Leaflet No. 164—October, 1942

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EDMUND HALLEY AND STELLAR PROPER MOTIONS

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The present year marks the tercentenary of the birth of Isaac Newton (born on Christmas Day, 1642), destined to be the author of the *Principia*, (see *Leaflet* 163), which Laplace said holds "a pre-eminence over all the other productions of the human intellect," and special attention is properly being paid to his outstanding career. It is worth noting, however, that the year also marks the *bicentenary* of the death of Edmund Halley (January 14, 1742), Newton's friend for more than 40 years and the man to whom we are chiefly indebted for the fact that the *Principia* was finished and published. It seems appropriate at this time, therefore, to remind our readers that he did something more for astronomy than get his name attached to a brilliant comet.

Born on October 29, 1656, the son of a well-to-do soap maker, Halley gave early promise of unusual intellectual powers and at the age of 16 had determined to find a career in astronomy. His first serious paper was laid before the Royal Society ere he had reached the age of 20, he was a member of the Society at the age of 22, and continued his very active career almost to the year of his death at the age of 86. The present paper will not attempt even to enumerate all of his contributions to astronomy, but will treat of only a few.

Let us turn, then, to the year 1684, and imagine ourselves strolling along the streets of London—less crowded then than now—on a summer afternoon. Near the entry to the rooms of the Royal Society we come upon three gentlemen engaged in earnest conversation. The youngest of these, only 28, but already enjoying a European reputation, we recognize as Edmund Halley. He was saying that he had been giving a great deal of thought to Kepler's Third Law and the nature of the force it expressed and had come to the conclusion that it must be a force varying inversely as the square of the distance of the body—planet or comet (he was specially interested in comets at the time)—from the sun and that the body must describe the curve of an ellipse, but he had been unable to prove it. It may be well to recall that the only comets then known were the brilliant, naked-eye ones which come into view from time to time from almost any direction in space.

The second man in the group, Sir Christopher Wren, who was almost as well known as a mathematician and astronomer as he was for the buildings he designed, had given the matter no thought; the third, Robert Hooke, the well-known physician and physicist, however, promptly said Halley was right. He had himself proved it conclusively some years before, but when challenged he could not produce the proof, nor could be outline his argument. It came out, in the course of the conversation, that Hooke knew that Isaac Newton, at Cambridge, had been at work on the theory of planetary motions a dozen or more years earlier, but had published practically nothing on the subject.

Whether or not the particular conversation I have just imagined took place, I do not know; but it is a matter of record that these three friends were in the habit of discussing their scientific problems with each other, that they discussed this particular problem in 1684 and that Halley, who had never met Newton, wrote to him in August 1684, asking for the privilege of calling upon him.

Newton at once replied, granting the request and received the younger man most cordially. Halley put his question, and gave his views, and Newton agreed that he was correct, and added that he had himself worked out the proof at least fifteen years earlier, but, becoming dissatisfied with the work had put it one side and had never arranged it for publication. He outlined his argument and Halley was not only convinced but delighted and urged upon Newton the desirability of at least presenting his papers to the Royal Society to assure his right to priority in the great discovery even if he were not ready as yet to publish.

Why Newton delayed the completion of the *Principia* so long, is a subject with which we are not here concerned. It is still unsettled. Here it is enough to state that Newton finally yielded to Halley's persuasive arguments, put his papers into the form in which they appear in Book I of the first edition of the *Principia*, and sent them to the Council of the Royal Society early in 1685. When the Council received them they turned them over to Halley with instructions to report and on his enthusiastic report it was voted that they be printed at the expense of the Society. A little later, they found it necessary to recall this vote, and, at Halley's generous offer, order them printed at the "personal expense of Mr. Edmund Halley." These papers practically constituted what became Book I of the first edition of the *Principia*. Newton a little later added Book II and later still Book III. He had planned to suppress this third book because he felt it to be incomplete, but Halley persuaded him to retain it.

Halley threw himself into the work of editing and printing what he in one place called "your divine treatise" with great enthusiasm. In March, 1687, after receiving the manuscript of Book III, he told Newton that he was "resolved to engage upon no other business till such time as all is done; desiring to clear myself from all imputations of negligence in a business in which I am much rejoyced to be anywais concerned in handing to the world that that all future ages will admire."

It thus appears that DeMorgan's statement of Halley's relationship to the *Principia* is justified. He wrote, "This miracle of energy, for Halley is nothing less, occupied himself with the question of gravitation, sought for information from Hooke, Wren and Newton, found out what the latter had done, induced him to begin the *Principia*, interested the Royal Society in its continuance, kept Newton up to his engagement, prevented him from mutilating it in disgust, undertook to see the work through the press, paid the expense of printing and made himself thoroughly master of its contents, the most difficult task of all."

The *Principia* out of the way, Halley returned to the problem he had in mind when he first went to see Newton, the problem of cometary orbits. At the present time, any well-trained graduate student in astronomy can compute an elliptic orbit in perhaps ten or twelve hours' steady work *after* he has his data assembled but he would stare aghast if he were asked to start with Newton's *Principia*, transform the analytical expressions into formulae suited for arithmetical computation, prepare tables of the solar motion (i. e., of the earth's motion about the sun) for the year in which the comet appeared, say 1682 or 1531, as a preliminary to *beginning* his computations.

As he found opportunity at intervals in his busy life Halley searched the literature back as far as 1300, noted all the comets that had been sufficiently observed to provide data necessary for orbit computation and found twenty-four. For each one of these he made the necessary preliminary computations and then computed its orbit according to Newton's Law of Gravitation and published the whole in June, 1705, under the title, *Astronomiae Cometicae Synopsis*, a truly prodigious task. On examining his table of orbits he was struck by the fact that the observed part of the comet's motion could be represented equally well by a greatly elongated ellipse as by a parabola. It was indeed his conviction that this might be so that had led him to undertake the immense task of compiling his great table. He also noted from the elements that the comet of 1531, the comet of 1607 and the comet he himself had observed in 1682, had elements resembling each other so closely that they might be returns of the same object. "Whence I would venture to predict with confidence a return of the same *anno scil* 1758." As we know, the comet did return and Halley's prediction was brilliantly verified. "Halley's Comet" it thereupon became and "Halley's Comet" it will remain as long as it continues to circulate about the sun.

These, and Halley's many other brilliant contributions to astronomy made him the natural candidate for the position of Astronomer Royal when Flamsteed died in 1719. We must pass over his career in this office with the simple remark that he undertook, at the age of 64, to make a continuous series of observations of the moon (*sidus contumax*, he called her) through one complete revolution of the nodes, 223 months, or nearly 19 years, hoping thus "to obtain a complete key to the errors of the current lunar tables." Happily, his health and strength continued until he had completed this great task.

Though I have passed over without even a reference many important researches, including his work on terrestrial magnetism, which involved his securing a commission as Captain in the Royal Navy and making two long sea voyages covering the greater part of the Atlantic Ocean, enough has been said to show that Halley deserved De Morgan's description as "this miracle of energy." Yet for all his activity in scientific research, he was no scholarly recluse but a man of the world, engaging in and enjoying the social life of his time to the full and quite as much at home at the royal court of King Charles II and his successors as at his desk translating the Greek text of Apollonius' Geometry, or in the rooms of the Royal Society, taking an active part in its proceedings, or at the Royal Observatory at Greenwich.

One of the very greatest of Halley's contributions to astronomy I have reserved for the latter part of this paper, because singularly little is made of it in current standard textbooks. That is his discovery, in 1718, that some of the brighter "fixed" stars really have motions of their own. Our textbooks limit themselves to this brief statement of fact and usually add the names of two of the stars, Sirius and Arcturus. Then they proceed to the discussion of stellar proper motions in general.

This is rather a summary dismissal of a discovery that opened up a remarkably fruitful field of astronomical investigation, a field which is still most actively cultivated, and which marked a new epoch in the history of cosmology.

Copernicus and Galileo had dethroned the earth, but they did not question the fixity of the sun and of the stars in space. Until Halley published his little paper in 1718, astronomers, including Isaac Newton, and Halley himself, regarded them as fixed. After Halley's discovery, and the researches it at once led to, man's concept of the universe and of his place in it, had to undergo complete revision. In fact, not until then was the way open to the development of our modern concept of the universe.

The short paper in its original form is almost inaccessible, and few, even of the professional astronomers, who read this Leaflet will have seen it. [1]One of the few sets of the unabridged first edition of the *Philosophical Transactions* of the Royal Society is kept in the Treasure Room of the Library of the University of California, where it may be consulted *in the presence* of a library attendant. Through the kind offices of Miss Nora Moylan, Secretary of the Students' Observatory, and of the Library officials, I am able to present here a photostat of the paper, one of the great source documents in the history of astronomy.[2]

Berkeley, California
September 1, 1942

[1]That is why one excellent text book makes Halley's List include four stars.

[2]*Palilicium* was the name given to the star we know as *Aldebaran,* in catalogues up to the time of Flamsteed's *Atlas Coelestis.*

The English translation of the Greek (Latin) sentence on page 738 is, ". . . A star was attached through which was split in two the illuminated limb of the moon."

I. *Considerations on the Change of the Latitudes of some of the principal fixt Stars.* By Edmund Halley, R. S. Sec.

HAving of late had occasion to examine the quantity of the Precession of the Equinoctial Points, I took the pains to compare the Declinations of the fixt Stars delivered by *Ptolomy*, in the 3*d* Chapter of the 7*th* Book of his *Almag.* as observed by *Timocharis* and *Aristyllus* near 300 Years before *Christ*, and by *Hipparchus* about 170 Years after them, that is about 130 Years before *Christ*, with what we now find: and by the result of very many Calculations, I concluded that the fixt Stars in 1800 Years were advanced somewhat more than 25 degrees in Longitude, or that the Precession is somewhat more than 50″ *per ann.* But that with so much uncertainty, by reason of the imperfect Observations of the Ancients, that I have chosen in my Tables to adhere to the even proportion of five Minutes in six Years, which from other Principles we are assured is very near the Truth. But while I was upon this Enquiry, I was surprized to find the Latitudes of three of the principal Stars in Heaven directly to contradict the supposed greater *Obliquity* of the *Ecliptick*, which seems confirmed by the Latitudes of most of the rest; they being set down in the old Catalogue, as if the Plain of the Earths Orb had chang'd its Situation, among the fixt Stars, about 20′ since the time of *Hipparchus*. Particularly all the Stars in *Gemini* are put down those to the *Northward* of the Ecliptick, with so much less Latitude than we find, and those to the *Southward* with so much more *Southerly*

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Latitude. Yet the three Stars *Palilicium* or the *Bulls* Eye, *Sirius* and *Arcturus* do contradict this Rule directly: for by it, *Palilicium* being in the days of *Hipparchus* in about 10 *gr.* of *Taurus* ought to be about 15 Min. more *Southerly* than at present, and *Sirius* being then in about 15 of *Gemini* ought to be 20 Min. more *Southerly* than now; yet *è contra Ptolomy* places the first 20 Min. and the other 22 more *Northerly* in Latitude than we now find them. Nor are these errors of Transcription, but are proved to be right by the declinations of them set down by *Ptolomy*, as observed by *Timocharis*, *Hipparchus* and himself, which shew that those Latitudes are the same as those Authors intended. As to *Arcturus*, he is too near the Equinoctial Colure, to argue from him concerning the change of the Obliquity of the Eclipt ick, but *Ptolomy* gives him 33′ more *North* Latitude than he now has; and that greater Latitude is likewise confirmed by the Declinations delivered by the abovesaid Observers. So then all these three Stars are found to be above half a degree more *Southerly* at this time than the Antients reckoned them. When on the contrary at the same time the bright Shoulder of *Orion* has in *Ptolomy* almost a degree more *Southerly* Latitude than at present. What shall we say then? It is scarce credible that the Antients could be deceived in so plain a matter, three Observers confirming each other. Again these Stars being the most conspicuous in Heaven, are in all probability the nearest to the Earth, and if they have any particular Motion of their own, it is most likely to be perceived in them, which in so long a time as 1800 Years may shew it self by the alteration of their places, though it be utterly imperceptible in the space of a single Century of Years. Yet as to *Sirius* it may be observed that *Tycho Brahe* makes him 2 Min more *Northerly* than we now find him, whereas he ought to be above as

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much more *Southerly* from his Ecliptick, (whose Obliquity he makes 2 ½ greater than we esteem it at present) differing in the whole 4 ½ Min. One half of this difference may perhaps be excused, if refraction were not allowed in this Case by *Tycho*; yet two Minutes, in such a Star as *Sirius*, is somewhat too much for him to be mistaken.

But a further and more evident proof of this change is drawn from the Observation of the application of the Moon to *Palilicium Anno Christi* 509 *Mart.* 11°. when in the beginning of the Night the Moon was seen to follow that Star very near, and seemed to have Eclipsed it. ἐπέβαλλε γὰρ ὁ ἀστὴρ τῷ ἀρκτῷ τὴν διχοτομίαν μέρει τῆς κυρτῆς περιφερείας τοῦ πεφωτισμένου μέρους. *i. e. Stella apposita erat parti per quam bissecabatur limbus Lunæ illuminatus*, as *Bullialdus*, to whom we are beholden for this Antient Observation, has translated it. Now from the undoubted principles of Astronomy, it was impossible for this to be true at *Athens*, or near it, unless the Latitude of *Palilicium* were much less than we at this time find it. *Vide Bullialdi Astr. Philolaica, pag* 172.

This Argument seems not unworthy of the *Royal Society*'s Consideration, to whom I humbly offer the plain Fact as I find it, and would be glad to have their Opinion.

But whether it were really true, that the Obliquity of the Ecliptick was, in the time of *Hipparchus* and *Ptolemy*, really 22 Min greater than now, may well be questioned; since *Pappus Alexandrinus*, who lived but about 200 Years after *Ptolemy*, makes it the very same that we do. *Vide Pappi Collect. Lib.* VI. *Prop.* 35.

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