The Updated Zwicky Catalog (UZC) [1] [2] [3]

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ABSTRACT

The Zwicky Catalog of galaxies (ZC), with $m_{Zw} \leq 15.5$, has been the basis for the Center for Astrophysics (CfA) redshift surveys. To date, analyses of the ZC and redshift surveys based on it have relied on heterogeneous sets of galaxy coordinates and redshifts. Here we correct some of the inadequacies of previous catalogs by providing: (1) coordinates with $\lesssim 2''$ errors for all of the 19,369 catalog galaxies, (2) homogeneously estimated redshifts for the majority (98%) of the data taken at the CfA (14,632 spectra), and (3) an estimate of the remaining "blunder" rate for both the CfA redshifts and for those compiled from the literature. For the reanalyzed CfA data we include a calibrated, uniformly determined error and an indication of the presence of emission lines in each spectrum. We provide redshifts for 7,257 galaxies in the CfA2 redshift survey not previously published; for another 5,625 CfA redshifts we list the remeasured or uniformly re-reduced value. Among our new measurements, 1,807 are members of UZC "multiplets" associated with the original Zwicky catalog position in the coordinate range where the catalog is 98% complete. These multiplets provide new candidates for examination of tidal interactions among galaxies. All of the new redshifts correspond to UZC galaxies with properties recorded in the CfA redshift compilation known as ZCAT. About 1,000 of our new measurements were motivated either by inadequate signal-to-noise in the original spectrum or by an ambiguous identification of the galaxy associated with a ZCAT redshift. The redshift catalog we include here is $\sim$ 96% complete to $m_{Zw} \leq 15.5$, and $\sim$ 98% complete (12,925 galaxies out of a total of 13,150) for the right ascension ranges $20^h \geq \alpha_{1950} \leq 4^h$ and $8^h \geq \alpha_{1950} \leq 17^h$ and declination range $-2\overset{\circ}{.}5 \leq \delta_{1950} \leq 50°$. This more complete region includes all of the CfA2 survey as analyzed to date. The Great Wall structure persists throughout the Northern survey region.

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[1]Dedicated to the memory of Jim Peters, whose friendship, skill and dedication were essential to this work.

[2]This research made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, Caltech, under contract with the National Aeronautics and Space Administration

[3]We have made use in part of finder chart(s) obtained using the Guide Stars Selection System Astrometric Support Program developed at the Space Telescope Science Institute (STScI is operated by the Association of Universities for Research in Astronomy, Inc., for NASA)

Subject headings: cosmology: observations — galaxies: distances and redshifts — astrometry — catalogs

1. Introduction

During the last 15 years, wide-angle redshift surveys of the nearby universe have provided a basis for statistical characterization of the local large-scale structure of the universe. The CfA (Huchra, Vogeley & Geller 1998; Huchra, Geller & Corwin 1995; Geller & Huchra 1989; Huchra et al. 1990; Huchra et al. 1983; Davis et al. 1982) and SSRS surveys (da Costa et al. 1994a; 1988) cover more than a third of the sky and reach to a limiting apparent magnitude $m_B \sim 15.5$.

There is a rich literature analyzing these surveys to extract, for example, the galaxy luminosity function (Marzke & da Costa 1997; Marzke, Huchra & Geller 1994), the power spectrum for the galaxy distribution (da Costa et al. 1994b; Marzke et al. 1995; Park et al. 1994) and the velocity moments (Marzke et al. 1994). One factor limiting these analyses is the inhomogeneous nature of the databases. Here we take a step toward remedying that situation for the CfA surveys which are based on the ZC (Zwicky et al. 1961-1968).

Measurement of redshifts for the CfA surveys began in 1978. The ZC provided an obvious and, at that time, seemingly adequate source of positions for galaxies in the northern hemisphere. The accuracy of the Zwicky catalog coordinates ($3'$ at the 3σ confidence level) was comparable with the typical pointing accuracy of the Tillinghast Reflector on Mt. Hopkins, the workhorse for the CfA surveys. Nowadays, more comprehensive scientific goals and significantly improved telescope pointing make arcsecond coordinates imperative. Fortunately, the general availability of the digitized POSS plates (DSS; Lasker et al. 1990) enables us to revise the ZC by providing $\sim 2''$ coordinates for each galaxy. Here we provide these coordinates for 19,369 galaxies with $m_{Zw} \leq 15.5$ that we were able to identify unambiguously.

The measurement of a redshift for a nearby galaxy is now a rapid, routine process. However, at the start of the CfA surveys, the much slower pace made it seem judicious to accumulate redshifts from the literature. Given the effort required to construct the UZC, it is now clear that it would have been better to remeasure the redshifts to provide a uniform database. Approximately 30% of the redshifts in the catalog we describe here are from the literature; the rest were measured at the CfA. Most of the CfA measurements were made with two very different spectrographs, the Z-machine (Latham 1982) and FAST (Fabricant et al. 1998). We have re-reduced all of the Z-machine and FAST data and have determined a uniformly calibrated error (Kurtz & Mink 1998; hereafter KM98).

The UZC contained here includes redshifts for 96% of the galaxies with $m_{Zw} \leq 15.5$ along with $\sim 1,400$ additional redshifts for galaxies within multiplets in the region $20^h \geq \alpha_{1950} \leq 4^h$

and $8^h \geq \alpha_{1950} \leq 17^h$, both for $-2\overset{\circ}{.}5 \leq \delta_{1950} \leq 50^\circ$ (where our completeness is 98%; hereafter we refer to this region as the CfA2 region). We define UZC multiplets as galaxies with magnitude differences $\Delta m < 0.5$ mag and positional differences $\Delta\theta < 3'$. The catalog is suitable for a wide range of statistical analyses.

Section 2 describes the contents of the original Zwicky-Nilson merged catalog (ZNCAT). Section 3 describes the ZCAT compilation. Section 4 outlines our procedure for matching galaxies in ZNCAT and ZCAT with the HST Guide Star catalog (GSC), as a first pass to obtain accurate coordinates, and a subsequent refinement that improved the yield of matched galaxies. Section 5 describes the CfA redshift observations and reduction procedures. Section 6 outlines the procedures we used for blunder identification and for blunder rate evaluation. Section 7 contains the catalog and comments on its possible applications, and limitations.

2. The Zwicky Catalog

Our starting point for constructing the UZC is the database of properties of galaxies in the ZC, the Zwicky-Nilson catalog (ZNCAT; Tonry & Davis 1979; hereafter TD79). ZNCAT was created in preparation for the first CfA Redshift Survey (Davis et al. 1982); it covers the entire northern sky and contains the union of CGCG galaxies in the Zwicky catalogs (Zwicky et al. 1961-1968) and UGC galaxies in the Nilson catalog (Nilson 1973). ZNCAT contains position, magnitude and some morphology entries for 30,813 galaxies. We restrict ourselves to the 18,901 objects with $m_{Zw} \leq 15.5$, the limit where Zwicky estimated that his catalog was complete. The CfA redshift surveys include redshifts for nearly all of the galaxies to this limit over large areas.

Each galaxy in ZNCAT is described by a "Zwicky Number", another catalog label such as NGC or IC, its B1950 coordinates, Zwicky's estimate of its Johnson m_B magnitude, m_{Zw}, and, if known, its morphological type and its position angle on the sky and $B-$ and $R-$band diameters in arcsec. The errors in the galaxy magnitudes are 0.3 mag (Bothun & Cornell 1990; Huchra 1976); the 3σ error circle for the galaxies has a radius of $\sim 3'$ (Zwicky et al. 1968).

3. ZCAT

ZCAT (Huchra et al. 1992) is a compilation of redshift data for galaxies that currently contains approximately 100,000 entries. ZCAT includes positions, redshifts, magnitudes, and types from a variety of sources. We used ZCAT as an initial list of redshifts to construct a complete catalog for part of the northern sky. The coordinates of $\sim 9,600$ objects in ZCAT are identical to the corresponding ones in ZNCAT; thus, ZCAT coordinates are often accurate to only $\sim 3'$ (3σ). Revised coordinates in ZCAT frequently remain good to $\sim 1'$ (3σ) at best. There is also possible confusion with neighboring bright galaxies in $\sim 15\%$ of the entries. Such confusion cannot be eliminated without both accurate coordinates and magnitudes (see de Vaucouleurs et al. 1991;

hereafter RC3). Without the latter, the only alternative was to determine accurate coordinates as we do here, and remeasure redshifts based on these coordinates. We recently began a program of redshift remeasurement; we include the current results of this program in the UZC.

Magnitudes from the ZC in ZCAT are problematic. In the ZCAT compilation, the magnitudes from the original ZC are often replaced with measurements from a multitude of other sources. In cases of "multiplets" defined as for the UZC, ZCAT often contains eye estimates of split magnitudes. For the UZC, we restore the original Zwicky magnitudes m_{Zw} because they are the only system uniformly available for all of the galaxies and because they determined the original selection of galaxies for inclusion in the CfA surveys. In the catalog, we flag these multiples; the split magnitudes are available for reference in ZCAT (Huchra et al. 1992). The arcsecond coordinates we provide make it easy to measure and/or include better magnitudes if more reliable sources of photometry are available (see also RC3).

In using the UZC for statistical analyses, it should be noted that the flagged magnitudes of multiplets could be systematically too bright for each galaxy at the coordinates listed in the catalog. A careful reading of Zwicky et al. (1961) reveals that magnitudes in the Zwicky catalog were not compiled for multiplets in a uniform fashion. In cases where the multiplet is unresolved, the magnitude listed by Zwicky et al. (1961) is probably too bright for any single component. In resolved cases, the listed magnitude may be that for the brightest member alone. In the absence of a clear indication of the procedure of Zwicky et al. (1961), the safer alternative that we followed was to list only the original Zwicky et al. (1961) magnitude along with the brightest member. Furthermore, ours is not an exhaustive catalog of multiplets: those listed in the UZC were included because the magnitudes (m_{Zw}) of the components differed by less than ~ 0.5 mag. However, the UZC is a source for further searches for and statistical studies of multiplets.

4. Matching Catalogs to Obtain Arcsecond Positions

We compared the positions of galaxies in ZNCAT and ZCAT with an independent source of accurate coordinates, the HST Guide Star Catalog (GSC). The GSC contains coordinates for stars, and for extended objects ("non-stars"). Typical accuracies for all GSC coordinates are $\sim 1''$. However, the main focus of the GSC was on $V < 14$ mag stars. Thus, the magnitudes and identifications of galaxies are less reliable than for the stars (e.g., Lasker et al. 1990; Alonso et al. 1993, 1994). With these limitations in mind, we selected objects from the GSC which match the positions of the objects in ZNCAT.

We matched GSC and ZNCAT positions with software written for this task. From a list of ZNCAT and GSC coordinates, we calculated the Cartesian distance on the sky between objects in ZNCAT and in the GSC, and searched for matches within a $6' \times 6'$ box centered on each ZNCAT position; we found 19,878 matches. Out of these, 1,854 were duplicates due to overlaps of the digitized sky survey plates, for a total of 18,024 non-duplicate matches.

We made $6' \times 6'$ finding charts extracted from the DSS, centered on each original ZNCAT position. Our software classified these charts as follows:

1. class Z: a GSC class 3 (a "non-star") object appears within a $6' \times 6'$ box centered on the Zwicky position. For the 16,268 fields in this category, there is a high likelihood that each GSC object is the Zwicky galaxy.
2. class N: no GSC class 3 object appears within $6' \times 6'$ box centered on the Zwicky position, but one GSC class 0 object (a "star") is within the box. For the 3,363 fields in this category, the object nearest the Zwicky position is probably a star in the GSC.
3. class B: no GSC object of any class appears within the $6' \times 6'$ box centered on the Zwicky position. There are 247 fields in this category. Here, either through an error in the GSC classification, or through an error in the ZNCAT coordinates, there is no obvious candidate galaxy at the ZNCAT position.

We printed DSS finding charts for all the objects in our sample. Charts of type Z and N are centered on the matching GSC coordinates. Charts of type B are centered on the ZNCAT coordinates. To each matched object, we assigned a running index increasing with apparent magnitude. Ordered in this way, objects of similar apparent brightness are sequentially indexed close together. Thus, the visual classification described below remains consistent as a function of decreasing apparent brightness.

We also matched objects in ZCAT and ZNCAT by searching each $6' \times 6'$ coordinate box (centered on each ZNCAT object with $m_{Zw} \leq 15.5$ mag) with corresponding objects in ZCAT (with no restriction on the magnitudes). We found 19,584 matches, a number exceeding our total count (18,024) of matched non-duplicate ZNCAT objects within our magnitude limit. The mismatch occurred because (1) there were multiple matches within our matching box and (2) there were matches with ZCAT objects fainter than our choice of magnitude limit.

Because there are significant errors in both the GSC classification and in the ZNCAT coordinates, we could not be certain that our Z or N-class field classifications corresponded to the actual Zwicky galaxies. However, we had a preliminary ranking of galaxies in order of decreasing likelihood (from Z to N to B) of matching a ZNCAT galaxy. We therefore examined all of the Z, N and B fields visually, to determine a second classification of the objects. This time-consuming classification substantially improved the likelihood that a matched object in the GSC is actually a ZNCAT galaxy. The new classification consisted of numerical indices $0-4$:

1. code 0: a "hit", where the GSC and ZNCAT objects are separated in position by $\Delta\theta \leq 180''$, are comparable in brightness as determined visually, and there is no other object within the field that could be a ZC galaxy. Our indexing scheme furnished a qualitative estimate for the range of magnitudes expected for each galaxy, which we used as a guide during the

visual inspection. Note that the magnitudes m_{Zw} (B band) and m_{GSC} (V or J bands) can differ significantly, because the expected colors for these galaxies are in the range $\sim 0.3 - 1.0$ mag (Frei & Gunn 1994).

2. code 1: a "hit" with $\Delta\theta \leq 180''$, again with a GSC brightness in the vicinity of the ZNCAT value. However, the field is centered on a GSC "star" rather than on a "non-star", but there is only one possible ZC galaxy nearby, within the field. Thus, index 1 merely indicated that the nearest GSC object to the ZCAT coordinates is a star rather than the appropriate galaxy;

3. code 2: a near "hit" with $\Delta\theta \leq 180''$. However, there is confusion because there are at least 2 galaxies with an estimated spread in magnitudes $|\Delta m|$ within the expected range, either of which could be a ZC galaxy;

4. code 3: also a near "hit" with $\Delta\theta \leq 180''$ but with $|\Delta m|$ outside the expected range, raising suspicions about the match of the GSC object to the ZC galaxy;

5. code 4: no "hit" at all for $\Delta\theta \leq 180''$, i.e., there is no match for a ZC galaxy.

One of us (B. Elwell) examined each chart and assigned it a code of $0 - 4$, according to these criteria. Our strategy was to print finding charts in order of increasing magnitude; thus, we always knew the range of brightness being examined.

The visual examination yielded refined, accurate estimates for the appropriate object to match to the ZC coordinates. There were 3 distinct outcomes:

1) For perfect "hits", there is no doubt that the Zwicky galaxy is matched. The coordinates are those of the matching object in the GSC. We examined our printed DSS finding charts to confirm the match visually. These $12,154$ galaxies are in class 0 above.

2) For near "hits" in class 1, there is no doubt that we have a match for the ZC galaxy, but the GSC coordinates did not fall within $\sim 2''$ of the center of brightness of the ZC galaxy. One of us (J. Peters) confirmed the identification with software which allowed interactive examination of the DSS finding charts for the coordinates of each ZC galaxy. These $2,799$ galaxies were in class 1 above.

3) For confused "hits" in classes $2 - 4$, there is more than one possible match. In these cases, we have 3 sources of confusion: (a) at least 2 objects of approximately the expected magnitude lie within the $3'$ error circle; (b) the nearest match to the ZNCAT position has the wrong magnitude (invariably fainter); and (c) the $3'$ error circle is empty. We found $4,631$ galaxies in these classes, leading to a second round of visual examination using software in the WCStools package (Mink 1999). We examined the original finding charts used for the redshift measurements to associate the galaxy with its ZC position and with its measured redshift. When a match was found, the coordinates were determined interactively, with WCStools software. The success rate for this

procedure was low, only $\sim$ 30 %, because of the non-uniformity of the record-keeping, and of poorly marked or missing charts. Furthermore, we found many cases ($\sim$ 20% of the charts we examined) where the redshift in ZCAT did not match the entry on the finding chart.

The total number of galaxies in classes 0-4 matches the total count of 19,584. At this stage we eliminated duplicates and thus pared the total number of entries to the number of unique ZNCAT galaxies. This total number is the count of galaxies in ZNCAT with non-zero magnitudes after eliminating (1) a small number of duplicate entries; (2) 19 entries for which no clear galaxy was found within $15'$ of the Zwicky position; and (3) the matches for 063024+44480 (NGC2242), a known planetary nebula, and for 065012+16590, a known open cluster, both of which were mistakenly included in the ZC. The completeness values reported above are slightly higher if we take into account the ZC entries that we eliminated.

5. Redshifts in the UZC

The redshifts and errors listed for CfA data here take precedence over values published previously, including those measured with the Z-machine. All the CfA redshifts in the UZC were determined from observations made at Mt. Hopkins with the MMT, or with the Z-machine or FAST spectrographs on the 1.5-meter Tillinghast reflector at the Whipple Observatory.

We include in the UZC 4,465 redshifts measured with FAST. Of these, 1,905 are previously unpublished redshifts in the CfA2 region, and the rest are in the remaining regions of the northern sky, as well as remeasurements. About 1,000 of the remeasurements were necessary in cases where there was ambiguity in the identification of unresolved galaxies even after looking at historical records. Our source of UZC redshifts from the literature was ZCAT; about 25% of the redshifts in ZCAT were compiled from the literature. In the CfA2 survey region, CfA measurements make a slightly larger contribution, with 1.4% of the redshifts from the MMT, 61% from the Z-machine and 17% from FAST.

The Z-machine (Latham 1982) measurements were made between 1978 and 1993. For these observations, a 600 line mm^{-1} grating yielded a resolution of 5Å in first order over the wavelength range 4500 - 7100 Å. The typical integration time for each object was 15-50 minutes. In 1993, the FAST spectrograph (Fabricant et al. 1998) was first mounted on the 1.5-meter Tillinghast. The FAST spectra have 6 Å resolution and coverage of 3700 - 7500 Å. Typical integration times were 3-10 minutes.

For our FAST observations, when there was more than one galaxy near the ZNCAT position and within $\sim$ 0.5 mag of the original Zwicky magnitude, we measured redshifts for all of the galaxies. We began the observing program in September 1996, and completed it in October 1997. All of these new redshift measurements are included in the UZC (see Table 1). We also updated the coordinates of all of these remeasured galaxies, using the DSS finding charts, with an estimated positional uncertainty of $\sim 2''$. FAST measurements (from our own and from other projects) replaced any previously measured redshifts, e.g. with the Z-machine, in the UZC.

6. Reliability of the Redshifts in the UZC

In many cases where the GSC galaxy is an unambiguous match to ZNCAT, we checked our DSS finding charts against those used for the CfA Redshift Survey. We corrected obvious typos found in this way. This procedure underscored our awareness of inadequacies in the reduction and record-keeping, and spurred us to make an objective *measurement* of the error rate in redshifts from the literature and from our own facilities by remeasuring redshifts for a significant number of objects chosen with a variety of criteria.

We first used our current archive of repeat measurements with FAST to estimate the error rate in these new data. For 620 pairs of FAST measurements, there were no blunders (KM98). Thus, we only have an upper limit of $\sim 0.2\%$ for the error rate, which is attributable to the much better pointing of the Tillinghast 1.5-meter, much improved observing protocols, and better record-keeping and archiving procedures. We are thus confident that for the 3,446 FAST redshifts in the UZC, the blunder rate is essentially zero.

We reduced the 4,366 FAST spectra of galaxies in our sample in a uniform manner, using the IRAF task **rvsao** (KM98). All spectra were cross-correlated with two templates, fabtemp97, a composite absorption line spectrum (KM98), which is generally used for all FAST redshifts, and femtemp97, a synthetic emission line template (KM98). We estimated the errors for our FAST spectra as in KM98: the values are obtained by dividing a constant by $1 + R$ (R values are a measure of the quality of fit of a template and of S/N for the spectra, see TD79, KM98), and adding $20/\sqrt{2}$ km s^{-1} in quadrature. For fabtemp97 the constant is 350 km s^{-1}, and for femtemp97 the constant is 220 km s^{-1}. These constants were selected from Figures 10 and 12 of KM98, to optimize the contributions of statistical and systematic errors from cross-correlation with each template. We required $R > 3$ for all the redshifts we report here. In cases where the difference for the two templates is less than 300 km s^{-1}, the redshift in Table 1 is the error-weighted combination of the two, as is its error. Of the 4,366 spectra, 30 were of insufficient quality, 1,872 matched the absorption line template fabtemp97, 692 matched the emission line template femtemp97, and 1,772 matched both templates.

We also re-reduced the 10,051 Z-machine spectra of the galaxies in our sample in a uniform manner with **rvsao** (KM98). All spectra were cross-correlated with the templates ztemp, a composite absorption line spectrum that has been used for all Z-machine redshifts since TD79, and femtemp97. Figure 1 shows spectrograms of ztemp and femtemp97 (compare with Figure 11 of KM98).

The Z-machine spectra do not have sufficient quality to permit fully automatic reduction; the initial reduction required visual inspection of every spectrum. We compared the new redshifts, obtained by correlation with the absorption and emission line templates, with those from the original reduction; we also checked for sufficient signal to noise, requiring $R > 3$. We accepted a redshift if it fell within 300 km s^{-1} of the original reduction; of the 10,080 Z-machine spectra we accepted 9,936. We found that 4,424 matched with the absorption line template, ztemp, 2,507 matched with the emission line template femtemp97, and 3,005 matched both templates. Among the remaining 156 low-S/N spectra (FAST and Z-machine), 125 are in our 98% complete region. These galaxies are flagged in Table 1 (see below); we plan to update their redshifts with FAST.

In the cases where a single template matches the original reduction, the redshift in Table 1 is that obtained from that template, and the error is calculated with the methods outlined in KM98. The Table also indicates which template matched best, with a label of A for ztemp, E for femtemp97, and B for both. We calculated the error as for FAST but with appropriate constants, again by dividing a constant by $1 + R$, and adding 35 km s^{-1} in quadrature. For ztemp the constant is 212 km s^{-1}, and for femtemp97 the constant is 140 km s^{-1}; these constants are 3/8 of the median width of correlation peaks where $R > 4$ (KM98). In cases where both templates match the original reduction, the redshift in Table 1 is the error-weighted combination of the two, as is the error. In cases where the match with the original reduction failed, we estimated errors individually to match the system defined by successful cross-correlation. ZCAT contains another 670 low-S/N spectra that would be included in the UZC if their S/N were sufficiently high. Any galaxy that was identified unambiguously but whose redshift remains unknown is entered in Table 1 with accurate coordinates, with nothing in its redshift column. Galaxies for which spectra were obtained at CfA but where the S/N was below our acceptance criterion are flagged in Table 1 (see below).

Even after the new measurements for ambiguous cases, the blunder rate in ZCAT is significant for the Z-machine data and for data from the literature. For evaluation of the reliability of redshift measurements including those obtained with the Z-machine and those compiled from the literature, we extracted a random sample of 129 galaxies from ZCAT and re-measured their redshifts with the FAST spectrograph. We also assembled several samples of FAST redshifts acquired for other projects: the Century Survey (106 galaxies: Geller et al. 1997); studies of groups of galaxies (66 galaxies: Mahdavi 1998, private communication); galaxies in voids (226 galaxies: Grogin et al. 1998); and other galaxy surveys (315 galaxies: Carter 1998, private communication). The total number of re-measured redshifts is 843. In the UZC, we have replaced the ZCAT redshift with the corresponding FAST measurement in all cases (the number of FAST redshifts discussed above includes these measurements and re-measurements).

For each sample, Figure 2 shows the differences between the FAST measurements of redshifts and the corresponding original ZCAT entry, plotted against the FAST redshifts represented as cz. The "blunder" rate for the overall test sample, as well as for the individual samples, is stable at $\lesssim 3$ % for measurements not made with FAST. We find the same rate regardless of the origin of the redshift in ZCAT (the literature, or Z-machine for example). An oddly large number of redshifts in ZCAT from the literature differ by 1,000 km s^{-1} from FAST measurements (only one of which happened to be included in Figure 2), making us suspect typographical errors or confusion of Hα

(6563Å) with [NII] (6548Å, 6584Å) emission lines as major sources for the discrepancy.

7. Discussion

We have assembled a new version of the Zwicky Catalog (ZC), the Updated Zwicky Catalog (UZC), with a magnitude limit of $m_{Zw} = 15.5$ mag. The UZC is a 98% complete redshift catalog to this magnitude limit, in the CfA2 region with $20^h \geq \alpha_{1950} \leq 4^h$ and $8^h \geq \alpha_{1950} \leq 17^h$ and $-2\fdg5 \leq \delta_{1950} \leq 50°$. The completeness of the UZC is lower at the northernmost declinations, e.g., if we restrict $\delta_{1950} \geq 50\,\mathrm{deg}$, it falls to 90%. The main advantages of the UZC over previous compilations are (1) uniformly accurate coordinates at the $\leq 2''$ level; (2) a robust estimate of the accuracy of the CfA redshifts in the range $cz = 0 - 25,000$ km s^{-1}, with a current total of $\sim$ 25% of redshifts with essentially no "blunders"; (3) an estimate of the reliability of catalog redshifts for data from the literature and from the Z-machine: the remaining 75% of the redshifts have a blunder rate of $\lesssim$ 3%. A continuing problem with the UZC is that magnitudes for the galaxies in the sample are still the original Zwicky mgnitudes, which have $\sim$ 0.3 mag errors. Multiples are flagged in the UZC (see Table 1), because we have not split the Zwicky magnitudes of their components. These magnitudes may be systematically too bright for each component of an unresolved UZC multiplet (§3).

Table 1 contains a sample listing of the UZC. Column 1 ("RA (J2000) DEC") shows the right ascension and declination (J2000) of each galaxy. Column 2 ("B") shows the B-band magnitude m_{Zw} from ZNCAT. Columns 3 ("cz") and 4 ("Δcz") show the heliocentric redshift and its error in km s^{-1}. Column 5 ("T") indicates the type of the redshift for each galaxy, E (emission), A (absorption) or B (both emission and absorption). Column 6 ("U") shows the the UZC code (0-4) assigned to each galaxy, according to the quality of the match with DSS galaxies (see §4). Column 7 ("N") shows the number of UZC neighboring galaxies to the current entry, within $3'$. Galaxies in the UZC with a number of neighbors larger than 0 are thus in UZC "multiplet" systems. All entries with $N > 0$ are flagged with a star in Column 12, to indicate membership in a UZC "multiplet". Column 8 ("ZNCAT Name") shows the ZNCAT or Zwicky label; multiplets generally share a single such label. Column 9 ("Ref. code") indicates the origin of the redshift measurement, for data taken at the CfA: Z for Z-machine, M for the MMT and F for FAST spectra taken for our (other) project(s). The label "X" flags a low-S/N spectrum for Z-machine (FAST) measurements and indicates a low S/N match with a spectrum at $cz < 100$ km s^{-1}, an indication that no redshift could be determined. Column 10 ("Ref.") shows a ZCAT literature reference number (in turn listed in Table 2), or a blank for CfA unpublished data. Column 11 ("Other Name") shows any other name may be associated with the current entry, such as an NGC number, as listed in ZCAT. Column 13 indicates whether the galaxy is a member of a Zwicky multiplet, as reported by NED ("P", "T" and "G" for pairs, triples and groups, respectively). Because of the size and limited utility of a printed version, the full table is available only with the electronic version of the journal article. This table, as well as additional measurements we will carry out with FAST will also be available at URL http://tdc-www.harvard.edu.

Figure 3 shows the distribution of the magnitude of the differences between UZC and Zwicky coordinates. The mode of the histogram is at $\sim 40''$, slightly better than the $1'$ (1σ) errors claimed by Zwicky. For additional confirmation of our positional accuracy, we matched the FIRST 1.4 GHz catalog (White et al. 1997) with the UZC, using a search radius of $10''$. We found matches for 1,347 FIRST sources. The distribution of coordinate differences for these sources has a narrow peak at $\sim 1''$, with a width $\sigma = 1\farcs45$. Thus, for these FIRST matches, the UZC positional uncertainty is $< 1\farcs5$, which confirms the significant improvement in positional accuracy that we have achieved with the UZC.

Figure 4 shows the sky distribution of UZC galaxies with measured redshifts, as listed in Table 1. The UZC covers only the northern sky; regions devoid of galaxies result from obscuration by the Milky Way. Figure 5 shows the sky distribution of galaxies without measured redshifts, also as listed in Table 1. A comparison of Figures 4 and 5 shows that there are no significant patterns in the distribution of galaxies without measured redshifts, other than, e.g., those north of $+50°$ and south of the equator, with a known lack of coverage. Figure 6 shows cone diagrams for the distribution of galaxies in the UZC as a function of α, δ and cz in km s^{-1}. Each "slice" spans $\sim 10°$ of declination and right ascension ranges of $8 - 17h$ in the northern galactic polar region and $20 - 4h$ in the South galactic cap. These slices cover the CfA2 region of the redshift survey.

The known structure of the distribution of galaxies is readily apparent in these diagrams (Geller & Huchra 1989). The large voids and coherent sheet-like structures appear in adjacent sets of the "slices". Figure 7 shows histograms of the number of galaxies $N(z)$ as a function of redshift for both polar galactic regions in the UZC. The structure known as the Great Wall (Geller & Huchra 1989) that persists at $7,000 - 10,000$ km s^{-1} in each of the $8 - 17h$ slices in Figure 6, as well as in Figure 7. The latter figure shows significant peaks at the redshifts of the Great Wall and the Virgo cluster in the North, and at the redshift of Perseus-Pisces in the South galactic hemisphere. Such peaks confirm the presence of these large-scale structures, and demonstrate their narrowness in redshift space. These in turn are characteristic of the sheet-like structures in Figure 6.

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Zwicky, F. & Kowal, C. 1968, *Catalogue of galaxies and of clusters of galaxies*, (Pasadena: California Institute of Technology) Vol. VI

This preprint was prepared with the AAS LaTeX macros v4.0.

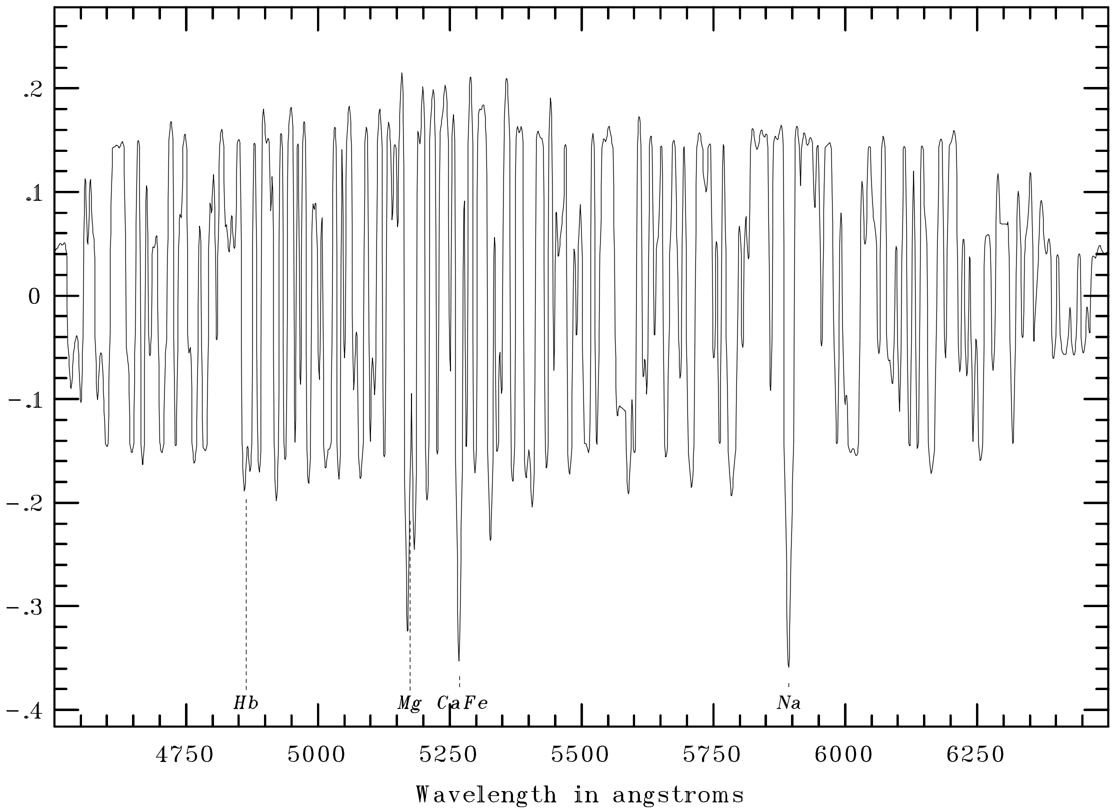


Fig. 1.— (a) The absorption template ztemp. Prominent metal and Balmer absorption lines are labeled. The less prominent but prevalent absorption lines in the absorption template are real features.

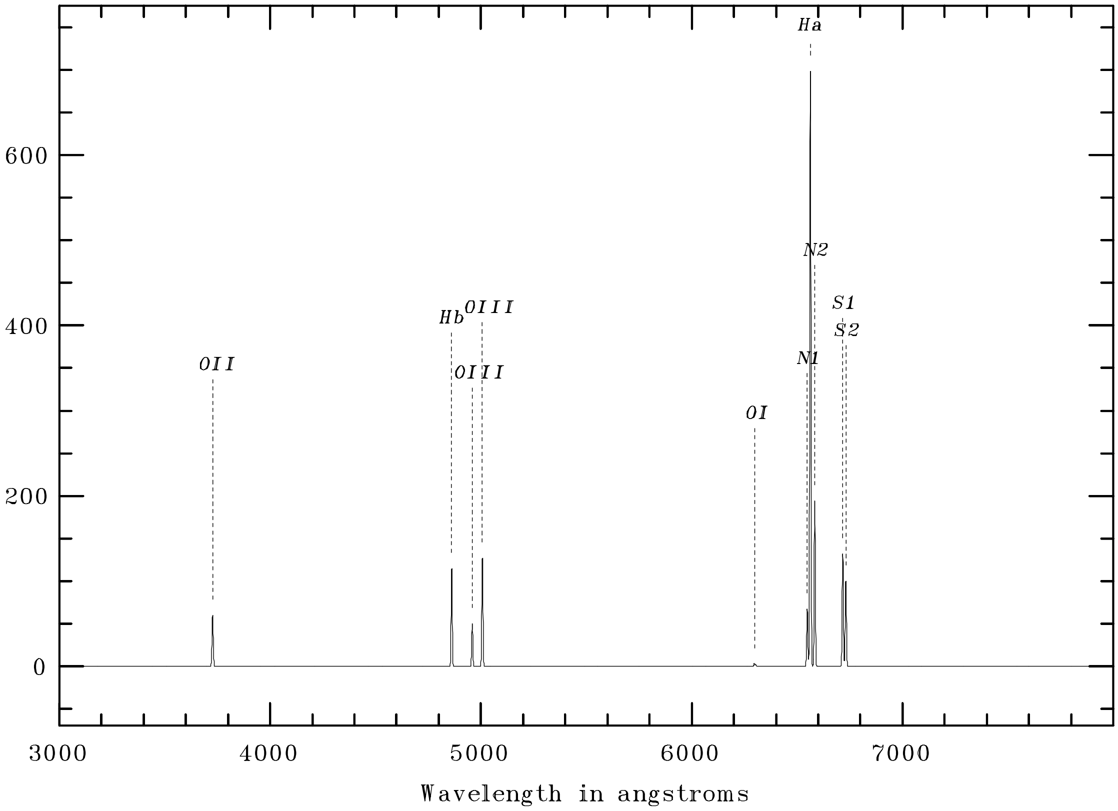


Fig. 1.— (b) The emission template femtemp97. Prominent metal and Balmer emission lines are labeled.

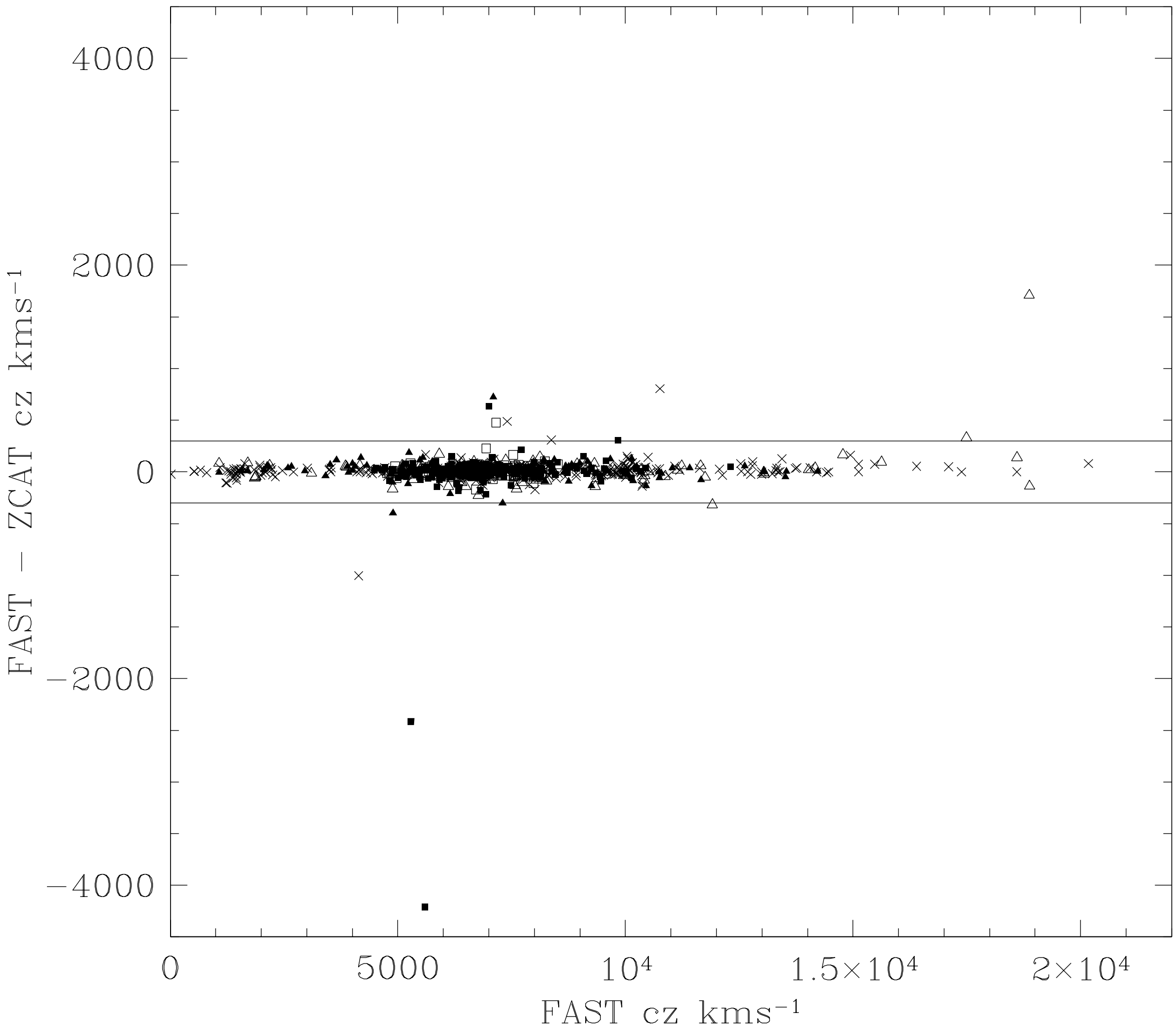


Fig. 2.— The differences between ZCAT and FAST redshifts, plotted as a function of FAST redshift. The symbols are: open triangles (Century Survey), filled triangles (Comparison survey), open squares (Mahdavi survey), filled squares (Grogin survey), and crosses (Carter survey). We chose the limits for clarity; therefore, a few "blunders" are outside the plot. Horizontal lines at $\pm$ 300 km s^{-1} are intended to guide the eye and provide a comparison across the plot.

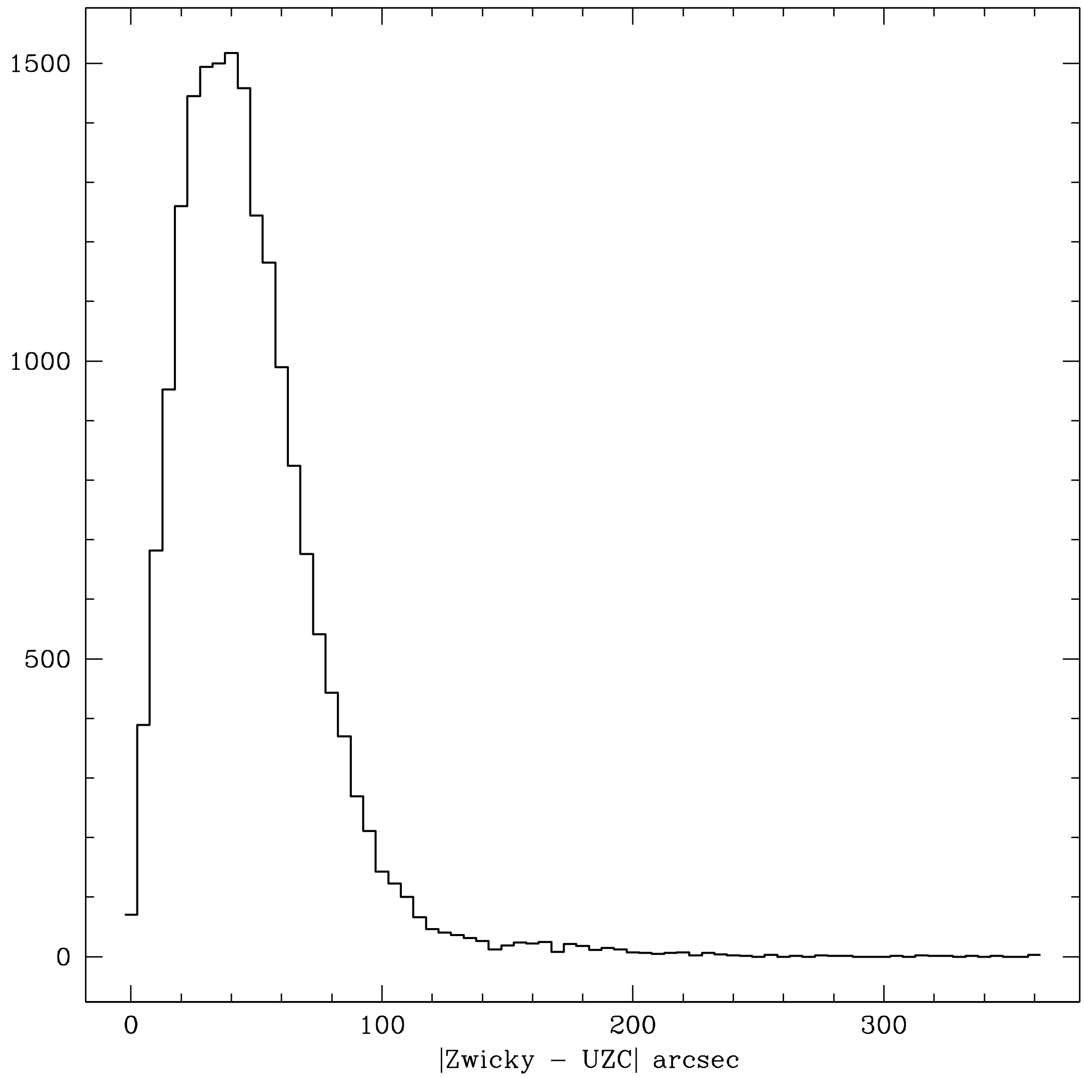


Fig. 3.— The distribution of the absolute value of the differences between UZC and Zwicky coordinates.

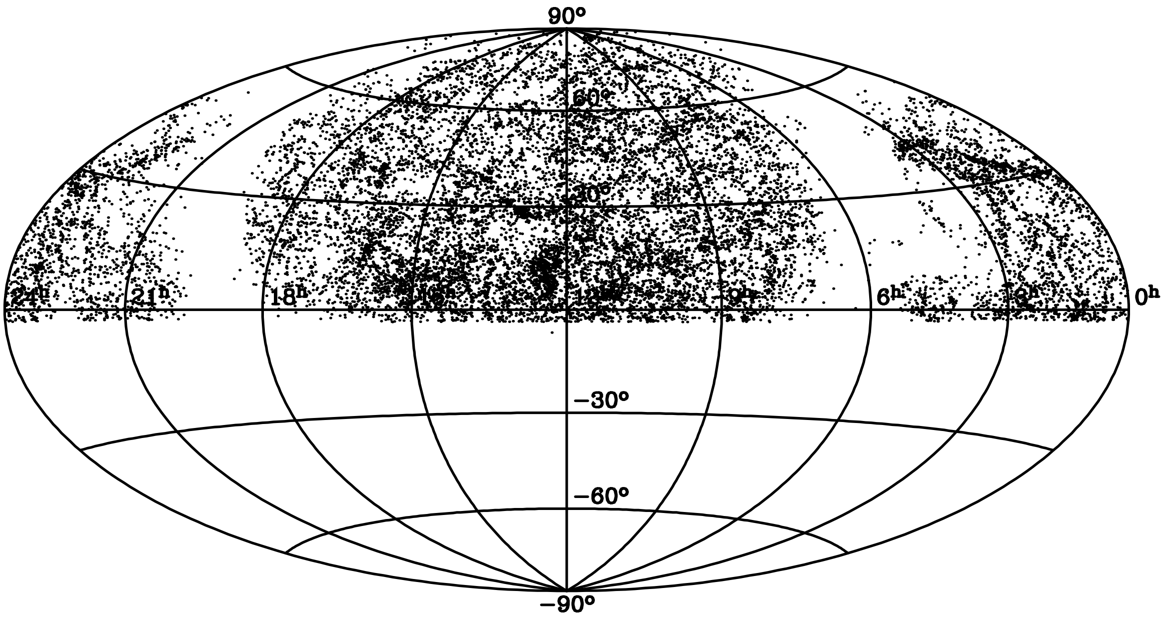


Fig. 4.— The distribution on the sky of the UZC galaxies. The Galactic plane appears as an empty band.

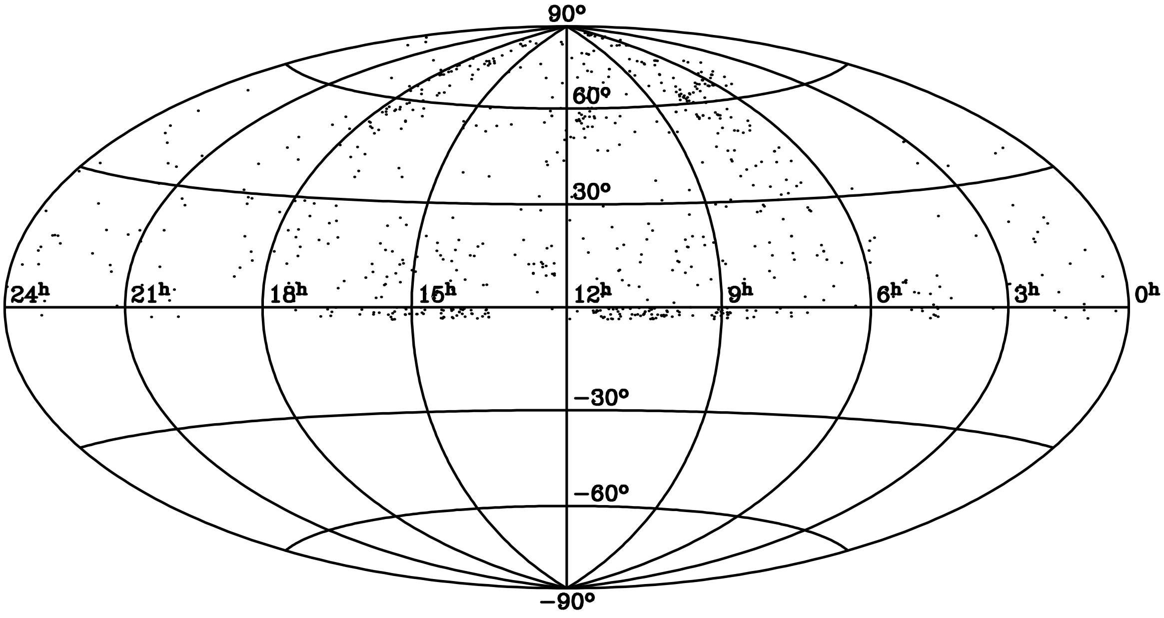


Fig. 5.— The distribution on the sky of Zwicky galaxies without measured redshifts in the UZC.

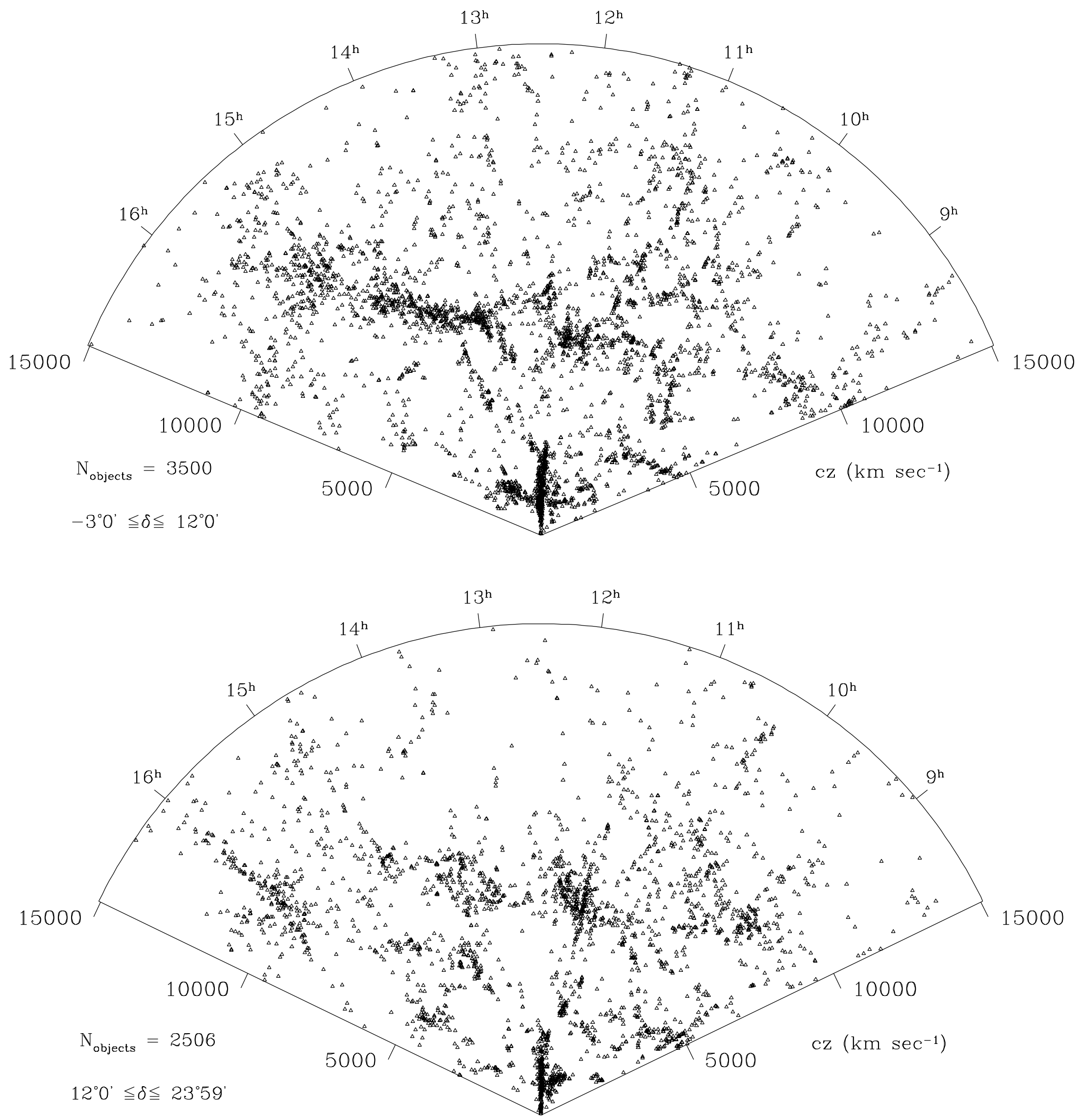


Fig. 6.— (a) Cone diagrams for $8 \leq \alpha_{1950} \leq 17h$. Each UZC galaxy is represented by a small triangle. The thickness of each "slice" is $\Delta\delta_{1950} \approx 12\,\mathrm{deg}$.

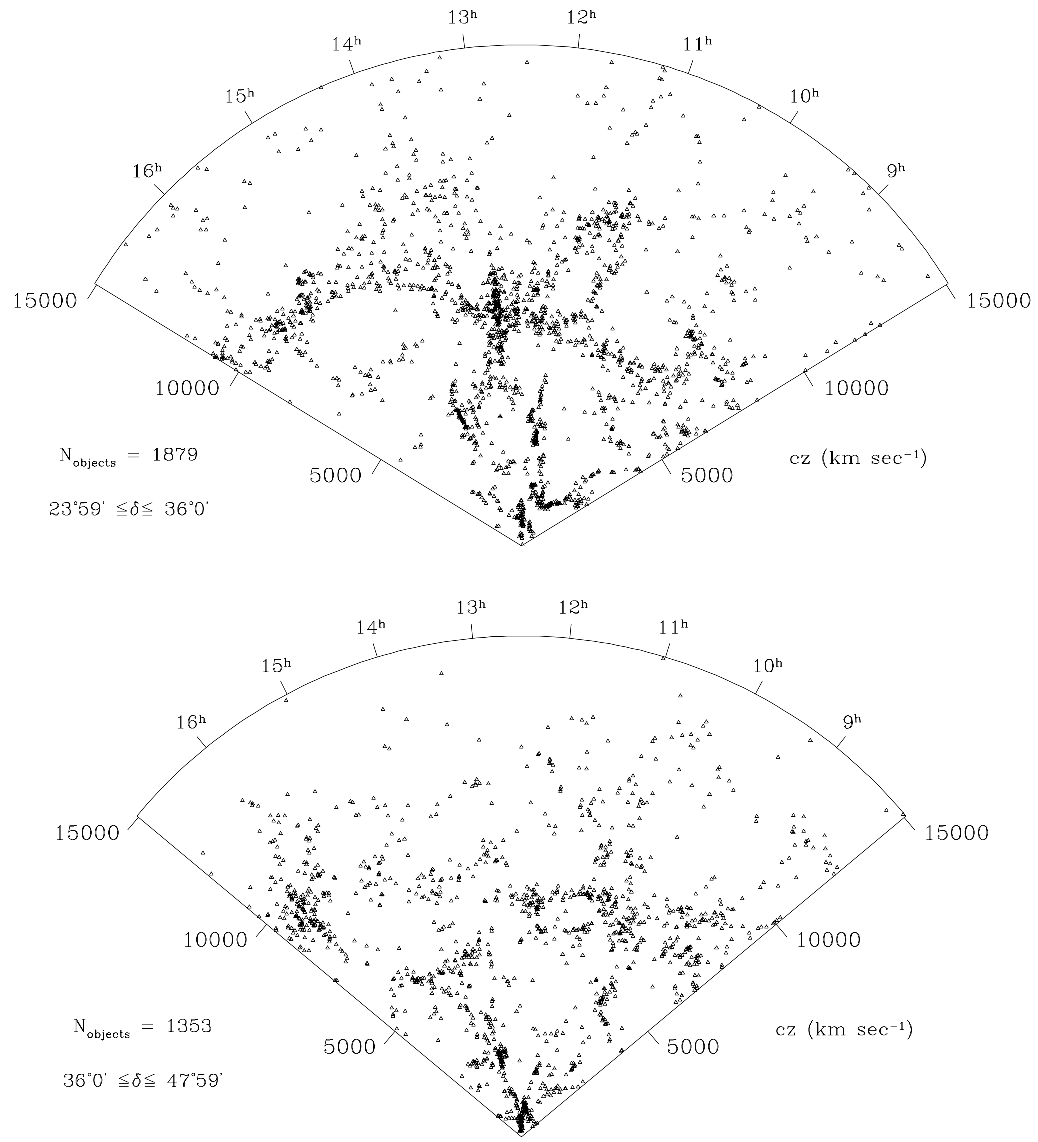


Fig. 6.— (b) Cone diagrams for $8 \leq \alpha_{1950} \leq 17h$. Each UZC galaxy is represented by a small triangle. The thickness of each "slice" is $\Delta\delta_{1950} \approx 12\,\mathrm{deg}$.

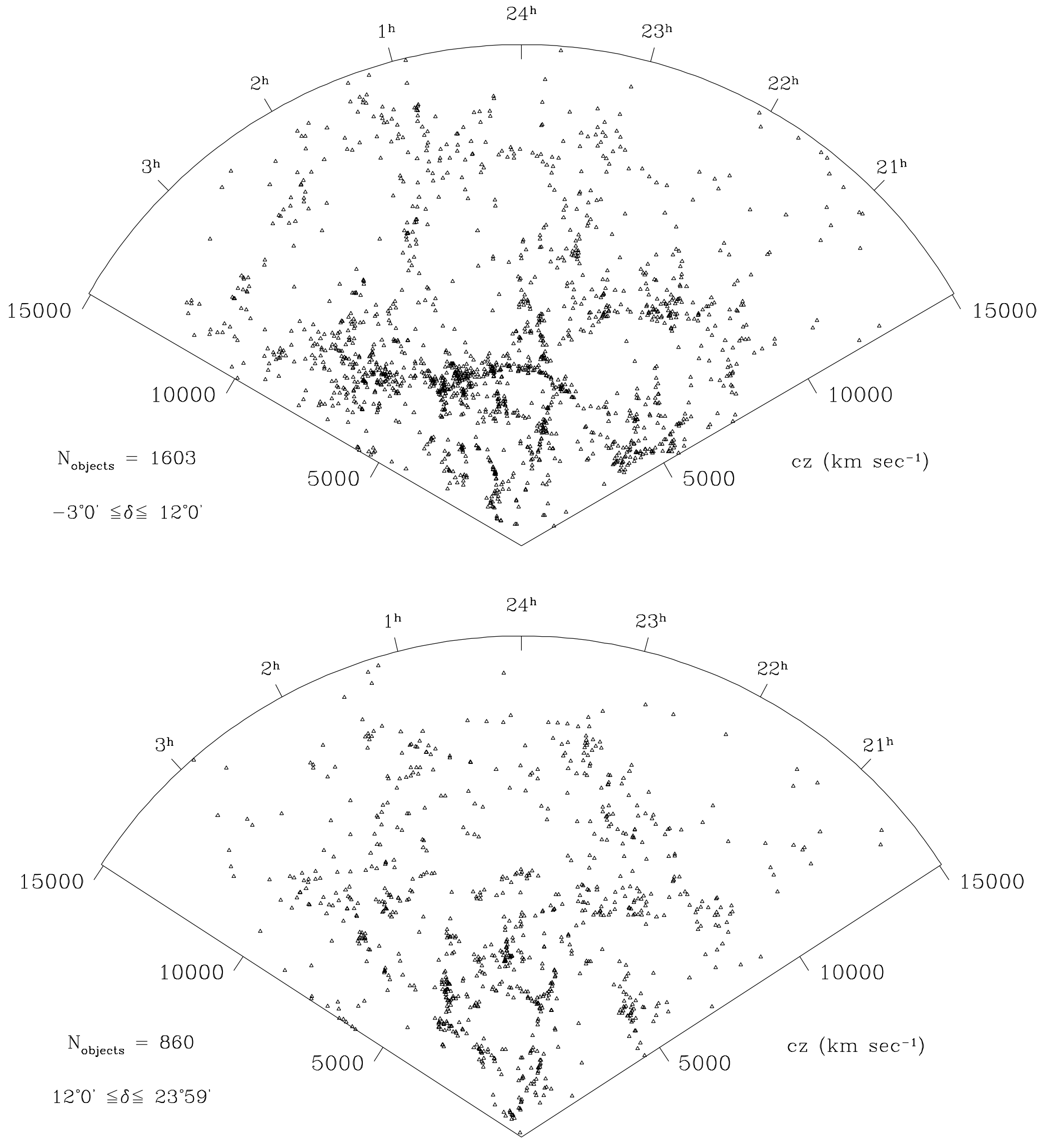
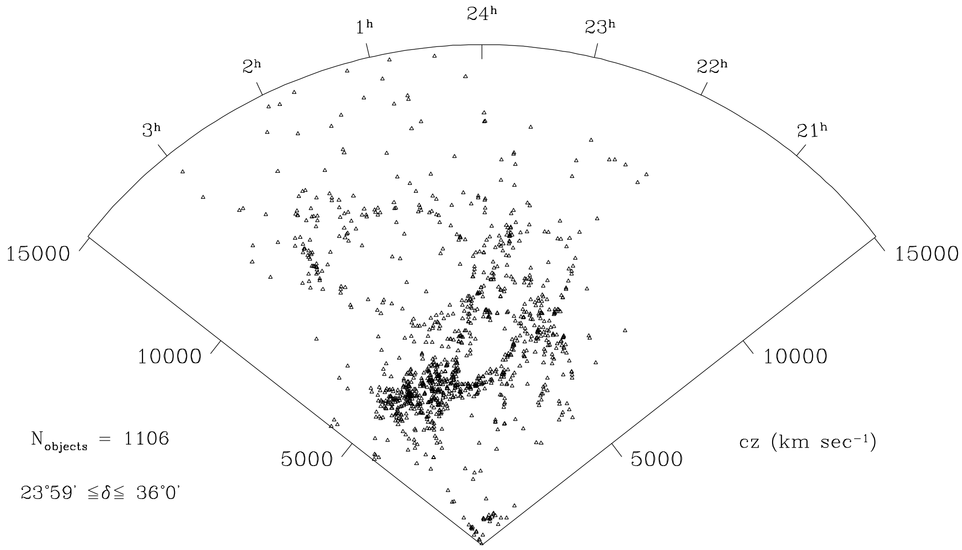


Fig. 6.— (c) Cone diagrams for $20 < \alpha \leq 24h$ and $0 < \alpha \leq 4h$. Each UZC galaxy is represented by a small triangle. The thickness of each "slice" is $\Delta\delta_{1950} \approx 12\,\mathrm{deg}$.



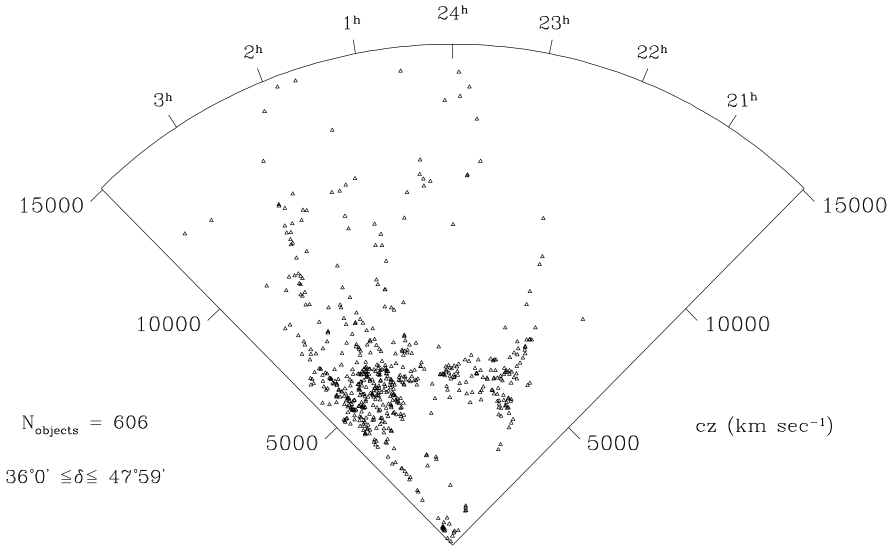


Fig. 6.— (d) Cone diagrams for $20 < \alpha \leq 24h$ and $0 < \alpha \leq 4h$. Each UZC galaxy is represented by a small triangle. The thickness of each "slice" is $\Delta\delta_{1950} \approx 12\,\mathrm{deg}$.

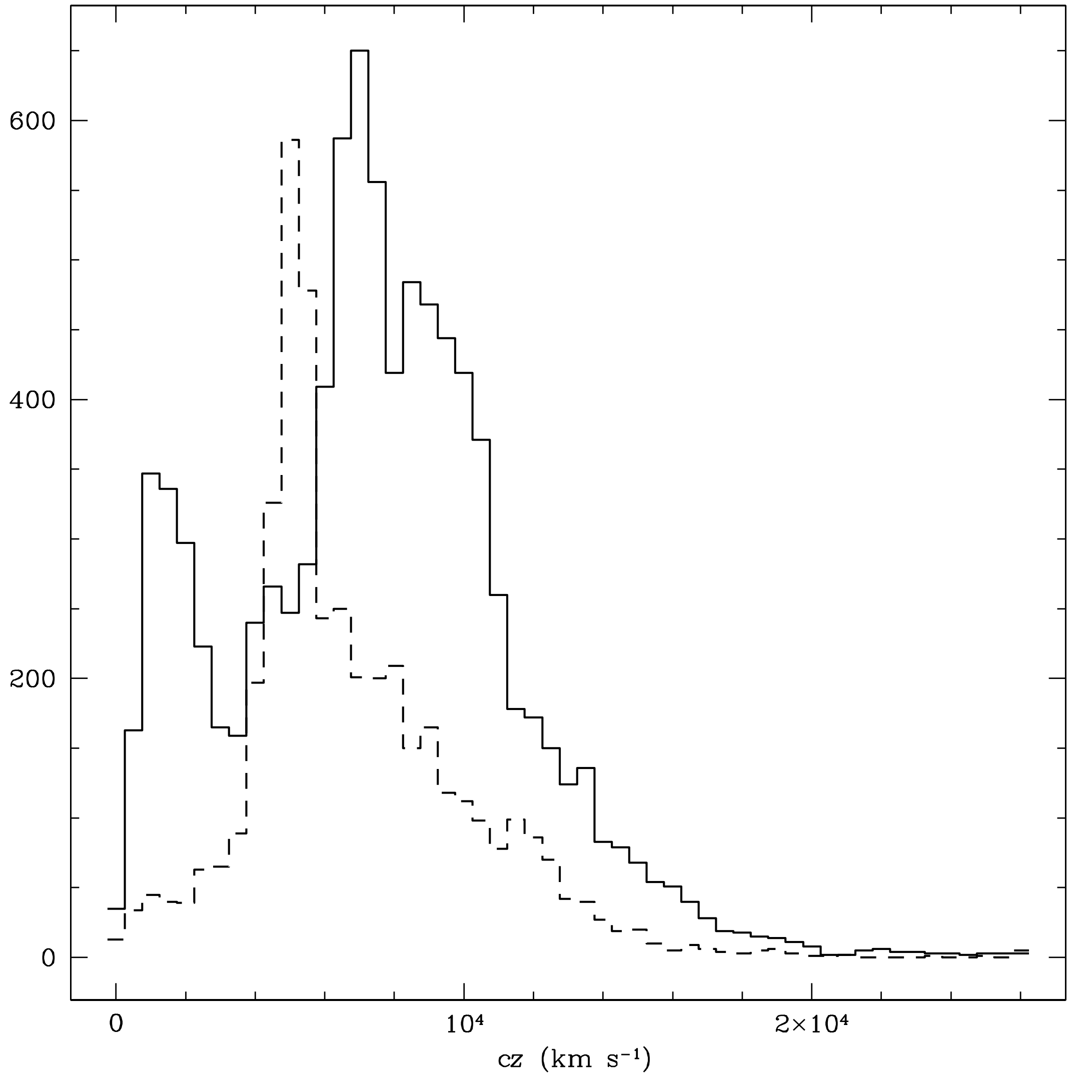


Fig. 7.— The number of galaxies $N(cz)$ per redshift bin for the North (solid) and South (dashed) galactic hemispheres. Note the prominence of the Great Wall structure at $cz = 7,000 - 10,000$ km s^{-1}, and of the Virgo cluster at $cz \sim 1,000$ km s^{-1}. Perseus-Pisces is also noticeable in the South at $cz \sim 5,000$ km s^{-1}. The differences between North and South reflect the inhomogeneities on the scale of these large surveys.

Table 1. Sample UZC Catalog

RA (J2000) DEC *hhmmss.s ddmmss*	*B* mag	cz km s^{-1}	Δcz km s^{-1}	T	U	N	ZNCAT Name	Ref. code	Ref.	Other Name	UZC Mult.	NED Mult.
130007.3+084155	15.2	13893	53	B	0	0	125736+08580	Z		12576+0858		T
130003.5+265353	14.7	5898	70	-	0	0	125736+27100		0000	N4892		
130002.1+332613	15.2	7253	35	E	0	0	125742+33420	Z	2700	12577+3342		
130004.7+275914	15.1	6412	25	A	0	1	125739+28153	F		N4886	*	
130010.5+122900	13.3	1516	71	A	0	0	125742+12450	Z	2700	N4880		
125956.4+471221	15.5	8696	46	A	0	0	125742+47280	Z		N4901		
130007.8+275838	13.0	6502	48	A	0	2	125742+28150	Z		N4889	*	
130013.9+284943	15.4	7365	24	A	2	0	125748+29060	F		12578+2906		
130017.5+275720	15.0	6848	15	-	0	1	125753+28135		3606	N4898W	*	P
130017.8+281210	14.3	8430	48	A	0	0	125753+28281	Z		N4895		
130016.1+361515	15.5	8297	47	B	0	0	125754+36310	Z	2700	I4028		
130024.9+134013	15.4	2030	40	E	1	0	125754+13570	Z	0625	12579+1357		
130022.0+280250	15.5	8153	55	-	0	0	125757+28189		1823	I4026		
130025.6+285206	15.4	6812	59	-	0	0	125800+29080		4200	I4032		
130033.2+100748	15.1	7169	42	B	0	0	125800+10240	Z		12580+1024		
130029.2+264031	15.2	7208	100	-	0	0	125800+26560		1502	12580+2656		
130039.1+023000	12.8	936	36	E	0	0	125806+02460	Z	0611	N4900		
130030.8+282047	15.1	5998	28	A	0	0	125806+28370	F		N4896		
130033.7+273816	15.4	7495	15	E	0	0	125806+27550	F		12581+2755		
130037.7+280329	15.1	7840	5	-	0	0	125813+28196		9000	I4040		
130039.7+275528	15.2	7505	15	-	0	1	125815+28116		3606	N4906	*	
130039.6+290110	14.6	7289	3	-	0	0	125812+29170		0661	I 842		
130042.6+275819	15.5	6255	70	-	0	1	125818+28142		0000	I4042	*	
130047.6+154217	15.5	6503	49	B	0	0	125818+15590	Z		12583+1559		
130054.5-012048	15.2	6813	42	B	0	0	125818-01050	Z	2774	12583-0105		
125956.2+734133	14.7	1665	5	-	1	0	125818+73580		2218	12583+7358		
130042.7+362044	15.3	8311	52	A	0	0	125824+36370	Z	2700	I4049		
130042.9+371855	12.7	4660	43	A	0	0	125824+37350	Z	2700	N4914		
130048.5+280528	15.1	6855	15	-	0	1	125824+28215		3606	I4045	*	
130048.7+280931	14.6	5879	10	-	0	0	125824+28255		9000	N4907		
130050.0+272420	15.5	6629	36	A	0	0	125824+27400	F		12584+2740		
130059.0-000145	13.2	1153	44	B	1	0	125824+00140	Z	2700	N4904		
130051.4+280235	14.9	8841	70	-	0	2	125827+28186		3900	N4908	*	
130052.0+282159	14.9	7665	23	A	2	0	125830+28380	F		12585+2838		
130103.6-015712	15.3	1419	10	-	0	0	125830-01420		3000	12585-0142		P
130054.6+280026	14.8	5050	30	A	0	1	125829+28165	F		I4051	*	
130055.9+274728	13.7	7939	51	A	0	0	125830+28030	Z		N4911		
130055.6+471320	15.0	7381	58	A	0	0	125842+47300	Z	2700	N4917		
130029.9+701155	15.3			-	2	0	125848+70280			12588+7028		
130106.7+395029	15.0	10620	46	A	0	0	125848+40070	Z	2700	12588+4007		
130122.4+071907	15.5	13576	59	A	0	0	125848+07350	Z	2774	12588+0735		
130117.5+274834	14.9	7344	31	A	2	0	125854+28040	F		N4919		
130124.3+291832	14.2	7187	24	A	2	0	125900+29350	F		N4922A		P
130125.1+284038	15.3	8775	82	B	0	0	125906+28570	F		12591+2857		
130126.1+275309	13.7	5480	31	A	0	1	125900+28080	F		N4921	*	
130116.6+480337	15.1	8975	14	E	3	1	125900+48190	F		12590+4819	*	P
130118.3+480332	15.1	8888	14	E	3	1	125900+48190	F		12590+4819	*	P
130131.7+275052	14.7	5469	31	A	2	1	125906+28060	F		N4923	*	
130141.5+044050	15.4	11458	47	B	0	0	125912+04570	Z	2774	12592+0457		
130133.6+290750	14.8	7387	25	-	0	0	125912+29240		2315	I 843		

Table 2. Velocity Sources for the UZC

ID	Bibliographic Reference
0000	de Vaucouleurs, G., de Vaucouleurs, A. & Corwin, H. 1976, The Second Reference Catalogue of Bright Galaxies University of Texas Press, Austin, Texas (RC2)
0001	Corwin, H. G. Jr. & Emerson, D. 1982, MNRAS 200, 621.
0002	de Vaucouleurs, G. et al. Third Reference Catalogue of Bright Galaxies, Springer-Verlag, New York (RC3)
0004	de Vaucouleurs, G., de Vaucouleurs, A. & Nieto, J. L. 1979, AJ 84, 1811
0005	Kelton, P. 1980, AJ 85, 89
0100	Sandage, A. & Tammann, G. 1981, The Revised Shapley-Ames Catalog Carnegie Institution of Washington
0104	Sandage, A. 1976, PASP 88, 367
0105	Sandage, A. 1978, AJ 83, 904, 1467
0109	Binggeli, B., Sandage, A. & Tammann, G. 1985, AJ 90, 1681
0200	Fisher, J. R. & Tully, R. B. 1981, ApJS 47, 139
0302	Huchra, J. & Sargent, W. L. W. 1973, ApJ 186, 433
0400	Rubin, V. et al. 1976, AJ 81, 687
0402	Rubin, V. et al. 1976, AJ 81, 719
0501	Arakelyan, M., Dibai, E. & Esipov, V. 1975, Astrofizika 11, 15
0502	Arakelyan, M., Dibai, E. & Esipov, V. 1975, Astrofizika 11, 377
0503	Arakelyan, M., Dibai, E. & Esipov, V. 1976, Astrofizika 12, 195
0504	Arakelyan, M., Dibai, E. & Esipov, V. 1976, Astrofizika 12, 685
0505	Arkhipova, V. & Esipov, V. 1979, Soviet Astron. Lett. 5, 140
0506	Arkhipova, V., Esipov, V. & Savel'eva, M. 1976, Soviet Astron. 20, 521
0508	Denisyuk, E. & Lipovetskii, V. 1977, Soviet Astron. Lett. 3, 3
0509	Denisyuk, E., Lipovetskii, V. & Afanasiev, V. 1976, Astrofizika 12, 665
0510	Dibai, E., Doroshenko, V. & Terebizh, V. 1976, Astrofizika 12, 689
0511	Doroshenko, V. & Terebizh, V. 1975, Astrofizika 11, 631
0512	Kopylov, I. et al. 1976, Astrofizika 12, 189
0513	Markaryan, B., Lipovetskii, V. & Stepanyan, J. 1980, Astrofizika 16, 5
0514	Markaryan, B., Lipovetskii, V. & Stepanyan, J. 1980, Astrofizika 16, 609
0515	Petrosyan, A., Saakyan, K. & Khachikyan, E. 1979, Astrofizika 15, 373
0516	Stephanyan, V. A. 1984, Astrofizika 21, 245
0517	Markaryan, B. E., Lipovetskii, V. A. & Stepanyan, V. A. 1984, Astrofizika 21, 419
0521	Kazaryan, M. A. 1987, Astrofizika 27, 399
0522	Lipovetskii, V. A. et al. 1989, Astrofizika 31, 425
0523	Kazaryan, M. & Kazaryan, E. 1987, Astrofizika 26, 5
0525	Denisyuk, E. & Lipovetskii, V. 1974, Astrofizika 10, 315
0526	Arakelyan, M., Dibai, E. & Esipov, V. 1972, Astrofizika 8, 177
0527	Arakelyan, M., Dibai, E. & Esipov, V. 1972, Astrofizika 8, 329

Table 2—Continued

ID	Bibliographic Reference
0528	Arakelyan, M., Dibai, E. & Esipov, V. 1970, Astrofizika 6, 39
0529	Arakelyan, M., Dibai, E. & Esipov, V. 1972, Astrofizika 8, 33
0530	Arakelyan, M., Dibai, E. & Esipov, V. 1970, Astrofizika 7, 177
0600	Giovanelli, R. & Haynes, M. 1981, private communication
0601	Giovanelli, R. & Haynes, M. 1985, ApJ 292, 404
0602	Williams, B. A. & Lynch, J.R. 1991, AJ 101, 1969
0604	Chincarini, G. L., Giovanelli, R. & Haynes, M. P. 1983, ApJ 269, 13
0605	Haynes, M. P. & Giovanelli, R. 1991, AJ 102, 841
0606	Gordon, D. & Gottesman, S. 1981, AJ 86, 161
0607	Freudling, W., Martel, H. & Haynes, M. P. 1991, ApJ 377, 349
0609	Krumm, N. & Salpeter, E. 1979, ApJ 228, 64
0610	Salzer, J. J. 1992, AJ 103, 385
0611	Krumm, N. & Salpeter, E. 1980, AJ 85, 1312
0612	Helou, G., Salpeter, E. & Krumm, N. 1979, ApJ 228, L1
0613	Peterson, S. 1979, ApJS 40, 527
0614	Olson, E. 1979, private communication
0615	Schombert, J. M. et al. 1992, AJ 103, 1107
0616	Williams, B. & Kerr, F. 1981, AJ 86, 953
0617	Haynes, M. & Giovanelli, R. 1984, AJ 89, 758
0618	Fontanelli, P. 1984, A&A 138, 85
0619	Bothun, G. et al. 1985, AJ 90, 2487
0620	Giovanardi, C. & Salpeter, E. 1985, ApJS 58, 623
0621	Scholl, J. & Grayzeck, E. 1984, PASP 96, 216
0622	Giovanelli, R. & Haynes, M. 1985, AJ 90, 2445.
0623	Bicay, M. & Giovanelli, R. 1986, AJ 91, 705 & 732
0624	Giovanelli, R. et al. 1986, AJ 92, 250
0625	Hoffman, G. L. et al. 1987, ApJS 63, 247
0626	Gavazzi, G. 1987, ApJ 320, 96
0627	Bicay, M. & Giovanelli, R. 1987, AJ 93, 1326
0628	Jackson, J. et al. 1987, AJ 93, 531
0631	Haynes, M. et al. 1988, AJ 95, 607
0633	Freudling, W., Haynes, M. & Giovanelli, R. 1988, AJ 96, 1791
0634	Hoffman, G. et al. 1989, ApJS 69, 65
0636	Sulentic, J. & Arp. H. 1983, AJ 88, 489
0637	Eder, J. et al. 1989, ApJ 340, 29

Table 2—Continued

ID	Bibliographic Reference
0639	Schneider, S. et al. 1990, ApJS 72, 245
0642	Giovanelli, R. & Haynes, M. 1989, AJ 90, 633
0643	Lewis, B. M., Helou, G. & Salpeter, E. E. 1985, ApJS 59, 161
0644	Lu, N. Y. et al. 1990, ApJ 357, 388
0645	Mould, J. R. et al. 1993, ApJ 409, 14
0647	Freudling, W., Haynes, M. P. & Giovanelli, R. 1992, ApJS 79, 157
0649	Wegner, G., Haynes, M. P. & Giovanelli, R. 1993, AJ 105, 1251
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