REPORT ON THE SCIENTIFIC INTEREST AND PROBLEMS *

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As is clearly apparent from the title of this colloquium my report should be concerned only with the astronomical experiments to be accommodated in ESRO rockets and satellites. It should also be considered only as an introduction to more specific and more detailed discussions or papers. Of course I can only give a brief summary. Several books, monographs, proceedings of conferences and reports of commissions have been published in the last two years. New important periodicals have come out; others have greatly increased their scope.

Let me first state what I am *not* going to talk about. I am excluding meteorology, aeronomy and anything related to the atmosphere and magnetic field of the earth, including the polar aurorae and even the Van Allen belts. Of course it is impossible to decide strictly on the boundary of the earth, but it seems logical to place it at some 15 to 25 earth radii. I also exclude the interplanetary medium, although this is an astronomical topic: the reason for this exclusion is that a colloquium of the corresponding ad hoc working group was held on June 19 under the chairmanship of C. de Jager.** I shall avoid the problems of tracking, which may already be treated with the existing American and Russian satellites. Also the problems of experimental celestial mechanics will be left out, although I fully realize that this old science has been completely renewed and rejuvenated by the space experiments. I shall consider neither the problems concerned with geodesy and navigation, nor those related to biology. Of course we all realize that the most exciting problems which may eventually be solved by space experiments concern life on Mars or Venus, or remnants of life on the Moon: we may expect very surprizing biochemical discoveries to be made on Venus or Mars.

As a matter of fact it is unavoidable that my report should be somewhat biased by my own scientific interests and tendencies. I hope that the shortcomings and gaps in this paper will be made up for in the papers and discussions which will follow. Of course my task is rendered much easier by the fact that A. W. LINES will report on the feasibility of the astronomical projects. I may thus take the easy and lazy point of view of not worrying much about the great technological difficulties involved, such as the transmission to the ground observer of the informations which will be collected by the orbiting telescopes.

It is an obvious statement that the space astronomers carry great moral responsibilities. What we wish most is to have at our disposal the expensive heavy stabilised

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orbiting telescopes. We know the enormous financial, scientific and technological costs of our European space endeavors. We realize the need for very thorough scientific planning, so that our programs and the results thereof would be commensurate with the costs involved. We do not hesitate to face this challenge. The exciting astronomical results which have already been obtained are only a modest preview of the future. Tremendous astronomical possibilities will open up with the increase in weight, height and guiding accuracy of the scientific payloads. We also know, and I shall try to make this clear in the course of this report, that even modest payloads may bring important results, if we adopt adequately conceived programs. And after all we must begin at the beginning, and this is why I shall devote a great part of my exposé to reviews or discussions of modest experiments.

I shall not dwell again in detail on the many advantages of astronomical observations outside the atmosphere, and shall simply restate them for the sake of convenience in the discussions which will follow. Details may be found in all the books or reviews on space astronomy.

(1) The considerable extension of the range of electromagnetic and corpuscular radiation. Instead of being limited on the short wavelength side at about λ 3000 Å we shall be able to observe down to a small fraction of the ångstrom. The only limitation in stellar spectroscopy (except for the nearest stars) will be the continuous absorption by interstellar hydrogen and helium which will cut all stellar radiation from the Lyman limit at λ 912 to about 20 Å. On the long wavelength side we may extend the present limit of about 15 meters to about 3 kilometers (for longer wavelengths there will be interference by the interplanetary electrons). In between the infrared will be greatly improved, since the absorption by H_2O, CO_2, O_3 and other atmospheric constituents may be avoided.

(2) The considerable improvement in "seeing" and the correspondingly higher resolution.

(3) The suppression of the bright sky foreground.

(4) The reduction or suppression of the effect of the terrestrial magnetic field.

(5) The possibilities of experimentation in celestial mechanics and in geodesy.

(6) The possibilities of direct sampling of a physical environment (upper atmosphere, interplanetary space, moon, planets, comets).

I shall be concerned mainly with point (1), a little also with (2), (3) and (6). In the beginning the main effort in space astronomy will probably be in the extension of the spectral range toward the short wavelengths.

A difficult problem which we, European scientists, are facing is to avoid duplication with American or Soviet astronomical experiments, whenever duplication is unnecessary. Indeed there are American and Russian programs which should be left entirely to them. But there are cases in which the repetition or the simultaneous carrying of experiments is highly desirable, as, for example, in solar physics, especially in relation to terrestrial phenomena. In all cases a close cooperation will be highly desirable: I have especially in mind the launching of artificial comets, the study of interstellar matter, the investigation of peculiar stars, etc. . . . Actually our conduct of space astronomy should not differ from that of ordinary astronomy, except for the fact that the costs of space astronomy are much higher, hence require a more thorough discussion of the possibilities of duplication. Of course our European space projects will undergo continuous modifications, especially in the beginning; but so did and still do certainly the space projects in the US and in the USSR.

One cannot stress too much the considerable need for a great deal of simultaneous laboratory and theoretical investigations. As an example in spectroscopy a great deal of data on atomic and molecular spectra in the vacuum ultraviolet and in the X-regions are still lacking. In his concluding remarks to our 1960 Liège Symposium F. L. WHIPPLE stated:

> "Here we are, being catapulted into space while we still have not finished an enormous backlog of necessary basic physical studies, for which there never has been adequate manpower or support."

And later on:

> "It is quite clear that we must attack the enormous task of building the spectroscopic foundation required for space science. Not only must we identify lines and bands, but we must also find *f*-values and establish theoretical relations if we are to use spectroscopy as an adequate tool for space. We need new laboratories and facilities, but particularly we need the enthusiasm of well-trained young men to carry on and expand the type of work that some of our theoretical people have been doing."

Indeed, in order to prepare efficiently the space experiments and to fully exploit the results, a great deal of experimental and theoretical work is required. We need essential data on the far ultraviolet spectra of many atoms, especially in the highly ionized states and of many molecules, such as H_2, N_2, O_2, N_2^+, O_2^+, NO, NO^+, OH, CN, NH_3, CO_2, etc. . . . We need many infrared spectra too. We must develop new optical techniques, such as the infrared spectrometry by application of the Michelson interferometer with Fourier transformations. Much experimental work is required on ultraviolet and infrared filters, on the ultraviolet reflectivity of mirrors and gratings; on special photo- and television tubes for ultraviolet; on metallic mirrors; on mass spectrometers, etc. . . . Many of these instruments have to be tested on ordinary telescopes on the ground or in high altitude balloons or aircraft. As I shall show later on there is a very special need for spectroscopic and optical work in the X ray-region.

Similarly a great effort has to be made in theoretical directions if we want to prepare and exploit the space experiments in the most efficient way. Many fields may be mentioned: models of stellar atmospheres (including the sun), line profiles, non thermal phenomena, mechanisms of X- and γ-emission, transition probabilities, etc. . . .

It is gratifying to know that in these experimental and theoretical fields our European institutions are well prepared; they can contribute greatly to space astronomy at very reasonable cost.

On the basis of theoretical considerations and of the recent observations of the far ultraviolet solar spectrum one may venture predictions on what will be found in various astronomical objects, by extending the observable spectral range, and indeed such predictions are essential to the planning. However, it is certain that the new observations will furnish quite unexpected results which will sometimes be much more exciting than the predicted and expected. To mention only one example, we may discover new unpredictable interstellar bands when looking for the expected ultraviolet or infrared interstellar absorptions. We are already excited at the prospect of being able soon to observe and measure predicted, thus far unobservable features which will furnish essential information in all chapters of astronomy: but we also know that unpredictable phenomena will be found at the same time.

I wish to insist first on the field of astronomical observations in the domain of the X- and γ-rays, not only because this is virgin field for stars, but also because we have in Europe outstanding research laboratories in this field. Nothing is known of the fine structures of the X- and γ-emissions of any astronomical body, not even the sun. To be sure numerous observations of the integrated solar X-emissions within certain wavelength limits have been made, but we need real spectra, not only integrated amounts of energy.

For the X-ray end of the solar spectrum ($\lambda < 80$ Å) we need new techniques of diffraction by grazing incidence gratings or by organic crystal gratings. A fortiori these techniques will be needed for stars and other astronomical objects. The region $\lambda < 80$ Å should reveal many discrete resonance lines of the highly ionized "coronal" ions in addition to any possible continuum.

Originally the term "X ray" was applied only to radiation emitted by a metallic target bombarded by high energy-electrons. Indeed this old point of view is still of astronomical interest for lunar, planetary and satellitic explorations: a beam of solar particles of high energy may create a lunar X-ray primary flux! An X-image forming device would be of great interest for studies of the surface of the moon, but the construction of an X-imaging device is not an easy matter. * The X rays are essentially produced in two ways: either as discrete lines resulting from transitions in the inner electronic shells of atoms, or as continua due to thermal radiation, collision- and magnetic Bremsstrahlung. The gamma rays used to be considered as nuclear transitions of higher energy, hence shorter wavelengths. However the spectral range is no longer a criterion: high energy electron or nuclear accelerators have produced X-continua at wavelengths which were considered the exclusive domain of γ-rays. Similarly the line of demarcation of the X- and UV-spectra is no better defined. The optical ultraviolet spectra are due to energy transitions of an outer electron, but in the case of highly ionized atoms a UV photon may have a wavelength shorter than an X photon of a light element. As an example the resonance lines of "coronal" ions such as Fe XIV which give rise to forbidden lines in the visible region of the solar corona fall mainly in the region $\lambda < 50$ Å.

* Much additional laboratory work is still required. The reflection of X-rays requires an angle of incidence of almost 90° depending on the wavelength and the material; for $\lambda \sim 10$ Å the total reflection requires an incidence angle greater than 89°. Various geometrical focussing systems have been designed. One may also use diffraction (Fresnel zone plates) instead of reflection.

Gamma- and X-ray astronomy is an entirely new chapter of astrophysics. New mechanisms are involved; simple extrapolations from known data are generally impossible; results of a wholly new character may be expected. Gamma ray-astronomy requires special coincidence-counting techniques for spectral and angular resolution that are quite unfamiliar to astronomers. No one really has any convincing idea of the amounts of γ- and X-energy which may be expected in stars and galaxies.

X-ray astronomy started in 1948 when photographic emulsions protected by Be- and Al-filters were sent in a V2-rocket and recorded solar X-rays. Since then the solar X-rays in the band 2–20 Å have been the object of many observations from rockets. Efforts to observe X-ray emission from astronomical objects other than the sun have yielded negative results with rockets; there is a need for the longer observing times available in satellites. As for gamma ray astronomy it was opened by Explorer XI launched at Cape Canaveral on April 27, 1961; important data are being collected, but this is only a first pioneering experiment.*

Gamma rays may have two cosmic origins. In the soft range 2×10^{-3} to 6×10^{-2} Å, they may result from the radioactive decay of excited nuclei, from the fusion of light elements, and possibly from the annihilation of electrons and positrons. In the hard range 5×10^{-5} to 2×10^{-4} Å they may result from the decay of neutral pi-mesons produced in the interactions of nuclei with high energy particles and from the annihilation of nucleons and anti-nucleons. For example, when a fast cosmic ray-proton encounters an interstellar nucleus (hydrogen or dust particle), the latter may be wrecked and give rise, after transformations, to a neutral pi-meson which decays rapidly into a pair of gamma rays travelling in opposite directions. The direction of the γ-ray points toward the region where the collision between the cosmic particle and the interstellar nucleus occurred (contrary to the primary cosmic particles whose trajectories are affected by the galactic, interplanetary and terrestrial magnetic fields).

We may expect to find production of γ-rays in the solar flares, in old supernovae (such as the Crab Nebula), in the nucleus of our galaxy, also in the radio sources in which the turbulent hydromagnetic regions give rise to radio noise through the synchrotron radiation of energetic electrons.

The stellar or interstellar production of continuous X-rays may be due to thermal radiation, K-ionization, collision (non magnetic) Bremsstrahlung (i.e. acceleration of electrons), and especially to magnetic Bremsstrahlung (or Schwinger radiation, or synchrotron radiation). The energetic electrons moving through the magnetic fields which are present in our galaxy emit continuous radiation which may be strong in the X-region. We may anticipate that X-rays are emitted in the same cosmic sources as the γ-rays. It has also been suggested that nuclear reactions occur in the peculiar A-stars with rapidly changing magnetic fields; as a result γ-rays would be emitted from the nuclei in excited states, and X-rays by Bremsstrahlung of electrons.

At any rate X-ray observations promise valuable information on the hydromagnetic forces in the sun, stars and galaxies.

* See SCHATZMAN's report on page 774.

Much work has been done on the X-emission – but not the X-spectrum – of the sun, or rather of the solar corona. Indeed, while the corona is a million times fainter than the solar disk in the visible region it is the only contributor to the spectrum shortward of 100 Å.

Many experiments on the solar X- and γ-rays are in preparation. Should we expect to be able to observe X-radiations from objects other than the sun? Predictions have been calculated, but they involve a considerable amount of uncertainties. Do all main sequence stars possess a corona similar to the solar corona ($T \sim 10^6$ degrees) or are stellar coronas exceptional features? Do objects such as supernovae, Wolf Rayet stars have brighter coronas than the sun? Certainly we may expect flare stars or the Crab nebula to be strong sources of X-emission. A convincing decision on all these questions must await direct observations.

Several teams prepare also X- and γ-instrumentation for the future lunar- and planetary explorations. A γ ray-spectrometer will measure the radioactivity of the moon at λ 8.5 $\times$ 10^{-3} Å which is associated with the decay of K_{40}. X ray spectrographs and diffractometers are also being designed. It is intended to study the moon's surface with an X-ray telescope.

Technically the imagery and spectroscopy in the far ultraviolet are easier than in the X- and γ-regions. I shall not review here again the remarkable results on the far ultraviolet spectrum and image of the sun by various teams: the NRL group (H. FRIEDMAN, R. TOUSEY, etc. . . .), the Colorado group (W. A. RENSE), the Geophysics Research Directorate (H. E. HINTEREGGER) and the Russian group. Let me only insist on a few important unsolved topics regarding the sun.

(1) There are still many unassigned emissions, especially below λ 300 Å, and we know nothing of the structure of the spectrum shortward of 80 Å.

(2) The admirable profiles of L_α obtained by NRL must be secured over longer periods.

(3) The spectrum of the corona is still unknown from λ 3000 to λ 1500.

(4) Spectroheliograms in lines other than L_α should be obtained; especially in lines of highly ionized atoms, such as OVI.

(5) High resolution profiles of lines other than L_α should be obtained.

Certainly much important work remains to be done with rockets; it should also be kept in mind that certain rockets may be equipped and launched on short notice, for the observation of sudden phenomena. Yet it appears clearly that we need the longer periods of observation provided by the satellites in order to progress substantially in solar physics. Despite all the recent observational results we have as yet no satisfactory model of the solar chromosphere and corona: this will be greatly helped when we shall have several high resolution profiles, beside L_α (especially of HeI and HeII lines, and of lines of the C, N and O-ions); when we shall know how the profiles, especially of L_α, vary with activity and location; when we shall observe the variations of the high energy emissions of the chromosphere and corona during rapid solar events. Preparations for such experiments by satellites are well under way in the U.S.

Neither shall I rediscuss the L_α-glow due to the neutral hydrogen of the outer fringe of the earth's atmosphere or to the interplanetary hydrogen. The ultraviolet spectra of the moon and planets may reveal unexpected absorptions on fluorescent emissions.

We are still very ignorant of the composition and physics of the interstellar gas, although the latter plays a dominant role in all the problems on the birth and evolution of stars. This is due to the fact that our present observations are limited to the absorption lines of a few neutral or ionized atoms and molecules which have their resonance transitions in the observable region. Actually most of our information is based on the observations of the interstellar lines of Ca^+ and Na, combined with data on the 21 cm-line of hydrogen; the other observed interstellar atoms or radicals Ca, K, Fe, Ti^+, CH, CH^+ and CN give only very weak lines. The situation will be quite different in the ultraviolet where we shall find the resonance absorption lines of C, N, O, Mg and Fe in several ionization states. There is a possibility that we may find the lines corresponding to the lowest ground state of diatomic hydrogen, λ 1108 and λ 1008. The discovery of interstellar H_2 would be of great significance.* Work is being prepared on high resolution spectroscopy of the ultraviolet interstellar lines by a team under LYMAN SPITZER, Jr.; the resolution would be of the order of 0.1 Å in the region 800–3200 Å.

In this field there is plenty of work for many astronomers and many satellites!

However the absorption continua of the interstellar hydrogen and helium cause a great disappointment in blocking completely the region λ 912–λ 20 Å. Except for the nearest stars no observation will be possible between λ 912 and about λ 20 Å. Even in the nearest stars the profiles of the Lyman lines will be affected by the interstellar Lyman lines. The L_α-emission of galaxies which have a Doppler shift greater than 1000 Km/sec will not be absorbed by the hydrogen atoms of our galaxy. We may expect to find hydrogen-rich and hydrogen-poor galaxies. If a galaxy has lost its hydrogen in a collision this hydrogen may reveal itself by its L_α emission in the space between galaxies.

The immense amount of information on stars which the region λ 921–λ 3000 will provide is obvious and has been stressed on many occasions. High dispersion ultraviolet studies of single objects will furnish a wealth of new data. Even scans of fairly low resolution will give valuable information.

The ultraviolet region is especially valuable in giving us a possibility to determine reliable abundances of the light elements in stars, nebulae, interstellar space, etc.... For these light elements, ionized as well as neutral, the lines falling in the region from 3000 Å to 1 μ are due to transitions between excited states. In many astronomical conditions we do not know the temperature with accuracy, or conditions are far from thermodynamic equilibrium. As a result accurate determinations of abundances are often not possible for H, He, C, N, O, the halogens and the noble gases. These abun-

* Raman scattering of L_α by interstellar H_2 molecules may give rise to a nebular emission at λ 1280 Interstellar H_2 may also reveal itself in infrared forbidden emission, either by the fundamental vibration-rotation band near 2.4μ, or by the pure rotational transitions: 84.392μ ($1 \rightarrow 0$, ortho to para), 28.217μ ($2 \rightarrow 0$, quadrupolar, para to para) and 42.392μ ($2 \rightarrow 1$, para to ortho).

dances which will be obtained in the far ultraviolet are important, because of their relationship to the processes of thermonuclear energy generation in stars. The new abundances may possibly also help in disentangling the picture of stellar populations, since chemical composition is linked to population type.

The ultraviolet spectra of planetary and diffuse nebulae will give us valuable information on electron densities, temperatures and atomic abundances.

Even in the relatively simple case of the far ultraviolet spectrum of the sun there remain a number of unassigned emissions. The number of puzzling lines will certainly be much greater in stellar spectra of all kinds. Hence the urgent need for the securing and analysis of spectra of many atoms and molecules of astronomical interest; also for the measurement or calculation of many transition probabilities of discrete lines and absorption coefficients in continua.

The permitted and forbidden vibration-rotation transitions of molecules (example: organic molecules) occur in the near infrared region, while the permitted and forbidden pure rotation transitions lie in the far infrared and in the millimeter-wave band. Very little astronomical work has been done in the infrared, and indeed much experimental work is also needed.

Actually much important infrared astronomical work which may be carried out from the ground or, at least, from balloon altitudes has not been performed yet. The essential reason is instrumental: progress on high sensitivity infrared receivers and adequate dispersing techniques will certainly be paralleled by astronomical observations. It is well known that certain infrared results, such as the detection of water vapor in the Cytherean atmosphere, may be obtained from balloons or high altitude aircraft. Much remains to be done in this field. Yet balloon observations will be subject to limitations: even at altitudes higher than 20 kilometers there remain appreciable telluric absorption bands; moreover the duration of the observations in balloons or aircraft is limited.

In the infrared we are chiefly concerned with fairly cool objects, but not exclusively. For example, as long ago as 1944, the desirability of obtaining the infrared spectrum of the solar corona was stressed, on account of the existence of infrared forbidden lines. Indeed new forbidden atomic lines – especially of low excitation – may be expected in nebulae and peculiar bright line stars. The infrared will also furnish important information on sources which are very heavily reddened by interstellar dust (example: infrared emission of obscured population II regions, like the galactic center), and on particular emissions or absorptions of long wavelength. Infrared stars of small mass should be discovered by an infrared scanning of the sky: indeed an "infrared celescope survey" of the sky is desirable.

The infrared spectrum of the sun, and especially of the sunspots, will certainly reveal new molecules. A fortiori we may expect new molecules, possibly polyatomic molecules, in the coolest M, S and N stars. Certain peculiar stars, such as R Coronae Borealis, deserve a special infrared spectroscopic investigation. The infrared spectra of planets will provide a wealth of information; even in the case of the moon the infrared may reveal interesting data.

Infrared observations on the interstellar matter may also bring rich rewards. One may possibly find the permitted vibration-rotation or pure rotation transitions of heteronuclear interstellar radicals such as CH, NH, OH, CN, CH^+. The forbidden H_2-lines have been suggested earlier in this report.

Infrared instruments are being prepared in various institutions for space observations, especially in view of planetary explorations. As an example, an infrared grating spectrophotometer for spectral scanning, of the Ebert type is in preparation. It will be used with a reflecting telescope and probably employ a lead selenide detector. Many areas of Mars should be observed, and the signal should provide accurate values of the wavelengths, widths and depths of the bands.

It seems probable that the interferometric techniques of infrared spectroscopy will help. This is especially the case for spectrometry by the Michelson interferometer with a Fourier transformation. The principle of this method dates back to MICHELSON himself (1891), and, actually, RUBENS and WOOD, in 1906, obtained the first spectra in the far infrared by using it. But it is the availability of the modern electronic computers which has made the method really efficient and practical. Promising astronomical applications have recently been made.

However, before going into infrared spectroscopic work from satellites it seems desirable to exploit more fully the possibilities from balloons or high flying aircraft. A balloon is relatively simple and cheap, compared with a satellite. It may carry a fairly heavy payload and the instrument may remain very stable. Observations may be made over an interval of time which is much greater than from a rocket, but shorter than a satellite. On the other hand a high flying place may be more easily available on short notice. The choice between balloon and plane may depend on the infrared problem considered. It must be made clear that, even at 30 kilometers, the infrared is not entirely free of absorption bands.

The field of radio astronomical observations by satellite is very promising also. Actually the range from 0.1 to 30 Mc/s (3000 m to 10 m) will be observable outside our atmosphere. In the first experiments it should be searched for in the sun, in the planets, also for the synchrotron radiation of our galaxy.

In stars with effective temperatures from 4000° to 9000°, most of the radiated energy lies in the observable portion of the spectrum; hence the bolometric correction is small, and may be considerably in error without modifying substantially the estimated total amount of stellar radiation. The situation is entirely different for hotter and cooler stars, since the amount of unobservable radiation (ultraviolet or infrared) may be much greater than the observable. Yet in various fields of astrophysics it is essential to know accurately the total luminosities. An example is the case of the hot stars which excite nebulae. Despite the important theoretical investigations on the far ultraviolet radiation of stars great uncertainties remain, and direct ultraviolet intensity measurements would bring most welcome data.

Far ultraviolet spectrophotometry of hot stars has already led to quite unexpected results. The amount of energy for $\lambda < 2400$ Å in the early type-stars is much smaller than is expected on the basis of the presently available models (or there may be too much energy for $\lambda > 2400$ Å!). This is an extremely important matter: additional observational data from rockets or satellites are urgently needed in the field of far ultraviolet spectrophotometry. Actually important projects are in preparation in the US, e.g. those of A. D. CODE (same vehicle as for the celescope-survey), STECHER and MILLIGAN, and others. There is much work for several teams. Indeed the work should not be confined to stars. Even the sun requires additional ultraviolet quantitative spectrophotometry, as well as measurements of the limb darkening. Similar experiments are needed also for the moon and planets.

Infrared and, especially, ultraviolet spectrophotometry will also be welcome in order to extend the law of interstellar "coloring" to a wider spectral range. This should furnish valuable information on the refractive index, the numbers and the diameters of the interstellar grains. It is known that the scattering by solid grains of radius a is a function of the ratio of a and of the refractive index: when a/λ is close to unity the function differs in a complex way from the Rayleigh law, and may even give rise to an "interstellar bluing" in the ultraviolet. The extension of the interstellar "coloring" curve over a wider spectral range would provide information which may eventually solve the problem of determining the nature and sizes of the scattering particles. Such a result would have a great number of applications, for example to the gaseous nebulae where the interstellar absorption alters the relative intensities of the bright lines. On the other hand the determination of the relative intensities of certain emission lines of nebulae may actually furnish information on the interstellar coloring; e.g. the comparison of the two forbidden lines of same upper level in [OIII] $\lambda\,2322$ ($^3P_1 - {}^1S_0$) and $\lambda\,4363$ ($^1D_2 - {}^1S_0$).

I have already mentioned previously the solar corona. Coronagraphs for satellites and rockets are in preparation at various institutions. Some are aimed at obtaining ultraviolet spectrograms, especially in the region $\lambda\,3000$–$\lambda\,1500$. Others to be placed in satellites will scan the white light corona and monitor its form and intensity over an extended period of time. Since the atmospheric diffusion will be absent the coronagraph, if properly built (perfect optics, protection from direct sunlight), could study the changes occurring in the K corona (produced by free electrons; no Fraunhofer line; strong radial polarization) and in the F-corona (due to dust scattering; presenting Fraunhofer lines; nearly unpolarized). The K- and F-coronas may be separated with polarization devices. Observations over a long period of time may possibly reveal the expulsion of the clouds of plasma which reach the earth following solar flares.

Thus far I have not stressed the possible increase in angular resolution, because this could already be reached with balloons, except if the ultraviolet is desired. It is easy to draw a long list of problems which could be treated, once a higher resolution is available: separation of close binaries, better parallaxes and proper motions, details on planets or nebulae, etc. . . .

After this systematic examination along the line of the physical principles it may be interesting to re-examine a few individual astronomical objects, and possibly add a few new problems to those which I have already mentioned.

First the *sun*. Little by little, after the first ESRO experiments with relatively modest means as to focal length and guiding accuracy (say to 1′ of arc), more sophisticated instruments should be built, involving, for example, a pointing and guiding accuracy greater than 1″ of arc. On orders from ground stations the solar telescope should point to specific regions of the solar surface and select the proper spectral range. X-ray pictures should be taken at times of solar activity. Terrestrial (especially ionospheric), solar (UV and X radiation, corona) and interplanetary (zodiacal light, . . .) observations should be carefully coordinated.

Solar system. We have already stressed the need for infrared and ultraviolet spectroscopy of the planets and the moon, and we have mentioned other problems, for example X ray-observations of the moon. The comets should not be neglected either. Their UV and infrared spectra have been predicted; it is quite certain that the corresponding observations will reveal exciting results. Experiments on artificial comets should be made. First with rockets: launching of gaseous clouds of cometary gases such as NH_3 at high altitudes, and study of the spectroscopic, photometric and geometric behavior of such clouds. Later models of cometary icy conglomerates could be satellized. Eventually a cometary probe should be sent through a cometary head and tail. Occultations of radio-objects by comets should be observed whenever possible. These cometary projects have been discussed extensively on various occasions. L. BIERMANN and R. LÜST plan to send a few kilograms of earth alkali metals in interplanetary space; this very interesting project is closely related to those on cometary physics.

The European space astronomers may possibly contribute to a survey of the sky with X ray-telescopes, using Fresnel zone plates or crossed mirrors. The present Wisconsin program of ultraviolet multicolor photoelectric photometry of bright stars and planetary or diffuse nebulae will probably be only a first pioneering endeavor which will require much additional work. The same is true for the other spectrophotometric or colorimetric programs prepared by our colleagues in the U.S. Since important ultraviolet photometric data on B-stars have been obtained with narrow band detectors mounted at the foci of 10 cm- and 15 cm-telescopes carried in rockets it will certainly be possible to gather valuable information with modest instruments.

An astronomical satellite such as the one which is at present being studied by A. W. LINES would provide a wealth of information on the ultraviolet spectra of individual stars with a resolution (1 Å) which suffices for much important study. Even smaller telescopes – with apertures of the order of 10 cm, carrying small UV dispersing systems, would lead to interesting results in this almost virgin field. I have mentioned the solar instruments for modest satellites before.

Yet, as stated in the beginning, what we are most waiting for is the big stabilized orbiting telescope which will enable us to obtain the UV and X spectra of many objects (such as Wolf-Rayet stars, planetary nebulae, interstellar matter, extragalactic nebulae, intergalactic L_α, comets, planets, etc. . . .), as well as the infrared spectra of others (cool stars, planets, comets, interstellar matter, etc. . . .).

For very refined work, such as profiles of ultraviolet stellar and interstellar lines, with a resolution of 0.1 Å from 800 to 3200 Å we shall need a telescope of the kind designed by the Princeton group: 60 cm diameter (primary f/3, cassegrain f/20). It would thus be possible to study the interstellar lines in the hot stars brighter than magnitude 5, with a precision of 1 %. Since the slit will subtend an angle of the order of 0.″1 guiding with this precision would be required. One will have to consider a telescope of similar aperture equipped with spectrometers of much lower resolution for ultraviolet studies of fainter individual objects of great interest, such as bright line stars. Still bigger orbiting telescopes on 24 hr-orbits as well as on near orbits are under study. It does not seem technically impossible to build a 125 cm-telescope with a guiding accuracy of 0.″1. But before such giant installations are launched we must gain much experience with modest instruments.