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The Swift Gamma – Ray Burst Mission and the Italian participation

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Abstract. I give a brief overview of the goals of the mission and of the operating set up. I describe only a few science cases in the attempt to better evidence the capabilities of the Mission and give a flavor of the broad range of the astronomical topics that could be covered by the data that will be collected. The instruments and the data center are also described together with the role of Italy in the Mission.

1. Introduction

Now that we are close to the launch of the Swift satellite (the launch is now scheduled for the 7th of October and it has been included in the schedule of Cape Kennedy) the interest of the astronomical community is rising. The preparation of the various groups and scientists that are part of the International Swift Team are getting close to a readiness Status for a Mission that will evolve in time. Even if we are dealing with a P.I. Mission dedicated to a very well defined Research program it will essentially be also a Mission broad in scope serving the community all over the world. It will evolve because we are fully aware that the Team and the planning will gain experience from the operation and by doing this we will likely pass from solving the most urgent and spectacular science issues to the understanding of the basic questions of primary (GRB) and secondary (Non-GRB) science.

A exhaustive and comprehensive description of the Mission has been published by Gehrels, N. et al. (2004) and we refer to that paper, and references therein, for more detailed information. The scope of this talk is to give a flavor of the Mission to those who are not familiar with the science goals, with the main characteristics of the satellite and with the organization of the mission. Finally I would like to make aware our Italian colleagues of the opportunities that may be at hand for everybody. As far the science is concerned I will mention only the essential since others discussed various issues related to the GRBs. In section 2 I will refer to the primary science and secondary science. The instrumentation will be described in section 3 and in section 4 I will describe how we are organized in following up the bursts and mention the Italian Guest Investigator Program that is still up in the air. Finally I will conclude in section 5.

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2. Science

2.1. Primary Science

The main characteristics of GRBs are the very large Luminosity, the rapid decay of the Luminosity as a function of time (typically t^{-1} or t^{-2}) and the emission over the whole electromagnetic spectrum. In addition we seems to have two families of bursts, short bursts with Gamma emission lasting only for a fraction of a second and long bursts lasting generally hundreds of seconds but sometime up to thousands of seconds. These characteristics, and the fundamental experience gained from the Beppo SAX Mission (Costa et al. 1997), drove the detailed design of the Mission, see section 4, and the planning of science.

While we do not know yet, indeed we do not have the data yet and this is a field in which the Swift Mission should give a fundamental contribution, whether or not the short and long bursts are the manifestation of a similar physical phenomenon it seems reasonable to adopt as a working hypothesis that bursts are related to the fast evolution of a very massive star. In small and very active Star Formation Regions we may witness among the many bright stars newly formed a catastrophic phenomenon leading to the emission of high energy followed by an afterglow due to the impact between the ultra relativistic beam and the ISM. Generally these regions that are very active in forming stars are also rich in dust so that, at times, the burst itself could be hidden to the observer at optical wavelengths or we may have the possibility to witness the forming of an expanding bubble destroying progressively the dust and ionizing the surrounding medium. And the emission, thanks to the variety of the physics involved, will cover the whole electromagnetic spectrum. Are the big HI bubbles observed in the spiral galaxies caused by the GRB event? I discussed this possibility years ago with Renzo Sancisi in a meeting we had in Naple at the Observatory of Capodimonte. Recently I also became aware of the paper by Loeb and Perna (1998).

By observing the afterglow soon after the burst we not only get information on the physics of the burst itself, especially when related to the gamma emission, but we will also gain information on the environment, parent population and progenitor, via the evolution of the absorption spectrum. The study of the Host Galaxy, and the details of the physics of the ISM, is also one of the information we must master. A puzzling matter for instance is the detection of a Supernova in the spectrum of many bursts and the evidence that is accumulating that the Host Galaxies of the Gamma bursts differ from the galaxies hosting SNe.

But these objects at maximum are very bright. They can be used as beacon for the study of the intergalactic medium. Furthermore it is our hope that thanks to the on board instrumentation and the ground based facilities we build to this end (the NIR Robotic Telescope REM), we might detect very high z objects. This might allow a real understanding of the epoch of re-ionization and its certain location. Naturally we assume that the star forming process, and galaxies eventually, is active in the redshift range $6 < z < 15$. The goal finally will be the mapping of the formation of galaxies and metals in the Universe. Indeed this is the beauty of the nowadays astronomy and cosmology: the capability to consider the Universe as a global laboratory.

2.2. Non GRB science

The BAT instrument (section 3) will carry out a survey of the whole sky in the Energy range 15 – 150 keV that will be 17 times more sensitive for one third of the sky and 5 times more sensitive for the rest than the best complete hard X-ray survey to date by HEAO A–4 (Levine et al. 1984). It will reach $2\ 10^{-11}$ erg cm^{-2} s^{-1} for high latitudes and $6\ 10^{-11}$ erg cm^{-2} s^{-1} for low latitudes.

Soft Gamma repeaters and Galactic and Extragalactic transients will be detected and studied. But to focus of a very well known problem in Cosmology we refer to the highly obscured AGN and to the full understanding of the population responsible for the background spectrum above 15 keV . Highly obscured objects (column densities NH $\sim 10^{24}$ cm^{-2}) can be detected as to allow a robust statistics, likely a new population of objects will be found.

From the experience based on previous surveys we figure to detect 4 AGN per BAT field at the 4 mCrab level (20 ks integration in one pointing) and about 80 – 100 per field when the survey will be completed. About 1/4 of these, using the rule of thumb, will be absorbed AGN. BAT, furthermore, will point the same region of the sky many times so that variability studies will be possible and this will lead to a firm characterization of the processes leading to the X ray emission and reprocessing.

3. The spacecraft, the payload and the communication system

As I said the spacecraft and the payload were designed to maximize the science return. To do this we had to design a spacecraft Swift moving to the target after detection, it will take about 10 second on average! This is essential to monitor the evolution of the burst since the very beginning not only with the Burst Alert Telescope (BAT) but also with the X Ray Telescope (XRT) and UltraViolet Optical Telescope (UVOT). Indeed these are the instruments of the payload. BAT will continuously monitor 1.4 steradian of the sky (Half coded Field of View). Soon after detection of a GRB (the detection and alert algorithm are very sophisticated tools to allow a characterization of the event and immediate automatic decision by the on board computer) the onboard computer will send the coordinates of the event, together with a set of parameters characterizing the burst, to the ground via the TDRSS. The accuracy of the position will be of about a few (4–5) minutes of arc and only imagery will be possible. At the same time it will instruct the spacecraft to point the target in order to allow the acquirement of the target by the two narrow field instruments. It will take a couple of minutes for XRT to send to ground the position with accuracy better than 5 seconds of arc. Again position and relevant information will be transmitted to the Ground immediately. Note that at this point it could be possible to point medium and large telescopes also for spectroscopy. Finally, and within 15–20 minutes, UVOT will be capable of transmitting a very accurate astrometry and also a card of the field.

XRT is sensitive in the energy range 0.2 – 10 keV, has a field of view of 23 minutes of arc with an effective area of 110 cm^2. Information can be obtained for sources in the range (Photon Counting Mode) from 2 10^{-14} to 2 10^{-11} erg cm^{-2} s^{-1}. UVOT consists of a 30 cm Ritchey Chretien telescope sensitive in the range of 1700 to 6500 Angstrom. It will reach a magnitude B=24 in 1000 s integration using white light. A filter wheel host filters and 1 grism.

The communication system consists of the NASA TDRSS data relay satellites that will be used for immediate download of the relevant data as needed and commands upload if anything urgent has to be carried out (ToO for instance). The Ground station for routine operation, however, is the Italian Space Agencys (ASI) located in Malindi, Kenya. This station which has been upgraded to serve the Swift operations, and those of other LEO orbit satellites, is the same station that served the operations with SAX. We plan to have about 10 contacts a day and all the data will be downloaded here.

4. The Burst Advocate, the data analysis and Archives

Discussion and experience from other satellites, Luigi Piro once illustrated very clearly to the Swift working group the organization of the bursts detected by Beppo–SAX, lead the Team to create and define the figure of the Burst Advocate (BA). In essence the BA will be in charge of a well defined burst and he will be the technical and scientific expert on it. He will advise the Mission Operation Center on the decision to be taken, whether to follow for longer time and how, and be a buffer between the astronomical community and the Mission Operation Center. He can consult with a Team of experts and communicate with whoever is necessary in order to get the best out of the data. He is in contact with the follow up team and will coordinate the activity for that burst to the publication of the results. He will be responsible for triggering the GCN. Indeed the BA is a key figure of the whole operation and because of that he must be unbiased in his/her decisions and contacts. Italy will alternate with the other partners GSFC, Penn State and Leicester in these duties so that an Italian BAs will be in charge for one week every five (GSFC has two weeks duty).

To this end we organized the Italian facilities in a way to be as efficient as possible and have a coverage around the clock. Naturally as time goes on and depending on how many bursts per week we will detect, we foresee at the moment about 2 – 3 per week, we may need to increase the number of scientists that are capable of carrying out such task.

The Team developed pipeline for all the instruments and the tools to reduce the data will be available. The ASDC (ASI) with the collaboration of the staff of the Swift Project developed the pipeline for the XRT data analysis and we plan to foster the data analysis facilities in order to help whoever may need in Italy. The archives will be located in the US (GSFC & Penn State University), Italy (Italian Swift Archive Center – ISAC – composed by the Swift project Office at OAB and ASI ASDC) and UK (Leicester University). Years ago and immediately after we discussed the issue in the US, I discussed with ASI a Guest Investigator Program aimed to help the funding of those Italian Scientists that without being part of the Team were interested in using the data of the Mission or in the future apply for observations needed for their work. We were on the verge of getting everything working when the Italian Astronomy of the Macro systems got to change again. I would like to stress here that such a program, expanded later by ASI also to other Space Projects, is fundamental to the Italian research and should be implemented as soon as possible.

5. The Follow up, Public Outreach & Education (PO&E) and Conclusions

The large activity in space that we will have with Swift will be tremendously enhanced by coupling to it both Space and Ground observing facilities. Indeed it is by pointing the large and very large telescopes on the event that we will gain basic information on the physics of the phenomenon and on the population of the host galaxies. Since the very beginning we did a large effort in coordinating the follow up as well. On an International basis Kevin Hurley is in charge of coordinating, or at least keeping track to avoid duplication and enhance complementarities, the effort from the Ground. In Italy, thanks to a coordinated effort with Luigi Stella, we were able to set up rules and agreements with ESO and other interested parties in order to have the maximum efficiency in the observations. In addition to the REM telescope that will swiftly get to the targets and measure the NIR flux immediately after the burst, the VLT has now the capability to stop an observing program and be ready on the target in only 6.5 minutes. It is a fantastic result achieved by the ESO staff at Cerro Paranal. These immediate follow ups will be relevant not only for the light curve of the burst but also for the study of the environment via the early absorption spectrum, for the study of the interlopers and IGM and finally for the ISM of the galaxy. It seems to me that we may be able to detect and follow in their evolution those rare cases in which we observe the absorption spectrum, due to the eventual dusty cocoon enveloping the burst, disappearing to let free the emission of the gas just ionized by the expanding energetic afterglow. In addition the REM telescope and many other small and efficient telescope will monitor the event in the NIR and trigger automatically the very Large Telescopes especially in those cases where the NIR is visible and the optical emission lacking. We may witness a very high z event.

Italy, in spite of the scarcity of means and ad hoc facilities, did an excellent job in the Public Outreach and Education and has been recognized for that on an International level. As usual we supplemented the shortage of funding and support, in our opinion not justified, with creativity, intelligence and hard work. The model we made, for instance, had a great success and so did the posters and the book for the model and the stories etc. In conclusion Italy performed well and hopefully will perform even better in the future. I also believe that those who dedicated most of their time to making the Mission and preparing for the data collection should be highly rewarded in science return that could not consists only in participating on the publication but rather getting deeper in the knowledge of Nature and be guided in that by the observations that they made possible and gathered. Italy provided know how, hardware and software in addition to management, design, testing and calibration support. The Ground Station is also a major contribution where we gave also a clear demonstration of efficiency and professionalism. In Milano participate to the Mission the IASF–Milano and the Observatory of Brera which is now part of INAF. The University of Milano Bicocca is represented via the Italian Principal Investigator. In Roma we have the participation of the ASDC (ASI) and of the Observatory of Roma–INAF. In Palermo we have the collaboration of the IASF–Palermo and in Florence a collaboration by a staff member of the Observatory of Arcetri.

The participating Institution and the contribution by Italy – GIP

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