How not to explain MRI

and common mistakes in technical MR writing

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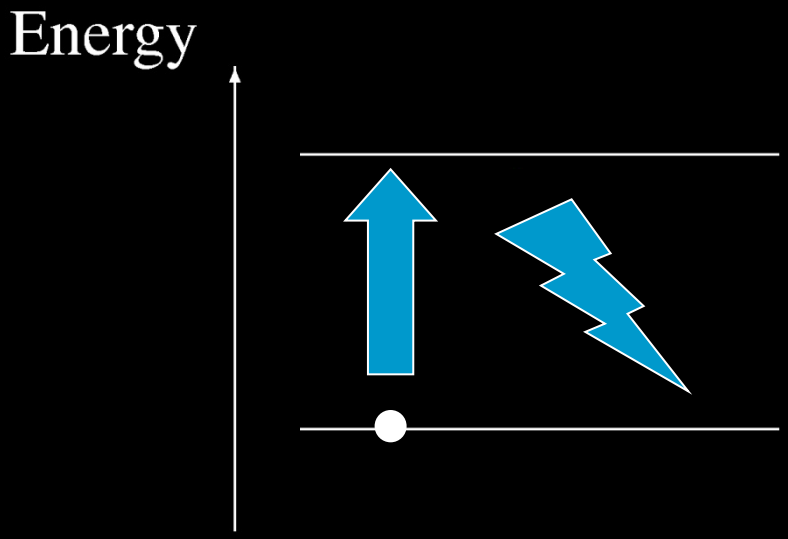
Highschool Quantum Mechanics

Well-known aspects of QM:

- Microscopic systems such as atoms can only exist in discrete states with specific energies.
- Transitions between these states happen in sudden "quantum jumps" and involve exchange of energy.
- The timings of the jumps are truly unpredictable.

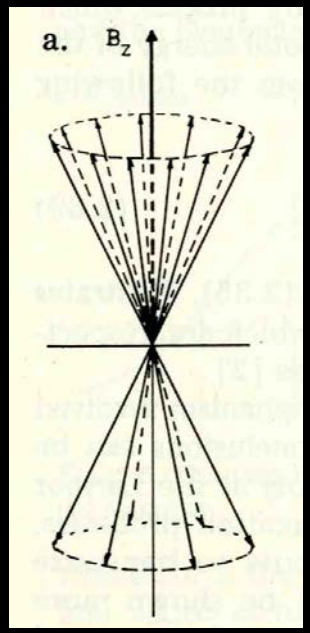


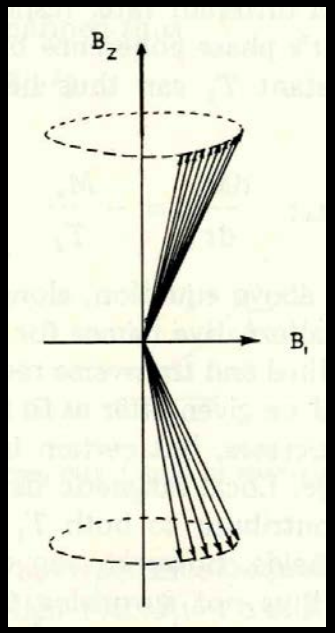
Ad hoc explanation of optical spectra…. So 1913.

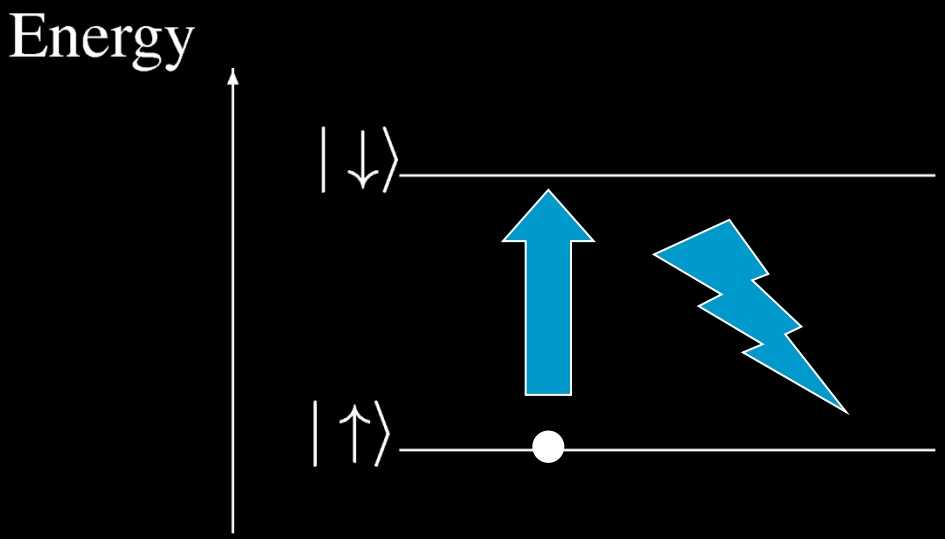
MR made wrong

Common explanation of MR inspired by QM:

- Nuclei can only point near parallel or anti-parallel to field:







- This explanation is utter nonsense (interpretation unsupported by QM). Opens more questions than it answers. Bad figures too.

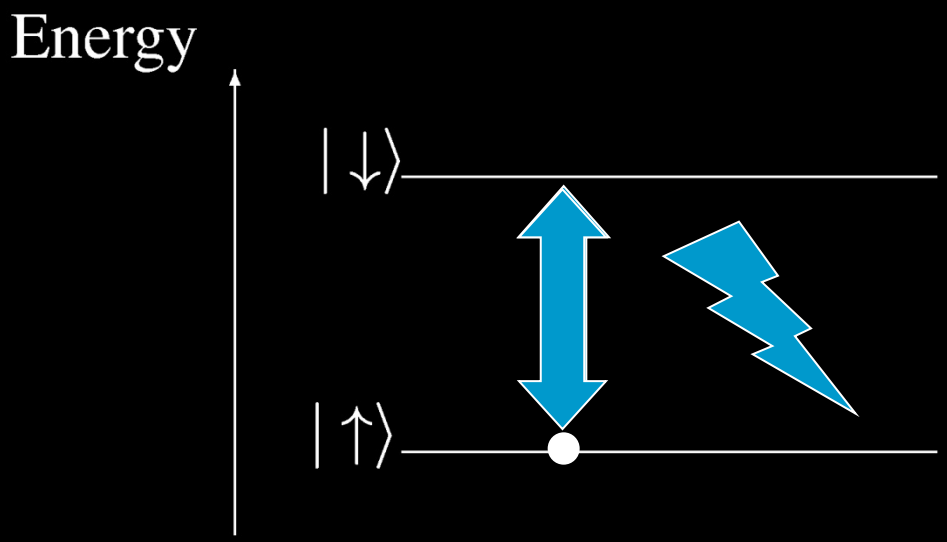
Why?

- Why would nuclei align anti-parallel to the field?
- Are nuclei forced into "cone states" instantly?
- How can radio waves limit the angular spread?
- Can radio waves change the magnetization size? It seems so.
- Why don't spin flips just equalize populations?

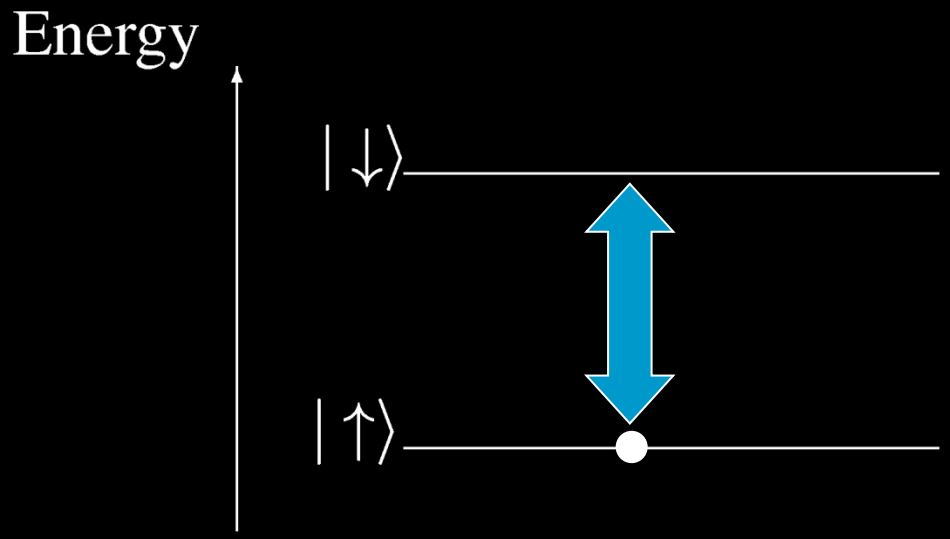
Good questions not well-answered by the model that does not qualify as a simplication (its useless). For most: Non-intuitive, no predictive power

A fix

- Can the picture below be improved?
  - Certainly – it does not show NMR.
    - Rather photoluminescence



Fixed version



This is meaningful, if you know QM well enough to realize that this picture describes vector dynamics.

Not great for providing the basic understanding. Little predictive power unless combined with the QM Schrödinger equation that proves the classical picture OK.

There is no benefit of invoking QM for MRI, so don't.

Summary of typical myths

- Nuclei can only be in the spin-up or the spin-down state (cone picture). The Bo field is somehow responsible.
- RF brings the precessing spins in phase, thus creating coherence.
- Quantum jumps play a significant role in MR.
- In particular, the spectra reflect sudden jumps between energy eigenstates.
- Magnetic Resonance is a quantum phenomenon, i.e. necessitates a QM explanation.

"Is QM necessary for understanding MR?", Concepts of MR, 2008

Typical other mistakes and advice of varying significance

Understanding

- Inaccurate:
  - The MR signal is emitted when nuclei relax back to equilibrium.
  - Variant: Nuclei absorb energy during excitation, and reemit it as MR signal.
    - Reality: It is precession, not relaxation, that gives signal.

- False:
  - Plexiglass/plastic is not seen on MRI since it does not contain protons.

- False:
  - T2 is short in solids and viscuous media because of short atomic distances or precession being slowed down.
    - Instead the random field fluctuations associated with free molecular motion and nuclear interaction are too fast to cause rapid dephasing. Fast field fluctuations average to smaller total effect than slow field fluctuations occuring for restricted motion.

- Inaccurate: Coils for MRI emit radiowaves.
  - Stricly speaking oscillating fields, not travelling waves like antennas.

Terminology

- True:
  - Precision of writing needs to be higher than for spoken language.

- True: Precession is not precision.

- Bad wording:
  - ”The lesion is bright on T2”
  - No, on T2-weighted images (T2w).

- True:
  - There are no such things as T1 signal or T2 signal.
    - The signal comes from the precessing transversal magnetization.
    - It may be influenced by T1 or T2,
      - i.e. weighted by these quantities (T1w signal, T2w signal).

- True: T1 and T2 cannot be fast/slow.
  - but T1 and T2 relaxation can be fast/slow.

Evaluation

- False:
  - Brightness on T1w reflects the T1 being long.
  - It is often opposite, but sequence dependent.

- Often true, but not in general:
  - CSF is white on T2w and black on T1w.
  - Normal T2-weighted FLAIR is a counter-example.

- Warning:
  - Images are typically not scaled similarly.
  - Grayscales intensities can typically not be compared between images.

- T1 and T2 do not only reflect nuclear mobility
  - Presence of magnetic molecules, e.g. deoxyhaemoglobin shortens them.
  - DeoxyHb is paramagnetic. Living and dead tissues differ.

- For T2w, fat often appears brighter than expected from TE/T2 ratio.
  - The reason is beyond this course (spin coupling is partly refocused)

Typography and similar

- Larmor is not pronounced L'amour.

- Typo: Units are not capitalized, when spelled out.
  - Wrong: The Larmor frequency at 3 Tesla is 127 mega Hertz.
  - Correct: 3 T, 3 tesla, 127 MHz, 127 megahertz

- Typo: Don't use notation specific to programming.
  - f(x)=a*x+b, sqrt(9)=3

- Complex number error and notation: *i=sqrt(-1)*
  - Corrected: $i^2 = -1$

- LaTeX typo (avoid typesetting word letters and units as multiplication):
  - $f_{Larmor} = 127 MHz$
    - should be $f_{\mathrm{Larmor}} = 127~\mathrm{MHz}$

- Advice: Use different notation for scalars and vectors/matrices, e.g. bold for the latter. Use roman non-italic for units.

Advice:

Reduce oversimplified lingo in daily life (makes it difficult for MRI newbies, especially)

Don’t trust every source: The net is overflowing with crappy descriptions.
Also many books on MRI are (slightly) flawed.

Be pedantic.

Make some other pedantic person read your texts.
You will be surprised what you have written.