**Astrophysics**. - *Radial velocities and ballistic theory of stars variables*. Note from Correspondent M. La Rosa ([1]).

**1**. Neither can I pass over in silence a new Note from prof. De Sitter ([2]), which also aims at the end: to demolish theories from their foundation's ballistics in general, and the one I sketched for the phenomena of the "stars variables" in particular.

The main argument, with which he believes he can prove his own *the absurdity* lies in this consequence, which he causes to spring from it of a short and unclear calculation: "*that the star would in a part of its orbit have three different velocities at the same time*". Now this calculation by prof. De Sitter is correct *only formally*, but it is substantially erroneous, since such is all the reasoning that serves base and guide to the calculation itself.

The proof that he gives is based, in fact, on certain hypotheses, which they are *a priori* irreconcilable; so that the strangeness of the final result proves not the absurdity of ballistic theory, but only the impossibility of putting together with the same assumptions.

I will therefore try to prove this defect in the reasoning opposed to me; and, moreover, to highlight and *comfort this deduction with facts correct* of my theory: *the possibility of observing, in the same instant, more values than the radial speed* which, however. correspond to rays which they reach the observer at the same time, but *departed from the star in moments and from different positions*.

**2**. The hypotheses on which the reasoning of prof. De Sitter is the following:

l[a]) that light obeys the ballistic principle (i.e., that its speed composes with that of the source):

2[a]) that the radial velocities observed in variable stars are represented from law

(1) $$V = V_0 + v \operatorname{sen} 2\pi \frac{t - t_0}{\tau};$$

3[a]) that, in the particular case to which he applies hypothesis 2[a], yes, we can also suppose that the constant $\alpha$, introduced by him (the *kb* of my work), is equal to 1/2.

(1) Presented in the session of November 2, 1924.

(2) Bull. of the Astron. Institutes of the Netherlands, vol. II, n. 64, October 3, 1924.

Finally, this hypothesis is still implicit:

4ª) that all variables have a companion, who rotates around to the central star. according to an orbit lying in a plane passing through the visual. The latter and the 1ª form - it is not superfluous to remember - the essential basis of my theory.

To proceed correctly, the professor, De Sitter should have left from these two fundamental hypotheses, and make sure if the 2ª and 3ª, taken both in isolation and simultaneously, are compatible with those. This is what I will do immediately myself.

Let us therefore assume (hypothesis 4ª) that the variable star has a companion, which moves along a circle and is therefore animated by the radial velocity *effective* (and *not observed*) given by (1).

We still admit (hypothesis 1ª) that a generic ray, starting from the star *t*, reaches the observation post at instant *T*, given by

$$T = t + \frac{\Delta}{c - V} . \tag{2}$$

As a consequence of these hypotheses, the law with which the radial velocities *upon arrival*, i.e., the law of *observed velocities*, will be

$$V = V_0 + v \operatorname{sen} \frac{2\pi}{\tau}\left[\left(T - \frac{\Delta}{c - V}\right) - \left(T_0 - \frac{\Delta}{c - V_0}\right)\right]$$

[*editor*: sen = sin] which, with the usual 1º order approximation in the *V/c* ratio, it is possible to write:

$$y = \operatorname{sen} 2\pi(x - \alpha y), \tag{3}$$

where it is placed

$$\frac{V - V_0}{v} = y ; \quad \frac{T - T_0}{\tau} = x ; \quad \frac{v\Delta}{\tau c^2} = \alpha .$$

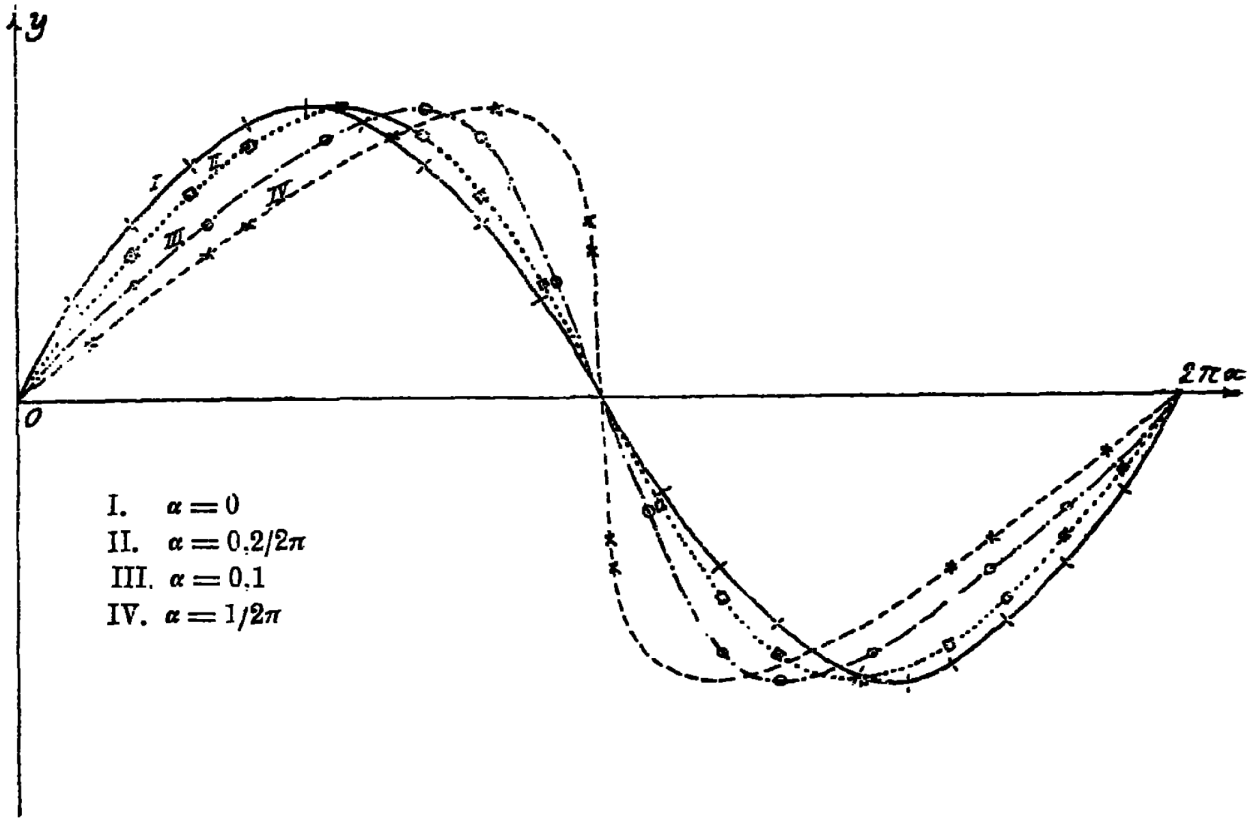
Thus, we see that the fundamental hypotheses of ballistic theory lead to assign the *law* (3)*, and not the simple sinusoidal one*, to the observed radial velocities. *is generally not compatible* with 1ª and 4ª. We will see further that it even becomes incompatible when we face α = 1/2 (hypothesis 3ª). Calculation alone gives us: a way to check correspondence of ballistic theory with observed facts, that is *a means of putting some to prove* not the "intrinsic coherence" but the "*truth" in the physical sense*.

If the law (3) proves incompatible with the observations, then (and only then), once the disagreement between theory and facts is proved, it would be rendered its abandonment is inevitable, even if its construction were -as it is- logically unassailable.

**3**. The task to be fulfilled was and is, therefore, this: to compare (3) with the observations. I will therefore resume the examination of what mine theory lets us wait in the field of observed radiation velocities, however, complete what is in my original memory.

The variety of aspects that can be presented in concrete terms these observations of "radial velocities" must depend on the value of the parameter α, the only one contained in (3).

It is certainly evident that, being $y<1$, every time that α is very small (3) is practically confused with the simple sinusoidal law. To give the reader an exact idea of the extent of the differences that I respect to this the (3) can introduce us, I think it is useful to reproduce the diagrams I- II- III- IV which gives rise to (3) for the values α = 0 (i.e., the pure sine wave), α = 0.032, α = 0.1, α = 0.16 respectively.




It can be seen, from the drawing, that, as long α <0.03, the deviations of the true law from the pure sinusoid are smaller than the measurement errors (far from small in this kind of observations); that the waste becomes more and more appreciable when α grows from 0.03 to 0.16, but which curves nonetheless (of type III) retain the general trend of a sinusoid, with these modifications: contraction of the time interval between the two extreme values; lower steepness of the ascending section, compared to the descending one.

But what matters to prove is that the general character of these curves, and more precisely, the essential property of being a function of one only value of *T*, is maintained until α ≤ 1/2π. We will easily achieve this end by referring, rather than to (3) itself, to the relation (2) that it binds the *T* to the *t*. We will reflect that, as long as each value of *T* corresponds to only one

value of *t*, will mean that at every instant the observer will see a coming only beam of rays from the moving star, and therefore will not be able to register except *one speed* only.

Indeed, more generally, if we look for the number of values of *t*, that correspond to the same *T*, we will find the number of beams of different rays which arrive crossed at instant *T*, and consequently *the number of the different radial velocities that the observer will have to record in that instant*.

In other words, our problem of determining the number of *speeds different radials observed* in each instant, boils down to the problem of the *overlaps* that I have extensively discussed.

Then the simplest way to take is this: look for the number of points where the curves $T = f(t)$, in my work drawn, are cut from a generic line $T$ = cost. Now so that such a straight line can cut the curves in *more points*, it is necessary that these have maxima or minimum, and therefore that the condition is satisfied

$$\frac{dT}{dt} = 1 + \frac{\Delta}{c^2} V' = 1 + 2\pi\alpha \cos 2\pi \frac{t - t_0}{\tau} = 0$$

which can only happen when it is

$$2\pi\alpha \geq 1, \quad \text{cioè} \quad \alpha \geq 1/2\pi .$$

[*editor*: cioè = that is] Examining the derivative. 2ª of *T*, we find that for the existence of more points of intersection, it must be $\alpha > 1/2\pi$.

So, until we have $\alpha \leq 1/2\pi$, the curve (3) of the observed velocities it has a single value: it still retains this fundamental character of sinusoidal law (for $\alpha = 1/2\pi$ we have the IV curve of the figure).

When instead $\alpha > 1/2\pi$, it is deduced from my analysis that the line T = cost. must meet the curve at a number of points that is between $2n - 1$ and $2n + 1$, when the product *kb*, i.e., α, satisfies the limitation

$$2n - 1 < 4kb - 2t_m < 2n + 1$$

where n can be and equal to 1, 2, 3, ... and $t_m$ is the time *t* that intercedes between the times *t* for which the radial velocity and the T pass for the respective extreme values.

It therefore follows from all this:

1º) that the law of variation of the observed radial velocities presents sinusoidal form until $\alpha < 0.03$;

2º) that this form is basically preserved but with scraps more and more remarkable. as long as $\alpha < 1/2\pi$;

3º) that the hypothesis of the quasi-sinusoidal of the observed speeds it becomes incompatible with the premises of ballistic theory when it is supposed $\alpha > 1/2\pi$;

4°) and in the latter case the number of observed radial velocities simultaneously it must be between $2n$- 1 and $2n$ + 1, when the quantity 2 ($2\alpha - t_m$) is included within the same limits.

It can be seen that conclusion 3ª highlights this other defect in De Sitter's reasoning: that of having applied to the observed velocities the sinusoidal law, in a concrete case ($\alpha = 1/2$) in which it was *incompatible* with the other hypotheses of the theory.

**4**. Thus find the predictions to which ballistic theory leads us for what concerns the observed radial velocities, let us briefly put them a comparison with the results of the observations.

To this end, it is interesting to recall this other result of my research: that the phenomenon of variability can be clearly appreciable, when the constant $kb = \alpha$ satisfies the relation

$$1/50 < \alpha < 5$$

and, moreover, that the changes in light are the more extensive the more α approximate l/2π, both for increasing values, and for decreasing values.

The theory, therefore, allows us to predict the existence of "doubles" non-variable and "airy", for which the observed radial velocities follow the sinusoidal law very closely. They fall precisely into this field the concrete examples that prof. De Sitter invokes.

On this point, therefore, there is no disagreement between theory and facts!!

Around such stars the theory alone compels us to admit that α is less than l/2π, and the more faithfully the simpler sinusoidal law.

But in truth, in most cases, the velocity curve, detected based on observations, it is not a pure *sine wave*.

The velocity curves provided by the observation are always sinusoids deformed, just like the curves Ill and lV of our figure ($0.03 < \alpha < 1/2\pi$). And it is known that these deformations are imputed to the ellipticity of the orbit, and that eccentricity can be calculated by means of them.

Everything that the ballistic hypothesis can then lead to different interpretation of those curves is therefore this: a change in the values of eccentricity ([1]). And this, of course, does not give rise to a contrast between theory and facts, but it does provide a daughter-in-law a way to push the investigation further into this little explored field.

Finally, the theory still allows us to predict the existence of "variables" which *present to observation three or more different speeds in the same moment:* that is *have spectra with multiple lines (double, triple, etc.)* or simply *with expanded lines* if the number of components is quite large, and their distances are small ([1]).

Now multiple *spectral lines* have been observed, in almost all "new" after Vogel first discovered the presence of double lines in the spectrum of "Nova Aurigae" (1892), and multiple lines were as well observed among the variables proper (just mention Mira Ceti, the most typical

([1]) This point will be developed on a future occasion.

of long-term variables, for which Campbell was able to discover the photograph the presence of *triple lines* in a part of the period; and the β Lyrae for which Vogel found double and more complex lines). Expanded lines come commonly observed in the spectra of variables, as you well know anyone who has had any photographs of these ghosts on their hands. And a broader agreement between theory and facts will occur - I am sure – when it will be possible to study the fine structure of these lines!

I can therefore say that the previous analysis gives us the key to a touch *observed and not yet explained*; that is, I can say that far from coming at odds with the facts, *my theory boasts in this as well field a real success* ([2])!

**5**. As for the other serious charge that prof. De Sitter does then my theory (that is, to have put itself in antithesis with the general theory of gravitation), I must sincerely declare that I really don't understand how such a misunderstanding could have arisen. No such antithesis only it does not exist, but it cannot exist, because the explicit and direct purpose of ballistic postulation is this: *to keep intact the whole edifice of classical mechanics*, as that branch of our science which is simpler and more advanced, and renew the conceptual foundations of optics and electromagnetism, which are all the younger, more complex and obscure branches ([3]).

But wanting to leave these general considerations aside and almost preliminary rulings, to stay on the modest ground of the case that concerns me, I do observe - as I have already said above - that the first hypothesis is essential of my theory is that the "variables" are made up of two or more, stars which revolve around the common center of mass, obeying the laws of mechanics, that is, to Newton's law.

**6**. Finally, I would still have to examine the statements that prof. De Sitter ago in the first part of his writing. But, while making my largest reservations on the acceptability of the law of proportionality between changes of frequency and changes in light intensity (proportionality which, in my opinion, it is not sustainable even on the ground of elastic theory and electromagnetic) it is enough for me to take note of the explicit renunciation that he makes the criticism of him in front of the fundamental problem of the renewal of our conceptions in this field.

Finally, he realized that the new facts that physics has been accumulating, have prepared a profound transformation in our conceptions on the essence of light; he saw well that the ballistic hypothesis, so strongly supported by the astronomical facts examined by me. requires

([1]) These distances depend and on the differences of the single speeds, and on the power separator of the spectra apparatus; the latter so far has not been big enough to be able to serve this new purpose of analyzing the structure of the individual lines.

([2]) Whoever wants to take the trouble to re-read my Memory will find all this and will see also how it has me allowed to approach these other two facts: non-existence of "variables" with periods greater than 550-600 days, and the existence of many stars non-variable with highly expanded line spectra; and to give a common explanation, considering them as systems for which the quantity *kb* exceeds a certain limit (approximately equal to 5),

([3]) I take this opportunity to correct an inaccuracy in which the distinguished compiler of the news concerning me has fallen into n. 2867, vol. ll4 of Nature (at the same time in which I offer him my warmest thanks for the attention paid to my work). They he believes that Michelson and Morley's interpretation of the experience may be an obstacle to ballistic theory. This is not, because the hypothesis admits precisely that, for the observer dragged by the Earth together with the light source. The propagation of rays must occur with the same speed in all the reactions.

that we take action immediately to the work of renewal, since it is *irreconcilable* with the classical conception of a "*sui generis*" perturbation of a universal medium.

The ballistic hypothesis necessarily takes us away from the conception of this continuous medium; it pushes us on that path, so strange and yet so fruitful and suggestive, already pointed out by the facts and by a powerful genius intuited: that of a discontinuous mechanism of issuance, of a constitution *quantum* of radiant energy *primordial*.

But this is not the occasion to let me pull up on this fascinating one subject ([1]). I hope to be able to deal with it in the near future.

([1]) A brief mention of these ideas is contained in my address to the Society for the Progress of the Sciences (Naples, April 30, 1924).