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AN ATLAS OF X-RAY–SELECTED QUASI-STELLAR OBJECTS

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ABSTRACT

We present coordinates, finding charts, photometry, and spectroscopy for 55 X-ray–selected quasi-stellar objects, most previously unreported. Our selection technique, the optical identification of X-ray sources observed serendipitously by the *Einstein Observatory*, preferentially discovers certain classes of objects interesting for further study. For example, the sample includes many QSOs projected near to bright galaxies (useful for probes of extended galaxian halos), pairs of QSOs with similar redshifts (candidates for membership in clusters/superclusters), and numerous low-redshift ($z < 0.5$) objects (well suited for imaging). We note certain peculiar or extreme objects, e.g., several very luminous ($\sim 10^{46}$ ergs s^{-1}) QSOs, a very high redshift X-ray–selected object ($z = 2.90$), and a high-luminosity ($M_V \sim -30$) object at moderate redshift ($z = 1.41$). The surprisingly weak dependence of the mean redshift of the sample on limiting magnitude suggests that efforts to identify optically very faint counterparts to serendipitous X-ray sources may yield chiefly intrinsically less luminous objects at $z < 1$.

Subject headings: galaxies: clustering — quasars — X-rays: sources

I. INTRODUCTION

Our program aimed at optical identification of X-ray sources discovered serendipitously by the *Einstein Observatory* has been described elsewhere (Chanan, Margon, and Downes 1981; Margon, Chanan, and Downes 1982), but these previous publications concerned themselves chiefly with the properties of X-ray–selected active galactic nuclei as a class, and gave little or no information on the individual objects. Our sample of objects has been enlarged since these publications, and many of the objects discovered are individually interesting in their own right. In this paper we present comprehensive information on each of the newly discovered QSOs, together with references to related work. We also make a few further comments on the properties of the ensemble.

The reader may find the details of the observing technique in the previous papers in the series. The majority of the X-ray positions are derived from the imaging proportional counter (IPC) aboard *Einstein* (Giacconi *et al.* 1979), prior to the postflight reprocessing of these data. These positions are therefore accurate to of order 1′, although our lengthy list of optical identifications now permits an empirical calibration of the entire procedure of optical identifications from IPC data; we address this issue in § IV. Spectra were obtained for all candidate objects within the X-ray position regions, to a limit of $B = 18.5$–19 (and occasionally fainter), until either a secure identification was discovered or all candidates were exhausted. The selection of candidates was performed without regard to color, as may be noted by the discovery of an (extremely red) faint carbon star during this program (Margon *et al.* 1984). Thus this technique has the potential of identifying red and non-UV excess active galactic nuclei, and such objects indeed appear in our list. This facet of X-ray selection has also been stressed by Stocke *et al.* (1983) and Gioia *et al.* (1984).

Approximately 100 X-ray fields meeting the criteria described by Chanan, Margon, and Downes (1981) were examined to obtain the 55 identifications discussed here. It is important to note that these criteria exclude spatially extended X-ray sources and also fields containing bright stars. The approximately 50% success rate for identification of new QSOs implied by our results is a lower limit to the actual QSO content of the survey, as our optical searches were not complete at faint magnitudes, and the large number of X-ray sources involved suggests that a few sources may be spurious or have particularly inaccurate positions which frustrated the optical identification effort. Our success rate is thus compatible with that of the other comparably extensive identification effort described by Gioia *et al.* (1984). The mean X-ray flux of the ~ 45 unidentified sources in our sample is slightly below that of the 55 identifications discussed here, as would be expected if the unidentified sources consist largely of a slightly

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TABLE 1

X-RAY–SELECTED QUASI-STELLAR OBJECTS

Name (1)	α_{1950} (2)	δ_{1950} (3)	l (4)	b (5)	$\Delta\alpha\cos\delta$ (6)	$\Delta\delta$ (7)	z (8)	V[a] (9)	$(B-V)$[a] (10)	$(U-B)$[a] (11)	M_V (12)	I_X (10^{-3} s^{-1}) (13)	log L_X (ergs s^{-1}) (14)	α_{ox} (15)	References (16)
0007−114	00h07m34s.3	−11°29′04″	89°34′	−71°21′	−69″	−39″	0.456	19.6	−0.1	...	−23.0	20	44.9	1.05	1FC
0015+162	00 15 56.7	+16 12 47	111 36	−45 39	...	...	0.553	18.2	0.0	...	−24.9	15[b]	44.9	1.32	2FC
0031−077	00 31 12.6	−07 42 26	110 06	−69 52	−24	+18	0.388	18.5	−0.4	...	−23.8	13	44.5	1.30	1FC, 3I
0031−076	00 31 45.0	−07 38 14	110 29	−69 49	+5	−17	0.291	17.9	−0.1	...	−23.6	33	44.6	1.23	4FC, 3I
0032−073	00 32 08.8	−07 22 50	110 57	−69 35	+21	−7	0.752	18.0	+0.1	...	−26.0	15	45.3	1.35	1FC
0037+061	00 37 42.2	+06 07 14	117 55	−56 22	−21	+25	0.063	17.03	+0.93	+0.12	−21.0	37	43.3	1.35	4FC, 3I, 5I
0044−209[c]	00 44 23.1	−20 59 52	113 25	−83 31	−11	−18	0.380	18.8	−0.2	...	−23.4	14	44.5	1.24	1FC
0100+020[d]	01 00 38.0	+02 05 05	128 54	−60 23	−29	+31	0.392	16.39	+0.42	−0.19	−25.8	21	44.7	1.54	6FC, 3I
0120+092	01 20 53.6	+09 16 13	136 00	−52 31	−24	−18	0.176	18.2	+0.5	...	−22.1	11	43.7	1.37	1FC, 3I
0121+034	01 21 58.1	+03 28 02	138 44	−58 08	−6	−21	0.336	18.5	−0.2	...	−23.4	10	44.2	1.34	1FC, 3I
0149−166	01 49 52.4	−16 39 29	178 48	−72 18	+21	+33	0.399	19.3	−0.1	...	−23.0	30	44.9	1.03	1FC
0214−033	02 14 57.3	−03 21 52	167 15	−58 24	−71	+28	0.323	16.8	−0.1	...	−25.0	16	44.4	1.52	1FC, 5I
0240+007[e]	02 40 03.9	+00 43 45	171 03	−51 14	−108	−27	0.569	16.52	+0.12	−0.62	−26.7	10	44.8	1.65	4FC, 3I
0302−223[f]	03 02 36.1	−22 23 34	211 05	−59 23	−24	−41	1.409	16.40	+0.03	−0.84	−29.4	19	46.1	1.55	4FC, 7FC
0318−196	03 18 05.5	−19 37 18	208 19	−55 05	+23	+17	0.104	14.86	+1.04	+0.86	−24.2	12	43.2	1.86	1FC, 3I
0335−350	03 35 25.3	−35 01 25	235 43	−53 53	+48	−46	0.321	19.2	+0.3	...	−22.5	35	44.7	1.02	1FC
0336−354	03 35 59.2	−35 23 30	236 21	−53 46	−65	+105	1.002	19.8	−0.2	...	−25.0	12	45.5	1.11	1FC
0350−280	03 50 34.2	−28 04 38	244 52	−50 10	+0	−64	0.170	18.2	+0.4	...	−22.0	21	43.9	1.26	1FC
0351+026	03 51 33.5	+02 40 33	186 03	−36 47	−12	+33	0.036	16.20	+1.09	−0.23	−20.5	100	43.2	1.31	4FC, 3I, 5I, 8I
0420+003	04 20 07.7	+00 23 22	193 19	−32 18	−57	−47	2.903	19.1	+0.3	...	−29.1	11	46.8	1.23	1FC
0721+690	07 21 15.0	+69 03 44	146 42	+28 19	−8	−15	0.111	16.8	−0.1	...	−22.4	59	44.0	1.30	1FC, 5I
0829+111	08 29 28.9	+11 06 34	214 20	+27 17	−16	−46	0.453	20.2	−1.5:	...	−22.4	18	44.8	0.98	1FC
0844+377	08 44 01.0	+37 43 54	185 02	+38 16	−38	+57	0.451	17.7	−0.5	...	−24.9	20	44.8	1.35	4FC, 3I, 5I
0845+378	08 45 07.1	+37 51 32	184 54	+38 30	+24	+36	0.307	17.9	−0.3	...	−23.7	18	44.4	1.33	4FC, 5I
0906−091	09 06 24.9	−09 06 39	238 58	+24 57	...	...	0.129	18.3	−0.7	...	−21.3	4[b]	42.9	1.52	1FC, 5I
0907−091	09 07 09.8	−09 06 05	239 05	+25 06	...	...	0.253	18.0	+0.1	...	−23.2	4[b]	43.6	1.57	1FC
0911+402	09 11 34.9	+40 15 34	182 14	+43 48	+9	+24	0.323	19.5	−0.1	...	−22.3	20	44.5	1.07	1FC
0919+515	09 19 19.6	+51 33 30	166 24	+44 12	−18	−7	0.161	17.9	−0.3	...	−22.2	41	44.2	1.20	4FC
0955+259	09 55 20.6	+25 55 23	204 57	+51 22	+30	+75	0.194	17.9	−0.3	...	−22.7	43	44.3	1.19	1FC
1059+730	10 59 08.4	+73 02 54	133 26	+42 03	−38	+12	0.089	16.40	+0.69	−0.28	−22.3	19	43.3	1.55	4FC, 3I, 5I

TABLE 1—*Continued*

Name (1)	α_{1950} (2)	δ_{1950} (3)	l (4)	b (5)	$\Delta\alpha\cos\delta$ (6)	$\Delta\delta$ (7)	z (8)	V[a] (9)	$(B-V)$[a] (10)	$(U-B)$[a] (11)	M_V (12)	I_X (10^{-3} s^{-1}) (13)	log L_X (ergs s^{-1}) (14)	α_{ox} (15)	References (16)
1216+695	12 16 57.3	+69 31 31	127 09	+47 37	−50	−17	0.627	17.0	−0.7	...	−26.5	21	45.2	1.45	1FC
1219+047	12 19 04.6	+04 47 13	284 11	+66 17	−53	+10	0.094	16.8	−0.1	...	−22.1	34	43.6	1.40	1FC
1220+160	12 20 58.6	+16 01 41	271 51	+76 54	...	...	0.081	15.9	+0.8	...	−22.6	125[b]	44.0	1.11	1FC
1225+317	12 25 04.8	+31 45 37	171 34	+83 13	−31	+44	0.083	16.0	+0.3	...	−22.6	10:	42.9	1.73	1FC
1339+053	13 39 35.3	+05 20 12	333 53	+64 52	−3	+23	0.266	16.8	−0.1	...	−24.5	51	44.7	1.33	4FC
1401+098	14 01 43.2	+09 51 59	350 48	+65 29	+7	−25	0.441	16.2	−0.1	...	−26.3	75	45.4	1.36	9FC
1403+546	14 03 29.7	+54 39 28	101 37	+59 33	+2	+3	0.082	16.8	−0.1	...	−21.7	32	43.4	1.41	1FC, 3I
1519+279	15 19 23.8	+27 55 11	42 51	+56 49	−62	+0	0.230	18.2	−1.0	...	−22.7	20	44.2	1.27	4FC, 3I
1519−065	15 19 47.4	−06 33 53	355 40	+40 11	−16	+0	0.084	14.9	+0.3	...	−23.7	67	43.8	1.57	1FC
1526+286[g]	15 26 33.4	+28 35 52	44 26	+55 21	−20	+12	0.450	16.39	+0.05	−0.60	−26.2	49	45.2	1.40	4FC, 10FC, 3I
1557+272	15 57 18.2	+27 12 04	44 02	+48 26	+71	−1	0.065	16.33	+0.91	+0.07	−21.7	22	43.1	1.55	4FC, 3I, 5I
1640+396	16 40 06.1	+39 40 48	63 08	+41 10	+26	+21	0.540	18.3	−0.6	...	−24.8	30	45.2	1.19	1FC, 3I
1640+401	16 40 13.9	+40 06 16	63 42	+41 10	−9	−27	0.986	17.1	−0.4	...	−27.6	11	45.4	1.54	1FC, 3I
1641.7+3998	16 41 46.0	+39 58 52	63 34	+40 52	+2	+3	0.704	16.8	−0.1	...	−27.0	14	45.2	1.54	1FC
1641.9+3998	16 41 54.1	+39 59 17	63 34	+40 50	−3	+13	0.594	19.3	−0.6	...	−24.0	13	44.9	1.17	4FC, 11FC, 3I, 5I
1701+610	17 01 32.4	+61 02 52	90 26	+36 39	+9	+60	0.164	17.0	+0.4	...	−23.1	14	43.7	1.51	4FC, 3I
1704+6076	17 04 43.0	+60 45 59	90 01	+36 19	...	...	0.080	17.73	+1.19	+0.47	−20.8	7[b]	42.7	1.52	4FC, 3I, 5I
1726+499	17 26 01.6	+49 55 29	76 39	+33 41	−21	−24	0.815	19.3	−0.6	...	−24.9	12	45.3	1.19	4FC, 3I
1847+335	18 47 24.8	+33 30 11	63 19	+15 00	−27	+33	0.509	17.7	−0.5	...	−25.2	36	45.2	1.25	4FC, 3I
2041−310	20 41 41.9	−31 04 24	13 09	−36 28	+9	+6	0.434	18.0	+0.0	...	−24.5	13	44.6	1.37	1FC
2141+040	21 41 51.5	+04 02 40	60 24	−35 01	−23	+56	0.463	17.1	−0.4	...	−25.6	22	44.9	1.42	1FC
2215−037	22 15 11.7	−03 47 50	58 51	−46 24	−26	+6	0.242	17.20	+0.05	−0.70	−23.9	41	44.5	1.30	4FC, 3I, 5I
2216−043	22 16 48.8	−04 18 52	58 37	−47 02	+42	−48	0.243	18.5	−0.4	...	−22.6	15	44.1	1.27	1FC, 3I
2344+184	23 44 53.3	+18 28 18	102 31	−41 34	+56	+26	0.138	15.9	+1.7	...	−23.8	13	43.5	1.69	1FC, 3I
2355−329	23 55 18.0	−32 54 59	4 24	−77 06	+21	−58	0.071	18.2	+0.5	...	−20.0	25	43.2	1.23	1FC

[a] Magnitudes and colors with two decimal places are photoelectric; remainder are photographic.
[b] HRI observation converted to equivalent IPC count rate.
[c] PHL 6625.
[d] PHL 959.
[e] PHL 1443.
[f] Ton-S 317.
[g] Ton 236.

REFERENCES.—FC = finding chart; I = imaging data. (1) This paper. (2) Koo 1981. (3) Malkan, Margon, and Chanan 1984. (4) Chanan, Margon, and Downes 1981. (5) Hutchings, Crampton, and Campbell 1984; Hutchings *et al.* 1984. (6) MacAlpine and Lewis 1978. (7) Chavira 1958. (8) Bothun *et al.* 1982*a*, *b*. (9) Kriss and Canizares 1982. (10) Iriarte and Chavira 1957. (11) Margon, Chanan, and Downes 1981.

fainter population of objects fundamentally similar to the identified group (and sharing a similar distribution of optical to X-ray flux ratios), although this effect appears in our data with only marginal significance.

The X-ray positional uncertainty of most of the sources implies that the validity of the identification of the X-ray source with the newly discovered QSO must rest on probabilistic arguments, as well as the expected ratio of X-ray to optical flux as defined by previous work. These arguments have been discussed in our previous papers. It seems likely that only one or two of the objects discussed here are misidentifications of the X-ray sources (but newly discovered quasars nonetheless), and candidate cases have been explicitly noted. A minority of the QSOs discussed here have high spatial resolution (~ 5″) X-ray data obtained with the *Einstein* high resolution imager (HRI), and in these cases the X-ray identification is virtually certain.

The spectroscopic observations were obtained with a wide variety of facilities, but all of the data have spectral resolution in the 8–20 Å range. The majority of the data were obtained with the Cerro Tololo 4 m telescope and SIT Vidicon detector, the Kitt Peak 2.1 m and intensified image dissector scanner, and the Lick 3 m Shane reflector with the image-tube scanner; a minority of the observations were made with the Hale 5 m reflector and SIT Vidicon, the Multiple Mirror Telescope (MMT) and Reticon, and the Mount Lemmon 1.5 m with image-tube scanner. Photoelectric photometry for a subset of the objects was obtained chiefly with the Kitt Peak 2.1 m with computer photometer and the CTIO 1.5 m telescope; a few objects were also observed with the KPNO 1.3 m reflector. For certain objects lacking photometry, we have uncalibrated *U* band photographic plates obtained as an auxiliary part of the optical identification process with the CTIO 1 m reflector and image-tube camera or with the Lick Crossley reflector and direct camera; these data are useful for a qualitative determination of a UV excess or lack thereof for objects in the sample, and are mentioned where applicable. A subset of the sample also has infrared photometry from the Hale 5 m available (Neugebauer *et al.* 1982) and digital imagery with the Palomar 1.5 m and SIT Vidicon (Malkan, Margon, and Chanan 1984); these data will not be further discussed here. The majority of the sample has also been observed at 6 cm with the VLA, and these results are reported elsewhere (Helfand *et al.* 1982); objects with positive flux detections are also noted in § III.

II. THE CATALOG

Data for each of the newly discovered QSOs are given in Table 1. Column (1) lists the name of each object, employing the IAU-recommended nomenclature, where the lowest-order digit is the truncated tenths-degree of declination. In several cases, literature searches revealed that the X-ray–selected object had been previously cataloged, usually in a color-selected survey, but without knowledge of the QSO nature of the object. In these cases we also provide the earlier nomenclature. For the sake of completeness we note that a variety of X-ray–selected QSO lists published by other workers have not noted such coincidences; we list such cases known to us in Table 2, as these objects are valuable for understanding the degree of uniqueness of X-ray selection, as well as for properly acknowledging previous nomenclature priority.

Columns (2) and (3) of Table 1 provide the right ascension and declination of the objects, for the equinox of 1950. The majority of these positions were measured from prints of the Palomar Observatory Sky Survey, using 5–10 nearby astrometric reference stars, and should not be considered more accurate than $\pm 5''$ in each coordinate. A minority of the astrometric data are derived from glass copies of the plates using Grant-type engines and are of substantially greater accuracy. The Galactic longitude and latitude of the objects are given in columns (4) and (5). The positional data are completed by noting the difference between the optical position of the QSO and that of the X-ray source (in the sense QSO − X-ray source) in each coordinate, in columns (6) and (7), for the sources with IPC positions. The X-ray positions

TABLE 2

PUBLISHED "X-RAY–SELECTED" QSOS REPRESENTING REDISCOVERIES OF PREVIOUSLY CATALOGED OBJECTS

X-Ray Name	Reference	Existing Name	Reference
0150−102	Reichert *et al.* 1982	PHL 1220	Haro and Luyten 1962
1304.1+3417	Kriss and Canizares 1982	AB 125	Braccesi, Formiggini, and Gandolfi 1970
1352.2+1820	Kriss and Canizares 1982	PB 4142	Berger and Fringant 1977
1352.5+1828	Kriss and Canizares 1982	PB 4145	Berger and Fringant 1977
1E 1533.5+1440......	Stocke *et al.* 1983	ZWG 107.010	Zwicky and Herzog 1963
1806+456	Reichert *et al.* 1982	LB 1086	Luyten and Miller 1968
1E 2348.6+1956......	Gioia *et al.* 1984	ZWG 455.055	Zwicky, Karpowicz, and Kowal 1968
2352+073	Reichert *et al.* 1982	PHL 585	Haro and Luyten 1962
		PB 5595	Berger and Fringant 1980

are derived from automatic source-location algorithms of the standard *Einstein Observatory* data reduction software.

The galactocentric redshift of each QSO is provided in column (8). All but a handful of objects have more than one emission line detected in their spectra, implying that these redshifts should be accurate to ± 0.001. The remaining objects are discussed individually in § III, but they generally still have redshift estimates regarded as secure, because of the presence of additional features in the spectrum (e.g., the Fe II emission complex near Mg II $\lambda 2800$) or the absence of expected strong emission lines for alternative candidate identifications of the single detected line.

The visible photometric data are given in columns (9)–(11). For the objects without photoelectric photometry (~ 80% of the sample), the magnitudes are derived either from our spectrophotometry or from image diameter measurements made from the Sky Survey prints with a 50× magnifier, using the calibrations and color equation of King and Raff (1977); experience shows such estimates are accurate to ± 0.3 and ± 0.5 mag, respectively, in the worst cases. The inferred V magnitudes are used to provide absolute magnitude estimates in column (12), assuming $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0$, which are adopted throughout.

X-ray characteristics of the sample appear in columns (13)–(15). The background-subtracted X-ray count rate in the IPC is given in column (13); an approximate conversion to flux is available through noting that 1 IPC count s^{-1} ~ 2.8×10^{-11} ergs cm^{-2} s^{-1}, although there is a slight spectral dependence to this multiplier, and we have no spectral information on these weak sources. This conversion and the measured redshifts have been used to tabulate X-ray luminosities (0.5–4.5 keV) in column (14). In column (15) we provide α_{ox}, a slope parameter for a line connecting the optical and X-ray fluxes, as defined by Tananbaum *et al.* (1979). An additional, approximate relationship which we have found quite helpful in analysis of *Einstein* IPC data is

$$\alpha_{ox} = (11.89 - 0.4V - \log I_X)/2.606,$$

where I_X is the background-subtracted IPC count rate in counts per 10^3 s, and a typical optical spectral slope appropriate for QSOs has been assumed to extrapolate the more commonly measured V flux to 2500 Å in the rest frame, where α_{ox} is defined. A small redshift-dependent term in this latter extrapolation has been neglected (cf. Schmidt 1968).

In column (16) we provide references for finding charts for each object, as well as citations to papers where high-resolution imaging is reported. Figure 1 (Plate 1) provides finding charts for those objects with no previously published charts, or for those not easily available elsewhere.

III. COMMENTS ON INDIVIDUAL OBJECTS

0007−114.—Only one discrete emission line (4078 Å) visible in 3600–6700 Å range; large UV excess on CTIO 1 m plate.

0015+162.—HRI X-ray data from White, Silk, and Henry (1981); [O III] weaker than Hβ; near rich cluster 0016+16 (Koo 1981) of similar redshift, and probably a cluster or supercluster member (Margon, Downes, and Spinrad 1983); upper limit on radio flux by Birkinshaw, Gull, and Moffet (1981) applicable to this object.

0031−077.—Near our QSO 0031−076, but with different z.

0031−076.—Identical with PB 8357 (Berger and Fringant 1984); [O III] weak, or possibly Fe II (42) emission; near our QSO 0031−077, but with different z; 3′ from galaxy MCG −01-02-033; inaccurate right ascension in Chanan, Margon, and Downes (1981).

0032−073.—Identical with PB 8364 (Berger and Fringant 1984); only one discrete emission line (4905 Å) visible in 3800–7600 Å range, but identification as Mg II secure because of Fe II emissions just blue and red of 2800 Å (see Grandi and Phillips 1980).

0037+061.—[N II], [S II] emission visible; photoelectric $(V-R) = 0.80$; identical with Abell 76 No. 3 (Dressler 1980), although not obviously a cluster member; the only cluster galaxy with a published redshift is IC 1565, 24′ distant, with $z = 0.038$ (Peterson 1970); H I limit and additional optical spectrum by Bothun *et al.* (1984); 18′ from QSO 0038+059 (= MCS 059, MacAlpine, Smith, and Lewis 1977), which is of comparable apparent magnitude.

0044−209.—Identical with PHL 6625 (Haro and Luyten 1962); only one discrete emission line (3865 Å) visible in 3600–6700 Å range; 4′ from NGC 247, $z = 0.001$.

0100+020.—Identical with PHL 959 (Haro and Luyten 1962) and UM (= MCS) 301 (MacAlpine and Lewis 1978; MacAlpine and Feldman 1982); Fe II UV emission discussed by Grandi (1981); photometric variability detected by Netzer and Sheffer (1983).

0120+092.—He I $\lambda\lambda 5876$, 6678 emission visible, possible [N II] $\lambda 6584$; 6′ from NGC 509; 9′ from UGC 946 = ZWG 411.046.

0121+034.—Hβ very broad (13,000 km s^{-1} in the rest frame); [O III] weak [Fe II (42) emission?]; 4′ from NGC 520 = VV 231 = Arp 157, $z = 0.007$; independently color-selected by Arp and Duhalde (1985); despite blue color and appropriate position and magnitude, not in PB list of Berger and Fringant (1980).

0149−166.—22′ from NGC 725; several faint galaxies within 2′.

0214−033.—Identical with PB 9130 (Berger and Fringant 1984); SW component of close pair; [O III] absent; strong Fe II (37, 38, 42); CTIO 1 m plate shows no obvious UV excess; spectrum of companion 10″ NE shows normal K star.

0240+007.—Identical with PHL 1443 (Haro and Luyten 1962) and PB 6856 (Berger and Fringant 1980); Hβ mutilated by telluric A band.

0302−223.—Identical with Ton-S 317 (Chavira 1958), but distinct from and not to be confused with Ton 317 (Iriarte and Chavira 1957); Mg II $\lambda 2800$, C III] $\lambda 1909$ very broad (15,000 km s^{-1} in the rest frame), but Mg II has a sharp emission core superposed; redshift quoted in Chanan, Margon, and Downes (1981) inaccurate due to typographical error, and this error has been propagated in the catalog of Véron-Cetty and Véron (1984); our photoelectric photometry of 1980 September and that by Malkan (1983) 1 year later shows the object ~1.5 mag fainter than given by Chavira (1958); genuine variability likely as our respective photometry agrees well for the other object in common (1526+286); the Ton magnitude implies $M \sim -31$,

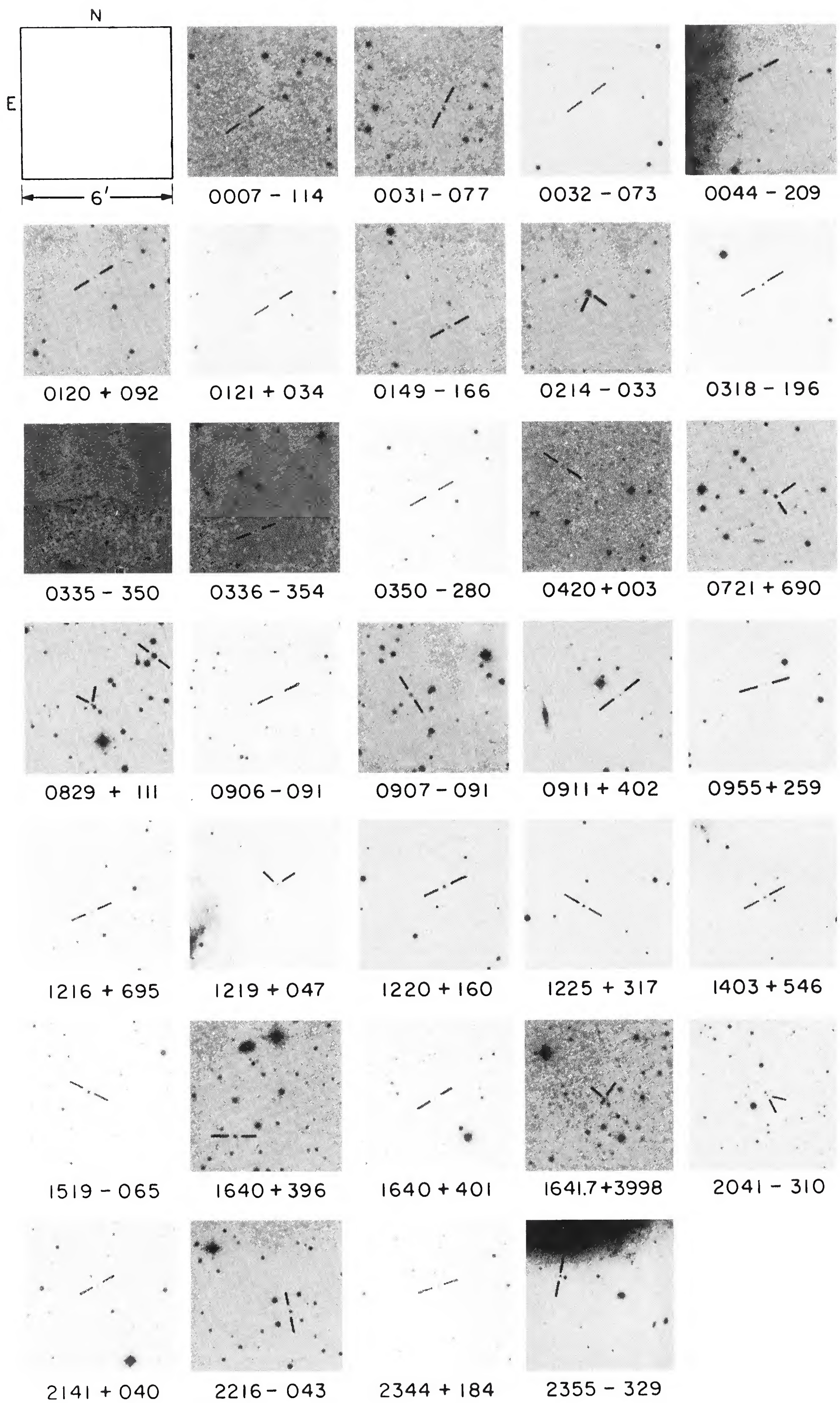

FIG. 1.—Finding charts for newly discovered X-ray–selected QSOs. All fields except for 0335−350, 0336−354, and 2355−329 are reproduced from the Palomar Observatory Sky Survey prints (© 1960, National Geographic Society–Palomar Sky Survey; reproduced by permission of the California Institute of Technology); the remaining three fields are from the "J" plate of the SERC Southern Sky Survey. All of the Palomar charts are from the E print, except for the following fields, where the object is easily visible only on the O print: 0031−077, 0044−209, 0120+092, 0149−166, 0214−033, 0420+003, 0721+690, 0906−091, 0907−091, 1640+396, 1640+401, and 1641.7+3998. The second object flagged on the chart for 0829+111 is the dMe star discussed in § III of the text.

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comparable to the most luminous known QSOs, but at much lower z; *IUE* spectrum LWR 10908 (1981 June) described by Malkan (1983); probably not the unidentified X-ray source 4U 0303−22 (Forman *et al.* 1978) despite good positional agreement, because of discrepancy of factor of 100 in reported flux; however, no other *Einstein* X-ray sources within 30′.

0318−196.—[O II], [S II] emission visible; absorptions due to Mg b, G band, and Ca II H and K visible; 10′ from NGC 1300, $z = 0.005$ (our spectrum shows strong Hα emission); *IUE* spectrum LWR 13498 shows Mg II λ2800 emission, rest frame EW = 70 Å; in late 1982, object 1 mag fainter than 1980 photoelectric photometry in the table; further spectra published by Bothun, Margon, and Balick (1984), who also report a weak radio detection at 1415 MHz (3 mJy).

0335−350.—Only one discrete emission line (3700 Å) visible in 3600–6700 Å range; large UV excess on CTIO 1 m plate.

0336−354.—[O II] λ2470 emission; large UV excess on CTIO 1 m plate; 15′ from Fornax Cluster galaxy NGC 1399, $z = 0.005$. Second serendipitous X-ray source 4′ S, 1.6 times stronger; three spectra show normal stars; no suggested identification. Third serendipitous X-ray source 8.5′ N, same strength as QSO; CTIO 1 m plate shows no obvious UV excess or extended candidates.

0350−280.—[Ne V] λ3426, [O II] λ3727, [Ne III] λ3869 emission strong; Fe II (42, 37, 38) present but [O III] also strong; large UV excess on CTIO 1 m plate.

0351+026.—See Bothun *et al.* (1982*a*, *b*); Hutchings, Campbell, and Crampton (1982); Balick and Heckman (1983); Heckman *et al.* (1984).

0420+003.—Largest z in our survey, and the most distant X-ray–selected QSO of which we are aware; equivalent width of Lyα is 90 Å in rest frame; continuum drops by a factor of 2 blueward of Lyα (multiple absorptions?); possible Lyman limit absorption; C IV has stronger blue wing similar to objects observed by Young, Sargent, and Boksenberg (1982); detected by VLA at 6 cm (35 mJy) (Helfand *et al.* 1982).

0721+690.—20′ from NGC 2366, $z = 0.0004$.

0829+111.—NE component of close pair; strong [O II] λ3727 emission, although close to night-sky λ5461; at this faint magnitude, the probability of a chance coincidence of the QSO with the X-ray source becomes a few percent; assuming the identification is correct, this is the most X-ray overluminous object in our sample ($L_X/L_{\rm opt} = 4$) and is comparable to the most extreme QSOs previously reported, 3C 279 and 3C 446 (Zamorani *et al.* 1981). An alternate candidate for the X-ray source is an anonymous $R \sim 13$ dMe star located 3′ NW of the QSO at $\alpha(1950) = 08^{\rm h}29^{\rm m}18^{\rm s}$, $\delta(1950) = +11°08'29''$, and also marked on Figure 1; our spectrum shows strong Balmer emission; this identification would imply $\alpha_{ox} = 2.2$, $(L_X/L_{\rm opt}) = 3 \times 10^{-3}$, near the extreme range for random field M stars (Helfand and Caillault 1982), but within the range of the most X-ray luminous such objects noted by Vaiana *et al.* (1981).

0844+377.—At 20 Å spectral resolution and moderate signal-to-noise ratio, Hβ, Hγ, and Hδ have anomalous profiles, possibly self-reversed, similar to but more extreme than the description of OX 169 by Smith (1980; see also Gaskell 1981); Mg II profile is normal; possibly weak [O II] λ3727 emission.

0845+378.—[O III] absent, strong Fe II (37, 38, 42) emission; see also Balick and Heckman (1983); additional serendipitous source 12′ E with same strength; we have one spectrum, no identification.

0906−091.—HRI X-ray position.

0907−091.—HRI X-ray position.

0911+402.—Hγ very strong; Fe II (37, 38) emission, but [O III] also strong; 8′ from NGC 2782 = Arp 215, $z = 0.008$; 3′ from MCG +07-19-041 = UGC 4872.

0919+515.—Balmer emission consists of narrow cores displaced slightly to red on broad wings, although Hα mutilated by telluric A band; [O III] weak or absent; strong Fe II (37, 38, 42) emission; 23′ from NGC 2841, $z = 0.002$; spectrum of companion 15″ NE shows normal G star.

0955+259.—Spectrum taken at MMT in collaboration with G. Bothun; [O III] weaker than Hβ; near Zwicky Cluster ZC 0955.3+2602.

1059+730.—[N II] emission strong; slightly extended image on POSS; POSS *O* print has two faint defects just north; our photoelectric photometry considerably fainter than POSS estimate by Chanan, Margon, and Downes (1981), but confirmed by Malkan, Margon, and Chanan (1984); see also Balick and Heckman (1983) and Kriss (1985).

1216+695.—Only one discrete emission line (4554 Å) visible in 3600–7000 Å range; z uncertain (± 0.01) because of data-processing problem; 20′ from NGC 4236, $z = 0.0001$.

1219+047.—Forbidden lines of [O II], [O III], [Ne III] λ3869, and [Ne V] λ3426 strong, while Balmer lines ($\beta, \gamma, \delta, \ldots$) not detected, although spectrum somewhat noisy there; unidentified emission line at 5842 Å (5340 Å in rest frame), strength comparable to λ4959 line; 5′ from M61 = NGC 4303, $z = 0.005$; further spectra published by Bothun, Margon, and Balick (1984).

1220+160.—HRI position. One very strong (84 Å EW in rest frame) emission line at 7095 Å and little else securely detected; however, suggested redshift, which identified this line as Hα, is almost certainly correct, as alternate identifications imply other emission lines which are not seen; at this z, Hβ is predicted at 5235 Å, and a weak noisy feature indeed appears in our spectrum there, but an unusually large decrement of ~ 11 is implied; 10′ from M100.

1225+317.—Statistical significance of X-ray source weak, but surface density of objects this bright is sufficiently small that the source and the identification are probably valid; narrow emission lines; Hα and [N II] $\lambda\lambda$6548, 6584 clearly resolved at 10 Å spectral resolution; very large Balmer decrement; probable stellar absorption features; if the identification is correct, the X-ray luminosity very substantially exceeds the mean of the narrow emission-line objects reported by Kriss, Canizares, and Ricker (1980); not to be confused with the very luminous, $z = 2.2$ QSO B2 1225+317 (Ulrich 1976), located 11′ distant.

1339+053.—Hα very strong; [O III] absent, strong Fe II (37, 38, 42) emission; faint blue galaxy 20″ S.

1401+098.—Near Zwicky Cluster ZC 1400.4+0940; 7′ from NGC 5438; X-ray data kindly provided by E. Böhm-Vitense; independently discovered on separate X-ray exposure by Kriss and Canizares (1982); detected by VLA at 6 cm (25 mJy) (Helfand *et al.* 1982).

1403+546.—Hα profile anomalous, possibly significant [N II]; Fe II (42) emission; [O III] absent; Ca II H and K, Mg *b*, and G band absorption; 18′ from M101 = NGC 5457, $z = 0.001$; 4′ from NGC 5477 = DDO 186, dwarf galaxy (van den Bergh 1966), $z = 0.001$.

1519+279.—Hα strong; λ5007 very weak.

1519−065.—Slightly extended image on POSS, but no stellar absorption lines in a well-exposed spectrum; Hα very strong (EW = 255 Å in rest frame), [O III] weak.

1526+286.—Identical with Ton 236 (Iriarte and Chavira 1957); photoelectric $(V-R) = 0.16$.

1557+272.—Strong [N II] emission, narrow Hα and Hβ; photoelectric $(V-R) = 0.81$; H I limit by Bothun *et al.* (1984).

1640+396.—In vicinity of 3C 345, but with different *z*; 3′ from galaxy MCG +07−34−136 (our spectrum shows strong Hα emission, $z = 0.034$); detected by VLA at 6 cm (31 mJy) (Helfand *et al.* 1982). This and three other of our objects in this field are also discussed by Crampton and Rensing (1982).

1640+401.—Strong Fe II λ2750 emission; in vicinity of 3C 345, but with different *z*; 2′ from galaxy MCG +070-34-137 (our spectrum gives $z = 0.034$); detected by VLA at 6 cm (6 mJy) (Helfand *et al.* 1982).

1641.7+3998.—NW component of close pair; large UV excess on Lick Crossley 0.9 m plate; near our QSO 1641.9+3998 and 3C 345, but with different *z*; spectrum of companion 10″ SE is featureless but noisy, probably not a QSO; 5′ from NGC 6212.

1641.9+3998.—In cluster/supercluster with 3C 345 (see Margon, Chanan, and Downes 1981); spectrum of companion 20″ SW shows normal star.

1701+610.—Lick 0.9 m refractor image-tube plates (1979 May 31) show the object substantially fainter (> 1 mag) than the POSS; HRI position (which agrees with optical object to less than 3″) as well as IPC position; galaxy VII Zw 674 is 1′ S but is unrelated to X-ray source, contrary to initially suggested identification by Ku (1979) and Ku *et al.* (1979); spectrum and photoelectric photometry (10″ aperture) of VII Zw 674 show normal absorption, $z = 0.065$, $V = 16.21$, $(B-V) = 1.24$, $(U-B) = 0.42$, and $(V-R) = 0.84$.

1704+6076.—In addition to strong Balmer, [O III], and [N II] emission, redshifted absorption of Na D, Ca II H and K, and λ4000 blanketing break (Mg *b* in night-sky λ5577); photoelectric $(V-R) = 0.90$; extended image on POSS *E* print; both HRI and IPC observations; statistical significance of X-ray source weak; contrary to the "note added in proof" of Feigelson, Maccacaro, and Zamorani (1982), this object is *not* a misidentification of the X-ray source; a second HRI X-ray source (1704+6077) is 90″ E, coinciding with a faint red object with featureless spectrum (BL Lac object?) (Chanan *et al.* 1982); 7′ from Mrk 892 (16 mag, presumably foreground); Hale 5 m prime-focus CCD image shows rich faint cluster of galaxies centered 3′ E; 5′ from bright QSO 3C 351, $z = 0.371$.

1726+499.—Only one discrete emission line (5080 Å) visible in 3800–7700 Å range, but identification of Mg II secure due to broad Fe II emission just to the blue of λ2800.

1847+335.—Strong Fe II (42) emission, but [O III] also strong; crowded field at low latitude ($b = 15°$), but object still blue on POSS *O* print.

2041−310.—Strong [Ne V] λ3426, [O II] λ3727, and [Ne III] λ3869; large UV excess on CTIO 1 m plate.

2141+040.—X-ray data kindly provided by J. P. Henry; 4′ from X-ray–selected QSO 1E 2141.6+0359; $z = 0.410$ (Maccacaro *et al.* 1982; Stocke *et al.* 1983); the latter object is also listed by Reichert *et al.* (1982), but with incorrect declination and somewhat different redshift.

2215−037.—Possible Fe II (42, 37, 38) emission; photoelectric $(V-R) = 0.52$; 15′ from QSO PKS 2216−038 = 4C −03.79, $z = 0.901$; near our QSO 2216−043, with similar *z* (cluster/supercluster with two QSOs?); faint galaxy 15″ N, apparently foreground (Heckman *et al.* 1984).

2216−043.—[N II] emission strong; near our QSO 2215−037, with similar *z* (cluster/supercluster with two QSOs?).

2344+184.—Hα partially mutilated by telluric A band, but [N II] probably strong; object noticeably red but no obvious stellar absorption features.

2355−329.—Very strong [O II] λ3727 (EW = 55 Å in rest frame); large UV excess on CTIO 1 m plate; 3′ from NGC 7793, $z = 0.001$.

IV. SOME ENSEMBLE PROPERTIES

For the 50 objects with IPC positions, we have available a valuable empirical estimate of the total positional uncertainties of IPC observations of weak, noncentral X-ray sources. As might be expected, there is no evidence for systematic bias in either celestial coordinate: the mean difference in right ascension between the X-ray and optical positions is 28″.2, and in declination, 28″.5. The distribution of the X-ray/optical position differences for each source is shown in Figure 2. The

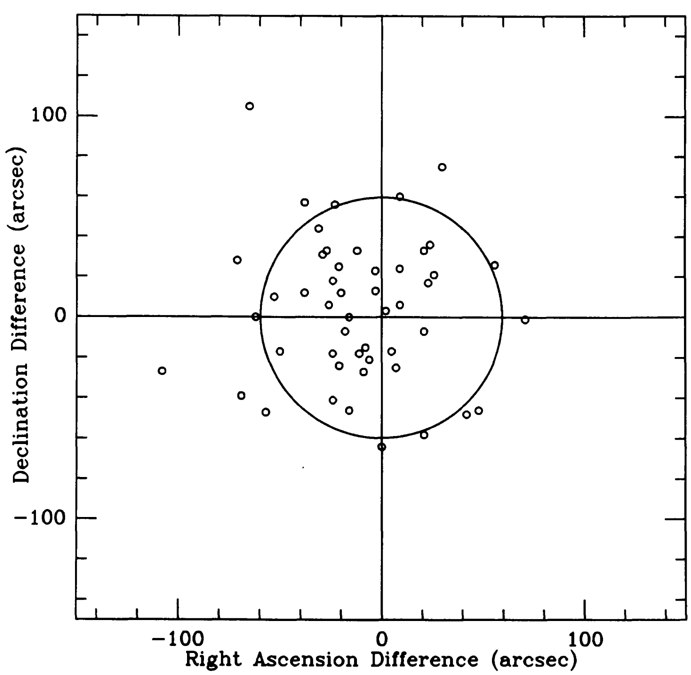

FIG. 2.—The difference between the optical position and the corresponding X-ray coordinates for each of 50 QSOs in the sample discovered from *Einstein* IPC data. For reference, the large central circle has a radius of 1′ and encloses 34 of the 50 objects.

mean position difference is 44″ ± 3″, and 68% of the 50 QSOs lie within 1′ of the X-ray position. We ignore here the uncertainties in the optical position measurements, which are very small compared with those of the X-ray data.

The mean physical properties of the ensemble are quite close to those we have previously reported and those of other published X-ray–selected QSO samples. The 55 objects have a mean redshift $\langle z \rangle = 0.40 \pm 0.06$, absolute visual magnitude $\langle M_V \rangle = -23.8 \pm 0.3$, and logarithm of the X-ray luminosity (in ergs s^{-1}) $\langle \log L_X \rangle = 44.4 \pm 0.1$. The arithmetic mean α_{ox} of the sample is 1.26 ± 0.03, again in excellent agreement with previous estimates.

Margon, Chanan, and Downes (1982) were the first to stress that for a given limiting magnitude, X-ray selection (at least at the flux levels attainable with the IPC) yields QSOs of significantly lower optical luminosity than other selection techniques. Those authors commented that some mechanism may act to suppress the X-ray emission from "typical" (i.e., luminous, high redshift) objects. Zamorani (1982) has suggested that this mechanism is a strong dependence of α_{ox} on L_{opt}, a functional dependence appearing in the analyses of Zamorani *et al.* (1981) and Avni and Tananbaum (1982). This dependence has also been noted by Reichert *et al.* (1982), but their analysis has been criticized by Avni and Tananbaum (1982).

This dependence appears weakly if at all in our current sample; in any case the incompleteness of our survey requires a far more detailed treatment than appropriate here to set new limits on this issue. Although physical significance has already been suggested for this correlation (e.g., Shull 1983; Tucker 1983), Chanan (1983) has pointed out an interpretation that is strictly mathematical rather than physical. In a simulation where α_{ox} is controlled to have no dependence on L_{opt}, a correlation identical with the "observed" one discussed above appears strongly, simply because of the large intrinsic scatter in both luminosities and luminosity ratios. This will hold true even in surveys that have 100% complete optical identification rates, and also proper treatment of X-ray upper limits. Until additional evidence is forthcoming that the observed correlations are indeed physical rather than mathematical, there seems little motivation for further consideration of this topic.

The small mean redshift of the sample has other implications, concerning future programs of optical identification of serendipitous X-ray sources. In Figure 3 we display the dependence of mean redshift on the magnitude cutoff of our sample. Once one considers objects at $V = 16.5$ and fainter, this function is remarkably flat; i.e., one gains very little if at all in mean redshift by pushing for identifications at fainter apparent magnitudes. This is consistent with what one would expect for a reasonably steep luminosity function. The last few data points of the figure must be considered to be lower limits only, due to the effects of incompleteness of identifications at $V \sim 19.5$ and fainter; nonetheless, one would clearly have to be extremely optimistic to interpret the data in this figure as indicating that $\langle z \rangle \sim 1$ could be achieved even with complete identifications at $V = 20$. Indeed, the extended Medium Sensitivity Survey (Gioia *et al.* 1984), which pushed to about this level to achieve completeness, has $\langle z \rangle$ virtually identical with our own. X-ray samples reaching fainter flux thresholds than that discussed here will apparently be required to identify substantial numbers of QSOs of higher redshift.

Ostriker and Heisler (1984) have suggested that very distant QSOs may be obscured by dust optically but still be identifiable as the counterparts of faint X-ray sources. The data of

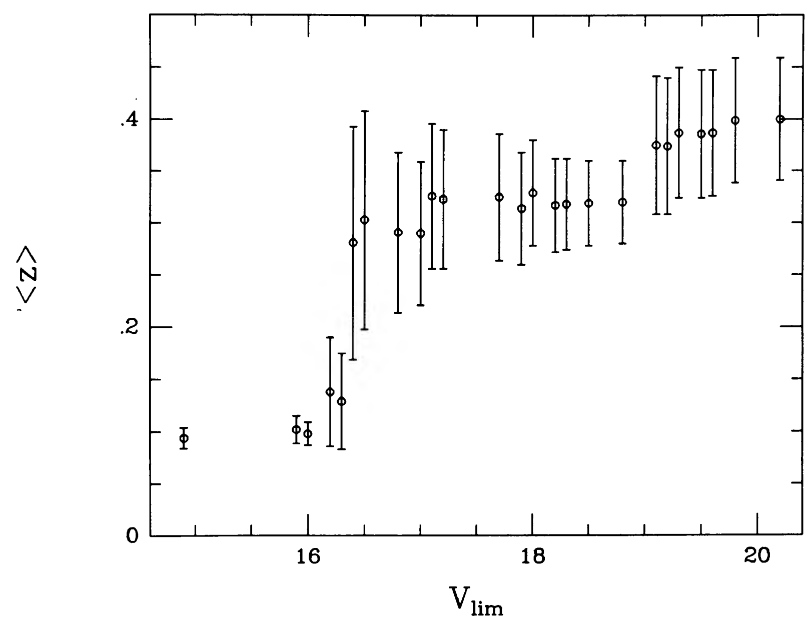

FIG. 3.—The dependence of sample mean redshift, $\langle z \rangle$, on the faintest object considered in the sample, V_{lim}. Uncertainties indicated are the mean standard deviations of the respective samples, and chance fluctuations of the very small number of objects in the sample at bright values of V_{lim} account for the anomalously small error bars on those points. The formal uncertainty estimates on the last few points, where incompleteness is clearly severe, are obviously lower limits only.

Figure 3 indicate that at least at the flux levels attainable by Einstein, a test of this will probably not be feasible; the very steep luminosity function conspires to contribute very large numbers of low-luminosity, low-redshift objects instead.

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