Optical Thickness of the Galactic Absorption Layer and Its Ratio of Total to Selective Absorption

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AS IS WELL KNOWN, the surface brightness within the galaxies decreases strongly with increasing distance from the center. Therefore, if the diameters of the galaxies are defined by the isophote of a distinct apparent surface brightness, these diameters become smaller and smaller with increasing galactic absorption. The diameters are defined in reference 1 in this manner (by the isophote $26^{\mathrm{m}}.5/\mathrm{sec}^2$); therefore, the mean surface brightnesses derived in that reference correspond more and more to the inner, brighter parts of the galaxies as the absorption increases. Consequently, in the derivation of the half optical thickness a of the galactic absorption layer from the variation of the mean surface brightnesses S of 113 spiral galaxies with galactic latitude β, the assumption in reference 1, $dS/d(\csc\beta) = a$, is not correct but has to be replaced by the more complicated formula

$$dS/d(\csc\beta) = \left[1 - \frac{5\log e}{m_{lim} - m_{center}}(1-R)\right] a$$

This formula holds for spirals whose brightness distribution may be represented by the law

$$m(\rho) = m_{center} + \frac{(m_{lim} - m_{center})\rho}{\rho_{lim}}$$

where

ρ	distance from center
ρ_{lim}	apparent radius of galaxy
m_{lim}	(photographic) surface magnitude at border
m_{center}	(photographic) surface magnitude at center
R	ratio of surface brightness at apparent border of galaxy to mean surface brightness within this border

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The ratio R is small compared with 1 and may be neglected. Assuming $m_{lim} - m_{center} = 5\overset{m}{.}0$ and taking the equation $dS/d(\csc\beta) = 0\overset{m}{.}26$ from reference 1, one gets $0\overset{m}{.}46$ for the half (photographic) optical thickness of the absorption layer.

Similar values are found from the galaxy counts in references 2 and 3 if the loss of galaxies with decreasing galactic latitude is considered to be an effect of decreasing diameters rather than being determined by the limiting magnitude of the plates. Since the diameters of the faintest galaxies which can be found are only a little larger than the diameters of the stars, even a small decrease of their diameters due to absorption will make them indistinguishable from the stars. A thorough treatment of the problem shows that the decrease of the galaxy numbers with decreasing galactic latitude depends not only on the optical thickness of the absorption layer but also on the brightness distribution within the galaxies. For elliptical galaxies, whose brightness distribution may be approximated by the formula $m = m_0 + 5 \log \rho$, one gets

$$\frac{d(\log N)}{d(\csc\beta)} = -\frac{3}{5(1 + dK/dm_c)}\,a$$

while for the spirals, the corresponding expression

$$\frac{d(\log N)}{d(\csc\beta)} = -\frac{1.3}{(m_{lim} - m_{center})(1 + dK/dm_c)}\,a$$

follows from their brightness distribution mentioned previously, where

$N = N(m)$ number of galaxies with magnitude less than m
K extinction
$m_c = m - a \csc\beta - K$

The differential quotient dK/dm_c considers the influence of the red shift. These two formulas have to be compared with the one used so far,

$$\frac{d(\log N)}{d(\csc\beta)} = -\frac{0.60}{1 + dK/dm_c}\,a$$

which obviously holds only for point sources as, for example, the quasars and, more accidentally, the ellipticals.

Values of $m_{lim} - m_{center} = 3$ magnitudes for the counts in reference 2 and $m_{lim} - m_{center} = 2$ magnitudes for the Lick counts are used since corresponding photographs showed these values to be the most probable. If values of $\frac{d(\log N)}{d(\csc\beta)}$ of 0.15 for Hubble's counts and 0.24 for the

Lick counts are also assumed, one finds values of $0^{m}.40$ and $0^{m}.45$, respectively, for the half (photographic) optical thickness a. These values are in good agreement with the former value, $0^{m}.46$, derived from the data of reference 1.

The mean value of about $0^{m}.45$ is approximately twice as large as the former value, $0^{m}.25$, found in references 1 and 2 and also twice as large as the value which follows from the observations of: (1) the colors of galaxies by Holmberg and (2) the colors of globular clusters by Kron and Mayall (ref. 4) (at the galactic pole $E_{B-V}=0^{m}.05$ and $0^{m}.06$, respectively, for (1) and (2)), if one assumes a ratio $R_B=A_B/E_{B-V}=4$. Because these last observations need no corrections, a value of R_B of about 8 results from these considerations.

This result is in quantitative agreement with the work published in reference 5 and indicates that there may be an appreciable amount of neutral absorbing material whose relative abundance perhaps increases with increasing distance from the galactic plane. The observations of the galaxies are confined to higher galactic latitudes, whereas the "normal" ratio $R=A_V E_{B-V}=A_B/E_{B-V}-1=3$ in general is determined near the galactic equator, where

R_B ratio of total extinction in blue to color excess, A_B/E_{B-V}
A_B extinction in the blue
A_V extinction in the visual

However, for a final solution of this problem, further special observations are needed.

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DISCUSSION

Borgman: This result was a controversial one, but was expected from counts of galaxies and would indicate that there is some neutral absorption which does not show up in the more traditional methods.

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Neckel: That is true. The neutral absorption probably is more important than was expected. The result agrees fairly well also quantitatively with Johnson's work (ref. 2).

Gehrels: I was wondering if the ratio A/E was assumed to be the same for E_{P-V} and E_{B-V}.

Neckel: The difference between total absorption A_B and A_P (where the subscript P refers to photographic extinction) can be neglected. The ratio of A/E_{P-V} to A/E_{B-V}, therefore, is approximately equal to the ratio E_{B-V}/E_{P-V}. This latter ratio has a value of about 0.8. From Holmberg's value of $0\overset{m}{.}06$ for the selective absorption at the galactic pole (ref. 1), one gets about $0\overset{m}{.}05$ in the BV system. This difference was taken into account, although it is not important in this case.

Wickramasinghe: Is it possible to separate completely the effects of absorption inside and outside the galaxy?

Neckel: It is not possible to separate the absorption inside and outside the galaxy. Only the absorption inside our galaxy can show up in the latitude variation of surface brightness and numbers of galaxies.

I first wanted to see if it was possible that the ratio A/E might vary with distance from the galactic plane. The adopted value of 3 for this ratio was derived from objects near the galactic plane. For the latitude variations of galaxy counts and brightnesses, the layers at larger distances from the plane are important. So far, I didn't doubt that within the galactic plane the ratio would be 3, because one can derive the spiral structure very well from early-type stars if one assumes this ratio when computing the distances.

The model I proposed was the following: A geometrically thin layer of selective ($A/E \approx 3$) absorption material near the galactic plane with an optical thickness of about $0\overset{m}{.}25$, and a geometrically thick layer of neutral absorbing material with the same optical thickness. While the contribution of the neutral layer in the galactic plane would be small because of the larger geometrical thickness, the total optical thickness would be $0\overset{m}{.}5$. This is the value derived from the galaxy counts. But this was only a first speculation. According to previous papers, there seems to be a large variation of the ratio A/E in the galactic plane. The value 3 seems to be the minimum value and, as a consequence, the average one will be larger than 3. This is exactly the result indicated by the galaxies.[1]

[1] Note added in proof: If the reddening law is uniform within the whole galaxy, one obviously gets the best spiral-arm structure when the distances of the stars are derived by using the true ratio A/E. If, however, the reddening law and the ratio A/E varies from star to star between two limiting values, but the distances are computed by using one single value of the ratio A/E for all stars, one gets the best concentration by using the smaller limiting value. Therefore, the fact that the best spiral-arm concentration is derived when reducing the distances of the stars with a value of 3 for the ratio A/E does not exclude the possibility of a general variable reddening law.

Wickramasinghe: I am wondering if the inference could be drawn that this is galactic absorption rather than absorption between galaxies.

Neckel: Our results depend on the variation with galactic latitude. I can't see how intergalactic absorption would depend on the galactic latitude.

Nandy: Are you assuming that there is no intergalactic absorption when you count the galaxies?

Neckel: If there were an appreciable amount of intergalactic matter, its influence could be considered in a first approximation as an increase of the term dK/dm_c, which so far only includes the loss of brightness due to the red shift. The result would be a still larger value for the optical thickness of the galactic absorption layer. But I think this would be an effect of the second order. The main assumption is that the intergalactic absorption does not depend on the direction.

Wickramasinghe: For directions close to the plane of the galaxy one would expect the dominant contribution to the extinction to come from dust grains inside the galaxy, but for directions at right angles to it one would expect the stuff between the galaxies to play the dominant role.

Greenberg: If this were true, the dependence of extinction on galactic latitude would be considerably different. The extinction depends on a geometrical configuration and is a function of the length of path in our galaxy. If there were intergalactic absorption in addition to that within the galaxy and it were uniform, an additional constant (independent of β) would result which could not be seen and which would have no effect on this function.

Borgman: What you actually get here is, in my opinion, the component in the galaxy which might be considered neutral with respect to every other component that has been found by variable extinction methods of color differences.

Behr: Is there not a discrepancy between these results and those of Johnson? Johnson finds that the neutral absorption is present especially in very young areas, or in areas near the galactic plane. At higher galactic latitudes we don't know any young regions.

Neckel: Johnson's observations of one star led to a value of A/E of about 15. The star was at a rather high latitude.