Martian Meteorite Contains RNA Precursor

Researchers from the University of Hawai‘i NASA Astrobiology Institute [UHNAI] have discovered high concentrations of boron in a Martian meteorite. When present in its oxidized form (borate), boron may have played a key role in the formation of RNA, one of the building blocks for life.

The Antarctic Search for Meteorites team found the Martian meteorite used in this study in Antarctica during its 2009–2010 field season. The minerals it contains, as well as its chemical composition, clearly show that it is of Martian origin. Using the ion microprobe in the W. M. Keck Cosmochemistry Laboratory at UH, the team was able to analyze veins of Martian clay in the meteorite. After ruling out contamination from Earth, they determined boron abundances in these clays are over ten times higher than in any previously measured meteorite.

“Borates may have been important for the origin of life on Earth because they can stabilize ribose, a crucial component of RNA. In early life, RNA is thought to have been the informational precursor to DNA,” said James Stephenson, a UHNAI postdoctoral fellow.

RNA may have been the first molecule to store information and pass it on to the next generation, a mechanism crucial for evolution. Although life has now evolved a sophisticated mechanism to synthesize RNA, the first RNA molecules must have been made without such help. One of the most difficult steps in making RNA nonbiologically is the formation of the RNA sugar component, ribose. Previous laboratory tests have shown that without borate the chemicals available on the early Earth fail to build ribose. However, in the presence of borate, ribose is spontaneously produced and stabilized.

This work was born from the uniquely interdisciplinary environment of UHNAI. The lead authors on the paper, Stephenson, an evolutionary biologist, and Lydia Hallis, a cosmochemist who is also a UHNAI postdoctoral fellow, first came up with the idea over an after-work beer. “Given that boron has been implicated Please see Martian Meteorite, pg 2

Black Holes Were Abundant among Earliest Stars

By comparing infrared and X-ray background signals across the same stretch of sky, an international team of astronomers, including IfA Director Günther Hasinger, has discovered evidence of a significant number of black holes that accompanied the first stars in the Universe. Using data from NASA’s Chandra X-ray Observatory and NASA’s Spitzer Space Telescope, which observes in the infrared, the team concluded one of every five sources contributing to the infrared signal is a black hole.

“Our results indicate black holes are responsible for at least 20 percent of the cosmic infrared background, which indicates intense activity from black holes feeding on gas during the epoch of the first stars,” said Alexander Kashlinsky, an astrophysicist at NASA’s Goddard Space Flight Center. The cosmic infrared background (CIB) is the collective light from an epoch when structure first emerged in the Universe. Astronomers think it arose from clusters of massive suns in the Universe’s first stellar generations, as well as black holes, which produce vast amounts of energy as they accumulate gas.

Even the most powerful telescopes cannot see the most distant stars and black holes as individual sources. But their Please see Black Holes, pg 2

The Cosmic Microwave Background (shown on left), the earliest light we can see, is from the hot, dense Universe after the Big Bang. This was followed by the Dark Ages, when there were no sources to produce light. Later, the first stars and black holes formed. While we can’t see these individually, their collective light is seen in the cosmic infrared and X-ray backgrounds.
combined glow, traveling across billions of light-years, allows astronomers to begin deciphering the relative contributions of the first generation of stars and black holes in the young cosmos. This was at a time when dwarf galaxies assembled, merged, and grew into majestic objects like our own Milky Way galaxy. “We wanted to understand the nature of the sources in this era in more detail, so I suggested examining Chandra data to explore the possibility of X-ray emission associated with the lumpy glow of the CIB,” said Hasinger.

The work began in 2005, when Kashlinsky and his colleagues studying Spitzer observations first saw hints of a remnant glow. The glow became more obvious in further Spitzer studies by the same team in 2007 and 2012. The 2012 investigation examined a region known as the Extended Groth Strip, a single well-studied slice of sky in the constellation Boötes. In all cases, when the scientists carefully subtracted all known stars and galaxies from the data, what remained was a faint, irregular glow. There is no direct evidence this glow is extremely distant, but telltale characteristics lead researchers to conclude it represents the CIB.

In 2007, Chandra took especially deep exposures of the Extended Groth Strip as part of a multiwavelength survey. Along a strip of sky slightly larger than the full moon, the deepest Chandra observations overlap with the deepest Spitzer observations. Using Chandra observations, lead researcher Nico Cappelluti (National Institute of Astrophysics, Bologna, Italy, and University of Maryland, Baltimore County), produced X-ray maps with all of the known sources removed in three wavelength bands. The result, paralleling the Spitzer studies, was a faint, diffuse X-ray glow that constitutes the cosmic X-ray background (CXB).

Comparing these maps allowed the team to determine whether the irregularities of both backgrounds fluctuated independently or in concert. Their detailed study indicates fluctuations at the lowest X-ray energies are consistent with those in the infrared maps. “This measurement took us some five years to complete and the results came as a great surprise to us,” said Cappelluti.

The process is similar to standing in Los Angeles while looking for signs of fireworks in New York. The individual pyrotechnics would be too faint to see, but removing all intervening light sources would allow the detection of some unresolved light. Detecting smoke would strengthen the conclusion that at least part of this signal came from fireworks. In the case of the CIB and CXB maps, portions of both infrared and X-ray light seem to come from the same regions of the sky. The team reports black holes are the only plausible sources that can produce both energies at the intensities required. Regular star-forming galaxies, even those that vigorously form stars, cannot do this.

in the emergence of life, I had assumed that it was well characterized in meteorites,” said Stephenson. “Discussing this with Dr. Hallis, I found out that it was barely studied. I was shocked and excited. She then informed me that both the samples and the specialized machinery needed to analyze them were available at UH.”

On our planet, borate-enriched salt, sediment and clay deposits are relatively common, but such deposits have never previously been found on an extraterrestrial body. This new research suggests that when life was getting started on Earth, borate could also have been concentrated in deposits on Mars.

The significance goes beyond an interest in the red planet, as Hallis explains: “Earth and Mars used to have much more in common than they do today. Over time, Mars has lost a lot of its atmosphere and surface water, but ancient meteorites preserve delicate clays from wetter periods in Mars’ history. The Martian clay we studied is thought to be up to 700 million years old. The recycling of the Earth’s crust via plate tectonics has left no evidence of clays this old on our planet; hence Martian clays could provide essential information regarding environmental conditions on the early Earth.”

The presence of ancient borate-enriched clays on Mars implies that these clays may also have been present on the early Earth. Borate-enriched clays such as the one studied here may have represented chemical havens in which one of life’s key molecular building blocks could form.
A Video Map of Motions in the Nearby Universe

The Universe is a dynamic place, as the video, *Cosmography of the Local Universe*, demonstrates. Created by an international team that includes Hélène Courtois (University of Lyon, France, and IfA) and Brent Tully (IfA), it shows the motions of the nearby Universe in 3-D in greater detail than ever before through the use of rotation, panning, and zooming. The video was announced at the conference “Cosmic Flows: Observations and Simulations” held in Marseille, France, during the first week of June to honor the career and 70th birthday of Tully.

The Cosmic Flows project has mapped visible and dark matter densities around our Milky Way galaxy out to a distance of 300 million light-years. The large-scale structure of the Universe is a complex web of clusters, filaments, and voids. Large voids—relatively empty spaces—are bounded by filaments that form superclusters of galaxies, the largest structures in the Universe. Our Milky Way galaxy lies in a supercluster of 100,000 galaxies. Just as the movement of tectonic plates reveals the properties of Earth’s interior, the movements of the galaxies reveal information about the main constituents of the Universe: dark energy and dark matter. Dark matter is unseen matter whose presence can be deduced only by its effect on the motions of galaxies and stars because it does not give off or reflect light. Dark energy is the mysterious force that is causing the expansion of the Universe to accelerate.

The video captures with precision not only the distribution of visible matter concentrated in galaxies, but also the invisible components, the voids and the dark matter. Dark matter constitutes 80 percent of the total matter of our Universe and is the main cause of the motions of galaxies with respect to each other. This precision 3-D cartography of all matter (luminous and dark) is a substantial advance.

The correspondence between wells of dark matter and the positions of galaxies (luminous matter) is clearly established, providing a confirmation of the standard cosmological model that explains how galaxies and other structures in the Universe formed. Through zooms and displacements of the viewing position, this video follows structures in three dimensions and helps the viewer grasp relations between features on different scales, while retaining a sense of orientation.

The scientific community now has a better representation of the moving distribution of galaxies around us and a valuable tool for future research.

The Cosmic Flows team also includes Daniel Pomarede, Institute of Research on Fundamental Laws of the Universe, CEA/Saclay, France; Yehuda Hoffman, Racah Institute of Physics, University of Jerusalem, Israel; and Denis Courtois, Lycée International, France. ■

Zahid Receives ARCS Award

IfA graduate student Jabran Zahid was recently awarded the 2013 Columbia Communications Award in Astronomy from the Achievement Rewards for College Scientists (ARCS) Foundation. For his dissertation, Zahid is studying the chemical evolution of galaxies across cosmic time under the guidance of Lisa Kewley. ■
Fourteen students entering grades 8–12 and two secondary school teachers participated in the 2013 HI STAR (Hawai‘i Student/Teacher Astronomy Research) program May 31–June 6 at IfA and UH Mānoa. The main goal of HI STAR is to equip interested and talented students and their teachers with the skills and knowledge necessary to pursue astronomy research during the school year so that they can work on a science fair project.

This year’s students and teachers came from California and Utah, as well as Kaua‘i, O‘ahu, Maui, and Hawai‘i island. Their projects covered stars, galaxies, heliophysics, exoplanets, and asteroids and comets. They used telescopes in Australia, Indiana, and the Faulkes Telescope North on Haleakalā. They also learned how to give impromptu talks under the direction of Jennifer Sur.

Mary Kadooka, IfA’s astronomy research/education specialist, directs HI STAR. Also working with the program were Michael Nassir, an instructor in the UHM Physics and Astronomy Department, IfA astronomer Andrew Howard, IfA graduate student Heather Kaluna, and Kira Fox, a HI STAR alumna.

Photos courtesy J. D. Armstrong

**HI STAR 2013**

**Top:** HI STAR instructor J. D. Armstrong (left) worked with Celeste Jongeneelen and Tony Almazan on a study of NGC 6031, a star cluster in the Southern Hemisphere. They observed it over the Internet using a telescope in Australia.

**Middle:** Mailani Neal, Kelsey Barber, Gabriel Salazar observed remotely using the DeKalb Observatory in Auburn, Indiana. The observatory belongs to amateur astronomer Donn Starkey (on laptop screen), who has worked with HI STAR for many years.

**Bottom:** IfA graduate student Marco Micheli (center) and postdoctoral fellow Bin Yang (second from left) worked with the asteroids and comets group of Stephanie Spear (left), Zoey Fox, and Kelsey Barber.

**HI STAR student Mailani Neal giving her impromptu talk.**
Discovered in September 2012 by two Russian amateur astronomers, Comet ISON is likely making its first passage into the inner solar system from what is called the Oort Cloud, a region deep in the recesses of our solar system, where comets and icy bodies dwell. Historically, comets making a first go-around the Sun exhibit strong activity as they near the inner solar system, but they often fizzle as they get closer to the Sun. Comet ISON’s main body was spewing some 850 tons of dust per second when observed by NASA’s Swift satellite at the beginning of the year, leading astronomers to estimate that the diameter of the comet’s nucleus is 3–4 miles (5–6 km).

Most comets brighten significantly and develop a noticeable tail at about the distance of the asteroid belt (about 3 times the Earth–Sun distance, between the orbits of Mars and Jupiter) because this is when the warming rays of the Sun can convert the water ice inside the comet into a gas. But this comet was bright and active outside the orbit of Jupiter, so some gas other than water was controlling the activity.

Meech concludes that Comet ISON “could still become spectacularly bright as it gets very close to the Sun,” but she cautions, “I’d be remiss if I didn’t add that it’s still too early to predict what’s going to happen with ISON since comets are notoriously unpredictable.” But even if Comet ISON completely disintegrates, skywatchers shouldn’t lose hope. When Comet C/2011 W3 [Lovejoy] plunged into the Sun’s corona in December 2011, its nucleus totally disintegrated into tiny bits of ice and dust, yet it still put on a glorious show after that event.
Are We Alone? by Louise Good

Does intelligent life exist beyond Earth? If so, how might we find it? These are some of the questions addressed by Jill Tarter, Bernard Oliver Chair at the SETI Institute in a Sheraton Waikiki Explorers of the Universe talk held at UH Mānoa’s Kennedy Theatre on May 3.

SETI, the search for extraterrestrial intelligence, seeks to answer the question, are we alone? “We don’t know the answer,” but it is a “legitimate scientific question to pose,” Tarter said. “Our journey thus far has brought us to the realization that we on this planet orbit one star out of something like 400 billion in the Milky Way and that the Milky Way galaxy is one of perhaps 100 billion galaxies in the observable Universe.”

Tarter said that the rover Curiosity is exploring Mars, not to find life, but to determine whether conditions for life ever existed on Mars. “If we find a second independent genesis of life in this one small solar system, we can be sure that life will be ubiquitous elsewhere among the stars.” Tarter listed other places in our solar system that might harbor life: Jupiter’s giant moons Ganymede, Callisto, and Europa, which are frozen on the outside but have salty oceans beneath the surface, and Saturn’s largest moon, Titan, which has liquid methane on its surface.

What about life beyond our solar system? The Kepler spacecraft has been looking for Earth-size planets that cross in front of (transit) their stars in a 100-square-degree section of the sky. The ultimate goal of Kepler’s work is to find what Tarter termed “Earth 2.0,” an Earth-size planet orbiting a Sun-like star in its habitable zone. She said she expects that we will find such a planet soon. (The recent troubles of the Kepler spacecraft may make this somewhat less likely.) Eventually, we may have telescopes capable of finding bio-signatures of life on other planets, for example, oxygen and methane coexisting in a planet’s atmosphere, but we are not there yet.

For now, the SETI Institute is looking for what Tarter termed “techno-signatures” of intelligent life: narrow radio signals and time-compressed optical signals, such as laser flashes that last only a billionth of a second, “the kind of thing that we have the technology to do but nature can’t do.” As our technology advances, SETI will be able to search the sky more and more efficiently.

Whether or not SETI will succeed depends on two things: Whether there is anyone out there and whether they will be there long enough for us to find them. She said technological civilizations would have to survive 100,000 years on average to be detected by other civilizations.

Tarter quoted MIT scientist Phil Morrison, who wrote the first serious SETI paper, saying, “SETI is the archeology of the future,” meaning that if we detect a signal from a distant civilization, we will be learning about another civilization’s past, since their signal will have taken a long time to reach Earth. But even if we detect a signal with “no information content,” it will still have a very important message for us: “If we work at it hard enough, we too can have a long future.”

In closing, Tarter said that SETI is something “we absolutely should be pursuing as a global project.” If there is a signal out there, it is coming to the planet Earth, and “should be information that becomes the property of all humans, so it should never be kept a secret.” She expressed the hope that her talk had gotten the audience “to look at who you are and where you are from a more cosmic perspective” and to understand that “we are all earthlings,” are not so different from each other, and that we can all work together and cooperate on both SETI and all of Earth’s challenges.

You can help with SETI by going to setilive.org and signing up.
Lu to Speak on Threat of Asteroid Impacts

Ed Lu, the chairman and CEO of the B612 Foundation, which seeks to protect Earth from asteroid impacts by finding such asteroids in time to deflect them, will give the next Sheraton Waikiki Explorers of the Universe public lecture, “Astronomy Saves the World: Protecting the Planet from Asteroid Impacts,” at 7:30 p.m. on August 15 at the UH Mānoa Kennedy Theatre.

Asteroids hit Earth more often than most people realize. In his talk, Lu will describe the risk of asteroid impacts and how we can prevent these cosmic natural disasters. He says, “We already know how to deflect an asteroid to keep it from hitting the Earth, but this technology is useless unless we do one crucial step first.” Lu will describe his efforts to accomplish this necessary first step and to literally help save the world.

Lu is a former NASA astronaut who flew three space missions, including six months on the International Space Station. From 2007 to 2010, he led the Advanced Projects group at Google, where his teams developed imaging technology for Google Earth/Maps, Google Street View, and energy information products including Google PowerMeter. He is the co-inventor of the Gravity Tractor, a spacecraft able to controllably alter the orbit of an asteroid.

Lu has published scientific articles on high-energy astrophysics, solar physics, plasma physics, cosmology, and statistical physics. He holds a PhD in astrophysics from Stanford University and a bachelor’s degree in electrical engineering from Cornell University. Prior to joining NASA, he was a postdoctoral fellow in solar physics at the IfA.

Tickets for this event are free but required. More information: www.ifa.hawaii.edu/specialevents
On June 24, NASA announced that the ten thousandth near-Earth object (NEO) had been found—by none other than our own Pan-STARRS 1 telescope on Haleakalā. In fact, PS1 had found nearly 600 of the 10,000 NEOs and continues to add to this total. Recently, the ability of Pan-STARRS to find smaller asteroids has been improved significantly, and we expect the system to dominate asteroid discoveries in the near future. It is important to find and plot the orbits of these objects to determine if any are on a collision course with Earth.

Finding objects with a potential to harm our planet is an important mission of NASA, which provides key funding for the Pan-STARRS project and others searching for NEOs, and of the IfA, where in addition to Pan-STARRS, we have ATLAS, the Asteroid Terrestrial-impact Last Alert System, also funded by NASA. The asteroid impact on the Russian city of Chelyabinsk last February brought the seriousness of this problem to the attention of the world.

Another interesting facet of NASA work on asteroids is the Asteroid Redirect Initiative, a plan to robotically capture a small near-Earth asteroid and redirect it safely to a stable orbit in the Earth-Moon system so that astronauts can visit and explore it. This will help us learn more about asteroids and the formation and history of the solar system. It will also help us prepare for human missions to Mars later in this century. Pan-STARRS and ATLAS will also play an important role in the endeavor of finding suitable asteroid candidates for this mission.

Also in June, NASA announced its Asteroid Grand Challenge to “find all asteroid threats to human populations and know what to do about them.” This endeavor will use partnerships with other government agencies, international organizations, industry, universities, nonprofit organizations, and citizen scientists. One of NASA's partners is the B612 Foundation, which plans to launch an infrared telescope called “Sentinel” into a Venus-like orbit around the Sun to find near-Earth asteroids in 2017–18. Its goal is to discover and catalog 90 percent of the near-Earth asteroids larger than 140 meters, as well as a significant number of smaller asteroids, during its 6.5-year mission. Ed Lu, chair and CEO of the B612 Foundation, will be in Hawai‘i in August to give a talk about the foundation and its work [see article on page 7]. The talk is part of the Sheraton Waikiki/IfA Explorers of the Universe lecture series. I urge all who are interested to attend.