

Des « IRM » pour étudier le sel dans les aliments

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Des “IRM” ?

Resonance Magnétique Nucléaire



Imagerie

Spectroscopie (...)



Quantitative

Dynamique (...)





Pieter ZEEMAN

Prix Nobel de physique 1902

“in recognition of the extraordinary service they rendered by their researches into the influence of magnetism upon radiation phenomena”

Un champ magnétique “influence” le rayonnement lumineux
(...)

Noyau atomique / Spin $s \neq 0$

$2s+1$ états distincts dans un champ magnétique

Resonance

Perturbation externe correspondant
aux differences entre quanta

Magnétique

Répartition selon des quanta d'énergie

Nucléaire

Noyaux des atomes

+

Imagerie

Localisation des noyaux

=

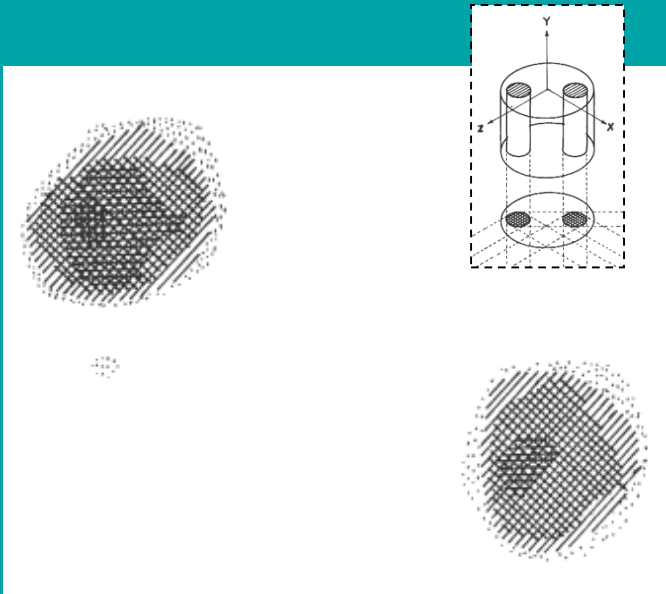
IRM



Paul LAUTERBUR

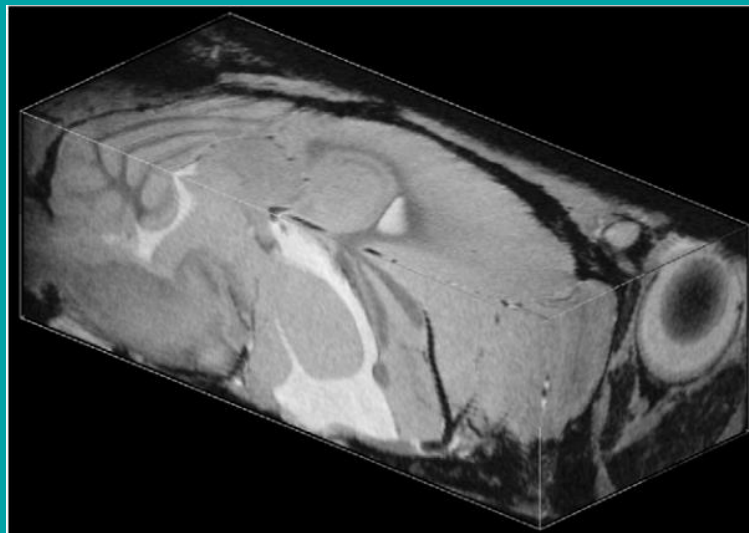
Prix Nobel de physiologie ou médecine 2003
“for their discoveries concerning magnetic
resonance imaging”

1ère image fondée sur le phénomène de RMN



Magnetic field ($B_0 =$) 1.4 T
 ^1H NMR

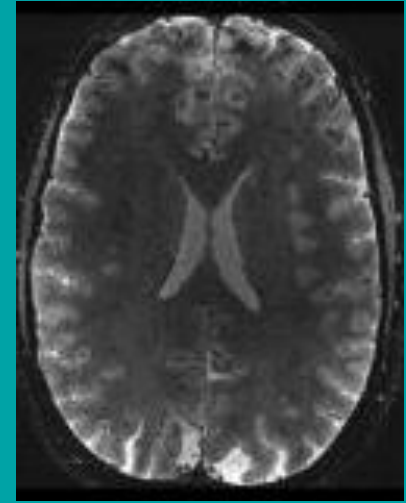
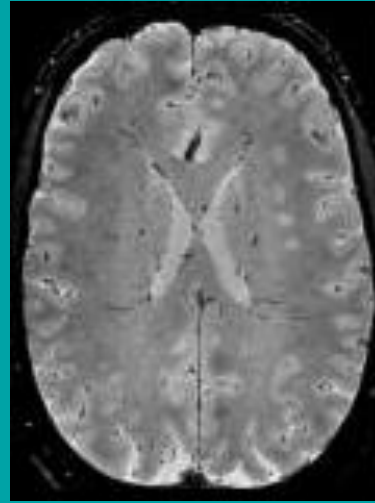
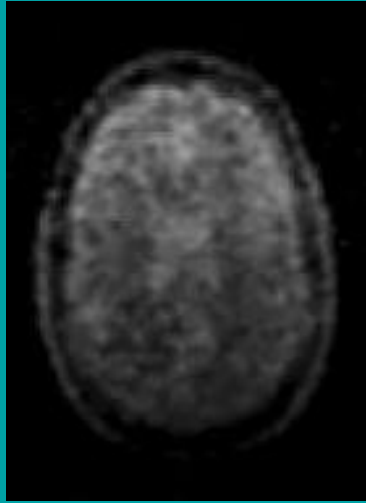
Lauterbur (1973) doi:10.1038/242190a0



$B_0 = 21.1$ T
 ^1H NMR

Schepkin et al. (2014) doi:10.1016/j.mri.2009.10.002

Noyau 1H



$50 \cdot 10^{-6} \text{ T}$ \Rightarrow

X 130

X 60000

X 140000

 74 mm³

 0.7 mm³

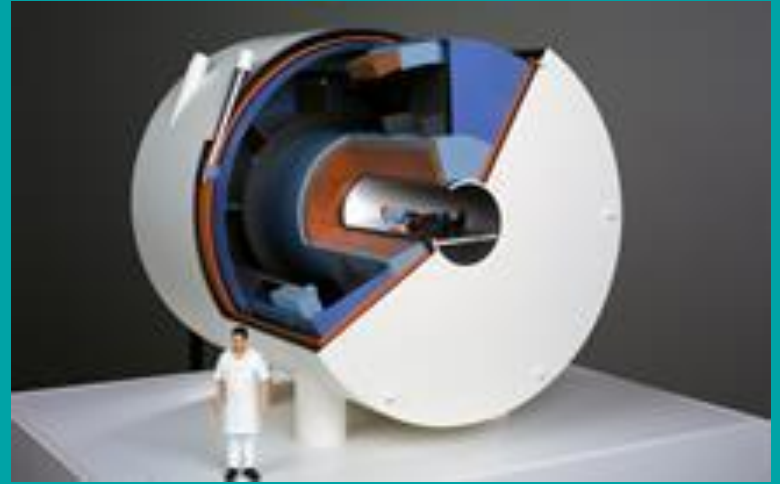
 0.5 mm³



$B_0 = 0.5 \text{ T}$
0.3 M€
Ningbo Xingyaoi
Magnetism, China



$B_0 = 7 \text{ T}$
14 M€
CRMBM, Marseille



$B_0 = 11.7 \text{ T}$
200 M€
CEA, Saclay

Propriétés du ^{23}Na

$$s = 3/2 \rightarrow 2 \times 3/2 + 1 = 4 \text{ quanta}$$

Sensible à la RMN

Sensibilité relative ~ 0.09

Quelle quantité de signal dans un aliment (très) salé ?

Jambon après 6 mois de séchage

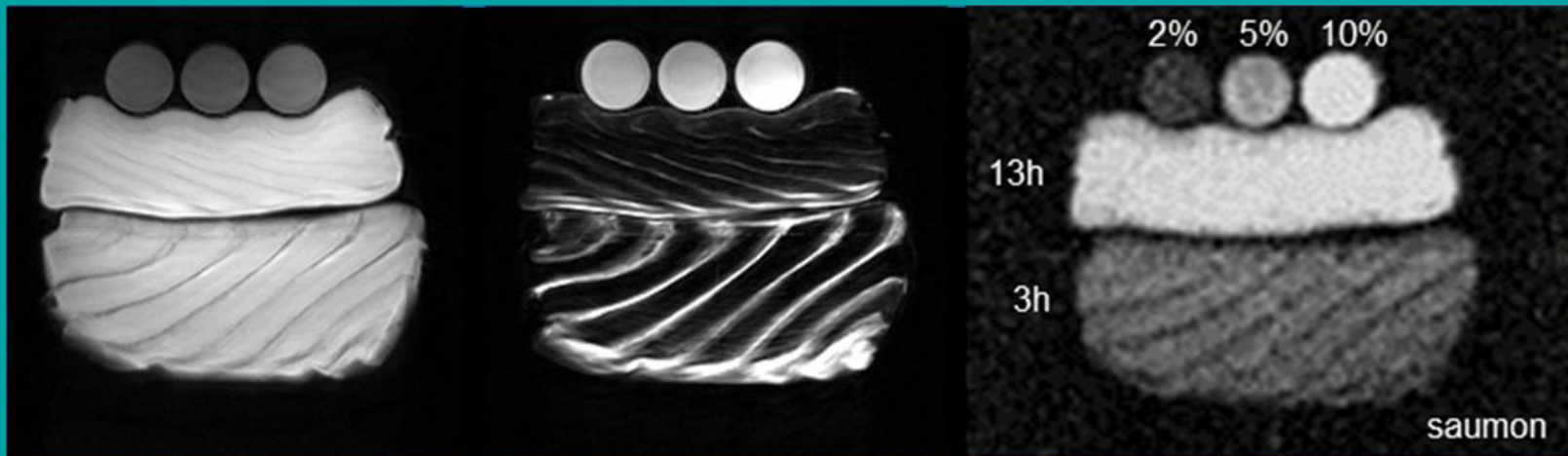
8% de sel

8g NaCl / 55g Eau

Signal ^{23}Na ~ Signal $^1\text{H}/500$

^1H

^{23}Na



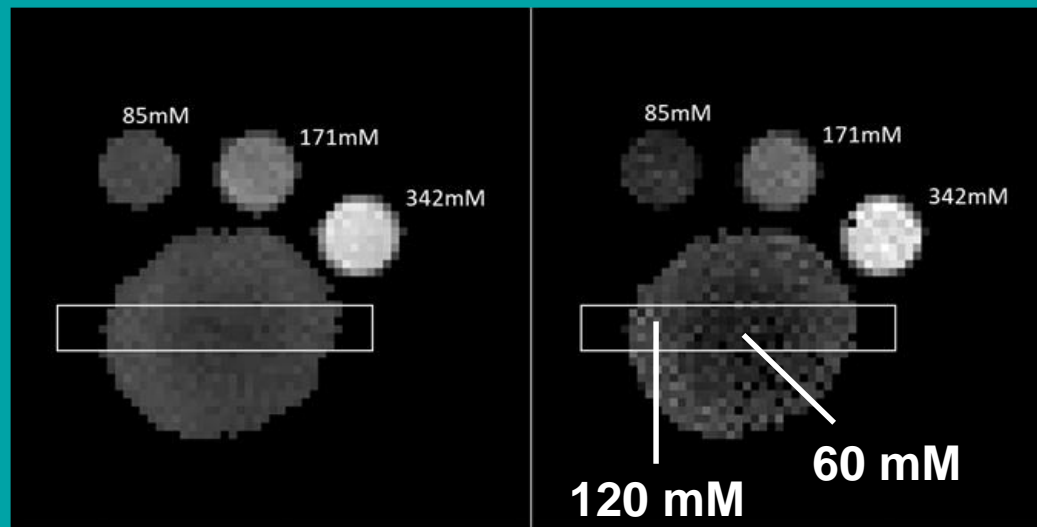
$B_0 = 4.7 \text{ T}$

Foucat et al. (non publié)

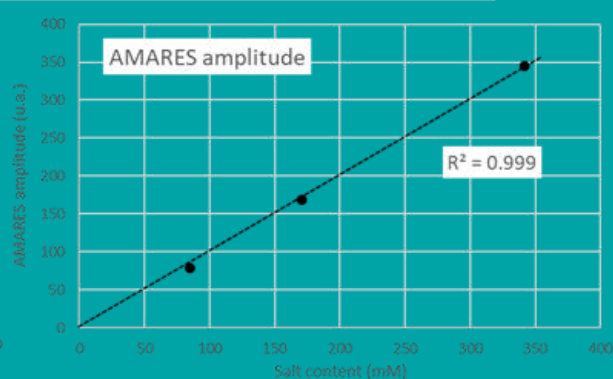
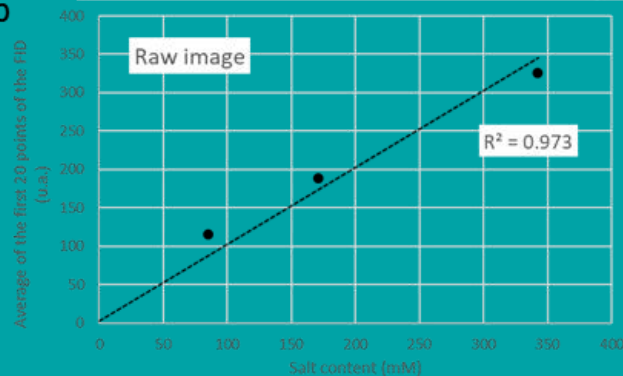
$B_0 = 9.4 \text{ T}$ Carotte salée

Clerjon et al. (2022) 10.1002/mrc.5239

a

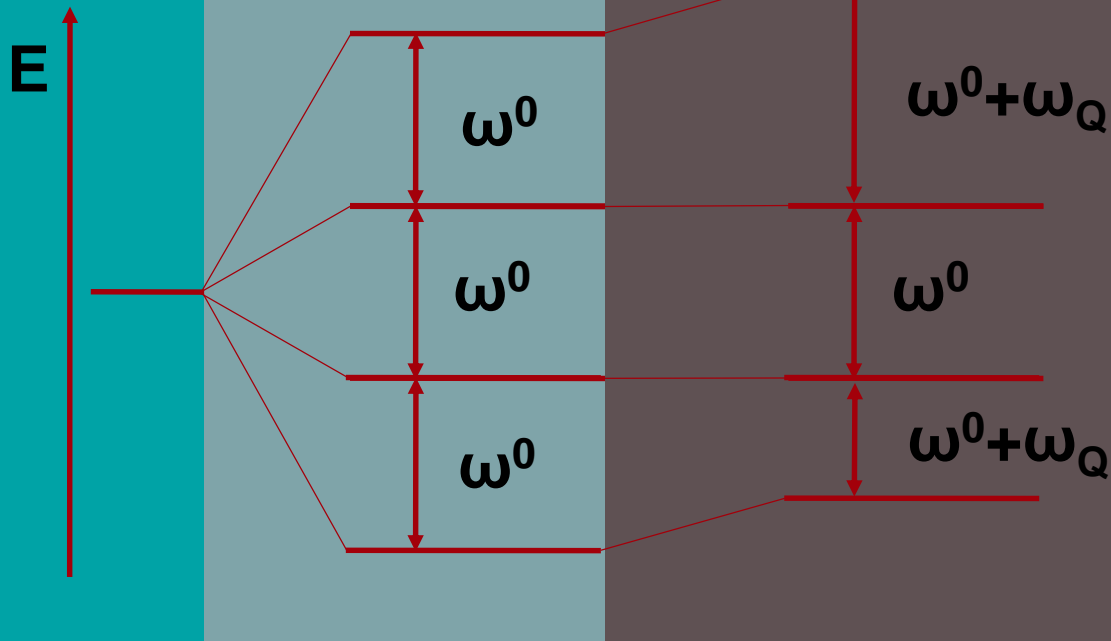


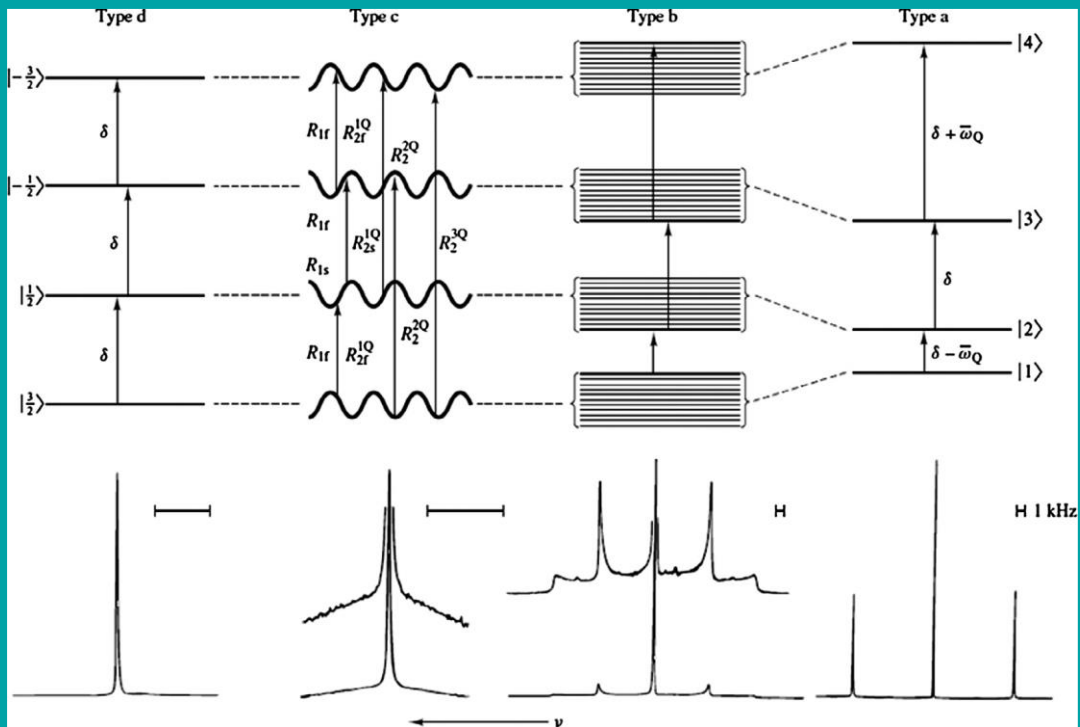
b



Zeeman

+ quadrupolar interaction





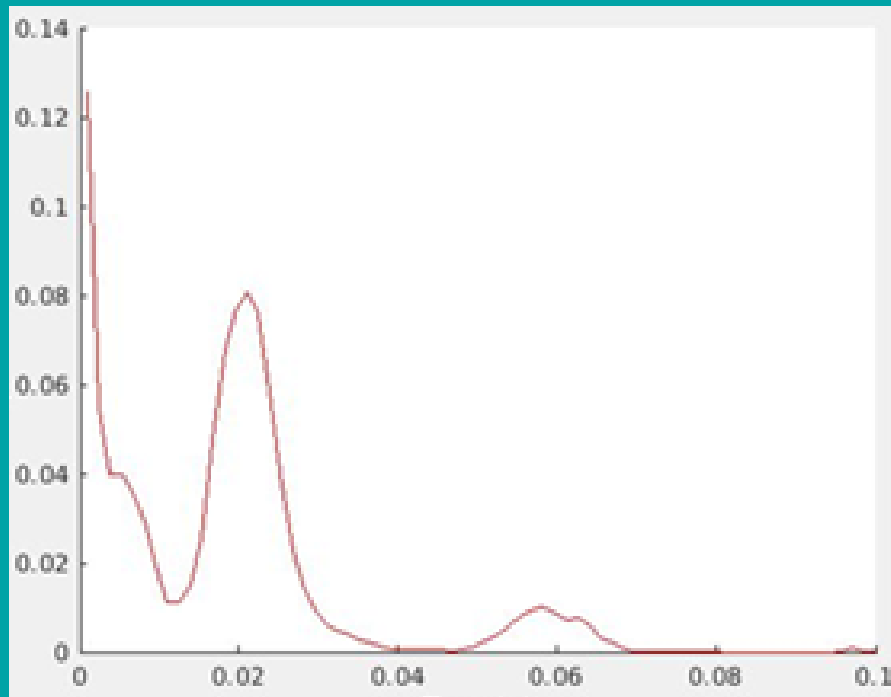
Liquide

Tissus
biologiques

Solides

$B_0 = 9.4 \text{ T}$
AgroResonance (2022)

Quantité relative



Sodium « lié » \Rightarrow Sodium libre

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Sodium visible en RMN

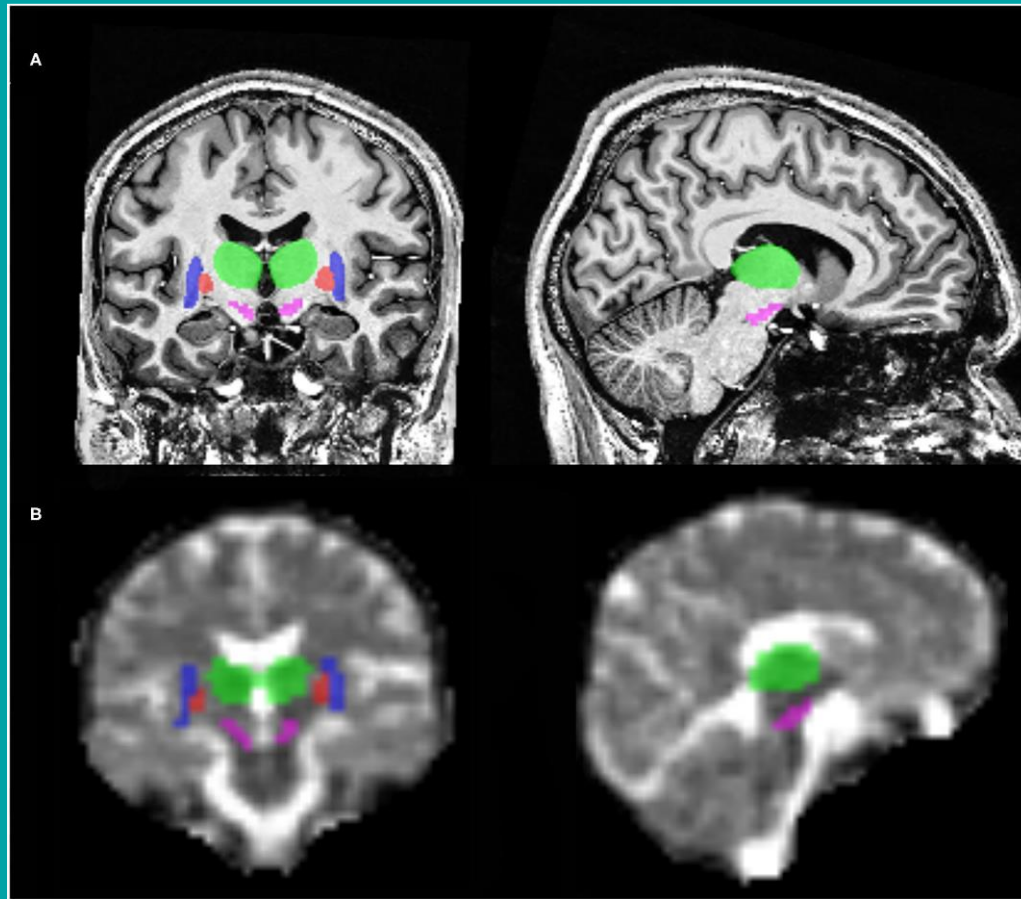
Nécessité d'un champ magnétique intense

Cartographie [Na] non destructive

Caractérisation des interactions sodium/matrice

$B_0 = 7\text{ T}$

^1H



Grimaldi *et al.* (2021) 10.3389/fneur.2021.715618

Académie d'agriculture de France, 19 Octobre 2022

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High field MRI

<http://www6.inra.fr/agroresonance>

AgroResonance



In vivo multimodal imaging

<https://www.ibisa.net/plateformes/detail.php?tri=&srch=&q=495>

IVIA IBiSA infrastructure

