PHILOSOPHICAL TRANSACTIONS.

I. *Observations on the* SOLAR SPOTS. *By* Alexander Wilson, *M. D. Professor of Practical Astronomy in the University of* Glasgow. *Communicated by the Rev.* Nevil Maskelyne, *Astronomer Royal.*

Read, Apr. 29, 1773. WHEN the great COPERNICUS had revived the true system of the world, it was objected against it, that the planet Venus ought to be seen with different phases like the moon; to which he answered, that some time or another that very thing would perhaps come to

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paſs. Who then would have thought, that this prophecy was ſo near being fulfilled, and that, by means of combining a convex and a concave glaſs, the common uſes of which had been known for near 300 years before, the ſight of man was to be extended almoſt to the remoteſt parts of the univerſe? This inſtrument, which nothing but its being ſo common hinders us from regarding with the greateſt wonder, was invented, about 170 years ago, by one of thoſe happy accidents, to which we owe many of the fineſt diſcoveries.

At that time flouriſhed the famous GALILEO, who was the firſt that conſtructed a teleſcope from ſome knowledge of the refraction of the rays of light. Having finiſhed one in 1610, he directed it to the heavens, and thus entered upon the moſt pleaſing and moſt ſtriking field of obſervation, which any philoſopher ever enjoyed. The name of GALILEO will always be familiar to us, ſo long as there remains any remembrance of thoſe celebrated diſcoveries, which he then made by the help of his glaſſes.

One of the moſt remarkable of them was that of the SOLAR SPOTS. So ſtrange a diſcovery, relating to the ſun, commanded a great deal of attention. At that time the authority of Ariſtotle, by controlling the reaſon of men, governed their opinions in all parts of philoſophy; and one of the abſurd doctrines, then taught in the ſchools, was, that the matter of the heavens was ungenerated, incorruptible, and ſubject to no alteration. But the arguments, which GALILEO now produced againſt that notion, were founded upon the evidence of ſenſe, and it was impoſ-

impoſſible to oppoſe them. The ſpots upon the ſun, and the many ſtrange variations, to which they were ſubject, convinced all, who were able to lay aſide the prejudices of a vain philoſophy, that there was not ſo great a difference, betwixt celeſtial and ſublunary bodies, as had been imagined.

To ſuch as were ſo reconciled to it, the diſcovery appeared grand and ſtriking; and great hopes were entertained, that, by duly attending to the phænomena of the ſpots, ſomething curious and important might be determined concerning the nature and conſtitution of the ſun itſelf.

We accordingly find, that many aſtronomers, of the firſt note, were very early engaged in this inquiry. Of all thoſe who applied themſelves this way, SCHEINER and HEVELIUS deſervedly hold the firſt place, and nothing but the charms of ſo noble an inveſtigation could have induced them to proſecute their obſervations with ſo much aſſiduity. SCHEINER began his in the year 1624, 14 years after GALILEO had firſt made the diſcovery. In the year 1630, he at laſt publiſhed his Roſa Urſina, in which we have a detail of his labours during that long interval of time. HEVELIUS came after SCHEINER, and diligently watched the appearances of the ſpots for two years, the reſult of which application he has given us in his Selenographia and Cometographia.

But notwithſtanding theſe attempts, ſo worthy of men actuated by a true deſire of knowledge, it muſt be confeſſed, that nothing of moment hath been derived from them. If we except a few concluſions concerning the rotation of the ſun round its axis, and the inclination of its axis to the plane of the

ecliptic, every thing elſe, which hath been inferred from the phænomena of the ſpots, ſeems altogether to be matter of conjecture. HEVELIUS, from his great fondneſs of the ſubject, and from a deſire to avail himſelf of that long courſe of obſervation, to which he had ſo patiently ſubmitted, has been led into many ſpeculations concerning the ſpots and the nature of the ſun's body. The following quotations furniſh us with a remarkable inſtance of this, and will ſerve to give us a view of the ideas, which he came to entertain upon theſe ſubjects. In his Cometographia, p 360, ſpeaking of the ſolar ſpots he expreſſes himſelf thus:

" Hæc materia nunc ea ipſa eſt evaporatio et ex-
" halatio (quia aliunde minime oriri poteſt) quæ ex
" ipſo corpore ſolis, ut ſupra oſtenſum eſt, expiratur
" et exhalatur: quæ penitus ex diverſis partibus
" heterogeneis, certos gradus opacitatis et denſitatis
" habentibus, conſtat, modo ex tenuioribus, modo
" opacioribus, modo ſiccioribus, modo magis viſ-
" coſis, glutinoſis (ut noſtro loquar more uſitato)
" ſive bituminoſis. Unde etiam diverſa procreantur
" phænomena; ex tenuioribus, purioribus, et ſicciori-
" bus, umbræ videlicet faculæ et luculæ; ex impuri-
" oribus vero craſſioribuſque illis viſcoſis, maculæ
" eorundemque nuclei progignuntur. Cum ergo
" ſolis exhalationes ejuſmodi partes ſint hetero-
" geneæ, quidni etiam illud ipſum corpus, quod eas
" ejaculatur, prout in præcedentibus fuſe aſſertum
" eſt, ex diverſis partibus heterogeneis conſtabit?
" Ad hæc, quia tales admirabiles et manifeſtiſſimæ
" generationes, mutationes, alterationes, condenſa-
" tiones, rarefactiones, coitiones, diductiones, imo

" motus

" motus locales corporum, ac rerum materiarumque
" ex ipſo ſole ejectarum evaporatarumque, pene
" continenter, ad inſtar nubium ac meteororum ſub-
" lunarium ex terrâ promanantium, peragi videmus;
" nonne clare ex eo evincitur, ſolem habere ſuam
" atmoſphæram, in eâque dari, pro virtutis ſuæ
" indole, generationes et corruptiones rebus ſublu-
" naribus haud diſſimiles rarioreſque? imo, non-
" nunquam longe frequentiores, et inſigniores ac-
" cidere (ſi præſertim obſervationes macularum a
" Scheinero nobiſque habitas exacte examinaveris)
" quam prope hanc terram unquam poſſint?" And again, when ſpeaking of the ſun's body: "Atque
" ita hic liquor igneus (ut ſic loqui liceat) eſt quaſi
" vaſtiſſimum luminum pelagus et mare igneum,
" quod ſuos habet abyſſus, occultos meatus, vora-
" gines atque vortices; quod, ad inſtar maris noſtri,
" perpetuis fluctuum quibuſdam voluminibus agi-
" tatur, et ſuo modo evaporationes et exhalationes
" jugiter evomit atque exhalat: eoque magis aut
" minus, quo magis vel minus materia iſta in viſ-
" ceribus ejus, atque intimis receſſibus, igneum
" illud pelagus, illiuſque fluctus commoventur ac
" concitantur."

But all that we here find, however plauſible and ingenious, can be regarded only as conjecture. It does not appear, that any who have followed HEVELIUS have met with more ſucceſs. Their obſervations ſeem not to differ from his in any remarkable circumſtance; nor do we find, that their inferences from them, although ſometimes different, have any better pretenſions to the truth. The many ſtrange and variable circumſtances of the ſpots, which were diſco

diſcoverable from a minute obſervation, ſtill remained unaccountable; and we often find them at a loſs, in framing any hypotheſis, which could fully ſatisfy the mind concerning them. In proceſs of time, aſtronomers began to withdraw their attention from a ſubject, which remained ſo dark and perplexing, and, for many years, all reſearches of this ſort have been, in a great meaſure, laid aſide.

Chance, or a happy concurrence of circumſtances, hath ſometimes effected more, than could have been expected from the moſt promiſing meaſures: a remark which, it is hoped, will, in ſome degree, be found juſtified in the ſequel of this paper. The obſervations upon the ſolar ſpots, which I now proceed to relate, appear to be totally different from any hitherto to be found, and ſuch as ſeem to open a new and curious field of ſpeculation into the whole of this ſubject.

Aſtronomers will remember, that a ſpot of an extraordinary ſize appeared upon the ſun, in the month of November 1769. The firſt notice, I had of it, was by a letter from a friend at London, but the weather continued dark and cloudy for ſome days after; at length, on the 22d day, I had a view of the ſun through an excellent Gregorian teleſcope, of 26 inch focus, which magnified 112 times. I then beheld the ſpot, which at that time was not far from the ſun's weſtern limb, and below his equatorial diameter. The atmoſphere being now very clear, and free from all tremor and undulation, it was pleaſant to ſee the nucleus of the ſpot, and the ſhady zone or umbra which ſurrounded it, ſo very diſtinct. It being afternoon when

when I firſt got ſight of it, I had not an opportunity of obſerving it long that day. Next day being the 23d, I had a curioſity to ſee it again, and ſo repaired to my teleſcope, in order to examine, if any alterations, in the ſize and figure, had taken place ſince laſt obſervation. The air was ſtill favourable, and I again ſaw the ſpot, it having its nucleus and umbra very ſharply defined. I now found however a remarkable change; for the umbra, which before was equally broad all round the nucleus, appeared much contracted *on that part which lay towards the center of the diſc*, whilſt the other parts of it remained nearly of their former dimenſions.

This change of the umbra ſeemed ſomewhat extraordinary, as it was the very reverſe of what I expected from the motion of the ſpot towards the limb. But next day, at 10 o'clock, I had another obſervation, and diſcovered changes, which were ſtill more unexpected. The diſtance of the ſpot from the limb was now about 24″. By this time, the contracted ſide of the umbra above mentioned had entirely vaniſhed; and the figure of the nucleus was now remarkably changed, from what it had been the preceding day. This alteration of the figure appeared evidently to have taken place upon that ſide which had now loſt the umbra, the breadth of the nucleus being thereby more ſuddenly impaired than it ought to have been, by the motion of the ſpot acroſs the diſc. Fig. 1, 2, [TAB. I.] repreſent the appearance which the ſpot had on the 23d and 24th days.

Regarding

Regarding theſe circumſtances as new, I began to conſider, what might be the cauſe of them. One of two things ſeemed neceſſarily to be the caſe; either, that they were owing to ſome phyſical alteration or waſting of the ſpot, and of that part of it where the deficiency of the umbra was obſerved; or elſe, that they were owing to the nearer approach of the ſpot to the limb, by the ſun's rotation on his axis.

The laſt of theſe two ideas had no ſooner ſtruck me, than I began to ſuſpect, that the central part, or nucleus of this ſpot, was beneath the level of the ſun's ſpherical ſurface; and that the ſhady zone or umbra, which ſurrounded it, might be nothing elſe but the ſhelving ſides of the luminous matter of the ſun, reaching from his ſurface, in every direction, down to the nucleus: for, upon this ſuppoſition, I perceived, that a juſt account could be given of the changes, of the umbra and of the figure of the nucleus, above deſcribed.

The opinion therefore, which I ventured to form from what I had ſeen this day, was, that this ſpot might, probably, be a vaſt EXCAVATION in the luminous matter of the ſun; the nucleus, commonly ſo called, being the bottom, and the umbra the ſhelving ſides of the excavation: and, moreover, that the umbra, next the center of the diſc, although out of my view, did ſtill however exiſt, and was rendered invifible by its preſent poſition only; and further, that the ſudden alterations, now diſcernible in the figure of the nucleus, were occaſioned by ſome part of it alſo being hid, by the interpoſition

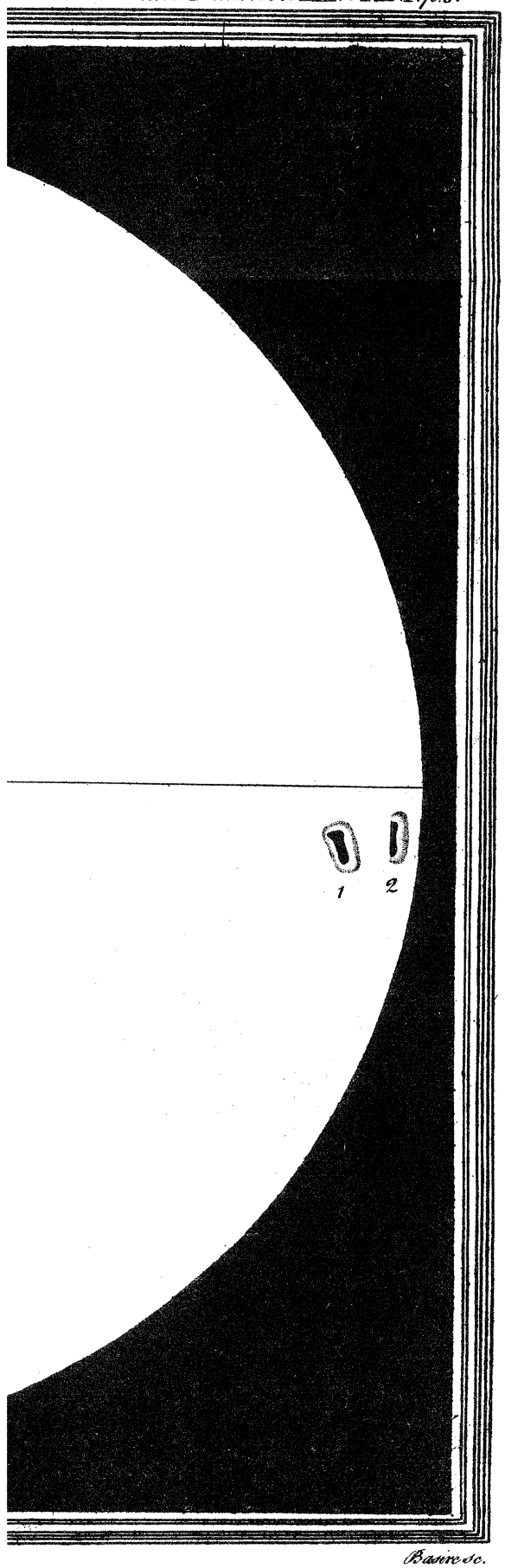
Suns Eastern Limb.


3


4


5

N.º 1. Great Spot Nov. 23. 1769.
2 ..... 24.
3 ..... Dec.r 11. for the second time.



Basire sc.

ine.

N°. 1. Great Spot Nov. 23. 1769.
2 ..... 24.
3 ..... Dec^r. 11. for the second time.
4 12
5 17

Basire sc.

ime.

poſition of the edge of the excavation, between the nucleus and the eye.

Theſe views, which now preſented themſelves, I remember to have communicated, that afternoon, to my ſon; when I then told him, that, if they were well founded, there would be room to verify them, if the ſpot ſhould again return upon the oppoſite ſide of the diſc. I was however uncertain, if it would laſt ſo long upon the ſun's body, as to be again viſible after the time of half a revolution; a circumſtance which I wiſhed to take place, as I was aware, that my preſent obſervations might juſtly be deemed inſufficient, for eſtabliſhing ſo ſingular an opinion concerning the nature of this ſpot; and that, notwithſtanding all which I had ſeen, we might ſtill imagine, that theſe changes were produced by certain phyſical alterations of the ſpot itſelf.

Theſe conſiderations made me attentively wait its return. At laſt, on December 11th, I again diſcovered it, on the oppoſite ſide of the diſc, it having by that time advanced a little way from the eaſtern limb, being diſtant from it 1′ 30″. And now I could only perceive three ſides of the umbra, namely, the upper and under ſides, and that towards the limb, which was the ſide that formerly had vaniſhed. The ſide towards the center of the diſc was not as yet viſible; but I concluded, upon the ſame grounds as formerly, that it was hid from my ſight, by its averted poſition only, and that, after the ſpot had advanced a little further, it would make its appearance. Accordingly, the next day, being December 12th, at ten o' clock, it came into

view, and I ſaw it diſtinctly, though narrower than the other ſides. After this, my obſervations were interrupted, by unfavourable weather, till the 17th, when the ſpot had paſſed the center of the diſc, the umbra now appearing to ſurround the nucleus equally. Fig. 3, 4, and 5, repreſent the ſpot, as it appeared on December 11th, 12th, and 17th, when it came upon the diſc for the ſecond time.

All the foregoing appearances, when taken together, and when duly conſidered, ſeem to prove in the moſt convincing manner, that the nucleus of this ſpot was conſiderably beneath the level of the ſun's ſpherical ſurface.

The next thing, which I took into conſideration, was to think of ſome means, whereby I could form an eſtimate of its depth. At the time of the obſervation I had on December 12th, I had remarked, that the breadth of the ſide of the umbra, next the limb, was about 14″; but, for determining the point in queſtion, it was alſo requiſite, to know the inclination of the ſhelving ſide of the umbra to the ſun's ſpherical ſurface. And here it occurred, that, in the caſe of a large ſpot, this would in ſome meaſure, be deduced from obſervation. For, at the time when the ſide of the umbra is juſt hid, or begins firſt to come in view, it is evident, that a line joining the eye and its obſerved edge, or uppermoſt limit, coincides with the plane of its declivity. By meaſuring therefore the diſtance of the edge from the limb, when this change takes place, and by repreſenting it by a projection, the inclination or declivity in ſome meaſure may be aſcertained. For in fig. 5. [TAB. II.] let I L D K be a portion

of the ſun's limb, and A B C D a ſection of the ſpot, S L the ſun's ſemidiameter, L G the obſerved diſtance from the limb, when the ſide of the umbra changes, then will the plane of the umbra, C D, coincide with the line, E D G, drawn perpendicular to S L, at the point G. Let F H be a tangent to the limb, at the point D, and join S D.

Since G L, the verſed ſine of the angle L S D, is given by obſervation, that angle is given; which, by the figure, is equal to F D E, or G D H; which angle is therefore given, and is the angle of inclination of the plane of the umbra to the ſun's ſpherical ſurface. In the ſmall triangle therefore C M D, which may be conſidered as rectangular, the angle M D C is given, and the ſide D C, equal to A B, is given nearly, by obſervation; therefore the ſide M C is given, which may be regarded as the depth of the nucleus, without any material error.

I had not an opportunity, in the courſe of the foregoing obſervations, to meaſure the diſtance G L, not having ſeen the ſpot, at the time when either of the ſides of the umbra changed. It is however certain, that, when the ſpot came upon the diſc for the ſecond time, this change happened ſometime in the night between the 11th and 12th of December; and I judge that the diſtance of the plane of the umbra, when in a line with the eye, muſt have been about 1′ 35″ from the ſun's eaſtern limb; from which we may ſafely conclude, that the nucleus of the ſpot was, at that time, not leſs than a ſemidiameter of the earth, below the level of the ſun's ſpherical ſurface, and made the bottom of an ama-

zing cavity, from the ſurface downwards, whoſe other dimenſions were of much greater extent.

Being thus perſwaded of the depreſſion of this great ſpot below the ſurface, I immediately ſet about examining ſmaller ones, in order to diſcover if they were of the ſame kind. With this view, I began a courſe of obſervations, that from them I might either make the inference univerſal, or limit it, as the phœnomena ſhould point out. I was not long engaged in this purſuit, before I perceived in them the ſame changes of their umbræ, which have been deſcribed above at ſo much length. This was manifeſt in ſpots of any conſiderable ſize, when the air was favourable, and the teleſcope well adjuſted for diſtinct viſion. The firſt, which I ſaw undergo this change upon its near approach to the limb, was on January 17th, 1770, as repreſented in Fig. 1. [TAB. II.] The figures 2, 3, 4, in this plate, and 1, 2, 3, 4, [TAB. III.] are ſo many other inſtances taken from the regiſter of the obſervations at that time. But, as this appearance, of the umbra changing, is evident from a bare inſpection of the figures, we have omitted any unneceſſary deſcription of them. Theſe eight caſes are taken out from above 40 others of the ſame kind; and in them all, the nuclei were in the middle of the umbræ, before their approach to the limb. It may be remarked, that in fig. 2. [TAB. II.] the ſame ſpot *c* traverſed the diſc and had its umbra changed, both in the coming on and going off. In general, we have found that the umbra thus changes, when a ſpot is about a minute diſtant from the limb, at a medium.

From

Fig. 1.

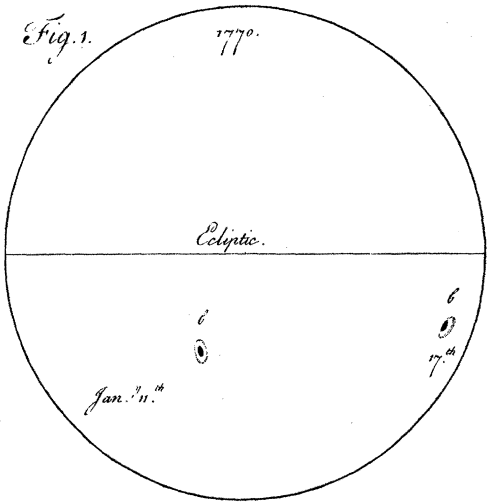


Fig. 2.

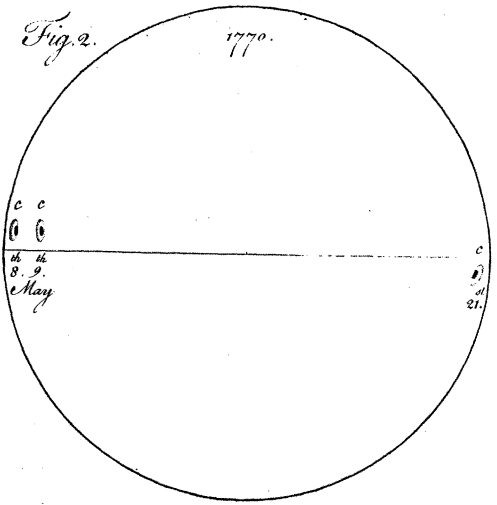


Fig. 3.

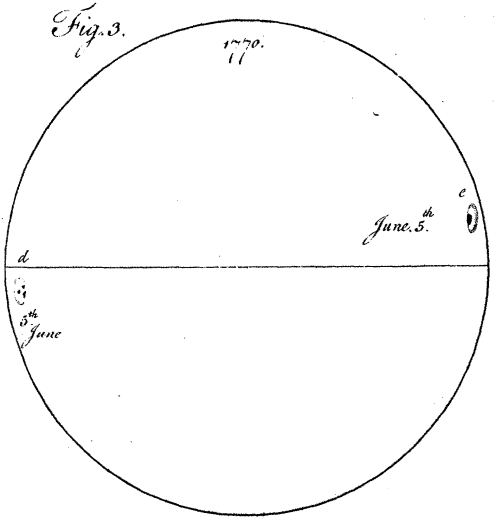
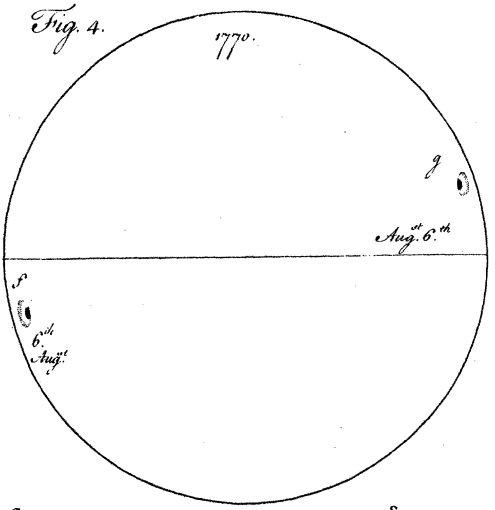


Fig. 4.



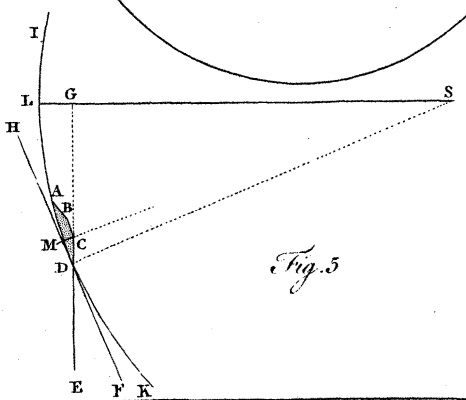


Fig. 5

From all theſe obſervations, may we not ſafely conclude, that every ſpot conſiſting of a nucleus and ſurrounding umbra, as defined by SCHEINER and HEVELIUS, is of the ſame kind with thoſe above deſcribed? But as, in reſearches of this ſort, we can never be too cautious in making a general concluſion, ſo I would humbly recommend theſe obſervations to every lover of the ſubject, to thoſe eſpecially who are provided with large and good teleſcopes; for, without this advantage, I have found by repeated trials, that I could not diſcern the minute changes of the ſmall ſpots.

In the courſe of the foregoing obſervations, I had occaſion to remark, five different times, another extraordinary circumſtance of the ſpots, which I have not ſeen mentioned, by any one who has written upon the ſubject. It conſiſts of changes, which ſeem to ariſe from a diſturbing force, when one ſpot breaks out in the neighbourhood of another. The firſt caſe of this ſort which I met with, was on Nov. 9th, 1770, when the umbra of the ſpot *m*, fig. 1. [TAB. IV.] although a great way from the limb, was deficient towards the right hand, at which ſide, and very near it, there lay another ſpot much ſmaller. In like manner, the two ſpots *n* and *o*, fig. 2. [TAB. IV.] which lay very near one another, had each of them that ſide of its umbra, which faced the other, taken away. But it was remarkable, that, three days after, the ſpot *o* had nearly vaniſhed, when the ſide of the umbra of the ſpot *n*, which faced it, began now to dilate. In fig. 3, the ſpot *p*, had its umbra flattened upon oppoſite ſides, by three ſmall ſpots on one hand, and one upon the

other. Again, in fig. 4, the two ſpots *q*, *r*, had their umbræ deficient, by the intervention of ſome ſmall ſpots, that lay between them.

Now it muſt here be particularly remarked, that though a ſpot, when undiſturbed, will, when near the ſun's limb, exhibit the change of the umbra formerly mentioned, yet it is plain, that a caſe may now and then occur, when this change will be counteracted, by means of the phænomenon which we have juſt now deſcribed. For if we ſhould ſuppoſe, for example, the ſpot *m*, fig. 1. TAB. IV. to have been on November 9th, near the weſtern limb, it is evident, that we ſhould have formed a different judgment concerning the change of the umbra. And accordingly, in the courſe of the obſervations formerly mentioned, I in reality met with three caſes, when this change did not take place.

I am ſenſible, that it may be thought ſtrange, that none of the obſervers, who had looked at the ſolar ſpots with ſo much attention, ſhould ever have taken notice of the gradual changes above deſcribed. This partly may be accounted for from the following conſiderations. We have already ſeen, that conjectures, concerning the nature of the ſun, were early indulged in the courſe of this inquiry. His body was thought to be an immenſe globe of fire, which was for ever raging with the moſt fervent heat. Hence the firſt obſervers, reflecting upon the perpetual generation, changes, and decay of the ſpots, and that through ſo wide an extent of his ſurface, very naturally imagined, that they could conſiſt of nothing but ſmoke and groſſer

groſſer exhalations, or ſuch tranſient and periſhable materials. This hypotheſis had at leaſt the air of being ſupported by a very plauſible analogy. The minds of men being carried away by ſuch prepoſſeſſions, it would leſs readily occur, that ſucceſsful obſervations were only to be made, by an accurate and critical attention to thoſe minute changes, which the ſpots ſometimes undergo. But what would ſtill more conduce to this overſight, was the method, which moſt of them followed, in making their obſervations. This was by the camera obſcura, which both SCHEINER and HEVELIUS often uſed, and which we find greatly extolled by them, and deſcribed at great length in their writings. But ſpots, when ſeen in this way, have nothing of that diſtinctneſs, which is ſo remarkable, and ſo pleaſing, when they are viewed directly through a good teleſcope armed with an helioſcope, or glaſs properly ſmoaked.

PART II.

IT appears then that the ſolar ſpots are immenſe excavations in the body of the ſun; and that what hitherto hath been called the nucleus is the bottom, and what hath been called the umbra the ſloping ſides of the excavation. It alſo appears, that the ſolar matter, at the depth of the nucleus, does not emit light, or emits ſo little, as to appear dark compared to that reſplendent ſubſtance at the ſurface; that this beauteous ſubſtance is at the ſurface, moſt fulgid; and when any of it is, ſeen below the general level, forming the ſides of an excavation, that then its luſtre is ſomehow impaired, ſo as to give the appearance of a ſurrounding umbra. Here our induction ends. To proceed further would be to carry it beyond its true limits, and to intermix with concluſions, which are certain and manifeſt, the ſuggeſtion of hypotheſes, which at beſt are precarious and liable to error.

But from what we have now ſeen, many curious ſpeculations do naturally preſent themſelves. By what myſterious proceſs is it, that thoſe aſtoniſhing excavations are at firſt produced? What is the nature of that ſhining ſubſtance, which is thereby perpetually diſturbed? To what are we to aſcribe the darkneſs of the nucleus, and the diminiſhed luſtre of the umbra? And what conceptions are we to form of the many ſtrange changes, and at length of the final decay of all theſe appearances, whereby thoſe regions of the ſun, that were ſo hurt and diſfigured, again undergo a renovation?

We

Fig. 1.

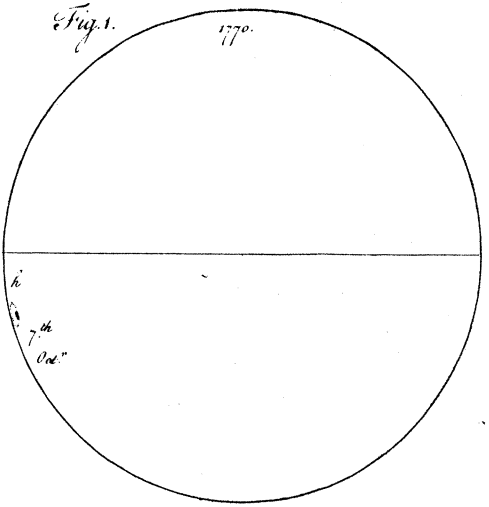


Fig. 2.

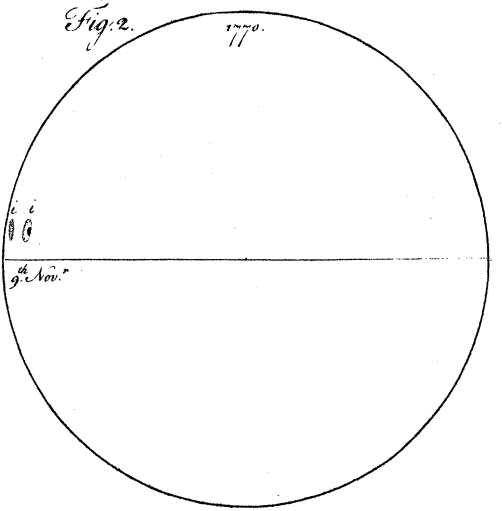


Fig. 3.

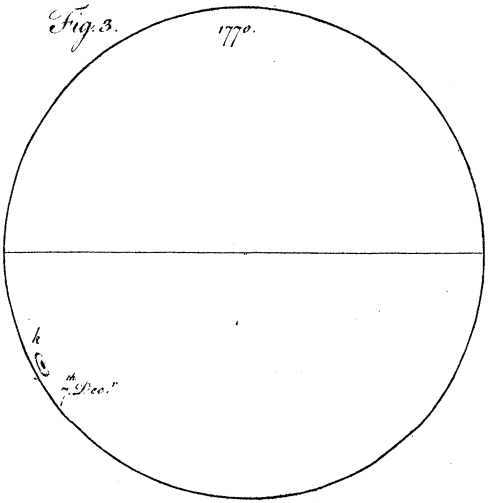
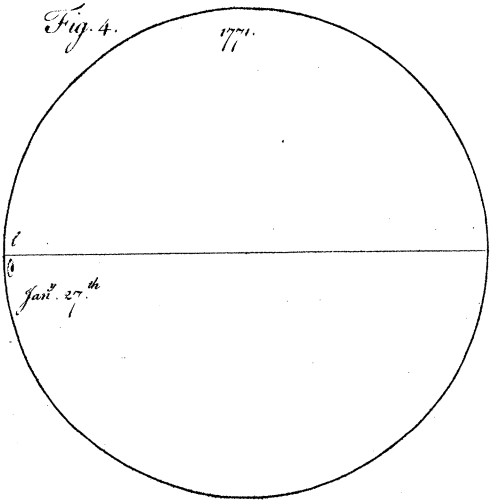


Fig. 4.



We often find SCHEINER and HEVELIUS mentioning many things concerning the ſpots, which appeared to them very inexplicable. HEVELIUS, when ſpeaking of the vaſt number of ſpots which break out upon the ſun, and of the prodigious ſize of ſome of them, admires how from his ſingle body ſo much matter, exhalations, &c. could be generated, as in any degree to be adequate to ſo many and ſo vaſt phænomena. "Nuclei autem, "(ſays he, Cometograph. p. 401) macularum "ſcilicet partes denſiores, ſæpius unam partem cen-"teſimam, imo quinquageſimam, de ſolari dia-"metro occupant; ſic, ut paucis dicam, immania "et admiranda ſunt corpora. Adhæc, intellectum "humanum fere ſuperat, quomodo unquam, ex "unico iſto corpore ſolis, tantum materiæ, totque "exhalationes vaporeſque erumpere ac produci "queant, quo talia vaſtiſſima phænomena procreari "poſſint." Again, SCHEINER, when ſpeaking of that property of the ſpots, where a large nucleus is often divided into two or more nuclei, ſeems greatly puzzled to account for it. Sch. Roſa Urſina, p. 498, ſays: "Ex uno ſæpe magno nucleo "fiunt duo, tres, plureſve, non locali partium ip-"ſius diſtractione, ſed intervallorum neſcio quâ "exinanitione. Manent enim illorum centra in-"ter ſe æqualiter diſſita." Many inſtances of this ſort could be brought; and indeed, conſidering the contrariety, betwixt any hypotheſis they had formed, and what would now ſeem to be the real condition of the phænomena, it is no wonder that ſuch difficulties ſhould occur. Every theory, how ingenious ſoever, which is founded upon a miſapprehenſion

of things, is apt to be preſſed with many difficulties; and whenever palpable contradictions appear, they may be regarded certainly as proofs of our having fallen into error. Upon this principle, I think, we might freely have rejected any theories, hitherto entertained, concerning the ſolar ſpots, tho' their falſity had not become manifeſt from more enlarged experience and obſervation. It muſt indeed be acknowledged, that it is very diſadvantageous to ſcience, to indulge much in hypotheſes, the truth being rarely hit upon in this way, and very often miſſed. Sometimes, however, it may not be improper, to throw out hints and conjectures, when we can attain to nothing better, provided we are at due pains to diſtinguiſh betwixt ſuch and that real knowledge, which we derive, by ſtrict induction, from inconteſtable principles. The beſt way therefore, of preſerving ſo proper and neceſſary a diſtinction, will be to propoſe what further remains to be ſaid, upon this ſubject, in the form of queries; becauſe, however plauſible they may appear, they are at beſt but matter of conjecture. Hints, when propounded in this way, are freed from the danger of making us reſt in any error, whilſt, ſooner or later, they may become helps in leading us to a right underſtanding of the ſubject.

The queries which we ſhall proceed to make, are chiefly founded upon the following phænomena of the ſpots, as deſcribed by Scheiner and Hevelius.

1. Every ſpot which hath a nucleus, hath alſo an umbra ſurrounding it. Vid. Scheiner, p. 496. Hev. p. 409. 349.

2. The boundary betwixt the nucleus and umbra is always diſtinct and well defined. Vid. Scheiner, p. 497.

3. The encreaſe of a ſpot is gradual, the breadth of the nucleus and umbra dilating at the ſame time. Vid. Scheiner, p. 491, &c.

4. In like manner the decreaſe of a ſpot is gradual, the breadth of the nucleus and umbra contracting at the ſame time. Sch. p. 491. 498.

5. The exterior boundary of the umbra never conſiſts of ſharp angles, but is always curvilinear, how irregular ſoever the out-line of the nucleus may be. Sch. 511.

6. The nucleus of a ſpot, whilſt on the decreaſe, in many caſes changes its figure, by the umbra encroaching irregularly upon it; inſomuch that, in a ſmall ſpace of time, new encroachments are diſcernible, whereby the boundary, betwixt the nucleus and umbra, is perpetually varying. Sch. 514. Hev. 412.

7. It often happens, by theſe encroachments, that the nucleus of a ſpot is divided into two or more nuclei. Sch. 498.

8. The nuclei of ſpots vaniſh ſooner than the umbræ. Many inſtances of this ſort are to be ſeen in Hevelius' plates, and the ſame is affirmed by Mr. Derham in The Philoſophical Tranſactions.

9. Small umbræ are frequently ſeen without nuclei. Sch. p. 497.

10. An umbra of any conſiderable ſize is ſeldom ſeen without a nucleus in the middle of it. Ibid.

11. When a ſpot, which conſiſted of a nucleus and umbra, is about to diſappear, if it is not ſuc-

ceeded by a facula, or more fulgid appearance, the place, which it occupied, is ſoon after not diſtinguiſhable from any other part of the ſun's ſurface. This is certain from the accounts of all obſervers.

QUERIES *and* CONJECTURES,

tending to explain the above properties of the ſpots.

When we conſider, that the ſolar ſpots, ſome of whoſe properties have juſt now been enumerated, are ſo many vaſt excavations in the luminous ſubſtance of the ſun, and that, wherever ſuch excavations are found, we always diſcern dark and obſcure parts ſituated below; is it not reaſonable to think, that the great and ſtupendous body of the ſun is made up of two kinds of matter, very different in their qualities; that by far the greater part is ſolid and dark; and that this immenſe and dark globe is encompaſſed with a thin covering of that reſplendent ſubſtance, from which the ſun would ſeem to derive the whole of his vivifying heat and energy? And will not this hypotheſis help to account for many phænomena of the ſpots in a ſatisfactory manner? For if a portion of this luminous covering were by any means diſplaced, ſo as to expoſe to our view a part of the internal dark globe, would not this give the appearance of a ſpot? In this caſe, would not that part of the dark globe, which is now laid bare, correſpond to the nucleus, and the ſloping ſides of the luminous matter to the umbra? And is not this conſonant to that property of a ſpot mentioned in the firſt atticle;

article; for would it not hence follow, that every ſpot, having a nucleus, ſhould alſo have an umbra ſurrounding that nucleus, a natural account being at the ſame time ſuggeſted, for the boundary betwixt the nucleus and umbra being always diſtinctly defined, as mentioned in the ſecond article.

Although we may never have a competent notion of the nature and qualities of this ſhining and reſplendent ſubſtance, or of the means by which the excavations in it are formed; we however diſcover, in their production, the agency of ſome mighty, though unknown, cauſe, which is there often exerting itſelf. Although we manifeſtly behold its effects, yet the mode of its operations may perhaps remain unſearchable. But if we were here to venture a conjecture, might we not ſuppoſe, that the luminous matter is ſo diſturbed, and the excavations in it occaſioned, by the working of ſome ſort of elaſtic vapour, which is generated within the dark globe? And might not this elaſtic principle, by its expanſion, ſwell into ſuch a volume, as to reach up to the ſurface of the luminous matter, which would thereby be ſeparated and laid aſide in all directions? And for as much as there is no regularity in the time of a ſpot's enlarging, compared to the time of its decreaſing, ſome enlarging quickly, and decreaſing ſlowly, and *vice verſa*, may we not imagine, that this is owing to the duration and quantity of the elaſtic principle now mentioned? and in general, may we not from hence form ſome idea of the production and ſubſequent enlargement of a ſpot, as mentioned in the 3d article?

But

But to proceed. As we know, from experience, that the ſpots are of a tranſient nature, not laſting upon the ſun for a long ſpace of time, does it not ſeem reaſonable to think, that their gradual decreaſe, as mentioned in article 4th, is occaſioned by the luminous matter encroaching again upon that part of the dark globe, which had been uncovered? And from this may we not infer, that the luminous matter gravitates, and is in ſome degree fluid; for thereby would it not have a tendency to flow down, in all directions, and encroach, ſo as at laſt to cover the nucleus? And do not theſe things appear further probable, when we reflect upon that uniform inclination, which the ſides of the umbra, or excavation, have to the external ſurface of the ſun's body? For does not this indicate a fluid ſort of matter gradually yielding to the force of gravity? And again, is not this notion further ſupported, when we conſider the property mentioned in the 5th article, namely, that the exterior boundary of the umbra never conſiſts of ſharp angles or turnings, but is always curvilinear, and, moſt frequently, of a round form: for we know, that this boundary is nothing elſe but the lip of the excavation, which, on ſuppoſition that the luminous matter poſſeſſes ſome degree of fluidity, will not be diſpoſed, either in enlarging or contracting, to become irregular by ſudden or ſharp turnings?

Upon ſuppoſition that the ſurface of the dark globe of the ſun is ſmooth and level, it may be urged, that the nucleus of a ſpot, whilſt upon the decreaſe, ſhould, according to the preſent view of things, always acquire a figure, at leaſt nearly, circular,

cular, and that the luminous matter, continuing to flow down on all ſides by an equal gravity, ſhould ſo encroach upon the nucleus, as to make it retain that figure, till at laſt it be entirely overflowed. But this not being the caſe, and becauſe it moſt frequently happens, that the encroachments of the umbra upon the nucleus are extremely variable, as mentioned in the 6th article, may we not from this infer, that the ſurface of the internal dark globe of the ſun, is by no means ſmooth and level, but on the contrary very irregular, for, upon this ſuppoſition, if for example the area of the nucleus of a great ſpot were ſo diverſified by mountains and vallies, would not the encroachments of the luminous matter be conſequently irregular; and, aucording as it was more or leſs retarded or accelerated, at different places, by being contiguous to prominencies or hollows, would not all the alterations in the figure of the decreaſing nucleus, how variable ſoever, be thus plainly accounted for? and becauſe it often happens, that the nucleus of a ſpot, whilſt on the decreaſe, is gradually cut in pieces by a luminous zone or zones, which wander acroſs it, as mentioned in the 7th article, does not this look like the gradual flowing in of the luminous matter, as it were, into deep channels, which would thus appear to abound in the ſurface of the ſun's dark body? If we reflect upon the irregularities, which are upon the ſurface of this earth, and upon the enormous mountains and cavities, which are in the moon, may we not, from ſuch analogy, imagine, that there may be the like, or much greater, irregularities in the ſurface of the ſun?

ſun? I may here take notice of a curious inſtance of a nucleus being divided into two parts, which fell under my own obſervation. On October 8th, 1770, the ſpot *s*, TAB. IV. had a ſmall jutting in of the luminous matter, upon the oppoſite ſides of the nucleus, which, by the 10th day, had advanced contrary ways, ſo as to meet, by which means the nucleus was now divided into two parts, as repreſented by fig. *t*. It was here very remarkable, that the parts of the umbra oppoſite to this cut in the nucleus, were dilated as in fig. *t*. May not this dilatation have been occaſioned by the rapid flowing in of the luminous matter into the deep channel below?

Is not the property mentioned in the 8th article, namely, that the nucleus of a ſpot vaniſhes ſooner than the umbra, alſo agreeable to the preſent views? from this ſtate of the phænomenon, we ſuppoſe that that part of the ſun's dark body, which had been uncovered and expoſed to our view, when the ſpot firſt broke out, is now again juſt overflowed by the gradual inundation of the luminous matter. But, after the nucleus thus diſappears, may there not however, in many caſes, be ſtill left a cavity in the luminous matter, large enough to be perceived? and will not this cavity, ſo long as it continues, give the appearance of a ſmall undivided umbra? and will not this umbra ſtill be perceivable, till the luminous matter, by continuing to flow in, has filled up the cavity? after which, will not the place of the umbra acquire the ſame luſtre with the reſt of the ſun's ſurface, and thus will not all traces of the ſpot

vaniſh

Fig. 1.

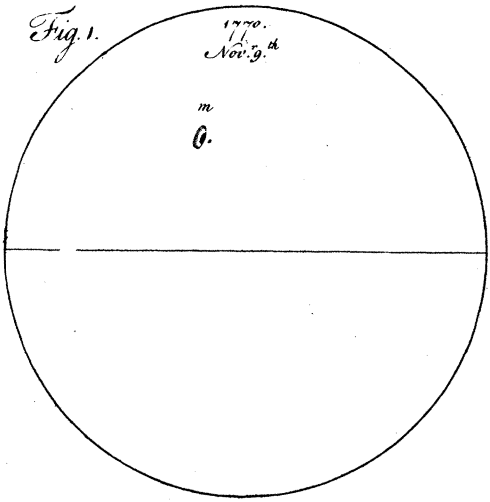


Fig. 2.

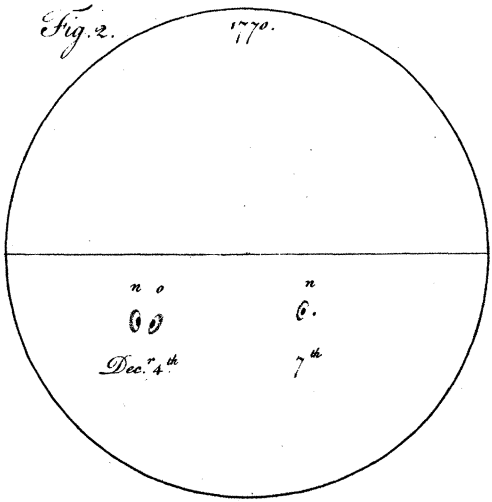


Fig. 3.

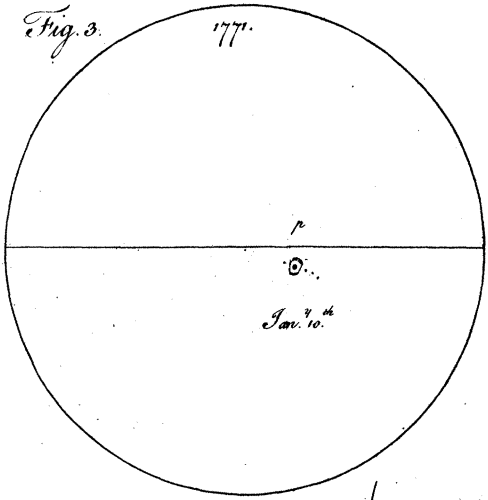
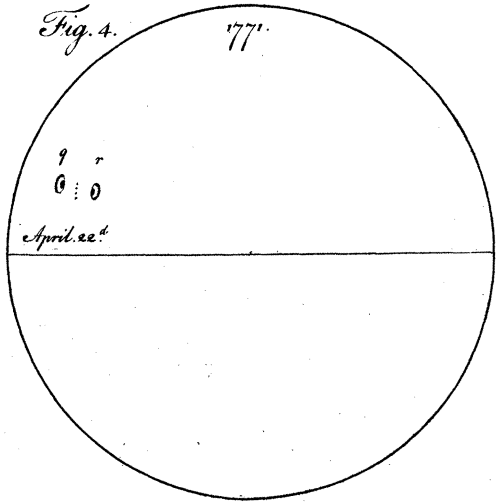
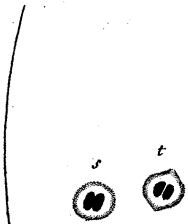


Fig. 4.





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vaniſh from his body? And do not the particulars mentioned in the 9th 10th and 11th articles ſeem agreeable to what is now ſaid?

Both SCHEINER and HEVELIUS ſeem to think, that ſpots ſometimes alter their place upon the diſc, not only by the ſun's rotation round his axis, but alſo by a motion, which they impute to the ſpots themſelves. This I could never obſerve. It is very true, that when a number of ſmall ſpots lye near one another, there may be from time to time a change of their relative ſituation, but it is plain, that this may proceed entirely from ſome of them encreaſing and others diminiſhing irregularly. But what would further contribute towards forming a judgment of this kind is, the apparent alteration of the relative place, which muſt ariſe from the motion acroſs the diſc on a ſpherical ſurface; a circumſtance which I am uncertain if it has been ſufficiently attended to.

What has been advanced, in the courſe of the foregoing queries, may perhaps be rendered ſtill more probable, by conſidering the obſervations related in the firſt part of this paper, concerning the changes which are made upon the figure of a ſpot, when another breaks out in its neighbourhood; and which ſeem to ariſe from a diſturbing force. For, from the caſes there laid down, would it not appear, that when a ſpot is breaking out, the luminous matter is then forced, in all directions, from the nucleus, and is affected much in the ſame manner, as it would be, were it a fluid matter encompaſſing the ſun's dark body?

As to the particular nature and qualities of this luminous matter, we have been ſometimes apt to imagine, that it cannot well be any very ponderous fluid, but that it rather muſt reſemble as to its conſiſtence a very denſe and thick fog, which broods on the ſurface of the ſun's dark body. How far will this idea tend to facilitate our conceptions of the various phænomena of the ſpots above deſcribed?

It has been gathered from many obſervations, that the time which the ſpots take to traverſe the whole diſc, is nearly equal to the time that they are hid by being on the oppoſite ſurface. It is plain, that the time of their appearing upon the diſc muſt be ſome ſmall matter ſhorter than that of their being hid behind it, on account of our not ſeeing a complete hemiſphere of the ſun. But further, it muſt now be conſidered, that when a ſpot juſt enters the diſc, the part, which is firſt viſible, is the fartheſt umbra, by which time the ſpot has really advanced a whole diameter of itſelf upon the diſc. And again, when the ſame ſpot goes off the diſc, it is evident, that the part, which is laſt viſible, is then the fartheſt umbra, on which account the continuance of the ſpot upon the diſc will be ſhortened by an interval of time, which correſponds nearly to the whole breadth of it. This, as well as the other appearances, deſcribed in the firſt part of this paper, concerning the change of the umbra and figure of the nucleus, when ſpots approach the limb, are all well illuſtrated, by making in a ſphere, an excavation ſimilar to what we have deſcribed, the bottom of which may be painted black

black to repreſent the nucleus, and the ſloping ſides ſhaded, if the ſphere be of a light colour.

According to the view of things given in the foregoing queries, there would ſeem to be ſomething very extraordinary in the dark and unignited ſtate of the great internal globe of the ſun. Does not this ſeem to indicate, that the luminous matter, which encompaſſes it, derives not its ſplendor from any intenſity of heat? For, if this were the caſe, would not the parts underneath, which would be perpetually in contact with that glowing matter, be heated to ſuch a degree, as to become luminous and bright? At the ſame time it muſt be confeſſed, that although the internal globe was in reality much ignited, yet when any part of it, forming the nucleus of a ſpot, is expoſed to our view, and is ſeen in competition with a ſubſtance of ſuch amazing ſplendor, it is no wonder, that an inferior degree of light ſhould, in theſe circumſtances, be unperceivable.

In order to obtain ſome knowledge of this point, I think an experiment might be tried, if we had an opportunity of a very large ſpot, by making a contrivance in the eye-piece of a teleſcope, whereby an obſerver could look at the nucleus alone with the naked eye, without being in danger of light coming from any other part of the ſun. In this caſe, if the obſerver found no greater ſplendor, than what might be expected from a planet very near the ſun, and illumined by as much of his ſurface as correſponds to the ſpots umbra, we might reaſonably conclude, that the ſolar matter, at the depth of the nucleus, is in

reality not ignited. But, from the nature of the thing, doth there ſeem any neceſſity for thinking, that there prevails there any ſuch raging and fervent heat, as many have imagined? It is proper here, to attend to the diſtinction betwixt this ſhining matter of the ſun, and the rays of light which proceed from it. It may perhaps be thought, that the re-action of the rays upon the matter, at their emiſſion, may be productive of a violent degree of heat. But whoever would urge this argument, in favour of the ſun being intenſely heated, as ariſing from the nature of the thing, ought to conſider, that all poliſhed bodies are leſs and leſs diſpoſed to be heated, by the action of the rays of light, in proportion as their ſurfaces are more poliſhed, and as their powers of reflection are brought to a greater degree of perfection. And is there not a ſtrong analogy betwixt the re-action of light upon matter, in caſes where it is reflected, and in caſes where it is emitted?

It may perhaps be expected, that, in this paper, mention ſhould be made of the other appearances, that are diſcernible upon the ſurface of the ſun, beſides the ſpots properly ſo called; I mean the faculæ, luculi, &c. as deſcribed by Scheiner and Hevelius. But all theſe phænomena ſeem to be ſo different from any thing we have conſidered, and ſo unconnected with the preſent diſcovery, that little aſſiſtance can be brought from that quarter towards a right conception of them. As to the faculæ, or brighter parts of the ſun, we are at a loſs for their origin. It may in general be remarked, that although we have obtained an experimental

rimental proof, that the luminous matter acquires ſome degree of ſhade, when forming the ſides of an excavation, yet it is uncertain, if this be merely the effect of poſition, and much more ſo, if any different modification of poſition could ever diſpoſe it to put on a brighter or more fulgid appearance. Yet, after all, may not theſe faculæ, &c. depend upon ſome irregularities in the bright ſurface of the ſun? For may not the luminous matter, by being agitated by the ſame cauſe to which the ſpots owe their origin, though in a leſs degree, have its ſurface perpetually diſturbed, and made irregular, and thus give occaſion to a variety of light and ſhade, ſufficient perhaps to produce the phænomena under conſideration? And does not this conjecture receive further confirmation, when we conſider, that theſe faculæ, &c. are found only in that zodiac, within which the ſpots appear, and that they always abound moſt in the neighbourhood of the ſpots themſelves, or where ſpots recently have been? For in thoſe undiſturbed regions of the ſun which lye towards his poles, and where no ſpots ever appear, and which SCHEINER calls the *plagæ æquabiles*, we never diſcover any diverſity of appearance.

Thus we have endeavoured to give a general idea of the production, changes, and decay of the ſolar ſpots, conſidered as excavations in the body of the ſun; a thing which ſeems to be eſtabliſhed from the obſervations deſcribed in the firſt part of this paper. But concerning the nature of that mighty agency, which occaſions thoſe amazing commotions in the luminous matter, or concern-

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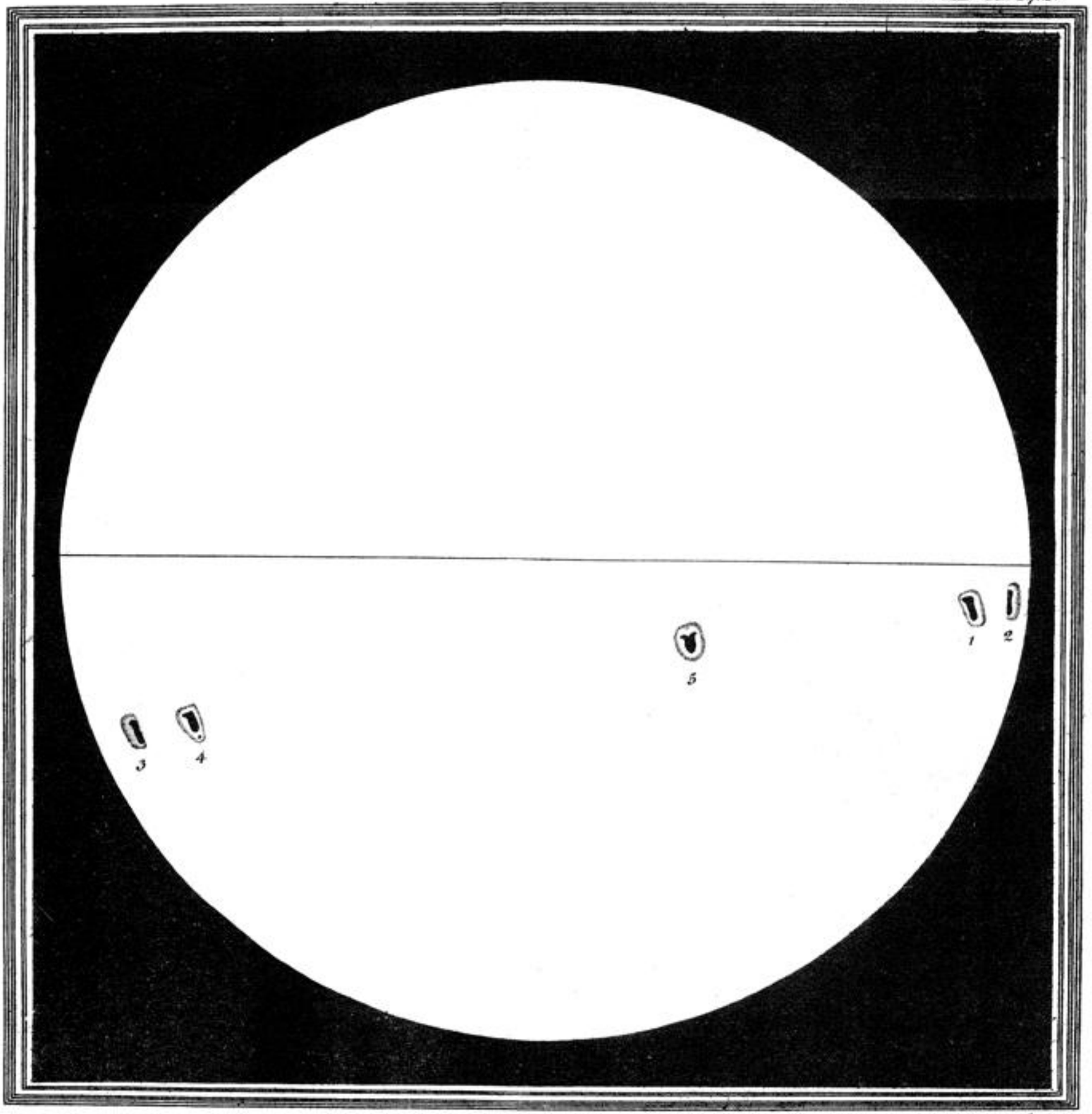
ing the denſity, viſcidity, and other qualities of this matter, or the manner in which it is diſturbed in the middle zone only, and not at the polar regions, and many ſuch other queſtions, I freely confeſs, that they far ſurpaſs my knowledge.

To conclude; as what hath now been ſaid may open a new field of inquiry into this ſubject, ſo a diſcuſſion of theſe curious points may, ſome time or other, fall to the ſhare of abler men, whoſe love of philoſophy may induce them to purſue ſo noble an inveſtigation.

Suns Eastern Limb.



Basire sc.

N°. 1. Great Spot Nov. 23. 1769.
2 ..... 24.
3 ..... Dec^r. 11. for the second time.
4 12
5 17