photographic emulsion technique was considered old-fashioned by that time; everyone was using modern bubble and spark chambers and large counter arrays backed up by computers. Also, particle physicists had shifted away from cosmic rays and were using accelerators. Finally, the theoretical interpretation of the effect called for new ideas, and few people were willing to accept it on the basis of evidence from a single scientist.''

During the early 1970's, Judek exposed a stack of photographic emulsion plates in the University of California's ''Bevalac'' accelerator which had recently been upgraded to accelerate heavy nuclei like oxygen. Putting the stacks into a beam of fast oxygen is akin to cosmic ray exposure. Sure enough, the results from Bevalac confirmed Judek's earlier cosmic ray observations. Despite reporting these results to a European conference on cosmic rays in 1975, she received little response from other scientists in the field. No real attempt was made by the international physics community to confirm or disprove her anomalous effect.

But Dr. Judek persisted in her conviction that anomalous nuclei really existed and were not simply an experimental misinterpretation or statistical fluctuation. Realizing that she needed support from more prestigious scientists, in 1979 she wrote about the effect to a colleague in California's Lawrence Berkely group. Her letter jogged the memory of one of the group's physicists, E.M. Friedlander, who recalled once having seen a few similar puzzling events in a stack of cosmic ray plates — possibly Judek's effect really did exist.

The California group decided to take a serious look for the effect with their particle accelerator in which they exposed emulsions to high speed iron nuclei. After carrying out observations on over 700 events (both normal and anomalous) they were satisfied that the anomalous effect was, indeed, there. The California results, in combination with those of Dr. Judek who had by then observed an equal number of events in the earlier Bevalac plates, confirmed the effect at a very high level of confidence (99.7 per cent). With the joint publication of their work in a September, 1980 issue of *Physical Review Letters* (see references), the U.S. and Canadian labs announced the Judek effect to the world, and 15 years of patient determination were rewarded.

The joint paper proved a challenge to theoretical physicists who were forced to explain how a super-collisional nucleus could exist. Examination of the results indicated that while a Judek nucleus is ten times more reactive than normal it is composed of quite ordinary elementary particles. After drawing a blank with a number of conventional explanations, two theoreticians at Carleton University in Ottawa came up with a model which could well explain the anomalous results.

The details of Drs. William Romo and Peter Watson's theory are mathematical but a simple analogy may help. A person swinging a rolled umbrella finds little difficulty walking along the street, but if he swings an open umbrella he is in danger of colliding with passers-by. The umbrella's composition is exactly the same on both cases — fabric, handle and ribs. The only difference is that in the latter case the ribs have been spread out so that the umbrella offers a larger target.

Romo and Watson assumed that nuclear material (like protons and neutrons) is composed of quarks, the elementary building blocks of matter. Their theoretical investigations showed them that a previously unexpected nuclear state could exist in which these particles would be spread out in space. Preliminary calculations indicate that such a nucleus would leave an otherwise normal track on a photographic plate except that it would become involved in far more collisions than usual. The two theoreticians speculated that an extended Judek nucleus would sometimes be formed when a cosmic ray primary hits a normal nucleus in a photographic emulsion.

For theoretical physicists, these extended nuclear states open a new range of exciting possibilities, such as negatively charged nuclei and structures which are mirror twins of each other. But the real test of the theory will come after more detailed experiments are carried out in the production of Judek nuclei using elementary particle accelerators.

What began as the observation of a curiosity on a photographic plate could well blossom into an exciting new investigation of nuclear matter. Many scientists would have dismissed that first anomalous result but, thanks to Barbara Judek's persistence, we are learning something new and unexpected about how nature works at the sub-microscopic level. □

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For further reading

Freidlander, E.M., Gimpel, R.W., Heckman, H.H., Karant, Y.J., Judek, B., and Ganssauge, E. Evidence for Anomalous Nuclei among Relativistic Projectile Fragments from Heavy-Ion Collisions at 2 GeV/Nucleon. *Physical Review Letters*, Vol. 45, No. 13. 29 September 1980.

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