (CC-BY-SA) and Baran Ivo (public domain)

Microwave oven: operation manual

- At **2.45 GHz**,
  large dielectric loss for water
- Microwaves reflected by the conducting walls (*Faraday cage*)
- With the wavelength $\lambda \simeq 12\,\mathrm{cm}$, metal grid on the door prevents microwaves from going out
- **Never run an empty oven**,
  the energy of $600 - 1000\,\mathrm{W}$ will be discharged into nowhere

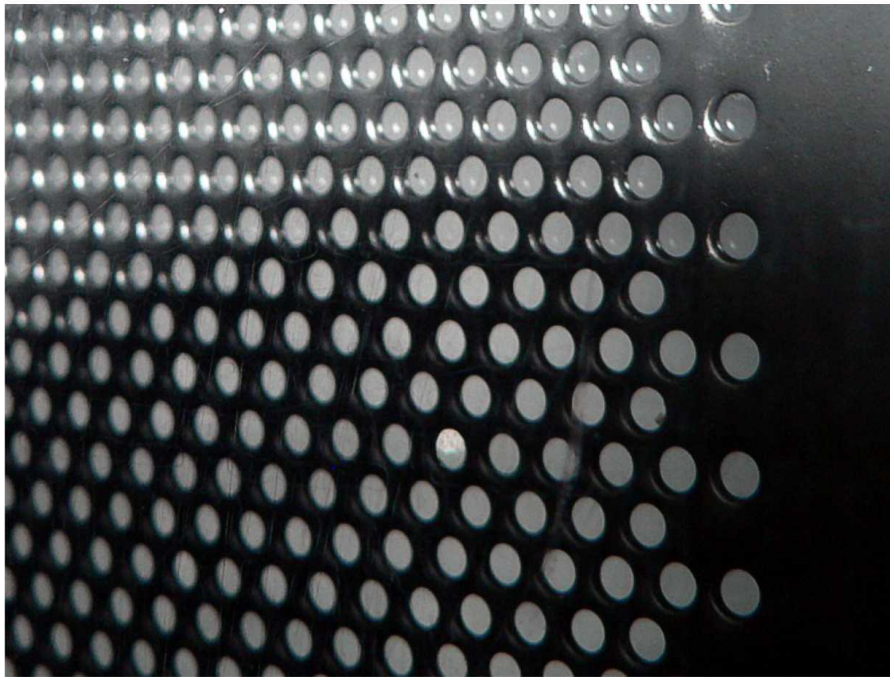


Image credits: DromoTetteh (CC-BY-SA) and Baran Ivo (public domain)

Microwave ovens: operation manual

- *Defrost option* should be used for frozen products (gentle heating, low power)

Microwave ovens: operation manual

- *Defrost option* should be used for frozen products (gentle heating, low power)
- Do not microwave **dry products**, they will burn

Image credits: heb@Wikimedia Commons and Benreis (CC-BY-SA)

Microwave ovens: operation manual

- *Defrost option* should be used for frozen products (gentle heating, low power)
- Do not microwave **dry products**, they will burn
- Do not microwave **metallic objects**

Image credits: heb@Wikimedia Commons and Benreis (CC-BY-SA)

Microwave ovens: operation manual

- *Defrost option* should be used for frozen products (gentle heating, low power)
- Do not microwave **dry products**, they will burn
- Do not microwave **metallic objects**
- Broken microwave ovens may be re-used

Experimental technique

dielectric spectroscopy

Dielectric measurements

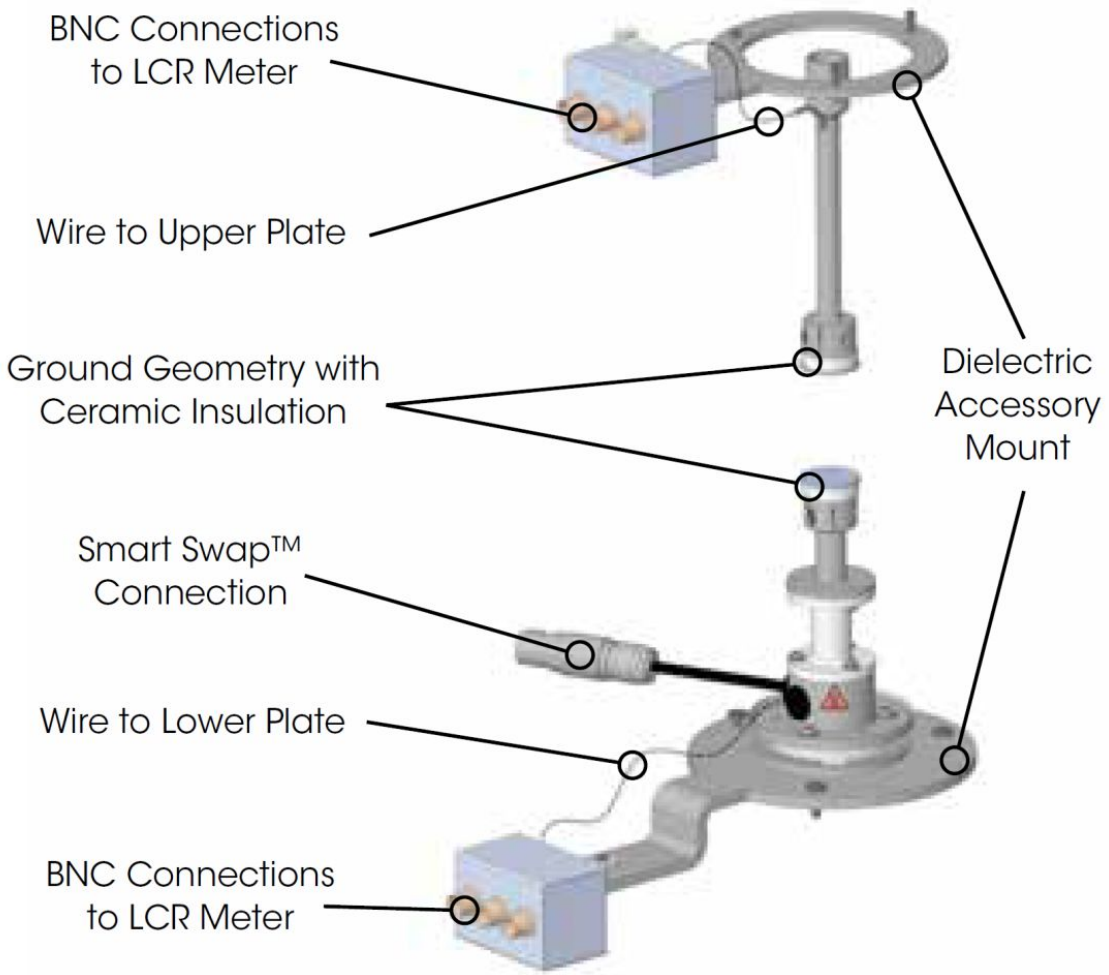


Image source: TA Instruments (fair use)

Cole-Cole plot

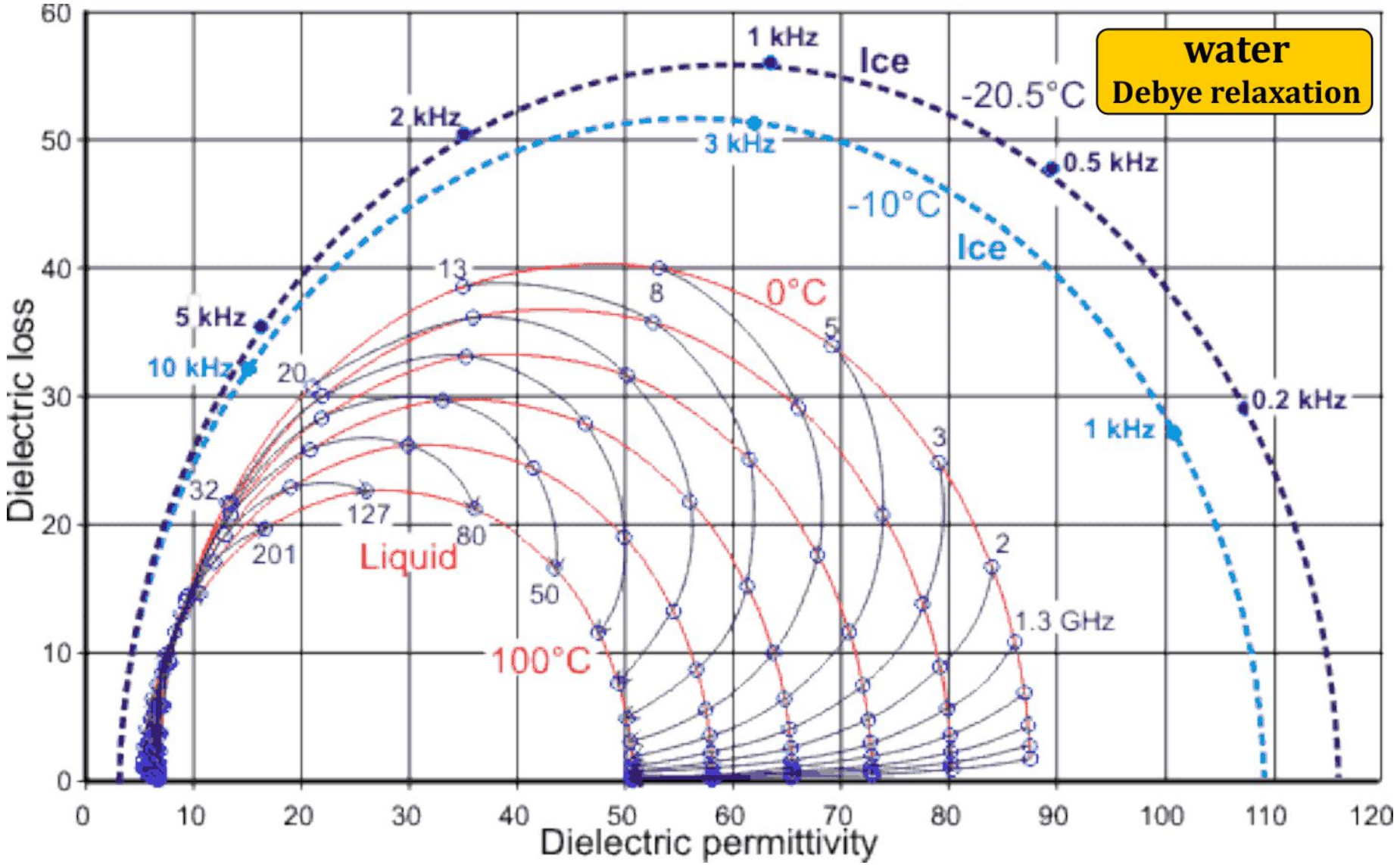


Image credit: Martin Chaplin (CC-BY-NC)

Quality control

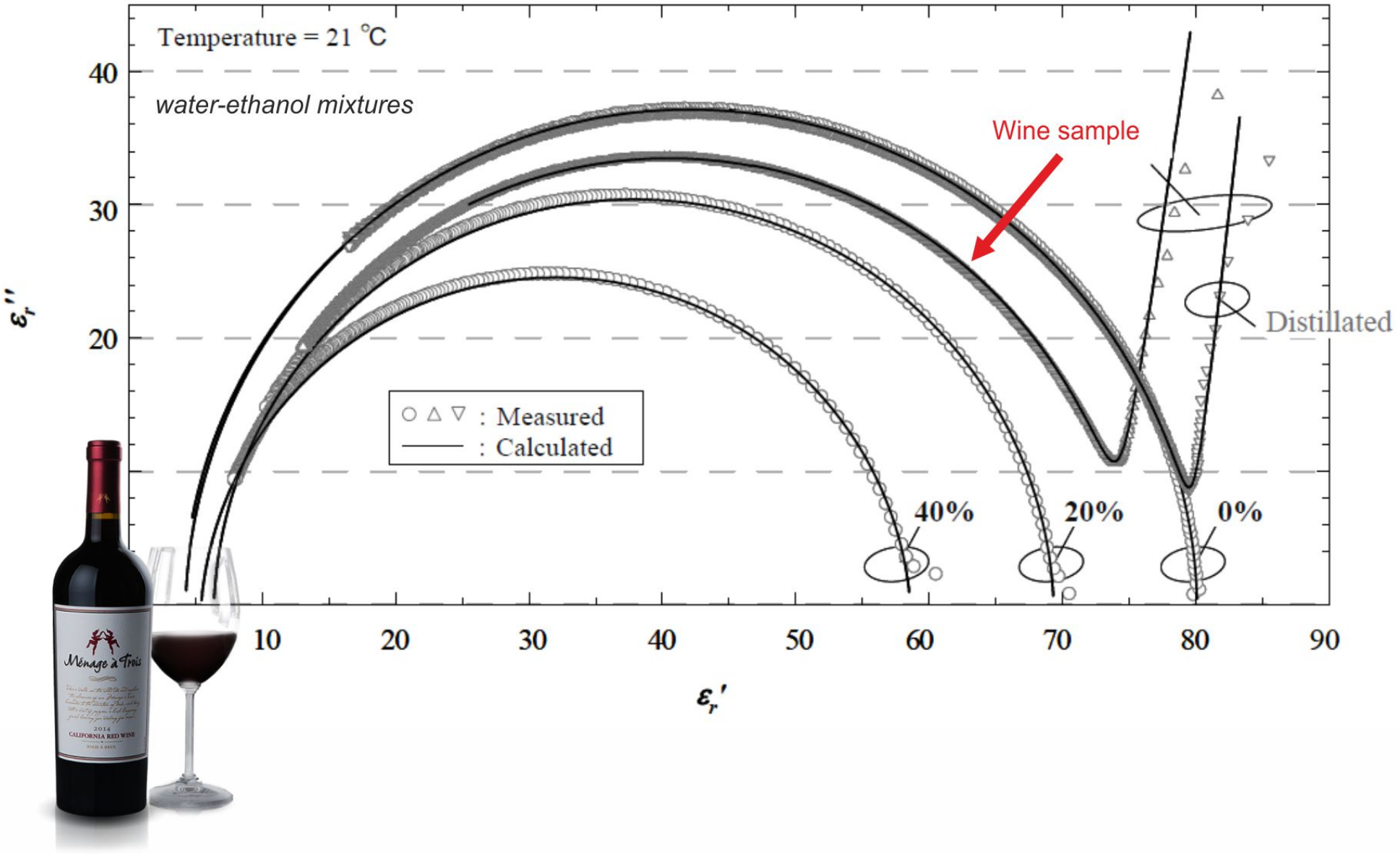


Image credit: K. Watanabe *et al.* EMC'09, Kyoto

Study of glaciers

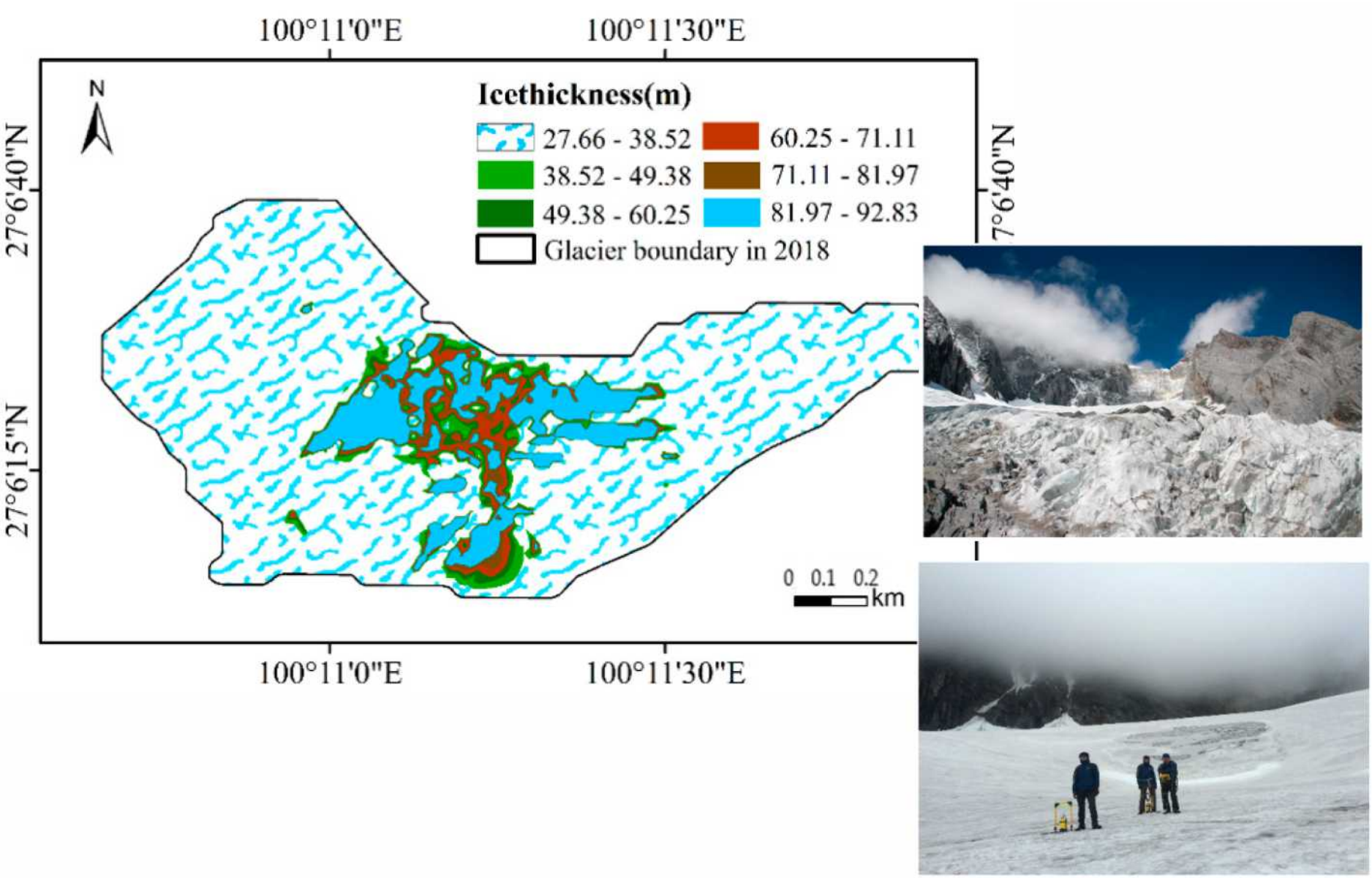


Image credit: Remote Sensing 12, 4105 (2020)

Physics Colloquium

Tuesday, November 14, 2023 at 16:30

Claudius Gros

Goethe University Frankfurt

Should physics pay attention to attention?

At the core of the current AI hype is the attention mechanism, which powers transformers and hence all modern large language models, such as ChatGPT.