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NEUTRAL HYDROGEN IN THE DIRECTION OF THE SMALL MAGELLANIC CLOUD AND THE LIMITS ON AN EXTRAGALACTIC SOFT X-RAY FLUX

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ABSTRACT

The X-ray data from the vicinity of the Small Magellanic Cloud (SMC) reported in a previous paper have been reanalyzed using new H I data from a more detailed and sensitive 21 cm survey of this region. The results support the previous conclusion: assuming that the interstellar material absorbs according to the cross sections of Brown and Gould, at least 75 percent of the observed $\frac{1}{4}$ keV X-ray flux is of local origin. The corollary problem of placing a cosmologically useful upper limit on the extragalactic flux will be difficult to solve until the behavior of the local component is better understood; but if the local flux is isotropic, a 3 σ upper limit of 240 photons $(\text{cm}^2\ \text{s sr keV})^{-1}$ at $\frac{1}{4}$ keV may be placed on a flux originating beyond the SMC.

Tables of H I column density are given for an area 30° × 30° about the SMC. The high-velocity component, presumably associated with the Magellanic Cloud system, and the galactic disk component are tabulated separately.

Subject headings: galaxies: intergalactic medium — galaxies: Magellanic Clouds — interstellar: matter — radio sources: 21 cm radiation — X-rays: general

I. INTRODUCTION

McCammon *et al.* (1971) reported an attempt to observe the absorption of an extragalactic component of the soft X-ray (120–284 eV) diffuse flux by the Small Magellanic Cloud. They concluded that at most 25 percent of the observed flux could originate beyond the SMC, if existing 21 cm measurements of total columnar hydrogen density and the effective absorption cross sections of Brown and Gould (1970) were assumed. The greatest weakness in their original analysis was the uncertainty and low resolution of the available neutral-hydrogen column densities. With the great improvements in receivers and data collection systems since the early surveys, a considerably more detailed and sensitive survey of the neutral hydrogen around the SMC could be made and the results applied to a reanalysis of the early X-ray data.

II. THE 21 CENTIMETER SURVEY

Between 1973 October 12 and 1973 October 20, the Parkes 18 m telescope was used to survey the region around the SMC. A series of drift scans with a 0°.8 beamwidth was performed at declination intervals of 1°15′. Using a cooled parametric amplifier, the overall system temperature was about 100 K and 4 minute integrations with the Parkes 33 kHz filter bank gave a baseline noise level of about 0.2 K. The 64 7 km s^{-1} channels extended from -140 km s^{-1} to $+300$ km s^{-1}, allowing simultaneous coverage of both the galactic component near zero radial velocity and the Magellanic Cloud gas at about $+200$ km s^{-1}. The local gas profiles had typical widths of 25 km s^{-1} FWHM and an estimated minimum detectable column density of 8×10^{18} H cm^{-2}. The minimum detectable area under the much wider high-velocity profiles was about 3×10^{19} H cm^{-2}, roughly 0.12 optical depths for $\frac{1}{4}$ keV X-rays.

Three methods of calibration were used: (*a*) Two total-power observations were made of Virgo A. The assumed beam efficiency, 0.8, had been obtained by observations of the Moon with the Parkes 64 m telescope using the same feed. (*b*) Observations were made of 21 cm profiles at two locations where the Maryland–Green Bank Survey (Westerhout 1969) showed uniform profiles over an area larger than our beamwidth. The corrections of Penzias, Wilson, and Encrenaz (1970) were applied to the Maryland–Green Bank brightness temperature scale. (*c*) The 21 cm profile measured at the South Celestial Pole was compared with the one used as a calibration reference in a Parkes galactic-plane survey (Kerr 1969). The Penzias *et al.* corrections were also applied to the Parkes brightness temperatures. The three methods agreed within 15 percent, which is only slightly larger than the 10 percent internal consistency variations observed at overlap points within this survey.

The system gain was checked with a low-temperature (4 K) diode noise source every hour, and the diode source was compared to the H I profile at the South Celestial Pole every 4–6 hours. Linear interpolation determined the calibration applied to individual profiles. Overall system gain was observed to vary by more than a factor of 2, but smoothly on a 24 hour cycle that probably followed the temperature of the long I.F. cable from the telescope to the control room.

The scatter of the South Celestial Pole–noise diode comparisons was surprisingly large, and the noise diode showed a gradual decrease in output relative to the South Celestial Pole profile, totaling almost 15 percent over the 11 day period. No explanation was found for this; but since the total change was of the same magnitude as the uncertainty in calibration, the problem was not pursued and a linear decrease of 15 percent in the noise diode output over the course of the survey was assumed in the analysis.

During the survey, the contents of the digital integrator memory were displayed on an oscilloscope and photographed by an automatic camera. Later, the profiles were digitized and integrated. Column densities were calculated from the integrated brightness temperatures using the approximation that the gas is optically thin at 21 cm. The high-velocity gas sometimes included two broad profiles, the second presumably due to gas in the Magellanic Stream (Mathewson, Cleary, and Murray 1974). For the sake of consistency, this profile was included in the total with the Magellanic Cloud gas, even in the cases where it was closer to zero radial velocity than to the velocity of the clouds. Figure 1 (Plate 1) shows a contour plot of the densities. These values are tabulated in Table 1 for the low-velocity gas and in Table 2 for the high-velocity gas.

Agreement between this H I data and the earlier surveys (McGee, Milton, and Wolfe 1966; Hindman, Kerr, and McGee 1963) is quite good, especially considering the great differences in spatial resolution and sensitivity. The greatest change is an overall increase of about 1×10^{20} H cm^{-2} in the local gas compared with the column densities of McGee *et al.* Given the tenfold increase in sensitivity of this survey, an increase of this size is not surprising (Murray 1974).

III. X-RAY DATA

The original analysis of the X-ray data showed that the models of expected absorption were rather insensitive to the assumed source spectrum and to changes in the exact shape of the collimator response due to reflection of low-energy X-rays (McCammon 1971). The data were essentially uncontaminated by electrons, ultraviolet, or scattered solar X-rays. A small uncertainty in the aspect solution for the rocket flight remained, but subsequent refinement of the position of SMC X-1 (Webster *et al.* 1972; Liller 1972) leaves little room for doubt that the scan path used was correct within about a degree. The principal weakness in the conclusions seemed to be uncertainties in the distribution of the interstellar gas.

The new column densities of the galactic H I are now at least 15 times the detection limit, instead of being uncomfortably close to it, and absolute values of the column densities should be accurate within 20 percent. There is no evidence for clumping of interstellar gas that would affect X-ray absorption. With the higher angular resolution used, gas closer than 150 pc would have to be *predominantly* in clouds of density greater than 200 H cm^{-3} in order to reduce its effective absorption significantly. In addition, the present data show no hierarchy of scales of structure extending down to the resolution limit: structure involving a large fraction of the gas appears only on scales larger than 10°. Recent comparisons of X-ray absorption measures for discrete galactic sources with 21 cm absorption and interstellar reddening values (Gorenstein 1975; Ryter, Cesarsky, and Audouze 1975) support the straightforward application of the Brown and Gould cross sections at energies slightly higher than $\frac{1}{4}$ keV, so there seems to be little justification for invoking exotic mechanisms which prevent the observed gas from absorbing as expected.

Since models which assume all of the observed flux to be of extragalactic (and presumably isotropic) origin are inconsistent with the data, one is faced with the problem of how to distribute a local component. It is shown in the next section that models with local emission proportional to gas density can be ruled out. Models where local emission anticorrelates with H I would result in even lower upper limits to the extragalactic flux. This analysis used the neutral assumption that the local flux is isotropic over this limited region of sky.

A two component model was assumed, with one component of extragalactic origin and the other component local, attenuated only by the atmosphere. The spectral shape assumed for each component was $I(E) \propto e^{-E/kT}/E$ photons (cm^2 s sr keV$)^{-1}$, with kT fixed at 0.3 keV for the local component. For each component, a $\frac{1}{2}° \times \frac{1}{2}°$ grid was used to integrate the incident spectrum, absorbed by the gas along each line of sight, over the field of view. Near the central regions of the SMC a $\frac{1}{8}° \times \frac{1}{8}°$ grid was used. This procedure was repeated along the scan path to produce a predicted counting rate variation as a function of time. The data were fitted to a model of the form

$$\text{counts}\,(t) = Af(t) + Bg(t)\,,$$

where $f(t)$ describes the variation of the local flux, $g(t)$ the extragalactic flux variation, and A and B are the intensity parameters to be determined. For fixed values of the extragalactic intensity, the local intensity was varied to minimize χ^2, and the χ^2 probability associated with each such fit was evaluated. The confidence of each fit is equal to one minus the χ^2 probability. For each fit the contribution to the total counts from the local flux was computed, and the extragalactic intensity was evaluated at $\frac{1}{4}$ keV. The fits used data taken when the atmospheric transmission was greater than 0.8.

Figure 2 shows the results of these calculations. Although the horizontal scales were derived for an extragalactic spectrum with $kT = 0.3$ keV, the results are essentially independent of kT. Varying kT from 0.1 keV to 0.4 keV caused the extragalactic $\frac{1}{4}$ keV flux at a given confidence level to vary less than 3 percent and the local fraction to vary less than 1.5 percent. Model 1 assumes that the extragalactic flux is absorbed by both SMC gas and galactic gas, while model 2 assumes a flux absorbed by only the galactic gas. The dashed line shows the results of fitting model 2 to the data from scans 1 and 2 alone, where the

TABLE 1

Low-Velocity Neutral-Hydrogen Column Densities (in units of 10^{19} H cm^{-2}; columns are labeled by declination; rows, by right ascension)

	-51°15'	-53°45'	-56°15'	-58°45'	-60°	-61°15'	-62°30'	-63°45'	-65°	-66°15'	-67°30'	-68°45'	-70°	-71°15'	-72°30'	-73°45'	-75°	-76°15'	-77°30'	-78°45'	-80°	-81°15'	-82°30'	-83°45'
22^h0^m					29		32				30	29	28	28	31	37	55		72					
4							32				30	29	26	26	30	37	52			80		81		
8					24		31				29	29	26	28	31	34	50						79	
12					22	32	32				27	28	25	26	30	31	48	62						76
16					22	31	30				25	29	26	26	27	30	45		70					
20					24	28	28			21	25	29	27	24	27	30	44			78	72			
24					23	26	25			22	27	29	26	26	28	31	40	60				79		
28					20	26	25		23	24	30	28	27	27	27	32	38		71				81	
32					20	26	26		21	24	31	30	27	27	27	32	38			76				74
36					19	26	24		18	24	31	30	28	30	29	31	38	50						
40					20	24	25		23	24	29	31	28	30	29	29	37				76			
44					19	24	23		25	23	28	30	31	30	29	30	37			76				
48					19	23	22		23	22	29	30	30	32	29	31	37	44				73		
52					19	24	20		22	21	29	30	29	31	30	31	33		69				84	
56					20	25	20		22	21	27	30	30	31	31	30	32			75				75
23^h0^m					19	24	20	24	19	20	26	30	31	33	31	29	31	43						
4					18	23	20	25	18	21	27	30	31	35	30	28	32		66		68			
8					19	23	20		20	22	25	30	32	31	29	28	32			73		80		
12					20	23	20	26	19	22	23	30	32	30	29	28	32	44					81	
16					19	21	21	26	20	21	25	30	32	30	29	28	29		60					78
20					18	19	21		20	21	26	30	32	30	28	27	31			69				
24					17	20	20	23	21	22	26	31	31	29	29	27	31	44						
28					16	19	20	22	25	22	26	31	32	29	29	27	31		51		68			
32					16	18	18	26	27	23	26	30	30	28	28	29	29			56		77		
36					18	18	18	25	27	24	25	31	30	29	29	28	28						83	
40					16	18	19	26	26	26	25	29	31	28	29	30	28	37						81
44					15	18	19	24	27	25	24	27	28	28	30	30	28		45					
48					14	18	20	26	22	21	23	26	26	29	30	30	28			52	68			
52	17		15	15	14	17	18	23	23	20	26	25	26	29	30	31	30	36						
56			15	16	12	16	19	22	22	19	26	25		30	29	32	29		43			70		
0^h0^m			14	16	13	17	16	20	22	19	26	24	24	28	29	34	30			52			84	
4	14	15	14	13	12	16	15	19	22	19	24	24	24	30	30	34	32	41						85
8	14	14	14	13	12	13	15	17	19	17	25	23	24	28	28	34	34							
12	14	14	14	14	13	12	14	19	18	16	24	24	23	29	28	33	35		42		64			
16	13	14	14	14	13	12	14	20	18	18	21	23	20	29	29	34	37			50		68		
20	14	14	15	14	14	12	14	20	18	16	19	23	22	28	29	34	34	43					82	
24	15	14	15	15	14	12	13	21	18	17	19	24	21	29	29	32	37							85
28	14	14	17	15	15	12	13	20	18	16	21	23	23	29	31	31	37		43					
32	14	15	18	14	14	12	14	20	17	14	21	23	21	29	30	32	35			51	63			
36	13	15	18	14	14	12	12	19	17	13	21	23	25	26	32	33	34	43				67		
40	13	14	19	16	15	12	14	22	18	15	20	22	22	26	33	34	35		44				76	
44	14	16	19	15	18	13	12	24	19	16	22	21	22	27	34	34	38			53				83
48	14	16	19	15	18	13	13	24	18	16	21	21	20	28	35	35	36							
52	14	15	19	17	20	14	15	23	19	18	22	21	20	26	36	34	38	45			62			
56	13	17	22	17	20	16	14	23	20	17	22	22	19	26	34	34	39		46					
1^h0^m	15	15	22	19	22	16	15	23	20	16	21	23	20	26	31	35	40			53		65		
4	14	14	22	18	20	16	15	22	20	15	22	22		26	30	35	40	43					73	
8	13	15	21	20	22	16	15	22	18	14	22	22	18	27	30	35	42		45					
12	13	15	24	18	22	16	16	21	18	14	23	21	18	28	32	35	44			52				83
16	13	16	23	17	21	17	16	22	17	16	21	23	20	31	32	35	41	46						
20	13	17	22	18	22	17	17	21	17	18	24	22	22	32	31	35	44		45		65			
24	12	18	23	19	24	17	17	22	17	17	25	21	22	31	30	36	44			54		63		
28	14	19	24	21	24	18	17	23	17	18	24	23	21	30	30	37	46	46					69	
32		20	23	18	22	18	19	23	18	17	25	23	20	28		38	46							87
36			25	23	21	17	19	23	20	20	24	24	21	28		39	44		44					
40			22	22	22	18	18	23	20	18	24	24	21	26	32	38	43			60	64			
44			25	25	23	18	18	25	20	17	23	23	22	25	33	38	42					66		
48			26	21	23	19	19	27	20	18	23	23	23	26	33	37	41	44					69	
52			25	21	21	19	20	28	22	19	24		21	25	32	38	40							75
56			24	23	23	20	20	28	24	20	26		19	25	31	37	40		48					
2^h0^m			26	21	24	21	22	29	24	24	24		21	24	31	37	38			61	64			
4			24	22	26		26	29	25	23	25		20	22	31	37	38	45						
8			25	27	25			30	24	23	28		23	25	32	39	40		53			63		
12			27	21	26			31	23	23	29		23	27	34	39	39			54			67	
16				27	28			28	22	23	28		24	27	35	38	38	46						76
20				31	31			27	23	21	26		25	28	32	38	39		50					
24								26	24	23	26		29	26	31	38	41			60	63			
28				27				25	25	22	24		32	26	31	36	41					63		
32				29				27		22	24		34	28	30	35	39		58				64	
36								29		22	28		36	27	30	35	42			62				73
40								30		22	23		33	25	31	35	43	48						
44								31		22	23		32	25	31	35	43		59					
48								31		23	26		31	26	31	35	46			63	61			
52										24	19		30	26	27	38	46					62		
56										24	28		31	26	25	40	47	51					69	
3^h0^m										24	28		30	26	34	38	50		62					78
4										24	28		31	29	36	39	53			59				
8										23	26		30	29	37	41	56				67			
12										22	25		30		38	44	59	61						
16										26	27		32		42	44	59		65			62		
20										30	28		33		42	46	61			61			67	
24											32		34		42	50	66	71						74
28											34		34		44	49	66		63					
32											36		32		45	46	70			57	60			
36													32		46	50	74	67				60		
40													34		47	51	73		57					

TABLE 2

HIGH-VELOCITY NEUTRAL-HYDROGEN COLUMN DENSITIES (in units of 10^{19} H cm^{-2}; dashes are places surveyed where the high-velocity H I was less than the minimum detectable 3×10^{19} H cm^{-2})

	-51°15'	-53°45'	-56°15'	-58°45'	-60°	-61°15'	-62°30'	-63°45'	-65°	-66°15'	-67°30'	-68°45'	-70°	-71°15'	-72°30'	-73°45'	-75°	-76°15'	-77°30'	-78°45'	-80°	-81°15'	-82°30'	-83°45'
23^h20^m					-	4	-		4	-	-	-	-	-	-	-	-							
24					-	7	-	-	4	-	-	-	-	-	-	-	-	5						
28					-	10	3	-	4	-	-	-	-	-	-	-	-		-		-			
32					-	8	-	-	4	-	-	-	-	-	-	-	-			-		-		
36					6	9	-	-	3	-	-	-	-	-	-	-	-						-	
40					-	5	-	-	-	-	-	-	-	-	-	-	-	-						-
44					-	-	-	-	3	-	-	-	-	-	-	-	-		-					
48					-	-	-	-	3	-	-	-	-	9	-	-	-			-	-			
52			-	-	-	-	-	-	6	-	-	-	-	7	-	3	-	-						
56			-	-	-	4	-	-	6	-	-	-	-	7	4	4	-		-			-		
0^h0^m			-	-	-	-	-	-	7	4	-	4	-	8	6	5	6			-			-	
4	-	-	-	-	-	-	6	-	5	4	-	3	-	14	10	9	8	8						-
8	-	-	-	-	-	-	4	-	4	3	-	-	-	11	16	17	14							
12	-	-	-	-	-	-	3	-	-	-	-	-	-	10	24	27	29		-		-			
16	-	-	-	-	-	-	3	-	-	4	-	-	-	10	31	56	46			-		-		
20	-	-	-	-	-	-	3	-	-	4	-	4	-	11	38	101	56	21					-	
24	-	-	-	-	-	-	-	-	-	5	-	5	-	17	44	133	61							-
28	-	-	-	-	-	-	-	-	-	4	-	5	-	25	51	157	67		-					
32	-	-	-	-	-	-	4	-	-	3	6	5	4	31	70	181	65			-	-			
36	-	-	-	-	-	-	6	-	-	-	5	6	5	36	119	206	63	25				-		
40	-	-	-	-	-	-	10	-	-	4	5	7	6	40	187	236	65		-				-	
44	-	-	-	-	-	-	7	-	3	4	10	8	9	52	265	262	60			-				-
48	9	6	-	-	-	-	4	-	4	8	9		10	79	341	264	49							
52	11	15	-	-	-	-	-	-	-	13	11	12	10	123	394	236	46	24			-			
56	20	14	-	-	-	-	-		-	6	10	13	11	161	407	196	42		8					
1^h0^m	14	6	-	-	6	-	-	6	-	10	11	11	12	166	386	159	36			-		-		
4	-	-	-	-	-	-	-	4	5	14	12	11	11	144	351	136	34	24					-	
8	-	-	-	-	-	7	-	5	7	12	14	13	10	130	307	134	37		11					
12	-	-	-	-	-	7	5	5	7	13	16	14	10	128	264	147	40			-				-
16	-	-	6	-	5	6	4	4	8	14	13	22	14	128	207	156	44	29						
20	5	-	11	-	7	5	4	-	8	10	11	23	19	112	157	155	47		19		-			
24	7	-	5	-	7	5	4	-	8	9	12	20	22	100	133	147	51			-		-		
28	4	-	-	-	7	5	3	-	8	7	9	18	22	88		135	55	28					-	
32		-	-	-	12	3	3	4	8	7	8	17	21	73		123	64							-
36			-	-	14	5	4	8	9	7	8	25	25	65		112	69		17					
40				-	13	7	4	10	12	9	11	29	31	53	66	104	79			7	-			
44			-	-	10	6	6	11	15	11	13	29	36	43	55	98	84					-		
48			3	-	6	6	8	10	15	16	22	32	36	43	50	92	86	28					-	
52			3	-	-	4	11	8	13	15	31		34	39	48	89	81							-
56			-	-	-	4	8	6	13	14	31		27	36	46	86	81		11					
2^h0^m			-	-	-	3	4	4	11	14	22		25	31		82	77			6	-			
4			-	-	-		3	4	11	15	20		21	28	45	77	76	35						
8			-	-	-			4	10	12	13		21	32	43	75	78		14			-		
12			-	-	-			-	6	9	17		19	31	36	76	64			7			-	
16				-	-			-	6	8	16		20	29	32	86	53	22						-
20				-	-			-	7	8	21		20	30	31	87	44		12					
24								-	4	-	18		17	29	34	87	40				-			
28				-				-	3	-	14		15	30	37	85	36					-		
32				-				4	4	-	4		12	28	38	80	35		15				-	
36								4		-	7		9	23	39	75	37			10				-
40								-		-	4		8	21	39	72	36							
44								-		-	11		5	20	39	72	36		15					
48								-		-	13		9	16	37	60	35			14	4			
52								-		5	12		7	14	28	53	31					-		
56								-		-	16		8	15	26	51	32	20					-	
3^h0^m										-	15		9	16	28	50	32		14					-
4										-	14		9	16	25	50	33			12				
8										-	13		14	16	20	47	31				5			
12										-	16		15	13	19	46	29	16						
16										-	14		14	11	19	41	32		19			-		
20										-	12		12	11	14	33	34			10			-	
24											8		9	11	12	32	38	16						-
28											9		5		11	34	35		14					
32											-		4		12	34	36			10	4			
36											-		-		12	36	41	19				-		
40											-		-		9	40	39		10				-	
44											-		-		8	31	41			11				-
48											-		-		10	32	41	19						
52											-		-		9	21	41		10					
56											-		4		8	24	43			11	5			
4^h0^m											-		5		8	24	44	16				-		
4											-		6		10	24	44		9				-	
8											3				10	22	41			7				-
12											3		7		9	19	33	19						
16											5		9		9	15	35				3			
20											7		10		11	14	32					-		
24											6		10		11	15	28							
28											9		13		12	15	29							
32											19		15		14	15	26							
36											31		17		15	18	25							
40											73		26		16	24	37							
44											105		42		21	29	35							
48											113		53		26	34	36							
52															27	45	39							
56															31	53	44							

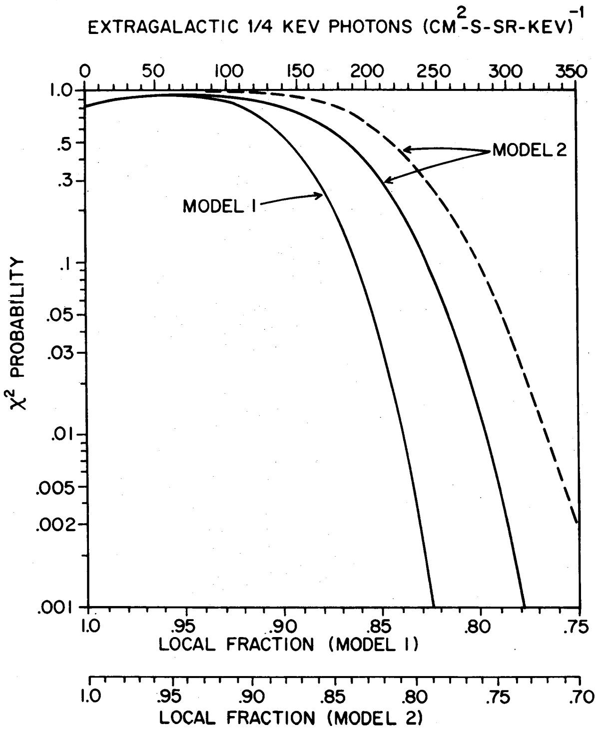

FIG. 2.—χ^2 probability as a function of the assumed extragalactic flux. The "confidence" of a given fit is one minus the χ^2 probability. Model 1 assumes that the extragalactic flux originates beyond the SMC. Model 2 assumes that the extragalactic flux originates in a galactic halo. The dashed line results from fitting only the data from the first two scans (away from the SMC) to model 2.

SMC does not significantly enter the field of view. Table 3 summarizes the best fits, the upper limits to the extragalactic flux, and the lower limits to the local fraction for both models.

IV. RESULTS

Since a sufficiently low upper limit on the extragalactic $\frac{1}{4}$ keV flux would further restrict the allowed range of temperatures of a hypothetical dense intergalactic medium, it is tempting to try to use these absorption data to place such a limit. The best-fit values of this analysis do not call for any emission in excess of an extrapolation to $\frac{1}{4}$ keV of the $11E^{-1.4}$ power law observed at X-ray energies above 2 keV. In fact, the data do not require any extragalactic component at all, as was pointed out by McCammon *et al.* (1971).

If the local component is isotropic, the upper limit to the extragalactic $\frac{1}{4}$ keV flux originating beyond the SMC is 200 photons (cm^2 s sr keV)$^{-1}$ with 95.5 percent confidence. This assumes that the $\frac{1}{4}$ keV emission from the SMC is not large enough to perturb the results of model 1. To keep the perturbations less than ~3 percent requires

$$L_{\rm SMC}(\tfrac{1}{4}\text{ keV}) < 5 \times 10^{37} \text{ ergs s}^{-1}\text{ keV}^{-1}\,.$$

It might be argued that the SMC emits enough soft X-rays to exactly compensate for those which it absorbs. This is equivalent to model 2, which assumes an isotropic flux incident on the galactic gas ("halo" origin). Model 2 gives a 95.5 percent confidence upper limit to the extragalactic $\frac{1}{4}$ keV flux of 260 photons (cm^2 s sr keV)$^{-1}$. It should be mentioned that invoking SMC emission to save a cosmic origin for the $\frac{1}{4}$ keV flux requires

$$L_{\rm SMC}(\tfrac{1}{4}\text{ keV}) \sim 2.6 \times 10^{36} F_{\rm EG} \text{ ergs s}^{-1}\text{ keV}^{-1}\,,$$

where $F_{\rm EG}$ is the extragalactic $\frac{1}{4}$ keV flux, in units of photons (cm^2 s sr keV)$^{-1}$, still subject to the confidence limits of model 2. For instance, if the SMC luminosity is less than 5×10^{37} ergs s^{-1} keV^{-1} at $\frac{1}{4}$ keV, model 1 rejects an extragalactic $\frac{1}{4}$ keV flux of 240 photons (cm^2 s sr keV)$^{-1}$ with 99.7 percent confidence. However, if the SMC emission exactly fills in for its own absorption, the same flux cannot be rejected with 90 percent confidence (model 2), but SMC emission of $\sim 6 \times 10^{38}$ ergs s^{-1} keV^{-1} is required at $\frac{1}{4}$ keV. One might postulate even more emission from the SMC, attempting to compensate for some galactic absorption as well as SMC absorption. However, upper limits to the extragalactic flux can be obtained from the data of scans 1 and 2 when

TABLE 3

EXTRAGALACTIC FLUX UPPER LIMITS AND LOCAL FRACTION LOWER LIMITS FOR EACH MODEL EVALUATED AT SEVERAL CONFIDENCE LEVELS

	MODEL 1: EXTRAGALACTIC FLUX ORIGINATES BEYOND SMC		MODEL 2: EXTRAGALACTIC FLUX ORIGINATES IN GALACTIC HALO			
					Scans 1 and 2 Only	
CONFIDENCE LIMITS	Extragalactic Flux*	Local Fraction	Extragalactic Flux*	Local Fraction	Extragalactic Flux*	Local Fraction
Best fit	53	0.96	66	0.94	64	0.95
90%	< 190	> 0.86	< 240	> 0.79	< 278	> 0.76
95.5% (2 σ)	< 204	> 0.85	< 257	> 0.78	< 297	> 0.74
99%	< 223	> 0.84	< 283	> 0.76	< 328	> 0.72
99.73% (3 σ)	< 237	> 0.83	< 300	> 0.74	< 350	> 0.70

* Units of flux are: $\frac{1}{4}$ keV photons (s cm^2 sr keV)$^{-1}$.

the SMC was not significantly in the field of view. Independent of the SMC, with 95.5 percent confidence at least 74 percent of the soft X-ray flux is local and the extragalactic flux is less than 300 photons (cm^2 s sr keV)$^{-1}$ at $\frac{1}{4}$ keV, consistent with the result of the original analysis.

An extreme approach to distributing the local flux is to arbitrarily have it vary in such a way that it produces the observed X-ray distribution while allowing as large an extragalactic contribution as possible. Using the method suggested by Bunner (1974), the minimum ratio at any point in the sky of observed flux to line-of-sight transmission becomes an upper limit to the extragalactic flux. A similar method was used by Margon *et al.* (1974) on a sample of three points at low galactic latitudes. However, better limits can be determined at higher galactic latitudes where, although the measured flux is larger, the line-of-sight transmission is much higher. Also, the lack of dense clouds and dust at high latitudes makes it unlikely that there is molecular hydrogen or other unexpected absorber present. Using the data around the SMC (at $\alpha \approx 0^h$, $\delta \approx -62°$, integrated transmission $\sim$0.44) gives an extreme upper limit of less than 900 photons (cm^2 s sr keV)$^{-1}$ at $\frac{1}{4}$ keV for the extragalactic flux.

One can also determine the minimum local contribution at other points on the sky by taking the difference between the measured flux and the transmitted portion of the maximum extragalactic flux as determined above. When the center of the field of view was at $\alpha \approx 22^h40^m$, $\delta \approx -72\overset{\circ}{.}5$, the galactic gas transmission integrated over the collimator was 0.25. With the observed flux being nearly constant, this gives a minimum of 160 photons (cm^2 s sr keV)$^{-1}$ of local origin at $\frac{1}{4}$ keV, which is larger than the total flux observed at most points near the galactic plane (Silk 1973). Simple models where local emission is proportional to gas density (Davidsen *et al.* 1972) are ruled out since toward the SMC the gas is not optically thick and the local flux should be smaller than near the plane.

Unfortunately, even the lower of these limits on the extragalactic flux is insufficient to place much additional restriction on a possible dense intergalactic plasma (Kraushaar 1973). There seems to be little possibility of significant improvement in limits set by direct measurement until the nature of the local component is sufficiently well understood that at least some definite predictions about its distribution can be made. A possible alternative would be high-resolution spectral observations at positions of low interstellar column density. Because of difficulties with point source models (Vanderhill *et al.* 1975) and diffuse nonthermal mechanisms, it seems highly likely that the local component is thermal radiation from an optically thin plasma (Williamson *et al.* 1974) which at the necessary temperatures would be almost exclusively in lines. A sufficiently low limit on the continuum between these lines, then, would place a rather direct limit on the presumably continuous radiation from an intergalactic plasma.

V. CONCLUSIONS

In the vicinity of the SMC, 21 cm observations with $0\overset{\circ}{.}8$ resolution show no evidence for small-scale structure which would significantly affect soft X-ray absorption. Assuming that the interstellar gas absorbs normally, an upper limit of 300 photons (cm^2 s sr keV)$^{-1}$ at $\frac{1}{4}$ keV can be placed on any flux incident on the Galaxy, provided the local flux is isotropically distributed. Under the most extreme assumption that the local flux is distributed so as to allow the greatest possible extragalactic flux, this limit becomes 900 photons (cm^2 s sr keV)$^{-1}$. Even under this assumption, the minimum local flux at some points in this region must be greater than 160 photons (cm^2 s sr keV) at $\frac{1}{4}$ keV. This is greater than the total flux observed at points near the galactic plane, and directly conflicts with any simple two-component model where local X-ray emission is proportional to interstellar hydrogen density. All of the above conclusions are independent of any possible emission by the SMC.

Although there is virtually no positive evidence for an isotropic extragalactic component, the problem of placing a significantly lower, and therefore cosmologically useful, upper limit on such a component will require a better understanding of the distribution of the local flux, or high-resolution spectral data which can place low limits on the continuum fraction.

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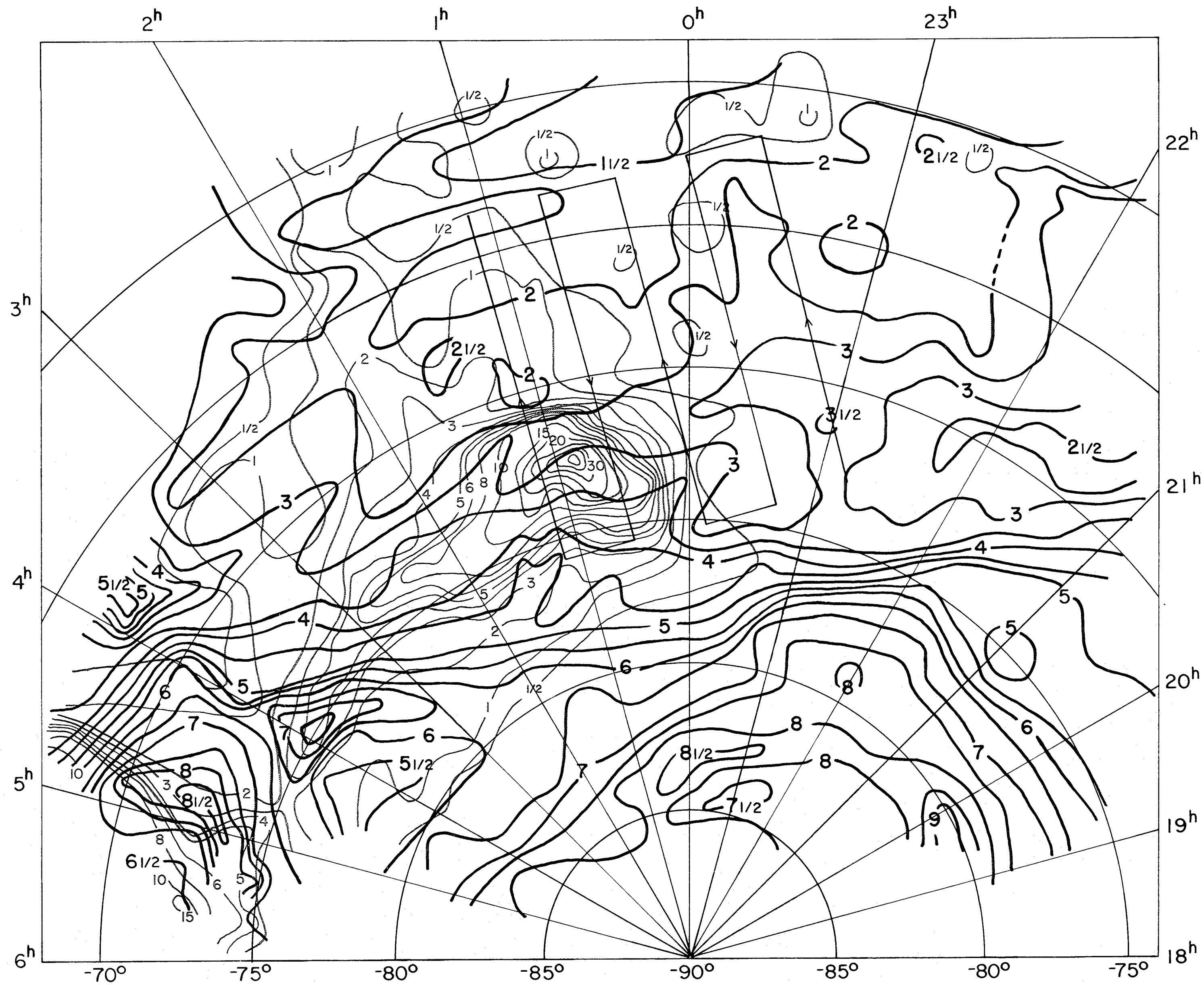

FIG. 1.—Black contours give the surface densities of the galactic H I near zero radial velocity; red contours are the high-velocity H I associated with the Magellanic Clouds. Contour units are 10^{20} H cm^{-2}. The scan path of the X-ray experiment is indicated by the straight black lines with arrows. Epoch of coordinates, 1975.

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