

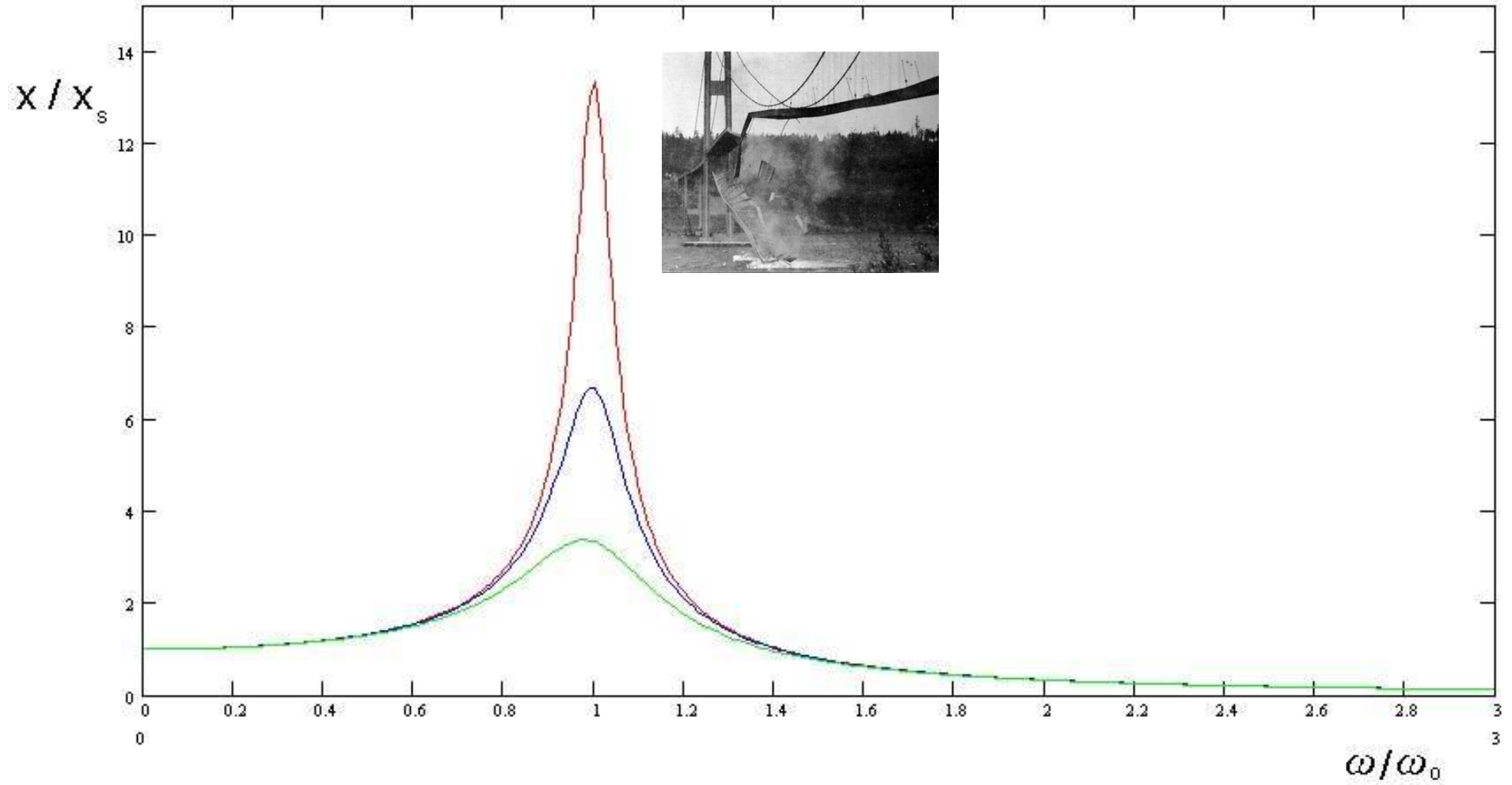
# Mágneses rezonancia módszerek: spinek tánca mágneses mezőben

**Kürti Jenő**  
egyetemi tanár

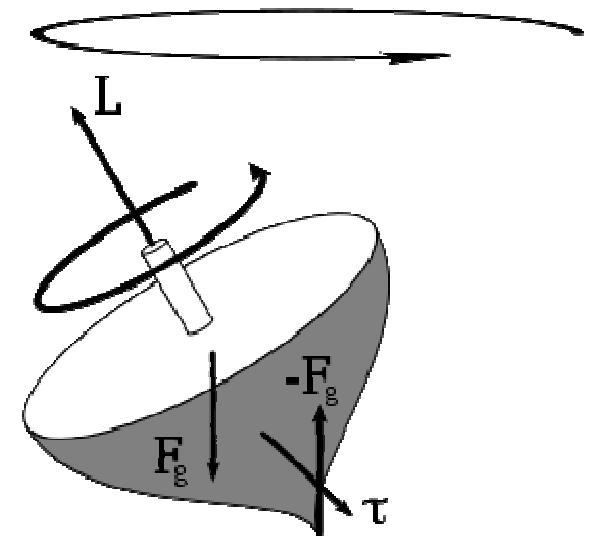
Eötvös Loránd Tudományegyetem  
Fizikai Intézet, Biológiai Fizika Tanszék  
Budapest

„Az atomoktól a csillagokig” előadássorozat  
2008. november 6.

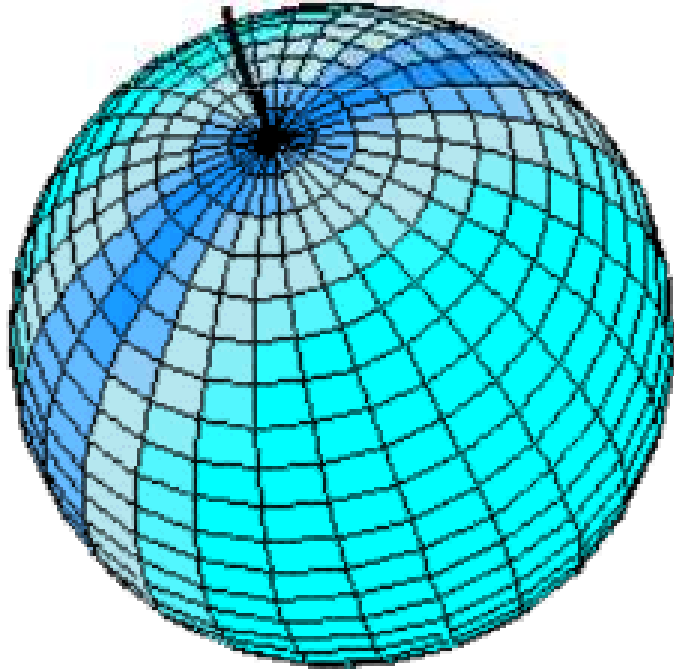
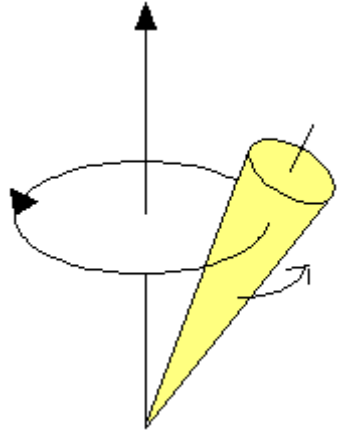
# Rezonancia

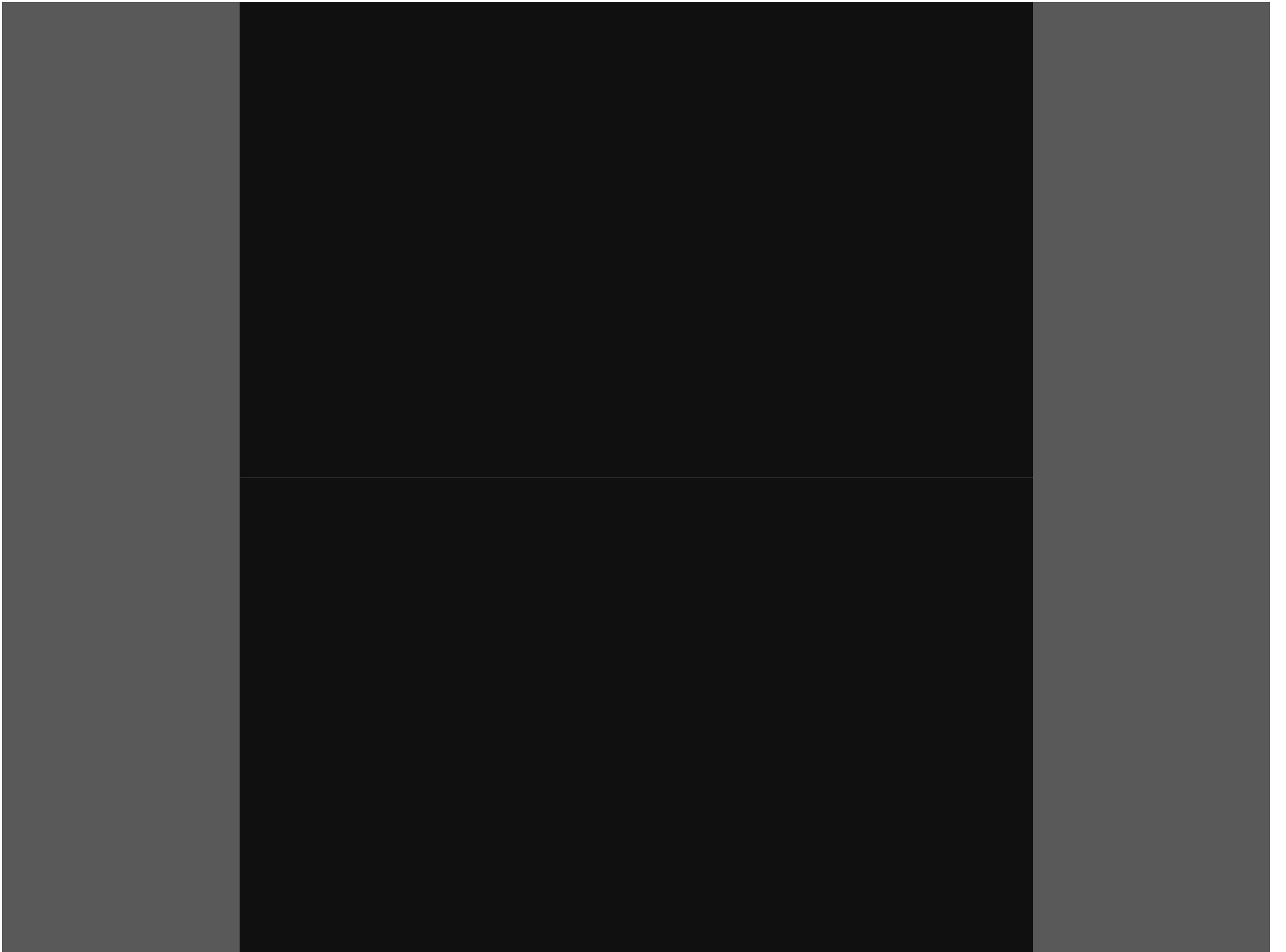


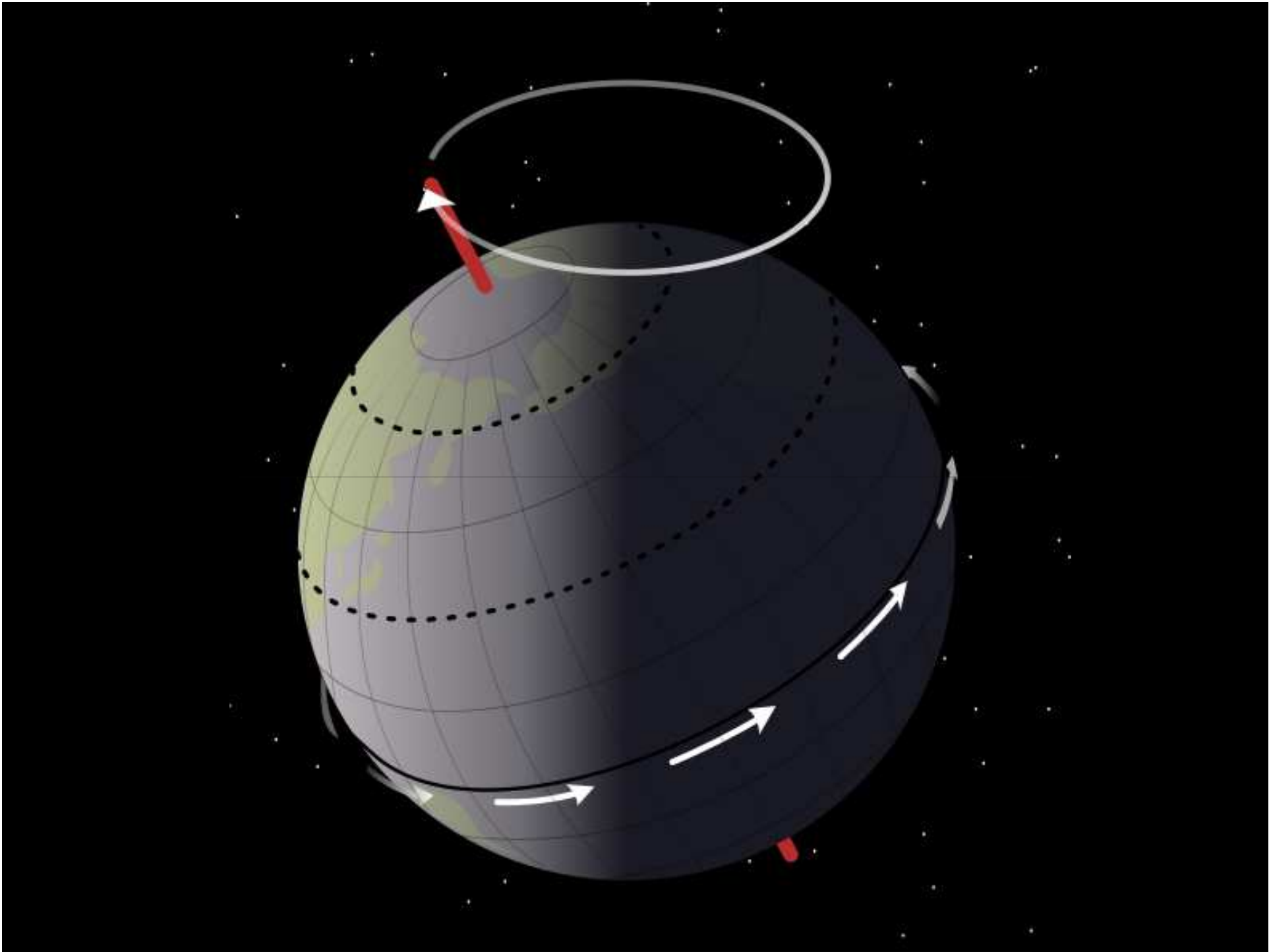
# PRECESSZIÓ

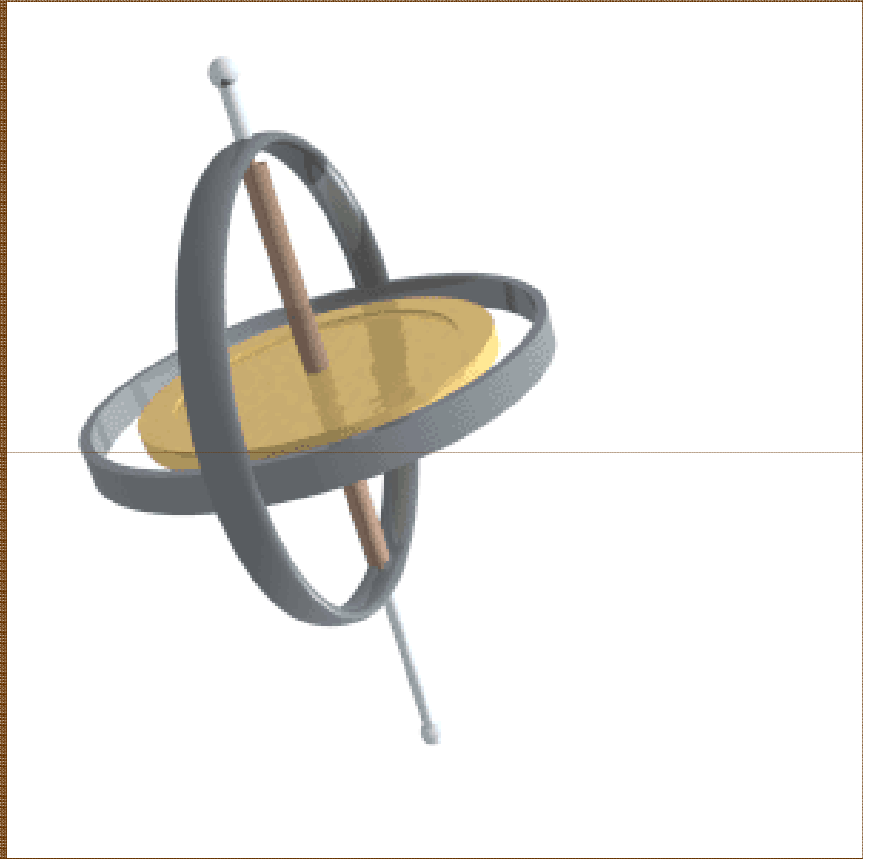
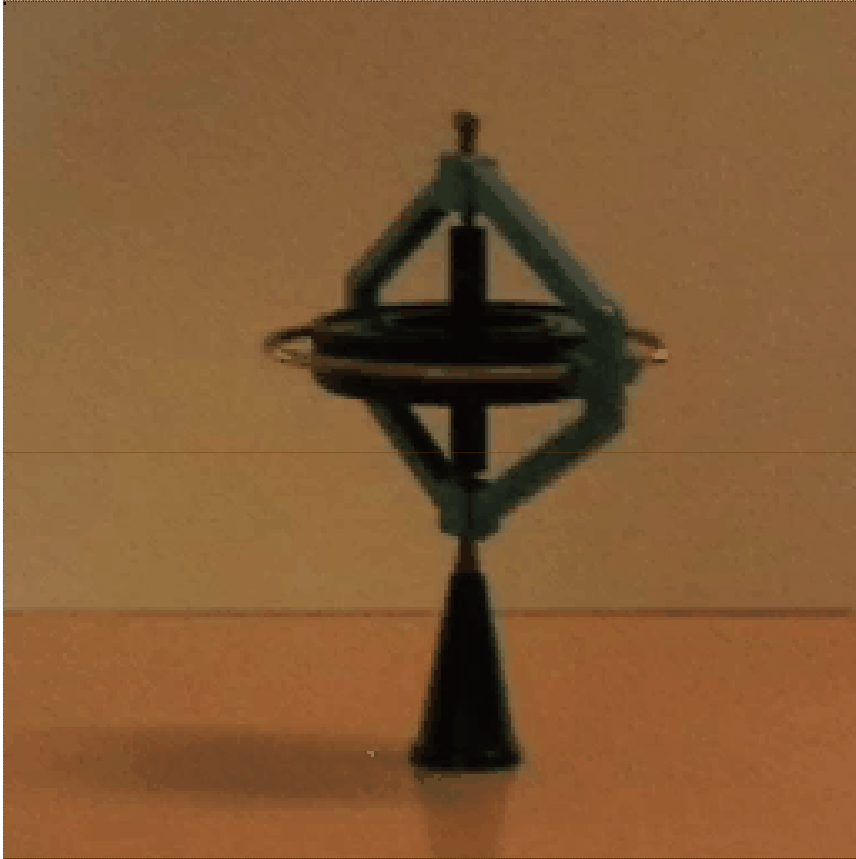


$$\Delta \underline{\mathbf{L}} = \underline{\boldsymbol{\tau}} \cdot \Delta t$$



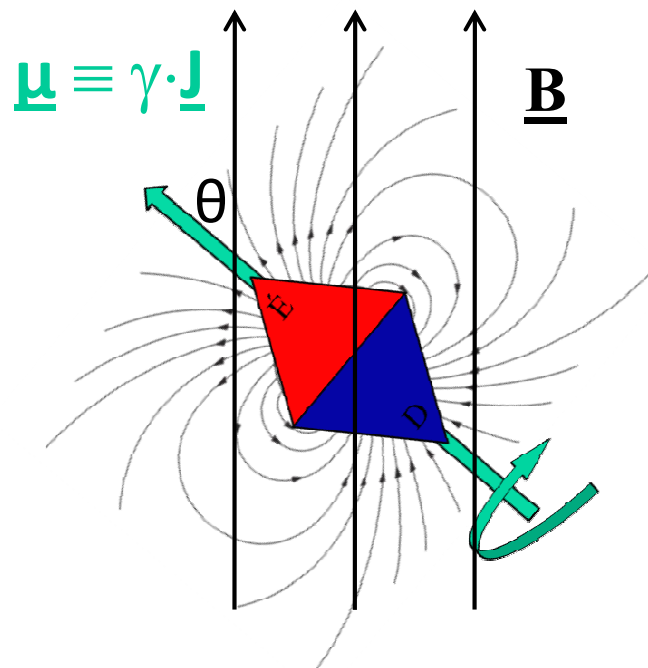






# LARMOR-PRECESSZIÓ: precesszió mágneses mező hatására

giromágneses objektum



$$|\underline{\tau}| = |\underline{\mu}| \cdot |\underline{B}| \cdot \sin\theta = |\underline{\mu} \times \underline{B}|$$

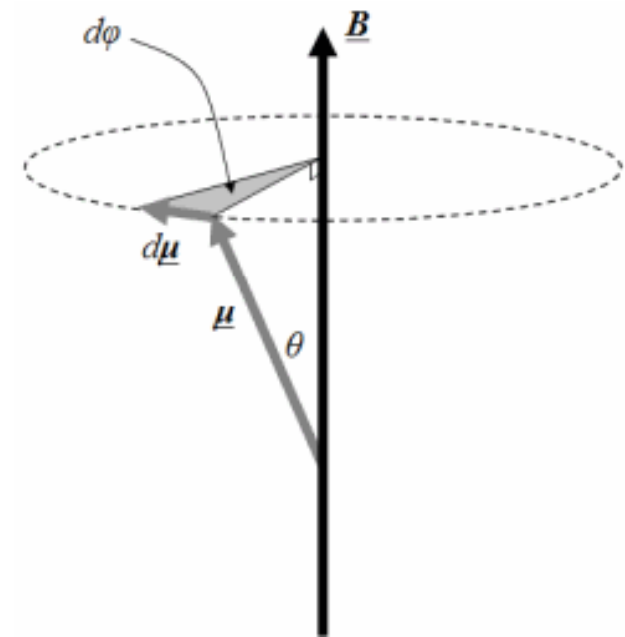
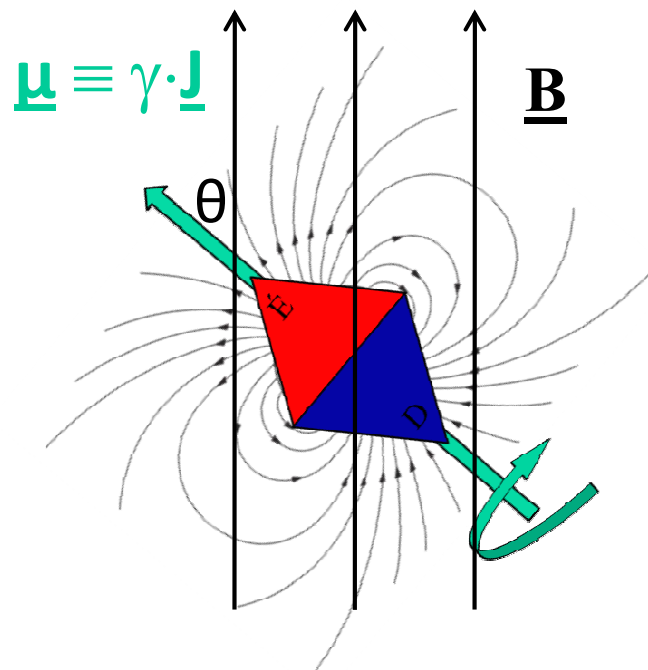


# LARMOR-PRECESSZIÓ:

precesszió mágneses mező hatására

giromágneses objektum

$$\omega_L = \gamma B$$

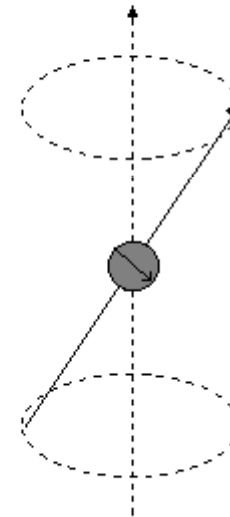
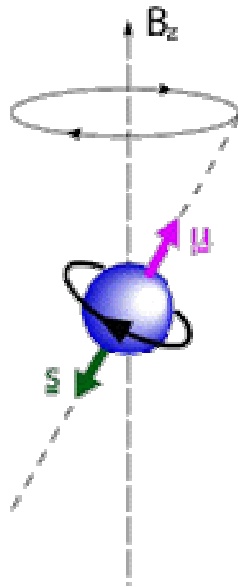


$$|\underline{\tau}| = |\underline{\mu}| \cdot |\underline{B}| \cdot \sin\theta = |\underline{\mu} \times \underline{B}|$$

$$\Delta \underline{J} = \underline{\tau} \cdot \Delta t$$

# LARMOR-PRECESSZIÓ: precesszió mágneses mező hatására

$$\omega_L = \gamma B$$



precesszáló spin

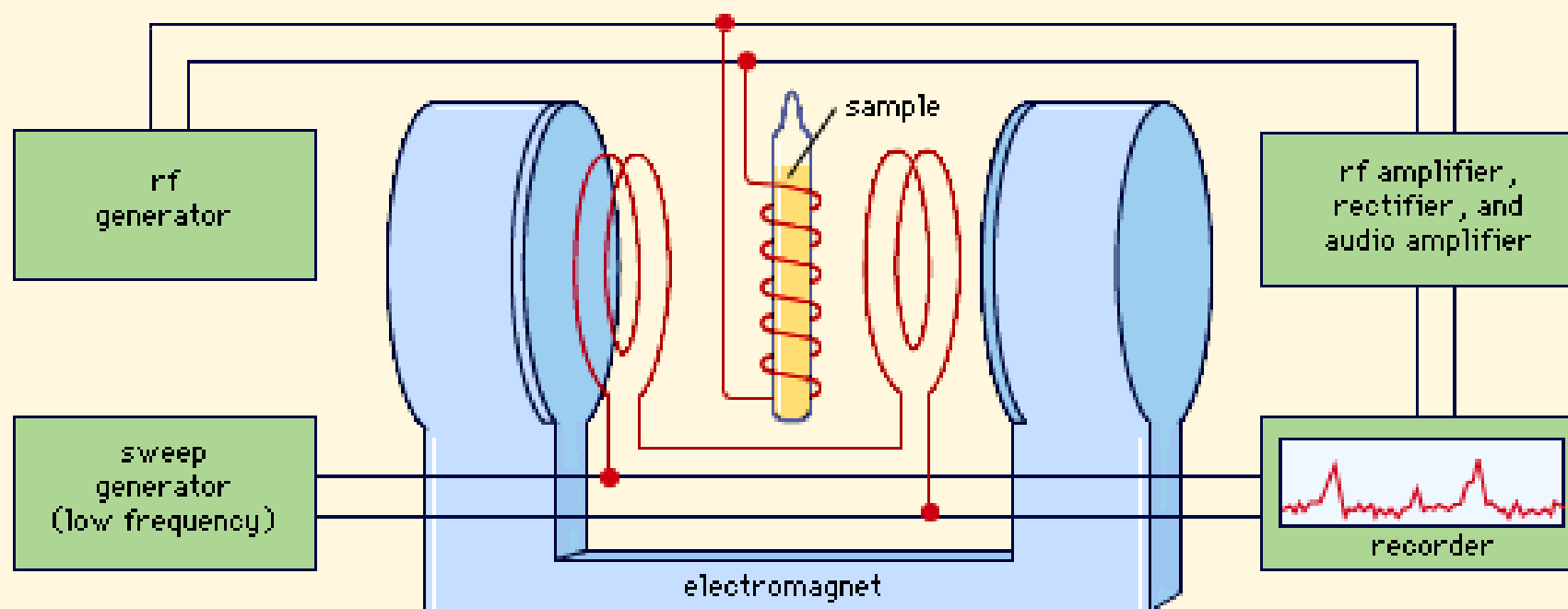
# Mágneses rezonancia

1944 Jevgenyij K. Zavojszkij :

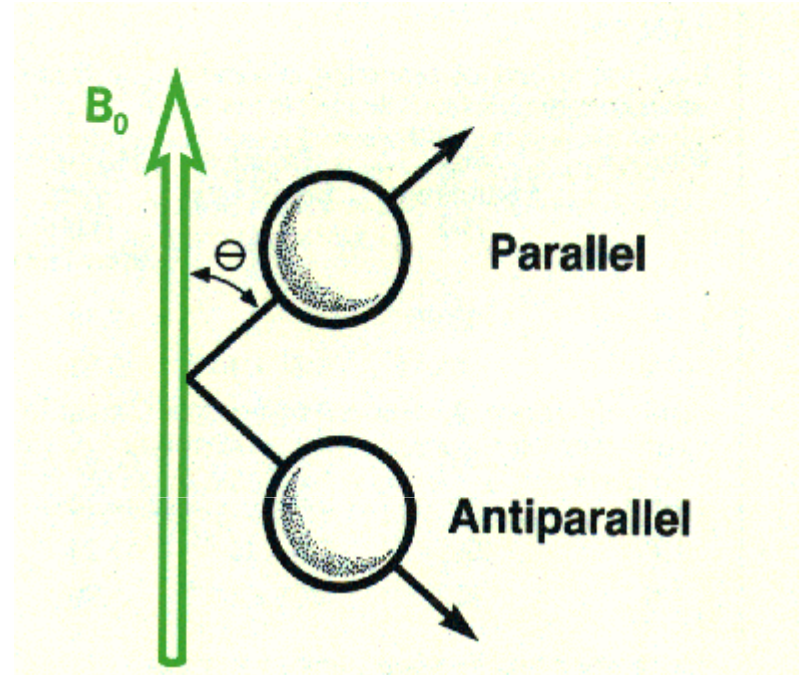
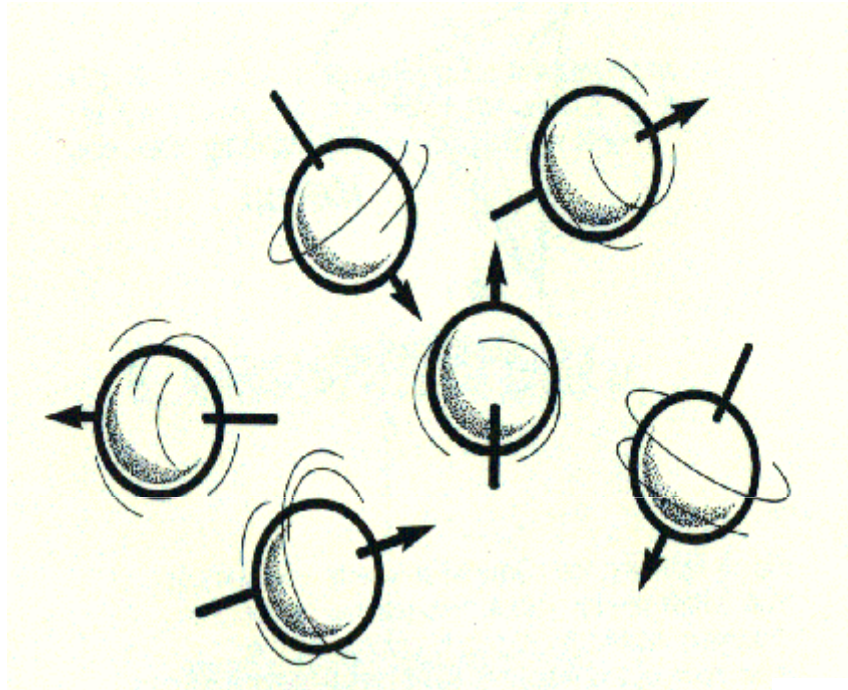
mágneses rezonancia elektronokon → ESR (=EPR)

1945 Felix Bloch, Edward M. Purcell:

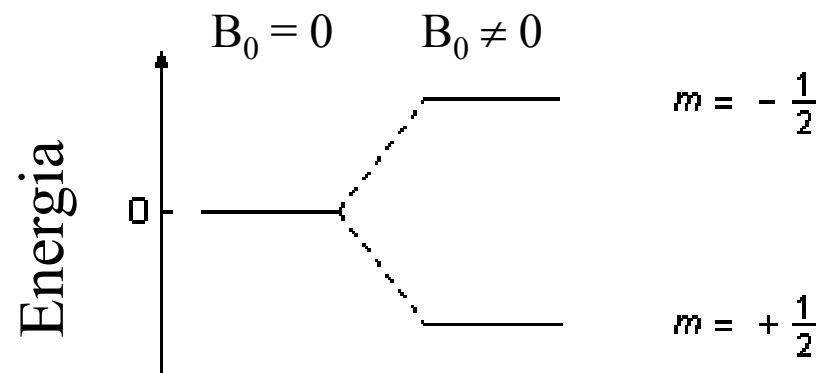
mágneses rezonancia protonokon → NMR

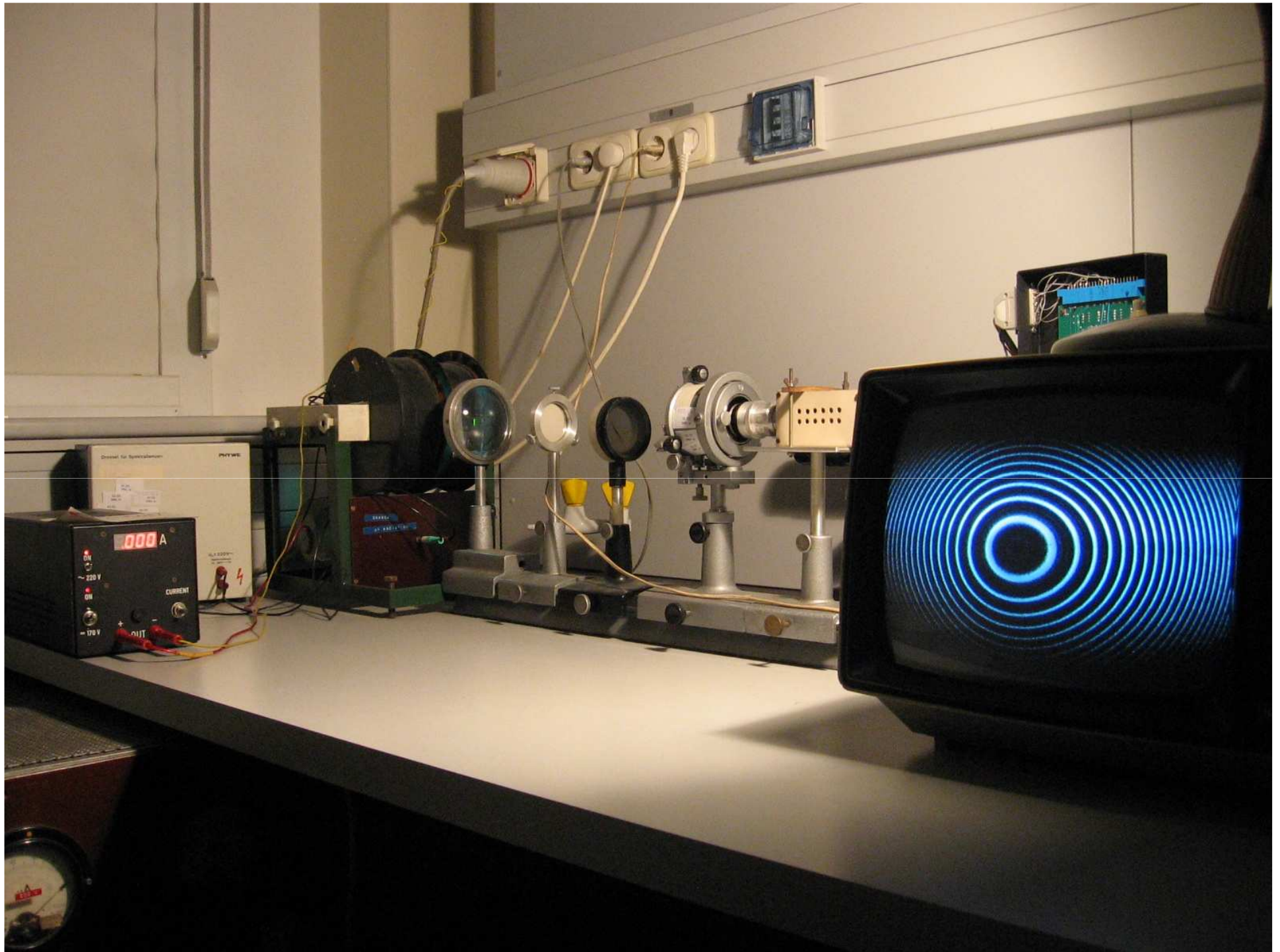


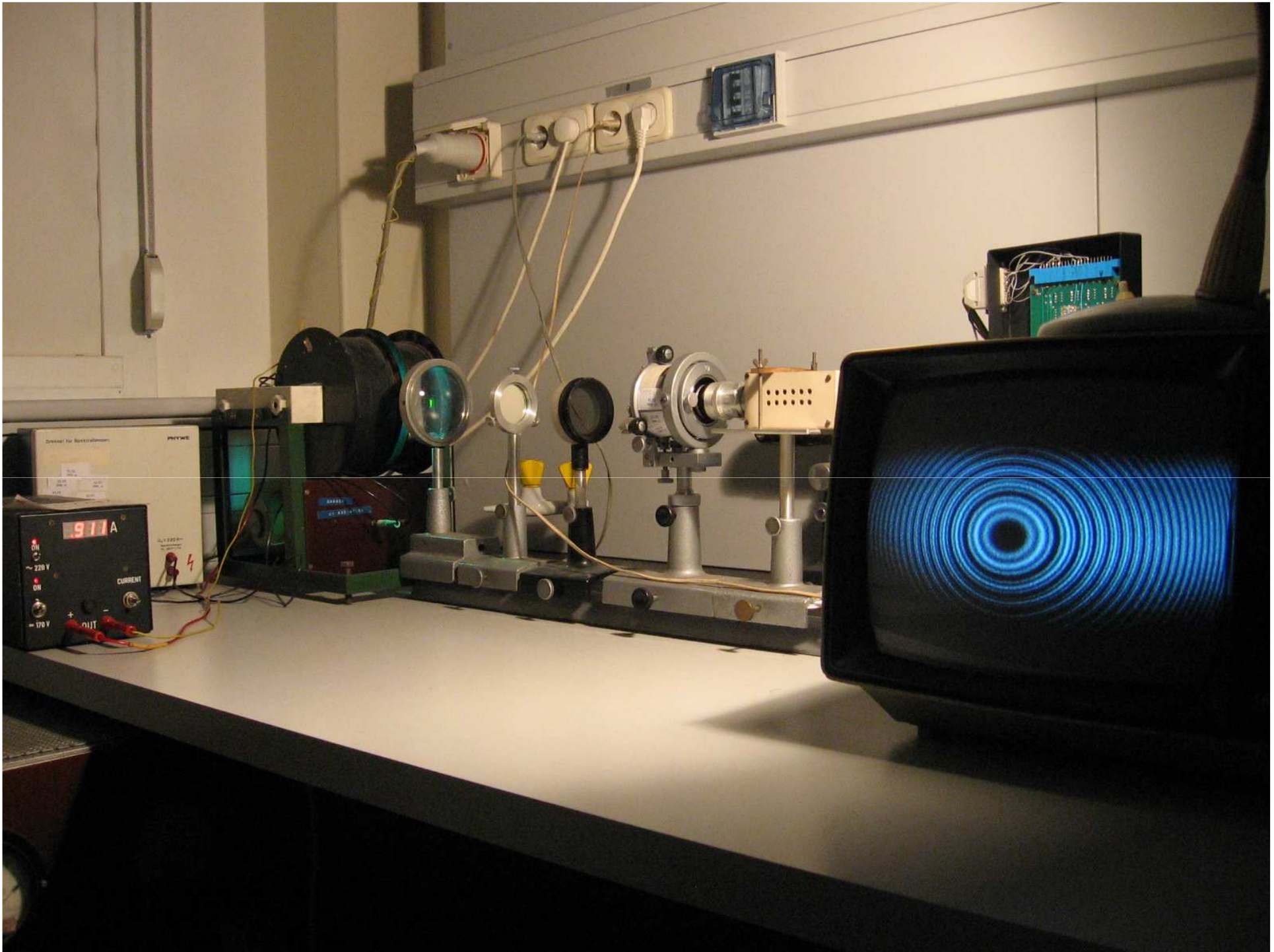
# Zeeman-felhasadás



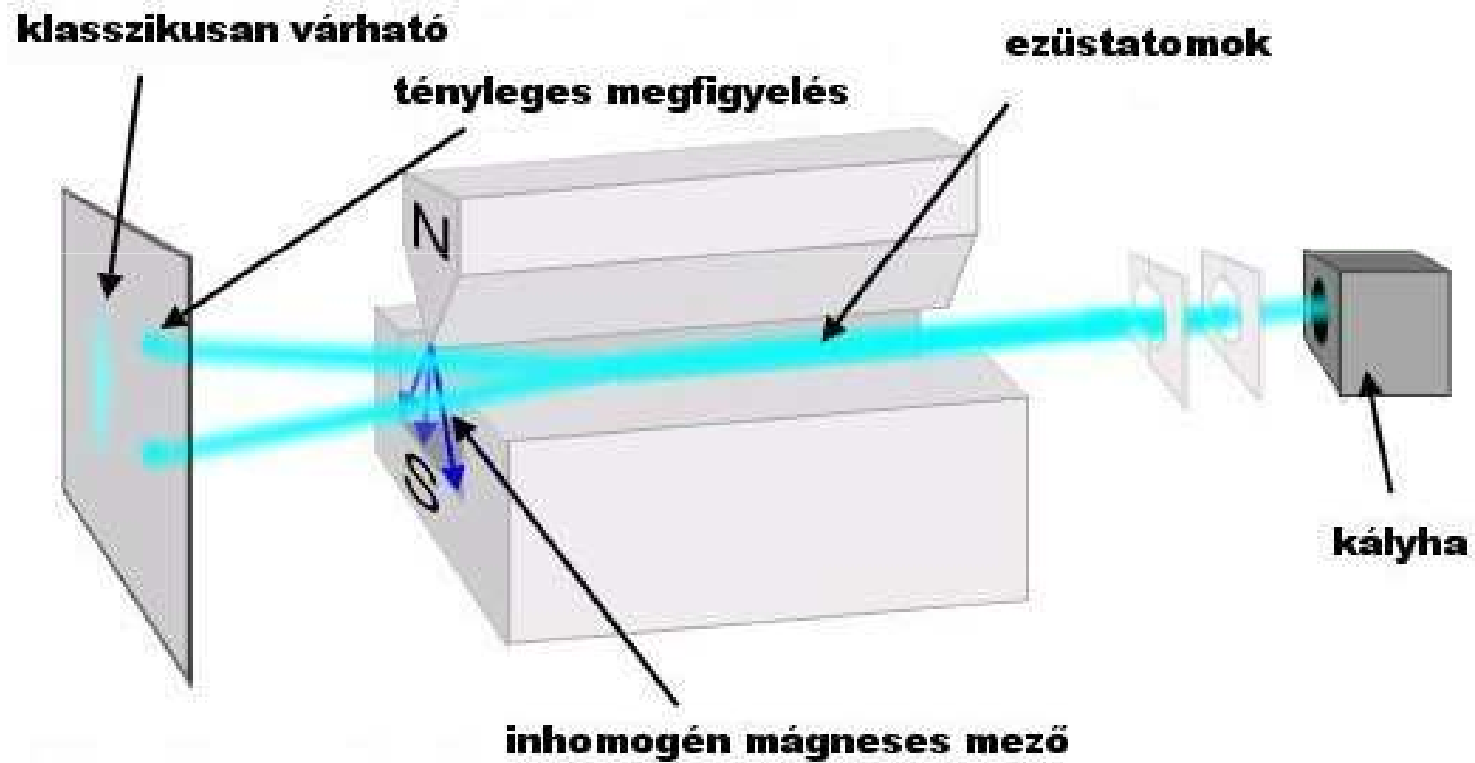
$$E = -\underline{\mu} \cdot \underline{B} = -\mu_z \cdot B = -\gamma \cdot \hbar \cdot m \cdot B$$



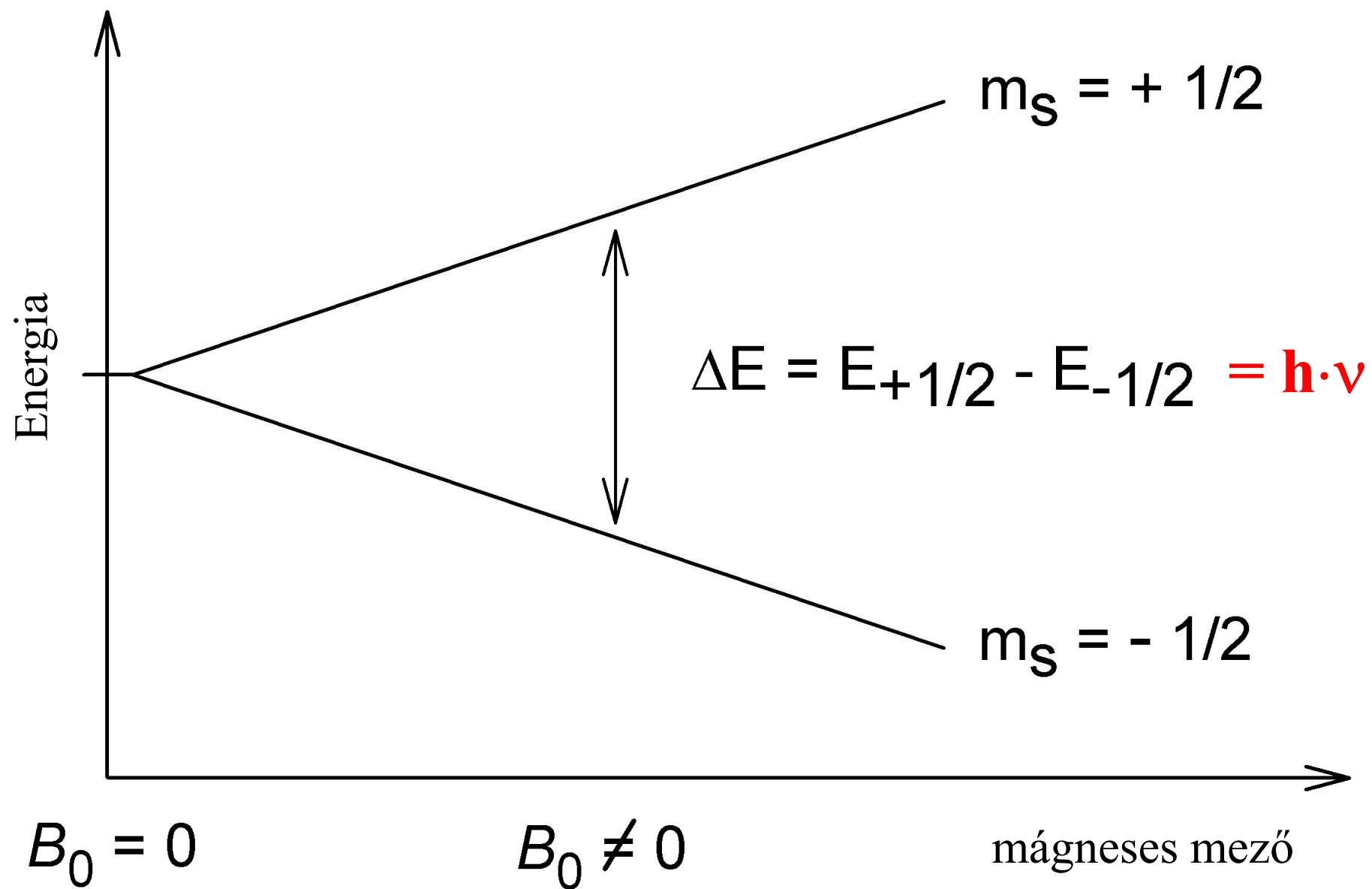




# Stern – Gerlach kísérlet



## Zeeman-felhasadás



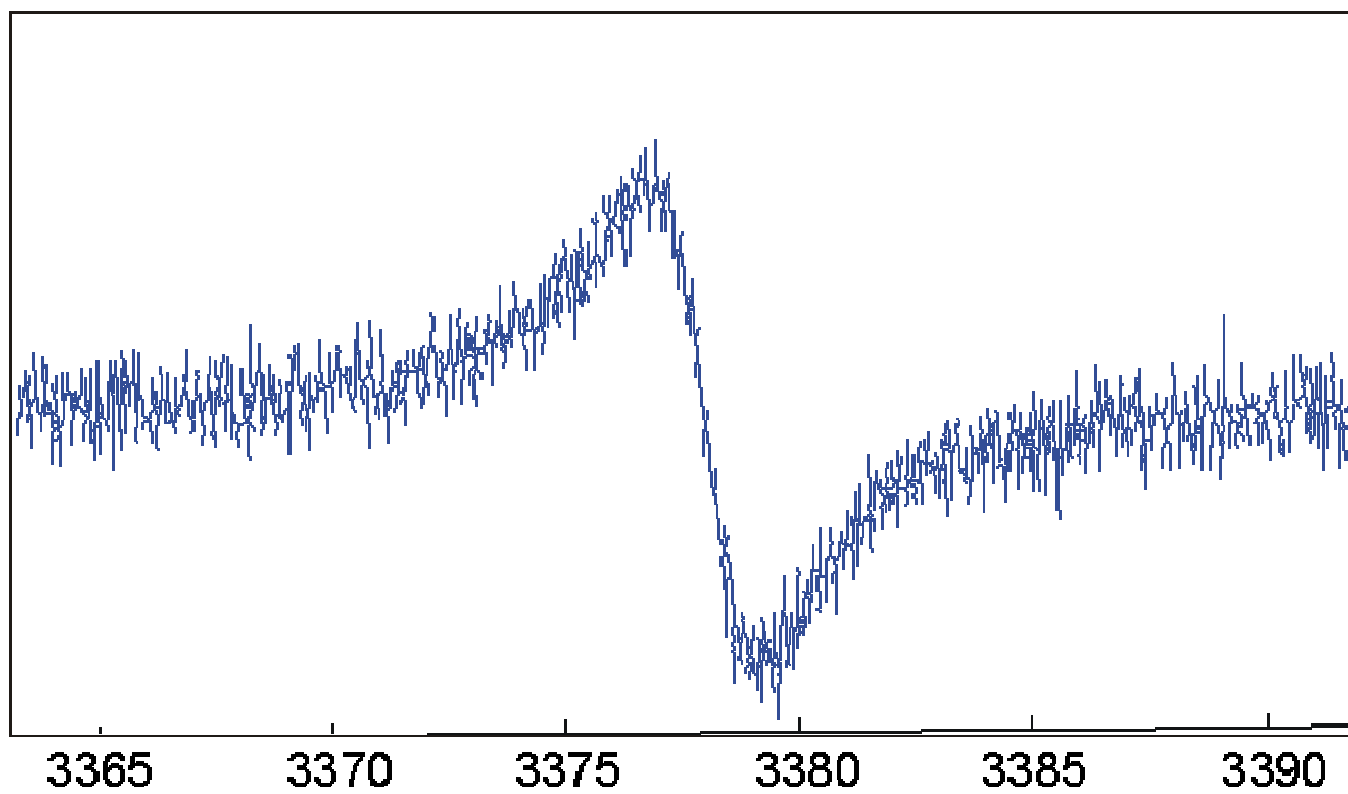


**ELEKTRON SPIN REZONANCIA (ESR)**

vagy

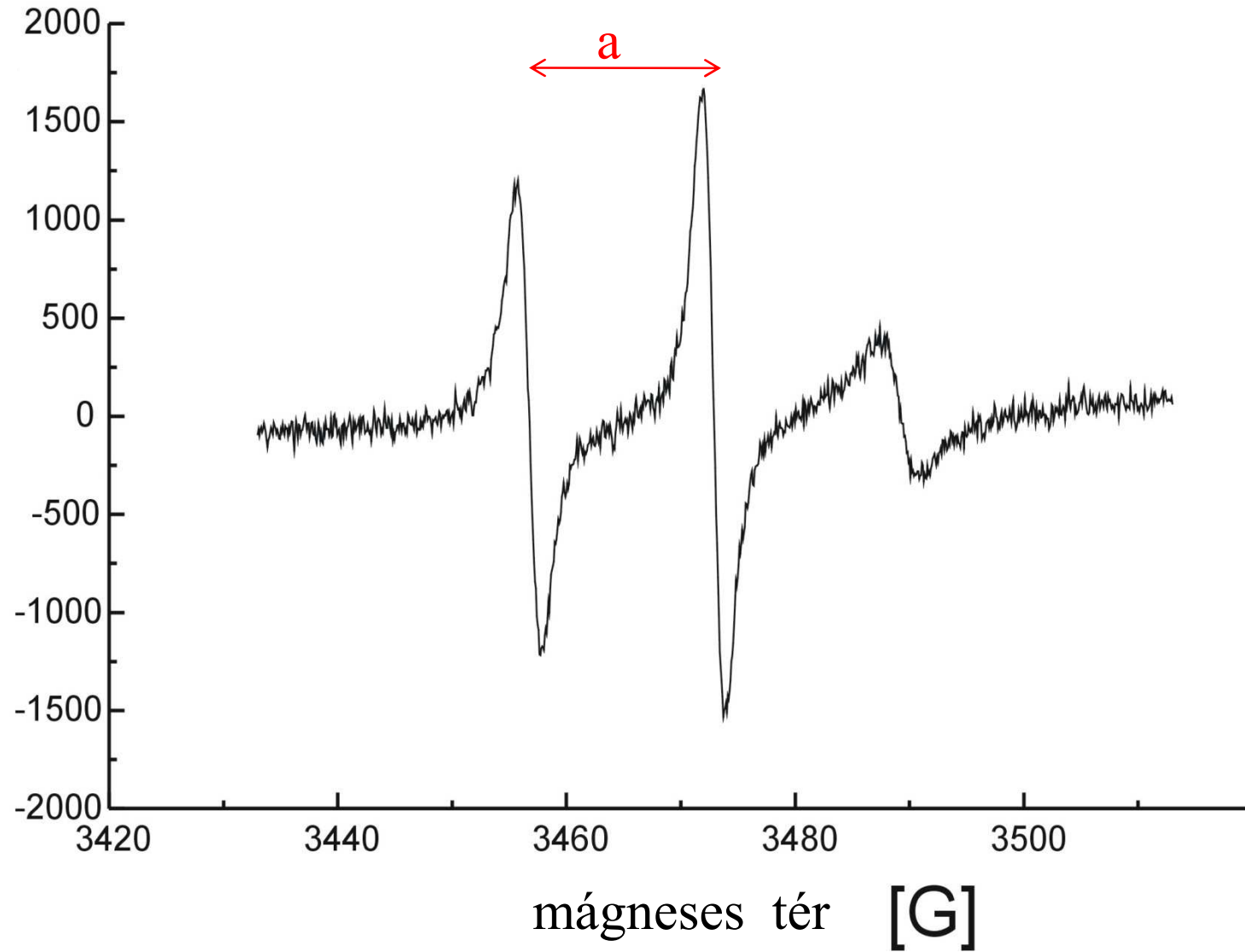
**ELEKTRON PARAMÁGNESES REZONANCIA (EPR)**





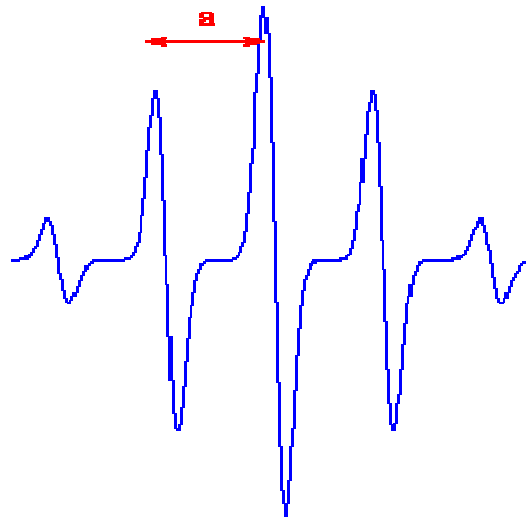
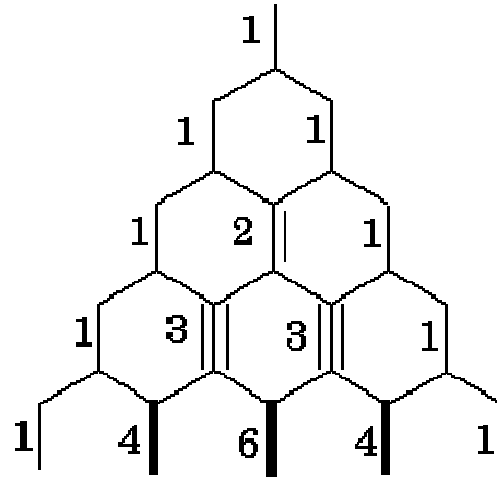
$\nu = 10$  GHz

# ESR – spektrum hiperfinom felhasadással ( $I=1$ )

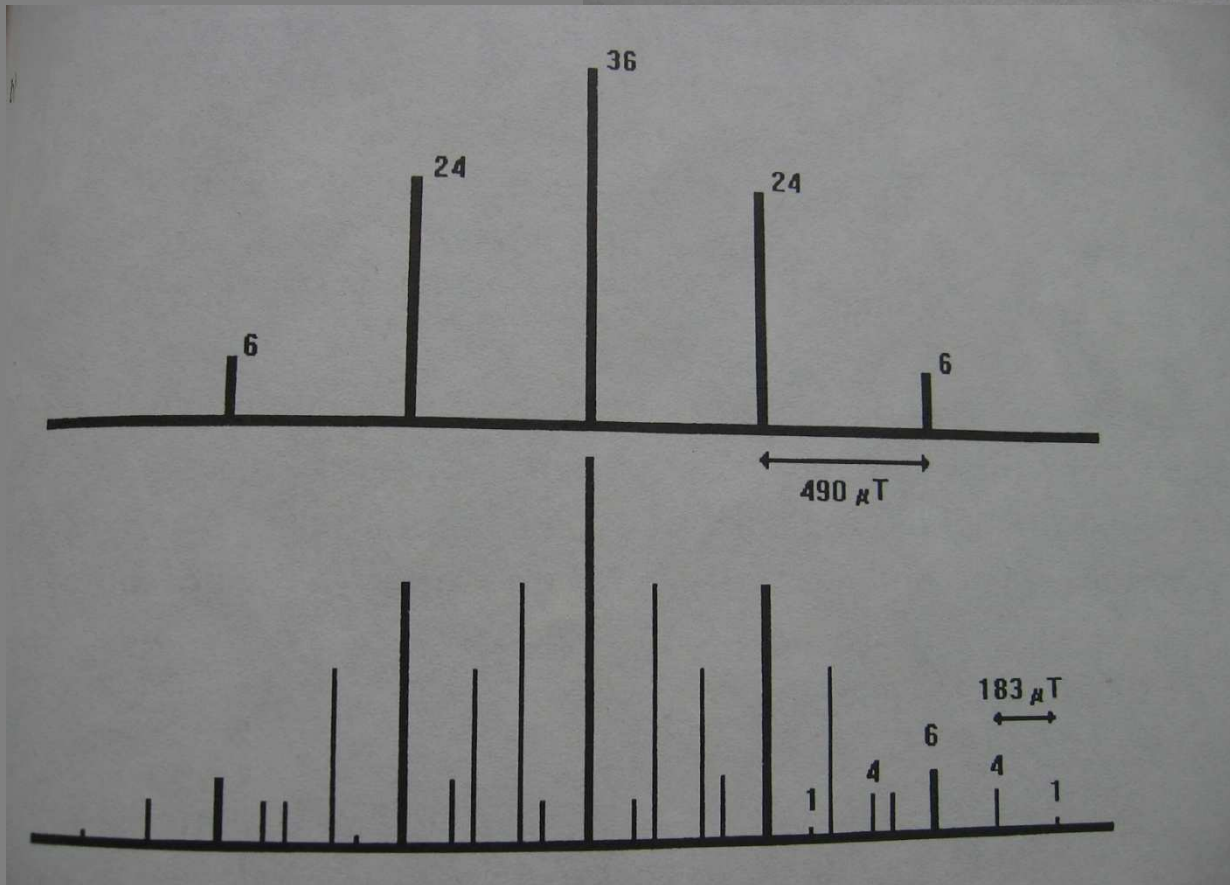
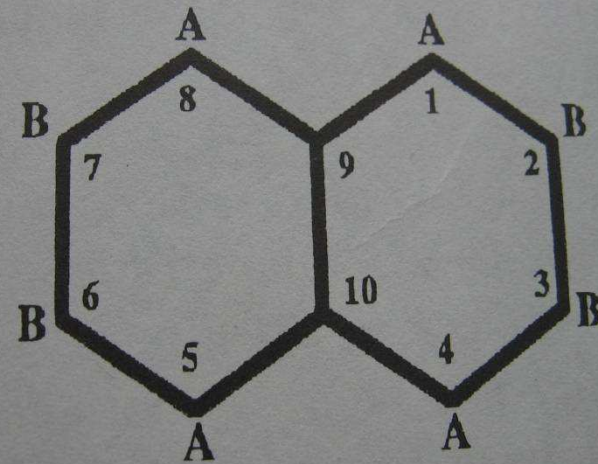


$\nu = 10 \text{ GHz}$

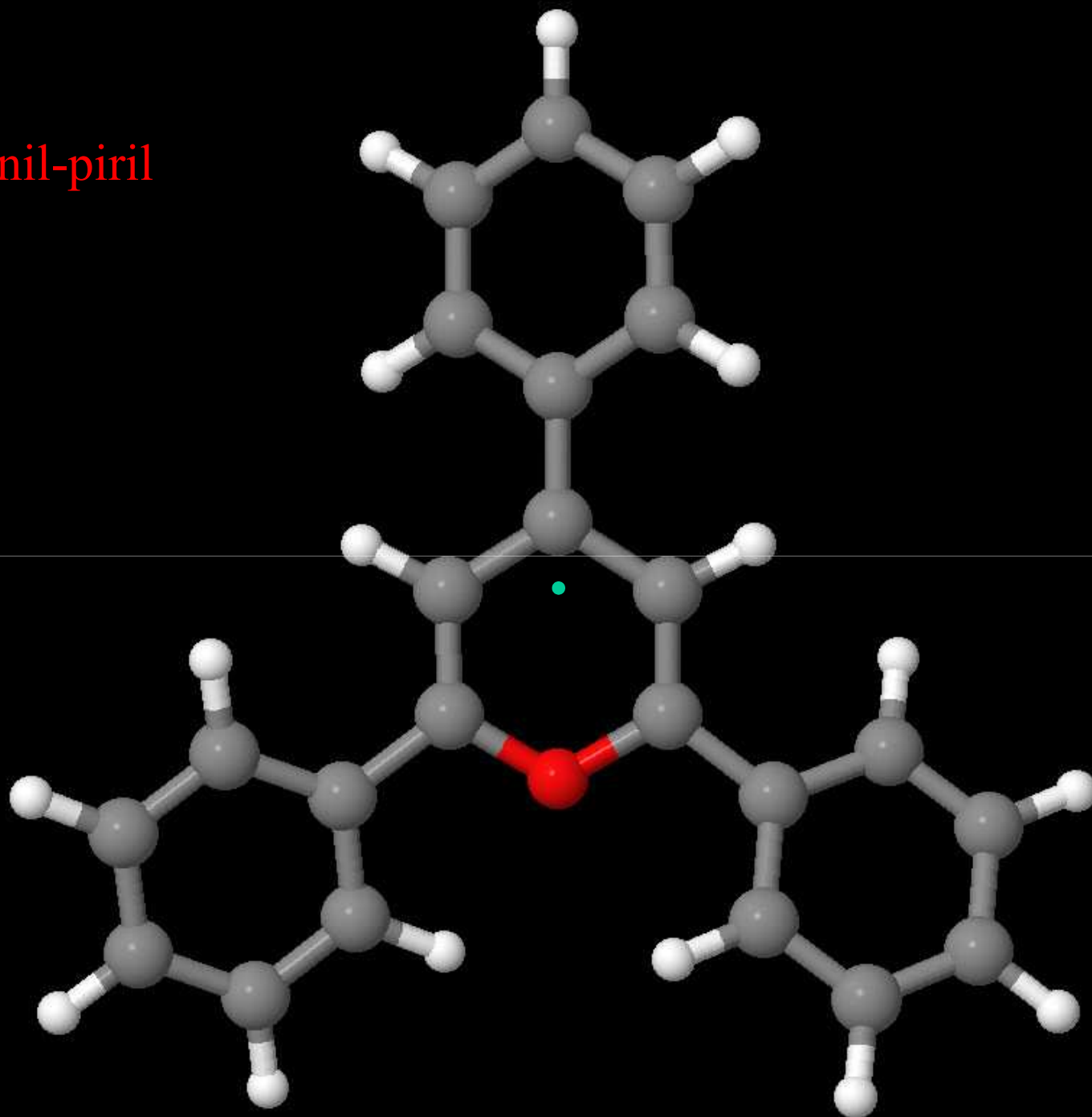
ESR – spektrum hiperfinom felhasadással  
(négy darab ekvivalens  $I=1/2$  mag hatására)

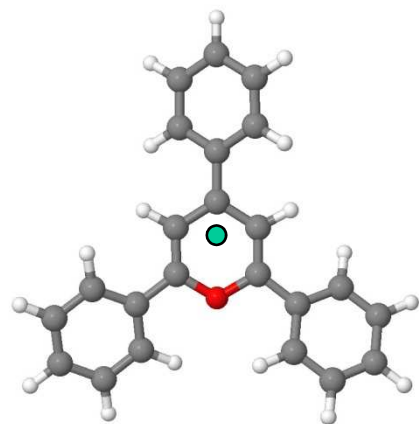


naftalin -



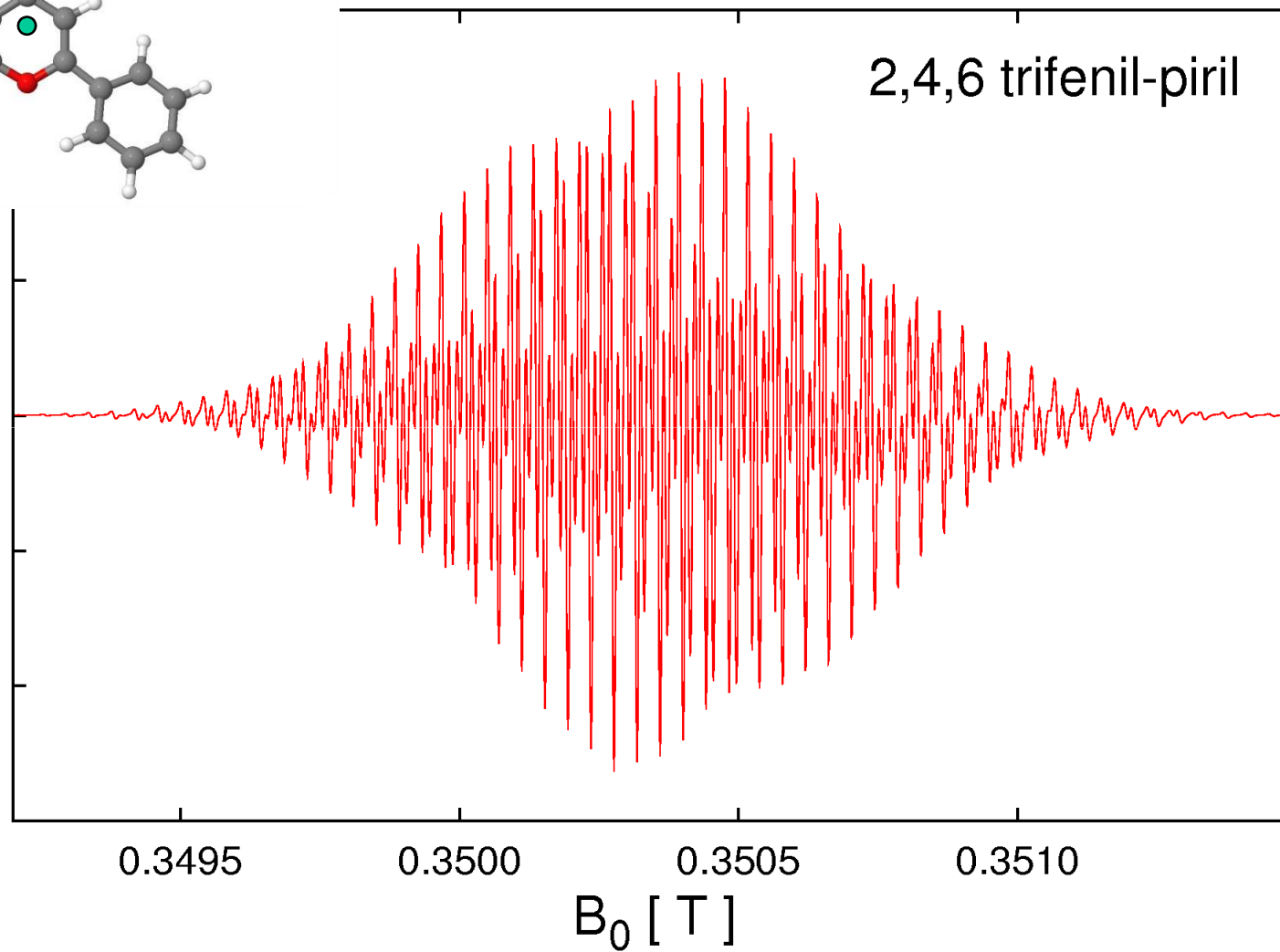
2,4,6 trifenil-piril





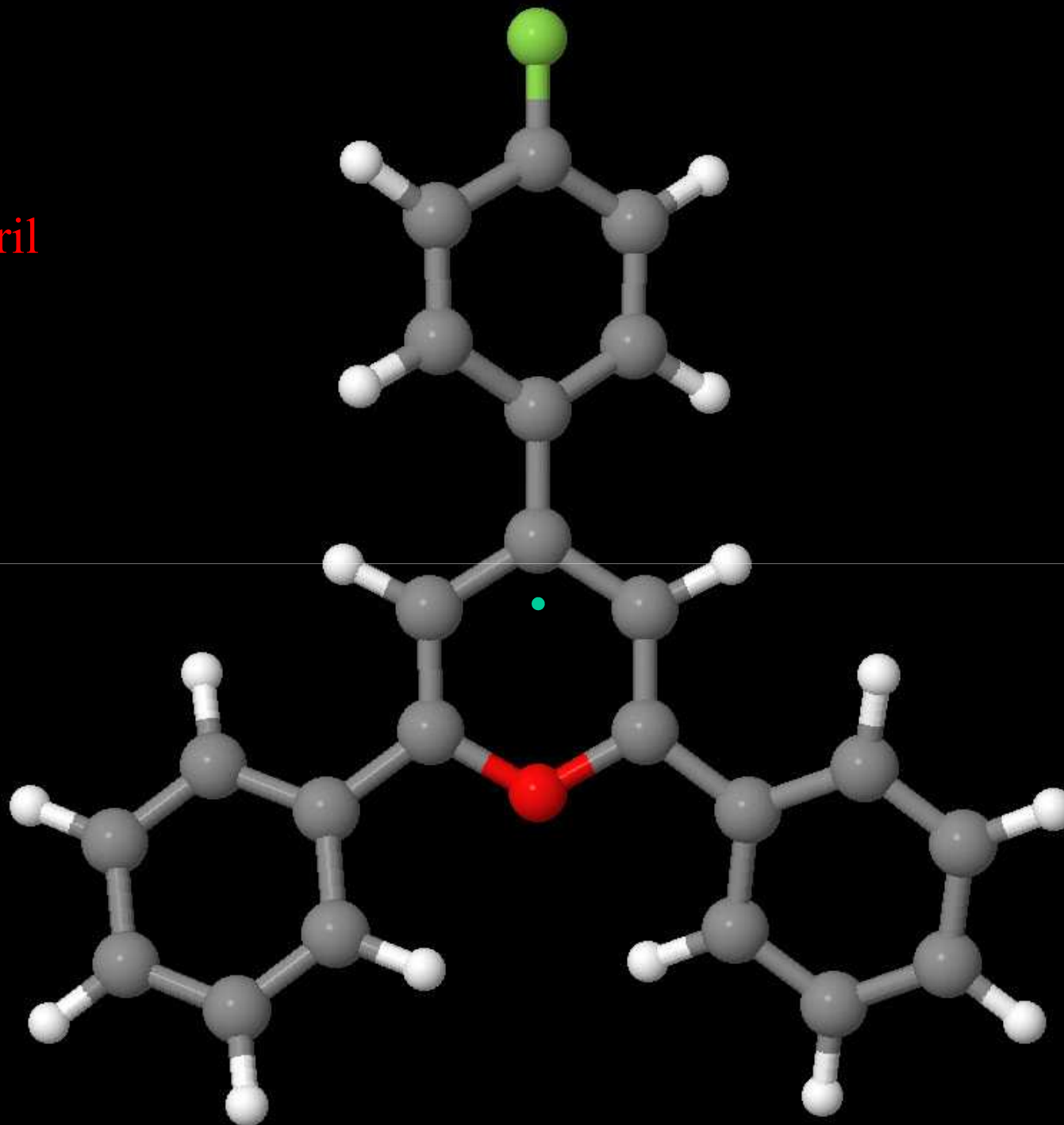
2,4,6 trifenil-piril

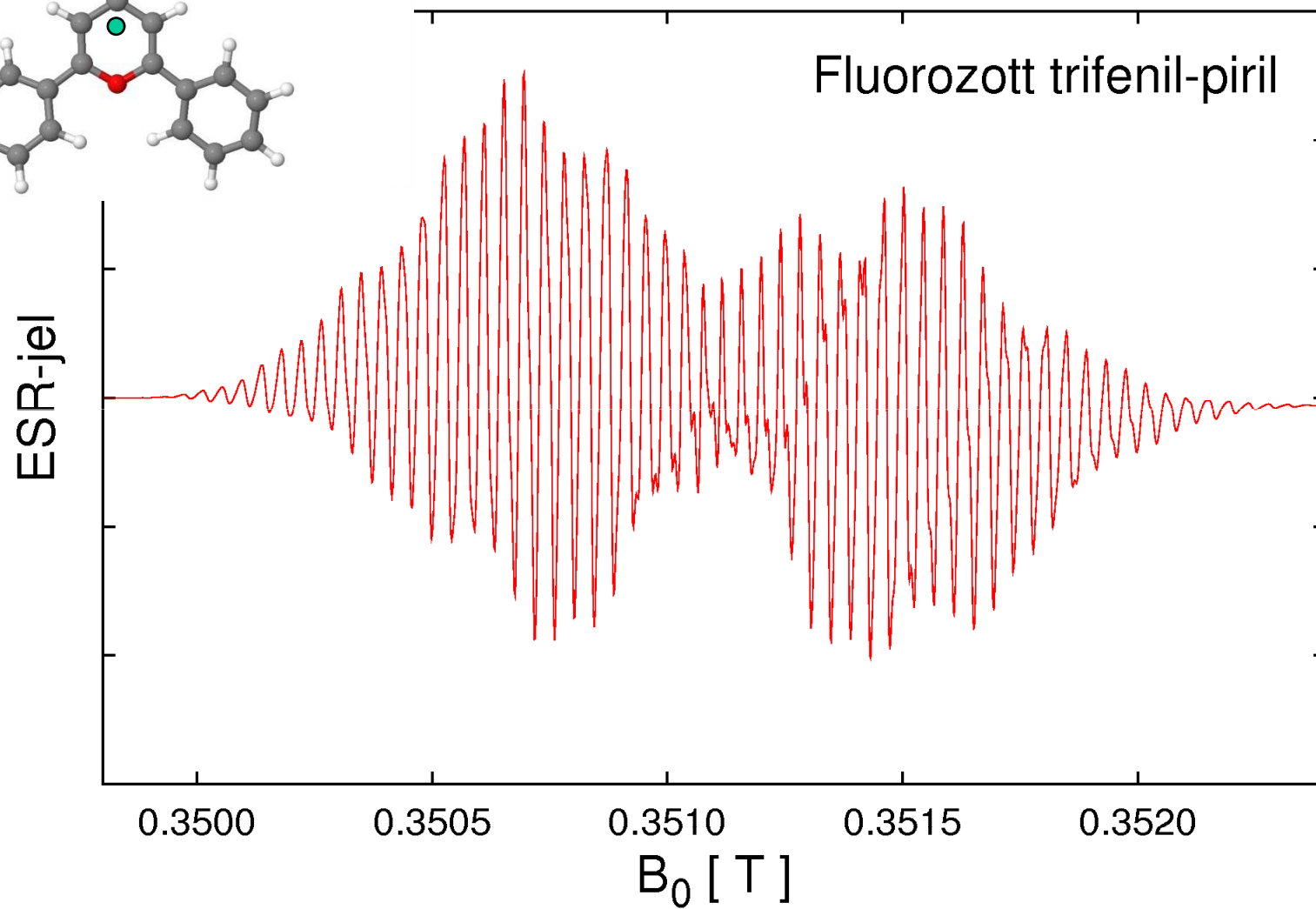
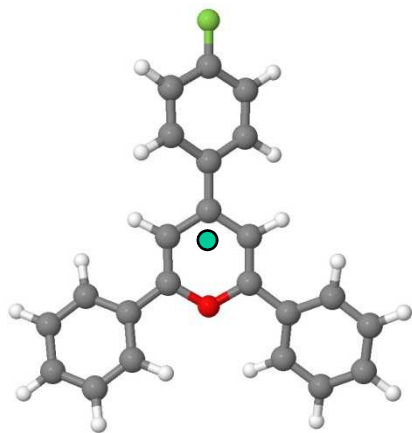
ESR-jel



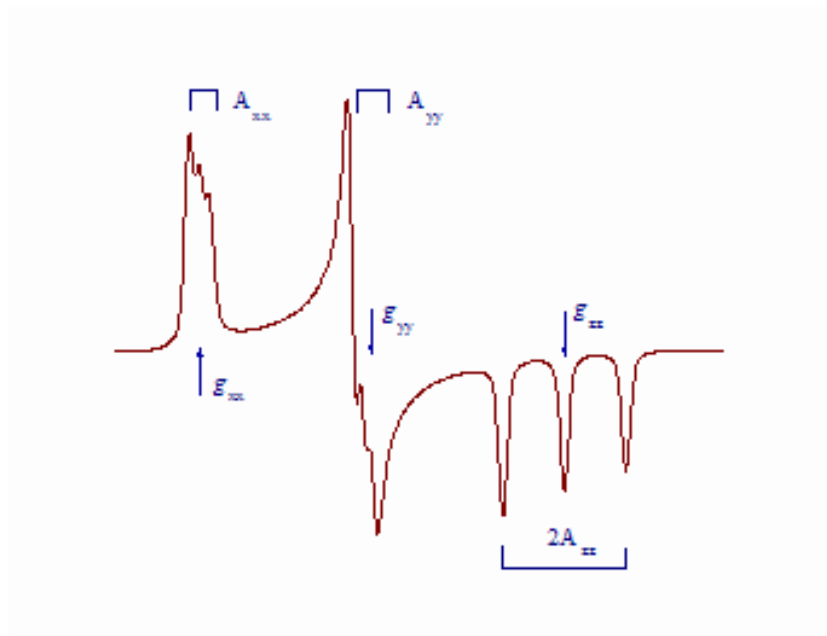


fluorozott  
trifenil-piril

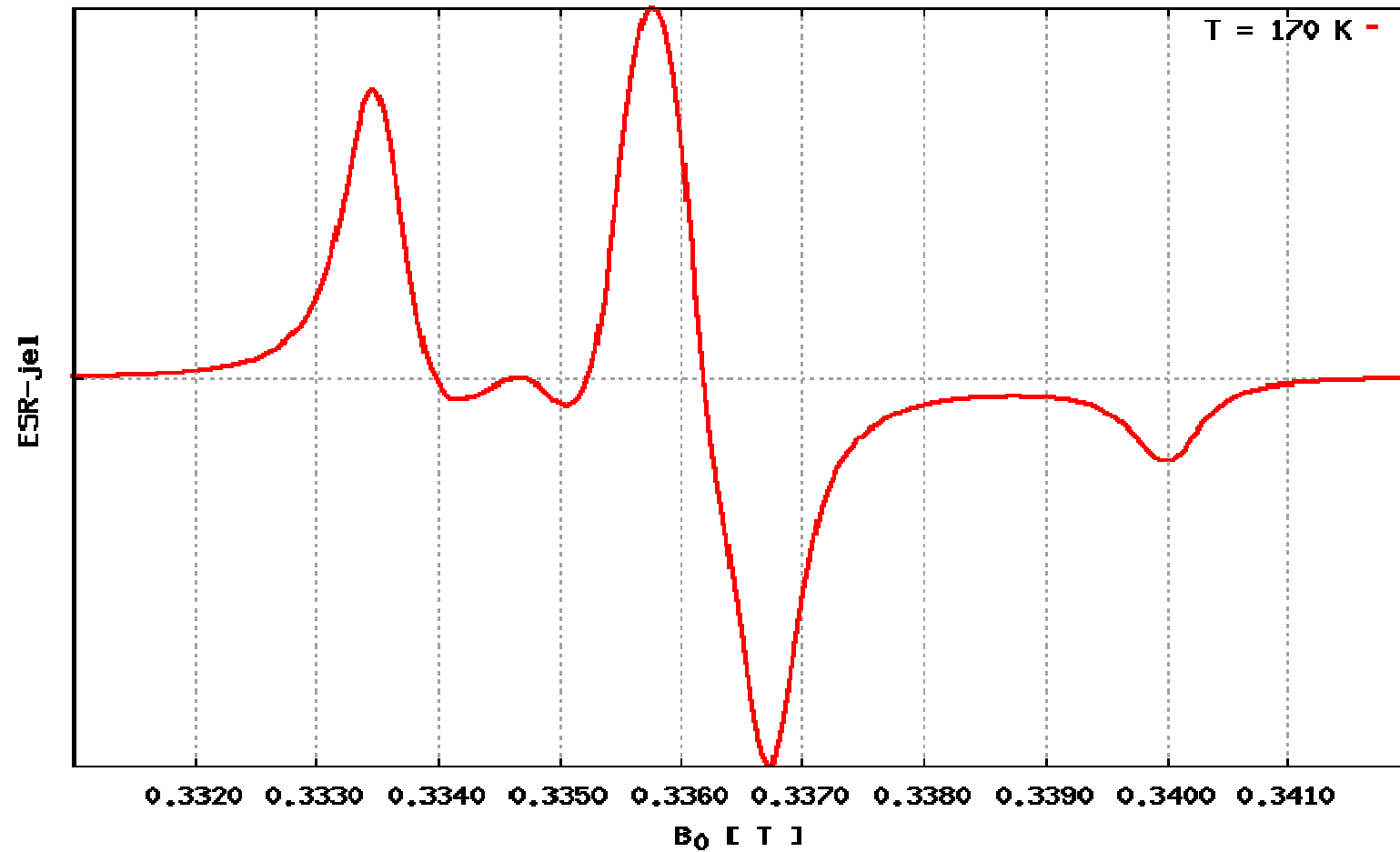




## spinjelző (anizotrop) ESR-spektruma



# spinjelző (TEMPO) – hőmérsékletfüggés



# NUCLEAR MAGNETIC RESONANCE (NMR)

(MAG MÁGNESES REZONANCIA)

$^1\text{H}$

$^{13}\text{C}$

$^{31}\text{P}$ ,  $^{15}\text{N}$ ,  $^{29}\text{Si}$ ,  $^{19}\text{F}$ ,  $^{17}\text{O}$ , ...

# NMR Nobel-díjak

1952, fizika: Felix Bloch



, Edward Mills Purcell



első NMR készülék

1991, kémia: Richard R. Ernst



FT-NMR és 2D-NMR, bonyolult molekulák szerkezetének meghatározására

2002, kémia: Kurt Wüthrich



NMR fejlesztése fehérjék 3D szerkezetének meghatározására

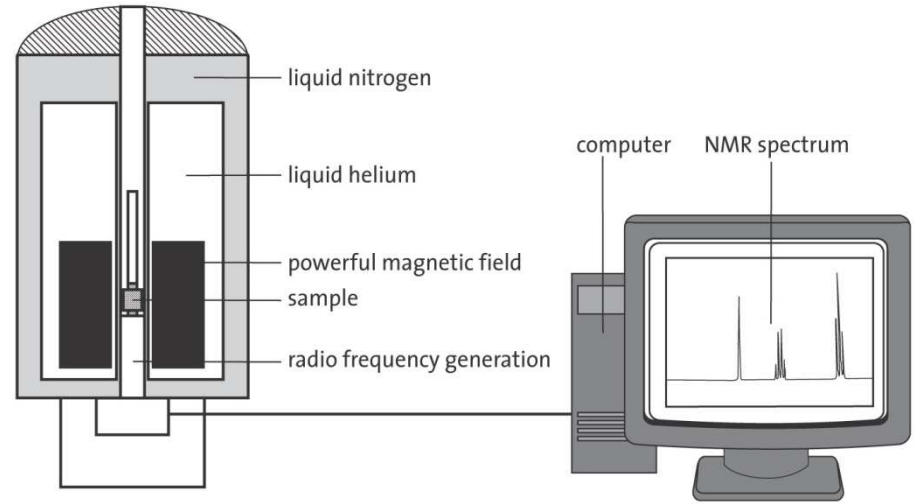
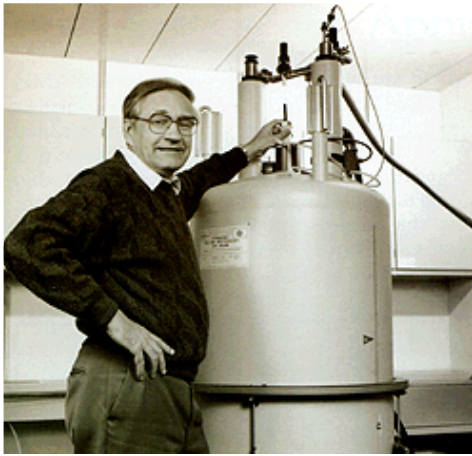
2003, orvosi: Paul C. Lauterbur



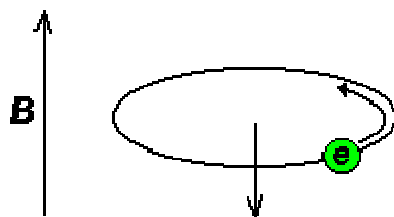
, Sir Peter Mansfield



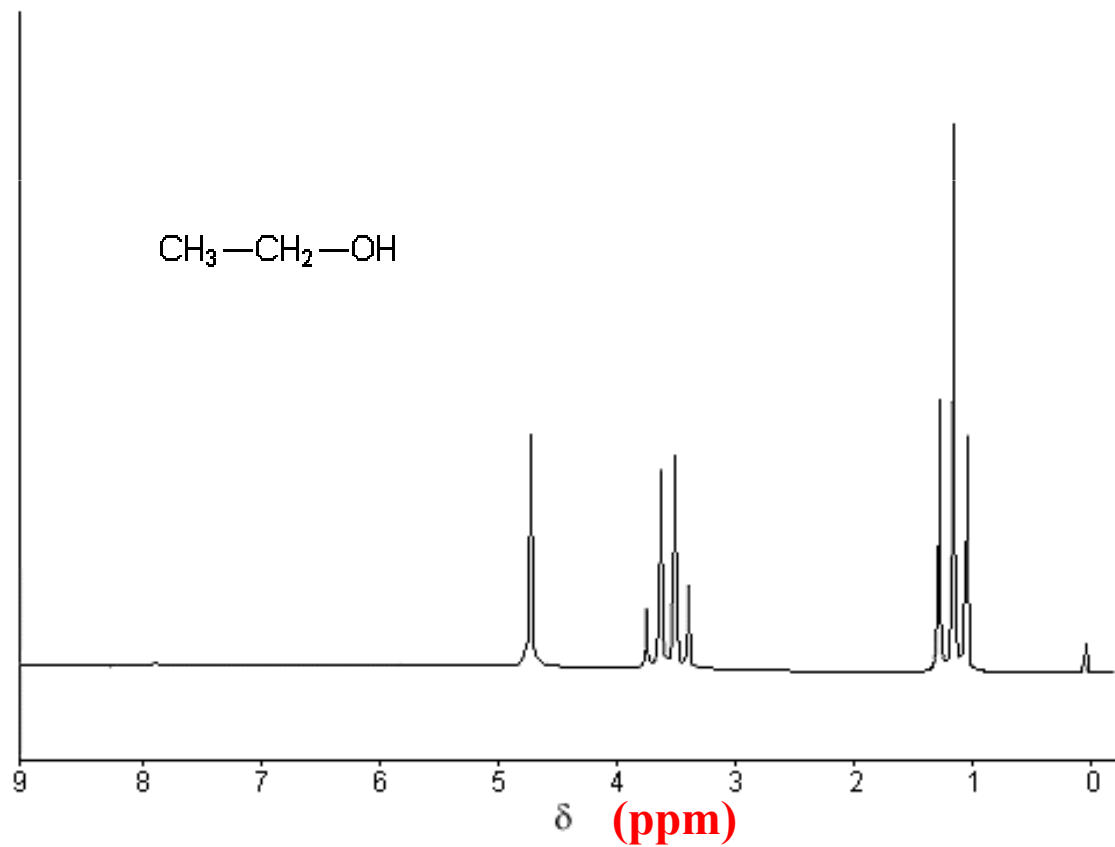
MRI kifejlesztése és orvosi alkalmazása



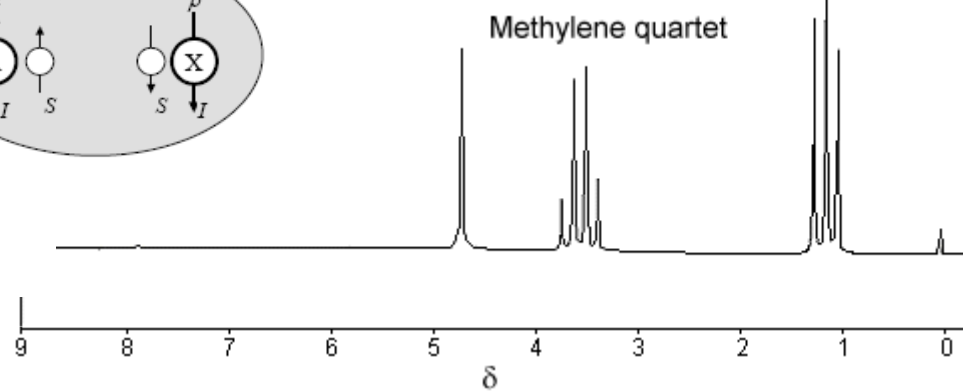
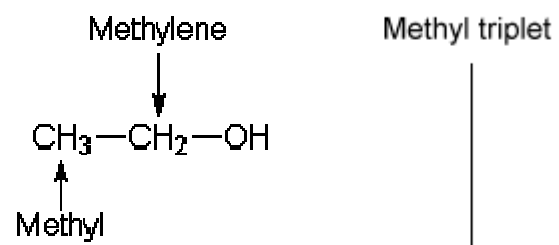
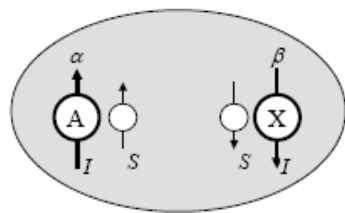
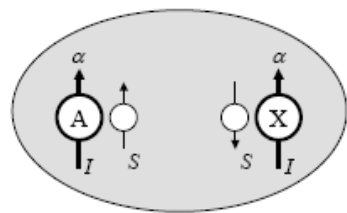
# kémiai eltolódás (diamágneses árnyékolás)

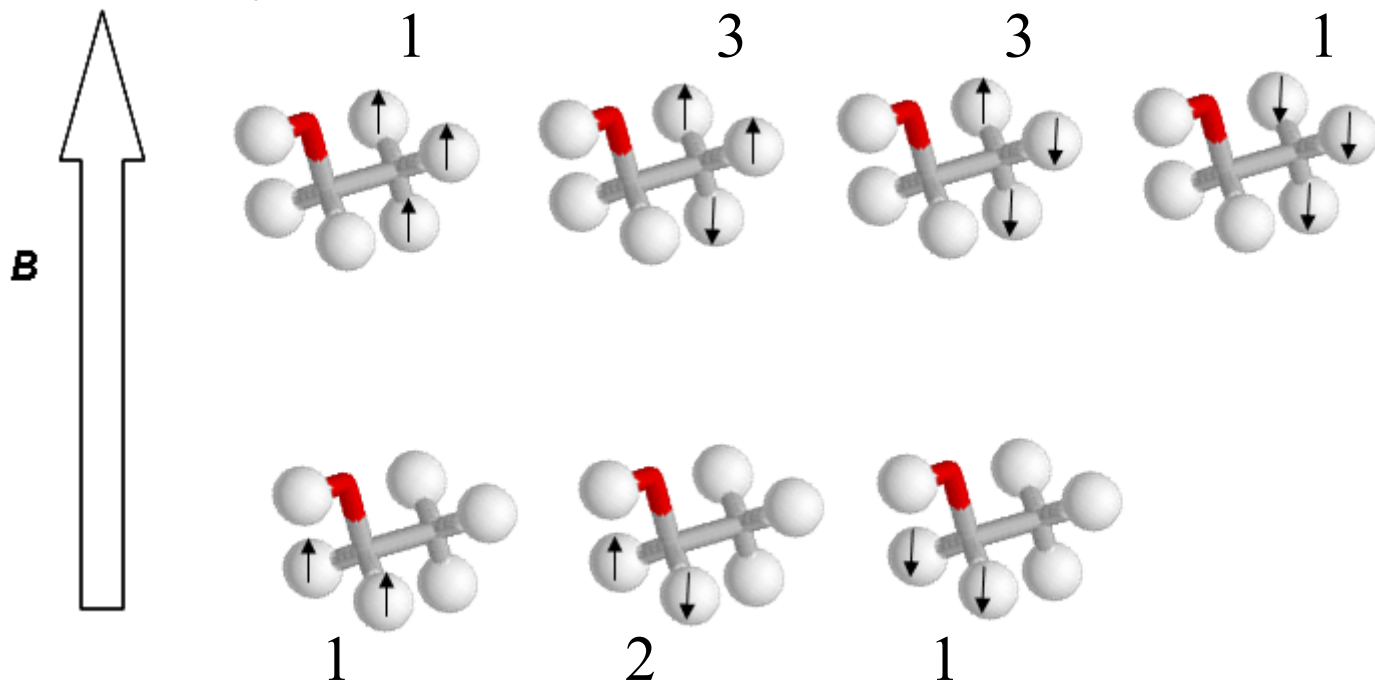
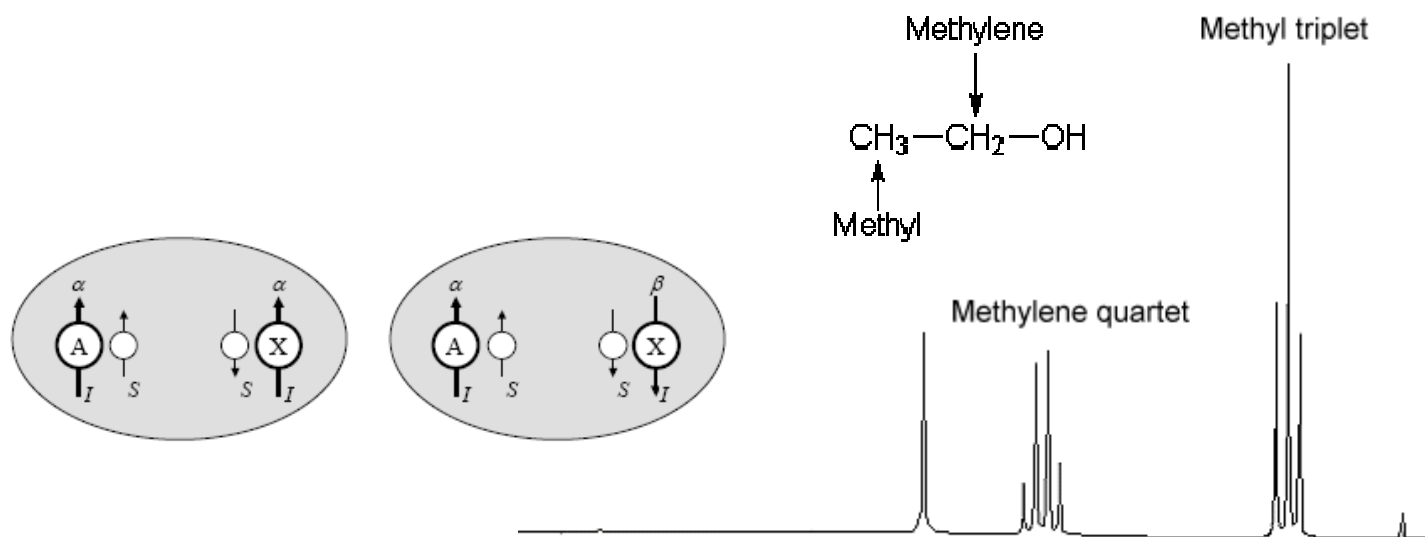


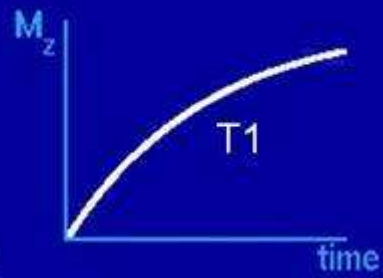
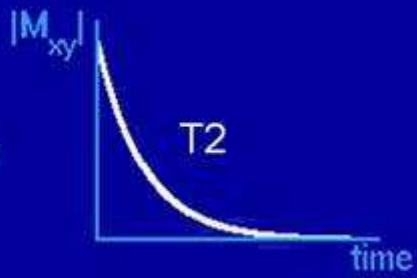
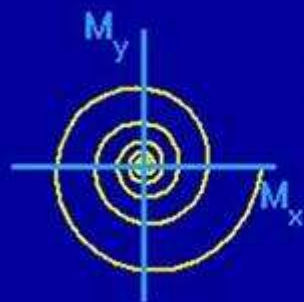
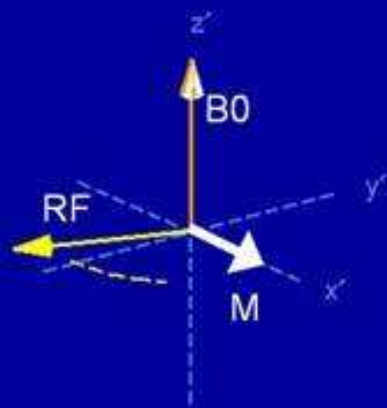
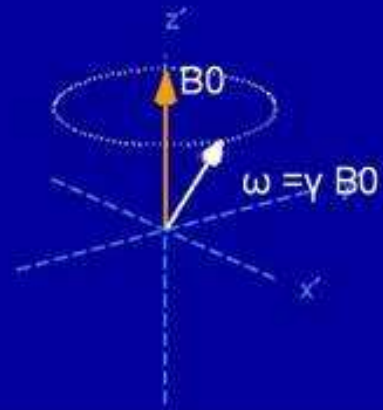
$$B_{\text{mag}} = B \cdot (1 - \delta)$$



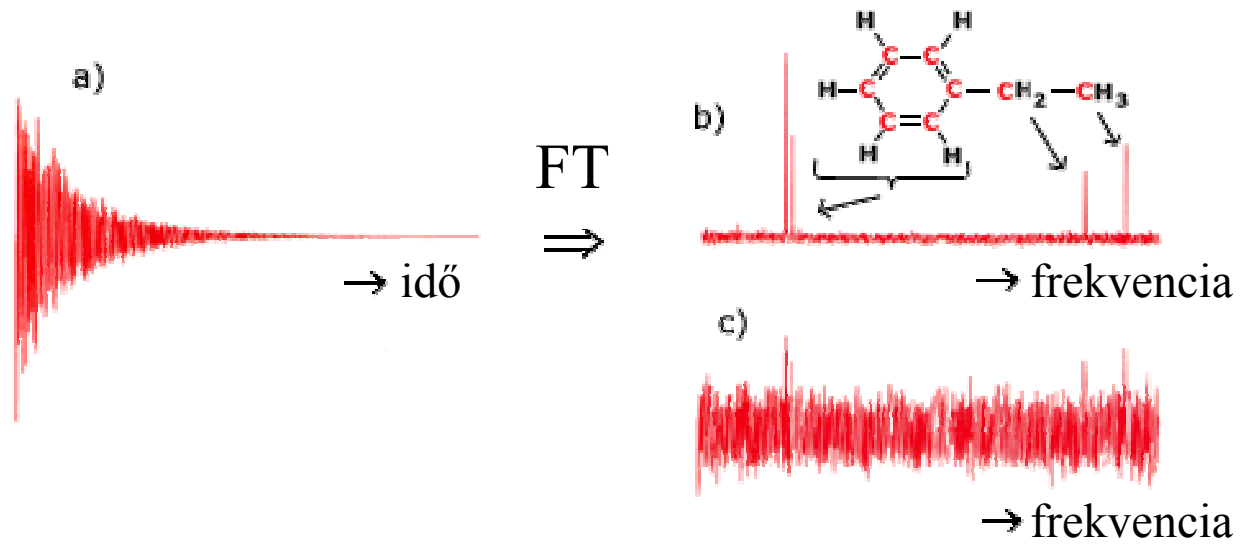
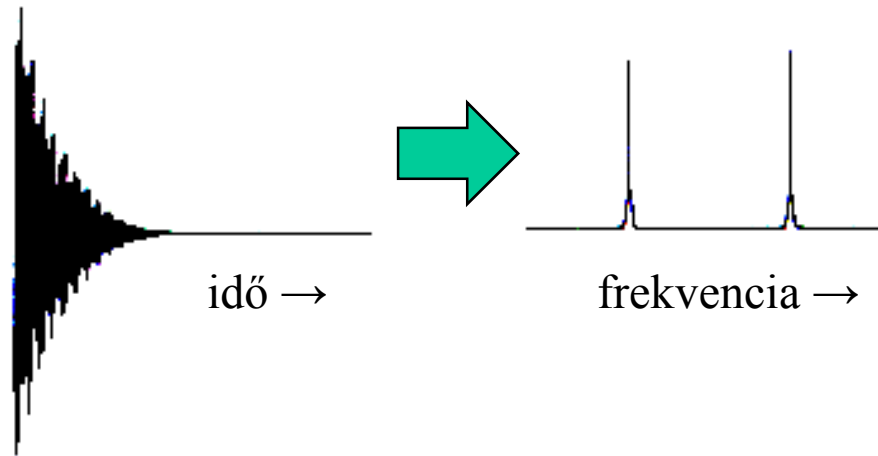


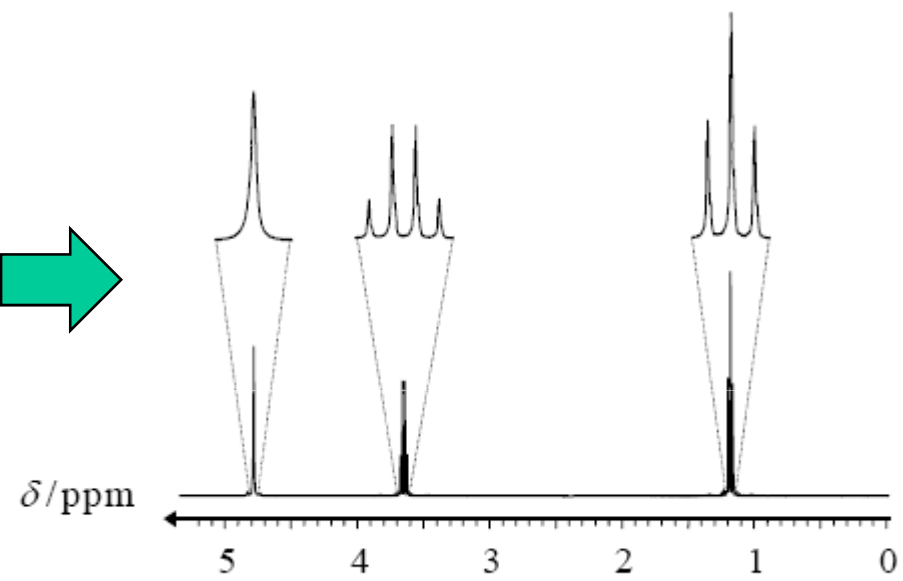
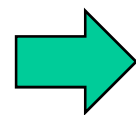
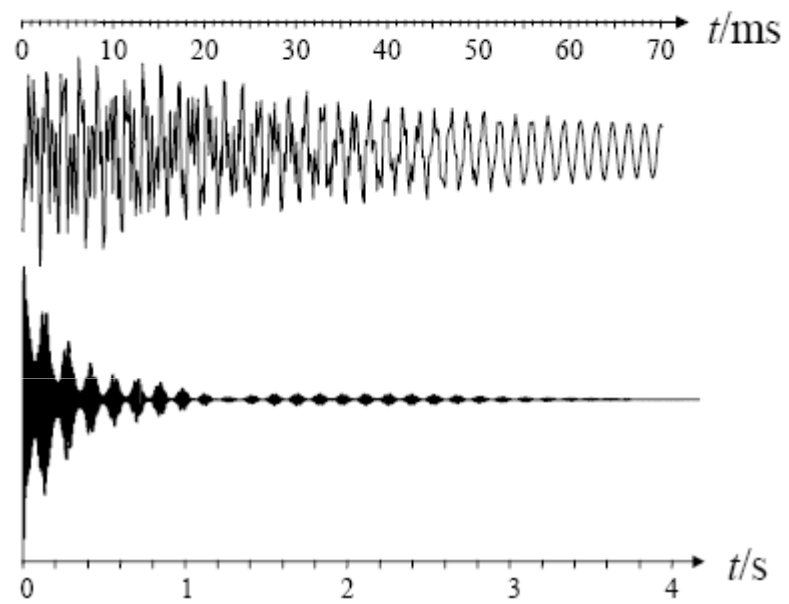


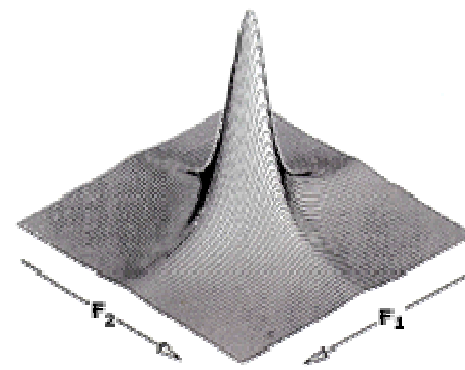
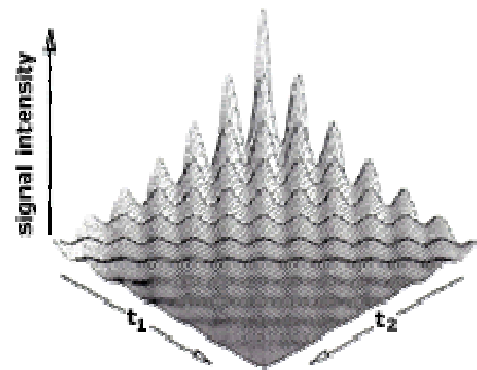
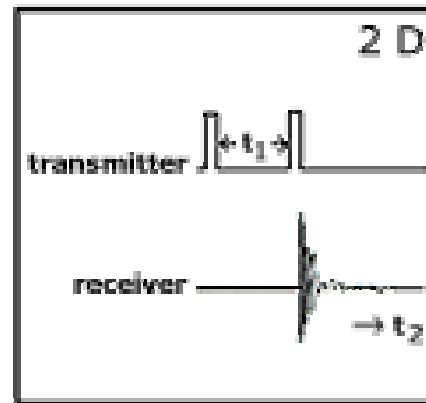
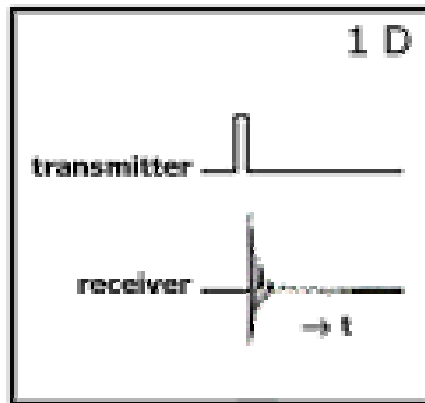




# Fourier-tanszformációs, FT-NMR

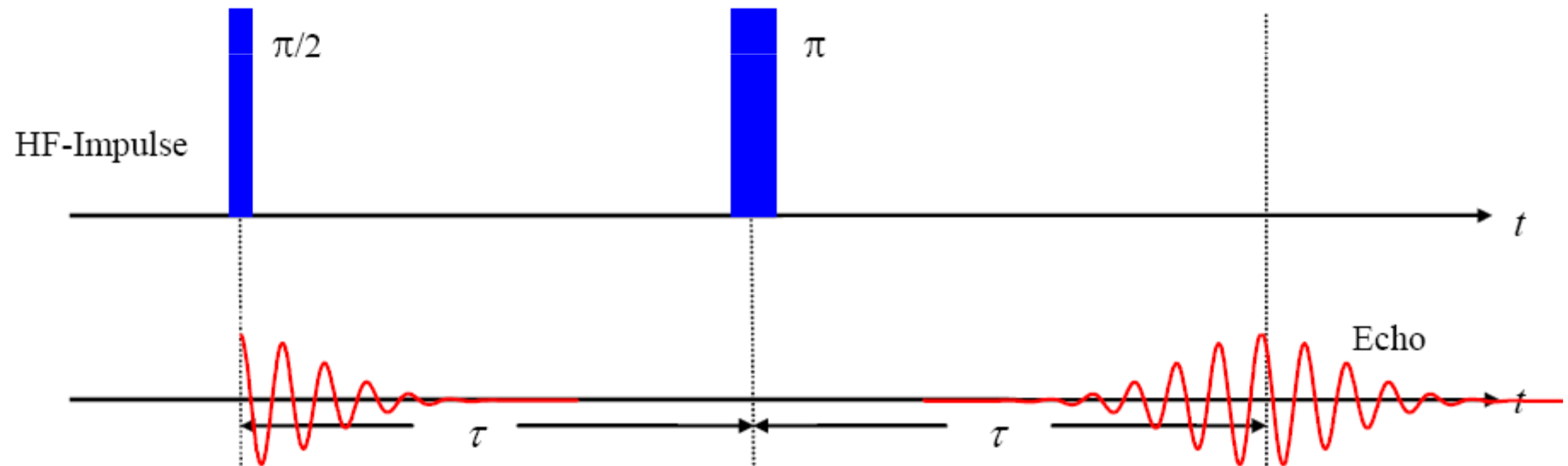
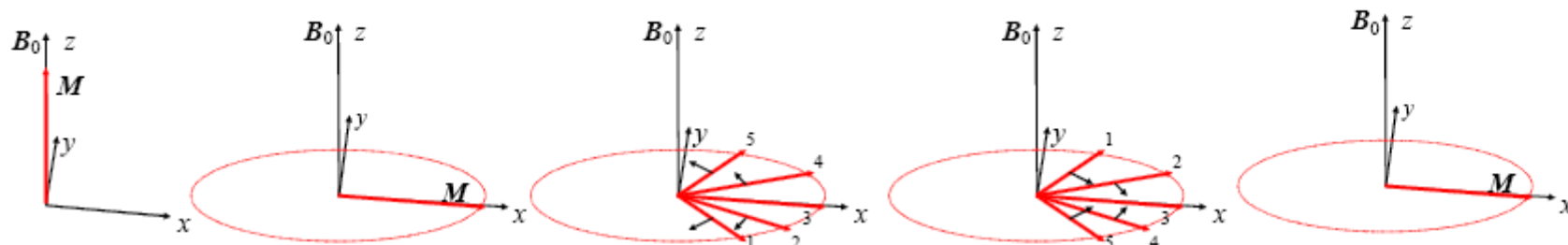




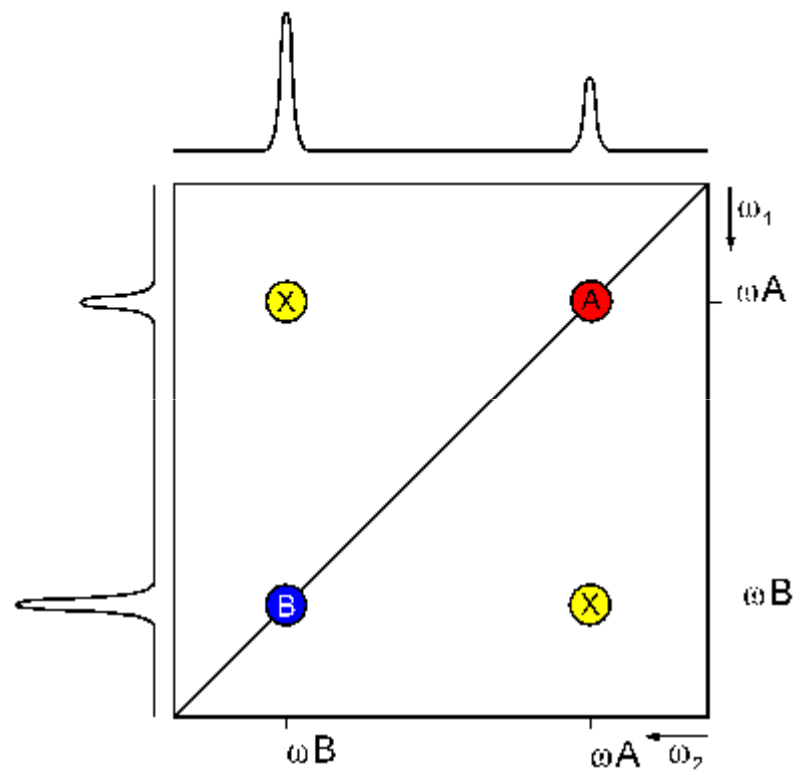


Ray Freeman, England

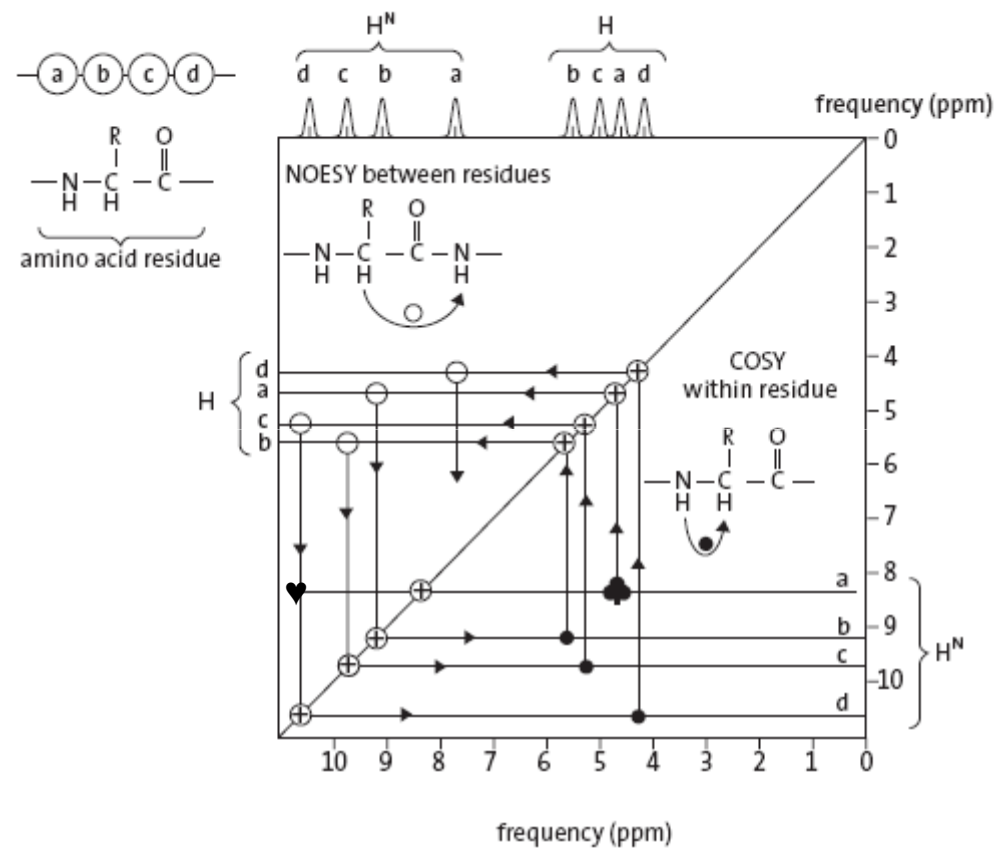
# Spin-echo (Hahn)

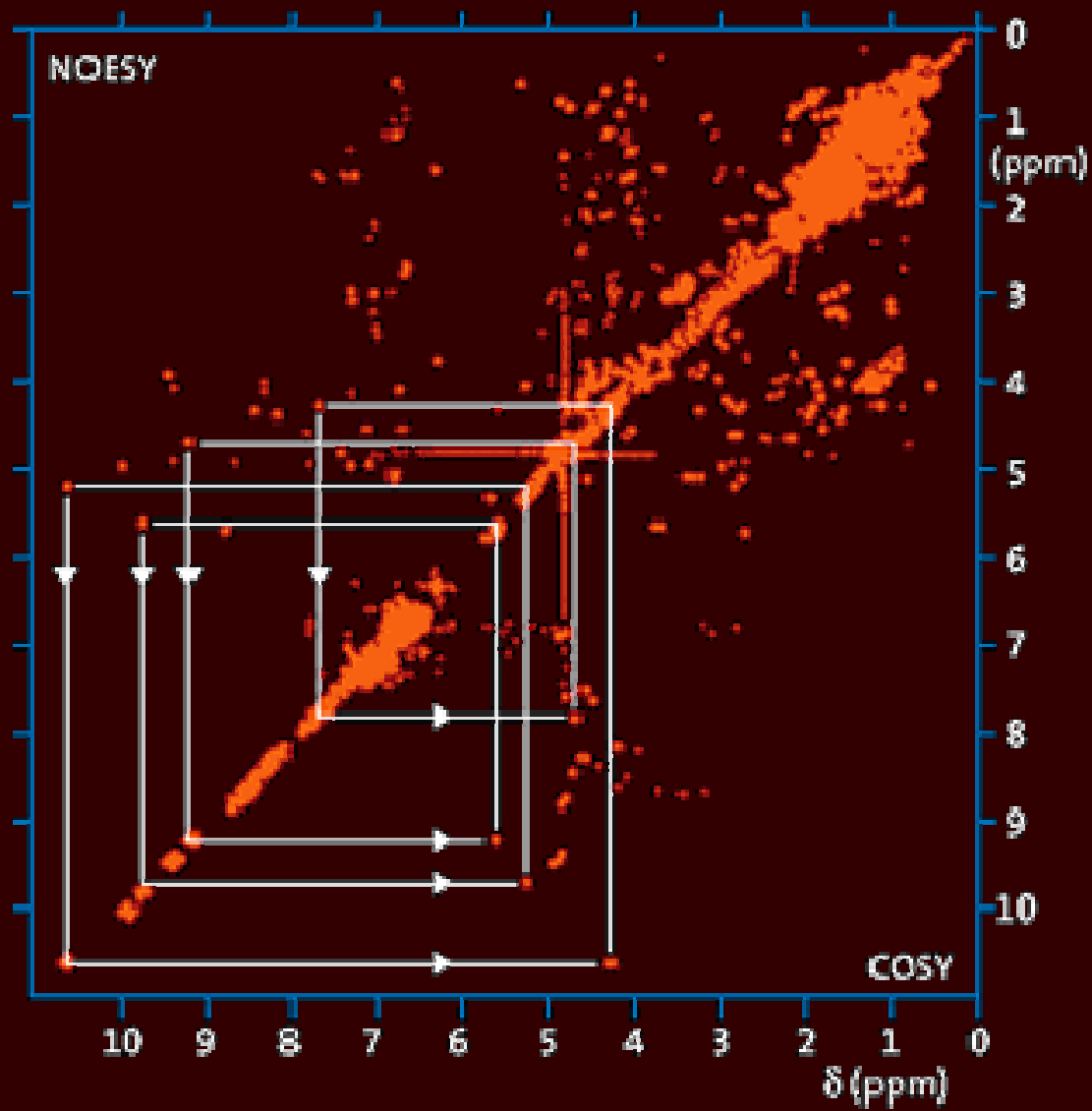


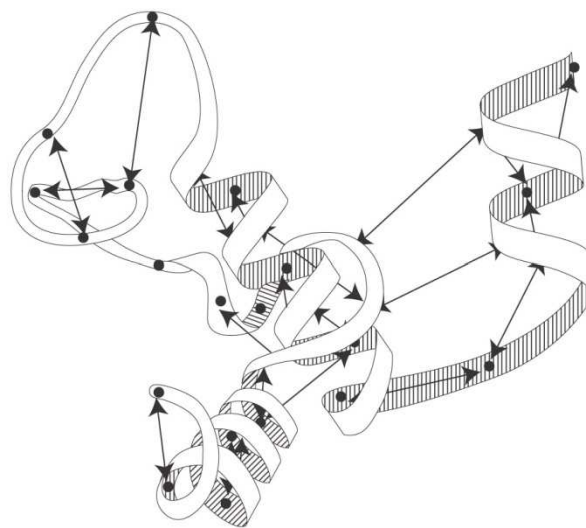
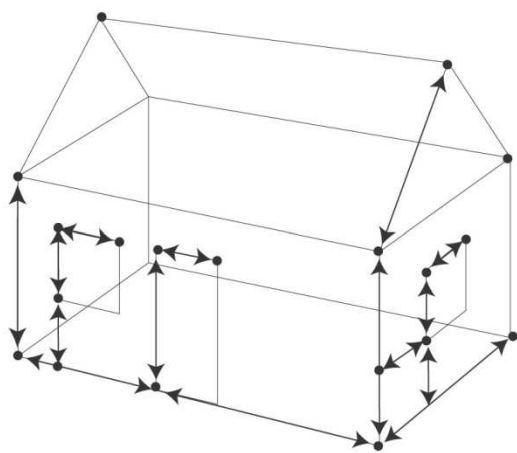
# 2D NMR

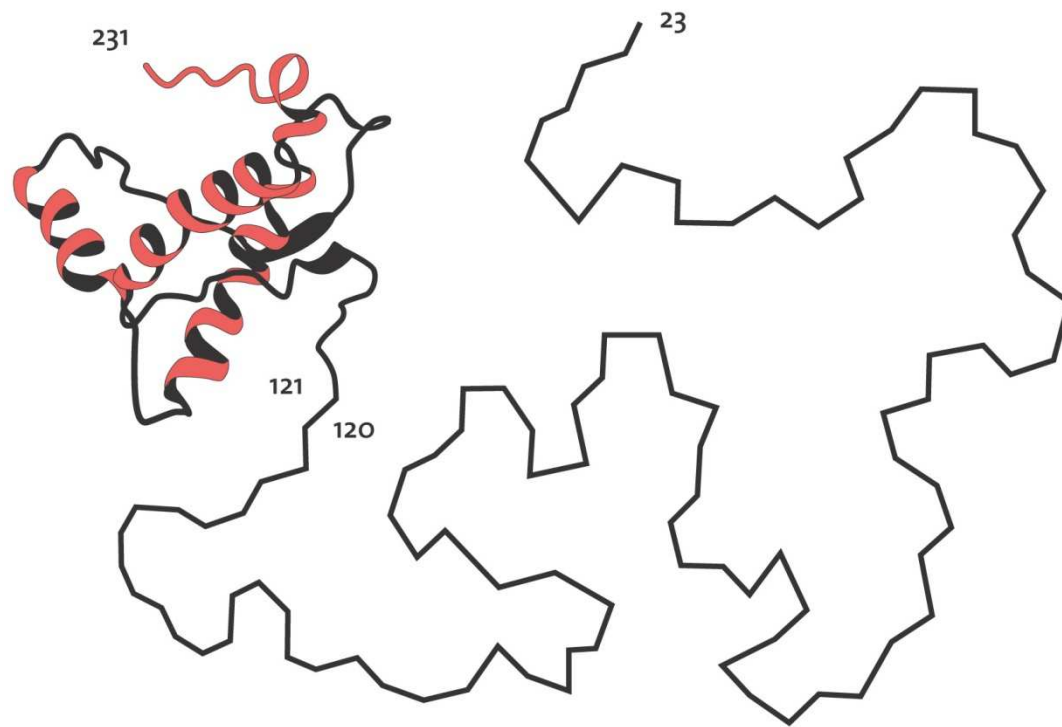








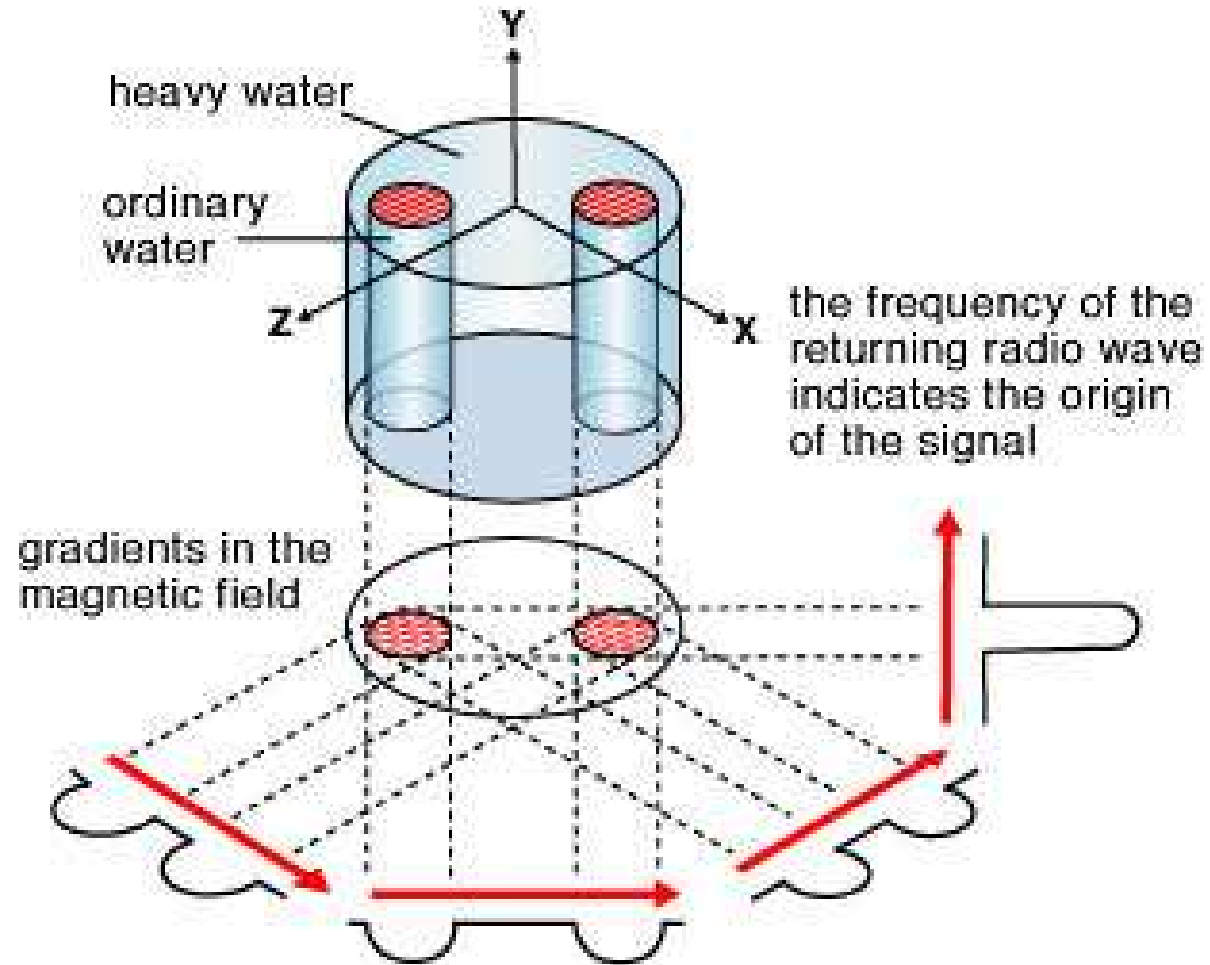


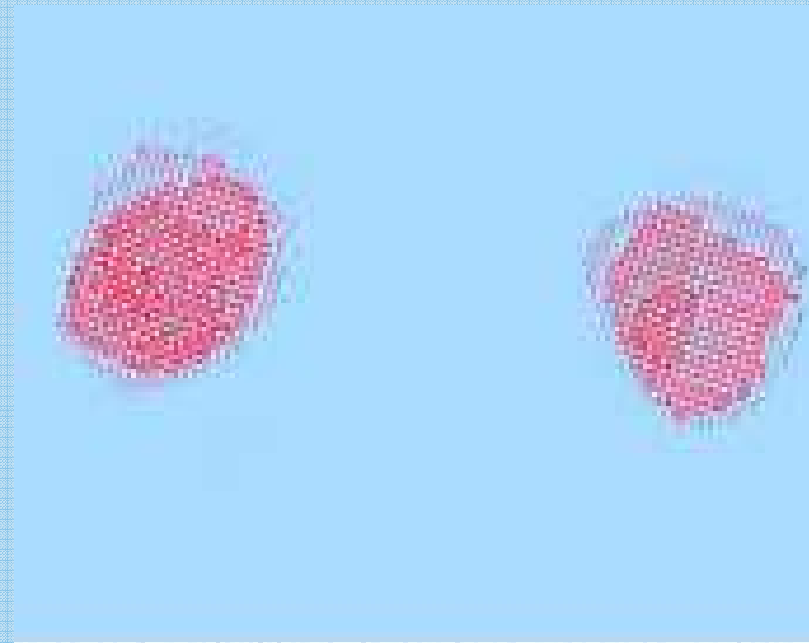




picture christofer lendel

# **NMR COMPUTER TOMOGRÁFIA**





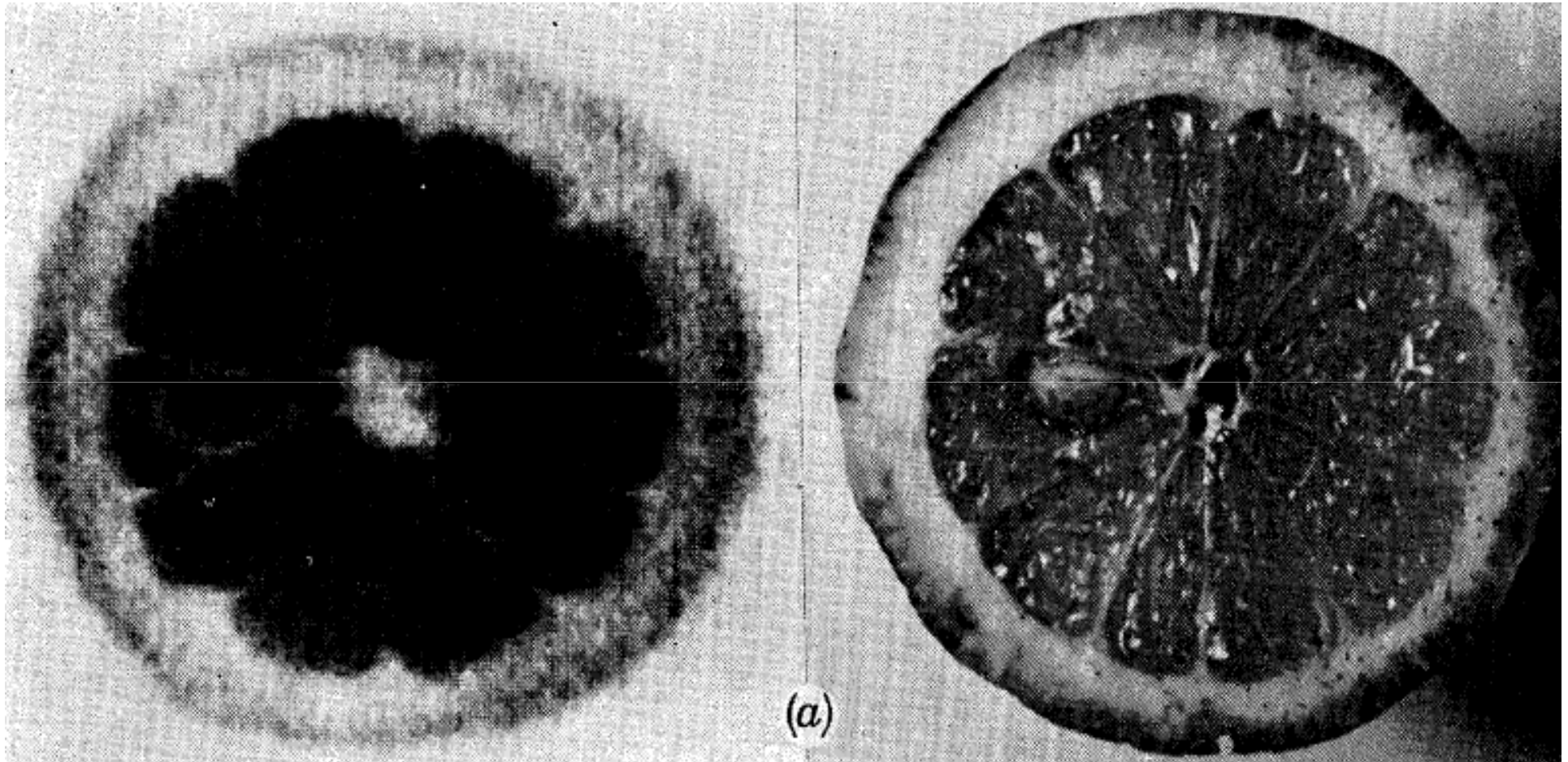
co-ordination of the curves with  
back-projection calculations  
results in a transaxial image

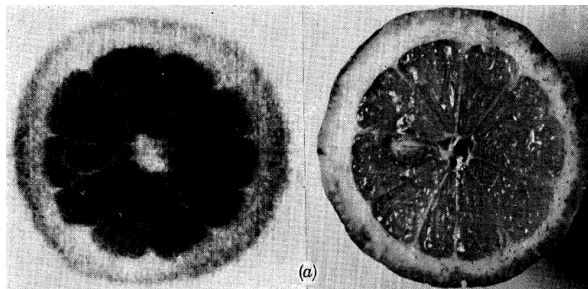
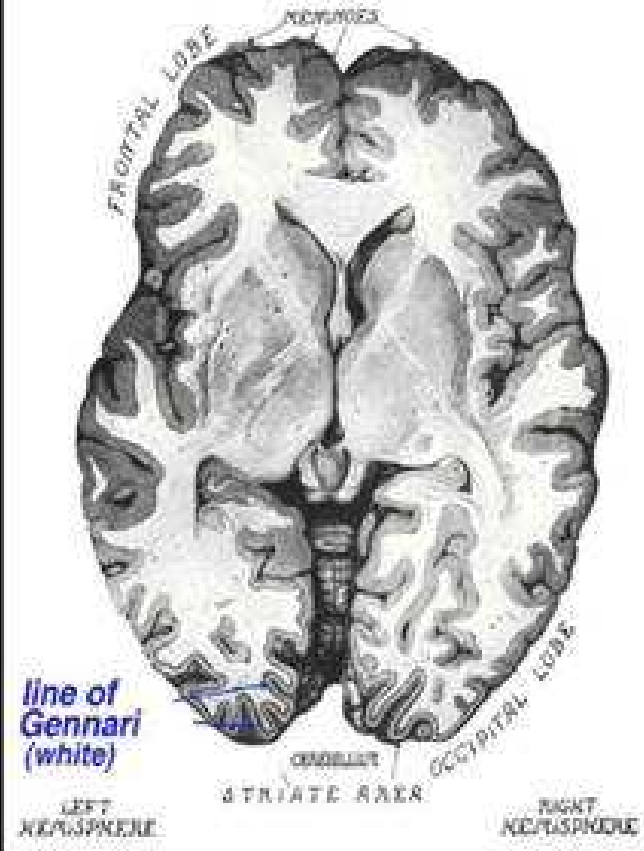
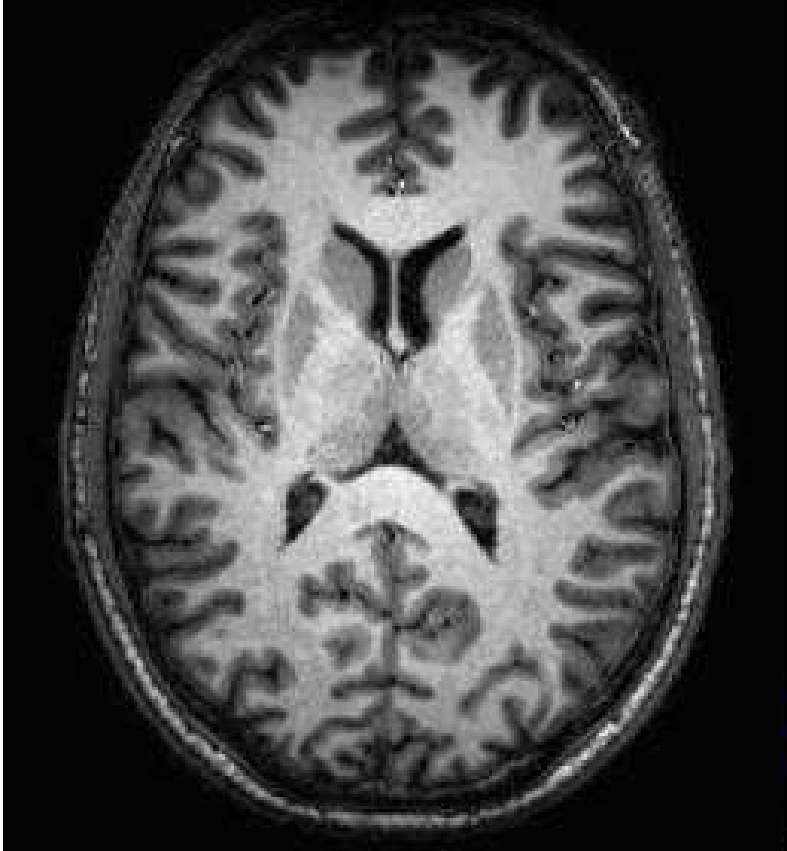


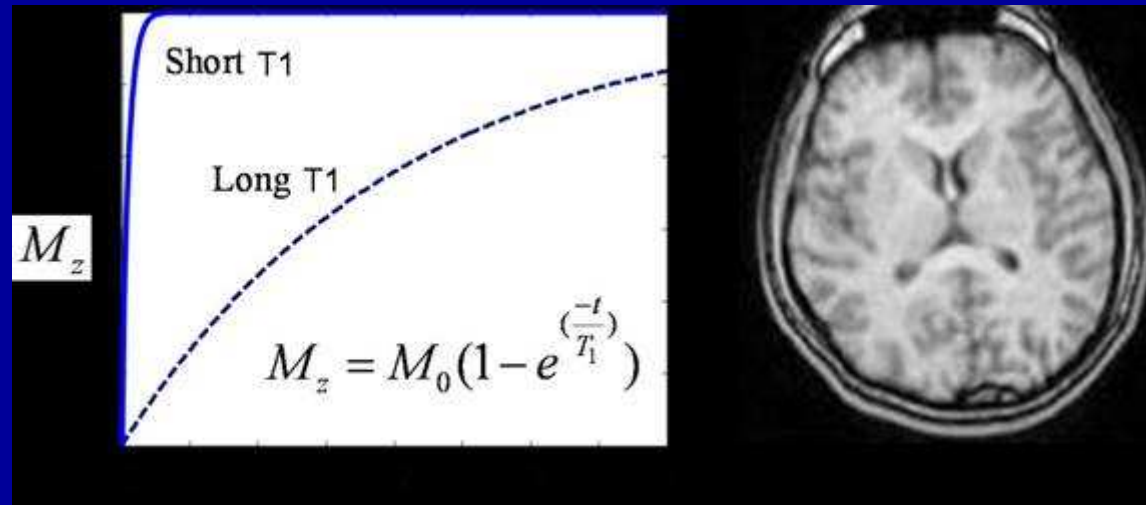
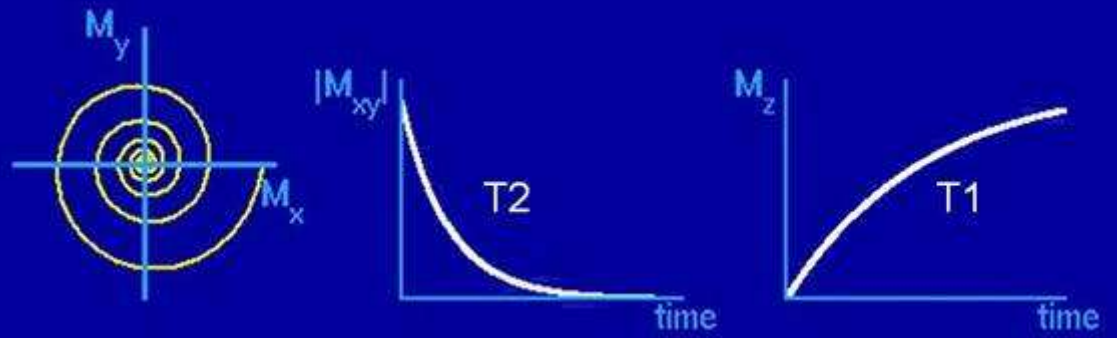
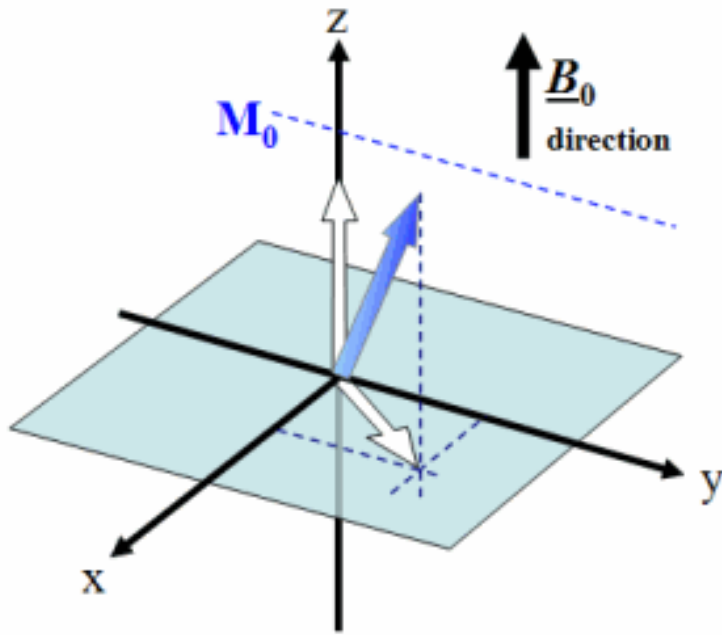
# CITROM

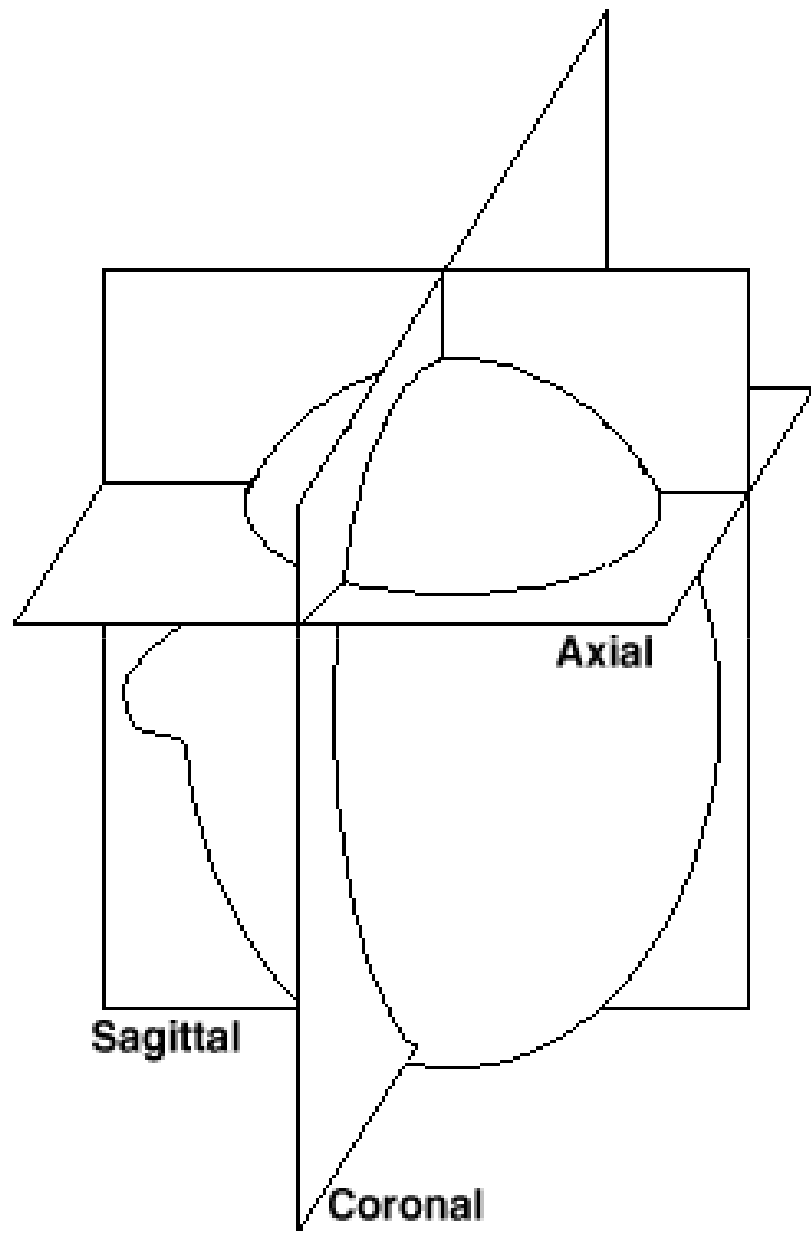
elvágás előtt (NMR)

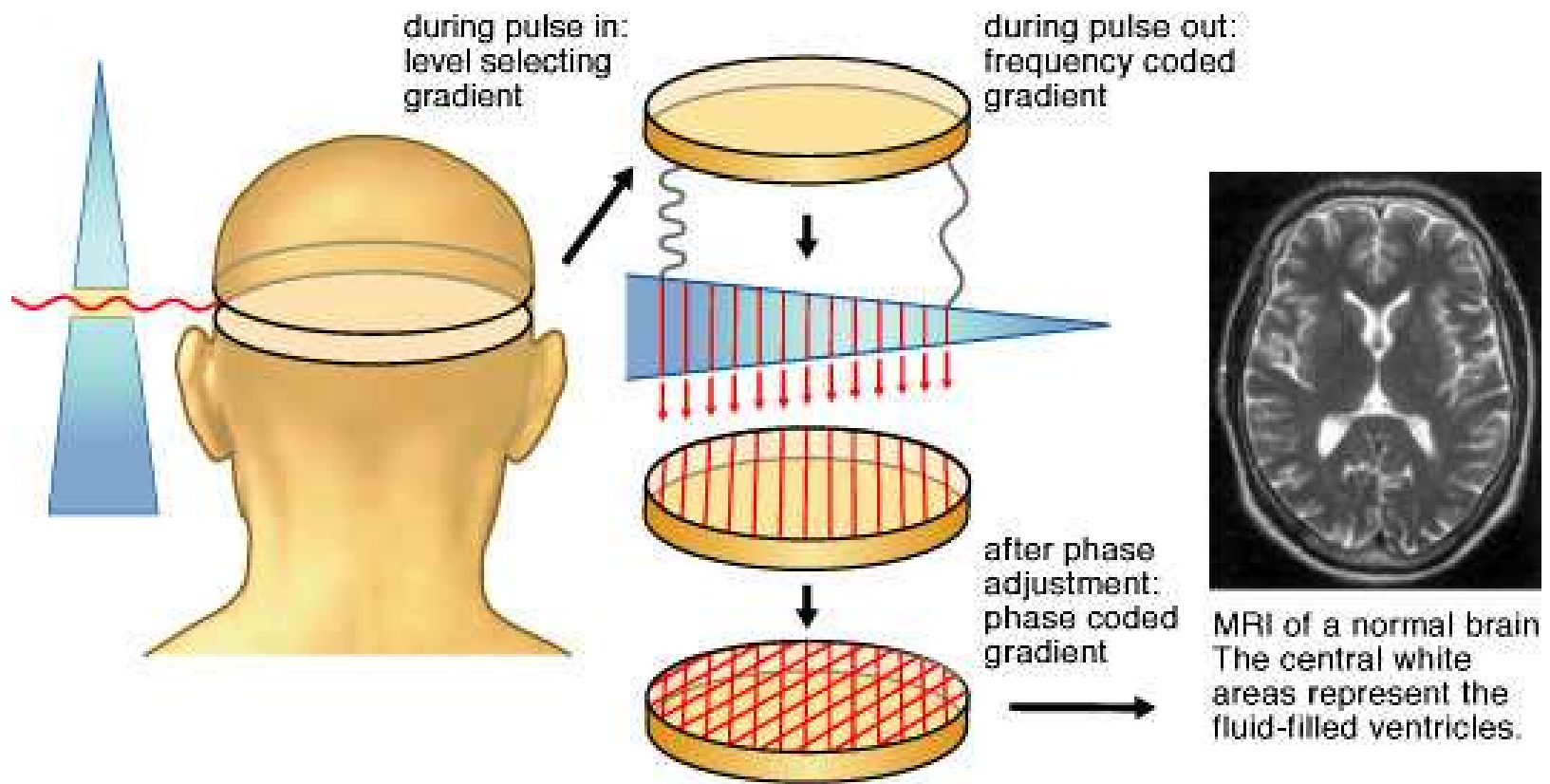
elvágás után (optika)

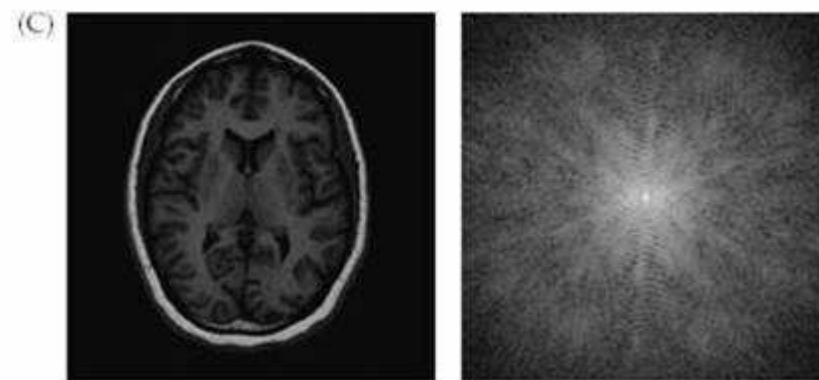
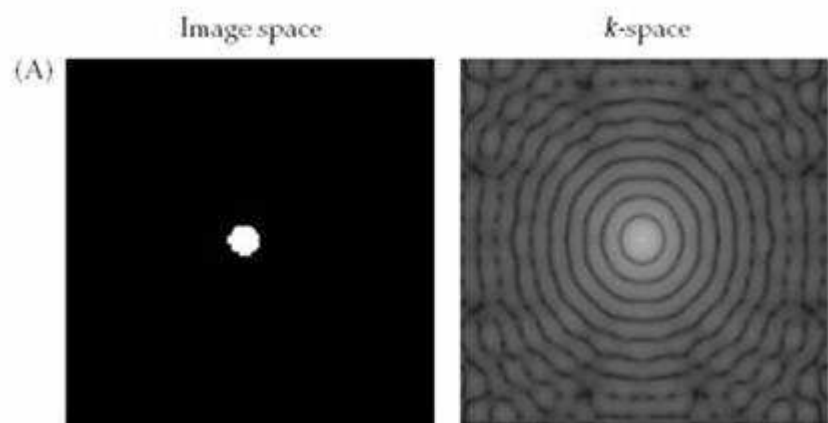
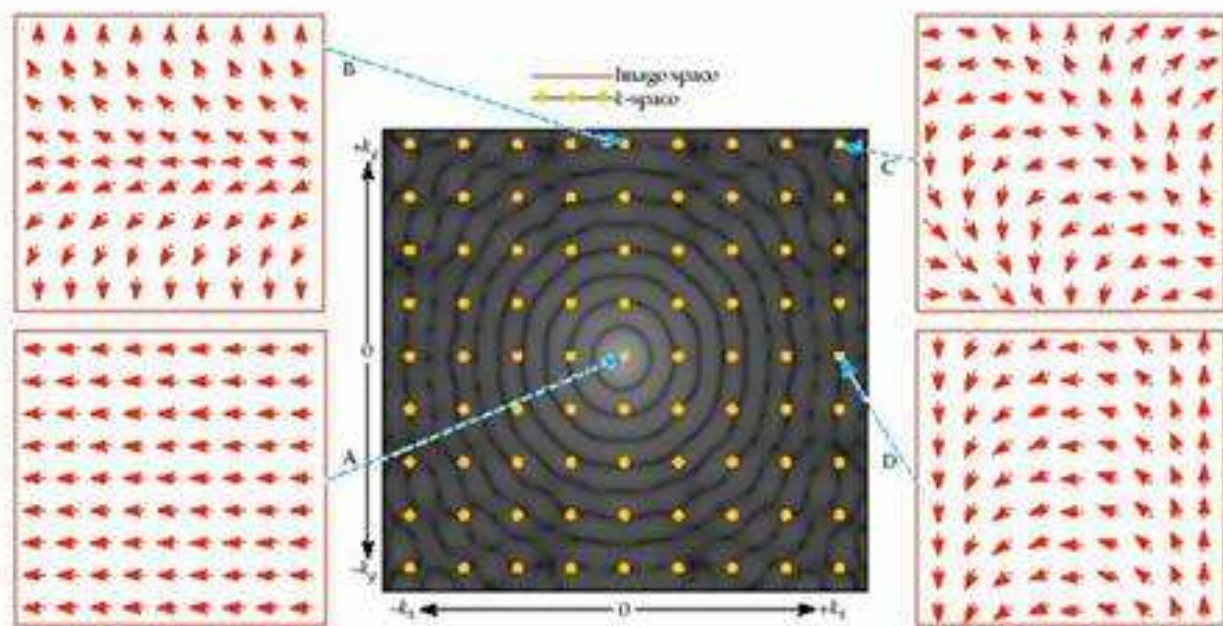


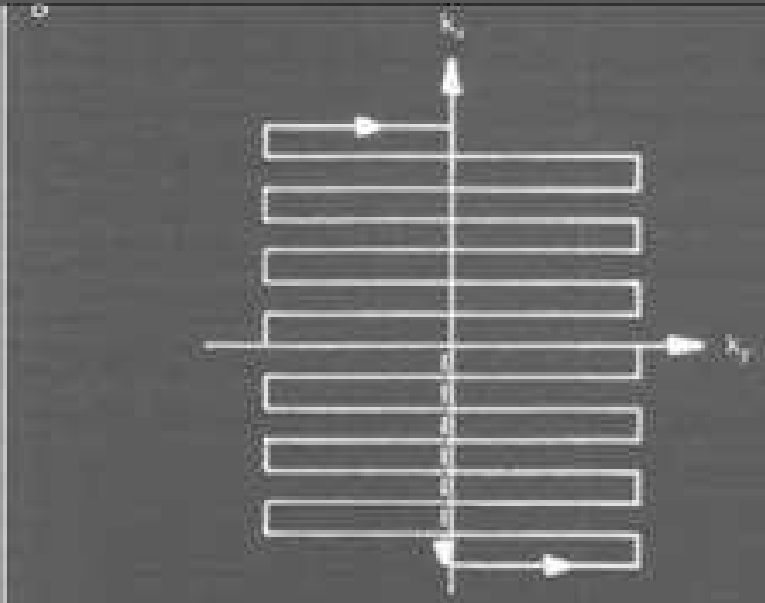
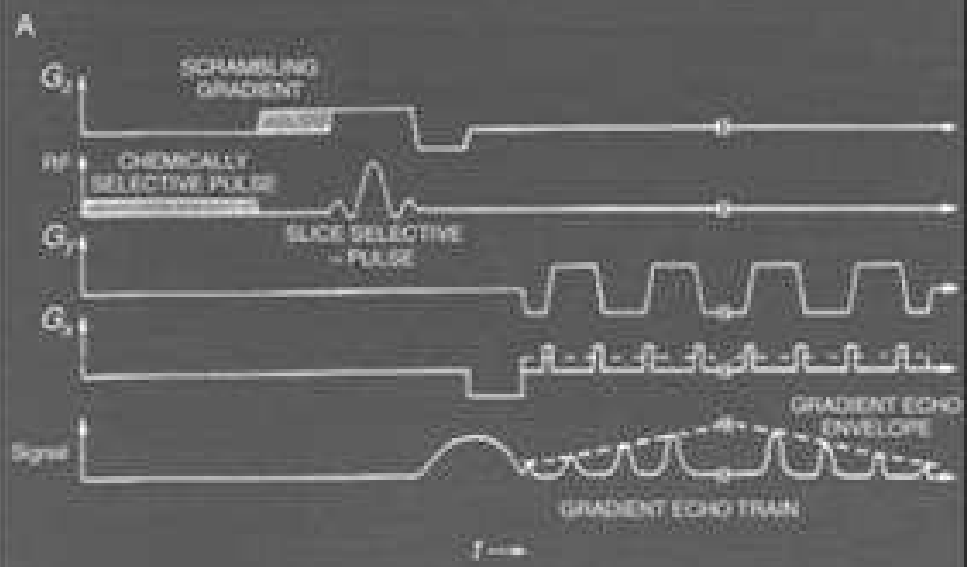












**MAGNETIC RESONANCE IMAGING (MRI)**

=

**NMR COMPUTER TOMOGRÁFIA**









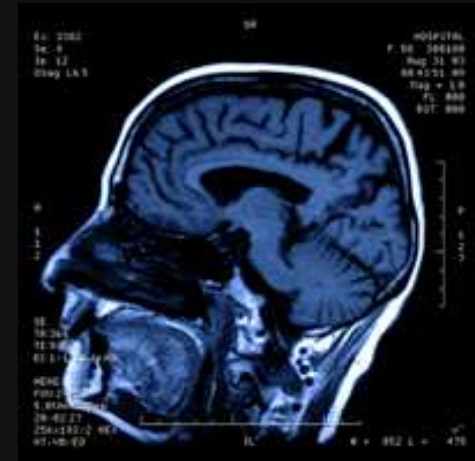
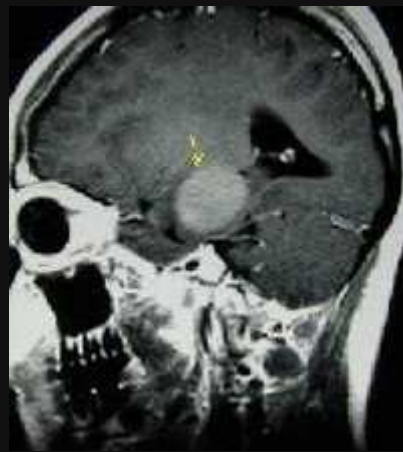
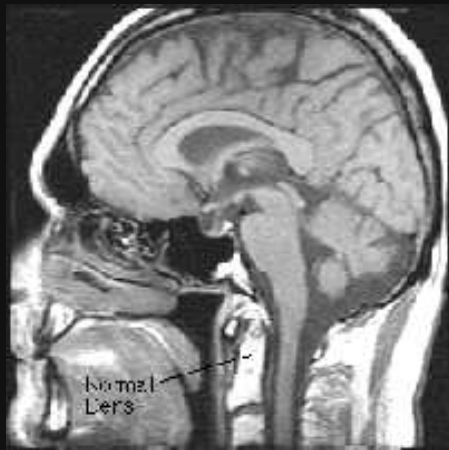
porckorong-sérv

belső szervek



gerinc-csontok





agytumor



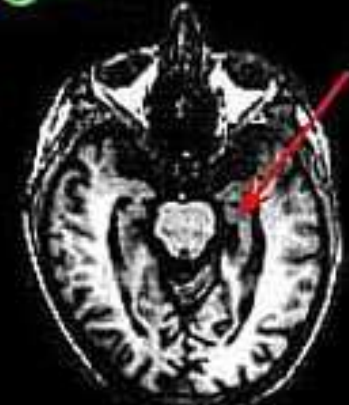
## MRI Brain Images



Normal 25  
year old

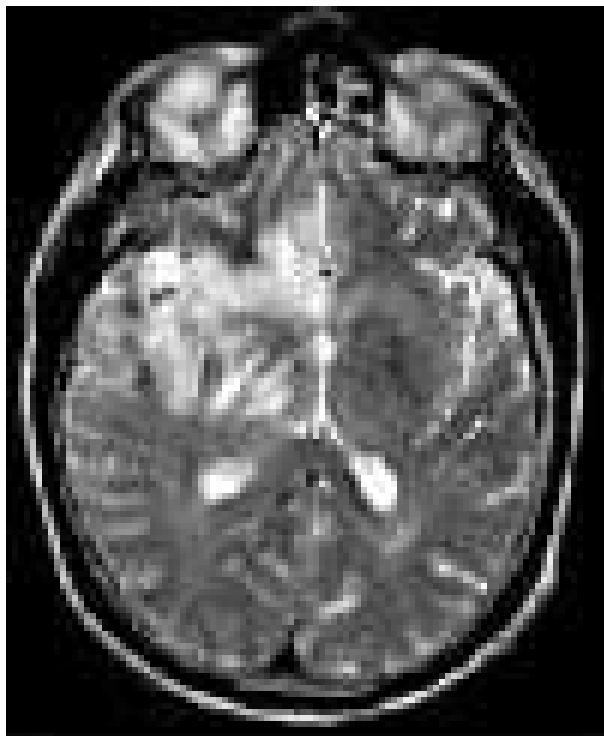


Normal Athlete  
86 years old

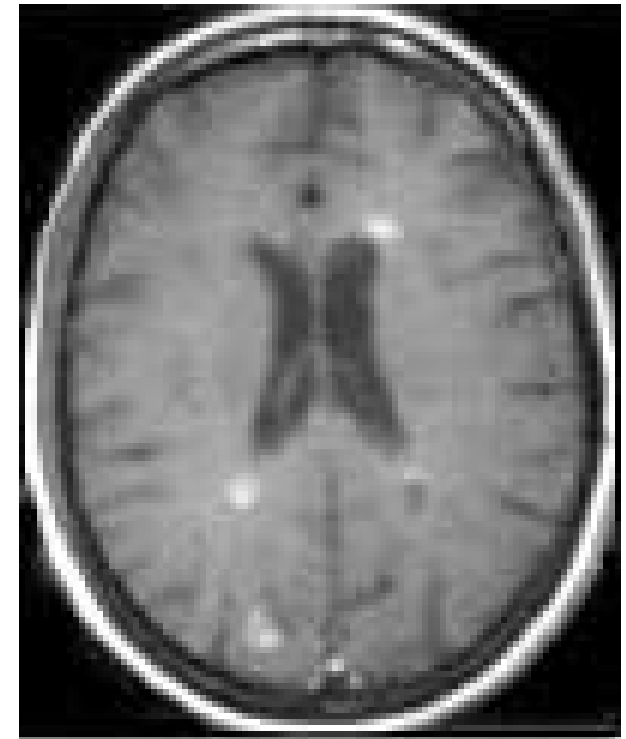
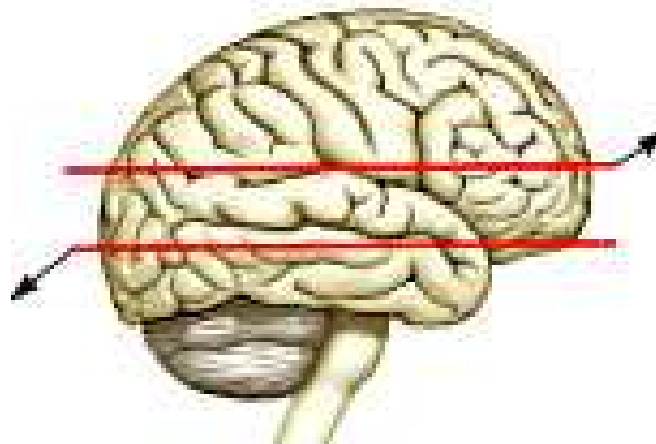


Alzheimer's Disease  
78 years old

fehér területek:  
herpes encephalitis  
(vírusos agyvelőgyulladás)



lateral view



fehér foltok:  
szklerózis multiplex

## funkcionális MRI (fMRI)

(pl. hemoglobin: paramágneses; hemoglobin + oxigén: diamágneses)

