members of his staff, past and present Treasurers of the Society, past Presidents, Council members, and so on. It has been a long haul so a good celebration is certainly called for. I give notice that the next A & G Highlights meeting will be on Friday, April 12th.

Editorial Note: The Editors wish to record their gratitude to Dr. Quentin Stanley for his invaluable help in compiling this report.

THE STRUCTURE OF THE GALAXY AS DESCRIBED IN BRITISH PROFESSIONAL JOURNALS 1820–1920 PART 1: 1820–1905

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When the Royal Astronomical Society was formed in 1820, the prevailing view of the structure of our Galaxy (also known as the Milky Way, the 'sidereal system', or even 'the universe') was that of William Herschel[1], derived from his 'star gauging', counting stars in different telescopic fields of view. As neatly summarized a little later by Alexander von Humboldt in his *Cosmos*, "The cluster of stars, to which our cosmical island [the Solar System] belongs, forms a lens-shaped, flattened stratum, detached on every side, whose major axis is estimated at seven or eight hundred, and its minor one at a hundred and fifty times the distance of Sirius." In addition there were the nebulae, which might be part of the galactic system, in which case it would encompass the entire Universe, or could be external 'island universes', the argument not being settled in favour of the latter until Hubble's work in the 1920s. A previous article[2] considered pre-Hubble papers in British professional journals (primarily *Monthly Notices of the Royal Astronomical Society* and *The Observatory*) which turned out to be about external galaxies (whether the original authors thought so or not). Here we similarly consider papers on the structure of our own Galaxy across approximately the same time period to explore what British readers could discover about the structure of the sidereal system (generally omitting papers merely describing, without interpreting, the appearance of the Milky Way on the sky). We take the end point as 1920 to cover papers up to the culmination of Harlow Shapley's series of contributions[3] from Mount Wilson which demonstrated essentially the modern view of the Galaxy. Given the rush of papers towards the end of the period, we split the time range into two very unequal parts; in this first part we cover the years up to 1905.

The Papers

1820–1877

The first reference to the Milky Way in *Monthly Notices of the* (then) *Astronomical Society of London* came in its first volume in 1829[4], in John Herschel's Presidential Address[5] on the awarding of the Society's Gold Medal to Professor Bessel of Königsberg "for his observations of stars in zones". Herschel noted that "continental astronomers" felt "the necessity of laying a foundation for future sidereal studies as deep and wide as the visible constituents of the universe itself [though to] say that every individual star in the milky way, to the amount of eight or ten millions, is to have its place determined and its motion watched, would be extravagant". Bessel won the Gold Medal again in 1841 for the parallax of 61 Cygni[6], the first step in the quantification of the size of the Galaxy.

In 1848, the Council's Report to the AGM[7] included reviews of two interesting contributions. Thomas Galloway FRS, a secretary of the RAS, had presented "an elaborate memoir" to the Royal Society[8] on 'The Proper Motion of the Solar System' which won him that society's Royal Medal. He correctly found the apex of the Sun's motion to be in the constellation Hercules, as determined using southern stars, in agreement with previous work based on northern stars. Assuming that the Sun's motion was in a circle around the centre of the system (in a plane defined by the Milky Way) he deduced a centre towards Norma, possibly by good fortune, not that far from the actual centre in Sagittarius. [We might note here that different authors used 'Milky Way' to denote either the star clouds as seen on the sky or the whole 3D stellar system.] The previous year, the Council had reported[9] on a related "curious calculation" by Johann Heinrich von Mädler, director of the observatory at Dorpat (now Tartu, in Estonia), which implied that the Sun was orbiting a centre near the Pleiades, 160 pc away, with a period of 18 200 000 years, his so-called 'central sun hypothesis'.

The second review was of the *Étude d'astronomie stellaire* by Wilhelm Struve, director of the Pulkowa (Pulkovo) Observatory, on the distribution of stars. This contained "an epitome of the whole of the author's views on the subject" and demonstrated that naked-eye stars were distributed on the sky in the same way as fainter ones and thus were part of the same Milky Way disc. The relative numbers of stars of different magnitudes were used to suggest that the faintest visible to William Herschel were 228 times further away than typical stars of the first magnitude (which from known parallaxes he took as 5 pc), while the inverse-square law suggested a factor of 664; "M. Struve considers that there is no other way [to account for this difference] than by supposing that light is extinguished in its passage".

In 1850[10], Astronomer Royal George Biddell Airy returned to the question of the Sun's proper motion, using a new method of his devising to obtain an apex position similar to previous estimates but a much larger implied velocity for the Sun.

In 1857, Prof. Secchi sent a letter to Mr. Carrington, the RAS secretary, which was published in *MN*[11]. Amongst other observations, he noted that he was "occupied in examining the brilliant places of the Via Lactea in Sagittarius, and especially in making figures and measures of clusters." He pointed out that "the greatest number of globular stellar clusters lies in this circle [the great circle delineating the maximum density of bright stars] also, or very near it … perhaps instead of a single star, a globular cluster has been formed under circumstances and laws which will remain most probably always a mystery to mankind."

Cleveland Abbe of the US Naval Laboratory presented a paper[12] at the 1867 May RAS meeting 'On the Distribution of the Nebulae in Space'. Given the known shortfall of nebulae in the region of the Milky Way, he had counted the objects from John Herschel's *General Catalogue of Nebulae and Star Clusters* in different areas of the sky and deduced that (*i*) the clusters (and planetary nebulae) were in the Milky Way system but closer than the average of the faint stars, (*ii*) the other nebulae were "in general without" the Milky Way, and (*iii*) "The visible universe is composed of systems, of which the *Via Lactea*, the two *Nubeculae* [Magellanic Clouds], and the *Nebulae*, are the individuals, and which are themselves composed of stars … and gaseous bodies". Suggesting that the low counts of nebulae in the Galactic Plane was because the "visible universe is less extended in that direction" he concluded that the nebulae (including the *Nubeculae*) were distributed throughout a prolate ellipsoid perpendicular to the plane.

In 1869 and 1870 we find four particularly relevant papers from the prolific Richard Proctor in *MN*[13] (he wrote 44 in total, on various topics, in these two years, mostly for the new journal *Nature*). He was a strong opponent of the island-universe theory of nebulae and also disagreed with the standard interpretation of the Milky Way as a more or less uniform disc of stars seen from the inside. The first paper considered the distribution of nebulae in a similar way to Abbe, but with an equal-area projection. He considered that nebulae avoiding the Milky Way was strong evidence for an "intimate association between the stellar and nebular systems", with the different types of nebulae "owing their present constitution to the fact that they are outside the region of most active stellar aggregation". The second concerned the relative distances of stars of different brightness, with Proctor arguing that the 'small' stars in the Milky Way were no further away, and in some cases nearer, than 'lucid' [*i.e.*, bright] stars. In a separate contribution to *Nature*[14] he noted several regions of the sky where stars of different brightness shared "a community of motion", or "star-drift", implying they were grouped together. He expanded on this in 'A New Theory of the Milky Way', where he proposed "that the Milky Way has not a great lateral extension (compared … with its thickness)", thus comprising a "stream of stars amidst the sidereal system", "the condensed part of a spiral of small stars, which has been swayed into its present figure by the influence of large stars". In the fourth he pointed out that it was unreasonable to suppose that the regions where faint stars were apparently more densely packed implied that the system extended further in these directions, as in Herschel's famous diagram, since this would imply spikes sticking out which all happened to point towards the Sun and which "could not result from any conceivable dynamical processes".

Proctor subsequently[15] created a chart on which he plotted 324000 star positions ("at the moderate rate of one minute for ten stars, 32,400 minutes, or 540 hours") as a detailed map of the sidereal system. He summarized his views in a further paper in 1873[16], asserting "without the slightest fear of contradiction … that the … chart of 324,000 stars disposes finally of all theories of the constitution of the sidereal universe which had previously been enunciated". (Note that Proctor used the term 'extra-galactic' for the 'irresolvable nebulae', but only in the sense that they were outside the main plane of the system.)

Also in 1873, Sydney Waters compiled a similar 'isographic' map of Herschel's nebulae and clusters ("both globular and irregular"), again concluding[17] that "the clusters are part of, if not immersed in, the Milky Way itself", that the nebulae (excluding the gaseous ones) "seem to form a distinct scheme", and that "the two schemes are probably subordinate parts of our sidereal system". A few years later[18], Waters produced a chart of the stars in similar fashion to Proctor's but for the southern hemisphere, and generally supported Proctor's views on fainter stars not being more distant.

In 1877, Maxwell Hall produced a lengthy *Memoir*[19] on 'The Sidereal System', looking at proper motions, parallaxes, and the new development of spectroscopic radial velocities. Though using a generally similar solar apex to other authors, he placed the centre of the rotation 150 pc away in the direction of Pisces (roughly similar to Proctor's earlier suggestion of a centre associated with the "great double cluster in Perseus"). He also determined a rotation period of 20 million years and thus a mass interior to the Sun's orbit of 78 million solar masses (consistent with solar-mass stars somewhat less than 1 pc apart on average). He spent many years attempting to refine his result, but without approaching the correct direction for the centre[20]. (A large number of other authors also investigated the solar apex over the next twenty years, but generally without any further implications for the structure of the system, so are not listed below unless of particular interest.)

Again in 1877[21], E. J. Stone presented his work 'On Apparent Brightness as an Indication of Distance in Stellar Masses'. He effectively demonstrated how to calculate the change in number counts with apparent-magnitude limit even if stars varied widely in intrinsic luminosity (and, though not explicitly showing it, if the density was not uniform), and noted that "the average distances of the fainter stars must be greater than those of the brighter stars". He later also reported[22] a group of four stars across a large area of sky with similar, but slightly diverging proper motions that might indicate that they were in a small group in the distant past.

1878–1890

The first volume of this *Magazine* in 1878 carried a review[23] — by the pre-Raphaelite painter and disputatious FRAS John Brett[24] — of a paper on the distribution of stars by Professor Geovanni Celoria of the Osservatorio Reale di Milano in Brera. From his star counts, Celoria is noted as interpreting the structure of the Milky Way as two intersecting rings. Brett himself concludes that "if a few of our hitherto idle astronomers … follow the lead of Prof. Celoria … we might, after a short interval of time, have laid before us a complete systematic survey of the heavens such as would almost inevitably produce a tenable thesis of the shape of the visible universe".

In 1879, *The Observatory* reviewed[25] a contribution 'Photometric Researches' from Harvard College Observatory by Charles S. Peirce, *via* a direct copy of a paper from the US journal *Popular Science Monthly* written by Henry Farquhar. This discussed the relative number of stars of different magnitudes and the implications for whether stars were uniformly distributed in space, suggesting a small peak of density near the Sun and a dense ring further out, rather like the Ring Nebula. Farquhar made a point of disagreeing with some of Proctor's inferences (above).

A further review followed[26], this time a summary of *Uranometria Argentina* by B. A. Gould (the director of the national observatory at Cordoba), which presented uniform measurements of all stars down to the seventh magnitude in the southern hemisphere. While agreeing that stars could have different intrinsic brightnesses, the anonymous reviewer noted that "it cannot be doubted that the average distance of all the 5th-magnitude stars, for instance, is nearer to us than the average of all the 6th-magnitudes". Gould explained the relative excess of bright stars as the effect of a flattened local cluster of stars containing the Sun (now known as Gould's belt). Gould was subsequently awarded the RAS Gold Medal for this work. In a later contribution of his own to *The Observatory*[27] he noted, in passing, plates taken of the "magnificent tract in Sagittarius which is too densely sown with stars to be considered merely a portion of the Milky Way, and yet too large and undefined to be regarded simply as a cluster".

In 1880, J. L. E. Dreyer reviewed[28] a contribution from M. Houzeau — more precisely Jean-Charles-Hippolyte-Joseph Houzeau de Lehaie — director of l'Observatoire de Bruxelles (whose rather fraught career included a hasty escape from Texas in the American Civil War, as he was an outspoken abolitionist). His *Uranométrie Générale* was another star-cataloguing and counting exercise, which agreed with earlier work by Wilhelm Struve "that the density of stellar layers parallel to the plane of the Milky Way decreases very regularly and gradually towards the poles of the latter". Gould's and Houzeau's papers were also summarized in *MN*[29].

Rev. T. H. E. C. Espin joined in with the equal-area projections in 1881, plotting the positions of known variable stars[30]. He found that they preferred a band at an angle to the plane and that the connection to the Galaxy appeared different in different areas of the sky. 'Temporary stars' (*i.e.*, novae) seemed to occur mostly around where this band crossed the Milky Way. (Following work elsewhere, noted in *The Observatory*[31], Espin[32] later found that very red stars congregated in a few regions in the Milky Way.)

E. C. Pickering contributed a lengthy and intriguing paper[33] on the same topic. Pickering proposed that if variability was due to star spots rotating around the star, then stars pole-on to the Earth would vary less (as the same hemisphere was always visible). "If we admit a common origin for the stars of the Milky Way, a general coincidence in their axes of rotation seems not improbable", *e.g.*, perpendicular to the Galactic Plane. In this case, as seen from Earth, the chances of variability would depend on position on the sky, with those in the plane most variable. Pickering found this effect in his data, the variables — the short period ones, especially — lying close to a great circle with its pole about 10° from the Galactic Pole, though he noted that this could just be due to their physical distribution, regardless of their rotation.

In 1885, *The Observatory*[34] reported work by Hugo von Seeliger, the director of the Gotha Observatory, on yet more star counts. From his observation that the counts increased faster towards the Galactic Plane for faint stars than bright ones, Seeliger surmised that the overall structure was spherical but with a higher density of stars close to the equatorial plane.

Another Note[35] the following year described the efforts of Hans Homann in Berlin to determine the velocity of the Sun through the stellar system by consideration of the spectroscopically measured velocities of other stars. (His paper in *Astronomische Nachrichten* appears to be his only contribution to astronomy.) Homann found a speed of around 30 km/sec, with an apex some distance from that found by earlier studies of proper motions, the reviewer (probably Walter Maunder, one of the Editors) being somewhat sceptical of the accuracy. Maunder had concluded[36] from his own compilation that these attempts were premature as there were too few velocities and insufficient coverage of the sky.

An interesting sidelight on many of these studies arose in the form of an International Congress in Paris in 1887 to consider proposals for a 'Photographic Chart of the Heavens' ('la Carte du Ciel'), which was first described in *The Observatory*[37] in a transcript of a Royal Institution lecture by David Gill. A keen proponent, Gill noted that at the agreed depth of magnitude 14 "as at present defined in France" (there was then no uniform scale at faint magnitudes) there would be around 20 million stars. Even he quailed at the thought of going to magnitude 16 as some had suggested, which would be much slower. ("Besides, what are you to do with pictures of 100 millions of stars when you have got them?") Gill suggested another objective was a catalogue of all stars down to 11th magnitude, around two million positions and magnitudes. This (and a technical note by Gill) prompted a response[38] from the Editors of *The Observatory* (A. A. Common and H. H. Turner) decrying Gill's "astounding proposition … to establish a Central Bureau … to take the photographs and *measure* them, and make a catalogue, the work to go on for twenty-five years at a cost of 250,000 franks, or £10,000, per annum" and stating that the Congress had not committed to such a scheme. However, Gill[39], supported[40] by the Congress president Admiral Mouchez and by RAS stalwart E. B. Knobel (even though he had voted against it), demonstrated that a catalogue had indeed been approved at the Congress, though Common and Turner remained unconvinced[41] and the discussion rambled on over future issues of this *Magazine*.

Leading astronomical author and commentator Agnes Mary Clerke wrote[42] a glowing (if in retrospect misguided) 1888 review of work recently reported to the Royal Society by Norman Lockyer. Lockyer's 'meteoric hypothesis' was based on his experiments on the spectra of meteoric samples heated to moderate temperatures, as compared to the spectra of comets and nebulae. The claimed similarities convinced Clerke that "the proof that nebulae … are closely allied to comets may be said to be complete. That comets are formed of meteoric materials is universally admitted". Summarizing, Miss Clerke states that Lockyer's finding is that "All self-luminous bodies in space are composed of meteorites variously aggregated and at various stages of temperature … the existing distinction between stars, comets and nebulae rests on no physical basis". She concluded that it "appears to follow that the Milky Way is a region of condensation for meteor-swarms as well as for stars".

Her review, in *Nature*[43], on 'Photographic Star-gauging' considered the form of star counts, which appeared to differ, at faint magnitudes, between the Milky Way and higher latitudes. She concluded that "the lower margin of the galactic aggregations lies at a distance from us corresponding roughly to the mean distance of a ninth magnitude star", which she set at 1400 light years, and that "the aggregated stars are … neither larger nor smaller than those in our nearer neighbourhood".

She also wrote a summary in *The Observatory*[44] of a paper on the Orion Nebula by William and Margaret Huggins, read at the Royal Society in 1889[45]. From the spectra of the stars and of the nebula, they concluded that "these stars of the trapezium are not merely optically connected with the nebula, but are physically bound up with it, and are very probably condensed out of the gaseous material of the nebula". The following year, roles were reversed, with Mrs. Huggins providing a book review in this *Magazine*[46] for Miss Clerke's *The System of the Stars*, which covered the types of stars (and nebulae, which she was convinced were local) and stellar distances and motions: "the translation of the heavens and their construction".

While the photography was getting under way, the (4th) Earl of Rosse's assistant at Birr Castle, Otto Boeddicker, produced probably the last great hand-drawn rendering of the Milky Way[47,48] the product of five years' continuous work. ("Can the pencil of the draughtsman be any longer profitably employed upon nebulae seen with the 6-foot when photography, to say the least, follows so closely on his heels?"[49])

Photographs did indeed follow, E. E. Barnard presenting to the RAS[50] his plates of Milky Way regions taken at Lick, noting particularly the presence of 'dark holes', the beginnings of his famous catalogue of dark nebulae (though in 1893[51], he still believed they were real gaps between star clouds, rather than due to obscuration). H. C. Russell similarly presented plates from Sydney[52] but noted that the appearance of the Milky Way on those plates differed from that on the Lick plates and from direct telescopic observation, leading to the question as to which to accept.

Isaac Roberts described, in 1890, his photographs of star clusters[53]. He suggested that purely stellar clusters like those in Perseus were the end point of a sequence, starting with largely nebulous objects like Orion or the Pleiades and moving (by way of spiral nebulae) through clusters such as M 5 and M 13 which he thought showed residual nebulosity as well as stars, thus providing "an intelligible classification of some of the stages in the evolution of the universe".

Dedicated amateur observer T. W. Backhouse sent an abstract of his work 'The Structure of the Sidereal Universe' to *MN*[54]. He had tabulated various specific features in an area of the Milky Way, *viz*. straight lines and parallel arrangements of stars and of 'nebulous wisps', which he found to be generally roughly parallel to the Galactic Plane. Backhouse was among those who considered that there was a real connection between bright stars and nebulosity, implying that the Milky Way was nearby and the faint stars were physically very small.

1891–1905

Moving on to 1891, the Council report in *MN*[55] included reference to work on the solar motion by Oscar Stumpe in *Astronomische Nachrichten* (taken from his doctoral thesis in Bonn), the "peculiar feature in the treatment (being) the addition of a term depending on a supposed orbital motion of the stars in the plane of the Milky Way".

Gill[56] presented a picture of 'An Astronomer's Work in a Modern Observatory'. In the concluding part he discussed Pickering's[57] prism survey of the sky which implied that "stars of the Sirius type" (*i.e.*, blue/white ones) "occur chiefly in the Milky Way". He interpreted this to mean "that the Milky Way is a thing apart, and that is has been developed perhaps in a different manner, or more probably at a different and probably later epoch from the rest of the sidereal universe". Gill also reckoned he saw in Isaac Roberts' photograph of Andromeda Laplace's nebular theory of solar-system formation playing out, "a very early stage in the evolution of a star-cluster or sun-system".

Agnes Clerke[58] reviewed photographic work by Max Wolf at Heidelberg, on the Cygnus region, which showed nebulosity around bright stars and apparently connected to the Milky Way. In Clerke's more poetic language "The brilliant orbs shown … to be intertwined by means of sinuous wreaths of nebula with minute clustering objects, must plainly belong to the same scheme of generative activity."

It is worth digressing at this point to note that 1890–1891 saw the formation of the British Astronomical Association (BAA), with its own journal for those seeking something less academic than *Monthly Notices*. Papers and reviews of papers concerned with the structure of the Galaxy were actually quite prevalent during the 1890s, with several members (who were also Fellows of the RAS) making regular appearances. These included W. H. S. Monck, J. Ellard Gore (who suffered an untimely end when run over by a horse-drawn hackney carriage), and A. C. Ranyard, the editor of *Knowledge* (in succession to Richard Proctor).

Returning to *The Observatory*, in 1893[59] there was a review of a translation (which had appeared in *Knowledge*) of a paper by J. C. Kapteyn, originally read at the Amsterdam Academy of Science. Kapteyn assumed that for a group of stars, the mean proper motion was entirely due to solar motion, thus comparing these mean proper motions gave relative distances to the groups. According to the reviewer, the "principal results found seem to be" that distant stars, both bright and faint, grouped themselves in the Milky Way plane, but nearby stars did not, and that the mean distance of stars of a given magnitude range is greater towards the Milky Way than in other directions.

The Observatory next carried a review[60] of J. Ellard Gore's 1893 book *The Invisible Universe: Chapters on the Origin and Construction of the Heavens*, which in turn reviewed theories of the sidereal universe from Kant to Lockyer's meteoric hypothesis. "In the second half of the book Mr Gore deals with [the] stellar distribution in space, and especially with the form of the Milky Way". The reviewer was Annie Scott Dill Russell, the future Mrs. Maunder.

Also noted in *The Observatory*[61] was a meeting of the BAA at which A. C. D. Crommelin reported on a physical model which he and his sister, Miss C. D. Crommelin, had constructed, using beads on strings, to show the 3D distribution of nearby stars.

Sidney Waters[62] mapped the distribution of star clusters, resolvable nebulae, and irresolvable nebulae, again demonstrating that the clusters were closely associated with the Milky Way but the nebulae (planetaries excepted) were distributed centred on the Galactic Poles. He proposed that both clusters and nebulae were part of the 'sidereal universe', but where "the clusters cease the nebulae begin, as though the conditions of the distribution of matter have been favourable to the production of clusters in the Milky Way, and of nebulae elsewhere". In response to Waters exhibiting his charts at the BAA, as reported in *The Observatory*, Dreyer[63] agreed with Pickering, that "the Milky Way was likely to be in an earlier stage of evolution as compared with other regions of the universe". Maunder added that the "various facts all pointed to the conclusion that the visible sidereal universe was … but one single organism".

In 1895 *The Observatory* reviewed[64] a paper 'On the Distribution of Stars in the Milky Way' by Cornelis Easton of Dordrecht which had been in *AN* (and originally published as *La Voie Lactée dans l'hemisphère boréal*). Easton found that the density of visible stars down to 11th magnitude was correlated to the brightness of surrounding diffuse Milky Way light. The previous year, there had been a review[65] by RAS stalwart W. H. Wesley of Easton's hand-drawn maps, which were noted as differing significantly from Boeddicker's (above). Surprisingly, it appears that the only UK mention of Easton's notable paper 'A New Theory of the Milky Way', in which he posited that the Milky Way disc contained a spiral, centred in the direction of the bright region in Cygnus, and with the Sun on the edge of it (but still at the centre of the whole system), came in the *JBAA* in 1898.

Yet another review of the solar-apex question, this time by G. C. Bompas, appeared in 1896[66], where it was noted that the apex appeared to vary with the distance of the comparison stars; the positions moving roughly along the Milky Way suggested to him that the Sun and stars were orbiting in a plane near to that of the Galaxy

An original contribution, by Alice Everett in *MN*[67], explored the orientation of the orbits of binary stars, but found that the poles of the orbits appeared to be randomly distributed on the sky.

At a special meeting of the RAS in 1897[68], Prof. Barnard (that year's Gold Medallist) presented slides of his latest photographs of nebulous regions. Similarly to Wolf (above), he pointed out that the 'great Nebula of Antares', which he had described in a paper in *MN* in 1895[69], and its associated bright stars were seen to be "connected with the vacant lanes and the small stars forming the ground-work of the Milky Way", concluding that "these stars are really small compared to our Sun and not simply more distant than others". H. H. Turner in response, though, "could not help feeling sceptical" about the latter conclusion. (Barnard was also involved in a long-running and fractious argument with Isaac Roberts[70] over whether nebulous regions were best studied with a small refractor — his 'portrait lens' — or Roberts' larger reflector.)

In 1899 *Nature* featured[71] a lengthy transcript of Lockyer's 'Lecture to Working Men' at the Museum of Practical Geology titled 'On the distribution of the various chemical groups of stars'. He added to the earlier result that bright-line stars were associated with the Milky Way, the observation that they nearly all occurred where the Milky Way looks double (around the 'Aquila rift'), noting that "it looks … as if there is something connected with this doubling of the Milky Way which produces the conditions which generate these bright-line stars". He found this was also true of novae, which he believed were due to collisions between his meteoric streams and unseen nebulae, and reiterated the view that nebulae with bright lines (*i.e.*, gaseous) were in the Milky Way but nebulae with continuous spectra were not. He also reviewed, and agreed with, Monck's work (published in the US journal *Astronomy and Astro-Physics*) which found that 'metallic' stars (later spectral types) were typically nearby while 'gaseous' (hotter) stars were further away. Lockyer had illustrated his talk with a clear globe with bands for the Milky Way and circles for the relevant stars stuck on. Lockyer subsequently[72] gave a précis of the part of his own book, *Inorganic Evolution*, which dealt with 'Our Stellar System', covering similar topics to the earlier lecture. He considered that his results disproved the notion that the stellar system was constructed in the same way as spiral nebulae, as these were densest at the centre. As an aside, he noted that the Milky Way was also likely densely populated with 'dark bodies', so that light from beyond was blocked, explaining the preponderance of nebulae towards the pole if they were "other universes", that is, "clusters of stars with which our own system has absolutely no concern or connection".

In passing, we can note that the 1899 RAS Gold Medal[73] went to Frank McClean for what can be regarded as the ancestor of all spectroscopic surveys of the Galaxy. Using instruments at his own observatory in Tunbridge Wells and at the Cape Observatory, he obtained photographic (objective prism) spectra of every star down to magnitude 3·5.

The Observatory of 1900[74] included a note on 'Spiral Nebulae', drawing on Keeler's discussion of the photographs taken at Lick with the *Crossley* reflector. Keeler estimated that 120000 previously unrecorded nebulae (which he considered were part of the sidereal system) were accessible to the telescope. Most of those he had observed had spiral structure, so if "the spiral is the form normally assumed by a contracting nebulous mass, the idea at once suggests itself that the solar system has been evolved from a spiral nebula".

In 1901, Lord Kelvin, in amongst a discourse to the British Association on the effect of gravity on the ether, as transcribed in *The Observatory*[75], made a calculation of the density of the Galaxy. If a thousand million suns were "at rest thousands of million years ago so distributed that now they were equally spaced throughout the supposed [1 kpc radius] sphere, their mean velocity would now be about 50 kilometres per second … not unlike the measured velocities of stars". This consistency (assuming stars of the same mass as the Sun) implied an average density of $1{\cdot}6 \times 10^{-20}$ kg m^{-3}, not that far from modern estimates for the solar neighbourhood. He also considered that stars would form from atoms spread throughout the Galaxy by gravitational contraction of over dense regions and eventually through particle collisions causing energy to be carried away. Kelvin also commented positively on the suggestion that the rapidly moving nearby star Groombridge 1830 (now identified as a halo star) was from outside the Galaxy and just passing through.

The Observatory[76] twice reviewed M. Stratonoff's *Études sur la Structure de l'Universe*, from the publications of l'Observatoire de Tachkent (Tashkent in Uzbekistan). This was another star-counts paper using the *Bonner Durchmusterung*, Stratonoff concluding that the distribution of stars down to magnitude 9·5 did not follow the details of the Milky Way and that the latter was best described as "an agglomeration of condensations or stellar clouds touching one another all along the galaxy". The first reviewer was Frank Dyson, the second Walter Maunder. In *MN* in 1902, A. M. W. Downing[77] essentially repeated Stratonoff's analysis, but using the *Cape Photographic Durchmusterung*, again finding a flattened stellar system for the fainter stars, but with no further interpretation.

Also in 1902, *The Observatory* carried a review[78] by Henry Hollis of Simon Newcomb's *The Stars: A Study of the Universe*. One point picked out was a calculation of the size of the universe (*i.e.*, Galaxy). Newcomb imagined dividing the universe into concentric spheres of increasing radius and counting the number of stars with corresponding parallaxes. He deduced that there was one star for every eight 'units', where one unit was a sphere of radius 1 pc, so to fit in his estimate of 125 million stars required a radius of 1 kpc (though he actually accepted Herschel's disc-shaped galaxy as a convenient working hypothesis).

This was followed by a Note[79] with a somewhat startling title (given today's usage) 'An Apparent Motion of the Universe', which concerned conclusions published by David Gill in *AN*. Based on the comparison of star positions in different catalogues he had found that "the brighter stars rotate with respect to the fainter stars as a whole about some centre". This was received doubtfully by H. H. Turner[80], in *The Observatory* and *MN*, and by the Greenwich observers in a Note[81] "communicated by the Astronomer Royal" (Sir William Christie) and presented by Dyson at the RAS. Dyson also reviewed[82] 'Prof. Kapteyn's researches on the distances, movements and luminosities of the fixed stars', but with no inferences concerning the overall stellar system. (A further review of Kapteyn's work was presented by Sir David Gill during his presidential address to the British Association, recorded in *The Observatory*[83], a few years later.)

Returning to star distributions, at another RAS meeting, Turner presented[84] a 'Preliminary Note on the possible existence of two Independent Stellar Systems', the Milky Way plus a proposed belt of stars which led to two separate minima in the star density near the North Galactic Pole, but subsequently withdrew the paper before it appeared in *MN*.

In 1904 in *The Observatory*[85], 'Ancient and modern Ideas about the Milky Way' were discussed in a multi-part paper by Puiseux (of Paris Observatory), which essentially summarized all the work noted above but viewed spiral nebulae as external and an indication of what the Milky Way would look like from the outside.

Finally, for this part, the only significant paper in 1905 was Dyson and Thackeray's on the Sun's motion[86], which agreed with earlier work showing that bright and Type II (solar-like) stars generally had larger proper motions than fainter and Type I (bluer) stars, the latter also tending to be in the Milky Way.

The Authors and Reviewers

N.B. The brief biographical notes on those involved are not repeated if they already appeared in recent contributions to this magazine[2,4,87,88].

Thomas Galloway was born in Lanarkshire in 1796 and educated at Edinburgh University, subsequently teaching at the Royal Military College at Sandhurst before becoming an actuary. He wrote astronomical articles for the *Encyclopaedia Britannica* and various magazines.

Father (Pietro) Angelo Secchi S.J. was born in 1818 and ordained in 1847. Already lecturing at Collegio Romano, he was forced into exile with the other Jesuits in the revolution of 1848 and spent some time at Stonyhurst College in Lancashire, which had a major observatory, before emigrating to the USA. He returned to Rome as professor of astronomy in 1850 and shortly afterwards founded an observatory at the Collegio. Said to have contributed 730 papers in all areas of science, his chief astronomical work was to provide the first steps in the classification of stellar spectra.

Maxwell Hall graduated from Cambridge in 1871 and moved to Jamaica the following year, building a notable observatory in Montego Bay, from where he made precise observations of Mars at its favourable opposition in 1877. By profession he was a barrister, but he also served as the Government Meteorologist and found time to publish around 60 papers, 25 in the British astronomy journals.

Edward James Stone FRS was Her Majesty's Astronomer at the Cape Observatory from 1870 until his appointment as Radcliffe Observer in Oxford in 1879. He had been 5th Wrangler in 1859 and shortly afterwards became Chief Assistant at Greenwich, winning the RAS Gold Medal in 1869 for his 'Rediscussion of the Observations of the Transit of Venus, 1769'. In all, he supplied around 150 contributions to the RAS, of which he was president 1881–82, and to the Royal Society.

Henry Hill Farquhar was a member of the US Coast Survey and acted as Charles Sanders Peirce's assistant in the photometric work at Harvard. He published a paper on 'Fundamental Right-Ascensions' in *AJ* in 1890 and later worked for the Census Bureau and other government departments. He was a delegate to the world peace conference at The Hague in 1907.

Though born in the USA, Benjamin Apthorp Gould spent three years gaining experience at European observatories (becoming friends with von Humboldt and Gauss) before working for the US Coast Survey and directing Dudley Observatory. He founded the *Astronomical Journal* in 1849 and edited it until 1861 (as well as when it was restarted in 1885). He moved to Cordoba as observatory director in 1865 and was an early advocate of large-scale stellar photography.

Edward Charles Pickering obtained the post of professor of physics at MIT when only 21 years old and shortly afterwards was responsible for the founding of the first 'physical laboratory' in the USA. He became director of Harvard College Observatory in 1876, remaining in post for over 40 years, and was responsible for instigating multi-epoch photographic surveys of the sky, as well as large-scale prism spectroscopic surveys, twice winning the RAS Gold Medal. He was also prominent in promoting women astronomers to senior positions.

Ernest Amédée Barthélémy Mouchez had entered the French navy at the age of 16, gaining promotion to captain by the time of the Franco–Prussian War in 1870. He spent many years in surveying and was appointed to the Board of Longitude before taking over the Paris Observatory in 1878, subsequently establishing a 'summer observatory' on Pic du Midi.

Edward Ball Knobel worked in several other trades before becoming managing director of the Ilford Photographic Company (who, *inter alia*, produced astronomical plates). A keen planetary and stellar observer, he also had a great interest in historical astronomy and compiled a 'Chronology of Star Catalogues'. He had joined the RAS in 1873 and was on its council continuously from 1876 to 1922 (when he was 80), twice serving as president.

The most famous of Agnes Clerke's many contributions was her *History of Astronomy in the Nineteenth Century*, first published in 1885. She supplied numerous astronomical entries in the *Dictionary of National Biography* and *Encyclopaedia Britannica* and became an Honorary Fellow of the RAS in 1903, well before women were allowed to be elected as Fellows.

The founding editor of *Nature* in 1869, Sir Joseph Norman Lockyer FRS was a civil servant until becoming a professor in the Royal College of Science in 1881. He was director of the Solar Physics Observatory in South Kensington from 1885. His main work was in the field of solar spectroscopy (identifying the new element helium while still an amateur observer) and what would now be termed laboratory astrophysics. His son W. J. S. 'Jim' Lockyer, a wartime major in the RAF, was also an FRAS and took over the running of his father's private observatory in Sidmouth.

Previously a mathematician — he published an application of Gauss' theory of knots to electrodynamics — Otto Boeddicker had been Astronomer at Parsonstown since arriving from Germany in 1880 and initially worked on observing Jupiter with the 36-inch telescope. He worked for the 4th Earl until the latter's death in 1908. He then assisted the 5th Earl on the estate and with opening Birr Castle Dairies and a technical school. He left Britain when classified as an enemy alien during the Great War. Then living in Freiburg, in 1936 he placed the somewhat battered original of his Milky Way drawing in the care of the RAS.

Jacobus Cornelius Kapteyn had started out at Leiden but from 1878 was professor of astronomy and mechanics at Groningen. As Groningen did not have an observatory, from 1896 he worked on the plates taken by Gill at the Cape Observatory to produce the *Cape Photographic Durchmusterung* of over 450 000 stars, winning the RAS Gold Medal in 1902. From 1906, he organized work at around 40 observatories to update William Herschel's old method of counting stars in different directions, and this led to his development of what became known as the Kapteyn Universe. This was essentially an oblate distribution of stars about 10 kpc across and 2 kpc thick, with the Sun about 600 pc from the centre. He published the definitive version of his work as 'First Attempt at the Theory of the Arrangement and Motion of the Sidereal System' in *ApJ* just before his death in 1922.

Annie Scott Dill Maunder (née Russell) had graduated from Girton in 1889 as a Senior Optime in the maths tripos, then became a 'lady computer' at Greenwich, working on Walter Maunder's sunspot programme. Obliged to give up her professional post on marriage, she nevertheless continued to work at the Observatory and went on numerous eclipse expeditions. She was an early member of the BAA, editing its journal for many years, and became one of the first female fellows of the RAS in 1916.

Andrew Claude de la Cherois Crommelin taught at Lancing College before being appointed to a post at the Royal Observatory in 1891. His main areas of expertise were asteroids and comets, making the most precise prediction of the 1910 return of Comet Halley. He was later involved in the eclipse observations from Sobral in Brazil in 1919 which Eddington used to verify Einstein's prediction of light bending. He was RAS president 1929–1930. His sister Constance de la Cherois Crommelin was a graduate of Newnham College, Cambridge, and became a teacher of mathematics and English at boarding schools, first in Brighton and then London. She married the poet John Masefield.

William Henry Wesley was a trained engraver, noted for his drawings of the solar corona and lunar maps. In a paper for *Knowledge*, Wesley carried out an inventive analogue version of a numerical simulation by sprinkling ink dots onto a piece of paper to see if strings and lines of dots appeared in the same way as lines of stars in the Milky Way. He was RAS assistant secretary, the main administrator of the Society, for 47 years.

In 1896 George Cox Bompas was a recently elected FRAS, though in his late sixties. He had been a solicitor in London for many years. He was also a fellow of the Royal Geographical Society, the Geological Society, and the Palaeontological Society.

Like many early female astronomers (Annie Russell was a direct contemporary), Alice Everett took the mathematical tripos at Girton College (her father was a professor of mathematics). Invited to take up a post at Greenwich in 1890, she next moved to Potsdam Observatory (1895) to work on the Carte du Ciel. She was a founder member of the BAA and an early council member. She later worked on optics at the National Physics Laboratory and (after technically retiring) made significant contributions to television broadcasting, still giving her occupation as radio and optical engineering in 1939, when she was 74.

William Henry Stanley Monck trained in theology at Trinity College, Dublin, and was subsequently professor of Moral Philosophy there, writing on logic and metaphysics. He was later a Chief Registrar of the High Court of Ireland. He published widely (over 180 papers) in *The Observatory*, the *JBAA*, *Nature*, *Popular Astronomy*, and the *Publications of the Astronomical Society of the Pacific* among others (but only once in *MN*), on topics ranging from ancient chronology to non-Euclidian geometry.

Frank McClean was a graduate of Trinity College, Cambridge, and followed his father (also an FRAS) in becoming an engineer. However, he was well off enough to retire at the age of 33 to concentrate on his scientific interests, particularly astronomy. Aside from his spectroscopic survey he was most noted for the discovery of oxygen in stellar spectra. He was elected an FRS (again like his father) in 1895 and endowed the Isaac Newton studentships in Cambridge. His father-in-law was John Greg, a Lancashire mill owner who also had his own observatory, while his son (eventually Lt-Col. Sir) Francis Kennedy McClean AFC was a pioneer aviator and also an FRAS, travelling to several solar eclipses.

William Thomson, Lord Kelvin, one of the leading mathematical physicists of his day, was professor of Natural Philosophy in Glasgow for 53 years from 1846, working most famously on thermodynamics. In astronomy, he is most remembered for his time-scale for the Sun to radiate at its present rate purely through gravitational contraction. He was president of the Royal Society 1890–95 and the first scientist awarded a peerage.

Placed second in the tripos at Trinity, Frank Watson Dyson was elected a fellow there and researched in gravitation before becoming Chief Assistant at Greenwich in 1894, leading the work on proper motions. Astronomer Royal for Scotland from 1906, he returned to Greenwich as Astronomer Royal in 1910. He is now best remembered for organizing the 1919 eclipse expeditions which led to the confirmation of the predictions of General Relativity. He was knighted in 1915.

A maths graduate from Trinity College Dublin, Arthur Matthew Weld Downing FRS was an Assistant at the Royal Observatory from 1873, working on star positions, and, from 1892 Superintendent of the Nautical Almanac Office. He communicated 75 papers and notes to *MN* and was a vice-president of the RAS.

Henry Park Hollis was an Assistant at Greenwich from 1881 for nearly 40 years and mainly involved with stellar-position-measurement programmes. He was also astronomical correspondent for *The Times* and an Editor of *The Observatory*.

Pierre Henri Puiseux, the son of a professor of celestial mechanics at the Sorbonne, worked at the Paris Observatory from 1885, primarily on photographic studies of the Moon and on the Carte du Ciel. He won the prestigious Prix Jules Janssen in 1900.

William Grasett Thackeray, a relative of the novelist William Makepeace Thackeray, was appointed to the staff of the Royal Observatory in 1875, spending many years on transit work and later superintending the computational work in Greenwich.

In summary, it is notable that despite the obvious interest in this area (as reflected in the number of review articles), there are only 19 British, or British-based, scientists who made original contributions to the debate on the structure of the Galaxy, across the 85 years covered, and only nine of those could be considered professional astronomers.

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