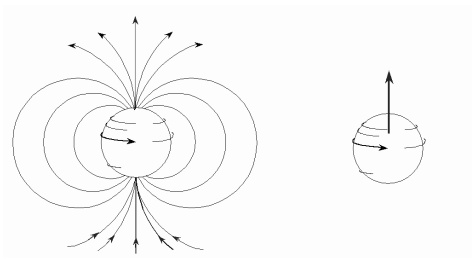
Bioengineering 278
Magnetic Resonance Imaging

Winter 2011
Lecture 1

Topics:

- Nuclear magnetization
- Spin excitation
- The NMR signal

Spins

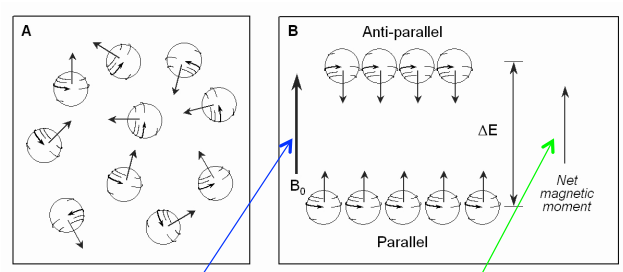


Hydrogen Nucleus = Proton

- Mass
- Spin
- Charge

} Angular Momentum

} Magnetic Moment



$E = \mu_z B_0$

$\Delta E = \gamma h B_0$

$E = -\mu_z B_0$

Boltzmann Distribution

$$\frac{down\_spins}{up\_spins} = e^{-\Delta E/kT}$$

Ratio = 0.99998 at 3T !

Corresponds to an excess of about 20 up spins per million

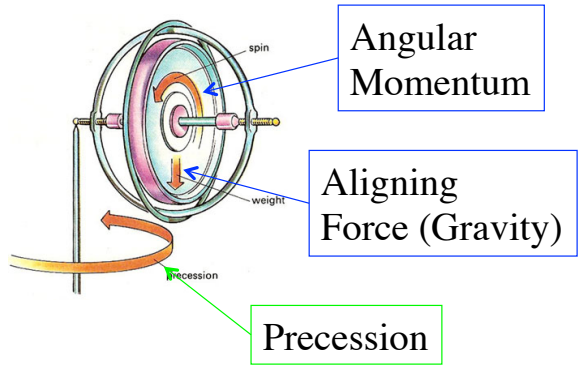
Magnetic Field

Net Magnetic Moment

Equation of Motion for Magnetization Vector **M**

Bloch Equation:

$$\frac{d\mathbf{M}}{dt} = \underbrace{\mathbf{M} \times \gamma\mathbf{B}}_{\text{Precession}} - \underbrace{\frac{M_x\hat{\mathbf{i}} + M_y\hat{\mathbf{j}}}{T_2}}_{\text{Transverse Relaxation}} - \underbrace{\frac{(M_z - M_0)\hat{\mathbf{k}}}{T_1}}_{\text{Longitudinal Relaxation}}$$



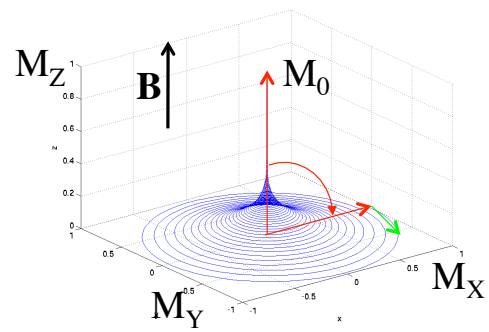
Solution:

$$M_z(t) = M_0 + (M_z(0) - M_0)e^{-t/T_1}$$

$$M_{XY}(t) = M(0)e^{-j\omega_0 t}e^{-t/T_2}$$

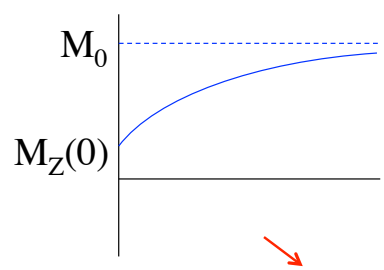
$$\omega_0 = \gamma\mathbf{B}$$

Precession Frequency | Gyromagnetic Ratio (4257Mhz/T) | Magnetic Field

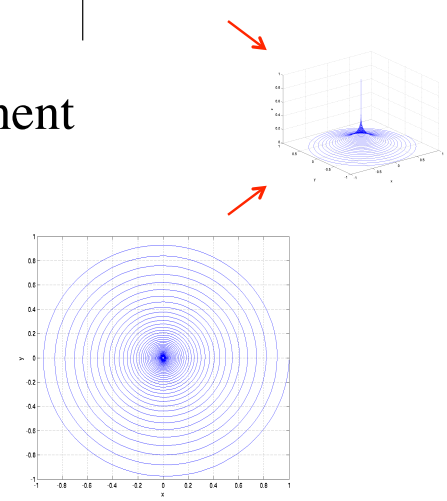


Relaxation: Z-component

$$M_z(t) = M_0 + (M_z(0) - M_0)e^{-t/T_1}$$



Relaxation: Transverse Component



$$M \equiv M_x + jM_y$$

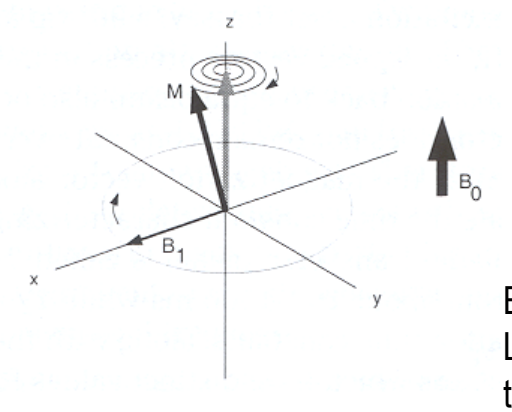
$$dM/dt = d/dt\left(M_x + jM_y\right)$$

$$= -\left(j\omega_0 + 1/T_2\right)M$$

$$M(t) = M(0)e^{-j\omega_0 t}e^{-t/T_2}$$

$$\omega_0 = \gamma\mathbf{B}$$

RF Excitation



Laboratory Frame
Nishimura, Fig. 3.2

Bloch equation says that magnetization will precess around the applied field.

B_1 radiofrequency field tuned to Larmor frequency and applied in transverse (*xy*) plane induces nutation (at Larmor frequency) of magnetization vector as it tips away from the *z*-axis.
- lab frame of reference

http://www-mrsrl.stanford.edu/~wro/defense/animations/

An NMR Experiment