PROPER MOTIONS AND DISTANCES OF QUASARS

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Abstract

The author's theory that quasars are stars raises the question of their proper motions. From the evidence presented in a previous paper, it is hypothesised that planetary nuclei and quasars are related objects and that their distributions in the galaxy are not very different. Proper motions of 30 quasars, calculated from existing measurements, are discussed. It is shown that three of these, namely PHL 1033, LB 8956 and LB 8991, have proper motions comparable to the largest proper motion known amongst the planetary nuclei. From this it is estimated that these three quasars lie within a few hundred parsecs from the sun. The evidence presented in a previous paper and the present one clearly supports our theory that quasars are stars. The possibility of using the interstellar K and H lines as distance indicators of quasars is discussed and the available evidence summarised. The desirability of determining more accurate values of the proper motions of quasars is emphasised.

1. INTRODUCTION

We have proposed a theory of quasars(1-8), based on sound physical principles, which does away with the artificial assumption of redshifts and provides satisfactory explanations of the various phenomena associated with quasars; according to our theory the quasars are a special type of stars. In the present paper we discuss the proper motions and distances of quasars(9,10). In the period, soon after the discovery of quasars, investigations on the proper motions of a total of 16 quasars were published(11-14).

In a previous paper(4) we have presented evidence which indicates that planetary nuclei and quasars are related objects. In Section 2 we estimate what sort of proper motions to expect for quasars if they are related to planetary nuclei. Section 3 deals with the proper motions of quasars. We have found that there are 30 quasars, in addition to those discussed in references 13 and 14, for which proper motion data are available from existing measurements; data for these 30 quasars are discussed. Three of them are found to have large proper motions as compared to the proper motions of planetary nebulae. The possibility of using the equivalent widths of interstellar K and H lines as distance indicators of quasars is discussed in Section 4, and the available information is summarised. Predictions concerning the proper motions of quasars and the observance of interstellar K line in their spectra are made in Section 5.

2. RELATION BETWEEN PLANETARY NUCLEI AND QUASARS

In a previous paper(4), we have shown that a continuity exists in the spectra of O VI sequence planetary nuclei(15), Sanduleak stars(16) and 10

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quasars. From this we were led to infer that these are related objects. We shall try to estimate the proper motions of quasars from this link. Two factors have first to be considered: (a) the distribution of quasars in the galaxy; and (b) the space density of quasars. As regards (a), we shall adopt here as a working hypothesis the assumption that planetary nuclei and quasars are related objects and that their distributions in the galaxy are not very different. In other words, we expect a concentration of quasars in the galactic plane and a gradual decrease with $|z|$, where $|z|$ is the distance to the galactic plane. The rate of decrease, $\partial \log N/\partial z$ is known to be different for different types of stellar objects, and it is entirely possible that $\partial \log N/\partial z$ for quasars may be much different from that for planetary nebulae. At present, about 1500 quasars have been identified[17]. All of them, except a few (~11) have $|b^{II}| > 10°$. We have discussed the reasons for this apparent lack of quasars in the zone $|b^{II}| < 10°$ in a previous paper[4]. As the saying goes, "Absence of evidence is not evidence of absence." No one has carried out any detailed investigation to look for quasars in the zone $|b^{II}| < 10°$. We may note here that there is no shortage of faint stellar objects in this zone[18,19]. But no systematic study of their spectra has ever been carried out.

Next we consider (b). It is known that the surface density of quasars increases as one goes to fainter magnitudes. The available data suggests[20] that a conservative estimate will be 5 quasars deg^{-2} to $B \leqslant 20$. This corresponds to $\sim 2 \times 10^5$ quasars over the whole sky. There does not seem to be any statistical data on the surface density of planetary nuclei available. We can, however, look at the problem in another way. The total number of planetary nebulae in our galaxy has been estimated[21] by a number of authors, from a low of ~10,000 to a high of about half a million. However the favoured value seems to be in the neighbourhood of 50,000. We have noted above that the total number of quasars visible from the earth (to $B \leqslant 20$) is estimated to be 2×10^5, that would mean that the total number of quasars present in our galaxy is much greater than this number and this would imply that the space density of quasars is greater than that of planetary nuclei.

Elsewhere[22] we have discussed the best available data[23] on the proper motions of the central stars of planetary nebulae and have given a diagram showing the proper motion against the distance for 60 planetary nebulae. The nearest planetary NGC 7293 has the largest proper motion and it stands out from the rest. However, its proper motion is only $0''.040 \pm 0''.003$ yr^{-1} and it is an isolated case. Proper motions for all other planetary nebulae (in Cudworth's list) are smaller than $0''.024$ yr^{-1}, with considerable uncertainty in many cases. A great majority of planetary nuclei have proper motions less than $0''.015$ yr^{-1}. If our hypothesis concerning the relationship between planetary nuclei and quasars is correct, it would be reasonable to expect that the proper motions of quasars will have the same sort of values as those of planetary nuclei. Also, if the space density of quasars is indeed greater than that of planetary nuclei, one would expect that for similar values of the proper motion, the number of quasars should be greater than that of planetary nuclei.

3. PROPER MOTIONS OF QUASARS

3.1 Results from the conventional photographic method

The proper motions (absolute) of 951 faint blue stars have been determined by Luyten[24]. We have searched for quasars in Luyten's list and have found that there are 30 quasars, in addition to those whose proper motions have been discussed by previous workers[13,14], for which proper motions are known. We list these 30 quasars in Table 1 (at the end of this article) together with their coordinate names, galactic coordinates and estimated photographic magnitudes (m_{pg}). The m_{pg} values are from reference 24. Table 2 gives $\mu_\alpha \cos\delta$, μ_δ and μ, together with their mean errors, for these quasars. The absolute proper motion, μ, and the mean error present in its determination were obtained as follows. μ is connected with $\mu_\alpha \cos\delta$ and μ_δ by the following well known relation

$$\mu = [\mu_\alpha^2 \cos^2\delta + \mu_\delta^2]^{1/2} \tag{1}$$

where δ is the declination. If ϵ_α, ϵ_δ and ϵ represent the mean (standard) errors in $\mu_\alpha\cos\delta$, μ_δ and μ respectively, then from the standard theory for determining the mean error of a compound quantity, we obtain the following expression for ϵ[22]:

$$\epsilon = [(\mu_\alpha^2 \cos^2\delta)\epsilon_\alpha^2 + \mu_\delta^2\epsilon_\delta^2]^{1/2}/\mu \tag{2}$$

The apparent red shifts are shown in the last column of Table 2; all of these values are from Schmidt[25], except those for PHL 1027, PHL 3632 and PHL 1186[26], and PKS 0237-23[27]. It will be noticed from Table 2 that there are three quasars which have proper motions comparable to the largest value amongst planetary nuclei. These three quasars and their respective proper motions (in yr^{-1}) are PHL 1033: 0″.049 ± 0″.013, LB 8956: 0″.061 ± 0″.018, and LB 8991: 0″.050 ± 0″.018. These values may be compared with the largest proper motion reported up to now for a planetary nebula, which is 0″.040 ± 0″.003 yr^{-1} for NGC 7293 (believed to be the nearest planetary nebula). The distance of NGC 7293 is estimated to be 212 pc[23]; from this it would be reasonable to estimate that the quasars PHL 1033, LB 8956 and LB 8991 lie within a few hundred parsecs from the sun. There are large uncertainties in the proper motions of quasars listed in Table 2. However, within the limitations of these uncertainties, it would be fair to say that the results for the other 27 quasars are similar to those of planetary nebulae, except, of course NGC 7293. We find that the proper motion evidence supports the hypothesis that we have advanced in Section 2.

The mean errors in the existing measurements of the proper motions of quasars are rather large. Any conclusion on this question is subject to this important qualification. In most of the reported cases, all that we can say is that the proper motion is about or less than 0″.015. What does it mean in practical terms as regards their distances? Our study[22] of planetary nuclei shows that at low values ($\mu \lesssim$ 0″.015 yr^{-1}), the proper motion is almost independent of the distance. If a star has a proper motion of less than 0″.015 yr^{-1} all we can say, from the trend of points on the proper motion-distance diagram[22], is that very likely its distance is greater than 500 pc. It may also be pointed out here that the volume enclosed within this radius of 500 pc is only about (1/27000) of the total volume of the galaxy and the galactic halo. Quasars having proper motions less than $0''.015$ yr^{-1} have 99.996% of the volume of the galaxy and the galactic halo available to them. We may also note here that some of the bright stars in the solar neighbourhood have quite small proper motions. As an illustration, in Table 3, we give proper motions and distance for a few bright stars which have a proper motion less than $0''.015$ yr^{-1} and which lie within 500 pc from the sun.[18]

The evidence presented in the previous papers[3-7] and the present one clearly supports our theory that quasars, in general, are stars.

We can estimate the distances of quasars by comparing them with planetary nuclei. Perek and Kohoutek[28] list 1036 planetary nebulae in their catalogue. An additional 226 planetary nebulae, discovered during the period 1966-1977, have been listed by Kohoutek[28]. Of these 1262, 201 planetary nebulae have $|b^{II}| > 10°$. Cahn and Kaler[29] give distances for 127 such planetary nebulae. The distance distribution of these, excluding two distant ones, is shown in Fig. 1; the two exceptions are K2 8 (distance 24 kpc) and PS 1 (distance 25 kpc). The average of the distances of these 125 planetary nuclei is 3.1 kpc, and the average of the apparent magnitudes of 85 planetary nuclei in this category for which data are available[28] is 15.0. We shall find it convenient to discuss the apparent magnitudes and distances in terms of "average" quasar. It is understood that there is a considerable spread on both sides of this average. If the distributions of quasars and planetary nuclei are similar, then this would indicate that the "average" quasar (with $|b^{II}| > 10°$) is at a distance of about 3 kpc. We can also do some speculation regarding the absolute magnitudes of quasars. The "average" quasar has an apparent magnitude of about 17.6[17]. Again assuming that the distributions of quasars and planetary nuclei are similar, this would indicate that the "average" quasar is intrinsically fainter than the "average" planetary nucleus. The photographic magnitudes of three near quasars, PHL 1033, LB 8956 and LB 8991 are 18.7, 17.9 and 17.3 respectively. This slender evidence appears to favour our speculation.

Purely as an academic exercise, we calculate the transverse velocities required for the three quasars PHL 1033, LB 8956 and LB 8991 on the cosmological red shift hypothesis. We take the smallest value of proper motion within the uncertainty range and assume the Hubble Constant to be 50 km sec^{-1} Mpc^{-1} and $q_o = 0$. Then we find that in terms of the velocity of light c, $V_t = 760c$, 5200c and 2300c for PHL 1033, LB 8956 and LB 8991 respectively. Needless to say these values are without any physical significance and clearly indicate that the cosmological red shift hypothesis is completely untenable (see also references 30-35).

3.2 A result from VLBI

Shapiro et al[36] have used very-long-baseline interferometry to obtain some evidence on the relative proper motion of two quasars, 3C 345 and NRAO 512. These two quasars are separated by half a degree, and were observed repeatedly with very-long-baseline interferometers over a period of four years. These two sources have approximately the same right ascension as the galactic centre. No relative proper motion in declination was detected with the upper bound being under 0."0002 per year. This result is fully consistent with our expectations. We note that the measured value gives the relative value of only the declination component of the proper motion, which for one particular pair could even be zero. More such studies would be highly desirable.

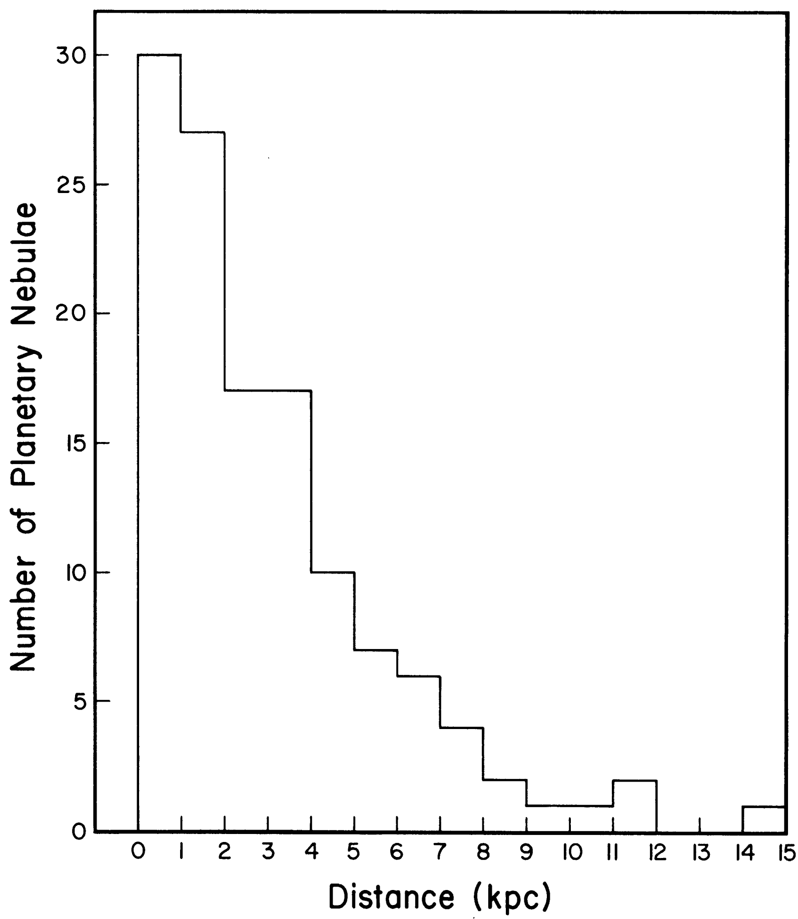

Figure 1. Histogram showing the distance distribution of 125 planetary nebulae which have $|b^{II}| > 10^{\circ}$. (The distances are on Cahn and Kaler's distance scale.)

4. INTERSTELLAR K & H LINES AS DISTANCE INDICATORS

The intensities of the two Ca II resonance lines (H and K) in the spectra of O- and B-type stars have been used as distance indicators for many years. The work prior to 1952 has been discussed in a comprehensive paper by Binnendijk[37], who also pointed out that the intensity-distance relation may be different in different directions. The subject has been reviewed by Munch[38]. A recent study is due to Hobbs[39]. The equivalent width of interstellar K has been measured for a great many stars at low galactic latitude;

however, for stars at high galactic latitude, the observational material is sparse and the nature and amount of the material at high galactic latitudes is unclear. The existing principal studies on stars at high galactic latitudes are those of Munch[40], Munch and Zirin[41], Greenstein[42], Rickard[43], Cohen[44] and Cohen and Meloy[45].

In the following we summarise the available information on the interstellar K and H lines in the spectra of quasars.

3C 273. Williams[46] records that Dr G. Preston, of Lick Observatory, obtained a number of optical spectra of the object at 48 Å/mm in which the interstellar H and K lines of Ca II are visible; a typical spectrum is reproduced in Figure 1 of Williams[46]. However, no equivalent widths or any other details of these observations have yet been published.

Greenstein and Schmidt[47] state: "Interstellar Ca II absorption lines have been found by Preston (private communication) and subsequently also on a Palomar spectrum with a dispersion of 85 Å/mm."

Greenstein[42] has reported the equivalent width of the interstellar K line in 38 objects, including 3C 273B. In his Table 1, the $W_\lambda(K)$ value for 3C 273B is recorded as "0.50?" (in Å). Also in the text the following statement occurs: "The quasi-stellar source 3C 273B was available on two plates at 38 Å/mm; unfortunately both are slightly contaminated by moonlight, so that the values of W are probably slightly too high."

3C 48. Greenstein and Schmidt[47] state: "A trace of weak, sharp Ca II absorption lines is seen . . . The stationary H and K lines are interstellar and are somewhat strong for the high latitude and low dispersion used." A mean of two microphotometer tracings of 3C 48 appears in their Figure 4. The caption attached to this includes the statement: "There is a possible slight contamination of λλ3935, 3969 by moonlight." No high dispersion study of the spectrum of 3C 48 has ever been published.

The expected equivalent width of the interstellar K line in quasars is expected to be of the same order of magnitude as that in the high galactic latitude stars, i.e. $W_\lambda(3934) \simeq 50$ to 250 mÅ[44].

The following quasars are known to show many (>10) absorption lines in their spectra: 0002-422, 3C 9 (0017+154), PHL 938 (0058+019), PHL 957 (0100+130), 0119-046, 4C 25.05 (0123+257), PHL 1222 (0151+048), 0237-233, 0424-131, 0453-423, 0457+024, 0528-250, 0537-286, OH 471 (0642+449), 0736-063, 3C 191 (0802+103), 4C 05.34 (0805+046), 0820+296, 0824+110, 0830+115, Markarian 132 (0958+550), 1158+122, Ton 1530 (1223+228), 1225+310, 1226+105, 1246-057, B 194 (1256+357), 1331+170, OQ 172 (1442+101), 1548+114b, 1756+237, 2126-158, 4C 24.61 (2251+244), 2351-154. The spectra of most of these quasars have been obtained at higher dispersion than those of quasars which show only emission lines. Amongst these absorption-line quasars, 0002-422, 0058+019, 0100+130, 0237−233, 0424-131, 0457+024, 0802+103, 0820+296, 0824+110, 0830+115, 1225+310, 1256+357, 1442+101 and 1756+237 show a line close to 3934 Å and it would be reasonable to identify it as Ca II λ3934. However, the interpretation of the intensity of this line in such quasars is beset with the difficulty that the observed intensity is the sum of circumstellar and interstellar contributions. Equivalent width data for the absorption lines are available for only a few of

Table 1

Coordinate name, galactic coordinates and apparent magnitudes for 30 quasars

Quasar	Coordinate Designation	ℓ^{II} (degrees)	b^{II} (degrees)	m_{pg}
PHL 3375	0128+074	139.7	–53.9	18.7
PHL 1027	0130+033	142.6	–57.6	17.8
PHL 3424	0131+055	141.8	–55.5	18.7
PHL 1033	0131+036	142.8	–57.3	18.7
PHL 1049	0132+077	141.3	–53.4	18.2
PHL 1070	0134+033	144.5	–57.3	17.6
PHL 1072	0135+056	143.4	–55.1	18.3
PHL 1092	0137+060	144.0	–54.6	17.0
PHL 1106	0139+060	144.7	–54.5	18.3
PHL 3632	0139+061	145.0	–54.2	18.6
PHL 1119	0140+081	144.1	–52.4	18.2
PHL 1127	0141+052	146.2	–55.0	18.5
PHL 1186	0147+090	146.3	–50.9	18.6
PHL 1194	0148+090	146.7	–50.8	18.5
PHL 1222	0151+048	150.4	–54.5	18.5
PHL 1226	0151+045	150.8	–54.6	18.2
PHL 8462*	0237-233	208.1	–64.9	16.6
LB 8741	0847+191	207.8	34.5	16.6
LB 8775	0848+164	210.9	33.7	16.9
LB 8863	0852+197	207.5	35.6	18.0
LB 8891	0852+180	209.4	35.2	18.2
LB 8956	0854+191a	208.4	36.0	17.9
LB 8948	0854+191b	208.2	36.0	16.9
LB 8991	0855+187	208.9	36.1	17.3
LB 9010	0856+186	209.2	36.1	18.3
LB 9013	0856+170	211.0	35.6	17.4
LB 9029	0856+189	208.9	36.4	17.7
LB 9308	0903+169	211.9	37.2	18.3
LB 9388	0906+168	212.4	37.8	17.2
LB 9707	1523+214	32.0	54.5	16.9

* This quasar is better known as PKS 0237-23.

Table 2

Proper motions and apparent redshifts of quasars. All proper motions and their mean errors are in the units of 0″.001 yr^{-1}

Quasar	Absolute						
	$\mu_\alpha \cos\delta$	ϵ_α	μ_δ	ϵ_δ	μ	ϵ	Apparent redshift
PHL 3375	5	±18	–3	±18	5.8	±18	0.391
PHL 1027	9	13	14	13	16.6	13	0.363
PHL 3424	1	18	12	18	12.0	18	1.851
PHL 1033	28	13	40	13	48.8	13	0.255
PHL 1049	–11	13	18	13	21.1	13	0.147
PHL 1070	–5	13	–28	13	28.4	13	0.079
PHL 1072	12	13	26	13	28.6	13	0.615
PHL 1092	7	13	16	13	17.5	13	0.396
PHL 1106	–16	13	–28	13	32.2	13	0.345
PHL 3632	22	18	12	18	25.1	18	1.479
PHL 1119	–16	13	17	13	23.3	13	0.119
PHL 1127	–20	13	–7	13	21.2	13	1.985
PHL 1186	13	13	13	13	18.4	13	0.270
PHL 1194	–3	13	26	13	26.2	13	0.297
PHL 1222	3	13	3	13	4.2	13	1.91
PHL 1226	0	13	–1	13	1.0	13	0.405
PKS 0237-23	14	13	19	13	23.6	13	2.223
LB 8741	8	18	–16	18	17.9	18	0.568?
LB 8775	5	18	–1	18	5.1	18	1.932
LB 8863	8	18	–13	18	15.3	18	2.214
LB 8891	–9	18	–13	18	15.8	18	0.215
LB 8956	49	18	36	18	60.8	18	1.891
LB 8948	8	18	16	18	17.9	18	0.331
LB 8991	–18	18	–47	18	50.5	18	1.013
LB 9010	–13	18	–1	18	13.0	18	1.711
LB 9013	–13	18	–26	18	29.1	18	1.449
LB 9029	–34	18	12	18	36.1	18	1.286
LB 9308	–18	18	–9	18	20.1	18	0.411
LB 9388	28	18	–13	18	30.9	18	1.070
LB 9707	–2	18	22	18	22.1	18	1.924

Table 3

Proper motions and distances of a few bright stars which have small proper motions and which lie within 500 pc from the sun. Data are from Allen[18].

Star	μ (yr^{-1})	Distance (pc)
Algol	$0''.007$	32
Rigel	$0''.001$	250
Mintaka	$0''.002$	460
Arneb	$0''.006$	300
Alnilam	0	470
Alnitak	$0''.005$	450
Mirzam	$0''.004$	200
Adhara	$0''.004$	200
γ Vel	$0''.010$	150
κ Vel	$0''.012$	130
θ Sco	$0''.012$	160
Sadir	$0''.001$	250
Deneb	$0''.003$	500

the quasars. In 1331+170[48], there are two lines whose equivalent width is recorded as ~ 0.2 Å; this does not necessarily imply, however, that all lines stronger than this have been detected. The equivalent widths of the weakest absorption lines recorded in Markarian 132 and 0453-423 are 0.2 Å[49] and 0.3 Å[50], respectively. At present, all that can be said as regards the absence of λ3934 in these three quasars is that the available data are consistent with our expectations.. Morton and Morton[51] have taken two spectra of Ton 1530 covering the region λλ4435-4655 and they give equivalent widths for five lines. Quasar 2126-158 has not been investigated shortward of λ4153[52]. No equivalent width data on any of the remaining quasars are available. It is of interest to note that PKS 0237-23 and PHL 1222 appear in Table 2.

5. PREDICTIONS & FUTURE POSSIBILITIES

It is possible to determine the proper motions of stars to an accuracy of $0''.002\ yr^{-1}$; if the same accuracy could be achieved for quasars, we predict that at least 15% of the known quasars will show proper motion $\geqslant 0''.005\ yr^{-1}$. More accurate astrometric investigations on quasars are clearly most desirable.

We predict that most quasars will show the interstellar K line in high-dispersion spectra. The expected range of its equivalent width is 25-350 mÅ. A systematic study of the interstellar K in quasars and high latitude stars can yield useful information on the distances of quasars. Because the interstellar material in the halo may be rather inhomogeneous the equivalent-width-distance relation may be different in different directions. Absorption-line quasars can, of course, have an additional contribution from the circumstellar shell. If the profile of the K line could be measured with sufficient accuracy, it may be possible to separate the interstellar and circumstellar contributions.

If, indeed, it is ultimately confirmed that the total number of quasars is ~ 200,000, it would not be unreasonable to expect that some of the quasars may be less than 100 parsecs away. The parallax of a star at a distance of 100 parsecs is $0''.01$. It is quite conceivable that one day it may be possible to measure the parallax of one of the nearest quasars.

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Reviewer Comments

The author's modifications to his paper have answered one or two of the questions that I raised previously, but a serious difficulty remains. Whereas the concentration of planetary nebulae toward the plane of the galaxy shows that they are galactic objects, the approximately isotropic distribution of quasars shows that they are either outside the galaxy or very close within the galaxy. Varshni himself points out that of 1262 planetary nebulae listed in the catalogues he uses, only 201 are situated more than 10° from the galactic plane, while all except about 11 of approximately 1500 quasars are so situated. If quasars were, as Varshni claims, star-like objects within the galaxy, then they would essentially all be concentrated within a distance from us about equal to the half-thickness of the galactic disc, namely about 1 kpc. Varshni does not make it clear whether or not this is what he is claiming. If this is what he is claiming, then he should expect many quasars to have readily observable proper motions, in contrast to what he predicts in Section 5.

I do not find Varshni's statistical discussion convincing. For one thing, his conclusions depend on a literal and uncritical acceptance of quoted errors. This is rather a risky thing to do, particularly when the quoted errors are roughly 30%. Also, as discussed in the last paragraph above, Varshni's theory would seem to require not only many more than three quasars to have readily observable proper motions, but also that some quasars should have much larger proper motions than the three non-zero values that he is claiming.

Although I consider that these are strong reasons for not agreeing with Varshni's interpretation of the facts, I think he should have the opportunity to publish his discussion, along with critical comment, in SST.

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