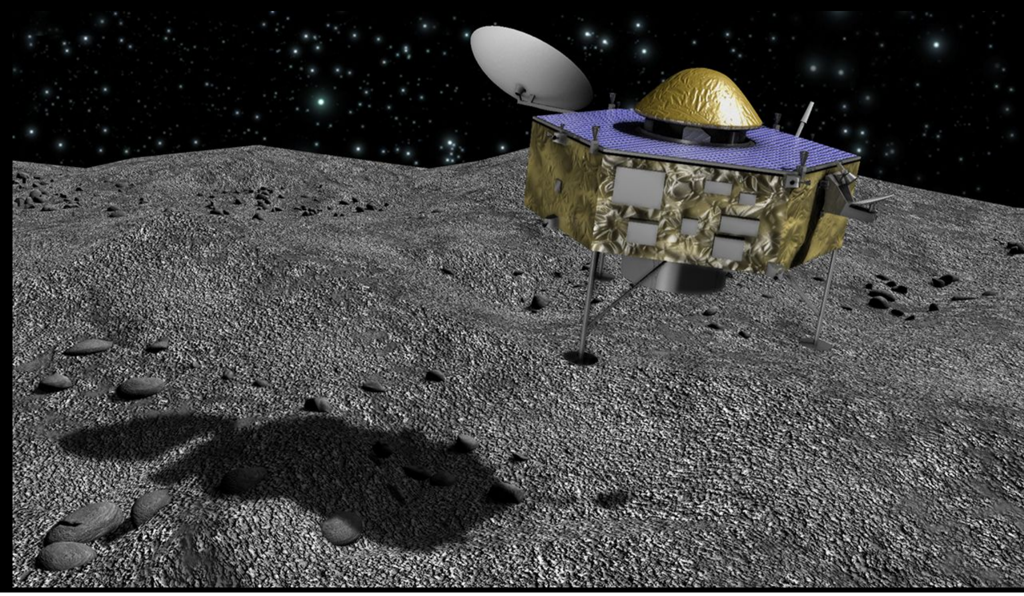
MARCOPOLO-R NEAR EARTH ASTEROID SAMPLE RETURN MISSION

M.A. Barucci, ESA Lead Scientist



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SBAG January 17, 2012 in Washington, DC

MarcoPolo-R was selected

(one out of four)

- Study Manager
  - David Agnolon (ESA - Advanced Studies and Technology Preparation Division)
- Study Scientist
  - Detlef Koschny (ESA - Solar System Missions Division)
- Study Payload Manager
  - Jens Romstedt (ESA - Advanced Studies and Technology Preparation Division)
- Science Study Team (SST):
  - A. Barucci (F), J. Brucato (I), H. Böhnhardt (D), E. Dotto (I), P. Ehrenfreund (NL), I. Franchi (UK), S. Green (UK), L. Lara (E), B. Marty (F), P. Michel (F) + A. Cheng (USA)
- Tasks of the SST:
  - To advise and to monitor the study from a scientific point of view

Introduction

- MarcoPolo-R is a sample return mission recommended by ESA as one of the concepts to be studied in the framework of Cosmic Vision 2 M3 missions with launch in 2020-2022.
- MarcoPolo-R is a mission to a primitive Near-Earth Asteroid (NEA). It will rendezvous with a primitive NEA, scientifically characterize it at multiple scales, and return a unique unaltered sample to Earth.
- The ESA assessment study started on May 2011 and will continue until middle 2013. Two European aerospace companies will study in detail the project.

Key Questions

1) What were the processes occurring in the early solar system and accompanying planet formation?

2) What are the physical properties and evolution of the building blocks of terrestrial planets?

3) Do NEAs of primitive classes contain pre-solar material yet unknown in meteoritic samples?

4) What are the nature and the origin of organics in primitive asteroids and how can they shed light on the origin of molecules necessary for life?

Answers to these fundamental questions can be derived by laboratory measurements on a sample from a primitive NEA

Scientific Objectives

A. Characterise the chemical and physical environments in the early solar nebula

B. Define the processes affecting the gas and the dust in the solar nebula

C. Determine the timescales of solar nebula processes

D. Determine the global of physical properties of an NEA

E. Determine the physical processes, and their chronology, that shaped the surface structure of the NEA

F. Characterise the chemical processes that shaped the NEA composition (e.g. volatiles, water)

G. Link the detailed orbital and laboratory characterisation to meteorites and interplanetary dust particles (IDPs) and provide ground truth for the astronomical database

H. Determine the interstellar grain inventory

I. Determine the stellar environment in which the grains formed

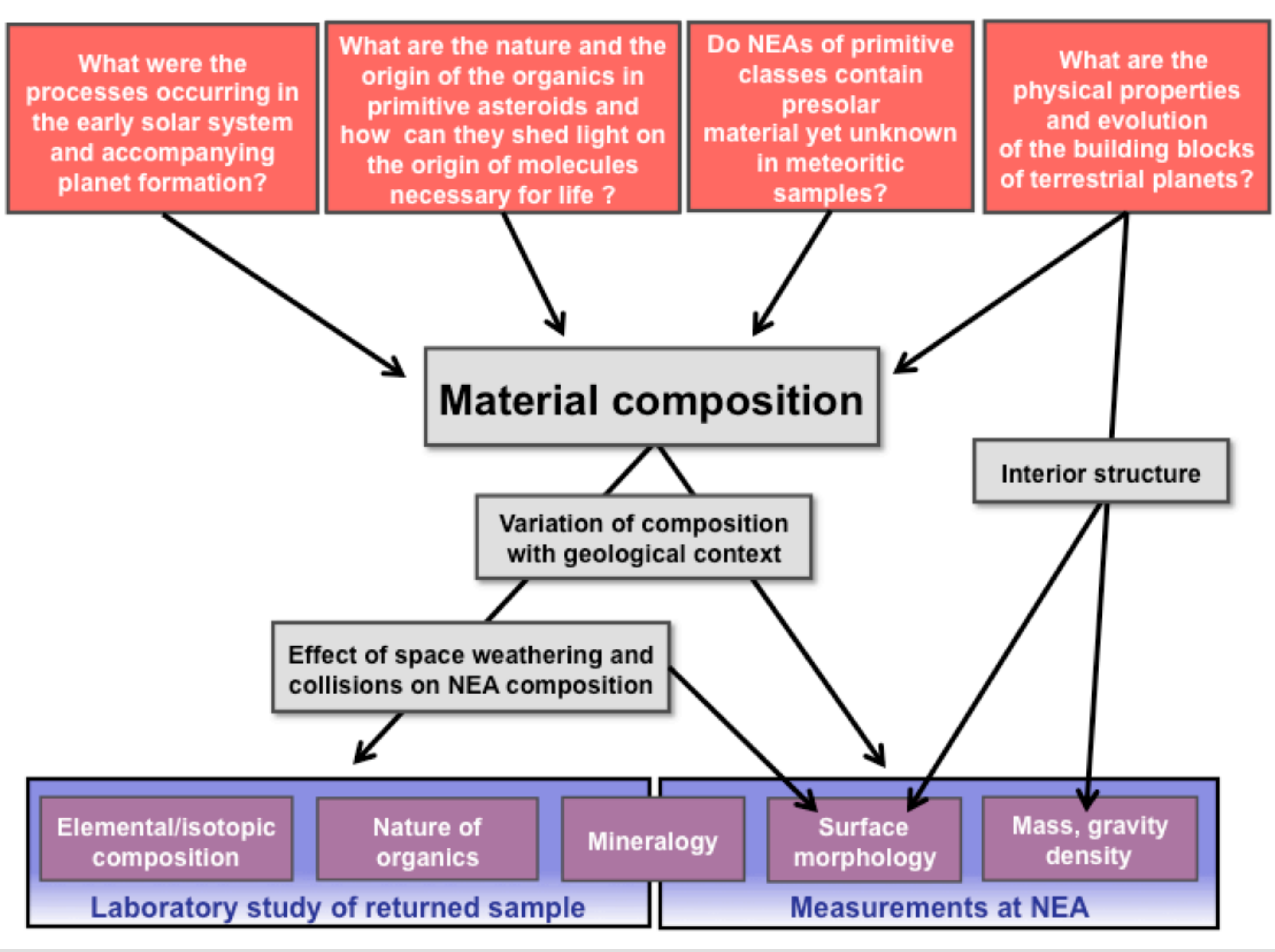
J. Define the interstellar processes that have affected the grains

K. Determine the diversity and complexity of organic species in a primitive asteroid

L. Understand the origin of organic species

M. Provide insight into the role of organics in life formation

Science Questions and Measurements



Mission and Spacecraft

Prime Target 1996 FG3 Binary System Low albedo, C-type

Orbital and Physical Characteristics

Orbit type	Apollo
Semimajor axis	1.054 AU
Eccentricity	0.350
Inclination	2.0
Perihelion distance	0.685 AU
Aphelion distance	1.423 AU
Absolute magnitude (H)	18.0
Diameter	~1.8 km
Rotation period	3.59 h
Pole direction	λ=242±96 deg, β=-84(+14/-5) deg
Lightcurve amplitude	<0.1 mag
Spectral class	C-class

3-axis spacecraft;
Soyuz-Fregat launch, 2020 and 2021 opportunities;
returns in 2027 and 2029 respectively

Nominal Science Payload

	Wide Angle Camera (WAC)	Narrow Angle Camera (NAC)	Close-Up Camera (CUC)	Laser Altimeter
Weight [kg]	2.0	8.92	0.82	4.0
Volume [mm]	237x172x115	520x380x197 250x170x120	364x78x68	150x100x100
Power [W] average	11.5	13.5	12.5	22
Data volume single measurement	67 Mbit	67 Mbit	67 Mbit	80 bit/shot

	Visible Near Infrared spectrometer (VisNIR)	Mid-Infrared spectrometer (MidIR)	Radio Science Experiment (RSE)	Neutral Particle Analyser (NPA)
Weight [kg]	3.6	3.0	Contained in the resources of the radio subsystem	2.2
Dimensions [mm^3]	270x110x90 150x180x82	160x220x370	Contained in the resources of the radio subsystem	200x200x100
Power [W] average	18	2		11
Data volume single measurement	0.45 Mbit	360 Mbit	Data recorded in the ground station in real time	0.72 kbit

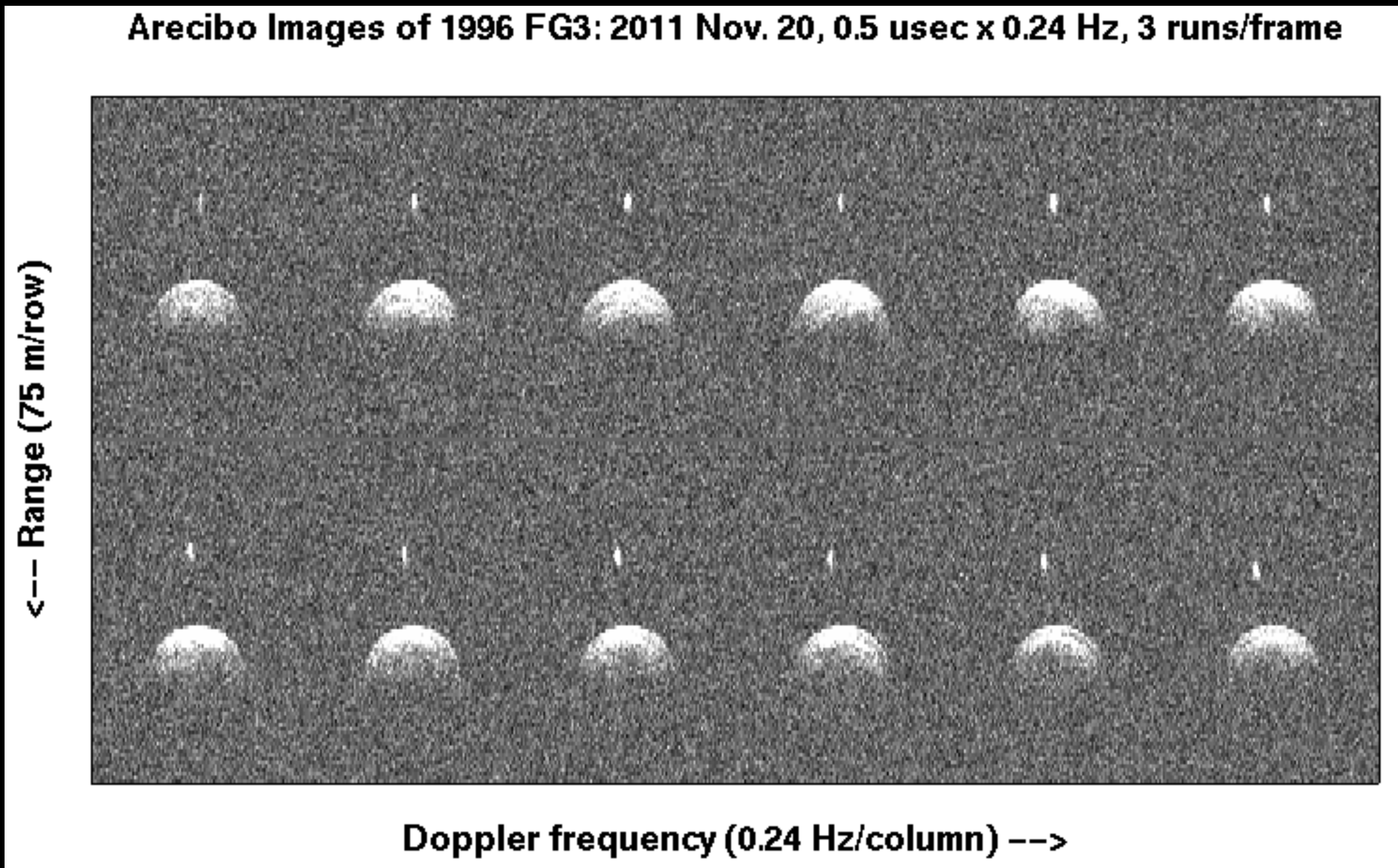
Complementary Science Payload

	Asteroid Charge Experiment (Ace)	Alpha Particle X-ray Analyser (APXS)	Thermal Sensor	Regolith Microscope / IR spectrometer	Lander
Weight [kg]	1.465	0.35	0.24	0.18	16.2
Volume [mm]	Various sensors	52(∅) x84 160x80x10	20x20x40 (e-box)	26 (∅) x 158	
Power [W] average	1.5	1.5	0.5	1.2	na
Data volume single measurement	170 bit/s	192 kbit	100 bit	21 Mbits	

1996 FG3: MarcoPolo-R Prime Target

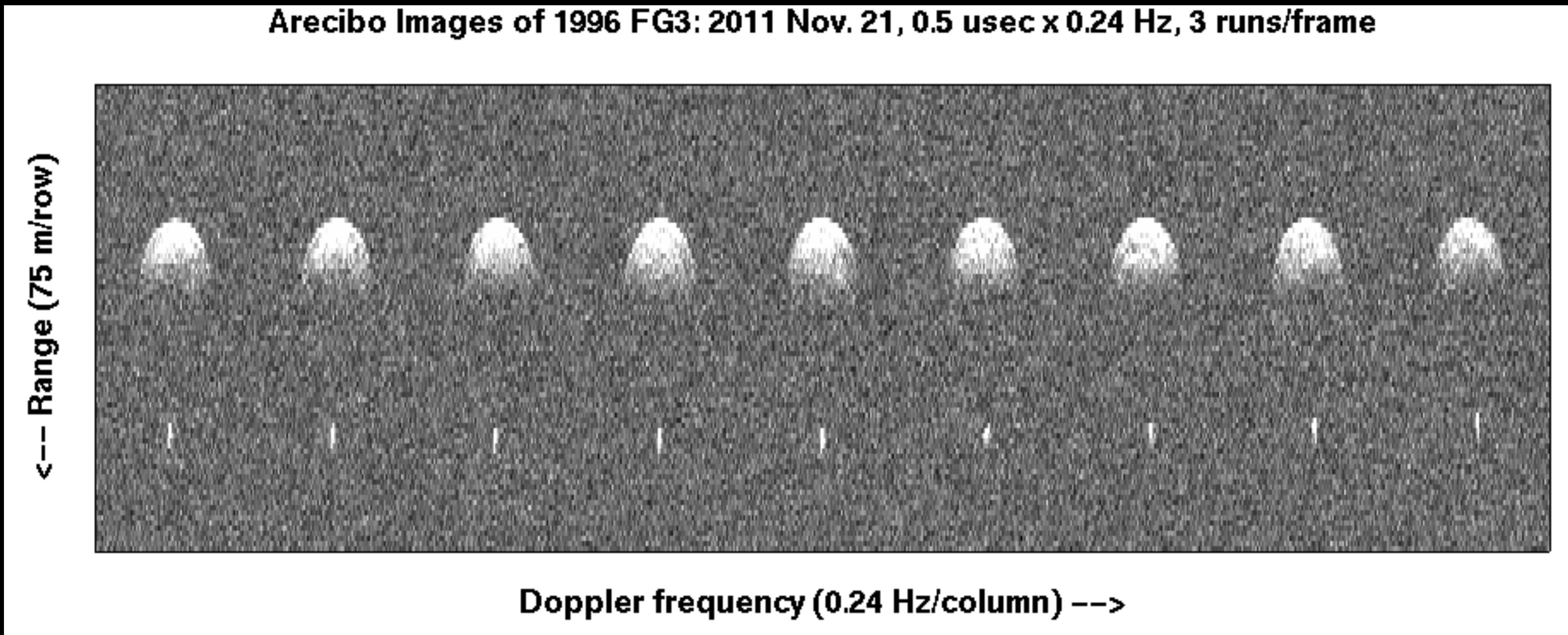
- Current apparition of 1996 FG3: approached to 0.101 AU of Earth in November, 2011
- Ongoing campaign to observe in radar, visible, IR
- Preliminary results from current apparition
  - Low thermal inertia (regolith present)
  - Likely 3-µm absorption band (hydrated minerals)
  - Possible visible-near IR spectral slope variation (compositional heterogeneity?)
  - Equatorial ridge seen in radar images, consistent with 1999 KW4-like shape

November 20

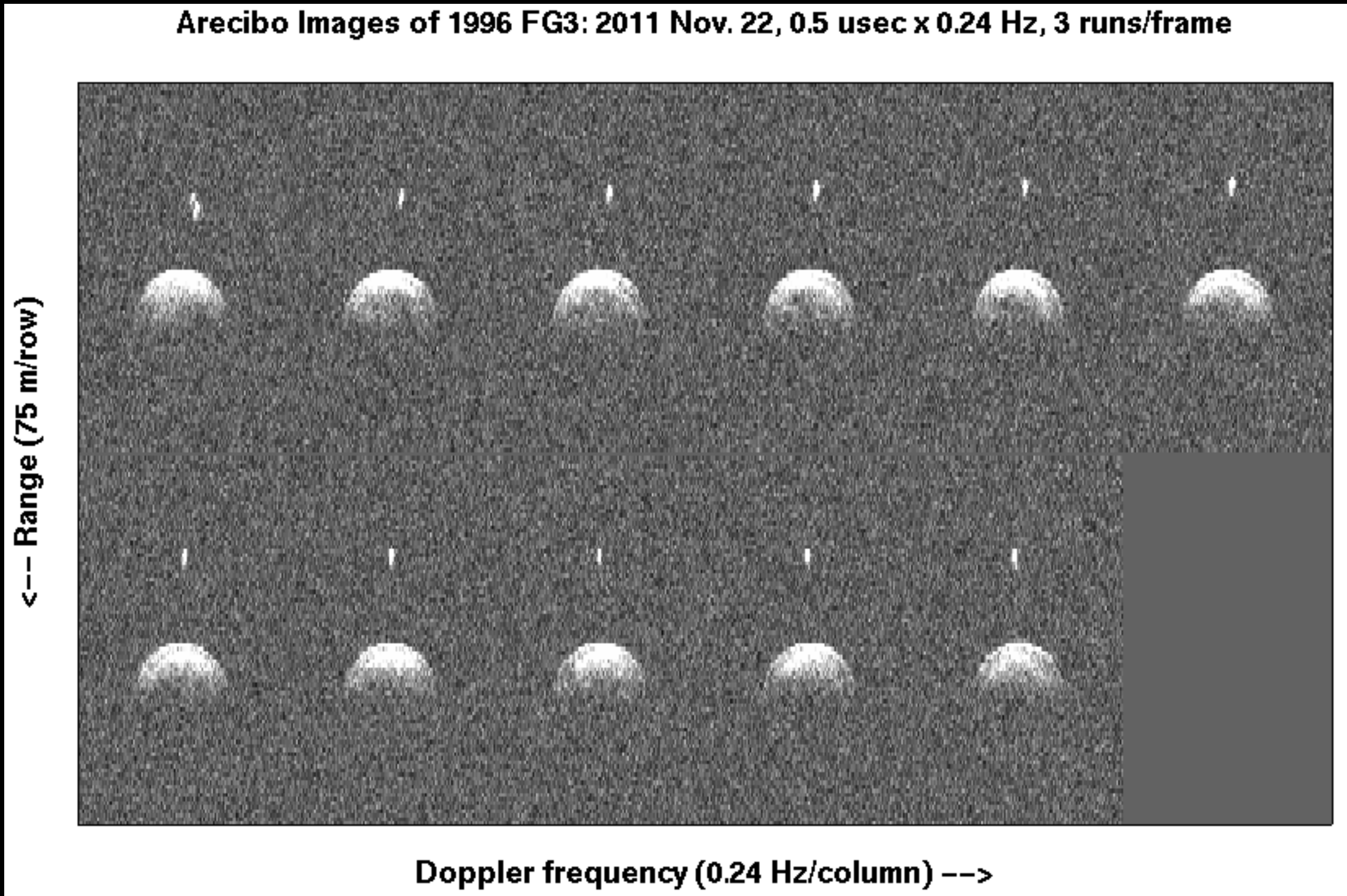


Lance Benner, private communication

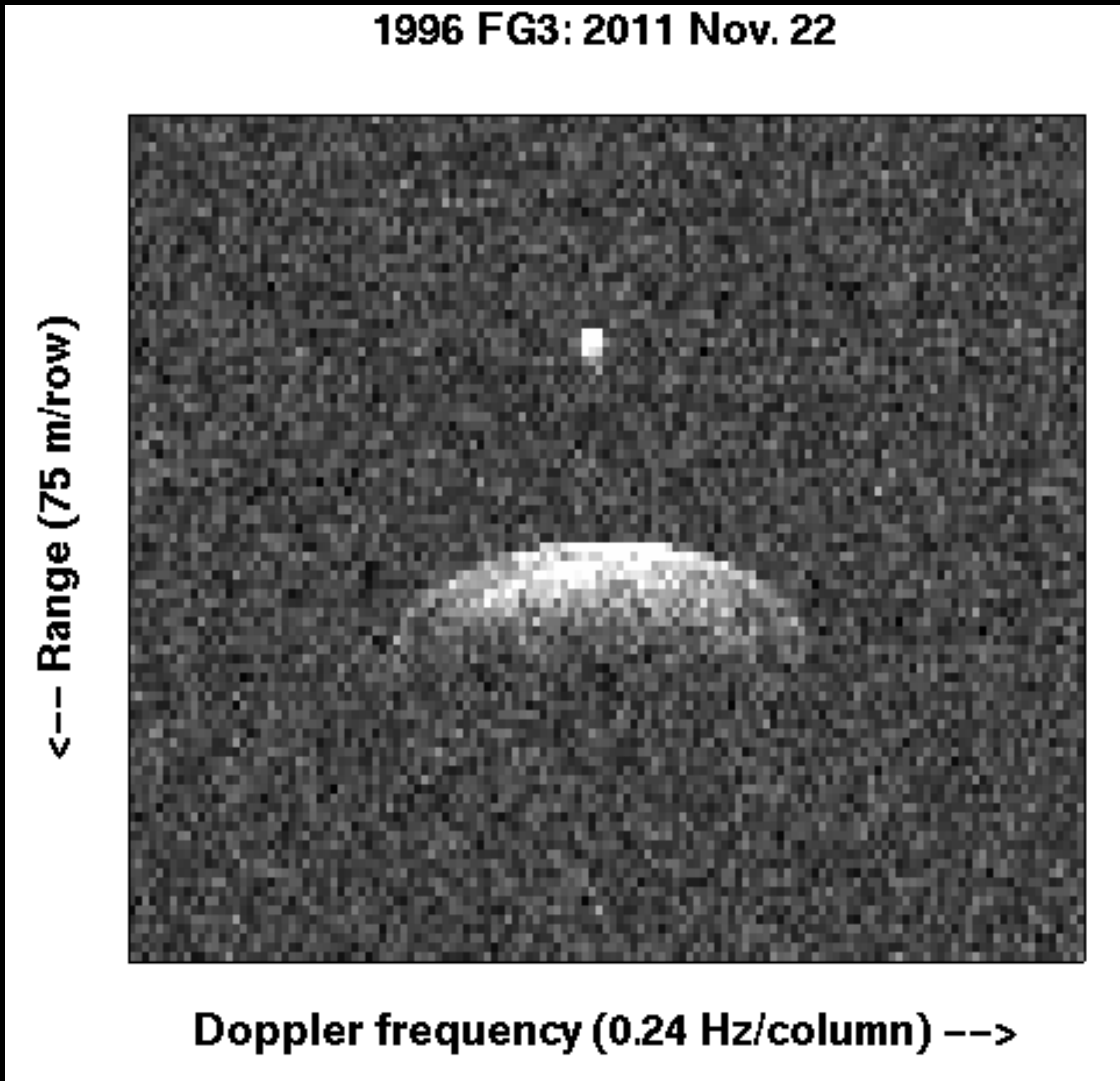
November 21


Arecibo Images of 1996 FG3: 2011 Nov. 21, 0.5 usec x 0.24 Hz, 3 runs/frame
<-- Range (75 m/row)
Doppler frequency (0.24 Hz/column) -->

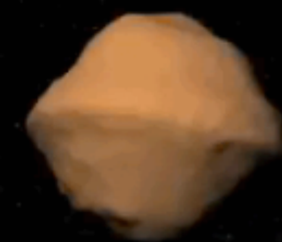
November 22


Arecibo Images of 1996 FG3: 2011 Nov. 22, 0.5 usec x 0.24 Hz, 3 runs/frame
<-- Range (75 m/row)
Doppler frequency (0.24 Hz/column) -->

Evidence for an equatorial ridge

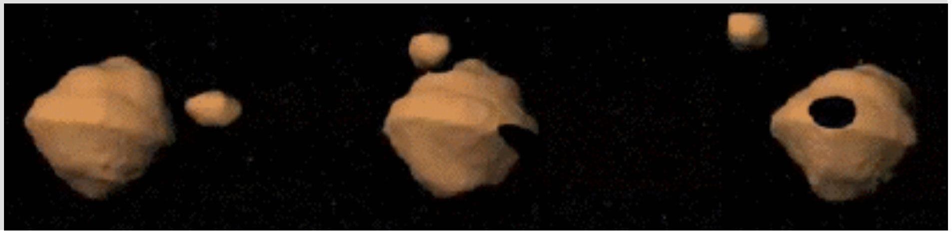


1999 KW4

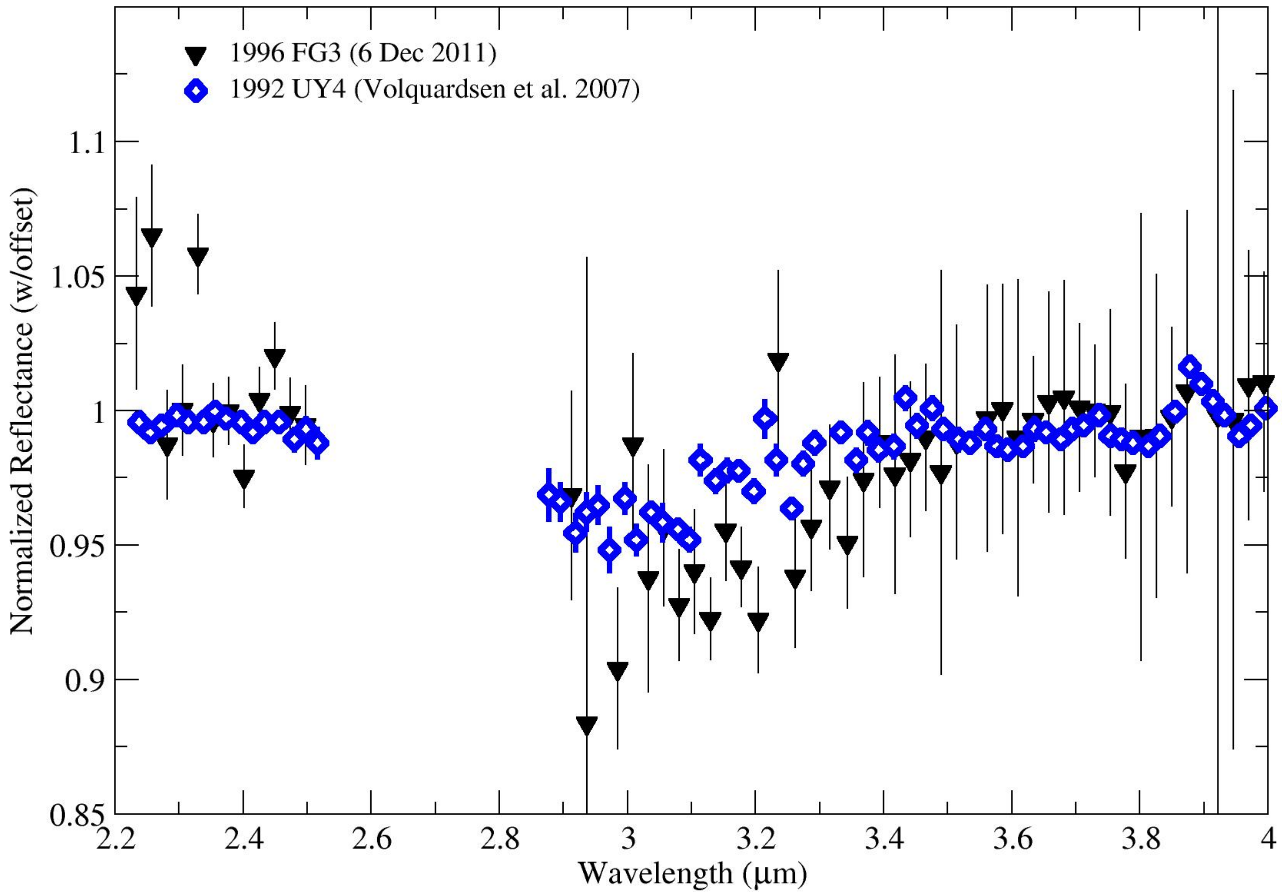


What unique science can be achieved at 1996 FG3?

- Binary system formation/life cycle
  - 1996 FG3 is a close binary system, with a rapidly spinning primary, like 1999 KW4
  - Such systems are common in the NEO population
- Asteroid surfaces with very low thermal inertia
  - Lower than those for Eros or Itokawa
- Preliminary detection of hydrated/hydroxylated minerals (unlike 1999 RQ36, the OSIRIS target)
- Possible spectral variation on surface
  - Geographic diversity of material?
  - Linked to changing orbital position?



1996 FG3, one of two NEOs with 3μm band detection



A. S. Rivkin, private communication

1996 FG3: an unusual object

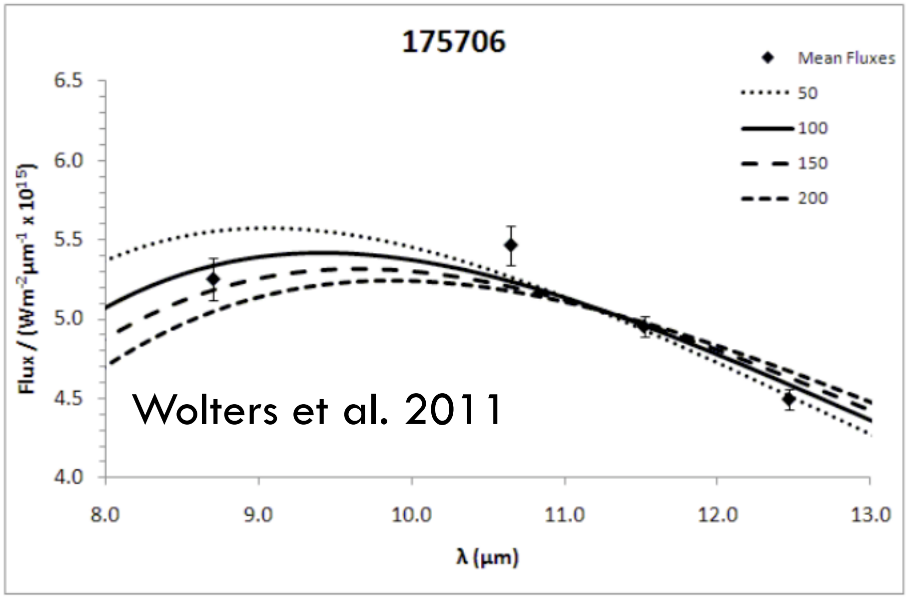
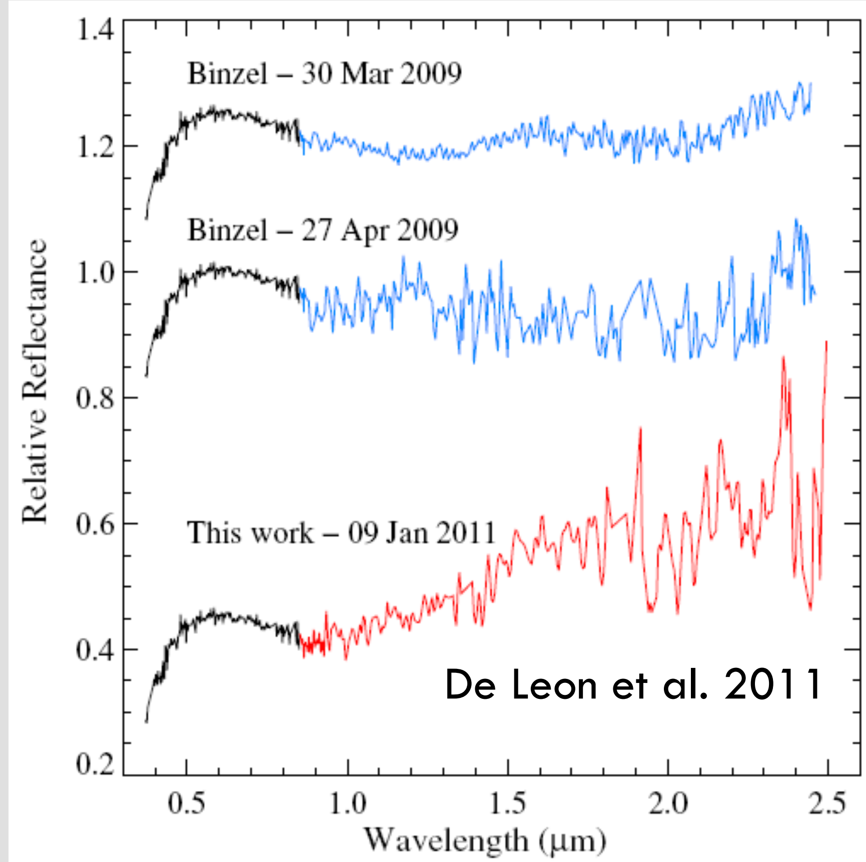


Fig. 7: ATPM fits to the thermal-IR observations of 1996 FG3, assuming $f_R = 0.4$, which corresponds to the level of surface roughness measured on the Moon (Rozitis & Green 2011). The different line styles correspond to different indicated levels of thermal inertia given in J m^{-2} K^{-1} s$^{-1/2}$. Although mean fluxes are plotted for clarity, fits were to all the fluxes (error-weighted) as given in Table 4.

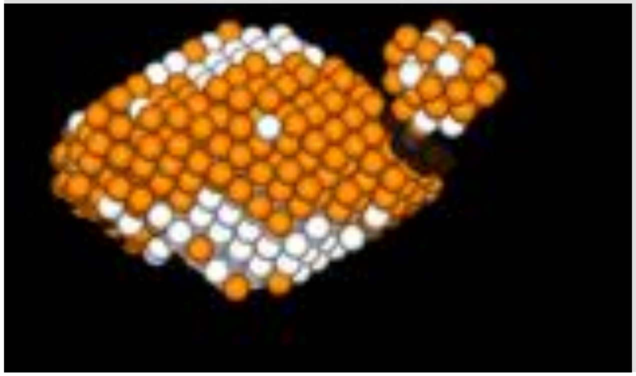


Very low thermal inertia

Unexplained spectral variation

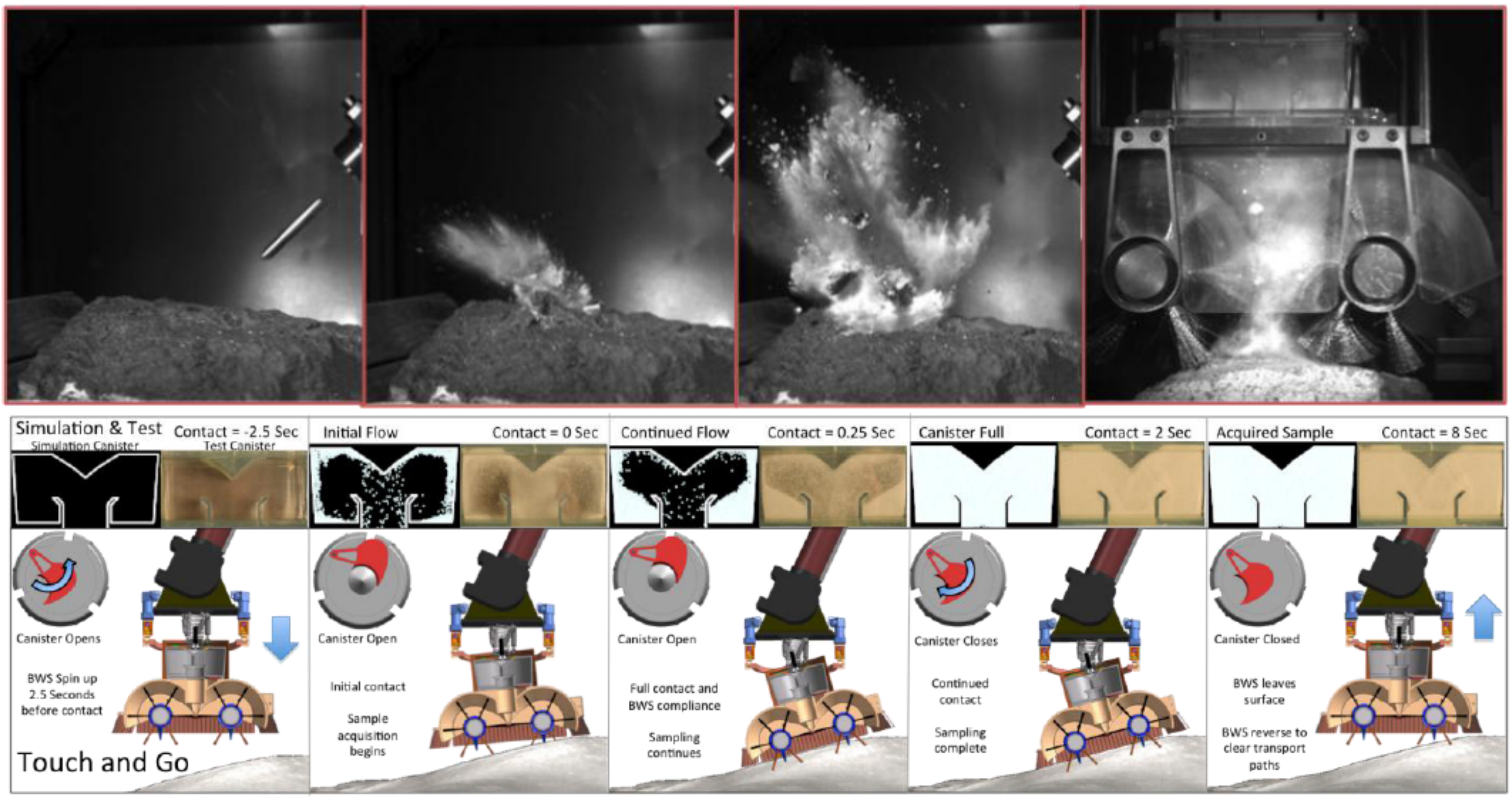
How do NEO binaries form and evolve?

1. Rapidly spinning primary loses mass at equator, and close-in secondary reaccumulates
2. Scenario may explain unusual spin state and shape of primary in 1999 KW4 and similar systems
3. Dynamical evolution may be driven by the YORP/Yarkovsky thermal effects (which can unbind the binary; is this how 1999 RQ36 formed?)
4. Possible migration of regolith on the primary from poles to equator revealing fresh (previously subsurface) material on the poles (good candidate sites for unaltered sample collection?)



Left, numerical simulation of mass loss and reaccumulation (Michel et al. 2008); right, radar shape model of 1999 KW4 (Ostro et al. 2006)

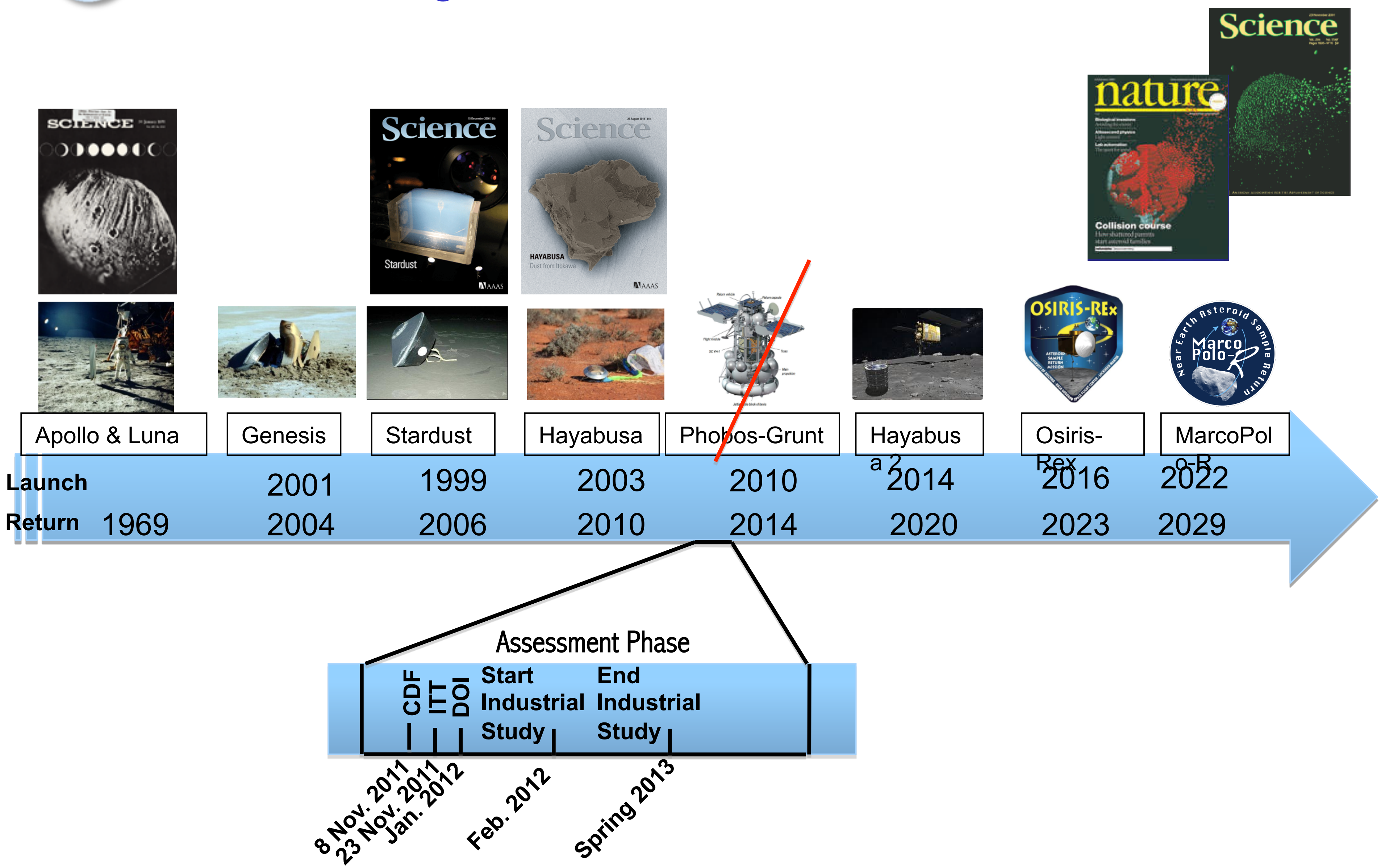
Sample collection for MarcoPolo-R



(upper row) test of rock chipper and brush wheel in Bandelier tuff rock;
(lower row) simulation and test of brush wheel collecting lunar regolith simulant

[Proposed as NASA contribution]

Programmatic Framework



Schedule

- **Class M Missions: up to ca. 470 MEuro**

Advisory structure

Selection of 4 missions

2011	ESA-internal studies in Concurrent Design Facility
2012	Industrial studies (2 competing for each mission)
2013	Final presentation; selection of two missions for definition study
2013 - 2015	Detailed definition study; selection of one mission
2015 - 2020	Implementation phase in industry, launch 2020 - 2022