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The dark side of the Universe

Something strange is happening in space. Whole galaxies are speeding towards the same point in the Universe and no-one knows why. **Robert Matthews** investigates the mysteries of the Dark Flow

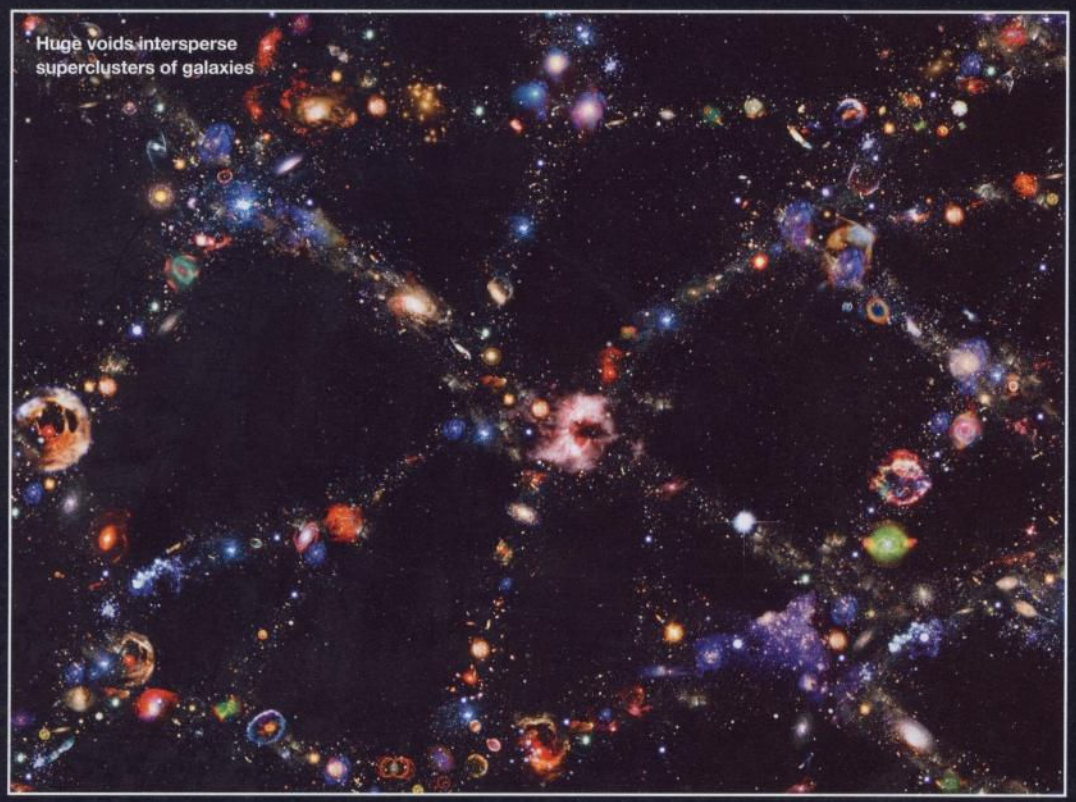
When NASA astronomer Dr Sasha Kashlinsky and his colleagues began their project, they thought they'd be just tidying up some cosmic loose ends. They planned to gather data about the motion of groups of distant galaxies, put it through a computer, and confirm that the Universe is behaving as our best models predict. Nice and simple.

But it didn't turn out that way. What the data told them was completely unexpected. "We are still a little jittery," admits Kashlinsky. Small wonder, as the results suggest those distant clusters of galaxies may be in the grip of a force from beyond the Universe.

The team calls the phenomenon they discovered 'the Dark Flow', a suitably enigmatic moniker for an effect that is causing huge controversy among scientists. Some insist the team has made a blunder, or been fooled by some subtle astronomical effect. Others believe the effect may be real, though of much less cosmic significance. But if the findings are confirmed, astronomers will just have to accept the Universe is an even weirder place than they thought.

They can hardly say they haven't been warned; the evidence has been building up for years. As long ago as the 1930s, there were the first signs that the Universe contains far more matter than is visible using telescopes. Astronomers found that the strength of gravitational fields among distant galaxies is far greater than would be generated by the objects we can actually see – so something else must be there. The latest studies suggest that this invisible 'Dark Matter' actually accounts for around 85 per cent of all matter in the Universe. Yet despite a host of suggestions, its nature is still unknown.

Astronomers got an even bigger shock in the 1990s with the discovery that the Universe is propelled by some kind of anti-gravitational force-field. Since the 1920s, they had believed that it exploded in a colossal Big Bang, and had been expanding ever since – with gravity gently slowing it down. The only question was whether the Universe would continue to expand, or one day grind to a halt and then collapse back in a cataclysmic 'Big Crunch'. But during the mid-1990s, studies of stars in distant galaxies revealed that the cosmic expansion isn't slowing down at all. Instead, it's accelerating. The force that appears from literally nowhere to combat gravity on cosmic scales has been called Dark Energy. And just like Dark Matter, no-one knows what it is.



Huge voids intersperse superclusters of galaxies

NASA X4, SCIENCE PHOTO LIBRARY

A shot in the dark

Now, astronomers face the challenge of trying to explain the Dark Flow. At least its basic features do not need a PhD to understand. As its name suggests, it's a current-like flow of clusters of galaxies through space, over and above that caused by the cosmic expansion. Nothing shocking there – standard theories of the Universe predict such movement. Following the Big Bang, matter ended up unevenly spread through space, resulting in gravity

Galaxies like NGC 4258 help gauge the speed of the Universe's expansion

fields that pull galaxy clusters more strongly in some directions than others.

This was what Dr Kashlinsky and his colleagues set out to confirm. "The trick was to get enough clusters of galaxies to sufficiently large distances," says Dr Kashlinsky. This would ensure any measurements would reflect what's generally going on – not just a freak phenomenon confined to a small area. So the team put together a catalogue of almost 800 clusters, spanning several billion light-years in distance.

"We anticipated that we would measure small velocities consistent with the dominant cosmological theory," Kashlinsky says. But instead they found a huge current-like flow of galaxy clusters moving at over three million km/h towards something located between the constellations Centaurus and Vela. "That was exciting, but also completely unexpected."

So what is causing the Dark Flow? "There are several possible explanations, all of them a little exotic," explains Dr Harald Eberling of the ▸

OTHER WEIRD COSMIC FORCES

The Dark Flow is not the only strange phenomenon in the Universe

THE PIONEER ANOMALY

In 1973 NASA's deep space probe Pioneer 10 made history by sending back the first close-up images of Jupiter. But as it travelled beyond the known planets, it sent back something else – evidence of an unknown force that seemed to be slowing the probe down. The effect was incredibly small, amounting to a loss in speed of just 1km/h over the course of a decade. But it was undeniably there.

Many explanations have been put forward for this 'Pioneer Anomaly', as it's been dubbed – which was also found with Pioneer 10's sister probe, Pioneer 11. Theories put forward have ranged from the invisible tug of Dark Matter to some hitherto unforeseen flaw in Einstein's theory of gravity. In 2007, Dr Slava Turyshev of the US-based Planetary Society announced that around 30 per cent of the effect may be due to thermal radiation pressure created by onboard sources of heat, acting in just the right direction to slow the probes down. But to this day, no-one has come up with a complete explanation.

THE MOND EFFECT

The billions of stars making up galaxies all follow orbits like the planets of our Solar System – those furthest from the centre move more slowly than those closer in. Just how slowly can be predicted using the famous law of gravity put forward over 300 years ago by Isaac Newton. But astronomers have noticed something odd about the outermost stars in galaxies – they're moving faster than predicted by Newton's law. One explanation is that they're being affected by the gravity of a huge amount of invisible Dark Matter surrounding galaxies. But there's another possibility – Newton's law might simply be wrong.

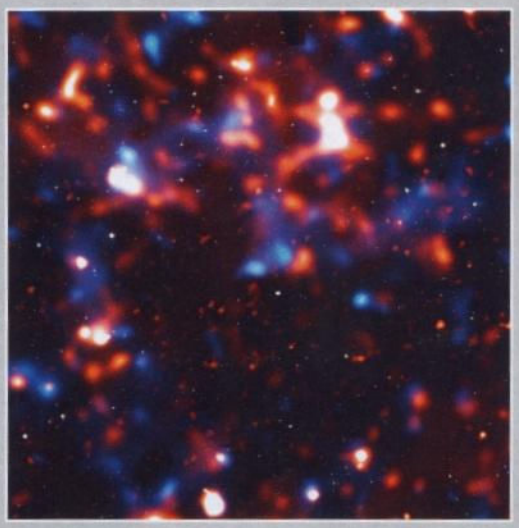
Since the early 1980s, theorists have been investigating the so-called MOND effect (MOdified Newtonian Dynamics), according to which the standard law of gravity breaks down when objects are accelerating very slowly. Quite why that should happen is unclear, but some theorists claim that the MOND effect does a better job than Dark Matter of explaining the observations.

THE FIFTH ELEMENT

According to the Greek philosopher Plato, the Earth was made from four elements – fire, earth, air and water – with the heavens being pervaded by a fifth element called quintessence. Now that quaint idea has been resurrected by theorists trying to explain the motion of distant galaxies.

Observation of the motion of these galaxies suggests that the expansion of the Universe is no longer accelerating as fast as it used to do, which may mean that Dark Energy is getting weaker. This has led some theorists to argue that Dark Energy is a special type of anti-gravity effect, which they have given the classically inspired name of quintessence.

There's no real understanding of where it comes from, or why it exists – which makes it unpopular with many theorists, who see it as just a messy extra complication to already mind-bendingly complex theories of the Universe. But if the slow-down in the cosmic acceleration is confirmed, we may simply have no choice but to accept that Plato was right, and the cosmos is filled with quintessence.



DR KASHLINKSKY

NASA Goddard Space Flight Centre, Maryland

What was your reaction when you first found evidence for the Dark Flow?
We were definitely surprised and, for a long time, suspicious of something else. When results are so unexpected, one has to be suspicious and examine all possible effects that could have tricked us. So we sat on it for a long time, checking everything we could think of.

What makes you confident that the Dark Flow is real?
All the tests we conducted, then and since, point to the robustness of the results. Also, just a few days after our results appeared, a different group released results from a completely independent analysis using galaxy distance indicators. Such methods cannot yet probe flows to distances exceeding 200-300 million light-years, but what they measured at those scales showed a flow that's in agreement with our results.

What's your personal best guess as to the explanation?
The flow seems to extend to at least a billion light-years away from us. According to standard theory you would expect that it should be negligible and of progressively lower amplitude at scales exceeding a couple of hundred million light-years. That the flow extends that far probably indicates that it extends across our entire part of the visible Universe. We think it's linked to the original structure of space-time, as it existed when the Universe was formed. Suggestions have also been made that it may reflect a modification of gravity produced by extra dimensions.

What's the next step?
We are now working on constructing an extended and much deeper galaxy cluster catalogue. Also, the new European satellite, Planck, should bring excellent quality data which would enable us to make still better measurements of the flow.

Planck will study the Universe's birth

ESA, SCIENCE PHOTO LIBRARY

The Dark Flow could indicate that multiple universes exist side-by-side

▶ University of Hawaii, another member of Kashlinsky's team.

One possibility is that we happen to be in a vast, relatively empty void in the Universe, whose lack of gravitational pull compared to its surroundings leads to a net outward flow of cosmic matter. "We think that this is highly unlikely," says Dr Eberling. "The signature of a void in our data would be different."

Then there's the idea that the law of gravity may have gone awry, a possibility already raised in connection with Dark Matter. But there's another possibility – that the galaxy clusters are being pulled by the gravity of something lurking beyond our Universe.

Theorists now believe that what we call the Universe is merely the visible part of an infinitely larger 'multiverse', most of which lies out of sight. The idea is that moments after the Universe was created, a powerful form of Dark Energy appeared, triggering a period of incredibly rapid expansion. By the time it ended, most of the Universe had been pushed forever beyond the reach of today's telescopes. This theory suggests the Dark Flow could be caused by the gravitational pull of matter lying far outside what we can see.

"The implications are rather profound," says Dr Eberling. "I am still not willing to rule out completely that we are missing some systematic effect or made a mistake somewhere."

That's certainly the view of other experts. Cosmologist Professor Ned Wright of the University of California is blunt. "There is no evidence for the Dark Flow," he says, calling the team's analysis "flawed". While less dismissive of the evidence, cosmologist Professor Douglas Scott at the University of British Columbia says the idea that the Dark Flow is due to the gravitational pull of matter beyond the visible Universe is "preposterous", because the theory is based on data covering only around one-tenth the size of the observable Universe. "Even if the result is correct, there's no need to jump to unreachable scales for an explanation," he says.

Watch this space

Dr Kashlinsky and his colleagues aren't about to give up, however. They've just finished a further study using more and better data – and it still shows evidence of the Dark Flow. Other astronomers have also uncovered evidence of this strange movement of galaxies, albeit at much smaller scales. And there's now hope of a final verdict from a newly launched space-based observatory called Planck, which is expected to provide a wealth of data about the movement of galaxy clusters. "It is important to verify if the Dark Flow does extend still further across our Universe," says Kashlinsky.

If it does, we may just have to accept that our Universe really is in the grip of the forces of darkness. ■

Robert Matthews is a visiting reader in science at Aston University, Birmingham

FIND OUT MORE

http://bit.ly/darkmatterfacts
Online resource about Dark Matter

Dark Side of the Universe
Iain Nicholson (Canopus, 2007)
An overview of our latest understanding of Dark Matter and Dark Energy