The Mystery of the Missing Atmosphere

Scientists have been investigating many possibilities for why Earth's atmosphere is so thin. Recently, researchers at Northwestern University and Harvard University explored the idea that all planets may initially form with thick gaseous atmospheres, but some planets lose the bulk of their atmospheres over time through **photoevaporation**. Photoevaporation is the removal of gas molecules from a planet's atmosphere through heating by high-energy light.

Photoevaporation is a vivid demonstration of the fact that heating a gas, even an entire planetary atmosphere, increases the kinetic energy of individual atoms and molecules. In photoevaporation, the speed of the particles' movement increases so much that it reaches **escape velocity**. At escape velocity, the kinetic energy of the molecule is greater than the gravitational potential energy keeping the molecule on the planet; therefore, the molecule escapes out into space ("evaporates").

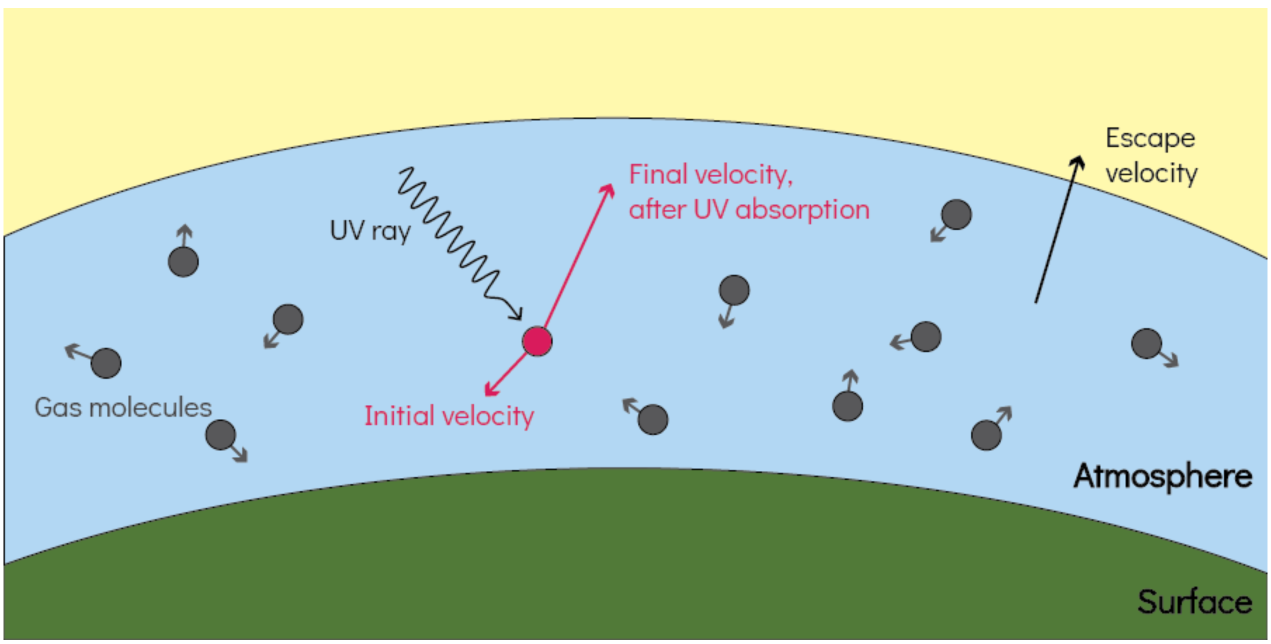

Figure 1. Photoevaporation. High energy UV light hits gas molecules in the atmosphere which increases the kinetic energy of the gas molecules enough such that they can escape the gravitational pull of the planet.

The key to the photoevaporation process is having a heating source that can increase the kinetic energy of the gas molecules. One source of heating is high energy, ultraviolet (UV) radiation (light) from stars. When UV light strikes molecules, it can be absorbed and cause the molecules to heat up.

Where else can this UV light come from? You might be surprised to learn that it can come from supermassive black holes that exist at the centers of galaxies. Black holes don't emit light themselves, but supermassive blackholes tend to have large amounts of matter spiraling into their centers. This matter, mostly plasma (like the stuff that makes up stars) is hot—very hot. Superheated matter associated with supermassive black holes can be hundreds of millions of degrees. That kind of heat generates incredibly bright ultraviolet light. So while the black hole doesn't emit light, the matter associated with it can be extremely bright.

Supermassive black holes are found at the center of galaxies. This suggests that photoevaporation may be more prevalent near galactic centers. The Milky Way galaxy, where we live, is an exception. While there is a supermassive black hole in the middle of the Milky Way, it doesn't happen to have a lot of matter swirling at its center, and so is not very bright. But if we are looking for terrestrial planets outside of the Milky Way, we might want to focus our search near the galactic centers. We should also keep in mind that the same high energy radiation that causes photoevaporation will also pose a danger for life; the planets may be terrestrial, but not habitable. While there are many other factors besides photoevaporation and high energy irradiation that affect whether a planet will have a terrestrial surface or is habitable, this work is a step forward in our understanding of what parts of our galaxy—and the universe itself—are the most likely to have a planet like our own.

Reference

Chen, Howard, John C. Forbes, and Abraham Loeb. "Habitable Evaporated Cores and the Occurrence of Panspermia Near the Galactic Center." *The Astrophysical Journal* 855, no. 1 (2018). doi:10.3847/2041-8213/aaab46.

BiteScientist Profiles

Nathan Sanders is an astrophysicist and statistician working in industry. His astronomical research focused on core-collapse supernovae, the explosive deaths of the most massive stars in the universe. Like the science in this bite, those explosions rely on laws of physics at scales unlike anything we experience day to day on Earth. In his free time, Nathan enjoys hiking, gardening, and analyzing volumetric flow data from municipal combined sewer systems.

Kristen L. Cacciatore is a full-time chemistry and physics teacher at Charlestown High School, an urban public school. Kristen, who has a doctorate in green chemistry, has led a high school-elementary school science mentoring program and the Advanced Placement science enrichment and support program for the Boston Public Schools. She also serves as a mentor for beginning and pre-service teachers. In her free time Kristen likes to run, cook and travel the world.