THE BRUCE AND PALOMAR – SCHMIDT PROPER MOTION SURVEYS

Willem J. Luyten
University of Minnesota

The Proper Motion Survey on plates taken with the Bruce telescope of the Harvard Observatory was begun in 1928 with a fellowship from the Guggenheim Foundation. The plates used have a scale of 1 mm = 59", generally go down to 16^m pg though a few long exposure plates almost reach 18^m pg and the survey is considered reasonably complete for the larger motions down to $14^m.5$ pg.

The blinking of the plates covering the Southern Hemisphere was completed and the discussion of the most important data was published in 1938. Another 300 plates in the Northern Hemisphere were then blinked, all motions found were measured by 1961 and all data were published in a General Catalogue in 1963. A brief summary of what was accomplished is given below.

Number of plates blinked	1,289
Area of Sky covered (square degrees)	28,750
Total Number of Moving Objects found	117,700
Total Number of different stars published	94,400
Total Number of New Motions found (at least)	80,000
Total cost (estimated)	\$ 170,000
Cost per new motion found and published	\$ 2.12

A small pilot program for an eventual proper motion survey on plates taken with the 48-inch Schmidt telescope was initiated in 1958. The systematic program - both the taking of the new red plates, the blinking of the plates and the measurement of the motions found was begun in September 1962.

A total number of 936 pairs of red and blue plates constitute the National Geographic Palomar Survey, north of declination -33 (1875) covering 77 percent of the sky. Generally the red plates go down to 20^m red, which, for most proper motion stars means $21^m.5$ pg. Only the red plates were repeated.

Here I should like to express my deep gratitude to the director and the staff of the Hale Observatories, for the taking of all these new plates has been possible only because I was given guest-investigator privileges and assigned more than 150 nights with the 48 - inch Schmidt telescope at the Palomar Observatory during the period 1958 - 1970. And it should be remembered that the 48 - inch telescope can be used only during the dark of the moon, hence 150 nights represent ten months' full operation of the telescope. I do not know of any other observatory that has been as generous to an outsider.

https://doi.org/10.1017/S0252921100027913 Published online by Cambridge University Press
https://doi.org/10.1017/S0252921100027913 Published online by Cambridge University Press

What has been accomplished to date can be summarized as follows: New plates taken - 907, Red plates remaining - 29.

Examined, and measured:	Plates blinked	Number of Objects Found	Number of Diff. Stars Published
North Polar Area (north of +69, 1855)	50	21,500	19,000
Zones +66, +60 (1855)	36	16,000	1,500
Hyades region	10	3,800	2,800
North Galactic Pole region	10	6,300	5,300
South Galactic Pole region	8	4,600	4,400
Scattered Areas completely measured	15	6,100	5,500
Scattered areas not yet measured	21	11,700	4,000
Totals	150	70,000	42,500

Originally it was not contemplated to blink the very crowded plates of low galactic latitude by the human-eye-cum-human-hand method. As a "tour de force" I have now blinked one such plate, P 234, centered at 21: 00 +42 (1855), which area contains the North America Nebula. This has taken 130 hours but on this same pair of plates, having an interval of 17 years, I found more than 2500 proper motion stars.

Of the 42,500 proper motions published, at least 40,000 are new. Total cost has been almost $\$$166,000 or $\$$4.15 per new motion found - not quite twice the cost of the Bruce survey, thirty years earlier.

One of the principal aims of such a Proper Motion Survey is to get down to stars of very low luminosity and to try and estimate their frequency in space - or, in other words, to determine the faint end of the Luminosity Function. As soon as the Bruce plates had been blinked, and the large motions measured, in 1937, I made a new determination of the Luminosity Function, and found that the maximum lay at $M = +14^{m}.5$ pg, with an indication of a much steeper decline than rise.

The average Palomar - Schmidt plate goes about 6^{m} fainter than the average Bruce plate and when, in 1967, I had blinked almost ten percent of the Schmidt Survey, I made a re-determination of the Luminosity Function and now found the maximum to lie at + 15.7 pg, with still a steep decline, and only a slightly larger mass density in space than thirty years before. The fact that now, with much better material the maximum has moved barely one magnitude fainter gives hope that we are, at last, getting close to the real maximum.

In one field the 48 - inch Schmidt telescope is pre-eminent viz. in the discovery of stars of low luminosity. Assuming arbitrarily a value of 0.001 of the sun's bolometric luminosity as the upper limit for "low-luminosity stars", and realizing that in the absence of parallaxes, spectra, and photo-

https://doi.org/10.1017/S0252921100027913 Published online by Cambridge University Press

electric colors we are forced to statistical methods for finding such stars, I have used the values of the reduced proper motion, $H = m + 5 + 5 \log \mu$ and my estimated colors to identify them. Details are given in a separate publication and it will suffice here to give the following summary:

Stars with $M_{bolo} \leq 0.001 \odot$

Found by all others	20
From the Bruce Survey	16
Identified thusfar on 48" Schmidt plates	1032

eloquent testimony to the power of this unique telescope.

DISCUSSION

Fricke: Have you ever estimated how many hours were spent on the work which was reported here in these 13 1/2 minutes?

Luyten: Forty years.

Herget: There were two prices for proper motions - two dollars and something, and four dollars and something. Have you an estimate how many cents per proper motion for the equipment we saw today?

Luyten: I have to take the fifth amendment on that; I think that would depend on inflation. I might add that there is one thing I should have mentioned about the present Palomar - Schmidt survey. One of the main reasons for building the machine was that we didn't think that we could blink the low galactic latitude plates by the human-eye and human-hand method. There are something like ten million stars per plate. After we started building the machine it was felt that in order to know how well the machine is really operating, the machine should blink a low latitude plate and then compare it with what we had done before. So I felt compelled to blink one low latitude plate, and I took the one with the North America Nebula on it. I haven't quite finished it yet, but thusfar, for almost three quarters of the plate it has taken 110 hours, and I have found 1900 proper motions. To finish the plate would take at least 150 hours including doing the magnitudes and colors. After that come the measures and with a total of close to 3,000 stars, my students would probably take another thousand hours. You can see that the cost would be a little higher than what we have had.

Gliese: Do you think that the numbers of low-luminosity stars that you presented here will change your derivation of the Luminosity Function you gave at Prague?

https://doi.org/10.1017/S0252921100027913 Published online by Cambridge University Press

Luyten: No, because most of these were known before 1967, and most of them were used in the derivation of that luminosity function. They were mostly published before 1967, but not unified into a single catalogue.

Strand: Could you briefly say what the results were, where does the maximum of the Luminosity Function lie?

Luyten: The maximum of the curve came at +15.7 pg. Because even though these are mainly red stars where we should use visual or red magnitudes we have only photographic magnitudes. Of course, one should caution about that. Kapteyn found the maximum at +7.7 in 1916, I think, and he felt he was definitely past the maximum. Van Maanen got it at +9.0, and he was also definitely past the maximum in 1921. Then I got one at +10.5, in 1923, and we also were very definitely past the maximum. From the Bruce motions I got +14.5, in 1937, and we were unquestionably past the maximum. Now it is +15.7. You notice the increment as now being much smaller so maybe we are finally getting close to rounding the corner.

Eichhorn: When you translate the Luminosity Function into a mass function, have you an idea roughly what power of the mass the mass-frequency is proportional to?

Luyten: I am afraid I haven't looked at it that way. The main thing is that the total mass per cubic parsec with the luminosity function from the Schmidt program is only very slightly higher than the total mass from the Bruce program thirty years earlier. I think this is simply because, unless all the present data we have are wrong - which is possible - we have few double stars among these very low luminosity objects. The total contribution of each absolute magnitude group to the total mass remains about constant, I think, from absolute magnitude to +8 to about +14. That curve is very flat, but after +14 it begins to go down. However, we should be very careful in saying that we are really around the corner.

Murray: I take it then that you would be interested in trigonometric parallaxes of very faint stars. Could you say something about how you'd start selecting an observing program from among the thousands that you've turned out? Bearing in mind that for a trigonometric parallax program of stars as faint as that you've got to use a big telescope, so you can't have a large program.

Luyten: I should like to change the adjective. You don't need big telescopes, you need Schmidt's. Because I don't think big telescopes that do not have the very small images can do the job. I was hoping Jerry Kristian would be here to give a paper on some parallax plates that he took with the 48-inch. From them I have just determined the parallax of the original pygmy - now

https://doi.org/10.1017/S0252921100027913 Published online by Cambridge University Press

don't quote me on this - on which the battle of the pygmies was started. This is a star at about 1: 47 and -17. It's about 18th magnitude, and we are still fighting about whether the color is really that of an a or a b star even, or whether it's more solar color and has strong ultraviolet because it is degenerate. There's a proper motion of a little over a second of arc going mainly south. If it is an ordinary white dwarf of ordinary luminosity, then the parallax should be of the order of 0.''006. This would mean a velocity of some 700 kilometers per second and the star would be escaping from the galaxy. On the other hand, if it is a pygmy the parallax could be as much as 0.''050 or 0.''060. Of course, I got a beautiful answer, exactly halfway between, 0.''027 ± 0.''024. So the battle of the pygmies is still joined. But I still feel that, as of now, the only type of telescope that could handle parallaxes for this kind of very faint star is a Schmidt. Remember that most of those 1,000 stars at the bottom of the luminosity list are fainter than the 20th apparent magnitude: that's where you begin to pick them up in large numbers. And, of course, this is why no other telescope ever found them. It's easy enough with the 48 - inch; you could train a monkey to find them, you don't need an astronomer. These things just roll out of the 48 - inch, but no other telescope has been able to do it. And, if you want parallaxes on a large scale, then we need automated and digitized machines, to measure the plates. If this isn't optical heresy I would say what we need is a Schmidt with a 48 - inch aperture but twice the focal length. Incidentally this also would do a good job on the Magellanic Clouds, much better than the present type of Schmidt telescope which would burn out the plates.

https://doi.org/10.1017/S0252921100027913 Published online by Cambridge University Press
https://doi.org/10.1017/S0252921100027913 Published online by Cambridge University Press