JULY 2025
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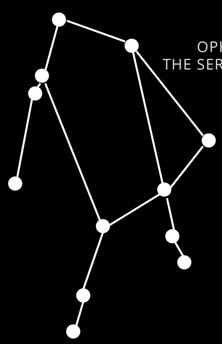

ASTRO DIGEST

LUPUS LIGHTS THE WAY

A COSMIC LIGHTHOUSE BLINKS INTO VIEW. FIND OUT HOW, AND WHAT WE STAND TO GAIN FROM IT.

TWA 7 B OR NOT TO BE?

WEBB SAYS IT IS! GET A RARE GLIMPSE INTO THE EARLY EVOLUTION OF PLANETARY SYSTEMS!

SO WHAT REALLY IS DARK MATTER?

ILLUMINATING LIGHT INTO DARK MATTER. YES, YOU READ THAT RIGHT.

TRIVIA

BECAUSE THE UNIVERSE LOVES TO KEEP US GUESSING!

EVENTS & STARGAZING

FEATURED STARGAZING LOCATION & OBJECTS

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LUPUS LIGHTS THE WAY

The cosmic curtains have drawn once again to reveal a divine gem. A stellar explosion designated V462 Lupi went off in the southern sky. Effectively, a new star has temporarily appeared in the heavens. Normally, the star system responsible for the explosion is much too dim to be visible to the unaided eye. Having come into visibility on 18 June, it continues to hover around visibility through late June, maintaining an apparent magnitude of 6.

ARTIST'S DEPICTION OF V462 LUPI'S STELLAR EXPLOSION.
The star becomes millions of times brighter during the explosion, before dimming back to quiescence as the accreted surface layer is blown away.

Is this a supernova?

Unlike supernovae which are the type of stellar explosions you are probably more familiar with, V462's explosion is much more modest, in both energy output and nature.

For one, it leaves the stars involved completely intact, with only material from the outer layer getting blown off. Supernovae on the other hand result in a complete or almost complete destruction of the star. Secondly, supernovae are typically so bright, they outshine their host galaxy. V462 Lupi's type on the other hand are about ten million times dimmer – certainly a cosmic contrast! The word 'super' is thus redacted for these types of explosions, being called merely a nova.

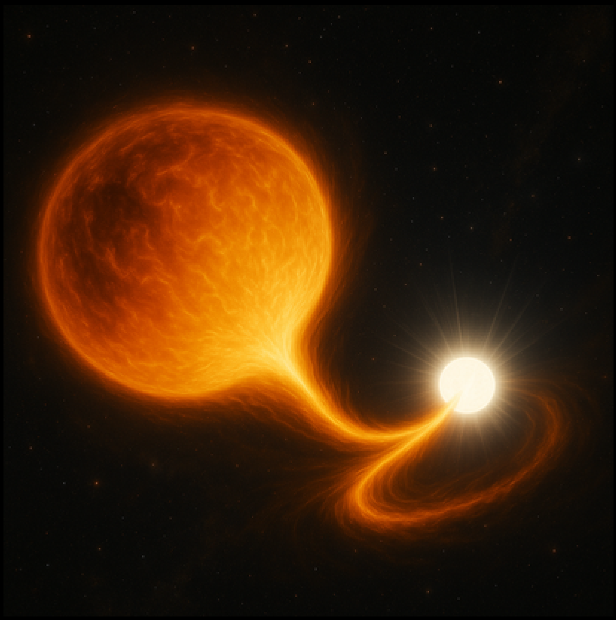
What's the story?

V462 Lupi is a binary system, home to a white dwarf and a companion star tied together in an extremely close orbit. Its orbital period is merely 1.797 hours. Put differently, by the time you finish your essay, the white dwarf and its companion star will have already finished an orbit! This also means that tidal interactions between the 2 stars are significant. This latter process is precisely what is responsible for the nova as we shall now see.

For novas to occur, mass transfer is required from one star to another. This happens when the companion star expands to fills its Roche Lobe. This occurs due to a gravitational force differential across its near and far end with respect to the white dwarf.

LUPUS LIGHTS THE WAY

To understand this in-depth, check out the article 'Double Trouble' in our previous newsletter.



DEPICTION OF MASS TRANSFER FROM THE BINARY COMPANION TO THE WHITE DWARF.

One might wonder why the converse does not occur, i.e. mass transfer from the white dwarf to its companion. This is because the white dwarf's surface gravity is far greater, and hence it does not expand and fill its Roche Lobe. Therefore, it remains intact.

Consequently, matter starts to transfer from the companion to the white dwarf, whose surface temperature and pressure start to rise. Bear in mind that the white dwarf's surface was already hot at about tens of thousands of kelvins and dense before this process ensued. As hydrogen accretes on the white dwarf's surface, the base of this layer reaches a temperature sufficient for thermonuclear ignition. This happens to be about 10 million K.

Put in other words, the hydrogen ions start to fuse into helium, releasing even more energy. It is not difficult to see why this process would be explosive, similar to setting gunpowder ablaze; the fusion process releases heat, which further increases the rate of fusion of the surrounding hydrogen ions in a positive feedback. The hydrogen envelope is thus explosively blown off the white dwarf's surface, the accretion process and nova. All in all, novae reach an average peak luminosity of about 100,000 times the Sun's. In the case of V462 Lupi, it brightened by about 4.4 million times compared to its initial brightness!

Furthermore, this also implies that in its quiescent stage, V462 Lupi is much dimmer than the Sun. This is to be expected based on what we know about the star system. The white dwarf in the star system, by its small size, is very dim. The companion star on the other hand is slightly trickier. It happens to be a protostar, with a thick gas and dust cloud shrouding and severely dimming its brightness.

With that, we get a much clearer picture of this star system – a protostar and white dwarf binary system, where the latter accretes matter from the former and periodically undergoes a nova.

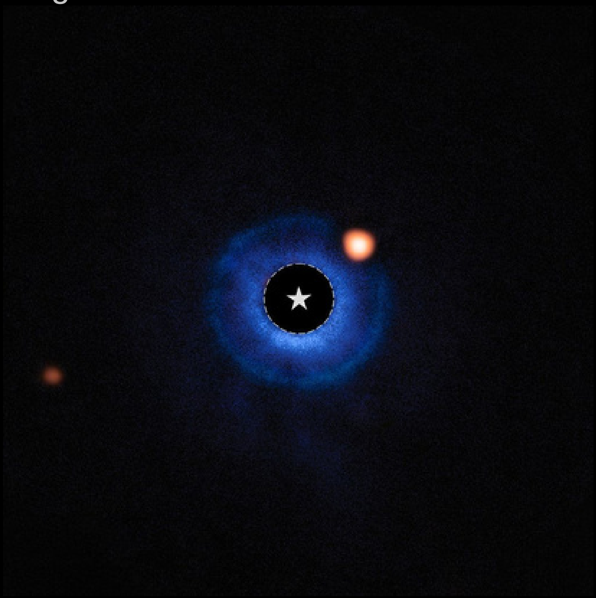
LUPUS LIGHTS THE WAY

Ultimately, this discovery marks a remarkable trifecta — a nova and a protostar coexisting in the same system, and bright enough to be seen with the unaided eye. It will certainly be incredibly exciting to see how this discovery is going to advance the frontiers of stellar evolution and astrophysics. Until then, keep looking up!

EXAMPLE OF A PROTOSTAR SYSTEM. SOURCE: NASA, ESA, CSA, STSCI
This particular one is enshrouded within the molecular cloud L1527, showing material being ejected from two poles in the signature hourglass pattern. Of course, it was captured by the James Webb Space Telescope.

TWA 7 b OR NOT TO BE?

The James Webb Space Telescope (affectionately called Webb) stubbornly continues to remain in the spotlight, with yet another major discovery. This time, it isn't extremely distant, early galaxies. Quite the contrary, in fact, as the finding lies in our own galaxy, a mere 110 light years away. More so, this finding is again a testament to Webb's instruments' sensitivity, which beats the previous discovery by an order of magnitude.

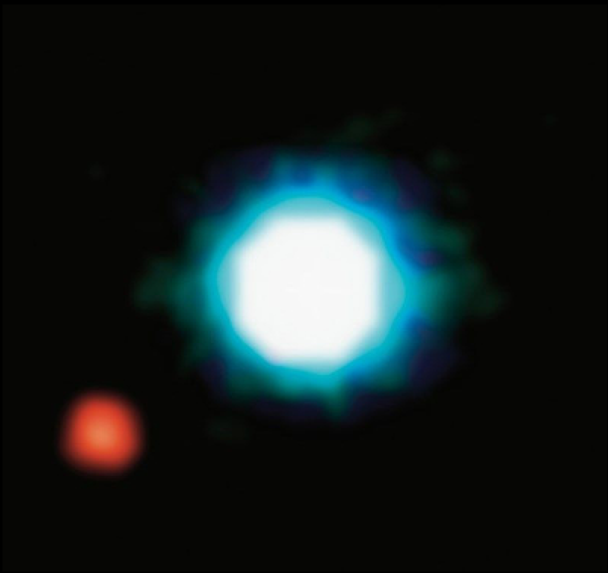


LO AND BEHOLD, THE IMAGE! SOURCE: NASA, ESA, CSA, ANNE-MARIE LAGRANGE (CNRS, UGA), MAHDI ZAMANI (ESA/WEBB)
The host star was blocked off using a coronograph as it strongly outshines its orbiting exoplanet. The exoplanet itself is seen as a bright orange dot in the first quadrant. The dim orange-red dot on the left of the third quadrant is an unrelated background star.

Orbiting its host star TWA 7, the planet TWA 7 b happens to be Webb's first direct image of an exoplanet. Naturally, this phrasing 'direct imaging', which you have probably seen elsewhere on astronomy news sites, is vaguely confusing – what even would an indirect image be, and does the preceding statement imply other exoplanets have already been observed by Webb? The answer to the latter question is easier – yes. Outstandingly, Webb has confirmed the existence of over 100 exoplanets! To answer the former, there are many ways to observe an exoplanet without directly imaging it and which are often much easier to carry out compared to direct imaging.

But, we digress – what makes this observation especially fascinating is the smallness of TWA 7b, which clocks in at about three-tenths the mass of Jupiter, or about 100 Earth masses. While this is thus still a massive planet, it falls much short of the mass range of directly imaged exoplanets. Usually, directly imaged exoplanets tend to be an order of magnitude greater in mass than this. This is simply due to the fact that exoplanets are extremely dim, and so only the largest and most prominent will be within the detectable range of most cameras.

TWA 7 b OR NOT TO BE?



THE FIRST IMAGED EXOPLANET, 2M1207 B. SOURCE: ESO
This exoplanet has 5 times the mass of Jupiter and its surface boils at a blistering 1200 K. This high mass and temperature are typical of directly imaged exoplanets.

This is precisely where the full might and power of Webb's strength, its remarkable sensitivity, comes into play. To give you an idea of just how powerful the camera used to image TWA 7b is, NASA scientists said it could detect the heat signature of a bee on the moon from Earth!

What do we know about TWA 7b and its host star system?

Currently, we only know basic details about TWA 7b – it is a gas giant about the mass of Saturn, and orbits about 50 times the Earth-Sun distance from its host star. Not only is it much lighter compared to other imaged exoplanets, it is also cooler at about 500-700 K.

Its coldness is due to its host star, TWA 7 a.k.a. CE Antliae, which happens to be a modest M2 type red dwarf, which is relatively small at 0.46 solar masses and cool, sitting at about 3,500 K.

ARTIST'S DEPICTION OF TWA 7 B AROUND ITS HOST STAR.

It is also important to note that TWA 7 is a newly formed star, being merely 5-10 million years old – compare this to our own Sun, which is 5 billion years old. As TWA 7 is so young, consequently so is its protoplanetary disk, which contains TWA 7b. This star system's nascence implies that it is still very dynamic, in that TWA 7b could still be accreting mass from the protoplanetary disk. This is also apparent from the figure on page six, which shows the image captured by Webb. This adds yet another layer of scientific insight and excitement to the discovery, as it allows us to study planet-disk interactions like never before, given this system can be directly imaged.

TWA 7 b OR NOT TO BE?

What's next for TWA 7b?

The immediate follow-up would be to get a spectroscopic characterisation of TWA 7b to ascertain its atmospheric composition, temperature structure and presence of clouds. There are also plans to map and analyse the protoplanetary disk in which TWA 7b resides for signs of possible accretion or other planet-disk interactions. Moreover, it is also highly possible that there are other, fainter, exoplanets, and so the search for these too continues. If TWA 7 hosts a multi-planet system, this would greatly boost its scientific potential. This is because we would potentially get to observe its complex interplay directly and better understand early planetary system evolution.

Zooming out, one realises that the study of other star systems is a reflection of our intense drive to understand our very own, and a manifestation of our desire to find out what our place in the universe is and whether there are others like us out there. Planetary systems like those of TWA 7 help us in plenitude toward answering both these. It thus goes without saying that much effort is going to be put into studying TWA 7 and similar star systems, with prospective fruits beyond our wildest imagination.

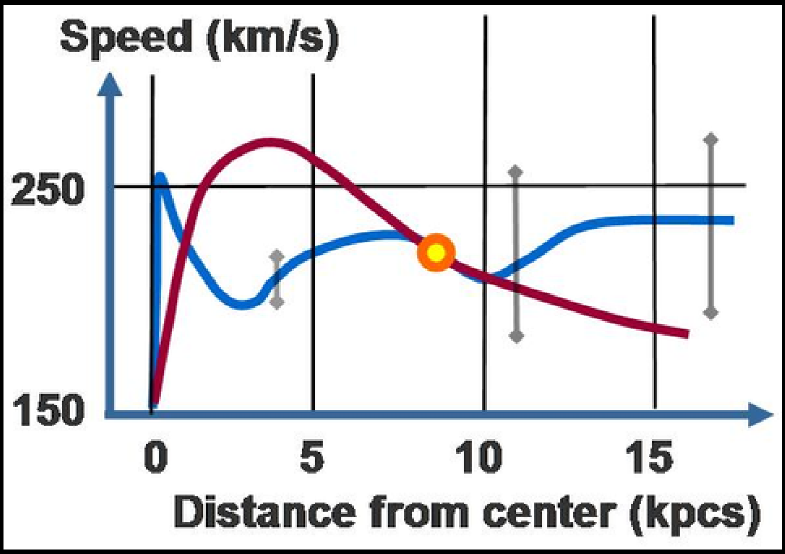
SO WHAT REALLY IS DARK MATTER?

How ironic it is, that dark matter, the invisible matter, as an idea is one of few concepts in astronomy that has spread beyond the confines of astrophysics and cosmology research papers and entered mainstream culture. Though its appearances in popular media is one greatly warped from its true reality, many are at least a bit familiar with it.

As many already know, its existence is only inferred from discontinuities between the observed behaviour of large-scale stellar interactions and our fundamental understanding of gravity. One example is the unusual speed at which outer sections of galaxies rotate. If we only consider gravity within galaxies coming from visible matter, the outer portions of galaxies should rotate slower as they experience a weaker pull to the centre.

The above observation suggests that there exists matter that we cannot see, that can interact with visible matter gravitationally; this is where most people's knowledge of dark matter's properties end. However, there are more implications from these observations, that explain more of its behaviour and sheds *light* on its identity.

If electromagnetic waves cannot interact with dark matter, as all our observations implies, dark matter is electrically neutral and so cannot interact with any particle electrically. This property is shared with neutrinos; in fact, some of the behaviour of dark matter is shared with neutrinos. Given this, it cannot behave in a way charged particles can. This property goes beyond being undetectable using light.



OBSERVED ROTATIONAL-VELOCITY CURVES OF THE MILKY WAY (BLUE) WITH PREDICTED ROTATIONAL CURVE SIMULATING VISIBLE MATTER

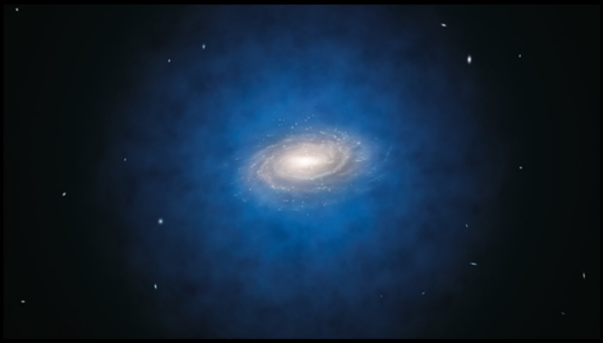
SOURCE: WIKIMEDIA

SO WHAT REALLY IS DARK MATTER?

This is why dark matter does not clump together the way ordinary matter does. Although it is gravity that causes particles to move together and approach a gravity well, it is mainly electric interactions in the form of friction and pressure that will cause particles of ordinary matter to lose their energy and clump together. Without this interaction, dark-matter particles will simply pass through the gravity well of other particles.

As such, dark matter is not distributed the way ordinary matter is: it will not come together to form large, bound structures; at most, dark matter will "orbit" around the center of a gravity well. Thus, it will loosely coalesce together with itself and visible matter, forming a general density around matter. In some perspectives, it will be better to see dark matter as a viscous medium that surrounds everything, it is everywhere around us, zooming through our bodies and everything around us, acting as a "dampener," keeping galaxies and large-scale structures together.

Given our assumption that dark matter does not interact with the electromagnetic field, and so can only interact via the nuclear forces which have a maximum effective radius similar to that of a proton, the probability that any dark matter particle falls within our detectors is incredibly small. A candidate of dark matter, the Weakly Interacting Massive Particle or WIMP, will only be able to interact via the weak force, similar to a neutrino. However, exists in far smaller quantities. Thus, as of present, no detection of dark-matter particles has been made, given our terrible odds, this can only be improved with better detectors.



ARTIST IMPRESSION OF DARK MATTER DISTRIBUTION WITHIN THE MILKY WAY. SOURCE: ESO/L. CALÇADA

SO WHAT REALLY IS DARK MATTER?

In this entire article, I have referred to dark matter as a particle. However, there is no irrefutable evidence of this. It is simply an assumption that the mismatch between theoretical and observed models of visible matter is caused by an excitation in a yet undiscovered quantum field, everything we know has always adopted this form and so all the information in this article thus far has been going off that assumption. An alternative to dark matter as an explanation of this mismatch is a theory of modified gravity that contains a component that becomes significant as we look at large scale structures and larger speeds.

SCALE OF LZ DARK MATTER EXPERIMENT DETECTOR. SOURCE: LZ COLLABORATION

Recent observations have cast doubt on the theory of modified gravity; observations of binary stars with large orbits where modified gravity should become significant do not yield a noticeable deviation from gravity as we know it. However, science should not only be concerned with theories with the most evidence: it was only a few centuries ago that heliocentrism was seen as a hinge theory lacking evidence. Galileo's proof for heliocentrism lacked scientific rigour and observational evidence. However, it was because such fringe theories were entertained that we were able to better understand our universe. As such, it is only with more work, better techniques and better detectors, such as the LZ Dark Matter Experiments can we be sure of our previous works and findings, the road to knowledge has no end!

TRIVIA

Welcome to the Trivia! Here, we will include interesting facts and problems that we have curated for you, the reader.

The answers to the problems can be found in the next newsletter, but for now, we hope you'll enjoy this new segment!

Problem I

Suppose there exists an infinitely extensible bridge connecting Earth and the Moon. If the Moon were to drift away from Earth at a constant speed of 1 m s^{-1}, and you placed an ant on the bridge walking toward the Moon at 1 cm s^{-1}, would the ant ever reach the Moon? If yes, calculate the time it would take. If not, provide a proof.
Initial Earth-Moon distance = D_0

Problem II

Picture this: You are a navigator on a naval voyage for a diplomatic mission in the late 1400s. What astronomical methods are you using to navigate the high seas?

TRIVIA

Fun Fact of the Month

If the universe is more than $10^{10^{29}}$ meters wide, there is bound to be a replica of you somewhere.

At the very least, this is guaranteed by MIT physicist Max Tegmark.

ANSWERS FOR THE PREVIOUS NEWSLETTER

Problem I

M53 (left) and M3 (right)

Problem II

Roughly 1 day to a few days. This is because very little energy is released in the fusion of silicon to iron, since the binding energy per nucleon for silicon is already near the theoretical maximum, which is where iron's isotopes lie. Hence, the rate of fusion has to be much greater compared to the fusion of lighter atoms to compensate for the decrease in energy released per atom, resulting in silicon getting consumed much faster compared to lower atomic mass nuclear fuel in stellar cores.

EVENTS AND STARGAZING

Featured Stargazing Location: Rowers Bay Park

SOURCE: NPARKS

Rowers Bay Park is a lush green reserve, a node in first phase of the 60 km Round Island Route. Located on the bank of Lower Seletar Reservoir, it offers an almost unobstructed view of the eastern and northern sky, depending on where you stargaze from. It beautifully blends the quiet intimacy of nature with the treasures the night sky has to offer. Whether you're an experienced astronomer or a novice stargazer, the points of light overhead and their reflections on Seletar Reservoir's tranquil waters combine to form a mystical night-time experience.

EVENTS AND STARGAZING

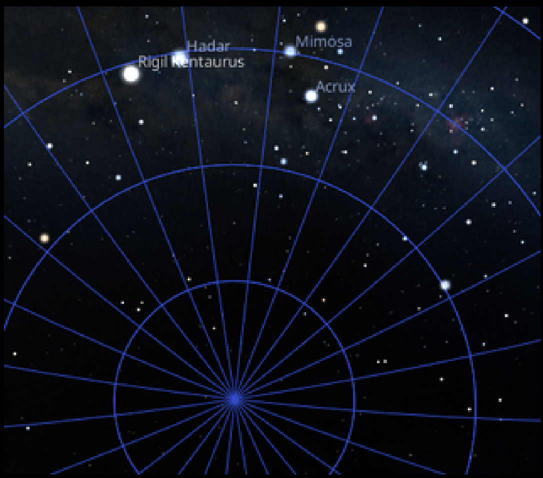
The July skies open the chapter for summer constellations and some very interesting deep-sky objects. Keep reading to find out!

Free-hand stargazing

- **The Southern Pointers -** Alpha and Beta Centauri, which are Rigil Kentaurus and Hadar, respectively, are called the southern pointers, as their perpendicular bisector points directly to the South Celestial Pole as seen from the Stellarium screenshot on the right.

- **Scorpius' Curving Tail -** While we often point out catalogued and named objects and asterisms, we feel Scorpius' tail deserves special attention. It is both aesthetically pleasing and very useful in finding nearby deep sky objects. One of its stars, Shaula, is not only the second brightest star in Scorpius but also a multiple star system!
  What to look for: Follow the bright star Antares, then trace down the curving tail to Shaula and Lesath

- **Teapot of Sagittarius + Milky Way Core -** The specialty of the teapot lies in its position in the sky. On a dark night, the steam seemingly emanating from the teapot happens to be the Milky Way's galactic core itself – how poetic!
  What to look for: A teapot shape rising in the southeast after 8–9 pm



THE SOUTHERN POINTERS
SOURCE: STELLARIUM

SCORPIUS' CURVING TAIL
SOURCE: STELLARIUM

TEAPOT OF SAGITTARIUS
SOURCE: STELLARIUM

EVENTS AND STARGAZING

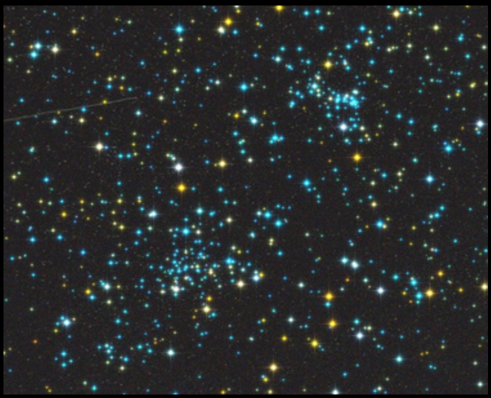
Binoculars

- **IC4665 -** Bright open cluster in the constellation Ophiuchus, containing about 30-50 stars. Contains a large number of distinctly blue stars. Lies just 1° north of the bright star Beta Ophiuchi. Its relatively wide span of 1° and sufficient brightness makes it ideal for binoculars.

- **Tweedledee Cluster (NGC6633) -** An open cluster located in the Serpens constellation, it holds stars that are in beautiful blue and orange contrast.

- **Small Sagittarius Star Cloud (M24) -** This star cloud consists of two prominent dark nebulae, which are thick molecular clouds of gas and dust. Their thickness is precisely what gives them their darkness, as they obscure any light passing out of or through them. On a good day and with the appropriate set of binoculars, these dark nebulae can be resolved against the bright backdrop of the Milky Way's core.

IC4665
SOURCE: WIKIMEDIA, STELLARIUM



TWEEDLEDEE CLUSTER
SOURCE: WIKIMEDIA

SMALL SAGITTARIUS STAR CLOUD (M24)
SOURCE: WIKIMEDIA

EVENTS AND STARGAZING

Telescope

- **Barnard 86 – The "Ink Spot" Nebula -** This dark nebula lies beside another prominent DSO, the open star cluster NGC 6520. Given its distinctive appearance as ink smeared across paper, it therefore got named precisely that.

BARNARD 86 - THE "INK SPOT" NEBULA
SOURCE: STELLARIUM

- **NGC 6822 – Barnard's Galaxy -** This galaxy happens to be the closest non-satellite galaxy to our own home galaxy, the Milky Way. Appearing more like a star cluster instead of a galaxy, this barred irregular galaxy is similar in structure and composition to the Small Magellanic Cloud and is part of our Local Group.

BARNARD'S GALAXY
SOURCE: WIKIMEDIA

SOURCES

Front page
GPT 4o Image Generation

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File:M82 HST ACS 2006-14-a-large web.jpg - Wikipedia

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Artist's depiction of V462 Lupi's stellar explosion: GPT 4o Image Generation
Depiction of mass transfer from the binary companion to the white dwarf: GPT 4o Image Generation
Example of a protostar system
NASA's Webb Catches Fiery Hourglass as New Star Forms
A new star just appeared in the sky—here's where to look

TWA 7 b or Not to Be?
Direct image of TWA 7 b
First Image of an exoplanet
Artist's depiction of TWA 7b orbiting its host star: GPT 4o Image Generation
Lagrange, A. M., Wilkinson, C., Mâlin, M., Boccaletti, A., Perrot, C., Matrà, L., ... & Langlois, M. (2025). Evidence for a sub-Jovian planet in the young TWA 7 disk. Nature, 1-4.
NASA's James Webb Space Telescope Uncovers New Exoplanet TWA 7b | AI News
For first time, Webb telescope discovers an alien planet | Reuters

So what really is dark matter?

LZ Dark Matter Experiment Detector
Rotational Curves of Milky Way
Dark Matter Halo of Galaxy

SOURCES

Trivia
Image of clones in outer space: GPT-4o Image Generation

Events and Stargazing
Rower's Bay Park
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