1913ApJ....37..105E

A PHOTOGRAPHIC CHART OF THE MILKY WAY AND THE SPIRAL THEORY OF THE GALACTIC SYSTEM

By C. EASTON

A more reliable and more detailed representation of the apparent distribution of the stars than can possibly be furnished by naked-eye observations of the Milky Way is badly needed. I am well aware that the accompanying chart supplies this want only to a very limited extent. First of all, the aid of drawings and descriptions, resulting from visual observations only, cannot yet be dispensed with entirely in estimating the comparative brightness of distant parts of the Milky Way, no complete, perfectly homogeneous series of photographs embracing the whole zone being available; photographs and naked-eye drawings of the Milky Way, however, must picture somewhat different portions of the stellar world. Nevertheless the advantages of the camera above the human eye, for most purposes connected with the study of star-distribution, appealed so strongly to my mind that I preferred the somewhat vexatious labor of combining the available photographs of the Milky Way in a general chart, rather than trying to discriminate between the often conflicting representations given by different observers of the galactic zone, although I have myself spent some years upon a naked-eye study of the Milky Way. As an independent evidence, and for certain well-limited purposes, the drawings, and particularly the "isophotal drawings"[1] of the Milky Way, retain of course their value.

The advantages of photographs are, first, trustworthiness, second, accuracy, third, wealth of detail. On the other hand, it is a drawback that a limited portion only of each photograph—the central parts—can safely be used, and that extensive nebulosities, mingled with the stars, may impair the general traits of their distribution. In combining the photographs, the draughtsman must be careful to avoid those difficulties as best he can.

[1] Houzeau, *Uranométrie générale*, 1878; Easton, "Distribution de la lumière galactique," *Proc. Amsterdam Acad. Sci.*, 1903.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

For some years I have been occupied in compiling materials[1] and training myself for the particular work of rendering an interpretation from photographs in a manner similar to that in which the visual observer interprets the corresponding parts of the sky. The result of this work was embodied in four sheets (not yet published) on the original scale furnished by Marth's galactic co-ordinates of the stars, about 17×10 inches.[2] In the accompanying chart, Plate III, constructed after these drawings, Marth's data have also been used. It shows the Milky Way between +20° and −20° galactic latitude. The circular projection renders a certain amount of distortion in the higher galactic latitudes inevitable, but this drawback is not serious since this is the only possible way to get an uninterrupted view of the whole galactic zone in the two hemispheres.

The photographs furnished each a certain amount of detail and the connecting of these details presented no great difficulties, overlapping photographs, often by different authors, being avail-

[1] A detailed list cannot be given here. I made use of the following photographs chiefly: Professor Barnard's "Lick photographs," published for the greater part in successive numbers of the *Astrophysical Journal*, *Popular Astronomy*, and *Knowledge*, since 1894; those of Professor Max Wolf, in *Knowledge*, since 1891, partly in *Die Milchstrasse*, Leipzig, 1908; Russell's photographs of the Southern Milky Way, Sydney, 1890; Pickering's "Harvard Series," covering the whole sky (prints of a number of these plates were prepared for me, in order to bring out the "cloud-forms," by Dr. Neuhauser, in Amsterdam); Bailey's "Southern Milky Way," *Harvard Annals*, **60**, 8, and **72**, 3; some photographs by Wilson, Mrs. Maunder, and others. Through the courtesy of Professor Kapteyn I was able to use a number of Professor Barnard's and Professor Pickering's photographs as early as 1906. I have also to thank the Leyden and Utrecht observatories for lending materials, and I am under great obligations to Professor Max Wolf, who kindly supplied me with a number of glass plates, among them two large-scale photographs especially taken for this purpose. Numerous photographs are scattered in different astronomical publications; the beautiful reproductions in the *Researches on the Evolution of the Stellar System*, **2**, by Professor T. J. J. See, deserving a special mention. Professor Barnard has just now completed a volume containing his "Lick photographs," his volume of "Mount Wilson plates," covering the entire galactic zone up to −20° S.P.D., published by the Carnegie Institution of Washington, being on the way to completion. In most cases, of course, I preferred the use of glass plates to prints.

For a complete catalogue of photographic charts of the sky, up to the year 1908, see *Harvard Annals*, **60**, 9.

[2] These indispensable data were given by Mr. A. Marth in *Monthly Notices*, **53**, 78, 384, 420.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

able in almost every case. In this manner the general picture of the Milky Way resulted with a minimum of bias on the part of the draughtsman. In comparing the brightness of widely separated regions it remained, however, necessary to resort to visual estimates, e.g., for the patches in *Sagittarius*, *Aquila*, and *Cygnus*.[1] Although I proceeded very critically, I must confess that this is the weakest part of the work, but it proved unavoidable, even the best photographic series not being sufficiently homogeneous to allow a direct comparison of such distant parts.

The contrast between the bright and dark patches and lanes has intentionally been somewhat exaggerated in drawing. The galactic equator, shown as a circle, was inserted after Marth's position of the galactic North Pole ($12^h\ 40^m + 30°$, 1880). I may, however, remark that the old determinations of the galactic plane, based on insufficient data, have but little value; the photographic chart furnishes a sound basis for a redetermination of the medial line of the galaxy.

The stars were inserted on the scale of their *visual* magnitudes.

Although great care has been taken to make the accompanying chart as complete and as reliable as possible, it will hardly be necessary to state that the author did not aim primarily at completeness and exactness of detail—for which the original photographs can be consulted—but to furnish a general representation of the galactic zone for orientation purposes, in the same way that small-scale maps are used in geography. We owe it to the great skill and the untiring perseverance of Barnard, Wolf, Pickering, Russell, Bailey, and other astronomers, that it is now possible to construct such a "photographic chart of the Milky Way."

There is a question as to whether we are justified in regarding this representation of the stellar distribution in the galaxy as something definite, in its *principal* features. I think we are.

It seems almost incredible that more sensitive plates and longer exposures, showing one or more magnitudes beyond the limits

[1] For the Southern Hemisphere: J. Herschel's description (*Outlines*, § 787); the *Uranometria Argentina;* Houzeau's "isophotal chart" in the *Uran. générale*, and T. W. Backhouse's valuable description in *Publ. of West Hendon House Observatory*, **2**.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

attained in the best photographs now available, will give a very different picture of the Milky Way. Theoretical considerations and actual counts of stars[1] point to the probability that the bulk of the small stars, at least of those within the range of the existing instruments, belong to the already known agglomerations, and that they will not fill up the vacancies between these bright parts. The remarkable correspondence between the visual and the photographic Milky Way *in their most characteristic features* is also very significant in this respect. Compare, for instance, my description of the *Aquila-Sagitta* region of the Milky Way (*La Voie lactée*, 1893, pp. 38 f.) with Professor Barnard's photograph (*Astrophysical Journal*, **2**, 35, 1895). Besides, in comparing photographs taken with different lenses and different exposures, we find that not only the main features of the galactic picture are the same, but that very minute details are preserved throughout. A comparison of two photographs of the η *Argus* region may serve as an example. The one is by Russell, 1890 (*op. cit.*, Plate 1) with a lens of 6 in. aperture and 32 in. focus (Dallmeyer), exposure 3 hours; the other by Bailey, 1909 (*op. cit.*, Plate 4) with a Cooke lens of $1\frac{1}{2}$ in. aperture and 13 in. focus, exposure 13 hours. The latter photograph contains perhaps three times as many stars as the first, but virtually all the features, here so vividly depicted, are already indicated in Russell's photograph.

If further researches disclose outlying parts of the system, the present picture will yet hold good for the inner parts, considered as a whole.

I have insisted on this point, because it is evident that the photographic chart would be of little value if we could expect that better instruments and longer exposures would give us quite a different picture of the Milky Way. Happily the photographs of the galaxy, at least of that part of the system now accessible to our researches, may be likened to a sketch of a drawing or map, whose broad outlines remain unaltered as more detail is filled in; rather than to a misty landscape, which presents continually changing

[1] Newcomb, *The Stars*, chap. xx, concl. 4; Easton, *Astronomische Nachrichten*, Nos. 3270, 3803, *Astrophysical Journal*, **1**, 216, 1895.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

views as the lifting fog discloses more and more distant houses and groves.

This picture, as we have it now before us, speaks for itself. It leaves next to nothing of the traditional simplicity of the galactic zone, as it is still described in textbooks: "a broad and ample road," vague and rather uniform, split in two over half its circumference. On the contrary, what strikes us most in our photographic chart is the sharp definition of many features, especially near the axis of the Milky Way, and the truly perplexing intricacy of structure, presented by the greater part of the zone. We even have a certain difficulty in recognizing the "two branches." It is true that a winding channel, composed of irregular vacancies and narrow lanes, frequently spanned by bridges of light, runs from about *α Cygni* along the galactic axis to *κ Circini*, where it is connected by a scarcely interrupted, serpentine lane with the "Coal Sack" in *Crux*.[1] This "great rift" (if we keep the name) can be traced on the other side as far as *κ Cassiopeiae* and even *μ Persei;* the remaining portion of the galactic zone presenting a somewhat different character.

Other striking features revealed by this chart are the long "lateral offsets," which often seem connected with groups of bright stars (as Boeddicker has already remarked), forming extensive lateral systems in *Taurus* and *Orion*, in *Cepheus*, and particularly in *Scorpius*. They were of course known beforehand, but the relations of these highly significant formations to the remainder of the zone were never so well exhibited. I would especially draw attention to the streams north and south of the galactic equator, converging to the bright central parts in *Auriga* and *Taurus*, a dark lane running between them, from the *Hyades* to *β Tauri* and *θ* and *β Aurigae* right across the Milky Way; then to the bright masses and streams encircling the "Northern Coal Sack," between *α Cygni* and *α Cephei*, and returning to the principal branch in *Cassiopeia;* also to a complicated structure, partly described by John Herschel (*Outlines*, § 789), in the constellations *Lupus*, *Scorpius*, and *Ophiuchus*. It is obvious that the extraordinary chasms

[1] Russell draws attention to these lanes, but does not state the connection of the rift with the "Coal Sack."

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

and bright and dark streams, discovered by Professor Barnard between *52 Ophiuchi* and *Antares*, form but a part of a much more extensive system of interlacing branches—perhaps there are *two* systems present, seen in perspective and projected one against the other—covering the whole region to the north of the galactic axis between *η Serpentis* and *β Centauri*, and certainly related to the principal (southern) branch of the Milky Way, though separated from it by rifts and cavities. It can hardly be by mere chance that most of the streams radiating from the gigantic assemblage of suns about *σ* and *ν Scorpii* are directed to the very brilliant patches of milky light in *Scutum* and *Sagittarius*. It is obvious that all these formations are interdependent and not merely the outcome of a chance projection; the unity in this apparent complexity is highly significant. This whole region seems the counterpart of the great appendage in the northern Milky Way between *β Cygni* and *γ Ophiuchi*.

Space forbids drawing attention to many other characteristic features, revealed by the photographic chart; the reader may easily discover them for himself. I only wish to enumerate some general divisions of the galactic zone which seem indicated by the characteristics of different parts.

1. The brilliant parts *β* to *γ* and *α* to *π Cygni*, and *π Cygni* to *κ Cassiopeiae*, with the northern extensions over *Cygnus*, *Cepheus*, and *Cassiopeia*, perhaps as far as *χ Persei* and *δ Aurigae*.—The region *β Cygni* to *γ Ophiuchi* seems loosely attached to these parts.....*Alpha Region*

2. The southern parts between *χ Persei* and *ε Cygni* and as far as *γ Sagittae*.....*Beta Region*

3. The varied region in *Sagitta*, *Aquila*, *Scutum*, *Sagittarius*, *Ara*, *Norma*, as far as *β Circini* or *α Centauri*.—The series of bright patches at *δ Sagittae* and *δ* and *ν Aquilae* seems to hold an intermediate position between the "Alpha" and "Gamma" regions.....*Gamma Region*

4. The northern parts between *η* and *ζ Serpentis*, covering *58*, *ρ Ophiuchi* and *δ Scorpii*, and stretching as far as *ρ Lupi* and *α Centauri*.....*Delta Region*

The characteristics of these four regions are easily recognized.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

The remaining portion of the Milky Way, between *Crux* and *Perseus*, has many distinguishing characteristics: its light is relatively faint, it has no central rift, but extensive lateral offsets. It can be subdivided in three regions:

5. Roughly between *β Circini* and *ζ Puppis* (225°–285° galactic longitude) we come to a region with extensive ramifications: the somewhat fan-shaped divisions originating about *η Argus*. Already in *Centaurus* and *Crux*, the bright part, narrow and perforated in these constellations, "twists around," so to speak; between *Crux* and *η Argus* and farther on, the light decreases gradually, not from south to north, as in *Sagittarius* and *Norma*, but from north to south.....*Epsilon Region*

6. From 225° galactic longitude (about *a* and *b Mali*) onward, the curved wisps on the north side take another direction, and the southern extensions cease. Toward *Canis Major*, there is nothing left of a central rift, and the central parts, broad and faint, are almost structureless; but in *Puppis* and *Monoceros* we find a maze of wisps and narrow lanes, typical for this region, and noticeable even to the naked eye.....*Zeta Region*

7. The remaining part (165°–110° galactic longitude) is characterized by a rather brilliant though much furrowed central region, with loose and extensive streamers emanating from it, as ribs from a spine; there is a lack of continuity between this region and the outer parts of Alpha Region.....*Eta Region*

In the photographic chart of the Milky Way we now possess solid ground from which to test the spiral theory of the galactic system, enunciated in the *Astrophysical Journal*, **12**, 136, September 1900. Since the appearance of that paper, the spiral form, till then something exceptional in the known stellar world, has revealed itself, in the late Professor Keeler's words, "as the usual or normal accompaniment of contraction in cosmical masses," and the theory of Moulton and Chamberlin testifies that it may lead to important theoretical developments. The researches of Kapteyn, Kobold, Dyson, Eddington, Schwarzschild, and others render a closer inquiry into the fitness of the spiral theory as a working hypothesis highly desirable, as it has lately been shown[1] that the Milky

[1] J. C. Kapteyn, *Proc. Amsterdam Acad. Sci.*, January 1912.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

Way is also of fundamental importance in relation to the star-streams.[1]

I am well aware that the great problem of the Milky Way can never be solved in this way, and that we may aim only at a plausible interpretation of known facts, and at a working hypothesis. I may be allowed to repeat what I wrote in the *Astrophysical Journal* twelve years ago: the figure in the center of our plate does not pretend to give even an approximate representation of the galactic system, but only to indicate in a general way how the stellar accumulations might be arranged so as to produce the phenomenon of the Milky Way—on the supposition of a spiral galaxy.

I have now taken as typical a figure intermediate between two of the best known spiral nebulae: *M 51 Canis Venaticum* and *M 101 Ursae Majoris*. The adopted spiral must answer to the condition that the principal features of the Milky Way result freely and plausibly from its projection on the sphere, viewed from the sun (*S*).

We must take into account:

1. The branches of the spiral are not situated in the same plane.[2] The first branch, stretching from the central nucleus outward, at first rises somewhat above the plane of the chart, but lies below it in its farther course. The second branch lies at first below, then comes nearer to the middle plane, crosses it somewhere in the direction *Se*, and continues to run above it for the greater part of its course. The central condensation itself would lie somewhat to the north of (above) the middle plane of the galaxy, as adopted by Marth (cf., however, what is said on p. 107).

2. Up to a certain distance from the sun, the stellar agglomerations must seem scattered, so that they cannot produce any milky light.

3. The apparent brightness of the patches and streams of the Milky Way depends not only on the richness of the stellar condensations and strata, but also on our point of view, in *S*, so that star-streams running almost exactly in our visual line must show as brilliant patches.

[1] Cf. T. J. J. See, *Researches on the Evolution of the Stellar Systems*, **2**, 1910, and Sv. Arrhenius, *Nord und Süd*, January 1912.

[2] Cf. the *Cassiopeia* to *Sagittarius* region of the photographic chart with a spiral nebula seen edgewise, e.g., "*H. V.*, 1 *Ceti*," *Lick Publications*, **8**, Pl. 2.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

I have indicated in the spiral figure the divisions α, β, γ . . . . corresponding to the "galactic regions" named above.

The central nucleus of the galactic spiral would project itself between β and γ *Cygni;* the northern continuation of this brilliant part, and the patch about α *Cygni*—a stream seen foreshortened in *D*—may be reckoned as belonging to the central condensation. The feeble interspiral streams to the left of the nucleus, together with the part of the first branch nearest to *S* (and therefore mostly resolved into stars), form the northern outlying parts in *Cepheus* and *Cassiopeia;* the apparent interlacing of these streams, as in *f*, producing the galactic condensations about ξ *Cygni;* they leave between them relatively dark spots, as the "Northern Coal Sack" indicated by *a*.

In the direction *SB*, the greater part of the spiral branch swings round (at κ and ι *Cassiopeiae*), bends somewhat to the south, and pursues its course through *Lacerta* and over ϵ *Cygni* ("Beta Region"). Some outlying streams in the direction *SC* form the branching structure between γ *Cassiopeiae* amd χ *Persei*, which terminates rather abruptly at η *Persei*. Here then ends the "Alpha Region," in this direction.

The second branch proceeds from the central nucleus mainly between β *Cygni* and *Sagitta*, being also in relation with the α *Cygni* stream. Descending in galactic longitude,[1] we find that the "knots" or "nodosities" of the branch in the direction of *F* must appear isolated, and the "fringes," curved away from those "knots," must be seen foreshortened—giving rise to the brilliant patches, somewhat in the shape of crescents or shields (*Scutum!*) from *Sagitta* up to the tail of *Scorpius* ("Gamma Region"). It is worthy of remark that "shield-forms" occur elsewhere in the Milky Way, the most remarkable instance being the series of bright patches between π *Cygni* and μ *Cephei* (Professor Barnard's photographs; see *Knowledge*, March 1894, and *Astrophysical Journal*, 21, 48, 1905).

The spiral branch No. II (see chart) then approaches the sun,

[1] I will use the term "ascending" to indicate, along the galactic axis, the direction in which the galactic longitudes increase, viz., from *Aquila* to *Cassiopeia;* "descending" the opposite direction, viz., from *Aquila* to *Sagittarius*.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

broadening and at the same time becoming vaguer and fainter ("Epsilon Region"). The bright stars are exceptionally numerous in those parts, as well as in the opposite direction (*SB* and *SA*), in accordance with the theory.[1]

Where shallow parts separate the "knots" in the convolutions, the lateral rifts, already present between the bright patches in *Sagittarius* and *Aquila*, become more evident. With increasing distance from the sun, beyond *Sc* (*descending*), the breadth of the central parts of the Milky Way again decreases. (The great width of the galactic zone in the regions *Scorpius* to *Sagittarius* and *Auriga* to *Taurus* is due to secondary streams, projected alongside the head-stream.)

We may look upon the "feeler" β *Cygni* to γ *Ophiuchi* as an appendage (*H*) of the central nucleus *A;* the series of patches from γ to ν *Aquilae* forming a side-branch (*E*) of the second convolution.

The interspiral region surrounding *S* is filled loosely with less condensed streams and strata of stars, whose general direction is tangential to the central nucleus, but which are crossed by others running between the great spiral branches and parallel to these. If those two main directions are everywhere present in the spiral system, as they show in the nebulae (cf. Ritchey's admirable photograph of *M 51*), they probably cause the intersecting streams in *Lupus* and elsewhere, and determine the outlines of the "blocks of light" about γ and μ *Sagittarii*, also of the "caves" near γ *Aquilae* and η *Argus*, etc. May not these two directions in the spiral strata be the expression of Kapteyn's two star-streams penetrating the whole stellar system?

The secondary streams between the branches of the spiral account readily for the aspect of the Milky Way in *Lupus*, *Scorpius*, and *Serpens* ("Delta Region"), and in the opposite direction ("Eta Region"); the bright and probably preponderating stars forming Gould's "belt," inclined at an angle of about 18° to the general plane of the galaxy. The "helium stars" are numerous in these parts. Beginning between *Cassiopeia* and *Perseus*, these

[1] Schiaparelli, "Sulla distribuzione . . . . ," *Publ. Brera*, **34**; Stratonoff, *Publ. Tachkent*, **1**; Easton, "Distribution de la lumière galactique," *Verhand. Amsterdam Acad. Sci.*, **8**, No. 3, p. 31.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

strata run first below the general plane, crossing it in the neighborhood of the sun (that is why the points of intersection of Gould's belt with the galactic equator lie about at 90° and 270° of galactic longitude) to rise above the plane, in *Scorpius* and *Ophiuchus*, before uniting with the central parts of the system. Vistas as in *Sd*, between the extensive lateral streams in *Orion* and *Taurus*, are readily explained, and the faintest parts of the Milky Way as a whole, seen from *S*, must of course lie in the direction of *e* (*Perseus*) and *b* (*η Serpentis*).

We may perhaps limit our interpretation of the Milky Way to these remarks; the analogy could easily be pushed farther.[1] No geometrical postulates for the shapes of "stellar spirals" having been found as yet,[2] such an interpretation is always more or less arbitrary. To give an example: the *Scorpius* (Delta) Region might perhaps as well be placed outside as inside the great spiral convolution. My aim was to show that the spiral theory holds good in the face of the more reliable and more detailed picture of the Milky Way, furnished by the photographic method.

Two objections have been raised against this theory. The central nucleus in the nebulae seems much more important in comparison to the remainder than would be indicated by the importance of the bright patches in *Cygnus*. This is true, but in the photographs this preponderance of the nucleus diminishes as the excellence of the photograph increases; i.e., the nucleus itself is often unduly magnified, on a rather poor plate, by adhering portions of the convolutions. I have already insisted on the excessive brilliancy which certain distant portions of the spiral acquire, owing to their running almost exactly in our line of sight. For the rest, the proportion in mass between the nucleus and the branches of a spiral does not seem a serious criterion for a theory, if it is otherwise acceptable.

[1] It is noteworthy that Arrhenius (*Nord und Süd*, January 1912) arrives independently at a somewhat similar structure of the galactic spiral.

[2] Wolf, *Die Milchstrasse*, p. 19. Cf. See, *Evolution*, **2**, 39 f.; also E. v.d. Pahlen, *Astronomische Nachrichten*, No. 4503, and W. Sutherland, *Astrophysical Journal*, **34**, 3, 1911.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

I can by no means share the opinion[1] that if the spiral theory is true, the many thousands of nebulae found by Keeler and Wolf must be "external galaxies," so that the confirmation or disproval of this supposition would be a test of the spiral theory. I wish only to remark that nobody will deny the existence of a whirlpool because he sees a number of small eddies in the convolutions of the great one. I think we may safely assume that the great majority of the small spiral nebulae, if not all, form part of our galactic system.

As to the part which those small nebulae play in the galactic system, I made an attempt, some years ago[2] to explain their relations to a spiral galaxy; contending in the first place that the usual idea of a quasi-symmetrical distribution of the nebulae in the two hemispheres, gathering around both galactic poles, is untenable; secondly, that (the *nubeculae* being excluded) the distribution of the nebulae shows maxima in galactic longitude 105° and 280°, about 90° from the supposed central nucleus in *Cygnus*. This peculiar distribution is readily explained if we may admit that our present observations only reveal to us, among those faint objects, those that are relatively near to us, and that the nebulae—perhaps remnants left behind by the rotatory movement of the system—chiefly fill up the space not occupied by the galactic convolutions, their distribution being complementary not to the distribution of the stars but to that of the "vast, irregular" nebulae.

On the other hand, the convolutions themselves seem to be extensively veiled by a stratum of nebulous light, which is perhaps nowhere wanting in the Milky Way proper, except in the "perforations," those singular holes and cracks discovered and studied by Barnard and Max Wolf. I see no evidence whatever of *continuous* masses of opaque matter lying between us and the stars, although such non-luminous matter must be scattered freely throughout the system. It is evident that the more or less luminous nebulosity is intimately connected with the stellar accumulations

[1] Ristenpart in Valentiner's *Handwörterbuch der Astronomie*, **4**, 123; cf. Newcomb-Engelmann, *Populäre Astronomie*, 3d ed., p. 618.

[2] Easton, "The Nebulae Considered in Relation to the Galactic System," *Proc. Amsterdam Acad. Sci.*, 1904, p. 189; *Astronomische Nachrichten*, No. 3969.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

and strata of the Milky Way. Those clouds, composed of stars and nebulous matter exhibit in various degrees the influence of what W. Herschel already has indicated as the "clustering power," breaking up the coils of the spiral, as we see it in the nebulae *M 101 Ursae Majoris* and *M 33 Trianguli*.

In this "clustering" of the galactic clouds, the star-clusters apparently play an important part. Certain clusters have evidently been formed at the expense of the strata in which they are imbedded (see photographs of the bright patch in *Scutum*). In many other cases, they seem to act as centers for the grouping of the galactic condensations, and it is natural to think that these clusters have far more important masses than is indicated by their size and brightness.

The study of the photographs, together with the theoretical considerations indicated above, lead to a similar inference in regard to certain stars. In the galaxy there must exist a number of stars, immensely surpassing in mass the components of the galactic star-clouds—true miniature suns even in comparison to our own luminary. Those gigantic globes, especially where they are grouped together, as in *Scorpius*, seem to act a leading part in the dismembering of the galactic convolutions.

Certain parts of the galactic zone, probably analogous to the "knots" in the great spiral nebulae, exhibit forms in which the spiral structure, though less apparent than in the small nebulae, and (I think) in the system as a whole, is not altogether wanting. We sometimes come across very curious little spirals in the galactic regions—e.g., to the south of ϵ *Carinae*—but great masses also exhibit this peculiarity. So we find a spiral structure of 150 sq. degrees between α *Crucis* and ϕ *Argus*.[1] In this case, we may note *two* central nuclei, at κ and η *Argus*, so that the term *bihelical* seems more appropriate.

A comparison of the different types of spiral nebulae (*Lick Publications*, **8**, "Keeler Memorial") leads to the conclusion that our galactic system would seem to be already in an advanced stage

[1] Speaking of the bright region in *Scutum*, Professor Barnard wrote (*Astrophysical Journal*, 1, 11, 1895): "I have often received the impression that this huge cloud of stars has been generated by some tremendous whirling motion."

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

of development, approaching rather to the *M 101* (*Lick*, Pl. 49), than to the *M 51* (*Lick*, Pl. 47) type.

It is natural to think that the Magellanic clouds should be analogous to the small nebula connected with Lord Rosse's spiral *M 51*. The analogy is strengthened by the resemblance in shape of the *nubeculae*, as seen in the well-known photographs of Russell, to the galactic formations about *η Argus* and elsewhere just described.[1] In any event, the actual connection with the main system, so obvious in the nebula, must be slight in the case of our galactic system. It is true that Backhouse[2] saw a wisp of galactic light uniting the Greater Magellanic Cloud with the Milky Way about *π Puppis*, and that, in some photographs, rows of stars seem to connect that *nubecula* with the galactic zone in *Carina*, but the evidence is doubtful. I must add, however, that Stratonoff's chart of the distribution of the nebulae shows a connection between the *nubeculae* and the *nebulae* in the southern hemisphere, and in my opinion the small nebulae form part of the galactic system.

AMSTERDAM
October 1912

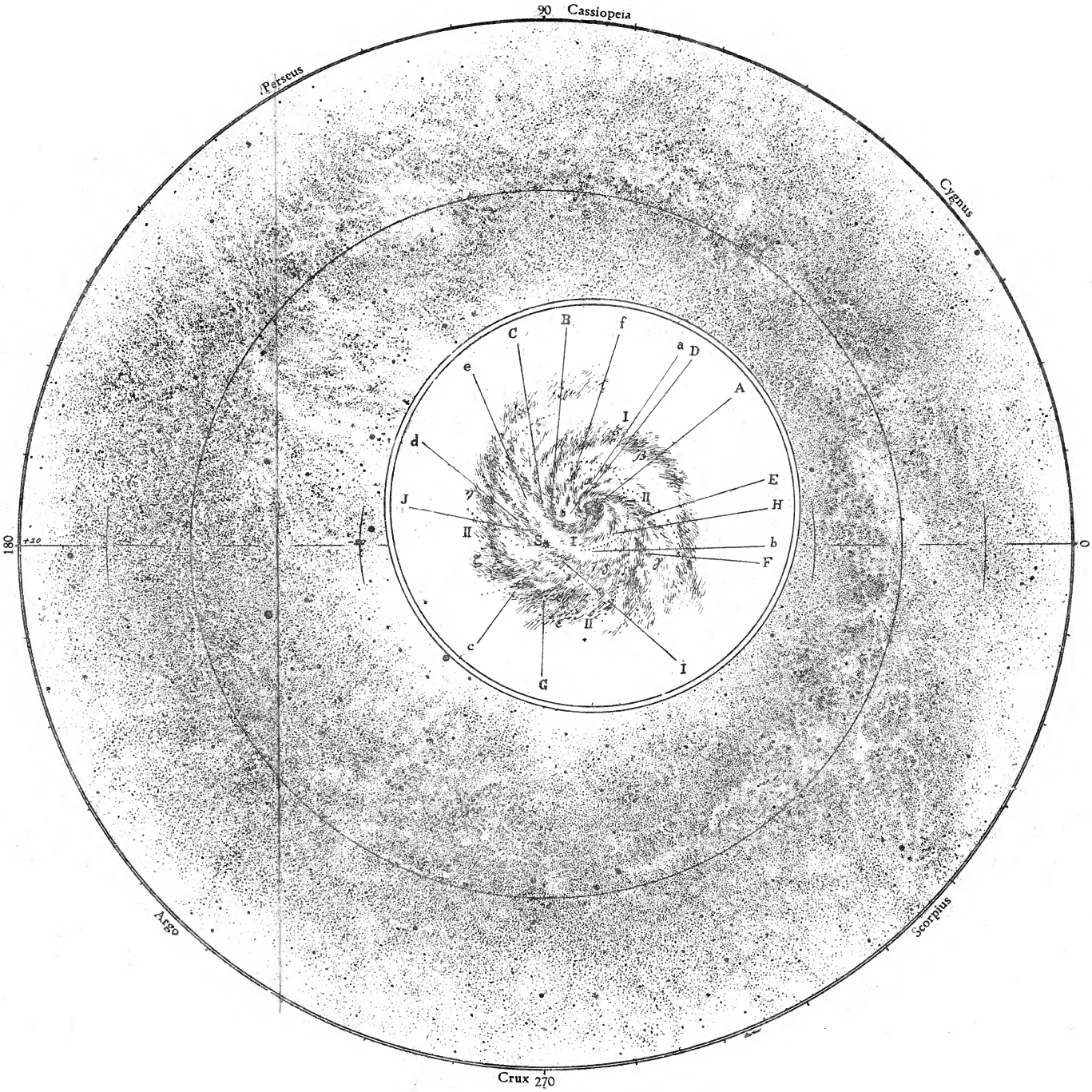
[1] I believe that the great structural resemblance between the *κ* and *η Argus* region and the *Nubecula Major* has never been insisted upon. Russell's photographs Nos. 1 and 14, however, show it at a glance.

[2] Backhouse, *Publ. of West Hendon House Observatory, Sunderland*, **2**, 30.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1913ApJ....37..105E

PLATE III



PHOTOGRAPHIC CHART OF THE MILKY WAY

© American Astronomical Society • Provided by the NASA Astrophysics Data System