Carl Vilhelm Ludvig Charlier, born Apr. 1, 1862, died Nov. 5, 1934, received the ASP's Bruce Medal in 1933 for his research achievements. Photo courtesy of the Mary Lea Shane Archives of the Lick Observatory, University of California, Santa Cruz.

Carl V.L. Charlier

The Twenty-Eighth Bruce Medalist

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Carl V.L. Charlier (1862–1934), who applied statistical analysis to the positions and motions of the stars, is famed for his hierarchical model of the universe, in which clustering extends to larger and larger systems.

Where are we? Generations of astronomers, philosophers, and theologians have endeavored to find our place in the universe. Until about 500 years ago, most people, or at least most people in Europe, thought the answer was obvious: We are at the center of the universe. In 1543, Nicholas Copernicus proposed that the Sun is at the center, but he retained the belief that the stars are all at the same distance from that center, on the surface of a sphere somewhere beyond the most distant planet. By 1687, when Isaac Newton finished the Copernican revolution with a complete theory that accounted for motions in the heavens and on the Earth with the same few mathematical laws, it was becoming clear that the Sun is one of a great many stars in an enormous volume of unknown size and shape.

Newton believed that the stars extend forever; in fact, he showed that a finite, static system would collapse. In the mid-18th century, Thomas Wright in England and Immanuel Kant and Johann Lambert in Germany suggested that we see the Milky Way because the system of stars is flattened and extends a much shorter distance perpendicular to the plane of the Milky Way than along that plane. Both Kant and Lambert suggested that the fuzzy objects called nebulae might be additional systems of stars — *island universes* — separate from the system in which we reside. A bit later, the great observer and telescope-maker, William Herschel, counted stars of different magnitudes and confirmed that the system of stars is indeed flattened, and finite as well. We see the Milky Way when we look along the direction in which the stars extend the farthest.

By the late-19th century the use of photography was allowing astronomers to record stars too dim to see, and also enabling those who analyzed the observations to be separate in both time and place from the telescopes. This was especially good for the Europeans, as their instruments and skies were being outclassed by large telescopes built by wealthy Americans in California and Arizona.

Readers of this series will recall the fruitful collaboration between David Gill (May/June 1990, p. 84), who photographed the southern sky from the Cape of Good Hope, and Jacobus C. Kapteyn (September/October 1991, p. 145), whose team measured the plates in the cloudy Netherlands. Kapteyn, at Groningen, and Hugo von Seeliger, in Munich, were the leaders in *statistical astronomy:* the attempt to find out where we are by analyzing the numbers and motions of stars throughout the sky. Several others, including Seeliger's student Karl Schwarzschild (November/December 1991, p. 179) and Arthur Stanley Eddington (July/August 1993, p. 119), entered the field in the first decade of this century. The one who delved the deepest into statistics as a branch of mathematics was a Swedish astronomer, Carl V.L. Charlier.

Leftist at Lund

Charlier's education, like that of Eddington and Frank Dyson (March/April 1993, p. 49), emphasized mathematics and celestial mechanics; in Charlier's case, at the venerable University of Uppsala, north of Stockholm. After earning his Ph.D., with a dissertation on Jupiter's effect on the orbit of minor planet 17 Thetis, he became assistant to celestial mechanician Hugo Gyldén at Stockholm. There he applied his mathematical skills to other problems. He repeatedly photographed the Pleiades to find the relation between photographic image size and visual magnitude, but astronomers were just discovering that photographic emulsions and human eyes are most sensitive at different wavelengths. From 1890 to 1897 Charlier was back at Uppsala as chief assistant at the observatory, and at age 35 he attained one of the highest positions in Swedish astronomy, professor and observatory director at the University of Lund.

The new professor faced a mixed welcome. Active in a political organization of students and young scientists, Charlier was considered a leftist by the conservative old guard who dominated the university and the press; many professors and students strongly opposed his appointment. His reaction was to ignore critics and work hard.

During the first of his three decades at Lund, Charlier continued his work in celestial mechanics. Later he explained to a group of colleagues, "Well, it was at the time when we still dreamed of reaching the solution of the problem of three bodies." By about 1905 he became convinced that astronomers had gathered sufficient data that for the first time there was real hope of learning our place in the universe. Characteristically, he did not jump in, but, according to historian E. Robert

Paul, "first published a long series of papers on the foundations of probability theory and the mathematical theory of statistics." Paul further noted, "Being in some respects first a statistician, Charlier added a rigorous statistical foundation to stellar statistics unheard of hitherto."

Charlier explained, in a series of lectures at Berkeley in 1924, that Herschel had begun stellar astronomy with three assumptions: that all stars have the same luminosity, that the stars are uniformly distributed in space, and that with his 19-inch telescope he could penetrate to the end of the system of stars. A century after Herschel's death, "All three of these assumptions must be abandoned and exchanged for others of more general character. First we must know how the magnitudes of the stars are distributed. Secondly, how the density in the stellar system depends on the distance from the Sun."

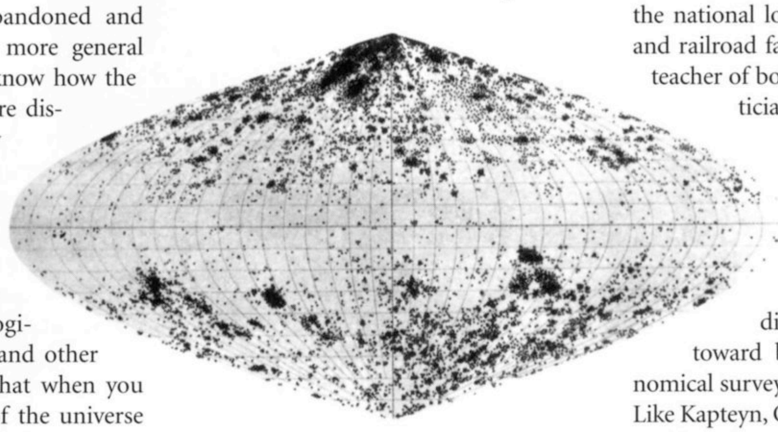
Charlier declared, "One thing is... to be learned from the cosmological speculations of Kant and other philosophers. You learn that when you will study the structure of the universe or any other problems regarding Nature, you may not, like the speculative philosophers, go into your chamber and try to construct the universe from the depths of your consciousness. You must go out and read in the great book of Nature. It is difficult to read in this book and it takes much time before you can add one syllable to another. But what you find is the truth, the simple but real truth, which in all its simplicity is in the long run better than attractive religious dreams or vain philosophical speculations."

Finding the Truth in Errors

According to Paul, Charlier reformulated the statistics of stellar astronomy by considering the mathematics of statistical errors. Recognizing inherent problems in any discussion of the statistics of a wide range of data (stars, in this case), Charlier showed that the situation could be improved greatly if star counts were organized not only according to apparent magnitudes, but also according to spectral types.

As Ejnar Hertzsprung and Henry Norris Russell (September/October 1993, p. 19) had shown, red M stars included both giants and dwarfs, with great differences in luminosity, but the bluish B stars were nearly all of the same brightness, making them much more useful as "standard candles" with which to determine distances. From this, it became clear to Charlier that the Sun is not at the center of the stellar system, and, unlike Kapteyn, he was receptive to Harlow Shapley's claim that the center is a considerable distance from the Sun in the direction of Sagittarius.

Today, although his name lives on in the Gram-Charlier series of statistics, Charlier is best known for his hierarchical model of the universe. In this he postulated that stars are clustered in galaxies of the first type, which are clustered in a second type (which we now call superclusters), and so on *ad infinitum*. If the distances between succeeding types of clusters increase at the right rate, the universe can be infinite yet have an average density of zero. Charlier's model solved two problems that an infinite universe seemed to imply: "Olbers' paradox" that the night sky should be as bright as the Sun [see "The Paradox of the Dark Night Sky," July/August 1980, p. 83] and Seeliger's paradox of infinite (negative) potential energy. Charlier was ready to accept the spiral nebulae as external galaxies, and he suggested that their spiral shapes are produced by gravitational interactions with each other, an idea in vogue among some astronomers today.



Charlier's 1924 map of nebula distribution. Most of the 12,000 dots represent galaxies. The knot near the top is the Virgo cluster, the center of our local supercluster. The Perseus cluster is in the top center of the lower right quadrant, and the Pavo cluster is on the left side of the lower left quadrant. The gap running across the horizontal centerline is the "zone of avoidance," otherwise known as the Milky Way. Diagram from PASP, volume 37, number 218.

Charlier raised Lund's position in the astronomical community. He expanded buildings and hired human computers. He published his early papers in German, Swedish, or French, but around 1910 switched to English, which was becoming the most important language in astronomy. In retirement, Charlier translated Newton's *Principia mathematica philosophiae naturalis* (*Mathematical Principles of Natural Philosophy*) into Swedish. He advised the Swedish government on statistical problems dealing with the national lottery, pensions, medicine, and railroad fares. He was an influential teacher of both astronomers and statisticians. His students included Gustav Strömberg, who did important spectroscopic research at Mount Wilson, and Karl G. Malmquist, whose work on the difficulty of avoiding bias toward brighter objects in astronomical surveys is frequently cited today. Like Kapteyn, Charlier showed that much could be done even with cloudy skies and modest instruments. ***m***

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