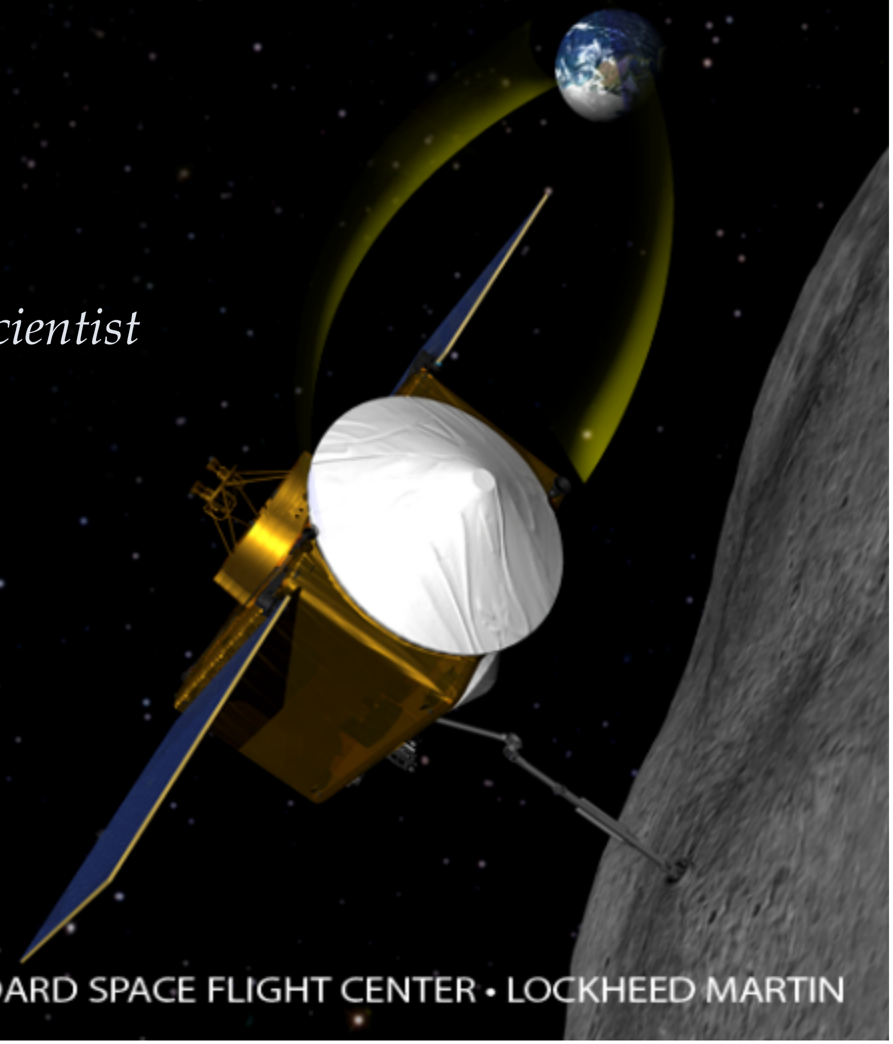
OSIRIS-REx
Asteroid Sample Return Mission

Lucy F. Lim– Assistant Project Scientist



OSIRIS-REx Asteroid Sample Return Mission

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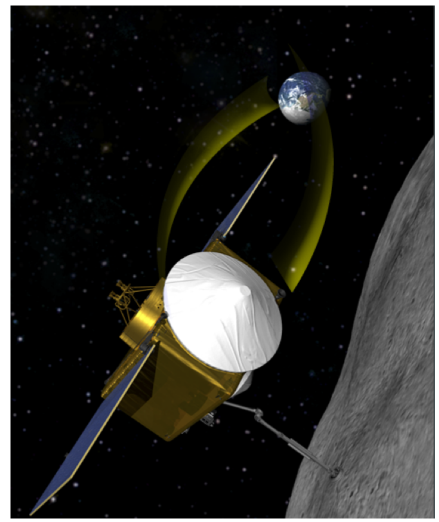
WHAT IS OSIRIS-REX?

- **OSIRIS-REx is a PI-led New Frontiers sample return mission to return at least 60 g (and as much as 2 kg) of pristine regolith from asteroid 1999 RQ36.**

- **Selected in 2011 under PI Mike Drake and Deputy PI Dante Lauretta**
- **Currently in Phase B**
  - **PI: Dante Lauretta**
  - **Deputy PI: Ed Beshore**
- **Recent Milestones:**
  - **System Design Reviews complete for five instruments**
  - **System Requirements Review complete for TAGSAM**
  - **Mission Definition Review (MDR) complete May 2012**
- **Mission PDR scheduled for March 2013**

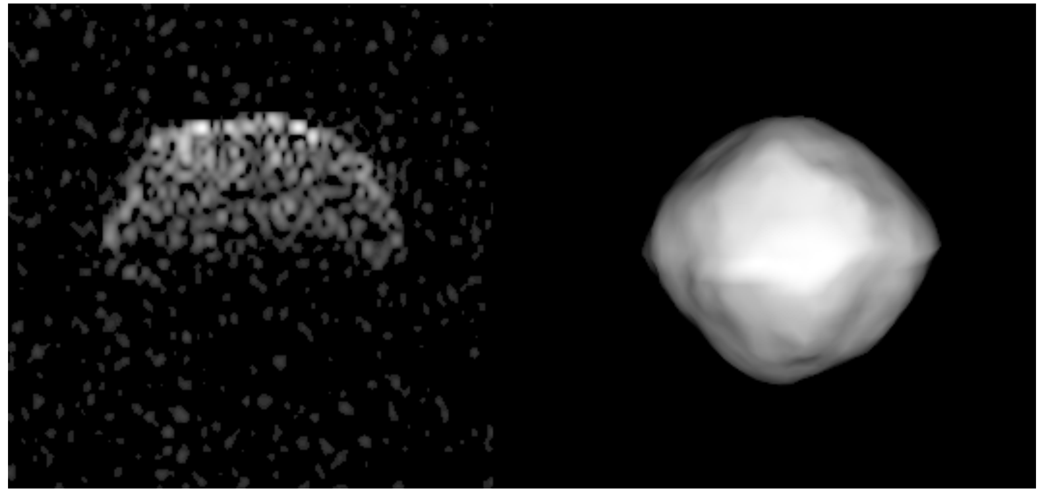


THE ASTEROID TARGET: 1999 RQ36

IRTF/SpeX in Sept. 1999, Sept. 2005, and August 2011 (Clark et al. 2011)

- B-type spectrum

Kuiper 1.5-m photometry in Sept. and Oct. 2005



Arecibo and Goldstone planetary radar observations in Sept. 1999 and Sept. and Oct. 2005. Delay-only Arecibo astrometry Sept. 2011. (Nolan et al. 2012)

- Mean diameter 493 ± 20 m; Mean equatorial diameter 545 ± 15 m
- Retrograde rotation: pole within 15 degrees of ecliptic south, 4.2968 ± 0.0018 hours
- Polarization ratio (CPR at 12.6 cm) 0.18 ± 0.02

Spitzer IRS (5-38 microns) observations May 2007: Moderate thermal inertia, 400 to 700 J m^{-2} $s^{-1/2}$ K^{-1} (Emery et al. 2010)

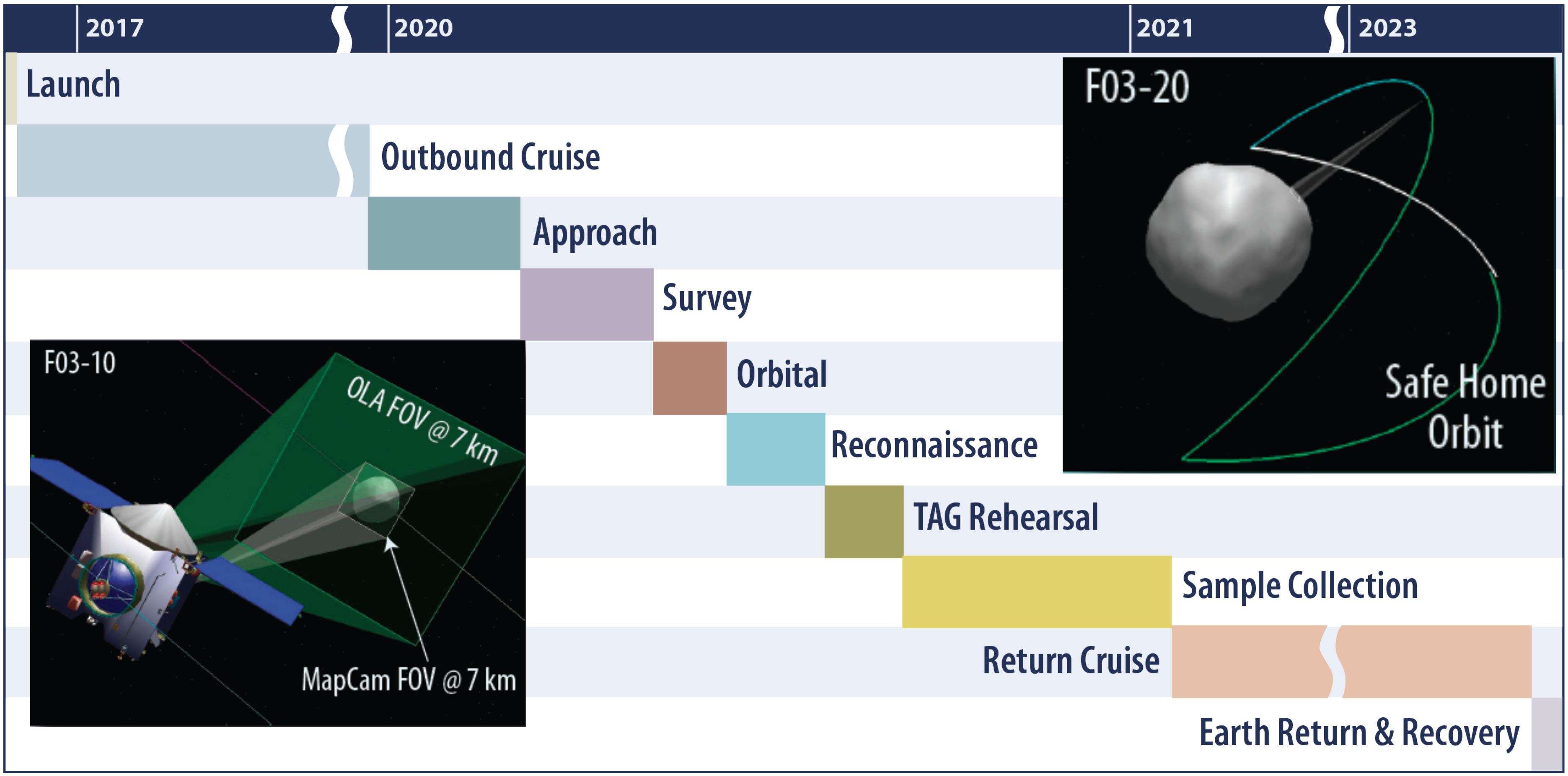
- Radar polarization and thermal inertia provide evidence for regolith on the surface available for sampling.

Herschel observations Sept. 2011 (Mueller et al. 2012)

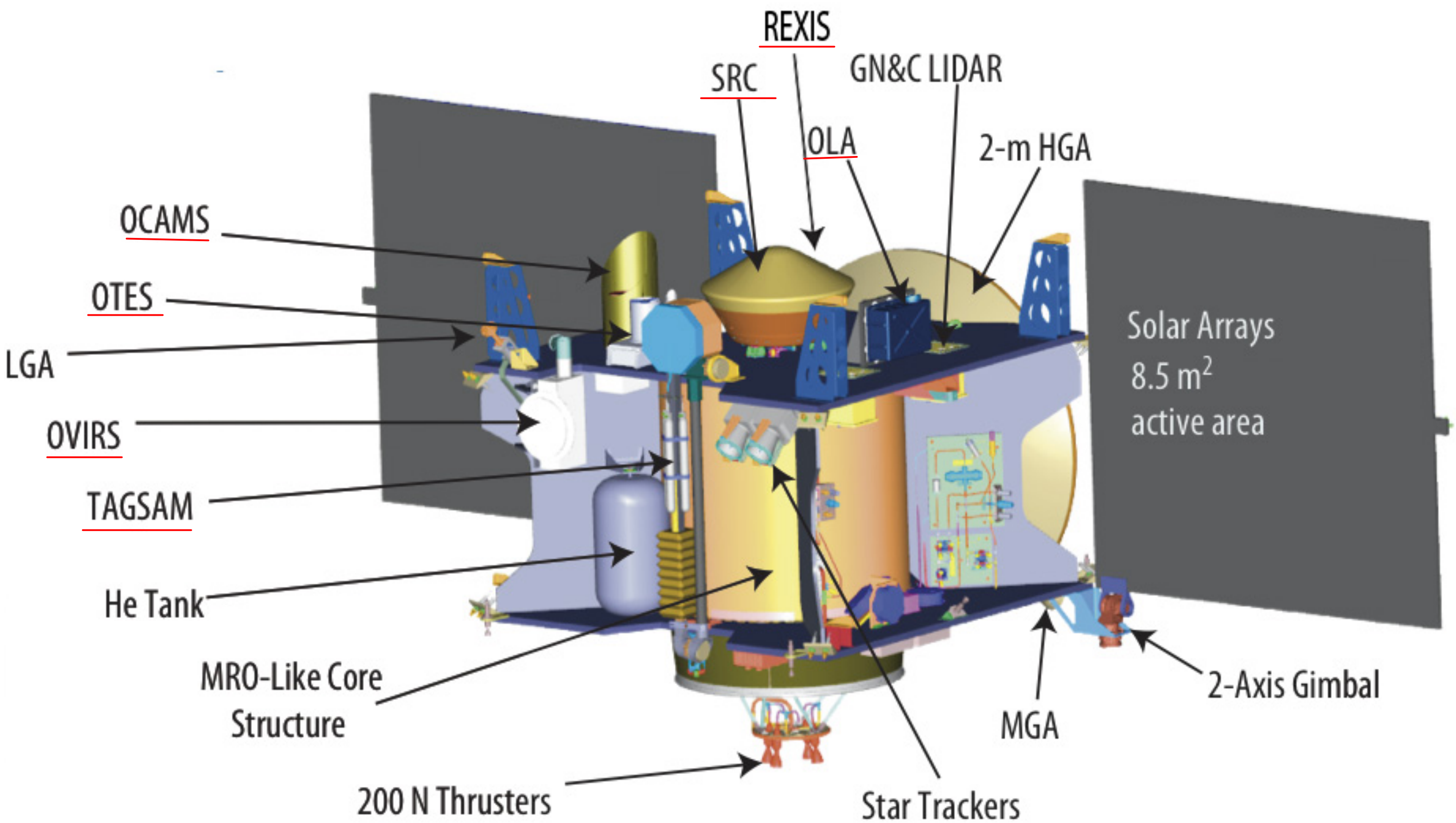
Yarkovsky analysis based on astrometry and Spitzer-derived thermal inertia

Chesley et al. (2012) derived a bulk density 0.97 ± 0.15 g/cm^3

OSIRIS-REX TIMELINE: SEVEN YEARS FROM LAUNCH TO SAMPLE RETURN

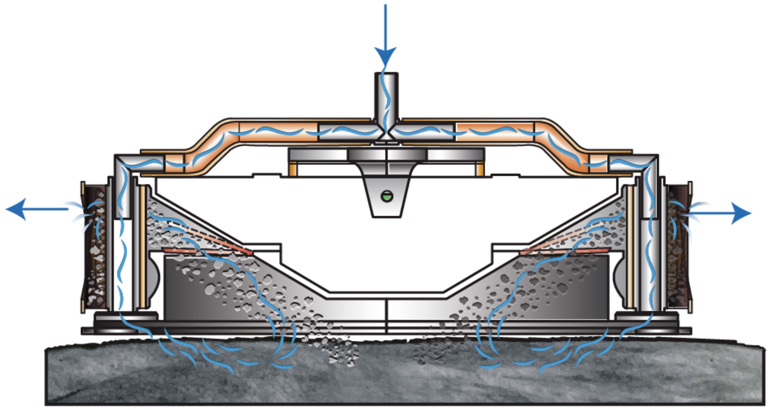


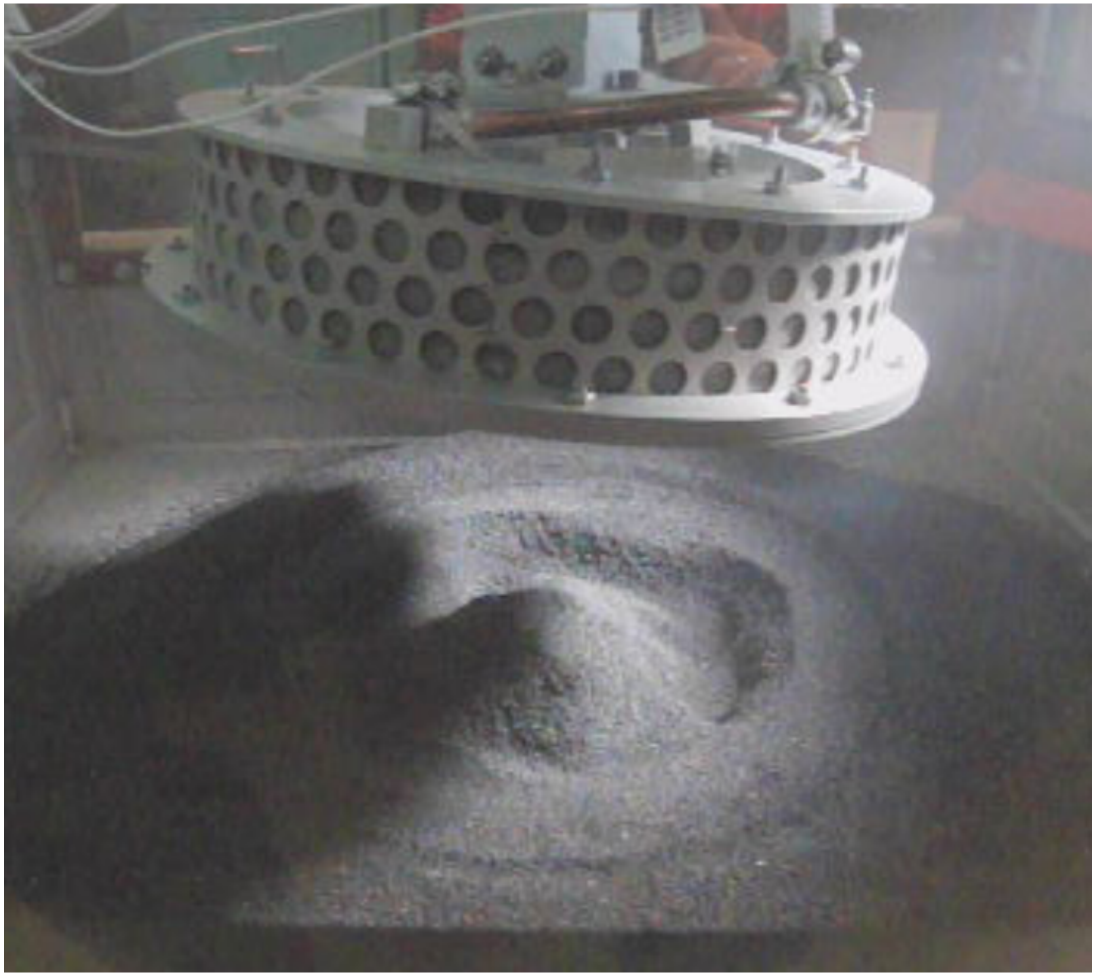
THE OSIRIS-REX SPACECRAFT AND PAYLOAD ELEMENTS



TAGSAM: SIMPLE SAMPLER DESIGN PROVEN RELIABLE IN TESTING

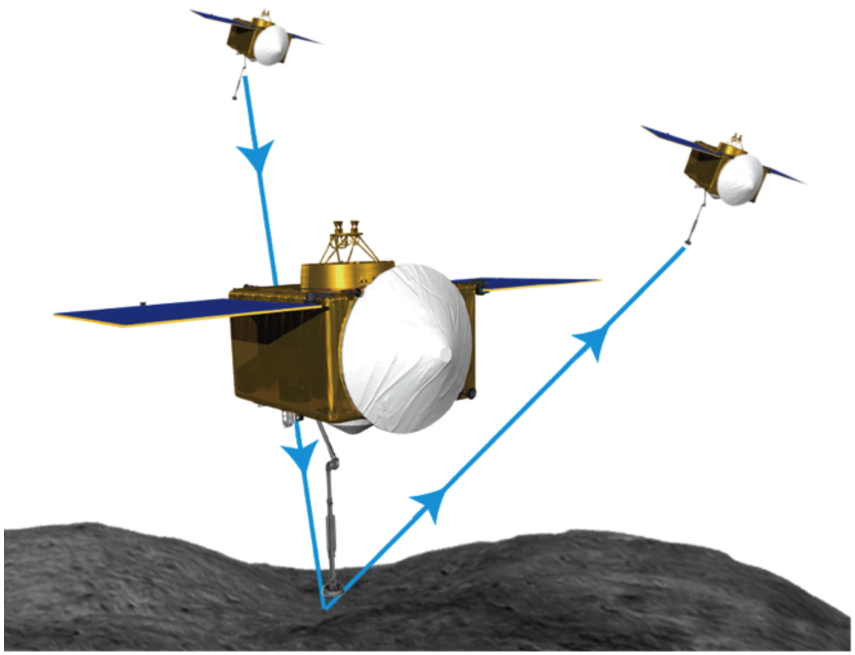
- Regolith fluidized by high-pressure annular N_2 flow
- Mylar check valve retains regolith
- Universal joint conforms to local slope





OUR SAMPLE IS COLLECTED DURING A FIVE-SECOND TOUCH-AND-GO MANEUVER

- Approach surface within vertical and horizontal speed constraints
- Surface contact is made with sampler head
- Compression of spring in the Touch-and-Go Sample Acquisition Mechanism (TAGSAM) arm
- Rebound from surface using stored energy in spring
- Fire thrusters to accelerate away from RQ36



SAMPLES WILL BE ARCHIVED IN THE ASTROMATERIALS CURATORIAL FACILITY AT JSC

- 11.5 g of bulk sample for immediate analysis after Earth return
- 3.5 g for margin
- 45 g archived for future generations
- Within six months of sample return, the OSIRIS-REx science team will produce a catalog containing sufficient information to allow the community at large to propose research with the samples.
- During the subsequent six-month period, the Science Team will be allocated samples to conduct the measurements required to address the mission science objectives.

MISSION TIMELINE

- Selection: May 25, 2011
- Mission Definition Review: May 8-10, 2012
- Preliminary Design Review: March, 2013
- Critical Design Review: April, 2014
- System Integration Review: February, 2015
- Launch: September, 2016
- Earth Gravity Assist: September, 2017
- Asteroid Arrival: October, 2019
- Asteroid Departure: March, 2021
- Earth Return: September, 2023
- End of Mission (Sample Analysis): September, 2025

OSIRIS-REx – The Right Team for the Job

Principal Investigator:	**Dante S. Lauretta (UA)**
Deputy PI:	**Edward Beshore (UA)**
Project Manager:	**Robert Jenkens (GSFC)**
Flight System Manager:	**Joe Vellinga (LM)**

University of Arizona
- Principal Investigator & Deputy PI
- Project Planning and Control Officer
- Mission Instrument Scientist
- Science Team Management
- OSIRIS-REx CAMera Suite (OCAMS)
- Science Processing and Operations Center (SPOC)
- Data Management and Archiving
- Education & Public Outreach

Goddard Space Flight Center
- Project Management
- Project Scientist & Deputy Project Scientist
- Mission Systems Engineering
- Safety & Mission Assurance
- OSIRIS-REx Visible and near Infrared Spectrometer (OVIRS)
- Flight Dynamics Lead

Lockheed Martin
- Flight System
- Sampling System
- Sample Return Capsule
- Mission Operations

Canadian Space Agency – OSIRIS-REx Laser Altimeter (OLA)
Arizona State University – OSIRIS-REx Thermal Emission Spectrometer (OTES)
KinetX – Navigation/Flight Dynamics
Johnson Space Center – Sample Curation
Indigo Information Services – PDS Archiving

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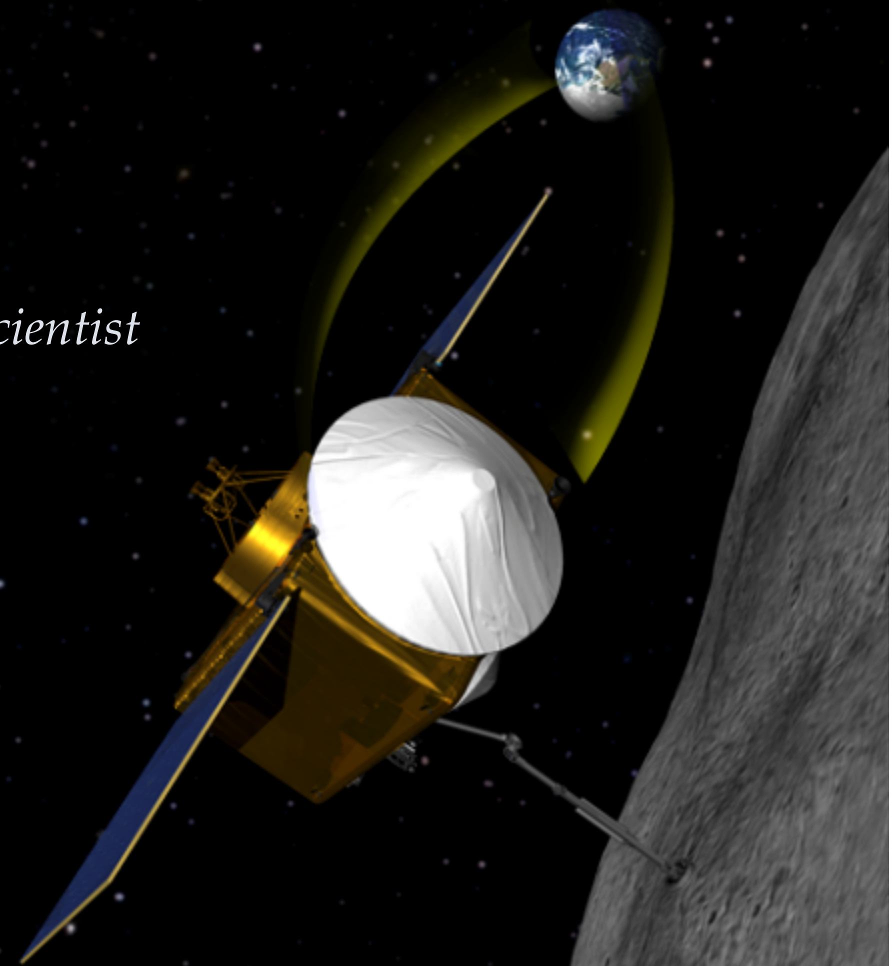

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Backup Slides

LEVEL-1 SCIENCE OBJECTIVES

1. Return and analyze a sample of pristine carbonaceous asteroid regolith in an amount sufficient to study the nature, history, and distribution of its constituent minerals and organic material.

2. Map the global properties, chemistry, and mineralogy of a primitive carbonaceous asteroid to characterize its geologic and dynamic history and provide context for the returned samples.

3. Document the texture, morphology, geochemistry, and spectral properties of the regolith at the sampling site in situ at scales down to the sub-centimeter.

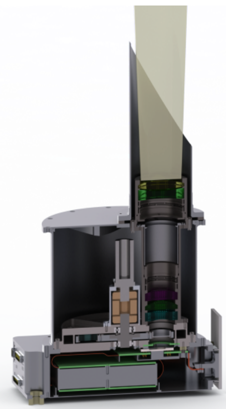
4. Measure the Yarkovsky effect on a potentially hazardous asteroid and constrain the asteroid properties that contribute to this effect.

5. Characterize the integrated global properties of a primitive carbonaceous asteroid to allow for direct comparison with ground-based telescopic data of the entire asteroid population.

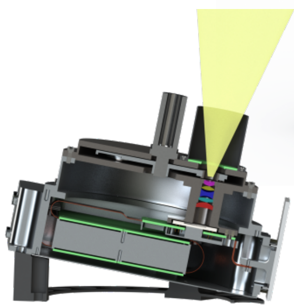
Instrument Capabilities

OCAMS

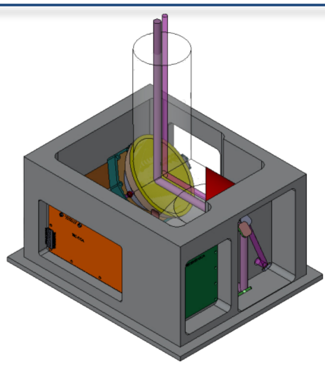
PolyCam acquires 1999 RQ36 from 500K km range, refines its ephemeris, and performs high-resolution imaging of the surface



MapCam provides narrow angle OpNav, performs filter photometry, maps the surface, and images the sample site

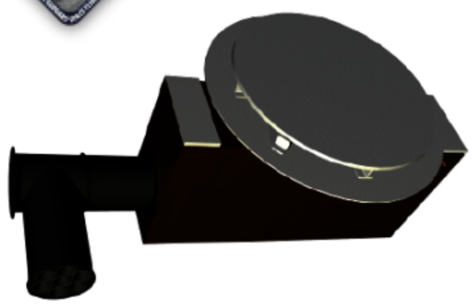


–**SamCam** provides wide-angle OpNav, images the sample site, and documents sample acquisition

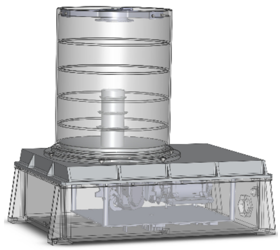


–**OLA** provides ranging data out to 7 km and maps the shape and topography

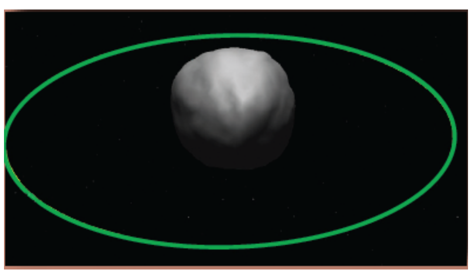
Instrument Capabilities



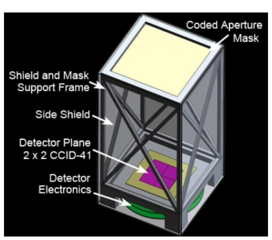
–**OVIRS** maps the reflectance albedo and spectral properties from 0.4 – 4.3 μm



–**OTES** maps the thermal flux and spectral properties from 4 – 50 μm



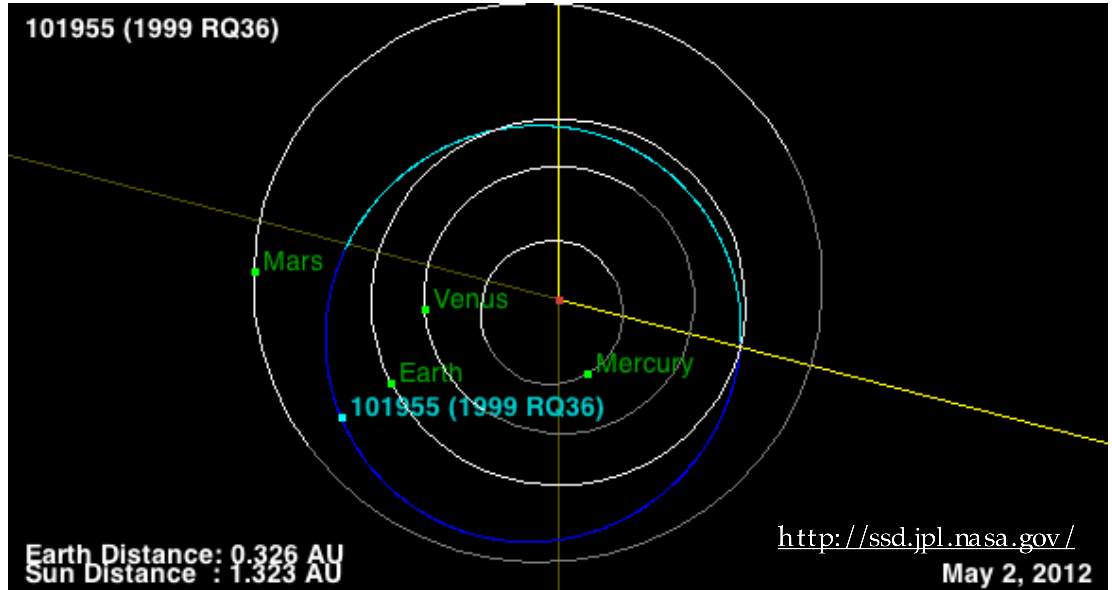
–**Radio Science** reveals the mass, gravity field, internal structure, and surface acceleration distribution

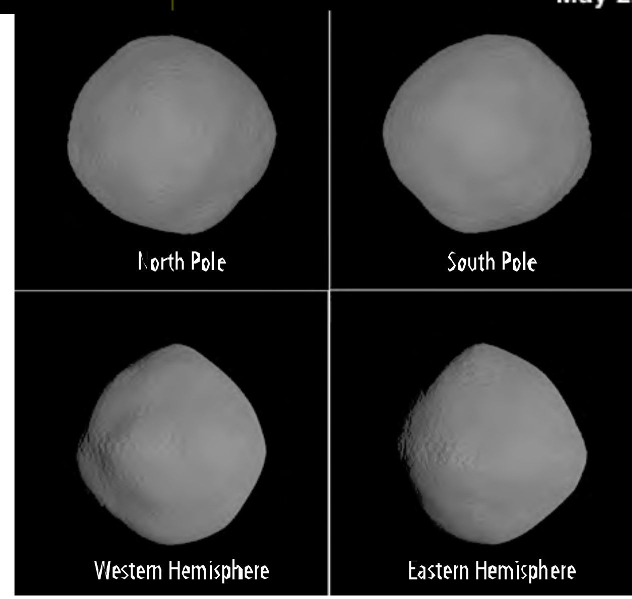


–**REXIS** is a Student Collaboration Experiment that trains the next generation of scientists and engineers and maps the elemental abundances of the asteroid surface

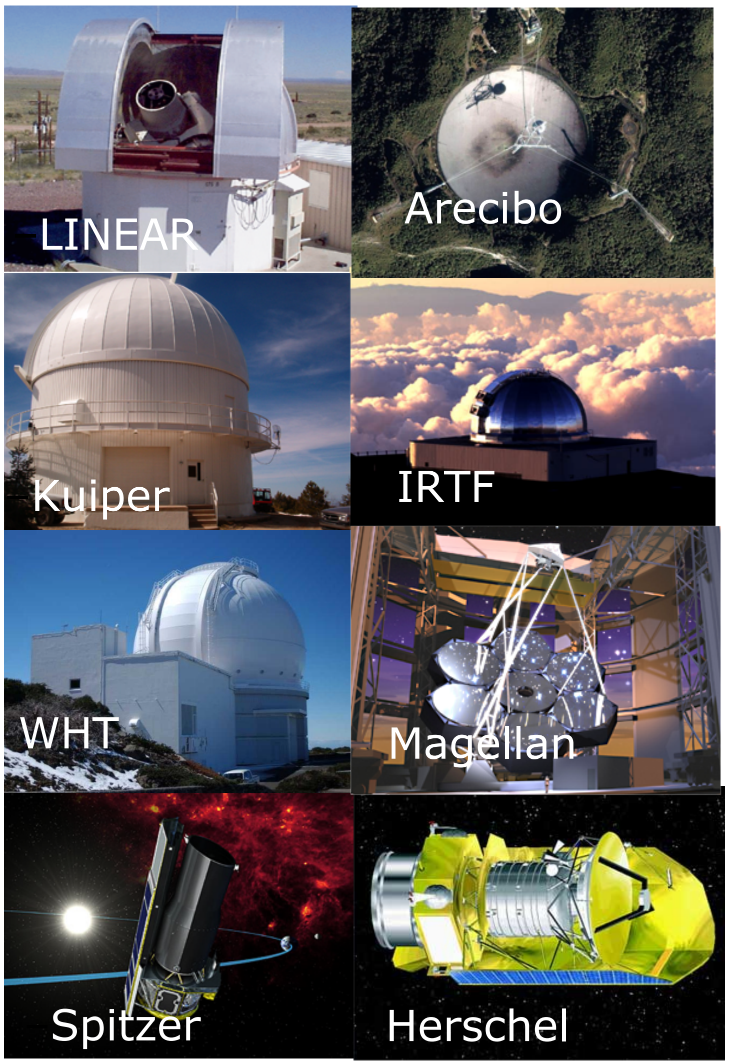
Can I have more details about the object?

Property	(101955) RQ36	
Epoch Date	1-January-2019 00:00 TT	
Reference Frame	Sun centered, Earth ecliptic & equinox of J2000	
Semi-Major Axis	1.126 AU	
Eccentricity	0.204	
Inclination	6.034°	
Longitude of Ascending Node	2.018°	
Argument of Perihelion	66.304°	
Perihelion	0.897 AU	
Aphelion	1.355 AU	
Orbital Period	1.195 years	
Mean Diameter	575±28m	
Volume	$7.1x10^7$ m^3	
Bulk Density	1.4 g/cm^3	± 0.7
Mass	$9.9x10^{10}$ kg	$(+5.4x10^{10})$ $(-4.5x10^{10})$
Rotation Period	4.2968 hrs	± 0.0018
Direction of Rotation	Retrograde	
Obliquity	0 - 15°	
Pole Position	(0, -90)	±15°
Taxonomy	B	
Albedo	0.030	± 0.003
Phase Function	0.043 mag/°	± 0.001
Magnitude of Opposition Effect (OE)	0.10 mags	± 0.10
Absolute Magnitude w/o OE (w/ OE)	20.51 (20.41)	± 0.20





1999 RQ36 is One the Most Extensively Characterized NEOs



–Discovered on Sept. 11, 1999 by the LINEAR survey

–Observed with the Arecibo Planetary Radar system in Sept. 1999 and Sept. and Oct. 2005 (also with Goldstone)

–Observed with the Kuiper 1.5-m telescope multiple times in Sept., Oct. 2005, Sept. 2011

–Observed with the NASA Infrared Telescope Facility in Sept. 1999, Sept. 2005, and August 2011

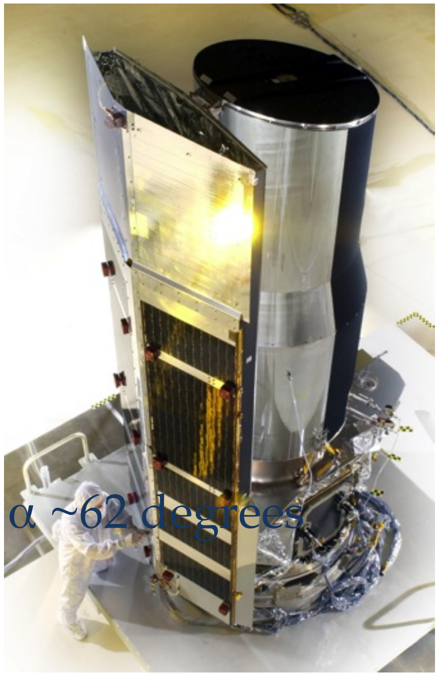
–Observed with the Spitzer Space Telescope between May 3rd-8th, 2007

–Observed with the Herschel Space Observatory, Giant Magellan Telescope, and WHT in Sept. 2011

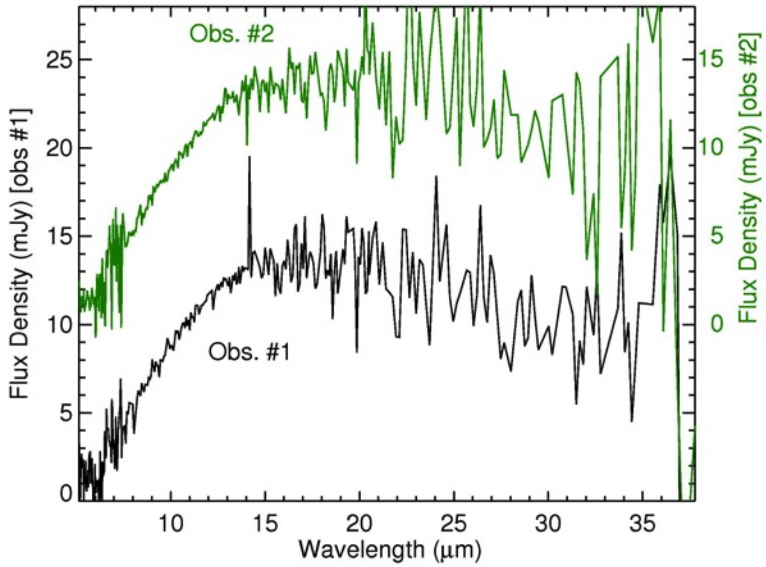
–Other observations planned for 2012

SPITZER OBSERVATIONAL CONDITIONS

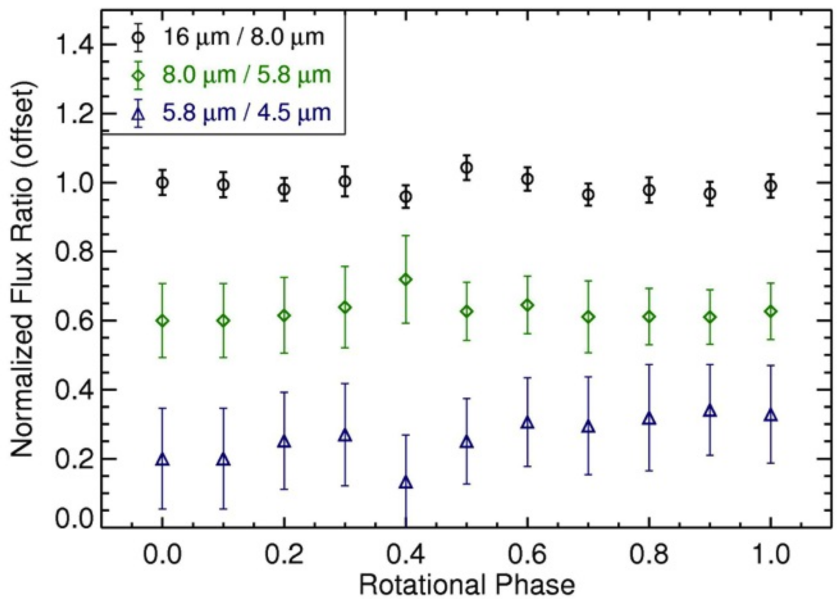
- 85 cm telescope in heliocentric (Earth-trailing) orbit
- Used two instruments
  - IRS (InfraRed Spectrograph)
    - 5.2 to 38 μm spectra – 2 longitudes
    - 16 & 22 μm photometry – 10 longitudes
  - IRAC (InfraRed Array Camera)
    - 3.6, 4.5, 5.8, 8.0 μm photometry – 10 longitudes
- Match rotational phases of IRS & IRAC
  - SED from 3.6 to 22 μm for 10 longitudes
  - Search for surface heterogeneity
- All observations performed at r ~1.1 AU, Δ ~0.5 AU, α ~62 degrees

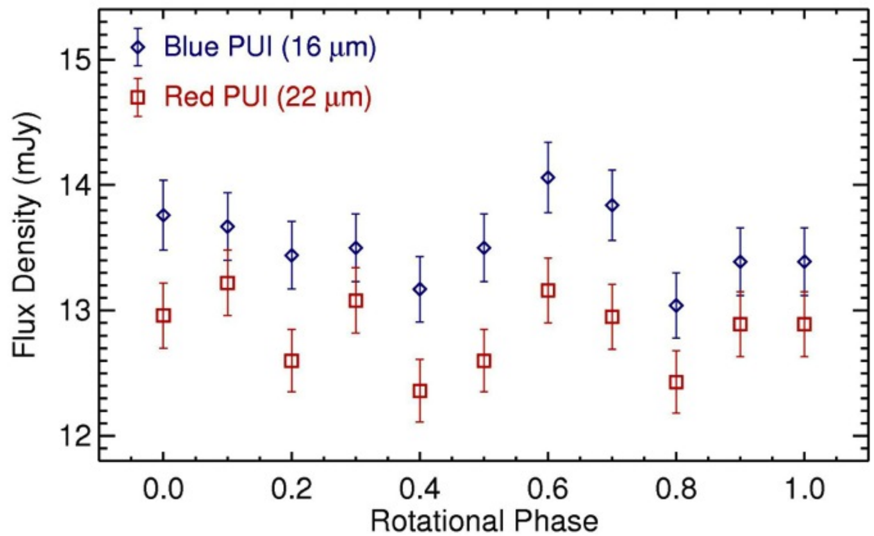


RESULTS FROM THE SPITZER OBSERVATIONS PROVIDE INPUT TO OUR THERMOPHYSICAL MODELS

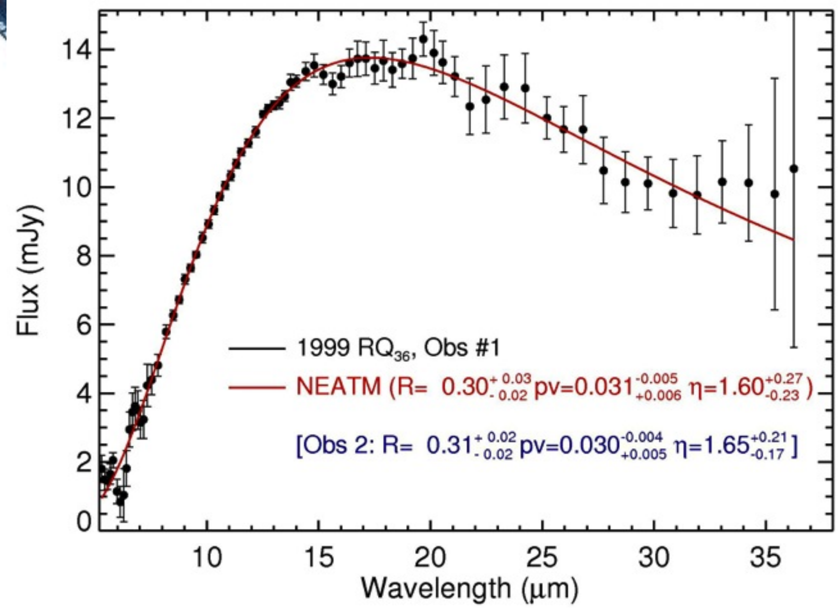


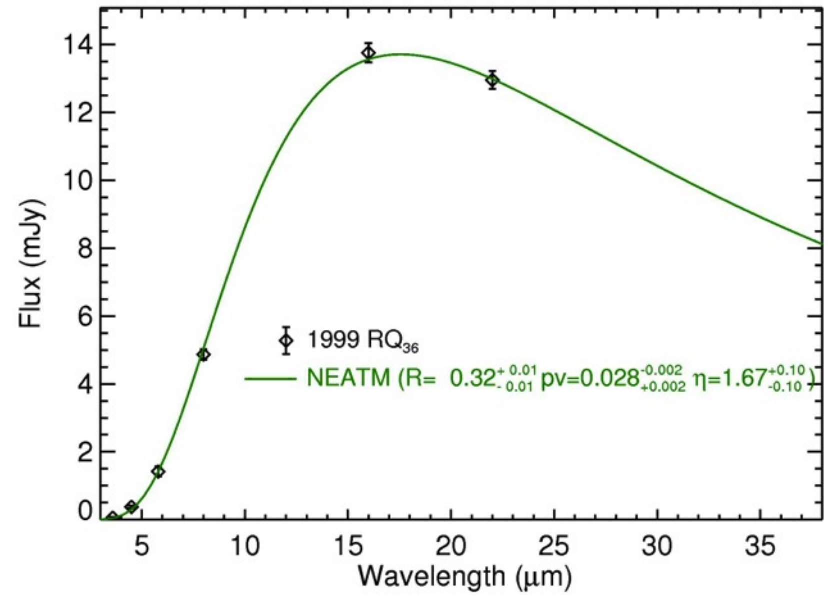
- IRS spectra
  - 8 < λ < 14 μm highest S/N
    - No silicate features
  - Two observations agree
- IRAC and IRS photometry
  - No obvious temperature variation with rotation

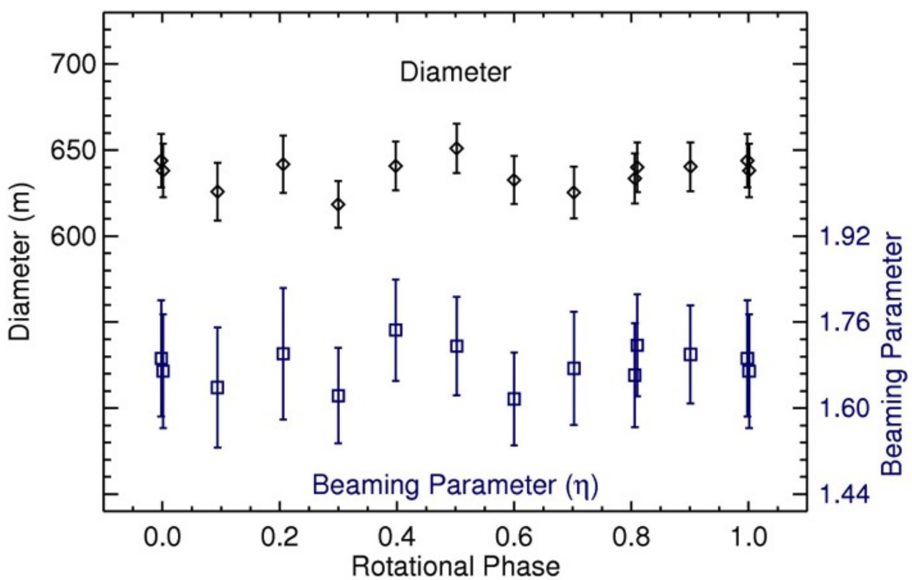




THERMAL MODELING (NEATM) CONSTRAINS THE ASTEROID PHYSICAL PROPERTIES



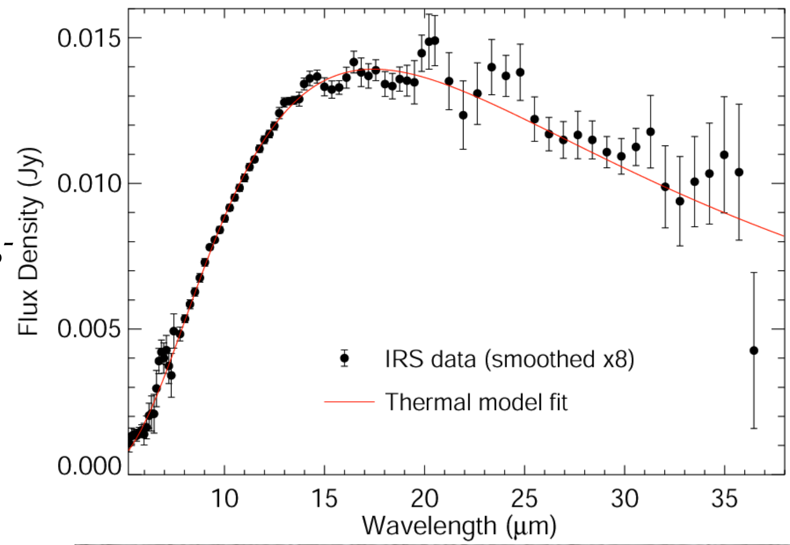




- NEATM results
  - D = 635 ± 15 m
  - pv = 0.028 ± 0.002
  - η = 1.68 ± 0.09
  - Tss = 332 ± 5 K
- All parameters appear uniform with rotation

OSIRIS-REX BENEFITS FROM AND COMPLEMENTS SPITZER SPACE TELESCOPE OBSERVATIONS

- Diameter slightly above radar observations: 635 ± 15 m
- Low albedo is consistent with a primitive composition: 0.028 ± 0.002
- Moderate thermal inertia: 400 to 700 J m^{-2} $s^{-1/2}$ K^{-1}
  - **Implies regolith with grain sizes of a few mm**
  - The thermal inertia of Itokawa is about the same as RQ36 and we know from in situ images that Itokawa has regolith
- Uniform temperature at all rotational phases
  - Suggests that the above properties are constant across the surface



POLARIZATION RATIO (SC/OC) COMPARISON WITH OTHER NEAS

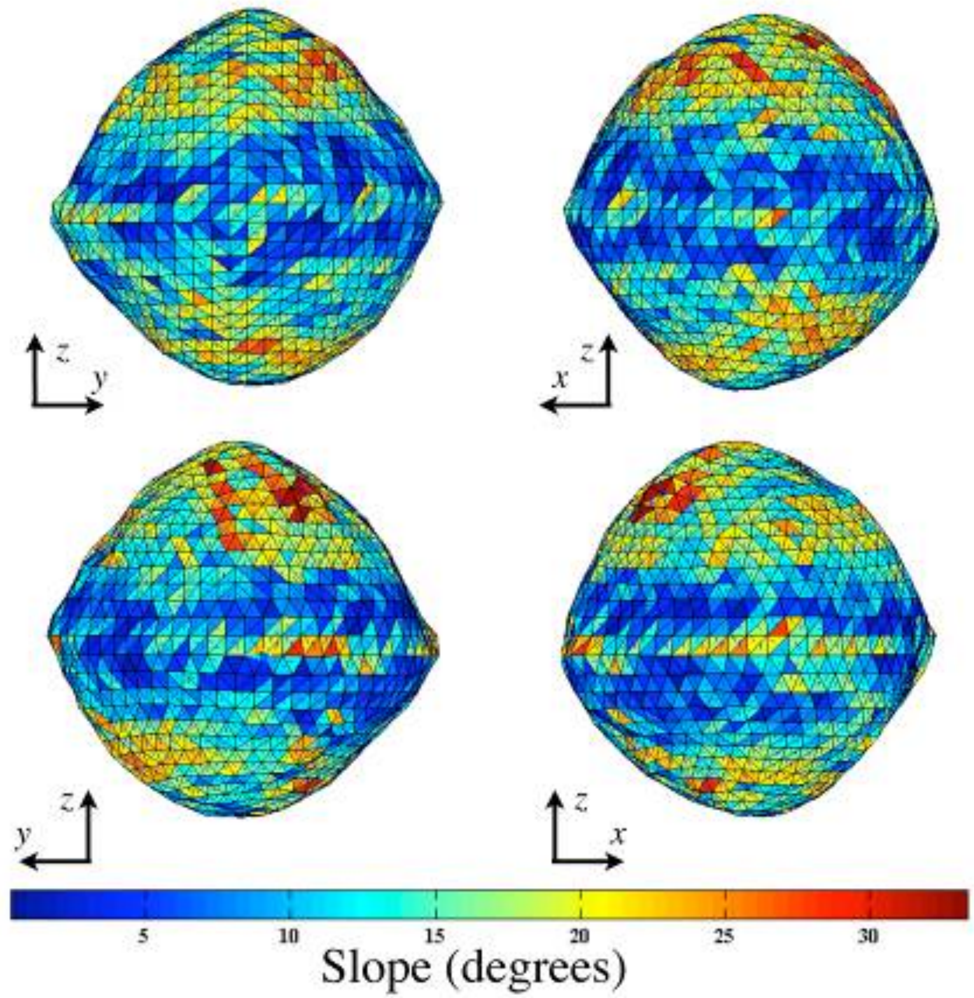
Object	SC/OC	Wavelength
• 2005 YU55	0.36+-0.05	3.5 cm
	0.40+-0.05	13 cm
• 1999 RQ36	0.18+-0.01	3.5 cm
	0.18+-0.05	13 cm
• Itokawa	0.24+-0.02	3.5 cm
	0.27+-0.04	13 cm
• Eros	0.28+-0.06	13 cm

- NEA Avg 0.34+-0.25 N = 214 range = 1.5
- Dark NEA Avg 0.29+-0.12 N = 17 range = 0.40

Results from Benner et al. 2008; dark NEA average excludes 2005 YU55

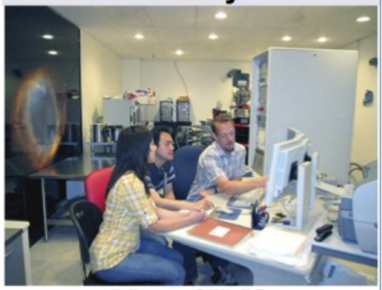
SURFACE SLOPE DISTRIBUTIONS SUGGEST A REGOLITH-COVERED BODY WITH A RELAXED SURFACE

- The rotation period and axial ratio imply a minimum density of 0.7 g/cm^3
- Assuming a plausible density of 1.4 g/cm^3 we find **a subdued slope distribution** for this asteroid at the spatial resolution of the shape model.
  - Maximum slopes of 33 degrees
  - Near zero slopes in the equatorial region
  - Average slope of 13 degrees

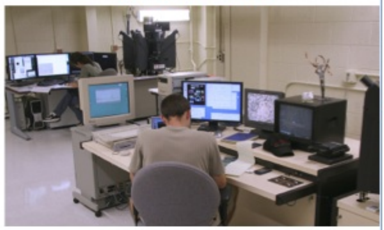


State-of-the-Art Analytical Instruments Cannot Be Flown on Spacecraft

Mineralogy & Petrology
Understanding Asteroid History



NanoSIMS

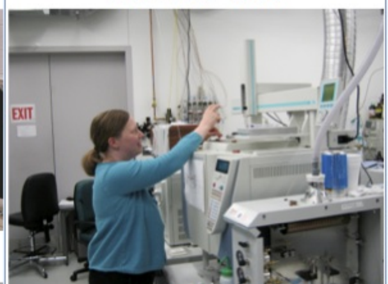


Electron Microprobes

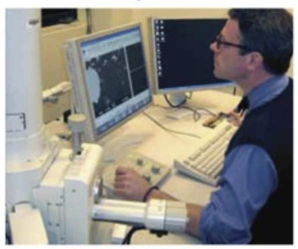
FIB

Elements & Isotopes
Understanding Solar System History

LA-ICP-MS



GC-MS/c-IRMS



TOF-SIMS

Organics
Detecting the Molecules of Life

LC-FT-MS

LC-TOF-MS

GC-MS

Spectroscopy
Linking Asteroids to Meteorites

FE-STEM

IR Microscope

Thermal
Understanding the Yarkovsky Effect

FT-IR

SEM

Future Scientists will Invent New Instruments

Accelerator Mass Spectrometer

ALS Synchrotron Beamline for XANES