Astronomy

A Curious Cosmic Beam

Scientists working at the Los Alamos National Laboratory in New Mexico have detected a strange, powerful beam of radiation of unknown type. The radiation seems to have come from a neutron-star system known as Hercules X-1, located some 16,000 light-years from Earth.

Two separate bursts of the mysterious radiation hit the Earth on July 23, 1986, according to signals picked up by a huge array of detectors at the laboratory. The bursts were a thousand times more energetic than the most powerful man-made particle-accelerator beams. And, the researchers suggest, they may have consisted of elementary particles of a type never before detected.

The possibility of this novel type of radiation has been suggested before, in the early 1980's, by other astronomers monitoring emissions from a binary system called Cygnus X-3. The new data makes this possibility much stronger, while still not ruling out other explanations. "It's a very interesting phenomenon," says Los Alamos physicist Darragh Nagle, "the type of challenge that captures a scientist's imagination."

The Los Alamos detectors were built as a giant gamma-ray telescope to keep track of the universe's most energetic photons, dubbed ultra-high-energy or UHE gamma rays. Millions of times more powerful than ordinary gamma rays, UHE gamma rays are extremely rare; a detector one meter square out in space might spot only one UHE event every few hundred years from a typical source, such as a supernova remnant or X-ray star.

On July 23, 1986, an array of detectors of the type shown above—emplaced at the Los Alamos National Laboratory in New Mexico—recorded a powerful beam of radiation of unknown type that seemed to come from the neutron star system Hercules X-1.

The Earth As A Target

Fortunately for astronomers, however, when UHE gamma rays do hit the Earth, they are completely absorbed by the atmosphere. In the process, they generate a shower of secondary particles, such as electrons and positrons, that reaches all the way to the Earth's surface. Thus, the entire atmosphere can act as a single, huge detector.

By analyzing each cascade with special detectors spread over thousands of square meters, investigators can calculate both the energy and trajectory of the original UHE gamma ray, as well distinguish them from cascades triggered by cosmic rays. Gamma rays, which are unaffected by magnetic forces, travel straight from the source. Cosmic rays, on the other hand, are charged particles from space; they are buffeted by interstellar magnetic fields and, as a result, are uniformly distributed all over the sky.

Encased in white fiberglass cones and distributed over the sloping grounds of the mile-high laboratory, the Los Alamos detectors resemble pawns in some Brobdingnagian chess game. Events recorded by the detectors are automatically recorded on a computer dozens of times each minute. Each shower, composed of ten thousand or more particles, passes by within billionths of a second.

Searching through these computer records, the Los Alamos group, a collaboration of 19 physicists from Maryland, California, Virginia, New Mexico, and England, had discovered two strange outbursts from Hercules X-1 that did not follow the standard script.

On a July afternoon, the detectors first registered 7 events from the direction of Hercules; then three hours later they recorded 10 more events. Both signals were far above normal levels. More importantly, the air showers sparked by each event were rich in muons, heavy relatives of the electron. The researchers know this because their array is positioned around a sensitive muon detector. Five years ago, data from a West German array hinted at a similar effect from Cygnus X-3, but the Los Alamos signal is much more persuasive.

Current theories of particle physics cannot easily explain how gamma rays slamming into the atmosphere can generate muons. It may mean that theories concerning such nuclear interactions must be radically amended. Some have already ventured that the muon surplus could indicate that leptons and quarks, now thought to be the ultimate bits of matter, are composed of even more basic units, called "preons."

Novel Elementary Particles?

"Or the radiation emanating from Hercules may be comprised of particles not yet seen in particle accelerators," says University of Maryland physicist Brenda Dingus, who analyzed the signal for her doctoral thesis. Such particles might be created by the neutron star. These compact objects spin rapidly on their axis—once a second for Hercules X-1. In addition, the tiny neutron star periodically goes in and out of view as it whips around a very close and more normal stellar companion, much like our Sun. The intense radiations from the spinning neutron star slam into a surrounding disk of material pulled off the companion star—possibly creating, in the process, novel elementary particles.

These particles could not be electrically charged, since they couldn't have maintained a straight course from Hercules after flying through interstellar magnetic fields. Ordinary neutrons—which carry no charge—would have decayed before they got here. And ghostly neutrinos, which can whiz through the Earth unimpeded, would have registered (if at all) even when Hercules X-1 was below the horizon. Thus, no known particle can do the job.

That those cosmic bursts from Hercules cannot be interpreted right away is not surprising: Each event involved energies as high as 1,000 trillion electron-volts, a realm unexplored by earthbound accelerators. The Los Alamos team is now checking its records for similar bursts from other sources; according to Dingus, "Cygnus X-3 is a possibility."

Whatever the final outcome, UHE gamma-ray detectors around the globe, such as the Los Alamos array, have already found that as few as a dozen sources, like Hercules X-1 and Cygnus X-3, could be the source of all the higher-energy cosmic rays that continually impinge on Earth's atmosphere. What the Los Alamos group and others are eager to know is whether a totally new particle is included in that flood. The answer may very well upset the standard laws of particle physics.

Physical Review Letters, vol. 61, p. 1906.

Geophysics

How the Oceans Formed: A Startling New Theory

The man-made greenhouse effect forecast for next century will be mild compared to what the Earth experienced during its formation. That's the growing consensus of geophysicists studying a new theory of how Earth's oceans formed put forward by two Japanese scientists. They propose that all the planet's water was in the form of steam, creating a thick, dense blanket of vapor that trapped heat so effectively Earth's surface was covered with seas of molten lava. As the Earth cooled, the scientists say, the steam condensed and rained from the skies to fill the oceans.

The new theory, proposed by Takafumi Matsui and Yutaka Abe of the University of Tokyo, rests on the generally accepted idea that the Earth formed by the accumulation of numerous planetesimals—small rocky or meteor-like objects abundant in the early solar system. Matsui and Abe believe many of these planetesimals contained such minerals as gypsum and serpentine, which normally include small amounts of water. As the objects crashed into the growing Earth, the shock of their impact would have released the water as well as enormous amounts of energy—turning the water into steam.

As the Earth grew, the scientists propose, it acquired a thick atmosphere of steam. But steam or water vapor is a powerful greenhouse gas, absorbing and trapping heat within the atmosphere. Thus the steam trapped the energy released by additional planetesimal impacts, making the young world hotter and hotter. Even when the earth had grown to only two-fifths its present size, the scientists calculate, the steam greenhouse trapped heat so effectively that the rocks on the earth's surface began to melt.

A Strange New Earth

The resulting Earth would seem strange to our eyes: A landscape dominated by seas of lava glowing a bright orange at temperatures well above 2000° F., while overhead, reflecting the glow from below, were the dense and never-breaking clouds. From time to time a planetesimal would come hurtling through, striking with the force of a nuclear explosion, delivering new material to our growing planet.

Yet once the rocks began to melt, the steamy atmosphere grew no denser and the greenhouse warming was also checked. The reason is that steam readily dissolves in molten rock; and the Earth's partially-melted surface thus could absorb some of the hot vapor in the atmosphere. Indeed, a key feature of Matsui and Abe's theory is a kind of global thermostat that maintained just enough steam to trap just enough heat to keep the earth's surface right at the melting temperature of rock.

A Steam Greenhouse

The thermostat worked as follows: If there was too much steam in the atmosphere, the scientists reason, it would trap more heat from the continuing planetesimal impacts, and the world would grow hotter. More rock would melt. The seas of lava would expand in size, and would absorb more water vapor from the dense blanket of clouds. That would make the atmosphere a little thinner and the world a bit cooler, restoring the balance. But if the world became too cool, the seas of magma would congeal, and would take up less steam. More vapor then would build up, brought in by the continuing impacts, and again the balance would return.

Eventually, when the Earth reached its present size, the impacts of planetesimals largely ceased—cutting off the source of the energy that maintained the high temperatures and letting the world cool down. Under the influence of the global thermostat, the atmosphere at that time would have contained about 1.9 billion billion metric tons of water—compared to 1.4 billion billion metric tons of water in today's oceans. That is close enough to make it plausible that the oceans actually formed through rainfall.

New studies by Jim Kasting of the NASA Ames Laboratory in California and others seem to confirm key aspects of the new theory. Under the conditions believed to have prevailed on both Earth and Venus as they were forming, the energy released by collisions with incoming planetesimals would indeed have vaporized water and created a runaway greenhouse effect. That in turn, the U.S. scientists find, would probably have melted the surface rocks, creating oceans of lava. Earth was far enough from the sun that it eventually cooled, allowing the steam to condense and form our present oceans. Venus is still too hot today for liquid water to exist. But if the planet had been much closer to the sun, Kasting finds, our planet's fate might have been the same as that of Venus.

An Embarrassment of Oceans

Until now, geolophysicists have not found it easy to explain the origin of the oceans. The usual explanation is that water vapor is released in volcanic eruptions. But there is no evidence in the early geological record of volcanic eruptions on the massive scale that would have been needed to fill the oceans. To the contrary, this record suggests that there have always been oceans much as we see today, with one exception: The earliest oceans may have had a temperature as great as 300° F.

The evidence of warm early oceans is consistent with the new theory. When the world began to cool, it still was at a temperature of over 2000° F., surrounded by steam at high pressure. Because of the high pressure, steam could condense to form water at temperatures far above the normal boiling point—in fact, Matsui and Abe calculate that the first rainfall was at a temperature of over 600° F.

And as the rain continued and the clouds thinned, the world could cool still further, till at last—perhaps 10 million years after it began to form—there would be seas of water rather than of magma, sparkling in the light of the weak young sun. *Journal of Geophysical Research*, vol. 90, p. C545. *Icarus.*, vol 74., p. 62 and p. 472.