

OSIRIS-REx Science Team

Telescopic Observations of Bennu

V1.0

List as of March 13, 2018

The OSIRIS-REx asteroid sample return mission will travel to the asteroid (101955) Bennu to retrieve an approximately 60g sample of the regolith and return that sample to Earth. A full description of the OSIRIS-REx mission can be found in Lauretta, 2015. (101955) Bennu was selected as the target of the sample return due to several factors including the many ground- and space-based observation opportunities. Hergenrother, 2013 described these observation opportunities “The asteroid was a 15th magnitude object when discovered on September 11, 1999 by the Lincoln Laboratory Near Earth Asteroid Research (LINEAR) survey (Williams 1999). Since discovery there have been three opportunities to conduct ground- and space-based observations. During the discovery 1999-2000 apparition Bennu passed within 0.015 AU of Earth and peaked in brightness at 14th magnitude. During the 2005-2006 apparition it approached to within 0.033 AU of Earth and brightened to 16th magnitude. The most recent apparition extended from mid-2011 to mid-2012 when it approached to within 0.177 AU of Earth resulting in a much fainter peak magnitude of ~19th magnitude.”

This document lists and describes the ground- and space-based telescopic observations made of (101955) Bennu during each apparition, as well as pointing readers to the appropriate archive to find the observational data. In some cases, the data has yet to be archived. Over the course of the OSIRIS-REx mission, these data sets will be archived, and this document will be updated. Any new data sets collected during the 2017/2018 timeframe will be also be added to the list.

Archived in PDS

[Asteroid \(101955\) Bennu Radar Shape Models \(Nolan\) archived in the Planetary Data System Small Bodies Node](https://sbn.psi.edu/pds/resource/bennushape.html)

(<https://sbn.psi.edu/pds/resource/bennushape.html>)

PDS citation:

"Nolan, M.C., Magri, C., Howell, E.S., Benner, L.A.M., Giorgini, J.D., Hergenrother, C.W., Hudson, R.S., Lauretta, D.S., Margot, J.L., Ostro, S.J., and Scheeres, D.J., Asteroid (101955) Bennu Shape Model V1.0. EAR-A-I0037-5-BENNUSHAPE-V1.0. NASA Planetary Data System, 2013."

Abstract: We present the three-dimensional shape of near-Earth asteroid (101955) Bennu (provisional designation 1999 RQ36) based on radar images and optical lightcurves (Nolan et al., 2013). Bennu was observed both in 1999 at its discovery apparition, and in 2005 using the 12.6-cm radar at the Arecibo Observatory and the 3.5-cm radar at the Goldstone tracking station. Data obtained in both apparitions were used to construct a shape model of this object. Observations were also obtained at many other wavelengths to characterize this object, some of which were used to further constrain the shape modeling (Clark et al., 2011; Hergenrother et al., 2013; Krugly et al., 1999).

Journal publications making use of this data:

M. C. Nolan, C. Magri, E. S. Howell, L. A. M. Benner, J. D. Giorgini, C. W. Hergenrother, R. S. Hudson, D. S. Lauretta, J.-L. Margot, S. J. Ostro, D. J. Scheeres. Shape Model and Surface Properties of the OSIRIS-REx Target Asteroid (101955) Bennu from Radar and Lightcurve observations. *Icarus* 226, 629–640.

[ECAS/R-band lightcurve, color and phase angle photometry images \(Hergenrother\)](#)

Journal publications making use of this data:

C. W. Hergenrother, M. C. Nolan, R. P. Binzel, E. A. Cloutis, M. A. Barucci, P. Michel, D. J. Scheeres, C. Drouet d'Aubigny, D. Lazzaroh, N. Pinilla-Alonsoi, H. Campins, J. Licandro, B. E. Clark, B. Rizk, E. C. Beshore, and D. S. Lauretta. Lightcurve, Color and Phase Function Photometry of the OSIRIS-REx Target Asteroid (101955) Bennu. *Icarus* 226, 663–670.

[Archived in non-PDS Archives](#)

[Spitzer Thermal and Physical Characterization Observations \(Emery\) archived in the NASA/ Infrared Processing and Analysis Center Infrared Science Archive](#)

<https://irsa.ipac.caltech.edu/about.html>

Thermal Observations of OSIRIS target 1999 RQ36

Program Name/Id: 1999RQ36/289

Category: solarSystem: near-Earth objects

PI: Emery, Joshua P

We propose to observe the near-Earth asteroid (101955) 1999 RQ36, the target of the OSIRIS sample return mission, with IRS and IRAC. These observations will provide characterization of the composition, structure, and thermophysical properties of this distinctive asteroid. Compositionally diagnostic emissivity features measured by IRS at two longitudes will be used to constrain the surface mineralogy and structure (e.g., grain size, porosity). IRS thermal flux spectra also provide some constraint on size, albedo, and thermal inertia. IRAC and IRS peakup imaging photometry of 1999 RQ36 will be dominated by thermal emission in all six bands and will be used to map the albedo and thermal inertia as a function of rotation, making observations at 10 different longitudes, and with higher accuracy than would be possible with only IRS spectra.

Physical characterization of Near-Earth objects: OSIRIS-REx targets

Program Name/Id: OSIRISREX_DDT/80232

Category: solarSystem: near-Earth objects

PI: Emery, Joshua P

We propose to use Spitzer/IRAC to physically characterize 7 near-Earth asteroids (NEAs). These seven targets have particular interest as the primary and potential backups for the OSIRIS-REx asteroid sample return mission. Specifically, we will measure the sizes and albedos of all 6 backup targets and the thermal inertias of three of these. We will measure thermal flux in both IRAC bands for a full rotation of the primary target, 1999 RQ36, to search for temperature variations indicative of small-scale albedo variation. Fluxes of NEAs in the two IRAC channels are dominated by thermal emission, measurement of which enables determination of size and albedo. Knowledge of these fundamental properties is critical for interpreting the origin and evolution of the NEA population, as well as for determining whether an object is

a good target for a given spacecraft mission. Three targets have both pre- and post-opposition apparitions during GO8. Obtaining thermal fluxes of both the morning and evening side of a target provides the opportunity to improve the size/albedo determination and constrain the thermal inertia.

Journal publications making use of this data:

J.P. Emery, Y.R. Fernández, M.S.P. Kelley, K.T. Wardennée Crane, C. Hergenrother, D.S. Lauretta, M.J. Drake, H. Campins, J. Ziffer. Thermal Infrared Observations and Thermophysical Characterization of OSIRIS-REx Target Asteroid (101955) Bennu. *Icarus* 234, 17 - 35.

[Hubble Space Telescope lightcurve images \(Nolan\) archived in Mikulski Archive for Space Telescopes \(MAST\) \(https://archive.stsci.edu/hst/search.php\)](https://archive.stsci.edu/hst/search.php)

[Lightcurve observations of OSIRIS-REx Sample-Return Mission target 1999 RQ36 HST Proposal 13118 Michael Nolan](#)

We propose photometric observations of near-Earth asteroid 1999 RQ36 to measure the lightcurve and determine its rotation phase in support of the OSIRIS-REx mission. The observations proposed here serve two purposes: 1} they will provide the rotational orientation that is needed to tie Spitzer observations scheduled for August 21 2012 to the shape model, and 2} they will allow measurement of the YORP effect, which needs accurate rotation phase information at several widely-spaced epochs. Currently, the observations in 1999 and 2005 cannot be directly linked in phase, leaving uncertainties of several rotations between the epochs. If we measure the lightcurve of the asteroid in 2012 and establish the phase, we will eliminate these uncertainties and link the lightcurve unambiguously to 2005 and 1999 and to the spacecraft encounter, improving our knowledge of the rotation state and allowing measurement of the YORP effect. This is the last opportunity to make these measurements before the 2016 launch of OSIRIS-REx.

Journal publications making use of this data:

M. C. Nolan, C. Magri, E. S. Howell, L. A. M. Benner, J. D. Giorgini, C. W. Hergenrother, R. S. Hudson, D. S. Lauretta, J.-L. Margot, S. J. Ostro, D. J. Scheeres. Shape Model and Surface Properties of the OSIRIS-REx Target Asteroid (101955) Bennu from Radar and Lightcurve observations. *Icarus* 226, 629–640.

Not Yet Archived

[McDonald Obs visible spectra \(Howell\)](#)

Journal publications making use of this data:

B. E. Clark, R. P. Binzel, E. Howell, E. A. Cloutis, M. Ockert-Bella, P. Christensen, A. Barucci, F. DeMeo, D. S. Lauretta, H. Connolly Jr., A. Soderberg. Asteroid (101955) 1999 RQ36: Spectroscopy from 0.4 to 2.5 μ m and Meteorite Analogs. *Icarus* 216, 462-475.

Binzel, R. P., DeMeo, F. E., Burt, B. J., Cloutis, E. A., Rozitis, B., Burbine, T. H., Campins, H., Clark, B.E., Emery, J.P., Hergenrother, C.W., Howell, E. S., Lauretta, D.S., Nolan, M.C., Mansfield, M., Pietraszi, V., Polishooka, D., and Scheeres, D. J. (2015). Spectral Slope Variations for OSIRIS-Rex Target Asteroid (101955) Bennu: Possible Evidence for a Fine-Grained Regolith Equatorial Ridge. *Icarus* 256, 22-29.

[MIT Near Earth Asteroid Survey \(Binzel\)](#)

Journal publications making use of this data:

B. E. Clark, R. P. Binzel, E. Howell, E. A. Cloutis, M. Ockert-Bella, P. Christensen, A. Barucci, F. DeMeo, D. S. Lauretta, H. Connolly Jr., A. Soderberg. Asteroid (101955) 1999 RQ36: Spectroscopy from 0.4 to 2.5 μ m and Meteorite Analogs. *Icarus* 216, 462-475.

Binzel, R. P., DeMeo, F. E., Burt, B. J., Cloutis, E. A., Rozitis, B., Burbine, T. H., Campins, H., Clark, B.E., Emery, J.P., Hergenrother, C.W., Howell, E. S., Lauretta, D.S., Nolan, M.C., Mansfield, M., Pietraszi, V., Polishooka, D., and Scheeres, D. J. (2015). Spectral Slope Variations for OSIRIS-Rex Target Asteroid (101955) Bennu: Possible Evidence for a Fine-Grained Regolith Equatorial Ridge. *Icarus* 256, 22-29.