PHOTOMETRIC AND SPECTROSCOPIC GAMMA-RAY OBSERVATIONS OF SOLAR TRANSIENT PHENOMENA USING LONG DURATION BALLOONS

Pelling, M.R. and Duttweiler, F.
UCSD/CASS, Code C-011
La Jolla, CA 92093

Lin, R.P., Levedahl, W.K., Primbsch, H., and Curtis, D.W.
UCB/SSL, Berkeley, CA USA

Hurley, K.C.
CESR, Toulouse, FRANCE

ABSTRACT

We describe a program, currently in progress at UCB and collaborating institutions, UCSD and CESR Toulouse to conduct extended duration spectroscopic and photometric observations of solar X-ray phenomena from balloons. High photometric sensitivity to weak hard X-ray bursts is attained using a 600 cm^2 array of phoswich scintillators. High spectral resolution for stronger bursts is available from an array of planar germanium detectors. These instruments are carried in a novel balloon gondola designed for the 15 to 20 day float durations available through using conventional zero-pressure balloons in the radiation controlled (RACOON) mode.

<u>1. Introduction</u> Important new results concerning energetic flare processes have been obtained using a unique instrumental complement combining high spectral resolution and photometric sensitivity in a conventional balloon flight. The excellent spectral resolution available through the use of germanium solid state detectors permitted the discovery of a superhot (3.5 x 10^7 K) flare emission component (1) and the high photometric sensitivity of a large area phoswich scintillation counter permitted detection of ~25 "μ-flares" with fluxes 10^1-10^2 lower than conventionally associated with major flare activity (2). The existance of superhot emission components has since been indirectly confirmed through Fe XXVI measurements (3) and continuum measurements below 30 keV (4). The optical counterpart of μ-flare events were subsequently discovered through analysis of co-ordinated H_α observations (5). The μ-flares have a non-thermal spectral distribution and show evidence for temporal structure faster than ~1 s.

<u>2. Scientific Objectives</u> The general significance of these phenomena is not clear since the superhot component has been directly observed in only one flare and the observed μ-flares were probably the product of a single active region. It is interesting to note; however, that the size/frequency distribution for the μ-flares suggests that their underlying particle population could be significant for heating of the active corona. Thus, it is of great interest to determine how general the acceleration of >20 keV

electrons is for transient processes on the sun. Other interesting questions include: How does the superhot component vary from flare to flare? Indeed, how hot do flare regions get? How are the heating and acceleration mechanisms related?

In order to clarify the role of these hard x-ray processes in overall solar energetic phenomena it is necessary to extend the observations to span a variety of solar activity conditions. The primary requirement for these follow-on studies is to attain a relatively long observing period (comparable to solar rotation period) using instrumentation having high photometric and spectroscopic sensitivity. For this purpose we have modified our original balloon instrument to provide additional sensitivity and to function within the constraints of a long duration balloon flight.

3. Flight Apparatus To attain the above objectives we have enlarged the collecting area of the original payload and adapted it to a unique balloon gondola designed to capitalize on the long float duration available using standard zero-pressure balloons in the radiation controlled (RACOON) mode. A block diagram for the detector system is shown in Figure 1.

Our detector complement consists of an array of four actively shielded high purity cooled planar germanium detectors totaling ~50 cm^2 active area plus three large area NaI(Tl)/CsI(Na) phoswich scintillation counters totaling ~600 cm^2. Cooling for the germanium detector array is provided by a 160 l dewar of liquid nitrogen. The aperture of the germanium array is oriented vertically with an acceptance angle of 40 degrees (full width, zero response). This permits sensitivity to solar transient events for roughly two hours of each day at >33% response. The phoswich scintillation counters have 3 mm thick primary detector elements and are optimized to respond in the 15 to 150 keV energy range. Each phoswich has a crossed slat collimator which defines a pyrimidal angular response with FWHM of 15 degrees.

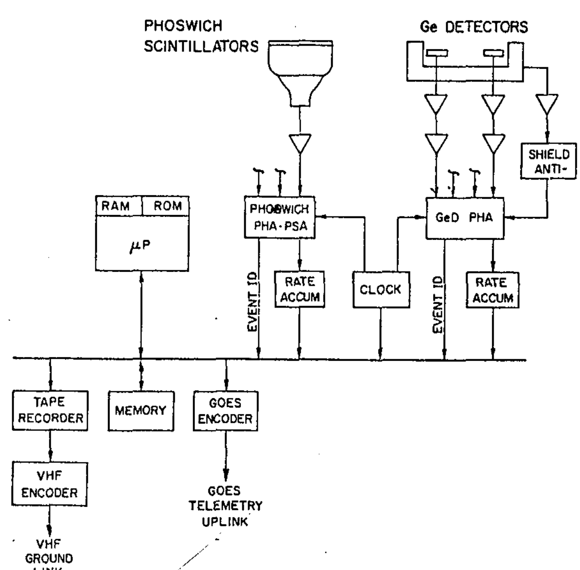

Figure 1 - The μ-processor based data system accommodates a wide dynamic range of detector event rates and prioritizes the data for storage or telemetered output (see text).

The phoswich array is carried in an alt-azimuth gimbal which is slaved to an external aspect sensor platform. The aspect sensor platform is programmed during the day to track the sun in azimuth and elevation with a precision of ~ 1 degree. During night operation or periods when the sun is too low in the sky to permit useful x-ray observations the aspect sensor platform may be reprogrammed to track the local magnetic field. This operating mode permits observation of non-solar sources via a pre-programmed tracking routine with an accuracy of ~2 degrees. The aspect sensor platform also incorporates a sunrise/sunset sensor to provide daily navigation updates to the tracking routines.

The data generated by these detector systems are processed by an on-board computor and prioritized for output via one or more of three channels as shown in Figure 1. Discrete x-ray event words in which pulse height and timing information are encoded are read directly into a large dynamic random access memory via direct memory access control. This memory is sized to hold the transient events totaling up to 10^6 discrete detected photons. The raw event rates are monitored in parallel with memory storage of the detector data streams by the on-board processor to detect the presence of solar burst events. Data segments which contain such burst events are then tagged for preferential storage and output. When ~50% of the main buffer RAM is filled (~2 hours under background rate conditions) the data are transferred to the on-board tape storage system. This system includes two 3M model HD-75 digital recorders having a total capacity of 136 Mbytes which is sufficient to hold all of the data generated during the nominal 20 day balloon flight. Burst event data from the previous day are read out of the burst memory section each night and transmitted via the Geostationary Orbiting Environmental Satellite (GOES) network at an effective rate of 60 bps. During the day this data channel is used in real time to transmit the integral rates in three broad energy windows as monitored by the the phoswich array. This channel provides a rudimentary data base for studying μ-flare characteristics should the tape recorder data not be recovered. An additional data transmission channel is provided via line-of-sight VHF telemetry to permit high rate monitoring of the payload during the initial float checkout phase of the balloon flight before the payload is committed to a circumnavigation. This channel will also be used to dump the data stored in the on-board tape recorders as a precautionary measure before cutdown and recovery of the payload.

Additional features are provided in the balloon gondola system to support a nominal 15-20 day float duration. Power is provided by an 8 m^2 solar panel array which is deployed after launch and operates in conjuction with a lead acid battery stogage system. The power system is scaled to support an average energy usage of 2500 watt-hours per day. The balloon/gondola system incorporates an auto-ballast system which functions in three stages. Nominal sunset cooling and settling of the balloon will trigger a minimal ballast drop of ~5% of the payload weight. An anomalous altitude change, as might occur over a cold cloud layer, will trigger an additional ballast drop of 10%. In the event of a very large altitude excursion (which might result in the payload descending below the tropopause) a ballast destruct occurs to provide some possibility of restoring the payload to a functional altitude. The primary payload is fully enclosed within an insulation blanket which includes additional thermal ballast to maintain tempertures above 0° C. Additional thermal isolation and heating is provided for the phoswich scintillator array which needs a 20-30 °C operating environment.

<u>4. Long Duration Balloon</u> Operation The RAdiation COtrolled balloON (RACOON) concept offers near ideal conditions for the study of solar phenomena (6, 7). Since essentially continuous exposure is possible for periods within ± 4 hours hours of local noon, one is not limited by the ~40 minutes of earth occulation which occur for a spacecraft instrument in

each 90 minute low earth orbit. The RACOON mode involves the use of a standard zero pressure polyethelyne balloon for multi- day flights without the use of extensive ballasting to maintain float altitude through sunset. The initial float altitude must be chosen such as to ensure that the sunset altitude change does not bring the balloon below the tropopause where the negative temperature gradient would result in loss of the flight. For the present system we require a daytime float altitude of ~3 gm/cm^2 residual depth to conduct x-ray observations. This is adequate to keep the balloon safely above the tropopause at night. Allowing 1 to 2 hours to reattain daytime float altitude we expect ~250 hours of total float duration at 3 gm/cm^2. This should be compared with the nominal maximum float durations of 25-40 hours which are occasionally attained under normal balloon flight conditions.

The balloon is to be launched in January, 1986 from Alice Springs, Australia, where the strong prevailing stratospheric winds will keep the system within ~2 degrees of a constant latitude for the 15-20 day duration of the global circumnavigation. Cutdown is planned for the Eastern coastal region of Australia.

5. Summary We have developed a sophisticated balloon gondola which will provide the first astronomical observations of solar and cosmic phenomena from long duration balloons. We will use the RACOON long duration mode which is ideally suited for observations of the sun. We expect one 20 day balloon flight to yield ~150 hours of solar and ~100 hours of cosmic source observations. We estimate that ~20 flare events strong enough for spectroscopic analysis should be observed in a January, 1986 flight.

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