that it is zero The branch cO_2c' of the binodal line has thus in point O_2 a somewhat angular shape, without however an angular point being really formed.

Fig. 14.

This shape is, indeed, the preparation to the wellknown form shown in fig. 14, generated in O_2 when the conjugated branch bO_1b' in fig. 13 begins to intersect the plait aO_1a'.

Moreover it is evident from the fact that ξ_2 and y_2 in the vicinity of the points O_1 and O_2 are of the same order of magnitude as y_1^3 and therefore much smaller than y_1, that the connode O_1 will displace itself there much quicker than the connode O_2.

Astronomy. — "*The Milky way and the star-streams.*" By Prof. J. C. KAPTEYN.

In a lecture, delivered before the Congress of Physicists and Physicians in the month of April, I arrived at the conclusion that "in passing from the stars of the spectral type B [1]) (Helium-stars) to those of the type A (Sirius-stars) and from these to those of the type G (solar-stars) there is a gradual change in the direction of the streams.

The stream-velocity was also found to be different. Owing to want of materials, however, the latter result was still even more uncertain than the former. Partly by the publication of CAMPBELL's radial velocities of B stars [2]), partly by (not yet published) observations made on Mount Wilson, I have been able this summer materially to diminish this uncertainty.

It is true, that the increase of our data represents but a small fraction of what is urgently wanted. Still however, so much seems to have been gained already, that there is a pretty strong probability in favour of the conclusion that: not only the direction but also the velocity of the two great star-streams *gradually* changes in passing from type B to type A and thence to type G.

In these circumstances I feel justified in no longer suppressing a conclusion which was not yet communicated in my April lecture.

In what follows, stream-direction and stream-velocity will mean direction and velocity relative to the solar system, unless the contrary

[1]) In what follows the notations of HARVARD college observatory have been adopted.

[2]) LICK Bulletin N°. 195.

is expressly mentioned. If the motion of different classes of stars relative to the solar system is different, the absolute motion must be different too.

How can we imagine such a different motion for our star-classes?

Are we to imagine, that instead of the two star-clouds which were assumed up to the present, there are six — I confine myself to the three spectral classes really investigated — of which three move permanently in slightly different directions, and three others approximately in another? Of the three former of which the first would contain only *B* stars, the second only *A* stars, the third only *G* stars, whereas for the latter set of three there is a similar distribution? Six wholly independent streams between which there would be differences in velocity, number and amount of the peculiar velocity [1]) gradually changing with the age of the stars.

All this seems hardly admissible. It seems infinitely simpler to assume, as I did in my April lecture, that originally there were only two star-clouds. That in course of time the stream-direction and the stream-velocity have slightly changed in such a way, that the oldest stars have deviated most, the youngest least, but all in a higher or lower degree from the original direction and velocity. In that lecture I also tried to show how we can imagine such a change in motion to have taken place.

I do not wish to enter again into this explanation, but I wish to draw attention to the fact that, unless we adopt the hypothesis of the six permanent streams, alluded to just now, we have to admit that the matter which originally composed the two star-streams is *expanding*.

For a better understanding of this expansion, it is necessary to know the elements of the two streams separately for the stars of the different classes of spectrum.

The most reliable elements, which up to the present I have been able to derive, are as follows: (see p. 526).

In this table the galactic latitudes and the velocities relative to the sun of the two streams have been denoted by the letters β_1 r_1 β_2 r_2.

The reliability of these elements is very different and for the greater part rather small. Those for the G- and B-stars of stream I are the most trustworthy. For the second stream of the B-stars, of which we still know but a few members, the position of the vertex is particularly uncertain, the stream velocity practically unknown.

For the change of the second stream with time, we have therefore

[1]) See the lecture quoted above. Congres of physicists and physicians April 1911.

Apparent vertices (convergents) and stream-velocities.

	Str. I.				Str. II.			
Spectr.	α_1	δ_1	β_1	λ_1	α_2	δ_2	β_2	λ_2
	h. m.			kil	h. m.			kil
G [1])	6 3	—14°6	—14·9	32·6	19 11	—64·1	—27°6	18·4
A [2])	6 22	—18·8	—12·6	26·2	19 11	—47·4	—24·5	24·7
B	6 20	—31·3	—17·9	22·0	18 0?	—38·?	— 9·?	?

exclusively to rely on the data for the G- and A-stars. For the first stream the data of the A-stars may practically be neglected [3]). The reason is that not only the elements of the A-stars are so much more uncertain, but also that the amount of the velocity both relative to the G- and to the B-stars is so small.

The only somewhat reliable results therefore are as follows [4]):

stars	*stream*	*relat. veloc.*	*inclination on Milky way*
G and B	I	12.8 kil.	7°.2
G and A	II	8.65 „	12 .0

What is particularly remarkable in these numbers is, that the inclinations on the Milky way are so small.

Former investigations have shown that the motion of the two streams of G-stars relative to the centre of gravity of all the stars is perfectly parallel to the plane of the Milky way [5]). In my first

[1]) The numbers on this line are those of EDDINGTON (Monthl. Not. Nov. 1910). In reality E. has treated together the stars of the spectres *A F G M K*. The mean type is *G* and I have considered E's results as being valid for this type. E's results for velocity were changed into kilometers by the aid of CAMPBELL's last determination of the sun's velocity = 19.5 kil. (Lick. Bull. N°. 196).

[2]) In reality only the early A-stars i. e. only the spectral classes $A_0A_1A_2A_3$.

[3]) They are of course particularly important for settling the question whether or not the change of the elements with time is really gradual.

[4]) For the benefit of those, who, in spite of their great uncertainty, might wish to know the corresponding results for the A-stars of stream I, I give the following numbers. I will attach a sign to the inclination in order to show that the two relative velocities deviate from the Milky way towards different sides.

stars	*stream*	*relat. veloc.*	*inclin. on Milky way*
G and A	I	7.0 kil.	+ 22°7
A „ B	I	5.9 „	— 10°4

[5]) In other words that the relative velocity of the two streams of G-stars is parallel to the Milky way.

investigation I found an inclination of two degrees. EDDINGTON in his last investigation, based on the superior, newly published, catalogue of Boss, is led to a value of exactly *zero* degrees. It now appears, from the results of the present paper, that both the star-clouds *expand* in that same plane or at least in directions only slightly deviating.

It would seem to me that we have here a *vera causa* for the origin of the Milky way. Even if originally the two star-clouds had been spherical and matter had been evenly distributed in them, this matter must have expanded in the neighbourhood of a definite plane, the plane of the Milky way.

At the same time, we have at least the beginning of an explanation of the two following facts:

1. That the Milky way has not been scattered long ago as a consequence of the divergence in the proper motions of the stars. For, the expansion of matter, now under discussion, must be at work even at the present moment.

2. That the phenomenon of the Milky way is shown in *both* the star-streams.

It is true that HALM and HOUGH have assumed, at least for a time, that the Milky way coincided with one of the two streams, but after EDDINGTON's work, such a theory seems hardly tenable.

Our conclusion tacitly assumes that what observation has taught us about the nearer stars, also holds for the more distant ones. If we consider how small the part of the universe is, about which we possess more or less adequate data, we feel that necessarily the bearing of our conclusion is restricted. As applied to the whole system it must necessarily be considered as only a provisional hypothesis. In order to give it a more solid foundation, it will have to be based on more ample materials and it will have to be extended to the greatest distances accessible to our observations.

How necessary an extension over the greater distances is, appears from the fact, that even now a totally different explanation of the phenomenon has been given. The above results for the A-stars were not yet known to its author. But it had been evident for some time that, whereas all the other stars investigated show the phenomenon of the two star-clouds, the helium-stars practically move in a single stream. Its motion does not agree with that of one of the two main streams but with the motion of the centre of gravity of the two. This fact led HALM to assume the existence of three streams [1]). EDDINGTON [2]), adopting this theory, conceives the matter to be as

[1]) Monthl. Not. June 1911.

[2]) Observatory Oct. 1911.

follows. It is a well-known fact that the astronomical proper motions of the helium stars are small. We conclude that their distance must be considerable. The mean distance of the stars of different spectral type, for which the existence of the two star-streams has been demonstrated, is undoubtedly much smaller. He concludes: "The "two star streams probably involve at least half a million of the "stars around us; but there has never been any evidence that they "prevail in the extremely remote parts, where the helium stars are "thinly scattered."

He thinks that the helium-stars must be almost entirely at rest. The stream-motion which they show, when the velocity is considered relative to the sun, is entirely due to the motion of the solar system itself.

The theory is very attractive. The more so because it furnishes a natural explanation of the fact, already mentioned, that the motion of the helium-stars coincides, at least approximately, with that of the centre of gravity of the two streams for the other stars. In our theory this fact is not so easily explained.

It is for this reason, that I kept back the preceding remarks, till I should have found an occasion of testing EDDINGTON's theory. Such a test which seems to me pretty decisive, is possible in the following way. From the same materials which served EDDINGTON for his last investigation, i. e. from the stars of Boss' Preliminary Catalogue (the helium-stars being excluded) I extracted the stars the proper motion of which lies between 0".030 and 0".079. The average proper motion is equal to that of those helium-stars — 40 percent of the total — which have a proper motion $\geqq 0''.030$. There is every reason to assume that the two classes of stars are approximately at the same distance. We thus have to find out whether or not these stars still show the phenomenon of the two star-streams. The execution of this plan led to the conclusion that the phenomenon is clearly shown; it is but little less evident than for the whole of the stars. That it is *somewhat* less evident is probably sufficiently accounted for by the greater influence of the errors of observation. Graphical representations show the matter at a single glance. They are however too extensive for this communication.

Meanwhile we may demonstrate the matter almost as well by giving the quantities

$$\Theta = log \frac{n_1 + n_3}{n_2 + n_4}$$

for the several parts of the sky. The letter n_1 represents the number of stars for a determined region of the sky, for which the proper

motion makes an angle of between 0° and 90° with the parallactic motion; n_2 similarly represents the number between 90° and 180° etc. If there were but one stream, the quantities Θ would be *zero* for the whole of the sky.

The results obtained are shown in the following table. For the sake of comparison I add, in the last column but one, the value Θ_2 computed from EDDINGTON's numbers for the whole of the stars. In the last column have been given the values of Θ as computed from the numbers yielded by his theory. The fact that the accidental deviations of column Θ_1 exceed those of the next one, will cause no surprise, if we remember that for the former we had to confine ourselves to a small part — the least reliable part — of the materials that served for the latter. Moreover we neglected the corrections due to the deviations from a plane of the several regions. The region of the Pole was left out, simply in order somewhat to abbreviate the work.

Centres of the regions α	δ	α	δ	Θ_1	Θ_2	Θ
0h	+ 50°	and 12h	− 50°	− 0·118	− 0·279	− 0·239
4	+ 50 „	16	− 50	− ·215	− ·222	− ·150
8	+ 50 „	20	− 50	− ·010	+ ·059	+ ·099
12	+ 50 „	0	− 50	+ ·155	+ ·176	+ ·137
16	+ 50 „	4	− 50	+ ·102	+ ·236	+ ·250
20	+ 50 „	8	− 50	− ·158	− ·161	− ·175
1h12m	+ 17°	and 13h12m	− 17°	− .062	− .201	− ·226
3 36	+ 17 „	15 36	− 17	− ·240	− ·266	− ·140
6 0	+ 17 „	18 0	− 17	− ·027	− ·063	− ·047
8 24	+ 17 „	20 24	− 17	+ ·150	+ ·142	+ ·146
10 48	+ 17 „	22 48	− 17	+ ·173	+ ·295	+ ·260
13 12	+ 17 „	1 12	− 17	+ ·137	+ ·182	+ ·228
15 36	+ 17 „	3 36	− 17	+ ·119	+ ·077	+ ·056
18 0	+ 17 „	6 0	− 17	·000	+ ·027	− .004
20 24	+ 17 „	8 24	− 17	− ·207	− ·087	− ·118
22 48	+ 17 „	10 48	− 17	− ·058	− ·147	− ·223

A second test was obtained from an investigation of the *A* stars, made for another purpose some time ago. In this investigation the materials for each region of the sky, were divided in two approximately equal parts, the one containing the greater proper motions, the other the smaller. In no case however, proper motions exceeding 0″06 were admitted in the latter group. Yet this group still shows the two streams with perfect clearness.

It would seem to me, that the conclusion towards which these results lead, is decisive.

The two star-stream-system is not confined to the nearest neighbourhood of the sun, but it extends at least to those parts of space which contain 40 procent of the observed helium-stars. We therefore need an explanation for the exceptional behaviour of the helium stars, different from that of EDDINGTON.

In HALM's theory the third stream is not confined to the more distant parts of space. Our theory differs from his in so far that it does not lead us to distinguish *three* sharply defined streams, but to conceive *two* stream-systems each consisting of a series of streams, gradually merging into each other. HALM's third stream is one of the extreme cases of our first stream-system.

In an extensive investigation of the helium- and early A-stars, undertaken by ADAMS, BABCOCK and myself, we intend to collect and discuss the materials necessary for a fully satisfactory determination of the elements of the two streams.

The present paper is to be considered as part of that joint labour.

Chemistry. — "*The system Iron-Carbon*". By Prof. A. SMITS. (Communicated by Prof. A. F. HOLLEMAN).

After BAKHUIS ROOZEBOOM[1]), led by his theory of mixed crystals, had set forth his view about the system iron-carbon, attention has been drawn by various scientists to the fact that though BAKHUIS ROOZEBOOM's considerations have contributed considerably to get a better insight into this so important system, his views are in opposition to practice in a single significant point.

BAKHUIS ROOZEBOOM had namely thought he was justified in concluding chiefly from experiments of ROBERTS AUSTEN, that the mixtures with more than 2 % C. must be subjected to a radical change in the neighbourhood of 1000° with stable equilibrium.

ROBERTS AUSTEN had namely found that the line indicating the

[1]) Zeitschr. f. physik. Chem. 34, 437. (1900).