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Balloon measurements of solar fluxes between 1960 Å and 2300 Å

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FOREWORD

This paper has been presented at the Third Conference on "Climatic Impact Assessment Program" held in Boston, February 26 - March 1, 1974. It will be published in the Conference Proceedings.

AVANT-PROPOS

Ce texte a été présenté à la 3e Conference du "Climatic Impact Assessment Program" qui s'est tenue à Boston du 26 février au 1er mars 1974. Cette communication sera publiée dans les comptes rendus de la réunion.

VOORWOORD

Deze tekst werd voorgedragen tijdens de derde conferentie over "Climatic Impact Assessment Program", gehouden te Boston van 26 februari tot 1 maart 1974. Hij zal in de "Conference Proceedings" uitgegeven worden.

VORWORT

Dieser Text wurde zum 3. Konferenz "Climatic Impact Assessment Program" in Boston vom 26. Februari zum 1. März 1974 vorgestellt. Er wird in dem "Conference Proceedings" herausgegeben werden.

BALLOON MEASUREMENTS OF SOLAR FLUXES BETWEEN 1960 Å AND 2300 Å

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P. SIMON

Abstract

New observational data in the 1960 - 2300 Å wavelength range have been obtained by means of a balloon borne spectrometer. Ultraviolet spectra for different zenith angles were recorded with an equivalent slit width of 6Å. The extrapolation at zero air mass leads to extraterrestrial solar fluxes lower than the previous measured values. The present results give an apparent blackbody temperature of the sun of the order of 4700° K at 2000 Å.

Résumé

De nouvelles observations du flux solaire entre 1960 et 2300 Å ont été faites à l'aide d'un spectromètre pour ballon stratosphérique. Des spectres ultraviolets du soleil ont été obtenus en fonction de l'angle zénithal pour une largeur équivalente de fente de 6 Å. L'extrapolation à masse d'air nulle donne de nouvelles valeurs plus basses que les précédents. La température apparente du soleil serait de l'ordre de 4700° K à 2000 Å.

Samenvatting

Nieuwe waarnemingen van de zonneflux tussen 1960 en 2300 Å werden gedaan door middel van een spectrometer aan boord van een stratosferische ballon. Ultraviolette zonnespectra werden bekomen in functie van de zenithsafstand en voor een equivalente spleetopening van 6 Å. De extrapolatie geeft waarden tot "zero air mass" die lager liggen dan degenen die vroeger werden bekomen. De schijnbare temperatuur van de zon zou de ordregrootte van 4700° K zijn bij 2000 Å.

Zusammenfassung

Neue Beobachtunger der Sonnenfluss zwischen 1960 und 2300 Å wurden mit einem Spektrometer für stratosphärischen Ballon gemacht. Ultravioletten Spektren wurden für verschiedenen Zenitdistanzen mit einer äquivalente Spaltbreite von 6 Å erreicht. Die Extrapolation zu einer null Luftmasse gibt neue Ergebnisse die kleiner sind als die vorherige Werte. Die scharzer Körpertemperatur der Sonne ist dann etwa 4700° K für 2000 Å.

INTRODUCTION

From the point of view of aeronomy, the knowledge of the spectral distribution of the ultraviolet solar fluxes reaching the atmosphere is fundamental to determine the photodissociation rate of atmospheric constituents. For instance, in the stratosphere, solar radiation in the wavelength range of 1800 to 2400 Å photodissociates O_2 to form O_3. Minor constituents such as N_2O, HNO_3, H_2O_2 are also photodissociated in that wavelength range (see for ex. Nicolet, 1972, 1973) for which the most recent measurements of solar flux have been reported by Ackerman et al (1971) and by Broadfoot (1972). The data obtained at wavelengths shorter than 1880 Å by Parkinson and Reeves (1969) and confirmed at 1700 Å by recent rocket observations (Ackerman and Simon, 1973 ; Rottman, 1973) and by satellite experiments (Heath, 1973) shows the need of new determination in the spectral range of the 2000 Å atmospheric optical window.

This is a report of new measurements of absolute ultraviolet solar fluxes between 1960 and 2300 Å, obtained by means of a balloon borne spectrometer integrated in a sun pointing gondola.

INSTRUMENTATION

The instrument is a modified version of the spectrometer used on board of rockets by Ackerman and Simon (1973). A ground quartz window used as a diffuser was placed in front of the entrance slit to integrate the radiation over the whole solar disk. The wavelength scanning was obtained by rotation of a 26 x 26 mm plane grating (Bausch and Lomb n° 35-53-04-020) ruled at 1200 grooves per mm and blazed at 2000 Å. The diffracted light was falling on a solar blind photomultiplier (EMR 542 P-09-18) with an RbTe photocathode. The equivalent triangular slit width of the spectrometer was 6 Å. The analog output signal was telemetered to the ground after measurement by a solid state electrometer and amplification. The flight instrument was aligned with fine sun sensors which pointed the balloon gondola to the sun better than 30 arc seconds. The instrument alignment accuracy was of the order of 5 arc minutes.

A more detailed description is given elsewhere (Simon, 1974).

CALIBRATION

The absolute calibration of the spectrometer is referenced to the International Pyrheliometric Scale 1956. Using a Reeder thermopile as a transfert detector, the irradiance of a low pressure mercury lamp was measured at 2537 Å. The spectrometer was directly and absolutely calibrated against this lamp before and after each flight. The relative sensitivity curve of the spectrometer was determined by comparison with a sodium salicylate coated photomultiplier of a monochromatic beam emerging from a McPherson 30 cm focal length monochromator (model 218).

An electroless discharge lamp filled with $SiCl_4$ and emitting silicon atomic lines in the 1800-2600 Å wavelength range and a deuterium lamp were used as light sources. The final accuracy of the flight instrument calibration is estimated to be ± 10%.

The resulting absolute sensitivity curve of the instrument is shown in figure 1.

OBSERVATIONS

The two flights were carried on respectively on September 23, 1972 and May 16, 1973, at Aire sur l'Adour in France. In the case of the first flight, the balloon (Raven, 300.000 m^3) reached a altitude of 41.5 km. The main purpose of this flight was the measurement of the stratospheric absorption of the solar radiation (Simon, 1974) and, for this reason, it took place at large solar zenith angles. The observation period extended from 16h40 to 17h40 G.M.T. Ultraviolet spectra between 1900 and 2300 Å were obtained for zenith angles increasing from 78° to 87°.

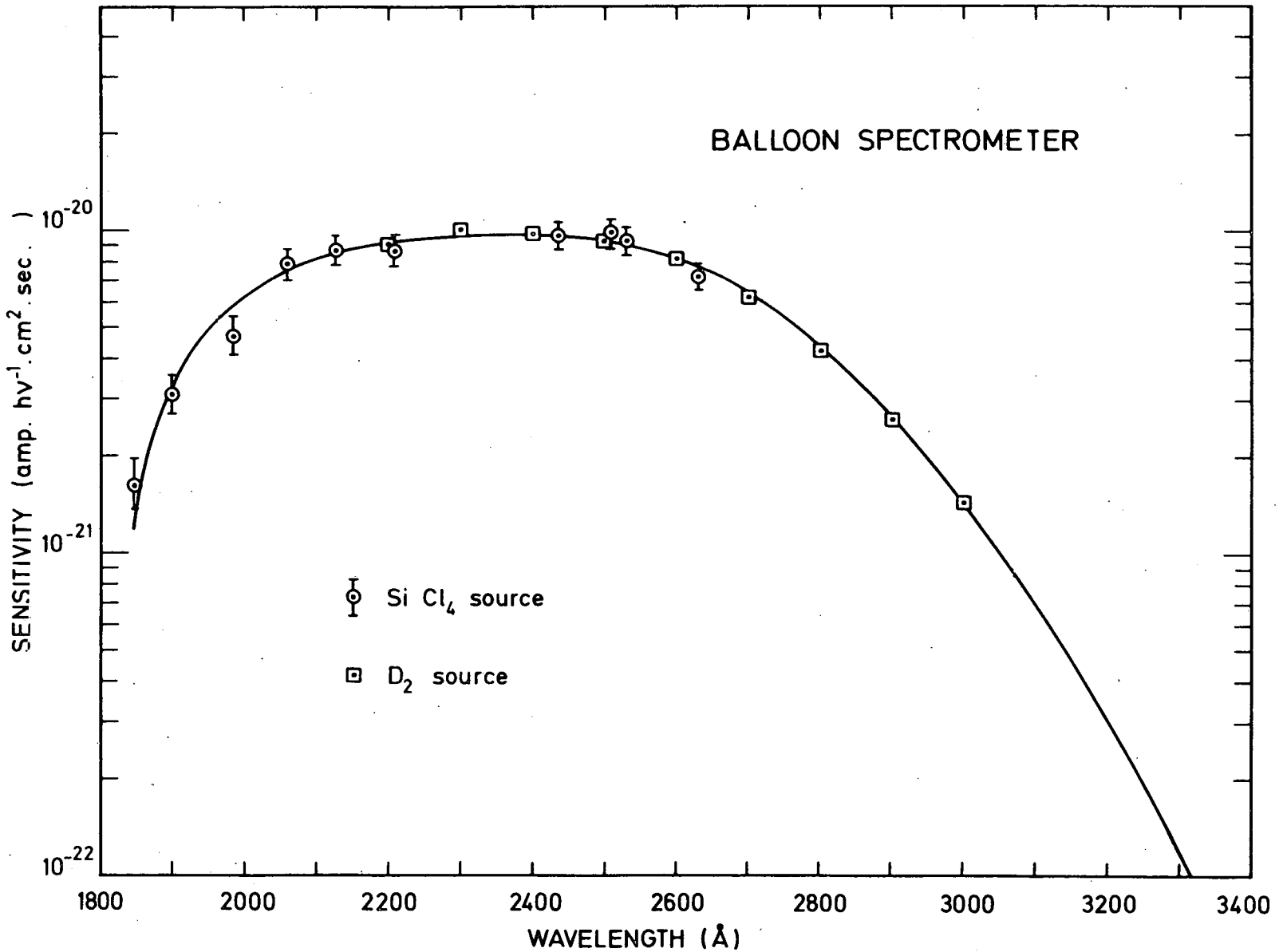

Fig. 1.- Absolute sensitivity curve of the flight instrument versus wavelength.

In the case of the second flight, the balloon (Winzen, 300.000 m^3) reached a altitude of 39 km. In this case, the main purpose of the flight was to determine the ultraviolet solar fluxes. For this reason, the experiment took place at relatively smaller solar zenith angles. Spectra were recorded from 16h to 17h22 G.M.T. The corresponding zenith angles were 54^0 and 70^0. Figure 2 shows one of the recorded spectra.

DATA REDUCTION

The classical Langley method was used to determine the optical depth and the extra-terrestrial solar fluxes. Some examples of extrapolation to zero air mass are given in figure 3.

For the first flight, the air masses were calculated using the approximation for large zenith distances given by Swider and Gardner (1967). As in the considered wavelength range there are two different absorbing constituents, oxygen and ozone, with different scale heights, the contribution at each wavelength of the two absorbers in the air mass calculation were taken into account. The oxygen and ozone column densities were respectively deduced from pressure measurement and from absorption data around 3000 Å. Using the ozone absorption cross section measured by Inn and Tanaka (1953) and oxygen absorption cross section published by Ackerman (1971), the optical depth has been calculated for a pure oxygen-ozone atmosphere between 1900 and 2400 Å. The Rayleigh scattering extinction was also taken into account. Figure 4 shows the good agreement between experimental optical depth values and oxygen-ozone absorption model.

RESULTS AND DISCUSSION

The solar flux results of the two flights are shown in figure 5. The best fitting curve is reproduced in figure 6 for comparison with other determination of solar fluxes in the 1700-2400 Å wavelength interval. The new values are roughly 40% lower than the previous

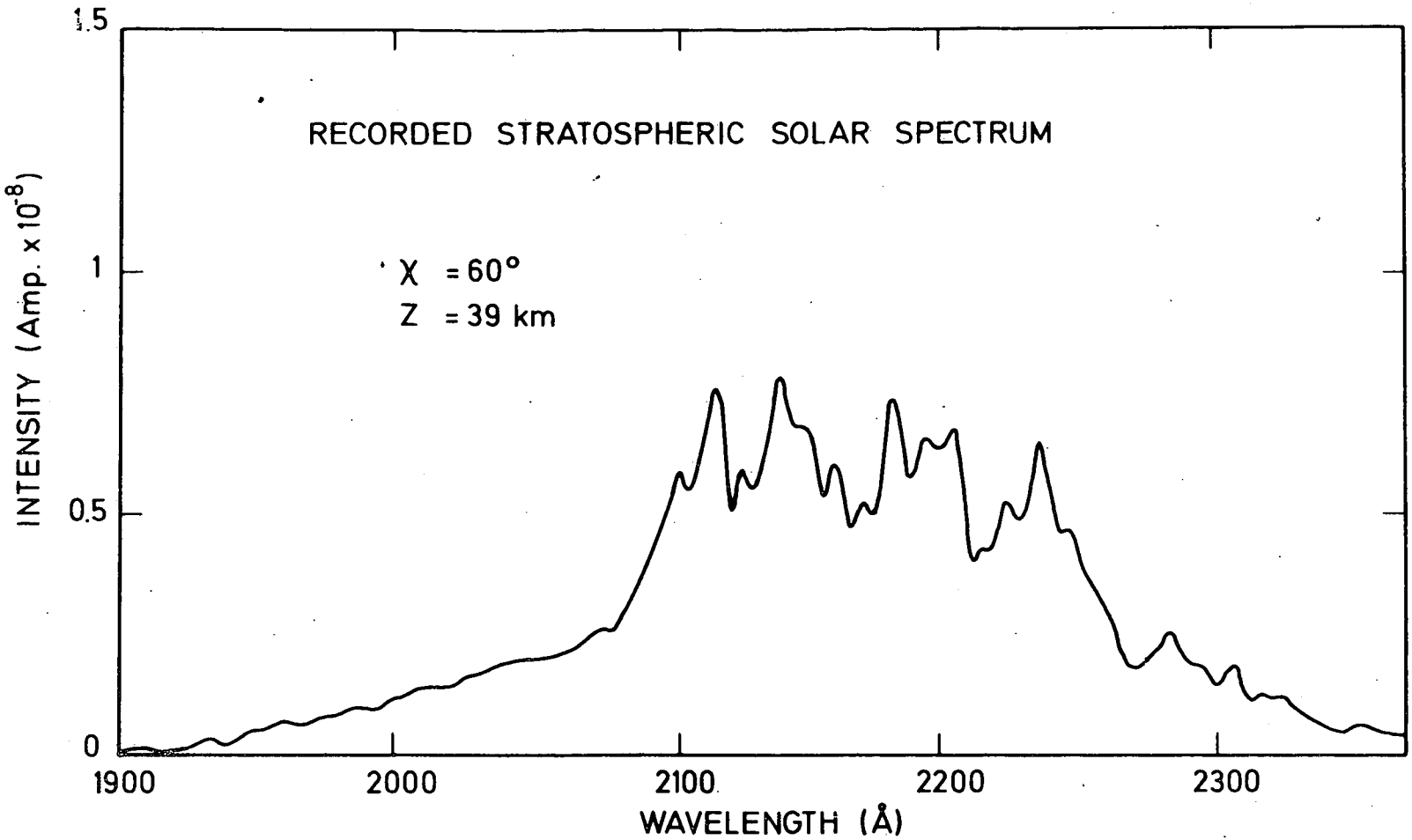

Fig. 2.- Stratospheric solar spectrum recorded during the second flight from 1900 Å to 2400 Å obtained by means of the balloon borne spectrometer for a solar zenith angle of 60^0 and an altitude of 39 km.

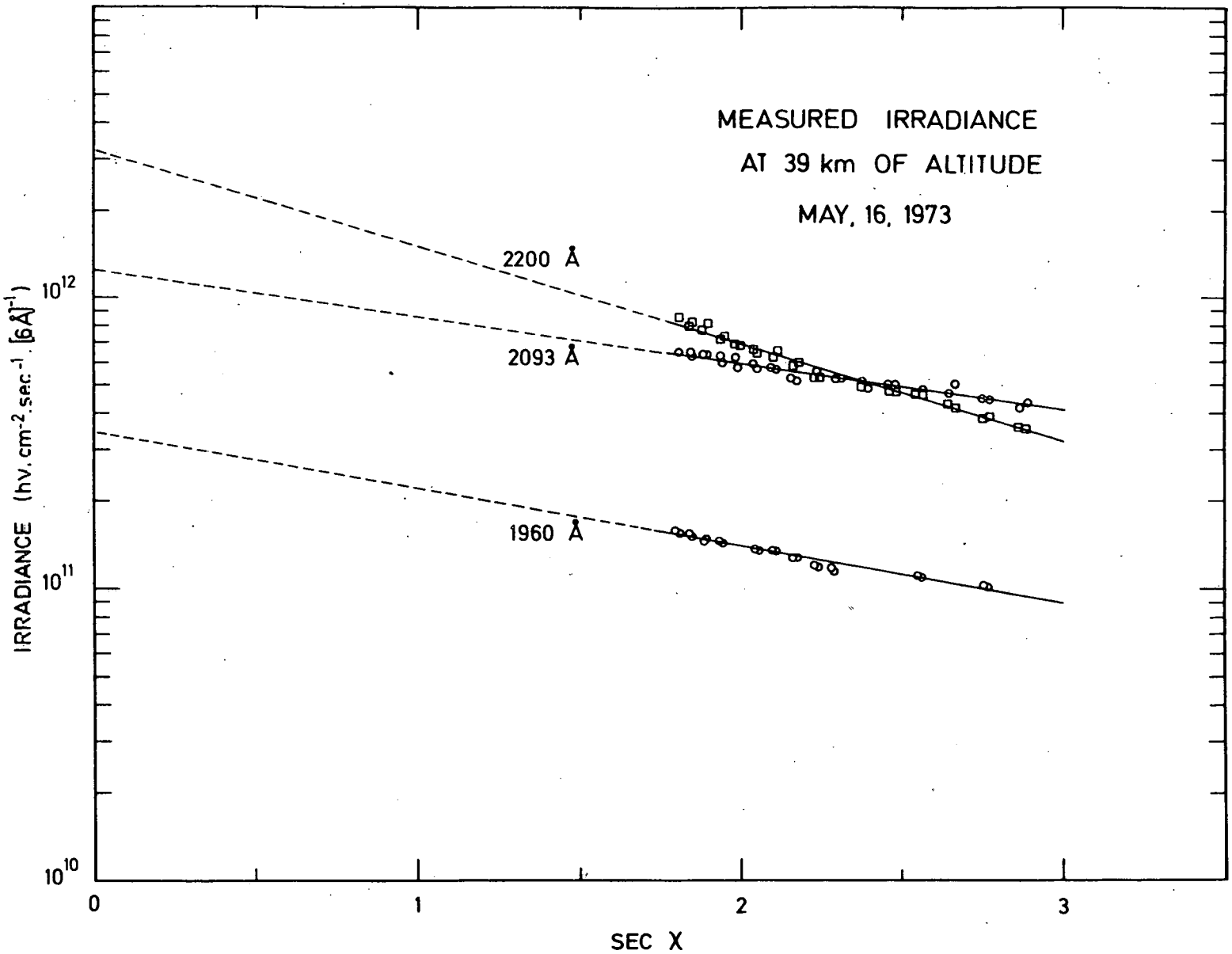

Fig. 3.- Measured solar irradiances versus the secant of the solar zenith angle, at 3 wavelengths.

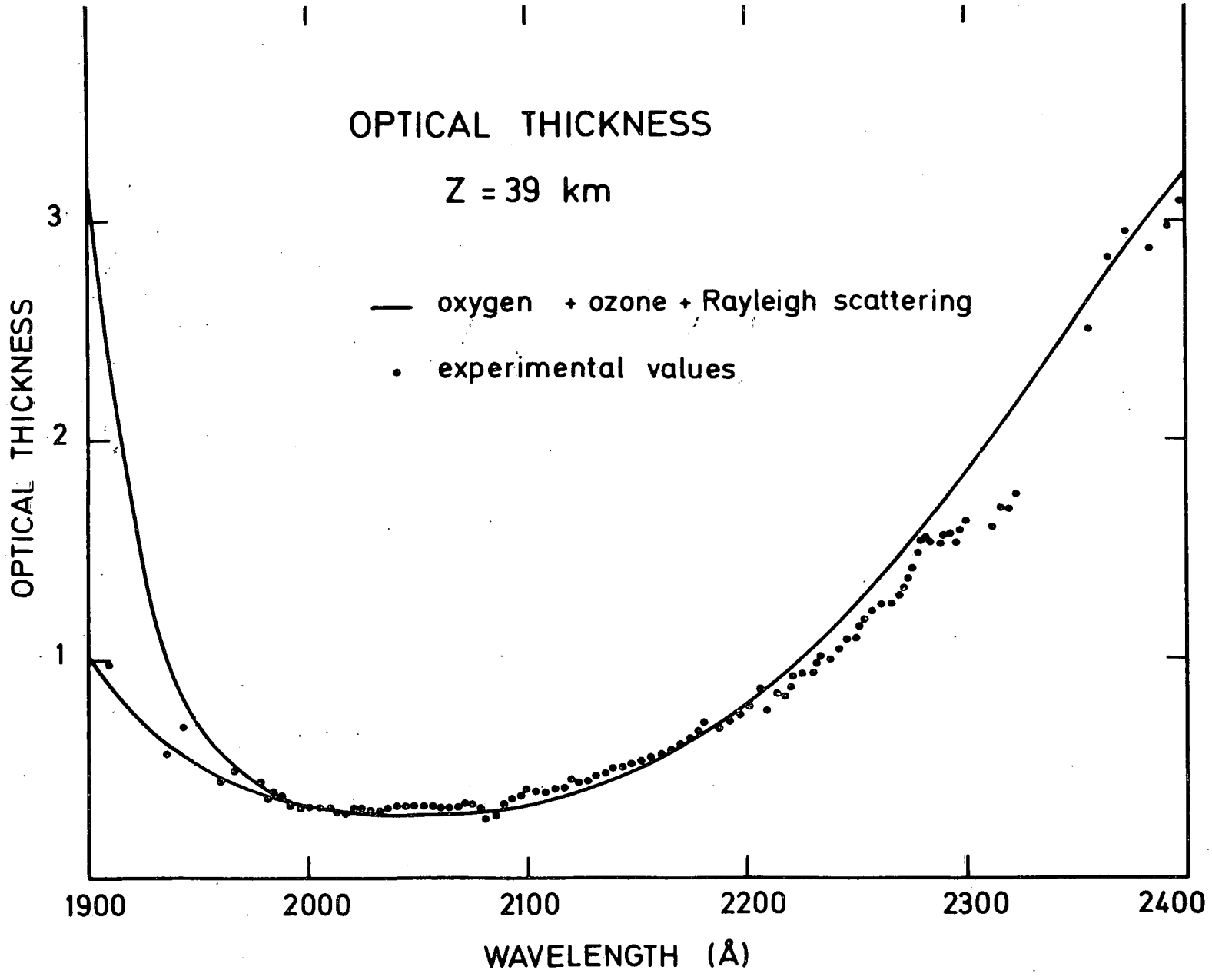

Fig. 4.- Experimental optical thickness (dots) and a pure oxygen-ozone absorption atmosphere curve in the wavelength range from 1900 to 2400 Å. The full curve was calculated for an ozone content of 4×10^{17} molecules/cm^2 and an oxygen content of 1.48×10^{22} molecules/cm^2. The splitting of this curve below 2000 Å corresponds to the lowest and to the highest values of the oxygen cross section in the Schumann-Runge band system.

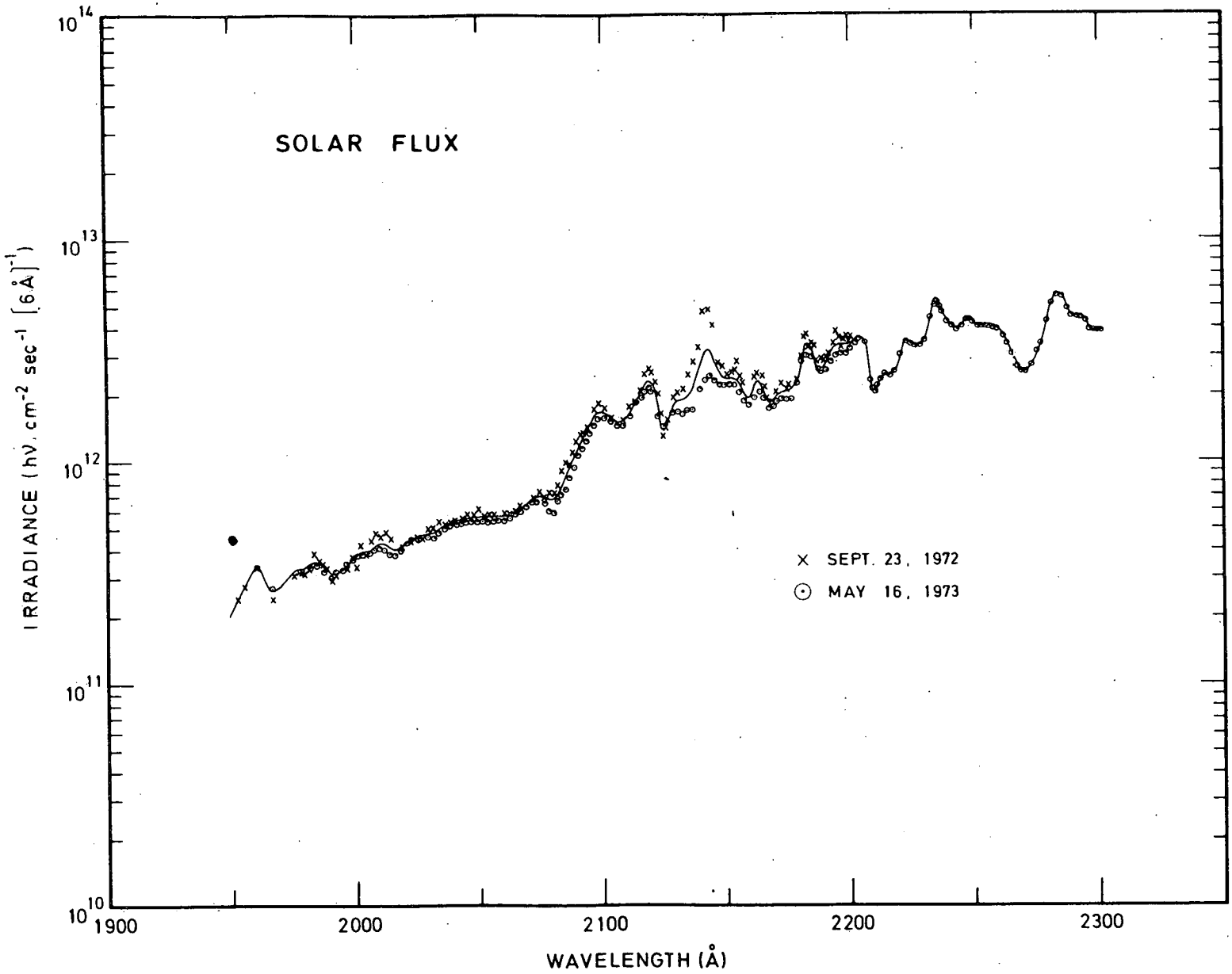

Fig. 5.- Solar fluxes versus wavelength at one astronomical unit deduced from the two balloon flights.

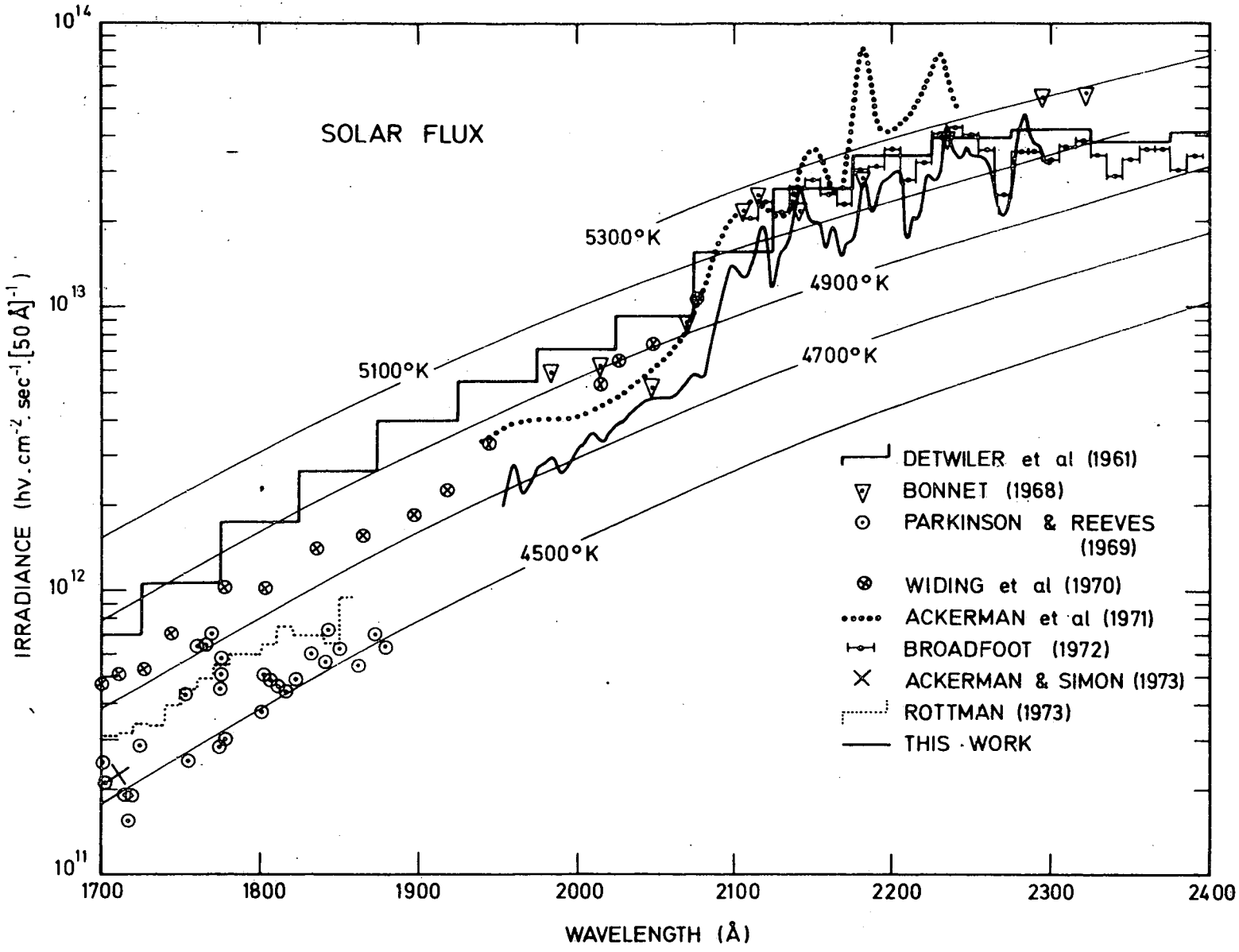

Fig. 6.- Comparison of ultraviolet solar fluxes reported by various experimenters from 1700 to 2400 Å. Fluxes for different blackbody temperature are also shown.

measurements of Ackerman et al (1971). They are in good agreement with Broadfoot's values for wavelengths larger than 2250 Å but also lower at shorter wavelengths. The comparison is also made in table 1 and in figure 7 with the values published by Ackerman (1971) and generally used in photodissociation rate calculations. The same conclusion can be drawn but the agreement is fairly good for some wavelength intervals defined in table 1.

Since the values of Parkinson and Reeves (1969) between 1400 and 1900 A have been recently confirmed by Ackerman and Simon (1973), by Heath (1973) and by Rottman (1973), the apparent blackbody temperature of the sun appears to be close to 4550° K at 1900. The present results indicate a decrease of only 150° K from 2000 Å down to 1900 Å. The intensity change from 2080 Å to 1700 Å could be nearly exponential as suggested by Donnelly and Pope (1973).

ACKNOWLEDGEMENTS

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TABLE 1.- Comparison between the solar flux measurements reported here and the values published by Ackerman (1971).

Wavelength interval (Å)	Flux (this work) $h\nu.cm^{-2}.sec^{-1}$	Flux (1) $h\nu.cm^{-2}.sec^{-1}$	Ratio between (1) and (this work)
1961 - 1980	1.01×10^{12}	1.39×10^{12}	1.38
1980 - 2000	1.20	1.53	1.27
2000 - 2020	1.44	1.60	1.11
2020 - 2041	1.80	1.74	0.97
2041 - 2062	2.08	2.31	1.11
2062 - 2083	2.45	4.20	1.71
2083 - 2105	5.09	7.30	1.43
2105 - 2128	7.12	9.42	1.32
2128 - 2150	9.23	1.06×10^{13}	1.15
2150 - 2174	8.42	1.34	1.59
2174 - 2198	1.20×10^{13}	1.32	1.10
2198 - 2222	1.22	1.73	1.42
2222 - 2247	1.77	1.80	1.02
2247 - 2273	1.60	1.82	1.14
2273 - 2299	1.96	2.26	1.15

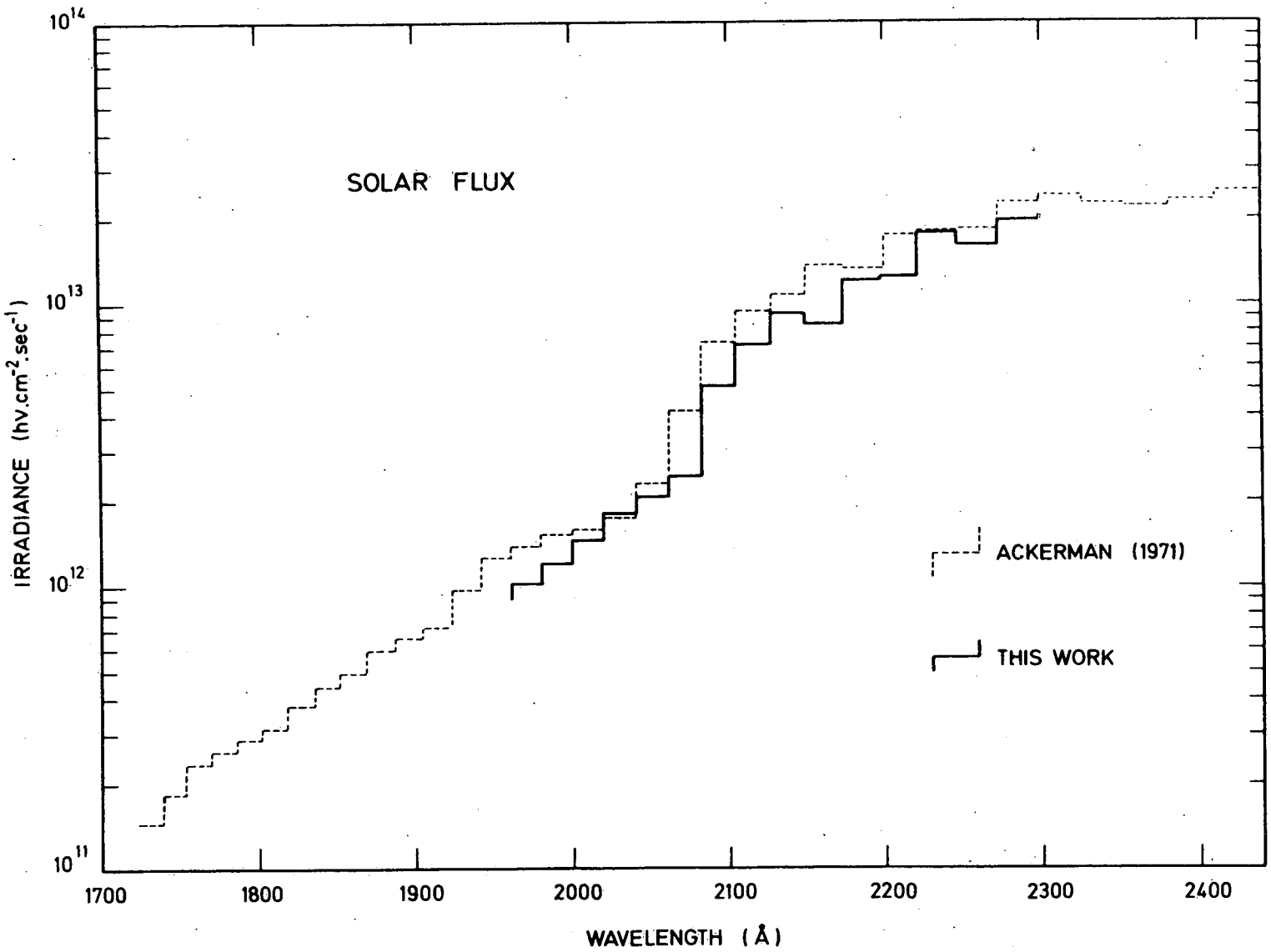

Fig. 7. Comparison of solar fluxes reported here with values published by Ackerman (1971). The wavelength intervals are defined in table 1.

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