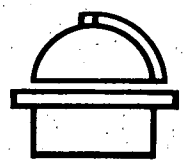
SOLAR SATELLITE PROJECT



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FINAL REPORT

OSO-VI

NAS5-9274

TO INSTRUMENT A SOLAR-POINTED SPECTROMETER-SPECTROHELIOMETER FOR OSO-G

Principal Investigator: Leo Goldberg

May 1972

INTRODUCTION

Contract NAS5-9274 between the National Aeronautics and Space Administration and Harvard College Observatory continued from June 7, 1966 through February 8, 1972. It provided for the preparation of a solar pointed spectrometer-spectroheliometer instrument for the orbiting solar observatory G, OSO-G, (also known as OSO-VI) and two and one half years of post launch data analysis.

This report completes the documentation requirements of NAS5-9274 with summaries of the hardware effort and post launch data analysis efforts. The following two sections, INSTRUMENTATION and SCIENTIFIC DATA ANALYSIS, are addressed to these two aspects of the final report requirement.

Virtually all of the scientific and technical aspects of work performed under this contract have already been reported elsewhere. The BIBLIOGRAPHY section of this report contains subcontractor documentation, in-house memoranda, scientific publications and presentations. Because so much published material is already available, this final report will be brief.

INSTRUMENTATION

The hardware effort involved two separate instrument designs. The first instrument design was subcontracted to American Science and Engineering, Incorporated (ASE) and the program proceeded through complete fabrication of a prototype instrument. Several problem areas surfaced which significantly affected schedule and cost, the most notable was the inability due to manufacturing problems to procure reliable integrated circuits. This impact upon the launch schedule and the additional constraint of limited available NASA funds compelled pursuance of a less desirable alternative, namely to refurbish the spare OSO-D instrument. The

ASE subcontract was terminated and the in-house effort entitled the OSO-G1 was begun. The historical record of the ASE subcontract was given in the monthly progress reports number 1 through 32 and in the specific ASE documents listed in the BIBLIOGRAPHY.

The OSO-D instrument was modified to improve its performance characteristics, increase its reliability, and meet spacecraft interface requirements. The more significant modifications included:

-a new high voltage power supply design with special emphasis placed upon construction of reliable transformer coils.

-reduced entrance slit size improving the spatial resultion from 60 to 35 arc seconds.

-replacing the spherical telescope mirror with an off axis paraboloid drastically reducing optical aberrations.

-interface bracket and connector box.

-improved UV detector and associated electronics.

The OSO-G1 instrument was calibrated, environmentally tested, integrated into the spacecraft and launched. The historical record of the instrumentation phase is given in progress reports number 26 through 32. Additional published material and in-house memoranda are given in the BIBLIOGRAPHY.

The OSO-VI instrument collected scientific data which were transmitted via the HCO quick-look data link for approximately nine months, from August 13, 1969 through May 12, 1970. During this period of time the instrument returned approximately 120,000 small rasters, 5500 large rasters, and 1500 spectral scans of a variety of solar features such as quiet areas, active regions, flares and filaments.

The instrument was operated continuously in a pre-programmed schedule from May 29, 1970 until July 10, 1971 for engineering evaluation of the various subsystems. Details are reported in progress reports numbers 33 through 38, however, no electronic or mechanical failures were observed.

SCIENTIFIC DATA ANALYSIS

The OSO-VI experiment has resulted in substantial advances in the available solar observations and greatly enlarged our understanding of the physics of the outer solar atmosphere. The spatial resolution of 35 arc seconds was the highest spatial resolution achieved to date in the wavelength range in question with photoelectric techniques. The versatility of the OSO spacecraft pointing system allowed us to obtain photometric spectra from any 35 arc second area of the solar disk or of features above the limb and the corona. As outlined below, we now have, for the first time, EUV spectra of numerous solar features (active regions, filaments, prominences, coronal holes), spectra of distinct regions of the quiet sun (equatorial regions, polar regions), as well as spectra of transient events such as solar flares. The small raster capability of the spacecraft has allowed us to obtain spectroheliograms

of a restricted region (7 arc minute square) with the excellent time resolution of approximately 30 seconds, thus allowing observations of the rapidly developing phenomena such as solar flares. During the instrument's lifetime of about nine months or nine solar rotations, it collected much unique data showing the temporal and spatial development of active regions and the solar corona.

Much of the data have been analyzed and reported in publications or presented at scientific meetings. The BIBLIOGRAPHY gives the updated list of reported findings however, analysis of these data continues. The photometric and aspect data, including calibration information and other aids, were forwarded to the National Space Science Data Center.

The next few paragraphs give a summary of the type of solar observations made and a brief synopsis of the resulting analyses.

QUIET SUN: The EUV quiet sun spectrum was obtained in absolute photometric intensities with the highest spatial resolution (35 arc seconds) to date. Fourier transform analysis is being applied to the spectrum to suppress noise and to allow resolution of closely spaced lines. This technique promises a greatly improved spectrum resolution. In addition, the equatorial center-to-limb variation in line intensity is being prepared from the spectra for most intense lines and continua. Such variations provide a powerful tool for the derivation of solar models. Spectra of polar regions have been analyzed to determine models of the transition layer. Studies of the Lyman continuum indicate that the density at the poles is approximately 30% less than at the equator. Lower polar densities have not

been detected below the temperature of formation of the Lyman continuum imputing these regions are features in the coronal spectrum.

A series of EUV spectra made at the center of the solar disk exhibited the chromospheric network and its extension into the corona. The network can be observed with almost identical structure, in lines formed in the chromosphere and chromospheric-coronal transition layer. At coronal heights, the network changes but some residual structure is observed in the lines of Mg X and Si XII, but little or nc evidence is found in Fe XVI.

The OSO-VI data have allowed the construction of an extended model of the solar atmosphere from the upper photosphere to the chromospheric-coronal transition layer. A non-LTE analysis was applied to the H I, C I, and S I spectra in order to interpret observations of their respective EUV continua. Most of the EUV observations can be reproduced with this model, and additional information from absolute continuous intensities at longer wavelengths in the visible and infrared.

Regions of abnormally low coronal EUV emission (so-called coronal holes) have been recognized for the first time. Detailed study of two such regions reveals that the coronal temperature is approximately 10^6 °K in contrast with the "normal" coronal temperature of 1.6 - 1.8 x 10^6 °K. The coronal electron pressure is lower than normal, by a factor of 2 to 3. Moreover, the temperature gradient in the chromospheric-coronal transition layer is lower by a factor of 4 to 10.

Diagnostic techniques for determining the electron density in regions of line formation have been developed for lines in the beryllium isoelectronic sequence. In particular, lines from C III and O V have proved valuable. Such techniques allow us to map the variation of electron density from quiet to active regions of the sun and provide a powerful diagnostic tool for other features as well. Investigation continues on the effects of structures smaller than 35 arc second of intensity gradients, of solar rotation and of spacecraft pointing jitter upon the accuracy of densities derived from line ratios.

ACTIVE REGIONS: This experiment obtained the first photometric EUV spectra at different positions in active regions, thus providing an unparalleled opportunity to study the structure and development of active regions. With the many plasma diagnostic techniques available these spectra allow us to determine the variation of temperature and density at different heights.

The enhancement of line intensities in active regions over the intensities observed in the quiet solar atmosphere provides a powerful diagnostic parameter for line identification as well as insight into line excitation processes. Two new members of the Li isoelectronic sequence (Na IX, Al XI) have been identified in this way. More line identifications will undoubtedly be found as study continues.

EUV spectroheliograms including both active and quiet solar regions can be used for mapping the spatial variation of the coronal electron density and the temperature gradient in the solar transition layer. The relationship between the coronal electron temperature, the transition-

layer temperature gradient, the EUV chromospheric emission, and the photospheric magnetic field strength was derived. In general, all of these parameters are increased in active regions when compared to their quiet sun values.

PROMINENCES AND FILAMENTS: The OSO experiment provided the first quantitative EUV spectra of prominences and filaments and enables investigation of the physical conditions within and the structure surrounding these features, at all temperature levels. Study continues on the analysis of EUV observations of prominences and filaments and the development of models for the transition region between cool prominence (or filament) material that is visible from the ground in Hα and the hot surrounding gas.

FLARES: Good time and spatial resolution of the instrument made possible extensive investigation of solar flares. Preliminary results indicate that all EUV lines brighten nearly simultaneously, thus indicating some type of rapid collective excitation during the flare. The close correlation between the EUV brightening, and impulsive X-ray and microwave bursts suggest a causal relation between emissions in these widely different wavelength regions. A model is being developed with non-thermal electrons as the primary source of plasma heating.

OTHER OBSERVATIONS: The spectroheliograms in EUV lines on the solar disk provide unique data to measure the solar rotation rate in the chromosphere, transition region, and corona. Differential rotation (variation of the rotation rate with solar latitude) was observed, but no apparent variation with height was found.

The total solar eclipse of March 7, 1970 provided an opportunity to investigate the solar atmosphere in the EUV and obtain information complementary to ground based observations. For a two-week period prior to the eclipse, EUV measurements were made on an intensive schedule, so that the development and state of the corona at the time of the eclipse was well recorded. Electron density maps from Mg X line intensities were constructed. Detailed study of coronal structure and its relation to the magnetic field configuration continues.

Properties of the terrestrial atmosphere can also be studied with the OSO experiment. The intensity variation of the Mg X 625 Å line while sighting through part of the atmosphere can be expected to supply values of the atomic oxygen density over the altitude range 350 - 450 km. Using dawn and dusk profiles, variations in exospheric temperature for August-December 1969 were correlated to solar and geomagnetic activity. Furthermore the molecular oxygen densities at lower altitudes can be obtained from the O VI 1032 Å line data gathered during the same period. Analysis of these data continues.

SUMMARY

As evidenced in the preceding summaries, the instrument returned a large quantity of well defined ultra-violet observations for a variety of solar features. Analysis of these photometric data contribute to a better definition of the solar atmospheric structure and to an increased understanding of the relationship among the various solar features. Analysis of the data, although extensive at this date, will continue for the next few years.

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NASA Contract #NAS 5-9274.

Abstract

The source function for resonance scattering normally is smaller than its equilibrium value throughout an extended atmospheric region measured from the boundary. This behavior not only can be cancelled but can be reversed by the effect of a high-temperature boundary layer of small optical thickness. The solar Lyman-continuum source function at unit Lyman-continuum optical depth is shown to be affected in this manner by temperatures in the transition region between the chromosphere and corona, when the Lyman lines are assumed to be in detailed balance. When this assumption is not made, the Lyman lines tend to reduce the Lyman-continuum intensity. The line and continuum intensities are correlated in the sense that a stronger Lyman-alpha line inhibits to a lesser extent the production of photons in the Lyman continuum.

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Bull. Amer. Astron. Soc., 2, #2 (1970) 181.

Abstract

We solve the hydrostatic equilibrium and ionization equilibrium equations for atomic hydrogen to obtain a solar model from an assumed temperature variation with height. From the model we compute a theoretical spectrum in the region 10 μ-1 cm, and compare the results with recent microwave observations. We exhibit a temperature-height distribution that leads to good agreement with these observations.

The atmospheric model also is used in the solution of statistical equilibrium and radiative transfer equations for a five-level Ca II ion. Profiles of the H and K lines, and infrared triplet lines are computed and are compared with observed profiles. The intermediate wings of H and K and the cores of the infrared lines are found to be sensitive to properties of the temperature-minimum region and the initial chromospheric rise in temperature. The temperature distribution that we adopt leads to reasonable agreement between computed and observed Ca II line profiles at the center of the solar disk.

The proposed temperature distribution has a minimum value of about $4300^{\circ}K$ at a value of τ_{5000} near 3×10^{-4}, and a steeper initial chromospheric increase than that of the Bilderberg reference model.

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NASA Grant #NGR-22-007-211.

Abstract

The rate of cooling for solar flare plasmas due to the effects of radiation cooling, expansion, thermal conduction, and the generation of hydromagnetic waves is estimated. The need for energy input subsequent to the flash phase of a solar flare is investigated. For flares not requiring subsequent heating, parameters are deduced to account for the ultraviolet and non-thermal X-ray burst and the more slowly varying soft X-ray flare. Also considered is the possibility that ohmic heating with anomalous resistivity can account for the heating necessary to produce the optical and soft X-ray emission in cases where heating is necessary.

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NASA Grant #NGR-22-007-211.

Abstract

We have made a detailed study of the formation of the strongest ultraviolet emission lines of Mg II, O I, C II, and C III in the solar atmosphere. We solve the equations of statistical equilibrium and radiative transfer for each ion, using a general computer program that is capable of solving non-LTE line-formation problems for arbitrary atmospheric and atomic models. Interpreting the results in terms of the structure of the solar atmosphere, we conclude that the HSRA atmosphere has a temperature too low by about 500 K near $h = 1100$ km and that a temperature plateau with $T_e \approx 18{,}000$ K and width close to 60 km exists in the upper chromosphere. We also investigate the structure of the solar atmosphere in the range 20,000 to 100,000 K and the effects of microturbulence on the formation of lines.

We solve some approximate analytic line-formation problems relevant to the more exact solutions derived later. In the Appendix we attempt to make the best possible fit to the Ca II K line center-to-limb profiles with a one-component atmosphere, with an assumed source function and micro-turbulent velocity.

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"Coronal Abundances and a Model of the Quiet Sun from Radio Observations"

[1]Harvard College Observatory. Solar Satellite Project.

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NASA Contract #NAS-5-9274.
NASA Grant #NGR-22-007-211.

Abstract

In this paper the best known measurements of the brightness temperature of the quiet sun are used as the basis for building up a model of the transition region. From the radio spectrum a simple equation relating electron density, electron temperature, and temperature gradient is obtained in a straightforward way. By means of this equation and known values of the total intensity of ultraviolet lines, absolute abundances are calculated that are in agreement with previous determinations. Finally, with thermal equilibrium assumed, the equation relating electron density, electron temperature, and temperature gradient is solved, yielding a model of the transition region and low corona. The conductive flux turns out to be constant in the upper transition region, its value being dependent on $T_c^{5/2}$ (T_c = coronal temperature). If the value of T_c derived from the radio observations is adopted, the value of the conductive flux turns out to be about four times smaller than the value based on the analysis of the ultraviolet lines. It is suggested that agreement between radio and UV models can be obtained if a nonuniformly emitting sun is assumed.

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Abstract

This report gives a comprehensive introduction to the Harvard College Observatory (HCO) Orbiting Solar Observatory (OSO-G1) instrument. This instrument is scheduled to orbit with the OSO-G spacecraft in the summer of 1969. The instrument is a spectrometer and spectroheliometer designed to examine the extreme ultraviolet (EUV) portion of the sun's electromagnetic radiation.

This report presents a summary of the scientific objectives of the instrument, a detailed description of the instrument's components, a list of instrument-spacecraft interface parameters, and a description of appropriate handling, storage, inspection, and testing procedures. The report attempts to give sufficient technical background material to make it useful to persons of varied technical knowledge. The report is also intended to be used as a major source of information for persons actually handling the instrument.

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Abstract

The Harvard College Observatory spectroheliometers aboard OSO-IV and OSO-VI obtained extreme ultraviolet (300-1400 Å) spectra of restricted regions on the solar disk. The spatial resolution of 1 arc minute (OSO-IV) and 35 arc second (OSO-VI) and the offset pointing capability of the spacecraft allowed spectral scans to be made of both the quiet sun and active regions. The averaged quiet sun spectrum from OSO-IV (Dupree, A.K. and Reeves, E.M., Ap.J., May 1971) and selected spectral scans from OSO-VI have been analyzed to determine relative coronal abundances of carbon, nitrogen, oxygen, neon, sodium, magnesium, aluminum, silicon, and sulfur. This analysis also leads to a determination of the temperature gradient in the transition region from which the temperature profile can be constructed.

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NASA Contract #NAS-5-9274.

Abstract

Spectral scans of active regions have been obtained with the Harvard photoelectric spectrometer-spectroheliometer by using the offset-point capability of the OSO-VI spacecraft. The wavelength interval of the instrument includes the resonance lines of a variety of elements and ionization stages: H I to Fe XVI. Spectra of a number of evolving active regions have been obtained. The paper will present wavelength identifications, a discussion of line intensities in active regions, and a comparison with the spectrum of the quiet sun.

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NASA Contract #NAS-5-9274.
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Abstract

A standard two-level approximation is found to be inadequate to analyze the intensities of multiplets from ions of the Beryllium sequence (i.e., C III, N IV, O V, Ne VII, Mg IX etc.). Statistical equilibrium calculations show that each multiplet in an ion has a different dependence on electron density. Consequently, ratios of multiplet intensity may be used as a direct measure of the electron density in the region of line formation. Theoretical intensity ratios are used in conjunction with far ultraviolet spectra from the Harvard experiment on OSO-VI to violet spectra from the Harvard experiment on OSO-VI to derive electron densities in both active and quiet regions of the solar atmosphere. The implications of these results upon abundance determinations will also be discussed.

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Abstract

Solar ultraviolet and X-radiation arriving at the Earth is emitted mainly by highly-charged ions in the outer layers of the Sun, where departures from thermodynamic equilibrium are extreme. Hence the diagnosis of physical conditions from spectral intensities entails the use of accurate cross sections for a variety of physical processes governing the excitation and ionization of emitting ions. Now that the full potential of satellites for solar data acquisition has begun to be realized, the need for atomic data of all kinds is more acute than ever before. In this review, I shall illustrate the importance of laboratory and theoretical investigations for the analysis of solar ultraviolet and X-ray data by referring to five problems to which space experimenters are currently devoting a great deal of attention:
(1) the temperature minimum at the interface between the photosphere and the chromosphere,
(2) the temperature and density profiles of the low chromosphere,
(3) the transition zone at the chromosphere-corona interface,
(4) the corona,
(5) solar flares.

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NASA Contract #NASw-184.

Abstract

A high voltage failure occurred in the Harvard Solar Spectrometer-Spectroheliometer experiment aboard the OSO-IV spacecraft five weeks after launch. This failure is analyzed and traced to a sequential process comprising two modes which took place within the high voltage power supply. The primary failure was within the transformer. The test history of this and previous instruments is discussed, including pertinent work on sub-assemblies and modules. This testing included extensive thermal-vacuum work and corona and plasma exposure. Preventive measures that are being taken on a later experiment to fly in August 1969 are discussed, including pertinent recommendations in manufacturing technique, qualification and acceptance tests, and an overload switch that automatically turns off the high voltage power supply.

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NASA Contract #NAS-5-9274.

Abstract

The photoelectric spectrometer-spectroheliometer designed by Harvard College Observatory was successfully flown aboard Orbiting Solar Observatory VI (OSO-VI). The experiment and its operational capabilities have been described. The instrument consists of a telescope mirror (off-axis parabola) illuminating the entrance slit plate of a normal-incidence spectrometer that is equipped with a solar-blind magnetic electron multiplier. Entrance and exit slits of the spectrometer give a spatial resolution of 35 arc sec and a spectral resolution of better than 2 Å, over the wavelength range 280-1370 Å. By combining the experiment operating modes with the spacecraft pointing and raster modes, spectra at any selected positions on or near the solar disk, as well as large and small spectroheliograms of many solar features, can be obtained. Observations made from 13 August 1969 to date comprise 1400 wavelength scans, 1800 large and 95 000 small raster pictures. We studies spectra at several positions in approximately 15 different active regions. Spectra of both active and quiet regions have been obtained at a number of positions on the disk, near and beyond the limb. Spectra and small spectroheliograms of prominences, of filaments, and of areas where the coronal emission is very low have also been secured. Four active regions (McMath Nos. 283, 351, 385, and 432) that produced numerous subflares as well as some class 1 and class 2 flares were monitored almost continuously as they crossed the solar disk.

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Harvard College Observatory. Solar Satellite Project. T.R. #19. June, 1971.

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NASA Contract #NAS5-9274.

Abstract

A flare surge at the limb was observed in C III 977 Å by the Harvard OSO-6 spectroheliometer. The kinematic behavior of the surge is the same in C III and in Hα. The amount of C III emission is consistent with a model in which the C III ions occupy sheaths with thickness ∿100 km surrounding the cooler Hα-emitting threads. The mass of the material containing C III ions is about 10^{-2} of the mass emitting Hα.

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NASA Contract #NAS-5-9274.

Abstract

The first part of the thesis is a history of observations of solar prominences. The importance of new types of instruments for the study of prominences is stressed. The similarity is noted between Secchi's discovery in 1860 that some prominences were recorded on photographs in the near ultraviolet even though they did not appear to the eye in the visible part of the spectrum and the fact that the Harvard OSO-6 instrument observed a prominence in the extreme ultraviolet which was not observed in the visible.

The second part of the thesis contains analyses of three groups of extreme ultraviolet observations. First, the surge of September 15, 1969, observed in C III 977Å with OSO-6, is examined; the kinematic behavior was the same in C III and in Hα.

Second, OSO-4 spectroheliograms have been examined to yield models of prominences. Third, spectral scans from OSO-6 have been used to derive temperatures and pressures at the centers of prominences. It is concluded that both surge and quiescent prominences emit most of their ultraviolet from thin layers surrounding cool threads. The temperature is about 10,000°K.

Macar, P.J.; Rechavi, J.; Huber, M.C.E.; Reeves, E.M.

"Solar-Blind Photoelectric Detection Systems for Satellite Applications"

Harvard College Observatory. Solar Satellite Project. T.R. #9. July, 1969.

Applied Optics. 9, #3 (Mar, 1970) 581-593.

NASA Contract #NASw-184 and NAS-5-9274.

Abstract

The characteristics of open Magnetic Electron Multipliers (MEM) with continuous dynode and field strips are discussed in view of their use in satellite borne detection systems. Special emphasis is placed on selection, thermal stabilization, calibration, and long-time performance of the detectors. Practical aspects of the design of satellite borne detection systems, such as monitoring capabilities, immunity to charged particles, and electrical breakdown are also described.

Laboratory studies with fast electronics showed that the useful linear range of an MEM is restricted, because of afterpulses. Most characteristics of MEM's reported in the literature appear to be due to the use of relatively slow electronics that did not resolve the afterpulses. Statistical studies of afterpulses are reported and a tentative explanation for the generation of afterpulses is outlined.

Munro, R.H.; Dupree, A.K.; Withbroe, G.L.

"Electron Densities Derived from Line Intensity Ratios: Beryllium Isoelectronic Sequence"

Harvard College Observatory, Solar Satellite Project. T.R. #23. February, 1971.

Solar Physics, 19, #2 (Sept. 1971) 347-355.

NASA Contract #NAS5-9274.

Abstract

A direct method for determining electron densities from emission line intensities of ions in the beryllium iso-electronic sequence is described and then applied to the analysis of extreme ultraviolet C III and O V spectra from both quiet and active areas in the solar transition region. The results are consistent with a value of $N_e T_e = 6 \times 10^{14}$ cm^{-3}K for the quiet sun at temperatures of 5×10^4 to 3×10^5K. Electron densities are approximately five times greater in active regions than in the quiet sun.

Munro, R.H.; Withbroe, G.L.

"Properties of a Coronal "Hole" from EUV Observations"

Harvard College Observatory. Solar Satellite Project. T.R. #31.

Submitted to the American Astronomical Society meeting, University of Maryland, College Park, Md., April 4-6, 1972.

NASA Grant #NGR-22-007-211.

Abstract

A coronal "hole" is characterized by significant deficiency in the intensity of coronal emission lines, yet there is little change in lines and continua formed below 800,000 K except for the He I and II emission features. Comparison of the hole with the normal quiet sun indicates that the electron pressure is reduced by a factor of three, the coronal temperature is lower by 600,000 K, and the temperature gradient in the chromospheric-coronal transition layer is less steep by an order of magnitude. The apparent insensitivity of the lines formed in the transition layer to the physical conditions of the hole imply that the conductive flux from the corona is proportional to the square of the electron pressure.

Noyes, R.W.; Withbroe, G.L.

"The Solar EUV-Emitting Plasma"

Harvard College Observatory. Solar Satellite Project.

Presented at the Third Symposium on Ultraviolet and X-Ray Spectroscopy of Astrophysical and Laboratory Plasmas, Utrecht, The Netherlands, August 24-26, 1971.

Space Science Review (to be submitted).

NASA Contract #NAS-5-9274.
NASA Grant #NGR-22-007-211.

Noyes, R.W.; Withbroe, G.L.; Kirshner, R.P.

"Extreme Ultraviolet Observations of Active Regions in the Chromosphere and Corona"

Harvard College Observatory. Solar Satellite Project. T.R. #14. October, 1969.

Presented at conference at High Altitude Observatory, National Center for Atmospheric Research, Boulder Colorado, August 25-27, 1969.
In: Proceedings Chromosphere-Corona Transition Region. Boulder, Colorado: NCAR, December 1969, pp. 125-149.

Solar Physics, 11 (1969) 388-98.

NASA Contract #NASw-184.

Abstract

New observations of solar active regions have been obtained by the Harvard College Observatory EUV spectroheliometer aboard the OSO-IV spacecraft. From the observations we have determined the enhancement in active regions of the emission from ions formed at various temperatures in the chromosphere and corona. The results are in accord with a simple model of active regions, for which the active region pressure is about five times the quiet sun pressure; the temperature gradient in the transition zone is about five times the quiet sun value; and the coronal temperature above active regions is slightly increased.

Noyes, R.W.

"Ultraviolet Studies of the Solar Atmosphere"

Harvard College Observatory. Solar Satellite Project.

Ann. Rev. Astron. Astrophys., 9 (1971) 209-236 (ed. by Leo Goldberg, David Layzer and John G. Phillips, Palo Alto, Calif: Annual Reviews Inc. 1971).

NASA Contracts #NASw-184, NAS-5-9274.

Abstract

Extreme ultraviolet (EUV) solar observations from space have made great progress in recent years, largely from the development of new instrumentation with improved spatial or spectral resolution. These observations advances have allowed EUV solar astronomy to progress from a young and largely qualitative discipline to a mature and quantitative one. Different investigations now appear to be converging on a common description of the average physical conditions in the solar atmosphere. At the same time, high resolution observations have begun to reveal the scarcely surprising existence of inhomogeneous structure, both in the active and in the quiet atmosphere. Solar EUV research in the next few years will undoubtedly focus on the physical nature of the inhomogeneous solar atmosphere, in order to determine for individual features the run of temperature, density, magnetic field, thermal conduction, mechanical flux, and other dynamic behavior. This in turn may be basic for understanding the physical nature of the atmosphere as a whole.

Although we will discuss below the evidence for inhomogeneous structure and some of its implications, the main emphasis of this review will be on the mean structure of the solar atmosphere, in both quiet and active regions. Of course, the mean solar atmosphere, like all idealizations, is in some sense fictitious. Nevertheless, it serves as a very useful zero-order framework for investigation of the problem of overall energy balance in the solar atmosphere, and, we hope, will be a valid starting point for the more sophisticated studies that surely will follow.

Noyes, R.W.

"Models of the Quiet and Active Solar Atmosphere from Harvard OSO Data"

Harvard College Observatory. Solar Satellite Project.

Presented at the NATO Advanced Study Institute on the Physics of the Solar Corona, Cavouri-Vouliagmei, Greece, September, 1970.
In: Macris, C.J. Physics of the Solar Corona. Dordrecht, Holland: D. Reidel Publishing Co., 1971, pp. 192-218.

NASA Contracts #NASw-184, NAS-5-9274.

Reeves, E.M.; Parkinson, W.H.

"The Contribution of Active Regions to the Total EUV Solar Flux"

Harvard College Observatory. Solar Satellite Project. T.R. #32. March, 1972.

NASA Contracts #NASw-184, NAS 5-9274.
NASA Grant #NGR-22-007-211.

Abstract

The paper discusses the contribution of active regions to the flux from the entire solar disk as measured in the extreme ultraviolet region from 300-1400Å. The contribution is measured as the ratio of the signal from the active regions on the disk and on the limb, reduced by the average background in the disk or limb, to the signal from the whole sun. The contribution from active regions as observed from the data from the OSO 4 satellite is found to be approximately constant at 10 per cent for lines formed between 10,000° and 500,000°, that is for lines of the chromosphere and transition region. As the temperature increases into the corona, the contribution from active regions rises quickly to approximately 50 per cent in the high corona at 3.5×10^6 °K. The data from the OSO 6 satellite in which the spatial resolution was increased from 1 arc minutes to 35 arc seconds are also discussed and indicate a slightly larger contribution from active regions.

Reeves, E.M.; Parkinson, W.H.

"EUV Observations of the Chromospheric Network"

Harvard College Observatory. Solar Satellite Project.
T.R. #28. December, 1971.

Solar Physics,

NASA Contract #NAS 5-9274.
NASA Grant #NGR 22-007-211.

Abstract

Extreme ultraviolet observations of a quiet region of the sun on August 18, 1969 with the Harvard spectroheliometer on OSO-VI indicate that the chromospheric network can be observed in lines of the chromosphere and transition region ($T = 8.4 \times 10^5$ K) with almost identical structure. At coronal heights, the network changes but some residual structure can still be discerned in Mg X and perhaps Si XII ($T = 2.3 \times 10^6$ K), although there is little or no evidence remaining in Fe XVI ($T = 3.5 \times 10^6$ K).

Reeves, E.M.; Dupree, A.K.; Goldberg, L.; Huber, M.C.E.; Noyes, R.W.; Parkinson, W.H.; Withbroe, G.L.

"OSO-VI: Surges, Flares, and the Development of Active Regions"

Harvard College Observatory. Solar Satellite Project.

Presented at 131st Meeting of American Astronomical Society, New York, December 8-11, 1969.

Bull. Amer. Astron. Soc., 2 (1970) 215 (Abstr.).

NASA Contract #NAS-5-9274.

Abstract

The small raster mode of the OSO-VI spacecraft provides spectroheliograms over a 7 min of arc field at 30-sec intervals in single-selected wavelength in the instrument wavelength range. Observations of a small flare in an active region on the disk will be presented together with a sequence showing a surge on the limb observed in C III. Full sun spectroheliograms over a range of ionization energies will be used to illustrate some other aspects of the observations.

Reeves, E.M.; Huber, M.C.E.; Withbroe, G.L.; Noyes, R.W.

"Real Time Control of the Observing Program of an Orbiting Solar Observatory"

Harvard College Observatory. Solar Satellite Project.

Presented at IAU Symposium No. 41, Munich, Germany, August 10-14, 1970.
In: LaBuhn, F. & Lüst, R. Proceedings of IAU Symposium No. 41, New Techniques in Space Astronomy. New York: Springer-Verlag, 1971, pp. 336-347.

NASA Contract #NAS-5-9274.

Abstract

This paper departs somewhat from the usual interpretation of the subject of this symposium, in which instrumental techniques normally deal with diverse aspects of experiment design or construction. Rather, we will concern ourselves here with some innovations in the ground control optimization of the modes of data acquisition once an instrument is in orbit. Although the fullest possible utilization of the data gathering capability of a device is of vital interest to the success of the experiment and the mission, the subject has not been discussed at length in the open forum of scientific meetings. The planning of the data gathering and processing aspects of a mission must receive as careful attention as instrument design and test if the characteristics of the instrument are to be fully exploited.

In this paper we discuss a specific example, namely, the Harvard experiment on OSO 6, although the elements of our problem apply to many types of experiments in space, particularly those in which the experimenter is required to choose from among many possible experiment modes in direct response to the telemetered data and the specific conditions at the source (in this case the Sun). Extensive preflight planning of diverse series of data gathering patterns is assumed to have been fulfilled, and the purpose of the real-time or near-real time mission control is to complete as many of the objectives as possible, in the fashion best suited to conditions on the Sun at the time, and to assess the quality of the data gathered in order to determine whether the observations are of the necessary quality and quantity to satisfy the observing objective.

Reid, R.H.G.; Withbroe, G.L.

"The Density and Vibrational Distribution of Molecular Oxygen in the Lower Atmosphere"

Harvard College Observatory. Solar Satellite Project. T.R. #16. April, 1970.

Planet. Space Sci., 18, (1970) 1255-1265.

NASA Contracts #NASw-184; #NAS-5-9274.
NASA Grant NGL22-007136

Abstract

Observations of solar ultraviolet radiation from the satellite OSO-IV are analysed. The atmospheric absorption of 1032 Å (O VI) can be reproduced theoretically by a static diffusion model of the O_2 density above 120 km with a density of $(3.6 \pm 0.4) \times 10^{10}$ cm^{-3} at 120 km. The atmospheric absorption of 1335 Å (C II) appears to require an effective absorption cross section of O_2 that decreases with increasing altitude. The decrease could result from an increasing vibrational development of O_2 such that the fraction of molecules in the ground vibrational state is less than about 0.9 at 130 km, 0.7 at 150 km and 0.5 above 160 km.

Simon, G.W.; Noyes, R.W.

"Observations of the Coronal Network"

Harvard College Observatory. Solar Satellite Project.

Presented at IAU Symposium No. 43, Paris, France, September, 1970.
In: Howard, R. ed. Solar Magnetic Fields. Dordrecht, Holland: D. Reidel, 1971, pp. 663-.

NASA Contracts #NASw-184, NAS 5-9274.

Simon, G.W.; Noyes, R.W.

"Observed Heights of EUV Lines Formed in the Transition Zone and Corona"

Harvard College Observatory. Solar Satellite Project. T.R. #27. October, 1971.

Solar Physics,

NASA Contracts #NASw-184, NAS5-9274.

Abstract

The heights of formation of a number of extreme ultraviolet lines in active regions have been measured from OSO-IV spectroheliograms. Using the Lyman continuum at 2000 km above the white light limb as a reference, we find heights for He I, He II, C III, N III, O IV, O VI, Ne VIII, Mg X, Si XII, Fe XV and Fe XVI that are in approximate agreement with models based on analysis of EUV emission intensities. The height of C II is anomalously high. The accuracy of measurement is typically about 2000 km. The data suggest that the transition zone is less steep than calculated from EUV emission intensities; however, higher resolution observations are necessary to resolve the discrepancy.

Simon, G.W.; Noyes, R.W.

"Observed Heights of EUV Lines Formed in the Transition Zone and Corona"

Harvard College Observatory. Solar Satellite Project.

Paper presented at American Astronomical Society meeting, Solar Physics Division, Huntsville, Alabama, Nov. 17-19, 1971.

Bull. Amer. Astron. Soc., 3, #2, Pt.II (1971) 264 (Abstr.).

NASA Contract #NAS-5-9274.
NASA Grant NGR 22-007-211.

Abstract

The heights of formation of a number of EUV lines in active regions have been measured from OSO-IV spectroheliograms. From a least square fit of these data we find Ly β 1026, Ly ε 938, Ly γ 972, and the Ly continuum at 2000 km above the white light limb, He I 584, He II 304, C II 1335, and C III 977 at 3000 km, N III 991 and O IV 791 at 4000 km; O VI 1032 at 5000 km, Ne VIII 770 at 8000 km; MgX 625 at 11000 km, Si XII 499 at 13000 km, Fe XV 417 at 14000 km, and Fe XVI 361 at 15000 km. Measurement errors are typically 2000 km, and all the quoted figures are rounded to the nearest 1000 km.

Simon, G.W.; Noyes, R.W.

"Solar Rotation as Measured in EUV Chromospheric and Coronal Lines"

Harvard College Observatory. Solar Satellite Project.

Presented at the American Astronomical Society meeting, Solar Physics Division, Huntsville, Alabama, Nov. 17-19, 1971.

Bull. Amer. Astron. Soc., 3, #2, II (1971) 263 (Abstr.).

NASA Contract #NAS-5-9274.
NASA Grant #NGR 22-007-211.

Abstract

Active regions were followed across the disk on OSO-IV spectroheliograms. Using the Ly Continuum, MgX, and Si XII, all the observations showed differential rotation, and an increase in the equatorial rotation with height. The sidereal rate is 14.3 degrees/day in the Ly Continuum and 15.0 degrees in MgX, with measurement errors of 0.6 to 1.1 degrees/day.

Vernazza, J.E.; Noyes, R.W.

"Inhomogeneous Structure of the Solar Chromosphere from Lyman-Continuum Data"

Harvard College Observatory. Solar Satellite Project. T.R. #25. September, 1971.

Solar Physics, 20, #2 (Nov. 1971) 514 (Abstr.).

NASA Contracts #NASw-184, NAS5-9274.

Abstract

We describe a new model of the chromosphere based on Lyman continuum observations by Harvard spectrometers aboard the satellites OSO 4 and OSO 6. The model assumes (a)that a random distribution of optically thick inhomogeneities overlies a plane-parallel homogeneous atmosphere, and (b)that the Lyman continuum in the chromosphere is optically thick and the only significant opacity source between 600 and 912 Å.

The temperature, gas pressure, electron pressure, particle densities, and b_1 (the hydrogen ground-state departure coefficient) are calculated as a function of height in the chromosphere.

The model reproduces the observed quiet-region intensities in the Lyman continuum from 912 to 750 Å, the millimeter brightness temperatures and the center-to-limb variation in the Lyman continuum. The inhomogeneous structures, which we believe to be spicules, are inferred to be optically thick in the Lyman continuum and to have a source function below that of the mean chromosphere. If they are also optically thick in the free-free (millimeter) continuum and cooler than about 5090 K, they could produce the observed limb darkening at 1 and 3 mm. Such low temperatures are at odds with current spicule models, but could exist in the cores of spicules.

The Lyman-continuum emission shortward of 750 Å shows an excess emission over the predicted by the above model. This is found to be consistent with the existence of a temperature plateau with T $\sim$ 22000 K in the very high chromosphere.

Vernazza, J.E.; Noyes, R.W.

"On the Difference between the Poles and Equator in the Region of Formation of the Lyman Continuum"

Harvard College Observatory. Solar Satellite Project.

Submitted to the 137th AAS Solar Physics Division meeting on Flares and Particle Acceleration--Space Observations of EM Radiation, College Park, Maryland, April 4-6, 1972.

Bull. Amer. Astron. Soc., to be published.

NASA Contract #NAS-5-9274.

Abstract

From the analysis of Harvard OSO IV Lyman continuum spectroheliograms, differences in brightness and color temperature between poles and equator are found. These differences are interpreted as a result of a lower chromospheric density and a smaller temperature gradient at the poles, as compared with the equator. Two models, one for the poles and one for the equator, giving temperature and density as a function of height explain the Lyman continuum observations. At $\tau_{912A^2} = 0.1$, the polar pressure is 0.10 dyne/cm^2. The differences begin in the middle chromosphere around 1300 km above $\tau_{5000} = 1$, and increase toward the transition zone.

Wang, Y.M.

"Temperature Density Structure in Two Regions of the Solar Atmosphere from OSO Observations"

Harvard College Observatory. Solar Satellite Project.

Senior Honors Thesis, Harvard College, 1971.

NASA Contracts #NAS-5-9274, NASw-184.

Abstract

This thesis is in two entirely distinct parts. The first part is an attempt to determine the temperature-density structure of the chromospheric-coronal transition region and low corona from OSO-IV spectroheliograms of four ions formed in this region; the second part is an attempt to determine part of the temperature structure of the low chromosphere from OSO-VI observations of the Carbon I continua. These two regions of the solar atmosphere have little in common. For instance, the radiation emitted by the chromospheric-coronal transition region and low corona is optically very thin because of the steep temperature gradient and/or low densities in this region; this allows certain approximations for the source function and makes the radiative transfer problem very simple. On the other hand, the radiation emitted by the low chromosphere is optically thick, but not enough so to allow an LTE approximation; thus a complex non-LTE situation must be handled. In the first part, then, it was much easier to deal directly with the structure of the region.

Watts, R.N.,Jr.

"Far-Ultraviolet Solar Observatory"

Smithsonian Astrophysical Observatory.

Sky and Telescope, 38, #6 (December 1969) 290-291.

NASA Contracts #NASw-184, NAS-5-9274.

Withbroe, G.L.

"The Chemical Composition of the Photosphere and the Corona"

Harvard College Observatory. Solar Satellite Project.

Presented at symposium held at Harvard College Observatory, Cambridge, Massachusetts, April 8-9, 1971.
In: Gebbie, Katherine B. The Menzel Symposium on Solar Physics, Atomic Spectra and Gaseous Nebulae, NBS, SP-353, August 1971, pp. 127-135.

NASA Contract #NAS-5-9274.
NASA Grant #NGL-22-007-006.

Withbroe, G.L.

"The Derivation of Temperature Gradient and Electron Density Maps from EUV Spectroheliograms"

Harvard College Observatory. Solar Satellite Project. T.R. #29. January, 1972.

Solar Physics, in press.

NASA Contract #NAS-5-9274.
NASA Grant #NGR 22-007-211.

Abstract

We discuss spatial variations in electron density at the base of the corona and in the temperature gradient in the chromospheric-coronal transition layer as determined from analysis of maps constructed from Mg X and O VI spectroheliograms. Both the mapping techniques and results of analyzing EUV spectra from OSO-VI observations are presented. Comparisons of these maps with photospheric magnetograms and spectroheliograms made in chromospheric EUV lines and continua indicate that the electron density and temperature gradient in the transition layer tend to be enhanced in areas where the photospheric magnetic field and chromospheric EUV emission are enhanced. The coronal electron density, transition layer temperature gradient, chromospheric emission, and photospheric magnetic field strength relationships are derived.

Withbroe, G.L.

"Observatory, Astronomical"

Harvard College Observatory. Solar Satellite Project.

In: The McGraw-Hill Yearbook of Science and Technology. New York: McGraw-Hill, 1971, p. 300.

NASA Contracts #NASw-184, NAS 5-9274.

Withbroe, G.L.

"Solar XUV Limb Brightening Observations and Interpretation. II: Lines Formed in the Chromospheric-Coronal Transition Region"

Harvard College Observatory. Solar Satellite Project. T.R. #13. November, 1969.

Presented at the High Altitude Observatory, National Center for Atmospheric Research Conference on the Solar Chromosphere-Corona Transition Region, as "Limb-brightening Observations and Determination of Density-Temperature Models", Boulder, Colorado, August 25-27, 1969, pp. 93-124.

Solar Physics, 11, (1970) 208-221.

NASA Contract #NASw-184.

Abstract

Limb brightening of XUV lines of the ions C III, N III, N IV, O III, O IV, O V and Si IV is compared with that predicted by a modified version of a coronal model developed by Dupree and Goldberg (1967). Systematic differences between the predicted and observed limb brightening are found. These differences can be eliminated by introducing into the model the effects of spicules that extend up into the chromospheric-coronal transition region. The spicules are assumed to be opaque to radiation between 500 and 900A because of absorption in the hydrogen Lyman continuum.

Withbroe, G.L.

"A Comparison of Solar EUV and K-Coronameter Intensity Measurements"

Harvard College Observatory. Solar Satellite Project. T.R.#22. April, 1971.

Solar Physics, 18, #3 (July, 1971) 458-473.

NASA Contracts #NASw-184, NAS5-9274.

Abstract

EUV data from the Harvard experiment on OSO-IV are compared with K-coronameter measurements in order to yield to hydrogen. Within the uncertainties of the analysis, these coronal abundances are in agreement with corresponding photospheric values.

Characteristics of the emission observed above the solar limb in four EUV lines, Si XII λ499, Mg X λ625, Ne VIII λ770, and O VI λ1032, are discussed. The mean temperature of the corona, derived from the ratios of the intensities of Si XII λ499 and Mg X λ625, is 1.8 million K. There do not appear to be significant temperature differences between regions with low and those with high EUV intensities, suggesting that the EUV emission from the lithium-like ions depends primarily on the integral of n_e^2 along the line of sight.

Withbroe, G.L.; Noyes, R.W.

"Solar EUV Observations: Lines of Lithium-like Ions"

Harvard College Observatory. Solar Satellite Project.

Presented at AAS Meeting, Division of Solar Physics, Huntsville, Alabama, November 17-19, 1970.

Bull. Amer. Astron. Soc., 3, #2, Pt.II (1971) 265-266 (Abstr.).

NASA Contract #NAS-5-9274.

Abstract

A preliminary analysis of OSO-VI observations of extreme ultraviolet (EUV) lines from the lithium isoelectronic sequence has shown that: (1) Differences in the intensities of the Mg X λ625 and Si XII λ499 lines from point to point on the solar disk appear to be caused primarily by differences in the density in the lower corona. (2) The coronal temperatures measured by the ratios of these lines are usually between 1.6 and 2.0 million ^{o}K, with a mean value of 1.8 million ^{o}K for both quiet and active areas. (3) The geometrical thickness of the chromospheric-coronal transition layer decreases with increasing pressure in the transition region until it reaches a minimum value and then it remains at the minimum thickness for further increases in pressure. The thickness in active areas is 3 to 5 times smaller than in quiet areas. (4) The chromospheric EUV emission does not appear to be directly correlated with the amount of heat conducted from the corona to the chromosphere.

Withbroe, G.L.; Dupree, A.K.; Goldberg, L.; Huber, M.C.E.; Noyes, R.W.; Parkinson, W.H.; Reeves, E.M.

"Coronal Electron Density Maps from March 7, 1970, Derived from Mg X λ625 Spectroheliograms"

Harvard College Observatory. Solar Satellite Project.

Presented at IAU Symposium on the Total Solar Eclipse of 7 March 1970, Seattle, Washington, June, 1971.

Solar Physics, in press.

NASA Contract #NAS 5-9274.

Wood, A.T.Jr.; Donnelly, R.F.*

"EUV Emissions of Solar Flares: A Comparison of OSO 6 Observations and SFD's"

Harvard College Observatory. Solar Satellite Project.
*American Science & Engineering Co., Cambridge, Mass.
Submitted to the 137th AAS Solar Physics Division meeting on Flares and Particle Acceleration--Space Observations of EM Radiation, College Park, Maryland, April 4-6, 1972.

Bull. Amer. Astron. Soc., to be published.

NASA Contract #NAS-5-9274.
NASA Grant #NGR 22-007-211.

Abstract

The time structure and energy flux of EUV emissions of solar flares observed with the Harvard College Observatory spectroheliograph aboard OSO 6 were compared with the 10-103Å energy flux enhancement deduced from SFD observations. The average ratio of the emission line flux enhancement to the 10-103Å flux enhancement during the impulsive rise of these emissions is 0.04 for C II 1335Å (2 flares), 0.02 for O IV 554Å 1 flare), 0.07 for O VI 1032Å (11 flares) and 0.003 for Mg X 625Å (4 flares). The C II emission rose rapidly like the 10-1030Å burst. The time structure of the O IV, O VI and Mg X flares generally showed good agreement with the 10-1030Å enhancements to within the time resolution of the OSO 6 data (∿1/2 min). The Mg X 625Å bursts studied were dominated by the impulsive component of the flares whereas OSO 3 EUV observations (L.A. Hall, Solar Phys., 21, 173.) indicated that coronal lines including Mg X were dominated by the slow component of the flares. An observational upper limit was determined for any contribution to the 10-1030Å flux enhancement from synchrontron emission. An empirical two-component model for the EUV flare emissions will be discussed.

C-2

Wood, A.T. Jr.; Noyes, R.W.; Reeves, E.M.

"EUV Observations of Solar Flares"

Harvard College Observatory. Solar Satellite Project.

Paper presented at American Astronomical Society Meeting, Division of Solar Physics, Huntsville, Alabama November 17-19, 1970.

Bull. Amer. Astron. Soc., 3, #2, Pt.II (1971) 266 (Abstr.).

To be published.

NASA Contract #NAS-5-9274.

Abstract

The Harvard College Observatory experiments flown on the satellites OSO-IV and OSO-VI have, for the first time, provided spatially resolved observations of solar flares in the extreme ultraviolet. Several hundred flares have been observed from both OSO-IV and OSO-VI, with time resolutions as short as 30 seconds. Analysis of these observations shows 1)the flare intensity usually reaches maximum in the EUV 2-3 minutes before Hα, and also 2-3 minutes before the soft x-rays; 2)the flare enhancement peaks for spectral lines normally formed in the solar transition zone; 3)the energy released in EUV lines in a flare is typically 3-4 orders of magnitude less than the energy released in Hα. We will propose a new model for the flare phenomenon which accounts for most of the observations.

Wood, A. T., Jr.

"Solar Flares in the Extreme Ultraviolet"

Harvard College Observatory. Solar Satellite Project.

Presented at 135th Meeting of American Astronomical Society, Amherst, Massachusetts, August 24-27, 1971.

Bull. Amer. Astron. Soc., 3, #3, Pt.I (1971) 382 (Abstr.).

NASA Contract #NAS-5-9274.
NASA Grant #NGR-22-007-211.

Abstract

Further observations of solar flares in the extreme ultraviolet ($\lambda\lambda$ 300A - 1300A) from OSO-4 and OSO-6 are reported. Correlations of EUV data with available Hα, X-ray, radio and SFD observations have been performed. The principal results of these studies are: 1)when a non-thermal X-ray burst is observed, the EUV, Hα, X-ray and radio burst all reach maximum intensity simultaneously, in agreement with the observations of Kane and Donnelly (1971 Astrophys. J., 164, 151.) and Parks and Winckler (1971 Solar Phys. 16, 186.); 2)the EUV peak intensity is correlated with burst rise rate and also with the reported Hα class; 3)detailed agreement of time structure in the EUV and other spectral ranges with time scales longer than 30 seconds has been observed. We conclude that the EUV is excited quasi-thermally in a high density ($N_e > 10^{10} cm^{-3}$) plasma which is heated by the collision of the flare-accellerated electrons responsible for the X-ray and radio burst.

Wood, A.T. Jr.

"EUV Emissions of Solar Flares: OSO 4 and OSO 6 Observations"

Harvard College Observatory. Solar Satellite Project.

Submitted to the 137th AAS Solar Physics Division meeting on Flares and Particle Acceleration--Space Observations of EM Radiation, College Park, Maryland, April 4-6, 1972.

Bull. Amer. Astron. Soc., to be published.

NASA Contract #NAS-5-9274.
NASA Grant #NGR-22-007-211.

Abstract

The observations of solar flares made by the HCO experiments on board OSO 4 and OSO 6 show that: 1) EUV flares have two components, analogous to the nonthermal (impulsive) and thermal (slow) X-ray bursts, respectively; 2) EUV peak intensity is a function of burst rise time and is correlated with the X-ray burst characteristics; 3) the detailed time structure of many bursts is identical in the X-ray, EUV and radio ranges. These results can be interpreted in terms of an empirical model in which nonthermal electrons, accelerated in the flare instability, lose their energy through coulomb collisions with the high density ($N_e \simeq 10^{11-12}$ cm^{-3}) ambient plasma. In this model, the impulsive X-ray and radio bursts are produced by nonthermal bremsstrahlung and synchrotron emission, while the EUV is produced quasi-thermally as a result of the excitation and ionization by the ambient electrons heated by the losses of the nonthermal flare electrons. The development of the post-impulsive phase can be explained by the redistribution of temperature in the ambient plasma through thermal conduction. The temperature structure that results is in substantial agreement with observations, not only in the EUV, but also in the soft X-ray and radio regions.

Wood, A.T. Jr.; Noyes, R.W.; Dupree, A.K.; Huber, M.C.E.; Parkinson, W.H.; Reeves, E.M.; Withbroe, G.L.

"Solar Flares in the Extreme Ultraviolet. I: The Observations"

Harvard College Observatory. Solar Satellite Project. T.R. #30. January, 1972.

Solar Physics,

NASA Contracts #NAS 5-9274, NASw-184.
NASA Grant #NGR 22-007-211.

Abstract

Solar-flare observations in the extreme ultraviolet (300-1350 Å) are reported. Some 269 flares observed by the Harvard College Observatory (HCO) experiment on OSO 4 and 211 flares observed by the HCO experiment on OSO 6 have been analyzed. The flares were observed in spectral lines and continua emitted by many ionic species over a temperature range from 10^4 to 3.5×10^6K. The EUV data have been correlated with X-ray, Hα, and radio observations, and a significant number of EUV bursts not associated with reported Hα, X-ray, or radio bursts have been identified and investigated. The results indicate that these latter EUV events are less energetic by about a factor of 2 than EUV bursts associated with -F subflares.

Wood, A.T.Jr.; Noyes, R.W.

"Solar Flares in the Extreme Ultraviolet.
II: Comparisons with Other Observations"

Harvard College Observatory. Solar Satellite Project.
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Solar Physics,

NASA Contracts #NAS 5-9274, NASw-184.
NASA Grant #NGR 22-007-211.

Abstract

Extreme-ultraviolet (300-1350 Å) observations of nearly 500 solar flares from the satellites OSO 4 and OSO 6 have been compared with data in X-ray and radio wavelengths. It is found that EUV flares are closely associated with nonthermal X-ray and microwave bursts. The EUV maximum intensity generally precedes the maximum intensity in Hα or soft X-rays by up to several minutes. The EUV e-folding rise time and peak intensity both depend on the X-ray burst characteristics. Nonthermal X-ray events are usually associated with weaker, more slowly rising EUV flares. These relations are consistent with a picture of the flare in which the EUV radiation is produced thermally in a region of high (chromospheric) density, which is being heated by collisional losses of the nonthermal electrons responsible for the impulsive X-ray and microwave burst.

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Abstract

A report was given based on the two OSO satellites (observations between 300 and 1400 Å with about 3 Å resolution) and on a 1969 rocket experiment with a photoelectric scanning spectrometer for the region 1350 to 1825 Å. A model of the chromosphere, the transition region and the corona has been built to fit these observations.

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