The 0.00155780644902 3-Second Pulsar

The Millisecond Pulsar is the fastest ever discovered, and it could be the best clock in the galaxy; are there more?

Some 15,000 light years from Earth in the direction of Vulpecula the Fox—a dim constellation that straddles the Milky Way just south of Cygnus the Swan—there lies a 10-kilometer ball of nuclear matter rotating 642 times every second. It is a pulsar, by far the fastest ever discovered: its equator is moving at one-fifth the speed of light; its rotational kinetic energy is comparable to the total energy output of a supernova; its surface gravity—roughly a trillion times that of the earth—is barely enough to keep the object from flying apart. Discovered on 14 November 1982, it has come to be known as the Millisecond Pulsar; it may very well be the first of a whole new class of pulsars.

The thing may also be the most accurate timepiece in the galaxy. So far, at least, the rotation period seems to be slowing at a steady rate of 10^{-19} seconds per second, which makes it somewhat more reliable than a rubidium clock.

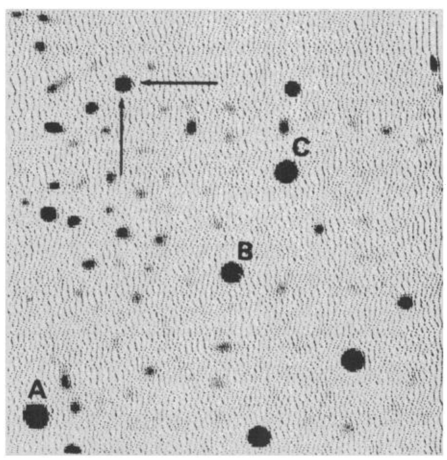
The discovery of the millisecond pulsar was a combination of perseverance and good luck. At first it was just another listing, number 4C21.53, in the fourth Cambridge catalog of radio sources. Only in 1972 did the radio astronomers at Cambridge notice that the object "twinkled" because of turbulent plasma in the interplanetary medium. This is the radio version of the twinkling of starlight in the atmosphere. Since these fluctuations average out in extended sources, the implication was that 4C21.53 is very small.

A further peculiarity was noticed in 1979, when researchers at the University of Iowa found that 4C21.53's radio spectrum rises rapidly with frequency. It was their report that first roused the interest of Donald Backer of the University of California, Berkeley. A small size and a rising spectrum happen to be characteristic of pulsars, he knew. The problem was that a pulsar survey had scanned that very region of the sky in 1973 and found nothing. So what was 4C21.53?

Actually, the problem only pointed up the limitations of pulsar surveys in general, says Backer. "Pulsar" is simply another name for a magnetized, rotating neutron star, the remnant core of a massive star that has gone supernova. The star somehow manages to emit beams of radiation along its magnetic field, and if one of those rotating beams happens to sweep across the earth, like the beam of a lighthouse, astronomers see pulses.

The assumption has always been that rapidly rotating pulsars must be young, says Backer, the prime example being the 33-millisecond pulsar in the Crab Nebula, remnant of a supernova in 1054. Older pulsars have presumably spent their energy in beaming away radiation and are slower. Thus, since young pulsars are thought to be rare, and since there is a lot of sky to look at, observers have always felt safe in cutting off their pulsar surveys at about 30 milliseconds.

Maybe, thought Backer, they had managed to cut off 4C21.53 in the process. He tried looking for short-period pulses in 1979. No luck. Later he looked again at still shorter periods. Still no luck. In September 1982, however, colleagues working at the Arecibo radio telescope in Puerto Rico found tantalizing hints of periodicity around 600 hertz. "I determined to go after it," recalls Backer. Within a few weeks he was in Arecibo himself, and on 14 November he verified pulses at an astonishing 642 hertz, equivalent to a period of 1.1558 milliseconds.



The fastest pulsar (arrows)

An optical candidate, taken by Berkeley astronomer S. Djorgovski on 14 October 1982.

At first, he says, everyone was terribly excited: a pulsar that fast should be very young, practically newborn. But within a week, says Backer, he and his colleagues had ruled that idea out. The pulsar is not surrounded by a gaseous supernova remnant. It is slowing down at a phenomenally low rate, 10^{-19} seconds per second, which means that its magnetic field is quite weak. And its surface is relatively cool, less than 1.5 million degrees Kelvin. In fact, says Backer, it seems that the Millisecond Pulsar is billions of years old.

But if pulsars are supposed to slow down as they age, how did this one get such an enormous spin?

The theorists rose quickly to the challenge. Within a month of the discovery, several groups had successfully modeled the object as a "recycled" pulsar. Originally, they said, the pulsar had been part of a binary system, with an ordinary star as its companion. (Several such binary pulsar systems are known.) The pulsar cooled and slowed in the normal way for eons but, eventually, matter from the companion began to pour across the gap. Perhaps the companion tried to swell into its red giant phase, for example, or perhaps the binary orbit shrank because of gravitational radiation. In any case, the falling matter streamed onto the pulsar surface in rapid spirals, forcing it to spin faster and faster. In the end the companion was utterly dissipated, and the ancient pulsar that had eaten it was spinning nearly a thousand times per second.

If this is indeed the correct explanation for the Millisecond Pulsar, then further searches should turn up quite a few more. Binary systems are common in the galaxy. Astronomers can look forward to studying a whole new class of objects.

But Backer, meanwhile, is fascinated by the pulsar's quality as a clock. "The Naval Observatory claims that their atomic time is accurate to one part in 10^{14}," he says. The pulsar is far more accurate than that—if it stays stable. Other pulsars show tiny, random glitches in their frequency due to shifts in their crust, he points out: "As soon as we get a starquake we don't have a clock." On the other hand, this pulsar seems very old and very quiescent. Nothing has shifted in 3 months.

If the pulsar is reliable, astronomers could refine the motions of the solar system to unprecedented accuracy, says Backer. "You have to translate the pulse arrival time on Earth to the arrival time at the solar system center of mass, which stays fixed," he says. "But that means extracting the variations in the earth's annual motion, which in turn depend on the masses and positions of all the planets. I'm just now learning the limits on what we know."—**M. Mitchell Waldrop**