Mapping Main Street

What does our galaxy look like?

It's an odd quirk of astronomy. Telescopes can look billions of light-years outward, allowing us to study a plethora of galaxies and to map their lacelike distribution through space and time with exquisite precision. Distant quasars have been thoroughly examined—by gathering their emissions from radio to gamma rays. And this past spring the European Space Agency's Planck satellite provided the best baby picture of the cosmos yet, an image depicting the universe when it was a mere 370,000 years old. The definitive cosmic atlas appears within our grasp.

And yet the topography of our local celestial landscape, within only tens of thousands of light-years, remains frustratingly murky. What seems like it should be the most familiar structure—that of the Milky Way, our home galaxy—is just the opposite. It's like owning the best globe of the world, with your hometown missing.

There's a simple reason for this conundrum: our solar system is embedded *inside* the dusty plane of the Milky Way. That makes viewing our galaxy's exact configuration a difficult task. Try discerning the pattern on a piece of china with your eyes level to the edge of the plate. That's what astronomers have long confronted when trying to map the Milky Way. How can you peer through that dish, full of dust and gas?

To find an answer, astronomers started with a hunch—a reasonable one at that. Since the disks of other galaxies displayed a beautiful spiraling architecture, they assumed that the Milky Way, too, has massive arms that wrap themselves around the galactic hub like coiled streamers. By the 1930s, identifying the Milky Way's spiral arms became a top item on astronomers' agenda. At first they tried just counting stars, all the ones in sight, hoping denser concentrations in the tally would outline the arms—but with little success. It took World War II, oddly enough, for astronomers to come across a new approach.

NASA/JPL-CALTECH/R. HURT

The Milky Way is a barred spiral galaxy, perhaps with two bars, one nestled inside the other.

Because of the fear that the Japanese might attack the West Coast of the United States, the Los Angeles area was blacked out nightly during the conflict. This was heaven for one particular astronomer working at the nearby Mount Wilson Observatory, which operated the biggest telescope in its day: the Hooker telescope with its 100-inch-wide mirror. While many observatory staffers had temporarily left to carry out war work, German-born Walter Baade was designated an "enemy alien" and restricted to the Pasadena area. That meant he had almost unlimited time on the 100-inch, allowing him get the best look ever at the Andromeda galaxy, the spiral galaxy closest to us at a distance of 2.5 million light-years.

Pushing the telescope to its limits over months of observations, Baade came to recognize that highly luminous blue and blue-white supergiant stars, along with bright gaseous nebulae, tended to reside only in Andromeda's spiral arms, acting much like the lights lining an airport runway. The reason spiral arms

stand out is because they are regions where young, hot stars are forming.

The stars making up an arm are not permanently connected, as if part of a ropelike structure attached to a galaxy's center. Rather, that appearance reflects underlying density or shock waves that, traveling through the galaxy's disk of gas, foment star formation. That mechanism wasn't identified until the 1960s, but nonetheless Baade still found the perfect objects to delineate a spiral galaxy's arms.

Soon after the war, others began applying this newfound knowledge to our own galaxy. Astronomer William W. Morgan at the Yerkes Observatory in Wisconsin got a head start on the problem, as he had already been carrying out a spectral study of the Milky Way's brilliant supergiant stars. He first teamed up with Jason Nassau at the Warner and Swasey Observatory in Ohio, and together they pinpointed the positions of some 900 supergiants. The distances from Earth of less than 6 percent of these could be nailed down, but this scanty evidence suggested that a spiral arm might be running from the constellation Carina over to Cygnus in our local solar neighborhood. It was a start.

Soon after, Morgan joined forces with two student assistants, Stewart Sharpless and Donald Osterbrock, to push the survey even further. Along with tracking down blue and blue-white stars, they also plotted the distribution of luminous nebulae (notable for their energized hydrogen). To quickly spot the nebulae, the two students set up a special camera that was originally designed as a wide-angle projector for training aerial gunners during World War II. The dozens of photographic plates they took, revealing many new nebulae for Morgan to analyze, provided the breakthrough.

Segments of two spiral arms could be reliably traced with the additional data. One arm (labeled Orion) passed within 1,000 light-years of the Sun; the other (Perseus), located farther from the galactic center, was at its closest point to us some 6,500 light-years away. There was also the hint that a third spiral arm (Sagittarius) swept closer to the center of the Milky Way, about 5,000 light-years away from us.

The Yerkes team announced its findings at a 1951 meeting of the American Astronomical Society, held in Cleveland, Ohio. Morgan presented a hand-made model of the spiral arms, which used cotton balls to depict the positions of the bright nebulae. This map was far from complete, because it's difficult for an optical telescope to peer much farther into the dust- and gas-filled plane of the Milky Way. But that didn't dampen the reception Morgan's work received at the astronomical conference.

"Astronomers are usually of a quiet and introspective disposition," University of California astronomer Otto Struve later wrote.

> They are not given to displays of emotion. . . . But in Cleveland, Morgan's paper on galactic structure was greeted by an ovation such as I have never before witnessed. Clearly, he had in the course of a 15-minute paper presented so convincing an array of arguments that the audience for once threw caution to the wind and gave Morgan the recognition which he so fully deserved.

There was clapping of hands and stomping of feet. And why not? The Yerkes astronomers were providing the first map (partial as it was) of our cosmic "hometown." A problem that astronomers had struggled with for decades, astronomy historian Owen Gingerich has written, had "finally found its solution by a quite different avenue from the numerical star-counting procedures."

And when it rains, it pours. Within two years, the spiraling segments were confirmed and extended with the use of a new instrument available to astronomers—the radio telescope, which could penetrate farther through the Milky Way's dust and haze by tuning in to a radio frequency emitted by hydrogen gas.

The map is still incomplete, but some overall patterns are emerging. For one, there is now strong evidence that the Milky Way galaxy is a *barred* spiral, which means its center is extended like a bar rather than bulbous (as in the Andromeda galaxy). More than two-thirds of present-day spirals have a center bar, a structure that likely evolves as a spiral galaxy matures.

And from the 1950s into the 1990s, continuing surveys revealed further sections of our galaxy's spiraling arms, piece by piece. By connecting the dots, astronomers came to believe that there were four gently curving arms, neatly arranged around the Milky Way's center.

Infrared images taken by NASA's Spitzer Space Telescope, released in 2008, changed that assumption, however. It now looks like our galaxy has two dominant arms. Each originates from an opposite end of the central bar and then bends outward, swirling nearly completely around our galaxy's core. One of them, the Perseus arm, was partially seen by Morgan in 1951. The other is known as the Scutum-Centaurus arm.

What happened to Morgan's other spiral-arm sightings? Much like the earliest maps of the New World, the cartography has been altered with better resolution. Morgan's Sagittarius arm has been demoted to a more minor appendage, while the Orion arm (where the Sun resides) is now known to be a mere "spur." Our view of the Milky Way arises within a shorter concentration of stars and nebulae positioned between the two major arms. We sit amid glory—but at a smaller table.

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