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This Week's Citation Classic®

Fano U & Cooper J W. Spectral distribution of atomic oscillator strengths. *Rev. Mod. Phys.* 40:441-507, 1968; and **Fano U & Cooper J W.** Addendum: spectral distribution of atomic oscillator strengths. *Rev. Mod. Phys.* 41:724-5, 1969.
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These papers describe basic concepts, experimental data, and their theoretical interpretation on the response of atoms to electromagnetic radiation extending from the optical to the X-ray range. Their material had been developed largely in the 1960s, but the papers remain of value as basic references on the subject. [The *SCI*® indicates that these papers have been cited in over 715 and 40 publications, respectively.]

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The concept that matter responds to electromagnetic radiation like an assembly of electron oscillators with a very broad spectrum of characteristic frequencies dates from H.A. Lorentz's electron theory of matter, developed at the turn of the century. In the 1950s the exploration of this spectrum by experimental determination of its "oscillator strengths" left major gaps, especially in the frequency range between the optical and X-ray regions, owing to difficulties in absorption measurements. This latter gap challenged me, as chief of the National Bureau of Standards (NBS) Radiation Theory Section at that time.

My friend Robert Platzman, later to be a University of Chicago colleague, stressed that experiments in the gap hinged on the use of synchrotron light sources, which had been demonstrated at Cornell University by D.H. Tomboulian and P.L. Hartman. He and I then started to encourage new source developments and applications at Cornell, Johns Hopkins University, and Florida State University. On the theory side I enlisted J.W. Cooper to do extensive model calculations of photoionization and discrete oscillator strengths in the far ultraviolet, which proved seminal.

A decisive step resulted from L.M. Branscomb's initiative in attracting R.P. Madden and K. Codling to use the NBS synchrotron as a light source in the gap region, from about 10 eV to 100 eV photon energy, for absorption measurements. Their very first spectrum revealed unexpected phenomena in helium,[1] soon interpreted theoretically,[2] thus opening up a rich field of research. Independently, A.P. Lukirskii's group in Leningrad had penetrated the same spectral range by skilled extension and application of X-ray techniques to longer wavelengths. By the mid-1960s the field literally exploded, with the help of concurrent developments in the field of electron spectroscopy. Synchrotron light sources soon multiplied and the major gaps in our knowledge of oscillator strength distributions were filled.

By 1965 Cooper and I felt our newly acquired knowledge to have gelled sufficiently to start preparing a comprehensive report, whose draft served as a text for my first course at Chicago in 1967. A curious incident occurred during its final revision early in 1968: a particular item, which I was reading casually, struck me as germane to a remark on spin-orbit coupling by J. Kessler. From this resulted a procedure to select spin-polarized electrons[3] that has since received wide application.

In our papers we tried not only to survey the theoretical and experimental information then available on oscillator strength distributions, but also to set up a theoretical framework for their analysis. This framework found application in molecular and solid-state physics and encompassed later theoretical treatments. The articles appear to be widely quoted within this context.[4,5]

While our reports dealt only with single atoms, their implications for molecules and solids were apparent. Molecular spectroscopy in the vacuum ultraviolet was developed at NBS in parallel with the synchrotron light work;[6] its procedures have been refined greatly, principally by W.A. Chupka and J. Berkowitz,[7] and their use remains a useful tool of molecular photoionization research.

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1. **Madden R P & Codling K.** New autoionizing atomic energy levels in He, Ne, and Ar. *Phys. Rev. Lett.* 10:516-8, 1963. (Cited 230 times.)
2. **Cooper J W, Fano U & Prats F.** Classification of two-electron excitation levels of helium. *Phys. Rev. Lett.* 10:518-21, 1963. (Cited 145 times.)
3. **Fano U.** Spin orientation of photoelectrons ejected by circularly polarized light. *Phys. Rev.* 178:131-6, 1969. (Cited 160 times.)
4. **Dehmer J L, Dill D & Parr A C.** Photoionization dynamics of small molecules. (McGlynn S P, Findley G L & Huebner R H, eds.) *Photophysics and photochemistry in the vacuum ultraviolet.* Dordrecht, Holland: Reidel, 1985. p. 341-408.
5. **Yeh J J & Lindau I.** Atomic subshell photoionization cross sections and asymmetry parameters: $1 \leq Z \leq 103$. *At. Data Nucl. Data Tables* 32:1-155, 1985. (Cited 75 times.)
6. **Dibeler V H & Walker J A.** Mass-spectrometric study of photoionization. VI. O_2, CO_2, COS, and CS_2. *J. Opt. Soc. Am.* 57:1007-12, 1967. (Cited 115 times.)
7. **Berkowitz J.** *Photoabsorption, photoionization, and photoelectron spectroscopy.* New York: Academic Press, 1979. 469 p. (Cited 185 times.)