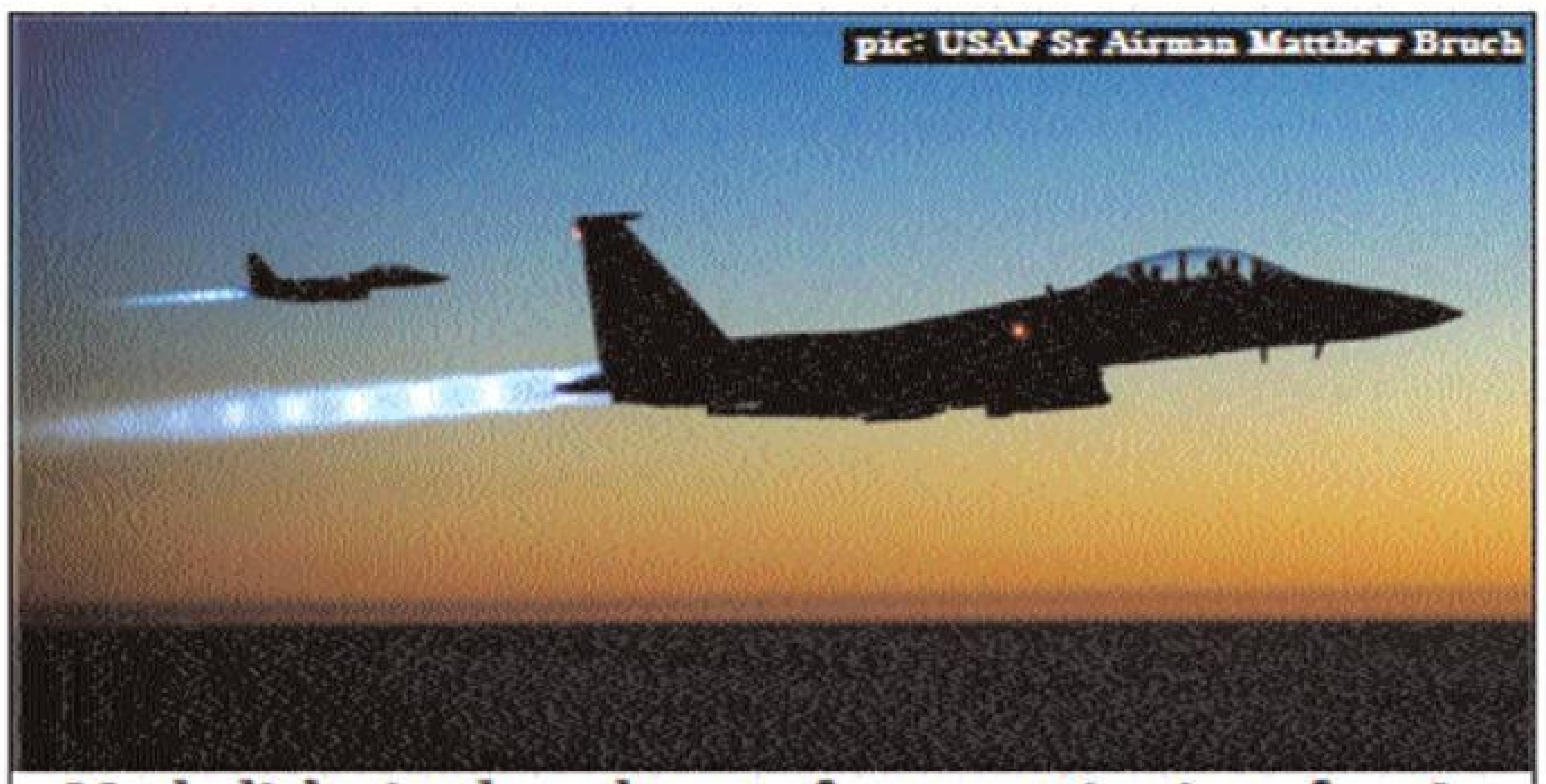
Shades of the sparkle

The plumes which appear when uncorking champagne can have different colours


Dom Perignon



Mach disks in the exhaust of supersonic aircraft aft

S ANANTHANARAYANAN

The "pop", when uncorking a bottle of sparkling wine, is iconic. Opening the bottle gently with a "subdued sigh" would be safer, but celebration and ceremony call for the explosion — a shower of champagne and the cork shooting out.

Gérard Liger-Belair and Daniel Cordier, from the Université de Reims Champagen-Ardenne, in the heart of the Champagne wine-growing region, and Robert Georges from the Institute of Physics, Université de Rennes, dissect, into microseconds, the process of the sharp report when the bottle opens. In a paper in *Science Advances*, the journal of the American Association for the Advancement of Science, they find that complex mechanisms are at play and the colour of vapours that arise when a bottle is opened depends on the temperature of the wine.

Sparkling wines are so called because of the stream of tiny bubbles that rise to the surface, and burst into a misty spray, as soon as a bottle is opened. The bubbles, of course, are carbon dioxide gas, dissolved in the wine under pressures, which issue forth when the cork is pulled. It is the same with soda water where carbon dioxide gas is dissolved in water.

The process of putting the gas into wine, by a natural process, however, dates earlier than the process for soda water. The first process was by Dom Pérignon, a 17th century monk in the Champagne region in France. Soda water was invented a century later when Joseph Priestly discovered carbon dioxide.

Carbon dioxide is given off in wine making when glucose in sugars, in the presence of yeast, breaks down into alcohol. The process is described like this — $C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$ where C_2H_5OH is potable alcohol. This reaction, in fact, amounts to partial burning of glucose into water and carbon dioxide — partial because the alcohol can again burn to $2CO_2$ and H_2O. In wine making, the CO_2 produced is allowed to escape, through an air lock, until all the sugar has fermented, and what is left is the wine. When, by accident, the wine was bottled a little early, some CO_2 was still produced, which bubbled out when the bottle was opened. Uijt xbt the beginning of sparkling wine.

Dom Pérignon is credited with refining the process. The first steps were to control the quantity of sugar for the second fermentation, and then to strengthen the bottle to withstand the pressure. But the important step was to keep the wine clear. During fermentation, spent yeast cells settle at the bottom as the "lees" and wine has to be decanted, to be free of lees. In the case of sparkling wine, the bottle is already corked and there is no occasion to decant the wine. And then, as the dissolved gas escapes vigorously when the bottle is opened, the lees that have settled to the bottom would be disturbed and cloud the wine.

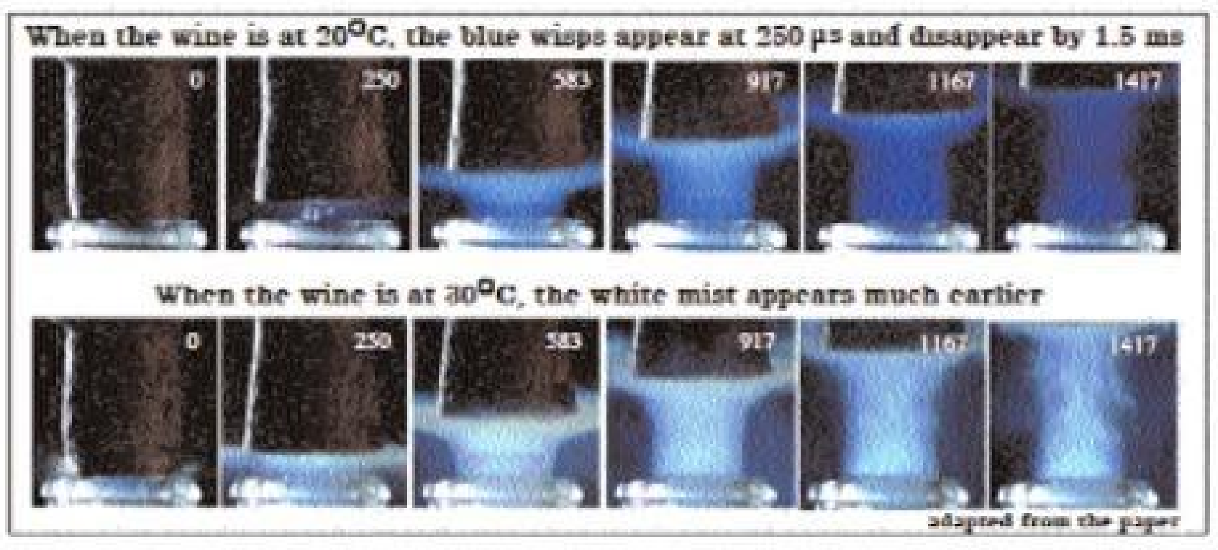
The Dom Pérignon method uses two sets of corks. The first cork is inserted when the secondary fermentation is happening, and the bottle is stored bottom-up. The lees hence settle in the neck of the bottle on the cork. When this process is over, the neck of the bottle is frozen, so that the frozen wine acts as a sealant. The cork and the lees are then extracted, and a fresh cork inserted — so that the wine is both carbonated and free from yeast residue.

Production of champagne has now become a huge industry and quality sparkling wines are produced in many more places in France and the world. And always, an important ritual at the start of many events, the launching of a ship, a product, a christening, or any kind of celebration is to open a bottle of champagne, and with a sound as loud as possible, of the cork being extracted.

The sound, in fact, is a case of the "sonic boom" when things cross the speed of sound. The pressure of the carbon dioxide gas dissolved in the wine is in the region of 7.5 times the atmospheric pressure. When the pressure is suddenly released, the gas, air and vapour in the bottleneck rush out, and so does carbon dioxide that leaves the dissolved state. The pressure difference is sufficient for the jet being expelled to exceed the speed of sound, and there are shock waves, the so-called

"Mach disks" (after an Austrian physicist who first described them), which constitutes the sharp crack when the bottle is opened.

Apart from the sound, the characteristic of a champagne opening is the fine mist, the cloud that appears around the mouth of the bottle. The usual understanding, the Reims paper says, is that the gas and vapour rushing out of the bottle expands rapidly, before it can absorb heat from the surroundings, and hence, it cools. And the surrounding air cools below the dew point, to form droplets of water, even tiny bits of ice. The grey-white colour, the paper says, is a result of scattering of light, an effect called "Mei scattering", where light is scattered by particles that are larger than the wavelength of light — an effect that is responsible for the white colour of clouds.


When the wine is at 20°C, the blue wisps appear at 250 µs and disappear by 1.5 ms

When the wine is at 30°C, the white mist appears much earlier

adapted from the paper

The paper refers to recent studies where the gas emerging from champagne bottles at different temperatures has been filmed with high-speed cameras. Contrary to what we would expect, the paper says, the warmer the wine in the bottle, the colder the gas gets when it expands on emerging. When champagne, usually drunk chilled, was warmed to 20°C, the temperature of the emerging gas went down to -90°C, which is below the freezing temperature of CO_2. And in place of the grey-white fog that we are used to, we found, to our surprise, a plume of short-lived wisps of blue.

The appearance of blue scattered light is Raleigh scattering, caused by particles that are smaller than the wavelength of light, just what accounts for the blue of the sky. The studies that found the blue wisps had noted that the blue haze was an indicator of freezing of the CO_2, which inhibited the condensation of water vapour, and kept the scattering centres small.

In the current study, the role of temperature in the progress of vapour formation as the gas expanded out to the bottle was studied more deeply, in the range from 20°C, when the pressure inside is 7.5 times that outside, and 30°C when the pressure is 10.2 times higher. It was found that as the temperature rose from 20°C, the wispy blue disappeared and turned grey-white, characteristic of Mei scattering, by larger particles. The authors explain the difference as caused by the way CO_2 and water vapour behave, leading to larger dry ice particles.

The paper carries a panel of pictures that display the growth of the blue mist, in the 20°C wine, from the 250th microsecond after the cork is pulled, and as it grows for some milliseconds. In the case of wine at 30°C, the white, CO_2 freezing plume appears much earlier, as a white cloud.

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Into the unknown

Here's why scientists believe in dark matter even though it cannot be directly detected


The motion of stars and gas in Andromeda provided some of the first evidence for dark matter


The direct detection of dark matter remains a challenge for particle physicists

MICHAEL JI BROWN

Dark matter, by its very nature, is unseen. We cannot observe it with telescopes, and nor have particle physicists had any luck detecting it via experiments.

So why do I and thousands of my colleagues believe most of the universe's mass is made up of dark matter, rather than the conventional matter that comprises stars, planets, and all the other visible objects in our skies?

To answer that question you need to appreciate what dark matter can and cannot do, understand where in the universe it lurks, and realise that "dark" is just the start of the puzzle.

Unseen influence

Our dark matter story starts with speed and gravity. Throughout the cosmos we see objects travelling in orbits under the influence of gravity. Just as Earth orbits the Sun, the Sun orbits the centre of our galaxy.

The speed required to keep a celestial body in orbit is a function of mass and distance. For example, in our Solar System, Earth moves at 30km per second, whereas the most distant planets dawdle at several kilometres per second.

Our galaxy is incredibly massive, so the Sun orbits at 230km per second despite being 26,700 light years away from our galaxy's centre. However, as we move further from the centre of the galaxy, the orbital speeds of the stars remains roughly constant. Why?

Unlike our Solar System, whose mass is dominated by the Sun, mass in our galaxy is spread across thousands of light years. As one moves to larger distances from the galactic centre, the stars and gas enclosed within this radius increases. Can this additional mass explain the vast speeds of the most distant stars in our galaxy? Not quite.

In the 1960s, the pioneering US astronomer Vera Rubin measured the orbital speeds in the Andromeda galaxy (the galaxy next to the Milky Way) to distances of 70,000 light years from that galaxy's core. Remarkably, despite this distance being well beyond the bulk of Andromeda's stars and gas, the orbital speed remained near 250km/s.

This phenomenon isn't unique to individual galaxies either. Back in the 1930s, Swiss-American astronomer Fritz Zwicky found that galaxies orbiting within galaxy clusters were moving far faster than expected.

What's going on? One possibility is that a vast amount of unseen mass extends beyond the stars and gas. This is dark matter.

Indeed, the work of Zwicky, Rubin and subsequent generations of astronomers indicate there's more dark matter in the universe than conventional matter. (As for dark energy, that's a whole other story.)

Remarkably, our inability to see or detect dark matter provides clues as to how it behaves. It must have few interactions with itself and conventional matter apart from the force of gravity — otherwise we would have detected it emitting light and interacting with other particles.

As dark matter mostly interacts via gravity alone, it has some curious properties. A cloud of hot gas in space can lose energy by emitting light, and thus cool down. A sufficiently massive and cold gas cloud can collapse under its own gravity to form stars.

By contrast, dark matter cannot lose energy by emitting light. Thus, while conventional matter can collapse into dense objects like stars and planets, dark matter remains more diffuse.

This explains an apparent contradiction. While dark matter may dominate the mass of the universe, we don't think there is much of it in our Solar System.

Simulation success

As the motion of dark matter is dominated solely by gravity; it is also comparatively easy to model analytically and in simulations.

Since the 1970s we have had formulae for the number of dark matter structures, which also happen to predict the number of massive galaxies and clusters of galaxies. Furthermore, simulations can model the build-up of structures through the history of the universe. The dark matter paradigm doesn't just fit data, it has predictive power.

Is there an alternative to dark matter? We infer its presence using gravity, but what if our understanding of gravity is wrong? Perhaps gravity is stronger at large distances than we think.

There are several alternative gravity theories, with Mordehai Milgrom's Modified Newtonian Dynamics being the best-known example.

How do we distinguish dark matter from modified gravity? Well, in most theories gravity pulls towards the mass. Thus, if there's no dark matter, gravity pulls towards the conventional matter, whereas if dark matter dominates then gravity will predominantly pull towards dark matter.

So it should be easy to tell which theory is right, right? Not exactly, as dark matter and conventional matter roughly follow each other around. But there are some useful exceptions.

Smash clouds of gas and dark matter together and something wonderful happens. The gas collides to form a single cloud, while the dark matter particles just keep moving along under the influence of gravity. This happens when clusters of galaxies collide with each other at vast speeds.

How do we measure gravity's pull in colliding galaxy clusters? Well, gravity pulls not just on mass but on light too, so distorted images of galaxies can trace gravitational pull. And in colliding galaxy clusters, gravity pulls towards where the dark matter should be, not towards the conventional matter.

Ripples in time

We can see the influence of dark matter not just today but in the distant past, right back to the Big Bang.

The Cosmic Microwave Background, the afterglow of the Big Bang, can be seen in all directions. And in this fireball we can see ripples, the result of sound waves travelling through ionised gas.

These sound waves result from the interplay of gravity, pressure and temperature in the early universe. Dark matter contributes to the gravity, but doesn't respond to temperature and pressure like conventional matter, so the strength of the sound waves depends on the ratio of conventional matter to dark matter.

As expected, measurements of these ripples taken by satellites and ground-based observatories reveal there's more dark matter than conventional matter in our universe.

So is the case closed? Is dark matter definitely the answer? Most astronomers would say dark matter is the simplest and best explanation for many of the phenomena we see in the universe. While there are potential issues for simplest dark matter models, such as the number of small satellite galaxies, they are interesting problems rather than compelling flaws.

But the fact remains that we are yet to detect dark matter directly. This doesn't particularly bother me, as physics has a history of particles that have taken decades to directly detect. If we haven't detected it 20 years from now I may be concerned, but for now I'm betting that dark matter is the real deal.

The writer is associate professor in astronomy, Monash University, Australia. This article first appeared on www.theconversation.com

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PLUS POINTS

Sneaking up

The largest asteroid to pass as close to the Earth in a century "slipped through" Nasa's detection systems, internal emails reveal. Named "2019 OK" by scientists, the asteroid nearly passed by undetected as it came five times closer to Earth than the Moon. This was revealed through documents obtained by *Buzzfeed* via freedom of information requests.

It was first detected by a Brazilian observatory on 24 July just hours before coming within roughly 73,000km of Earth. Nasa's failure to spot the 100-metre wide space rock highlighted long-standing concerns about a lack of US government funding for asteroid detection efforts.

"This object slipped through a whole series of our capture nets, for a bunch of different reasons," Paul Chodas, manager of Nasa's Centre for Near Earth Object Studies, wrote to colleagues on 26 July. "So, was this just a particularly sneaky asteroid? I wonder how many times this situation has happened without the asteroid being discovered at all?"

The emails showed space agency employees rushing to discover how the asteroid avoided detection, after a colleague alerted them to the near-miss "because there may be media coverage tomorrow".

Nasa telescopes did spot the asteroid on 7 July, but it was moving too slowly to be identified as a near-Earth object. By the time it sped up it was too close to a nearly full moon for astronomers to detect, according to the emails. A planetary defence officer at Nasa had written that "2019 OK" appeared to be the largest asteroid to pass so close to Earth in the last century. Another such event was not expected to occur until 2029, they said.

The independent

Faster glacier flow

Surface meltwater draining through the ice and beneath Antarctic glaciers is causing sudden and rapid accelerations in their flow towards the sea, according to new research.

This is the first time scientists have found that melting on the surface impacts the flow of glaciers in Antarctica. Using imagery and data from satellites alongside regional climate modelling, scientists at the University of Sheffield have found that meltwater is causing some glaciers to move at speeds 100 per cent faster than average (up to 400m per year) for a period of several days multiple times per year.

Glaciers move downhill due to gravity via the internal deformation of ice, and basal sliding — where they slide over the ground beneath them, lubricated by liquid water. The new research, published recently in Nature Communications, shows that accelerations in Antarctic Peninsula glaciers' movements coincide with spikes in snowmelt. This association occurs because surface meltwater penetrates to the ice bed and lubricates glacier flow.

The scientists expect that as temperatures continue to rise in the Antarctic, surface melting will occur more frequently and across a wider area, making it an important factor in determining the speed at which glaciers move towards the sea.

Ultimately, they predict that glaciers on the Antarctic Peninsula will behave like those in present-day Greenland and Alaska, where meltwater controls the size and timing of variations in glacier flow across seasons and years. The effects of such a major shift in Antarctic glacier melt on ice flow has not yet been incorporated into the models used to predict the future mass balance of the Antarctic Ice Sheet and its contribution to sea level rise.

Jeremy Ely, independent research fellow at the University of Sheffield's department of geography and author of the study, said, "As atmospheric temperatures continue to rise, we expect to see more surface meltwater than ever, so such behaviour may become more common in Antarctica. It's crucial that this factor is considered in models of future sea level rise, so we can prepare for a world with fewer and smaller glaciers."