

30. The Jaynes-Franken Bet

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One of the central concerns of quantum optics, particularly the Rochester variety, has been the range of validity of semiclassical treatments of the interaction between light and matter. In the semiclassical theory the electromagnetic field is treated classically according to Maxwell's equations, while the matter is treated quantum mechanically according to Schrödinger's equation. Particularly intriguing was the question of whether spontaneous emission and the associated Lamb shift could be properly treated using classical fields.

This question was the subject of three lectures given at successive Rochester Coherence and Quantum Optics conferences in the 1960s and 1970s by Edwin T. Jaynes.¹⁷ Jaynes, who moved from Stanford to Washington University in 1962, supervised a number of students whose theses bore on the question. These students included Joseph Eberly and Carlos Stroud, current faculty members of The Institute of Optics. In 1967, at the second conference, Jaynes gave a lecture in which he outlined a semiclassical approach, which he called "neoclassical theory," in which the classical radiation reaction field of an emitting atom was allowed to act back on the atom. This theory led to nonlinear equations of motion for the atomic variables. Although he did not provide detailed solutions of the equations, Jaynes claimed that they should be adequate to treat spontaneous emission and the Lamb shift, two of the most notable successes of the fully quantized theory.

During the question period, Peter Franken of the University of Arizona stood to challenge Jaynes to actually carry out the detailed calculation of the Lamb shift using the theory that he had outlined. The challenge took the form of a bet: Franken offered to bet one



Peter Franken challenges Ed Jaynes with a bet that he cannot derive the Lamb shift without quantizing the electromagnetic field.

hundred dollars whether Jaynes could carry out the Lamb shift calculation during following ten years. Willis Lamb, who was in the audience, would be asked to hold the stakes and decide the winner. Furthermore, Franken was willing to take either side of the bet: Jaynes could bet that he could, or that he could not, do the calculation! Not too surprisingly, Jaynes accepted the bet that he could indeed do the calculation. Lamb agreed to hold the stakes and to invest it in Xerox stock—a very wise choice at the time. The bet was reported with accompanying photographs by David MacAdam in the October 1966 issue of the *Journal of the Optical Society of America*.¹⁸

The bet and surrounding controversy stimulated a great deal of work by Jaynes and his students and by others exploring the limits of semiclassical theory, and testing the predictions of neoclassical and related theories in various experiments. This work represented a large fraction of the work reported at the third conference in June 1972, when Jaynes made a progress report but did not either claim or concede the stake. The next coherence conference was held in 1977. By that time, Jaynes and his students had carried out calculations exploring most of the predictions of neoclassical theory.¹⁹ They found that indeed the theory predicted that an excited atom would spontaneously emit radiation with the proper decay constant, and that there was a radiative frequency shift which agreed at least semi-quantitatively with the Lamb shift of quantum electrodynamics. However, the dynamics of the theory was quite different from that of conventional theory. The decay of the atomic inversion was a hyperbolic tangent rather than exponential function of time, and the radiative frequency shift was also a time-dependent function, proportional to the inversion. Experimental tests of this dynamics by Hyatt Gibbs²⁰ and Stroud's group in Rochester²¹ did not support the new theory. Still, the theory had predicted a form of spontaneous emission and Lamb shift without field quantization, so that it was not clear which way Willis Lamb would decide the bet.

The session in which Jaynes reported his progress and Lamb announced the results was packed. Lamb expressed appreciation for Jaynes's progress on the problem but decided to award the stakes to Franken on the basis that Jaynes had not produced an accurate numerical value of the shift using semiclassical theory. Unfortunately, Lamb had forgotten to invest the stakes in Xerox stock so that Franken did not become a rich man on the basis of winning the bet.



Ed Jaynes gives Willis Lamb the \$100 for his stake in the bet.



Willis Lamb agrees to decide the winner of the bet.

It is interesting to note that in his article in the proceedings of the conference, Jaynes cited the experiment of Clauser²² on Bell's inequalities, and said that if the results reported there were correct, that all his work on alternatives to quantum electrodynamics would "go down in flames." Indeed those results have been verified and extended, but the bet and the research that it stimulated played an important role in the history of the Rochester conferences and of quantum optics in general.