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Design of Optimal RF Pulses in MRI: Practical Applications

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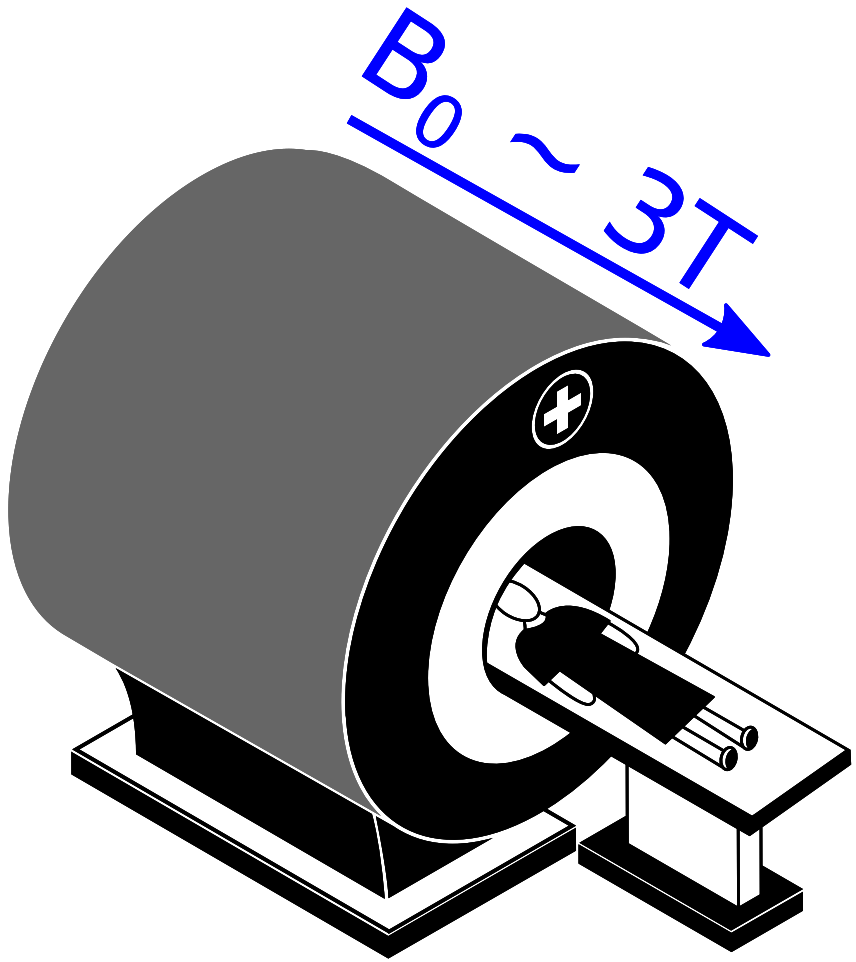
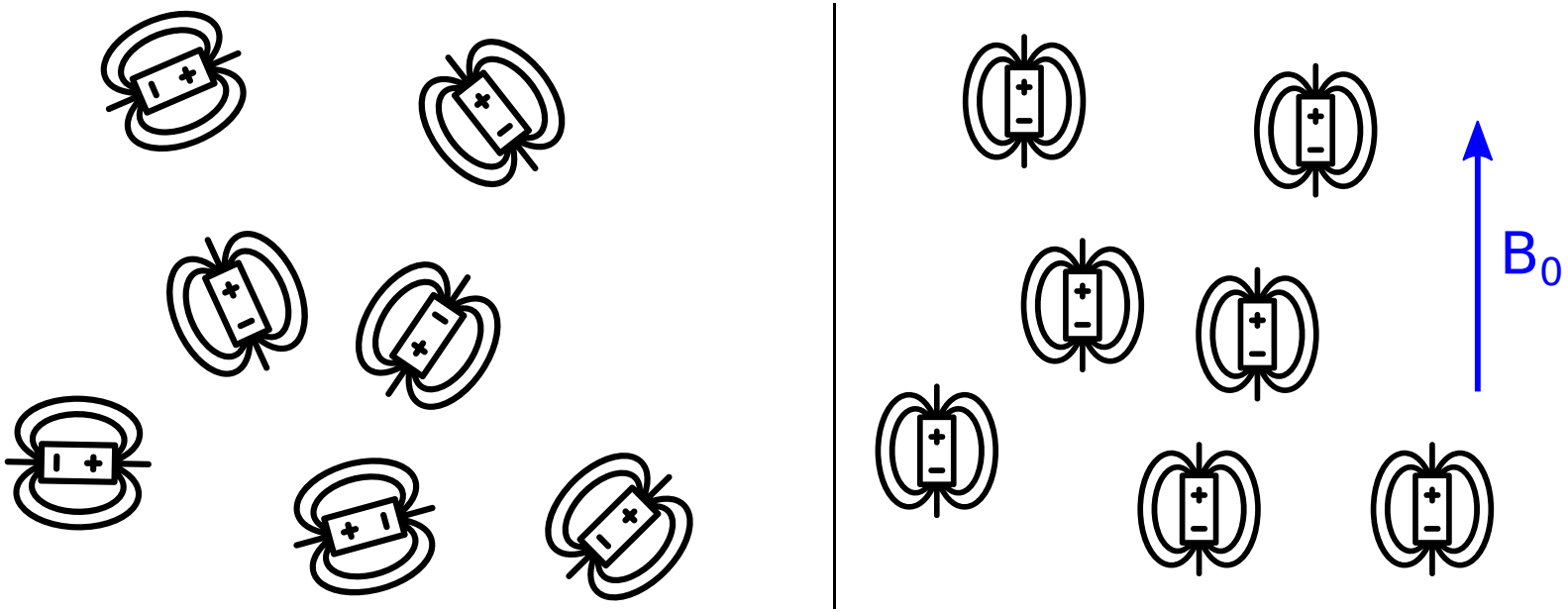
MRI and Magnetic Fields

Introducing B_0



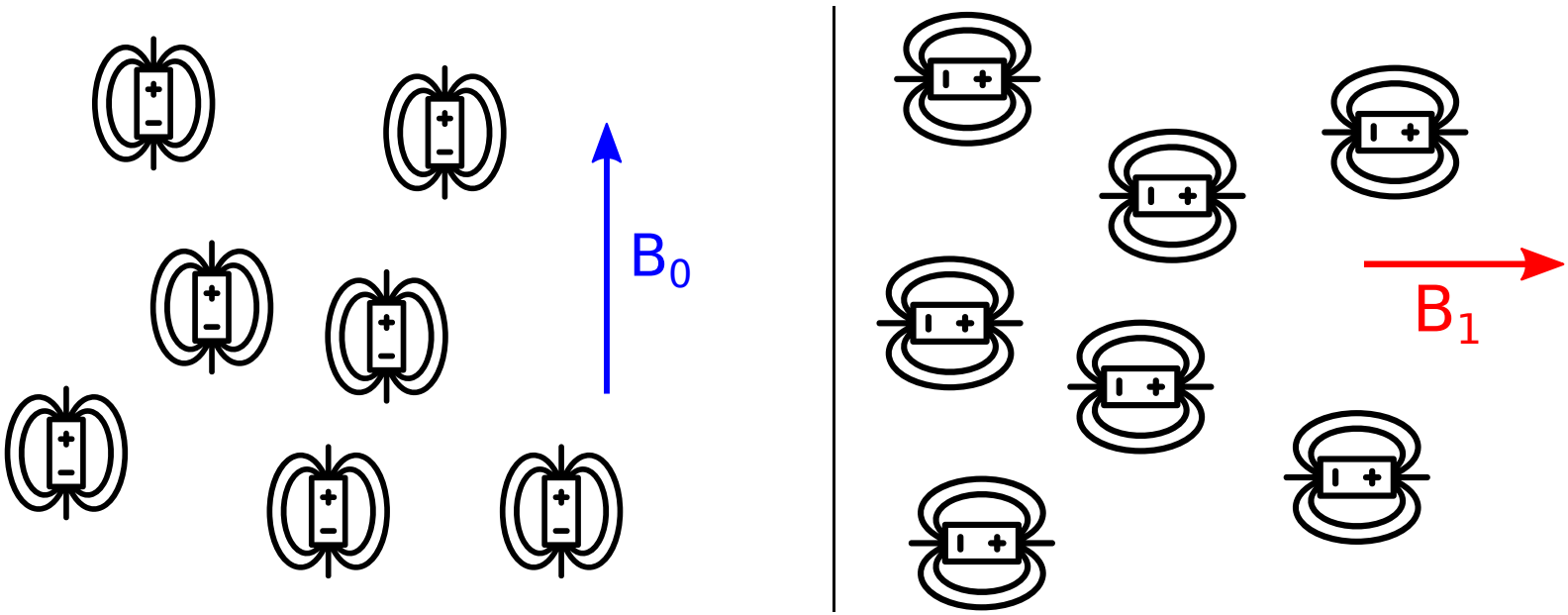
MRI and Magnetic Fields

Introducing B_0



MRI and Magnetic Fields

Introducing B_1



$\Rightarrow$ NMR signal becomes measurable!

Bloch Equations

Macroscopic Magnetization Evolution

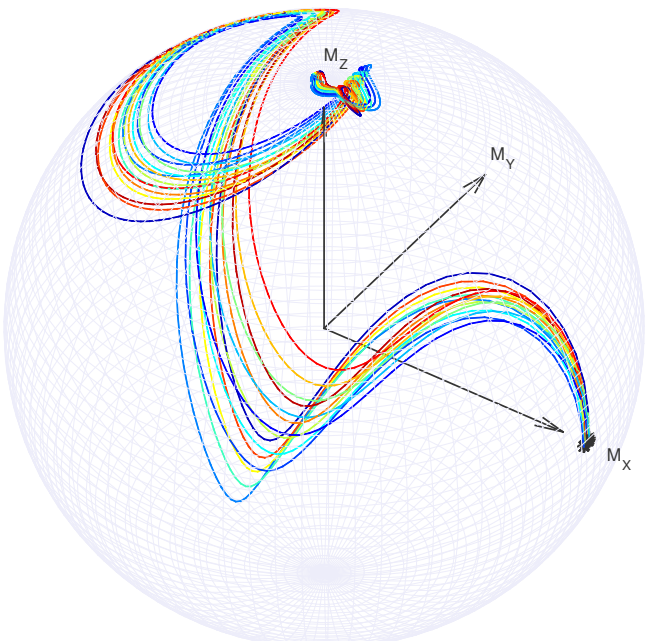
$$\begin{pmatrix} \dot{M}_x \\ \dot{M}_y \\ \dot{M}_z \end{pmatrix} = \begin{pmatrix} -\frac{1}{T_2} & \gamma B_0 & -\gamma B_1^y \\ -\gamma B_0 & -\frac{1}{T_2} & \gamma B_1^x \\ \gamma B_1^y & -\gamma B_1^x & -\frac{1}{T_1} \end{pmatrix} \begin{pmatrix} M_x \\ M_y \\ M_z \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \frac{M_0}{T_1} \end{pmatrix}$$

Optimizing B_1 fields

Rocket Science Applied to MRI

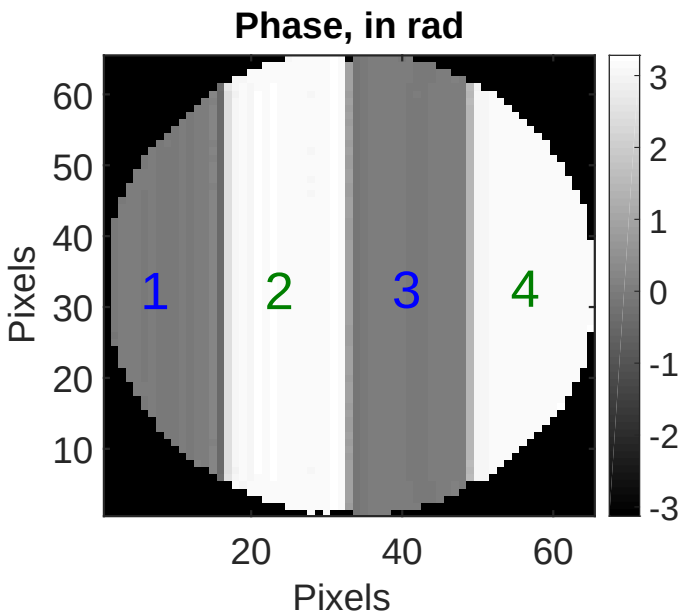
Optimal Control

- Initially developed for rocket engine control
- Provides the control (B_1) & trajectories to reach a target state
- Theoretical guarantees about the solutions' optimality

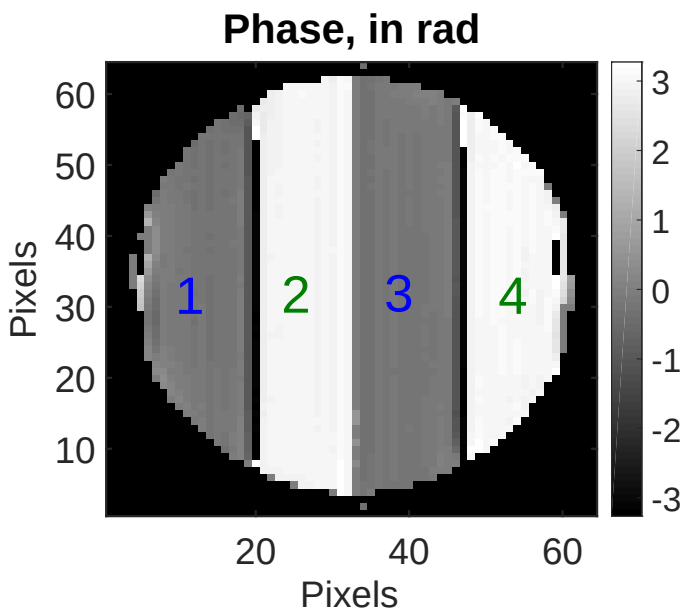


Proof of Concept

Create non-trivial phase patterns[1]



(a) Target State



(b) MRI Acquisition

[1] P.M. Lefebvre et al., *Active Control of the Spatial MRI Phase Distribution with Optimal Control Theory*, JMR 2017

Application to Elastography

Encoding the wave propagation

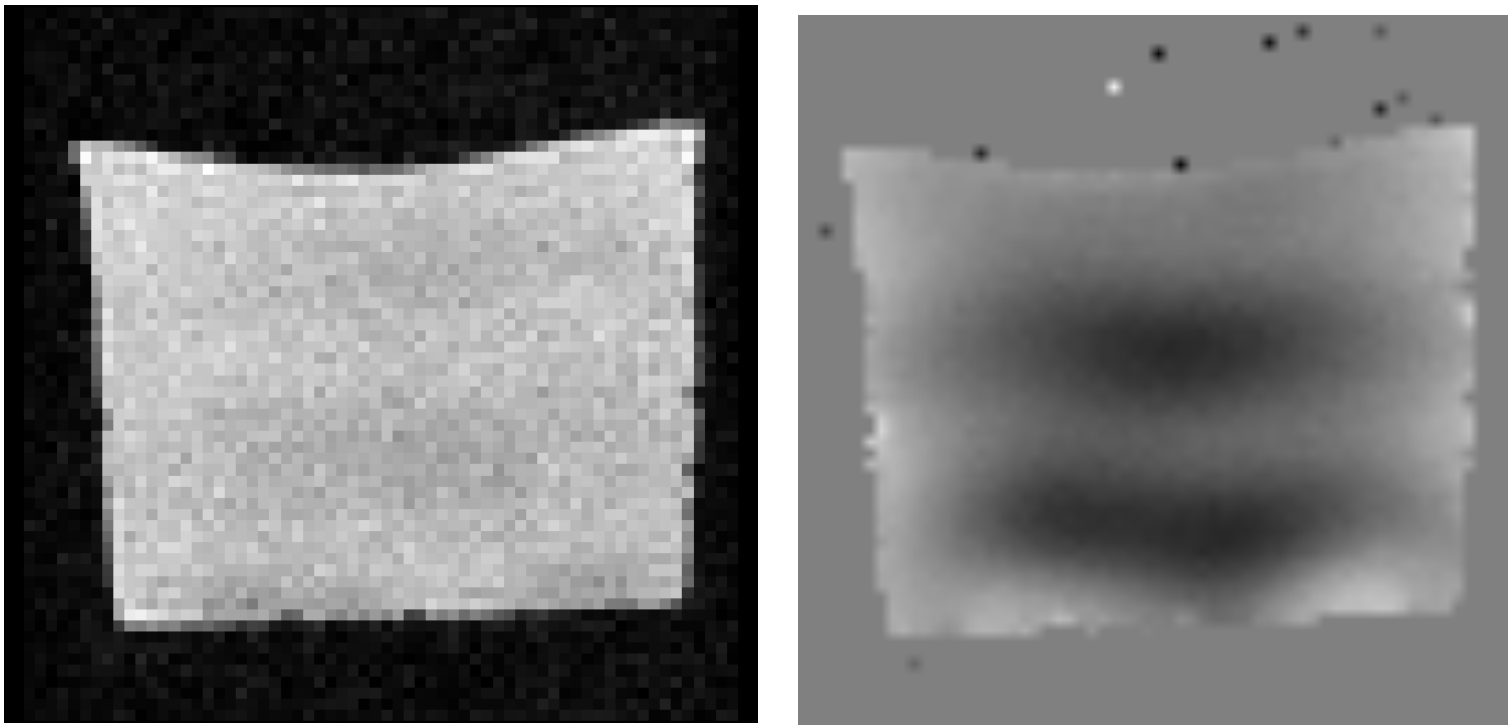
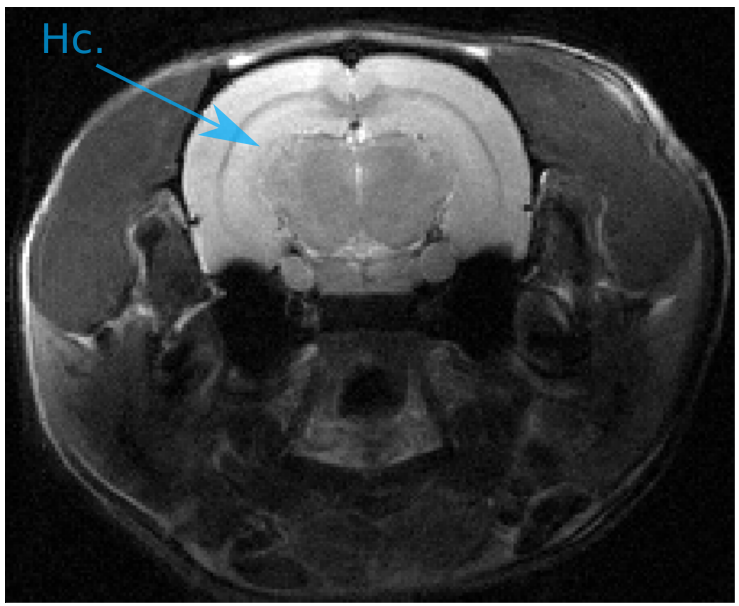


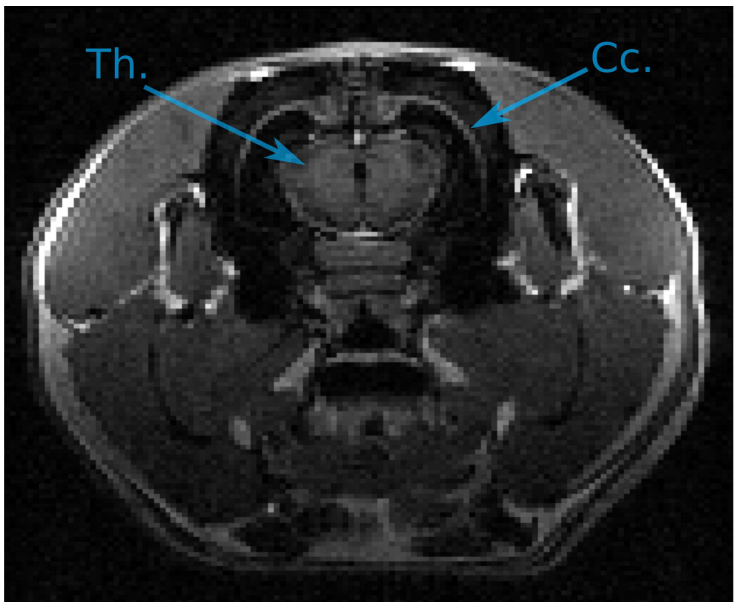
Figure: Plastisol phantom $-T_2 \approx 25$ ms $-$ $f_e = 400$ Hz $-$ Gradient Echo $-$ 4 steps

Application to MR Contrast

Visualizing White Matter in a Rat Brain[1]



(a) Natural MR Contrast

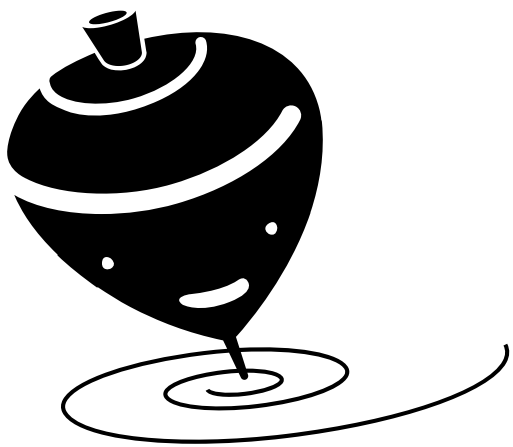


(b) White Matter Discrimination

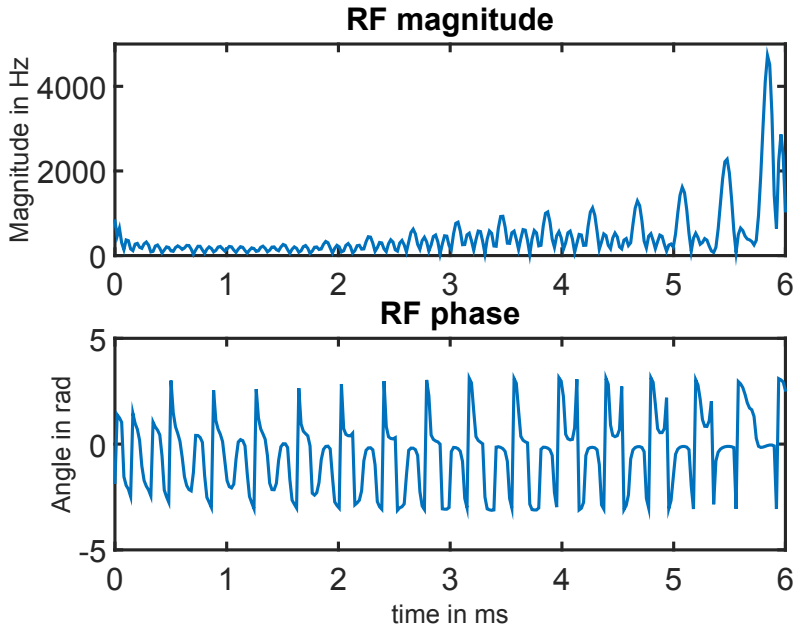
[1] E. Van Reeth et al., *Optimal control design of preparation pulses for contrast optimization in MRI*, JMR 2017

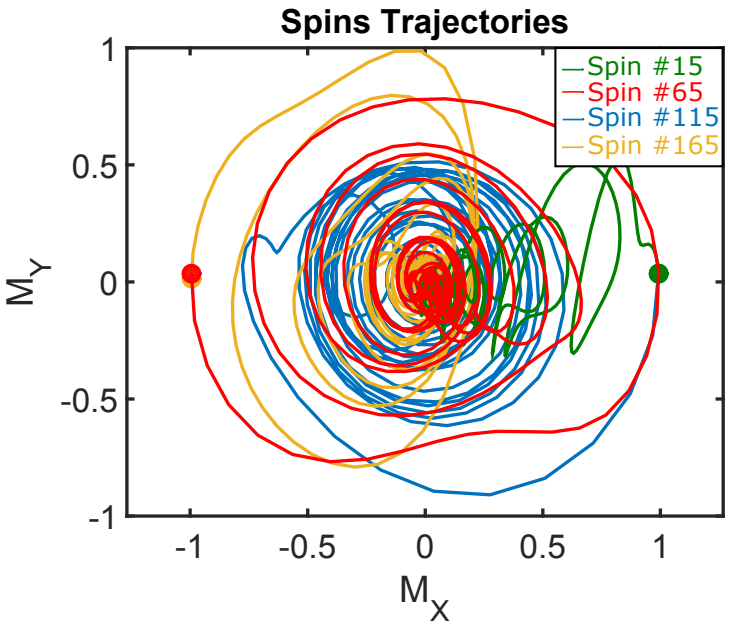
Thank you!

Questions?!



B_1 Pulse and Trajectories





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