THE ROTATION OF THE GALAXY

being

THE HALLEY LECTURE

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BY

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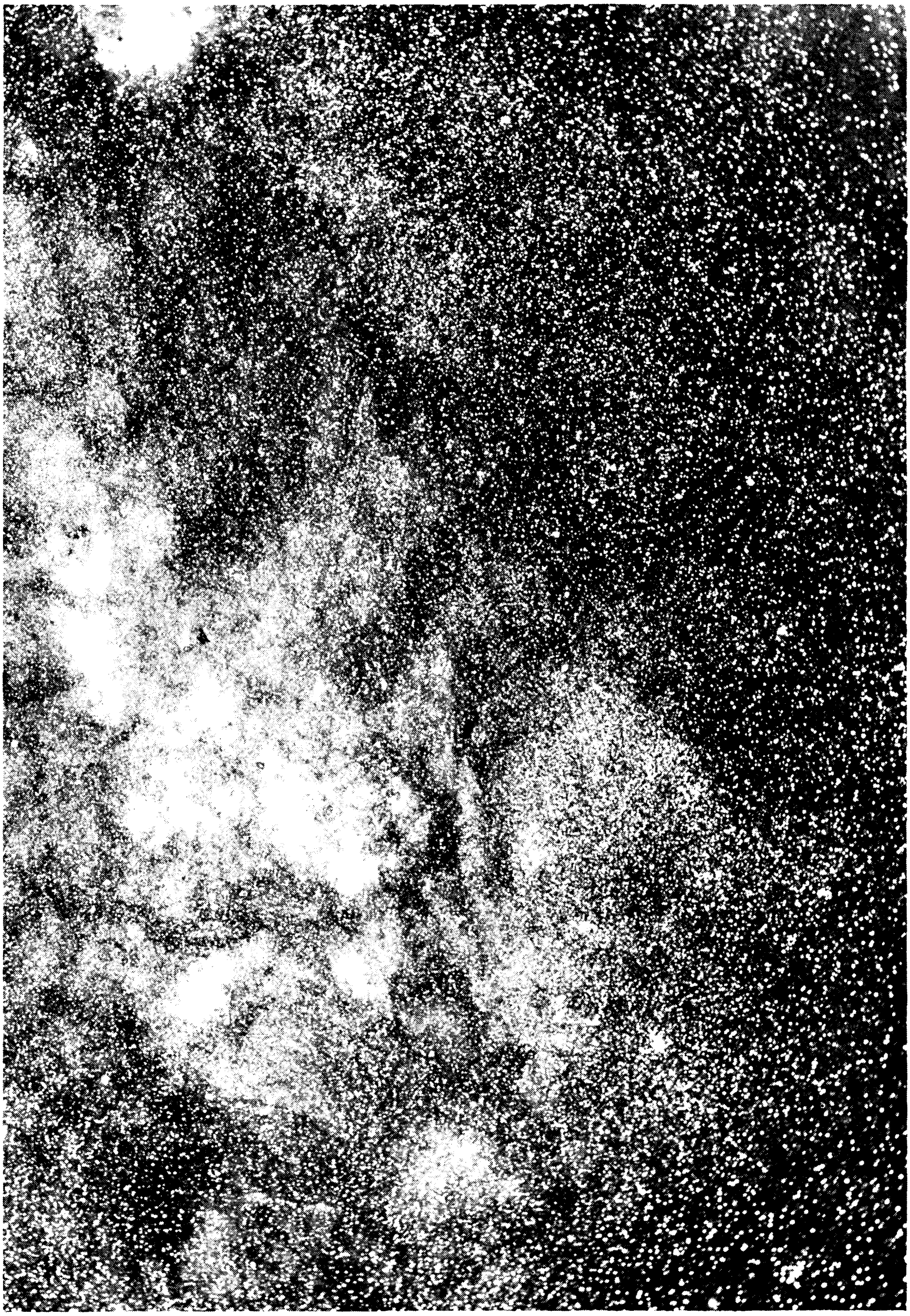

STAR CLOUD IN SAGITTARIUS

The centre of our galaxy (hidden by obscuring matter) lies near the middle of the right-hand edge of the photograph

Frontispiece

STAR CLOUD IN SAGITTARIUS

Photograph E. E. Barnard

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The Rotation of the Galaxy

EARLY in 1718 Edmund Halley communicated to the Royal Society the paper announcing his discovery of the proper motions of the stars, under the title *Considerations on the Change of the Latitudes of some of the principal fixt Stars.* Referring to a comparison he had made of modern places of stars with the ancient observations collected in Ptolemy's Almagest, he wrote:

> 'I was surprized to find the Latitudes of three of the principal Stars of Heaven directly to contradict the supposed greater *Obliquity* of the *Ecliptick*, which seems confirmed by the Latitudes of most of the rest, they being set down in the old Catalogue as though the Plain of the Earths Orb[it] had changed its Situation, among the fixt Stars, about 20′ since the time of Hipparchus. . . . Yet the three Stars *Palilicium* or the *Bulls* Eye, *Sirius* and *Arcturus* do contradict this rule directly. . . . What shall we say then? It is scarce credible that the Antients could be deceived in so plain a matter, three Observers confirming each other. Again these Stars being the most conspicuous in Heaven, are in all probability nearest to the Earth, and if they have any particular Motion of their own, it is most likely to be perceived in them, which in so long a time as 1800 Years may shew it self by the alteration of their places, though it be utterly imperceptible in the space of a single Century of Years. . . . This Argument seems not unworthy of the *Royal Society*'s Consideration, to whom I humbly offer the plain Fact as I find it, and would be glad to have their opinion.'

Two hundred years have gone by, and now we are faced with a great accumulation of data concerning these apparent movements of the stars. This has been supplemented, mainly during the last twenty years, by extensive

determinations of their velocities in the line of sight by use of the spectroscope. We have therefore a mine of material from which we are trying to learn what we can of the nature of the motions of the stars as a system and to reach some kind of dynamical theory of what is going on. A caution must be given at the outset. According to modern views the dimensions of our galaxy are immense; and although our survey of stellar motions extends over a region containing perhaps 10 to 100 million stars, this is but a small part of the whole. We have to take a risk in inferring the nature of the complete system from the small sample within reach.

Throughout the nineteenth century astronomers working on stellar motions concentrated their attention on one main theme—the solar motion, or velocity of our sun as an individual star with respect to the system as a whole. For our present discussion of the system of the stars this has no particular interest, being merely a distorting factor in our outlook which is sometimes troublesome to eliminate. We are concerned with the stellar motions remaining after our own translational velocity has been allowed for; they are by no means those of an unorganized crowd. By later researches four leading peculiarities have been discovered. I give them in historical order:

(1) Star-streaming, i. e. a tendency of the stars to move to and fro along one particular axis in space rather than in directions at right angles to it.

(2) A strong correlation between the velocity and the physical characteristics of the stars. For example, stars classed as of 'late' spectral type have a higher average speed than those of 'early' type.

(3) Stars of exceptionally high velocity (greater than 80 km. per sec.) are found to be moving exclusively towards one hemisphere of the sky.

(4) An effect rather complicated to describe which we interpret as evidence of rotation of the whole system. This is the main theme of my lecture.

In conjunction with these results we have to consider a matter of common knowledge inferred from the apparent distribution (not the motions) of the stars. Our stellar system has a very oblate form. It is believed to be almost a disk—resembling the spiral nebulae seen abundantly in the vast universe beyond the confines of our galaxy.

Nature of the Rotation

The discovery of the fourth effect and the interpretation placed on it are due to J. H. Oort of Leiden. Among other investigators should be mentioned especially B. Lindblad, who had been developing the hypothesis of galactic rotation for other reasons, and J. H. Plaskett, to whom we owe the most convincing observational evidence.

It will help us to understand what kind of indication of rotation we might look for in a system of stars, if we transfer our attention for a moment to a phenomenon nearer home, namely Saturn's rings. These have a rough resemblance to the disk-like form attributed to our galaxy. At one time there was a division of opinion as to whether the rings were solid structures, or whether they consisted of swarms of small particles. In a famous mathematical investigation, which is one of the classics of celestial mechanics, Clerk Maxwell showed that the solid type of ring was dynamically impossible; it would be unstable. The only permissible constitution was a swarm of separate bodies. Many years later Maxwell's theory of the ring was strikingly confirmed by Keeler; and it is his method of confirmation which especially interests us. If a solid ring rotates, its outer edge must necessarily travel faster than the inner edge; on the other hand, if the ring is a swarm of meteoric particles, they will follow the same rule as the planets in the solar system, viz. the inner particles must travel faster in order to counterbalance the stronger gravitational pull of the planet. Keeler found by spectroscopic observation that the inner edge of Saturn's