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The Surprising Tale of Mercury's Tail

The innermost planet sports a comet-like appendage.

A planet's ability to retain an atmosphere depends on its mass, temperature, and the types of gases present. Massive planets have high *escape velocities* — the speed required for atoms and molecules of gas to break free of a planet's gravitational influence. If temperatures are sufficiently high and escape velocities low, even heavy gases will gradually diffuse into space.

Mercury is both the smallest planet in the solar system and the closest to the Sun. The planet is only 5.5% as massive as Earth, with surface temperatures reaching a blistering 430°C (800°F) near the equator. Prior to NASA's Mariner 10 spacecraft flyby in 1974, astronomers suspected that Mercury might have a thin but appreciable atmosphere composed of heavy gases like carbon dioxide and argon produced by radioactive potassium decaying in the planet's crust.

The sensitive ultraviolet spectrometer aboard Mariner 10 failed to detect these gases but did find an exceedingly tenuous envelope of hydrogen, helium, and atomic oxygen. More rarefied than the best vacuum that any laboratory can produce, the isolated atoms detected rarely collide with one another. The absence of mutual collisions is also characteristic of Earth's *exosphere* — the outermost layer of our planet's atmosphere that begins at an altitude of about 700 kilometers (435 miles) and extends over 9,000 km to the boundary of interplanetary space.

▲ Italian amateur Andrea Alessandrini captured Mercury's tenuous sodium tail using a 66-mm f/4.8 refractor and a Pentax K3-II DSLR camera equipped with a narrowband sodium filter. His striking image taken on May 13th, 2021, required a 7-minute exposure guiding on the planet.

Hydrogen and helium are the lightest of all gases and quickly escape Mercury's feeble gravity. They are continuously replenished by the *solar wind*, the stream of charged particles that emanates from the upper atmosphere of the Sun. This hot plasma buffets Mercury up to ten times more intensely than it does Earth.

In 1985, American astronomers Andrew Potter and Thomas Morgan detected sodium in the atmosphere of Mercury using a high-resolution spectrograph and the 107-inch reflector at the McDonald Observatory in Texas. The abundance of this highly reactive metal proved to be greater than either hydrogen or helium.

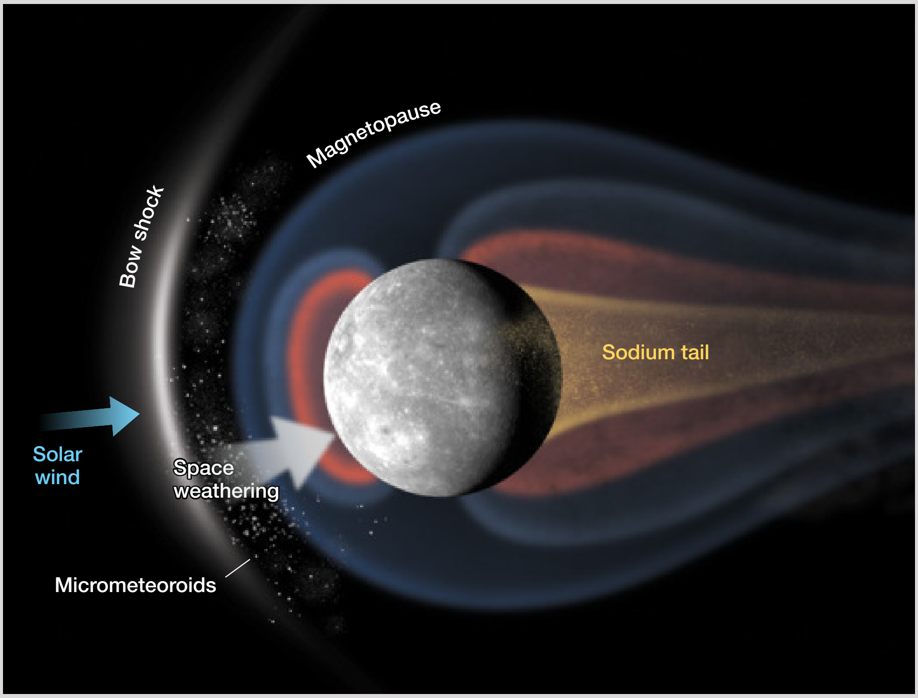
The presence of sodium had eluded Mariner 10's UV spectrometer because the element lacks an appreciable signature in the ultraviolet region of the spectrum but does emit a very strong signal in visible light. When a crystal of table salt (sodium chloride) is held in a gas flame, it imparts an intense yellow color because sodium's spectrum is dominated by a pair of very closely separated lines at wavelengths of 589.1 and 589.6 nanometers in the yellow region of the spectrum.

The ions in the solar wind are electrically charged, so their trajectories are influenced by magnetic fields. Earth's magnetic field deflects the solar wind and prevents our atmosphere from being stripped away, but Mercury's magnetic field has only 1% the strength of our planet's and provides scant protection. The ions from the solar wind strike Mercury at velocities of hundreds of kilometers per second, transferring their energy and dislodging atoms from surface minerals in a process known as *sputtering*.

Micrometeorite bombardment appears to be a second source of Mercury's sodium. The flux of meteoric material increases near the Sun and is about eight times more intense at the orbital distance of Mercury than at Earth's. Instruments aboard NASA's Messenger spacecraft, which orbited Mercury between 2011 and 2015, detected a transient plume of sodium during a meteor shower on Mercury associated with material shed by Comet 2P/Encke. No coronal mass ejection or other energetic solar event occurred at the time, so an impact origin for the plume seems highly likely.

In addition to sodium, Messenger's instruments also detected potassium, calcium, and magnesium in Mercury's exosphere, but these elements lack sodium's strong spectral signature. The same solar radiation that sputters atoms of sodium and other metals off Mercury's surface sweeps them away from the Sun to form a comet-like tail, fulfilling a 1986 prediction by the Chinese planetary scientist Wing-Huen Ip. A tail extending 41,000 km from Mercury was detected in 2001 by Andrew Potter of the National Solar Observatory using the huge, 1.6-meter-aperture McMath-Pierce Solar Telescope atop Kitt Peak in Arizona.

Seven years later, Jeffrey Baumgardner and his colleagues at Boston University's Center for Space Physics tried wide-angle imaging using a narrowband filter that selectively transmitted sodium's yellow emission lines. They were amazed to record a tail extending more than 2.6 million km from the planet. From an Earthbound vantage point, this tail extended 1½°, three times the apparent diameter of the full Moon. Baumgardner's team determined that an atom of sodium blasted from Mercury's surface takes only 15 hours to be driven to the end of its tail.



▲ Mercury's sodium tail is produced when ions from the solar wind and a constant rain of micrometeoroids vaporize Mercury's surface rocks. At high altitudes the released sodium atoms overcome the planet's gravitational influence and are accelerated in the anti-sunward direction by radiation pressure to form a tail.

GREGG DINDERMAN / *S&T*, MERCURY: NASA / JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY / CARNEGIE INSTITUTION OF WASHINGTON

The Messenger spacecraft found dramatic changes in the abundance of sodium in Mercury's exosphere and the intensity of sodium emission from its tail. In 2020 Japanese investigators presented evidence that increases in the amount of sodium released by micrometeoroid impacts during encounters with cometary dust streams are responsible for this variability.

Amateurs can record images of Mercury's tail using surprisingly modest equipment. A Wratten 12 or 15 yellow filter will darken the background sky by selectively transmitting light emitted by ionized sodium while blocking other wavelengths. Even higher contrast can be achieved with a narrowband dielectric interference filter centered at 589.2 nanometers like the one available at **https://is.gd/Sodiumna**. Still, the tail is exceedingly faint and requires an exposure of several minutes. Stacking several short exposures is also a viable option.

Mercury is notoriously difficult to observe due to its close proximity to the Sun. This spring, the planet has its most favorable elongation for northern observers, reaching greatest eastern elongation on April 29th. At sunset on that date the planet will be nearly 19° above the western horizon for observers at a latitude of 40°N. During the last week of April and the first week of May it should be possible to image Mercury against the backdrop of a reasonably dark sky. The planet sets as twilight deepens, so the window of opportunity will be brief. A transparent sky free of light-scattering haze is essential. Careful preparation and no small amount of luck are required to record one of the solar system's largest but most insubstantial features.

■ Although Contributing Editor **TOM DOBBINS** regards Mercury as an unrewarding telescopic target, he's keen to try to capture an image of its tail.