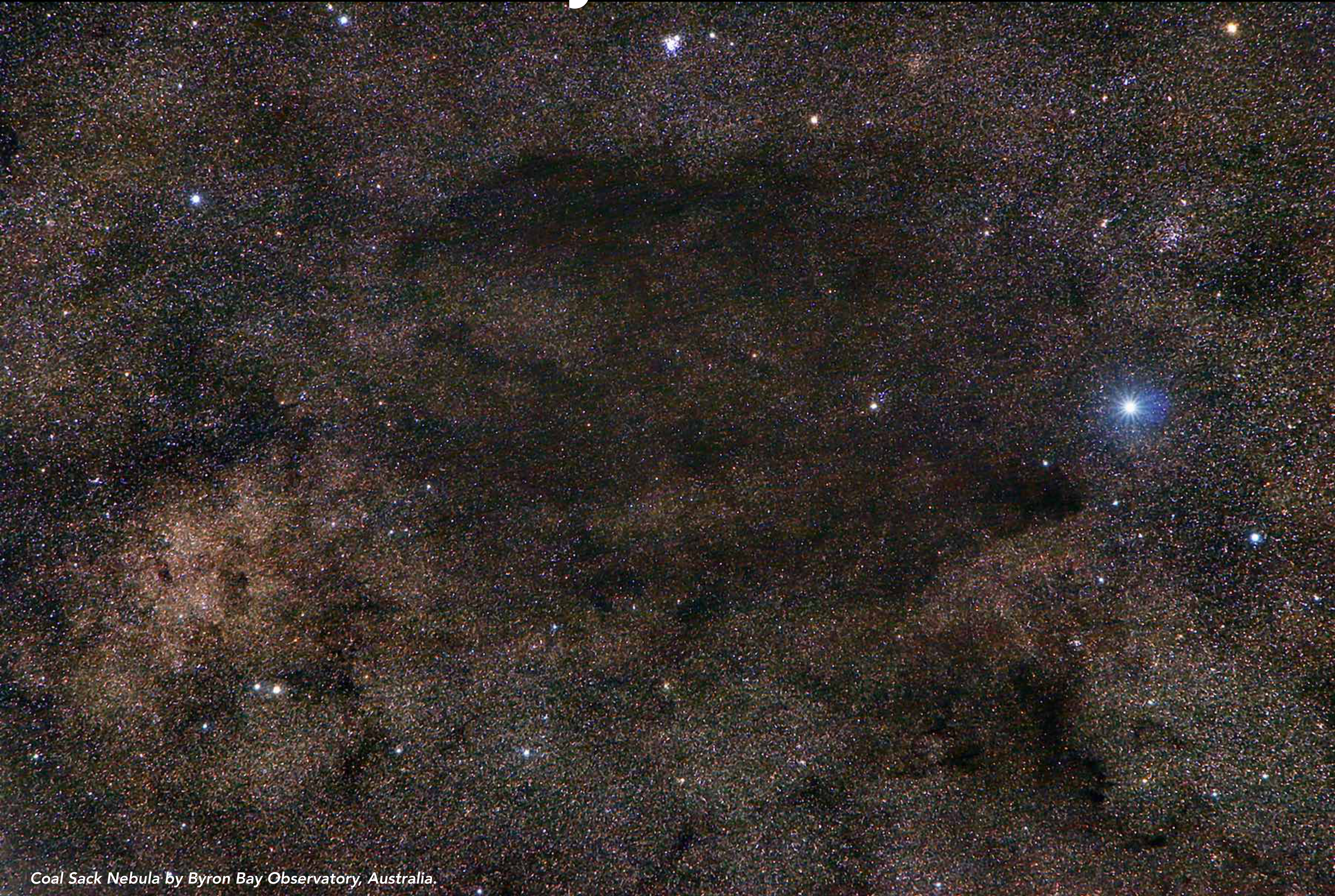
Seeing the Dark



Coal Sack Nebula by Byron Bay Observatory, Australia.

Holes in the Heavens

One night in 1784 the usually reserved William Herschel exclaimed to his sister Caroline recording his observations on the ground below, '*Hier ist wahrhaftig ein Loch im Himmel!*', or 'Here is truly a hole in the heavens!'. She dutifully recorded it, even including the exclamation mark.

Herschel's telescope pointed towards the Ophiuchus region. He had glimpsed one of the dark nebulae in the Ophiuchus Nebular Complex. He reported the discovery the following year *(Philosophical Transactions Series I* 75:2135, 1785). For the next century until astrophotography arrived in the hands of E. E. Barnard, astronomers were undecided whether these dark objects were true voids or regions that simply lacked stars (after all, that's what the great Herschel himself said). Or perhaps they might by nebulae just like bright ones except that they didn't shine.

When Edward Emerson Barnard fitted the focal plane of his telescope with glass plates covered with a thin silver-halide emulsion, he found that the dark patches were suffused with significant density gradients of emission. They ranged from light grey to truly black. They exhibited a potpourri of clumpy and filamentary morphologies (shapes). They could absorb emission from behind them while not emitting any of their own. Barnard published the best of the plates in the first systematic dark-cloud photographic survey, *On the Dark Markings of the Sky** (Barnard E.E., *Astrophysical Journal* 49:1-24, 1919. Eight years later the plates were published in book form, *Catalogue of 349 Dark Objects in the Sky*, Univ. of Chicago Press, 1927). Today that book is a collector's treasure, in part because the images were printed on heavy photographic paper and glued on to the pages where they were described by the text (a printing technique known as a 'tip-in'). The contrast detail in Barnard's images matches the better efforts of image processing techniques today.

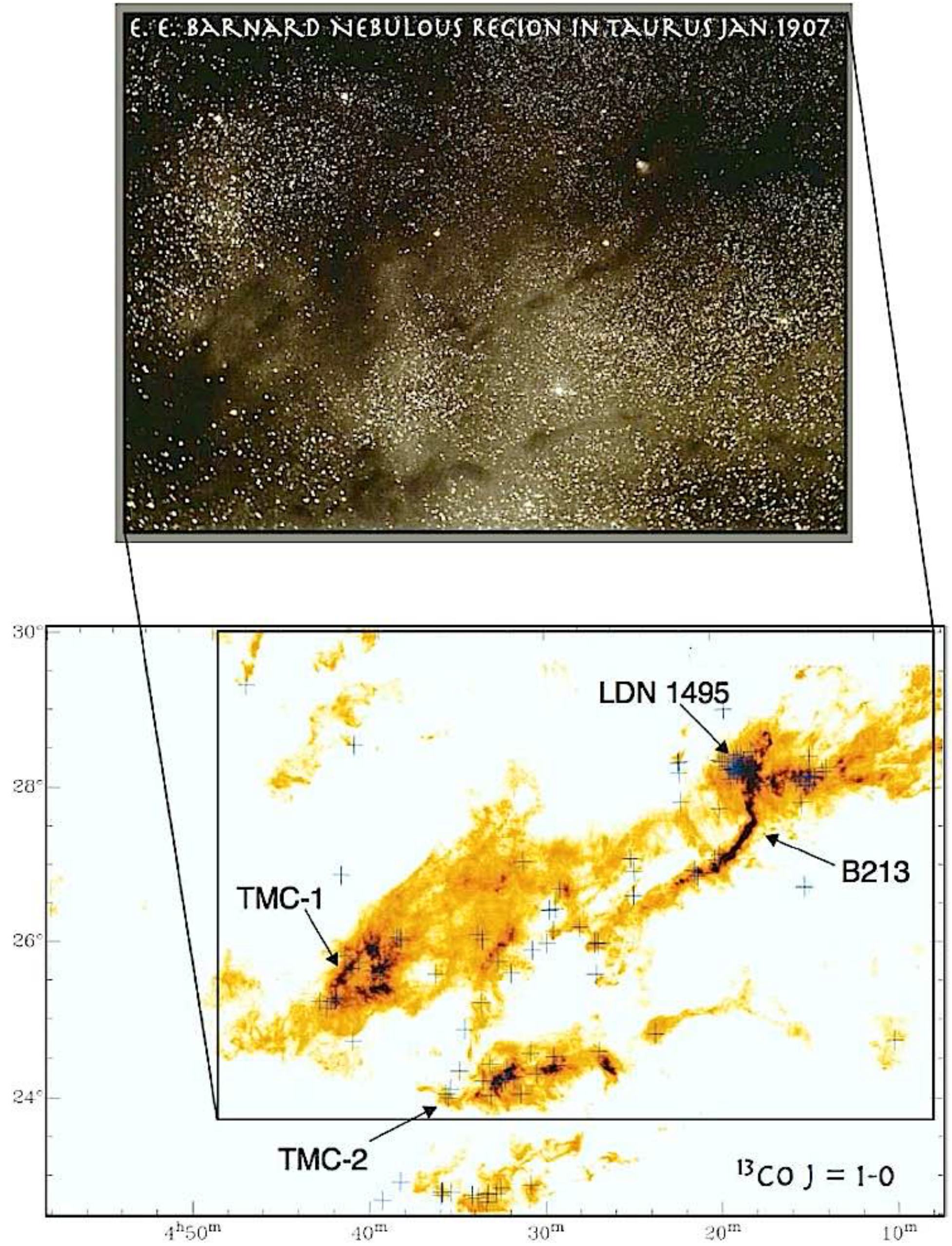
Barnard argued that his deep photographs provided increasing evidence that many of these dark areas were 'obscuring bodies nearer to us than the distant stars.' The overdense clumps were considered curious but unimportant clouds until the 1950s, when they were conclusively shown to be associated with star formation by Bart J. Bok in 1946 (Bok, B.J., *Centennial Symposia*, Harvard Observatory Monograph No. 7, 531948, not available online). Bok went further to demonstrate that star clusters were born in the compact, round dark blobs that now bear the name *Bok Globules.* (*Launhardt et al, 2010.*)

As equipment and technique improved steadily from 1950s through the 1970s a picture slowly emerged in which dark clouds were known to be a vital part of the gas/stellar dynamics of galactic behaviour. At phase scales of several parsecs or more, clouds were observed to be predominantly filamentary structures constantly barraged by high-velocity turbulent shocks. Over time the disruptive shocks were quenched by powerful magnetic fields. Magnetic pressure overcomes turbulence pressure, decreasing the ambient energy field. Large parcels of the gas go subsonic. Stars can form out of free-fall collapse if their ambient energy field is subsonic. At gas densities above $N_H > 10^4$ cm^{-3} gravitational energy surpasses the gas's internal energy density. The cloud free falls rapidly into protostars.

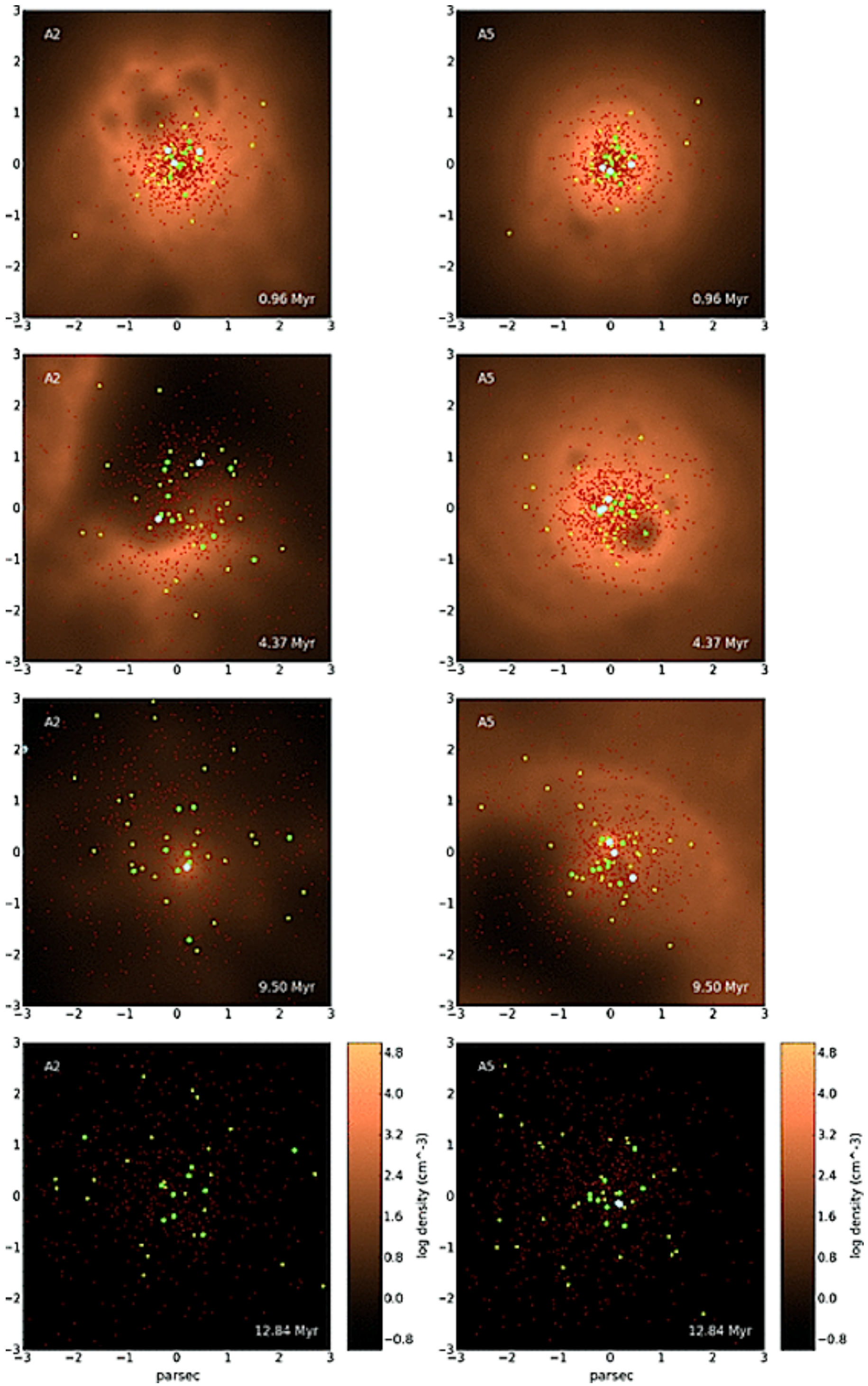
* This easily downloadable 2.8 MB PDF is a wonderful read. It contains some of the most exact at-the-eyepiece observational astronomy writing available. Barnard clearly enjoyed his eyepiece time. The plates which begin on p.25 reproduce acceptably in PDF, though readers need a bit of experience viewing dark nebulae to get a sense of the startling intensity of the dense blacks in the original book.

Starting in the 1960s the technology of modern infrared and millimetre-wave astronomy detailed ever more clearly the relation between dark clouds and the formation of stars and planetary systems. A key discovery was that complex molecules such as CN (cyanogen), OH (hydroxyl), and CO (carbon monoxide) were being made in space. Among them was the key molecule needed to initiate the complex reactions of astrochemistry, HII. HII is simply ionised hydrogen (*see this interactive example of the process*). Astronomers conventionally use the designation HII; other scientific disciplines use H^2. One reason is that the term H_2 designates molecular hydrogen. A typo that gets H^2 and H_2 wrong can ruin a lengthy calculation.

Molecular clouds are dark not because of their hydrogen molecules; they are dark because of their enormous populations of tiny soot-sized dust grains that absorb starlight. Dust grains tend to first aggregate atoms on their surfaces and then congregate into closer proximities. When they gather in quantities large and compact enough to block



Right: Taurus Molecular Cloud Complex.
Top: The Taurus Molecular Cloud was first imaged by E. E. Barnard in1919. He wrote, 'Very few regions of the sky are so remarkable as this one. This cloud is one of the most important of the collection for it bears the strongest proof of the existence of obscuring matter in space'. *Bottom:* B211 and B213 clouds in the Taurus Complex, courtesy of the Observatories of the Carnegie Institution of Washington. *Bottom:* ^{13}CO J=1–0 submillimetre-band emission map of the same region. The orange colour represents hydrogen gas insufficiently dense to collapse into a filament or cloud; this gas will eventually dissipate back into the Galactic disc for future recycling. The brown-black regions are clumps or cores collapsing into star clusters. The colour scale ranges from 0.5 to 10 K km s^{-1}. At only 140 pc or 430 ly away the Taurus Cloud is the nearest star-forming cloud to Earth. (*Watch the Wiki video pan across the cloud here.*)



light, they become the dense dark clouds that William Herschel expostulated to his sister Caroline.

By 1975 astronomers knew that the precondition for complex chemical structures (including us) was the freeze-out of HII molecules onto cold dust grains. (Weinreb et al., *Nature* 200:829 1963, and Wilson et al., *Astrophysical Journal Letters* 161:L43 1970).

Space has been with us a long time, and it's going to stick around for an even longer time. Even after thirteen billion year of nonstop stellar gas guzzling, an incalculable number of atomic hydrogen gas clouds dot the universe in the form of tenuous self-bound HI gas clouds. They are referred to as CHVCs or Compact High-Velocity Clouds. They have existed nearly untouched since the earliest epochs of the early universe. Dark clouds feed future galaxies since CHVCs are the primary source of fresh, pristine gas on which galaxies continue to thrive. Hydrogen is converted to helium and all the other elements via the atomic reactions inside stars, so if star formation is to continue there must be a continuous supply of fresh fuel from deep space. Without it our Milky Way would run out of gas in 2.6 billion years.

When a CHVC approaches a galaxy, it is absorbed into the galaxy's halo. That cools the halo ever so slightly, and, being now cooler, the halo contracts a bit to retain its disc–halo equilibrium. The process is called *virialisation.* A portion of the incoming gas cloud does retain its

Left: Dark clouds can be brutally cold inside. At visual extinctions greater than $A_V > 1$ mag) so much starlight is removed that temperatures in the centres plummet to within a few degrees of the 2.73 K cosmic microwave background. A few nearby dark clouds have become so dense they absorb even the CMB radiation; their cores drop to 1 K. At such cold temperatures there is virtually no internal energy to resist gravitational collapse into a star cluster. In this numerical or *N*-body simulation, two different initial densities produce different collapse rates and internal distributions. *Source:* *Pelupessy & Portegies-Zwart, 2012.*

shape. Slowly it descends toward the disc. The densest part elongates into a comet-like structure, which flattens once it hits the dense disc. Once hydrogen enters into a galaxy disc, things change rapidly and violently. A CHVC is soon disrupted and its once serene life far out in space becomes just another tidbit of hydrogen tossed hither and thither by every force in the lexicon of physical dynamics. Perhaps one day it will be part of another giant cloud that collapses into a star cluster or association of them. Perhaps it will remain a wanderer forever.

Time to head out to the eyepiece

Dark nebulae are stellar chocolates. They're not much on the outside, but wow on inside. For many observers light pollution eats them before you can open the wrapper. Half a magnitude of LP can drain the thrill out of all but the densest of them. In visual 6+ skies and a good pair of binocs, dark nebulae acquire an intensity that surpasses the emission sky. In southern skies when the Sagg/Sco/Lupus dark nebulae loom directly overhead the darks look like a crumpled black lace doily over a river of diamonds. In a pair of 10 x 50 binocs the Coal Sack becomes a tissue-thin balloon in which one can see both the inside and the outside — an illusion, of course, but oooohh what a pretty one. It's uncanny to see it as a ball of ragged tatters floating there, like a still frame from a super slow-mo punctured balloon shredding itself to pieces in front of a wall of stars.

Vinyl record collectors say that the sound detail of their old pressings has a 'presence' that CDs do not. Dark nebulae have a 'presence', too. They can be as textured visually as Brahms is to the ear. Pan across the *Lupus 3* or the molecular murk that tints *NGC 6726* a silvery blue before it streams into the inky puddle of SE Corona Australis, and the mood of the view goes from glittery to dusky to icky to cimmerian to gloom. It's a creepy place to be. It's everything stargazing is not. The sky looks like a wriggling spiderweb on quicksand in a gyre in a dungeon. Move away into the stars again and it's like taking a shower. Whew! All clean again.

Imagine for a moment that there you are at the eyepiece. What would you see if *you could see what the Universe does on its own time scale*.* Night after night, our wondrous eyepiece entertainment keeps us lifting our faces to the sky. By day we nourish our minds with them. Dark clouds are among the most astrophysically complex structures in the Galaxy — orbital mechanics, the cosmochemistry lab of supernova remnants, the Janus faces of electricity and magnetism, urantology (space weather). Fluid dynamics describes states of gases so dense they are almost completely stripped of their electron shells and behave like fluids. All the laws of mechanical heat — convection, advection, conduction, adiabatic heating and cooling — are right there in our eyepiece balcony as we watch the drama of the sky. We can't hear the song the universe sings because it's 50 decibels below Middle C. It's hard to follow the cosmic plot line because the 'instants' through which the stellar actors move are 100,000 years. Indeed, astronomers who specialise in star cluster use the term 'instantaneous' as shorthand for 100,000 years. Galactic astronomers consider 'instantaneous' as a million years. Cosmologists think instants are 100 million years.

Even aerodynamics gets into the cosmoquest of a particle in space trying to find a peaceful place to settle down. We can err if we visualise

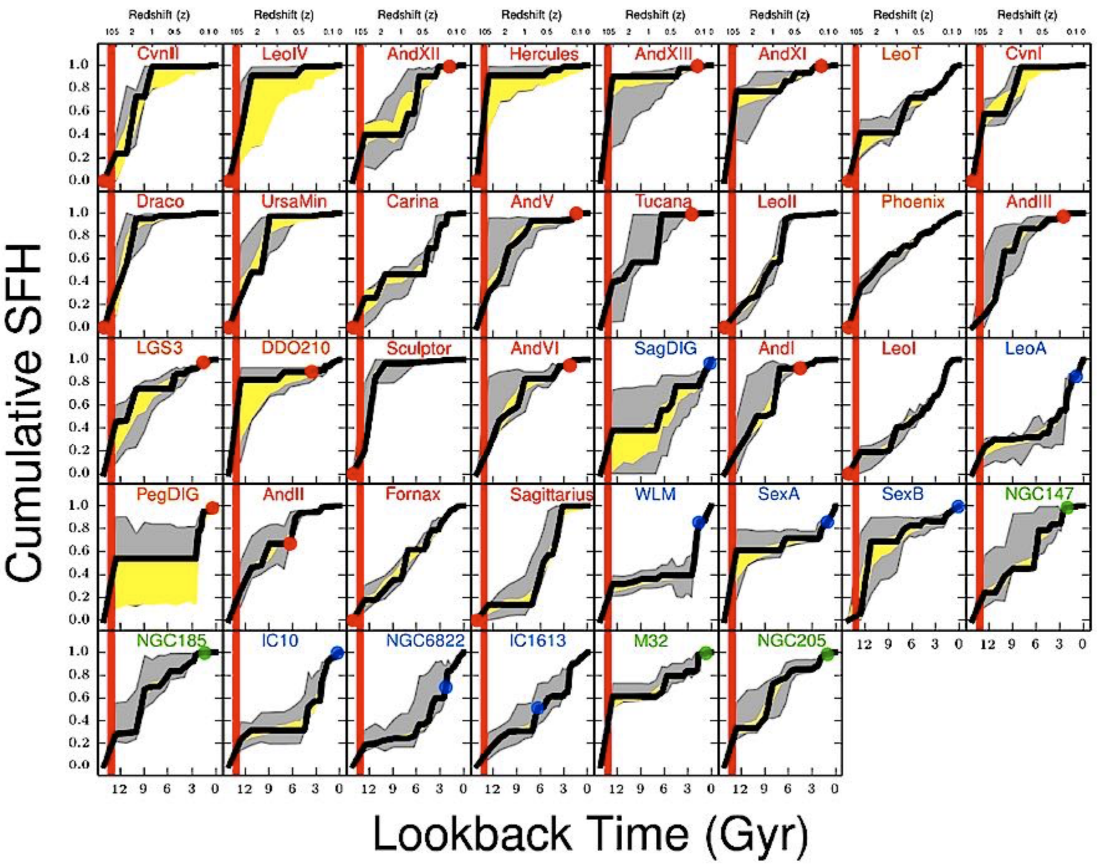
* This *Illustris* simulation box is 10 Mpc on each side, 495 million years in time, at *z* = 0. You can find them *here* and *here* (the stills are above, the sims below). Readers can calculate the exact halo mass, stellar mass, gas mass, and U-band luminosity *for any point on this sim here*.

objects as hurtling hypersonically through a still medium; sometimes the medium streams hypersonically past them. The energy perturbations of shock fronts are a hydrodynamist's paradise. They are the battleground of matter density -vs- energy density in a combat neither side can really win. The winner is always entropy and entropy never gives anything back.

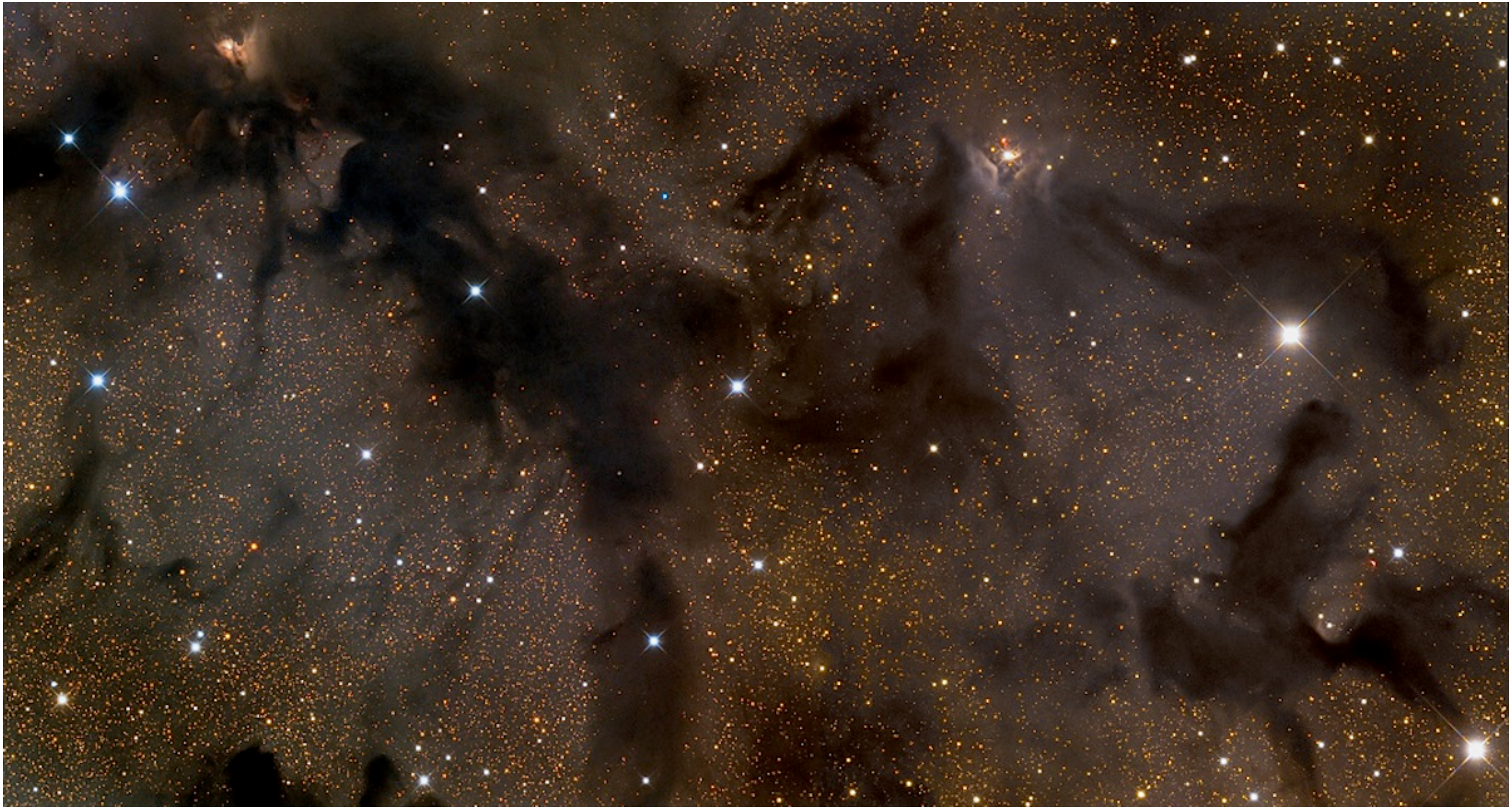
Most molecular gas in the interstellar medium (ISM) resides in giant self-bound clouds (GMCs), with masses of ~10^5 solar masses tens of parsecs in diameter, whose densities of averaging N_H 100 cm^{-3}. (N_H is shorthand for 'number of hydrogen atoms'.) GMCs are inhomogeneous. Visually they appear as filamentary webs dotted with dank musty clumps. Their typical mass is on the order of $10^3 – 10^6\ M_\odot$, average sizes of ~1 pc^3, and densities of $10^3\ N_H$ cm^{-3}. They are the coldest places in the universe. Clumps can be contrarily inhomogeneous, clotted with pocket-like overdensities as high as N_H 10^4 cm^{-3} and underdensities as low as N_H 10^{-4} cm^{-3}.

In the really big picture, lasting multiple billions of years, the complete cycle of star formation recycles roughly 99% of the original gas mass back into space. During the relatively brief ('instantaneous') star formation epoch, only around 3 to 10 percent of the original gravitationally bound gas mass condenses into stars. Once the stars are made, sooner or later they eject nearly all their unused natal mass back into space, mainly through UV radiation from hot massive stars and particles ejected from their hot surfaces. Our Sun's coronal mass ejections that raise such holy hell with our electrical systems on Earth are piffles compared with what an O or B star can do. We would be toast so fast we wouldn't feel it.

Even when stars spectacularly blow up, they re-seed their galaxies with more stuff to make into stars. Because each stellar recycle leaves traces of heavier and heavier atoms, we can build up a history book of almost any galaxy's star formation history.



Star formation histories of local group dwarf galaxies, from *Weisz 2014*. Dwarf galaxies are especially sensitive to the amounts of ambient gas around them. Remote dwarfs tend to have made all their stars very early and then remain quiet. Dwarfs closer to large galaxies undergo steady but irregular mass injections from giant CHVCs which fuel new starbursts throughout their evolution.

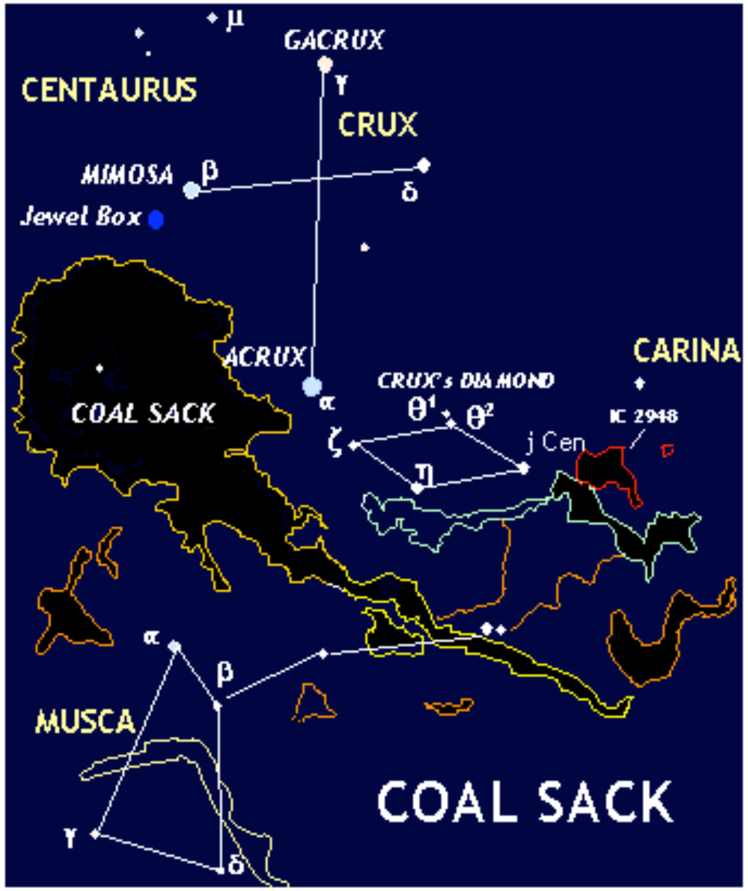


Lynd's Dark Nebula in Aquila (LDN 673) is a dense, turbulent dark cloud complex in the centre of the Aquila Rift, some 300 – 600 light-years from Earth. It is about 7 ly across. The Aquila, Vulpecula, and Cygnus Rifts comprise just part of the much larger Great Rift. LDN 6573 is a loosely associated stream of molecular dust clouds located between the Solar System and the Sagittarius Arm of the Milky Way. The Great Rift appears as a dark lane that splits a dark canyon along the crowded plane of our Milky Way galaxy into two as seen from Earth. Each cloud contains about 1 million solar masses of plasma and dust. LDN 673's dusty molecular clouds contain enough raw material to form many thousands of stars. Visible indications of energetic outflows associated with young stars include the small red tinted nebulosity RNO 109 (at top left of this image) and Herbig-Haro object HH 32 (above and right of centre). Learn more about Beverly Lynd's dark nebulae here: *1*, *2*, *3*, *4*. Read *more about Beverly Lynds here*.

Coal Sack

The Coal Sack is a big softie. In that whole, huge blob of dark, only one of its cores will form a star cluster. The rest will be recycled into space. The unused gas can take a hundred million years or more to glue its way into another dark cloud. Perhaps a given parcel of gas will be lucky enough to compact into the burning-bright stage, but the chances are 9-to-1 it won't.

The Coal Sack is the dark blob between Hadar/Beta Centauri (upper left off the image) and Acrux. Unfortunately for urban dwellers the Coal Sack is obscured by even modest amounts of light pollution. In country skies the region is startlingly obvious. It looks like the deep hole in the firmament that so astonished Herschel. In reality the Coal Sack it is just another giant dustbag of obscuration that just happens to lie in the Carina Arm in a location noticeable to us. Binocular inspection finds the Coal Sack edges to be ill-defined. Shift your attention to the stars behind it and it suddenly seems 3-D, a bag of feathers in front of a fan. The image on the next page parses the Coal Sack into its densities. In binoculars the Coal Sack is the lacemaker of Crux. On the darkest night the main body oft his dark cloud slowly diminishes to the south-west.



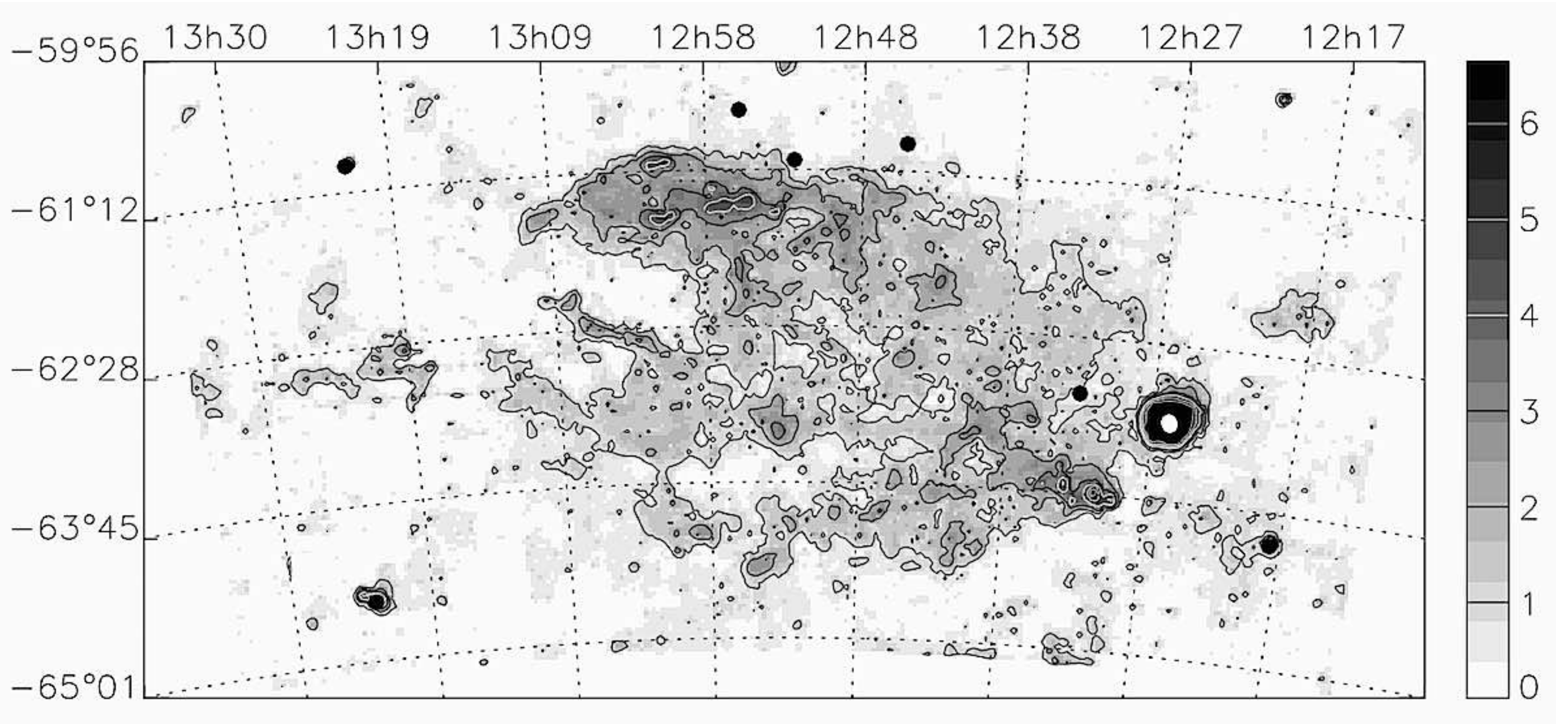
Below Acrux it dwindles into a slender stream of blackness.In reality this is a longitudinally compressed filament shaped by a magnetic field. Eventually the overall structure descends further SW until it loops up again towards the red HII emission nebula IC 2948, finally fading completely near the famed Eta Carinae Nebulae NGC 3372. We do not yet know whether this structure exists in phase space the way it appears in visual space. The term 'phase space' is shorthand for viewing a particular field using criteria other than visual appearance. Dimensional phase space is how the object occupies 3-D space. Metallicity phase space would be a map of the object in a specific set of metal abundances, e.g, the [Fe/H] ratio commonly used to age-date an object. Velocity phase space is the pattern of internal velocities made by specific parcels moving in 3-D in relation to each other and to the background.

Back to the Coal Sack, other wisps of dark nebulosity surround the area as well. A prominent one is is the Dark Doodad Nebula (see below) which elongates down the west side of Musca to the south.

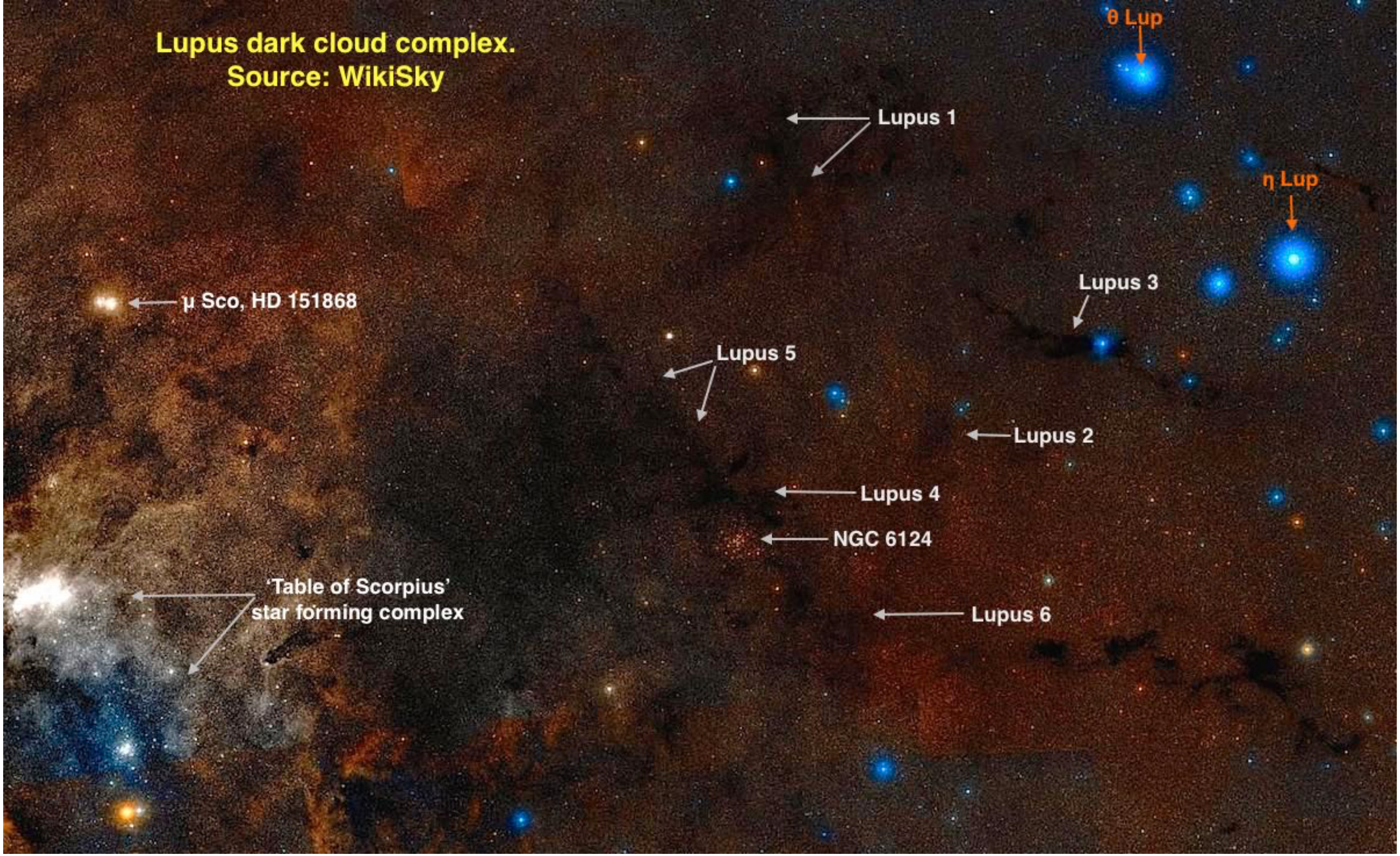
If your eyes are acute enough, you can possibly notice the faint 6.5 magnitude star within the nebulosity (white dot above the word 'Coal' in the schematic). This is *HD 110432 (BZ Crucis)*, a furiously fast-rotating gravitationally unstable Be star of 12 $M_{\odot}$. The star's spectrum shows very rapid variations on very short times scales (e.g., across just one night of observing). These are attributed to very brief, irregular strongly magnetised bubbles blasting high-velocity holes in the star's circumstellar clouds. Imagine life in the middle of a boiling tea kettle. If the Sun behaved like this we would be treated to a lifelong fireworks show all across the entire sky, day and night.

The Coal Sack is estimated to be 190 parsecs or 620 light years from the Sun. The Coal Sack's nebulosity was first recorded in 1752 from the Cape of Good Hope by Abbé Nicholas-Louis de la Caillé (1713–1792), who wrote in his '*Mémories de l 'Academie Royale des Sciences', 1755* (p. 286–296), 'One might again include the phenomenon which strikes the eye of those who observe the Southern sky; a space of almost three degrees extent in all directions which appears as dense blackness in the eastern part of the Southern Cross. This appearance is caused by the intensity of the whiteness of the Milky Way which encloses this space and surrounds it on all sides.'

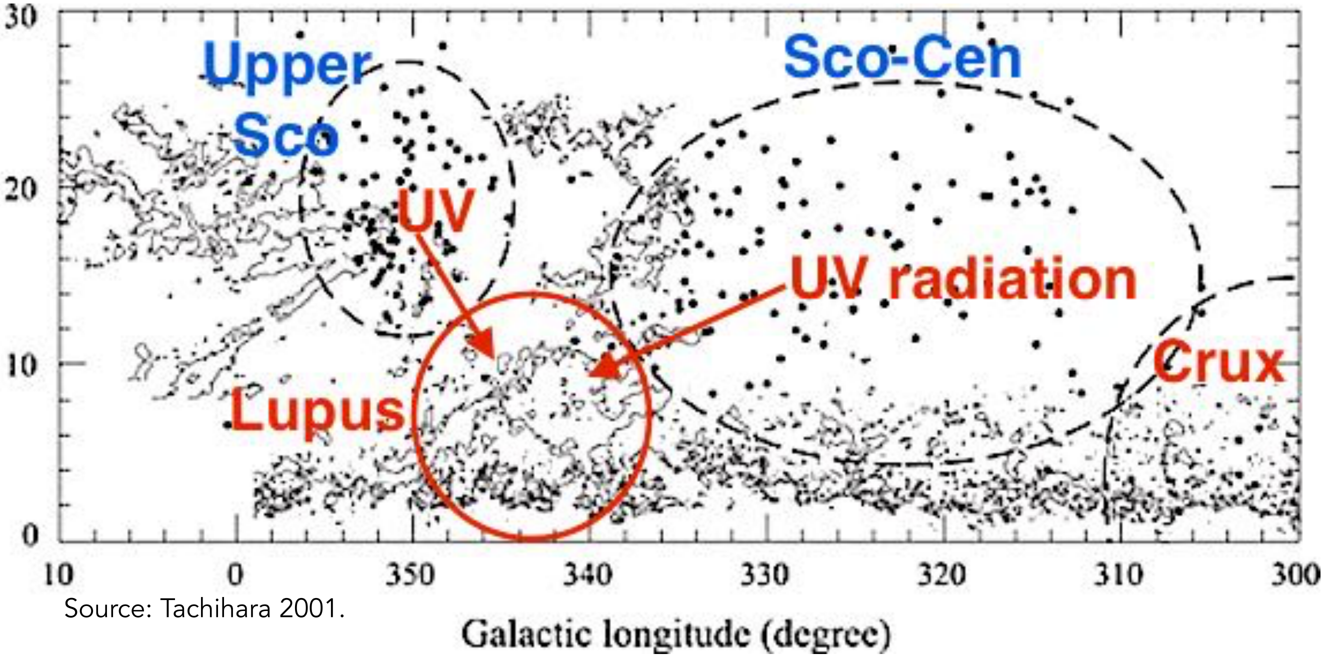
Legend has it that the moniker Coal Sack derives from drovers or miners in the Australian outback. At night these men described this region as 'black as coal' compared to the surrounding bright Milky Way. Sir John Herschel advanced an alternative explanation of the origin of the name, saying it was used in the early 1800s by sailors when visiting the southern seas. Occasionally one comes across a reference to the Coal Sack as the Black Magellanic Cloud. You name it, you own it.



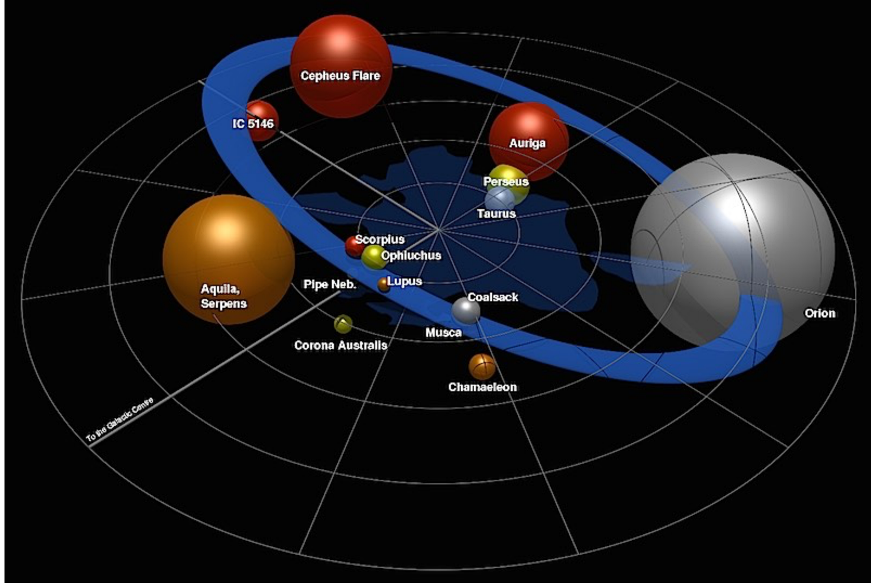
Extinction map of the Coal Sack from *Cambresy 1999* (Fig 4). The densely black pocket on the right is the only clump compact enough to collapse into a star cluster. As the round shape suggests, the collapse is underway even now. The Coal Sack is roughly 150 pc (490 ly) in diameter, but it comprises only 1.4 x 10^4 $M_{\odot}$ of gas. Its maximum extinction in the darkest core is A_V 6.6, which would dim starlight from behind by 3980 times. Dramatic as this scene appears (and is even more dramatic in the sky), the cluster that eventually forms will be a rather modest one. The rest of the gas will continue doing what it is right now: dissipating back into the spiral disc. The poor thing just didn't get its gravitational act together. Indeed, many nascent star forming clouds never make it to stars. And we think *our* weather is so fickle!



The Lupus molecular cloud complex covers such a large section of the sky that it has not yet been fully examined with a molecular line survey. There is considerable star-formation activity at various ages among the Lupus clouds. This is attributed to an interaction with a very large expanding HI shell that reaches as far as the ρ Oph cloud. In a 1996 ^{13}CO survey Tachihara et al. found a molecular outflow in the Lupus 1 cloud. In 1993 Gahm et al. observed the Lupus 2 cloud in ^{12}CO, finding multiple-velocity components in the line of sight. Hara et al. studied the region in 1999 using $C^{18}O$ observations, finding 36 embedded dense cloud cores. Some cores that are starless. These typically have larger line widths than similar active star forming regions,a sign that their molecular gas is disrupted by strong turbulence. Turbulent shock waves interacting with each other counteract the inherent self-gravitation of molecular cloud cores. (*Source: Tachihara et al. 2000a*).

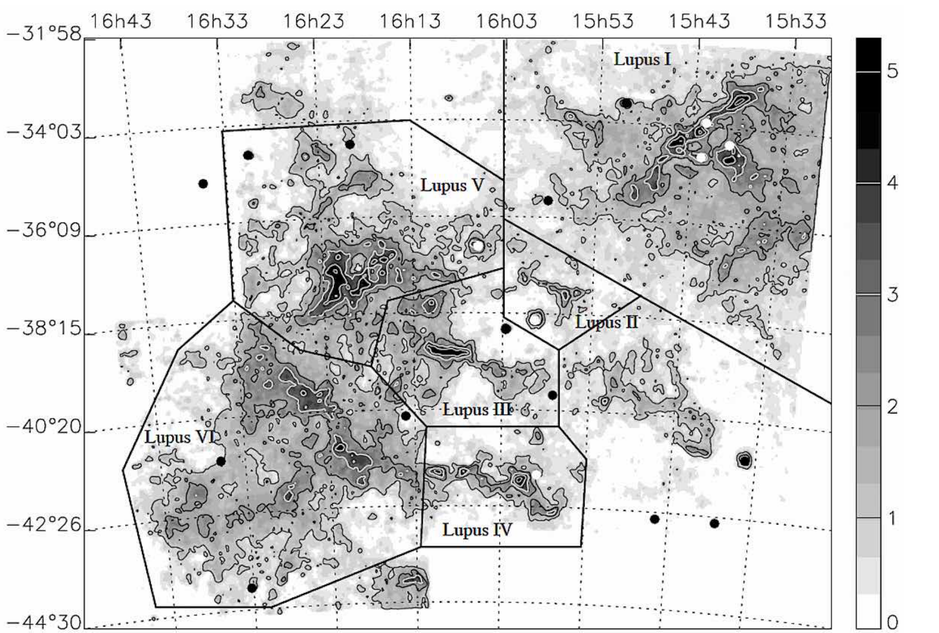


Source: Tachihara 2001.

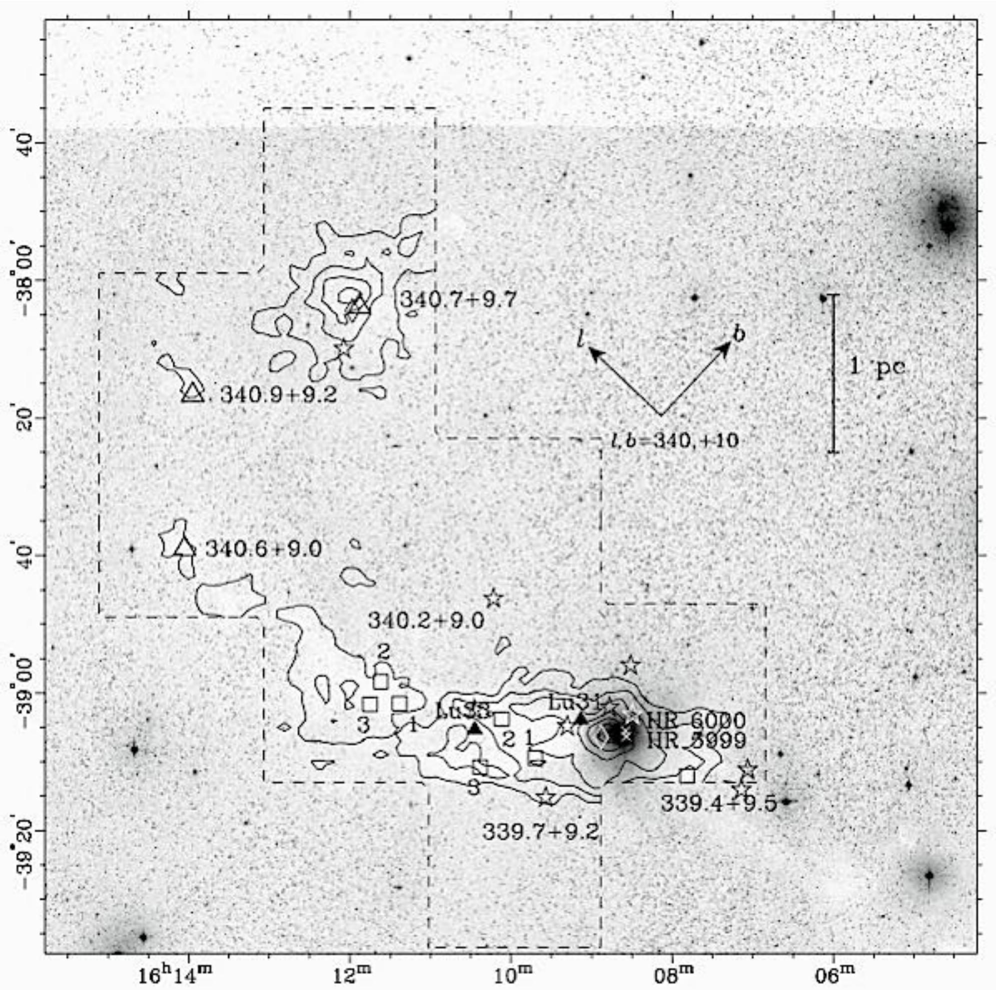


Schematic of Gould Belt OB and dark cloud associations. Gould Belt is in blue. *Credit: J. Kirk & V. Konyves*.

The Lupus clouds are part of the Scorpius-Centaurus OB group, one of the best studied of the OB associations. Sco-Cen is a huge complex — over 300 early-type O and B stars spanning nearly 90° in Galactic longitude at an average distance of ~140 pc (456 ly) from us. There is a strong likelihood of physical interaction between Lupus and Sco-Cen. In turn, Sco-Cen, the Perseus OB2 association, and the Orion complex are the principle structures comprising the Gould Belt. The Gould Belt is an extended planar arrangement of OB associations that dominate the the energy density field of the solar neighborhood out to ~600 pc (1956 ly). The Belt's outer apsis (furthest extent) lies not far from the Lupus clouds. The Lupus assemblage itself lies at a relatively high Galactic latitude, suggesting that it did not originate from infalling clouds but rather local pressure from the nearby massive associations. The Sco-Cen region is an assemblage a number of distinct groups. The evidence that Lupus is associated with them is partly seen in age-luminosity bins observed among the photometric ages of both group's stars. At 14 Myr the Lupus clouds occupy a gap between the Upper Scorpius and Upper Centaurus-Lupus age bins, This suggests that the Lupus clouds are participating in a more recent episode of star formation than the Upper Sco and Sco-Cen. The region surrounding the Lupus clouds is devoid of the early-type O and B stars found in those groups. Moreover, the Lupus clouds are not presently undergoing high-mass star forming activity. The abundance of so many OB stars in the nearby Sco-Cen implies that Lupus lies in Upper Sco and Sco-Cen's intense ambient UV radiation field. High-energy radiation increases the mechanical energy already being injected into the Lupus clouds by stellar winds from the nearby OB stars. All these energy sources have played an important role in the origin and evolution of the Lupus cloud group.



Lupus 3 molecular cloud complex located 184 pc away at RA 16h 08m 34s, Dec –39° 05′ 35″. The double star in the middle is HD 144667–68, some 240 PC away. The blue reflection nebula shows the effects of foreground scatter, when light from a distant source is reflected at shallow angles off tiny dust particle in between the source and our eyes. To the left, the soft edges of the elongated absorption clouds are evidence that magnetohydrodynamic quenching is slowing the swirling maelstrom of supersonic turbulence associated with cloud collapse. The intense darkness of the filament centres is caused by molecule densities greater than 10,000 particles per cubic cm plus the large amounts of dust in HII clouds.



Astronomers use the term “extinction” as a unit of measure. They cite the number of hydrogen atoms in a cubic centimetre from 1 to 10,000. At N_H 10^4 cm^{-3} the gas density is high enough to 'extinguish' a star or galaxy on the far side by one magnitude. At densities of 10^4 cm^{-3} astronomers use extinction in visual magnitudes as a calibration measure. The extinction in the Lupus 3 core is 25.5 magnitudes (roughly 62 million times fainter than a 6th magnitude star). At such density levels the star enters the protostellar phase and generates internal heat from gravitational contraction. *Source:* *Tachihara et al 2001a*.

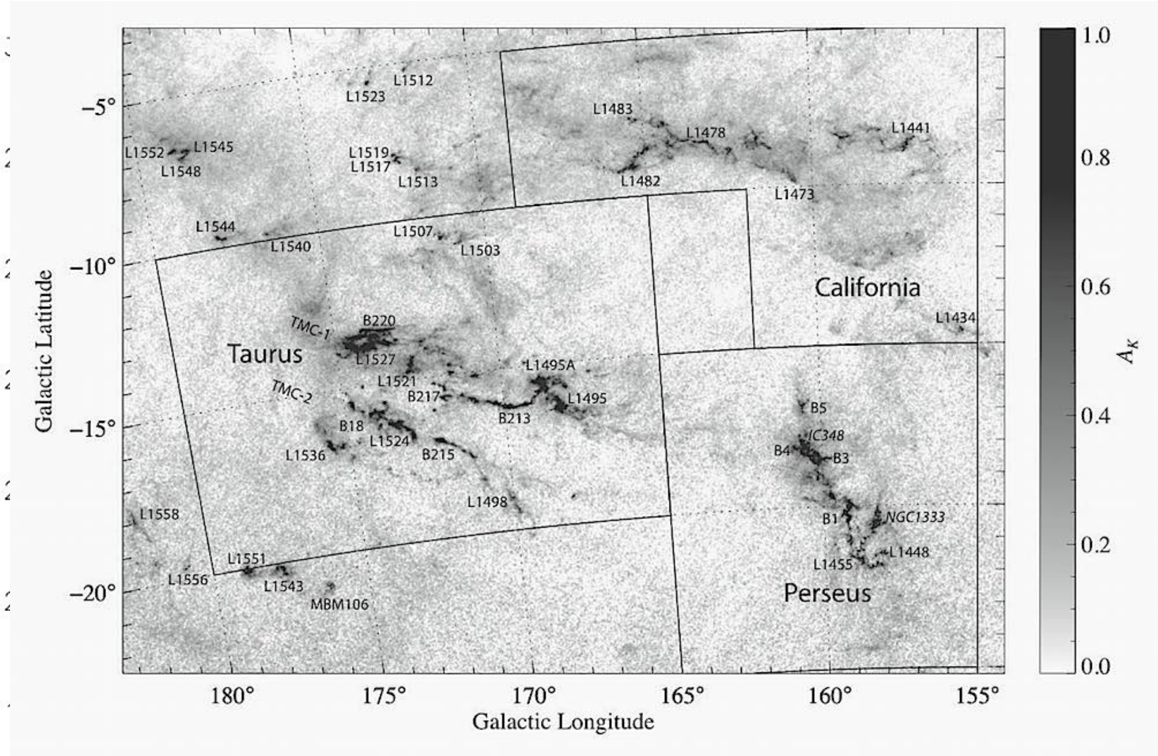
Left: Optical image of Lupus III in Tothill et al 2009, Fig 2. The contours are density levels of ^{13}CO, a carbon monoxide molecule in which the carbon is the isotope of normal ^{12}CO with one extra proton, making it ^{13}CO. ^{13}CO is produced in the carbon-fusing cores of AGB stars that were already rich in carbon from previous generations of other AGB stars. The neutron surplus in such stars can pack an additional proton into the nucleus of a totally or near totally ionised carbon atom if the core temperature is high enough. In the absence of the electrostatic barrier of an electron shell (the Coulomb barrier), the only barrier a proton has to overcome to penetrate a Carbon nucleus is the Strong Force. The temperatures in AGB fusion cores are well in excess of 100 million K. At energies that extreme a footloose proton can cram its way into the nucleus before the normal rejection response time of the Strong Force, which exists in part to keep them out. Here is a case where the speedy bird gets the worm. The contour lines mark gas temperatures of 2, 4,...12 Kelvin per km s^{-1}. (The crosses are stars.) This map covers only the Lupus 3 region; the Tothill paper analyses the entire Lupus molecular complex. The authors were able to observe the ^{13}CO J=1–0 molecular transition. The J refers to the near-infrared (NIR) spectral band. The 1–0 refers to an electron emitting a photon as it drops from the first valence shell to the ground state. The real info the authors were after was the HII mass in these clouds, because HII is the primary ingredient in gas clouds dense enough to collapse into star forming regions. By determining the HII mass the authors would know if the Lupus complex would form any more star clusters in the future. However, HII is a very weak emitter; data based on it alone would be inconclusive. HII is very often associated with carbon monoxide (CO) which is another by-product of the prolific molecule formation that occurs on dust grains. ‘Prolific’ in a molecular cloud can mean one new HII or CO molecule every 10,000 years or so. For space, that’s fast. ^{13}CO emits more strongly in this band than ^{12}CO so the authors chose ^{13}CO as their HII tracer. By tracing the ^{13}CO emission levels, the authors could calculate the mass of the entire Lupus III cloud. In the end it came out to a rather timid 10^4 $M_\odot$ — much too low to form stars.

Eventually the myriad disruptive forces that occur in a spiral arm will dissipate Lupus 3 back into the thin medium whence it originally came. ‘Easy come, easy go’ is a useful philosophy in space.

Taurus

The Taurus Molecular Cloud (TMC) is a star-forming region located 450 light-years from Earth. The vast cloud complex is one of the nearest large stellar nurseries to Earth. It contains over 400 young stars.

The TMC contains numerous deeply embedded T Tauri protostars. These are very young low-mass stars still in contracting gravitationally. Some undergo a phase in which they eject narrow jets of gas at velocities of several hundred km sec^{-1}. TMC also has a large number of brown dwarfs, dark substellar objects that are too low in mass to sustain hydrogen fusion, so fuse hydrogen into deuterium instead. Brown dwarfs can be as small as 0.08 $M_{\odot}$, or 13 Jupiter masses.



Star formation is ongoing in the TMC. The cloud contains stars undergoing all the various stages of stellar evolution.

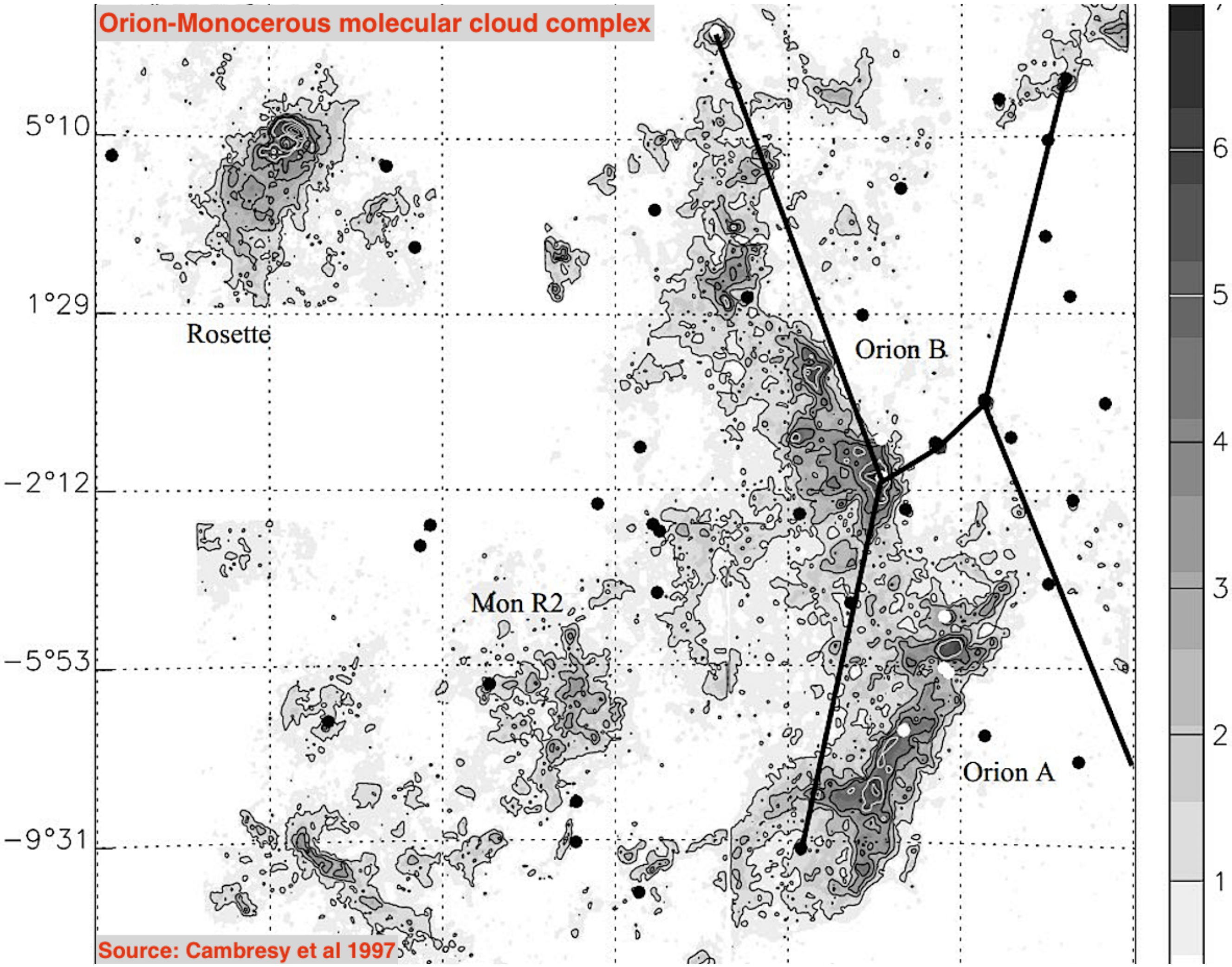
The Taurus Molecular Cloud contains the cold pre-stellar cloud Lynds 1544 (L1544). The ESO's Herschel far-IR and submillimetre space observatory detected the equivalent of more than 2,000 Earth oceans of water vapour liberated from icy dust grains by high-energy cosmic rays passing through it. H_2O forms on dust grains as hydroxyl (HO) molecules bond at the extremely cold temperatures within molecular clouds. The term 'water ice' means just that in space.

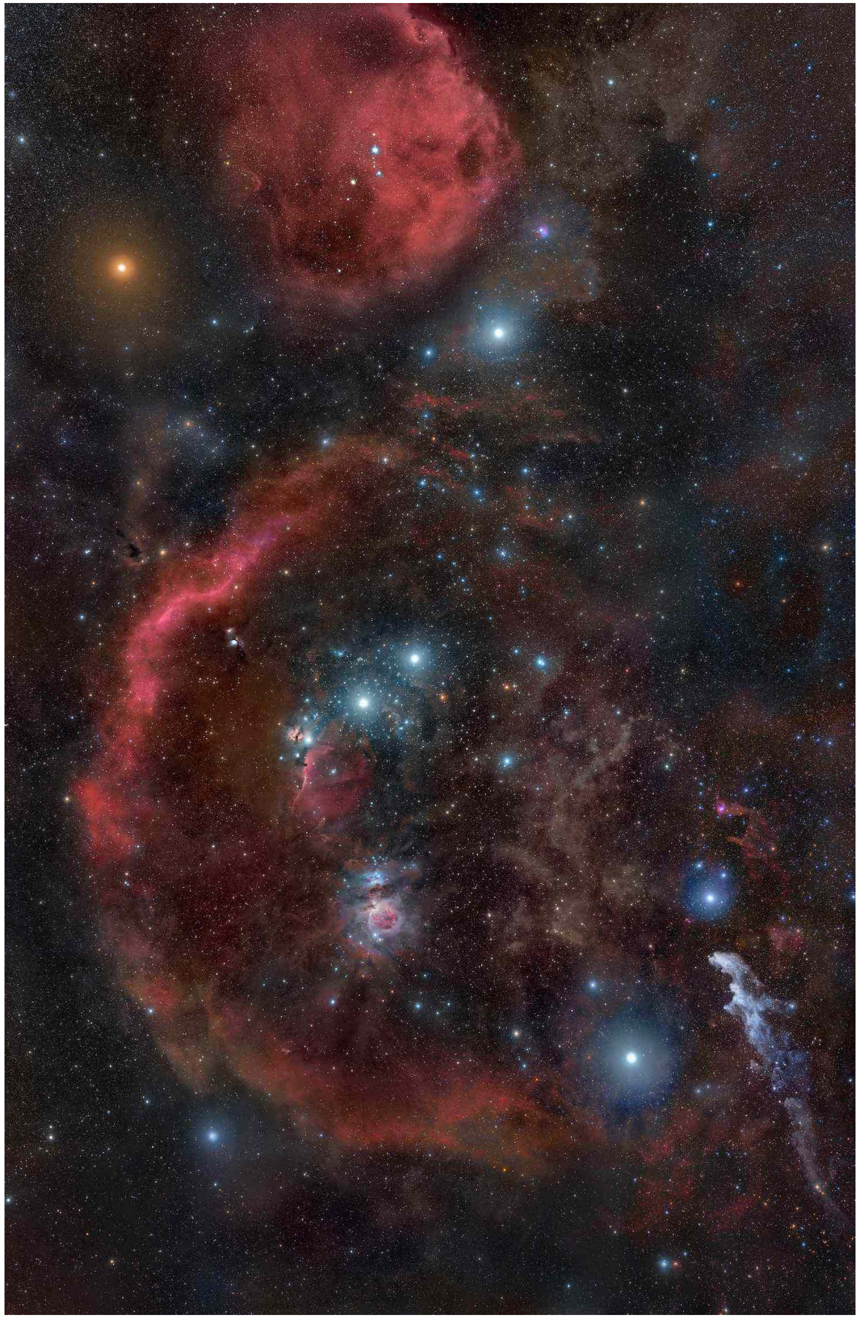
Lynds 1544 must have more than three million frozen Earth oceans' worth of H_20 to produce that amount of vapour. The Herschel observations also revealed that the water molecules are migrating towards the heart of Lynds 1544, where a new stars may possibly form. That indicates gravitational collapse is underway. There is enough material to form a star at least as massive as our Sun. Some of the H_2O in Lynds 1544 will go into forming the star, but the rest will be incorporated into the surrounding disk, providing a rich water reservoir to feed potential new planets.

There are no large stars to illuminate the Taurus Molecular Cloud. It is black in visible light but glows in the IR bands.

Orion Molecular Cloud Complexes A & B

Take away all those bountiful stars. Take away all the writhing beauties of nebulosity. Take away the billowy shock waves and magnetic tentacles. What's left? *Dust.* If we could put a Dust filter on our telescopes, this is what we would see in M42 and M43.





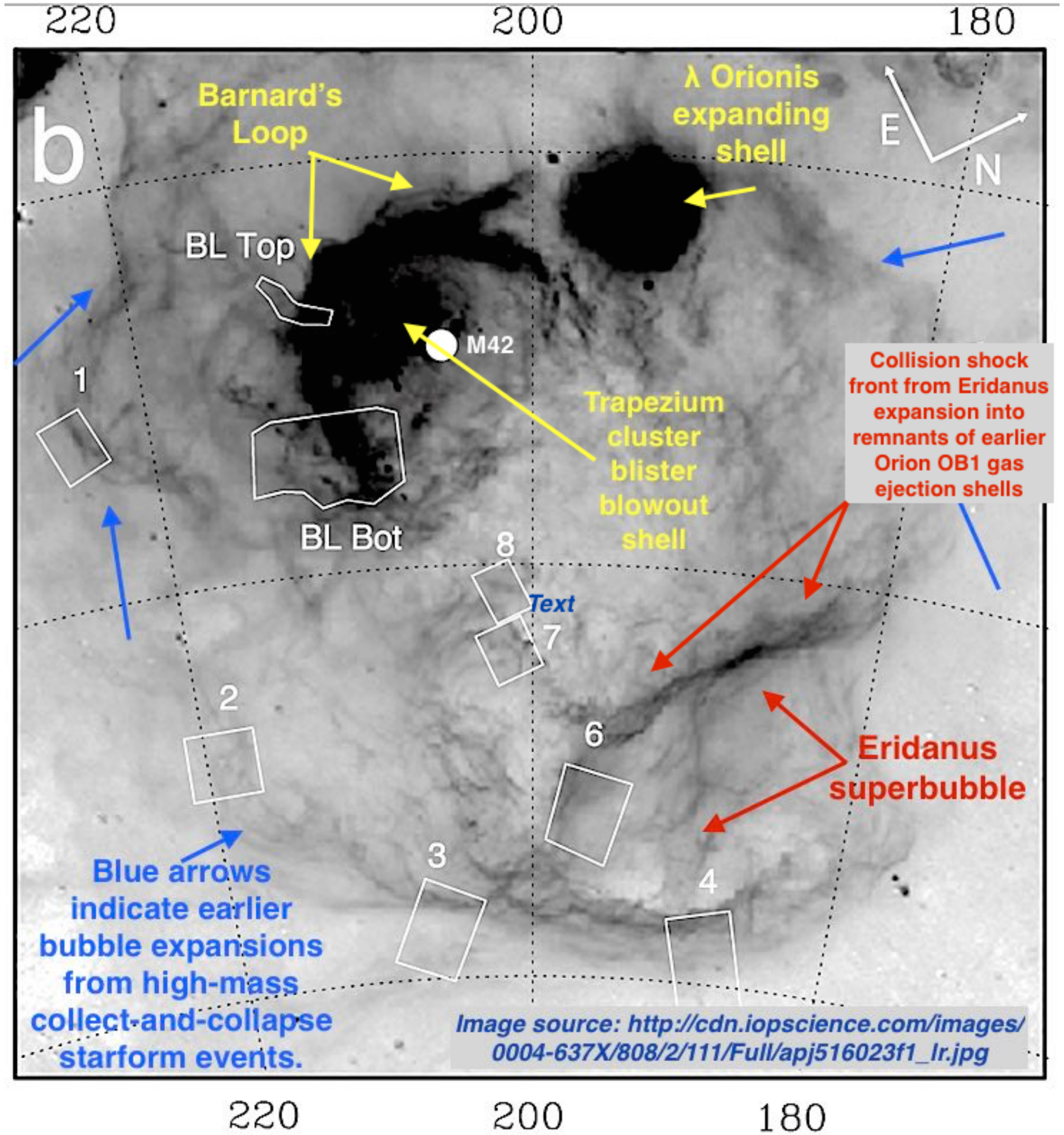
The multiband images on this and the next pages make very clear how limited is the evidence our visual observations provide for a complete understanding of the objects we see. Rogelio Bernal Andreo's panopticon image of Orion is spectacular, but provides little evidence of the time frame over which the image has evolved, from where, and in what way. It's an unfortunate fact that no matter how much we see with our eyes, it is <1% of what's there.

The Orion Molecular Cloud Complex is a giant bubble of interstellar gas and dust surrounding the Orion Nebula. At 1,450 ly distant and ~240 ly in dia.the OMCC contains M42 and M43, Barnard's Loop, the Horsehead Nebula, the Orion OB1 association, and M78 reflection nebulae, and the λ Orionis molecular shell that surrounds Orion's head.

Orion OB1 has three components: OB1a surrounds Orion's Belt (an obvious and beautiful cluster in binoculars). OB1b lies NW of the Belt stars (not shown in image here). OB1c surrounds the Orion's Sword cluster/nebulosity association. The stars of M42 and M43 are the youngest stars in the association. The Orion Molecular Cloud 1 (OMC-1) lies NW of the Trapezium.

The Trapezium itself is a vivid example of a blister-blowout bubble. These are a lopsided variant of the appx. spherical shell produced when a high-mass star-forming region emits intense UV radiation and high-energy protons from the surfaces of luminous stars. (When our Sun does this we experience aurora and EM spikes in electrical transformers.) Blister formations occur when a spherical shell expands against a pre-existing high-density shell; the expanding shell slows or even stalls, while the rest of the shell fills out into a sphere normally. In the Orion Nebula, the radiation blazing out of the Trapezium has blown out a shell easily visible behind it to the E, but the shell advancing in our direction has stalled, causing the Trap to appear glued to one side. In a lower-power wide-field eyepiece, if one stops looking at stars and instead takes in the entire emission region and a single entity, the bubble is seen to look like one. If conditions are right, in 3D.

Some 60% to 70% of the stars in the Orion Complex have dusty disks of the type associated with precursors of planetary systems. More evolved nascent planetary systems have been speculated to exist in proplyds and Herbig-Haro polar-jet emitting young protostars.

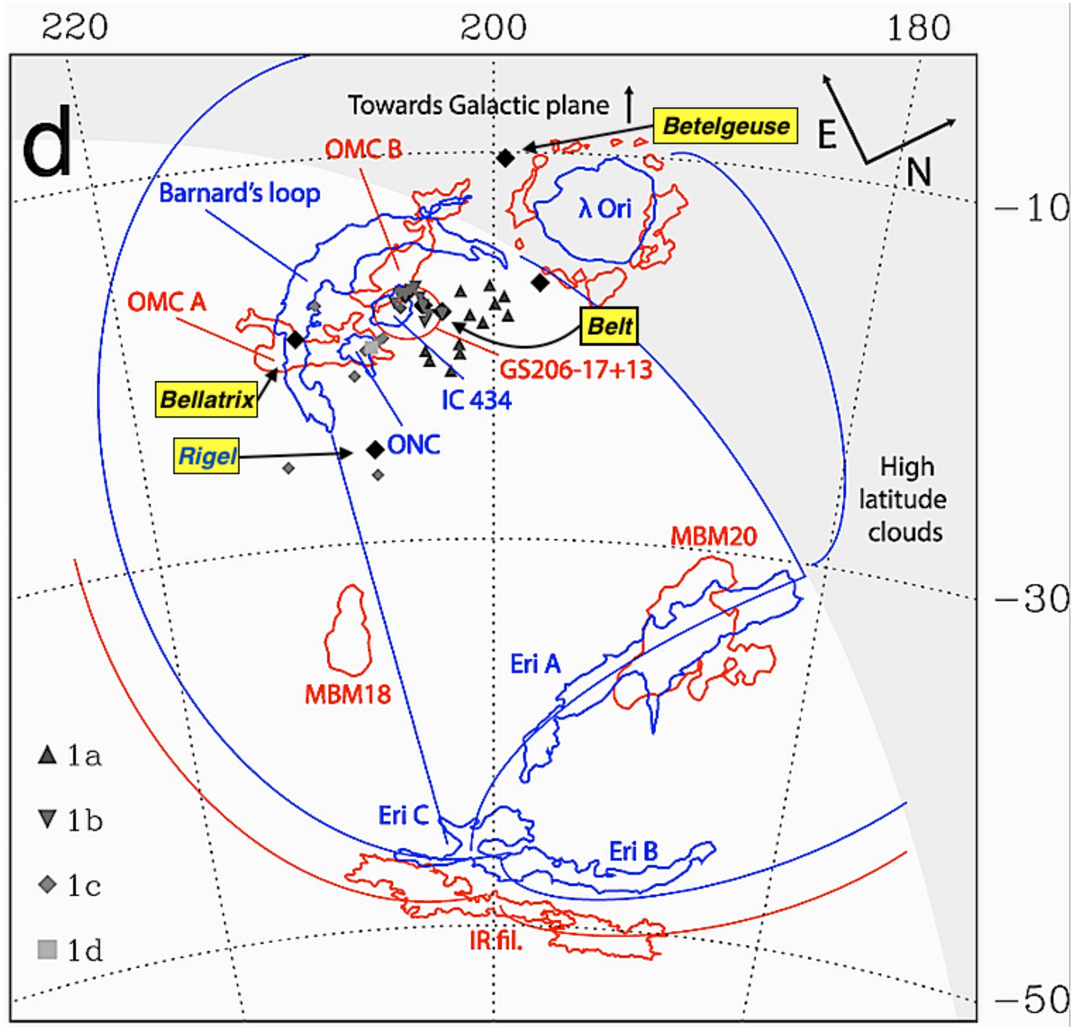


Source: Ochsendorf et al., *Nested Shells Reveal the Rejuvenation of the Orion-Eridanus Superbubble.* Astrophysical Journal, Volume 808, Issue 2, article id. 111.

The Orion–Eridanus superbubble is an expanding structure 20° x 45° on the sky. It is a series of nested supernova expansion shells. Each new SN generates a high-velocity bubble of its own, which is 'nested' within the earlier shells. The Eridanus Superbubble is an unrelated set of nested bubbles, which interacts with the Orion SSB along the shock front shown on the previous page. SN shells sweep up and compress any plasma gas the advance into. The expansion energy of the bubble is a combination of ionising UV radiation, stellar winds, and a progression of supernova (SN) explosions from the Orion OB1 association.

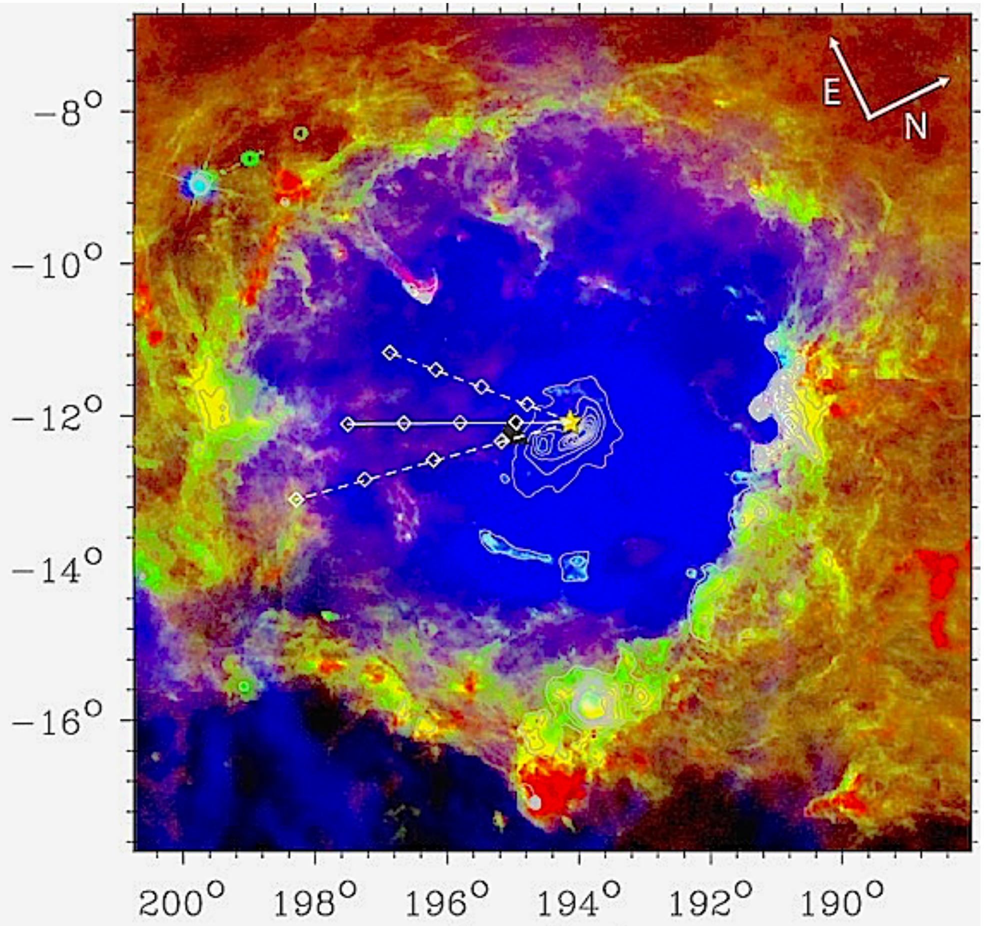
The line-of-sight (LOS) expansion of the Orion–Eridanus superbubble toward Earth is ~15 km s^{-1}, determined from line splitting of Hα. The total ionised gas component of the OB1 system is ~8 x 10^4 $M_\odot$. The aggregate kinetic energy of the OB1 is 3.7 x 10^{51} erg, which is about twice the total energy released during a supernova explosion (1.2–1.7 x 10^{51} erg). Kinetic energy (in this instance the momentum energy of all the gas particles within the system) is only one component of an ambient energy field. The total electromagnetic radiation comprising all the bandwidths from radio to gamma generated by all the physical reactions within the system adds up to a significant fraction of the total system energy budget. For example, soft X-rays emanate from the 10^6 K plasma in the interior of the superbubble, and this is only one small portion of the entire EM spectrum.

Barnard's Loop is a complete bubble structure all its own, nested within the Orion–Eridanus superbubble. BL sweeps up the mass of any preexisting superbubble matter as it passes through. Altogether, BL, the λ Ori region (surrounding Orion's head), and a few smaller-scale bubbles, are all nested within the Orion–Eridanus superbubble.



Source: Ochsendorf 2015 http://iopscience.iop.org/article/10.1088/0004-637X/808/2/111/meta

In this schematic of the entire Eridanus and Orion superbubble system, Hα gas structures are shown in blue contours. Dust structures are plotted in red. Solid lines trace faint filamentary structures. The Orion '*Hunter*' stars are plotted as black diamonds to show the immense size of the overall OB-energised region. Different subgroups of Orion OB of spectral type B2 or earlier are in different grey symbols. *Source: Ochsendorf et al. 2015 Fig 1d.*



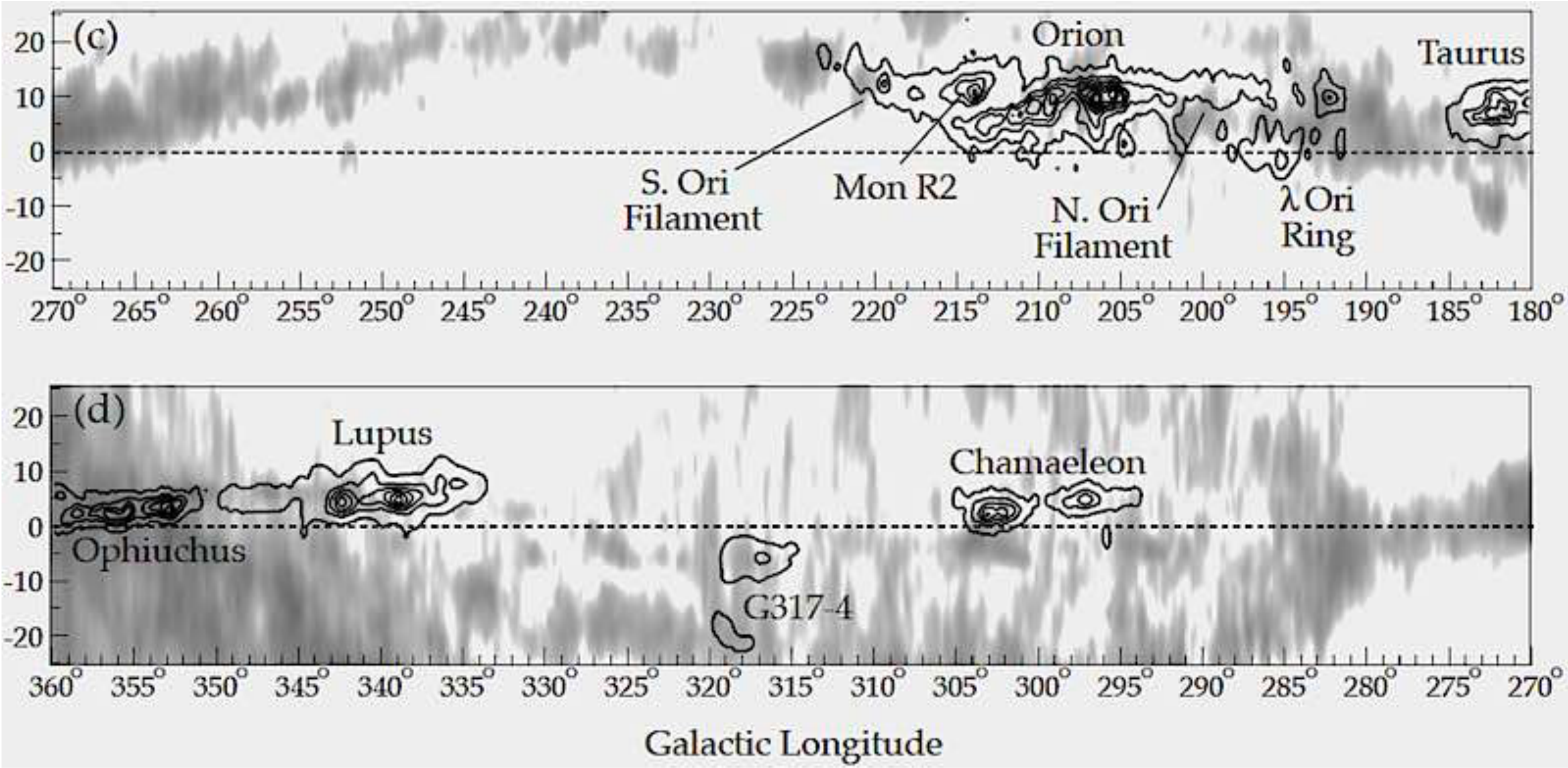
Three-colour image of the λ Ori bubble. The colour codes are the same as in Figure 1a. Overlain are contours of *IRAS* 60 μm. The solid line marks the trajectory of the star λ Ori starting 4 Myr given its current space motion. Open diamonds mark intervals of 1 Myr. The dashed lines are possible space motion errors in proper motion and distance. *Source: Ochsendorf et al. 2015 Fig 5*.

The symmetric HII region surrounding λ Ori has been known for a long time. About 1 Myr ago, a supernova injected a rapidly expanding shell into the parent molecular cloud (outside the bright circular emission ring. The SN shell expanded into the HII bubble to the right. The expansion velocity of the HII region is traced by observations of the dense molecular shell surrounding the ionised gas (blue) in the middle.

The Orion superbubble region has seen many SN explosion creating bubbles like this one. When the surface shock fronts begin to interact with each other, several types of structures result. The λ Ori bubble to the right is the simplest type of bubble, a spherical shell. The shell contains not merely the old SN's ejected gas. The expanding shock front sweeps up and compresses all the gasses and dust in front of it; this both pressurises and diversifies the chemical make-up of the gas.

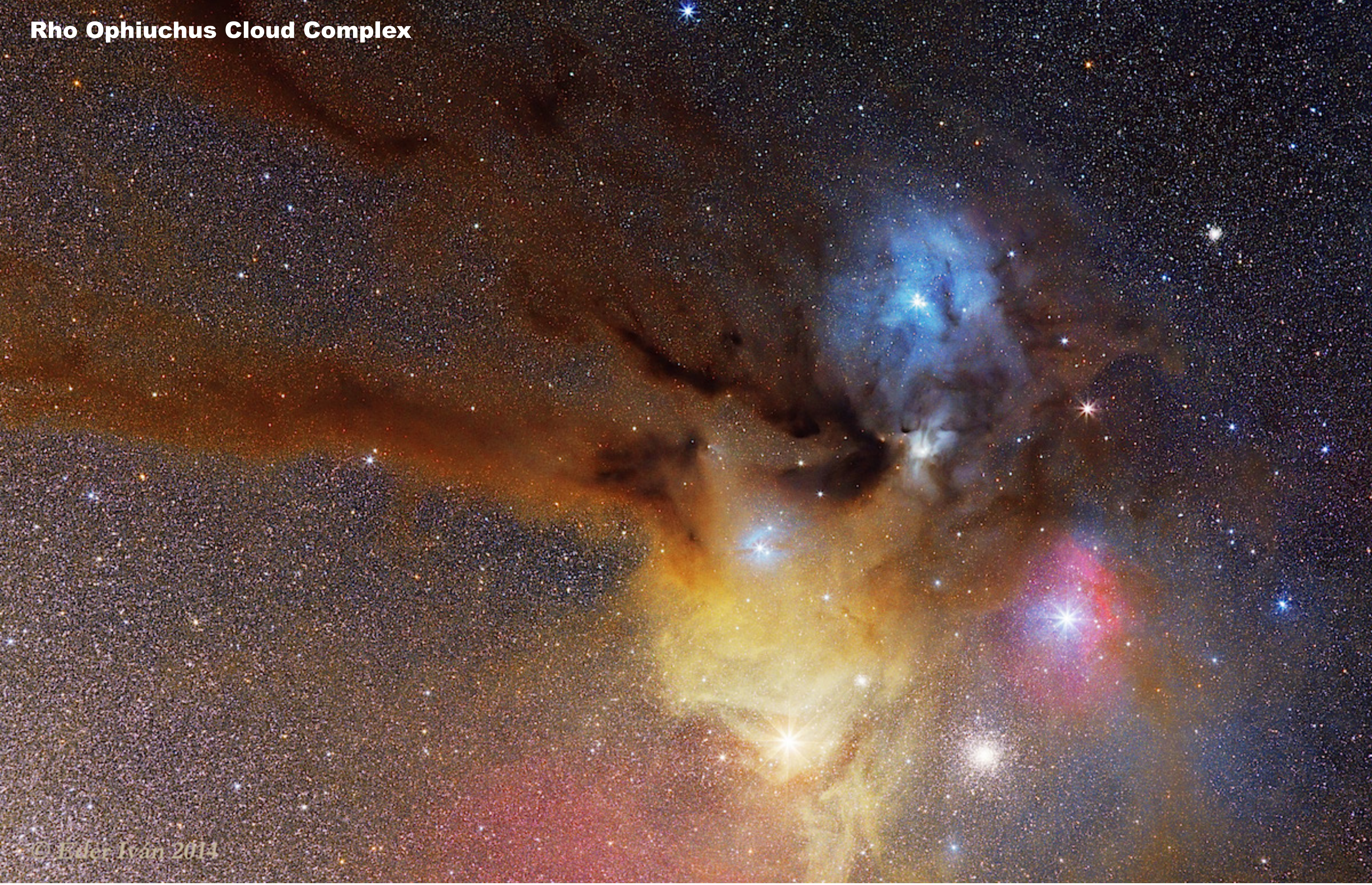
When multiple bubbles intersect, their dense, rich shock fronts are fertile ground for new star cluster formation. The life cycle from new, clusters forming until they produce their own shock bubbles can be 5 to 10 Myr. The OMC will power the expansion and evolution of the Orion–Eridanus superbubble for another 20–30 Myr. Eventually the superbubbles will be depleted of further energy and run out of steam. The superbubble will disappear and merge with the surrounding ISM.

We see the spectacular and beautiful results every time we look at the Orion Nebula, the Heart and Soul Nebulae, or the Eta Carinae complex (the richest such assemblage in the Galaxy). Outside our galaxy we see the same superbubble-driven massive cluster-formation events in 30 Doradus (Tarantula Nebula), NGC 604 in the M33 Triangulum Galaxy, IC 1613's tri-bubble collect-and-collapse rings, and many many others. It's a safe bet that any bright region in a spiral galaxy that is rich with bright stars and red HII zones is one or more superbubbles at work. The long-term effect is a gradual consumption of a galaxy's star-forming gas reservoir. The inflow of pristine hydrogen along cosmic filaments can provide only about 15% of a MW type spiral's gas needs. The term 'red and dead' is very real future for galaxies.



A large fraction of the interstellar gas in a spiral galaxy such as ours is molecular hydrogen, and much of that is contained in the giant molecular clouds (GMCs) with masses of 10^4 – 10^6 $M_\odot$ and 50–200 pc in size. The simple, stable carbon monoxide CO molecule has played an essential role in the study of GMCs and molecular gas in space generally. HII does not have a permanent electric dipole moment, rendering it very difficult to observe in the cold interstellar regions where molecules form. But molecular clouds also emit CO spectral lines, which are easily observed. The molecular CO J=1–0 transition line (energy emitted in eV electron volts) at 115 GHz, has become the GMC's molecular analog to the 21-cm line of atomic hydrogen. Carbon monoxide surveys play a crucial role in many studies of star formation and galactic structure. Radio continuum, infrared, and optical observations of HII regions, OB associations, and other Population I objects, show that nearly all star formation occurs in molecular clouds. High resolution CO observations of dense cloud cores and molecular outflows have contributed the most to our understanding of how stars form. The contours above are spaced at 3.5 K deg, starting at 0.35 K. *Source*: *Dame & Hartman, 2000*.

Rho Ophiuchus Cloud Complex



Rho Ophiuchus molecular cloud complex, incl. Antares, M4, NGC 6144, M80, and the triple Rho Oph itself. This image has been processed in a way that gives is a 3-D feel, notably with the dust streamer entering from centre left. Credit: *Iván Éder*, *AstroEder.com*. Image captured at *Hakos Farm, Namibia* using home-modified Canon EF 2.8/200mm @ f/4, 23 x 2.5 min @ ISO 1600.

Rho Oph is the youngest and closest star-forming region to us. The 2MASS catalog lists over 300 association members. The young stellar objects inside the star-birthing cores of the Lynds 1688 (L.1688) have a median age of 0.3 Myr. At 100,000 to 1 million years, L.1688 is a rumbustious youth compared with the multimillion year old cluster-rich, gas-pummeled, high-mass cores in the Orion Molecular Cloud. By compare, the 30 Doradus Tarantula Nebula is a retirement community.

The ρ Oph cloud complex has been intensely studied since the early X-ray and IR space observatories revealed how young and active some of its cores are. The dense gas–dust core of Lynds 1688 in the r. centre of the image on the previous page has an exceptional gas/dust proportion for a molecular cloud complex — gas column densities of A_V 50–100 mag have been measured in the deep infrared, which is usually little affected by dust. ρ Oph is the nearest star-forming regions to us. At a declination of –23° to –28° it can be observed at +25° sky elevations from the mid-latitudes of both hemispheres. Its proximity makes even the low luminosity substellar objects in the region accessible to spectroscopy. The complex is an astro-imager's delight — colourful, detailed, comely, contrasty, both bright and faint enough for multiply stacked images to show their best.

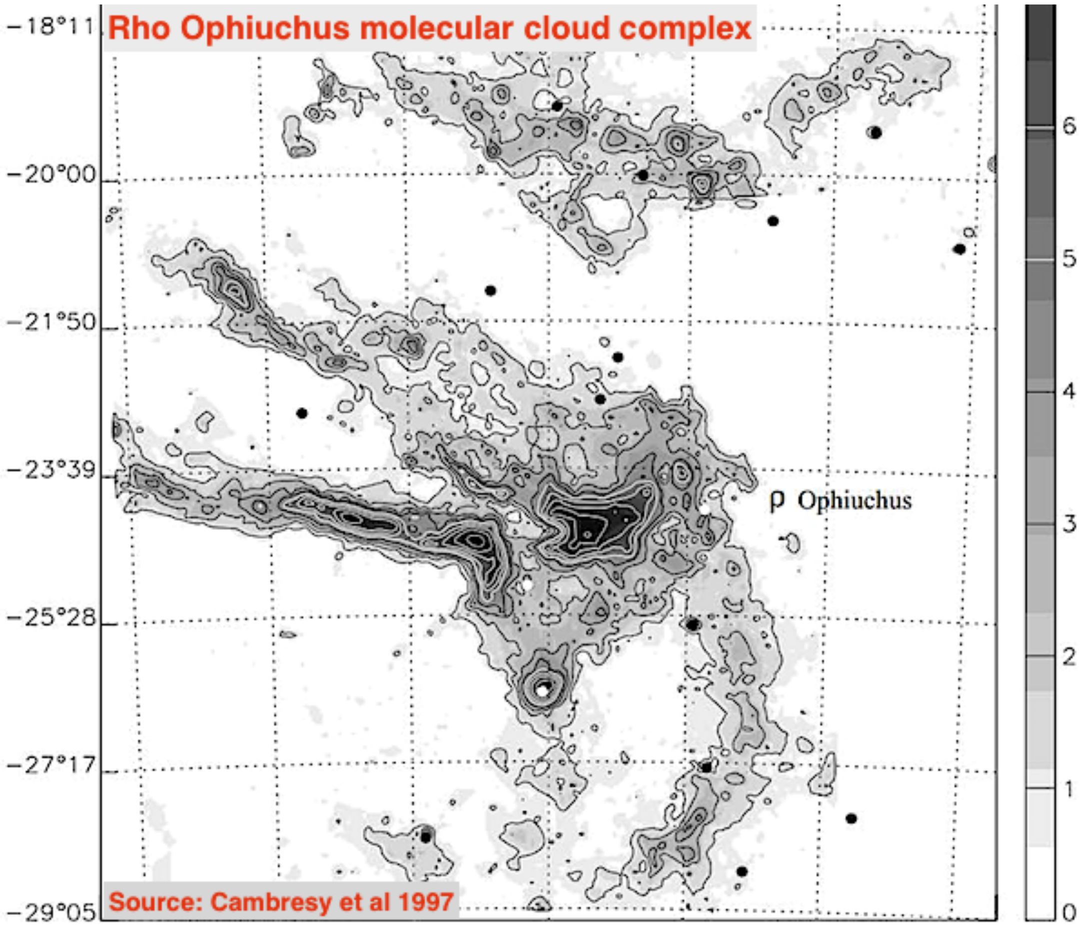
The sophisticated wide-field imaging and narrow-band spectroscopy data acquisition brought to bear on ρ Oph is impressive: ROSAT, Chandra, XMM-Newton search for and identify the polar-jet and accretion-disc X-ray signatures of young stellar objects (YSOs). Ground-based near-infrared (NIR) camera surveys sample sources over a large area. The HST NICMOS deep near-infrared (NIR) imager, the earlier IRAS Infrared Space Observatory, and the Spitzer Space Telescope all have surveyed the warm dust that surrounds ρ Oph's YSOs. The millimetre-band telescopes at ALMA have made large scale surveys of ρ Oph's gas and dust composition.

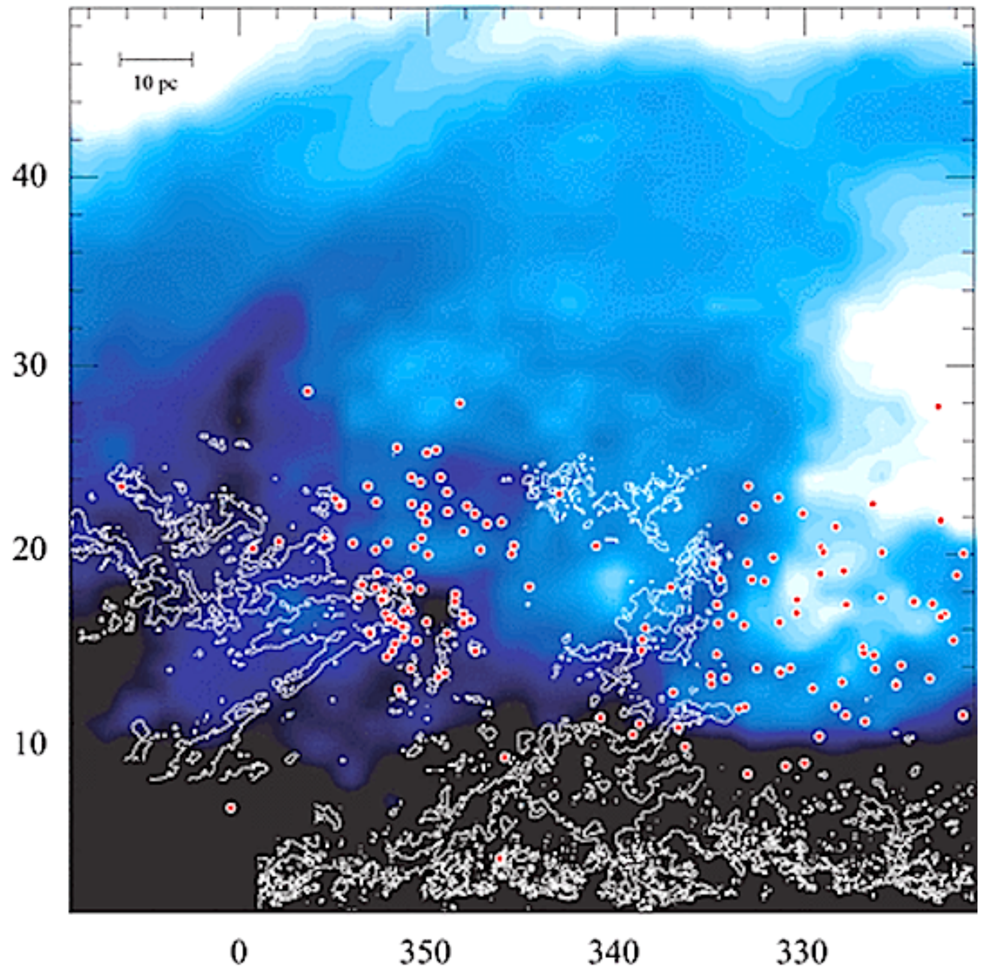
. The ρ Oph cloud covers approx. 4.5° × 6.5° on the celestial sphere. The dense star-forming cloud Lynds 1688 (centre l. on previous page) and two filaments L.1709 (above l.) and L.1755 (above r). These contain ~3,000 of H I, H II, and the simpler molecules such as CN, OH, and CO that are produced on dust particles in the cold molecular cores of dark clouds. ρ Oph contains a higher proportion of dust than many other molecular cores in the ρ Oph complex. Moreover, over 25 polycyclic aromatic hydrocarbons (PAH) have been identified. Their 3D distribution has not been fully established, but there appears to be stratification and fractionating activity in the clouds due to as yet undetermined chemical activity.

The ρ Oph complex's filamentary structures extend from 10 – 17.5 pc (32 – 57 ly) and can be as thinly striated as 0.24 pc (0.8 ly). Over half of that mass is concentrated around the L.1688 cloud, which is also the most active star-forming region. The bright compact objects centre l. are young stellar objects (YSOs) just now forming and still embedded in their natal gas. About 425 embedded infrared sources have been detected in and near the L1688 cloud. Of these, 16 are probable protostars, 123 are T Tauri stars with dense circumstellar disks, and 77 are weak T Tauri stars with thinner disks. ρ Oph's most-evolved stars range from 100,000 to a million years in age.

Magnetic fields in molecular clouds

The role magnetic fields play in molecular cloud contraction, collapse, and star-formation is crucial. Many amateur observers shy away from any sentence with the word 'magnetic' in it, assuming this to be one of astronomy's most conceptually and mathematically complicated. True, and yet not so true. This *2013 study by Hua-bai Li et al.* is the most readable yet comprehensive, summary of the subject seen by this author.





The active star-forming cloud of the ρ Oph cloud core is a well studied active cluster forming GMC notable for its peculiar filamentary streamers. Shock triggered star formation has been suggested by many authors. The three somewhat parallel horizontal features in the upper three bands suggests a morphology related to a supernova explosion that occurred in Upper-Sco OB Association 1.5 Myr ago. The blast completely dissipated the parent giant molecular cloud that formed the Upper-Sco. Evidence of a HI expanding shell has been detected,. The ρ Oph cloud is located right at the edge (image at right above) suggests that this shock wave also may have affected the Lupus clouds below and to the W. The SN shock wave would have terminated star formation in Lupus, but also would have triggered the present active star formation in the ρ Oph cloud. In the image on the right, the integrated intensity map of the HI emission is shown in blue. The ^{12}CO contours of the cloud boundaries and the OB stars (red dots) in Lupus, Centaurus, Ophiuchus, and a part of the galactic plane are shown. Note how much HI is available (in blue) for future generations of stars.

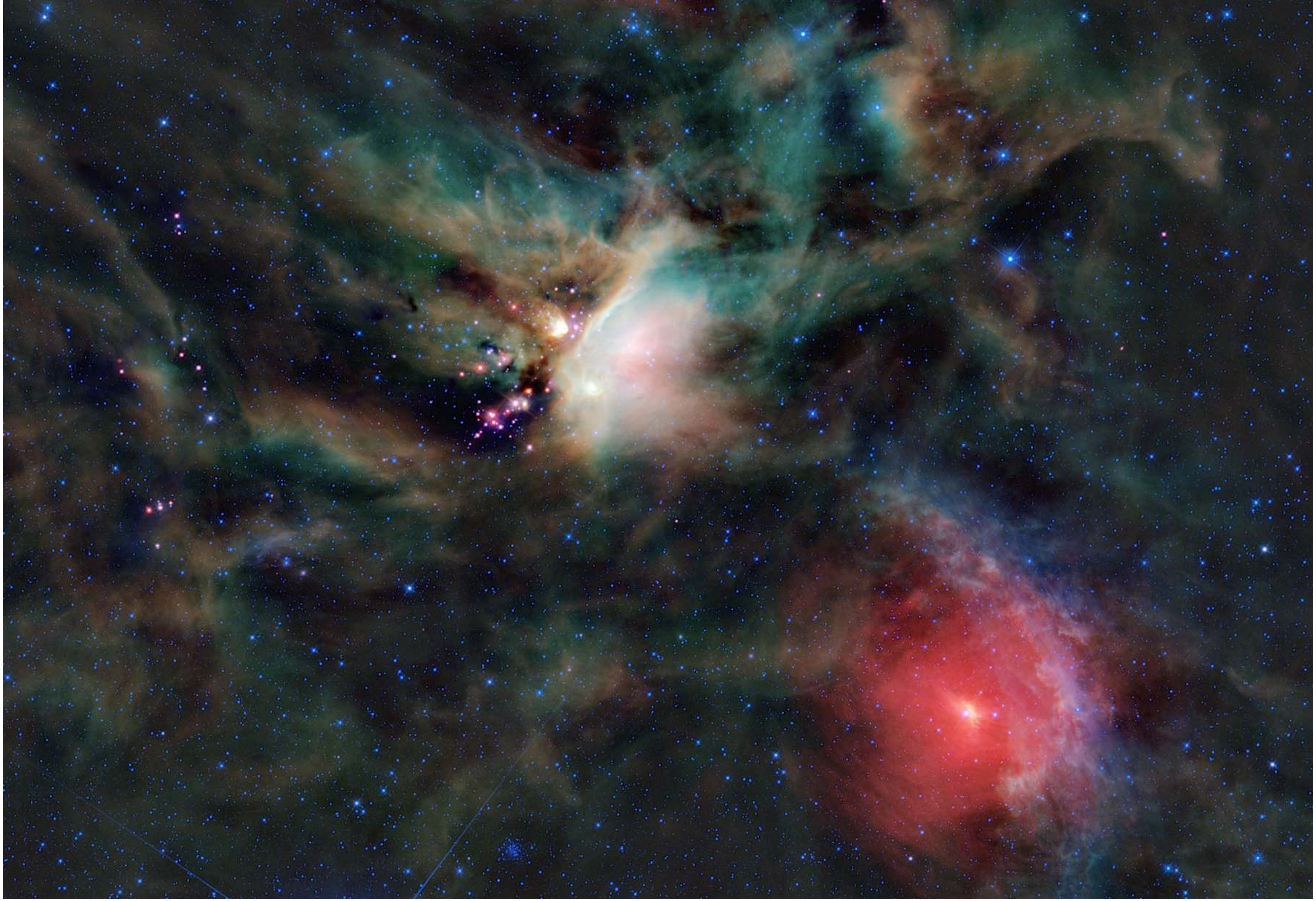
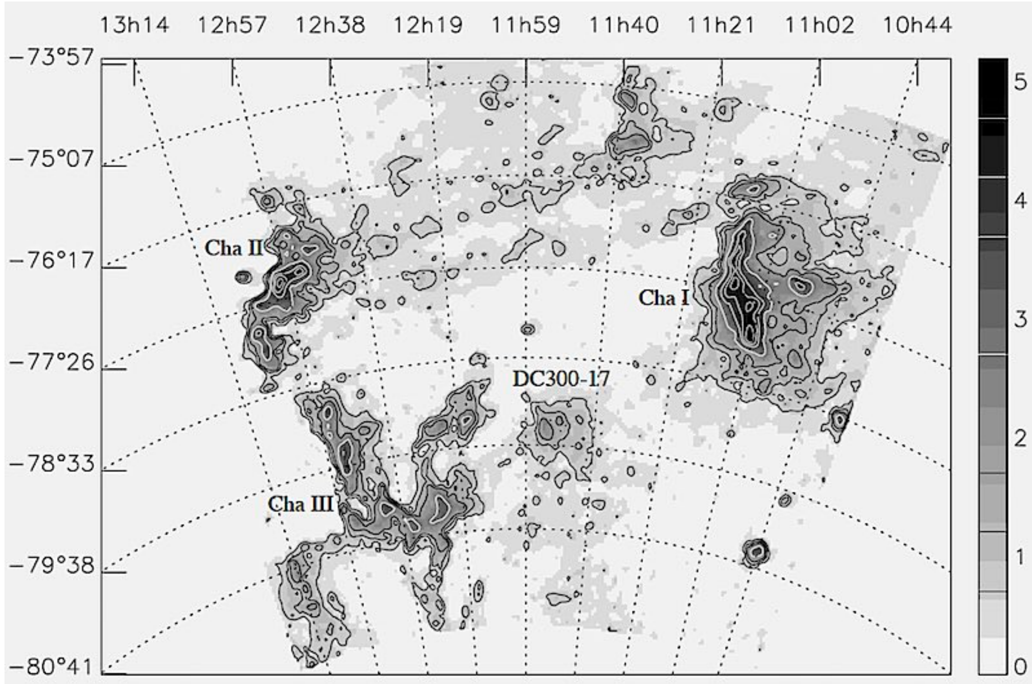


Image: *NASA/JPL-Caltech WISE* (*Wide-field Infrared Explorer*) Team

The L.1688 cloud was among the first regions imaged in X-rays by the 1980s era Einstein X-ray Observatory. In 1983 *Montmerle et al.* discovered 70 highly variable X-ray sources in a 2° × 4.5° field centred on L.1688. Since then hundreds of X-ray sources have been associated with Class I-III YSOs using ROSAT, ASCA, XMM, and Chandra satellites. Although YSOs emit less than 1% of their bolometric luminosity in the 0.1–10 keV soft X-ray band, X-ray surveys are a good way to identify cloud members because the X-ray-to-bolometric luminosity ratio is much higher than nearby field stars. The absorption cross sections of HI, He I and He II decrease rapidly with increasing energy; hence X-rays in the 2 –10 keV band can be detected through A_V = 75 mag of extinction. Most L.1688 YSOs have hard, time-variable X-ray spectra associated with thermal heating of magnetically confined plasma. The mechanisms that trigger flares and magnetic heating are not yet fully clear. *Imanishi et al. 2003* found that numerical models of X-ray flares on Class I – III YSOs in ρ Oph produced large magnetic loops with magnetic field strengths of 200–500 G (the Earth's is ~0.5 G). *Sources:* *Favata et al. 2005*; *Giardino et al. 2007*.

Chameleon I and II molecular cloud / star forming complex. *Credit:* *Gerald Wechselberger*.

Chamaeleon in the southern skies lies in an *extended Molecular Cloud* about 500 ly from Earth. This is a low-density, low mass region in which relatively few new stars are born. The brightest of which then illuminate their natal gas and surrounding dust. In the image to the left, in the l. centre is the bright blue Reflection Nebula IC 2631. Upper right of centre is the blue reflection nebula *Cederblad 111* (Ced 111); left above it is the pale yellow crescent-shaped nebula *Cederblad 110*. The arrow-like object below-left of Ced 111 is the infrared nebula GN 11.07.3.



Chameleon region extinction map from Cambresy 1999. All three of these clouds can be seen naked eye from very dark, LP-free southern skies.

Left: Part of Chameleon I star-forming molecular cloud. *Credit:* Iván Éder, AstroEder.com.

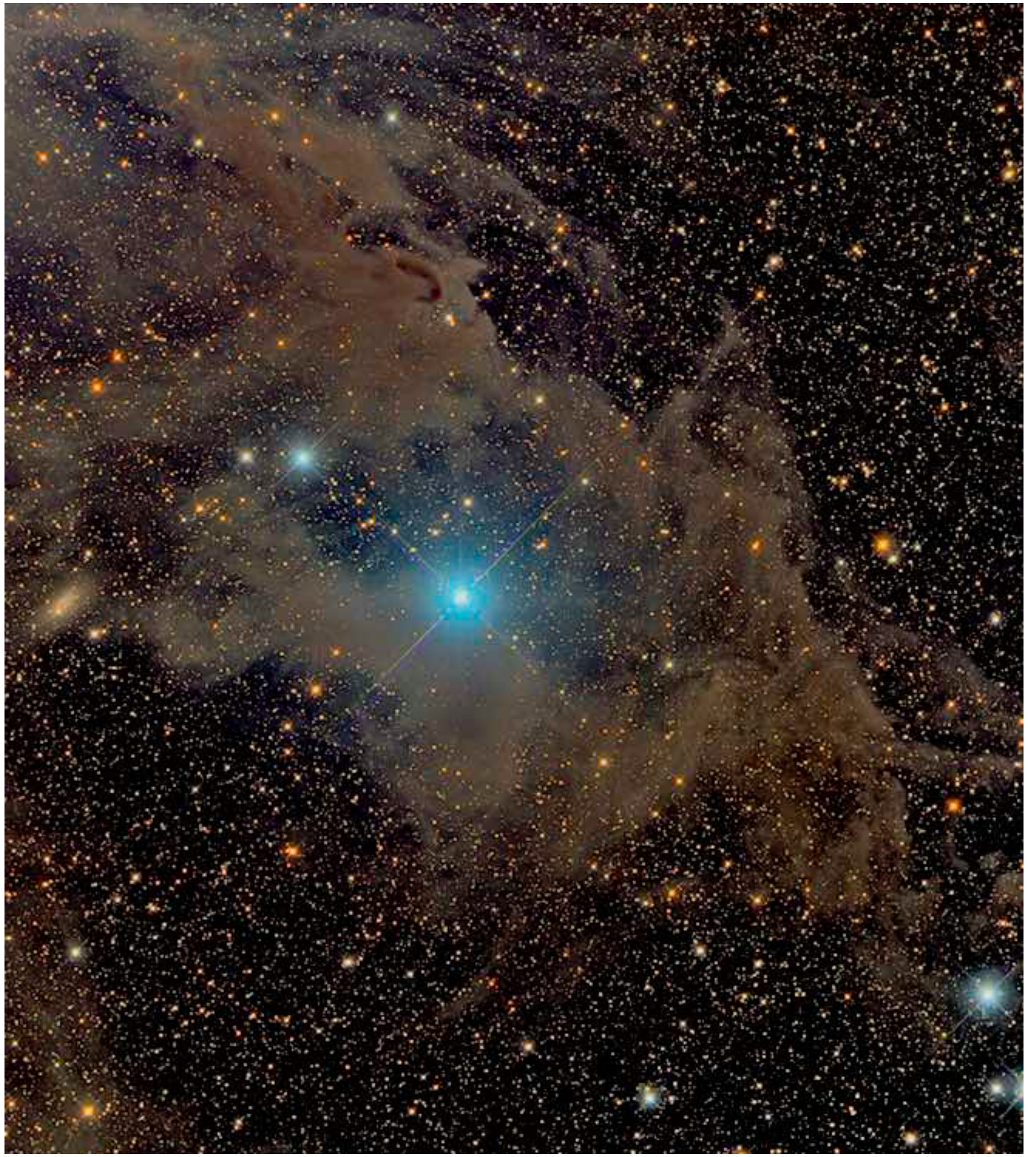
Chamaeleon dark clouds I and II are forming low-mass T Tauri stars. Chameleon III is quiescent. The complete cloud complex lies 400 to 600 light years from Earth and contains tens of thousands of solar masses of gas and dust. The most prominent cluster of T Tauri stars and young B-type stars are in the Chamaeleon I cloud, and are associated with the reflection nebula IC 2631. The two most-active star-forming cloud cores are Cederblad 110 (Ced 110) and Ced 111.

Ced 110 is a typical low-mass star forming core. Its new stars are affecting the collapse rate and contents of infant stars about to be born around them. Ced 110 contains nine low-mass stars crowded into a 0.2 pc region presently forming in evolutionary stages from Class 0 to Class II/III. Ladd et al. 2012 prepared N_2H+ J=1→0 maps that identified an additional 13 ±3 $M_\odot$ of dense (n ~10^5 cm^{-3}) gas undergoing gravitational collapse. The molecular component of the gas outflow in the ^{12}CO J=1→0 line shows a jet-like feature through the lower column density portions of the core.

The jet can be likened to a cometary head–tail object hurtling through its less-dense surroundings. A dust temperature gradient across the MMS–1 core is being gradually warmed by the nearby IRS 2 HII region (Cederblad 110). This region has produced several young stars in the recent past. Emission from the polar jets and accretion regions of the nine stars that formed first are now influencing the remaining dense gas in the region. Cederblad 110 is thus an example of the sequential character of small-cluster evolution, wherein already low-mass stars affect the future formation of even more modest-mass stars. Even when a star cluster originates in modest circumstances and thus produces modest results, the overall evolutionary pattern suggests that the first stars to form greatly influence what happens to the later ones. Even a tiny waterfall will cascade down into a pool and generate eddies,

Want to learn more? Here are some not too technical brush-up papers:

Williams, Blitz, & McKee, 1999
Bergin & Tafalla, 2007
Lada & Lada, 2003
Pelupessy & Portegies-Zwart, 2012



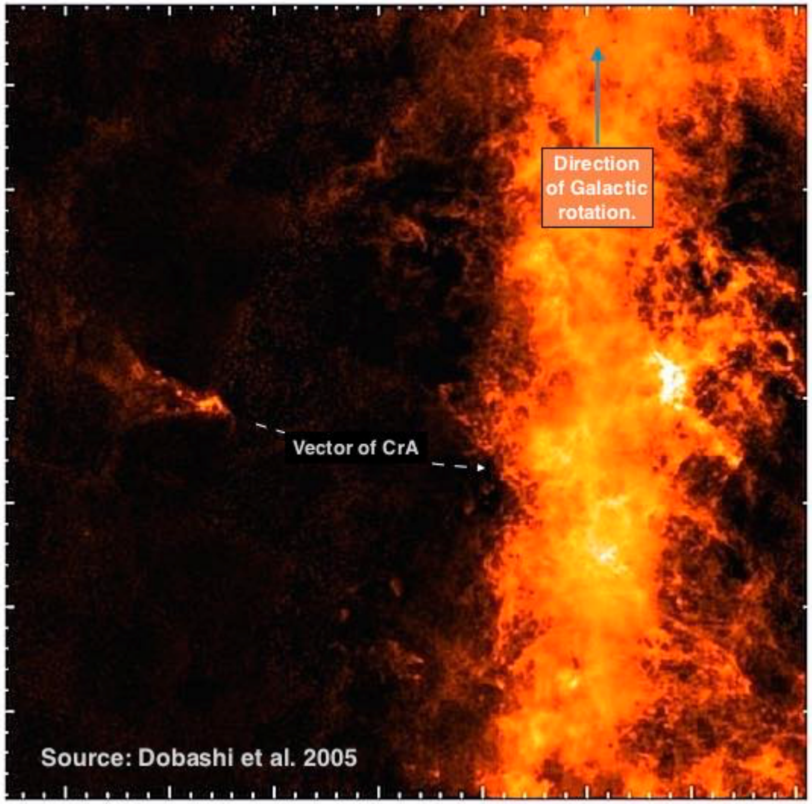
Part of the Chamaeleon III cloud. The small ellipsoid in left centre is the Local Group dwarf galaxy IC 3104. *Credit:* *Jose Joaquin Perez. Astrofotografia Austral*.

Corona Australis molecular cloud complex. The globular cluster NGC 6723 has shrewdly managed to avoid the clutches of reddening, delighting owners of ≥100mm refractors or ≥150mm reflectors who live southerly enough to see it. Visually it's like jumping from a fireworks show into a mud puddle.
Credit: Astrophotografía Australe by José Joaquin Pérez

The sword of Doom hangs by a thread above the Corona Australis molecular cloud (CrA). CrA has been widely surveyed at infrared wavelengths, in X-rays, and in the millimetre continuum. These reveal CrA to have highly variable extinction of up to A_V = ~45 mag at its core. In that core is a young cluster still so deeply embedded in its natal gas that the only radiation we receive on Earth is in the infrared. The infant cluster has been dubbed *Coronet*. There are now 55 known optically detected members, from the late B spectral type descending far into the low-mass stars, with two confirmed brown dwarf members and seven more candidates.

Detailed models of CrA's H_2CO radiative transport demonstrate that a rapid radial density gradient of $\varrho(R) \propto R^{-3/2}$ to R^{-2} describes drop from N_H 10^6 in the core to N_H 10^{-3} in the envelope. A decline in H_2CO abundance with increasing density suggests gas condensing onto dust grains. For the observed values of core radius and core mass (19 – 110 $M_{\odot}$), the velocity dispersion due to rotation or turbulence is too small to stabilise the cloud against gravitational collapse. The observed magnetic field strength also appears to be inadequate to prevent cloud contraction and eventual star formation. Put succinctly, the CrA cloud is in free fall even as its first protoclumps condense through pre-main sequence Herbig Ae/Be and T Tauri stars. *Source: Loren & Sandqvist 1983*.

CrA's stellar cycle began at the bottom of the cometary-shaped compression pressure well rather than the traditional spherical gravitational well. The pressure well therefore lies on minimum galactic gravitational potential but maximum gas pressure. This is favourable for dust freeze-out. Observed 1 – 3 μm emission confirms that dust grains are stratify by grain size with increasing depth into the

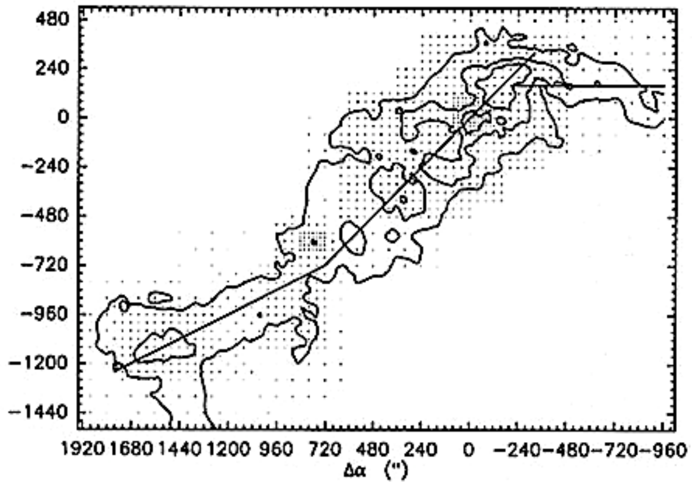


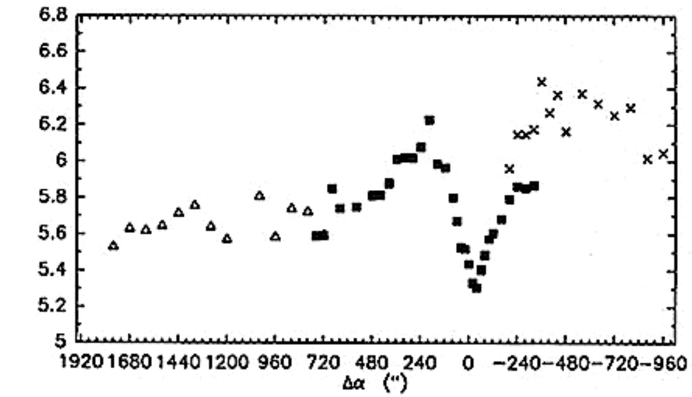
The CrA cloud lies ±130 pc (424 ly) beneath the Galactic disc. The cometary head-tail shape is characteristic of the second-stage in the evolution of a cosmic CHVC infalling from deep space through the Galactic halo *(Putman et al. 2002)*. As a cloud of this type encounters the denser gas nearing the thin disc, the shock dissipates the original cloud, but it's denser head continues at lower velocity. As its headwinds become more dense, the head deforms into a flat button shape. This initiates a compression cycle that will end in low-mass star cluster formation. The cluster's natal gas tail dissolves into the surroundings, as we see here. In CrA's case the gas loss is exacerbated by the pressure of the disc on the remaining gas, which will soon be consumed to the slight benefit of the Milky Way's gas reservoir. The amount is probably equivalent to the amount of calories we would gain by eating one peanut a week. *Text source: Forbrich 2008. Image source: Dobashi et al. 2005.*

cloud because of the cloud's gravitational and magnetic fields. As can be seen in the figure to the right, dense clumps begin rotating as they shrink because of the tidal potential from the Galactic disc. The observed rotation and star formation rates of the cloud are consistent with the magnetic field strength implied by the grain alignment scales. Hence the general evolution of the CrA cloud is controlled by the ratio of its internal magnetic and gravitational potentials as they are affected by the Galactic magnetic and gravitational potential. *Source: Vrba et al 1981*

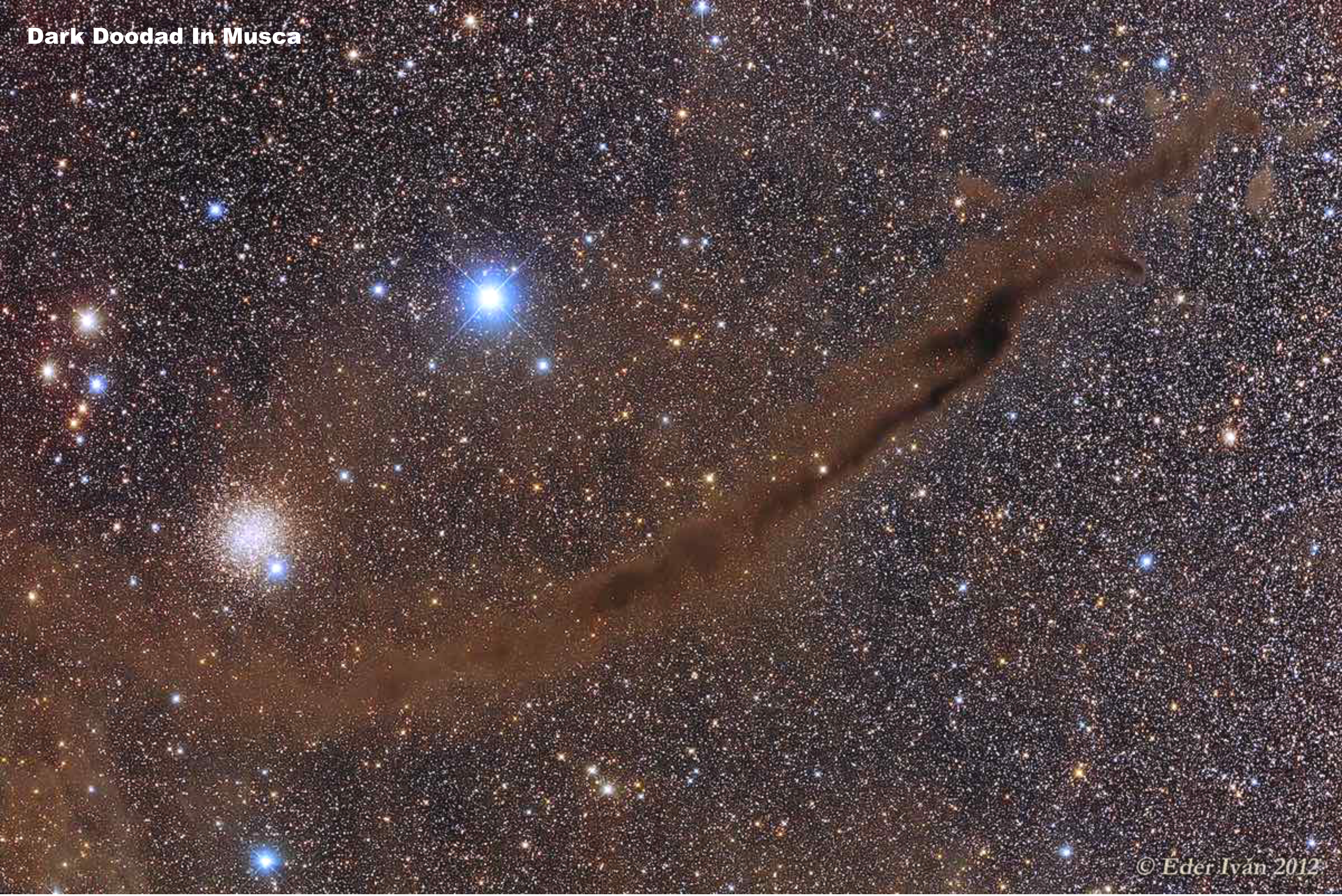
There is evidence that a gravitationally bound stellar subgroup is forming within the dense core of the molecular cloud. Photometry in the 1.6 – 20 μm bands reveal 2 $L_\odot$ sources near the core. Thirteen embedded sources are found within a 0.08 pc^2 area within the core. They exhibit a variety of evolutionary states whose bolometric luminosities range from 1 – 130 $L_\odot$. The most luminous sources are the B8 – A0 stars R CrA and TY CrA.

The estimated total mass for CrA's embedded cluster is ~19 solar masses, which implies a high star-formation efficiency of about 45% within this cloud. The overall gas use efficiency from the time the original gas mass entered the halo up to the protocluster stage today is 4%. The average efficiency of disc-shocked cluster formation in a molecular cloud rotating within the disc is about 5%. Surprisingly, a high-angle, high-velocity crash into a spiral galaxy is only slightly more ruinous to a molecular cloud that waiting inside the disc for the next spiral shock to arrive. Spiral galaxies are a poor career choice for a gas blob looking for a future. *Source:* *Wilking et al. 1986*.





Example of fractional rotation in CrA molecular core. This cloud is named Condensation A or *R CrA* for short. The line through the cloud density map at the top is the centroid along which velocity points were measured. The bottom image shows the actual velocities in km s^{-1}. The approx. planar line at 5.6 – 5.8 km s^{-1} is sharply interrupted at ~300 arcsec left of the zero point, rises to 6.2 km s^{-1} then swiftly drops to 5.3 km s^{-1}, rises again to 6.3 – 6.4 km s^{-1}, then returns to a new, slightly faster baseline at ~6.3 km s^{-1}. From our line of sight we do not know where the rotation's N and S poles point to, but with respect to us the cloud is rotating at half a kilometre per second towards us on the left and receding on the right. This indicates that the cloud is now undergoing gravitational free-fall into a rotating ball.



Dark Doodad in Musca. *Credit*: *Éder Iván, astroeder.com*.

Dark Doodad In Musca

Rather officiously named *[DB2002b] G301.70-7.16 Dark Cloud (nebula)* on SIMBAD, the Dark Doodad easily qualifies for the Best-Known Least Known Object in the Sky. Bequeathed many names — Sandqvist 149, CG 21, BHR 80, TGU H1875, DCld 301.7-07.2, [DB2002b] G301.70-7.16, HMSTG436 — reported by *a great many observers*, *imaged by so many amateurs* that *a Google Images search* can clog your bandwidth for hours, try to find a professional paper that studies it in any meaningful detail.

Compared with the SIMBAD's Garden of Heavenly Delights results when querying any of the earlier objects in this report, the Dark Doodad brings up a pathetic eight citations under the IAU moniker for the object, *[DB2002b] G301.70-7.16* — the *least number of citations* this writer has encountered for an object so popularly known and oft-commented. All of those citations are mere entries in catalogs of one type or another. NED does not respond to *any* of the above query terms. Picky-picky. The *German Astrophysical Virtual; Observatory* (GAVO), which is the astro-researcher's first resort if SIMBAD comes up empty-handed, has the largest selectable *database of databases* one can find. Try to find the Dark Doodad on it.

The Dark Doodad is 3° long and has an aspect ratio of 20:1 at its widest. Surprisingly even given than slenderness, it is visible naked eye from a mid-latitude southern dark site. The site has to be totally LP free, though. This writer has seen it so many times that it is a test object with which to gauge how worthwhile the faint-fainty hunting will be. A brief *thread on IceInSpace* records several other visual sightings of it. But even if it is visible, that still doesn't tell us what it is.