December 21, 2000
ANAG/URE/SPQ8

Final Technical Report

NASA Grant NAG5-8656

Education and Public Outreach Proposal
(in association with CGRO Cycle 8 Guest Investigator Program)

University-Level Research Projects for High School Students

Principal Investigator :
Dr. Mark L. McConnell
University of New Hampshire

Summary

The goal of this project was to provide an opportunity for high school students to participate in university-level research projects. In this case, students from Pinkerton Academy (Derry, New Hampshire) were invited to participate in efforts to catalog data from the COMPTEL experiment on NASA's Compton Gamma-Ray Observatory (CGRO). These activities were part of a senior level honors course at Pinkerton. Although the success of this particular program was rather limited, we feel that the general concept is a sound one. In principle, the concept of partnerships between local schools and university researchers is one that could be especially attractive to soft money researchers. Programs can be carefully designed to benefit both the students and the research program.

The Project

During the course of this program, two students from Pinkerton Academy worked together with the PI in an effort to catalog gamma-ray burst (GRB) and solar flare data from CGRO/COMPTEL. The project required a familiarization with COMPTEL and its data products, an introduction to certain aspects of computing (especially the Unix operating system, on which many of our analysis tools are based), and the use of html programming skills (for potential web page development). The goal was to generate two web-based catalogs – one for GRBs and one for solar flares.

Although two students started the program in the Fall of 1999, one dropped out of the course at the end of the year. The remaining student concentrated on an effort to catalog the GRB data. Although it was clear that time would not permit the complete cataloging of all nine years of COMPTEL data, it was hoped that the effort would lead to the point where the cataloging could be automated and passed on to subsequent students. This goal was never achieved. However, a procedure for processing each GRB event was established and the first few events were processed.

The major reason for the limited success of the project was that the time required to generate the cataloging tools and to begin the cataloging effort was underestimated. In addition, the time available from the students was overestimated. Given the amount of time that was available, significant progress was, however, made. The students were exposed to the university research environment and they were acquainted with some more advanced computer and data analysis skills that are typically not acquired outside of the University environment. These included an exposure to the Unix operating system, PV-WAVE programming language (a derivative of the IDL programming language), and some basic statistical concepts (such as the significance of a source detection).

Lessons Learned

We have clearly demonstrated that such a program could, in principle, be effective in a way that mutually benefits both the high school participants and the university researchers. However, there are some practical issues that should be addressed.

1) Limited Research Time for High School Students

Students often have a limited amount of time available for direct contact. In part, this is due to their class schedule. In addition, the amount of time available can also be dictated by transportation issues. In other words, how easily accessible are the university laboratories? Pinkerton Academy is about 30 minutes by car from UNH. A problem of limited parking on the UNH campus adds an additional 15 minutes or so to the total travel time. Pinkerton students therefore needed to have a significant fraction of a day available for a trip to the UNH campus. Although the Pinkerton program is limited to senior-level students, any effort to expand to lower grade levels would be difficult, given the need to drive to the UNH campus. These types of programs would clearly work much better for high schools that are more conveniently located to the university campus.

2) Remote Computer-Based Activities

Since this project involved extensive computer work, we tried to allow for students to continue their work from off-campus, either from their school-based computer labs or from their home internet connection. For such remote-access activities to work, however, the remote connections must provide the proper tools. For example, some of the tools we had available for analyzing COMPTEL data were PV-WAVE-based tools that provided a graphical user output. In this case, the most convenient output was to an X-terminal window. However, X-terminal tools are not universally available from home computers (PC or Mac) without the use of costly software. Although remote can be a great benefit, especially if transportation and scheduling issues are involved, but some consideration must be given to insuring the availability of appropriate tools. In hindsight, we should have researched this issue a bit further and perhaps provided Pinkerton Academy with software tools that might have facilitated the effort.

3) <u>Limited Time for University Staff</u>

Soft money researchers, who worry about insuring their own salary support, are often reluctant to take time out for extensive outreach activities that do not provide some tangible benefit. Although NASA encourages outreach activities, there are no provisions to provide direct salary support or any other type of reward. Since soft money researchers do make up a significant fraction of the NASA research community, this can be an important issue. Our goal in this case was for the students to provide meaningful achievements that would help meet the goals of the research program. In this way, the outreach program could be made more attractive to soft money researchers. This is clearly one benefit of fostering partnerships between local schools and university research laboratories. It can achieve a level of public outreach while, at the same time, provide soft money researchers with something more tangible than the just having the satisfaction educating the public.

Future Activities

We intend to build upon the progress made in this program to continue our efforts to catalog GRBs (and solar flares) that were detected by COMPTEL. We are currently re-evaluating the program with Pinkerton, but have opted not to continue the partnership, at least for the current academic year. It may be that once we can establish improved tools for the cataloging effort, the participation of high school students may prove more effective in that effort. We are also considering other possible research projects that would be amenable to future partnerships.

We have also used some of the available funds from this program to purchase a copy of the Hands On Astrophysics package from the American Association of Variable Star Observers. We are considering the use of this package as the basis for a program that may involve younger students (perhaps involving several school districts) in an effort to acquaint them directly with the night sky. This might be a program that would be more directly available to a broader segment of the student population.

Addendum

Attached to this report is a copy of the final report provided by the student participant (Dana Mahoney) to the teacher at Pinkerton Academy, Mrs. Cathy Little. In addition, two figures are attached showing the time history and energy loss spectra for GRB 910601, as seen by the COMPTEL burst spectrometer detectors. These are data processed by Mr. Mahoney.

Dr. McConnell's Copy

Gamma-Ray Physics
(An Independent Look At COMPTEL)

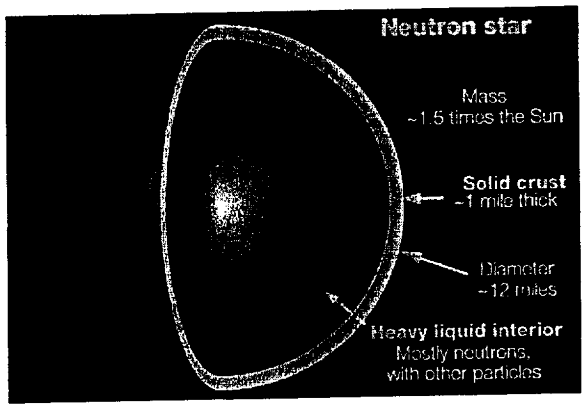
Dana Mahoney
Independent Research
Mrs. Little
June 7, 2000

Vocabulary

Pulsar
A rotating neutron star which generates regular pulses of radiation. Pulsars were discovered by observations at radio wavelengths but have since been observed at optical, X-ray, and gamma-ray energies.

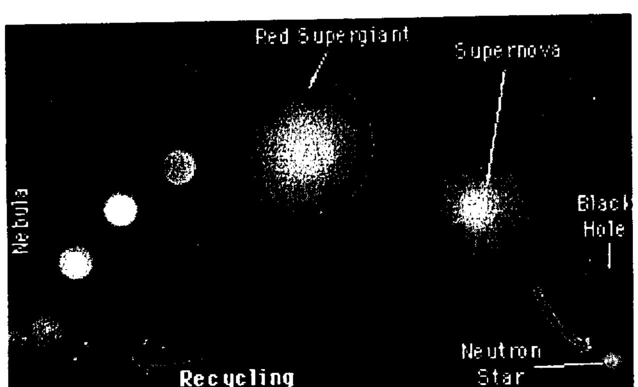
Neutron star
the imploded core of a massive star produced by a supernova explosion. (Typical mass of 1.4 times the mass of the Sun, radius of about 5 miles, density of a neutron.) According to astronomer and author Frank Shu, "A sugar cube of neutron-star stuff on Earth would weigh as much as all of humanity!" Neutron stars can be observed as pulsars.

The picture to the right shows just how big a Neutron Star "Really" is! Further Explanation of it's importance is to follow.



Neutron
A particle commonly found in the nucleus of atoms with approximately the mass of a proton, but zero charge.

Supernova (plural: supernovae)
The death explosion of a massive star, resulting in a sharp increase in brightness followed by a gradual fading. At peak light output, supernova explosions can outshine a galaxy. The outer layers of the exploding star are blasted out in a radioactive cloud. This expanding cloud, visible long after the initial explosion fades from view, forms a supernova remnant (SNR).



Stars, which are 5 times or more massive than our Sun, end their lives in a most spectacular way; they go supernova. A supernova explosion will occur when there is no longer enough fuel for the fusion process in the core of the star to create an outward pressure that combats the inward gravitational pull of the star's great mass. First, the star will swell into a red supergiant...at least on the outside. On the inside, the core yields to gravity and begins shrinking. As it shrinks, it grows hotter and denser. A new series of nuclear reactions begin to occur.... temporarily halting the collapse of the core... but alas, it is only temporary. When the core contains essentially just iron, it has nothing left to fuse (because of iron's nuclear structure, it does not permit its atoms to fuse into heavier elements). Fusion in the core ceases. In less than a second, the star begins the final phase of gravitational collapse. The core temperature rises to over 100 billion degrees as the iron atoms are crushed together. The repulsive force between the nuclei overcomes the force of gravity, and the core recoils out from the heart of the star in an explosive shock wave. As the shock encounters material in the star's outer layers, the material is heated, fusing to form new elements and radioactive isotopes. The shock then propels the matter out into space. The material that is exploded away from the star is now known as a supernova remnant.

The hot material, the radioactive isotopes, the free electrons moving in the strong magnetic field of the neutron star... all of these things produce X-rays and gamma-rays. All that remains of the original star is a small, super-dense core composed almost entirely of neutrons -- a neutron star. Or, if the original star was very massive indeed (say 15 or more times the mass of our Sun), even the neutrons cannot survive the core collapse...and a black hole forms

Supernovae were named because they were objects that appeared to be 'new' stars, *that had not been observed before in the well-known heavens. Of course, the name is actually a bit ironic, since* supernovae *are actually stars at the end of their life cycle, stars that are going out with a bang, so to speak.*

Sunspots
Cooler (and thus darker) regions on the sun where the magnetic field loops up out of the solar surface.

Solar flares
violent eruptions of gas on the Sun's surface.

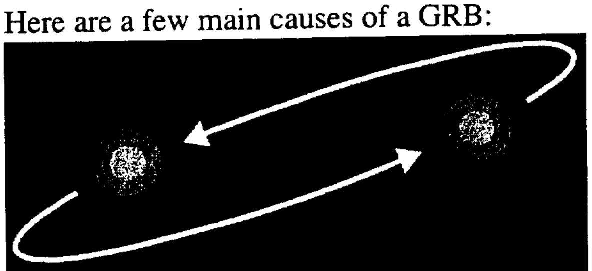
Red giant
A star that has low surface temperature and a diameter that is large relative to the Sun.

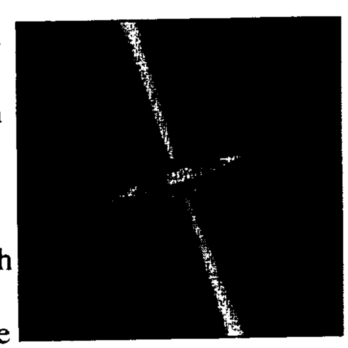
Nova (plural: novae)
A star that experiences a sudden outburst of radiant energy, temporarily increasing its luminosity by hundreds to thousands of times before fading back to its original luminosity.

Black hole
an object whose gravity is so strong that not even light can escape from it.

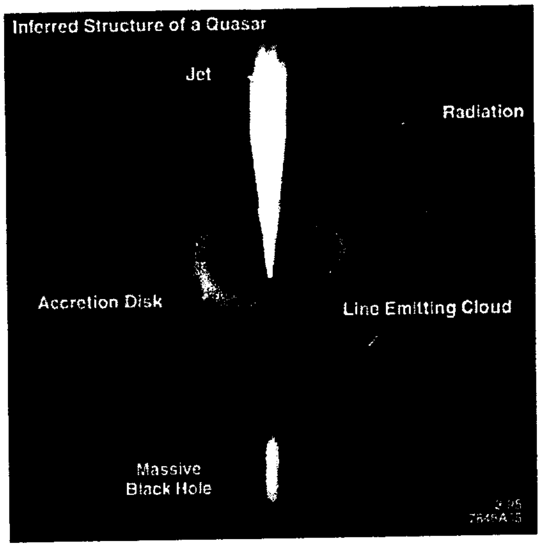
Gamma-Ray Burst (GRB)
Plural is GRBs. A burst of gamma rays from space lasting from a fraction of a second to many minutes. There is no clear scientific consensus as to their cause or even their distance.

Here are a few main causes of a GRB:

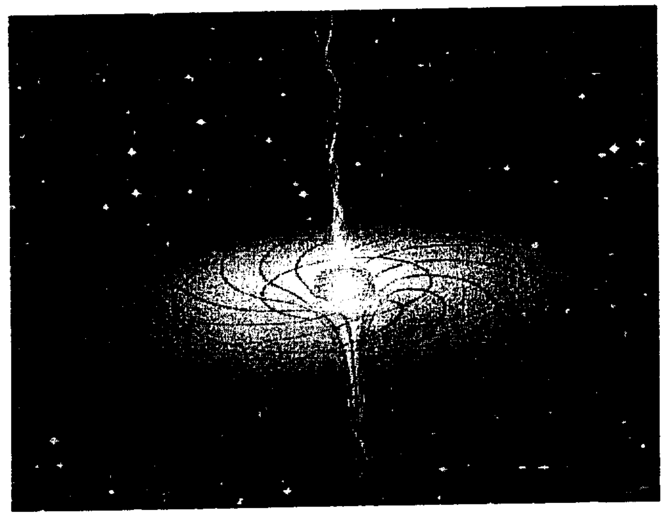




(Left) When two dense objects, like that of a Neutron Star, pull each other together; a Gamma-Ray Burst is emitted (Right) perpendicularly on both ends of the resulting collision. The density of the objects plays a key Role because the energy from the collision is what is said to cause the Gamma-Ray emissions.



(Left) The Gamma-Ray emission from a collision of two or more dense objects will occur in a Jet Stream-like way. A wave-effect will also occur from a GRB emission. This wave is the excess energy in other various high energy radiation forms.



(Right) Another way a High-Energy Gamma-Ray Burst forms is when a dense object, i.e.-Neutron Star, gets pulled into a black hole. As the Black Hole crushes the Neutron Star, Gamma-Rays are emitted.

COOK BOOK

(A How-To On My Work)

Via Dr. McConnell, I have decided to prepare a "cook book" for those who might continue my work. Many, many, many hours were spent learning how to use the five major programs necessary for all scientists who study with the use of a satellite. The COMPASS tables, Pv-Wave, Unix, Ghost View and Emacs are those vital programs. With the following, however, only background information on the characteristics of a gamma-ray are necessary. I have prepared virtually all information necessary to work on the COMPTEL data as I did. Unix in particular is used widely amongst scientists because unlike Windows, Unix does not crash. Very much like DOS, these programs are not run with ease. Everything must be typed in by hand. To bring up a file, you have to know the complete address. For me this was different. I only had experience with Windows before. However, through long periods of trial and error I was able to learn a significant amount of commands in all of the programs. I am definitely no pro but I can get the job done.
The following is a program by program explanation:

UNIX

Unix is the mainframe of our computer. From Unix, we can enter Pv-Wave, Ghost View, EMACS and COMPASS. All of our categorized data resides in directories in Unix and so it is the most used of all the programs. An important reason for Unix's use amongst the science community is its reliability that Unix does not crash. This program is not only vital to us but to Dr. McConnell and everyone else in the Morse Hall building. Without it, they would move at a turtle's pace and NASA's E/PO grant would be non-existent, making this opportunity non-existent. *(No example available)*

PV-WAVE

This is the second most used program. Pv-Wave does all of the calculations for us. It is opened up from Unix where you will be prompt to pick the use of the calculations, which for us is "pbsplt". The full path name of the tpt file is then entered. After that, the computer will take approximately five minutes to accumulate the data, which is a page long. The program breaks the data into six files in addition to the original tpt file. We then place them into one directory for that single event. In doing this, Dr. McConnell will be able to easily go back and organize the data as a whole onto a web site, the main reason for this project.

EMACS

This program is where we create the tpt file. An old tpt file, or template, is opened and all of the information is corrected to fit the current entry. This method is quicker then creating a tpt file from scratch. After the tpt file is created and checked, the file is saved as "grb#.tpt". However, because there is often more than one event for each TJD, we must have a method of separation for each event. We classify this separation by assigning a letter, starting with "B" to the end of the second most intense event and so on. The file is then ready to be analyzed by the Pv-Wave program. *(An example of a tpt file can be seen "A"; A step by step change of a tpt file is provided.)*

COMPASS

COMPASS is actually comprised of several little programs or tables. My partner and I have yet to use most of them. The one we do use is the ITOG table. ITOG gives the period summary of a specific entry or entries based on the given data. For example, I could find the period of the satellite for TJD, Truncated Julian Day, 8473 by just typing in that TJD. If I did not have the TJD I could use the GRB, Gamma Ray Burst, number instead and so on. This table is very useful when making a tpt, text parameter table, file. Placing an inaccurate period of the satellite in the tpt file could ruin any further data that would be taken from that file because the period is a vital part of the calculations we run when categorizing the data. *(No example available)*

GHOST VIEW

Ghost View is a tool that AJ and I use to learn about a specific gamma ray burst entry. What Ghost View does is it takes the same tpt file as Pv-Wave does and uses it to create a graph of the event. The graph visually shows the intensity and style of the gamma ray burst, which allows us to put a picture to the data and therefore accustoming us to the data more. We refer to this when we can not understand the data.

TPT FILE INSTRUCTIONS

(A chart with a number summary has been provided, "A")

1. Bring up the EMACS program (enter "emacs" at home screen)
2. Bring up an "Old" buffer (old name in "ls pbs_data" command)
3. Change title GRB# to the new GRB#
4. Change TJD

5. Change start time (in seconds)
6. Change End time (in seconds)
7. Change Period (in seconds)
8. Change the GRB#'s at the bottom (the file names)
9. Change the PBS#'s (they appear in the order of Middle, Before, & After)

All Input Information Required From #3 To #9 Can Be Obtained Through Dr. McConnell.

EMAC COMMANDS

- ^P Moves up one line
- ^N Moves down one line
- ^K Kills entire line
- ^M Adds space (enter)
- ^A Scroll to beginning of line
- ^E Scroll to end of line
- ^B Move left one character
- ^F Move right one character
- ^H Adds a Window
- ^V Move up one page
- ^L Centers cursor
- ^U Repeats command (follow with digits and then function)
- esc/%/(old name)/(new name) {"!" fills all in query; "y" fills one at a time}

Using "Shift-Arrow Keys", also moves the cursor Up, Down, Left, & Right.

AT HOME SCREEN

rm (path name)	removes the file
rm –r (path name)	removes the directory
mv (old path name) (new path name)	moves a directory/file to a new path
cp (old path name) (new path name)	copies a directory/file to a new path

The above have the following abilities:

"*" includes all characters after the path name

"?" includes one character after the path name

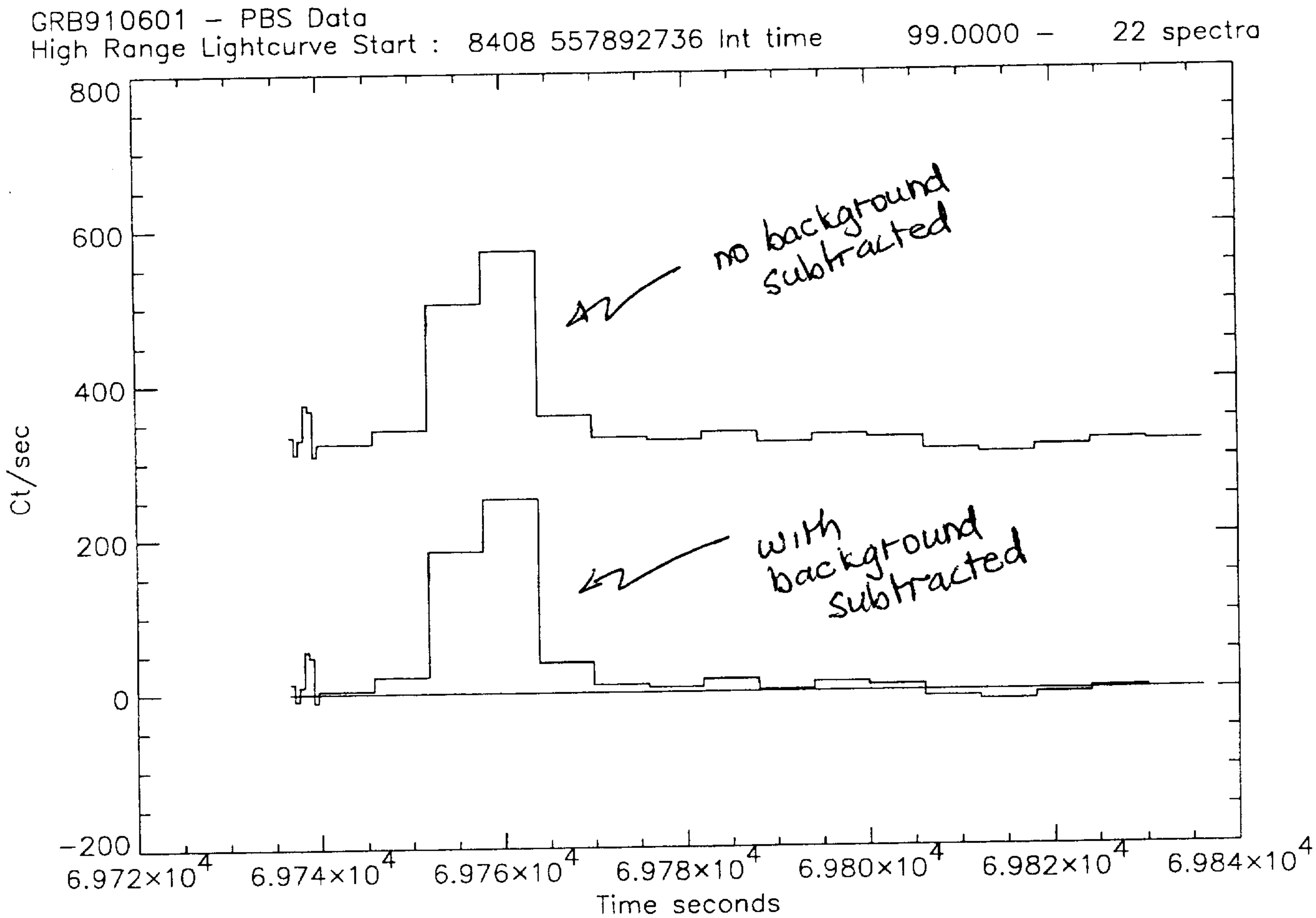
mkdir (path name)	Makes a new directory
ls (path name)	Shows everything in that directory

Dr. McConnell has a worksheet on Pv-wave and Compass if needed.

PUT IT ALL TOGETHER

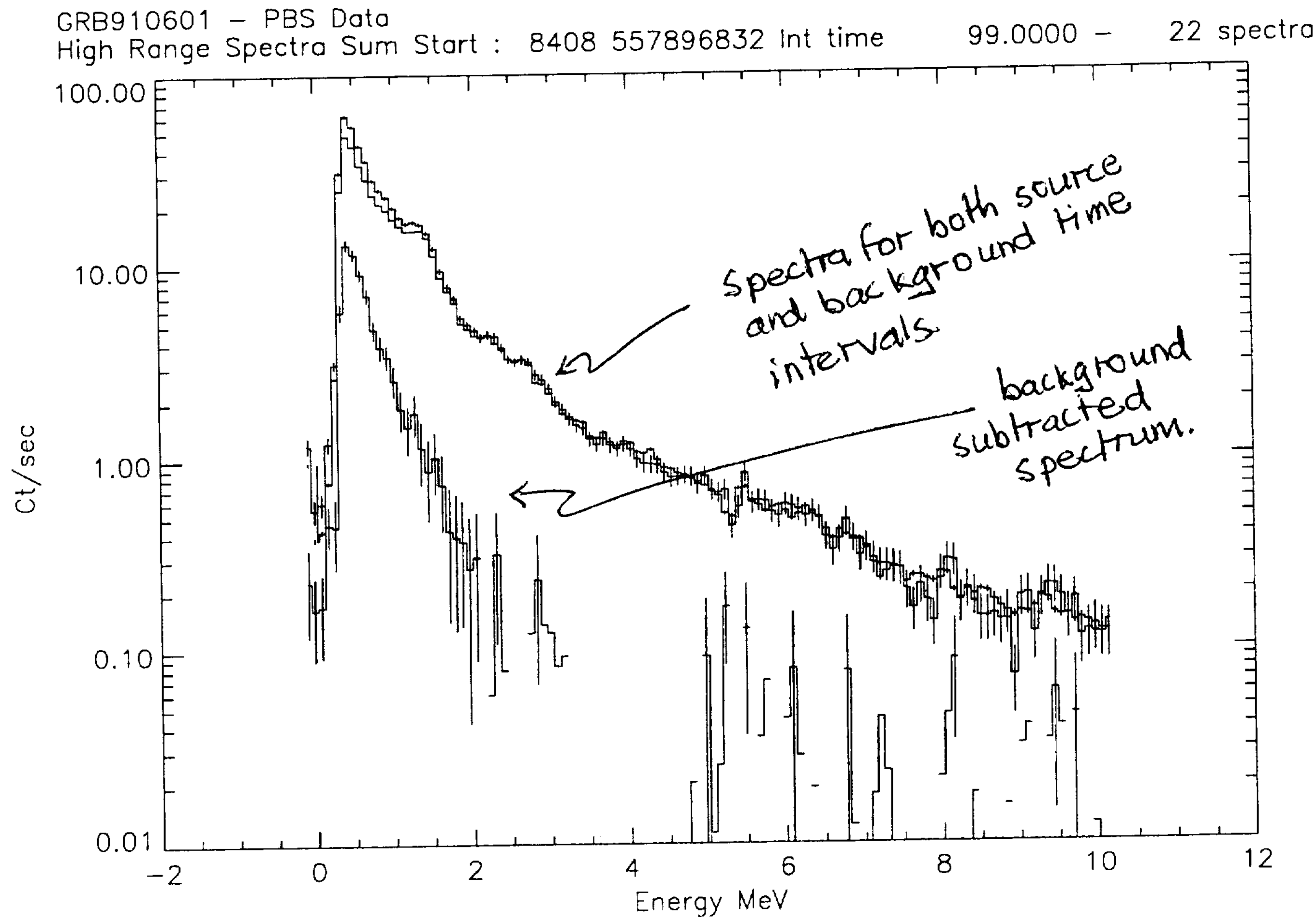
OK, HERE IT GOESSSSSSSSSS:

1. Log ON
2. Go to EMACS and then follow the emac steps.
3. Take the tpt(task parameter table) and put it through pv-wave.
4. Move all desired data from Pv-Wave to the desired location using the "emac commands"
5. Print out the high energy and low energy light curves for review.
6. Review printouts with Dr. McConnell for further instruction.



COMPTEL Time Histories

GRB910601



COMPTEL Spectra of GRB910601