Boom and Bust at R Leonis

John Baldwin is hoping for some frosty nights in the next few weeks. They won't help his garden but could benefit his astronomy. At this time of year, frost goes hand in hand with clear night skies. And clear skies are a prerequisite for using an innovative telescope—set in a damp, low-lying field near Cambridge, England—to watch a star more than 300 light-years away puff up and shrink.

In a dramatic demonstration of the power of optical interferometry, a technique for linking separate telescopes into the equivalent of a much larger one (see main text), Baldwin and his colleagues at Cambridge University have made the first-ever observation of regular changes in a star's size. The star in question, a variable star called R Leonis, changes diameter by up to 35% over the course of nearly a year, an amount that one of Baldwin's Cambridge co-workers, Chris Haniff, calls "outrageous."

The result, to be published in the *Monthly Notices of the Royal Astronomical Society*, "is very exciting in itself," says Michael Feast, an astronomer at the University of Cape Town, South Africa. He notes that it promises insight into the behavior of these old, bloated stars, called Mira variables, and how they eventually throw off much of their mass and turn into white dwarfs. But he adds, "I also think it's exciting for what it shows [the Cambridge interferometer] can do, and what is now going to be done by them and by other groups too."

Ordinarily, picking out detail on something as distant as a star defeats even large telescopes. The Cambridge instrument, dubbed COAST, or Cambridge Optical Aperture Synthesis Telescope, does the job by capturing light with four small mirrors—each just 16 centimeters across—spaced as much as 6 meters apart (*Science*, 16 February 1996, p. 907). By adding light from the separate telescopes, COAST simulates a telescope with an aperture of 6 meters and—just as important—is able to see through the atmospheric distortion that turns R Leonis and every other star into a bright smudge with even the largest conventional telescope. And because COAST has four mirrors rather than the two of some other interferometers, it can produce complete images of objects, rather than just measuring them along a single dimension.

"We've followed the diameter of this star throughout its cycle," for a total of 2 years, says Baldwin, "and we've seen that throughout a large part of its cycle, the diameter changes from being very small when it's brightest to being much larger when it's at its faintest." The diameter varies from 450 times the diameter of the sun to 600 times, explains Baldwin, even though R Leonis is no more than twice the sun's mass. Its internal instability is thought to drive the cycle: When the star is most compact, its atmosphere dams up radiation, which forces the star to expand so the energy can dissipate.

R Leonis is not just pulsing; it's also losing mass. One day soon, judging from other Mira variables, it will be down to a tiny fraction of the sun's mass, and Baldwin and his colleagues hope their observations will help explain how these stars shed material. The COAST measurements show, for example, that R Leonis expands at the rate of up to 10 kilometers per second, and Haniff suggests that the star might throw off material as it reaches its maximum size, when gravity is less able to hold on to the rapidly expanding, tenuous atmosphere. Another possibility, says Baldwin, is that the surface of the star is churning, with "large convection cells 'boiling,' so that mass comes to the surface in some great sort of blob and then is thrown off."

If so, the surface of the star might look mottled. "There is some small evidence for variations on the surface of this particular star," says Baldwin. Checking out these hints is one goal for future observations, as is trying to capture images crisp enough to see signs of material floating away from the star's surface. **–Andrew Watson**

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long as 640 meters, enabling it to make measurements as fine as 0.05 mas. And the Navy Prototype Optical Interferometer (NPOI) near Flagstaff, Arizona, will have as many as six telescopes spaced out along intersecting baselines as long as 437 meters. Like some other interferometers with multiple baselines, including one in Cambridge, U.K., and the CHARA array in California, NPOI is able to reconstruct actual images, rather than being limited to simple features such as the shape of an orbit or the radius of a star (see sidebar).

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Pipelines to the stars. Light pipes carry beams from the two outlying telescopes of the Palomar Testbed Interferometer to the beam-combining building.

Vital stats of the stars

So far, the lion's share of results on binary systems and giant stars has come from PTI. One effort, led by JPL's Andy Boden, fished out the orbits of the stars in close binary systems. Boden first determined the shape and apparent size of each orbit; then he added high-precision data from other astronomers on the Doppler shifts of the starlight. This "train-whistle" effect reveals each star's velocity toward and away from Earth, making it possible to compute how fast the stars are whirling around each other.

By using methods developed by other astronomers to analyze the orbital trajectories, Boden could then calculate the masses of both companions to within 1%. He was also able to measure the apparent diameters of the stars. Mass and diameter—along with temperature, which is derived from other observations—are stars' vital statistics, the numbers theorists need to test their understanding of how stars evolve. Such data are "few and far between," especially for stars with masses less than the sun's, says Daniel Popper, a veteran astronomer at the University of California, Los Angeles. "If you don't know the fundamental properties of stars," asks Popper, "what do you know about them?"

So far, says Boden, the sizes and masses "are landing right where we expected them to be." Likewise, the sizes of 70 older, bloated, and solitary stars measured for the first time by van Belle and others fall roughly in line with predictions based on computer models of how the stars burn successively heavier elements in fusion reactions.

But starting in the summer of 1996, it looked as if some of the first data out of PTI might undermine a different claim. A year earlier, Michel Mayor and Didier Queloz of the Geneva Observatory had discovered, from Doppler measurements on an ordinary telescope, that the star 51 Pegasi was wobbling toward and away from Earth with a period of 4.23 days (*Science*, 20 October 1995, p. 375).