OSIRIS-REx *Target Asteroids!* Involving the Public in Asteroid Research and Scientists with the Public. Anna H. Spitz[1], Carl W. Hergenrother[2], Dolores H. Hill[3], and Dante S. Lauretta[4]. [1]University of Arizona 1415 N. 6th Street Tucson AZ 85705, aspitz@lpl.arizona.edu, [2]1415 N. 6th Street Tucson AZ 85705, chergen@lpl.arizona.edu, [3]1629 E. University Boulevard Tucson AZ 85721, dhill@lpl.arizona.edu, [4]University of Arizona 1415 N. 6th Street Tucson AZ 85705, lauretta@orex.lpl.arizona.edu.

Introduction: NASA's OSIRIS-REx asteroid sample return mission's education and public outreach (E/PO) program will deliver several formal and informal education and outreach opportunities during the 14-year mission. One component, citizen science programming, provides both data for scientists and educational experiences for the public. OSIRIS-REx plans two major citizen science projects during the mission. The first, *Target Asteroids!*, began in April 2012 and serves as a model for future efforts.

Target Asteroids! is a citizen science program for amateur astronomers that contributes to basic scientific understanding of near-Earth objects (NEOs). One hundred amateur astronomers representing twenty states in the United States and twenty-three countries are currently working with OSIRIS-REx science and E/PO team members to provide needed data for selected asteroids. These citizen scientists deliver astrometry and photometry data to the *Target Asteroids!* coordinators, who analyze them and publish results, and directly to the Minor Planet Center. These data enable scientists to refine orbits, test models of the dynamical evolution and determine the composition of NEOs. The observations directly support the OSIRIS-REx mission and aid future mission designers and scientists.

Since the launch of the program in April 2012, observers have submitted more than thirty-four sets of observations including astrometry, photometry and even spectroscopy for eight asteroids. Observers also provide feedback about the program for evaluation.

OSIRIS-REx Science Team Involvement: Coordinators Dolores Hill and Science Team member Carl Hergenrother worked with the OSIRIS-REx E/PO Lead to establish the program early in the mission. Audience characteristics provided a strong foundation on which to build *Target Asteroids!*. The amateur astronomy community is highly skilled and practiced in recording and submitting observations. Professional astronomers and amateur astronomers have a long history of collaboration. Working with partners, we established the program goals and expected outcomes and defined metrics and processes. Amateur astronomer and partner input was important to developing the program.

The coordinators initially recruited amateurs with significant observing experience and high-end equipment. They encouraged those with minimal asteroid observing experience and modest equipment to participate as well (although observing faint, small asteroids is difficult). Hergenrother and Hill selected objects. Hergenrother periodically updates the list of NEOs to account for observing conditions, to support scientific needs and to include objects accessible for more observers. There are currently eighty-five asteroids on the list. Hergenrother and Hill review, reduce and publish data. The organization of and responsibilities within this program also serve as a model for our Science Team members' involvement in other citizen science programs, e.g., asteroid mapping later in the mission.

Science Investigations: The *Target Asteroids!* observing campaign is based on a list of NEOs with orbits conducive for spacecraft sample return. The list is constrained to objects with absolute magnitude (H) < 21.5, perihelion distance (q) > 0.8 astronomical units (AU), aphelion distance (Q) < 2.0 AU, and inclination (i) < 8°. These parameters were chosen to reflect the likely limitations of manned or unmanned missions to the targets. These limitation include the duration, delta-V (change in velocity which measures the amount of effort needed to change a trajectory), and complexity of a mission design.

In response to the large interest in the program by observers equipped with small aperture telescopes, the target list was expanded to include asteroids that are analogous to the OSIRIS-REx target asteroid, (101955) 1999 RQ36. One of the benefits of this expanded list is that many of these asteroids are bright enough for small telescope users.

A common question is what can small telescopes contribute to our understanding of NEOs that can't be learned with large professional class telescopes? Large telescopes can be used to determine rotation periods, colors, taxonomies, albedos and such. But usually these observations require many different large telescopes equipped with specialized instruments. Due to the intense competition for use of large telescopes, history has shown that insufficient time on these instruments is available for comprehensive studies of large numbers of asteroids.

While smaller telescopes cannot produce high signal to noise (S/N) observations for many fainter objects, they do have the advantage of making many observations. Even lower S/N observations are useful if made often over many different observing geometries. This is why our main goal is to acquire photometry of asteroids over a large range of phase angles. The rela-

tionship between the brightness of an asteroid and its phase angle (the Sun-asteroid-observer angle) is called its phase function (see Fig. 1) [1]. The slope of the phase function is correlated with the albedo of the asteroid [2][3][4]. Combining the phase function slope with the absolute magnitude provides a measure of albedo.

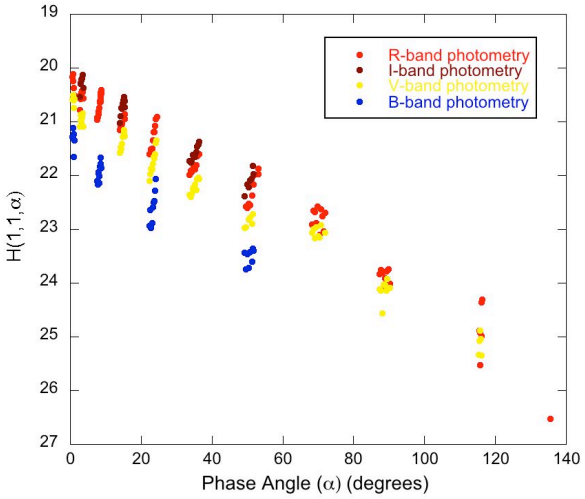

Figure 1 - *BVRI* photometry of the near-Earth asteroid 2012 QG42 taken over a phase angle of 0.7° to 139.5°.

Additional photometry time-resolved and filter photometry is used to determine rotation state and taxonomy. All of these data are used to better understand properties of NEOs and the processes by which Main Belt Asteroids may become NEOs.

In September of 2012, the 200-500 meter in diameter near-Earth asteroid 2012 QG42 passed within eight lunar distances of Earth. Over the course of two weeks observers obtained multi-filter photometry over a wide range of phase angles form 0.7° to 139.5° (see Fig. 1). *Target Asteroid!* observers from three countries (United States, Colombia and Bulgaria) contributed observations. Due to a very long rotation period of ~48 hours, having observers at various Earth longitudes facilitated the determination of the rotation period.

Partnerships: This program is greatly enhanced through external partnerships. Public and private organizations work with the coordinators to encourage participation and data collection. Partner organizations include: Association of Lunar & Planetary Observers (ALPO), Astronomical League, Catalina Sky Survey, International Astronomical Search Collaboration (IASC), iTelescope.net, Mt. Lemmon SkyCenter, NASA Night Sky Network, Oceanside Photo & Telescope and Sierra Stars Observatory Network (SSON). NASA's Near-Earth Object program contributes expertise and collaboration especially for newly discovered NEOs. Through the course of their normal observations, *Target Asteroids!* participants can provide much needed follow-up observations important to NASA's NEO program.

The Astronomical League runs a companion *Target NEOs!* observing program in collaboration with the OSIRIS-REx mission. *Target NEOs!* observation list and data requirements are the same as those of *Target Asteroids!*

Target Asteroids! is modeled on processes and structure used in other highly successful collaborations between professional and amateur astronomers such as those of the Association of Variable Star Observers, ALPO and IASC. Ongoing partnerships with such organizations also increase *Target Asteroids!* demographic and geographic reach.

Target Asteroids! reaches out to generate interest, form new collaborations and engage citizen scientists through presentations, articles and participation in amateur club activities. The coordinators, E/PO Lead, Principal Investigator and other OSIRIS-REx team members have focused outreach efforts on amateur astronomy clubs, star parties and publications for amateurs.

Future Development: *Target Asteroids!* is a small but growing program in which citizen scientists provide critical data for asteroid studies. Program evaluation contributes to continued improvement and refinement of the program – to ensure high-quality data and high-quality educational experiences. *Target Asteroids!* is scheduled to grow through addition of skilled amateurs and through expansion to other audiences. The coordinators are already working to expand the program to audiences, such as students, to engage them in authentic science experiences. *Target Asteroids!* partner organization IASC provides a working model for such an expansion. Partnerships with observatories such as SSON, which provides data to customers, will allow participants who do not necessarily have astronomical equipment or optimal observing conditions available to them. *Target Asteroids!* is also important to the OSIRIS-REx mission as a model for citizen science programs: it creates templates for mission scientist engagement, data handling, educational opportunities and partnering among educators, scientists and the public.

References: [1] Bowell E. et al. (1989) In Asteroids II, 524. [2] Belskaya I. N. and Shevchenko V. G. (2000) Icarus , 147, 94. [3] Oszkiewicz D. A. et al. (2011) J. Quant. Spect. Rad. Transfer , 112, 1919. [4] Hergenrother et al. (2013) Icarus, in prep.