Researchers Produce Images of Gases Escaping from Jupiter's Moon Io

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Boston University researchers published today the first clear evidence of how gases from Jupiter's tiny moon's volcanoes can lead to the largest visible gas cloud in the solar system. Jupiter, the largest planet in the solar system, has a moon named Io that is just 100 km larger in radius than Earth's Moon.

According to lead researcher Michael Mendillo, professor of electrical and computer engineering and astronomy at BU, there are over 100 active volcanic sites on Io making it the most active place for volcanic activity known anywhere.

"Of the various gases that come from Io's volcanoes, sodium atoms can be detected using ground-based telescopes because the light they emit is in the visible part of the spectrum – the same familiar orange glow from sodium street lights that are in most American cities," said Mendillo. "Therefore, sodium atoms become a tracer of other elements that might be more abundant, but less easy to see."

In 1990, BU scientists discovered a large gas cloud – or nebula – of sodium atoms (Na) spanning great distances to either side of Jupiter.

"If this faint structure could be seen by the naked eye, it would be over ten times the size of the full Moon, and thus the largest permanently visible object in our solar system," Mendillo explained. "Computer models suggested the types of escape processes needed to feed this giant nebula, but actual pictures of those sources eluded observers for many years."

The research team from Boston University's College of Engineering and Center for Space Physics (CSP) solved this problem by developing a novel way to photograph these sources using a high-definition imaging (HDI) system that combines several images into one clear picture.

The new images, published in the July 19th issue of the journal *Nature*, reveal two distinct sources of sodium atoms escaping from Io. One is a symmetrical cloud of escaping gas produced by collisions of the streaming ions and electrons in Jupiter's so-called plasma torus. These plasma particles are trapped in Jupiter's strong magnetic field and rotate with the planet's 10-hour period, much faster than the 2-day orbital period of Io. "So, there is a continuous plasma wind hitting Io, causing sodium atoms to be sputtered from its atmosphere," Mendillo explained.

According to the scientists, this sputtering source is distinctly different from a localized source of atoms produced chemically in the wake of the streaming torus flow past Io. The images define the extent of the sputtering and stream sources for the first time.

"Since the giant sodium nebula that they create varies over periods of months to years, the source of the variability is probably not the symmetrical sputtering cloud, but the streaming-wake source that waxes and wanes with volcanic activity on Io," explained Jody Wilson, CSP senior research associate and a study co-author.

The observations were made using a 4-meter telescope operated by the U.S. Air Force on Maui, HI. To capture the faint signals from sodium atoms close to Io, the observers had to find a way to cope with the bright sunlight reflected from Io's surface, as well as from the even stronger light from nearby Jupiter. In addition, ever-present turbulence in the Earth's atmosphere causes the image of Io to jitter about randomly.

Thus, any attempt to capture the faint Na light by long time-exposures would result in a highly blurred image.

“Our HDI system solved this problem in two ways. First, by taking very short exposures – 1/60th of a second – the atmosphere might be steady for that instant and thus occasional sharp images could be found; and second, by dividing the full spectrum of light from Io into a narrow wavelength range,” explained CSP senior research associate Jeffrey Baumgardner, the HDI instrument designer and a co-author of the study. “That is, capturing only the color needed to see sodium above the glare of full light and then using most of the remaining light to simultaneously follow the fluctuating positions of Io.”

The goal was to then reposition Io to the same place in each frame and use only the very clearest of those frames to make what Mendillo calls “the ideal time exposure, one made with the target stationary, a good spectral signal, and the best possible seeing.”

The CSP observing team returned to Boston with 62,500 such images stored on a computer and Mendillo wondering how the goal would be achieved. Study co-author Sophie Laurent, a doctoral candidate at the time in Electrical and Computer Engineering, assumed responsibility for the required signal processing, with guidance from Professors Clem Karl and Janusz Konrad, signal processing experts. Dr. Laurent devised automated ways to center all of the images and then to find the highly-defined ones needed to make the best possible images.

“These images provide specific spatial scales and relative strengths of these sources that now can be put into computer models that attempt to simulate how all types of gases escape from Io to populate the vast regions of space surrounding Jupiter,” Mendillo added.

Source: Boston University