10-22-2016

High Altitude Dependence of Ionizing Radiation from Cosmic Rays

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Recommended Citation
Gibson, Zack; Nagata, Akihiro; Morikawa, Midori; Sakai, Takuyuki; Shimizu, Takahiro; Takahashi, Yuta; Okita, Shusuke; Ramirez, Raul; Hughlett, Alexandra; Kameda, Toshihiro; and Dennison, JR, “High Altitude Dependence of Ionizing Radiation from Cosmic Rays” (2016). Fall 2016 Joint Meeting of the Four Corner and Texas Sections of the American Physical Society. Posters. Paper 44.  
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Cosmic radiation was measured as a function of altitude using a compact Geiger counter aboard a high altitude balloon. Researchers from University of Tsukuba developed and flew the payload with the Utah State Get-Away-Special team. Dose rate, temperature, pressure, humidity, altitude and position data were acquired during a ~4 hour flight up to an altitude of almost 40 km in August 2016 and again in a second flight planned for November 2016. The magnitude and non-monotonically increasing profile of the dose curve with altitude were found to agree well with previous measurements and with theoretical predictions based on the production of showers of daughter products generated by interactions with the atmosphere of cosmic rays.

From previous data it was inferred the Geiger counter may need to be calibrated for changes in efficiency for temperature. To account for this the Geiger counter was placed in a thermally isolated chamber with dry ice and a constant radiation source. It was then allowed to cool and warm up. Above are graphs displaying the results. There is a very weak trend seen in the temperature versus counts per minute graph (lower). The fit line suggests that from ~20 to 20 degrees Celsius there is only a change of about 4 counts per minute, or a percent error of about 7%. Note that on the flight the lowest temperature reached was -7 degrees Celsius. The percent error for number of counts goes as one over the square root of the number of counts and on average is about 60, implying an error of about 8 counts per minute or a 13% error. This “trend” is well within the error.

The dose rate as a function of altitude was determined from the measured pressure in the balloon flight. A simple model was used: 

$$h = h_0 \ln(t_0 / t)$$

Where $h_0$ is the scale height, $h$ is the altitude, $t_0$ is the atmospheric depth at sea level, and $t$ is the atmospheric depth.\[22\] The atmospheric depth is the pressure divided by the acceleration due to gravity. The results can be seen below in the graph of counter per minute versus altitude.

The shape of the non-monotonically increasing curve agrees very well with a long term cosmic ray observational experiment from 1957 to 2001.\[3\] In this study the count rate varied drastically over solar cycles and different latitudes but the peaks of the count rate always fell around 18-22 km altitude. This is in agreement with our findings with a peak at about 22 km. Their data suggested a peak was at about 70 g/cm², for our latitude, which translates to a pressure of about 7 hPa, and our peak was found to be at about 6 hPa. Although this may seem discrepant, the peaks are wide and these values are in general agreement with each other. We can see that the dose rate increases exponentially with altitude until about 22 km at which it starts to decrease. This is the point where there is no longer as much atmosphere to interact with, and this peak is kind of the penetration depth of cosmic rays into the atmosphere. This is analogous to penetration depth of electrons in dielectric materials.

### References


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**Acknowledgments:**

Partially funded by Japan Student Services Organization (JASSO) and University of Tsukuba
Support for the USU Get-Away-Special (GAS) team comes from the Office of the Vice President for Research at USU and the USU Space Dynamics Laboratory (SDL)

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**Figure 1:** (Top) Diagram of payload. (Middle) Counts per minute versus time. (Bottom) Counts per minute versus temperature.

**Figure 2:** Graph of counts per minute as a function of altitude.

**Figure 3:** (Top) View from the balloon. (Left) The balloon being prepared for launch. (Right) Picture of the payload after the flight.