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RADIO ABSORPTION BY THE INTERGALACTIC MEDIUM

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ABSTRACT

The infrared-radio correlation for spiral galaxies has been used to measure the absorption of 1.49 GHz radiation by the intergalactic medium. Contrary to conventional expectation, a sample of 237 galaxies shows a strong inverse correlation of radio luminosity (at a given IR luminosity) with distance, $L_r \sim D^{-0.4}$, over a range of distances from 0.7–55 Mpc. Strong absorption by the intergalactic medium is the only reasonable explanation of this correlation, which is statistically significant at the 2×10^{-12} level.
Subject heading: galaxies: intergalactic medium

I. INTRODUCTION

Conventional theories of the cosmic background radiation (CBR) assume that the intergalactic medium is highly transparent to radiofrequency radiation. CBR photons are assumed to have traveled 3–6 Gpc without absorption significant enough to even affect the degree of isotropy, now estimated at less than 10^{-5}.

Is this assumption correct? The correlation between the far-infrared and radio luminosities of spiral galaxies discovered by Dickey and Salpeter (1984) provides a way of observationally measuring the radio absorption of intergalactic space. If there is in fact no absorption, the radio luminosity L_R of galaxies with a given IR luminosity L_{IR} will remain unchanged with distance from Earth (assuming only that there is no significant IR absorption). However, a strong radio absorption will cause an inverse correlation between L_R at a given L_{IR} and distance.

The sample of 237 optically bright galaxies used by Devereux and Eales (1989) to study the IR-radio correlation is used here to determine if such a radio luminosity–distance correlation, indicating intergalactic absorption, exists.

II. DATA AND RESULTS

The sample used here includes all spiral galaxies in the Revised Shapely-Ames Catalog (Sandage and Tammann 1981) with $B_t < 12$ and $\delta > -45$, excluding 14 Seyfert galaxies and 56 galaxies with confusing radio or FIR background sources. No elliptical or S0 galaxies are included. The FIR radio and distance data were obtained from N. A. Devereux (1989, private communication). He based the IR data on Infrared Astronomical Satellite (IRAS) observations, the radio flux measurements on Condon (1987) and the distances on Tully (1988).

The data are presented in Table 1. Column (1) is galaxy name, columns (2) and (3) are S_{60} and S_{100} respectively in Jy, column (4) is 1.49 Ghz flux (mJy), and column (5) is distance in Mpc.

Following Devereux and Eales (1989) the *IRAS* 60 μm and 100 μm fluxes were combined to create a single IR flux:

$$F_{IR} = 2.58 S_{60} + S_{100} . \quad (1)$$

Radio and IR fluxes were converted to luminosities by multiplying by D^2, where D is distance in Mpc.

To determine the correlation of L_R on L_{IR}, independent of distance, a standard multiple linear regression was used. When L_R is considered as a function of L_{IR} and D, its partial regression on L_{IR} yields $L_R \sim L_{IR}^{1.29}$. When L_{IR} is considered as a function of the other two variables, its partial regression on L_R yields $L_R \sim L_{IR}^{1.54}$.

Taking the average value of these two slopes, 1.41, to be the true relationship, we can determine for each galaxy a radio luminosity index $I = 0.43 + \log(L_R) - 1.41 \log(L_{IR})$. If there is absorption, I should decrease as column density increases. Since the density of galaxies and thus, presumably, of an absorbing medium, decreases as $\sim D^{-1}$ within 40 Mpc of Earth, column density is proportional to $\sim \log D$. I should therefore be a linear function of log D. Figure 1 shows I plotted against log D. A least-squares fit of I on log D yields a relationship $I = -0.69 - 0.41 \log D$, equivalent to a decrease in radio luminosity with $D^{0.41}$. The correlation coefficient is 0.42 and the correlation is significant at a level of 2×10^{-12}. A zero slope is excluded at a 7 σ level. This relationship is thus statistically highly significant.

The correlation is considerably better than it appears to the eye. The best way to see this is to cover the three points with highest I and the three with lowest I. It will then be clear that the remaining 231 points follow a clear downward trend.

An alternative index using only the correlation of L_R on L_{IR} is $I' = 0.43 + \log L_R - 1.29 \log(L_{IR})$. With this index, $I' = -0.46 - 0.27 \log D$, the correlation coefficient is 0.30 and a zero slope is excluded at a 5.2 σ, or 5×10^{-7} level. Essentially the same result is obtained using Devereux and Eales's exponent of 1.28. (Their value is lower than the 1.41 used here because more distant galaxies tend to have higher L_{IR} because of the nature of the sample. L_{IR} increases approximately as $D^{1.18}$. Since the more distant galaxies have relatively lower L_R for a given L_{IR}, their effect is to reduce the exponent in the radio-IR correlation when determined as a simple two-variable regression. The multivariable regression, including D, automatically eliminates this effect, resulting in a somewhat higher exponent.)

III. DISCUSSION

There appears to be no source of bias in the data that would spuriously produce this correlation. Devereux and Eales used Coadd fluxes, which integrate surface brightness maps to determine IR fluxes for all galaxies with angular sizes above 8′ (Rice *et al.* 1988). They found that Addscan fluxes are highly accurate for smaller galaxies, so there is no possibility for

TABLE 1

THE GALAXY SAMPLE

Galaxy NGC or IC (1)	S_{60} (Jy) (2)	S_{100} (Jy) (3)	1.49 GHz Flux (mJy) (4)	Distance (Mpc) (5)
55........	77.00	174.09	381.0	1.3
110........	95.06	148.64	298.0	0.7
134........	17.23	61.18	191.0	19.0
150........	9.90	19.60	51.9	19.2
157........	18.18	46.61	171.0	20.9
224........	536.18	2928.40	8400.0	0.7
253........	998.73	1861.67	5594.0	3.0
278........	26.99	48.29	138.0	11.8
289........	6.07	16.64	47.0	19.4
428........	2.62	5.47	18.9	14.9
488........	2.35	11.45	7.6	29.3
578........	4.92	14.59	35.0	19.5
598........	419.65	1256.43	3300.0	0.7
613........	29.82	58.85	220.0	17.5
628........	20.86	65.64	180.0	9.7
660........	67.27	104.89	387.0	11.8
672........	4.04	9.66	13.9	7.5
772........	7.11	25.24	71.4	32.6
779........	2.12	7.73	11.8	17.3
864........	4.70	10.88	28.9	20.0
891........	61.10	198.63	701.0	9.6
908........	17.73	53.86	178.0	17.8
986........	24.58	54.60	110.0	23.2
IC239......	1.97	5.82	5.7	14.2
1042........	2.42	7.97	4.3	16.7
1055........	24.68	67.86	213.0	12.6
1084........	31.00	60.41	281.0	17.1
1097........	46.73	116.34	415.0	14.5
1187........	12.61	28.20	69.0	16.3
1232........	9.25	31.09	58.5	20.0
1255........	4.74	12.37	32.5	19.9
1291........	1.76	10.13	4.4	8.6
1300........	4.18	13.81	35.2	18.8
1309........	6.22	15.90	67.1	26.0
1326........	8.19	13.81	30.6	16.9
1337........	1.57	5.07	6.2	15.0
1350........	0.90	5.32	1.1	16.9
1365........	84.20	185.40	530.0	16.9
1371........	0.42	2.02	14.8	17.1
IC342......	255.96	661.68	2250.0	3.9
1385........	18.54	39.06	172.0	17.5
1421........	11.81	25.87	102.0	25.5
1425........	1.89	6.92	12.7	17.4
1448........	9.92	34.07	95.5	12.9
1356........	7.29	31.17	29.5	16.2
1512........	4.05	13.34	7.0	9.5
1532........	10.05	33.88	95.8	13.6
1560........	2.15	5.32	9.4	3.0
1569........	56.97	54.17	411.0	1.6
1637........	6.67	16.18	16.5	8.9
1744........	1.43	5.03	6.4	7.8
1792........	37.36	95.35	276.0	13.6
1961........	7.65	26.31	182.0	55.2
1964........	9.89	24.61	47.8	20.0
2090........	3.66	12.94	8.6	10.2
2146........	141.3	185.7	1087.0	17.2
2207........	18.96	43.91	310.0	33.3
2217........	1.78	6.86	29.7	19.5
2276........	14.33	32.68	283.0	36.8
2336........	3.40	13.16	17.7	33.9
2403........	51.55	148.49	330.0	4.2
2613........	7.69	29.41	50.6	21.9
2655........	1.94	5.60	121.0	24.4
2681........	7.17	12.22	12.0	13.3
2683........	8.33	34.02	65.9	5.7
2715........	3.74	13.00	23.7	20.4
2770........	2.14	5.80	14.7	29.6
2805........	2.82	6.81	14.7	28.0
2841........	4.41	24.21	83.8	12.0
2903........	52.38	147.36	407.0	6.3
2935........	4.88	12.93	40.0	30.6
2976........	13.78	36.94	50.8	2.1
2985........	5.45	18.87	61.9	22.4
2997........	32.28	85.14	290.0	13.8
3034........	1271.32	1351.09	7657.0	5.2
3077........	16.51	28.86	33.2	2.1
3079........	43.68	100.35	849.0	20.4
3147........	8.93	32.97	100.0	40.9
3166........	5.48	13.05	54.2	22.0
3169........	8.17	23.67	92.6	19.7
3184........	9.49	31.34	55.9	8.7
3198........	6.46	17.69	27.6	10.8
3223........	4.85	17.16	32.2	38.1
3256........	105.87	127.83	659.0	37.4
3310........	32.96	40.79	383.0	18.7
3338........	3.68	12.20	28.1	22.8
3344........	10.09	30.87	85.5	6.1
3359........	6.96	18.44	50.1	19.2
3368........	11.31	30.76	30.0	8.1
3432........	8.87	17.97	86.1	7.8
3486........	6.65	17.90	59.4	7.4
3504........	18.91	32.06	265.0	26.5
3511........	9.11	24.44	68.3	15.5
3513........	3.46	8.27	16.1	17.0
3556........	32.19	80.77	306.0	14.1
3593........	20.18	39.87	84.7	5.5
3621........	29.62	90.12	198.0	7.1
3627........	56.31	144.96	458.0	6.6
3628........	48.51	122.17	525.0	7.7
3631........	10.75	29.60	80.8	21.6
3642........	1.90	5.72	26.9	27.5
3672........	9.86	26.36	64.5	28.4
3675........	11.43	39.77	43.7	12.8
3686........	4.29	12.04	15.4	23.5
3705........	4.14	11.39	20.4	17.0
3718........	0.76	2.52	27.3	17.0
3729........	3.11	8.40	20.6	17.0
3810........	15.19	38.69	115.0	16.9
3887........	6.45	16.11	33.9	19.3
3893........	16.68	40.46	134.0	17.0
3938........	9.82	29.79	61.7	17.0
3949........	10.11	27.40	112.0	17.0
3953........	7.70	33.47	41.1	17.0
3992........	3.55	15.71	21.3	17.0
4013........	7.13	26.02	34.6	17.0
4027........	12.06	26.16	101.0	25.6
4030........	20.48	51.73	151.0	25.9
4041........	13.64	30.4	103.0	22.7
4062........	2.94	11.97	11.6	9.7
4088........	27.66	62.55	202.0	17.0
4096........	8.18	25.76	52.2	8.8
4100........	9.87	23.00	52.7	17.0
4123........	6.46	11.49	22.0	25.3
4136........	2.13	5.37	9.0	9.7
4157........	18.93	52.13	180.0	17.0
4178........	4.47	10.57	23.3	16.8
4192........	7.19	23.18	73.9	16.8
4212........	7.01	18.56	23.7	16.8
4214........	18.37	31.38	51.9	3.5
4216........	2.27	12.79	13.4	16.8
4217........	12.50	45.71	109.0	17.0
4254........	31.25	89.01	422.0	16.8
4258........	21.60	78.39	790.0	6.8
4274........	4.52	16.38	11.2	9.7
4293........	4.71	10.09	17.6	17.0
4303........	35.03	78.01	416.0	15.2
4314........	4.06	8.52	12.5	9.7
4321........	21.39	67.69	340.0	16.8

TABLE 1—*Continued*

Galaxy NGC or IC (1)	S_{60} (Jy) (2)	S_{100} (Jy) (3)	1.49 GHz Flux (mJy) (4)	Distance (Mpc) (5)	Galaxy NGC or IC (1)	S_{60} (Jy) (2)	S_{100} (Jy) (3)	1.49 GHz Flux (mJy) (4)	Distance (Mpc) (5)
4394........	1.04	5.13	0.7	16.8	5194........	108.68	292.08	1490.0	7.7
4414........	32.11	78.29	231.0	9.7	5204........	3.20	6.21	5.0	4.8
4448........	1.46	5.55	1.0	9.7	5236........	266.03	638.63	2445.0	4.7
4449........	38.99	75.85	266.0	3.0	5248........	22.55	53.44	140.0	22.7
4450........	1.88	9.15	8.3	16.8	5253........	33.70	30.89	83.8	3.2
4457........	5.42	10.30	37.4	17.4	5300........	1.39	4.57	2.5	23.1
4487........	2.91	8.15	4.5	19.9	5371........	6.09	18.27	50.3	37.8
4490........	51.74	91.08	774.0	7.8	5377........	1.28	4.02	3.5	31.0
4496........	5.22	10.52	21.1	13.1	5457........	88.04	252.84	750.0	5.4
4501........	19.04	64.43	278.0	16.8	5474........	2.43	6.51	1.3	6.0
4517........	6.92	20.20	32.0	9.8	5530........	4.43	12.63	14.1	16.9
4527........	34.36	65.33	214.0	13.5	5556........	2.21	5.84	2.6	20.9
4536........	33.71	49.64	203.0	13.3	5566........	1.58	7.41	8.5	26.4
4559........	9.69	27.05	65.4	9.7	5584........	2.83	6.97	21.3	27.4
4565........	9.83	47.23	131.0	9.7	5643........	23.55	46.08	203.0	16.9
4568........	22.55	61.39	136.0	16.8	5669........	2.37	5.87	10.7	34.9
4569........	9.19	27.33	83.4	16.8	5676........	12.83	34.80	96.7	34.5
4571........	1.65	6.99	4.2	16.8	5713........	23.62	38.94	154.0	30.4
4579........	6.49	18.56	103.0	16.8	5792........	9.76	20.22	51.8	30.6
4594........	4.26	22.86	137.0	20.0	5850........	1.43	5.29	17.9	28.5
4605........	15.70	35.11	85.5	4.0	5907........	8.78	45.76	89.5	14.9
4618........	5.51	13.66	31.9	7.3	5921........	4.31	12.07	23.1	25.2
4631........	82.90	208.66	1200.0	6.9	5985........	1.94	7.79	6.5	39.2
4651........	6.35	15.71	24.0	16.8	6015........	4.67	15.05	14.4	17.5
4654........	13.26	41.31	117.0	16.8	6118........	3.22	11.62	14.2	25.4
4656........	5.90	11.46	62.6	7.2	6217........	12.05	23.37	78.4	23.9
4666........	36.92	89.51	417.0	14.1	6384........	4.54	19.46	34.9	26.6
4689........	3.17	10.91	9.6	16.8	6503........	10.72	32.44	36.5	6.1
4691........	14.97	21.10	47.5	22.5	6643........	12.28	35.73	92.2	25.5
4699........	4.61	18.01	15.9	25.7	6907........	15.62	32.77	136.0	42.5
4731........	2.35	6.14	9.2	25.9	6946........	136.69	344.37	1395.0	5.5
4736........	62.41	135.34	254.0	4.3	7184........	2.09	7.93	13.4	34.1
4775........	4.59	9.57	28.5	26.6	7217........	6.21	22.11	16.2	16.0
4781........	7.79	17.64	75.9	22.5	7314........	5.66	17.96	33.8	18.3
4818........	20.00	25.86	48.3	21.5	7331........	35.29	115.07	373.0	14.3
4826........	33.86	77.38	103.0	4.1	7410........	0.91	3.68	7.3	20.1
4902........	4.40	11.68	52.0	39.2	7418........	6.62	17.23	45.6	17.8
4939........	2.99	9.81	24.2	44.3	IC5267.....	1.38	7.46	7.7	21.0
4941........	1.92	5.18	19.0	6.4	IC5273.....	5.06	12.87	33.4	16.0
4981........	3.22	11.05	21.0	27.8	7479........	12.72	27.58	109.0	32.4
4984........	11.18	15.14	29.7	21.3	7552........	72.52	99.46	276.0	19.5
4995........	4.11	12.15	28.4	28.0	7606........	3.38	12.14	15.5	28.9
5033........	17.20	51.05	178.0	18.7	7640........	3.70	11.45	29.3	8.6
5054........	11.25	27.48	87.2	27.3	7713........	5.13	10.55	16.8	8.2
5055........	40.02	157.74	390.0	7.2	7723........	4.53	11.87	10.4	23.7
5068........	13.19	33.43	39.0	6.7	7727........	0.36	1.08	3.4	23.3
5101........	1.36	4.75	5.7	27.4	7741........	3.40	8.71	13.3	12.3
5112........	2.80	7.68	14.6	20.5	7793........	19.62	56.34	103.0	2.8
5161........	2.19	7.39	7.5	33.5	7814........	1.85	7.33	1.1	15.1
5170........	1.08	4.84	4.8	24.0					

underestimating the IR flux of nearby galaxies, thus skewing the results.

In any case, errors in the data must be large to eliminate the correlation. Underestimates of IR flux of the nearest galaxies by a factor of 3 and of galaxies at 5 Mpc by a factor of 2 are needed to approach a zero correlation. It seems implausible that such errors exist.

Even if the nearest six galaxies are dropped from the sample, the results change very little. I now falls as $D^{-0.39}$, the correlation coefficient is 0.35, and a zero slope is excluded at a 5.6 σ level.

A second source of possible bias is that galaxies with low L_{IR} which tend to be closer are systematically brighter in the radio than those with high L_{IR}. In other words, the relationship between L_R and L_{IR} is nonlinear. To test this hypothesis, we divided the galaxies into two groups, those with log $L_{FIR} > 9.5$ and the rest. Here L_{FIR} is L_{IR} measured in units of solar luminosity, as in Devereaux and Eales ($L_{FIR} = 3.65 \times 10^5 L_{IR}$).

If the drop in radio luminosity with distance is a selection effect caused by the high L_{IR} galaxies being dimmer than expected at radio frequencies, these galaxies will have a lower I than average at a given distance. But this hypothesis is excluded by the data.

As shown in Table 2, there is no significant difference between the low L_{IR} and high L_{IR} groups, and the correlation with distance is significant for both groups by themselves at a 3 σ level. In this table, column (1) is the sample considered, column (2) is the average value of Y, where Y is the difference between I and the regression line for the entire sample, $Y = I - 0.69 - 0.41 \log D$, column (3) is the deviation of Y

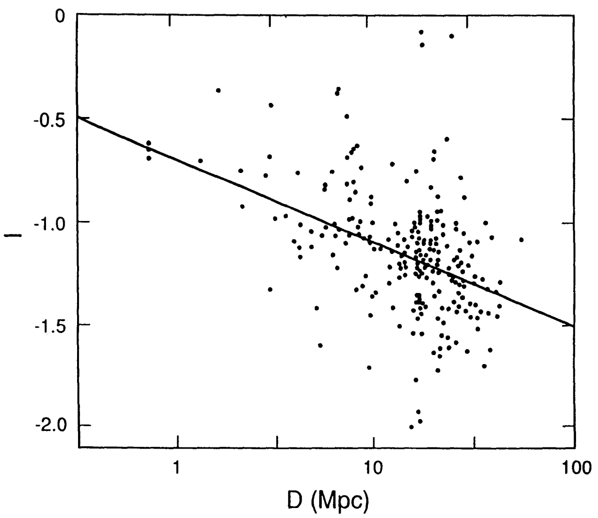

FIG. 1.—The correlation between radio luminosity index $I = 0.43 + \log (L_r) - 1.41 \log (L_{IR})$ (where L_R is radio luminosity and L_{IR} is infrared luminosity) and distance D from Earth. Each point is one galaxy and the solid line is a least-squares fit with slope -0.41.

from the total sample average in standard deviations, column (4) is the slope of I on log D, column (5) is the derivation of the slope from that of the entire sample in standard deviations, column (6) is the intercept of the regression of I on log D, column (7) is the standard deviation of I about the regression line, column (8) is the correlation coefficient, and column (9) is the level of significance of the slope of I on log D in standard deviations.

Thus the luminosity distance correlation cannot be a Malmquist-type selection effect. In fact, the correlation is strong in subsamples that have essentially identical IR luminosity. For example, 72 galaxies, 30% of the sample, have $9.9 > \log L_{FIR} > 9.5$. These galaxies are thus all within a single magnitude of each other in IR luminosity. For this subsample, $I \sim D^{-0.48}$, slightly, but not significantly, greater than the slope for the sample as a whole. The correlation coefficient is 0.44, $S_{I/D} = 0.21$ and a zero slope is excluded at a 4 σ level.

A third possible bias is in the exclusion of the galaxies with confused IR or radio fluxes. Forty-four galaxies were excluded because of confusion with background radio sources. Not surprisingly, these galaxies were somewhat closer and intrinsically dimmer in the IR than the average of the included sample since both conditions increased the likelihood of having a significant confusing background source. Average log D was 0.22 less for the excluded 44 galaxies than for the 237 included galaxies and average log L_{IR} was 0.82 less.

Since the excluded galaxies tend to be closer, it seems possible *a priori* that their exclusion could have affected the luminosity-distance relationship. To test this possible source of bias, the 11 included galaxies with $D < 3$ Mpc were compared with the eight excluded galaxies in the same distance range. The average radio luminosity index, I, for the excluded eight was -0.78 as compared with -0.68 for the included 11. The average I for all 19 galaxies was -0.72, a difference of only 0.04 from the average for the included 11 alone. This is an insignificant difference, far too little to significantly affect the correlation of I with D. Even if the background sources caused the radio fluxes in the eight galaxies to be overestimated by 50% in all cases, the average I for all 19 galaxies would be only 0.11 less than for the included 11. This would at most decrease the dependence of I on D to $I\ D^{-0.33}$ rather than $D^{-0.41}$. Again, this source of bias cannot account for the luminosity-distance relationship.

Alternatively, the effect may be explained as the result of changes in the intergalactic environment of the galaxies, which causes those close to the Milky Way to be actually more radio-luminous. Again, this seems a difficult hypothesis to defend. If, for example, radio luminosity depended on the density of galaxies, high values should be obtained for the densest local region—the Virgo Cluster. But, as can be seen from Figure 1, where Virgo is the obvious concentration at 17 Mpc, Virgo galaxies are in no way exceptional, but conform to the overall correlation with distance from Earth. The average Y for 16 Virgo galaxies is -0.02, insignificantly different from the average for the whole sample.

In any case a density effect could not produce the observed fall in I with D. While the density of galaxies averaged over the line of sight generally declines with increasing distance, the largest density of galaxies in a given region is at Virgo, with an intermediate distance. So this hypothesis is also excluded.

Nor can the effect be explained as some consequence of different Hubble types at different distances. Neither E, S0, nor extreme starburst galaxies are in the sample—only normal spirals.

It should be emphasized that this is not a small effect. The farthest 13 galaxies at $D > 30$ Mpc are 3.6 times dimmer at 1.4 Ghz than the closest 15 galaxies at $D < 4$ Mpc, relative to the level expected from the radio-IR correlation.

By far the simplest and most reasonable explanation for the strong inverse correlation of I with D is that radiofrequency radiation is, in fact, strongly absorbed by the intergalactic medium, in contradiction with extremely widespread assumptions.

If the correlation is in fact caused by absorption of radiofrequency radiation, the implications for cosmology and radio astronomy are profound. The results imply an absorption of ~ 1 mag, or a factor of nearly 3, within 30 Mpc of Earth. Thus the intergalactic medium has an optical depth *in this region* of about unity in the radiofrequency band (at least at 20 cm). Such an absorption would severely distort the CBR if this radiation in fact originated at a distance of several Gpc and would convert it into a graybody spectrum. In fact, Kirchoff's

TABLE 2
COMPARISON OF HIGH AND LOW L_{FIR} GALAXIES

Sample (1)	Y (2)	$Y\text{-}Y_t/S_I/Dn^{1/2}$ (3)	b (4)	$b\text{-}b_t$ (5)	a (6)	$S_{I/D}$ (7)	r (8)	b/s_b (9)
High L_{FIR}	-0.01	1.18	0.31	1.0	-0.73	0.23	0.33	3.5
Low L_{FIR}	0.05	1.36	0.37	0.3	-0.64	0.35	0.35	3.7
Total	0.02	...	0.41	...	-0.69	0.27	0.42	7.2

law dictates that for a body of optical depth unity to have a blackbody spectrum, it must be both emitting and absorbing radiation in near equilibrium. The CBR must therefore originate locally, if radio absorption is strong.

This does not by itself exclude the big bang as the ultimate source of the CBR energy, but it implies that the isotropy and blackbody spectrum of the CBR, long used as primary evidence of the big band, are caused, or at least greatly modified, by the local intergalactic medium, and have no direct cosmological significance.

Given the importance of the correlation it is of great interest to see if the absorption continues outward to greater D. To do this, samples are required that contain virtually no galaxies that are undetected at radio frequencies, since such galaxies will severely bias the average apparent radio luminosity. For this reason, samples such as that of Dickey and Salpeter (1984) for the Hercules Cluster are not usable. However, a new sample based on the *IRAS* Bright Galaxy Catalog (Condon *et al.* 1990) is suitable and extends outward to over 300 Mpc. A complete analysis of this larger sample is planned.

There are preliminary indications that the absorption effect is evident at larger distances. While there is only one normal spiral galaxy beyond 100 Mpc in the *IRAS* Bright Galaxy sample, starbursts and interacting galaxies can be used to greater D. Francheschini *et al.* (1988) have found a closely linear relation between 60 μm and 1.4 GHz luminosity for such galaxies. We can use this relationship to generate a second radio luminosity index, $J = \log L_R - \log L_{60}$, where L_{60} is the 60 μm luminosity.

With this index, we can compare two groups of starburst galaxies within the *IRAS* Bright Galaxy sample, both consisting of galaxies with $\log L_{\rm FIR} > 11.3$. Group 1 is the 14 such galaxies with D between 80 and 160 Mpc, and group 2 is the 13 galaxies with D between 160 and 320 Mpc. These latter are the farthest in the sample. The average $\log L_{\rm FIR}$ for group 1 is 11.5 and for group 2, 11.9. The average J for group 1 is 0.75 and for group 2, 0.45. Thus, for a given L_{60}, L_R is only half as great for the more distant group than for the closer one. Since the standard deviation for J is only 0.16 for group 1 and 0.3 for group 2, the difference of 0.3 between the groups is highly significant. Put another way, the more distant group is 2.5 times as bright at 60 μm as the closer group, but only 25% brighter at 1.4 GHz.

For all 27 starburst galaxies, a linear regression yields $J \sim D^{-1.26}$ with a correlation coefficient of 0.58. A zero slope is excluded at the 3.5 σ or 10^{-3} level.

This preliminary result indicates a decrease in J of 1 mag per 160 Mpc, about one-quarter the rate for the region with 40 Mpc of Earth. This is not unreasonable, if absorption is proportional to galaxy density. Although there are superclusters just as dense as the local supercluster within 300 Mpc of Earth, the *average* density for the whole region between 80 and 320 Mpc is considerably less (Tully and Fisher 1987).

If such an absorption is real, it would also affect the apparent luminosities of high-z radio sources and may account for the existence of radio-quiet sources (Lerner, 1988, 1990). The exact degree of the expected absorption would depend on the average density of galaxies on Gpc scales, which is not known by direct observation. If the average is the same as that within 400 Mpc of Earth, which Tully estimates to be about 0.04 of that within 40 Mpc of Earth, an absorption of 1 mag per Gpc is expected. On the other hand, thus far direct observations have consistently found larger and larger inhomogenities on larger scales, and a decline in average density, so absorption could be considerably less than this, and much more uneven.

Observations do indicate that, while radio luminosity appears to increase with z, optical luminosity rises far faster. For example, Peacock, Miller, and Longair (1986) find an approximate 10-fold *decrease* in the proportion of radio-loud quasars at $z > 1$ compared with $z < 0.4$. Such observations are consistent with continued absorption of radiofrequency radiation at increasing z. Peacock's data could be accounted for by an absorption of about 10-fold around $z = 1$, similar to the absorption anticipated within a few hundred Mpc of Earth. There would be relatively little absorption between $z = 0.1$ and 0.8. Alternatively, if the apparent densities of optical and radio sources are fitted to a curve of the form e^{mt}, where t is look-back time, m is 3–6 larger for optical than radio sources. This would be consistent with an absorption of 0.5–1 mag Gpc^{-1}.

The abundance of both radio and optical galaxies appears to peak at around $z = 1$, but again the rise in the number of optical sources is steeper than that at radio frequencies, consistent with an absorption effect.

IV. THEORY

While the observed inverse correlation of radio luminosity with distance is extremely surprising from the standpoint of conventional theories of the CBR, it was correctly predicted by the author's own theory (Lerner 1988, 1990). In this model, CBR photons are absorbed and reemitted by GeV electrons trapped in the filaments emitted by active galactic nuclei. This synchrotron process, based on well-known physical laws, in effect scatters the CBR producing the observed isotropy. The main source of energy for the CBR is taken to be dust heated by early intermediate mass stars. The filaments are spread throughout intergalactic space, following the large-scale magnetic field.

If the density of galaxies, of the intergalactic medium, and thus of the GeV electrons is approximated as inversely proportional to distance for the range 1–400 Mpc, the model predicts that apparent radio luminosity, after absorption, will fall as $D^{-0.36}$, in excellent agreement with the observed correlation of $D^{-0.41}$.

This theoretical explanation, detailed in Lerner (1988, 1990), naturally accounts for the large scatter evident in the $I-D$ correlation. The amount of absorbing material varies proportionately to the density of galaxies along the line of sight. Since the galaxies are extremely inhomogeneously distributed, absorption will vary greatly from one direction to another, at least for small z.

Whatever the theoretical explanation, it appears that the observed correlation reported here, if taken as evidence of absorption, rules out all conventional theories of the cosmological origin of the isotropy and spectrum of the CBR.

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REFERENCES

Condon, J. J. 1987, *Ap. J. Suppl.*, **65**, 485.
Condon, J. J., Helou, G., Sanders, D. B., and Soifer, B. T. 1990, *Ap. J. Suppl.*, **73**, 359.
Devereux, N. A., and Eales, S. A. 1989, *Ap. J.*, **340**, 708.
Dickey, J. M., and Salpeter, E. 1984, *Ap. J.*, **284**, 461.
Fraceschini, A., Danese, L., DeZotti, G., and Toffolatti, L. 1988, *M.N.R.A.S.*, **233**, 157.
Lerner, E. J. 1988, *Laser Particle Beams*, **6**, 457.
———. 1990, *IEEE Trans. Plasma Sci.*, **18**, 43.
Peacock, J. A., Miller, L., and Longair, M. S. 1986, *M.N.R.A.S.*, **218**, 265.
Rice, W., Lonsdale, C. J., Soifer, B. T., Neugebauer, G., Kopan, E. L., Lloyd, L. A., DeJong, T., and Habing, H. J. 1988, *Ap. J. Suppl.*, **68**, 91.
Sandage, A., and Tammann, G. A. 1981, *A Revised Shapley-Ames Catalog of Bright Galaxies* (Washington, DC: Carnegie Institution of Washington).
Tully, R. B. 1988, *The Nearby Galaxies Catalog* (Cambridge: Cambridge University Press).
Tully, R. B., and Fisher, J. R. 1987, *Atlas of Nearby Galaxies* (Cambridge: Cambridge University Press).

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