(SM) Gill

National Aeronautics and Space Administration [redacted]
Goddard Space Flight Center
Contract No. NAS-5-2078

N10

ST - SP - 10153

GPO PRICE $

CFSTI PRICE(S) $

Hard copy (HC) 1.10

Microfiche (MF) .50

ff 653 July 65

SOLAR CORONA EMISSION IN THE SPECTRUM REGION $\lambda < 10$ Å

by

E. P. Fetisov

[USSR]

10 JUNE 1964

DRAFT TRANSLATION ST-SP-10153

SOLAR CORONA EMISSION IN THE SPECTRUM REGION $\lambda < 10$ Å *

Astronomicheskiy Zhurnal,
Tom 41, vyp. 2, 299-301,
Izd-vo "NAUKA", 1964

by E. P. Fetisov

SUMMARY

The spectral emission flux of the corona in the $\lambda < 10$ Å region has been determined theoretically. Considered are the line, recombination and bremstrahlung emissions. The continuous emission from heavy ion recombinations prevails. The theoretical flux is less than that observed, which is evidence of corona's high nonhomogeneity.

* * *

The hard emission of the solar corona has been lately the object of intensive study. However, the available experiments in the X-ray region provide only the aggregate intensity in separate portions of the spectrum and a fairly rough "smoothed" pattern of spectral distribution. These measurements do not allow the ascertaining of the question of line contribution, of correlation between the free-free and recombination emissions. In the current work the corona emission flux in the region $\lambda < 10$ Å is determined theoretically. The line, recombination and bremstrahlung emission, occurring at electron motion in the field of ions under solar corona conditions, are considered here.

In order to compute the emission intensity, it is necessary to know, first of all, the relative concentrations of ions in chemical elements' corona. Inasmuch as the Sach formula is inapplicable in the corona, in order to compute the concentration we must determine the

* IZLUCHENIYE SOLNECHNOY KORONY V OBLASTI SPEKTRA KOROCHE 10 A.

cross sections of ionization and recombination processes. Since sufficiently well-founded formulas for cross sections are not available, we conducted two computations in the current work. Formulas obtained in [1] were utilized in the first calculation and those obtained in [2] — in the second one. Both methods give close values for the 20 considered elements (such elements as Mn, Cr, Fe, S, Ca drop out somewhat) . In the second case the concentrations are somewhat lower, which leads to higher temperature determined from the ionization equilibrium.

The flux of the continuous as well as of line emission is proportional to the integral of the square of electron density over the volume of the corona. The value of $3.2 \cdot 10^{49}$ is taken for this quantity, which corresponds to the Baumbach formula. In considering the bound-free transitions we limited ourselves by the recombination at basic level. The accounting of transitions to upper levels may increase the recombination emission (though insignificantly). The line emission is considered in the assumption that the ions are excited by electron impact and are de-excited by way of spontaneous transitions, the computation being at the same time conducted in the Born approximation. The increase in population of upper levels at the expense of recombination was disregarded, as was done in other works.

The results of computations are partially presented in Table 1. in which the flux of continuous and line emissions, summed up by all heavy element ions, the emission of hydrogen and helium and also the total emission flux of the corona in the region shorter than 10 Å, are given in erg / $cm^2 \cdot$ sec. Two columns for each temperature correspond to the calculation of ion concentration by two different formulas. It follows from the Table that the continuous emission is prevalent. At the same time, for temperature to 3 million degrees the main contribution is conditioned by heavy element ion recombination. Let us note that basically these are the N, O, Fe, Mg, H, He ions, whose limit wavelengths are of the order of 10 Å or more. The line emission flux is significantly lesser and the lines contribute notably only for temperatures above $3 \cdot 10^6$ °K. Particularly substantial is the emission of ions Mg XI, Na X, Ne X, Ne X, Si XIII and Fe XVII — Fe XVIII.

TABLE I

ELEMENT	FORM OF EMISSION	TEMPERATURE IN MILLIONS OF DEGREES							
		1.0		1.5		2.0		2.5	
HEAVY ELEMENTS	LINE EMISSION	$1.37\cdot10^{-10}$	$5.90\cdot10^{-11}$	$5.53\cdot10^{-8}$	$4.26\cdot10^{-8}$	$1.12\cdot10^{-6}$	$9.85\cdot10^{-7}$	$8.56\cdot10^{-6}$	$7.56\cdot10^{-6}$
	BREMSTRAHLUNG	$1.14\cdot10^{-10}$	$1.09\cdot10^{-10}$	$1.97\cdot10^{-8}$	$1.85\cdot10^{-8}$	$2.75\cdot10^{-7}$	$2.62\cdot10^{-7}$	$1.62\cdot10^{-6}$	$1.36\cdot10^{-6}$
	RECOMBINATION	$4.96\cdot10^{-8}$	$2.66\cdot10^{-8}$	$6.04\cdot10^{-6}$	$3.57\cdot10^{-6}$	$6.18\cdot10^{-5}$	$3.90\cdot10^{-5}$	$2.21\cdot10^{-4}$	$1.51\cdot10^{-4}$
He III	BREMSTRAHLUNG	$2.28\cdot10^{-9}$		$3.52\cdot10^{-7}$		$4.54\cdot10^{-6}$		$2.17\cdot10^{-5}$	
	RECOMBINATION	$5.41\cdot10^{-9}$		$4.50\cdot10^{-7}$		$3.93\cdot10^{-6}$		$1.41\cdot10^{-5}$	
He II	BREMSTRAHLUNG	$2.85\cdot10^{-9}$		$4.39\cdot10^{-7}$		$5.67\cdot10^{-6}$		$2.70\cdot10^{-5}$	
	RECOMBINATION	$1.05\cdot10^{-9}$		$1.02\cdot10^{-7}$		$9.70\cdot10^{-7}$		$3.63\cdot10^{-6}$	
TOTAL EMISSION		$6.11\cdot10^{-8}$	$3.84\cdot10^{-8}$	$7.46\cdot10^{-6}$	$4.98\cdot10^{-6}$	$7.84\cdot10^{-5}$	$5.53\cdot10^{-5}$	$2.86\cdot10^{-4}$	$2.25\cdot10^{-4}$

TABLE I (cont'd)

ELEMENT	FORM OF EMISSION	TEMPERATURE IN MILLIONS OF DEGREES							
		3.0		3.5		4.0		4.5	
HEAVY ELEMENTS	LINE EMISSION	$3.15\cdot10^{-5}$	$2.72\cdot10^{-5}$	$9.18\cdot10^{-5}$	$7.86\cdot10^{-5}$	$2.01\cdot10^{-4}$	$1.75\cdot10^{-4}$	$3.55\cdot10^{-4}$	$3.25\cdot10^{-4}$
	BREMSTRAHLUNG	$4.93\cdot10^{-6}$	$4.82\cdot10^{-6}$	$9.33\cdot10^{-6}$	$9.10\cdot10^{-6}$	$1.71\cdot10^{-5}$	$1.65\cdot10^{-5}$	$2.79\cdot10^{-5}$	$2.71\cdot10^{-5}$
	RECOMBINATION	$4.70\cdot10^{-4}$	$2.39\cdot10^{-4}$	$7.81\cdot10^{-4}$	$5.73\cdot10^{-4}$	$1.11\cdot10^{-3}$	$8.30\cdot10^{-4}$	$1.41\cdot10^{-3}$	$1.09\cdot10^{-3}$
He III	BREMSTRAHLUNG	$6.23\cdot10^{-5}$		$1.34\cdot10^{-4}$		$2.41\cdot10^{-4}$		$3.82\cdot10^{-4}$	
	RECOMBINATION	$3.23\cdot10^{-5}$		$5.80\cdot10^{-5}$		$8.91\cdot10^{-5}$		$1.23\cdot10^{-4}$	
He II	BREMSTRAHLUNF	$7.69\cdot10^{-5}$		$1.68\cdot10^{-4}$		$3.01\cdot10^{-4}$		$4.78\cdot10^{-4}$	
	RECOMBINATION	$8.63\cdot10^{-6}$		$1.58\cdot10^{-5}$		$2.47\cdot10^{-5}$		$3.47\cdot10^{-5}$	
TOTAL EMISSION		$6.86\cdot10^{-4}$	$5.50\cdot10^{-4}$	$1.26\cdot10^{-4}$	$1.04\cdot10^{-3}$	$1.98\cdot10^{-3}$	$1.68\cdot10^{-3}$	$2.81\cdot10^{-3}$	$2.45\cdot10^{-3}$

Note also that the obtained flux values practically characterize only the relative role of the various emission processes. Only at temperatures of the order of $1 - 1.5 \cdot 10^{6}$ °K the consideration of the absolute values of all corona emission fluxes makes sense, inasmuch as higher temperature values cannot be combined with the emission in other regions of the spectrum, and with radioemission in particular. The experimental values of the flux in the 2 — 10 Å region [3, 4] in the maximum years is of the order of $10^{-4} - 10^{-3}$ erg/cm$^2 \cdot$ sec, which at $T < 2 \cdot 10^{6}$ °K significantly exceeds the data of Table 1.

A more precise value for the electron density will somewhat increase the theoretical values of the flux. The remaining discrepancy can be partly connected with the contribution by nonthermal mechanisms of emission, and on the other hand, it points to an essentially inhomogenous character of the corona. Taking into account the presence of condensations, constituting centesimal fractions of corona volume, the experimental and theoretical values of fluxes can be matched.

In conclusion I should like to express my gratitude to S. L. Mandel'shtam, L. A. Vaynsteyn and Yu. N. Zhivkyuk, for their interest and the valuable comments.

**** THE END ****

Institute of Physics in the name of
P. N. Lebedev
of the USSR Academy of Sciences.

Received on
11 February 1963.

Translated by ANDRE L. BRICHANT
under Contract No. NAS-5-2078
at Consultants & Designers, Inc.
Arlington, Virginia
10 June 1964.

REFERENCES

1. G. ELWERT, Z. NATURF., 9a, 637, 1954.
2. G. S. IVANOV-KHOLODNYY, G. M. NIKOL'SKIY, R. A. GULYAEV., Astron. zh, 37, 799, 1960.
3. S. L. MANDEL'STAM, B. N. VASIL'EV, I. P. TINDO, YU. K. VORON'KO, A. I. SHURYGIN. Dokl. AN SSSR, 142, 77, (NASA TT F-8195) 1962.
4. R. W. KREPLIN, T. A. CHUBB, H. FRIEDMAN. J. Geophys. Res., 67, 2231, 1962.

DISTRIBUTION

GODDARD SFC

610	MEREDITH
614	LINDSAY (12)
611	McDONALD (3)
612	HEPPNER
613	KUPPERIAN (5)
615	BOURDEAU (2)
	BAUER
640	HESS (6)
651	SPENCER
252	LIBRARY (5)
256	FREASE

NASA HQS

SS	NEWELL, CLARK
SP	STANSELL
SG	NAUGLE
	FELLOWS
	DUBIN
	HIPSHER-HOROWITZ
	ROMAN
	SMITH
	SCHARDT
SL	LIDDEL
SM	GILL
RTR	NEILL
AFSS	SCHWIND
AO-4	

OTHERS

AMES
Sonett (3)

JPL
Newburn (3)

ISS
Jastrow (5)

NRL
Friedman