Stars and their variability observed from space
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ASTRONOMICAL POTENTIAL OF SATELLITE STAR TRACKERS

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Abstract. An initiative is proposed to develop photometric data from satellite star trackers for astronomical use. A feasibility study undertaken for XMM-Newton shows clearly the enormous potential of the high cadence and long exposures of the bright guide stars used for the purposes of ensuring stable satellite pointing. Calibration is required to ensure photometric integrity and allow routine generation of science-ready data products for ultimate distribution to the astronomical community through archives.

Keywords: Stars: variables: general, Instrumentation: photometers, Astronomical databases: miscellaneous

1 The Star Tracker aboard the XMM-Newton satellite

One of the vital operational components of the European Space Agency's XMM-Newton X-ray Observatory satellite is the so-called AOCS system that ensures stable pointing during observations of the sky. In common with most space observatories, this is partly achieved with the use of a Star Tracker designed specifically to lock on to bright stars in its own field-of-view which is much larger than those of the X-ray instruments. Data pertaining to the set of bright stars forms part of the telemetry data stream and finds its quiet way into material delivered to observers through archive services. Measurements of stellar brightness in magnitude units and position within the Star Tracker field-of-view are reported every 0.5 s for many hours at a time to a precision of 0.05 mag. Despite these limitations, combinations of 50 or 100 successive points, for example, increases the precision of the measurements.

1.1 Chandra Variable Guide-Star Catalog

In 2010, XMM's US counterpart the Chandra X-ray Observatory published a catalogue by Nichols and colleagues `http://cxc.harvard.edu/vguide/index.php` confined to the 827 guide stars which showed significant variability along similar, if more limited, lines to the work proposed here ultimately to be fully integrated into routine pipeline and archive services of all space missions both past and present.

2 Astronomical potential of the XMM-Newton Star Tracker

In addition to their operational use, data of this type constitute a photometric sampling density and length of exposure of bright stars over the whole sky essentially otherwise unknown in routine astrophysics, certainly before TESS, as other missions often deal with generally fainter stars. The XMM Star Tracker could offer rich possibilities to observers of investigating uncharted parts of the time domain of whatever bright stars were used in an observation for pointing purposes. The tens of thousands of guide stars used over the course of the 20 years of the XMM mission have covered the magnitude range between 2.4 and 8.5 about a median of 7.4; spectral types between O6 and M5; and luminosity classes I-V. About 5000 light curves provide continuous uninterrupted coverage for longer than 1 day. The total body of data is an untapped astronomical resource of extraordinary value for stellar astronomy for both research and teaching purposes and likely to be of interest to communities in many of the dozens of variability classifications in one of the key resources in stellar astronomy, the General Catalogue of Variable Stars.

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2.1 Scientific rationale

XMM-Newton has been observing 5 bright stars on a more-or-less continuous basis for the 20 years since launch and will probably continue to do so for many years to come. In an initial feasibility study performed without access to documentation other than definition of telemetry contents, light curves have been extracted for 44128 XMM guide stars in public data of which 38510 have been assigned preliminary SIMBAD identifications on the basis of their reported star-tracker coordinates. Inspection of the light curves accumulated in intervals of 25 or 50 seconds reveals many examples of variability in the optical relevant to the study of a full variety of variable systems from eclipsing binaries through rotation and various forms of pulsations to stochastic changes of uncertain origin. Their potential value is demonstrated by considering a few examples identified from a short initial more-or-less random inspection of the tens of thousands of light curves available.

Shown in Figure 1 are three stars that illustrate the possibilities for binary systems; for pulsators; and for simultaneous X-ray and optical observations. Among binaries, ellipsoidal variables are tidally-distorted close systems without eclipses: TV Pic, shown on the left, was perfectly captured by the XMM-Newton Star Tracker. The central plot shows the light curve of the newly-discovered rapidly variable F0 IV star HR 1882 in 1 of 14 separate observations that showed remarkable long-term modulations. The target of an X-ray observation was also selected by accident as a guide star including the prominent Wolf-Rayet star EZ CMa whose optical light curve shown on the right was obtained precisely simultaneously with the star's X-ray light curve in a way otherwise almost impossible to obtain.

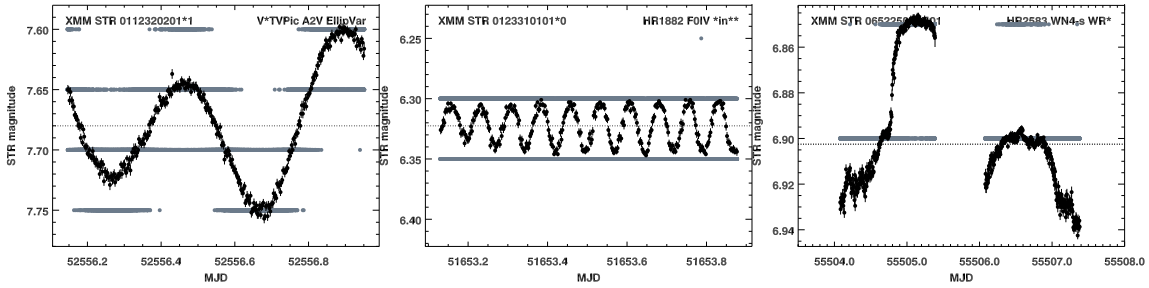

Fig. 1. Examples of optical light curves from the XMM-Newton Star Tracker. **Left:** TV Pic. **Centre:** HR 1882. **Right:** EZ CMa. The grey points show raw photometric measurements accurate to 0.05 magnitudes, the black points show the higher precision achievable with longer-term averages.

3 A Simple and profound conclusion

In the era of the Open Science data revolution, all space missions old and new should calibrate and publish all Star Tracker photometry.