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THE TONANTZINTLA SEARCH FOR HIGH LUMINOSITY STARS

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RESUMEN

A partir del artículo de G. González y G. González, 1952, BOTT, 1, 5, 1 en el primer volumen del Boletín, fueron varios los astrónomos que trabajaron durante años para encontrar las estrellas OB que delinean los brazos espirales locales. Quizás se desanimaron cuando aparecieron los mapas de radio en 21 cm, pero no lo debieron haber hecho ya que los datos ópticos proporcionan distancias, mientras que los datos de radio solamente miden movimientos radiales que se requieren interpretar con un modelo de los movimientos de nuestra Galaxia. Estos movimientos son más complicados que lo que se había pensado, por lo que sus mapas son muy inexactos. El mapa reciente de 4.5 μm muestra que nuestra Galaxia tiene una barra central, dos brazos espirales mayores y cinco pequenos.

ABSTRACT

Starting with the paper by G. González and G. González, 1952, BOTT, 1, 5, 1 in the first volume of the Bulletin, various Tonantzintla astronomers worked for years to find the OB stars that delineate the local spiral arms. Perhaps they became discouraged when the 21 cm radio maps appeared, but they should not have been because the optical data produce distances while the radio data measure only radial motions, that need to be interpreted with a model of the motions in our Galaxy. Those motions are more complicated than they thought, so their maps are very inaccurate. The recent 4.5 μm infrared map shows our Galaxy to have a central bar, two major spiral arms, and five small ones.

Key Words: Galaxy: structure — stars: early-type

In 1925 Edwin Hubble announced that Cepheids in the Andromeda Nebula, compared with Henrietta Leavitt's calibration of Cepheids in the Small Magellanic Cloud, gave a distance to Andromeda of about 275,000 pc (Hubble 1929). That was much larger than the radius of 15,000 pc of the Milky Way and proved that Andromeda and other galaxies are separate systems from the Milky Way. Hubble also described the various forms of galaxies as spirals, barred spirals, ellipticals, and irregulars.

What is the shape or type of the Milky Way galaxy? For example, when one is standing in a forest, it is very difficult to tell the outer shape or size of the forest if it is impossible for a person to walk to the edge. How can we tell the type of galaxy in which we live?

Astronomers realized that the spiral arms in spiral galaxies consist of the most luminous stars, star clusters and associations, gaseous nebulae, gas, and dust. So if we could locate the most luminous stars in our galaxy, we would be able to map the nearby part of the Milky Way and tell whether it has spiral arms.

This was first done by W. W. Morgan and his colleagues. From color-magnitude diagrams of open clusters they could determine the absolute brightnesses of O and B stars relative to solar-type stars. Then by measuring the apparent brightnesses of individual OB stars they could determine their distances. That was done by Morgan, Sharpless, & Osterbrock (1952) and Morgan, Whitford, & Code (1953). The resulting map (Figure 1 of the latter paper) showed sections of three spiral arms: the Orion-Cygnus arm that contains the Sun, an inner Sagittarius arm, and an outer Perseus arm. With more observations they derived the arms shown in Figure 2 (taken from Bok 1959). So the Milky Way is a spiral galaxy.

That is fine, but we would like to see a map of a larger section of our Galaxy to see how many spiral arms there are and its overall shape and size. Morgan's map was based on stars generally brighter than 9th mag. What was needed were identifications and distances of much fainter high-luminosity stars. That is where the astronomers at Tonantzintla Observatory and other observatories having Schmidt telescopes came to the rescue. In a series of 16 papers, starting with González & González (1952), in the first three volumes (1952–1962) of the "Boletín de los Observatorios de Tonantzintla

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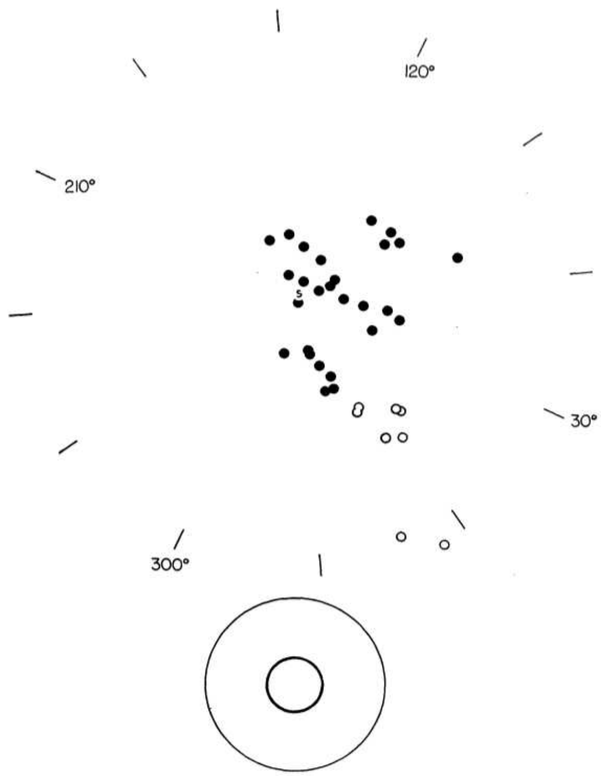

Fig. 1. Morgan's map of the distribution of stellar associations showing parts of three spiral arms. The circles represent the galactic center at 9 kpc from the Sun. (Figure reproduced from Morgan et al. 1953, ApJ, 118, 318 by permission of the American Astronomical Society).

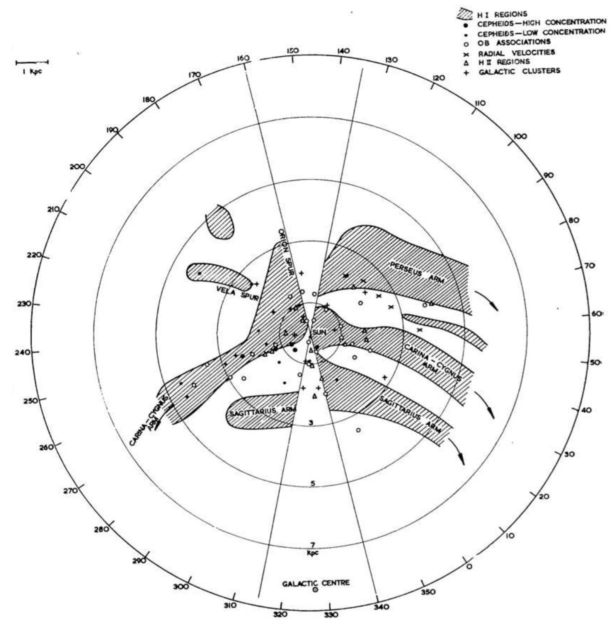

Fig. 2. The local spiral arms based on optical data. (Figure reproduced from Bok 1959, Obs., 79, 58 by permission of The Observatory).

y Tacubaya" astronomers found thousands of luminous stars from magnitudes 9–18. The participating astronomers were Guillermina González, Graciela Gonzáalez, Luis Münch, Braulio Iriarte, Enrique Chavira, Guillermo Haro, and Willem J. Luyten. They used the 4° prism on the 26 inch Tonantzintla Schimdt telescope to identify OB spectra. For the last paper (Haro & Luyten 1962) they used the 48 inch Palomar Schmidt with the Tonantzintla three-image method of photographing through ultraviolet, yellow, and blue filters.

Meanwhile, the radio astronomers were using observations of the 21 cm radio line and derived a more complicated pattern of spiral arms in distant parts of the Milky Way, e.g., see Figure 3 taken from Westerhout (1957). But they measured only velocities and fluxes, not positions and distances, as did the optical astronomers. The radio astronomers depended upon a model of galactic rotation to interpret the measured radial velocities. However, we know now that the interstellar medium is very turbulent. For instance, Points, Lauroesch & Meyer (2004) studied interstellar Na I lines toward stars in h and χ Persei and found large difference in line strengths down to stellar separations of 0.35 pc. They visualize the interstellar medium as consisting of sheets, ropes, and blobs of gas with different motions. Therefore the assumption of a smooth galactic motion is inappropriate. The complex spiral arm patterns obtained by the radio astronomers may show the complex interstellar motions rather than complex structures. Other galaxies do no show arms like in Figure 3.

The astronomers at the Warner & Swasey and Hamburg Observatories were also searching for faint luminous stars with Schmidt objective prisms. Their techniques were explained by Slettebak & Stock (1957). Those were somewhat different than at Tonantzintla because they had an ultraviolet-transmitting (Schott UBK7) prism. Although they (e.g., Nassau, Stephenson, McCuskey, Sanduleak, Pesch, MacConnell, etc.) spent huge amounts of time on those surveys, but they never finished the job of determining spiral structure. There were three problems. One was that Pesch (1963) found that their luminosities were overestimated by 1–2 luminosity classes. Another problem was that the astronomers at Warner & Swasey Observatory and at Tonantzintla Observatory did not have the telescopic equipment to obtain more precise luminosities. Per-

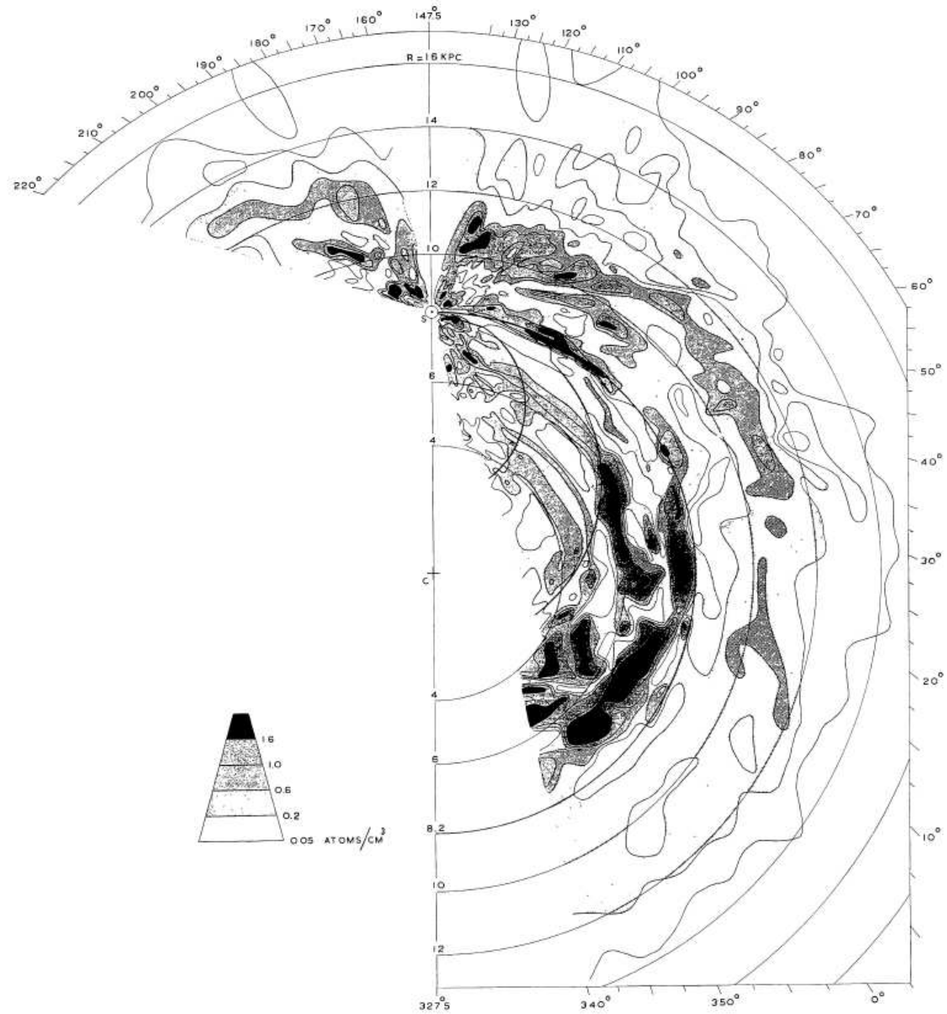

Fig. 3. The 21 cm map of most of our Galaxy obtained in 1957 and showing many irregular arms, some of which reverse directions. (Figure reproduced from Westerhout 1957, BAN, 13, 201).

haps what is needed is narrow-band photometry on a large telescope, such as at San Pedro Martir Observatory, to get better luminosity accuracy than the MK's ± 2 mag. But mostly they thought that the spiral structure had been solved by the 21 cm observations. Not so. They should have pursued the problem because the optical observations derive distances while the radio observations derive only motions that need to be interpreted. The optical observations were needed to calibrate the radio data. Thus it was unfortunate that the luminous stars found at Tonantzintla and Warner & Swasey were not studied further to derive spiral structure.

The next step was the use of infrared data to derive spiral structure. The 2MASS and Spitzer/Glimpse surveys used observations at 3.6 and 4.5μ m to find the distribution of red giants. Red giants have a narrow range of luminosities nearly independent of temperatures, so they can be used as standard candles. At shorter wavelengths the interstellar extinction becomes great and at longer wavelengths there is confusion with dust emission. However, the 4.5 μm measures showed the presence of a central bar 4400 pc long and tilted 44° to the line of sight (Benjamin et al. 2005). Also, the Milky Way has two pronounced spiral arms, called Scutum-Centaurus and Perseus, and five minor arms: called the 3 kpc Arm, Norma Arm, Sagittarius Arm, the Orion Spur (which contains the Sun), and the Outer Arm (Churchwell et al. 2009). This shows that the Milky Way is a barred spiral with two major arms and other minor features (Figure 4, taken from Churchwell et al. 2009), not significantly different than many other giant spirals.

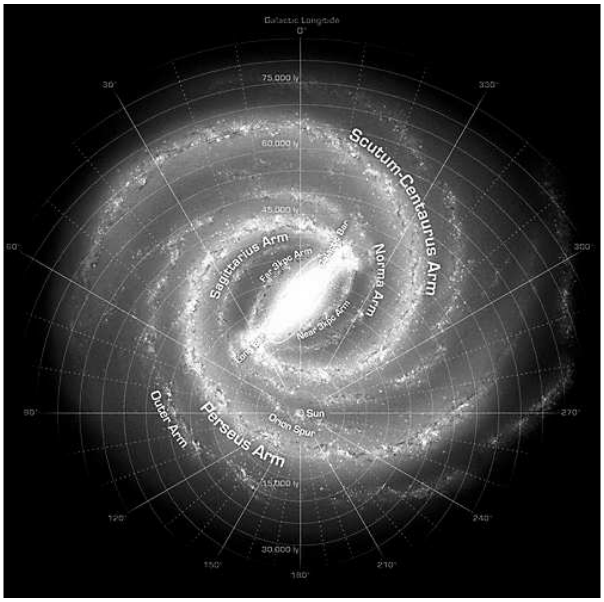

Fig. 4. The current map of the Galaxy drawn from optical, radio, and infrared data. The arms are labeled and the faint radial lines show galactic longitudes from the Sun. (Figure reproduced from Churchwell et al. 2009, PASP, 121, 213 with permission from the author).

We are grateful to the Tonantzintla astronomers and other users of Schmidt telescopes for helping to derive this map of our Galaxy. In 50 years we have gone from just barely knowing that our Galaxy is a spiral galaxy to a picture that seems very normal compared with other galaxies.

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