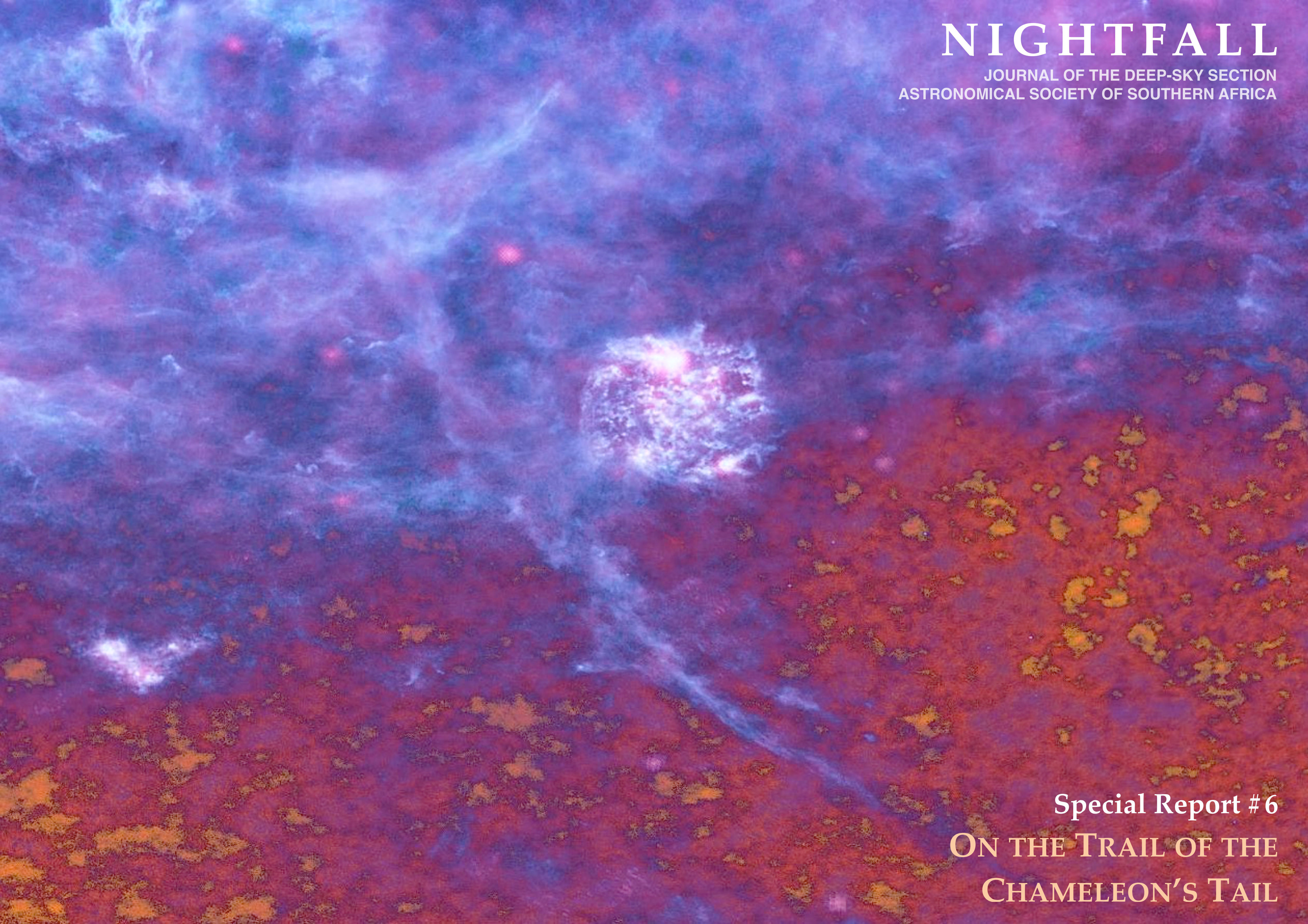
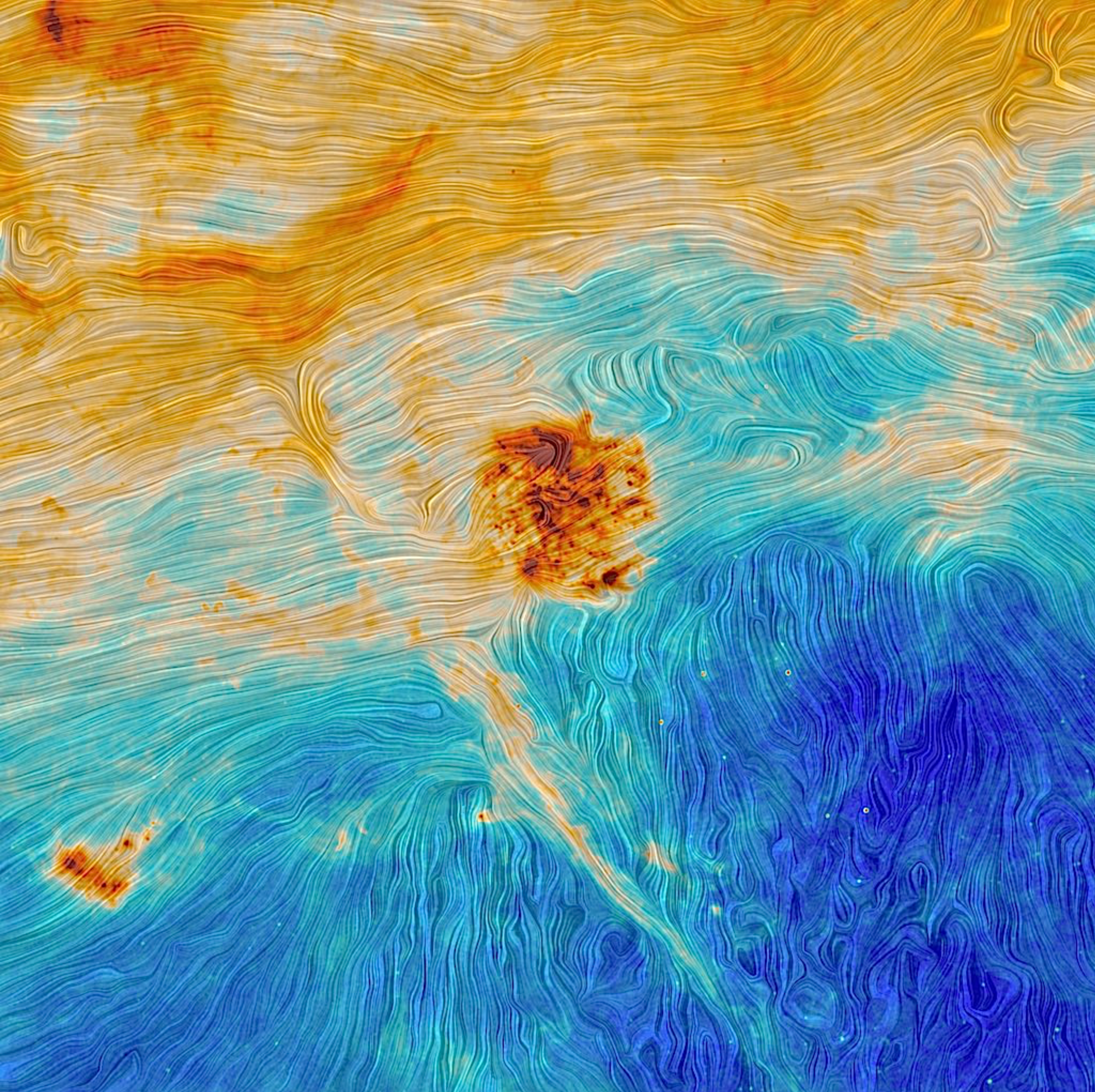


NIGHTFALL

JOURNAL OF THE DEEP-SKY SECTION
ASTRONOMICAL SOCIETY OF SOUTHERN AFRICA

Special Report # 6

On the Trail of the Chameleon's Tail



NIGHTFALL

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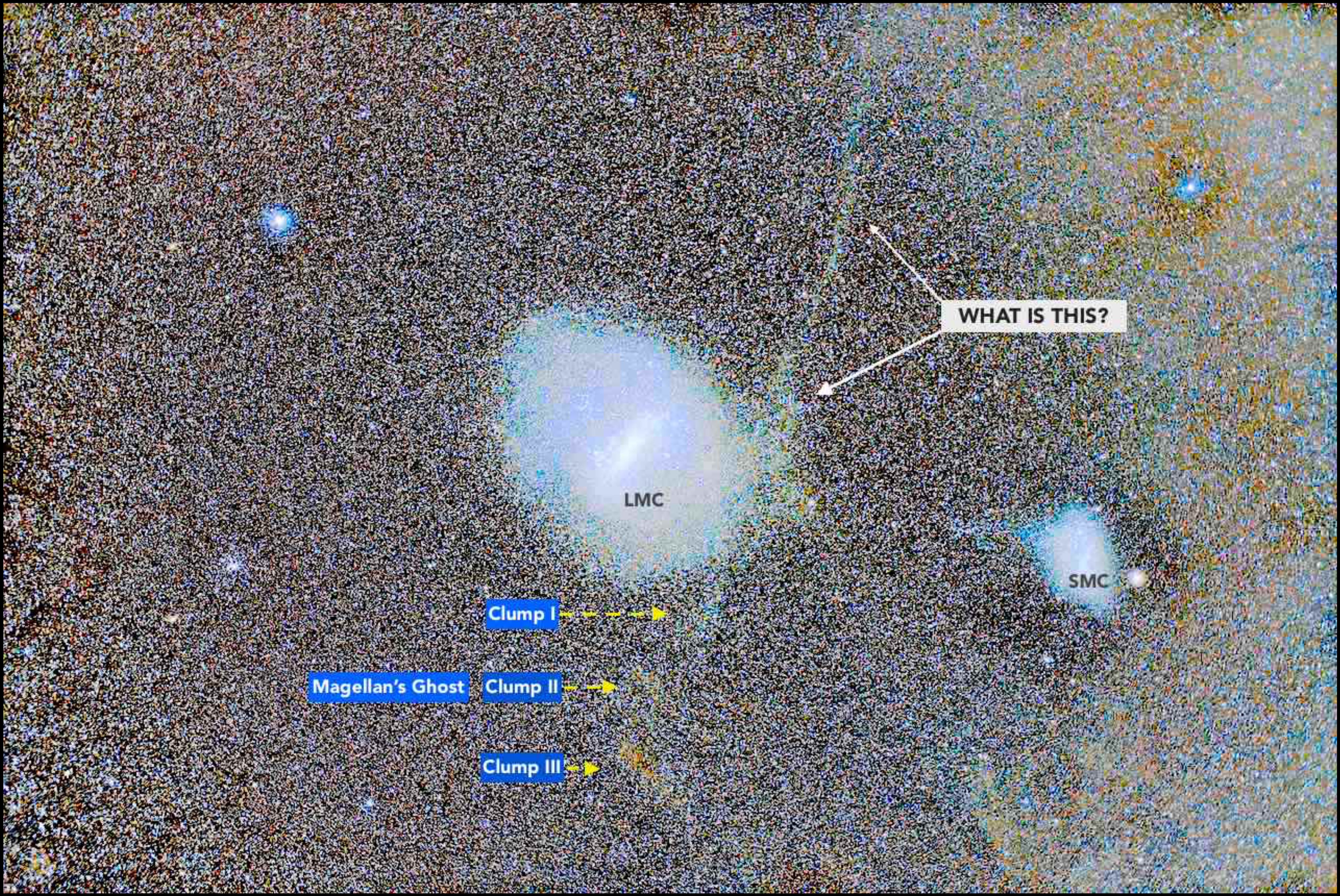
On the Trail of the Chameleon's Tail



Greg Bradley's DSLR image above shows us that properly thought out imaging runs can discover things that the professionals have overlooked.

The thrill of spotting something that's not been noticed before

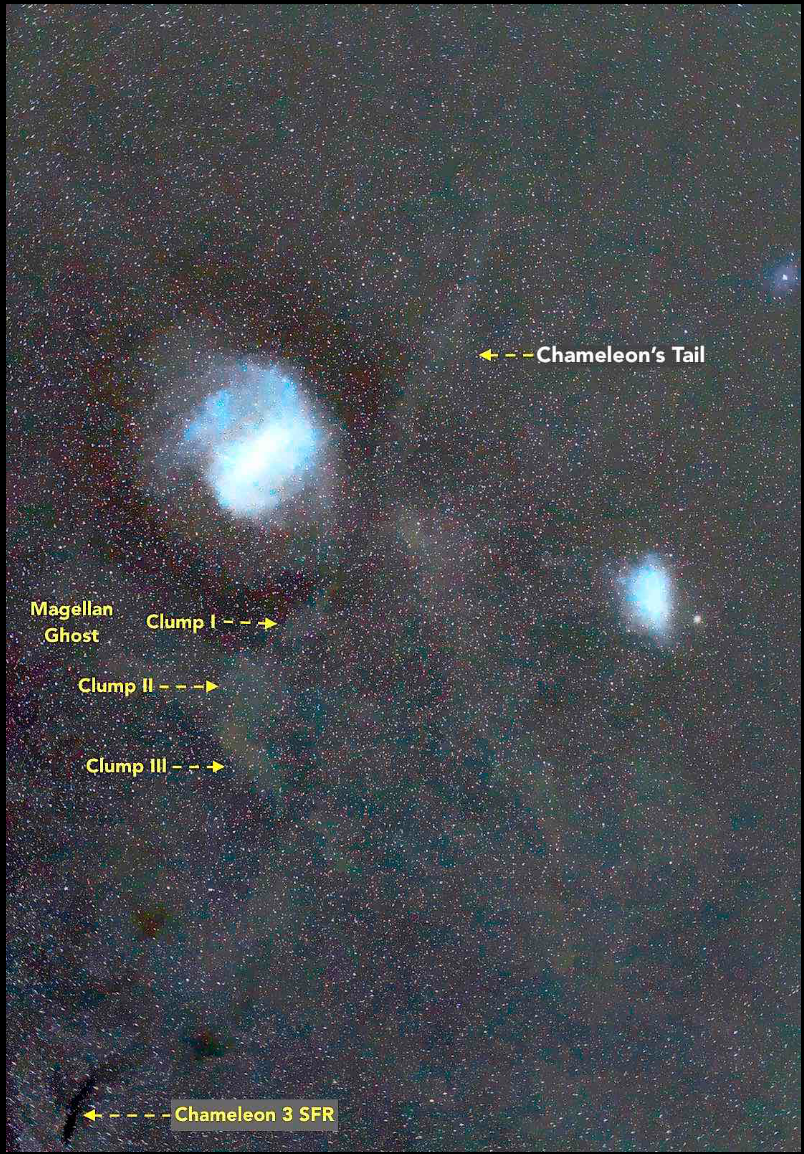
On the night of January 11, 2019, astro-imager *Greg Bradley* of Sydney, Australia imaged a curious feature. Greg was using his remote observatory located in Bigga NSW. Australia to capture a super wide-field image of the field surrounding the LMC and SMC. Greg was dipping his toe in the water of superwide imaging using an off-the-shelf DSLR with a 35mm lens.

Greg has been doing wide-field images for some time now using different cameras. See his images of *M8/M20/Simeis 188*, Vela SNR (*1*), (*2*), (*3*); Hα *Eta Carinae*, and *Crux/Coalsack*. Recently Greg has been whetting his knife on super wide-fields and getting some promising results. So promising, indeed, that he successfully captured in optical wavebands an unusual feature that is hardly ever been seen in images obtained using commercially available equipment. At ±26.5 magnitudes per sq. arcsecond (MPSAS), it is normally 2 magnitudes or 6.3 times fainter than the dimmest light visible to human eyes.

Using the *Chromoscope application*, the emission can be traced weakly visible in Hα, vanishes in the near-IR, brightens considerably in the far-IR, becomes mottled with structure in the microwave bands, fades in 21 cm neutral hydrogen, and vanishes in radio images. All this practically shouts "dust". But why there? This streak is 18°–24° below the Galactic disc plane.

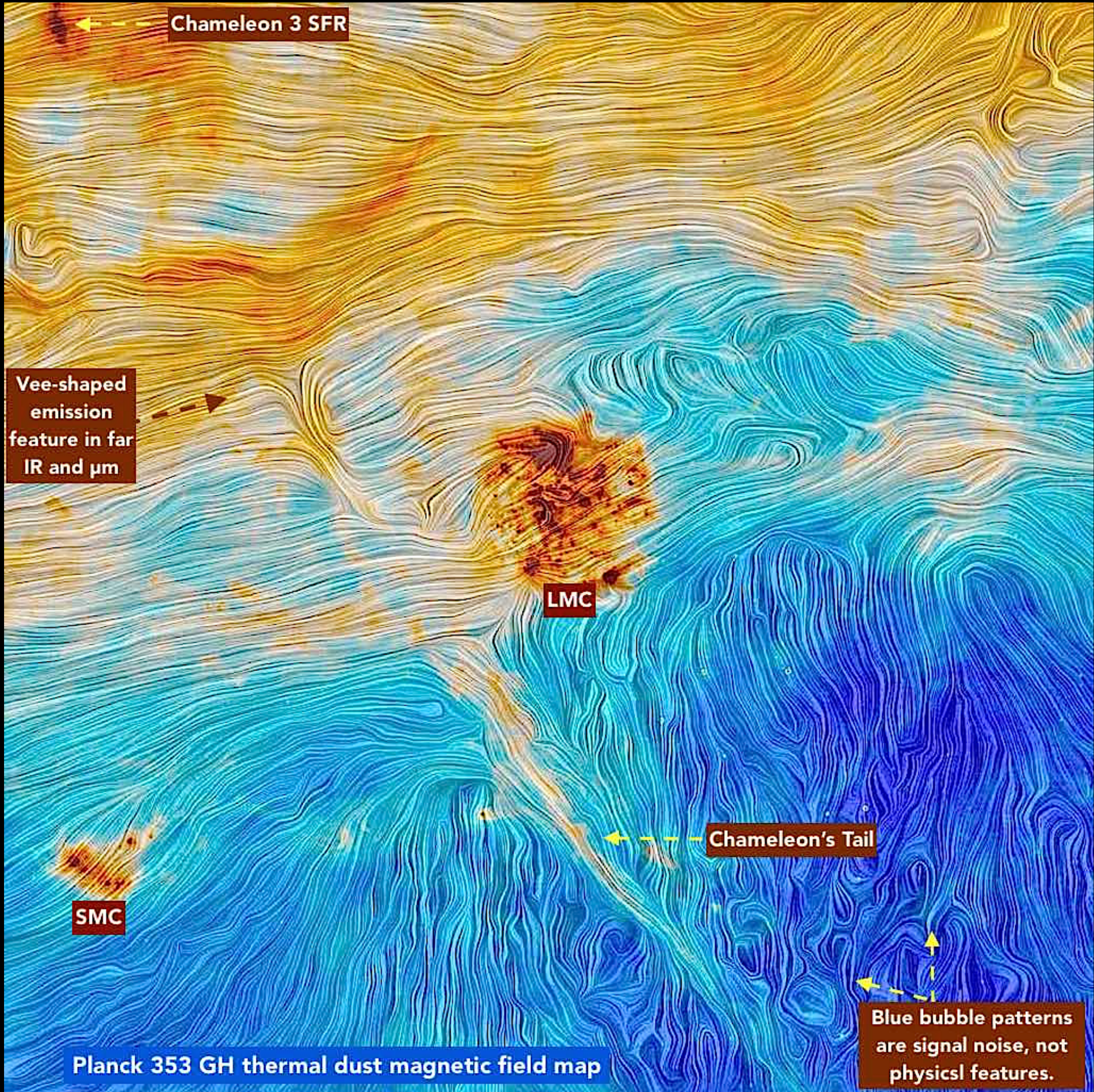
Initially, Greg was not after dust emission. *Nightfall* editors asked if he could push his processing to bring out the faint dust and let the rest of the image do whatever it wants. Sure enough, Greg captured an angular spike rising to the right of the LMC toward Eridanus that was pointed out last year in a *Nightfall* article about three inexplicable faint emission clumps descending from the LMC toward Apus. That emission had been reported by visual observers only seven times starting in 1989. Dubbed "*Magellan's Ghost*" it proved to be three ultra-faint Galactic cirrus clumps illumined by the faint light of the Milky Way disc. The light reflected off the faces of tiny siliceous dust particles 80 pc below the Galactic plane. Normally invisible, the dipolar silica grains were fortuitously aligned by an unexplained wave-like perturbation in the Galactic magnetic field, such that the grains reflected just enough light to be spotted visually.

Nightfall editors dubbed this new dust feature "Chameleon's Tail" because it emanates from the same Galactic cirrus structure in Chameleon as Magellan's Ghost. Greg's images are the first images taken by an amateur to clearly reveal the underlying dust structure shared by both features.



Neither Magellan's Ghost nor the Chameleon's Tail are IAU-assigned names. Due to their extended size and extremely low ~26.5 MPSAS surface brightness, they are among the most difficult objects to capture using optical wavebands. Greg Bradley has done a service to science by imaging it. Now astro-imagers have a new target in the sky to play with.

Closing the door of a mystery opens the door of an enigma



Two primary sources of light in our galaxy are stars and dust. We see dark or bright nebulae because they are composed of optically visible dust particles.

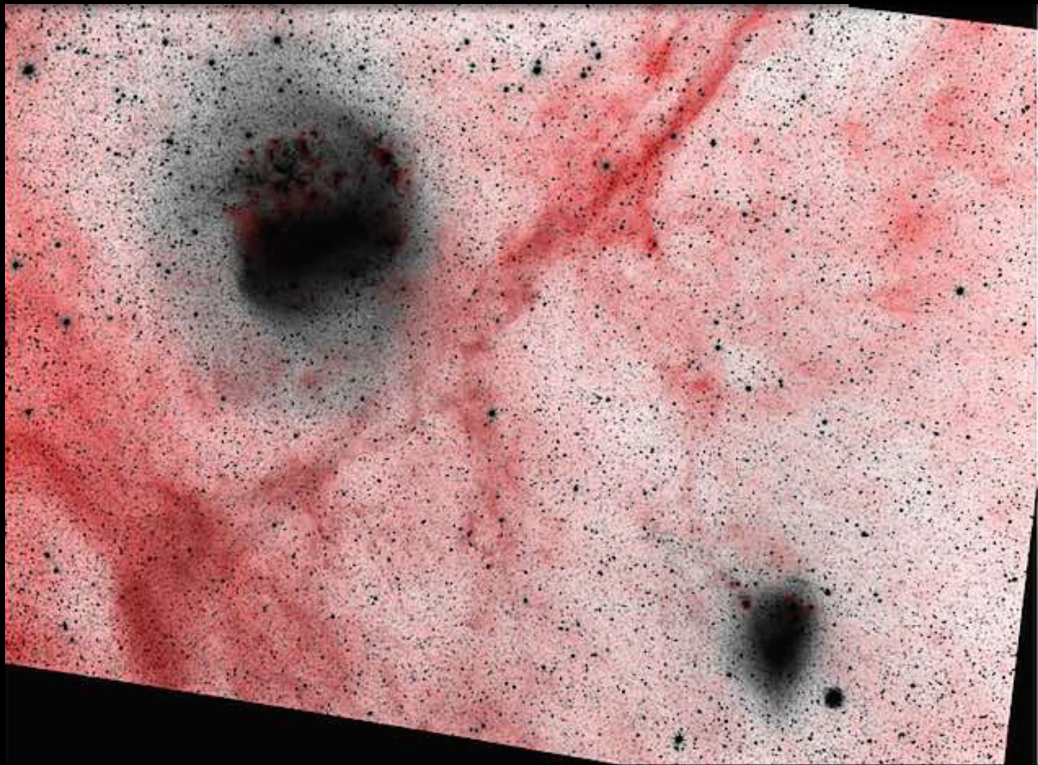
The 2009–2013 Planck satellite mission was designed to detect the cumulative emission from all intervening sources between the satellite and Cosmic Microwave Background (CMB). An exact numerical value of the CMB temperatures in every square arcminute of the entire sky required astronomers to remove all foreground emission and absorption from the Planck data. This was subtractive sculpture and the result is as beautiful with light as it is with marble or paint.

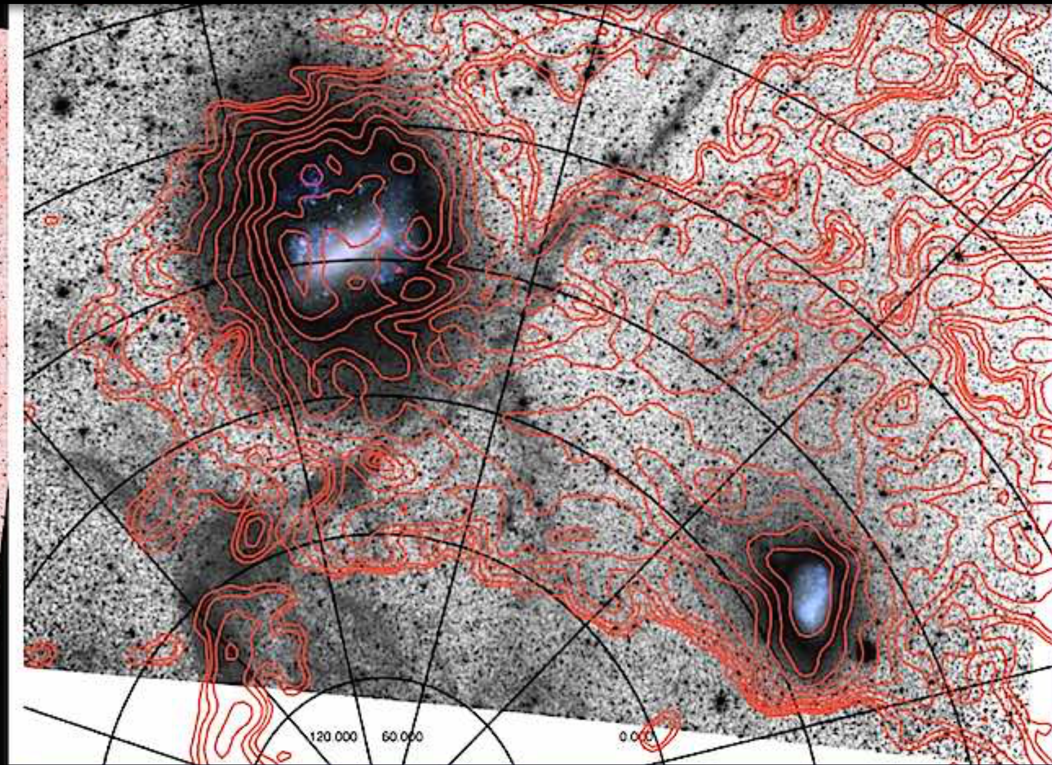
That goal handed a small army of astronomers the multi-year job of zeroing out the photon data of every star, all gas emission, all dust absorption, synchrotron glow, and excess light of indeterminate source. Subtract all these and the light left over was the faint glow of the CMB, which emits only in the microwave band. Planck's ultimate gift to us was the familiar blue and gold speckled ellipse we see so frequently with the letters "CMB" under it.

Accurate values of the CMB gave astronomers the tools to test theories of the early Universe, the origin of cosmic structure, the average density of ordinary matter and dark matter, and the age of the universe.

The Planck mission also revealed a few surprises. One of them was an odd feathery eruption out of the Chameleon/Mensa region in a part of our galaxy that already shows unusual electromagnetic activity. The Chameleon's Tail is a physical feature of the Milky Way disc and is unrelated to the Magellanic clouds off to each side. At first glance it looks like a magnetic flux tube or electric Birkeland current. It emits in FIR and micron wave bands that are usually associated with dust, but there are no massive gas/dust clouds in the small triangular patch where it originates. It is a dust-transport perturbation with no readily discernible origin.

What is this streak? Why is it there?





The structural complexity of the Chameleon's Tail is revealed in this image from *Besla & Martínez-Delgado 2016*, A-J 825, 1. The *Astrophysical Journal* paper in which this appeared addressed the interaction history of the Magellanic Clouds, and thus did not investigate the morphology or dynamics of the Chameleon Tail filament of interest to us here.

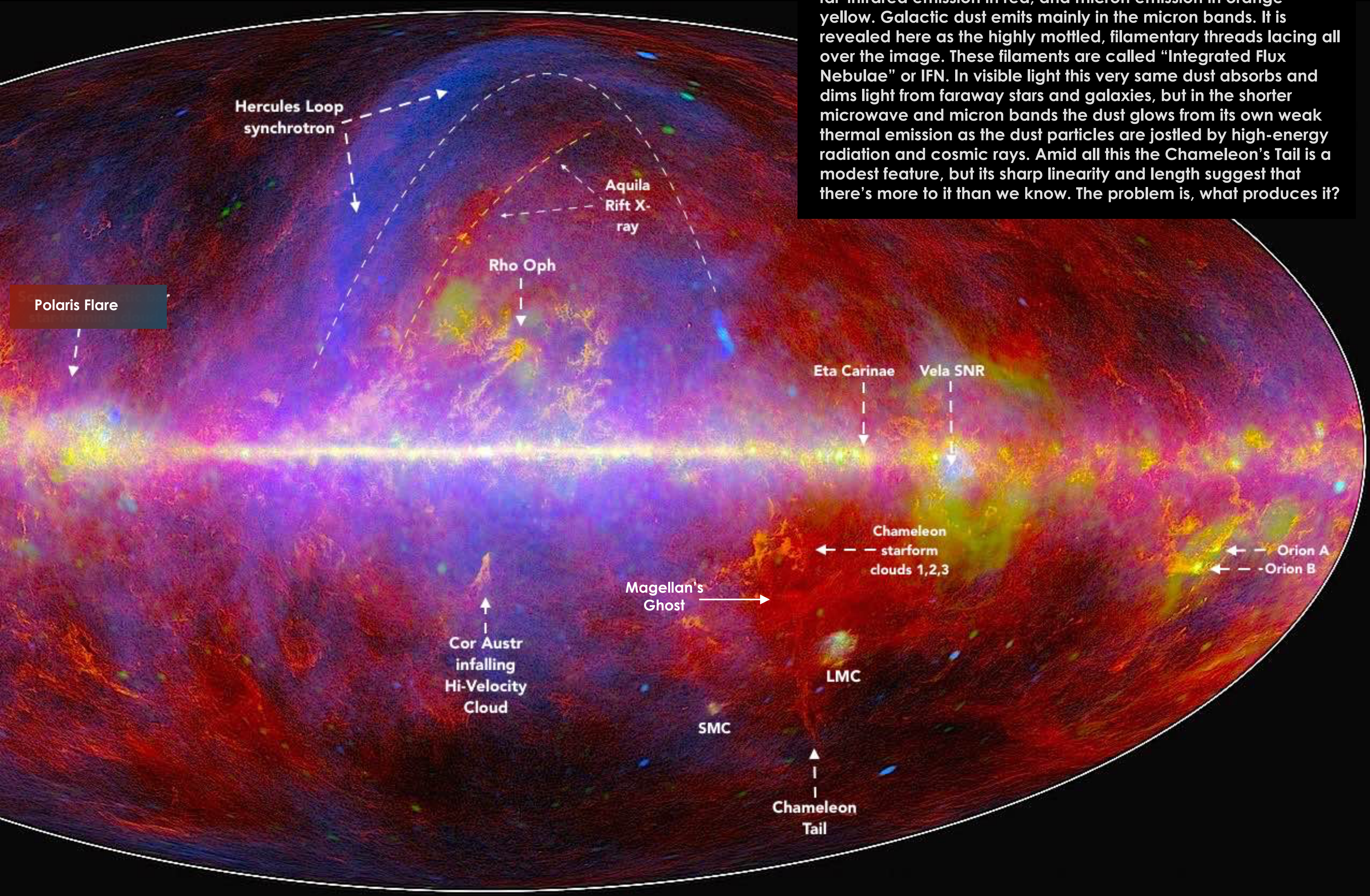
However, David Martínez-Delgado did describe the equipment and processing used to produce these images. This is of great interest indeed to us, as similarly well-thought out contributions from the amateur imaging community can add science value to their imaging runs. Martínez-Delgado points out: "Ultra-deep, wide-field imaging using amateur telescopes can provide an alternative solution to map out substructure in the Galactic disc and LMC/SMC halos out to large radii. Small-aperture, high plate-resolution image data help professionals trace the substructures as diffuse light features, similar to the approach used in stellar stream surveys undertaken with similar facilities. Galactic cirrus typically has surface brightnesses of 26.5 to 32mag arcsec^{-2}."

The above image was acquired using a portable SBIG-11000M CCD camera behind a Canon EF 50 mm f/1.4 USM. Higher-resolution images used a Canon EF 200 mm f/2.8 L II USM. The fields were 39° × 27° and 10° × 7° respectively. Each image set stacked multiple 600-second exposures using a Baader Luminance 4000–7500 Å filter and Baader RGB filters.

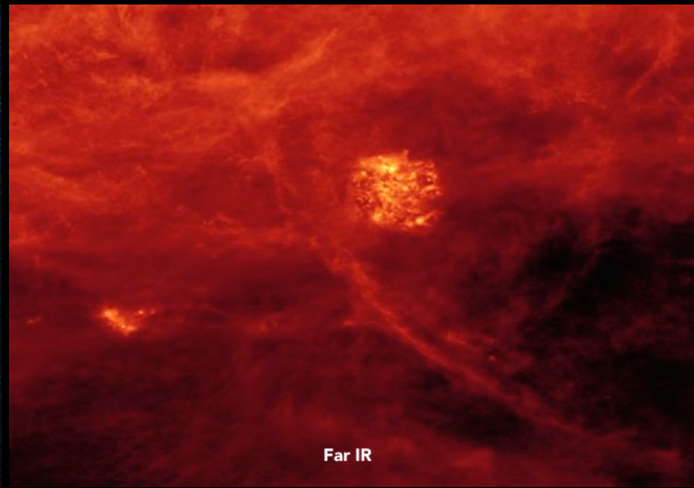
Except for the SBIG 11000, the above equipment is affordably off-the-shelf. Amateurs can use less exotic cameras with fewer pixels/mm yet still provide value-to-science images. The filamentary structures visible in the above two images are Galactic cirrus, which are abundant at high galactic latitudes, typically having surface brightness limits fainter than 26 mag arcsec^{-2}. The Chameleon's Tail shows abundant detail that can help us constrain the possible energy inputs which drive the Tail.

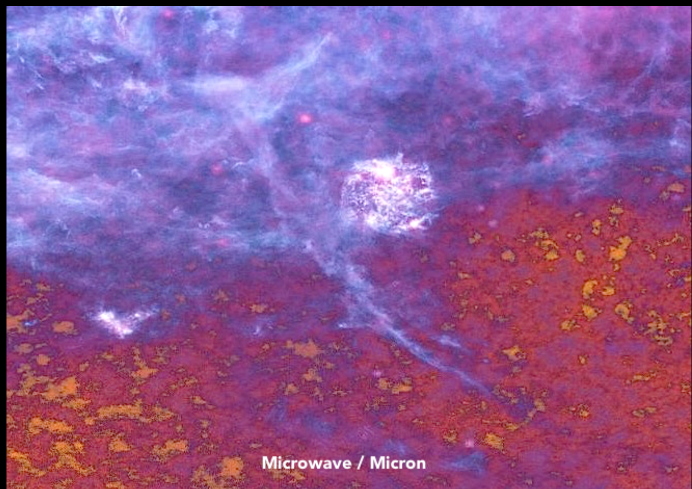
All of this demonstrates the main point of this article: Amateurs can do more than take pretty pictures. Greg Bradley shows us how to value-add science content by thinking beyond the pretty picture.

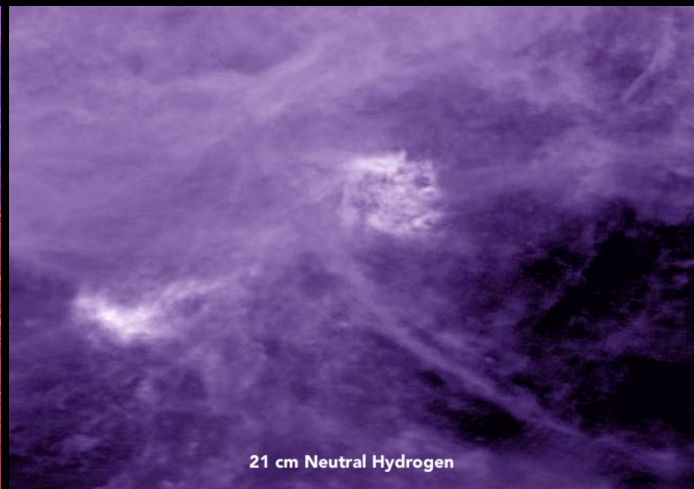
This image is a composite of X-ray synchrotron emission in blue; far-infrared emission in red; and micron emission in orange-yellow. Galactic dust emits mainly in the micron bands. It is revealed here as the highly mottled, filamentary threads lacing all over the image. These filaments are called “Integrated Flux Nebulae” or IFN. In visible light this very same dust absorbs and dims light from faraway stars and galaxies, but in the shorter microwave and micron bands the dust glows from its own weak thermal emission as the dust particles are jostled by high-energy radiation and cosmic rays. Amid all this the Chameleon’s Tail is a modest feature, but its sharp linearity and length suggest that there’s more to it than we know. The problem is, what produces it?



We begin by deconstructing the Chameleon's Tail







The Chameleon's Tail is weak in the optical and near-IR bands but prominent in far IR, micron, and 21 cm radio. These suggest elevated dust concentrations. In regions of a galaxy disc/halo with particle densities of 5 to 100 particles per cm^{-3}, gas and dust are only weakly coupled. The CO/H^2 column density ratio is not constant, typically ranging from 10^{-7} to $10^{-5}/cm^3$, with a mean of 10^{-6}. In such densities dust particles decouple from gas and move aerodynamically through the gas. The gas responds to thermal and density-pressure forces, while dust (especially dipolar particles) responds to magnetic forces. The question posed by these images is whether the Tail is a gas/dust radial inflow or outflow, and if so, where is its energy source? The shallow vee-shaped feature above and to the left of the LMC appears to be a dust overdensity associated with the Tail. But the average CO temperature in this region is 4.1 K and the average H_2 rotational excitation temperature is 74 ± 24 K. These are not energy potentials of the type needed to energise so prominent a dust feature as the Chameleon's Tail. Well then: If not these, then what is?

What is Galactic dust?

The multiband images on the previous page hint that the Chameleon's Tail is a dust feature responding in a jet-like structure to forces not fully documented. How do we determine what causes so prominent a feature?

We begin with the basic properties of the dust itself. From our human perspective, dust is the most important matter in the universe after atoms. That's because we were made from dust. For all its minute inconspicuousness, space dust is where the seeds for living organisms were planted. And like us, space dust is a lot more complicated than it looks.

Space dust falls into two main categories: *carbonaceous* (~50%) and *siliceous* (>45%) with smaller amounts of *polycyclic aromatic hydrocarbons* (PAH), and *water ice*. The Milky Way dust's mass density is about 1% of the gas density.

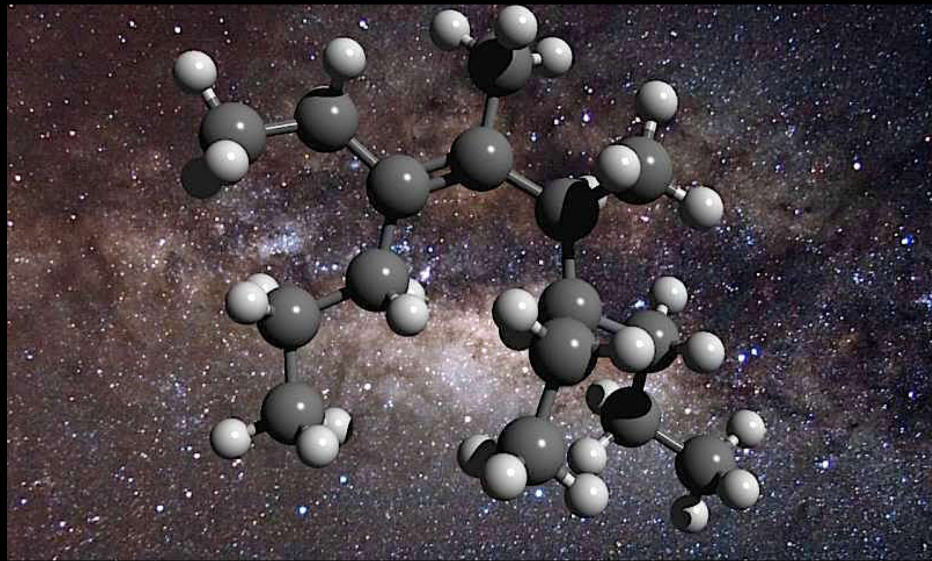
Silicates are exceedingly minute silicon-rich composite particles that condense in the atmospheres of cool, oxygen-rich red-giant stars. The particles are ejected along with the atoms and molecules in the stars' stellar wind. Siliceous particles are usually dipolar (longer on one axis than the other), which means they can align one axis along magnetic field lines. Being more extended on one axis than the other, they are also spun up by photon pressure until they reach astonishing rotation rates, e.g. 10 million times per second. Silicates are best detected as 9.7 μm (micron) emission in the infrared band.

A smaller number of silicon carbide particles are formed in cool evolved *carbon-rich* giant stars. A spectral emission at 11.5 μm is a signature of silicon carbide. Silicate compounds are *refractory*, meaning that they are stable at high temperatures (e.g., >1000 K). Silicates are called "stardust" because they originated in old red stars.

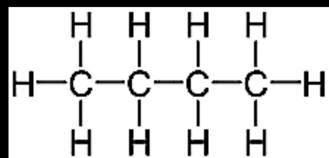
Most important for this discussion is that silicates readily reflect photons off their surfaces, A large number of silicate grains spinning rapidly with their poles aligned perpendicular to the local magnetic field lines can act as a reflective surface to incoming light arriving normal (perpendicular) to the grain's long axis. That's how we can see Magellan's Ghost, Fortuitous chance alignment raises the Ghost's emission from 26.5 yo 24.6 MPSAS. Unfortunately, the Chameleon's Tail's magnetic alignment is not normal to any bright illumination source, hence it is not visible to visual astronomers, although imagers can catch it (as Greg Bradley did above).

Carbonaceous grains are formed out of the abundant carbon atoms ejected along with stellar winds from red giant stars, asymptotic giant (AGB) stars, and cool carbon stars. Carbon bonds readily with hydrogen, forming hydrocarbons.

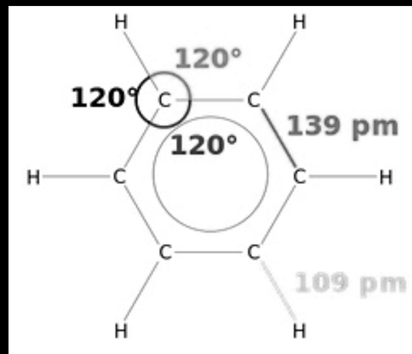
These come in two flavours: *aliphatic*, meaning long chains, and *aromatic*, meaning ring-like. The word "aromatic" has nothing to do with smell; it is shorthand for "carbon-hydrogen molecule".



Aliphatic or chain-like carbon-hydrogen molecules comprise about 100 carbon atoms for every million hydrogen atoms. In any given dust cloud aliphatics comprise between a quarter and a half of the available carbon compounds. The other carbon-hydrogen mix produces ring-like structures called *aromatic hydrocarbon* molecules.



Butane is an aliphatic carbon compound. Aliphatics contain only carbon and hydrogen.



Benzine is an aromatic carbon compound. Aromatics can also contain nitrogen, oxygen, sulphur, fluorine, and other atoms.

A lot of chemistry in little specks

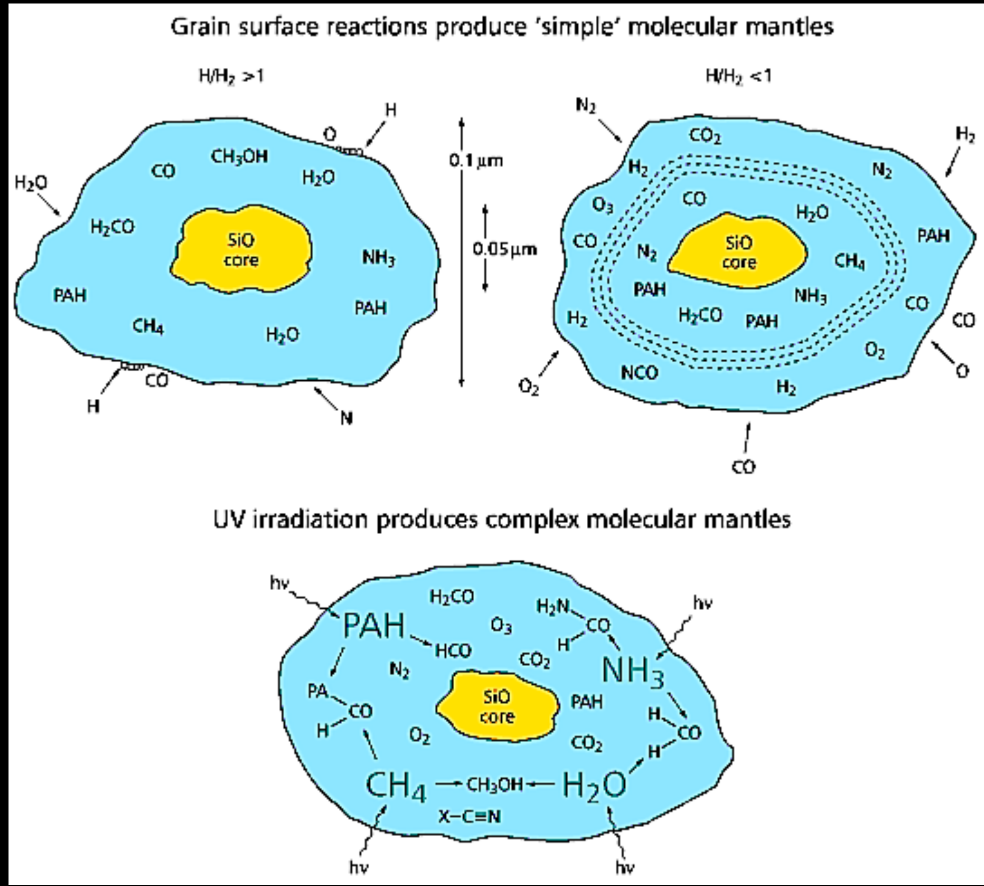
Galactic dust is a complex and involved subject. Here we are mainly concerned with what happens when dust and magnetic fields mix it up. While the interstellar medium is mainly composed of gas, gas is not our main concern here. In many gas-dust clouds, the behaviour of the gas is decoupled from the behaviour of dust. A gas mass and a dust mass often coexist in a single cloud, but they respond in different ways to external forces. Gas is less affected by magnetic fields and produces *Faraday Rotation* and *Zeeman line splitting*, while dust can be very strongly affected by turbulent shocks which form lens-like compression surfaces that interact with each other and also respond to magnetic fields.

Gas responds physically to pressure, shock waves, and temperature; and electromagnetically to magnetic fields. Dust responds to all four of those forces, though its response depends on whether it is carbonaceous or siliceous. The properties of the two dust compositions differ so much that they, too, sometimes act as decoupled masses, even when the two masses are mixed with each other. Silicate grains respond positively to magnetic forces but not temperature. Carbonaceous grains respond negatively to temperature by boiling off its surface gases such as H_2 molecules and water ices at relatively cold temperatures of <70 K.

The cores of silicates begin with a silicon oxide molecule born in cooling supernova debris and the ejecta of certain variable stars such as R Coronae Borealis. It takes a long time to build a silicate grain like the ones on the right.

Carbonaceous dust is the opposite: notoriously acquisitive. It bonds so easily to hydrogen, oxygen, and nitrogen that we preponderately carbonaceous human beings are one of its end products. We are. irreverently enough, a huge mulligatawny of carbonaceous compounds with herbs and spices from all over the Periodic Table. We can simmer away at 37 C for ages and only get better.

As hot as stars may be, they require brutal cold to get started, 5 to 10 K being just about right. The recipe to make a star starts with a simple H_1 and H_2 molecular clouds in a galactic disc. The torque and shear of the rotating disc soon twists and churns the cloud into multiple dense clumps. The more massive clumps collapse into a nice glittery star cluster, but in the millions to tens of millions of years between cold particle and hot star, the dust particles are shattered by collisions with other particles, sputtered by heavy molecular ions pitting the surface, twisted by supersonic shocks, turned into dipolar strings by magnetic fields, and broiled by ultraviolet and X-ray photons. Today we know that PAHs have assembled into *amino acids* and *nucleotides*, the raw materials of proteins and DNA,



The history of refractory grains in the Galactic disc is complex and not yet fully understood. The materials in a single siliceous dust grain accumulates in different locations and different times during the long time spans between the original seed particle's formation in supernovae debris and the stellar atmosphere of variable stars. The conglomerate character of silicate grains was unraveled only recently with purpose-built space telescopes like the *Spitzer Space Telescope's* mid-infrared spectra 5–36 µm and the *Japanese satellite AKARI*'s 2.5–5 µm spectra.

The upper two images above show how siliceous dust originates as simple silicon oxide particles which gradually acquire a surface coating of many different molecular types, most notably aromatic and aliphatic C–H bonds in organic dust, plus a variety of ices such as H_2O, CO_2, and CO.

In the bottom image we see how the unending bombardment of destructive UV photons converts simple C, N, and O–based molecules from stars undergoing CNO core fusion, into the lengthy molecular strings known as *polycyclic aromatic hydro-carbons* (PAHs), Hundreds of PAH species have already been identified; more are surely to come as satellite and ground data are studied at higher resolution.

Beautifully irritating

The Milky Way's dust was one of the three main interferences astronomers had to overcome when mapping the Cosmic Microwave Background (CMB). The other two were stars and galaxies. All these either emit or absorb radiation, and all of them lie in front of the sky-spanning CMB. In order to see the CMB as it really is, everything else had to be removed. That meant nulling out all astronomical objects from dust particle at the top of the Earth's atmosphere to the remotest 13-billion-light-year galaxy. Radiation from even the faintest of these would alter the CMB's faint cold signal. When it came to the problem of Galactic dust, the job astronomers faced was removing every single grain of light-dulling sand in a galaxy-sized sandbox.

Dust did not ease the lives of astronomers one bit. Dust was the most contrarian of the obscurants to deal with. It both emits and absorbs radiation. It presents us with both fact and concealment. In the visual bands dust is an absorber because it dims or blots out light from behind it. While it is an irritant to visual observers, dust's complex shapes and densities are an astro-imager's great joy. Dust tends to align in filaments, films, and clumps, rewarding us with beauteous hues and shapes in what is tantamount to the largest accidental art in creation. We have an art gallery filled with the Rembrandts, Van Goghs, and Jackson Pollocks of the heavens up there, and it's free. The trouble is, an even more beautiful art masterpiece lies beyond it, and that's the one we want to see. Dust the the sky's palimpsest.

Professional astronomers have a different take on the matter. To them, dust is a complex mess made of relatively simple components that are far too acquisitive and gregarious for their own good. Dust absorbs and scatters ultraviolet light and re-emits the absorbed energy thermally in the mid- through far-infrared bands. Hence it 'reddens' or blocks any objects lying behind it. Yet at the same time, dust also emits radiation in the infrared to micron spectral bands, especially 353 to 857 GHz (GHz = gigahertz, billion cycles per second). For astronomers dust is both friend and foe. The friendly side is that dust aggregates into filaments and sheets which leave clues about star and planet formation. The unfriendly side is that dust reshapes the radiation field of the Galaxy, making it difficult for astronomers to accurately define the properties of nebulae and distant galaxies. A good portion of an astronomer's time is occupied with photometrically getting rid of the stuff.

A dust particle's interaction with electromagnetic radiation depends on the particle's cross section, molecular composition, refractive index, size, and the wavelength of the incoming electromagnetic radiation. The radiation process for an individual grain is called its *emissivity*, which depends on the grain's extinction, scattering, absorption, or polarisation. Several important signatures identify the composition of the emitting or absorbing dust particles. Chief among them is *scattering*.

Dust particles scatter light non-uniformly. *Forward-scattered* light means that light is diffracted slightly off its path by something closer to us than the star. *Back-scattered* light is reflected off an object (mainly dust particles) behind the star. A familiar example is the reflection nebula behind the Pleiades which casts a blue aura around the cluster. It is visible even in 15 cm telescopes under dark, clear skies.

Dust scatter and *extinction* give us information about the dust grain sizes. Objects in the data that are many times brighter in forward-scattered light than in back-scattered light indicate that a significant fraction of the particles are about a micron (μm) in diameter. In X-ray images dust scatters light from X-rays into diffuse haloes visible in X-ray images. *X-ray images of the Crab Nebula* reveal it vividly as a light blue haze. Watch a video of *1 year in the life of the Crab Nebula* here.

The *Planck images of concern to us here* show interstellar dust from the Milky Way's diffuse gas/dust medium red, orange, and yellow. The blue background of low dust dust density at temperatures <18 K. (The burbles are signal noise from the Planck instrument itself.) The jet-like Chameleon Tail filament appears to be associated with the two Magellanic Clouds, but that is an illusion. In actuality, the filament lies in the Galactic disc about 300 light-years away from us and 86 to 92 parsecs below the disc plane.

The Planck images show how coherently the filament aligns with the Galaxy's magnetic field. By comparing the structure of the magnetic field with the distribution of interstellar dust in the Milky Way, astronomers can measure the relative distribution of interstellar clouds in the Milky Way's magnetic field. In the Chameleon Tail filament described in this article, the dust structures are aligned with the direction of the magnetic field. In the denser clouds of star-forming dust cores the filaments tend to align perpendicular to the local magnetic field.

Read more on *phys.Org*.

The magnetodynamics of dust

We can measure dust in interstellar cloud's size, density, internal motions, and temperature gradients in several ways.

- Cosmic dust absorbs and scatters radiation from the stars. This diminishes the amount of light getting through. We call this 'extinction'. Since the dust absorbs higher-energy radiation more than lower energy radiation, the dust soaks up blueish light but lets some reddish light pass. The spectrum of stars passing through dust is 'reddened' in the same way that dust in the atmosphere makes sunsets red. One result is that the electromagnetic radiation becomes less energetic while the dust becomes more energetic as it warms up. Dust is an energy transfer medium with important astrophysical implications.
- Absorbed stellar light heats the dust to between 10 K and 100K. The dust subsequently radiates away some of the energy in the far-infrared and sub-mm bands of the electromagnetic spectrum, meaning wavelengths of about 10μm to 1mm. Imprinted on this spectrum are signatures of dust composition, structure, and chemistry. That is how we know that a simple silicon oxide molecule like the one shown above can be surrounded by such an amazing variety of compounds.
- The alignment of dust grains in a magnetic field polarises the starlight passing through. Coming under the influence of a magnetic field exerts a stabilising influence on a molecular cloud because magnetic flux dampens the incessant turbulence of multiple interacting shock waves.
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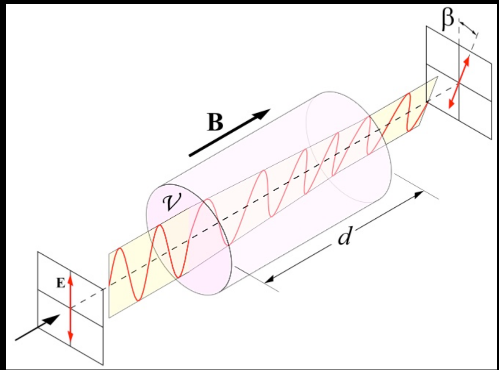
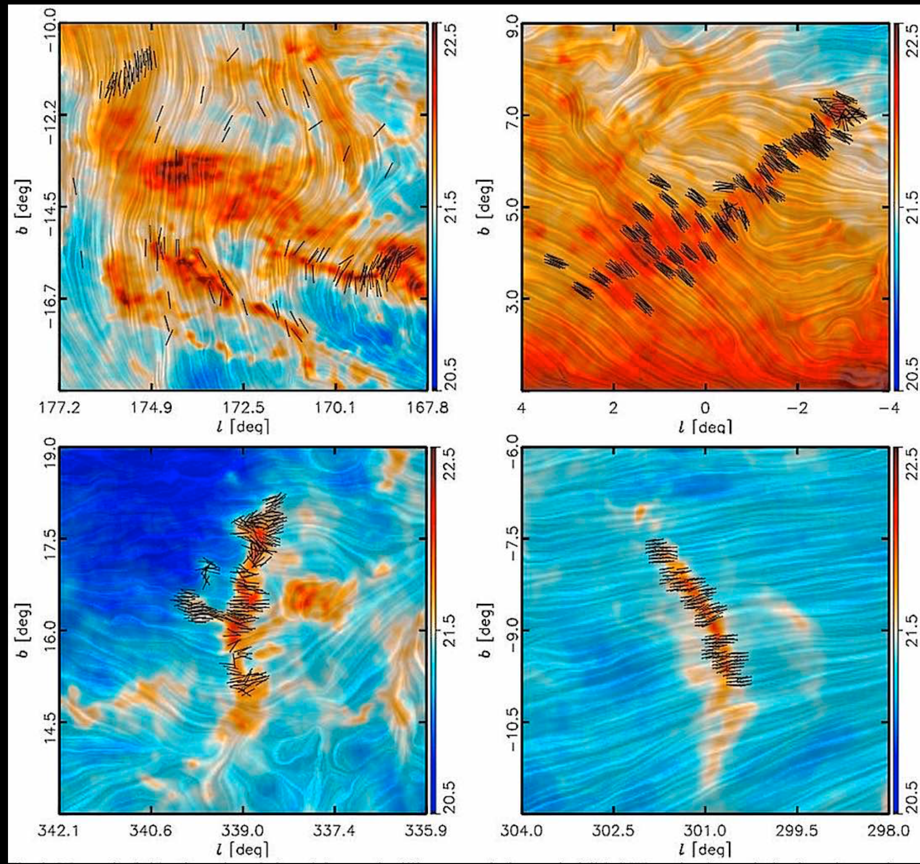


Dust passing through a magnetic field is altered by Faraday rotation, described below. Image from Wikiwand.

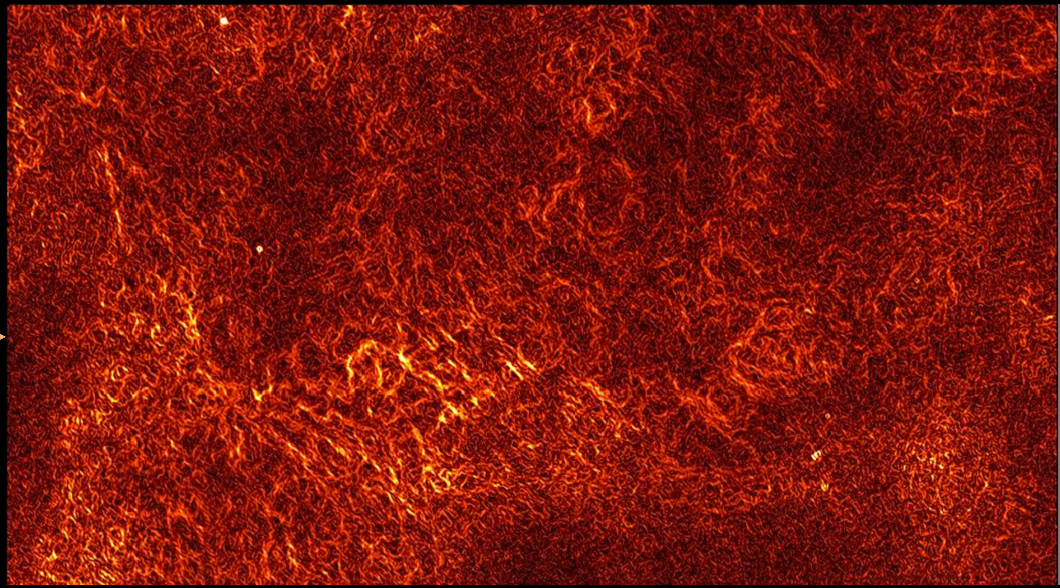
Dust both absorbs and emits radiation. A metals-enriched gas contains about 60% atoms or molecules of its metals in the gas phase and about 40% as dust grains. About a quarter to a third of all dust grains are siliceous, in which a hodgepodge of elements and molecules aggregate around a core particle of silicon oxide. The grains' *aliphatic* or elongated structure becomes dipolar when charged particles are on the ends. The grains line up to match the local electric field, which aligns the grains perpendicular to magnetic fields lines. They also spin about their axes at prodigious rates of ≥10 million sec^{-1}. The net effect is that distant light passing through a medium filled with such particles becomes polarised.



Dust grains tend to align with their longer axes perpendicular to the local magnetic field of the interstellar gas. Magnetic fields also control the density and distribution of cosmic rays, which can comprise as much as 25% of the local energy density distribution. Synchrotron emission, dust polarisation, and Faraday rotation reveal the structure of magnetic fields in regions embedded with cold dust clouds. Over time up to 20% of the long axes of the particles align coherently with the magnetic field lines. Although the particles themselves have a low albedo (they're soot after all), the water ices and molecular structures adhering to the grain surfaces reflect a small percentage of incident light if the light arrives at a shallow angle with respect to the grain surfaces. Source: *Planck Collaboration XX, 2016*.

Polarisation is a boon to astronomers because it is easy to measure by *Faraday Rotation*, which indicates the strength of a magnetic field by the degree to which the polarised lines are rotated around the field line (see the image on the previous page). The four polarisation plots (also on the previous page) show that there is a direct correlation between the axis around which the dust particles spin and the direction and strength of the local magnetic field. The field itself is perpendicular to the field lines, which are the axes of the centrelines of each field.

With this information astronomers can make large-scale maps of the Milky Way's myriad local magnetic structures. The result is a unique portrait of our galaxy (see right).



This image shows the gradient of linear polarisation over an 18-square-degree region of the Southern Galactic Plane. Magnetic fields arise from the turbulent flow of ionised material. The turbulence is associated with shock waves propagating supersonically though a galaxy's disc. The shock waves are caused in part by supernova explosions and by high-speed winds from hot, young stars. The rotation of the Galactic disc and spiral density waves impose shear and torque forces on both gas and dust. In the above image the twisty tendrils are filamentary corridors of gas in which the gas density and magnetic field are changing rapidly from shock turbulence and torque. Electromagnetic potentials in disk galaxies are amplified by the *dynamo effect* generated by the rotation of the galaxy disc. Galactic magnetic fields can form spiral patterns related to the density waves of the spirals themselves. In this image we are looking down at the Milky Way disc from above. Not shown here is the vertical component of magnetic field structures extending above the disc into the halo. Read more at *https://phys.org/news/2011-05-cosmic-magnetic-fields.html#jCp*. *Source: Gaensler et al. Data: CSIRO/ATCA*.

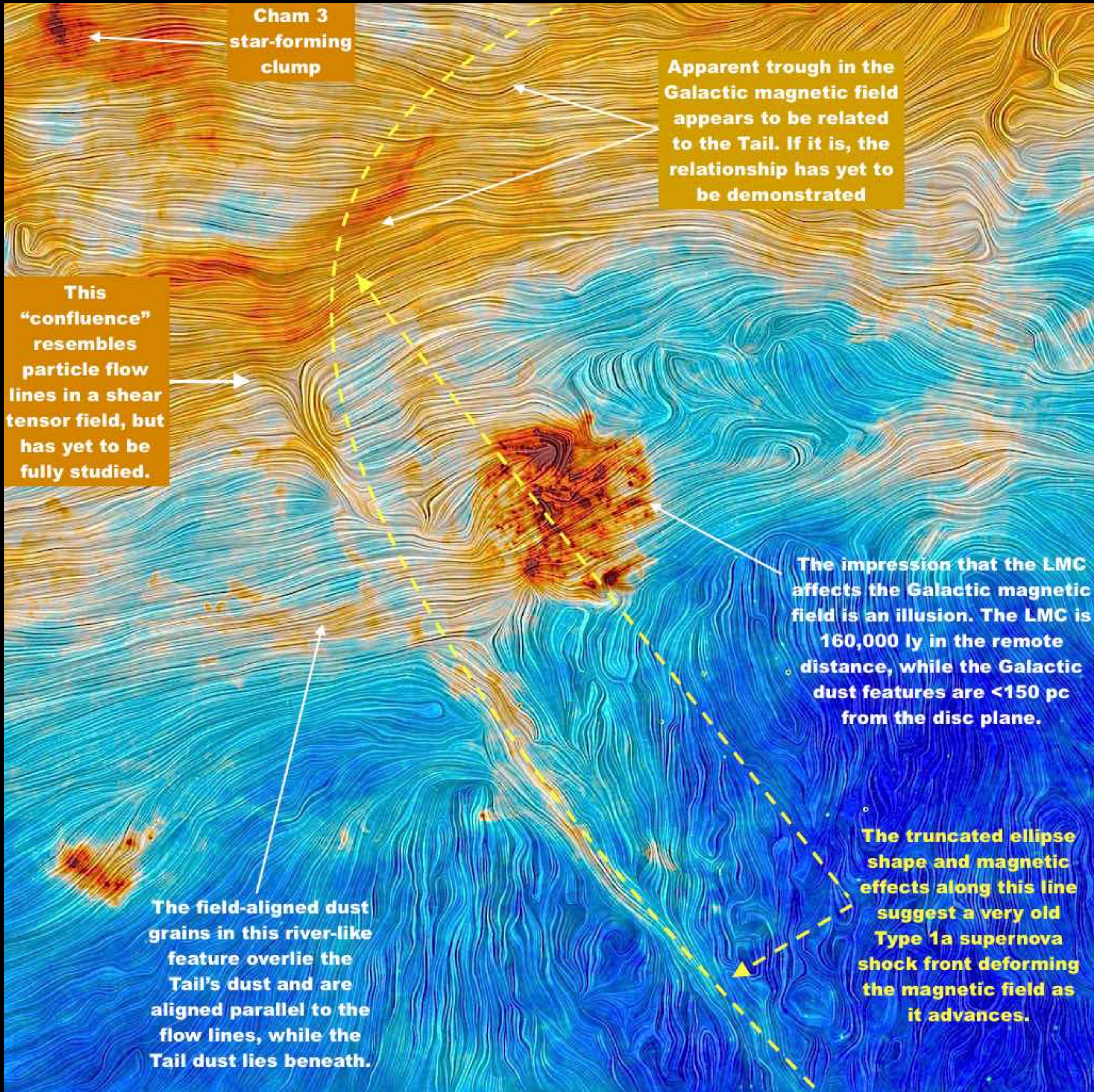
The second main dust type is carbonaceous. As the name suggests, these originate as tiny aggregates of carbon atoms that have been hurled from the surfaces of red supergiants and carbon stars. Carbon stars are not actually carbon; the name derives from the very high abundance of carbon atoms in their atmospheres. They glow a strikingly beautiful deep red; amateur astronomers are fond of chasing them down just to enjoy their colour.

Professional astronomers think of carbonaceous dust as 'greasy' because carbon binds easily with hydrogen, oxygen, nitrogen, sulphur, phosphorous, and other α-elements to form *aliphatic* chains. There are about 100 carbon atoms for every million hydrogen atoms, accounting for between a quarter and a half of all the available carbon. When carbon molecules bind into rings they form six-sided benzene rings. *Benzene rings* attract carbon and hydrogen atoms in huge quantities. We on Earth have been driving, jetting, and cruising around our globe using hydrocarbon chains which started off as carbonaceous grains that formed as early as 10 billion years ago.

The most important feature of aliphatic carbon is that hydrogen and carbon atoms bind easily on a carbonaceous grain. Two vital molecules result: carbon monoxide CO and molecular hydrogen H_2. The most important molecule in the universe is H_2, two bound hydrogen atoms. H_2 is the only form of hydrogen that can collapse to densities high enough to initiate fusion into helium and thus become a star. H_2's electrical charge is negative while atomic H_1 is neutral. H_2 emits radiation so weakly that astronomers have to trace it using CO, which does emit a strong signal and is an important component of a molecular cloud which can eventually form stars,

Fly through our Galaxy's dust clouds here.

If the Tail is a dust feature, what explains its evocative shape?

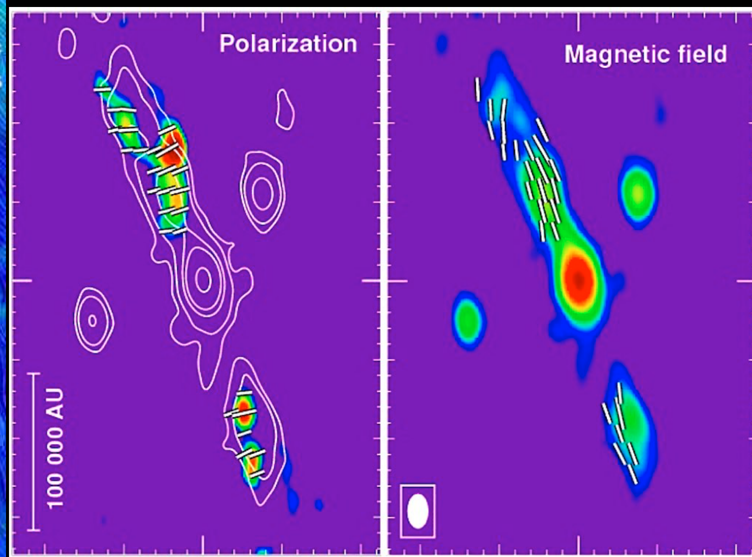


Is it plausible to attribute some if not all of the features of the Chameleon Tail to magnetic field effects on Galactic dust?

The Chameleon Tail is a cross between an enigma and contrarian. The enigma is what exactly it is – magnetic dust jet, Birkeland current, or something else that has not yet been fully explored?

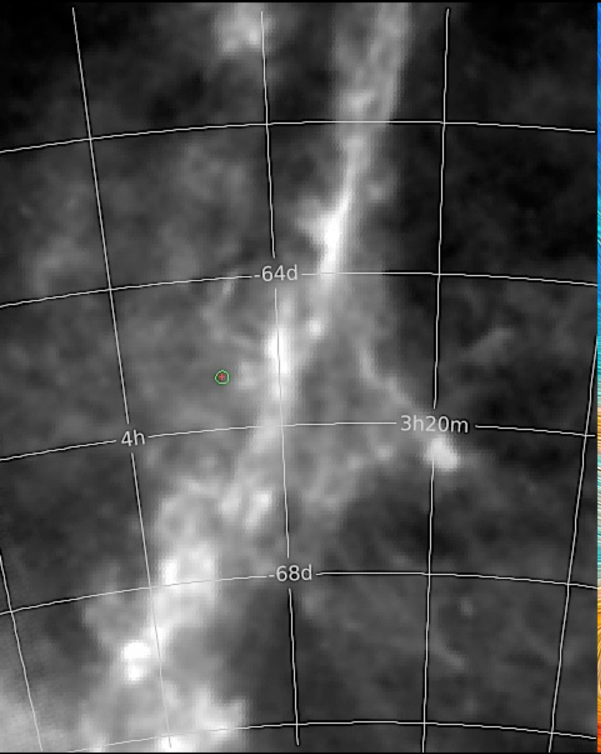
The contrarian rejects the general rule that interstellar filamentary clouds are preferentially aligned with the direction of the ambient magnetic field lines. Instead, the Tail shoots off at 90° to the field lines and along a descending vector away the spiral arm's magnetic field. The source and magnitude of its energy field have yet to be demonstrated with observations or smooth-particle hydrodynamic models.

If it we could see the >27 MPSAS Tail on a dark night it would be a faint 3≠4° wide linear emission stretching 35° across the sky.

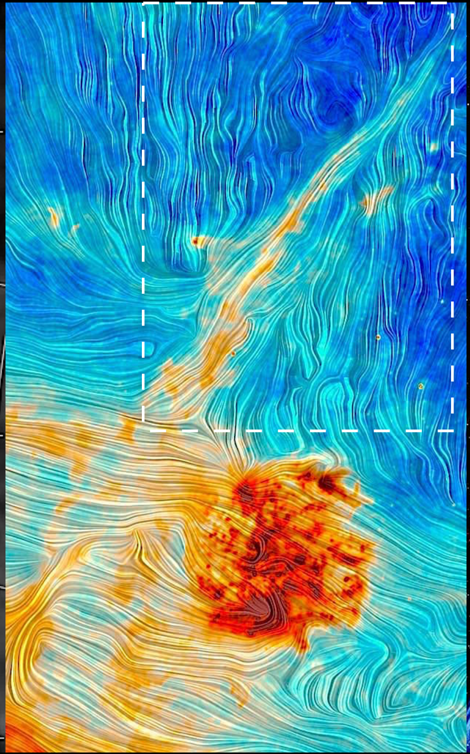


The distinction between a magnetic field and magnetic field lines is shown here. The lines on the left are polarisation vectors, not field strengths.

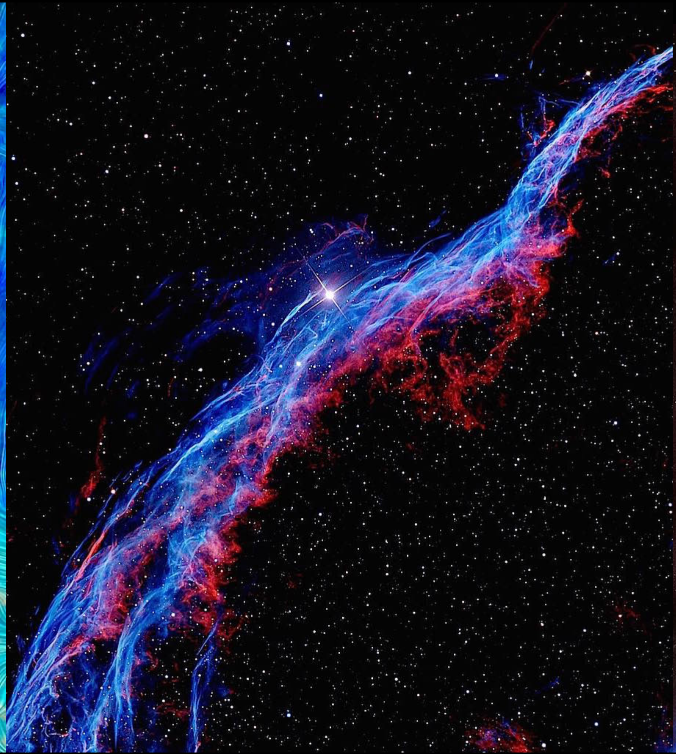
What can we learn about the Chameleon's Tail from the Veil Nebula?



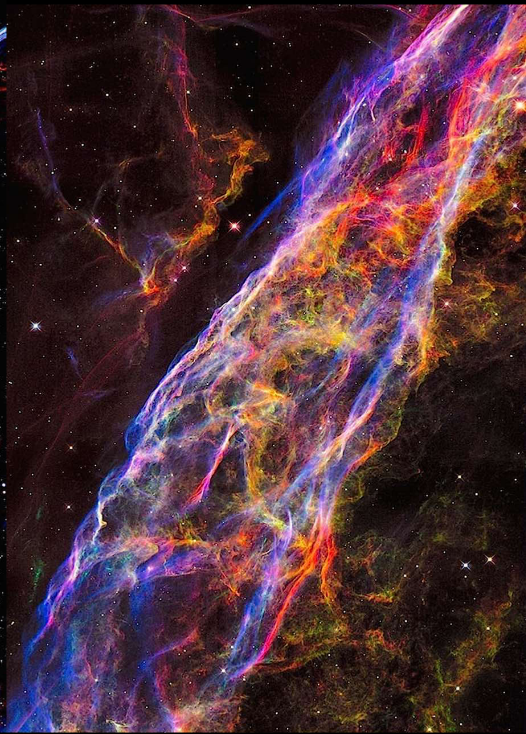
Galactic dust extinction from Schlafly and Finkbeiner 2011 and Schlegel, Finkbeiner & Davis 2013 on the *Interactive NASA/IPAC Infrared Science Archive*. The utility of Hα as accurate extinction marker is vivid here, but beyond quantifying dust's shadow effects Hα tells us little about composition, morphology, spin, or emissivity. Those are the most important factors in the Tale of the Tail.



Chameleon Tail in 353 GHz Planck image. The dashed box shows area of the *Green, Schlafly, Finkbeiner, et al, 2015* image to left. The mottled patch is the LMC, a chance alignment not associated with the the Tail. The 353 GHz dust within our own Galactic disc lies at a relatively nearby distance of <100 pc. See 3-D rotating models *here* and *here*.



Western Veil Nebula interacting shock fronts appear to be an undulating surface formed when the velocity of a supernova shock advances into cold ambient gas (blue). The ambient gas (left) is marked by subtle density gradients which explain the overall undulating morphology. There are a few hints of magnetic shear or braiding. The red traceries behind the shock fronts indicate thermal rebound shock heating. https://imgur.com/gallery/crHwY

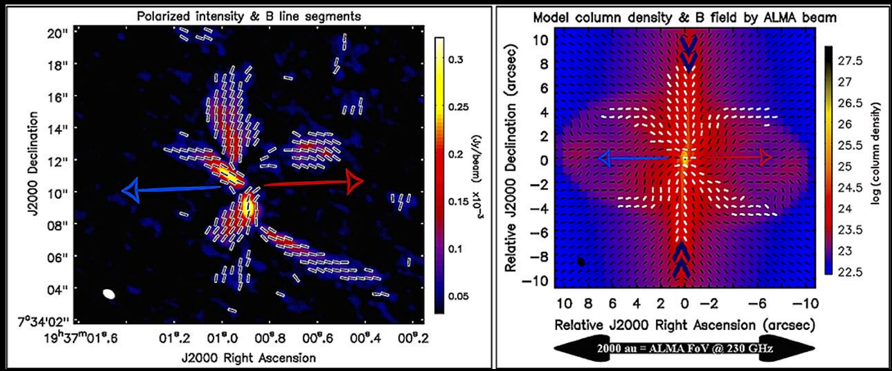


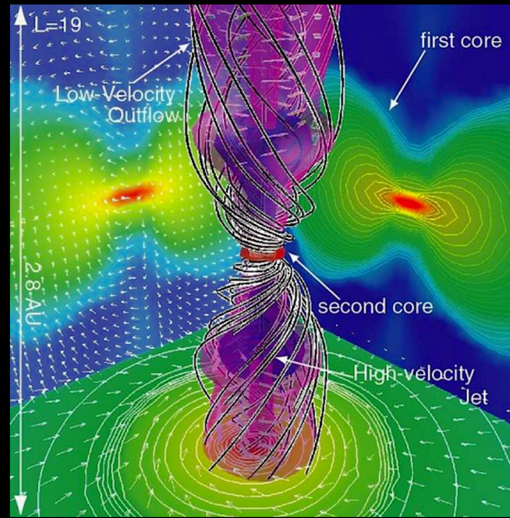
Cygnus Eastern Veil SNR. This complex mix of hot and cool filaments is not a flat surface as the eye suggests.Rather, it is like looking at at a painted balloon from the side, gazing directly through the balloons surface. The depth of this field from near to far is greater than the small segment shown. For a more exact description, see this PDF by William P. Blair dissecting information on numerous Hubble Telescope images.

An examination of the above images suggests that the Chameleon Tail shares some morphological features with the Western Veil but not the Eastern Veil, The difference between the two Veils is attributed to magnetic field effects. The Western Veil appears to be a straightforward hot supersonic shock front advancing into a low-density gas field while the Eastern Veil shows signs of magnetic interactivity. The two are 77 light years apart with the Eastern being the nearer to us. UV images of the Veil show distinct shock heating in the Eastern Veil. Shock heating is associated with shear effects that can induce magnetic activity.

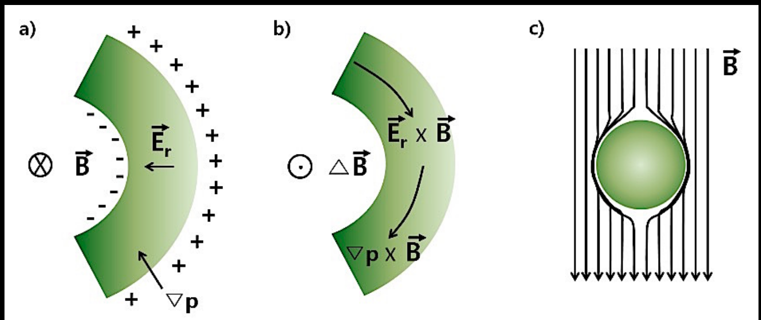
Magnetic heating and cosmic rays

Heating 101: Molecular clouds are only weakly ionised. The dissipative effects of magnetic field strength, cosmic ray ionisation rate, and gas and dust grain properties diffuse the magnetic field to weaken it. Supernova shocks change the geometry of the local magnetic field to promote or hinder filament formation. *Source: Wurster & Li 2018.*



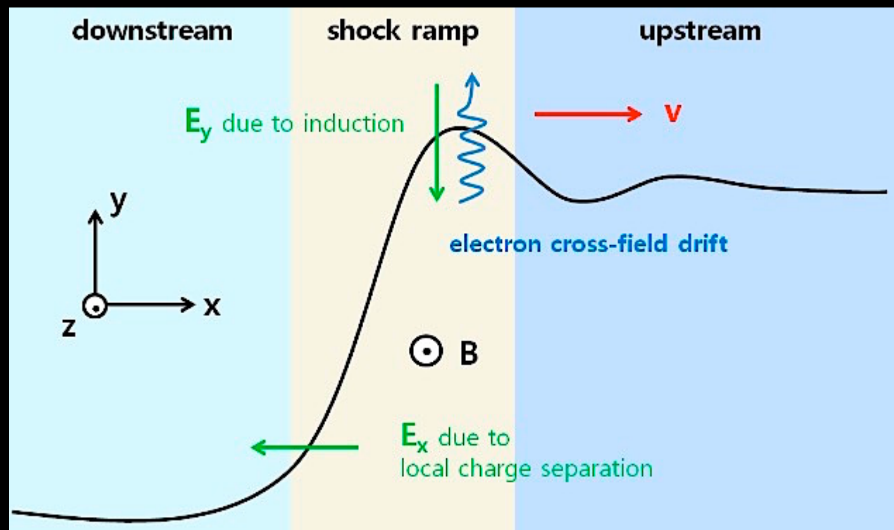


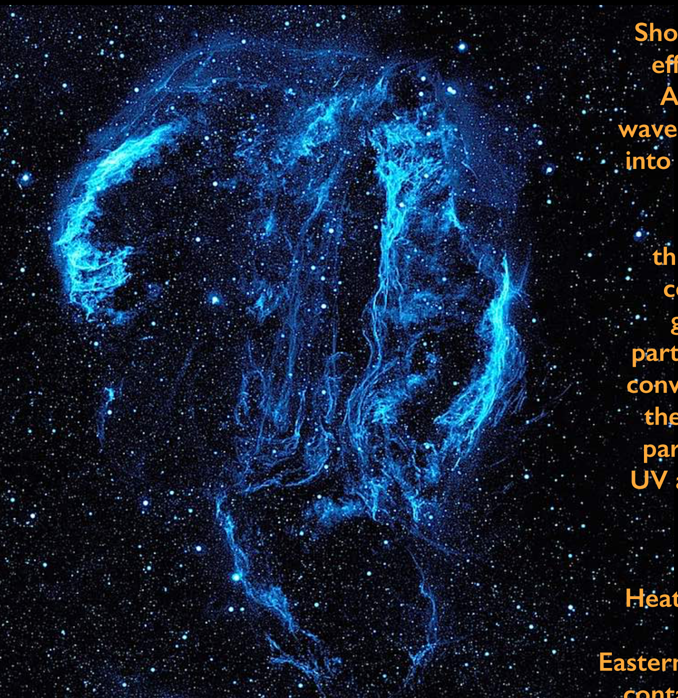
Although individual stars are not our topic here, the physics we are discussing applies to them as well. The example here is the density of magnetic field lines in a protostellar jet. The jet has an inner core and an outer sheath. Braiding affects generate synchrotron radiation at X-ray energies, which is how we find them.



Heating 102: Schematic of a subcritical shock propagating in one-dimension. The charge separation of the particles in the shock ramp differs because of the different ion magnetisation generated by a radial electric field which, in turn, induces *E*×~ß drift, an azimuthal drift which compresses the magnetic field, which in turn propagates as a magnetosonic pulse (i.e., shock surface) into the upstream region. This is important to our study of the Chameleon Tail because we need to know if and why the Tail either effects or is affected by magnetic induction. Presently we do not know. *Source: Dissertation von Bo Ram Lee, Seoul, Korea*.

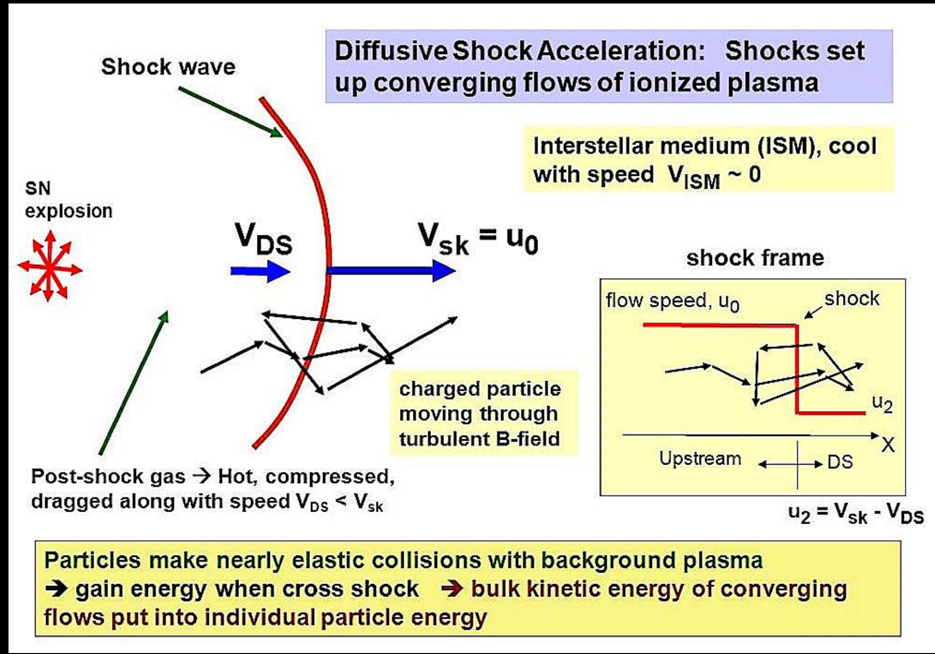
Heating 103: A supernova shell is an intense plasma expansion into a weak ambient magnetised plasma, in this case our Galactic disc ß-field. In the interaction between two plasmas with different densities under the influence of a magnetic field, hydromagnetic waves are generated. These are called magnetised collisionless shocks. They are thought to be the main source of ultra-high energy particles or cosmic rays. In this graphic the shock energy is traced left to right. The downstream side is the region behind the advancing front. The shock ramp is the width of the shock wave itself, typically 4 light years thick in a Sedov-phase bubble. Here two electromagnetic effects occur: (a) charge separation when heat dissociates electrons from protons in galactic neutral hydrogen (typically 6000 K); (b) magnetic induction, the process by which an object or material is magnetised by an external magnetic field. Induction adds kinetic energy to the particles. The particles are accelerated to high velocity. At the surface between the shock ramp and the upstream side, electrons become trapped in the magnetic front. They are subjected to the same induction force multiple times, gaining kinetic energy (velocity) each time. When they finally reach an escape threshold they are cosmic rays. The upstream side shows the kinetic (temperature) increase of the moving wave, Source: ESA 2009.



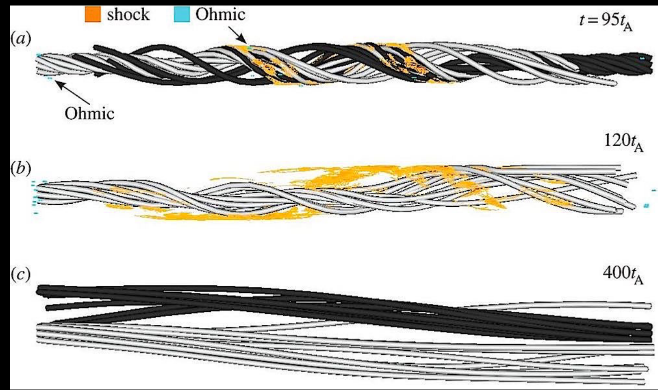


The Veil Nebula in UV. Source: *NASA/JPL*.

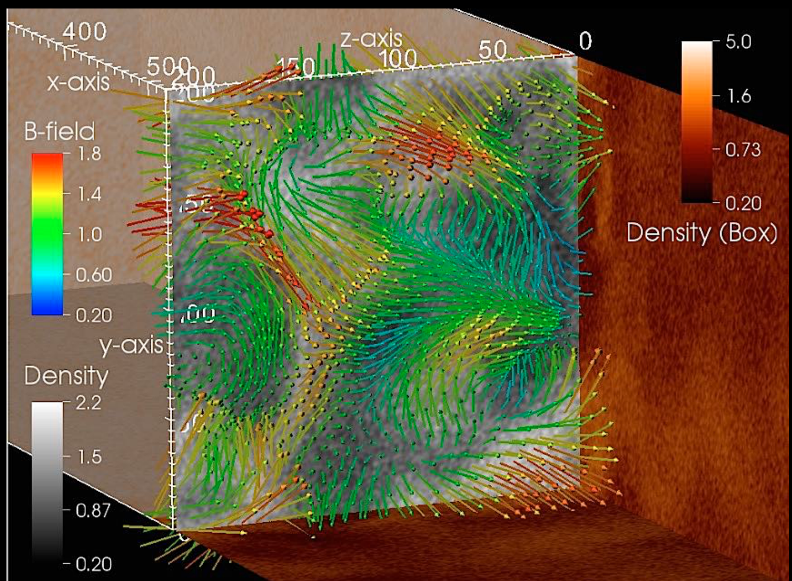
Heating 104: This image is an elaboration on #103. The rather formidably named diffusive shock acceleration is easier to explain with words than with equations. Shocks set up converging flows of ionised plasma. One effect is the braiding we saw in the Eastern Veil (left). Another is flash heating on the frontal surface of the wave. The front edge of the Eastern Veil shock advances into the cool interstellar medium to its right, which has essentially zero velocity of its own (i.e., nil kinetic energy). Intra-shock charged particles ricochet throughout the turbulent, imparting countless elastic collisions with the background plasma. The particles gain energy, but do not lose it. At each collision the particles gain velocity. The sum of all such particles is a converging bulk flow. When the bulk flow moves out of the shock front it transmits its acquired energy to the particles in the cold medium. They are flash heated to UV and X-ray energies. Source: *Gamma-ray (and broad-band) emission from SNRs*.



Heating 105: (a) An observed configuration of a solar coronal loop with a coil-induced instability. This relates to the braided configuration we see in the Eastern Veil. UV images of the Veil (left) show intense radiation from the shocks' contact surfaces with the interstellar medium. At issue here is how the energy contained in a shocked field is converted into heat. In (b) and (c) kink instability converts a planar azimuthal field (i.e. *Bx* and *By*) into Lorentz force, which is the rate at which linear momentum is transferred from the electromagnetic field to the particle—i.e., the Lorentz Force converts magnetic into kinetic energy, which in turn amplifies the kink. The result is a feedback mechanism of compressed plasma which generates helical currents. This initiates a feedback loop which accelerates the field's particle velocity. Sharp velocity gradients in compressed shear fields explain at the expanding surface of the Eastern Veil.



Source: *Bareford & Hood 2015* Fig 10.



Heating 106: The 3-D surface of a shock front, advancing back to front. The coloured vectors show strength and direction of the magnetic field. There is a correlation between underdensity and low ß-field, and how the magnetic field aligns along filaments and coil inside cavities. *Source: Cosmic Ray Ray Induced Filamentation Instability in Collisionless Shocks*

The importance of these images taken together is that they suggest that the Chameleon's Tail is an ancient and attenuated supernova shock front whose dimensions in the sky are larger than any others known.

Electromagnetism's 800-lb gorilla

There are advantages to being a supernova shock. One is that you're the only thing bigger than the 800-lb gorilla. Two is that you can pretty much do what you want, Who's going to stop you. Three, the problem is that you are pretty limited in what you can do. And four, you never really leave, you just keep fading.

This may sound a bit flippant, but every one of those points can be found in mathematical form in the legions of professional papers dealing with supernova remnants. There are thousands of these papers, going back as far as Fritz Zwicky, Gérard de Vaucouleurs, and Lyman Spitzer from the 1930s through the 1970s.

Even so, they can be boiled down to those four points above, even given that the phraseology of the statements would outrage astronomy professors if it was in a student paper. Picky-picky.

All the more so, then, is the duty to substantiate the point that the Chameleon's Tail just may be the fragment of a previously unnoticed supernova remnant. So here we go . . .

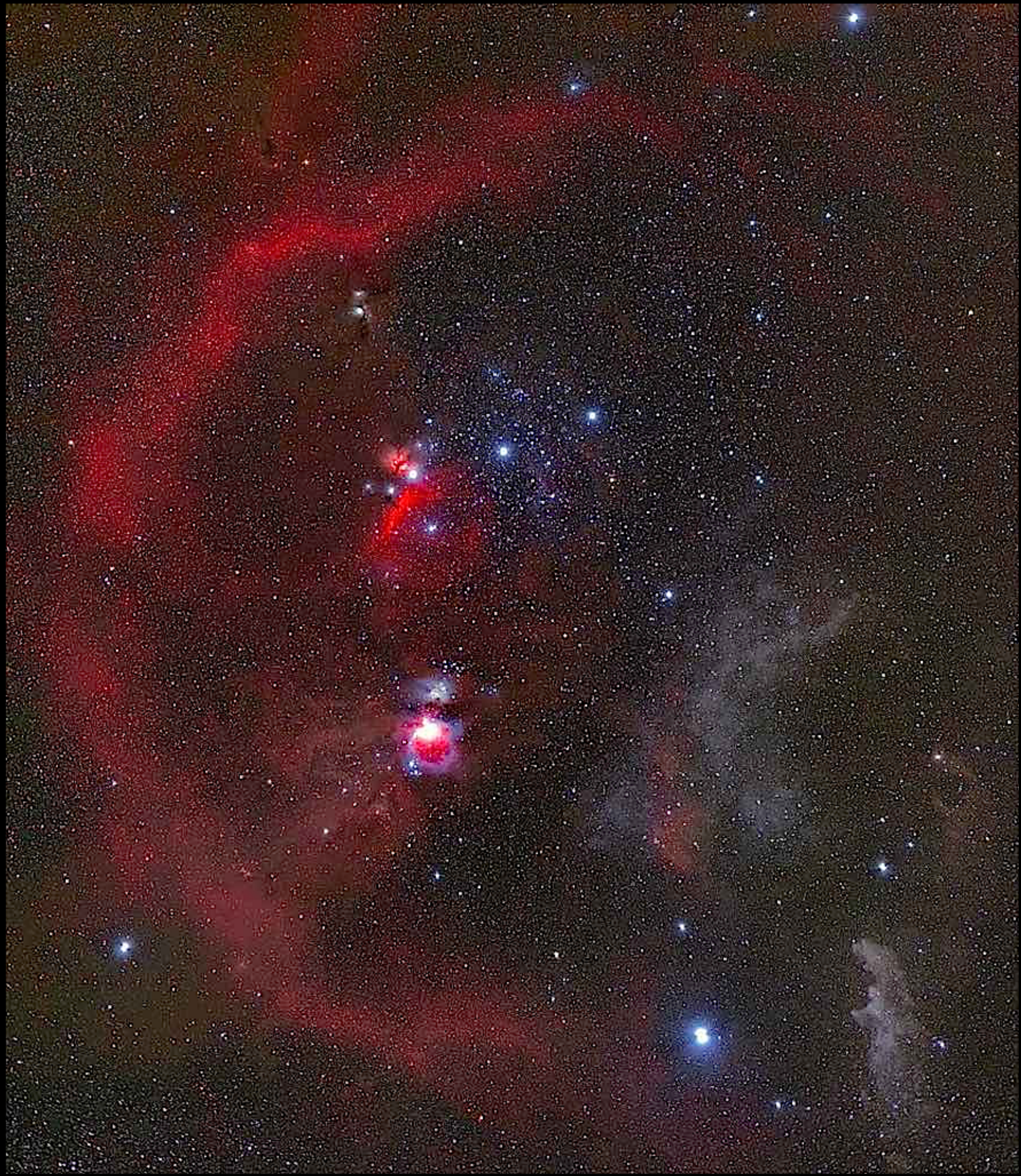
Barnard's Loop

We begin with an old friend, the shock front from a supernova some two million years ago in the stellar generation that formed part of a multiple star system in which one component exploded as a supernova.

Beloved of budding astrophotographers, Barnard's Loop is named after E. E. Barnard, who in 1903 published the first (and many say is still the most beautiful) catalogue of dark nebulae. Today we know these are not inherently dark, they are just the long shadows of myriad dust particles blocking light from behind.

Dust particles are the astronomer's Coyote Old Man, a cosmic trickster who masquerades as something easy to see while being in truth its very opposite. Cosmic dust is dark to us because we have the unfortunate ability to see only in the optical wavelengths. Dust is indeed dark in the optical.

Coyote Old Dust Man is not dark at all. Dust glows wanly at temperatures of a few K up to the temperature at which it dissipates, in the low hundreds of K.



The four phases of supernova shock expansion

The initial energy of a supernova explosion is ~1 x 10^{51} erg in a core-collapse Type II supernova and ~2 x 10^{51} erg in a Type 1a white dwarf detonation. This 10^{51} erg number is such a widely-used measure that it has acquired the shorthand slang FOE, an acronym derived from"ten to the power of **F**ifty-**O**ne **E**rgs. The erg is about the same energy as that exerted by a caterpillar doing a push-up, or a mosquito traveling at 1 metre per second striking your skin.

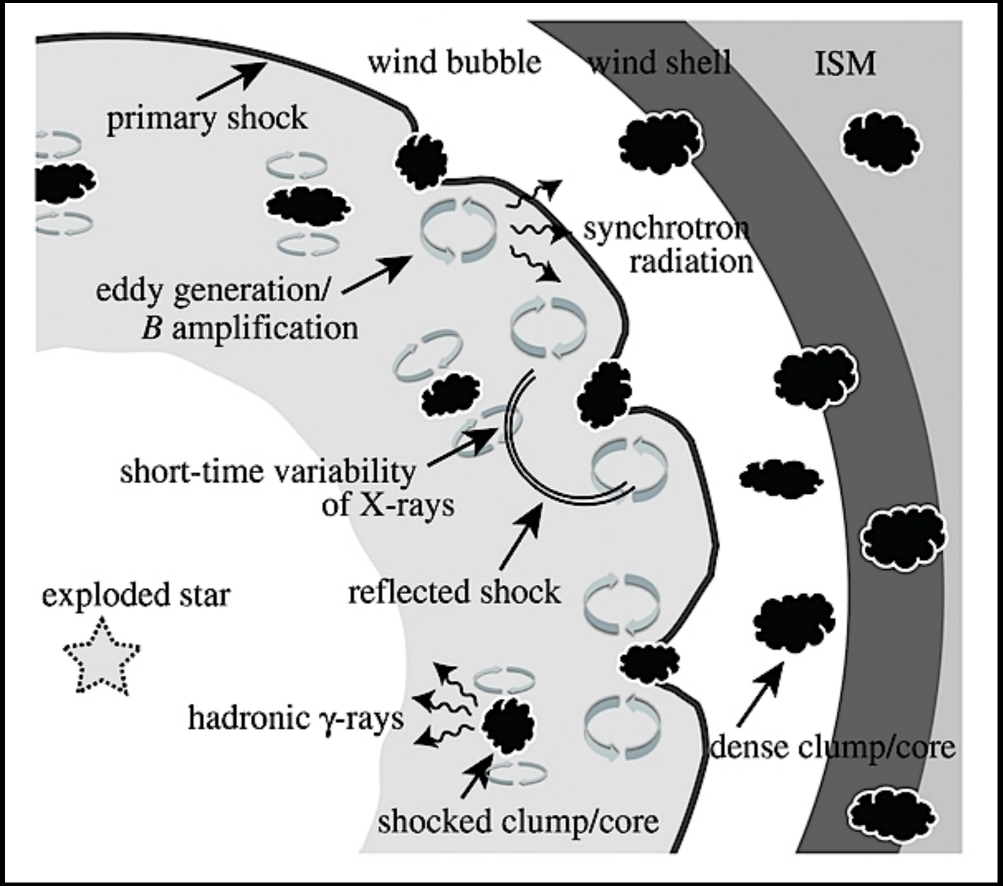
As the shock wave propagates out from the star, it goes through four phases, each with its own set of spectral signatures.

- **Free expansion**
  A supernova explosion begins by ejecting mass with a range of velocities ranging from supersonic to hypersonic. The shock wave propagates into the ISM at a nearly constant velocity of >10,000 km s^{-1}. This phase lasts for a few hundred years. Much of the Cassiopeia A ejecta is in the free expansion phase. Slower ejecta gas with a highly enriched metals content is currently moving outward at a slower, constant velocity. When it catches up to the slowing blast wave it will form a reverse shock wave. The Cassiopeia A SNR is presently catching up to the outer shock and is located at ~60% of the outer shock radius.

- **Sedov-Taylor phase**
  The shock wave expands into the earlier rings of ejecta, the pressure of which becomes very high compared to its surroundings. Hence the shock front sweeps up cold gas and becomes dense, cooler, and slower. This is called the "blast wave". Newer ejecta still coming from the star catches up from behind, forming a reverse or reflected shock moving back toward the star. *See the last simulation on this web page*. The hot interface between shock wave and incoming ejecta gas rises to X-ray emitting temperatures above 1 million K. The spectrum shows increased heavy metals content from the astrochemical reactions earlier as the extremely hot ejecta seethed out from the star. This phase lasts about a thousand years.

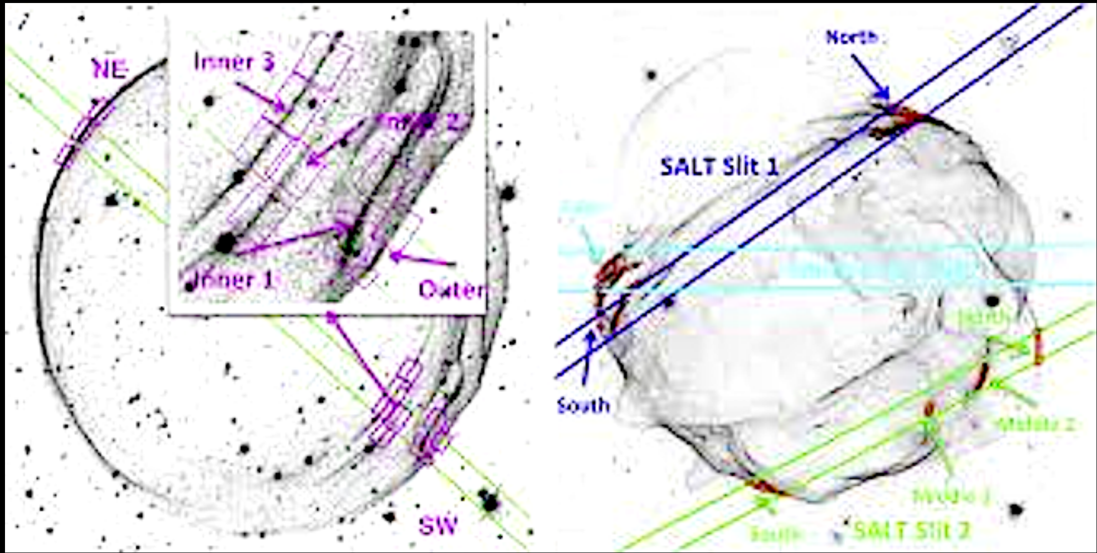
- **Snowplow phase**
  When the age of the SNR slows down to about 200 km s^{-1}, the thermal pressure behind the shock drops and the shock wave stalls. The shock front becomes a shell of cool gas at the surface of a hot interior. For typical SNRs, the phase lasts about a million years, although local gas density and dust content modify the average time span considerably.

- **Fadeaway**
  Eventually the shock speed approaches the sound speed in the gas, and turns into a sound wave. The "fadeaway time" is on the order of several million years.



For vivid simulations of supernova shock dynamics, watch the bottom two videos on this Max Planck Institute page.

Supernova shock waves are the primary source of cosmic rays



A forward shock moves supersonically into interstellar/circumstellar medium Reverse shock propagates into ejecta, starting from outside. *Source: SALT*.

Free Expansion

- Ejecta expand without deceleration. Core collapse SN have initial velocities of >5000 km/sec and several $M_{\odot}$ of ejecta, SN Ia expand >10,000 km/sec with ~1 $M_{\odot}$ of ejecta.

Sedov-Taylor

- Ejecta are slowed down as they sweep up to 10 times their own mass of ISM. Energy is held within and not drained away by radiation, so the only way for the wave to cool toward equilibrium with its surroundings is by expanding; this phase is *adiabatic*, meaning that its net heat transfer is zero. High-speed ejecta gas from the interior collides with the blast wave, forming reverse shock. The temperature increases inward but its pressure decreases to zero as it is imparted to the shock wave in front.

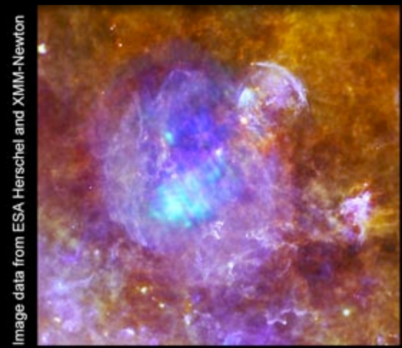
Radiative-Dissipation

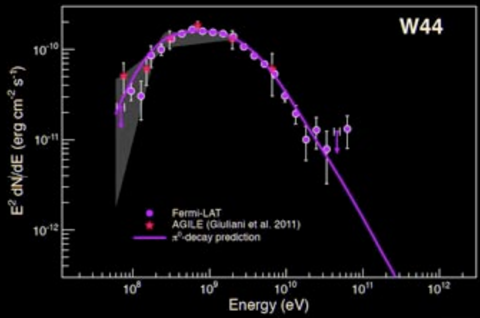
- The remnant energy forms a thin, very dense shell which cools rapidly. The interior remains hot. Typical shock wave velocities drop to around 200 km/sec.

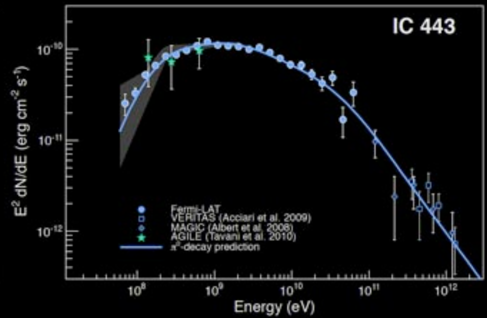
Fadeaway

- Shock velocity drops below local sound speed ~20 km/sec and dissolves into the galactic gas field.

Source: *Lecture notes by Prof. Richard, UMD*.







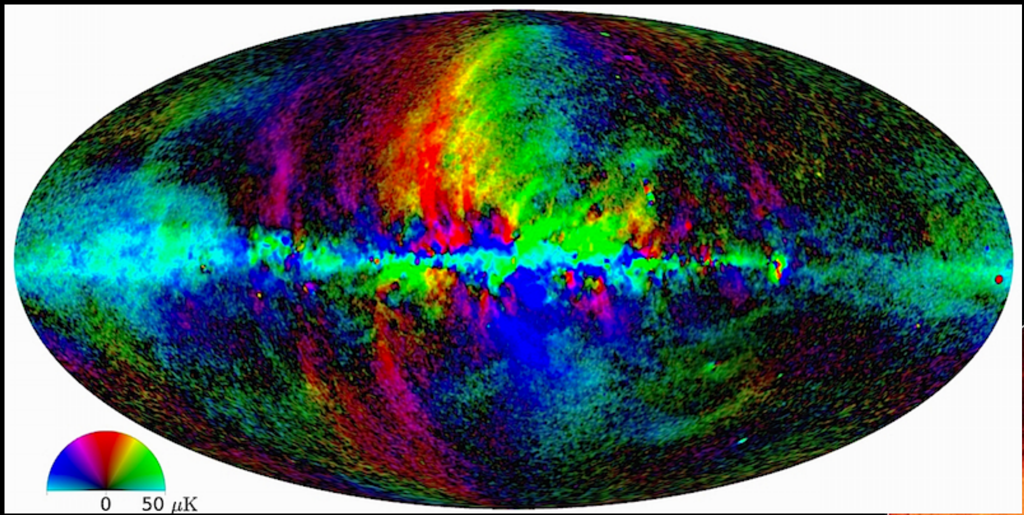
When a star goes supernova, its remnants retain the star's already strong magnetic fields. Hydrogen ions (protons) are accelerated by the shock front created in the supernova. These are in turn accelerated by the star's now strongly compressed magnetic fields. At lower X-ray energies they remain trapped in the shock shell, which can be up to 4 light years thick. They gain considerably more energy via elastic collisions in which they gain, but do not lose, the energies in the shell. Eventually they gain enough energy to radiate gigahertz gamma ray photons so energetic that they escape out the front surface of the shock as cosmic rays. (See *Heating 103 and 104* above.)

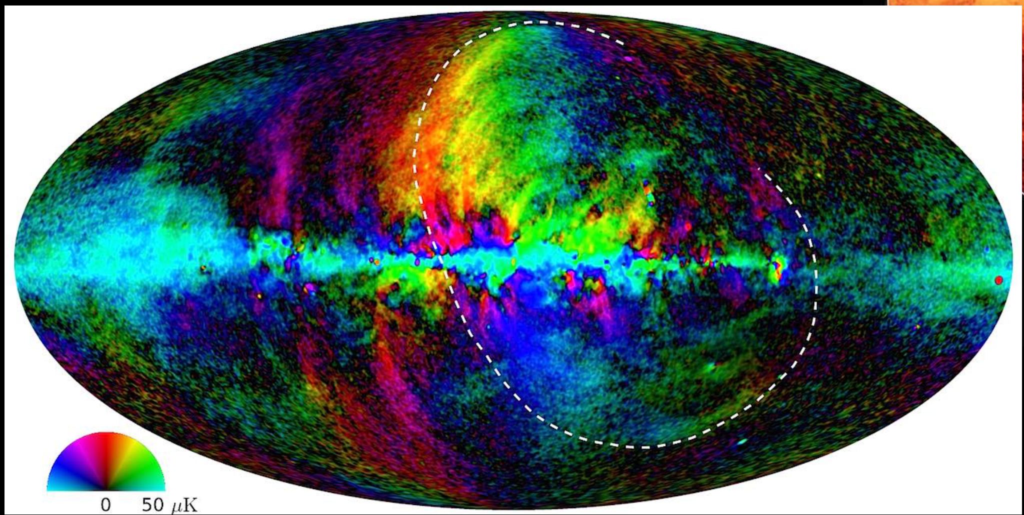
Between 2008 and 2012 the 2008 Fermi Gamma Ray Telescope gathered numerous samples of the radiation emitted when gigahertz-level protons collide with other protons. The reaction produces a neutral pion, which decays almost instantly into two gamma-ray photons. Analysis showed that supernovae shock shells are the only places where protons can be accelerated to such high energies.

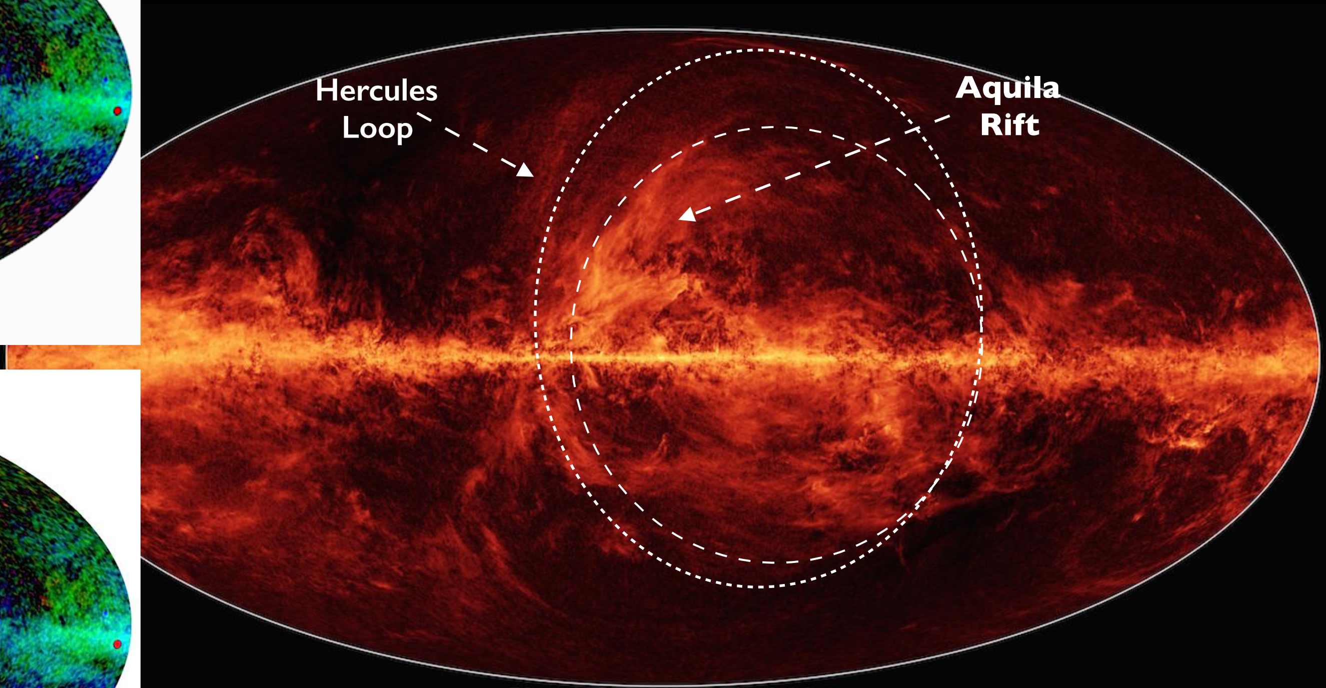
Cosmic rays were first observed by Victor Hess in the early 20th century. A five-telescope imaging array in Namibia was named the H.E.S.S. telescope in his honour. Source: Physics World.

The ubiquity of cosmic catastrophes

The Milky Way's dust was one of the three main interferences astronomers had to remove while mapping the Cosmic Microwave Background (CMB). The other two were stars and galaxies. While astronomers were processing the Planck 353, 545, and 857 GHz polarisation data, they made a number of significant discoveries. They were able to trace for the first time the full extent of the Hercules Loop and the Aquila Rift. They seemed immense. What could they possibly be?

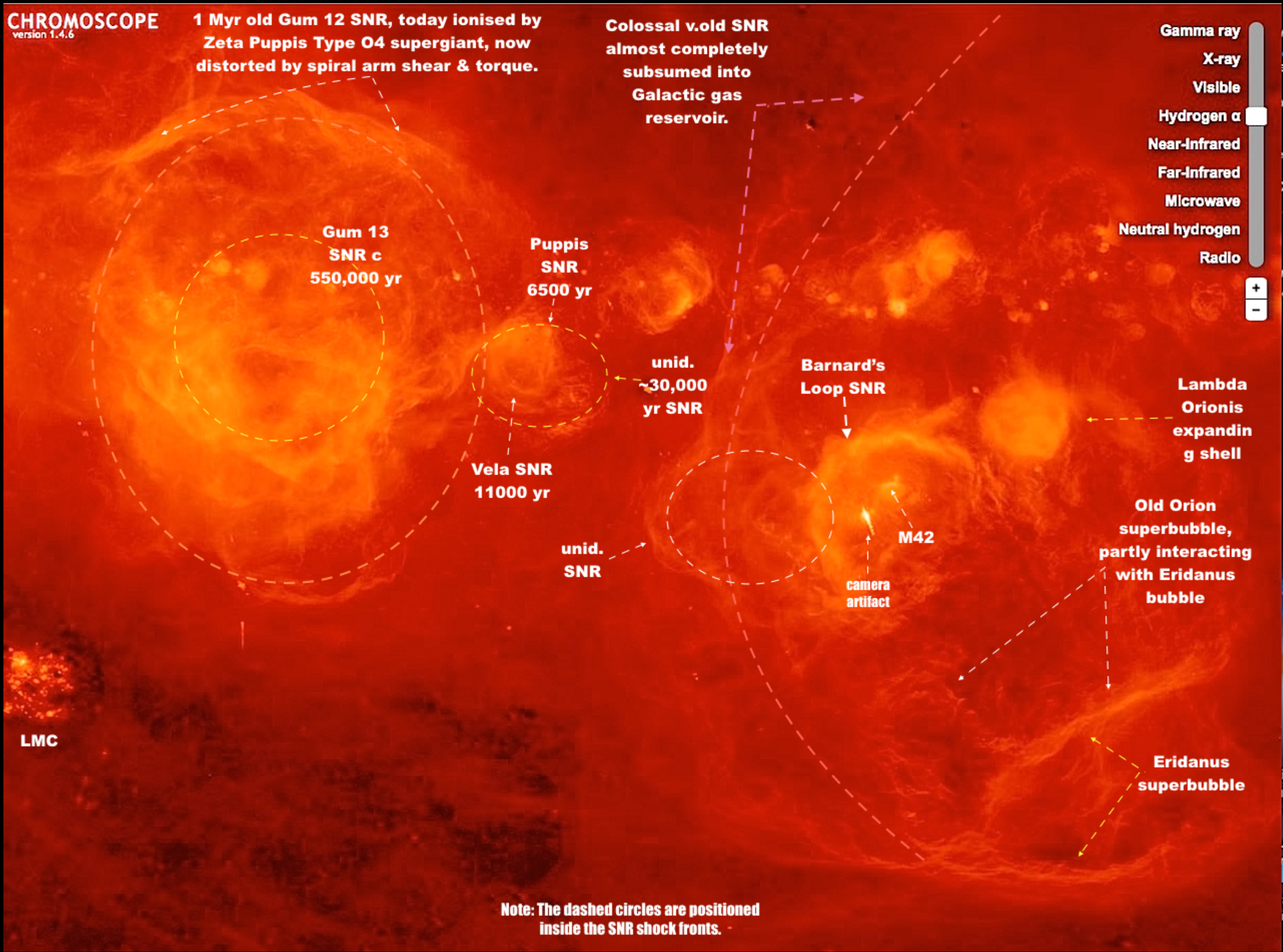






Planck 353 GHz Gaactic dust

This composite image shows that the Hercules Loop and Aquila Rift are streamers of dust and neutral hydrogen blown into expanding shells. The astronomers traced their original supernovae to a region of the sky centred on the Scorpius-Lupus–Crux star forming complex. The two distinct loops were obscured by numerous chaotic filaments of Galactic dust whose polarisation was revealed in the 2015 Planck data.

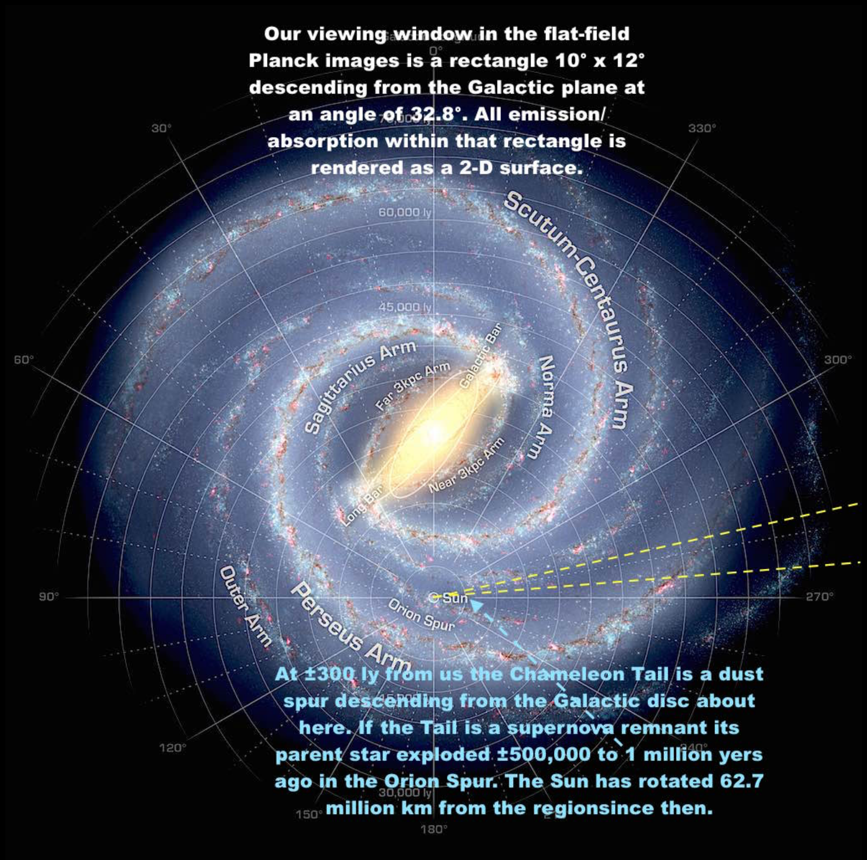


The giant molecular clouds which produced the Vela supernovas remnant (left centre) has been serving them up steadily for up to a million years or more. Vela is a relative youngster at ~11,000 years old. This field covers approx. 40° x 35° on the sky.

There are two constraints in our use of Planck and Chromoscope images such as the previous page to depict electromagnetic events in their fields of view: *scaling* and *flat-fielding*.

Scale: The spectral line images used in this part of the article embrace different-sized areas and are scaled to different map projections, Aitoff and Mercator. The Planck images are Aitoff in Planck-derived images and modified Mercator in the Chromoscope images. The Planck images are particularly misleading. They view the Galaxy as a 2-D surface seen from off to one side. This is called **Flat-Field** effect.

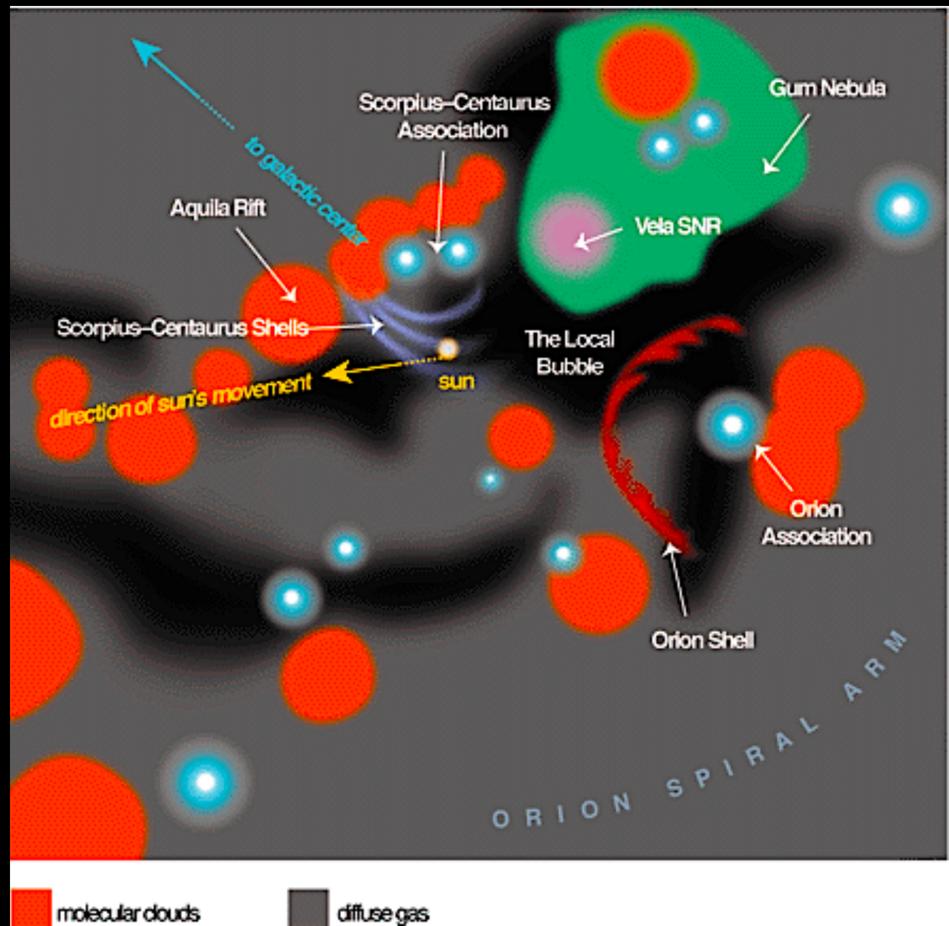
The Planck mission was devised to measure these exact temperature of the CMB over the entire sky because so much of what we know about the universe—visible and dark matter, visible and dark energy—hangs of the patterns in those tiny variations. The 353 GHz line we refer to is the primary wavelength of light emitted by magnetically charged dust particles. What we are describing as 353 GHz polarisation lines are actually patterns in the distribution of magnetically charged dust.



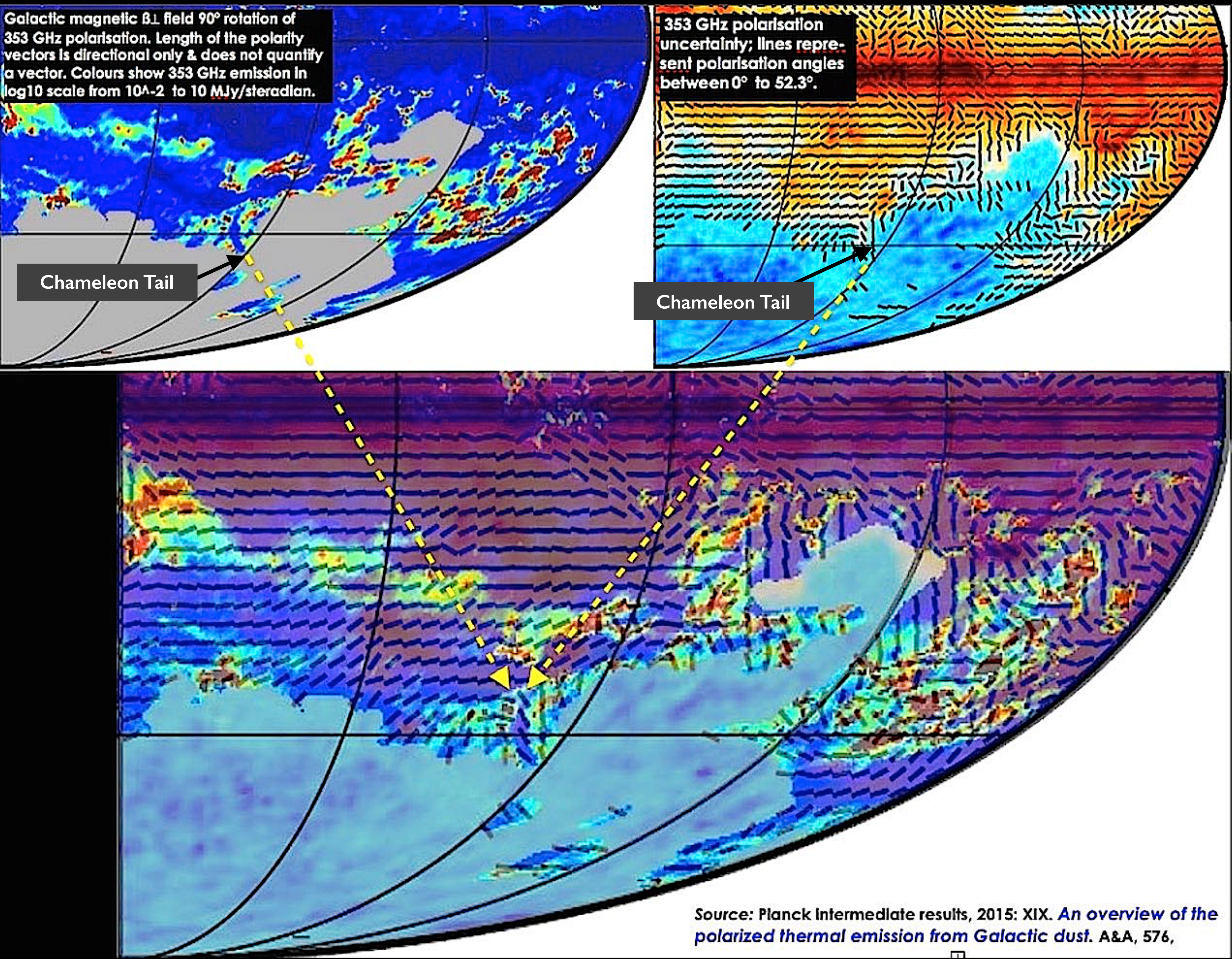
The 353 GHz map is especially useful for spotting large-scale features which aren't easily visible in other bands. Look at the size of the Hercules Loop and Aquila Rift above—they seem as big as the Galaxy. We have no way of knowing where or what size these features really are. The Hercules Loop and Aquila Rift loop across what appears to be half the entire Milky Way.

Alas, no. The dazzling red and yellow hydrogen alpha map on the previous page shows a small section of the sky centred on the Vela Supernova Remnant. (

Where exactly *are* the Hercules Loop and Aquila Rift, anyway? To cut to the chase, here is a map made by Priscilla Frisch of Princeton University that introduces us to our neighbourhood. The fearsome-looking Aquila Rift is actually a run-of-the-mill supernova remnant quite close by. Its position near the sun makes it seem sky-high and galaxy-wide. Perspective is false impressions appearing to be real,



Hints from magnetic memory



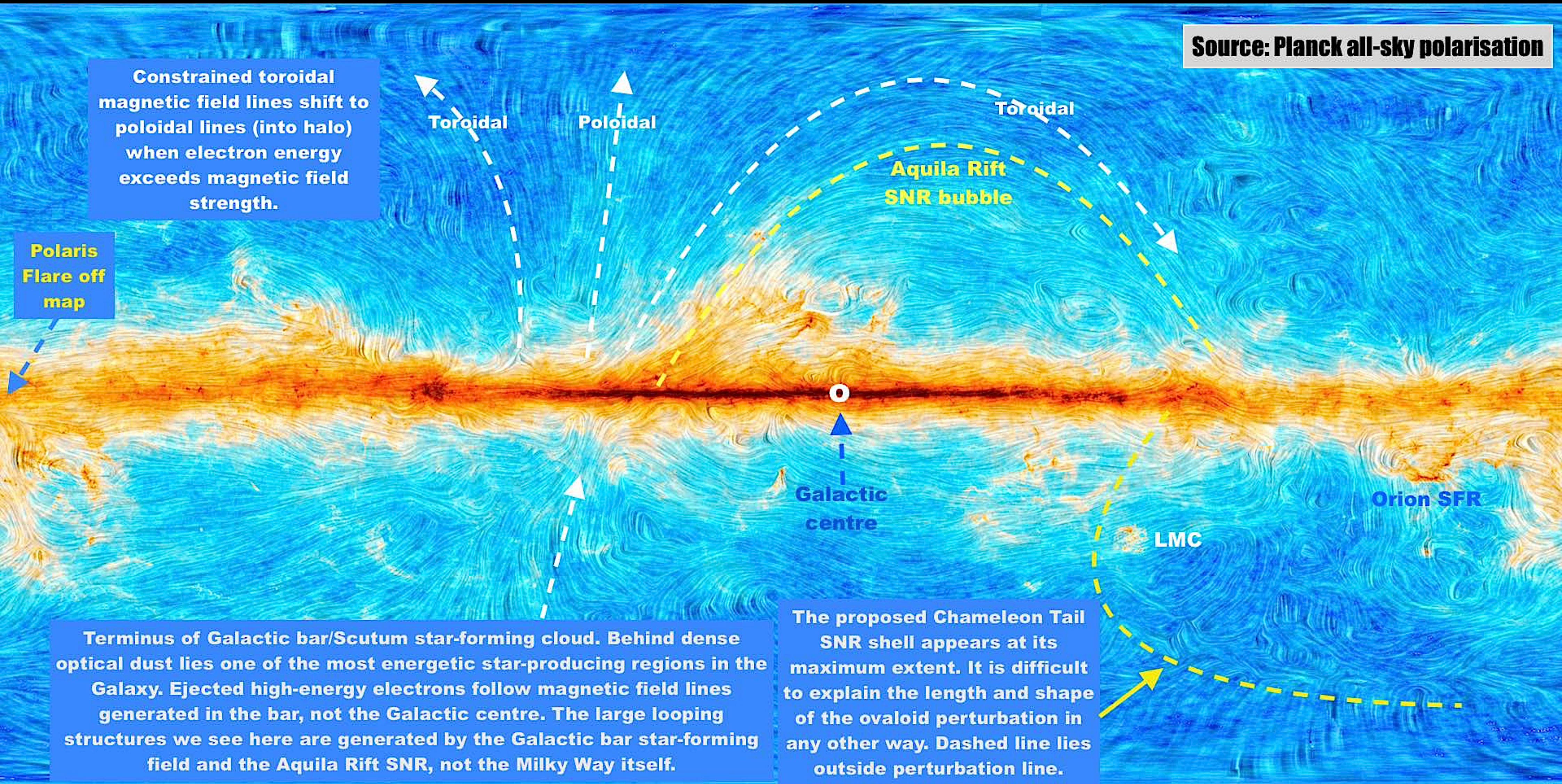
Source: Planck Intermediate results, 2015: XIX. *An overview of the polarized thermal emission from Galactic dust.* A&A, 576,

The most striking enigma of the Tail is why it does not have a readily detectable energy source; there is no obvious driver. The moderately energetic Chameleon I, II, & III star-forming region appears as the dusky brown mottled patches near the top left edge. The Chameleon Tail erupts at a point ~1.5 times the diameter of the Chameleon star-forming complex. That puts the Tail well outside the Cham I–II–III virial radius.

High-resolution optical, Swift X-ray, and Chandra gamma band images show no extended high-energy sources in this location. In the lower-energy bands, FIR, mm/μm, and 21 cm neutral hydrogen all show the jet-like morphology, but do not suggest any 'hot spot' activity at any point along its length.

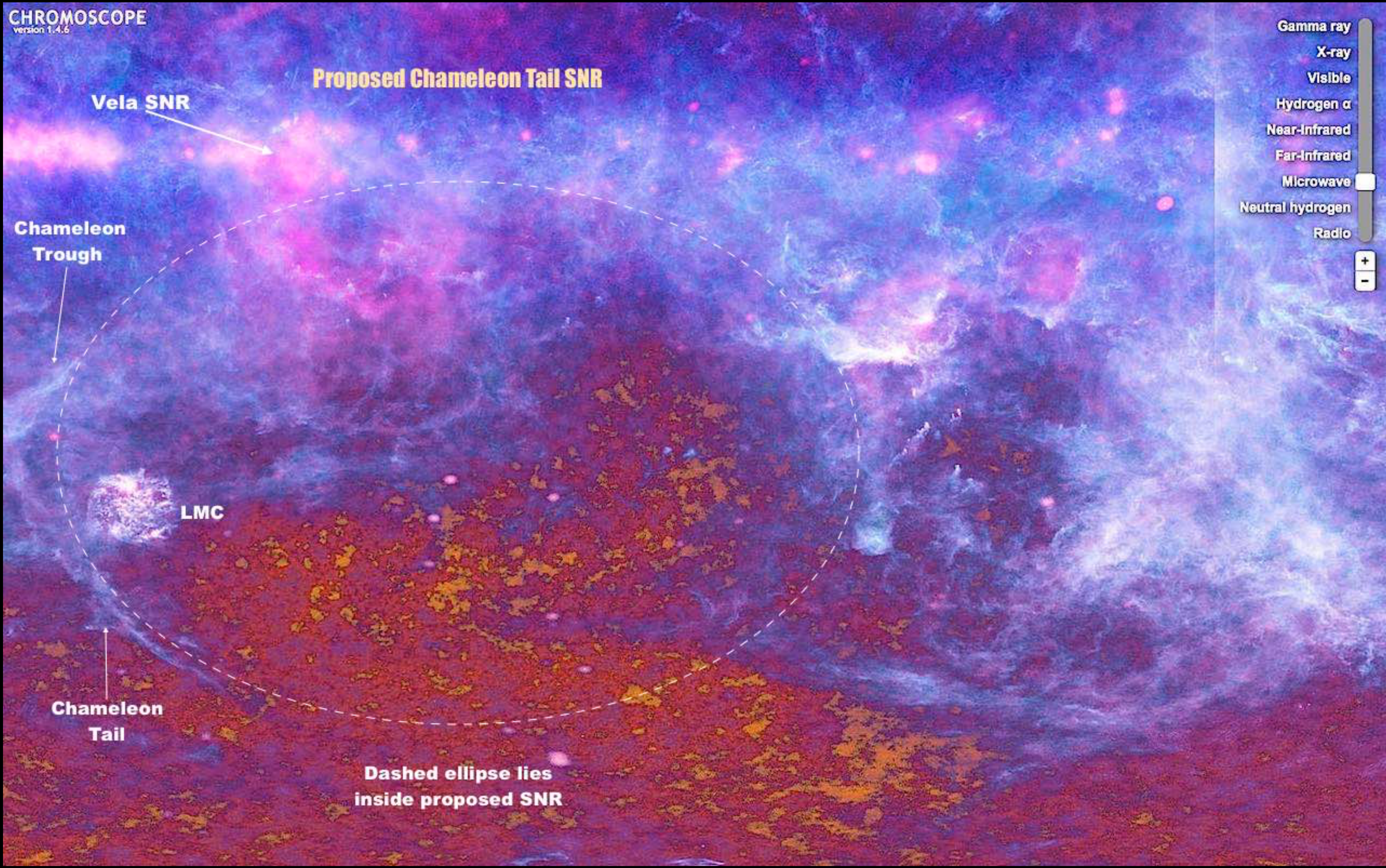
A clue to the Chameleon Tail's aetiology is shown in the upper right image. The anomalous shift in the field line directions lies directly atop the observed Chameleon Tail dust feature (slightly offset for clarity). This suggests that the magnetic anomaly might be a dissipating shock wave from an ancient supernova.

Scaling the Chameleon Tail to the Galactic context



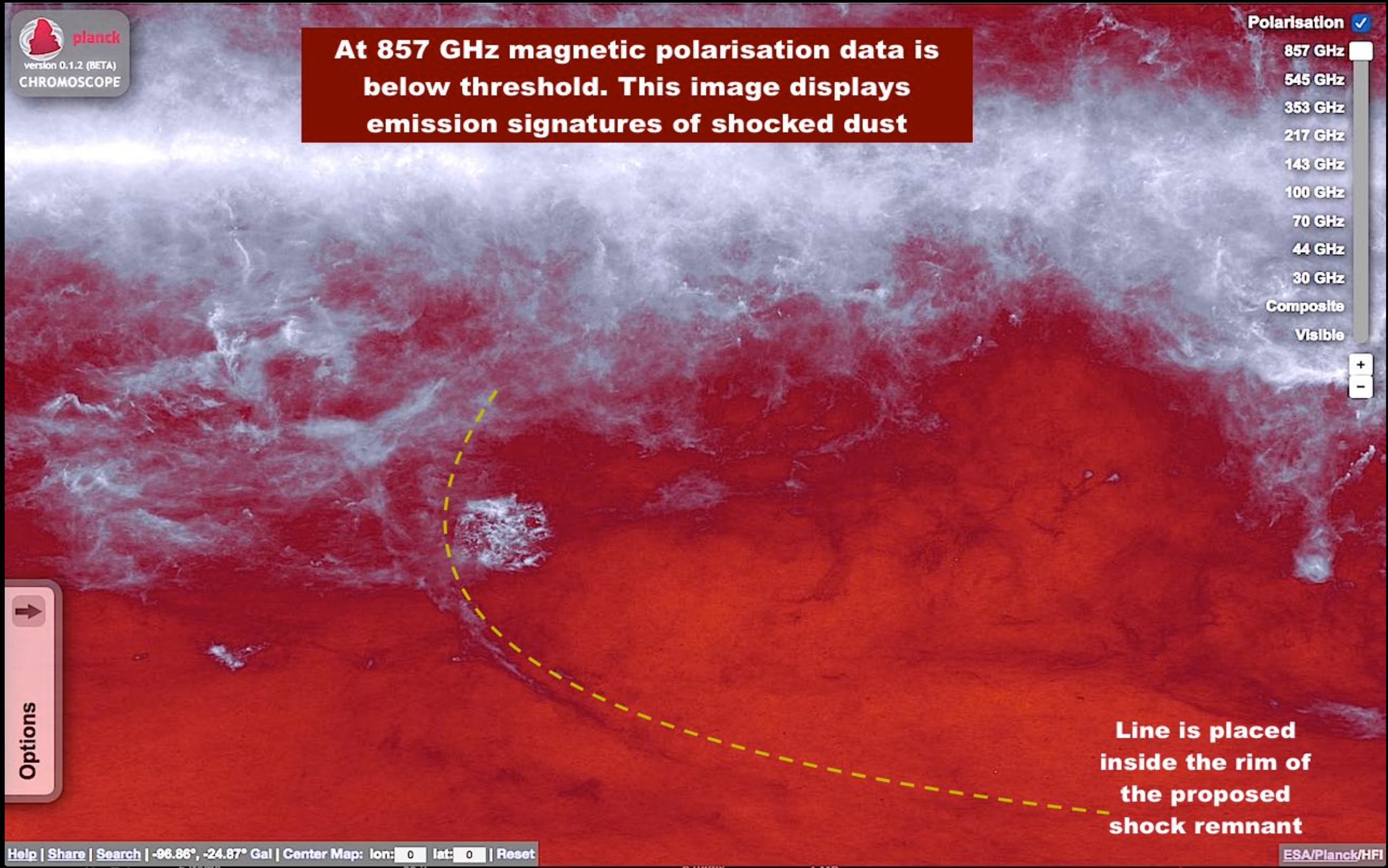
Watch this overview of magnetic fields from Planet Earth to the large-sale structure of the Cosmic Web.

Is the Chameleon's Tail a relict shock wave?



All Planck images used in this article are provided by Chromoscope and Planckscope, Cardiff University Wales Astronomy and Astronomy Instrumentation Groups. For a 3-D fully interactive rotatable model of the CMB as a spherical surface see CMB.org.

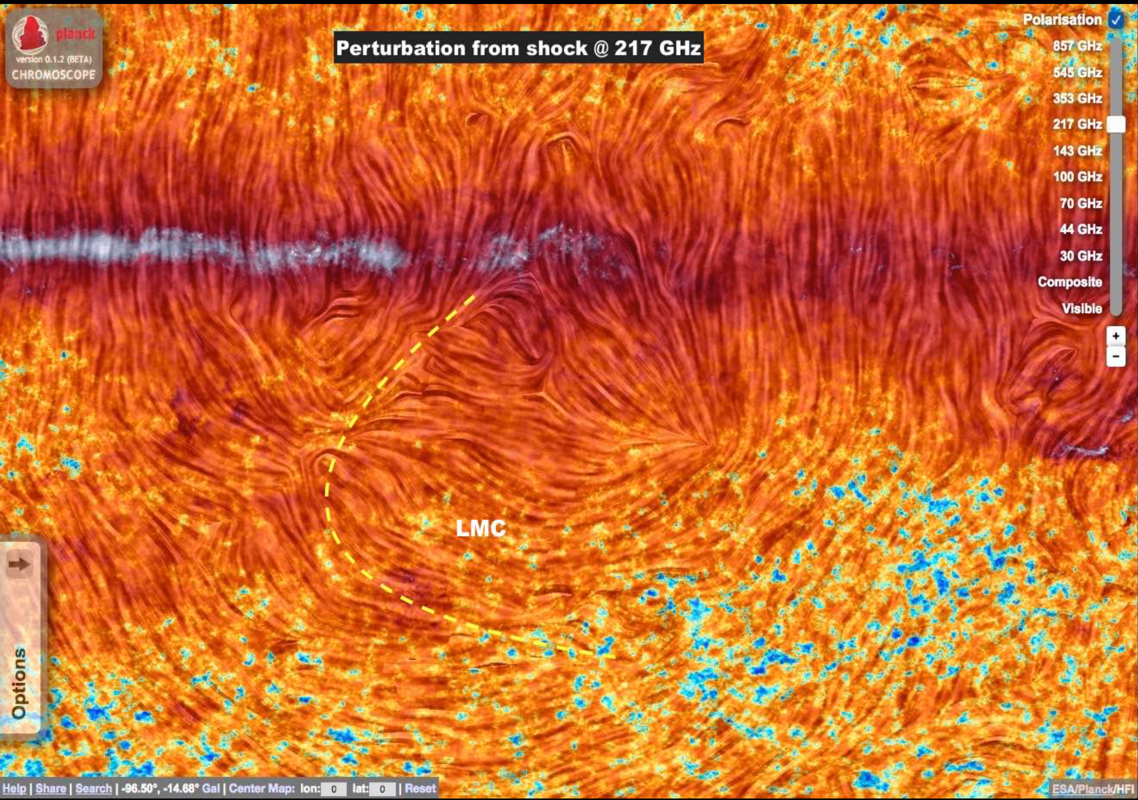
Polarisation signatures in the Galactic 240° to 290° quadrant

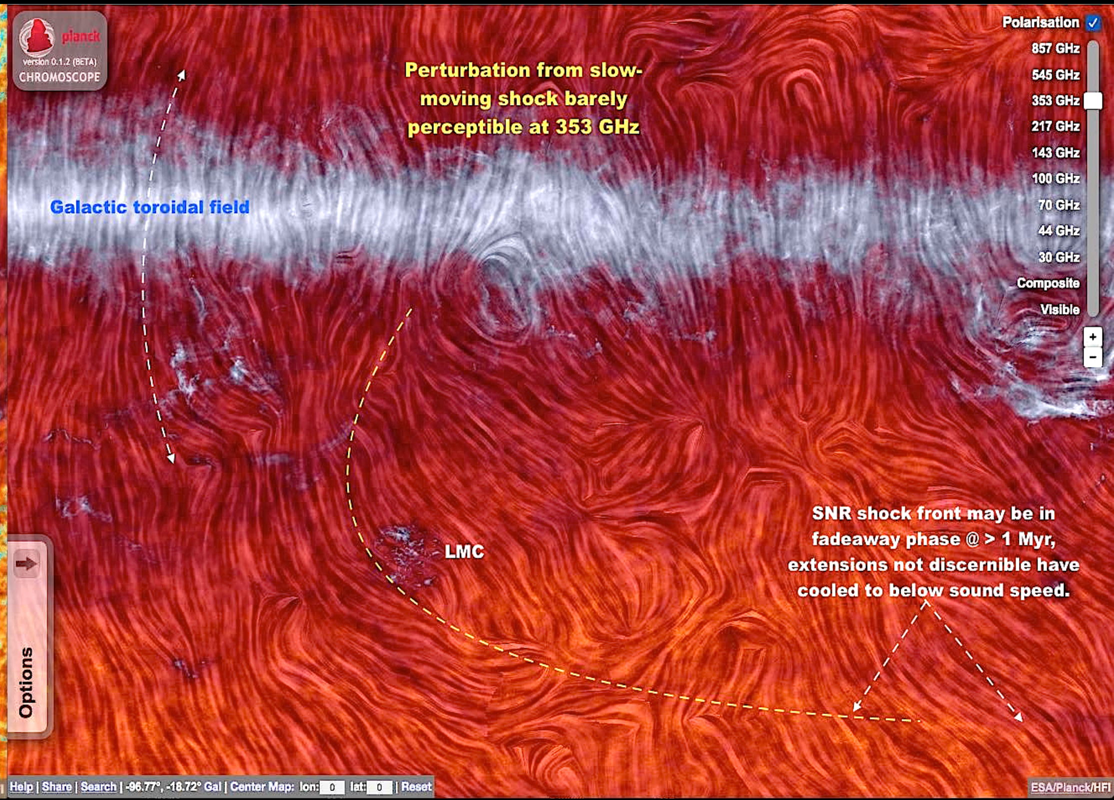


The Chromoscope, Planckscope, and CMB.org research pages are colour-coded based on data from these websites:

- Gamma ray (Fermi),
- X-ray (ROSAT),
- Optical (DSS/Wikisky),
- H-alpha (WHAM, SHASSA, VTSS, Finkbeiner),
- Near Infrared (WISE),
- Far Infrared (IRAS),
- Microwave (Planck),
- Neutral hydrogen (HI4PI)
- Radio (Haslam).

Inconclusive evidence from narrow-band polarisation data

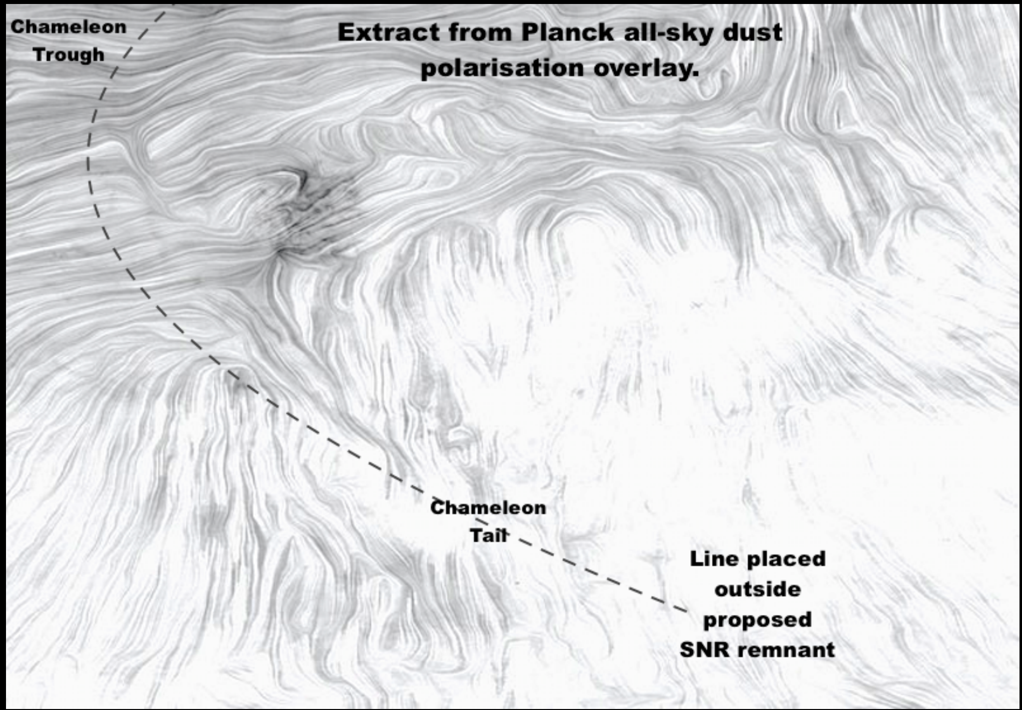




The 217 GHz and 353 GHz millimetre bands trace polarisation attributed to magnetically aligned dust grains. Both images indicate some degree of disturbance to the dust in and near the feature we suggest may be the relict shell of an ancient supernova. Any direct evidence of a SN shock compression wave passing through the region is somewhat vitiated by the flat-fielding property of the Planck imaging method. We really do not know which, if any, of the patterns in these two images are associated with the Chameleon Tail region. Recall that the longitudinal axis and strength of a magnetic field line is determined by *Faraday Rotation* and *Zeeman line splitting*. The numerical value of the rotation angle of a polarised line is a product of the magnetic flux density and the length of the path along which the light and magnetic field interact. It is probable that most of the writhing lines in these images is induced within our own nearby Orion Spur region.

Another important consideration when interpreting these maps is that the area of the sky which we study here is near the 270° Galactic quadrant as seen from Earth (the LMC is 280° –32.8°). We are looking longitudinally through a considerable amount of activity tangent to the Carina and Scutum-Crux arms. All those nasty-looking vertical field lines look like they are tearing the Galactic disc to shreds. In reality we are looking through 20- to 25,000 light years of disc matter, much of which is unassociated with the magnetic activity we see here at on;y 250 to 300 light years out. Our analysis is not helped by the direction of the spiral disc's ambient field. It is clockwise in the Orion Spur and Carina arms, but counter clockwise in the Scutum-Crux arm. We can readily see the region's overall magnetic activity, but we do not know where in the disc, in which arm, or in relation to which star-forming region any of these lines originate and terminate. Most of them are likely to be quite close by.

The whiff of suspicion falls upon dust



Cutout of the Planck Galactic dust overlay used to mask out dust emission/ absorption from the Planck composite data images. Since 353, 545, and 857 GHz spectral bands reveal Faraday Rotation in magnetic field lines, we can see in this cutaway that layers of Galactic dust (aka "cirrus") have been perturbed by what looks like a pressure wave. Given the seeming elliptical shape, a plausible candidate for the perturbation is a shock wave from an ancient supernova passing through this field of view. Is has weakened over time and significant portions have gone subsonic and dissipated, leaving no evidence. For whatever reason, this fragment is still mildly supersonic shock perturbation in the local gas/dust field.

Certain types of dust particles have a dipole moment because they are longer than they are wide, hence one or the other end is electrically charged. A particle with an electric charge aligns itself perpendicular to the ambient magnetic field in its vicinity. That lies behind the directionality of these long filament-like features.

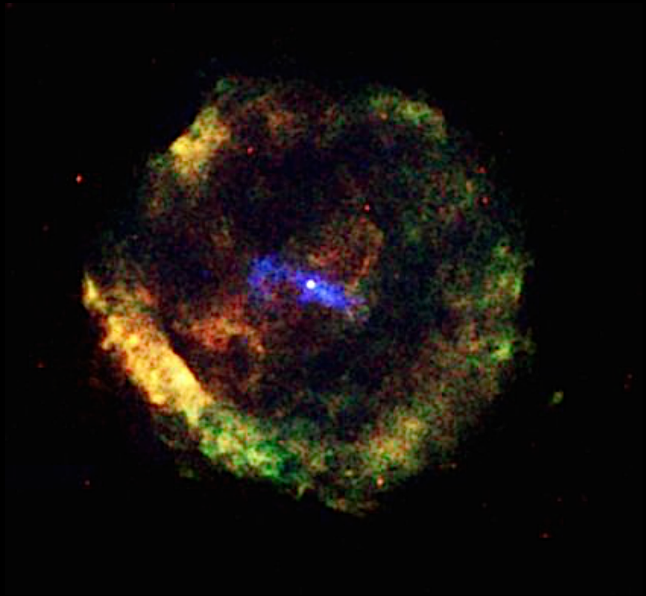
DIY cosmology

The complete set of image maps from all of the Planck narrowband slices are available for study on the *Planckscope* website. The slider bar in the right side brings up the map made with the data Planck collected with its detectors tuned to that GHz band. Notice the "Polarisation" box at the top right. Toggle it a few time to see how the striated or blotchy patterns in each image show the effect the magnetic field has on incoming photons in that wave band. The photons originate at a unknown distance between the detector's surface and the end of the visible universe.

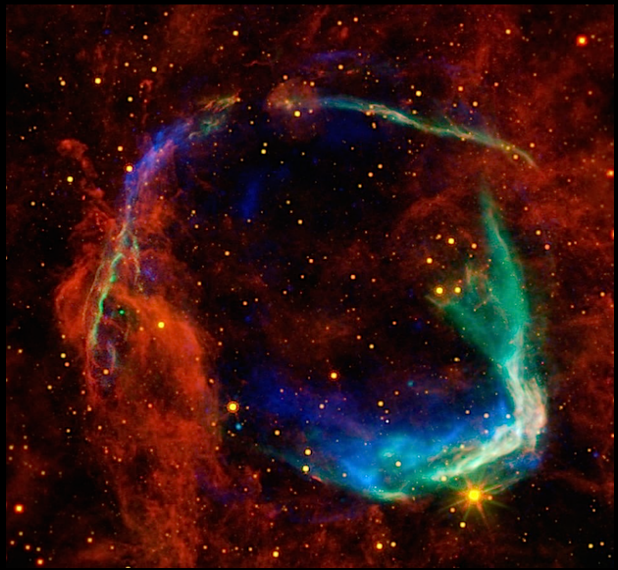
That may seem extravagant, but it is a fact: the Planck mission was configured to record the number of photons reaching the detector surface that originated anywhere along the line of sight between the detector and the CMB. In reality, most of these photons originate within our own Galaxy. But small, even incremental, numbers of photons set out from quasars, pulsars, remote galaxy clusters, and other far-sky objects. However little light they contributed, it had to be nulled out for the Planck CMB to be as exact as possible.

It is worth the serious astronomy enthusiast's time to peruse the entire *Planckscope* and *Chromoscope* all-sky maps. Don't neglect to click the arrow on the "Options" menu lower left. A slider bar pops out with every user aid the map's compilers felt users at all levels would be likely to need. If you find yourself getting lost, click on "Constellations" and "Labels".

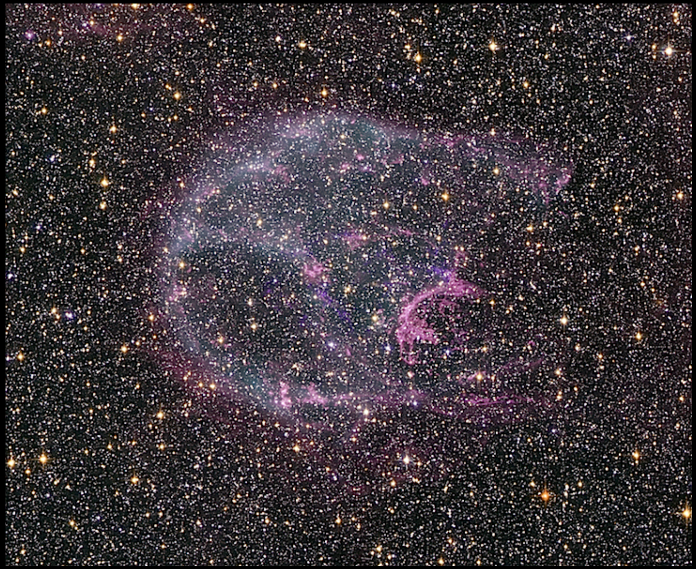
Examples of dissipating SNR shells



The supernova remnant G11.2-0.3 in Sagittarius is a energetically asymmetrical ring that contains a dense, rotating dead star at its centre, This image is a textbook case of what the remnant of an exploding star can look like after a thousand years. The asymmetry here can be traced to an off-centre detonation. Other causes for an irregular like this are a nearby binary or uneven interstellar medium density. Source: *Chandra*.



This composite Chandra and and XMM-Newton X-ray image of RCW 86 reveals a misshapen expansion ring formed when the expansion wave moved into a region with significant large-scale turbulent shocks and gas density inhomogeneities. When turbulent shock shells interact with each other they produce thin, dense, high-temperature surfaces (upper & lower right quadrants) that do not readily lose their energy. The diffuse ring on the left is thinner than it looks because we are gazing tangentially through a ring of gas in the manner as with the Veil remnants. Here low energy X-rays are in red, medium energies in green, and high energies in blue. Tempting as it is to view this as a flat plane between us and the galaxy stars, in 3-D it is misshapen balloon. The properties of the shell along with the remnant's size were used to determine the age of RCW 86 as ±2,000 years old. This age matches observations of a new bright star recorded by Chinese annalists in 185 A.D. Source: *Chandra.*



This composite from NASA's Spitzer Space Telescope and Chandra X-ray Observatory shows a remnant known as N132D in the Small Magellanic Cloud. In this image, infrared light at 4.5 microns is mapped to blue, 8.0 microns to green, and 24 microns to red. Broadband X-ray light is mapped purple. The remnant itself is a wispy shell of gas which appears to have a second, smaller, denser SNR ring in lower right centre. The pinkish colour reveals an interaction between the explosion's high-energy shockwaves and surrounding dust grains, producing temperatures in excess of 1 million K and as high as 10 million K. Bleeding off energies that high in a low-density gas medium can take 100,000 to a million years

Outside of the central remnant organic Polycyclic Aromatic Hydrocarbons (PAHs) are coloured in hues of green. The blue dots are stars that lie along the line of sight between Chandra / Spitzer and N132D. Source: *Chandra*.

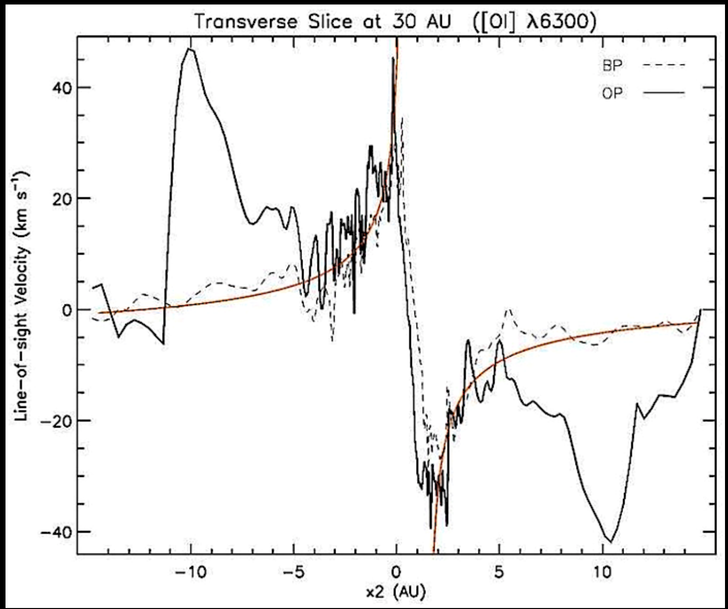
What further evidence do we need?

We have taken this quest as far as we can with the data resources available on the Internet. We are lacking key information about the Chameleon Tail that has not yet been acquired.

There are pluses and minuses to the proposition that the Chameleon's Tail is a feeble remnant from an ancient supernova. If we are to confirm one way or the other that the proposition has any merit, the Chameleon's Tail needs a closer look.

As always in astronomy, we need better data. There is little enough information in the literature about the dust composition and distribution in this part of the sky, yet it is straightforward to determine through CO, CIII, CIV, OVI and OVII absorption studies. This can be done with metre class and greater telescopes here on Earth.

The list of desirables (Desiderata) follows in the next column. Ideally, the plots to come out of these studies would look something like this:



This cross section of the velocity structure in a toroidal protostellar jet is modelled in *Staff 2010*. This is what we would like to see for several cross sections and one longitudinal section of the Chameleon's Tail.

Desiderata

- Gas/dust velocity dispersion along the full length of the Tail.
- Gas/dust velocity dispersion along four planes normal to the Tail's axis
- Faraday rotation in the central core of the Tail's jet-like feature
- CO, H1, alpha-element, OH, H_2O SED in four lines normal to jet axis and one line along the axis of the Tail.
- Dust density gradients in 4 planes normal to Tail's axis.
- Gas composition in 4 planes normal to the jet, bisecting the "Bird in Space" feature, and one line normal to each "wing".
- Magnetic field lines along outer edges of the Tail.
- SiO [5→4] outflow tracers (*Zapata 2009* & *Klaassen 2011*)
- Evidence of H_2O and HO masers in the "Bird in Space" wings to determine whether they may be molecular rings seen edge-on.
- Determine whether there is helical rotation along the Tail which would suggest toroidal braiding (*Fendt 2000 p.10*).

With Chromoscope and Planckscope, the Cardiff University Astronomy and Astronomy Instrumentation Groups in Wales have giving astronomy enthusiasts from beginner to Pro-Am a most useful cosmology tool for understand how the universe looks and works.

Electronic editions are available free of charge from the *Deep-Sky Observing Section* of the Astronomical Society of Southern Africa, Observatory, Cape Town.

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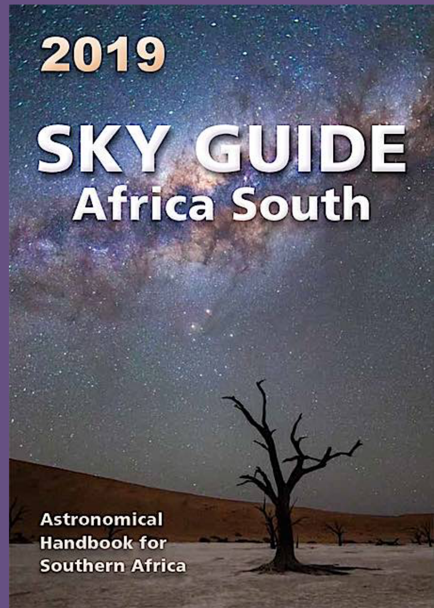

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