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REPORT ON OSO-7 DATA ANALYSIS

ABSTRACT

This report reviews the progress on analysis of data from the University of New Hampshire (UNH) gamma ray experiment on OSO-7 through 31 August 1974. A list of papers published and in progress is appended at the end of this report. Plans for continued analysis of the data are briefly described.

Further detailed information on the data processing may be found in "Documentation of the Data Analysis System for the Gamma Ray Monitor Aboard OSO-H," submitted to the OSO-7 project office. Details of scientific results may be found in the referenced and listed papers.

REPORT ON OSO-7 DATA ANALYSIS

1.0 Introduction

This report reviews the progress of the analysis of the data from the University of New Hampshire (UNH) gamma ray experiment on the OSO-7 satellite through August 31, 1974. The instrument operated continuously for more than 18 hours per day over a 16-month period until a power supply failure occurred on December 25, 1972. Data accumulated over this time period includes 50% real time day-to-day observations of the Sun and at least two complete scans of all points on the celestial sphere. Any point on the celestial sphere within $\pm 30°$ of the ecliptic has been observed for at least 10^5 to 10^6 seconds. Furthermore, because of the detector's large acceptance angle (70° FWHM) and our policy of placing the detector in an alternate quadrant viewing mode for two orbits each day, approximately 80% of the celestial sphere was observed for $\sim 3 \times 10^3$ seconds every day.

The data has been applied to a search for both visually observed and unobserved transient phenomena from the Sun, from supernovae, and from other sources. The data analysis effort can be divided broadly into two categories:

- The search for solar gamma rays during both active periods and quiet times and
- The search for gamma rays from cosmic sources both transient (for example, Vela-type bursts) and stationary (for example, the Galactic Center).

The study of a constant, isotropic phenomenon, such as the cosmic gamma ray flux (Metzger et al., 1964; Trombka et al., 1972), demands an understanding of the local production background. This is, therefore a part of the overall effort. The local background in itself is of secondary interest as is the gamma ray flux from the Earth's atmosphere.

This report presents a summary of the data processing and analysis programs and the results of the search for both solar and cosmic gamma rays. A brief description of the instrument is also presented.

2.0 The Gamma Ray Detector and the X-Ray Detector

The UNH gamma ray monitor consisted of a 7.6 cm x 7.6 cm NaI scintillator-photomultiplier central detector covering an energy region from about 300 keV to 10 MeV. This detector was surrounded on all sides, except for a forward aperture by a 4 cm thick CsI scintillator shield. This shield acted as a collimator for gamma rays and also rejected direct charged particle counts. The instrument was on the wheel section of OSO-7, which spun with a 2-second period in a plane that always included the Sun. Data was accumulated separately during two 0.5 second intervals when the detector was "looking" at the Sun and when it was looking directly away from it. These two intervals were called the "solar" and "background" quadrants.

The gamma ray monitor was supported by an auxiliary X-ray detector in order to monitor solar activity. It consisted of an uncollimated NaI crystal, 3.2 cm x 0.6 cm diameter, with a 10 mil Be window. Data was accumulated in the same quadrants as for the main instrument. The detector covered the range 7.5-120 keV in four energy channels. The counting rate in each bin was sampled for about 0.5 seconds and a complete spectrum was accumulated every 31 seconds.

3.0 Description of Data Analysis

The most important information from the monitor consisted of two 370-channel pulse height spectra. Data in these spectra were accumulated over a 180 second real-time interval when the detector was pointing in the solar quadrant and the background quadrant. Analysis of this data required that the channel numbers in the pulse height spectra be calibrated with incident gamma rays of known energy. This calibration was accomplished twice per orbit when a radioactive source (RS CAL) was electronically gated into the pulse height analyzer instead of the normal spectrum.

Data was transmitted to UNH in the form of experimenter tapes consisting of semiprocessed and cleaned up data containing all of the information received from the experiment. This included the sets of pulse height spectra, the RS calibration spectra, counting rates from the various shield elements and X-ray detector, and housekeeping measurements. The experimenter tapes were the prime data source for all scientific analysis.

Two pieces of hardware were used to process this data: a Varian 620/i mini-computer and the University's IBM-360-H50 computer. The latter was used to process the experimenter tapes into a format which could be more closely analyzed and manipulated on the Varian.

3.1 Treatment of Data

3.1.1 Gain Correction

In order to combine and compare gamma ray spectra accumulated at different times, it was necessary to correct for changes in detector gain. The gain variations were due both to the natural aging of the detector and to adjustments of the amplifier electronics. Gain correction was accomplished by processing the RS calibration spectra, from which a continuous gain calibration function versus time was obtained. This function was then used to normalize each gamma ray spectrum to the quadratic relationship

$$E = c\ n^2$$

where n is a fictitious channel number, c is a constant equal to 5×10^{-4} MeV $(\text{channel})^{-2}$, and E is the energy of the channel in MeV. The gain corrected spectra were placed on magnetic tape, called "Pass-III" data because of its place in the data processing chain. Associated with each spectrum on the tape was a group of relevant housekeeping measurements, and geophysical and spacecraft parameters. The magnetic tape output of Pass-III constitutes the prime data bank that was used in most of the scientific analysis efforts with the data from the gamma ray monitor.

3.1.2 Parametrization

Included with each gamma ray spectrum in Pass-III is a list of parameters which were known or suspected to be important in characterizing the spectrum. The parameters included the following:

- Begin and end times for the scan in which the spectrum was accumulated.

- Spacecraft status, which shows whether a spectrum was accumulated during solar or background quadrant, spacecraft day or night, normal or alternate quadrant, and calibration or normal time.

- Vertical cutoff rigidity at time of midpoint of scan.
- B and L coordinate.
- Latitude, longitude and altitude.
- Right ascension and declination of satellite, Sun, look direction, and the spin axis of the satellite.
- Earth based coordinates of the look direction and satellite spin axis.
- The time and proton flux of the previous fourteen passages through the South Atlantic anomaly region of the Van Allen Belts.
- X-ray counting rate between 7.5 and 15 keV.
- Live time and dead time.
- Indicators for bit errors, flagged words, quality of data, bookkeeping etc.

These parameters can be used in subsequent analysis programs for selective investigation, summing and other processing.

3.1.3 Gamma Ray Data Analysis

In general, the scientific analysis consists of selectively summing together numerous spectra in search of gamma ray sources and events. The selection process consists of using only data in the proper time interval and with the proper geophysical and spacecraft parameters. The objective of the selection process is to maximize the gamma ray signal while minimizing the gamma ray background.

Scans can be checked in a preliminary way by printing out scan parameters for the desired times. Programs also exist which dump out the spectra in raw form, together with auxiliary measurements and housekeeping data. One of the most useful programs is the parameter selection routine, which pulls out scans associated with preselected parameters and stores them on a new magnetic tape. This program also lists the value of each parameter for each spectrum. This tape is then used with a spectrum summing program which adds the spectra channel-by-channel, prints the sum spectrum, and deposits it on magnetic tape. This tape can then be used to get a computer-controlled plot of the sum spectrum. It is possible to sum spectra with different parameter values obtained over the same time period in separate buffers. This makes it possible to directly compare, for example, spectra accumulated in the solar and antisolar directions over the same time span. A program has also been written which plots individual scans.

3.1.4 Subsidiary Gamma Ray Programs

The programs which handle the calibration data are an essential part of the gain correction process. The program Cal 1 processes the RS calibration spectra for visual inspection and for use in another program, Cal 2. Cal 1 calculates the parameters in the energy-channel relationship:

$$E = c(n + n_o)^2$$

for the calibration spectra. By displaying the value of c in the above calculation, variations in the gain of the detector can be monitored. The program Cal 2 provides a continuous gain calibration function versus time from Cal 1 and a manual input. This output allows the calibration of all the gamma ray spectra that were taken between the RS calibrations. We can, therefore, gain correct as much of the gain variable real pulse height spectra as possible into the gain corrected, known and nonvariable pulse height spectra output from Pass-III. These gain corrected spectra can then be directly compared or combined over any time period in a search for gamma ray sources.

Another useful subsidiary program is the Van Allen Belt Predict Program, which calculates the times and magnitudes of satellite exposures to trapped protons . Briefly, the VABELT program interpolates values from a 15° interval grid map of proton fluxes of energy $E > 15$ MeV shown in "World Maps of Constant B, L, and Flux Contours," (Stassinopolous, 1967). An Ephemeris data tape supplied by NASA was used to determine satellite position versus time. The predict program computes, for a given period of time, the peak flux encountered, the time of the peak flux, the integral flux during the orbit, and the times when the satellite encountered and left regions with fluxes $> 10^3$ protons cm^{-2} sec^{-1} with the corresponding positional information.

At the 3σ confidence level, the VA data is estimated to be incorrect by a factor of 2 at worst.

In order to perform detailed analysis of gamma ray sources having a complicated angular distribution, such as might be expected from the Earth or supernova remnants, the angular response of the gamma ray monitor was carefully measured before flight, using several radioactive sources. This calibration was done with the detector located in the spacecraft in its final configuration with room scattering effects subtracted from the calibration spectra. Spectra for a matrix of source positions have been stored on tape. Details of the calibration method have been published by Higbie et al. (1973).

3.1.5 X-Ray Printout Programs

Since hard X-ray emission is an important indicator of solar activity, the counting rate of the first X-ray channel (7.5-15 keV) is associated with the corresponding gamma ray spectrum. This rate is therefore printed out as a spectrum parameter in several of the gamma ray analysis programs. A running list of X-ray rates for all channels can also be printed out along with a schematic display of the rates. A program also exists which averages cycles of 10 X-ray scans and prints the average. In order to search for transient events (solar flares, trapped particle encounters, etc.), a program has been written which compares the X-ray rate with a running average of previous scans. If the current rate exceeds the average by a preselected amount, the data is marked for further analysis.

3.1.6 X-Ray Plotting Programs

A program has been written which displays, in graphical form, all the X-ray data taken in channels 1 and 3 (7.5-15 and 30-60 keV) over one satellite orbit. The data is displayed on a Tektronix CRT terminal. The plots can be printed using a Hard Copier. Another program displays only solar data taken in channels 1 and 2.

3.2 Shield and Gamma Ray Integral Rates

3.2.1 Rate Meters

The charged particle shield consisted of a large CsI cup section, which partially surrounds the central detector, and a thin CsI slab, which covers the forward aperture. The rate of interactions of energy 100 keV and greater in the detector shield and slab were monitored using logarithmic rate meters. These meters had a logarithmic response function and were calibrated before launch. The meters were sampled every 15 seconds. This rate is especially useful in monitoring passes in the vicinity of the South Atlantic anomaly. A similar meter was used to monitor the integral gamma ray rate between 0.3 and 9 MeV. The events counted here are the same that enter the gamma ray spectrum but with a time resolution of 15 seconds instead of 180 second; however, spectral information is not obtained.

3.2.2 Rate Meter Printout Programs

The program ASCPRT prints coded numbers corresponding to the slab, cup and integral gamma ray rates. Other analog housekeeping data is printed out by this program.

3.2.3 Rate Meter Plotting Programs

A program similar to the X-ray plotting program is used to display integral gamma ray and slab counts on a Tektronix terminal. Hard copies can be made.

4.0 Solar Analysis

4.1 Analysis of the 4 August and 7 August Events

The primary goal of the UNH gamma ray monitor was the measurement of gamma ray lines and continua which would presumably be emitted from solar flares. This goal was realized during the solar activity during 2-11 August 1972. Study of this flare data was begun immediately and has continued to the present time. The important observational results of this study are the following:

- Lines from positron annihilation (0.511 MeV) and deuterium formation (2.23 MeV) have been positively identified (Chupp et al., 1973a). Lines from nuclear excited states of ^{12}C and ^{16}O were seen at a 99% confidence level on August 4 (Chupp et al., 1973a). Predicted lines from excited states of ^{7}Li and ^{7}Be (Kozlovsky and Ramaty, 1974) could not be resolved in the data.

- A gamma ray continuum was seen over the entire observable energy range (0.3-7 MeV). The continuum fit a smooth extrapolation from other observations at lower energies and could be characterized by a power law below about 1 MeV and an exponential above 1 MeV (Suri et al., 1974a).

The measurements have lead to the following interpretive results:

- The observed lines agree qualitatively with previous theoretical predictions (Lingenfelter and Ramaty, 1967; Cheng, 1972). To that extent they verify the current understanding of high energy solar flare mechanisms.

- Ratios of the gamma ray line intensities from 4 August 1972 have been used to arrive at an important flare particle parameter; namely, the characteristic rigidity of the high energy protons (Ramaty and Lingenfelter, 1973a).

- The intensity and time behavior of the deuterium formation line places restrictions on the density of the region in which the deuterium is formed (Reppin et al., 1973; Ramaty and Lingenfelter, 1973b).

- The intensity of the 0.511 and 2.22 MeV lines require $\sim 3 \times 10^{32}$ protons with E_p(>30 MeV) (Chupp et al., 1973b). It should be noted that this number is model dependent.

- The width of the 0.511 MeV line places an upper limit of 7×10^6 °K on the temperature of the region in which the positrons annihilate (Dunphy et al., 1973). The rise time of the 0.511 MeV line indicates a lower limit of 10^{12} electrons cm^{-3} in the annihilation region (Chupp et al., 1974a).

- Analysis of the continuum emission on August 4, 1972 indicates an emission measure (E.M. = Vn_pn_e) of 1×10^{45} cm^{-3}, where V is the emitting volume, n_p is the proton density, and n_e is the electron density (> 100 keV).

- The line measurements, taken together with knowledge of the flare proton spectrum and isotopic composition as measured at 1 AU, place restrictions on the density of the flare region and on the fraction of energy of the flare proton which goes into the gamma producing interactions. This is independent of the flare model which is used (Forrest et al., 1974).

4.2 Emission from Small Solar Flares

In view of the positive results from the August 1972 flares, a search is being carried out for gamma emission from smaller flares. Spectra accumulated during times of solar activity as determined from flare catalogs will be summed and compared with a background sum spectrum. A preliminary investigation has shown no significant contribution from small flares.

In connection with the search for gamma rays from small flares, the program which searches the X-ray data for nonstatistical increases in the counting rate can be used to find times during which hard radiation is emitted by the Sun. From this a catalog of solar-active times will be made. This can be used in conjunction with the X-ray rate parameter in the gamma spectrum data to give an alternate method for summing small flare data.

4.3 Search for Preflare and Postflare Events

The Pass-III computer programs have been used to more carefully analyze the flares of 4 and 7 August. It appears that emission of the 2.22 MeV deuterium line remains about 30 minutes after flare maximum, on August 4, 1972 although at only a borderline statistical significance ($\sim 3\sigma$). Otherwise, no evidence has been found for a significant flux from the flare regions for times before or long after the impulsive phase of the flares in question (Chupp et al., 1973c). This is significant with respect to the evaluation of flare models which predict such fluxes (Forrest et al., 1974).

4.4 Solar-Geophysical Events (4 August 1972)

About 8 hours after the 4 August solar flare, a large (a factor of ∿ 10) enhancement was seen by the UNH monitor. Lines at the energies 1.6, 2.3, and 4.5 MeV which lie near excited state energies of nitrogen and oxygen also appeared at this time. A smaller enhancement in the continuum was also seen. These effects were seen at low L values (< 2) but at times when the cutoff rigidity at the satellite was low (< 8 GV). The evidence indicates that these gamma rays were produced locally in the Earth's atmosphere and perhaps also in the spacecraft by protons of energy > 10 MeV. As yet a mechanism to explain the precipitation of high energy protons in regions of low L values and the production of the observed spectrum has not been formulated. A geophysical gamma ray event was also seen on August 7, 1972, starting at ∿ 1600 UT.

4.5 Collaboration with CINOF and AFCRL

A study of solar bursts from McMath plage 11976 on 31 July 1972 was carried out in collaboration with Air Force Cambridge Research Laboratories (AFCRL) (Castelli et al., 1974). This was the active region which produced the gamma rays of 4 August 1972. A study of the spectral charactersitics of short centimeter radio bursts led to conclusions about properties of the burst region. X-ray data from OSO-7 supplied by UNH were used to characterize the relativistic electrons which evidently caused both the X-ray and radio emission.

Because of funding limitations no steps have been taken to collaborate with the "Campaign for Integrated Observation of Solar Flares" (CINOF).

4.6 Continuous or Quasi-Stationary Solar Emissions

In an attempt to observe gamma rays from the Galactic Center, which is described in the section on Cosmic Analysis, a sum spectrum from the solar quadrant was compared with a corresponding spectrum from the background quadrant. The observational live time for each spectrum was $\sim 10^4$ seconds. No significant excess in either direction was observed. This yields limits for quiet-time solar line emission of 2×10^{-3} photons $cm^{-2}sec^{-1}$ for both the 0.511 and 2.22 MeV lines at the 2σ level. Previous experiments have set upper limits of $8.4 \times 10^{-4} cm^{-2} sec^{-1}$ photons/cm^2 (Haymes et al., 1968) and 5×10^{-3} photons/cm^2 sec (Womack and Overbeck, 1968) for the annihilation and deuterium lines respectively.

4.7 Gamma Rays from Solar M Regions

Since no positive results have been obtained from the summation of data from small flares or from long quiet-time periods, the analysis of emissions from solar M regions has not been pursued.

5.0 Cosmic Analysis

5.1 Supernovae and Supernovae Remnants

Theoretical predictions of gamma ray line and continuum radiation from supernovae and their remnants have been published (Ramaty and Boldt, 1971; Clayton et al., 1969; Brown, 1973). A search of the data from the UNH detector has, therefore, been made for two likely candidates: the Gum Nebula, a possible supernova remnant associated with the Vela pulsar 0833-45, and the supernova SN-1972-Kowal discovered on 13 May 1972. An upper limit of 5×10^{-2} photons $cm^{-2}sec^{-1}$ for the lines due to ^{28}Si (1.78 MeV), ^{12}C (4.43 MeV) and ^{16}O (6.13 MeV) was obtained from the Gum Nebula (Chupp et al., 1974b). The UNH detector also gave upper limits for SN-1972-Kowal of 4×10^{44} erg sec^{-1} (7.5- 15 keV) for the period 10 April to 23 May 1972, 1×10^{-2} photons $cm^{-2}sec^{-1}$ for the lines 0.511, 2.22, and 0.847 MeV (^{56}Co) before and after optical maximum, and 3×10^{-2} photons $cm^{-2}sec^{-1}$over the energy range 350 keV to 1 MeV on May 1, 3 and 23 (Chupp et al., 1974b). Summing of all data available could reduce the Gum Nebula limits by an order of magnitude.

5.2 Gamma Ray Burst Events

Evidence of transient gamma ray events of < 100 sec duration which are of cosmic origin has been discovered recently (Klebesadel et al., 1973). A preliminary examination of the OSO-7 data at the burst times reported by Klebesadel and coworkers in 1973 has been carried out for the six events which occurred during the detector's lifetime (Forrest et al., 1973). No evidence of increases correlated with the gamma bursts has been found in any of the detector counting rates. This null result is quite likely due to the low duty cycle ($\sim$ 15% or less) for the sampling time of the detector. In order to determine if rate increases can be correlated with similar increases in other gamma ray detectors, the search programs described in Section II can be used to compile a catalog of "glitch" times. This catalog can then be used in conjunction with the "glitch" lists of other experimenters.

5.3 Gamma Ray Lines from the Galactic Center

The interesting report by Johson et al. (1972) of a gamma ray line feature at 473 keV from the direction of the Galactic Center led to considerable speculation as to the mechanism which produces it (Leventhal, 1973, and Ramaty et al., 1973 among others).

In particular, Rygg and Fishman (1973) predict other nuclear lines in association with the 473 keV feature which is hypothesized to be the deexcitation line of ^{7}Li. We have searched the OSO-7 data (Suri et al., 1974b) for the prominent deexcitation gamma ray lines which the above hypothesis predicts. Upper limits at 4.43 MeV ($^{12}C^*$) and 1.63 MeV ($^{20}Ne^*$) of 1.7×10^{-3} photons $cm^{-2}sec^{-1}$ and 2.0×10^{-3} photons $cm^{-2}sec^{-1}$, respectively, put constraints on the spectral index of low energy cosmic rays in the model. Our upper limit flux for a line at 473 keV from the Galactic Center is 2×10^{-3} photons $cm^{-2}sec^{-1}$, just at level of the predicted flux.

5.4 Isotropic Gamma Ray Flux

Since gamma rays produced locally in the spacecraft and detector contribute the bulk of the counting rate in satellite experiments with the OSO-7 orbit parameters, (Dyer and Morfill, 1971; Dyer et al., 1972) the measurement of an isotropic gamma ray flux (Metzger et al., 1964) becomes a problem of determining the local production background. At the present time a program is underway to collaborate with several experimenters, under the direction of J. Trombka and C. Dyer of GSFC, to synthesisze a model of gamma ray production in satellite detectors. It is hoped that this program will lead to a quantitative evaluation of the local production contribution to the OSO-7 data, and thus to a measurement of the contribution from cosmic gamma rays.

6.0 Summary and Conclusions

6.1 Solar Analysis

The foregoing discussion of results from the OSO-7 data shows that the solar flares of August 1972 have been exhaustively analyzed. This has led to more detailed theoretical calculations of gamma ray emission from flares (Ramaty and Lingenfelter, 1973a; Ramaty and Lingenfelter, 1973b; Wang and Ramaty, 1974). The pre- and postflare limits are also valuable in evaluating flare models (Forrest et al., 1974). Thus one of the main goals of the present experiment has been accomplished. Clearly, further advances along this line will require future experiments of equal or greater sophistication. We have yet to complete the search for gamma rays in small events or under unusual conditions.

6.2 Cosmic Analysis

In the search for cosmic sources further work remains to be done. The observation of the Galactic Center has put constraints on the model of Rygg and Fishman (1973) which attempts to explain the line feature observed by Johson et al. (1972). The study of supernovae and their remnants have led to limits on nuclear line emission from radioactive isotopes which are expected to be produced. With additional analysis these limits could be reduced by about an order of magnitude, which would put more stringent restrictions on supernova models.

The burst search programs described above can be used to compile event lists in the hope of identifying previously unreported gamma ray bursts. Finally, the study of the local production background in cooperation with other experimenters will yield a better understanding of this problem and possibly a more accurate measurement of the diffuse cosmic gamma ray flux.

We have requested additional funds from the Solar Physics Office, NASA Headquarters to complete work on the solar aspects of the OSO-7 data discussed in this report. Additional support will be required to continue work on cosmic gamma ray emissions.

7.0 List of Reports and Publications

The work described in the following papers was supported by NASA under Contract NAS 5-11054 and NGR 30-002-104.

"A Data Analysis System for the Gamma Ray Monitor on OSO-7," P. R. Higbie, A. Buck, S. Croteau, M. Simmons, E. L. Chupp, and D. J. Forrest, in-house report, 1972.

"Flare Nuclear Gamma Ray Line Search by OSO-7," D. J. Forrest, A. N. Suri, and E. L. Chupp. Presented at the 3rd Workshop on OSO's, Stanford University, September 5-8, 1972.

"Solar Gamma Ray and Neutron Observations," E. L. Chupp, D. J. Forrest, and A. N. Suri. Presented at Symposium on High Energy Phenomena on the Sun, GSFC, September 28, 1972.

"Solar Gamma Ray Line Observations Associated with Solar Flares in Early August 1972," D. J. Forrest, E. L. Chupp, A. N. Suri, P. R. Higbie, C. Tsai, and P. P. Dunphy. Paper presented at AGU Meeting, San Francisco, October 1972.

"OSO-7 UNH Gamma Ray Monitor Central Detector Gain in Orbit," I. U. Gleske, in-house report, 1972.

"Background Effects from the UNH Gamma Ray Monitor on OSO-7," D. J. Forrest. Paper presented at Gamma Ray Local Production and Shielding Conference, Univ. of N. H., June 1972.

"Gamma Ray Observations from OSO-7 (26 July to 14 August 1973)," E. L. Chupp, D. J. Forrest, C. Reppin, A. N. Suri, and C. Tsai. UAG Report-Retrospective World Interval July 26-August 14, 1972. Report-28.

"Gamma Ray Production in Solar Flares," E. L. Chupp, D. J. Forrest, and A. N. Suri, Presented at APS Meeting, New York, January 29, 1973.

"Experimental Gamma Ray Response Function for the OSO-7 Spacecraft," P. R. Higbie, D. J. Forrest, I. U. Gleske, E. L. Chupp, and D. W. Burtis. Nucl. Inst. Meth. 108, 167 (1973).

"Gamma Ray and Neutron Measurements and Their Relation to the Solar Flare Problem," E. L. Chupp. Present at COSPAR Conference, Lake Constance, Germany, May to June 1973.

"Review of Solar Gamma Ray Observations in August 1972," E. L. Chupp. Presented at ESLAB Conference, Saulgau, Germany, May 22-25, 1973.

"Search for Solar Nuclear Gamma Rays Associated with $\geq$ Class M X-rays on OSO-7," E. L. Chupp, D. J. Forrest, P. R. Higbie, and C. Tsai. Presented at 53rd Meeting of the AGU, Washington, D. C.

"Observations of Gamma Ray Emissions in Solar Flares," D. J. Forrest, E. L. Chupp, A. N. Suri, and C. Reppin. Presented at International Symposium and Workshop on Gamma Ray Astrophysics, GSFC, April-May 1973.

"Gamma Ray Emissions from McMath Region 11976," E. L. Chupp, D. J. Forrest, A. N. Suri, and C. Reppin. Paper presented at 13th International Cosmic Ray Conference, Denver, Colorado, August 17-30, 1973.

"Observation of Solar Gamma Ray Lines During the Solar Activity of 02 August to 11 August 1972," E. L. Chupp, D. J. Forrest, P. R. Higbie, A. N. Suri, C. Tsai, and P. P. Dunphy. Nature <u>241</u>, 335 (1973).

"Continuum Solar X-ray and Gamma Ray Observations on August 4, 1972," A. N. Suri, D. J. Forrest, E. L. Chupp, and C. Reppin. Paper presented at APS Meeting, Washington, D. C., April 23-26, 1973.

"Line Width of Solar Flare Gamma Ray Emissions," P. P. Dunphy, E. L. Chupp, D. J. Forrest, and A. N. Suri. Paper presented at APS Meeting, Washington, D. C., April 23-26, 1973.

"Solar Neutron Production During the Events on 04 and 07 August 1972," C. Reppin, E. L. Chupp, D. J. Forrest, and A. N. Suri. Presented at 13th International Cosmic Ray Conference, Denver, Colorado, August 17-30, 1973.

"Search for Gamma Ray Lines from Supernovae and Supernova Remnants," E. L. Chupp, D. J. Forrest, A. N. Suri, Ron Adams, and C. Tsai, in Supernovae and Supernova Remnants (ed. by C. B. Cosmovici) D. Reidel Publishing Co., Dordrecht-Holland, p. 311-316, 1974.

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"High Energy Gamma Ray Radiation Above 300 keV Associated with Solar Activity," E. L. Chupp, D. J. Forrest, and A. N. Suri. In Proc. of the Joint IAU-COSPAR Symposium, Buenos Aires, Argentina, 1974.

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"OSO-7 Limits on the Line Emissions from the Galactic Center Region," A. N. Suri, P. P. Dunphy, E. L. Chupp, and D. J. Forrest. Paper presented at Washington Meeting of the American Physical Society, April 22-25, 1974.

"General Characteristics of Gamma Ray Counting Rates from the OSO-7 Spacecraft," M. R. Fernald, in-house report, 1974.

"A Function to Predict Integrated Counting Rates from the OSO-7 Gamma Ray Detector," Mark R. Fernald, in-house report, August 1974.

"Interpretation of the Width and Energy of the Positron Annihilation Gamma Ray Line Observed During the Flares of 4 and 7 August 1972," P. P. Dunphy, E. L. Chupp, D. J. Forrest, A. N. Suri, and C. Tsai. In preparation.

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