Comm. in Asteroseismology
Vol. 152, 2008

BRITE Orbits - Visiblity and Feature Plots

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Abstract

The goal of this investigation was the development of analysis tools in form of a software bundle to investigate the opportunities of feasibility during the BRITE mission, before the mission itself takes place. The simulation software and analysis tools will help to make critical mission decisions on the one hand, and on the other hand will help the observer to plan their observing strategies, thus to answer two fundamental questions:
1) Which orbit should be chosen for BRITE?
2) Which stars may be observed during mission time best, depending on the scientific purpose?

BRITE Visibility

To calculate the possible observation times for BRITE-stars during a defined time interval, we have to check their visibility, e.g. if and when they are occulted by the sun, moon, earth or other planets during this time period. We define a discrete time step Δt, which is the minimum time interval between two consecutive simulation states of the BRITE mission. The whole simulation starts at mission time t=0 and ends up at time T, which is a multiple of Δt. In the next simulation step we check, if the stars of interest from a given database are visible or not:

We define $True/1$ (light blocks in Fig. 1 for visible and $False/0$ (dark in Fig. 1) for invisible. If we do so for each star at each time step we end up in a set of multivariate dimensional time series (one time series for each star, dimension depending on the number of BRITE satellites), with only two possible states: visible or not.

The results of the simulation are stored in a global database and can be accessed via filter functions, leading to a report for explicit objects or a visibility plot for the whole set of stars defined in the database. A report returns

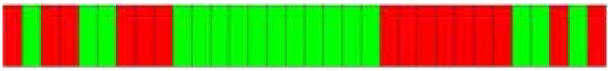


Figure 1: Binary time series example for a BRITE star. Light gray means visible, dark gray not visible.

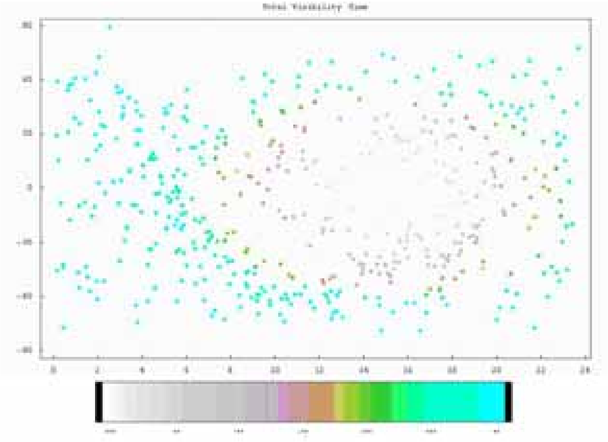


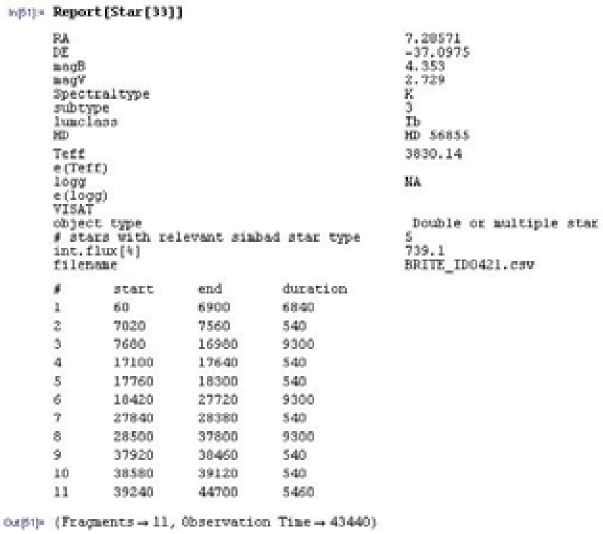
Figure 2: Total visibility time of the BRITE-sky during a simulated mission of 1 month.

the information associated with a single object in the database, the physical characteristics and its possible observation times.

A visibility plot shows the whole sky with all BRITE-stars, defined in the database, color-coded according to a qualitative or quantitative feature, the observer or mission planner wants to know. The features can be accessed and calculated via filter functions: Fig. 2 e.g. shows the total amount of visible time steps during the simulation at all or the size of the longest consecutive visibility time. Other characteristics may be plotted as well, like the min., mean or max observation time, or the number of fragments during a specific mission period. A report for a specific star defined in the database delivering all neccesary information the observer wants to know is shown in Fig. 3.

To clarify the way of calculating the visiblity we use Fig. 1 as an example:

The simulation time T is 32xΔt, where Δt is, say, 60 seconds, thus we did the simulation for 32 minutes or 1920 seconds. The total possible observation time for a star, with this time series would be 17xΔt $=$ 17 minutes, the longest consecutive possible observation is 11xΔt $=$ 11 minutes, the mean observation time would be 17/32 therefore 53% of the simulation time, the smallest window of observation is 1xΔt $=$ 1 minute. If we want to observe this star more than



```
In[81]:= Report[Star[33]]

         RA                                              7.28571
         DE                                              -37.0975
         magB                                            4.353
         magV                                            2.729
         Spectraltype                                    K
         subtype                                         3
         lumclass                                        Ib
         HD                                              HD 56855
         Teff                                            3830.14
         e(Teff)
         logg                                            NA
         e(logg)
         VISAT
         object type                                      Double or multiple star
         # stars with relevant simbad star type          5
         int.flux[%]                                     739.1
         filename                                        BRITE_ID0421.csv

         #       start     end       duration
         1       60        6900      6840
         2       7020      7560      540
         3       7680      16980     9300
         4       17100     17640     540
         5       17760     18300     540
         6       18420     27720     9300
         7       27840     28380     540
         8       28500     37800     9300
         9       37920     38460     540
         10      38580     39120     540
         11      39240     44700     5460

Out[81]= {Fragments → 11, Observation Time → 43440}
```

Figure 3: Report for a specific BRITE star defined in the database of BRITE star objects.

one time, we may need information about the amount of fragmentation, which is for our example 5 (consecutive visibility times shown in green).

A general filter function may return a plot (or report) according to the sentence:

Show me all stars with physical parameters X (spectral type, brightness, etc...) during mission time T (modelled in time steps Δt), showing visibility times similar to the distribution D color-coded according to other features K, resulting from the visibility time series.

Free parameters during the simulation are the mission length T, the discrete time steps Δt, number and orbit of the BRITE satellites and the regions around occulting objects like the earth, moon and the sun (called exclusion angles). The number of observers (number of BRITE satellites) and the number of occulting objects (sun, moon, planets) is arbitrary in the calculation and only limited due to computational and therefore memory limits.

For our study we used the well known NORAD satellite propagator particularly the SGP4 propagator, which was developed by Ken Cranford in 1970 and is used for near-Earth satellites. To compare the results of the Norad program with the STK program we used the two line elements of different orbits, e.g. the ISS and the MOST mission, and integrated the orbits with both progamms for one and two months. Therefore we used the SGP4 Model, implemented in the STK (Satellite Toolkit) as well as in the Norad Package. First tests showed that the orbits, calculated with the two programs, fit quite well. In a second step we compare the results of numerical and analytical propagators. In the STK Program one can choose one numerical integrator (hpop), which is the most precise one we have up to this moment. Therefore we have investigated the differences between this propagator and the analytical propagators (SGP4, SGP8) and found good agreement for less than 24 days to give accurate results. For longer time scales statistical properties still can be deduced from the simulation done so far.

Acknowledgments. The authors whish to thank the SAPS (Stellar Atmospheres and Pulsating Stars) and the ADG (Astro Dynamics Group) for the resources and fruitful discussions.