29th International Cosmic Ray Conference Pune (2005) **00**, 101–104

Ground gamma radiation associated with lightning and rain precipitation

U.B. Jayanthi[a],A.A. Gusev[b], J.A.C.F. Neri[a], T. Villela[a], O. Pinto Jr.[a], G.I. Pugacheva[c], K.C. Talavera[a], I.M. Martin[d]

(a) Instituto Nacional de Pesquisa Espaciais(INPE), CP 515, São José dos Campos, SP, 12201-970 Brazil
(b) Space Research Institute of the Russian Acad. of Sciences (IKI), Moscow, Russia
(c) Unidade Regional de Sul de Pesquisas Espacias (INPE), Santa Maria, RS, Brazil
(d) Universidade de Taubate (UT), Taubate, SP, Brasil
Presenter: U.B. Jayanthi (jayanthi@das.inpe.br), bra-jayanthi-UB-abs1-og13-oral

Gamma-rays with energies of $\sim$ 20 MeV associated with lightning phenomena by satellite and ground instruments in recent times has triggered interest in this natural phenomena. The inability of satellites to monitor the Brazilian Geomagnetic Anomaly (BGA) region and the extensive multi-parameter observational efforts of lightning phenomena in Brazil has provided incentive for this GGR experiment. A monitor system with a large area NaI(Tl)detector was set up near two rocket launchers for induced lightning. In few months of operation in 2005, increases in gamma-rays with intensity proportional to rain precipitation and an increase due to lightning induced by a rocket launch is monitored. The decay period of $\sim$ 30 min, definitely identified the radon progeny in rain but we have not identified the source in the case of lightning. The spectral information indicates a power law index for both the phenomena. Although not conclusive, we report here an indication of a gamma-ray line at 1240 keV. Interestingly, proton interactions with Ar (an atmospheric constituent) produces an isotope ^{39}Cl which has emission at this energy.

1. Introduction

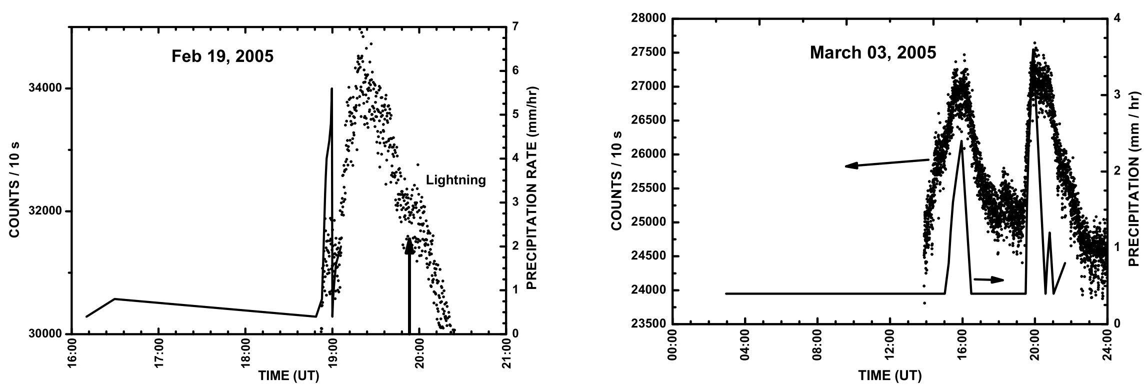
The detection of Terrestrial gamma-ray flashes (TGF) by Compton Gamma Ray Observatory (CGRO) and recently by RHESSI from the Earth's upper atmosphere is explained as due to electrical discharges as also the radio pulses [1]. The energies involved correspond to electrons $\leq$ 40 MeV. Ground observations at sea level of the x and gamma-rays with detectors has considered different aspects of the lightning discharges.The x-ray measurements with time resolutions of μs, at a rocket triggered lightning site, observed bursts of x-rays associated with dart leaders and return strokes [2]. This group and also Moore et al (2001) [3] observed γ-rays of energies up to 10 MeV in bursts of duration $\geq 300\mu$s attributed to cloud processes. Also at sea level, observations of x and γ-rays for durations 30s to 2000s due to natural lightning and in few cases inevitably also observed emissions associated with snow and rain [4]. Our experiment of much higher sensitivity, located at a rocket triggered lightning site in Brazil, started observations of x and γ-rays recently and the preliminary results are presented in this paper.

2. Experiment and Results

The Ground Gamma Radiation (GGR) experiment utilized a NaI(Tl) detector of very large area compared to any previous experiments for the monitoring of γ-rays. This detector was employed earlier in an imaging of cosmic gamma-ray sources with mask-anti-mask system [5]. The cylindrical detector had dimensions of 40 cm X 5 cm and showed relatively poor resolution of $\sim$14% for Cs (661 keV). The signals from the 19 photomultipliers and pre-amplifiers are weighted and mixed before input to a single shaping amplifier. This principal NaI(Tl) detector is surrounded by a plastic scintillator on the sides and another NaI(Tl) crystal on the bottom, and in this experiment it is employed in a passive mode to permit free access of only x and γ-rays from top. A thick aluminum housing served as a support and as an hermetic sealing. The standard electronics consisted of high voltage units besides the amplifiers and an PCA (ORTEC) card for monitoring the pulse height in 512 channels encompassing the energy range of 60 keV to 2.12 MeV. The pulse height data is monitored every 10 s and acquired by a PC into memory. The data is retrieved once in a week and a GPS system provided the time stamping. The electronics units are all protected against surges and transients utilizing Faraday Cages, lightning protectors etc., and further the power supply is supported by a no-break system.

The complete experiment, with detector $\sim$ 3m above the ground, is mounted on an aluminum frame and placed in an open field with wood and plastic sheets cover to protect against rain and wind. The experiment was placed at a distance of $\sim$ 100 m between two rocket launch towers, in the INPE campus at Cachoeira Paulista, SP, Brazil, a rain forest valley region. The lightning activity is photographed and parameters like electric field, meteorological measurements etc, are available and the INPE Atmosphere Electrical Group has a natural lightning localization system.

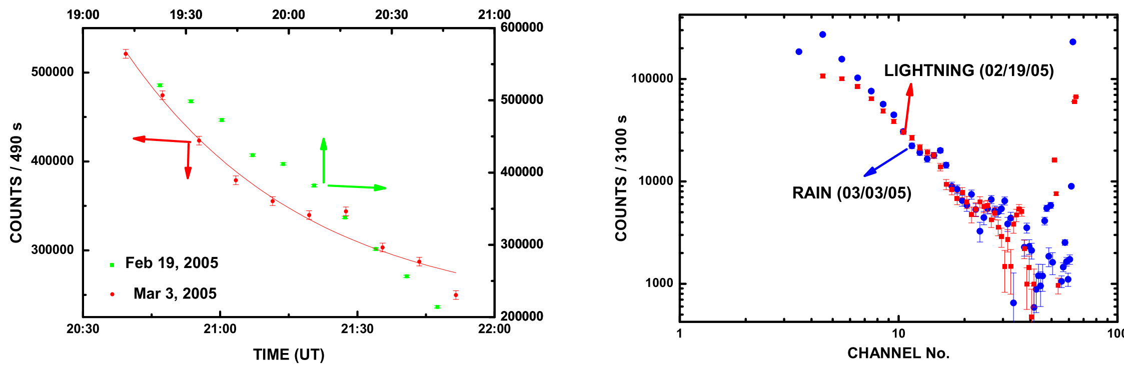
It was possible to install the equipment only in February 2005, almost near the end of rainy season, and we have collected data until the present time. The preliminary analysis of an event of artificial lightning following a rain precipitation (02/19/05) and an event when rain alone (03/03/05) with similar time history occurred are considered for analysis. Figure 1 shows the total count rate due to Ground Gamma Radiation (GGR) in these two events. An hour after the occurrence of lightning, the data accumulation ceased due to the battery pack in a stand alone mode could not provide supply beyond four hours from the start of the launch operation.



(a) (b)

Figure 1. The total gamma ray count rates including the background per every 10 s along with the rain precipitation rate is shown against UT for events (a) lightning and rain (02/19/05) and (b) rain alone (03/03/05).

All the raw count rate (GGR) show diurnal influence and we have chosen GGR data of 02/15/05 (no rain at all for 2 days) for background subtraction for these events to obtain the γ-ray count rates in events of rain precipitation alone (GPR) and rain precipitation followed by lightning (GPLR). Immediately following the rain the γ-ray count exhibit increases and later decrease in intervals upto an hour and correlated increases in GPR are clearly seen with rain precipitation rate. At the start of artificial lightning, an increase in the γ-ray count rate is evident as seen in figure. However, the influence of rain which occurred approximately an hour before the lightning event on 02/19/05 has contributions (of the rain decline phase) during the lightning phase. To obtain the time history of the events due to rain (GPR) and rain with lightning (GPRL), we have accumulated the data for 490 s. The decay rate in the figure 2a. for the event of 03/03/05 shows systematic decay of GPR with a period of $\sim$ 30 min indicating radio activity. No such a trend is seen with unique decay time in GPRL, indicating GPRL has contributions of rain in addition to lightning. To obtain further information from the data, we attempted the spectral information.



(a) (b)

Figure 2. (a)The time history of total gamma ray count rate due to the rain and lightning together (GPRL) and the effect of rain alone (GPR) against UT. The arrows indicate the respective axes and values. The lightning arrow indicate the time of the artificial lightning. (b) The observed gamma ray spectrum indicating count rate against energy channel no. is shown for the rain event (GPR) and the lightning event(GLR).

To obtain the spectra, we utilized the data of GPL alone and the lightning data with duration of $\sim$ 1 hour, the period corresponding to the data after rocket launch. Initially, the PHA counts vs channel data were accumulated for a period of 1 hour, for the background event of 02/15/05, the rain precipitation event of 03/03/05 and the lightning event of 02/19/05. The 512 channels are compressed into 64 channels for the analysis. After subtracting the background, the spectrum of GPR for the precipitation event of 03/03/05 is obtained. The rain event of 03/03/05 is of lower intensity compared to the rain preceding the lightning on 02/19/05. To obtain the spectrum of the lightning alone, the 64 channel data of the rain event of 03/03/05 was normalized and then subtracted from the 64 channel data of the 02/19/02 event. Although, this procedure is not rigorously satisfactory it provides us the estimate of GPL spectrum. These spectra of GPR and GLR are shown in figure 2b.

3. Discussion

The gradual decay of the count rates after the peak either in GPR or GPLR shows radioactive products are present in the atmosphere. In case of rain or thunderstorm it is explained in terms of radon progeny exhaled and accumulated at ground levels. These in secular and temporal equilibrium are adsorbed predominantly on rain drops and enable monitoring by detectors. This permits the good correlation between GPR and rain precipitation rate. The observed decay period in figure 2a. for the GPR indicates $T_{1/2}$ of 30.44±2.54 min and is consistent with the decay periods of 26.9 and 19.7 min respectively of $^{214}Pb_{82}$ and $^{214}Bi_{83}$. Incidentally the rain observations made by Greenfield et al (2003) have shown similar periods. However, the decay shown here for GPRL does not show any simple period relation as in case of GPR indicating the probable effect of GLR on GPR. The spectra of GPR and GPL shown in figure 2b., encompassing the energy range of 60 to 2250 keV, show essentially similar power law index for both of these populations, excepting the indication of a line in GPL at 1238 keV (channel no. 36).

Although this analysis is preliminary, it is interesting to note that ^{39}Cl isotope has energy level at this energy (of $T_{1/2}$ = 55 min). The recent hypothesis of runaway electron acceleration to $\geq$ 20 MeV energies, in the atmosphere by electric field at thunderstorm times to explain the TGR flashes, if accepted, should also provide protons of high energies directed towards the earth surface. These protons or even cosmic ray secondaries (protons or neutrons) can be expected to interact with the atmospheric constituents of C, N, O and Ar to produce the isotopes (^{11}C,^{13}N, ^{16} F, ^{39}Cl and ^{38}Cl) whose $T_{1/2}$'s are in the 10-100 min range. More definitive identification of the decay periods and the energies of the radioactive components through spectroscopic lines, in future observations of rain and lightning phenomena with more sensitive equipment will provide the understanding of the radiation processes involved in the lightning phenomena.

4. Acknowledgements

We thank Luiz E. Almeida Marcos A. Okada and Edson R. Siva for the help in the construction and operation of the GRR experiment. Also thank the CPTEC group of INPE, Brazil, for the meteorological data and acknowledge the kind advise and support of Andr Eybert-Berard of Indelec, France.

References

[1] D.M. Smith et al., Science. 307, 1085 (2005).
A.V. Gugurevich et al., Phys. Lett 312 (A), 228 (2003)
[2] J.R. Dwyer et al., GRL. 31, L05118 (2004).
[3] C.B. Moore et al., GRL. 28(11), 2141(2001).
J.R. Dwyer et al., GRL. 31, L05119 (2004).
[4] M.B. Greenfield et al., J. Appl. Phys. 93(3), 1839 (2003).
D.M. Suszcynsky et al., JGR. 101, 23505 (1996).
[5] T. Villela et al., Astrophys Space Sci. 214, 161 (1994).