The brightness of scattered star light in different galactic latitudes and longitudes

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Özet: Muhtelif galaktik boylamlarda fotografik ve fotovizüel yüzey parlaklığı iki muhtelif metoda göre hesaplanmıştır.

İlk metotdaki yüzey parlaklığı değerleri, doğrudan doğruya yıldızların rasat edilen yüzey dağılımına dayanır. İkinci metotda yüzey parlaklığı yıldızların mutlak kadir eğrileri ve uzayda dağılımlarından hesaplanmıştır.

Bu iki muhtelif yoldan elde edilen yüzey parlaklığı değerlerini mukayese ederek, yıldızların uzay dağılımı ve absorbsiyonu hakkında bazı neticeler çıkarılabilir.

Denklemlerimize giren birçok bilinmeyen sabitlerden ve rasat mutaları kâfi olmayışından, şimdilik sadece, muvakkat neticeler verebilir. Bu neticelere dayanan sonuçlar kaydı ihtiyatla kabul edilebilr. Sonuçlar şunlardır:

a. Galaktik merkeze doğru, yıldızlar tabakasının kalınlığının arttığı görülür. Aksi istikamette ise azalır.

b. Galaktik düzlemde, yıldızların yoğunluğu, galaktik merkez istikametinde arttığı görülür. Aksi istikamette ise azalır.

c. Güneşin hemen etrafında ve galaktik düzleme dik istikamette, yıldız sistemimiz hemen hemen, tamamen transparen olarak görülür.

d. Her 1000 parsek için ortalama absorbsiyon bir boylamdan diğer bir boylama değişir. Galaktik merkez ve mütekabilen antigalaktik merkez istikametinde iki maksimum olduğu görülür. Orta boylamlarda minimum olduğu görülür.

e. Bizim sistemimizdeki yıldızların ortalama renk indisi, dış galaksiler için rasat edilenle ayni olduğu görülür.

Abrevations

In the present paper the following list of symbols is used:

$\log A(m) = \alpha + \beta m - \gamma m^2$	total number of stars per square degree from the brightest up to fotographic magnitude m.
$N(m)\, dm = \frac{\partial A(m)}{\partial m}$ . . .	numbers of stars of given magnitude.
$\mathfrak{L}_{\lambda,\beta}$ and $\mathfrak{L}'_{\lambda,\beta}$	apparent surface brightness on the fotographic and fotovisual scale respectively.

z	distance perpendicular to the galactic plane, measured in parsecs.
s	distance from the sun measured along the galactic plane in parsecs.
r	distance from the sun in parsecs.
ρ	space density of stars.
ρ_0	space density near the sun.
T	thickness of a layer of uniform star density ρ_0 which contains the same number of stars as the actual layers from pole to pole.
$(\rho_0\Im_0)$	total amount of light emitted by stars of all magnitudes together contained in a volume of space of one cubic parsec in the neighbourhood of the sun.
G	total absorption from sun to pole.
λ and β	galactic longitude and galactic latitude.

1. The total amount of scattered star light as derived from the observed surface distribution of the stars.

For the various galactic latitudes and longitudes P. J. van Rhijn [1] has derived the numbers A(m), where A(m) represents the total number of stars from the brightest down to the magnitude m, while the limits of magnitude are $m = 8$; $m = 9 \cdots$ $m = 18.0$. The magnitudes are on the international fotographic scale.

For each separate area the numbers A(m) can be represented by a function of the shape

$$A(m) = 10^{\alpha+\beta m-\gamma m^2} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1.1)$$

while the coefficients α, β and γ are obtained from a least squares solution.

If the numbers of stars of a given apparent magnitude are represented by N(m), the curves N(m) are obtained from (1.1)

$$N(m)\,dm\,\frac{\partial A(m)}{\partial m} = 10^{a+bm-cm^2} \quad . \; . \; . \; . \; . \; . \quad (2.1)$$

where a, b and c are found to be equal to

$$\left.\begin{aligned} a &= \alpha - \log\log e + \log\beta \\ b &= \beta - \frac{2\gamma}{\beta}\log e \\ c &= \gamma + \frac{2\gamma^2}{\beta^2}\log e \end{aligned}\right\} \quad \ldots\ldots \quad (3.1)$$

Consequently the intensity of scattered starlight, emitted by stars of all magnitudes together, is

$$\mathfrak{J} = \int_{-\infty}^{+\infty} 10^{a+bm-cm^2-0.4\,m} \cdot dm = 10^{a - \frac{(b-0,4)^2}{4c}} \sqrt{\frac{\pi \log e}{c}}$$

while the apparent surface brightness, expressed in magnitudes, will be

$$\mathfrak{L} = -2,5 \log \mathfrak{J} = -2,5 \left\{ a - \frac{(b-0,4)^2}{4c} - \tfrac{1}{2}\log c + 0,07 \right\} \quad (4.1)$$

When the relations (1.1) · · · (4.1) are applied to the numbers given by van Rhijn for the different galactic latitudes, we obtain the «observed» values $\mathfrak{L}_{\lambda,\beta}$ expressed on the international fotographic scale.

The correction $m_v = R + Q.m_f$ applied to the argument, transforms a grouping according to fotographic magnitudes into one on the visual scale. If for the visual curve we write:

$$N'(m) = 10^{\alpha'+\beta' m-\gamma' m^2} \quad \ldots\ldots\ldots \quad (5.1)$$

$$\text{we have: } \left.\begin{aligned} &\alpha' = \alpha + \beta R - \gamma R^2;\ \beta' = \beta Q - 2\gamma R \cdot Q \\ &\text{and } \gamma' = Q\gamma^2 \end{aligned}\right\} \quad \ldots \quad (6.1)$$

For the various latitudes the values R and Q are also given by van Rhijn [2]. Inserting these values in the same way as before for the different galactic latitudes and longitudes, we obtain the apparent visual surface brightness in magnitudes expressed on the international visual scale

$$\mathfrak{L}'_{\lambda,\beta} = -2\cdot 5 \left\{ a' - \frac{(b'-0,4)^2}{4c'} - \tfrac{1}{2}\log c' + 0,07 \right\} \quad \ldots (7.1)$$

Hence from (4.1) and (5.1) we find the value of the colour index

$$\Delta\mathfrak{L}_{\lambda,\beta} = \mathfrak{L}_{\lambda,\beta} - \mathfrak{L}'_{\lambda,\beta} \quad \ldots\ldots\ldots \quad (8.1)$$

In the following the values $\mathfrak{L}_{\lambda,\beta}$; $\mathfrak{L}'_{\lambda,\beta}$ and $\Delta\mathfrak{L}_{\lambda,\beta}$ are indicated as the "observed" values, because they are directly based on the observed distribution of the stars.

2. The total surface brightness as derived from the space distribution of the stars.

According to J. H. Oort [3] in the neighbourhood of the sun the density of the stars at a distance z from the galactic plane can be represented by the relation

$$\rho = \rho_0 \exp\left(-\frac{2|z|}{T}\right) \quad \cdots\cdots\cdots \quad (1.2)$$

where ρ_0 is the density in the immediate vincinity of the sun. If the density in the galactic plane at a distance s from the sun is taken to be $\rho_s = \rho_0 \exp(-ls)$, the star density at a distance r from the sun and in latitude ρ_0 is given by

$$\exp\,(-lr\cos\beta - 2r\sin\beta/T)$$

Consequently for stars of all distances together in the latitude β the total intesity of scattered starlight on a surface ω is:

$$\mathfrak{I} = \omega\int_0^{\infty}(\mathfrak{I}_0\,\rho_0)\exp\left(-lr\cos\beta - \frac{2r\sin\beta}{T}\right)dr \quad \cdots \quad (2.2)$$

where $(\mathfrak{I}_0\,\rho_0)$ is the total amount of light emitted by all stars contained in a volume of one cubic parsec in the neighbourhood of the sun.

For evaluating the influence of interstellar absorbtion, only a rather crude method can be used. It was supposed that the decrease of the coefficient of interstellar absorption along the z axis can be represented by: $p(z) = p(z)\exp(-A^2z^2)$ so that the total absorption up to the distance r is equal to:

$$\int_0^r p(o)\exp(-A^2Z^2)dr = \int_0^r p(o)\exp(-A^2r^2\sin^2\beta)\,dr \cdot \cdot \quad (3.2)$$

For all but very small distances (3.2) is equal to $\frac{p\sqrt{\pi}}{2A\sin\beta} =$ $= P\,\mathrm{cosec}\,\beta$. So apparently the influence of absorption can be represented by the usual cosecans law and instead of (2.2) we have

$$\mathfrak{J}_\beta = \omega \cdot (\rho_0 \mathfrak{J}_0)\, 10^{-0.4\,\mathrm{P}\,\mathrm{cosec}\,\beta} \int_0^\infty \exp\left(-lr\cos\beta - \frac{2r\sin\beta}{\mathrm{T}}\right) dr =$$

$$= \frac{\omega(\rho_0 \mathfrak{J}_0)\, 10^{-0.4\,\mathrm{P}\,\mathrm{cosec}\,\beta}}{l\cos\beta + 2\sin\beta/\mathrm{T}}$$

Consequently in this way for the apparent surface brightness, expressed in magnitudes, we have:

$$\mathfrak{L} = -2{,}5\left\{\log\omega + \log(\rho_0\mathfrak{J}_0) - \mathrm{P}\,\mathrm{cosec}\,\beta \log\left(l\cos\beta + \right.\right.$$

$$\left.\left. + \frac{2\sin\beta}{\mathrm{T}}\right)\right\} \quad \ldots \ldots \ldots \ldots \ldots (4.2)$$

Developing the term $\log\left(l\cos\beta + \frac{2\sin\beta}{\mathrm{T}}\right)$ into a series and omitting the terms of higher order (4.2) reduces to:

$$\mathfrak{L} = -2{,}5\,\{\log\omega + \log(\rho_0\,\mathfrak{J}_0) - \mathrm{P}\,\mathrm{cosec}\,\beta + \log\mathrm{T} - \log\sin\beta -$$

$$- \log 2 - l\,\mathrm{T}\,\mathrm{cotg}\,\beta \,.\, \tfrac{1}{2}\log e\}$$

Inserting the numerical values of ω and e and also the numerical value of $\log(\rho_0\,\mathfrak{J}_0)$ as computed from the absolute magnitude curves [4], we finally have for the fotographic arrangement:

$$\mathfrak{L}_{\lambda,\beta} = -2{,}5\{5{,}136 - \mathrm{P}\,\mathrm{cosec}\,\beta + \log\mathrm{T} - \log\sin\beta -$$

$$- 0{,}217\, l\,\mathrm{T}\,\mathrm{cotg}\,\beta\} \quad \ldots \ldots \ldots (5.2)$$

and for the visual one:

$$\mathfrak{L}'_{\lambda,\beta} = -2{,}5\,\{5{,}028 - \mathrm{P}'\mathrm{cosec}\,\beta + \log\mathrm{T}' - \log\sin\beta -$$

$$- 0{,}217\, l\mathrm{T}'\,\mathrm{cotg}\,\beta\} \cdot \ldots \ldots \ldots (6.2)$$

while the colour index is given by:

$$\Delta\mathfrak{L}_{\lambda,\beta} = -2{,}5\{-0{,}108 - (\mathrm{P} - \mathrm{P}')\,\mathrm{cosec}\,\beta + \log\mathrm{T}/\mathrm{T}' -$$

$$- 0{,}217\, l(\mathrm{T} - \mathrm{T}')\mathrm{cotg}\,\beta\} \quad \cdot \cdot \cdot (7.2)$$

In the following the values $\mathfrak{L}_{\lambda,\beta}$ $\mathfrak{L}'_{\lambda,\beta}$ and $\Delta\mathfrak{L}_{\gamma,\beta}$ obtained in this way are indicated as the computed values.

The numerical values of (4.1); (7.1) and (8.1) should be equal to the values of (5.2); (6 2) and (7.2). However, while the former are directly based on the observed quantities, the latter contain various coefficients, which are related to the space distribution of the stars and to the interstellar absorption and which therefore are to be considered as unknown variables. Consequently by comparing the observed and the theoretical values, it should be possible to obtain some information about these unknown coefficients.

It will appear from the following, that due to the lack of sufficient observational data and also due to the large number of variables, it is not always possible to derive definite values for the various coefficients. Consequently for the present the numerical results derived in the following, must be considered as provisional ones only.

Before proceeding to derive these preliminary values, it is worth while to convert the relations (5.2); (6.2) and (7.2) in a less unwieldy form. We put:

$$\left.\begin{array}{ll} K_{\lambda,\beta} = \mathfrak{L}_{\lambda,\beta} - 2{,}5 \log \sin \beta - 2{,}5 \times 5{,}136 & (a) \\ F = -\log T & (b) \\ H = 0{,}217\, l T & (c) \\ \Delta K = \Delta \mathfrak{L} - 2{,}5 \times 0{,}108 & (d) \\ \Delta F = \log T'/T = \log T_v/T_f & (e) \\ \Delta T = T' - T = T_v - T_f & (f) \\ \Delta P = P' - P = P_v - P_f & (g) \\ \Delta H = -0{,}217\, l\, (T' - T) & (h) \end{array}\right\} \quad (8.2)$$

Inserting these values, the relations (5.2); (6.2) and (7.2) reduce to:

$$0{,}4\ K_{\lambda,\beta} = F + P \operatorname{cosec} \beta + H \operatorname{cotg} \beta \quad (9\ 2)$$

$$0{,}4\ K'_{\lambda,\beta} = F' + P' \operatorname{cosec} \beta + H' \operatorname{cotg} \beta \quad (10.2)$$

$$0{,}4\ \Delta K_{\lambda,\beta} = \Delta F - \Delta P \operatorname{cosec} \beta - \Delta H \operatorname{cotg} \beta \quad (11.2)$$

(the index *v* indicates values based on the fotovisual scale and the index *f* values based on the fotographic scale).

3. The influence of space density.

In a stellar system which is completely transparent and in which the stars are arranged in layers of uniform density parallel to the Milky Way, both $K_{\lambda,\beta}$ and $\Delta K_{\lambda,\beta}$ must be constant. Actually the observed values $K_{\lambda,\beta}$ and $\Delta K_{\lambda,\beta}$ systematically depend both on galactic longitude and latitude. From (9.2); (10.2) and (10.3) we see that there are three different possibilities.

a The variations of $K_{\lambda,\beta}$ and $\Delta K_{\lambda,\beta}$ are entirely due to the influence of absorption i.e. the coefficients H and ΔH are equal to zero, while the coefficients of interstellar absorbtion P and ΔP systematically depend on longitude.

b. The variations are due entirely to variations of the density, while $P = 0$ and $\Delta P = 0$.

c) The variations result from the combined effects of absorption and of the change of stellar density.

As strong absorptions are known to occur, the second possibility can be discarted without more.

The first possibility can not be rejected a priori and merits some further consideration. In a previous article [5] the author has showa that the distans stars ($r > 1000$ parsecs) contribute a small fraction only of the total surface brightness.

Within this distance the influence of density fluctuations might be so small as to be negligeable.

If the influence of density is neglected, instead of (9.2); (10.2) and (11.2) we have :

$$K_{\lambda,\beta} = F + P \operatorname{cosec} \beta \quad \text{. . . . . (1.3)}$$

$$K'_{\lambda,\beta} = F' + P' \operatorname{cosec} \beta \quad \text{. . . . . (2.3)}$$

$$\Delta K'_{\lambda,\beta} = \Delta F - \Delta P \operatorname{cosec} \beta \quad \text{. . . . . . . (3.3)}$$

Both for the Northern and Southern hemisphere and for each longitude separately the values $K_{\lambda,\beta}$; $K'_{\lambda,\beta}$ and $\Delta K_{\lambda,\beta}$ as derived from van Rhijn's starcounts [1] were tabulated in order of increasing (absolute) galactic latitude. All values for which $|\beta| < 5^\circ$ were excluded.

In this way for each longitude we obtain two series of eleven equations, of which one is valid for the Northern, the other for the Southern sky.

For regions for which the coefficient γ in (1.1) is negative, no acceptable values $K_{\lambda,\beta}$ and $\Delta K_{\gamma,\beta}$ can be derived. Therefore in some longitudes, especially in those near the galactic centre, the various series contain 10 equations only as the one valid for $\beta = 5^\circ$ had to be omitted. In one instance the equations corresponding to $\beta = 10^\circ$ are also unavailable. From the various series of equations the numerical values of F, P, ΔF and ΔP (1.3 and 3.3) are obtained by least squares solutions.

It then becomes immediately apparent that the suppotision *a* is untenable. The numerical values, obtained from this supposition, are quite evidently erroneous. For nearly all longitutes within 90° from the anticentre for the selective absorption negative values were obtained, which is absurd. Therefore the supposition *a* can also be discarded and we conclude that the observed variations of $K_{\lambda,\beta}$ and $\Delta K_{\lambda,\beta}$ are due to the combined influence of fluctations in density and of absorption.

Before an attempt is made to find the correct values of the coefficients, we first consider the question how variations of the density in the galactic plane can affect the mean colour. Imagine we have a cross section of the stellar system at right angles to the galactic plane (see figure 1). The axis OS coincides with the galactic plane while OZ is the polar axis. On both

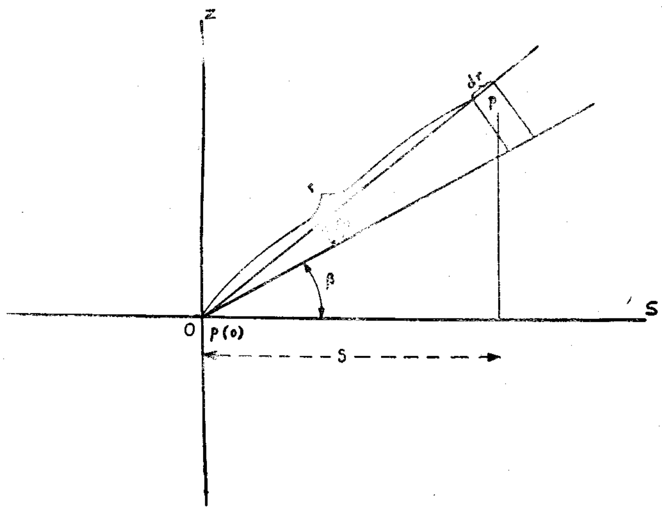

Fig. 1

sides of the galactic plane with increasing value of $|z|$ the stellar density ρ decreases while the mean colour of the stars increases. For the density in the galactic plane at a distance r from the origin we have $\rho_s = \rho_0 \exp(-ls)$ so that the density at P is $\rho_P = \rho_0 \exp(-ls).\ \exp\left(\frac{-2\,|\,z\,|}{T}\right) = \rho_s \exp\left(\frac{-2\,|\,z\,|}{T}\right)$

From this we see that:

a. In the latitude β the amount of light contributed by the stars within the limits of distance r and $r + dr$ is proportional to ρ_s.

b. In the direction β the mean colour of the stars increases with increasing value of r.

From this reasoning we find that $K_{\lambda,\beta}$ and $\Delta K_{\lambda,\beta}$ must systematically depend on the numerical value of the coefficient l and on the galactic latitude β. But as the numerical value of l will vary from one longitude to the other, we find that $K_{\lambda,\beta}$ and $\Delta K_{\lambda,\beta}$ must systematically depend both on galadic longitude and latitude. This is exactly what we find from the observed values

Finally it is evident that:

a. If $l = 0$ the density in the galactic plane will be constant and $\Delta K_{\lambda,\beta}$ will be the same in all latitudes.

b. If the density decreases in outward direction ($l > 0$) the mean colour ΔK in the lower latitudes is smaller than in the higher latitudes.

c. Inversely if the density increases ($l < 0$) the values ΔK must increase with decreasing values of β.

For $\beta = 0°$ apart from the influence of absorption ΔK should correspond to the mean colour of the stars in the galactic plane From this also we conclude that in (9.2) and (11.2) the coefficients H and ΔH can not be neglected Also on these facts is based our expectation, that from a comparision of the observed and computed values of the surface brightness, some insight may be gained both about the fluctuations of the density in the galactic plane and about the absorption in this plane. At the same time it is evident, that it will be difficult to discriminate between the two effects in an entirely satisfactory way.

4. The coefficients P. H. ΔP and ΔH (equations 9 2 and 11.2).

As stated before, at present a wholly satisfactory solution of the equatious (9.2) and (11.2) is not possible. If from the two sets of equations, valid in a given longitude from a least squares solution we try to determine the numerical values of P. H,

ΔP and ΔH, we are confronted by the difficulty that the variations with β of the parameters cosec β and cotg β are broadly the same. So it is difficult to discriminate between the effect of the terms P and H and also between the terms ΔP and ΔH. An approximate solution is possible only if for the ratio $\Delta P/P$ a constant value is adopted. This involves the tacid assumption, that in all parts of the stellar universe the distribution of the absorbing materials is sufficiently homogeneous for the coefficient of selective absorbtion to be a constant fraction of the total absorption Although this assumption may be fulfilled if sufficiently large areas of space are included, we can in no way be sure that it is fulfilled in our case also. This study is concerned with the density fluctutations and the variations of the absorption in different galactic longitudes. Moreover the distances which enter into our considerations are relatively small. (Compare note 5, section 3). This is one of the main reasons why it must be emphasized that the numerical values obtained here are provisional ones only.

For the present the mean value $\Delta P = -0{,}15\,P$ as given by Beals [6] is adopted for all longitudes.

Then by a number of successive approximations the values of the coefficients are obtained. We proceed as follows.

The influence of the term ΔP on the numerical value of $\Delta K_{\lambda,\beta}$ must be considerably smaller than the corresponding influence of P on $K_{\lambda,\beta}$. In first aproximation we put $\Delta P = 0$ so that (11.2) reduces to $4{,}0\,\Delta K_{\lambda,\beta} = \Delta F - \Delta H \operatorname{cotg}\beta$ and from a least squares solution approximate values of ΔF and ΔH are obtained. Next from (8.2) we have $H = \Delta H \cdot T/(T - T')$.

To the numerical values $0{,}4\,K_{\lambda,\beta}$ the corrections $-H \operatorname{cotg}\beta$ are applied, so that we obtain a set of equations of the form $0{,}4\,K_{\lambda,\beta} = F + P \operatorname{cosec}\beta$ and by a least squares solution first approximations of F and P are obtained. Next the corrections $\Delta P \operatorname{cosec}\beta = 0{,}15\,P \operatorname{cosec}\beta$ are applied to the original values of $\Delta K_{\lambda,\beta}$ and with the corrected values from the equations $0{,}4\,K_{\lambda,\beta} = \Delta F - \Delta H \operatorname{cotg}\beta$ second approximations for ΔF and ΔH are obtained. By repeating this procedure it appears that the numerical values of the successive approximations for F, P, ΔF and ΔH rapidly converge towards definite limiting values. As a rule only two or three approximations are needed to obtain these final values. However, as remarked previously, even these final values are to be considered as preliminary ones only. They have been compilated in table I.

TABLE I.

Provisional values of T, G and l

Legenda.

λ = galactic longitude. The values $^1/_2\ T_n$; $\frac{1}{2}\ T_s$ and $\frac{1}{2}(T_n+T_s)$ are all expressed in parsecs and refer to the fotographic scale.

In the ratios T_v/T_f the values T_v are on the fotovisual and T_f on the fotographic scale.

G_n; G_S and $(G_N + G_S)$ give the absorption throught the stellar system in a direction perpendicular to the galactic plane and expressed in magnitudes. G_N is the total absorption on the Northern side of the plane, G_S that on the Southern side.

Positive values of l indicate a decrease of the density in the galactic plane, while negative values of l indicate an increase of the density.

: indicates uncertain values, e. g. the values obtained in those longitudes where for the latitude $\beta = \pm 5°$ the observed surface brightness $\mathfrak{L}_{\lambda,\beta}$ could not be computed (see section 3).

: : indicates very uncertain values, e. g. the values obtained in those longitudes where also the observed surface brightness for $\beta = \pm 10°$ had to be exluded.

Further we have

$$\frac{1}{2}\,T = \frac{1}{2}\ \text{num log F}$$

$$G = 2{,}5\ P$$

$$T_v/T_f = \text{num log}\ \Delta F$$

$$l = -\ \frac{\Delta H}{0{,}217\ \Delta T}$$

ΔF, ΔP, F and P are the values determined in section 4 (cumf also the relations 7.2 and 9.2). The columns B are explained in section 5.

TABLE I

$\lambda°$	$\frac{T_n}{2}$	$\frac{T_s}{2}$	$\frac{T_r+T_s}{1}$	$\left(\frac{T_n}{T_t}\right)_n$	$\left(\frac{T_n}{T_t}\right)_s$	G_n	G_s	G_n+G_s	$l_n \times 10^5$	$l_s \times 10^5$	B $\beta=0$	B $\beta=-2$
0	221	203	424	1,827	1,626	+,16	+,22	+,38	+ 7	− 68	1.3	1.8
20	207	187	394	1,774	1,629	+,12	+,15	+,27	+ 6	− 30	1.1	1.3
40	189	168	357	1,702	1,648	+,09	+,09	+,18	− 5	− 27	0.9	1.0
60	167	158	325	1,660	1,706	+,09	+,05	+,14	− 4	− 14	0.8	1.0
80	170	158	328	1,644	1,820	+,13	+,07	+,20	+ 13	+ 6	1.2	1.1
100	159	148	307	1,663	1,782	+,09	+,10	+,19	+ 30	+ 8	1.4	1.7
120	146	136	282	1,644	1,589	+,08	+,10	+,18	+ 29	− 3	1.2	1.4
140	140	139	279	1,694	1,667	+,11	+,02	+,13	+ 8	+ 19	1.2	1.0
160	133	154	287	1,710	1,545	+,08	+,01	+,12	+ 7	+ 22	1.0	1.0
180	132	178	310	1,754	1,687	+,07	+,07	+,14	− 1	+ 16	1.1	0.9
200	152	188	340	1,622	1,698	+,11	+,08	+,19	− 23	− 9	1.1	0.9
220	160 :	144 :	304 :	1,531 :	1,690 :	+,20	+,02 :	+,22 :	− 78 :	−100 :	—	—
240	173	187 :	360 :	1,334	1,476 :	+,49	+,35 :	+,84 :	−355	−187 :	—	—
260	160	214 :	374 :	2,080	1,542 :	+,03	+,38 :	+,41 :	− 33	− 69 :	0.7	1.0 :
280	167	162	329	2,118	1,875	,00	+,02	+,02	− 46	− 21	0.9	0.7
300	132 ::	172	304 ::	1,758 ::	1,687	−,04 ::	+,11	+,07 ::	− 59 ::	− 69	1.0 ::	1.1
320	—	166	—	1,667	—	—	—	—	—	—	—	1.5
340	207 :	383 ::	590 ::	1,623 :	1,213 ::	+,18 :	+1,11 ::	+1,19 ::	− 20	−275 ::	1.1	3.6

5. The absorption in the galactic plane

If in the galactic plane the absorption be a magnitudes per parsec, the theoretical amount of scattered starlight is

$$\mathfrak{J} = \omega \int_0^{\infty} (\rho_0 \, \mathfrak{J}_0) \, r^2 \frac{dr}{r^2} \, . \, 10^{-0,4 \cdot ar} \cdot \exp(-lr) = \frac{\omega . (\mathfrak{J}_0 \, \rho_0)}{0,902 + l} \quad \cdots (1\ 5)$$

while the surface brightness expressed in magnitudes is equal to

$$\mathfrak{L} = -2.5 \{ \log \omega + \log (\mathfrak{J}_0 \, \rho_0) - \log (0,902 + l) \} \quad \cdots\cdots (2.5)$$

and so after a few reductions and inserting the numerical values of $\log \omega$ and $\log (\rho_0 \, \mathfrak{J}_0)$ we have

$$a = \frac{1}{0,902} \left(10^{-0.4\mathfrak{L} - 4,796} - l \right) \quad . \ . \ . \ . \ (3\ 5)$$

When in (3.5) the observed values for $\mathfrak{L}_{\lambda,0}$ and $\mathfrak{L}_{\lambda,-2}$ are inserted, we find the amount of absorption in the galactic plane. In the various longitudes for $\beta = 0$ the values l valid in the Northern hemisphere were used and for $\beta = -2°$ those obtained for the Southern hemisphere were used (see table I). The values, entered in the final two columns of table I are equal to $B = 1000 \cdot a$. When comparing the values of l and B it is evident that, at least between $\lambda = 20° - 200°$ the influence of l on the numerical value of B is small. Consequently the values of B giving the fotographic absorption may be considered as the true mean values of the absorption in the different longitudes.

At present no attempt has been made to determine the corresponding values $-\Delta P/P$. Especially in the lower latitudes the coefficients of the relation $m_v = R + Q\, m_f$ may rapidly vary from one longitude to the other. Therefore the conversion from the fotographic scale to the visual might be entirely unreliable.

6. Apparent surface brightness of the galactic system for an outside observer.

We consider a cylindrical tube with a diameter of one square parsec and with an axis which coincides with the line from the hypothetical observer towards the sun.

The amount of light emitted by all stars contained within a slice of this tube of thinkness dr at a distance r from the sun is

$$(\rho_0\, \mathfrak{J}_0) \exp\left(-(2\, r \sin \beta)/T\right) dr$$

The apparent surface brigheness is independent from the distance of the observer to our system. Consequently for an outside observer the apparent surface brigtness at the end of the tube is

$$\mathfrak{J} = \omega \int_{-\infty}^{+\infty} (\rho_0\, \mathfrak{J}_0) \,.\, \exp\left(\frac{-2r \sin \beta}{T}\right) dr = 2\omega \,.\, (\rho_0\, \mathfrak{J}_0)\, \frac{T}{\sin \beta} \quad . . (1.6)$$

or, expressed in magnitudes

$$\mathfrak{L} = -2.5 \{ C + \log (\rho_0\, \mathfrak{J}_0) + \log T - \log \sin \beta \} \quad . . . (2.6)$$

In this relation the influence of absorption and that of the variations of density have been neglected. Evidently the galactic latitude β is equal to the inclination of the galactic plane to the plane perpendicular to the observer's line of sight From (1 6) we conclude that to an outside observer the surface brightness of our system in the region round the sun is twice as bright as the surface brightness of our system as it will appear to an observer near the sun as seen in the direction of the hypothetical outside observer.

Apart from the influence of absorption the colour index should be a constant for all values of β.

From the observed surface distribution of the stars we find that near the galactic pole the apparent surface brightness $\mathfrak{L}_{90} = 6^m,75$ while for the colour index $\Delta\mathfrak{L}_{90}$ the value $C.\mathfrak{J} = + + 0^m.85$ is obtained.

So for $\beta = 90°$ to an outside observer the surface brightness of our galaxy near the sun will appear to be $m_f = 6^m.05$ and $m_v = 5^m.20$ while $C.\mathfrak{J} = + 0^m.85$.

For other values of β the apparent surface brightness, expressed in magnitudes, will be $(6{,}05 - 2{,}5 \log \sin \beta)$ magnitudes.

If for all longitudes together the apparent surface brightness is directly computed from the observed distrubution of the stars, it appears that these latter values slightly deviate from the theoretical values $(6{,}05 - 2{,}5 \log \sin \beta)$ magnitudes. This appears from table II where the differences $D = m_{obs.} + 2{,}5 \log \sin \beta - 6{,}05$ are tabulated.

TABLE II.

Differences $D = (m_\beta)_f + 2{,}5 \log \sin \beta - 6{,}05$

β	D	β	D
+ 90°	+ 0,03^m	− 90°	− 0,02^m
+ 80	+ 0,03	− 80	− 0,10
+ 70	0,00	− 70	− 0,12
+ 60	+ 0,04	− 60	− 0,11
+ 50	− 0,08	− 50	− 0,08
+ 40	− 0,09	− 40	− 0,06
+ 30	− 0,14	− 30	− 0,12
+ 20	− 0,11	− 20	− 0,23
+ 15	− 0,07	− 15	− 0,47
+ 10	+ 0,03	− 10	− 0,57
+ 5	+ 0,41	− 5	+ 0,03

7. The provisional results.

It has repeately been stated that the numerical results, obtained in the present article, are provisional ones only and cannot be accepted without reserve.

However, it is expected that the method, developed here, may yield accurate results as soon as sufficient observational data for the separate areas becomes avaliable. This should be explained in some furher details.

a. For converting the photopraphic scale into a visual one, the relation $m_v = R + Q \cdot m_f$ was used, while the numerical values were taken from the tables given by van Rhijn [7]. These tables for the various latitudes gives the numerical values P and Q valid for the mean of all longitudes together. So when using these values, it was tacidly assumed that one and the same relation holds in all longitudes. Especially in the very low latitudes it seems doubtful whether this actually is the case. On the contrary there are many indications [8] that in the galactic plane the colour varies from one area to the other. Therefore the results in table I can certainly be improved if for the separate longitudes the relation between mean colour and latitude is studied. However, for this the observational material which is avaliable will not always be sufficient.

b. It was supposed that for a given longitude the amount of interstellar absorption is a constant. Although this may be true for large volumes of space, it must be feared that for small areas deviations may occur. All authors agree that in interstellar space the absorbing materials appear to occur in cloudlike formations, while the various clouds have unequal densities. Consequently also the ratios $\Delta P/P$ may vary from one area to the other.

It will be evident that the effect, mentioned sub a, will have no influence on the observed values $\Omega_{\lambda,\beta}$, but on the other hand may systematically affect the observed colours $\Delta\Omega_{\lambda,\beta}$. As was pointed out in section 4, it is diffucult to discriminate between the effects of distance and of absorption. From our relations the numerical values of P, H, ΔP and ΔH could only be obtained if for the ratio $\Delta P/P$ a certain numerical value is adopted.

In this article for $\Delta P/P$ a certain mean value, which is valid for all longitudes together, was used. However, we certainly cannot be sure that the ratio $\Delta P/P$ will not be different in the different parts of space or in different longitudes.

It cannot be doubted that when solving the equations of section 4, other numerical values of the ratio $\Delta P/P$ are used, different values for T, G and l will be obtained. Consequently an error systematically depending on longitude, may effect all values given in table I.

Obviously the difficulties stated here, can only be avoided by a detailed study of the individual longitudes.

It may not be necessary to study the function $f(z) = \frac{(\Im\rho)_v}{(\Im\rho)_f}$ for the separate longitudes, because it may be anticipated that this ratio will hardly depend on longitude, but at any case the relation between z and $(\Im\rho)_f : (\Im\rho)_v$ should be considered. On the other hand the functions $m_v = P + Qm_f$ and $\Delta P/P$ will almost certainly depend on longitude and therefore will have to be determined for each longitude separately, before reliable results can be obtained from the method exposed in the present article. In subsequent papers we hope to consider these questions.

8. Discussion of the provisional results.

When discussing the provisional results given in table I, we have to bear in mind the various objections stated in section 7. Our conclusions cannot definitely be accepted without additional proof, while this additional proof can only be obtained from a careful study of the individual longitudes.

a. In (figure 2) the values $\frac{1}{2}T_n$ and $\frac{1}{2}T_s$ of table I are plotted against the corresponding longitudes. The distance between the curves T_n and T_s is proportional to the thickness of a slab of uniform density at right angles to the galactic plane, which contains as many stars as the actual layers from pole to pole. Apparently the thickness of this slab systematically depends on galactic longitude. Its minimum value seems to occur around $\lambda = 140°$ that is to say in the direction of the anticentre.

Towards the direction of the galactic centre the thickness seems to increase, but for the longitudes $\lambda > 240°$ most of our values T_n and T_s are indicated as being uncertain so that here the results are rather undeterminate.

In this same figure crosses indicate the values $\frac{1}{2} T_n - \frac{1}{2} T_s$ From the curve, connecting these points, it seems possible that near our sun the plane of symmetry might slightly be inclined relativily to the galactic plane.

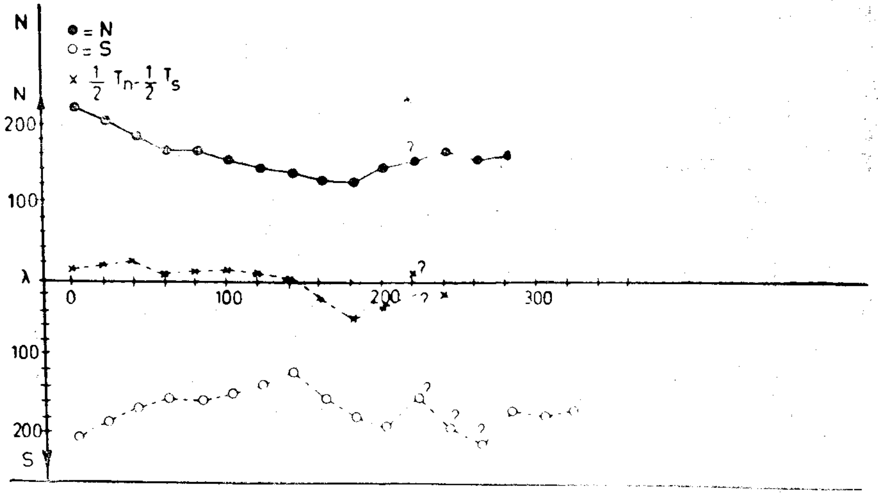

Fig 2

Partly at least this conclusion may be spurious as it is difficult exactly to define for which distances from the sun the values T_n and T_s are valid. In any case these distances will depend on the density distribution and on the absorption and therefore may vary from one longitude to the other.

b. From our values G_n, G_s and $G_n + G_s$ it would appear that in a direction, perpendicular to the galactic plane, our stellar system is almost completely transparent. This result certainly is not improbable. From the investigations by Baade [9] it is known that in the outside galaxies the absorbing materials are largely confined to the spiral arms. Between the spiral arms the outside galaxies seem to be transparent so that between the spiral arms other more distant systems can be observed. Recent results from radio astronomy strongly indicate that the position of the sun in our galactic system is such that our sun is situated between two spiral arms, in a part of the system, which therefore actually may be transparent.

c. In (figure 3) the values l_n and l_s are plotted against the corresponding galactic longitudes. Positive values of l indicate a decrease of density in the galactic plane, while negative values l indicate an increase in density.

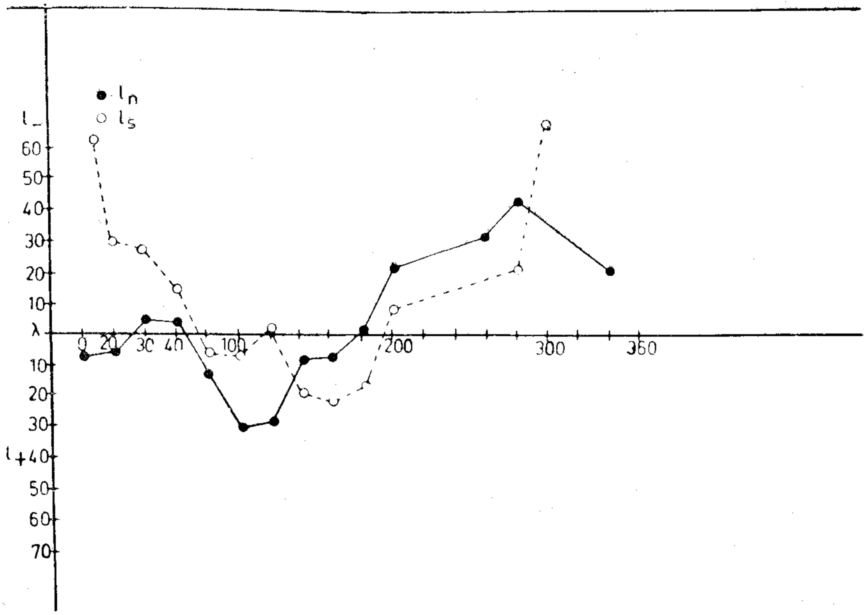

Fig. 3

Therefore from our provisional values it would appear, that between the longitudes 80° — 200°, that is in the general direction of the anticentre, the density decreases. On the other hand the density increases in the general direction of the galactic centre.

d. In figure 4 the value B_n and B_s are plotted against longitude. Although the values B_n and B_s are rather consistent inter se, the run of the curves is rather irregular. Various maxima and minima seem to be indicated. As far as evidence goes, the maxima of absorption occur in the directions both of the galactic centre and of the anticentre, while minima occur in the two intermediate regions. (see fig. 4).

e. For the mean colour index of our galactic system as seen by an outside observer, we have found $C\cdot\text{Ɔ} = +0^{m}\cdot 85$. For the various groups of extra galactic spirals the following values [10] have been obtained

$S_a + 0^m,89$; $SB_a + 0^m,89$; $S_b + 0^m,86$; $SBb + 0^m,86$; $S_c + 0^m{\cdot}55$ and $SBc + 0^m{\cdot}55$

Our values therefore compare very well with those obtained for the outside galaxies.

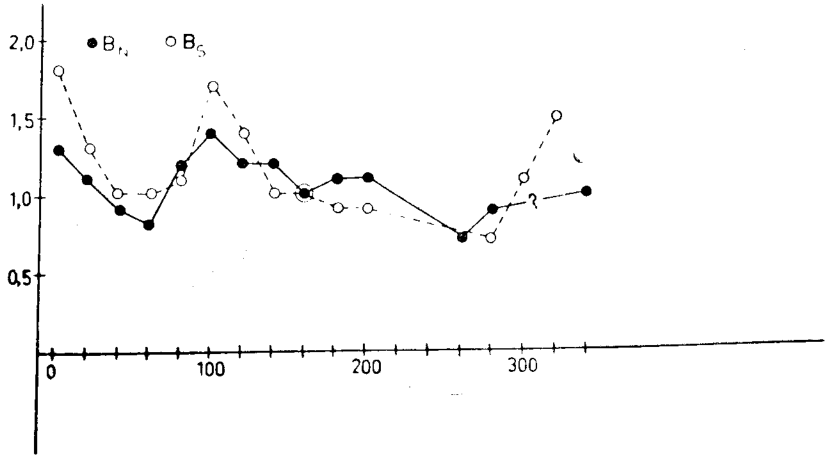

Fig. 4

f. When computing for small values of β the value of the surface brightness and of the colour (table 2), the influence of the absorption was neglected. This was necessary as we have no information about the amount of absorption in the outer parts of our galactic system. As extensive dark streaks seem to be projected on the images of the spirals which are seen edgewise, it is probable that dense absorption occurs in these outer parts. Therefore a detailed comparison of the values in table II, with the corresponding values of the outside galaxies, would be meaningless.

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