

## INTRODUCTION: A GREAT ATTRACTION

*Will you sleep at night?  
With the Plough and the stars alight?*

-- MARILLION ("EASTER")

Sometimes, your own Galaxy gets in the way. Between the Milky Way's glowing stars weave clouds of gas sprinkled with the dark ash of ancient suns. Although these interstellar clouds can assume fanciful shapes -- eagles, horseheads, seagulls, swans -- they obscure the universe beyond, cloaking a fifth of the sky in perpetual fog.

"We knew that finding galaxies behind the Milky Way would be very difficult," said Renée Kraan-Korteweg, a Dutch-born astronomer at the University of Guanajuato in Mexico. "At optical wavelengths, it was not believed possible to uncover these galaxies, because they would be so hard to see." Indeed, this daunting region which girdled the sky had long been labeled the "zone of avoidance," since galaxies seemed to shun it.

So did galaxy-seeking astronomers. In 1994, however, Kraan-Korteweg and her colleagues trespassed into the forbidden zone and took aim at the constellation Cassiopeia with a radio telescope. The radio waves zipped past the gas and dust, betraying a large galaxy, never before seen, only 10 million light-years from Earth -- in astronomical terms, just around the block. It looked like the letter S, as if to say it had surrendered. Without the Milky Way's gas and dust, the galaxy would appear as one of the ten brightest in Earth's sky. Meanwhile, other astronomers dug up the wreckage of a small galaxy in Sagittarius, on the far side of the Milky Way. It proved to be the closest galaxy ever seen, a mere 80,000 light-years from Earth. It got torn apart when it strayed too close to the Milky Way's shores.

Even with these discoveries, a far mightier entity lurked behind the Milky Way. Astronomers had earlier discovered that the gravitational pull of something they christened the Great Attractor was trying to suck in all galaxies, including our own, for hundreds of millions of light-years around. The Great Attractor had accelerated our Galaxy to a speed of 1 million miles per hour, but its exact center eluded detection by concealing itself behind the southern Milky Way.

Kraan-Korteweg and her colleagues got to work, projecting magnified images of optical photographic plates onto a small screen in a darkened room. "It was a very slow process going through these plates -- finding galaxies, identifying them, classifying them," she said. "They're smudges that you can't see without enlarging them." Not only did the Milky Way's gas and dust dim the galaxies, but also hordes of foreground stars speckled the photographs, raindrops on a celestial windshield, further obstructing the view.

Nevertheless, she and her colleagues persevered. "We were charting thousands and thousands of new galaxies," said Kraan-Korteweg, "and it became very clear that there was an enormous concentration of galaxies very close to the predicted center of the Great Attractor." Deploying telescopes in Chile, South Africa, and Australia, the astronomers then measured the new galaxies' distances, finding them all 250 million light-years from Earth, nestled in a dense cluster like candles lighting an immense chandelier.

The cluster's galaxies dwelt in and around Norma, a forgettable southern constellation invented by an eighteenth-century astronomer best known for inventing forgettable southern constellations.

Norma lies southwest of Scorpius, the striking zodiacal constellation that bears the brilliant red star Antares.

"The Norma cluster is like Manhattan in New York," said Kraan-Korteweg: "the business district with all the tall buildings." The cluster abounds with giant elliptical galaxies, the celestial equivalent of skyscrapers, which throb through the richest galaxy clusters. The Norma cluster isn't the Great Attractor any more than Manhattan is New York City; it accounts for only a tenth of the Great Attractor's mass, but it does mark the monster's heart -- supergalactic downtown.

Strangely, astronomers had catalogued the Norma cluster a few years earlier, but because of the Milky Way's dusty veil, they thought it only a minor affair. In actuality, the Norma cluster rivals the greatest clusters known, such as the famous Coma cluster, yet until recently no one knew it existed. "In astronomy," said Kraan-Korteweg, "there's still so much to explore."

Time after time, the universe has astonished those who explore it -- offering hidden galaxy clusters, mysterious halos of dark matter, even a bizarre "antigravity" force that seems to pervade empty space. For millennia, of course, people have gazed heavenward and contemplated great cosmological questions -- How did the universe begin? What is it made of? What will be its ultimate fate? -- but only in the last hundred years have astronomers begun to acquire the data about the stars and galaxies that may answer these provocative questions.

*The Universe at Midnight* aims to tell this story of cosmological inquiry and discovery. During the day, scientists and philosophers can construct elegant theories of how they think the universe should operate; but at night, at midnight, when powerful telescopes swing toward distant galaxies, the universe delivers its verdict. Sometimes it validates existing observations and theories. Often, though, it repudiates them, forcing scientists to devise new conceptions of the cosmos. Drawing upon extensive interviews with the scientists who made the key discoveries, *The Universe at Midnight* tells the twisted, tangled, riveting story as it happened. It is part mystery novel, part detective story, part human drama. It is also, I hope, an up-to-date portrait of the state of cosmology today and how observers and theorists have arrived there. The book therefore proceeds chronologically, as one surprising discovery led to another. It starts with cosmology's oldest observation -- of the darkness that falls every evening -- and ends with the recent discovery that the universe's expansion may be speeding up.

Nearly half of *The Universe at Midnight* examines work from the past decade, illustrating how rapidly cosmology has progressed. But the book also sounds a note of caution, for this progress has often come at the expense of overturning previous truths. A hundred years ago, for example, astronomers thought that the universe was static, when today we know that it is expanding; forty years ago, they thought that the glittering stars within galaxies constituted the bulk of the universe, when today we think they are mere gems floating on a black velvet sea of dark matter; and ten years ago, they thought that the universe's expansion must be slowing, as the gravitational attraction of the galaxies braked its speed. Furthermore, some features of modern cosmology, such as the mysterious dark matter which sheathes the galaxies, and the repulsive force which seems to drive them apart, are so peculiar that they suggest crucial elements in cosmology remain missing. Although revolutionary discoveries add drama to the story, they also make one wonder which truths presented herein may themselves be overturned, the next time astronomers atop tall mountains point their telescopes at the heavens, at midnight.

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## **ONE: HIGH MIDNIGHT**

*Stars in my pocket like grains of sand  
Radiant pinpoints, they sting my hand  
I grab a fistful, a gift for the breeze  
Who will carry them far and away with ease*

-- WHITE WILLOW ("THE BOOK OF LOVE")

It is just before midnight, and stars spangle the sky: newborn stars emerging from magenta gas clouds, middle-aged suns dutifully towing planets through space, elderly red giants about to puff their atmospheres into the void. Every star the naked eye can see races around a giant black hole buried behind the dust clouds of the constellation Sagittarius. In the next hour, we too will dash half a million miles through space, as the Sun pursues its orbit around the Sagittarian black hole. The Sun, the Earth, and the canopy of stars all belong to the same celestial kingdom, the Milky Way, which boasts more stars than the Earth does people.

Yet most of the universe lies beyond the Milky Way. In the constellation Andromeda, a faint wisp betrays another Milky Way, another titanic empire of stars, planets, and possibly people, all anchored to one another by gravity. Call it a *galaxy*, after the Greek for "Milky Way." So distant is the Andromeda Galaxy that the light we see tonight set out from its spiral shores 2.4 million years ago, before the human race arose. Both Andromeda and the Milky Way belong to a flock of galaxies called the Local Group. Among Local Group galaxies, Andromeda ranks number one in size and brilliance, our own Milky Way number two -- not bad, since altogether the Local Group houses three dozen galaxies.

Yet most of the universe lies beyond the Local Group. Long ago, stargazers pictured a star pattern south of the Big Dipper's handle as a woman holding a spike of grain, and they named her Virgo. Here cluster thousands of galaxies that rule the center of a huge galactic metropolis which a maverick astronomer named the Local Supercluster. At the time, other astronomers didn't believe him, but in fact galaxies



on its farthest-flung outposts would be slightly less secure. Thank you for choosing to live in the Milky Way.

Gravity herds the entire Local Group, preventing its galaxies from fleeing the flock. Gravity might do the same to the universe itself. If the universe is dense enough, the gravity of all its galaxies will eventually halt its expansion. Then the universe will start to collapse, ending its days in a fiery inverse big bang -- a "big crunch." For decades astronomers have known that the universe harbors far more matter than meets the eye, dark material whose gravity tugs on the stars and galaxies. However, despite all this dark matter, the universe is not dense enough to collapse. Moreover, empty space seems to exert a repulsive force that speeds up the universe's expansion. If so, not only will the universe expand forever, it will expand forever faster. In only about 150 billion years, all galaxies beyond the Local Supercluster will vanish from the sky, because the space between them and us will be expanding so fast that their light can no longer reach the Earth.

These remarkable deductions come from large telescopes, some perched atop mountains, others lofted into space, that have helped decipher the tangled clues left behind in the wake of the big bang. The first cosmological observation, however, required no telescope at all. Look at the night sky: it is dark. Why?

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