Designing Protocols for MR imaging and Spectroscopy

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Examples taken from the project proposed by and worked out with

P.T. NARASIMHAN

To combine imaging and spectroscopy in the study of the mouse brain using intermolecular multiple quantum coherences.

ACKNOLEDGEMENTS

Tim Hiltner

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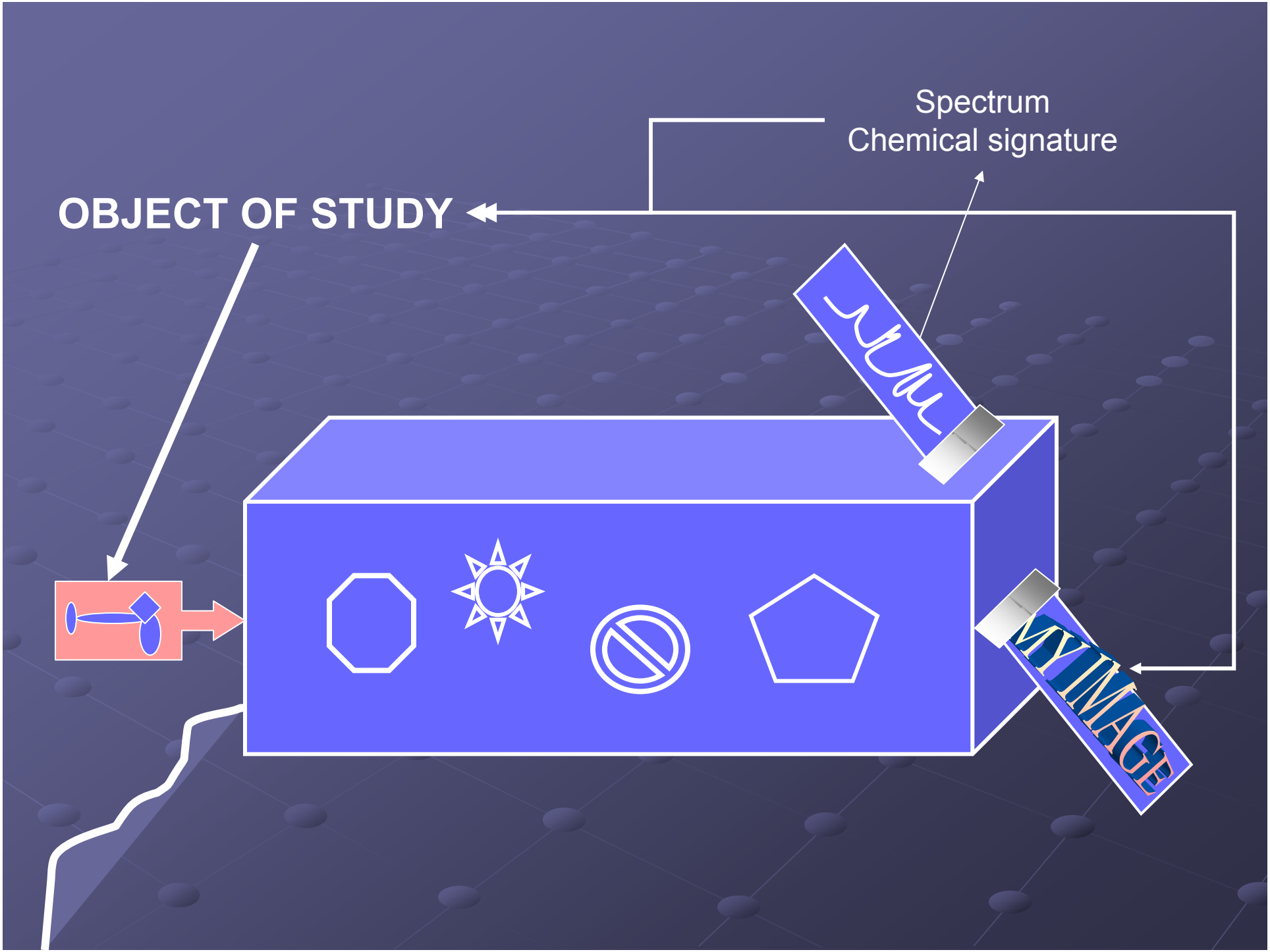
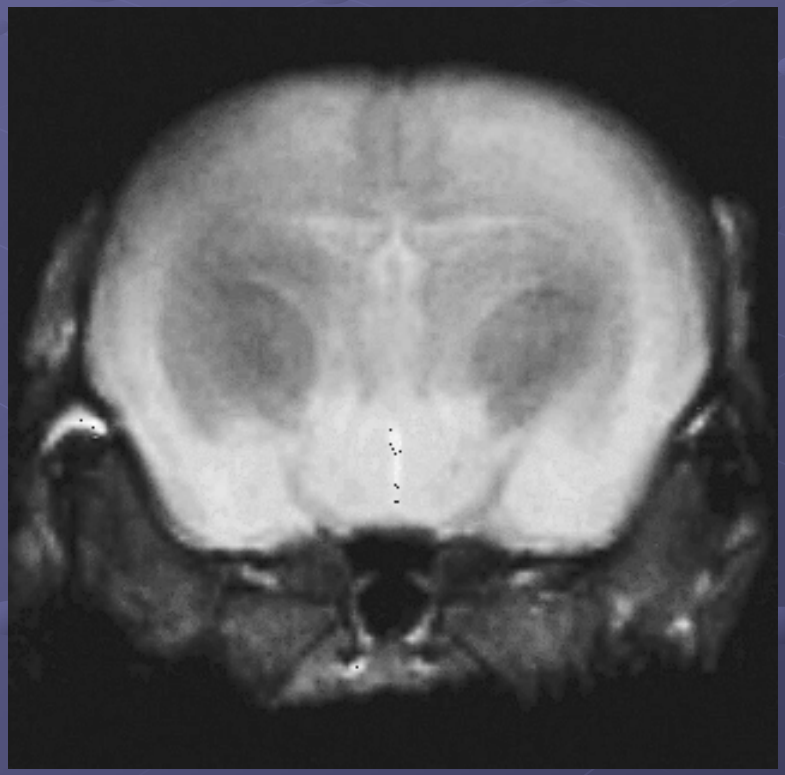
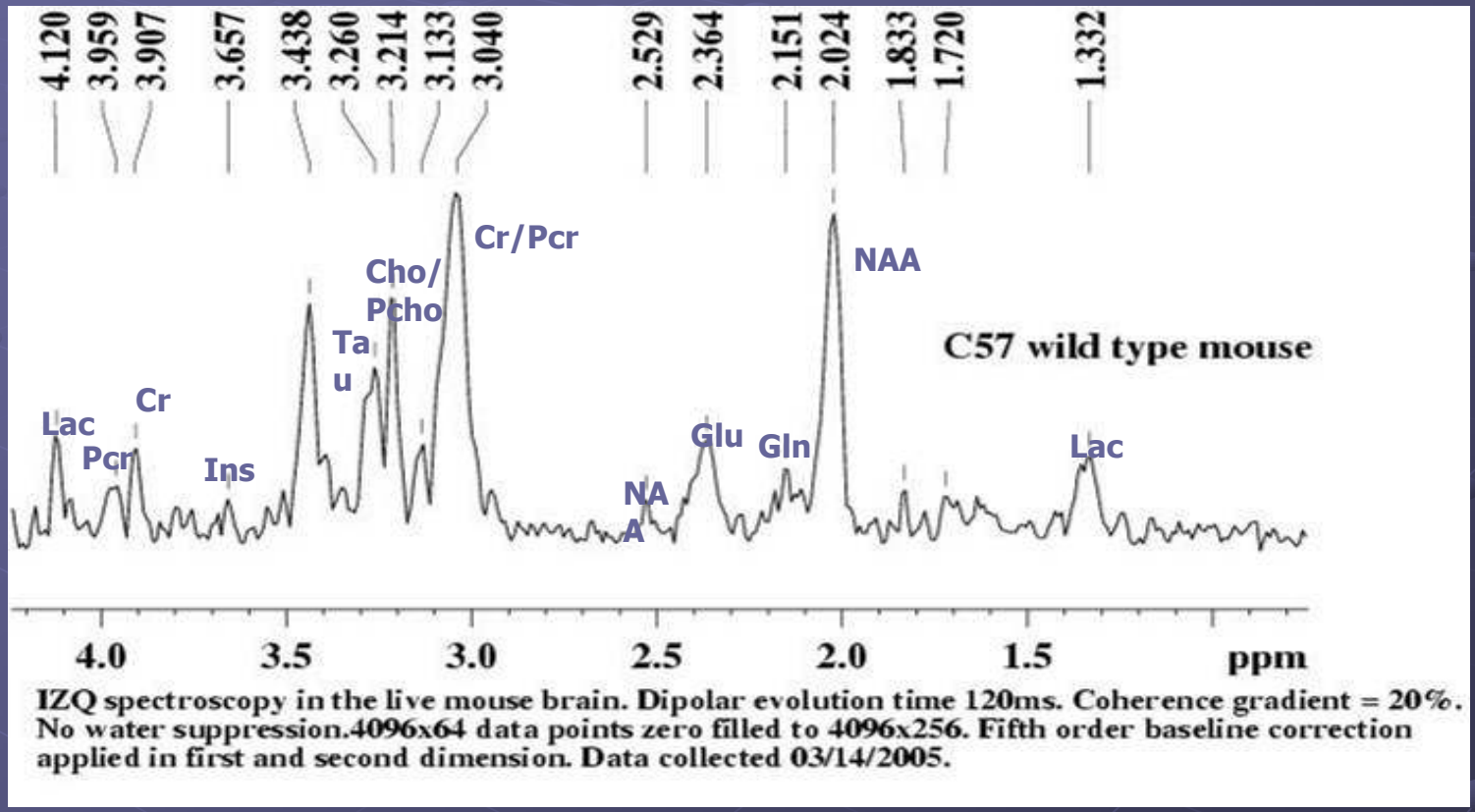

Spectrum
Chemical signature
OBJECT OF STUDY
MY IMAGE

IMAGE → CONTRAST



TO CARE FOR OR TO DESIGN IMAGING PROTOCOLS YOU NEED TO KNOW THE DETAILS OF THE TECHNIQUE THAT GIVES RISE TO THE CONTRAST(S).

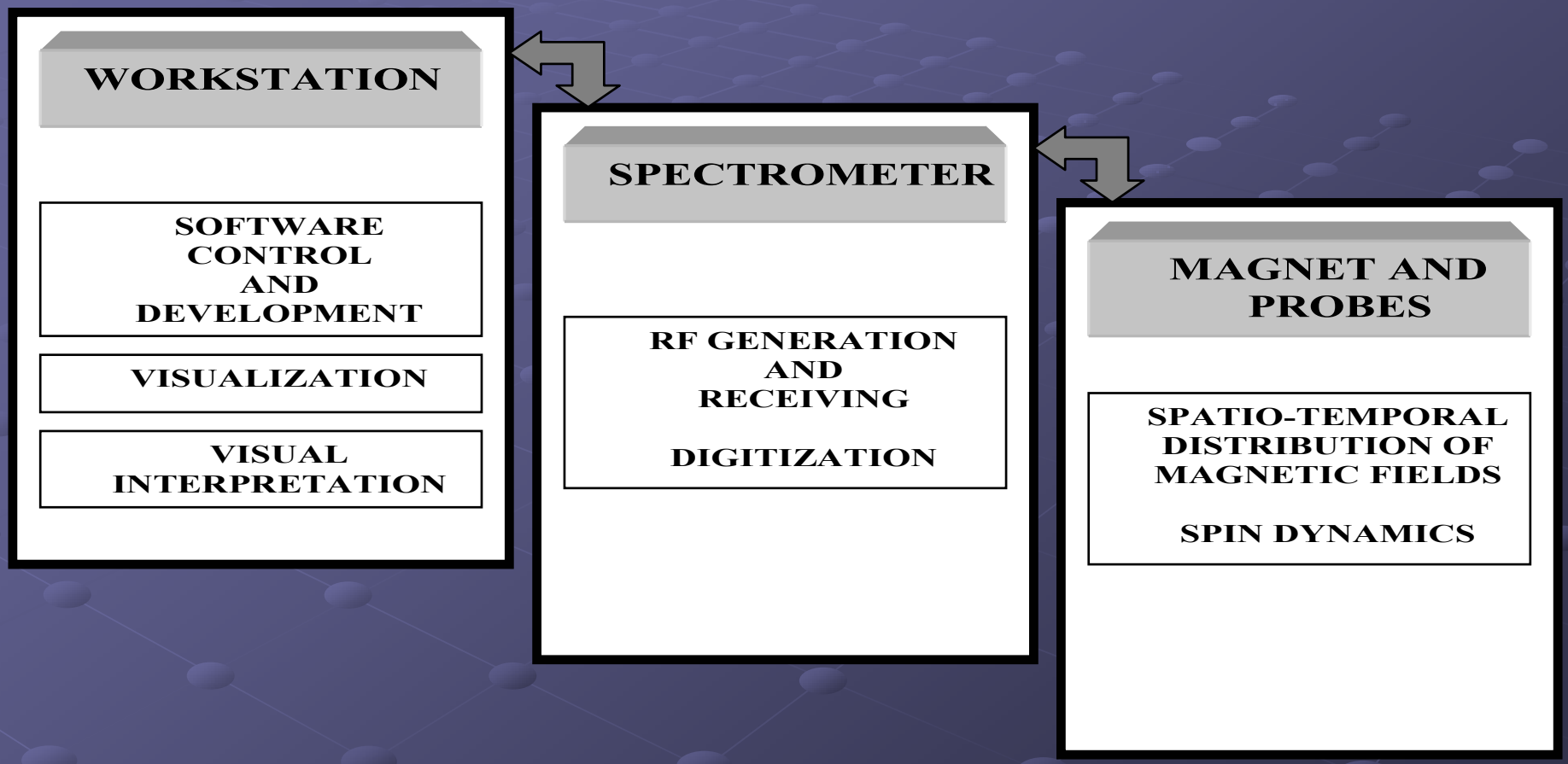
SPECTRUM → FREQUENCIES AND AMPLITUDES

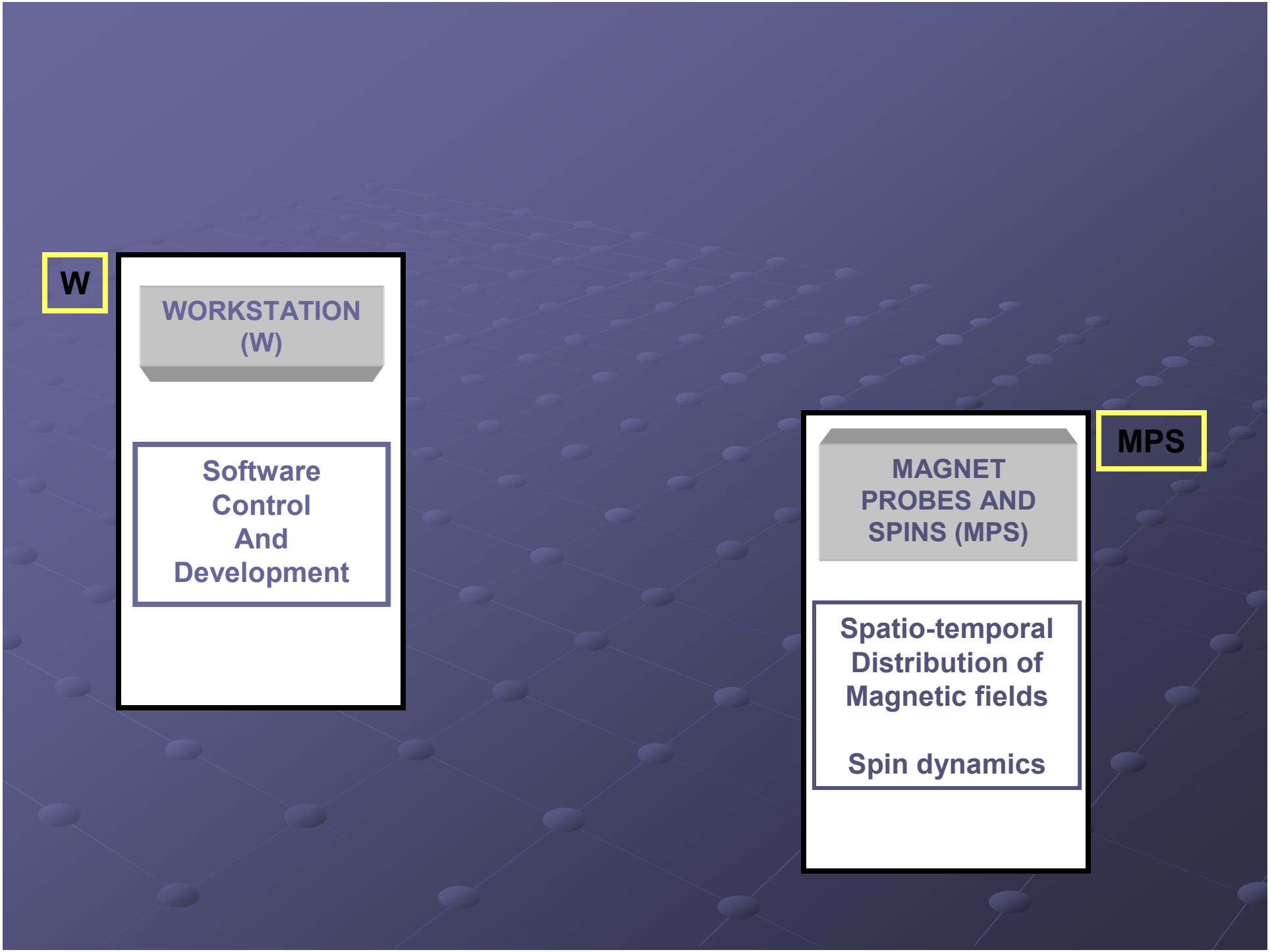


IZQ spectroscopy in the live mouse brain. Dipolar evolution time 120ms. Coherence gradient = 20%. No water suppression.4096x64 data points zero filled to 4096x256. Fifth order baseline correction applied in first and second dimension. Data collected 03/14/2005.

YOU NEED TO KNOW THE DETAILS OF THE TECHNIQUE THAT GIVES RISE TO THE SPECTRUM.

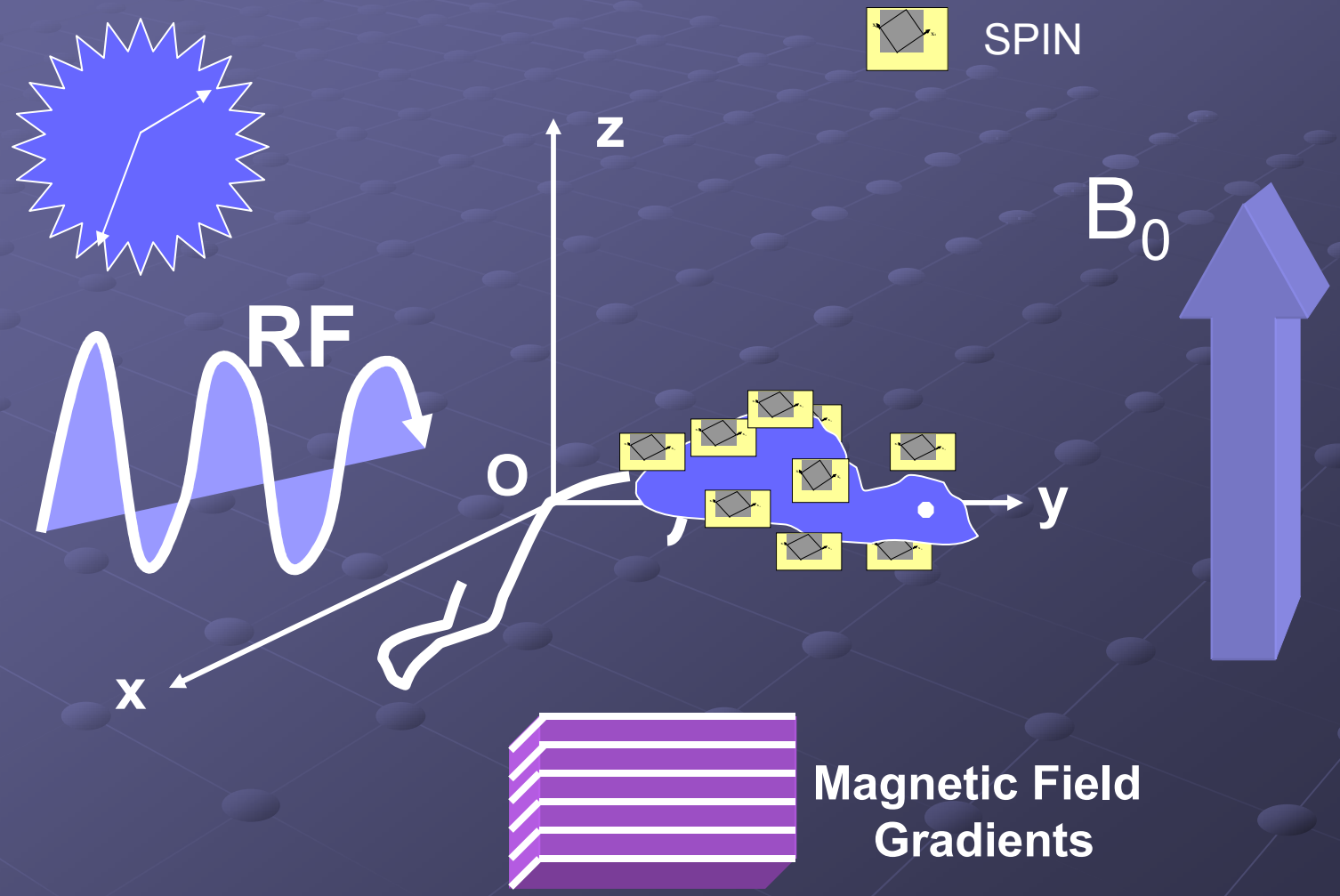
SCHEMATIC OF THE BRUKER MR IMAGER




W
WORKSTATION (W)
Software Control And Development
MPS
MAGNET PROBES AND SPINS (MPS)
Spatio-temporal Distribution of Magnetic fields
Spin dynamics

MPS

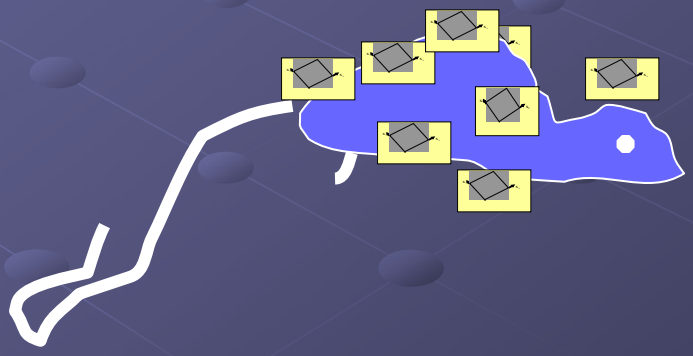
MAGNETIC RESONANCE



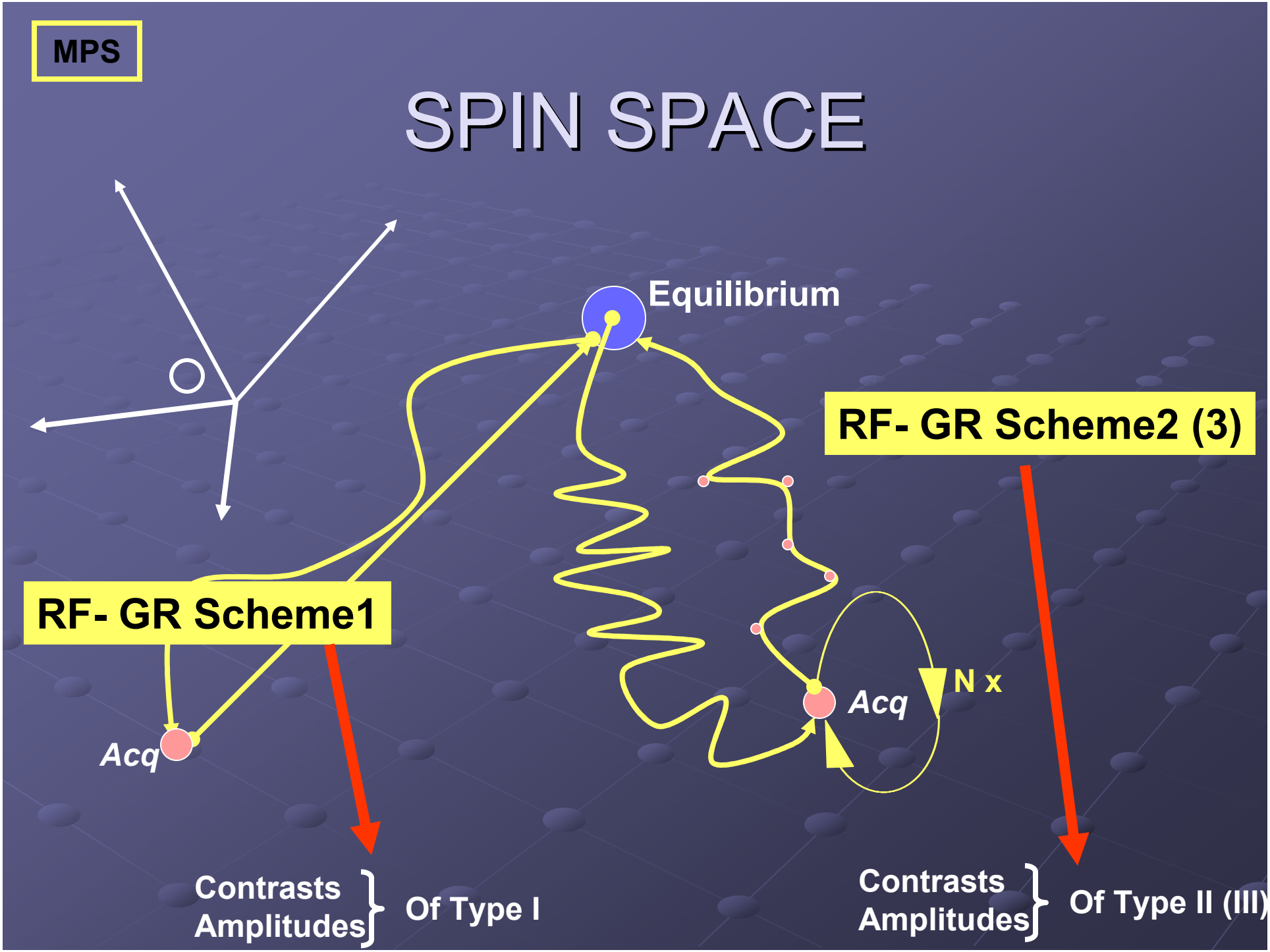
MPS

SPIN DYNAMICS

Ultimately the dynamics imposed on the nuclear spins by the rf and the gradients will be reflected in the contrasts of the image or in the amplitudes of the resonance lines in the spectrum.



At this point the precise material nature or shape of the object of study does not count much for us. Our objective is to precisely control the nuclear spins it carries.


MPS
SPIN SPACE
Equilibrium
RF- GR Scheme2 (3)
RF- GR Scheme1
Acq
N x
Acq
Contrasts
Amplitudes
Of Type I
Contrasts
Amplitudes
Of Type II (III)

- The spin manipulations are contained in the pulse sequence which is a summary of the procedures to be carried out to run the experiment. At this point the jargon used should relate to some model of spin dynamics the experimenter has in mind.

W

MPS

- Ideally we want to build a software tool that will initialize a maximum of these values with the aim of allowing the method to be used by people who may not be experts in spin dynamics.

W

- We want to optimize the method with regard to the speed of acquisition, especially if applications to living systems are sought.

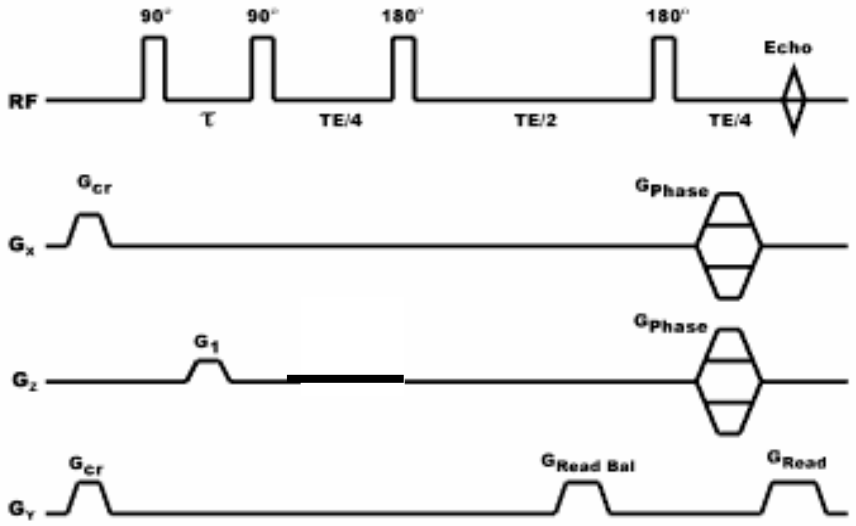
W

MPS

What we are given or have come up with:

```
start, 10u      sgrad r2d
slice, 10u      fq8b:f1
        d4      rgrad r2d
        d4      groff
        d3      fq1:f1
        p11     ph11    ; excitation pulse
        d3
        d4      grad{ (t10) | (t10) | (t10) }   ;coherence filter on
        2m
        d4      groff           ;coherence filter off
        d28                     ;adjustment for zq
        vp      ph12    ;45/135 degree pulse
        d30
        d4
        d4      grad{ (t4) | (0) | (0) }
        d11
        d4      groff
; ---------------------------------- ECHO ----------------------------------
echo,   d3
        d4      grad{ (t15) | (t15) | (t15) }
        d5
        d4      grad{ (t2) | (t2) | (t2) }
        d3
        p1:sp1  ph1
        d3
        d4      grad{ (t15) | (t15) | (t15) }
        d5
        d4      groff
```

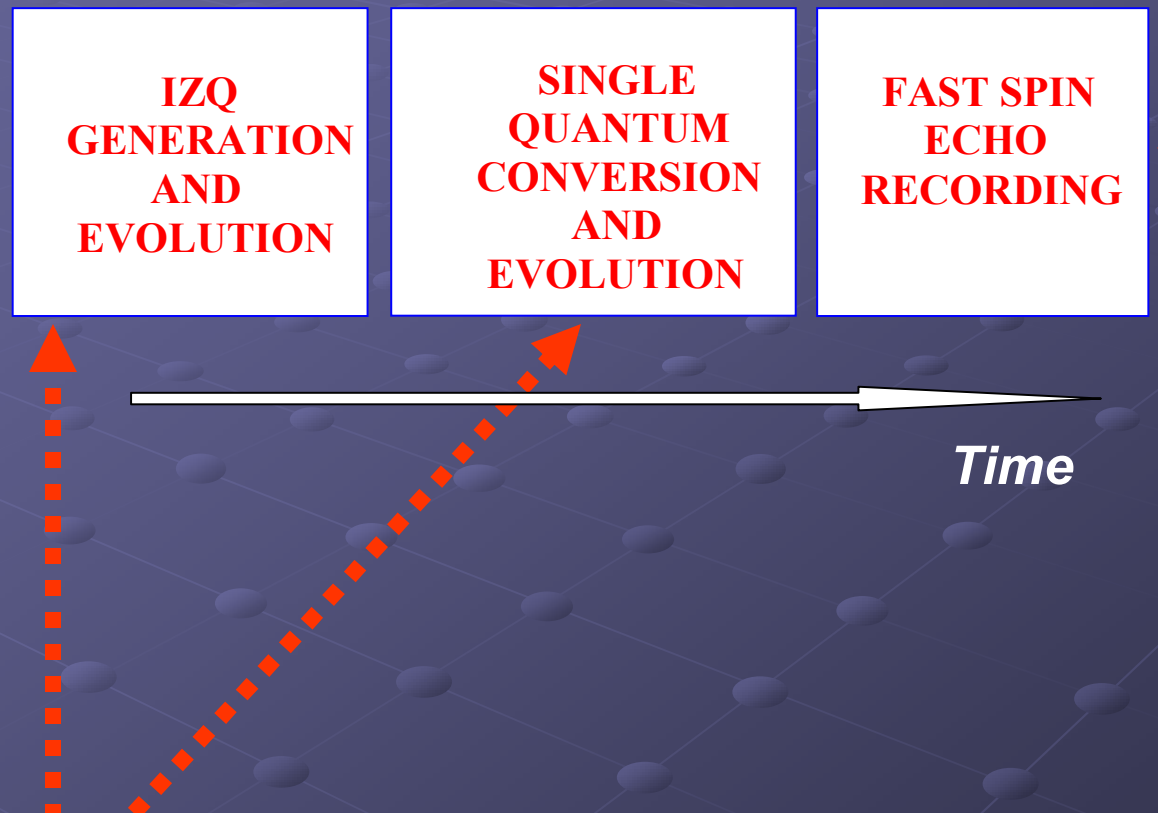
Pulse sequence for IZQC 3D-imaging



Build a method to initialize the parameters

MPS

IZQ - FSE



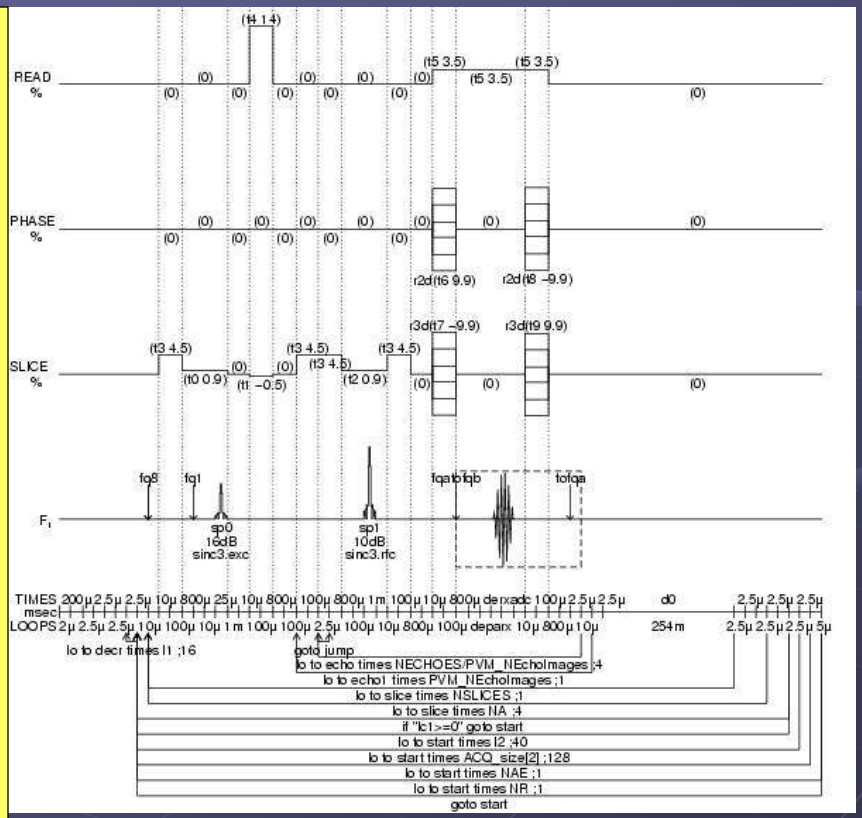
Generation of “unique” contrast

To speed up the acquisition

Fast Spin Echo (RARE)

```
;
slice,  10u fq8b:f1


        d4  grad{(0)|(0)|(t3)}
        d5
;-----------------------------------slice selection-------------------
      d4    grad{(0)|(0)|(t0)}
      d3    fq1:f1
        d8  gatepulse 1
      p0:sp0      ph0
      d4    groff
      10u
;-----------------------------------slice rephase---------------------
      d4    grad{(t4)|(0)|(t1)}
      d11
      d4    groff
      d1
;---------------------------------- refocusing group ----------------------
echo1,  d4  grad{(0)|(0)|(t3)}
      rgrad r2d
      goto jump
echo, d4      grad{(0)|(0)|(t3)}
jump,   d5
        d4      grad{(0)|(0)|(t2)}  gatepulse 1
        d3
        p1:sp1    ph1
        d3
        d4      grad{(0)|(0)|(t3)}
        d5
        d4      groff
;---------------------------------- refocusing group - end -----------
      d2
;-----------------------------------read on + phase encoding----
if( ACQI_cur_dim == 1 )                         ; no phase encoding
{
        d4    grad{(t5)|(0)|(0)}
}
if( ACQI_cur_dim == 2 )
{
      d4    grad{(t5)|r2d(t6)|(0)}      ; 2nd dim only
}
if( ACQI_cur_dim == 3 )
{
        d4    grad{(t5)|r2d(t6)|r3d(t7)} ; 2nd and 3rd dims
}
      d6
      denab   REC_ENABLE grad{(t5)|(0)|(0)}
        ADC_INIT_B(ph0, ph1)
      aqq   ADC_START
      d3
;-----------------------------------read on + phase encoding----
if( ACQI_cur_dim == 1 )                         ; no phase encoding
{
        d4  grad{(t5)|(0)|(0)}
}
if( ACQI_cur_dim == 2 )
```



A method exists to initialize the parameters

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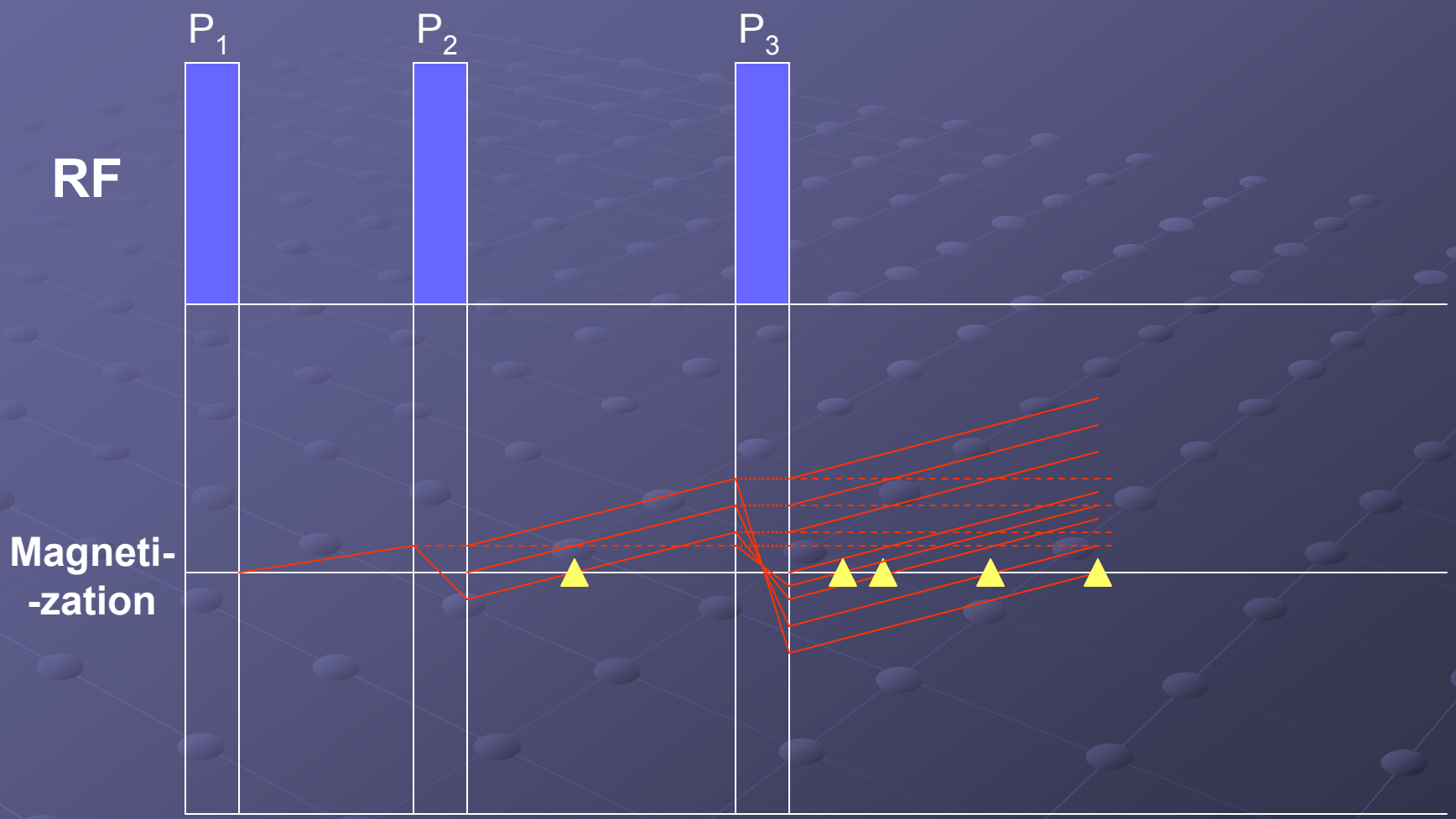
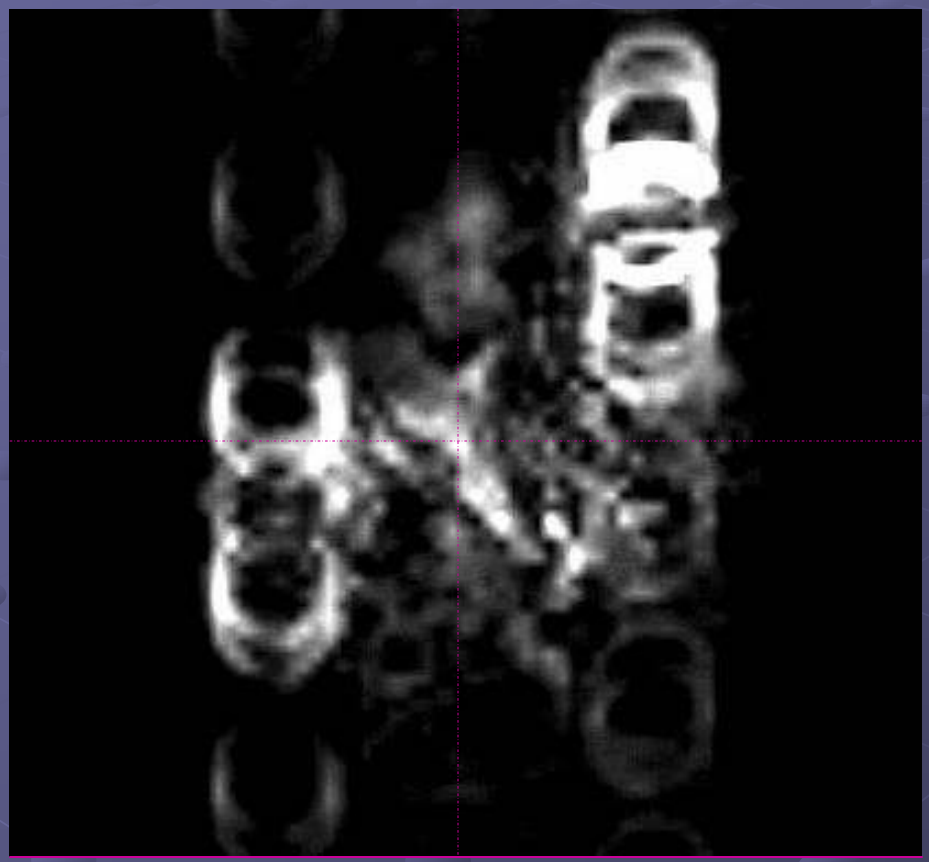
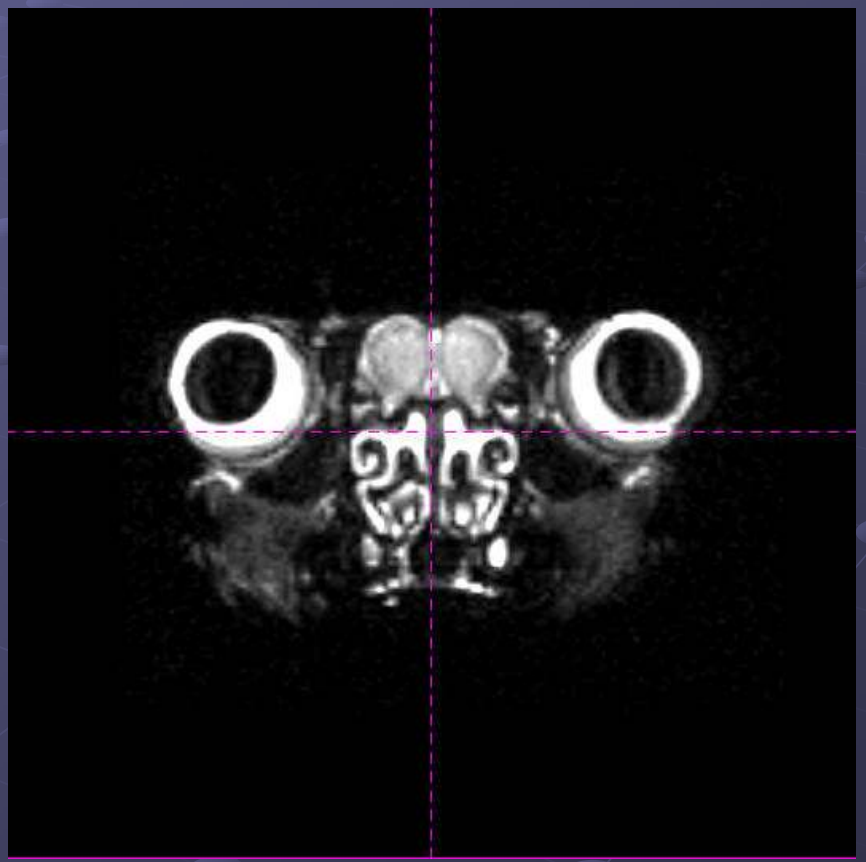
FAST SPIN ECHO: SOME DETAILS

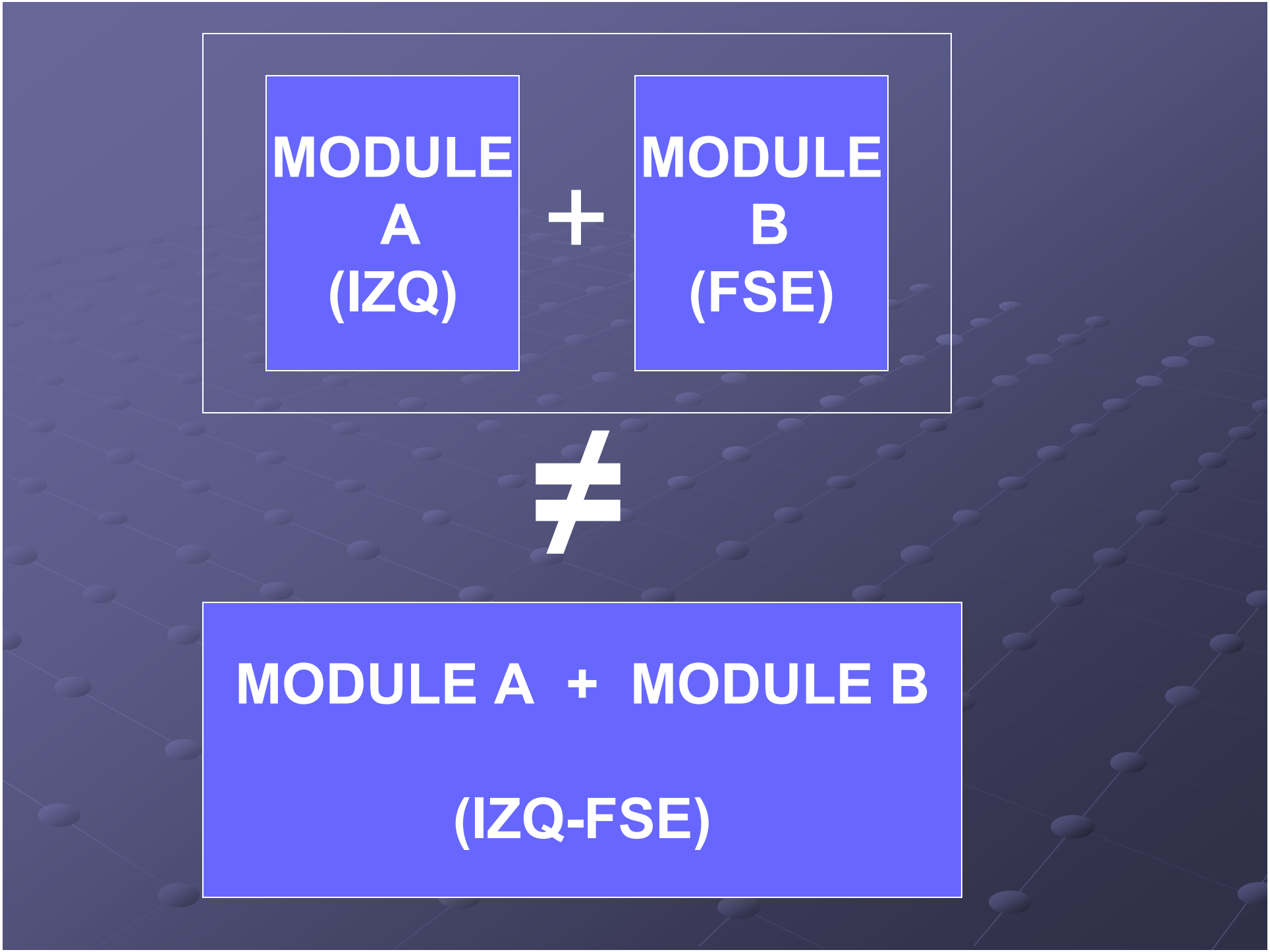


: Echo

Fast Spin Echo






MODULE A (IZQ)
+
MODULE B (FSE)
≠
MODULE A + MODULE B
(IZQ-FSE)

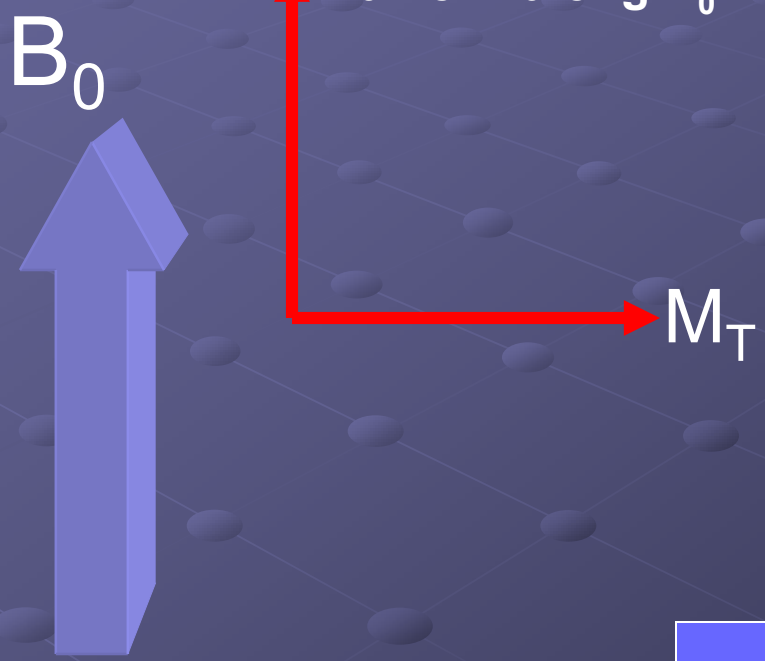
ModuleA (IZQ) --- ModuleB (FSE)

Solutions found to solve problems of the stand alone module B do not necessarily work when some module A is placed in front of it, since the initial conditions to module B have been changed.

END of IZQ MODULE

MPS

FSE



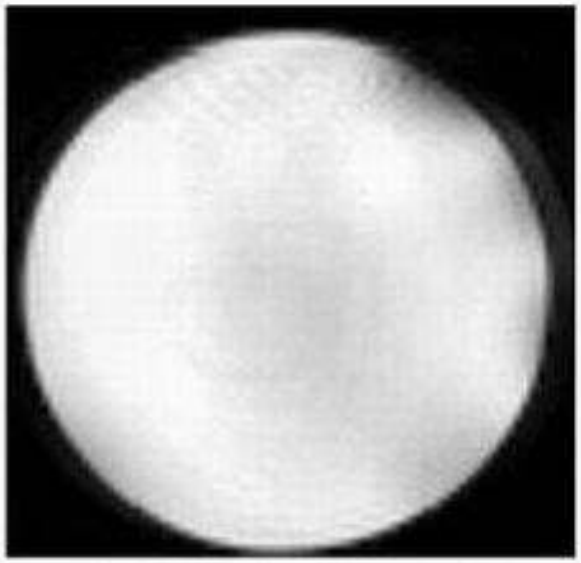
To preserve the "unique" contrast of IZQ we do not want to mix M_L and M_T inside FSE

Need to work out a new solution for

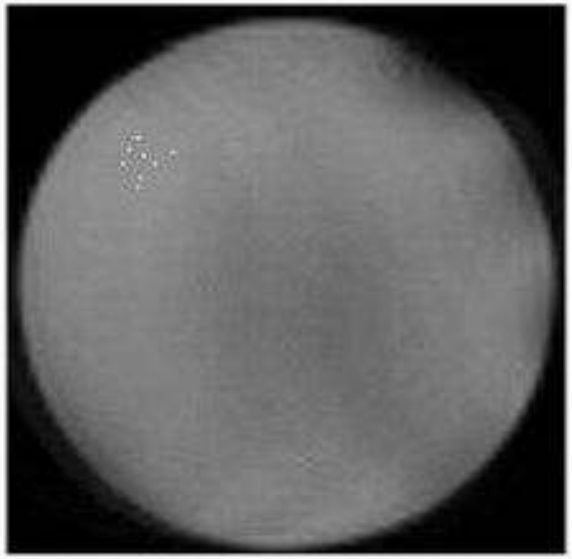
W

MODULE A + MODULE B

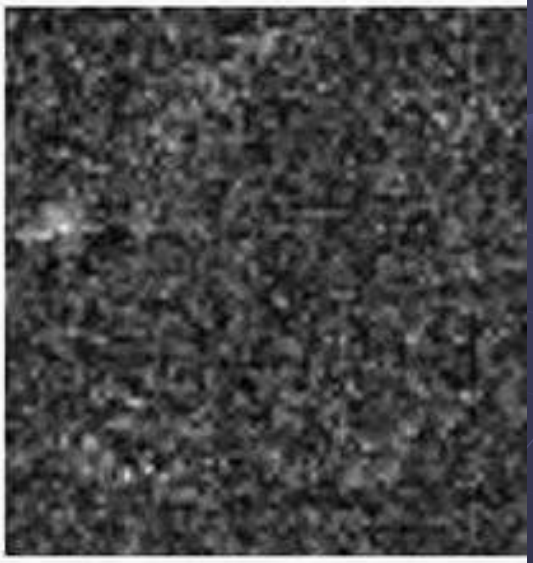
BENCHMARK TO TEST MODIFICATIONS



Gradient along B0



Gradient orthogonal to B0



Gradient at the magic angle relative to B0

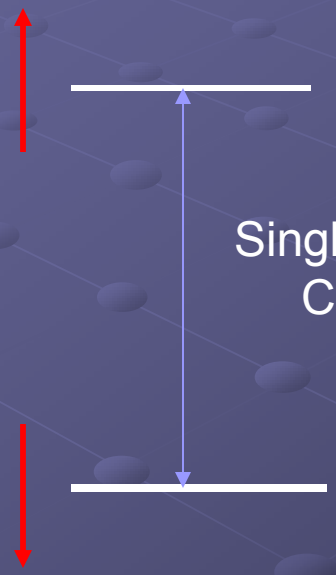
SPECTROSCOPY

- Spectroscopy can provide a wealth of information about living systems
- To obtain a good resolution of the spectral lines one needs to perform a good shimming of the main static field. Shimming is still pretty much an art. Only a few automated methods exist and they do not work in all situations.
- At best, shimming procedures yield a uniform field over small volumes only. Thus signal intensity is proportionately reduced.
- Field drift can be taken care of by a “field frequency lock” which is usually not available in imaging systems.
- “Block” averaging can mitigate the situation only partly and suffers other drawbacks.
- We explored the possibilities of implementing IZQ spectroscopy in our imaging system to overcome the shimming and drift problem.

MPS

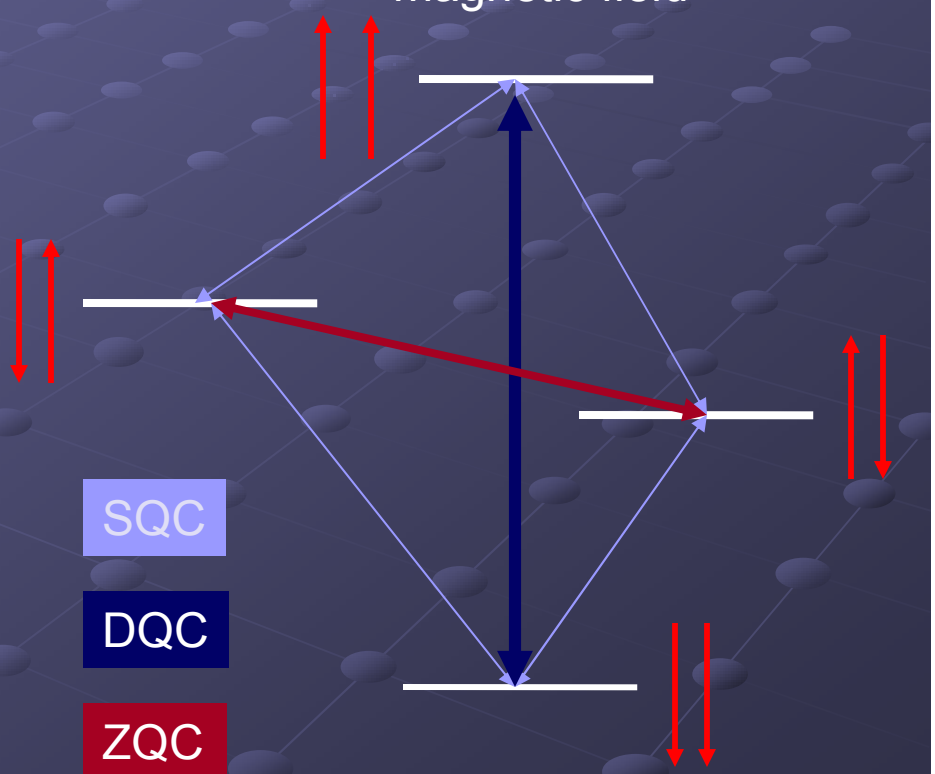
Spin Systems

One spin System in a magnetic field



Single Quantum Coherence

Two spin system in a magnetic field



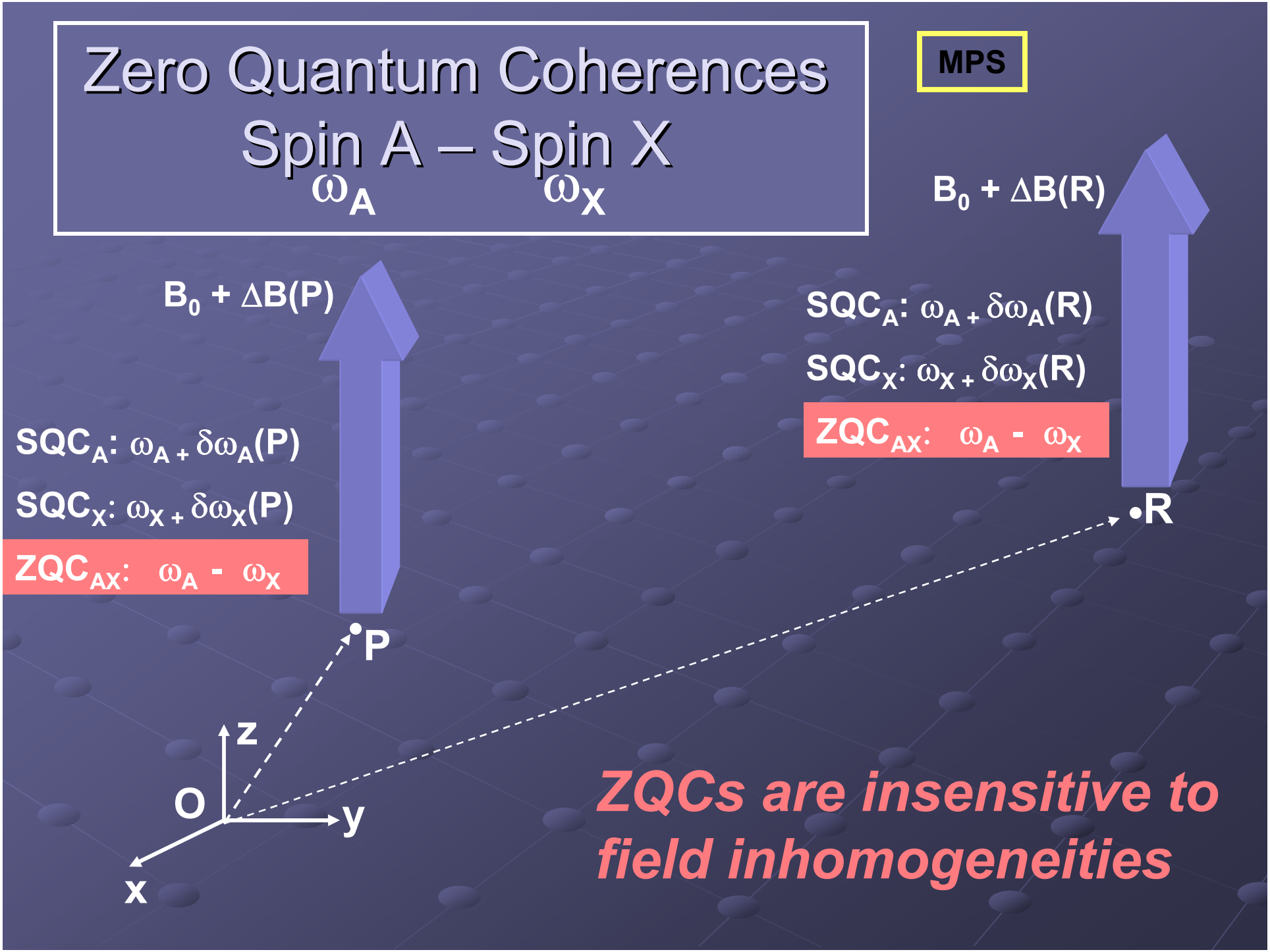
SQC

DQC

ZQC

Zero Quantum Coherences
Spin A – Spin X
ω_A ω_X

MPS



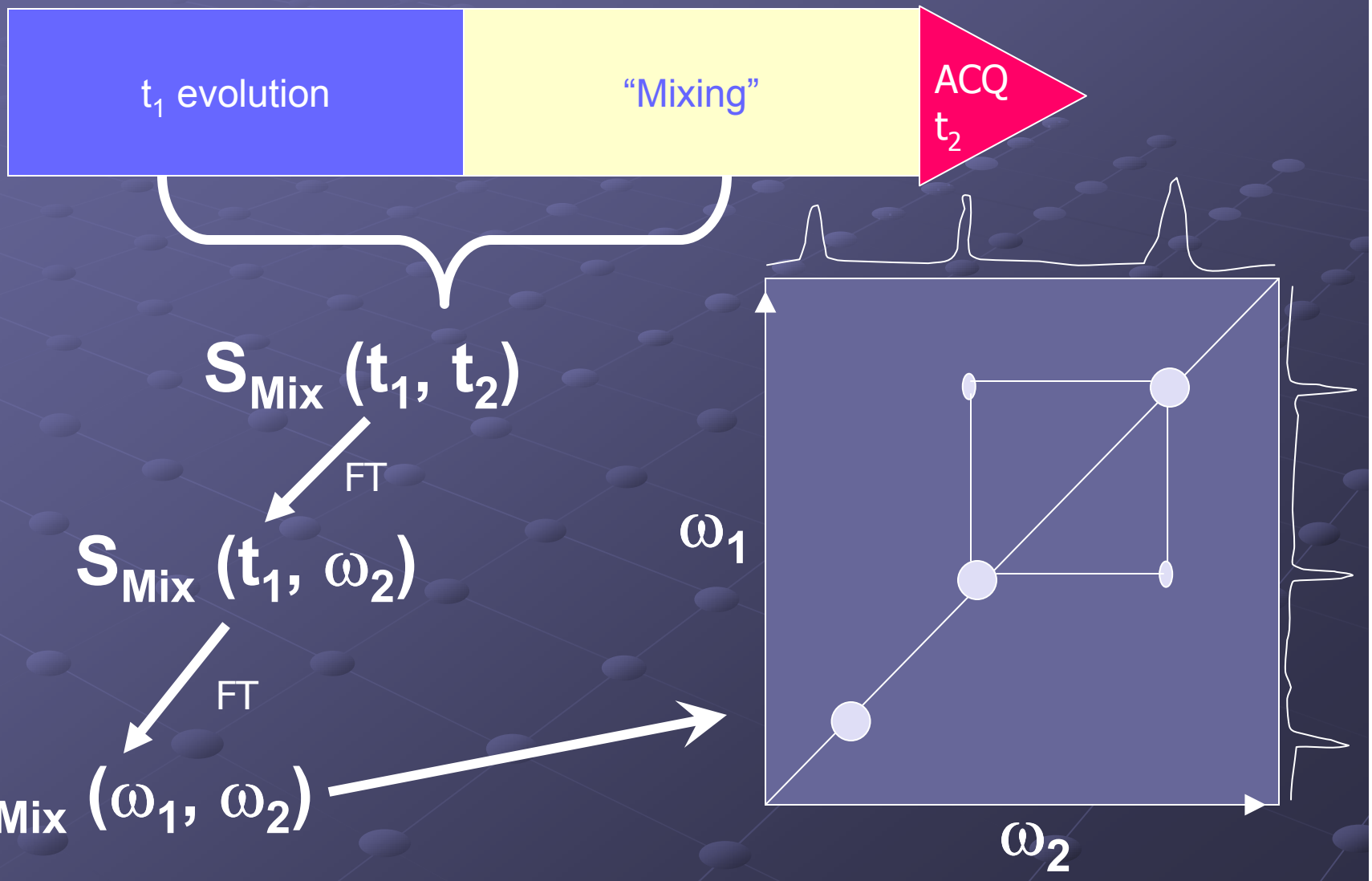
ZQCs are insensitive to field inhomogeneities

- One cannot directly detect through the RF coil coherences of order different from one.
- We therefore need to detect zero quantum coherence indirectly.
- We do this by using the framework of 2D spectroscopy, labeling zero quantum frequencies along the indirect dimension.

W

MPS

2D SPECTROSCOPY



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MPS

2D IZQ SPECTROSCOPY

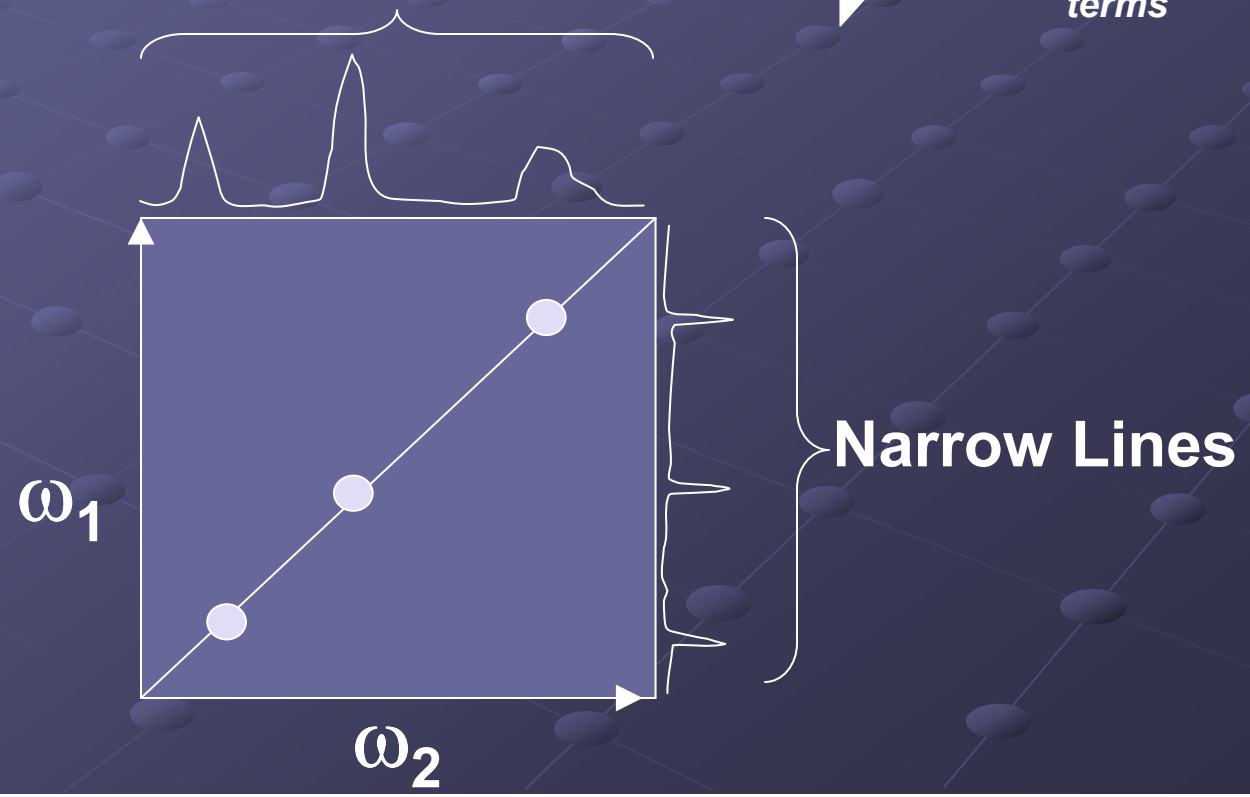
t_1 evolution
IZQC

Evolution under the influence of distant dipolar field created by the spins of the solvent

ACQ

Insensitive to static magnetic field inhomogeneities

Generation of observable terms



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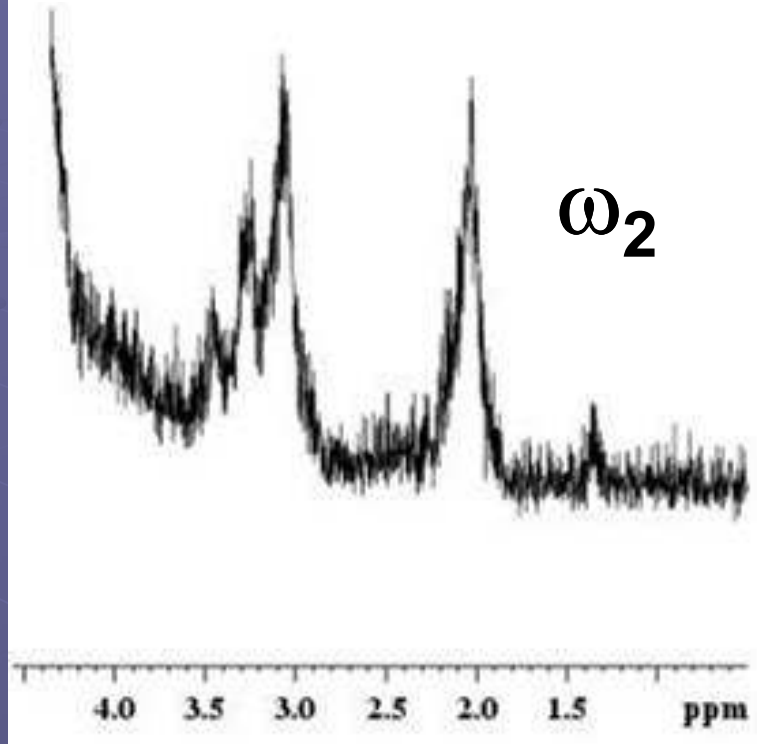
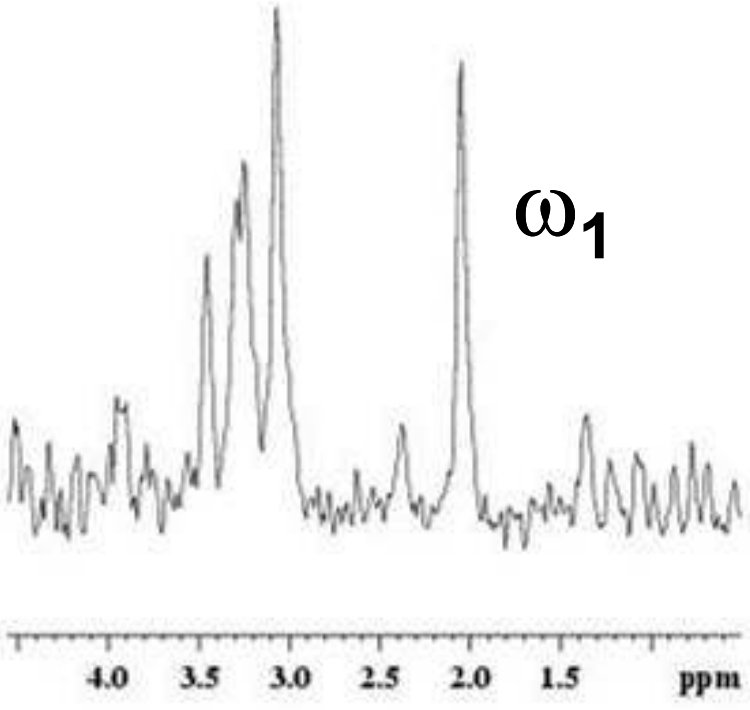
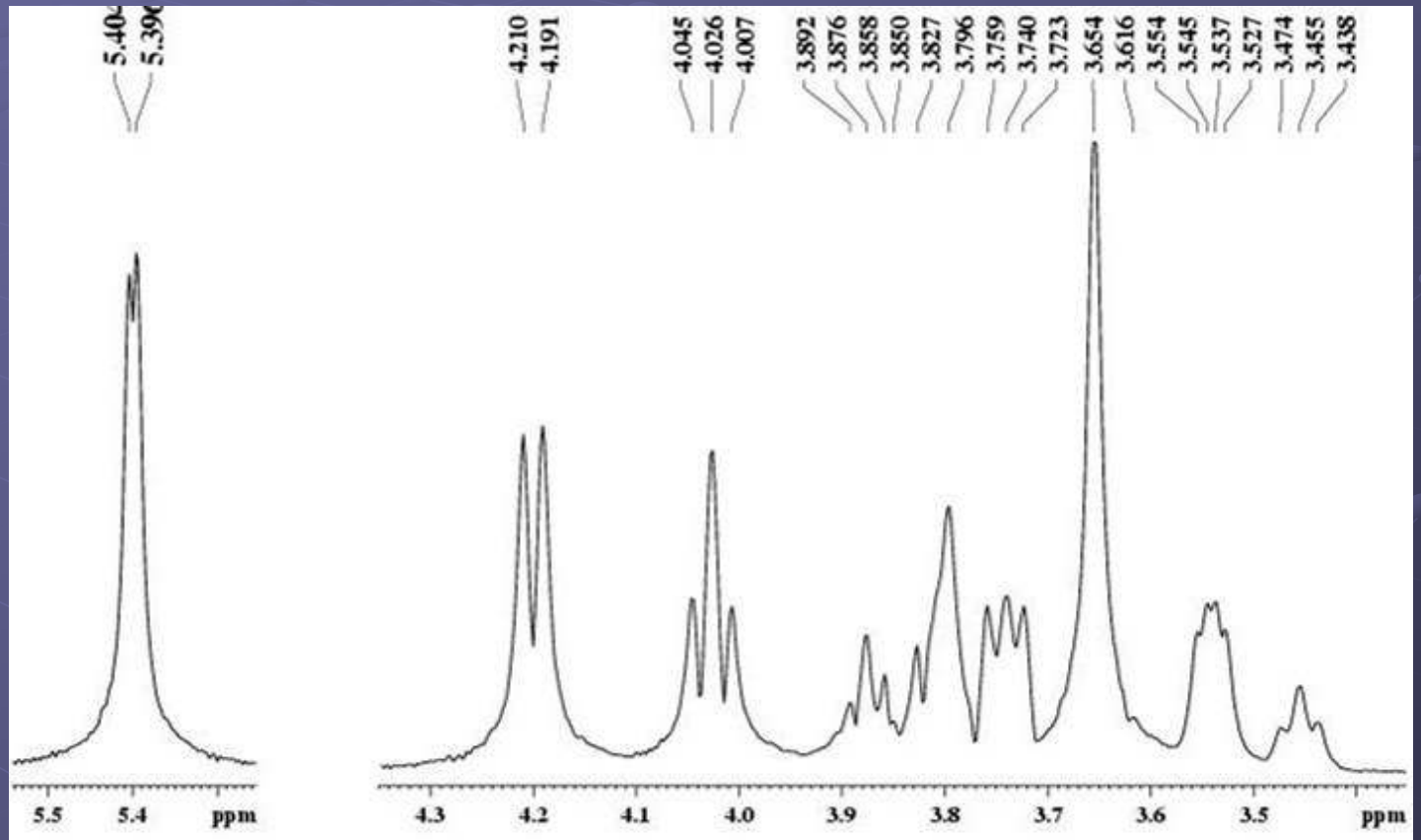
ONE DIMENSIONAL PROJECTIONS





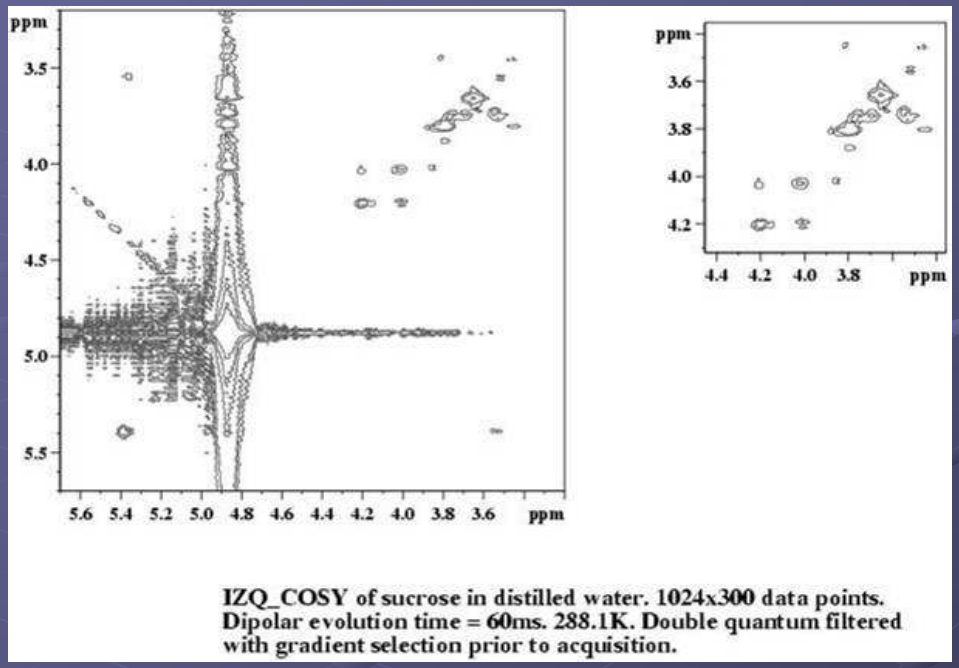
IZQ spectroscopy in the live mouse brain. Dipolar evolution time = 120ms. Relaxation delay = 5s. 4096x512 data points zero filed to 4096x1024. Micro2.5. 20mm birdcage coil. Two averages per t1 increments.

BENCHMARK TEST I

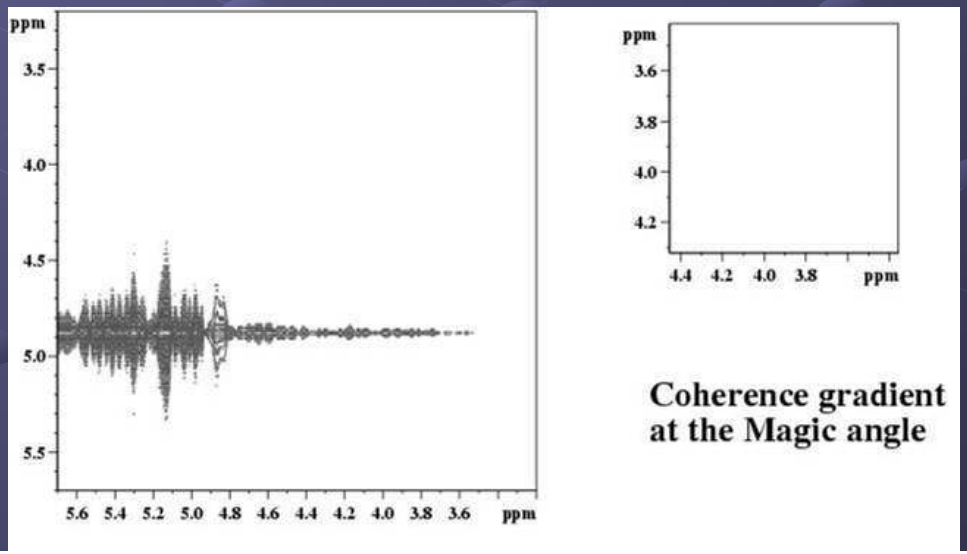


IZQ spectroscopy of sucrose in distilled water.
Dipolar evolution time = 230ms. TR = 2seconds.
4096x1024 data points. One average 288.1K.

BENCHMARK TEST II

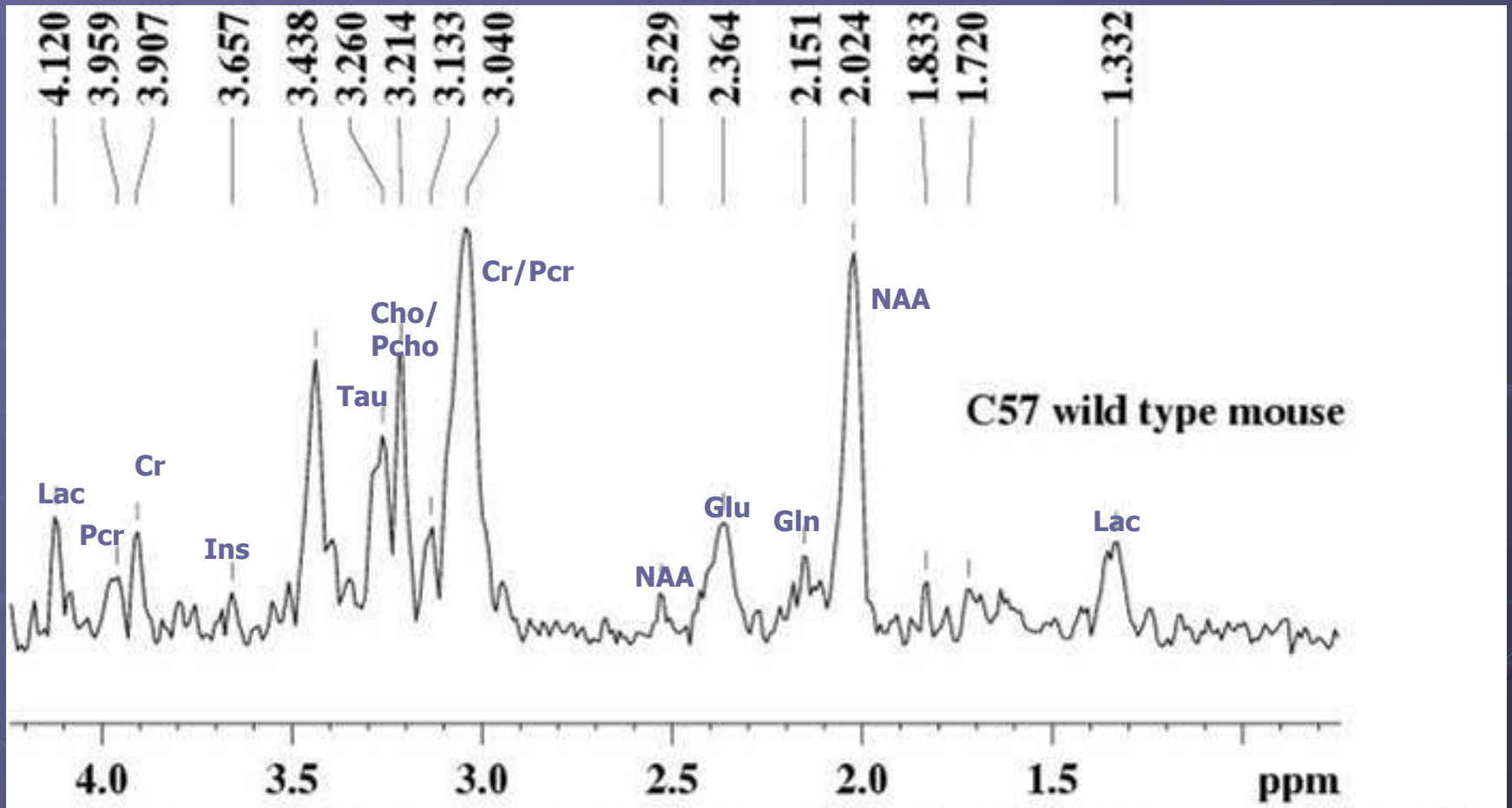


IZQ_COSY of sucrose in distilled water. 1024x300 data points. Dipolar evolution time = 60ms. 288.1K. Double quantum filtered with gradient selection prior to acquisition.



Coherence gradient at the Magic angle

W



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