XXXIV. Memoir on the variations of the reflective, refractive and dispersive powers of the atmosphere, &c.

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XXXIV. *Memoir on the Variations of the reflective, refractive and dispersive Powers of the Atmosphere, &c.* By T. FORSTER, M.B. F.L.S. Member of the Astronomical and the Meteorological Societies of London, and Corresponding Member of the Academy of Natural Sciences at Philadelphia, &c.*

IN the infancy of every science, the first great object to be achieved is the accumulation of phænomena appertaining thereto. In proportion as we are enabled to lay out these in their natural order and arrangement, in the same proportion we advance the science; and where we are enabled to unravel the particular causes of each, we promote a knowledge of it in the highest degree.

In the following observations it will be found that I have been enabled by observation and reflection to collect a considerable number of facts, and to place them in some sort of arrangement. And though much progress has not yet been made on the development of their precise causes, yet such as has been already known has been arranged in a way which is likely to facilitate and direct the future inquiries of more able and industrious speculators than myself; and it is with a view of thus engaging the cooperation of the many intelligent members which compose the Meteorological Society, that I have ventured to obtrude the ensuing crude observations on their notice at this early stage of our investigations.

The refractive power of the atmosphere has been long well known, and corrective tables of mean refraction intended to be applied to astronomical observations have been employed for many years. In my endeavour, therefore, to be brief, in order not to become obscure, I shall avoid as much as possible the reiteration of observations already before the public, as the reader may refer immediately to Bradley's tables, and to various works on refraction. But though the refraction of light by the intervention of the atmosphere is well known, that part of the subject which more immediately belongs to meteorologists, has been particularly neglected; I mean the *Variation in the Atmosphere's reflective, refractive and dispersive powers, resulting from the diffusion therein of different modifications of cloud at different times and places. And the various effects which this aforesaid variation produces, considered as a fluctuation in the prismatic property of the air through which the modified light of the sun, moon and stars severally is transmitted to the inhabitants of our globe.*

The object of this paper is therefore to show the liability of the

* Read before the Meteorological Society of London in February and March 1824, and published by permission.

atmosphere to great variations in this its power of reflecting, refracting and dispersing the rays of celestial luminous bodies, and consequently the necessity of some further corrective tables of refraction; and to show what particular modifications of cloud produce these properties of the atmosphere in the highest degree by being diffused therein.

Previous to entering into the ensuing inquiry, I wish to caution the general reader against ever confounding reflection, refraction, and prismatic dispersion, which are distinct properties. For example, the lightness of the sky in the day time is produced by the reflective power; while its appearing of a blue colour is an effect of a certain property which accompanies it, whereby certain blue rays are separated from the rest. As a more striking example of the dispersive power, I may instance the beautiful red, crimson, and yellow colours of the clouds produced on certain occasions by the light of the sun *reflected* by their surfaces, being *refracted* and *dispersed* by the aqueous atmosphere in its passage to the earth's surface.

I am aware that the clouds themselves may on some occasions possess the property of separating light; and to this cause I was formerly inclined to ascribe their colour; but subsequent experience and reflection have convinced me that the most brilliant tints seen in the clouds are the result of the dispersive power of the aqueous vapour existing in a state of general diffusion in the lower atmosphere, whereby the light reflected from the surface of the cloud is prismatically dispersed into separate rays in its passage through the lower atmosphere to the earth.

It must be borne in mind, that my observations below do not relate to those remarkable and special refractions which occur in certain definable clouds, as the rainbow, which results from reflections and special refractions of certain rays at a determinate angle in the *nimbus* or raincloud, producing concentric rings of colours conformable to their different degrees of refrangibility. Nor do I include those special refractions of light in its passage through the *cirrostratus*, called *halos*, whereby concentric coloured rings are produced in the order of their respective refrangibility, and reflected at an angle which equals the angle subtended by the semidiameter of the *halo*.

I allude in this paper to the ordinary effects of more thinly diffused and almost invisible cloud in the atmosphere, through which the luminous celestial bodies appear clear and distinct, but which nevertheless refracts and disperses their rays in some degree, even in apparently the clearest nights.

Refraction has been hitherto considered as so general an effect of the atmosphere, and so unconnected with any particular

ticular cloud, that universal tables of mean refraction have been made out, as if they would apply to all places. This is, however, an essential error: and in developing it I find the subject naturally divides itself into three distinct considerations, as follows:

I.

On the Variation in the refractive Power of the Atmosphere at different Times of the Night and Day and on different Occasions and Seasons.

There is one question in the history of refraction which for obvious reasons ought, if possible, to be cleared up; namely, Wherein consists the dispersive power of the atmosphere, which is found to vary at different times and in different places? To me it appears that this variation is owing principally to the quantity and nature of the aqueous particles suspended in the air. Astronomers have hitherto confined their considerations too exclusively to the refractive property of pure air, and have overlooked the circumstance that the atmosphere is seldom pure for any length of time; they have consequently not taken into account the varied effects of different sorts of diffused vapours, which, though unseen by the common observer, exist in the air in different proportions at sundry times and places, and which prevail much more at some places than at others. I was led to discover this by observing the vast disproportion between the result of my observations on the stars made at different times and seasons. In observing the planets and brightest of the stars through prismatic glasses, I found that the spectrum was less oblongated while the red colour was more distinctly apparent at the time of the first falling of the dew than at almost any other time of the same nights. Venus and Jupiter afforded a fine opportunity of ascertaining this fact last spring, as these planets could be both seen of an evening as early as the period of the vapour point*.

* The vapour point is that precise period which occurs in the progress of evening, when, from the declining temperature, the air can no longer hold in solution the same quantity of aqueous gas that it maintained during day; and when consequently the aqueosity is first deposited in the form of visible vapour or cloud, and gradually descends to the earth; on arriving at the surface of which it eventually forms a *stratus* or fog, called for this reason the fallcloud. In the morning the counterpart of this process takes place, and the gasified water being taken into the composition of the air again, ascends, till rising into a colder region it is again condensed into visible clouds which float on the vapour plane, or that precise elevation whereat the air begins to be too cold to hold the vapour in solution. At this elevation it forms clouds dissimilar in their modifications, according to electrical causes which exist in the air, but generally speaking *cumuli*, the lighter modifications of cloud occurring higher up from local electrical and other causes which disturb the equilibrium of the temperature of the atmosphere.

And

And the most common observation on the rising and setting moon will always confirm it on favourable nights.

On other occasions, at the same time of night, I found an unexpected difference in the appearance of the spectrum of the very same planets; the violet and in general the most refrangible colours being most conspicuous, and the spectrum being more oblongated than ordinary.

To reconcile this difference of effects with existing causes apparently so similar, was now an interesting object; and at last I found out that the difference was referable to a difference in the quality of the falling dew, or diffused cloudiness.

The greater prevalence of the red in the spectrum uniformly accompanied that state of the atmosphere when the *cirrostratus* or wanecloud diffused itself after sunset; while the more oblongated spectrum with the violet and most refrangible colours attended an atmosphere in which the descending dew was *stratus* or fallcloud. I will not say positively that in the first case the falling mist was itself *cirrostratus*, but it was a different kind of mistiness and less purely white, when seen in the valleys, than the common mist, and it happened when there were *cirrostrati* in the higher air. Another circumstance which confirms my explanation of the phenomenon is, that during the falling of ordinary dew in clear and settled weather, particularly with east wind, the horizontal haze shows beautiful tints of the more refrangible colours, varying upwards, so that the atmosphere becomes a sort of natural prism, of which I have cited many examples in my "*Researches about Atmospheric Phenomena*." Whereas when *cirrostratus* prevails, particularly before wind, the red is the predominant colour of the haze, and also of the clouds above it, which appear of the finest crimson and vermilion. In some cases I believe the clouds may themselves become prismatic, and the colour of which they appear may be produced by their own structure; but it is more generally the effect of the haze through which reflected rays pass in coming down. Clouds in this case may be compared to planets viewed in a prismatic glass, their surfaces reflecting the borrowed light of the sun, which becomes dispersed by the chromatopoeitic properties of the atmosphere through which it passes.

Another circumstance which I witnessed several times in November 1822, and which is of common occurrence, strikingly corresponds with the above observations; namely, that clouds whose irregular surfaces and depending fringes were of a golden or silvery colour, that is, reflected all the sun's rays just as they received them, during a whole afternoon, were, on the occurrence of the vapour point, suddenly turned red as if

by some dispersive power imparted to the circumjacent atmosphere by the first falling of the dew.

The state of the atmosphere which shows the red colour for any length of time is a forerunner of high wind.

There is an obscurity of a denser kind which often causes an apparent dilatation of the disks of the celestial bodies, which it elevates without colouring them. The moon for instance looks pale, expanded and confused. This state is a prognostic of rain, and is contrasted to the former as well as to the clearness of the serene sky which follows an ordinary fall of dew, in a well known proverb expressive of the prognosticative colour of the moon on each several occasion:—

“ Pallida luna pluit, rubicunda flat, alba serenat.”

Another state of the *cirrostratus*, when diffused, seems to possess dispersive properties of a very peculiar nature, refracting certain coloured rays at an angle of *about* 5° ; and others at an angle of *about* 23° , so as to cause two concentric *halos* or rings of colours; the inner one being about 10° , and the outer one about 46° in diameter. Sometimes single rings occur which are colourless; but as all these phenomena do not properly belong to our subject, and are elsewhere treated of, I shall not dwell longer on them.

All the above circumstances show that the changes in the qualities of the diffused vapour in the air must cause a great variety in the atmospherical refraction. They also explain how the atmosphere about different places may have a different mean refractive power, according to the local prevalence of the above diversified vapours which hang in it. For I am not certain whether, independent of temperature and pressure, the pure atmospheric air differs in its refractive power all over the world: I believe the difference to arise from the vapours always more or less suspended therein and generally electrified.

Two more facts confirming my hypothesis must now be cursorily mentioned. The east wind produces changes in the appearance of the spectra of the celestial bodies, even in the field of ordinary telescopes: the spectrum seems to vibrate or dance about in the field of the glass in a way that defeats many very delicate observations. Had not this remark been confirmed by other people, I should have ascribed it to the nervousness of the observer, the east wind being very liable to produce nervous disorders of the eyes and other parts. I have not observed the precise effect of the east wind on the larger prismatic spectra, as far as respects their colours; but the whole spectrum seems often on such occasions to move, and to fluctuate more than ordinarily.

Astronomers, ever since the time of Newton, have known
that

that pure atmospheric air will vary gradually in its refractive powers according to the degree of heat; and remarkable instances of the great elevation of the disk of the sun above the horizon in cold climates, when calculation showed him to be below it, have been adduced as striking examples. But it should be remembered by all, and it is already known to meteorologists, that changes in temperature are never unattended with changes in the quantity and modification of aqueous vapours suspended in the air. And this circumstance must add considerably to the effect of low temperature, and may impart to an atmosphere condensed by cold some great and peculiar dispersive properties. The inordinate elevation of the mast of ships at sea by refraction is an instance and proof of the undoubted great effect of vapours occasionally suspended in the air. The east wind is connected with the arrival of peculiar vapours in it, and the vibration or irregular movement of the star in the telescope may be owing to such vapour being agitated by the electrical commotions that so generally attend a change of wind from any other quarter to one blowing from the east.

Besides the general want of correspondence between the results of different observations, where it is necessary to subtract a given quantity of refraction, we may make a particular observation on the still greater disagreement that is found to exist in the declination of several particular stars, as published by different observers; for this disagreement, when applied to certain individual stars, is referable to a compound cause; for the light of the stars severally being composed of different proportions of the primitive colours, the red ones, as *Aldebaran*, *Arcturus*, and *Betalgeus*, are less refrangible than *Sirius*, *Lyra*, *Capella*, and the white stars in general. Of this I shall treat in the third section. It may suffice to remark it slightly here, in order that, when we are considering the varieties in the atmosphere's dispersive property, we may also take into account the compound effect produced by the various colours of the stars whose light is thus variously dispersed.

The projection of *Aldebaran* and other red stars on the disk of the moon when the conjunction happens near to her upper limb, as noticed by Mr. Lee*, is an illustration of the above fact; the greater proportionate refrangibility of her white light, than that of the red light of the star, elevating her apparent disk so as to cause the star to seem to be within it just before or after the respective points of contact.

When the wind first changes to become east, and when the

* I wish my readers to peruse the whole of Mr. Lee's ingenious paper in Phil. Trans.; for though it becomes necessary to cite it, in order to make due acknowledgements, nevertheless every individual Essay should be read entire, and not in citations.

air is encumbered with the cirrostrativeness of the wanecloud, then all the celestial bodies appear redder than at other times, from the greater disposition of the air at those times to separate and transmit the red colour, which must considerably influence the foregoing observations.

The last observation I have here to make relates to a phenomenon hitherto entirely unexplained. I allude to rapid alternations in the colour and brilliancy of the light of certain stars viewed near the horizon.

Some years ago, on looking towards the constellation of the Scorpion, I observed a remarkable changing of colour in the fluctuation of *Antares*: for a second or less of time it appeared of a deep crimson colour, then of a whitish colour; then the crimson was resumed; and so on at alternating periods. Sometimes every other twinkle showed the red colour, while the alternating twinkle appeared of the ordinary colour of starlight.

What is commonly called the twinkling of a star seems to be an apparent fit of dilatation and increased brilliancy rapidly succeeded by the opposite state of apparent contraction of surface and dulness. I have observed, also, that the twinkles are of longer or shorter duration, at different times: now, in general, the intense red light I allude to occurs in every alternate dilatation; but sometimes only in every third, and at other times quite irregularly: moreover, it lasts longer sometimes than at others, and scarcely ever exceeds two seconds of time at once. This phenomenon as viewed in *Antares* was particularly conspicuous at Clapton, in autumn 1809, at Tunbridge Wells on June 19, 1817, and during the whole summers of 1822 and 1823 at Hartwell. I saw this phenomenon also in other stars, in France, in September 1823; and I have seen it in the summer of 1822, in the atmospheres of Switzerland, Alsace, and all along the Rhine: it is evidently not confined to any local cause.

I have formerly published accounts of this phenomenon in the Journals, and have ascribed it to some sort of change in the star itself, or to a revolution round an axis, whereby different coloured portions of the luminous sphere might be presented to us: but this explanation vanishes on a moment's reflection; and I am inclined to ascribe it to some atmospherical cause. I have sometimes thought that the upper portions of the atmosphere might have some undulatory motion, and that the alternating colour might be produced by its refractive powers: for the atmosphere, in this case, acting as an imperfect prism, might present different colours, according to the varying inclinations of its wavy surface*. I have thought, too, that por-

* See Phil. Mag. vol. xlix. p. 452; and the Perennial Calendar, Jan. 16, p. 17.
tions

tions of the aqueous atmosphere, possessing different prismatic powers, might be transmitted downwards in dew, or that there might be some other unknown motion in the real air, which might cause the appearance. *Antares*, *Betalgeus*, and some other red stars, show this change of colours very strongly, particularly the former: while *Sirius* and the brilliant white stars show this alternation of colour in a less degree. It is not observed in *Procyon*, is weak in *Capella*, but is considerable in *Vega* and in *Arcturus*, the latter being a red star. *Antares* shows this phænomenon more brilliantly than any of the others. Differences in the composition of the light of stars may explain these varieties of effect.

Nobody can, I think, reflect on all the above details, hasty and imperfect as they may be, without at once seeing the importance of extending our observations on the phænomena to which they relate, in constructing tables of refraction; and I shall still be excused, I trust, in the absence of more matured and extended details, for this imperfect attempt to excite the attention of philosophers to facts which seem calculated to produce an important influence on many of our most useful astronomical calculations.

II.

Of the Variation of the mean refractive Power of the Atmosphere in different Places.

Although the refractive and dispersing power of the atmosphere varies at different times in the same place of observation, yet by dividing the sum of a vast number of observations by their number, we shall get at a mean or average of the refractive power of the atmosphere of any particular place. This I call the mean refractive power of the atmosphere, and this *mean* differs very much in different situations, so that tables of mean refraction will not apply universally, but must be made out separately for each place of observation. Thus a correction which would be applicable to observations made at Greenwich, would not equally apply to Dublin or to Paris, much less to Palermo or the Cape of Good Hope: and they would be still less applicable in Peru, where the dispersive power of the atmosphere is prodigious. I was led to the adoption of this opinion, in the first instance, by analogy, it being strictly conformable to a thousand other corresponding instances of local variation in atmospheric phænomena. Experiment seemed to confirm it. And I have lately heard of a further corroboration which this opinion has received from the able observations of Dr. Brinkley, communicated to the Royal Society. But as I have only heard casually of that paper,

paper, and have never seen his observations, I cannot speak positively to that point.

If the opinion which I have long entertained, that the mean refractive power of the atmosphere varies in different places, be correct; its promulgation may lead to important results: it may explain certain apparent discordances in the places assigned to the fixed stars as described in different catalogues. For if corrective tables calculated for Berlin or Paris were to be applied to observations at Greenwich, there might be a considerable difference in the result.

Another very important observation results from this consideration. Suppose, for example, a given corrective table of mean refraction were to be applied to a catalogue of apparent places of the fixed stars observed at Pisa a hundred years ago, and that the same table were to be applied to a catalogue observed this year at Dublin, the result of a comparison of the two catalogues would be a positive error. For Dublin and Pisa requiring a different correction, altogether independent of longitude and latitude, and depending solely on the different refractive powers of their respective atmospheres, the consequence of applying the same corrective table to the observations of both places would be the certain error of one of the catalogues. And as one catalogue would, according to our supposition, be a hundred years older than the other, the stars would be thought to have changed their places. Some misapplication of tables of refraction seems to me to be the cause of an idea of a southern motion recently promulgated by certain astronomers. Independently of the great *prima facie* improbability of such a motion, it seemed to me, when I first heard the opinion mentioned, that it would turn out to be an error depending on the want of a proper application of corrective tables of refraction. I speak, however, on the point with deference to the better judgement of learned astronomers.

III.

Of Varieties in the Composition and Nature of the Light of different Stars, considered as still further varying the Effects of atmospherical Refraction, Reflection and Dispersion.

It must have occurred to almost every body to perceive that the colour of different stars is very dissimilar; that some appear more red or copper coloured, others yellow like brass; some of a bright and almost silvery whiteness, while yet others are of a dull white colour. These differences become much more striking when viewed through such bad telescopes as, being but imperfectly achromatic, become in a measure prismatic, and separate the primitive rays of light, producing a coloured

coloured spectrum in the field of the glass. By the adaptation of a more perfectly prismatic lens to the telescope, we get a still more distinct spectrum, and are enabled to contemplate the particular composition of light possessed by each star respectively. I was not aware of the best means of detecting these differences, till I read the excellent paper On the Dispersive Power of the Atmosphere, by Mr. Stephen Lee, published in the Transactions of the Royal Society*. As some of my own observations coincide with those detailed in the aforesaid paper, I feel additional confidence in giving them to the public, as the acuteness and ability of that gentleman as an astronomer are well known. Mr. Lee viewed the stars through a prism adapted to the eye glass of a reflecting telescope; and, prompted by a laudable desire to ascertain how far the dispersive power of the atmosphere could produce an effect on astronomical observations, he proceeded to examine several stars, with a view to ascertain, if possible, the exact degree of separation of the several rays. As the above paper ought to be read by all observers, I shall not extract any of the observations now, but proceed to the subject under consideration,—the varieties of stellar light.

According to my observations, the stars should be classed according to their colours, into the red, the yellow, the brilliant white, the dull white, and the anomalous. For though each star may differ somewhat from every other, yet we shall be assisted by this general classification.

When observed with a prismatic glass as above described, *Sirius* shows a large brush of extremely beautiful violet colour, and, generally speaking, the most refrangible rays in great quantity. The same applies more or less to all the bright white stars.

Procyon is far less beautiful than *Sirius*, and shows more of the yellow colour.

Aldebaran, together with many of the other red stars, exhibits a very small proportion of the more refrangible colours.

Arcturus much resembles *Aldebaran*, but differs in the lesser proportion of the red to the other rays.

Betalgeus is another red star, little inferior in magnitude to the two above. This star shows also but little of the more refrangible rays; but the spectrum is always a bad one, and is for some unknown cause more liable to fluctuation than the above two.

Antares, the most extraordinary star of all, contains, like *Aldebaran* and *Arcturus*, much red light; but owing to its

* See Supplement.

greater southern declination, as well as to something very peculiar in the composition of its light, we cannot get so perfect a spectrum as might be desirable. This star, too, exhibits in the greatest degree a peculiar and hitherto unexplained phenomenon, which will always interfere with our observations on its permanent spectrum. I allude to the rapid permutations of the colour of its light, every alternate twinkling, if I may so express myself, being of an intense reddish crimson colour, and the alternate one of a brilliant white. As I have before described and speculated on this phenomenon, common, though in a less degree, to other stars when near to the horizon, I shall not further dwell on it here, but observe that *Antares*, considered with reference to its light, must be put among anomalous stars.

Atair in the *Eagle*, and also the dull white stars, exhibit a vast quantity of intense green light. This is very conspicuous in many stars of the 2d and 3d magnitudes.

The planets likewise present spectra very considerably differing from each other. *Jupiter* possesses all the colours; but from something in their respective proportions, or from some unknown cause, this planet is liable to produce, even in good and almost achromatic glasses, so bad and so coloured a spectrum, that I have always found him a disagreeable star to observe. As a prismatic spectrum, however, he is beautiful. The green colour seems somewhat deficient in his spectrum; nevertheless *Jupiter* appears green in comparison with *Sirius* when an opportunity offers of viewing both at one time*. *Venus* appears less green than *Jupiter*, but still she is not of so bright and blueish a white as *Sirius*. Her spectrum in the prismatic glass shows most of the rays, but the green colour is very pale.

Saturn seems composed chiefly of the mean rays, and has a very small quantity of the extreme colours. Mr. Lee, who also notices this, subjoins the following judicious question—Whether this may not explain why *Saturn* bears magnifying better than *Jupiter* or *Venus*?

Mars, who shines with a red light, appears as a spectral image on the prism to possess less of the middle and most refrangible colours. The red is very conspicuous in the prismatic spectrum.

Mercury is said to show a similar spectrum: I confess I have not made observations on *Mercury* myself.

* We may imitate the different colours of the spectra of the several stars and planets, by burning antimony, steel, and other metallic filings, in pyrotechnical jerbs, and viewing them through a prism. Compare the prismatic spectrum of ignited steel with that of *Jupiter*, of burning antimony with *Sirius*, of copper filings with the spectrum of *Mars*; and so on.

Of the varying spectra of the *Moon*, and the composition of moonlight, I shall speak hereafter.

The next consideration is, the effects which the above-described variety in the colour of the light of the celestial bodies will have on our astronomical observations: and it appears to me that this effect will be very considerable. Sir William Herschel has already noticed this circumstance, and has observed, that the prismatic power of the atmosphere should not be overlooked, as in observations on very low stars it must make a great difference in the correction which might become necessary. He has stated the measure of two diameters of ϵ *Sagittarii*, and from his observations thereon deduced the refraction of the extreme rays as being about $\frac{1}{94} \pm$ the mean refraction*.

To me it appears evident that the different stars will, in consequence of the different composition of their light, require very different corrections; and that tables of refraction should not only be made out for each observatory, in order to apply to the mean refractive power of the air in different places as before described; but also, that some rules should be appended for applying a correction for each particular class of stars, according to their predominant colour.

As a natural deduction from the foregoing facts, we must infer that the real declinations of *Sirius* and of *Aldebaran*, for example, cannot have been determined by the application of the same correction to the apparent places of both of them; since *Sirius* is composed of a large quantity of the most refrangible colours, while *Aldebaran* is particularly deficient in them.

We cannot, I think, easily pass by the above facts, without inquiring into their particular causes, which will be found to involve us in some exceedingly curious speculations.

The difference in the colour of the light of the fixed stars is probably owing to a real difference in the proportions in which the several rays are combined. Thus *Sirius* sends forth more of the violet; *Aldebaran* more of the red; and perhaps *Capella* more of the yellow rays. *Altair* and the dull white stars perhaps have more of the yellow and blue together, and less of the red, so as to make green light; and so on†. The stars differ too in the intensity or brilliancy of their light; the largest apparently not being always the brightest. And it is curious to observe that some stars seem

* Phil. Trans. vol. lxxv. On Double Stars, by Dr. Herschel.

† I have worded it thus on the very doubtful supposition of three primitive rays, merely in conformity to received opinion: phænomena are decidedly against that notion; for I cannot separate their green light in the spectrum.

to possess a greater power of penetrating through an imperfectly obscure atmosphere than others of equal apparent brightness, as the *Pleiades* and the *Hyades*. On the other hand, the two small stars in *Cancer*, called *Aselli* by the Romans and *ὄνοι* by the Greeks, were found to be obscured much before the rest during the progressive condensation of the atmosphere; and their dimness and progressive disappearance, together with that of the nebula *Presepe*, was consequently regarded as the first sign of approaching rain, as is mentioned by Aratus in his *Diosemea*, and which had been before observed by Theophrastus in his treatise *Περὶ σημάτων ὑετῶν*. The passage is exceedingly curious, and is as follows:

Ἐν τῷ Καρκίνῳ δύο ἀστέρες εἰσιν, οἱ καλούμενοι ὄνοι, ὧν τὸ μεταξὺ τὸ νεφέλιον ἢ φάτνη καλουμένη· τοῦτο δὲ ἂν ζοφῶδες γένηται, ὑδατικόν.

And afterwards he observes respecting the signs of rain:

Ἡ τοῦ ὄνου φάτνη εἰ συνίσταται καὶ ζοφερά γίνεται χεῖμωνα σημαίνει.

Aratus in following up this observation makes a distinction between the indications of the northern and those of the southern of the two stars, which we can hardly reconcile with any conceivable hypothesis.

Εἰς μὲν παρ' βορέαο, νότῳ δ' ἐπιέρχεται ἄλλος·
Καὶ τοὶ μὲν καλέονται ὄνοι· μέσση δέ τε φάτνη,
Ἦτε καὶ ἐξαπίνης πάντῃ Διὸς εὐδιάοντος
Γίνετ' ἄφαντος ὅλη· τοὶ δὲ ἀμφοτέρωθεν ἰόντες
Ἀστέρες ἀλλήλων αὐτοσχεδὸν ἰνδάλλονται·
Οὐκ ὀλίγῳ χειμῶνι τότε κλύζονται ἄρουραι.
Εἰ δὲ μελαίνηται, τοὶ δ' αὐτίκ' εἰοκότες ὥσιν
Ἀστέρες ἀμφοτέροισι περὶ χ' ὕδατι σημαίνοισιν.
Εἰ δ' ὁ μὲν ἐκ βορέω φάτνης ἀμενηνὰ φαιίνη
Λεπτὸς ἐπαχλυῶν, νότιος δ' ὄνος ἀγλαὸς εἴη,
Δειδέχθαι ἀνέμοιο νότου· βορέω δὲ μάλα χεῖρ
Ἐμπαλιν ἀχλυόεντι φαινομένῳ τε δοκεύειν.

The peculiarity of this observation has struck many commentators, and I find the following note appended to the above passage.

Meteorologica astronomicis confundit. Nam diversæ harum stellarum species, non a propria ipsarum atmosphæra, sed a nostro aëre efficiuntur; quare, ergo, hæ, magis quam aliæ stellæ, per obscuritatem suam tempestates portendere possint? Si quidem ab ipsarum aëre aut aliquo circa eas fieri possit speciei variatio; quis credit tantam inter tam remota sidera relationem existere, ut aliquid, in stellis visum pluviam in mundo præmoneret? Sensus est—Quod etiam confestim, cælo sereno, fit evanidum

evanidum totum ; atque stellæ utrimque coeuntes, si invicem vicinæ apparent ; non modica tempestate arva inundant. Si autem nigrescat, rursus vero eodem colore ambæ stellæ existunt, pluvias significant. Si vero hic (ὅς) qui est e præsepis borea modice tenebrescens, languide splendeat, cum austrinus asellus lucidus sit, ventum Austrum expecta. Boream vero e contra tenebrescente lucenteque observare oportet.—Arat. Dios. 167.

Many corresponding quotations might be added.

Some years ago Mr. Barker published a paper in the Philosophical Transactions, tending to prove that many of the stars had changed colour in the lapse of ages ; some being described as red, which are now white. I do not, however, attach any importance to the remark, because the ancients used the names for colours with the utmost latitude and variety of significations. *Rubere, splendescere, purpurascere*, and many others only signified to shine brightly*.

Nevertheless, certain remarkable changes in some stars, and the alternate disappearance and reappearance of others, while some have been actually lost, seem to warrant an opinion that the gradual work of destruction and reproduction, so conspicuous through all mundane nature, is likewise going forward on a grand scale among the ponderous systems of worlds which fill eternal space. This consideration does not bear immediately on the subject under discussion, but it ought to be kept collaterally in view.

Hitherto we have been discussing the probable causes of the colour of the fixed stars shining by their own light, and have supposed the differences of colour to result from the respective composition of the light of each. But in considering the planets which shine only by reflecting the light of the sun, we have other things to take into the account. If the planets have no light of their own, the difference observable in their respective colours must arise from a difference in the dispersive powers of their own respective atmospheres, through which the sun's reflected rays may be separated in their passage. We know, indeed, little or nothing about the composition of planetary atmospheres ; but analogy would lead us to ascribe the variations of their light rather to properties of their surrounding atmospheres, than to the colour or other qualities of the substance of the planet itself. It may be observed, that the particular position of the Ring of *Saturn* does not affect the colour of his prismatic spectrum, and therefore probably it throws back the same sort of light as the body of the planet does. Of what are called the Belts of *Jupiter*, we know almost nothing ; but we may conjecture that they may have some-

* See Phil. Mag. vol. xlix. p. 49, where I have endeavoured to refute this idea.
thing

thing to do with the peculiar tendency of this planet to produce a bad spectrum for observation even in the best telescopes. Out of the consideration of the chromatopoeitic property of the atmospheres of the planets, a question arises, Whether that property be subject to variation? There is a manifest difficulty in ascertaining this, because the reflected light of the sun passes through our own atmosphere as well as that of the planet; and consequently we cannot always tell to which atmosphere to refer any colour which we may observe in the spectrum. Observations made on two or more planets at once, where the changes in the light of the two or more severally did *not* correspond, might lead more directly to the solution of this question. But we are getting now away from our object, and must retrace our steps before we wander too far into the wide field of speculation which lies open before us. Observations are as yet wanting to establish and systematize the facts briefly alluded to above; but it is to be hoped, from the united efforts of numerous astronomers and meteorologists now beginning to be in communication with each other all over the world, that the desiderata, *quantum possunt*, will be supplied. The present subject affords an example of the natural connection between the two sister sciences, and affords a hope that the many learned men who compose the Astronomical and Meteorological Societies will cooperate in the attainment of a common object, and that the peculiarities and variations of atmospheric refraction will be more fully known than they have been hitherto, by the multiplied observations of individuals acting in concert*.

Of the Colours of the Moon.

The *Moon* viewed in the prism seems to possess all the colours; and their proportions, as far as we can judge, are very similar to those observed in *Venus*. But the observations I am about to make on the lunar disk, are intended rather to confirm a point that I am contending for in meteorology, than to establish the proportion which her component rays of light bear to

* It appears that the ancients were not inattentive to the different colours of the planets.

Pliny thus distinguishes them; which, though not a very clear description on account of the very promiscuous use of names for colour among the ancients, shows at least that considerable differences in their light had been observed even in his time. In *Hist. Nat.* lib. ii. cap. 18. we find, "*Suis quidem cuique color est; Saturno candidus, Jovi clarus, Marti igneus, Lucifero candens vesperi refulgens, Mercurio radians, Luna blandus. Soli cum oritur ardens postea radians.*" He then goes on to notice the varying colours of the same planets and of the Sun at different altitudes and in different states of the atmosphere. Of the observations of the ancients I shall say more in a future Number.

each

each other. Viewed as I have seen her from the heights of mountains and in the clearest nights, she appears of a brilliant white light. And the varying colours of her disk seem to be caused by varieties in the colouring power of our atmosphere alone. What I am trying to clear up is, that astronomers, in considering the refractive powers of atmospheric air, have overlooked the circumstance that there is almost no state of the air in which the diffusion more or less of aqueous gases or cloudiness does not exist, though in a very small degree; and that on this diffusion of cloudiness depends in a greater degree than is imagined, the dispersive power of the atmosphere and the peculiar colours of the celestial bodies seen through it.

I shall conclude my remarks on the *Moon* with the description of a curious lunar refraction, which I observed some years ago. About seven o'clock in the evening, the *Moon* being five days old, I noticed a remarkable double refraction of her image of the following form and relative position D D , that is, two distinct crescents instead of one, and both so precisely similar as not to be distinguished; so that I said to a gentleman who was with me, "Which do you think is the *Moon*, and which the *paraselene*?" Neither of these images was coloured, and both were as bright as the ordinary brightness of the *Moon*. The cause of this phenomenon did not suggest itself at the time; but I have since thought that it so much resembled the double refraction by which two images are seen in certain laminated spars, that it might be referrible to the same cause, and that it might be an indication that there existed atmospherical laminæ at that time. I do not conceive that the existence of laminated air is by any means improbable, and it may be connected possibly with the various contrary currents of air, which exist contemporaneously in successive altitudes in the atmosphere, of which observations on the varying direction of small air balloons have furnished me with abundant proof.

The above subjects deserve more consideration than they have hitherto met with, and I trust many members of the Society will co-operate with me in pursuing them.

P.S. Since I wrote the above, I have repeated various observations on the stars and planets with a prismatic glass of another kind, the adaptation of a prism to the eye glass of the telescope being at all times an awkward contrivance. The results have varied, however, but little from those above stated, and I subjoin the following rude table of the spectra of the stars observed during the present month, and arranged according to the intensity of light of the stars severally.

Hartwell, Feb. 3, 1824.

Table representative of the Singularities of Starlight.

N.B. The signs under the names denote whether the stars require that of a mean correction of plus +, or of minus -, than the ordinary Refraction Tables; = signifies they equal it; doubtful is marked with a ?.

Name of star.	Brilliance or dullness.	Apparent colour.	Whether or not twinkles much.	Alteration of colours in the fluctuation.	Prismatic spectrum.
SIRIUS. +	Very brilliant.	White.	Considerably.	Alternates with red faintly.	Beautiful violet, and the most refr. colours.
PROCYON. +	Brightish.	White.	Less than the preceding.	Not discernible.	Less violet, and more yellow than Sirius.
VEGA. +	Brilliant.	Blueish white.	Considerably.	Alternates slightly with red.	Resembles Sirius, but more blue.
CAPELLA. =	Bright.	Yellowish.	Less than the preceding.	Very little.	Much yellow light, and the mean colours.
ARCTURUS. -	Bright.	Reddish.	Considerably.	Not strong.	Much red light, and the less refr. colours.
ALDEBARAN. -	Steady.	Red.	Inconsiderably.	Very slight, with a greater degree of red.	Much red light, and the less refr. colours.
BETALGEUS. -	Steady.	Red.	Rather more than the last.	Rather more than the last, and the same sort.	Much red light, and the less refr. rays.
SPICA VIRGINIS. = ?	Somewhat less bright.	Blueish white.	Very little.	Inconsiderable.	Much intense green light, and also the more refr. colours.

It may be noticed that the alternating colours observed in the fluctuation, and recorded in the 5th column of the table, are *cæteris paribus* most observable when the stars are near to the horizon; and I have observed that the maximum of the intense red colour which distinguishes the alternate change happens at the elevation of about 10 degrees above it.

The phenomena noticed by Kepler in the new star discovered by him in 1604 in *Serpentarius*, and now lost, if rightly recorded, afford a striking instance of the converse of what we usually observe. For in that large and memorable star, the colours were continually changing when the star was *high*, but when it got *near to the horizon it was uniformly white*. It is much to be wished that observations had been made on the changeable stars and on those that are now quite lost. The *Stella mira* may afford interesting observations. Comets ought also to be very accurately observed. The great comet of 1680, which is expected again in 1833, will probably be the subject of much curious research.

The ordinary distribution of stars into the 1st, 2d and 3d degrees of magnitude, and so on, though it may serve common purposes, is nevertheless very imperfect; the stars recorded as being of the first magnitude differing as much among themselves as some of them do when compared with those of the reputed 2d magnitude. In the above table of large stars, I have endeavoured to arrange them in the order of their apparent size and intensity of light, the best way of ascertaining which is by observing the relative degrees of light in which each can first be seen, either at evening or morning, measured by a photometer. But it is evident that this plan will include also their brilliancy, which is a thing quite different from their apparent size. Some small stars have a more piercing light than others for their size, as the Pleiades, for example. In order therefore to ascertain and compare the relative apparent size alone, we must trust a good deal to our own judgement.

It is my intention to pursue the above subjects, and to make as accurate comparisons as I am able between the light of individual stars, dispersed by means of prismatic glasses adapted to telescopes, and the light of various combustible substances in a state of ignition viewed through prisms.

There have appeared to me to result some very extraordinary phenomena, from the adaptation of a prismatic glass to different parts of the telescopes: but as I cannot account for them on any known principles, I only state the fact as a hint, in order that others may repeat the experiments. Finally, we must ever bear in mind that the retina, and the cerebral parts in connection with it, are a necessary part of the optical ap-

paratus which we employ in all experiments on light; and we must guard against being deceived by any peculiarities or affections in our own organs of vision, which we need not fear, provided only we make the same experiments repeatedly and with due attention.

[To be continued.]

XXXV. *Description of a new Micrometer.* By M. FRAUENHOFER of Munich.*

THERE is probably no instrument, if we except the heliometer, better adapted for determining the right ascension and declination of two stars, than the circular micrometer. To this simple instrument, which can be applied to any telescope provided with a good stand, we owe, besides many other important observations, a great part of those made on comets. Improvements in this instrument are therefore desirable.

Some astronomers still prefer the rhomboidal micrometer for determining the relative places of two stars. It cannot be denied that the calculation of observations made with such a micrometer, is more simple than that made by the circular micrometer, and that the result possesses about the same degree of exactness, whether the difference of declination of both stars be great or small; while in observations with the circular micrometer we ought to have, for a smaller difference of declination, a smaller circular micrometer also. Any one possessed of practical knowledge will soon perceive that a rhomboid, in whatever manner it may be made, cannot obtain the prescribed form to such a degree of accuracy as is required for good observations; whilst, on the contrary, there are several means of making a circle to a great degree of exactness. It cannot be expected to file out a hole exactly in a rhomboidal shape. We may indeed obtain a rhomboid with straight lines, by screwing together bars of equal breadth ground perfectly straight; but to give the required angles of the rhomboid is not very practicable. In stretching four wires, in the form of a rhomboid, we have to encounter the same difficulties, as far as regards the angles of the rhomboid; besides this, there is seldom a piece of wire exactly straight, even if ever so strongly stretched; but thin wires cannot be made use of for the purpose, because in a dark field of view they cannot be seen. This is the reason why circular micrometers have such a decided preference.

With the circular micrometer, consisting merely of the dia-

* From M. Schumacher's *Astronomische Nachrichten*, No. 43.