README for CRaTER GCR LET Spectra

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New March 20, 2024

This dataset is a continuation of that presented by Looper et al. (2020a, b). It consists of energy-deposit spectra as measured in lunar orbit behind approximately 9.9 g/cm$^2$ of shielding. These energy deposit spectra are commonly referred to as spectra of “linear energy transfer” or LET; see Looper et al. (2013, 2020a) for discussion of the distinctions between LET, “lineal energy,” and measured energy deposit in detectors. The dataset is restricted to solar quiet times, so the radiation exposure being measured is that due to galactic cosmic rays (GCRs). These are a steady constituent of the radiation environment in space, partially shielded by the geomagnetic field for spacecraft in Earth orbit but not at all at the Moon. They vary slowly with the 11-year solar activity cycle, and the purpose of this dataset is to track this variation over the lengthy and ongoing Lunar Reconnaissance Orbiter (LRO) mission.

The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) has been in orbit around the Moon aboard LRO since 2009 (Spence et al., 2010). Its six silicon solid-state detectors, numbered D1 through D6, form a telescope whose axis, in the nominal spacecraft orientation, points straight up and down with the D1 end facing space and the D6 end facing the lunar surface. The even-numbered detectors are 1 mm thick and are sensitive to energy deposits from lighter ions, mainly H and He, while the odd-numbered detectors are thinner and have lower gains so as not to saturate from the larger energy deposits of heavier ions.

A requirement that D2, D4, and either D5 or D6 or both be triggered selects particles that penetrate the entire telescope stack, including two thick cylinders of tissue-equivalent plastic (TEP) between sets of detectors. Since very few charged particles energetic enough to penetrate this much matter rise up from the lunar surface, this subset of the data consists almost entirely of particles coming from interplanetary space, and by omitting periods when the sun was producing significant fluxes of energetic particles we can sample the LET spectrum of the steady flux of GCR ions. Looper et al. (2020a) used the Geant4 Monte Carlo radiation-transport code (Agostinelli et al., 2016) to model the foreground and background response of the CRaTER sensor, and thereby to devise cuts on energy deposits in the different detectors to reject much of the background. The scrubbed LET spectrum of GCR ions was accumulated over six-month intervals to build up statistics for deposits at high LET from rarer heavy ions like iron.

As part of the Supporting Information for the journal article, Looper et al. (2020a) provided a movie showing the changes in these six-month spectra alongside the varying sunspot number as a representation of the state of the solar activity cycle. This movie extended through day 65 of 2020, and Looper et al. (2020b) provided a cover illustration for the journal issue with one more six-month spectrum, through day 247 of 2020. The present dataset adds more spectra, through day 66 of 2024, and corrects an error from the original publication’s plots in the combining of two or three channels at high LET to improve statistics.

Figure 1 shows the highest (solar minimum activity) and lowest (solar maximum activity) GCR intensities measured during the mission to date, along with the most recent six-month spectrum. LET spectra are calculated from a combination of the energy deposits in D5 and D6, which are adjacent in the detector/TEP stack, so that that GCR ions must penetrate 9.9 g/cm$^2$ of matter (mostly TEP) to reach them.  Spectra are multiplied by the square of the LET on the abscissa of the plots, to compress the many-decade dynamic range and make differences between the curves more visible, and some bins are combined at high LET to improve statistics. Figure 2 shows the same spectra, focusing in on the low-LET portion (mostly due to H and He) to make such differences even clearer.  Figure 3 shows the ratio of each six-month LET spectrum to the most intense one (blue curve in Figures 1 and 2) over the LRO mission to date. Finally, Figure 4 shows the dose rates calculated from each of the LET spectra using the method in Appendix A from Looper et al. (2020a).  The dataset itself consists of a single comma-delimited ASCII file, "CRaTER_GCR_LET_spectra.txt," with one column for the LETs on the abscissa of Figures 1 and 2 and one column giving the spectrum during each of the six-month periods analyzed to date.  Headers of each of these columns label the time period for the spectrum in that column, e.g., "2009259-2010065" for the period at the start of the mission.

**Acknowledgements**

This work was supported by the NASA LRO program under contract NNG11PA03C.

**References**

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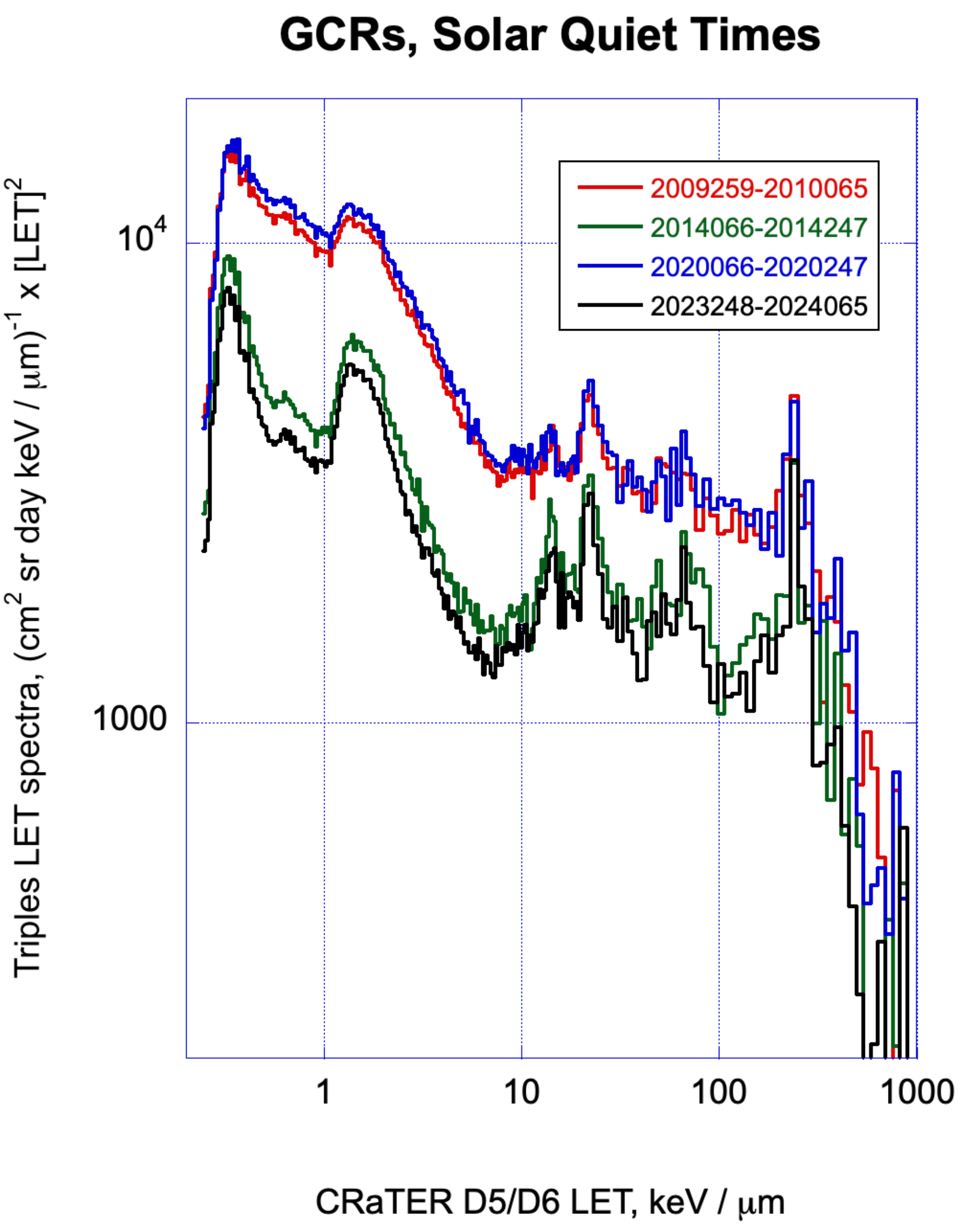


*Figure 1: GCR LET spectra from CRaTER detectors D5 and D6, multiplied by the square of the LET on the abscissa to reduce dynamic range. The red curve is the spectrum measured during the deep solar minimum at the start of the LRO mission, the green curve is the lowest intensity reached during the subsequent solar maximum, and the blue curve is the highest intensity reached during the following solar minimum, even higher than the one at the start of the mission. The black curve shows the most recent spectrum, which has now dropped below the level reached during the previous solar maximum. Based on Figure 7 of Looper et al. (2020a).*

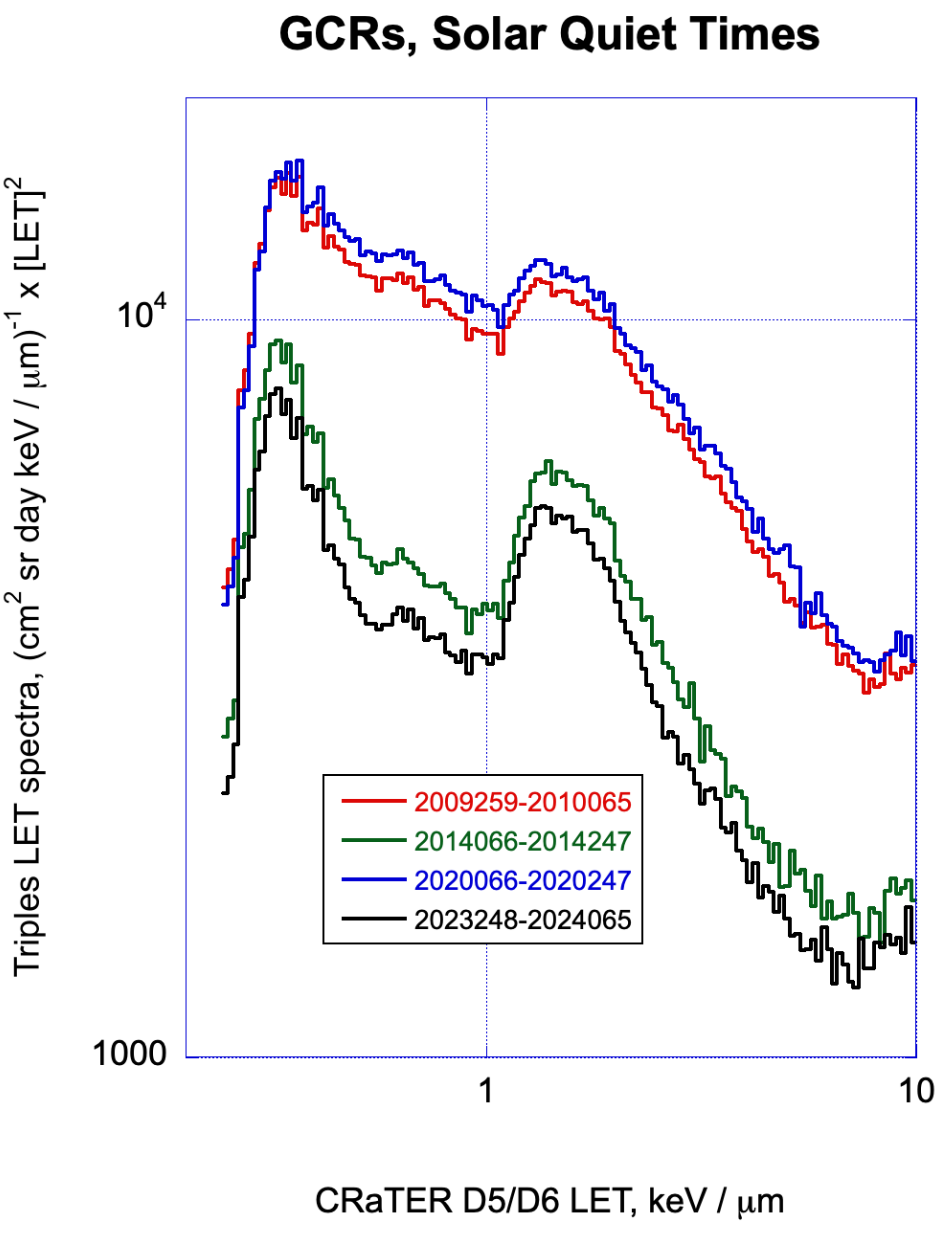


*Figure 2: Same LET spectra as in Figure 1, again multiplied by the square of the LET on the abscissa, but focusing on the low end of the LET range to make differences between the curves more readily visible.*

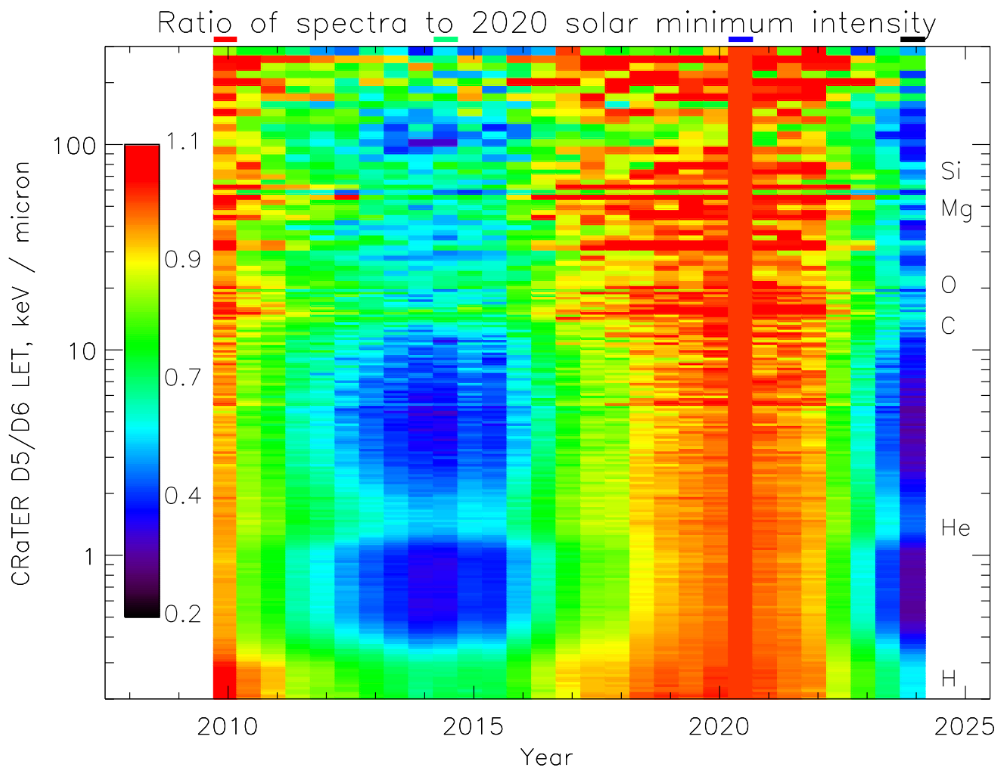


*Figure 3: Ratios of 6-month LET spectra to the most intense period, shown by the blue curve in Figures 1 and 2. Colored bars above the plot area correspond to the colors of the curves for the corresponding periods in Figures 1 and 2, and element symbols at right indicate locations in LET of the relativistic (minimum-ionizing) GCR peaks for each element, which are less modulated over time by solar activity than the spectra at LET values between peaks. Based on Figure 6 of Looper et al. (2020a).*

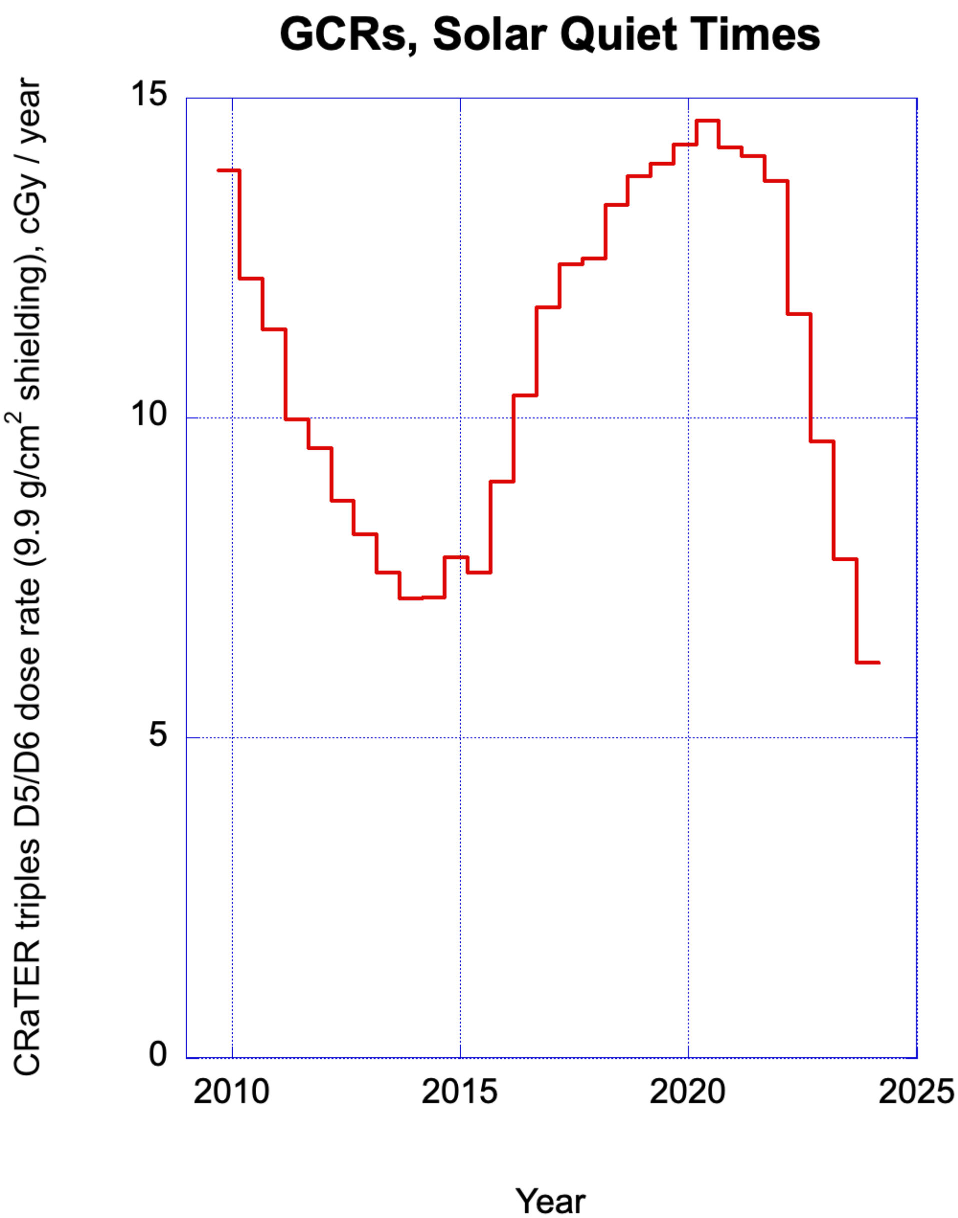


*Figure 4: Dose rates calculated from the six-month LET spectra in the dataset. Based on Figure A2 of Looper et al. (2020a).*