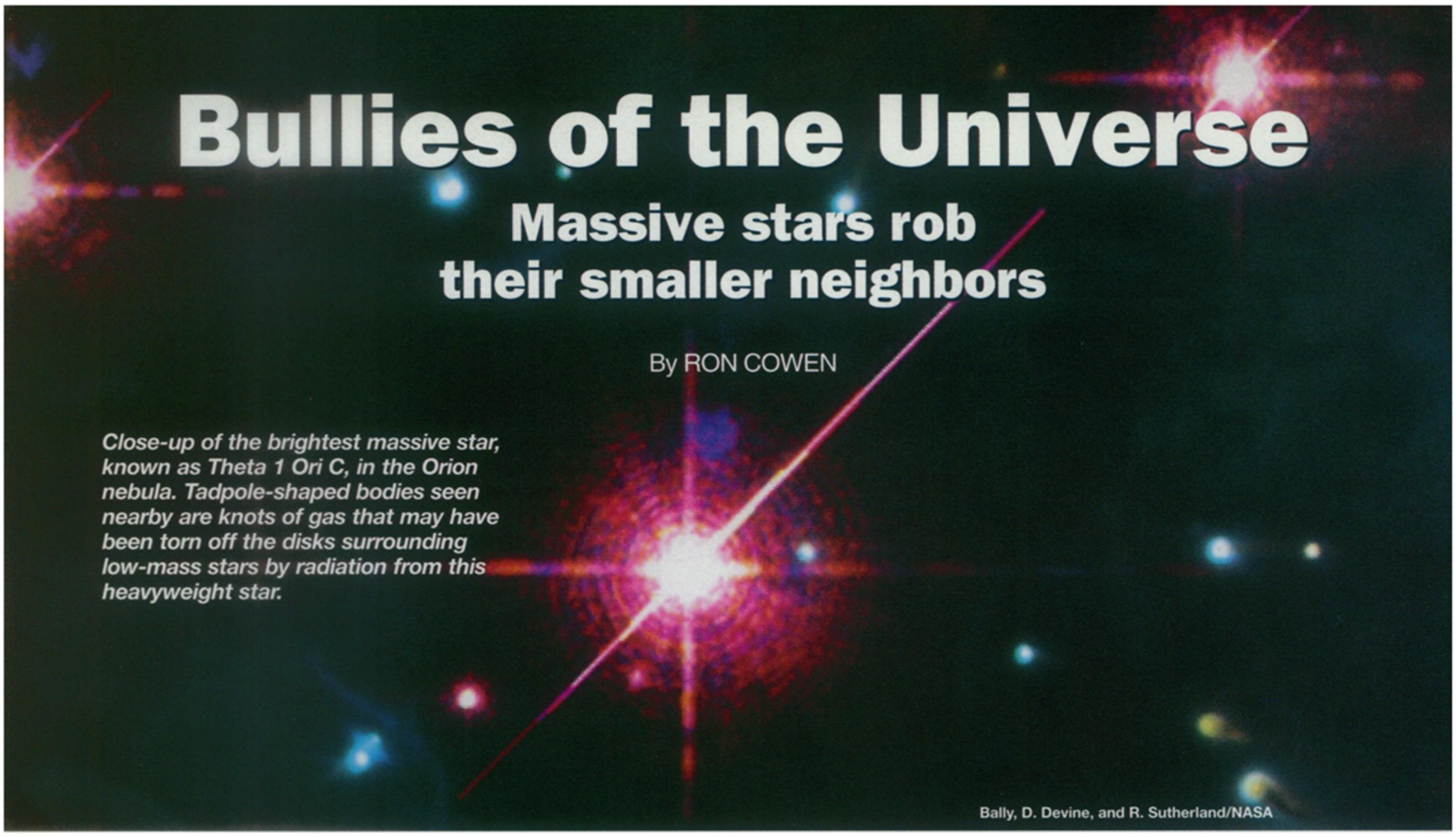
Bullies of the Universe

Massive stars rob their smaller neighbors

By RON COWEN



Close-up of the brightest massive star, known as Theta 1 Ori C, in the Orion nebula. Tadpole-shaped bodies seen nearby are knots of gas that may have been torn off the disks surrounding low-mass stars by radiation from this heavyweight star.

Bally, D. Devine, and R. Sutherland/NASA

Somewhere in the spiral reaches of our galaxy, a stellar womb slowly assembles. As this cloud of dust and cold hydrogen gas draws together, an embryo takes shape deep inside. A dense ball surrounded by a vast disk, the embryo grows hotter and more compact as its gravity pulls more and more material from its mother cloud.

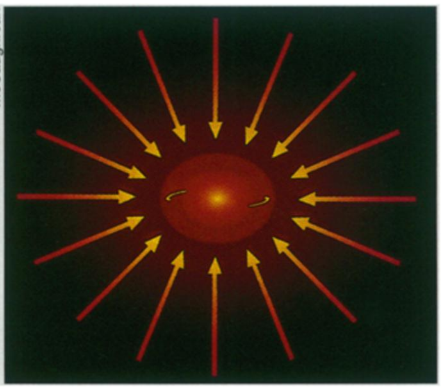
Suddenly, the womb disintegrates. Alone in the harsh environment of interstellar space, its supply line severed, the fledgling star can grow no bigger. Although it may go on to shine for several billion years, the star's premature birth has irrevocably altered its destiny.

Recent observations of several crowded stellar nurseries in the Milky Way confirm what astronomers have long suspected: Although massive stars are always in the minority, they have a profound influence on the birth of stars around them. During their brief but fiery lives, these heavyweights spew out intense ultraviolet radiation and fierce winds that eat away at the mother cloud and expose newborns that had been swaddled inside.

In stellar nurseries where massive stars are common, these behemoths limit the maximum mass a newborn can have. They may also determine whether a young star's dusty disk will hold together long enough for its material to condense into planets.

"The key is the massive stars," asserts J. Jeffrey Hester of Arizona State University in Tempe, who presented an overview of star formation at the University of Maryland's annual October astronomy conference in College Park. "As soon as massive stars start forming, then ongoing star formation in their vicinity is going to start feeling their presence."

McCaughrean



Drawing of an embryonic star swathed in a dense cloud of gas and dust.

Some star-forming regions, such as the Milky Way's Taurus-Auriga molecular cloud, contain only low-mass stars, he notes. At these sites, star birth proceeds uninterrupted as the infant star matures and then becomes independent of its mother cloud. Images of young stellar objects in these regions reveal that many are still embedded within their birth clouds.

In regions that contain massive stars, however, the picture changes dramatically.

The sharp eyes of Hubble and other new telescopes are now capturing images of young stars as their gaseous cocoon is torn apart by their massive neighbors. Hester describes the new observations as a smoking gun showing that "it is the massive stars that are responsible for shutting off the process in which an infant star accretes material."

Given their outpouring of energy, it isn't surprising, admits Hester, that high-mass stars would have a profound influence on star formation. "The problem is that lots of things might have an effect on star formation. The difficulty is sorting out which of those things really do have an effect."

One of the most stunning images ever taken by the Hubble Space Telescope reveals just how meddlesome massive stars can be. The color image zeros in on diaphanous pillars of gas, nicknamed elephant trunks, in the Eagle nebula, about 7,000 light-years from Earth (SN: 11/4/95, p. 294). These gas pillars are capped by oval tips, called EGGs (evaporating gaseous globules). Studies show that some of the EGGs serve as birthplaces for stars.

Ultraviolet radiation from hot, massive stars eats away the surface of the EGGs, stripping off material and laying bare the newborn stars hidden inside.

"Essentially, there's a clear path between the [pillars] and the massive stars," says Hester. "The radiation strikes the pillars and drives material off it. That flow of material is then ionized by the same radiation responsible for driving it off. The wispy structures that point away from the surface of the pillars are the material being driven away.

"Some 10,000 years ago, the EGGs were buried inside the molecular cloud, where they had a reservoir of material available to them," Hester argues. "Now they're uncloaked, blasted by fierce winds and ionizing radiation. How they got there has nothing to do with their own properties, it has to do with the effects of massive stars."

Elsewhere in the Eagle nebula, in a region outside Hubble's small field of view, low-mass stars cluster around their more massive neighbors without seeming to suffer any ill effects, notes Mark J. McCaughrean of the Max Planck Institute for Astronomy in Heidelberg, Germany. However, "these [low-mass] stars probably managed to form before their loud neighbors moved in," he adds.

Hubble images of another stellar nursery, the crowded Orion nebula, also show the influence of massive stars. Because Orion lies even closer to Earth than the Eagle nebula does, the telescope surveys this star-forming region in greater detail. For the first time, astronomers can see directly the disks around young stars.

Standing out in silhouette against a background glow of hydrogen gas, the disks are clearly visible. They range in diameter from 50 to 1,000 times the distance between Earth and the sun. If the gas and dust in such disks gather into clumps, they could give rise to planets.

McCaughrean and C. Robert O'Dell of Rice University in Houston found that the six most distinct silhouettes have sharp edges—as if the disks had been abruptly truncated by some external force. In contrast, the standard model of a circumstellar disk, which assumes that a star develops in isolation rather than in a crowded cluster, predicts no such truncation.

McCaughrean and O'Dell/NASA

Silhouetted disk surrounds a star in the Orion nebula.

The researchers offer several explanations for the sharp edges. High on the list are the intense radiation and high-speed winds emanating from Orion's collection of massive stars, which tear away material that the young star's gravity cannot hold.

"At a totally arbitrary place in [a star's] evolution, it's as if along came a hatchet and said 'that's it, that's all the mass you get,'" comments Hester.

McCaughrean cautions that astronomers haven't yet quantified the role that massive stars may play in determining the size of disks. "Higher-resolution Hubble Space Telescope imaging of the dark disks will allow more detailed study of the . . . structures in the disks, at least at their edges, and in tandem with theoretical work, perhaps allow us to establish the most likely cause of the apparent disk truncation," he and O'Dell wrote in the May Astronomical Journal.

Despite the depredations of massive stars, about half of the stars in Orion still show evidence of circumstellar disks, McCaughrean and O'Dell note. In October, at a Space Telescope Science Institute workshop in Baltimore, McCaughrean presented further details of his ongoing work with O'Dell and John Bally of the University of Colorado at Boulder.

McCaughrean

Near-infrared image of the inner part of the Orion nebula shows that it's jam-packed with stars. Blue, green, and red indicate emissions at 1.25, 1.65, and 2.2 micrometers, respectively.

He reported that although silhouetted disks are apparent around only 10 percent of low-mass stars in the Orion star-forming cluster, an additional 30 percent of the stars lie near ionized knots of gas (SN: 6/18/94, p. 391). These knots are thought to be material boiled off from unseen, nearly intact disks that surround these stars. Observations from ground-based infrared telescopes support the Hubble findings and suggest that disks encircle an additional 20 percent to 40 percent of the stars in the cluster.

Those statistics suggest that although massive stars severely interfere with star birth, they don't obliterate the disks that surround many newborn stars, McCaughrean notes.

If disks are common in the crowded confines of Orion, they may also have the fortitude to survive the trials and tribulations of life near massive stars in other stellar nurseries, says McCaughrean. That's reassuring for astronomers who hope to find planetary systems throughout our galaxy.

Do massive stars limit the size of neighboring stars and the mass of their disks? The answer may come with the completion of a new generation of large telescopes that view the galaxy in the near- and mid-infrared. These instruments will peer into distant, dust-cloaked patches of the Milky Way where star birth is common, McCaughrean notes.

"Most stars in our galaxy form in dense clusters, embedded in their natal dust and gas and often surrounded by massive, disruptive stars. It's thus important that we try to understand how stars form in such regions, and with the rapid developments in telescope technology, we stand to learn a great deal in the next few years." □