

Planetary Pretzels

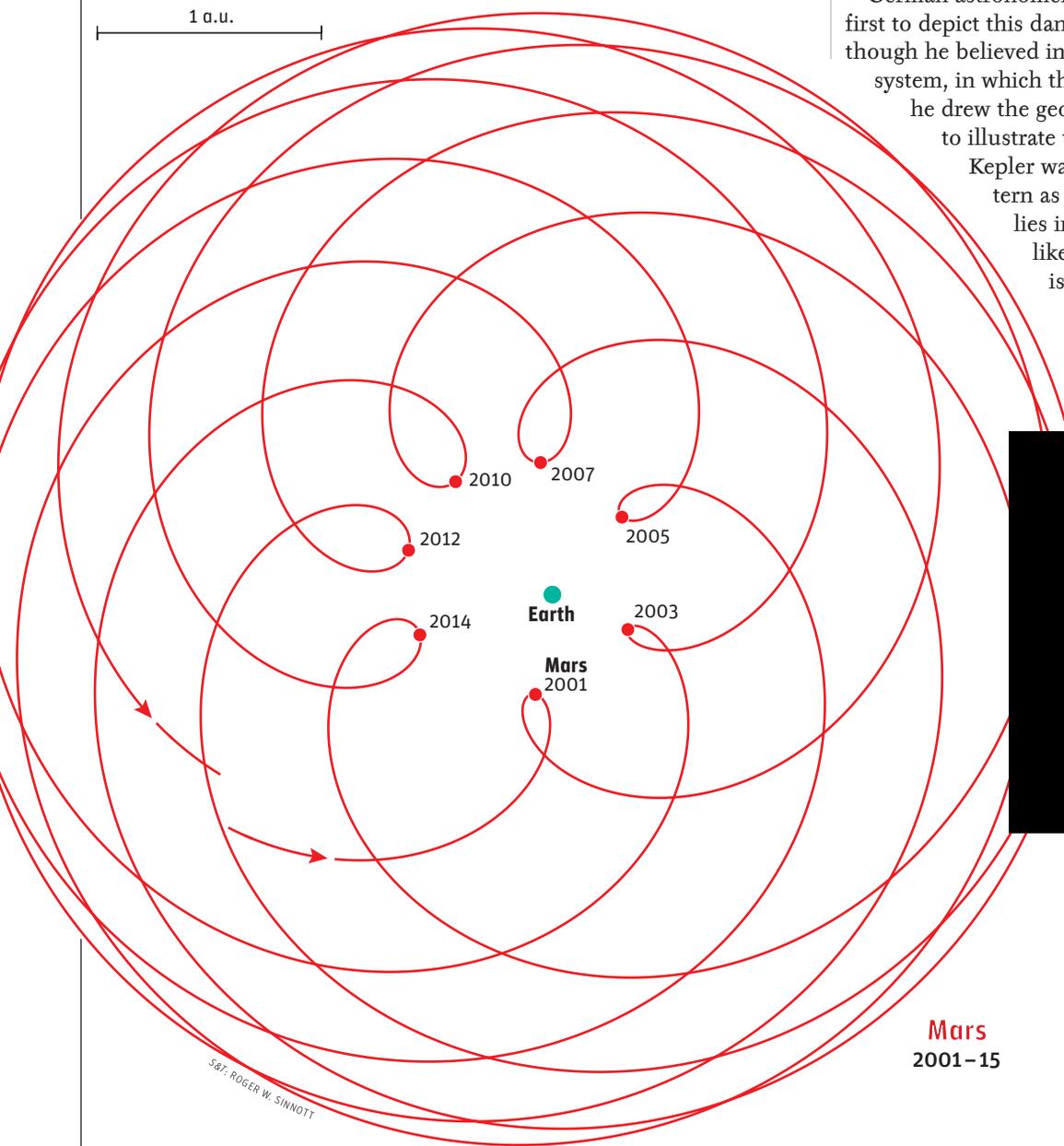
Three diagrams show the inner workings of the orbits of Mercury, Venus, and Mars. *By Owen Gingerich and Richard Conn Henry*

IN AUGUST 2003 the Red Planet made an unusually close approach to Earth. As noted in that year's June issue of *Sky & Telescope* (page 94), Mars had not come this close to our home planet in recorded history, nor would it again be as close for nearly three centuries. How did astronomers know this? Did they calculate the distance of Mars for every single day between now and August 28, 2287?

The answer is that the calculation can be much easier than that. Mars makes a close approach whenever it's near opposition to the Sun in our sky, and this happens every

2.135 years (on average), including the one this November. And the closest of these comes every 15 or 17 years, when the opposition takes place in July, August, or September. This is because Mars's orbit is not concentric with the Sun. It's slightly off center, and the closest possible approach to Earth comes when the Red Planet reaches *perihelion*, its closest point to the Sun, in late August when Earth is also close to the Mars-Sun perihelion line. Therefore, it's necessary to check Mars's position only for a couple of days every 15 or 17 years.

German astronomer Johannes Kepler (1571-1630) was the first to depict this dance of Mars with respect to Earth. Although he believed in the Copernican model of the solar system, in which the Sun was the center of the universe, he drew the geocentric (Earth-centered) path of Mars to illustrate the planet's apparent motion. At first, Kepler was tempted to describe the orbital pattern as a ball of yarn, but since the pattern lies in a flat plane, he reconsidered and likened it instead to a pretzel. To the left is a modern version of Kepler's pretzel diagram, and it shows how the 2003 opposition of Mars brought it a little closer to us than the one this November and how the 2007 opposi-

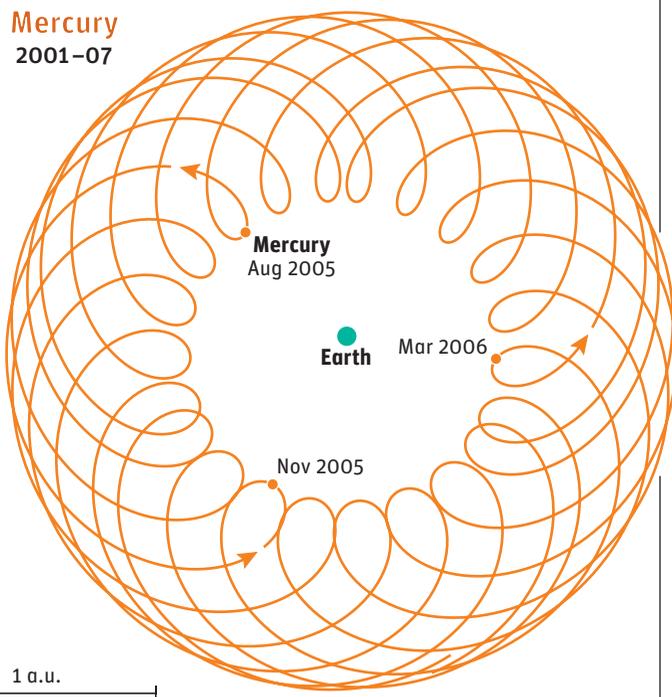
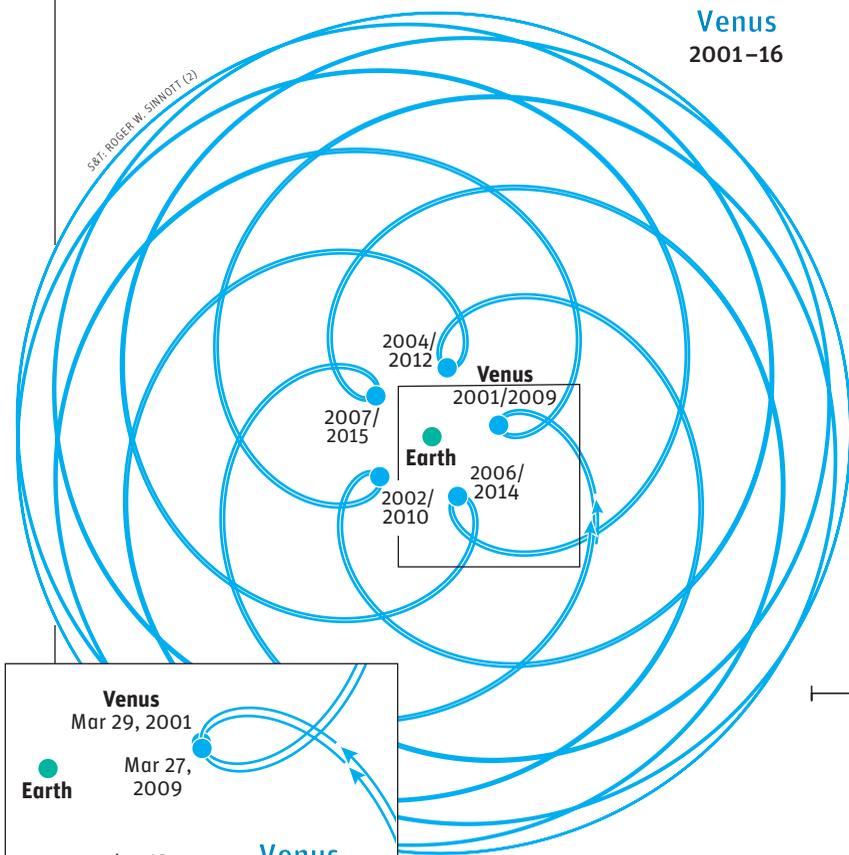


Mars
2001-15

This diagram and the two on the next page show each planet's motion with respect to Earth, beginning January 1, 2001. All are plotted at the same scale; 1 astronomical unit (a.u.) is the mean Earth-Sun distance. Mars shows a greater variation in close approaches than either Mercury or Venus. But the current one is only slightly less favorable than the historic close approach of 2003. *Inset:* Mars last August 22nd, when it was 13" wide.

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Above: Mercury makes a close approach to Earth in late November 2005, but the planet comes a little closer next March. Left: Two 8-year cycles of Venus are superposed to show how closely they repeat. The inset at far left shows the dates when Venus is closest to Earth. These dates fall within a day of Venus's inferior conjunction with the Sun.

tion will keep the Red Planet still farther away.

The same kind of pretzel diagram for swift Mercury shows more frequent loops — roughly three a year — and an approximate repeat of the entire wickerwork pattern every 21 years. Because Mercury is an inner planet, with its orbit lying between the Sun and Earth, it will come closest to us when it's at *aphelion*, or farthest from the Sun (see the upper part of the diagram above, right). At this time, Mercury moves most slowly (according to Kepler's law of equal areas in equal times), and the retrograde loops are narrowest. Note that Mercury never comes as close as Mars.

The most extraordinary diagram of this sort is for the

planet Venus. Notice that it repeats almost identically every eight years. Both the Babylonians and the Maya discovered this cycle, and it became an important feature in the Maya calendar. It's tempting to suppose that somehow the period of Venus is gravitationally locked with Earth's, but their orbits are too nearly circular for this to be a strong effect. It seems this is just a wonderful coincidence!

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eye and I by fred schAAF

CONQUERING KUMA In last June's Eye & I (page 86), I noted that the tightest double star rumored to have been split by anyone's unaided vision is Nu (ν) Draconis, also known as Kuma. The components of Kuma, both shining at magnitude 4.9, are only 62 arcseconds apart. That's almost a dozen times closer than Mizar–Alcor and nearly $3\frac{1}{2}$ times tighter than Epsilon¹ and Epsilon² (ϵ^1 and ϵ^2) Lyrae. Would any reader report being able to conquer Kuma?

So far, I've received only one such report. Turkish amateur astronomer Tunç Tezel writes that back in 1993, when he was a teenager, he managed to split ν Draconis using a bit of a trick. He had slight astigmatism and, when he tilted his head at different angles, he saw the star either as a single slightly elongated point or a pair of slightly elongated points. Tezel says the pair appeared to be oriented nearly, but not exactly, north-south. (The position

angle of Nu's companion is 311° .)

Tezel now wears eyeglasses, and the sky conditions at his observing site have worsened. His latest attempts to split Nu, as well as 17 and 16 Draconis (separation $85''$; magnitudes 5.1 and 5.5, respectively), have failed. But he can still split ϵ^1 and ϵ^2 Lyrae and, in recent years, has seen Venus as elongated, perhaps even with a slight curve, when the planet was near inferior conjunction with the Sun. *

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