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Contributors

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A
DISCOURSE
ON THE

Attraction of Mountains,

DELIVERED AT THE

Anniversary Meeting of the ROYAL SOCIETY,
November 30, 1775.

By Sir JOHN PRINGLE, Baronet,
PRESIDENT.

PUBLISHED BY THEIR ORDER.



LONDON:

Printed for the ROYAL SOCIETY,

M.DCC.LXXV.

D I S C O U R S E

ON THE
NATURE OF

ANNUAL MEETING OF THE ROYAL SOCIETY

November 22, 1875

BY SIR JOHN FRIEDEL, Bart.

PRESIDENT.

PUBLISHED BY THE ROYAL SOCIETY

LONDON:

Printed for the ROYAL SOCIETY

1875



GENTLEMEN,

THE satisfaction you discovered when a proposal was laid before you, *for measuring the attraction of mountains*, and the manner in which you received the account of what had been done to fulfil that view, were such indications of your applause, that your Council, ever attentive to your sentiments, have adjudged the prize-medal of this year to the Reverend *Nevil Maskelyne*, his Majesty's Astronomer at Greenwich, the author and conductor of that experiment. The many and valuable communications of our worthy brother, preceding this inquiry, you have never failed to distinguish; but these his late labours, undertaken at your request, with their successful result, related in his Paper, intitled *Observations made on the Mountain Scheballien for finding its Attraction*, and inserted in the second part of the volume of your Transactions for this year, seemed to lay the

Society under such obligations, as your Council presumed you could not otherwise express than by the highest mark of your approbation. In consequence of this reflection, I have by their authority caused Mr. *Maskelyne's* name, with the date of the present year, to be engraven on the medal, in order to perpetuate to him the honour you were this day to confer upon him ; if, after allowing me to recall to your remembrance some of the more interesting particulars of this disquisition and his operations, you should not refuse your sanction to the judgment of your Council.

I shall not consider the subject of attraction at large, nor touch upon any species of it, excepting what in latter times, by the effects, has been distinguished by the name of *gravity* or *gravitation*; a property of bodies perceptible to the vulgar when things fall to the ground, but long acknowledged by this Society, to be a quality impressed by the Creator on all matter, whether of the earth or of the heavens, whether at rest or in motion : *He commanded, and it was created.*

The discovery of this extensive principle, the physics of astronomy, depended upon a just notion
of

of the arrangement and motions of the spheres; for to understand their œconomy, it was necessary previously to know, which of the stars were quiescent, which moved, and in what manner. Whoever therefore found out the true celestial system, might be said to have paved the way to the knowledge of that sublime truth, the law by which the natural world is governed. But who were the inventors here? Were they Chaldeans or Ægyptians? Was it *Pythagoras*, or *Philolaus*, or any other Greek, either in their own country, or transplanted to the mathematical schools of Alexandria? I shall not enter upon that inquiry, as fruitless as obscure. All that is clear and to our purpose is, that some of the ancient Greeks conjectured rightly about the stability of the sun and the circular motion of the earth; but this was never a general persuasion, nor does it seem to have been mentioned any more after the age of *Ptolemy*, who in the second century did not so much invent a new system, as adopt that which now goes under his name, the prevailing one of his time, and nearly the same with that of *Aristotle*. This, though erroneous, was not perhaps incapable of improvements from celestial observations; but when the philosophy of the schools was united with the Ptolemaic hypothesis, and both were subjected.

subjected to judicial astrology, then was astronomy debased to the level of the pretended learning of the dark ages that ensued, and increased their darkness.

But at the appointed time, when it pleased the supreme Dispenser of every good gift to restore light to a bewildered world, and more particularly to manifest his wisdom in the simplicity as well as in the grandeur of his works, he opened the glorious scene with the revival of a sound astronomy. *Copernicus* of Thorn (a Polish city in the Regal Prussia) endowed by nature with excellent talents, improved by a superior degree of mathematics, and by travelling, became early in life disgusted with the contradictions about the causes of the celestial phænomena. He had recourse, as he himself informs us *, to every author upon the subject, to see whether any had been more consistent in explaining the irregular motions of the stars, than the mathematical schools; but received no satisfaction, till first, from *Cicero*, he found that *Nicetas* had maintained the motion of the earth; and next from *Plutarch*, that others of the ancients had been of the same opinion. *Cicero* had said, that *Nicetas the Syracusan* (according to Theo-

* Præf. ad lib. de Revolutionibus Orbium Cœlestium.

phraustus)

phraftus) held that the heavens, the sun, the moon, the stars, in a word, the whole celestial bodies stood still, and that, excepting the earth, nothing moved in the world; but that whilst the earth with the greatest celerity turned round its axis, the same phenomena were produced, as if it stood still, and the heavens moved. And this some thought was also Plato's notion, but somewhat obscurely expressed*.

Plutarch's words were, Others suppose the earth to be at rest; but Philolaus the Pythagorean, that it is carried in the ecliptic round the fire, like the sun and the moon. Heraclides of Pontus, and Ecphantus the Pythagorean, make the earth move like a wheel about its center from West to East, but not to change its place†.

From these quotations, and what Copernicus farther says‡, we find how little disposed that great man was to plume himself with the inventions of others; nay, rather anxious not only to do justice to those who had gone before him, but by their authority to screen himself from the censure of innovation, absurdity, and impiety, that awaited the publication of his doctrine. After all, the original genius of Copernicus was but little beholden for the discovery of those sublime truths, to

* Cicer, Quæst. Academic. † Placit. Philos. lib. 3. cap. 3. ‡ Ibid.

either

either *Nicetas* or *Plato*, since it appears from *Cicero* that these two believed both the moon and the planets to be motionless. Nor could he be more assisted by *Philolaus*, who taught that *the earth turned round a fire*; but this fire could not be the sun, because that ancient compares the motion of the earth about *the fire*, to the revolution of the sun and moon about the earth. Lastly, what little light *Copernicus* could draw from *Heraclides* and *Ecphantus*, I scarcely need say, since they, though admitting the diurnal motion of the earth, denied the annual.

But if *Copernicus* fought to do justice, why did he not rather cite a clear and express passage in the *Arenarius* of *Archimedes* for the fixed state of the sun, and for the motion of the earth in a circle round his body? *What most philosophers call the world* (says that famous ancient) *is a sphere, of which the center is that of the earth, and whereof the semi-diameter is equal to a right line joining the centers of the earth and the sun.* But *Aristarchus the Samian*, refuting this opinion, has advanced an hypothesis, whereby the world should be many times greater than what is here said; for he supposes that the fixed stars and the sun remain immoveable, and that the earth is

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carried

carried in a circle round the sun, placed in the middle of it's course *.

Thus far *Archimedes*, who seems not to disapprove the system, but who explains it no farther, as what he had quoted was sufficient for his purpose. It is probable that the penetrating genius of *Aristarchus* had discovered the true arrangement of the whole celestial bodies, and thereby totally anticipated *Copernicus*; but that circumstance is no where, that I know of, recorded; and otherwise, we should acquit our illustrious reformer of plagiarism with regard to *Aristarchus*, since neither the *Arenarius* of *Archimedes*, where that passage is found, nor indeed any other of his valuable remains, had seen the light before the death of *Copernicus*. This extraordinary person had even before the meridian of life completed his discoveries, and comprised them in his book *de Revolutionibus Orbium Cœlestium*, his only work; but which he had prudently suppressed, till he had maturely considered his subject, and had found a necessary and powerful patron, the pope himself, *Paul III*, a lover of astronomy, to protect him. Alluding to the admonition of the poet, he tells the Pontif, *he had*

* *Archimed. Arenar. ed. Oxon. 1676.*

suffered that fruit of his labours to ripen, not nine years only, but four times nine *. Consenting at last to the publication, he committed the care of the impression to some friends in a distant city, from whom he received the finished copy a few hours before he expired †.

Few compositions have destroyed more riveted errors, or established more important truths. Here, instead of an absolute state of rest for the earth, it's triple motion is ascertained, the diurnal about it's axis, the annual about the sun, and that other known by the term *precession of the equinoxes*; all which till then had been referred to the motion of the heavens. He likewise demonstrated the double orbit of the moon, that is, her menstrual motion about the earth, and her annual about the sun. Nor did the wise *Copernicus* stop here; for, after laying this solid foundation of the celestial physics, he began the superstructure, by furnishing a principle of *attraction* to be inherent in all matter. Thus, in refuting the peripatetic notion, that bodies fall to the ground, because by a law of nature every thing heavy tends to the center of the universe (which they supposed to be in the center of the earth) he observed, that *the earth could not be the center of the orbits of several of the*

* Præfat. ad lib. de Revolut. † Gassend. in vita Copernic.

planets, because of the apparent irregularities of their motions, and therefore could not be the center of the universe : hence, according to these philosophers, there must be more centers than one ; and if so, who could tell the true center, toward which all bodies were to gravitate ? As for gravity, says he, I consider it as nothing more than a certain natural appetence (*appetentia*) that the Creator has impressed upon all the parts of matter, in order to their uniting and coalescing into a globular form, for their better preservation ; and it is credible that the same power is also inherent in the sun and moon and planets, that those bodies likewise may constantly retain that round figure in which we behold them *. Farther, Copernicus looked upon the sun as the chief governing power of the earth and all the other planets ; for after placing the great luminary in the center, he cries out with rapture, *Profecto tanquam in solio regali sol residens circumagentem gubernat astrorum familiam* †. Nor was this government understood to be exercised by any other power than that of attraction ; as may be inferred from some of the last words of the celebrated Tycho Brahe, who perceiving the approach of death, called for the famous Kepler (then a young man, and his assistant in his observatory

* De Revolut. Orb. Cœlest. lib. 1. cap. 9. † Ibid. cap. 10.

at Prague) and after charging him with completing and publishing the astronomical tables which he was leaving unfinished, thus addressed him: *My friend, although what I ascribe to a voluntary, and as it were an obsequious motion of the planets round the sun, you attribute to an attractive energy of that body; yet I must entreat you, that in the publication of my observations, you would explain all the celestial motions by my hypothesis, rather than by that of Copernicus, which I know you would otherwise incline to follow* *.

From this passage, which I have taken from the life of *Tycho Brahe*, it would seem, that though that other excellent astronomer was not insensible of some influencing power of the sun over the planets, he would not however express it by so strong a term as *attraction*. But in what manner *Kepler* complied with the request of his dying patron, it is not to our present purpose to mention, and therefore we shall only observe, that in his own works he constantly maintains the doctrine of attraction, and carries it even farther than ever *Copernicus* had done. Thus he calls gravity *a corporeal and mutual affection between similar bodies, in order to their union* †. Again he remarks with *Copernicus*, against the peripatetics, that

* Gassend. in Vit. Tych. Brah. cap. 5. † Astron. Nov. in Introduct.

heavy bodies do not tend to the center of the universe, but to the center of those larger round bodies of which they make a part; so that if the earth were not spherical, things would not fall from all points towards its center. If a stone were to be placed at a distance from another stone, in any part of the universe, without the sphere of action of a third body, like two magnets, they would come together in some intermediate point, each advancing, in space, in the inverse proportion of their quantities of matter. Hence if the moon and the earth were not by some power kept asunder in their respective orbits, they would move towards one another; the moon making 53 parts of the way while the earth made one, supposing their densities equal*.

From the same principle Kepler accounted for the general motion of the tides, to wit, by the attraction of the moon, and expressly calls it *virtus tractoria que in luna est* †. He adds, that if the earth did not exert an attractive power over its own waters, they would rise and rush to the moon ‡. Farther, we find him suspecting certain irregularities in the motion

* Astron. Nov. in Introduct.

† Ibid.

‡ Ibid.

of the moon to be owing to the combined action of the earth and sun upon it's body*. These, and other reflections concerning the universality of attraction, he accompanies with an ingenious anticipation of a law of nature, from conjecture only, but which was afterwards made out by experiments. The schools had taught, that *some bodies were by their nature heavy, and so fell to the ground, and that others were by their nature light, and therefore mounted upwards*: but Kepler pronounced, that *no bodies whatsoever were absolutely light, but only relatively so; and consequently, that all matter was subjected to the law of gravitation*†.

Hitherto the genius of Kepler had been fortunate, in tracing out that great principle which hindered the planets from flying off from the sun: but what kept them from falling into that mass of fire, and what power perpetuated their motion in their orbits? Here his sagacity failed him, and left his imagination to furnish the idea of a system of *vortices* for Descartes.

But howsoever incomplete these notions were concerning gravitation, yet in justice to their distinguished

* Astron. Nov. cap. 37.

† Ibid. in Introduct.

authors,

authors, *Copernicius* and *Kepler*, I thought proper to commemorate them on this occasion, as none before them had expressed themselves so fully, and with so much truth on that curious subject; and as none, from their days, to those of Dr. *Hooke*, made any such improvement, as would apologize for my taking up so much more of your time in recalling their sentiments to your remembrance. Let it suffice to mention, that the first who in this country embraced that doctrine was Dr. *Gilbert* * ; but who did not properly distinguish between attraction and magnetism; and that the next was lord *Bacon*, who, though not a convert to the *Copernican* system, yet acknowledged an attractive power in matter †. In France we find *Fermat* and *Roberval*, mathematicians of great eminence, of the same opinion ‡; and in Italy *Borelli*, after *Galileo* ||, who was the first in that country who conceived that idea, but far from that precision and extension we find it in his contemporaries *Bacon* and *Kepler*.

Before we pass from *Kepler*, it will be proper to observe, that this great improver of astronomy did not, perhaps,

* De Magnete. † Nov. Organ. lib. 2. aphor. 36, 45, 48. Sylv. Sylvar. cent. 1. exp. 33. ‡ Montucla Hist. des Mathem. part. 4. liv. 8. || Syft. Cosmic.

after

after all, contribute so much to the advancement of this theory, by those conjectures which I have related, as by some astronomical deductions from *Tycho Brabe's* observations, since known by the name of *Kepler's Laws*. The first was, that the planets move not in circular, but in elliptical orbits, of a small eccentricity, whereof the center of the sun makes one of it's *foci*. The second, that the same planet describes about the sun equal areas in equal times. The third, that in different planets, the squares of the periodic times are as the cubes of their mean distances from the sun.

Such were the preparatives to the true philosophy, and indeed excellent materials for the architect then unborn. But till sir *Isaac Newton* appeared, notwithstanding the numerous and momentous discoveries that had been made in the heavens, by *Copernicus*, *Tycho Brabe*, *Galileo*, *Kepler*, and others, yet astronomy, as lord *Bacon* complained, still remained but a mathematical study. The passage to which I allude is long, but, as tending to illustrate more than one particular relating to my subject, I cannot forbear trespassing on your indulgence by the citation. *Although astronomy (says Bacon) has not been founded amiss upon observation of the phenomena, yet the superstructure has hitherto kept low and weakly.*

In truth that science presents to the human understanding such an object as Prometheus did of old to Jupiter, when, meaning to impose upon that deity, he offered upon his altar, instead of a live victim, the hide of a large bullock, stuffed with straw, leaves and osier branches. In like manner astronomy exhibits the externals of the celestial bodies, as the cuticular part of heaven, fair indeed and artificially formed into a system; but the entrails and the fountains of life are wanting, that is, the physical causes and reasons; from which and from astronomical hypotheses, a theory should be drawn, not adequate only to account for all the phenomena; but for the substance, the motion, and influx of the heavens as they are in nature.... Scarcely is there one to be found who has inquired into the natural causes, either of the substance of celestial matter, or into the reason of the swiftness or slowness of the heavenly bodies, acting upon one another; or into the various degrees of motion of the same planet, or into the motion from East to West, or of the contrary direction; nor into the progressions, stations, and retrogradations of those bodies.... Nor into the causes of the apogæum and perigæum.... I say, inquiries of this kind have scarcely been attempted, nor indeed any labour bestowed upon the subject, excepting in the way of mathematical observations and demonstrations. So that

*astronomy, such as it now is, can only be reckoned among the mathematical arts ; not without considerable diminution of its dignity ; since were it to maintain its rights, it might rank itself as the noblest branch of philosophy. For he that shall reject the fictitious divorces between the superlunary and sublunary bodies, and shall duely attend to the appetences and most general affections of matter (which both in the earth and in the heavens are exceedingly powerful, and indeed pervade the universe) will receive from what he sees passing on the earth clear information concerning the nature of celestial bodies : and contrariwise, from motions which he shall discover in the heavens, will learn many particulars relating to the things below, that now lie concealed from us. Wherefore the physical part of astronomy we mark as wanting, and call it the astronomia viva, the animated astronomy, in opposition to the stuffed bullock of Prometheus *.*

The great *desideratum* was supplied, and from the bosom of this Society, in the publication of the *Principia*, the immortal work of *Newton*. There the illustrious author evinces truths that had been only surmised before; and after establishing by a just analysis the laws

* De Dign. & Augm. Scient. l. 3. c. 4.

of attraction, in a synthetical method proceeds to explain by them the motions and appearances of the heavenly bodies. Had not *Newton* lived, *Bacon* might have passed for a visionary speculator; but since the demands of that noble author upon the human intellects have been so fully answered in the productions of sir *Isaac Newton*, shall we not revere those powers of his own mind, that could, in that dawn of philosophy in which he lived, so well descry what parts were wanting, and what were the means of attaining them?

Newton in a posthumous treatise, *de Systemate Mundi*, composed before the publication of the *Principia*, and mentioned there, has said, that *some of the latter philosophers had sought to account for the course of the planets in their orbits by the action of certain vortices, as Kepler and Descartes; or by some other principle of impulse or attraction, as Borelli, Hooke, and others of our nation.* From this passage it would seem, that in those times there had been more conjectures formed concerning attraction, than what were published; for excepting *Gilbert*, who vainly attempted to explain the mundane system by magnetism, and lord *Bacon*, who never acceded to the *Copernican* hypothesis *, I have found none of our na-

* Atque harum suppositionum absurditas, in motum terræ diurnum (*quod nobis constat falsissimum esse*) homines impegit. *Bac. de Dign. & Augm. Scient.* lib. 3. cap. 4.

tion, *Hooke* excepted, who in this way have left any thing on record worthy of your notice. He indeed, the early, the ingenious and most useful member of this Society, advanced in this research far beyond all that had gone before him. But I shall not enlarge upon his improvements, as you have in your hands his *Cutlerian Lectures*, which contain them, and as I have already but too long dwelt on this part of my subject. It will ever redound to the praise of *Hooke*, that *Newton* has associated him with himself in maintaining the true regulating cause of the course of the planets*. As to *Borelli*, though I have found in one of the pieces (a scarce one) of that learned Italian, a passage that certainly favours attraction; yet as it is neither so full, nor so explicit upon that point, as several others which I have cited, I must suspect that those parts which *Sir Isaac* had in his eye have escaped my observation†.

* M. Montucla has done great justice to Dr. *Hooke*, in this and other particulars, in his excellent work, *Hist. de Mathem. part. 4. liv. 8.*

† This is the passage alluded to: *Præterea manifestum est, quemlibet sive primum, sive secundarium planetam aliquem insignem mundi globum quasi virtutis fontem circumdare, qui ita eos stringit, atque conglutinat, ut ab ipso nullo pacto abstrahi possint; sed ipsum, quacunque contendente, perpetuis continuisque orbibus cogantur consequi: videmus enim Saturnum, Jovem, Martem, Venerem, atque Mercurium Solem ipsum, Medicæa Sidera Jovem, Hugonianumque Sidus Saturnum circumire, non secus, ac circa Telluris Globum Luna ipsa revolvitur. Joa. Alph. Borelli Theor. Medic. Planetar. ex causis Physicis deductæ, lib. 1. cap. 2. p. 5. Florent. 1666. 4º.*

The great completer of the doctrine of universal gravitation had the satisfaction to find, from the reception it met with in this Society, that he had not laboured in vain ; nay, perhaps no philosophical author was ever more admired and followed in his own time, and in his own country, than *Newton* was in these kingdoms. With regard to others, *we are not to wonder*, as remarked by his eloquent Eulogist, *if philosophers upon the first publication of the Principia took the alarm at the term attraction, as fearing the return of the occult qualities ; or if, considering the difficulty of the subject, and the few words employed in explaining it, they wanted time fully to comprehend it* *. These obstacles have been removing by degrees, and the way at last has been so effectually cleared, that the name of *Newton* is not perhaps held in more estimation here, nor his principles more cordially embraced, than in those very societies of the learned, abroad, which at first shewed most unbelief, and at whose conversion therefore we ought most to rejoice.

The Royal Academy of Sciences, whilst in an uncertain state between the old and new system of philosophy,

* Eloge de *Newton*, par M. de Fontenelle.

having, for one of the decisive experiments, measured some degrees of latitude upon an arch of a meridian passing through Paris, and compared this mensuration with others, inferred the earth to be a spheroid with the longest diameter passing through its poles; but sensible that this operation had not been so unexceptionably conducted, as to satisfy either the followers of *Newton* or those of *Huygens*, who both required a spheroid flattened at the poles, resolved upon a farther and more accurate trial. With this view, in the year 1735, some chosen members from that illustrious Body were sent to the polar circle, and others to the equator; at which places the differences of degrees being greater, the point in dispute might be determined with less danger of error. How much to the honour of *Newton* and *Huygens* the result was, is sufficiently known. All that is necessary to be mentioned here, is that in the year 1738, whilst the academicians were still in Peru, it occurred to M. *Bouguer*, one of that number, to put the *Newtonian* system to another test, by inquiring into the attraction of mountains. This idea, which was originally from *Newton* himself, M. *Bouguer* communicated to his colleague M. *de la Condamine*, who readily assisted in making the trial*. Those gentlemen

* *Bouguer*, Figure de la Terre, sect. 7. *De la Condamine*, Journal du Voyage à l'Equateur.

were persuaded, that if the whole mass of the earth were really possessed of such a property, a high mountain, such as nature had abundantly provided in that country, would shew some proportionable degree of it. That the largest of the *Andes* was indeed but a small object in comparison of the earth; nevertheless they reckoned, by a rough computation, that the attraction of *Cchimborazo*, which they deemed the best for their purpose, would be equal to about the 2000th part of the attraction of the whole earth. Now, here the mountain acting as one, whilst the earth as 2000, the direction of gravity would be visibly turned out of the vertical line, for as much as this direction would be 1' and 43" towards the mountain. But how was this deflexion to be estimated? Only by finding the quantity of deviation of the plumb-line from a vertical position, by means of stars. In order to attain this point, they found it most convenient in their present circumstances to take the distance of several stars from the *zenith* at two stations, one on the south side of *Cchimborazo*, and the other a league and a half to the west; that is, at such a distance from the first station, as that the plumb-line should be but little affected by the mountain. This disposition being made, they proceeded

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to their operations, of which we have a full and clear account by M. *Bouguer*, in his valuable treatise intituled *Figure de la Terre*; but of M. *de la Condamine*, we have only a short abstract of the narrative he presented to the Academy; which abstract is contained in his curious *Journal of his Voyage to the Equator*.

From both it appears, that though those learned persons, during the time employed in this experiment (which the inclemency of the air, at that height in the atmosphere, forced them to make very short) I say, though during this time they spared no pains, yet their observations not only varied from one another, but seemed to be little satisfactory to themselves. M. *Bouguer* says, that instead of $1' 43''$, which the plumb-line ought to have declined from the true vertical line, the total declension amounted only to seven seconds and a half: an effect that fell far short of the expectations of a *Newtonian*. But those candid gentlemen take notice, that, *as on one hand we are ignorant of the density of the internal parts of the earth, which may be considerably greater than what appears by its surface; so, on the other, Chimborazo, which they believed likely to be as solid as any other parts of the surface of the earth, might nevertheless*

in many places be hollow. Nay, M. de la Condamine tells us, that he was afterwards informed of a tradition in the country, that this very mountain had once been a volcano; and adds, that whilst he and his colleague were about their experiment, they had actually found some calcined stones upon it. From which circumstances he infers, that if one cannot just draw from this trial an absolute proof of the Newtonian attraction, one can far less form any conclusion against it. M. Bouguer goes farther and observes, that if we will be satisfied with the bare fact, it is certain from this experiment, that mountains do act at a distance, but that their action is much less than what might be expected from their bulk. He concludes his account in the true spirit of a philosopher, by saying, that as in France, or in England, a hill may be found of a sufficient height for the purpose, and especially if the observer would double the action, by making a station on each side; he should be happy to hear, on his return to Europe, that the experiment had been repeated, whether the result tended to confirm his observations, or to throw some better light upon that inquiry. If the Society have fulfilled the views of that worthy man, who thus called upon them, we have to regret that he did not live long enough to share the satisfaction with us.

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I come

I come now to Mr. *Maskelyne's* labours, upon which I shall not expatiate, as I have already taken up too much of your time, and as I judge it unnecessary to dwell long upon that part of my subject, which you have so lately heard in his own words, and which you will have in a few days published at large in your Transactions.

I need only remind you, that the zenith distance of a star on the meridian being observed at two stations under the same meridian, one on the south side of a mountain, the other on the north; if the plumb-line of the instrument be attracted by the mountain out of its vertical position, the star will appear too much to the north by the observation at the southern station, and too much to the south by that at the northern station; and consequently the difference of the latitudes of the two stations will be found by these observations greater than it really is. And if the true difference of their latitudes be determined by measuring the distance between the two stations on the ground, the excess of the difference found by the observations of the star above that found by this measurement, must have been produced by the attraction of the mountain, and it's half will be the effect of such attraction on the plumb-line at each observation, supposing the mountain attracts equally on both sides.

To perform this experiment, Mr. *Maskebyne* made choice of the Mountain Schellien in Perthshire, in North Britain, of which the direction in length is nearly east and west, its height above the surrounding valley at a medium is about 2000 feet, and its highest part above the level of the sea is 3550 feet. As the greatest attraction of the mountain was to be expected about half way up its sides (which happened conveniently for the purpose of the experiment to be pretty steep) two stations for an observatory were accordingly chosen, one on the north, and the other on the south side of Schellien. The instrument with which he observed the stars was an excellent sector made by Mr. *Sisson*; and Mr. *Maskebyne* has related at large all the precautions he took both for adjusting this instrument in the meridian at each station, and for satisfying himself that the line of collimation remained unaltered. From observations of ten stars near the zenith, he found the apparent difference of the latitudes of the two stations to be $54''{,}6$; and from a measurement by triangles, formed from two bases on different sides of the mountain, he found the distance of their parallels to be 4364 feet, which, in the latitude of *Schellien*, viz. $56^{\circ} 40'$, answer to an arch of the meridian of $43''$: this is $11''{,}6$ less than that found by

the sector. It's half therefore $5''$, 8 is the mean effect of the attraction of the mountain: and from it's magnitude, compared with the bulk of the whole earth, Mr. *Maskeelyne* discovered the mean density of the earth to be about double that of the mountain.

In the execution of this interesting experiment, our worthy brother has not only exerted a patience and perseverance, but a sagacity and judgment which must ever redound to his honour. All doubts about an universal attraction must at last be terminated, and every philosopher in that respect must now become a *Newtonian*.

If I have related but two experiments that have been made, the first by the *French* academicians, and the other by Mr. *Maskeelyne*, it is because no more have come to our knowledge; nor do I believe that more have actually been executed. For if, in occasional measurements of degrees of the meridian in different parts of Europe, those employed have found varieties arise in their measures that they could not otherwise account for, than from the attraction of the mountains among which they carried on their operations, and accordingly

have referred those irregularities to that very cause ; such conjectures we admit may be well founded, but the measurements whence they arise we cannot reckon among the experiments we now treat of.

But was not the doctrine of an universal attraction fully demonstrated by *Newton*, as not to require any farther proofs from experiments ? Demonstrated it was, but not to the conviction of every individual. True Philosophy condescends to adapt her instructions to different capacities, and is as willing to inform by palpable experiments as by geometrical demonstrations. But to say the truth, something seemed wanting here for the satisfaction of even the more enlightened minds. Such we reckon those were who first made the trial. And did not *Huygens* himself, one of the greatest philosophers and geometricians of his age, find difficulties about this principle, even after the publication of *Newton's Principia* ? nor do we learn that the doubts of that great man were ever removed *. To say nothing of the celebrated *Leibnitz*, and his numerous followers, who to this day are either wholly unbelievers in attraction, or at best but sceptics on that article.

* Vid. Hugen. Dissert. de Caus. Gravitat.

You have therefore, Gentlemen, the satisfaction to think that you have completed a great and acceptable work to the scientific world ; and that, though this has been a costly experiment, your gracious PATRON, who so liberally furnished the means, will highly approve your expending his benefaction so much for the advancement of Natural Knowledge and for the benefit of the public ; and will so much the more be disposed to shew you the like favour on future occasions.

But for those who wanted no fresh proofs of the universality of attraction, they must still partake of the advantages accruing from this experiment, as being not only the first that has been made, but the best that could be devised, for estimating the mean density of the earth. The operation in Peru was too imperfect for that purpose, and had the circumstances of that trial been more favourable, yet the suspicion of their mountain having been once a volcano, was a sufficient reason for admitting no evidence from it in this part of our inquiry. But for Schehallien, as it's appearance was particularly rocky, and as several specimens of those rocks have been presented to the Society, and acknow-

ledged to be mineral substances that had never passed through fire, we may consider that mountain as one of the proper patterns of the density of the surface of the earth.

These, Gentlemen, are the fruits of the operations of Mr. *Maskelyne*, during a residence of four months in a mean hut, on the side of a bleak mountain, and in a climate little favourable to celestial observations. To these inconveniencies, however, he submitted with patience and complacency, as he went at your request and in pursuit of science. You have heard his chief conclusions; but permit me to add, that as this is a new mine opened in the field of nature, I am confident that these will not be the only productions; but that, as in all great and successful experiments, there will be in the prosecution of this subject some valuable truths brought to light, of which at present we can form no particular conjecture. Mean while we have the pleasure to find the doctrine of *universal gravitation* so firmly established by this finishing step of analysis, that the most scrupulous now can no longer hesitate to embrace a principle that gives life to Astronomy, by accounting for the various motions and appearances of the Hosts of Heaven.

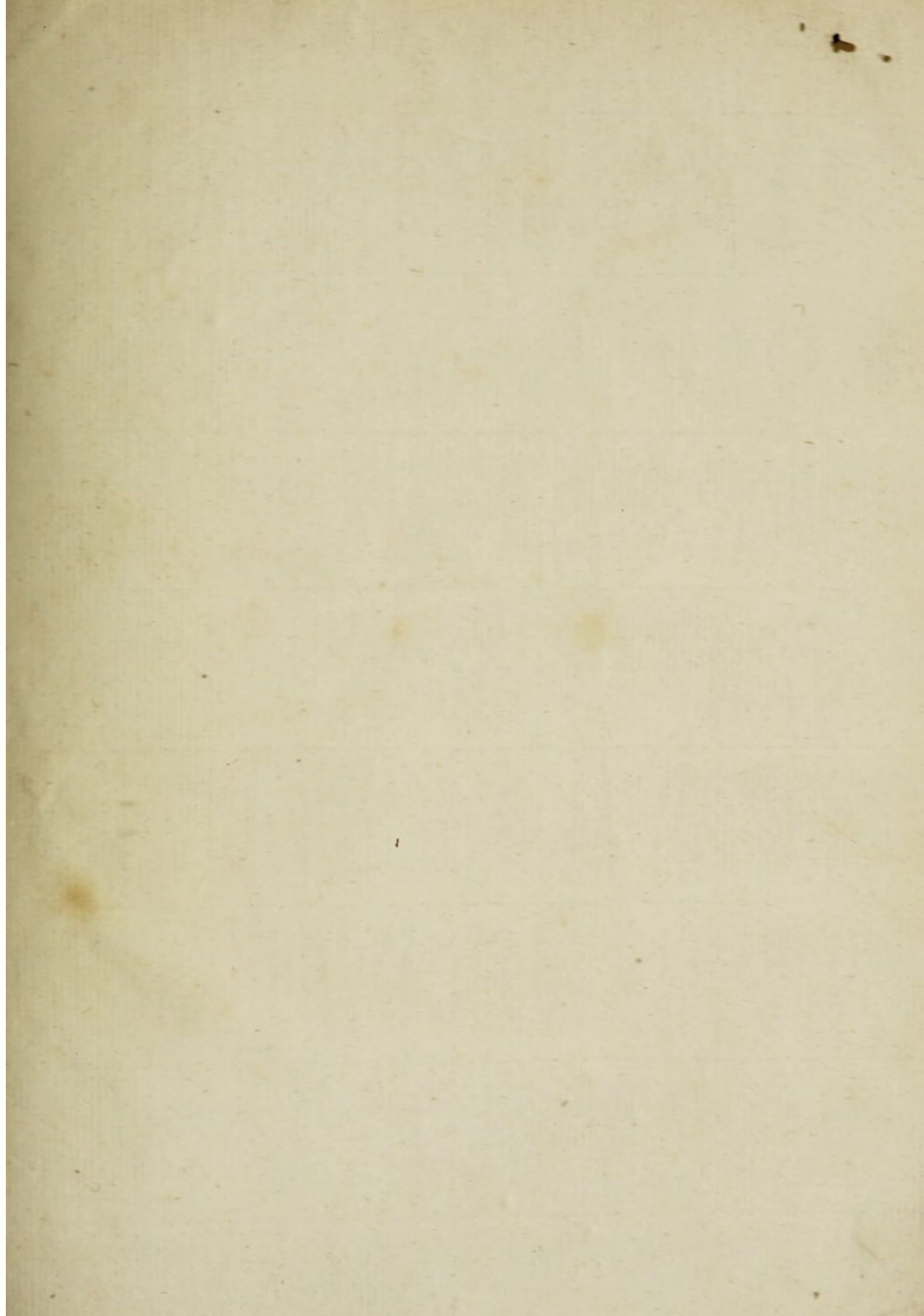
MR. MASKELYNE,

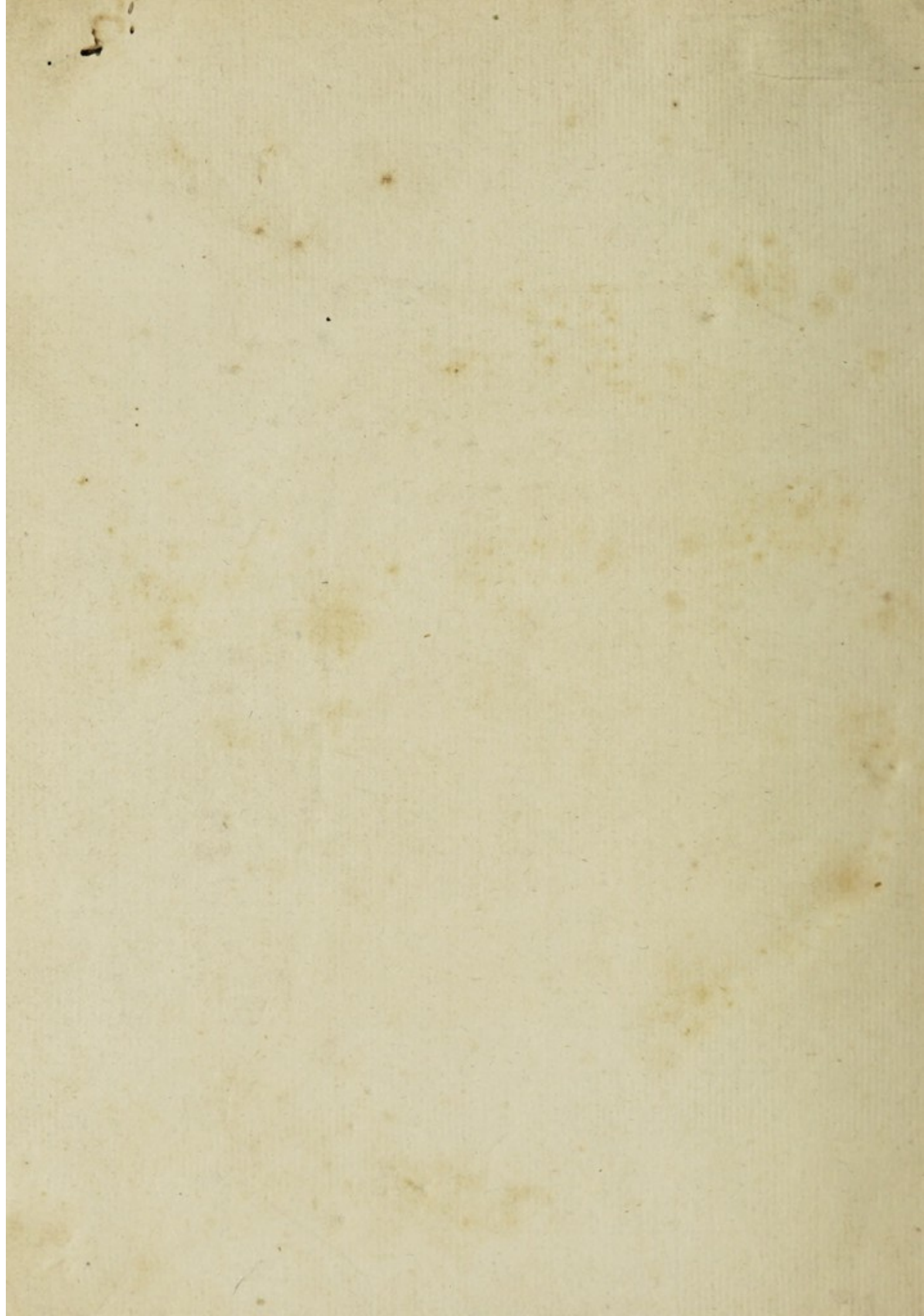
THE judgment, Sir, of the Council, in awarding you the prize, having received the sanction of the ROYAL SOCIETY, I do, in the name and by the authority of that illustrious Body, present you, their most worthy Brother, with this sincere pledge of their affection; as the lasting token of their acknowledgment for your several ingenious and useful communications, and more particularly for this last painful and capital experiment, which adds no small lustre to their Transactions. And after expressing their grateful sentiments for what you have already done for their service, I would farther say, that they persuade themselves, from your talents, your love of your profession, and your happy period of life, you will continue steadily to pursue that path which you have so early entered upon, and which so surely leads to great and useful discoveries. You have, Sir, in charge the noblest branch of Natural Philosophy: such it has ever been held by this Society, and as such it ever has been cherished and cultivated by them. And they flatter themselves that their cares and solicitude have not been fruitless

fruitless; since, from their first institution to this day, there have never been wanting some excellent men in that line, to promote the science, and do honour to this Community. But so transcendently great is that part of the creation, that though the Divine Author has vouchsafed, in these latter days, to open to the humble and patient inquirers into Nature the *Causes of Things*; yet we must still cry with the ancient sage, *Lo, these are part of His ways, but how little a portion is heard of them!* As much then remains to be explored in the celestial regions, you are encouraged, Sir, by what has been already attained, to persevere in these hallowed labours, from which have been derived the greatest improvements in the most useful arts, and the loudest declarations of the power, the wisdom, and the goodness of the Supreme Architect in the spacious and beautiful fabric of the World.

F I N I S.

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