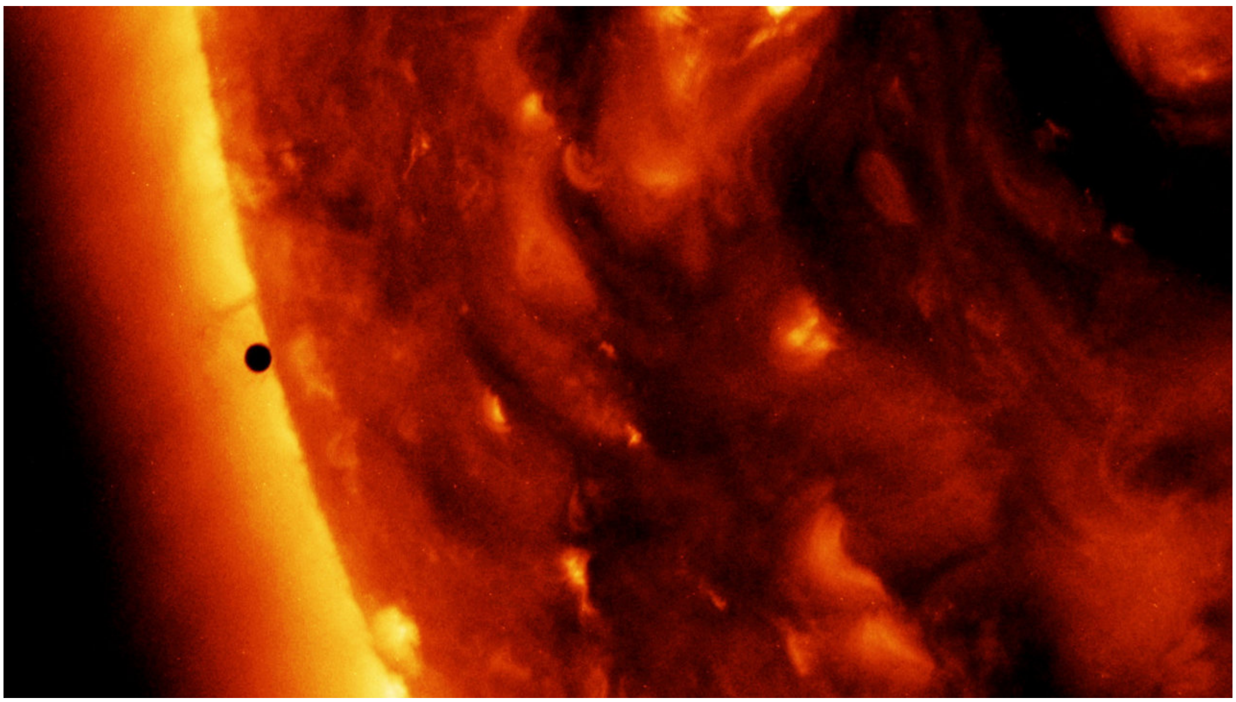
NASA team studies middle-aged Sun by tracking motion of Mercury

January 18 2018, by Elizabeth Zubritsky



Mercury's proximity to the Sun and small size make it exquisitely sensitive to the dynamics of the Sun and its gravitational pull. Credit: NASA/SDO

Like the waistband of a couch potato in midlife, the orbits of planets in our solar system are expanding. It happens because the Sun's gravitational grip gradually weakens as our star ages and loses mass. Now, a team of NASA and MIT scientists has indirectly measured this mass loss and other solar parameters by looking at changes in Mercury's orbit.

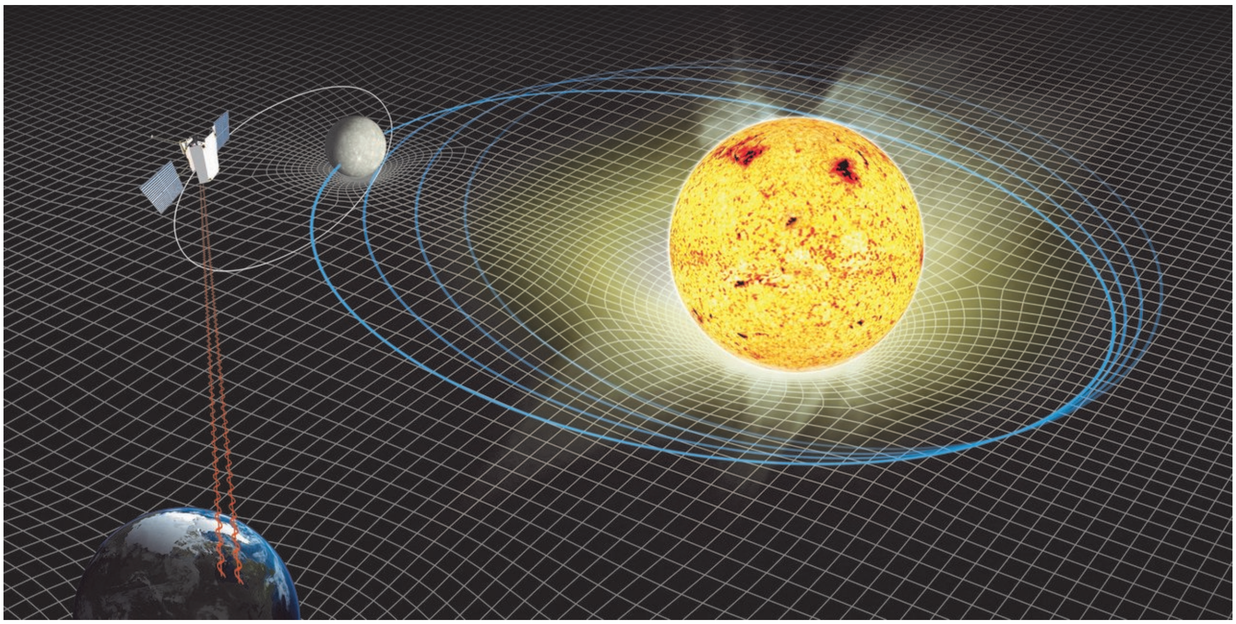
The new values improve upon earlier predictions by reducing the amount of uncertainty. That's especially important for the rate of solar mass loss, because it's related to the stability of G, the gravitational constant. Although G is considered a fixed number, whether it's really constant is still a fundamental question in physics.

"Mercury is the perfect test object for these experiments because it is so sensitive to the gravitational effect and activity of the Sun," said Antonio Genova, the lead author of the study published in *Nature Communications* and a Massachusetts Institute of Technology researcher working at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

The study began by improving Mercury's charted ephemeris—the road map of the planet's position in our sky over time. For that, the team drew on radio tracking data that monitored the location of NASA's MESSENGER spacecraft while the mission was active. Short for Mercury Surface, Space Environment, Geochemistry, and Ranging, the robotic spacecraft made three flybys of Mercury in 2008 and 2009 and orbited the planet from March 2011 through April 2015. The scientists worked backward, analyzing subtle changes in Mercury's motion as a way of learning about the Sun and how its physical parameters influence the planet's orbit.

For centuries, scientists have studied Mercury's motion, paying particular attention to its perihelion, or the closest point to the Sun during its orbit. Observations long ago revealed that the perihelion shifts over time, called precession. Although the gravitational tugs of other planets account for most of Mercury's precession, they don't account for all of it.

The second-largest contribution comes from the warping of space-time around the Sun because of the star's own gravity, which is covered by Einstein's theory of general relativity. The success of general relativity in explaining most of Mercury's remaining precession helped persuade scientists that Einstein's theory was right.



NASA and MIT scientists analyzed subtle changes in Mercury's motion to learn about the Sun and how its dynamics influence the planet's orbit. The position of Mercury over time was determined from radio tracking data obtained while NASA's MESSENGER mission was active. Credit: NASA's Goddard Space Flight Center

Other, much smaller contributions to Mercury's precession, are attributed to the Sun's interior structure and dynamics. One of those is the Sun's oblateness, a measure of how much it bulges at the middle—its own version of a "spare tire" around the waist—rather than being a perfect sphere. The researchers obtained an improved estimate of oblateness that is consistent with other types of studies.

The researchers were able to separate some of the solar parameters from the relativistic effects, something not accomplished by earlier studies that relied on ephemeris data. The team developed a novel technique that simultaneously estimated and integrated the orbits of both MESSENGER and Mercury, leading to a comprehensive solution that includes quantities related to the evolution of Sun's interior and to relativistic effects.

"We're addressing long-standing and very important questions both in fundamental physics and solar science by using a planetary-science approach," said Goddard geophysicist Erwan Mazarico. "By coming at these problems from a different perspective, we can gain more confidence in the numbers, and we can learn more about the interplay between the Sun and the planets."

The team's new estimate of the rate of solar mass loss represents one of the first times this value has been constrained based on observations rather than theoretical calculations. From the theoretical work, scientists previously predicted a loss of one-tenth of a percent of the Sun's mass over 10 billion years; that's enough to reduce the star's gravitational pull and allow the orbits of the planets to spread by about half an inch, or 1.5 centimeters, per year per AU (an AU, or astronomical unit, is the distance between Earth and the Sun: about 93 million miles).

The new value is slightly lower than earlier predictions but has less uncertainty. That made it possible for the team to improve the stability of G by a factor of 10, compared to values derived from studies of the motion of the Moon.

"The study demonstrates how making measurements of planetary orbit changes throughout the solar system opens the possibility of future discoveries about the nature of the Sun and planets, and indeed, about the basic workings of the universe," said co-author Maria Zuber, vice president for research at MIT.

More information: Antonio Genova et al. Solar system expansion and strong equivalence principle as seen by the NASA MESSENGER mission, *Nature Communications* (2018). DOI: 10.1038/s41467-017-02558-1

Provided by NASA's Goddard Space Flight Center