This Week's Citation Classic®

We explained circumstances under which quantum-mechanical scattering can be analyzed using semiclassical methods and showed how to correlate classical and quantum results when special features such as interference, rainbow scattering, or glories are present. [The *SCI*® indicates that this paper has been cited in more than 555 publications.]

New Light on the Correspondence Principle

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For 60 years I have been a pilgrim through the world of quantum mechanics. This paper, written in the middle of that pilgrimage, is of a practical bent.

Since my postdoctoral year with Gregory Breit at New York University in 1933-1934,[1] had been fascinated by scattering theory. (When Richard Feynman was working on his dissertation, "The Principle of Least Action in Quantum Mechanics," in 1942, we liked to say, "Everything is scattering.") Since a second postdoctoral year with Niels Bohr in 1934-1935,[1] had been equally fascinated by the correspondence principle— the deep and mysterious relationship between classical and quantum physics.

These threads of interest came together in the 1959 paper, the seeds of which go back to my first effort to try to untangle information on forces from information on scattering.[1] More proximate triggers of interest were courses I taught at Princeton in the 1950s, on classical mechanics and relativity. The classical mechanics course gave me a chance to think more about waves and particles in the prequantum world. After taking the course, Kenneth Ford calculated classical and quantum cross sections for scattering of one magnetic monopole by another, an example that we later used in a follow-up to this paper. The relativity course led me to think more about quantum mechanics in extreme situations (such as in a neutron star), which added to my armory of weapons to attack quantum-mechanical problems.

One other thread is optics. I learned about rainbows and glories from the master showman Robert W. Wood when I was a graduate student at Johns Hopkins. Years later, as a visiting Lorentz Professor at Leiden in 1957,[1] was able to talk with H.C. Van de Hulst, whose book on light scattering,[2] published that year, was an inspiration.

It is easy to have more ideas bubbling in one's brain than can ever be exploited. For this work I was fortunate to round up Ford as a colleague. He was then a junior faculty member at Indiana University and had been my PhD student (as well as my classical mechanics student) at Princeton. Like me, he enjoyed burrowing behind the formalism to understand what was really going on, and he worked at presenting things clearly, in both words and graphs.

We had fun correlating classical and quantum behavior in scattering, and before long had produced a series of three papers. The first, with coauthors D.L. Hill and M. Wakano, explored special features of barrier penetration. The second (the one under discussion here) provided general methodology for semiclassical analysis of scattering, emphasizing some phenomena, such as rainbow scattering and the glory effect, that were also known in optics. The third showed, through examples, that the methodology was not just a mathematical exercise but had practical value. Since then, many workers have found numerous other applications.

We sent the papers as a group to *Physical Review*. The letter of rejection from then-editor Sam Goudsmit was polite, almost apologetic. The papers were too long, he said, and too pedagogical. Instead of getting out the scissors and glue that would have been needed to meet the *Physical Review* requirements, we sent off the papers to the relatively new journal *Annals of Physics*. They were promptly published.

Ford tells me that the requests he received for reprints of our methodology paper exceeded the requests for all of his other papers combined. So we knew, even before we learned that our paper is a *Citation Classic*", that it had been found to be useful and interesting to people working in many fields. In retrospect, the interest is perhaps not so surprising. There is many an example in nuclear, atomic, and molecular physics—and even in particle astrophysics[3]— where semiclassical methods are the best way to gain insight into the forces at work in collision phenomena.[4]

This is not a profound paper. It is workaday physics. But it is pleasant to know that it has found wide application.[5]

l. **Wheeler J A**. Interaction between alpha-particles (abstract). *Phys. Rev.* 45:746, 1934.
2. **Van de Hulst H C.** *Light scattering by small particles.* New York: Wiley, 1957. 470 p. (Cited 2,700 times.)
3. **Anninos P, DeWitt-Morette C, Matzner R A, Yioutas P & Zhang T R.** Orbiting cross sections: applications to black hole scattering. *Phys. Rev. D*46:4477-94, 1992.
4. **Schleich W & Wheeler J A.** Oscillations in photon distribution of squeezed states and interference in phase space. *Nature* 326:574-7, 1987.
5. **Knoll J & Schaeffer R.** Semiclassical scattering theory with complex trajectories. *Ann. Phys. NY* 97:307-66. 1976. (Cited 140 times.)
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