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GAMMA-RAY BURSTS: AN OVERVIEW

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The second AP program will consist of FORTRAN subroutines to compute the components of a solar vector magnetic field by a non-linear least squares fit method using Marquardt's algorithm.[2] The first subroutine computes the derivative of the Q, U, and V Stokes parameters with respect to eight different independent variables. The rather complex arithmetic operations are performed on vectors containing up to 64 elements, each of which represents the difference between a wavelength near the center of a given spectral line and the center wavelength itself. Ultimately, when the programming is completed, the vector magnetic field components will be computed. The results of the AP derivative routine are precisely the same as those obtained from a similar routine executed on the MicroVAX. It is here that it was discovered that computations on the AP should be limited to six significant figures to avoid systematic roundoff errors.

Opportunities for Undergraduate Participation. Perhaps the most important purpose of the JOVE program is to involve undergraduates in "real world" research. Three students at Centre College have expressed interest, and should begin participation in the project during the fall term of the 1990-91 academic year, provided the requisite hardware and communications are made available. Clearly, AP programs can only be executed on the MSFC Magnetograph Facility's MicroVAX (or a similarly equipped machine), therefore a suitable data link to "MAGVAX" is required. After an introductory course in AP programming (taught by the author), these students should be able to produce FORTRAN code to support magnetograph data reduction at MSFC. The following problems lend themselves to student programming:

(1) Expand the subroutine which calculates magnetic fields in the APVMAP system to include those configurations of the Zeiss filter prior to October 4, 1989. The existing program is valid only for the present configuration.

(2) Modify the entire set of APVMAP subroutines to utilize an expanded vector memory in the AP. At present, the 16384 element arrays must be processed in 4KB segments. If the vector memory is increased to 128KB in each partition, a 128 by 128 array can be processed in its entirety.

(3) Continue the development of routines to implement the non-linear least squares fit method of magnetic field calculation.

The support for research in solar vector magnetic fields need not be limited to programming the AP. It is certainly possible that students can become involved in any type of programming in this project, and conceivable that their participation evolve to data analysis, definition of new observing programs and the implementation thereof.

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Reduction of Solar Vector Magnetograph Data using a MicroMSP Array Processor

Background. The processing of raw data obtained by the solar vector magnetograph located at the Marshall Space Flight Center requires extensive arithmetic operations on large arrays of real numbers. A device which can perform these calculations with very high speed is the MicroMSP Array Processor produced by the Computer Design and Applications Division of the Analogic Corporation. This machine is installed in the DEC MicroVAX 3500 computer located at the MSFC Magnetograph facility, where the MicroVAX acts as the "host" computer for all array processor functions. The objectives of this study are to

(1) learn the "programming language" of the MicroMSP Array Processor and adapt some existing data reduction routines to exploit its capabilities

(2) identify other applications and/or existing programs which lend themselves to array processor utilization which can be developed by undergraduate student programmers under the provisions of project JOVE.

This work was performed during the summer faculty fellowship period from June 4, 1990 to August 17, 1990 as the initial phase of the JOint VEnture between NASA and Centre College.

Operations. The MicroMSP Array Processor (hereinafter called AP) is a high speed, multi-user vector computer which operates as a peripheral of the host. The four major subsystems of the AP are the host interface, a control processor, a vector processor and multiport memory. The host interface provides for programmed I/O and DMA (direct memory access) for all data transfers between the AP and the host. The 68020 control processor performs overall processing control of the AP system. The vector processor performs all floating point arithmetic operations, while the multiport memory provides high speed storage which is shared by the host interface, control processor and vector processor. The memory is divided to a 4MB data memory (called DMEM) and two 32KB vector memories (HMEM and LMEM). DMEM and LMEM store both integer and real numbers, while HMEM may contain only reals. Data is transferred to and from the host via the data memory.

A software library is provided with the device containing FORTRAN callable subprograms for I/O control, extensive arithmetic operations on vector arrays, some matrix operations, and a few logical operations. An additional library of image processing routines is also available. The AP is best suited for computations on real numbers, but provision is made for downloading integer quantities and conversion to real format within the AP. Real number arithmetic is performed with up to seven digits of accuracy, but it was found that consistent results are obtainable when only six significant figures are used. At present, all programs are written in VAX FORTRAN and executed on the MicroVAX. The AP library routines are called as FORTRAN functions, which execute on the AP, returning a SUCCESS flag to the host.

Computing on the AP is accomplished by using the following general programming procedure:

(1) Allocate the AP memories for array storage.

(2) Download arrays from the host to the AP data memory.

(3) Transfer arrays from data memory to vector memory.

(3) Perform arithmetic and/or logical operations.

(4) Transfer results from vector memory to data memory.

(5) Upload results to the host.

(6) De-allocate (free) the AP memories for other users.

If the memory requirements of a given application are not large, and the AP memory is managed properly, it is entirely possible that multiple users access the AP at one time. The number of users is limited only by the free AP memory available for an application. Data and results stored in any segment of an AP memory will remain there until changed or the segment is de-allocated. This allows the results (output) of one subroutine to be the data (input) to any other routine provided that the proper memory addresses are global to that routine. This is accomplished by passing the AP memory addresses as COMMON variables.

Applications. During the Summer 1990 period, two existing programs were adapted for computations on the AP in support of the operation of the Solar Vector Magnetograph at MSFC. The first of these, entitled APVMAP, is a set of routines which accept as input raw integer data proportional to the light intensities detected by charged-coupled devices for six different configurations of the polarizing optics of the magnetograph. These data are formatted in square arrays of 128 rows by 128 columns, each element corresponding to one pixel of the display of the magnetograph as it scans a 5′ by 5′ area on the surface of the sun. After masking the ten most significant bits (noise), the numbers are downloaded to the AP, converted to reals, loaded into vector memory, and processed to produce the sum and difference arrays used to determine the Stokes parameters Q, U, and V.[1] These results are filtered using a finite impulse respose filter if desired. A follow-on subroutine then computes the magnitudes of the longitudinal and transverse magnetic fields, the angle with the line-of-sight of the vector magnetic field, and the polarizing angle. An additional routine is called for correlation plots to determine bias and crosstalk values, while another subroutine is used for photocalibration. Results are uploaded to the MicroVAX host and stored for future plotting by conventional graphics routines. It should be noted that although the magnetograph data is stored in a two-dimensional array data structure, the AP treats these data as if they were in a one-dimensional vector having a length of 16384 elements. As of this writing, this software is undergoing beta test.

Gamma-Ray Bursts: An Overview

Abstract

Gamma-Ray Bursts were discovered in 1967 by researchers studying data from gamma-ray detectors aboard the Vela satellites. These satellites were launched with the original intent of assuring Soviet compliance with the 1963 Geneva Limited Nuclear Test Ban Treaty. Since this original discovery, over 500 bursts have been observed by more than a dozen experiments on planetary spacecraft, earth orbiters, balloon flights, and even ground based instruments.

Unfortunately, we are no closer today to describing the nature of these transient phenomena than we were two decades ago. Part of the problem lies in the large variability in their physical characteristics. This variability has spawned more than 40 γ-ray burst models. Each model claims some subset of the 500 observed bursts that conclusively proves its validity.

In this paper I present a very brief overview of the γ-ray burst phenomenon. The interested reader is referred to summary papers by Meegan (1990) and Hurley (1989).

1. Introduction:

1.1 The Discovery of Gamma-Ray Bursters

The original discovery of gamma-ray bursts was made in 1965 by Ray Klebasadel and Roy Olson from data recorded by the Vela satellite. These satellites were originally intended to discourage nuclear testing in space – presumably by the Soviet Union. Such testing was banned by the limited test ban treaty first proposed in Geneva, Switzerland and signed in 1963. Both satellites carried detectors that were sensitive to fluxes of charged particles, neutrons, x-rays, and most importantly, γ-rays.

The first two Vela satellites were launched in 1964. Placed in nearly circular orbits at an altitude of approximately 120,000 km and on opposite sides of the earth, the satellites looked for sharp increases in flux that would indicate a thermonuclear test. Several factors inhibited the early detection of cosmic bursts. First, there were many false signals, "local" events, caused by interactions of the spacecraft with the local environment. Second, each satellite tagged γ-ray events with its own local time. This made the search for simultaneous events difficult.

It wasn't until 1967, with the launch of Vela 4, that Klebasadel began to attempt correlative studies between the observations of all Velas. The first step was to convert satellite times to Universal Time (UT). A manual search was then started through the reams of output looking for simultaneous events. After a short period they found an event that was detected by both Vela 3 and Vela 4 separated by only 2 seconds. According to Klebasadel (1990), it was clear from the time profile that this event was not due to a nuclear test, but rather, some other cosmic event. Also, the time profile and direction of the burst excluded solar phenomena as the cause.

One of the first significant characteristics of gamma-ray bursts (grb's) emerged from the Vela database: their (apparent) isotropic distribution in the sky.

1.2 Recent Observations

Since those first observations, more than 500 grb's have been detected by several different experiments. Spacecraft that have flown gamma-ray detectors include the *Pioneer-Venus Orbiters*, the Soviet *Venera* and *Phobos* missions, the Japanese *Ginga* satellite, and the recently launched French-Soviet *Granat* satellite. To date, the best "published" observations of grb's have been made by the APEX experiment on *Phobos* (Mitrofanov, 1990). These have high resolution in both time and energy. The recently launched *Granat* satellite is expected to produce better data but that has not yet happened.

The simultaneous detection of a single burst by three or more spacecraft, widely separated in space, allows the determination of the position of the burst through triangulation. This method requires relatively high resolution in the burst time profile so that unique features can be time tagged. The exact positions of the spacecraft and the time delay for arrival of the radiation at the different locations leads to position error boxes as small as a fraction of an arc-minute.

One topic that always emerges in a discussion of grb's is the lack of quiescent counterparts. With several very accurate determinations of grb positions, only one† has been associated with a counterpart. This lack of verification at other wavelengths or of an identifiable binary companion means that we do not know the distance to grb's. Consequently, we cannot calculate their luminosities. Furthermore, since counterpart searches have been carried out in known error boxes down to a level of 24^{th} magnitude and at peak intensity the apparent visual magnitude is estimated to be +2, we are dealing with a phenomenon which changes by 22 magnitudes in apparent brightness. For comparison, supernovae show an apparent magnitude change of one-fifth this amount (i.e., +20).

A second noteworthy fact arising from all of the observations is the lack of repeaters. Of the hundreds of burst sources detected only four have been found to repeat and, based on their spectral characteristics, these four appear to be in a separate burster class.

† The March 5, 1979 event was peculiar for many reasons. It remains the brightest γ-ray burst in apparent magnitude. Its position is in the center of the N49 supernova remnant in the Large Magellanic Cloud (LMC). Because of the perhaps unrealistic energy output required at this distance (10^{43}-10^{44} ergs/sec) some dispute this association and think it is a chance alignment.

2. GRB Spectra:

2.1 Time Profiles

Most grb's have a duration of approximately 10 seconds. Although there have been some that have lasted for only milliseconds and others have lasted for a good part of an hour. Figure 1 shows a typical† burst time profile (Hurley, 1989). With a time resolution of 0.05 seconds, this event shows intensity structure with no apparent correlation between peaks. Apparently there are no rules. Some profiles are smooth and slowly varying, others show large random swings in intensity, and one even showed an 8-second periodicity. Some bursts show a small precursor just before the main burst while others have a long slowly decaying tail.

2.2 Energy Spectra

Most efforts to determine the physical cause of γ-ray bursts have centered around the energy spectra. Figure 2 shows a generic energy spectrum of a burst (Murakami, 1989). The most important features are the approximate power-law continuum at high energies, the absorption lines near 20 and 40 keV and the emission line at 400-500 keV. The first puzzle is the fact of the paucity of flux at x-ray wavelengths. Nearly all imagineable cataclysmic events happening near the surface of a neutron star that release γ-rays should also emit an abundance of x-rays. If this release does not come directly from the event itself, it should arise from the reprocessing of the emission by the surrounding medium and/or the stellar surface.

The second puzzle concerns the temperature of the environment where the spectrum is formed. The continuum is approximately fit by a thermal bremsstrahlung model. Such models require high temperatures, a sea of relativistic electrons, strong electro-magnetic fields, and massive particles to decelerate the electrons thus releasing radiation.

The two absorption lines at about 20 and 40 keV could be due to "cyclotron" motions of electrons in very strong magnetic fields. The shape and positions of these lines imply a magnetic field strength of approximately 2×10^{12} gauss. Such a field is consistent with the belief that bursts are associated with neutron stars. In apparent contradiction to the hot continuum, the narrowness of these absorption lines implies their formation in a cool region – where doppler and collisional broadening are reduced. One model attempts to explain this with a thin absorbing layer of gas around the neutron star overlying the hot region where electrons radiate. This layer is optically thin except at the cyclotron frequencies (Lamb, 1990). A second model avoids the absorption phenomenon completely and claims that the spectral depressions are caused by the overlap of different continua: blackbody radiation, thermal bremsstrahlung, and perhaps synchrotron continuum.

Complicating factors in the above studies include a) not all bursts show the same features, b) some show absorption and emission lines at very different energies, and c) it has recently been discovered that these spectra are variable on timescales at short as 100 msec (Mitrofanov, 1990).

† Many researchers in the field, with an eye on the great variability in every grb physical characteristic, would balk at using this term – for them, 'sample'

3. Conclusion

For more than two decades the study of γ-ray bursts has been hampered by poor observations and a phenomenon that is perhaps much more complicated than we first imagined. Fortunately, help is on the horizon. My work here as a NASA/ASEE fellow involves the energy calibration of a new γ-ray detector, the Burst And Transient Source Experiment (BATSE) on the Gamma-Ray Observatory (GRO). As described in my previous summer reports, detailed measurements and calculations of the sensitivity of the BATSE modules are required for the correct interpretation of burst observations.

In early 1991, GRO will be lifted into a low, earth orbit by the shuttle. This experiment will provide definitive answers to the γ-ray burst puzzle.

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