Newkirk

7 May 1958

High Altitude Observatory
of the
University of Colorado
Boulder, Colorado

Solar Research Memorandum No. 105

Subject: Coronal Emission Intensity Gradients*

From: Robert H. Cooper

On January 6 and 7, 1958 yellow coronal line emission was detectable above the southwest limb of the sun. The observers at Climax obtained good graded height sequences in the red, yellow and green coronal emission lines and good quality K-coronameter records.

Figure 1 shows isophotal contours of the 5303 A. intensities for the same general yellow line region on the two successive days. The spectrograms from which these maps were prepared cover about 90° of arc and were taken at successive 4,500 Km. intervals above the limb to a height of about 90,000 Km.

A semi-logarithmic plot of the average 5303 A. intensity at each observing height is shown in Fig. 2(A). The average intensity is determined from 34 position angles on the two days. An interesting feature of Fig. 2(a) is that two straight lines provide a very good fit to the plotted points and an abrupt discontinuity occurs at 45,000 Km. above the chromosphere. This height is about 10,000 - 15,000 Km. above the height of the tops of the greatest number of prominences as found by Billings and Kober (1957).

The same procedure of plotting the average intensity vs. height, when used for the 6374 A. emission line, results in the graph at 2(B). The dashed line is drawn parallel to the solid line in 2(A) and provides a good fit to the plotted points. The greater scatter of points in 2(B) is the result of the fainter intensity of 6374 A. emission as compared to 5303 A. emission. Also, only regions of appreciable 6374 A. intensity were traced on the microdensitometer resulting in fewer measurements.

The logarithm of the ratio $I_1(\text{avg.})/I_2(\text{avg.})$ is plotted at the top of Fig. 2. The circles indicate the raw readings and show rather bad scatter.

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*This research has been supported by the I.G.Y. under Grant Number 50.3 for Pilot Studies.

If succeeding pairs of plotted raw readings are averaged, as indicated by the X's on the graph, we may draw two straight dashed lines at different levels which will fit the plotted X's. The standard deviation of the points from the two dashed lines is less than from the single solid line, thus bearing out the conclusion concerning the abrupt discontinuity in the intensity gradient. The average $\log(I_1/I_2)$ per 1,000 Km. interval is .0087 between 0 and 45,000 Km., and .0047 between 45,000 and 80,000 Km.

If one interprets the two straight lines of Fig. 2(A) to indicate an atmosphere consisting of two isothermal layers, each in hydrostatic equilibrium, and assumes the number ratio of Helium to Hydrogen atoms to be 1/10, he finds the temperature of the lower layer to be 1.87×10^{6}°K., and the upper layer 3.16×10^{6}°K.

The temperature corresponding to the average 5303A./6374A. ratio shown in Figs. 2(A) and (B), when corrected by a factor found by Billings(1957), is $2.15\text{-}2.20 \times 10^{6}$°K. for the region from 0 to 30,000 Km.

The abrupt change in temperature in a region where 5694A. emission occurs leads one to investigate the possible existence of such a discontinuity in regions of lower overall coronal intensity. Five regions of low 5303 A. intensity during January, February and March of 1956 were analyzed and the results are plotted in Fig. 3(B). In this graph, as in Fig. 2, the number appearing beside each plotted point indicates the number of measurements contributing to the final location of the point. The abrupt discontinuity in intensity gradient occurs again in this graph, but at a height of 60,000 Km.

Both Figs. 2(A) and 3(B) result from the averaging of intensities at low coronal line intensity as well as high intensity portions of the solar limb. The graph plotted at 3(A) is derived by averaging measurements of intensities at all available heights, but only at the position angle of greatest intensity for 60 coronal regions occuring during the year 1956. The greater scatter of points between 0 and 48,000 Km. may be attributed to the greater complexity of the coronal structure in the regions of high intensity, especially at lower heights, as in R.B.Dunn's photographs of the corona at 5303 A. taken through a Lyot birefringent filter.

Three straight lines appear to give a reasonable fit to the plotted points in Fig. 3(A). The same discontinuity appears at 48,000 Km as in Fig. 2(A), but shows a much smaller change in gradient. Another change in gradient occurs at 90,000 Km., but may be spurious because of the small number of points contributing to the change in slope.

Evidence of temperature discontinuities is not nearly as strong in curve 3(A) as in curve 2(A).

The isothermal curve:

$$I = 122 \times 10^{-6} e^{-2.355 \times 10^{-5} n \left(\frac{r_0}{r}\right)^2} \qquad (T = 1.71 \times 10^6 °K.)$$

as shown in Fig. 4, fits the points from Fig. 3(A) about as well as the three straight line segments.

A tabulation of the temperatures of the various regions as indicated by the gradient in each region and corrected for the gravitational acceleration is shown in Table 1. It is dangerous to form any definite conclusions concerning the average coronal temperature from the tabulation because:

(1) the three graphs shown in Fig. 2 and 3(A) and (B) are derived from three different types of coronal regions and,

(2) marked changes in general coronal activity took place during the period under consideration, namely January 1956 to January 1958.

Table 1

Period	Height Region	log (I_1/I_2) (6,000 Km. Intervals)	Temperature (10^6°K.)
Jan. Feb. Mar. 1956	0-60,000 Km.	.0426	2.20
	60,000-81,000 Km.	.0197	4.26
Jan. to Dec. 1956	0-48,000 Km.	.0596	1.60
	48,000-90,000 Km.	.0417	2.02
	90,000-132,000 Km.	.0237	3.21
6 and 7 Jan. 1958	0-45,000 Km.	.0510	1.87
	45,000-81,000 Km.	.0272	3.16

The writer wishes to acknowledge with gratitude the valuable advice and suggestions of Dr. D. E. Billings concerning the analysis of this data.

References

Billings, D. E. and Kober, C., Sky and Telescope, 2, 63, 1957.
Billings, D. E., A. J., 58, 211, 1957.

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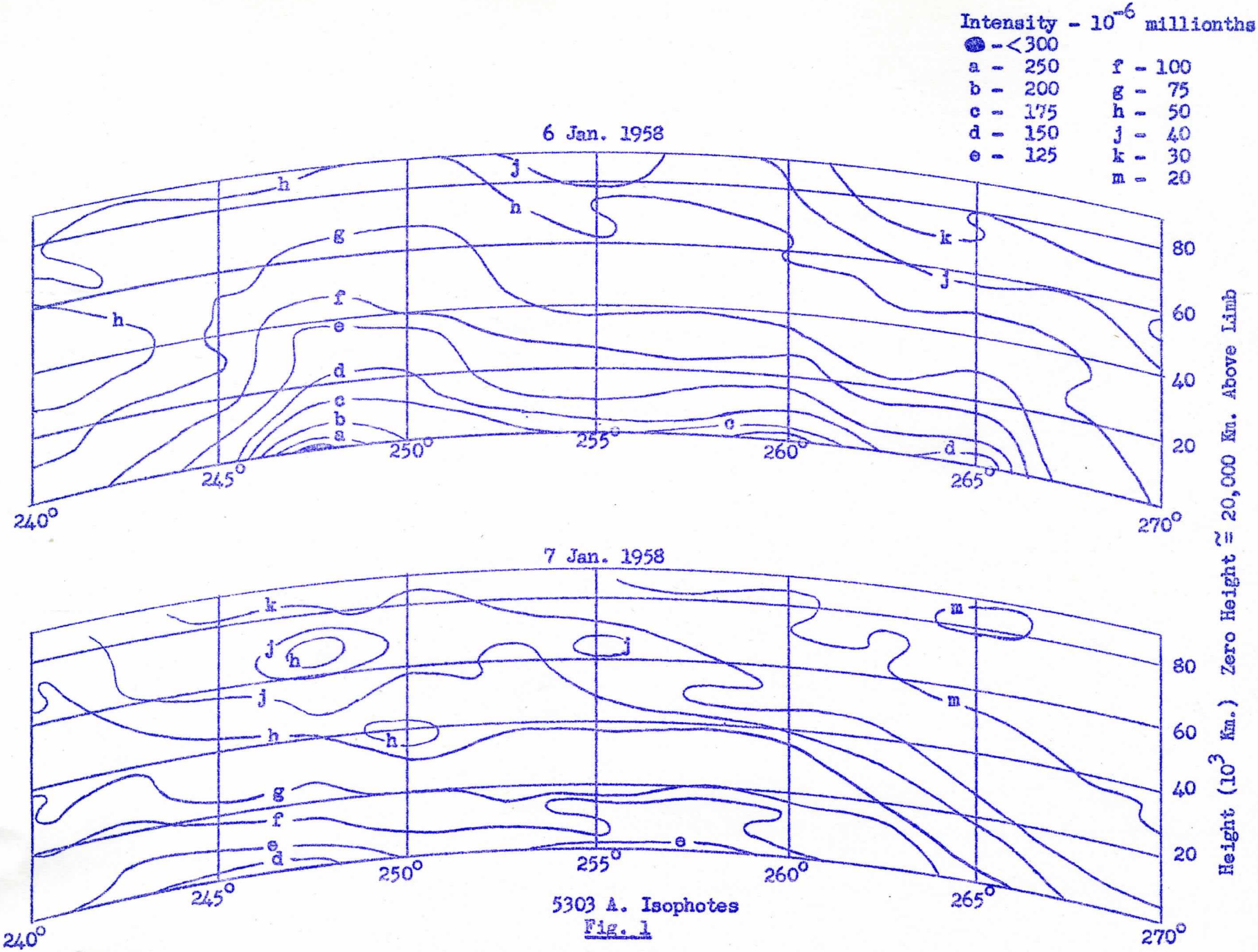


5303 A. Isophotes

Fig. 1

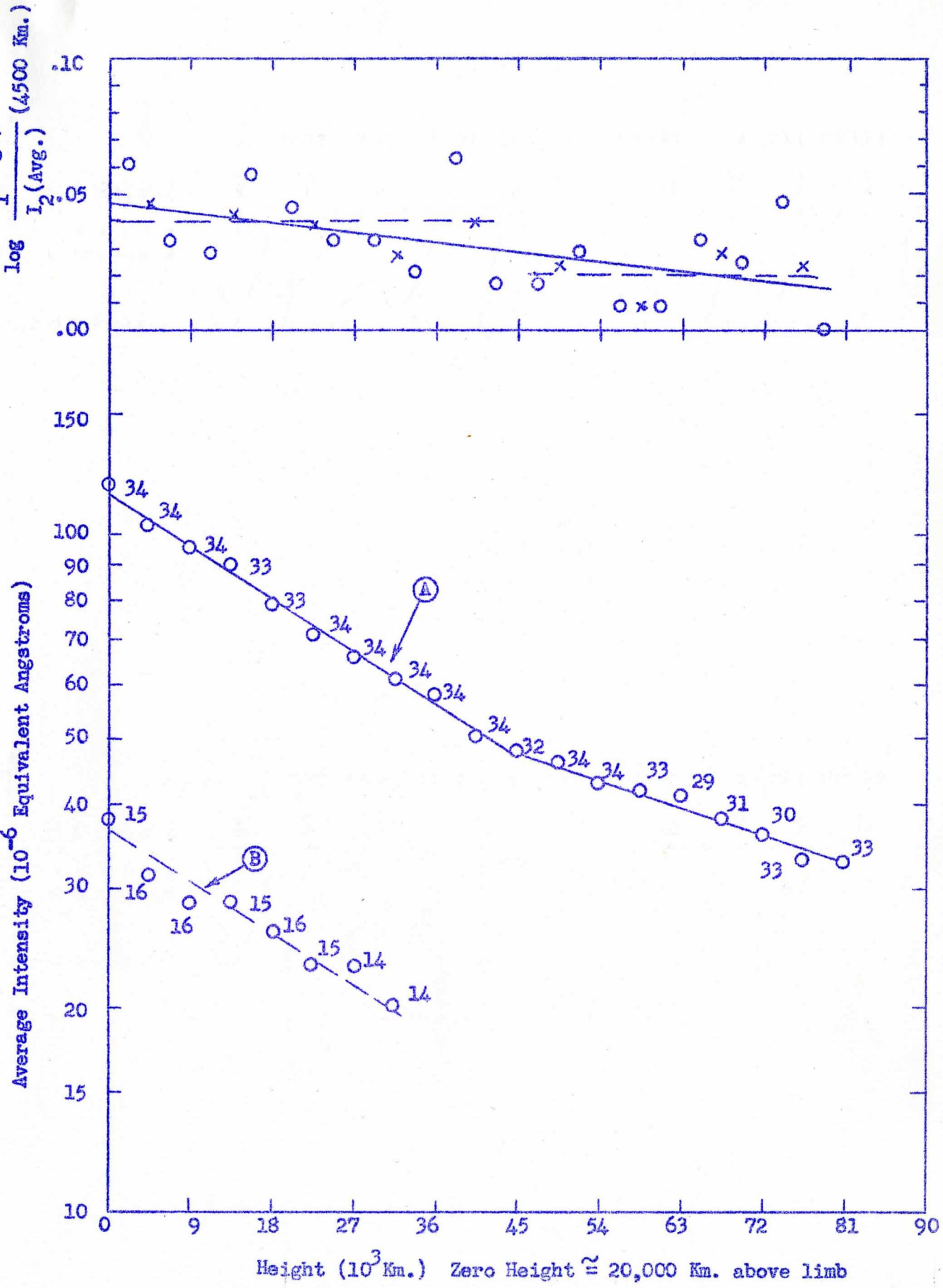

log $\frac{I_1(Avg.)}{I_2(Avg.)}$ (4500 Km.)
.10
.05
.00
150
100
90
80
70
60
50
40
30
20
15
10
Average Intensity (10^{-6} Equivalent Angstroms)
34 34 34 33 33 34 34 34 34 34 32 34 34 33 29 31 30 33 33
A
15 16 16 15 16 15 14 14
B
0 9 18 27 36 45 54 63 72 81 90
Height (10^3 Km.) Zero Height ≅ 20,000 Km. above limb

Fig. 2

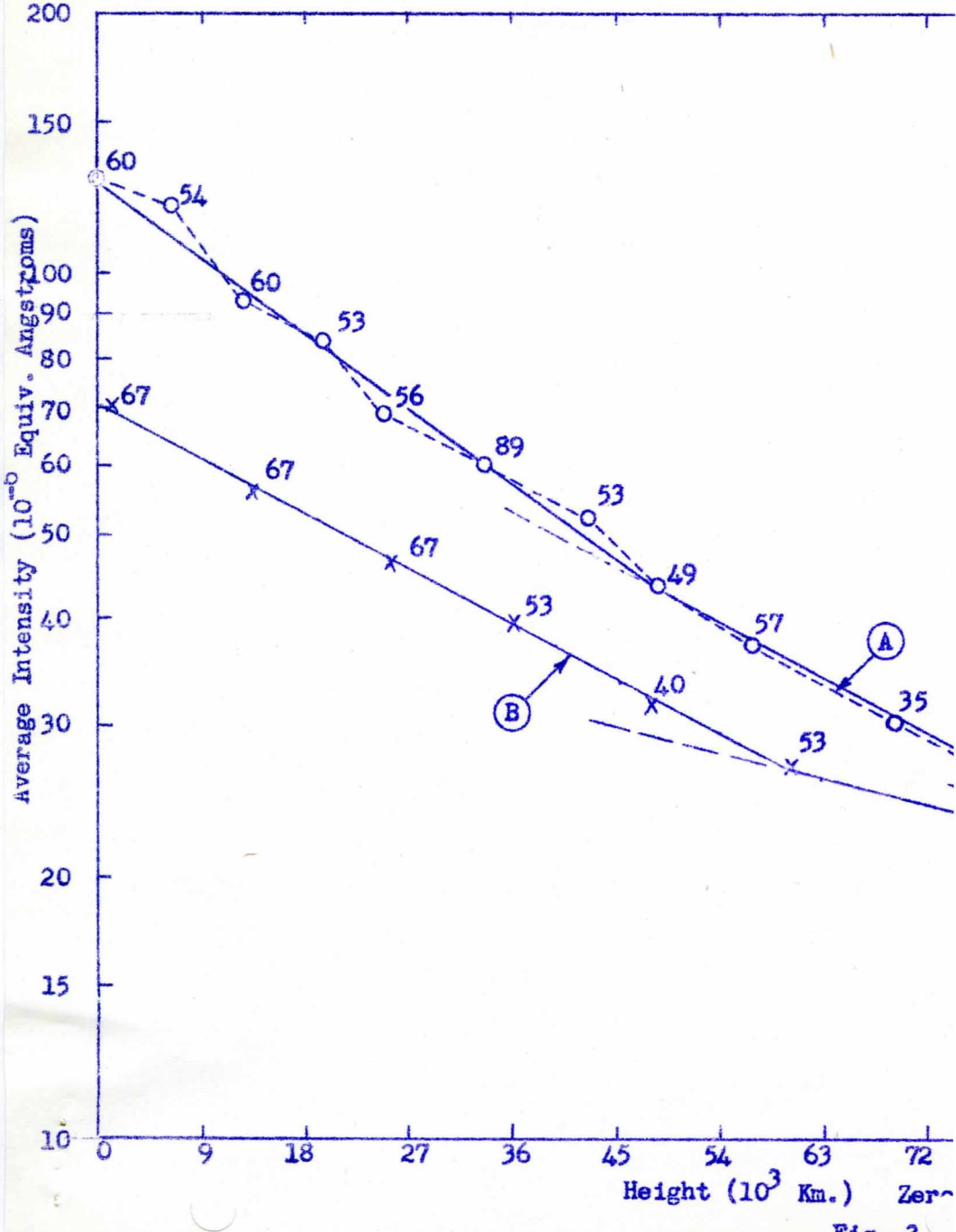
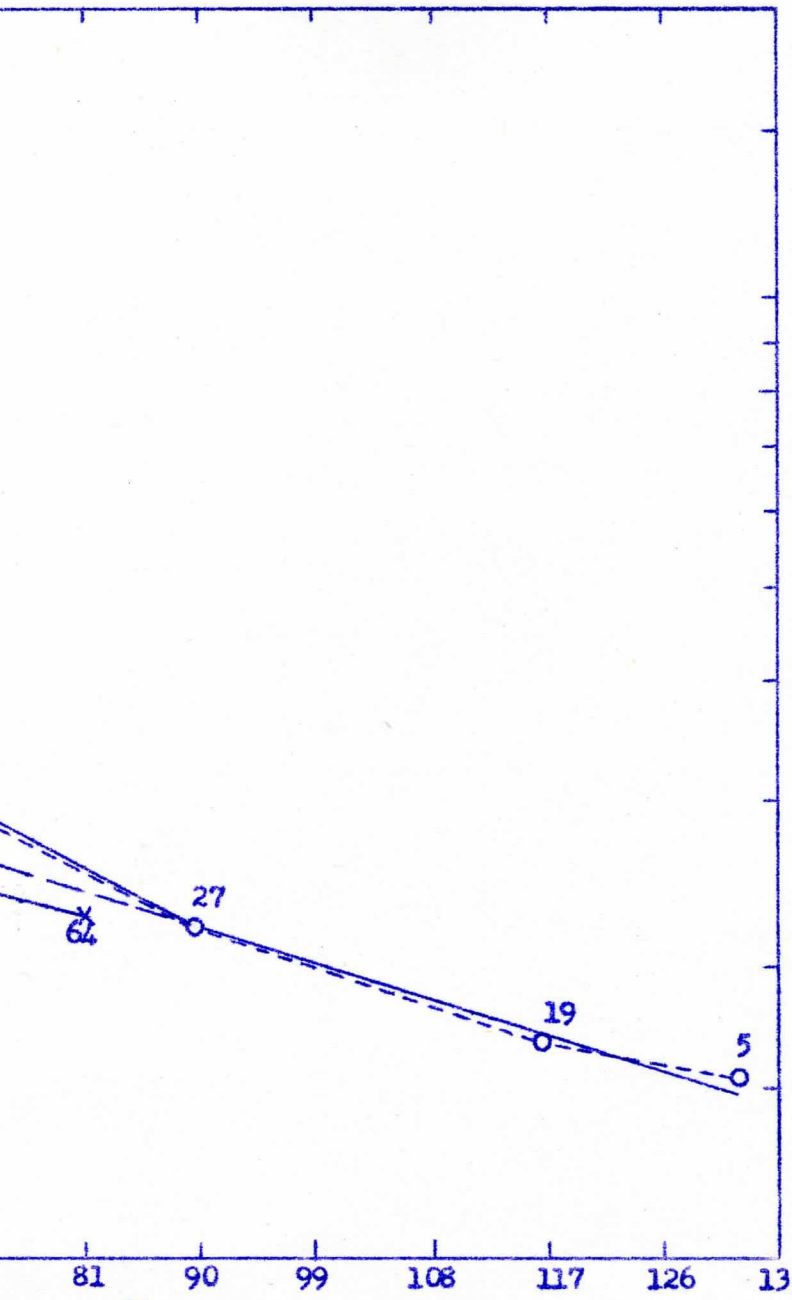

200
150
100
90
80
70
60
50
40
30
20
15
10
Average Intensity (10^{-5} Equiv. Angstroms)
0
9
18
27
36
45
54
63
72
Height (10^3 Km.)
60
54
60
53
56
89
53
49
57
35
67
67
67
53
40
53
A
B

Fig. 3



height ≅ 20,000 km. above limb

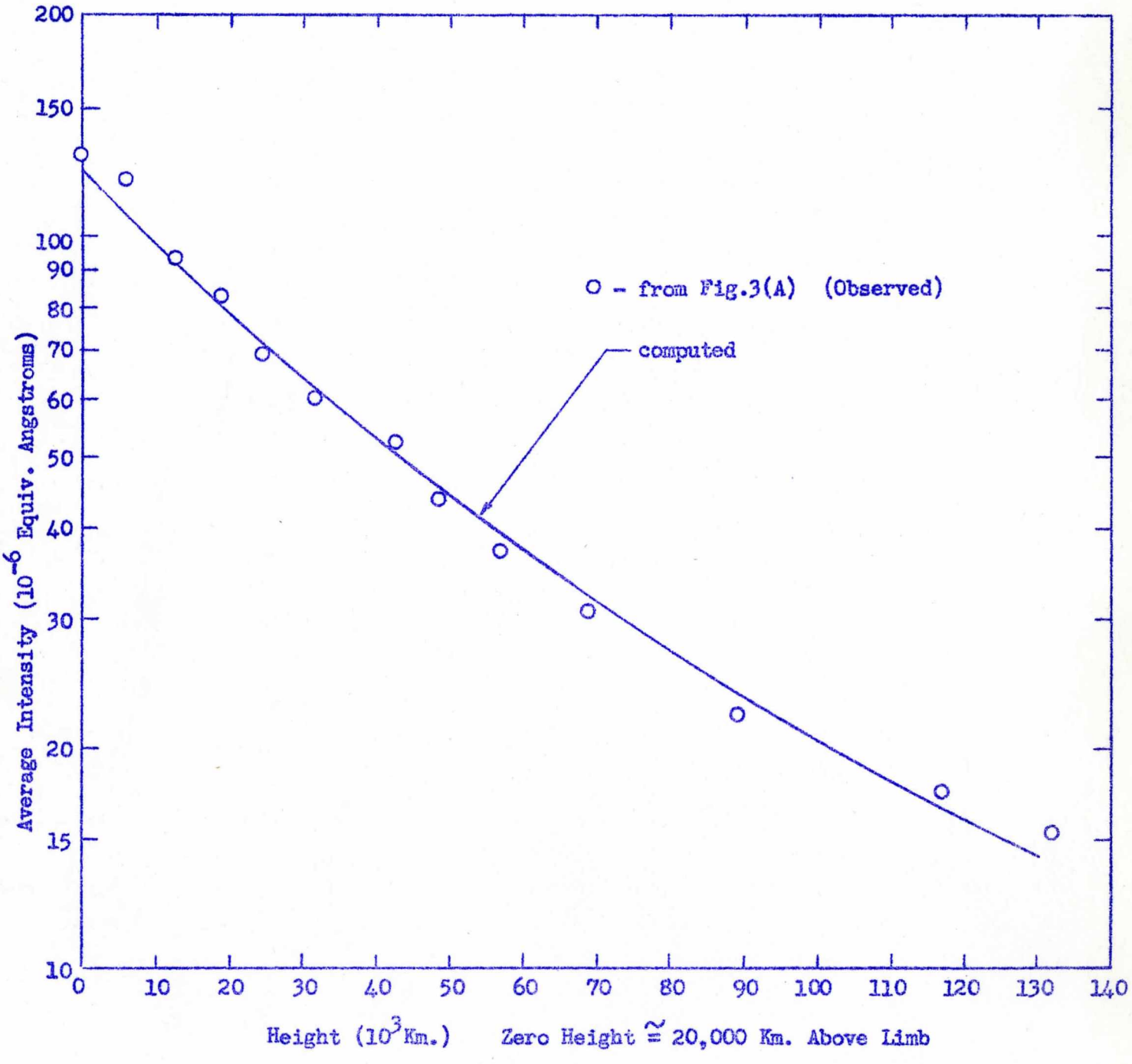

200
150
100
90
80
70
60
50
40
30
20
15
10
Average Intensity (10^{-6} Equiv. Angstroms)
O - from Fig.3(A) (Observed)
computed
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Height (10^3 Km.)
Zero Height ≅ 20,000 Km. Above Limb

Fig. 4