search & discovery

The parton: "It works even if you don't believe in it"

A picture of the proton at high energies is emerging from the work of many theorists trying to explain the deep inelastic scattering observed with the SLAC electron linac. These theories visualize the proton as consisting of pointlike constituents with charge less than the electron charge and a spin of 1/2. The deep inelastic scattering, they say, measures the momentum distribution within the proton of these pointlike constituents, be they quarks, partons or "stratons" (a term coined by the Chinese to refer to the stratification of atoms, nuclei and nucleons).

To get a clearer idea of the parton picture, we chatted with Victor Weisskopf (MIT) and Sidney Drell (SLAC), who along with J. D. Bjorken (SLAC) and Richard P. Feynman (Cal Tech) and others have been leading contributors to the development of the concept.

The theorists have been studying inelastic structure functions, which are analogous to the form factors used in elastic scattering. These structure functions are roughly total cross sections for a proton to absorb the virtual photon exchanged by the electron and proton; they depend on the energy transferred to the proton by the electron and on the invariant four-momentum transfer.

For elastic scattering the relation between momentum and energy is fixed because the final state of the proton is just the mass of the proton. For inelastic scattering, however, final hadronic states of any mass can be formed, depending on the particles produced; so energy and momentum transfer are two independent dynamical quantities.

Bjorken argued that the structure functions, instead of depending in an arbitrary way on energy transfer ν, and four-momentum transfer squared q^2, depend only on the ratio of those two quantities ν/q^2, when both of them become large, namely in the deep inelastic-scattering region. This scaling concept was put forth even before the SLAC data were analyzed.

Independently Feynman said we can think of the proton sitting still in the laboratory as made of certain constituents tightly bound inside the proton, and these constituents might look very different if we take their snapshot in the bound state than they do as debris that emerges from nuclear reactions in the free final states. For example, on the nuclear scale a neutron inside a deuteron is stable, but when it emerges it lives only a short time. Thus strong binding affects the appearance of constituents.

If instead, we observe the proton from a very rapidly moving frame (say a trolley car) then time dilation makes whatever is living inside the proton last a long time. If we then do deep inelastic scattering, the conditions of the impulse approximation are satisfied. As in nuclear physics, if we give

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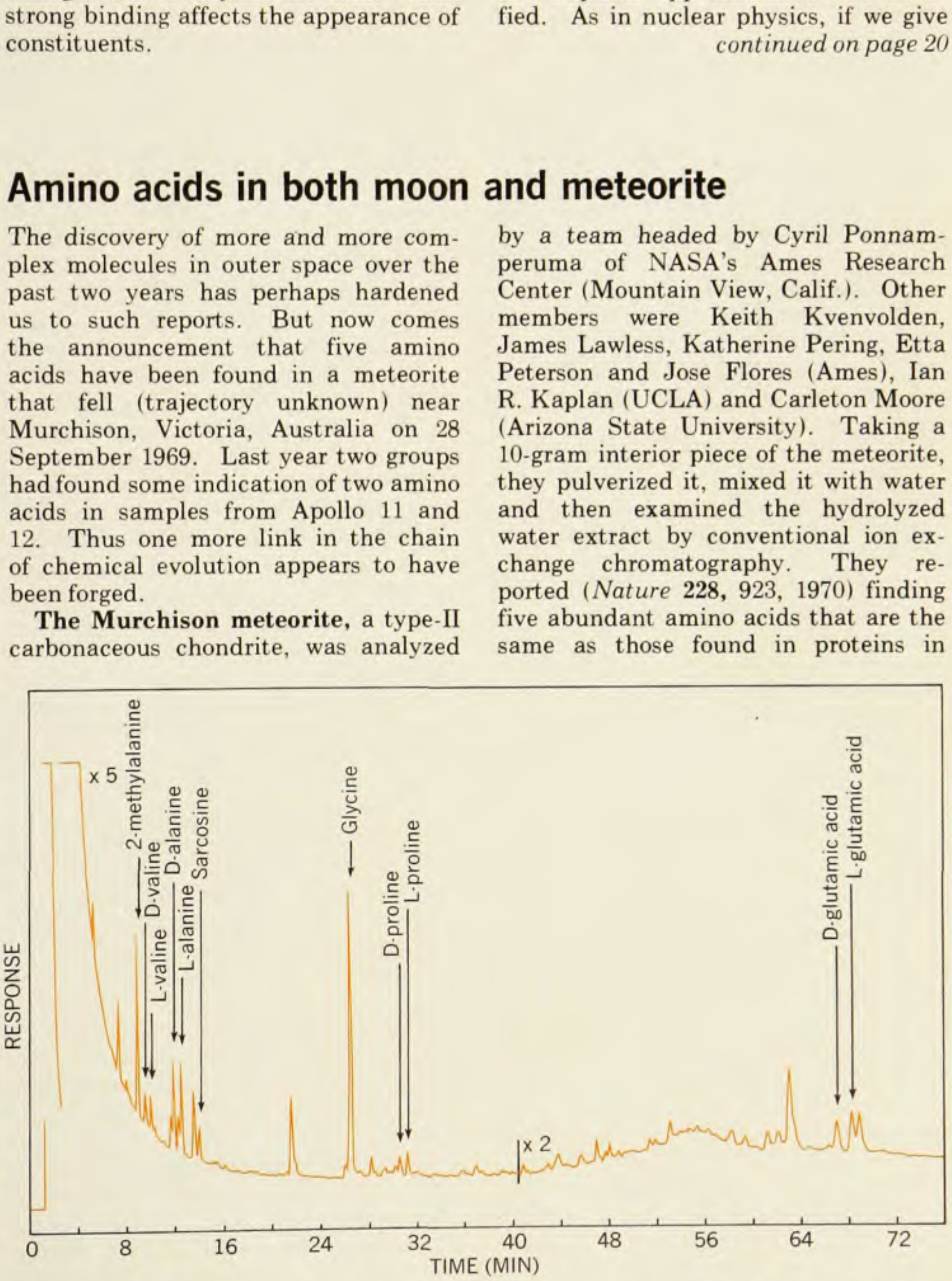
Amino acids in both moon and meteorite

The discovery of more and more complex molecules in outer space over the past two years has perhaps hardened us to such reports. But now comes the announcement that five amino acids have been found in a meteorite that fell (trajectory unknown) near Murchison, Victoria, Australia on 28 September 1969. Last year two groups had found some indication of two amino acids in samples from Apollo 11 and 12. Thus one more link in the chain of chemical evolution appears to have been forged.

The Murchison meteorite, a type-II carbonaceous chondrite, was analyzed by a team headed by Cyril Ponnamperuma of NASA's Ames Research Center (Mountain View, Calif.). Other members were Keith Kvenvolden, James Lawless, Katherine Pering, Etta Peterson and Jose Flores (Ames), Ian R. Kaplan (UCLA) and Carleton Moore (Arizona State University). Taking a 10-gram interior piece of the meteorite, they pulverized it, mixed it with water and then examined the hydrolyzed water extract by conventional ion exchange chromatography. They reported (*Nature* **228**, 923, 1970) finding five abundant amino acids that are the same as those found in proteins in



Gas chromatogram of hydrolized water extract from Murchison meteorite shows left-handed (L) and right-handed (D) forms of four amino acids are present in roughly equal quantities. Ponnamperuma and his colleagues say that the even distribution supports the idea that the amino acids are not recent biological contaminants.

living systems: glycine (6 micrograms/gram), alanine (3 micrograms/gram), glutamic acid (3 micrograms/gram), valine (2 micrograms/gram) and proline (1 microgram/gram). In addition they found 11 other amino acids rarely found in living systems, suggesting that they were formed in outer space rather than on earth.

In addition to the ion exchange chromatography, the Ponnamperuma group studied the optical activity of the sample by gas chromatography (see diagram). Both the left-handed and right-handed molecular forms of four of the amino acids were found in roughly equal quantities. The workers say that even distribution of right- and left-handed forms supports the idea that the amino acids in the meteorite are not recent biological contaminants. In modern living things on earth, amino acids are almost all left-handed, be they elephant or eucalyptus.

Some critics have pointed out that left-handed amino acids automatically become equal mixtures of left-handed and right-handed ones over geological time periods. Kvenvolden said that he doubted that they could have formed mixtures of left- and right-handed molecules in their laboratory. For the past three years his group has been trying to determine the distribution of the right- and left-handed forms of amino acids in rocks, and they say they have invariably seen an outstanding dominance of the left-handed form.

The experimenters found that the ratio of C^{12} to C^{13} in the extractable organic material in the meteorite had a value of 88.5. On earth the C^{12}/C^{13} ratio ranges from about 90.2 to 92.1 for extractable organic material. So the workers conclude that their organic material is indigenous to the meteorite. Other meteorites studied usually have a value of 90.2 or so for this ratio, in which case their extraterrestrial origin would not be clear. The total amount of carbon found in the Murchison meteorite, on the other hand, is typical for type II carbonaceous chondrites.

In the past many organic compounds have been reported in meteorites, the group notes; in particular amino acids were reported in 1963 by Kaplan, E. T. Degens and J. H. Reuter.[1] However, the Ponnamperuma group remarks that because the distribution patterns of these amino acids resemble amino acids in fingerprints, such observations of amino acids in meteorites are commonly attributed to contamination. Kaplan and his collaborators found a total concentration of glycine, alanine, valine, proline and glutamic acid that was one half the amount found in the Murchison meteorite. Furthermore Kaplan's most abundant amino acid was serine (and the next most abundant was glycine), which is the most abundant amino acid in fingerprints, whereas the Murchison meteorite has shown no serine. The Ponnamperuma group feels that the unique distribution of amino acids found in the Murchison meteorite cannot be explained on the basis of handling contamination.

Subsequently John Oró (University of Houston) and his collaborators have confirmed the results in the Murchison meteorite, finding almost equal quantities of left-handed and right-handed amino acids.

Moon dust. Although Ponnamperuma says the observations on the Murchison meteorite are probably the first conclusive proof of extraterrestrial chemical evolution, two groups have reported finding glycine and alanine in moon dust from Apollo 11. Sidney W. Fox, Kaoru Harada, Gertrude Hinsch and George Mueller (University of Miami) and P. Edgar Hare (Carnegie Institution of Washington) in one group,[2] and Bartholomew Nagy (University of Arizona), Charles M. Drew (Naval Weapons Center, China Lake), Paul B. Hamilton (Alfred I. DuPont Institute), Vincent E. Modzeleski, Ward M. Scott and Maria Young (University of Arizona), Harold C. Urey (University of California at San Diego), and Sister Mary E. Murphy (St Joseph College)[3] in the other, cautioned that the presence of the amino acids could be the result of atypical terrestrial contamination.

However, Fox believes that this work plus subsequent analysis of samples from Apollo 12 are the first valid evidence for nonterrestrial amino acids. Besides finding glycine and alanine in the free state his group showed that the glycine, alanine and four other amino acids could be observed by applying hydrolysis to an extract of lunar dust.[4] The patterns observed, he said, were very atypical of earthly contamination. Both the Nagy and Fox groups used an ultramicro amino acid analyzer sensitive to 1 part in 10^9. Other groups, headed by Ponnamperuma and Oró directly hydrolyzed their lunar samples and examined them with ion exchange chromatography and by gas chromatographic methods, finding no evidence for amino acids.

The Fox group on the other hand, first extracted their sample with water to separate it from the bulk of the minerals and then hydrolyzed the water extract. The Fox group claims that this method was proven to be valid by running control experiments in which they showed that amino-acid precursors present in lunar dust at very low levels are lost by direct hydrolysis. Fox pointed out that the Ponnamperuma group used the method of indirect hydrolysis in their studies on the meteorite, although they had employed direct hydrolysis for lunar dust.

The Miami group found amino acids at a level of 20 to 70 parts in 10^9. Although minor suggestions of other free amino acids appeared, glycine and alanine were overwhelmingly dominant. Subsequently Fox and his collaborators have been attempting to develop a method for assaying optical activity at these low levels. They have not examined the C^{12}/C^{13} ratio, although the Oró group did, and found it to be atypical of terrestrial matter.

Laboratory simulation. Recently Fox and Charles Windsor reported[5] heating formaldehyde and ammonia to produce seven amino acids: aspartic acid, glutamic acid, serine, proline, valine, glycine and alanine. Both formaldehyde and ammonia have been found in galactic clouds. These syntheses are the most recent in a series of attempts to simulate in the laboratory the early stages of chemical evolution that eventually culminated in life. Long after theoretical arguments by A. I. Oparin (1924) and J. B. S. Haldane (1928) on the origin of life, Stanley Miller, then (1953) a graduate student of Urey, applied an electrical discharge to a primordial soup, consisting of methane, ammonia, water vapor and hydrogen. He produced amino acids and other organic compounds found in living systems.

Since then others, including Ponnamperuma, Fox and Oró have varied the parameters, changing the initial constituents, their proportions, and the source of energy, using for example, ultraviolet radiation or electron beams.

Oró, Ponnamperuma and Leslie Orgel and their colleagues have made adenine and guanine (constituents of RNA and DNA) and urea (an important biochemical intermediate) by starting with hydrogen cyanide and formaldehyde.

Fox told us that he and his collaborators have demonstrated "how a primitive living cell could come into existence from amino acids that might be formed by intermediates that are widespread in the galaxy. These would by spontaneous heating form protein-like molecules; these molecules, on contact with water, form microsystemic units that have a remarkable number of properties of contemporary living cells." The microsystemic units, he said, are self-assembled units typically 1 to four microns across. "They have not only the size but the shape and a number of other properties in common with coccoid bacteria and yeasts." Many have questioned the significance of these observations.

Molecules in space. The list of molecules found in space has grown remarkably rapidly, and the molecules themselves have had increasing complexity. For some time OH, CH, CH^+ and CN molecules have been known. Recent molecules in space reported include, besides H_2CO (formaldehyde) and NH_3 (ammonia), H_2O, H_2, CO, HCN (hydrogen cyanide), HC_3N (cyanoacetylene), CH_3OH (methyl alcohol) and most recently HCOOH (formic acid). In addition an unidentified molecule known as "X-ogen" has been reported.

That such complex molecules can exist as a gas in space, constantly bombarded by radiation, has surprised many observers. By contrast the materials found in the Murchison meteorite and the moon are protected inside of solids, thus preventing their dissociation by the solar wind; accordingly, amino acids, though delicate in structure, would have a chance for survival.

Some observers are hopeful of finding amino-acid clouds in space, too, though some spade work in the laboratory is probably needed—doing microwave spectroscopy on gaseous amino acids. Complex organic molecules might survive by being absorbed onto grains of silica.

Thus chemistry, biology, physics, geology and astronomy are coming together in a magnificent effort to understand evolution in its very broadest sense. —GBL

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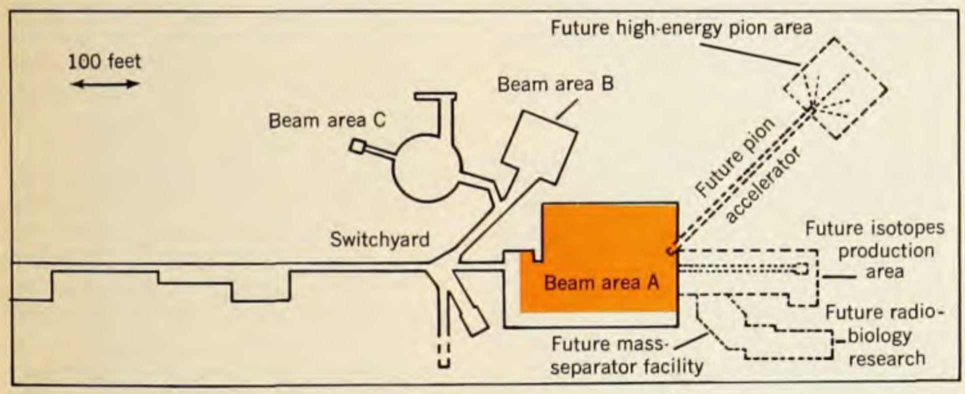
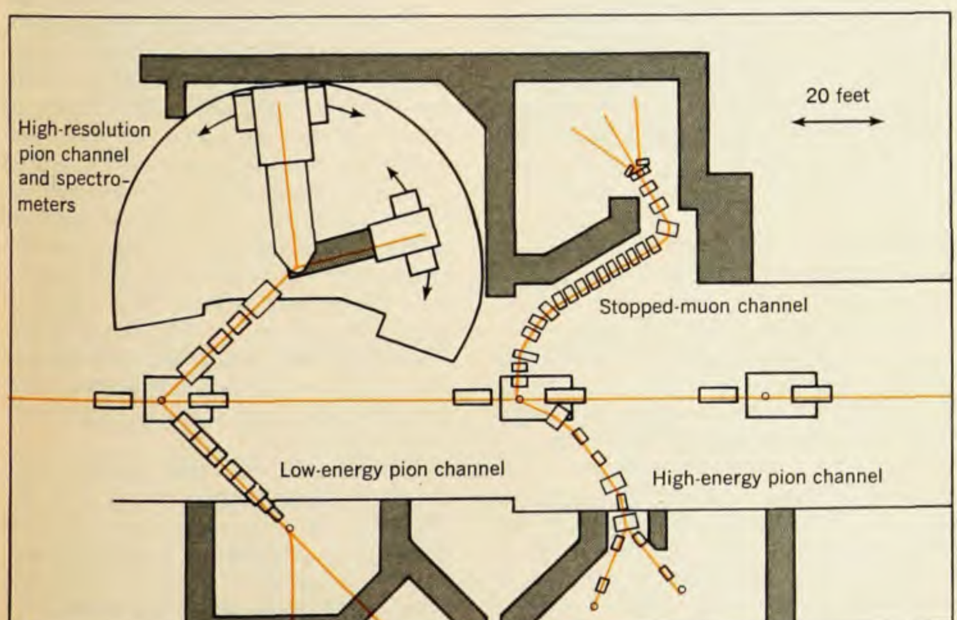
LAMPF meson factory calls for beam-time proposals

Do you have an idea for an experiment that needs an 800-MeV meson-factory beam? If so, it is time to submit it to the Los Alamos Meson Physics Facility. Louis Rosen, LAMPF director, recently summed up the current status of the accelerator and experimental areas, issued a call for proposals for beam time, and announced the formation of a program committee to consider proposals. The 11-member program committee, plus Rosen as chairman and Darragh Nagle (LAMPF deputy director) as alternate chairman, will hold its first meeting during March.





Experimental areas of the Los Alamos Meson Physics Facility. Two simultaneous 800-MeV beams (1 milliamp of protons and 0.1 milliamp of H^- ions) enter the switchyard from the left after acceleration in the half-mile-long linac. Colored region in the top illustration, "beam area A," is shown in greater detail below.

The accelerator is an 800-MeV proton linac capable of about 1 milliamp average current. A unique feature is the trick of using different parts of the rf phase to accelerate both protons and negative hydrogen ions simultaneously. Last June the first beam (5-MeV protons) was obtained; by mid-1971 a 100-MeV beam is expected, and the full energy of 800 MeV should be available by mid-1972. An experimental beam is scheduled for use about six months after the full energy is first attained.

Three experimental areas are to be ready by the time the beam is made available to experimenters. The 1-milliamp proton beam goes to area A (see figure) for meson physics. Areas B and C will take the negative hydrogen-ion beam, at about 10% of the intensity of the main proton beam, for nucleon physics and high-resolution proton spectroscopy respectively.

Meson physics. Area A will consist of four channels, for low-energy pions, pion spectroscopy, stopped muons and high-energy pions.

The low-energy pions (20–300 MeV pi-plus and pi-minus) will have good momentum resolution, achromatic and isochronous output, variable spot size and beam divergence at the output, and high intensity at moderate resolution.

The pion-spectroscopy channel includes spectrometers, a scattering chamber and a detection system. Energy resolution will be better than 50 keV, with angular resolution less than 10 milliradians. The energy range will be 50–300 MeV. Initially one spectrometer (low momentum, 680 MeV/c) will be built, with another (high momentum, 1000 MeV/c) being planned for later.

Currently the most advanced secondary beam is the stopped-muon channel; several of its magnets are already on order. The channel will consist of a pion collection system, a pion-decay portion, and an analyzer, which selects