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The Spectroscopic System Theta Ophiuchi

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THE SPECTROSCOPIC SYSTEM THETA OPHIUCHI

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The star θ Ophiuchi ($\alpha = 17^h\ 15^m.9$; $\delta = -24°\ 54'$) was discovered by the writer to be of the β Canis Majoris type[1]. It was already mentioned as situated in one of the most beautiful regions of the sky, and its position at the intersection of well-marked dark currents is significant, suggesting that stars of this type are situated in the midst of large clouds of nebulous matter. Possibly the rapid shift of the spectral lines is due to the influence of these clouds or it is merely the effect of the semi-giant nature of these stars, having densities and periods of rotation so related, that free rotation would give the star a Jacobian ellipsoidal shape. It may be that a combination of these conditions is responsible.

The spectrum of θ Ophiuchi has rather diffuse lines and is much poorer than that of δ Ceti or of β Canis Majoris. The rather large southern declination also prevents adequate study of the star here at Ottawa. The front page photograph was taken by Mr. Thorn with our Zeiss camera (lens, four inches aperture and twelve inches focal length) with an exposure of two and a half hours on June 19, 1922. The very bright object on this photograph is the planet Mars, which at the time was nearly in opposition. The two dark lanes that seem to extend from θ Ophiuchi on the left and on the right are conspicuous. Theta is the bright star at the centre of the plate.

In the present spectroscopic study in which Mr. J. F. Frédette's assistance is acknowledged it is found that θ Ophiuchi is definitely to be classified among the stars of the β Canis Majoris type, but the object of the paper is to show the great probability that many of these stars are connected with extensive absorbing clouds. The idea that nebulous clouds have a certain rôle in the mechanism of stellar systems is not new and it is interesting to refer here to the article "Nebulous Double Stars"[2], by Miss Clerke. This great English woman, who has given us in her books a wonderful conception of modern astrophysics, advanced the proposition that nebulous matter would have largely to be considered in sidereal dynamics.

Among the principal paragraphs of Miss Clerke's article we might cite the following:

(1) "At last we seem to be fairly confronted with the pregnant question whether nebulous matter can effectively impede motion. It has long been hovering on the verge of astronomical consciousness. Stars plunged in diffuse nebulosities could not be supposed stuck fast like fruits in a jelly; but their velocities, and the changes possibly impressed upon them, remained conjectural."

(2) "Chiefly through the researches of Professors Frost and Adams, with the Bruce Spectrograph, into the radial velocities of stars of helium type, we have been made acquainted with at least seven swiftly circulating pairs, the actual envelopment of which in nebulosity is scarcely open to question. We have accordingly, to choose between two alternative views. Either such systems are not destined for permanence, the canker of a resisting medium lying at their root; or matter can exist in the state of frictionless fluid."

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[1]Pub. Dom. Obs., Vol. V, p. 343.

[2]The Observatory, Vol. 27, 1904, p. 303.

(3) "Most of our readers still vividly recall the surprise which greeted the announcement, in 1885, that Maia (20 Tauri) in the Pleiades appeared on the Henry plates of four hours exposure to be adorned with a nebulous appendage in the shape of a squirrel's tail. Professor Adams now enrols the star among close binaries".[1]

(4) "And a range of 50 kilometres has since been determined for changes in the velocity of σ Scorpii by Mr. Slipher, of the Lowell Observatory. This star was described by Professor Barnard in 1897[2] as forming the nucleus of a conspicuously dense region of the great nebulous field centered on θ Ophiuchi. Prongs of inchoate stuff extend far to the north and southwest of the spectroscopic binary, and may be inferred to issue more or less immediately from it."

(5) "Seven star couples are thus so far known to circulate rapidly in a nebulous medium; the circumstances of their revolutions have, however, still to be ascertained; and the critical details will need careful and unprejudiced consideration. The supposition is admissible that the widening of their orbits through tidal friction might, for a long time, serve to neutralize the accelerative effects of resistance, if resistance to their motion be indeed offered. But the equilibrium would not be permanent; the momentum of the system would be subject to a two-fold waste; and eventual collapse should ensue. Only its postponement could, in this way, be brought about. The alternative hypothesis that nebulous matter does not, in any degree, check motion, though strange to our experience and bewildering to our conceptions, should not therefore be peremptorily rejected. Strictly terrestrial ideas of what is possible inevitably widen in scope as we search the skies."

A fairly large number of stars of the β Canis Majoris type have now been found, all of them in or near the Milky Way; one of these, σ Scorpii, which was mentioned by Miss Clerke as most likely plunged in an enormous nebula, seems to show us surprising anomalies in its motion.[3] In θ Ophiuchi we have an instance strongly suggesting nebular influence. At present a great deal of doubt exists as to the very short-period binary nature of the stars of the β Canis Majoris type, involving two bodies performing one revolution around their common center of gravity in four or six hours. In explanation of the nature of the phenomenon producing the oscillations of the spectral lines, two hypotheses now present themselves. It may be an effect of the giant size of stars, bodies of exceedingly large volumes and low densities, or it may be due to the influence of nebulous or other material forming extensive surrounding clouds. Perhaps both circumstances contribute.

A study, undertaken here, of later class giant stars has not yet indicated very rapid radial velocity variations, particularly among those away from the Milky Way. Few stars as late as Class F have been identified with the β Canis Majoris type and they usually have rather diffuse lines. Among them we might mention τ Cygni and δ Aquilae (the latter having been discovered by the writer) both in the Milky Way. The surroundings of δ Aquilae on Barnard's photographs[4] are indicative of absorbing matter. A most remarkable fact found on some plates taken here is that the little stars which surround τ Cygni seem to be disposed in three spiral branches originating at τ and extending in the same direction. The vacant spaces between the three spirals seem to be nebulous; a photograph from a large reflector of this field would, however, be required to ascertain this.

It is of interest to consider what might be the influence of an interstellar cloud on the motion of a giant star which it surrounds.

The problems of gravitational attractions, even when not complicated by other influences, are so difficult that celestial mechanics has only been able to solve the very simplest of them. Probably the density of an interstellar cloud is very small, so that

[1]Ap. J. Vol. 19, p. 341. See also Pub. Dom. Obs., Vol. V, p. 50.
[2]Pop. Ast., Sept. 1897, pp. 229, 232.
Pub. Dom. Obs., Vol. V, p. 303.
[4]Pub Lick Obs., Vol. XI, 1913, plate 67.

its resistance to the motion of a body is almost negligible. Its total mass, however, must be considerable, and it is not impossible, on account of the form taken, frequently long and narrow lanes, that it would have a great influence on the shape of the body. The latter possibly assuming a spherical shape, if isolated in space and devoid of rotation, would alter this shape considerably when plunged in one of the cosmic nebulosities or acted upon by dense stellar clouds of the Milky Way. Planetary nebulae, for instance, are usually not spherical and an idea of their appearance may be gathered from the very interesting memoir of Dr. H. D. Curtis on these objects.[1]

As only sufficient data have been obtained to suggest further study of θ Ophiuchi by observers more favourably situated, no theory will be developed here. In a paper on β Canis Majoris some mechanical suggestions will be brought forward.

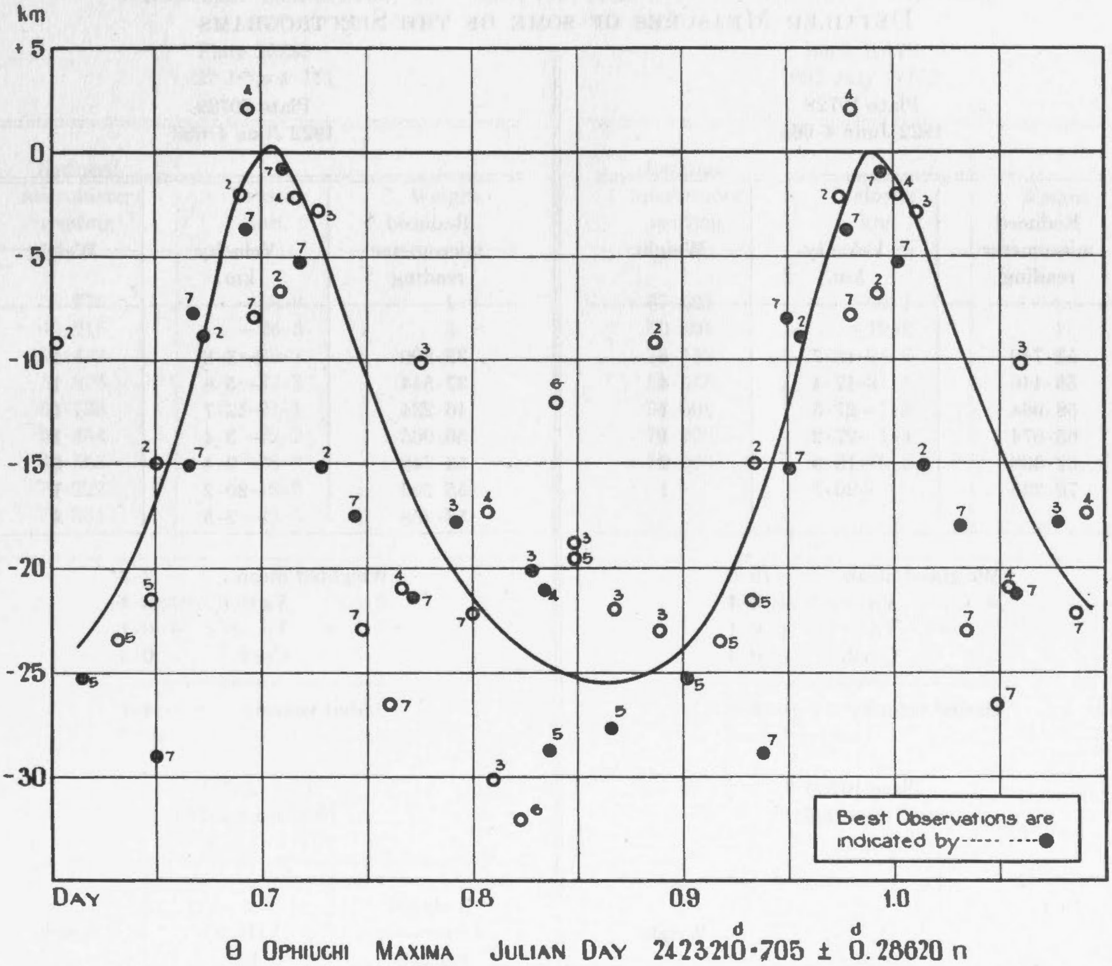
The table of radial velocities of θ Ophiuchi obtained here is now given; it is followed by the detailed measures of some of the spectrograms.

[1]The Planetary Nebulae, Pub. Lick Obs., Vol. 13, part III.

Radial Velocities of θ Ophiuchi

Date	Julian Day	Velocity km.
1920, June 13	2422489·683	− 6·2
	·707	−16·4
	·732	− 4·1
	·806	+17·5
1922, June 4	2423210·665	−15·8
	·693	− 4·1
	·718	− 5·9
	·743	−17·9
	·771	−21·8
June 12	218·615	− 9·3
	·663	−14·9
	·685	− 8·9
	·703	− 2·0
	·722	6·7
	·742	−15·2
June 19	225·608	− 2·8
	·658	−10·3
	·676	−17·8
	·694	−30·2
	·712	−20·2
	·731	−18·9
	·751	−22·7
	·773	−23·0
June 23	229·581	+ 2·0
	·601	− 2·1
	·654	−20·9
	·695	−17·3
	·721	−20·9
June 26	232·583	−28·8
	·599	−19·5
	·614	−27·7
	·652	−25·3
	·667	−23·6
	·683	−21·5
	·722	+ 4·8
July 2	238·581	−32·1
	·601	−12·0
July 5	241·562	−29·0
	·577	− 7·7
	·605	− 7·7
	·619	− 0·9
	·656	−23·1
	·671	−26·5
	·688	−37·0
	·708	−22·2

The above observations of 1922 apparently determine a velocity variation whose period is $0^d.28620$. Taking the epoch J.D.2423210.705 as maximum and plotting the observations according to the period we obtain the accompanying curve. The black circles indicate the best observations. The numbers 1 to 7 indicate, respectively, the observations from June 4 to July 5. the same number being used for the same day.



The observations of 1920 together with the accompanying velocity curve seem to indicate that a large variation of mean velocity and perhaps other complications have to be expected.

If the above velocity variation indicated by the curve was due to the motion of one of the components of a short-period binary system, the orbit would apparently have a fairly large eccentricity.

In the following detailed measures of some of the spectrograms, the principal lines corresponding to the micrometer readings can be identified by using the table given in the article on δ Ceti.[1]

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[1]Pub. Dom. Obs., Vol. V, p. 419.

Detailed Measures of some of the Spectrograms

Plate 10728
1922 June 4·665

Reduced micrometer reading	Velocity km.	Weight
53·740	−18·7	5
58·446	−17·4	4
58·964	−27·5	1
65·674	−27·2	1
67·338	−13·9	2
76·335	−20·7	1

Weighted mean	−19·0
Va	+ 3·4
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	−15·8

Plate 10729
1922 June 4·693

Reduced micrometer reading	Velocity km.	Weight
35·800	+ 3·8	1
37·544	− 5·8	1
46·234	−12·7	1
50·905	− 3·4	1
53·748	− 9·4	6
55·296	−20·2	1
58·458	− 2·5	3

Weighted mean	− 7·3
Va	+ 3·4
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	− 4·1

Plate 10730
1922 June 4·718

Reduced micrometer reading	Velocity km.	Weight
37·529	−20·2	3
39·389	−28·4	1
46·231	−15·9	1
50·904	− 4·5	3
53·751	− 5·8	5
58·458	− 2·5	3
63·455	+ 1·3	1

Weighted mean	− 9·0
Va	+ 3·4
Vd	0·0
Curv.	− 0·3
Radial velocity	− 5·9

Plate 10731
1922 June 4·743

Reduced micrometer reading	Velocity km.	Weight
28·082	−11·3	1
34·302	− 5·6	1
35·773	−21·6	1
37·532	−17·3	1
46·226	−20·1	1
50·892	−18·1	3
53·730	−30·4	4
58·444	−19·8	2
76·363	−23·8	1

Weighted mean	−21·0
Va	+ 3·4
Vd	0·0
Curv.	− 0·3
Radial velocity	−17·9

Detailed Measures of some of the Spectrograms—*Continued.*

Plate 10732
1922 June 4·771

Reduced micrometer reading	Velocity km.	Weight
35·776	−18·8	1
46·215	−26·5	3
49·432	−29·1	2
50·875	−37·3	1
53·738	−21·1	5
58·434	−32·2	3
64·568	−26·8	1
70·222	−13·0	2
76·334	−22·3	1

Weighted mean	−24·8
Va	+ 3·4
Vd	− 0·1
Curv.	− 0·3
Radial velocity	−21·8

Plate 10778
1922 July 5·562

Reduced micrometer reading	Velocity km.	Weight
37·521	−22·1	1
50·891	−19·2	1
53·743	−24·6	2
58·445	−21·1	2
58·992	+ 7·5	1
70·229	− 1·4	1
76·329	−30·2	1

Weighted mean	−17·4
Va	−11·5
Vd	+ 0·2
Curv.	− 0·3
Radial velocity	−29·0

Plate 10779
1922 July 5·577

Reduced micrometer reading	Velocity km.	Weight
35·796	− 2·8	1
46·220	−21·2	1
50·911	+ 3·4	2
53·756	+ 2·3	1
58·471	+12·4	4
59·013	+33·8	1
63·798	+ 9·4	1
70·211	−29·0	1

Weighted mean	+ 4·1
Va	−11·6
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	− 7·7

Plate 10781
1922 July 5·605

Reduced micrometer reading	Velocity km.	Weight
28·080	−13·0	1
34·283	−23·2	1
37·555	+10·6	1
46·258	+19·1	1
50·910	+ 2·3	4
53·757	+ 3·5	2
58·456	− 6·2	2
70·255	+36·2	1
76·363	+23·8	1

Weighted mean	+ 4·1
Va	−11·6
Vd	+ 0·1
Curv.	− 0·3
Radial velocity	− 7·7

DETAILED MEASURES OF SOME OF THE SPECTROGRAMS—*Concluded.*

Plate 10782
1922 July 5·619

Reduced micrometer reading	Velocity km.	Weight
31·754	+25·2	1
35·785	−13·2	2
37·574	+28·8	1
46·262	+23·3	2
50·916	+ 9·0	3
53·763	+10·5	2
58·470	+ 9·9	4
76·357	+14·3	1

Weighted mean	+11·0
Va	−11·6
Vd	0·0
Curv.	− 0·3
Radial velocity	− 0·9

Plate 10783
1922 July 5·656

Reduced micrometer reading	Velocity km.	Weight
46·232	− 8·5	1
50·915	+ 7·9	2
53·716	−44·5	2
58·455	− 8·7	4
76·351	+ 4·8	1

Weighted mean	−11·2
Va	−11·6
Vd	0·0
Curv.	− 0·3
Radial velocity	−23·1

Plate 10784
1922 July 5·671

Reduced micrometer reading	Velocity km.	Weight
52·473	−38·0	2
53·760	+ 7·0	2
58·460	− 2·5	2
58·957	−35·0	1

Weighted mean	−14·6
Va	−11·6
Vd	0·0
Curv.	− 0·3
Radial velocity	−26·5

Plate 10785
1922 July 5·688

Reduced micrometer reading	Velocity km.	Weight
46·227	−13·8	1
53·739	−17·6	1
58·437	−31·0	3
76·332	−25·4	1

Weighted mean	−25·0
Va	−11·6
Vd	− 0·1
Curv.	− 0·3
Radial velocity	−37·0

All qualities of spectrograms obtained here for θ Ophiuchi are represented in the above measures.

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