Nozières P & De Dominicis C T. Singularities in the X-ray absorption and emission of metals. III. One-body theory exact solution. *Phys. Rev.* 178:1097-107, 1969. [Univ. California, San Diego, CA and Lyman Lab., Harvard Univ., Cambridge, MA]

This paper is concerned with absorption (emission) X-ray spectra near the Fermi level threshold. The transition creates (destroys) a hole in the atomic core, which yields a transient one-body scattering potential on the conduction electrons. The latter must rearrange to meet this new configuration—hence singularities near threshold. The problem is solved exactly using Green's functions in a time representation. [The *SCI*® indicates that this paper has been cited in over 485 publications since 1969.]

P. Nozières
Institut Max Von Laue—Paul Langevin
156 X—38042 Grenoble
France

February 21, 1984

"Theoretical research is supposed to proceed in a logical way: in a clearly set problem, more and more elaborate approaches are expected to give better and better answers. My paper with Cyrano de Dominicis on threshold singularities in X-ray spectra is a typical counterexample in which significant results emerged rather fortuitously through a very devious route. Neither of us was concerned with X-rays. In the fall of 1967, I noticed a paper by G. Mahan,[1] pointing out the existence of logarithmic singularities in metallic spectra at the Fermi level threshold. At that time, I was interested in one-dimensional conductors, and I had been striving my way into the summation of fancy 'parquet' diagrams introduced by the Soviet school. I immediately recognized the formal analogy with Mahan's problem, and I embarked into elaborate perturbation theory, together with B. Roulet and J. Gavoret, who were working with me at the University of Paris. Shortly afterward, I moved to La Jolla for a six-month visit. There I developed an unbelievably intricate self-consistent summation procedure (which actually was the first step beyond parquet diagrams in a renormalization group analysis—a point I realized only much later). I was very proud of myself at having sorted out so many diagrams.

"I then went to give a seminar at Harvard University, where I had been invited by P.C. Martin. There I met Cyrano, who was an old friend of mine, but with whom I had never worked, despite the fact he was in Saclay, only 15 miles from Paris. There we were across the ocean in Paul's office. Our real concern was not with physics but with students rioting in Paris, then raging: should we return or not? Between two news broadcasts, I tried my brand new many-body theory on my hosts. They were impressed—but Cyrano kept saying it was too complicated: after all, I was considering the final state interaction of *one* electron with an impurity: it should be a one-body problem. Of course, I defended my algebra with vigor—but in the end, I had to admit he was right: our problem was indeed a transient one-body problem.

"The whole discussion took less than two hours. Then Cyrano returned to Paris, and I went back to La Jolla. There, I quickly realized I should work in real-time space and use a long-time approximation. Digging into ancient knowledge in Muskhelishvili's book[2] on singular integral equations, the work was over in two weeks.

"In the end, thanks to Cyrano's seminal idea, we had a far simpler, far more general treatment. The work had proceeded in a totally illogical way, from complicated many-body theory to simple time dependent one-body phenomena. Our collaboration was accidental: we are still close friends—but we have never worked together again.

"Depending on parameters, we predicted enhanced or reduced X-ray absorption near threshold. Our theory was asymptotic, and what was meant by 'near' was not specified. As a result, a long controversy on experimental implications developed, in which neither Cyrano nor myself took part, but which may explain why the paper was so often quoted. I prefer to imagine that people enjoyed the introduction of perturbation theory in real-time space in order to deal with logarithmic singularities, a method which was to be used shortly afterward for the Kondo effect by Anderson, Yuval, and Hamann.[3] But who knows? Had we sorted out the cutoff problem more precisely, maybe the paper would have caused far less controversy—and therefore less attention.

"Mahan[4] and von Barth[5] have recently published papers on this subject."

1. **Mahan G D.** Excitons in metals: infinite hole mass. *Phys. Rev.* 163:612-17, 1967. (Cited 280 times.)
2. **Muskhelishvili N I.** *Singular integral equations.* Groningen, the Netherlands: P. Noordhoff N.V., 1953. 447 p.
3. **Anderson P W, Yuval G & Hamann D R.** Exact results in the Kondo problem. II. Scaling theory, qualitatively correct solution, and some new results on one-dimensional classical statistical models. *Phys. Rev. B* 1:4464-73, 1970. (Cited 115 times.)
4. **Mahan G D.** Core-hole Green's function: dispersion theory. *Phys. Rev. B* 25:5021-31, 1982.
5. **von Barth U & Grossmann G.** Dynamical effects in X-ray spectra and the final-state rule. *Phys. Rev. B* 25:5150-79, 1982.

