

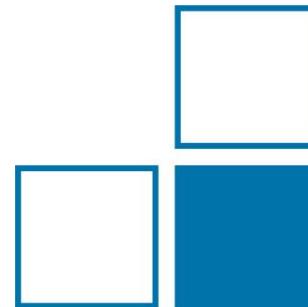
Neural MRI – Basics of MR Spectroscopy

Thematic Einstein Semester on
Mathematics of Imaging in Real-World Challenges

Ariane Fillmer, PhD

Physikalisch-Technische Bundesanstalt, Berlin and Braunschweig, Germany
Department for Biomedical Magnetic Resonance
AG 8.12 - In-vivo MRT

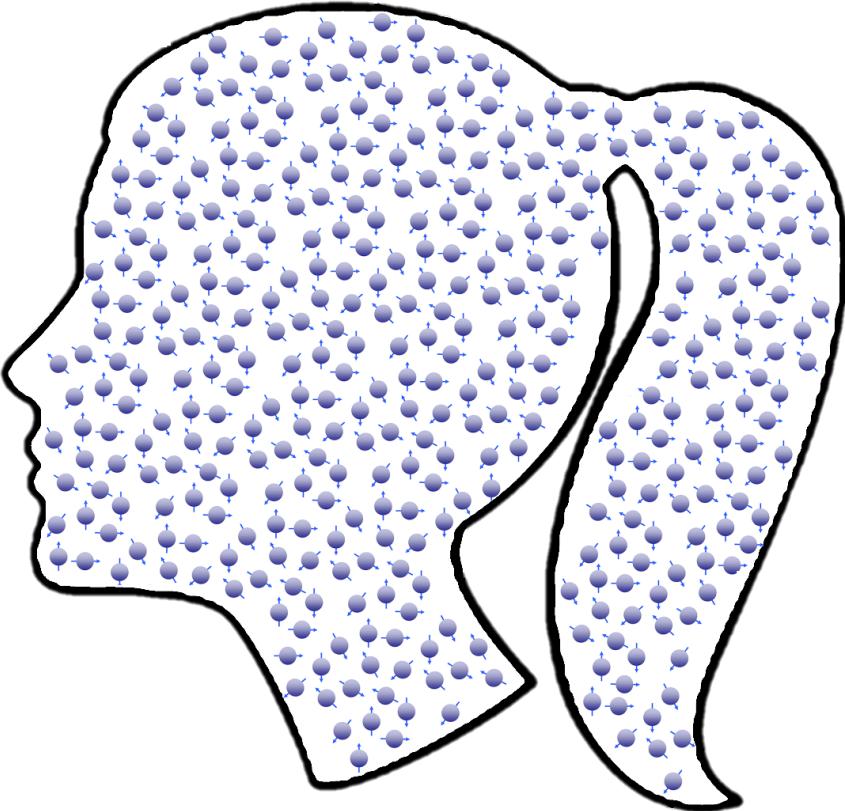
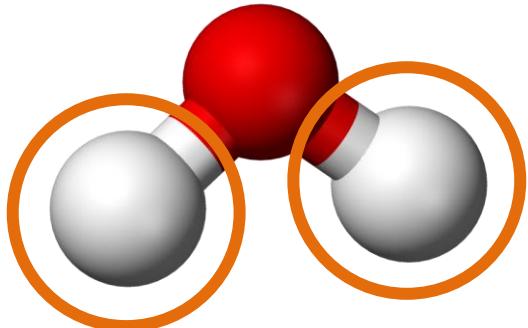
February 18th, 2022



MRI in a nutshell

average water content in adult humans of both sexes:

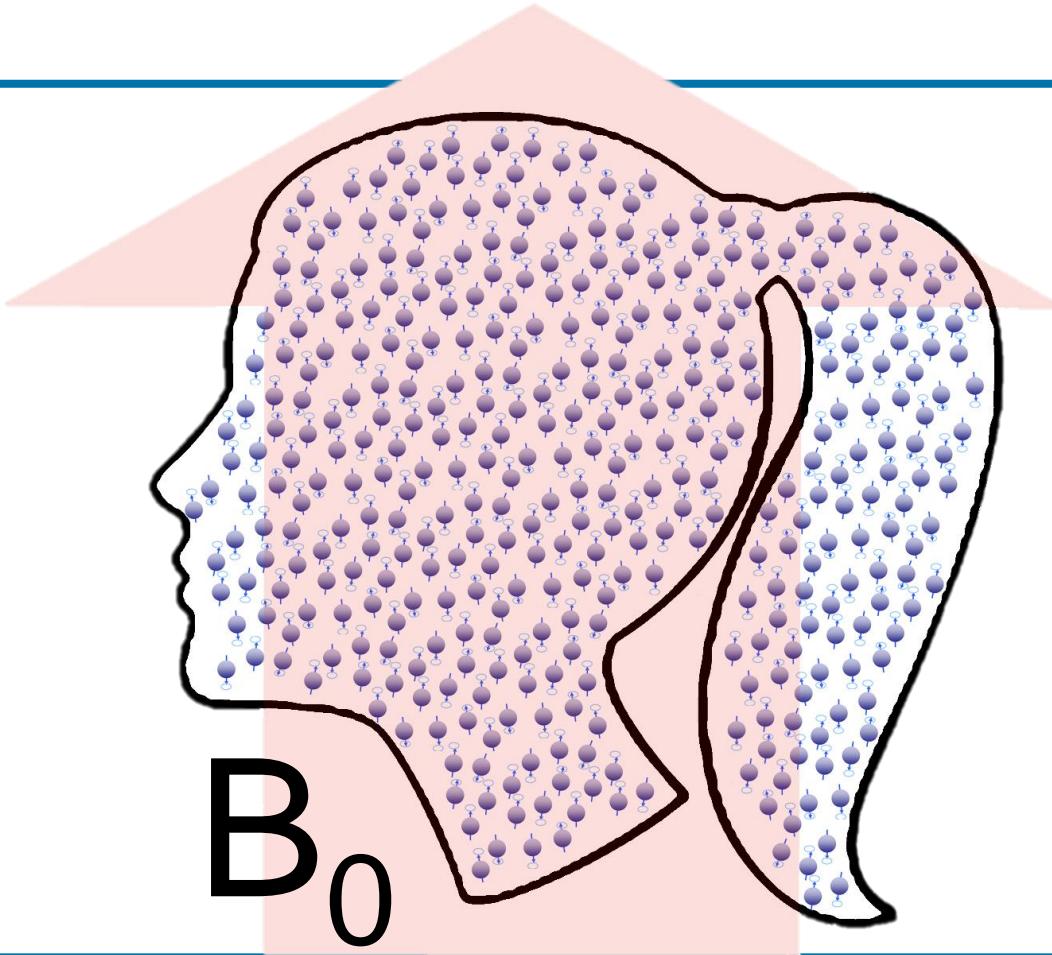
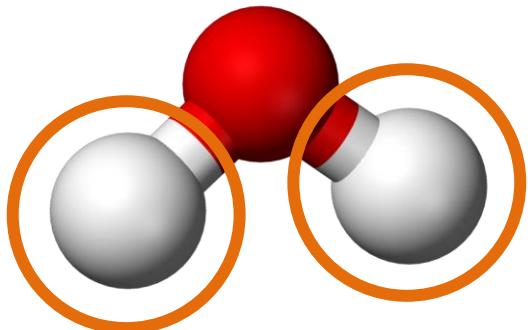
~ 65 %



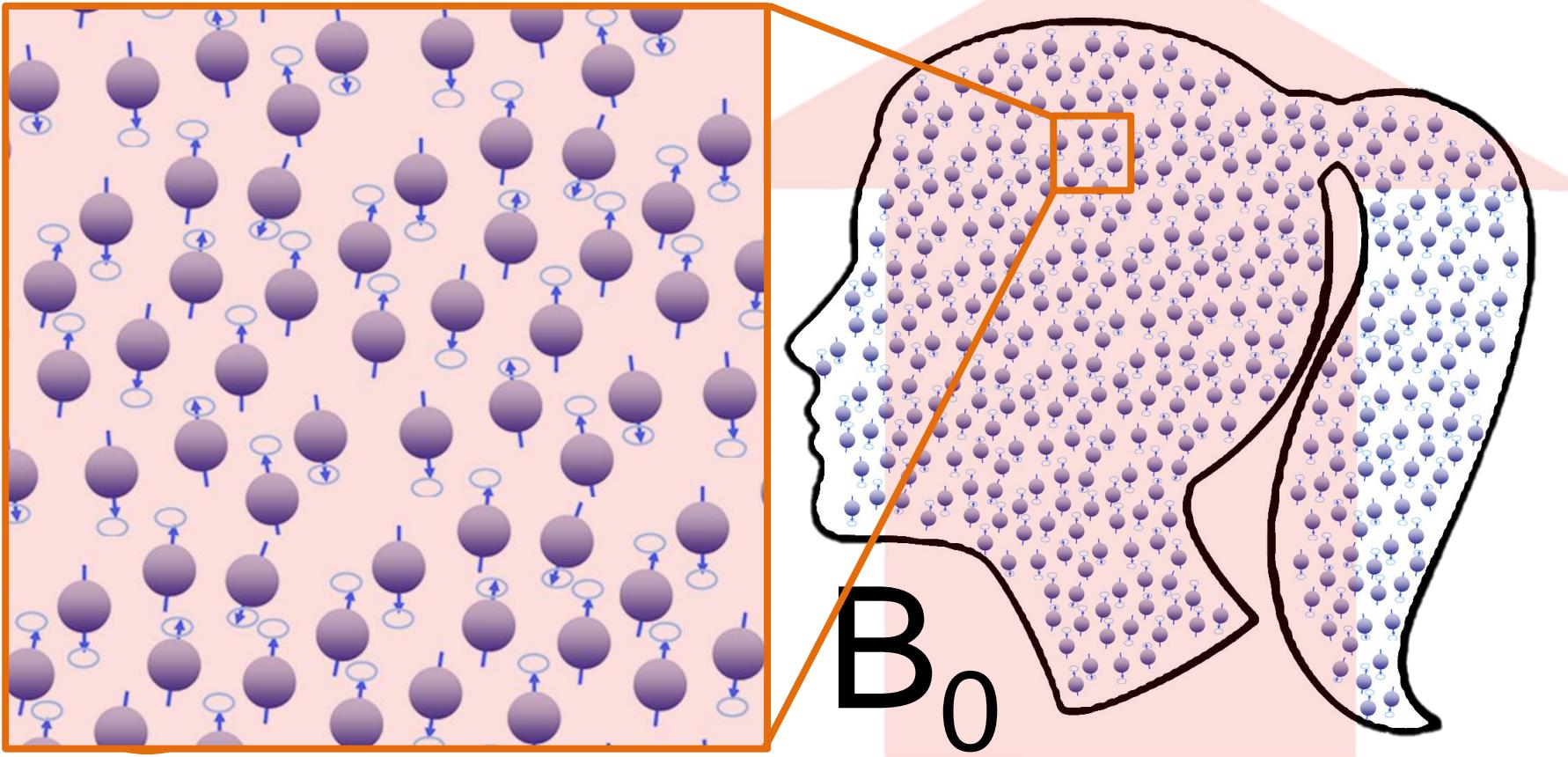
MRI in a nutshell

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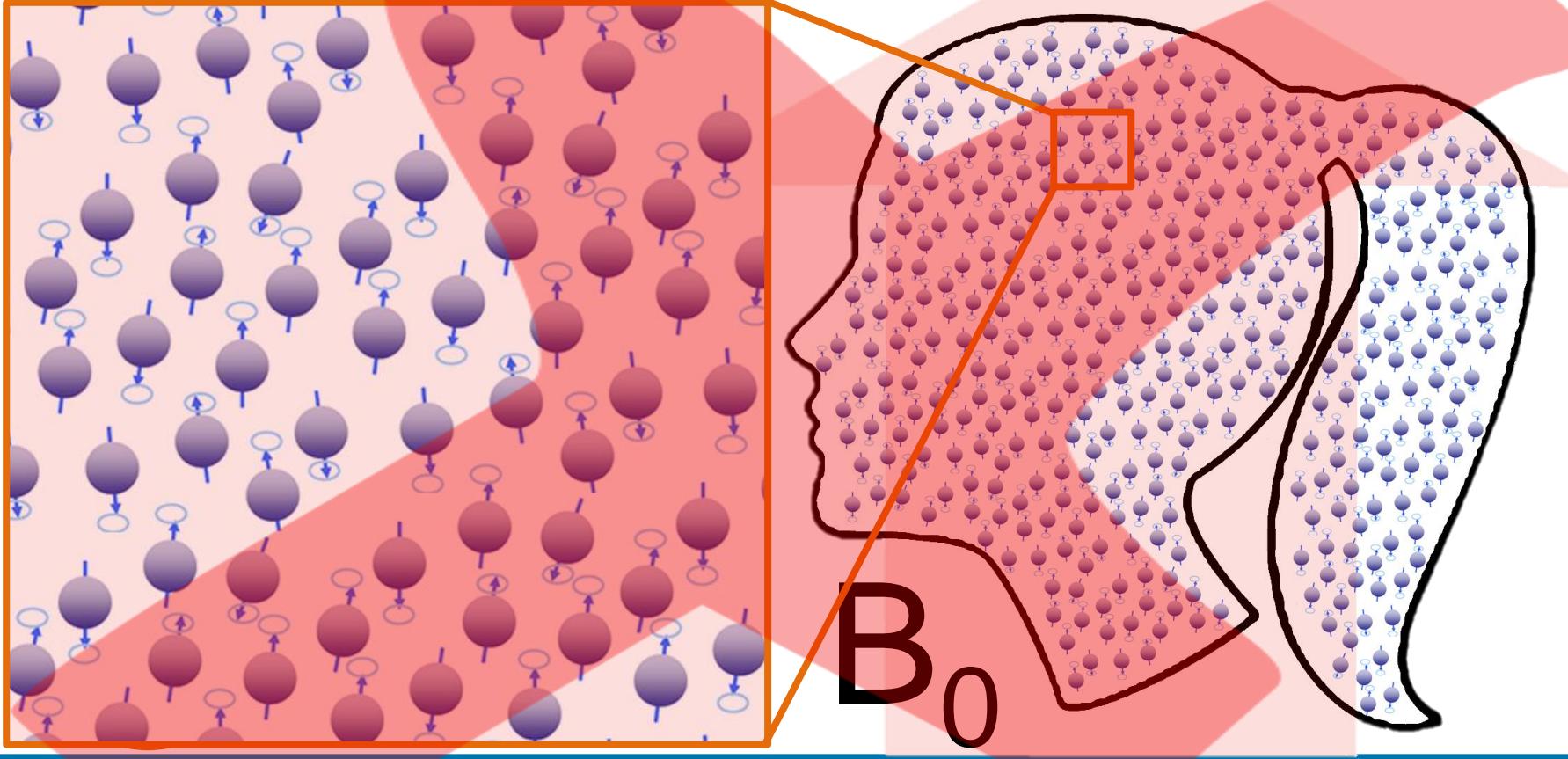
~ 65 %



MRI in a nutshell



MRI in a nutshell

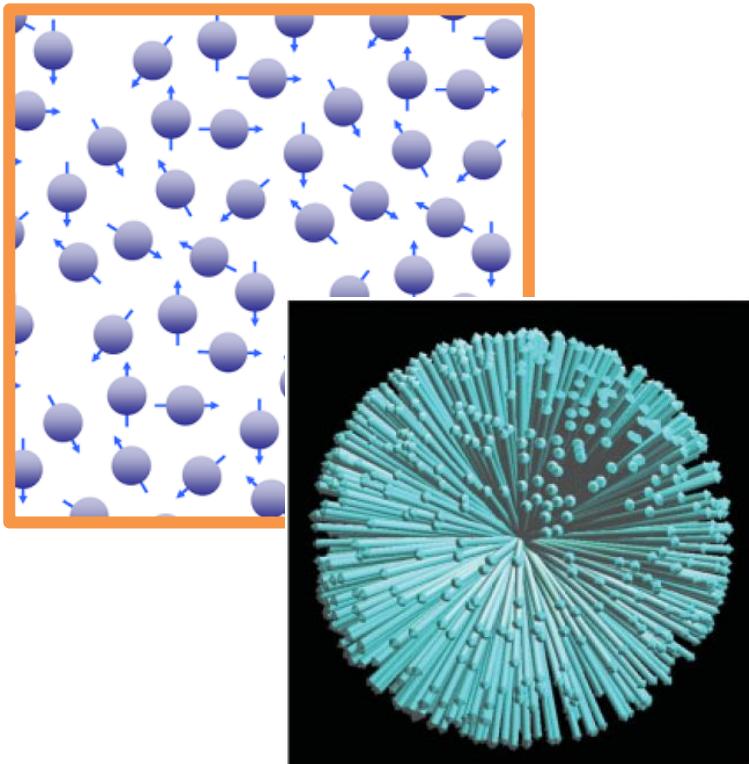


Is Quantum Mechanics Necessary for Understanding Magnetic Resonance?

LARS G. HANSON

Danish Research Centre for Magnetic Resonance, Copenhagen University Hospital, Hvidovre, Denmark

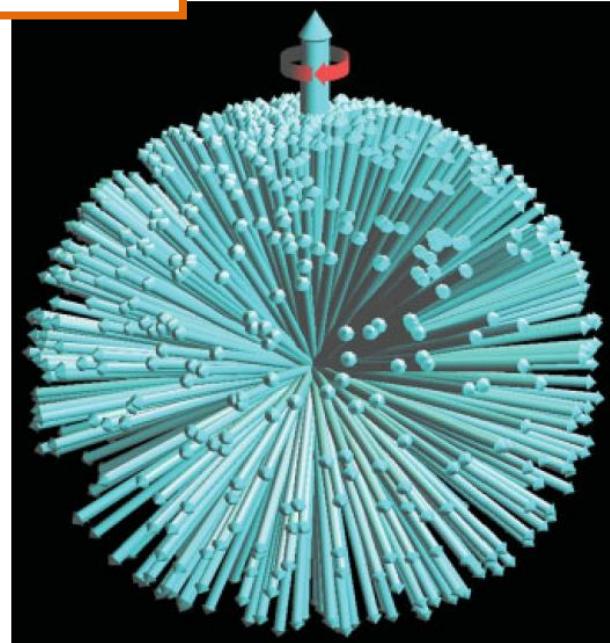
ABSTRACT: Educational material introducing magnetic resonance (MR) typically contains sections on the underlying principles. Unfortunately the explanations given are often unnecessarily complicated or even wrong. MR is often presented as a phenomenon that necessitates a quantum mechanical explanation whereas it really is a classical effect, i.e. a consequence of the common sense expressed in classical mechanics. This insight is not new, but there have been few attempts to challenge common misleading explanations, so authors and educators are inadvertently keeping myths alive. As a result, new students' first encounters with MR are often obscured by explanations that make the subject difficult to understand. Typical problems are addressed and alternative intuitive explanations are provided. © 2008 Wiley Periodicals, Inc. Concepts Magn Reson Part A 32A: 329–340, 2008.



Hanson, CONCEPT MAGN RESON A: 32A, 329 - 340 (2008)
<https://www.drcmr.dk/BlochSimulator/>

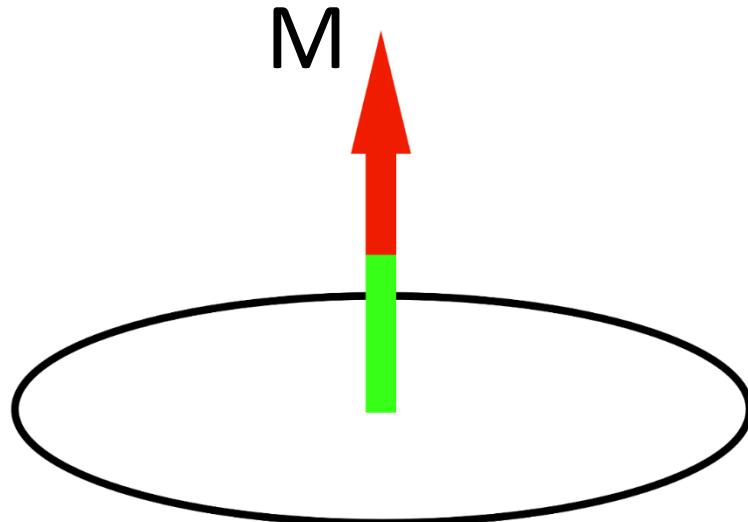
MRI in a nutshell

$$\omega_L = -\gamma \cdot \mathbf{B}_0$$

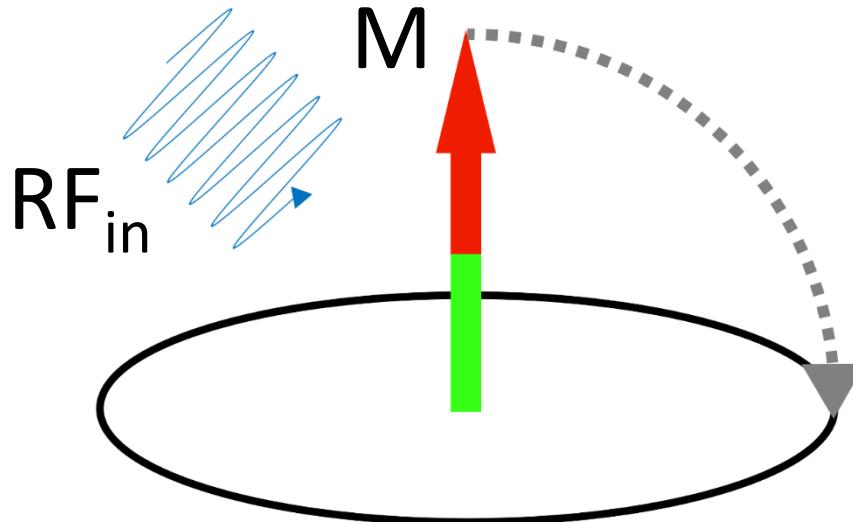


Hanson, CONCEPT MAGN RESON A: 32A, 329 - 340 (2008)
<https://www.drcmr.dk/BlochSimulator/>

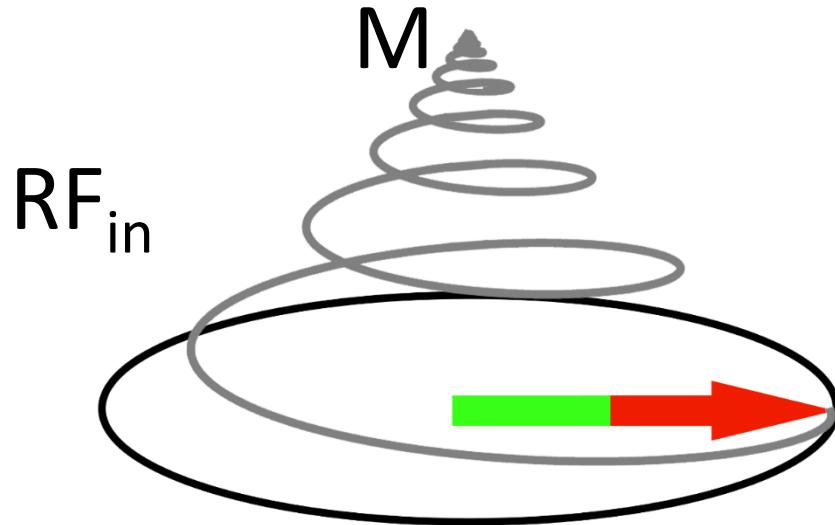
MRI in a nutshell



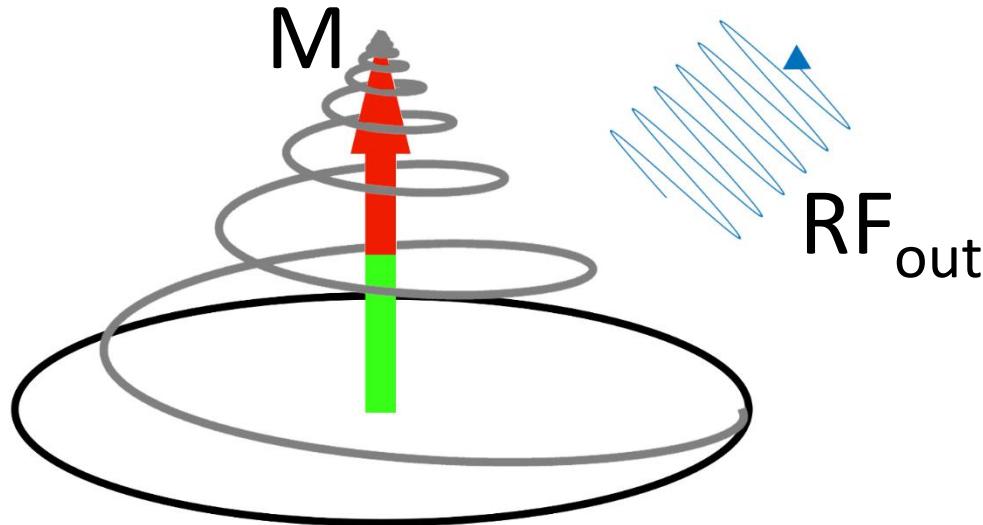
MRI in a nutshell



MRI in a nutshell

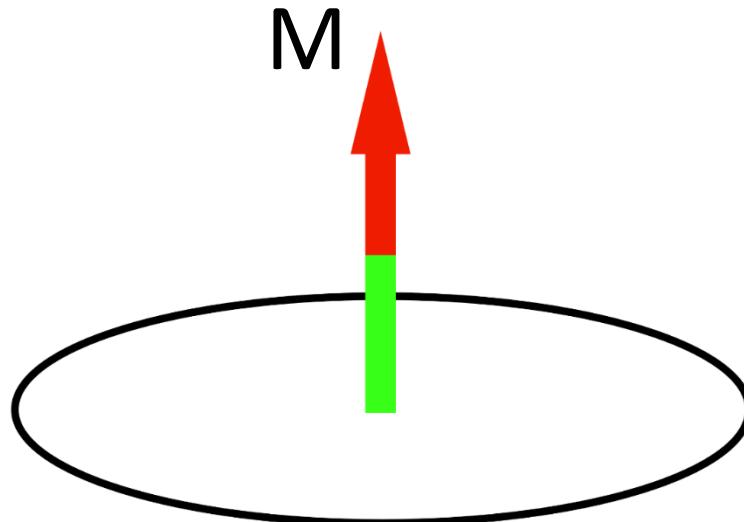


MRI in a nutshell

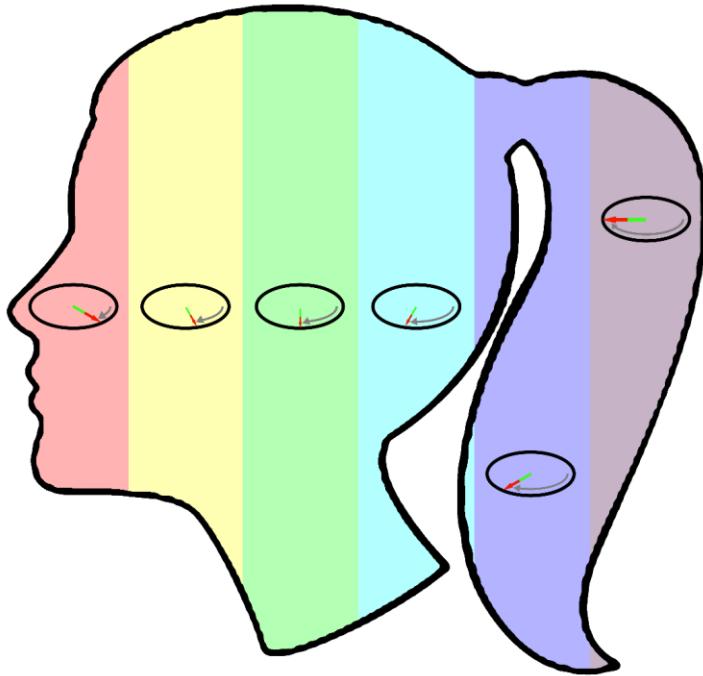


MRI in a nutshell

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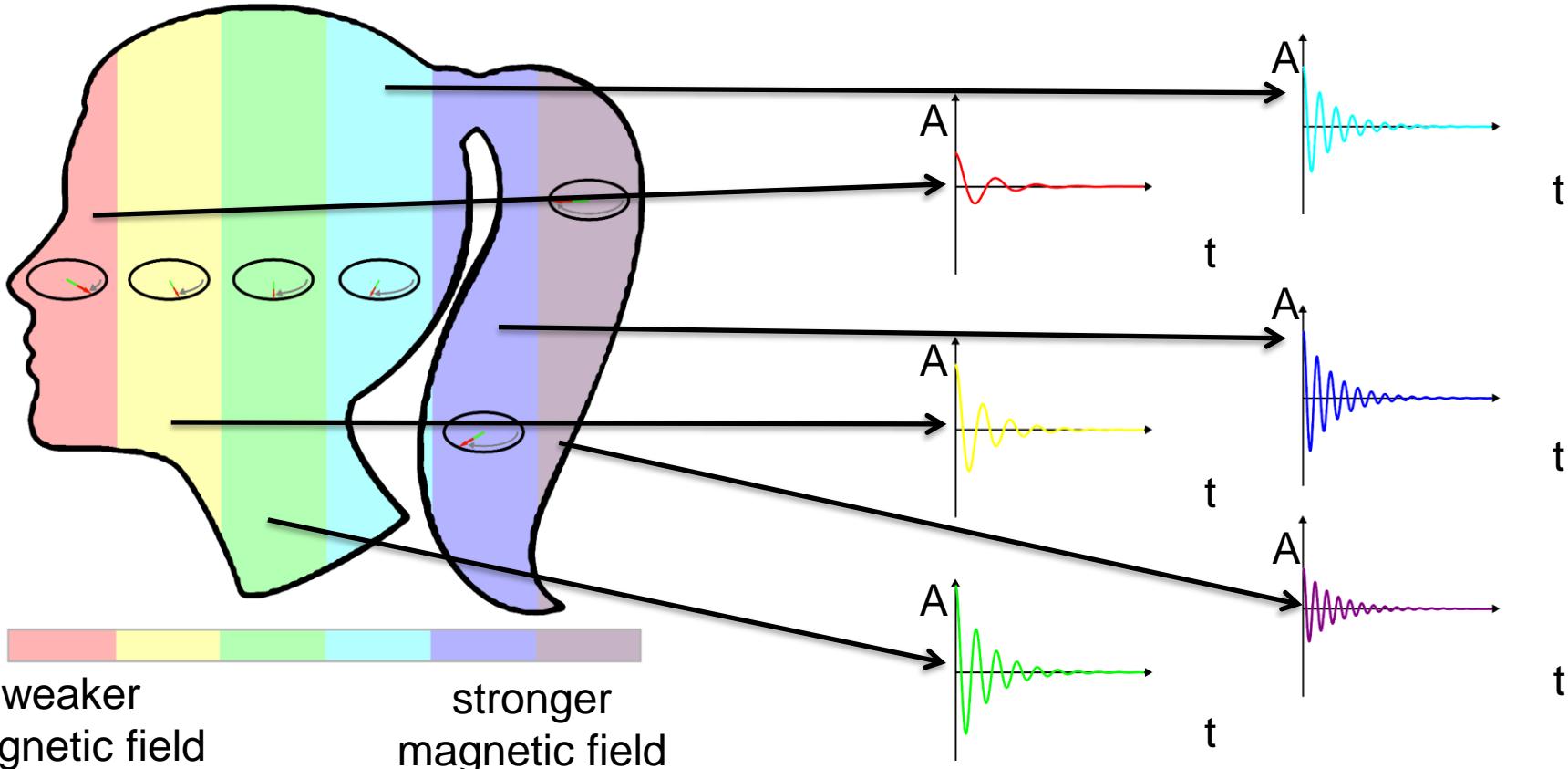
MRI in a nutshell



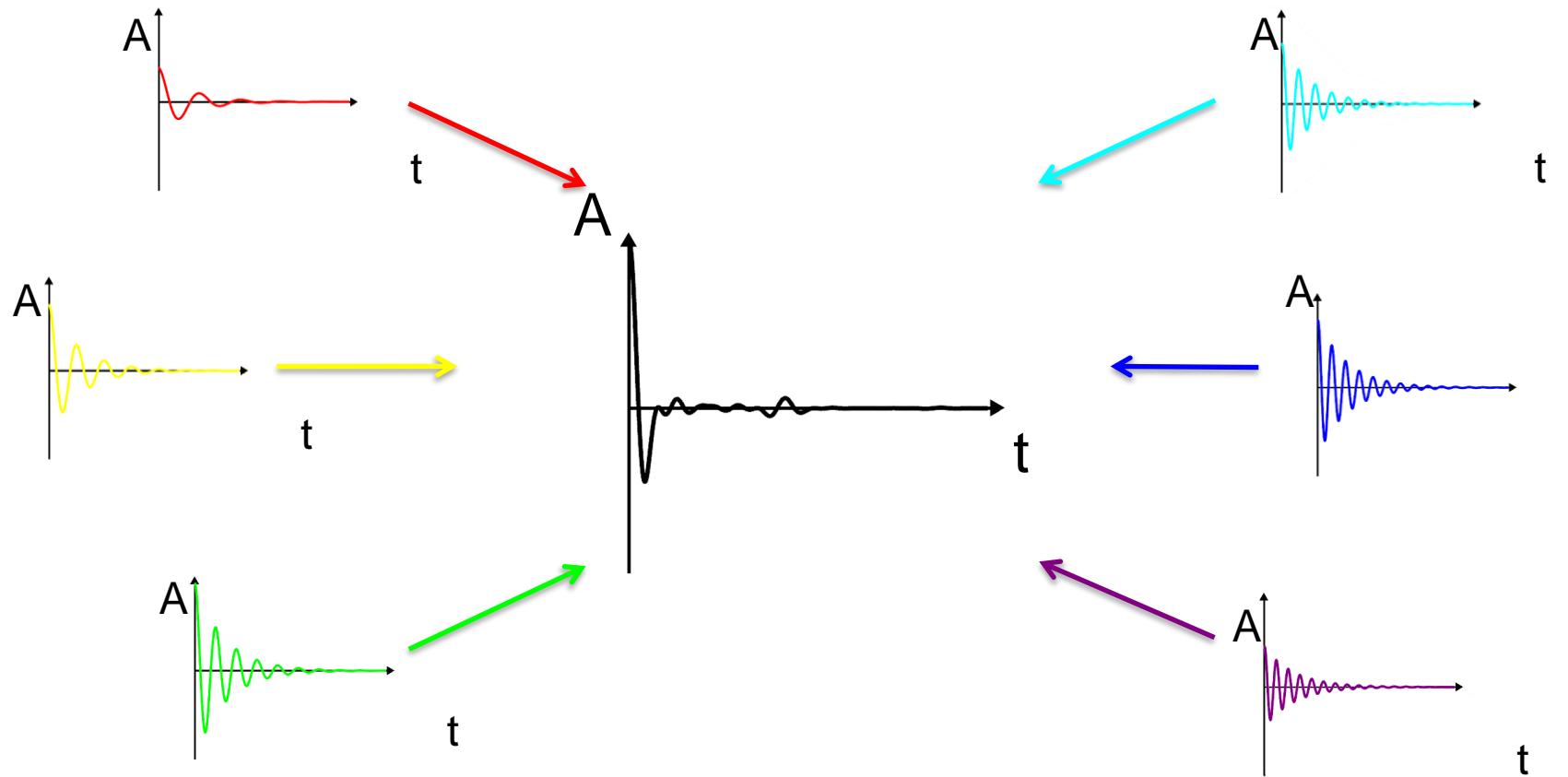
weaker
magnetic field

stronger
magnetic field

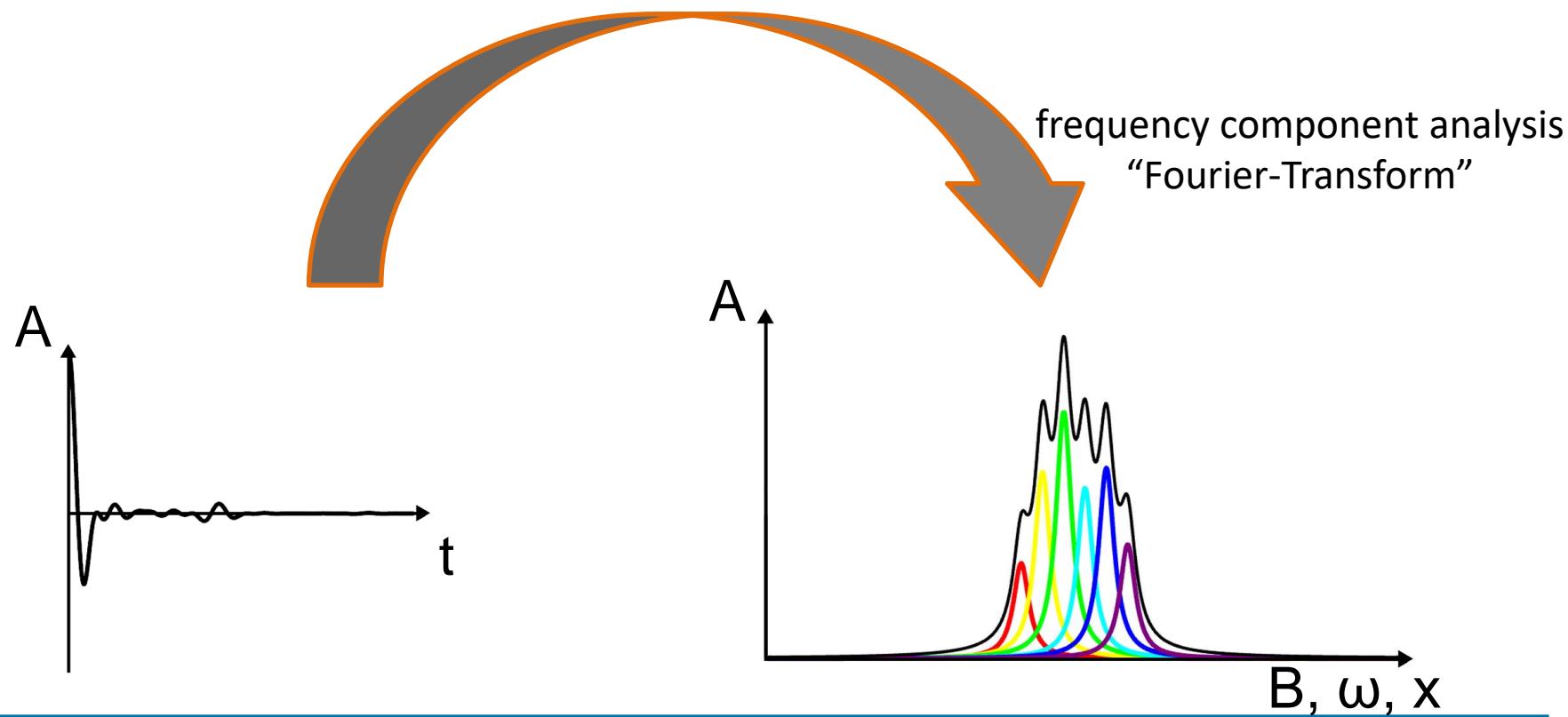
MRI in a nutshell



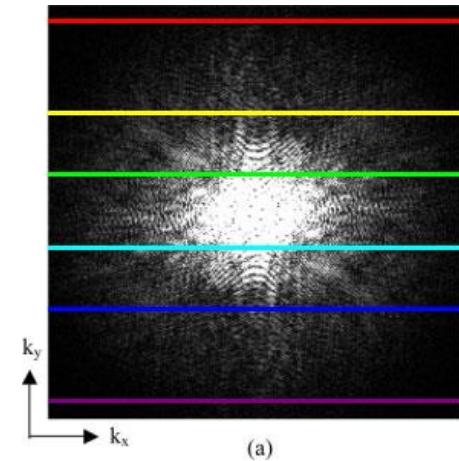
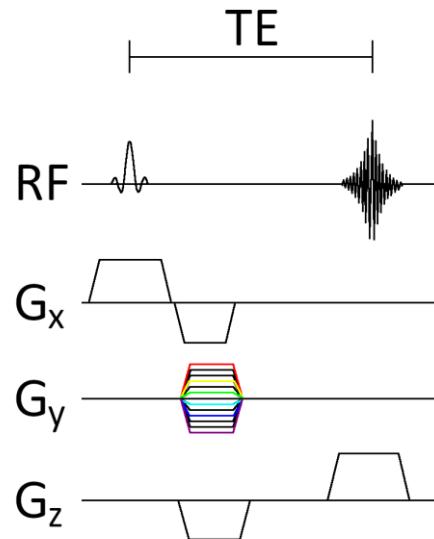
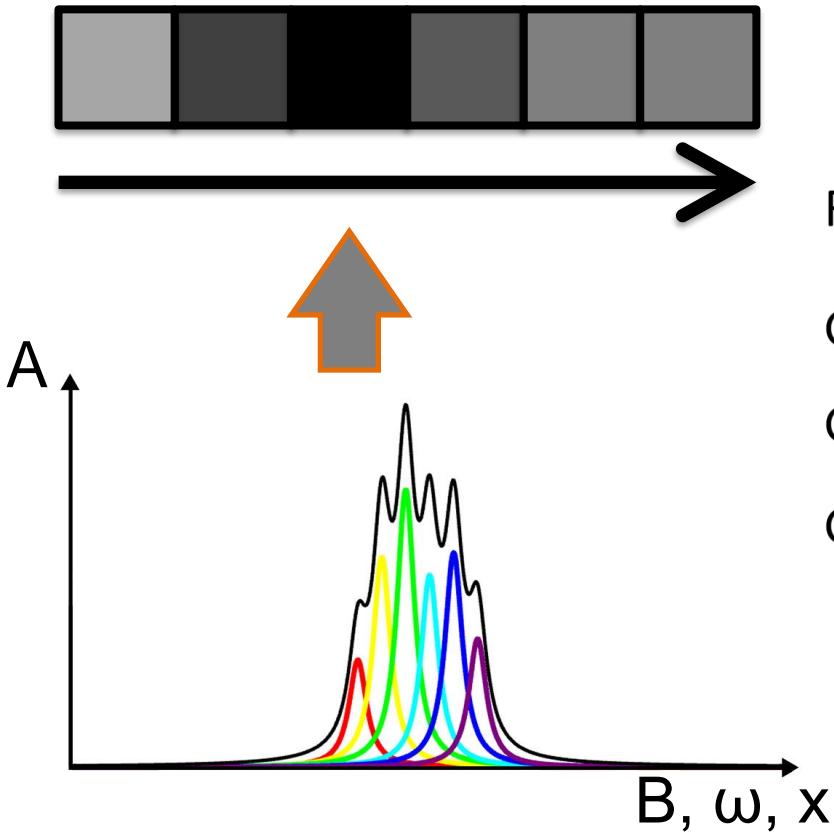
MRI in a nutshell



MRI in a nutshell

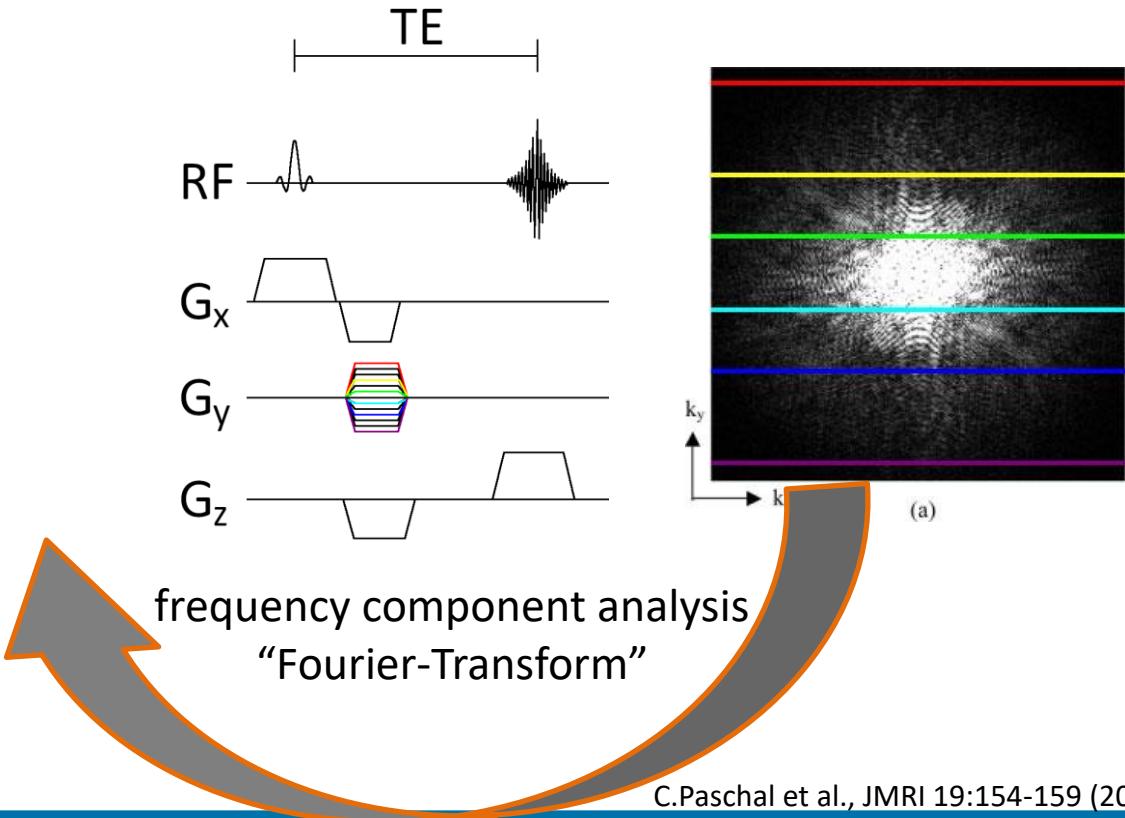
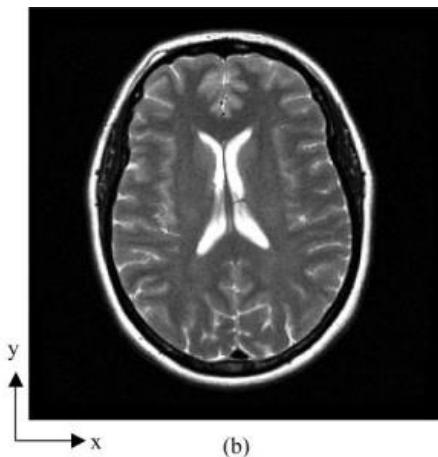


MRI in a nutshell

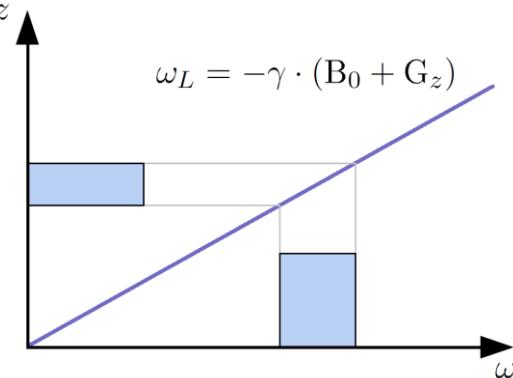
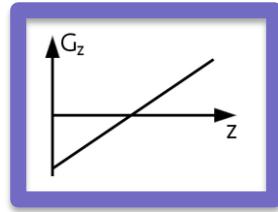
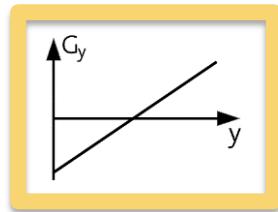
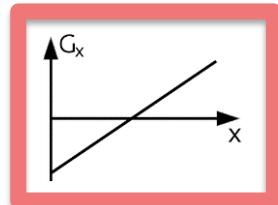


C.Paschal et al., JMRI 19:154-159 (2004)

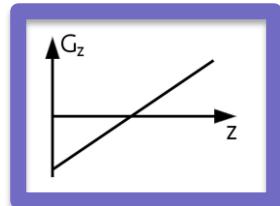
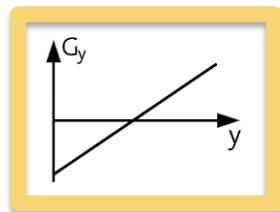
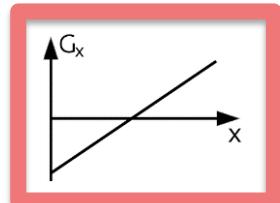
MRI in a nutshell



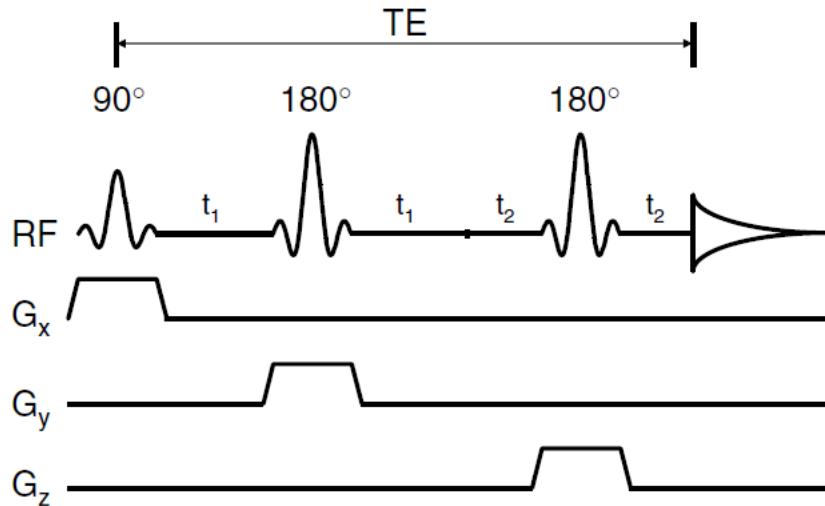
MR Spectroscopy: Difference from Imaging



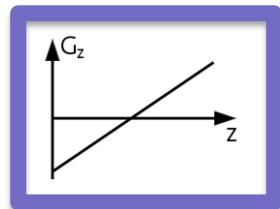
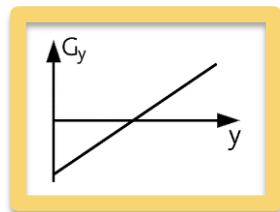
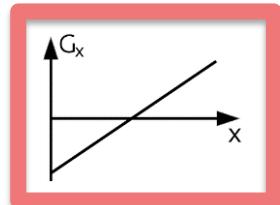
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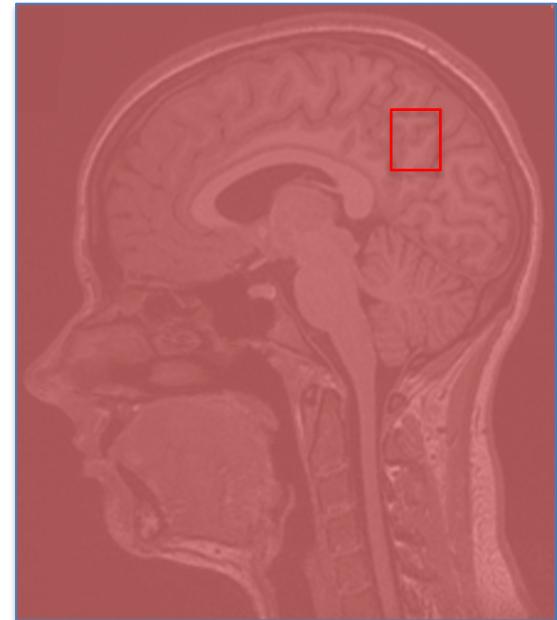
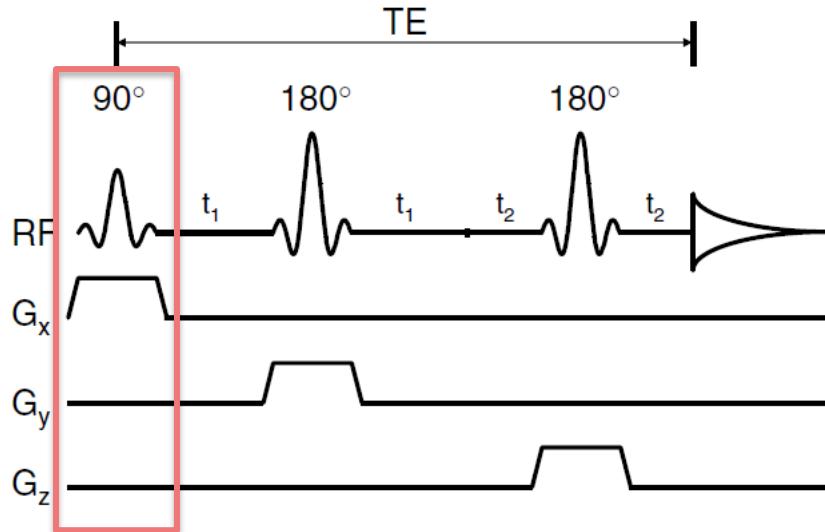
Point Resolved Spectroscopy (PRESS)



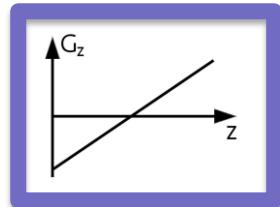
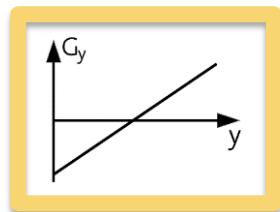
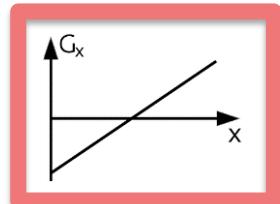
MR Spectroscopy: Difference from Imaging



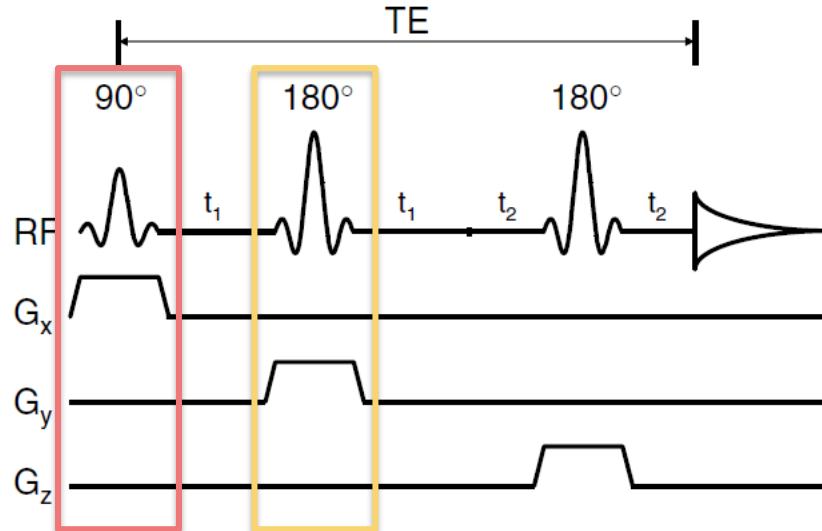
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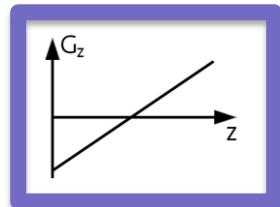
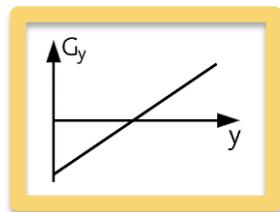
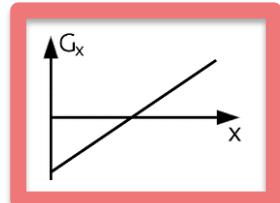
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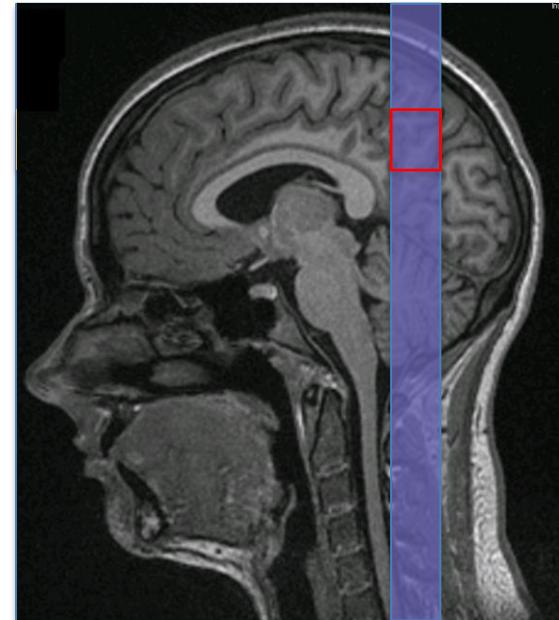
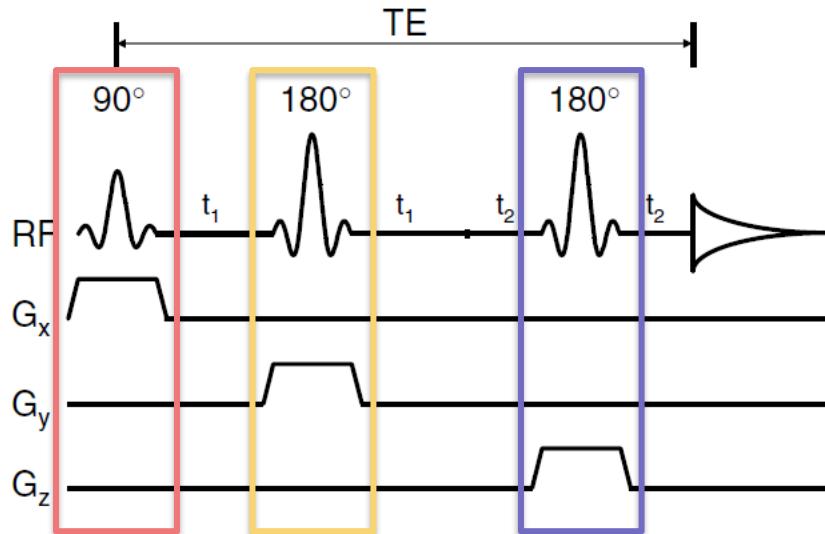
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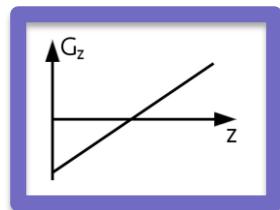
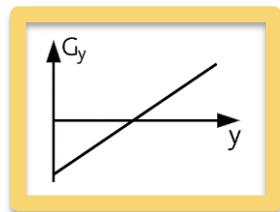
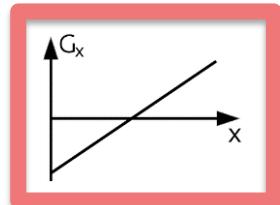
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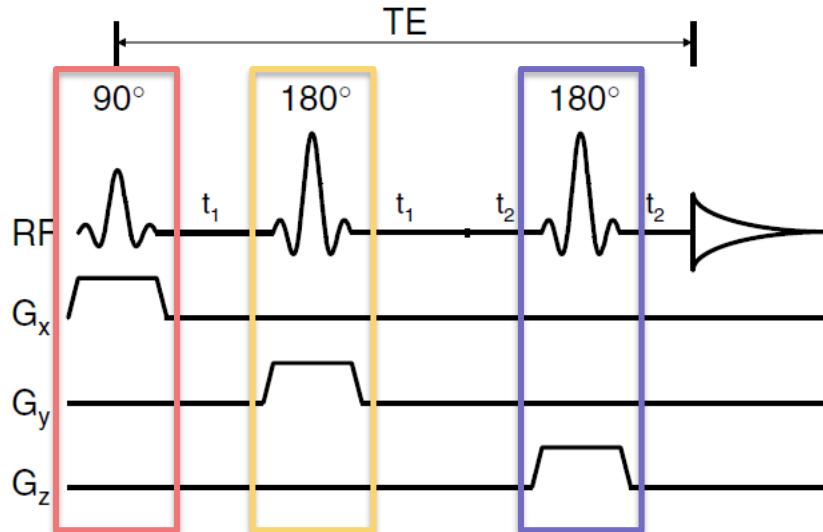
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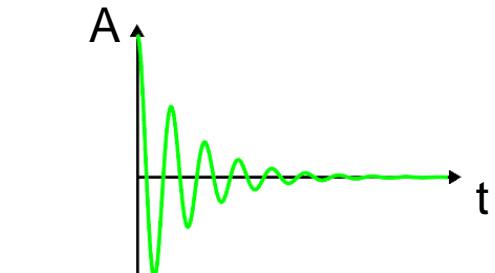
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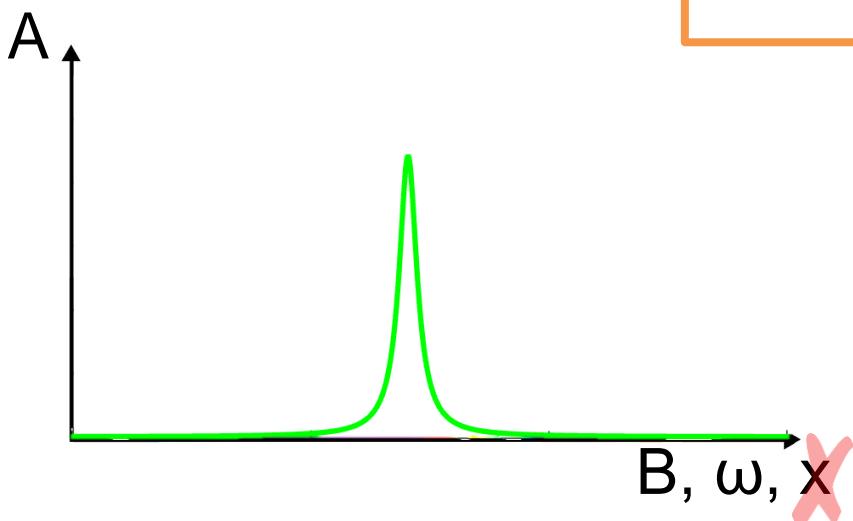
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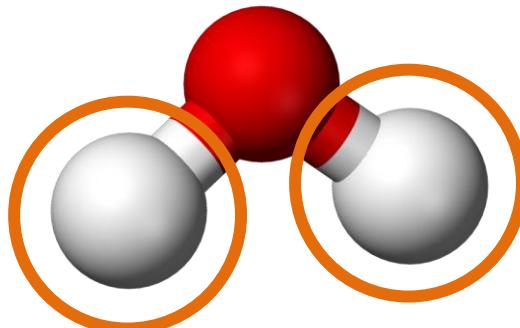
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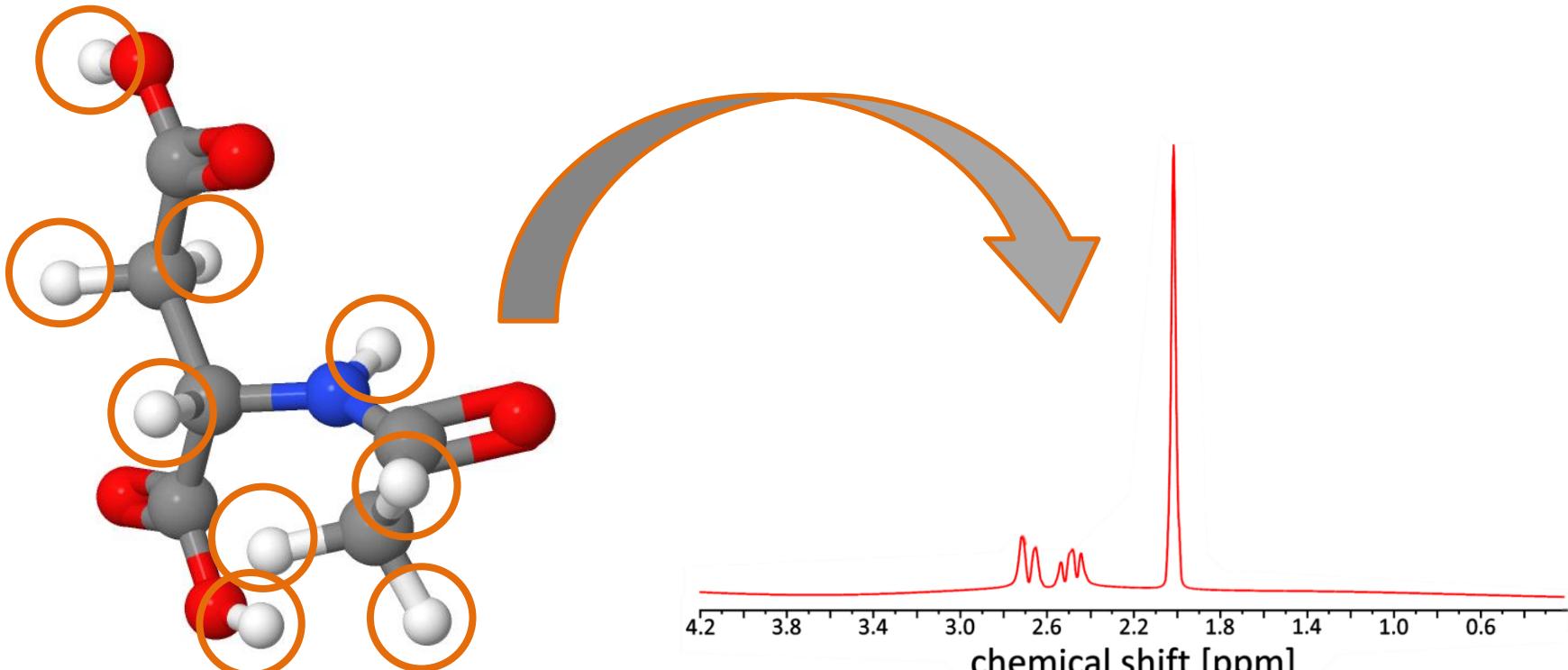
Why do we do this?



Remember, so far we have only talked about water molecules!

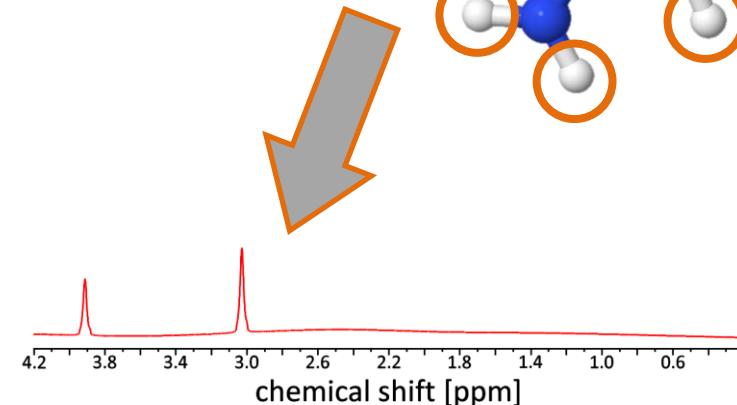
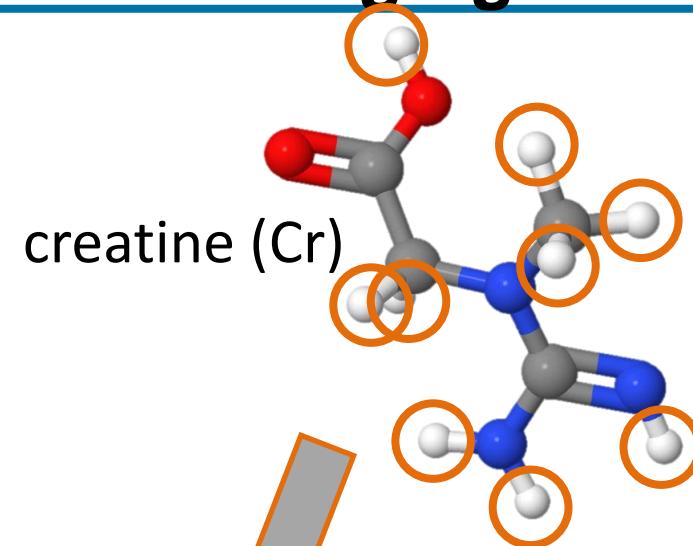
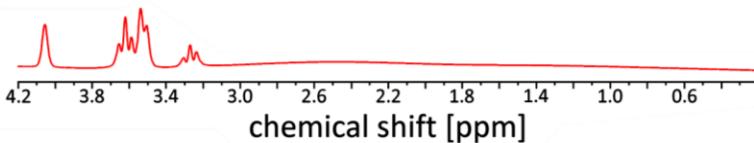
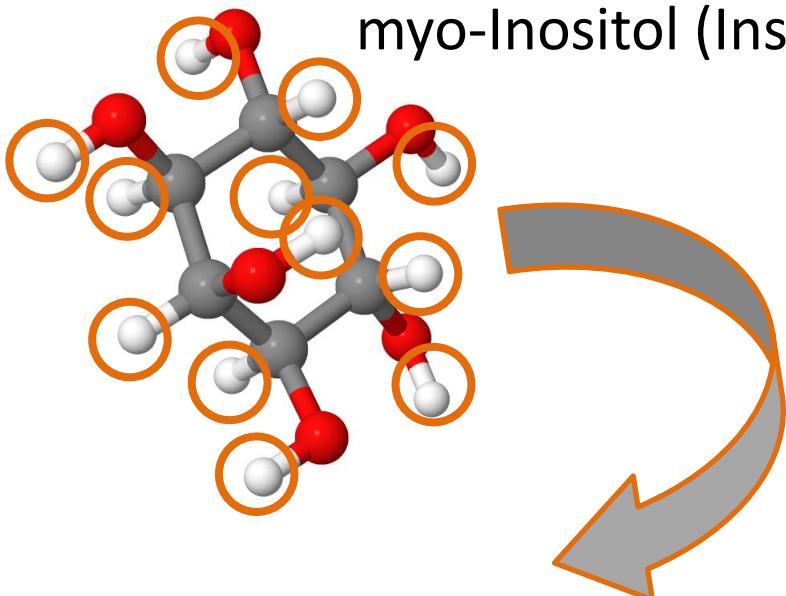


MR Spectroscopy: Difference from Imaging

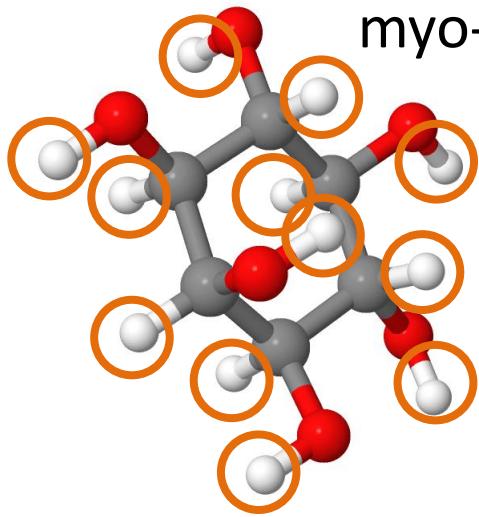


N-acetyl aspartate (NAA)

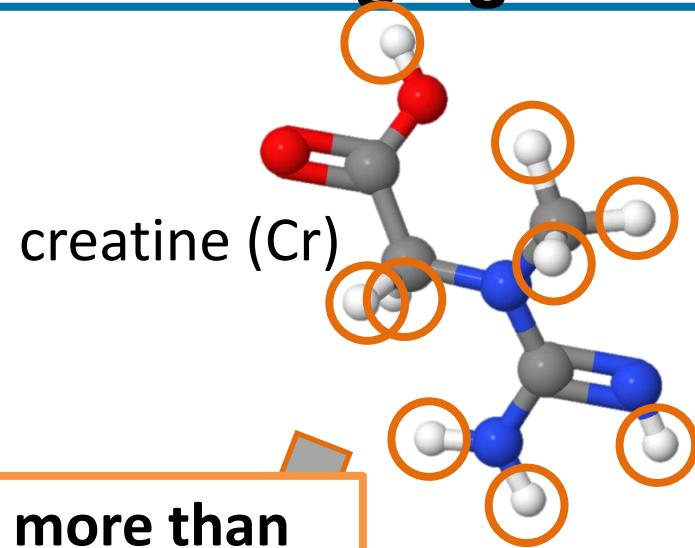
MR Spectroscopy: Difference from Imaging



MR Spectroscopy: Difference from Imaging

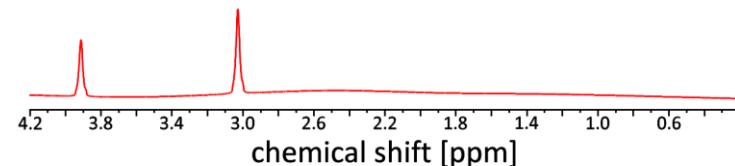
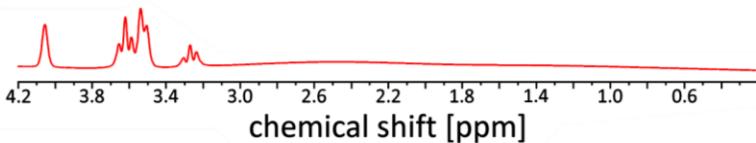


myo-Inositol (Ins)

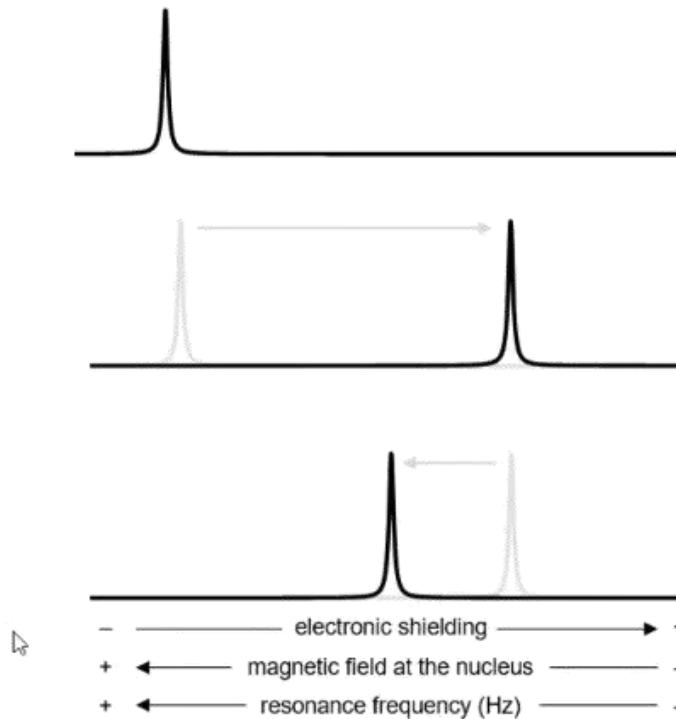
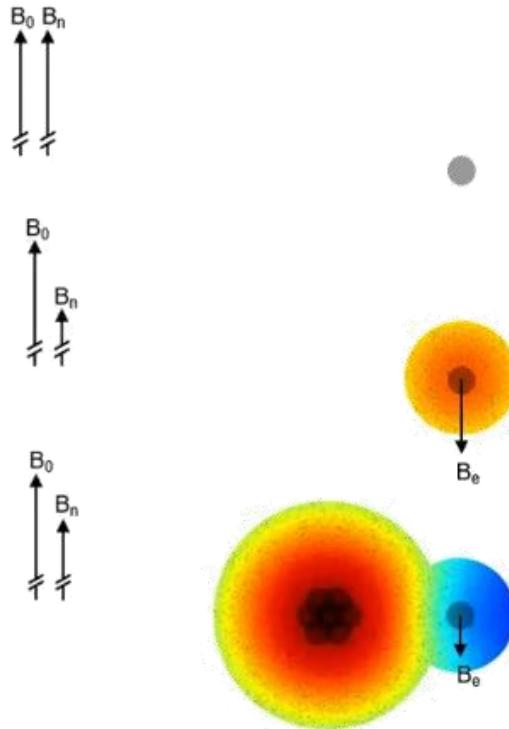


creatine (Cr)

Why do we see more than
one peak?

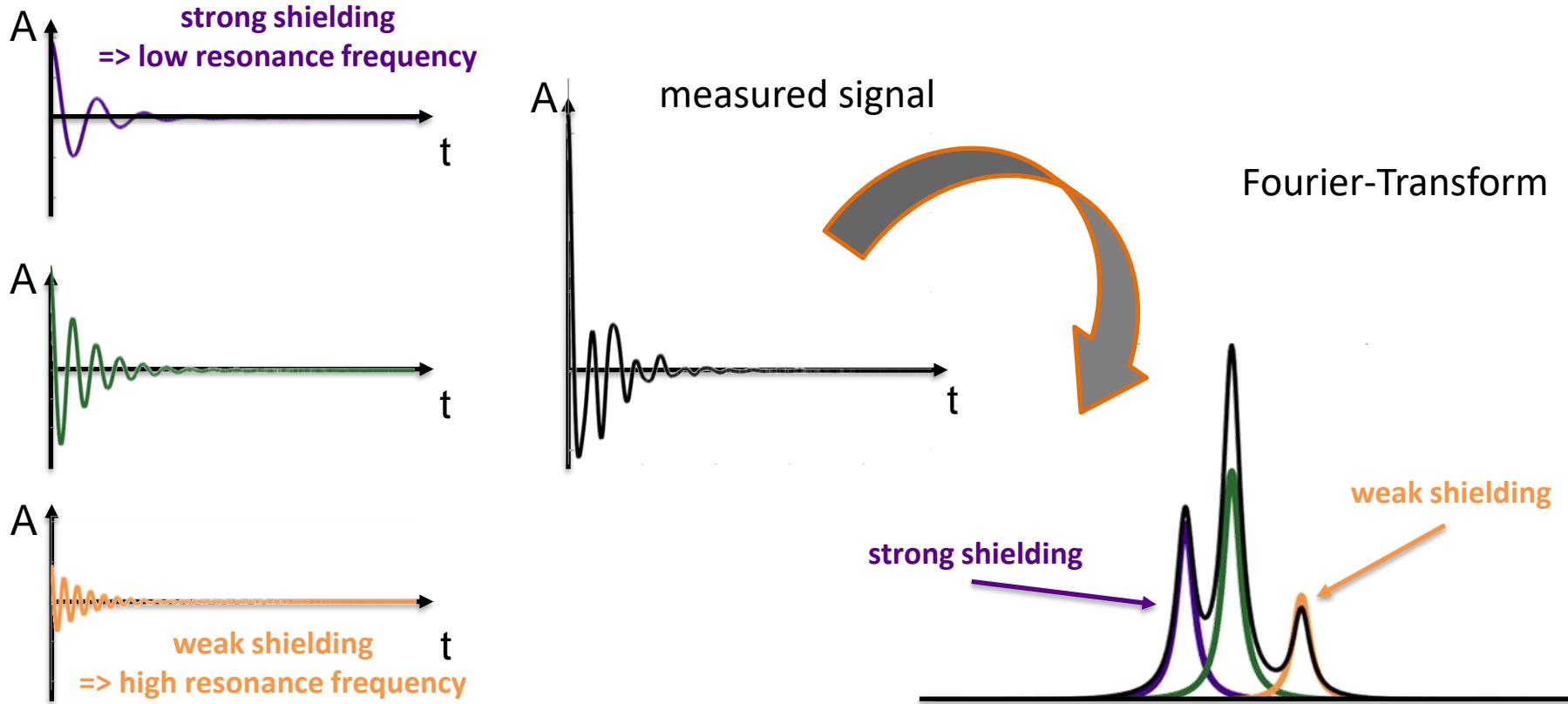


MR Spectroscopy: Chemical Shift



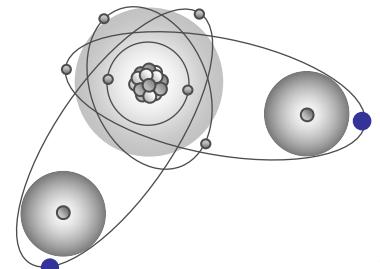
<https://www.youtube.com/watch?v=ImITvTIQeFQ>

MR Spectroscopy: Chemical Shift

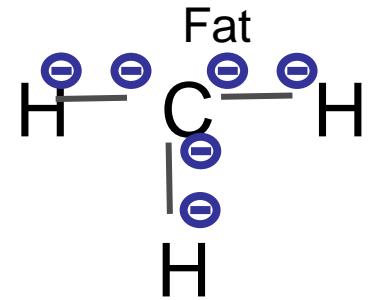
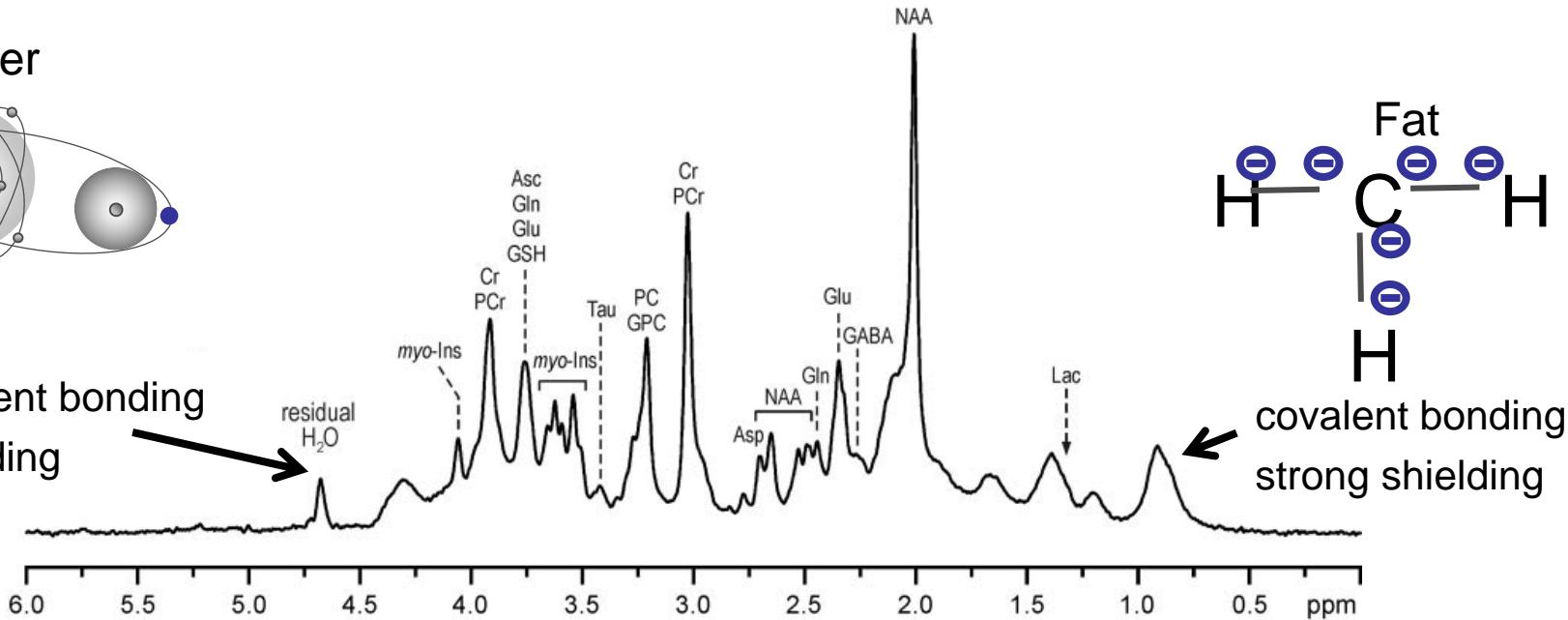


MR Spectroscopy: Chemical Shift

Water



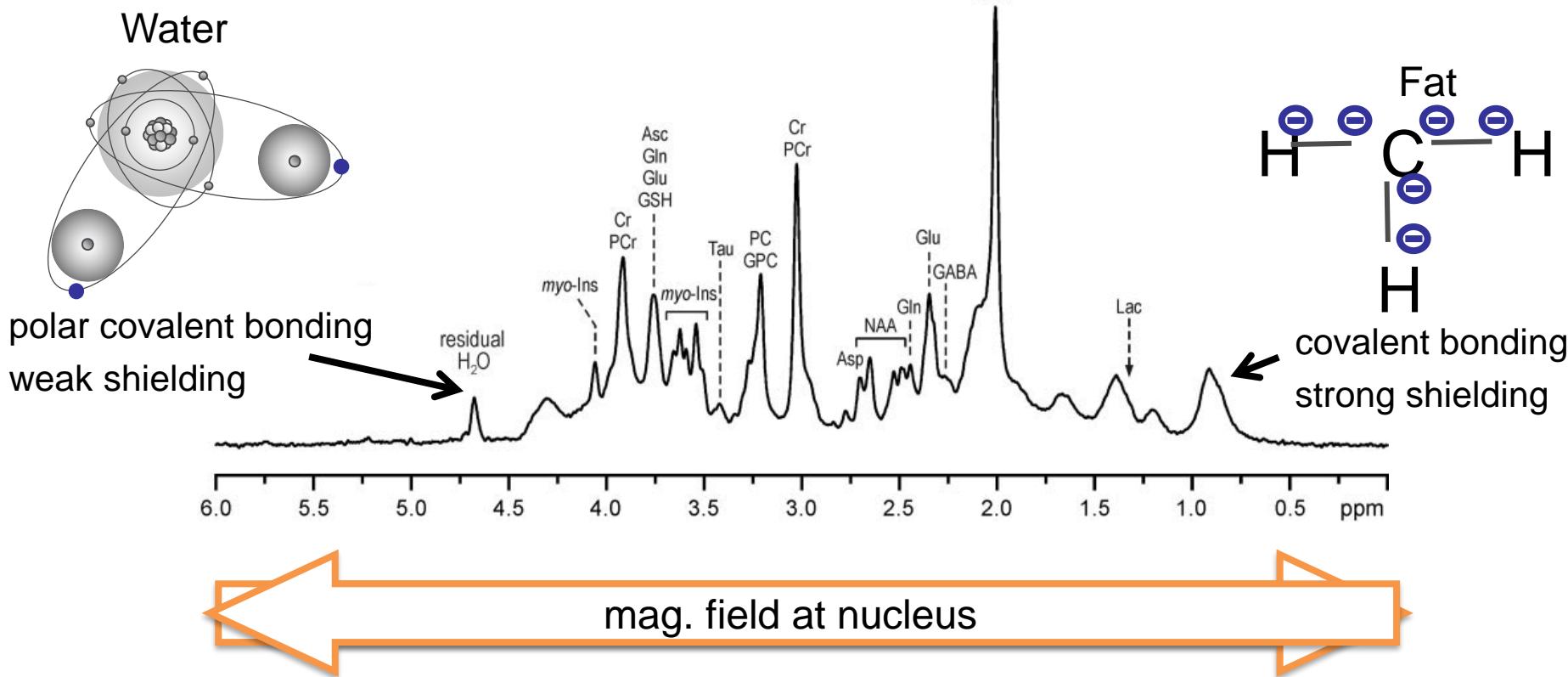
polar covalent bonding
weak shielding



covalent bonding
strong shielding

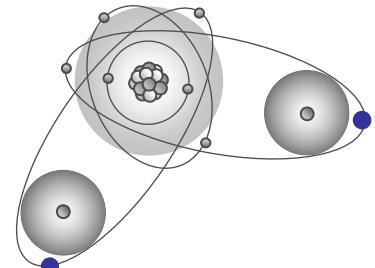
electronic shielding

MR Spectroscopy: Chemical Shift

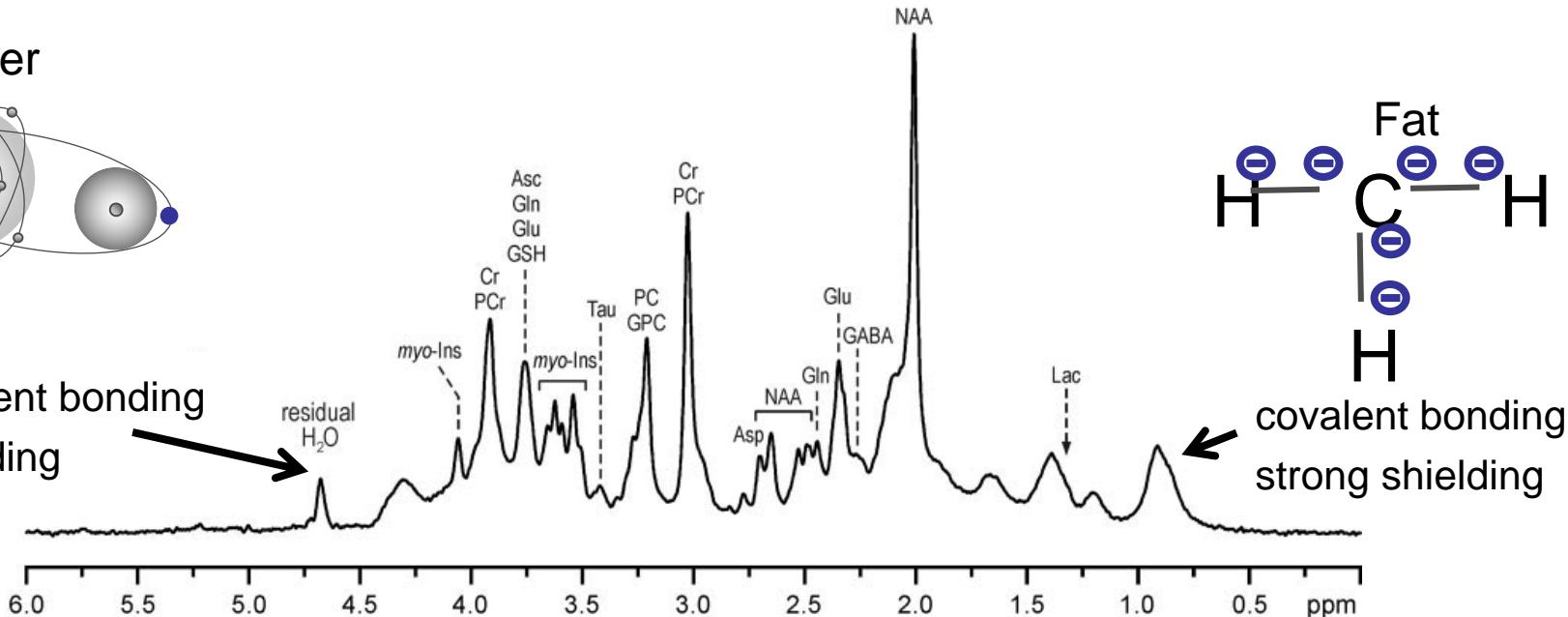


MR Spectroscopy: Chemical Shift

Water

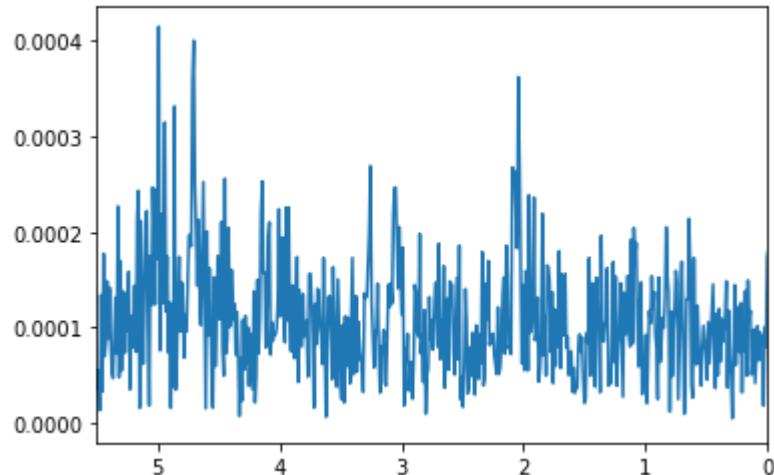


polar covalent bonding
weak shielding

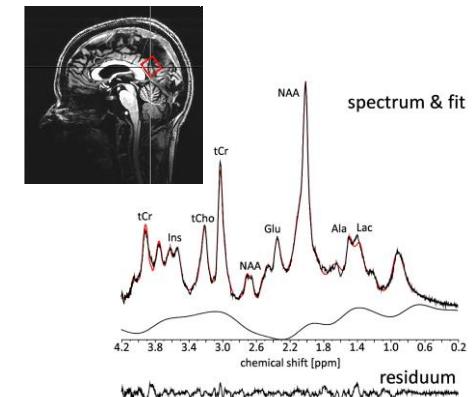
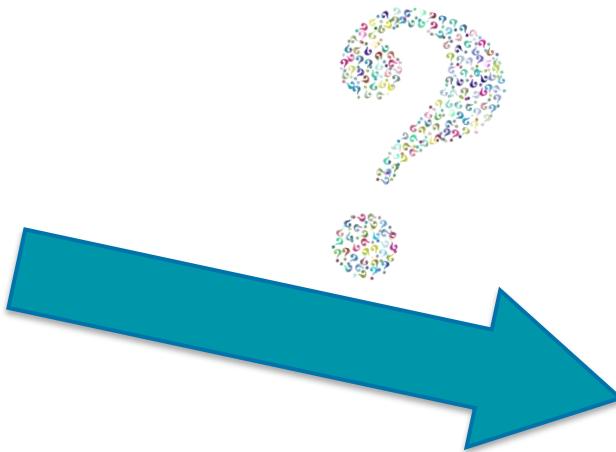
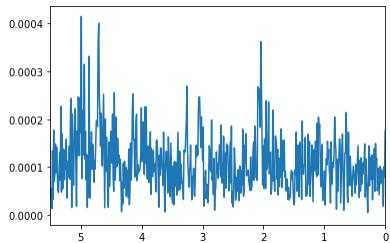


resonance frequency (energy)

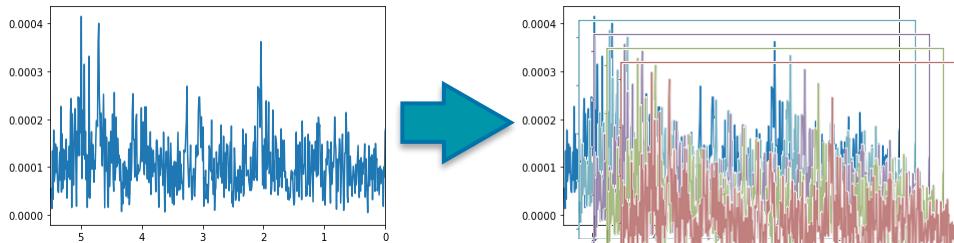
MRS: Data Pre-Processing and Analysis



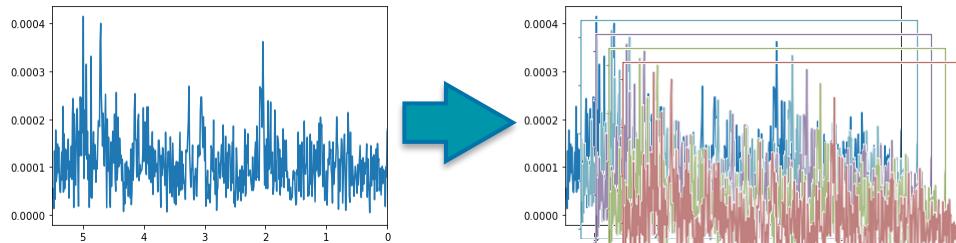
MRS: Data Pre-Processing and Analysis



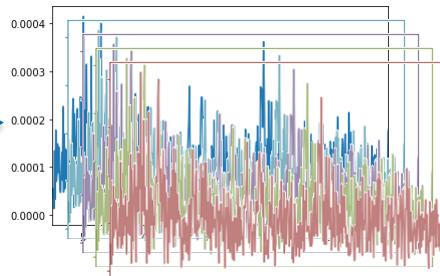
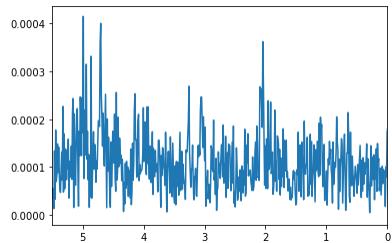
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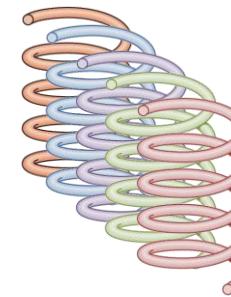
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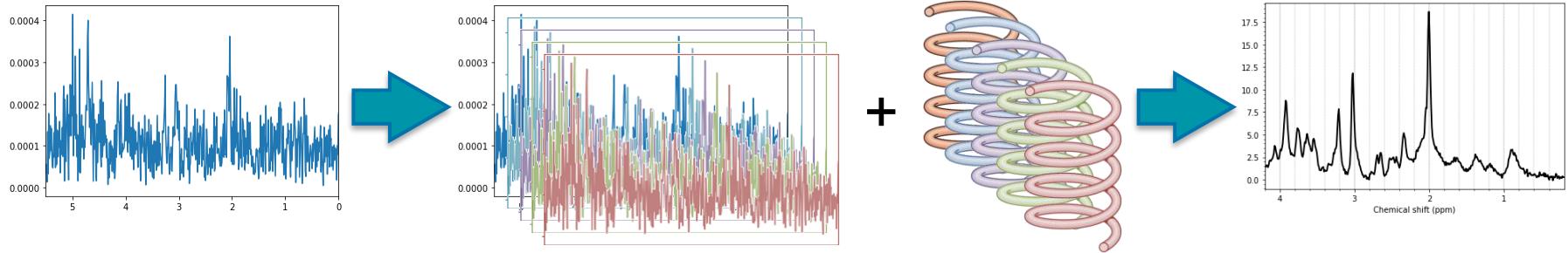
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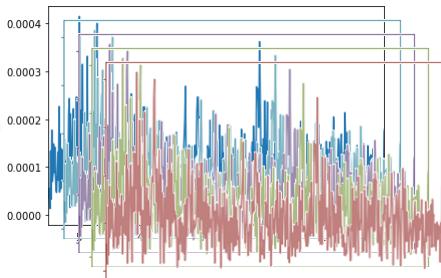
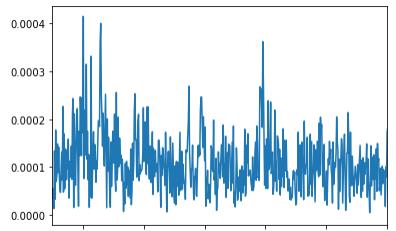
+



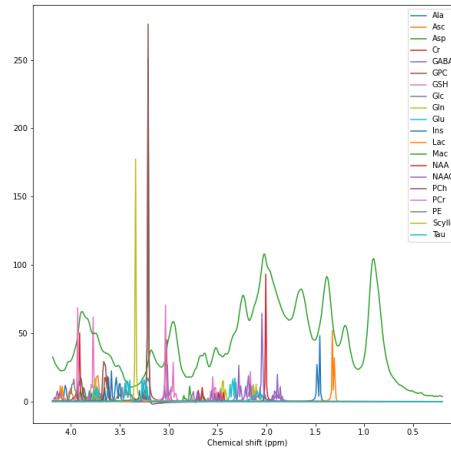
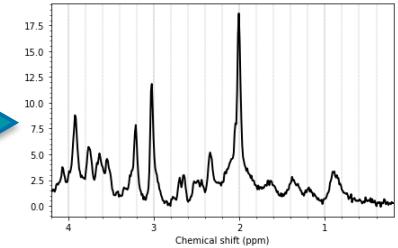
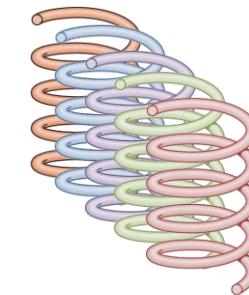
MRS: Data Pre-Processing and Analysis



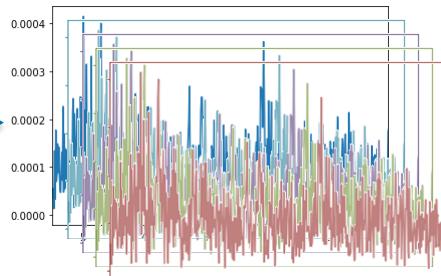
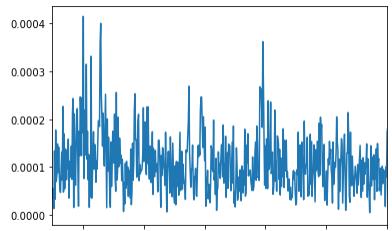
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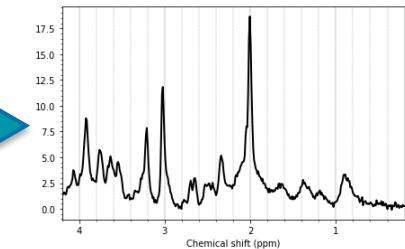
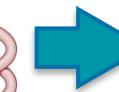
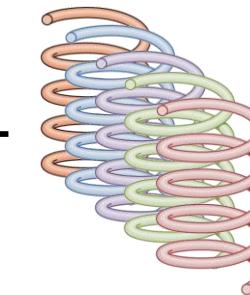
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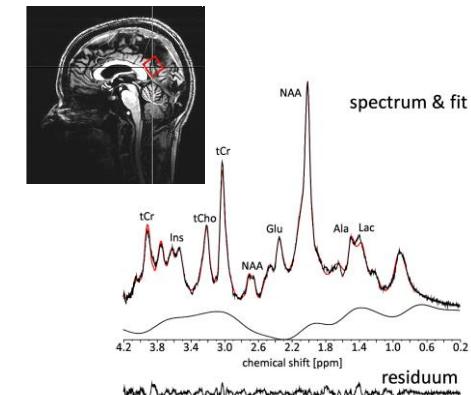
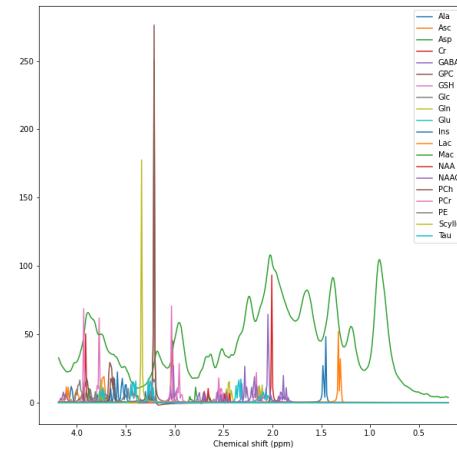
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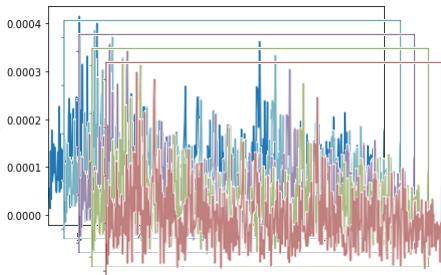
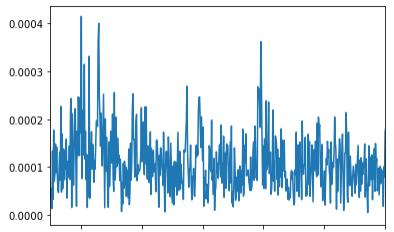
Chemical shift (ppm)



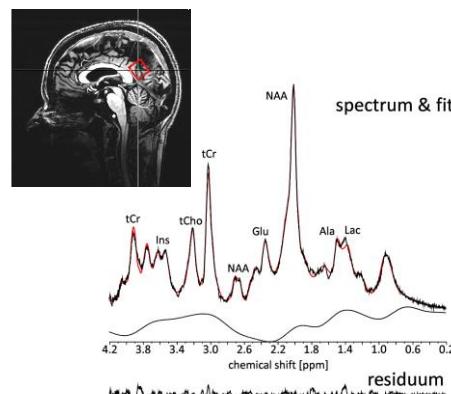
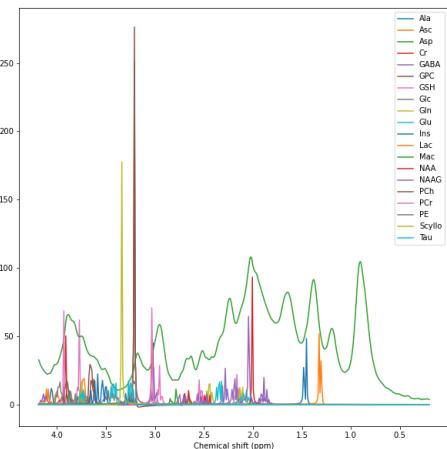
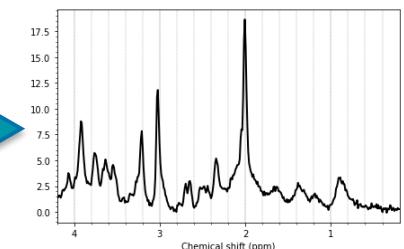
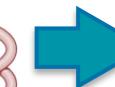
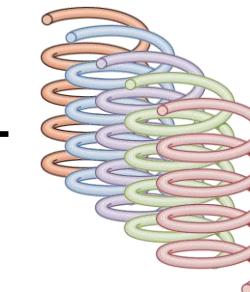
spectrum & fit

residuum

MRS: Data Pre-Processing and Analysis

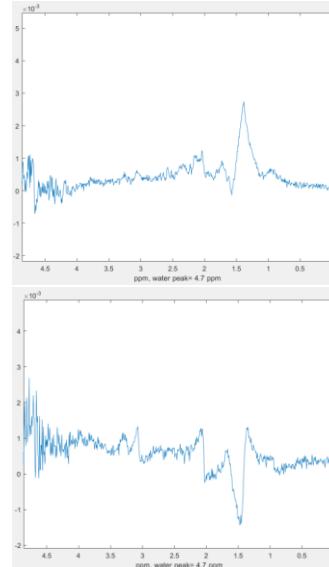
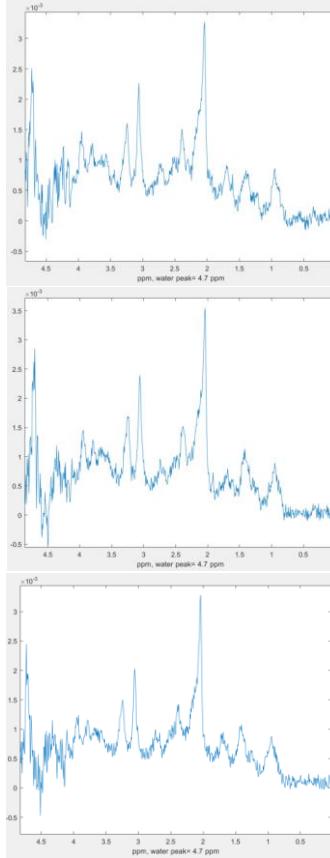
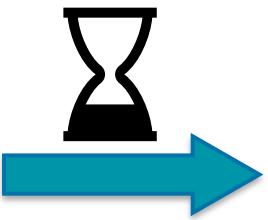
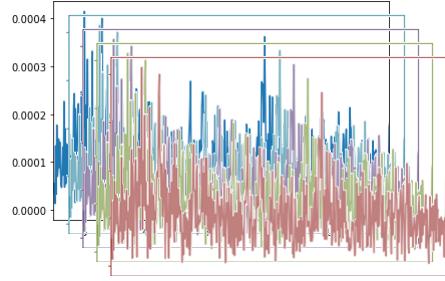


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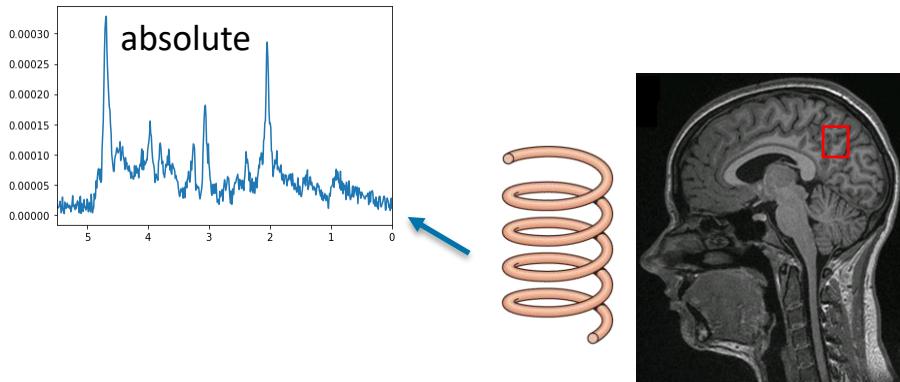


Metab	mMol/k	CRLB	%CRLB	/Cr+PC
Ala	0	0.2	999	0
Asc	0.19	0.37	192.3	0.02
Asp	1.71	0.59	34.1	0.16
Cr	6.82	0.53	7.8	0.65
GABA	2.12	0.29	13.6	0.2
GPC	1.47	0.23	15.7	0.14
GSH	1.8	0.19	10.5	0.17
Glc	0	0.55	999	0
Gln	1.72	0.36	20.9	0.16
Glu	11.18	0.37	3.3	1.06
Ins	8.2	0.35	4.3	0.78
Lac	0.85	0.19	22.2	0.08
Mac	0.78	0.07	8.4	0.07
NAA	14.62	0.43	2.9	1.39
NAAG	2.09	0.2	9.5	0.2
PCh	0.5	0.25	49.6	0.05
PCr	3.71	0.53	14.2	0.35
PE	1.81	0.38	21.2	0.17
Scyllo	0.73	0.09	12.8	0.07
Tau	2.07	0.34	16.6	0.2
Cr+PCr	10.53	0.35	3.3	1
NAA+N _A	16.71	0.38	2.3	1.59
Glu+Gln	12.9	0.47	3.7	1.23
GPC+PC	1.97	0.11	5.4	0.19
Glc+Tau	2.07	0.42	20.4	0.2

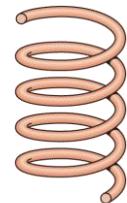
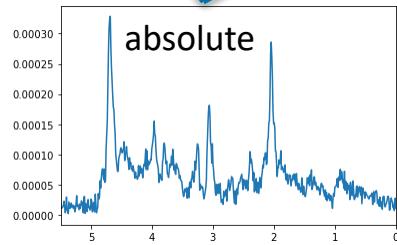
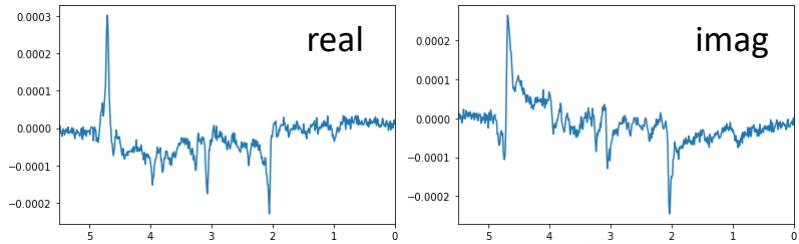
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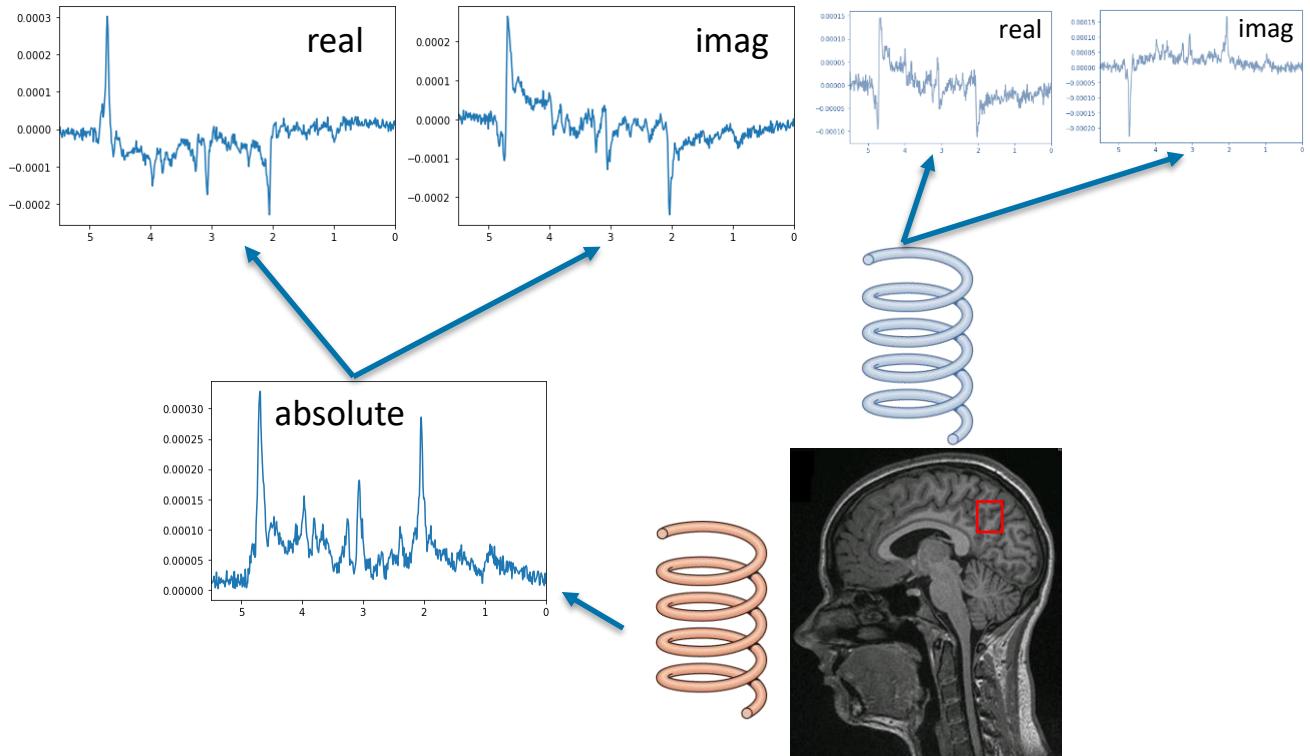
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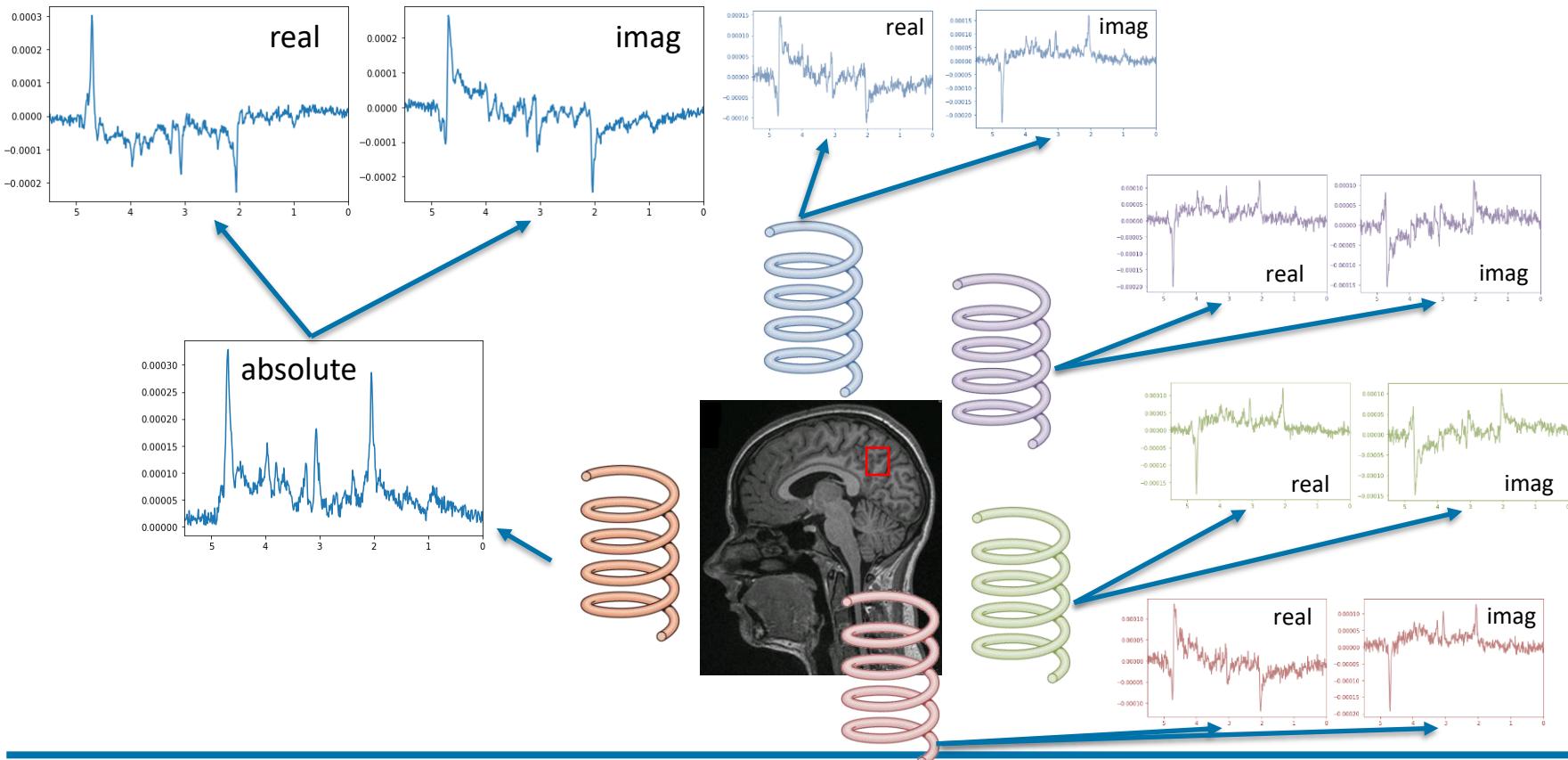
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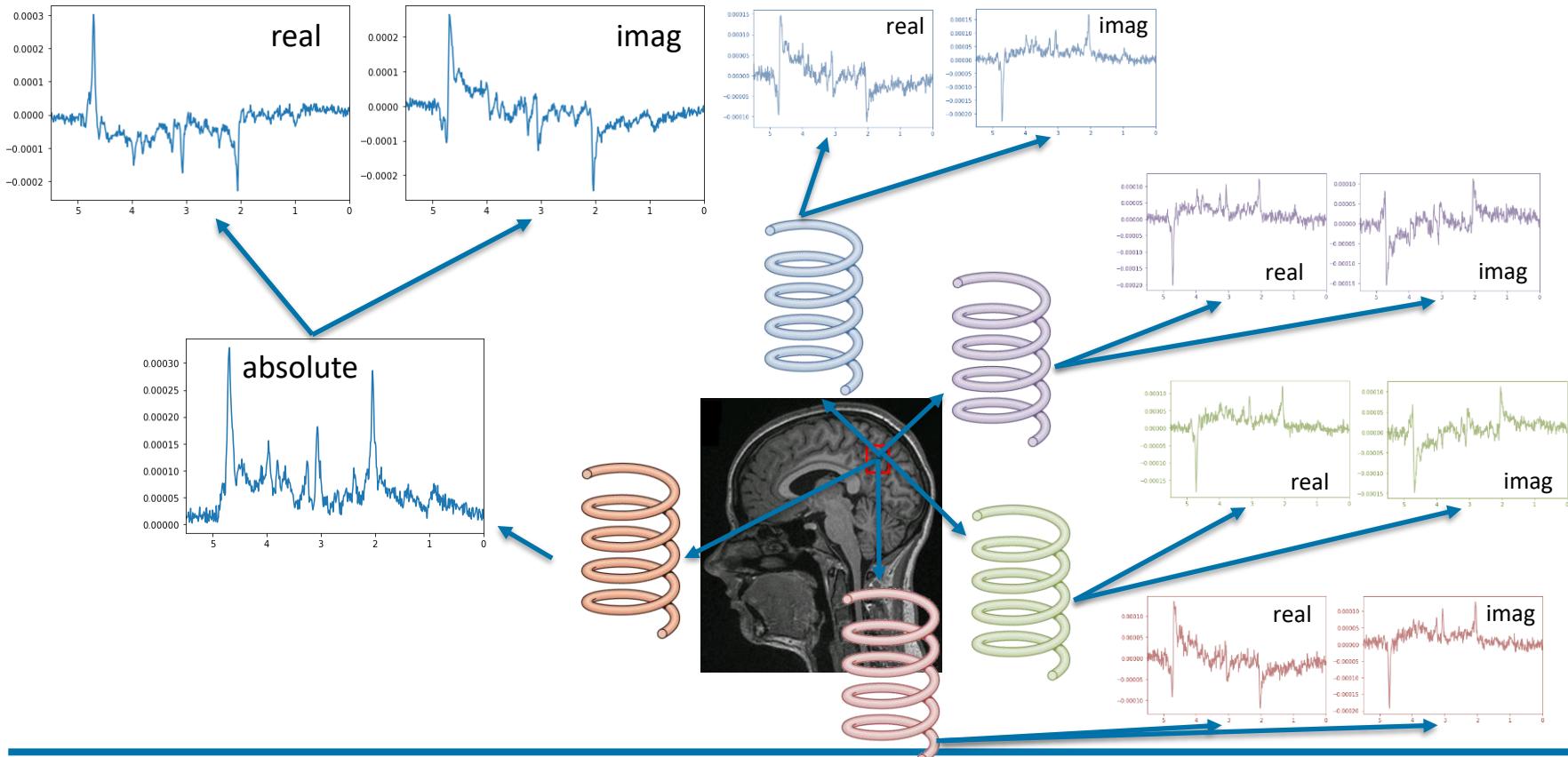
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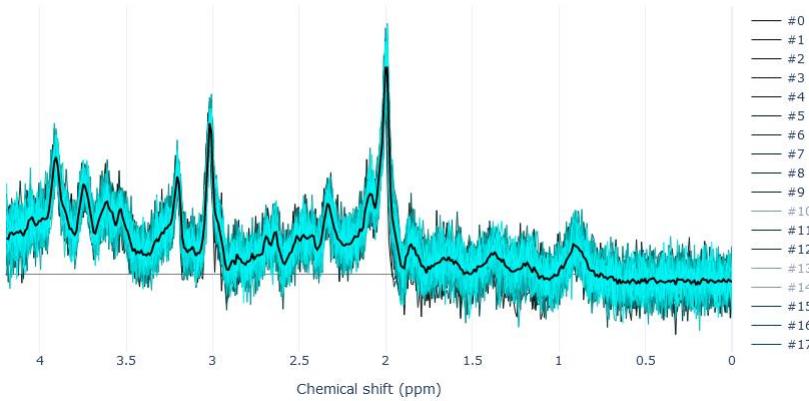


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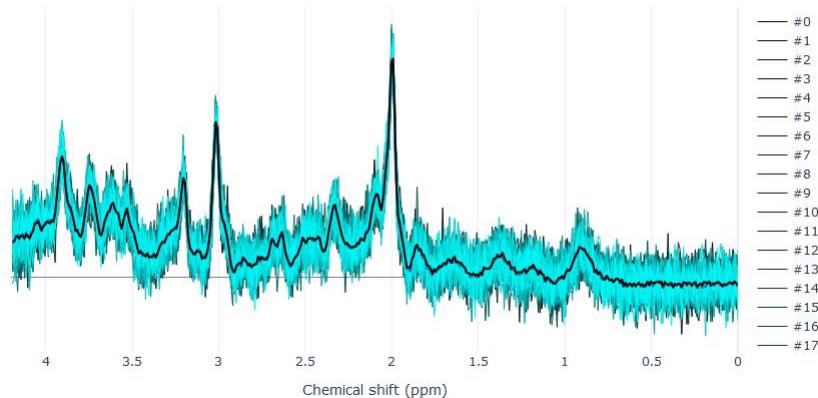


MRS: Data Pre-Processing and Analysis

Unaligned



Aligned

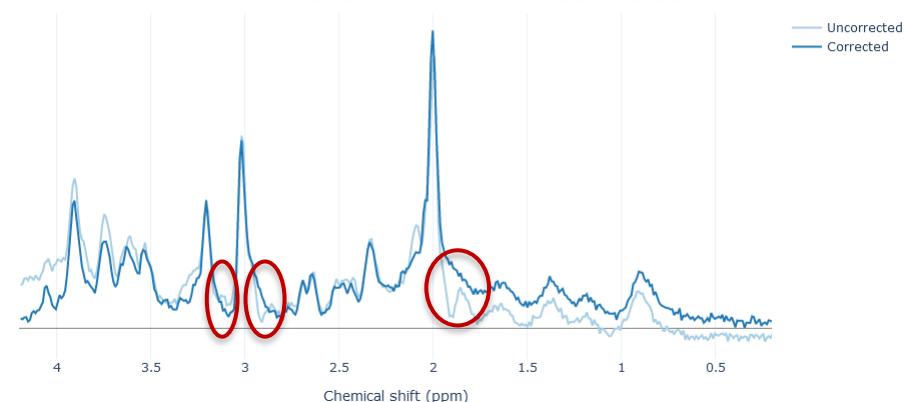
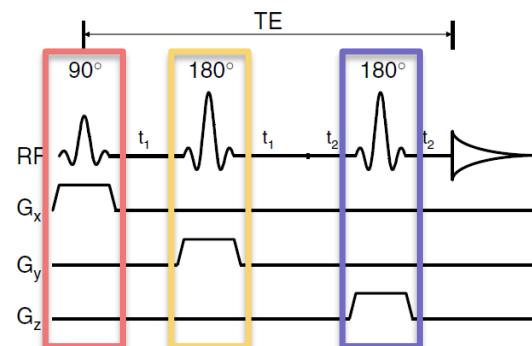
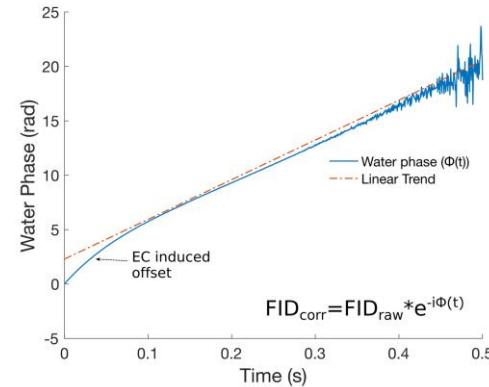


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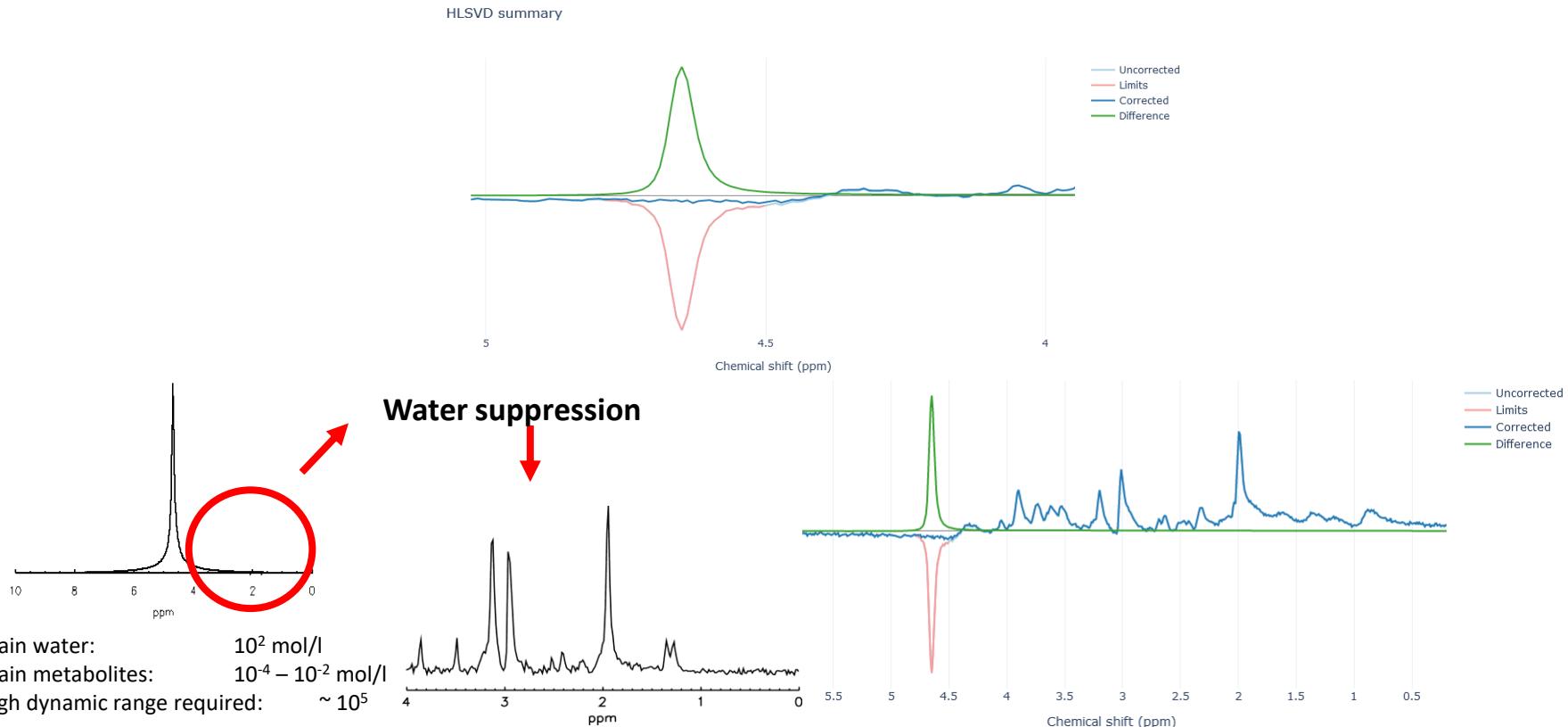


Outer Volume Suppression (OVS)

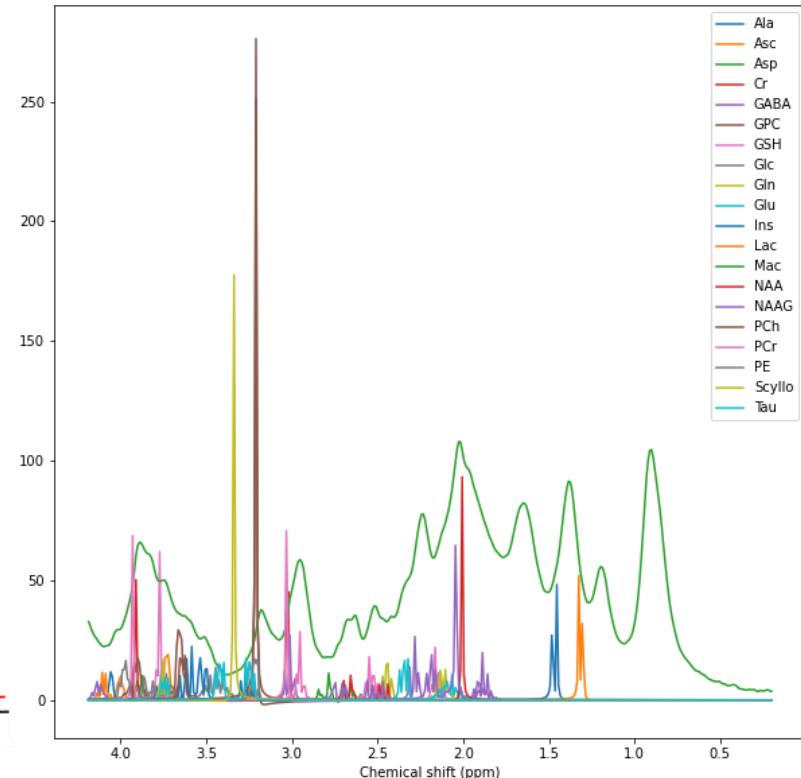
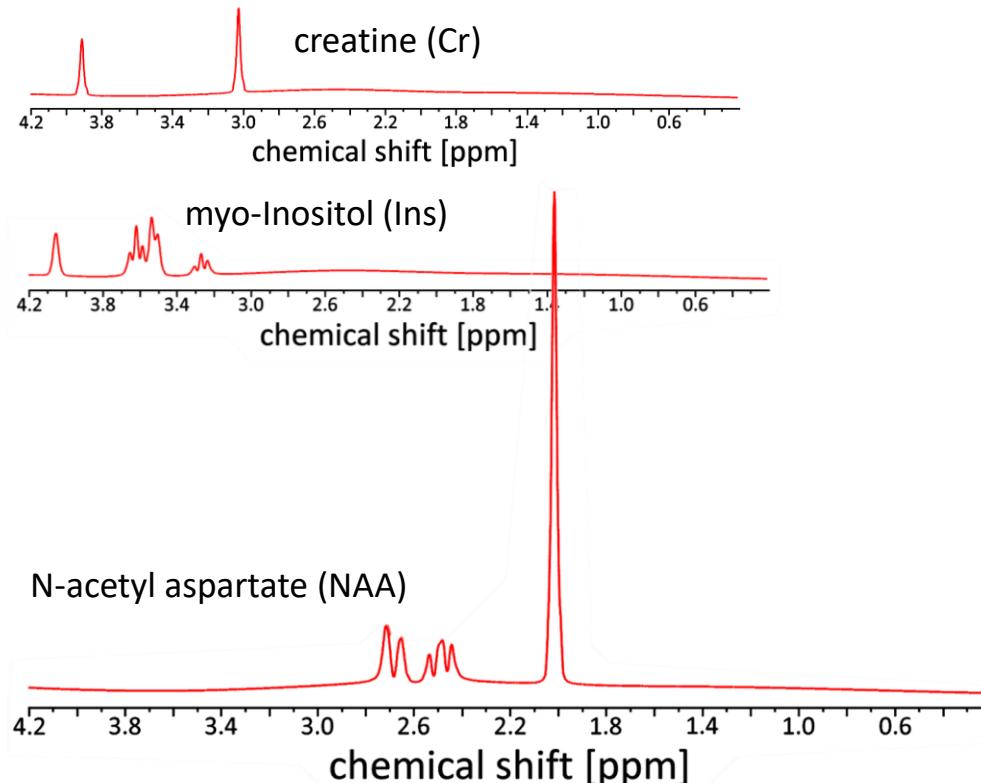
ECC summary



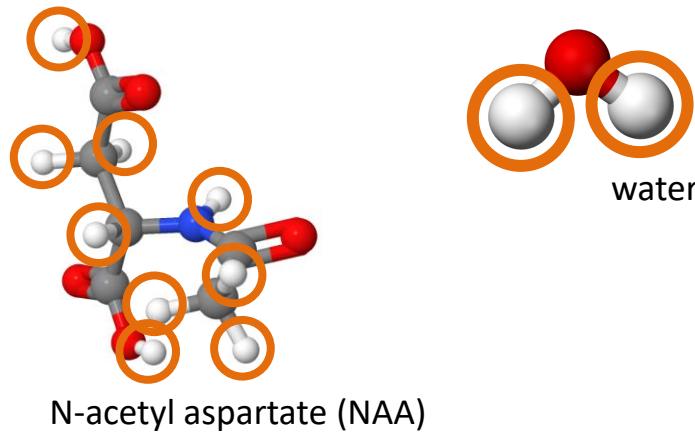
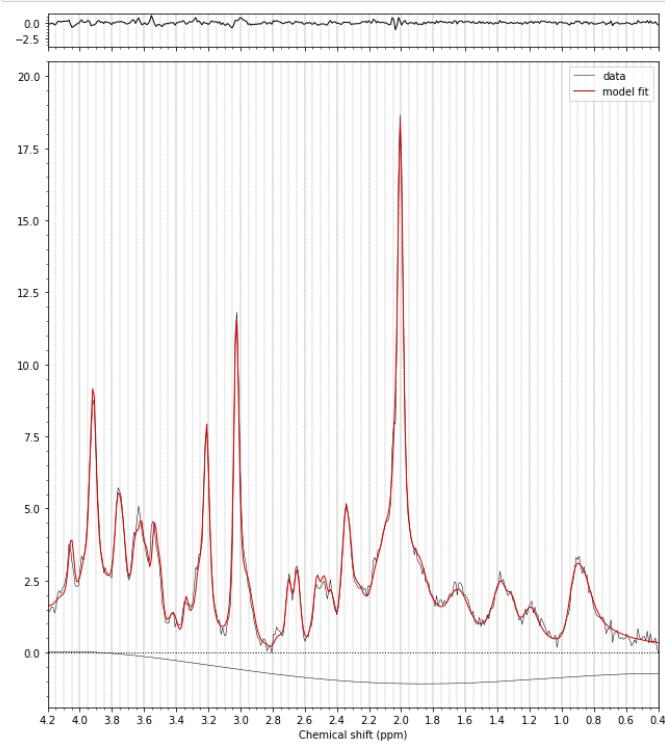
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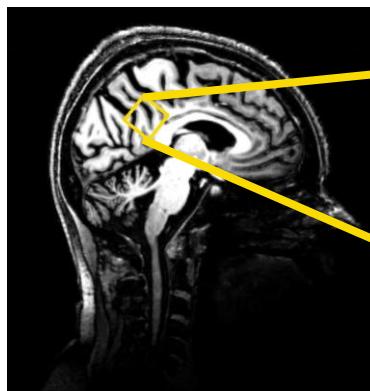
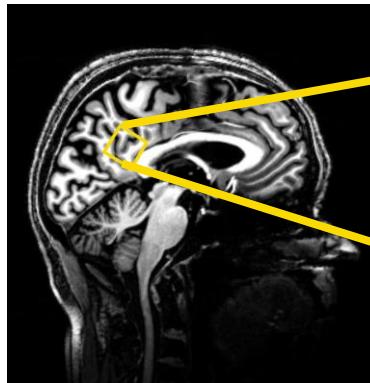
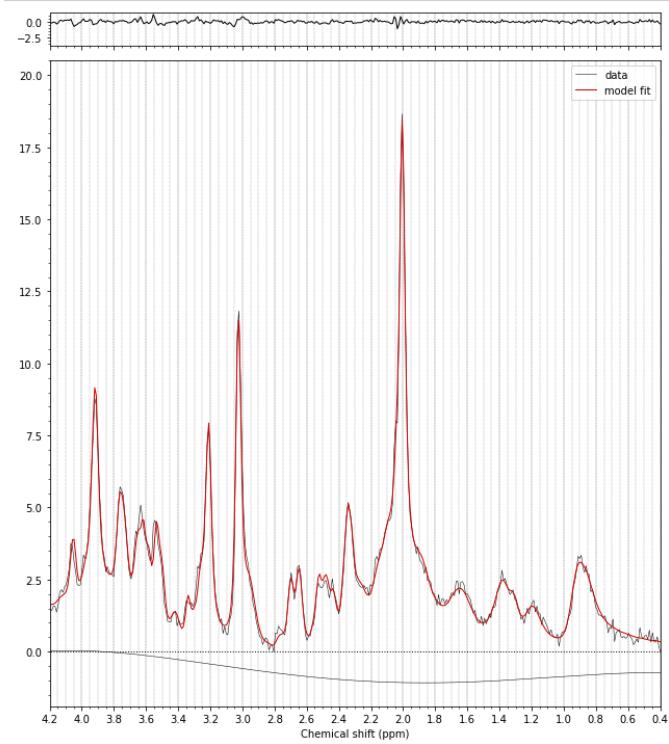
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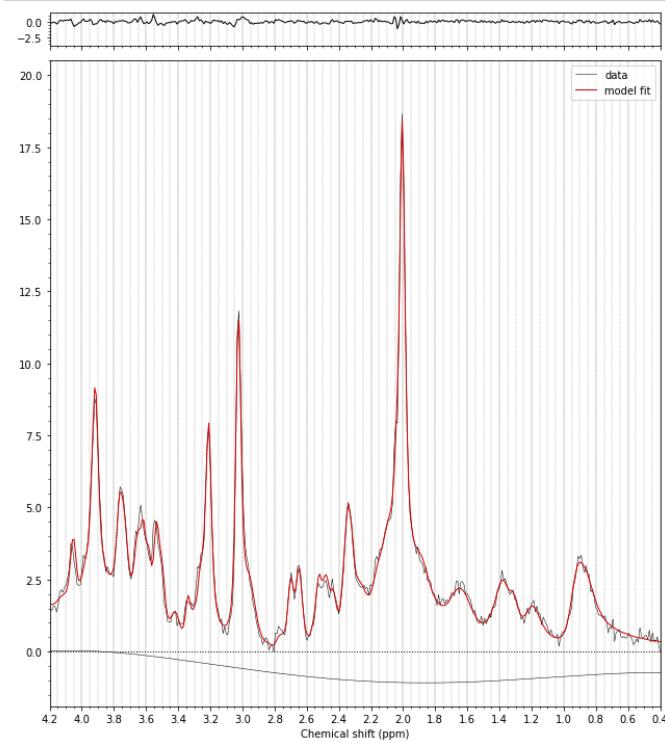
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Scyllo	0.73	0.09	12.8	0.07
Tau	2.07	0.34	16.6	0.2
Cr+PCr	10.53	0.35	3.3	1
NAA+NA	16.71	0.38	2.3	1.59
Glu+Gln	12.9	0.47	3.7	1.23
GPC+PC	1.97	0.11	5.4	0.19
Glc+Tau	2.07	0.42	20.4	0.2