DEEP-SKY OBSERVING

Massive, energetic stars carve out voids in space and produce some spectacular targets. /// BY STEVE GOTTLIEB

How to observe cosmic bubbles

In 1867, Paris Observatory astronomers Charles Wolf and Georges Rayet uncovered a mystery they could not solve. While scanning the constellation Cygnus with a visual-prism spectroscope, they discovered three 8th-magnitude stars with strange spectra. More than a century later, the nebulae surrounding a handful of similar objects — dubbed Wolf-Rayet (WR) stars — make outstanding deep-sky targets for amateur astronomers.

What caught Wolf and Rayet's eyes in the three stars' spectra were broad, bright emission lines. (Most spectra show dark absorption lines.) The nature of these emission lines was puzzling, and here's why: One of the strongest lines was due to the element helium — which wouldn't be discovered until it was seen in the Sun's spectrum the following year.

It wasn't until the last few decades that astronomers figured out where Wolf-Rayet stars fit in the life cycle of stars. Multiwavelength research in infrared, radio, ultraviolet, and X ray — as well as visible light — has revealed Wolf-Rayet stars represent a late evolutionary phase in the lives of luminous, massive stars. These short-lived supergiants are rare — the *Seventh Catalogue of Galactic Wolf-Rayet Stars* (2001) lists a mere 227 members.

During the stable phase of a hot, massive star, a fast but tenuous stellar wind plows into the interstellar medium, sweeping away the ambient material and creating an interstellar bubble. Depending on its initial mass, the star will evolve into either a red supergiant or a luminous blue variable star. In either case, mass loss continues, forming a dusty circumstellar nebula inside the larger interstellar bubble.

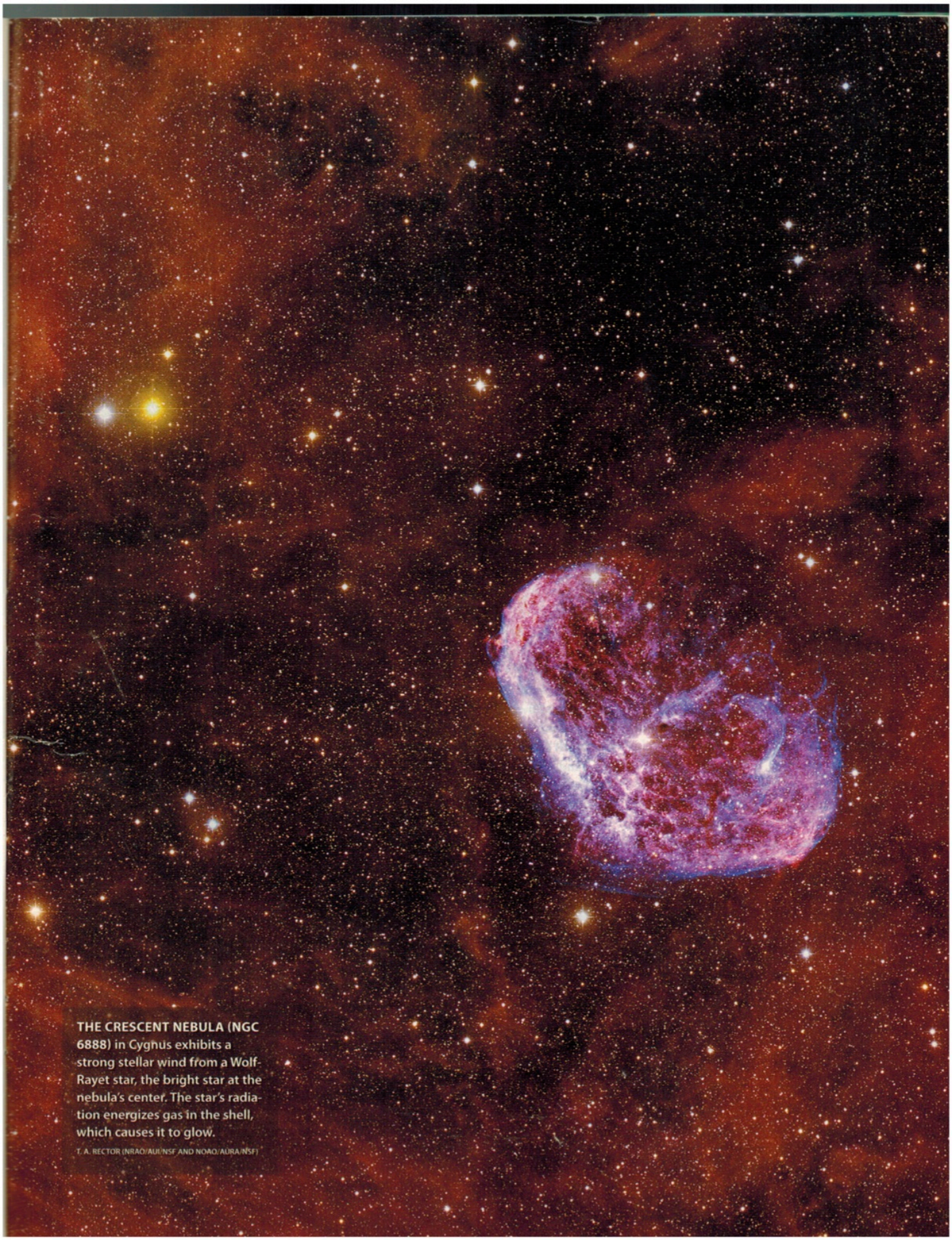
As the star further evolves into the Wolf-Rayet stage, a powerful stellar wind of up to 6 million mph (10 million kilometers per hour) ejects the star's outer envelope, which slams into the surrounding interstellar medium, and sculpts a beautiful shocked shell of ionized gas. The freshly exposed core equals between 10 and 20 solar masses and has a surface temperature between 25,000 and 60,000 kelvins. Extreme cases approach 90,000 K.

Wolf-Rayet stars' spectra show strong, broad emission lines. This implies copious amounts of ionized helium, carbon, oxygen, and nitrogen in their rapidly expanding envelopes. Two main subgroups are identified by their spectra. Strong nitrogen (N) emission lines characterize WN stars, while WC stars have strong carbon (C)

RICHARD CRISP

SHARPLESS 2-157 in Cassiopeia is an emission nebula energized by an intensely hot Wolf-Rayet star. Although the nebula spans more than the width of the Full Moon, it's surprisingly easy to observe because it has a high surface brightness.

Steve Gottlieb *has observed 9,000 deep-sky objects during the past 25 years under the dark skies of northern California.*



THE CRESCENT NEBULA (NGC 6888) in Cygnus exhibits a strong stellar wind from a Wolf-Rayet star, the bright star at the nebula's center. The star's radiation energizes gas in the shell, which causes it to glow.

T. A. RECTOR (NRAO/AUI/NSF AND NOAO/AURA/NSF)

DANIEL VERSCHATSE

NGC 6357 is a stellar-wind-blown complex in Scorpius driven by the Wolf-Rayet star HD 157504. Open star cluster Pismis 24 lies just below the nebula's brightest part.

lines. These classes may represent different phases in the evolution of Wolf-Rayet stars. One possibility is that WN stars develop into WC stars.

What's the fate for Wolf-Rayet stars? Due to their mass and advanced evolutionary stage, they are strong supernova candidates. We may have witnessed one such event March 29, 2003, when NASA's High Energy Transient Explorer (HETE-II) detected the powerful nearby gamma-ray burst GRB 030329. According to UC-Santa Cruz astronomer Stan Woosley, this event heralded the first direct link of a gamma-ray burst with a violent supernova. The likely progenitor of this explosive event was a Wolf-Rayet star.

Bubbles through the eyepiece

The best-known Wolf-Rayet nebulae are the **Crescent Nebula** (NGC 6888) in Cygnus and **Thor's Helmet** (NGC 2359) in Canis Major. These two observing targets are favorites among amateur astronomers, but I wanted to track down other, lesser-known Wolf-Rayet shell nebulae.

Regardless of aperture, the key to viewing these celestial bubbles is to maximize contrast. So, observe under a dark sky, use a wide-field telescope/eyepiece combo (one with a 45' or larger true field of view), and use a narrowband nebula filter.

Sharpless 2–308 is a huge Wolf-Rayet bubble easily located 15' north of 16 Canis Majoris. With my 17.5-inch reflector at 62x, a dim glow 35' to 40' across fills most of the field of view. An OIII filter transforms this ghostly nebula into a visual delight with a prominent 20' scalloped edge forming the western border. A brighter patch lies along the north side. On the south end, the nebula bends east, crosses through the center of a trio of magnitude 8 stars, and then passes just south of 16 CMa. A bit west of center is the massive WR star responsible for sculpting this celestial bubble. EZ Canis Majoris is a variable star that ranges from magnitude 6.71 to 6.95.

/// OBSERVE THESE WOLF-RAYET BUBBLES

Name	Right ascension	Declination	Wolf-Rayet star	Spectral type	Size
Sharpless 2–308	6h54m	–23°56'	HD 50896	WN	40'
NGC 2359	7h19m	–13°13'	HD 56925	WN	27'
NGC 3199	10h17m	–57°55'	HD 89358	WN	22'
HD 92809 nebula	10h42m	–58°46'	HD 92809	WC	30'
NGC 6357	17h25m	–34°12'	HD 157504	WC	40'
NGC 6888	20h12m	38°21'	HD 192163	WN	17'
Sharpless 2–157	23h16m	60°28'	HD 219460	WN	50'

Thor's Helmet is faint but visible in a 4-inch scope, while an 8-inch mated with a narrowband filter reveals a fascinating, high-surface-brightness structure. A 5'-wide bubble illuminated by Wolf-Rayet star HD 56925 forms the central "helmet," although I'm drawn to a brighter rim along the west side that creates a distinctive "C."

Through my 17.5-inch, the bubble has a complex structure with a tangled nest of irregular knots, faint streaks, and looping arcs of nebulosity. At the south end of the helmet, a bright 4' bar juts west of a 9th-magnitude star. This extension narrows into a 10'-long streamer of nebulosity forming the southern "horn" of the helmet. The matching horn extends northwest of the center. A thin filament begins on the north end of the bubble and shoots 10' due east.

Wolf-Rayet star HD 89358 illuminates emission nebula **NGC 3199**. This bubble lies 4° northwest of the Eta Carinae Nebula (NGC 3372) in a rich Milky Way star field. It's bright enough to be visible through a 2-inch finder scope under a dark sky.

Through an 18-inch scope, NGC 3199 appears as a fairly bright, thick crescent roughly 10' by 6' and opening toward the east. The surface looks irregular and mottled through a UHC filter, appearing brighter on the south end near a pair of embedded stars. Low-surface-brightness haze extends off the main crescent toward the southwest and increases the total length to 15'. In size and structure, NGC 3199 is similar to the Crescent Nebula.

The Eta Carinae Nebula is home to several Wolf-Rayet stars, although it can be difficult to distinguish possible Wolf-Rayet bubbles against the high-surface-brightness mix of the region's nebulosity. Nevertheless, in 1980, a group led by French astronomer Marie-Claire Lortet identified a ring-shape, filamentary nebula at the north edge of the Eta Carinae Nebula surrounding the 9th-magnitude Wolf-Rayet star **HD 92809**.

I found a huge, broken ring, nearly 40' in diameter, centered on this star. The brightest sections are a narrow north-south crescent on the west side, a wide east-west arc of nebulosity forming the southern rim, and an isolated 4' by 3' oval patch to the southeast. Using an 8-inch scope from a dark site, you should be able to ferret out this little-known nebula.

Find **NGC 6357**, a stellar-wind-blown complex in southern Scorpius, by heading north along a ½° trail of four equally

NGC 3199 in Carina is the windblown partial "ring" around the Wolf-Rayet star HD 89358, leftmost of the three blue stars left of center. NGC 3199 lies about 11,700 light-years from us. WR stars represent the final evolutionary stages of very massive stars.

THOR'S HELMET (NGC 2359) is a bubble powered by the Wolf-Rayet star HD 56925. Rapidly moving material ejected from the star interacts with surrounding hydrogen and carves out the distinctive shape, which glows because of the star's intense radiation.

spaced 6th- and 7th-magnitude stars. English astronomer John Herschel discovered NGC 6357 in 1837 from South Africa's Cape of Good Hope. He found a "milky nebulosity, 2' by 1.5', close to and almost involving a double star." A 6-inch scope reveals a faint glow just north of the magnitude 9.6 open cluster Pismis 24. In the 17.5-inch, NGC 6357 appears as a distinct, high-surface-brightness slash roughly 4' by 1.5' in an east-west orientation. When I added an OIII filter, the surrounding field appeared weakly luminous, which increased the nebula's size to 30'.

The northern showpiece of Wolf-Rayet bubbles is the Crescent Nebula. Through a 6-inch telescope, you'll glimpse a faint arc of nebulosity passing through two stars of magnitudes 7 and 8. Through 10-inch and larger scopes, the Crescent Nebula comes to life. A few years back, I had a memorable view through my 17.5-inch reflector while at an altitude of 8,200 feet (2,500 meters) in California's Lassen National Park.

Under a dark, transparent sky, the entire 18' by 11' annulus appeared as a huge cosmic egg embedded in a rich Cygnus star field. The irregular rim is thickest on the southwest side but brightest to the north, where several knots and wispy tendrils are located. The large weakly glowing interior has an irregular surface brightness and contains an isolated bright knot. On this night, wispy striations radiated from the central magnitude 7.4 Wolf-Rayet star HD 192163 toward the northwest edge of the rim. The intricate structure gave a three-dimensional feel to the nebulosity.

Sharpless 2–157, a filamentary ring, sits 1° southwest of the Bubble Nebula (NGC 7635). (Despite its name, the Bubble Nebula results from stellar wind given off by a non-Wolf-Rayet star.) Sharpless 2–157 is a sprawling complex surprisingly easy to observe using an OIII filter through an 18-inch reflector. At 63x, a huge gossamer arc spans 35' by 8' in a rich star field and compares to one of the main strands of the Veil Nebula (NGC 6992–5) in a small scope.

Markarian 50, a compact open cluster, is a knot of 10 to 15 stars at the west edge of the nebula and is home to the magnitude 10 Wolf-Rayet star HD 219460. Near the arc's southern edge, an isolated 3' knot surrounds a double star whose components shine at magnitudes 11 and 13.5. A second, ill-defined river of nebulosity flows north-south about 20' west of the cluster. The sections merge at their southern extremities.

Now it's your turn to head out and observe bubbles — the results of some of the most energetic stars known. The brightest of these pose no problem for observers. The fainter ones, however, classify as challenge objects. Exercise patience, and you'll have no problem. Good luck!