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Remembering Martin Deutsch

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Introduction

I have known of Martin Deutsch since the time I was a beginning graduate strudent with Stephan Berko at Brandeis University in 1962. I met him on two rather formal occasions – after Berko, Canter and myself observed light from the excited state of positronium in 1974, and at the 6th International Conference on Positron Annihilation at Arlington, Texas in 1982 – and several informal occasions. Since I did not know him very well, and do not have much first hand knowledge about his career in high energy physics, I will give here the bare outlines of his biography [1-4] and then attempt to retell the story of how his great contribution to the field of positron physics burst forth in one magic year half a century ago.

Martin Deutsch was born in Vienna on Jan. 29, 1917, the only child of a distinguished pair of physicians, Felix and Helene Deutsch. He died at his home on Aug. 16, 2002 after a long and successful career at the Massachusetts Institute of Technology in the fields of nuclear, atomic and high energy physics. Martin and his parents emigrated to the United States of America in 1935 and Martin thereupon entered the Massachusetts Institute of Technology (known simply as MIT). Martin was a precocious student and received a bachelor's degree in only two years and a Ph.D. also from MIT in 1941 under the supervision of Robley D. Evans, author of the famous book on nuclear physics [5]. During World War II, Deutsch worked on the Manhattan Project and in 1946 returned to MIT as a lecturer and researcher. He continued his work on nuclear physics, developing methods for measuring delayed gamma ray emission from nuclei using the then new high speed detectors made from scintillation crystals coupled to photomultiplier tubes. The stage was now set with a mind well prepared and the tools of discovery in his hands.

In 1948 Deutsch began work on measuring the annihilation rate of antielectrons, *i.e.* positrons, in gases in order to test Dirac's prediction that the rate should equal the electron density times $\pi r_0^2 c$, and therefore should be proportional to the gas density. Surprisingly, the measurement was not characterized by a simple exponential decay, and the annihilation rate was not proportional to the density! This was a signal that the positrons were becoming trapped in some metastable state, but it was not at all clear what this might be, since people at the time were used to thinking in terms of scattering events involving free particles. Furthermore, a nuclear physicst of the day was trained on spectroscopy, where alpha, beta and gamma ray emission energies, rates and branching ratios were the immutable results of mysterious nuclear interactions and could be significantly affected neither by the extensive state variables of thermodynamics under ordinary laboratory conditions nor the chemical state of the atoms in which the nuclei happened to reside. Deutsch was aware of Wheeler's 1946 paper on polyelectrons [6], but it was not obvious that a positronium atom, the predicted bound state of an electron and its antiparticle, would be stable while undergoing frequent collisions with the molecules of a dense gas. It was an enigma awaiting a brilliant way to prove that the suspected new elemental form of matter, positronium, was making its transient presence known.

The magic year

The positron lifetime experiments were set aside until late in the year 1950 when Deutsch was inspired to go back to the problem by an invitation to speak at a February 1951 meeting of the

American Physical Society. Deutsch knew that oxygen gas caused a decrease in the long lifetime component of his annihilation decay measurements and a concomitant increase in the prompt component. At first he had thought that the latter was an artifact associated with positrons annihilating in the material of the cavity walls. Just before the meeting he suddenly realized that the oxygen was probably destroying long-lived ortho-positronium triplet states by converting them to short-lived para-positronium singlet states, thus accounting for the increase in the intensity of the prompt component. At the meeting, Anthony Turkevich (who was in fact my first year chemistry teacher in 1958 at Princeton University) suggested that NO would be a better quenching gas if spin exchange was the mechanism for the positronium quenching. Subsequent experiments showed this to be the case, and provided the basis for an unassailable proof that positronium atoms, which could interact chemically with their environment, had been discovered. In his discovery paper, received by the editors of *Physical Review* on March 13, 1951 [7], Deutsch showed that positronium atoms are abundantly formed in pure N_2 gas and produce a long lifetime signature expected from ortho-positronium atoms. Upon addition of 3% NO gas, the number of long lifetime counts is reduced by a factor of three, while the number of prompt counts increases. In addition, the gamma-ray energy spectrum exhibited the expected change from the low energies characteristic of the ortho-positronium three-photon continuum, to the higher energies associated with the monoenergetic 511 keV pairs of photons from annihilation of the singlet state.

The experiments were quickly refined by using freon as the positronium-forming gas. Deutsch reported in a second paper, received June 25, 1951 [8], that the decay rate of triplet positronium extrapolated to a zero pressure value of 6.8 μsec^{-1} ±10%, in agreement with the calculation of Ore and Powell [9].

A third paper, received September 11, 1951 [10], reported a first measurement of the positronium hyperfine interval from observations of the magnetic quenching of ortho-positronium formed in freon. The fraction of positrons annihilating into three quanta, f, was deduced from the energy spectrum of the annihilation photons. Fitting f to a theoretical magnetic quenching expression, Deutsch and Dulit deduced that the hyperfine interval is E = 0.94 meV ±15%, in agreement with the calculation of Pirenne [11], who explained that E contains nearly equal contributions from the Fermi contact interaction and virtual single quantum annihilation of the triplet state. The latter is peculiar to an atom consisting of equal parts matter and antimatter.

A fourth paper, received February 6, 1952, was a precise determination of the positronium hyperfine interval by inducing microwave frequency resonant transitions between the m=0 and m=1 Zeeman-split triplet levels in a magnetic field. From the Breit-Rabbi formula Deutsch and Brown [12] deduced that the hyperfine interval is (203.2±0.3) GHz, and clearly shows the calculated radiative corrections that shift the line center approximately one line width [11,13]. This result was particularly significant because quantum electrodynamics (QED) had only been born a few years previously in the work of Feynman, Schwinger and Tomonaga.

These four experiments were reported within the space of 11 months. They measured, confirmed and reconfirmed the existence and properties of positronium, a new type of element for which countless uses have been found. This astoundingly prolific work was the crowning achievement of Deutsch's career, and he was only 35 years old. He went on to make a more precise measurement of the hyperfine interval, made precise measurements of positron annihhilation in flight [14], and attempted to form the excited states of positronium [15]. The latter experiment turned out to be too far ahead of its time because lasers and slow positron beams had not been invented yet. Instead, a Sn arc lamp was employed, and a small but not statistically very significant effect on the positronium formed in a gas was observed when it was excited at the expected 243 nm wavelength for 1S-2P transitions. In 1955 a positronium quenching experiment in which the magnetic field was reversed by his two undergraduate students P. M. Platzman and D. H. Levine brought him face-to-face with some evidence for the violation of parity conservation in beta decay just before the famous paper by Lee and Yang [16]. In 1956 Deutsch was nominated for, but did not receive, a Nobel award for his work on positronium. After the 1950's Deutsch switched his interests to high energy physics and most recently he was working on solar neutrino experiments with Raju Raghavan of Bell Labs [17-20]. I last saw him at my 60th birthday celebration at a Vietnamese restaurant in Cambridge, Massachusetts in October, 2000, where the candid photo displayed here was taken.

"My son, the philosopher"

These gems from the autobiographical writings of Martin Deutsch [1-3] speak for themselves:

Of MIT Professor George Harrison, Deutsch wrote, "It was Harrison's junior course in atomic physics that had the greatest influence on me. The course was totally disorganized, and seemed to consist of a series of scientific anecdotes or vignettes. Somehow this style kindled my enthusiasm, and I still charge many of the insights into physics and the creative process which I acquired there to this influence."

"I have always been a hard worker, but a lazy learner. Therefore, I naturally gravitated to the relatively new field of nuclear physics where there was much to do but not yet too much to learn."

"My attitude to prizes is peculiar, not clearly pathological but peculiar. I'm really glad that I did not get the Nobel Prize in 1956. It would have spoiled my life." He remembered an incident in the summer as a six year old, when the family spent a summer at a Baltic resort. A sack-hopping race had been organized for the children. He writes, "I was leading. I recall that I deliberately slowed down in order to come in second. The reasons for this action were quite complex but an oversimplified description could be that I did not want to give my mother the satisfaction of saying, 'My son, the sack race winner.'"

Epilog [21]

O Lucretious, Mendeleev, Dalton,
  Now hear: your periodic table's found
Column naught for atoms born of photons,
  Two anti-particles by Coulomb bound!
Youthful Martin Deutsch recieved a vision,
  Which his positron measurements made plain:
A new atom's quenching interaction
  Had startled him from sleep on midnight train.
Let all that speak of positronium
  Remember its discoverer Martin,
Precocious, generous, ingenious,
  Who "had not a shred of envy in him".
    Ye blest by daughters of Mnemosyne,
    Thus humble be, and use their gifts wisely.

References

[1] Biographical material taken from a news release prepared by Kenneth D. Campbell and posted on the MIT News Office web site, August 20, 2002.

[2] Autobiographical material from the δ-volume of *Adventures in Experimental Physics*, edited by Bogdan Maglich (World Science Education, Princeton, 1974) pp 64-127, "Discovery of Positronium", with original contributions by Deutsch and Vernon Hughes.

[3] Further autobiographical material may be found in Martin Deutsch's keynote address to the Sixth International Conference on Positron Annihilation, Arlington, Texas, 1982. [*Positron Annihilation*, edited by P. G. Coleman, S. C. Sharma and L. M. Diana (North-Holland, 1982) p 3-8.

[4] See the obituary for Martin Deutsch by V. L. Telegdi, *Physics Today*, October (2003) p 79-81.

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[20] G. Ranucci, et al., "Borexino", *Nuclear Physics B-Proceedings Supplements* **91,** 58-65 (2001).

[21] The quoted words are those of Martin Deutsch's wife, Suzanne, from Ref 1.