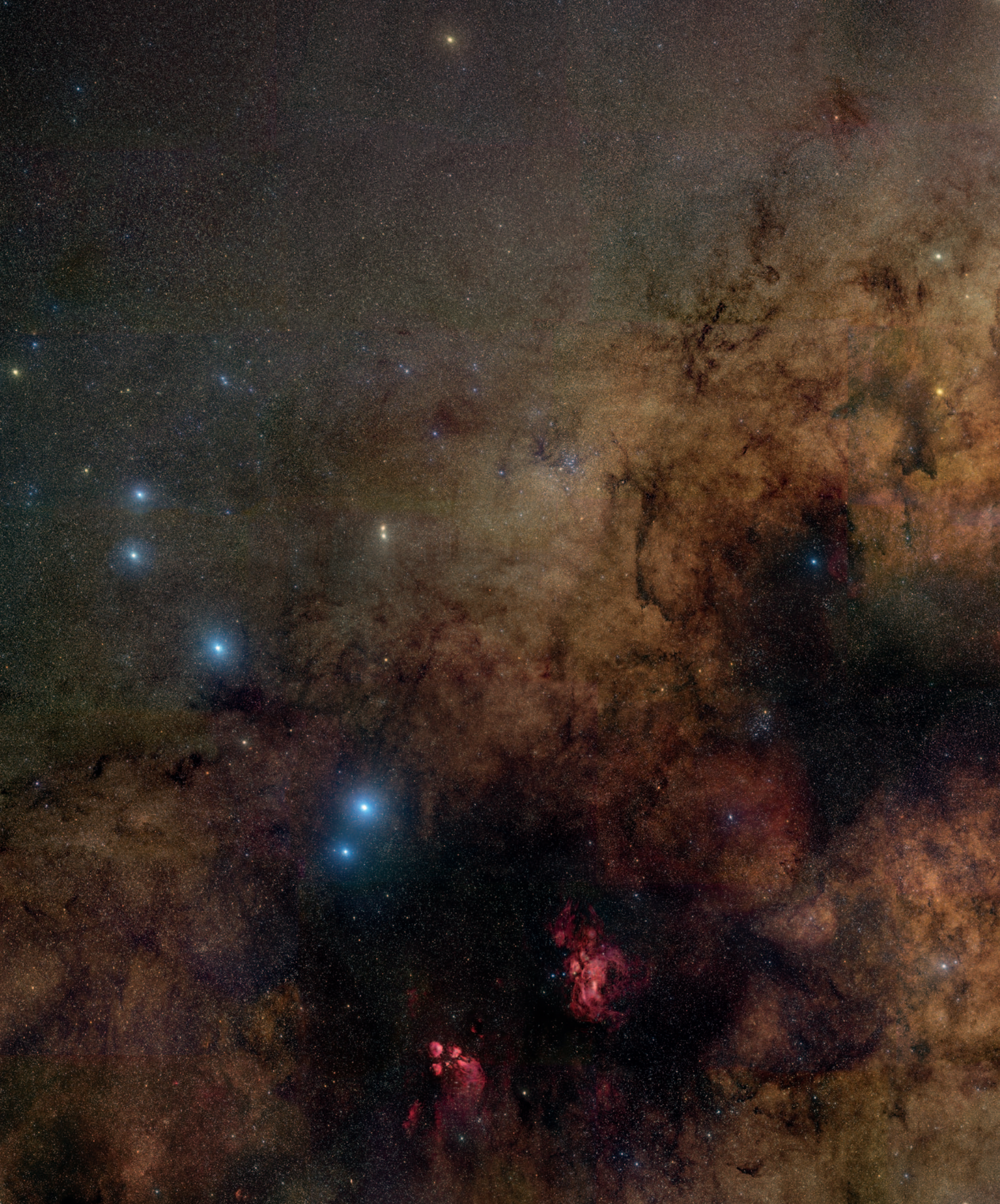


The Southern Winter

16.00 to 22.00 Hours Right Ascension

The Southern Winter

The long nights of the southern winter are filled by the Milky Way, arching from horizon to horizon. The combined brightness of its myriad stars is interrupted by dark spaces that we now know to be dust between and among the stars. As the hidden center of our galaxy passes overhead, we can understand why the form of our own galaxy, the Milky Way, remained mysterious for so long. The mystery is solved, but the majesty remains. This panoramic scene reveals our galaxy's central galactic bulge which can be seen in the southern winter sky just a few degrees west of the large Sagittarius Star Cloud.

IC 4592 and IC 4601

Reflected blue light from massive stars forms the shape of a horse's head in the southern constellation of Scorpius, sometimes nicknamed the Blue Horsehead (IC 4592). It is seen here looking northwest, towards the lower right corner. The nebulosity is mostly faint, and covers about two square degrees of sky, about twice the area seen here, and a much greater area than the better-known Horsehead Nebula in Orion (p. 56). The smaller complex of blue and faint yellow reflection clouds in the upper left corner, in the horse's neck, is known as IC 4601. Adjoining it near the left edge of the image is the faint red outline of the dark cloud Barnard 41, and this extends towards the center of the picture, joining with Barnard 40.

The source of much of the scattered blue starlight in the more massive cloud comes from the bright star Nu Scorpii, which makes up the eye of the horse. This is a large structure with delicate, muted colors, probably because we see it through the dust that gathers close to the plane of the Milky Way. This dust selectively absorbs blue light, just as the dust that surrounds the bright stars selectively scatters it. Elsewhere, the faint reddish hues mark the diffuse outskirts of molecular clouds and is probably emission excited by the ultraviolet light from hot stars within the Milky Way.

The Blue Horsehead

This complex of mostly dusty reflection nebulosity in Scorpius is illuminated by a small number of young bright stars. The image covers a field approximately 2.5 by 1.5 degrees and was taken with an amateur telescope from the southwestern United States.

The Rho Ophiuchi Nebula

Splashes of vibrant of color and light adorn the spectacular region surrounding the bright triple star Rho Ophiuchi, close to the border of Scorpius. Probably no other part of the sky provides such an impressive range of hues juxtaposed with entwining dark rivers of Milky Way dust. The scene is highlighted by the bright star Antares (lower left, Latin for "rival of Mars"), a cool, red supergiant 40,000 times more luminous than the Sun and 600 light-years distant. Seemingly close to it (lower middle), but 4000 light-years further away is one of the nearest globular clusters, Messier 11 (NGC 6121, p. 156). The colorful reflection nebula at the top of the picture surrounds the group of stars that is Rho Ophiuchi. The nebula is the blue light reflected by dust, the visible counterpart of a much larger but unseen molecular cloud permeating the region, known as the Ophiuchus Molecular Cloud. Infrared observations penetrate the dust and show it to be heated by young stars, in the dust and unseen in this photograph.

The Rho Ophiuchi Nebula

The dusty region between Ophiuchus and Scorpius contains some of the most colorful and spectacular nebulae ever photographed. The upper part of the picture is filled with the bluish glow of light from hot stars reflected by a huge, cool cloud of dust and gas where such stars are born. This dust is also seen as a dark nebula, a molecular cloud, hiding the light of background stars, especially on middle left of the picture. Dominating the lower half of this cosmic landscape is the over-exposed image of the red supergiant star Antares, a star that is steadily shedding material from its distended surface as it nears the end of its life. These tiny, smoke-like solid particles reflect light from Antares and hide it in a nebula of its own making. Partly surrounding Sigma Scorpii at the right of the picture is a red emission nebula, completing perhaps one of the most comprehensive collections of nebular types that it is possible to capture in one photograph.

NGC 6164–6165

The designation NGC 6164–6165 implies two objects, but the bipolar nebula surrounding the peculiar star HD 148937 is a single entity, a bright star surrounded by two lobes of material the star itself has ejected. The inner parts of these appear in the corners of the photograph. Although the nebula was initially believed to be a planetary nebula, to which it has a superficial resemblance, its central star is young and very massive, quite unlike the old, lightweight stars at the center of planetary nebulae. The central star of NGC 6164–6165 shares many characteristics with Wolf–Rayet stars, which are evolved O-type stars that have left the main sequence. But in this case the central star is not a Wolf–Rayet star but something rather similar, a young, O-type supergiant of 40 solar masses, ejecting a substantial part of its surface as the two symmetrical bright nebulae. Deeper, wide-angle images show much larger faint nebula centered on the star, indicating that this outburst is not the first. Knowing the unstable temperament of these types of stars, and the vigor with which they seek to lose mass, it is unlikely to be the last.

Wide Field View of NGC 6164–6165
This wide-angle image shows that NGC 6164–6165 lies within a larger cavity presumably cleared by the radiation of its powerful central star. The central star is 40 times more massive than the Sun and is about three to four million years old — past the middle of its life span. Stars this massive may only live a few million years, so it is quickly depleting its fuel and will likely end its life in a violent supernova explosion.

NGC 6164–6165
Some astronomers suggest that NGC 6164–6165 has been ejected from its star as it spins on its axis, in much the same way a rotating lawn sprinkler shoots out water as it spins. It is also possible that the magnetic fields surrounding the star may play a role in creating the complex shapes clearly seen in the image. However, evidence of the stellar wind interacting with dust, can be seen in the corners of this Gemini Telescope picture, which suggests that the outer nebula consists of material remaining from an earlier stage in the star's life.

NGC 6188 and NGC 6193

NGC 6193 is a remarkable young star cluster at the center of the Ara OB1 stellar association, which spans a full square degree of the southern sky. The cluster NGC 6193 is composed of at least two superimposed star clusters, the nearest being about 4500 light-years away and less than three million years old. The stars are embedded in a region cloaked by thick gas clouds and obscuring lanes of dust, and some features are reminiscent of the better-known Horsehead Nebula in Orion.

The hottest stars of the cluster, and the brightest stars in the image, are two closely spaced, O-type giants, HD 150135 and HD 150136. They illuminate the emission nebula NGC 6188. The cluster NGC 6193 and its emission counterpart NGC 6188 are seen in projection along a dark rim, which is the edge of a molecular cloud marking an immense, expanding bubble of neutral hydrogen gas spanning some 300 light-years. Ultraviolet radiation from the O-type giants of NGC 6193 is presently eroding the eastern edge of the parent molecular cloud and may be triggering and sustaining further star formation hidden within it.

The Region around NGC 6188 and NGC 6193
This wide-field view includes the objects in the main picture and shows the vast network of nebulosity and dust encompassing the region that extends to the north (bottom) of the picture and disappears into dark clouds at both extremities. Also seen at the northwest edge of the image (lower right) is NGC 6164–6165 (p. 124). Deeper images show it interacting with the same emission clouds, suggesting it is located at a similar distance.

NGC 6188 and NGC 6193
NGC 6188 is a molecular cloud that is in the process of being destroyed by intense ultraviolet radiation from hot, massive stars in the nearby stellar cluster NGC 6193, seen in the center of the photo. NGC 6188 is a strip of bright nebulosity running north–south (right to left in the photo) in the constellation Ara (The Altar), deep in the southern sky.

The Dark Tower

Bright-rimmed globules and their more evolved and smaller cousins, cometary globules, are fascinating dynamic structures formed by the interplay of cold molecular clouds and hot ionizing stars. In the northern hemisphere, many of these dark clouds were cataloged by E. E. Barnard in the 1920s, and later by Beverly Lynds. In the southern hemisphere a similar but more comprehensive catalog had to await the commissioning of the UK Schmidt Telescope in the 1970s, and the first author of the southern *Catalogue of 1101 Dark Clouds* (1986) was Malcolm Hartley, of comet fame. The object seen here is HMST 343.0+02.8 in that catalog, in the star-forming region Gum 55, nicknamed the Dark Tower.

Typically, the head of the globule faces a hot O- and B-type star or stars. Intense radiation from the stars warms the cold surface of the molecular cloud, releasing the hydrogen gas that has condensed on the dusty grains. This is instantly ionized by the intense ultraviolet light from the stars, forming a red plasma — an HII emission nebula. The radiation pressure also blows away the dust, creating a comet-like shape, as seen in this picture. The ionizing stars involved in shaping the Dark Tower are members of the famous open cluster NGC 6231, the Scorpius OB association, off the top of this picture and outside the scene.

The Dark Tower

Silhouetted against a crowded star field toward the constellation of Scorpius, this dark cloud is sometimes nicknamed the Dark Tower, a name that is only appropriate when the image is oriented with east at the top, as it is here.

NGC 6302

The Bug Nebula, NGC 6302, is one of the brightest and most extreme planetary nebulae known. A planetary nebula is a small emission nebula excited by an extremely hot, but moribund, star. Like most planetary nebulae, the Bug Nebula is symmetrical, in this case with two distinct lobes. It was first studied by the famous astronomer E. E. Barnard in 1907, but its true beauty was not revealed until the Hubble Space Telescope observed it in 2000 and 2009.

What we are seeing here is the disassembly of a moderate-mass star. After a long life it has transformed most of its hydrogen into helium in the nuclear reactor core of the star. This leads to instability, and the star throws off its outer layers, predominantly made of the elements mentioned above. At the center of the denuded star, the nuclear reactor is exposed and, with a temperature of over 220,000 degrees C, it is violently hot, with most of the radiation being emitted in the extreme ultraviolet part of the spectrum. This causes the expanding outer layers of the star to glow in their characteristic colors.

The image reveals a complex history of ejections from the star, which first evolved into a huge red giant, with a diameter of about 1000 times that of our Sun. It then lost its extended outer layers. Some of this gas was cast off from its equator at a relatively slow speed, perhaps as low as 32,000 kilometers per hour, creating the doughnut-shaped ring. Other material was ejected in a direction perpendicular to the ring at higher speeds, producing the elongated “wings” of the butterfly-shaped structure. Later, as the central star heated up, a much faster stellar wind, a stream of charged particles traveling at more than 3.2 million kilometers per hour, ploughed through the existing wing-shaped structure, further modifying its shape.

The image also shows numerous finger-like projections pointing back to the star, which may mark denser blobs in the outflow that have resisted the pressure from the stellar wind.

One day, this will be the fate of the Sun. Its outer layers will be shed, and its retinue of planets will be evaporated in a flurry of butterfly wings.

Hubble Image of the Bug Nebula

The NASA/ESA Hubble Space Telescope obtained this image of the planetary nebula, cataloged as NGC 6302, but more often called the Bug Nebula. NGC 6302 lies within the Milky Way, roughly 3800 light-years away in the constellation of Scorpius. The glowing gas is the star’s outer layers, expelled over a period of about 2200 years. The central star itself cannot be seen, because it is hidden within a doughnut-shaped ring of dust, which appears as a dark band pinching the nebula in the center. The thick dust belt constricts the star’s outflow, creating the classic “bipolar” or hourglass shape displayed by some planetary nebulae. This image was made by combining six separate images recording light emitted by the elements sulfur, nitrogen, oxygen (two wavelengths), helium and hydrogen, all of them fluorescing in the intense ultraviolet radiation from the invisible central star.

The Cat's Paw Nebula

Located in the constellation of Scorpius, the Cat's Paw Nebula resembles a faint, luminous pawprint on the sky. Deep images reveal that the nebula is about a degree across, or about twice the apparent diameter of the Moon. However, it is about 5500 light-years away, so it is truly huge — almost 100 light-years across. The sculpted gases of NGC 6334 are illuminated by the light of numerous powerful stars, some exceeding 10 solar masses. Such stars are hot, and even at the distance of this nebula might be expected to be clearly visible. That they are not confirms what we know about this part of the sky — that we are looking at it through the dusty plane of the Milky Way.

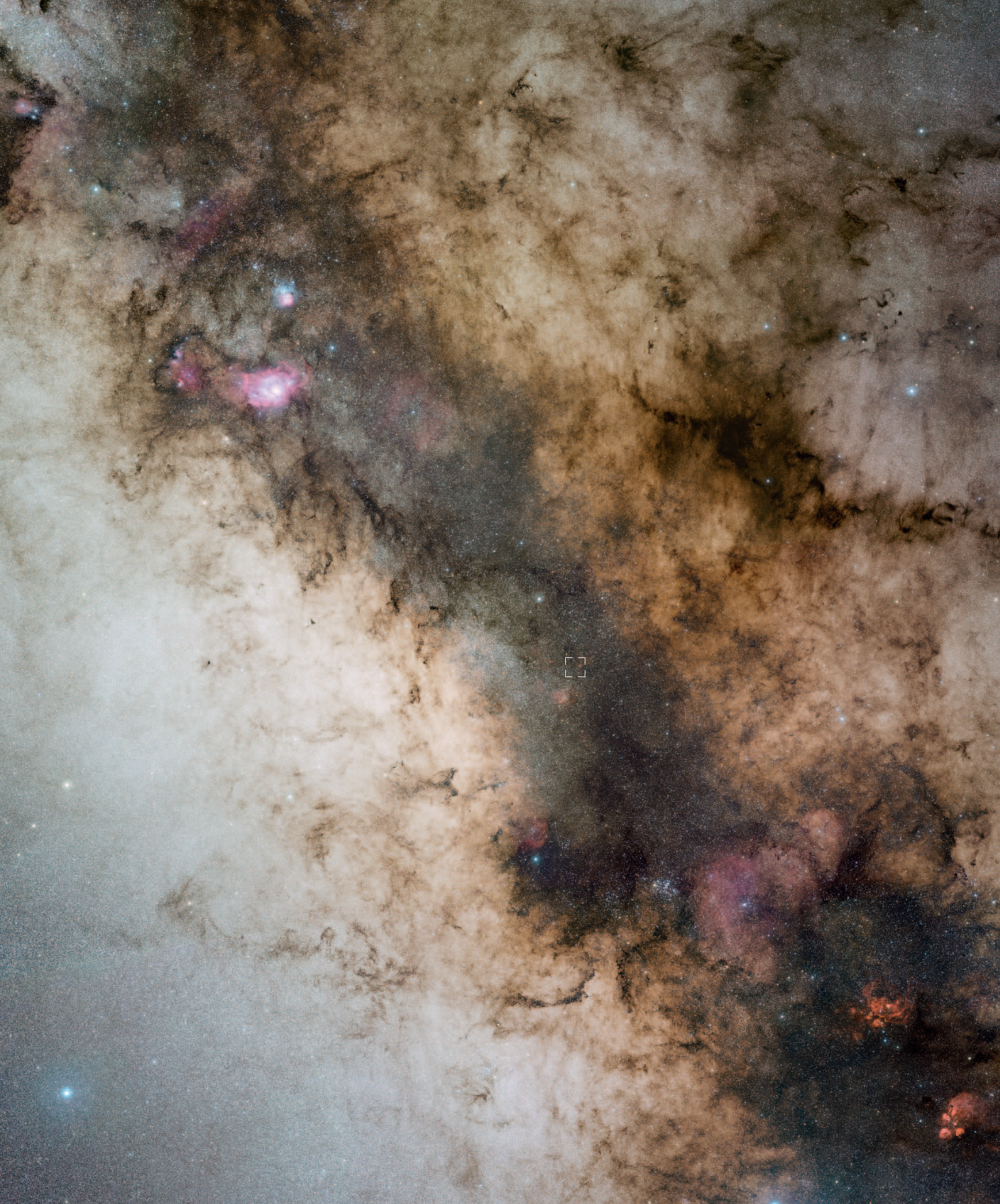
The nebula was discovered by John Herschel in 1837, and the brief and uninformative description in his Cape Observations catalog is a testament to its faintness. The ruddy hue of this complex is the result of the absorption of blue light by the ubiquitous dust clouds along our line of sight in the plane of the Milky Way.

A Celestial Cat

Few objects in the sky have been as well named as the Cat's Paw Nebula, several separated patches of a glowing gas cloud that together resemble the gigantic pawprint of a celestial cat. It is one of the most active nurseries of massive stars in our galaxy and has been extensively studied by astronomers. The red, intricate bubble in the lower right of the image is particularly striking and is most likely either a star expelling large amounts of matter at high speed as it nears the end of its life or the remnant of a star that already has exploded.

Infrared View of the Cat's Paw Nebula

The Cat's Paw Nebula, NGC 6334, is the birthplace of hundreds of massive stars. In a magnificent view taken with ESO's Visible and Infrared Survey Telescope for Astronomy (VISTA), the glowing gas and dust clouds obscuring the view are penetrated by infrared light, and some of the Cat's Paw's hidden young stars are revealed. Infrared light also reveals countless stars from the Milky Way, overlaid with spectacular tendrils of dark dust, seen here fully for the first time. The dust is sufficiently thick in places to block even the near-infrared radiation to which VISTA's camera is sensitive. In many of the dusty areas, such as those close to the center of the picture, features that appear orange are apparent — evidence of otherwise hidden active young stars and their accompanying jets. Elsewhere, the hot dust in the star-forming regions is shown in blue.



Towards the Center of the Milky Way

The Milky Way is a large spiral galaxy, a flattened disk containing billions of stars mixed with dust and gas. Knowledge of what lies at the center of our Milky Way may very well hold the secret to the forces that shape billions of other spiral galaxies throughout the Universe. However, the view towards the center of our galaxy (middle, marked) and its lurking supermassive black hole is obscured at visible wavelengths and difficult to interpret.

Most of the light in this spectacular scene, 34 by 20 degrees across, comes from the myriad of old, cool stars that are gathered in the bulge around the center of our galaxy. Many of the dark patches are actually a series of overlapping silhouettes — starlight blocked by patchy clouds and streamers of dust. We see this complex vista from our vantage point on Earth, almost 30,000 light-years from the Milky Way's central black hole, safe in our distant galactic suburbs. Our line of sight passes through the dust that gravity constrains to the flat disk of the Milky Way, and, as is the way with silhouettes, it is difficult to determine the distance of the obscuration, although there are clues.

To the right in the picture is the bright orange star Antares at a distance of about 600 light-years. Antares and stars like it are the main source of the dust we see in spiral galaxies, but around Antares the dust glows with the reflected light of the star itself (p. 122). Close to Antares is a blue reflection nebula at a distance of about 460 light-years, and this appears to be joined to the Milky Way by a slender stream of dust. This dust is nearby!

Fortunately, astronomers can peer through this opaque material by using instruments capable of observations at radio, infrared, and X-ray wavelengths. The Milky Way's central bulge can be seen overhead in the southern winter sky just a few degrees west of the large Sagittarius star cloud, the brightest patch of stars that dominates this wide angle mosaic. The dusty lane of the Milky Way runs obliquely through the image, dotted with remarkable bright, reddish nebulae, such as the Lagoon and the Trifid nebulae (upper left, p. 142 and 140), as well as NGC 6357 and NGC 6334 (bottom, middle, p. 136 and 132). All these star-forming regions straddle the equator of the Milky Way.

Wide View of the Central Milky Way

The unique and remarkable image spanning this page shows the region of the sky from the constellation of Sagittarius (The Archer, left) to Scorpius (The Scorpion, right). The very colorful Rho Ophiuchi and Antares region features prominently to the right, as well as much darker areas, such as the Pipe and Snake Nebulae. The image was taken under the clear skies of ESO's Paranal Observatory with an amateur telescope and is composed of a total of 1200 exposures through blue, green, and red filters.