Magnetic Resonance Contributions to Other Sciences

Norman F. Ramsey
Harvard University

Principles of Magnetic Resonance
First experiments
Extensions to other fields
Summary

MAGNETIC RESONANCE:

Electrons and nuclei spin like tops and are magnetized like compass needles. In mag.field B the spin precesses at frequency f_0,

Rabi in 1937 proposed add oscillating field at frequency f. Resonance when $f=f_0$. Detect by change in magnetic state of molecule.

NUCLEAR MAGNETIC MOMENTS:

From f_0: ^{7}Li and many others.

MAGNETIC INTERACTIONS IN MOLECULES:

H_2. First experiments gave no single sharp resonance. Noise. Ph.D. thesis. Lower power. 6 resonances. Due to nucleus interacting with magnetic fields of the other nucleus and the magnetic field of the rotating nuclei. Molecular structure of interest to chemists, such as $<1/R^3>$.

NUCLEAR ELECTRIC INTERACTIONS IN MOLECULES: HD and D_2. Deuteron electric quadrupole moment (deuteron is slightly cigar shaped). Shows there is a previously unsuspected nucleon tensor force in the field of Particle Physics.

ATOMIC HYPERFINE STRUCTURE AND QED: Electron in atom interacts magnetically with nucleus giving rise to a small frequency shift called $\Delta\nu_{hfs}$. In 1947, it was thought that for atomic H, $\Delta\nu_{hfs}$ could be accurately calculated, but magnetic reson. expts showed theory was wrong, so Schwinger and others developed the theory of relativistic Quantum Electrodynamics (QED).

NMR: In 1946 Purcell, Bloch and others detected magnetic resonance by its effect upon the oscillator making possible magnetic resonance studies on liquids, solids and dense gases. Collision narrowing gave resonances but also also lost much molecular information, but other information could be substituted.

OTHER NMR MOLECULAR INFORMATION: Additional molecular information from chemical shifts in magnetic shielding, from the thermal relaxation time T1 and the phase relaxation time T2 and from the electron coupled spin-spin interaction Ernst and others developed powerful Fourier transform methods for NMR and Hahn developed spin echo techniques for measuring relaxation times. With this information the location of an atom in a molecule can be characterized, making NMR a valuable tool for chemical analysis by chemists, biologists and others. Diseased tissues were studied.

NEUTRON MAGNETIC RESONANCE: With neutron beams similar to atomic beams. With neutrons stored in suitably coated bottles.

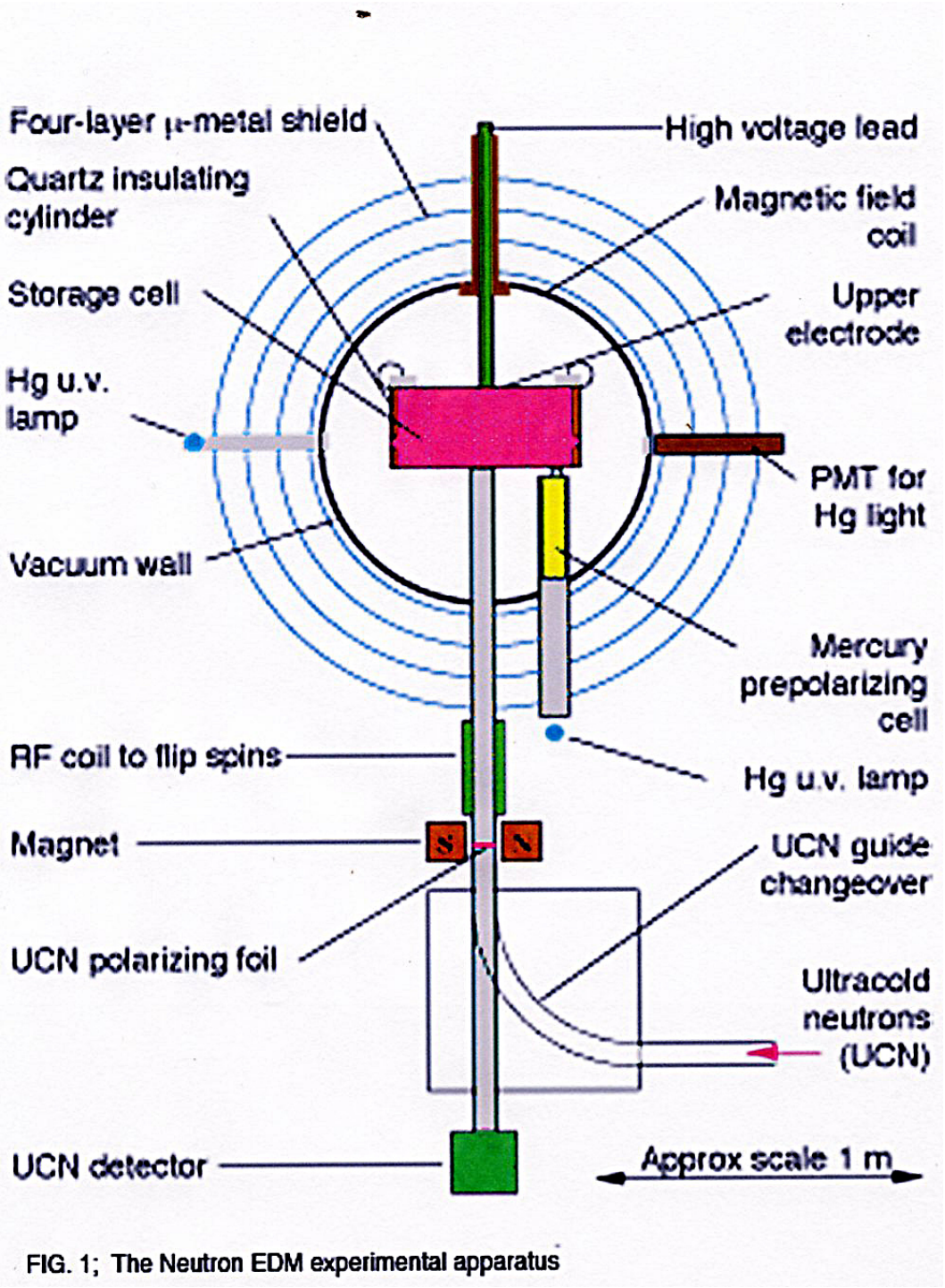
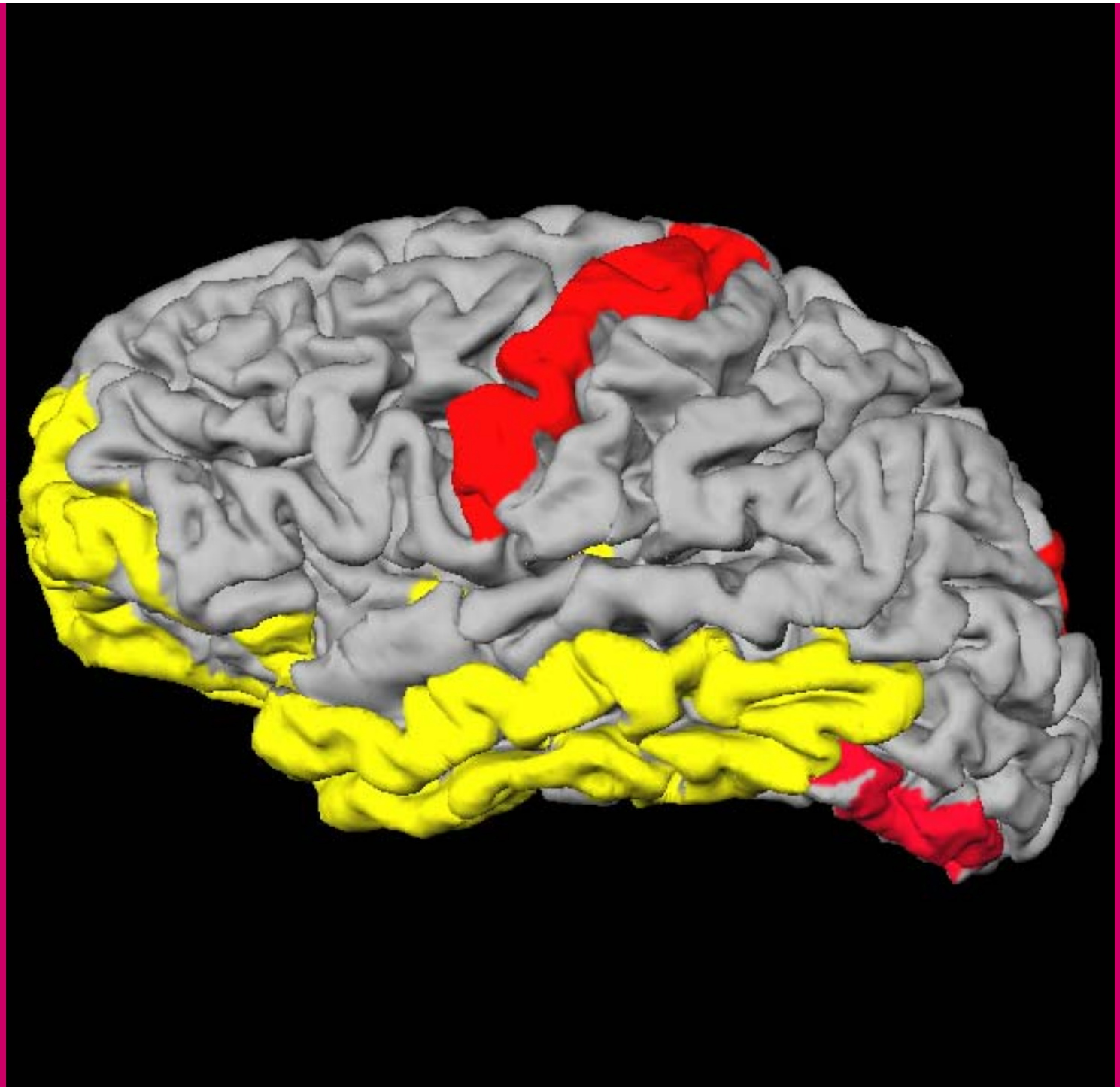


FIG. 1; The Neutron EDM experimental apparatus

ATOMIC CLOCKS: Atomic hyperfine structure $\Delta\nu_{hfs}$ is a natural quantized atomic constant and hence suitable for atomic clock. But need Separated Osc. Fields. Definition of second. Leap second. Contribute to radio astronomy, tests of relativity, GPS, seismology, precision ground, air and space navigation, including air traffic control.

MRI: Although NMR provided valuable information about the materials being studied the observations were not localized in the material. P.C. Lauterbur, P. Mansfield, R.V. Damadian and others developed methods for using inhomogeneous magnetic fields to localize the NMR signals in the sample, leading to the present beautifully detailed magnetic resonance images (MRI)'s and functional (fMRI)'s.



MAGNETIC RESONANCE: Nuclear Magnetic Moments, Molecular Structure, Quantum Field Theory, Particle Physics, QED, Chemical Analysis, Chemistry, Navigation on Earth and in Space, Biology, Time and Frequency, Astronomy, Seismology, Metrology, Tests of Relativity, Medicine, MRI and fMRI.