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STEPS TOWARD THE HUBBLE CONSTANT. V. THE HUBBLE CONSTANT FROM NEARBY GALAXIES AND THE REGULARITY OF THE LOCAL VELOCITY FIELD

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ABSTRACT

Distances to very nearby bright spiral galaxies from Paper IV are combined with individual redshifts to obtain the mean local Hubble expansion rate of $H_0 = 57 \pm 3$ km s^{-1} Mpc^{-1}. This is the same as $H_0 = 57 \pm 6$ km s^{-1} Mpc^{-1} from the Virgo cluster alone ($D \simeq 20$ Mpc) found in Paper IV, and is also closely the same as the global value of $H_0 = 55 \pm 6$ km s^{-1} Mpc^{-1} found from remote Sc I galaxies ($D \gtrsim 60$ Mpc, $v_0 \gtrsim 3000$ km s^{-1}) in Paper VI. The agreement of the three rates shows that there is no measurable velocity anisotropy in the *mean* velocity field of nearby spiral galaxies, and further that there is no systematic variation of the Hubble constant with distance. This is the same result as obtained earlier by Sandage, Tammann, and Hardy in 1972, using the nearer clusters and groups of E galaxies.

To investigate further, the sample is increased by using luminosity-class distances to Sc I, Sc II, and Sc III galaxies classified by van den Bergh in the north and by us in the south. A bias is identified, and the sample is cut to 71 objects to form a distance-limited list. The mean Hubble rate for these is found to be the same in the hemisphere toward and away from the Virgo cluster to within 1 σ of the combined errors, despite the large density contrast of the Coma-Virgo complex.

A more refined analysis fails to isolate any periodicities in the Hubble ratio (v_i/r_i) along the supergalactic equator that are significant at the 3 σ level. The data in our unbiased sample also give the same Hubble rate (to within the combined errors) in the two areas where Rubin and Ford had previously suggested that a significant anisotropy exists in the local expansion rate.

An upper limit to the mean random motion of the field galaxies here can be put at $\sigma(\Delta v) \lesssim 50$ km s^{-1}. Therefore, distances that are accurate to better than ~ 20 percent can be obtained from the velocity-distance relation for galaxies whose velocities are as small as 200 km s^{-1}. The accuracy of the distance increases with the velocity.

The local velocity field is as regular, linear, isotropic, and quiet as it can be mapped with the present material. The lack of measurable velocity perturbations, in spite of the observed density inhomogeneities, suggests that the gravitational potential energy is small compared with the kinetic energy of the expansion (provided that there is no high-density, uniform intergalactic medium), and hence that $q_0 < \frac{1}{2}$.

Subject headings: cosmology — galaxies — redshifts

I. INTRODUCTION

The Hubble constant could be determined solely from the velocities and distances of nearby galaxies if the velocity field were ideally regular. Suggestions that it is not so regular have been put forward by de Vaucouleurs (1958, 1964, 1966, 1972), who concluded that significant velocity perturbations exist, organized about the inhomogeneous distribution of galaxies in the Ursa Major, Coma, and Virgo regions (Shapley and Ames 1932, figs. 3 and 4; Reiz 1941; de Vaucouleurs 1956), often called the Local Supercluster. A further idea has been advocated by Haggerty and Wertz (1972) that a systematic *gradient*, dH/dr, exists in the Hubble rate due to a supposed hierarchical organization of matter on the largest scale. If so, any *local* value of H, even if freed from effects of the Local Supercluster, should differ systematically from the global value. De Vaucouleurs (1972) discussed the problem using his distances to nearby galaxies. Sandage, Tammann, and Hardy (1972) could not find such an effect in their study of nearby E-galaxy groups.

Important information about the present state of the Universe is obviously contained in such systematic and random velocity perturbations, should they exist, because they are related in some way to the conditions of the formation of galaxies out of a turbulent medium (cf. Zel'dovich and Novikov 1970; Dorochkevich, Sunyaev, and Zel'dovich 1973; Ozernoy 1973; Peebles 1973), or to the initial density perturbations that have produced the present inhomogeneous distribution of the Local Supercluster.

We are naturally led to the problem in this series because the regularity of the local velocity field affects our determination of the Hubble constant at some level. Although a method has been devised (Paper VI) to circumvent the effects of any very local velocity peculiarities ($v_0 \leq 5000$ km s^{-1}; $D \lesssim 100$ Mpc), the data in Paper IV (Sandage and Tammann 1974) are just those necessary to map the local velocity field, which we discuss in this paper.

The results show that the value of $\langle H \rangle$, obtained by naïvely forming v/r for each galaxy in our sample, is ~ 55 km s^{-1} Mpc^{-1}. This is the same as obtained from the Virgo cluster (Paper IV), which itself is the

TABLE 1

VELOCITIES AND DISTANCES FOR GROUPS AND FOR SINGLE GALAXIES

Galaxy (1)	v (2)	σ(v) (3)	300 cos A (4)	v_o (5)	Sources (6)	r(H II) (7)	L_c (8)	$m_{pg}^{o,i}$ (9)	$(m-M)^o$ (10)	r (L_c) (11)	⟨r⟩ (H II, L_c) (12)
South Polar Group:		⟨v⟩$_o$ = 281, σ = 197								⟨r⟩ = 3.4	3.4
NGC 24	+ 564	29	+ 34	+ 598	23, 70	...	...	...	...	...	...
45	+ 469	6	+ 40	+ 509	1, 3, 4	...	S$^-$ IV-V	(11.08)	27.47	3.0	...
55	+ 130	7	- 34	+ 96	5, 6, 7, 8, 9	...	...	...	...	...	...
247	+ 156	15	+ 31	+ 187	(1), 5	3.4	S$^-$ IV	9.47	27.28	2.9	....
253	+ 254	12	+ 11	+ 265	3, 10, 11, 12, 68	...	...	...	...	...	...
300	+ 144	1	- 48	+ 96	4, 5, 7, 13	...	Sc III-IV	(9.66)	28.33	4.6	...
7793	+ 212	5	+ 5	+ 217	1, 2, 14, 75	...	...	...	...	...	...
NGC 428	+ 1147	31	+ 103	+ 1250	2, 15, 16	17.1	Scp III-IV	11.67	30.37	11.9	15.4
NGC 628	+ 658	6	+ 139	+ 797	1, 4, 12, 16, 17	19.6	Sc I	9.69	30.95	15.5	18.2
NGC 672 Pair:		⟨v⟩$_o$ = 540,				⟨r⟩ = 10.95				⟨r⟩ = 10.8	10.9
NGC 672	+ 383	8	+ 167	+ 550	2, 3, 4, 12	11.1	SBc III	10.73	29.94	9.7	...
IC 1727	+ 362	50	+ 167	+ 529	1	10.8	⌈Sc III-IV⌉	11.68	30.38	11.9	...
NGC 1023 Group:		v_o = 721, σ = 33				⟨r⟩ = 16.4				r = 10.1	14.3
NGC 891	+ 520	10	+ 183	+ 703	1, 80	...	...	...	...	...	...
925	+ 570	6	+ 162	+ 732	1, 2, 4, 14, 16, 18	14.8	Sc II-III	10.12	29.84	9.3	...
1003	+ 585	60	+ 168	+ 753	1	...	...	...	...	...	...
1023	+ 580	8	+ 163	+ 743	1, 16, 20, 21	...	...	...	...	...	...
1058	+ 517	1	+ 156	+ 673	22, 23, 81	19.6:	Sc III-IV:	11.47	30.37:	11.9:	...
IC 239	...	...	+ 165	...	...	...	...	...	...	...	...
NGC 1068 Group:		⟨v⟩$_o$ = 1332, σ = 244								⟨r⟩ = 19.1	18.1
NGC 936	+ 1348	45	+ 34	+ 1382	1, 21	...	...	...	...	...	...
1055	+ 1062	50	+ 28	+ 1090	14, 16	...	...	...	...	...	...
1068	+ 1080	17	+ 25	+ 1105	1, 2, 21, 24, 25	...	...	...	...	...	...
1073	+ 1216	10	+ 30	+ 1246	2, 26	16.5	S(B) c II	11.32	31.55	20.4	...
1084	+ 1430	30	- 7	+ 1423	1, 78	...	Sc I-II	10.96	31.70	21.9	...
1087	+ 1724	180	+ 20	+ 1744	1	...	Sc* III:	11.29	30.50:	12.6:	...
Eridanus Group:		⟨v⟩$_o$ = 1520, σ = 203								⟨r⟩ = 23.8	22.8
NGC 1187	+ 1421	30	- 79	+ 1342	2, 70	...	S(B?) c I	(11.01)	32.26	28.3	...
1201	+ 1622	50	- 92	+ 1530	1	...	...	...	...	...	...
1232	+ 1722	39	- 77	+ 1645	2, 23	20.7	Sc I	10.58	31.83	23.2	...
1255	+ 1731	39	- 99	+ 1632	23	...	Sc II	(11.68)	31.91	24.1	...
1297	+ 1560	38	- 79	+ 1481	67	...	...	...	...	...	...
1300	+ 1536	10	- 81	+ 1455	2, 27	...	...	...	...	...	...
1302	+ 1630	75	- 105	+ 1525	1	...	...	...	...	...	...
1325	+ 1640	30	- 92	+ 1548	67	...	...	...	...	...	...
1325A	...	...	- 92	...	...	...	...	...	...	...	...
1331	+ 1308	88	- 93	+ 1215	2	...	...	...	...	...	...
1332	+ 1499	42	- 93	+ 1406	1, 2	...	...	...	...	...	...
1353	...	...	- 96	...	...	...	...	...	...	...	...
1359	+ 1892	60	- 93	+ 1799	2	...	SB$^+$ p IV	(12.69)	30.5:	12.6:	...
1371	...	...	- 113	...	...	...	...	...	...	...	...
1385	+ 1912	73	- 113	+ 1799	2	...	Sc I-II	(11.49)	32.23	27.9	...
1395	+ 1621	35	- 109	+ 1512	1, 2	...	...	...	...	...	...
1398	+ 1424	57	- 120	+ 1304	2	...	...	...	...	...	...
1407	+ 1711	50	- 94	+ 1617	1	...	...	...	...	...	...
1415	+ 1408	50	- 109	+ 1299	1	...	...	...	...	...	...
1426	+ 1258	50	- 109	+ 1149	1	...	...	...	...	...	...
1439	+ 1897	100	- 110	+ 1787	1	...	...	...	...	...	...
IC 1953	+ 1932	76	- 100	+ 1832	67	...	...	...	...	...	...
NGC 2841 Group:		⟨v⟩$_o$ = 601, σ = 116								⟨r⟩ = 7.5	7.6
NGC 2500	+ 496	31	+ 53	+ 549	2, 16	7.7	S$^+$ IV	12.01	29.82	9.2	...
2537	+ 404	19	+ 27	+ 431	1, 2, 20						
2541	+ 575	12	+ 43	+ 618	16, 23	...	S$^+$ IV	11.78	29.59	8.3	...
2552	+ 511	20	+ 47	+ 558	70	...	Ir$^+$ IV-V	(12.31)	28.70	5.5	...
2681	+ 709	27	+ 51	+ 760	1, 2	...	...	...	...	...	...
2841	+ 640	14	+ 49	+ 689	1, 2, 15, 21, 27	...	...	...	...	...	...
NGC 2903	+ 574	18	- 103	+ 471	1, 2, 14, 15, 16, 17, 28	(16.5)	Sb$^+$ I-II	...	...	...	...
NGC 2985 Pair:		⟨v⟩$_o$ = 1274									
NGC 2985	+ 1177	50	+ 154	+ 1331	1	...	...	...	...	...	...
NGC 3027	+ 1062	20	+ 154	+ 1216	2, 27	15.6	[Sc (t) III]	11.97	31.18	17.2	16.1
M81 Group:		⟨v⟩$_o$ = 226, σ = 89				⟨r⟩ = 3.25					
NGC 2366	+ 136	19	+ 145	+ 281	14, 16, 23	...	...	...	...	...	...
2403	+ 129	2	+ 126	+ 255	1, 3, 4, 5, 7, 12, 17, 29, 30, 31, 74	...	...	...	...	...	...
2976	+ 42	30	+ 133	+ 175	2	...	...	...	...	...	...
3031	- 44	5	+ 139	+ 95	1, 2, 3, 5, 12, 26, 32, 33, 34	...	...	...	...	...	...
3034	+ 242	3	+ 142	+ 384	35, 36	...	...	...	...	...	...
3077	+ 10	3	+ 138	+ 148	2, 81, 83	...	...	...	...	...	...
4236	- 6	4	+ 161	+ 155	4, 12, 74	...	...	...	...	...	...
IC 2574	+ 48	4	+ 139	+ 187	2, 4, 5, 76	...	...	...	...	...	...
Ho I	+ 117	6	+ 148	+ 265	81	...	...	...	...	...	...
Ho II	+ 170	10	+ 147	+ 317	2, 3, 4, 5, 12, 14	...	...	...	...	...	...

TABLE 1—*Continued*

Galaxy (1)	v (2)	σ(v) (3)	300 cos A (4)	v_o (5)	Sources (6)	r(H II) (7)	L_c (8)	$m_{pg}^{o,i}$ (9)	$(m-M)^o$ (10)	r(L_c) (11)	⟨r⟩(H II, L_c) (12)
NGC 3184 Group:		$\langle v\rangle_o$ = 673, σ = 77								⟨r⟩ = 15.8	15.4
NGC 3184	+ 583	13	+ 5	+ 588	1, 2, 81	14.8	Sc II	10.27	30.60	13.2	...
3198	+ 676	10	+ 26	+ 702	2, 14, 15	...	Sc II	10.46	30.69	13.7	...
3319	+ 754	21	+ 11	+ 765	2, 15, 16	...	S(B)c II	11.45	31.68	21.7	...
3432	+ 646	9	- 11	+ 635	2, 15, 37	...	...	...	...	...	...
NGC 3486	+ 724	100	- 47	+ 677	1, 70	18.7	Sc II	10.92	31.15	17.0	18.1
NGC 3631	+ 1164	24	+ 78	+1242	2, 15, 26	23.1	Sc I	10.86	32.11	26.4	24.2
NGC 3726	+ 882	80	+ 53	+ 935	1, 15	21.7	Sc (*) I-II	10.72	31.46	19.6	21.0
Leo Group:		$\langle v\rangle_o$ = 799, σ = 213								⟨r⟩ = 26.8	23.4
NGC 3338	+ 1230	75	-126	+1104	2	...	...	...	...	...	...
3351	+ 795	20	-134	+ 661	1, 20, 26	...	...	...	...	...	...
3368	+ 927	23	-133	+ 794	1, 20, 21, 70, 81	...	...	...	...	...	...
3377	+ 718	40	-123	+ 595	1	...	...	...	...	...	...
3379	+ 877	26	-129	+ 748	1, 20, 21	...	...	...	...	...	...
3384	+ 767	27	-129	+ 638	1, 20	...	...	...	...	...	...
3389	+ 1234	65	-129	+1105	2	...	Sc* III:	(12.07)	31.28:	18.0:	...
3412	+ 861	75	-124	+ 737	1	...	...	...	...	...	...
3489	+ 690	62	-119	+ 571	1, 21	...	...	...	...	...	...
3593	+ 627	16	-118	+ 509	1, 38	...	...	...	...	...	...
3596	+ 1134	20	-109	+1025	67, 70	...	Sc* II	(11.93)	32.16	27.0	...
3605	+ 693	65	- 93	+ 600	1	...	...	...	...	...	...
3607	+ 934	35	- 93	+ 841	1, 2	...	...	...	...	...	...
3608	+ 1110	50	- 92	+1018	1	...	...	...	...	...	...
3623	+ 755	28	-114	+ 641	1, 20, 21, 39	...	...	...	...	...	...
3626	+ 1352	100	- 90	+1262	1	...	...	...	...	...	...
3627	+ 714	37	-114	+ 600	1, 16, 20, 21	...	...	...	...	...	...
3628	+ 842	10	-112	+ 730	2, 3, 15	...	...	...	...	...	...
3686	+ 1022	60	- 92	+ 930	1	...	Sc II	12.02	32.25	28.2	...
3810	+ 988	46	-111	+ 877	1, 2	17.5	Sc I	11.20	32.45	30.9	...
NGC 3938 Group:		$\langle v\rangle_o$ = 873, σ = 201								⟨r⟩ = 21.1	20.3
NGC 3893	+ 1001	35	+ 66	+1067	1, 2	...	Scn I:	(10.83)	32.08:	26.1:	...
3938	+ 792	41	+ 47	+ 839	2, 15, 26	19.5	Sc I	10.76	32.01	25.2	...
4096	+ 493	30	+ 67	+ 560	27, 70	...	Sc* II:	10.14	30.37:	11.9:	...
4157	+ 782	20	+ 83	+ 865	27, 70	...	...	...	...	...	...
4217	+ 962	100	+ 70	+1032	27, 70	...	...	...	...	...	...
CVn I Cloud:		$\langle v\rangle_o$ = 339, σ = 98				⟨r⟩ = 4.3				⟨r⟩ = 5.8	5.0
NGC 4136	+ 445	50	- 12	+ 433	1		Sc (n) III	(11.62)	30.83	14.7	...
4150	+ 244	50	- 9	+ 235	1	...	...	...	...	...	...
4214	+ 289	5	+ 21	+ 310	1, 2, 4, 5, 7	6.3	Ir* III-IV	10.12	28.82	5.8	...
4244	+ 242	10	+ 29	+ 271	2, 4, 5, 7, 12, 17, 71	...	S^- IV:	10.48	28.29	4.5	...
4248	...	...	+ 72	...	...	...	...	...	...	...	...
4258	+ 470	8	+ 72	+ 542	1, 4, 21, 23, 40	...	...	...	...	...	...
4395	+ 294	50	+ 14	+ 308	1	2.6	S^+ IV-V	10.66	27.05	2.6	...
4449	+ 201	4	+ 62	+ 263	1, 2, 4, 5, 16, 21	3.9	Ir III	9.90	29.11	6.6	...
4736	+ 246	12	+ 61	+ 307	1, 2, 4, 12, 21, 41	...	...	...	...	...	...
4826	+ 405	30	- 20	+ 385	1, 21, 42, 70	...	...	...	...	...	...
IC 4182	+ ...	...	+ 54	+ ...	...	...	...	...	...	...	...
Virgo Cluster:		$\langle v\rangle_o$ = 1111, σ = 724,				⟨r⟩ = 19.5					
NGC 4321	+ 1546	10	- 68	+1478	2, 27, 70	22.2	Sc I	10.05	31.30	18.2	...
Coma I Cloud:		$\langle v\rangle_o$ = 922, σ = 189								⟨r⟩ = 10.5	10.2
NGC 4203	+ 1001	150	+ 6	+1007	1	...	...	...	...	...	...
4245	+ 890	65	- 9	+ 881	1	...	...	...	...	...	...
4251	+ 1014	75	- 15	+ 999	1	...	...	...	...	...	...
4274	+ 719	16	- 8	+ 711	1, 81	...	...	...	...	...	...
4278	+ 632	38	- 9	+ 623	1, 43	...	...	...	...	...	...
4283	+ 1089	57	- 9	+1080	1, 43	...	...	...	...	...	...
4314	+ 883	65	- 5	+ 878	1	...	...	...	...	...	...
4414	+ 715	100	+ 3	+ 718	1	...	Scn* II:	(10.89)	31.12:	16.8:	...
4448	+ 693	65	- 7	+ 686	1	...	...	...	...	...	...
4494	+ 1221	52	- 18	+1203	1, 2	...	...	...	...	...	...
4559	+ 794	13	- 6	+ 788	2, 14, 16	10.0	Sc II-III	9.87	29.59	8.3	...
4565	+ 1183	45	- 14	+1169	1, 2, 21	...	...	...	...	...	...
4670	+ 1110	70	- 4	+1106	2	...	...	...	...	...	...
4725	+ 1114	65	- 8	+1106	1	...	...	...	...	...	...
Anon 1244	+ 879	70	- 5	+ 874	2	...	...	...	...	...	...
CVn II Cloud:		$\langle v\rangle_o$ = 698, σ = 85				⟨r⟩ = 5.2				⟨r⟩ = 10.7	7.6
NGC 3675	+ 696	37	+ 34	+ 730	1, 20	...	...	...	...	...	...
4051	+ 672	13	+ 53	+ 725	1, 23, 25, 44, 81	...	Sc (*) II	10.70	30.93	15.4	...
4485	+ 786	...	+ 53	+ 839	43	...	Ir III-IV:	12.24	30.94:	15.4	...
4490	+ 565	3	+ 52	+ 617	1, 4, 16, 20, 37, 43, 45, 81	...	Scn*t III:	9.81	29.02:	6.4	...
4627	+ ...	...	+ 18	+ ...	...	...	...	...	...	...	...
4631	+ 606	5	+ 18	+ 624	3, 4, 5, 23, 46, 47, 79	5.2:	Sc* III?	8.5:	(27.7)	(3.4)	...
4656/7	+ 634	10	+ 18	+ 652	2, 3, 5, 14, 15, 16, 79 25, 47	5.2	...	...	...	...	...
NGC 5128 Group:		$\langle v\rangle_o$ = 317, σ = 92				⟨r⟩ = 8.5				⟨r⟩ = 6.6	7.9
NGC 4945	+ (250)	...	-238	+ (12)	48, 49	...	...	...	...	...	...
5068	+ 570	70	-169	+ 401	2	8.1	S(B)c III-IV	(10.84)	29.54	8.1	
5102	+ 414	30	-208	+ 406	23, 27, 50	...	...	...	...	...	...
5128	+ 460	15	-218	+ 242	1, 51, 52, 53, 54, 55	...	...	...	...	...	...
5236	+ 515	12	-181	+ 334	1, 5, 9, 16, 21, 23, 82 52, 56	8.9	Sc I-II	(7.91)	28.65	5.4	...
5253	+ 388	3	-184	+ 204	1, 52, 57, 58, 66, 81, 85	...	...	...	...	...	...

TABLE 1—*Continued*

Galaxy (1)	v (2)	σ(v) (3)	300 cos A (4)	v_o (5)	Sources (6)	r(H II) (7)	L_c (8)	$m_{pg}^{o,i}$ (9)	$(m-M)^o$ (10)	r(L_c) (11)	⟨r⟩(H II, L_c) (12)
M 51 Group:		$\langle v \rangle_o$ = 606, σ = 48									
NGC 5055	+ 513	9	+ 78	+ 591	1, 2, 4, 12, 21, 59	...	...	...	...	...	...
5194	+ 464	5	+106	+ 568	60, 72	9.6	Sc I	8.73	29.98	9.9	9.7
5195	+ 554	15	+106	+ 660	1, 20, 21, 43, 61	...	...	...	...	...	...
NGC 5248	+1148	4	− 44	+1104	1, 2, 62, 70, 81	20.9	Sc I	10.24	31.49	19.9	20.6
M 101 Group:		$\langle v \rangle_o$ = 402, σ = 79, ⟨r⟩ = 7.2			63						
NGC 5486	+1317	21	+152	+1469	19	16.0:	⌜Scp III-IV:⌝	...	...	...	...
NGC 6015	+ 834	35	+214	+1048	1, 2, 3, 15, 16	33.8	Sc II	11.27	31.50	20.0	29.2
NGC 6643 Group:		$\langle v \rangle_o$ = 1842, σ = 259 ⟨r⟩ = 21.4				⟨r⟩ = 21.4			⟨r⟩=	28.3	24.4
NGC 6217	+1331	20	+233	+1564	1, 2, 15, 70	...	Sc* I-II	11.86	32.60	33.1	...
6340	+1906	50	+243	+2149	1, 27	...	...	...	...	...	...
6412	+1408	65	+245	+1663	2	13.9	Sc II	12.02	32.25	28.2	...
6643	+1500	24	+255	+1755	1, 2, 15, 27	28.9	Sc I-II	11.19	31.93	24.3	...
6654	+1824	75	+257	+2081	2	...	...	...	...	...	...
NGC 6946	+ 43	4	+292	+ 335	1, 4, 5, 14, 31, 77	10.5	Sc I	9.12	30.37	11.9	11.0
NGC 7640	+ 364	8	+274	+ 638	2, 4, 12, 14, 16 23, 76	(17.8)	S(B) b^+ II:	...	...	...	...
NGC 7741	+ 795	7	+240	+1035	1, 15, 23	30.7	SBc II	11.52	31.75	22.4	27.9
IC 342 Group:		$\langle v \rangle_o$ = 122, σ = 126				⟨r⟩ = 4.0:			⟨r⟩=	(4.7)	4.5:
NGC 1569	− 93	5	+174	+ 81	1, 2, 4, 12	...	Irp III-IV?	11.34	(30.0)	(10.0)	...
IC 10	− 343	2	+262	− 82	1, 4, 5, 12, 14, 31, 73, 77, 86	3.0	Ir (IV)	8.9:	(26.7)	(2.2)	...
IC 342	+ 26	4	+197	+ 223	1, 2, 3, 5, 26, 31, 57, 77	(8.0)	⌜Sc I-II⌝	...	...	...	...
Maffei 1	− 10	50	+209	+ 199	64	...	...	...	...	...	...
Maffei 2	− 18	5	+206	+ 188	(65), 69, 81, 84	...	...	...	...	...	...
Anon 0103	+ 983	75	+ 80	+1063	20	20.3	⌜Sc III⌝	12.15	31.36	18.7	19.8

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global value according to the arguments given there. The result is also the same as we obtain in Paper VI where the local velocity field plays no role. The agreement of the three numbers shows that (1) if systematic local velocity perturbations exist, they average out in our sample of nearby galaxies to give closely the global value of H, and (2) no gradient dH/dr exists in the present data since H is the same for nearby (this paper) and for distant (Paper VI) systems.

Because these results differ from the well-known opposite viewpoint (de Vaucouleurs 1958, 1966), we have looked in detail at the angular properties of the velocity field along the supergalactic longitude coordinate L_{SG}. The data are provisional because the sample can be increased, and the distances improved by further work on classification and photometry. Nevertheless, analysis of the present material uncovers no local velocity perturbations to within $\sim 3\ \sigma$ of the residuals of $H_i (\equiv v_i/r_i$ for galaxy i). (Such residuals arise naturally from the intrinsic scatter of the absolute magnitudes of the galaxies in the sample.)

The unexpected result is that the local velocity field, mapped with the present material, is as regular, linear, and isotropic as we can measure it ($\sim 3\ \sigma$).

The results that lead to these conclusions are developed in the remaining sections. The Hubble constant from the galaxies whose distances are known from Paper IV, treated both as isolated cases and as members of groups, is discussed in § II; the sample is increased in § III to include galaxies whose distances are determined by the luminosity classes via the calibration of Paper IV; the bias in this larger sample is identified in § IV; a restricted subset of the material is used in § V to investigate perturbations of the Hubble ratio v_i/r_i along the supergalactic equator and in the Rubin-Ford areas; and finally the value of the mean *random* velocity for the galaxies in the sample is derived in § VI.

II. VALUE OF H USING LOCAL SPIRALS WITH KNOWN DISTANCES

For a first look at the problem we use the list of galaxies with newly derived H II distances from Paper IV (table 2). Many of these are members of pairs, groups, or clusters. The assignment of galaxies to groups is generally not straightforward because it depends on arbitrary limits to the velocity dispersion and to the angular extent of the group in the sky. However, from the precepts of Humason, Mayall, and Sandage (HMS 1956), van den Bergh (1960), Holmberg (1964), de Vaucouleurs (1969), and Karatchentsev (1970), we have made group assignments with an attitude that generally lies between Holmberg's (1964) very conservative memberships and de Vaucouleurs's (1969) more comprehensive assignments. The results are listed in table 1.

Although the table is not complete for groups closer than $D \simeq 20$ Mpc because it is only a subset whose members were studied in Paper IV rather than the set of all groups that are known to exist, nevertheless a large number of galaxies are represented, and the data listed there define our distance scale for local galaxies.

Besides the detailed entries, we have adopted the M81 group as originally defined by Holmberg (1950) at the distance determined by Tammann and Sandage (1968), and the M101 group as described in Paper III. We have added a new probable pair of NGC 2985/3027, and have accepted a group around IC 342 by adding NGC 1569, IC 10, and Maffei 1 and 2 as members (cf. van den Bergh 1971).

Table 1 contains the following information:

Column (1). The name of the galaxy; if in a group, the group name.

Column (2). Mean weighted velocity v from published values, corrected to the Sun. HMS values are corrected by -100 km s^{-1} in the range $1200 \leq v \leq 2500$ km s^{-1} (Roberts 1972).

Column (3). Error estimate for the entry in column (2).

Column (4). Correction for galactic rotation of 300 $\sin l^{\mathrm{II}} \cos b^{\mathrm{II}}$, which is close to that adopted by HMS [$300 \cos (l^{\mathrm{I}} - 55) \cos b^{\mathrm{I}}$].

Column (5). Weighted velocity v_0 corrected for solar motion. If a member[1] of a group, the section is headed by the mean velocity of the group together with the standard deviation of a single group member from this mean.

Column (6). Sources for velocities in column (2), listed at the end of table 1.

Column (7). Distance (Mpc) from H II regions, when known from Paper IV. If the galaxy is a member of a group, and when several distances from H II regions are known in the group, the section is headed by the weighted mean ($w = 1$ for good distances, $w = \frac{1}{2}$ for distances marked by a colon in Paper IV).

Column (8). Type and luminosity class from van den Bergh (1960) for Sc and Ir galaxies. Our classification is enclosed in brackets.

Column (9). Apparent magnitude in Holmberg's (1958) system, corrected for galactic absorption and inclination effect. The magnitude is in parentheses if it is transformed from the de Vaucouleurs (1964) $B(0)$ system by $m_{pg} = B(0) + 0.149\,(B - V) - 0.22$. The Sc galaxies are corrected to face-on values by the precepts given in Paper IV.

Column (10). The true modulus for those galaxies with known luminosity classes, obtained by combining magnitudes from column (9) with the absolute magnitude calibration of Paper IV. Moduli for galaxies with an uncertain luminosity class (L_c) are shown by colons ($w = \frac{1}{2}$) or in parentheses ($w = \frac{1}{4}$).

Column (11). The luminosity-class distance (Mpc) computed from column 10. If more than one such distance is known within a group, the section is headed by the weighted group mean.

Column (12). The weighted mean distance of a group or a single galaxy from the H II distances ($w = 2$) and luminosity class distances ($w = 1$).

[1] To be precise, the barycenter velocity of the group should be used in the following rather than the mean, but the necessary masses are generally not well enough known to justify the refinement.

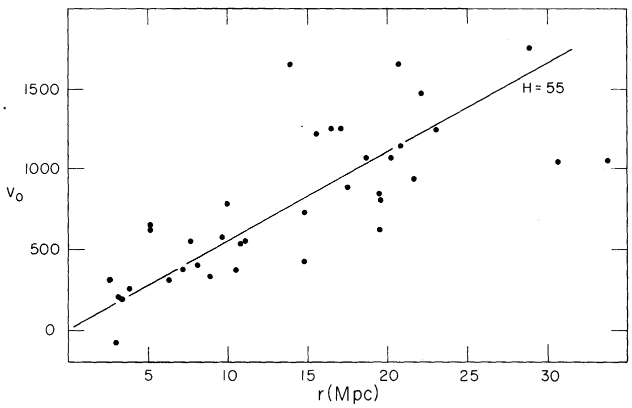

FIG. 1.—Velocity-distance relation for 37 Sc galaxies whose H II region distances were determined in Paper IV. The nature of the scatter indicates that most of the errors are due to percentage uncertainties ($\Delta r/r$) in the distances.

The distance scale defined by data in table 1, together with the measured velocities, permit a determination of the local velocity-distance relation. We first make two preliminary solutions here: (*a*) using only galaxies whose H II distances are known and (*b*) using the *mean* velocities and distances for the groups in table 1.

a) *Hubble Diagram for Individual Galaxies*

The velocity-distance relation is shown in figure 1 for galaxies from Paper IV (listed also in table 1 here) that have H II distances. Of the 39 listed systems, two Sb$^+$ galaxies (NGC 2903, 7640) are omitted, as are IC 342 (the strong galactic absorption makes the distance uncertain) and NGC 5486 where the luminosity class is uncertain. The NGC 2403 and M101 groups are added at their mean distance and velocity adopted earlier, giving a sample of 37.

The most striking features of figure 1 are the relatively small residuals and the nature of their scatter. Nearly all the points are confined within limiting lines $v_0 = 100r$ and $v_0 = 30r$. From these data alone, without further analysis, it can be seen that any mean random motion of the galaxies is less than 200 km s^{-1}, and that no large (say, $\delta v \simeq 1000$ km s^{-1}) systematic velocity *perturbation* exists in the data (cf. § III that follows).

Least-squares solution for H(in $v_0 = Hr$) is made twice, alternatively considering r and v_0 to be the independent variable. There clearly are errors in both variables; in r due to our measurement of distance, and in v_0 due to errors in measuring the spectrograms ($\sigma[v] \simeq 50$ km s^{-1}, cf. HMS 1956), and to any random motions superposed on the expansion velocity. Considering all the errors to be in r gives a solution

$$H = 58.3\,(+3.9, -3.5)\ \mathrm{km\ s^{-1}\ Mpc^{-1}}\,, \qquad (1)$$

while the solution if all errors are in v is

$$H = 51.2 \pm 3.2\ \mathrm{km\ s^{-1}\ Mpc^{-1}}\,. \qquad (2)$$

We show later that the errors in v are less than those in r, hence equation (1) is to be given more weight. Adopting a ratio of errors of 2 to 1 gives

$$\langle H \rangle = 56 \pm 4\ \mathrm{km\ s^{-1}\ Mpc^{-1}} \qquad (3)$$

from these data. The error is formal and internal, and says nothing about the *systematic* uncertainty, which depends on the accuracy of our distance scale.

b) *Hubble Diagram for the Groups in Table 1*

The velocity-distance relation using the mean distances (col. [12], table 1) and mean velocities (headings for each group in table 1) for the 20 groups plus 10 field galaxies is plotted in figure 2. The data are summarized in table 2, where they have been abstracted from table 1. Column (1) gives the group name (if it is a field galaxy, it is in parentheses with the NGC number); columns (2) and (3) list the supergalactic coordinates following de Vaucouleurs and de Vaucouleurs (1964); columns (4) and (5) are the distance and corrected velocity from table 1; column (6) is the standard deviation of the *mean* velocity of column (5) computed from the σ value in table 1; column (7) is the individual velocity-to-distance ratio for the group in question.

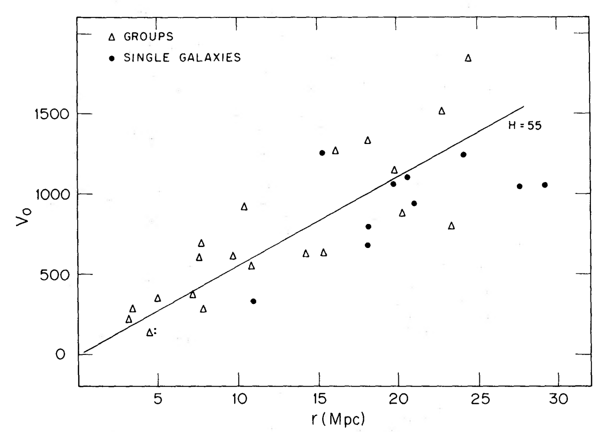

FIG. 2.—Velocity-distance relation for 20 groups and 10 field galaxies from data in table 1 as summarized in table 2. Note the decreased scatter from fig. 1.

TABLE 2

DISTANCES TO GROUPS AND TO SINGLE GALAXIES BY THE MEAN OF THE H II AND THE $M = f(L_C)$ METHODS

Group (1)	L_{SG} (2)	B_{SG} (3)	r (Mpc) (4)	v_0 (km s^{-1}) (5)	σ (6)	v/r (7)	log v_0 (8)	log r (9)	$(m-M)_0$ (10)
G 253	265	−3	3.4	281	±74	82.6	2.449	0.531	27.66
(NGC 428)	299	−4	15.4	1250	...	81.2	3.097	1.188	30.94
(NGC 628)	315	−5	18.2	797	...	43.8	2.901	1.260	31.30
G 672	327	−4	10.9	540	...	49.5	2.732	1.037	30.19
G 1023	342	−9	14.3	721	±13	50.4	2.858	1.155	30.78
G 1068	305	−26	18.1	1332	±100	73.6	3.125	1.258	31.29
Eridanus G	278	−43	22.8	1520	±59	66.7	3.182	1.358	31.79
G 2841	50	−16	7.6	601	±47	79.1	2.779	0.881	29.40
G 2985	39	+3	16.1	1274	...	79.1	3.105	1.207	31.03
G M81	42	+1	3.25	226	±28	69.5	2.354	0.512	27.56
G 3184	64	−16	15.4	673	±39	43.7	2.828	1.188	30.94
(NGC 3486)	80	−16	18.1	677	...	37.4	2.831	1.258	31.29
(NGC 3631)	61	−1	24.2	1242	...	51.3	3.094	1.384	31.92
(NGC 3726)	67	−2	21.0	935	...	44.5	2.971	1.322	31.61
G Leo	94	−26	23.4:	799	±48	34.1:	2.903	1.369:	31.85:
G 3938	71	0	20.3	873	±90	43.0	2.941	1.307	31.54
G CVn I	69	+6	5.0	339	±33	67.8	2.530	0.699	28.49
Virgo Cl	104	−2	19.8	1111	±75	56.1	3.046	1.297	31.48
G Coma I	88	+2	10.2	922	±49	90.4	2.965	1.009	30.04
G CVn II	76	+6	7.6	698	±35	91.8	2.844	0.881	29.40
G 5128	160	−5	7.9	317	±41	40.1	2.501	0.698	29.49
G M51	72	+17	9.7	606	±28	62.5	2.782	0.987	29.93
(NGC 5248)	111	+13	20.6	1104	...	53.6	3.043	1.314	31.57
G M101	64	+23	7.2	402	±32	55.8	2.604	0.857	29.30
(NGC 6015)	51	+33	29.2	1048	...	35.9	3.020	1.465	32.33
G 6643	30	+31	24.4	1842	±116	75.5	3.265	1.387	31.94
(NGC 6946)	11	+42	11.0	335	...	30.5	2.525	1.041	30.21
(NGC 7741)	319	+22	27.9	1035	...	37.1	3.015	1.446	32.23
G IC 342	11	0	4.5:	122	±56	27.1:	2.086	0.653	28.27
(A0103)	292	−4	19.8	1063	...	53.7	3.026	1.297	31.48

Figure 2 shows the same features as figure 1, but has somewhat less scatter, illustrating the improvement in the distances and velocities when the group averages are used. The scatter again increases with distance, showing that the distances are affected by a constant percentage error $\sigma(\Delta r/r)$, and that such errors dominate over velocity errors, which of course are distance-independent (cf. § V).

Least-squares solutions for H using the data of figure 2, giving most groups weight 2, and field galaxies and IC 342 and NGC 2985/3027 weight 1 yield

$$H = 58.7\,(+2.7,\ -2.5)\ \mathrm{km\ s^{-1}\ Mpc^{-1}} \tag{4}$$

if all errors are assumed to be in r, and

$$H = 53.9 \pm 2.4\ \mathrm{km\ s^{-1}\ Mpc^{-1}} \tag{5}$$

if all errors are in v. Again, the true case is expected to lie between. However, the most distant systems have the least accurate values; three of the four most distant points are single galaxies rather than groups. Excluding the six most distant points (i.e., retaining all points with $r < 20$ Mpc; cf. § V) gives

$$H = 59.8\,(+2.7,\ -2.5)\ \mathrm{km\ s^{-1}\ Mpc^{-1}} \tag{6}$$

if all errors are in r, and

$$H = 55.7 \pm 2.5\ \mathrm{km\ s^{-1}\ Mpc^{-1}} \tag{7}$$

if all errors are in v.

The equations (4)–(7) are all compatible with our final adopted value from figure 2 and table 2:

$$\langle H \rangle = 57 \pm 3\ \mathrm{km\ s^{-1}\ Mpc^{-1}}\,. \tag{8}$$

III. ADDITIONAL DATA FOR FIELD SPIRALS

Most of the galaxies in figures 1 and 2 have redshifts smaller than 1200 km s^{-1}, yet the Hubble constant determined from them is the same as the global value from Paper IV using the great galaxy clusters via the Virgo cluster, and from Paper VI using remote Sc I field galaxies. Hence, although any local perturbation should affect the velocities of such nearby systems, no effect is present in the *mean*. Does, then, a measurable perturbation exist? More data are needed for an adequate answer.

To this end we have added 75 galaxies, 44 of which are Sc I to Sc III systems (mostly in the northern hemisphere) classified by van den Bergh (1960), and 31 similar galaxies (mostly in the south) classified by us. The data are listed in tables 3 and 4, which follow the format of table 2. The distances in column (7) are calculated from the apparent moduli given in column (6), which follow from the corrected magnitudes in column (5) and the luminosity calibration of Paper IV. Some of the velocities in tables 3 and 4 have not been previously published, and are from the Mount Stromlo redshift survey by one of us. Mean velocities are given for groups; they are marked with an exclamation point (!) in table 4.

The velocity-distance relation for the complete

TABLE 3

DISTANCES TO GALAXIES WITH VAN DEN BERGH LUMINOSITY CLASSES USING THE $M = f(L_C)$ METHOD OF PAPER IV

Galaxy (NGC) (1)	L_C (2)	L_{SG} (3)	B_{SG} (4)	$m_{pg}^{0,i}$ (5)	$(m - M)_0$ (6)	r (Mpc) (7)	v_0 (km s^{-1}) (8)	v_0/r (9)	log v_0 (10)	log r (11)
157.......	Sc I	288	+ 3	11.04	32.29	28.7	1808	63.0	3.257	1.458
908.......	Sc I	281	−26	10.38	31.63	21.2	1585	74.8	3.200	1.326
1566.......	Sc I	236	−41	9.85	31.10	16.6	924!	55.7	2.966	1.220
2336.......	Sc I	28	+ 6	10.65	31.90	24.0	2389	99.5	3.378	1.380
3294.......	Sc I	70	−16	11.94	33.19	43.5	1352	31.1	3.131	1.638
3642.......	Sc I	55	+ 2	11.46	32.71	34.8	1625	46.7	3.211	1.542
3646.......	Sc I	91	−15	11.65	32.90	38.0	4198	110.5	3.623	1.580
4030.......	Sc I	114	−13	11.34	32.59	33.0	1260	38.2	3.100	1.518
5427.......	Sc I	128	+15	11.96	33.21	43.9	2516	57.3	3.401	1.642
6070.......	Sc I	133	+47	12.19	33.44	48.8	2057	42.2	3.313	1.688
6181.......	Sc I	105	+56	12.20	33.45	49.0	2209	45.1	3.344	1.690
7678.......	Sc I	315	+26	12.40	33.65	53.7	3680	68.5	3.566	1.730
309.......	Sc I–II	288	− 3	12.16	32.90	38.0	...	...	...	1.580
1385.......	Sc I–II	278	−43	11.49	32.23	27.9	1790	64.1	3.253	1.446
3963.......	Sc I–II	58	+ 6	12.36	33.10	41.7	3313	79.4	3.520	1.620
5230.......	Sc I–II	106	+13	12.64	33.38	47.3	...	...	...	1.675
7314.......	Sc I–II	260	+22	11.42	32.16	27.1	1739	64.2	3.240	1.433
578.......	Sc II	277	−13	11.23	31.46	19.6	1904	97.1	3.280	1.292
864.......	Sc II	309	−17	11.54	31.77	22.6	1544	68.3	3.189	1.354
1832.......	Sc II	294	−65	11.82	32.05	25.7	1769	68.8	3.248	1.410
2715.......	Sc II	34	+ 6	11.26	31.49	19.9	1329	66.8	3.124	1.299
2742.......	Sc II	43	− 9	11.94	32.17	27.2	1467	53.9	3.166	1.435
2776.......	Sc II	53	−22	12.04	32.27	28.4	2682	94.4	3.428	1.453
3052.......	Sc II	128	−47	12.56	32.79	36.1	3327	92.2	3.522	1.558
3344.......	Sc II	82	−21	10.35	30.58	13.1	506	38.6	2.704	1.117
3359.......	Sc II	50	+ 1	10.72	30.95	15.5	1115	71.9	3.047	1.190
3756.......	Sc II	61	+ 2	11.78	32.01	25.3	1155	45.7	3.063	1.403
3780.......	Sc II	59	+ 3	12.27	32.50	31.6	2862	90.6	3.457	1.500
4041.......	Sc II	55	+ 8	11.46	31.69	21.8	1312	60.2	3.118	1.338
4145.......	Sc II	70	+ 2	11.45	31.68	21.7	1109!	51.1	3.045	1.336
4162.......	Sc II	91	− 3	12.46	32.69	34.6	2510	72.5	3.400	1.539
5468.......	Sc II	128	+16	12.23	32.46	31.0	2789	90.0	3.445	1.491
5962.......	Sc II	109	+42	12.15	32.38	29.9	1988	66.5	3.298	1.476
7309.......	Sc II	275	+30	12.93	33.16	42.9	4084	95.2	3.611	1.632
7721.......	Sc II	285	+16	11.81	32.04	25.6	2171	84.8	3.337	1.408
1309.......	Sc II–III	290	−39	12.24	31.96	24.7	2179	88.2	3.338	1.393
2339.......	Sc II–III	33	−55	12.02	31.74	22.3	2159	96.8	3.334	1.348
5147.......	Sc II–III	117	+ 8	12.53	32.25	28.1	1042	37.1	3.018	1.449
5668.......	Sc II–III	120	+25	12.17	31.89	23.9	1631	68.2	3.212	1.378
5970.......	Sc II–III	115	+42	12.15	31.87	23.7	2136	90.1	3.330	1.375
1659.......	Sc III	313	−57	13.07	32.28	28.6	4426	154.8	3.646	1.456
3370.......	Sc III	90	−24	11.98	31.19	17.3	1190	68.8	3.076	1.238
3512.......	Sc III	81	−16	12.96	32.17	27.1	1349	49.8	3.130	1.433
3684.......	Sc III	94	−15	12.40	31.61	21.0	1229	58.5	3.090	1.322

material (tables 2, 3, and 4) is plotted in figure 3. As in figures 1 and 2, the most striking feature is the nature of the scatter. The points are again contained within the boundary lines $v_0 = 100r$ and $v_0 = 30r$. Because of this, it is clear that the residuals increase with distance such that $\sigma(\Delta r/r)$ is a constant. This requires that most of the errors occur in the distances because velocity residuals will not be percentage errors.

As a prelude to the analysis of the mean random motion in § VI, we show the redshift-magnitude diagram in figure 4 for each galaxy in figure 3, where the Sc I systems are plotted at their corrected $m_{pg}^{0,i}$ magnitudes, and galaxies of other luminosity classes are made brighter by the mean differences between the classes (Paper IV, table 5). The boundary lines of this diagram are parallel and have a slope of 5. This is a natural consequence of the linear boundary lines of figure 3.

The Hubble constant cannot properly be found from the combined data of tables 2, 3, and 4 because the sample is severely *biased*. Tables 3 and 4 are from catalogs that are magnitude-limited, while table 2 is more nearly a distance-limited sample (the H II regions must be resolved). The conditions that lead to the bias are similar to those in the statistical problem of Eddington (1914) and Malmquist (1920). But rather than make a model-dependent correction, which can never be precise, we analyze the material in the next section and produce a more unbiased list by an appropriate restriction of the sample.

TABLE 4

DISTANCES TO GALAXIES WHOSE LUMINOSITY CLASSES HAVE BEEN ESTIMATED BY US

Galaxy (1)	L_C (2)	L_{SG} (3)	B_{SG} (4)	$m_{pg}^{0,i}$ (5)	$(m-M)_0$ (6)	r (Mpc) (7)	v_0 (km s^{-1}) (8)	v_0/r (9)	log v_0 (10)	log r (11)
NGC 991...	Sc III–IV	297	−26	12.47	31.14	16.9	1570	92.9	3.196	1.228
{1310...	Sc I–II	263	−41		30.69	13.7	1294!	94.4	3.112	1.137}
{1365....	Sc I. 4			9.85						
IC 1953...	Sc II	282	−42	12.37	32.60	33.1	1823	55.1	3.261	1.520
NGC 1376...	Sc II. 8	304	−40	12.76	32.16	27.0	4388	162.5	3.642	1.431
1448...	Sc II. 8	251	−41	10.49	29.89	9.5	1010	106.3	3.004	0.978
1667...	Sbc I–II	311	−58	12.91	33.65	53.7	4501	83.8	3.653	1.730
1672...	Sc I–II	228	−40	10.99	31.73	22.2	1078	48.6	3.033	1.346
{2196...	Sb I–II	251	−80	11.97	32.70	34.6	2166!	62.6	3.336	1.539}
{2223...	Sc I. 25			11.69						
2280...	Sc I	218	−78	11.44	32.69	34.5	1758	51.0	3.245	1.538
2397...	Sc II–III	204	−36	12.44	32.16	27.0	1006	37.3	3.003	1.431
2442...	Sc I. 6	203	−36	11.46	32.10	26.3	1073!	40.8	3.031	1.420
2713...	Sbc I–II	88	−54	12.48	33.22	44.1	3745	84.9	3.573	1.644
2815...	Sbc II	136	−56	11.94	32.17	27.2	2285	84.0	3.359	1.434
2889...	Sc I–II	116	−53	12.41	33.15	42.7	3143	73.6	3.497	1.630
2935...	SBc I	132	−51	11.85	33.10	41.7	1946	46.7	3.289	1.620
2989...	Sb$^+$ II	127	−49	12.99	(33.22)	(44.1)	3876	(87.9)	3.588	1.644
2997...	Sc I. 2	147	−48	10.15	31.19	17.3	770	44.5	2.886	1.238
3124...	S(B)c I	129	−44	12.17	33.42	48.3	3093	64.0	3.490	1.684
3437...	Sc II–III	85	−20	12.34	32.06	25.8	1037	40.2	3.016	1.412
4835...	Sc II	162	−11	11.46	31.69	21.8	1984	91.0	3.297	1.338
5483...	Sc II	164	+ 2	11.74	31.97	24.8	1649	66.5	3.217	1.394
5643...	Sc II. 8	166	+ 5	10.84	30.24	11.2	984	87.8	2.993	1.049
{6215...	Sc II. 8	192	+11	11.19	30.59	14.1	1346!	95.5	3.129	1.149}
{6221...	Sc II. 2			10.84	30.89					
6744...	Sc II	209	+10	9.33	29.56	8.2	544	66.3	2.736	0.914
6878...	Sc I. 3	223	+27	13.83	34.75	89.1	5831	65.4	3.766	1.950
7083...	Sc II	224	+ 5	11.78	32.01	25.2	2952	117.1	3.470	1.401
7125...	Sc I	227	+ 6	12.30	33.55	51.3	2930	57.1	3.467	1.710
IC 5201...	Sc II. 8	241	+13	11.22	30.62	13.3	2098	157.7	3.322	1.124
7412...	Sc I. 4	248	+10	11.81	32.65	33.9	1699	50.1	3.230	1.530
{7418...	Sc II. 1			11.83	31.55					
{IC 5269 A.	Ir V	253	+12			21.9	1742!	79.5	3.241	1.340}
{IC 5273...	Sc II. 2			11.62	31.85					
NGC 7424...	Sc II	249	+10	11.30	31.38	18.9	3011	159.3	3.479	1.276

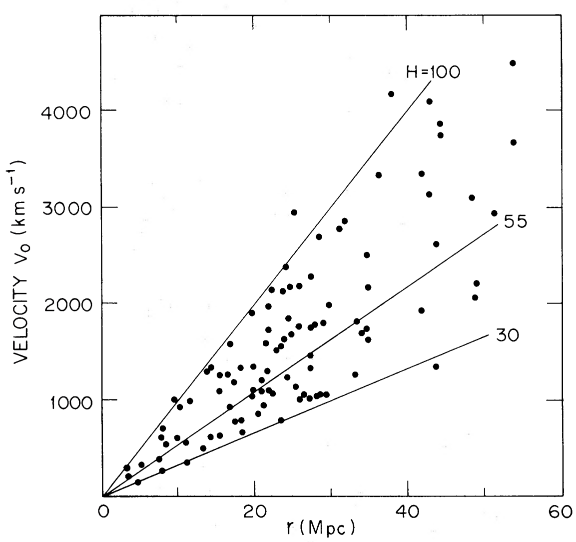

FIG. 3.—Velocity-distance relation for the combined data of tables 2, 3, and 4. Most of the points lie between the boundary lines for the Hubble rates of $H = 100$ km s^{-1} Mpc^{-1} and $H = 30$ km s^{-1} Mpc^{-1}.

IV. THE BIAS IN THE SAMPLE

Any sample that is magnitude-limited is improper for the determination of the Hubble constant because of the bias illustrated in figure 5.

Suppose galaxies in a particular sample have a well-defined luminosity function, with dispersion σ about the mean magnitude $\langle M \rangle$. If the distribution is Gaussian, then 99.7 percent of the galaxies will occur within the boundary lines $\langle M \rangle + 3\,\sigma$ and $(M) - 3\,\sigma$. Galaxies that are brighter in absolute magnitude than normal will fall to the left of the mean line, and vice versa.

However, a mean *luminosity distance* to every galaxy in the sample is computed by assuming it to have the mean absolute magnitude $\langle M \rangle$. Hence, some distances will be underestimated, and others overestimated. In the range of velocities where the sample is complete per unit volume, there will be as many on one side of the mean as on the other, and the average value of

$$\langle \log H \rangle \equiv n^{-1} \sum_i^n (\log v_i - \log r_i)$$

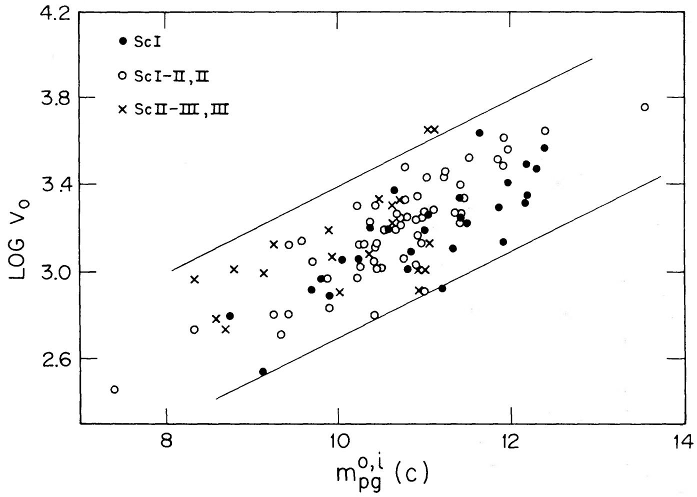

FIG. 4.—Redshift-magnitude relation for the galaxies in fig. 3. The boundary lines are parallel and have the theoretical slope of 5 corresponding to a linear velocity-distance relation. The magnitudes are corrected for galactic absorption, tilt to face-on, and absolute magnitude differences between the luminosity classes.

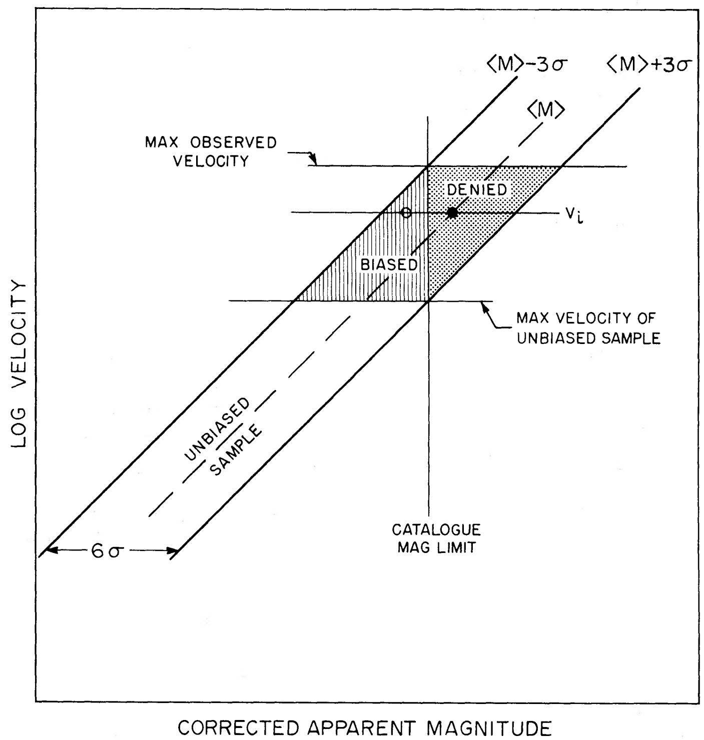

FIG. 5.—Schematic redshift-magnitude relation showing the bias caused by incompleteness in a sample that is magnitude-limited (region marked *denied*) compared to a sample that is distance-limited (chosen by velocity).

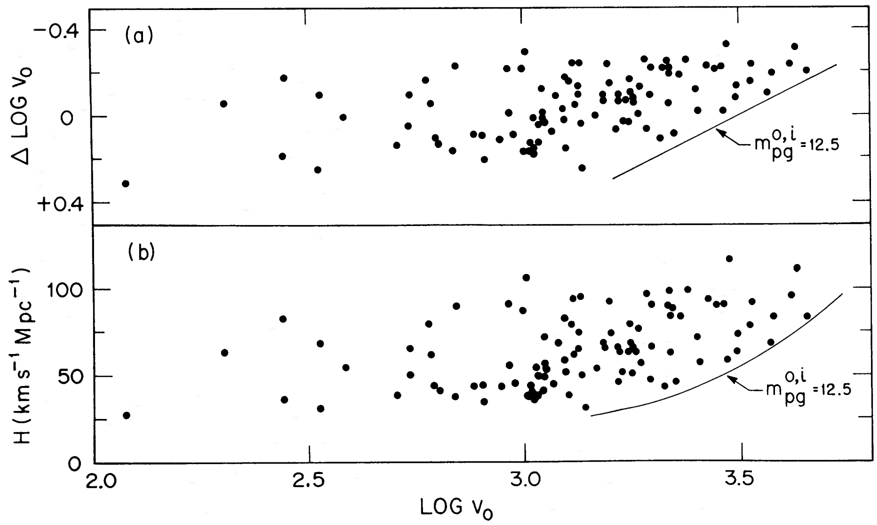

FIG. 6.—(*a*) Residuals read as velocity differences $\Delta \log v_0$ about the $H = 55$ line for the data in fig. 3 (tables 2, 3, and 4), showing that the incompleteness expected from the model in fig. 5 occurs in the present data. (*b*) The Hubble ratio (v_i/r_i) for each galaxy of the sample, showing that the mean value will be artificially too large due to the bias described in fig. 5 unless the sample is cut at $\log v_0 \simeq 3.3$.

will be unbiased.[2] But when the velocity becomes larger than a certain critical value (the lower horizontal line in fig. 5), intrinsically faint galaxies are progressively lost if the sample is magnitude-limited, as shown by the vertical line. Galaxies in the region marked "denied" would have *calculated* values of H that are smaller than the galaxies that are still in the sample, and the mean value of H from these biased galaxies will be higher than $\langle H \rangle_{\text{true}}$, because the mean absolute magnitude of the galaxies remaining in the sample at v_i is brighter than $\langle M \rangle$. The open and closed circles on the v_i line in figure 5 show the difference schematically.

Neglect of the effect will give an apparent but unreal correlation of $H_i \equiv v_i/r(\text{lum})_i$ with v for velocities between the two horizontal lines, and hence an erroneously high value of $\langle H \rangle$.

This bias, or ones related to it, has caused confusion in the past when a deviation in the slope of Hubble diagrams from $dm/d(\log v) = 5$ has been interpreted as a deviation from linearity of the expansion; in reality it has often been the artificial increase in mean absolute magnitude with increasing velocity in a sample that is biased due to the nature of its selection.[3]

[2] The logarithmic form is unbiased because, if the luminosity function for Sc I's, $\phi(M)$, is assumed to be symmetric (as for a Gaussian), the distribution of errors in distance is symmetric in $\Delta r/r$, (i.e., in $\Delta \log r$), but not in Δr. The difference between $\langle H \rangle$ and antilog $\langle \log H \rangle$ is generally smaller than the mean error if the distances to the sample galaxies themselves have small errors, as in § II, and the effect was ignored there. However, the nature of the percentage error in r (i.e., $\sigma[\Delta r/r] \simeq$ constant) is important for several aspects of the analysis in § V, and should be kept in mind in that section.

[3] We believe that an effect similar to the one described here may be present in the data of Rubin, Ford, and Rubin (1973), and that their suggestion that a different Hubble ratio exists in two directions of the sky comes about due to a form of this bias (cf. Paper VI of the present series, yet to appear), coupled with the apparent velocity inhomogeneity of their sample.

The bias explained in figure 5 is present in our data, as can be seen from figure 6 where the residuals in figure 3, read as velocity residuals $\Delta \log v_0$, are plotted against $\log v_0$ for each galaxy in the complete sample, where v_0 is the measured velocity corrected for galactic rotation.[4] The number of positive velocity residuals in figure 6*a* becomes progressively fewer as $\log v_0$ increases for $\log v_0 \gtrsim 3.3$, as it should by the argument from figure 5. Similarly in figure 6*b*, the number of low values of H_i becomes less as $\log v_0 >$ 3.3. The rather abrupt cutoff starts where the line for the catalog magnitude limit in figure 5 intersects the lower boundary line $\langle M \rangle + 3\,\sigma$. We can see from figure 6 that this occurs at $\log v_0 \simeq 3.3$, which, from figure 4, corresponds to a catalog limiting value of $m_{pg}{}^{0,i} \simeq 12.5$. The value evidently is reasonable because all galaxies in tables 2, 3, and 4 are from the Shapley-Ames catalog, which has about this limiting magnitude (when corrected for absorption and to face-on).

Hence the "unbiased" sample from tables 2, 3, and 4 consists of those galaxies whose measured redshifts are less than $\log v_0 = 3.3$ ($v_0 \lesssim 1995$ km s^{-1}). Restricting the velocities to be less than this value produces a distance-limited sample where the limiting distance corresponds to $r_c = 36$ Mpc (assuming that $H = 55$ km s^{-1} Mpc).

[4] It is important to note that the measured velocity $\log v_0$ is used as the independent variable in figure 6 rather than r(lum) because yet another bias exists in r due to the nonsymmetrical nature of the distribution of errors Δr. For those galaxies with abnormally large values of r on the high end of the $\Delta r/r$ error distribution, $H_i(\equiv v_i/r_i)$ is abnormally small and uncompensated for by equal numbers of high values due to the lack of symmetry in Δr itself. A plot of H_i versus r_i would show a *pseudo*-decrease of H_i with r_i (seen by plotting the data in tables 2, 3, and 4 directly). But the effect is not real. It does not occur when the residuals are plotted versus $\log v_0$, as in figure 6, because there is no such proportional error in the velocity v_0.

But it must be stressed that even this sample, especially from tables 3 and 4, is not entirely unbiased for three reasons: (*a*) only part of the Shapley-Ames galaxies have known radial velocities; (*b*) of the spiral and irregular galaxies with known radial velocities, the objects in tables 2, 3, and 4 still represent a somewhat arbitrary subsample; and (*c*) the total sample contains Sc II and Sc III galaxies whose $\langle M \rangle$ and $\sigma(M)$ differ from Sc I systems, hence the model in figure 5 is too simple for part of the material.

Points (*a*) and (*b*) introduce a number of small but presently uncontrollable selection effects. An observational program now in progress here for the measurements of redshifts for the complete Shapley-Ames catalog, combined with new determinations of luminosity classes, will eventually remove most of this bias due to incompleteness. As for point (*c*), it is true that even exceptionally faint Sc I galaxies (i.e., $\langle M \rangle + 3\,\sigma$) to $\sim$36 Mpc will be contained in our present sample, but the fainter luminosity classes fade out at smaller distances—e.g., an *average* Sc II galaxy with $M_{\mathrm{Sc\,II}} = -20.2$ mag (Paper IV) would have an apparent magnitude of $m_{\mathrm{pg}}{}^{0,i} = 12.6$ at 36 Mpc ($m - M = 32.8$), and therefore would just marginally enter the sample—however, all underluminous Sc II galaxies would be excluded. Sc II galaxies are complete only to $(m - M)_0 = 31.7$ or 21.9 Mpc (this assumes $\langle M \rangle_{\mathrm{Sc\,II}} + 2\,\sigma \simeq -19.2$ mag for the faintest Sc II's). The Sc III's, being still fainter by 1 mag, are complete only to $(m - M)_0 = 30.7$ or 13.8 Mpc in a sample with $m_{\mathrm{pg}} \leq 12.5$ mag. From this it is evident that in our sample, galaxies of luminosity classes II and III will be slightly brighter than the mean absolute magnitude $\langle M \rangle$ of their luminosity class in a distance-limited sample. This will necessarily lead to too high a value of $\langle H_i \rangle$. The existence of the effect is shown in figure 3 by the relative absence of points near the lower boundary (marked 30) for $r \geqslant 35$ Mpc; i.e., with increasing distance, fewer small values of H_i occur for Sc II and Sc II galaxies, and this trend starts somewhat before $v_0 = 1955$ km s^{-1} (or $\log v_0 = 3.3$ in fig. 6). Although present, the problem is not prominent in these diagrams, and will be neglected in what follows, as it has only a small effect on the results, and there is no precise way to correct for it.

V. THE HUBBLE CONSTANT TOWARD AND AWAY FROM THE VIRGO CLUSTER AND THE VELOCITY ISOTROPY ALONG THE SUPERGALACTIC EQUATOR

We are now interested in a more detailed description of the velocity field than is given by only average properties such as $\langle H \rangle$ inferred from figures 1, 2, and 3. A solution with significant weight for the generalized velocity field, containing arbitrary shear and rotation components (in addition to the underlying Hubble flow), should be possible when sufficiently numerous and precise data on velocities and distances of nearby galaxies become available. Our present material is not sufficient in these regards, nor is it well enough spread over the celestial sphere for such a general solution now.

However, the material is sufficient to indicate the accuracy to which certain specific classes of velocity perturbations can be eliminated, and hence the level at which the velocity field can be said to be unperturbed.

In the absence of shear and rotation, the simplest perturbation can be imagined to be a contraction of the Local Supercluster toward its center somewhere near the Virgo cluster. This can be tested by inspecting the value of $\langle H \rangle$ at different distances in hemispheres toward and away from the Virgo cluster itself.

A more general motion having shear, rotation, expansion or contraction, again organized about the Virgo cluster complex, has been discussed by de Vaucouleurs (1958), Stewart and Sciama (1967), de Vaucouleurs and Peters (1968), and others, using earlier material. The search for solutions of this type can be made by looking for periodicities of H_i with supergalactic longitudes.

Further, these two types of special local perturbations might be superposed on a large scale gradient dH/dr as proposed by Haggerty and Wertz (1972), but shown not to exist either in the present data (§ I), or in the data for nearby E clusters and groups (Sandage *et al.* 1972).

In this section, the present material is used to search for perturbations of the first two types by comparing the individual Hubble ratios (v_i/r_i) at different distances both toward and away from the Virgo complex, and by inspecting the correlation of H_i with supergalactic longitude.

The sample consists of the 71 galaxies or groups with $\log v_0 \leq 3.3$ in tables 2, 3, and 4 which would be unbiased if the three minor incompleteness effects for $20 \leqslant r_c \leqslant 36$ Mpc, mentioned at the end of § IV, can be neglected.

a) Dependence of H_i on Distance in the Center and Anticenter Hemispheres

Following de Vaucouleurs (1958, 1972), we divide the sample into two hemispheres that are related to the Local Supercluster. The region toward the "center" contains the Virgo cluster, and is defined to be between supergalactic longitude $195° > L_{\mathrm{SG}} \geq 15°$ (the Virgo cluster is at $L_{\mathrm{SG}} = 105°$); the anticenter hemisphere has $15° > L_{\mathrm{SG}} \geq 195°$.

The dependence of the apparent Hubble constant per galaxy $H_i \equiv v_i/r_i$ on distance[5] within each hemisphere is tested in figure 7; the data are combined in the lower panel. There clearly is no significant dependence of H_i on distance for $r_c < 20$ Mpc, nor on the particular hemisphere (the open and closed circles mingle well in the lower panel). The slight increase of H_i with distance for $r_c \gtrsim 20$ Mpc *in both hemispheres* is hardly significant, amounting to only $\sim 1\,\sigma$, and we discount its reality because the progressive incompleteness of the Sc II and Sc III galaxies

[5] The redshift distance $r_{c,i} \equiv v_i/\langle H \rangle$ is used in figure 7 because it eliminates a bias that exists in r(lum) due to the unsymmetrical error distribution of Δr (cf. nn. 2 and 4).

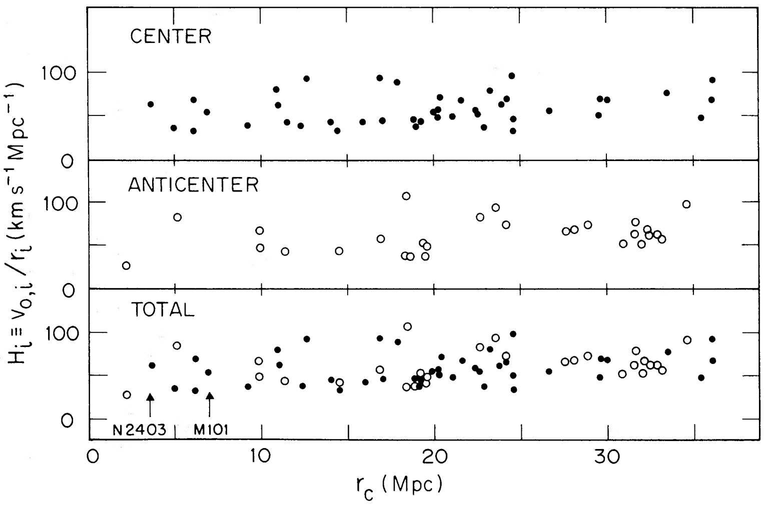

FIG. 7.—The Hubble rate for each galaxy versus calculated distances ($r_c \equiv v_0/55$) for galaxies in the restricted sample in the center ($195° > L_{SG} \geq 15°$) and the anticenter ($15° > L_{SG} \geq 195°$) supergalactic hemispheres.

in the sample at the larger distances (§ IV) will produce a trend in this direction.

Formal solutions for $\langle H \rangle$ in the two hemispheres put limits on any conjectured contraction field. If galaxies at all distances in the unbiased sample are used, mean values of H for the center and anticenter are

$$\langle H \rangle_C = 57.0 \pm 2.8(\sigma) \text{ km s}^{-1} \text{ Mpc} \quad (n = 42)\,, \quad (9)$$

and

$$\langle H \rangle_{AC} = 62.3 \pm 3.7(\sigma) \text{ km s}^{-1} \text{ Mpc} \quad (n = 29)\,. \quad (10)$$

Due to the unsymmetrical distribution of Δr errors, logarithmic means are more appropriate (n. 2), giving the closely similar values of $\langle H \rangle_C = 55.4 \pm 2.7(\sigma)$ and $\langle H \rangle_{AC} = 60.8 \pm 3.5(\sigma)$.

If the sample is restricted to $r_c \lesssim 20$ Mpc to avoid galaxies that are beyond the Virgo cluster, the simple mean is

$$\langle H \rangle_C = 52.9 \pm 4.4(\sigma) \text{ km s}^{-1} \text{ Mpc} \quad (n = 19)\,, \quad (11)$$

and

$$\langle H \rangle_{AC} = 53.2 \pm 6.1(\sigma) \text{ km s}^{-1} \text{ Mpc} \quad (n = 13)\,, \quad (12)$$

while the logarithmic solution gives $\langle H \rangle_C = 62.9 \pm 4.5(\sigma)$ and $\langle H \rangle_{AC} = 65.9 \pm 6.4(\sigma)$, showing the non-negligible sensitivity of the solution to different methods of weighting (the logarithmic solution is a weighting essentially by geometric means in the distance).[6]

[6] Note that the logarithmic solution for equations (11) and (12) gives numbers that are considerably larger than those for the simple mean themselves, whereas the opposite is true but with a much smaller difference for the corresponding equations (9) and (10). This is because of the very high weights given to a few of the nearest galaxies in the logarithmic solutions for $r_c \leq 20$ Mpc. Because of these abnormal weights, we believe that the logarithmic solutions corresponding to equations (11) and (12) go too far in the other direction from the simple means, and should be given low weight.

However, regardless of the merits or demerits of the various weightings, in all four solutions *taken in pairs* (i.e., eqs. [9] and [10] taken together, eqs. [11] and [12] together, or their logarithmic counterparts), the *center* value agrees with that for the *anticenter* to within 1 σ of their combined errors.

There is, then, no evidence here for a large velocity perturbation centered on the direction of the Virgo cluster. A simple collapse model should show a dependence of H_i on distance and on hemispherical direction of a type that clearly is not present in figure 7. Rather, the diagram shows no differences from an ideal Hubble flow that are greater than $\sim 1\ \sigma$ of the combined errors.

b) *Dependence on Supergalactic Longitude*

We next test for periodicities of H with L_{SG} such as would be present in a model that has rotation, shear, and expansion. Clearly, many forms of periodicity are possible, depending on the details of the motion, but the simplest will show a distorted double sine wave for $r < 20$ Mpc, whose shape and amplitude will depend upon distance (cf. Oort 1927 for the famous specific case). An early discussion of such motions in the Virgo-Coma complex and along the supergalactic plane was given by de Vaucouleurs (1958).

Our material is too small, and is not precise enough, to make a detailed analysis that would have any objective weight, but again an idea of limits to possible periodicities with L_{SG} can be obtained from figure 8 where the H_i values from table 2, 3, and 4 are shown against L_{SG} for galaxies with $r_c \lessapprox 20$ Mpc.

In a similar diagram, de Vaucouleurs has restricted his sample to galaxies with supergalactic latitudes $B_{SG} \leq 30°$. Less severely, we consider $B_{SG} \leq 60°$ (where the projection onto the supergalactic plane remains greater than half of the effect) to be still acceptable. Only two galaxies of the sample in figure

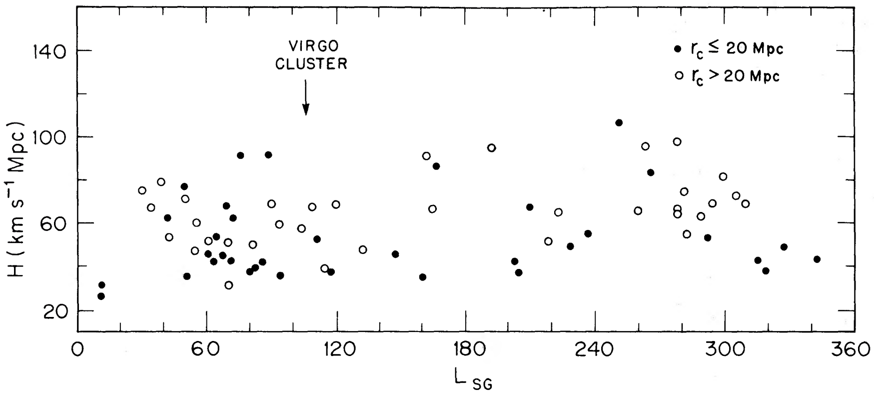

FIG. 8.—The Hubble rate for each galaxy in the restricted sample versus supergalactic longitude for $r_c \gtrless 20$ Mpc

8 have $B_{SG} > 60°$, and their inclusion or exclusion has a negligible effect on the results.

There is no obvious periodicity in our data. The large scatter shows that any that might be present is buried in the errors, and could only be discussed at a level less significant than $\sim 2\,\sigma$, even if a formal analysis were made. Hence, we believe that a perturbation cannot be established with the present material, although a judicious and arbitrary choice of the samples to be averaged might be made to give the appearance of some systematic periodicities.

For these reasons we have not made a formal solution, but have taken averages in various narrow longitude zones, centered on the Virgo cluster and its antidirection, and on those longitude zones where previous work (de Vaucouleurs 1958, 1966) indicated the largest amplitude for deviations from uniform flow. None of the deviations in our material are significant at the 3 σ level of the combined errors, and hence are considered not to be proved. The results are also consistent with a recent analysis by Bahyl' (1974), using a larger sample but from less restricted material.

Our appraisal of the present data is that no anisotropies have been detected, and that the local Hubble is as regular, linear, and isotropic as we can measure it. The accuracy of the mapping is about $\sigma(\Delta H/H) \simeq 10$ percent, which means that we have detected no unaccountable variations in the local Hubble rate (either with distance or with position in the sky) that are larger than $3\,\sigma \simeq 30$ percent. What small effects appear to remain are within the stated limits, and these are determined by the true errors and the bias of the present material. Our present inability to detect any perturbation may be consistent with a small ratio of gravitational potential energy to kinetic energy expansion, and hence to a small ($q_0 < 1/2$) value of the deceleration parameter (cf. Sandage *et al.* 1972; Zel'dovich 1974). But clearly the next goal is to greatly increase the sample size, and to reduce the errors and the biases so as to map the velocity field much more completely.

c) The Isotropy in the Two Rubin-Ford Regions for Nearby Galaxies

Rubin, Ford, and Rubin (1973) have presented evidence from *remote* Sc I galaxies that a significant anisotropy exists in the Hubble rate between two roughly opposite hemispherical regions of the sky. Further, they present supporting evidence from *nearby* Sc I and Sc I–II galaxies. Our material of the same type for remote Sc I galaxies is the subject of Paper VI of this series; the present material, which contains class Sc III galaxies not considered by Rubin *et al.*, can be used to discuss the nearby galaxies in the two Rubin-Ford regions to test the second part of their discussion.

We divide the galaxies in our unbiased sample into the Rubin-Ford regions I and II, defined by figure 1 of their paper. From the data in tables 2, 3, and 4 we obtain

$$\langle H \rangle_{\rm I} = 60.6 \pm 2.9(\sigma)\ \text{km s}^{-1}\ \text{Mpc}^{-1} \quad (13)$$

for 36 galaxies in region I, and

$$\langle H \rangle_{\rm II} = 55.1 \pm 3.6(\sigma)\ \text{km s}^{-1}\ \text{Mpc}^{-1} \quad (14)$$

for 28 galaxies in region II.

The two Hubble rates are the same to within 1 σ of their combined errors. Furthermore, the sense of the formal difference between equations (13) and (14) is opposite to that of Rubin and Ford who used *Reference Catalogue* data on magnitudes and velocities of nearby Sc I and Sc I–II galaxies alone. Their argument for believing that the *remote* Sc I sample does not suffer a bias of the type discussed in § IV was that these data for nearby Sc I, Sc I–II galaxies gave the same result. Because we cannot confirm this for our sample of the *nearby* galaxies, and because we believe that the *remote* data do contain a bias, the conclusion here again is that the entire velocity field is isotropic to within the accuracy we can measure it.

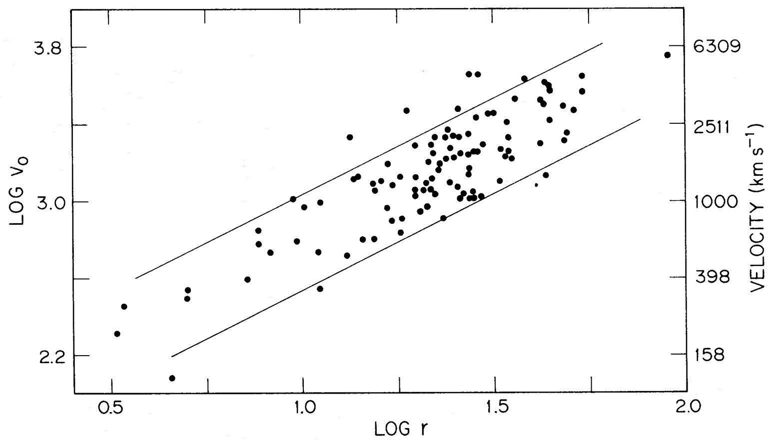

FIG. 9.—Velocity-distance relation of fig. 3 on a log-log scale to show that the scatter has the nature of symmetry in $\Delta \log r$ or $\Delta \log v_0$, and hence that the scatter is due to percentage errors $\Delta r/r$.

VI. NATURE OF THE SCATTER IN THE VELOCITY-DISTANCE DIAGRAM AND THE MEAN RANDOM VELOCITY FOR FIELD GALAXIES

Perhaps the most striking feature of figure 3 is the nature of the scatter. Most of the points are confined between two straight lines, and the scatter increases with increasing distance. This can be seen directly from figure 9, which is figure 3 plotted on a log-log scale. The two boundary lines are now parallel, showing that either $\sigma(\Delta \log r)$ or $\sigma(\Delta \log v)$, or a combination thereof, is constant with distance. As before, it follows that the predominant errors must be percentage errors, and therefore that most must be due to errors in distance. Is the scatter due entirely to errors in distance?

Residuals about the mean line of figure 9 (read as velocity differences $\Delta \log v_0$) for the unbiased sample ($n = 71$) give $\sigma(\Delta \log v_0) = \pm 0.139$. Because the velocity-distance relation is linear (slope of 5 in fig. 4, or unit slope in fig. 9), the residuals read as errors in distance alone are also distributed as $\sigma(\Delta \log r) = \pm 0.139$. Hence, if all the errors were in r, $\sigma(\Delta r/r) \equiv (2.303)(0.139) = 0.32$, which is only slightly larger than the value obtained from other considerations, therefore leaving very little of the scatter in figure 9 for velocity residuals by the following argument.

Most of the distances in tables 2, 3, and 4 are determined from luminosity classes. Hence most of the errors in distances are due to the dispersion in *absolute magnitude*. From a small sample we estimated in Paper IV that $\sigma(M) \simeq 0.4$ mag for Sc I galaxies. In Paper VI of this series, it will be shown that a biased sample of 61 *remote* Sc I galaxies gives $\sigma(M) \simeq 0.52$ mag. From other considerations, van den Bergh (1960) estimated $\sigma(M_{\mathrm{Sc\,I}}) \simeq 0.5$ mag.

But our nearby sample contains Sc II and Sc III galaxies as well, where the dispersion in M is greater than for Sc I alone. Hence, we take $\sigma(M) = 0.60$ mag as a lower limit; this leads to $\sigma(\Delta \log r) \geq 0.12$, or $\sigma(\Delta r/r) \geq 0.28$ for the distribution of errors in the luminosity distances.

The observed dispersion of $\sigma(\Delta \log r) = 0.139$ is compounded of the distance error $[\sigma_{\mathrm{true}}(\Delta \log r)]$ and any dispersion in velocity $[\sigma_{\mathrm{true}}(\Delta \log v_0)]$ such that $\{\sigma_T{}^2(\Delta \log r) + \sigma_T{}^2(\Delta \log v_0)\}^{1/2} = 0.139$. This gives an *upper limit* for the true velocity dispersion to be $\sigma_T(\Delta \log v_0) = 0.07$, or $\sigma(\Delta v_0/v_0) \leq 0.16$. But, since the true errors in v_0 cannot be of this *form* (i.e., cannot be proportional to v_0), we use the upper limit in $\sigma(\log v_0)$ here to estimate Δv_0 itself by an earlier method (Sandage 1972, § VI*a*) used for E galaxy clusters. Because the value $\sigma(\Delta v_0/v_0) \leq 0.16$ holds for all v_0 for which the parallel boundary lines apply to the scatter (fig. 6*a*), it holds for any v_0. The smallest v_0 where the scatter still has this form is $v_0 \simeq 300$ km s^{-1} (figs. 3, 6*a*, and 9). Hence it follows that $\sigma(\Delta v_0) \leq 50$ km s^{-1} is a generous limit for the mean random motion. The result is similar to an earlier conclusion by de Vaucouleurs (1958, appendix) from less restricted material.[7]

This is a remarkably small value, but we are forced to it by the nature of the scatter for the six nearest groups of galaxies (with $v_0 \leq 200$ km s^{-1}) in figures 1, 2, and 3. Clearly, if $\sigma(\Delta v_0)$ had been of the order of, say, 200 km s^{-1}, the nearby groups would have shown a much larger dispersion in these diagrams. The mean random motion is, then, smaller than we can measure. If it were measurable here, the lower boundary line in figures 4 and 9 would not be linear but would curve downward.

The final conclusion is then that the velocity field for nearby galaxies ($D \lessapprox 36$ Mpc, $v_0 \lessapprox 2000$ km s^{-1}) is not only as isotropic as it can presently be determined ($3\sigma[\Delta H/H] \simeq 30$ percent), but the flow is also as *quiet* as we can measure it. This is not to say that individual perturbations of perhaps a few hundred km s^{-1} might not occur, but they apparently do not

[7] It is clear that our value for the random motion applies to single field galaxies and to the mean velocity of groups—it does not apply to *individual members of bound groups* and certainly not to Virgo cluster members, which show a velocity dispersion of several hundred km s^{-1} due to virial motions.

occur in our present sample of galaxies with $v < 500$ km s^{-1}. (Such perturbations could not be detected by our methods for higher-velocity galaxies.)

We take this to mean that the best distances can be determined directly from the velocity-distance relation ($r = v_0/H, H = 55$) even for the nearest galaxies, and that the error in the distances for such galaxies will be less than $\sigma(\Delta r/r) \simeq \sigma(50/v_0)$ caused by the velocity dispersion itself, with the error decreasing with increasing velocity.

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