

I. *A Proposal of a Method for finding the Longitude at Sea within a Degree, or twenty Leagues. By Dr. Edmund Halley, Astr. Reg. Vice-President of the Royal Society. With an Account of the Progress he hath made therein, by a continued Series of accurate Observations of the Moon, taken by himself at the Royal Observatory at Greenwich.*

**I**T is now above twenty Years since I added an *Appendix* to the second Edition of *Mr. Street's Caroline Tables*, containing a Set of Observations I had made in the Years 1683 and 1684, for ascertaining the Moon's Motion; and giving a *Specimen* of what I thought, at that Time, might be the only practicable Method of attaining the *Longitude at Sea*. What I printed so long ago, is as follows:

“ The Advantages of the Art of finding the  
 “ Longitude at Sea, are too evident to need any Ar-  
 “ guments to prove them. And having by my own  
 “ Experience found the Impracticability of all other  
 “ Methods proposed for that Purpose, but that deri-  
 “ ved from a perfect Knowledge of the *Moon's Moti-*  
 “ *on*; I was ambitious, if possible, to overcome the  
 “ Difficulties that attend the Discovery thereof.

“ And first, I had found it only needed a little  
 “ Practice to be able to manage a five or six Foot Te-  
 “ lescope, capable of shewing the Appulses or Occulta-  
 “ tions of the *Fix'd Stars* by the *Moon*, on Ship-  
 “ board, in moderate Weather; especially in the First

“ and Last *Quarters* of the *Moon's Age*, when her  
 “ weaker Light does not so much efface that of the  
 “ *Stars*. Whereas the Eclipses of the *Satellites* of  
 “ *Jupiter*, how proper soever for *Geographical*  
 “ Purposes, were absolutely unfit at Sea, as requi-  
 “ ring Telescopes of a greater Length than can well  
 “ be directed in the rolling Motion of a Ship in  
 “ the Ocean.

“ Now the Motion of the Moon being so swift,  
 “ as to afford us scarce ever less than two Minutes for  
 “ each Degree of Longitude, and sometimes two  
 “ and a half; it is evident, that were we able per-  
 “ fectly to predict the true Time of the Appulse or  
 “ Occultation of a Fix'd Star, in any known Meridi-  
 “ an, we might, by comparing therewith the Time ob-  
 “ served on Board a Ship at Sea, conclude safely how  
 “ much the Ship is to the Eastward or Westward of the  
 “ *Meridian* of our *Calculus*.

“ But after much Examination, and carefully col-  
 “ lating the *Caroline Tables* of Mr. *T. Street* (though  
 “ generally better than those that went before him)  
 “ as likewise those of *Tycho*, *Kepler*, *Bullialdus*, and  
 “ our *Horrox*, with many accurate Observations of  
 “ the *Moon*, carefully made on Land; it does not ap-  
 “ pear that any of these *Tables* do represent the Moti-  
 “ ons with the Certainty required; and though many  
 “ times the Agreement seems surprizing, when the  
 “ Errors of the several *Equations* compensate one ano-  
 “ ther; yet in those Parts of the *Orb* where they  
 “ all fall the same Way, the Fault is intolerable, and  
 “ the Result many times not to be depended on, to  
 “ more than one hundred Leagues; that is to say, it is  
 “ wholly insufficient.

“ Yet

“ Yet still this Fault is *Artificis*, not *Artis*: For  
 “ observing the *Period* of the *Lunar Inequalities*,  
 “ which is performed in eighteen Years and eleven  
 “ Days, or two hundred and twenty-three *Lunati-*  
 “ *ons*; it is found that the Returns of the Eclipses,  
 “ and other Phænomena of the Moon’s Motion, are  
 “ very regularly performed; so that whatever Error  
 “ you found in a former Period, the same is again re-  
 “ peated in a second, under the like Circumstances of  
 “ the same Distance of the Moon from the Sun and  
 “ *Apogæon*.

“ Thus, from the Observation made of the E-  
 “ clipse of the Sun, which was *June 22, 1666*, in  
 “ the Morning, seen at *London* and *Dantzick*, I  
 “ was enabled to predict, with great Certainty, that  
 “ other, which I observed *July 2, 1684*, by al-  
 “ lowing the same Error I found in the *Calculus*  
 “ of the former. And the like with equal Certainty  
 “ will do, in the Cases *extra Syzygias*, when the  
 “ Mean and Synodical Anomolies are nearly the  
 “ same, about the same time of the Year.

“ Being thus assured, from the Certainty of these  
 “ Revolutions, that all the intermediate Errors of our  
 “ *Tables* were not uncertain Wandrings, but regular  
 “ Faults of the *Theories*; I next thought how I might  
 “ best be informed of the Quantity and Places of these  
 “ Defects: That being apprized how much, and which  
 “ Way my Numbers erred, I might apply the Dif-  
 “ ference, so as at all times to represent the true Mo-  
 “ tion of the *Moon*. Nor was there any other Way,  
 “ but from the Heavens themselves, to derive this  
 “ Correction, by a sedulous and continued *Series*

“ of *Observations*, to be collated with the *Calculus*,  
 “ and the Errors noted in an *Abacus*: From whence,  
 “ at all Times, under the like Situation of the *Sun*  
 “ and *Moon*, I might take out the Correction to be  
 “ allowed.

“ And having by me the *Sextant* I made to  
 “ observe the Southern *Stars* at *St. Helena*, in  
 “ the Year 1677, I fixed it for this Purpose; re-  
 “ solving to have continued to observe, till I had  
 “ filled my *Abacus*, so as it might have the Effect  
 “ of exact *Lunar Tables*, capable to serve at Sea,  
 “ for finding the *Longitude* with the desired *Cer-*  
 “ *tainty*.

“ With this Design, I applied the Leisure I had  
 “ procured myself about the Year 1683, to observe di-  
 “ ligently, as often as the Heavens would permit, the  
 “ true Place of the Moon, especially as to Longitude;  
 “ and in the Space of about sixteen Months I had  
 “ gotten near two hundred several Days Observations,  
 “ most of which I collated with the *Horroxian*  
 “ *Theory* (whose *Calculus* is something more com-  
 “ pendious than that of Mr. *Street*) and having pla-  
 “ ced the Errors in an *Abacus*, I perceived how re-  
 “ gular the Irregularities were, and that where the  
 “ Moon had been exactly observed formerly, at the  
 “ Distance of one or more Periods of two hundred  
 “ twenty-three Months, I could even predict the  
 “ Error of the *Tables*, with a Certainty not much  
 “ inferior to that of the Observations themselves.  
 “ But this Design of mine was soon interrupted by  
 “ unforeseen domestick Occasions, which obliged me  
 “ to postpone all other Considerations to that of the  
 “ De-

“ Defence of my Patrimony: And, since then, my  
 “ frequent Avocations have not permitted me to re-  
 “ assume these Thoughts.

“ In the mean time I have taken Care to present my  
 “ Observations, such as they are, to the Publick, in  
 “ order to preserve them; assuring, that as on the  
 “ one Hand they were made with a very sufficient *In-*  
 “ *strument*, with all the Care and Diligence requisite;  
 “ so in the remote Voyages I have since taken to as-  
 “ certain the *Magnetick Variations*, they have been  
 “ of signal Use to me, in determining the *Longitude*  
 “ of my *Ship*, as often as I could get Sight of a  
 “ near *Transite* of the *Moon* by a known *Fix'd*  
 “ *Star*: And thereby I have frequently corrected  
 “ my *Journal* from those Errors which are unavoid-  
 “ able in long Sea-Reckonings.

“ If therefore you happen at *Sea* to observe nice-  
 “ ly the Time of an *Occultation* or close *Applica-*  
 “ *tion* of a *Star* to the *Moon*; and can find a cor-  
 “ respondent Observation, about the same mean *Ano-*  
 “ *maly* and Distance of the *Moon* from the *Sun* (either  
 “ among these of mine, or in any other Collection  
 “ of Observations accurately made) especially near  
 “ the same Time of the Year; and, above all, after  
 “ the aforesaid *Period* of eighteen Years and eleven  
 “ Days, you may, without sensible Error, from  
 “ thence pronounce in what *Meridian* your *Ship* is;  
 “ taking Care in so operose a Calculation, to commit  
 “ no Mistake; and, notwithstanding the Direction  
 “ the Moon gives you, not coniding so much there-  
 “ in as to omit any of the usual Precautions to preserve  
 “ a Ship when she approaches the Land.

“ I had

“ I had intended to insist more largely upon this  
 “ Method of obtaining the *Moon's Place*, and, by  
 “ Consequence, the *Longitude* at *Sea*, but that I  
 “ find, that it requires a just Treatise, too long to  
 “ be here subjoined: And, more especially, that  
 “ the great Sir *Isaac Newton* (to whom no Ma-  
 “ thematical Difficulty is insuperable) has been  
 “ pleased to give us a *True* and *Physical Theory* of  
 “ the *Moon's* Motions, whereby the Defects of all  
 “ former *Tables* are so far amended, that it is hoped  
 “ the Error may scarce ever exceed three Minutes of  
 “ Motion, or so little in *Longitude*; that, perhaps,  
 “ it may be thought a sufficient Exactness for all the  
 “ Uses of *Navigation*. If therefore what is here offer-  
 “ ed find a kind Acceptance from those that it chiefly  
 “ concerns, I shall be encouraged to proceed on a  
 “ Work I have long meditated, to improve the above-  
 “ mentioned *Period*, as to the abbreviating the Com-  
 “ putation of *Eclipses*, and, in general, to facilitate  
 “ the too laborious *Calculation* of the *Moon's Place*  
 “ *extra Syzygias*.

Not long after her late Majesty Queen *Anne* was  
 pleased to bestow upon the Publick, an Edition of  
 the much greater, and most valuable Part of Mr.  
*Flamsteed's* Observations; by Help of which the great  
 Sir *Isaac Newton* had formed his curious Theory  
 of the *Moon*, a first Sketch of which was inserted  
 by Dr. *David Gregory* in his *Astronomiæ Physicæ*  
 & *Geometricæ Elementa*, published at *Oxford*,  
 1702; and again, in the second Edition of Sir *Isaac's*  
*Principia*, which came out in 1713, we have the  
 same

same revised and amended by himself, to that Degree of Exactness, that the Faults of the *Computus* formed therefrom rarely exceed a quarter Part of what is found in the best *Lunar Tables* before that Time extant.

Being thus provided with proper Materials, *viz.* a large Set of Observations, and a *Theory* of the *Motions* so very near the Truth, I resumed my former Design of filling up my *Abacus* or *Synopsis* of the Defects of this *Lunar Theory*, and made Tables to expedite the *Calculus* according thereto, and compared the Numbers thereof with many of the most certain of Mr. *Flamsteed's* Places observed. By this it was evident that Sir *Isaac* had spared no Part of that Sagacity and Industry so peculiar to himself, in settling the *Epoches*, and other *Elements* of the *Lunar Astronomy*, the Result many times, for whole Months together, rarely differing two Minutes of Motion from the Observations themselves; nor is it unlikely but good Part of that Difference may have been the Fault of the Observer. And where the Errors were found greater, it was in those Parts of the *Lunar Orb* where Mr. *Flamsteed* had very rarely given himself the Trouble of observing; *viz.* in the third and fourth Quarter of the *Moon's* Age, where sometimes these Differences would amount to at least five Minutes.

Mr. *Flamsteed* was long enough possessed of the *Royal Observatory* to have had a continued Series of Observations for more than two *Periods* of eighteen Years; by which he had it in his Power to have done all that could be expected from Observation,  
towards

towards discovering the *Law* of the *Lunar Motions*. But he contented himself with sparse Observations, leaving wide Gaps between, so as to omit frequently whole Months together; and in one Case the whole Year 1716. So that notwithstanding what he has left us must be acknowledged more than equal to all that was done before him, both as to the Number and Accuracy of his Accounts; yet for want of an uninterrupted Succession of them, they are not capable of discovering, in the several Situations of the *Lunar Orbit*, what Corrections are necessary to be allowed, to supply the Deficiencies of our *Computus*.

On Mr. *Flamsteed's* Decease, about the Beginning of the Year 1720, his late Majesty King *George I.* was graciously pleased to bestow upon me the agreeable Post of his *Astronomical Observer*, expressly commanding me *to apply my self with the utmost Care and Diligence to the rectifying the Tables of the Motions of the Heavens, and the Places of the Fix'd Stars, in order to find out the so much desired Longitude at Sea, for the perfecting the Art of Navigation.* These are the Words of my *Commission*; and here I might have thought myself in a Condition to put in Execution my long projected Design of compleating my *Abacus*, or Table of the Defects of our *Lunar Numbers*; but on taking Possession, I found the *Observatory* wholly unprovided of *Instruments*, and indeed of every thing else that was moveable, which postponed my Endeavours till such Time as I could furnish myself with an *Apparatus* capable of the Exactness requisite. And this was the more grievous to me, on account of my advanced  
Age,



Age, being then in my sixty-fourth Year, which put me past all Hopes of ever living to see a compleat *Period* of eighteen Years Observation.

But, Thanks to G<sup>o</sup>D, he has been pleased hitherto to afford me sufficient Health and Vigour to execute my Office in all its Parts with my own Hands and Eyes, without any Assistance or Interruption, during one whole *Period* of the *Moon's Apogee*; which *Period* is performed in somewhat less than nine Years. In this Time I have been able to observe the *Right Ascension* of the *Moon* at her *Transit* over the *Meridian*, near fifteen hundred times (and with an Exactness, I am bold to say, preferable to any thing done before) a Number not less than those of the noble *Tycho Brahe*, *Hevelius* and *Flamsteed*, taken in one Sum, there being near four of my Lunar Observations for each Degree of the Zodiack, as also for each Degree of the *Argumentum annum*, or Distance of the *Sun* from the *Moon's Apogee*. And that these might be duly applied to rectify the Defects of our *Computations*, I have myself compared with the aforementioned Tables, made according to Sir *Isaac's* Principles, not only my own Observations, but also above eight hundred of Mr. *Flamsteed's*.

This *Comparison* of my own *Observations* (from the Time I esteem them compleat) with the *Computus* by the said Tables, being now continued for above nine Years, I design speedily to communicate it to the Publick, together with the Tables themselves, which have been printed, and should long since have been published, had not my Post at *Greenwich* given me an Opportunity to examine, with proper Nicety, in

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what

what Parts of the *Lunar Orb*, and how much, our Numbers erred. So useful an Addition as this, it is hoped may fully answer the long delayed Expectation some Persons may have had of seeing the said Tables sooner. By Means thereof, those that are qualified may, if they please, examine by their own Observation the Truth of what is here asserted.

Comparing likewise many of the most accurate of Mr. *Flamsteed*, made eighteen or thirty-six Years before (that is one or two *Periods* before mine) with those of mine which tallied with them, I had the Satisfaction to find that what I had proposed in 1710 was fully verified; and that the Errors of the *Calculus* in 1690 and 1708, for Example, differed insensibly from what I found in the like Situation of the Sun and Apogee, in the Year 1726. The great Agreement of the *Theory* with the *Heavens* compensating the Differences that might otherwise arise from the Incommensurability and Excentricity of the Motions of the Sun, Moon and Apogee.

Encouraged by this Event, I next examined what Differences might arise from the Period of nine Years wanting nine Days, in which Time there are performed very nearly one hundred and eleven *Lunations*, or Returns of the *Moon* to the *Sun*; but the Return of the *Sun* to the *Apogee* in that Time differing above four times as much from an exact Revolution as in the Period of eighteen Years, I could not expect the like Agreement in that. However, having now entered upon the tenth Year, I compared what I had observed in the Years 1721 and 1722, with my late Observations of 1730 and 1731, and have rarely found a Difference of  
more

more than one single Minute of Motion (Part of which may probably arise from the small Uncertainty that always attends Astronomical Observation) but most commonly this Difference was wholly insensible; so that by the Help of what I observed in 1722, I presume I am able to compute the true Place of the Moon with Certainty, within the Compass of two Minutes of her Motion, during this present Year 1731, and so for the future. This is the Exactness requisite to determine the Longitude at Sea to twenty Leagues under the Equator, and to less than fifteen Leagues in the *British* Channel.

It remains therefore to consider after what Manner Observations of the Moon may be made at Sea with the same Degree of Exactness: But since our worthy Vice-President *John Hadley*, Esq; (to whom we are highly obliged for his having perfected and brought into common Use the *Reflecting Telescope*) has been pleased to communicate his most ingenious Invention of an Instrument for taking the Angles with great Certainty by Reflection, (*Vide Transact.* No 420.) it is more than probable that the same may be applied to taking Angles at Sea with the desired Accuracy.

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## II. *An Account of the Contrayerva, by Mr. William Houstoun, Surgeon in the Service of the Honourable South-Sea Company.*

**C**ONTRAYERVA is a *Spanish* Word, signifying as much as *Herba contra* [*Venena*] or an Herb against Poisons. And as there are in all Countries