to over 40,000 tons per annum in five plants, with others building. The material as produced is used directly as a fertilizer, but it is a simple matter to obtain ammonia from it and by a contact process this may be directly converted into nitric acid.

Yet another indirect source of supply of nitric acid and, therefore, of saltpeter is found in the manufacture of coke, for an important product of the by-product coke industry is ammonia, which is obtained usually nowadays as ammonium sulphate. I have elsewhere shown¹ that 15,773 tons of ammonium sulphate were produced in this country in 1905. But as only 3,317,585 tons of the 37,376,251 tons of coal coked in the census year were coked in by-product ovens it was possible, had all been so treated, to have obtained 359,560 tons of ammonium sulphate, all of which if desired could have been converted into nitric acid for use in the manufacture of saltpeter or of any desired variety of explosive.

From this account of recent chemical progress it is evident that it is possible to conduct a prolonged war on the soil on which the people depend for their existence, and further, that, notwithstanding the constantly increasing demand for nitrogen compounds in agriculture and manufacture, this country has reached a potential degree of independence, as regards its supply of nitrogen compounds for military uses, such as it never before enjoyed, so that it needs hereafter to consider foreign sources of supply only from the economic standpoint. However, I desire to say regarding the plants for the fixation of nitrogen what I have repeatedly advised regarding plants for the manufacture of explosives, viz., that it is a wise policy for our Government to foster, and in a measure supervise, these manufacturing operations, and to look to it that plants for these purposes are so strategically located throughout the country as to be reasonably well protected from attack, so that they may serve the military establishment in case of foreign invasion from any quarter or of internal uprisings in any locality.

On the Proper Motions of the Fixed Stars*

By W. DOBERECK, Ph.D., F.R.A.S., M.R.I.A.

HAILEY found that some of the brightest fixed stars had changed their places since they had been observed by the ancient Greeks, and such changes are so obvious as to be recognized on ancient coins. Sir William Herschel, in 1783, arrived at the conclusion that a relative motion of the sun among the fixed stars in the direction of a point situated near λ Hercules would account for the greater part of these proper motions: the motion of the sun towards the "apex" must cause the fixed stars in half the sky to apparently move away from that point, and in the other half of the sky to move towards the diametrically opposite point, the "anti-apex." Since then a great many astronomers have determined the situation of the "apex," but the results do not agree very well, especially as regards the declination. Bessel investigated the matter and declared himself dissatisfied with the evidence. When the direction of the proper motion of a fixed star has been ascertained, a great circle laid through the positions of the star observed at two epochs is thereby determined, and if the great circles belonging to different stars intersect in a point (the apex), it is easy to see that the poles of these great circles must lie on another great circle, of which the apex is the pole. Bessel found that the poles do not lie on or near a great circle, but are scattered over the sky. Kobold, the editor of the *Astronomische Nachrichten*, who some years ago took up Bessel's investigations, proceeds as follows. He imagines the celestial sphere inscribed in a cube which touches the sphere at the two poles and at four points on the Equator. He supposes the eye of the observer situated in the center of the sphere, and any great circle on the sphere is then projected as a straight line on one or more of the faces of the cube. Kobold had already used maps made on this principle in determining radiants of shooting stars, and the writer had subsequently, in Hongkong, used similar maps for the same purpose. Kobold projected the poles of a great number of proper motions in such maps. Those that correspond to proper motions intersecting in the apex should lie on a straight line corresponding to the great circle of which the apex is the pole, but that is not clearly shown on the maps.

Kapteyn, who has the merit of having originated many hypotheses that appear destined to aid greatly in the astronomy of fixed stars, solves the difficulty by accounting for a great number of proper motions on the supposition that there are two distinct apices both close to the galaxy. It had, indeed, in course of years, become the general impression that the galaxy is made up not of isolated heavenly bodies, but of a conglomerate of clusters of stars and nebulae. There was, therefore, nothing extraordinary in the circumstance that the stars belonging to two clusters did

not move in the same direction. Kapteyn's hypothesis has been examined at the Greenwich Observatory and confirmed there by the independent evidence of proper motions, other than those used by Kapteyn. It has been confirmed also at the Cape of Good Hope. It has been to some extent confirmed by spectroscopic evidence at the Cape Observatory and at the Lick Observatory.

The speed in miles with which a star is moving towards or away from the earth can be measured in the spectrum, the wave-length of the lines being respectively shortened or lengthened, and it is found that the stars on opposite sides of the sky indicate a general drift, or even two drifts; but the objects used should be evenly distributed over the whole sky, and the spectra of only a few faint stars are known with sufficient accuracy for this purpose.

Meantime other radiants have been found. Boss, editor of the *Astronomical Journal*, has shown that the Hyades form a greater cluster moving in parallel lines towards a certain radiant point. Another apparently (but perhaps only apparently) much larger cluster, which has been investigated at the Potsdam Observatory, contains the stars in the Great Bear, Sirius, and other bright stars.

As mentioned above, the spectroscope enables astronomers to measure the motion of a heavenly body in the line of sight in miles per hour. The proper motion, expressed in seconds of arc, shows how much it is moving in the line perpendicular to the line of sight. When the direction of motion in space is known, then the parallax is at once obtained from these two quantities, and that direction is given by the radiant. Parallaxes of fixed stars are more accurately determined in this way than by any other method. Numerous results have been obtained. They show that the magnitude of a star forms no guide to its distance from us. Stars of different intrinsic brightness are mixed in space. Therefore, it would be no wonder if some of the small telescopic stars should turn out to be comparatively near the Solar System. Proper motions have hitherto been determined by comparing positions recently determined by the meridian circle with older results. Burnham, at the Yerkes Observatory, has of late years determined a number of proper motions by aid of micrometric measures compared with previous measures made by Struve, Sir Robert Ball, and others. In those cases where his results differ from the result of meridian work, the difference is probably caused by hitherto unsuspected proper motions of faint stars, which it will be possible to determine by future micrometric measures compared with Burnham's observations. At Heidelberg proper motions of faint stars are discovered by simply looking in a stereoscope at photographic plates of the same part of the sky taken several years apart. Turner has discovered large proper motions of stars as faint as the eleventh magnitude marked on photographic plates, and states that stars with proper motions greater than fifteen seconds per century are scattered with no sensible reference to the galaxy.

It may be asked what becomes of Herschel's explanation of the apex caused by the sun's proper motion when there are not one but many apices. It should be kept in mind that all motion is relative, and it is quite legitimate to attribute the apex of the cluster that contains the largest number of stars to the proper motion of the sun. Boss has lately discussed about six thousand proper motions, and he determines the apex without taking into account the existence of different systems, and also without excluding any objects.

It appears that all the radiants so far found lie near the galaxy, and it is much easier to determine additional radiants on the supposition that they all lie near the galaxy, than if they were scattered over the sky. If the pole of the galaxy is projected on Kobold's maps, and also the straight line (or rather lines) corresponding to the great circle of the galaxy, any straight lines from the projected pole to any point on the projected galaxy represents a great circle perpendicular upon the galaxy, and the projected poles of proper motions that lie near this line indicate stars the radiant of whose proper motions is the pole of the galactic meridian in question. By investigating the proper motions all round the sky in this manner it should be easy to discover all the radiants that lie near the galaxy.

Kapteyn, on the supposition that there are only two radiants, explains these as being caused by stars moving in two diametrically opposite directions, and the fact that they do not appear to be diametrically opposite he explains by combining the proper motion of the sun with each of them. In this way the direction of the sun's proper motion is determined, but it is seen that the sun belongs to neither of the clusters. However, there are probably more than two star streams, and there is so far no reason to suppose that they move in exactly opposite directions.

It is conceivable that two globular clusters might attract each other, approach, and pass through to the opposite side. When they had reached the same distance apart on the other side, they would stop, and their motion would be reversed. The period of the swing of such a pendulum would exceed millions of years. But when the enormous distances between the stars are taken into account, and their relatively insignificant sizes, the forces are found too insignificant to account for existing proper motions. The energy of runaway stars cannot be derived from attractions between fixed stars or clusters: it may be due to explosions.

As all observations of heavenly bodies are made by comparison with positions of fixed stars, the accurate determination of the proper motions of the latter may be said to be in some sense the most important object of astronomical observation. Several astronomers, especially Porter in Cincinnati, have devoted their energies to the discovery and determination of proper motions. An international co-operation between observatories in all parts of the world is being arranged to make a determination with the utmost accuracy of the positions of a very great number of fixed stars evenly distributed over the sky to serve as standards for determining the positions of faint stars recorded on photographic plates. But however perfectly the catalogue embodying the results of such co-operation may reflect the actual situation in the sky of the stars it contains, it must in a few years become quite inaccurate as the stars change their places, and for the determination of these changes the catalogue must rely on observations made in the past, so that the old observations, far from being superseded, gain in importance; and the older they are, the more important it becomes to take them into consideration.

Plate for Indexing in Degrees.

At one time it became necessary to affix an indexing plate to a machine so as to be able to set a pointer at any one of the 360 degrees of a circle. The ratchet A was not large enough to allow cutting 360 teeth in it, as these teeth had to withstand a moderate straining due to a flat coiled spring not shown in the illustration. Accordingly 120 divisions were provided

Plate which, by the Aid of Pawls of Unequal Lengths, indexes to Degrees.

in the ratchet and the pawls B were made so that they differed in length by $1/3$ the distance between two of the ratchet teeth, or in other words by $1/3$ the pitch of the teeth. The action of the pawls is, therefore, consecutive; No. 1 first engages the ratchet, then if the pointer is moved $1/360$ of a revolution, or one degree, No. 2 engages and so on. The pawls are kept in engagement with the ratchet by means of the flat steel springs S, as shown. The whole fixture is supported on the plate P, which is part of the machine.—*Machinery.*

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* From *Knowledge*.