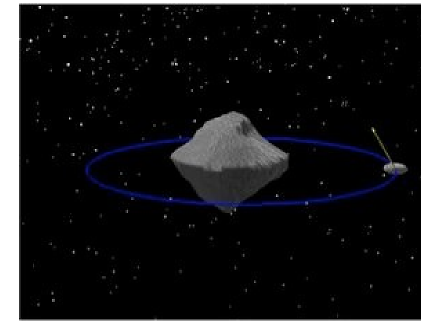


AIDA: mission to Didymos

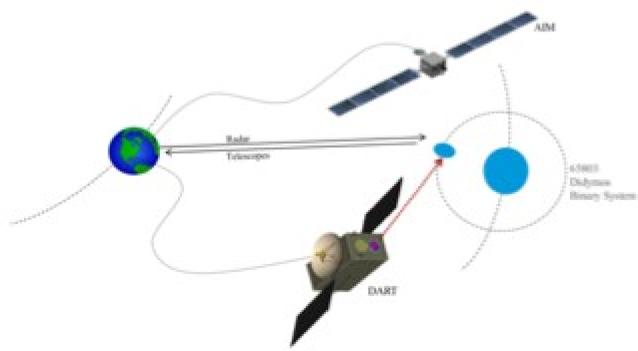
Asteroid Impact & Deflection Assessment

a joint ESA (AIM) – NASA (DART) mission

Asteroid Impact Mission — **Double Asteroid Redirection Test**

Kleomenis Tsiganis (AUTh)

and the AIM Investigation Team



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Simon GREEN (OU, UK), Jurgen BLUM (TU BRAUNSCHWEIG, GERMANY), Marco DELBO (OCA, FRANCE), Petr PRAVEC (ONDREJOV OBS., CZECH REP.), Pascal ROSENBLATT (ROYAL OBS. OF BELGIUM, BELGIUM), Kleomenis TSIGANIS (AUTh, GREECE), Jean-Baptiste VINCENT (MPS, GERMANY)

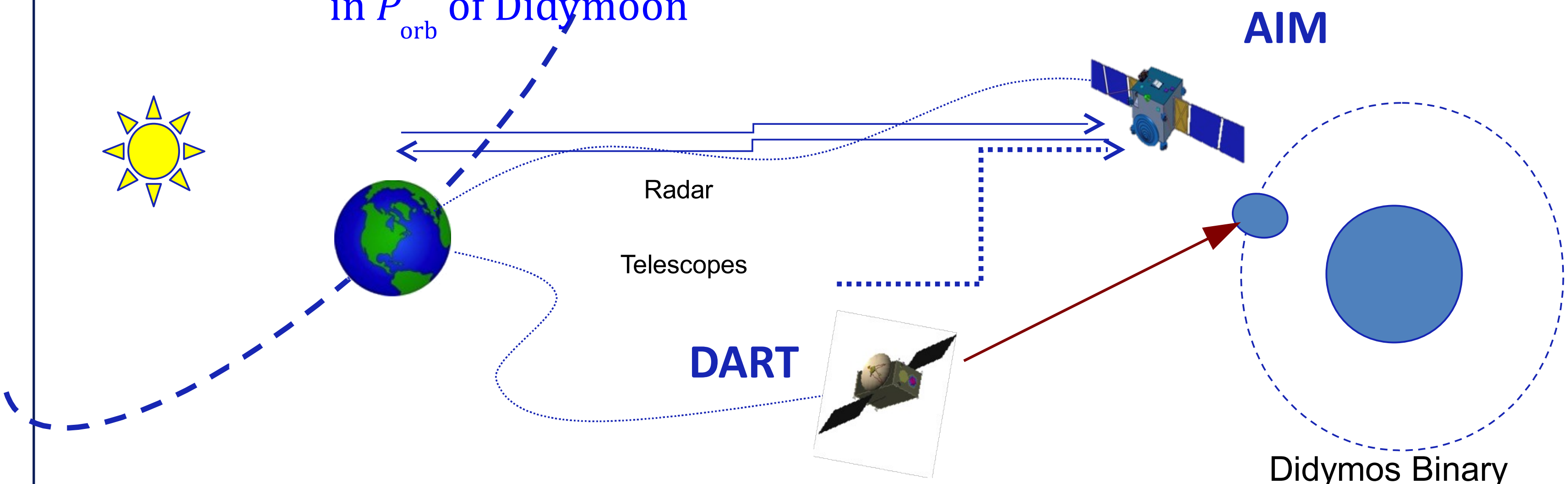
12th Hel.A.S Conference, Thessaloniki 28/6-2/7, 2015

The Mission Concept (1):

<u>Goals:</u> demonstrate the **ability to modify the orbital path of the secondary asteroid** of the (65803) Didymos binary system and **obtain scientific and technical results** that can be applied to other targets and missions.

AIM ⇨ rendezvous mission (physical charactrization by imaging and a lander + Cube-sats / test optical communications)

DART ⇨ kinetic impactor + radar/optical ground-based opps to determine change in P_{orb} of Didymoon



AIDA

Target and **Dates** (AIM Oct, 2020, DART July 2021) are fixed by Didymos' close encounter with the Earth (2022)

The Mission Concept (2):

AIM will also observe (visual + thermal imaging) the hyper-velocity impact of DART on Didymoon

Cube-sats payload will also focus on impact monitoring (crater / ejecta)

Induced change in orbital period should be detectable from ground

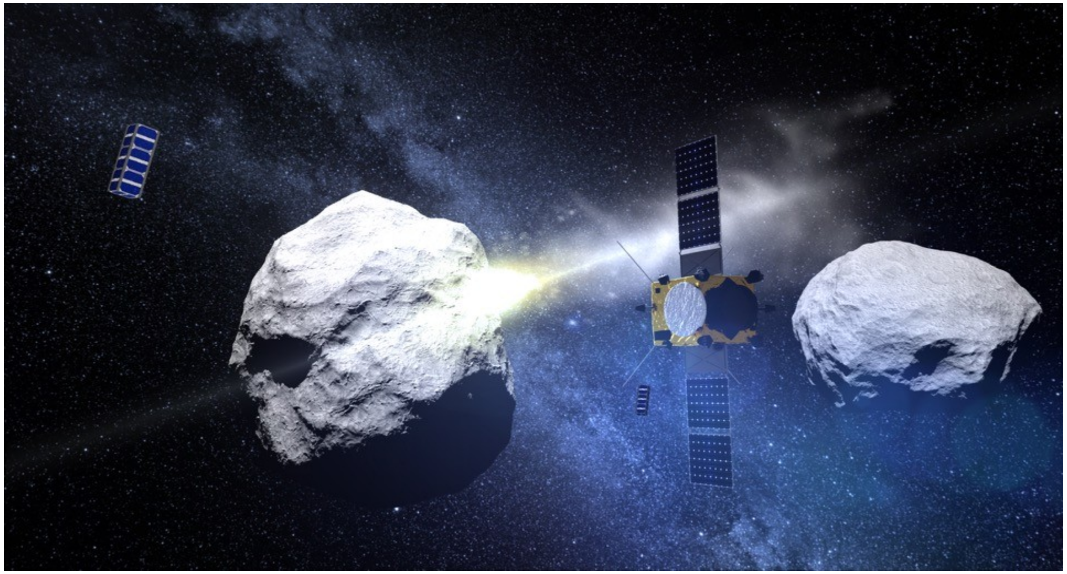
First time to have an impact experiment of this scale!

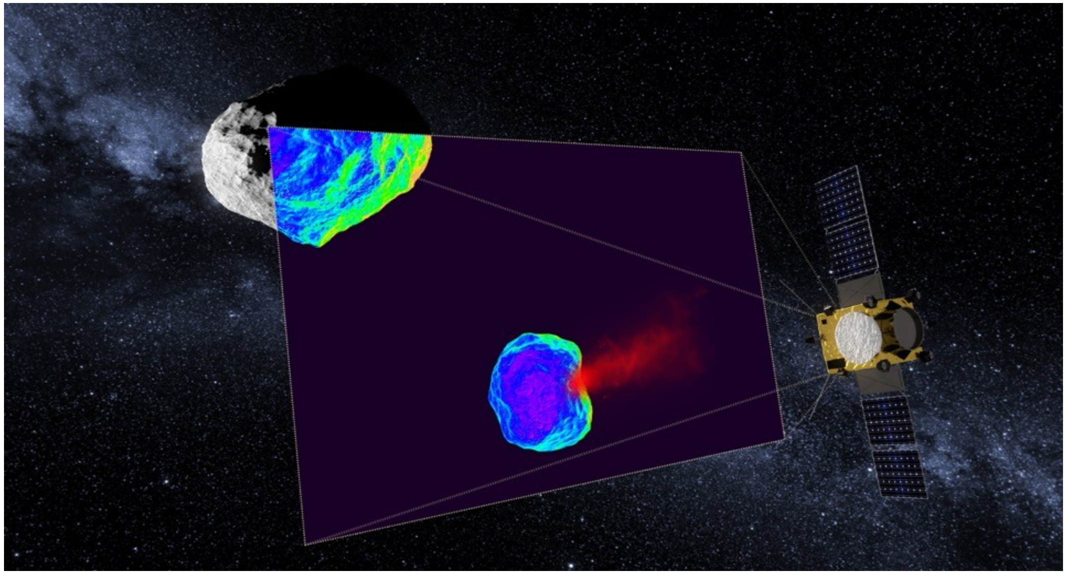
Will provide valuable data for internal structure of asteroids, impact models, formation theories etc..

Will test our ability to delfect a small asteroid by a kinetic impactor

Landing on Didymoon (MASCOT-2) will be extremely challenging!

lander should give valuable pre- and post-imapact data on internal structure (LF radar)





Credit: ESA

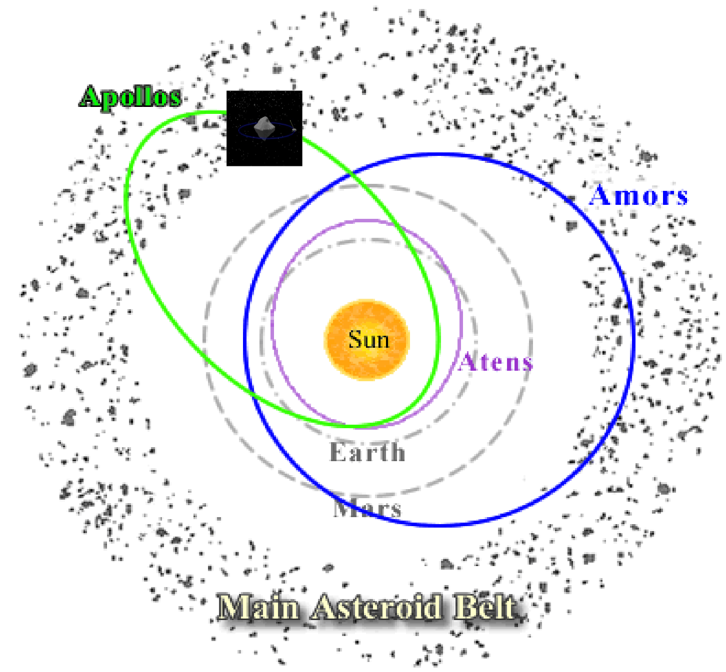
Facts on NEAs

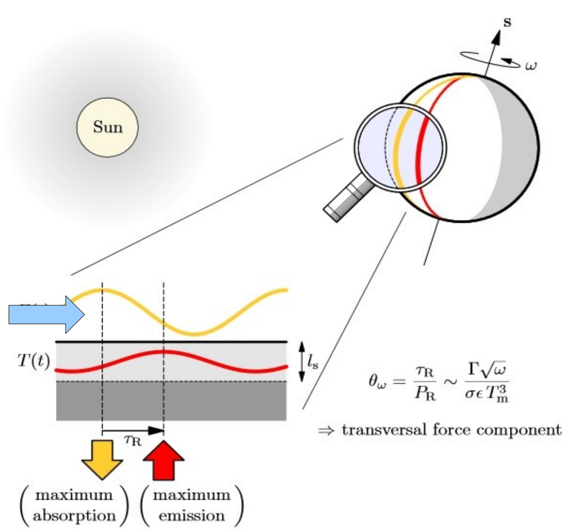
Didymos is a ***binary*** Near-Earth Asteroid (Apollo type)

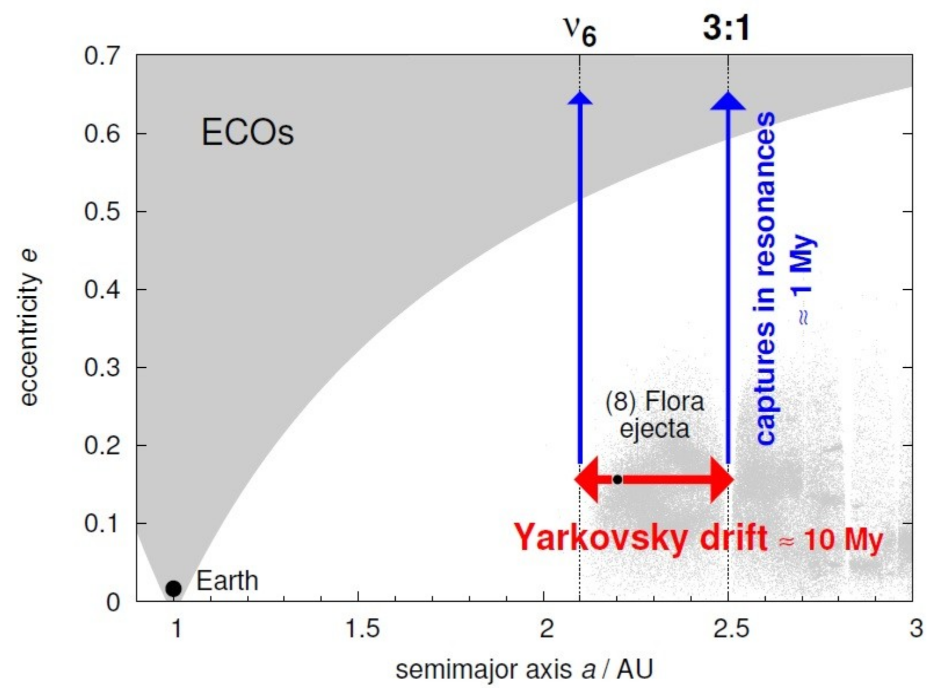
Origin: inner main asteroid belt (MB)

Yarkovsky thermal force moves the asteroid's semi-major axis, a (torque changes rotationl state)

- falls in a major orbital/secular resonance
- develops planet-crossing eccentrcity
- encounters a planet (extracted from MB)







Some Mission Facts:

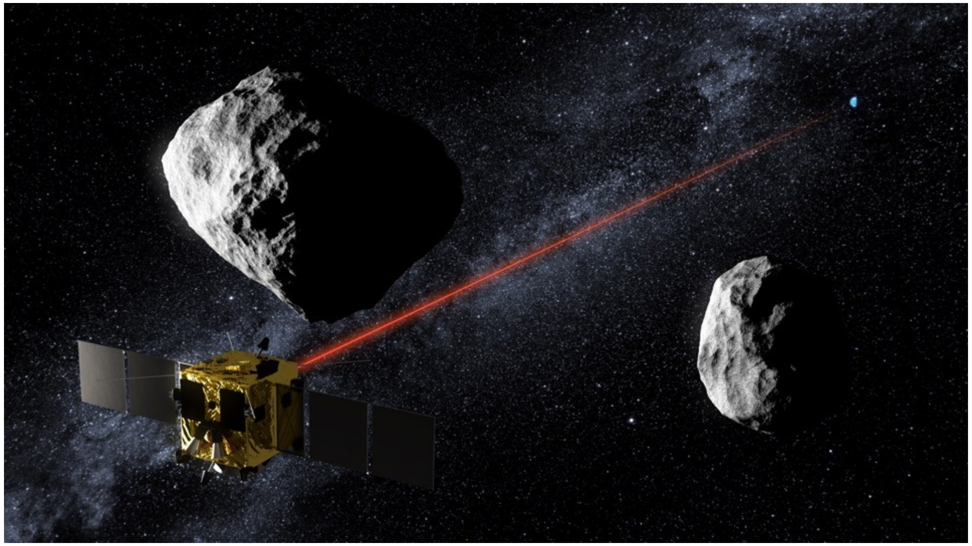
AIM and DART are developed as *stand-alone missions* to be integrated into AIDA

Investigation/Advisory Teams for AIM (lead: Patrick Michel) and DART (lead: Andy Cheng) interface through the *AIDA Coordination Committee* and its Working Groups.

AIM is intended to be a *technology demonstartion mission*

AIM currently in *Phase A/B$_1$* Study (not yet for DART)

→ AIM Investigation Team integrates all science info (observational data and modeling) and provides support to ESA and industrial partners



Credit: ESA

* If you're interested in helping, contact me!
(tsiganis@auth.gr)

Kleomenis Tsiganis

- AIM Investigation Team

- Co-chair of AIDA Coordination Committee WG4: “Dynamical properties of Didymos”

... if approved (early 2017) AIM should fly ***tomorrow(!)*** by space standards...

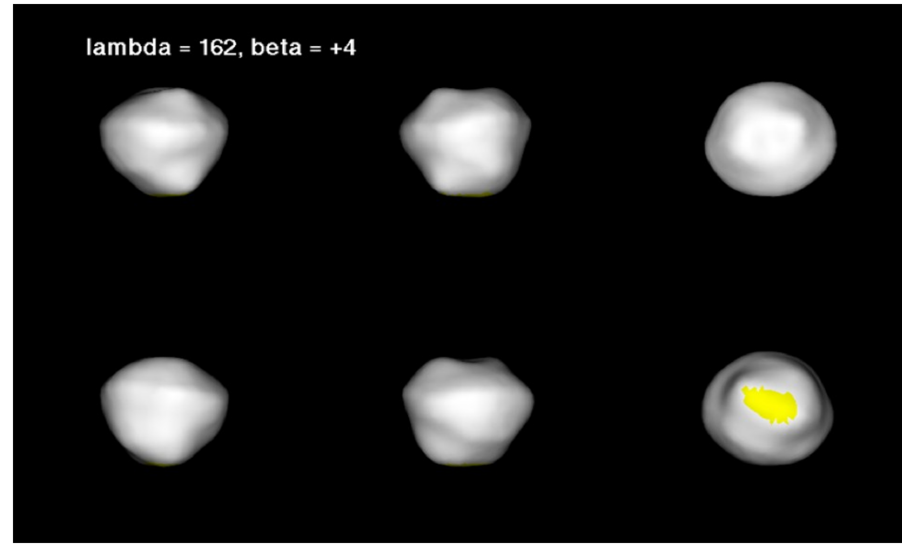
The Target (1):

Radar images available from last encounter provided a preliminary shape model for the primary

- data not sufficient to determine Didymoon's shape

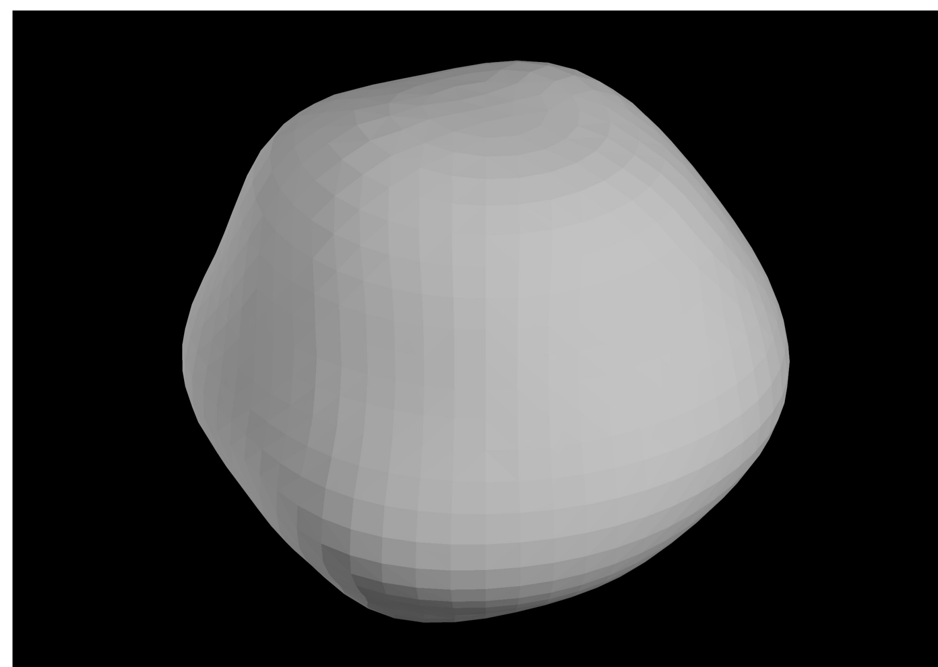
- suggest an elongated shape (triaxial ellipsoid)

- Compatible with recent optical data supporting ~30% elongation on NEA moons (Pravec et al)



Credit: Lance Benner, JPL

Recompilation of data gives the current shape model, for the baseline pole solution



Will improve further when we combine radar with optical lightcurve data

The Target (2):

The system's heliocentric orbit is typical of Apollo-type NEAs

Low orbital inclination very good!
→ low Δv requirements

A compact binary system with a relatively fast rotator as primary (expected by NEA binary formation theories..)

Diameter of Primary D_P[1]	0.75 km +/- 0.08 km
Diameter of Secondary D_S	0.157 km +/- 0.018 km
Bulk density of the primary ρ_P[2]	2400 kg m^{-3} +/- 30%
Secondary (shape) elongation a_s/b_s (assumed)[3]	1.3 +/- 0.2
Distance between the centre of primary and secondary a_{orb}	1.18 km +0.04/-0.02 km

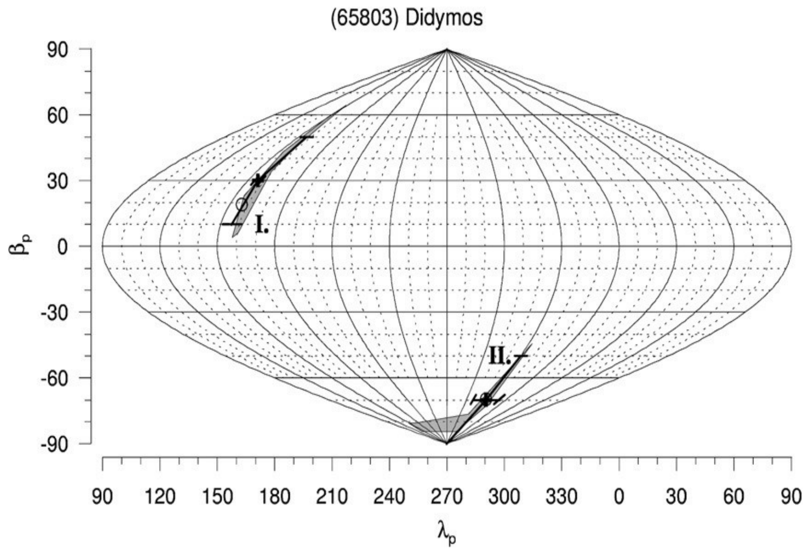
Total mass of system	5.27e11 kg +/-0.54e11 kg[4]
Geometric Albedo	0.16 +/- 0.04
Rotation period of the primary	2.2593 h +/-0.0008 h
Radar albedo	0.27 +/-25%
Heliocentric eccentricity e	e = 0.383752501 +/- 7.7e-9
Heliocentric semimajor axis a	1.6444327821 +/- 9.8e-9 [5]AU
Heliocentric inclination to the ecliptic i[6]	3.4076499° +/- 2.4e-6°
Absolute magnitude of the primary H	18.16 +/- 0.04

Almost circular orbit of ~1.8 km (~12h period)
Data compatible with *synchronous* rotation for Didymoon (i.e. T_{rot}=11.92h)

Diameter ratio D_S/D_P	0.21 +/- 0.01
Secondary orbital period P_{orb}	11.920h +0.004/-0.006
Secondary eccentricity e	0.02 +0.01/-0.02

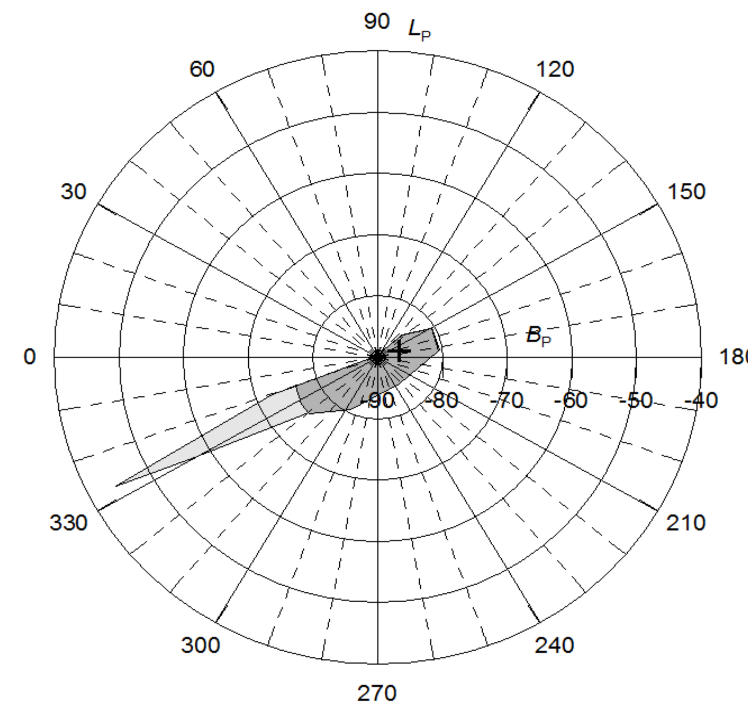
The Target (3):

Lightcurve inversion with previous data gave two possible pole solutions *for the binary orbit*



Pravec et al managed to constrain the pole solution using new data (April 2015)

λ=290°, β=-87 °+11°/-3°



Perfectly compatible with our understanding of asteroid spin evolution and NEA production

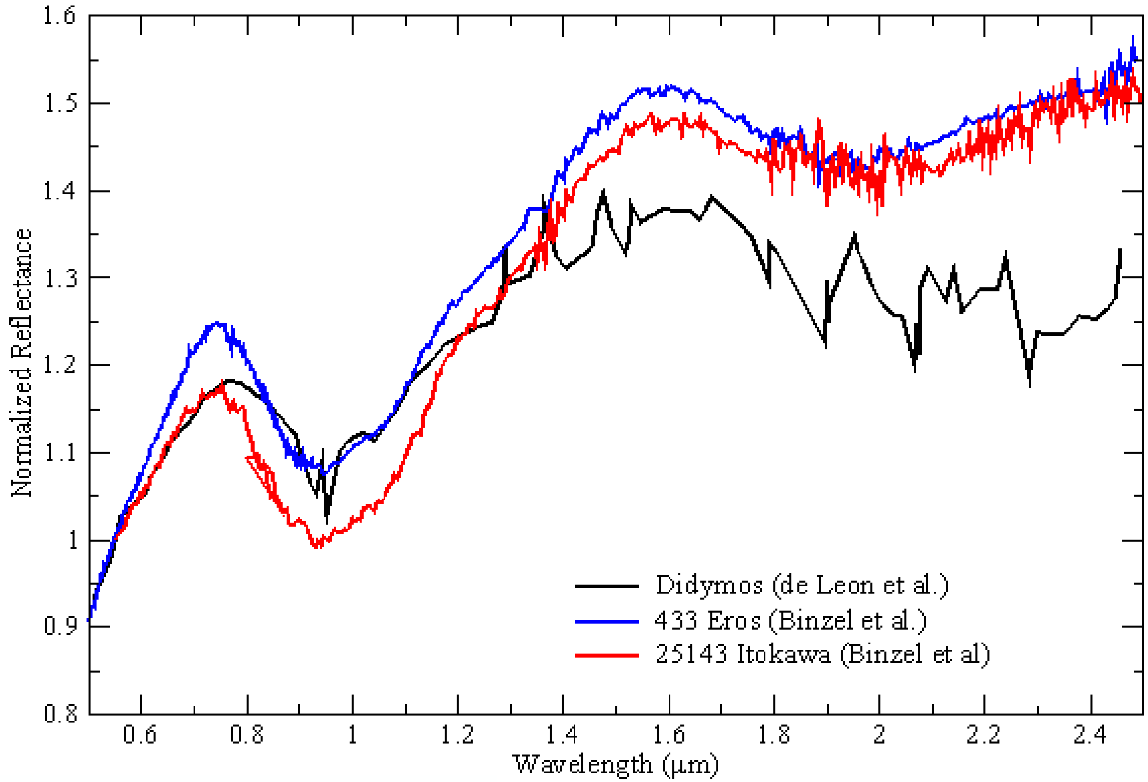
- almost perfectly *retrograde* w.r.t orbital plane

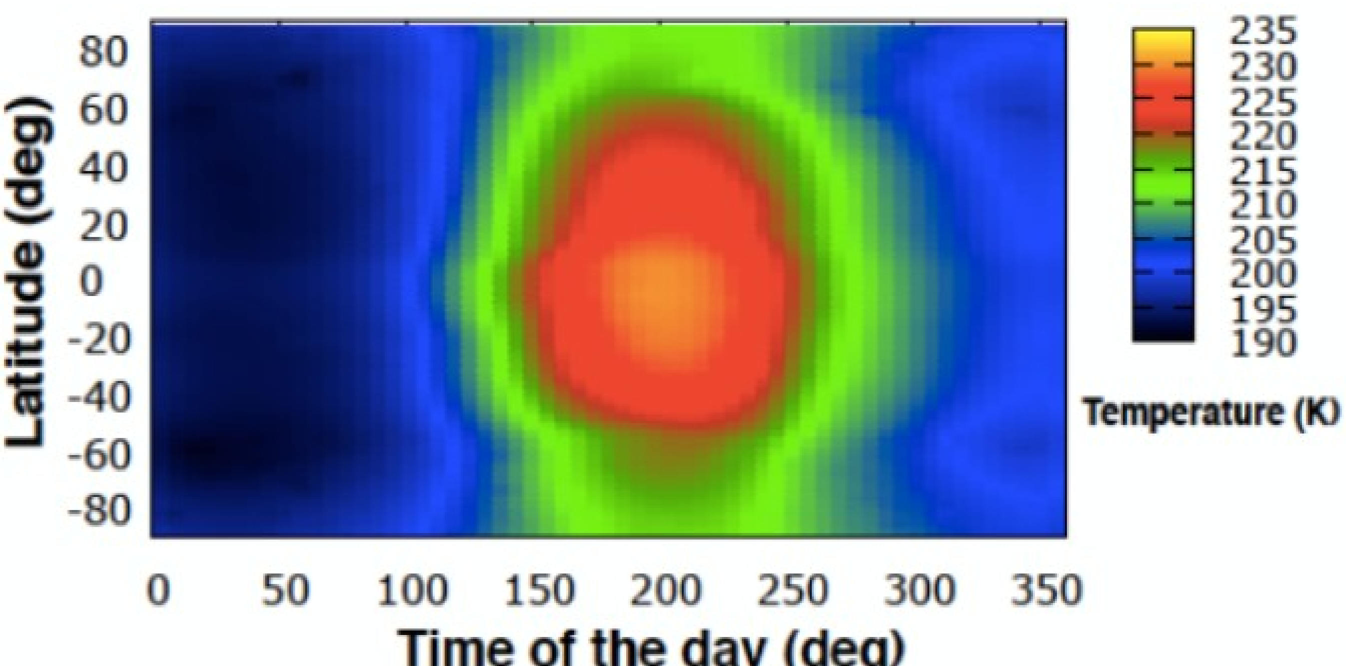
- *Inner MB origin,* likely through ν6 resonance (da/dt<0 for 'spin down' // $P_{\nu 6}$>45% in Bottke et al's NEO model)

** one parameter less to consider in models **

The Target (4):

Visual and IR Spectra show a typical *S-type* asteroid (silicates) with bulk density ~2.0-2.7 gr/cm^3. Data suggest ~2.6 gr/cm^3.



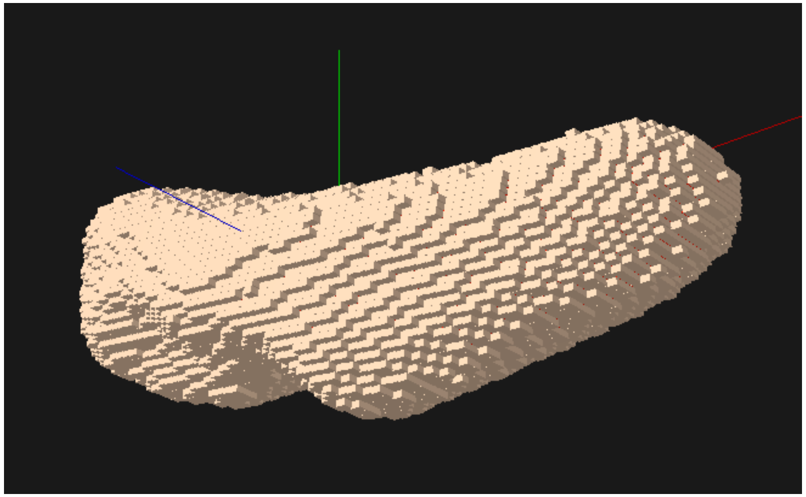


Thermal properties largely unknown, need to be determined

and thermal imager data should be combined with all other data

Modeling the Dynamics of the System

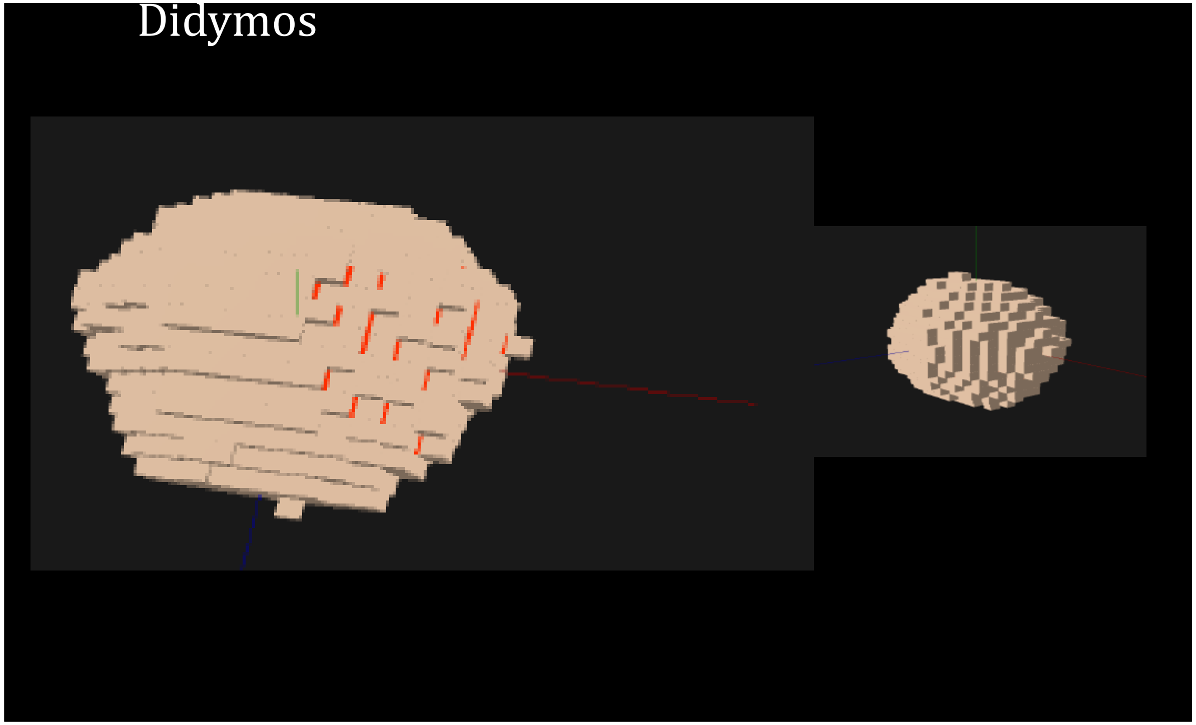
(in collaboration with G. Voyatzis / WG4)



433 Eros model

We can build a mass distribution model for the two bodies, by packing cubes (or spheres...) whose size is given *by best-fitting the shape model* data

Various density / porosity models can be used



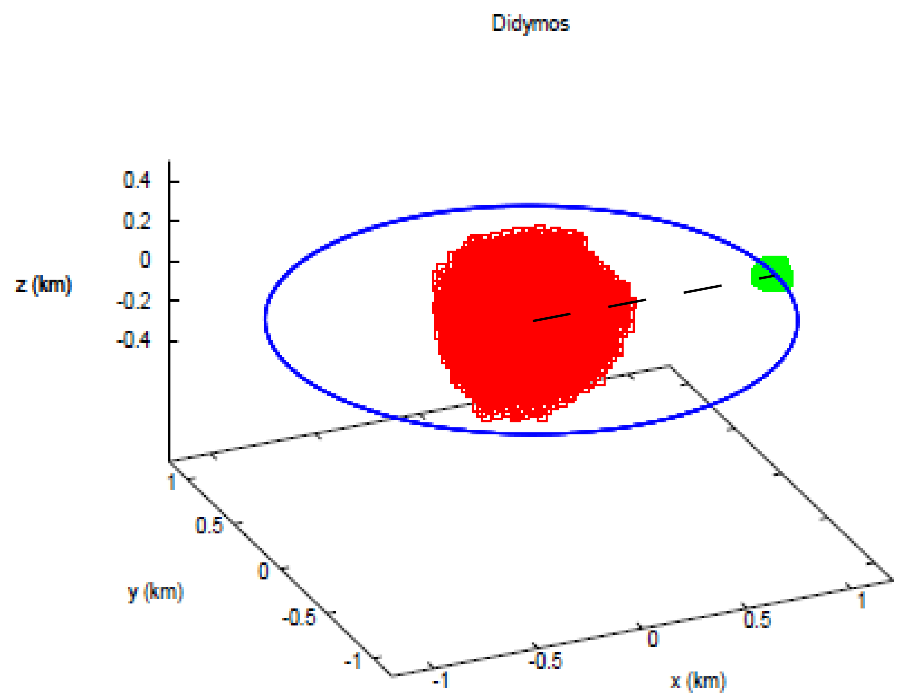
Here we used NEA *Bennu* as a shape model (scaled for size and axial ratio)

The model returns N~2,000 mass elements for each body

~ 20-50m side of cube

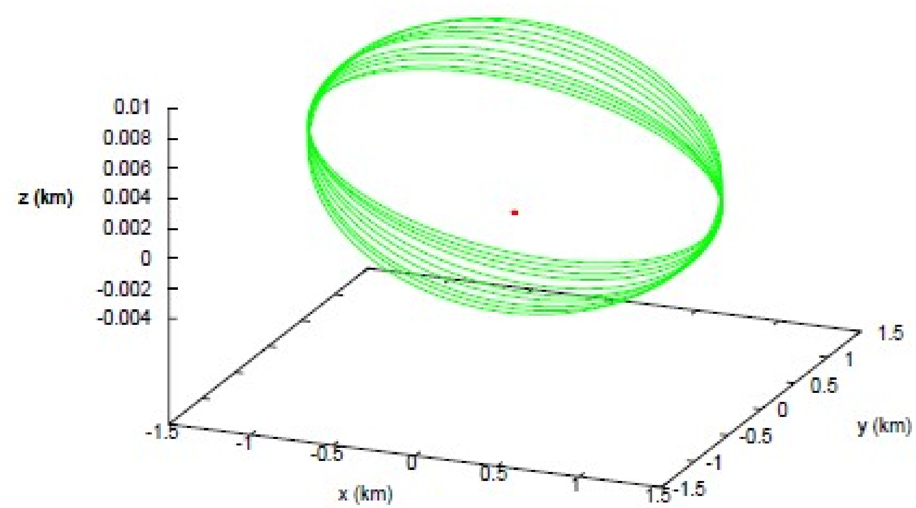
Modeling the Dynamics of the System

We have developed a symplectic integrator that computes all (N^2) forces and torques between mass elements and gives the orbital and rotational motion



... to be extended by including s/c motion external forces

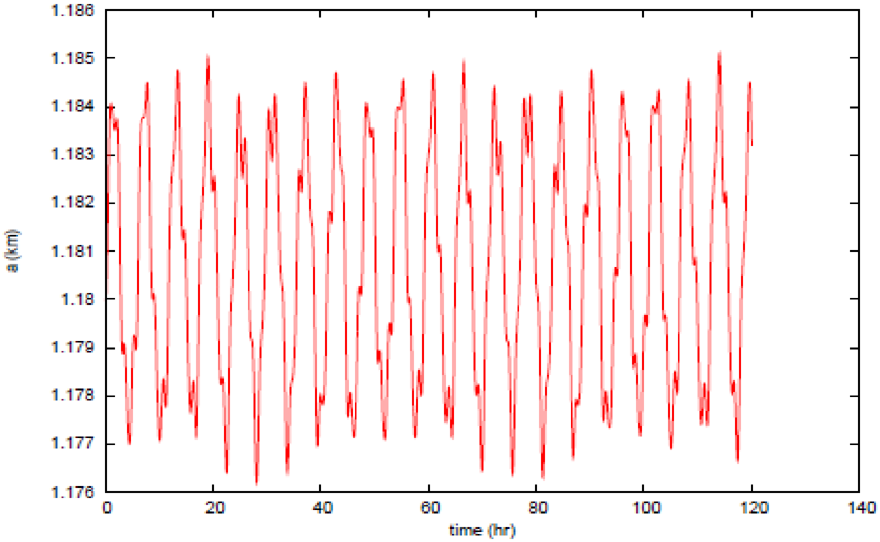
a few meters deviation in Oz (orb.plane precession)

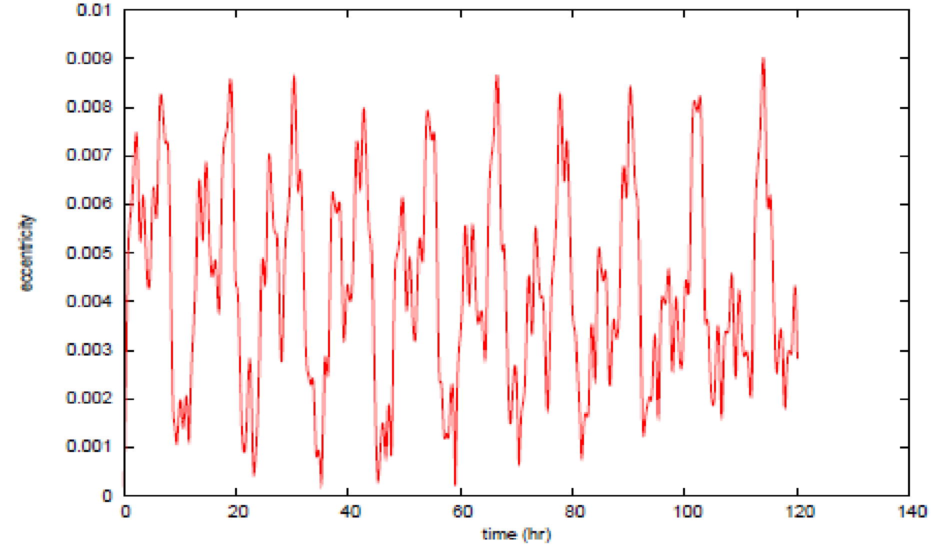


Orbital motion

Orbit is very stable: ~10 m variations in relative semi-major axis (~1% in orbital period) and eccentricity <0.01

These figures may depend strogn ly on Didymoons' exact shape/density profile



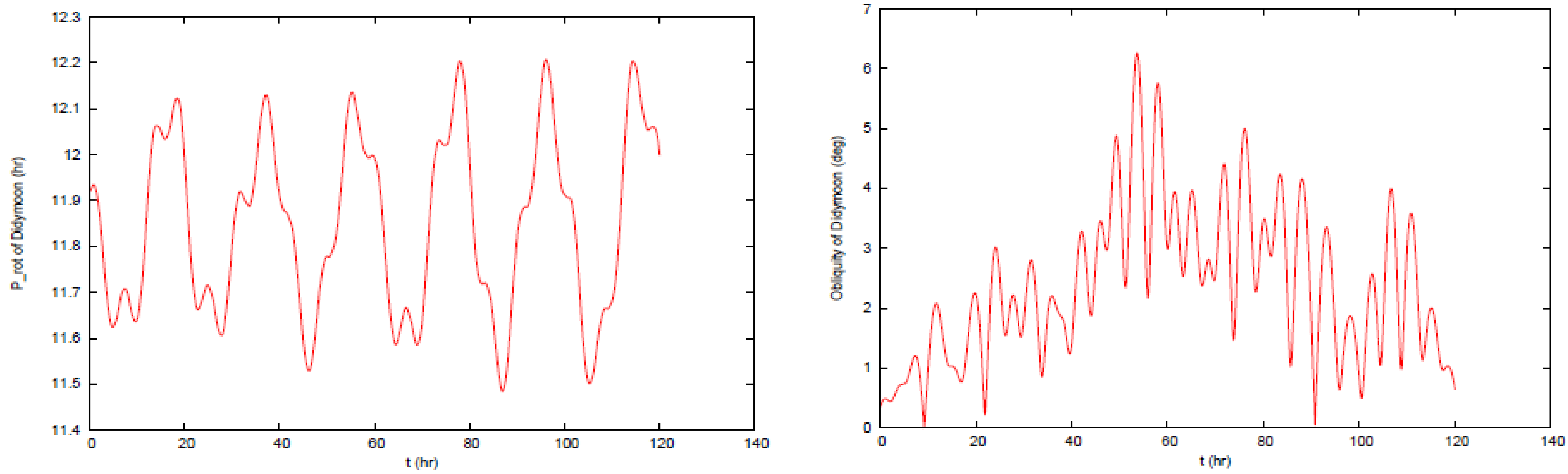


The *wobbling* of the c.o.m may be used to provide Didymoon's mass to +/- 10% accuracy

Rotational motion

Rotation of Didymoon is *even more sensitive* to its exact shape/mass sitribution and initial rotation state

Changing the axial ratio by 10% (in this example), *libration* around principal axis results in variations in rotational period and a *varying obliquity* of order $\mathbf{\Delta} \boldsymbol{P}_{\mathbf{rot}}$ **= +/- 20 min** and **Δε ~ *6* deg**



For this model, obliquity seems to be not very stable...

Conclusions

- AIDA may be *the only chance* we'll have to go to a minor body of the solar system for the next *~20 years*
- Goals very important for *planet protection* and solar system *science*
- Valuable *technology demonstration* (impact monitoring / asteroid deflection / deep-space optical communications)
- *Cheap* mission! *Great* scientific return as added value

Q's:

- Very interesting dynamics due to *sensitivity* on (unknown) Didymoon's shape
- Can the primary have *nutation*? Is the *rotation* of Didymoon stable ?
- How to best measure Didymoon's small *mass* with enough precision ?
- How to *land* on such a small object ?

Check out AIDA's web-site: https://www-n.oca.eu/michel/AIDA/