There's enough acoustic power to blow the star apart half a second after core bounce in Burrows' simulation.

How important this process is remains an open question. It's the accreting material that keeps a lid on the explosion, preventing neutrinos from moving the shock out. "If the neutrino mechanism worked, we would have seen it in our model," Burrows says.

The sound waves push streams of accreting matter to one side of the core while energizing the shock on the opposite side. So, by creating a path of least resistance, sound may help neutrinos revitalize a stalled shock. "It's unproven," he says, "but very interesting." Moreover, the oscillating core could be a prominent source of gravitational radiation.

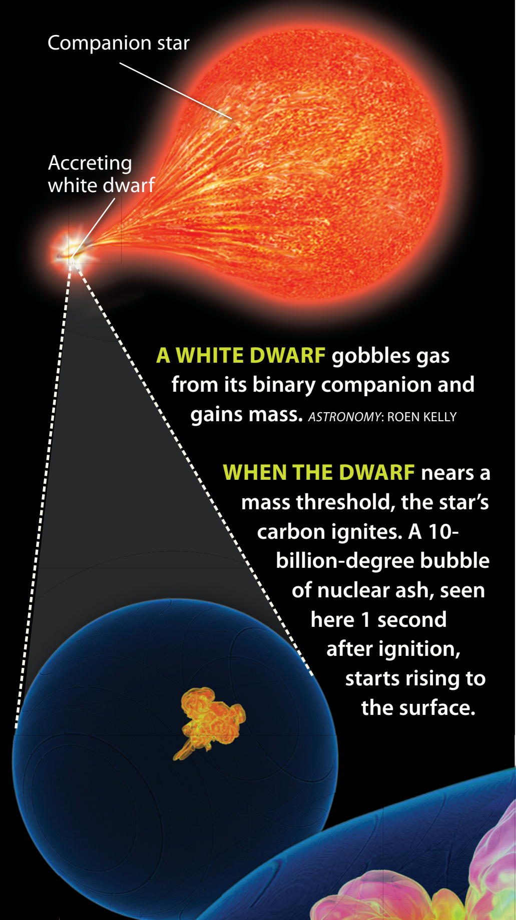
Shattered dwarfs

Large-scale computer simulations are also providing new insights into how white dwarfs, the end state of low-mass stars, destroy themselves as type Ia supernovae. Brighter and more uniform than core-collapse explosions, type Ia events are important probes of the distant universe. The discoveries of dark energy and cosmic acceleration add urgency to deciphering how they work.

A Sun-like star ends its days as a white dwarf, with the star's carbon-oxygen-rich core crushed to Earth's size. Most shine for billions of years, gradually cooling until they fade into dark stellar cinders. Electron pressure prevents further collapse, but it works only if the dwarf weighs less than 1.44 Suns — the so-called Chandrasekhar limit. Exceed that, and collapse resumes until the dwarf becomes a neutron star.

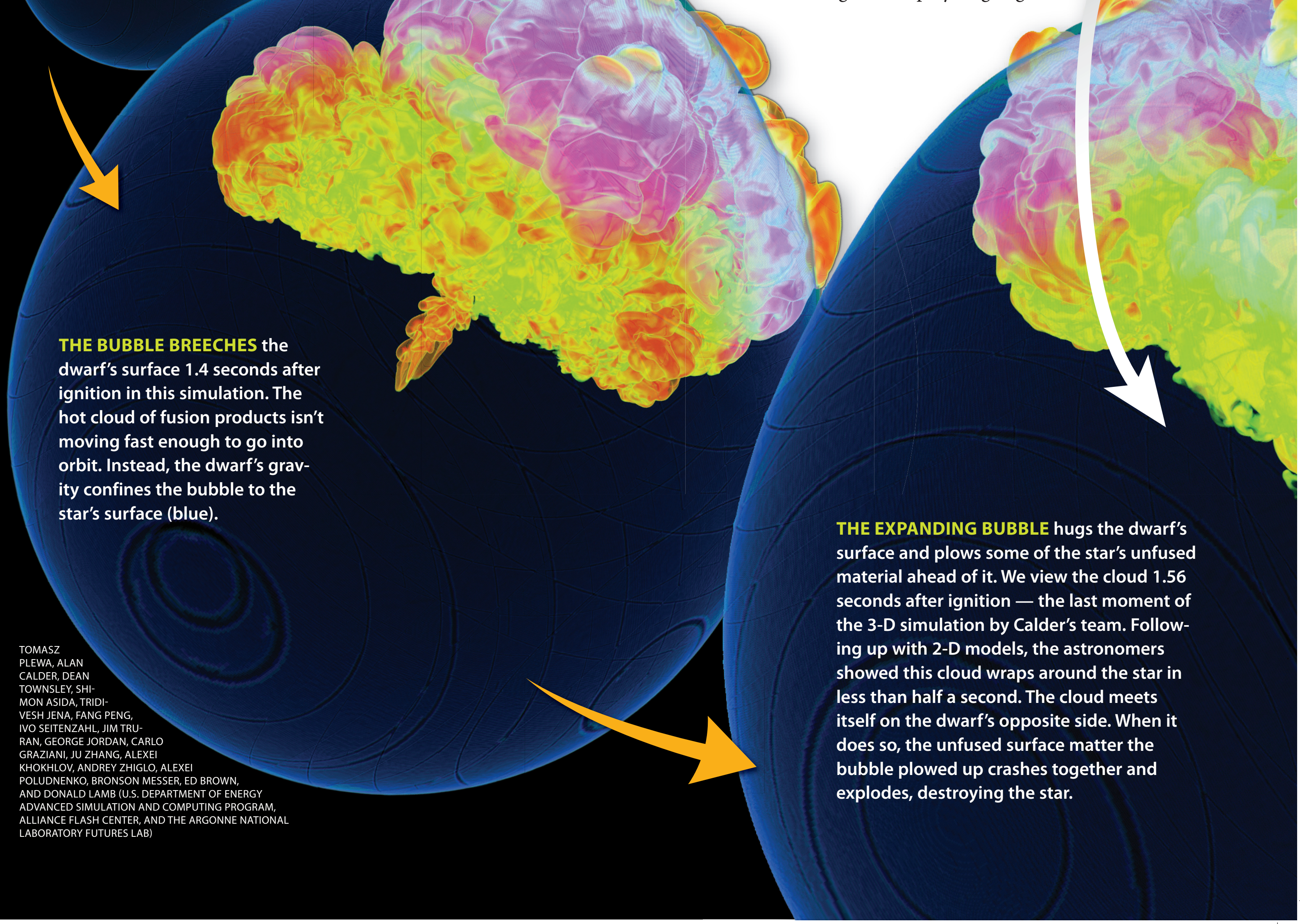
In 1960, University of Cambridge astronomer Fred Hoyle and Caltech's William Fowler realized a white dwarf near this limit could be a giant thermonuclear bomb. Place a white dwarf in close proximity to a normal star, and the dwarf can gain mass until it nears the 1.44-Sun threshold and explode. The dwarf gobbles up hydrogen gas

STELLAR BOMB



A WHITE DWARF gobbles gas from its binary companion and gains mass. *ASTRONOMY*: ROEN KELLY

WHEN THE DWARF nears a mass threshold, the star's carbon ignites. A 10-billion-degree bubble of nuclear ash, seen here 1 second after ignition, starts rising to the surface.



THE BUBBLE BREECHES the dwarf's surface 1.4 seconds after ignition in this simulation. The hot cloud of fusion products isn't moving fast enough to go into orbit. Instead, the dwarf's gravity confines the bubble to the star's surface (blue).

THE EXPANDING BUBBLE hugs the dwarf's surface and plows some of the star's unfused material ahead of it. We view the cloud 1.56 seconds after ignition — the last moment of the 3-D simulation by Calder's team. Following up with 2-D models, the astronomers showed this cloud wraps around the star in less than half a second. The cloud meets itself on the dwarf's opposite side. When it does so, the unfused surface matter the bubble plowed up crashes together and explodes, destroying the star.

TOMASZ PLEWA, ALAN CALDER, DEAN TOWNSLEY, SHIMON ASIDA, TRIDIVESH JENA, FANG PENG, IVO SEITENZAHL, JIM TRURAN, GEORGE JORDAN, CARLO GRAZIANI, JU ZHANG, ALEXEI KHOKHLOV, ANDREY ZHIGLO, ALEXEI POLUDNENKO, BRONSON MESSER, ED BROWN, AND DONALD LAMB (U.S. DEPARTMENT OF ENERGY ADVANCED SIMULATION AND COMPUTING PROGRAM, ALLIANCE FLASH CENTER, AND THE ARGONNE NATIONAL LABORATORY FUTURES LAB) from its partner at a probable rate of about 1/30 of an Earth-mass per year. If it's much slower than this, the dwarf's stellar wind prevents the gas from reaching the surface; if it's any faster, the gas will flash-fuse rather than accumulate.

As a white dwarf tips the scale toward 1.44 Suns, its carbon ignites somewhere inside. Before 2004, no one could figure out how to make a carbon-oxygen star detonate, so theorists first invoked turbulent thermonuclear fusion. These models failed to match the energy and element mix of type Ia blasts. Models that followed a period of turbulent burning with a detonation better matched reality, but theorists simply decided where and when the explosion would occur and inserted it into the simulation. "I sometimes refer to this as the 'Here, a miracle occurs' mechanism," says the University of Chicago's Don Lamb.

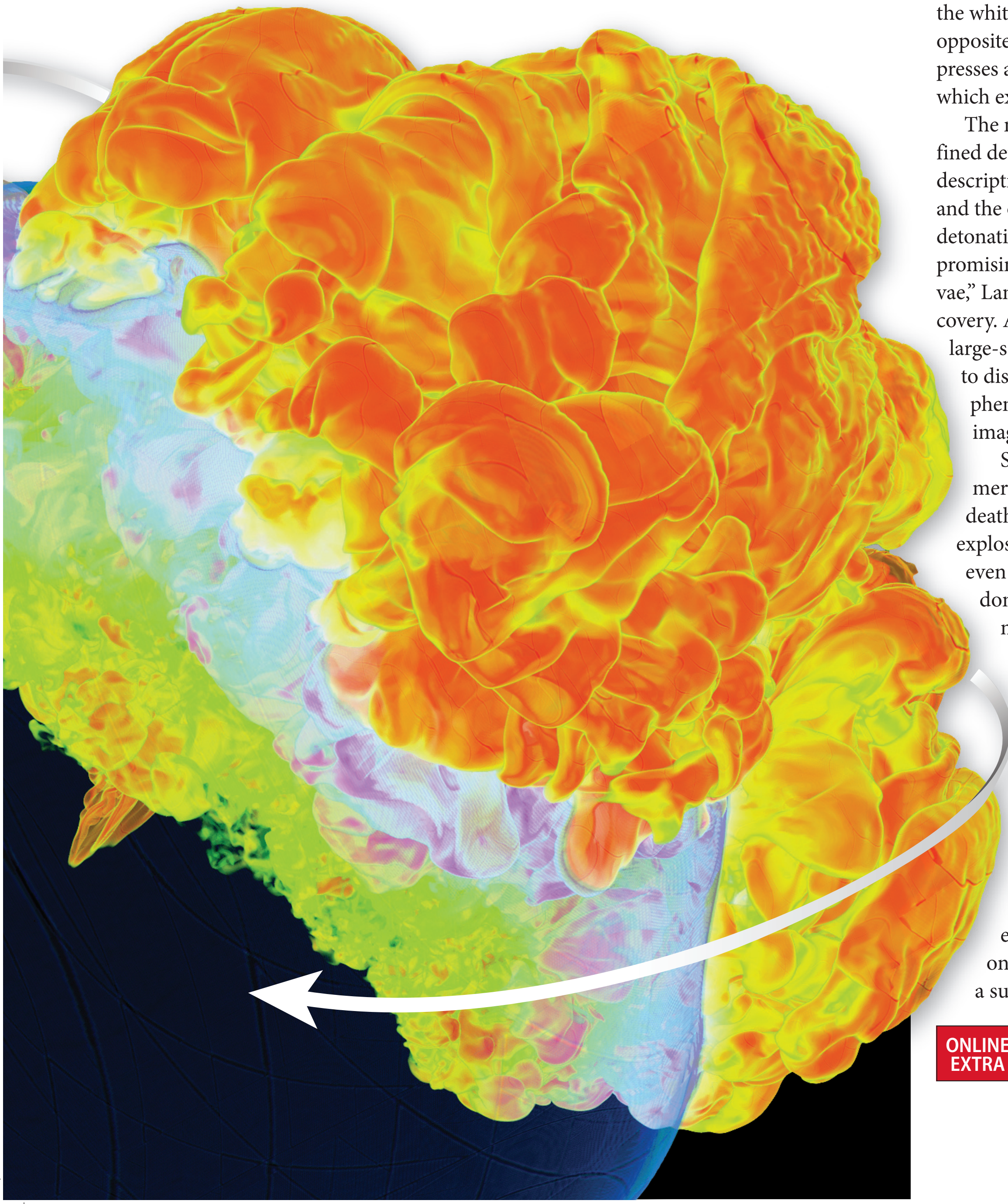
For this reason, Wolfgang Hillebrandt and his group at the Max Planck Institute for Astrophysics in Munich, Germany, tried a different tack. They found that models using turbulent burning alone can better match observations, but, to do so, the dwarf's thermonuclear fires must ignite in about 100 different points at once. That's very unlikely. Says Lamb: "We worry one miracle has been replaced by another."

In 2004, a team led by Alan Calder at the University of Chicago including Lamb, stumbled onto a way to blow up a white dwarf. Thanks to the U.S. Department of Energy's computational resources, the team had the hardware to simulate an entire white-dwarf star. After ignition, a narrow front of nuclear flame expanded through the star, leaving behind a 10-billion-degree ash bubble. When this bubble broke through the dwarf's crust, less than 10 percent of the star's mass had been fused — too little to disrupt the dwarf or produce a strong explosion. "It looked like it might be a dud," Lamb recalls.

Then, team member Tomasz Plewa performed additional 2-D simulations to see what happens after the bubble breeches the star's surface. The nuclear ash erupts, moving at around 6.7 million mph (10.8 million km/h), just shy of orbital speed. The hot cloud hugs the dwarf's billion-degree surface and rapidly spreads. As it does so, it plows up cooler, unfused surface matter. The superheated ash-cloud wraps around the white dwarf and meets itself at the point opposite its breakout. The collision compresses all of the unfused surface material, which explodes and rips the star apart.

The model, called "gravitationally confined detonation," is the most complete description of a type Ia supernova to date — and the only one in which a full-scale detonation naturally occurs. "It's a very promising model for most type Ia supernovae," Lamb says. "It was a serendipitous discovery. And it is a perfect example of how large-scale numerical simulations can lead to discoveries of complex, non-linear phenomena that are very difficult to imagine ahead of time," he adds.

Seventy-four years after astronomers connected supernovae with stellar deaths, the universe's most powerful explosions still tax astrophysicists. Yet, even the most complete simulations don't yet capture the complex environment of an exploding star. Modelers are beginning to probe how neutrino emission, magnetic fields, and rotation affect the picture. Observers watch and catalog new events, using them both as cosmic yardsticks and to find holes in current understanding. And new facilities designed to capture neutrinos and gravitational waves — signals that directly escape an exploding star's core — one day soon may give us a glimpse of a supernova's chaotic heart.



ONLINE EXTRA See movies of supernova simulations at www.astronomy.com/toc.