outer parts of the eclipse curve the intensities are mostly too large. We may infer that additional light of 2 or 3 % of the intensity of the system was frequently present during DUGAN's epoch, and that this light was eclipsed and released around phases − 12° and + 12°. From the fraction of eclipse at these phases, a rough location of the hot spots can be given. For RV Ophiuchi, they lie at mean astrocentric latitudes if one assumes that the axis of rotation of the bright star is perpendicular to the orbital plane. For SW Cygni they were found to lie at high latitudes.

That the hot spots at times prefer mean and high latitudes is a fact which we suspect to be caused by magnetic fields which influence the path of the ionized gas streams.

Investigations of this kind will give us opportunity to study the effects of gas streams approaching stars — magnetic or nonmagnetic — with velocities of some hundred km per s. Observations of some systems have shown that asymmetries of primary eclipses are changing with time. It is suspected that these variations are strongly connected with variable magnetic fields on the bright components of these systems and that the locating of the hot spots is equivalent to the locating of the magnetic fields. I think that this may be improved to provide a concrete way to contribute also to the solution of the general problems of variability of stars.

Discussion to the paper of WALTER

HALL: I have unpublished UBV photoelectric observations of SW Cyg which are very interesting. In V the primary eclipse is total, with a duration of about 2.5 hours, but in U the primary eclipse is partial! This is a very large photometric effect in magnitude units, several tenths of a magnitude, but small in luminosity units, only about 2 % of the total luminosity of the hot star. This would imply that much of the circumstellar material lies far from the hot star, about one stellar radius away. But it is not possible to say whether it is in the equatorial plane or as you would suggest, above the pole of the hot star.

SMAK: Concerning the location of the hot spot: As it can be seen from the published trajectories and angular momentum considerations (see, e. g., KRUSZEWSKI, Acta Astr., Vol. 17, No. 3) a disk *must* be formed when the primary component is small and at least *can* be formed even if the primary is large. Thus the spot must usually be produced in the disk rather than on the star's surface.

WALTER: The observations of the mentioned systems seem to contradict this assumption. They make it probable that also regions in higher latitudes may be met.

Variable Star Observations from outside the Earth's Atmosphere: Review and Prospects

YOJI KONDO (Houston)

Abstract

The scientific rationale for variable star observations from outside the Earth's atmosphere will be discussed, followed by a review and discussion of existing observational techniques with reference to their capabilities and limitations. Existing techniques to be discussed will cover aircraft-, balloon-, rocket- and satellite-borne experiments, and observations thus far obtained will also be reviewed. Experiments, planned or under consideration, and also future prospects of obtaining variable star observations from outside the terrestrial atmosphere will be discussed.

I. Introduction

During the past quarter of a century it has become possible to send astronomical telescopes to above much of the terrestrial atmosphere in order to observe celestial objects in the spectral region hitherto unaccessible to ground-based telescopes. The new spectral regions thus opened are γ-ray, x-ray, ultraviolet (UV), infrared (IR) and radio regions, although parts of the UV and IR and a significant portion of the radio regions are accessible to ground-based telescopes. The astronomical spectral regions that are not accessible to the ground-based observer are shortwart of about 3000 Å (0.3 micron) in the UV, the region between 25—700 microns in the IR and longward of the decametric radiation in the radio. The region of the IR outside the above limit is intermittently accessible.

It appears that the γ-ray, x-ray, IR and radio regions will be covered by other papers at this colloquium. We shall therefore restrict our discussion of the variable star observations from outside the Earth's atmosphere to primarily the UV region of the electromagnetic spectrum, although other spectral regions will also be discussed briefly where such a discussion appears appropriate. In addition to the electromagnetic radiation, particle radiation from cataclysmic variables may in the future become an area of observational interest as the state of the art in cosmic ray research makes progress. However, due to their short life time, detection of the neutrons from supernovae or novae does not appear feasible.

We shall now attempt to enumerate some of the reasons why ultraviolet observations of variable stars are of serious astronomical interest.

For intrinsic variables, especially those with early spectral types, ultraviolet observations will provide new and powerful means of investigating the physical processes that cause the variability. It will be of importance to obtain light curves in the UV and compare them with those obtained from the ground. Such a comparison will enable us to develop more realistic models for these variables. In pulsating variables, observation of pressure sensitive lines such as C IV lines at 1548 Å and 1551 Å (KLINGLESMITH, 1970) may lead to improved understanding of the pulsation mechanism. Should there be mass loss from these stars, that may also be detectible in the UV spectra since resonance lines of ionized atoms are mostly found in the UV. The resonance lines of Mg II doublet at 2795 Å and 2802 Å as well as C III (at about 1908 Å), C IV (1560 Å), Si IV (1380 Å) and N V (1250 Å) will be excellent candidates for such investigation. The Mg II doublet is also expected to provide a powerful means for investigation of chromospheres of giant and supergiant variables. It has been reported that the period-luminosity relation of Cepheid variables depends upon the shape of the light curve in the visible light. It will be of interest to find out if a similar dependence exists between the period-luminosity relation and the shape of the UV light curves. Such investigations will no doubt yield valuable data to enhance our understanding of these pulsating stars that are believed to be in the late stage of their evolutionary processes. Improved understanding of RR Lyr and Cepheid variables is also desirable since they are important means of determining galactic distances.

A significant fraction of the eclipsing (close binary) systems are early-type stars. It is particularly important to observe these systems in the UV where the eclipses are deeper and therefore, hopefully, more clearly defined. Analysis of UV light curves will reveal the UV reflectivity of stellar atmospheres and UV limb-darkening coefficients. Solutions of UV light curves of early type contact and semi-detached binary systems will provide valuable information on evolutionary processes in these massive close binary systems. Special attention must be paid to Of type stars, such as UW CMa, and Wolf-Rayet stars, such as γ Vel and V 444 Cyg. It is also important to obtain UV observations of the atmospheric eclipses of stars such as ζ Aur, 31 Cyg, VV Cep, 32 Cyg, and AL Vel (a suspected case). An atmospheric eclipse is more pronounced in the UV (ROACH and WOOD, 1952), and offers unique opportunity to obtain direct data on the extended atmospheres of supergiant stars. High resolution UV spectrophotometry of eclipsing variables, particularly those of early spectral types, should provide interesting information on the mass flow from close binary systems. Such changing stellar masses have a bearing on stellar evolution, and mass loss affects the „OORT cycle" between stars and interstellar material. U Gem stars are also of interest for investigations in the UV (and also in the IR) because of their peculiar characteristics and their potential connection with novae.

Accurate observations of eclipsing variables are essential for general understanding of stellar masses and radii, the mass-luminosity relation, limb-darkening, and for constructing realistic stellar models, particularly for early type stars. However, in relatively few cases do we have sufficiently accurate observations to enable derivation of reliable absolute dimensions for the stars. Because there are complications in analyzing the orbits of very close binary systems (contact or semidetached systems with periods of a few days or less) we need to observe detached systems with periods longer than a few days to obtain really good determinations of absolute dimensions. The light curves are known to vary from one orbit to another in many cases, so it is highly desirable to follow the light curve during one complete orbital period in order to obtain reliable values. The eclipse phase must be covered in one uninterrupted run, and the out-of-eclipse phase covered by appropriately timed intermittent observations. Ground-based observations are hampered and interrupted by meteorological conditions, and it is very difficult indeed to cover the light curve as prescribed above. A telescope placed outside the Earth's atmosphere will be freed from meteorological restrictions, as observations of light curves from OAO—2 clearly demonstrates.

The UV spectral energy distributions of intrinsic and eclipsing variables as well as those of spectroscopic binaries may reveal any deviation of such stars from their „normal" cousins that may not be apparent from the ground-based observations. Unusual opacities that are related to their variable or binary nature may also be detected in the spectral photometry of such stars. Through UV and IR spectral photometry a more reliable determination of the atmospheric temperature will become possible; it will also yield improved values for bolometric corrections.

The variability of γ-ray and x-ray sources is a subject of much theoretical speculation as are the physical processes that give rise to the astronomical γ-ray and x-ray emissions. This subject will be covered by Dr. KELLOGG in this section, and I shall, therefore, refer the reader to his paper.

There are several types of variable stars that are of interest in the IR. These include T Tau stars, R Mon stars, ε Aur and β Lyr. The latter two should radiate more strongly in the IR than stars of similar spectral types if they are indeed associated with fairly dense dust cloud. However, in these cases, we do not anticipate important portion of their IR flux to be located in the region longward of 25 μ where observation from above the tropopause becomes necessary. In the case of T Tau or R Mon stars, about 20% of the stellar flux is expected in this region. Therefore, so far as the variable star observations are concerned, it appears that the greatest interest in the IR observations conducted from above the tropopause will be in the potential discovery of unanticipated results as has happened not infrequently in space observations.

In the radio region, the strongest source in the sky, the Sun, is a variable radio source. The variability of quasars is a celebrated case over which an active discussion is still continuing. In still more recent years, discovery of ultra-short period variable radio sources, called pulsars, has attracted much attention. It is not certain whether or not the radio observations longward of the decametric wavelength from above the ionosphere will prove to be crucial in furthering understanding of these objects. In order to conduct such observations, antennae longer than the wavelengths to be measured will be required. Since relatively short antennae have been used in space radio astronomy experiments, only the diffuse galactic background radiation has been observed except for the Sun.

II. Previous and Current Experiments

A. Ultraviolet Experiments

The spectral region shortward of about 3000 Å is not accessible to the ground-based astronomer due to the extinction by the Earth's atmosphere. In order to observe in the region between about 3000 Å and 2100 Å it is sufficient to take the telescope up to an altitude of some 36 km, although the atmospheric absorption is greater near about 2550 Å than in the regions on both sides of that wavelength. The atmospheric extinction at 2250 Å from the altitude of 36.6 km was reported by COFFEEN and GEHRELS (1970) to be 1.1 magnitude per air mass. In order to observe down to the Lyman limit (Lyman continuum begins at 912 Å) it is necessary to take the payload above about 100 km.

The Lyman limit constitutes a natural break between the far UV and extreme UV regions; the extreme UV region merges with the soft x-ray region at the wavelength of a few hundred Angstroms. (100 Angstroms correspond to 124 electron volts.) Because of the Lyman-alpha emission originating in the circum-terrestrial atomic hydrogen cloud, which comprises the outermost region of the Earth's atmosphere, observations at or near Lyman-alpha become somewhat restricted for fainter sources even at an altitude of several hundred kilometers. This restriction will depend on the altitude, field of view and the f-ratio of the telescope. Observations made with Earth satellites in highly eccentric orbits and interplanetary probes indicate that the Lyman-alpha emission from this atomic hydrogen cloud, sometimes called the geocorona or geocoma + geotail, decreases only slowly with increasing distance from the Earth and is still not insignificant at several Earth radii. It was first reported by BYRAM et al. (1956), followed by numerous other investigations. The typical intensity of this night-time Lyman-alpha emission at an altitude of a few hundred kilometers is a few kilo-Rayleighs (kR): it is several times as intense on the day side. (1 R is an emission rate of 10^6 photons per sec per cm^2-column). UV spectra of early type stars thus far obtained indicates that distant stellar radiation at the wavelength of Lyman-alpha is absorbed by the interstellar atomic hydrogen, as was first reported observationally by MORTON (1967). However, recent observation of Arcturus by ROTTMAN et al. (1971) indicates that Lyman-alpha emission from nearby stars may not be obliterated by the interstellar atomic hydrogen absorption, and that such emission may be detectible. If so, it may be useful to observe Lyman-alpha emission in the variable stars in the solar vicinity in order to further our understanding of the active „chromospheres" in these stars.

The radiation shortward of the Lyman limit from outside the solar system is absorbed by interstellar atomic hydrogen [first verified observationally by SMITH (1969)] and also by atomic helium at shorter wavelength until we reach the very soft x-ray region (or the very extreme UV region). At these very short wavelengths the opacity due to the continuum absorption by the hydrogen and helium has decreased sufficiently that the interstellar space is relatively transparent to these photons.

Let us now turn our attention to the vehicles that are available for taking telescopes outside the atmosphere. A large high altitude balloon (5×10^5 m^3) can take a payload weighing several hundred kilograms to an altitude of some 40 km. Sounding rockets, such as Aerobee, Skylark, Lamda, or Black Brandt, are capable of taking a payload of some 100 kilograms to an altitude of a few hundred kilometers. Earth orbiting satellites maintain typical orbital altitudes of a few hundred kilometers or greater. For example, OAO-2 has an orbital altitude of some 800 km. The orbital altitude is partially restricted by the radiation belt interference.

A balloon-borne astronomical telescope may be capable of observing the same target for up to a few hours continuously, depending on the season and the relative position of the star with respect to the balloon. Since atmospheric extinction in the UV region is still not insignificant at the balloon float altitude, one must think in terms of relative photometry or spectroscopy. Since the continuous observing time is limited, one can hope to obtain light curves only for variables with short periods. Spectroscopy, either using photometric or photographic techniques, appears to be the more fruitful means of investigating variable stars from balloons. For instance, a balloon-borne ultraviolet stellar spectrometer flown in June 1971 by KONDO, GIULI, and MODISETTE (1971) observed the Mg II doublet emissions in β Lyr. In terms of the cost of the vehicle, a balloon is the least expensive, costing an order of magnitude less than a sounding rocket. One disadvantage is that, since the balloon launching is strongly dependent on the meteorological conditions, one cannot really count on flying an experiment on a predetermined date.

A sounding-rocket-borne telescope has a typical observing time of a few minutes (3—5 minutes) as compared with that for a balloon of a few hours. This limits the rocket observation of variable stars almost exclusively to spectroscopic observations. To cite an example, a rocket-borne spectrograph was flown in May 1971 to observe the UV spectrum of β Lyr as a part of an IAU sponsored campaign to observe that eclipsing variable (KONDO and SCHUERMAN, 1971). Rocket experiments by CARRUTHERS (1968) and MORTON et al. (1969) also produced far UV spectra of γ Vel.

Of the experiments conducted thus far, the satellite-borne telescopes appear the most suitable for variable star observations. To this date, we have had one such experiment, the Orbiting Astronomical Observatory 2 (OAO-2), successfully in operation.

The University of Wisconsin experiments on OAO-2 consist of a 40 cm prime-focus filter photometer, four 20 cm telescopes with similar photoelectric photometers as for the 40 cm, and two objective grating scanning spectrometers with rectangular apertures. The scanning spectrometers have an effective collecting area of 265 cm^2. The 20 cm telescopes are equipped with three filters each, totaling 12 filters, with a typical half-band width of about 200 Å, and cover a spectral range from approximately 4200 to 1300 Å. The scanning spectrometer I covers a region from about 3800 to 1800 Å, while the spectrometer II scans the range 2000 to 1050 Å. The Wisconsin experiments are described in detail by CODE et al. (1970). The Smithsonian Astrophysical Observatory experiment consists of ultraviolet cameras (vidicons), and has mainly been used for cataloguing work; it is not of direct interest to variable star research.

Because of the restriction imposed upon the operation of telescopes by the position of the Sun, the OAO-2 is typically capable of observing continuously for 15 to 30 minutes. For relatively long period variable stars, the interval of observation due to the orbital period of the telescope, which is about 100 minutes, presents no serious problem. By repeating the observation of the same star, a light curve may be completed for a star of intermediate or short period as well.

Roughly 10% of the observing time on the Wisconsin experiment has been used in variable star observation. Both scanning spectrometers and filter photometers were employed in this effort. Table 1 shows the variable stars that have thus far been observed by the Wisconsin team. One observation refers to one observing session through one OAO night typically consisting of a sequence of filter observations or complete spectrometer scans. They will be discussed in further detail by Dr. HOUCK. A paper by this author, Dr. McCLUSKEY and Dr. HOUCK will also discuss the OAO observation of β Lyr, followed by another paper by Dr. MOLNAR on α^2 CVn observations.

B. X-Ray and γ-Ray-Experiments

For simplicity we shall not differentiate x-ray and γ-ray experiments and simply refer to the x-ray experiments. The somewhat artificial dividing line between the two is about 1 Mev. For the first few years since its inception in 1962 (GIACCONI et al., 1962), the stellar and galactic x-ray observations were obtained from rocket-borne payloads. In the late 1960's, some relatively crude observations were obtained from the OSO-3 and Vela Satellites. Among their contributions were observation of the transient x-ray source Cen X-4. The SAS-A (Uhuru) satellite launched in December 1970, has been observing in the 2-20 KeV region continuously, yielding important scientific information including variability of some x-ray sources. Uhuru satellite is described in detail by GIACCONI et al. (1971).

Table 1: Variable Stars observed from OAO-2

Star Name	No. of observations *)	P	Comments
o And	26	$1\overset{\mathrm{d}}{.}60$	B5 + A2p Photometry and Spectrometry
RT Aur	127	3.73	F5 — G9Ib (δ Cep) Photo. (and Spectro.) **)
α^2 CVn	132	5.47	A0pIII Photo. and Spectro.
UW CMa	120	4.39	O8f + O8f Photo. and Spectro.
CW Cep	34	2.73	B3 + B3 Photo.
β Cep	60	0.19	B2III (B3) Spectro. II
δ Del	20	0.14	A7pIII (δ Scu) Photo
β Dor	112	9.84	F6Ia - G2Ia (δ Cep) Photo.
BN Gem	70		O8Vp (Irregular) Photo.
β Lyr	235	12.9	Bp + ? Photo. and Spectro.
RR Lyr	32	0.57	A7 — F7 Photo.
U Oph	67	1.68	B5n + B5n Photo.
VV Ori	67	1.49	B1V + ? Photo. + Spectro. I
β Per	8	2.87	B7 + G8 Spectro. I and II Only thru primary minimum.

*) One observation is one observing sequence thru one OAO „night".

**) Limited scans.

C. Infrared Experiments

First IR spectrometric observations of variable stars from above the tropopause were made with the balloon-borne Stratoscope by a group of Princeton University astronomers (WOOLF et al., 1964). The stars observed in this experiment include α Tau, μ Cep, α Ori, *o* Cet, and R Leo. The first rocket-borne IR detector was flown in the mid-1960's; however, no work has thus far been done on variable stars from rockets. Dr. F. LOW of the University of Arizona and of Rice University has been conducting IR observations from Lear-jet aircraft. To an observer flying above an altitude of about 12 km, almost the entire IR region, save some limited absorption bands due to the residual H_2O, becomes accessible. The location of the tropopause is variable, but it is on the average located at about 12 km. From an altitude attained by rockets or satellites even such limited absorption features will cease to interfere.

D. Radio Experiments

Various rocket- and satellite-borne experiments have been conducted in radio astronomy although these experiments were not related to variable star observations. To name a few, Alouette (Canada) was launched in the mid-1960's; a series of Electron satellites (USSR); Radio Astronomy Explorer 1, or RAE 1 (USA) in 1968; Interplanetary Monitoring Probe 6, or IMP 6 (USA) in 1971; and the Mars Probe (USSR) in 1971. The groups that have been active in this field include the Goddard Space Flight Center, University of Michigan, and Harvard University groups in the USA; the Sternberg Observatory and Gorkii groups in the USSR; the Meudon group in France; the Jodrell Bank group in the United Kingdom; and the National Research Council in Canada.

Table 2: Eclipsing Binaries

Star	P	Sp. Tp.	No. Obs.	Type of Obs.	Light Curve	
EA Types						
CW Cep	$2^{\mathrm{d}}73$	B3 + B3 V:	34	Phot.	P	SOBIESKI, GSFC
U Oph	1.68	B4n + B5n	67	Phot.	Y	WARD, UW
β Per	2.87	B7V + G8 III	8	Sp1, Sp2	N	
EB Types						
Omi And	1.60	B5 + A2p	26	Phot, Sp2	P	—
UW CMa	4.39	O8f + O8f	120	Phot, Sp2	Y	—
β Lyr	12.91	cB8 + ?	235	Phot, Sp2	Y	HOUCK, UW KONDO, MSC; McCLUSKEY, LEHIGH U.; HOUCK, UW.
VV Ori	1.49	B1 V	66	Phot, Sp1	Y	—
Classical Cepheids						
RT Aur	3.73	F5 → G9 Ib	127	Phot.	Y	—
β Dor	9.84	F6 → G2 Iap	112	Phot.	Y	—
W Virg Types						
α UMi	3.97	F7 → F8 Ib	55	Phot, Sp1	Y	—
RR Lyr Types						
RR Lyr	0.57	A8 → F7	32	Phot.	Y	—
β Cep Types						
β Cep	0.19	B2 III ev	33	Sp2	Y	FISCHEL SPARKS GSFC
σ Sco	0.25	B1 III	23	Sp2	Y	—
α CVn Variables						
α CVn	5.47	A0p III	132	Phot, Sp2	Y	MOLNAR, UW
ξ UMa	5.09	A0 Vp	100	Phot, Sp2	Y	MOLNAR, UW
δ Scuti Variables						
δ Sct	0.19	F3 III	22	Phot.	?	—
δ Del	0.14	A7p III	20	Phot.	P	—
Irregular						
BN Gem	—	O8 V: pe	70	Phot.	Y	—
Nova Ser. 1970	246 Obs. over 54 days			Phot, Sp1	Y	CODE, UW

III. Experiments Planned for the Future and Prospects

A. Ultraviolet Experiments

Several Earth orbiting astronomical telescopes are currently scheduled for launching or are under study. The S019 UV astronomy experiment of Dr. HENIZE, which is planned as an integral part of the Skylab scheduled for 1973 and 1974, will be a very useful facility for observing the UV spectra of variable stars among other interesting astronomical objects. It is a 15 cm objective prism telescope and has a resolution of 2.5 Å at 1500 Å. The spectral coverage is 1300 Å — 5000 Å, but it will be used most effectively in the 1400—3000 Å region. This author will be collaborating with Dr. HENIZE in the data reduction and analysis, particularly in planning observations of spectroscopic (and, by implication, eclipsing) binary systems. The observations will be conducted by astronauts and photographically recorded spectra will be returned to the Earth for analysis.

Also plannned for launching as UV experiments are OAO-C, which has been developed under the direction of Dr. SPITZER at Princeton University, and the 20 cm telescope on the Astronomical Netherlands Satellite (ANS) under Drs. JAN BORGMAN and VAN DUIEN at Kapteyn Laboratory. Neither of these has specific plans for observing variable stars, but brief descriptions of these experiments may be in order because of their potential interest. OAO-C is an 80 cm, high resolution spectrometer (resolution 0.1 Å) designed primarily for observation of interstellar absorption lines, and it operates in the spectral region 1000—3100 Å. The telescope is planned for launching in 1972. OAO-C will be accompanied by an x-ray telescope of Dr. POUNDS of the University College, London. The Netherlands telescope will be launched together with three x-ray telescopes and is designed to do filter photometry at 3295 Å (halfband width 100 Å), 2500 Å (150 Å), 2200 Å (200 Å), 1750 Å (150 Å) and 1500 Å (150 Å). The principal scientific objective of the experiment is to observe stellar clusters, and it should be capable of observing stars down to the 10th magnitude. Perhaps more suitable for ultraviolet observations of variable stars would be the following satellite telescopes currently under study. Drs. UNDERHILL and BOGGESS at Goddard Space Flight Center are planning the Small Astronomical Satellite (SAS) D experiment, which is a 40 cm Cassegrain telescope, with an ultraviolet spectrometer. The resolution is designed to be 0.1 Å, and the telescope will be placed in a geo-stationary orbit. It is conceived as an international astronomical facility, and the design study is currently underway. It is being considered for launching in 1976. There are a few ultraviolet and infrared telescopes currently under consideration for the late 1970's as an integral part of manned Space Shuttle Sortie missions. These include the Large Space Telescope (1—2 m) and Intermediate Size UV Telescopes. Also under consideration is a 40 cm Small Astronomy Telescope, a UV telescope-spectrometer system which is being considered as an international facility for interested astronomers. It is conceived with the expressed objective of providing opportunities for investigators associated with relatively small universities or research organizations to participate in UV space programs.

B. X-Ray, γ-Ray Experiments

Several satellites are currently scheduled for launching or under consideration. OSO-H and OSO-I, scheduled for launching in the latter half of 1971 will carry some x-ray experiments. They are MIT's 1—40 KeV survey experiments (Dr. CLARK) and Wisconsin's soft x-ray experiment (Dr. KRAUSHAAR), respectively.

The SAS-B experiment, which is designed to observe in the γ-ray region utilizing a spark chamber technique, is planned for launching in 1972. Dr. FICHTEL of NASA Goddard Space Flight Center is responsible for the project. In 1973, the SAS-C experiment of MIT (Dr. CLARK) and UK 5 by University College, London, (Dr. POUNDS) and University of Leicester (Dr. BOYD) are scheduled, followed by ANS (Dr. DE JAGER at Utrecht) in 1974. In the period after 1975, HEAO (High Energy Astrophysical Observatory) A, B, and C are planned. In the late 1970's when the Space Shuttle becomes available, a grazing incidence telescope for Shuttle missions is under consideration.

C. Infrared Experiments

A balloon-borne 70 cm telescope, formerly known as Polariscope, is now being modified for IR work with coverage over the 50—350 micron region. It is scheduled for launching in the first half of 1972 by a NASA Ames Research Center team headed by Dr. F. WITTEBORN. They plan to do photometry of numerous Seyfert galaxies to be followed by another flight in about 6 months in order to detect variation of their light in the far IR. Ames Research Center is also planning an air-borne 90 cm telescope program aboard the C141 aircraft, which takes the payload up to an altitude of 13.7 km. They plan to cover the region from 1 micron to 1 millimeter except for some limited regions still obscured by the residual H_2O vapor. This facility is open for use by interested astronomers. Dr. R. CAMERON of Ames is coordinating this program.

Still further ahead in the future, a one meter IR telescope is under consideration for Space Shuttle Sortie Missions. At satellite altitude there will be no H_2O absorption interference and the telescope will be capable of covering the entire IR region. According to the study conducted by Dr. A. E. POTTER of NASA Manned Spacecraft Center, with proper cooling it should be possible to reduce the telescope noise to a point where very low temperature astronomical radiation, such as the 3°K cosmic background, becomes effectively observable.

D. Radio Experiments

Currently planned are two satellite experiments, Radio Astronomy Explorer 2 and HELIOS. RAE 2 will be placed in an orbit around the Moon in 1973, and HELIOS around the Sun at $^1/_3$ A.U. in 1974. Neither of these is designed for work on variable objects outside the solar system. In the late 1970's or perhaps early 1980's, a long antenna (1 km) radio astronomy satellite and a pair of satellites with a few hundred meter antennae for interferometric observations are under consideration. If realized, such experiments may yield results of scientific value for enhancing understanding of the variable radio sources.

IV. *Concluding Remarks*

We are only beginning to realize the full potential of astronomical observations of variable stars from outside the Earth's atmosphere. Two compelling reasons for such observations are: (1) coverage of the spectral region unaccessible to ground-based telescopes, and (2) freedom from meteorological interference.

Clearly, satellites are preferred means of obtaining variable star observations, although rocket-, balloon-, and aircraft-borne observations can also yield results of considerable value.

Although it is currently not under consideration, a telescope placed on the Moon would be an excellent facility for observing variable stars. The advantages of such a telescope will be: long uninterrupted observing time of up to some 340 hours at the equator, spectral regions not accessible to the ground-based telescopes, and the reduced Lyman-alpha background. The terrestrial Lyman-alpha background, which amounts to a few kR at night, is reduced to a few hundred Rayleighs at the Moon. A feasibility study conducted by astronomers at NASA Manned Spacecraft Center shows that such a project it not beyond the state of the art today. Perhaps, toward the end of this century, an opportunity to seriously entertain such a project will arrive.

Finally, it should be emphasized here that coordinated ground-based observations are crucial in interpreting and making maximum use of the observations obtained from outside the atmosphere. This is particularly true in relation to variable star observations where the information sought is time dependent. The IAU Commissions concerned may play an important role in coordinating such efforts.

It is a pleasure to acknowledge discussions with Dr. T. E. HOUCK of the University of Wisconsin (concerning OAO-2), Dr. H. GURSKY of American Science and Engineering (x-ray), Dr. F. J. LOW of the University of Arizona and Rice University (IR), and Mr. J. K. ALEXANDER of Goddard Space Flight Center (radio). Also, partial support of this work by National Science Foundation is appreciated.

References:

BYRAM, E. T., CHUBB, T. A., FRIEDMAN, H., and KUPPERIAN, J. E., **1956**, Ap. J. **124**, **480**.
CARRUTHERS, G. R., **1968**, Ap. J. **151**, **269**.
CODE, A. D., HOUCK, T. E., McNALL, J. F., BLESS, R. C., and LILLIE, C. F., **1970**, Ap. J. **161**, **377**.
COFFEN, D. L., and GEHRELS, T., **1970**, Space Research, **X**, **1036**.
GIACCONI, R., GURSKY, H., PAOLINI, F. R., and ROSSI, B. B., **1962**, Phys. Rev. Letters, **9**, **439**.
GIACCONI, R., KELLOGG, E., GORENSTEIN, P., GURSKY, H., and TANANBAUM, H., **1971**, Ap. J. **165**, **L27**.
KONDO, Y., GIULI, R. T., and MODISETTE, J. L., **1971**, in preparation for publication.
KONDO, Y., and SCHUERMAN, D. W., **1971**, in preparation for publication.
KLINGLESMITH, D. A., **1970**, unpublished work.
MORTON, D. C., **1967**, Ap. J. **147**, **1017**.
MORTON, D. C., JENKINS, E. B., and BROOKS, N. H., **1969**, Ap. J. **155**, **875**.
ROACH, F. E., and WOOD, F. B., **1952**, Ann. Astrophys. **15**, **21**.
ROTTMAN, G. J., MOOS, H. W., and BARRY, J. R., **1971**, Ap. J., **165**, **661**.
SMITH, A. M., **1969**, Ap. J., **156**, **93**.
WOOLF, N. J., SCHWARZSCHILD, M., and ROSE, W. K., **1964**, Ap. J., **140**, **833**.

Discussion to the paper of KONDO

BAKOS: What would be the limiting magnitude of HENIZE's objective prism program?

KONDO: With an exposure time of 4.5 minutes, a 6.0 magnitude star of spectral type B0 should be observable with Dr. HENIZE's S019 experiment. This limiting magnitude will depend on the spacecraft stability.

HERCZEG: What is the pointing accuracy of an airplane-borne telescope? Is it possible to study individual stars by this type of instrumentation?

KONDO: The aircraft-borne IR-telescope by Ames should be capable of observing individual stars.

HERCZEG: Can you tell us something about the system of data storage and communication? Especially, what is the way for astronomers not immediately involved into the experiments to get access to these data?

KONDO: Data obtained in space experiments are usually made available through: National Data Center, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, USA.

NOTE ADDED IN PROOF:

In their recent paper, based on the observations obtained with the UHURU satellite, SCHREIER et al. (Ap. J. **172**, L79, 1972) report results that indicate the discovery of an x-ray eclipsing variable system in Cen-X3.

Metal Line-Blanketing and Opacity in the UV of α^2 CVn

MICHAEL R. MOLNAR (Madison)

Abstract

Ultraviolet photometric observations by OAO-A2 were made of α^2 CVn covering the entire $5\overset{\mathrm{d}}{.}5$ period of this magnetic Ap variable. The light curves ranging from 1250 A to 3330 A indicate the dominant role of rare-earth line-blanketing in redistributing flux. In a broad depression of the continuum covering 2300 A to 2600 A scanner observations identify strong lines of Eu III as major contributors to this feature. At maximum intensity of the rare-earth lines the ultraviolet continuum shortward of 2900 A is greatly diminished while the longer wavelength regions into the visual become brighter. Thus, the light variations in α^2 CVn are due to the variable strong line-blanketing by the abundant rare-earth elements.

In addition, the far ultraviolet light curves indicate an opacity source not in phase with the rare-earths. This is attributed to the photoionization of Si I from the ^{1}D level at 1680 A which is a prominent feature in all scans of α^2 CVn; however, the edge due to the ^{3}P ground level is not identifiable.

These ultraviolet observations suggest the importance of metal line-blanketing and opacity in the redistribution of flux in Ap variables.