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A STUDY OF UPGREN 1

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ABSTRACT

Upgren and Rubin have suggested that a small group of bright F stars, in the direction of the galactic north pole, may be the remnant of an old cluster. Utilizing the multichannel astrometric photometer (MAP) we have determined the parallaxes of six of the candidate stars with an average precision of 1.1 thousandths of an arcsecond (1.1 mas). The derived distances are, as suggested, similar, and an unusual space density of F stars seems indicated. However, the derived space velocities indicate that the proposed cluster is composed of members of two dynamically different groups.

Subject headings: astrometry — clusters: open — stars: stellar dynamics

I. BACKGROUND

Upgren and Rubin (1965) note that an area approximately $\frac{1}{4}°$ in diameter, centered at galactic longitude 142°.3 and latitude +80°.1, contains seven bright ($V = 7.3$ to 9.9) spectral type F stars (see indicated stars in Table 1). In their study of the spectral types, luminosity classifications, and radial velocities of this group, they conclude in this initial paper that the seven stars form the core of a very old nearby star cluster.

The first astrometric study of the region was by Anderson (1966). Anderson concluded, from the study of two Palomar Schmidt and two Hyderabad astrographic catalog plates, that two of the stars (Upgren and Rubin numbers 3 and 5) were a nearby comoving pair. She also suggested that stars 4 and 7 were "lone stars" not associated with the others, while there was no conclusive evidence that the other stars had "common space motions."

Osborn (1966) combined all of the published positions, between 1863 and 1953, of the seven stars to determine their proper motions. While the data were more extensive, and did not overlap that used by Anderson, Osborn reached essentially the same conclusion as Anderson. Osborn corrected his motions for the effects of solar motion, showing that their apparent similarity was partially due to this effect. In each of these studies the standard errors of the proper motion studies was on the order of 6 mas per year.

Upgren, Philip, and Beaverrs (1982) then reexamined the photometry and radial velocities of the proposed cluster members. Their study reported photoelectric photometry in *UBV RI* (Kron-Cousins), and *uvby* systems, and distance moduli were given. Improved radial velocities (at considerable variance with those in the initial paper) were also presented. Their study concluded that "stars 3, 4, 5, 6, and 7 are associated since the radial velocities, photometry, and spectral classifications all indicate membership and the proper motions for nos. 4 and 6 are not grossly different from those of the other three stars."

Table 1 lists the numbers, spectral types, and radial velocities for eight of the brightest stars in this region. The first seven stars are those studied by Upgren and Rubin. Their numbers are listed in column (1). The spectral information for these stars comes from the original paper. Upgren and Rubin's star number 2 was not included in the MAP program; thus its astrometric parameters were derived from photographic plates (to be discussed below) and a parallax was not computed. The radial velocities are all from Upgren, Philip, and Beavers (1982). The photometric data and spectral type for star 697 were taken from the *MK Classification Extension Catalogue* (Morris-Kennedy 1983).

II. METHOD AND DATA

As a star cluster, Upgren 1 would be unusual in its proximity to the Sun. Only three recognized open clusters are nearer (Mermilliod 1979), and it might be unique in that, unlike other star-poor clusters, it appears to be very old (Upgren, Philip, and Beavers 1982).

The recently developed multichannel astrometric photometer (MAP) (Gatewood 1987) and new optical system of the Thaw refractor (Gatewood *et al.* 1986) of the Allegheny Observatory (AO) combine to give that instrument a precision of several thousandths of an arcsecond per observation. Thus, with careful attention to the adjustment to absolute, the system may be used to measure the direct trigonometric parallax of objects within several hundred parsecs of the Sun.

Observation of this region with the MAP was started in the spring of 1986 with the installation of the new objective lens. These were continued in 1987 (when we obtained the first winter observations of the field) and on into early 1988. Seventy-two MAP observations were obtained over this 3 yr period, but only 14 were acquired while the parallax factor for the region was greater than +0.5. Thus the parallax precisions illustrated here can probably be obtained with fewer observations, if they have a better balance with respect to parallax factor, over a similar period.

The reduction of the photometric-phase measurements of the MAP to astrometric positions has been described by Gatewood (1987) and the transformation of these to the star constants listed below is similar to that described by Eichhorn and Jefferys (1971) and by Gatewood (1972), except that equations (2) of the latter document are used instead of equations (7). This latter phase of the reductions is known as the central overlap technique (Gatewood and Russell 1974; Eichhorn 1988).

TABLE 1

NUMBERS, SPECTRAL TYPES, AND RADIAL VELOCITIES OF BRIGHTEST STARS

Upgren 1 No. (1)	AO (2)	BD (3)	Spec (4)	RV km s^{-1} (5)	se R_{v_1} km s^{-1} (6)
1	695	37°2296	F4 V	6.4	3.2
2	698	37°2296	F6 V	−0.3	1.8
3	699	37°2297	F6 IV	−16.3	1.0
4	702	37°2298	F4 III	−11.0	4.0
5	704	37°2299	F3 V	−16.2	1.2
6	709	37°2300	F6 V	−20.0	10.0
7	703	36°2284	F8 V	−16.9	1.8
	697	37°2295	K1 III		

Columns (1), (2), and (3) list: the Upgren and Rubin (1965); Allegheny Observatory parallax; and BD numbers. The spectral information for the first seven stars is from Upgren and Rubin, their radial velocities (with standard error of that measurement) are from Upgren *et al.* The spectral classification of AO 697 is from Morris-Kennedy (1983).

Photographic observations of the region include a plate taken with the Thaw refractor's 76 cm photographic objective (focal plane scale = 14″.62 per mm) in 1983; one acquired with the new red-light objective lens (14″.52 per mm) in late 1985; and two plates taken with the USNO 155 cm reflector (13″.55 per mm) in 1966, just after the Washington group (which included Upgren) became interested in the field. All of the stars listed in Table 2 were measured on these plates in an attempt to identify any group motions. Data listed there denoted with a blank space in column (2) are derived from the photographic material.

Data listed with a "2" in the second column were derived entirely from MAP observations. The relative parallaxes of these stars may be determined by removing the reduction to absolute discussed below, and given at the end of Table 2. Thus that correction may be improved as additional information on the distance of any of these stars becomes available. Star 702 was treated as the region target.

TABLE 2

ASTROMETRIC PARAMETERS FOR STARS IN THE REGION OF UPGREN 1

AO No. (1)	d (2)	V mag (3)	$B-V$ (4)	abs Pi mas (5)	RA (2000) (6)	PM (r.a.) (7)	Dec. (2000) (8)	PM (Dec.) (9)
691..........		10.40	0.0		12^{h}32^{m}59^s.73694	0^s.000845	36°33′42″.8044	−0″.04685
					516	420	156	127
692..........	2	10.3	0.9	7.4	12 33 42.76040	0.000095	36 14 6.0716	−0.03817
				1.1	4	88	8	101
693..........		11.7	0.3	...	12 33 50.42045	0.001661	36 11 10.2326	−0.02260
					239	236	94	93
694..........		12.9	0.9	...	12 34 21.76702	−0.000429	36 9 27.2875	−0.02787
					237	179	313	236
695..........	2	9.09	0.49	10.9	12 34 43.51973	0.001237	36 19 5.6314	−0.03416
				1.3	6	114	10	130
696..........		12.3	0.5	...	12 34 52.53219	−0.000254	36 31 5.7552	−0.01469
					470	354	255	192
697..........	2	9.41	1.09	2.2	12 34 53.57814	−0.003182	36 35 8.8991	−0.00388
				1.0	4	84	8	95
698..........		9.86	0.54	...	12 34 54.94813	−0.005274	36 24 36.1283	−0.03879
					363	274	171	129
699..........	2	8.13	0.51	9.4	12 34 59.31011	−0.007689	36 19 30.1789	−0.06127
				1.1	5	93	8	105
700..........		12.50	−0.2	...	12 35 0.18135	−0.001358	36 23 22.9222	−0.01849
					652	491	352	265
701..........		11.90	0.4	...	12 35 8.45578	−0.001139	36 16 15.0545	−0.02581
					149	112	518	390
702..........	2	7.27	0.50	9.9	12 35 10.87858	−0.001837	36 25 30.9035	−0.01468
				1.1	3	68	6	77
703..........	2	9.35	0.56	4.2	12 35 16.27671	−0.005006	36 7 34.2572	−0.03727
				1.5	7	152	12	176
704..........	2	8.20	0.45	8.0	12 35 18.80846	−0.007964	36 20 17.0905	−0.06407
				0.9	4	76	7	88
705..........	2	11.9	0.6	−1.1	12 35 22.40751	−0.000090	36 12 58.5401	−0.05083
				2.2	10	206	18	247
706..........		12.2	0.4		12 35 42.97608	0.000212	36 3 22.9152	−0.03882
					117	88	107	81
702..........		12.2	0.2		12 35 44.47773	−0.002510	36 14 28.3069	−0.03099
					173	130	80	60
708..........		13.1	0.1		12 35 54.13437	−0.002007	36 15 27.0884	−0.00817
					455	343	360	271
709..........	2	8.76	0.52	8.7	12 35 59.83712	−0.001494	36 15 27.5602	−0.04274
				0.9	4	72	6	81

Column (2; "d") denotes the device used to gather the astrometric data. A blank space indicates photographic plates measured on either the USNO SAMM or on a MANN measuring machine, in an attempt to detect any stars sharing the motion of Upgren 1. A "1" indicates plates measured on the AO Theiss machine. A "2" indicates that the data were obtained with the MAP. The photoelectric photometry (2 place significants) is from Upgren *et al.*

The absolute parallaxes listed above were obtained by adding a correction to absolute of 7.7 mas. All standard errors, for example those of the positions, are strictly internal and do not allow for the zero point errors of the reference system. The precession for +50 yr at the target object, is 2.440 minutes of time in R.A. and −16.52 arcmin in Decl.

The resultant positions and motions are listed in the last four columns of Table 2, over their standard errors. The system of the positions and motions is that of the AGK 3. The errors are given in the units of the least significant digit of the quantity to which they refer. They are strictly internal and are for the epoch 1987.0. They do not include allowance for the zero-point uncertainty of the reference system.

Photometric data listed in Table 2 to one decimal place only were derived by fitting iris photometer measurements of our blue and red bandpass plates to the B and R magnitudes published by Upgren *et al.* These estimates of V and $B-V$, which were interpolated from the photographic B and R values, have a precision of approximately 0.2 mag.

The fifth column of Table 2 lists the absolute parallaxes. While parallax was included in each iteration after the initial reference catalog pass (which used a weight of 1 for all measurements), no constraints were placed on their weighted mean. Thus the system of equations converged on the relative, not absolute, parallaxes. The adjustment value applied to the relative parallaxes may be derived in several ways, see van Altena (1974). In that work, mean and secular parallaxes are computed from a model incorporating the approximately known luminosity function, galactic distribution of stars and dust, solar velocity, and stellar kinematics. From this a table is produced in which galactic latitude and apparent magnitude predict an average parallax. For the mean magnitude and galactic latitude of our region, this table yields an adjustment of +7.7 mas.

Of course the validity of such a statistical adjustment depends on the correctness of the model and the number of reference stars. If the target object of a region is relatively near, errors of 10% in the estimation of the distance of the reference stars (which may then amount to a percent or less of the parallax of the target) will be relatively unimportant. However, for more distant targets, such errors become relatively important. As pointed out by van Altena, the most reliable approach is to determine the mean spectroscopic parallax of each reference star and average the results. This requires the photometric and spectroscopic calibration of the individual reference stars. Fortunately, most of the necessary photometric and spectroscopic studies were performed in the above citations. To be complete, similar studies of stars 692 and 705 should be compiled and an adjustment value based on all of the reference stars applied in Table 2.

AO 697 is listed in the *MK Classification Extension Catalogue* as a K1 III giant with an apparent visual magnitude of 9.41. Interpolating from the tabular values listed in *Astrophysical Quantities* (Allen 1973), we find an approximate absolute magnitude of +0.35 for this star. Assuming no perceptible interstellar dust, at a galactic latitude of +80°, we find a distance modulus of 9.06. Upgren *et al.* derive the distance moduli for the other six stars listed in Table 3. In column (3) we convert these to predicted absolute parallaxes and list the observed relative parallaxes for the same stars in column (4). The individual estimates of the value necessary to adjust the relative parallaxes to absolute are listed in column (5).

Computation of the mean adjustment, more specifically its standard error, suggests that both the trigonometric and spectroscopic parallaxes are of unusually high accuracy. The mean of the adjustment is 7.7 mas with a standard error of 1.5 mas, in excellent agreement with the value from van Altena. The standard error of a comparison is of course the square root of the sum of the estimated variances of the compared values. The average internally computed standard error of the trigonometric parallaxes of these seven stars is 1.1 mas. Assuming that this is a good estimate of the external error of the trigonometric parallaxes suggests that the standard errors of the spectroscopic parallaxes is only 1.0 mas. This is probably fortuitous and a result of the small number of comparisons. In any case it does give weight to the contention that the trignometric parallaxes are very accurate.

Table 4 lists the galactic X, Y, Z coordinates in parsecs and the velocities in km s^{-1} corrected for the average motion of the Sun relative to F5 main-sequence stars (Delhaye 1965). Listed under each of the velocities is its propagated error.

TABLE 3

DISTANCE MODULI AND RELATIVE PARALLAXES

AO No. (1)	Distance Modulus (mag) (2)	Spectroscopic Parallax (mas) (3)	Relative Parallax (mas) (4)	Adjustment to Absolute (mas) (5)	Residual (mas) (6)
695......	5.43	8.2	3.2	5.0	−2.7
699......	4.82	10.9	1.7	9.2	1.5
702......	5.04	9.8	2.2	7.6	−0.1
704......	5.28	8.8	0.3	8.5	0.8
709......	5.28	8.8	1.1	7.8	−0.1
703......	6.27	5.6	−3.5	9.1	1.4
697......	9.06	1.5	−5.5	7.0	−0.7

Average adjustment to absolute = 7.7 mas
Standard deviation one comparison = 1.5 mas

The standard deviation of the mean is a measure of the combined errors of the spectroscopic and trigonometric parallaxes. The average estimated standard error of the trigonometric parallaxes of the above stars is 1.1 mas which implies that the spectroscopic parallaxes have similar errors of estimation.

III. CONCLUSION

The motions obtained for the Upgren-Rubin stars with the MAP, though several times more accurate, are in general agreement with the previous much longer term studies and with our own photographic study of the same objects. The validity of the derived distances is also attested to by the agree-

TABLE 4

GALACTIC RECTANGULAR COORDINATES AND SPACE VELOCITIES

		X	Y	Z	V_x	V_y	V_z
$U-R$	AO		(parsecs)			(km s^{-1})	
1......	695	12.5	9.4	90.4	−22.2	3.6	15.3
					1.3	1.7	3.2
3......	699	14.5	11.0	104.8	12.3	−39.8	−8.0
					5.1	4.2	1.2
4......	702	13.8	10.6	99.5	−6.0	−0.3	−4.2
					1.3	1.1	3.9
5......	704	16.9	13.0	123.2	17.4	−51.1	−7.3
					5.9	5.0	1.4
6......	709	15.2	12.0	113.3	−16.0	−14.7	−10.4
					2.0	2.4	9.9
7......	703	31.7	24.1	234.7	25.1	−60.5	−8.2
					22.3	18.1	3.2

The coordinates, in parsecs, and the space velocities, in km per second, are given for the six stars with known radial velocities. The velocities have been corrected for the average velocity of the Sun with respect to F5 stars (Delhaye 1965). Under each velocity is its respective error which includes the effects of the errors in proper motion, parallax, and radial velocity but not the uncertainty of the Delhaye correction. The two groups mentioned in the text are most obvious in the velocities in X and Y.

ment found between the trigonometric and spectroscopic values.

The derived parallaxes confirm the unusually high density of stars in the region of Upgren 1. Excluding Upgren-Rubin star 7, which both the trigonometric and spectroscopic values suggest is behind the group, we find a mean parallax of 9.4 mas (106 parsecs) with a standard deviation (per star) of only 1.1 mas for Upgren-Rubin stars 1, 3, 4, 5, and 6. Since the average estimated standard error of the parallax measurements is 1.1 mas, this would seem to imply that there is very little difference in the distances of these stars. Within, or more probably slightly behind, this group there are two other stars. Upgren-Rubin star 2 has a photometric parallax of 7.5 mas, while AO 692 appears to be a somewhat later spectral type star with a trigonometric parallax of 8.0 ± 0.9 mas.

However, the space velocities, listed in Table 4, do not substantiate the proposal that the Upgren-Rubin stars (or the subgroup suggested by Upgren *et al.*) constitute a cluster. Instead, the group seems to be made up of two dynamically different subsets. Upgren-Rubin stars 3, 5, and 7 appear to be intermediate-velocity stars moving at approximately 55 km s^{-1} mostly in a minus Y direction. Because these stars are passing over the galactic plane in the vicinity of the Sun, the radial velocities shown in Table 1 fail to give any hint of their nature. The other subset, composed of Upgren-Rubin stars 1, 4, and 6, does not show a significant motion relative to the local standard of rest and their relative velocities are similar to those found for unassociated field stars. These motions would lead to the dissolution of the group in a few times 10,000 yr. Thus we are forced to conclude that Upgren 1 is only an interesting chance alignment of F stars resulting from the close passage of members of two dynamically different sets of stars.

The proper motions of Upgren-Rubin stars 3 and 5 are certainly significantly larger than those of the other stars and differ by less than 4% while their parallaxes differ by 1.0 times the standard error of their difference. This comoving pair has a mean trigonometric distance of 115 parsecs giving them a separation of approximately 45,000 AU or 0.22 parsecs. The wide separation of the members of this system and the apparent density of the space through which they are passing raises questions of interaction with neighboring stars.

The resolution of such questions may in fact not be that far off. The planned astrometric telescope for NASA's Space Station (Levy *et al.* 1986) will have a precision of 0.01 mas. This is sufficient to resolve differential distances of a tenth of a parsec at this distance.

We feel a special obligation to those who have supported our effort during its long development period. The development and implementation of the MAP and the refurbishment of the scientific facilities and plant of the Allegheny Observatory have extended over a period of more than a decade. This support has included a number of private gifts, most notably those from the estate of George H. Theiss. We also received support from the Frick Foundation of Pittsburgh, the Extrasolar Planetary Foundation, the Planetary Society, from Barnard Oliver and the SETI Foundation. Both the National Science Foundation, most recently through grant AST-8617642, and the National Aeronautics and Space Administration, through grant NAG 253, have supported the effort continuously throughout this entire period.

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