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CONTRIBUTIONS

from the

BOSSCHA OBSERVATORY

No. 21

PROCEEDINGS OF A SYMPOSIUM ON STANDARDS FOR STELLAR PHOTOMETRY AND SPECTRAL CLASSIFICATION

Edited by

PIK-SIN THE

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FOREWORD.

Some years ago Unesco, Southeast Asia Science Cooperation Office offered financial help to the Bosscha Observatory in the organization of an International Astronomical Symposium in Indonesia. In addition to Unesco's offer the Department of National Research was also willing to support the symposium financially.

After consulting Drs. V.M. Blanco and A. Blaauw it was decided to have as the topic discussed at the symposium, Standards for Stellar Photometry and Spectral Classification.

The symposium was held in Bandung in the building of the Indonesian Society of Natural Science, from March 30 to April 2, 1963. The following persons were invited to participate in the symposium:

L.H. Aller	K. Purbosiswojo
V.A. Ambartsumian	U. Steinlin
G. Haro	A.D. Thackeray
S. Nitisastro	Pik-Sin The
K. Osawa	G.L. Vandervort
L. Perek	B.E. Westerlund.

A total of eight papers were presented at the symposium. These papers were read in two seperate sessions. Drs. L.H. Aller and V.A. Ambartsumian respectively, were chairman of the first and the second sessions. In addition to the symposium, lectures were given by several persons, and a discussion about the publication of a catalogue of planetary nebulae was also held.

It is a great pleasure to acknowledge with many thanks the help of Dr. L.H. Aller, Dr. Gordon L. Vandervort, Mrs. Bernice Vandervort, Mr. Lim Kee Giap and Mr. Oei Pek Lim in the preparation of the texts of the discussions after each paper.

I would like to express herewith my deepest gratitude also to all my coleagues at the Bosscha Observatory, to all the students of the Bandung Institute of Technology, and to all the individuals who have helped in making the symposium a succes.

Pik-Sin The.

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The Honorable Ministers of Higher Education and Sciences and of National Research.

Honorable Gentlemen The representative of the Governor of West Java, Head of Unesco Southeast Asia Science Cooperation Office.

President of the Bandung Institute of Technology, Dean of the Department of Science.

Distinguished Delegates,
Ladies and Gentlemen.

It is a great honour to welcome you to the opening ceremony of our scientific meeting, which is sponsored by Unesco, Southeast Asia Science Cooperation Office and our Government, through the Department of National Research. It is a great honour indeed to have all of you distinguished guests and participants of the symposium, gathered in this building.

Ladies and gentlemen,

As you probably know the subject of our symposium is, "Standards for Stellar Photometry and Spectral Classification". This choice has something to do with the location of our observatory. It has been pointed out many times that the importance of our observatory is that it is located near the equator. Our location is of fundamental importance for the transfer of standard magnitudes set up by astronomers from the northern hemisphere to the southern sky. It is for this reason that we have chosen this topic as the subject of our symposium. Another important thing I would like to point out, in connection with our location, is that from our place we can see almost the entire Milky Way, the "Bima Sakti", while its centre almost passes overhead. I think that my colleagues will agree with me that our geographical location is very good for the study of galactic structure.

My dear friends from abroad,

I hope that you will agree with me that, because of the worldwide nature of our science, it is necessary to have close cooperation between astronomers throughout the world. For this reason I am very greatful for the help we have always received from our friends abroad, even though Indonesia is not a member of the International Astronomical Union. But I am certain that in the near future it will be possible for us to join your organisation.

Ladies and gentlemen,

Finally I would like to express my deepest gratitude to Unesco, Southeast Asia Science Cooperation Office and the Department of National Research for the financial help I have received in organizing this symposium. Furthermore I would like to express my deepest gratitude also to all my friends who are helping me in organizing this symposium.

Thank you.

Director of Bosscha Observatory.

Dr. Pik-Sin The.

Excellencies the Ministeres of Higher Education and Sciences and of National Research,

Honorable gentlemen the Governor of West Java,
Other members of the Tjatur Tunggal,
Head of Unesco, Southeast Asia Science Cooperation Office,
Guests and Indonesian Astronomers,

Dear Colleagues, visiting Scientists and Friends,

Ladies and gentlemen:

May I begin by welcoming all of you to Bandung and to our conference room and by expressing my heartiest thanks and appreciation for your attendance.

First I would like to thank my Government q.c. our ministers for the firm support — morally and materially — provided to organize an Astronomical Symposium to be held in Bandung within the scope of scientific activities of our Institute.

For their understanding and very valuable help in realizing this symposium we also owe Unesco a great debt of gratitude and I must not forget to express my thanks and deep appreciation to our friends Dr. The and his staff members who successfully undertook the preparation of the symposium.

Dear ladies and gentlemen:

It is really a satisfaction and a big honour for our institute of higher learning, the Institut Teknologi Bandung, to have the opportunity to organize a Symposium of International character, which is due to the activities of the leader and staff members of the Bosscha Observatory in Lembang.

Because of its position near the equator, the Bosscha Observatory is unique and thus has drawn more and more attention of astronomers, since this observatory may play an important astronomical role in the near future and may possibly fulfill a specific function also by closing the gaps in information existing between northern and southern hemispheres.

I am fully aware, that tremendous progress has been made in techniques and technology since world war II. Many instruments, to measure many kinds of physical as well as astronomical phenomena with a high degree of accuracy are being developed, and thus enable many scientists to search further and deeper and to uncover and dismantle a lot of secrets of the universe. Consequently the open space of yesterday becomes wider and wider today. Outerspace becomes daily talk, the moon, the planets come nearer and nearer to us. But in spite of all this progress men still have to face thousands and thousands of problems which must be solved for the well-being of humanity.

Dear friends, and honorable astronomers.

Now you are here and some days ago you were in Australia, coming from far distances to discuss astronomical problems. If the information I have is correct, one of the aims, of this symposium, is to arrive at an international agreement in defining standards for stellar photometry and spectral classifications to be used everywhere in both hemisphere. This is necessary since there are in use different systems of measurement at present, which may cause inconsistencies after translation from one to the other.

The importance of a joint conclussion you all are seeking follows clearly from your gathering here for several days from such great distances.

I can not refrain from saying here, not for the benefit of the astronomers who I suppose already know, but mainly as information for the Indonesian friends, how impressed and proud I am after being informed that our observatory in Lembang has announced an important discovery made by Dr. The, the director there, who used the newly build Unesco Schmidt telescope which is equipped with the newest and most accurate instruments. I would also like to express my appreciation for the work done by Dr. Purbosiswojo on background effects in photographic photometry and also the work of Mr. Nitisastro in photoelectric photometry.

It is, perhaps, in astronomical evaluation a humble contribution from Indonesia and from the Bosscha Observatory to the tremendous world sollection of discoveries and important work made in the past, but that is why we eagerly hope that with this start Indonesia will be able to contribute increasingly more astronomical findings as a result of the important site of our observatory.

Ladies and gentlemen:

It fell to my share the honour to officially open this symposium, which I eagerly accept and with this:
"I declare this Astronomical Symposium opened on March 31st, 1963, in Bandung, and wish all of you success in your efforts".

Thank you.

President of the Bandung Institute of Technology

Prof. Ir. O. Kosasih.

Your Exellencies, distinguished delegates, ladies and gentlemen,

It is to me a great honour to welcome you all to this important scientific meeting which Unesco is co-sponsoring with the Government of the Republic of Indonesia. The Director-General of Unesco wishes me to convey to you all his greetings and the expression of his best wishes that this symposium may be successful in attaining its objective of making a contribution to the advancement of international astronomical sciences.

May I, on behalf of Unesco, express our deep gratitude to the Government of the Republic of Indonesia for hosting this symposium. In particular we wish to express our appreciation to His Excellency the Minister for National Research, Prof. Sudjono Djuned Pusponegoro, who despite his multitudinous duties has still found it possible to find time to attend this symposium; to the Minister for Higher Education and Sciences, Prof. Tojib Hadiwidjaja; to the Council for Sciences of Indonesia and its Chairman Professor Sarwono Prawirohardjo; to the Bandung Institute of Technology and its President Prof. Kosasih; and last but not least to Dr. The Pik Sin, the Director of the Bosscha Observatory, who has spent so much time and effort in the organisation and material arrangements of this symposium.

We are very pleased to see this gathering of very outstanding specialists, who have come from so many different countries: Australia, Czechoslovakia, Indonesia, Japan, Mexico, South Africa, Sweden, Switzerland, U.S.A. and U.S.S.R. Their very attendance in fact suffices to guarantee the succes of this meeting. I should like, if I may, to extend my special greetings to Dr. Ambartsumian, President of the International Astronomical Union. We are certainly very pleased to have his presence here and we are looking forward very much to close cooperation with the Union in the development of astronomy in Southeast Asia.

By its Constitution Unesco has the task to promote international co-operation in science. Science is no doubt one of the most international of all human activities, and astronomy the most international of all sciences.

It was in astronomy that the need for international scientific cooperation was first felt and the astronomers were the first scientists to organize international cooperation among them, and this international cooperation has been so effective that even during times of war astronomers have been able to exchange data. It is therefore very logical that Unesco maintains very close relations with the International Astronomical Union and other institutions which sponsor research in Astronomy.

With the development of its programme in geophysics and space sciences the cooperation of Unesco of with the astronomers is increasing. I may mention the assistance given to the Federation of Astronomical and Geophysical services which collects data which form the basis of astronomical and geophysical research. Activities such as the International Quiet Sun Year and the study of the earth by means of artificial satellites receive increased support. Within the framework of Unesco's programme for the peaceful uses of outer space, Unesco offers assistance to member states in the development of astronomical and geophysical observatories especially in geographical areas of particular scientific interest such as the equatorial regions of the earth.

The Bosscha Observatory is one of the outstanding observatories in the equatorial regions and it is therefore a very great pleasure for us to sponsor this international symposium in Bandung.

The fact that such an outstanding group of experts has accepted our invitation to attend this meeting is, I believe, a testimony of the importance which the international astronomical world attaches to the work at the Bosscha Observatory and to its future possibilities I believe that astronomy is a branch of science where Indonesia through the Bosscha Observatory can make a very important contribution to international scientific development, and I would like to take this opportunity to express our appreciation for the interest shown by the Indonesian Government and by the Bandung Institute of Technology in supporting these activities. The Unesco Southeast Asia Science Cooperation Office has been pleased to cooperate closely with the Bosscha Observatory in some of its acitivities. I may mention the donation to the Observatory of the Schmidt telescope which in itself was an example of international cooperation in a very practical way, with institutions in the US and the Netherlands cooperating with Unesco in making possible the installation of this telescope which has already given interesting results.

We are looking forward very much to the discussions in this symposium and also to the exchange of ideas, both formally and informally, about possibilities of future cooperation in astronomical research with the Bosscha Observatory.

I wish you all a succesful meeting.

Director, Unesco Southeast Asia
Science Cooperation Office.

Mr. Lennart Mattsson.

Your Excellencies, Ladies and Gentlemen.

On behalf of the International Astronomical Union and on behalf of my colleagues who have reached this country from different distant countries of the world to take part in this symposium, allow me to express my deepest appreciation of the great attention you are paying to our symposium. The fact that the Government of Indonesia attaches much inportance to the development of sciences is very encouraging. Your interest in our symposium reminds us that the science of astronomy plays a constantly increasing roll in man's civilization.

The exceptional geographical situation of Indonesia makes it necessary to have here a good astronomical observatory. And the discussions we began today, before the official opening of the symposium, have shown how important is the work of an observatory situated in this part of the world.

We astronomers are convinced that the number of observatories we have now on the earth's surface is very small compared to the immense problems we have to solve. In order to show how great the problems are which we have to confront in our science let us take only one example.

Let us try to construct a map of the part of the Universe which is within reach of the largest optical telescopes of our time. Let this map be the size of the territory of the Soviet Union. On such a map, of what size must the image of our solar system be including the orbits of all known planets? Would it be larger or smaller than one square centimeter ?

I asked one astronomer of world reputation to answer this question, but he told me that he had not made the corresponding calculations and could not give an instant answer. Then I told him that the size of the solar system on such a map must be smaller than one square micron. This example shows you how large the volume of space under our investigation is. If I add to this that not only the observable space is great, but that the physical phenomena we meet on large distances are often of essentially new type, when compared to what we see in our neighbourhood, you may conclude what a remarkable variety of innumerable problems are to be solved by astronomers.

New observatories, new telescopes, trained astronomers are badly needed, but as it has been emphasized here they are of prime importance in these latitudes and longitudes. You have a small group of competent astronomers which can develop our science here. They work at the observatory under Dr. The. I hope that their work will soon bring many interesting results for astronomy.

President of the International
Astronomical Union.

Prof. Dr. V.A. Ambartsumian.

The Honourable Members and Members of the Executive Committe of the International Astronomical Symposium.

May I hereby express my pride in the honour given to me to witness this most important event and to have the opportunity to meet the prominent scientists in astronomy.

It is my conviction that astronomy is one of those sciences which are of great importance for mankind, for instance it involves the drafting of the calender, the determination of coordinates of stars in connection with journeys across land and sea, predictions about seasons and other benefits that are already well known to you.

Moreover by observing the cosmos and meditating on the results of astronomy I become more and more convinced of the greatness and powerfulness of God, The Almighty, Who has created and regulates the universe for the benefit of mankind.

That is why I understand very well the importance of this symposium, and the discussion of the choice of the system to determine uniform standards for measuring starlight and the spectra of stars. This program is very important I think because it can be of great use to mankind directly as well as indirectly.

In this context I express my profound hope, that God may lead you all during this symposium so that it will become a great success and be able to elevate science, in general, and astronomy, in particular, to higher levels.

I hope also that through investigations of outer space we shall obtain more strength in our efforts to tighten the friendship and brotherhood between nations on this earth for the benefit of mankind itself.

The Governor of West Java,

Colonel Mashudi.

Your Excellencies, Ladies and Gentlemen.

I deem it a great honour to have the opportunity to say a few words on behalf of the Council for Sciences of Indonesia on the occasion of the official opening today of the Symposium on Standards for Photometry and Spectral Classification in Astronomy. We are indeed fortunate to have in our midst so many distinguished foreign scientists who are here to participate in the Symposium. The Unesco Science Cooperation Office for S. E. Asia, the Institute of Technology Bandung and the Bosscha Observatory are to be congratulated in having succeeded in bringing so many foreign participants here to the city of Bandung. To our foreign guests I would like on behalf of our Council to extend to them a hearty welcome and I hope that they will enjoy their stay in this country.

This symposium is in itself of great significance. We are here in the tropics and the Bosscha Observatory is one of the few observatories in the equatorial belt. Astronomical research undertaken in this institute is, because of its location, therefore, of special significance. The forthcoming discussions at this Symposium will certainly stimulate the activities of the Institute and will make an important contribution to the development of astronomical research in Indonesia.

However this Symposium is important too for other reasons. I see this Symposium as a symptom of the trend towards increasing cooperation in scientific matters between Indonesia and the outside world. Since independence Indonesia has, in science and research gone through a very difficult period, mainly because of the departure from the country of so many foreign scientists who previously formed the bulk of the research personnel. Luckily, the situation is gradually improving. Thanks to the remarkable development of education, including higher education, during the last years, the number of students graduating from universities is increasing year by year, making available in larger members, those who have the necessary background to be trained in research. The problem of scientific manpower is at present not as critical as it was several years ago and it will certainly improve in the time to come.

We can therefore view the future of science and research in Indonesia with more confidence and it is to be expected that under the dynamic leadership of the Minister of National Research science and research will show a satisfactory growth. In this relation the Council for Sciences of Indonesia, which is the national research organization, entrusted with the task of conducting research which will foster the economic development of the nation, is determined to play its part in the process of scientific growth.

With the increase of research activities the need for international cooperation and for exchange of information and ideas on an international level will certainly be felt here more and more. This symposium is one of the steps in the direction of more and more scientific cooperation between Indonesia and the outside world and it is to be hoped that it will be followed by more scientific gatherings in this country.

In closing I would like to extend my very best wishes for the success of this International Astronomical Symposium.

President of the Council Of Sciences
of Indonesia.

Prof. Sarwono Prawirohardjo.

Distinguished Delegates, Ladies and Gentlemen.

I am very pleased indeed to address today's gathering of outstanding world-astronomers who have come to Indonesia to discuss matters related to the establishment of standards for stellar photometry and spectral classification. The strategic geographical location of the Indonesian archipelago presents an excellent opportunity for astronomical science to establish the extension of the application of standards which are now established only for the northern hemisphere. On account of the limited number of astronomical observatories in the middle latitudes of the southern hemisphere there has been little opportunity to develop such standards of stellar photometry for use in the southern region of the globe. It is exactly in this problem-area of scientific endeavour that Indonesia through the Lembang Observatory will have to make its contribution to astronomy.

Hence, it is my pleasant duty to commend the international initiative of holding the present symposium at Bandung which, needless to say, represents an important step in making available to mankind the benefits of astronomical science. Astronomy, being essentially a science heavily reliant upon actual observations, can best be developed through an effective network of international cooperation. In fact, it has been remarked that both optical and radio astronomy are among the sciences which have profited most from such an international joint effort. The present occasion is illustrative of this fact as can be attested by the impressive list of participants representing key astronomical organizations and leading observatories.

Scientific Research in Indonesia, as you may have noticed since your arrival, occupies a vital place in the nation's social and economic development. The incorporation of scientific efforts into the National Eight Year Plan, the establishment of the Ministry of National Research, the creation of national laboratories, the coordination and stimulation of scientific endeavours, and a stepped-up training of scientific manpower, are concrete testimony of the determination and the sincerity of the Indonesian Government to make research an instrument of national growth.

Thus, it is the firm conviction of the Indonesian scientific community that a national research plan for action will best provide the platform from which Indonesia can give its share to the growing body of scientific knowledge. The recently held United Nations Conference on the application of Science and Technology for the Benefit of the Less Developed Areas has, in my opinion, revealed this point very clearly. It become evident during the fruitful deliberations of the Conference that the general area of the Application of Science and Technology for the Benefit of the Developing Countries can be made effective and functional only if and when it is considered as a two-way street. Both the technologically advanced and the developing nations can and must contribute towards scientific development.

In conclusion, I would like to express my warm appreciation for the work of the Unesco Southeast Asia Science Cooperation Office under the able leadership of Mr. Lennart Mattsson, the International Astronomical Union, the Bandung Institute of Technology, and all those individuals, who have contributed in paving the way for this symposium. To all delegates I would like to extend my best wishes for success in the forthcoming discussions.

Thank you.

Minister of National Research,

Prof. Dr. Sudjono D. Pusponegoro.

Distinguished Delegates, Ladies and Gentlemen.

It is a great pleasure to welcome you to this scientific meeting which is the first of its kind to be held in Indonesia.

With the rapid development in recent years of space techniques astronomy has attained a very important place among other sciences. While formerly astronomy was not of very much direct use for the common people, its progress at present plays an important role in the development of our knowledge of nature as a whole as for example in the use of earth satellites. This increase of knowledge will certainly have its impact on the world's philosophy about nature, which at present we feel is already beginning to change.

With the development of technology in general, larger and larger telescopes have been build in recent years, equipped with more and more modern accessories. A development in another direction, i.e. the building of giant radio telescopes, also helps its optical counterparts in penetrating deeper and deeper into the universe. I believe, therefore, that within not too long the knowledge of our immense universe will be increased considerably. It is my sincere hope that this knowledge will not only be used for its own sake, but primarily for the benefit of mankind in general.

It becomes more and more clear that the developments of new ideas in astronomy has its influence in other branches of science such as physics, mathematics, etc. This is understandable since working as an astronomer is more or less practising ones knowledge of physics, mathematics and astronomy in astronomical problems. It is therefore regrettable that in Indonesia only the Bandung Institute of Technology has its department of astronomy. It is my hope that the other universities in Indonesia having a faculty of science will work towards the setting up of an astronomical department as well.

As mentioned earlier this international astronomical symposium is the first of its kind to be held in Bandung. Less than 10 persons from abroad are participating. I hope that in the future a larger symposium will be held in order to promote more mutual understanding between nations through the sciences. In fact this is one of the trilogy aims of the Indonesian National Revolution in promoting friendship among all nations and world peace. I wish you all success in this symposium.

Thank you.

Minister of Higher Education and Sciences,

Prof. Dr. Tojib Hadiwidjaja.

(Presented by Prof. Dr. Sumantri Hardjoprakoso).

PART II.

Papers presented at the symposium.

AN EXPERIMENT CONCERNING THE WIDTH OF THE TRANSMISSION BAND OF THE U FILTER.

K. OSAWA.

Tokyo Astronomical Observatory.

The three-color photometry, or the UBV system of Johnson and Morgan,(1,2,3,4) is now currently adopted as the standard system of stellar photometry. This system, not only enables one to know the approximate temperatures of stars, but also to know the amount of space reddening, and also in some cases to know the peculiarity of the chemical composition of stellar atmospheres.

However, it is sometimes argued that the widths of the transmission bands of standard filters are too wide to allow simple transformations between different equipment or between different sky conditions. Especially the color U is known to present important problems which have to be considered carefully.

First, the extinction coefficients of the red and ultraviolet ends of the transmissions band of U differ very much. By a moderate sky condition [5]), the entinction at the zenith is about 0.55 mag. for λ 3900 Å and 0.91 mag. for λ 3400 Å. At a zenith distance of 60°, the extinction amounts to 1.1 mag. and 1.8 mag for λ 3900 Å and 3400 Å respectively. For poor sky conditions or for low altitudes, the difference of extinction is much more pronounced. Numerical examples of this kind have been shown by Melbourne [7]) and by Arp. [6]) In theory, a simple formula such as k. sec Z does not work for U. The reason why, nevertheless, a simple formula like k. sec Z appears to work approximately for reduction of (U-B), is only because the radiation for very short wavelengths does not make an appreciable contribution to the intensity of light measured through the U filter, at least for stars later than A. In other words, the extinction coefficient for U as a whole is substantially determined by the amount of light passing through the red-side half of the U filter. To make the situation worse the contribution by the ultraviolet light is not completely negligible for high temperature stars. This is the main reason why the transformation between different equipment or between different sky conditions is sometimes quite complicated.

Second, as was pointed out by Tifft at the Berkeley meeting of the I.A.U.[8]), poor definition at the ultraviolet limit of the U filter may lead to trouble when the time comes to compare existing color indices with observations made outside the atmosphere.

The present author has made experiments to observe some standard stars using normal filters plus a filter U′ which has a narrower transmission band as compared with the normal U filter. Fig. 1 is the familiar picture of the responce curves of the UBV system together with the responce curve of our U′. This filter U′ is a combination of a normal U filter and a filter called "UV 35" which cuts out the radiation beyond 3400 A completely and has 50 percent transmission at about 3500 Å, and about 85 percent transmission for longer wavelengths than 3600 Å.

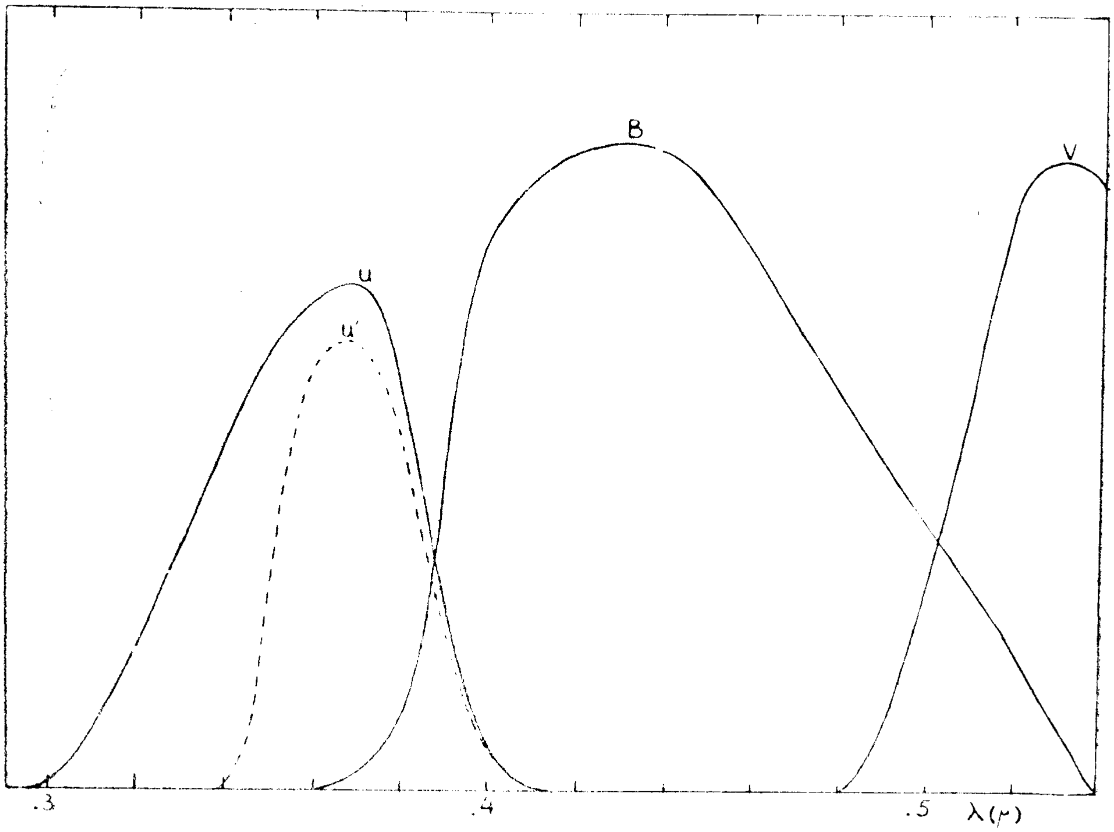

Fig. 1. Response curves of U, B, V and U′

The 12-inch aluminized reflector telescope with 1P21 of the Tokyo Astro nomical Observatory was used for the experimental observations with U′. Stars were chosen from the list of standard stars of H.L. Johnson[4]). Blue, white and red stars including a few reddened early type stars were included. The observed results are shown in Fig. 2, where the observed U′-U values are plotted against standard values of U-B. Similar experimental observations were made with an EMI 6256B using the 36-inch reflector of the Okayama Astrophysical Observatory. Similar results were obtained with the EMI, though the values of U′-U for the EMI were smaller than those for the 1P21 by about 0.10 magnitudes.

It is found in Fig. 2 that the variation of U′-U against U-B is approximately represented by two straight lines. U′-U is almost constant for all positive values of U-B. Actually there are slight deviations between individual points and the mean curve. Perhaps these individual deviations may include absolute magnitudes effects and accidental observational errors. Fig. 2 shows that the stellar radiation below 3400 Å actually has very little contribution to the measured intensity of magnitude U for stars later than A. The contribution by the radiation below 3400 Å is appreciable only for B and O stars. According to Fig. 2, the difference of U′-U between the bluest stars and the reddest stars amounts to about one tenth of a magnitude. This amount, however, strongly depends upon the spectral response of the equipments including the aluminized mirrors and the kind of phototube, and depends also upon the sky conditions and altitude at which the observation is made.

This quantity easily escapes inclusion in the appropriate correction of extinction when extinction coefficients are determined by standard stars not earlier than A. Errors are also introduced if extinction coefficients are determined with very blue standard stars only and applied for stars of type A or later. Observers always encounter the situation that better results can be obtained if they make separate reductions of U-B for B stars and A stars than if they treat stars of different types together. This fact also can be understood from Fig. 2.

Fig. 3 is an extreme example of this wide-band effect. This Figure, shows the calculated colors U-B and U′-B, with various zenith distances for model atmospheres of

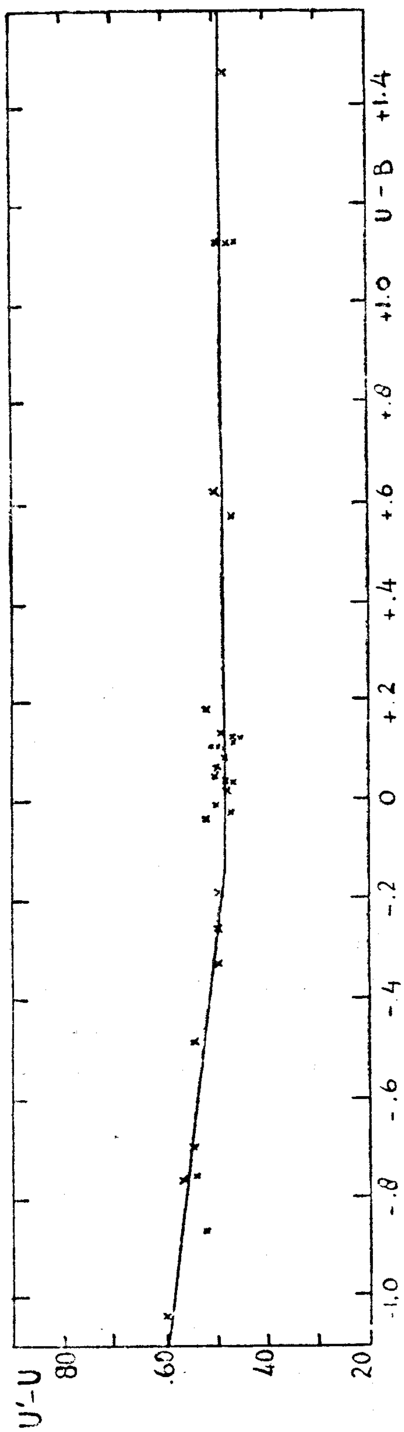

Fig. 2.

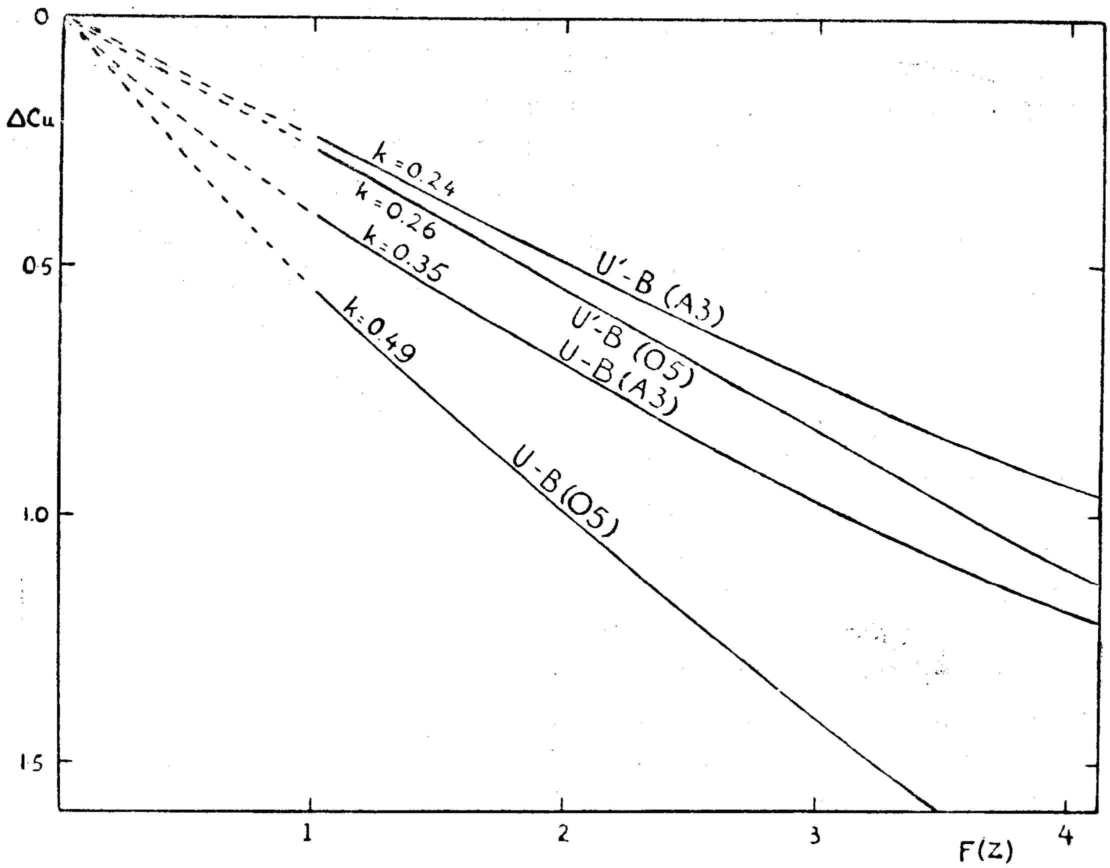

Fig. 3. Calculated values of U′-B and U-B for O5 and A3 model atmospheres.

stellar types O5 and A3. For O5, a model stellar atmosphere with an effective temperature of 44,600°k (calculated by Miss Underhill[9]) was adopted. For A3, Osawa's model atmosphere with an effective temperature of 8900°k was used [10]). From Fig. 3 it is easily understood that the extinction coefficient of U-B is considerably different for O5 and A3 stars and that there is not much difference in the extinction coefficients between O5 and A3 stars for U′-B.

In this connection, it should also be remembered that the refractor color $(U\text{-}B)_C$ of the Cape Observatory has the great virtue of stability under transformation, with consequent ease in reductions, giving at the same time all the necessary informations that can be expected from the three-color photometric system.

From Fig. 2 it is obvious that if U′-B is used as the substitute for U-B, all the useful characters of the UBV system are not affected.

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DISCUSSION:

Pik-Sin The: What is the percentage of the light lost when the U′ filter is used rather than the U filter ?

Osawa: For O5 stars, the loss is more than 40%. For A3 stars the loss is much less; about 30% at the zenith and less than 10% for low altitudes.

Westerlund: Extinction is generally found to be independent of colour for U-B. This does not seem to agree with the graph calculated from the theoretical energy distributions for O5 and A3 stars.

Osawa: The effective temperature for the theoretical O5 model is probably too high, so the effect of the wide band is very much exaggerated.
However, it is certain that the extinction coefficient of U-B varies considerably with color in a complicated way, and consequently better results are obtained for U-B if early B and A, F stars are treated separately.

Aller: Miss Underhill has recently revised her theoretical model atmospheres for a number of high temperature stars. The effective temperatures are lowered.

Westerlund: The luminosity effect has to be considered when reducing instrumental systems to U, B, V system.
The difinition of U′ includes the Balmer jump. The effective wavelength of the system ought to be moved further towards the ultraviolet to avoid inclusion of the Balmer discontinuity.

Aller: Since the U′ system includes the region of confluence of the Balmer lines, luminosity effects enter in a disagreeable way. Line overlap and broadening differ considerably in super-giants and dwarfs.

Thackeray: Have you observed stars in common with those measured by the Walravens, whose L manitudes (which include effects of the higher members of the Balmer series) probably correspond rather closely to your U′ ?

Osawa: There were not enough stars common to the two lists to make possible a meaningful comparison.

STANDARD MAGNITUDES AND MAGNITUDE SEQUENCES IN THE SOUTHERN HEMISPHERE.

A.W.J. COUSINS

Royal Observatory, Cape.

(Presented by A.D. Thackeray).

The situation in the southern hemisphere as regards standard magnitudes and magnitude sequences for general use can now be considered satisfactory, and in several respects markedly better than it is in the northern hemisphere.

The basic southern standards are in the Harvard Standard E regions at -45° declination. Considerable effort has been made to ensure that these magnitudes are on a consistent system and that they reproduce the UBV-system of Johnson and Morgan as nearly as possible. These sequences contain the most accurately determined magnitudes and colours and in some cases extend to the fifteenth magnitude. Most of the data is of a precision acceptable for photoelectric standards, but special attention was given to the choice of stars so that these sequences would be suitable for photographic transfers. For this purpose they are better than the stars in galactic clusters, where there is usually a too close correlation between magnitude and colour.

To supplement these sequences, for purely photographic purpose, stars have been selected and measured in the three F regions at -75°, but these are of lower precision.

For general purposes it is sometimes convenient to have 'zero point stars' more widely distributed than are the nine E regions, and the position in the southern hemisphere is now decidedly better than it is north of +10°, so far as bright stars are concerned. Almost all nonvariable stars brighter than V = 5.0 and south of +10° declination have now been measured photoelectrically at the Cape and for most of these there are now two or more independent determinations of V and B-V available, and usually at least one determination of U-B and $(U\text{-}B)_C$. Work is in progress to measure V and B-V and either U-B for $(U\text{-}B)_C$ for all HR stars south of +10°, and not far short of half of those between 5.0 and 6.5 have already been completed, as well as all those brighter than 5.0. As the s.e. is $\pm\ 0^m.01$ (or less) for all stars they should be satisfactory for use as zero point stars for work with small telescopes. (It should be emphasised that *one* star is not sufficient to fix a zero point and that a minimum of three should be used to guard against possible variability of one of them). The position becomes less satisfactory as the stars become fainter, but there are now some hundreds of stars between magnitudes 6.5 and 11.0, scattered over the southern sky, that have been measured photoelectrically to obtain V, B-V and $(U\text{-}B)_C$. (Measures of U-B for these stars are practically confined to the E regions). These data are of comparable accuracy with those for the brighter stars (exept sometimes for $(U\text{-}B)_C$) and these stars could be used as zero point stars for larger telescopes, to supplement the E region data.

For investigations in selected areas of the sky — galactic and globular clusters, the Magellanic Clouds, etc. — it is highly desirable to have sequences available locally and this aspect of photometry is receiving much attention at the Mount Stromlo Observatory and, to a lesser extent, at the Radcliffe Observatory. Little has been done at the Cape as the largest telescope presently available is a 24-inch refractor, but this aspect of photometry will receive more attention when the 40-inch reflector is in operation.

It was mentioned earlier that special efforts had been made to ensure that the southern photometric system reproduces the UBV-system in the North. It would be reassuring if some careful observations were made from an observatory further north, from which a larger and more representative sample of the northern standards could be observed under more favourable conditions than can be done from this latitude, to establish beyond doubt the identity of the two systems. Little doubt remains with regards V and B-V, but it is not yet certain that there are no differences for U-B. (The relatively low precision of U-B makes it desirable to use more standards than can be observed satisfactory from the Cape). Great care would have to be exercised to ensure that the natural system of the photometer is close enough to Johnson's to give consistent results for all types of star, otherwise ambiguity will arise when attempting transformations. This has, unfortunately, not been completely successfully achieved at the Cape.

The most important (and in some ways the most exacting) photometric observations required in the southern hemisphere are those required to set up reliable sequences going to faint limits wherever they may be needed for more extensive photographic investigations. These observations necessitate having a large telescope. Work on the bright end of these sequences, including the fixing of the zero points, can and should be done with smaller telescopes.

There are many individual stars for which photometric data are still required, many variable stars worth investigating, and the revision of the variable star sequences used in the past for visual and photographic studies is a programme worth considering.

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R.O.B. 25, 49

R.O.B. 64 (5000 stars)

R.O.B. 69 giving a critical discussion of the relation between N. and S. systems and R.O.B. 70 describing the setting up of the zero points. } in press.

DISCUSSION:

Westerlund: The Mount Stromlo U, B, V system agree very well with the Cape system exept possibly for U-B near U-B = 0. Similar deviations appear in a comparison by Eggen of his observations with observations by Stock et al.

Thackeray: I think that Eggen's work must have been done with the Cape 24-inch refractor and that Stock's work was probably done at the Boyden station. Cousins' U-magnitudes are probably similar to Osawa's U′ magnitudes.

Aller: Cousins has established a good system of colors and magnitudes that is homogeneous over the entire southern sky and is tied in to the northern standards. A valuable feature of this work is the fact that colors and magnitudes are set up for the standard areas in the sky rather than in clusters where color and scale errors can get mixed together, in a fashion particularly disastrous for photographic photometry.

BASIC REMARKS ABOUT THE CHOICE OF COLORS FOR SYSTEMS OF MULTICOLOR PHOTOMETRY.

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Multicolor photometry should give some information about the physical properties of the star under consideration. To put it more specifically: it should say something about the energy distribution in the spectra of the stars. Multicolor photometry is a method of investigation of these properties which stands in between simple measurement of a star's magnitude and more detailed analysis of its spectra. The color indices obtained should be an abbreviated study of this energy distribution which can be obtained easily for a large number of stars.

From this it follows that, whenever one wants to set up any photometric system for multicolor photometry, one has to start with an investigation of the spectral distribution of energy and with a consideration as to what properties of a star, which find their expression in this distribution, one plans to measure. As it will hardly be possible to find a system of only few, i.e. three or four, colors which allow one to measure all possible features in the spectra of stars or all kinds of types, one has to decide carefully as to which features are the essential or most useful ones for the work to be undertaken. One naturally tries to include the effects of as many different features as possible whithin the range of the colors chosen. But much care has to be taken when two or three independent features affect the same color or color index. One has then to check whether the effects of the two features just cancel each other or have the same influence and make it therefore impossible to distinguish them and to make use of any one of them.

Up to now most attempst in multicolor photometry give the impression that they have not been undertaken with a clear picture of what should be measured. It seems that one has started with a more or less accidental selection of filters or plates wich, as one might believe, just happened to be at hand or which were used for some kind of work other than multicolor photometry and were taken over without any thought of what they might produce in the way of color indices. The attitude sometimes seemed to be: let us take these filters we happen to have and let us see what comes out. Only in a few cases was the attempt made to decide in advance which types of filters are most suitable in the way to be described in the following discussion. It was, for instance, obviously not done in establishing the UBV-system. This system is a good example, of how reasons from outside the frame work of the problem can anticipate the solution in an unlucky way. There was available a photographic magnitude used for a long period, dating back to the time of the first photographic plates used in astronomy whose sensitivity was centered in the blue region of the spectrum. The choice of this spectral range had only to do with this historical primary range of photographic plates, but nothing whatsoever with the properties of stellar spectra. To this choice, and determined by reasons outside the field of astronomy, came historically in second place an other spectral range in the yellow which, as one happily pointed out, duplicated more or less the sentivity of the human eye. This was quite useful for certain investigations but again as far as stars are concerned, a choice based on viewpoints other than astronomical. Later one found that adding to these two colors, which were given by tradition, a third color in the ultra-violet would produce some striking possibilities of three color photometry. However nobody involved in establishing this system ever seemed to investigate whether these three colors really produced the best system possible. Unfortunately it turned out that they did not, which is all the more regretable for at the time of the introduction of the UBV-system the principles according to which one should choose an astrophysically

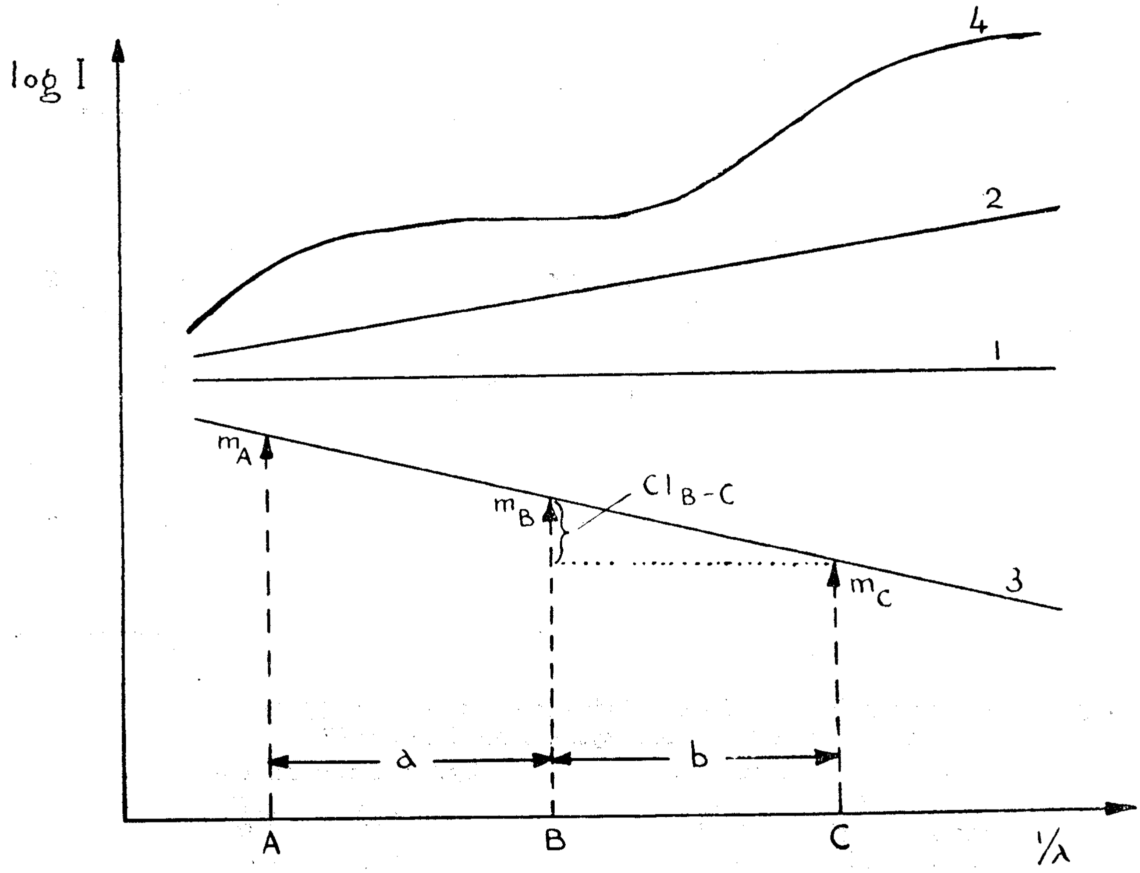

Fig. 1. 1 black body of standard temperature.
2, 3 black body radiation of higher and lower temperature than 1.
4 intensity distribution of a radiator which is not a black body.
ABC three color system with color index CI (B-C).

sound system of colors were already long published. But it seems that still today, in many cases, one does not see clearly what are actually the essential points in the choice of any multicolor system, so that it may be excusable to recall them.

The spectral energy distribution of black bodies with different temperature as well as of any other radiating bodies can be drawn in a $\frac{1}{\lambda}$/log I diagram relatively to a black body of one specific standard temperature taken as a reference. A color index, defined as the difference of the log I (or magnitudes) in two places of the spectrum, is then nothing but a measure of the slope of this energy distribution in the range between these two colors (Fig. 1).

All black body radiators show as intensity distribution a straight line whose gradient gives a measure of the temperature. If the stars would radiate as perfect black bodies nothing else but the gradient of these lines could be

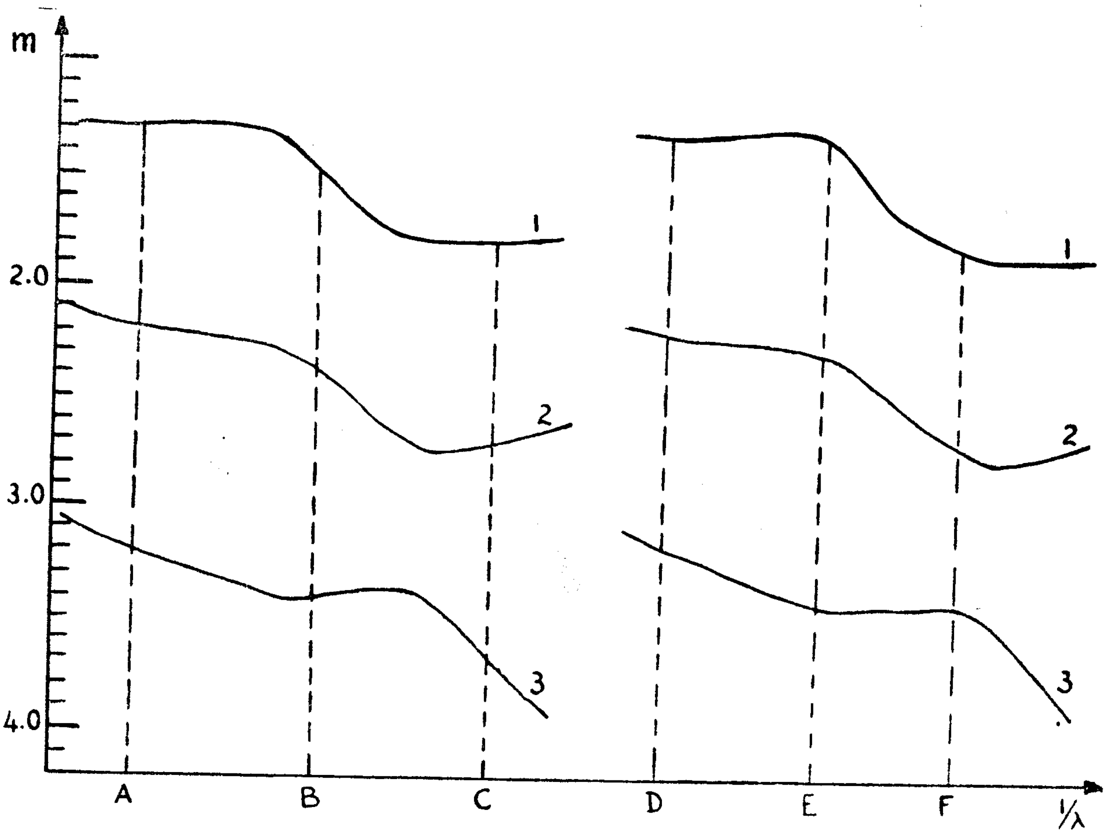

Fig. 2. Energy distribution of three different types of stars (1,2,3) with two different three color systems ABC and DEF.

System ABC: unsuitable

	A-B	B-C
star 1	0.20	0.30
„ 2	0.20	0.30
„ 3	0.20	0.30

System DEF: suitable

	D-E	E-F
star 1	0.00	0.50
„ 2	0.10	0.40
„ 3	0.25	0.00

In system ABC all three stars have the same color index, no separation of different types; in system DEF there is a clear differentiation of different types.

measured. A two color photometry would already give everything there is to measure, and any third color would be superfluous.

Fortunately stars are not ideal black body radiators, and their deviations from black body radiation, that is the deviation of their relative intensity distributions from straight lines, lead to some more possibilities for forming meaningful color indices.

Even before looking at the actual intensity distributions of different types of stars one can formulate some rules on how the colors should be chosen to form meaningful color indices. Fig. 2 shows schematically some possibilities of how not to select (left hand side) and how to select (right hand side) the colors for multicolor photometry. In the left hand figure the two color indices of the color system ABC are the same for all three rather different intensity distributions. They do not say anything about the type of radiation we have in the three radiating bodies, and the gradient of the color index does not have any physical meaning regarding the radiation. It is a purely artificial value. In the right hand figure which shows the indentical energy distribution as on the left, the three colors DEF lead to color indices which characterize very sensitively the type of radiation. The gradients suggested by the color indices really reproduce the gradients of the intensity distributions and give therefore automatically a value for the temperature of the radiation in the respective spectral range. It is clear that for any photometry that should make sense one has to choose the colors DEF.

To decide what colors are best to use for astronomical purposes one has to know the energy distribution in stellar spectra. Unfortunately only few investigations which give these distribution for a wide variety of spectral types and luminosities are available. Besides the work done at Greenwich, one of the best is still the one by Kienle, Strassl and Wempe (Zs. f. Astrophysik 16, 201, 1938). It is highly desirable to obtain spectral photometry of a great number of stars of all different types either with measures of at least about 25 to 30 points along the spectrum with band widths comparable to those used in photoelectric or photographic photometry, that is of the order of 30 to 50 Å. It would be much better to obtain continous registrations of spectra with a photometer with an aperture of some 25 to 40 Å which may for instance be moved along the focal plain of a spectograph and which would register such intensity curves as we need them. Unfortunately the equipment of our observatory does not allow such observations, but we would certainly be happy to undertake them in cooperation with an observatory which is accordingly equipped.

In choosing the widths of the bandpasses for the different colors one has two opposite arguments fighting each other. The first consideration asks for bands as broad as possible to get as much light as possible and therefore to be able to reach stars as faint as possible. On the other hand one likes to have narrow bands for two reasons. First one does not want to smear out characteristic properties of the spectra. Take for instance a wide bandpass centered on the Balmer discontinuity, which includes large parts of the spectra on both sides. It is rather insensitive to variations of the Balmer absorption, whereas a narrow band, put close to it on one side together with a second color farther away to the other side gives a color index which is a very sensitive measure of the Balmer jump. Secondly a broad band makes the isophote wavelength shift appreciably with the temperature of the radiating body and with all other effects which change the slope of the intensity distribution, as for instance interstellar reddening. The redder a star, the farther to the red is the isophote wavelength, that is the center of gravity of this radiation within the band. It stems from this fact that, for instance, in UBV-photometry with a very broad band for B we obtain second order terms in the relation between the two color excesses CE (U-B) and CE (B-V) caused by interstellar reddening and therefore have reddening lines in a two color diagram which are not straight lines but curves, a very annoying fact in all reduction work of observations including reddened stars. This is caused of course by the fact that if in a system of colors ABC as shown in Fig. 1 one color is shifted, the proportion of the two "base lengths" of the system, a/b, and therefore the proportion between the two color indices is altered. Of course this effect is, strictly speaking, always present as long as one does not use monochromatic light. But even with reasonably narrow bands it is quickly reduced below the limit of the mean error of the color indices and can therefore be neglected.

The relatively scant and not very uniform material about energy distribution in spectra especially of late type stars with different luminosities does so far not allow as yet a really throughout investigation of the most efficient multicolor system. But enough material is available to put down some basic considerations. The following deals primarily with systems of three color photometry, but most of the results are of course also valid for systems with more than three colors.

Early type stars: O-stars and the earliest B-stars with no appreciable Balmer discontinuity show an energy distribution almost like a black body, thus there is not much to gain from any system with more than two colors, since one color index gives the slope of the distribution and can be obtained between any two wavelengths. Perhaps a more refined investigation of the energy distribution reveals some slight but systematic deviations which may give some hints where to put best the colors.

Stars with Balmer absorption (B-and A-stars): any significant system has to put one color on each side of the Balmer discontinuity. This has its limitations as the Balmer jump is already close to the limit towards the ultraviolet which is set by the ultraviolet absorption of the air. There is not much

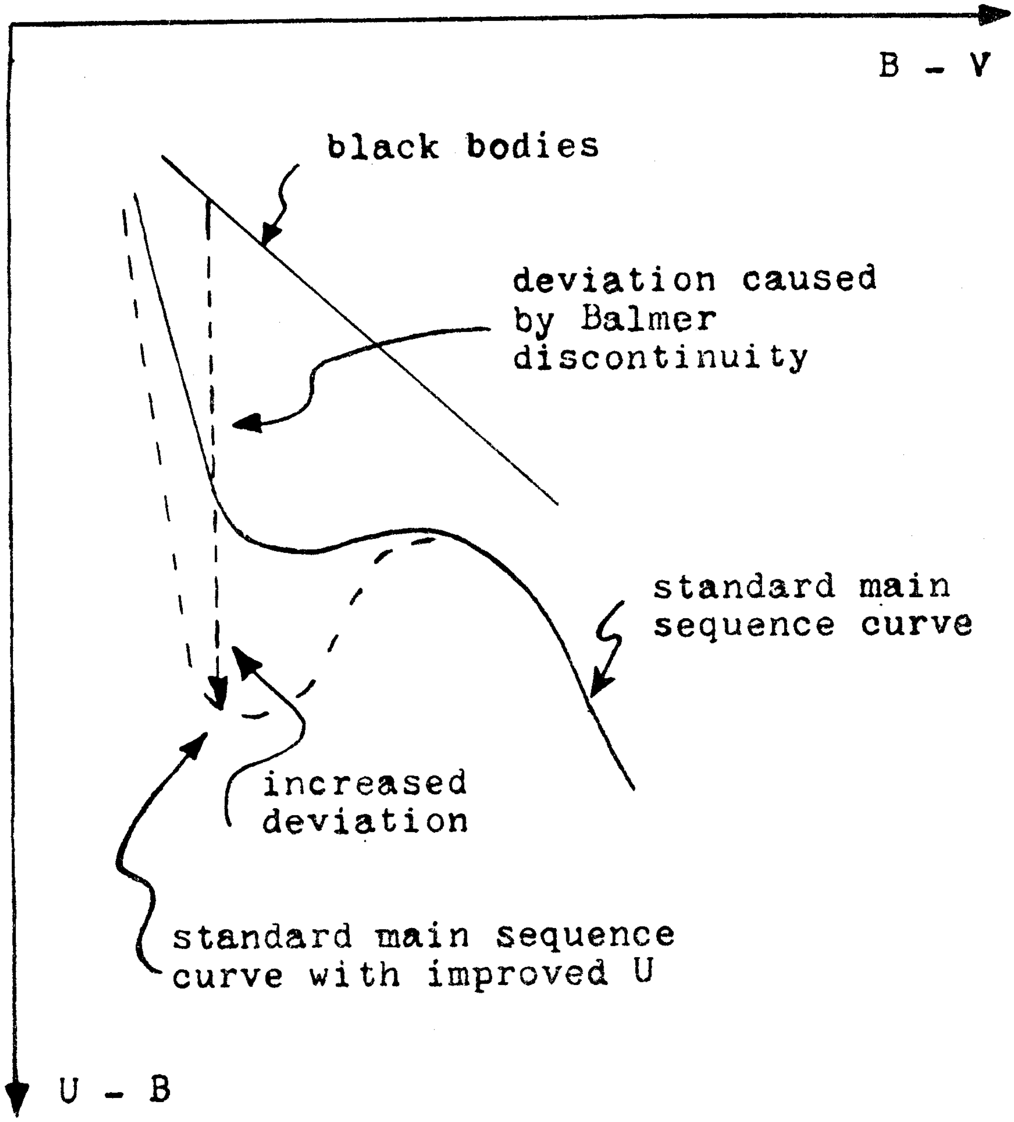

Fig. 3.

choise but to take the traditional U color common to most systems used so far, although in this band a rather large amount of light from the red side of the Balmer discontinuity is included and the sensitivity of the color index formed with this U is not as great as it might be. For special purposes it may however be useful to take a narrower band which does not go as far towards longer wavelengths. This would make the U more sensitive to the amount of Balmer absorption and, in a two color diagram of the standard form, show a much larger effect (Fig. 3). Walraven has been trying various combinations of several narrow bands in this region and has obtained results of this kind For this advantage one has, however, to pay with a much reduced amount of light in the new U, that is with a much brighter limiting magnitude. Attention has also to be paid to the findings of Osawa, reported at this symposium, which suggest the advantage of a more clearly defined limitation towards the shorter wavelengths.

Besides the Balmer discontinuity the energy distribution in these stars remains still quite straight, so that — as long as one works only with these stars — the position of the two other colors in the spectra is rather unimportant. UBV, RGU and the old $m_{vis} - m_{phot}$ magnitudes together with the U fulfill their purpose equally well. The fact that a large amount of the work in three color photometry until today has been done with these types of stars (open clusters, associations etc), where there is in fact no appreciable difference between these systems, has led to the assumption that the choise between these systems is rather meaningless and arbitrary. Thus in most cases the system most readily available was used and hardly anybody really took the troubles of investigating the differences which were thought to be only

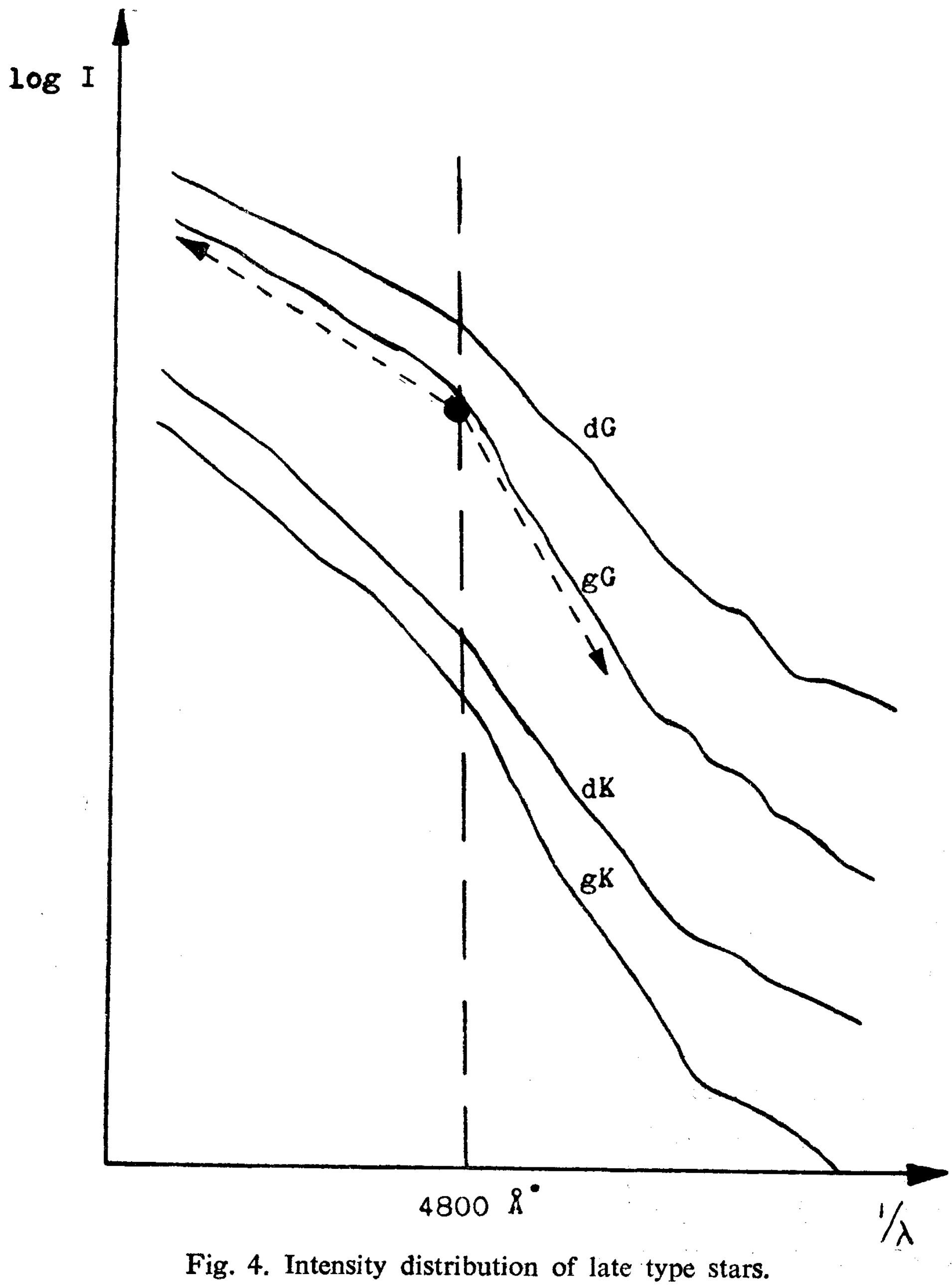

Fig. 4. Intensity distribution of late type stars.

superficial. But as soon as one proceeds to later type stars these differences become fundamental.

Later types: The intensity distribution is getting more and more complicated due to intence line and band-absorptions. A systematic investigation of these distributions is still mising: it is time to have one. One fact however has long been known: late type stars show a readily appreciable change in the gradient around 4800 Å. In other words not one single color temperature can be attributed to the whole spectrum, but rather two temperatures result

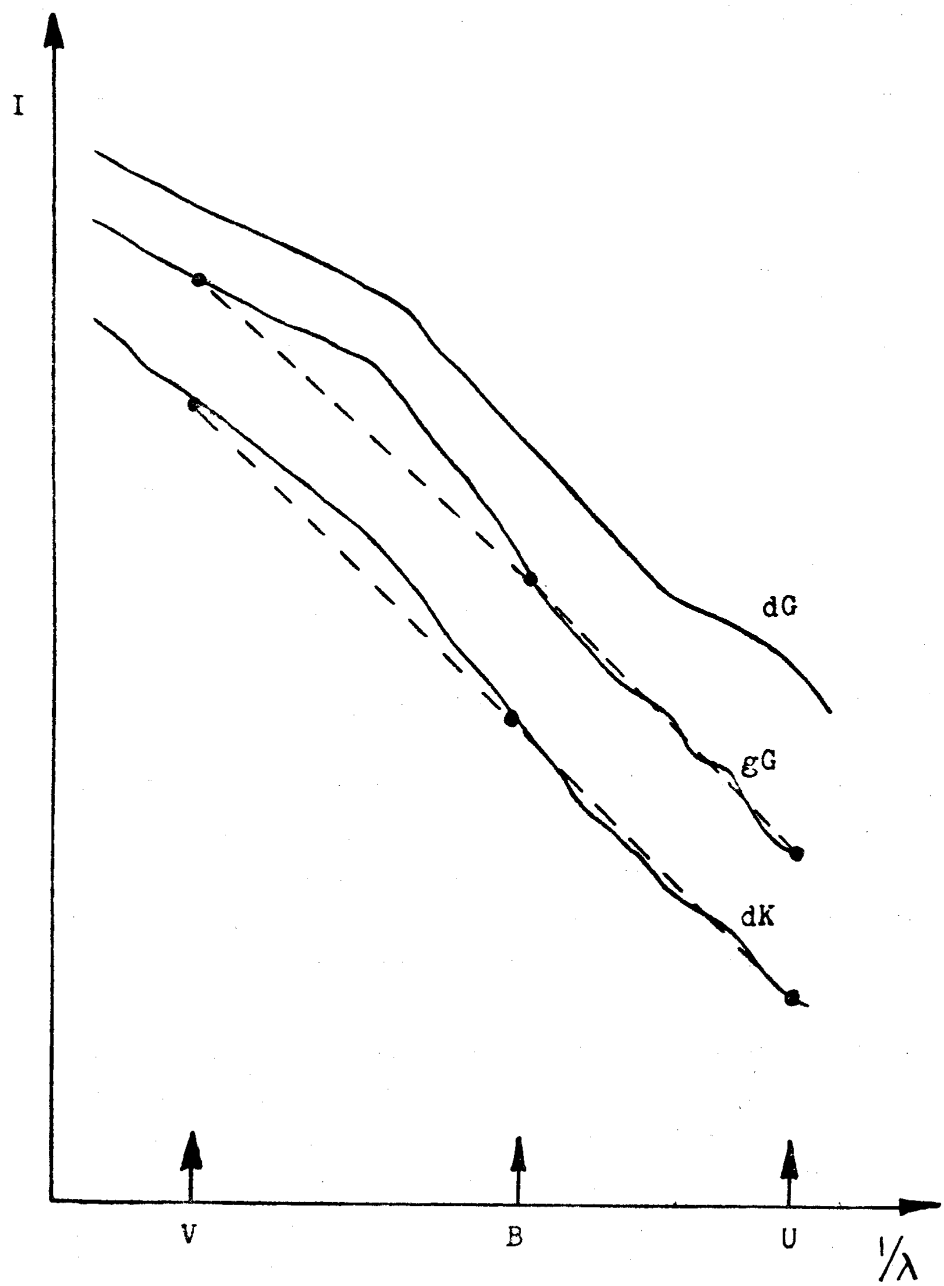

Fig. 5. Late type stars in the UBV system.
B-V (gG) = B-V (dK)
U-B (gG) = U-B (dK)

for the two parts on either side of 4800 Å. Moreover this change in the gradient is stronger in giants than in dwarfs of the same spectral type (Fig. 4). It is not so much a sharp change in the slope but more a transition zone with slowly changing gradient in that area of the spectra. Nevertheless a reasonable three color system will take advantage of this fact and put its colors in those positions where the two different gradients are measured. This means that the middle color has to be around 4800 Å; the two others can be any where to the left and to the right, thus producing two color indices as indicated by dashed arrows in Fig. 4. It makes of course sense to let the one color, which

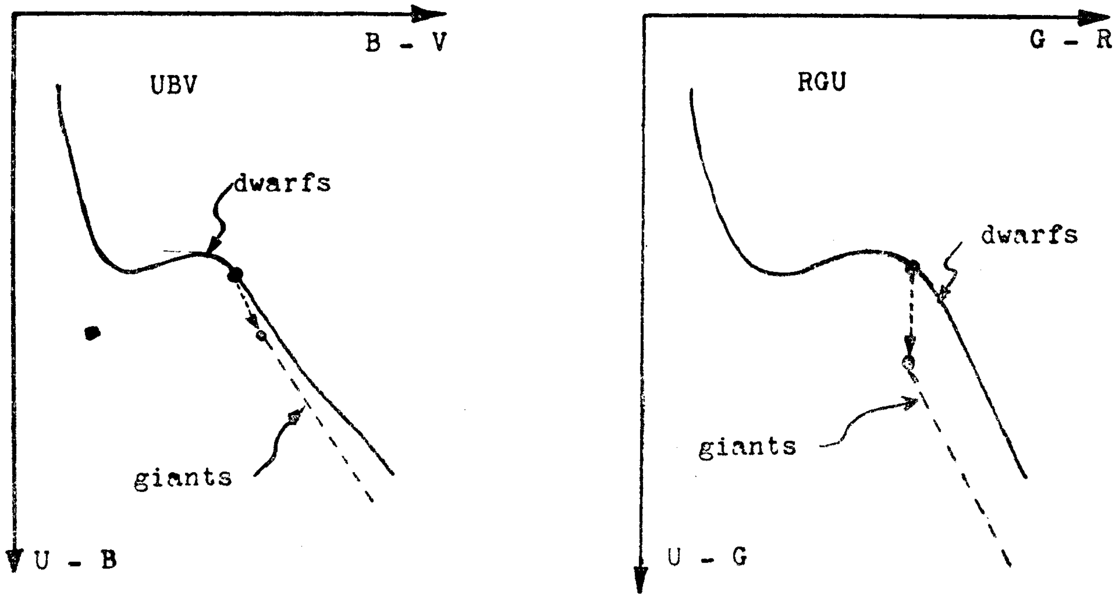

Fig. 6. Seperaton of dwars and giants in UBV and RGU.

is towards the shorter wavelengths, coincide with the U which is needed for early type stars, so that one has a system U — 4800 Å (G in RGU-system) — one color towards the red. The UBV system has its two colors, B and V at just about in the same distance to the left and to the right of this region and is therefore unable: a) to represent the two gradients properly, b) to separate giants and dwarfs, something which is possible to do in a system with one color at 4800 Å. Fig. 5 shows that in the UBV system just the unlucky case. demonstrated in Fig. 2, left hand side, is realised. The change of slope with the transition from dwarf to giant in the left hand part of the spectrum affects both indices (B-V and U-B) equally and a gG-star has both color indices equal to those of a dK-star. In the two color diagram for UBV in Fig. 6 the giants and dwarfs therefore fall on the same line, whereas in RGU they are separated. In the latter system the change of slope affects mainly the U-G index and only very slightly the G-R index, so that a giant star is therefore in the two color diagram moved almost vertically down from the dwarf of the same spectral type.

A confirmation of this point comes from the recently investigated blanketing effect. At least part of this feature of changing gradients is due to line absorption which is moderate in the region from the red down to around 4800 Å and is from there on increasing rapidly, thus causing the steeper

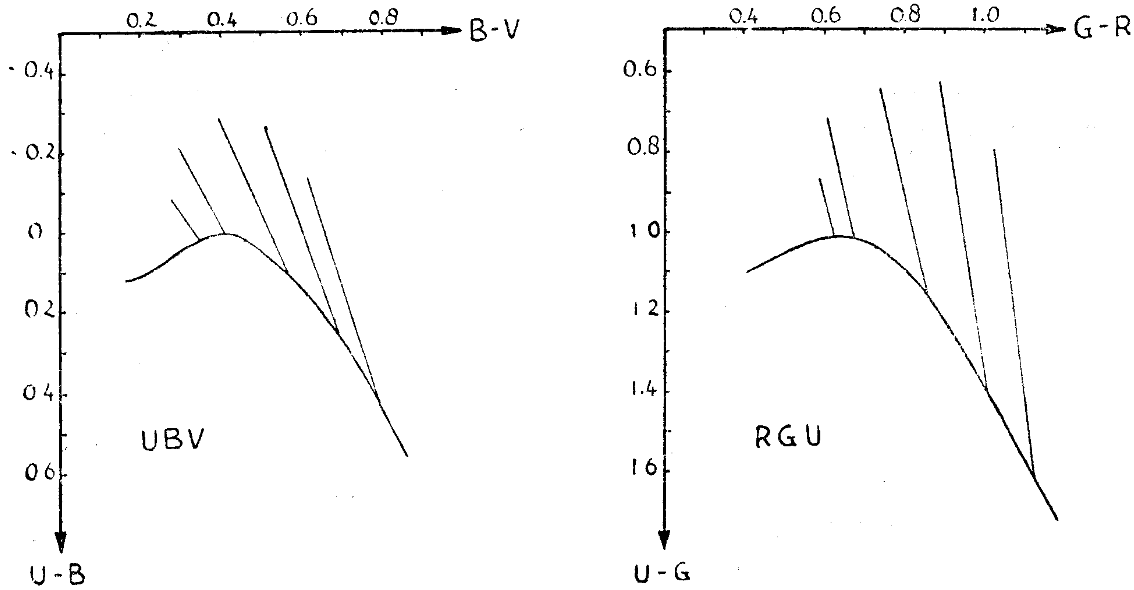

Fig. 7. Blanketing effect.

decline of the overall intensity. In UBV the effect of this line blanketing affects both the B-V and U-B color index, as was just shown. In the two color diagram, stars of the same spectral type but with varying metal abundance are on an inclined line. In RGU the overwhelming part of blanketing goes into the U-G and only a small amount into RG. The blanketing lines are therefore much steeper, coming close to vertical, and the amount of the effect is in this index of course appreciably larger than in U-B. We obtain thus a much wider spread of stars with different metal abundances. (Fig. 7) Besides, we get the added benefit that, while red magnitudes are increased (through backwarming) and blue magnitudes are decreased (through line absorption), the G magnitudes remain almost unaltered for different metal abundances (maximum of change about $0\overset{m}{.}04$).

Although all this may look as if one were intending to propagate the RGU system as the perfect system for three color photometry, it should be emphasized that there is certainly not any one system for three color photometry that is perfect. The points to be brought out can be summed up as follows:

1). Any attempt to establish a photometric system of three or more colors has to be based on a thorough in vestigation of the spectral intensity distributions of the stars to which it should be applied. The colors have to be chosen according to the properties of this distribution and not according to ephemeral, technical or historical reasons as it is often done. This point suffers only from the absence of a uniform and comprehensive material in the field of intensity distributions. This should above all be done in conection with the recently aroused interest in more systematic infrared photometry and multicolor photometry from satellites in the ultraviolet.

2). To satisfy point 1 it would be highly desirable to have an investigation of the intensity distributions undertaken for as many different types of stars as possible in the way described earlier.

3). No single system of three colors will probably satisfy all wishes one may have for such a system. For the one or the other more refined investigation it may be necessary to use four or five colors to bring out all possible distinction between different features or to use two different systems side by side to make use of the different merits of both systems. I think one should therefore encourage the use of more than one system and try not to have only one system generally adopted, because this may lead to an unnecessarily narrow approach to new problems, in contrast the healthy competition between different systems may lead to new discoveries which might go unnoticed when there is only one system in which they might accidentally not show up. Perhaps it is possible to establish a comprehensive system of six or eight or even more general adopted colors from which any three may be chosen for a three color photometry adopted to the specific problems in each case.

4). In defending the RGU system however one can say that, although it is most probably not a perfect system either, it shows, compared with the usually applied UBV system, considerable advantages and up to now only minor disadvantages.

5). The disadvantages of RGU stem mainly not from its properties, as they have been shown here, but from technical aspects of observations. The RGU, that is the R at 6400 Å, cannot be reached with the most commonly used multiplier, the 1P21, and therefore photoelectric standards have so far not been readily available, which may have prevented many observers from using it. But in the long run one should not attach oneself to any passing technical limitations which introduce aspects foreign to the real astrophysical problems, and not take them just for granted. This would again be the same mistake as has been the adoption of the m_{vis} and m_{phot} as stardard magnitude ranges, where the choise was equally based on technical and historical arguments and not on astronomically sound reasons. There are today enough multipliers available whose range of sensitivity comprises the whole RGU system and any other system that may even stretch into the infrared. Photoelectric standards, so far badly missing, can today very well be obtained also for this system.

DISCUSSION:

Perek: There is of course, the difficulty of finding enough standards. For a new system, new standards must be established or the work has to be limited to relative photometry.

Steinlin: Why not choose six or eight colors according to the needs of the problem? Standards would accumulate as the system came into widespread usage.

Aller: Kron has actually done this with his six-color photometry, but has been limited to relatively bright stars for the whole.

Steinlin: The EMI cell is good even in the infra-red.

Thackeray: I think that one certainly ought to welcome this logical approach to the problem of color systems and not be too tied to whatever filter happens to be available. This applies especially to extending color systems into the ultraviolet through the use of rockets.

Purbosiswojo: Is the separation between dwarfs and giants in the U-G versus G-R diagram always larger than the statistical scatter?

Steinlin: The separation differs from place to place, perhaps due to variations in the metal abundance.

Pik-Sin The: How will the variability of the red stars influence your separation of red dwarfs and giants?

Steinlin: There are troubles, naturally, for any colour.

Westerlund: The U, B, V system will probably continue to exist as the dominating 3-color system because of all the information available in it now. The U magnitudes may possibly be improved. For astrophysical investigations several narrow band-pass multi-color systems exist.

Steinlin: We are now using R, G, and U magnitudes for statistical work with late spectral types, especially to effect dwarf-giant separations. We are studying 2000 stars (on photographic plates) at various galactic latitudes, to determine R, G, U magnitudes and in some areas B and V and therefore 5 colors.

In appropriate plots of color indices against one another, you can separate the giants and dwarfs, but some stars seem to show a spread, probably as a consequence of differing metal-hydrogen ratio.

Haro: It is virtually impossible to tell the difference between certain high temperature dwards and stars of very high luminosity.

Steinlin: For such black-body-like objects, the use of colors is very limited.

Haro: A sub-luminous high temperature star mistaken for a main sequence object would be interpreted as lying at the distance of the Andromeda nebula. How can we separate high luminosity stars in the Magellanic Clouds from foreground subluminous O or B stars ?

Thackeray: Proper motions will help for the nearer foreground stars. It was generally agreed that such a separation would be very difficult perhaps impossible from color measurements alone. It would be necessary to obtain spectra; no easy task for objects between the 13th and 18th magnitudes.

Aller: What we want to get out of our color and magnitude measurements for any particular star is the following information:

(1) The temperature of the star (essentially the color temp.)

(2) The luminosity class.

(3) The metal/hydrogen ratio.

(4) Effects of space absorption.

Basically, one should start with spectral scans of stars that differ in effects (1) through (4), e.g. supergiants, giants, and dwarfs of different temperatures, extreme metal-deficient and normal stars, reddened, unreddened B stars. Then, from a careful assessment of the tracings-corrected for atmospheric extinction it might be possible to select — 3 or more probably 4 basic colors that would give the maximum information on these quantities.

THE URCENT NEED OF A WELL EQUIPED OBSERVATORY NEAR THE EQUATOR FOR FUNDAMENTAL SPECTROPHOTOMETRY OF SELECTED STANDARD STARS.

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Bosscha Observatory Lembang.

When you open the world map where the names of places with observatories, equipped with either refractors or reflectors of small, moderate or large sizes are drawn most of them are places in the northern part of the globe, a small number are in the south and only one is near the equator. When we consider that the view of an observatory is limited, by the shape of the globe, then this situation will cause difficulties in making a complete study of our galaxy.

Our galaxy, a very important object of research in astronomy since the development of astronomy, stretches from north to south. Not only do the methods of search become more and more accurate with time, but also the instruments used in this work have become more and more accurate thanks to the rapid development of technology.

After the northern part of the Milky Way had been well searched, work was started southward. A good example is the work in radio astronomy, which was undertaken by van de Hulst in Leiden (Holland) and F. Kerr in Sydney (Australia). For searching the southern Milky Way, many observatories in the north built field stations south of the equator. As these stations south of the equator are field stations, they require extra expenses from the northern observatories. There is no other choise then working in this way. But lately this situation is improving. South Africa and Australia, for instance, are developing astronomy, both optical or radio, very fast, using sons of South Africa and Australia themselfs.

Although in South Africa and Australia work has started and is progressing well in searching the southern part of the Milky Way, still astronomers realize that the northern and southern centers of observations are seperated too far from one another. They feel that there is a gap between the two halves. This gap is felt, more and more especially as it concerns fundamentals, such as the need for a well established sequence of standard stars. They are sure that a well equipped observatory, on or near the equator, working in this field will help to solve this difficult problem. Also, it is very important to obtain a more complete knowledge of the central part of the Milky Way, which goes overhead at places near the equator.

The radio astronomers from Leiden and Australia will be very pleased when they can get a third participant in their search of the galaxy, who would be located near the equator and who would help them in completing their radio search. They especially need data about the centre of the Milky Way, which forms the chain of their observations.

An observatory which can fulfill this need exists, but it is not yet well known to the world. It was known in the past only through double star work, but is not yet known for photometric work.

The main programme of such an observatory in the future is to transfer the sequence of known established standard stars from the north to the south photoelectrically. Because only this kind of determination, I mean photo-electrically, of sequences of standard stars, is the most accurate method of magnitude determination.

The main thing now is: "Will this observatory, the Bosscha Observatory in Lembang, the only observatory in Indonesia, able to do this very important work ?" In a sence it is now, with the instruments it possesses, and with the present staff.

Let us start with the instruments: Unesco, as an official international institution, has given a very important push to the Bosscha Observatory in this direction, by supporting the observatory in obtaining the optics for a Schmidt telescope, which has been operated since 1960.

Photoelectric photometry, one of the most accurate methods of determining star magnitudes in use up till now, has been started at the observatory using a refractor, which has several bad habits, as all of you saw yesterday on your visit to the observatory. To do this important work, a reflector of at least 40″ or 100 cm diameter will be enough as a start. Not only is a reflector of 40″ easy to handle, it is also big enough for other kinds of work, for instance spectroscopy. Also using this telescope for photoelectric work will help the Schmidt telescope in providing standard stars for the Schmidt telescope. One thing we have to keep in mind is where to put this new reflector, if there is to be one in the near future. The location of a place for this reflector has to be chosen accurately. My experience with the photoelectric photometer last year showed me that Lembang is not good for photoelectric work. To speak about the financial probabilities, it can be said, that financial help from the Government of the Republic of Indonesia in the coming two or three years will be very minimal, as our Government is concentrating all their budget in the coming two years on food and clothing. I am sure that all of you will agree with me, or those of us from Lembang, that the need for a well equipped observatory near the equator should not be postponed any longer. The only way to obtain such an observatory will be in cooperation between your observatories or your institutes and ours under the auspices of the International Astronomical Union. We are indeed very pleased to have you here in our midst, so that you may see personally, what we have, what we have done in the past, what we are doing and what we are going to do in the future.

Indeed it sounds very ridiculous to ask help from the I.A.U., when one is not a member of that body. Also about this matter I would like to ask your attention, now that you have seen the situation of the observatory. The Lembang astronomers realize, that it is not easy to be a member of the I.A.U. It is not proper indeed to become a member of the I.A.U. only in order to receive help from the I.A.U., but it is more important to work in the other direction and that is to serve the I.A.U. But on the other hand, our membership in the I.A.U. will be an incentive for us at the Bosscha Observatory to work more intensely in the future, even more so than we have done in the past. Also it is worthwhile to bring to the front here, the idea that the electronics faculty of the I.T.B. might go into radioastronomy in the near future. Last year they started working with radar. This important idea of going into radio astronomy, put forth by the people of the electronics faculty, shows you how much we would like to cooperate with you in solving problems concerning the universe.

In summary I would like to emphasize the following:

1. The Bosscha Observatory, the only observatory near the equator is able to fulfill the urgent need of transferring the sequence of standard stars from north to south photoelectrically.
2. For this purpose the Bosscha Observatory needs more instruments.

DISCUSSION:

Ambartsumian: If our discussions here lead to a general agreement that it is desirable to install a photoelectric telescope here in Java, the International Astronomical Union will support such a program scientifically and morally. It seems to me that for the work of the transfer of color and magnitude systems from one hemisphere to another, it is not necessary to have a 40-inch instrument. A much smaller telescope will make possible the transfer of magnitudes and colors of bright stars.

Perek: The Bosscha Observatory has the unique advantage that it is the one observatory in the world that can reach comfortably the entire Milky Way. There is some advantage in carrying out investigations with a single telescope and observing procedure.

Nitisastro: It is important to establish a photoelectric telescope at a better site than Lembang where sky conditions are not favourable for photoelectric work.

Perek: It would be useful to undertake an extensive sitetesting program. This should be fairly easy, since much preliminary work can be done by local people. If a really good site is found, it is quite possible that other countries would be interested in putting up their own telescopes in Indonesia and working in close cooperation with the Indonesian astronomers.

Pik-Sin The: The most difficult task in setting up a good observatory in the tropics is to find a site where there is as little rain as possible. Extensive rainy seasons make it difficult to carry out programs that require observations in all intervals of right ascension. For example very few observations are possible between October and May at Lembang. I think this difficulty can be overcome by international cooperation in the equatorial belt.

Osawa: Optimum transparency and seeing conditions may not be found in the same place. Which is the more important ?

Nitisastro: I prefer to have both but if I have to make a choice I will take the site with good seeing.

Osawa: Transparency is more important than good seeing for photometric work.

Thackeray: Good photometry is done at the Cape although the seeing is bad there.

A lively discussion then followed concerning the size of the telescope or telescopes that ought to be secured.

Westerlund: A 15-inch telescope is suitable for transferring zeropoints, a forty inch telescope is needed to follow up with sequences. A transparency monitor is a very useful device in photometry.

Osawa: It is best to have two telescopes of different apertures. A 40-inch telescope is good for observing the programme stars and a smaller telescope, e.g. a 12-inch is useful for monitoring transparency.

Aller: If you are developing a new site, it would be useful to start with a telescope of about 16-inch aperture. Then one could do the bright star work and check out the site. If the site is favorable, one should then try for a larger telescope (e.g. about 40-inches) with which serious work in fainter stars, spectral scanning, and spectroscopy could be done. If a modern telescope is constructed, the setting time for a 40-inch need not be inconveniently long. Furthermore, it is extremely important to have sufficient light gathering power to take advantage of new technological developments such as image tubes.

Haro: Much work can be done with telescopes of moderate size if one applies imagination, enterprise and organization. We need only refer to the work of Thackeray and his group with the 74-inch telescope at Radcliffe. Harold Johnson has done excellent photometric work with 20-inch and 36-inch telescopes. And of course the kind of work that can be done with a Schmidt type telescope in the South is of major importance, for instance in the problem of T Tauri stars and related objects, planetary nebulae, faint blue stars in the halo, Wolf-Rayet stars, Be stars, flash and flare stars, etc., etc.

THE ROLE OF SPACE TELESCOPES IN FUNDAMENTAL SPECTRO-PHOTOMETRY OF SELECTED STANDARD STARS.

L.H. ALLER.

University of California, Los Angelos.

It seems scrarcely necessary to repeat the obvious statement that no other science has the stake in space research that astronomy has. Not only can observations from space paltform yield data on the heretofore inaccessible ultraviolet and infrared, but they can sometimes yield better observations than we can secure from the ground even in the ordinary spectral regions.

Observations secured by Schwarzschild and his co-workers from balloons have revolutionized our ideas on solar granulation, and shortly high resolution photographs of planetary surface detail and galactic nebulae will become available. Thus, substantial improvements in resolution are already at hand even without sending equipment into space.

Photometry is another field in which telescopes flown in balloons or on space platforms may play important roles. A limiting factor in broad-band pass photometry or spectrophotometry is the transmission of the earth's atmosphere.

When I went to Australia in 1960 to undertake a spectrophotometric investigation of nebulae, star clusters, and certain exotic stars, we were immediately confronted with the problem of setting up accurate energy distributions for a number of southern standard stars. If one had time and ample laboratory facilities one could do this in a "fundamental" way by comparing the stars with a standard lamp. Under actual circumstances, such an approach was not possible and we had to set up our southern standards by comparing them with northern standards of "known" energy distribution.

D.J. Faulkner and I used mostly the 26-inch reflector at the Mt. Stromlo field station, then at Mt. Bingar. Some observations were also made with the 50-inch reflector on Mt. Stromlo. We used the photoelectric spectrum scanner designed and built by Wm. Liller (1957) at the University of Michigan. It was originally designed for an f/5 optical system and therefore had to be modified for use on the Australian telescopes which had focal ratios of 15 and 18. All observations were made with a spectral purity of 9 Å, and covered the spectral range from 3200 to 6100 Å. For wavelengths longer than about 4800 Å, a yellow filter cut out blue radiation from the 3rd order. An unsilvered glass plate, tilted at an angle of 45° threw enough light into an auxilliary eyepiece to permit accurate guiding.

The programme of observations entailed the following steps. We observed an "extinction" star (usually it also served as a southern standard) both at low and high altitude. We always observed the nothern standard near the meridian to minimize its zenith distance. Thus the spectrum of the extinction star was always scanned at zenith distances both greater and less than that of the northern standard. In this way we hoped to minimize the troublesome influences of atmospheric extinction.

We suppose that the atmospheric extinction can be written in the form

$$k = A + B\lambda^{-4}$$

The first term represents the grey extinction due to dust, water droplets, etc. The second term represents the Rayleigh scattering which should remain constant from night to night at a given site. We secured atmospheric extinction measurements on 20-odd nights, comparisons with northern standards on 18 nights. We scanned the spectra first in the direction of increasing wave lengths and then in the reverse direction. In this way, changes in atmospheric transparency, or difficulties with the equipment, could be detected. From measurements of each tracing at 30 different wavelengths, we determined k. Then, from the dependence of k on wavelengths we assess the factors A and B.

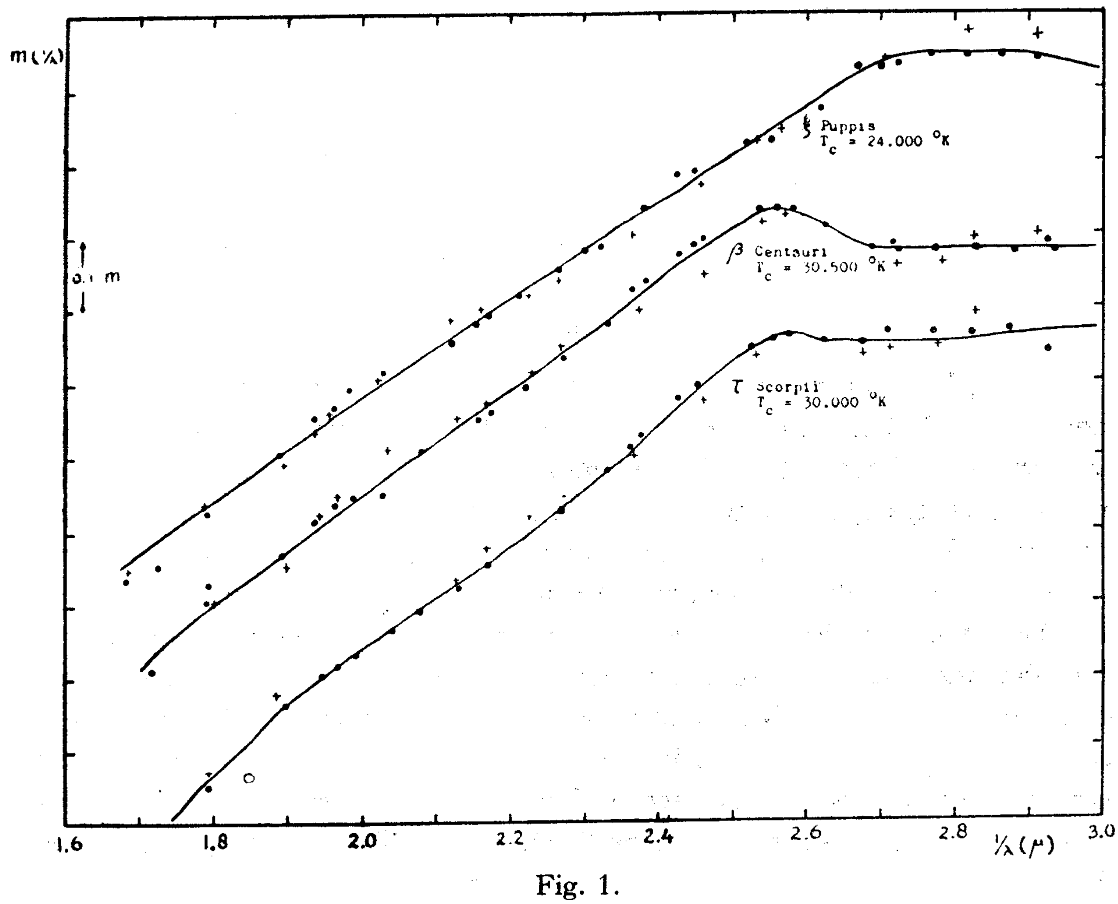

Fig. 1.

Fortunately, the Jet Propulsion Laboratory in Pasadena was interested in accurate measurements of the energy distributions in certain stars, among them Canopus, in connection with guidance systems for space probes. Robert Norton of JPL undertook the proccesing of our data with their IBM 7090. Plotting of resultant energy distributions, detailed comparisons, and assessment of the machine output has been undertaken at University of California in Los Angeles. Detailed results are to be presented elsewhere but I shall summarize here some of the main conclusions as they pertain to methods of photometry and advantages to be gained by observations from space platforms.

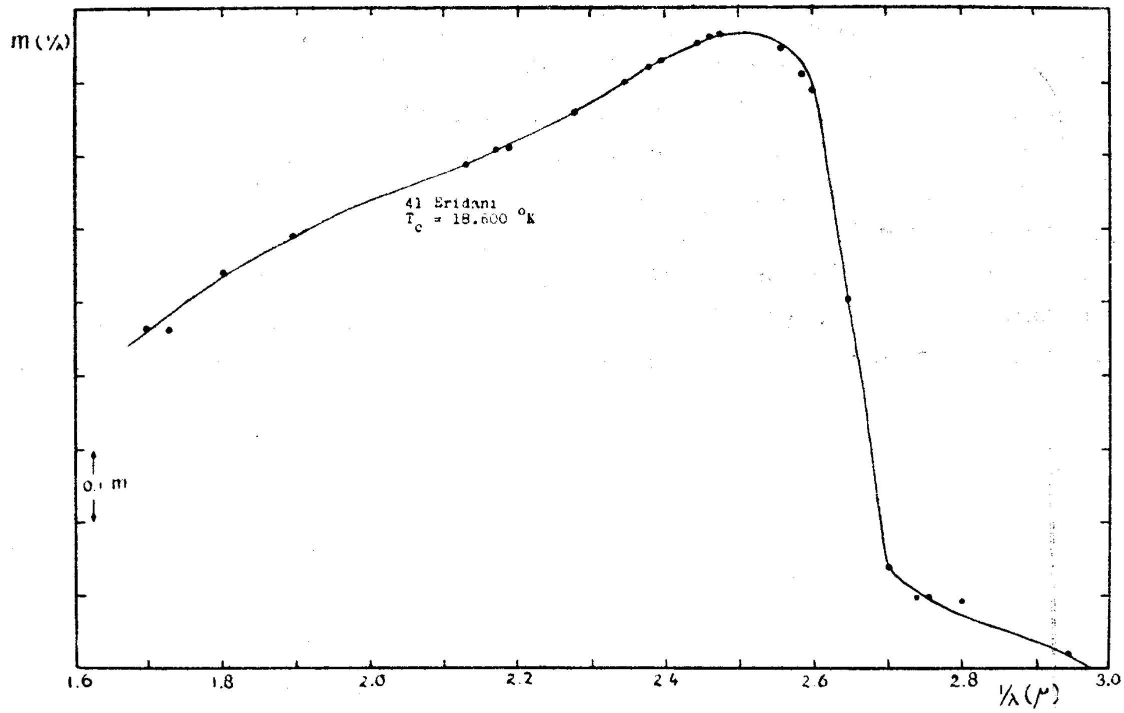

Fig. 2.

First, let me explain why I believe that accurate measurements of stellar energy distributions are necessary for both the northern and southern hemispheres. The theory of stellar at mospheres enables one to calculate the emergent flux, $F\nu$, once one is given the effective temperature, surface gravity, and gross features of the chemical composition. Although straightforward in principle, the detailed workingout of a model stellar atmosphere is beset by a number of difficulties. Some arise from the nature of the problem and the fact that the boundary conditions can be imposed only at the end of a long chain of calculations. Others may be due to as yet unidentified sources of continuous absorption in stellar atmosphere. How far amiss some of the earlier theoretical work has been is illustrated by the energy distribution in several early-type stars measured by Stecher and Milligan (1962) from rockets fired above the earth's atmosphere. Hence much more work remains to be done on model atmosphere theory before we can predict the energy distribution and line spectrum of a star as accurately as it can be observed, at least for very luminous or hot stars.

Color-magnitude plots for clusters and stellar associations are frequently interpreted in terms of stellar evolution arguments. The interpretation of a stellar-color-or Stromgren luminosity index in terms of surface gravity and interpretations of colors and line spectrum details in terms of spectrophotometric measurements. As predictions of stellar structure theories become more precise, the more urgently necessary does it become to translate surface gravity and effective temperature into observable quantities such as energy distributions and line profiles and these in turn into colors and luminosity indices. Steadily increasing accuracy in stellar colors and such things as $H\beta$ — indices point up the necessity of more accurate theory of atmospheres and more accurate spectrophotometry. Ultimately, stellar colors have to be understood quantitatively in terms of stellar energy distributions and it is therefore we seek the highest attainable accuracy in stellar energy distributions.

Establishment of energy distribution standards is dependent in practice on the following steps:

1) The energy distribution in some star is established by comparison with a standard energy source of known spectral energy distribution. Vega, which is at a convenient latitude for many northern observers, has often been used as a fundamental standard, although some observers, e.g. Kienle, (1956), Barbier and Chalonge (1941) have measured energy distribution in a number of stars.

2) Next, the northern stars are used to set up "secondary" standards elsewhere in the sky. It is particularly urgent to set up standards in the equatorial zone $\pm$ 15° so they can serve in turn as "primary" standards for the southern skies.

3) Finally we set up basic southern standards such as α Pavonis, Zeta Puppis, α Crucis, and ξ Scorpii by comparing them with the equatorial standards.

It is better to establish the southern standards by comparing them with the whole system of northern secondary standards, rather than basing the calibration on a single star. When this is done, however, we find that the northern standards used, namely those established by Oke (1960) and by Code (1960) did not agree among themselves, so ultimately one has to refer everything to a single star or a combination of stars.

Notice further that the establishment of southern standards of energy distribution requires two steps, each of which is done with different instruments in different locations and at different elevations, etc. The basic photometry might be substantially improved if the photometric transfers were carried out by stations near the equator. At least all measurements would then be affected by the same systematic errors which could be assessed and eliminated eventually.

Atmospheric extinction may cause considerable difficulty in accurate work. It may vary from night to night or even change during the course of one night. Changes in the A and B coefficients in the atmospheric extinction formula as calculated for Mt. Bingar and Mt. Stromlo are shown in the following table.

SITE	DATE	A	B
Mt. Stromlo	Aug. 1960	0.082 ± 0.046	0.00965 ± 0.00047
	Jan. — May, 1961	0.075 ± 0.024	0.0085
Mt. Bingar	Sept.—Nov. 1960	0.069 ± 0.025	0.00856 ± 0.00035
	Jan.—March, 1961	0.045 ± 0.035	0.0106 ± 0.00041

The grey term is particularly uncertain and while it plays no important role in energy distribution studies it becomes significant as soon as actual magnitudes or surface brightnesses are to be measured. Part of the variation in the B-term is to be attributed to uncertainties in the least squares fit for equ. (1) transparency in the course of a single night, which of course would vitiate determinations of the atmospheric extinction. Throughout most of our work we used mean values of the extinction, obtained by taking averages over several good determinations.

The way out of this difficulty would appear to be observations of the energy distribution secured from above the earth's atmosphere. Not only would it be possible to extend the spectral range involved, but one could accurately compare energies over narrow band-passes for stars in widely separated parts of the sky. Furthermore, it would be possible to link all stellar measurements to a single fundamental standard without the troublesome influence of atmosphere extinction. It is suggested, therefore, that stellar energy observations from above the earth's atmosphere be so designed as to include accurate measurements of radiation in the ordinary spectral regions as well as in the ultraviolet and infra-red. The apparatus should be carefuly calibrated so that deflections can be converted readily into intensities.

If possible, observations should be secured for the stars in the $\pm 15°$ equatorial band which have been proposed by Oke and Kron as fundamental standards for color and spectral energy distributions.

The spectrophotometric observations of southern stars was made possible by a senior postdoctoral fellowship from the National Science Foundation, and generous cooperation from the Australian National University. Assistance for the assessment of the observations was provided from a NASA grant to the Space Science Center at University of California, Los Angeles.

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DISCUSSION:

Osawa: At what wavelength is the grating blazed?

Aller: Liller discusses this question in his description of the scanner in Publications of the Astronomical Society of the Pacific in 1957. I think it is blazed near 4200 Å in the second order.

Osawa: Does your empirical formula, $k = A + B\lambda^{-4}$ fit well? According to my experience at Okayama, it was difficult to express k_λ by such a simple formula.

Aller: On good nights the equation seems to fit well for data at Mt. Stromlo and Mt. Bingar.

Westerlund: In what direction does the deviation between the energy distribution in the ultraviolet from the scans and from the U-filter transmission curve go?

Aller: Melbourne discusses this question in his 1960 paper in the Astrophysical Journal. Difficulty arises from the fact that atmospheric extinction varies substantially from one edge of the U-filter region to the other.

Westerlund: The absorption caused by ozone in the ultraviolet and in the green might be considered more than is done at present.

Thackeray: It may be of interest to mention that Dr. R.V. Willistrop of Cambridge, worked at the Radcliffe Observatory in 1962 on a similar spectral scanning survey of southern and northern stars. It will be agreed that the extinction problem mentioned by Dr. Aller is important, and it will certainly be valuable to extend such a comparison to a latitude like that of Bosscha Observatory at 20° further north than Pretoria. Willistrop's work is not yet published and is distinct from that already published as a result of his earlier visit to the Cape Observatory.

SPECTROSCOPIC STANDARDS FOR STARS OF THE HIGHEST LUMINOSITY.

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Historically, the first spectroscopic clue to stars of very high luminosity came in the early years of this century when Hertzsprung pointed out that the stars with Miss Maury's "c" prefix in the Harvard classification had very small proper motions. It was clear that bright stars like α Cygni must be very distant and have exceptionally high luminosities.

The calibration of the luminosities of these rare supergiants is an exceedingly difficult problem, more difficult than for the numerous less luminous Cepheid variables. It is easiest for the B types of which a considerable number occur in galactic clusters. But supergiants of type A5 and later in clusters with known distances are much too rare for calibrating the MK system satisfactorily. In Blaauw's latest calibration there is a range of 7 magnitudes between MK class II (F to M) and the brightest supergiants known. The use of the term "super-supergiant" for stars with absolute magnitudes about —9 seems to be justified; the existence of such stars was first established in the Magellanic Clouds (Feast and Thackeray, 1956) and more examples in the Clouds have been discovered by Fehrenbach's objective prism technique (1962).

Owing to the difficulty of finding such rare objects in the Galaxy and measuring their distances, the Magellanic Clouds clearly offer by far the best opportunity of studying the super-supergiants. Absorption problems are not serious and variations in apparent magnitude due to position in depth are for most purposes quite negligible. In passing, three important photometric results on Magellanic Cloud super-supergiants may be mentioned:

(1) the intrinsic colours can be more securely determined than in the Galaxy because of serious problems of absorption in the latter,

(2) the B-V colours become suddenly redder for types later than G0; this behaviour does not yet seem to be adequately explained,

(3) in the U-B, B-V plot the hydrogen dip is scarcely present; this behaviour can be readily understood as a result of the narrow hydrogen lines and presumably small absorption at the Balmer limit.

These last two points were already reported at the Rome Semaine (Thackeray, 1957).

Although the uncertainty of the distance modulus of the Clouds must still be regarded as at least ± 0.25 m, these Magellanic Cloud stars are already superior as spectroscopic standards than the few isolated galatic examples.

This statement is based on the fact that many galactic supergiants are only recognised as such through their spectral peculiarities; if a galactic star presents the usual criteria of high luminosity in exaggerated form we call it a supergiant, but with a residual doubt of order 1 magnitudes in its true absolute magnitude. Even then we are not sure that through some quirk of nature a star of only moderate luminosity may mimic a supergiant in its spectral characteristics; deficiency of hydrogen, rendering the atmosphere exceptionally transparent could be one way in which this might happen. A circumstellar shell is probably characteristic of stars of extreme luminosity; but can we be sure that a similar phenomenon may not be associated occasionally with some far less luminous but peculiar stars? In the Magellanic Clouds we know that the brightest stars (with apparent magnitudes around 10) *must* be supergiants not only on account of their peculiar spectra but also because of their measured radial velocities.

Suppose we try to set up a system of standards of high luminosity stars in the Magellanic Clouds for application to the Galaxy. We may then be able to assign luminosities of galactic supergiants, with otherwise unknown distances, either through direct comparison of spectra, or more accurately by using the Walraven, Strömgren or Petrie techniques. Any such attempt presupposes two things:

(1) that Magellanic Cloud and galactic supergiants with the same surface temperature and absolute magnitude have identical spectra (implying identical composition),

(2) that the standards, to have any useful application, must remain constant in time (e.g. at least for an astronomer's lifetime).

This is hardly the occasion to discuss possible differences between the Magellanic Clouds and the Galaxy, but suffice it to say that among the representatives of Population I in the Clouds (i.e. the brightest known stars and the gaseous component), no definite sign of a difference from the Galaxy has yet been detected. The behaviour of some A stars in the Small Cloud still poses some problems in this context.

With regard to the second point, we must recognise a certain difficulty. Abt (1957) has given reasons to suppose that *all* stars in the top right-hand portion of the HR diagram are variable in light and radial velocity. Wesselink (Feast et al., 1960) has found small variations in light of order 0.1 to 0.2 mag. commonly among the red super-supergiants in the Clouds. There are also theoretical reasons to believe that very massive stars, near the limit of stellar stability, must be subject to pulsation.

The well-known eclipsing supergiant variable Epsilon Aurigae shows small irregular variations in light and radial velocity outside eclipse. Many such examples are known. These supergiants with enormously expanded atmospheres also show spectroscopic signs (double lines) of being surrounded by expanding shells. Many years ago, Adams and MacCormack found the H and K lines systematically shifted to the violet by a few km/s in a number of galactic supergiants. The same phenomenon has recently been observed in coudé spectra of the brightest stars in each Magellanic Cloud (Thackeray, 1962).

In the face of such variations is it possible to set up a satisfactory system of standards at all. Two gross examples come to mind: (a) the variable *S* Doradus undergroes marked spectroscopic variations — for instance, with the enhancement of [Fe II]. emission when faint (Wesselink, 1955). Very probably the [Fe II] emission arises in a vast envelope, like that surrounding Eta Carinae, and is swamped by stellar light at miximum phase; (b) the irregular variable Rho Cas, most frequently found with a supergiant F8 spectrum, developed a supergiant M spectrum during the deep minimum of 1946.

If we avoid such extreme examples and ignore the minor variations which are probably universally present among supergiants, there does appear to be scope for setting up a reliable system of supergiants with luminosities that can be eventually calibrated accurately via the Magellanic Clouds.

Mention should be made of the Wilson-Bappu calibration of galactic supergiants of type later than G0, which uses the structure of Calicium K emission. Unfortunately, even with the 200 inch telescope it is difficult to push the required observations fainter than 6^{th} magnitude, and it is highly probable that a number of galactic super-supergiants fainter than 9^{th} magnitude exist, unrecognised on account of absorption. High quality objective prism spectra might reveal new supergiants in a survey of the Milky Way.

The strategic situation of Lembang, slightly south of the equator, means that not only are the Magellanic Clouds accessible to observation, but also the complete circle of the Milky Way. Every known supergiant in the galactic plane could be studied with the same equipment. Admittedly the altitude is uncomfortably low for the Northern Milky Way and for the Magellanic Clouds. That would rule out some photometric work, but need be no bar to spectroscopic observations.

The same argument regarding the strategic position of Lembang for a *complete* survey around the Milky Way applies of course to any rare object confined to low galactic latitudes, such as Wolf-Rayet stars, N types etc.

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DISCUSSION:

Aller: If the supergiant stars in the Magellanic Clouds are suspected of variability, would it not be worthwhile to monitor them with small scale plates? Is *S* Doradus a spectrum variable?

Thackeray: Yes.

Westerlund: Bolometrically the central star in 30 Doradus may be the brightest in the LMC.

Thackeray: The central star in 30 Doradus may not be a single object. *S* Doradus is certainly not suitable as a standard of any kind, but it is a fascinating object in its own right.

Westerlund: Be stars can be separated from OB stars by aid of low dispersion objective prism spectra by measurements of the total absorptions of Hγ and Hδ. Hγ tends to be filled in by emission more than Hδ.

Thackeray: If the Bosscha Observatory could find additional supergiants along the Milky Way we could use them to study spiral structure, etc. It is diffcult to tell the difference between supergiants with narrow hydrogen lines and main sequence early type stars whose lines are narrowed by emission. In the Henry Draper catalogue, supergiant A stars are sometimes called B stars because Hγ is so weak.

Pik-Sin The: We certainly can do it if there is time available. As to your suggestion to survey the entire Milky Way for Wolf-Rayet stars I would like to point out that Stephenson at the Warner and Swasey Observatory is looking for Wolf-Rayet stars in the anti-center region of the Milky Way in connection with the fact found by Roberts that no Wolf-Rayet star is known sofar to be located in this region. We are requested to take several plates for him.

Haro: Have you drawn on the Tonantzintla list of OB stars?

Thackeray: Yes. We found that most of your OB stars are earlier than B2, but many are dwarfs. Can you use H-alpha to distinguish between I and V luminosity class stars on objective prism plates?

Haro: No. What is the limiting magnitude with the Lembang Schmidt?

Pik-Sin The: We can reach the 11th magnitude. The limiting magnitude depends also on overlap and widening. With less widening, of course we can reach fainter stars.

Haro: Bad seeing affects image quality in long exposures. For a faint OB star you need exposures greater than 30 minutes and seeing effects tend to make it hard to recognize an Ia from a Ib star.

Thackeray: Could we distinguish luminosity classes with a dispersion of 300-400 A/mm?

Westerlund: I do not try to separate the Morgan classes, but devide the stars into OB stars and main sequence stars later than B2. In a twenty-minute exposure, the limiting magnitude in the Magellanic Clouds is 12.5 mag. In about 2 hours, you can reach 15.0 in highlatitude fields, but visual inspection of the prism plates will not do. We must use tracings.

Thackeray: Among OB, B2 stars and earlier, everything in the U, B, V plot seems to converge to a point photometrically and spectroscopically; luminosity classes also become more difficult to distinguish. For spectral classes earlier than B2, we can scarcely distinguish between Ia, Ib or even II; we use classes I, II and V. In spectral class O, no luminosity criteria exists at all.

Ambartsumian: Are the supergiant A, F and G stars in the Magellanic Clouds closely connected with the associations?

Thackeray: We are not sure because of incompleteness of survey. We depend on the Henry Draper extension for the B stars. Fehrenbach's work will help greatly, but a few of these high velocity stars may not be cloud members. Some may be high velocity stars seen in projection on the clouds.

Ambartsumian: Have you used ξ Scorpii as a comparison star. It certainly belongs to the group of very luminous supergiants in our galaxy.

Thackeray: Yes, this is a very luminous star. The lines are narrow and H alpha and H beta appear in P Cyg in emission.

Aller: Faulkner and I observed Zeta (1) Scorpii with the spectrum scanner but were unable to secure very good results. The weakness of the lines made difficult the interpretation of the scans.

Haro: How many such stars are there between -8 and -9 absolute magnitude in the Magellanic Clouds ?

Thackeray: The 18^{th} brightest star in the Large Magellanic Cloud has an apparent magnitude of 10.7 and M = -8.

Haro: How many such stars are known in our own galaxy ? Are we sure there is not a difference between the brightest stars in our galaxy and in the Magellanic Clouds ?

Thackeray: There is a one magnitude difference between the brightest stars in the two Magellanic Clouds, but this probably only means that the large cloud is the richer system.

Ambartsumian: I wonder if we have a considerable number of such super-supergiants in our own galaxy (M about -8). Except for ζ' Scorpii in the Sco I association. I remember only one very luminous star in the highly reddened association Cyg VI, and also one highly reddened star in about one degree south of Cyg VI with a bright H-alpha line. This last star is apparently variable and is included in Kukarkin and Parenago's catalogue of suspected variables.

Thackeray: Rho Cass is possibly an analogue of one of the cloud super-supergiants, and this star showed remarkable variations. In 1946 it faded 2 magnitudes and showed a TiO spectrum, possibly associated with a circumstellar shell rather than a second star.

Aller: We observed HD 7585 (and I think HD 33579) with the spectrum scanner at Mt. Stromlo. Also we made scans of S Doradus which in January 1961 showed strong emission lines of hydrogen.

LOW DISPERSION SPECTRAL CLASSIFICATION AND MULTI-COLOUR PHOTOMETRY.

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ABSTRACT.

Some suggestions are given for deriving maximum information from objective prism spectra. Methods for the identification of very blue or very red stars are discussed. Preliminary results from a photoelectric multicolour programme are presented.

INTRODUCTION.

In climates where the observational seasons are limited for one reason or another, it becomes extremely important to derive the maximum information from the gathered observational material, and, of course, to plan the observations accordingly. Among the richest sources of information are the plates secured with astrographs or Schmidt telescopes equipped with objective prisms. This was realized early at several observatories where extensive measurements in the spectra were carried out with important results regarding the galactic structure in the solar neighbourhood. However, modern astronomy has developed in such a way as to increase the demand for distance indicators. Thus the survey plates have to a great extent been used for finding the most luminous stars only. These objects are then studied by photoelectric means, and, if they are bright enough, also by slit spectra. It appears possible to derive, for statistical purposes, all the necessary data from the objective prism plates themselves. It is, therefore, suggested that for the study of galactic structure the objective prism plates themselves are used for the brighter stars ($V<11$ - 12 mag). Several methods for the identification of fainter very blue or very red stars exist and will be discussed below. In these cases, multicolour photometry may be applied for deriving the fundamental data; spectral type, luminosity class, intrinsic colour, metal abundance and interstellar absorption.

MEASUREMENTS IN OBJECTIVE PRISM SPECTRA.

Measurements in unwidened or, preferably, widened objective-prism spectra have been used in the Uppsala-Stockholm classification system since the introduction of the wide-slit method by Ohman (1930) From this direct method of measurements in the spectra or from measurements in microphotometer tracings of the spectra (introduced by Lindblad and Stenquist, 1933) the following quantities may be derived:

1. A monochromatic magnitude
2. A colour quivalent
3. Classification criteria

   A. Early-type stars:

      a. The total absorption of Hγ and Hδ
      b. The total absorption of the K line
      c. The Balmer discontinuity
      d. The depression at λ 3780 Å.

   B. Late-type stars:

      a. The CN absorption at λ 4190 Å or at λ 3883 Å.
      b. The equivalent "g", the break in the continuum at the G-band.
      c. The total absorption of the G-band itself.

4. A metallic-line index.

1. **The monochromatic magnitude.** It is most practical to use as apparent magnitude the long wavelength base-point of the colour-equivalent (normally λλ 4400 — 4800 Å). The calibration of the plates should be carried out by photoelectric observations with narrow-band filters and possibly combined with the "prism-crossed-by-grating" method.

2. **The colour equivalent.** The base-points are to be chosen so that a good description of the gradient of the continuum is obtained, e.g. 4600 Å and 4030 Å. In metal-rich stars a shift towards longer wavelengths may be preferred.

3. **Classification criteria.** The two-dimensional classification of the early-type stars is best done with the aid of the Balmer discontinuity as a criterion of spectral class, and the depression at λ 3780 Å as a luminosity criterion. The absorption at λ 3790 Å is mostly due to the overlapping wings of the hydrogen lines (Westerlund 1951, 1956).

   The total absorptions of the hydrogen lines depend, on temperature as well as on luminosity and are not as pure criteria as the other two. However, they may serve also as valuable indicators of hydrogen line emission as Hγ will be filled in more than Hδ — The K-line is useful for separating B-A0 stars from late A and F stars, and is, of course, of interest as an interstellar line in OB stars.

The classification of late-type stars is best carried out with the aid of the two fundamental quantities "g" and "c" in the Uppsala-Stockholm system. They are generally defined:

$g = m_{4260} - m_{4360}$ and $c = m_{4180} - m_{4260}$. Similar quantities are used nowadays in photoelectric classification. In the case of strong interstellar absorption they may be seriously affected by reddening and corrections have to be applied (Westerlund, 1953, p 36).

4. **The metallic-line index.** Recent investigations have shown that it is possible to determine the metal abundance in stars from multicolour photometry. Consequently, it should be possible to derive similar quantities from wide-slit measurements in objective-prism spectra. A quantity similar to Strömgren's metal index m (1958) can definitely be derived.

   Finally, it may be mentioned that the use of well widened spectra and measurements *inside* the spectra with a wide slit will make the probable error in one determination smaller than $\pm$ 0.03 mag.

METHODS FOR THE IDENTIFICATION OF FAINT BLUE OR RED STARS.

1. **The Tonantzintla three-image method.** Haro (1956) has introduced a method in which three exposures, one in the ultra-violet, one in the yellow and one in the blue, are made on an Eastman Kodak 103a-D plate with suitable filter. The exposures are chosen so that blue stars will show a weak central yellow image surrounded by the stronger blue and ultra-violet ones. Objects which are easily identified by this method are: (Haro and Luyten, (1962)

   1. Extremely blue stars
   2. Extremely red stars, such as N stars
   3. Ordinary red stars, such as M stars
   4. Flare stars, T Tauri stars, stars with UV excess
   5. Definitely blue galaxies.

2. **The grating method.** A method for the determination of stellar magnitudes and colours by aid of a Schmidt-telescope equipped with an objective grating has been described previously (Westerlund, 1949). The exposures are made on Kodak 103a-E plates. The spectral sensitivity curve of this emulsion shows two pronounced maxima, in blue and in red light, seperated by a minimum in visual light. In widened spectra accurate measurements can be made.

   For the identification of red and blue stars measurements are not necessary. Inspection of the plate will immediately reveal the red stars and the blue stars. Calibration of the plates with stars of known spectral types will permit the identification of other classes. Reddened early-type stars may be separated from red late-type stars by studies of the way in which the visual region is filled in.

3. **Low dispersion prism spectra.** Morgan, Meinel and Johnson (1954) have introduced a method using a Schmidt telescope combined with an objective prism to derive spectra with a dispersion of about 30,000 A/mm for the identification of blue stars. The method is similar to the one described in (2) and uses also the sensitivity curve of the 103a-E emulsion to pronounce the desired features. It has the advantage over the grating method that no light is lost in a central image. The grating method has its strength in providing two images in each of the three colours for measurements, thus making accurate colour determinations possible.

MULTICOLOUR PHOTOELECTRIC PHOTOMETRY.

The methods for spectral classification by direct photoelectric measurements of spectra criteria (for references, see Strömgren 1958, Gyldenkerne. 1958, or Crawford, 1958) is being used at present at Mt. Stromlo Observatory, The Hβ photometry for the classification of early type stars is carried out by Graham and will be published elsewhere (Graham, 1963).

Here, some results will be presented from an investigation of the two-demensional classification of late-type stars with the aid of the indices $g = m_{4265} - m_{4370}$ and $c = m_{4160} - m_{4265}$ (the break in the spectrum at the G-band and the absorption in the CN band with band head at 4216 Å) as well as from a study of stars of all spectral types using Stromgren's four-colour system. The filters used are similar to those described by Crawford (1961).

Classification of late-type stars with the aid of "g" and "c". The observations have been carried out with the 50-inch reflector of Mt. Stromlo Observatory and with the 26-inch reflector at its Field Station on Mt. Bingar. The data obtained so far indicate that a very good agreement with the Morgan system may be expected, luminosity clasess V, III, II and I are well separated for G and K stars (Fig. 1) The relation between the index "g" and the intrinsic colour $(B - V)_0$ is, for luminosity class III, a straight line:

$$(B - V)_0 = 2.56\ (g - 0.10).$$

The maximum deviation in $(B - V)_0$ is 0.01 mag for the stars observed so far. It appears therefore likely that in a (g, c) diagram lines for equal $(B - V)_0$ may be drawn and intrinsic colours read with high accuracy. However, as mentioned above, care has to be taken when dealing with very reddened stars.

With the 50-inch telescope stars brighter than V = 14 mag are easily observed for classification. A programme has been started for the classification of the yellow and red stars previously identified in the region of the Large

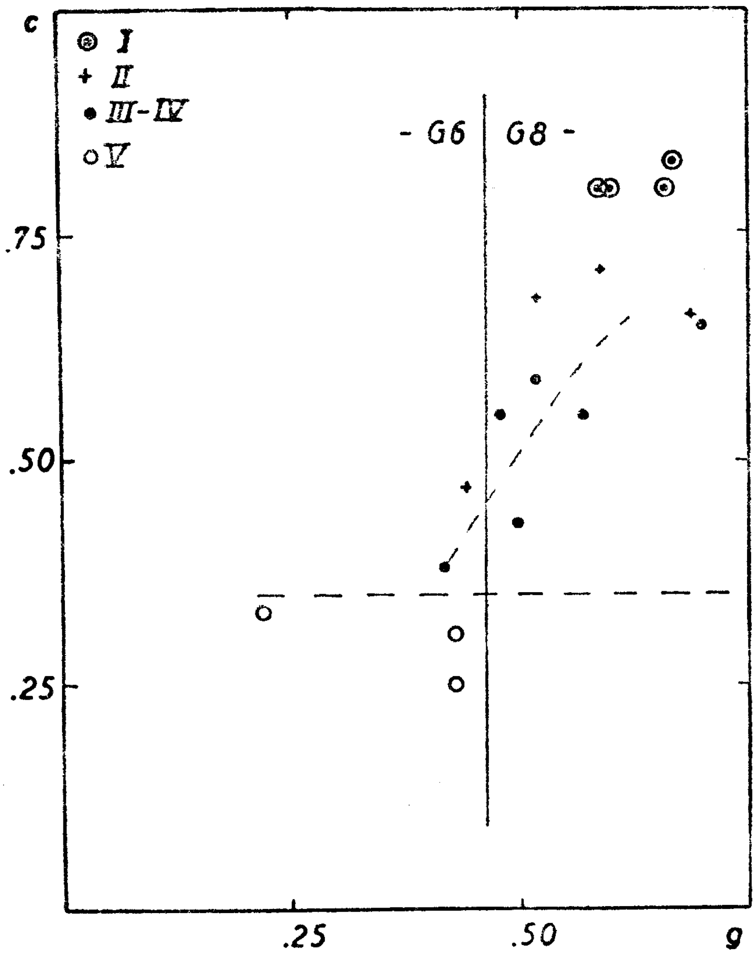

Fig. 1. The two-dimensional classification diagram for G and K stars. Open circles denote stars of luminosity class V, dots class III, plus signs class II, and dots in circles class I. The class II star at g = 0.69 is of clas M.

Magellanic Cloud (Westerlund, 1961). So far two of the stars in NGC 2100 have been observed (No. 30 and 51) and appear to be supergiants. Out of five stars observed in the region "a" (No. 1, 14, 15, 19, and 36) only one, No. 19, is a possible member of the Cloud.

Some result from the four-colour photometry. The four colours give a magnitude *y* at 5480 Å, a colour index *b-y*, 4700/5480, measurements of the Balmer discontinuity D, and a metallic-line index, *m*. In the present investigation, the two last quantities are defined:

$$D = m_{3450} - m_{4090} - 1.4\ (m_{4090} - m_{4700}),$$
$$m = m_{4090} - m_{4700} - (m_{4700} - m_{5480}).$$

The method has been successfully applied to the central cluster in 30 Doradus in combination with photographic observations with the 74-inch telescope, using 2 × 2 inches interference filters. These results will be published elsewhere.

The quantity D has been determined for about 20 stars in an association in Puppis. It appears possible to derive accurate intrinsic colours for OB stars directly from D, although the relation is not a single straight line. However, classification is likely to be improved by introducing the depression at λ 3780 Å as a luminosity criterion (see above), or by combining D with the total absorption of Hβ, as was done by Strömgren (1958).

Fig. 2 shows the metallic-line index, m, plotted against the colour index, b-y. We note that the metallic-line A stars appear to form a well-defined

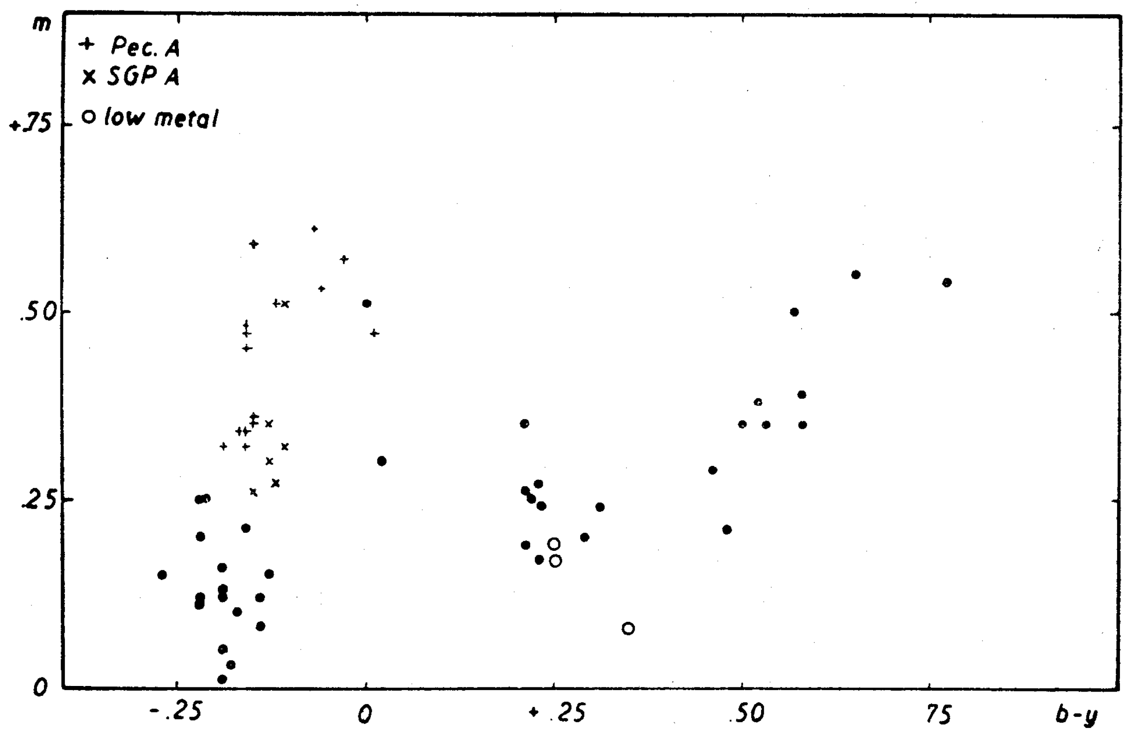

Fig. 2. The metallic-line index *m* plotted against the colour, *b-y*, Metallic-line A stars are denoted by plus signs, open circles represent stars with low metal content. A type stars near the south galactic pole are ploted as "x", all other stars as dots.

group in the diagram. The star ν Ind (m = 0.08, b-y = + .35) falls very low in the diagram in aggreement with its low metal abundance (Przybylsky, 1962). Two high-velocity stars are found in the same part of the diagram. The material is still very scanty and selection effects are likely to exist.

Strömgren's four-colour system appears most promising, however, and is likely to give valuable information about most types of stars. This system is therefore recommended to be used whenever astrophysical data are desired. The addition of an infrared and a red magnitude to the existing four would make the system cover efficiently all stars, even the extremely red stars, which are rich in disturbing absorption bands in the blue and visual.

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DISCUSSION:

Aller: When you observe spectra in crowded fields is it not advantageous to take several spectra, each with a seperate narrow band pass filter so chosen as to select criteria of particular luminosity, temperature, and metal/hydrogen ratio.

Westerlund: I have tried several combinations; a GG13 filter plus a blue sensitive plate reaches to the K line. A UG2 filter plus blue sensitive plate covers the ultraviolet region and includes the K line. We can use a thin UG2 and GG13 filter to cover a region from 4000 Å to 3600 Å. This is very valuable since it covers the Balmer discontinuity in hot stars and the 3883 Å cyanogen line in later type stars.

Haro: In practice you must increase the exposure time by about three times in order to reach the same limiting magnitude.

Westerlund: You do not use this method unless it is necessary, as for example in crowded fields of the Milky Way.

Haro: The use of multicolor systems, UBV etc. are fundamentally the same. The method is good, not for identifying luminous stars, but rather for picking out stars of different color. In a highly reddened region, it is hard to separate an OB star from an unreddened G or K star. In an unreddened region, you cannot seperate a dwarf blue star and a supergiant.

Westerlund: With care, I believe you can often seperate a reddened star from a non-reddened one, e.g. by Morgan's method or from blue grating spectra.

Thackeray: You quoted F8 as the latest class at which the K line is usable for classification. What is the earliest class at which the K line is useful? I ask because of the danger of confusion of interstellar K among stars of low galactic latitude. We have found some stars in the HD catalogue classified as B2 or B5 which are really O stars. I can only understand this if Miss Cannon saw a K line which is of interstellar rather than stellar origin.

Westerlund: You can use the K line for stars later than B9.

Pik-Sin The: Is the determination of M-type supergiants by the infrared technique reliable?

Westerlund: If the total absorption is about 2 magnitudes an ordinary M giant can simulate an M supergiant on an infrared spectral plate. Without photometry, separation is difficult.

Steinlin: The importance of having one color in the region of 4700 Å (B of Strömgren) and 4800 Å (G of RGU) comes out very well. The metal index m in this system measures the same change in slope of the energy distribution around 4700-4800 Å which was found so important in RGU. Is it now possible in this system to distringuish between the effect of metal abundance and of luminosity, perhaps by using one of the other color indices? This system shows rather clearly that for the differentiation between these different factors a three-color system is not sufficient and that you must probably use four or five colors.

Osawa: I have calculated model atmospheres with temperatures between 8900 and 7600°K, and have computed theoretical metal indices assuming no absorption lines and have found only small variations from the theoretical values of m over this temperature sequence.

Aller: Unless, they are very large, the variations in the metal/hydrogen ratio can be determined only if the stellar temperature is known very accurately. Therefore, we must have accurate independent criteria for fixing the temperature and the metal/hydrogen ratio.

OBJECTIVE PRISM SPECTROSCOPY WITH THE LEMBANG SCHMIDT TYPE TELESCOPE.

PIK-SIN THE

Bosscha Observatory Lembang.

The most extensive work done on spectral classification using an objective prism is certainly that of Harvard Observatory published as the Henry Draper Catalogue. It is a standard work on spectral classification, and has a great influence on the progress of astrophysics.

In recent years the demand for spectral classifications of fainter and fainter stars has become greater and greater. For instance at the recent I.A.U./U.R.S.I. symposium No. 20, held at Canberra and Sydney, it was pointed out that a search for faint B stars up to a visual magnitude of 15 is needed for the study of galactic structure.

In this short paper I would like to present our experience with the 6° objective prism used on the 20-28″ Lembang Schmidt type telescope.

During the last observing season spectral plates were taken to study the stars in a new OB-association (R.A. = 17^h08^m; Dec. = -33° (1900)) which I have found in Scorpius. The dispersion obtained by using the 6° objective prism is 312 Å/mm at $H\gamma$. Six plates were taken, of which three were taken with the prism in the usual orientation while the other three were taken with the prism rotated 90°. The exposure times were 75 sec., 10 min. and 45 min. The emulsion used was Eastman Kodak IIa-O exposed without a filter. With this emulsion we obtain spectra of stars which extend from about $H\beta$ to about H12. Because of poor transparancy and seeing not all the plates were of first class quality. Nevertheless I have attempted to classify the stars in the region of the OB association. As criteria for the classification I have used those published for the spectral classification with the Warner and Swasey Schmidt type telescope. Most of the stars in the region are late type B and early type A stars. A comparison of my spectral classifications with those published in the Henry Draper catalogue shows that the agreement between the two classifications is quite good.

The plate limit of our 45 min. Plate is about the 11^{th} visual magnitude. When one wants to go fainter than this limit, one has to make the widening smaller in order to avoid overlapping of the spectra of the stars and also in order to shorten the total exposure time. When one wants to go to still fainter limits one has to make the widening still smaller, but this will make the classification more uncertain. Perhaps we can enlarge and widen the spectra by using a photographic enlarger, that is by moving the plate in the direction of the spectral lines.

No luminosity classification has thus far been attempted.

The spectral classification of M-type stars using the infrared technique introduced by Nassau et al., can be done without difficulty. The plate-filter combination is: Eastman Kodak IN and an RG8 filter. As it has been usually encountered by Nassau et al., the classification of the aerly M-type stars with this plate-filter combination is very uncertain. Perhaps this difficulty can be overcome by using another type of filter.

For the identification of S and Carbon type stars we can also use the infrared technique, although according to Haro certain type of S stars can be detected more easily on red spectral plates, using 103a-E emulsion plus an RG1 filter.

Furthermore I would like to make some short remarks about my experience in my survey of H-alpha emission line objects. Since our Schmidt type telescope has been put into operation I have used it extensively for a survey of H-alpha emission objects in selected regions of the Milky Way. For this purpose we use the following plate-filter combination: 103a-E emulsion plus an RG1 filter. Using this combination we obtain very short spectra with H-alpha located just on the redward edge.

The major aim of this project is the detection of faint T Tauri stars associated with nebulosity. As a by product we will also detect all kinds of stars having H-alpha in emission, such as WR stars, Novae, Be, Ae, Me-type stars etc. Using the same plates we are also able to detect planetary nebulae. These appear on the red plates without continuum. Usually only the H-alpha emission appears although sometimes, if they are strong enough, other emission lines can be observed.

The difficulty in detecting planetary nebulae with certainty is caused by the following reasons. Be-type stars, in which the H-alpha emission is strong, can appear on our red plates without continuum because this continuum is underexposed. This fact was pointed out for the first time by Minkowski. In a very crowded region it is possible that a very distant planetary nebulae is situated almost in front of a star. On our Schmidt plate it will not be possible to determine whether this object is a planetary nebula or an emission star. Another difficulty in detecting a planetary nebula in a very crowded region is that often the spectrum is overlapped by that of a nearby star, so that we are not able to detect the nebula. This difficulty can be partly overcome by taking another spectral plate for which the prism is rotated 90°.

DISCUSSION.

Thackeray: Your suggestion to widen initially unwidened spectra by enlargement was (I think) commonly used in the early reproductions of stellar spectra. These are then beautifully wide, but of course any small defect on the original narrow spectra will appear as a spurious sharp line. The only way I can see to avoid this would be to take several unwidened spectra and superpose them in a widened enlargement. This would of course require proper registration, but it could be done.

Aller: For certain stars in crowded associations it might be useful to employ Ramberg's technique on unwidened tracings. K. Yoss, at Michigan, was very enthusiastic over this method. A defect at one or two points in the spectrum will not vitiate the luminosity and spectrum calibration. It would be very good if the Bandung Institute of Technology would obtain a microphotometer that could be used for this purpose.

Westerlund: I find widened objective prism spectra more useful than unwidened ones even in crowded regions. If tracings or rectangular slit measurements are used, many of the disadvantages discussed can be eliminated.

PART III.

Lectures on several topics and a discussion on the publication of a catalogue of planetary nebulae.

SURVEY OF H-ALPHA EMISSION OBJECTS.

PIK-SIN THE

Bosscha Observatory Lembang.

Since the installation of the Unesco Schmidt-type telescope at Lembang, one of the major projects of the Bosscha Observatory in using this telescope has been the survey of H-alpha emission objects in selected regions of the Milky Way.

The coordinates of the centre of these regions and their approximate locations in the stellar constellations are given in Bosscha Observatory Report for the Year 1961.

Not all the plates needed for this survey have been taken yet, but the plates for several regions which were completed were surveyed and the results published.

H-alpha emission stars in the vicinity of NGC 6334 and NGC 6357 (1).

The region under survey contains the bright nebulae NGC 6334 and NGC 6357, and the small nebula NGC 6302. NGC 6334 and NGC 6357 are seen projected on a dark nebula. The region is centered at R.A. = 17^h18^m; Dec. = 35°06′ (1950) and contains a field of approximately 25 square degrees. A total number of only 15 new H-alpha emission stars were found, of which one is a new Wolf-Rayet star.

H-alpha emission objects in a dark region in Aquila and Scutum (2).

The centre of this region is at R.A. = 18^h46^m; Dec. = -4°34′ (1855) and contains a field of approximately 45 square degrees. A total number of 42 new H-alpha emission objects were found. Of these objects 12 are doubtful cases, while one is a planetary nebula. From a study of the surface distribution of the H-alpha emission objects as compared with the occurance of dark and clear regions it is concluded that a greater part of these objects are really associated with the dark nebulosity. It is thus highly probable that many of the H-alpha emission stars are actually T Tauri stars which form a T association. This region will be studied further in the future.

H-alpha emission stars in Lupus and Scorpius (3).

A dark lane in Lupus in which Henize found 6 H-alpha emission stars, and a region of 25 square degrees centered at R.A. = 16^h02^m; Dec. = -38°00′ (1950), located to the southeast of Henize's dark lane, were searched for H-alpha emission objects.

Henize published a paper concerning 6 H-alpha emission stars he had discovered in a dark lane in Lupus. It is of interest to restudy this region including fainter stars. In addition to the six stars found by Henize only one star with H-alpha in emission is detected. One of Henize's stars appears to be definitely embedded in the dark matter; a fan shaped patch of it is brightened by the star. It will be of much interest to make a further study of these stars.

As to the H-alpha emission stars lying to the southeast of Henize's dark lane, the following report is of interest.

Five of the H-alpha emission stars found in the survey region are located in the vicinity of a small dark cloud in which is situated the well known T Tauri variable RU Lup. For this reason it might possibly be that they are a group of T Tauri type stars forming a T association.

The rest of the H-alpha emission stars (about 30) are mostly located near or in another dark cloud of greater dimensions. Outside the darkest portion of the cloud is located the variable star EX Lup which according to Herbig has definite T Tauri characteristics.

There is no doubt that this region is of sufficient interest for further study. Therefore it is planned to study the stars photometrically using a photometric sequence set up by Lyngå in the galactic cluster NGC 6124 to a limiting visual magnitude of about V = 16, which is located not far from the detected T association.

H-alpha emission stars in nebulosities surrounding the star m Cen and in the southern Coalsack (4, 5).

Another interesting region found in the survey of H-alpha emission stars is the region to the east of the southern Coalsack. This region contains dark as well as bright nebulosities.

A total number of about 78 H-alpha emission objects were found many of which are faint. They show a tendency of clustering to the north of the star m Cen. A discussion about their average absolute magnitude shows that these stars might be T Tauri stars forming a T association, with three separate condensations. It is planned to study these stars further in the future.

The region of the Coalsack itself has also been studied by Bambang Hidajat. He found 48 H-alpha emission stars. No further study of these stars has sofar been made.

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(1) Contributions from the Bosscha Observatory No. 10.
(2) ,, ,, ,, ,, ,, No. 14.
(3) ,, ,, ,, ,, ,, No. 15.
(4) ,, ,, ,, ,, ,, No. 16.
(5) ,, ,, ,, ,, ,, No. 17.

SOME REMARKS ON BACKGROUND-EFFECT IN PHOTOGRAPHIC PHOTOMETRY.

K. PURBOSISWOJO

Bosscha Observatory Lembang.

Any one who does much statistical work using a photometer with variable diaphragms knows that background effect is a kind of a bad troublemaker. One often gets erroneous magnitudes and colors which do not give him the desired results. The method of correction which I am going to describe is one of several and surely not the best one. I used an Eichner type of photometer at the Warner and Swasey Observatory, a type which is also in use here in Lembang. As you know, in this photometer a beam of light projects an image of a variable diaphragm onto the emulsion of the plate, centered on the image of a star, the magnitude of which we are going to measure. The beam, which has traversed the plate, is then compared with a comparison-beam. The trouble is that the emulsion around the star has non-zero density especially in nebulous areas where the background light of the standard sequence is not the same as that of the unknown. The principle of the correction I describe in my paper is: To compute the area of the variable diaphragm, as if the emulsion were free from density, that is if it had zero density, or generally, the same density as that of the standard sequence. The formula relating the erroneous area to the expected area is:

$$S_C = 10^{-D} S_0 + (1 - 10^{-D}) Si_0.$$

where S is here the area of the image of the variable diaphragm which is projected onto the emulsion. The problem now is whether we can express S and D in terms of instrumental readings, then we shall know the desired readings, i.e. the one obtained if the emulsion has zero density.

The relation between D and the instrumental readings may be obtained by measuring points of a photographic wedge with known densities. The area S can be obtained first roughly from the actual areas of the diaphragm times the reduction by the optical parts of the instrument, while the correct areas can be obtained by trial and error which is valid only for each plate and one measuring-period. The second term of the right hand side of the formula is not a critical one because it is usually small, and can be measured even by a relatively inaccurate astrometric machine. One of the best ways to handle the problem in practice is as follows: (This I did not include in my paper). The plate-carrier of the photometer ideally should have 3 frames for placement of 1) wedge, 2) the plate to be measured, 3) a plate with two magnitude sequences, one of which should lie in a nebulous area (I have been using

NGC 6530 and NGC 6531). Since the last mentioned plate should have the same thickness as the plate to be measured, one should use plates made by the same firm, and of the same type. This plate is used to establish a list of the erroneous S_0 vs. the corrected areas S_c. Si_0 of the unknowns need not be measured once we have made the list, because there is a one to one correspondence between S_0 and Si_0. There are many ways to simplify the procedure, either by electronic computers, by graphs or by making interpolation tables especially for the background correction. I do not need to emphasize that the list finally does not contain a list of areas, but instrumental readings. But anyhow, from my experience, establishing the relation between instrumental readings and S_0 required no more than half an hour. The results of the corrections give much promise as you can see from page 10 of my paper (Contributions from the Bosscha Observatory No. 18), second and third columns from the right hand side of the table. After having measured the plate, to establish the relation between S_0 and the readings we measure the unknowns (of cource after measuring the standard sequence) plus at least two diametrical points in their immediate neighbourhood. Thus we know the varying densities of the emulsion as well as the readings for the magnitudes. This then is the principle of the procedure I described in the paper, to which you can refer to my paper for details.

The formula and the procedure produce some other aspects, which I did not mention in my paper. Since we have relations between D and readings, we may use them for isophote determinations, for example. For the change of intensities of the continuum of a spectrum one can use the minimum intensity of the comparison-beam of the instrument. Fogged plates need not be discarded. It can be used for other kinds of investigations requiring differences of densitities of points. The formula may be a modified, for example:

$$S_{01} = 10^{-D} S_{02} + (1 - 10^{-D})\ Si_0$$

Where D is now the difference between the densities of the knowns and the unknowns.

DISCUSSION ON A CATALOGUE OF PLANETARY NEBULAE.

L. PEREK.

Astronomicky Ustav Praha.

The participants of the Bandung Astronomical Symposium met on March 31 to discuss the advisability of compiling a catalogue of planetary nebulae containing basic observational data, in particular identification charts.

The time seems to be convenient for this project, since the whole Milky Way has been surveyed for planetary nebulae. The survey by K.G. Henize and B. Westerlund of the southern Milky Way has not yet been published, but it is hoped that it will be possible to include the material in the catalogue.

The meeting agreed upon the following content of the catalogue:

1. Position 1950, galactic coordinates in the new system, direction cosines.
2. Designation according to previous catalogues or discovery lists.
3. Classification by Vorontsov-Velyaminow types, eventually excitation class.
4. Dimensions in H-alpha light.
5. Surface brightness (with details on method used, accuracy, etc.)
6. Total brightness (with details on spectral region).
7. Radial velocity.
8. Magnitude and spectral type of the central star.
9. Other data (internal motions, isophotes etc.)
10. Identification charts in red. Approximately $10 \times 10'$ on a 50×50 mm size.

All data will be accompanied by references to original sources.

It was felt that efforts should be made to measure dimensions and to give identification charts for all planetaries. Other data only when available.

Identification charts are available at the Astronomical Institute of the Czechoslovak Academy of Sciences for more than 600 out of the 680 published planetaries. The charts or measurements of diameters for the remaining planetaries will be taken care of by us in the following way.

Dr. Westerlund announced his willingness to cover all planetaries south of $-20'$ and Dr. The to cover the region between 16^h and 20^h right ascension and $-20'$ to $+30'$ declination. Dr. O'Dell will be asked for cooperation in the northern zones and Prof. Charadze for identification charts of planetaries discovered at the Abastumani Observatory.

The editor of the catalogue will be L. Perek. The Publishing House of the Czechoslovak Academy of Sciences will be asked to take care of the publishing of the catalogue.

A preliminary copy of the catalogue (without the identification charts) will be circulated to a number of interested astronomers as soon as it is prepared. The editor would appreciate very much receiving any information about running programs on planetary nebulae. Deadline for including new objects or new data will be the end of the General Assembly of the I.A.U. in Hamburg in 1964.