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The Andromeda Galaxy is similar to the Milky Way Galaxy in many ways. But what will happen if these two collide in the next 4.5 billion years?

When it comes to next-door neighbours, the Andromeda Galaxy, which rests within the constellation Andromeda, takes the cosmic biscuit. At a hefty 700 billion solar masses and an estimated 220,000 light years in diameter, this galactic giant does not follow its mythological namesake as a princess, but as a queen of the Local Group – a family of galaxies that, almost like Andromeda's minions, lie close by in the trillion star-strong galaxy's queendom. The group also includes the Triangulum Galaxy and our own whirlpool of stars, the Milky Way Galaxy, along with a collection of puny dwarf and irregular galaxies scattered around the more striking trio.

Around 2.5 million light years from the Andromeda Galaxy our own Milky Way, while smaller than the gargantuan queen, almost challenges its galactic ruler, threatening to steal her throne with a contending mass believed to be about 80 per cent of its superior. However, what the Milky Way very nearly matches in weight thanks to the hefty yet elusive dark matter, it loses in presence with a respectable if inferior diameter of 100,000 light years, making it about half the size of its brighter companion and therefore failing to steal the crown of 'size queen'. That said, there's no mistaking that the pair share a similar galactic type with both possessing winding arms that snake their way into space, protruding from luminous cores. Such breed of galaxy is known as the spiral.

While we have never seen our own galaxy from the outside, astronomers believe that its centrepiece is a glowing bulge of stars with a bar cutting through its middle, joining its arms. The origin of the bar is uncertain, perhaps having formed through some gravitational instability, but regardless it is funnelling stars and gas through the galactic centre and out the other end. Structurally Andromeda is not too dissimilar and so, when we look at this galaxy, it is almost as if we are looking at a larger version of how

our own Milky Way Galaxy might look were we able to jump into a spaceship and travel hundreds of thousands of light years into intergalactic space to look at it from the outside. A brief glance at the majestic form of a spiral galaxy can easily fool you into thinking that its gigantic structure is just a pattern of swirling stars emanating from a great ball of light at its core. However, there is more to the likes of the Andromeda and Milky Way galaxies than meets the eye and such illusions start at the very heart; what is commonly known as the central bulge of a galaxy.

Through the eyes of visible light, the Andromeda Galaxy is just your typical spiral galaxy with a classic, bulbous central condensation of stars. However, when we look in infrared light, it's a different story as the galaxy's centre takes on a more boxy, angular appearance, leading astronomers to believe that the Andromeda Galaxy is even more similar to the Milky Way than previously thought; a galactic twin with matching barred centres. Perhaps their similarities are not so surprising as studies show that 70 per cent of spiral galaxies have bars.

There's something mysterious about the centre of our Milky Way's grand neighbour. The Hubble Space Telescope peered deep into its heart and found a pair of bright objects at the centre orbiting the dark monster that is a black hole up to 230 million times heftier than our Sun. Again, Andromeda shows our Milky Way to be inferior, with the black hole at the centre of our home only accounting for 4 million times the mass of our star. One of the glowing objects within the centre of Andromeda, which is also known as Messier 31 or M31 for short, is thought by astronomers to be a dense and compact star cluster. The other object is fainter and disc-shaped, spiralling hot gas swirling around the gravitational sinkhole of the black hole. The black hole and the cluster are snugly positioned just five light years from each other. The cluster is dicing with devastation so close to a giant black hole.

Out from the centre the bar links two spiral arms that wrap around Andromeda in a tight embrace. In the spiral arms is gas and dust and stars, with nebulae formed of the former two making the latter. Here too Andromeda triumphs over the Milky Way - deep images of the galaxy reveal a hidden outer layer that expands the spiral arms to around 220,000 light years, about twice the diameter of our galaxy.

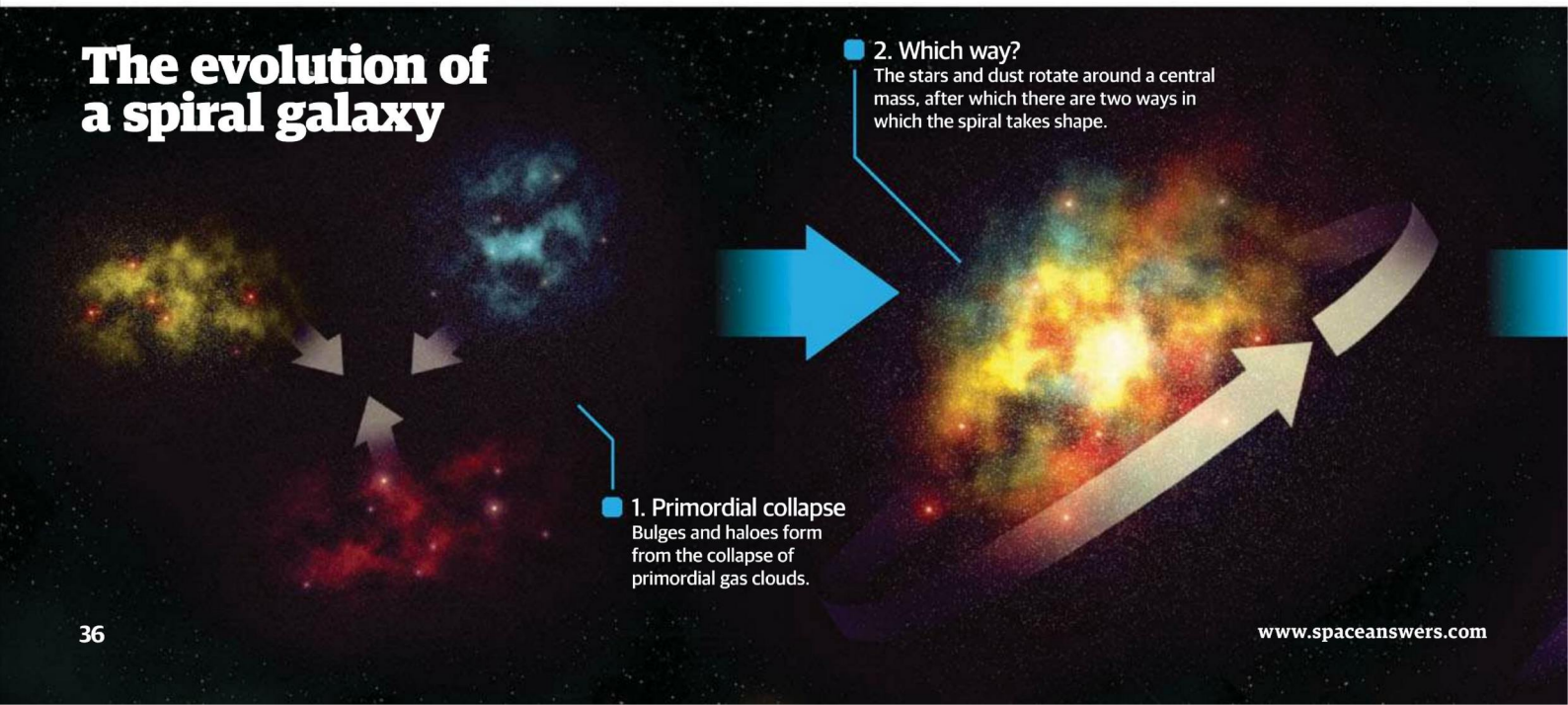
Around the spiral arms and the centre is the stellar halo and while the spiral arms may be fresh-faced youngsters relatively speaking, the halo is positively ancient, home to the oldest of Andromeda's hundreds of billions of stars. The visible stellar halo also merges with the invisible dark matter halo that surrounds and encases the entire Andromeda Galaxy and holds it all together. Inside the halo there are also globular clusters, numbering around 460 in total and the biggest of them is called Mayall II, or alternatively G1, but this cluster of many guises is vastly greater in size and number of stars than any globular cluster around the Milky Way. It seems as though everything about Andromeda is bigger - a true giant.

Flanking Andromeda are around 14 dwarf galaxies which stick close to the structure. Perhaps the most famous of the group are the dwarf elliptical galaxies known as M32, also nicknamed Le Gentil, and M110. Messier 32 may have once been a larger galaxy - there is evidence that it is interacting with its bigger neighbour which is using its gravity to pluck the stars and gas from M32 and shrinking it. The evidence for this is that it has its own supermassive black hole about a million times greater in mass than our Sun, and only big galaxies get black holes so massive. Our Milky Way has its own satellite galaxies, including the Magellanic Clouds, but neither of them have black holes as big as M32. Andromeda wins again.

Watching Andromeda strut its stuff in visible light can only tell us so much about our nearest big neighbour but high above Earth are robotic eyes that have X-ray, ultraviolet and infrared vision. The Hubble Space Telescope isn't alone in space, with other space observatories covering the other parts of the electromagnetic spectrum of light. These include the Spitzer Space Telescope, which can see infrared light from cool things like clouds of gas that are turning into stars, or faint stars that only shine with a feeble glow. Meanwhile there is also the Galaxy Evolution Explorer that can see ultraviolet light from hot things such as bright, young stars - if a region of a galaxy is shining bright in ultraviolet light, then it is very young, forming lots of new stars. On the other hand, if it is dim in ultraviolet and bright at infrared wavelengths, it implies that the region of the galaxy is far older, with only the cooler, long-lived stars around. Together they have stared at Andromeda, showing the galaxy in a new light. At the wavelengths of ultraviolet and infrared, sunglasses aren't needed to cut down on the glare of the galaxy that we see in normal light. GALEX and Spitzer look right through, revealing the spiral disc to be harbouring several rings expanding away from the centre, possibly caused by M32 passing through the Andromeda Galaxy, causing ring-like ripples similar to waves in a pond where a stone has been dropped in. Some galaxies in the universe are ring shaped, with a starry circle of gas and dust lopping around and separated from a bright centre. Andromeda may be on the way to growing into a ring-shaped galaxy.

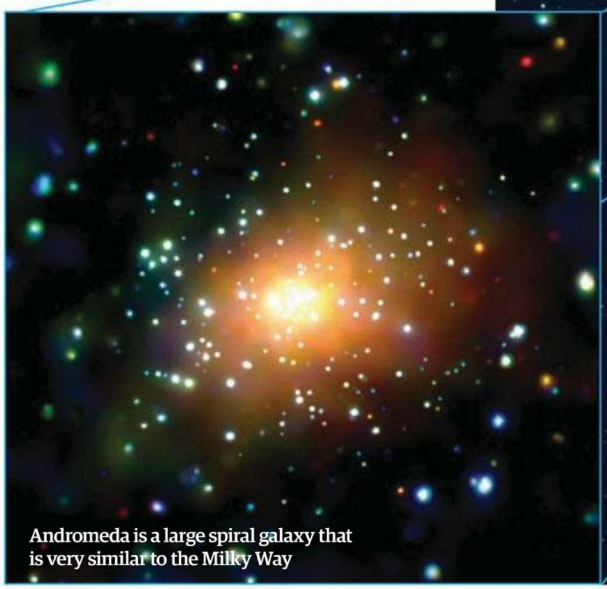
Across the vast reaches of the universe, galaxies are steadily rushing away from our own as the

"The Hubble Space Telescope found a pair of objects at the centre orbiting the monster that is a black hole up to 230 million times heftier than our Sun"



A galactic map

GALEX being mated to its Pegasus XL Rocket on 7 April 2003



Andromeda is a large spiral galaxy that is very similar to the Milky Way

Centre of Andromeda
The heart of M31 sports a black hole up to 230 million solar masses in size.

Spiral arms
Andromeda's spiral disc is twice the diameter of the Milky Way.

Satellite galaxies
Mini dwarf galaxies, such as M110, buzz around Andromeda.

Dark matter
All galaxies form inside giant haloes of mysterious dark matter.

The bulge
The centre contains some of the oldest stars in M31.

The halo
A spherical halo containing 460 globular clusters surrounds M31.

Stars
M31 contains a trillion stars, twice as many as our galaxy.

Messier 32
Andromeda's brightest satellite passed through the spiral arms millions of years ago.

4. Slow and steady evolution
Internal process created by the spinning disc can also create arms and bars found in spirals.

3. A meeting of galaxies
The rotation can contract the cloud forming the galactic disc.

Anatomy of Andromeda

Tell-tale dust ring
Close examination of Andromeda in the infrared reveals a dusty inner ring believed to have been caused by satellite galaxy M32 ripping straight through its disc more than 200 million years ago.

S-shaped disc
Inclined at roughly 77 degrees relative to the Earth, Andromeda has a strange warped disc in the shape of an 'S', possibly caused by the gravitational interaction of satellite galaxies.

A 'misleading' bulge
In visible light, you wouldn't think that a bar streaks through Andromeda's centre. That is until you look at this section of the galaxy in the infrared.

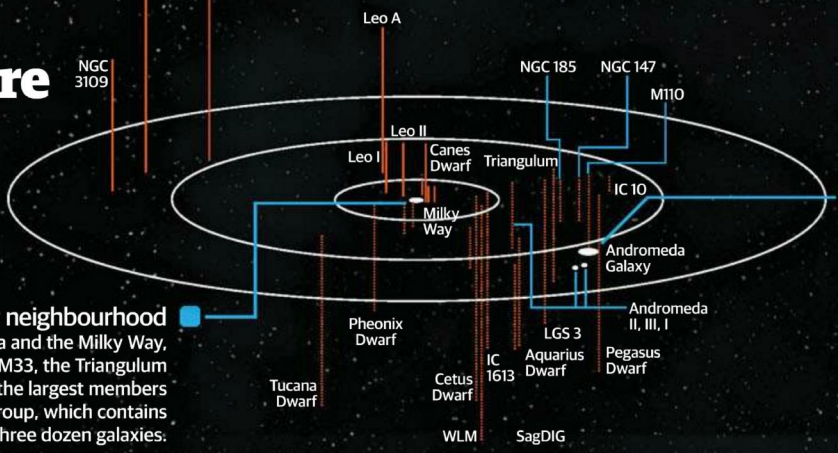
Winding arms
Wound up in a clockwise direction, M31's spiral arms are outlined by low-density clouds of partially ionised gas where the formation of young hot blue stars have recently formed.

Dust and gas
Cold dust and gas is arranged into overlapping rings according to an infrared to ultraviolet view, causing astronomers to believe that Andromeda may be transforming into a ring galaxy!

Heavyweight supermassive black hole
Nestled at the centre lies an ultraluminous X-ray-belching supermassive black hole that's significantly larger than the Milky Way's at up to 230 million solar masses.

Brilliantly bright double nucleus
M31's double inner nucleus with both parts, which are separated by 4.9 light years, consists of compact discs of hot, A-class stars. One concentration is brighter than the other.

Where is it?



Our neighbourhood
Andromeda and the Milky Way, along with M33, the Triangulum Galaxy, are the largest members of the Local Group, which contains around three dozen galaxies.

Collision course
Andromeda and the Milky Way are speeding towards each other at 400,000km/h. There's also evidence that Andromeda and the Triangulum Galaxy interacted in the past.

Dwarf galaxies
Andromeda is accompanied by around 14 known dwarf galaxies, the most famous being M110 and M32, along with around 460 globular clusters. Faint galaxies around Andromeda could help astronomers learn more about dark matter.

Galactic star paths

'Jumping' stars and clusters
Stars found in the galaxy's halo (and globular clusters) may 'jump' high above the disc before diving back in again popping out of the bottom of the galaxy before starting the cycle again.

Staying and moving
Stars found in Andromeda's disc are influenced by gravity and generally stay where they are, occasionally bobbing up and down as they orbit the galactic centre.

Alternating speeds
In the vicinity of Andromeda's centre speeds of up to around 225km/s are reached up to a radius of around 1,300 light years. Further out at 7,000 light years the speed of rotation drops as low as 50km/s before reaching speeds of around 250km/s even further from the centre. Finally, at around 80,000 light years, the speed becomes constant suggesting the presence of dark matter.

From the side

Globular clusters
The stellar halo is home to groups of stars called globular clusters. The largest around M31 is called Mayall II. It's twice as big as the Milky Way's largest.

Bulging out
The reason for the bulge's name is clear when the galaxy is viewed from the side. It hides a huge black hole, much heavier than the Milky Way's.

Thick and thin
The discs are divided into 'thick' and 'thin'. The thick disc contains stars over 8 billion years old, while a thinner disc houses younger stars.

Gas and dust
The spiral disc is filled with gas and dust. Dust is produced by dying stars and recycled into new stars born in nebulous regions of gas.

cosmos expands. It seems, however, that the Andromeda Galaxy has other ideas as it moves like a juggernaut in the opposite direction, charging at the Milky Way in what seems like slow motion – at a speed of around 400 light years every million years, Andromeda is set on a path of destruction that could see our galaxy getting walloped by it in the next four and a half billion years.

Crashes and cannibalism between galaxies isn't uncommon in the universe. Both the Milky Way and Andromeda Galaxy have form when it comes to gobbling up small galaxies and smashing into others. The former – our galaxy – is currently gaining more mass by snapping up several dwarf galaxies and cannibalising them – its next meal is likely to be our small elliptical companion the Sagittarius Dwarf Elliptical Galaxy (SagDEG), which has been drawn out into a loop around the Milky Way some 10,000 light years across by our galaxy's gravity. The loop is made up of spherical collections of stars also known as globular clusters, which are set to slowly merge with the larger Milky Way Galaxy. Meanwhile, evidence abounds in the form of tattered remnants of dwarf galaxies that shows the Andromeda Galaxy also has a track record of indulging in the odd galaxy or two.

While being in the path of a galaxy twice the size of our own would spell disaster in the minds of many, astronomers have been left wondering if the collision between our two giant stellar conurbations could happen at all. If the ultimate crash does come to pass, stars in both parties would largely miss each other as the space between stars is so enormous that the likelihood of any colliding is mind-bogglingly tiny. However, the gravitational fields of both galaxies will play havoc with the stars and gas clouds in both galaxies, throwing them around like toys. Just what will happen to our Solar System by the time 4.5


Spitzer after cryogenic telescope assembly integration

When galaxies collide

Although Andromeda is currently over two and a half million years from our own galaxy, in the next several billion years it will collide with the Milky Way. For any humans who are still around then, the sight is set to be remarkable. Our neighbouring galaxy will gradually grow larger and larger in the night sky before the two collide in a collage of exploding stars, twisting spirals and merging black holes.

2 billion years

The disc of the approaching Andromeda Galaxy will be noticeably larger.

3.75 billion years

Andromeda will fill the field of view and begin pulling the Milky Way.

4 billion years

Andromeda will be tidally stretched and the Milky Way will become warped.

5.1 billion years

The cores of the Milky Way and Andromeda will appear as a pair of bright lobes.

billion years rolls around almost seems irrelevant and will not affect us in the slightest for one main reason; our planet as we know it will by then have a swelteringly hot surface so high in temperature that water will boil away, ending all life upon it. The massive change from tranquility to hell on Earth will not be down to a sudden alteration on our planet's part, but will be down to the ageing of our Sun with it becoming brighter and therefore hotter a good 1.4 billion years from now, long before the end of its life.

The great event between the two galaxies might be a show that human beings are very unlikely to see, but that has not stopped astronomers from modelling just what will happen to our Solar System when the two do finally meet. They found that if Andromeda and the Milky Way do unite in the form of a merger, there is a possibility that our Solar System will be thrown out a good three times further away from its current position in the crook of the Orion arm, which rests around 28,000 light years from the centre of our galaxy. Another possibility, albeit a small one, is that our Solar System will be discarded and thrown out completely by the pair just as they collide to form a giant elliptical galaxy that astronomers have already nicknamed 'Milkomeda'.

That is not all. The mammoth collision between the gigantic duo could create a quasar at the centre of the newly formed Milkomeda. As the galaxies merge, so do the black holes, as the forces of the merger assist in pushing gas down the mouth of the giant black hole, and the gas heats up before it reaches the black hole, glowing brightly as it is sent to its doom. Such active black holes are called quasars, which are so bright they can be seen across the universe. Meanwhile the gas-laden cores of the galaxies will erupt with star formation – a final generation of new stars before all the gas is used up and the quasar runs out of gaseous food to chomp on. Then Milkomeda will become a quiet, ancient galaxy that will grow old respectably.

1. Clean room

White-suited workers at the Kennedy Space Center in Florida inspect the Spitzer spacecraft after its trip back to the clean room in May 2003.

2. Ready for launch

Spitzer is moved into position to have its launch faring installed atop its Delta rocket on 10 April 2003, ready for its launch later that year.

3. GALEX covered

Workers check the deployment of the cover of the telescope on the GALEX satellite.

4. CTA testing

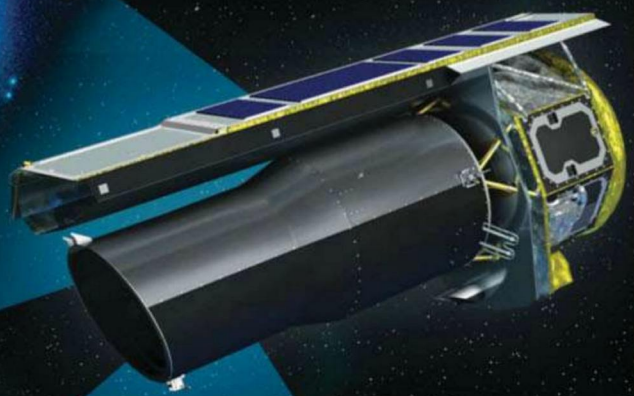
The Spitzer cryogenic telescope assembly (CTA) being prepared for vibration testing.

5. GALEX launch

Being attached to a Lockheed L-1011 TriStar in preparation for launch.

Viewing our galactic neighbour

An old face
This Spitzer image shows Andromeda's older population of stars.



Ancient core
The halo and bulge of a spiral galaxy contain its oldest stars.

Old and young
This false-colour composite of images reveals the ring structure of M31's disc, and the populations of old and young stars.

Hot and cold
The hottest stars (blue) are also the most massive and youngest, whereas older stars (green) are less massive and cooler.

Ring galaxy
M31 seen in ultraviolet light by GALEX. All the glare has gone, showing rings of hot young stars.

Dusty galaxy
Dark dust lanes line dense clouds of gas where star formation is actively taking place.

Mission Profile
Spitzer Space Telescope

Launch date: 2003
Launch vehicle: Delta II rocket
Mass: 950kg (2,100lb)
Telescope diameter: 0.85m (33in)
Mission: NASA's Spitzer Space Telescope observes the universe in infrared wavelengths, which can penetrate through interstellar dust.
Key discoveries: Spitzer probes the interiors of star and planet-forming regions, as well as the structures of galaxies, determining the interstellar chemistry of those regions. It has also probed the atmospheres of exoplanets.

Mission Profile
Galaxy Evolution Explorer (GALEX)

Launch date: 2003
Launch vehicle: Pegasus rocket
Mass: 280kg (620lb)
Telescope diameter: 0.5m (19.7in)
Mission: This NASA ultraviolet space telescope is designed to study the structure and evolution of galaxies by observing its stars.
Key discoveries: GALEX has watched active black holes, captured images of galaxies plunging through other galaxies and spotted starbirth in the outer realms of galaxies.