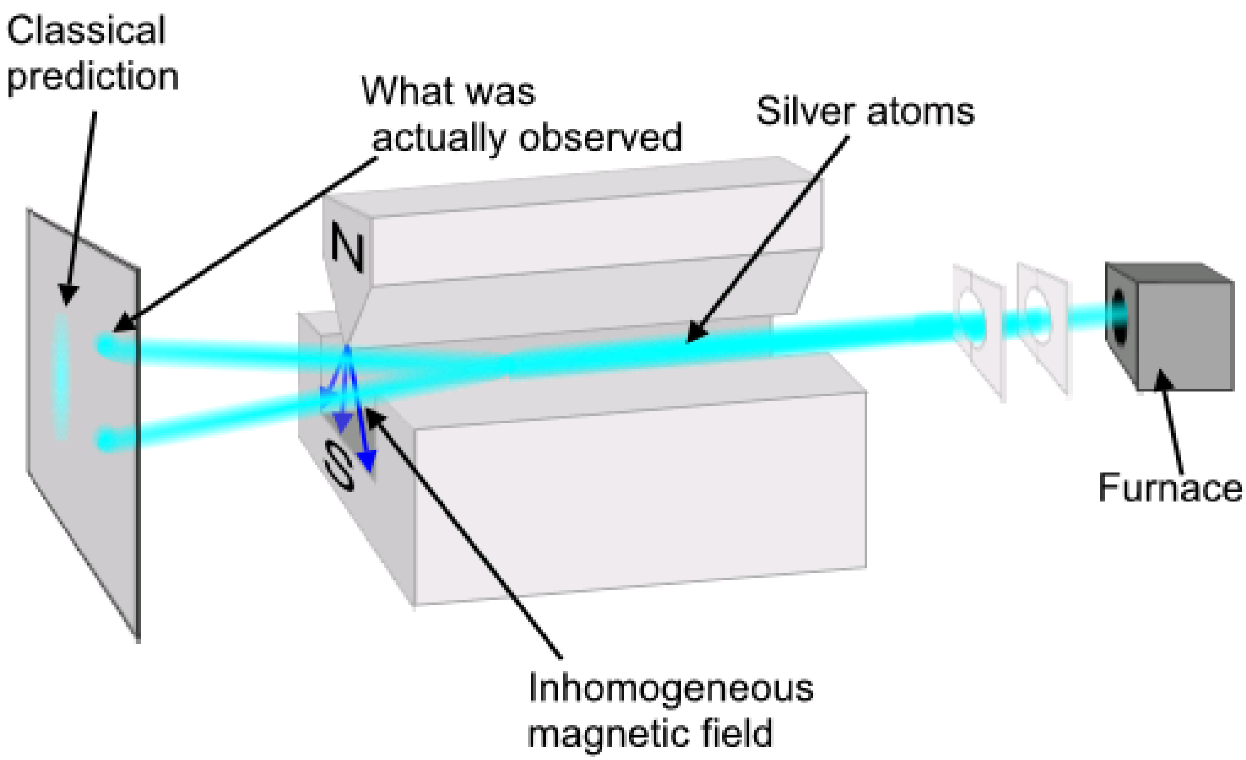
Structure Determination Using NMR

"Basic One- and Two-Dimensional NMR Spectroscopy,"
H. Friebolin,
5th Ed.,
VCH, 2010
(ISBN 3527327827)

Stern-Gerlach experiment



Otto Stern

Discovered the Proton's Magnetic Moment

Electrons and atoms can be regarded as rotating charges giving rise to a magnetic field. In a 1922 experiment, Otto Stern and Walter Gerlach sent a beam of silver atoms through an inhomogeneous magnetic field. According to classical physics, the beam should have spread out to a distribution but instead, two distinct beams were observed. The result was in accordance with quantum physics: electrons and atoms occupy only certain states of energy and movement. Angular momentum was shown to be quantised.

The Nobel Prize in Physics 1944

Isidor Isaac Rabi

1899-1989

The Nobel Prize in Physics 1944 was awarded to Isidor Isaac Rabi *"for his resonance method for recording the magnetic properties of atomic nuclei"*.

The Nobel Prize in Physics 1952

Felix Bloch

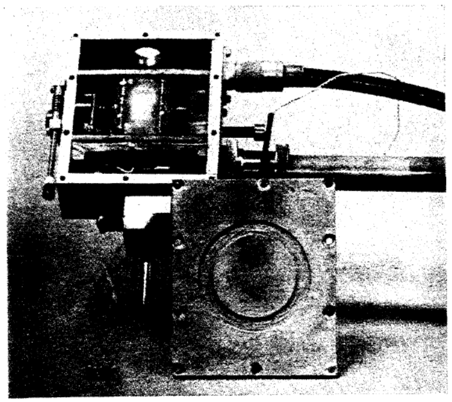
Edward Mills Purcell

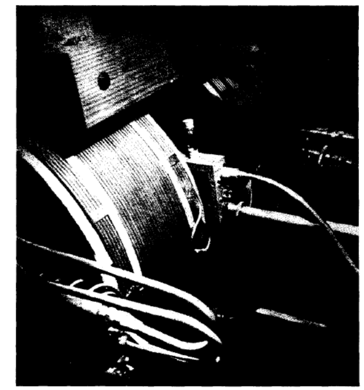
The Nobel Prize in Physics 1952 was awarded jointly to Felix Bloch and Edward Mills Purcell "for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"

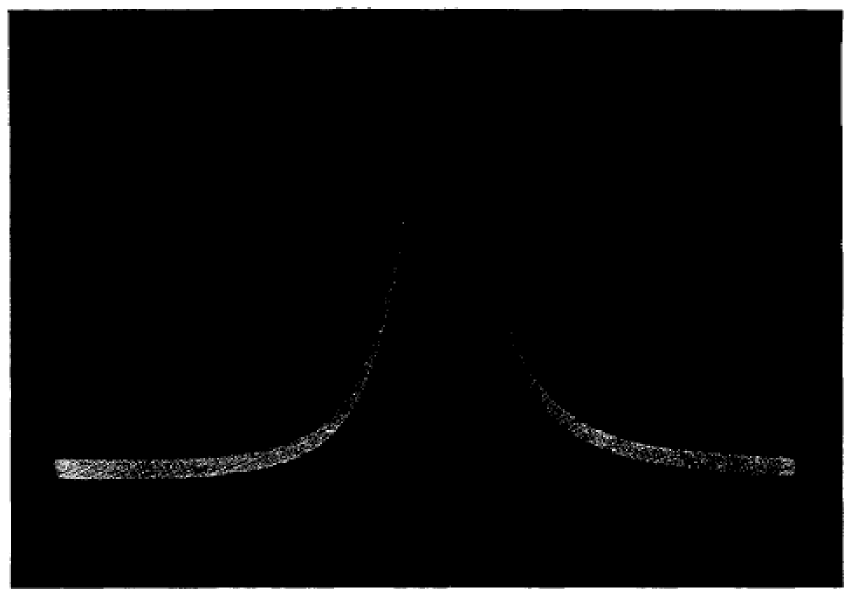
FELIX BLOCH

The principle of nuclear induction

Nobel Lecture, December 11, 1952







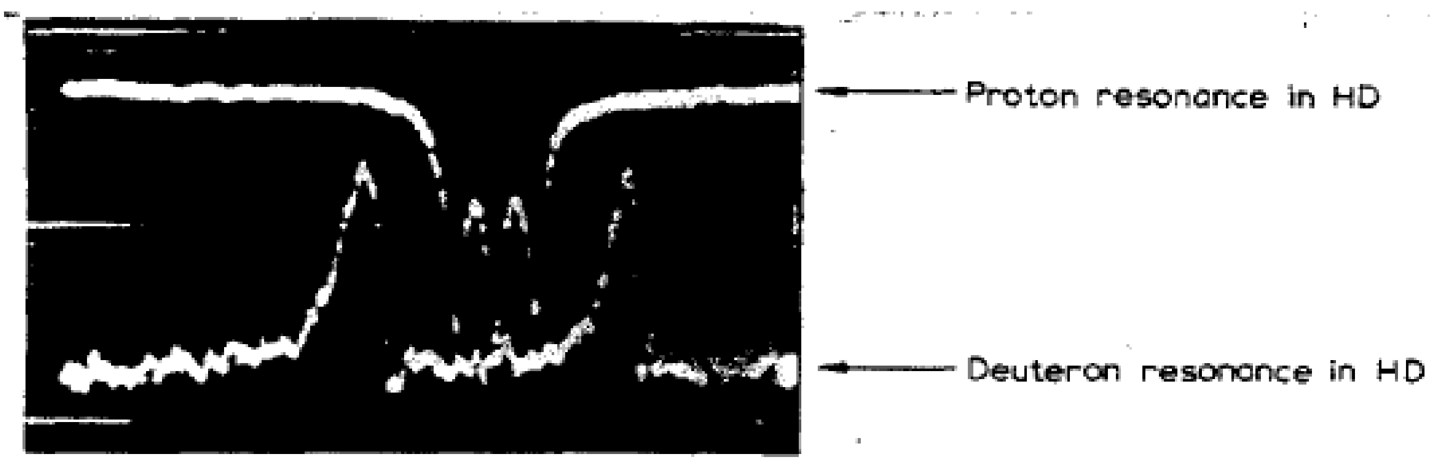
EDWARD M. PURCELL

Research in nuclear magnetism

Nobel Lecture, December 11, 1952

Let us begin with the most direct application of nuclear induction methods, the measurement of nuclear magnetic moments. The basis for this is the resonance condition

$$f = \frac{\mu H_0}{Ih}$$



$$\frac{\mu(^2H)}{\mu(^1H)} = 0.307012189 \pm 30$$

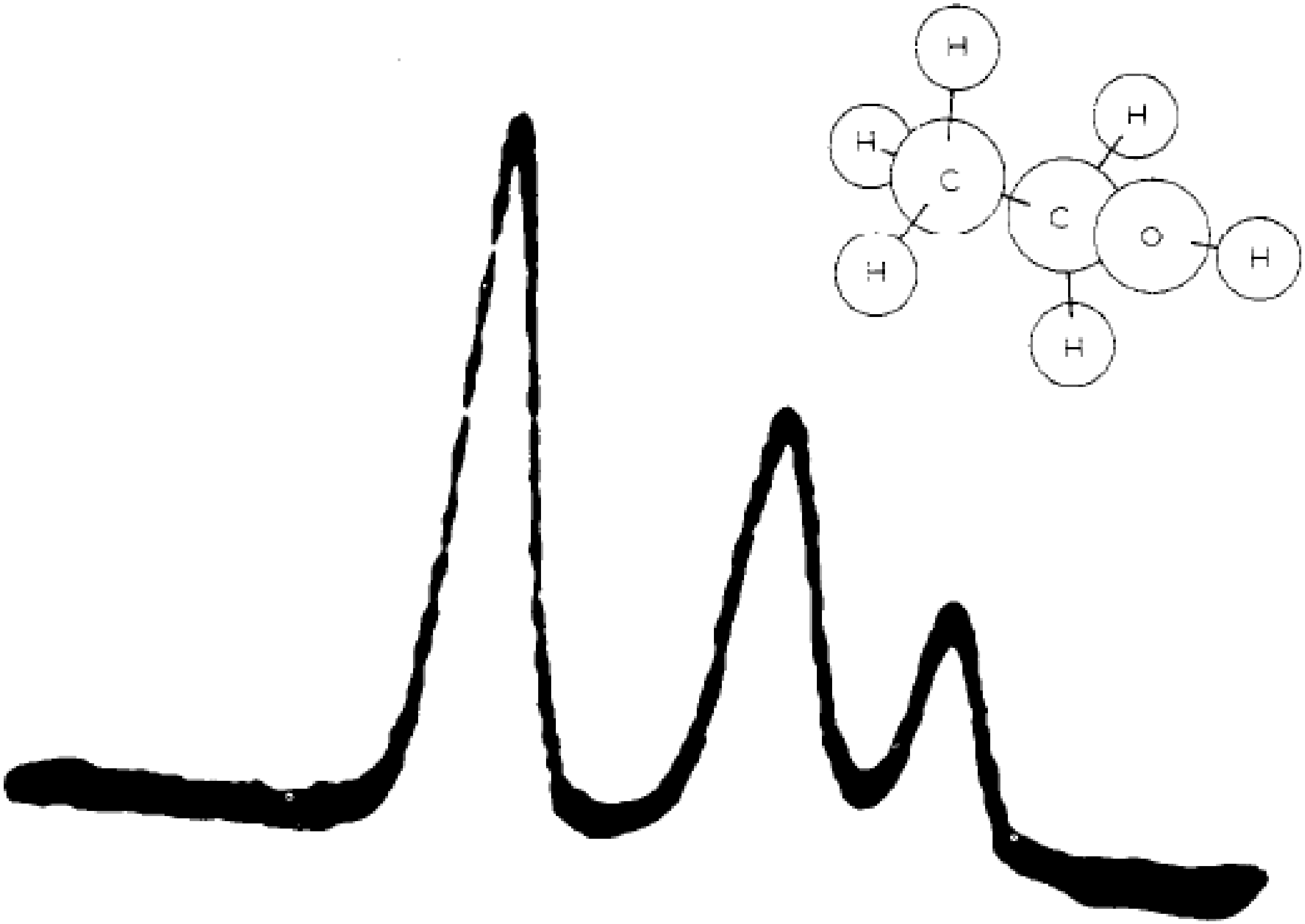
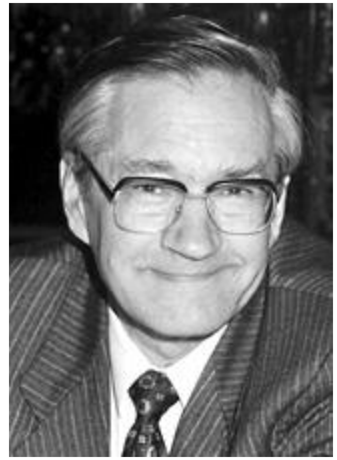


Fig. 6. The proton resonance in ethyl alcohol, observed with high resolution. The three lines arise from the CH_3 hydrogens, from the CH_2 hydrogens, and from the OH hydrogen, respectively.

The Nobel Prize in Chemistry 1991



Richard R. Ernst

Born: 14 August 1933, Winterthur, Switzerland

The Nobel Prize in Chemistry 1991 was awarded to Richard R. Ernst ***for his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy"***

NUCLEAR MAGNETIC RESONANCE FOURIER TRANSFORM SPECTROSCOPY

Nobel Lecture, December 9, 1992

by

RICHARD R. ERNST

Laboratorium für Physikalische Chemie, Eidgenössische Technische Hochschule, ETH-Zentrum 8092 Zurich, Switzerland

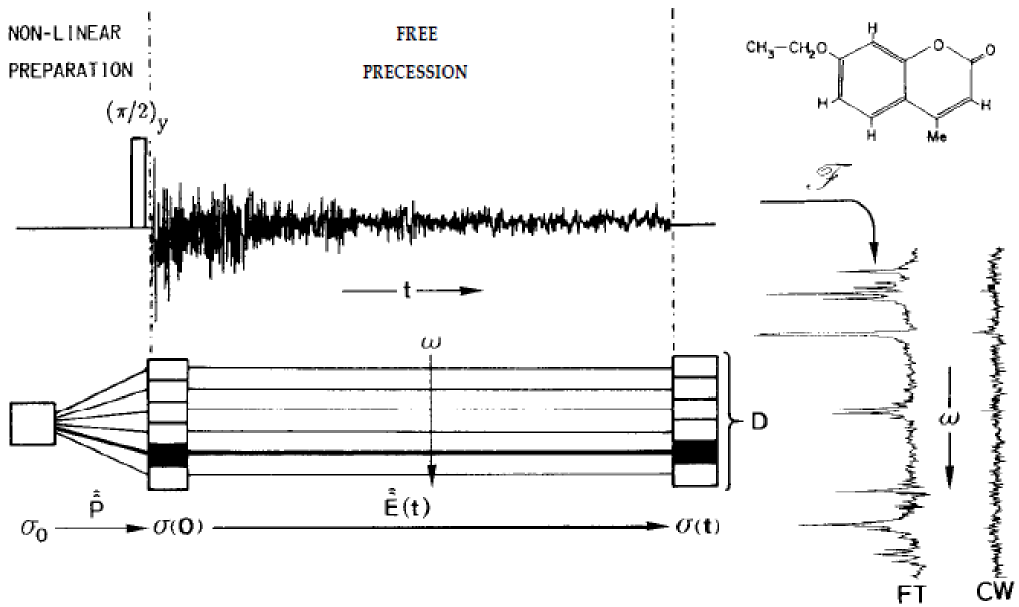


Figure 1. Schematic representation of pulse Fourier transform spectroscopy by the example of 60MHz proton resonance of 7-ethoxy-4-methyl-coumarin (22). An initial $(\pi/2)_y$ rf pulse, represented by the rotation superoperator P, excites from the equilibrium state σ_0 transverse magnetization $\sigma(0)$. Free precession of all coherences in parallel under the evolution superoperator E(t) leads to the final state $\sigma(t)$. Detection with the detection operator D produces the shown FID (sum of 500 scans) which, after Fourier transformation, produces the spectrum FT. For comparison, a continuous wave spectrum CW is shown that has been recorded in the same total time of 500 s under identical conditions.

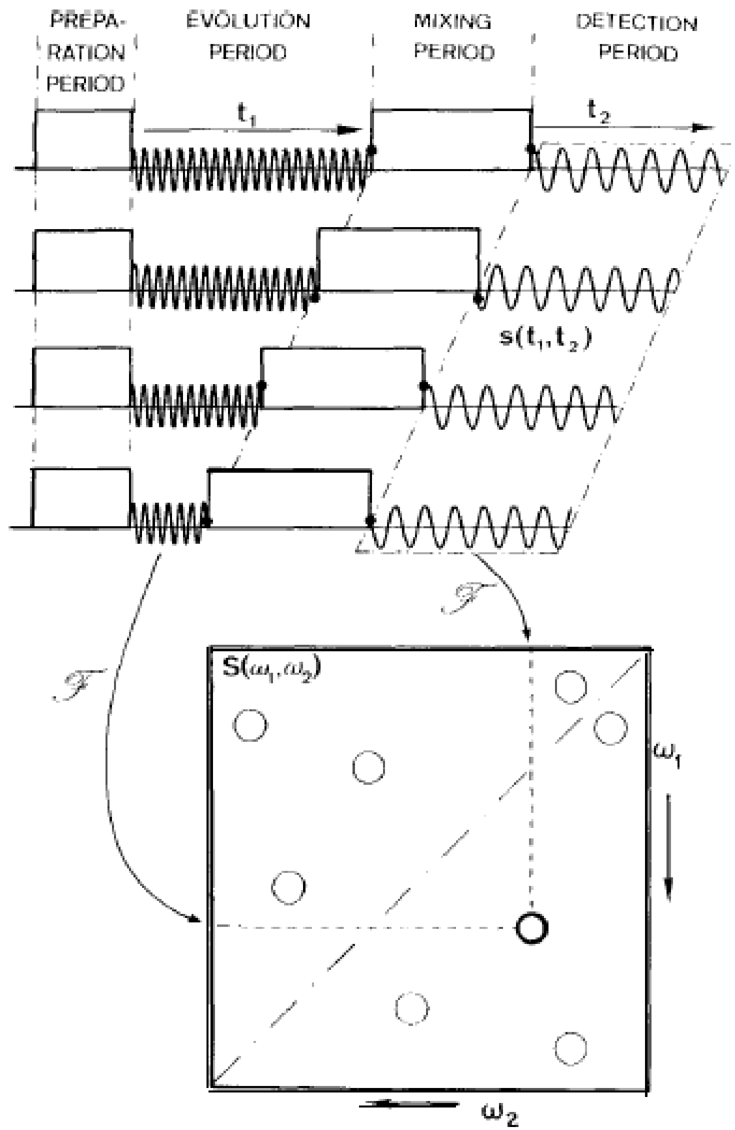


Figure 7. General 2D experiment consisting of a preparation, an evolution, a mixing, and a detection period. The duration t_1 of the evolution period is varied systematically from experiment to experiment. The resulting signal $s(t_1, t_2) \propto \langle D \rangle (t_1, t_2)$ is Fourier-transformed in two dimensions to produce the 2D spectrum $S(\omega_1, \omega_2)$.

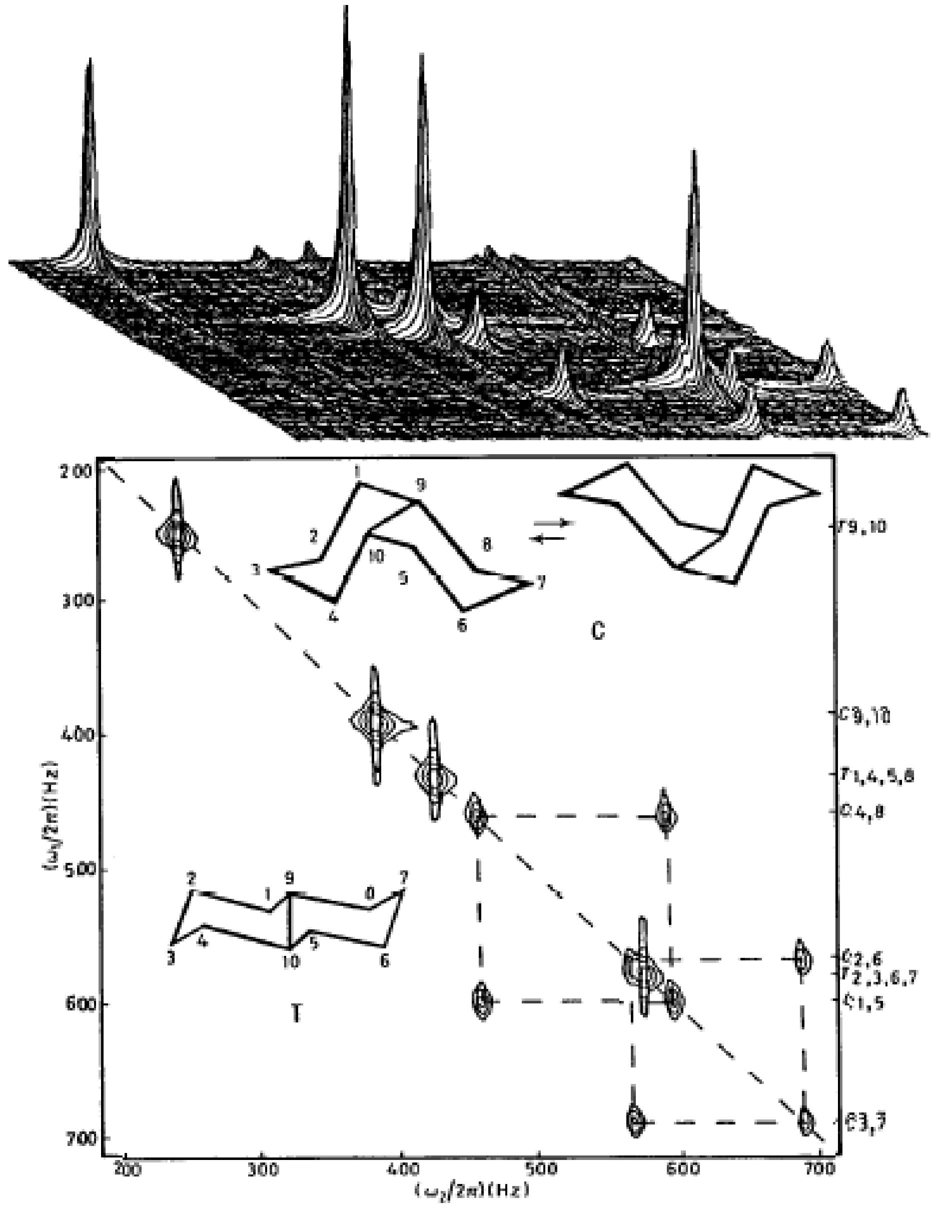


Figure 12. 2D ^{13}C chemical exchange spectrum (EXSY) of a mixture of cis- and trans-decalin recorded at 22.5 MHz and 241K (76). A stacked plot and a contour representation are given with the assignment of the peaks.

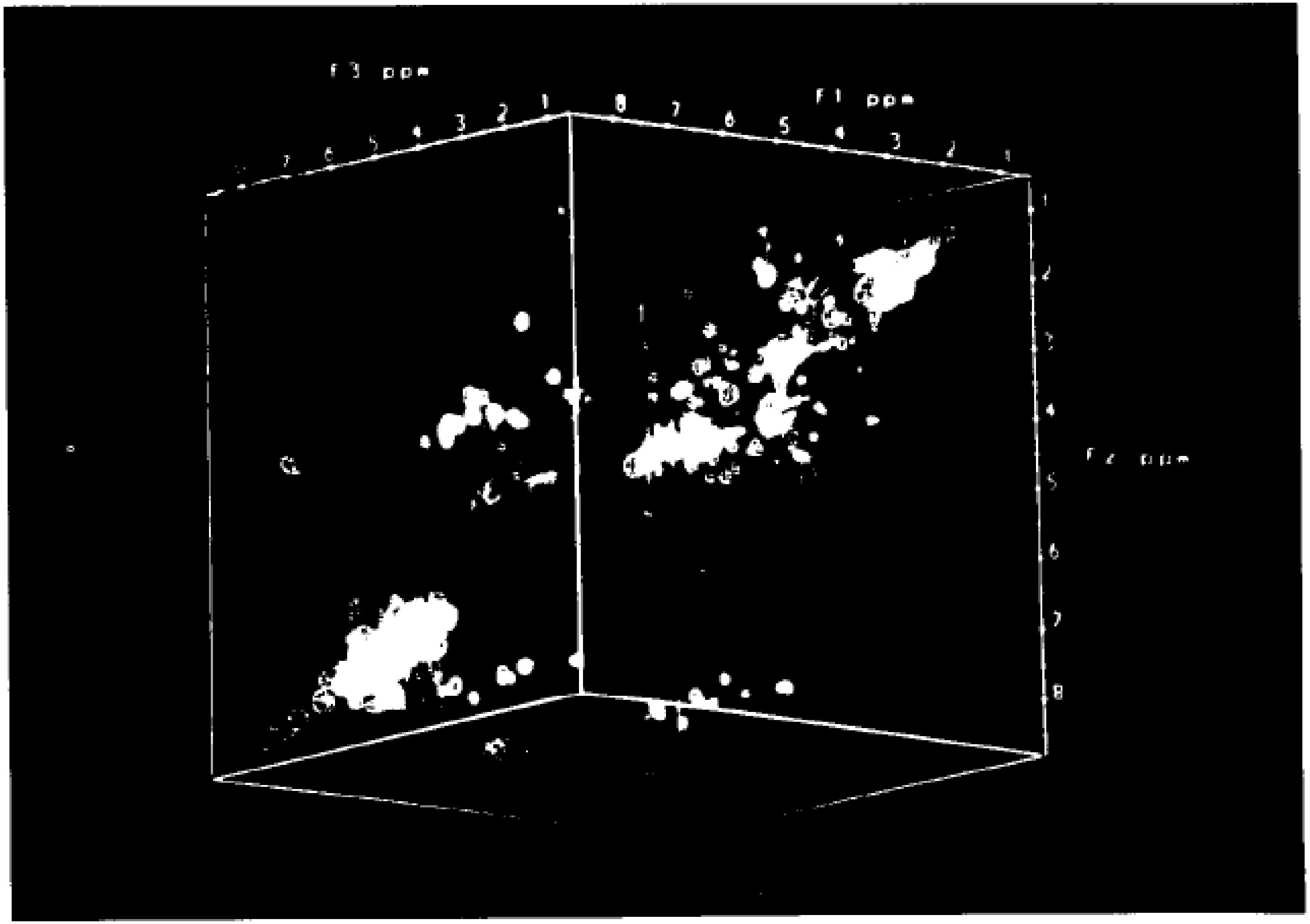


Figure 22. 3D view of a 300 MHz *3D* homonuclear ROESY-TOCSY spectrum of buserilin in DMSO-d_6 photographed from a picture system (116).

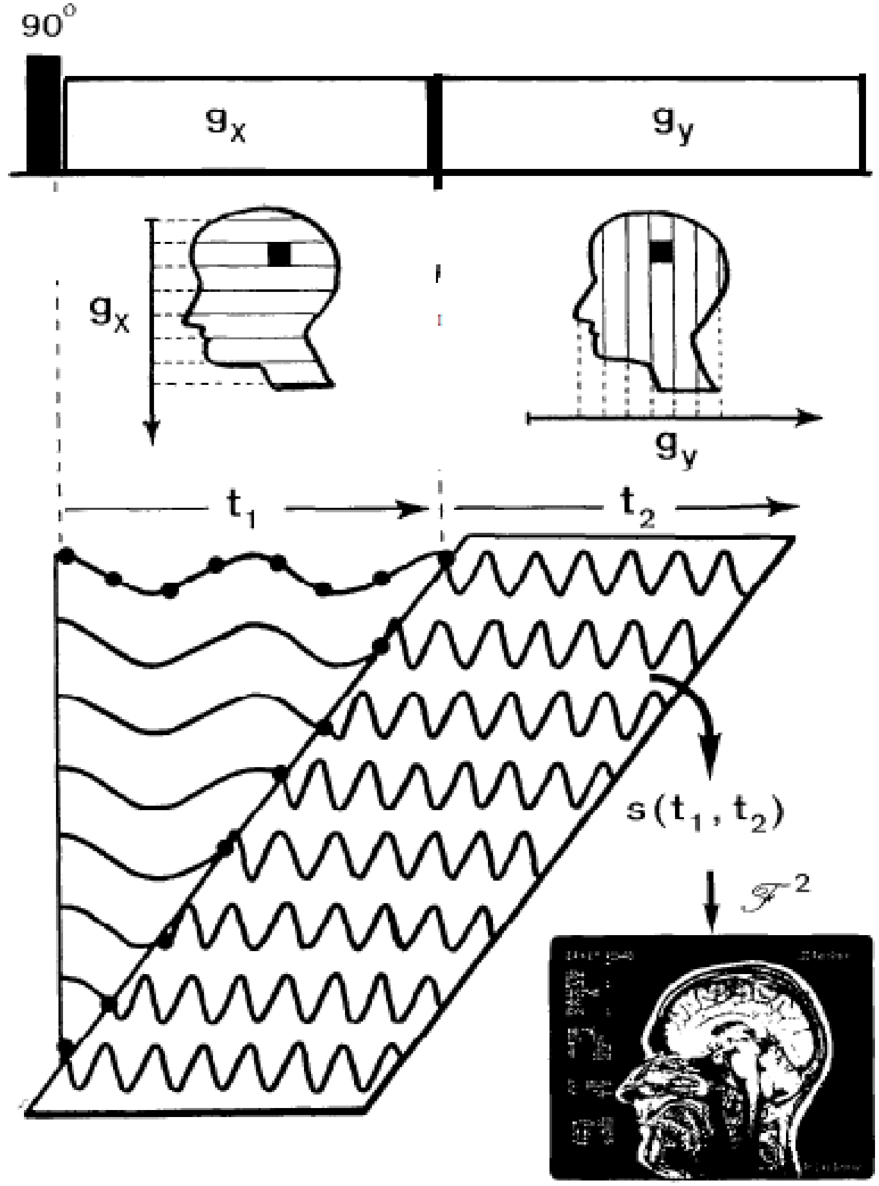


Figure 28. Schematic representation of Fourier NMR imaging, here shown in two dimensions. Two orthogonal gradients are applied during the t_1 and t_2 periods of a 2D experiment. A 2D Fourier transformation of the data set $s(t_1,t_2)$ produces a 2D image of the investigated subject (R.R.E.).

The Nobel Prize in Chemistry 2002

John B. Fenn

Koichi Tanaka

Kurt Wüthrich

The Nobel Prize in Chemistry 2002 was awarded "for the development of methods for identification and structure analyses of biological macromolecules" with one half jointly to John B. Fenn and Koichi Tanaka "for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules" and the other half to Kurt Wüthrich "for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution".

NMR STUDIES OF STRUCTURE AND FUNCTION OF BIOLOGICAL MACROMOLECULES

Nobel Lecture, December 8, 2002

by

KURT WÜTHRICH

Eidgenössische Technische Hochschule Zürich, CH-8093 Zürich, Switzerland, and The Scripps Research Institute, 10550 N. Torrey Pines Rd., La Jolla, CA 92037, USA.

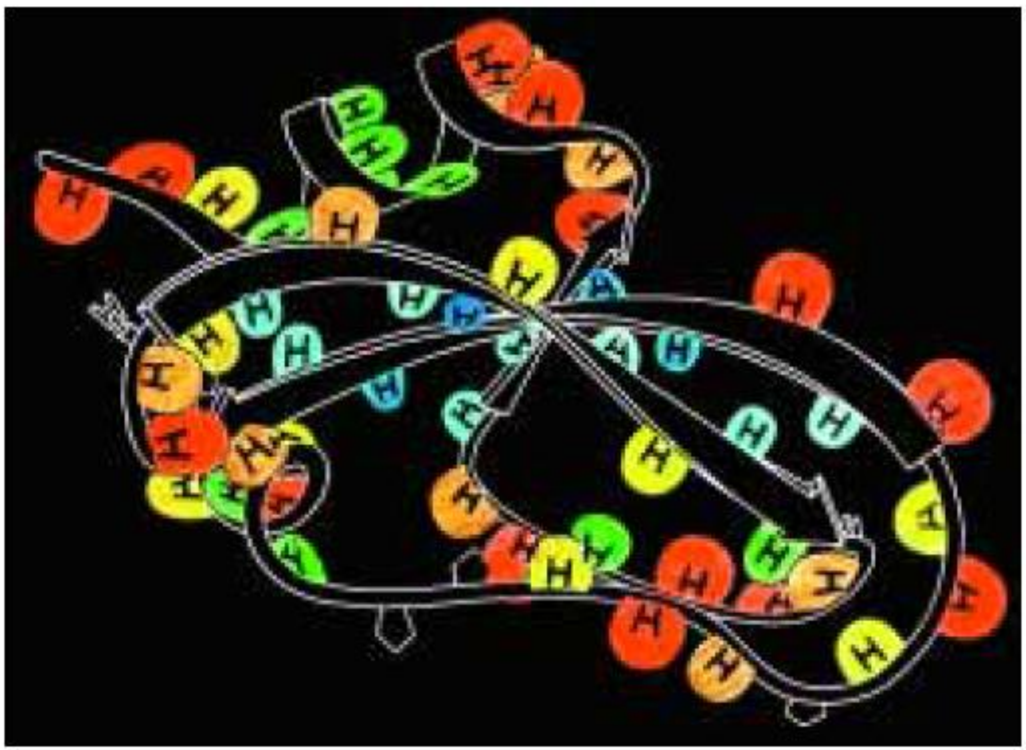


Figure 21. Complete sequence-specific resonance assignments for BPTI obtained using 2D NMR experiments (34). Assigned residues are identified by coloured patches covering their amide protons. (The colour code indicates variable amide proton exchange rates; drawing by Jane Richardson, 1982).

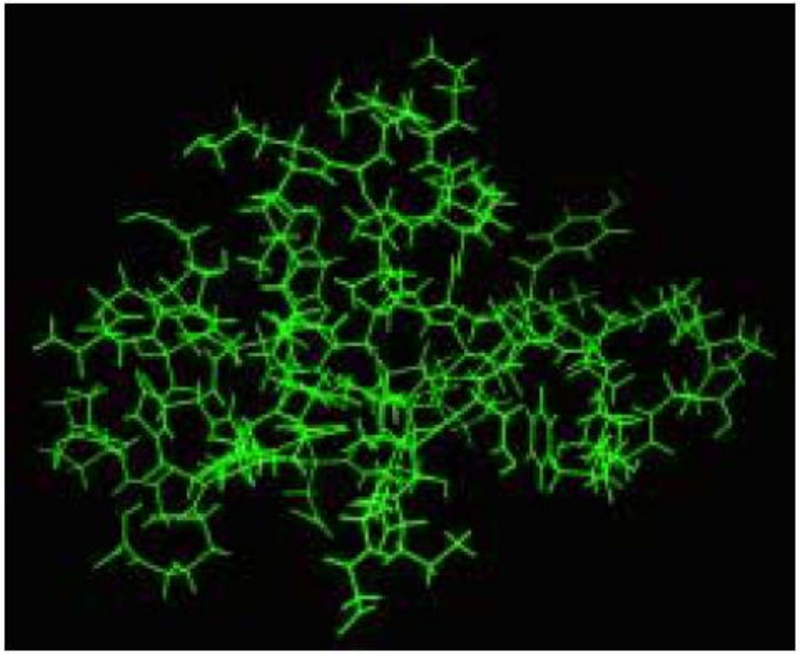


Figure 25. NMR structure of BUSI IIA (43).

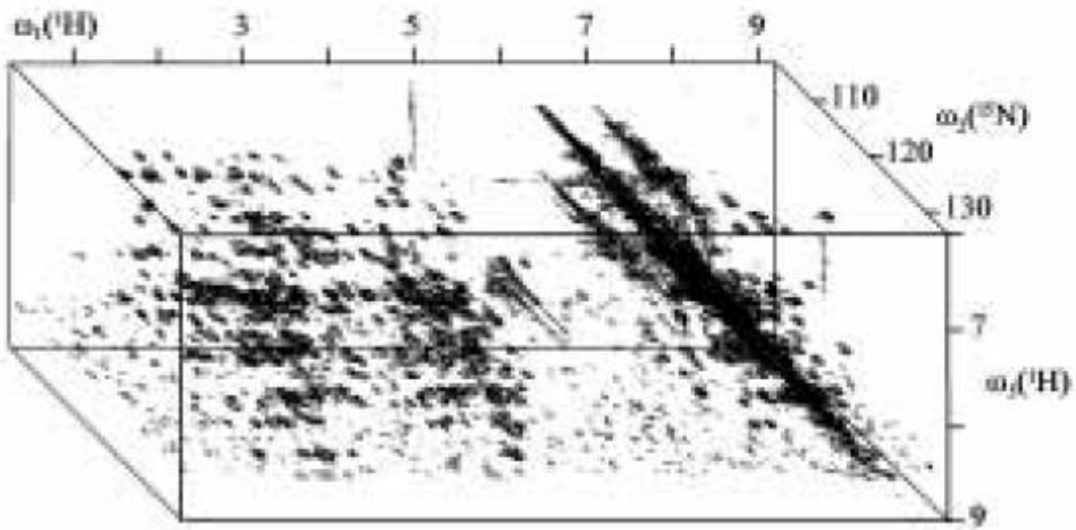


Figure 26. Three-dimensional (3D) ^{15}N-resolved [^1H,^1H]-NOESY spectrum (600 MHz, 28°C, H_2O-solution) of the DNA-binding domain of the P22 c2 repressor (M ≈ 10000, uniformly ^{15}N-labeled).

Figure 36. My collaborators at the ETH Zürich from 1970 to 2002.

The Nobel Prize in Physiology or Medicine 2003

Paul C. Lauterbur

Sir Peter Mansfield

The Nobel Prize in Physiology or Medicine 2003 was awarded jointly to Paul C. Lauterbur and Sir Peter Mansfield *"for their discoveries concerning magnetic resonance imaging"*

ALL SCIENCE IS INTERDISCIPLINARY – FROM MAGNETIC MOMENTS TO MOLECULES TO MEN

Nobel Lecture, December 8, 2003

by

PAUL C. LAUTERBUR

Biomedical Magnetic Resonance Laboratory, University of Illinois, Urbana, IL 61801, USA.

That evening, over dinner, it occurred to me that, as the frequencies of NMR signals depended on the local magnetic field, there might be a general way to locate them in a non-uniform magnetic field. I knew, however, that a static field could not have a unique value in each location in three dimensions, but that a complex shape could be represented by an expansion in a set of functions such as those provided by the correction, or "shim" fields, available on NMR machines to cancel unwanted magnetic field non-uniformities, term by term, with linear gradients, quadratic ones, etc. Could this be the an-

SNAP-SHOT MRI

Nobel Lecture, December 8, 2003

by

PETER MANSFIELD

Sir Peter Mansfield Magnetic Resonance Centre, Department of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, U.K.

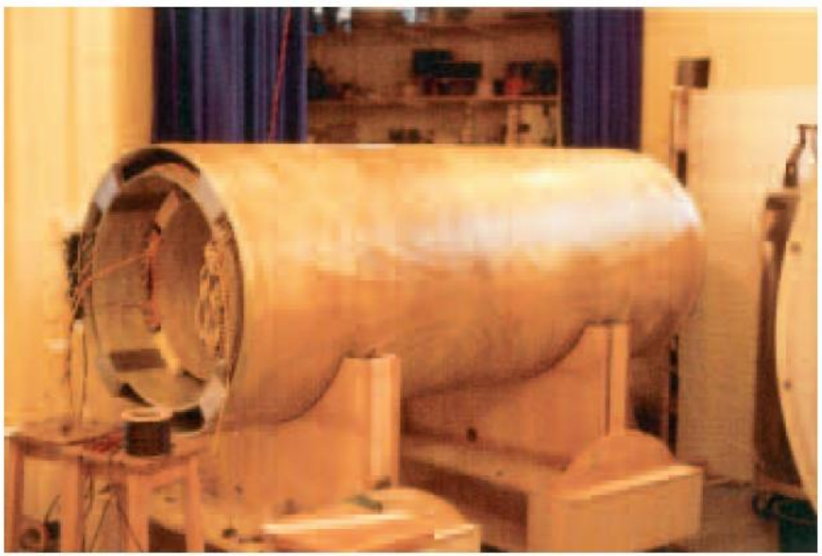


Figure 2. Photograph of a doubly screened active magnetic shielded gradient coil set for insertion in the super-conductive magnet of Figure 1.

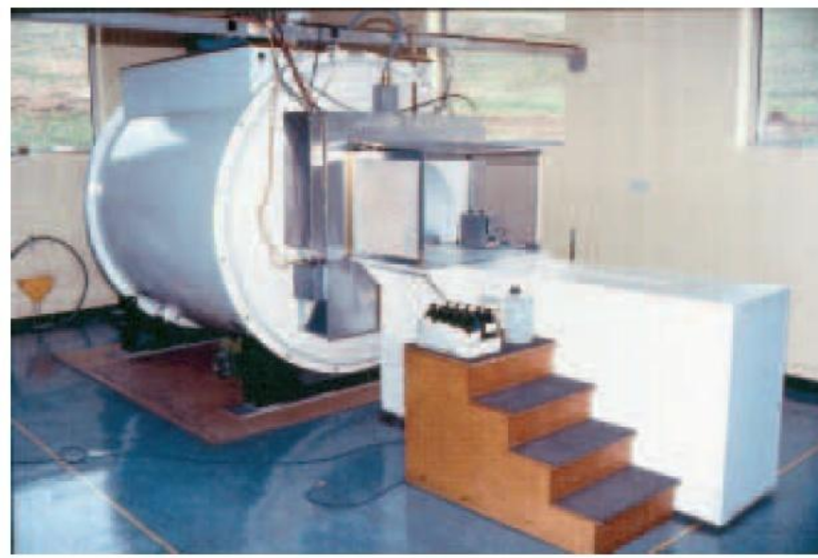


Figure 1. Photograph of home built magnetic resonance imager based on a 0.5 T super-conductive magnet.

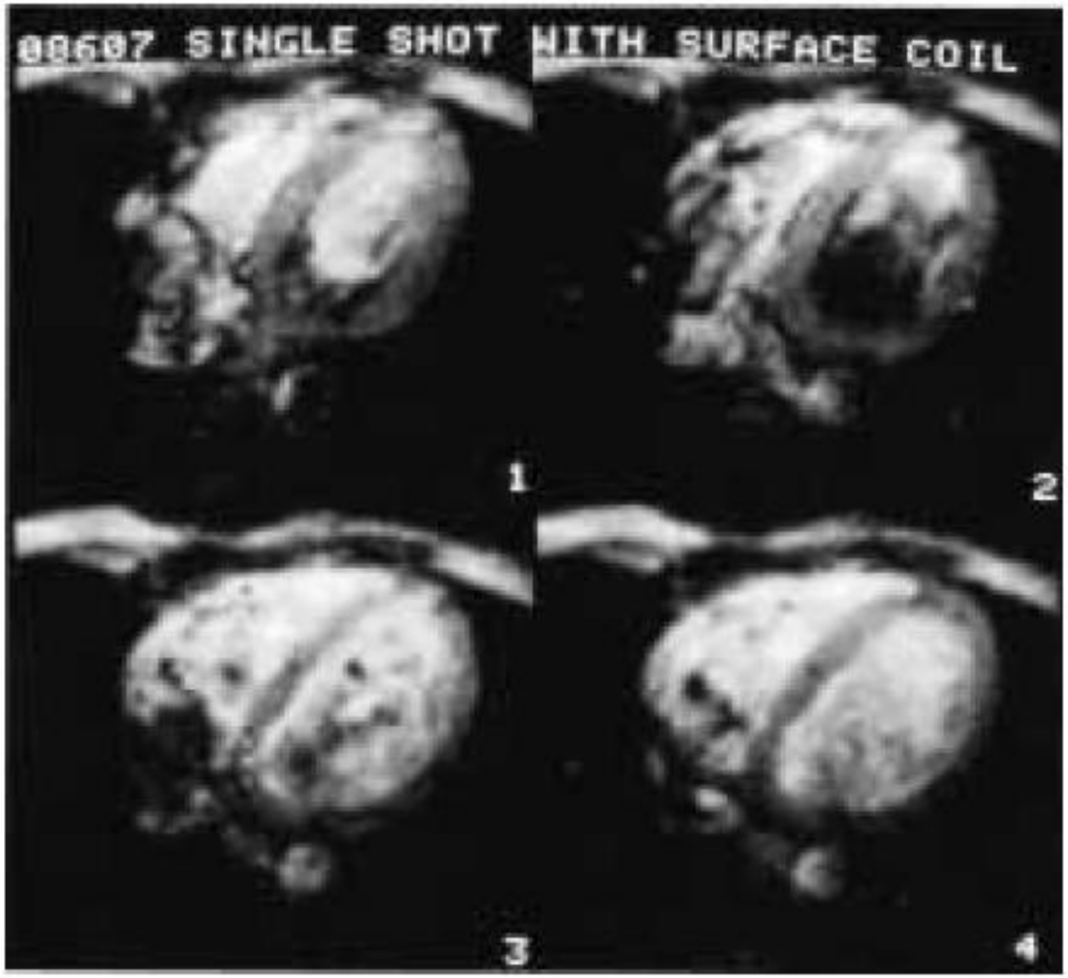


Figure 5. Snap-shot EPI images through the heart obtained with use of a surface coil. (1) Transection during systole shows left ventricular myocardial wall thickening. (2) Rapid ventricular filling in late systole. (3, 4) Transections obtained during diastole show thinner myocardial walls. The spatial resolution of these images is less then 2 mm. (Reproduced with permission from M J Stehling *et al.*, RADIOLOGY, 170: 257–263, (1989).)