Oort 328

9.5.1958

328 (a)

Baum
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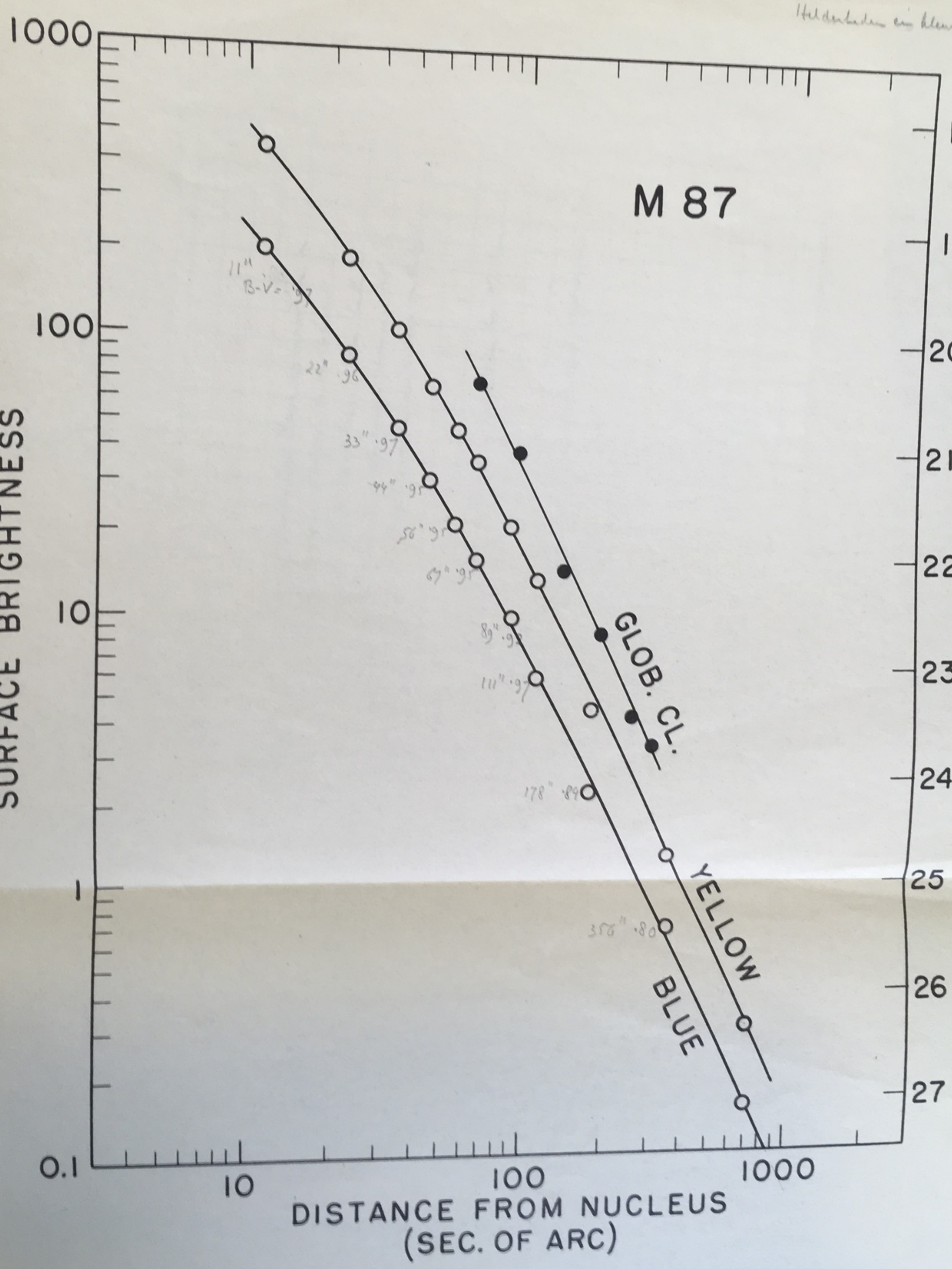

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"The rotation of the spiral nebula M33", Mayall & Aller (Ap J 95, 5-23, 1942; Lick Contr. Series II, No. 1)

3 Sept. '45 aan Mayall en Lindblad gezonden

Note on the direction of rotation of M33.

In a recent article+) Mr Dingens suggested that H. Babcock's measures of the velocity of an emission nebula near the minor axis of the Andromeda nebula would indicate that the emission nebula moved away from the center of the system. Combining this observation with the situation of the emission nebula he concluded that the north-western half of the Andromeda nebula is turned towards us, and that the rotation is such that the arms trail. The conclusion, based on a residual motion of only ± 38 km/sec ± 17 (p.e.) shown by a single object, is evidently quite uncertain.

But the suggestion is an interesting one. Indeed, if emission nebulosities <u>which are situated in the arms of a spiral</u> show radial motion with respect to the centre of the system we may safely assume that this motion will be away from the centre and not towards it. Therefore, if such a radial motion is large enough to be measured it will make it possible to decide which side of the system is turned towards us. In the following I have tried to apply this principle to the velocity measures of emmission nebulae in M33++).

Let i be the angle between the line from the centre of the nebula to the earth and the eastern half of the plane of the spiral, let θ be the position angle as measured in the plane of the spiral in the direction of the arms, i.e. from north toward east, the zero point being the north-eastern end of the line of intersection between the spiral and the plane of the sky, and let R be the distance from the centre of the spiral as measured in the spiral's plane in minutes of arc. Let, further, Π denote the sytematic velocity in the direction of the radius vector, away from the centre, and Θ the transverse velocity, to be counted positive in the direction of the arms (so that, if the orbits of the nebulae would coincide with the spiral arms, Θ would be positive. Both Π and Θ are measured in the plane of the spiral. If V_0 is the observed radial velocity of an emission nebula and V_s the velocity of the system, we have the following equation of condition for the determination of Π and Θ

$$-V_0 + V_s = \Pi \sin\theta \cos i + \Theta \cos\theta \cos i.$$

According to Mayall and Aller the angle between the line of sight and the spiral is 33°. So i, in our notation is either 33° or 147°. If Π proves to be of a measurable size the choice between the two values of i will have to be made such that Π becomes positive.

The sytematic velocities Π and Θ will vary with the distance from the centre. On the basis of Mayall and Aller's results I have divided the 25 nebulae for which velocities have been determined into three groups of distance as shown in the table below. It was assumed that Π and Θ could be considered as constant in each of the two groups with $R > 16'$, while for the smaller distances they were assumed to be proportional to R. Putting $\Pi = pR$, $\Theta = tR$ the constants p and t were determined by least squares in this group, while in the more distant groups the unknowns solaved were Π and Θ. In all solutions V_s was considered as a known quantity, for which I used the value adopted by Mayall and Aller, viz $V_s = -167$ km/dec ± 5 (p.e.). The solutions were made with i = 33°. The results are shown in the table. The numbers of nebulae are given under n. The mean errors were computed with Mayall and Aller's value ± 32.1 km/sec for the probable error corresponding to unit weight. This corresponds to a <u>mean</u> error of ± 47.5 km/sec; the mean error of unit weight as found from the residuals of the solution is rather smaller, viz. ± 32.7 km/sec. The weighted average of R in the last group is 25!3

R	n		m.e.		m.e.
0' - 16'	10	p = + 4.30	± 2.25	t = + 6.99	± 1.91
16 - 20	6	Π = +14.9	∓ 34.8	Θ = + 98.7	∓ 25.5
> 20	9	Π = -23.1	∓ 22.8	Θ = + 63.7	∓ 22.5

+) Mededeelingen Kon. Vlaamsche Ac. 5, No. 4, p. 20, 1943.

++) Mayall and Aller, Ap. J. 95, 5, 1942; Lick Contr. II, No. 1.

"The rotation of the spiral nebula M33", Mayall & Aller (Ap J 95, 5-23, 1942; Lick Contr. Ser. II, No. 1)

In the first interval a systematic radial motion is indicated, though still uncertain. If it is real its positive sigh would show that the eastern side of the nebula is directed towards us, and that the emmisson nebulae move approximately along the arms, in the sense advocated by Lindblad. In any case the results do not seem compatible with a rotation in the opposite sense accompanied by considerable outward motions.

It may be noted that the nebula NGC 604, which was excluded by Mayall and Aller from their final solutions because it showed an inexplicably large residual, fits in very well in the present solutions. This emission nebula is by far the brightest one in M33 and its velocity is the best determined of all. The present solution leaves a residual velocity of only -15 km/sec ± 24 km/sec (m.e.); the residual from Mayall and Aller's final solution was - 48 km/sec. A larger number of observations in these inner parts of M 33 would evidently be required to settle definitely the question of its sense of rotation; this number would have to be <u>much</u> larger if an answer is also to be obtained to the extremely important question whether the paths of the individual nebulae co-incide with the spiral arms.

In the two more distant groups there is no indication of any systematic motion away from the centre. A combined solution from all nebulae with $R > 16'$ gives Π = - 4.1 ± 18.1 (m.e.), Θ = + 85.3 ± 15.7 (m.e.). It may be that the nebulae in these regions are near or past the "apocentres" of their orbits; there is a distinct indication that the principal arms reach a turning point somewh~~at~~ere near $R = 16'$. The values found for Θ do not differ appreciably from the rotational velocities derived by Mayall and Aller.

It is clear that the possibility of systematic deviations from circular motions must make us very careful in deriving masses from the observed values of Θ. This applies principally to the parts with $R < 16'$. The motions of the outer parts may still give fairly reliable estimates of the mass.

I may add some remarks concerning the inclination of M 33 to the line of sight. A value of 33° was adopted by Mayall and Aller on apparently good grounds. However, if with this value for the inclination one tries to reconstruct the course of the spiral arms in the plane of the nebula the main arms get an improbable shape, as shown in the full-drawn curves of the diagram. The vertical line is the intersection with the plane of the sky. The shape of the arms indicates strongly that they have been too much drxawn out in the horizontal direction. They start out at a fairly small angle with the radius vector; after about 3/8th of a revolution they become nearly perpendicular to it, while beyond that the angle decreases again. This unlikely shape can only be got ridd off by assuming a larger value of i. The dotted curves in the figure show the shape obtained for the arms if i is assumed to be 50° instead of 33°. These curves are much more plausible. It would probably be best in future to adopt some compromise between these two values for the inclination. In order to see how the solutions for rotation and expansion are influenced by a change in i the various quantities (including R and) have been recomputed with the extreme value of 50° for i. The results come out approximately the same as in the previous solution, only the rotations are increased by a factor of approximately $\frac{\cos 33^\circ}{\cos 50^\circ} = 1.30$.

Pl. uit Dev. Form 21-

De 5 sterkst afwijkende [illegible] op de [illegible] zijde v/d Andr nevel

± 7 km/sec.

Aanteekeningen over spiraalnevels.

Indien men zoo de afbeeldingen van late-type spiralen bekijkt kan men zich moeilijk aan den indruk onttrekken dat uitwendige oorzaken van vrij ernstige kaliber aan het werk geweest moeten zijn.

Wel is het opmerkelijk dat gedurende de laatste paar honderd millioen jaar die spiraalarm-vorming uit (?) door heeft kunnen gaan (dit weten we, want overal zitten ze nog aan den kern vast). Dit is op zichzelf een interessant dynamisch probleem, en een vrij concreet en definitief probleem ook.1) Hierom moet toch in een bepaald model wat gezocht kunnen worden.

Voor de schatting der massa's der spiraalnevels en de meting van de rotatie-snelheden in de armen zou het grootste belang zijn.

Van belang is ook te weten of de armen voornamelijk uit B sterren bestaan, want dan zou de arm-vorming in het melkwegstelsel ook wel eens in hoofdzaak tot dergelijke langzaam-bewegende sterren beperkt kunnen zijn.

Trouwens het lijkt niet goed mogelijk zich in te denken dat de armen uit andere sterren zouden bestaan, die aanmerkelijke relatieve snelheden hebben. Want 10 km/sec beteekent reeds 2000 ps in één omloopstijd en dus zouden dan van de armen reeds na één omloop geen spoor meer over zijn en reeds bij $\frac{1}{4}$ omloop zouden ze bijna geheel uitgedeeld (?) zijn. Het lijkt me niet onwaarschijnlijk dat die geheele structuur beperkt is tot deze langzaam-bewegende sterren en dat de Sco Cent groep een typisch brokje van die structuur is. Dat de spiraal-armen toch zoo duidelijk uitkomen komt door de groote lichtkracht der B sterren en wellicht ook door het feit dat deze in andere nevels (of ook op andere plekken in ons melkwegstelsel) relatief veel frequenter zijn.

Het verband van den bouw der centrale gedeelten der spiraalnevels.

Het is van groot belang wat meer inlichtingen over den omloopstijd dezer nevels te krijgen. Want het ziet er bijna naar uit of de expansie van het heelal van de ontwikkeling dezer nevels nog te langzaam gegaan is. Indien de omwentelingstijd zooals bij N.G.C. 4594 slechts 20 millioen jaar is dan zou deze sedert de geboorte der aarde (2 milliard jaar geleden) 100 maal rondgedraaid moeten zijn en 't is niet w.s. dat bij dan nog structuur zou ontstaan. Dat doet deze nu ook juist niet! Misschien is 't wel zoo dat alleen degenen die een heel lange omloopstijd hebben nog duidelijke armen vertoonen.

In hoeverre komt de onderstelling van spiraalarmen in ons melkwegstelsel in conflict met de dynamische resultaten over de verandering van Θ_c met ϖ? (Hierover Lindblad's artikel nog eens nalezen. Het is natuurlijk denkbaar dat waar wij ons buiten een spiraalarm bevinden de verandering van Θ_c met ϖ hier anders zou zijn dan in den arm.) De onderstelling kan ons echter helpen om een afwijking der sterrotaties, [illegible] I etc. te verklaren.

Indien men een gelijkmatige gasmassa als begin aanneemt moeten dunkt mij in ieder geval eerst de groote gasmassa's die later de sterrenstelsels vormden daaruit afgezonderd zijn, en niet eerst de sterren, want het is ondenkbaar hoe deze sterren zich later niet in kleinere eenheden samen zouden kunnen trekken (Lemaître's redeneering volgend: het zouden dan alleen pulseerende stelsels geworden zijn). Ook hun snelle rotatie moeten zij in gasvorm gekregen hebben (zooals Strömberg een tweetal argumenten).

Wat het ontstaan der spiraalvormen aangaat: Deze moeten bij het begin gevormd zijn reeds uit de min of meer symmetrische roteerende stelsels. De kernen moeten er eerst geweest zijn en daarna pas de dynamische oorzaak die hen uit elkaar trok.

Z. O. Z.

1) Want we weten dat het proces op 't oogenblik niet bezig zijn/te gaan.

Als het heel lang geleden begonnen was dan zouden zulke nevels als M51 zich toch in gladde nevels hebben kunnen ontwikkelen, dus met de spiraalarm-materie glad uitgespreid om een ongeveer bolvormige kern.

Stel het zóó eens: Een groeiende plant. Als alleen op verschillende tijden gezaaid zijn dan zijn alle stadia die gelijke hebben evenveel planten. Maar nu is in duur ∞, d.w.z. die van de gladde nevel. Het kunnen dan zowel in de zoo regelmatige jonge spiraal. Staat zij er nog geen in dien eindtoestand. Tenzij ze allen jong zijn?

...halo population ...
...stars must hav...
...of 50 km/sec ...
B.A.N.).

...ellanden van emissienevels in M31 gemeten door Mayall in 1950-51 (na het Michigan symposium).
met de kunstlichtopstelling aan het Newtonfocus van de 100".

Mich. Publ.	MtW 100" snelh.	Mich. Publ. II, p. 21 X	Y	U	Nieuwe waarde van Mayall (brief)	21 cm kwantum	MtW 100" −21 cm	X	5.2Y	R	R/X	Θ_c coll°	21-cm	uit MtW snelh.
	−509	+114′	+2′.5	−496 (1)		−520	+11							
	−558 (2)	96	+2.5	−455 (3)	−465 (4)	−530	−28							
	−576	66	−1.2	−544 (2)		−550	−26							
	−494	a = 56		—		−560	(+66?)							
	−452	a = 33	x = +33′.0	y = +2′.9		−570	(+118)	33.0	51.5	61.2	1.85	281	262	
	−533	x = 22	y = +8.0	−366 (2)	−486 (2)			22.0	41.6	47.1	2.05	478	273	
	−581	a = 44				−560	−21							
	−549 (2)	a = 41			−410 (3)	−570	+21							
	−462	a = 16	x = −15′.2	y = +6′.5				15.2	33.8	37.1	2.44	395	277	
	−359	a = 27	x = −26′.8	y = −6′.9		−550:	(+191:)	26.8	35.9	44.8	1.67	99	275	
	−443	a = 22	−22.2	−7.2		−540:	(+ 97:)	22.2	37.4	43.5	1.98	283	276	
	−411	a = 23	−23.2	+10.6		−540:	(+129:)	23.2	55.1	59.8	2.58	286	263	
	−310	—			−298 (3)									
	−239	a = − 4.5												
	− 82	− 70	−0.7	+72 (2)		− 50	−32							
	− 47 (2)	−69	+3.1	− 1: (1)		− 50	+ 3							
	− 68 (2)	−53	+6.2	−25 (2)		− 40	−28							

$a <= 45'$ zijn de 21-cm resultaten onzeker. Neem ik alleen de waarden met $a > 40'$ dan vind ik uit
welke een gemiddelde snelheid MtW 100" minus 21-cm = − 4 km/sec. Het gemiddelde residu is
6 km/sec. De w.f. van het systeem. Residu is ± 7 km/sec.

Interessant is ook om de helling
van de snelh. ellipsoïde op het Melk-
wegvlak te bepalen (zie college 1961/62)

UNIVERSITY OF CALIFORNIA

LICK OBSERVATORY
MOUNT HAMILTON, CALIFORNIA

Some remarks concerning the determination of absolute proper motions of faint stars.

1. High latitudes. Velocity distribution of halo population.

Near the galactic poles 17 th and 18 th magnitude stars must have average random motions in the Z co-ordinate of the order of 50 km/sec, (cf. a recent new determination of K_Z to be published in the B.A,N.). This ranks them probably among the objects with highest known velocities in the Galactic System. The average random motion in the Π-coordinate may be estimated at about 100 km/sec, the systematic motion relative to the sun may be about 100 km/sec. The mean parallax of these stars is roughly ".0005, so that 100 km/sec corresponds to π_a.010. If the probable errors of individual motions would be of the order of π_a.005, the motions of these faint stars in high latitudes would give extremely important information on the distribution of a pure high-velocity (halo) population, a thing that at present we know very little about.

I should think that 500 proper motions within 30° of the two galactic poles would be ample for this purpose. It would be of great importance to have photo-electric multi-colour observations (including measures of uv excess) for a large fraction of them, while rough radial velicities of, say, hundred stars would add enormously to the value of this material, (a probable error of 20 km/sec should be considered as satisfactory for these stars.)

To complete the information on this halo population it would be valuable to add a certain number of fields, with in total a few

hundred stars, at about 45° latitude. These fields should be preferably at longitudes differing about 90° from that of the centre, as this may give the best separation between Z and ⊙components. On the other hand, regions near 328° and 148° longitude would be extremely interesting in furnishing information on the variation of the velocity distribution with ~~such~~ distance from the centre. Radial velocities would be quite essential for such 45° latitude fields. At this latitude stars that are at the same distance from the galactic plane are about $0^m.9$ fainter that$\overset{n}{}$ at the galactic poles.Special attempts might be made in this part of the programme to reach the faintest possible limits.

As in this programme individual accuracy is the important factor, it would pay to select preferably fields for which two or more first-epoch plates are available. All the information to be obtained from this programme would be in a field of which at present we know practically nothing. Similar data for stars between, say, 12^m and 16^m would of course, also be valuable, but not nearly as much as that on the faintest stars.

2. Galactic Rotation.

There are two rather different lines of approach, which may both give valuable results.

One is, as Dr Vasilevskis suggested, to obtain systematic corrections $\Delta\alpha_\alpha$,etc. to the AGK3 (by comparing this with the ultimate nebular standards// on both sides of the Milky Way and by interpolating these corrections for the galactic zone in which no nebular standards are available). Corrected proper motions of all extreme-population I stars

in the AGK3 (OB stars, galactic clusters, cepheids, supergiants of later type, etc.) can then be used to determine the constants of galactic rotation. The success of this method will primarily depend on whether the interpolated systematic corrections are sufficiently accurate to give a substantial improvement of the FK4 fundamental system. Moreover one will need several hundreds of such objects to get a significant determination.

The other method is to determine the rotation directly from the stars in the lowest galactic latitudes where a strong direct tie-up with the nebulae is possible. In most longitudes this will probably be around 20°.

In this case the faintest stars may not be the most suitable because their high velocities will considerably reduce the rotation (in the case of the halo stars perhaps by a factor of $\frac{1}{2}$). For stars of the 14th pg magnitude at b= 20° this factor will have lost its importance, and we shall practically get the full effect. Nevertheless, I would suggest to try to use also 17th magnitude stars, because their high velocities present also an advantage, viz. that they will probably be less susceptible to irregularities in distribution and motion.

We may distinguish two rotation constants, viz. the mean angular velocity of rotation, ω, and the derivative of ω with respect to R (distance from the centre). The angular rotation should be determined from longitudes approximately 90° from that of the centre. Theoretically it can also be determined from regions in the direction of the centre and anticentre, but in practice the rotation effects in these longitudes are complicated by non-linearity of the variation of ω with R.

Let us consider the minimum accuracy to be aimed at. From the best recent values I would estimate ω to be 23.6 km/sec.kpc, or $\pm$".0050/a,

with an uncertainty of not more than 10%. One must therefore get a probable error of less than $^{"}/_{a}$.0005 if one wants to add significantly to the existing knowledge.

At m_{pg}=14 and b=20° the mean random proper motion in galactic longitude is about $^{"}/_{a}$.007 (cf.Binnendijk, B.A.N.No.361), while for m_{pg}=12 it would be about $^{"}/_{a}$.009. These are averages for all longitudes. Because of the ellipsoidal velocity distribution the mean random motions at 90° from the centre might be about $^{"}/_{a}$.010 and $^{"}/_{a}$.013. Supposing one would measure 200 14th magnitude stars per plate, and 100 galaxies, then from one plate one might attain a probable error of about $^{"}/_{a}$.0010 for the mean absolute motion of these 200 stars. With 25 plates one would then get down to ± $^{"}/_{a}$.0002, which would give an exceedingly fine determination of ω. Using the zones between, say, b=17° and 27° on either side of the galactic plane one would need to use a sector of about 30° in longitude to get this many plates.

The great difficulty will be the elimination of the solar motion. At l=58° this enters into μ_l with a coefficient of about $\frac{1}{2}$, and would amount roughly to $^{"}/_{a}$.0025. The best prediction one could make, from knowledge derived from brighter stars in our vicinity, would have an uncertainty of at least 10% of the total solar motion, or $^{"}/_{a}$.0005. In order to obtain high accuracy for ω one would therefore have to eliminate the solar-motion effects by using the Lick motions themselves. The best way to do this is by combining opposite regions of the sky. But at l=238° even b=+20° would still be outside the regions ~~of the sky. But at l=238°~~ covered by the present survey. So the only possibility will be to combine with plates at somewhat lower longitude, say between 200° and 220°, and to determine the way the reflection of the solar motion varies with longitude from the region between (l= 40° and 120°.

Occurence of multiple systems among stars of low and high velocity.

by J. Wolterbeek

~~Summary.~~

A comparison is made between the occurrence of multiple systems (which term will be used here to denote systems with two or more components) among stars of low and high velocity. For the stars within 30 parsecs from the sun a real difference seems to be present: 34% multiples among the low- and 20% among the high-velocity systems. For all stars contained in Wilson's catalogue of radial velocities we also find some difference, the percentages being 15 and 9, respectively. Both percentages are lower than for the near-by stars, probably owing to the greater difficulty of recognising multiplicity visually among these more distant stars. However, the ratio of the percentages is the same. A catalogue is given of all stars within 30 pc from the sun which have space velocity higher than 62 km/sec relative to the local standard of rest.

This article is an extension of an investigation by Oort (1926) into the number of multiple systems occurring among stars of high velocity compared to the number among stars of low velocity. In the first half of the article all stars within 30 pc from the sun have been investigated, thus linking up closely with Oort's investigation; in the second half all stars from R.E. Wilson's catalogue of radial velocities are considered (Wilson 1953).

A scarcity of eclipsing binaries among high-velocity stars has been noted by Buscombe and Morris (1958). Among 1315 southern stars of high velocity they find only 4 eclipsing variables, which they remark that a random sample of stars with similar distribution in magnitude would show about 2% eclipsing binaries.

1. Stars within 30 parsecs. These have been taken from Miss Jenkins' catalogue of trigonometric parallaxes (Jenkins 1952). As Miczaika (1940) has done in his work on stars of high velocity, all stars have been used whose probable error in π_{tr} is less than 28%. For some of the remaining stars a spectroscopic parallax is known; this was taken chiefly from Miss Roman (1935 and 1952). The average between π_{tr} and π_{sp} has then been used. Proper motions were taken from Miss Jenkins' catalogue, thus indirectly from the GC and Cincinnati Publ. 18 and 20; the radial velocities are from Wilson's catalogue (Wilson 1953). All of the following were considered to be

multiple systems: physical systems taken from the ADS, SDS and BDS (the three catalogues of visual double stars of Aitken, Innes and Burnham), all spectroscopic binaries contained in Moore's catalogue (Moore 1948) and in Wilson's radial-velocity catalogue; the eclipsing binaries as mentioned by Wilson and Jenkins, the astrometric binaries as mentioned by Jenkins, and stars with common space motions. The space motions are referred to a rectangular coordinate system whose origin coincides with the local standard of rest, and whose axes are directed towards $l=0^\circ$, $b=0^\circ$; $l=90^\circ$, $b=90^\circ$ (old galactic coordinates). The motion of the sun relative to this origin was taken to be 20 km/sec towards $\alpha=270^\circ$, $\delta=+30^\circ$, corresponding to velocity components +17,0 , +7,4 , +7,3 km/sec in this coordinate system. The velocities are separated into "low" (0-63 km/sec) and "high", the latter being subdivided into the following intervals: 63-83, 83-100, 100-150 and > 150 km/sec. The multiple systems are subdivided into: visual (including stars with common space velocity, astrometric binaries and systems with visual as well as spectroscopic components) and spectroscopic systems (including the eclipsing binaries). Only the Pleiades were omitted.

The following tables give the numbers of systems in various categories, as well as the percentages of multiple systems and their mean errors.

Table 1.

	single	multiple			percent. mult. and m.e.		
		vis.	spectr.	total	vis.	spectr.	total
low veloc.	501	202	60	262	26% ± 3%	8 ± 1	34 ± 3
63-83 km/sec	81	14	7	21	14 ± 4	7 ± 3	21 ± 5
83-100	39	9	2	11	18 ± 6	4(± 3)	22 ± 6
100-150	44	7	0	7	14 ± 5	0	14 ± 5
>150	13	4	2	6	21(±11)	11(± 7)	32 ±13
all high vel.	177	34	11	45	15 ± 3	5 ± 2	20 ± 3

The percentage of multiple stars among the high velocities (20% ± 3% m.e.), appears to be sensibly lower than among the low velocities (34% ± 3% m.e.), but the difference is considerably less than found previously by Oort (cf.Table 3). It may be noted that the ratio of visual to spectroscopic binaries is found to be the same for low-velocity and high-velocity stars.

Subdividing according to spectral type we find:

Table 2

	Spectral type	single	multiple			percent. mult. and m.e.		
			vis.	spectr.	total	vis.	spectr.	total
low velocities	gGKM	54	13	4	17	18 ± 6	6 ± 2	24 ± 6
	B	1	2	0	2	67	0	67
	A	45	22	7	29	30 ± 8	9 ± 3	39 ± 8
	F	116	62	25	87	31 ± 5	12 ± 2	43 ± 6
	G	107	47	10	57	29 ± 5	6 ± 2	35 ± 5
	K	112	39	9	48	24 ± 4	6 ± 2	30 ± 5
	M	66	17	5	22	19 ± 5	6 ± 2	25 ± 5
	All	501	202	60	262	26 ± 3	8 ± 1	34 ± 3
high velocities	gGKM	5	0	1	1	0	(17)	(17)
	B	0	0	0	0			
	A	4	0	0	0			0
	F	13	1	2	3	(6)	13	19 ± 8
	G	53	10	2	12	15 ± 5	3	18 ± 5
	K	71	15	5	20	16 ± 4	6 ± 2	22 ± 5
	M	31	8	1	9	20 ± 8	2	22 ± 8
	All	177	34	11	45	15 ± 3	5 ± 1	20 ± 3

At each spectral type we see a lower percentage of multiple stars among the high than among the low velocities; this difference seems the more pronounced the earlier the spectral type. Going from early to late spectral types we see the percentage of multiple stars among the high velocities increase and among the low velocities decrease until at type M they become almost equal.

For comparison, the numbers and percentage which were derived by Oort are shown in Table 3. The difference with the new result may be due to the much smaller material available in 1926.

Table 3

spectral type	low veloc.		high veloc.		percentage multiple and mean errors	
	single	mult.	single	mult.	low veloc.	high veloc.
gGK	9	5	4	0	36% ± 18%	0%
F	27	29	9	1	52 ± 12	10
G	37	15	24	3	29 ± 8	11
K	40	17	18	5	30 ± 8	22
M	3	2	8	0	40 -	0
All	116	68	63	9	37 ± 4	12 ± 4

The high-velocity systems within 30 pc from the sun are listed in Table 5 at the end of this article. The table gives: the number in Miss Jenkins' catalogue, the coordinates for 1900.0, the parallax used in thousandths of a second, an asterisk denoting values differing from Miss Jenkins' parallax, the components X, Y, Z of the space velocity and the space velocity V_{sp} itself, all in km/sec.

The following ten stars of Miczaika's list, denoted here by their Jenkins and Miczaika numbers, turned out to be low-velocity stars:

281- 33	1380-119	1456-127	2453-212	2462-213
2879-258	2885-260	3823-375	4009-401	5561-526

One misprint was found in Miczaika's list: no. 127 has μ_α=-162 instead of +14.

Miss Roman's Catalogue of High-Velocity Stars (Miss Roman 1955) appeared after our list had been computed.

2. Stars with known radial velocity. In this section only one component of the space velocity has been used, viz the radial velocity, as given in Wilson's catalogue. The same division into velocity groups has again been made, the velocities having first been corrected for the effect of solar motion. I have also made the same subdivision of the multiple systems, into visual and spectroscopic ones. For finding spectroscopic binaries I used primarily Wilson's catalogue, in which most binaries have been indicated. Some use was also made of Moore's catalogue. Stars with composite spectrum were generally considered as single, unless some additional indication for duplicity was present, e.g. the two spectra being of the same type. Stars mentioned as RR Lyrae or δ Cephei variables were considered to be single. Almost all of the 292 objects with a NGC or IC number were omitted. Stars forming associations (e.g. the Orion nebula association) were included. The criteria for visual duplicity in that case were always the ADS and SDS and sometimes BDS. A spectral subdivision has also been made, but the variables of classical types were considered separately. No multiples occurred with spectra Q, R, S; nor were variables of type RR Lyr, δ Cep, RV Tau, RW Tau, irregular, semiregular, long-period, Orion, RCrB or "U" (unknown) ever found to be multiple. These variables were not included in the groups corresponding to their respective spectral types. Among "W" are included the spectral types given as W, WR, WC and WN.

Table 4

The number of visual multiples is greatly diminished compared to Table 2, owing to the increasing difficulty of observing duplicity at the much larger distances of the stars studied. The numbers ~~It~~ are ~~is~~ too small to draw any conclusion. For the spectroscopic multiples, however, we find slightly larger perdentages than in Table 2. The total average for the high velocities is 7.3% ± 1.4 (m.e.), as compared to 11.8% ± 0.3(m.e.) for the low velocities. There is an indication that the percentage of multiple stars is less for the velocities above 83 km/sec than for those between 63 and 83 km/sec.

Table 4

	spectral type	single	multiple			percent. multiple and m.e.		
			vis.	spectr.	total	vis.	spectr.	total
low velocity 63 - 83 km/sec	W	3	0	5	5		62 ±25	62 ±25
	O	99	7	13	20	6 ± 2	11 ± 3	17 ± 4
	B	2181	41	363	404	1.6 ± 0.3	14.1 ± 0.7	15.7 ± 0.8
	A	1841	91	483	574	3.8 ± 0.4	20.0 ± 0.9	23.7 ± 1.0
	F	1714	104	265	369	5.0 ± 0.5	12.7 ± 0.8	17.7 ± 0.9
	G	1962	78	188	266	3.5 ± 0.4	8.4 ± 0.6	11.9 ± 0.7
	K	2318	44	148	192	1.8 ± 0.3	5.9 ± 0.5	7.6 ± 0.6
	M	913	10	63	73	1.0 ± 0.3	6.4 ± 0.8	7.4 ± 0.9
	N	70	1	0	1	1		1
	Pec	2	0	1	1			
	All	11103	376	1529	1905	2.9 ± 0.2	11.8 ± 0.3	14.7 ± 0.3
	W	0	0	2	2			
	O	9	0	0	0			0
	B	21	1	2	3	4	8 (± 5)	12 (± 7)
	A	5	1	4	5	10	40 (±20)	50 (±23)
	F	20	1	3	4	4	13 (± 8)	17 (± 9)
	G	59	2	5	7	3	8 (± 4)	11 (± 5)
	K	61	1	2	3	2	3	5
	M	31	0	1	1		3	3
	N	4	0	0	0			0
	All	210	6	19	25	2.6 ± 1.0	8 ± 2	11 ± 2
higher than 83 km/sec	O	3	0	0	0			
	B	12	0	1	1		8	8
	A	12	0	0	0			0
	F	43	1	1	2	2	2	4
	G	54	0	1	1		2	2
	K	37	0	3	3		8	8
	M	23	0	3	3		12	12
	N	1	0	0	0			
	No Sp	0	0	1	1			
	All	185		10	11		5 ± 1.5	6 ± 1.5

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