ABSTRACT

Rubber balloons are being used to obtain weather related parameters, such as wind velocity, pressure and temperature profiles. They are also excellent tools for initiation in balloon borne experiments in colleges and universities. With the advent of miniaturization, it is now possible to have light weight X-ray detectors and gamma-rays detectors which can be flown to space using these small inexpensive balloons. We describe here the efforts of Indian Centre for Space Physics to carry out scientific experiments in this direction.

1. INTRODUCTION

With the miniaturization of the detectors in X-rays and gamma rays, it has become possible to imagine that space science could be done using latex balloons which can fly as high as 33-42km. There are several advantages of using weather balloons as opposed to conventional large sized balloons. A mission with a weather balloon is most certainly less expensive (by a factor of say 100 or so). It is possible to launch them in a matter of hour’s notice. Thus solar flares or flares/outbursts in black hole binaries can be picked up easily. There is no need to have a canonical launching pad of ‘facility’ for small balloons and indeed they can be launched from anywhere (including boats) as long as predicted trajectories ensure that they may be recovered at desirable places. Long term planning (often running to decades) are not required and errors made in a mission is easily corrected in the next mission.

Of course, there are disadvantages. Due to severe weight restrictions limited to a few kilograms, it is hardly possible to have large gyroscopes for stabilization and accurate pointing. Similarly large ballasts are not possible to be loaded. Large area proportional counters must be replaced by small area solid state detectors, for instance. Instead of pointed observations, we may have to have observations in survey mode (all sky monitoring) or ‘hit or miss’ mode where a particular object may be observed in every few seconds. Innovative imaging may have to be done so that all the bright sources may be images and their variabilities studied. However, ‘serious’ science can still be done with appropriate approach. In future, we plan to use with zero pressure plastic balloons to have longer flight time without a need for ballasts.

With these goals in mind, Indian Centre for Space Physics (ICSP) has been carrying out small weather balloon missions named Dignity (D) for the last three years. So far, fourteen un-tethered missions have been launched (D-1 to D14) in which two were lost, and several tethered missions were used to test indigenously made ejection system, photography, radio communication with the payload from ground, telemetry, on board storage etc. Although we have been successful only to carry out real measurements of cosmic rays by Geiger Counters while ascend and descend, judging from the GEANT4 simulation results of various detectors which we have built and are going to complete in near future, we are certain that significant scientific goals could be achieved using these low cost balloon missions.

2. INITIAL TESTS WITH VIDEO CAMERAS

Figure 1 shows an example of the trajectory [1] of the balloon from lift-off till landing. Here the ground communication with the payload was tested and real time trajectory could be seen on a Google map. Two video cameras, one scanning the horizon and the other pointing to the earth were functioning till about 80 minutes after lift-off. Heath parameters inside the payload was also computed and transmitted back.

Figure 1. Real time GPS data at the ascending and descending phases of the D8 mission when the payload was recovered about 130km away.
Figure 2. Stratospheric clouds just below the camera (left) at about a height of 22km while blue Earth and tropospheric clouds are seen below.

Figure 3. Details of a cloud in a video frame pointing to the ground in D10 Mission.

Figure 4. Reconstruction of the cloudy Earth by stitching several frames from D10 Mission.

Figure 5. 360 degree panoramic view from D8 payload. From top to bottom: 250s before totality; 150s before totality; 50s before totality; during totality (1); during totality (2) and when the totality at the site is over. Note that the shadow moves in from south west in the second panel and moved to north-east in the final (bottom) panel.

3. STUDIES OF COSMIC RAYS

This is the first real scientific instrument that was sent. Before that X-rays plates were sent (D3) to see how much they were fogged and whether imaging could be done with plates also. We also sent a rat and brought back safely [1].

For the cosmic ray studies we used a Geiger Muller (GM) counter with on board storage plus GPS/telemetry and radio communication system. The Counter was very
small (two inches long and about two centimetres in diameter) operating at 400 volts. Figure 6 shows [3] the GM counter payload onboard D10 mission. In D10, D12, D13 and D14 GM counters were sent, though the results from the D13 is more complete as the data came from the liftoff to landing. Figure 7 shows the counts/minutes as a function of the time since liftoff.

Figure 6. ICSP GMC payload for D10 Mission.

Figure 7. Rate of cosmic ray counts per minute plotted against time in minutes after liftoff in D13 Mission. The peaks of particles at ~15km are observed while going up and coming down by parachute. The burst occurs at 33km. There is some noise after the burst and before opening of the parachute.

The classic curves obtained by the GM shows a count of about 250 per minute at a height of 15-16 kilometers while going and coming back. We also obtained about 50 counts per minute at 33km where the curve is flattened for about 10 minutes. These are clearly primary rays and we plan to fly more payloads to determine their compositions.

Figure 8. Our X-ray Detector (XRD) payload undergoing text and evaluation. It consists of Si-PIN diode

4. FUTURE MISSIONS

Figure 8 shows the actual payload (700gms) constructed by our team with Si-PIN photo diode [1, 4]. The pre-amplifier and post-amplifier assembly have been tested already. In Fig. 9 we show its shape used for GEANT4 simulations.

Figure 9. The computer made XRD payload of ICSP which was used for GEANT5 simulation.

Fig. 10 and Fig. 11 show the spectra of calibrating materials which were obtained from XRD. In Fig. 10, Eu152 was used and in Fig. 11 Ba133 was used. We also used sources like Cs and Am. We made a calibration curve from these standard spectra (Fig. 12) which will be used for spectral study of solar flares.
In Figures 13-15, we show the GEANT4 simulation results of the possibility to detect a Solar M class flare by XRD using the configuration shown in Fig. 9 [4]. In Fig. 13 we show how the incoming M-class flare spectrum is absorbed by the atmosphere at different heights, ranging from 32 to 42km. In Fig. 14, we show how the Si-PIN detector would actually see it at different heights. In Fig. 15, we show the same results for CdTe detector in XRD. It is quite clear that without increasing the size of the detector we can detect better if we reach at least a height of 42km. Second, the soft photons below about 15 keV are absorbed by the residual atmosphere above 42km. Third, there are secondary particles generated inside the detector at lower energies and those have to be taken care of while data analysis is carried out. We have done a similar analysis with X-class flare. We find that we will be able to detect the X-class flare (also see, [5-6]).

In Figure 16-18, we present similar results for a typical Gamma Ray Burst (GRB) [4]. Figure 16 shows the data after it is partly absorbed through the atmosphere of different heights. Figures 17 and 18 show the GEANT4 simulated results obtained using SiPIN and CdTe detectors onboard XRD. It is clear that in both of these cases we can get significant photons only in the range of 15-80keV or so. Thus we need to either go even higher or increase the surface area of the detectors.
Figure 15. The simulation of the same flare when detected through the CdTe detector of XRD.

Figure 16. Example of a typical GRB spectrum absorbed by atmosphere at different heights.

Figure 17. GEANT4 simulation of the same GRB observed by our SiPIN detector.

Figure 18. GEANT4 simulation of the same GRB observed by our CdTe detector.

5. FUTURE PAYLOADS

So far, we discussed about the XRDs fabricated by us. We are also assembling commercially available solid state X-ray detectors.

It is clear from our GEANT4 simulations that we need to have a larger area detector to gather more photons at lower energy, since our height limit is around 40km. For this reason we are preparing detectors with larger photon gathering capabilities, such as Photo-multiplier tubes with NaI or CsI scintillators and CZT detectors. For charge particles we want to use plastic scintillators as well.

For imaging, we are in a position to send a payload using CMOS detector with masks, such as Coded Aperture masks (CAMs) or Fresnel Zone Plates as used in our earlier RT-2 payloads on-board CORONAS-PHOTON satellite [6-8].

For test and evaluation inside the laboratory, we have assembled a climate chamber capable to going up to -40 degree Celsius and one millibar. Figure 19 shows the climate chamber used for testing and evaluating our payload.
6. SUMMARY AND CONCLUDING REMARKS

There is a niche in the subject where smaller weather balloons may be used to achieve serious scientific goals. We have made a professional approach to this issue and constructed prototype instruments. We have carried out the GEANT4 simulations for estimation of the background and found that due to atmospheric absorption we cannot capture the soft X-rays up to about 15keV, but from 15 keV to 50-80keV we can have statistically significant X-rays coming from solar flares, black hole systems and gamma ray bursts. We are in the process of launching our XRD payload and hope fully will improve upon the instruments from the results obtained.

In future we are planning to launch CZT and CMOS detectors both for spectral and imaging studies. We have also found that photo-multiplier tubes together with appropriate scintillators one could obtain statistically significant number of photons in 20-80keV energy ranges.

We have already developed the basic necessary systems in house: These include ejection system, radio tracking with GPS and successful recovery by predicting the landing location using the velocity data in the ascending phase. So we are now ready to conduct these scientific experiments.

7. ACKNOWLEDGMENTS

We acknowledge the members of the balloon inflation/electronics team: H. Ray, U Sardar, R.C. Das and recovery/logistics team members: S. Ray, S. Mondal and S. Chakrabarti.

8. REFERENCES


