Reviewer's Comment

The zodiacal light is a cone of light that may be seen over the horizon when the sun is depressed more than about 18° below the horizon. Blackwell and Ingham[1] have published a photograph of the phenomenon.

The basis of the paper by Fesenkov is the realization that the zodiacal light is due almost solely to the scattering of sunlight by dust particles in interplanetary space. This was the original theory of the zodiacal light which remained unchallenged for more than two centuries until 1953, when Behr and Siedentopf suggested that approximately half of the total brightness may be due to scattering of sunlight by free electrons in interplanetary space; the electron density required by this theory is about 600 cm^{-3} at 1 au from the sun. Fesenkov demonstrated (see his Refs. 1 and 3) that this theory of electron scattering is probably not true by showing that the polarization of the zodiacal light may be accounted for by scattering by dust. However, Fesenkvo does not mention that Rossi and associates at Harvard[2] have measured directly the ion density in interplanetary space at 1 au from the sun and shown it to be so much lower than the 600 cm^{-3} required by Behr and Siedentopf's theory that the contribution from electron scattering must be quite insignificant. Similar Russian investigations[3, 4] have yielded the same result. Furthermore, he does not mention the work of Blackwell and Ingham,[5] who obtained a similar result from spectrophotometric observations of the zodiacal light from a very high mountain station.

Fesenkov then considers the maintenance of the interplanetary dust cloud. The dust particles are drawn into the sun by the Poynting-Robertson effect, a phenomenon considered in some detail by Wyatt and Whipple.[6] The dust cloud is consumed at such a rate that it must be continually replenished, and Fesenkov considers the theory that the fresh dust arises from the disintegration of asteroids. He shows in an elegant way that no theory based on the properties of asteroid orbits can explain the large observed width of the isophotes of the zodiacal light, and he therefore concludes that the dust probably originates in the disintegration of comets, the orbits of which often have high inclinations to the ecliptic. However, he does not mention that comets may move in a direction opposite to that of the planets. Hence it will be of interest to see, from spectroscopic observation, whether the interplanetary dust cloud does in fact orbit in one direction only (corresponding to the disintegration of asteroids) or in both directions (corresponding to the disintegration of comets).

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Measurement of the Absorbed Radiation Dose on the Third Soviet Satellite Spaceship

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The third Soviet satellite spacecraft, launched on December 1, 1961 [sic] 1960 into an orbit with perigee 187 km, apogee 265 km, and angle of inclination to the plane of the Equator 65°, carried radiometric equipment of the kind used on the second satellite spacecraft.[1] This consisted of two scintillation counters and one gas-discharge counter, and differed from that used on the second spacecraft in the following ways:

1) Instead of two gas-discharge counters operating alternately there was a single counter in continuous operation, thus increasing the amount of information received.

2) The sensitivity of the channel measuring the energy release in the Na I (T1) crystal was increased by more than an order of magnitude.

3) The high voltage batteries for the photomultiplier and the gas-discharge counters were replaced by semiconductor voltage transformers.

The measurements made on the second spacecraft enabled investigators to establish the radiation distribution and to measure the absorbed dose at a height of 320 km above the earth's surface.[2] The trajectory of the third spacecraft, which averaged 100 km lower, made it possible to locate the lower boundaries of the radiation belts with greater precision.

Fig. 1 shows the readings of the radiometric counters on the third spacecraft for most of its trajectory. The picture differs only slightly from that observed during the flight of the second spacecraft. Superimposed on the maximum counts due to the latitude effect of cosmic rays are peaks created by the passage of the spacecraft through sections of the radiation belts. The geographical positions of these sections of the belts were about the same as the positions obtained on the second spacecraft,[2, 3] but the intensity of the bremsstrahlung from electrons in the outer radiation belt was lower—by $2\frac{1}{2}$ times on the average in the northern hemisphere and by 30% in the southern. The value of the average energy release of bremsstrahlung in the Na I (T1) crystal, determined as in Ref. 1, was 2×10^5 ev per quantum.

The intensity of bremsstrahlung declined markedly in the region of the Brazilian magnetic anomaly. The intensity of the proton component in this region also decreased by almost an order of magnitude.

The geographical distribution of the strength of the absorbed dose, determined on the basis of the energy release in the Na I (T1) crystal (Fig 2), was almost exactly the same as the distribution obtained on the second spacecraft. A slight difference is evident in the South Atlantic region alone.

The average strength of the absorbed dose was 6.9 mrad

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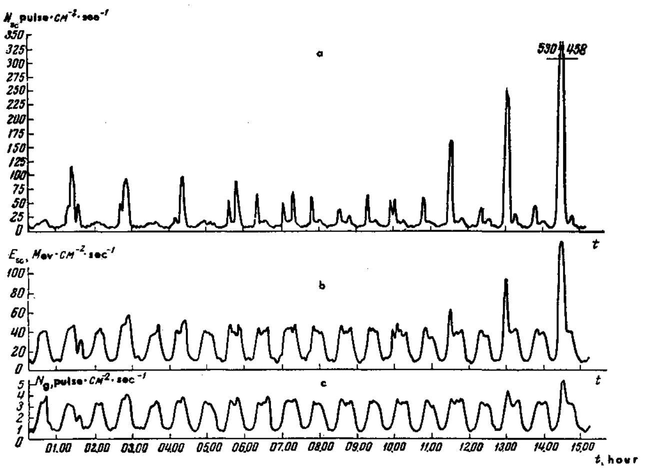

Fig. 1 Readings of radiometric gages on one section of flight of third spacecraft, December 1, 1960: a) Intensity registered by the scintillation counter with a threshold of 25 kev; b) energy release in the crystal of the scintillation counter; c) intensity registered by the STS-5 gas-discharge counter

per day, in complete agreement with the results obtained on the second spacecraft. The integrated dose for one orbit varied from 0.35 to 0.6 mrad depending on its geographical position.

Figure 4 in Ref. 3 shows the contours of equal counting rate of the scintillation counter. They mark the position of the radiation belts, since the scintillation counter registers bremsstrahlung with high efficiency. The radiation belts make their largest contribution to the cumulative dose in the South Atlantic and South Pacific regions and over North America. But taken as a whole this contribution is not large; just as in the case of the second spacecraft, the bulk of the dose is contributed by cosmic rays.

It should be noted that the scintillation counting rate in the equatorial regions averaged 30% lower than that of the second spacecraft—intensity of 4.1 cm^{-2} sec^{-1} compared with 5.5 cm^{-2} sec^{-1}—while the energy release in the Na I (Tl) crystal and the counting rate of the Geiger counter remained practically the same in those regions. This shows that the lower scintillation counting rate on the third spacecraft was due to low energy gamma quanta.

A comparison of the energy release in the Na I (Tl) crystal and the counting rate of the STS-5 Geiger counter (Fig. 1) shows that these two parameters vary very similarly; their curves in Fig. 1 are almost identical. Physically, this is because the energy release of penetrating charged particles in the crystal has a value in the region of 10^7 ev, whereas the energy release for one absorbed quantum has a value of about 10^5 ev, that is, it is smaller by 2 orders of magnitude. And although the Geiger counter is 100% efficient for penetrating charged particles, it is only about 1% efficient for x rays, that is, it is also less efficient by 2 orders of magnitude. Thus upon satellite's entrance in the outer radiation belt the relative increment of the energy release in the crystal closely coincides in order of magnitude with the relative increment in the counting rate of the STS-5. This makes the Geiger counter a convenient instrument for dose measurement in these conditions, especially if the "rough running" in the crystal is taken into account.

The dose measurements made on the second and third spacecrafts produced the following basic results:

Global maps of the distribution of the absorbed dose at heights of 180–250 km and 306–339 km were obtained.

The existence of the outer radiation belt at these heights was detected, the borders of this belt defined, and the average energy and intensity of radiation in it determined.

The fact that the inner radiation belt drops lower in the region of the Brazilian magnetic anomaly was established.

The presence of relatively intense streams of soft corpuscular radiation in the equatorial latitudes was revealed.[4]

The chief result of these investigations is the conclusion that there is practically no danger in space flight at heights of less than 350 km over a considerable period of time, in the absence of solar flares. Furthermore, a comparison of the experimental data obtained on the second and third spacecrafts makes it possible to draw practical inferences of the degree of danger from radiation in flight at greater heights as well.

In conclusion we wish to thank A. F. Tupikin, Yu. V. Trigubov, and L. A. Smirnov for their help in preparing for the experiment and T. V. Kurakina and V. P. Spirina for organizing the material.

—*October 10, 1961*

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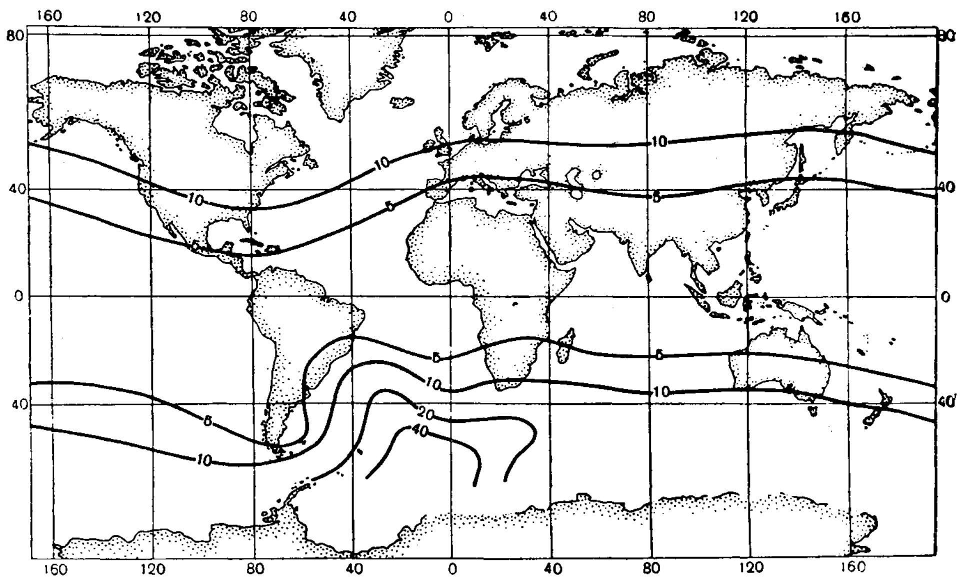

Fig. 2 Distribution of strength of absorbed dose from measurements made on third spacecraft. Figures on lines show strength of dose (mrad per day)