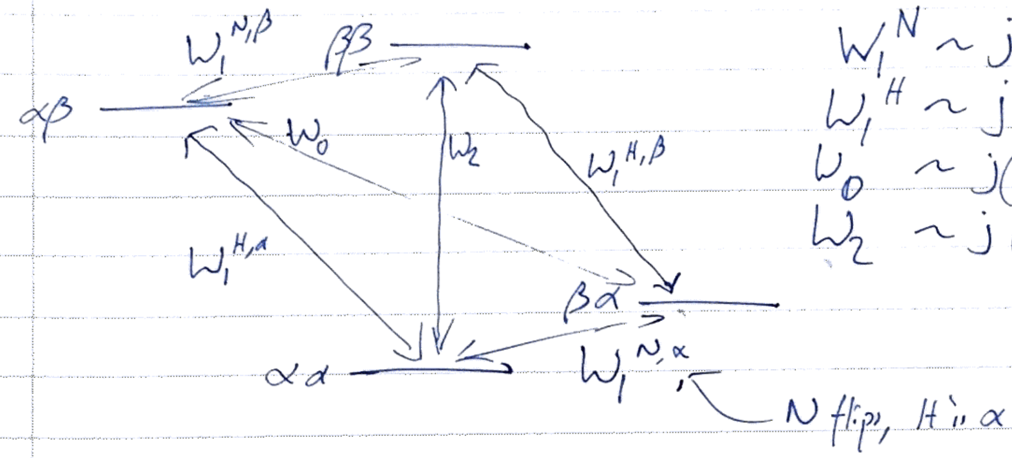
TROSY

Relaxation recap: Solomon equations for longitudinal relaxation



$$W_1^N \sim j(\omega_N)$$
$$W_1^H \sim j(\omega_H)$$
$$W_0 \sim j(\omega_H - \omega_N)$$
$$W_2 \sim j(\omega_H + \omega_N)$$

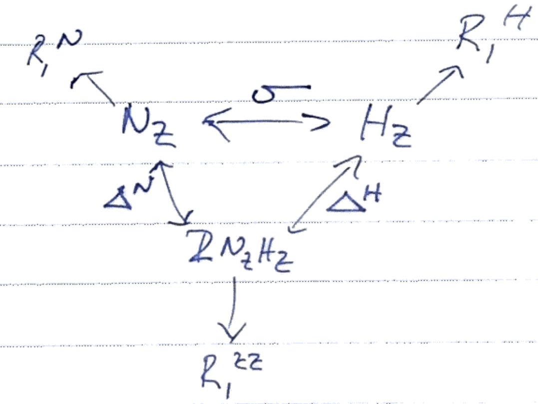
Soloman equations:

$$\frac{dN_z}{dt} = -R_1^N \Delta N_z - \sigma \Delta H_z - \Delta^N \cdot 2N_zH_z$$

self relaxation

cross relaxation (NOE)

interconversion with zz



$$R_1^N = W_1^{N,\alpha} + W_1^{N,\beta} + W_2 + W_0$$

$$\sigma = W_2 - W_0$$

$$\Delta^N = W_1^{N,\alpha} - W_1^{N,\beta}$$

Sources of relaxation:

fluctuations in both arise from tumbling

- dipole-dipole – fluctuations $b \sim \frac{\gamma_H \gamma_N}{r^3} \cdot \frac{\mu_0 \hbar}{4\pi}$
- CSA – fluctuations $c_N \sim \gamma_N B_0 (\sigma_{\parallel} - \sigma_{\perp})$ ~170ppm

CROSS CORRELATION

- chemical exchange, paramagnetism, scalar couplings ...
- more distant dipolar interactions

N.B.!

D-D relaxation – strength of fluctuations don't depend on spin state

$$\Rightarrow W_1^{N\alpha} = W_1^{N\beta} \quad \Longrightarrow \quad \Delta^N = W_1^{N\alpha} - W_1^{N\beta} = 0$$

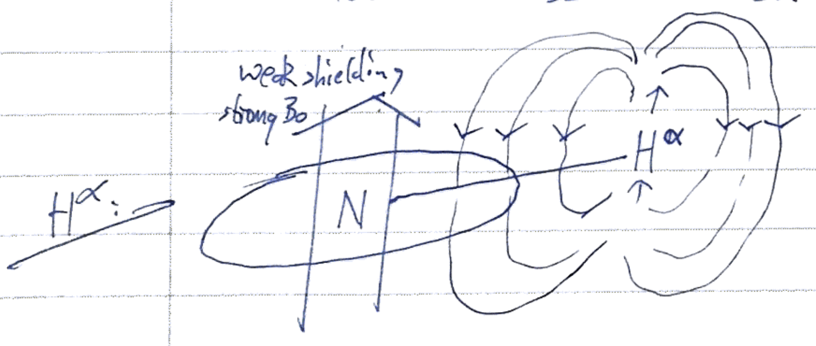
$\therefore$ N_z and H_z cannot cross-relax with $2N_zH_z$.

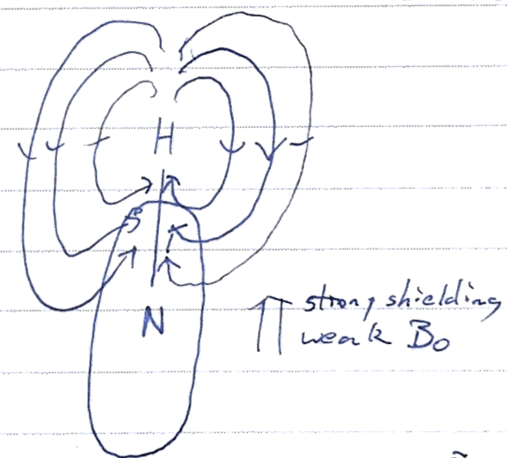
CSA relaxation – also independant of spin states

$$\Rightarrow \Delta^N = 0.$$

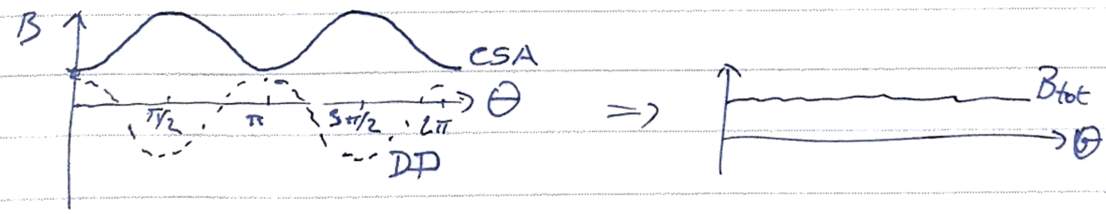
What about combination of DD and CSA? CROSS CORRELATION EFFECTS.

$$\vec{B}_{loc} = \vec{B}_{DD} + \vec{B}_{CSA}$$





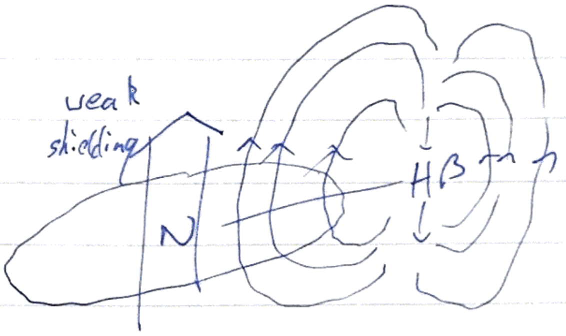
$B_{loc} = \uparrow B_{CSA} + \downarrow B_{DD} = \uparrow$ $\qquad$ $B_{loc} = \uparrow B_{CSA} + \uparrow B_{DD} = \uparrow$

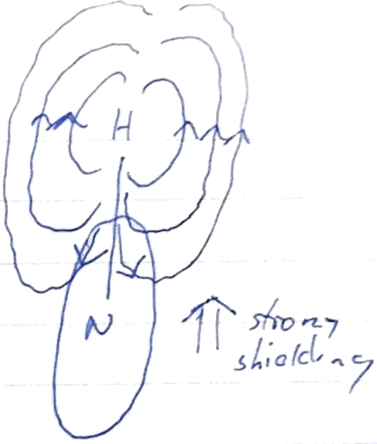


CSA and DD fields cancel! destructive interference

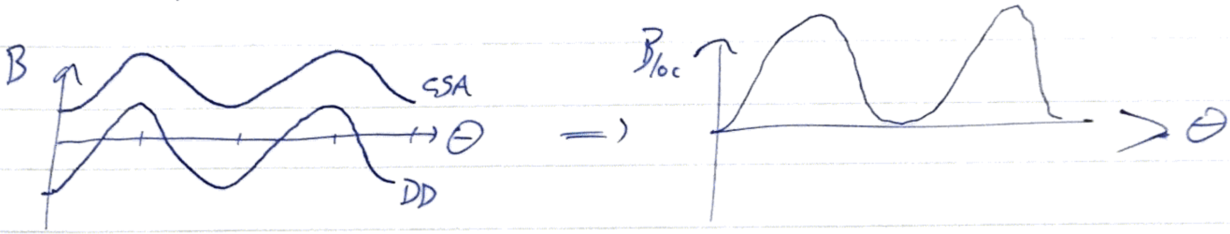
(but not necessarily equal in magnitude)
ie. not perfect cancellation

H^{β}:



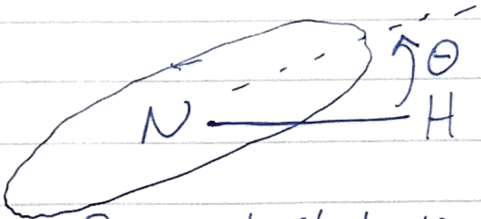


$B_{loc} = \uparrow B_{CSA} + \uparrow B_{DD}$ $\qquad$ $B_{loc} = \uparrow B_{CSA} + \downarrow B_{DD}$



CSA and DD fields interfere constructively.

N.B. interference depends on alignment of CSA tensor with N–H bond vector



In practise, this alignment is quite strong, $\sim 21°$

Power of fluctuations $\sim b^2 + c^2 \pm \underbrace{bc\, P_2(\cos\Theta)}_{\text{cross-correlation term}}$

Returning to Soloman equations:

$$W_1^{N\alpha} = \left[W_{DD} + W_{CSA} - \frac{1}{10} bc\, P_2(\cos\Theta)\right] j(\omega_N)$$
$$= \left[\frac{3}{40} b^2 + \frac{1}{15} c^2 - \frac{1}{10} bc\, P_2(\cos\Theta)\right] j(\omega_N)$$

$$W_1^{N\beta} = \left[\frac{3}{40} b^2 + \frac{1}{15} c^2 + \frac{1}{10} bc\, P_2(\cos\Theta)\right] j(\omega_N)$$

Now $\Delta^N = W_1^{N\alpha} - W_1^{N\beta} = -\frac{1}{5} bc\, P_2(\cos\Theta)\, j(\omega_N) \neq 0$!

In other words, there is a cross-relaxation induced transfer between N_z and $2H_zN_z$.

- this can be used to measure the CSA orientation, $\cos\theta$

- must be suppressed for measurement of ^{15}N R_1 relaxation rates, using a train of ^1H π pulses during relaxation period to interchange H^α and H^β spin states.

- watch out for 'hidden' signs arising from γ's in b and c terms!

- field strength dependence: $\frac{3}{40}b^2 + \frac{1}{15}c^2$ vs $\frac{1}{10}bc\,P_2(\cos\theta)$
  - show plot
  - minimum around 500 MHz, cancellation not great.

Transverse relaxation

Theory is essentially identical, just get different numbers:

$$R_2^N = \left[\frac{1}{10}b^2 + \frac{2}{45}c^2 \pm \frac{2}{15}bc\,P_2(\cos\theta)\right] j(0) \; (+\,j(\omega_N)\,\text{etc})$$

- excellent cancellation, around 900 MHz.

What about ^1H relaxation? $c_N = \gamma_N B_0 \Delta\sigma_N$
$c_H = \gamma_H B_0 \Delta\sigma_H$

Proton CSA much smaller (~10 ppm), but luckily/happily this is offset by the increased γ_H.

Question - if cancellation is this good, why is there a size limit at all?