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ASTRONOMERS REVEAL FIRST ALIEN I.D. CHART

Cambridge, MA — It is only a matter of time before astronomers find an Earth-sized planet orbiting a distant star. When they do, the first questions people will ask are: Is it habitable? And even more importantly, is there life present on it already? For clues to the answers, scientists are looking to their home planet, Earth.

Earth's early atmosphere of nitrogen, methane and carbon dioxide was hostile to life as we know it, but friendly to the first methane-loving bacteria. Astronomers modeled the history of Earth's atmosphere to learn what fingerprints to seek on alien worlds. Image available online at: **http://www.cfa.harvard.edu/press/pr0625image.html**
Credit: David A. Aguilar (Harvard-Smithsonian Center for Astrophysics)

Astronomers Lisa Kaltenegger of the Harvard-Smithsonian Center for Astrophysics (CfA) and Wesley Traub of NASA's Jet Propulsion Laboratory and CfA, propose using Earth's atmospheric history to understand other planets.

"Good planets are hard to find," said Kaltenegger. "Our work provides the signposts astronomers will look for when examining truly Earth-like worlds."

Geologic records show that Earth's atmosphere has changed dramatically during the past 4.5 billion years, in part because of life forms developing on our planet. Mapping what gases comprised Earth's atmosphere during its history, Kaltenegger and Traub propose that by looking for similar atmospheric compositions on other worlds, scientists will be able to determine if that planet has life on it, and if so, that life's evolutionary stage.

To date, all extrasolar planets have been studied indirectly, for example by monitoring the way a host star wobbles as the planet's gravity tugs it. Only four extrasolar planets have been detected directly, and they are massive Jupiter-sized worlds. The atmosphere of one of these worlds was detected by another CfA scientist, David Charbonneau, using NASA's Spitzer Space Telescope. The next generation of space-based missions such as NASA's Terrestrial Planet Finder (TPF) and ESA's Darwin will be able to directly study nearby Earth-sized worlds.

Astronomers particularly want to observe the visible and infrared spectra of distant terrestrial planets to learn about their atmospheres. Particular gases leave signatures in a planet's spectrum, like fingerprints or DNA markers. By spotting those fingerprints, researchers can learn about an atmosphere's composition and even deduce the presence of clouds.

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Today, Earth's atmosphere consists of about three-fourths nitrogen and one-fourth oxygen, with a small percentage of other gases like carbon dioxide and methane. But four billion years ago, no oxygen was present. Earth's atmosphere has evolved through six distinct epochs, each characterized by a particular mix of gases. Using a computer code developed by Traub and CfA colleague Ken Jucks, Kaltenegger and Traub modeled each of Earth's six epochs to determine what spectral fingerprints would be seen by a distant observer.

"By studying Earth's past, we can learn about the present state of other worlds," Traub explained. "If an extrasolar planet is found with a spectrum similar to one of our models, we potentially could characterize that planet's geological state, its habitability, and the degree to which life has evolved on it."

To better understand these time periods, or "epochs," and to put them into perspective, one can scale the Earth's 4.5-billion-year history down to one year, attaching dates beginning with January 1—the date the Earth formed.

EPOCH 0 – February 12

At Epoch 0 (3.9 billion years ago), the young Earth possessed a turbulent, steamy atmosphere composed mostly of nitrogen, carbon dioxide and hydrogen sulfide. The days were shorter and the Sun was dimmer, shining as a red orb through our orange brick-colored sky. The one ocean that covered our entire planet was a muddy brown that absorbed bombardment from incoming meteors and comets. Carbon dioxide helped warm our world since the infant Sun was a third less luminous than today. Although no fossils survived from this time period, isotopic signatures of life may have been left behind in Greenland rocks.

EPOCH 1 – March 17

About 3.5 billion years ago (Epoch 1), the planet landscape featured volcanic island chains poking out of the vast global ocean. The first life on Earth was anaerobic bacteria – bacteria that could live without oxygen. These bacteria pumped large amounts of methane into the planet's atmosphere, changing it in detectable ways. If similar bacteria exist on another planet, future missions like TPF and Darwin could detect their fingerprint in the atmosphere.

EPOCH 2 – June 5

About 2.4 billion years ago (Epoch 2), the atmosphere reached its maximum methane concentration. The dominant gases were nitrogen, carbon dioxide, and methane. Continental landmasses were beginning to form. Blue-green algae began pumping large amounts of oxygen into the atmosphere. Big changes were about to happen.

"I'm sorry to say the first signs of E.T. probably won't be a radio or TV broadcasts; instead, it could be oxygen from algae," lamented Kaltenegger.

EPOCH 3 – July 16

Two billion years ago (Epoch 3), these first photosynthetic organisms shifted the atmosphere's balance

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permanently—they produced oxygen, a highly reactive gas that cleared out much of the methane and carbon dioxide, while also suffocating the anaerobic, methane-producing bacteria. In doing so, the planet's atmosphere gained its first free oxygen. The landscape now was flat and damp. With volcanoes smoking in the distance, brilliantly colored pools of greenish-brown scum created a sheen on the stench-filled water. The oxygen revolution was fully underway.

"The introduction of oxygen was catastrophic to the dominant life on Earth at that time; it poisoned it," Traub said. "But at the same time, it made multicellular life, including human life, possible."

EPOCH 4 – October 13

At 800 million years ago, the Earth entered Epoch 4, with continuing increases in oxygen levels. This time period coincides with what is now known as the "Cambrian Explosion." Beginning 550 to 500 million years ago, the Cambrian Period is a significant marker post in the history of life on Earth: It is the time most major animal groups first appear in the fossil records. The Earth was now covered with swamps, seas and a few active volcanoes. The oceans were teaming with life.

EPOCH 5 – November 8

Finally, 300 million years ago in Epoch 5, life had moved from the oceans onto land. The Earth's atmosphere had reached its current composition of primarily nitrogen and oxygen. This was the beginning of the Mesozoic period that included the dinosaurs. The scenery looked like Jurassic Park on a Sunday afternoon.

EPOCH 6 – December 31 (11:59:59)

The intriguing question that remains is: What would Epoch 6, the time period humans occupy today, look like? Could we detect the telltale signs of alien technologies on distant worlds?

As the general consensus builds among scientist that human activity has altered Earth's atmosphere by inputting carbon dioxide as well as gases like Freon, could we identify the spectral fingerprints of those byproducts on other worlds? Although Earth-orbiting satellites and balloon experiments can measure these changes here at home, detecting similar effects on a distant world are beyond even the capabilities of upcoming programs like Terrestrial Planet Finder and Darwin. It will take gigantic flotillas of future space-based infrared telescopes to be able to accomplish those measurements.

"As daunting as this challenge sounds," said Kaltenegger, "I do believe in the next few decades we will know whether or not our little blue world is all alone in the Universe or if there are neighbors out there waiting to meet us."

This research was funded by NASA.

Headquartered in Cambridge, Mass., the Harvard-Smithsonian Center for Astrophysics is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.

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