# Other techniques

## A comparison with neutron scattering

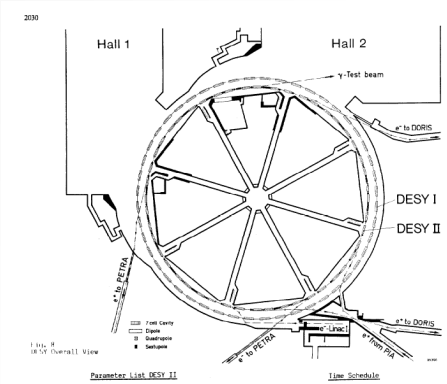
*Robert McGreevy*

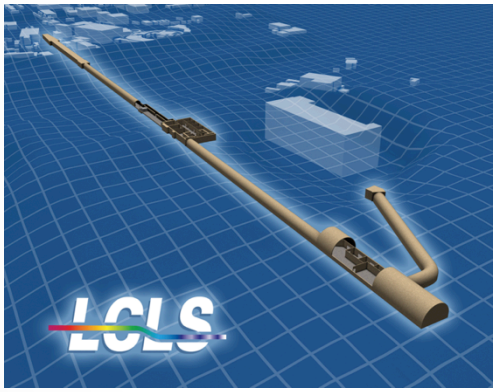
# Why are we learning about other techniques?

## Eddie the Eagle

Because being a heroic failure is not a business strategy!
(at least in science)

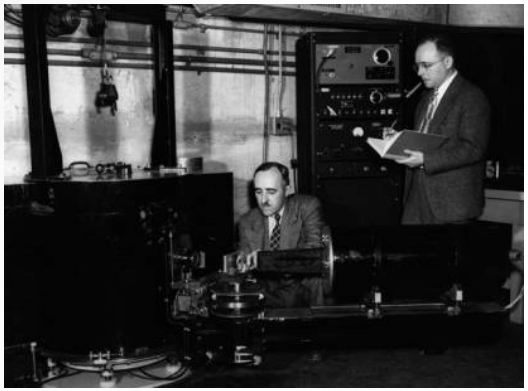
# Why are we learning about other techniques?





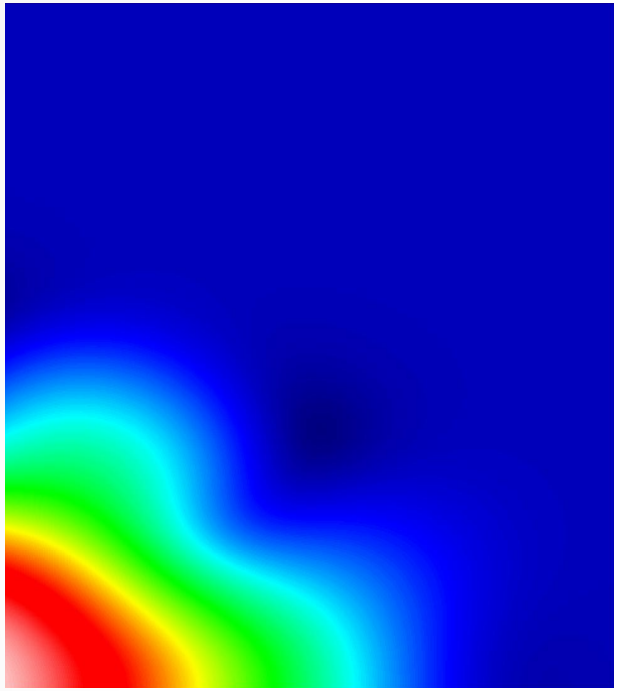
Synchrotron x-rays have evolved from parasitic to custom built
Brightness increase is orders of magnitude more than cost increase

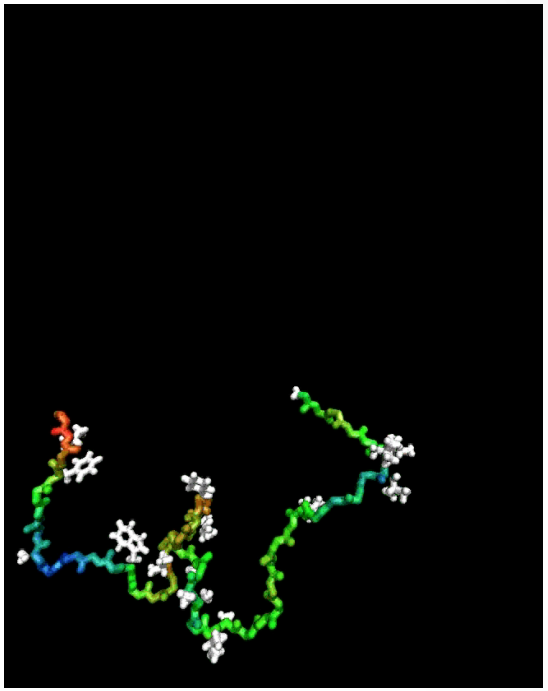
# Why are we learning about other techniques?



Neutron scattering sources have also evolved from parasitic to custom built
Brightness increase matches cost increase

# Why neutrons? – five good reasons

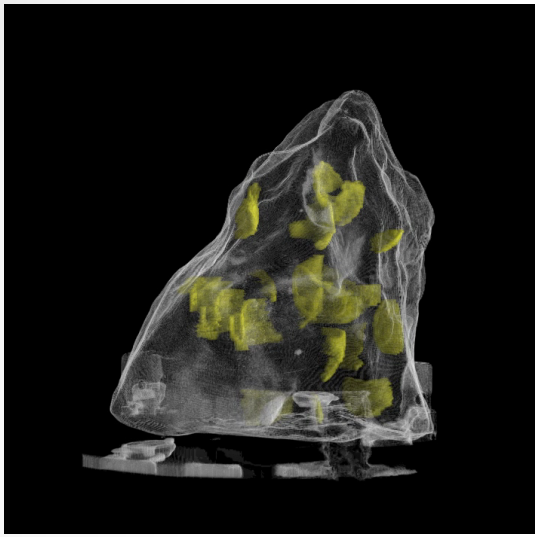


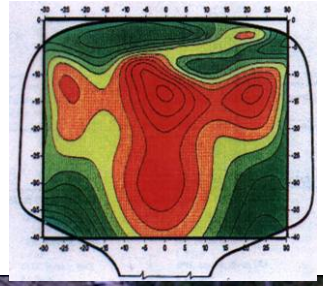


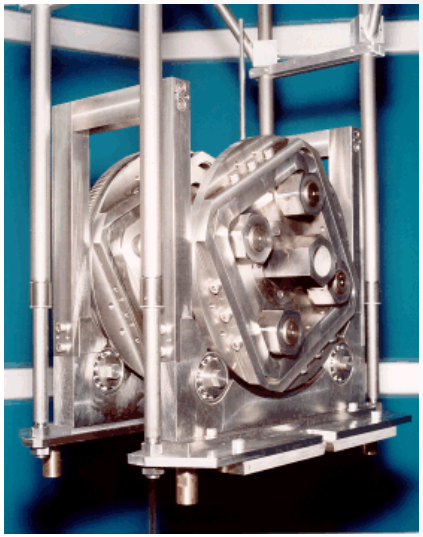
Length and time scales

$10^{-11}$ – $10^{-6}$ m $10^{-14}$ – $10^{-6}$ s

# Why neutrons? – five good reasons



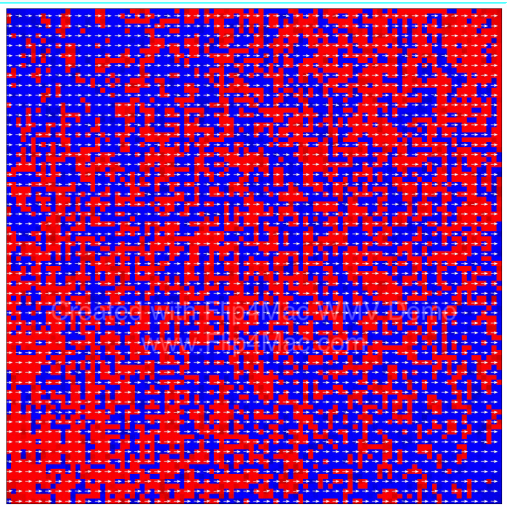


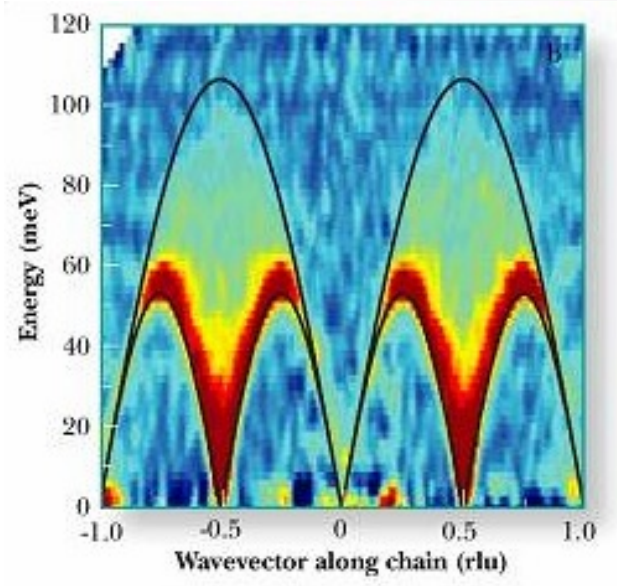


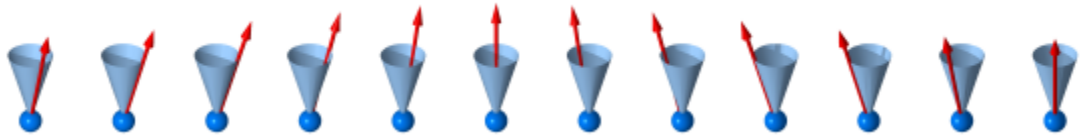
Penetration

Large samples, buried interfaces, extreme conditions, non-destructive

# Why neutrons? – five good reasons



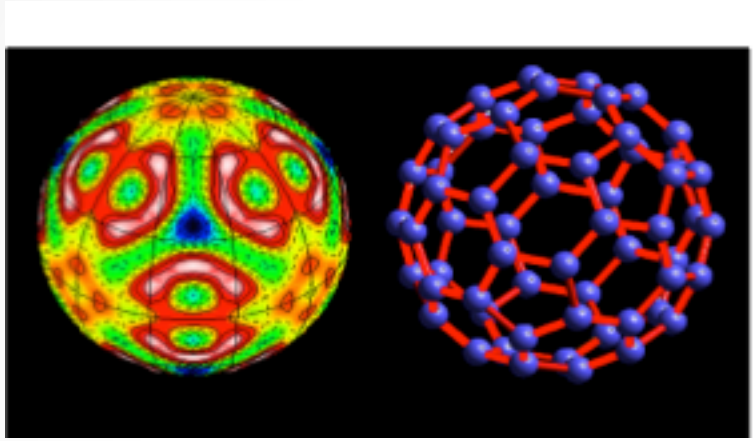


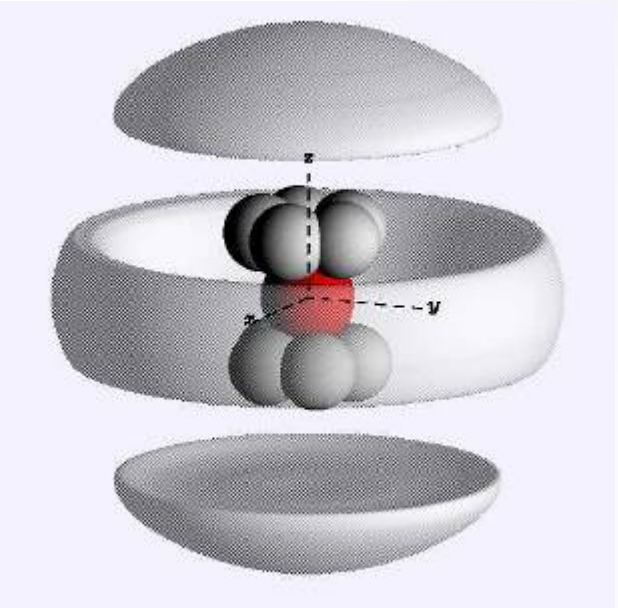



Magnetism

The neutron has a magnetic moment but no charge

# Why neutrons? – five good reasons

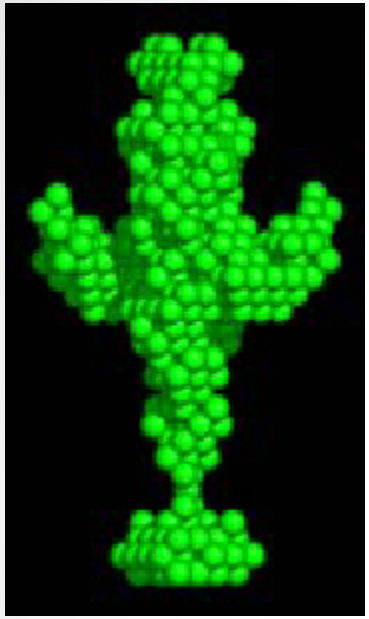




Precision

Weak interaction, simple interaction

# Why neutrons? – five good reasons



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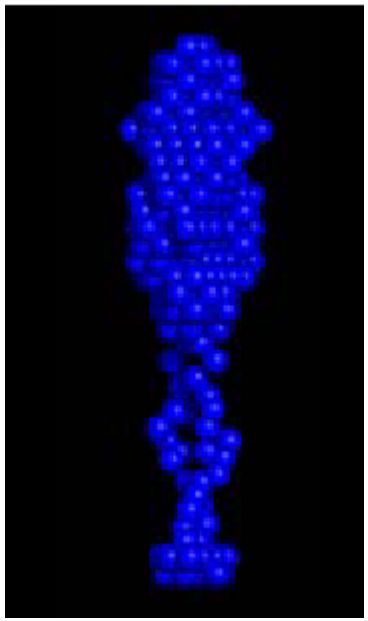

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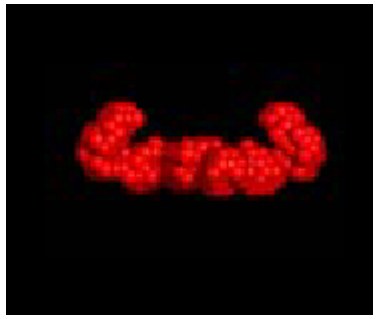

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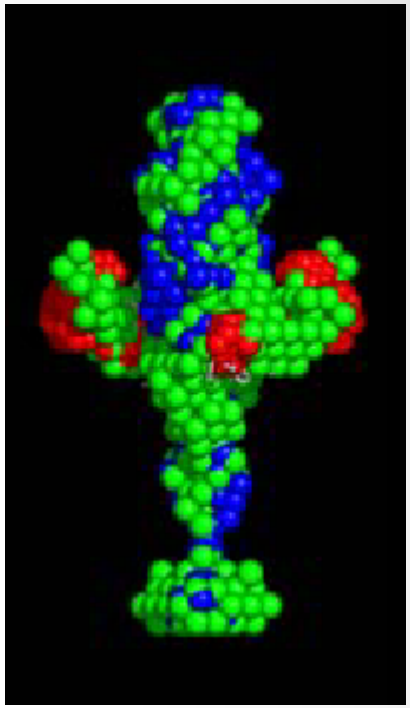
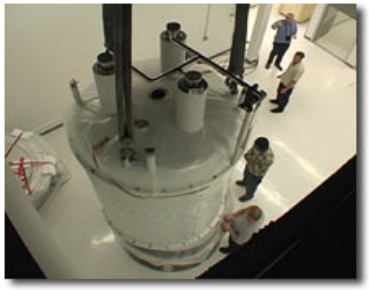
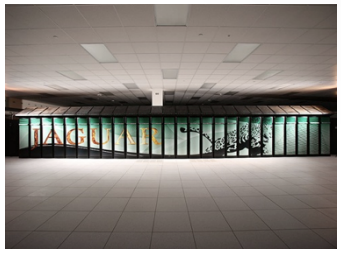


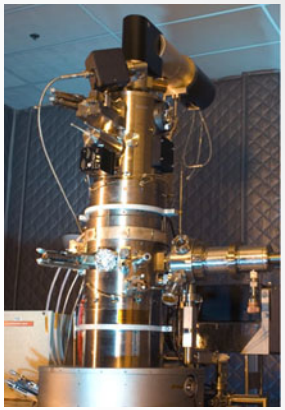
Sensitivity and selectivity

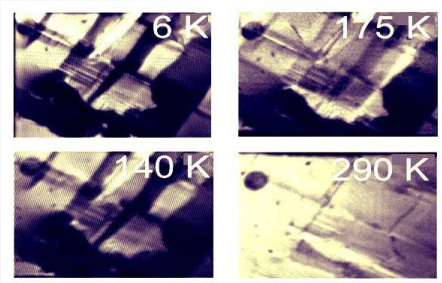
Isotopic substitution/contrast variation

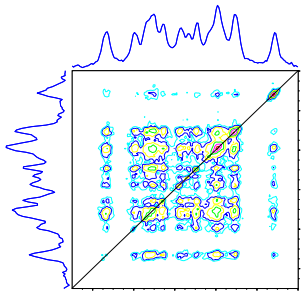
# But …

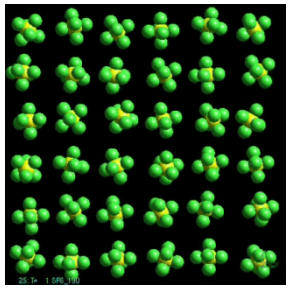


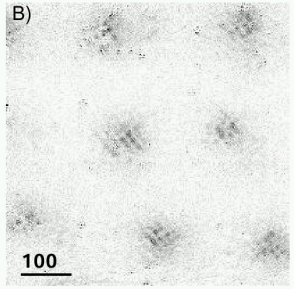






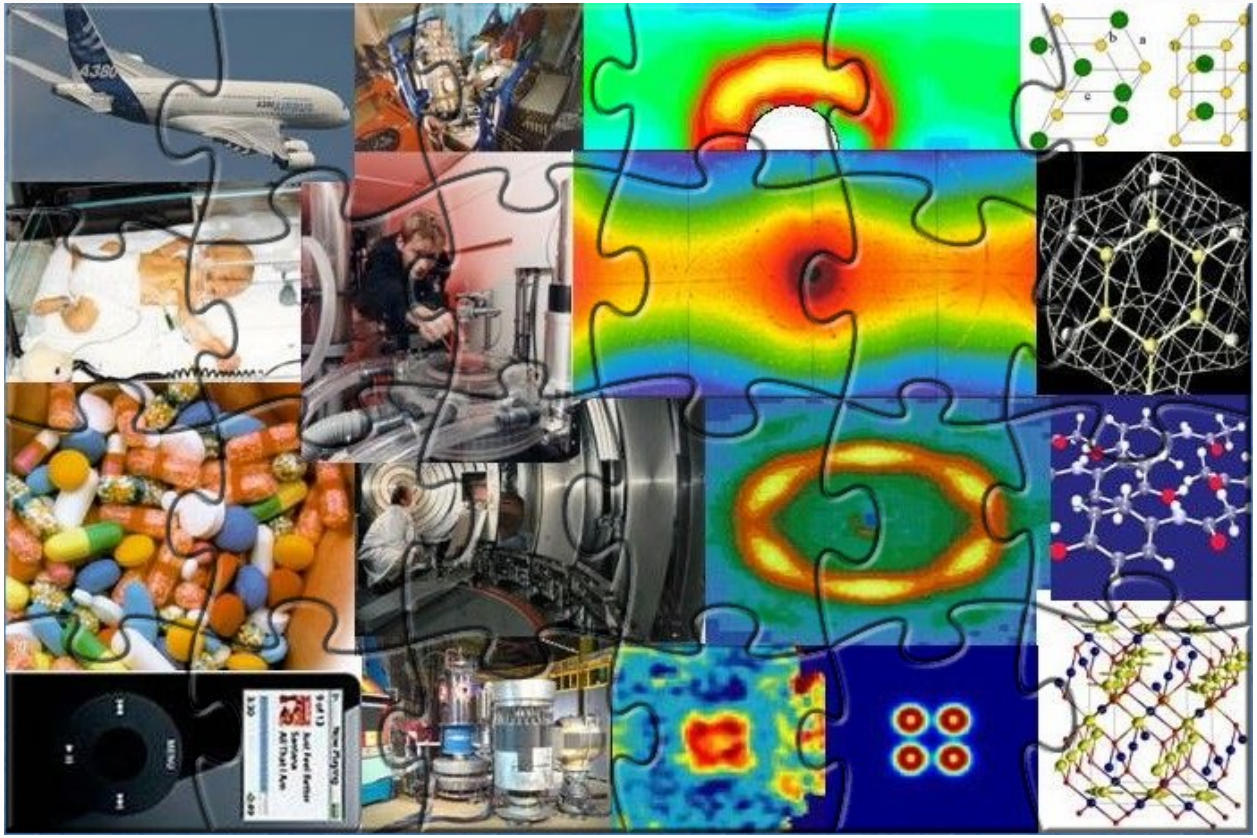





Synchrotrons NMR Computing Microscopy

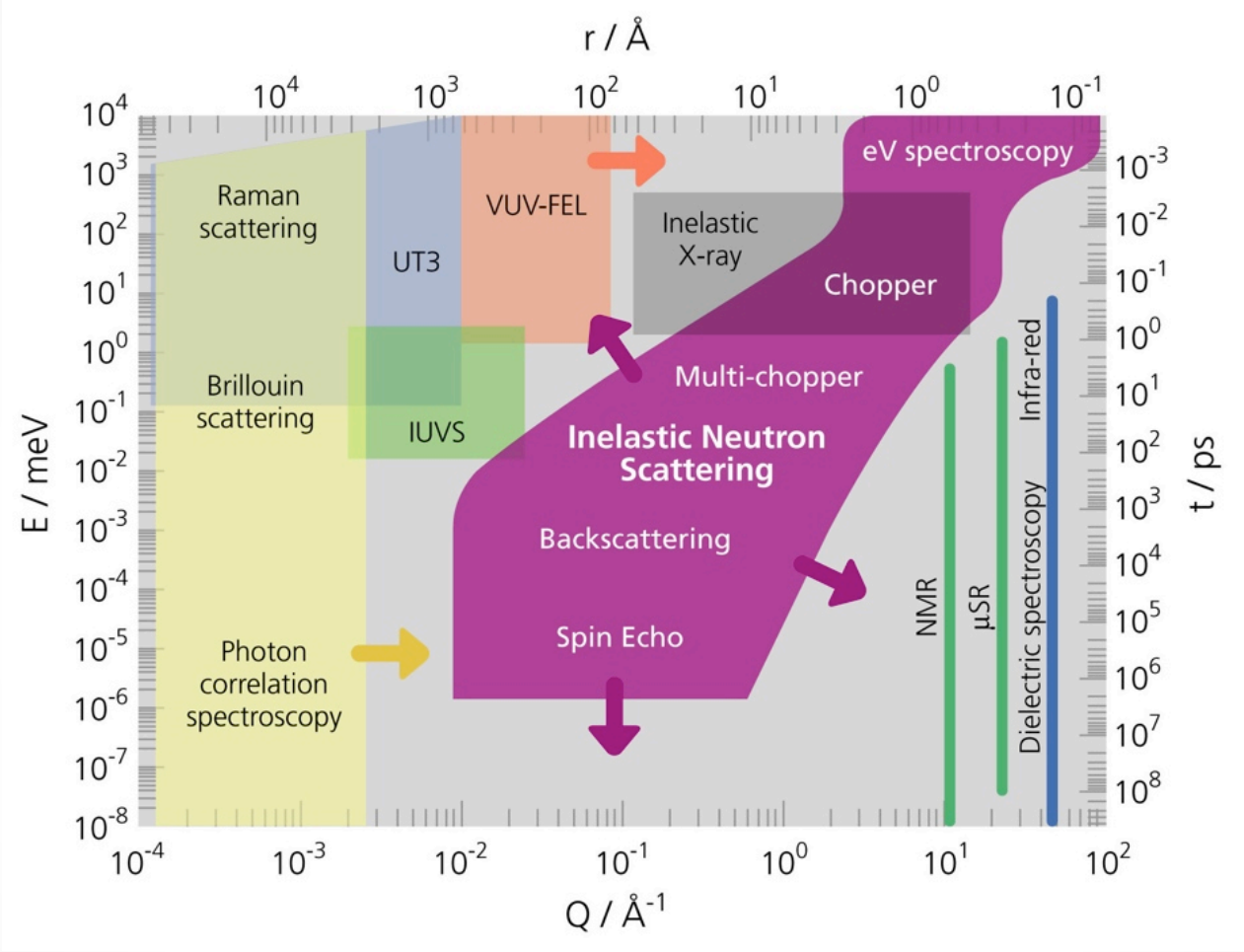
Most research that use neutron scattering also uses several complementary techniques

# Why neutrons?



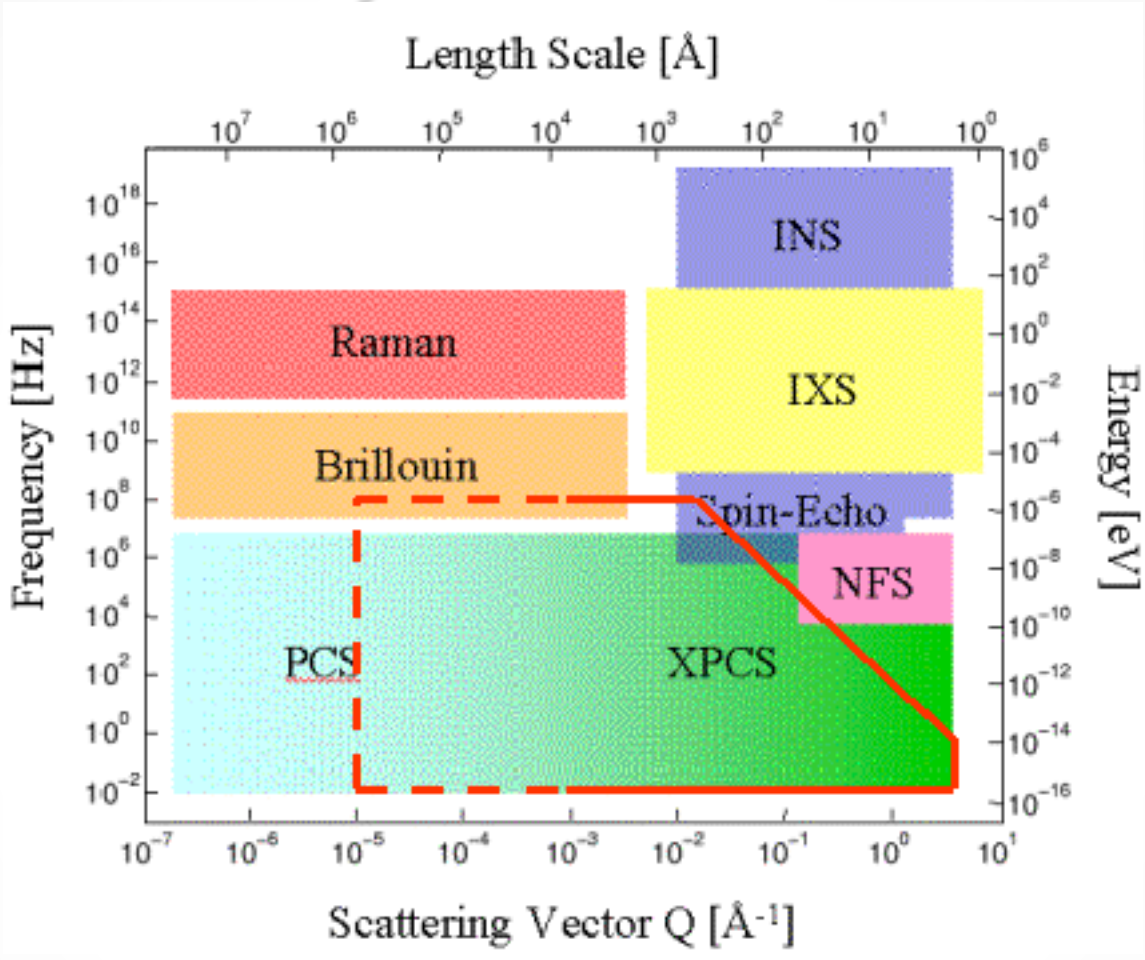
Neutron scattering is <u>part of</u> the solution, it is not <u>the</u> solution

# Why neutrons?




Neutron scattering 'simultaneously' covers a broad (Q,ω) range

# Why 'not neutrons'?

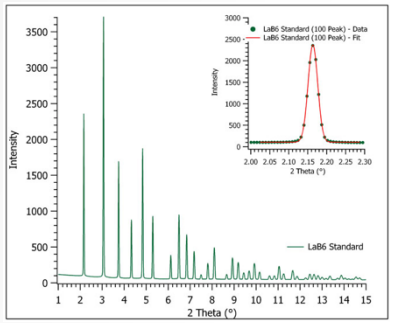


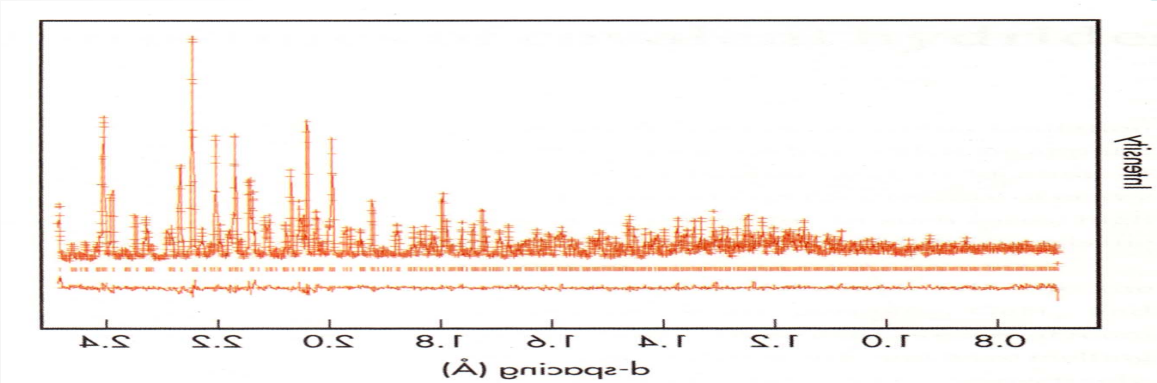

It may not look so broad when viewed from a different perspective!

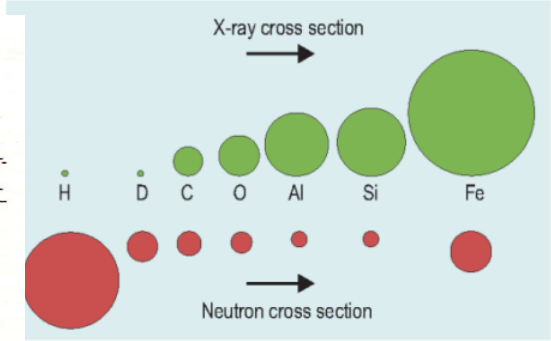
# Macroscopic property measurements

- Density
- Specific heat
- Conductivity
- Susceptibility
- …

# X-ray diffraction

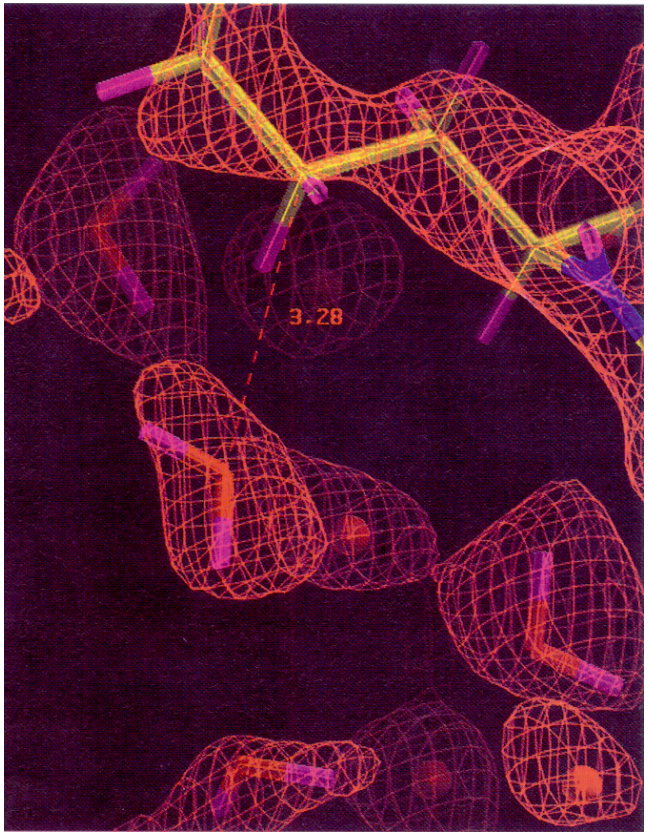




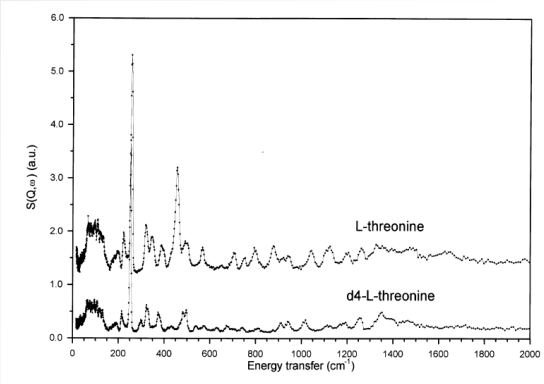

X-ray diffraction is cheap, convenient and can do many, many things
Neutrons help for high Q, light atoms, similar Z atoms, magnetism

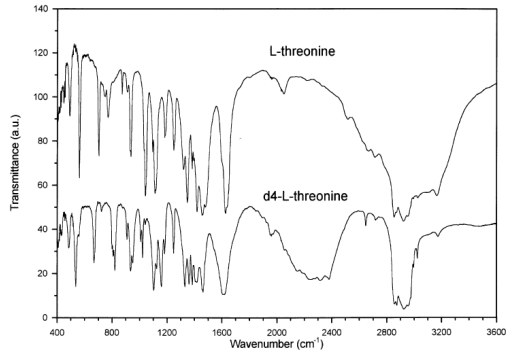
# Lesson …

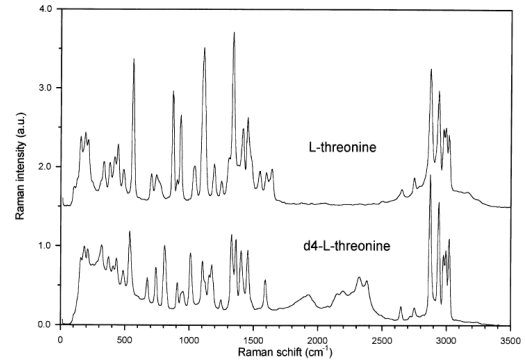


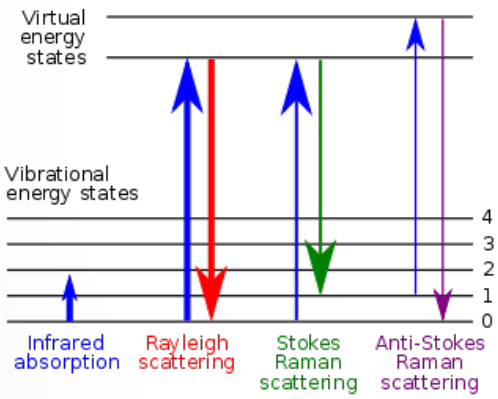

Don't say 'X-rays can't see hydrogen'
Say 'neutrons can help see hydrogen better, when used together with X-rays'

# Raman scattering/Infrared spectroscopy



Photons are cheap, convenient and can do many, many things
Neutrons give absolute intensiities with no selection rules

# Dynamic light scattering

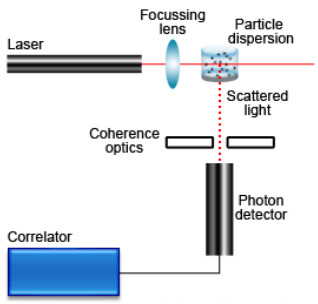
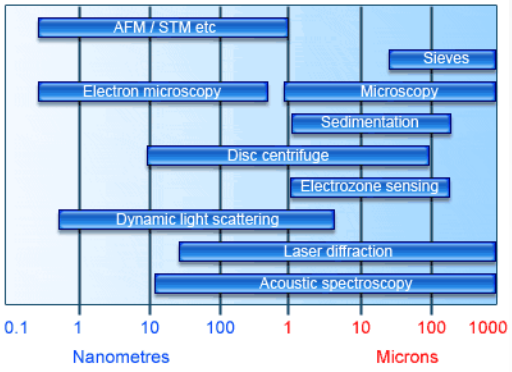
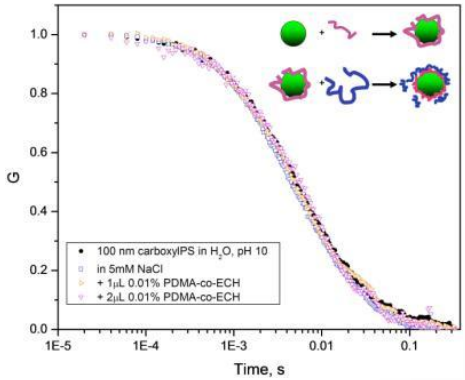


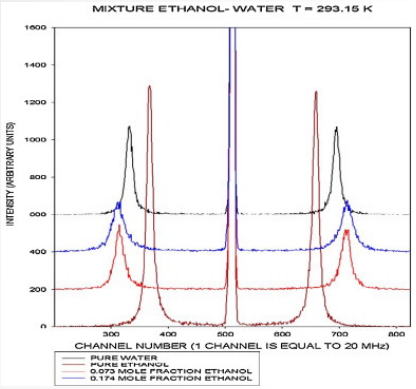

**Figure 1:** Schematic diagram of a conventional, 90° dynamic light scattering instrument.

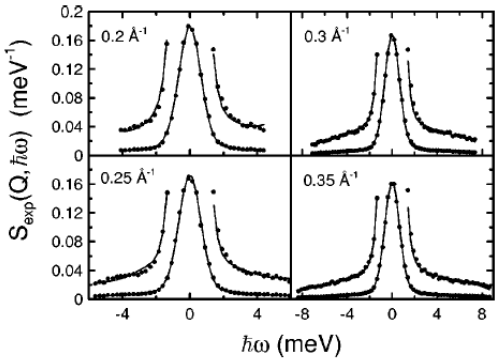


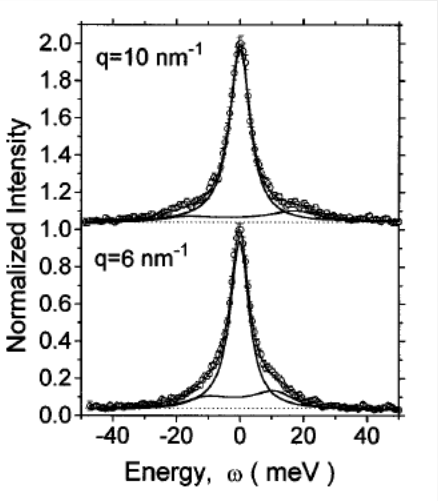


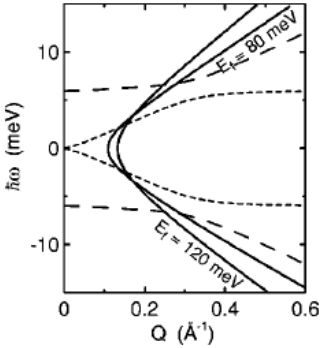

DLS exploits coherence, covers many decades in time
1-D information only, needs transparent samples

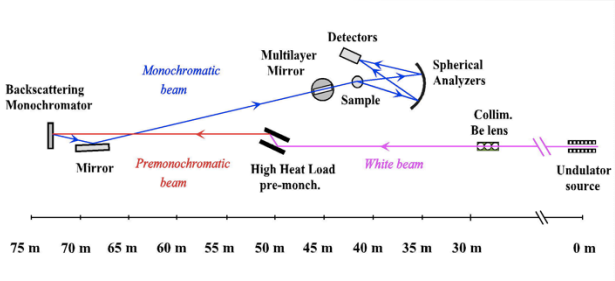
# Brillouin scattering, Inelastic X-ray scattering



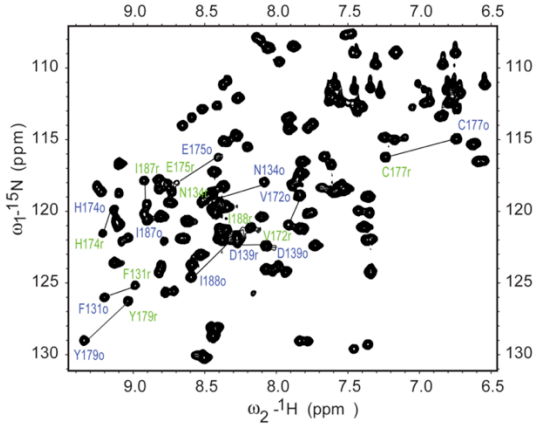



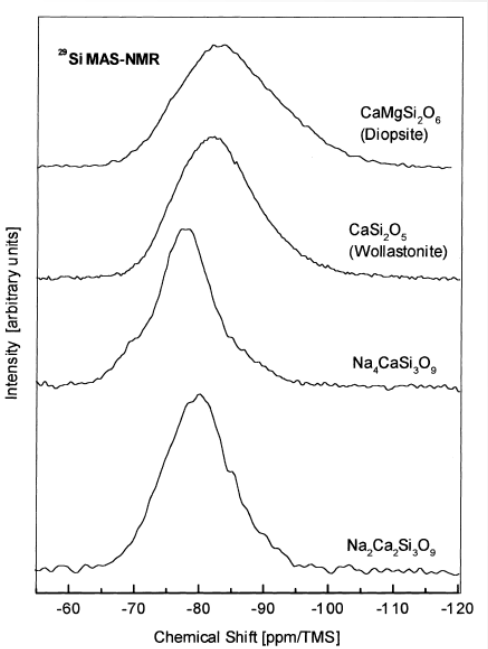



X-rays now 1-2 meV resolution; complementarity poorly exploited
Neutrons struggle at low Q because of kinematic restrictions

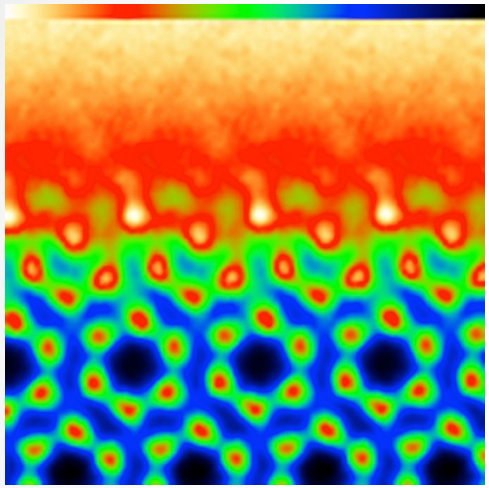
# NMR (1D, 2D, FT, MAS …)

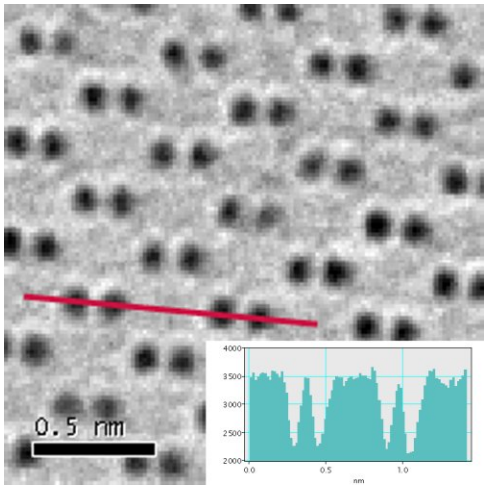



NMR naturally provides many-body correlations
In all normal circumstances neutrons provide only 2-body correlations

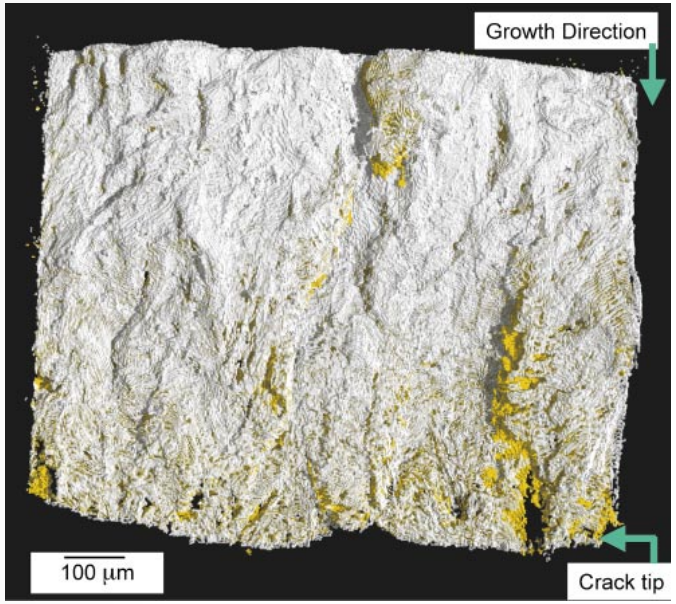
# Electron diffraction/microscopy

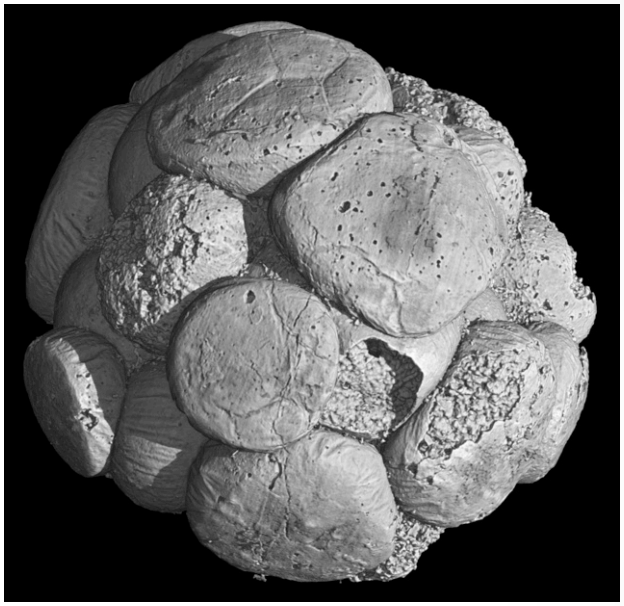




Now close to 1 Å resolution; can do liquids and glasses
Small samples, 'local' structure

# Imaging

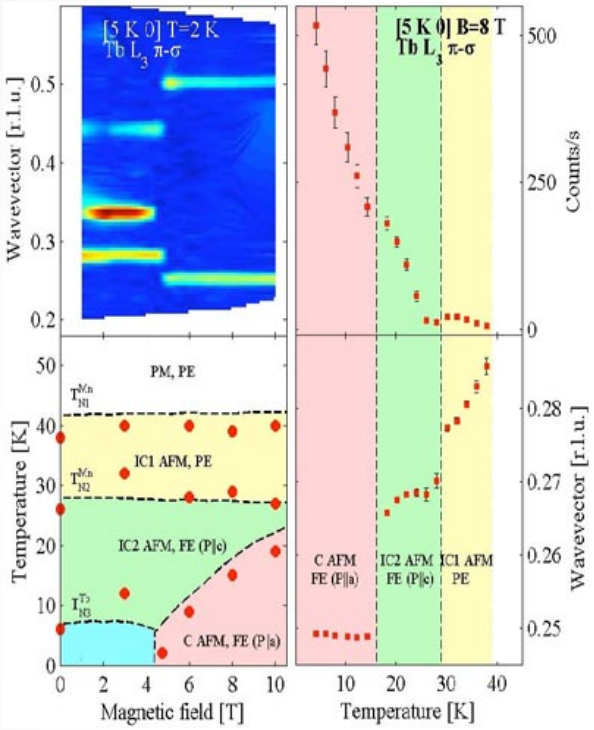


http://paleo.esrf.eu/

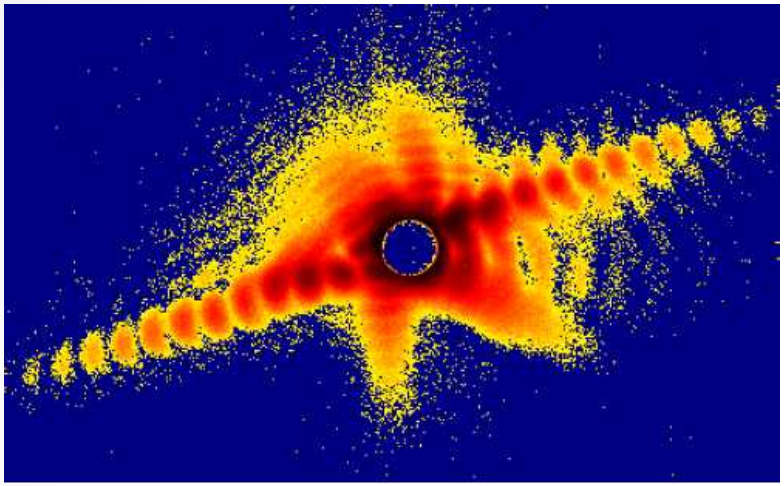
Sub-µm resolution; keV x-rays give high penetration
Neutrons only 50µm, but better for light elements

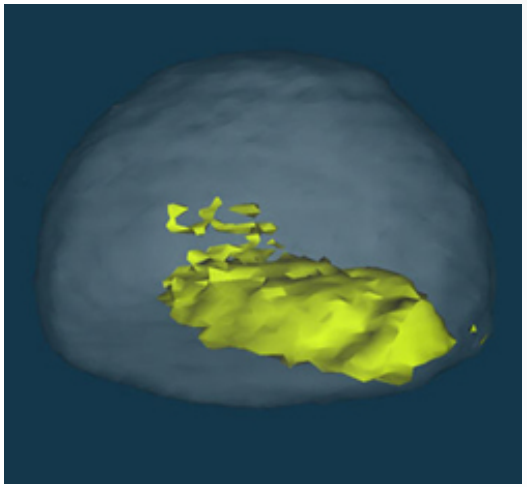
# Resonant X-ray scattering

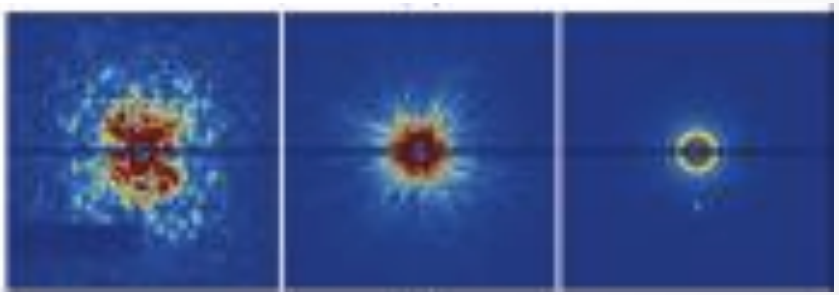


Element and electron shell selective (e.g. orbital ordering)
But probably can't interpret without neutron data as well …

# Coherent X-ray diffraction, FEL

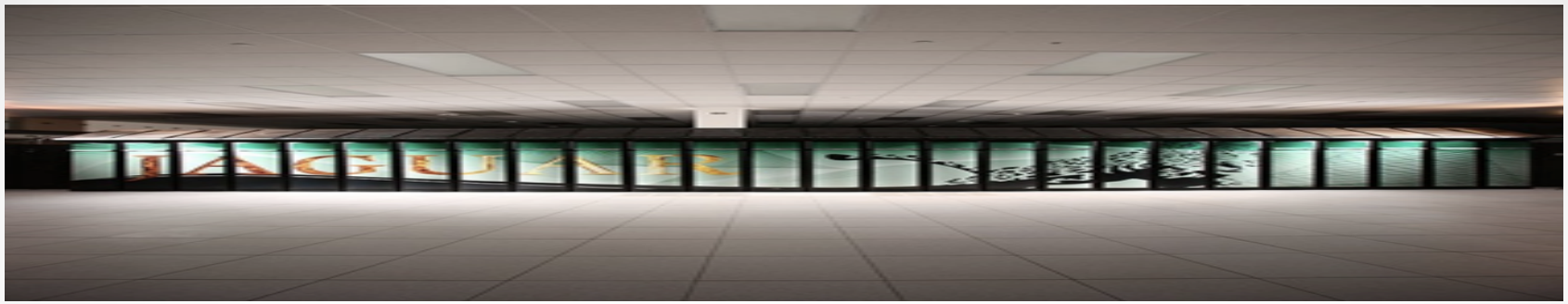


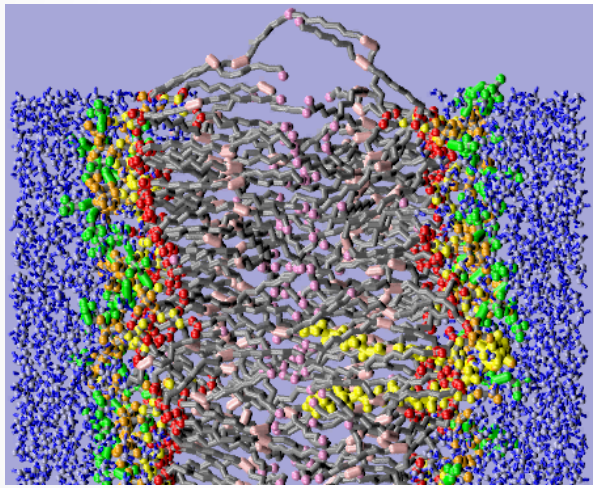


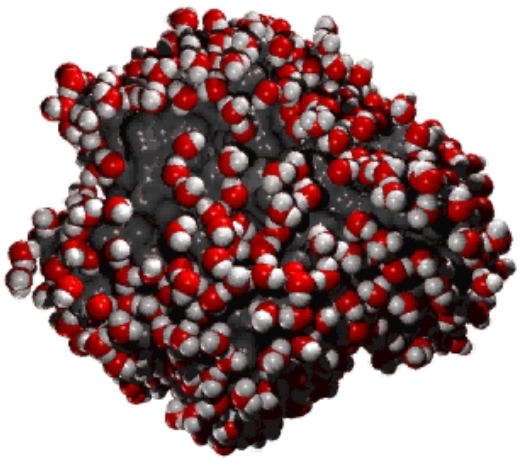


Structure and stress distribution in single nano-particles; fs diffraction
But sometimes you need to look at more than one …

# Computers







Simulation and modeling cover a very similar (r,t) range to neutrons
Neutron data can be calculated directly and easily from simulations

# Conclusions

- Neutron scattering is (always going to be) an expensive technique

  We must provide a quality product

- Neutron instruments must exploit neutron strengths, not amplify neutron weaknesses

  e.g. absolute accuracy, signal to noise

- Neutron instruments must exploit complementarity

  e.g. molecular spectroscopy, computer simulation

- Do not design or build a neutron instrument just because it's better than another neutron instrument …

  … which is usually the first thing do …