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Late-Type Membership of the Open Cluster NGC 2232

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ABSTRACT

NGC 2232 is one of the nearest open clusters (~360 pc) with an age of ~25 Myr. This places it in the unique position to study the transistion from T Tauri activity to the Zero Age Main Sequence. In order for those studies to begin, late-type members must be identified for the cluster. X-ray observations combined with ground-based photometry and spectroscopy offers the best way to accomplish this goal. We present photometry in the *VRI* bands, 2MASS near-infrared measurements in the J, H, K_S bands and spectra for the suspected optical counterparts to the X-ray sources in the field of NGC 2232. 46 candidate members were identified though these efforts ranging from F5 to M5.

1. Introduction

NGC 2232 is a nearby open cluster (d ~ 360 pc) with an age of ~25Myr. Because of its recent formation, it provides a well-defined sample of young stars to test models of stellar evolution. In particular, the characteristics of solar-type stars between the T Tauri phase at ~10Myr and Zero Age Main Sequence (ZAMS) at ~50 Myrs can be investigated with this cluster. A number of optical photometry studies, in addition to spectroscopy for NGC 2232, have not identified any cluster members later than a spectral type of F5. Without well-studied late-type members to place constraints on theory, the T Tauri to ZAMS transition remains poorly understood. Most stars in the Galactic disk were formed in open clusters, so our knowledge of the details of star formation and the characteristics of open clusters improves our understanding of the Galatic system as a whole.

In figure 6, a wide field centered on NGC 2232 is presented without visual aids to identify cluster members. The classifications done by Collinder (1931) and Ruprecht (1966) did not have the benefit of photometric observations or other more modern methods to identify clusters. In more modern times, even with photometric measurements 20% or more of the nearly 200 clusters noted in *AstrophysicalQuantities* are in doubt as gravitationally bound groups of stars. Previous studies of NGC 2232 have done well to establish it as a legitimate open cluster. 20 candidate members were identified in Clarià (1972) through photometric analysis, which were mostly bright early-type stars that hold most of the mass of the cluster. The legitimacy of NGC 2232's clusterhood is discussed later in this report.

The best way to confirm a cluster's existence is to identify more candidate members. X-ray imaging combined with ground-based photometry and spectroscopy offers the best way to identify late-type candidate members in open clusters since many pre-main-sequence stars with a spectral type earlier than F5 are X-ray emitters. The Roentgen Satellite (ROSAT) proved to be well suited for these X-ray observations as demonstrated by a number of previous studies. A good summary of the results of ROSAT observations of 13 open clusters can be found in Randich (1997). The X-ray sources in the field NGC 2232 have been analyzed to determine likely optical and infrared counterparts while optical spectra have been used to confirm their spectral types. The sources have been circled on the field of NGC 2232 in figure 1.

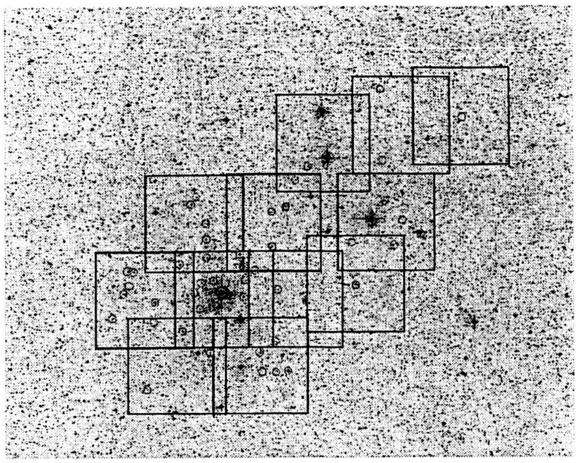


Fig. 1.— The NGC 2232 region with HRI X-ray sources circled, and the CCD frames used in optical photometry in boxes.

Proper motions provide an important diagnostic for cluster membership. These data are particularly valuable since all of the stars in an open cluster are thought to have formed together and remain gravitationally bound until they become tidally disrupted by the Galaxy and disperse. Cluster members will have similar proper motions across the sky since they move together as a group. Thus proper motions provide a completely independent method of determining cluster membership. Unfortunately proper motion surveys do not yet extend to the magnitudes of the late-type members in NGC 2232, however, analysis of early-type members can be accomplished. This study presents only the photometric data on these early-type members identified in Clarià (1972).

Color-color and color-magnitude diagrams constructed from photometric observations along with spectra form another principle means of determining cluster membership. Volumes of information about a star can be gleaned from spectral observations, the most important being the spectral type and luminosity class, which can be used to predict the unreddened photometric colors which are then compared to the position on the Color-Color diagram to determine the amount of reddening, that appears as an offset from the color relation of normal main sequence stars. All of the members of the cluster can be assumed to be at the same distance away, and have approximately the same amount of extinction since the physical size of most clusters are small in comparison to their distance. A color-magnitude diagram reveals the cluster members since the stars appear in a sequence offset from the field stars. Knowledge of the absolute magnitude of each spectral type can be used with extinction and best fit to the stars to determine the distance to the cluster.

Refining the membership of this cluster can fuel future studies with late-type stars to investigate a variety of characteristics of NGC 2232. Of particular interest is age determination since many different methods exist in addition to the well-established cluster turnoff age (or isocrone fitting) of 25Myr quoted previously. Studies of X-ray emission from the late-type members of other open clusters with the ROSAT mission have suggested that many of these late-type stars that begin their main sequence lives as strong X-ray emitters exhibit an overall decline of X-ray activity with time, as shown in the X-ray luminosity functions of open clusters with varying ages in Patten and Simon (1996).

The cluster age can also be estimated from Lithium depletion in brown dwarf stars, detected from the presence of Lithium absorption lines as was demonstrated for M stars in IC 2391 in Barrado et al. (1999). Our results may provide candidate members to be observed for this signature in future studies using this method. The Space Infrared Telescope Facility (SIRTF) may also observe late-type pre-main-sequence stars to investigate the accretion disks and their characteristics. Knowledge of late-type members for these clusters will benefit those efforts as well.

2. OBSERVATIONS

NGC 2232 (6h 28m -4deg) and has been extensively imaged with the ROSAT High Resolution Imager (HRI) and optical data has been taken at the Cerro Tololo Inter-American Observatory (CTIO), including *VRI* photometry and spectroscopy of possible optical counterparts to X-ray sources, with additional spectroscopy from observations at the Mt. Hopkins Fred Whipple Observatory. The 2 Micron All Sky Survey (2MASS) All Sky Point Source Catalog has recently become available for photometry in 2003, and is also included in our analysis.

2.1. ROSAT

The ROSAT HRI camera, designed and built at the Harvard-Smithsonian Center for Astrophysics, features a 38' field of view and 10" FWHM. The data were taken from the High Energy Astrophysics Science Archive Research Center (HEASARC) online database. The camera's high resolution allows excellent source discrimination and minimizes source confusion when searching for optical counterparts to the X-ray sources and its wide field of view allowed NGC 2232 to be covered in two pointings. An observation of the first of the two NGC 2232 fields is presented in Figure 2. A total of 67 ks of integration were taken in each field for NGC 2232. Dr. Brian Patten reduced these data using x-ray packages in IRAF and found 55 sources with a signal to noise higher than 2.5 in the NGC 2232 field. 77-35A and 78-07 are the same source because they lie in the overlap between these two fields. Three optical counterparts are considered for 77-35 since the X-ray position differs by a few arcseconds. The Point Spread Function (PSF) increases slightly towards the edge of the field, which explains this discrepancy. 77-02A and 78-10 are also the same source.

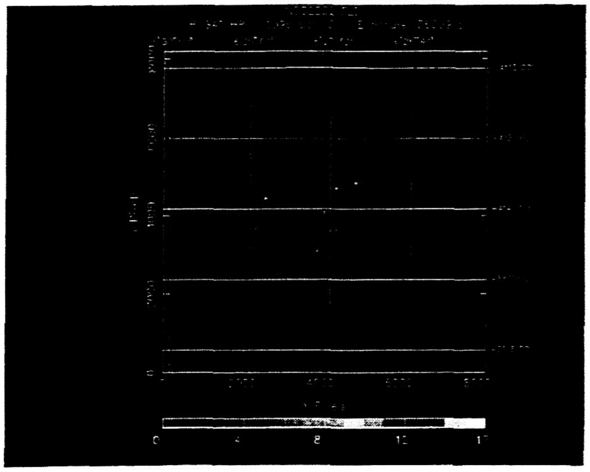


Fig. 2.— An example of a typical X-ray field is shown above. This particular image is of the first pointing of NGC 2232. Bright X-ray sources can be seen above the background.

2.2. Optical Ground-Based Photometry

Photometry for both clusters in the *VRI* bands were taken at the CTIO-.9m telescope by Dr. Brian Patten during the nights of 4-7 January 1999. These data have been bias-subtracted and flat-fielded and calibration data have been extracted to put subsequent photometry onto a standard VRI system by Dr. Patten. The following transformations convert the instrumental magnitudes and colors to the standard Cousins *VRI* system:

1999 January 5:

$$V = v + 0.0401(R - I) - 2.9571$$
$$(V - R) = 1.0081(v - r) + 0.1298$$
$$(R - I) = 0.9837(r - i) + 0.7987$$

1999 January 6:

$$V = v + 0.0161(R - I) - 3.0041$$
$$(V - R) = 0.9964(v - r) + 0.0804$$
$$(R - I) = 0.9541(r - i) + 0.8297$$

1999 January 7:

$$V = v + 0.0513(R - I) - 2.9704$$
$$(V - R) = 1.0625(v - r) + 0.0917$$
$$(R - I) = 0.9519(r - i) + 0.7955$$

This conversion is estimated to be in agreement with the standard system to within ~2-3% for the three nights. Photometry for the possible optical counterparts to the X-ray sources was performed by Chris Orban and Dr. Brian Patten. Table 1 presents the results of these observations.

2.3. Ground-Based Spectroscopy

Spectra of possible optical counterpart stars in the neighborhood of the X-ray source were also taken by Dr. Brian Patten with the Mt. Hopkins Fred Lawrence Whipple Observatory (FLWO) 1.5m telescope and the CTIO 1.5m telescope. The spectrographs achieved ~9 Angstrom resolution in a range of about 4200 to 7650 Angstroms for the purpose of determining the star's spectral type and noting emission lines. These data have been reduced and spectral types assigned by BMP. The results of the spectroscopy also appear in table 3.

Colons indicate uncertainty in the assigned spectral type and an "e" notes the presence of emission lines. The assignments are considered to be accurate to one subclass. In table 3 asterisks beside the spectral assignments for 77-29 and 78-05 indicate that in each case only one spectra was taken with both counterparts on the slit. The asterisk by 77-31 and 77-43 indicates that two spectra were taken, and one discarded as unreliable in each case.

2.4. 2MASS Near-Infrared Photometry

The recent release of the 2MASS All Sky Point Source Catalog in 2003 has enabled infrared bands J, H, and K_S to be included in the photometry for most of the possible optical counterparts to the X-ray sources. These data have been extracted by Chris Orban from the 2MASS database. Color-color diagrams have been constructed from these data which serve as a diagnostic to test if the spectral type is consistent with the near-infrared colors, and if not it helps to answer the question of whether the star is simply reddened, or something more bizarre. Not all of the late-type stars mentioned in this study have 2MASS data. The Point Source Catalog is limited to 15.8 magnitude in J, 15.1 in H, and 14.3 in K_S with error levels of 0.109 magnitude. (2MASS website) This excludes some of the dimmer optical counterparts from 2MASS analysis.

The late-type dwarf color relations in figure 4 are taken from Leggett (1992). The giant relations were derived from Bessel & Brett (1988), and the early-type relations derived from Kenyon & Hartmann (1995). The lattter two were transformed to the CIT photometric system which is close to the standard bands used in the 2MASS survey.

3. Analysis

3.1. Optical Counterparts

By scanning Table 1 it becomes obvious that in many cases there is more than one optical counterpart within the error radius of the ROSAT X-ray source since many in the counterpart list are A, B's and even C's to the 4 digit X-ray IDs. The first step towards refining cluster membership is first to determine which of these possible optical counterparts are actually producing X-rays from the *VRI* photometry, $J-H$ and $H-K$ colors as well as

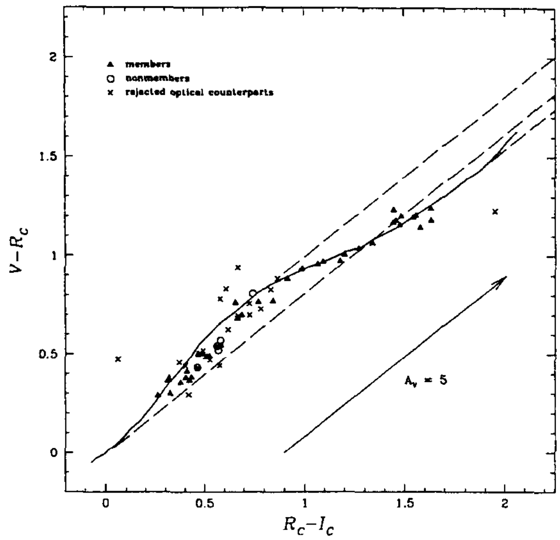
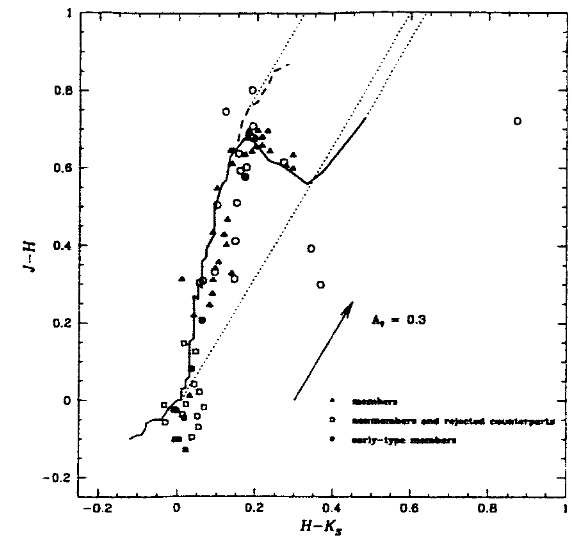


Fig. 3.— The color-color diagram for the *VRI* photometry in this study. The black line marks the unreddened colors for normal dwarf stars. The arrow on the diagram shows the direction of the reddening vector, and its magnitude corresponds to 5 magnitudes of extinction. The cluster is not significantly offset from the unreddened main sequence colors, so it is easily shown that the cluster does not have a large extinction.

the spectral classes assigned by BMP. An optical counterpart is considered to be the source of the X-rays if it passes the following tests: 1. It must lie within the error radius (5 arcseconds) of the X-ray source. 2. Its spectral type must be consistent with stars expected to produce X-rays. Spectral Types later than B6 and earlier than F5 are not expected to be strong X-ray sources. 3. If a spectral type is known for the source the reddening can be determined from the color-color diagram. ROSAT was sensitive to soft X-rays only, which are particularly succeptable to extinction effects, so highly reddened objects are less likely to be an x-ray source. Those considerations in addition to ROSAT's sensitivity make the case for detecting stellar sources at distance modulae greater than 10 quite difficult. 4. Considerations for non-stellar emitters such as pulsars or galaxies must be taken into account as well as well as ROSAT UV leak.

In each of the cases with complete or nearly



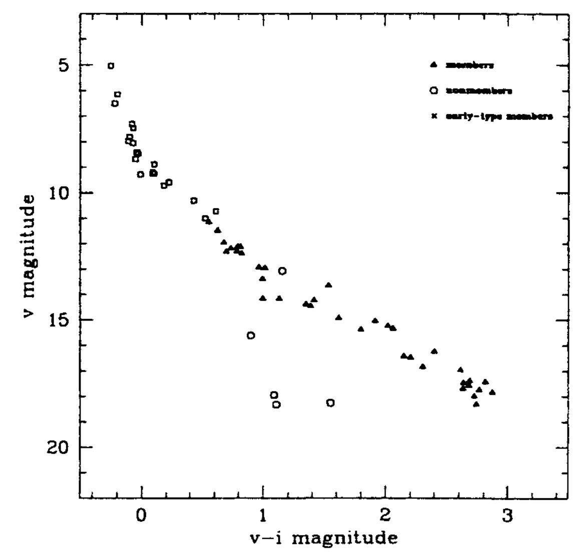


Fig. 4.— A color-color diagram for the near-infrared counterparts to the X-ray sources detected in the field of NGC 2232 and previously studied early-type members from 2MASS data. The theoretical, unreddened color relations of dwarf stars are indicated with a solid line, and similarly for giant stars, indicated with a dotted line. Notice that the points lie close to the dwarf relations, indicating very little reddening. The departure from the color relations near the origin are likely an artifact of the 2MASS bands being slightly off from the CIT photometric system, the standard that the dwarf tracks are based.

Fig. 5.— A color-magnitude diagram for the *VRI* observations. The cluster sequence spans from upper left to lower right.

complete data on table 1 except for 77-33 where no convincing optical counterparts were found and 77-14 which had two very closely spaced stars, a suitable optical counterpart to the X-ray source was found to pass all of the above tests, while the other counterparts failed or did not meet the criteria nearly as well. Counterparts nearer to the center of the X-ray position were considered more convincing than those further away, yet still within the error radius.

In tables 1 and 2, the stars eliminated as a possible optical counterpart are marked with an NC in the notes column.

3.2. Candidate Members

There are a few special cases of note in this data set. A few of the X-ray sources correspond to stars studied in Clarià's previous work on the cluster. (Clarià 1972) Sources 77-05, 77-07, 77-10, 77-24A, 78-03, 78-11, and 78-16 were confirmed as cluster members in that study and numbered 22, 8, 1, 18, 2, 3, and 12 respectively. The *VRI* photometry quoted for these sources except for Star 22 have been generated from *UBV* measurments in Clarià's study with main sequence polynomial relations supplied by BMP since many were so bright that they were saturated in all of the CTIO CCD fields. Star 22 (77-05) was dim enough to provide good photometry in the short exposures so the quoted *VRI* photometry is from our measurements. There is actually a large discrepancy between the Clarià's *V* magnitude and our study. We quote 11.481 in table 1 wheras it is quoted as 9.28 in Clarià's study, which analyzed the brightest stars in the field progressively down to 11.36 magnitude. The discrepancy seems too large to attribute to variability in the star.

Many of the sources studied by Clarià which also appear as X-ray sources may not be legitimate emitters since they fail or fall near the boundary outlined the second criteria. It is likely that for some of these stars a late-type companion may be the source of the X-rays, as is likely the case with 77-10, a bright B star with a variable radial velocity, confirming the existence of a companion. 77-09, a bright A0 star, is labeled BD-04 1526B in previous study also is a confirmed binary system. Another possibility is that these bright, hot early-type stars may be causing spurious detections because of ROSAT's suspected UV leak.

Another interesting source is 78-13; the galaxy LEDA 7571 (also referred to as CGMW 1-108) is its optical counterpart. It was previously unknown as a source of X-ray emission, and a few smaller galaxies can be seen nearby in the CCD frames. The appearance of galaxies in this field corroborates the low extinction apparent in the color-color diagrams.

In order for the X-ray source to be considered a candidate member, it must pass the following critera: 1. It must have a low level of reddening since the cluster has very little reddening (~0.05 magnitudes). 2. The spectral type of the star must be consistent with the predicted unreddened colors to within 0.15 magnitudes. 3. On a color-magnitude diagram it must lie near the cluster sequence. Quantified, the star must have a distance modulus on the order of 7.82 (366 pc, the distance determined from the Hipparcos parallax of the early type members). 4. This cluster is expected to be quite young, ~25 Myrs from previous studies (Clarià 1972) and thus the late-type stars are expected to still be evolving towards the main sequence and are likely to have emission lines. This feature in the spectra is expected to be common for late-type members.

4. Conclusions

Almost 90% of the optical counterparts to the X-ray sources meet the critera to become candidate members. 46 new members have been identified, bringing the total number (Clarià and this study) to 66. The positions of the confirmed cluster members are circled on figure 7. Any doubts of the existence of the cluster as a gravitationally bound group of stars has been eliminated. A significant number of bright, high mass early-type stars and lower mass late-type stars have been confirmed as cluster members. Yet another cluster has proven ROSAT to be well-suited for identifying late-type members in open clusters.

REFERENCES

Barrado y Navascuès, D., Stauffer, J. R., & Patten, B. M. 1999, ApJ, 522, L53

Leggett, S. K. 1992. ApJ, 81, 1.

Patten, B. M., & Simon, T. 1996, ApJ, 106, L489

Clarià, Juan J.1978, Å, 19, 303.

Rosner, R., Golub, L., & Vaiana, G. S. 1985, ARA&A V23

Simon, T. 1992 in Cool Stars, Stellar Systems, and the Sun, 7th Cambridge Workship, M. S. Giampapa & J.A. Bookbinder (eds), ASP Conf. Series, v. 26, 3

Bessel, M. S., & Brett, J. M. 1988. PASPvol. 100 p1134-1151.

Kenyon, Scott J., & Hartmann, Lee. ApJS, v.101, p117.

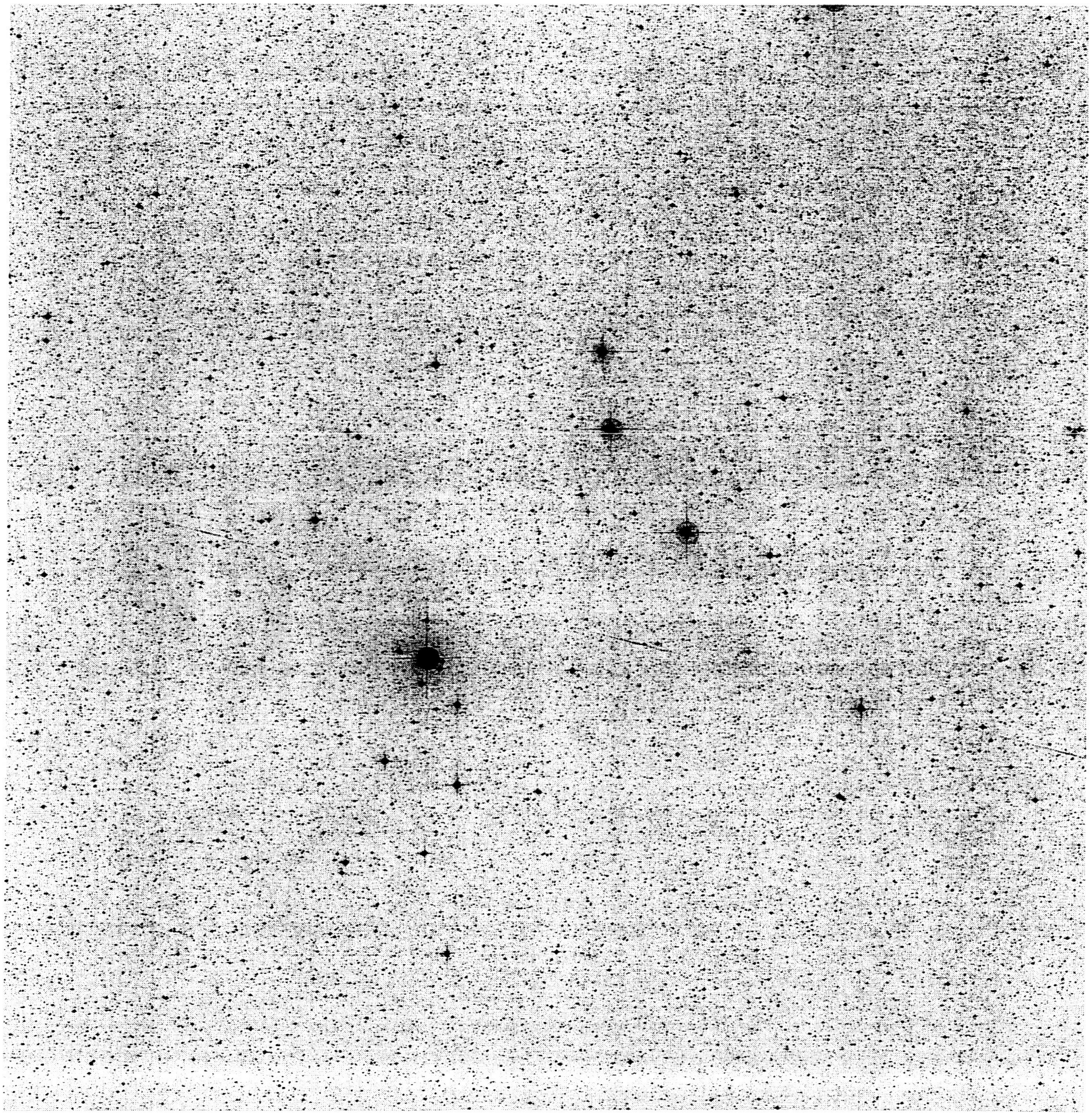


Fig. 6.— A two degree by two degree field of NGC 2232 is presented without visual aids to mark the confirmed cluster members or X-ray positions. This cluster was originally identified by the apparent visual concentrations of stars above the normal conscentration of field stars.

Table 1

Possible Optical Counterparts to X-ray Sources in the Field of NGC 2232

X-ray ID	RA	Dec	J	$(J-H)$	$(H-K_S)$	V	$(V-R)$	$(R-I)$	Notes
77-01	06:27:27.576	-04:45:22.99	12.087	0.680	0.196	15.346	0.967	1.096	
77-02A	06:27:30.797	-04:39:31.58	10.851	0.311	0.088	12.114	0.367	0.424	
77-02B	06:27:31.405	-04:39:31.03	101	...	...	18.455	0.624	0.619	
77-03	06:27:40.252	-04:42:45.73	13.774	0.681	0.214	17.986	1.142	1.579	
77-04A	06:27:44.767	-04:44:03.24	13.404	0.656	0.198	17.837	1.237	1.633	
77-04B	06:27:44.942	-04:44:09.33	15.039	0.505	0.097	19.910	0.828	0.837	
77-05	06:27:45.871	-04:42:14.74	10.524	0.208	0.062	11.481	0.300	0.327	prob w/ V mag
77-06	06:27:46.019	-04:46:22.04	11.011	0.275	0.087	12.178	0.356	0.380	
77-07	06:27:47.599	-04:49:28.79	7.886	-0.046	0.018	...	...	...	
77-08	06:27:47.762	-04:40:32.87	11.116	0.357	0.102	12.375	0.413	0.412	
77-09	06:27:52.494	-04:46:00.43	9.251	0.011	0.032	...	...	...	need vri
77-10	06:27:57.551	-04:45:42.44	5.459	-0.129	0.022	...	...	...	
77-11	06:28:00.095	-04:47:34.71	13.533	0.607	0.276	17.574	1.231	1.449	
77-12A	06:28:04.164	-04:53:54.06	11.114	0.635	0.170	13.645	0.763	0.774	
77-12B	06:28:04.27	-04:54:13.2	12.741	0.802	0.187	15.755	0.883	0.871	
77-12C	06:28:04.328	-04:54:04.76	...	...	...	19.591	0.295	0.419	
77-12D	06:28:03.86	-04:54:05	15.361	0.393	0.341	17.636	0.694	0.672	
77-13	06:28:05.533	-04:40:58.18	13.083	0.697	0.203	16.477	1.004	1.202	
77-14A	06:28:05.6	-04:38:28.2	13.419	0.616	0.269	...	...	...	spec case
77-14B	06:28:06.0	-04:38:28.2	13.077	0.709	0.189	...	...	...	spec case
77-15	06:28:06.015	-04:36:20.88	12.555	0.696	0.227	16.234	1.063	1.340	
77-16	06:28:08.505	-04:44:23.97	13.472	0.689	0.177	17.467	1.178	1.460	
77-17	06:28:09.588	-04:47:54.18	13.247	0.679	0.211	16.835	1.036	1.271	
77-18	06:28:12.363	-04:45:42.52	14.135	0.634	0.293	18.305	1.194	1.545	
77-19A	06:28:18.834	-04:50:57.85	12.557	0.674	0.193	15.376	0.881	0.920	
77-19B	06:28:19.233	-04:50:52.85	...	...	...	19.299	0.832	0.611	NC
77-21	06:28:48.049	-04:42:43.85	11.380	0.468	0.124	12.959	0.490	0.524	
77-22	06:28:49.945	-04:45:48.17	10.864	0.329	0.136	12.124	0.384	0.434	
77-23A	06:28:56.296	-04:49:09.15	11.383	0.429	0.116	12.932	0.500	0.465	
77-23B	06:28:56.327	-04:49:03.11	14.052	0.630	0.235	16.570	0.826	0.856	NC
77-24A	06:27:10.546	-04:46:48.63	8.932	0.081	0.036	...	...	...	
77-24B	06:27:10.954	-04:46:57.17	14.386	0.309	0.063	15.935	0.445	0.579	NC
77-26A	06:27:29.095	-04:52:22.71	13.083	0.600	0.293	17.423	1.178	1.635	
77-26B	06:27:28.6	-04:52:28.9	13.636	0.603	0.173	16.101	0.700	0.730	NC
77-28	06:28:01.841	-04:44:06.95	12.476	0.403	0.122	14.161	0.488	0.510	
77-29A	06:28:10.765	-04:32:41.77	12.188	0.578	0.170	14.387	0.682	0.668	
77-29B	06:28:10.529	-04:32:42.80	13.822	0.594	0.157	15.691	0.474	0.529	NC
77-30A	06:28:14.1	-04:33:43.5	12.350	0.646	0.138	14.928	0.769	0.848	
77-30B	06:28:13.6	-04:33:40.5	12.680	0.638	0.153	15.047	0.757	0.729	NC
77-31	06:28:37.959	-04:58:56.17	12.027	0.679	0.178	15.041	0.929	0.989	
77-32	06:28:44.979	-04:42:49.88	12.126	0.697	0.178	15.237	0.954	1.067	

TABLE 2
OPTICAL COUNTERPARTS *Continued*

X-ray ID	RA	Dec	J	$(J-H)$	$(H-K_S)$	V	$(V-R)$	$(R-I)$	Notes
77-33A	06:28:47.603	-04:44:48.04	16.356	0.299	0.367	18.324	0.542	0.564	NC
77-33B	06:28:47.162	-04:44:41.02	...	...	...	20.365	0.474	0.062	NC
77-34A	06:27:21.601	-04:56:26.63	9.422	0.304	0.055	...	...	...	
77-34B	06:27:21.062	-04:56:32.21	10.165	0.429	0.066	11.602	0.458	0.438	NC
77-35A	06:27:22.224	-04:34:08.29	12.316	0.548	0.097	14.177	0.545	0.584	
77-35B	06:27:22.666	-04:34:19.85	14.204	0.747	0.118	16.750	0.728	0.785	NC
77-35C	06:27:22.942	-04:34:12.65	...	...	...	19.923	0.939	0.671	NC
77-36A	06:27:28.626	-04:56:32.51	...	...	...	17.952	0.521	0.569	
77-36B	06:27:28.964	-04:56:34.51	...	...	...	19.936	1.229	1.949	NC
77-37	06:27:30.920	-04:34:53.41	13.766	0.690	0.185	17.693	1.155	1.479	
77-38	06:27:37.727	-04:53:58.95	11.768	0.434	0.087	13.384	0.502	0.491	
77-41	06:27:36.233	-04:56:34.06	13.514	0.644	0.233	17.738	1.203	1.559	
77-43	06:28:20.057	-04:41:51.66	11.189	0.412	0.145	13.073	0.571	0.581	
77-44	06:28:33.698	-04:46:57.89	11.034	0.342	0.093	12.294	0.381	0.406	
77-45	06:28:33.764	-04:49:40.95	16.451	0.511	0.148	15.611	0.435	0.465	
78-01A	06:26:27.771	-04:33:21.44	11.126	0.313	0.009	12.303	0.379	0.321	
78-01B	06:26:27.869	-04:33:27.40	...	...	...	15.350	0.519	0.492	NC
78-01C	06:26:28.072	-04:33:27.89	...	...	...	15.653	0.442	0.405	NC
78-02A	06:26:17.290	-04:35:56.03	13.777	0.332	0.092	15.462	0.508	0.474	NC
78-02B	06:26:18.328	-04:35:57.35	12.830	0.659	0.213	16.965	1.168	1.446	
78-03	06:26:34.464	-04:35:50.12	6.466	-0.102	-0.00	...	...	...	
78-04	06:26:34.342	-04:36:21.67	...	...	...	16.424	0.971	1.179	
78-05A	06:27:09.160	-04:28:40.64	11.784	0.611	0.136	14.222	0.761	0.658	
78-05B	06:27:08.890	-04:28:40.65	14.402	0.314	0.143	15.914	0.462	0.374	NC
78-06	06:27:16.212	-04:30:31.79	12.285	0.646	0.132	14.455	0.699	0.690	
78-07	06:27:22.203	-04:34:08.36	12.316	0.548	0.097	14.177	0.545	0.584	
78-08	06:26:23.016	-04:39:21.88	10.810	0.246	0.080	11.951	0.366	0.313	
78-09	06:26:45.856	-04:38:57.59	...	...	...	20.977	0.781	0.581	
78-10	06:27:30.797	-04:39:31.58	10.851	0.311	0.088	12.114	0.367	0.424	
78-11	06:27:00.897	-04:21:20.07	6.734	-0.102	0.004	...	...	...	
78-12	06:26:29.209	-04:18:17.66	13.192	0.643	0.187	17.383	1.200	1.485	
78-13	06:25:45.613	-04:22:04.80	15.538	0.721	0.872	18.252	0.808	0.746	Galaxy
78-14	06:26:43.466	-04:44:41.45	10.206	0.219	0.041	11.143	0.291	0.262	
78-16	06:26:07.966	-04:37:41.56	8.473	-0.026	-0.00	...	...	...	

Table 2. NGC 2232 Membership decisions

X-ray ID	Other Name	Spectral Type	Member
77-01		M1 Ve	Y
77-02A		F9 V	Y
77-03		M5 Ve	Y
77-04A		M5 Ve	Y
77-05	Clarià 22	F7 V	Y
77-06		G3 V	Y
77-07	Clarià 8	B4/5 V	Y
77-08		G8 V	Y
77-09	BD-04 1526B	A0 V	Y
77-10	Clarià 1	B2 V	Y
77-11		M5: Ve	Y
77-12A		K8 Ve	Y
77-13		M1 Ve	Y
77-14A		M3 Ve	I
77-14B		M0 Ve	I
77-15		M4 Ve	Y
77-16		M4.5 Ve	Y
77-17		M0 Ve	Y
77-18		M5 Ve	Y
77-19A		M0 Ve	Y
77-21		K0 V	Y
77-22		G4 V	Y
77-23A		K0 V	Y
77-24A	Clarià 18	A0 V	Y
77-26A		M4.5 Ve	Y
77-28		G8 V	Y?
77-29A		K6 V*	Y
77-30A		M0 Ve	Y
77-31		M0 Ve*	Y
77-32		M0 Ve	Y
77-33A			N
77-34A		F7 V	I
77-35A		K5 V	Y
77-36A			N
77-37		M4 Ve	Y
77-38		K0 V	Y
77-41		M4.5 Ve	Y
77-43		G-K I:*	N
77-44		F9 V	Y
77-45			N
78-01A		G0 V	Y
78-02B		M4.5 Ve	Y
78-03	Clarià 2	B3 V	Y
78-04		M4.5 Ve	Y
78-05A		K8 Ve*	Y
78-06		K7 V	Y
78-07		K0 V	Y
78-08		G0 V	Y
78-10		G0 V	Y
78-11	Clarià 3	B3 V	Y
78-12		M5 Ve	Y
78-13	LEDA 75751		N
78-14		F5 V	Y
78-16	Clarià 12	B8	Y

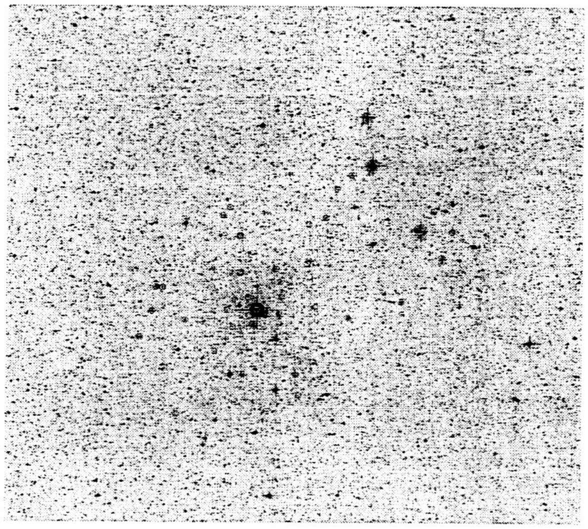


Fig. 7.— The x-ray sources that have been confirmed as candidate members are circled on the field of NGC 2232.