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Spin-layers and packing of large spin-networks

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Eight spins, Yess!

LAOCOON group, which gave the name for the early QMSA program

3 Layers, yeah!

From LAOCOON to ChemAdder

Spin-layers

How to simulate the pentyl CH_3 signal

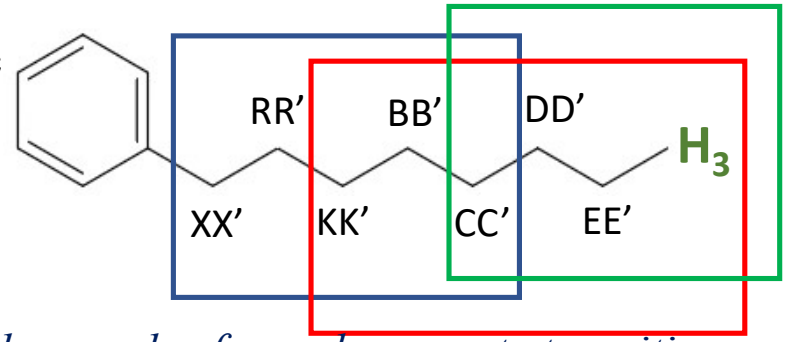
- The A3-particle is strongly coupled to BB' particle, which leads to the characteristic triplet. - The BB' particle forms here the 1st Spin-Layer.
- The A3-particle couples to CC' particle with ^4J couplings which are not usually resolved with normal line-width: - The CC' particle forms here the 2nd Spin-Layer.
- The A3-particle couplings to DD' particle are very small and may lead at most to small broadening of triplet lines, DD' forms the 3rd Spin-Layer… However, DD' is coupled strongly to CC' which is coupled to BB', and if the chemical shift differences are small (as they typically are for $(CH_2)_n$-systems), also the 2nd and 3rd layer particles affect the outlook of the A_3-triplet, through *the second-order effects*.

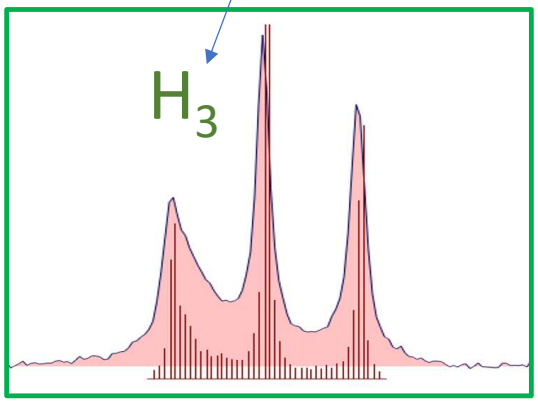
Structure:	H_3C_A-	C_BH_2-	C_CH_2-	C_DH_2-	C_EH_2-	X
System:	A3	BB'	CC'	DD'	EE'	
Layer:	0	1	2	3	4	

To get nearly complete description for the CH_3 signal, one needs the 3 layers, and to optimize the BCD chemical shifts! ChemAdder builds up automatically the sub-systems when the number of layers is given. The sub-systems giving the BB', CC', DD' and EE' transitions are built up in the same way .. See the octyl simulation on next page.

Spin-system packing

- Compression of spin-networks
  - XX'RR'KK'BB'CC'DD'EE'H_3 → **XX'RR'KK'**BB'CC' + KK'**BB'CC'DD'EE** H_3 + DD'EE'**H_3**. The **underlined** species are got from the system**.**
  - Transitions separated by < 0.01 Hz and belonging to the same species are combined, if also their derivatives are similar.
  - 58 000 000 → 24 000 Transition, from 64 to **4** sec
- Multithreading
  - Analysis of 16 serum samples: 16 min → 4 min.





"Spin dust"

The H_3-signal is composed of thousands of non-degenerate transitions – which yield its diagnostic outlook.

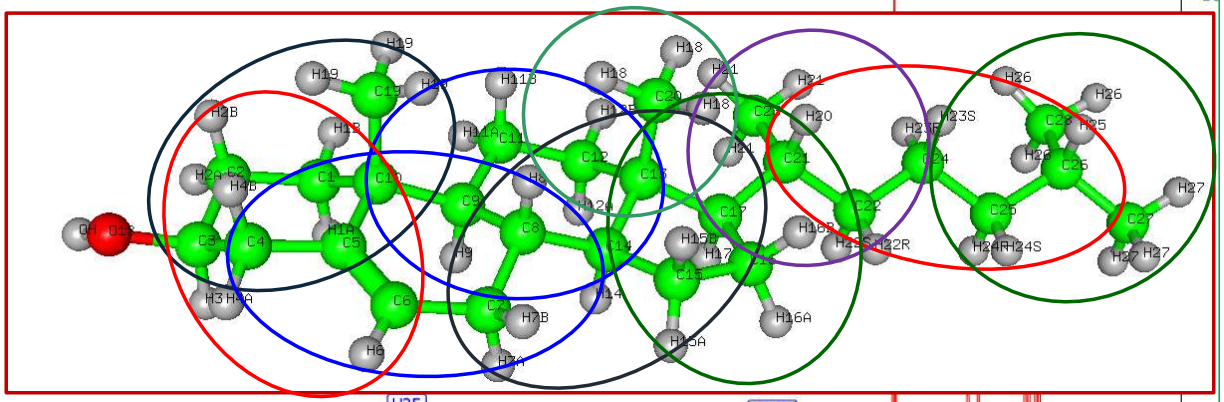
The effect is not rare, for example leucine methyl signal has a similar shape. See more at page 10.

How to describe the shape in another way than QMSA, we ask?!

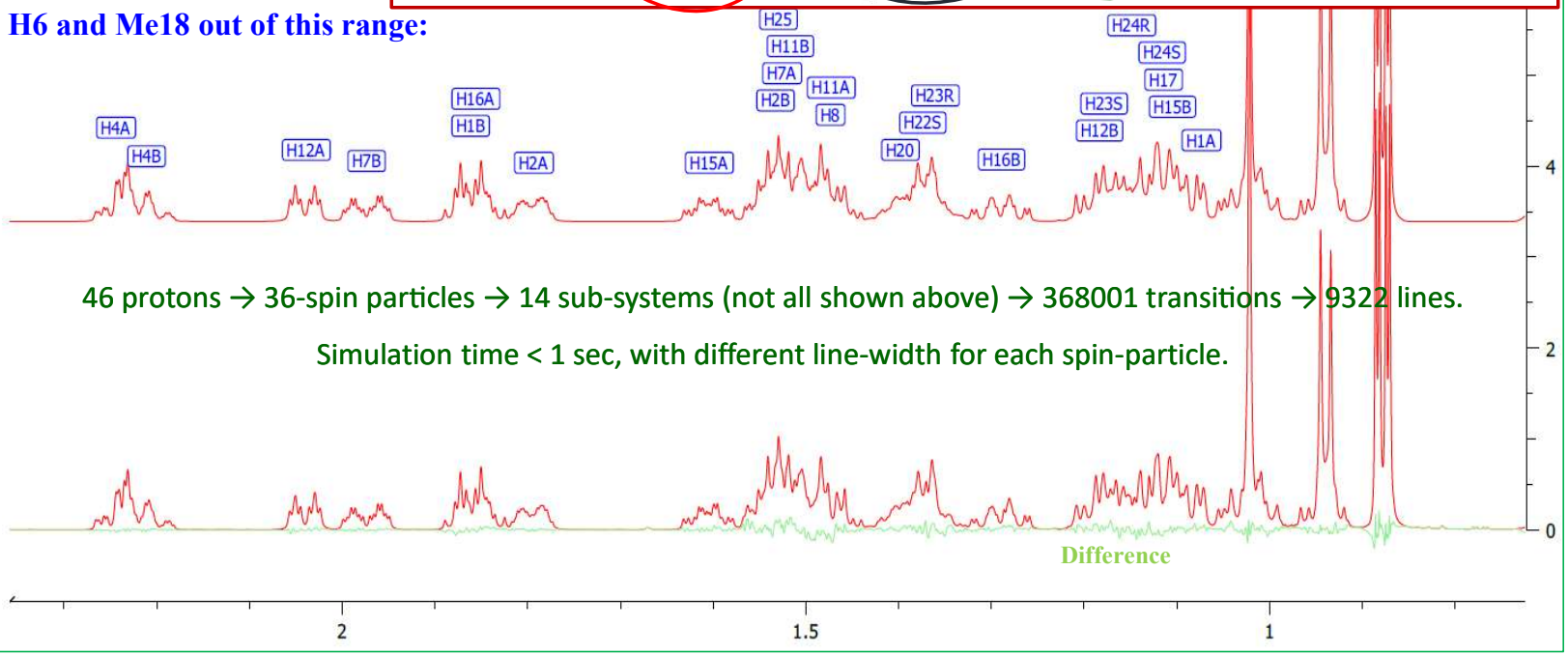
CHOLESTEROL_MIX.QMT

Large spin-networks: Cholesterol

All the protons coupled with each other through the ***spin-network***



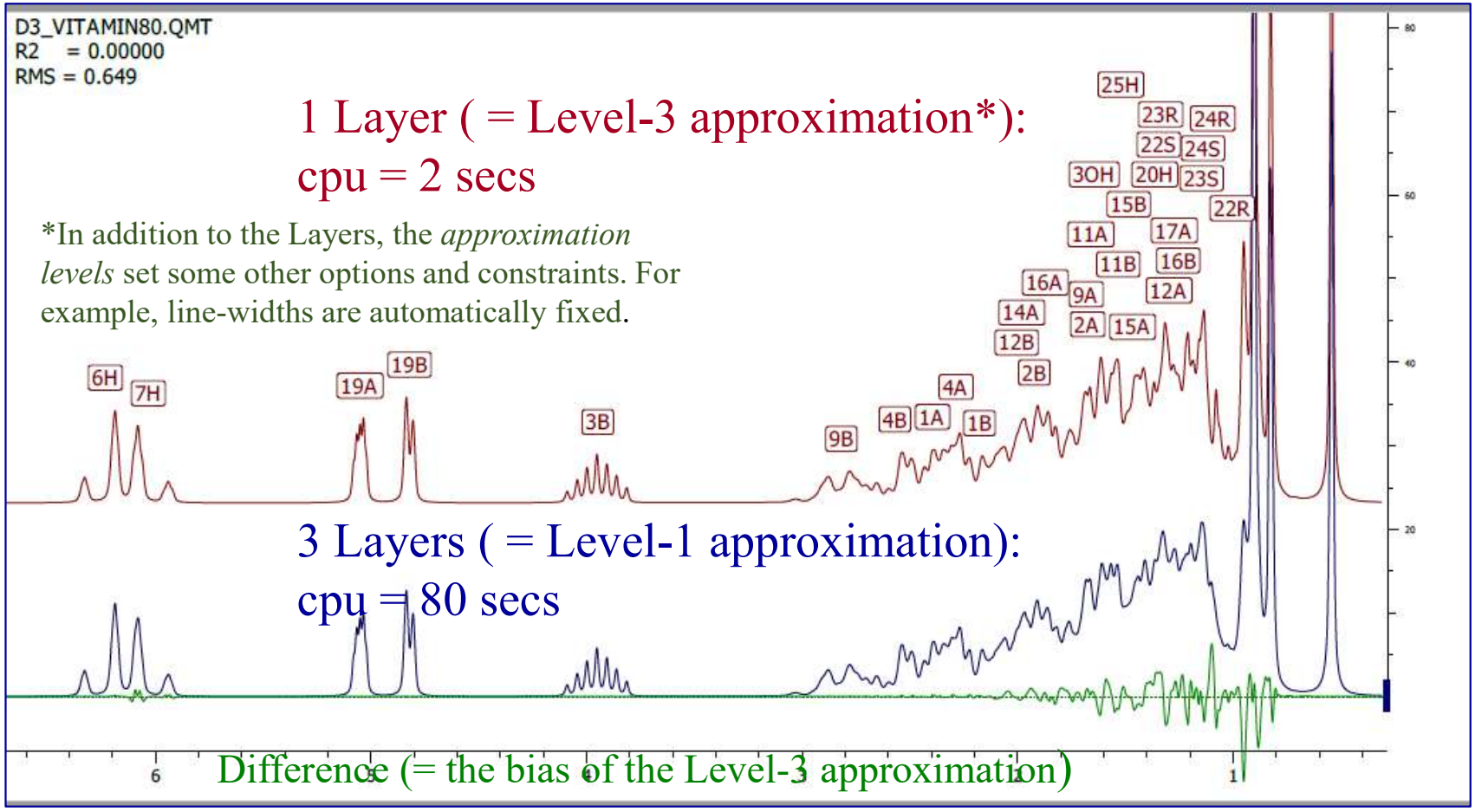
H3, H6 and Me18 out of this range:



46 protons → 36-spin particles → 14 sub-systems (not all shown above) → 368001 transitions → 9322 lines.

Simulation time < 1 sec, with different line-width for each spin-particle.

D_3-vitamin 80 MHz simulation quality and time depend on the *number of layers* (1-3)

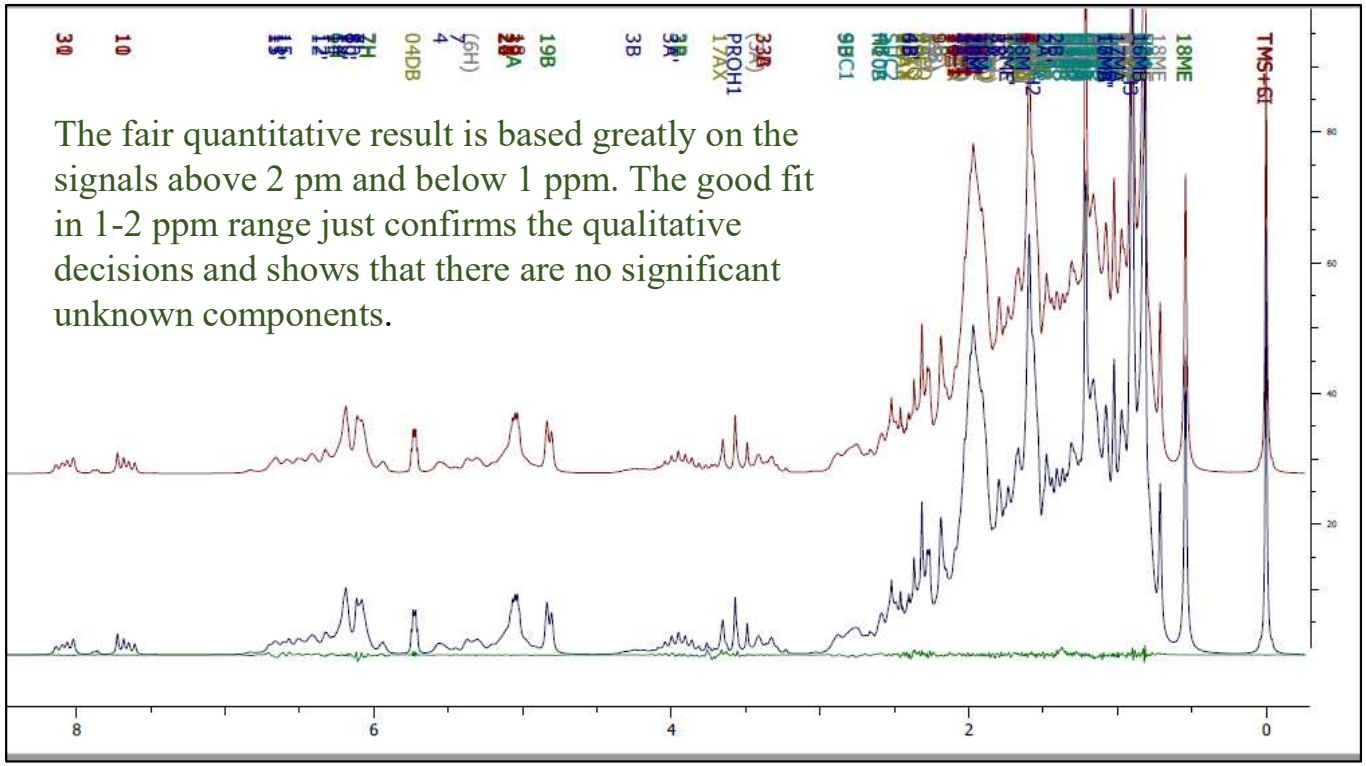


ANALYSIS of MIXTURE of D3-VITAMIN, CALCIFEROL, TESTOSTERONE, CHOLESTEROL, A-TOCOPHEROL, MENAQUINONE-7, LUTEIN, DOCOSAHEXAENOICACIDETHYL ESTER (10 mg each) + 1 mg of PROPANOL, SYNTHETIC SPECTRUM at 80 MHZ

The spectrum was simulated at approximation level 2 (5 min), then analyzed with highest approximation level 3 (< 5 sec/cycle).

When the 250 chemical shifts & line-widths were optimized (to compensate the approximation bias), RMSE dropped from 0.42 to 0.14% and gave concentrations within bias < 3%.

Conclusion: benchtop analyses of large molecule systems can be done in acceptable time.



FELIX* of MILLIONS TRANSITIONS

Experimental: normal ^{1}H spectrum,

*Spin-system of **74** protons :*

XX'RR'AA'BB'CC'DD'EE' H_3(Ar-octyl) +

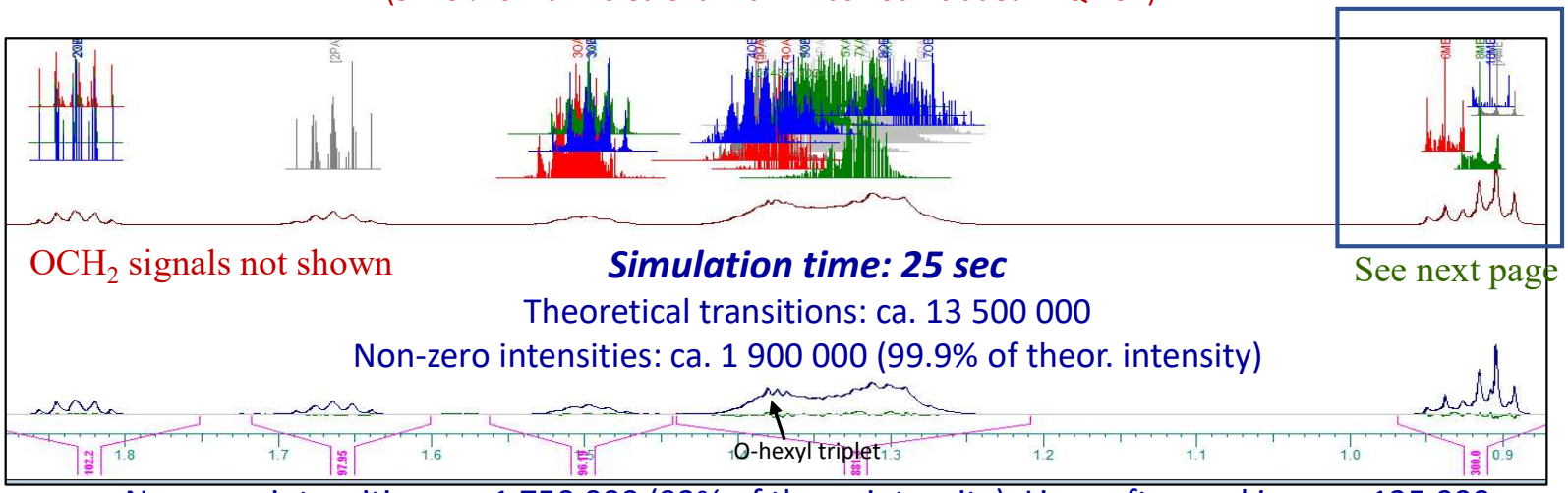
XX'RR'ZZ' BB'CC'H_3 (O-hexyl) +

XX'RR'ZZ' BB'CC'DD'EE'H_3 (O-octyl) +

XX'RR'ZZ'BB'$(CC')_3$DD'EE'H_3 (O-decyl) +

XX'YY'ZZ'

(5 mol% *chiral incredient* with F was not included in QMSA)



OCH_2 signals not shown

Simulation time: 25 sec

See next page

Theoretical transitions: ca. 13 500 000

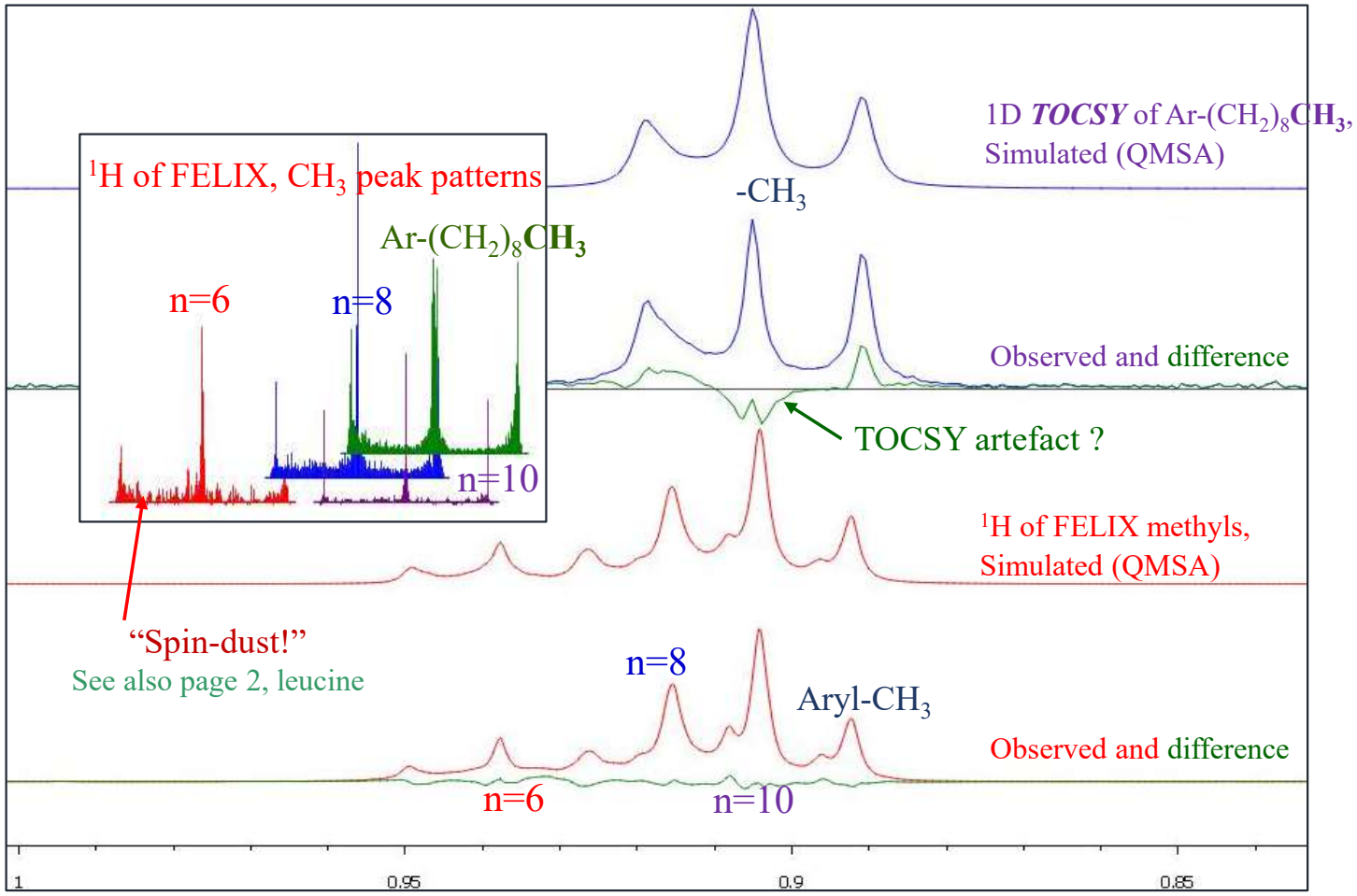
Non-zero intensities: ca. 1 900 000 (99.9% of theor. intensity)

Non-zero intensities: ca. 1 750 000 (93% of theor. intensity), Lines after packing: ca. 135 000

Although the CH_2-shift order is somewhat unclear, the analysis gives the alkyl lengths with a fair confidence

* S.K.Ahola, L.P.Ingman, R.Laatikainen, J.Sinkkonen & J.P.Jokisaari, ^{21}Ne and ^{131}Xe NMR study of electric field gradients and multinuclear NMR study of the composition of a ferroelectric liquid crystal. *J.Chem.Phys*. **149**, 234901 (2018); https://doi.org/10.1063/1.5052499

The FELIX methyl signal carries the information from the alkyl populations



The Layers is an easy way to define the level of approximation and optimize the calculation time

Full MENU

1. Analyse the system at highest approximation level: 1 layer and broadening.
2. Remove the broadening and optimize system with 1-2 layers.
3. Finalize with 3 layers.