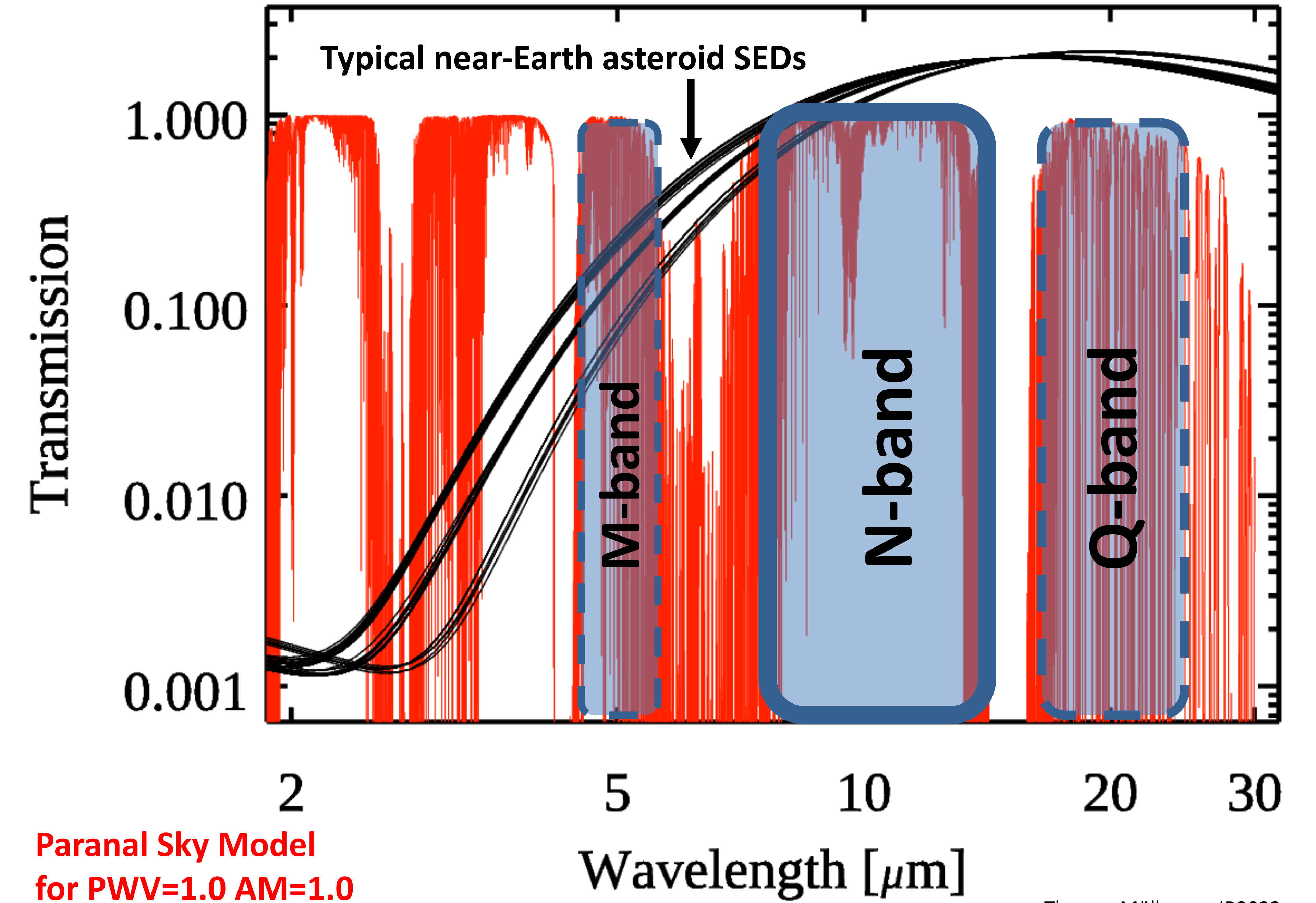
# Mission target asteroids: thermal-IR characterization from ground

**Thomas Müller**[1], Sunao Hasegawa[2], Fumi Usui[2], Tatsuaki Okada[2], Tomohiko Sekiguchi[3]
[1]Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany
[2]ISAS, JAXA, Sagamihara, Japan
[3]Hokkaido University, Japan

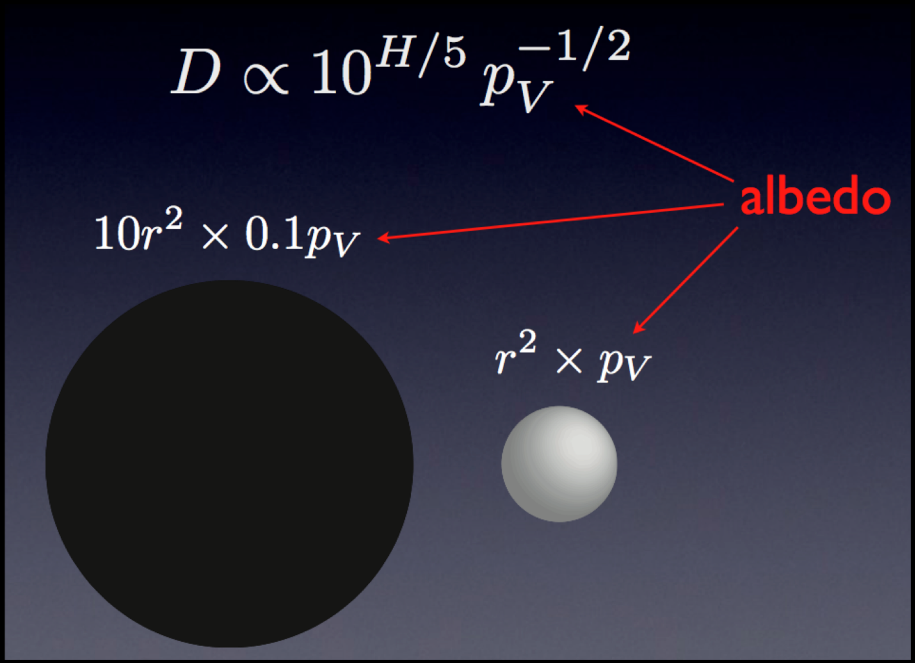
- Thermal-IR photometry to characterize the object (size, albedo, spin-shape solutions, the sense of rotation, thermal & physical surface properties, surface temperatures, etc.)
- To provide input for Yarkovsky, YORP, B-YORP effects (non-gravitational forces which change the object's orbit and rotational properties)
- Deep IR imaging to detect activity (or impact effects) in form of ejected dust clouds or trails
- Ground-based IR to monitor asteroids/comets over time (daily or seasonal changes), over wide phase-angle or helio-centric ranges, to observe closer to the Sun, objects with high apparent motion

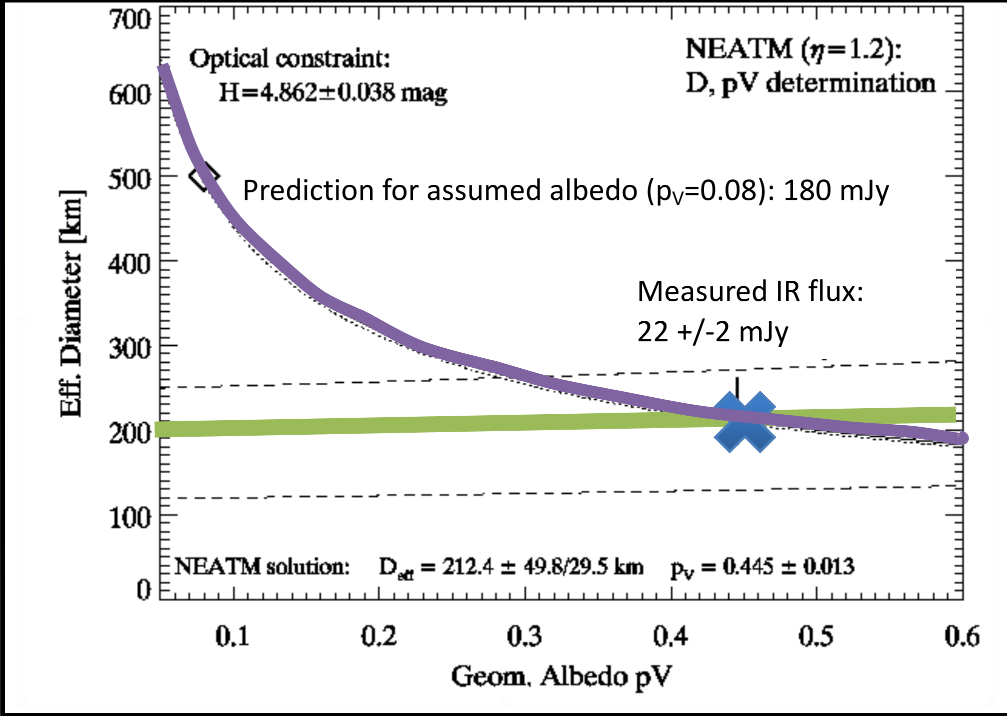



Thomas Müller IR2022

# Fundamental Properties: Size & Albedos

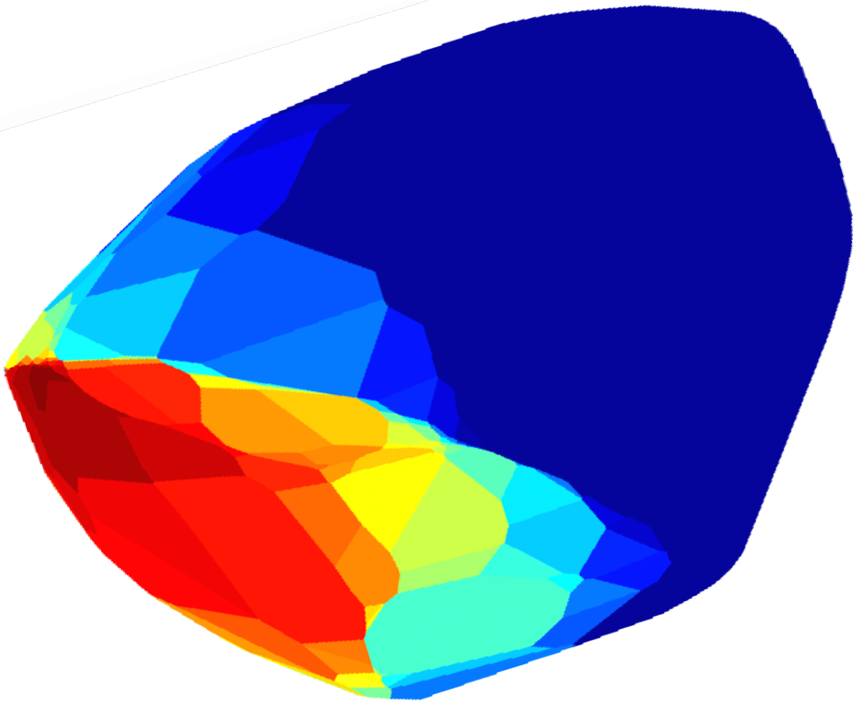
- Optical (V-band) measurement to obtain H magnitude
- Infrared measurement for the thermal emission



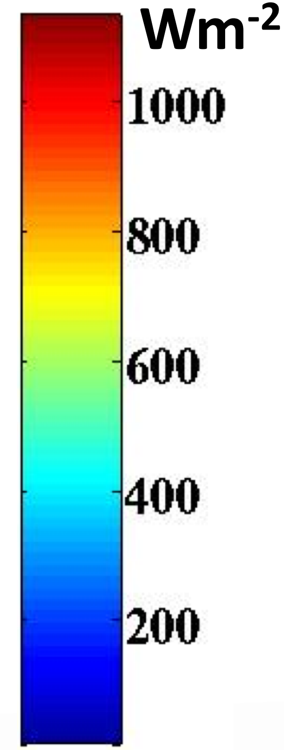




**Radiometric method:**

- Preferentially multi-band and/or multi-epoch IR measurements
- Using well-tested and calibrated thermal models (NEATM, TPM)
- Solving for size-albedo (with constraints on thermal properties)

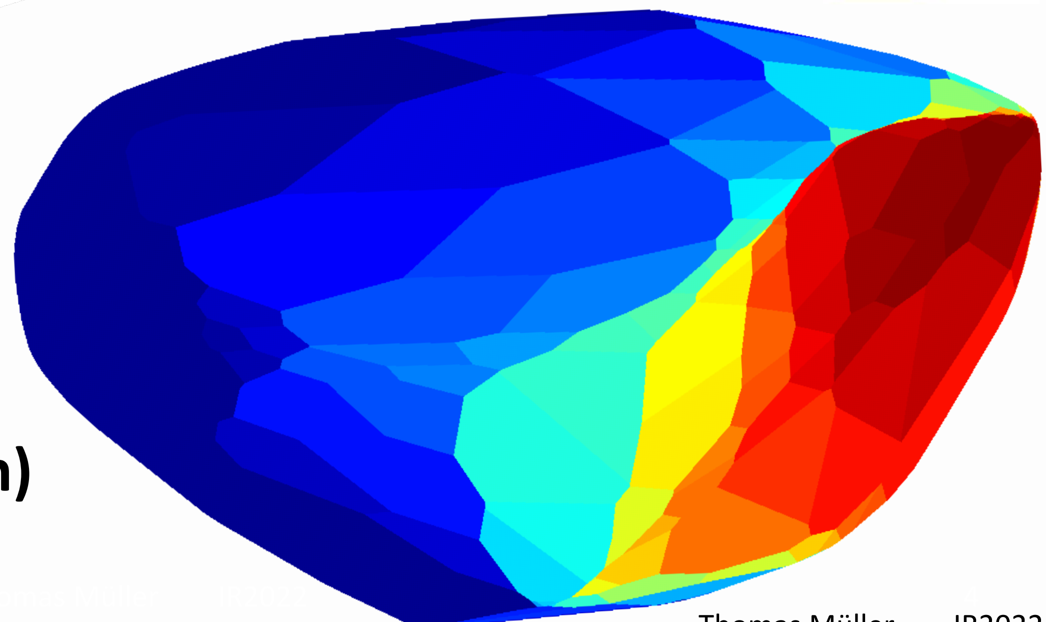


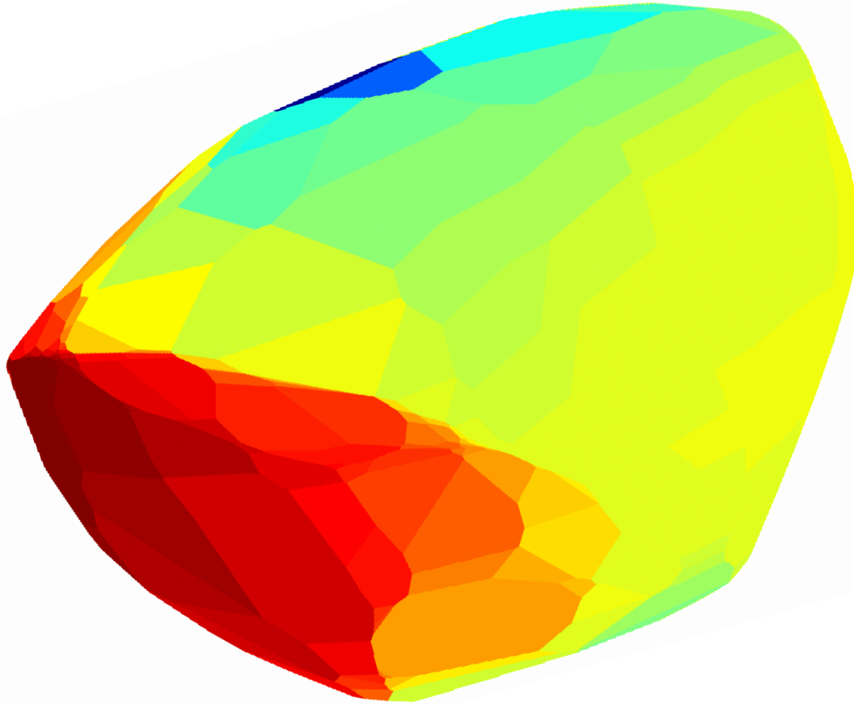
1st epoch at
α = +60.4°
(before opposition)



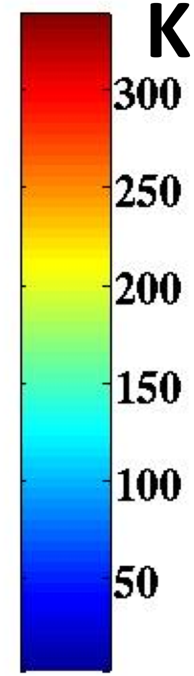

Apophis (potential OSIRIS-REx mission target)

2nd epoch at
α = -61.4°
(after opposition)



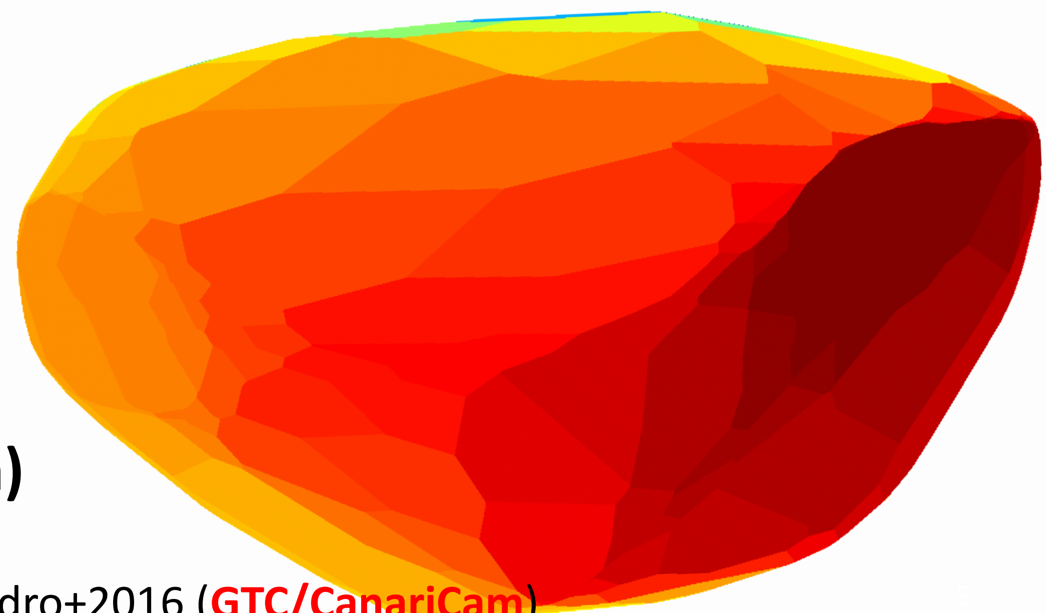


**1st epoch at**
**α = +60.4°**
**(before opposition)**

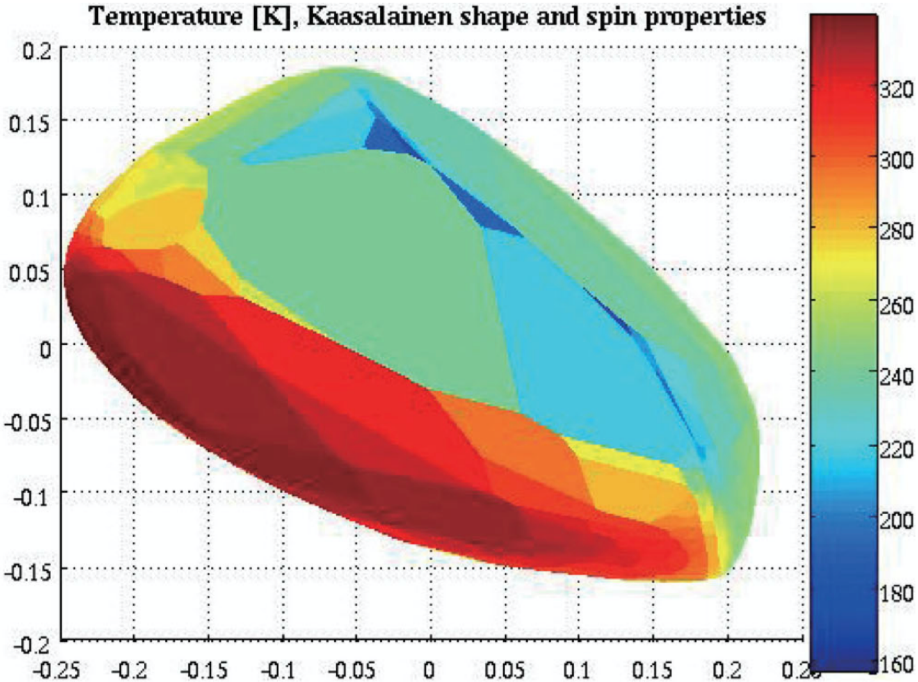


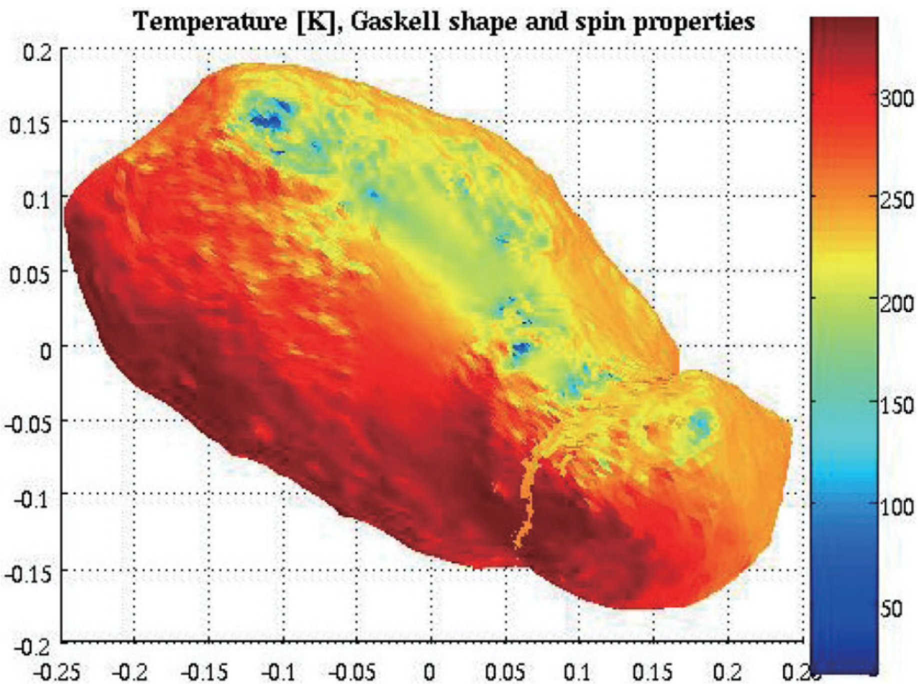

**Apophis (potential OSIRIS-REx mission target)**

**2nd epoch at**
**α = -61.4°**
**(after opposition)**



Müller+2014;Vokrouhlicky+2015; Licandro+2016 (**GTC/CanariCam**)




# Hayabusa mission target:

*Near Earth Objects, our Celestial Neighbors: Opportunity and Risk*
*Proceedings IAU Symposium No. 236, 2006*
*A. Milani, G.B. Valsecchi & D. Vokrouhlický, eds.*
doi:10.1017/S1743921307003316


## Itokawa: The power of ground-based mid-infrared observations

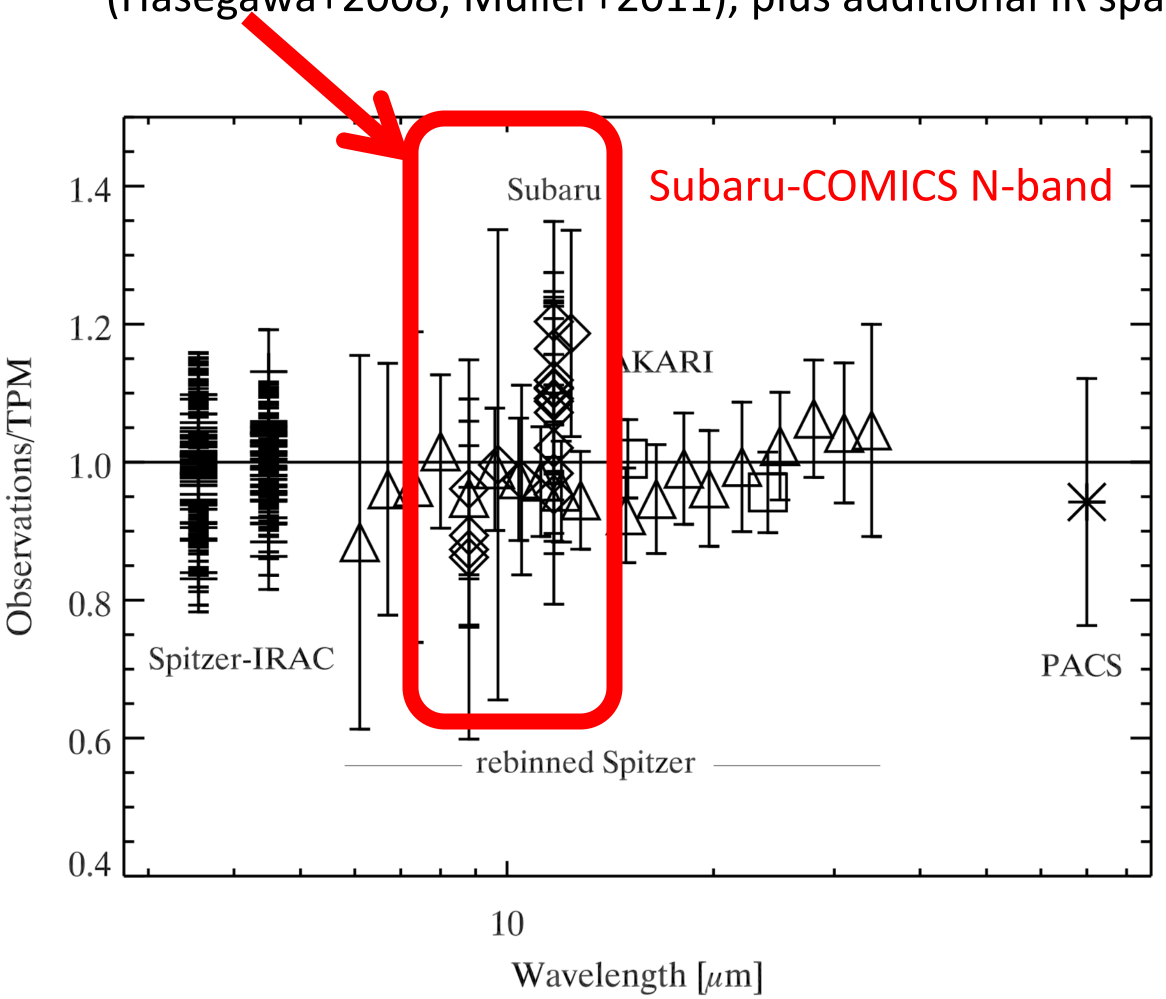
**Thomas G. Müller[1], T. Sekiguchi[2], M. Kaasalainen[3], M. Abe[4] and S. Hasegawa[4]**

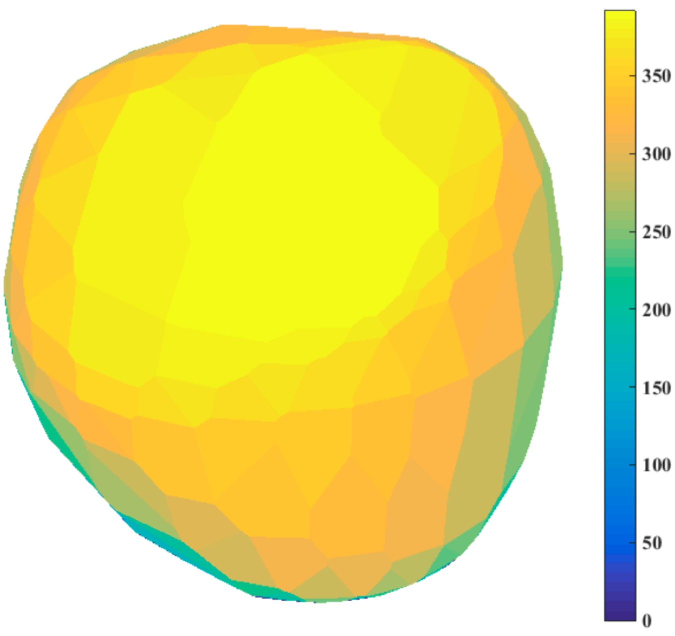
[1]Max-Planck-Institut für extraterrestrische Physik,
Giessenbachstraße, 85748 Garching, Germany;
tmueller@mpe.mpg.de

Thermal comparison between pre-mission (Müller+2005/2007) and in-situ study: "(25143) Itokawa: The power of radiometric techniques for the interpretation of remote thermal observations in the light of the Hayabusa rendezvous results" (Müller+2014):

- Excellent agreement of spin, shape, albedo, and thermal properties
- Volume-equivalent size prediction (based on thermal measurements) was within 2% of the true value!
- Ground-based IR data were taken with ESO's 3.6-m telescope + TIMMI2

162173 Ryugu (target of the JAXA Hayabusa-2 mission): pre-mission studies included ground-based Subaru-COMICS N- and Q-band observations (Hasegawa+2008; Müller+2011), plus additional IR space data (Müller+2017)

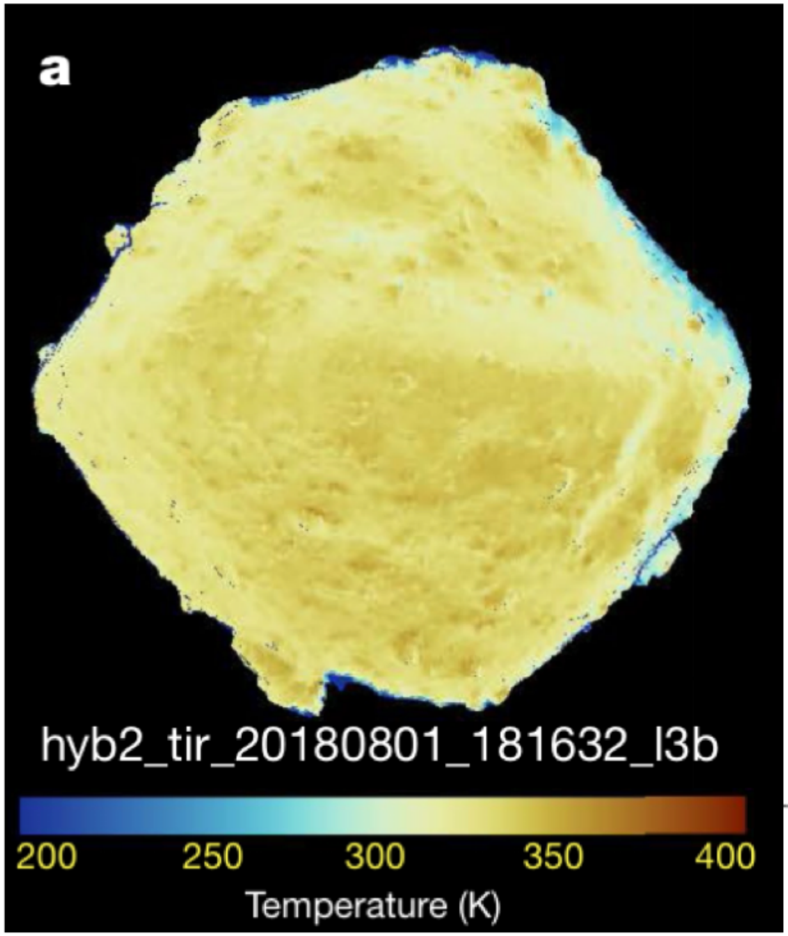


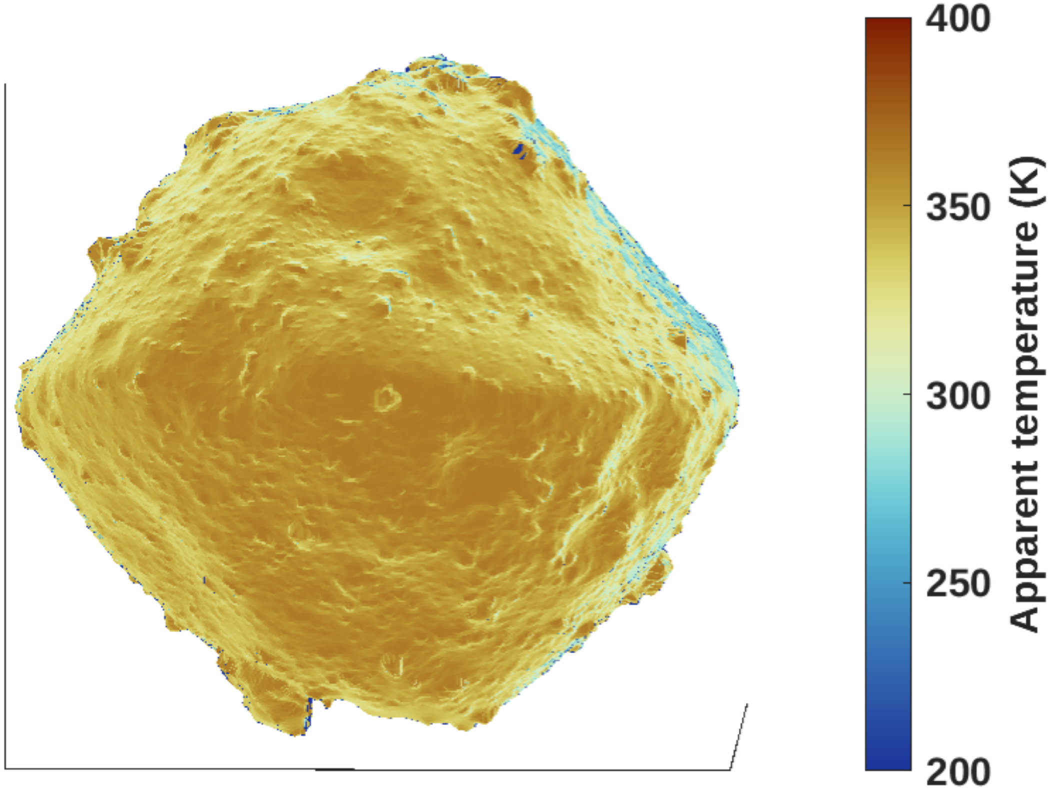

Müller+2017

# Near-Earth asteroid Ryugu

Hayabusa2-TIR 10-$\mu$m image (from 20 km distance), Okada+2020, Nature




Thermophysical model calculation, based on thermal properties derived from before mission (Wada+2018) and in-situ studies (Shimaki+2020)

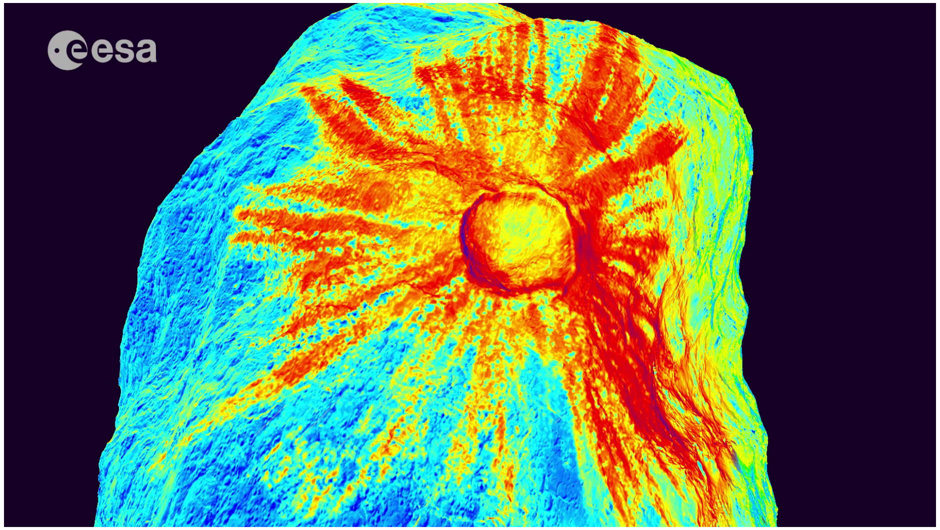



Müller+, in preparation

Including also Subaru-COMICS N-band

# NASA DART (launched: 2021) & ESA Hera mission (launch 2024) to double asteroid system Didymos/Dimorphos

- DART mission with impact Dimorphos in late Sep 2022 (planetary defence test to change Dimorphos' orbit); Hera will characterize the impact structure and the entire system in detail during 2026
- Characterization of system properties, including thermal inertia and surface roughness, with the help of mid-IR photometry and spectroscopy with **VLT-VISIR** in summer 2022 when the object comes close to Earth (PI: S. Green)
- Pre- and post-impact thermal IR studies (VISIR) in Sep/Oct 2022
- Study of the effects of the non-gravitational Yarkovsky force (orbit changes) and YORP torque (spin-axis)
- Thermal emission of impact dust cloud
- Monitoring of dust cloud after impact
- Constraints on dust properties
- Critical for the success of the mission
- Reference for later Hera thermal studies



# Mission target asteroids: thermal-IR characterization from ground

## Summary

- Thermal and physical characterization of  asteroids (size, albedo, spin-shape solutions, the sense of rotation, thermal & physical surface properties, surface temperatures, etc.)
- Important input for orbit and spin evolution (Yarkovsky, YORP, B-YORP non-gravitational forces/effects)
- Monitoring of ejected dust clouds or trails
- Rotational, seasonal, orbital flux changes are indicative of surface properties
- Linking in-situ (small-scale) results to remote (global) measurements, as ground-truth for objects without in-situ data
- Near-Earth asteroid observations are often time-critical and/or require fast turnaround times (DDT channel), special observing techniques (fast apparent motion, at small solar elongation), special care in data reduction & calibration