

pages 138 and 139, so that the true parallax is  $8''.578 (1 + \mu)$ , the value of  $\mu$  is determined as follows:—

Compared with the Cape Obs.	Limb.	Value of $\mu$ .	Parallax of $\odot$ from mean of preceding.
Cambridge .....	North .....	+ 0.0127	} ..... $8''.588$
.....	South .....	— 0.0102	
Greenwich } ...	North .....	+ 0.0895	} ..... $9''.076$
(Troughton) } ...	South .....	+ 0.0265	
Greenwich } ...	North .....	+ 0.0632	} ..... $9''.343$
(Jones) ..... } ...	South .....	+ 0.1152	

“The chief inference,” Mr. Henderson remarks, “to be drawn from the above observations appears to be, the probable accuracy to be expected from similar observations at future periods.”

Mr. Henderson states that the season in which these observations were made was not favourable for delicate astronomical observations at the Cape, as the south-east wind was generally prevalent, during which the atmosphere is in a disturbed state. The season best adapted for accurate observations there is from March to October, or during the winter months.

#### IV. On a Clock for giving Motion in Right Ascension to Equatorial Instruments. By the Rev. R. Sheepshanks.

The usual mode of measuring the distances and angles of position of double stars, or the diameters of planets, is, to give a motion in right ascension to the whole instrument with one hand, equivalent to the apparent motion of the heavens, while the micrometer is managed with the other. The whole difficulty of the manual part of the operation consists in giving the former of these motions; for if by one hand we could *exactly* give the motion of the heavens, the management of the micrometer would be identical with the use of a circular protractor with one hand. The higher the magnifying power of the telescope, and the larger the instrument, the more troublesome, of course, it is to give this most delicate motion. It is probably owing to a difficulty of this kind that Sir John Herschel found “that the disuse of this species of observation for three or four years, had so far impaired his habit of exact measurement as to deprive him for some time of confidence in his results,” and that the measures of distances are less satisfactory than those of position.

At first sight it might be thought that the increased difficulty of manipulation which accompanies an increased size of the instrument, depended solely on the greater magnifying power. This is by no means the case. The hand, it is true, in a large as well as a small instrument, is capable of giving a tolerably smooth and regular motion for about half a revolution of the wrist, after which it must be relieved, but this motion must be communicated to the hour circle by a handle and Hook’s joint. Now the Hook’s joint does not *transfer* an equable motion, unless the tangent screw and the handle are nearly in the same straight line; a condition obviously impossible in a large instrument, except for a small portion of the heavens. Hence the observer is required to

humour the instrument, and accommodate his hand to the compounded motion of the heavens and the Hook's joint, which will be different in almost every situation. The increased weight and flexibility of a long handle adds very materially to the difficulty.

But this is not all, nor the worst consequence of greatly increased dimensions. When one hand is exhausted in giving the motion in  $\mathcal{R}$ , the other must be immediately brought from the management of the micrometer to its aid, in order to continue the motion, otherwise there will probably be a bobbing or rocking motion given to the whole machine, arising from the *inertia* of the mass. It seems almost unnecessary to do more than advert to this obvious consequence of increased magnitude; but as the subject is one of primary importance, and as upon this point the necessity of clock-work motion for large equatorials mainly rests, it is proper to explain it very briefly.

Matter when at rest requires force to put it in motion, and matter once put in motion requires force to stop it; in either case the matter does not move or stop until a sufficient force is brought into action. When the matter is movable about an axis, the force required for moving or stopping its motion is proportional to a quantity which is called the "moment of inertia." This moment of inertia is estimated by the quantity of matter multiplied into the square of the radius of gyration. Now in similarly constructed instruments the quantity of matter is as the cube of the linear dimension, and the radius of gyration is as the linear dimension; hence, the moment of inertia varies as the *fifth* power of the dimension. Thus, if there were two equatorial instruments similarly constructed, one of which was four times as large as the other, the moment of inertia in the one case would be more than 1000 times that in the other. It is certain, therefore, that after any change from motion to rest, or *versá vice*, the tendency of the instrument to shoot beyond, or to lag behind its proper place, would be a thousand times greater in the large than in the small example; and it is almost certain, that no clamp or strength of framing could resist this tendency to produce oscillation or tremor in a stand of such colossal dimensions as would be required for the large refractors now constructed, and in the telescope itself.

From these remarks it seems to follow, that if a large equatorial is to be successfully used by hand, not only must one hand be perpetually employed in giving a uniform motion by varying and ununiform means, but that after every half revolution of that hand, handle, and tangent-screw, the other hand must be withdrawn from the micrometer to keep up the motion until the former can resume its grasp.

Whether, with all these precautions, the operation could really be performed with high magnifying powers, it is difficult to predict. The perfect education of both hands, and the subordination to the eye and judgment required for giving a smooth and equable motion in right ascension, would be a hard lesson to learn, and yet the attention must be left perfectly free for the purpose of actually

measuring the angle of position and the distance of the stars. If clock-work can be applied to give this uniform motion in  $\mathcal{R}$ , without injuring the performance of the telescope, it evidently reduces a great difficulty to a very simple operation.\*

The essential qualification of a clock for moving an equatorial is, that it should go *smoothly*. It is comparatively of little importance that it should be well regulated, provided the variations in the rate are not such as to cause any jerk or tremor in the telescope. Hence, almost any train of well-cut wheels, with a heavy fly-wheel and a fan for regulating the velocity, would, I believe, answer the purpose of a clock movement in  $\mathcal{R}$  for the measurement of double stars. By a little care in proportioning the weight and the fan, it would be easy to bring the rate tolerably near—to one-hundredth of the truth. There would, therefore, be a small, and, it might be, a varying motion, which is to be corrected by moving the whole of the eye-piece, micrometer and all, that quantity each minute. Now this is precisely the same thing as giving a direct motion by the fine screw carrying the eye-piece, without a Hook's joint, to an instrument of 100th part of the magnifying power, and is therefore easy enough; and if the hand does for a moment forget its duty, there will be no bobbing or rocking. With a little attention to the clock, the star is easily kept in the best part of the field. A movable or slipping piece, pressed by a screw against a spring, instead of the fixed eye end, is all the addition to the ordinary fitting up of the telescope that is required; and the motion of this is as smooth and within command as that of the micrometer itself. Such an addition to the eye-end is convenient, and perhaps necessary, wherever clock-work is to be applied.

A clock of this kind, but with every disadvantage of workmanship, contrivance, &c., I have applied and used; and so far as the limited power of the telescope would allow others as well as myself to form an opinion, with perfect success. (The telescope was a good  $3\frac{1}{2}$ -feet, with a magnifying power above 100.) It may, therefore, be considered as proved, that a smooth motion communicated to a tangent screw, will produce a smooth motion in a properly constructed polar axis of very large dimensions; and besides the trial above alluded to, which was perhaps as unfavourable and coarse as could be imagined, I may add, that I was informed by Sir J. Herschel that he had given a tolerably satisfactory motion to his 7-feet equatorial, with machinery of no higher pretensions than could be made out of a worn-out smoke-jack.

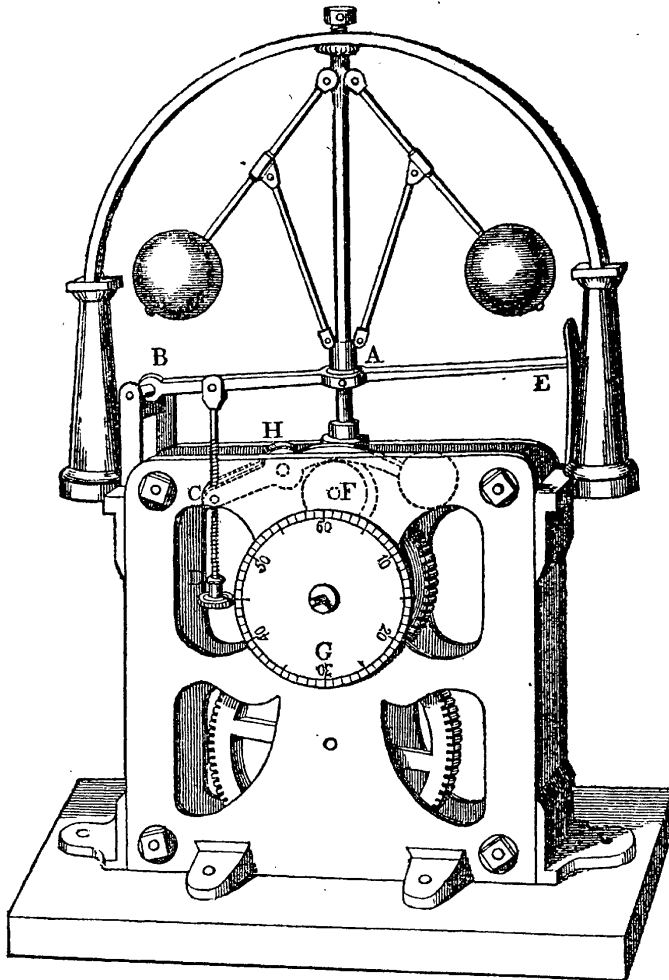
But such a movement as this, though incomparably better

\* In the description of the large equatorial at Dorpat by Fraunhofer, Professor Struve says of the clock movement: "A main use of the clock is for measurements with the wire micrometer, since by it the diurnal motion of the heavens is destroyed, and the measures taken as if the heavens stood still. This is an invaluable advantage. The convenience of an equatorial movement and clock-work is evident for observing emersions of stars behind the moon," &c.

than the unassisted hand, is deficient in one respect, viz. in *regulation*, or keeping a uniform rate. I know but of two attempts which have been made to produce a *uniformity of rate*, one by M. Gambey of Paris, and the other by Fraunhofer.

The construction of Gambey may, perhaps, be understood by the following description:—Take a very powerful half-seconds clock, that is, a clock possessing a much more powerful spring or going weight than is needed for the performance of the clock. Now if the tangent screw of the equatorial were attached to one of the arbors of this clock, the instrument would go *regularly* but not *smoothly*; it would receive a small motion every half second, with a following rest, and (leaving out of view the subordinate oscillations produced) the stars would appear to move forward for half a second and then skip back perpetually. It would therefore be quite impossible to use such an instrument, which would be in continual agitation and tremor. M. Gambey, therefore, instead of attaching the arbor of the clock *directly* to the tangent screw, attaches it to one end of a spiral spring, the other end of which is fixed to the circumference of a toothed wheel, which in other respects revolves freely upon the same arbor. This toothed wheel moves the tangent screw of the equatorial. It is evident that the clock, when going, coils the spiral spring, and coils it ever until the toothed wheel gets relief by moving the tangent screw. The variation of force upon the tangent screw, when the whole is in motion, is only equal to the additional coiling of the spring by the motion of the arbor in half a second, which may be made insensible.

The construction of the clock-work applied by the celebrated Fraunhofer to Professor Struve's telescope is, in principle, scarcely different from that which is described hereafter. In the Dorpat telescope, the train of wheels gives motion to a horizontal flyer, through which again motion is given to the tangent screw of the equatorial. The *regulation* lies wholly in this flyer. Conceive a cross piece fixed on a vertical axis, and to each end of this cross piece an arm to be attached, turning upon a joint, and carrying a bob at its extremity. The arms are not allowed to turn round so far upon the joint as to be a continuation of the cross piece; there are springs adjustable with screws, which, pressing at their shorter ends, keep them inclined at an angle. When the machinery is put in motion, the vertical axis turns round, carrying the cross piece; and the bobs, on account of the centrifugal force, extend the arms which carry them. A sort of cover, not unlike an extinguisher, is brought over the balls, against the inner surface of which they rub, and lose all extra force, and by raising or depressing the vertical axis within the extinguisher, the rate can be altered at pleasure. In the actual construction of the Dorpat equatorial, the tangent screw does not carry the instrument, but is assisted by a counterpoise weight.



The clock\* which I propose to employ for carrying a large equatorial, has been executed, as in the accompanying wood-cut, by Mr. Simms, partly at my suggestion, and will be easily comprehended. A train of wheels carries a *governor*, the same in every respect as the ordinary governor of a steam-engine. The balls, when extended, elevate a well-turned collar marked A. This collar raises the lever BE, movable upon a fulcrum B, by means of two opposite pins closely fitted into a groove in the collar. A second lever CH, movable round a fulcrum H, is attached to EB by a connecting rod CD, which can be shortened or lengthened at pleasure by turning the screw-head at D. When the balls are at the proper elevation, the other side of the lever CH presses upon a wheel F, which is carried on the arbor of seconds, and by its friction prevents any increase of rate.† At E is a scale, upon which may be

\* This clock was exhibited, and the power and steadiness of its motion shewn, at the meeting.

† Friction has been objected to as a regulating power, but, as it seems to me, from not duly considering the problem to be solved. In a machine for the purpose required it is a matter of no moment what quantity of power is thrown away, provided the motion retained be uniform; the object is to get a smooth and regular motion, at any cost, not to regularise and make the most of a given supply of power. Additional wear is not worth consideration; and there are many reasons, both of convenience and accuracy, why the clock should be at all times far above its work.



marked the position of the lever when going sidereal, solar, lunar, or other time, to any of which the clock is adjustable at once by turning the screw D.

The graduated circle G is fixed by friction to the minute arbor, and revolves with it, so that the seconds of the equatorial clock may be set at once to the standard clock, and a clicking spring is fixed on the second's arbor, which may easily be put into beat with the standard. If wanted, minute and hour circles might be added. A going-spring is applied, so that there is no stoppage in winding.

It is proposed to attach the end which carries the tangent screw of the equatorial to the arbor of minutes, which, however, requires the wheel-work above that arbor to be very truly made; or the motion may be transferred by a worm on the arbor of seconds, the regularity of which depends solely on the truth of the bevel-wheels, as the governor must necessarily revolve uniformly. The double lever is exactly counterpoised by the balance-bob, seen on the right of F.

By making the attachment of the rod DC nearer to B, or by increasing the radius of the wheel F, the action of the break may be made just what we please; but I believe the clock here described is nearly as insensible and steady under alterations of weight and work as can be wished.

The largest and heaviest equatorial I have ever seen, was moved, as well as I remember, by a force of about 12lbs. applied at the hour circle, and the diameter of the hour circle being four feet, we may take the force required to carry such an instrument to be 12lbs. descending six inches per hour, or 1 lb. descending 72 inches in the same time.

The weight of this clock falls about four feet in an hour, hence if we conceive the friction of the tangent screw to be nothing, a weight of  $1\frac{1}{2}$  lbs. on the clock would carry the equatorial above alluded to.\* Now two pretty careful trials have shewn me that the addition of a weight of 12 lbs. accelerated the clock three seconds per hour, and a weight of 28lbs. accelerated it seven seconds per hour. Hence 4 lbs. alteration in weight or work alters the rate only one second per hour; the duty, therefore, of carrying the large equatorial above alluded to would not alter the rate  $0^s.5$  per hour, excluding friction. If the clock were very nearly rated by the lever apparatus, the addition or subtraction of weights would afford a very delicate means of completing the adjustment to time. The gain of the clock in these trials was so uniform and regular as to lead me to imagine that it might be used for short intervals as a journeyman.

The motion is to be transferred from the clock to the tangent

\* As it is only a *variation* of weight, resistance, friction, &c. that is to be guarded against, I conceive, with proper care, and abstracting unnecessary sources of error, such as bad balancing of the instrument, rough handling, exposure to gusts of wind, &c. this variation cannot be estimated to be more than a very few ounces added to or subtracted from the moving weight of the clock.

screw of an equatorial by a rod and Hook's joint. The rod is formed of one tube working for a little space within another tube, and the friction between these may, by screwing a nut, be made any quantity required. In use it would be proper that this friction should be great enough to insure the motion of the tangent screw when carrying the instrument, yet not so great as to resist *violently* the turning the tangent screw by hand in order to bring the star into the best portion of the field. With a little practice, any defective setting for the star would be corrected very nearly by a single touch of the tangent screw.

The final bisection would be then completed by the motion of the eye-piece in right ascension, and the observer be enabled to make his measures with great ease, I conceive almost, if not altogether, as satisfactorily as if the stars were immovable.

V. Stars observed with the Moon at Cambridge Observatory, in the month of March 1834. Long.  $23^s,54$  east of Greenwich.

Month and Day.	Name of Object.	Clock Time of Transit.			Clock's losing rate.
		h	m	s	
March 16.	Moon 1 L. ....	4	8	26,45	2,24
	$\alpha$ Tauri ....	4	25	54,92	
18.	$\zeta$ Tauri ....	5	27	9,98	1,80
	$\epsilon$ Tauri ....	5	42	20,02	
	Moon 1 L. ....	5	59	39,86	
	$\mu$ Geminorum ....	6	12	21,58	
	$\epsilon$ Geminorum ....	6	33	9,58	
19.	$\mu$ Geminorum ....	6	12	20,12	1,57
	$\epsilon$ Geminorum ....	6	33	8,06	
	Moon 1 L. ....	6	59	58,97	
	$\beta$ Geminorum ....	7	34	34,40	
20.	$\beta$ Geminorum ....	7	34	32,69	1,68
	Moon 1 L. ....	8	2	13,46	
	$\delta$ Cancr. ....	8	34	38,34	
	$\zeta$ Cancr. ....	8	59	12,17	
21.	$\delta$ Cancr. ....	8	34	36,84	1,80
	$\zeta$ Cancr. ....	8	59	10,54	
	Moon 1 L. ....	9	4	58,63	
	$\nu$ Leonis ....	9	48	39,58	
	$\alpha$ Leonis ....	9	58	53,86	
22.	$\nu$ Leonis ....	9	48	37,70	2,00
	$\alpha$ Leonis ....	9	58	52,04	
	Moon 1 L. ....	10	6	59,11	
	$\rho$ Leonis ....	10	23	24,42	
	53 Leonis ....	10	39	52,23	
25.	$\delta$ Virginis ....	12	46	28,57	1,85
	Moon 2 L. ....	13	7	1,34	
	$\alpha$ Virginis ....	13	15	41,48	
	$m$ Virginis ....	13	32	8,39	

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