The Institute for Advanced Study

Princeton, New Jersey

Proposal to

The National Science Foundation

for a grant in support of

Completion of the book on Stellar Spectroscopy

by Otto Struve and Margherita Hack

Funds Requested: $7,950 Period: 1 January 1965 - 31 December 1965

Submitted by: Bengt Strömgren
Professor
The Institute for Advanced Study

Approved: Robert Oppenheimer
Director
The Institute for Advanced Study

During the period October - December 1962 Dr. Otto Struve and Dr. Margherita Hack collaborated at the Institute for Advanced Study on the completion of their book, "Stellar Spectroscopy." This work was supported by a grant from the National Science Foundation.

At the end of the period mentioned most of the work on the book was done, but after Dr. Otto Struve's death in 1963 a considerable amount of work remained for Dr. Margherita Hack to carry out.

Dr. Hack is anxious and willing to complete the work and requests financial support toward this purpose, as follows:

PROPOSED BUDGET

Salaries	
Principal investigator, 25 per cent of time during 8-1/2 months	$2,150
Principal investigator, full-time during fall term, 3-1/2 months	3,500
Secretarial assistance for typing, English style, proof reading, preparation of drawings, etc., half-time for 1 year	1,700
Travel	
Italy to Princeton, N.J. and return	600
	$7,950

Dr. Hack finds that it would help her project if she could carry out the last part of the work during a stay at the Institute for Advanced Study, Princeton, New Jersey.

In view of the great importance to Astronomy of the project of completing the book on Stellar Spectroscopy by Otto Struve and Margherita Hack, the Institute for Advanced Study is willing to provide Dr. Margherita Hack with the facilities necessary for her work during the fall term of the academic year 1965-66, and to sponsor the project. A grant-in-aid in the amount of $7,950 is herewith requested.

COPY

22 September 1960

Dear Mr. Morgan:

Herewith I would request you to pay out of my NSF research grant an amount of $200 to Dr. David Crawford, AURA National Observatory, 950 North Cherry Avenue, Tucson, Arizona. This is for travel Tucson-Mount Palomar-Tucson.

Sincerely,

by me

Bengt Strömgren

Mr. Minot C. Morgan, Jr.
The Institute for Advanced Study

19 September 1960

Dear Mr. Morgan:

Herewith I would request you to arrange for my reimbursement out of the N S F research grant in the amount of $18.30. The expense in question is for dry ice for the photoelectric photometer I use at Mount Palomar Observatory. Three vouchers are enclosed.

It would be most convenient for me if you would arrange to have the amount credited to my checking account with the Princeton Bank and Trust Company.

Sincerely yours,

Bengt Strömgren

Enc.: 3

Mr. Minot C. Morgan, Jr.
The Institute for Advanced Study

31 August 1960

Dear Mr. Morgan:

Herewith I would request you to pay out of my NSF research grant an amount of $300 to Mr. Charles Perry, Berkeley Astronomical Department, University of California, Berkeley, California. This is a travel advance for 2 trips, namely, Palomar - Berkeley - Tucson - Palomar, and Palomar - Tucson - Berkeley.

Mr. Perry is at present assisting me with the Palomar Observations. August 15 - 16 he goes to Berkeley and Tucson to do reductions of our observations with an electronic computer. On September 23 he is going to drive the equipment used on Palomar to Tucson (National Observatory) in a rented car.

Sincerely,

Bengt Strömgren

Mr. Minot C. Morgan, Jr.
The Institute for Advanced Study

30 August 1960

Dear Mr. Morgan:

Herewith I would request you to pay out of my NSF research grant an amount of $25 to Mr. M. Johnson, Mt. Wilson Observatory, Optical Shop, 813 Santa Barbara Street, Pasadena 4, California. This is for 2 fused quartz lenses (statement attached).

Sincerely,

Mr. Minot C. Morgan, Jr.
The Institute for Advanced Study

Bengt Strömgren

Fac Strömgren

NATIONAL SCIENCE FOUNDATION

WASHINGTON 25, D. C.

November 3, 1959

Director of Public Information
Institute For Advanced Study
Princeton, New Jersey

Dear Sir:

In keeping with your request as a member of the American College Public Relations Association to be notified when Dr. Alan T. Waterman, Director of the National Science Foundation, announces award of an NSF grant in a letter to the president of your institution, I hope you may find a lead to a news story in the following information:

The Institute for Advanced Study, Princeton, New Jersey, has been awarded a grant of $19,800 by the National Science Foundation for the support of basic research entitled "Investigations of Age, Space Velocity and Chemical Composition for 3000 A and F Stars Brighter Than 7^m on the basis of Photoelectric Narrow-band Photometry," under the direction of Bengt Strömgren, Department of Astronomy. The grant became effective on October 30, 1959, and will be two years in duration.

You are welcome to develop the story as you see fit as part of your regular program of public information. If you recover extra clips from newspapers which use your story, we will appreciate receiving one of them.

Thank you for your continuing help in carrying to the public news about the Foundation and its cooperative programs with your institution. If I can be of further assistance, please do not hesitate to call on me.

Cordially yours,

Clyde C. Hall
Public Information Officer

FL 7-4

Final Report

to the National Science Foundation
for NSF Grant 2280

O - B Stars Photometry Research

by

B. Strömgren and R. Weitbrecht

The investigations supported by NSF Grant 2280 and reported on herewith aimed at the construction of a photoelectric photometer for the standard U B V wave-length regions which would yield U, B and V magnitudes through simultaneous measures in the three bands. The main advantage of simultaneous U, B and V measures is the greater possible speed of the work at the telescope. However, there is an additional advantage in that the effects of variations of atmospheric transparency are somewhat reduced in comparison with photoelectric photometry where the U, B, and V measures are taken in succession.

Our work toward this goal has been carried out as follows:

1. The first step was the development of a suitable current integrator unit for astronomical photoelectric photometry. From the beginning it was clear that the method of measuring photoelectric currents through the use of capacity integrators was more suitable for our purposes than either the employment of D C amplifiers or the use of pulse counters. In comparison with the D C amplifier the integrator type is more conveniently adaptable to simultaneous photometry. The advantage of the integrator over the pulse counter for our purposes derives mainly from the much greater range in magnitude that can be conveniently and accurately covered.

A current integrator was developed by R. Weitbrecht at Yerkes Observatory. A number of successively improved units were built and tested. According to laboratory tests and experience at the telescope the resulting unit satisfies all requirements with respect to accuacy and convenience.

It is described by R. Weitbrecht, "Current Integrator for Astronomical Photoelectric Photometry", The Review of Scientific Instruments, Vol. 28, 883-888, Nov'57.

The Weitbrecht type current integrator unit has now been used at a number of observatories including McDonald Observatory, Indiana University Observatory and Lick Observatory. It has been employed in both U B V and Hβ photometry, and photoelectric U B V or Hβ photometry of more than 5000 stars has been made with it.

Certain technological advances have made it possible to improve integrator

units built recently so that they are now quite rugged and reliable even when they have to be transported from place to place many times. In 1959 and 1960 seven integrator units of this improved Weitbrecht type have been built for the photoelectric work supported by NSF Grant 10285 to one of us (B. Strömgren).

2. A programming unit was developed and constructed by R. Weitbrecht. This controls the three integrators which measure the U, B and V intensities, respectively, in a sequence in such a way that (a) the photoelectric currents from the three photomultipliers which measure the U, B and V radiations charge a selected capacitor in each of the three integrators during a pre-set time, (b) the accumulated charges are in succession channeled through the amplifier in each integrator unit to the Brown Recorder, a few seconds being allowed for the Recorder to reach its final deflection corresponding to each of the three charges (cf. the paper referred to, R. Weitbrecht, Rev. Sc. Instr. 28,883.). A corresponding 2-unit programmer has been extensively used by us in Hβ photometry.

3. A spectrograph-photometer suitable for isolation and photoelectric measurement of the three broad bands of U B V photometry was designed. A copy of the drawings (made by Mr. Harold Thompson, now at the A U R A National Observatory, Tucson, Arizona) accompanies this report.

However, at this stage the principal investigators decided that the construction of this instrument was not possible within the frame of the present project due to limitations in the available time of the investigators and financial limitations. Instead it was decided to construct a photometer utilizing a beam splitter and a dichroic filter plus the standard U, B and V glass filters to produce the separate U, B and V beams needed for simultaneous measure with three photomultipliers. This arrangement would be somewhat less economical of light than the spectrograph-photometer but otherwise quite suitable for our purpose.

We wish to add in this connection that although Mr. Thompson's drawings were not used for the present project they have turned out to be of help in the design by one of us (B. Strömgren) of a four-channel spectrograph-photometer now being constructed for use in a project supported by the Office of Naval Research. Proper credit will of course be given to the National Science Foundation when this instrument is described in a future publication.

4. As the first step toward the construction of the 3-channel instrument we had a crude experimental 2-channel unit built in the Yerkes Observatory shops and tested it on the 40-inch refractor, using two Weitbrecht integrators and a Weitbrecht programming unit. The results were quite encouraging and showed that precision U B V

photometry with the planned 3-beam photometer would be entirely feasible provided adequate arrangements were made for frequent intercomparisons of the sensivities of the three photomultipliers.

5. A 3-beam photometer for simultaneous observation of intensities in the U, B and V bands was constructed according to the plan. Since both investigators had now left Yerkes Observatory the construction could only progress relatively slowly. We wish to acknowledge the efficient help of Dr. David Crawford, now at the AURA National Observatory, in supervising parts of the construction.

The 3-beam photometer was completed in January, 1960. Fig. 1 is a schematic drawing showing the design. The unit itself is shown in Fig. 2, and Fig. 3 shows the three Weitbrecht type current integrator units.

The instrumentation is now complete, consisting of the 3-beam photometer, three integrator units, a Weitbrecht programmer and high voltage supply. It has been assembled at Kitt Peak Observatory and has been tested on the 16-inch reflector by Dr. David Crawford. The tests show that the instrumentation is quite satisfactory with respect to photometric accuracy, speed and convenience of operations and reliability of performance. The instrument will be described and the results of the tests presented in a forthcoming publication by D. Crawford, B. Strömgren and R. Weitbrecht.

The principal investigators are of the opinion that the most useful result of the work of this project is the development of the current integrator unit. However, we believe that the constructed photoelectric U B V photometer is an efficient instrument particulary useful for U B V photometry of large numbers of program stars measured relative to a fairly dense net of standard stars.

March, 1960 Bengt Strömgren Robert H. Weitbrecht

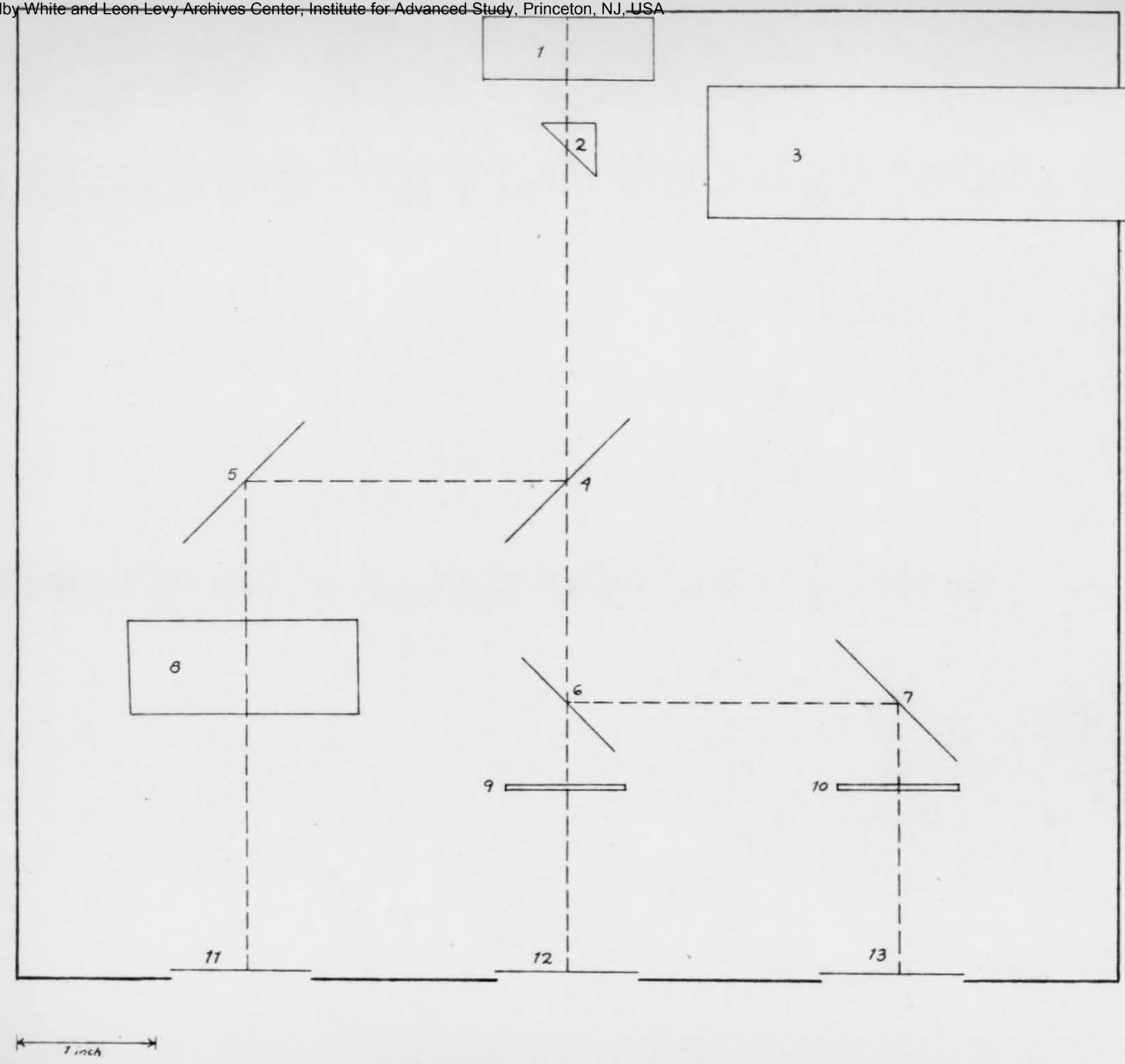

Fig. 1

1. Diaphragm slide and shutter
2. Sliding prism.
3. Microscope tube.
4. Beam splitter.
5. Plane mirror.
6. Dichroic filter, transmitting blue and reflecting yellow light.
7. Plane mirror.
8. Filter slide. Three filters: Ultraviolet, blue and yellow. Normally the ultraviolet filter is used. The blue and yellow filters are used to determine the variations of the sensitivity ratios of the three photo-multipliers.
9. Blue filter.
10. Yellow filter.
11. Field lens imaging objective on cathode of photomultiplier 1.
12. Field lens imaging objective on cathode of photomultiplier 2.
13. Field lens imaging objective on cathode of photomultiplier 3.

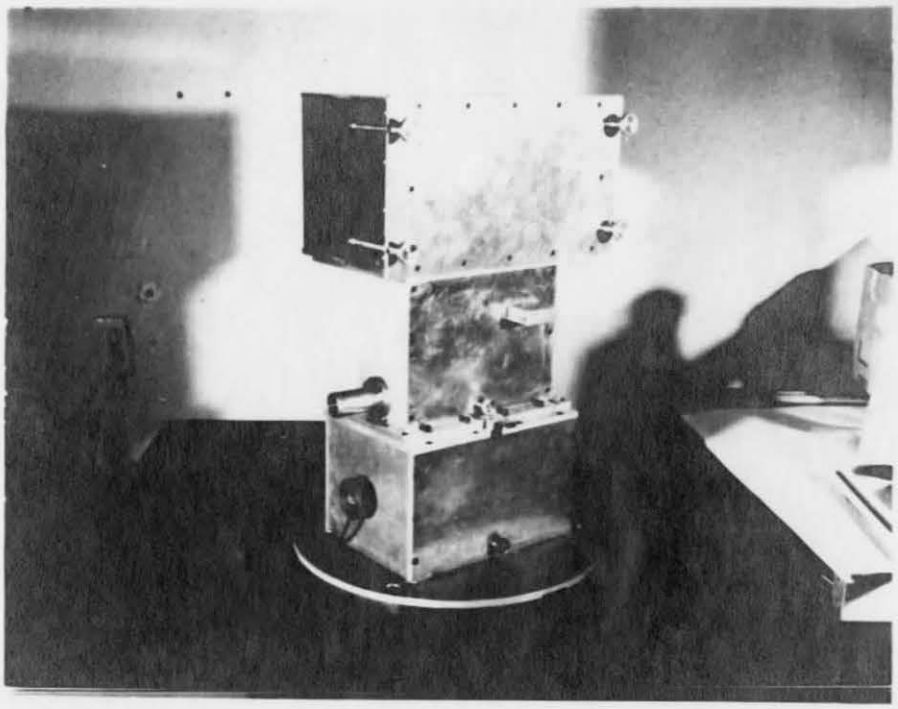

Fig. 2. The 3-beam photometer is shown with the circular plate by which it is attached to the telescope resting on a table. The lower box holds a sliding prism and a large-field eyepiece for checking the field in front of the photometer diaphragm in the telescope focal plane. When the prism is pulled out, the light enters the middle box (4" x 7" x 8") which contains the components shown in Fig. 1. The microscope through which the centering of the star in the diaphragm is checked is above the large-field eyepiece. The upper box is a dry-ice refrigeration box containing the three field photomultipliers.

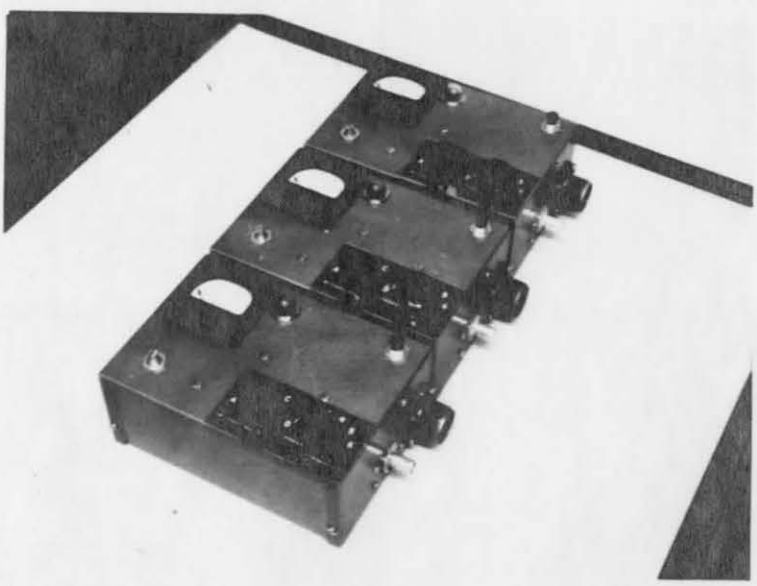

Fig. 3. Three Weitbrecht type current integrators.

The Institute for Advanced Study

Princeton, New Jersey

Proposal to

The National Science Foundation

for a grant in support of

Investigations of age, space velocity and chemical composition for 3000 A and F stars brighter than 7^m on the basis of photoelectric narrow-band photometry

Funds requested: $19,780.00 Period: September 1959 - September 1961

Principal Investigator: Bengt Strömgren
The Institute for Advanced Study

Approved: _____

Director
The Institute for Advanced Study

Methods for spectral classification through photoelectric narrow-band photometry have been developed during the last ten years (B. Strömgren, 1956a, 1956b, 1958a, 1958b, 1958c, also B. Strömgren and K. Gyldenkerne 1955). With the help of these methods it is possible to determine absolute magnitudes and intrinsic colors of relatively high precision for stars of the spectral types B, A and F. It has also been found possible to calibrate the photometrically determined indices in terms of stellar age and mass. Furthermore, for a certain spectral range (F stars) the photoelectric narrow-band photometry yields an index which is a sensitive indicator of the metal-hydrogen ratio in the stellar atmosphere.

With the support of the National Science Foundation I have in collaboration with W. W. Morgan undertaken a program of determination of the distribution of interstellar dust particles within 1000 parsec. The observations on this program have been practically completed, with the cooperation of D. L. Crawford, Research Associate on the NSF project in question. Photoelectric narrow-band and UBV photometry has been obtained with the 36-inch reflector of the McDonald Observatory for approximately 3000 stars brighter than visual magnitude 9^m during three observing periods in 1957, 1958 and 1959 of altogether 5 months. For the stars in question absolute magnitudes and distances as well as intrinsic colors and color excesses have been derived on the basis of the photometry. The color excess and distance data will lead to a determination of the space distribution of interstellar matter, more detailed than previous determinations. The program has emphasized the B8 and B9 stars, and most of the B8 and B9 stars in the Henry Draper catalogue brighter than the limit mentioned and north of declination -20° have been observed. It is expected that the reductions and the discussion of the observational results

obtained will be completed within the next six months.

The experience obtained through work on the program just referred to, as well as my previous experience and results in the field of photoelectric narrow-band photometry has led to the formulation of new research programs. These include a program of observation of 3000 A and F stars brighter than visual magnitude 7^m and north of declination -20°, a program for which support in the form of a grant from the National Science Foundation is herewith requested. The program is described below.

It has been found that for A and F stars photoelectric narrow-band photometry of two hydrogen features, namely the Hβ intensity (measured by a photoelectric index l) and the Balmer discontinuity (measured by a photoelectric index c), yields absolute magnitudes with an accuracy of $0.^m1 - 0.^m2$ (probable error), and intrinsic colors (B - V) with an accuracy of $0.^m005 - 0.^m008$ (probable error), cf. B. Strömgren 1956b and 1958a. From the photoelectrically determined indices l and c the stellar age can be estimated with an accuracy of 10 - 20 per cent of the life-time of the star near the main sequence.

I propose that the relatively high accuracy obtainable in this fashion in the determination of absolute magnitudes, distances and ages of individual field stars now be utilized for a study of space velocities and ages of stars in the spectral range A2 - F5 in the solar neighborhood (within about 100 parsec). The following points are of importance in this connection:

1. Sufficiently accurate proper motions are already available for all the stars in question, and radial velocities are available for the large majority of the stars. From the narrow-band photometry distances with an accuracy of 5 - 10 per cent will become available. When these are combined with the

proper motions and radial velocities, space velocities will result which are accurate to within a few km sec^{-1}.

2. The ages for the selected groups of stars range from some million years to about 10^9 years, and the average velocities of these population I stars are relatively small (about 20 - 30 km sec^{-1}). The galactic tracks of the individual stars can therefore be computed with considerable accuracy. Furthermore, since the stellar ages can be estimated with inaccuracies presumably less than 100 - 200 million years even for the older stars in the group, the spatial range of the possible place of origin of each individual star can be narrowed down sufficiently for a mapping of regions of star formation in our galaxy, as a function of time, to become possible.

From previous studies, particularly by Delhaye (Delhaye 1948) and Blaauw (Blaauw 1958) it is already clear that the distributions of space velocities for groups of stars younger than 10^9 years are quite uneven. As has been emphasized by Lindblad, and others, this phenomenon can be connected with the properties of the distribution in the galaxy of regions active in star formation (presumably sectors of spiral arms).

Unpublished work by the undersigned, based on spatial velocities and ages for A and F stars brighter than visual magnitude $5.^m5$ obtained with the help of photoelectric narrow-band photometry, indicates that the observed unevenness in the velocity distribution becomes even more pronounced than that noted by Delhaye and Blaauw when the accuracy of the observational data is increased. From the results already obtained (to be published in the October issue of the Journal of the Franklin Institute) it appears quite probable that a program such as that outlined would lead to significant results concerning the distribution of regions active in star formation in our galaxy.

The correlation between chemical composition as indicated by the atmospheric metal-hydrogen ratio and place of formation of the star would be investigated.

The proposed program consists of two parts:

A. Photoelectric narrow-band photometry and UBV photometry is to be obtained for 3000 A and F stars brighter than 7^m and north of declination -20°. A photometer is already available, but it would be desirable to add another photometer of the same type, and also to acquire new interference filters of improved types. I have been promised observing time in 1959, 1960 and 1961 for the program, as follows

20-inch Mount Palomar Observatory, 1960, 61	Approximately	600 hours
60-inch Mount Wilson Observatory, 1960		50
36-inch refractor, Lick Observatory, 1959		50
36-inch Crossley, Lick Observatory, 1959		200
16-inch National Observatory*, 1959, 60		150
36-inch National Observatory*, 1959, 60		150
		1200 hours

* In collaboration with D. L. Crawford

The promised observing time is adequate for the purpose. It would be desirable to have the collaboration of a Research Associate for six months to carry out the observations.

The reduction of the observations should be done with the help of electronic computers as far as possible, and financial support for obtaining computer time is therefore desirable.

B. The calibration of the indices obtained by photoelectric narrow-band photometry in terms of mass, age and chemical composition (cf. B. Strömgren, 1958c) requires model atmosphere calculations beyond those already available, in particular with regard to calculation of the effect of total line absorption as a function of relative metal content. Financial support for the salary of

a Research Associate (6 months) and electronic computer time is very desirable in this connection.

Referring to the description of the proposed program I would herewith request a grant from the National Science Foundation in the amount of $19,780.

The proposed project budget is as follows

Cost of an additional photometer for photoelectric narrow-band photometry	$ 2,000.
Cost of interference filters of new improved type (Spectrolab)	1,100.
Salary of a Research Associate who would collaborate on the observing and the reductions, 2 periods of 3 months each	4,000.
Salary of a Research Associate who would collaborate in the computational work on model stellar atmospheres, 6 months	5,000.
Time with electronic computers, for reduction of observations and model stellar atmosphere calculations	4,500.
Travel	600.
	$17,200.
Overhead and contingencies, 15% of $17,200.	2,580.
Total	$19,780.

June 24, 1959

Bengt Strömgren

References

A. Blaauw 1958, Le Problème des Populations Stellaires, p.333.

J. Delhaye 1948, B. A. N. 10, p. 409.

B. Strömgren 1956a, Vistas in Astronomy (Ed. A. Beer), Vol. 2, p. 1336.

B. Strömgren 1956b, Third Berkeley Symposium (Ed. J. Neyman), Vol. 3, p. 49.

B. Strömgren 1958a, Le Problème des Populations Stellaires, p. 385.

B. Strömgren 1958b, Le Problème des Populations Stellaires, p. 245.

B. Strömgren 1958c, Observatory, Vol. 78, p. 137.

B. Strömgren and K. Gyldenkerne 1955, Ap. J., Vol. 121, p. 43.

Concerning the method which will be used in the calculation of the structure of model atmospheres for A and F stars, cf.

T. L. Swihart 1956, Ap. J., 123, 139.

K. Osawa 1956, Ap. J., 123, 513.

2 November 1959

Dear Dr. Waterman:

Thank you for your letter of October 30th, informing us that the National Science Foundation will grant the Institute for Advanced Study the sum of $19,800 for the support of research entitled "Investigations of Age, Space Velocity and Chemical Composition for 3000 A and F Stars Brighter than 7^m on the Basis of Photoelectric Narrow-band Photometry" under the direction of Bengt Strömgren, identified as Research Grant NSF-G10285. The Institute is indeed grateful to the Foundation for this action.

Very sincerely,

Robert Oppenheimer

Dr. Alan T. Waterman
National Science Foundation
Washington 25, D. C.

copy made for Mr. Morgan 11/2/59

NATIONAL SCIENCE FOUNDATION
WASHINGTON 25, D. C.

OCT 30 1959

Dr. Robert Oppenheimer, Director
The Institute for Advanced Study
Princeton, New Jersey

Research Grant NSF-G10285

Dear Dr. Oppenheimer:

I am pleased to inform you that the sum of $19,800 is hereby granted by the National Science Foundation to The Institute for Advanced Study, for the support of research entitled "Investigations of Age, Space Velocity and Chemical Composition for 3000 A and F Stars Brighter Than 7^m on the Basis of Photoelectric Narrow-band Photometry," under the direction of Bengt Strömgren, Department of Astronomy, for a period of approximately two years. Until further notice this grant will be paid as follows: $12,800 on or about two weeks from date of this letter; $4,200 on or about January 15, 1961; and $2,800 on or about July 15, 1961.

It is a condition of this grant that it may be revoked in whole or in part by the Foundation after consultation with the principal investigator and the grantee, except that a revocation shall not affect any commitment which, in the judgment of the Foundation and the grantee, had become firm prior to the effective date of the revocation; and that funds not committed by the grantee prior to the conclusion of the work contemplated under this grant shall be returned to the Foundation.

It is a further condition of this grant that disposition of patent and other rights in any inventions or discoveries made or conceived during the research shall be the responsibility of the grantee; that the grantee shall give the Foundation reasonable notice of application by the grantee or other person or institution for a foreign or domestic patent on any such invention or discovery; and that upon issue of any patent on any such invention or discovery, the patentee shall grant the Government an irrevocable, royalty-free, nonexclusive license for use of such invention or discovery for governmental purposes.

The Foundation desires that this grant be administered in general accordance with the Foundation's policies for research grants as stated in "Grants for Scientific Research," April 1955, and in conformity with the other understandings reached between the Foundation and the grantee relating to this grant.

Please acknowledge receipt at your earliest convenience.

Sincerely yours,

Alan T. Waterman

Alan T. Waterman
Director

NATIONAL SCIENCE FOUNDATION
WASHINGTON 25, D. C.

June 30, 1959

Dr. Bengt Strömgren
The Institute for Advanced Study
Princeton, New Jersey

Re: P-6464

Dear Dr. Strömgren:

This will acknowledge receipt of the proposal entitled "Investigations of Age, Space Velocity and Chemical Composition for 3000 A and F Stars Brighter Than 7^{m} on the Basis of Photoelectric Narrow-band Photometry" in which you are named as the principal investigator. The proposal will be reviewed by the Astronomy Program, of which Dr. Geoffrey Keller is Program Director.

When evaluation of this proposal has been completed, you will be informed of the decision reached.

Sincerely yours,

William N. Ellis, Head
Program Analysis Office
Mathematical, Physical and
Engineering Sciences Division

cc: Dr. Robert Oppenheimer

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY

25 June 1959

Dr. G. Keller
Program Director for Astronomy
The National Science Foundation
1951 Constitution Avenue
Washington, D. C.

Dear Geoffrey:

Enclosed I am sending you 15 copies of the proposal that we have talked about. As I mentioned to you, the term "Overhead and contingencies" was used instead of "Overhead" at Dr. Robert Oppenheimer's suggestion to indicate that the Institute would be willing to spend part of the Overhead money for the project if this should appear desirable.

Under separate cover I am sending 5 reprints of each of five relevant papers.

Since you mentioned that today is the unofficial deadline for proposals to be considered by the Board meeting in August, I am sending you a wire saying that the proposal is in the mail, hoping that the proposal will make the deadline.

With best wishes,

Sincerely,

Bengt Strömgren