

# search & discovery

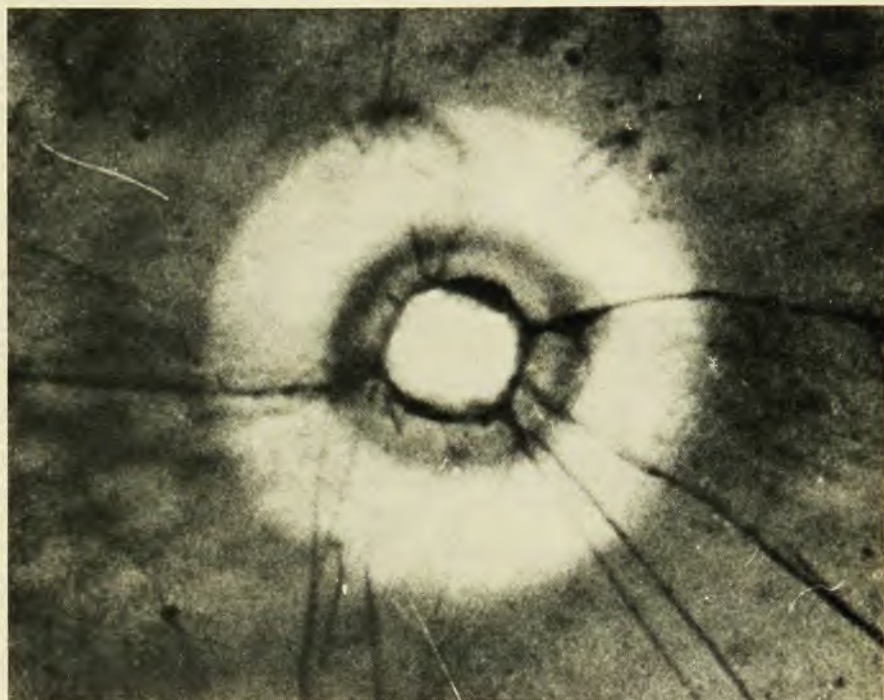
## Mica giant halos suggest natural superheavy elements

Evidence for the existence of element 126 and possibly numbers 116, 124 and 127 has been found in several mica samples from Madagascar, implying that these superheavy elements or their parents have been present since the Earth was formed. Most recent theoretical work had predicted an island of stability centered around element 114.

The announcement was met with surprise, excitement and a large measure of skepticism. If true, the observation is bound to have a sizable impact on many fields, but it is too early to be sure of its validity.

The new experiment was reported in a postdeadline paper on 17 June at the Quebec meeting of The American Physical Society, the Canadian Association of Physicists and the Sociedad Mexicana de Fisica by a group consisting of Robert V. Gentry (Oak Ridge National Laboratory and Columbia Union College), Thomas A. Cahill (University of California at Davis and Florida State University), Neil R. Fletcher, Henry C. Kaufmann, Larry R. Medsker, J. William Nelson (Florida State) and Robert C. Flocchini<sup>1</sup> (University of California at Davis). If the new

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**Giant-halo inclusion 19D**, when bombarded with low-energy protons and x-ray analyzed, showed evidence for the presence of a number of superheavy elements (see figure, page 19). The monazite crystal in the center of the mica sample is approximately 60 microns in diameter.

## Colliding-beam data offer evidence for charmed particle

Probably the most convincing evidence for charm yet produced is a new resonance found at SLAC in electron-positron interactions. The particle, of mass  $1865 \pm 15$  MeV, decays into hadrons—either into one kaon and one pion or one kaon and three pions. Many believe that the new particle consists of a bound state of a charmed quark and an uncharmed quark so that it has a net charm. Skeptics of the charm hypothesis would be more convinced if electron-positron annihilators would also observe lepton production, as the charm theory predicts.

The discovery, announced in press releases from SLAC and ERDA early in June, was made by the same SLAC-Lawrence Berkeley Laboratory magnetic-detector group<sup>1</sup> that found the long-lived  $\psi$  particle in November 1974 at the same time as an MIT-Brookhaven group, headed by Samuel C. C. Ting, reported the  $J$  particle. The  $\psi/J$  at 3.1 GeV has been interpreted by charm propo-

nents as charmonium, a bound state of a charmed quark and a charmed anti-quark.

About a year ago, experimenters found that when the center-of-mass energy of SPEAR, the SLAC colliding-beam device, was raised above 4 GeV, hadron production increased markedly. However, preliminary searches to uncover the nature of possible new particles were unsuccessful. When more data became available, Gerson Goldhaber (LBL) and Francois Pierre (at LBL on leave from Saclay) found evidence for the resonance at 1865 MeV. Unlike earlier analyses, this time the SLAC-LBL experimenters used time-of-flight information to help identify hadrons.

Among 29 000 hadronic events collected at center-of-mass energies between 3.90 and 4.60 GeV, they found signals consisting of roughly 100 events that were either a charged  $K$  and a single charged  $\pi$  or a charged  $K$  and three charged  $\pi$ 's in

both cases forming a neutral combination. Masses for the  $K\pi$  signal center at 1870 MeV/ $c^2$ ; those for the  $K3\pi$  signal center at 1860 MeV/ $c^2$ . The SLAC-LBL group believes both signals are consistent with being decays of the same state. They deduce an upper limit of 40 MeV/ $c^2$  for the decay width of the state. Unfortunately, the group is unable to determine the actual lifetime of the state. If it were a charmed meson, its lifetime would be expected to be about  $10^{-13}$ – $10^{-14}$  seconds.

**The concept of charm**, which requires a fourth quark, was introduced originally on symmetry considerations by J. D. Bjorken (SLAC) and Sheldon Glashow (Harvard University) and also by Y. Hara (Tokyo). Later Glashow, John Iliopoulos (Ecole Normale Supérieure) and Luciano Maiani (Istituto di Sanita, Rome) used charm in a theory of weak interactions.

In 1974, soon after the discovery of the  $\psi/J$ , many theorists predicted masses for

clearer, with just one or two gaps remaining to be filled. —GBL

## References

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## Mica giant halos

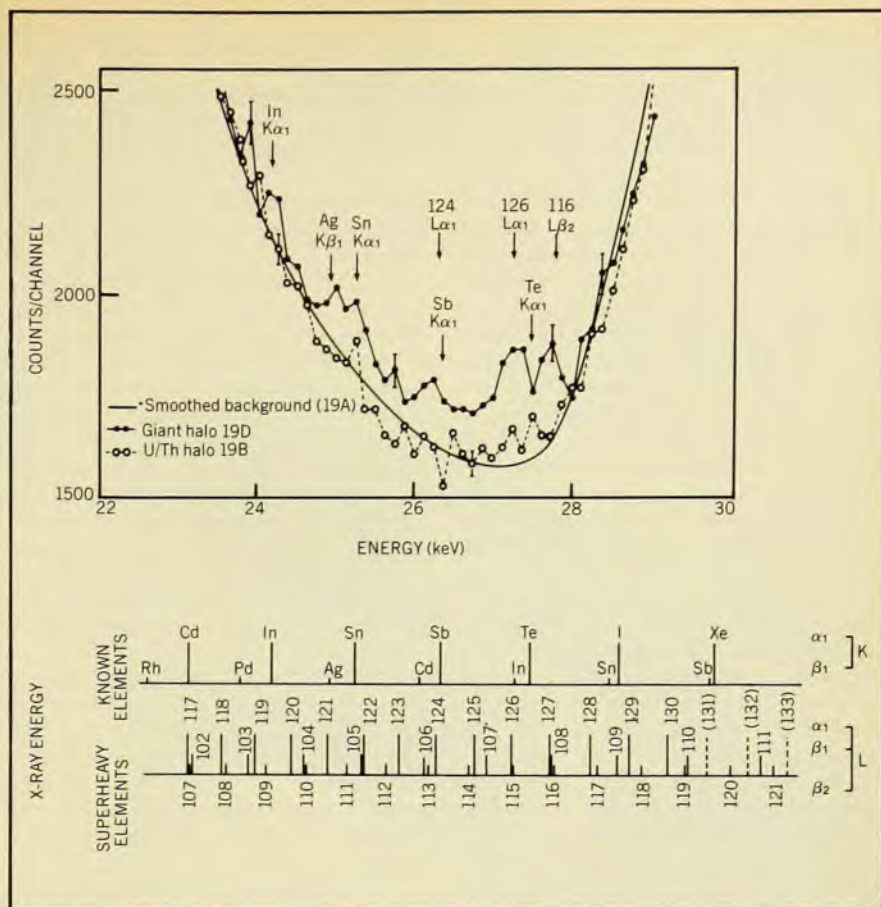
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superheavies hold up, they would be the first primordial elements found that are heavier than plutonium (which was reported in 1971 as occurring in a rare-earth mineral bastnasite by Darleane Hoffman<sup>2</sup> of Los Alamos and her collaborators). Manmade elements have gone as high as element 106 with the 1974 announcements by Albert Ghiorso, Glenn Seaborg and their collaborators at Lawrence Berkeley Laboratory and by Georgi Flrov and his collaborators at the Joint Institute for Nuclear Research, Dubna, USSR.

Previous evidence for superheavy elements has come from meteorites. Last December Edward Anders (University of Chicago) and his collaborators described evidence<sup>3,4</sup> that a volatile superheavy element (115, 114 or 113) may have been present in a rare chromium mineral when the Allende meteorite was formed. Their main clue was an apparently fission-produced xenon component, first seen in meteorites in 1964 by John Reynolds (Berkeley). In 1974 A. G. Popeko (Dubna) had detected possible neutron emission from large (10–20 kg) samples of Allende and two other primitive meteorites, suggesting the presence of a superheavy element.

**Experiment.** For fifty years or so, the existence in transparent materials (such as mica) of inclusions, each surrounded by a halo, had been known. The inclusions turned out to be minerals containing thorium and/or uranium, whose alpha decay caused the halos. For the past seven years Gentry has been studying mysterious giant halos, which are 100–150 microns in diameter; these halos did not appear to be caused by thorium or uranium decays because the required alpha energies were as great as 14 MeV. Many of the giant halos are believed to be caused by chemical interactions, but not all.

Recently Gentry enlisted the cooperation of the Davis and Florida State ex-



**Comparison x-ray energy spectra showing evidence for the presence of superheavy elements.** The top figure contains spectra for two inclusions from the same mica chip: giant-halo inclusion 19D and uranium–thorium inclusion 19B. The figure below is the x-ray energy scale.

perimenters, who decided to bombard the mica samples with low-energy (4.7–5.7 MeV) protons from the Florida State Tandem Van de Graaff (the beam had an effective diameter of about 30 microns) and look for characteristic x rays from elements between  $Z = 105$  and  $Z = 134$ . Cahill had noticed that an approximate x-ray window exists in the spectrum between the last L transitions of uranium, 21.54 keV, and the first K transitions of the rare earths, 33.03 keV.

The inclusion in the center of the giant halo is a monazite crystal [(Ce,La,Th) PO<sub>4</sub>], which has a chemical affinity for rare earths, actinides and presumably superactinides so that other elements in the rhodium to cesium range should be present at most in only trace amounts, they argued.

Predictions of the superheavies' x-ray spectra had been made in 1969 and 1971 by Thomas Carlson (Oak Ridge) and his collaborators, who made use of a relativistic atomic wave-function program and included secondary relativistic effects by means of an experimental extrapolation. Carlson recently reevaluated his calculation and believes it is good to 50 eV.

Another reason the experimenters used the L x rays, instead of K x rays, is that the cross section for K-vacancy production is down by several orders of magni-

tude relative to L-vacancy production.

The experimenters examined six inclusions with giant halos, five of which were removed from the halo, and compared the results with measurements on uranium–thorium halos, giant halos with inclusions removed, and so on.

Evidence for element 126 is most convincing, the group says, because structure at 27.25 keV is found in five out of the six crystals studied, the mean deviation from the calculated energy is only about 10 eV, and there are no other known alternatives for that line. The line at 27.73 keV, on the other hand, could be attributed to the L<sub>β2</sub> line of element 116 or the L<sub>α1</sub> line of element 127. Evidence for element 116 is based upon the simultaneous presence of both the L<sub>α1</sub> and L<sub>β2</sub> transitions. But the intensity ratio is a factor of four different from predictions. Accordingly, the experimenters believe the line is more likely to be from the L<sub>α1</sub> transition in 127. The evidence for element 124, near 26.30 keV, is less strong, the group feels, because of the possible presence of an antimony line. In addition they see some weak structure suggesting element 114 or 125 from some of the inclusions. The experimenters quote an x-ray line stability of 9 eV with an absolute accuracy of 20 eV.

The experimenters had gained six or-

ders of magnitude by having the giant halos there, acting as beacons, so to speak, with the mica serving as an ideal particle detector. The inclusions had to be removed from the mica in order to see the characteristic x rays; otherwise, background was too high. The giant halos themselves are very rare, Gentry told us. Out of the thousands of mica samples he examined, there is only one that contains giant halos. He has about a dozen of the giant halos that have not been bombarded, which are apparently caused by radioactive decay. Gentry said that if one assumes that all the superheavies are in the crystal, only 1 part in  $10^{12}$  of the bulk material would presumably contain superheavies.

**Objections.** The elemental composition of the inclusions appears to vary from sample to sample, Fletcher notes, so that the elements present are not radiogenetically connected; that is, 125 is not totally produced from the alpha decay of 126. Ghiorso, too, points out that the elements are not likely to be separated in geological time in the same batch of ore. He observes that if superheavies are decaying in the sample, he would expect a series of rings, which are not seen. Another prominent experimenter wonders why certain L x rays are seen, but not others; the complete fingerprint is missing. Fletcher notes that all other lines are either too weak to be observed or they are obscured by x rays from known elements. Although the  $\chi^2$  fits tend to be better if one assumes superheavies, K x rays from other elements are very close in energy. Another possibility is a gamma ray from some contaminant.

**Potentialities.** The mass of superheavy elements present in monazite inclusions showing giant halos could be as much as several hundred picograms, the group says. With as much as  $10^{10}$  to  $10^{12}$  atoms, one might hope to do mass spectroscopy. Another possibility is to do high-resolution x-ray spectroscopy that is wavelength-dispersive instead of energy-dispersive.

Some theorists have predicted that the superheavy elements might be very fissionable, and might yield more than 10 neutrons per fission. (For comparison  $U^{235}$  gives 2.4 neutrons per fission.) If the superheavies in the monazite are indeed fissionable, by bombarding the sample with neutrons, one could observe a torrent of fission neutrons.

Seaborg notes that if the half-life is roughly  $10^9$  years, the small samples available would not give good radiochemistry results because the decay rate would be too small. If one were perspicacious, however, Seaborg believes one could do wet chemistry.

If element 126 exists and one has  $10^{12}$  atoms, even with a half-life of  $10^9$  years, the alpha particles should be emitted with such a high energy that they would be easily distinguished from any back-

ground, another noted experimenter observed.

Ghiorso would like to obtain a monazite inclusion for himself, bombard it and look for still more varieties of superheavies.

The Florida State-Davis experimenters hope in the next few weeks to study a small chromite sample from the Allende meteorite by proton bombardment and subsequent x-ray spectroscopy.

**Theory.** Before 1966, theoretical thinking on superheavies predicted that a closed shell would occur at  $Z = 126$ , in analogy with lighter nuclei, where both protons and neutrons exhibit the same magic number. However, subsequent analysis predicted that a whole island of stability would occur in the region of  $Z = 114$  and  $N = 184$ , where the shell is doubly closed. This stability occurs because certain shell effects are included that essentially increase the nuclear force to a point where it dominates coulomb repulsion.

The new generation of heavy-ion accelerators has been built in part out of hope that new superheavies could be made. Searches in nature have largely concentrated on searching for a superheavy by assuming that it follows the chemistry of the lower homologue and decays by spontaneous fission.

If the interpretation of the experiments at Florida State includes element 116, two islands of stability would be required, Seaborg notes—one at element 114 and one at element 126. In between the two islands, elements would be more unstable.

A group of theorists at Florida State, Fred Petrovich, Donald Robson, John Philpott, Joseph Bevelacqua, Mickie Golin and Douglas Stanley, have extended shell-model calculations to higher values of  $N$  than most other workers and say they have found that for both the combinations  $Z = 114$  and  $N = 184$  and  $Z = 126$  and  $N = 228$ , one would obtain good stability for both alpha and beta decay. They also note that the high-energy alpha particles associated with the giant halos do not appear to come from the elements identified in the experiment, which might imply the presence of still heavier elements. Last year A. Sobczewski and A. Lukasiak (Institute for Nuclear Research, Warsaw) had speculated on a shell closure at  $N = 228$  but had not focused on  $Z = 126$ .

Element 126 would be a superactinide, a chemical group obtained by filling the 5g and then the 6f shells, beginning at  $Z = 122$  and going to 153. Presumably the superactinides should be found in rare-earth minerals, Seaborg remarked. The chemistry of element 126, Seaborg said, would probably not be exactly analogous to plutonium, although plutonium would be a close relative.

Obviously a lot more experiments must be done to convince the physics community that relatively stable superheavy el-

ements have been found. But if superheavies are primordial, we will have to revise our thinking about astrophysical element formation, nuclear theory and chemistry. —GBL

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## Fermilab accelerator reaches 500 GeV . . .

On 14 May the Fermilab accelerator reached 500 GeV,  $2\frac{1}{2}$  times greater than the original design energy of the accelerator. The machine had been operating normally at 400 GeV for some time, an energy just reached by the CERN Super Proton Synchrotron on 17 June. At 500 GeV Fermilab continues to have the highest-energy accelerator in the world.

The energy increase from 400 to 500 GeV was made possible by several improvements in the accelerator power supply. Among these were a few primary transformer, a capacitor tree for better matching the accelerator load to the incoming electrical line, new high-voltage feed lines and improvements in the magnet cooling systems.

## . . . and the CERN SPS hits 400 GeV

The CERN Super Proton Synchrotron reached its design energy of 400 GeV on 17 June. Testing began with extraction of a 100-GeV beam on 5 April. One month later, on 3 May, the beam was injected and moved around the circumference without being accelerated. On 26 May, protons were accelerated to 80 GeV, and on 4 June to 200 GeV.

With 400-GeV energy, the SPS is the accelerator with the second highest energy in the world. Fermilab, with 500 GeV, has the highest. The third highest energy is produced by the 76-GeV proton synchrotron at Serpukhov, USSR.

## in brief

The National CTR Computer Network for controlled-fusion research has begun operation, centered at Lawrence Livermore Laboratory, under the direction of John Killeen.