PLANETARY NEWS: CASSINI-HUYGENS (2006)

CASSINI OBSERVES THE ORBITAL DANCE OF EPIMETHEUS AND JANUS

By Emily Lakdawalla
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Saturn is surrounded by a crowded family of rings and moons, and two of those moons -- Epimetheus and Janus -- orbit Saturn so close together that it seems as though their different orbital speeds should make them crash into each other. But due to the complex interplay of their mutual gravitational attraction and their very slightly different distances from Saturn, they never get closer than about 15,000 kilometers (9,000 miles) from each other. Instead of crashing, they exchange orbital positions in a gravitational do-si-do, an event that has been unfolding for the last 3 months and culminates tomorrow at 02:24:57 UTC (today at 18:24:57 PST).

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Epimetheus
Cassini captured this view on March 30, 2005. Credit: NASA / JPL / SSI

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Janus
Voyager 2 captured this view of on August 25, 1981. Credit: NASA / JPL

"The satellites do their swap once every 4 years," explains Carl Murray, a member of Cassini's imaging team who is coordinating the Janus and Epimetheus observations. "During the current swap, Janus moves from the outside to the inside while Epimetheus moves from the inside to the outside. The swap itself takes about 100 days. Each moon is on an eccentric orbit and so they are always moving in and out -- what changes during a swap is their semi-major axes as they exchange angular momentum."

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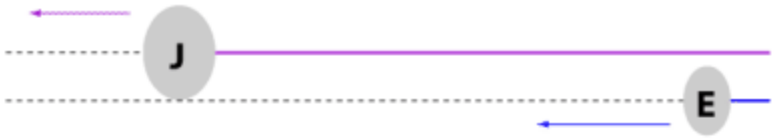
Here is how the dance works. Epimetheus and Janus are small, irregularly-shaped moons with diameters of about 120 and 180 kilometers (about 75 and 110 miles), respectively. Their orbits around Saturn differ in size by only 50 kilometers (30 miles). Since Cassini arrived at Saturn, Epimetheus has been the inner of the two satellites. Because it is closer to Saturn, Epimetheus travels at a faster angular rate than Janus, so inner Epimetheus has slowly, inexorably been catching up to outer Janus. As the two have approached each other in their orbits, Epimetheus tugs on Janus from behind as Janus tugs on Epimetheus with equal and opposite force.

The mutual tugging causes them to exchange angular momentum. Epimetheus gains momentum and rises in orbit as Janus loses an equivalent amount of momentum and falls. Because Janus is four times more massive than Epimetheus, it falls four times less than Epimetheus rises. The switch of orbital altitudes makes Janus -- still ahead of Epimetheus in its orbit -- the faster of the two. As a result, Janus creeps ahead. It will continue to creep slowly ahead of Epimetheus until it catches up from behind in 4 more years.



Epimetheus orbits closer to Saturn, so has a shorter orbital period and eventually approaches Janus from behind

As they get closer, they tug on each other gravitationally

The tugging by Epimetheus slows down Janus, which makes it fall toward Saturn in its orbit; Janus speeds up Epimetheus, which makes it rise Janus has four times the mass of Epimetheus, so it moves inward by less than Epimetheus moves outward

Closer to Saturn, Janus speeds up in its orbit; farther from Saturn, Epimetheus slows down. Janus will slowly creep ahead of Epimetheus; four years later, they'll do the same dance in reverse.

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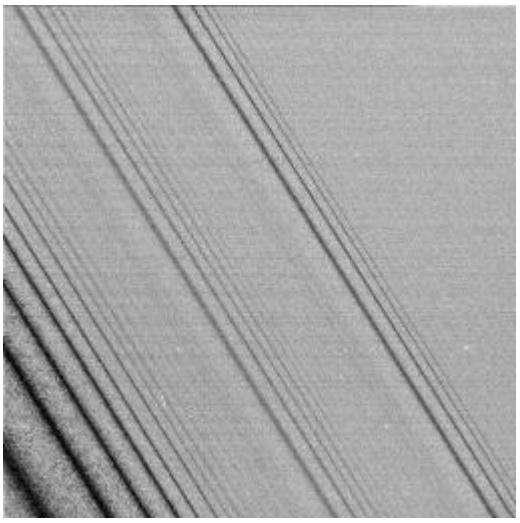
Credit: Emily Lakdawalla

Of course, the full situation is a little more complicated than the above explanation. "In reality, the satellites always experience each other's gravitational effect," explains Murray. Observing this orbital interaction can allow Cassini scientists to determine some physical data describing the two moons. "If we were very restricted in our observations then we could observe the changes in the semi-major axis to get the ratio of the two masses and then use observations of the closest approach distance to get the sum of the masses, allowing us to solve for each. This is all based on the dynamics of the three-body problem."

But, he goes on to say, Janus and Epimetheus aren't only tugging on each other. They also tug on the particles in Saturn's rings, and that complex interplay is one of the main targets of his investigation of the dancing moons. All of Saturn's moons create complex wavelike structures within Saturn's rings, which make them appear finely corrugated. The waves are excited because of orbital resonances between ring particles and moons -- at certain distances from Saturn, ring particles and the moons have orbital periods that are integer ratios of each other, so they meet and part and meet again over time, and repeated, rhythmic gravitational tugs by the masses of the moons accumulate to change the orbits of the ring particles. The wavelength of the structures, how quickly they damp out, and other parameters are very subtly responsive to the orbits and masses of the moons.



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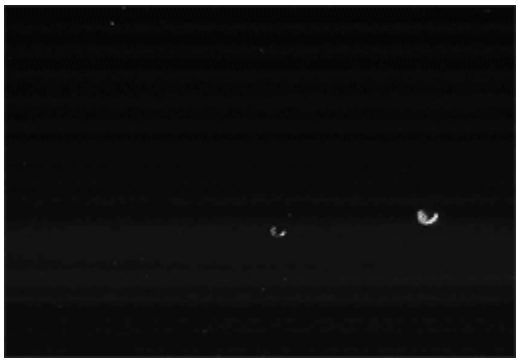
Ultra-close view of Saturn's rings

Just after entering Saturn orbit on July 1, 2004, Cassini turned to capture the closest views it will ever achieve of Saturn's rings. The views were from the north (shadowed) side of the rings. This image, of the outer part of the A ring, contains density wave structures excited by the gravitational influences of the tiny moons Janus, Pandora, and Prometheus. The view spans about 207 kilometers. Source Credit: NASA / JPL / Space Science Institute

So, Murray says, "A key observation is how the rings will respond to the fact that the resonances (and associated density waves) of the two satellites have 'suddenly' changed. Theory predicts that the time scale for the rings to respond [to the swap] should be several months, so that by the time Cassini gets out of the ring plane again at the end of the summer we should have a good view of the interacting density waves." Cassini currently orbits within Saturn's ring plane and has an edge-on view of the Saturn system, from which it is impossible to observe these subtle structures. However, being within the ring plane gives Cassini the chance to watch moons pass in front of and behind each other in so-called "mutual events." Murray says that they will be paying particularly close attention to the outer edge of the A ring. "The Janus 7:6 resonance is located at the edge of the A ring. What happens when that shifts inwards will be interesting to watch!"

Understanding the structure of the rings and their relationship with Janus and Epimetheus requires two sets of observations: finely detailed scans of the structure of Saturn's rings, both before and after the swap, and "movies" of Janus and Epimetheus mutual events against a background of bright stars. "The mutual event observations were designed by Mike Evans and Kevin Beurle at Queen Mary," Murray says. "The reason they are in the tour is because the timing of the exact conjunction allows us to improve [our understanding of] the orbits of both objects. They have the additional advantage that they produce some spectacular movies."

One such spectacular movie is below. This "mutual event" of Epimetheus and Janus as observed by Cassini took place on November 29, 2005. Epimetheus and Janus do not actually pass each other; the apparent crossing is caused by Cassini's shifting point of view as it traveled on its own orbit at a distance of about 1 million kilometers (600,000 miles) from the pair.



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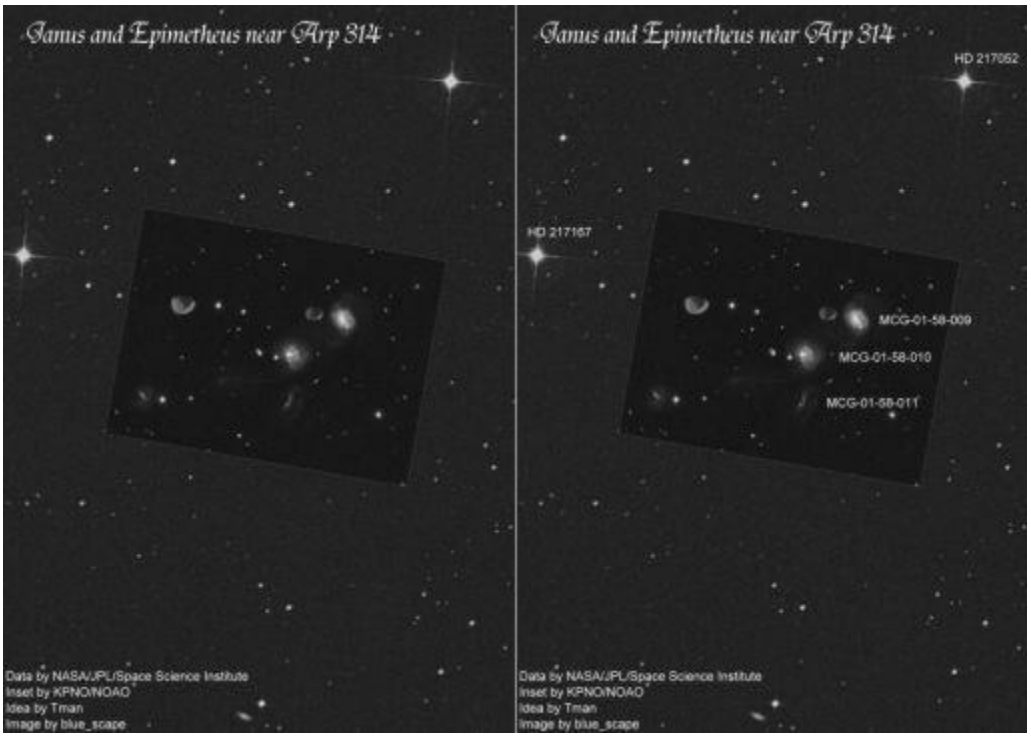
Mutual event of Janus and Epimetheus
On November 29, 2005, Cassini caught a "mutual event" of Janus and Epimetheus from a distance of about a million kilometers (600,000 miles). Most of the specks in the image are cosmic ray hits on the camera detector, but a few that appear to move from frame to frame are background stars. The faint double band of light below the two moons is the G ring, seen nearly edge-on. The moons are observed from their night sides; they are illuminated from the lower right by the Sun into thin crescents, and their night sides are faintly lit by reflected light from Saturn. Credit: NASA / JPL / SSI / Emily Lakdawalla

In addition to Janus and Epimetheus, it is also possible to see a few bright stars moving in the background of the animation. Here, an individual frame from the animation, with its background subtracted, is superimposed on a star field:



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Janus and Epimetheus against a star field

On November 29, 2005, Cassini captured a "mutual event" animation of Janus and Epimetheus. Several background stars were visible in the raw images, so amateurs Peter Greutmann and Nico Schmidt cut Janus and Epimetheus from the Cassini raw images and superimposed them on an image of the star field from an NOAO telescope. Credit: Data: NASA / JPL / SSI / KPNO / NOAO; image by Peter Greutmann and Nico Schmidt

In a particularly beautiful animation produced by enthusiast Peter Greutmann, the entire animation, with background subtracted, is here superimposed on the same star field.

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Janus and Epimetheus "mutual event" against a star field

On November 29, 2005, Cassini captured a "mutual event" animation of Janus and Epimetheus. Janus and Epimetheus do not

actually pass each other in their orbits; it is Cassini's motion that makes them appear to. Several background stars were visible in the raw images, so amateur Peter Greutmann cut Janus and Epimetheus from the Cassini raw images and superimposed them on an accurately scaled and oriented image of the correct star field from an NOAO telescope. Credit: Data: NASA / JPL / SSI / KPNO / NOAO / Animation by Peter Greutmann

So, from today on and for the next 4 years, Janus will be the closer of the two to Saturn, while Epimetheus will be the farther. "In January 2010, the reverse swap takes place, so the configuration is repeated on a cycle of 8 years," Murray says. That date falls 18 months after the end of Cassini's nominal mission, so "We will only be able to observe the reverse swap if there is a Cassini extended mission."
