DELLA REALE ACCADEMIA NAZIONALE DEI LINCEI

Session of 13 January 1924.

V. Vor.TERRA, President.

MEMBERS AND NOTES OF MEMBERS

Astrophysics. - *The constitution of variables of the "Mira Ceti" according to the ballistics hypothesis on the velocity of propagation of the light*.

Note from Correspondent **M. La Rosa** ([1]).

In a brief Note presented to this R. Academy ([2]), I had the opportunity to hint at a new explanation of the phenomena of the "stars variables", based on the following assumptions:

1°) that the speed of light is composed with that of the source bright;

2°) that all variable stars are double, or more generally "complex stars".

This second hypothesis contains the extension of a fact directly revealed by observations, telescopic and spectral, in the case of variables of the 3rd class of Scheiner (those of type Algol, and of type β Lirae, 45 in all). For which, indeed, the knowledge of their "double" nature is served to give, albeit in an imperfect way ([3]), the reason for the periodic change of apparent size; ascribing it - as is known - to occultation periodicity of one of the component stars for part of the other.

For the remaining variables - a few thousand are known - it is not it has never been admitted that they can be "double", not by virtue of results directly acquired, although due to the impossibility of explaining: on the basis of this

([1]) Presented in the session of 2 December 1923.

([2]) Vol. XXXII Ser. 5a, 1st sem, phase. 12, p. 590, 1923.

([3]) Cf. in this regard my work on Memorie della Società Astr. Ital., July 1923.

eventual constitution of theirs, the complex details of the periodical change in size.

Now a recent discovery, made in the Lick Observatory, assures us that *the most typical and most interesting of the 2nd class "variables", the Mira Ceti, has an optically visible companion* ([1]).

Not many words are needed to emphasize *as important confirms this discovery has led* to the theory of variables that I traced, and how I feel encouraged by it to develop those here considerations that I had already sketched around variables of this type a previous Memoir of mine ([2]).

The o Ceti, which was already called Mira for its wonderful behavior, has the following important characteristics:

a) a *variable* period whose average value is approximately 332 days;

b) periodic changes also in the values of the maxima and minima of the apparent size, since the maxima (minimum order of the class) vary between steps 1.7 and 5.0 on the scale of magnitudes, and the lowest between steps 8 and 9.5.

Our aim is therefore to show how these characteristics can be found, in a simple and flat way, admitting that the light obeys the law of composition of velocities, and that the "variables" of the type or Ceti are "systems" analogous to our planetary system, constituted, that is, of a large central star around which other bodies revolve, however strongly incandescent.

On the contrary, it helps to clarify and evaluate the broad scope of the our considerations, put ourselves on the ground of concrete facts, and yet let us propose ourselves to examine what hypothetical distant inhabitants could have observe on our solar system, when the bodies that compose it (per simplicity we consider only the major planets and assume their orbits circular) were still in a state of very vivid incandescence. Remembering what I have explained in the aforementioned Note, and keeping in mind the average distances *r* of the various planets from the Sun (which are given by the following numbers, being 1 the mean radius of the Earth's orbit). It is certainly evident, that for a certain point of

	r	r^2		r	r^2
Mercury	0.89	0.150	Jupiter	5.20	27.04
Venus	0.72	0.515	Saturn	9.54	91.01
Earth	1.00	1	Uranus	19.18	368
Mars	1.52	2.31	Neptune	30.05	900

observation, place at the distance *a* from the Sun, not all these planets could have given rise, with their motion, to the light fluctuations that are the object of our study.

([1]) To the Ch.mo prof. V. Cerulli, who has had the kindness to inform me of this news, I offer my warmest thanks!

([2]) Mem. Soc. Astr., l. c.

In my Note ([1]) I showed indeed, that in order for these fluctuations can be appreciable it is necessary that the quantities indicated with the symbols K and b satisfy the (approximate) limitation,

(1) $$0.1<\mathrm{K}b<5$$

indeed because these fluctuations can be really *conspicuous* it is necessary that the product itself satisfies the limitation:

(1') $$0.16<\mathrm{K}b<1$$

Bearing in mind that $\mathrm{K} = a/\tau$, being τ the period of revolution, and that $b = v/c$, v being the (average) tangential speed of the revolving star, we have:

(2) $$\mathrm{K}b = 2\pi ar/\tau^2$$

and then making the ratio between the Kb products belonging to two planets different, and keeping in mind Kepler's 3rd law we have:

(3) $$\frac{\mathrm{K}_1 b_1}{\mathrm{K}_2 b_2} = \frac{r_1}{r_2}\left(\frac{\tau_2}{\tau_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^2$$

This relationship - taking into account the limitation (1') - shows us that not all planets could have given rise to fluctuations *simultaneously* conspicuous of light in the observation post.

With the help of the last relation and of the numbers reported in the 3rd column of the previous table (i.e. the squares of the distances) we can in fact verify that if for example at a certain observation point, Mercury showed very conspicuous light fluctuations (Kb close to 0.2) no other planet could give rise to fluctuations comparable to those of Mercury, only Venus (Kb = 0.2 x 150/515) could have exhibited weak fluctuations which would have had little effect on the changes of the other.

Equally we see, that in another observation point, for which the condition Kb = 0.2 had been satisfied for Venera; only Mercury it would have featured noticeable light changes superimposed on those of Venus (since for Earth we would have had Kb =0.2 x 515/1000 and for Mercury Kb = 0.2 x 515/150); so also in a place where Terra had satisfied the condition Kb = 0.2 also Venus and Mars would have given rise to considerable fluctuations, while at a point where the usual condition was satisfied for Mars, only Earth (Kb = 0.2 x 2.31) would have given give rise to perceptible light variations, as it would have occurred for Venus Kb = 0.2 x 231/51; and for Jupiter Kb = 0.2 x 2.3/27; and so on.

([1]) Rend. Lincei, loc. cit.

In conclusion, it can be seen that in certain regions of the world there are only three planets at most they could have satisfied simultaneously and well at the limitation related to K*b*, in certain other regions two, in certain others one, and outside these regions none.

Depending on the observer's position in the sky, our system solar would, therefore, have appeared: or as a star of invariable luminosity (last case), or as a "variable" star with simple periodicity, or as a variable with complex periodicity, due to the superposition of light effects given by two, or at most three components of the system.

Now what should be the effect of this superposition of two or of three of our light curves, of *different periods* is not difficult a guess.

Our investigation brings us back to the bottom of the problem of superimposition of more harmonic vibrations, of different periods, that presents itself in Acoustics, and may be approached and discussed by the same methods that apply in that branch of science.

Of course, I cannot afford to insist on these procedures here. It is enough for me to remind you that the simplest and most effective method of study is that of the "rotating vectors".

We know that a pendulum motion can be considered as a projection on a straight line of a *vector*, of tensor a_1 *equal to the amplitude of the motion* and rotating about an end with constant angular velocity $\omega = 2\pi/\tau$, where τ is the period of motion. We also know that if x is the projection line, and if OA and OB are the positions in the generic instant t, of the two vectors that serve to give us the two component motions, the resulting motion is given from the projection onto x of the vector OC, which results from the composition of OA and OB. Taking into account the difference between the periods of the component motions, the resulting motion is therefore given to us by the projection of the diagonal of a jointed parallelogram whose sides rotate with the angular velocities $2\pi/\tau_1$and $2\pi/\tau_2$; *diagonal* resulting *of variable size and animated with speed also variable*.

We also know that the diagram is usually constructed from this resulting motion, taking the axes of times normal to the straight line x, and reporting, with simple construction of parallel to the axes the successive positions of the projection C' of C.

These same considerations and constructions can be applied to ours case. supposed for example that two rotating bodies of the system, those of period τ_1 and τ_2, and they alone, give rise to luminous fluctuations in the observation point appreciable, our problem boils down to the study of the effects of overlapping of the two light curves.

Although these are "periodic", they generally do not have a simple form, and therefore to use the indicated method it will be necessary to decompose them into oscillations harmonics, by means of Fourier's theorem, with which we will obtain two systems of oscillations, with respective periods τ_1; $\tau_1/2$; $\tau_1/3$; ...; τ_2; $\tau_2/2$; $\tau_2/3$; ...; and of the amplitudes a_1, a_1', a_1'', …; a_2, a_2', a_2'', ….

We will then compose, with the procedure mentioned, the pairs τ_1, τ_2; $\tau_1/2$, $\tau_2/2$; $\tau_1/3$ .... (in general the first two pairs will suffice) and we will be led to a resulting oscillation whose characteristics will basically be determined by the resultant of the first pair (τ_1, τ_2), which will be more or less modified in "shape" by overlapping "harmonics" analogous to that of the fundamental oscillation.

It is easy to understand therefore, that the general character of the curve of light that results from the composition of two of different periods will be analogous to that of beat curves (in a very broad sense); it will have one double periodicity, that is, it will constitute a system of oscillations in which the amplitude and the period are successively changing, with more law or less simple, depending on the value of the ratios the (in a very broad sense); it will have one double periodicity, that is, it will constitute a system of oscillations in which the amplitude and the period are successively changing, with more law or less simple, depending on the value of the ratios τ_1/τ_2; a_1/a_2; and we will have as an inevitable result, remarkable changes in the *highs and lows of the light curve*, and changes in the period of subsequent fluctuations.

When the ratio τ_1/τ_2 is rational the resulting light curve will be *pure periodic*, that is, it will admit a period of time after which a certain succession of vicissitudes, it returns to reproduce. In other words, it exists in such case a more or less numerous group of oscillations different from each other in shape, amplitude and period, which at constant time intervals *returns* to repeat itself.

Otherwise we cannot speak, *strictly*, of *a periodic phenomenon*, not therefore the change of light will always consist of a succession of real more or less capricious oscillations of form, *variable* for amplitude and per period, which are slowly and continuously changing over time.

In any case we therefore find the characteristics of the changes of the "variables" of type "Mira Ceti".

The natural hypothesis of the existence of "complex stars" and the simple ones considerations on the composition of two periodic changes give us, therefore, enough for us to explain the behavior more than clearly irregular and full of mystery offered by the strangest of the "variable stars".

The harmonic analysis of the exactly detected light curves will allow us to get to the bottom of our problem; it will confirm us – none I doubt – my assumptions. and will teach us many things about these stars. Meanwhile, tele - or spectroscopic observation - will let us know directly *at least one second mate* of *Mira Ceti*, and complex constitution of other variables of the same type.

Strong arguments of a spectroscopic nature support and validate these my views, but I hope to dwell on them in a future study.

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