The Astronomical Journal, 130:319–336, 2005 July

STARS IN THE USNO-B1 CATALOG WITH PROPER MOTIONS BETWEEN 1.0 AND 5.0 ARCSECONDS PER YEAR

Stephen E. Levine
US Naval Observatory, Flagstaff Station, 10391 West Naval Observatory Road, Flagstaff, AZ 86001-8521; sel@nofs.navy.mil
Received 2005 February 1; accepted 2005 March 22

ABSTRACT

This paper examines a subset of objects from the USNO-B1 catalog with listed proper motions between 1″.0 and 5″.0 yr^{-1}. We look at the degree of contamination within this range of proper motions and point out the major sources of spurious high proper motion objects. Roughly 0.1% of the objects in the USNO-B1 catalog with listed motions between 1″.0 and 5″.0 yr^{-1} are real. Comparison with the revised version of Luyten's Half-Second Catalogue indicates that USNO-B1 is only about 47% complete for stars in this range. Preliminary studies indicate that there may be a dip in completeness in USNO-B1 for objects with motions near 0″.1 yr^{-1}. We also present two new stars with motions between 1″.0 and 5″.0 yr^{-1}, 36 new stars with confirmed motions between 0″.1 and 1″.0 yr^{-1}, several new common proper motion pairs, and the recovery of LHS 237a (VBs3).

Key words: astrometry — binaries: visual — catalogs — stars: kinematics

1. INTRODUCTION

Can the USNO-B1 catalog (Monet et al. 2003) be used to find previously unknown objects with large proper motions? Our motivation for examining the set of objects with large proper motions that are in the USNO-B1 catalog is twofold. First, we are looking to see whether we have found any objects with large proper motions that were missed in previous surveys; these could well be interesting in their own right and for studies of the local neighborhood. Second, we would like to understand how well the motion-finding algorithm used in the construction of USNO-B1 worked and how contaminated the high-motion sample is.

Because objects with large proper motions tend to be relatively nearby, they are often intrinsically interesting astronomically. Given this consideration, we would like to know what fraction of objects in USNO-B1 with listed large motions are actually real and how we can go about selecting clean samples of objects with large motions. In the construction of USNO-B1, Monet et al. (2003) erred on the side of retaining dubious objects. Some of the lessons learned here about cleaning up subsamples should be readily applicable to many other subsets of objects in USNO-B1.

Gould (2003) has already examined in some detail how well USNO-B1 has done in finding previously known objects that are in the revised version of Luyten's Two Tenths Catalogue (NLTT; Luyten 1979b; Gould & Salim 2003; Salim & Gould 2003) (which contains stars with $\mu > 0''.180$ yr^{-1}). Only 6% of the NLTT stars are missing from USNO-B1, and an additional 4% have what they term large errors (Gould 2003). Hence, their conclusion is that USNO-B1 is roughly 90% complete, with incompleteness rising at both the brighter and fainter ends. They also find that incompleteness increases at larger proper motions (it is roughly 30% at $\mu = 1''$ yr^{-1}) and near the Galactic plane. The proper-motion values given in USNO-B1 are generally in agreement with those in the NLTT.

The aim here is complementary. We are looking at the contents of the catalog and trying to assess what fraction of the moving objects in the high-motion portion of the catalog are in fact real objects. We also wish to know whether the derived motions are reasonable. For the entries in the catalog that correspond to non-real objects, we hope to gain some understanding of their characteristics and hence learn how to exclude them in the future.

USNO-B1 is an all-sky catalog that has been compiled from digitizations of 7435 Schmidt plates taken over the last 50 years (see Table 1 for a summary of the plate material that was used). Every point on the sky is covered at several epochs and at several wavelengths, making it possible to construct a catalog that includes positions, proper motions, optical colors, star-nonstar discriminators, and the appropriate uncertainties (Monet et al. 2003). This catalog is the natural successor to the USNO-A series of catalogs (Monet et al. 1996, 1998) and should fix a number of problems associated with them. Because of the nature of the plates, the images (and hence the catalog) are best for fainter objects (in the magnitude range $V = 14-22$). The Tycho-2 catalog (Høg et al. 2000) was copied in for completeness at brighter magnitudes. (Tycho-2 is complete at the 99% level down to $V_T = 11$.) In regions in which confusion is not the limiting factor, the catalog is complete to photographic magnitudes $B_{\rm phot} \approx 21$ and $R_{\rm phot} \approx 20$ (Monet et al. 2003; Munn et al. 2004).

It is prudent to note that USNO-B1 is an inclusive catalog, by which we mean that in the construction of USNO-B1, Monet et al. (2003) erred on the side of including all possible objects, real and false. The aim was to avoid removing real objects during the assembly of the catalog and to give users some flexibility in designing their own selection algorithms. One of the results, however, is that some fraction of the objects in the catalog are either contaminated or completely false, and it is desirable to avoid selecting these entries.

One of the key improvements of this catalog with respect to its predecessors is the determination of proper motions for all objects in the catalog. Proper motions provide important information about the objects and about the structure of our Galaxy. In addition, the proper motion can be a very useful discriminant when trying to find objects meeting specific criteria (e.g., objects that are close to us or those in the halo often have large apparent proper motions). To see this, one needs only to look at how fruitful studies have been of the objects in the catalogs of high proper motion stars of Luyten (1979a [Luyten Half-Second Catalogue (LHS)], 1979b) and Giclas et al. (1971, 1978) (e.g., proper-motion information has aided in the selection of nearby objects for study), as well as how much has been learned about things like the structure of the local neighborhood in the Galaxy from the *Hipparcos* (Perryman et al. 1997) and Tycho-2 (Høg et al.

TABLE 1
Photographic Source Material Used in USNO-B1

Survey	Emulsion	Wavelength (nm)	Color[a]	Declination[b] (deg)	Epoch
POSS I	103a-O	350–500	*B*	−30 to +90	1949–1965
POSS I	103a-E	620–670	*R*	−30 to +90	1949–1965
POSS II	IIIa-J	385–540	*B*	0 to +90	1985–2000
POSS II	IIIa-F	610–690	*R*	0 to +90	1985–2000
POSS II	IV-N	730–900	*I*	0 to +90	1989–2000
SERC-J	IIIa-J	395–540	*B*	−90 to −20	1978–1990
SERC-EJ	IIIa-J	395–540	*B*	−15 to −5	1984–1998
ESO-R	IIIa-F	630–690	*R*	−90 to −35	1974–1987
AAO-R	IIIa-F	590–690	*R*	−90 to −20	1985–1998
SERC-ER	IIIa-F	590–690	*R*	−15 to −5	1979–1994
SERC-I	IV-N	715–900	*I*	−90 to 0	1978–2002
SERC-I[c]	IV-N	715–900	*I*	+5 to +20	1981–2002

Note.—The contents of this table follow from Table 1 of Monet et al. (2003).
[a] The colors listed here are rough photographic colors. They correspond to the magnitudes given in USNO-B1.
[b] The range in declination of the field centers in each survey used in the construction of USNO-B1.
[c] These fields are an extension of the SERC-I that was done to fill in fields that were not taken during the POSS II IV-N survey.

2000) catalogs (e.g., Dehnen & Binney 1998; Olling & Dehnen 2003).

The proper motions in the USNO-B1 catalog have some known idiosyncrasies. Among these are that the motions given are strictly relative proper motions, since least-squares has set the mean motion for stars of roughly 18th magnitude to zero on a field-by-field basis. The component of solar motion relative to this zero point is small when compared with the motions we are interested in here.

Both Munn et al. (2004) and Gould & Kollmeier (2004) have produced improved proper-motion catalogs for the region contained in the intersection of the Sloan Digital Sky Survey Data Release 1 (SDSS DR1; Abazajian et al. 2003) with USNO-B1. In both cases, the contamination problem has largely been dealt with by using SDSS DR1 data as truth and recalibrating the overlapping region of USNO-B1. In addition, both catalogs use sources external to our Galaxy, such as other galaxies (Munn et al. 2004) or quasars (Gould & Kollmeier 2004) found in the SDSS sample, to put the revised proper motions onto an absolute scale. Munn et al. (2004) note, and we concur, that as the number of detections of an object in USNO-B1 decreases from the maximum possible of five, the likelihood that the object is contaminated or totally false increases dramatically (see Fig. 11 of Munn et al. 2004).

Section 2 briefly explains the moving-object detection algorithm used in the construction of the USNO-B1 catalog. Sections 3 and 4 discuss how we went about finding fast-moving objects in the catalog, what portion of the listed objects are real, and what additional objects we found along the way. Notes about specific objects are given in § 5. Section 6 briefly discusses a comparison of the high proper motion samples in LHS and USNO-B1. The paper concludes with a bit of discussion.

2. MOVING-OBJECT DETECTION ALGORITHM

In the construction of USNO-B1, finding objects with large proper motions was handled as a special case of measuring proper motions for all objects. (The discussion here closely follows Monet et al. [2003], which should be referred to for more complete details.) The search for moving objects can be broken down into two parts: the first part was to find objects that do not move, or move only a little bit, and the second was to look for objects with large motions.

In the catalog construction, the sky was broken up into rings of $0\overset{\circ}{.}1$ width in declination. Each ring initially contained the complete set of detections from all the plates (at all epochs) that intersected that ring. Although magnitudes in USNO-B1 are referred to as being of first or second epoch, in reality the second epoch can cover a wide range of time; for example, for the second-epoch Palomar Observatory Sky Survey (POSS II), the three "second-epoch" plates could cover as much as 10 or 15 yr. A $3''$ aperture was moved through each ring. The cases in which only a single detection fell within the aperture were ignored at this point. If detections from one or more first-epoch surveys and one or more second-epoch surveys were within this aperture, then these detections were matched up as an object and removed from the lists. This should have matched up detections for objects that move less than about 60 mas yr^{-1}.

Only those detections that were not matched up under the slow-motion search radius were passed on to the high proper motion search routine. For this step, when searching a band in declination, the two adjoining bands were also included, so that in fact the search regions were $0\overset{\circ}{.}3$ in width and in steps of $0\overset{\circ}{.}1$ in declination. The search aperture was expanded to $30''$. Within the aperture, all combinations of second-epoch detections were fit for linear motion. If a fit was significant, then the motion was extrapolated back to the first-epoch surveys. A search around the predicted point was done using a search radius that scaled with the size of the extrapolated error ellipse. All possible combinations with first-epoch observations were followed up. If the best fit had a standard deviation less than $0\overset{''}{.}4$ in the tangent-plane coordinates and a motion less than $10''$, $3''$, or $1''$ yr^{-1} for five, four, or three survey detections, respectively, then the object was considered matched, and the detections were removed from the lists.

After the explicit search for high-motion objects, a last effort was made to match up any remaining objects. A search aperture of $20''$ was used, and all combinations of five, four, three, and two survey detection objects were examined. The first groups of observations with a standard deviation of less than $5''$ in both tangent-plane coordinates were considered matched, called an object, and removed from the detection lists. Only a small fraction of the objects in USNO-B1 came from this step in the processing. Presumably, many matches made at this stage will look like high-motion objects.

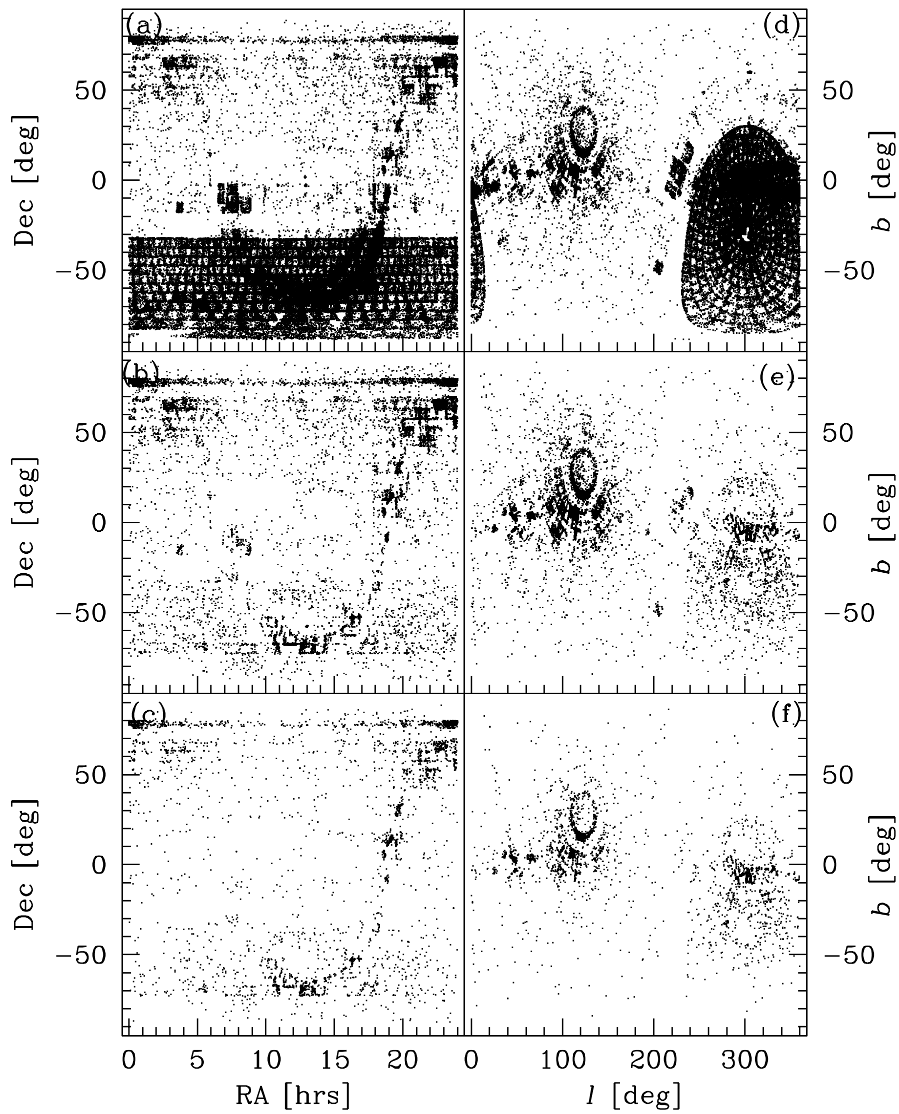

FIG. 1.—Positions of candidate objects shown in equatorial (*a, b, and c*) and Galactic (*d, e, and f*) coordinates. In (*a*) and (*d*) are all the objects in USNO-B1 with $1'' \le \mu \le 5''$ yr^{-1}. The points in (*b*) and (*e*) are those remaining after basic sanity checks have been applied ($N_{\rm FitsPts} \ge 4$, $\sigma_\alpha < 999$ mas, and $\sigma_\delta < 999$ mas). The points in (*c*) and (*f*) are those remaining after a subsequent cut on the second-epoch red magnitude ($0 \le R_2 \le 18.0$).

It is useful to point out that no use was made in the matching process of magnitude data or star-nonstar separator information. After the object matching was done, duplicate objects were removed (Monet et al. 2003).

3. SELECTING REAL HIGH-MOTION OBJECTS

Retrieving real objects with large proper motions from USNO-B1 is not quite as simple a task as just asking for all the catalog objects with motions in a given range. To demonstrate this, we chose to search for previously unknown objects with proper motions (μ) between 1ʺ0 and 5ʺ0 yr^{-1}.

We began by requesting all objects in USNO-B1 with $1\overset{''}{.}0 \le \mu_{\rm total} \le 5\overset{''}{.}0$. This netted a total of 187,134 objects (see Figs. 1*a* and 1*d*). We then applied some basic sanity checks. We required each object to be detected in four or five of the five possible surveys ($N_{\rm FitsPts} \ge 4$) used in the construction of USNO-B1. This reduced the number of objects to 186,554. This also had the effect of removing all the Tycho-2 stars that were added in, since the number of survey detections for these stars was set to zero in the catalog. Then we required that they have position errors less than 0ʺ999 in both right ascension and declination ($\sigma_\alpha < 999$ mas and $\sigma_\delta < 999$ mas). This decreased the number of objects to be considered to 11,019 (see Figs. 1*b* and 1*e*). Further limiting the sample by applying limits to the second-epoch photographic *R* magnitude ($0 \le R_2 \le 18.0$) brought the total down to 3348 objects (see Figs. 1*c* and 1*f*). Not too surprisingly, after the application of the basic sanity checks, most of the potential objects lie near the Galactic plane and near the celestial poles (where the plate overlap regions grow larger).

This remaining sample of 3348 objects was next examined by eye. The catalog data around each potential high-motion object were plotted, and a decision was made as to the likelihood that this was a real object with a large proper motion. Typical things to look for and select against were diffraction spikes and other artifacts caused by bright stars (see Fig. 2, *middle*) and extended objects. These all tended to produce groups of objects in the catalog that were closely clumped or showed obvious large-scale structure (like the linear arms of the diffraction spikes or the arcs of the halos of bright star ghost images). From the sample, 951 objects passed this somewhat subjective test. Of the other 2397 potential objects, only seven turned out to be real, already known objects that we failed to recognize, 672 objects were rejected as

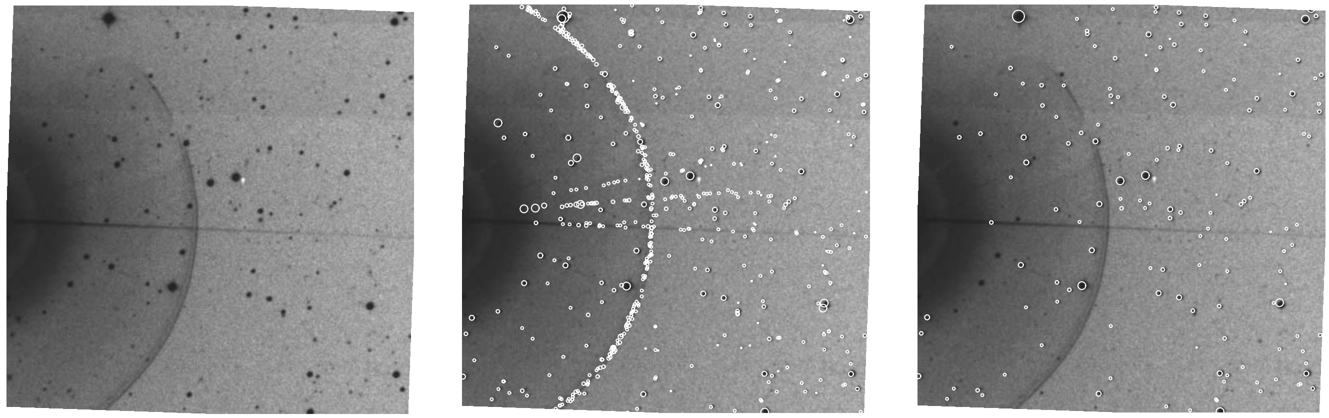

FIG. 2.—*Left:* POSS II IIIa-F image of a field near a bright star. *Middle:* Same image, with all 704 USNO-B1 objects that lie in the field overplotted. *Right:* Only those 163 USNO-B1 objects that satisfy the criteria $|R_1 - R_2| \leq 1$ mag, $\sigma_{\rm position} \leq 500$ mas, and $\sigma_\mu \leq 100$ mas yr^{-1} are overplotted.

TABLE 2
KNOWN UNFLAGGED OBJECTS WITH MOTIONS BETWEEN 1.″0 AND 5.″0 yr^{-1}

USNO-B ID	μ[a] (arcsec yr^{-1})	θ[a] (deg)	R.A. (hr)	Decl. (deg)	l (deg)	b (deg)	B_2[b] (mag)	R_2[b] (mag)	I_2[b] (mag)	AltID[c]
LHS Objects[c]										
0121-0045493	1.03	142.7	09.28481	−77.8234	292.5559	−19.5296	14.38	12.11	10.14	263
0185-0249424	1.16	338.8	12.47781	−71.4644	301.1041	−8.6735	15.15	12.72	11.10	328
0185-0249438	1.18	338.9	12.47866	−71.4656	301.1083	−8.6743	16.48	14.72	12.19	329
0222-0190851	2.14	136.6	07.88561	−67.7924	280.2038	−19.4322	14.53	13.77	13.02	34
0289-0005722	1.11	93.7	00.82473	−61.0424	303.3558	−56.0842	13.03	11.50	10.05	124
0560-0118956	1.67	351.6	07.76069	−33.9311	248.9038	−4.6752	17.40	15.67	15.60	237a
1611-0086923	1.91	256.0	10.61735	+71.1830	136.8566	42.1223	17.31	16.14	15.47	285
1688-0078160	1.16	63.0	21.68144	+78.8227	114.2010	19.3348	14.77	12.91	10.89	514
1695-0027702	1.20	136.2	05.63677	+79.5221	133.7772	23.4244	19.93	17.26	13.77	207
LSR02 Objects[c]										
0872-0489450	1.01	214.9	18.16393	−02.7953	25.6449	7.9460	17.29	15.42	13.03	1809−0247
1042-0321115	1.00	235.4	17.97303	+14.2939	40.0841	18.0868	17.24	16.35	15.57	1758+1417
1068-0333681	1.00	117.0	17.92576	+16.8164	42.2300	19.7325	17.00	14.84	12.49	1755+1648
1207-0075220	1.10	148.5	05.08660	+30.7256	173.6030	−6.2643	18.12	16.33	14.73	0505+3043
1325-0110870	1.54	159.6	04.33114	+42.5585	158.6564	−5.4068	20.26	17.35	14.43	0419+4233
1491-0005115	1.47	217.9	00.19217	+59.1445	117.8254	−3.3310	16.70	14.85	11.38	0011+5908
1491-0151160	1.01	173.5	05.25859	+59.1883	151.5063	11.9084	19.97	16.60	14.35	0515+5911
Assorted Objects										
0143-0198407	1.04	143.8	21.25418	−75.6977	317.0296	−34.8155	16.13	13.44	11.24	SC, P
0258-0023144	1.06	140.9	03.71595	−64.1322	278.5502	−44.0139	17.15	15.04	12.66	SC
0279-0008695	1.10	82.3	00.87091	−62.0317	302.7644	−55.0962	19.65	16.72	13.33	SIPS
0300-0785973	1.42	165.4	20.20883	−59.9476	337.1327	−33.3064	16.63	15.37	14.86	P
0358-0039309	1.07	168.6	05.00438	−54.1077	261.9192	−37.7847	19.88	17.61	15.45	P
0393-0108806	1.00	326.5	08.50019	−50.6624	267.4696	−6.7440	15.67	13.76	12.52	L
0443-0286531	1.31	281.9	12.46300	−45.6879	298.6155	16.9854	16.37	14.49	13.16	L
0477-0913359	1.03	171.7	19.94933	−42.2729	357.5855	−29.5013	18.72	17.03	13.71	R, P
0500-0227632	1.52	229.4	10.80405	−39.9353	278.6839	17.0658	18.58	15.93	12.66	D
0510-0792885	1.07	109.6	22.24298	−38.9852	2.7952	−55.3720	16.39	15.05	15.09	P, O
0533-0785516	1.29	184.6	19.27960	−36.6349	1.3299	−20.5417	18.08	15.76	14.85	L
0847-0018930	1.04	67.3	02.08655	−05.2983	165.0326	−61.9816	18.86	17.86	17.24	O

[a] The proper motions are relative to the reference frame established by the YS4.0 catalog stars (see Monet et al. 2003 for details).

[b] Photographic magnitudes from the second-epoch Schmidt surveys (POSS II in the north and SERC-J, SERC-EJ, AAO-R, SERC-ER, and SERC-I in the south).

[c] For the LHS objects, the AltID is the LHS (Luyten 1979a) catalog number. For the LSR02 objects, the AltID is the ID given in LSR02. For the assorted objects, the source is as follows: (D) Delfosse et al. 2001; (L) Lépine 2005; (O) Oppenheimer et al. 2001; (P) Pokorny et al. 2003, 2004; (R) Reylé et al. 2002; (SC) Hambly et al. 2004; (SIPS) Deacon et al. 2005.

TABLE 3
OBJECTS WITH MOTIONS LESS THAN 1.″0 yr^{-1}

USNO-B ID	μ^a (arcsec yr^{-1})	θ^a (deg)	R.A. (hr)	Decl. (deg)	l (deg)	b (deg)	$B_2{}^b$ (mag)	$R_2{}^b$ (mag)	$I_2{}^b$ (mag)	J^c (mag)	H^c (mag)	$K_s{}^c$ (mag)	Class[d]	AltID[e]
0338-0848607	0.31	71.8	23.41315	−56.1517	325.1606	−57.0780	12.36[f]	10.41	10.06	9.36	8.74	8.59	d	NLTT 9526
1180-0331814	0.09	210.6	18.08276	+28.0142	54.2204	21.8639	14.93	14.45	14.05	13.46	13.24	13.12	sd	...
1686-0094267	0.40	75.0	23.96100	+78.6681	120.2067	16.0819	17.64	17.46	17.55	16.31	15.49	15.68	wd	...
1698-0001063	0.09	63.0	00.23815	+79.8183	121.2218	17.0701	19.18	17.29	16.46	14.89	14.30	14.05	d	...

[a] The proper motions are relative to the reference frame established by the YS4.0 catalog stars (see Monet et al. 2003 for details).
[b] Photographic magnitudes from the second-epoch Schmidt surveys (POSS II in the north and SERC-J, SERC-EJ, AAO-R, SERC-ER, and SERC-I in the south).
[c] Near-IR magnitudes are from the 2MASS final release point source catalog (Cutri et al. 2003).
[d] (d) dwarf; (sd) subdwarf; (wd) white dwarf.
[e] (NLTT) Luyten 1979b.
[f] Magnitude taken from another USNO-B1 catalog entry, which was made up of additional detections of this object.

being caused by proximity to a bright star or a bright star's diffraction spikes, and 1725 objects were misidentifications and mismatches caused by a variety of forms of confusion (dense field, extended object[s] that created multiple detections, etc.). All seven missed real objects fell into the latter category.

Of the 951 objects reaching this stage, 177 were stars that were already flagged in USNO-B1 as being known proper-motion objects, leaving us with 774 candidates to check. The objects that were left were presumed to be decent candidates for being new high proper motion stars. Images from several epochs were extracted from the USNO Image and Catalogue Archive,[1] and the images of each potential object were again looked at by eye. Of these, 741 objects turned out to be confused, diffraction spikes, near a bright star, or extended objects, leaving only 33 real, moving stars. To this we added one more star found during preliminary testing.

The 34 real, unflagged moving objects were then checked against catalogs of known objects. Nine were found to be LHS objects that somehow did not get flagged in the construction of the catalog (including LHS 237a, which we have recovered, and about which we have more to say below). (As a side note, it is worth pointing out that just by counting the number of objects in the USNO-B1 catalog with the "known proper-motion star" bit set shows that a fair fraction of these objects that were already known did not get flagged properly in the catalog.) Seven turned out to have been found recently by Lépine et al. (2002, hereafter LSR02) and three more or less simultaneously by us and Lépine (2005). One was a brown dwarf found by the Deep Near-Infrared Survey (DENIS; Delfosse et al. 2001; DENIS-P J104814.7−395606.1). One was a halo dwarf found by Oppenheimer et al. (2001; WD 0205−053). Two other objects were recently found by Hambly et al. (2004) using SuperCOSMOS (SCR 0342−6407 and SCR 2012−5956). Three were found by Pokorny et al. (2003, 2004; LEHPM 4051, 3861, and 4466) and one by Reylé et al. (2002; APMPM J1957−4216); one object was recently found by Deacon et al. (2005; SIPS 0052-6201) (see Table 2).

[1] See http://www.nofs.navy.mil/data/fchpix.

Of the six remaining objects, four are moving objects with incorrect proper motions in USNO-B1; the objects are moving, just more slowly than the catalog indicates. One of these objects is NLTT 9526, and the other three appear to be new (see Table 3). The final two objects are (to the best of our knowledge) new, high proper motion stars (see Table 4). The 30 objects with proper motions larger than 1″ are plotted in Figures 3*a* and 3*b* as triangles for the new objects and three-pointed stars for previously known but unflagged objects. The four with proper motions less than 1″ are plotted as hexagons for the three new ones and a six-pointed star for the one already known. Finder charts showing the plate material for the two new high proper motion objects are given in Figures 4 and 5. In all, 6%, or 213, of the 3348 objects are stars with motions between 1″ and 5″ yr^{-1}.

In the 774 fields that were examined by eye, 71 of them had a total of 82 other objects with apparent proper motions. These are discussed in more detail in § 4 on serendipitous objects.

3.1. *How to Speed Up the Winnowing Process*

Did we learn anything from the winnowing process described above that would help us to more easily generate clean(er) subsamples out of USNO-B1? Without using information from outside of USNO-B1, the following simple things can be done quickly to help preselect for objects that are likely to be real.

We can specify that objects have positional errors less than 999 mas in both right ascension and declination. This reduces the sample by over an order of magnitude, from $\sim 10^5$ to 10^4 objects. In Figure 6 are plotted the distributions of position and motion errors of the 3348 objects examined by eye. We see that almost all the real objects have a total positional error less than 350 mas. The false objects have a much wider distribution. An optimal cut is probably closer to 350–500 mas.

TABLE 4
NEW OBJECTS WITH MOTIONS BETWEEN 1.″0 AND 5.″0 yr^{-1}

USNO-B ID	μ^a (arcsec yr^{-1})	θ^a (deg)	R.A. (hr)	Decl. (deg)	l (deg)	b (deg)	$B_2{}^b$ (mag)	$R_2{}^b$ (mag)	$I_2{}^b$ (mag)	J^c (mag)	H^c (mag)	$K_s{}^c$ (mag)	Class[d]
0484-0243338	1.20	282.6	11.13220	−41.5980	282.9517	17.2231	16.88	14.27	13.04	12.19	11.69	11.47	sd
0867-0249298	1.08	226.9	11.62128	−03.2934	269.6031	54.7070	16.23	14.12	12.35	10.87	10.36	10.09	d

[a] The proper motions are relative to the reference frame established by the YS4.0 catalog stars (see Monet et al. 2003 for details).
[b] Photographic magnitudes from the second-epoch Schmidt surveys (POSS II in the north and SERC-J, SERC-EJ, AAO-R, SERC-ER, and SERC-I in the south).
[c] Near-IR magnitudes are from the 2MASS final release point source catalog (Cutri et al. 2003).
[d] (d) dwarf; (sd) subdwarf.

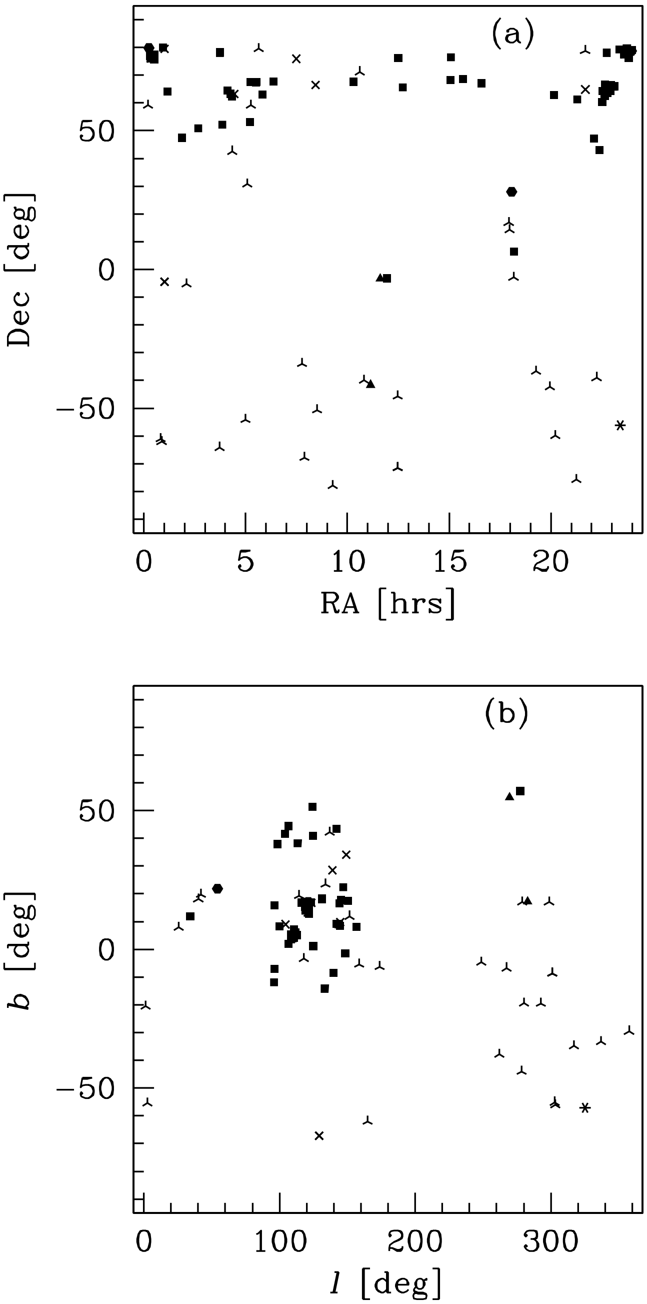

FIG. 3.—High-motion objects that made it all the way through the winnowing process. Triangles and three-pointed stars represent objects with proper motions larger than 1″ that are, respectively, new and known but not flagged in USNO-B1. Hexagons and six-pointed stars represent objects listed in USNO-B1 with large motions that actually have motions less than 1″ and are new and previously known, respectively. Squares and crosses represent new and known serendipitous objects, respectively. Panels (*a*) and (*b*) show the objects in equatorial and Galactic coordinates, respectively.

The next simple cut that we can apply is to the proper-motion error and is based on Figure 6 (*right panels*). This shows that most of the real high-motion objects have a proper-motion error less than 12 mas yr^{-1}, while the false objects have a larger secondary hump at 30 mas yr^{-1}.

Another thing that can be done is to insist that objects be detected in at least four surveys. The benefit from this one is a little less clear. For the objects with large proper motions, insisting on detection in four or five surveys out of a possible five only removed 580 objects out of 187,134 (or 0.3% of the total) in the original search. It is also reasonable to presume that the position and proper-motion errors will be anticorrelated with the number of detections. On the other hand, this is a very quick and simple culling criterion to implement, as the number of detections is carried as an integer in each object's catalog record. In addition, for objects with lower motions, there will be more catalog objects with three or two detections; hence, this will likely be more useful for searches of things other than the high proper motion objects.

It is also instructive to be aware of where in the sky you are looking. In Figure 1*a* there is a change across the line of $\delta \approx -33°$ that is largely due to the difference in the number of first-epoch plates and the epoch difference between the first and second epochs. North of this line, POSS I provides two plates at a mean epoch near 1950. South of this line, the first epoch is a single red plate with a mean epoch around 1980. There is a much shorter southern temporal baseline, and there is one fewer plate per field. Internal tests done during the construction of USNO-B1 showed that each additional plate dramatically reduced the false positive rate when looking for high-motion objects (D. Monet 2002, private communication). This is not particularly surprising, as the motion is presumed to be almost linear, and it becomes increasingly unlikely that N random points will be nearly colinear as N increases.

We can now apply magnitude-related criteria. This was not done in the original search but is a simple test that enforces an additional degree of consistency on the data. Requiring that the difference between the first-epoch red magnitude (R_1) and the second-epoch red magnitude (R_2) be less than 0.5 (or 1.0) mag helps to exclude improperly matched detections.

We redid the search for high proper motion objects, this time applying all the criteria listed in this section. We made one modification, which was to allow zero, four, or five plates to be accepted. (This meant we included the Tycho-2 stars, which are the only ones in the catalog with a value of 0 plates set.) After applying cuts based solely on the position and motion errors, the sample size is reduced to 8576 and includes 196 of 207 known and flagged high proper motion objects (not including Tycho-2 objects). Once magnitude-related cuts are applied, the data volume is reduced to 1478 objects, where $|R_1 - R_2| < 0.5$ mag (or 2556 for a magnitude difference of 1), including 137 (168) of the already known high proper motion objects. Finally, when we limited our list to R_2 brighter than magnitude 18 (the same de facto restriction we used in generating our original list), we were left with 688 (or 1090) objects out of an original 187,134 (a reduction of roughly 270 times). Of the 688 (1090) objects, all 174 known Tycho-2 stars are included, bringing down the number to search to 514 (916). Included are 135 (163) stars that were flagged as previously cataloged high proper motion objects (from either Giclas's or Luyten's catalogs).

We can see that we have lost 72 (44) flagged high-motion objects, since there were 207 of them found in the original extraction, which only had a limit on the value of the proper motion. Of the 72 (44), 23 fall below the R_2 brighter than 18.0 mag cutoff. Three more had position errors larger than 350 mas in each coordinate. Another seven had proper-motion errors larger than 12 mas yr^{-1}. An additional 39 (11) were removed by the requirement that the difference in R magnitudes be less than 0.5 (1.0) mag. Magnitude-related selection criteria removed the bulk of the deleted real objects, 62 (34) out of 72 (44), leaving only 10 that were caught by the position and/or motion error criteria. The magnitude criteria also removed a very large fraction of the false objects. These numbers imply that 65% (79%) of the high-motion objects make it through this set of culls, and that as we make

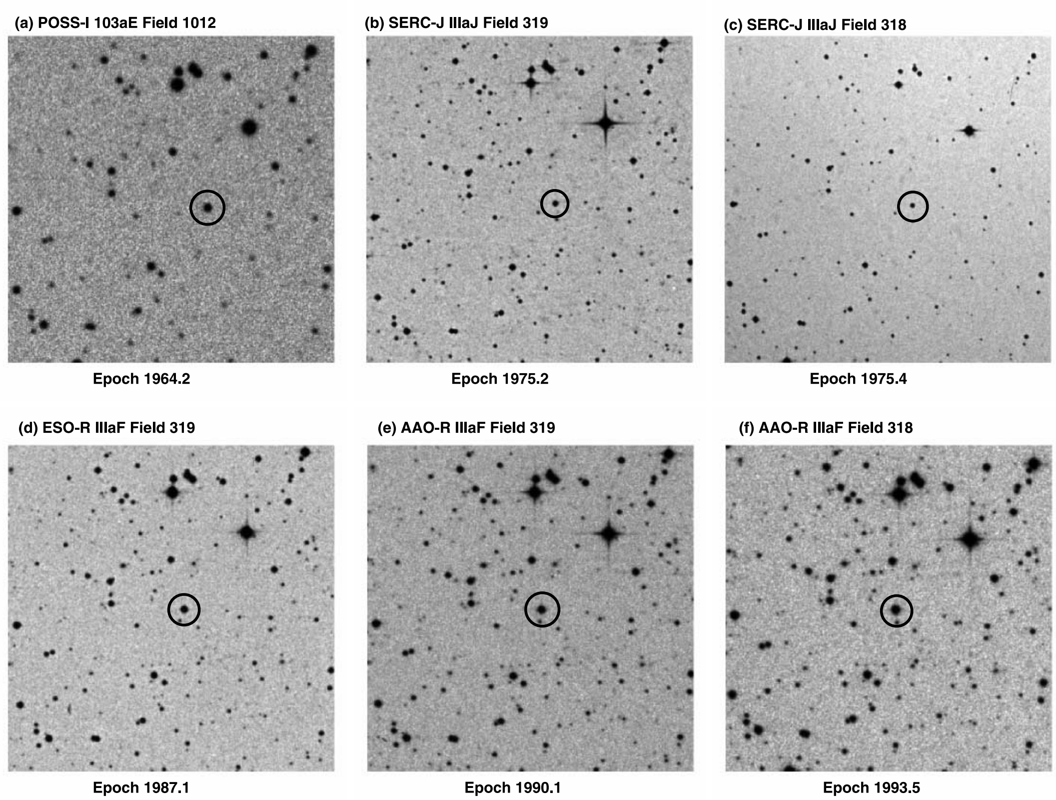

Fig. 4.—Finder charts showing the motion of object USNO-B1 0484-0243338 ($\alpha_{2000} = 11^{\rm h}07^{\rm m}55\overset{\rm s}{.}9$, $\delta_{2000} = -41°35'53''$) on the six available Schmidt plates. North is up, east is to the right, and all images are $6' \times 6'$ in size.

the magnitude match tighter, while we lose more real objects, we also lose a larger number of not-real objects. Comparing the samples left after the two magnitude cuts, we are left with only 56% of the candidate stars to check versus retaining 82% of the known real high-motion stars in the larger ($|R_1 - R_2| < 1.0$) subsample.

4. SERENDIPITOUS NEW OBJECTS

As noted above, 774 fields, each $6' \times 6'$, were examined by eye. Of these, 71 contained 82 objects that appeared to show proper motions by simple examination of the images in sequence. Because these objects were not the nominal objective of the search, initially there was no systematic effort to look for other moving objects in each field. Once several were noticed, an effort was made to keep track of them, so in fact the 71 fields were found among a subset of the 774 fields checked. Taking a conservative approach, we treat 774 as an upper bound on the total area examined.

Each field covers 0.01 deg^2, meaning we checked 7.74 deg^2. Of the possible 82 moving objects, two were found to be not moving on more careful examination, leaving 80. Within the set of 80, there were two Tycho-2 stars (4492 01044 1 and 4133 00625 1) and three stars that were flagged as already known high proper motion stars (with motions of $0\overset{''}{.}218$, $1\overset{''}{.}307$, and $0\overset{''}{.}263$ yr^{-1}). Thirteen of the stars have proper motions greater than $0\overset{''}{.}180$ yr^{-1}, 20 greater than $0\overset{''}{.}150$ yr^{-1}, and 46 greater than $0\overset{''}{.}100$ yr^{-1}. The positions of these objects are plotted in Figure 3, where the new objects are shown as squares and the previously identified objects as crosses. The distribution of proper motions is shown in Figure 7.

Under the simplest assumptions, this implies that there could be at least 69,000 objects with motions greater than $0\overset{''}{.}180$ yr^{-1} and on the order of 240,000 objects with detectable motions above $0\overset{''}{.}1$ yr^{-1}. The number of objects with motion greater than or equal to $0\overset{''}{.}180$ yr^{-1} is in line with the number of objects already in the NLTT (just under 60,000), which has a nominal lower detection threshold of $0\overset{''}{.}180$ yr^{-1}.

4.1. *Position and Proper-Motion Determination*

A quick look at the USNO-B1 catalog data for these serendipitous objects led to the realization that about half of the objects had incomplete or incorrect USNO-B1 entries: detections were mismatched or missing. As a result, we decided to redo the position and proper-motion determinations by hand for all these objects.

We extracted digitized Schmidt plate material for fields around each of the 80 objects and recomputed the positions and proper motions of the moving objects. Because the scans of the Schmidt plates served by the USNO Archive server have not been merged spatially, if a pointing lies in the overlap region of two plates, the image data from *both* are available. For many of these serendipitous objects, there are more than five images of the field available (from a minimum of four plates to a maximum of 14, with a mean of eight plates per field; 65 out of 80 of the objects were in plate overlap regions).

In each field, a moderate number of nearby stars (within several arcminutes of the object of interest) with no detectable motion (both by eye and per the USNO-B1 catalog information) were chosen as reference stars. We measured their centroids and the centroid of the moving object and then did a linear plate solution for each set on each plate. To the measured positions of the moving object we fit a straight line for position and proper motion.

Among the caveats to keep in mind is that many objects in USNO-B1 have proper motions of zero, with zero errors. This

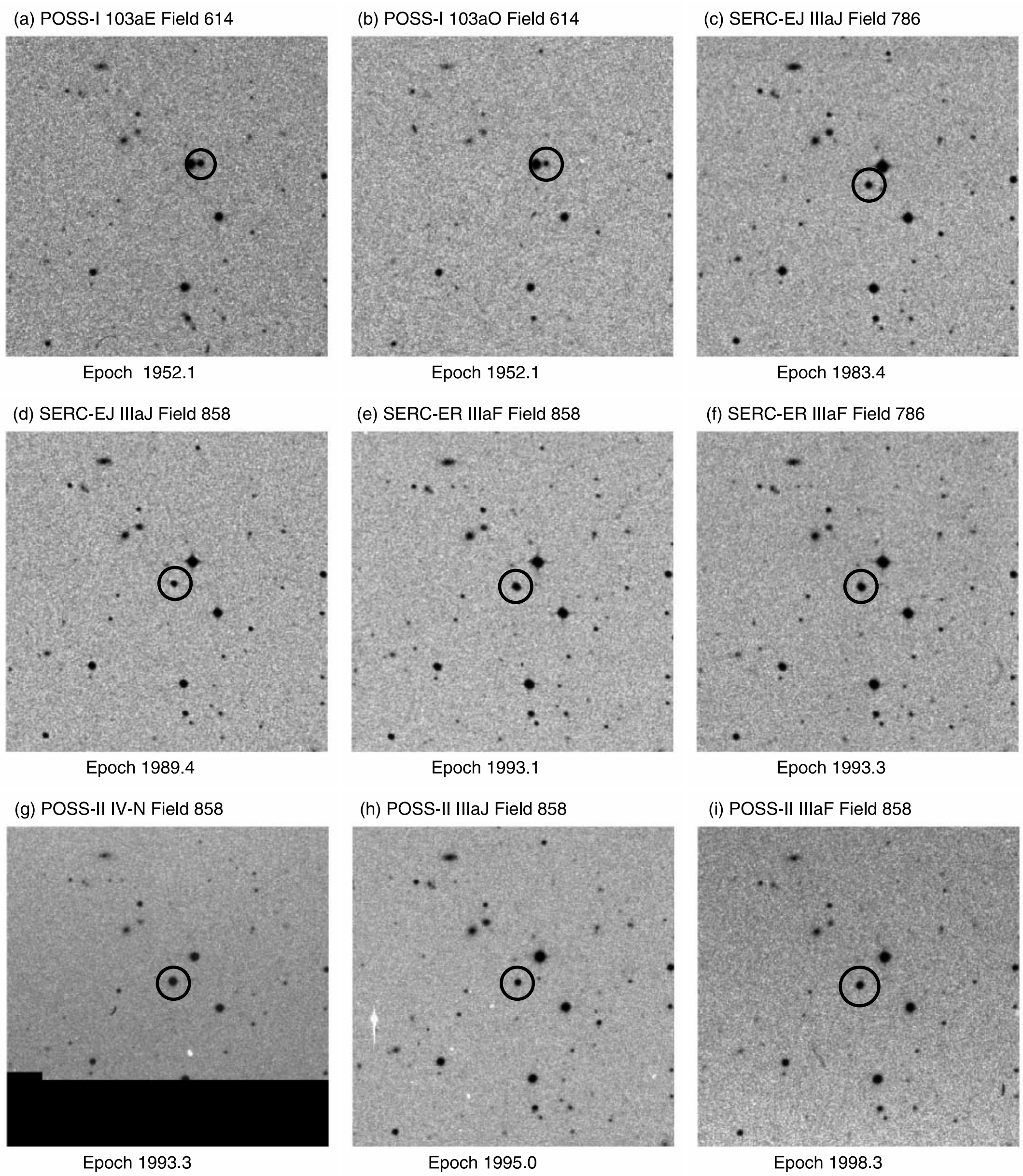

Fig. 5.—Finder charts showing the motion of object USNO-B1 0867-0249298 ($\alpha_{2000} = 11^{\rm h}37^{\rm m}16\overset{\rm s}{.}6$, $\delta_{2000} = -03°17'37''$) on the nine available Schmidt plates. North is up, east is to the right, and all images are $6' \times 6'$ in size.

indicates that the fit for position and motion was not very good. No new work has been done to correct for the degradation in the astrometric solutions on the Schmidt plates out near the edges. (See § 4 and Fig. 1 of Monet et al. [2003] for their discussion of the fixed pattern astrometric errors on the plates; these rise to the order of arcseconds out near the plate edges.) Finally, it is important to remember that the proper motions listed in USNO-B1 are relative proper motions, and the zero point was set by the least-squares solutions for the plates at around magnitude 18 (Monet et al. 2003).

4.2. *Results from the Serendipitous Objects*

Of the 80 objects, 41 had good solutions in USNO-B1. By virtue of having redone the fits for all the objects, we had a reference sample for the astrometry. The results of our hand fits were in good agreement with the numbers given in USNO-B1. This gave us a certain degree of confidence in the results for the other 39 for which USNO-B1 does not have complete or correct data.

Not all the 39 objects for which we redid the solutions had bad data in USNO-B1. Looking at objects for which the USNO-B1 solution was based on three out of five possible plates ($N_{\rm Fit\,Pts} = 3$), for six of them USNO-B1 has reasonable positions and proper motions, and for another 10 (14) USNO-B1 has a position that is correct to within $2''$ ($4''$). For objects with $N_{\rm Fit\,Pts} = 4$, all eight are mismatched. For objects with $N_{\rm Fit\,Pts} = 2$, all eight have positions at least $5''$ away from the recomputed positions. In all these cases, when determining the position and motion by hand, we found the objects on at least four plates. So, it would be fair to say that USNO-B1 has reasonable positions and motions for 47 out of the 80 objects (59%) and decent positions for 10 more (71%).

These numbers are not as complete as we might hope, but they are actually not out of line with the completeness seen by Gould (2003), although the sample used does not contain many stars with motions slower than 150 mas $\rm yr^{-1}$. Our own check against the complete revised LHS (Bakos et al. 2002) similarly shows USNO-B1

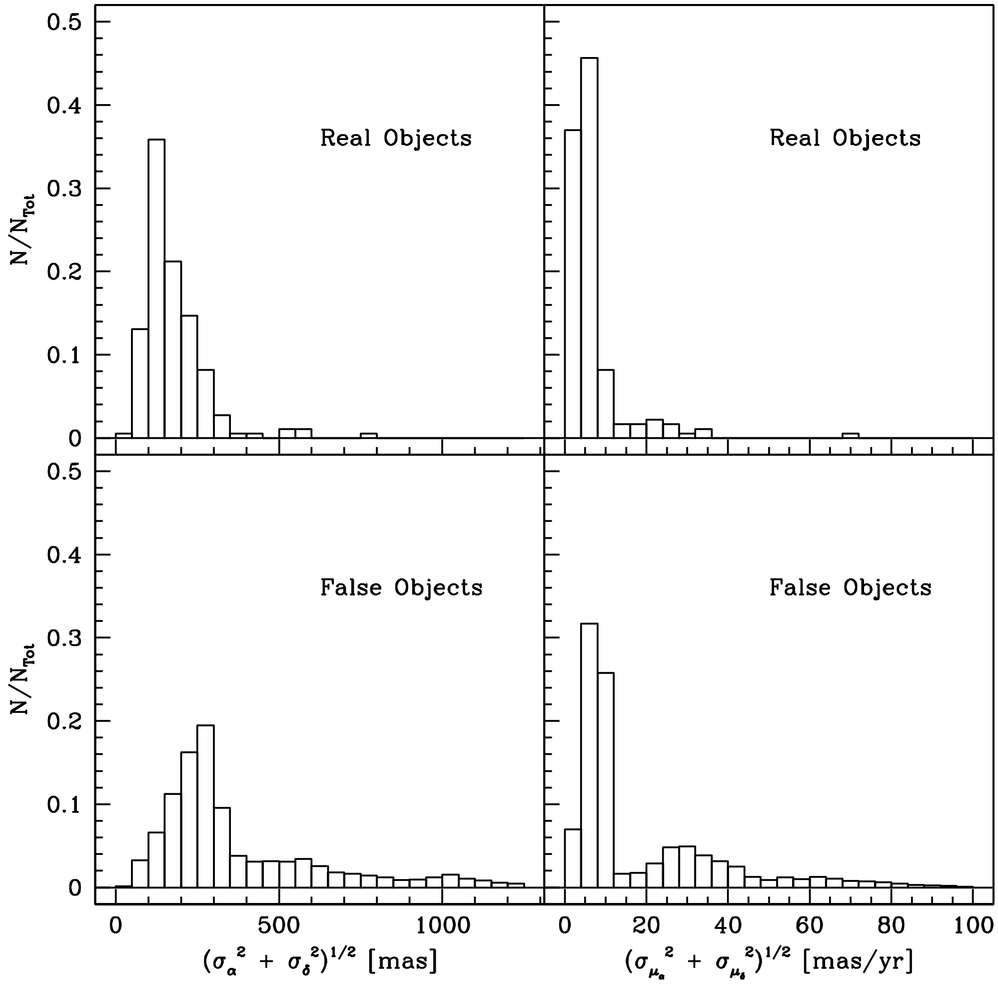

Fig. 6.—Histograms of the errors for the positions (*left panels*) and motions (*right panels*) for the real (*top panels*) and false (*bottom panels*) high-motion objects. This is for the subsample of 3348 possible objects for which the catalog-based finders were reviewed by eye.

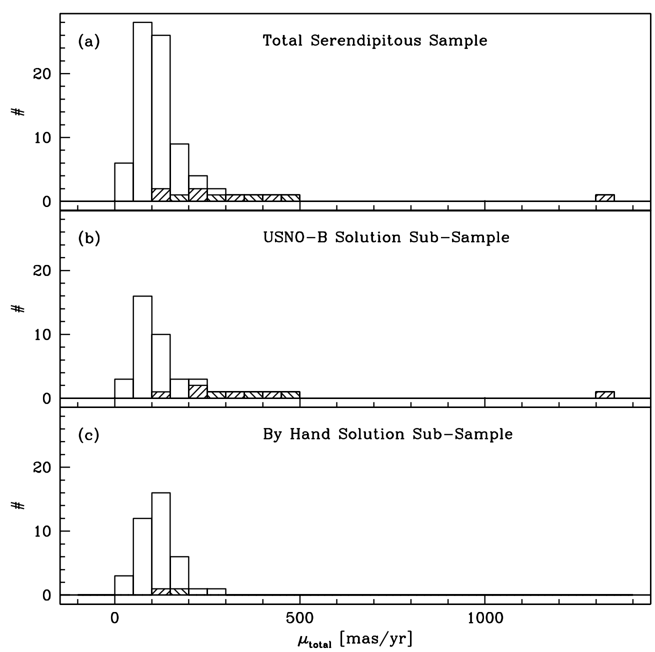

Fig. 7.—Histograms of the total proper motions of the serendipitous objects. The hatched histograms represent the known objects, while the open histograms represent the combined new and known. (*a*) Total set of serendipitous objects. (*b*) Distribution of objects with good solutions in USNO-B1. (*c*) Set of objects with solutions done by hand.

to be roughly 80% complete between 0″ and 1″ yr^{-1}, although there are only a few hundred objects in that catalog with motions below 500 mas yr^{-1} (see the § 6 discussion comparing the revised LHS with USNO-B1). In addition, we would be very cautious about deducing too much about the completeness of USNO-B1 from this sample, as it suffers from a variety of biases. First, almost half of the 80 objects were found in just three POSS I fields, so if a given plate had some problem, that could affect the results. Second, when the objects were found, there was initially no systematic effort to keep track of them. Finally, the sample is small. With those caveats in mind, it is interesting to note that all the objects for which we provide redone solutions have motions between 0 and 300 mas yr^{-1}. J. Munn (2005, private communication), when comparing USNO-B1 to the SDSS DR1 data, sees a dip in completeness from about 95% to about 65% at motions of around 80–100 mas yr^{-1}, which does roughly correspond to where we find most of the objects that had incorrect data in USNO-B1. A more thorough study of this is warranted.

From examination of the digitized images, it appears that one of the primary reasons that almost half of these objects were mismatched in the catalog is that they fall in the overlap zones between fields (at least 65 of the objects lie in plate overlap regions). The detections on adjoining plates apparently were not culled completely in the duplicate-detection removal process. Since the duplicate removal depends on spatial coincidence and the plate solutions are at their worst out near the plate edges, this

TABLE 5

Serendipitous Objects with Good Solutions in USNO-B1

ID[a]	μ[b] (mas yr^{-1})	θ[b] (deg)	R.A. (hr)	Decl. (deg)	l (deg)	b (deg)	B[c] (mag)	R[c] (mag)	I[c] (mag)	J[d] (mag)	H[d] (mag)	K_s[d] (mag)	Number[e]	Class[f]	AltID[g]
4492 01044 1	225.6	65.9	0.33483	76.1291	121.0064	13.3746	12.7	11.4	10.9	9.2	8.6	8.4	0	d	TYC2 4492-1044-1
1660-0002691	78.2	94.4	0.34624	76.0645	121.0401	13.3055	18.2	16.2	15.0	13.4	12.8	12.5	5	d	...
1662-0002920	87.3	110.1	0.37893	76.2253	121.1795	13.4513	17.5	15.8	14.2	12.1	11.5	11.3	5	d	...
1657-0005791	164.1	9.1	0.49845	75.7001	121.5699	12.8853	16.0	13.9	12.7	10.8	10.3	10.0	5	d	...
1698-0004712	81.2	99.9	0.92103	79.8888	123.1074	17.0183	18.1	16.3	15.8	14.3	13.7	13.4	5	d	...
1695-0005846	373.4	69.6	1.00922	79.5763	123.3623	16.7121	17.4	15.2	12.8	11.7	11.1	10.8	5	d	NLTT 3242
0855-0009685	189.7	65.1	1.01479	−4.4809	129.0295	−67.2407	14.7	12.8	11.8	10.7	10.1	9.9	5	d	UCAC2 30296684
0855-0009698	1321.5	70.3	1.01566	−4.4490	129.0551	−67.2077	14.4	12.3	10.4	9.0	8.5	8.2	5	d	LHS 130
1540-0035963	128.6	5.4	1.17036	64.0343	124.9866	1.2375	17.2	16.8	17.2	16.1	15.5	15.1	5	sd	...
1407-0071339	120.9	145.8	2.66405	50.7820	139.8638	−8.4912	15.4	12.7[h]	11.4	10.7	10.1	9.9	4	d	...
1683-0025701	93.3	135.0	3.73783	78.3068	131.3389	18.3639	15.5	14.7	13.9	12.4	11.8	11.7	5	d	...
1544-0112254	84.4	148.6	4.12699	64.4990	142.1650	9.2308	20.2	17.4	16.6	15.2	14.4	14.3	5	d	...
1522-0148544	113.6	118.4	4.32810	62.2920	144.7008	8.5851	19.8	17.5	16.4	15.2	14.5	14.4	5	sd	...
1574-0111126	80.6	156.6	5.51495	67.4569	145.1288	17.6793	17.7	15.8	14.6	13.5	12.8	12.6	4	d	...
1578-0121823	235.8	169.7	6.37029	67.8010	146.8259	22.2983	15.9	14.1	11.4	10.7	10.2	9.8	5	d	...
1659-0050193	324.0	173.6	7.48851	75.9009	138.8070	28.5491	19.1	16.6	14.2	12.0	11.5	11.1	5	d	NLTT 17835
4133 00625 1	502.0	180.5	8.42792	66.4623	149.1560	34.0631	9.3	8.3	7.8	7.2	6.8	6.7	0	d	TYC2 4133-00625-1
1575-0148828	26.9	132.0	10.29553	67.5945	141.9665	43.4178	14.2	12.5	11.2	10.8	10.2	10.1	5	d	...
1576-0150230	58.1	229.2	10.29363	67.6537	141.9141	43.3712	13.2	11.7	11.0	10.5	10.0	9.9	5	d	...
0867-0255298	58.5	262.1	11.95509	−3.2049	277.5471	56.9749	16.6	15.6	14.2	13.5	12.8	12.6	5	d	...
0867-0255338	57.3	282.1	11.95771	−3.2520	277.6467	56.9463	15.3	14.2	14.2	13.6	13.1	13.0	5	sd	...
1662-0061497	84.3	292.3	12.50206	76.2446	124.6039	40.8144	19.7	17.2	16.0	14.3	13.8	13.6	5	d	...
1663-0069093	76.1	273.0	15.09013	76.3685	113.4095	38.1747	14.8	14.3	14.0	13.2	12.9	12.9	5	sd	...
1570-0182321	101.1	245.5	16.58837	67.0294	98.7379	37.8952	17.2	15.3	12.9	11.9	11.3	11.1	5	d	...
1548-0247178	273.9	83.3	21.69641	64.8562	104.4654	9.0259	17.9	16.1	13.3	12.0	11.4	11.1	5	d	NLTT 51912
1371-0540717	90.0	90.0	22.12871	47.1923	96.2810	−7.0307	17.5	15.1	13.7	13.4	12.8	12.7	5	d	...
1503-0343417	74.7	195.5	22.52417	60.3793	106.4534	2.0660	18.7	16.2	14.5	13.3	12.8	12.6	5	d	...
1543-0282460	152.3	103.7	22.66878	64.3816	109.3223	5.0372	17.9	15.8	14.2	12.4	11.8	11.5	5	d	LDS 4990
1543-0282475	55.7	111.0	22.66946	64.3670	109.3190	5.0222	15.4	13.4	12.7	11.2	10.5	10.4	5	d	...
1680-0117205	106.0	54.2	22.73451	78.0837	116.3959	16.8607	17.0	15.4	14.3	13.1	12.6	12.3	5	d	...
1544-0281760	86.3	166.6	22.76294	64.4808	109.9080	4.8349	19.4	17.2	16.2	14.5	13.9	13.6	5	d	...
1543-0289304	48.7	70.8	22.92054	64.3196	110.7505	4.2318	18.1	15.8	14.8	13.2	12.6	12.3	5	d	...
1558-0247908	69.4	41.5	23.07854	65.8848	112.3157	5.2374	17.4	15.2	14.7	13.7	13.0	12.8	5	d	...
1558-0247969	116.3	310.8	23.08128	65.8882	112.3325	5.2338	20.6	18.3[h]	16.5	14.8	14.3	14.1	4	d	...
1559-0249177	139.7	99.1	23.14135	65.9357	112.6906	5.1324	17.8	15.4	14.6	12.7	12.0	11.8	4	d	...
1691-0087337	154.1	92.2	23.36841	79.1872	118.6554	17.0646	16.8	15.4	13.8	12.4	11.8	11.6	5	d	...
1675-0139929	157.5	82.0	23.59605	77.5049	118.7623	15.2500	17.4	15.4	14.2	12.6	12.1	11.8	5	d	...
1675-0140048	103.7	129.5	23.60936	77.5253	118.8113	15.2566	16.8	15.0	14.0	12.8	12.2	12.0	5	d	...
1675-0140100	109.3	34.6	23.61504	77.5031	118.8228	15.2300	17.4	16.1	14.2	12.4	11.8	11.5	5	d	...
1675-0140133	434.8	93.4	23.61889	77.5720	118.8562	15.2922	14.7	12.9	10.8	10.2	9.7	9.4	5	d	NLTT 57436
1663-0113155	71.0	80.3	23.82149	76.3079	119.1870	13.8901	17.9	15.8	15.2	14.1	13.3	13.3	5	d	...

[a] IDs of the form ZZZZ-NNNNNNN are from USNO-B1, and those of the form ZZZZ RRRRR N are from Tycho-2.
[b] The proper motions are relative to the reference frame established by the YS4.0 catalog stars (see Monet et al. 2003 for details).
[c] B, R, and I magnitudes are photographic magnitudes from the USNO-B1 catalog. The B and R magnitudes are preferentially from the second-epoch plates; if no second-epoch magnitude was available, then the first-epoch magnitude was used.
[d] J, H, and K_s magnitudes are from the 2MASS final release point source catalog (Cutri et al. 2003).
[e] Number of surveys out of the five in USNO-B1 in which the object was detected in the construction of USNO-B1.
[f] (d) dwarf; (sd) subdwarf.
[g] Alternate identification, if this is a previously known object: (TYC2) Høg et al. 2000; (NLTT) Luyten 1979b; (LHS) Luyten 1979a; (LDS) Luyten 1940; (UCAC2) Zacharias et al. 2004.
[h] First-epoch magnitude.

TABLE 6

Serendipitous Objects with New Position and Proper-Motion Solutions

ID	μ[a] (mas yr^{-1})	θ[a] (deg)	R.A. (hr)	Decl. (deg)	l (deg)	b (deg)	B[b] (mag)	R[b] (mag)	I[b] (mag)	J[c] (mag)	H[c] (mag)	K_s[c] (mag)	Number[d]	Class[e]	AltID[f]
MUSR 01	155.5	94.3	0.30014	76.9962	120.9982	14.2501	18.2	16.3	14.8	13.0	12.5	12.2	3	d	...
MUSR 04	64.2	39.9	0.36642	76.2059	121.1315	13.4372	17.5	15.9	14.6	13.0	12.4	12.1	3	d	...
MUSR 07	91.4	95.6	0.52378	77.4410	121.8091	14.6129	19.3	17.2	15.7	14.2	13.5	13.3	4	d	...
MUSR 13	114.0	121.7	1.86147	47.4891	133.3661	−14.1583	15.8	15.0	11.4	10.7	10.1	9.8	3	d	...
MUSR 16	137.4	127.3	3.74106	78.0435	131.5250	18.1683	19.1	16.9	15.4	14.1	13.5	13.3	3	d	UB 1680-0031453
MUSR 17	194.3	122.7	3.84409	52.2317	148.5094	−1.5079	17.7	16.0	14.2	12.7	12.1	11.8	3	d	UB 1422-0127233
MUSR 19	85.3	130.6	4.26547	63.3473	143.6395	9.0300	16.8[g]	14.8[g]	13.4[g]	12.7	12.0	11.8	2	d	...
MUSR 21	185.9	120.6	4.44636	63.1542	144.6443	9.7688	18.6	16.3	14.5	13.3	12.8	12.5	3	d	NLTT 13207
MUSR 22	85.1	138.6	5.22302	52.9614	156.5483	8.1374	15.1	13.8	13.4	12.2	11.5	11.4	3	d	...
MUSR 23	150.3	115.9	5.25623	67.5593	144.2512	16.4504	18.5	16.6	14.9	13.7	13.2	13.0	3	d	...
MUSR 25	41.7	210.3	5.52282	67.4864	145.1243	17.7331	16.6	15.4[h]	...	13.5	12.9	12.8	3	d	UB 1574-0111219
MUSR 27	230.9	145.9	5.84567	62.9571	150.3206	17.4703	13.5	12.4[g,h]	10.7[g]	9.9	9.3	9.2	3	d	...
MUSR 31	57.6	74.8	10.28827	67.6570	141.9380	43.3458	17.3	15.4	14.1	13.3	12.6	12.4	4	d	...
MUSR 35	115.7	286.0	11.95683	−3.2109	277.5956	56.9792	19.6	17.0	15.4	14.1	13.5	13.2	4	d	...
MUSR 39	156.7	219.6	12.71622	65.7056	124.3272	51.3997	17.5	16.8[h]	15.7[g]	16.6	17.1	16.1	3	wd	UB 1557-0144114
MUSR 40	150.7	187.5	15.06479	68.2484	106.4694	44.4086	18.6[h]	16.3[h]	15.4	14.7	14.3	14.0	3	sd	UB 1582-0176403
MUSR 42	101.2	181.9	15.67851	68.6857	103.8286	41.6052	19.2[h]	16.5[h]	...	14.4	13.8	13.6	2	d	...
MUSR 44	138.0	210.5	18.18237	6.3899	34.0677	11.9007	17.3	15.2	14.6	13.3	12.6	12.5	3	d	...
MUSR 45	256.0	259.9	20.13456	62.8713	96.3361	15.8208	18.8[h]	16.5	15.0	13.4	12.9	12.7	4	d	...
MUSR 46	102.6	38.1	21.28918	61.1952	99.8812	8.3154	18.1	15.8	14.1	12.6	11.9	11.7	3	d	...
MUSR 49	49.6	90.3	22.38069	43.0352	96.1106	−11.9656	17.9	15.3	13.6	13.4	12.7	12.5	4	d	...
MUSR 51	89.7	52.7	22.52580	60.3778	106.4630	2.0585	18.1	15.9	14.8	13.5	12.9	12.6	3	d	UB 1503-0343496
MUSR 52	119.0	78.1	22.54173	64.3235	108.5745	5.3966	19.3[h]	16.4[h]	...	13.5	12.9	12.7	2	d	...
MUSR 53	89.2	119.2	22.62082	63.5496	108.6377	4.4657	18.3[h]	16.2[h]	...	13.1	12.4	12.2	2	d	...
MUSR 54	144.0	14.8	22.64093	62.5719	108.2758	3.5469	16.4	14.5	14.1	13.1	12.5	12.4	3	sd	...
MUSR 55	44.8	233.1	22.66454	66.7672	110.4644	7.1352	17.9	15.8	15.3	14.0	13.2	13.0	5	d	...
MUSR 56	127.4	107.4	22.66674	64.3870	109.3132	5.0483	14.3	12.2	10.6	9.6	9.0	8.8	3	d	LDS 4990
MUSR 61	129.6	71.9	22.76775	64.5190	109.9534	4.8543	16.7	14.9	13.8	12.2	11.6	11.4	3	d	...
MUSR 62	149.7	62.5	22.76936	64.5065	109.9568	4.8384	15.2[h]	14.1[h]	...	11.5	10.9	10.8	3	d	...
MUSR 63	122.0	100.0	22.76986	63.6424	109.5576	4.0713	19.8[h]	19.3	17.9	13.6	12.9	12.6	4	d	...
MUSR 64	107.7	263.0	22.79564	65.6343	110.6280	5.7618	15.5[g]	13.5[g]	13.1[g]	11.7	11.1	11.0	3	d	...
MUSR 65	95.8	44.1	22.83035	64.2553	110.1941	4.4338	17.8[h]	16.4[h]	...	14.4	13.8	13.7	2	sd	...
MUSR 67	105.4	241.7	22.94335	66.5543	111.8480	6.1862	20.3[g,h]	17.1	15.4	13.7	13.1	12.8	3	d	...
MUSR 76	85.9	83.7	23.68831	78.5560	119.3635	16.1732	19.8[h]	16.6[h]	...	14.2	13.6	13.4	2	d	...
MUSR 77	80.6	83.2	23.72320	78.5201	119.4573	16.1100	19.9[h]	16.8[h]	...	14.2	13.6	13.3	2	d	...
MUSR 78	125.8	82.8	23.73681	79.7080	119.8311	17.2433	18.8[h]	16.3[h]	...	13.7	13.1	12.9	2	d	...
MUSR 80	97.9	55.7	23.83274	78.5106	119.7836	16.0163	16.2	14.6	12.8	11.0	10.3	10.1	3	d	...
MUSR 81	86.9	83.3	23.94682	79.1474	120.2736	16.5586	17.0	15.2	13.6	12.0	11.5	11.2	4	d	...
MUSR 82	138.3	65.3	23.97094	78.9788	120.3055	16.3792	15.4[g]	14.4	13.8	13.1	12.7	12.6	3	sd	...

[a] The proper motions are relative to the reference frame established by the YS4.0 catalog stars (see Monet et al. 2003 for details).

[b] B, R, and I magnitudes are photographic magnitudes from the USNO-B1 catalog. The B and R magnitudes are preferentially from the second-epoch plates; if no second-epoch magnitude was available, then the first-epoch magnitude was used.

[c] J, H, and K_s magnitudes are from the 2MASS final release point source catalog (Cutri et al. 2003).

[d] Number of surveys out of the five in USNO-B1 in which the object was detected in the construction of USNO-B1.

[e] (d) dwarf; (sd) subdwarf; (wd) white dwarf.

[f] Alternate identification, if this is a previously known object: (NLTT) Luyten 1979b; (LDS) Luyten 1940; (UB) USNO-B1 object ID, where the USNO-B1 has a decent position and motion match but used incomplete data.

[g] Magnitude taken from another USNO-B1 catalog entry, which was made up of additional detections of this object.

[h] First-epoch magnitude.

could lead to larger than expected offsets between images of the same object on different plates, and hence alternate detections might slip through the duplicate removal process; the occurrence of multiple entries in USNO-B1 for the same object and the inability to properly match up some first- and second-epoch detections of the same object could also be explained by this. This type of error should be most pronounced among objects with moderate to large proper motion. This is potentially important as well, because a nonnegligible portion of the sky lies in overlap zones (on the order of 30%–50% of the sky).

As noted above, five of the objects were flagged in USNO-B1 as previously known (i.e., in Tycho-2 or one of the high proper motion catalogs). We checked the rest of the objects against the catalogs and journal tables made available at CDS.[2] Another six turned up as previously known (including two that comprise the common proper motion pair LDS 4990; Luyten 1940). We have treated the remaining 69 as previously unknown. The distribution of total proper motions is shown in the histograms in Figure 7. Position and motion data for all the objects are given in Tables 5 and 6; Table 5 has the data for the objects with good solutions in USNO-B1, and Table 6 has the information on those objects that were redone by hand.

5. NOTES REGARDING SPECIFIC OBJECTS

The serendipitous objects were originally numbered 1–82 starting with the prefix MUSR (hence, MUSR 01 to MUSR 82). For those objects with good positions in USNO-B1, we refer to each by the USNO-B1 designator. For the objects refit by hand, we use the MUSR designator.

We constructed a reduced proper motion diagram to aid in the rough classification of the newly found objects (Fig. 8). The reduced proper motion in the photographic R band is defined as

$$H_R = R + 5 + 5\log_{10}(\mu) = M_R + 5\log_{10}(v_{\rm tan}) - 3.38,$$

where R is the apparent magnitude, M_R is the absolute magnitude, and $v_{\rm tan}$ is the transverse velocity in kilometers per second. The reduced proper motion has the benefit of being insensitive to the distance to the object, as the distance dependence of M_R and $v_{\rm tan}$ cancel out. This has been plotted against $R - K_s$ color and, as previously shown by Salim & Gould (2002) and Lépine et al. (2003a), does a reasonable job of distinguishing between disk dwarfs, halo subdwarfs, and white dwarfs. Tentative classifications are given in Tables 3–6. Possible white dwarfs include USNO-B1 1686-0094267 and MUSR 39. Possible subdwarfs include USNO-B1 1180-0331814, 0484-0243338, 1540-0035963, 1522-0148544, 0867-0255338, and 1663-0069093 and MUSR 40, 54, 65, and 82.

LHS 237a (0560-0118956).—This object was originally thought to be new. On closer inspection (H. Harris 2005, private communication), it was found to be LHS 237a (or VBs3). The LHS position given for this is off by 8′ in declination. The right ascension and the proper motion both match. The finder given in van Biesbroeck (1961) matches the images of this object. In Bakos et al. (2002), this object is listed as not found. Correct positions and motions are given in Table 2 (see Fig. 9).

5.1. *Objects with Relatively Large Proper Motion in Galactic Latitude*

In a modest effort to point out stars that might be halo stars, we have singled out objects that meet the following criteria: $\mu > 0''.75\ {\rm yr}^{-1}$ and $\mu_b > 2\mu_l$.

[2] See http://cdsweb.u-strasbg.fr.

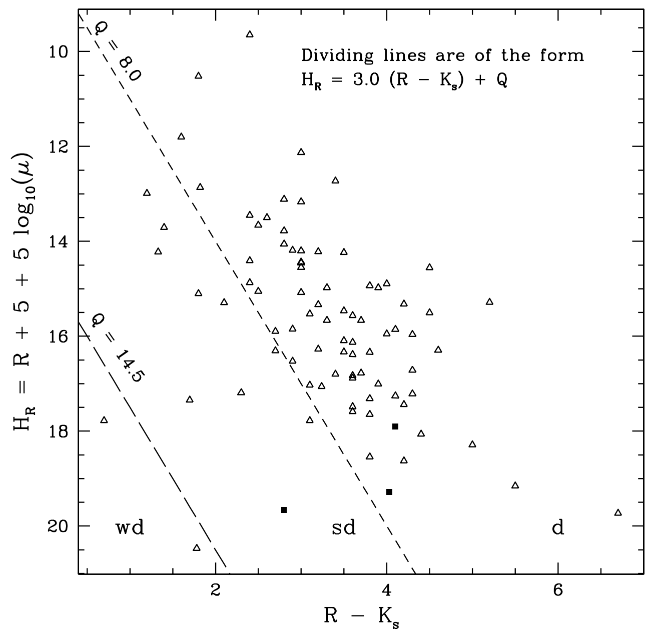

FIG. 8.—Reduced proper motion diagram for the objects listed in Tables 3–6. The reduced proper motion is $H_R = R + 5 + 5\log(\mu[{\rm arcsec\ yr^{-1}}])$. The lines dividing the space into regions occupied by dwarfs (d), subdwarfs (sd), and white dwarfs (wd) are based on the work of Lépine et al. (2003a, 2003b) and Lépine (2005) and give a rough guide to likely stellar type. Objects with motions larger than 1″ yr^{-1} are marked with squares.

0258-0023144.—At $(l,\ b) = (278^\circ.5505,\ -44^\circ.0139)$ moving along $(\mu_l,\ \mu_b) = (391.8,\ 999.8)$ mas yr^{-1} (Fig. 10*a* and Table 2).

0867-0249298.—At $(l,\ b) = (269^\circ.6031,\ 54^\circ.7070)$ moving along $(\mu_l,\ \mu_b) = (-357.1,\ -1037.0)$ mas yr^{-1} (Fig. 5 and Table 4).

1657-0005791 (MUSR 06).—At $(l,\ b) = (121^\circ.5699,\ 12^\circ.8853)$ moving along $(\mu_l,\ \mu_b) = (39.8,\ 159.2)$ mas yr^{-1} (Fig. 10*b* and Table 5).

1540-0035963 (MUSR 12).—At $(l,\ b) = (124^\circ.9866,\ 1^\circ.2375)$ moving along $(\mu_l,\ \mu_b) = (2.6,\ 128.5)$ mas yr^{-1} (Fig. 10*c* and Table 5); possible subdwarf.

1570-0182321 (MUSR 43).—At $(l,\ b) = (98^\circ.7379,\ 37^\circ.8952)$ moving along $(\mu_l,\ \mu_b) = (-6.5,\ 100.9)$ mas yr^{-1} (Fig. 10*d* and Table 5).

1544-0281760 (MUSR 60).—At $(l,\ b) = (109^\circ.9080,\ 4^\circ.8349)$ moving along $(\mu_l,\ \mu_b) = (-21.4,\ -83.7)$ mas yr^{-1} (Fig. 10*e* and Table 5).

1558-0247969 (MUSR 69).—At $(l,\ b) = (112^\circ.3325,\ 5^\circ.2338)$ moving along $(\mu_l,\ \mu_b) = (-50.2,\ 104.9)$ mas yr^{-1} (Fig. 10*f* and Table 5).

5.2. *Objects with Companions*

In the process of putting together the tables and images of serendipitous objects, we noticed several pairs with very similar motions. They are listed here.

MUSR 40.—There is a possible faint companion to the east of this object that is visible on the POSS I 103a-O (blue) plate for field 68 and on the POSS II IV-N (near-IR) plate for field 67 (see Figs. 11*a* and 11*c*). The faint companion is at the same position angle and distance with respect to MUSR 40 on both plates, although they were taken over 40 years apart. The POSS I 103a-O plate for field 69 also shows something peculiar near MUSR 40 (Fig. 11*b*). The object is not seen on the other POSS I and POSS II plates that cover this object. The corresponding 103a-E

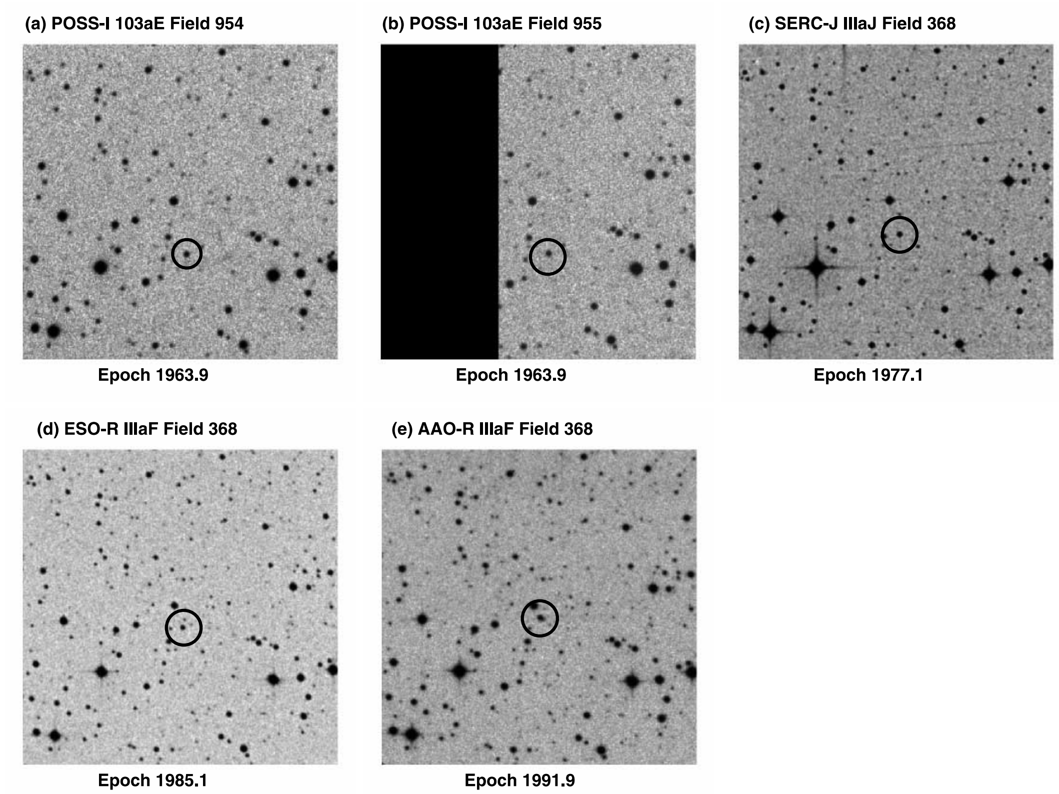

Fig. 9.—Finder charts showing the motion of object LHS 237a (USNO-B1 0560-0118956) ($\alpha_{2000} = 07^{\mathrm{h}}45^{\mathrm{m}}38\overset{\mathrm{s}}{.}5$, $\delta_{2000} = -33°55'52''$) on the five available Schmidt plates. North is up, east is to the right, and all images are $6' \times 6'$ in size.

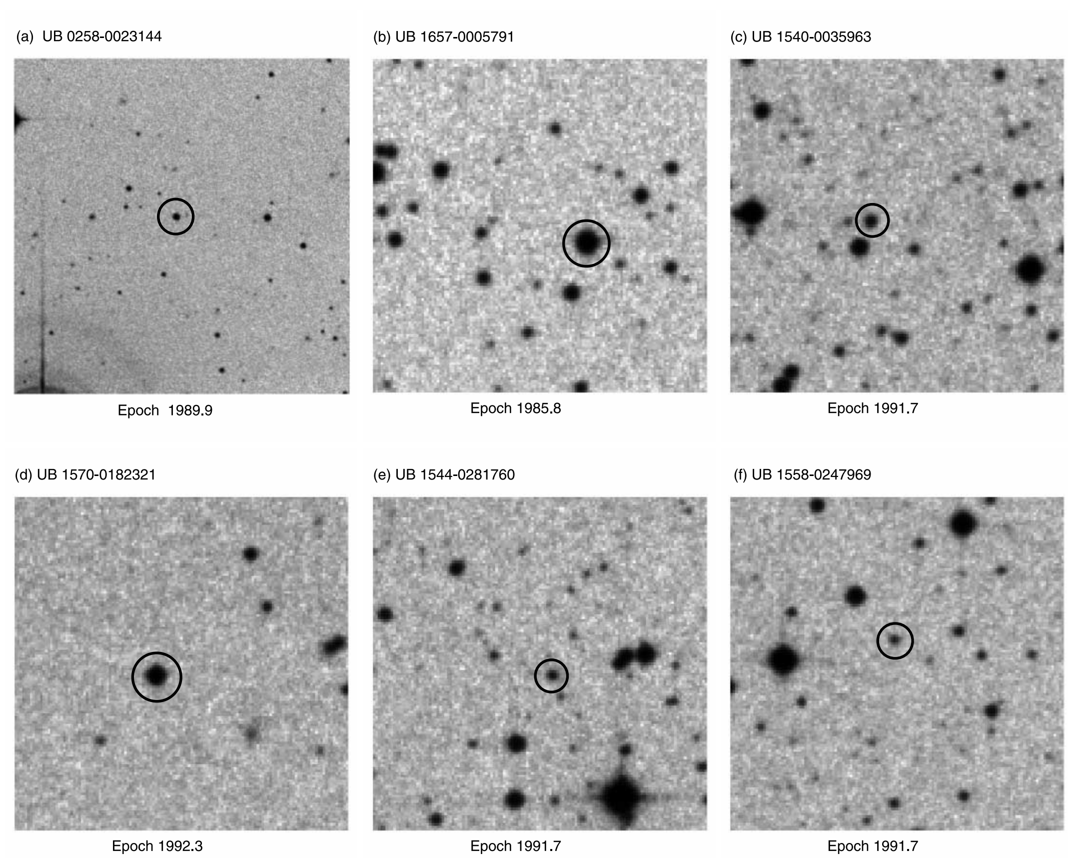

Fig. 10.—Finder charts showing the six objects with large relative μ_b. Image (*a*) is $6'$ square, and images (*b*)–(*f*) are $2'$ square. North is up, and east is to the right. Image (*a*) is from an AAO-R IIIa-F plate, and images (*b*)–(*f*) are from POSS II IIIa-F plates. (*a*) USNO-B1 0258-0023144. (*b*) USNO-B 1657-0005791. (*c*) USNO-B 1540-0035963. (*d*) USNO-B 1570-0182321. (*e*) USNO-B 1544-0281760. (*f*) USNO-B 1558-0247969.

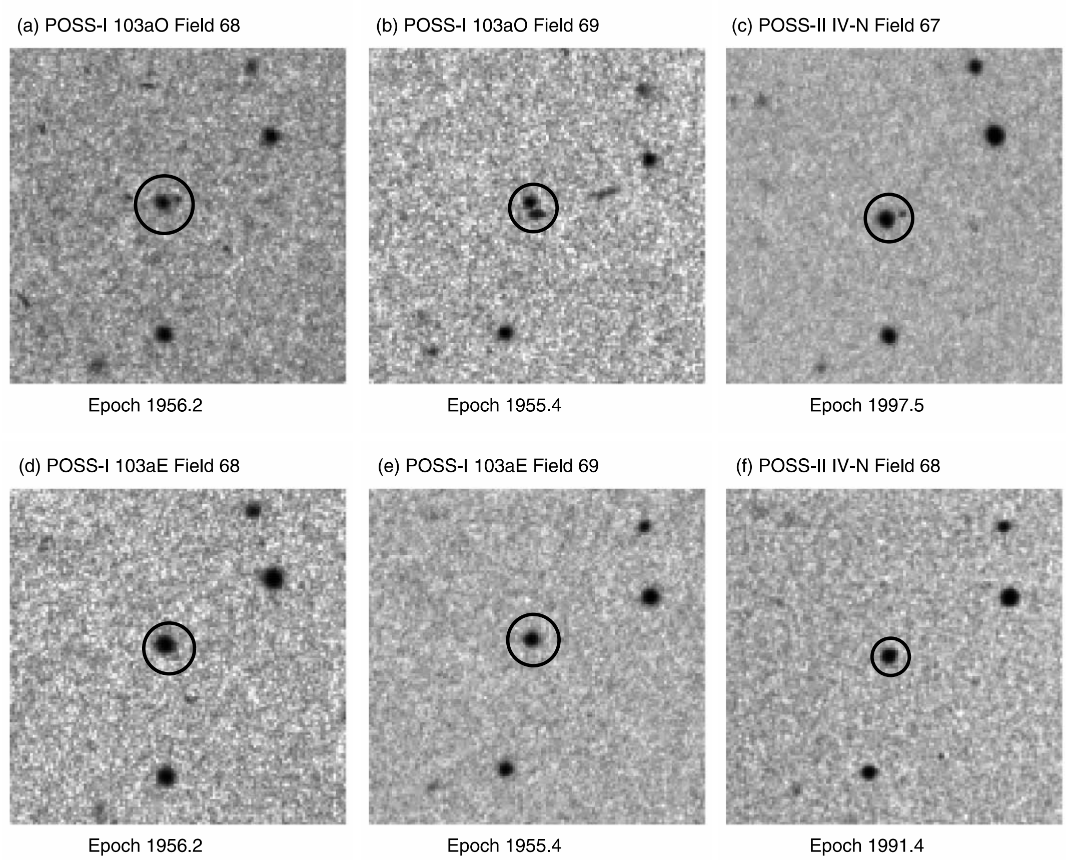

FIG. 11.—Region around MUSR 40 (*circles*). All images are 2′ square. Images (*a*)–(*c*) show more than one object within the circle around MUSR 40. Images (*d*)–(*f*) show only MUSR 40 within the circle. Images (*a*) and (*d*) are from the POSS I 103a-O and 103a-E images, respectively, of field 68. Images (*b*) and (*e*) are from the POSS I 103a-O and 103a-E images, respectively, of field 69. Images (*c*) and (*f*) are from the POSS II IV-N images of fields 67 and 68, respectively. North is up, and east is to the right.

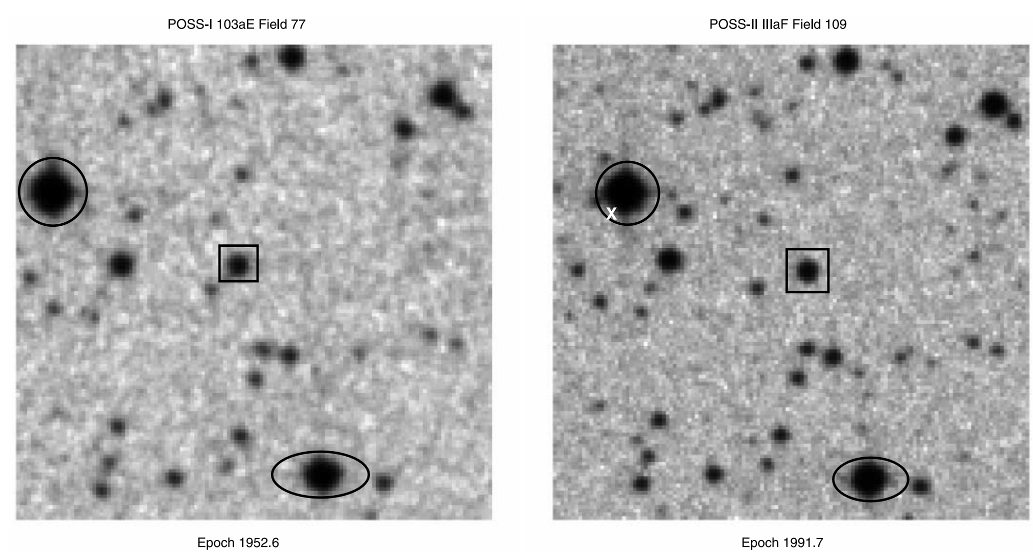

FIG. 12.—Region around LDS 4990 (MUSR 56; *circles*), USNO-B1 1543-0282460 (MUSR 57; *squares*), and USNO-B1 1543-0282475 (MUSR 58; *ellipses*). The position of 1RXS J224000.2+642310 is marked with a white cross (*right*). Both images are 2′ square. *Left*: POSS I 103a-E image of field 77. *Right*: POSS II IIIa-F image of field 109. North is up, and east is to the right.

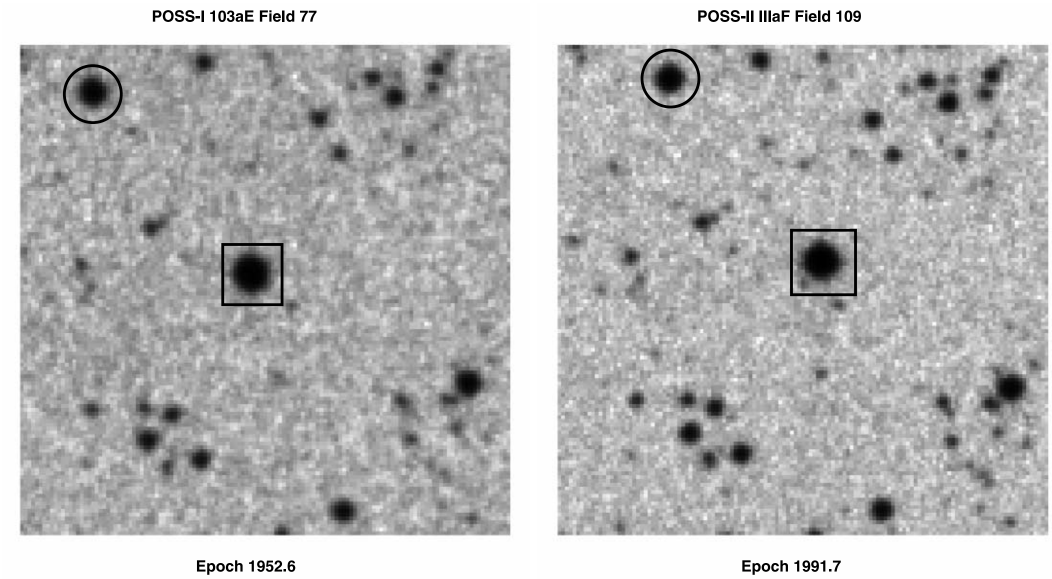

FIG. 13.—Region around MUSR 61 (*circles*) and MUSR 62 (*squares*). Both images are 2′ square. *Left*: POSS I 103a-E image of field 77. *Right*: POSS II IIIa-F image of field 109. North is up, and east is to the right.

images for both POSS I images are shown as Figures 11*d* and 11*e*, and an additional POSS II IV-N image from field 68 is shown in Figure 11*f* (see Table 6). MUSR 40 is a possible subdwarf.

LDS 4990 (MUSR 56) and 1543-0282460 (MUSR 57).—The two components of LDS 4990 (Luyten 1940) are shown in Figure 12, with data in Tables 5 and 6. In both images in Figure 12, MUSR 56 is marked with a circle, MUSR 57 is marked with a square, and MUSR 58 (see next item) is marked with an ellipse. We note in passing that MUSR 56 is coincident to within 3″ with 1RXS J224000.2+642310 (marked with a white cross on Fig. 12, *right*; Voges et al. 1999).

1543-0282475 (MUSR 58).—Very near to LDS 4990. This object's motion is in the same direction as that of the components of LDS 4990, but the magnitude of the motion is markedly smaller (see Fig. 12 and Table 5).

MUSR 61 and MUSR 62.—A probable comoving pair, with a separation of roughly 58″ (see Fig. 13 and Table 6). MUSR 61 is marked with a circle, and MUSR 62 is marked with a square.

MUSR 76 and MUSR 77.—A probable comoving pair, with a separation of almost 6′.6 (see Fig. 14 and Table 6). MUSR 76 is marked with a circle, and MUSR 77 is marked with a square. They have very similar magnitudes in both the optical and near-IR, and their motions are quite similar as well.

MUSR 81.—Its motion is very similar to that of MUSR 76 and MUSR 77 (Table 6), but it is yet further separated from the previous two objects (about 57′ away) and is somewhat brighter than either one.

6. COMPARISON WITH THE HIGH-MOTION PART OF rLHS AND LSR02

As part of our effort to understand how well the motion finder has done, we looked at the entries in the USNO-B1 catalog for all the objects with motions between 1″.0 and 5″.0 yr^{-1} in the revised

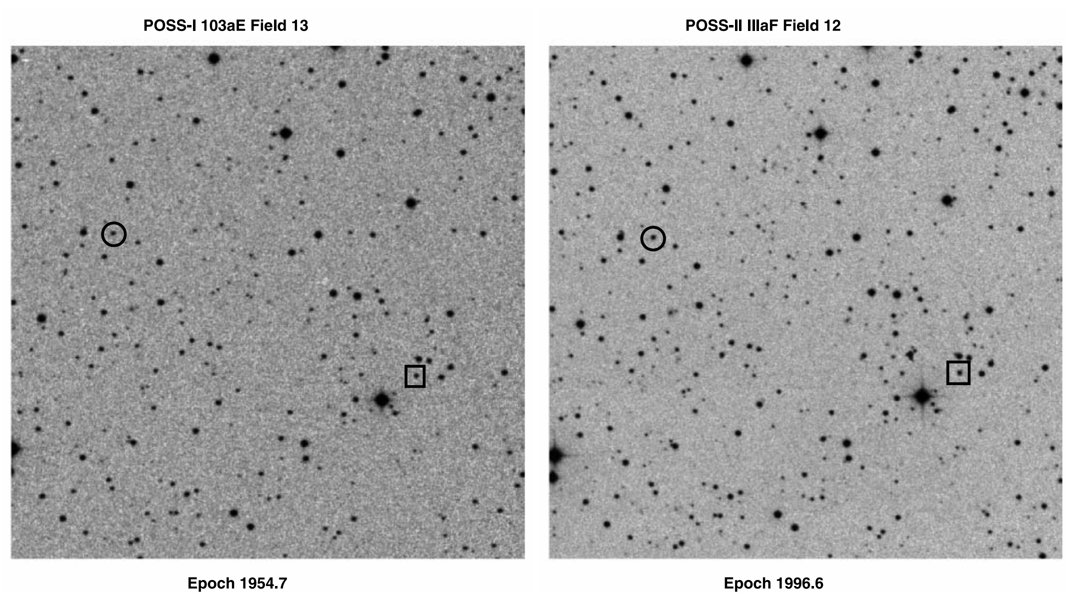

FIG. 14.—Region around MUSR 76 (*circles*) and MUSR 77 (*squares*). Both images are 10′ square. *Left*: POSS I 103a-E image of field 13. *Right*: POSS II IIIa-F image of field 12. North is up, and east is to the right.

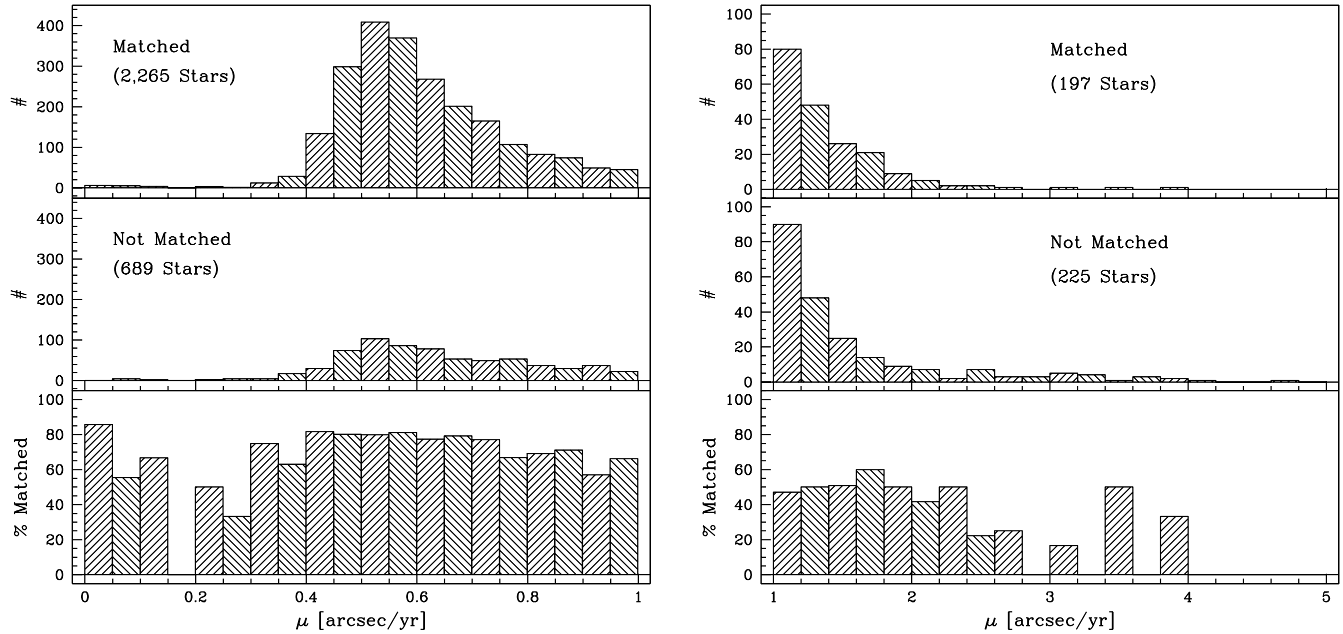

FIG. 15.—Histograms of the number of rLHS objects matched (*top panels*) and not matched (*middle panels*) with objects in USNO-B1. The percentage of objects matched is shown in the bottom panels as a function of proper motion. The left panels show the statistics for those objects with motions between 0″ and 1″ yr^{-1}, and the right panels show the data for those objects with motions between 1″ and 5″ yr^{-1}.

LHS catalog (rLHS; Bakos et al. 2002) and the 18 new objects that meet this criterion found by LSR02.

For each of the 18 objects in LSR02 with motions between $1\farcs0$ and $2\farcs0$ yr^{-1}, we extracted the appropriate portion of USNO-B1 and images from the Schmidt photographic surveys that cover that object. Of the 18 objects, seven were matched in USNO-B1 (the seven found in our search and given in Table 2). Of the other 11, three were in fields confused enough that we had only modest expectations that we would find them. One object was on a diffraction spike of a brighter object and likely would not have been found by USNO-B1 because it would have been in a removed region. Seven of the 11 objects we should have found. In several of those cases, it looked like USNO-B1 matched up the wrong set of objects among the various survey epochs. It appears this happens because there are other objects near or along the line of motion that cause the code that predicts the motion to get confused. The LSR02 image difference method is complementary to the "comparison of detection lists" method used for USNO-B1. We would expect that LSR02 should be more sensitive to objects in highly confused areas (such as the Galactic plane).

The rLHS has 593 objects with motions between $1\farcs0$ and $5\farcs0$ yr^{-1}. We found that 171 of these objects are flagged in USNO-B1 as being Tycho-2 stars (these were added to USNO-B1 directly from Tycho-2) and so do not tell us how well Monet et al. (2003) did in the construction of USNO-B1. For the remaining 422 rLHS stars, we compared the rLHS proper motions with those given in USNO-B1. Of these, 197 had proper motions that matched within $0\farcs20$ yr^{-1} and 20° position angle (although most are much closer). Of these, 174 are flagged in USNO-B1 as being known high proper motion stars; 23 more are matched to other USNO-B1 entries, although they are not flagged as known proper-motion stars.

There were 225 objects that did not have proper motions matched within the above limits. For the 158 of them with LHS catalog numbers less than or equal to 552, we searched a 6 $arcmin^2$ box around their position. For the other 67, we searched a 3 $arcmin^2$ box. Figure 15 (*top right and middle right*) shows the distribution of proper motions of the matched and unmatched sets of rLHS objects, respectively. The bottom right panel shows the percentage of rLHS objects that were matched as a function of proper motion. For objects with motions between 1″ and 2″ yr^{-1}, the mix is pretty even. Above 2″ yr^{-1}, more objects are not matched (although we are getting into the realm of small number statistics).

Similar data are shown in Figure 15 (*left panels*) for objects in the rLHS with motions between 0″ and 1″ yr^{-1}. For objects with motions below about 400 mas yr^{-1}, the completeness appears to dip a bit, but the sample size per bin is much smaller than for those bins with proper motions above 500 mas yr^{-1} (which is not surprising, given that the catalog is only supposed to contain objects with motions larger than 500 mas yr^{-1}).

The USNO-B1 catalog has decent matches for the position and motion of 47% of the rLHS objects with motions between $1\farcs0$ and $5\farcs0$ yr^{-1}. For these objects, the median distance between the rLHS and USNO-B1 positions is about $1\farcs9$ (Fig. 16). This displacement is consistent with the typical uncertainty in position in the rLHS, which is about 2″ (Bakos et al. 2002). Figures 16*b* and 16*c* show the displacement between matched rLHS and USNO-B1 objects in total proper motion and position angle. The median difference in proper motion was $0\farcs03$ yr^{-1}, and the median position angle difference was $1\fdg4$.

Gould (2003) has recently undertaken a more extensive comparison of USNO-B1 with their revised version of NLTT (Gould & Salim 2003; Salim & Gould 2003). As noted above, they found USNO-B1 to be roughly 30% incomplete when $\mu = 1''$ yr^{-1}; that the incompleteness should get worse as the motion increases above this is a natural assumption.

In preliminary testing of the moving-object-finding algorithm used in the construction of USNO-B1, we found that below 1″ yr^{-1}, the object-finding algorithm did substantially better at finding real motions than it did for the faster moving objects. Since a much greater percentage of the moving objects move more slowly than 1″ yr^{-1}, even though we appear to have missed

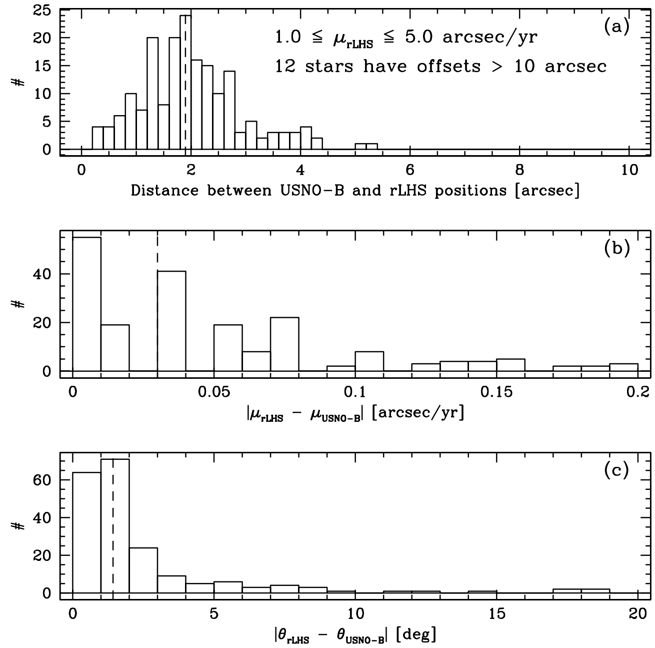

Fig. 16.—Histograms showing the difference between rLHS objects that have been matched up to an object in USNO-B1. Tycho-2 objects have been removed. (*a*) Mismatch in the position between USNO-B1 and rLHS for objects in USNO-B1 that matched high-motion objects in the rLHS. Twelve objects have position differences greater than 10″. (*b*) Difference in magnitude of the proper motion. (*c*) Difference in position angle. These are effectively truncated at $\delta\mu < 0''.2$ yr^{-1} and $\delta\theta < 20^\circ$, respectively, by the initial matching search. In all three panels, the median offset is indicated by the dashed line.

many with large motions, this is consistent with the work of Gould (2003).

7. DISCUSSION

Out of 187,134 objects in USNO-B1 that had listed motions between 1″.0 and 5″.0 yr^{-1}, there are 207 objects in USNO-B1 with the flag bit set indicating that they match a high proper motion catalog star (no cuts have been applied to these yet). Of those, 184 have a second-epoch red magnitude less than or equal to 18, and 174 are matched from the LHS. There are another 23 unflagged objects that match LHS objects, 19 that were recently found in other searches, and two new ones, for a total of 251 objects. There are another 174 Tycho-2 stars with motions in this range that were added in. Excluding the added Tycho-2 stars, 0.1% of the objects in USNO-B1 in this range are real. It seems fair to say that it is possible to find new high-motion objects in the USNO-B1 catalog, even with the large contamination fraction, although it is not easy. Given that we found just under half of the previously known high-motion objects, and also found another two new ones, this would imply that there should be at least another few waiting to be found.

In addition, we found another 80 objects in the fields we searched for high-motion objects. For almost half, we had to match up the detections by hand and compute positions and proper motions. Out of the combined high-motion and serendipitous sample, seven objects have motions with relatively large μ_b, and there are four pairs that appear to be common proper motion pairs, and maybe even one common proper motion triple. In the end, we found two new stars with proper motions larger than 1″ yr^{-1} and 36 with proper motions between 0″.1 and 1″ yr^{-1}. We also recovered one previously known but recently missed star (LHS 237a) with a motion of 1″.67 yr^{-1}.

Applying several simple cuts to the catalog reduces the number of false objects dramatically:

1. Require each object to have a positional error in each coordinate less than 0″.999 (or smaller, e.g., less than 0″.350).
2. Require each object to have a small proper motion error (less than 12 mas yr^{-1}).
3. Limit objects to those for which the difference between the R_1 and R_2 magnitudes is less than 1.0 or 0.5 mag. These cuts alone can reduce the contamination in the returned data by several orders of magnitude.
4. Require each object to be detected in four or five out of five surveys.

By placing a limit on the position and motion errors, we are putting a tight constraint on the acceptable matches, since we are imposing a linearity requirement in addition to the proximity criterion. Hence, there is a much greater reduction in the number of spurious objects. Figure 2 shows an example of this. The left panel shows a POSS II image of a field near a bright star. In the center panel, all the objects in USNO-B1 that lie in this field are plotted (they number 704). If we require $|R_1 - R_2| \leq 1$, the total $\sigma_{\rm position} \leq 500$ mas, and the total $\sigma_\mu \leq 100$ mas yr^{-1}, then we are left with the 163 objects overplotted in the right panel. Almost 75% of the objects have been rejected by this cut. As can be seen, most of the artifact objects caused by the diffraction spikes and the halo around the star are gone. A few real objects have been deleted as well.

Requiring objects to be detected in at least four surveys did not appear to contribute much to reducing the contamination in the high-motion sample. I would attribute this to several factors. First, the diffraction spikes on plates taken at the same pointing tend to line up well (hence the fairly large number of objects discarded as being due to diffraction spikes) and so provide a large pool of objects close together at both epochs. These then often project onto or very near to other diffraction spike detections, thus making up spurious, although complete, objects with potentially large motions. Second, extended objects, much like diffraction spikes, often give rise to multiple detections all in close proximity to each other. These again provide fertile territory for mismatching.

The high-motion problem is particularly taxing for the object matching, since there are often very many possible pairings of objects. With the larger motions, it becomes more likely that something will fall within the large projected error ellipse and hence make up an object with at least four detections.

Finally, it is important to know what the object density is like in the region(s) you are interested in: if it is high (e.g., near the Galactic plane), then the contamination rate will rise as it becomes progressively more difficult to unambiguously match up detections (see Fig. 1). J. Munn (2004, private communication) noted during the construction of the merged proper-motion catalog using USNO-B1 and SDSS DR1 data (Munn et al. 2004) that requiring objects from USNO-B1 to have no neighbor within 7″ also helped to clean up the contamination.

This particular work examining the high proper motion part of USNO-B1 has not made use of additional outside data. As is clear from Munn et al. (2004) and Gould & Kollmeier (2004), it is possible to do a better job of cleaning up the contamination in USNO-B1 if you have external data with which to compare (e.g., the SDSS DR1 data). If not, then you are limited to methods similar to those used here, but it is fair to say that the prospects of doing a decent job are still good.

The author would like to thank D. Monet and all the staff at USNO for the production of the USNO-B1 catalog and all the scans of the Schmidt plates that have made this modest work possible. I would like to thank C. Dahn and J. Munn for helpful discussions related to the USNO-B1 catalog and high proper motion objects. The author is grateful to the referee for several helpful suggestions. This research has made use of the USNOFS Image and Catalogue Archive, operated by the United States Naval Observatory, Flagstaff Station (http://www.nofs.navy.mil/data/fchpix).

The USNO-B1 catalog contains data from a diverse collection of photographs, reductions, and catalogs. All the plates used were scanned at the US Naval Observatory, Flagstaff Station, and the digitized images are made available through their Image and Catalogue Archive Web site. A large number of different organizations claim copyright and/or intellectual property rights on the various components. This work is based partly on photographic plates obtained at the Palomar Observatory 48 inch (122 cm) Oschin Schmidt Telescope for POSS I and POSS II. POSS I was supported by grants from the National Geographic Society and the California Institute of Technology. POSS II was partially supported by the Eastman Kodak Company, the National Geographic Society, the Samuel Oschin Foundation, the Alfred P. Sloan Foundation, National Science Foundation grants AST 84-08225, 87-19465, 90-23115, and 93-18984, and National Aeronautics and Space Administration grants NGL 05-002-140 and NAGW-1710.

Some of the plates come from the UK Schmidt Telescope, which was operated by the Royal Observatory Edinburgh with funding from the UK Science and Engineering Research Council until 1988 June and thereafter by the Anglo-Australian Observatory. Additional plates (ESO-R) come from the European Southern Observatory and were scanned with the permission of ESO.

This research has made use of the SIMBAD database and the Vizier service operated at CDS, Strasbourg, France (http://cdsweb.u-strasbg.fr). This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center, California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

REFERENCES

Abazajian, K., et al. 2003, AJ, 126, 2081
Bakos, G. A., Sahu, K. C., & Nemeth, P. 2002, ApJS, 141, 187
Cutri, R. M., et al. 2003, Explanatory Supplement to the 2MASS All Sky Data Release (Pasadena: IPAC), http://www.ipac.caltech.edu/2mass/releases/allsky/doc/explsup.html
Deacon, N. R., Hambly, N. C., & Cooke, J. A. 2005, A&A, 435, 363
Dehnen, W., & Binney, J. 1998, MNRAS, 298, 387
Delfosse, X., et al. 2001, A&A, 366, L13
Giclas, H. L., Burnham, R., Jr., & Thomas, N. G. 1971, Lowell Proper Motion Survey, Northern Hemisphere (Flagstaff: Lowell Obs.)
———. 1978, Lowell Obs. Bull., 8, 89
Gould, A. 2003, AJ, 126, 472
Gould, A., & Kollmeier, J. A. 2004, ApJS, 152, 103
Gould, A., & Salim, S. 2003, ApJ, 582, 1001
Hambly, N. C., Henry, T. J., Subsavage, J. P., Brown, M. A., & Jao, W.-C. 2004, AJ, 128, 437
Høg, E., et al. 2000, A&A, 355, L27
Lépine, S. 2005, AJ, in press (astro-ph/0501266)
Lépine, S., Rich, R. M., & Shara, M. M. 2003a, AJ, 125, 1598
Lépine, S., Shara, M. M., & Rich, R. M. 2002, AJ, 124, 1190 (LSR02)
———. 2003b, AJ, 126, 921
Luyten, W. J. 1940, The LDS Catalogue, Publ. Astron. Obs. Univ. Minnesota, vol. III, part 3 (Minneapolis: Univ. Minnesota Press)
Luyten, W. J. 1979a, LHS Catalog (Minneapolis: Univ. Minnesota Press)
———. 1979b, New Luyten Catalogue of Stars with Proper Motions Larger than Two Tenths of an Arcsecond (Minneapolis: Univ. Minnesota Press)
Monet, D. G., et al. 1996, USNO-A1.0 (Flagstaff: US Naval Obs.)
———. 1998, USNO-A2.0 (Flagstaff: US Naval Obs.)
———. 2003, AJ, 125, 984
Munn, J. A., et al. 2004, AJ, 127, 3034
Olling, R. P., & Dehnen, W. 2003, ApJ, 599, 275
Oppenheimer, B. R., Hambly, N. C., Digby, A. P., Hodgkin, S. T., & Saumon, D. 2001, Science, 292, 698
Perryman, M. A. C., et al. 1997, The *Hipparcos* and Tycho Catalogues (ESA SP-1200; Noordwijk: ESA)
Pokorny, R. S., Jones, H. R. A., & Hambly, N. C. 2003, A&A, 397, 575
Pokorny, R. S., Jones, H. R. A., Hambly, N. C., & Pinfield, D. J. 2004, A&A, 421, 763
Reylé, C., Robin, A. C., Scholz, R. D., & Irwin, M. 2002, A&A, 390, 491
Salim, S., & Gould, A. 2002, ApJ, 575, L83
———. 2003, ApJ, 582, 1011
van Biesbroeck, G. 1961, AJ, 66, 528
Voges, W., et al. 1999, A&A, 349, 389
Zacharias, N., et al. 2004, AJ, 127, 3043