Hera Radio Science Experiments through Ground-Based and Satellite-to-Satellite Doppler tracking

Paolo Tortora[1], Marco Zannoni[1], Edoardo Gramigna[1], Riccardo Lasagni Manghi[1], Sebastien Le Maistre[2], Ryan S. Park[3], Giacomo Tommei[4], Ozgur Karatekin[2], Etienne Le Bras[5], Paolo Martino[6], Paolo Concari[6], Michael Kueppers[7], Patrick Michel[8], Ian Carnelli[9]

1 University of Bologna, Department of Industrial Engineering, Forlì, Italy (paolo.tortora@unibo.it)
2 Royal Observatory of Belgium, Brussels, Belgium
3 CalTech/ Jet Propulsion Laboratory, Pasadena, CA, USA
4 Università di Pisa, Pisa, Italy
5 GomSpace Luxembourg S.à.r.l., L-4370 Belval, Luxembourg
6 ESA/ESTEC, 2200 AG Noordwijk, The Netherlands
7 ESA/ESAC, Villanueva de la Cañada (Madrid), Spain
8 Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France
9 ESA/HQ, 75738 Paris Cedex 15, France

The DART and Hera Missions

AIDA (Asteroid Impact and Deflection Assessment):

- International collaboration supported by ESA and NASA to assess the feasibility of the **kinetic impactor technique** to deflect an asteroid.

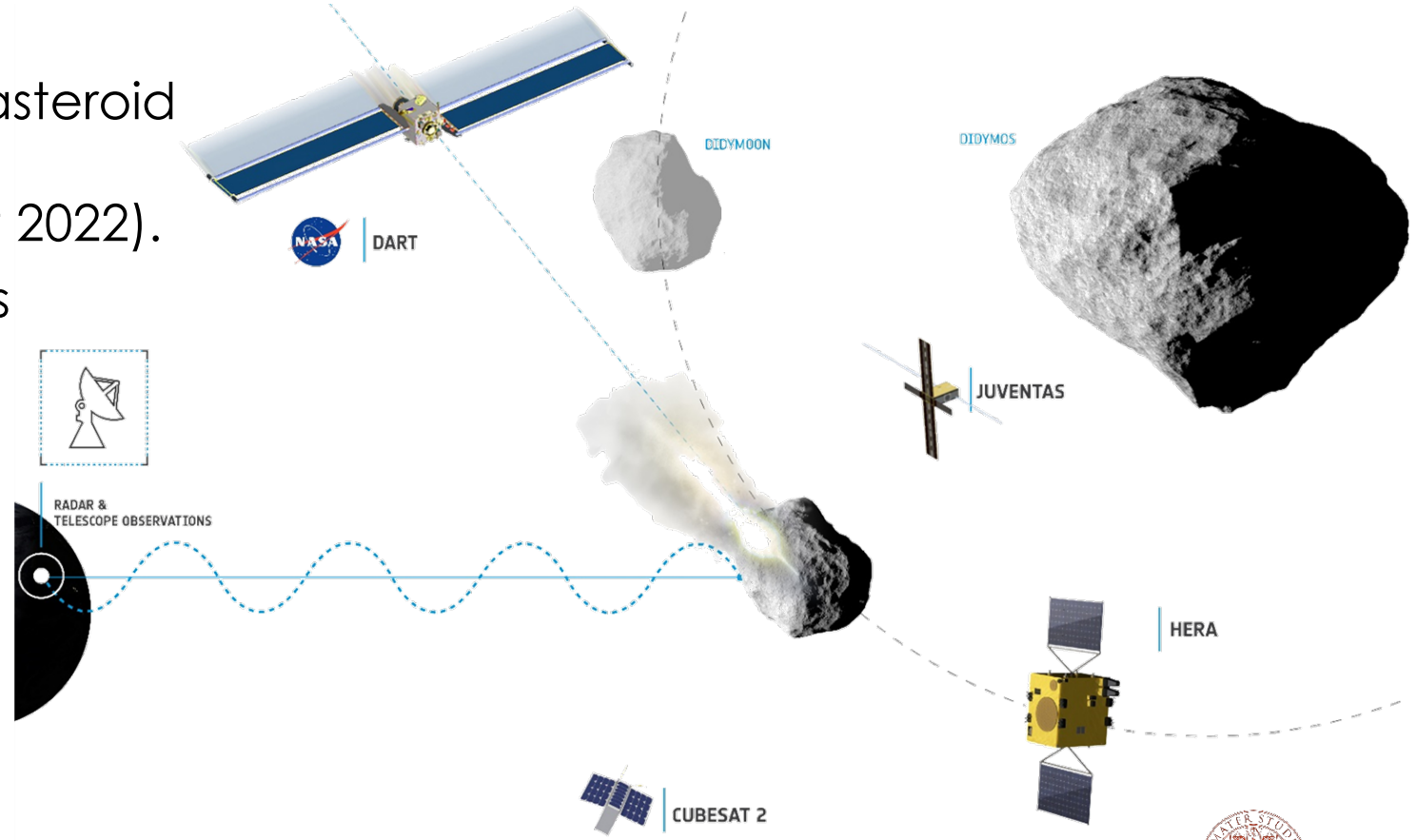
Target: **Didymos**+**Dimorphos** binary asteroid

NASA/DART: impact Dimorphos (Oct 2022).

- Measure change of mutual orbit's period from ground telescopes.

ESA/Hera: arrive to Didymos in 2024.

- Detailed post-impact survey of the asteroid.
- Release 2 cubesats: Juventas and Cubesat-2 (TBD).



Hera Gravity Science Experiment

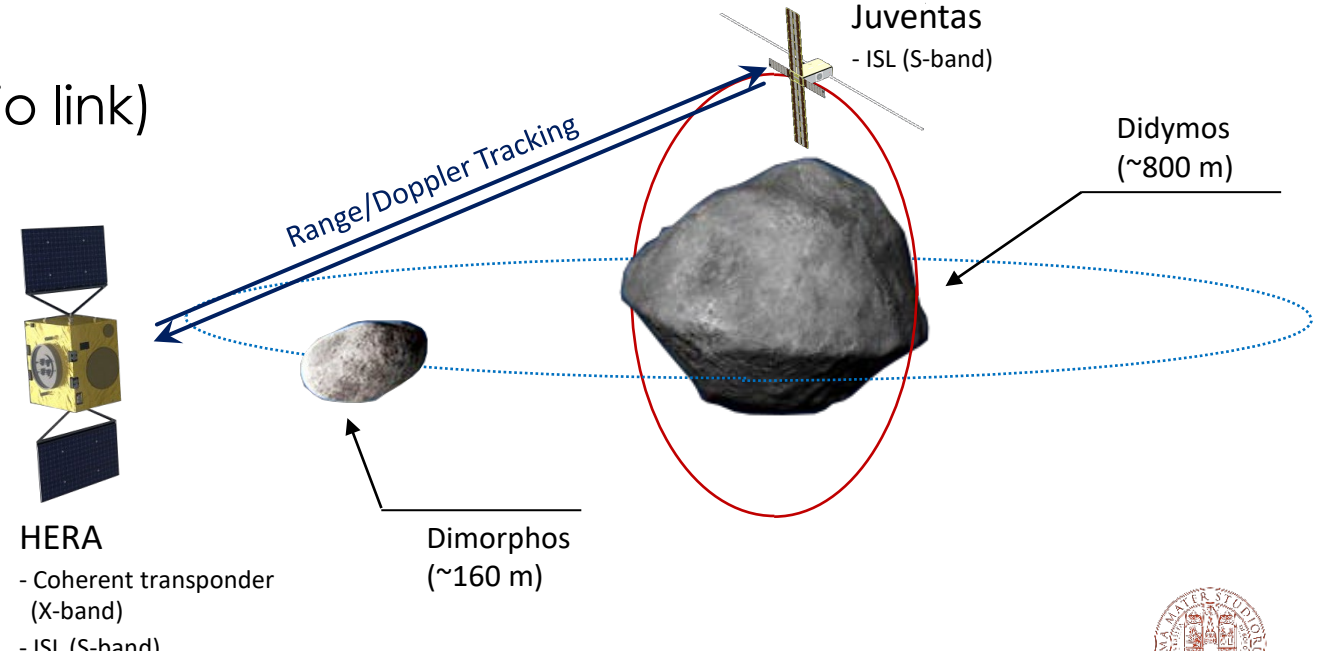
Experiment objectives:

- Measure the asteroids' gravity to constraint their interior structure.
- Characterize the post-impact mutual orbit and rotational states.

Physical parameters estimated reconstructing the trajectory of Hera and Cubesats.

Measurements:

- **Ranging** and **Doppler** (Hera-Earth radio link)
- **OPNAV**: Hera optical images.
- **Inter-Satellite Link (ISL)**
  (Hera-Cubesats radio link)



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Numerical Simulations

The experiment expected accuracy were obtained through **numerical simulations** of the orbit determination of Hera and Juventas in the Didymos system.

Simulated scenario:

- Hera + Juventas (Doppler):
  - Hera-Earth Range+Doppler and Optical
  - Hera-Juventas ISL Range+Doppler
- Duration:
  - 2.5 months after cubesat deployment
    - 1 month Hera DCP and Juventas SSTO 3.3 km altitude
    - 1 month Hera COP and Juventas SSTO 2.0 km altitude
    - Last 7 arcs Hera COP, without ISL

DCP = Detailed Characterization Phase
COP = Close Observation Phase
SSTO=Sun Synchronous Terminator Orbits

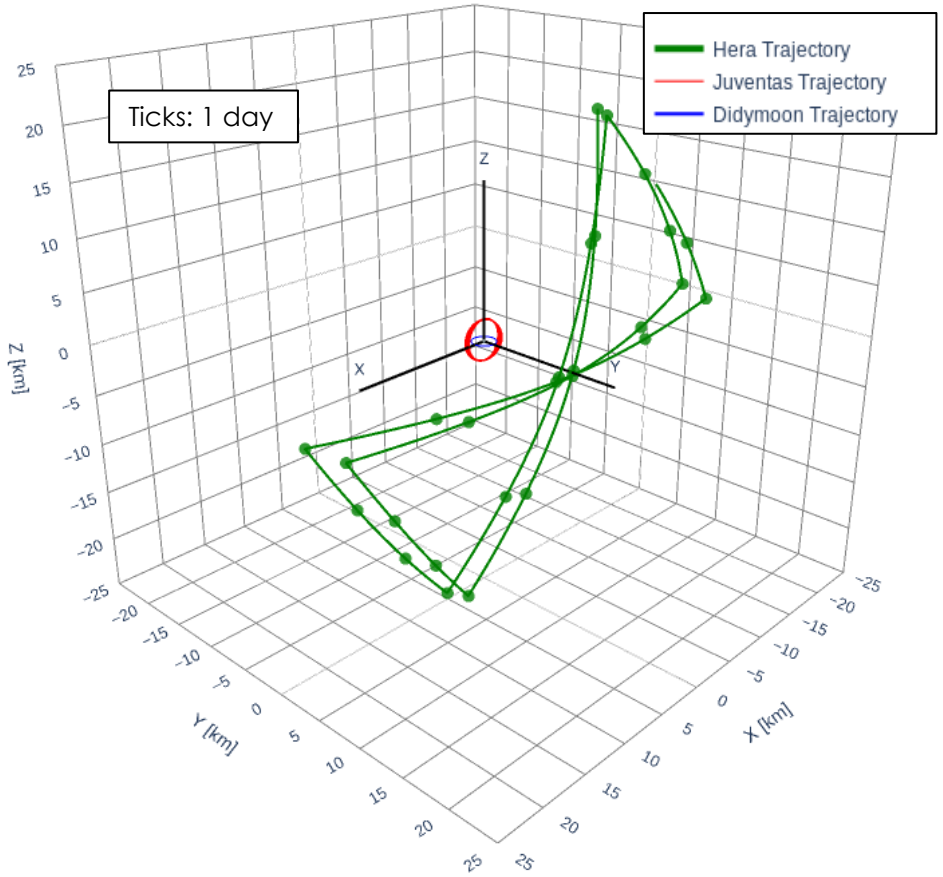
Hera Trajectory and Observables Assumptions

Hera trajectory: series of **hyperbolic arcs** connected by impulsive maneuvers (Rosetta concept)

- **All trajectory arcs** are used for radio science.
- **No thruster maneuvers** during arcs (wheel off-loading).

Measurements assumptions:

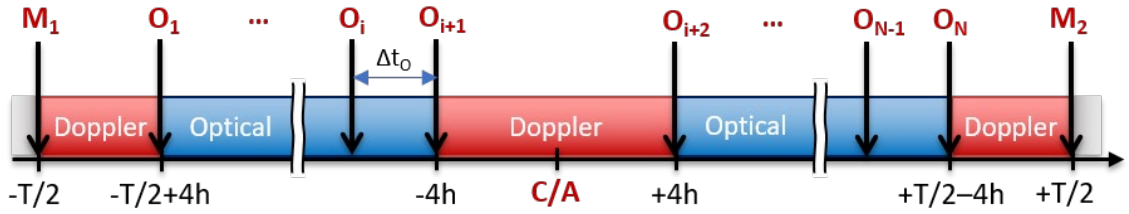
- Radio tracking around the maneuvers and near C/A.
- Optical measurements acquired outside tracking (maximum Sun phase angle: 60 deg).



HERA distance from Didymos:
Min. : ~10 km
Max. : ~23 km

Z=Dimorphos Orbit-Normal
Y=Vernal Equinox

Single Arc Timeline



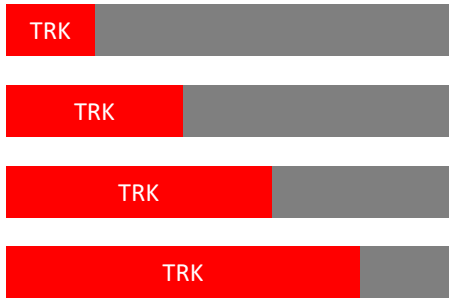
Juventas Trajectory and Observables Assumptions

Juventas trajectory: **SSTO** at 3.3 and 2.0 km altitudes from Didymos

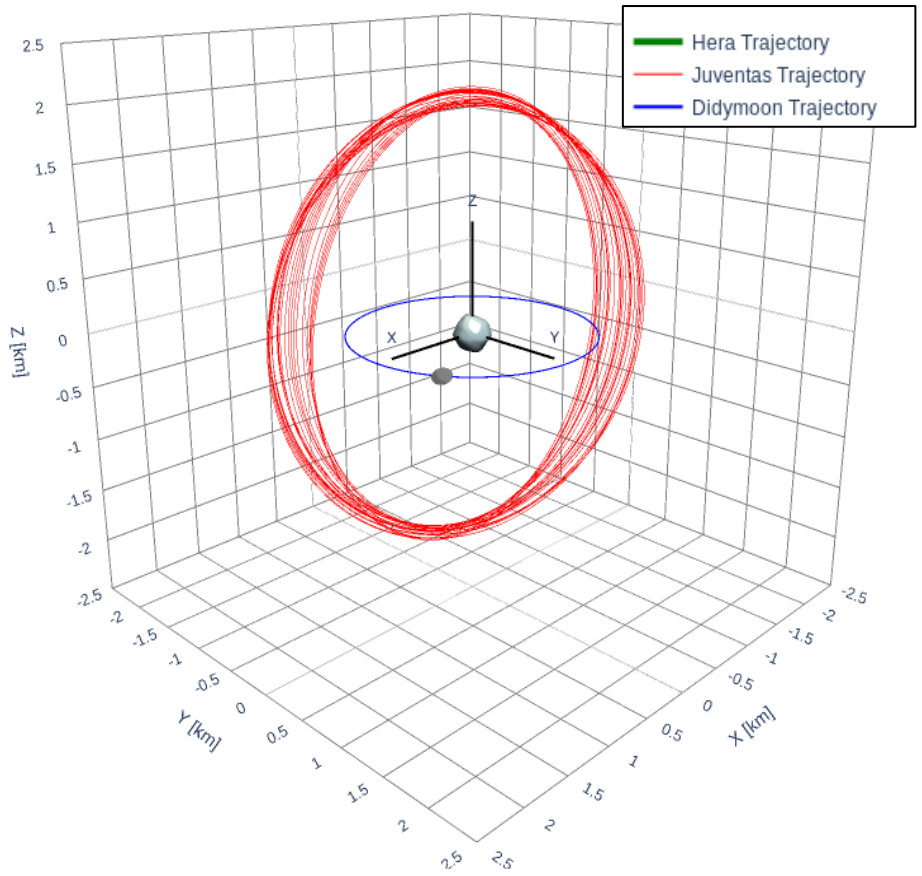
- **No thruster maneuvers** during Hera arcs. (3-4 days)

Measurements assumptions:

- **Continuous ISL** with scheduled Duty Cycle (DC) (quasi-omnidirectional S-band patch antennas):
  - DC 20%: tracking 1 min/5 min
  - DC 40%: tracking 2 min/5 min
  - DC 60%: tracking 3 min/5 min
  - DC 80%: tracking 4 min/5 min



- **ISL Ranging noise**: 50 cm.
- **ISL Doppler noise**: 50 microns/s (60 s integration time).



Z=Dimorphos Orbit-Normal
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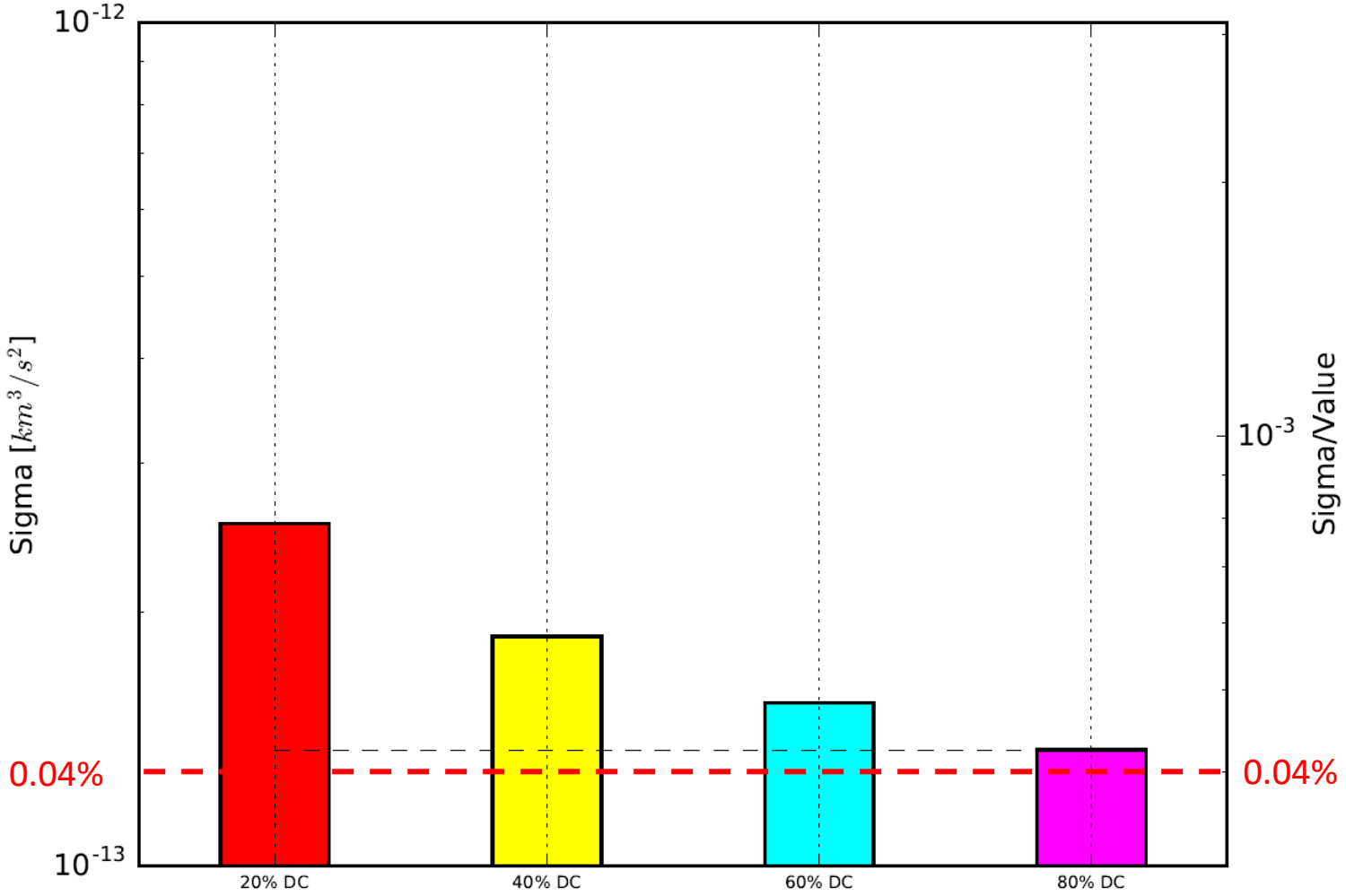
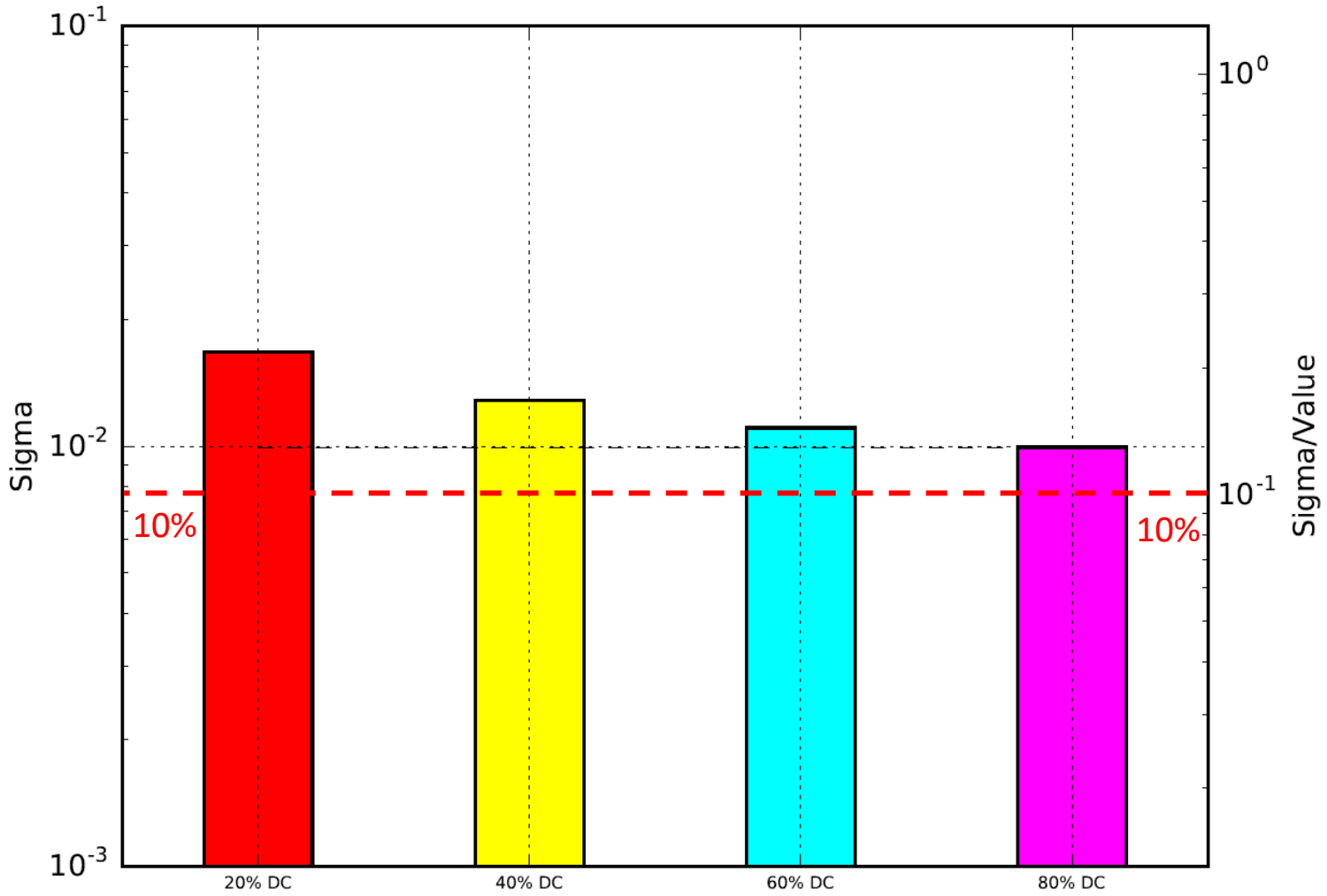
Results: Dimorphos mass

- In this simulation scenario Dimorphos' mass can be estimated with a formal uncertainty between 0.04-0.09%.



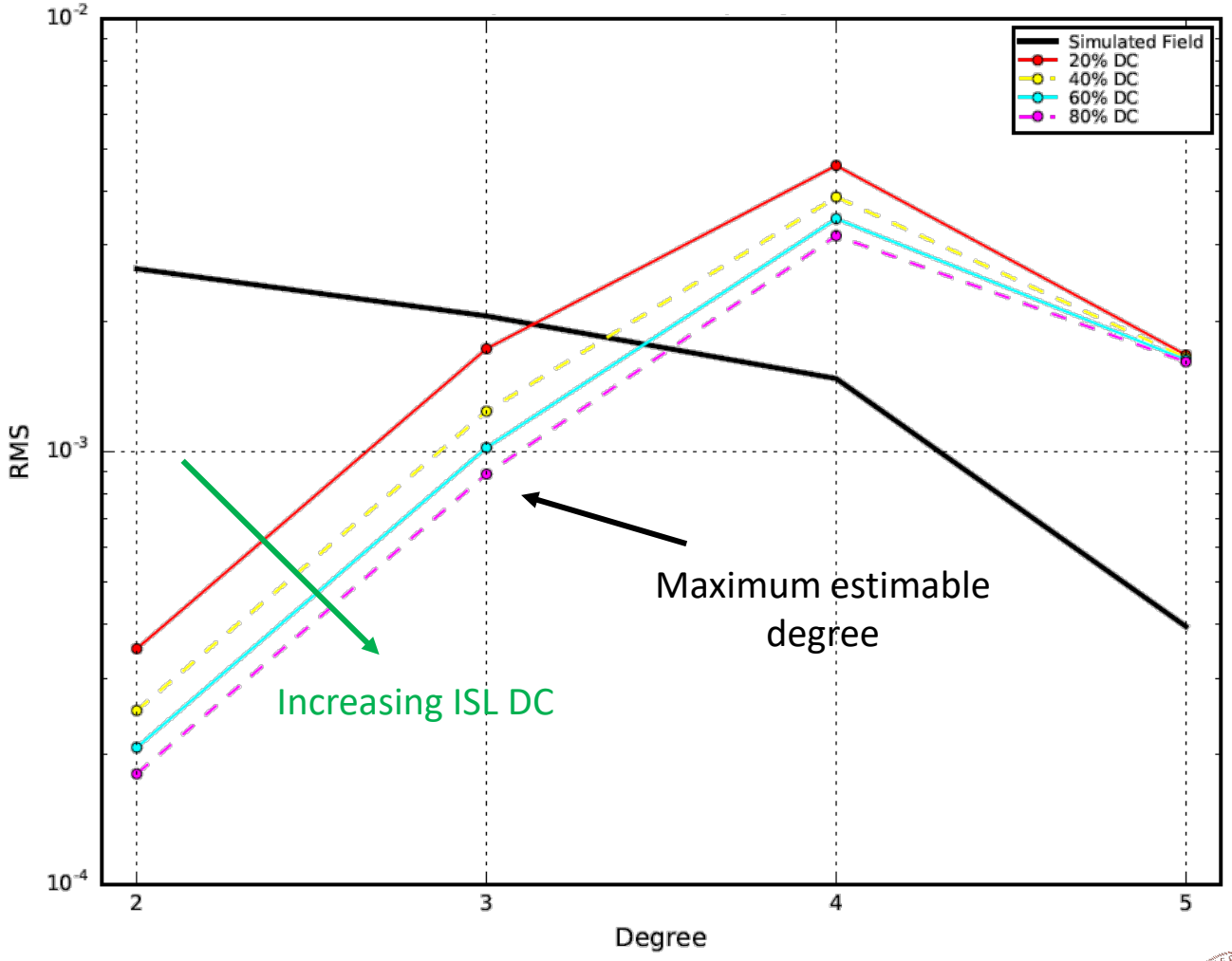
Results: Dimorphos J_2

- Hera-only does not allow to observe J_2.
- The ISL allows to observe J_2 with a formal uncertainty of 10-11%.
- The Duty Cycle is less important



Results: Didymos gravity field

- Hera only does not allow to estimate Didymos' extended gravity field
- ISL Ranging+Doppler allows to estimate degree 2 and 3
- Degree 4 would be observable only by exploiting lower altitudes (SSTO 1.5 km)



Summary and Future Work

- The Hera gravity science experiment at Didymos **proves feasible**, using realistic assumptions on the technological capabilities of the space and ground segment.
- **Optical Navigation** (OPNAV) images are essential to estimate Hera's trajectory.
- **Hera-Juventas ISL Doppler** improves the overall accuracies and enables to estimate the extended gravity field of Didymos and (marginally) Dimorphos:
    - Didymos max observable degree: 3 (20%-80% DC).
    - Dimorphos: J_2 uncertainty 10-11% (20%-80% DC).
- **Future work:**
    - Simulate with detailed operational constraints.
    - Add Milani Cubesat.
    - Better characterization of ISL performance.
    - Improve modeling of the Didymos system (F2RBP, BYORP, tides).

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Thank you!

paolo.tortora@unibo.it

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Near Earth Object Modelling And Payloads for Protection

NEO-MAPP

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