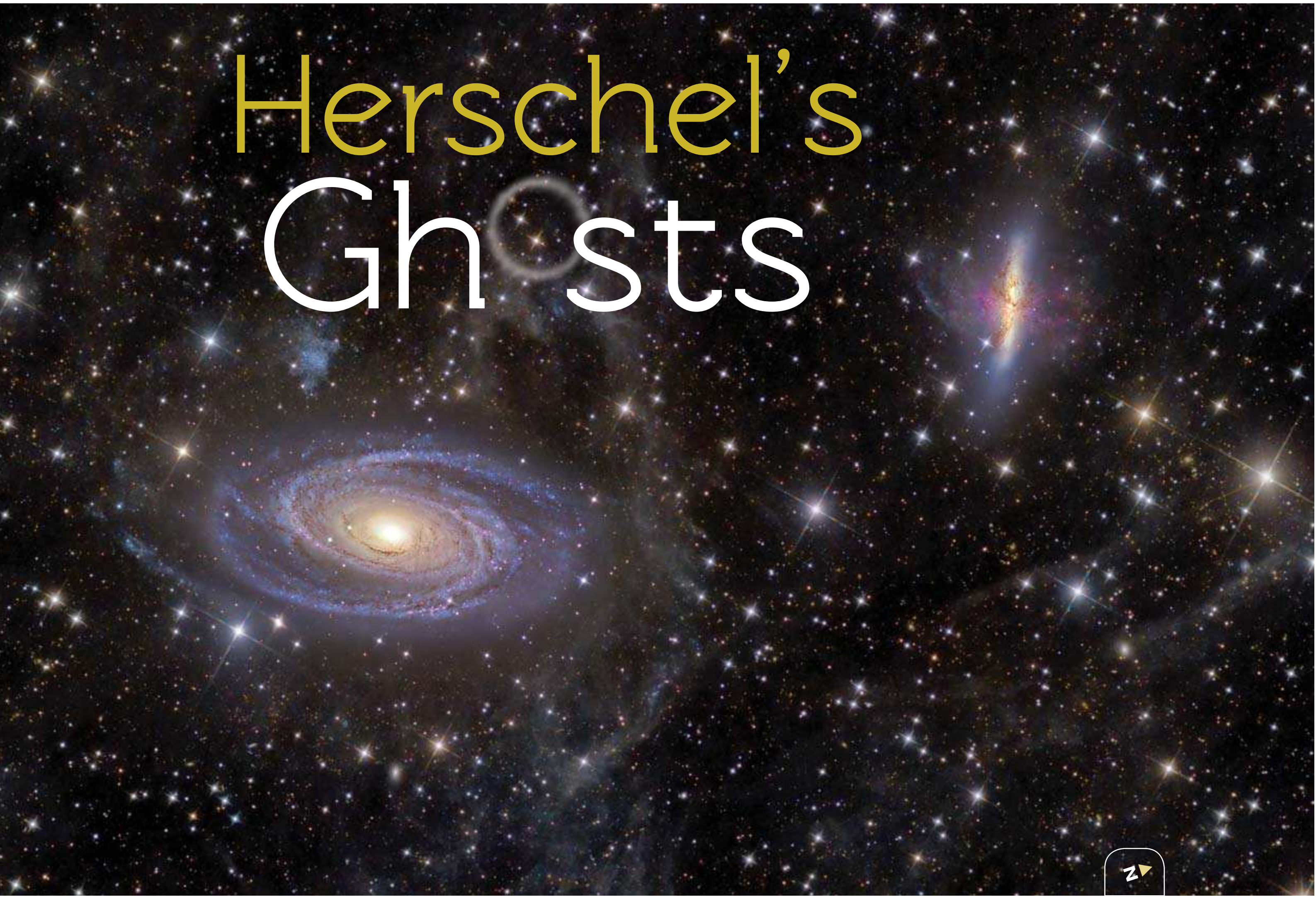
Herschel's Ghosts



With the right small scope, you can track down these dusty wraiths first observed in the late 18th century.

▲ **ROBES OF DUST** Galactic cirrus enshrouds the galaxies M81 (left) and M82 (right) in Ursa Major. It takes commitment to image these dim structures. This image represents nearly 25 hours of exposure time with a 12-inch f/4 reflector. Data was collected over three observing seasons: 2009, 2011, and 2012.

IVÁN EDER

WE SEE OUR GALAXY, the Milky Way, as a band of light stretching across the sky. There's a ghostly aspect to it; faint streamers of gas and dust extend far above and below the galactic plane, reaching the galactic pole. This *galactic cirrus* — twisted clouds of interstellar dust particles at high galactic latitudes first observed in the far infrared in 1983–84 by the Infrared Astronomy Satellite (IRAS) — glows in the dim red region of the spectrum. But the dust also reflects blue light from countless millions of stars, as shown by amateur astronomer Steve Mandel in 2004. Mandel noticed the subtle blue glow of the spooky dust tendrils associated with M81 and M82 and captured it in images. These images, which formed the basis of his Unexplored Nebula Project (**galaxyimages.com/UNP1.html**), demonstrated that the dusty interstellar medium could be seen not only in the far infrared, but in visible light as well.

Mandel called these clouds *Integrated Flux Nebulae* (IFN), and, taking their cue from his work, many amateur astronomers use this term whether referring to galactic cirrus or dusty *interstellar medium* (ISM) in the galactic plane. Professional astronomers distinguish more carefully between the two, though the boundary between them is somewhat, well, nebulous. ISM, the dust and gas between the stars, is distributed throughout our galaxy, but can be found relatively close by — say 200 light-years from us at its nearest — in the galactic plane. Galactic cirrus, on the other hand, technically lies at high galactic latitudes (above and below the zodiac) and thousands of light-years distant.

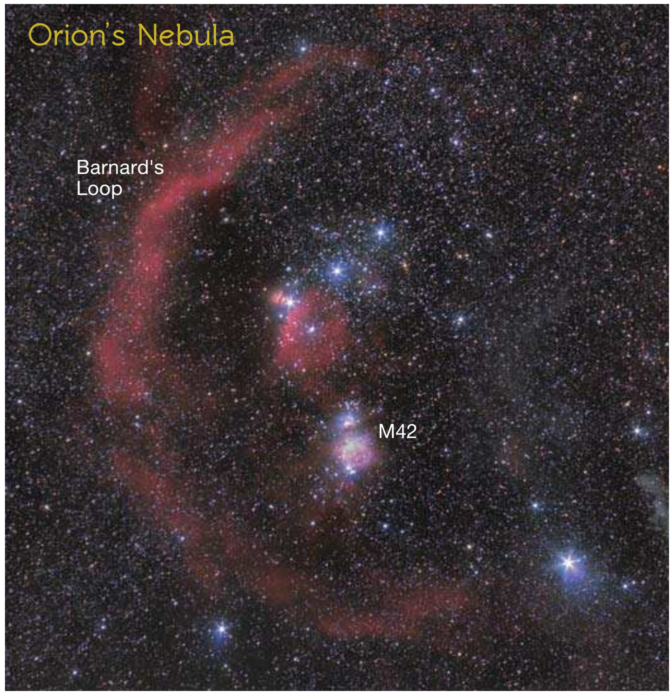
Whatever you choose to call it, you may be surprised to learn that you can see it with amateur observing equipment. For instance, I can detect faint glows tangling with well-known objects like the Pleiades and the Andromeda Galaxy with my improved richest-field (the widest possible view at lowest possible magnification) telescopes. My sketches at the eyepiece match deep digital images of the dark clouds, letting me know it's not just my eye playing tricks on me.

My first view of galactic cirrus was accidental and astonishing, and it made me wonder: Who else had spotted this ghostly dust? Turning to my library, my astonishment only grew as I uncovered a history of visual observations stretching back to William Herschel.

A Dusty Discovery

The typical discovery story you'll read for galactic cirrus goes something like this: It was first noticed on glass plates taken with the 48-inch Schmidt telescope at Palomar Observatory, one of the most productive telescopes of the modern age. Cataloged as dark clouds or nebulae in 1965 by Beverly T. Lynds, the dust's infrared emissions were discovered in the early 1970s and studied in detail by IRAS in the 1980s. In the 1970s, David Malin also found cirrus on images taken with the 1.2-meter UK Schmidt Telescope at Siding Spring Observatory, Australia, and Allan Sandage wrote about it and the scattering of optical light in 1975–76.

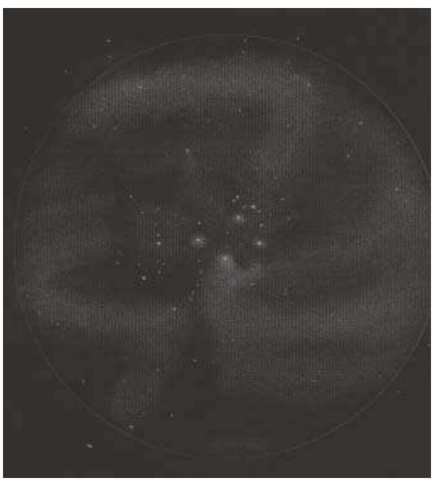
The discovery story you won't read goes back another 150 years, however, to one of the greatest visual astronomers of all time, William Herschel, who detected very faint nebulosity across large areas of the sky. What we call the sky background, Herschel called the sky "bottom" or "ground."



▲ **TRUE NEBULA** Even casual observers may be familiar with Orion's Nebula (M42), a naked-eye object in suburban skies. Less well-known is the nearby arc comprising Barnard's Loop, an emission nebula included by Herschel in his list of 52 nebulous regions.

From 1783 to 1811, Herschel cataloged 52 nebulous regions of the sky bottom, including the emission nebula behind the Horsehead Nebula in Orion (Williamina Fleming, a computer at Harvard College Observatory, discovered the Horsehead Nebula itself in 1888; E. E. Barnard's 1919 catalog of dark nebulae popularized it). Herschel's observations also included the North American Nebula and Barnard's Loop, as well as the nebulosity surrounding M81 and M82.

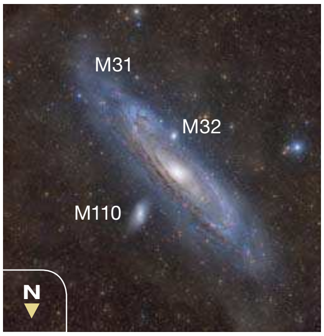
Herschel initially believed that even these faint, diffuse structures were resolvable; that is, the nebulosity could be explained as aggregations of stars too faint to be

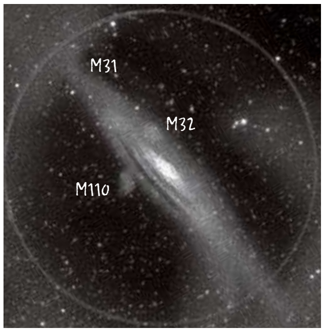


◀ **CAPTURING THE BUBBLE** A five-hour total exposure reveals not just the Merope reflection nebula, but also the dust through which the Pleiades cluster happens to be passing. The so-called Pleiades Bubble defines the margins of the galactic cirrus.

◀◀ **FINDING THE EDGE** The author sketched the Pleiades Bubble as seen through a 6-inch f/2.8 richest-field telescope with no filter.

BARNARD'S LOOP: SCOTT ROSEN; PLEIADES: VALERIE ROSEN; ALL SKETCHES: MEL BARTELS





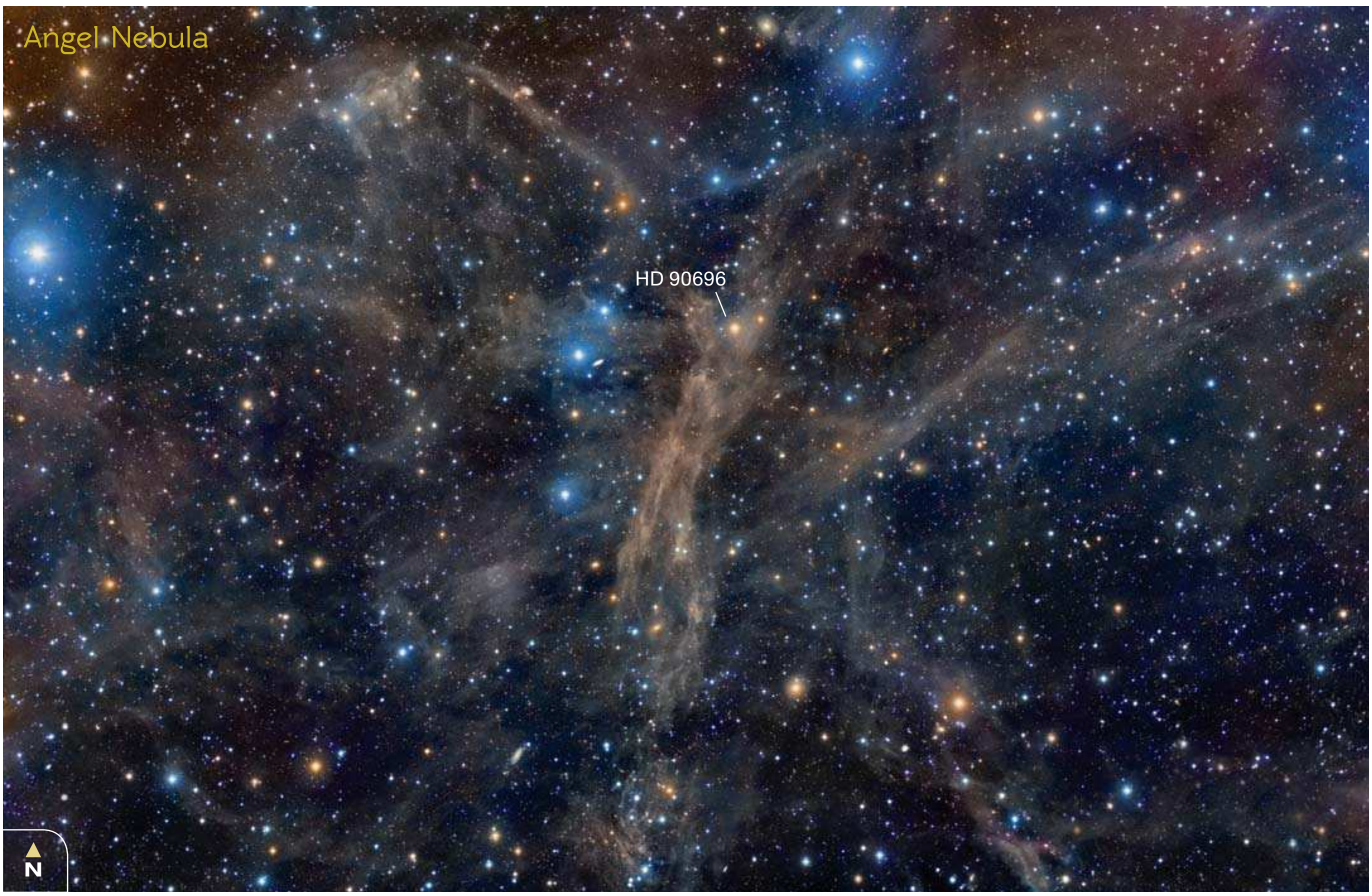
▲ **SHIFTING VIEWS** The galactic cirrus surrounding M31, the Andromeda Galaxy, makes it difficult to measure the galaxy's dimensions visually. The shelf "below" M32 is subtle; use images and sketches to guide your search. **Right:** Dark, transparent skies are your best assistant when it comes to tracing dust structures. The author made this sketch at the Oregon Star Party, which is known for its dark skies and an observing field protected from white light.

seen individually. He didn't consider brightness variations in sky ground important — after all, there were no stars to be counted in these fields. Frankly, these ghostly nebulous regions really didn't interest astronomers of the day, and Herschel himself acknowledged that they could "only be seen when the air [was] perfectly clear, and when the observer had been in the dark long enough for the eye to recover from the impression of having been in the light." This nebulosity was difficult to see even for him, and there were no telescopes equal to his for nearly a century.

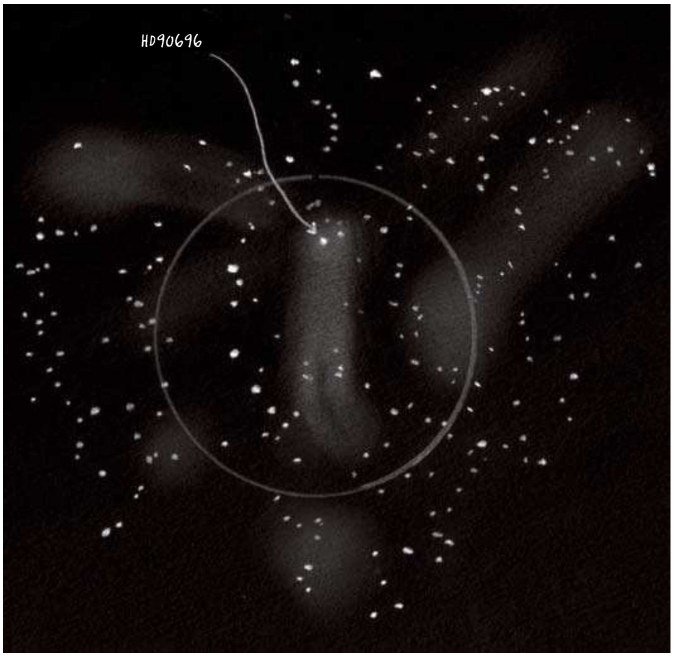
So it's no surprise that his 52 diffuse nebulae never made it into his most popular catalogs of deep-sky objects. By the end of his career, however, Herschel came to believe that cloudy material was very common, so he published a catalog of extensive diffuse nebulosities in 1811. However, neither his son, astronomer John Herschel, nor John Dreyer, who compiled the *New General Catalogue*, included Herschel's nebulosities in their own catalogs. Herschel's diffuse areas became historical, mere observational ghosts.

In 1896 Isaac Roberts began systematically photographing Herschel's 52 nebulous regions using an exposure time of 90 minutes. The idea of using photographs to verify or correct Herschel's observations had been bouncing around in his head for several years. The results, obtained with a 20-inch reflector and 5-inch-aperture lens, were largely negative. Only four regions showed any hints of nebulosity. Roberts concluded that Herschel's observations were illusory. Reaction to Roberts' work was harsh: E. E. Barnard criticized him, saying

▼ **WINGS OF AN ANGEL** This uncataloged stretch of dust, crossing the far west region of Draco, was detected by Steve Mandel and designated the "Angel Integrated Flux Nebula" by his son.



M31: HYTHAM ABU-SAFIEH; DUST ANGEL: ROGELIO BERNAL ANDREO



▲ **BRIGHT EYES, DUSTY FEET** The spooky streak of dust known as the Angel Integrated Flux Nebula requires a very wide field of view. The brightest star in its "head," HD 90696, lies about 5° 08′ northeast of M81, 48′ south of star HD 92148, and 6° 13′ northwest of Lambda (λ) Draconis.

Targets in the Galactic Cirrus

Object	Size	RA	Dec.
Pleiades Bubble	4° × 12°	00^h 10.0^m	+22° 00′
Andromeda Shelf	5° × 3°	00^h 45.0^m	+41° 00′
Angel IFN	0.5° × 2°	10^h 40.0^m	+73° 30′
M33 Bridge	1° × 4°	01^h 30.0^m	+30° 10′
M15 Nebulosity	0.5° × 2°	21^h 30.0^m	+12° 15′
Leo Triplet	1° × 3°	11^h 20.0^m	+13° 00′
Markarian's Chain	2° × 4°	12^h 20.0^m	+13° 20′
M64	2° × 4°	13^h 00.0^m	+21° 20′
Volcano IFN	1° × 2°	09^h 40.0^m	+70° 20′

Angular sizes are from the author's observation logs and recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

that 90-minute exposures weren't long enough, as he himself had photographed some of Herschel's regions (especially what we now call Barnard's Loop) — nebulosity that Roberts claimed didn't exist (*S&T:* June 2016, p. 36).

In the 1920s Herschel's observations were taken up by the Austrian-American astronomer Johann Hagen, the first Jesuit director of the Vatican Observatory in Rome. Hagen visually surveyed the sky for so-called "cosmic clouds" using a 6-inch f/15 refractor. He eventually claimed to have observed all 52 of Herschel's nebulae, results that were derided when presented to the Royal Astronomical Society in 1921 because the clouds weren't detectable photographically. Hagen continued to compile his list of faint clouds up until his death, coming to believe that they covered much of the night sky. Hagen was a true visual observer, favoring the visual record over photographs and arguing that many hours of long exposures couldn't match what he could see in minutes. He advised astronomers to put away their cameras and look through the telescope, lamenting that visual skills were a dying art.

In something of a plot twist, Isaac Roberts' widow, French astronomer Dorothea Klumpke Roberts, collaborated with Hagen that same decade, perhaps to rehabilitate her husband's reputation, which suffered after his criticism of Herschel. Despite Hagen's emphasis on visual observing, he joined Klumpke to publish Roberts' photographs as *Isaac Roberts' Atlas of 52 Regions, a Guide to Herschel's Fields* (1928). The photos received attention and applause; even Edward Hubble, a sharp critic of Hagen, suggested more images should be published.

The French amateur Marcel de Kérolyr, who has been called one of the greatest astrophotographers of all time, also worked to detect Herschel's specters during this time period. He successfully photographed some of Herschel's nebulosities, first with a 5-inch (130-mm) f/4.6 Derogy portrait lens from his "Astrophotographic Station" in Digne, Alpes-de-Haute-Provence, then with a 32-inch (800-mm) reflector from Forcalquier. In addition to the photos, which de Kérolyr published in 1931, the work at Forcalquier resulted in a list of visual observations of most of Herschel's original targets. However, de Kérolyr's 1931 paper didn't make much of an impact. Hagen had died a year earlier, and interest in his — and Herschel's — observations of nebulous fields had all but disappeared. The astronomical world lost this fascinating thread reaching back to Herschel.

At the Eyepiece

My own study of Herschel's fields started with first light through my 6-inch f/2.8 telescope. The 21-mm Ethos 100° apparent field-of-view (AFOV) eyepiece dominates the tiny scope; indeed, I offset the scope's center of gravity with the massive eyepiece in mind (*S&T:* Sept. 2014, p. 72). I aimed for the Pleiades, the Seven Sisters of mythology. The 4.3° true field of view swallowed the cluster. The Pleiades' stars shone brilliantly through the eyepiece; the Merope Nebula looked like a waterfall. I noticed a smudgy ring of grayness surrounding the cluster at the edge of the field. Was there something wrong with my baffling? Was there some sort of fog in the eyepiece or coma corrector? I moved the scope back and forth; the bubble stayed painted on the sky. Maybe the stars were casting some sort of glow? I followed the ring all the way around, keeping the cluster near the edge. No, it was real — a real mystery.

I shared the view through my scope with dozens of people. The nebulosity surrounding the Pleiades was visible in other scopes as well, albeit not as easily with narrower fields and higher magnifications. In fact, many have noted this so-called **Pleiades Bubble**: Walter Scott Houston described observations submitted by Stephen Knight of East Waterford, Maine, in his Deep-Sky Wonders column (*S&T:* Dec. 1985: p. 628). And Howard Banich points out that the German-French astronomer Hermann Goldschmidt, a painter and prolific discoverer of asteroids, observed the Bubble in 1863 (*S&T:* Jan. 2017, p. 60). Yet I'd never heard of it before spotting it through my scope!

From the Pleiades, I turned to M31, the Andromeda Galaxy. For many years amateurs have disagreed over the galaxy's extent, claiming widths from three to five degrees. Through my little telescope, the galaxy's edges merged with the Milky Way. When the ghostly Milky Way extensions are visible, the galaxy appears 5° wide; when not, it appears only 3° wide. Further, I discovered that the most prominent feature in my field of view is a "shelf" below M32, situated such that the companion galaxy appears to float on an ocean of faint gray-white nebulosity. Was the **Andromeda Shelf** part of M32 or its own entity? Familiar with images of galactic cirrus taken by Steve Mandel and Rogelio Bernal Andreo, I contemplated the unthinkable: Was I seeing parts of the galactic cirrus?

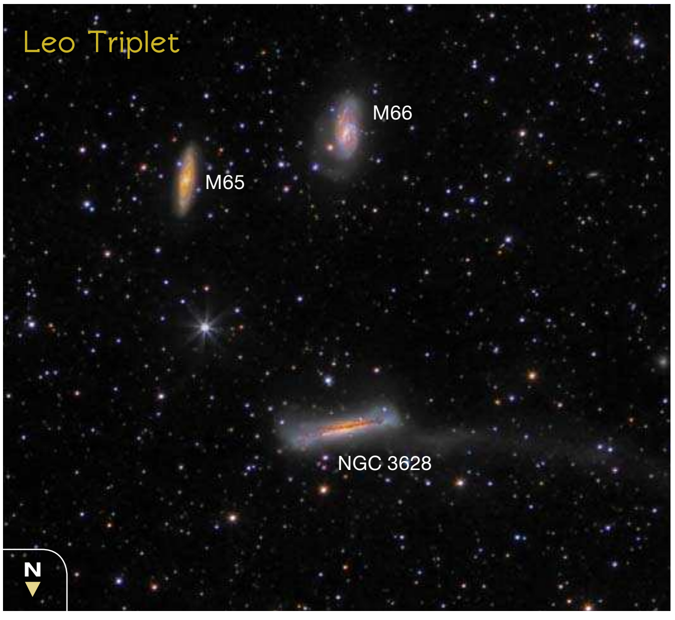
I decided to find out. I started with the brightest cirrus next to the galaxies M81 and M82 in Ursa Major. I selected my 10.5-inch f/2.7 richest-field telescope, aimed the red-dot finder at the area as I have so many times over the decades, and placed my eye at the eyepiece. My elation was unbounded — cirrus was clearly present. I sketched the **Angel Integrated Flux Nebula** (Mandel-Wilson 2), an area not associated with a deep-sky object. Beautiful, bright, subtle, deeply gratifying, an observation I'll never forget. I found myself agreeing with Father Hagen: The sky is awash in faint, dusty but surprisingly detailed cirrus.

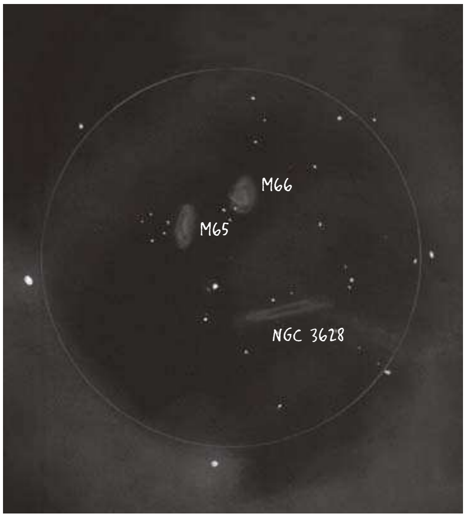
During one night out, I found a Milky Way extension that reached **M33**, the Triangulum Galaxy. How could I have missed it all these years? I found galactic cirrus in the fields of the globular cluster **M15**, M44 (the Beehive cluster), the galaxy trio **M65**, **M66**, and **NGC 3628** (the Leo Triplet), and **Markarian's Chain** in the Virgo Galaxy Cluster. Perhaps sketching 243 dark nebulae helped me tune into subtle variations in skyglow.

Maximize Your Potential

There are a few things you can do to prepare yourself for your own galactic ghost hunt. First, consider your equipment. Since cirrus structures are large, select telescopes and eyepieces with the widest possible true field of view, at least 2° across. Make dust more visible with lower magnifications and larger exit pupils; don't select for an exit pupil of 3–5 mm usually recommended for dark-sky observing — the background will be too dark. Filters won't help as much as they do with bright nebulae, but I've found broadband filters like DGM Optic's NPB and Orion's Skyglow modestly useful.

Herschel and others noticed that one field might be ever so slightly brighter than another field. In other words, they didn't see structure or form, just variations in brightness. The galactic cirrus adjacent to M81 and M82, for instance, has a brightness of 24.5 mag/arcsec^2 according to Sandage. On a good night with a Sky Quality Meter (SQM) reading of the sky background at 21.4 mag/arcsec^2, I estimate the faint-

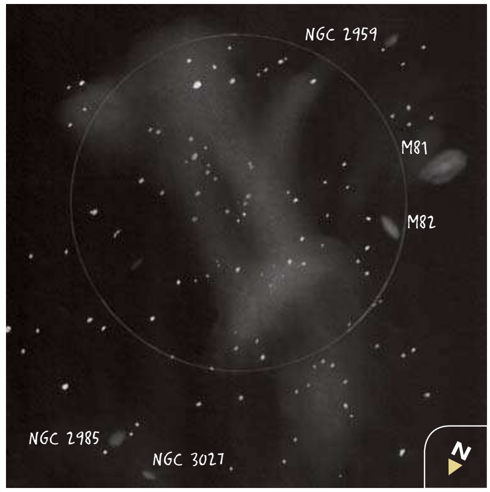




◀ **AS WIDE AS POSSIBLE** To see the dust encircling the Leo Triplet of galaxies, you need a wide field of view — the one here is 1.8°. Keep the magnifications low and meticulously protect your dark-adapted eyes from outside light sources. Try to spot the arc of dust that stretches from the surrounding cirrus to NGC 3628.

◀ **GALAXY TRIO** This composite image combines three sets of data, captured over the course of 43 hours, to reveal the faint galactic structures near the Leo Triplet of galaxies.

LEO TRIPLET: SCOTT ROSEN



▲ **AT THE EYEPIECE** Visually, the Volcano Integrated Flux Nebula appears as two parallel bands of dust capped by an equally bright, shorter band. The base of the volcano is broad and bright.

◀ **VOLCANIC ASH** The Volcano IFN "erupts" across the expanse between M82 and NGC 2985. Look southwest of M82 for the faint extension.

VOLCANO NEBULA: SCOTT ROSEN

est visible portions of the M81/M82 cirrus are 25.5 mag/arcsec^2, offering a contrast of a scant several percent in terms of field brightness.

Once you have your equipment sorted, you can start by inspecting the field of view for subtle variations in the background glow — Herschel's sky bottom. Since the brightest cirrus glows at 24.5 mag/arcsec^2, the sky needs to be dark. A very dark sky, say a SQM reading of 21.5, means a three-magnitude difference between the background skyglow and the cirrus. That's a contrast difference of a meager 6%. If not for their large extended size, the dust structures would be invisible. Slightly less pristine skies that glow at 20.5 mag/arcsec^2 have a four-magnitude difference and a practically undetectable contrast of 3%.

I aim for high *etendue* (throughput, or the amount of light flowing through the system). More aperture and larger field means higher etendue. My 10.5-inch f/2.7 with coma corrector and 100° AFOV eyepiece produces an etendue of 4,400 cm^2 deg^2; a 10-inch f/5 coupled with an 82° AFOV eyepiece produces half the etendue of 2,400 cm^2 deg^2. Seeing subtle background variations takes time and practice — a lot of time and practice. Unlike tiny dark gray galaxies huddled in a cluster whose visibility comes and goes, the broad strokes of cirrus are more definitive: either you see them or you don't.

When planning my observing sessions, I use infrared all-sky maps like the Planck Thermal Dust map to scout out galactic cirrus. One arm of dust arcs through the eastern portion of Leo into Coma Berenices, just south of **M64**, the Black Eye galaxy. On a night under less than ideal conditions with a SQM reading of 21.1, I barely saw a bright patch to the southeast of M64. Two nights later in excellent conditions with a SQM reading of 21.4 I detected several patches. The patches don't perfectly match the dust; there must be an additional faint blue reflection component.

The easiest cirrus to spot is the **Volcano Nebula** (Mandel-Wilson 3), which lies north of M82. The Pleiades Bubble and Andromeda Shelf also offer good tests for burgeoning skills. Don't hesitate to try a variety of telescopes and filters under varying sky conditions; negative reports are useful, too.

Digital imagers tell me that they edit out variations in the background glow, aiming for dramatic and colorful objects floating against a black background. After all, noise needs to be suppressed and variations in illumination removed by flat-fielding. I encourage imagers to think of the background itself as an interesting object. Showing it at its best requires fast systems, wide fields, and very long exposure times.

Perhaps the illusive nature of these ephemeral "ghost nebulae" and their forgotten observations will capture your interest in sketching deep-sky objects. Until digital imagers increase their exposure times and search for dusty wraiths in the background, visual observers will lead the way.

■ During the day **MEL BARTELS** manages a software development team. On moonless clear evenings, he scans the skies with handcrafted richest-field telescopes. Mel's catalog of IFN observations can be read at https://is.gd/bartels.

◖ **FURTHER READING:** To learn more about the observational history of Herschel's nebulous regions, read Arndt Latussek's 2008 paper "William Herschel's Fifty-Two Fields of Extensive Diffused Nebulosity — A Revision" in the *Journal of Astronomical History and Heritage* (**https://is.gd/Herschel52**).