TAROT: A status report

Michel Boër, J.L. Atteia, M. Bringer, A. Klotz, C. Peignot*,
R. Malina, P. Sanchez†,
H. Pedersen‡
G. Calvet, J. Eysseric, A. Leroy, M. Meissonier∥
C. Pollas, J. de Freitas Pacheco¶

* Centre d’Etude Spatiale des Rayonnements (CNRS)
  BP 4346, F 31028 Toulouse Cedex 4, France
† Laboratoire d’Astronomie Spatiale (CNRS), Marseille, France
‡ Copenhagen University Observatory, Denmark
∥ INSU-CNRS, Division Technique, Paris, France
¶ Observatoire de la Côte d’Azur, Nice, France

Abstract. TAROT-1 is an automatic, autonomous ground based observatory whose primary goal is the rapid detection of the optical counterparts of cosmic gamma-ray burst sources. It will be able to begin imaging any GRB localization 8 seconds after receipt of an alert from CGRO/BATSE or HETE-2. TAROT-1 will reach the 17th V magnitude in 10 seconds, at a 10σ confidence level. TAROT will be able to observe GRB positions given by Beppo-SAX or RXTE, EUV transients from ALEXIS alerts, etc. TAROT will also study a wide range of secondary objectives and will feature a complete automatic data analysis system, and a powerful scheduling software. TAROT will be installed this fall on the Plateau du Calern, 1200m above sea level. We report on the status of the project.

SCIENTIFIC GOALS

Cosmic Gamma-Ray Bursts

The Télescope à Action Rapide pour les Objets Transitoires (Rapid Action Telescope for Transient Objects) has as primary objective the detection of optical transients associated with gamma-ray bursts. Its construction was decided in 1995, at a time when the optical emission of GRBs was unknown, but predicted by a few models [1]. At that time we thought that the best chance was to observe the GRB source in optical during its gamma-ray activity, meaning a fast moving wide field telescope. We also decided, given the various constraints, to reach a sensitivity level somewhat below the theoretical constraints, i.e. V_{min} ≥ 16 or 17. The recent
detection of the afterglow from GRB 970228 and GRB 970508 [2,3] at optical and X-ray wavelengths demonstrates that this objective is achievable, since given the time delays involved, the light emitted by GRB 970508 would have been easily detectable by TAROT-1. Popular models [4] invoke the chock of a relativistic fireball with the interstellar medium. TAROT will be able to detect it quite early, but also, it will detect the emission due to internal chocks within the fireball itself [5]. In this later case, the optical emission is predicted to be simultaneous with the gamma-ray emission, and in the range of V magnitude between 14 and 16 [1]. With a maximum delay of 8 seconds from the burst onset to the TAROT observation, we will be able to catch 70% of the sources while they are still active, provided that the error box is small enough (4 square degrees). In the case of BATSE we hope to detect one or two bursts per year within this delay.

Detection of this emission by TAROT or by a similar experiment would be an important objective, since it may lead to the confirmation of the model, and give data on the physical source conditions. An early detection of a fireball at a relatively high level (e.g. magnitude 16) would trigger observations at larger telescopes, in order to take spectrum of the source itself, as well as of the host, and to detail the light curve of the optical transient from the beginning of the event, and to see the transition between the internal chock regime and the afterglow.

Moreover, since TAROT has a large field of view (4 square degrees) and will operate continuously, it will be able to detect optical transients which may be related to undetected GRBs if the emission is beamed [6]. Large areas of the sky will be surveyed both for secondary objectives and to establish a reference catalogue for later detection of GRB optical counterparts. This has two advantages. 1) In the case we detect an object within the error box of a GRB, from the inspection of our catalogue we can precise its nature, real new object or variable or flaring object active at the GRB time; 2) During this survey we will detect a large number of variable or new objects, since a substantial fraction of the sky will be observed every night. How we will be able to separate GRB afterglows from variable or flare stars is another problem which is currently under study, but the information will be in our data.

**Secondary Objectives**

An automated, versatile telescope like TAROT has a wide range of possible applications. Objects may be observed upon alert or in a systematic mode. In addition, the wide field of view will result in a lot of serendipitous detections.

In alert mode we shall try to identify EUVE transients detected by the ALEXIS satellite and so far of unknown nature, as well as X-ray transients upon alert from the SAX, RXTE, BATSE, HETE-2, INTEGRAL, MOXE, etc.

In the routine mode we plan to observe systematically several late type flare stars in order to test our ability to detect optical transients. Our programme includes also the detection of supernovae, symbiotic stars, asteroids and comets.
The detailed program of TAROT is currently being elaborated and will be made available through our server and in later publications.

**TECHNICAL DESIGN**

The actual design of TAROT is summarized in Table 1. As it can be inferred from the table, the goal of observing GRBs while they are active has driven the design. We list below some technical features.

- **Mechanics:** The mechanical design has been extensively studied in order to ensure the stability and the reliability of the telescope. The requirement was that TAROT should be able to track (without a guiding star) an object for at least 5 minutes, without any noticeable displacement on the CCD camera. Also, TAROT will accommodate wind speeds as high as 80 km/h (50mph). The behaviour of the mount has been simulated to ensure that no vibrations are generated during the acceleration/deceleration phase.

- **Motors and controls:** The drives have been chosen in order to accommodate for the large accelerations needed by TAROT. They will be able to make a move to any point in less than 3 seconds, meaning a maximum speed of 120 degrees/second., and accelerations as large as 100 deg/s². For simplicity, we decided to use the same motors for the declination and right ascension axis. All drives, including the focus and filter wheel mechanisms are controlled from the telescope control software via a single PC card. An extensive protection of all electric and electronic parts is used against lightning.
Filter wheel: We use a custom designed filter wheel with 6 positions. In addition to a transparent position, a set of standard Cousins B,V, I filters will be used, and two wide band filters, of transmission approximating the overall band pass of the B+V and R+I filters.

SOFTWARE

The software is one of the most sensitive parts of TAROT, since it should run in complete autonomy. The interfaces for the alerts and routine observations will use the Web, the mail, and socket processes (for GCN/BACODINE). In addition, a local interface will be available, mainly for testing and debugging purposes. Our objective is that the telescope operates unmanned for periods as long as 3 months. Hence the control program will be responsible for night operations, day/night transition, calibrations, focusing, etc. This software will take into account the data from the environmental sensors to decide what operation to perform, and will run the telescope accordingly. Routine operations can be interrupted at any time to process an alert. In addition the control software will perform general tasks such as housekeeping, logging...

Routine observations, and follow-up alert observations will be scheduled through a particular software called the Majordome. This software implements several algorithms in order to ensure a maximum efficiency of the observations. Objects should be observed at minimal airmass (unless they are other constraints), and the number of possible observations should be maximized, according to various parameters such as the Moon, user constraints, observation types (periodic, repeated, time tagged...) and priorities. If an alerts occurs, the routine program is interrupted, and the alert processed according to a predefined sequence. The alert modifies in turn the input of the Majordome in order to introduce follow-up observations.

We began to design a module to process automatically the data taken by TAROT. Our decision was based on the fact that TAROT will produce an average of 3Gb per night, and on the necessity to react quickly after an alert. This software will produce a list of sources detected in the image, together with their characteristics (photometry, spatial extension, apparent motion, etc.) will compare each object with the TAROT database (whenever possible), and with other available catalogues to search for a possible variability, or change in properties, or to detect candidate new objects. In order to ensure their nature, each observation will be done twice.

In addition to the above mentionned routine and alert mode, TAROT will be able to scan the sky according to two modes: in imaging mode we take a normal 2K x 2K image, and in scanning mode the telescope scans a wide area, while the CCD is read-out continuously. This later mode will be mainly used for BACODINE/BATSE alerts. In this mode a typical error box is scanned in less than 5 minutes. The scanning mode may be used also to build quickly a first database of TAROT objects, to a limiting magnitude of 17 (V).
CURRENT SCHEDULE

The mechanics and the optics of TAROT have been delivered and integrated in September 1997 together with the drives. The software is currently being integrated and tested in the lab., and the optics will soon be submitted to interferometric measurements.

This fall (1997), the telescope will be moved to its final location, the "Plateau du Calern", 1200m above sea level and French Riviera. It will be installed in a building with a fully retractable roof, which has been recently refurbished in order to ensure maximum sky coverage.

After that the telescope will enter in an extensive test period (mechanics, software, security checks, optics, scientific validation...). During it we hope to be able to receive alerts at least through the GCN network. Routine scientific observations and automatic image processing should start running during the second semester of 1998.

CONCLUSION

Though its dimensions are rather modest, TAROT will be a very efficient instrument, optimized for its prime objective, the detection of high energy transients. Given that 5 seconds are needed to obtain the coordinate information from BATSE/BACODINE or HETE-2, TAROT will be able to get data from the source less than 8 second after the burst onset, while most sources are still active, and to eventually detect the internal chock from the GRB fireball. TAROT will be able also to estimate the background of transient events over the sky, to detect putative "optical GRBs", and to address a wide range of secondary objectives. Its schedule is well in accordance with BATSE, SAX, RXTE and HETE-2 satellites.

Acknowledgements

The TAROT project is funded by the Centre National de la Recherche Scientifique (CNRS / INSU) in France, and by the Carlsberg Fondation in Denmark.

REFERENCES

1. Mészáros, P., and Rees, M., 1994, ApJ, 432, 181.
2. Costa, E. et al., 1997, Nature, 387, 783.
3. Piro et al., 1997, IAUC 6656.
4. Wijers, R.A.M.J., Rees, M.J., and Mészáros, P., 1997, MNRAS, 288, L51.
5. Mészáros, P., and Rees, M.J., 1997, ApJ, 476, 232.
6. Rhoads, J.E., 1997, ApJ, 487, L1.