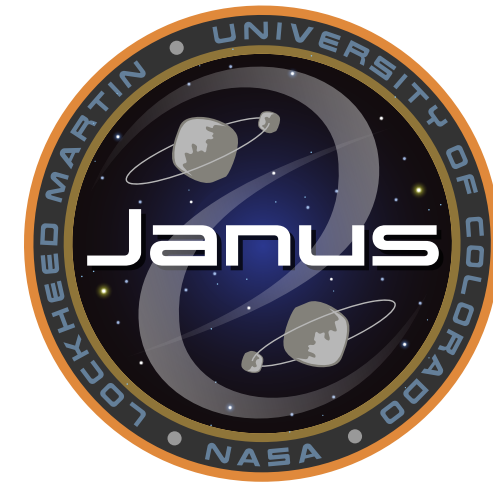




Celestial and Spaceflight  
Mechanics Laboratory



# *Janus*

A NASA SIMPLEx mission to explore two NEO Binary Asteroids

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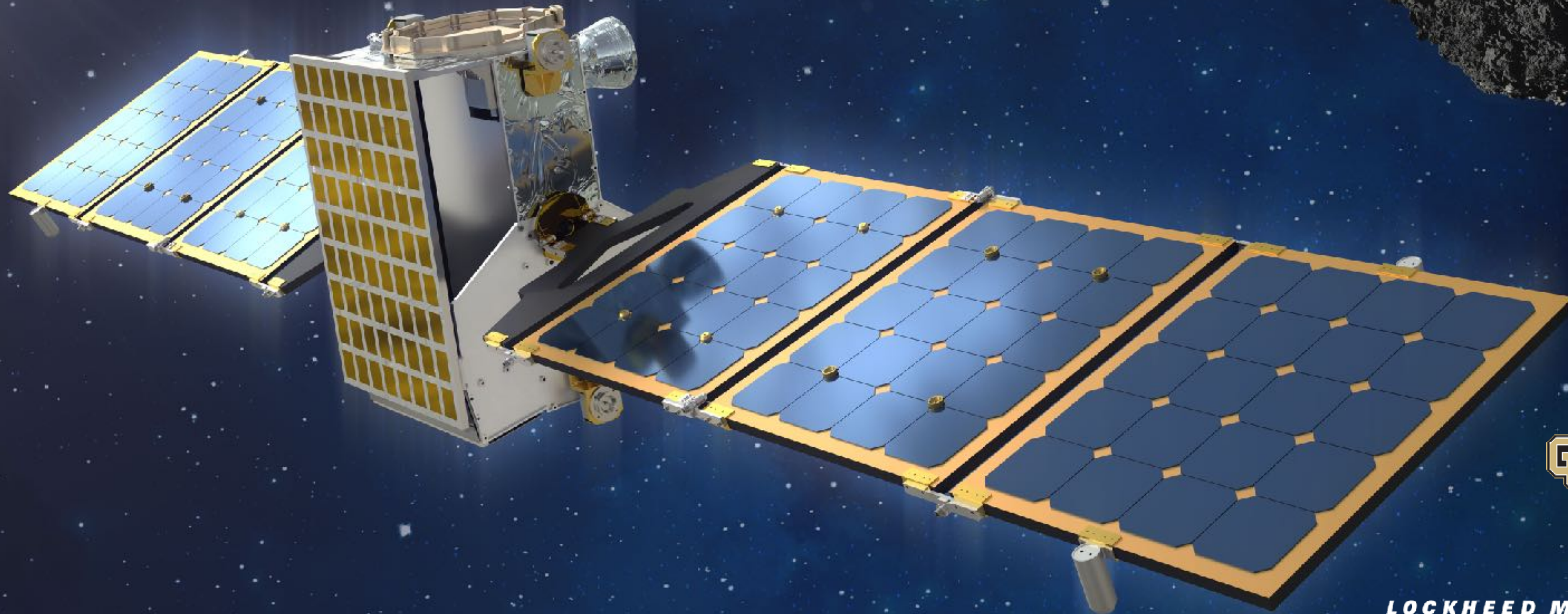
*<sup>1</sup>The University of Colorado Boulder, USA; <sup>2</sup>Lockheed Martin Inc, USA; <sup>3</sup>Jet Propulsion Laboratory, USA; <sup>4</sup>University of Maryland, USA; <sup>5</sup>LASP, University of Colorado Boulder, USA; <sup>6</sup>University of Hawaii, USA; <sup>7</sup>Planetary Science Institute, USA; <sup>8</sup>Astronomical Institute of the Academy of Sciences, Czech Republic; <sup>9</sup>Malin Space Science Systems Inc, USA*






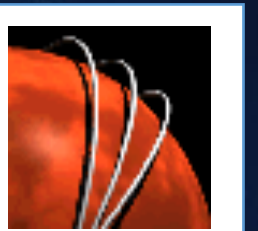
# Janus

*A dual spacecraft mission to open a gateway to understand the transitions and lifecycles of rubble pile asteroids*



 University of Colorado  
Boulder

LOCKHEED MARTIN 




Malin SSS

## NASA SIMPLEx Program

- **SIMPLEx Lead PE:**
  - C. Mercer (HQ)
- **Program Manager:**
  - K. Sykes (MSFC)
- **Program Executive:**
  - W. Knopf (MSFC)
- **Program Scientist:**
  - M. Kelley (MSFC)


○ **Class D Mission**
○ **Cost cap < \$55M**

## Institutional Partnerships




University of Colorado  
Boulder

PI Office  
Mission Oversight



**LOCKHEED MARTIN**

Project Management  
Spacecraft  
Mission Operations



**Malin SSS**  
Instrument Suite

## Science Team

- **PI: Dan Scheeres** (CU) — OREX, NEAR, Hayabusa, Hayabusa2
- **Deputy-PI:** J. McMahon (CU) — OREX, Hayabusa2
- **Project Scientist:** E. Bierhaus (LM) — OREX
- **Instrument Scientist:** M. Ravine (MSSS) — OREX
- **Mission Scientist:** C. Hartzell (UMd) — OREX
- **Visible Imaging:** L. Le Corre (PSI) — OREX, Dawn, Hayabusa2
- **IR Imaging:** P. Hayne (CU-LASP) — DIVINER

○ **Radar Astronomers:**

- L. Benner (JPL)
- S. Naidu (JPL)

○ **Ground-based Observers:**

- R. Jedicke (UH)
- P. Pravec (CAS)

- **Graduate Student Researchers (PhD Students):**
  - Alex Meyer (CU)
  - Kya Sorli (CU-LASP)
  - Chloe Long (CU)

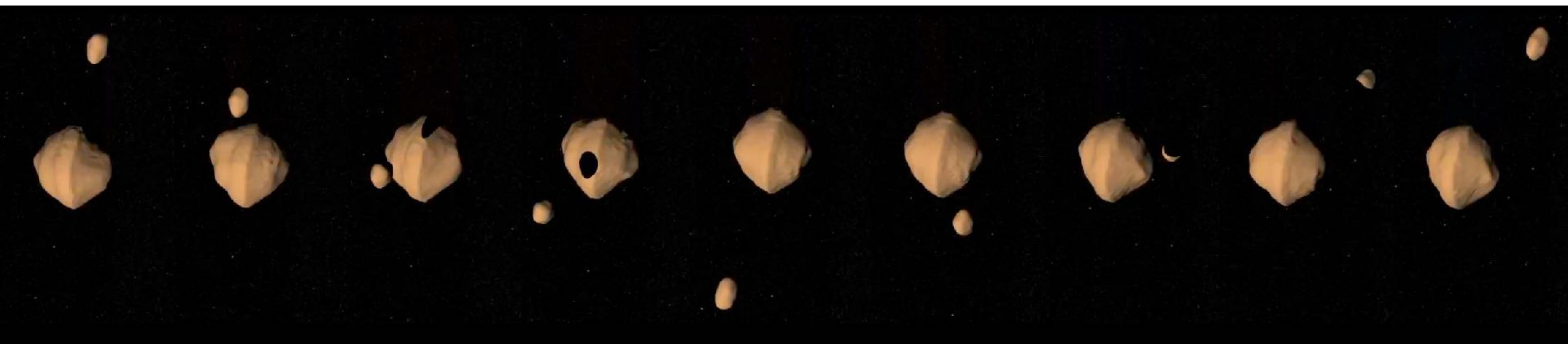


*Janus Mission Science:  
A first close look at binary asteroids*



# Why Study Binary Asteroids?

- Binary Asteroids are...
  - ... ubiquitous at ~15% of the asteroid population
  - ... thought to form when rubble pile asteroids fission due to high spin rates
  - ... just one of several “pathways” that small rubble pile asteroids travel down
  - ... the key to understanding the mechanical properties of rubble pile asteroids, and by extension the geophysics of microgravity aggregates.





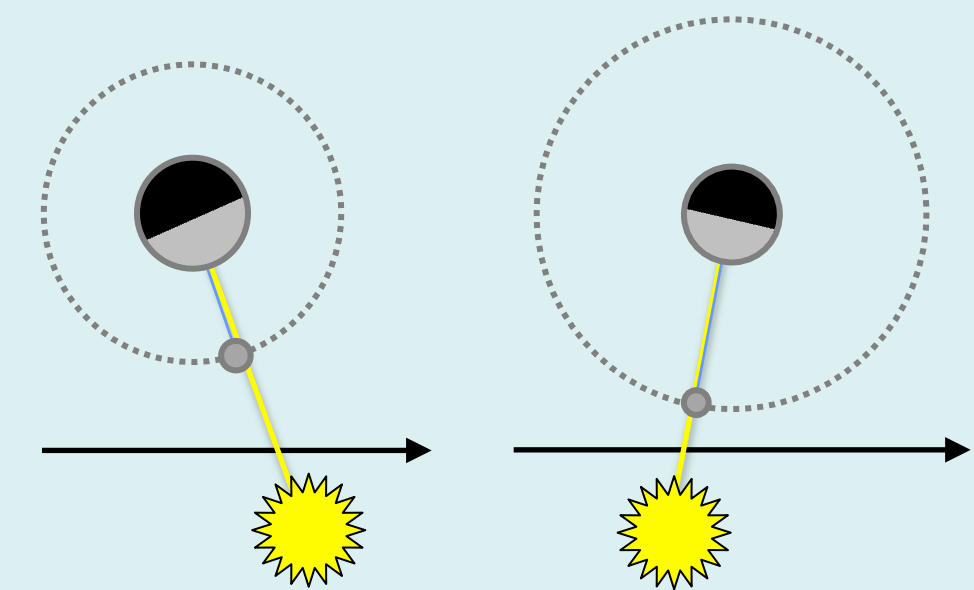
# Target Binary Asteroids: (175706) 1996 FG3 and (35107) 1991 VH

## Ideal Targets Enable Janus' Science Goals

- Binary near-Earth asteroids that have been subject to multiple transitions and have similar shapes and morphologies
- Distinct systems that lie at different evolutionary stages and which have different compositional properties
- Both have been extensively characterized by ground-based observations providing known mass, shape, rotation and orbit
- Potentially Hazardous Asteroids

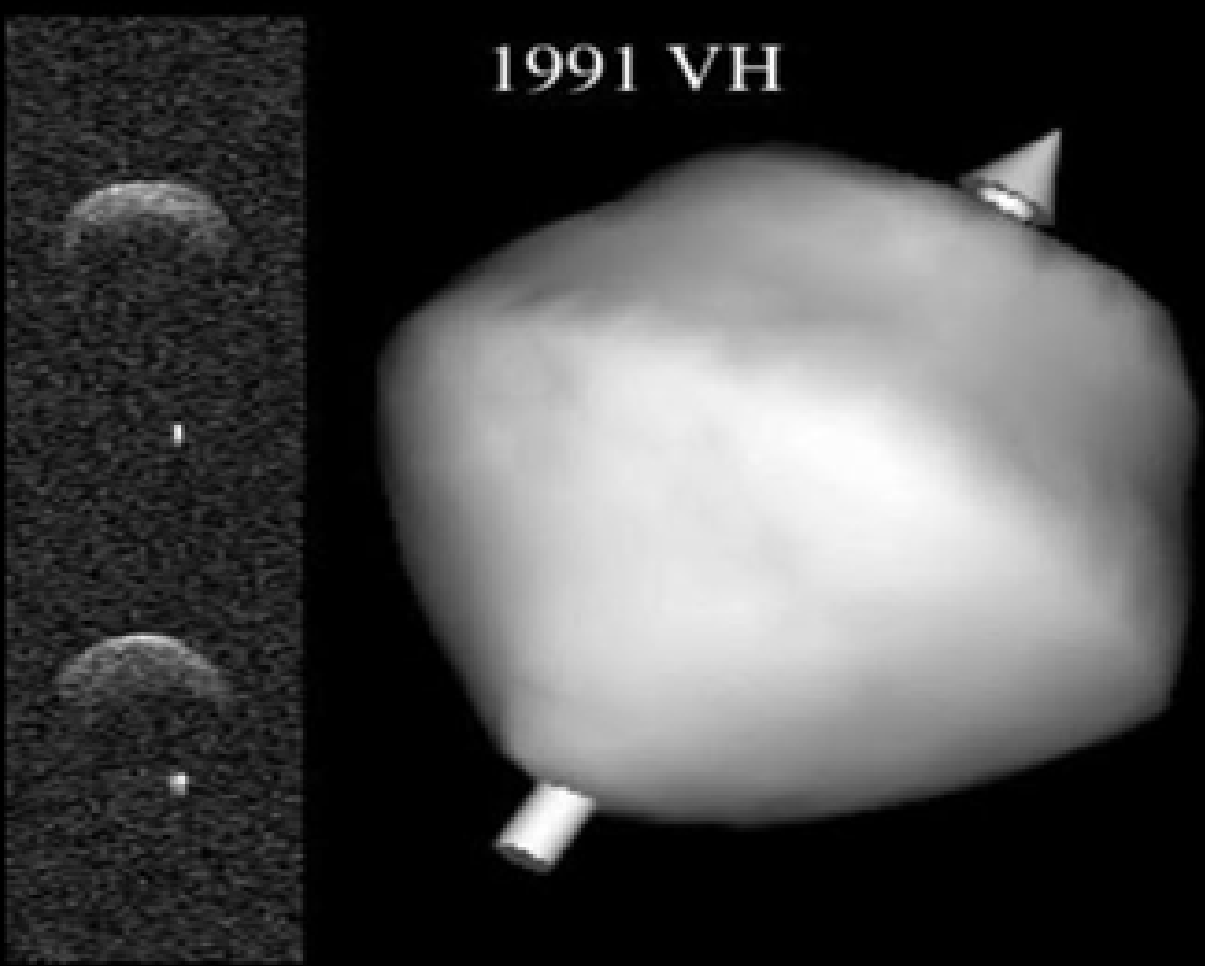
## Binary asteroid system details and spacecraft flyby conditions are similar.

### Relative size of systems



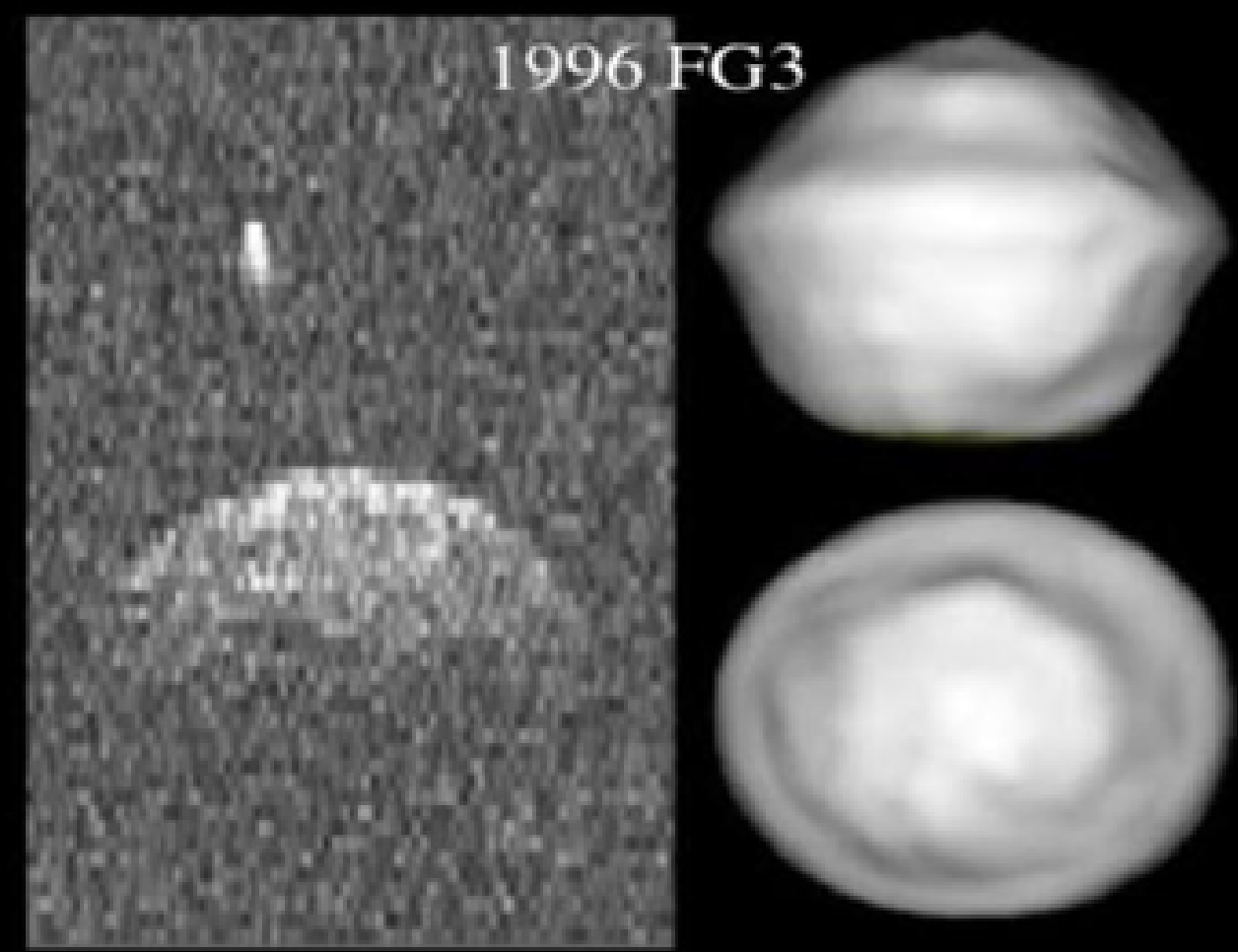
### System and Encounter Details

	1996 FG3	1991 VH
Diameter of primary	1690 m	1040 m
Diameter of secondary	490 m	420 m
Orbit semimajor axis	2520 m	3295 m
Spacecraft close approach distance	70 ± 10 km	70 ± 10 km
Encounter speed	4-5.5 km/s	2.8-3.7 km/s
Approach phase angle	97°-120°	65°-80°



1991 VH

A rocky S-Type in an excited state and a non-synchronous secondary rotation state



1996 FG3

A primitive C-Type in a long-term stable state and a synchronous secondary

# The *Janus* instrument suite has high-heritage and proven performance

*JCam* supports visible and near-IR imaging of our target binaries.

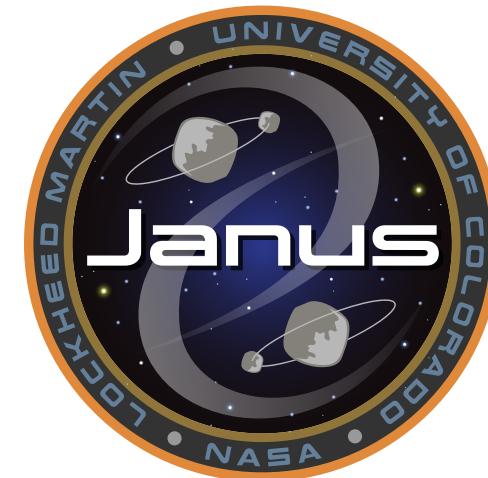
*JCam* is provided by Malin SSS, with detectors and electronics copied from proven instruments.

*JCam* DVR allows for on-board data compression, windowing and selective downloading of images.

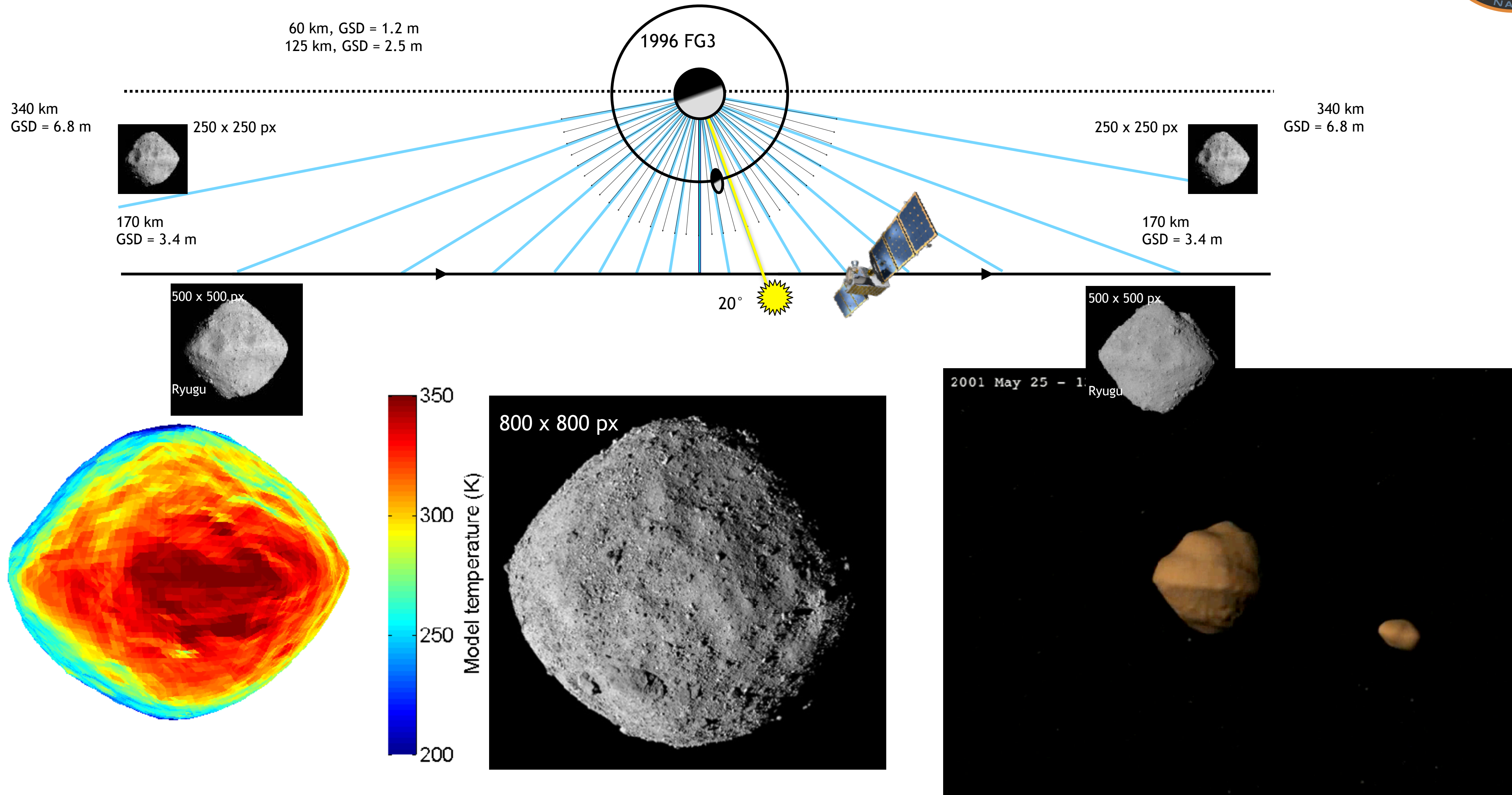
Science Instruments		
Instrument	Description	Heritage
Visible Imager	ECAM-M50, 2592 x 1944 pixel CMOS sensor with 2.2 $\mu\text{m}$ pixels, 420-680 nm bandpass, and an electronic rolling shutter	OSIRIS-REx, Undisclosed Mission
Infrared Imager	ECAM-IR3a, 640 x 480 pixel uncooled Long-Wave Infrared (LWIR) microbolometer sensor array with 8-12 $\mu\text{m}$ bandpass, integral Read-Out Integrated Circuit (ROIC) and 17 $\mu\text{m}$ pixels.	Undisclosed Mission
DVR	ECAM-DVR4, power conditioning, camera control, image processing, compression, subset windowing, and storage.	OSIRIS-REx, Undisclosed Mission







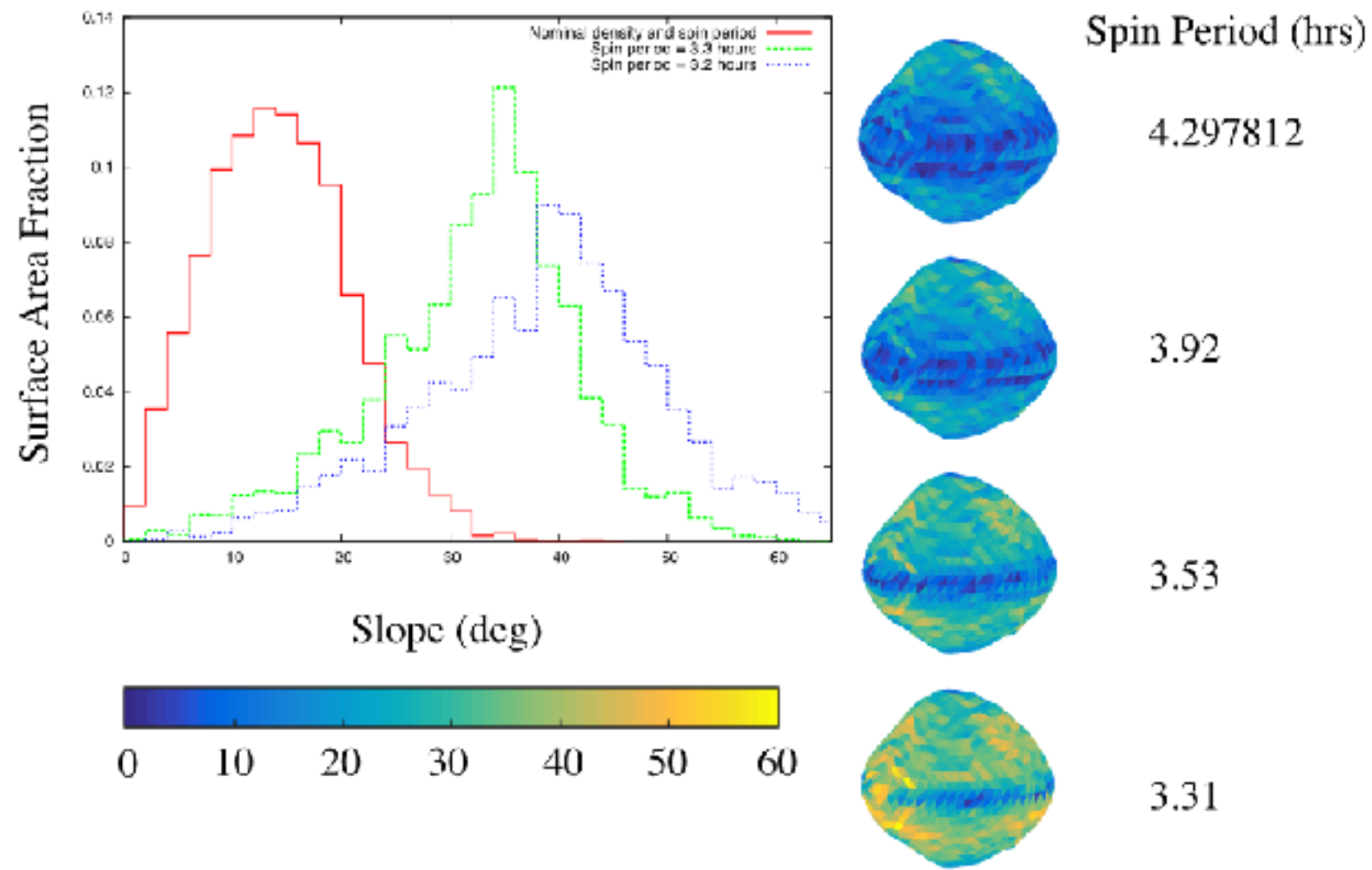
# Science Observations During Flyby



# Goal I: How Do Binary Asteroids Form?

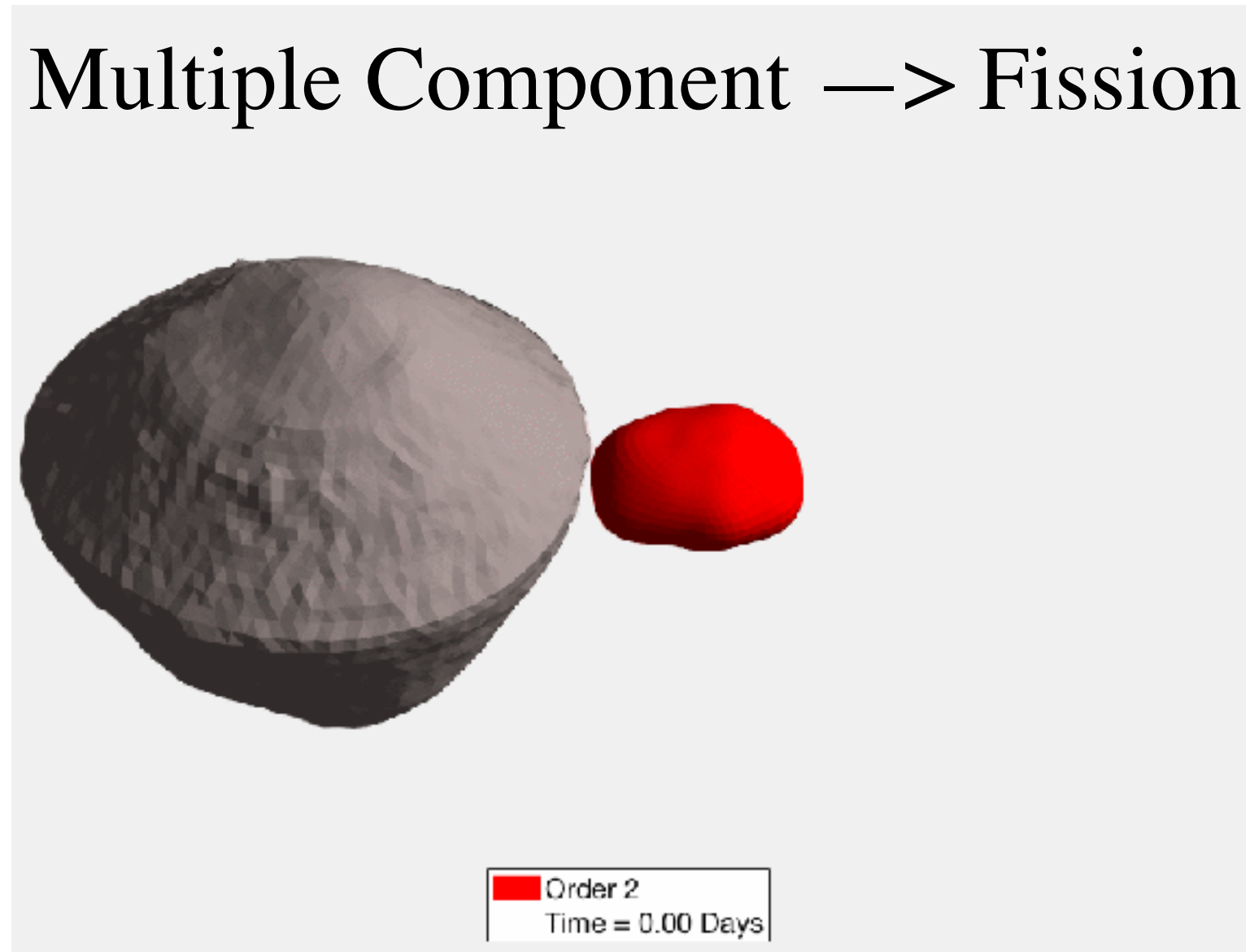
## Strong Interior —> Surface Shedding

Slopes at Limiting Spin Rates



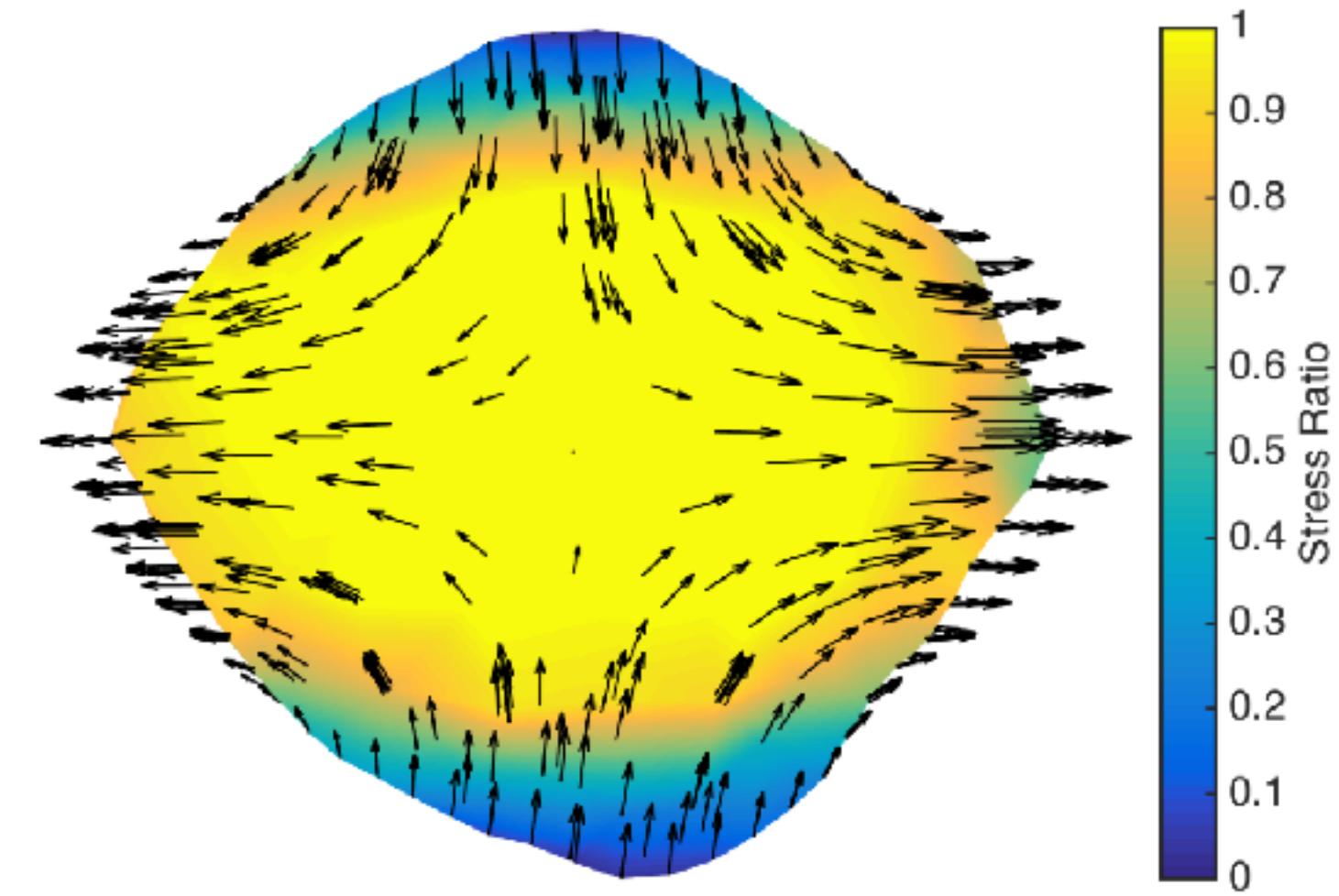
Regolith flows to equator  
 Secondary accumulated in orbit  
 Similar secondary and primary surfaces?

## Multiple Component —> Fission



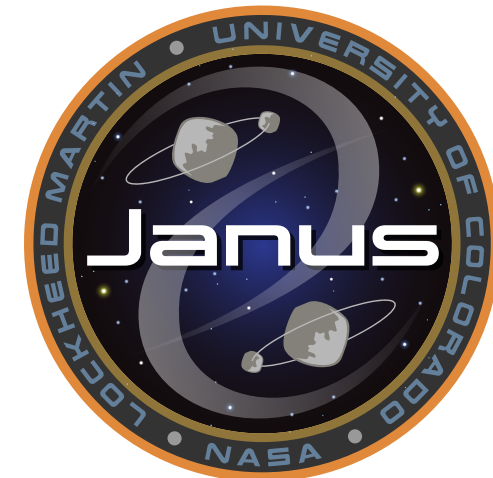
Cavity or scar on the surface  
 Evidence of secondary fission:  
 Infall on primary  
 Fission evidence on secondary

## Weak Interior —> Internal Failure



Outcropping of equator  
 Secondary accumulated in orbit:  
 Potential for a “seed” larger component from equator  
 Lack of regolith flows

Imaging provides morphology -> insight on formation



# Goal II, SO3: Asteroid (175706) 1996 FG3

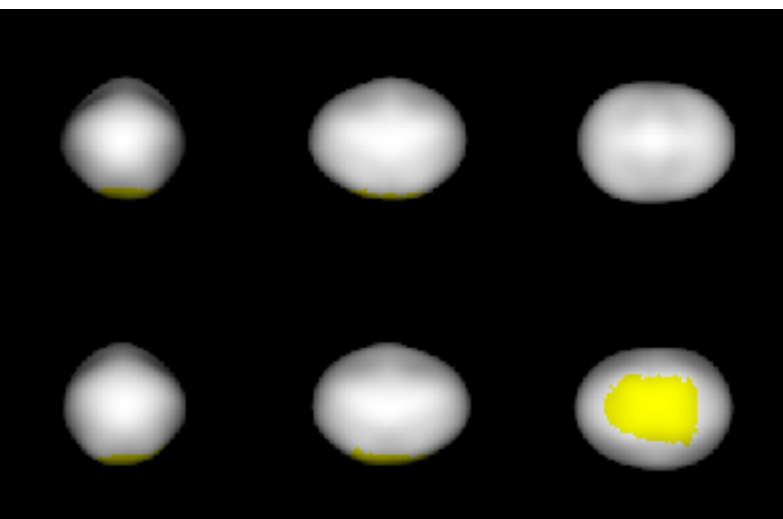
Most precisely measured NEO binary:

Primitive C Type: Similar to Ryugu and Bennu in composition and shape

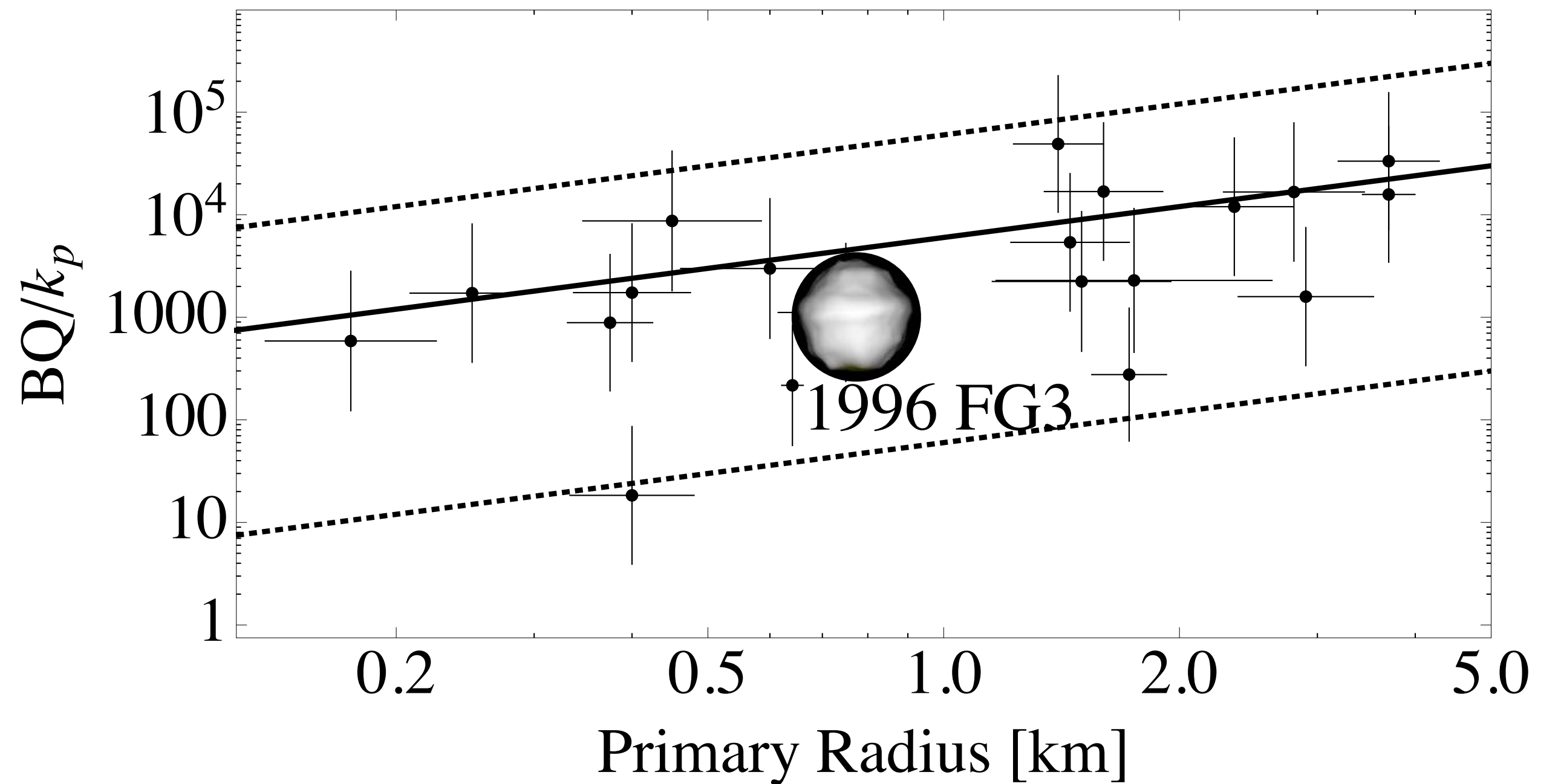
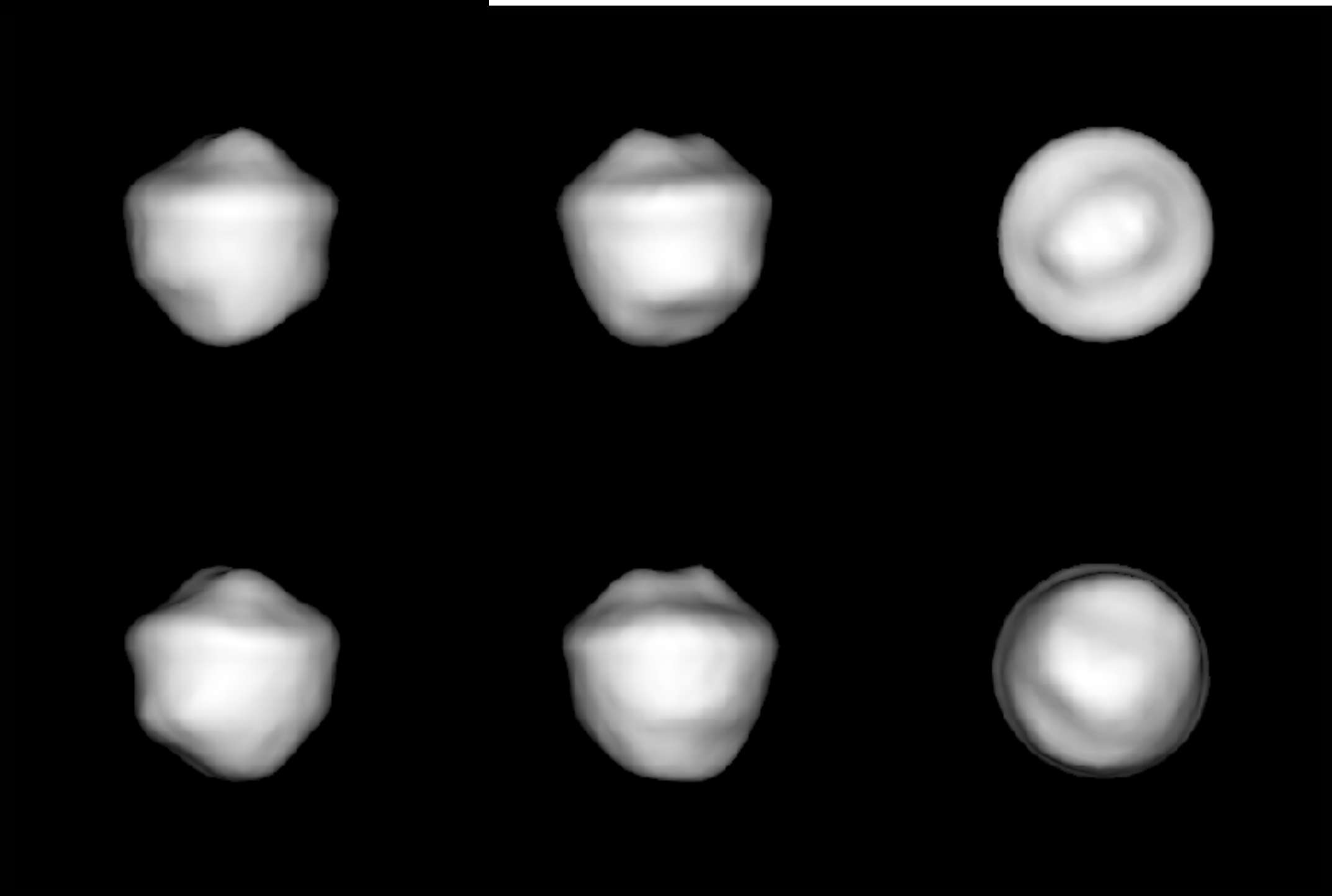
Lies in a Binary YORP — Tide equilibrium: extremely stable and predictable orbit

Measurement of BYORP coefficient from thermal modeling and observations will enable constraints on  $Q/k_p$  for a rubble pile

Secondary



Primary





# Goal II, SO4: Asteroid (35107) 1991 VH

Asynchronous binary — secondary is in a chaotic spin state

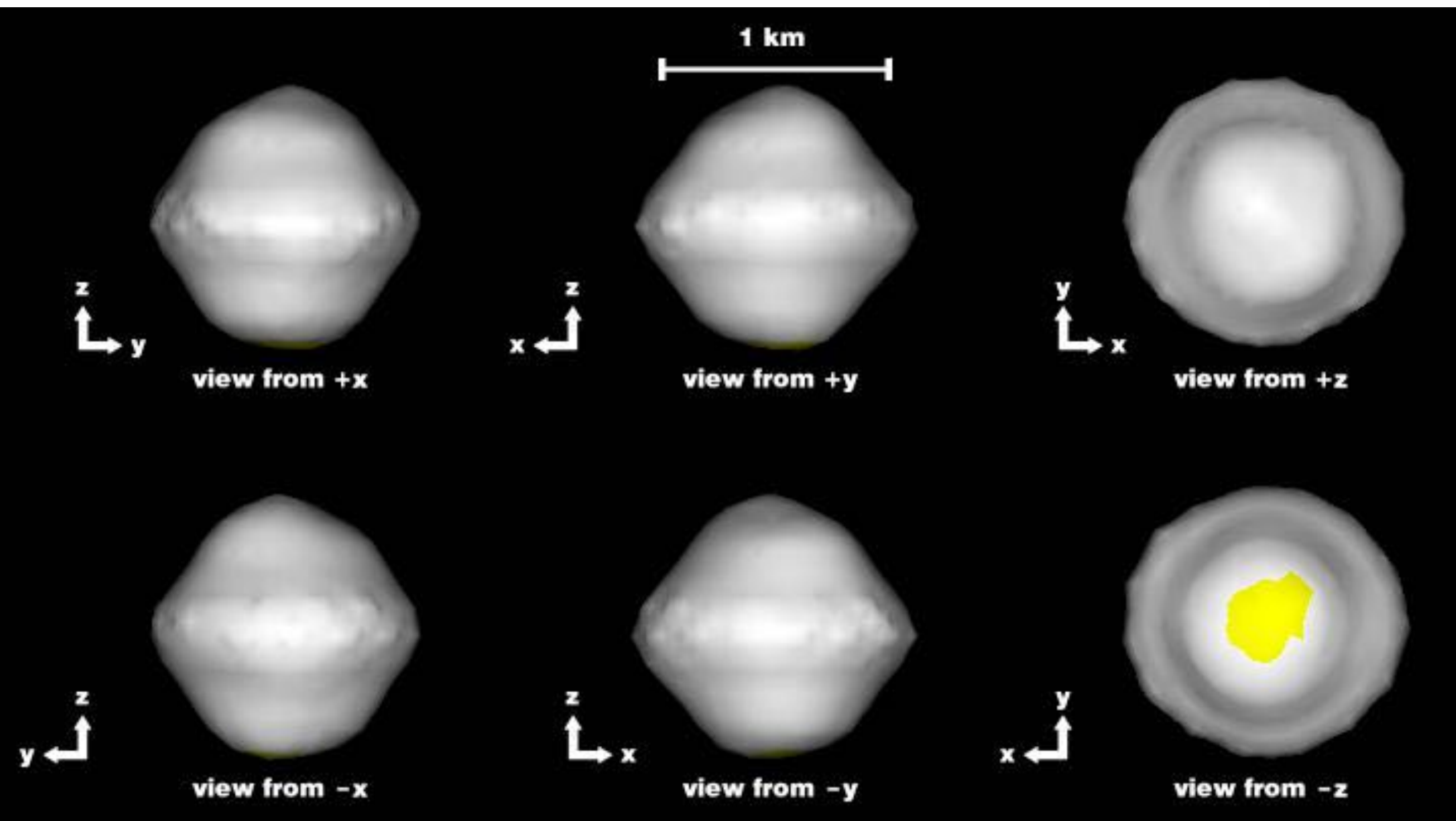
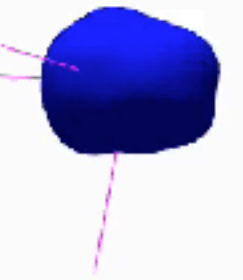
S Type binary asteroid — why do both FG3 and VH look the same?

Complex spin state provides an opportunity to constrain the secondary inertia tensor

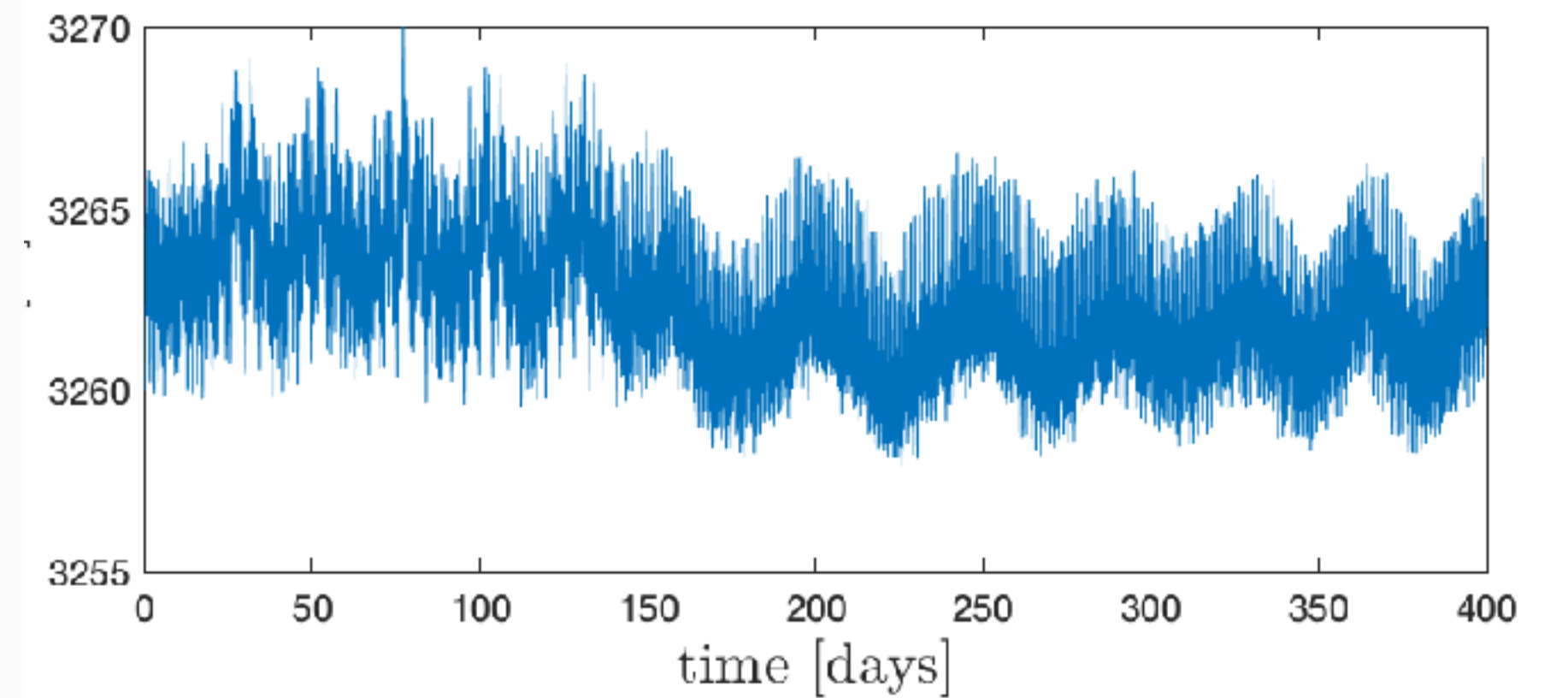
Observations can test theories for its excited state.

Primary model (still in development)

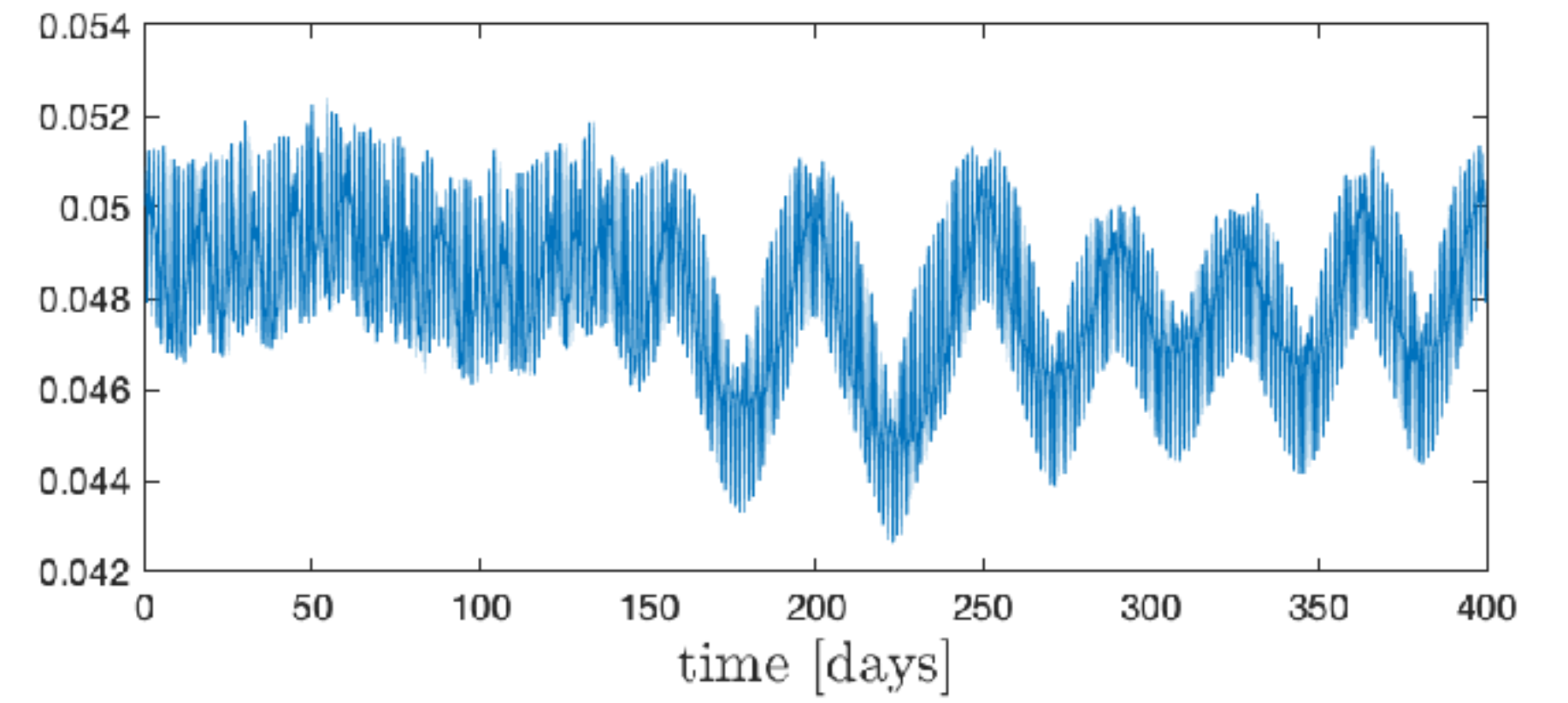
Secondary model constrained only



Semi-Major Axis



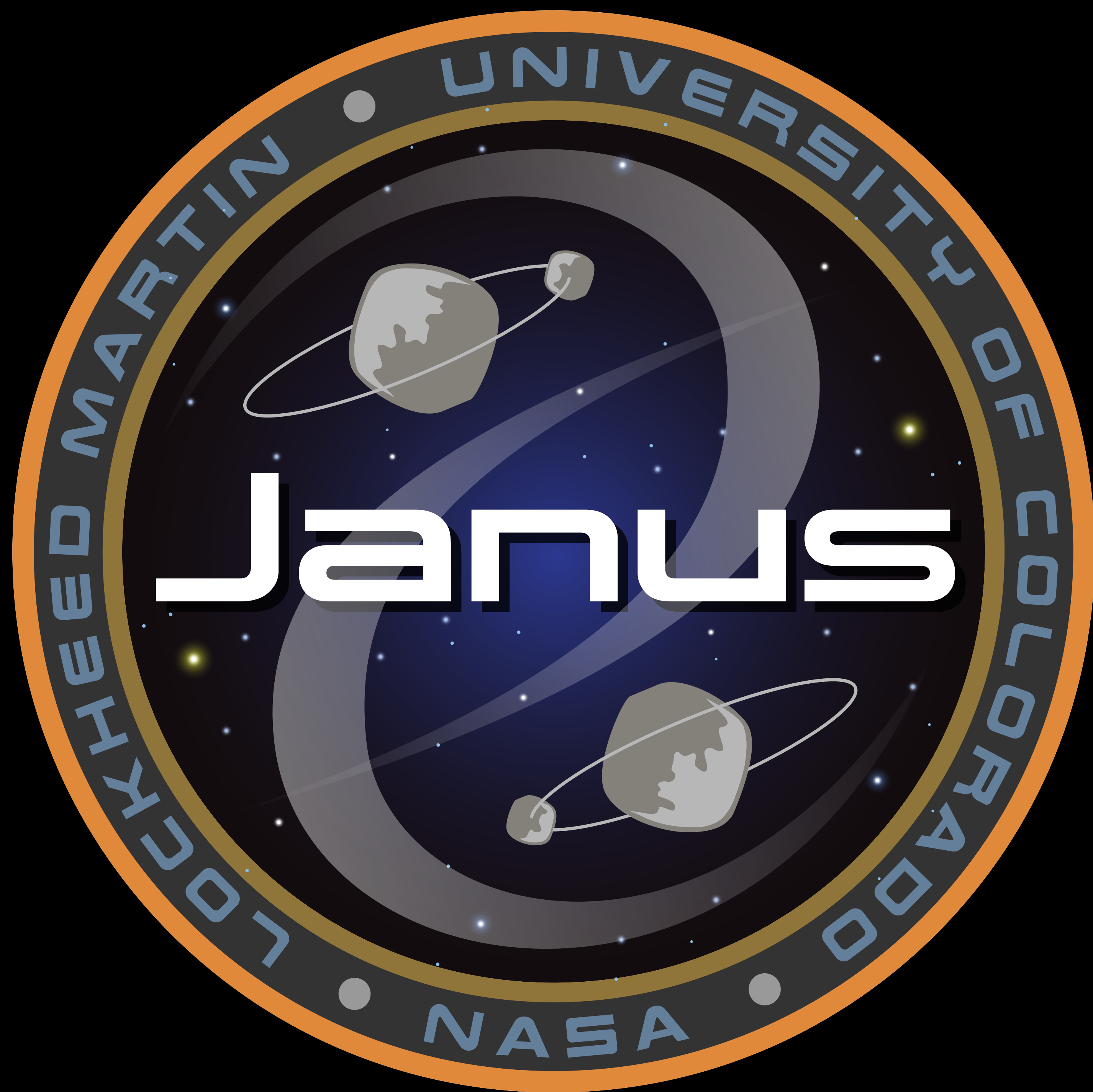
Eccentricity



# *Janus* Summary

- *Janus* will provide the first high resolution, scientific observations of NEO binary asteroid systems that have significant diversity
- *Janus* can provide insight into the mechanics of rubble pile bodies, and into microgravity geophysical processes in general
- *Janus* defines a new S/C and mission profile that can provide a responsive scientific and planetary defense capability for NEO characterization
- *Janus* has passed PDR and is confirmed by NASA!
- *Janus* is ready and able to serve as an inaugural member of NASA's SIMPLEx Program





Janus

LOCKHEED MARTIN UNIVERSITY OF COLORADO  
NASA