coming from that direction, and if the crew still saw flashes, it probably could not be from the highly directional Cerenkov effect. Another experiment is designed to narrow the search. The astronauts will put pressure on the eye, keeping signals from passing from the eye to the brain. If the flashes continue, the stimulus is coming from some place other than the retina: impact on the optic nerve itself, for instance.

The value of astronaut observations of these flashes, explains Dr. Barnes, is manifold. "One big problem is that people do not take radiation seriously. Now that its effects can be seen, and the crew can count them, we can correlate the frequency with the incident-rate recorded on the dosimeters."

What is known to date about astronaut exposure comes largely from several dosimeters, or radiation measurement devices that fly on each trip to the moon. One such device is the film badges that the men wear on their ankles, thighs and chests. Dr. Herman Schaefer of the School of Aerospace Medicine at Pensacola, Fla., has examined the microscopic pictures, which show tracks made by light radiation particles, and the huge swaths cut by the heavy, high-energy particles. From this, NASA officials report the incidence of high-energy particles is about five to six times as high as was expected, but still within what they say is a safe dosage.

Impelled by the now dramatic evidence of astronaut exposure, NASA is also pressing toward a broader, earth-bound experimental program in an effort to anticipate and forfend trouble.

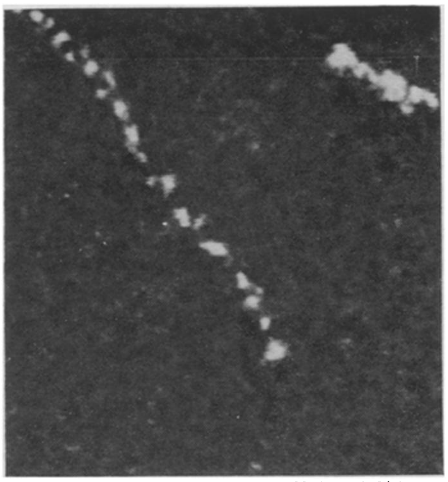
Since the particles are unique to the space environment outside of the earth's magnetic field, they can be studied only with accelerators on earth. "What we really need is one such accelerator," says Dr. Barnes. NASA and the Atomic Energy Commission are currently exploring the possibility of redesigning or modifying an existing accelerator for this purpose. The University of California at Berkeley currently has a proposal before the AEC for modifications to its heavy ion linear accelerator, which could fill the bill.

When the decision is made on the accelerator, it would still take up to five years to accomplish modifications and the particle experiments with human tissue. Space officials who are now studying estimated radiation doses for long-duration interplanetary and space station flights believe that knowledge of the heavy particle effects will be obtained before such flights occur.

For the shorter Apollo flights still scheduled, NASA officials are less concerned about the effects of the heavy ion radiation. Continuing tests on the Apollo astronauts who have gone to the moon have turned up no ill effects of the radiation. □

ELECTRON MICROSCOPY

Individual atoms photographed



Univ. of Chicago

Thorium atoms: A microscopic first.

"There is," said Dr. Albert Crewe in 1964, "no law of nature that says you cannot look at an atom."

Last week, the University of Chicago physicist reported that he has done just that. Using an electron microscope designed and built in his own laboratory, Dr. Crewe, with graduate students Joseph Wall and John Langmore, took pictures of single uranium and thorium atoms that had been hooked to a standard laboratory chemical called benzene-tetracarboxylic acid. Their unique technique, which enabled them to take what are considered to be the first verifiable photographs of individual atoms, paves the way for new studies of the structure of biological molecules, including chromosomes and aberrant cells.

At present, X-ray crystallography is the preferred method of determining the molecular architecture of biological materials. It has been employed successfully in deciphering the three-dimensional structure of some dozen proteins, but it has limitations. A major handicap lies not with the technique itself, but with the fact that it requires crystallization of the sample; scientists have thus far been unable to grow crystals of a number of biological substances, including DNA.

Says Dr. Crewe, "DNA is such a long sloppy molecule it is extremely difficult to crystallize. We can, and are, examining it with our microscopes without having to worry about crystallization." He speculates that in one or two years he and his colleagues will determine the sequence of the component bases in DNA. This will reveal the precise order of bases in an entire molecule much the way scientists now sequence the amino acid order of proteins. According to Wall, base sequence up to now has been determined only for very small portions of DNA molecules. "We hope to expand on a technique originated by Dr. Michael Beer at Johns Hopkins for tagging each of the four bases with specific heavy atoms," he says. Some of the necessary chemistry is in hand.

Already, Dr. Beer has shown that a compound of osmium, with atomic number 76, reacts preferentially with thymine, one of the four DNA bases. When the chemistry of attaching other specific heavy atoms to the remaining three bases is worked out, the researchers will be able to identify the sequence of those bases by detecting the appropriate heavy atom under the electron microscope.

The Crewe microscope, which can be reproduced for an estimated cost of $150,000, has several distinguishing features. Its electron source is a tiny tungsten point 30 angstroms across that operates in an extremely high vacuum. "This electron source," says Dr. Crewe, "is the smallest which is known and enables us to produce a very small focused spot of electrons on the specimen."

The specimen is supported on a thin carbon film approximately 20 angstroms thick. A beam of electrons sweeps back and forth across the specimen. As focused electrons pass through the specimen, the scientists are able to measure simultaneously two types of scattering, elastic and inelastic. The former refers to large angle bending that occurs when electrons from the tungsten source collide with the nucleus of the atom; the latter to patterns obtained from their collisions with electrons surrounding the atom's nucleus.

"We collect all the electrons that pass through the specimen," Dr. Crewe explains. "With conventional electron microscopes you can collect only a few of the electrons—perhaps only one percent." On an oscilloscope attached to the microscope, the revealed atoms appear as bright spots on a dark background.

The Crewe microscope is a comparatively small, 25,000-volt machine that can resolve separations of about five angstroms. For this reason, the specimen was constructed with heavy atoms (uranium has an atomic number of 92, thorium of 90) whose spacing is greater than five angstroms. A 100,000-volt machine now under construction and expected to be ready for use within six months in Dr. Crewe's laboratory will enable the researchers to single out smaller atoms. The larger instrument will have a resolving power of about three angstroms.

Dr. Crewe will publish his findings in SCIENCE within the next month. □