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# A (1). OVERALL STRUCTURE: NUCLEAR REGION AND HALO

The objects from which the structure and the kinematical properties of the nuclear region and the halo can be derived are in general those classified as population II objects: the RR Lyrae variables, population II Cepheids, RV Tauri variables, long-period variables with periods near 200 days, novae, planetary nebulae, bright red giants as found in globular clusters, and the blue stars found near the galactic poles which are probably similar to those found in globular clusters.

Although the separation of halo and nuclear region is somewhat arbitrary, it is convenient for the discussions to use those terms. Some differences in populations of the two regions are indicated by the observations, and the observational approach presents different problems.

## WORK ON VARIABLE STARS IN THE HALO

Experience gained through large surveys of variable stars (Harvard, Leiden, Sonneberg) and the statistical investigations based on their results have shown that this is a very promising field of research.[1] The aim of an extension of this work is more precise knowledge of the density distribution in the halo and near the galactic centre.

### *Large-scale structure of the halo*

From all the evidence available at present it seems that the distribution of the population II objects is symmetrical with respect to the axis of rotation of the Galaxy. (Distribution of globular clusters in the Galaxy, distribution of population II objects in extra-galactic nebulae.) The first task of future work, therefore, will be to determine the way in which the density varies with the distance from the galactic centre, as measured along the galactic plane, and with the distance from this plane. The determination of possible deviations from rotational symmetry is a problem for the more distant future. This assumption implies that it is not necessary to observe in all galactic longitudes. The following proposal was made by Baade.

For the determination of the surfaces of equal density in the halo, we can restrict ourselves to determining the density distribution in a cross-section, perpendicular to the galactic plane and going through the Sun and



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the axis of rotation. The fields to be studied then will be at galactic longitudes 147° and 327°. The number and size of the fields depends on the number of objects to be expected and on the number of times one wants to cross a certain surface of equal density for the determination of its location. The surveying (observing, blinking) and the determination of light curves and apparent magnitudes involves a large amount of work. It is proposed that, to begin with, three fields be chosen, centred at approximately

$l = 327°$, $b =$ about 20° (latitude as close to the nucleus as interstellar absorption permits);
$l = 327°$, $b = 45°$;
$l = 147°$, $b =$ somewhere about 10°.

The ideal instrument for such a survey would be the 48-inch Palomar Schmidt, which may become free in the next few years after the sky survey is concluded. It gives fields of $7° \times 7°$ free from vignetting and can easily reach the 20th photographic magnitude in 10-min. exposures. This provides an ample margin to make sure that the survey will be complete up to 17·5 median magnitude corrected for absorption, i.e. distances up to 30 kiloparsecs for the RR Lyrae variables—even if the absorption in one of the fields should amount to one or one and a half magnitudes. In the case of the two latter fields it is very probable that regions of heavy or irregular absorption can be avoided. As to the first, it is a matter of searching the sky survey plates in this general direction before deciding on the most suitable co-ordinates.

The question has been raised if this new survey is justified in view of the large amount of work which has been done already in previous surveys.[1] The opinion of most of the participants at the conference was that little duplication will be involved because the new survey extends to fainter limiting magnitudes than the previous ones which, moreover, are mostly much nearer to the galactic plane. The most important feature, however, will be that strong emphasis would be placed upon completeness of the survey up to apparent magnitude 17·5. Exhaustive studies of variable-star fields at the intermediate galactic latitudes, up to this magnitude, have not been made and thus the extension of work in existing surveys would be considerable anyway. Another important consideration is that the existing surveys are made with telescopes which require fairly large field corrections, so that the limiting magnitude varies considerably over the field.

The exhaustive search for variables is a tedious task and has to be done by an experienced investigator who fully realizes the importance of



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searching a field very carefully, even by the time it is almost exhausted and only a few new discoveries are to be expected. The completeness factors to be applied to the final number of variables found should be so well determined that their uncertainty does not affect the final discussion. In every field, 300 plates should be taken for the determination of periods and light curves, and thirty pairs of these plates should be blinked. All RR Lyrae variables, long-period variables and semi-regular variables should be studied. From experience in this sort of work, Baade thinks that the variables of small amplitudes will be difficult to detect if they are more than five magnitudes brighter than the plate limit. For the brighter stars we need supplementary surveys (see pp. 7 and 8). Blue plates are recommended. There is strong evidence that the composition of the halo is similar to that of the globular clusters and in these we find the red variables at maximum to be 1·5 magnitudes brighter than the RR Lyrae variables. Therefore, if the survey will be complete for the RR Lyrae variables, it will also be so for the red variables. The use of photo-visual or red plates would reduce the amplitudes of the variables and considerably diminish the chances of discovery. This latter experience was also reported by Bok.

The amount of work required by this new survey can be roughly estimated on the basis of the following figures provided by Dr Plaut:

The time needed to blink ninety pairs of plates is hard to predict, but may be of the order of 2000 hours.

The total number of RR Lyrae variables to be expected in the 48-inch Schmidt field nearest to the galactic centre is about 200. The time needed to estimate the brightness of those 200 RR Lyrae variables on 300 plates and to determine periods and light curves is about 6000 hours.

The number of long-period and irregular variables is difficult to estimate. From the best evidence available one would guess that they are less numerous than the RR Lyrae variables. In any event the complete study of these objects will be less time-consuming than that of the RR Lyrae variables.

The total amount of time required for the field nearest to the galactic centre will thus be about 10,000 hours, and for the three fields together we would expect something of the order of 15,000 hours or six man-years.

Experiments to develop a more rapid process of finding the variables than by regular blinking or comparing negative and positive plates have not yet been successful.

Since the conference was held, it has become likely that Dr Plaut will be able to undertake the blinking, and that at least part of the further work will also be carried out at the Kapteyn Laboratory.



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*The photometric scale*

For the above programme as well as for those mentioned below the precise reduction of the observations to a well defined photometric system is of fundamental importance. This phase of variable star work has been neglected too much in the past. It is strongly recommended that the sequences transferred to the variable star fields represent with very little tolerance the international system. If this condition is not satisfied, the results of the variable star statistics cannot be used for the accurate measurement of the dimensions and structure of the Galaxy.

An excellent basis for the transfer of the photometric scales will be the sequences in nine Selected Areas established by Baum. This work, which includes photo-electric observations of photographic magnitudes and colour indices from 9 to 19·5 magnitude will be completed about the time this report is published. In zero point and scale they will be copies of the polar sequence, but the internal accuracy will be much higher. Their transfer to the variable star fields, which may be either photographic or photo-electric, will be technically much easier than that of the polar sequence. The list of these precision areas follows:

| S.A. | R.A. | Dec. | $l$ | $b$ |
|---|---|---|---|---|
| 68 | $0^h\ 11^m$ | +15° | 79° | −47° |
| 94* | 2 51 | 0 | 143 | −48 |
| 71 | 3 11 | +15 | 135 | −34 |
| 51 | 7 24 | +30 | 157 | 22 |
| 54 | 10 24 | +30 | 168 | 60 |
| 57 | 13 4 | +30 | 25 | 85 |
| 107* | 15 34 | 0 | 334 | 40 |
| 61 | 16 59 | +30 | 19 | 34 |
| 89 | 21 8 | +15 | 33 | −22 |

* For transfers to southern hemisphere.

*Soviet survey of variable stars in Kapteyn's Areas*

From communications by Dr B. V. Kukarkin we derive the following. The Moscow and Engelhardt (Kasan) Observatories have started (in 1948) a survey of variable stars in the Kapteyn Selected Areas from the equator up to the North Pole. The limiting magnitude is about 17·5 and the areas studied cover about 100 square degrees each. For every area, thirty pairs of plates will be blinked, and completeness will be achieved up to about $m = 17$. The instruments used are a 38 cm. Schmidt and a 40 cm. astrograph.

This programme will be a very valuable addition to the one outlined above. It does not penetrate to as large distances, but will permit a much more detailed study of the nearer regions, especially with regard to the



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different behaviour of various sub-groups among the RR Lyrae and long-period variables, and the properties of the uncommon types of variables, as for instance the RV Tauri stars.

*General survey of the brightest variables*

It is generally considered desirable, that in addition to the surveys mentioned above, a complete search over the whole sky be made for the stars brighter than, say, magnitude 12·0. This will provide information on the local density of RR Lyrae and long-period variables which are typical halo-objects. We also want to study the kinematical properties of these objects. This survey, therefore, should be supplemented by measurements of proper motions and radial velocities (see also Sections C (1) and C (4)).

Such a survey should be made with an instrument of short focal length, so that the density of the stellar background on the plates is sufficient for the blinking. Perhaps a meteor camera, if free of vignetting, would be the suitable instrument. Again, as in the other surveys, completeness is required; some of the stars discovered will be known already as variables and have known elements of the light variation (Harvard, Sonneberg, Odessa, etc.).

In this connexion it may be mentioned that another project under way in the Soviet Union (Odessa, and other observatories) is the sky patrol between declination minus 45° and the North Pole. Its purpose is to determine the complete characteristics (periods, light curves) of the *known* variables, brighter than 12·0 photographic magnitude. As Dr Bok pointed out, the Harvard sky patrol plates will be available for further study of the brighter variables to anybody interested in using them. Dr Kukarkin suggested that the trained staff of the three Soviet institutions working on variable stars may help in studying variable star plates obtained elsewhere.

## LOW LUMINOSITY BLUE STARS IN THE HALO

To the surveys of variable stars one might add a survey of the blue stars of population II of the kind which have been discovered near the North Pole by Humason and Zwicky. Although the character of the stars found in their survey has not yet become quite clear, it seems highly probable that they have absolute magnitudes around $M=0$ or fainter.[1] The brighter ones—$m_{pg}<12$—could be picked up from objective prism plates as in the case of the star observed at Cleveland.[2] For a general survey extending to fainter magnitudes, red and blue exposures with one of the existing



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Schmidt telescopes could provide the necessary material. An experimental programme for finding the stars, based on simultaneous ultra-violet and yellow exposures with a small Schmidt camera, is now under way at the Yerkes and McDonald Observatories. The blue stars are expected to stand out as conspicuous objects on these plates. This method may prove to be more efficient than that of the objective prism spectra. The surveys should be followed up with photo-electric observations of the colours and slit spectra of the stars found.

## NUCLEAR REGION

### *Radio surveys*

The most accurate determination of the position of the galactic nucleus follows from radio surveys at decimetre and metre wave-lengths and from observations of the 21-cm. line of interstellar hydrogen. A very interesting question is, how steeply the intensity falls from the nucleus towards its immediate surroundings. The solution of this problem requires instruments of high resolving power.

### *Variable stars*

Baade[1] has investigated the frequency of the variable stars in a small region of 16′ radius, $l = 328{^\circ}2$, $b = -4{^\circ}3$ up to $m = 20{\cdot}0$, and from the distribution in apparent magnitude he was able to determine the distance of the galactic centre and the density of the RR Lyrae variables for distances from 0·6 to 2·6 kiloparsecs from the nucleus. A similar investigation based on plates of a region at latitude $-7{^\circ}3$ near the galactic centre, observed at the Radcliffe Observatory, will probably be made at the Leiden Observatory. An investigation at galactic latitude $-20°$, longitude 307° down to the 17th magnitude had been published earlier by Shapley.[2] The region observed by Baade was picked out after careful scanning of the nuclear regions on films taken with the Palomar 18-inch Schmidt telescope. A field equally close to the galactic centre and probably somewhat more homogeneous is the region just south of Co $-29°14299$ ($l = 329{^\circ}2$, $b = -4{^\circ}1$). The important criterion for the selection is not only sufficiently low absorption, but the absorption should also be uniform over the field and wisps of dark clouds which are frequent in these directions must be avoided. This condition is much easier to meet in somewhat higher latitudes and a second Pretoria field, centred on Co $-28°14334$ ($l = 331{^\circ}7$, $b = -6{^\circ}5$) should be nearly ideal. Use of red or infra-red plates which would penetrate the absorption better is not to be preferred because in red light enormous numbers of faint stars come up which not only complicate the



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search for variables but are the cause of too much overlapping. There are two important additional reasons why red and infra-red plates should be avoided in investigations of the variable stars of the nuclear region: the small amplitudes of the RR Lyrae variables and Cepheids in the red and the complete lack of faint red and infra-red standard magnitudes.

Because of the high star densities in the nuclear region of our Galaxy and the strong overlying absorption large reflectors of sufficiently great focal length are required for the investigations just described. Large Schmidt telescopes with their relatively short focal lengths should become useful in latitudes greater than 7°.

Baade's field was centred on the globular cluster NGC 6522, which is imbedded in the centre region of our Galaxy at a distance of 10·1 kiloparsecs from the Sun, and he inferred the absorption for his field from the observed colour excess of NGC 6522. Obviously a determination of the absorption from the reddening of a number of the RR Lyrae variables in the field is highly desirable and attempts have been made both on Mount Wilson and Palomar Mountain to determine photo-electrically the colour excesses of a few of these variables. These attempts failed because the Sagittarius region is too far south for such precise measures. It is hoped that they can be provided in the future by observations from the southern hemisphere. Baade thinks there is no way of allowing for variable absorption over a field in a statistical investigation. It might be that very close to the centre even a smaller field than the one used by Baade would be sufficient because of the higher frequency of RR Lyrae variables to be expected there.

At distances of about 10° from the galactic centre, particularly in negative latitudes where the absorption is lower than at positive latitudes, a region may be found with sufficiently low and uniform absorption and large enough to give statistically significant numbers of the variables. This is a matter of further searching. If fields sufficiently large can be found in this latitude, large Schmidt telescopes undoubtedly will be the proper instruments. Investigation of these directions should give information on the densities at distances $\geqslant 1500$ parsecs from the nucleus itself. According to Bok, Schmidt plates taken with the ADH telescope show that at negative latitudes about $-7°$ the absorption becomes uniform.

Other types of variable stars in the nuclear region were discussed only briefly. In the Cleveland infra-red survey variables are picked out on the basis of the presence of the vanadium oxide bands. The possibilities of this work for a general survey of long-period variables are being investigated. Near the nucleus in the region investigated by Baade, the number of Mira variables with periods about 200 days and that of the



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variables with periods between 60 and 150 days and amplitudes about one magnitude, is about half of the RR Lyrae variables, and an equal number of semi-regular and irregulars were found. However, it is quite possible that they are relatively more numerous farther from the centre. It is to be borne in mind that the RR Lyrae variables discovered by Baade near the nucleus have shorter periods in general than those more distant from the centre, and seem to form a somewhat different class.

Dr Kulikovsky reported on work done by Vorontsov-Velyaminov and his associates on the distribution of long-period variables, and drew attention to an apparent concentration of these objects in the direction $l = 335°$, $b = -7°$. Whether indeed such concentrations are real or not, or are caused by local transparency of the interstellar medium, remains to be investigated.

*Planetary nebulae*

Minkowski's[1] and Henize's surveys of planetary nebulae are being supplemented by a new survey with the Schmidt telescope of the Tonantzintla Observatory. This survey covers the central region between approximately galactic longitudes 305° and 345° and latitudes ± 15°. Until now 437 $H_\alpha$ emission objects were found. Of these 121 correspond to previously discovered planetaries while sixty-seven are classified as new planetaries and forty-eight as probable ones, small diffuse nebulae or novae. The majority of the rest are probably peculiar emission stars. A general programme of checking the emission objects is planned at Tonantzintla.

The determination of radial velocities of the planetary nebulae would add very important information on the dynamics in the nuclear region. Two projects are already under way: Dr Mayall of the Lick Observatory is observing the spectra of all planetaries north of −25° which are not too heavily obscured, while Dr Minkowski at Mount Wilson and Palomar will observe the faint planetaries in the nuclear region. There is some overlap of the two programmes in order to check for systematic errors in the radial velocities of the two series. It is expected that the Radcliffe Observatory will observe planetary nebulae in the remaining part of the sky.

*Infra-red survey of M giants*

The work undertaken at the Warner and Swasey Observatory,[2] and recently extended to the southern hemisphere in collaboration with the Tonantzintla Observatory, will give important information on the space



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distribution of the late M giants. On plates of the Sagittarius cloud, Nassau classified between 300 and 400 late M's per square degree in the direction $l=330°$, $b=-9°$ and a somewhat smaller number at $l=326°$, $b=-8°$. The limiting infra-red magnitude of these counts is about 12·7. As the infra-red absorption in this direction is of the order of one to two magnitudes and the mean infra-red luminosity between −3 and −4, the survey reaches at least the distance of the nucleus. Thus, from these objects another measure of the density distribution in the central part of the Galaxy may result. The results announced by Nassau are part of a general survey at galactic latitude −8° in a belt of 22° in longitude symmetrical with respect to the direction of the centre, for which plates are being taken by Haro.

*Novae survey*

The strong concentration of the novae to the galactic nucleus makes them interesting objects for the study of the nuclear region. A basic difficulty in the interpretation of the results from any survey will be the uncertainty in the interstellar absorption. There seems no means of evaluating this. However, important problems may be solved without exact knowledge of the locations in space. Examples are: the frequency of the novae phenomenon in our Galaxy, the apparent (projected) concentration to the galactic nucleus, the shape of the light curves and their correlation with spectral peculiarities. Apart from the interest of these investigations for the study of the intrinsic properties of the novae, they are of great importance for the comparison of the properties of our Galaxy with neighbouring systems like M31, M33, M81, M101. A thorough study of the novae in the Andromeda nebula, to extend the early results of Hubble's survey, is now under way with the 60-inch Mount Wilson reflector. It will provide full coverage for the two seasons 1953 and 1954, each extending from June to February.

A search for novae in the central directions of the Galaxy is being made by Haro with the Tonantzintla Schmidt telescope. It covers about 600 square degrees up to apparent photographic magnitude 13. Two plates a week are taken, and in addition one spectral plate (dispersion of 240 *A*/mm.) every month in order to detect faint novae showing $H_\alpha$ emission. Objects brighter than $m=10$ are observed photo-electrically, those between 10 and 13 photographically.

As was pointed out by Kukarkin, the combination of data from sky patrols carried out by observatories in different parts of the world can be extremely useful for obtaining well-covered light curves of novae.



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# A (2). OVERALL STRUCTURE: SPACE DISTRIBUTION AND MOTIONS IN THE DISK

The population of the disk consists of a great variety of objects with a wide range of concentration towards the galactic plane and of peculiar motions. The extreme population I objects like interstellar gas and dust and supergiant stars, show quite different properties with respect to space distribution and motions, compared to such stars as, for instance, the common G and K giants. The discussions at the conference have concentrated on the observational possibilities of studying the correlation—or the lack of correlation—between the space distributions of different kinds of objects. From recent theoretical as well as observational work it has become apparent that there is a wide range in the ages of the stars contributing to the disk population, from a few million so some 1000 million years. The differences in the distributions of the various kinds of stars very probably must be interpreted in terms of these differences in age and evolution. The most intriguing problem for the present thus seems to be this: Can we trace large-scale structure in the distribution of objects of different ages, and can we derive information on the evolution of the galactic system and of the stars themselves from the degree of resemblance in the large-scale structure exhibited by different objects?

Of great importance in this study is the comparison between our Galaxy and other stellar systems, particularly the nearest spiral nebulae. From these objects we derive information on the distribution of the most luminous stars of various types and of the interstellar medium and on their mutual relation. It is, therefore, appropriate first to summarize some of the results of the studies in this field communicated by Baade.

## INFORMATION DERIVED FROM THE ANDROMEDA NEBULA

The Andromeda nebula is particularly suited for study of the properties of spiral arm and inter-arm populations, because it exhibits a well-defined spiral structure. Its arms are relatively thin and secondary branches which so easily confuse the picture are rare. Evidence of heavy absorption in the arms was derived from the fact that on $H_\alpha$ photographs emission nebulae appear by the hundreds in the arms—and the brightest and largest among



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