

ASTRONOMY

Distance of the Stars

"A Classic of Science"

While the Orbits of the Planets Fell Into Line When Newton Applied His Theory, the Stars Remained Remote

THE MATHEMATICAL PRINCIPLES OF NATURAL PHILOSOPHY, by Sir Isaac Newton; translated into English by Andrew Motte: to which are added NEWTON'S SYSTEM OF THE WORLD . . . London: 1819. (Philosophiæ Naturalis Principia Mathematica, 1687).

IF THE earth is supposed to stand still, and the fixed stars to be revolved in free spaces in the time of 24 hours, it is certain the forces by which the fixed stars are retained in their orbs are not directed to the earth, but to the centres of the several orbs, that is, of the several parallel circles, which the fixed stars, declining to one side and the other from the equator, describe daily; also that by radii drawn to the centres of those orbs the fixed stars describe areas exactly proportional to the time of description. Then, because the periodic times are equal (by cor. 3, prop. 4, book I), it follows that the centripetal forces are as the radii of the several orbs, and that they will perpetually revolve in the same orbs. And the like consequences may be drawn from the supposed diurnal motion of the planets.

That forces should be directed to no body on which they physically depend, but to innumerable imaginary points in the axis of the earth, is an hypothesis too incongruous. It is more incongruous still that those forces should increase exactly in proportion of the distances from this axis; for this is an indication of an increase to immensity, or rather to infinity; whereas the forces of natural things commonly decrease in receding from the fountain from which they flow. But, what is yet more absurd, neither are the areas described by the same star proportional to the times, nor are its revolutions performed in the same orb; for as the star recedes from the neighboring pole, both areas and orb increase; and from the increase of the area it is demonstrated that the forces are not directed to the axis of the earth. And this difficulty (cor. 1, prop. 2) arises from the twofold mo-

tion that is observed in the fixed stars, one diurnal round the axis of the earth, the other exceedingly slow round the axis of the ecliptic. And the explication thereof requires a composition of forces so perplexed and so variable, that it is hardly to be reconciled with any physical theory.

That there are centripetal forces actually directed to the bodies of the sun, of the earth, and other planets, I thus infer:

The moon revolves about our earth, and by radii drawn to its centre describes areas nearly proportional to the times in which they are described, as is evident from its velocity compared with its apparent diameter; for its motion is slower when its diameter is less (and therefore its distance greater), and its motion is swifter when its diameter is greater.

The revolutions of the satellites of Jupiter about that planet are more regular; for they describe circles concentric with Jupiter by equable motions, as exactly as our senses can distinguish.

And so the satellites of Saturn are revolved about this planet with motions nearly circular and equable, scarcely disturbed by any eccentricity hitherto observed.

That Venus and Mercury are revolved about the sun, is demonstrable from their moon-like appearances: when they shine with a full face, they are in those parts of their orbs which in respect of the earth lie beyond the sun; when they appear half full, they are in those parts which lie over against the sun; when horned, in those parts which lie between the earth and the sun; and sometimes they pass over the sun's disk, when directly interposed between the earth and the sun.

And Venus, with a motion almost uniform, describes an orb nearly circular and concentric with the sun.

But Mercury, with a more eccentric motion, makes remarkable approaches to the sun, and goes off again by turns; but it is always swifter as it is near to the sun, and therefore, by a radius

drawn to the sun, still describes areas proportional to the times.

Lastly, that the earth describes about the sun, or the sun about the earth, by a radius from the one to the other, areas exactly proportional to the times, is demonstrable from the apparent diameter of the sun compared with its apparent motion.

These are astronomical experiments; from which it follows, by prop. 1, 2, 3, in the first book of our *Principles*, and their corollaries, that there are centripetal forces actually directed (either accurately or without considerable error) to the centres of the earth, of Jupiter, of Saturn, and of the sun. In Mercury, Venus, Mars, and the lesser planets, where experiments are wanting, the arguments from analogy must be allowed in their place. . . .

One System of Bodies

Because the fixed stars are quiescent one in respect of another, we may consider the sun, earth, and planets, as one system of bodies carried hither and thither by various motions among themselves; and the common centre of gravity of all (by cor. 4 of the laws of motion) will either be quiescent, or move uniformly forward in a right line: in which case the whole system will likewise move uniformly forward in right lines. But this is an hypothesis hardly to be admitted; and, therefore, setting it aside, that common centre will be quiescent: and from it the sun is never far removed. The common centre of gravity of the sun and Jupiter falls on the surface of the sun; and though all the planets were placed towards the same parts from the sun with Jupiter, the common centre of the sun and all of them would scarcely recede

The American Bald Eagle

Our National Emblem
as described by
the great naturalist

AUDUBON

will be the next

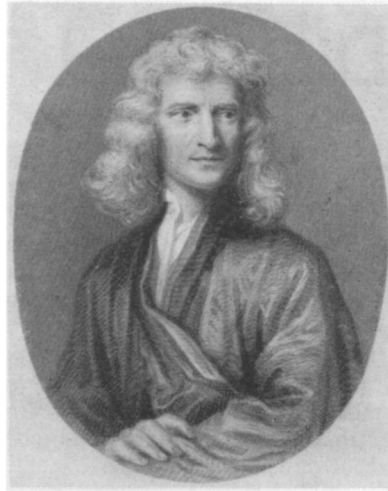
CLASSIC OF SCIENCE

twice as far from the sun's centre; and, therefore, though the sun, according to the various situation of the planets, is variously agitated, and always wandering to and fro with a slow motion of libration, yet it never recedes one entire diameter of its own body from the quiescent centre of the whole system. But from the weights of the sun and planets above determined, and the situation of all among themselves, their common centre of gravity may be found; and, this being given, the sun's place to any supposed time may be obtained.

About the sun thus librated the other planets are revolved in elliptic orbits, and, by radii drawn to the sun, describe areas nearly proportional to the times, as is explained in prop. 65. If the sun was quiescent, and the other planets did not act mutually one upon another, their orbits would be elliptic, and the areas exactly proportional to the times. (by prop. 11, and cor. 1, prop. 13). But the actions of the planets among themselves, compared with the actions of the sun on the planets, are of no moment, and produce no sensible errors. And those errors are less in revolutions about the sun agitated in the manner but now described (by prop. 66, and cor. prop. 68), especially if the focus of every orbit is placed in the common centre of gravity of all the lower included planets; viz. the focus of the orbit of Mercury in the centre of the sun; the focus of the orbit of Venus in the common centre of gravity of Mercury and the sun; the focus of the orbit of the earth in the common centre of gravity of Venus, Mercury, and the sun; and so of the rest. And by this means the foci of the orbits of all the planets, except Saturn, will not be sensibly removed from the centre of the sun, nor will the focus of the orbit of Saturn recede sensibly from the common centre of gravity of Jupiter and the sun. And therefore astronomers are not far from the truth, when they reckon the sun's centre the common focus of all the planetary orbits. In Saturn itself the error thence arising does not exceed 1' 45". And if its orbit, by placing the focus thereof in the common centre of gravity of Jupiter and the sun, shall happen to agree better with the phenomena, from thence all that we have said will be farther confirmed. . . .

To Immense Distances

Thus I have given an account of the system of the planets. As to the fixed stars, the smallness of their annual parallax proves them to be removed to immense distances from the system of



ISAAC NEWTON

As he appeared at the time the "Principia" was published.

the planets: that this parallax is less than one minute is most certain; and from thence it follows that the distance of the fixed stars is above 360 times greater than the distance of Saturn from the sun. Such as reckon the earth one of the planets, and the sun one of the fixed stars, may remove the fixed stars to yet greater distances by the following arguments: from the annual motion of the earth there would happen an apparent transposition of the fixed stars, one in respect of another, almost equal to their double parallax; but the greater and nearer stars, in respect of the more remote, which are only seen by the telescope, have not hitherto been observed to have the least motion. If we should suppose that motion to be but less than 20", the distance of the nearer fixed stars would exceed the mean distance of Saturn by above 2000 times. Again; the disk of Saturn, which is only 17" or 18" in diameter, receives but about 1/2,100,000,000 of the sun's light; for so much less is that disk than the whole spherical surface of the orb of Saturn. Now if we suppose Saturn to reflect about 1/4 of this light, the whole light reflected from its illuminated hemisphere will be about 1/4,200,000,000 of the whole light emitted from the sun's hemisphere; and, therefore, since light is rarefied in the duplicate ratio of the distance from the luminous body, if the sun was 10,000√42 times more distant than Saturn, it would yet appear as lucid as Saturn now does without its ring, that is, something more lucid than a fixed star of the first magnitude. Let us, therefore, suppose that the distance from which the sun would shine as a fixed star exceeds that of Saturn by about

100,000 times, and its apparent diameter will be 7^v. 16^{vi}. and its parallax arising from the annual motion of the earth 13" : and so great will be the distance, the apparent diameter, and the parallax of the fixed stars of the first magnitude, in bulk and light equal to our sun. Some may, perhaps, imagine that a great part of the light of the fixed stars is intercepted and lost in its passage through such vast spaces, and upon that account pretend to place the fixed stars at nearer distances; but at this rate the remoter stars could be scarcely seen. Suppose, for example, that 3/4 of the light perish in its passage from the nearest fixed stars to us; then 3/4 will twice perish in its passage through a double space, thrice through a triple, and so forth. And, therefore, the fixed stars that are at a double distance will be 16 times more obscure, viz. 4 times more obscure on account of the diminished apparent diameter; and, again, 4 times more on account of the lost light. And, by the same argument, the fixed stars at a triple distance will be 9 x 4 x 4, or 144 times more obscure; and those at a quadruple distance will be 16 x 4 x 4 x 4, or 1024 times more obscure; but so great a diminution of light is no ways consistent with the phenomena and with that hypothesis which places the fixed stars at different distances.

Science News Letter, June 18, 1932

ECOLOGY

One Acre of Forest Yields Browse For One Deer

HOW much ranging land does a deer need if it is to find sufficient food? This question, perplexing to foresters and others associated with game reserves, has been answered for the Pennsylvania woodlands by Drs. E. B. Forbes and L. O. Overholts of Pennsylvania State College.

Their observations indicate that at least one acre of the best forest browse, or greenery, is needed during the growing season to support a single deer, while during the winter a much larger area of sparser browse is required.

The investigators obtained their data from the study of four deer who were confined in a woodland inclosure of 4.87 acres from one spring through the following autumn. The results, they state, represent the upper limit of the very wide range of variation in the capacity of forests to support deer.

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