The Magdalena Ridge Observatory's 2.4-meter Fast-Tracking Telescope: Space Situational Awareness and the Near-Earth Environment

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ABSTRACT

To address Space Situational Awareness (SSA) needs, researchers at the Magdalena Ridge Observatory 2.4-meter telescope are investigating various methods to enhance and improve existing capabilities for unique spectral discrimination of resident space objects in low-Earth orbits. As a synergistic compliment to this endeavor, we are working to provide astrometric follow-up and physical characterization (including spectral studies) data of newly discovered near-Earth asteroids and comets in a framework important to planetary defense. One objective is to derive rotation rates for these bodies, and to place the results in context with previous data to enhance our understanding of asteroid impact physics and better address the threat from NEOs having Earth-crossing orbits. Rotation rate can be used to infer internal structure, which is a physical property important to assessing the energy required for object disruption or other forms of hazard mitigation.

1. INTRODUCTION

The Magdalena Ridge Observatory's (MRO) fast-tracking 2.4-meter telescope facility (see Fig. 1) is operated by the New Mexico Institute of Mining and Technology, and is located outside Socorro, NM at an elevation of 10,600 feet. The telescope is used primarily to study solar system bodies and man-made satellites in low-Earth orbit. The facility began observations in 2007, and its researchers are actively involved in the characterization of potentially hazardous Earth-crossing asteroids and comets, as well as the tracking, imaging, and spectral classification of artificial satellites.

Fig. 1. The Magdalena Ridge Observatory 2.4-meter fast-tracking telescope (right) and support facility (left) located outside of Socorro, NM on Magdalena Ridge. The observatory performs target-of-opportunity scientific research and work in the area of space situational awareness.

2. TELESCOPE CAPABILITIES

The 2.4-meter telescope's capabilities include slew speeds of 10 ° per second, precise tracking, and the ability to look as far as 2° below horizon. The site has exceptional seeing, typically at or below 1 arcsecond, even at elevations as low as 5° (see Fig. 2). Further, the telescope design permits the mounting of up to six (6) instruments simultaneously, and a tertiary mirror enables switching between instrument ports in about 20 seconds. This system has detected objects as faint as visual magnitude V=23.9 in a single, unstacked image. The facility excels at target-of-opportunity observations, and can usually acquire data on time-critical targets with just a few hours notice.

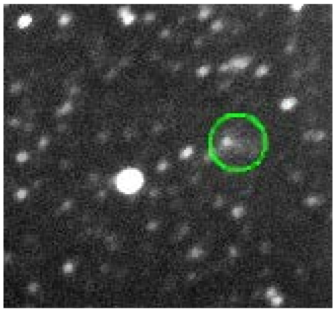

Fig 2. Seeing at the telescope site can be sub-arcsecond quality even at very low elevations. Above is an image of Comet Temple 1 taken in mid-January, 2011 for ground-based astrometry in support of NASA's Stardust-NeXT spacecraft mission. The comet was only ~5° above the horizon, and it was astronomical (morning) twilight when the observation was taken. Astrometric residuals were sub-arcsecond; airmass was about 9.

Fig. 3. Single image taken of the International Space Station taken with the 2.4-meter telescope on December 14, 2010.

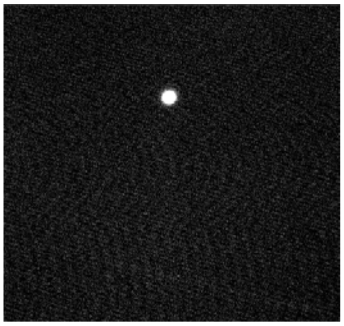

Fig. 4. Tracked image taken with the 2.4-meter telescope of newly generated space debris: the tool-bag lost by a shuttle astronaut while servicing the International Space Station on November 19, 2008.

3. SPACE SITUATIONAL AWARENESS

The near-Earth environment presents many opportunities for the 2.4-meter facility to contribute to monitoring and characterizing resident space objects. The areas of space situational awareness work that we have had previous experience with include detection and/or tracking of man-made objects and the identification (and characterization) of detected objects, as well as the determination and prediction of orbital status, and spacecraft maneuvers. The telescope is capable of tracking objects in low-Earth orbits, with a modest 0.5° keyhole at zenith where targets may be temporarily lost (and later reacquired). The following subsections outline focus areas for our ongoing initiatives.

LEO Tracking and Characterization

The 2.4-meter facility researchers have tracked hundreds of low-Earth orbiting objects (LEOs) since September 2007 for the Air Force and others. Additionally, researchers are currently active in spectral studies of LEOs and associated identification techniques. Fig. 3 is a single image of the International Space Station taken with the 2.4-meter telescope for tracking refinement purposes.

Debris Tracking

Space debris can pose a collision threat to operational satellites, and the problem is likely to become a major concern in the next decades. The 2.4-meter telescope has been used to track various debris targets, including those in LEO orbits (see Fig. 4). With the ability to deploy personnel for target-of-opportunity observations within hours of an alert, the facility is capable of tracking small, faint, fast-moving debris.

Rocket Body Lightcurves

Rotating rocket bodies can be observed in low, mid, and high-Earth orbits, and can be monitored for how their orbital positions and rotation rates alter in response to solar activity. Since solar storms can occur on a daily/weekly frequency, affecting atmospheric density, photometric measurements taken over an extended time period are very useful.

Figures 5 and 6 depict lightcurves of rocket bodies previously studied. Long-term studies would yield insights

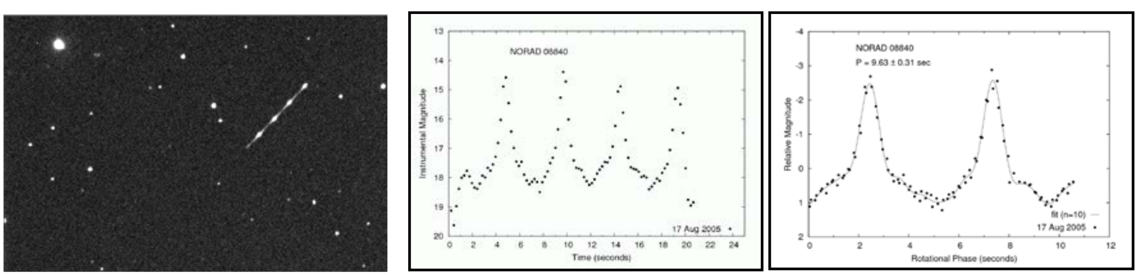

Fig. 5. Image of NORAD 08840 (trailed streak), lightcurve, and derived rotation period (9.8 sec).

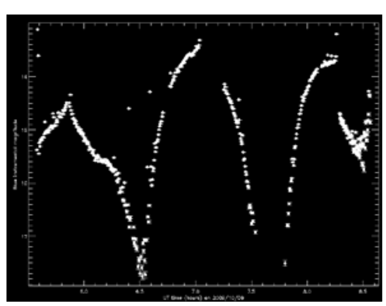

Fig. 6. Lightcurve of a tumbling Centaur rocket body taken on October 9, 2010 using the 2.4-meter telescope.

4. NATURAL HAZARDS IN THE NEAR-EARTH ENVIRONMENT

In addition to the space situational awareness work described above, researchers at the 2.4-meter telescope facility are actively involved as a station for follow-up astrometry and characterization of potentially hazardous near-Earth asteroids and comets. This research area is very closely aligned with our investigations of artificial satellites: both require very similar instrumentation and personnel expertise to implement. Sometimes small asteroids can come very close to the Earth without hitting it, but instead pass through the geosynchronous satellite zone (this occurred several times in 2011). Tracking such bodies can have implications for the health and safety of man-made objects in orbit around the Earth.

Since the 2.4-meter telescope was designed to track resident space objects in low-Earth orbit, we can easily compensate for the motion of rapidly moving near-Earth objects (NEOs) during their close approach and obtain accurate astrometry. Fig. 7 is an example of this tracking capability as applied to studying NEO 2010 GA6 during its close approach of ~1.2 lunar distances from the Earth. The target images had profiles of about one arcsecond while the object traveled at 350 arcseconds per minute.

Fig. 7. Image of asteroid 2010 GA6 (dot at the center of image) taken on April 9, 2010 (5 second exposure). 2010 GA6's location at the time was ~1.2 lunar distances from Earth, and it was moving at 350"/min. Its absolute magnitude is H=26.0.

We are leveraging our hazardous natural object follow-up work to obtain characterization data (primarily rotation rates) on the most interesting, newly discovered (including potential spacecraft targets). As a result of this strategy, we have one-of-a-kind, real-time access to the study of unique objects before they leave the near-Earth vicinity. We recently obtained spin rates for the fastest and third fastest asteroids in the Solar System, each body had a diameter smaller than 100 meters [1].

5. SUMMARY

To address Space Situational Awareness (SSA) needs, researchers at the Magdalena Ridge Observatory's 2.4-meter telescope are investigating various methods to enhance and improve existing capabilities for unique spectral discrimination of resident space objects in low-Earth orbits. As a synergistic compliment to this endeavor, we are working to provide astrometric follow-up and physical characterization (including spectral studies) data of newly discovered near-Earth asteroids and comets in a framework important to overall planetary defense.

6. REFERENCES

1. Ryan, W.H, and E.V. Ryan (2011). Rotation Rates for Very Small Near-Earth Asteroids, *Icarus, in preparation.*