GEORGETOWN COLLEGE OBSERVATORY
WASHINGTON 7, D. C.

June 27, 1957

Office of the Director
Programs for Physics and Astronomy
National Science Foundation
Washington 25, D.C.

Dear Sir:

Enclosed herewith is a description of the equipment and other available facilities at Georgetown University's Astronomical Observatory for research in spectroscopy. The description also tells what projects have been completed up to the present with this equipment and indicates what projects are planned for the future.

As is evident from reading the description in this proposal, there are plenty of projects to be done with the existing equipment at Georgetown. Two difficulties in the past which have slowed down the work have been the lack of expert personnel and time. This proposal is aimed at reducing these two deficiencies to a minimum in the most economical way possible.

The shortage of personnel can be relieved by the payment of a part-time salary to two experienced spectroscopists, one of whom is now an assistant professor on the staff of the physics department of Georgetown University. This department shares the use of the spectrographs and other equipment in the observatory that is used for spectroscopic research. The other has been an instructor in optics and applied spectroscopy at the observatory for ten years. Since university funds have been available up to now only for payment for courses taught in these fields, the burden of directing research and developing the installation of the equipment to its present state has fallen on the director of the observatory.

Provision is also made in the proposal for paid assistants to make observations, measure spectroscopic plates and reduce the measurements to wavelengths by operating the electronic computer. It is felt that with the present equipment and the additions requested under this proposal three part-time assistants would be kept occupied.

The additional equipment which will speed up the time devoted to the measurement of spectrograms and the feeding of these measurements into the E 101 computer will shorten the time now spent on this work to one-tenth its present length. For example, as mentioned in the description accompanying this letter, the Telereadex has many special advantages in the enlarged projected image which eliminates the need of a microscope and in the speed with which the setting wires can be moved from one place to another. By actual tests with a similar instrument at the Aberdeen Proving Grounds, the accuracy of a Telereadex is comparable with the best micrometer measuring engine at the Observatory at Georgetown.

The tape input for the E 101 and the output for the tape on the Telecordex, both of which are designed to eliminate the sources of error and the waste of time in transferring the readings of the Telecordex to the keyboard of the E 101 electronic computer, are facilities which should make possible the greatest amount of accurate results with the least time and fatigue.

It is felt that with these advantages much of the spectroscopic data still not analyzed at Georgetown can be made available to the scientific world and new data obtained and reduced at a rate hitherto not anticipated.

Therefore, Georgetown University, through its Department of Astronomy and with the assistance of its Department of Physics, requests funds for the following:

(1)	Part-time salary for one Ph.D. Assistant Professor (2 yrs.)	$8000.00
(2)	Part-time salary for one Ph.D. research director (2 yrs.)	5000.00
(3)	For three research assistants at $1800.00 per yr. (2 yrs.)	10800.00
(4)	Type 29A Telereadex with lenses and plate holder	14000.00
(5)	Flexowriter to punch tape from Telecordex	2475.00
(6)	Adapting of Flexowriter to Telecordex by Telecomputing Corporation	1500.00
(7)	Paper tape input reader by Burroughs Corporation	3765.00
		$45540.00

Yours very respectfully,

Francis J. Heyden S.J.

Francis J. Heyden, S.J.
Director

GEORGETOWN UNIVERSITY

Washington 7, D.C.

OFFICE OF THE PRESIDENT

July 1, 1957

Office of the Director
Programs for Physics and Astronomy
National Science Foundation
Washington 25, D.C.

Dear Sir:

The proposal submitted herewith has been prepared by Matthew Thekaekara, S.J., who has just completed his doctorate at The Johns Hopkins University and has been assigned to the Physics and Astronomy Departments of Georgetown University. The equipment described in the proposal has been assembled over the past six years by the Director, Francis J. Heyden, S.J. and Dr. Carl Kiess of the National Bureau of Standards.

With the addition of the Reverend Matthew Thekaekara, Father Heyden hopes to see much more work done with the spectrographs than he has been able to do with the limited time available to him in the past few years.

The special additions to the computing and measuring equipment requested in this proposal are beyond the reach of either the Physics or Astronomy Department in the foreseeable future. Yet, the addition of these pieces will greatly speed up the research work and at the same time make it less fatiguing to the members of the Physics and Astronomy Departments who will work in spectroscopy.

Yours very sincerely,

Very Rev. Edward B. Bunn, S.J.
Director

A PROPOSAL FOR AND DESCRIPTION OF SPECTROSCOPIC PROJECTS AT THE GEORGETOWN OBSERVATORY

The spectroscopic work of the Georgetown Observatory has recently been expanded on a considerable scale thanks to the addition of some highly expensive, but very necessary, pieces of equipment. Improvements in the experimental and data processing techniques have gone hand in hand with addition to the observatory staff of several physicists fully conversant with the significance of spectroscopy in physics and astrophysics and familiar with the techniques of the new instruments.

The projects in spectroscopy on which the Observatory is currently engaged include the following: (1) the spectra of titanium, hafnium, zirconium and yttrium, (2) the spectrum of chlorine in chlorides of different metals, (3) faint iron lines in the solar spectrum, (4) hydrocarbon lamp spectrum and its comparison with the solar spectrum, (5) mapping of the solar spectrum, (6) interferometric measurements of certain lines in the solar spectrum (7) the spectra of Saturn and Venus, (8) study of the lines from the newly discovered preionized levels in xenon and krypton.

Several of these projects are auxiliary to the extensive spectroscopic work being done at the National Bureau of Standards, Washington, D.C. and have in fact been endorsed by two successive directors of NBS, Lyman Briggs and E. U. Condon. It would not be necessary to set forth here in detail the aims, scope and importance of this aspect of the work of the Georgetown Observatory. In the course of some previous correspondence regarding these projects, Dr. C. C. Kiess, physicist at the NBS, wrote, "They are an outgrowth of our work at the NBS to which we cannot at present devote either time or personnel. But the results expected from them are of great importance and are urgently needed for our main work on the Tables of Atomic Energy Levels, the revised Rowland and the Multiplet Table of astrophysical interest." For additional information reference may be made to Dr. C. C. Kiess or Dr, C. M. Sitterly.

The source of light for several of these projects is a new type of electrodeless lamp developed at the NBS by Corliss, Bozman and Westfall[1], the first two of whom are graduate students in the Department of Astronomy at Georgetown. The lamp contains a small amount of a metal halide, e.g., iron chloride or titanium chloride. A noble gas at a pressure of a few mm Hg is needed to initiate the discharge. The lamp burns steadily in an oscillating field of about 2000 mc/sec which is supplied by a Raytheon oscillator.

The spectrum emitted by the lamp consists of a mixture of those of the halogen, of the noble gas and of the metal. The exposures in juxtaposition of two different halogens of the same metal permit one to identify easily the lines due to metal.

The special advantages of these lamps are that they give a very bright arc spectrum of the metal, that they operate for a long time steadily and at almost constant intensity, and, above all, that their spectra are uncontaminated by the band spectrum of the oxide which is a serious inconvenience of the arc in air between metal electrodes. In TiO, for example, there are several strong bands in the region 4500 to 8000 A which previously had prevented a complete mapping of the Ti I spectrum. Some preliminary work done at the Georgetown Observatory on titanium has been reported by A. K. Wardakee[2] who measured 113 new lines of Ti I in the range 5600 to 5900 A. They were classified as due to transitions

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[1] Corliss, Bozman and Westfall, J. Opt. Soc. Am. 43, 398 (1953)

[2] A. K. Wardakee, J. Opt. Soc. Am. 45, 354 (1955).

between the energy levels found by H. N. Russell and tabulated by C. E. Moore in Atomic Energy Levels, Vol I. The work done thus far indicates that the whole photographic region of Ti I should be carefully analyzed.

The mapping of the solar spectrum is a project on which considerable work has been done at the Georgetown Observatory. The entire photographic region of the solar spectrum was covered with triplicate sets of plates. Nearly 200 sets of plates have been taken and all of them carry the iron arc comparison spectrum. The plates have now to be measured and enlarged photographs of the plates have to be prepared for publication.

The spectrographic equipment of the Georgetown Observatory includes the following items: (1) Two Wadsworth mounting spectrographs with concave gratings, one a six-inch Rowland grating with 20,000 lines per inch, and the other a five-inch Gale grating with 30,000 lines per inch, (2) Various accessories for excitation of different kinds of spectra and for iron standards, and a vacuum system for the making of discharge tubes, (3) Two heliostats for astrophysical work, (4) Three comparators, all of which are high precision instruments measuring correctly to a micron. The largest of these is specially suited for interferometric work since distances along both the x- and y- axes can be measured with the same accuracy, (5) An analog-digital converter (Telecordex) for automatic recording of the comparator settings, (6) An electronic digital computer (Electrodata), Model E 102, for calculation of plate constants, wavelengths and wavenumbers. The other small items which might be needed in the course of any spectroscopic project can be either easily obtained or be made in the workshops of the physics department or astronomy department.

The telecordex costing $12,000 and the E 102 computer $40,000 have been added quite recently. Assistance is nwo being sought for two more additional items, namely, a telereadex, which would eliminate the task of making comparator settings with the aid of a microscope, and a punched tape output and input assembly, which would transfer data directly from the telecordex to the computer. The cost of these items will be about $22,000. With these additions wavelength measurements will become almost completely automatic, a much higher degree of accuracy than has hitherto been possible will be ensured and the time spent in gathering and processing data can be reduced to 5 per cent of what it was previously.

Most of the basic work in spectroscopy is that of wavelength measurement. It is well known that many of the spectra, especially the more complex ones, are quite unsatisfactorily presented in existing literature. The earlier measurements were made at a time when the demand for accuracy was not as great as it is today. New methods of producing spectra have revealed the possibility of making significant additions to spectroscopic literature. Complete and reliable information about different spectra is needed not only for spectroscopists whether in physics or astrophysics but also for workers in many allied fields like physical chemistry and in various branches of technology and industry for whom spectroscopy is an important tool of research. When hundreds or thousands of lines are involved the necessary measurements and all the subsequent calculations constitute a tedious and time-consuming task. That few are willing to undertake such drudgery is a great handicap to future progress in the field and impedes the work of others, who are not directly interested in spectroscopy but need the data for other purposes. Hence it is that any attempt to lighten the burden of data compilation must be welcomed, and where new techniques ensuring speed and accuracy are available, maximum use should be made of them.

Hitherto the Georgetown Observatory had employed the conventional techniques of wavelength measurements The plate is viewed through a microscope and the microscope is moved until the center of a line coincides with the crosshair of the eyepiece. The position of the microscope is read on the head scale and the pitch scale and the value is written down on paper. Apart from the time required for these operations, considerable strain is involved in the continual readjustment of the eye to different distances and different degrees of illumination. With the telecordex to record the comparator settings the observer can keep his eye on the microscope eyepiece and positions will be typed out as fast as the lines can be made. The telecordex is a dual indicating and recording device which stores electric pulses. Magnetic reading heads are attached to the horizontal and vertical screws of the comparator and electric pulses are generated each time the microscope travels a thousandth of a millimeter. The number of pulses which represents the position of the microscope is available for reading at any time the "Readout" button is pressed.

Indicator lamps display the total number of counts. An automatic electric typewriter prints the information in tabular form on a continuous roll of paper. The circuits are arranged so that the counts are subtracted when the microscope moves backwards and added when it goes forward. There are two independent counters for the x- and y- axes movements of the microscope, and stepper switches to number the "readouts" in succession. On the front panel of the telecordex there are 16 selector switches for manual introduction of other information about the line, such as its intensity, whether it is diffuse or a blend, or pertains to the iron comparison spectrum, etc.

The positions of the lines being known, the next step in the conventional method is to determine the plate factor from the positions of two known lines and to calculate the approximate values of wavelengths for all measured positions according to the linear dispersion formula:

$$\lambda = \lambda_0 + f\,(x - x_0).$$

This is done with a desk calculator. A calibration curve for the plate is drawn using known wavelengths, and the wavelengths of the unknown lines are obtained by adding the residual corrections which are often very large. Greater accuracy and considerable saving of time can be obtained by using the electronic computer instead of the desk calculator. Four known wavelengths and their positions are supplied to the computer which then solves a 4x4 matrix in about one minute and 20 seconds. The constants a, b, c and d of the matrix are thus known from the computer. The next step is to calculate the wavelength λ for each value of x, using an equation of the fourth power:

$$\lambda = a + bx + cx^2 + dx^3.$$

The following are sample values of the constants: a = 4138.36945; b = 1.80933465; c = 0.000352981; d = 0.00000029038. For each plate there would be over a thousand lines, each x having six significant figures. A problem of this complexity plainly cannot be attempted on a desk calculator. The residual corrections in this case being very small the wavelengths can be determined with greater accuracy. The computer types out automatically x and λ. The conventional way of determining the wavenumber, making due correction for the dispersion of air, is by using Kayser's well known table of wavenumbers. This also is a tedious operation which can be eliminated by programming the computer for an accurate dispersion formula. Electrodata Model 102 has a magnetic drum memory of 220 words of 12 digits each. Full use can be made of this storage facility when new lines have to be classified or new energy levels have to be found. Thus it is obvious that a computer with the speed, accuracy and all-purpose adaptability of the E 102 can facilitate each successive step in the processing of observational data.

(Rev.) Matthew P. Thekaekara, S.J., Ph.D.

1958

GEORGETOWN UNIVERSITY
DEPARTMENT OF ASTRONOMY
WASHINGTON, 7, D.C.

PROPOSAL FOR GRANT IN AID FROM THE NATIONAL SCIENCE FOUNDATION

NAME AND ADDRESS OF INSTITUTION: Georgetown University, Washington, 7, D.C.

NAMES OF PRINCIPAL INVESTIGATORS: Rev. Francis J. Heyden, S.J. of Georgetown University
Dr. Francis A. Jenkins, Prof. of Physics, U. of California.

TITLE OF PROPOSED RESEARCH: Analysis of Molecular Spectra

DESCRIPTION OF THE PROPOSED RESEARCH : This proposal is supplementary to one made by Dr. Francis A. Jenkins and Dr. John G. Phillips of the University of California for research on the analysissof molecular spectra. For a description of the research, reference is to be made to the application made by Dr. Jenkins and Dr. Phillips.

Dr. Jenkins in the course of a visit to Washington, D.C. in the fall of 1957 discussed with the spectroscopy groups of Georgetown College Observatory a plan whereby his group would cooperate in the analysis of molecular spectra to be undertaken at the University of California. The original suggestion was that an application would be made from the University of California for a grant from the NSF and that in that application would be included also the salaries of two part-time assistants who would be employed at Georgetown for measurement of the plates and computationof wave-numbers. The original proposal was later modified at the request of the Dean of the Graduate Division of the University fo California since salaries for persons not working in Berkeley may not be included in a grant to the University of California.

Dr. Jenkins in a letter of June 17,1958 to the first principal investigator named above (Francis J. Heyden) suggested that a request be made to the National Science Foundation by Georgetown University for a separate grant to cover the salaries of the student assistants who will work here. The portions of the original proposal referring to the cooperation of Georgetown with the project and the items in the budget for this purpose were accordingly deleted from the proposal submitted by Dr. Jenkins and Dr. Phillips. The cooperation of our spectroscopic group will be limited to the measurement of the plates and for computation of wavelengths and wave-numbers.

PROCEDURE: The plates will be taken on the Berkeley campus and will be shipped to Georgetown for measurement and reduction. Georgetown has a few excellent measuring and

GEORGETOWN COLLEGE OBSERVATORY
GEORGETOWN UNIVERSITY
WASHINGTON 7, D.C.

and computational devices. They are being used for geodetic and astrog... as well as for two spectroscopic projects: the spectrum of Ti I and Faint Lines in the solar spectrum. One of the three measuring engines is fitted with magnetic reading heads which generate electric pulses each time the comparator screw travels 1/1000 mm. An analog digital converter (the Telecordex) which is a dual indicating and recording device stores the electric pulses, and whenever the read-out button is pressed an electric typewriter prints out the information on a continuuos roll of paper. Modification to fit a card punch or paper tape punch is not difficult for the Telecordex which has an outlet for these components.

Time on the Telecordex is readily available since the machine speeds up the normal measuring process by almosta factor of ten. It is proposed that Georgetown employ two graduate students, part-time during the school year and full time during the summer period to make measurements and reductions for Dr. Jenkin's program.

In connection with the other spectroscopic projects, the E 101 computer at Georgetown has already been programmed for the reduction of wavelengths, calculation of wave-numbers according to the Edlein dispersion formula and for sorting out energy levels. Since time on the computer is now greatly in demand for other projects at the Observatory, and further since the IBM 701 computer at Berkeley will be available for the final stages of the analysis, it is expected that Georgetown's cooperation with the program for Molecular Spectra will be mainly that of measurement of plates.

6. FACILITIES: For greater understanding of the project being undertaken at Berkeley and for better possible cooperation in every detail, students at Georgetown who will work on this project will be familiar with the following equipment:

a) Two Wadsworth mounting spectrographs with concave gratings, one a six inch Rowland grating with 20,000 lines per inch and the other a six inch Gale grating with 30,000 lines per inch.

b) Various accessories for excitation of different kinds of spectra.

c) Three comparators, all of which are high precision instruments measuring to a micron. The largest of these with a 20 centimeter travel is especially suited for interferometric work since it is equally accurate in "x" and "y".

d) An analogue digital converter (Telecordex) for automatic recording of comparator settings. The large comparator and the Telecordex will be the instruments used for the present project/

e) An electronic digital computer (Electrodata) for wavelenght and wave-number reduction.

Arrangements are being made for two more additional items, namely, a Telereadex which will not nly eliminate the need for making comparator settings with the aid of a microscope but will also enable the observer to seefaint lines on projection which cannot be seen with transmitted light, and a punched tape output and input assembly which will transfer data directly to the E101 computer and eliminate the source of error in transribing directly from typed copy to the key board of the E 101. The Telereadex is charged to the main spectroscopic project at Georgetown approved by a NSF grant.

7. <u>Personnel</u>: Joint supervisors of the project: are

Francis J. Heyden, S.J. Director of Ge orgetown College Observatory who will take charge of the wo k to be done at Georgetown.

Francis A. Jenkins, Professor of Physics of the University of C alifornia who will direct the projec t at Berkeley and assign specific portions of it to Georgetown.

Matthew Thekaekara S.J., Assistant Research Physicist, who will directly supervise the work of the two students.(His salary is not charged to the present project.) He has been responsible at Georgetown for developing the programs for the E 101 computer for deriving the wavelenghts and wavelnumbers from the readings off the measuring comparators.

Carl C. Kiess (Bureau of Standards, retired) Director of spectroscopic research projects at Georgetown. Dr. Kiess was instrumental in starting all of the spectroscopic research at Georgetown while still at the Bureau of Standards.

W. F. Meggers(Bureau of Standards, retired after October 1958) will join the staff of Georgetown and be available for consultation in con nection with problems concerned with this project.

Graduate students in Physics and Astronomy to do the routine parts of the work; to be employed part time during the shool year and full time during the summer months.

8. **BUDGET:** The proposed budget covers three periods. The items given here are those originally entered by Dr. Jenkins and Dr. Phillips in their first draft of the project and deleted in the final proposal.

	First Year.	Second Year	Third Year
Two Research Assistants	$ 5000.00	$ 5000.00	$ 5000.00
Overhead for maintenance of equipment	750.00	750.00	750.00
Yearly total	$ 5750.00		
Grand total	$ 17,250.00		

9. CONTRIBUTIONS OF GEORGETOWN UNIVERSITY:

Salaries of Francis J. Heyden, Matthew Thekaekara, Carl Kiess, W. Meggers

Computer time onnthe E 101 and measuring equipment.

The requested overhead is asked to partly cover the maintenance on the Telecordex and Telereader machines.

Submitted by Francis J. Heyden, S.J.

1958

Spectroscopic Projects with Electrodata Digital Computer, Model 102

The branch of physics known as spectroscopy had its origin in the celebrated experiment of Sir Isaac Newton who showed that the white light of the sun is in reality a mixture of different colors and that a prism can spread it out into a spectrum as in a rainbow. Nearly two centuries later another English scientist, Young, showed that light propagates itself as waves, much in the same manner as ripples on the surface of water. The distance between successive crests is called a wavelength. Blue or violet light has shorter wavelength than red or yellow light. Atoms and molecules can be made to emit their own specific wavelengths. A familiar example is the neon advertising sign. The composite light emitted by a gas discharge tube can be spread out into its component wavelengths by means of a spectrograph. These wavelengths register themselves on a photographic plate as narrow lines parallel to each other in order of increasing wavelengths. A given atom may emit several hundreds or several thousands of lines according to the complexity of the atom.

The wavelengths are related in a simple manner to the energy changes which take place within an atom when the light is emitted. Dividing the velocity of light by the wavelength one gets the frequency or the number of vibrations per second. The frequency is of the order of a quadrillion (10^{15}) per second. Einstein discovered the famous relation $E = h\nu$ which states that the energy given out as light radiation by a single atom due to its transition from one energy state to another is the product of the frequency and a universal physical constant known as Planck's constant, h.

In the realm of the physical sciences the most accurate measurements are those in spectroscopy. Nowhere else are instruments constructed with such rigorous precision; nowhere else are observations made with such elaborate care. wavelengths are infinitesimally small; the wavelength of the yellow lines of sodium is about 6000 A. The unit A, called the Angstrom unit, is a hundred-millionth of a centimeter. Though so small, wavelengths can be measured with an accuracy of one part in 50 million. Francis M. Grimaldi, an Italian Jesuit of the 17th century, showed that gratings have the same property as prisms of dispersing light into its component colors. Gratings are made by ruling a large number of fine lines on silvered glass. The best spectrographs of today are grating instruments and some of the finest gratings ever made are those ruled by Rowland of The Johns Hopkins University, Baltimore, Maryland. The large spectrograph of the Georgetown Observatory is fitted with an original Rowland grating. It has a six-inch wide concave reflecting surface with 20,000 lines per inch.

Spectroscopy has an important role in physics and astronomy. It has been said half-humorously but very truthfully that trying to learn about the atom or molecule through spectroscopy is like trying to learn all about the piano by dropping millions of pianos down several flights of stairs and listening to the sound they make when they crash. Spectrum lines are the messengers which come to us from within the atom. They bring us abundant, very useful and highly precise information about the inner structure of atoms and about the laws which hold them together. The light which reaches the earth from the sun and the stars when analyzed by a spectrograph reveals the constitution of these distant bodies. Photographing the spectrum is only a small part of the work of a spectroscopist. The relative positions of the hundreds of lines which appear on a photographic plate are measured with an accuracy of one thousandth of a millimeter. The task of writing down on paper the positions of these lines has in recent years been considerably lightened by the electronic register, "Telecordex", which types out automatically the positions of the lines. The time taken up in measuring has thus been reduced to one-tenth of what it had been formerly since the information supplied by the large measuring engine of the Georgetown Observatory is typed out at high speed by a telecordex.

What still remains to be done is the most tedious and time consuming part of a spectroscopist's work. It is here that a computer with the speed, accuracy and all-purpose adaptability of the E 102 comes to be extremely useful in an observatory where processing abundant data of varied kinds forms so large a part of the research program. Wavelengths have to be calculated from the positions of the lines. This has hitherto been done with a desk calculator, but with some sacrifice of accuracy and at considerable expense of time. A new technique has been devised for wavelength calculation which ensures high accuracy but would be far too laborious for a desk calculator. Four known wavelengths and their measured positions are supplied to the computer which then solves a four-by-four matrix in about 1 minute and 40 seconds. The constants a, b, c, and d of the matrix are thus known from the computer. The next step for the computer is to calculate the wavelength λ for each value of the position x given by the telecordex, using an equation of the fourth power,

$$\lambda = a + bx + cx^2 + dx^3.$$

Sample values of a, b, c and d are a = 4138.36945; b = 1.80933465; c = 0.0003529; d = 0.00000029368. For each plate there would be a thousand values of x, each having six significant figures. A problem of this kind cannot evidently be attempted by a desk calculator for which a first power equation of the form $\lambda = a + bx$ represents the maximum possible accuracy and errors will have to be corrected by a calibration curve. A further stage in the calculation is finding for each wavelength the corresponding wavenumber, which is the reciprocal of the wavelength making due correction for the refraction of the air. The usual practice is to use Kayser's well-known tables of wavenumbers. But the computer can be made to type out the wavenumbers along with the wavelengths using an accurate dispersion formula.

The following are some of the projects in spectroscopy in which the Georgetown Observatory is interested: (1) Hydrocarbon spectrum and its comparison with the spectrum of the sun; (2) Spectrum of chlorine in chlorides of different metals; (3) Spectra of titanium, zirconium, hafnium and yttrium; (4) Faint iron lines in the solar spectrum; (5) Mapping of the solar spectrum; (6) Interferometric measurements on solar lines; (7) Spectra of Saturn and Venus; (8) Newly discovered lines from the preionized levels in xenon and krypton. Work on some of these was temporarily discontinued due to the great amount of time and labor involved in reducing the data. These projects are auxiliary to projects on which the National Bureau of Standards in Washington, D.C. is currently engaged and are of considerable importance for our understanding of the physical world and for supplying workers in allied fields with reliable standards. With a staff of physicists and astronomers now at the Georgetown Observatory fully trained in techniques of spectroscopy and familiar with programming for the E 102 computer, it is expected that several large spectroscopic projects can now be undertaken.

(Rev.) Matthew P. Thekaekara, S.J., Ph.D.

1958

GEORGETOWN UNIVERSITY, DEPARTMENT OF ASTRONOMY

WASHINGTON 7, D.C.

A PROPOSAL FOR GRANT-IN AID FROM THE NATIONAL SCIENCE FOUNDATION

1 - NAME AND ADDRESS OF THE INSTITUTION: Georgetown University, Washington 7, D.C.

2 - NAMES OF THE PRINCIPAL INVESTIGATORS:

Dr. Carl C. Kiess

Dr. William F. Meggers

3 - TITLE OF THE PROPOSED RESEARCH: Investigations of the sun's spectrum comprising the following: (i) identification of faint Fraunhofer lines due to iron and titanium; (ii) observation and analysis of the spectrum of neutral titanium in the ultra-violet and in the longer regions ordinarily masked by oxide bands in arc spectra; (iii) precision measurement of solar wavelengths by interferometric methods.

4 - PRESENT STATUS OF THE RESEARCH PROJECT.

This proposal will continue and extend by the above principal investigators the research authorized by the National Science Foundation under N.S.F. grant 5217 to Georgetown University. Under the above grant the following work has been done.

(i) The spectrum of Ti I has been measured in the range 3100 - 2100 A on spectrograms obtained with the large quartz-prism spectrograph of the National Bureau of Standards. These measurements have been made with very high reciprocal dispersions ranging from 0.8 to 0.3 A per mm, and yield wavelengths of high precision for about 720 lines. Of these 283 are new additions to the lists of Ti I lines, 153 are given in Russell's list and the remainder belong to Ti II or to various impurities such as Fe, V, Si, and Al. 53 of the new lines have been classified as combinations between known levels. Six new odd levels have been established which in combination with known levels account for about 25 unidentified faint solar lines. The measurements were made with a telecordex, as described in the previous proposal. The average positions of the lines were fed into a Burroughs E 101 computer and calibration of the plates was carried out accurately by the method of least squares. This computer offers certain advantages over the giant electronic computers, such as low initial cost, considerably lower expense of maintenance, and saving in time owing to its system of decentralized computing. With it the wavenumbers of the lines, corrected for dispersion of air according to Edlen's formula, and the recurring constant differences between related lines are automatically derived. A paper by M. Thekaekara, describing these techniques and results was presented at the Annual Meeting of the Optical Society of America, October 1958. A copy of that paper accompanies the present proposal.

(ii) To increase the accuracy of calculated term-combinations it has been found desirable to re evaluate the Ti I terms determined from interferometer measurements by Kiess, about 30 years ago. This has meant changing them from the older formula of Meggers and Peters for the dispersion of air, to the more recent and more accurate one of Edlen. This calculation would have been a formidable task had it not been possible to perform it with the E 101 computer. Two papers bearing on this phase of the project are in preparation, one by M. Thekaekara and C. Wilson dealing with the new results for Ti I and their analysis, the other by C. C. Kiess and M. Thekaekara dealing with revision of the Ti I terms.

(iii) The grating spectrograph which will be used in the solar work has been reconstructed during the summer months so as to increase its flexibility and adaptability for laboratory sources as well as celestial sources. This set-up will accomodate either of two concave gratings of 21 ft. radius of curvature, one ruled with 15 000 lines per inch by R.W. Wood and the other ruled with 30 000 lines per inch by H.G. Gale at the University of Chicago with the machine now being operated by Bausch and Lomb.

(iv) Dr. Vera Rubin is now engaged in examining the solar spectrograms taken several years ago by Fr. Heyden and Dr. Zalubas with the Rowland grating ruled with 20 000 lines per inch. The region which is being measured at present covers the wavelength range 5950 6450 A. It is anticipated that this region will be read and reduced within two months and that a significant number of "new" lines will be recorded. Following this the regions 4740 - 5000 A and 3300 - 4100 A will be investigated similarly. The object of this investigation is to check the faint lines against those published originally by Rowland and given in the Revision of Rowland's Table issued by the Carnegie Institution of Washington in 1928.

5 - PROPOSED RESEARCH FOR THE IMMEDIATE FUTURE.

The aim of the research work listed in this project is to supply chemical identifications for the faint solar lines that will be listed in the new table of Solar Wavelengths now in preparation by Mrs. Charlotte Moore at the National Bureau of Standards. This work was undertaken for and at the request of the International Astronomical Union. At present nearly 7 000 out of a total of 26 000 solar lines are still unidentified. The question has been raised as to whether all of these lines are genuine or whether some are spurious. To give an answer it is proposed to make an intercomparison of solar spectra obtained with high-dispersion gratings ruled with different engines. Available for such an investigation are Rowland's original list based on spectrograms taken with his earlier gratings, and the Utrecht Atlas derived from gratings made at Mount Wilson Observatory with the Rowland 20 000 line per inch grating. It is our intention to supplement this material with a set of spectrograms taken with the Gale grating mentioned above. Faint lines that appear on all or several different spectrograms are to be accepted as real; those appearing on one spectrogram are to be rejected.

For the identifications of the lines accurate wavelengths are necessary. For a great part of the solar spectrum such data are available from the interferometer measurements made more than 30 years ago by Burns, Meggers and Kiess at the Allegheny Observatory and by H.D. Babcock at Mount Wilson. But this work has never been finished owing to the use of glass optical accessories in the experimental set-up. We now propose to bridge the remaining gap in the solar spectrum, between 3500 and 3000 A, by measuring selected lines in this ultraviolet region with Fabry-Perot interferometers.

Such observations will furnish valuable evidence for another problem of great scientific importance. Einstein has deduced, from his relativity theory, the conclusion that spectrum lines produced in a gravitational field will be shifted toward longer wavelengths by a calculable amount from the positions as measured in the laboratory. The interferometric measurements at Allegheny and Mount Wilson do indeed show that the solar lines are shifted, but in a way not envisioned by the theory. The stronger lines are shifted by amounts greater than that postulated by the theory, and the fainter lines by amounts less than the theoretical. It is obvious that the longward shift of solar lines is the resultant of more than one effect. Furthermore it has been found, at the University of Oxford, England, that lines formed at the sun's limb, that is, in atmospheric layers high above the photosphere, are shifted by still greater amounts. Of these earlier observations some (Allegheny) were made in integrated sunlight, and others (Mount Wilson) in light from the center of the disk. The Oxford observations are few in number, less than two dozen. We propose to make an extensive set of observations in light from the center of the disk and from the limb so as to supply an abundance of data for a statistical discussion of the problem of shifted wavelengths.

Our work on Ti I during the past few months has convinced us that many of the unknown faint solar lines are due to this element. The lines which we have measured in the range 3100 to 2100 A are mostly due to transitions from the very high levels of Ti I to the very low levels. We have prepared a tentative list of new levels. If they are real, many lines involving these levels and others in the middle of the energy level diagram should be observed in the longer wavelength region. The realier measurements given in literature were incomplete because of the oxide bands. The electrodeless discharge lamps give a very bright spectrum of high purity. The vacuum equipment for producing these lamps has been set up during the past six months and all our new lamps are being made with it. Preliminary studies which have been made in limited ranges of the photographic region show that the wavelength list of Ti I can be considerably augmented and hence also the list of energy levels. Among the solar lines listed in Rowland's Table nearly 1100 are due to titanium, which is a larger number than due to any other element except iron. It would seem that a very large number of the still unclassified lines are due to titanium, since iron, the other very abundant element, has a spectrum which is considerably better known than the spectrum of titanium. Hence the new levels which we hope to find in titanium are likely to help considerably for a complete analysis of the solar spectrum.

Our computation of the energy levels from the interferometric measurements of C. C. Giess revealed some significant gaps in the data. Most of the lines measured by Kiess are due to transitions within the triplet system of levels. Only very few of the lines involving the quintet and singlet systems have been measured. Even more significant is that only four intersystem lines are available in the interferometric list. Thus the term values of the quintet and singlet levels and their relative separation from the triplet levels are known to a less degree of accuracy than the triplet levels. Hence more interferometric measurements on Ti I are needed.

We think we are in an advantageous position for interferometric work since our measuring engine has the telecordex attachement for both the x- and y-axes and our E 101 computer presents the special features of simplicity in programming and speed in computing.

6 · FACILITIES

The following pieces of equipment are available for the present project.

(i) Wadsworth spectrograph in the basement of the Observatory, with a Rowland grating, 20 000 lines per inch.

(ii) Wadsworth spectrograph with a Gale grating, 30 000 lines per inch, more sensitive than the older instrument in the ultraviolet. It is housed in a seperate building and has been redesigned recently to give a greater flexibility.

(iii) Various accessories for excitation of different kinds of spectra.

(iv) Three comparators all of which are high precision instruments measuring to a micron.

(v) An analog digital converter (Telecordex) for automatic recording of comparator settings.

(vi) An electronic digital computer (Burroughs E 101) for reduction of wavelengths and wavenumbers and for analysis of spectra.

(vii) Telereadex specially suitable for faint lines in the solar spectra.

(viii) A punched tape input and output assembly to transfer data directly from the telecordex to the computer. Arrangement to install this unit is beirg made.

(ix) Interferometers for which we are making a request in the present proposal. For interferometric work which we undertook at the Georgetown Observatory from time to time the National Bureau of Standards used kindly to loan us one of their interferometers. This arrangement is not possible any more since our inter ferometric work under the present program will be extended over a long time. Hence we are including in the budget of the present proposal the cost of two pairs of interferometer plates.

The plates are to be supplied by Gaertner. Two pairs of plates of Corning fused silica (super quartz), 2 3/8" diameter, 5/8" thickness, with a tolerance of one-hundredth of a fringe for one plate and one fiftieth of a fringe for the other will have to be purchased; the accessories for temperature control, etc., will be made in our workshop.

7 - PERSONNEL

The principal investigators for the present project are C.C. Kiess and W.F. Meggers. Dr. Kiess who has been a member of the Georgetown University faculty since 1950 has personally supervised the designing and layout of our spectroscopic instruments. At present he is teaching one course in the graduate school of Astronomy. Dr. Meggers will bring to the project his vast experience in the field of spectroscopy. A bibliography of the publications of Dr. Kiess and Dr. Meggers contains well over 200 titles. The main contributions which refer directly to the present proposal are in The Publications of the Allegheny Observatory, Vol VI, pp. 13 - 45, 105 - 141, (1929).

Directly engaged on this research project will be M. Thekaekara and Vera Rubin. M. Thekaekara joined the staff of the Georgetown Observatory in June 1957 and has since done considerable work in developing the automatic techniques in spectroscopy. Previously he had spent five years with the spectroscopy group under Dr. G.H. Dieke at Johns Hopkins University. His work on the spectrum of Xe I and Kr I formed the subject of two Spectroscopic Reports of Johns Hopkins University. Two reports on the work done during the past year are soon to be published from the Georgetown Observatory.

Mrs. Vera Rubin who completed her doctorate at Georgetown three years ago had previously been working as a research associate on the Observatory's solar eclipse program. She has published recently four papers on the analysis of photo-electric light curves obtained from a total eclipse of the sun. Presently she is engaged on the project of measuring the faint lines of the solar spectrum.

In addition, five graduate students, Harvey Banks Jr., William Bozman, Arthur Hook, John Giuliani and George Coyne, are engaged in studies of titanium and yttrium which are complementary to the solar project. We are proposing that George Coyne be made a research assistant.

8 - BUDGET

	First Year	Second Year
(i) Funds to cover part-time salaries of W.F. Meggers, C.C. Kiess, M. Thekaekara, V. Rubin	$12,000.00	$12,000.00
(ii) Part-time salary for Research Assistant G. Coyne	1,800.00	1,800.00
(iii) Overhead for maintenance, equipment, etc. 15%	2,070.00	2,070.00
(iv) Computer time and photographic plates	500.00	500.00
(v) Two pairs of interferometer plates and accessories	2,000.00	
Yearly total	$18,370.00	$16,370.00
Grand total	$34,740.00	

9 - CONTRIBUTIONS FROM THE GEORGETOWN UNIVERSITY

Maintenance of the spectrographs and of the equipment for producing spectra will be the responsibility of the Observatory. Several graduate students and a few senior undergraduates who have expressed interest in getting trained in spectroscopy will be doing limited projects connected with the research program.

10 - SIGNATURES:

Principal Investigators

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Carl C. Kiess

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William F. Meggers

Department Head

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Rev. Francis J. Heyden, S.J.

Treasurer and Contract Administrator

____

Rev. Joseph F. Cohalan, S.J.

RESEARCH PROPOSAL: to the National Science Foundation, Section for Astronomy and Physical Sciences.

SUBMITTED BY: Georgetown University, Washington, 7, D. C.

PRINCIPAL INVESTIGATORS: Dr. Francis J. Heyden, S. J. and Dr. Carl C. Kiess

TITLE OF PROPOSED RESEARCH: "ANALYSIS OF THE SOLAR AND SUNSPOT SPECTRA"

STARTING DATE: October, 1, 1961 (This proposal is primarily a continuation of the research carried out under the National Science Grant, 8193)

PERIOD: Two years from starting date.

GEORGETOWN UNIVERSITY
DEPARTMENT OF ASTRONOMY
WASHINGTON 7, D. C.

PROPOSAL FOR GRANT IN AID FROM THE NATIONAL SCIENCE FOUNDATION

NAME AND ADDRESS OF INSTITUTION: Georgetown University, Washington 7, D. C.

NAMES OF PRINCIPAL INVESTIGATORS: Dr. Francis J. Heyden, S.J.
Dr. Carl C. Kiess

PROPOSED TASKS:

REVISION OF THE SPECTRUM OF Ti I FROM 2000 Å TO 10000 Å

A consolidated list of 10,000 wavelengths and their corresponding wavenumbers, determined using Edléns formula, has been completed under the previous National Science Foundation Grant, 8193. This work represents over 75,000 observations made on spectrograms obtained from the Wadsworth mounting spectrograph with the six inch Rowland grating with 20,000 lines per inch, located in Georgetown College Observatory. Each line was measured on at least two spectra or as as many as twenty spectra. The overall consistency is very good and the average mean deviation from the predicted wavelengths is 0.003 Å. The uniqueness of this analysis of the Ti I spectrum is that all of the observations, measurements, and reductions were made at Georgetown College Observatory on the same instrument using identical methods. Therefore, as in the case of most analysis over a large spectral region, the evaluation of data was unnecessary. One Ph. D. and two Masters Theses have been obtained from this analysis.

The intensities of the spectral lines are corrected visual estimates which are not reliable for faint lines. All of the faint lines appear of the same intensity even to the well trained eye. Thus, the further determination of new levels and the classification of more lines are very improbable with the present intensity values. At least four tracing of the lines on four plates of different exposures should be made in each region of the spectrum with the micro-densitometer. A uniform intensity sclae will be established from the calibration of the line profiles. Then, a further search will be made for new levels using these intensities for confirmation and the classification of more lines.

After the above refinement, the first spectrum of titanium from 2000 A to 10000 A will be published. The analysis and preparation for publication will be completed and directed by Dr. Francis J. Heyden, S.J., Dr. Carl C. Kiess, Dr. Harvey W. Banks and Mr. William Bozman.

2. ANALYSIS OF THE SECOND SPECTRUM OF TITANIUM

During the analysis of the first spectrum of titanium, it was observed that all the Ti II lines both present and predicted in the literature, were present in the consolidated list of titanium lines. This observation revealed that the excitation energy of the electrodeless lamp was high enough to excite the second spectrum of titanium. A careful check was made to insure the existence of this spectrum of titanium in order to account for a large portion of the unclassified lines in the Georgetown list. It is almost imperative that this analysis be done to remove this spectrum from the list of Ti I lines. The existing literature on the Ti II spectrum are based on observations obtained from many observers on different instruments during the late twenties.

At present, a careful search is being made for all correlations between lines from the list and those in the literature. It should be noted that the second spectum of titanium may be analyzed without observations, measurements and reductions, since these were incorporated in the analysis of the first spectrum. It will be necessary to prepare a predicted list of Ti II lines from the known levels, to search for new levels and to classify new lines. This investigation is in progress by Mr. Whiting Willauer.

3. OBSERVATIONS OF THE SUNSPOT SPECTRA THROUGHOUT THE ENTIRE SPECTRAL RANGE

The sunspot spectra is significant in that it represents the spectra from a cooler area of the sun's photosphere around the temperature of the M and N stars. It is extremely difficult to obtain high dispersion spectra of stars less than 0 magnitude, because of the small amount of light and they are point sources. The sunspot spectra is of interest because of the presence of the molecular bands such as Mg H and Ti O and most of the hydride and oxide bands. It will be significant to study the effect of the presence of a source in a magnetic field at such a distance, even though the lines may not be too sharp because of the extreme temperature .

In order to insure a complete and comprehensive study of the sunspot spectra, spectrograms of the entire spectral region will be studied. of each sunspot observed. The focal positions for the entire range must be determined and the guidance system arranged in such manner that one single spot may be positioned on the slit of the spectrograph throughout exposures of the entire region. The instrument used to obtain the high dispersion spectra of the sunspots will be the Wadsworth type mounting spectrograph with the Gale grating (30,000 lines per inch) and the Rowland grating (20,000 lines per inch). This instrument is housed in a separate installation at the observatory. Dr. C. C. Kiess and Dr. F. J. Heyden, S. J. will be the investigators.

4. MEASUREMENTS OF INTERFEROMETERIC STANDARDS OF WAVELENGTH IN THE SUN WITH THE NEW INTERFEROMETER FROM 3400 DOWN TO 3000 Å

A 130 mm vacuum interferometer with quartz optics and water circulation systems is in the last stage of construction in our machine shop. This instrument is similar in design to the interferometer at the National Bureau of Standards, Washington, D.C. The cost of the instrument was supplied by the National Science Foundation under grant 8193. However, this grant did not include the cost of the vacuum and water circulation systems.

The first task to be undertaken with the new instrument will be the determination of wavelengths to be used as standards in the region from 3400 to 3000 Å in the solar spectra. This region begins around the cut off point for glass optics which in all probability is the reason for the lack of solar standards. Hence, there should be no difficulty in obtaining the standards with the quartz optics of the new interferometer. These standards will offer reliable internal standards for wavelength determination in the faint line study of the solar spectrum. These standards will also be of considerable use in spectroscopic investigationsof the moon and the planets.

The measurement and reductions of plates will utilize the the automatic techniques developed at Georgetown College Observatory. The investigators will be Dr. C. C. Kiess, Dr. F. J. Heyden, S.J. and Dr. H. W. Banks.

5. MEASUREMENT AND REDUCTION OF EXISTING SUNSPOT PLATES

This is a continuation of the study of molecular bands in the solar spectrum under National Science Foundation grant 8193. Mrs Sitterly has made availiable sunspot plates from Mt. Wilson. Molecular lines in the region 4000 Å to 4200 Å will be observed for coincidence with the laboratory lines in the (0, 0) and (1, 1) bands of SiH. These plates contain several hundred molecular lines that will be observed in the order of their astronomical importance in the range availiable on the plates. This investigation in molecular study will be directed by Dr. Vera Rubin and Mrs. Sitterly.

6. FAINT LINES IN THE SOLAR SPECTRUM FROM 5000 A TO 9000 A

The number of faint lines in the solar spectrum is exceedingly large. However, in order to make a complete study of the solar spectrum, these lines must be identified. These lines are not shown on spectral charts and are missing in the literature. But, thesefaint lines may be easily observed on the spectroscopic plate of high dispersion. The difficulty in this analysis in the past resulted from the laborious methods of spectroscopy: writing down of measurements, estimation of intensities and the extensive use of the desk computer and the correction curve. The practically automatic proceeduresdeveloped at the observatory lend themselves well to spectral analysis. That is, the individual lines are positioned on the cross hair of either of two measuring engines, the measurements are simultaneously printed out and coded on paper tape. The tape output is placed in the reader of the Burroughs E 101 computer, that has been tape programmed, and the corresponding wavelengths and wavenumbers are printed out. These wavelengths may be immediately associated with the intensities from a calibrated tracing of the lines recorded from the micro-densitometer, located in the basement of the observatory. Mr. Ahmad Kiasat and Mr. Varkey are making this investigation under the direction of Dr. F. J. Heyden, S. J. and Dr. C. C. Kiess.

7. THE ANALYSIS OF THE MOLECULAR SPECTRUM OF YTTRIUM AND ZIRCONIUM

a. Electrodeless discharge tubes of the chlorine salt of yttrium are being prepared by Mr. Gareth Janney to study the (Y, O) bands that occur in the solar and star spectra. At present Mr. Janney is preparing more substantial tubes. High dispersion spectrograms will be taken on the Wadsworth type mounting spectrograph using the 20,000 lines per inch Rowland grating. The spectrograms will be measured and investigated for the occurrence of these bands and rotational analysis will be made.

b. Mr. Y. R. B. Chowdary is investigating the spectra of the halides of zirconium. The region of his investigation is from 5600 A to 6200 A. Electrodeless halide lamps have to be prepared for the region and spectrograms obtained, measured and reduced. New lines will be classified and the known lines verified, thus the identification of zirconium in this region of the solar spectrum will be greatly facilitated. Dr. Matthew Thekaekara will direct this investigation.

EQUIPMENT AT GEORGETOWN COLLEGE OBSERVATORY FOR SPECTROSCOPY

Graduate students on the respective projects have more than a year's experience in the operation of the equipment and with the techniques involved. The following equipment will be availiable for spectroscopic analysis;

1. Two Wadsworth type mounting spectrographs
2. Three concave gratings, a six inch Rowland grating with 20,000 lines per inch, a Gale grating with 30,000 lines lines per inch and a Rowland gratinghaving 15,000 lines per inch. These grating are interchangeable on the two spectrographs.
3. Littrow prism spectrograph with quartz optics.
4. Vacuum interferometer, two inch plates, quartz optics.
5. Accessories for excitation of different kinds of spectra.
6. Three high precision comparators calibrated to a micron. Horizontal and vertical measuring is availiable on two of the comparators for interferometeric measuring.
7. An analogue digital converter, Telecordex, for automatic recording of comparator settings.
8. A motorized tape punch output which prepares the data from the Telecordex for tape input to the readers of the E 101 computer.
9. A micro-densitometer with four ranges of sensitivity. The profile of the plate is plotted by a Brown Electronik Recorder in the output from the micro-densitometer.
10. Burroughs E 101 electronic digital computer equipped with dual tape input.
11. Equipment for making electrodeless lamps.
12. Three coelostats with 8 and 12 inch flats.
13. One 16 inch parabola of 15 ft. focal length.
14. One 12 inch parabola of 50 ft. focal length.
15. One 30 inch parabola of 15 ft. focal length.
16. One 12 inch lens of 15 ft. focal length.

EQUIPMENT NEEDED

A vacuum pump for the interferometer is necessary to maintain the correct pressure of the chamber. This pump is in stock with the leading manufactures and may be obtained for $ 175.00

TELECORDEX. - An analogue digital converter with IBM typewriter output. While there are three comparators availiable for spectroscopy, only one may be operated in combination with the Telecordex. If another comparator is desired, the operator must wait until the Telecordex is not in use and change the connections and reset the balance circuit of the Telecordex.

We have learned that a used Telecordex in excellent condition may be purchased from the company, Telecomputing, for $6,500.00. This is a little less then one third of the cost of a new machine. The service and maintenance of the Telecordex at the observatory has been very adequately performed by the staff, with very little down time. Thus, it is felt that no difficulty will be encountered in the connections and maintenance of this equipment.

This instrument will enable the observatory to obtain the maximum efficiency from the comparators and increase the output of spectroscopic analysis by almost 100%.

PERSONNEL AND SALARIES

Dr. Francis J. Heyden, S.J. - Director of Georgetown College Observatory, who will be in charge of the research. $ 5000.00

Dr. Carl C. Kiess. - (Bureau of Standards, retired) Director of spectroscopic research projects at Georgetown. $ 2000.00

Dr. Matthew Thekaekara, S.J.- Assistant Professor of Physics, will supervise the work of two graduate students. $ 2600.00

Dr. Vera Rubin. - Lecture in Astronomy, co-author of Faint Iron lines in the Solar Spectrum. $ 2100.00

Dr. Harvey W. Banks. - Research Assistant, Post Doctorial Fellow, Dissertation. - The First Spectrum of Titanium From 3000 Å to 6000 Å. $ 2600.00

Mr. Whiting R. Willauer. - Graduate Assistant and Fellow in charge of Ti II analysis $ 5200.00

Two Graduate Assistants. $ 5000.00

TOTAL SALARIES $ 24,000.00

COST SUMMARY

	First Year	Second Year
Salaries	$ 24,500.00	$ 24,500.00
Overhead for maintenance of equipment	1,000.00	1,000.00
Telecordex and typewriter	6,500.00	
Spectroscopic plates	500.00	
Vacuum Pump	175.00	

PERCENTAGE OF TIME DEVOTED TO RESEARCH IN SPECTROSCOPY

Dr. Francis J. Heyden, S.J. -	33.3 %
Dr. Carl C. Kiess. -	33.3 %
Dr. Matthew Thekaekara. -	12.0 %
Dr. Vera Rubin. -	25.0 %
Dr. Harvey W. Banks. -	50.0 %
Mr. Whiting Willauer. -	100.0 %
Two Graduate Assistants. -	100.0 %

The graduate assistants will work twenty hours per week during the school year, receiving $ 2,500 each.

It should be noted that much more than the time indicated above will be spent on each project .

COST SUMMARY (Cont)

	First Year	Second Year
Yearly Total	$ 32, 675.00	$ 25, 500.00
Grand Total	$ 58, 175.00	

N. B. University overhead is included in the above total.

CONTRIBUTIONS OF GEORGETOWN UNIVERSITY

Computer time on the E 101 and Measuring Equipment

The requested overhead is asked to partly cover the maintenance of the Telecordex and Telereadex and associated equipment.

Submitted by Francis J. Heyden, S. J.

Director, Georgetown Observatory
10 August 1961

STATEMENT

1. Brief Summary The research program in atomic and molecular spectroscopy is an extension of the work which we have been doing during the past five years in the departments of physics and astronomy. We propose to develop further the techniques of gas discharges, of semi-automatic methods of data reduction, and of interferometric methods of precision measurement.

Two students have been enrolled under the program and they have started work at the beginning of the fall semester. Office space has been made available for them in the physics department. While taking the basic courses in physics which are required of every graduate student in the department, they also spend a certain part of their time working alongside the more advanced students who are engaged on projects in spectroscopy. As soon as they gain sufficient familiarity with the equipment they will start on their own individual projects.

2. Expansion of faculty and facilities Several major changes in teaching schedules were made, so that more time is available for research for each faculty member. No faculty member teaches more than two courses according to our present schedule.

Dr. Ralph S. Henderson has rejoined the faculty as a full time member. Mr. Edward J. Finn has also rejoined the faculty. Both of them had been on a year's leave. In place of Dr. Leroy Furlong, Asst. Prof., and Mr. Donald E. McCarthy, Instructor, who resigned last year, the department has made two new appointments, Dr. Edward M. Corson, Professor and Dr. Misri L. Vatsia, Asst. Professor.

Faculty members directly involved in the spectroscopy program are Fr. Matthew P. Thekaekara, program director, and Dr. Misri L. Vatsia. Dr. Vatsia's special field is experimental spectroscopy. Fr. Thekaekara's teaching schedule has been reduced to half so that he can devote more time to this program. A new course entitled Advanced Spectroscopy Laboratory has been introduced this fall and is taught by Fr. Thekaekara. This course is of special interest to students enrolled in this program.

Funds committed for the establishment of the program include the following:

Faculty	
Direct salary Rev. M. P. Thekaekara, 30% of time	$ 3,000.00
Depreciation Costs of equipment allocated to this program	$ 2,620.00
Time on two Burroughs E 101 computers	780.00
	$ 6,400.00

No funds have been committed from this program for the time which Dr. M. L. Vatsia contributes to it and his whole salary is from University funds. Under depreciation costs of equipment, and time on two Burroughs Computers, the amounts committed form only a small part of the actual cost to the departments of physics and astronomy.

3. Changes in the original Plan There have been no changes in the original plan as set forth in the proposal which was approved last year.

4. Expansion of the Program Two additional fellowships are highly desirable. Available space and facilities easily permit the addition of more than two, perhaps of four or six.

The physics department will move to the new Science Building in June 1962. About ten thousand square feet of space in the new building will be available either directly or indirectly for projects in spectroscopy.

These very substantial additions to our facilities are entirely outside the regular budget of the physics department or of any specific program, and will be provided from funds raised by the University Development Office.

There is provision in the departmental budget for the addition of two more faculty members. More of the time of Associate Professor Thekaekara and Asst. Prof.Vatsia will be released for the research program in atomic and molecular spectroscopy.

5. Student Enrollment The student enrollment figures given below include both the departments of physics and astronomy. Many of the pieces of equipment used in the

program of atomic and molecular spectroscopy are located in the Observatory and have been developed by the astronomy department. The basic training in spectroscopy is given mainly through courses offered in the physics department. Students of both physics and astronomy departments are engaged in spectroscopy projects. Hence it would seem that figures including both departments are relevant to the present proposal.

The enrollment in the fall semester of 1961 are for the first year 22, second year 18, third year 22. Of our students, nearly half the number are part time, and the rest full-time.

The anticipated enrollment for fall semester 1962 is about 15 full-time and 10 part-time in these two departments.

The number of degrees given in June 1961 was: 4 Master's, 0 Doctoral in Physics; 1 Master's, 3 Doctoral in Astronomy; 87 Master's 26 Doctoral in all departments of the graduate school.

6. Financial Aid for Students There are six teaching assistantships in the physics department and one in the astronomy department. The amount is $1,800 for first year, $2,100 for second year and $2,400 for third year. Of the seven teaching assistants, three are in the spectroscopy program.

Three of our graduate students hold the National Science Foundation Cooperative Fellowships, and of these one student is doing research in spectroscopy. Three other graduate students engaged in this program are partially supported by research assistantships, from government sources other than Title IV.

7. Institutional Support The Georgetown University development plans include more intensified research in different branches of the physical sciences. Hence the University is constructing the new Science Building. Some preliminary plans have been drawn up also for a separate new building for astronomy.

Spectroscopic research is likely to become our strongest field in physics and astronomy, partly because of the century-old tradition of the Georgetown College Observatory and partly because of our close association with the Spectroscopy Division of the National Bureau of Standards.

Faculty members in both physics and astronomy are exploring the possibilities for more outside support from private foundations so that we might increase the number of our full-time students.

The University has authorized a substantial increase in the physics department budget, so that the spectroscopy program may be adequately supported. The expenses involved in starting the new course, "Advanced Spectroscopy Lab" are covered solely by the University.

The new Science Building is straining the resources of the University to the utmost. The University cannot give much beyond the shell of the building. Resources must be found elsewhere for what keeps a research program going - competent students and faculty men, and adequate equipment.

The present proposal is one to ensure us more of competent students for the spectroscopy project.

8. <u>Spectroscopy in the Washington Area</u> Georgetown is the only university in the area which has facilities for any extensive program in spectroscopy. No other university has an observatory attached to it. The Georgetown Observatory, which dates back to 1841 is well-equipped for astrophysical and spectroscopic research.

There are indeed in the area a very large number of research laboratories maintained by the government. The work they achieve and the training they give to their workers, though of indisputably high caliber, are nonetheless of a very different type from what an educational institution and a university atmosphere can achieve.

Many of these government laboratories need trained workers in all fields of basic physics research, in particular in atomic and molecular spectroscopy.

Hence the program we propose is a very essential complement to the research installations of the Federal Government.

9. <u>Development of Graduate Work</u> Detailed plans for development of graduate work at Georgetown were drawn up when the new Science Building was first planned. Basic to these plans was the realization that the various fields of research are closely related. Hence it is that one large building close to the Medical Center was thought of. Rev. Edward B. Bunn, President of the University, was responsible for these plans and he worked in close cooperation with scientists representing each of the active fields of research. Development of spectroscopy is essential to the plan, since it is a field common to physics and astronomy, and has applications in chemistry and chemo-medicine.