# Basics of MRI

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# Outline

- System overview
- Components of the acronym
    - What's the Magnet for?
    - Where does Resonance come in?
    - How is Imaging accomplished?
- Some basic types of MR contrast
- Re-cap of System overview

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# System overview



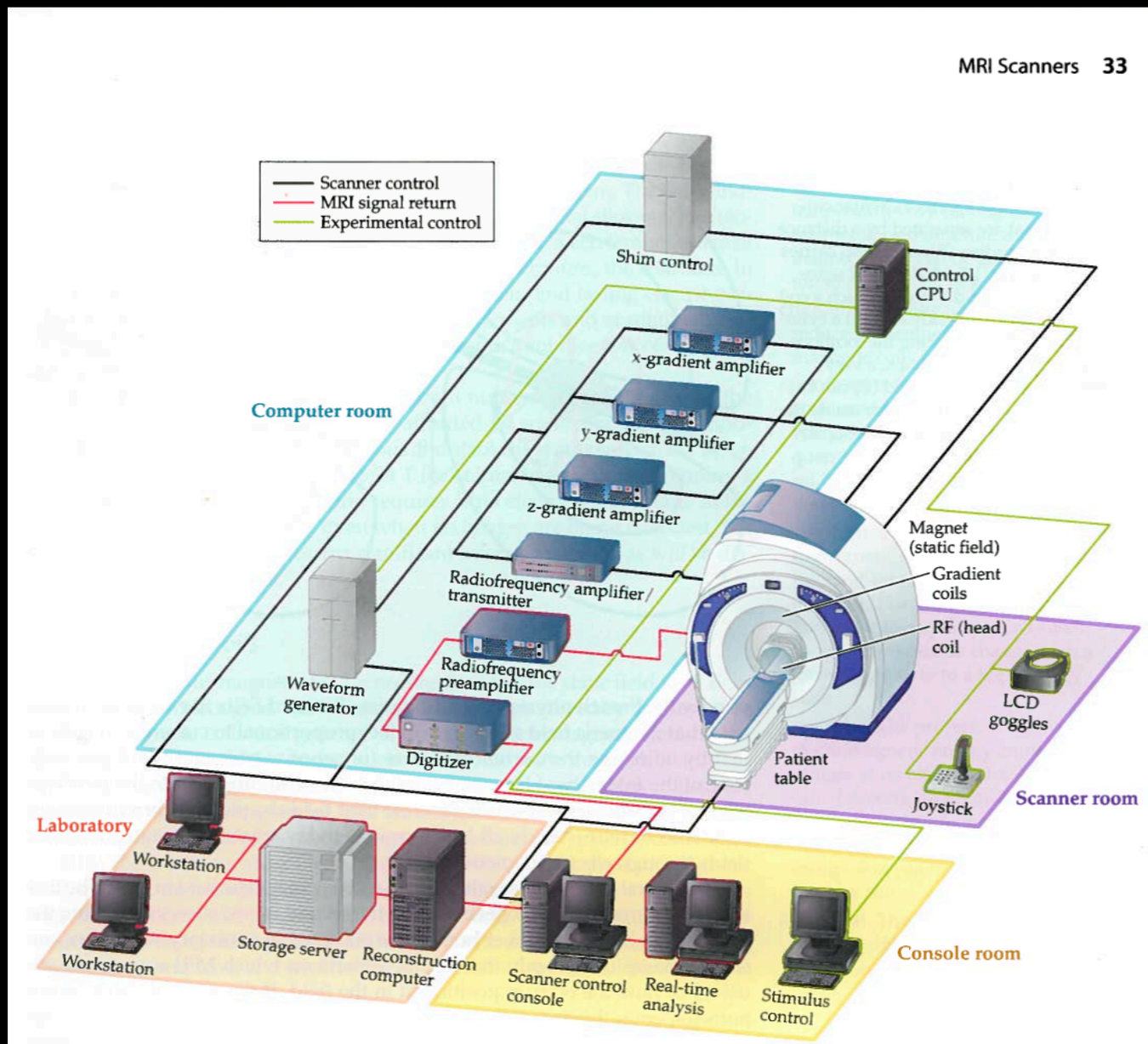


Figure 2.2 Schematic organization of the fMRI scanner and computer control systems. Two systems are important for fMRI studies. The first is the hardware used for image acquisition. In addition to the scanner itself, this hardware consists of a series of amplifiers and transmitters responsible for creating the gradients and pulse sequences (shown in black), and recorders of the MR signal from the head coil (shown in red). The second system is responsible for controlling the experiment in

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# Magnets, magnets, everywhere

- Certain nuclei (odd number of protons and/or neutrons) have magnetic properties (i.e. magnetic moment - 1952 Nobel Prize in Physics, to Bloch and Purcell).

- Include $^{13}C$, $^{23}Na$, $^{31}P$, $^{129}Xe$, and …

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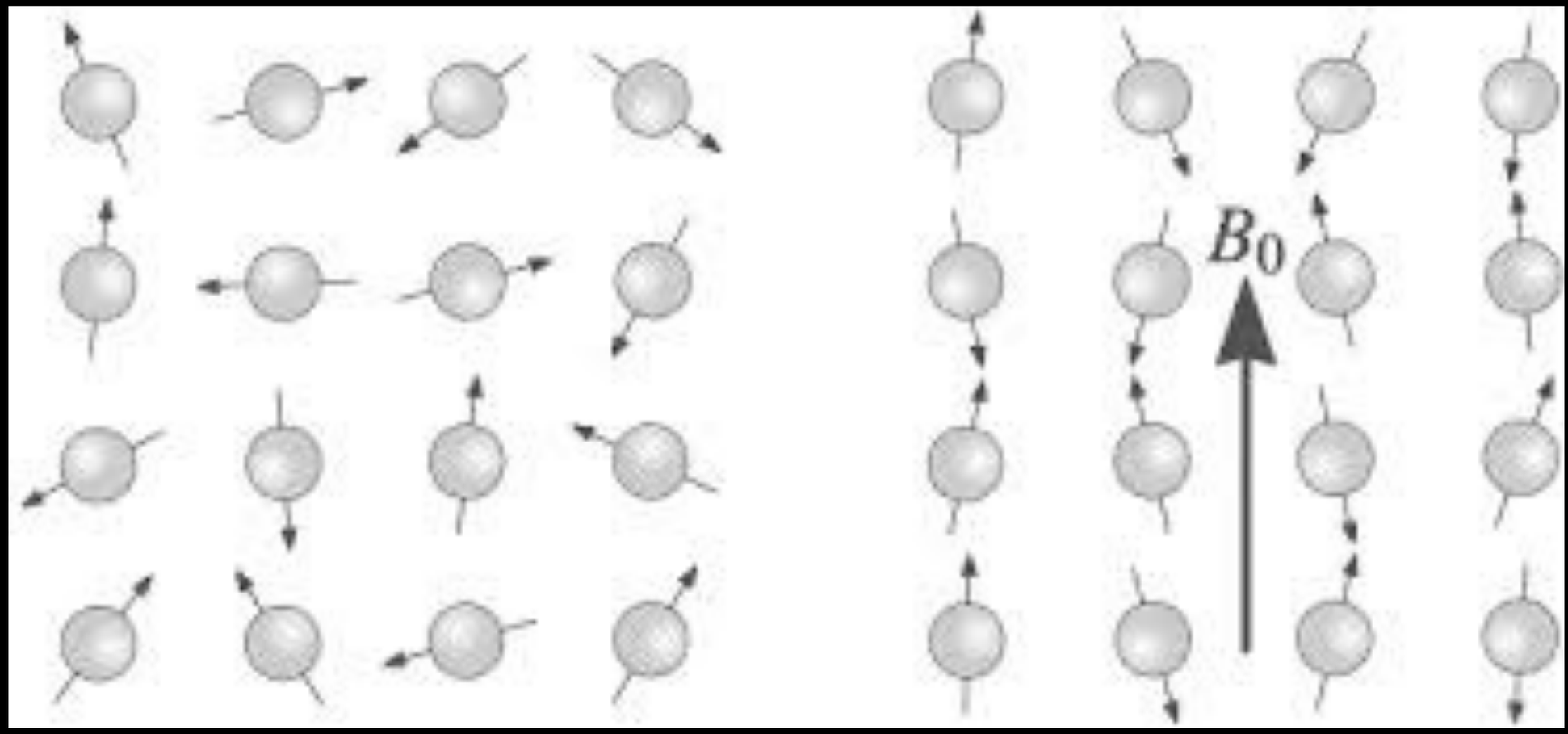
- $^{1}H$ !

# Magnets, magnets, everywhere

- Protons randomly aligned naturally
- Magnetic poles line up when exposed to strong magnets

# Magnets, magnets, everywhere




http://wikidoc.org/index.php/Basic_MRI_Physics

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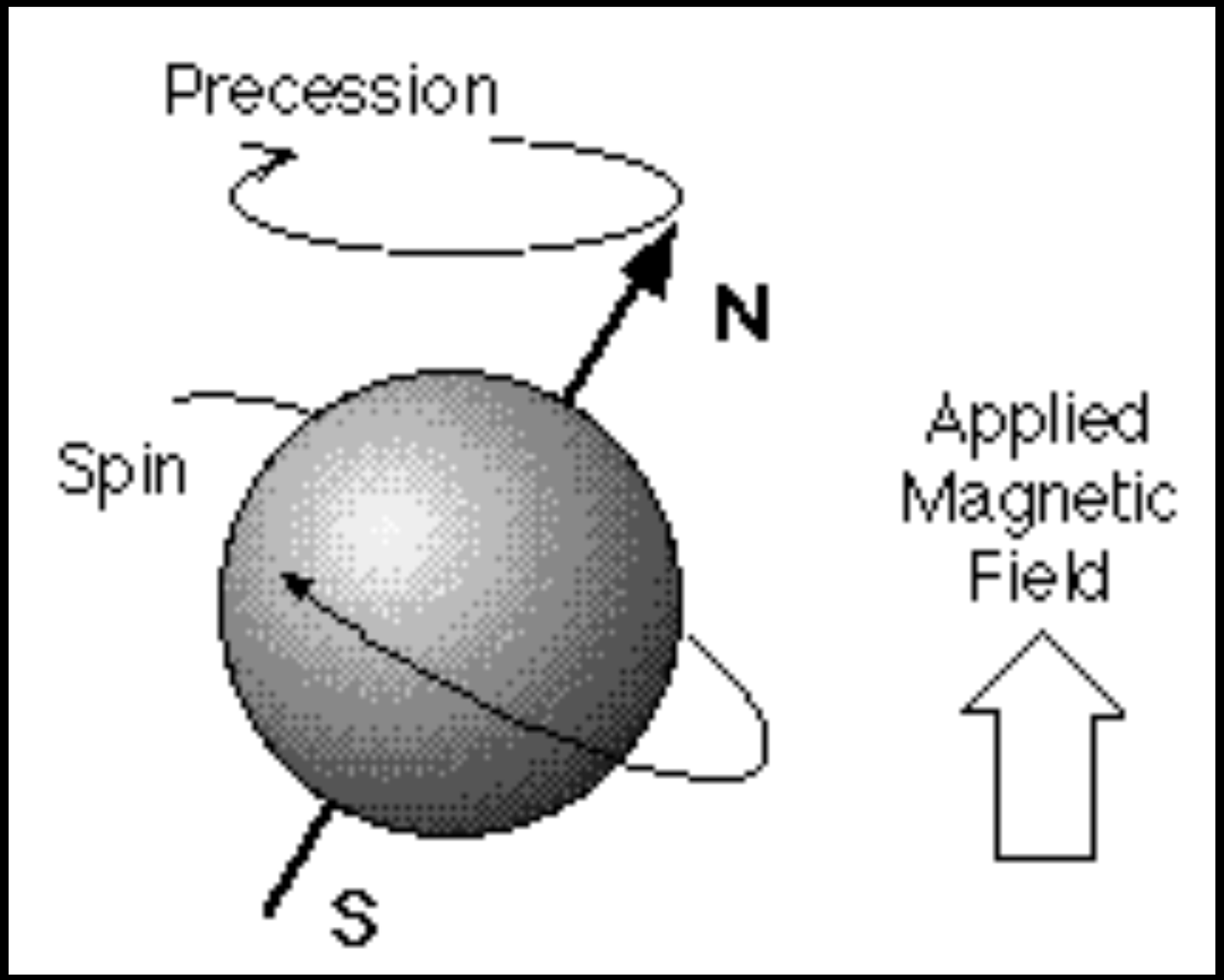
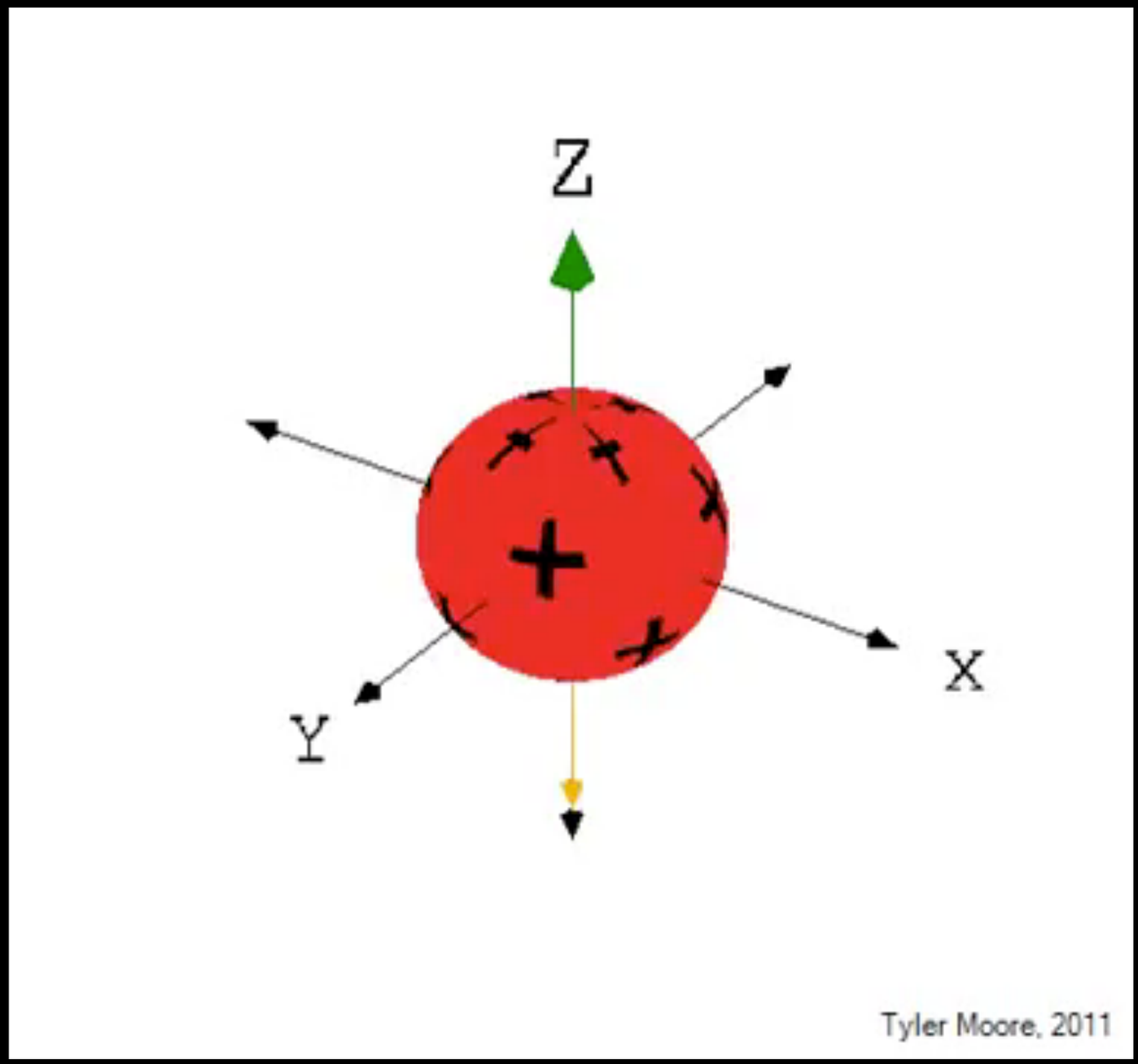



http://ccn.ucla.edu/BMCweb/SharedCode/TINS/FMRI-TINS.html

# Magnets, magnets, everywhere




https://www.youtube.com/playlist?list=PLAE12114468910462

# Magnets, magnets, everywhere

$$\omega_0 = \gamma \; B_0$$

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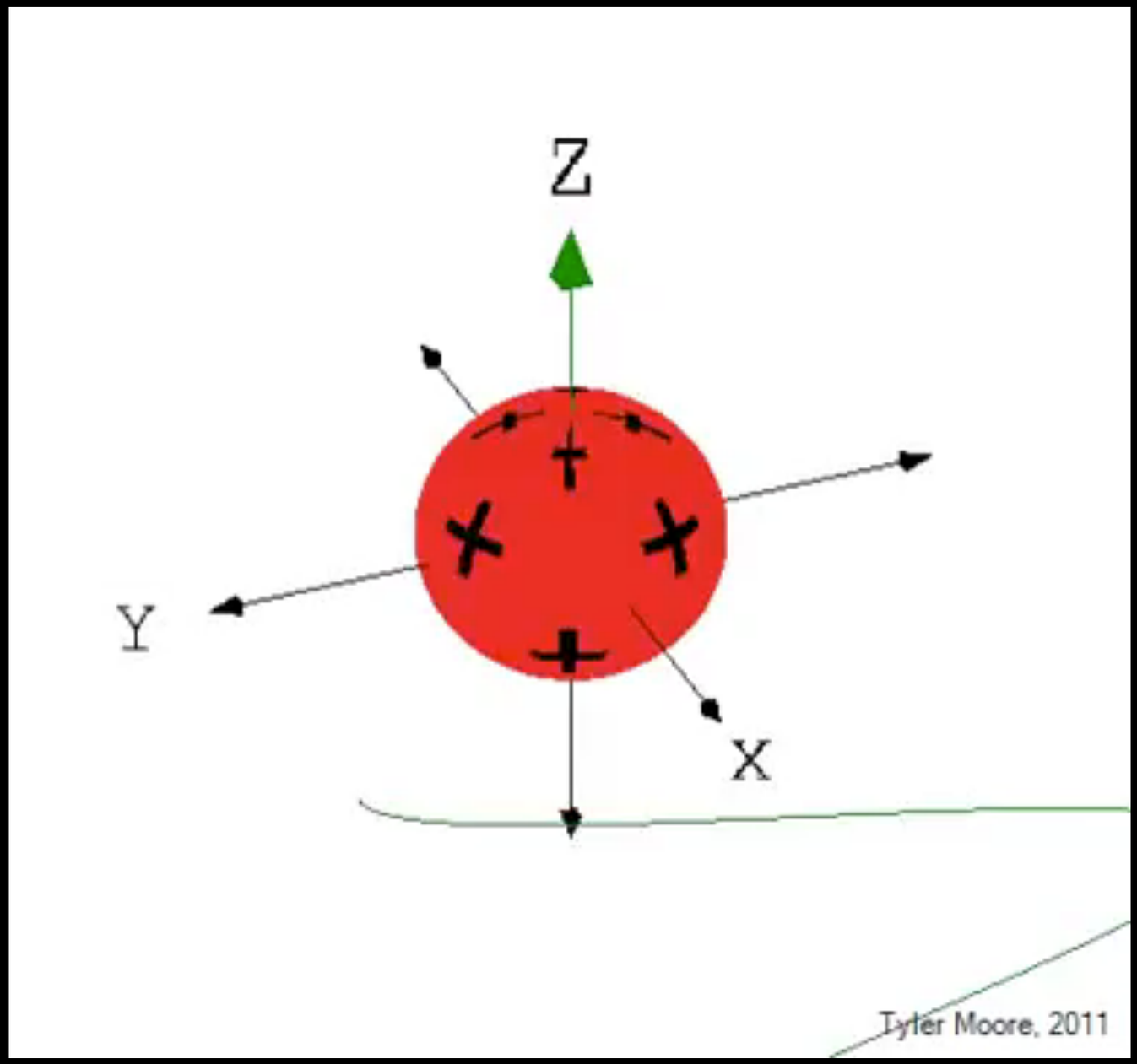
# Resonance

- Protons aligned with main magnetic field ($B_0$) are not visible / detectable in MR imaging
- “Flip” / excite into visibility by applying energy at the same frequency as precession …
- == Resonance !

# Resonance




https://www.youtube.com/playlist?list=PLAE12114468910462

# Resonance

- Perpendicular protons (partially or completely) are visible in typical MR experiment.

- “Flip” angle ≈ degree of tip - a type of contrast

- High RF power for short time vs. low power for longer time.  Same flip angle - but can give different contrast

- Uniform $B_0$ → uniform signal - cannot localize …

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# Imaging

- Uniform $B_0$ → uniform signal - cannot localize …
  so how to image?

# Imaging

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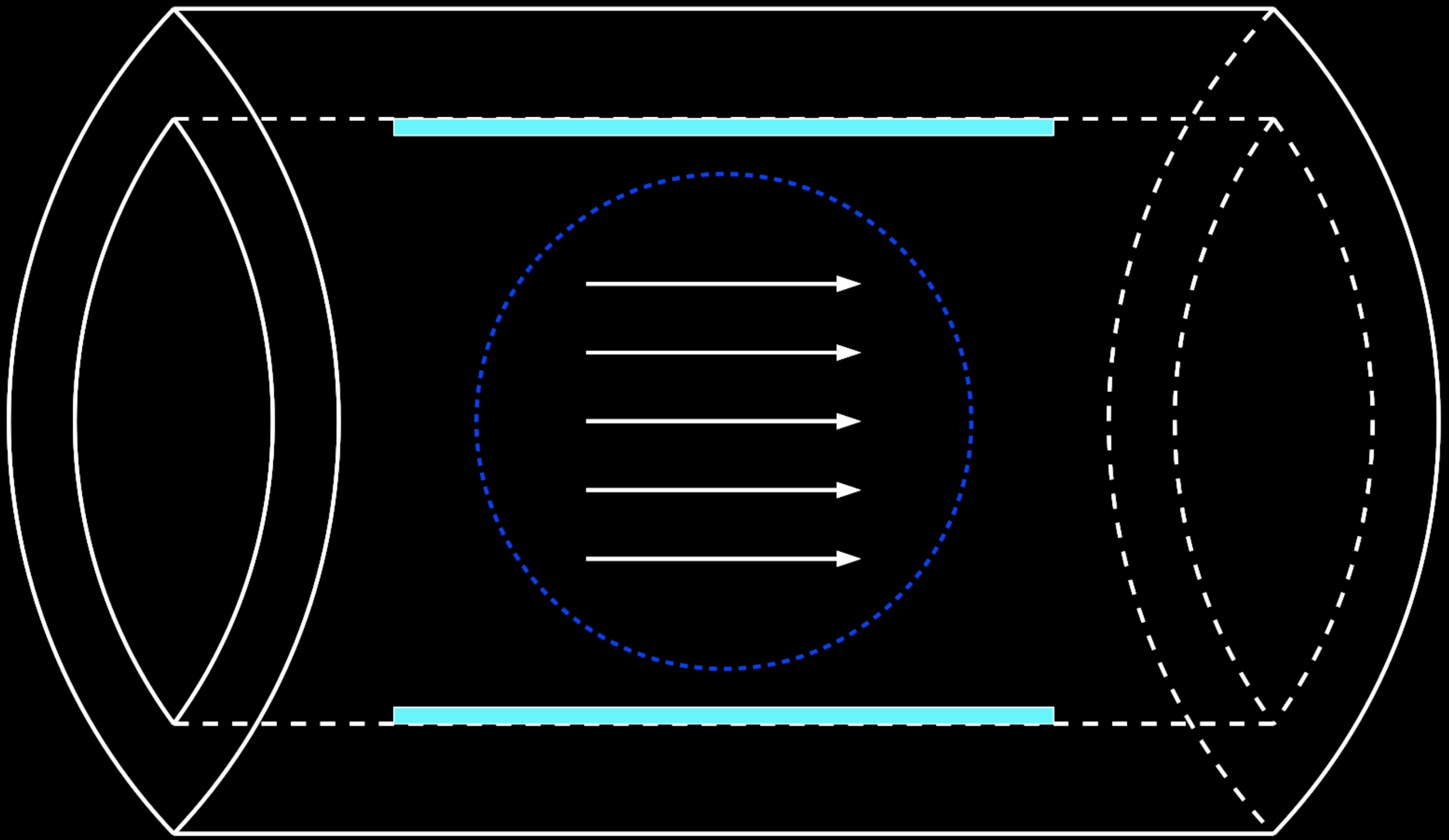
- Apply controlled distortion to $B_0$

# Imaging



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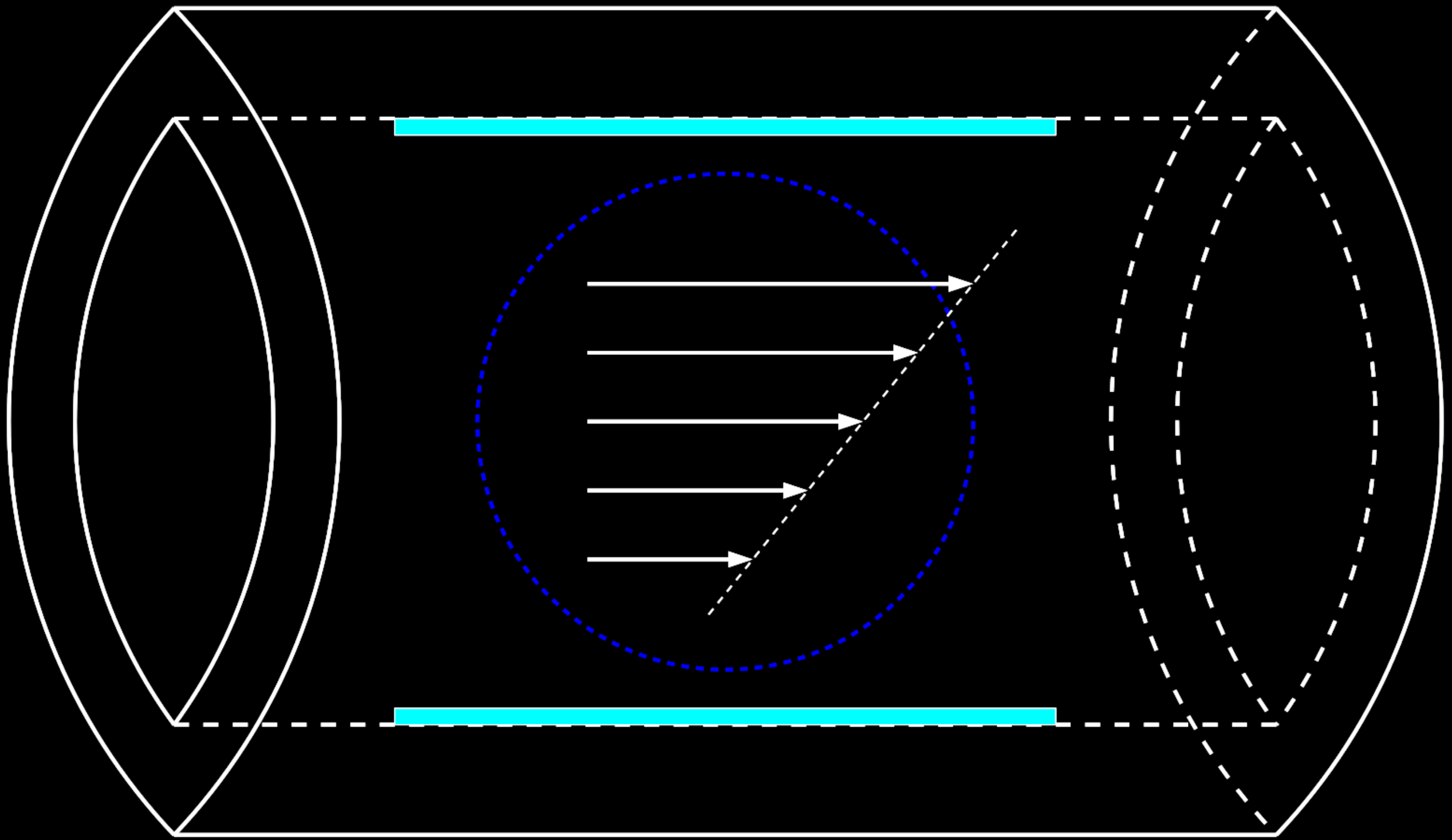


# Imaging

- Uniform $B_0$ → uniform signal - cannot localize … so how to image?

- Apply controlled distortion to $B_0$

- → → → Spatially varying frequency

# Imaging

$$\omega_0 = \gamma \; B_0$$

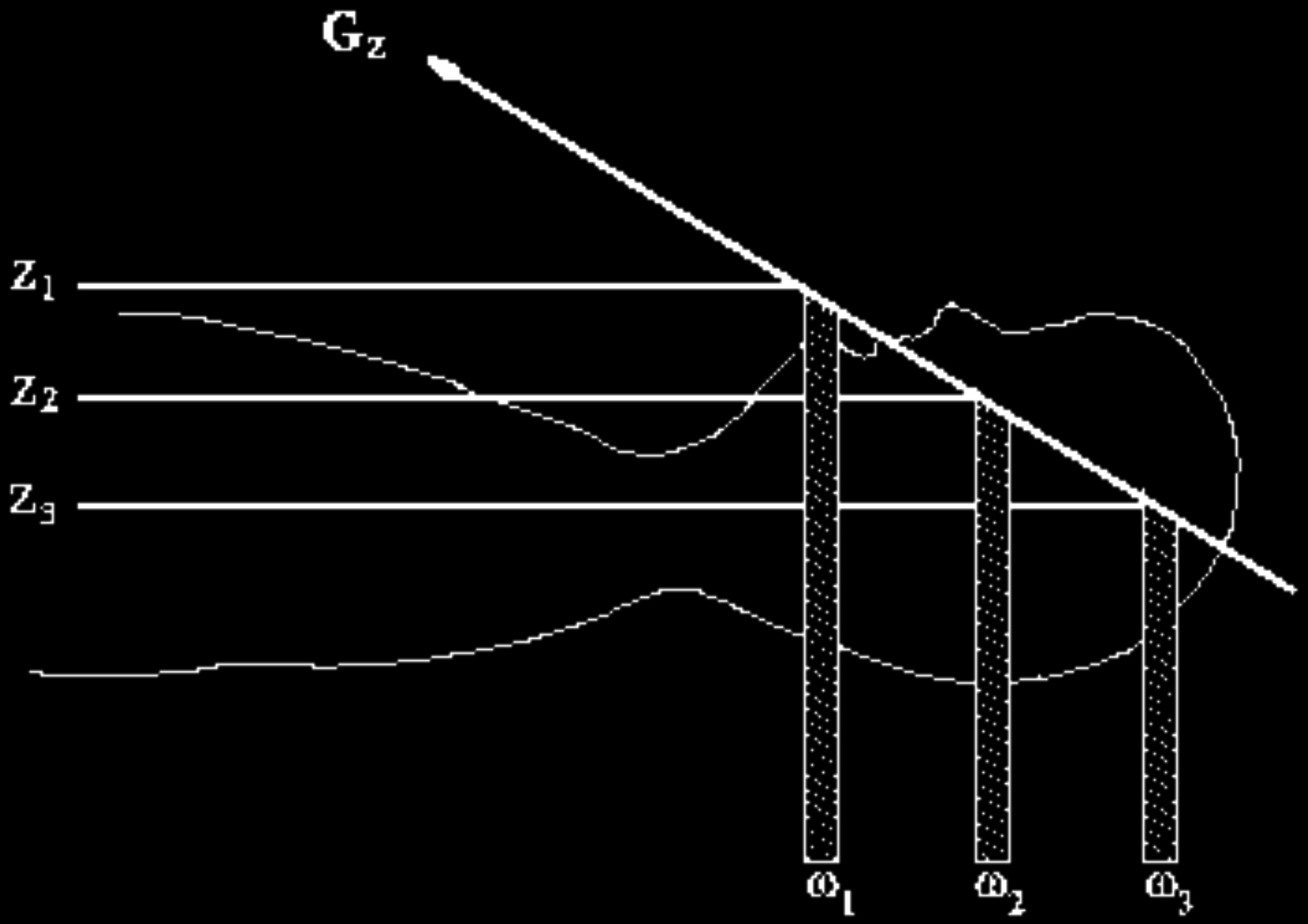
# Imaging

$$\omega_x = \gamma \; B_x$$

# Imaging

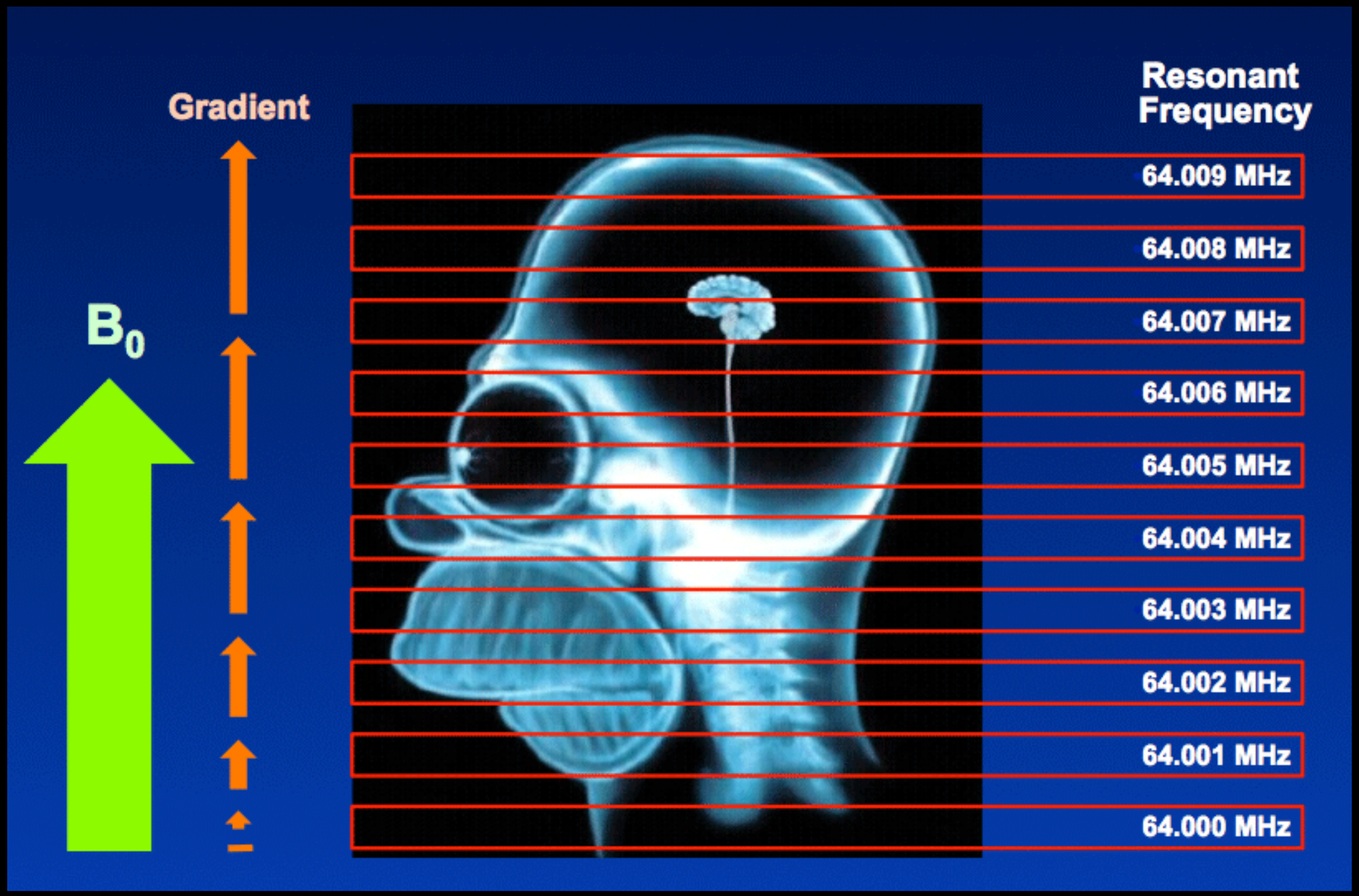
$$\omega_x = \gamma\ (B_0 + G_x)$$

# Imaging




http://sfb649.wiwi.hu-berlin.de/fedc_homepage/xplore/ebooks/html/csa/node255.html

# Imaging




http://mri-q.com/frequency-encoding.html

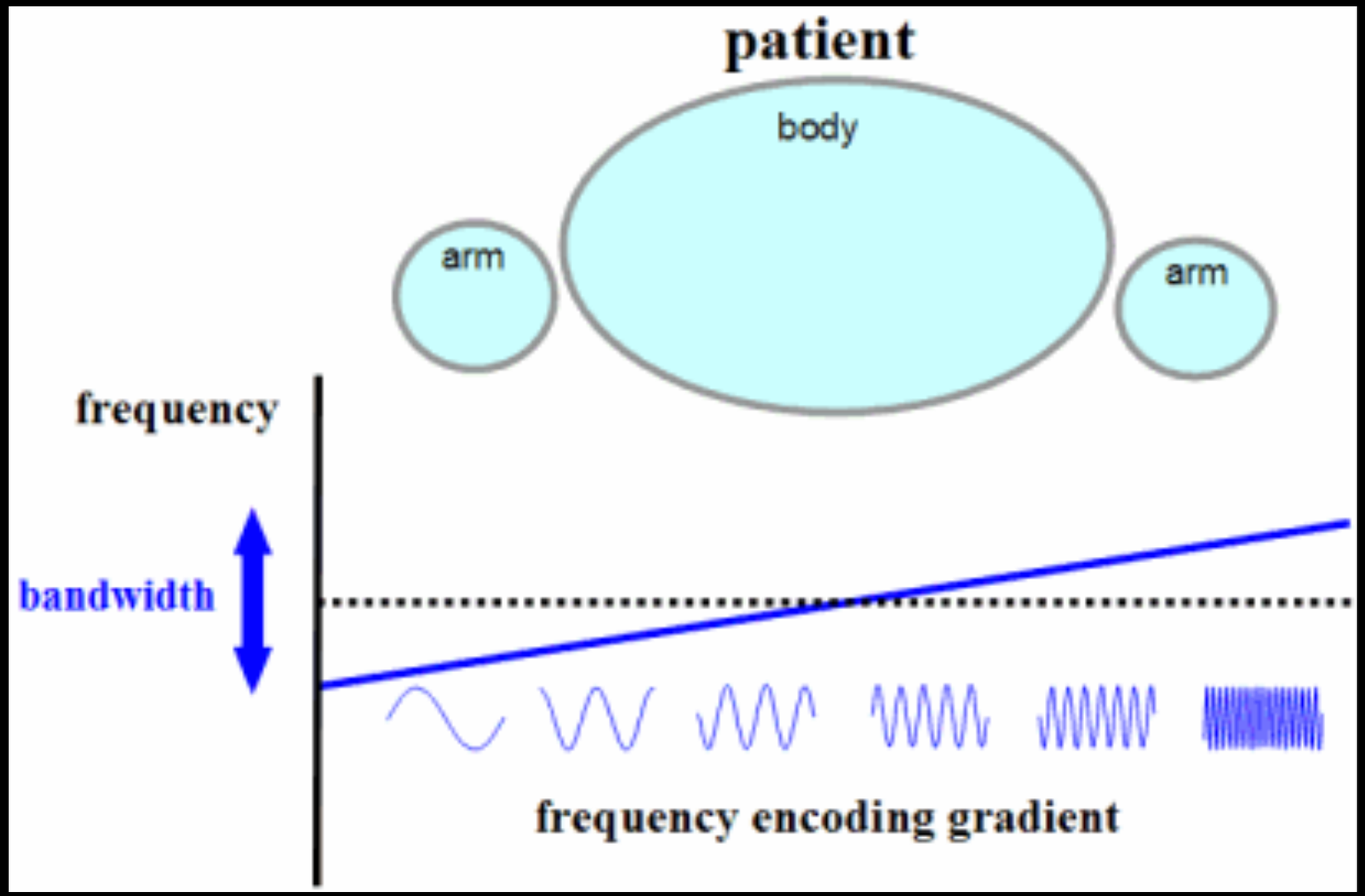
# Imaging

- Extend frequency change to other dimensions (x, y) for image encoding.

- 1st dimension → frequency encoding

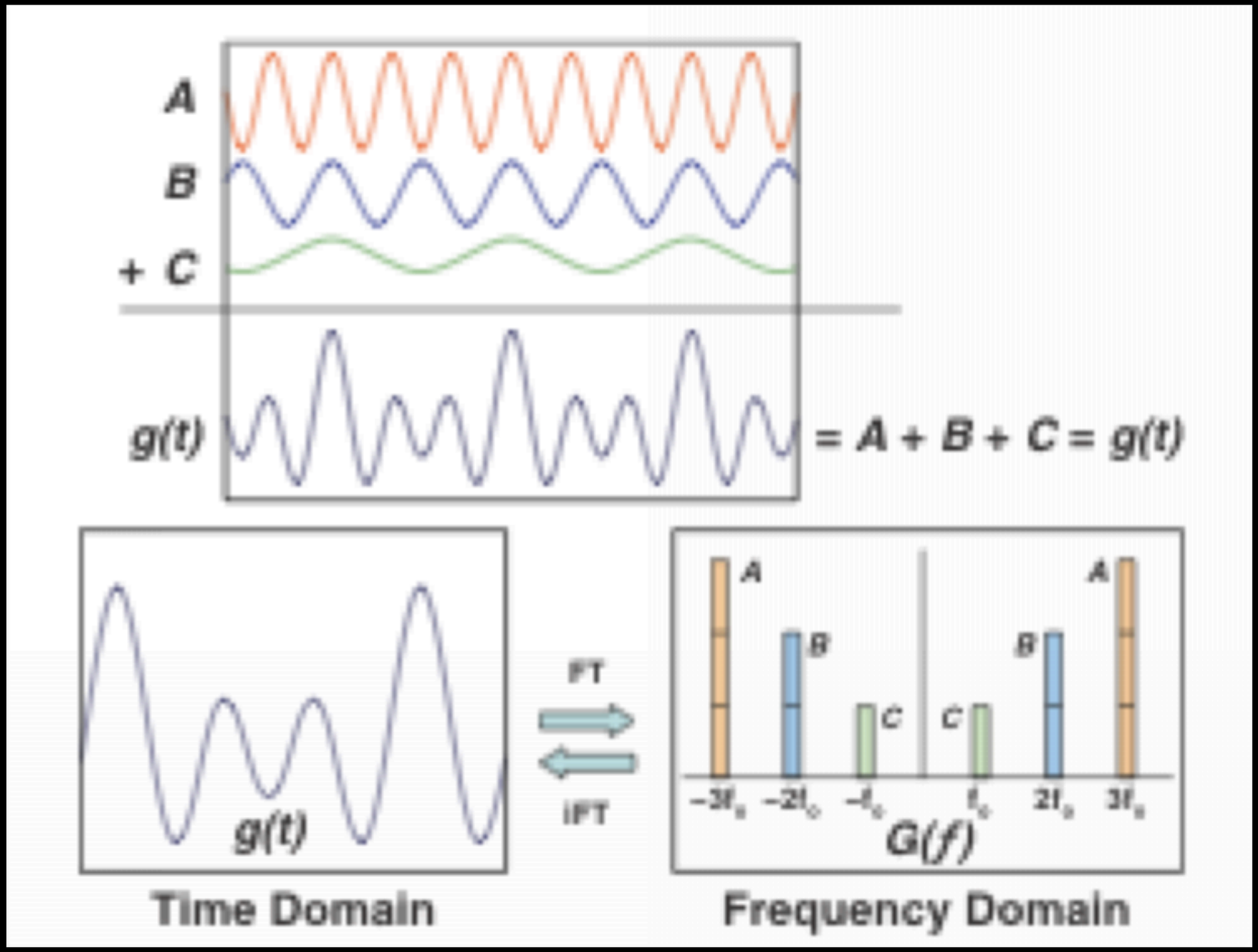
- 2nd dimension → phase encoding

# Imaging




http://www.revisemri.com/questions/creating_an_image/frequency_encoding_gradient

# Imaging




AJNR, Gallagher, DOI:10.2214/AJR.07.2874

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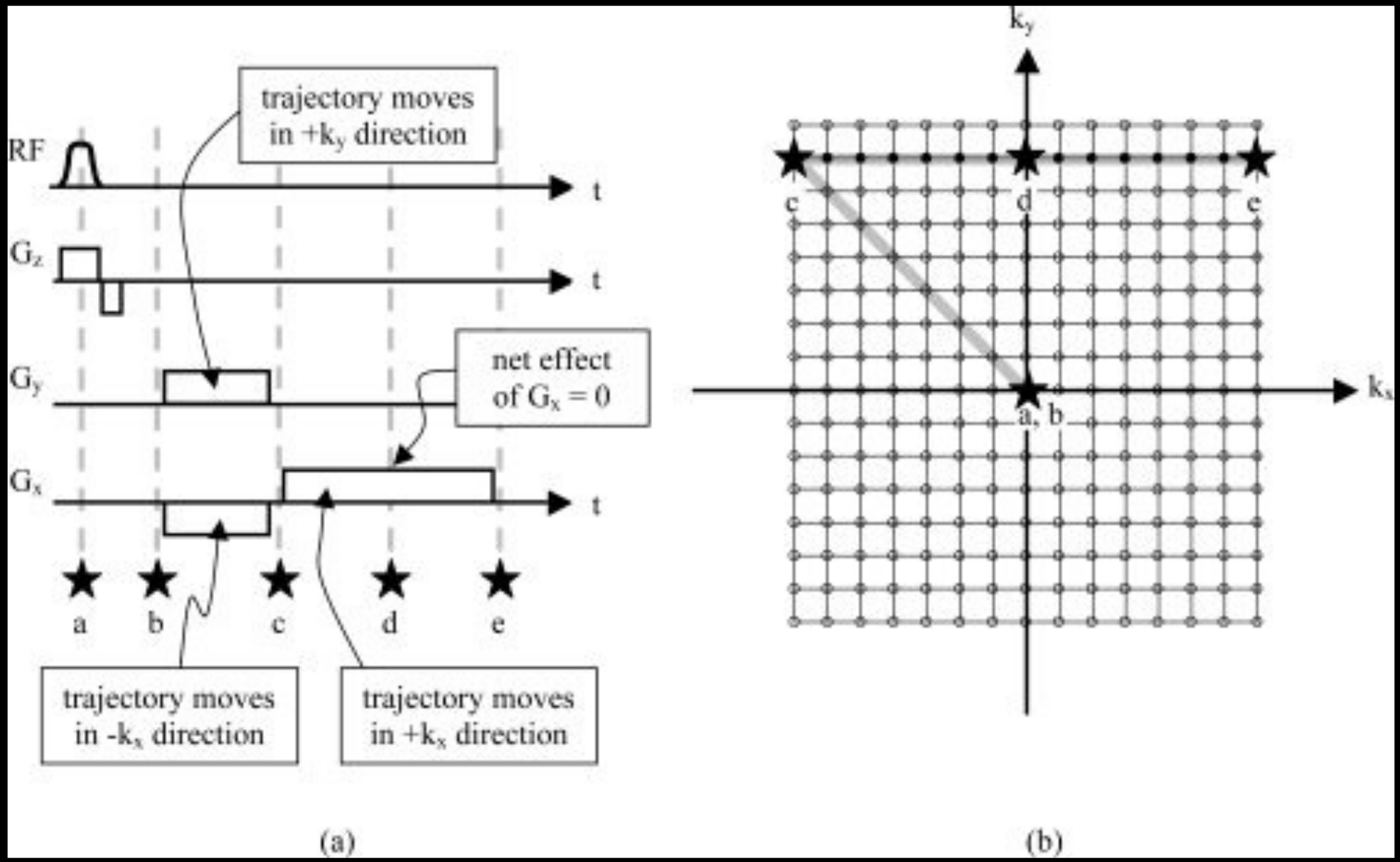
- Effects of gradients encodes “*k*-space”

# Imaging




JMRI, Paschal and Morris, DOI: 10.1002/jmri.10451

# Imaging

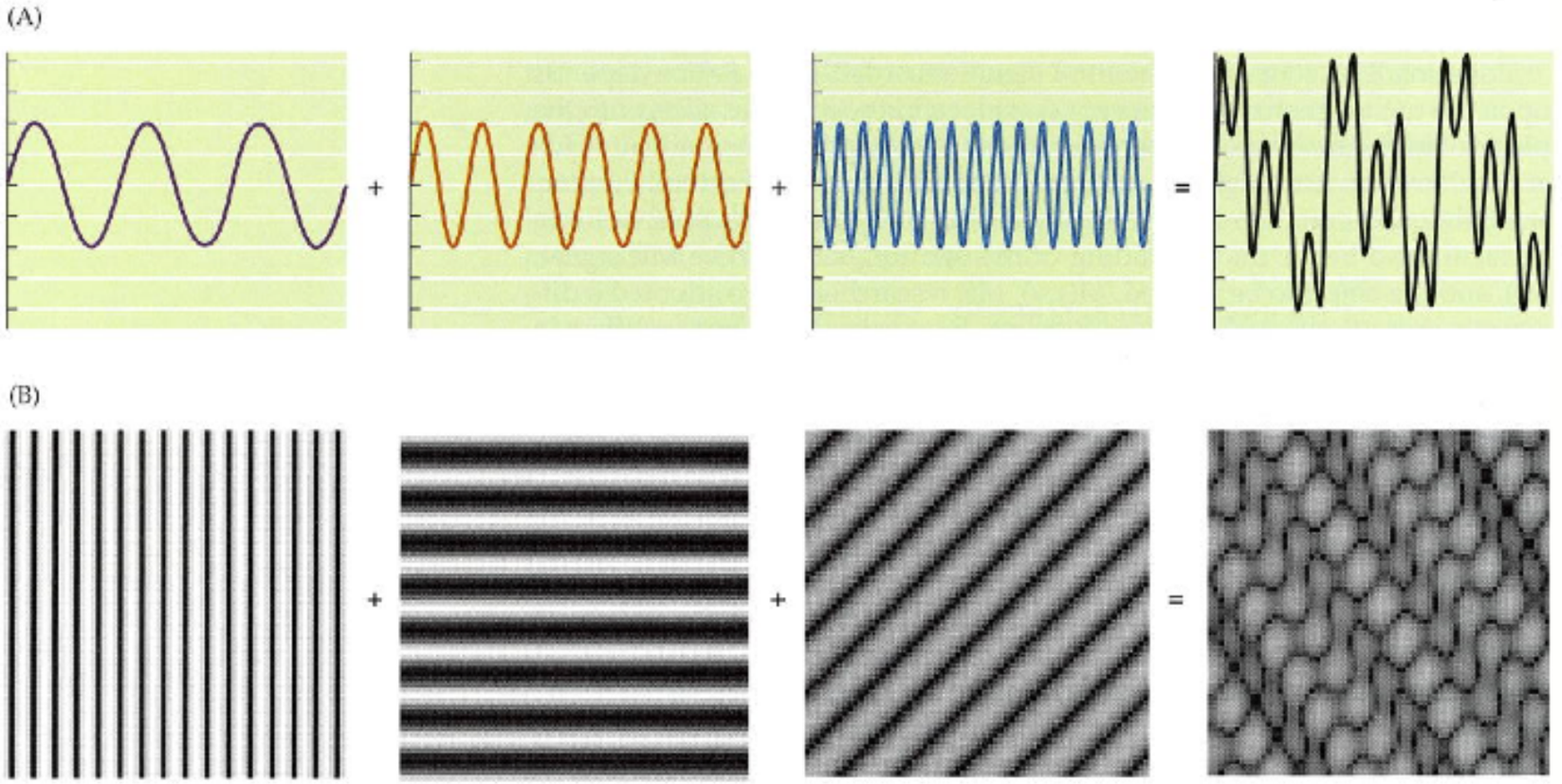


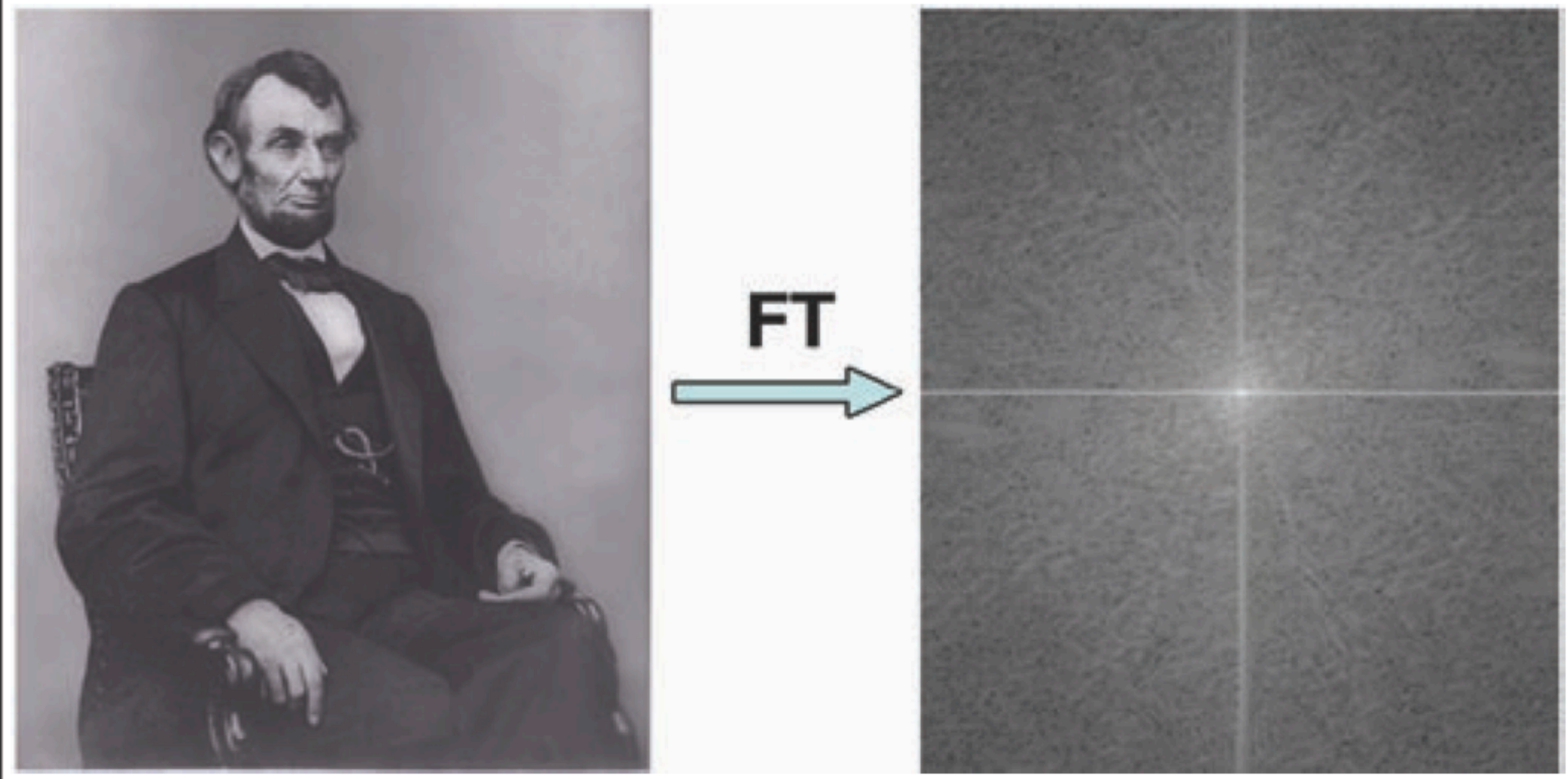

**Figure 4.5** Constructing a complex waveform or image from simpler components. Any data, no matter how complex, can be constructed from simpler components. Shown in (A) are three sine waves, each with a different frequency. When combined, they form the waveform at right. By combining more and more sine waves of different frequencies and phases, very complex waveforms can be created, such as that of music. The same principle holds for two-dimensional data (B), except that here the components are gratings of particular spatial frequencies (i.e., how closely spaced are the bars), phases, and angles. By combining a very large number of these gratings, complex images can be created, such as those used in MRI. Shown in (C) is the *k*-space plot of the summed image; the individual gratings are associated with the three bright pixels.

Huettel - Functional Magnetic Resonance Imaging

# Signal (Fourier Transform) Equation in MRI

$$s(t) = \int_{\vec{r}} M_{xy}(\vec{r}, 0) e^{-i2\pi \vec{k}(t)\cdot\vec{r}} d\vec{r}$$

# Imaging

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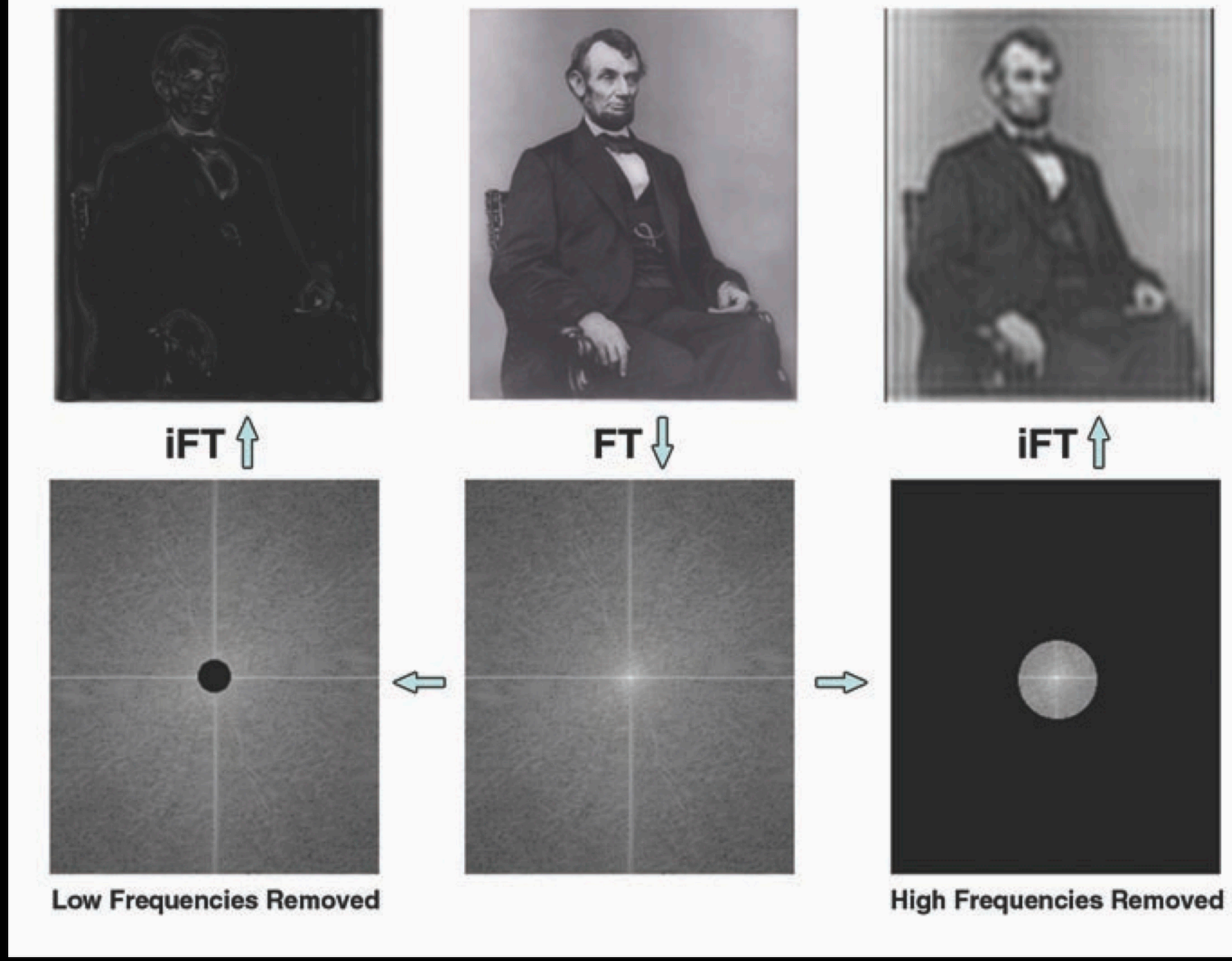


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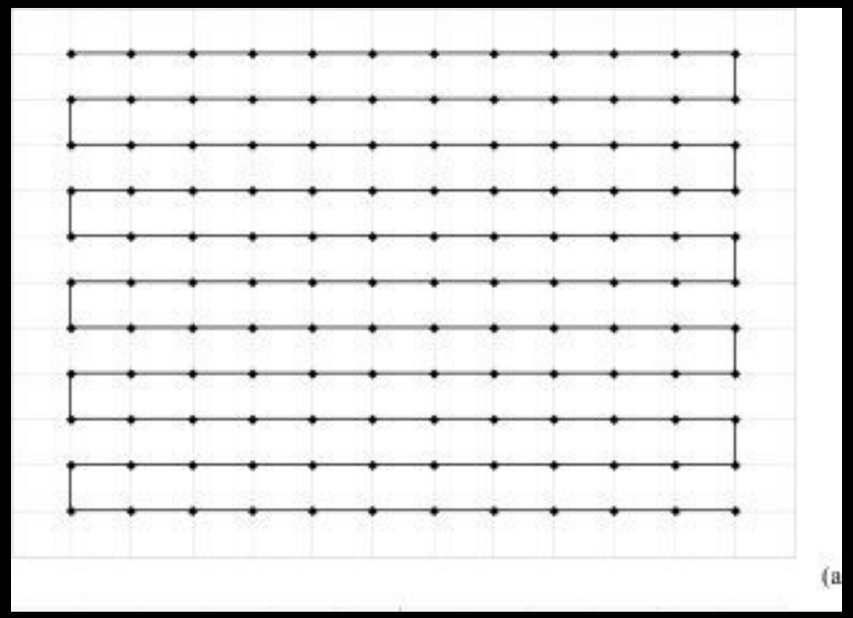

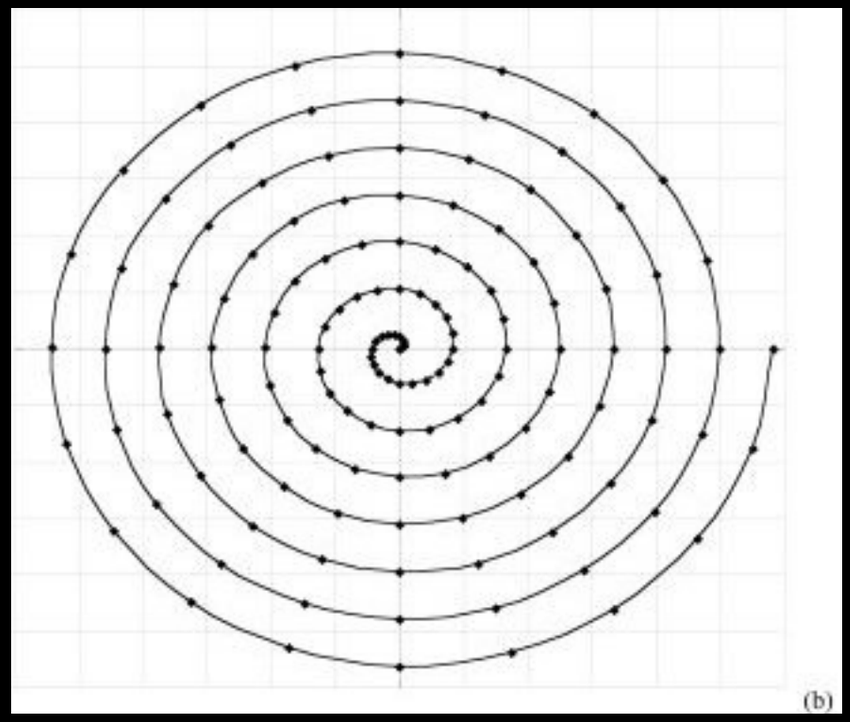

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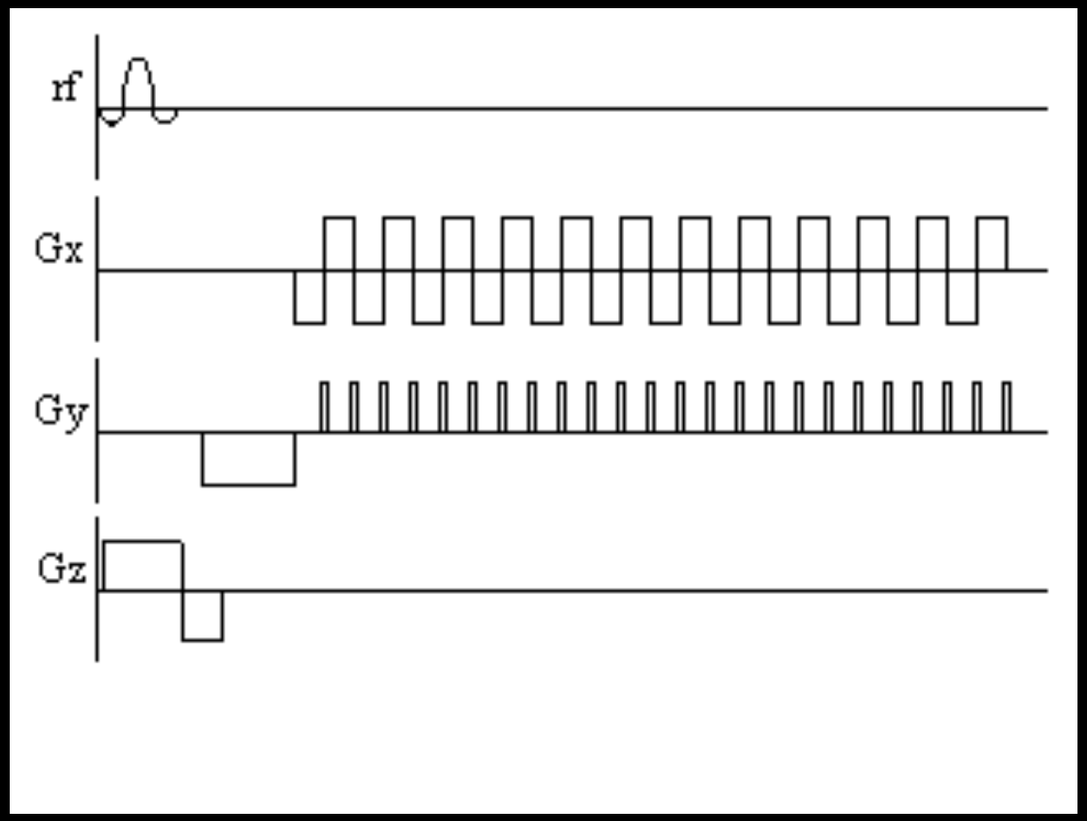


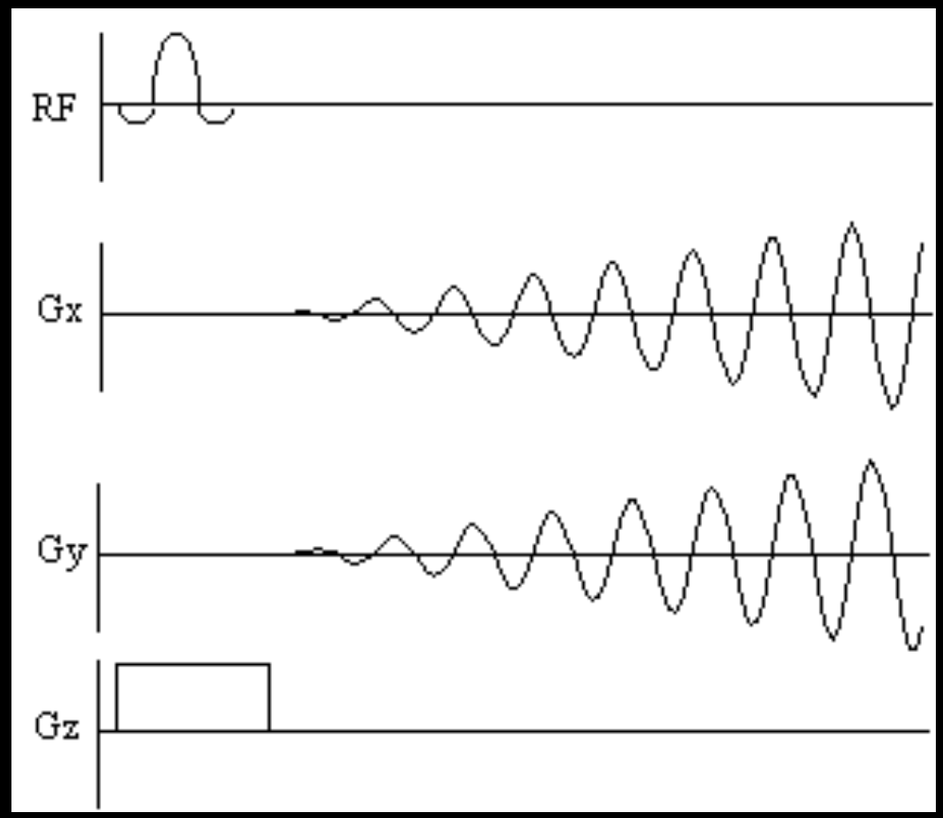


https://users.fmrib.ox.ac.uk/~stuart/thesis/chapter_2/section2_3.html

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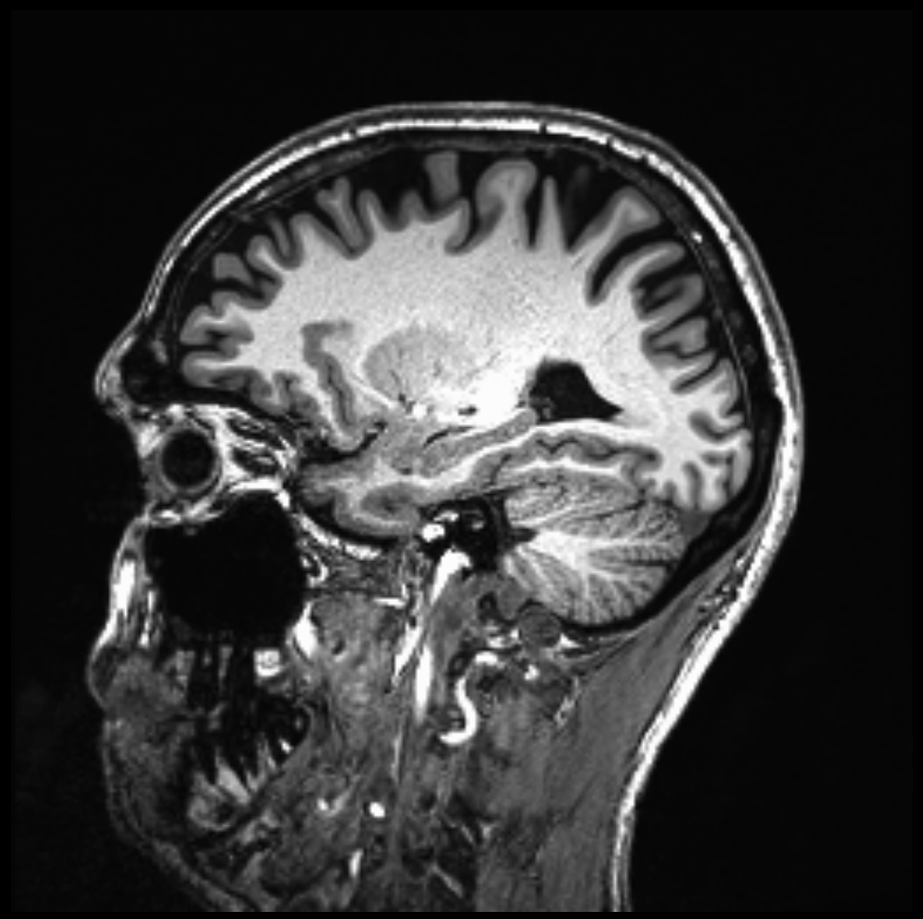
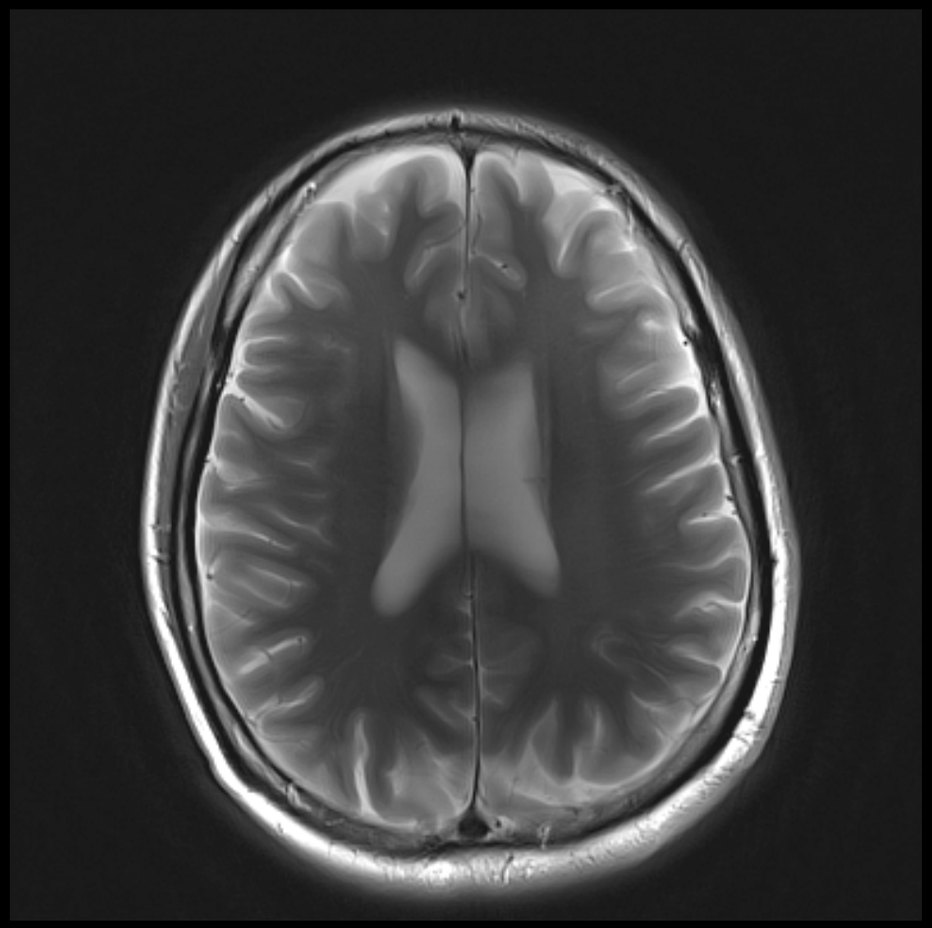
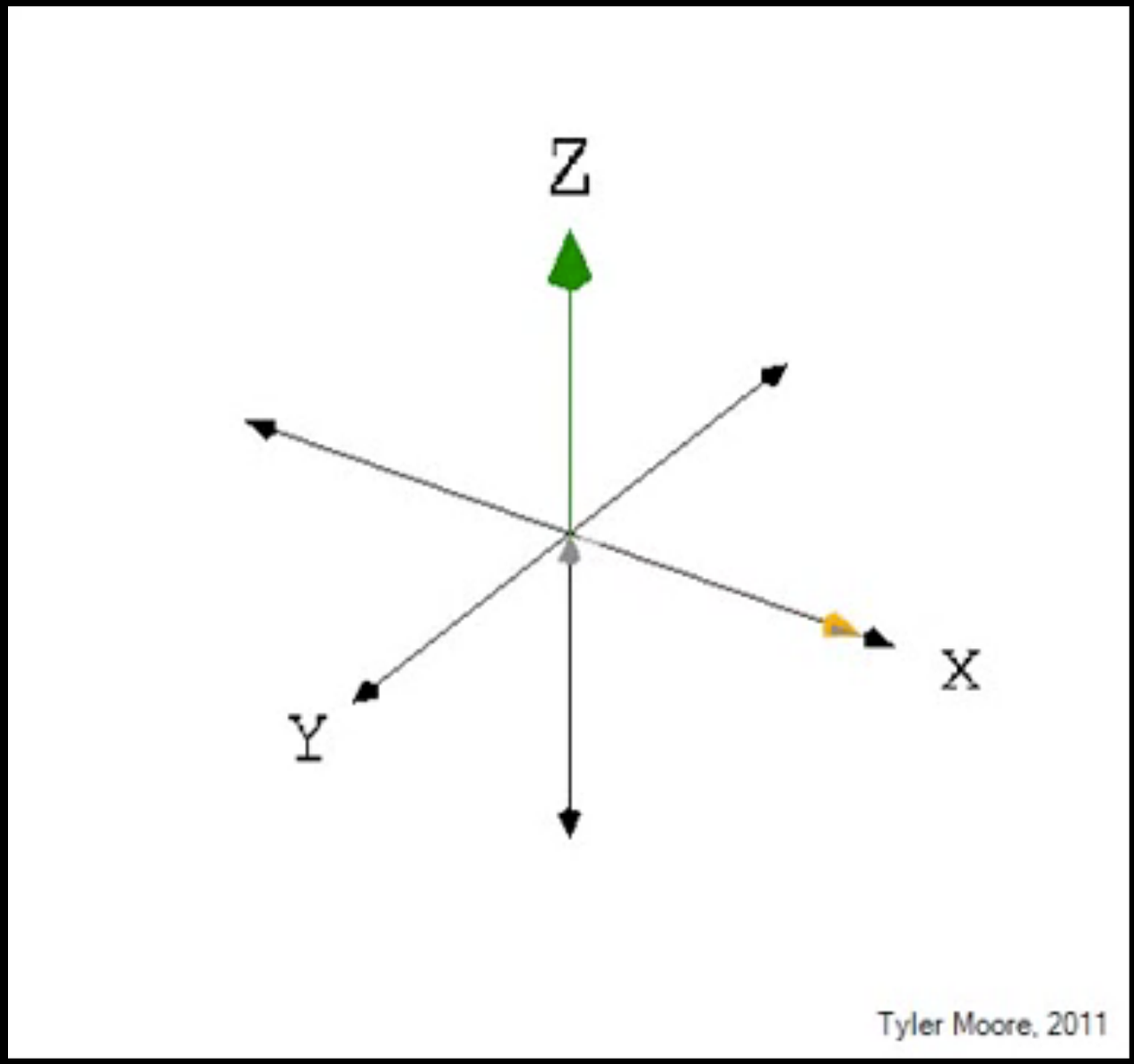
# Contrast





# Contrast - $T_1$

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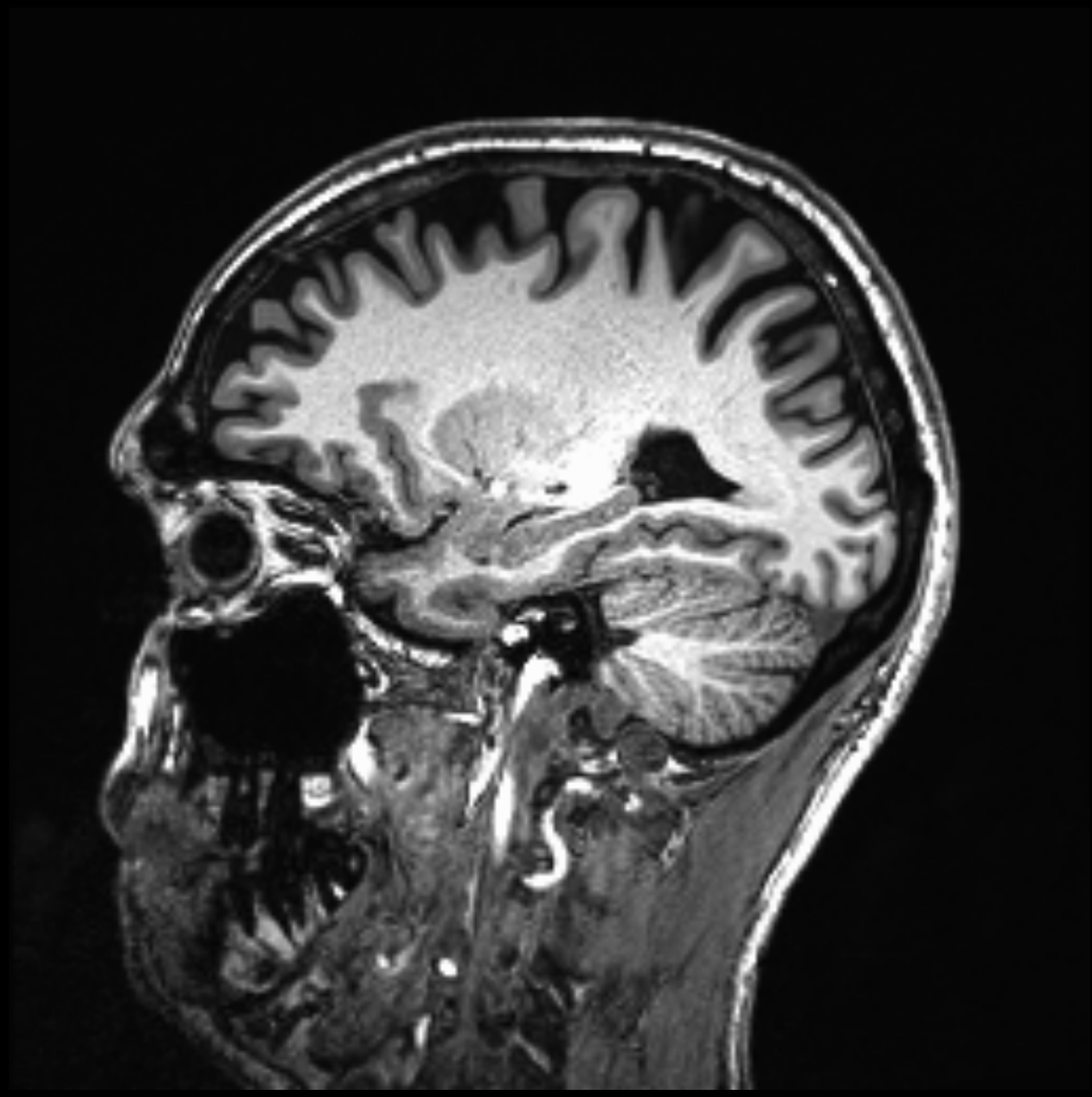
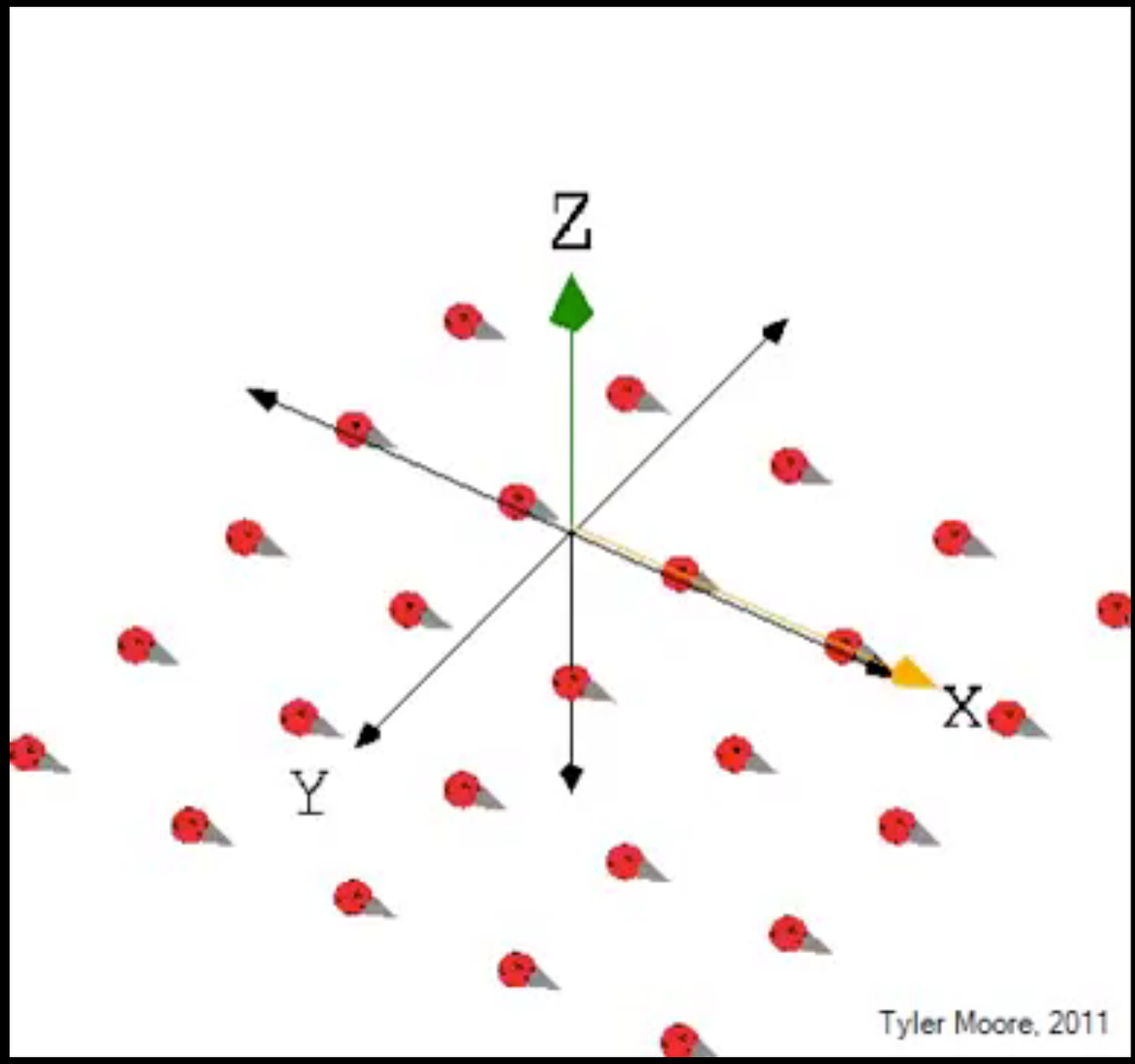
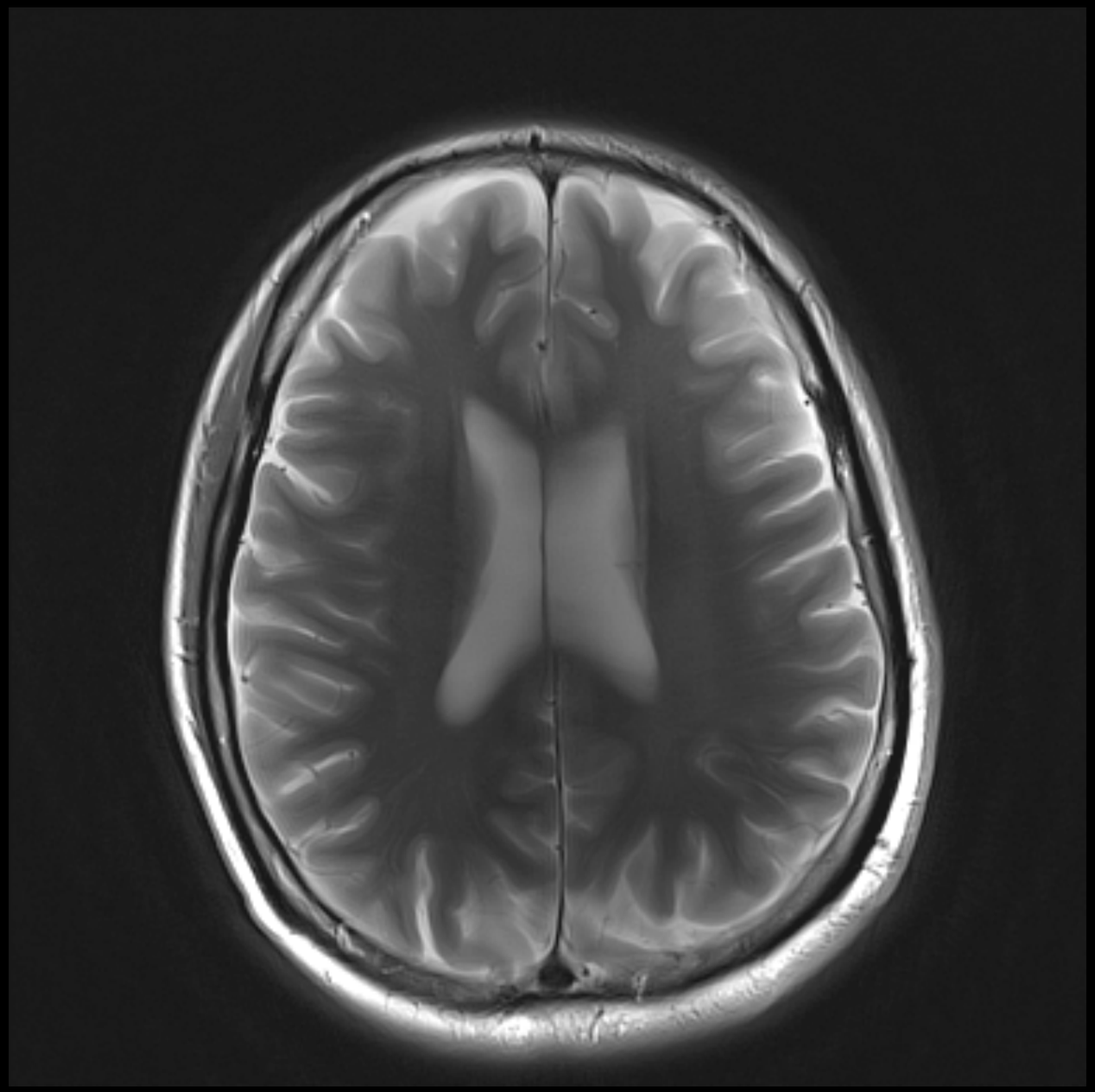


# Contrast - $T_2$

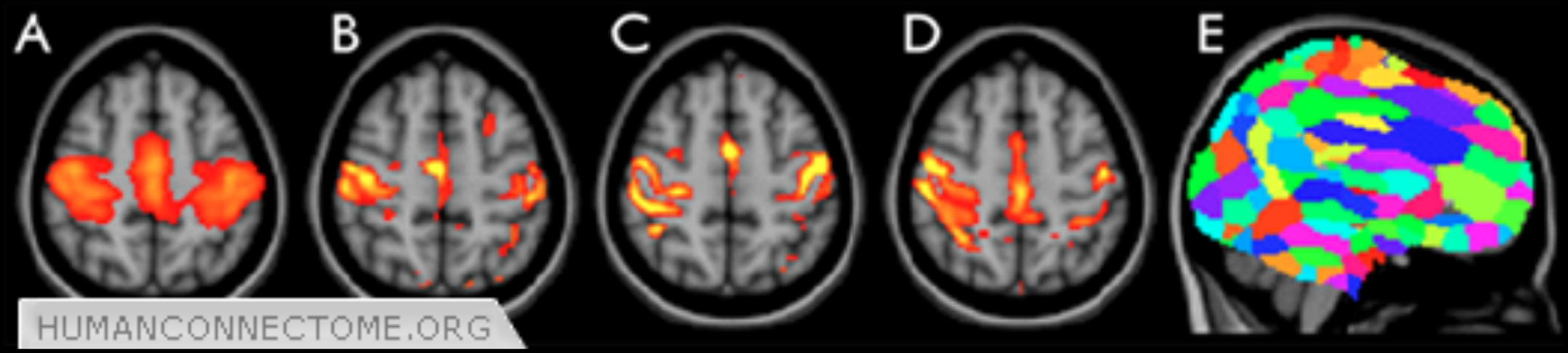



https://www.youtube.com/playlist?list=PLAE121144689104 62

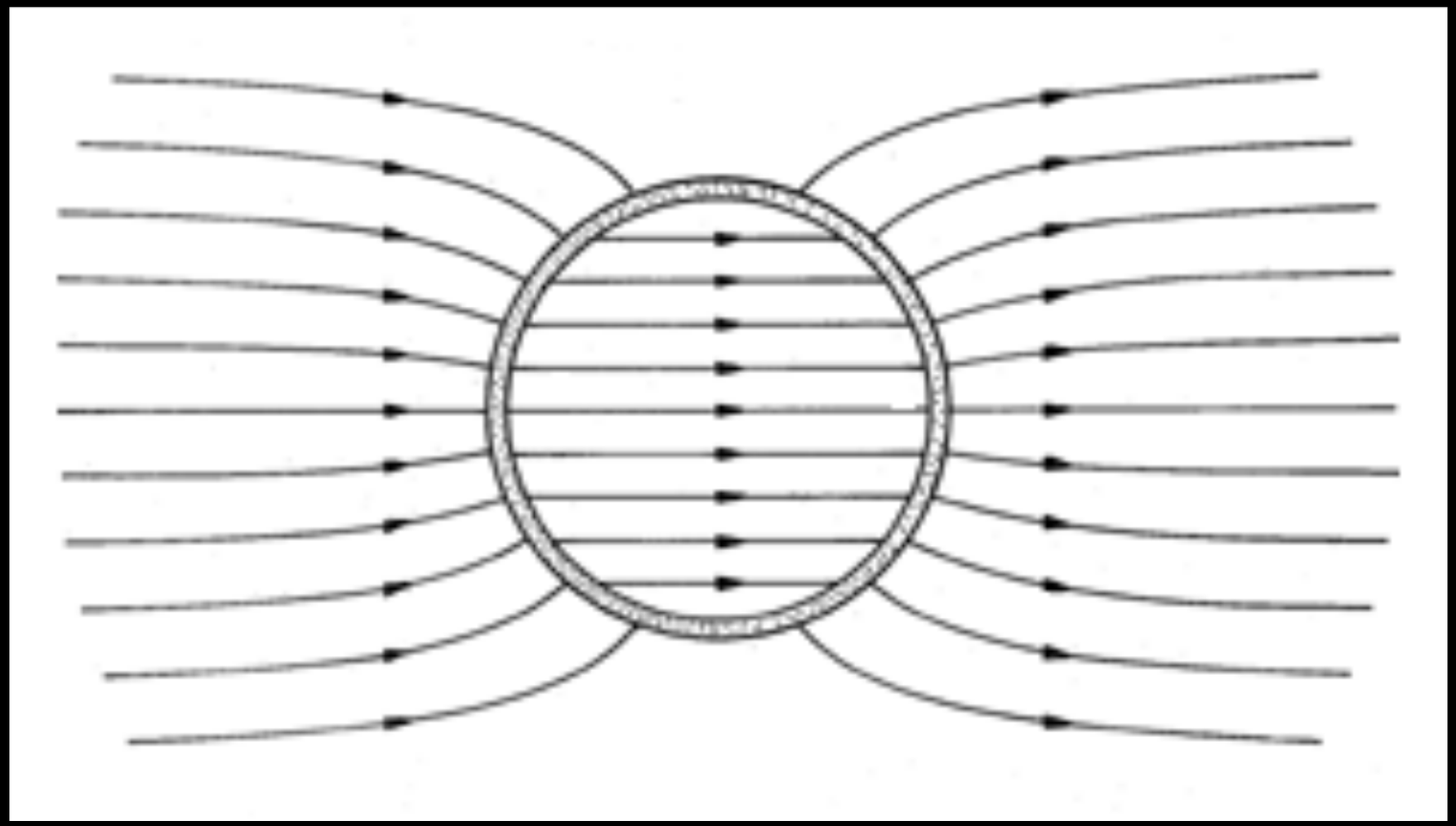
# Contrast - $T_2$



# Contrast - BOLD



# Contrast - BOLD



http://web.mit.edu/6.013_book/www/chapter10/10.4.html

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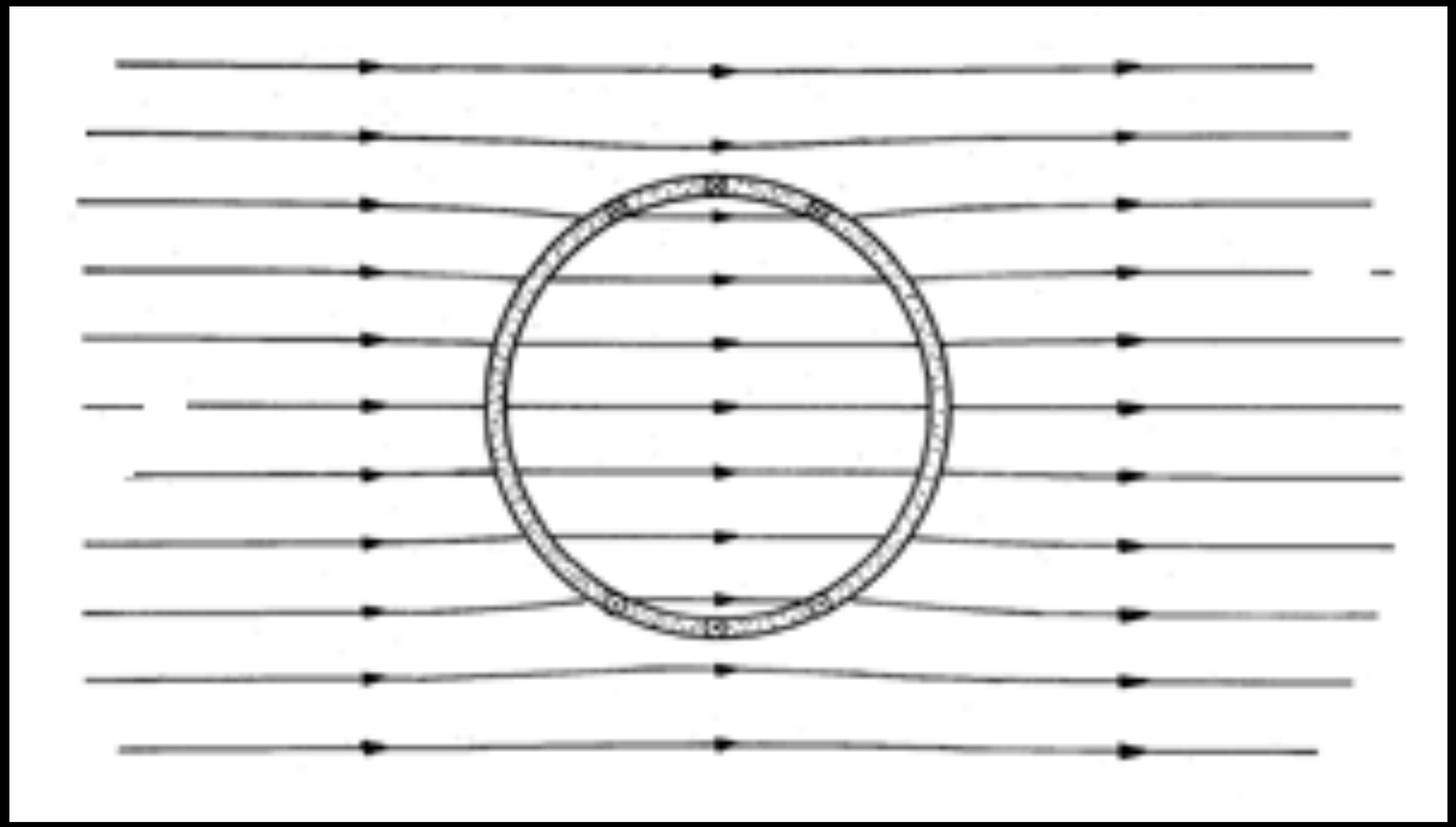

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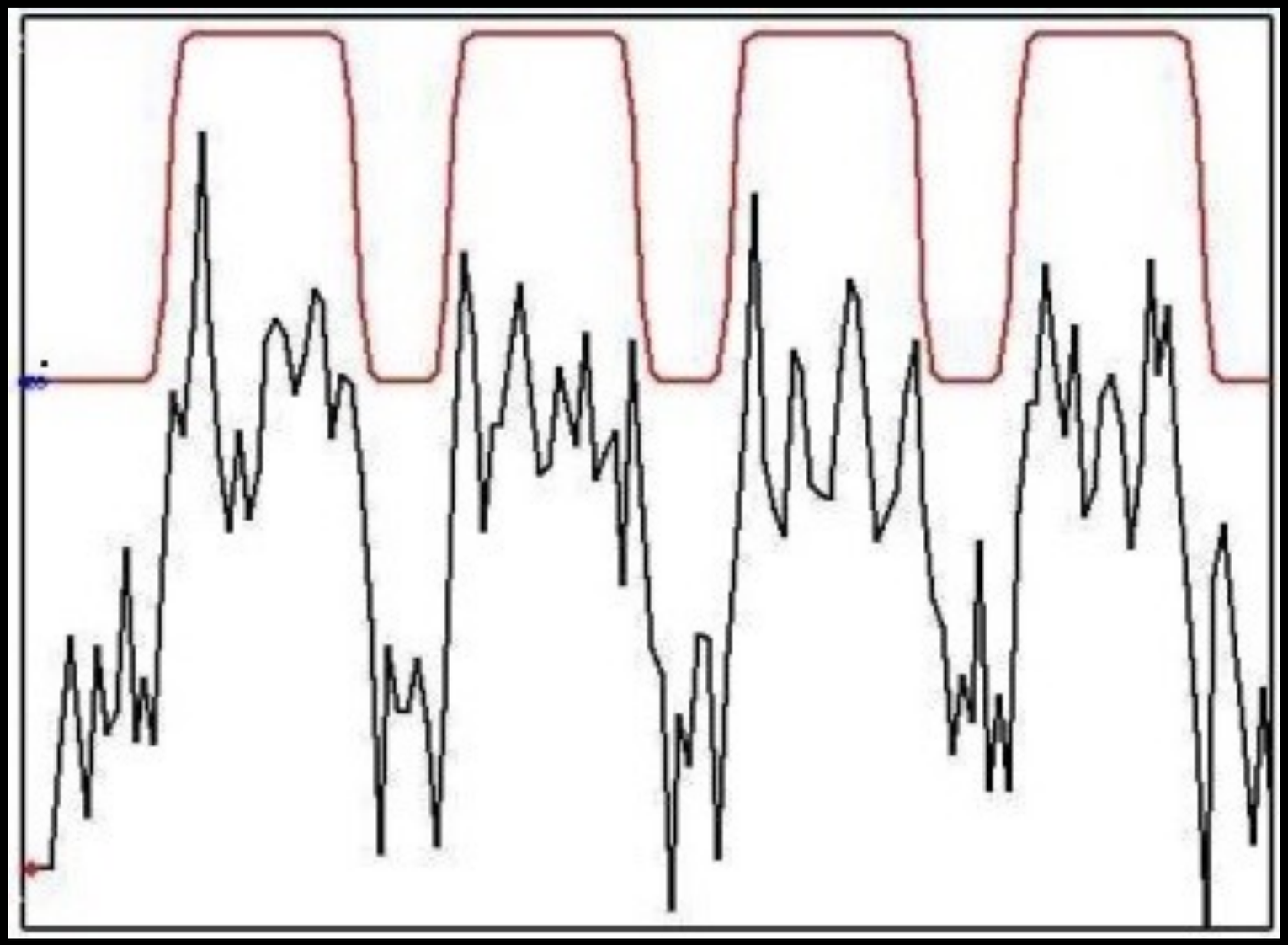

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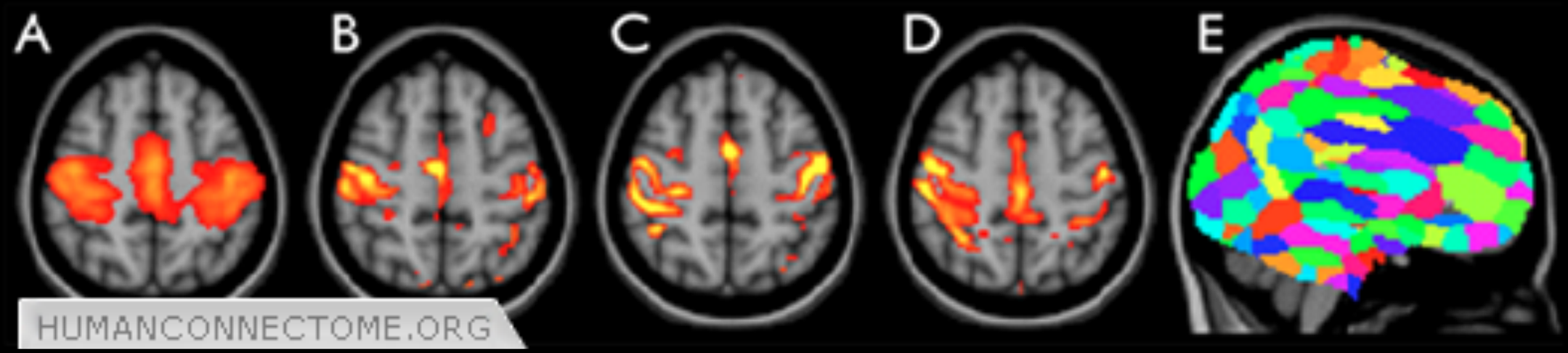

# Contrast

- BOLD == $T_2$*
- FLAIR (Fluid Attenuated Inversion recovery)
- Magnetization Transfer (MT) - MRM, 1989 Vol 10:135-144 - Wolff and Balaban
- Perfusion imaging - MRM, 1992 Vol 23:37-45 - Detre et.al.
- Diffusion imaging - Nature Reviews Neuroscience 4, 469-480 (June 2003) - DOI:10.1038/nrn1119 (review paper)
- Phase imaging - PNAS, 2007 Vol 104(28):11796-11801 - Duyn et.al.
- …

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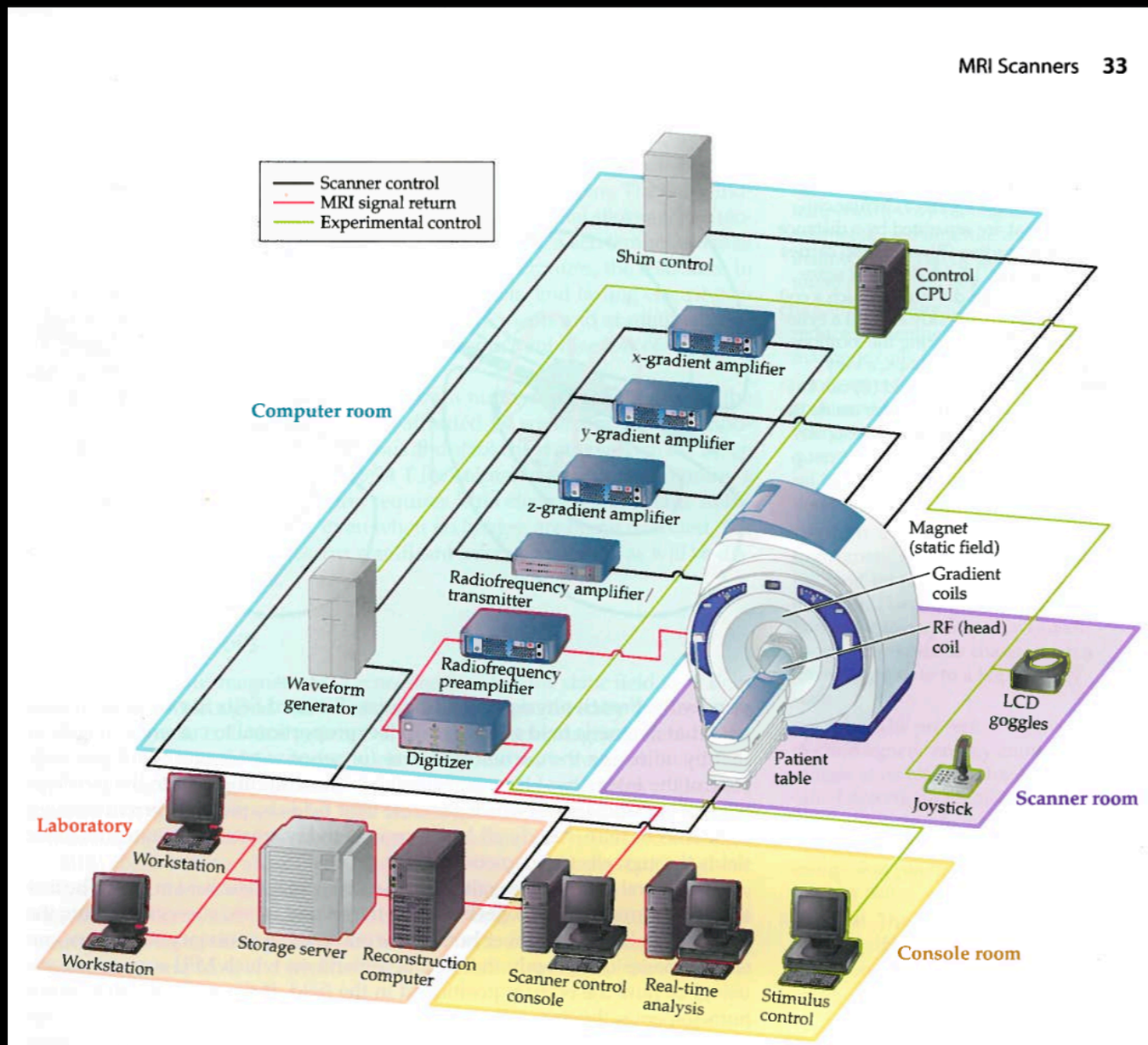


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