Numerical modeling of interactions of a lander with low-gravity asteroid regolith surfaces

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INTRODUCTION

- **Hayabusa2** (JAXA) will reach the asteroid Ryugu in 2018 and release the lander **MASCOT** (DLR/CNES) on the asteroid surface to perform various in-situ measurements [1].
- **MASCOT's behavior at landing** will allow us to derive unobservable and non-directly measurable properties of the regolith (e.g., depth, elasticity), as well as to build a large database of possible outcomes in support of landing site selection.
- A first campaign of numerical simulations of the lander's first bounce was carried out by Maurel et al. (submitted). Here, **we investigate a new part of the parameter space and take the analysis further by looking at the fate of the lander after its first bounce**.

RESULTS

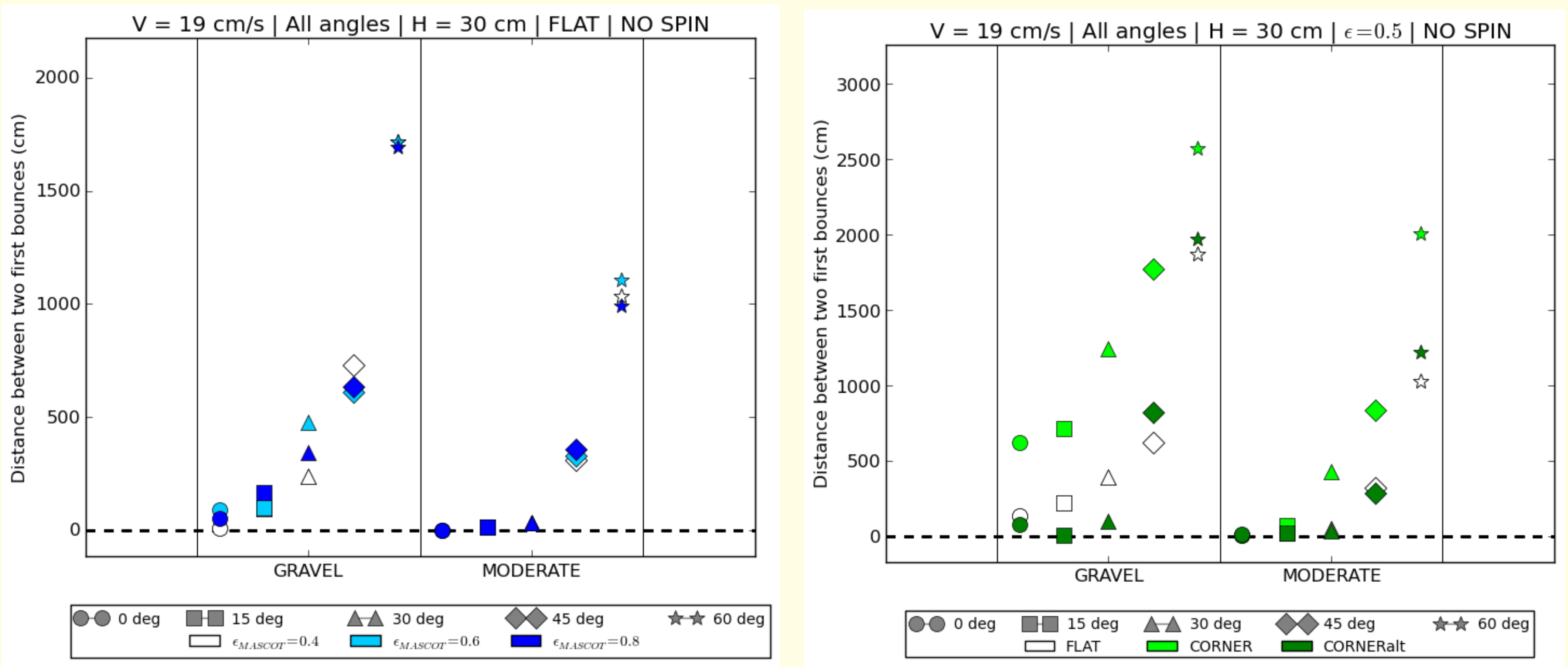

Figure 2: Distance between first and second impacts of MASCOT as a function of regolith frictional properties, first impact angle and MASCOT's structural coefficient of restitution

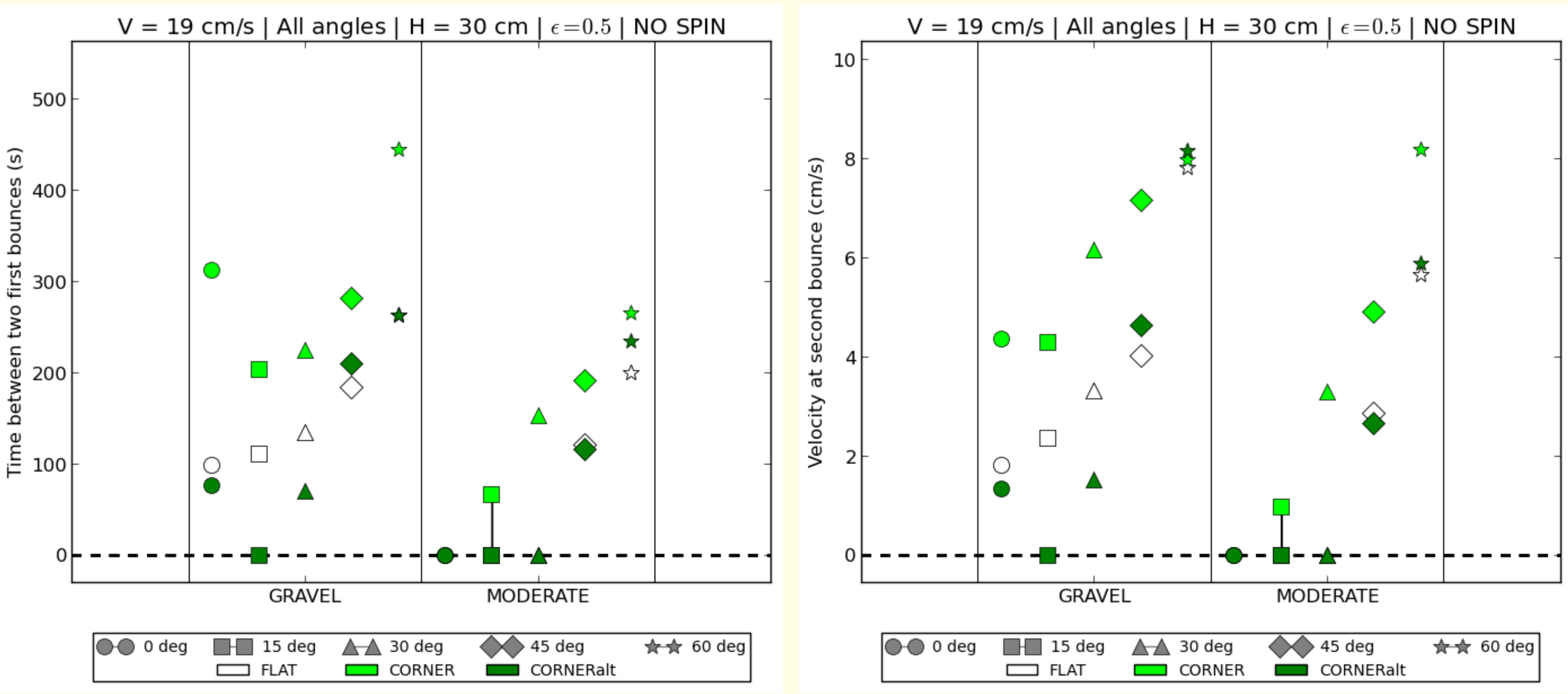

Figure 2: Time between first and second impacts and MASCOT's speed at second impact as a function of regolith frictional properties and first impact angle

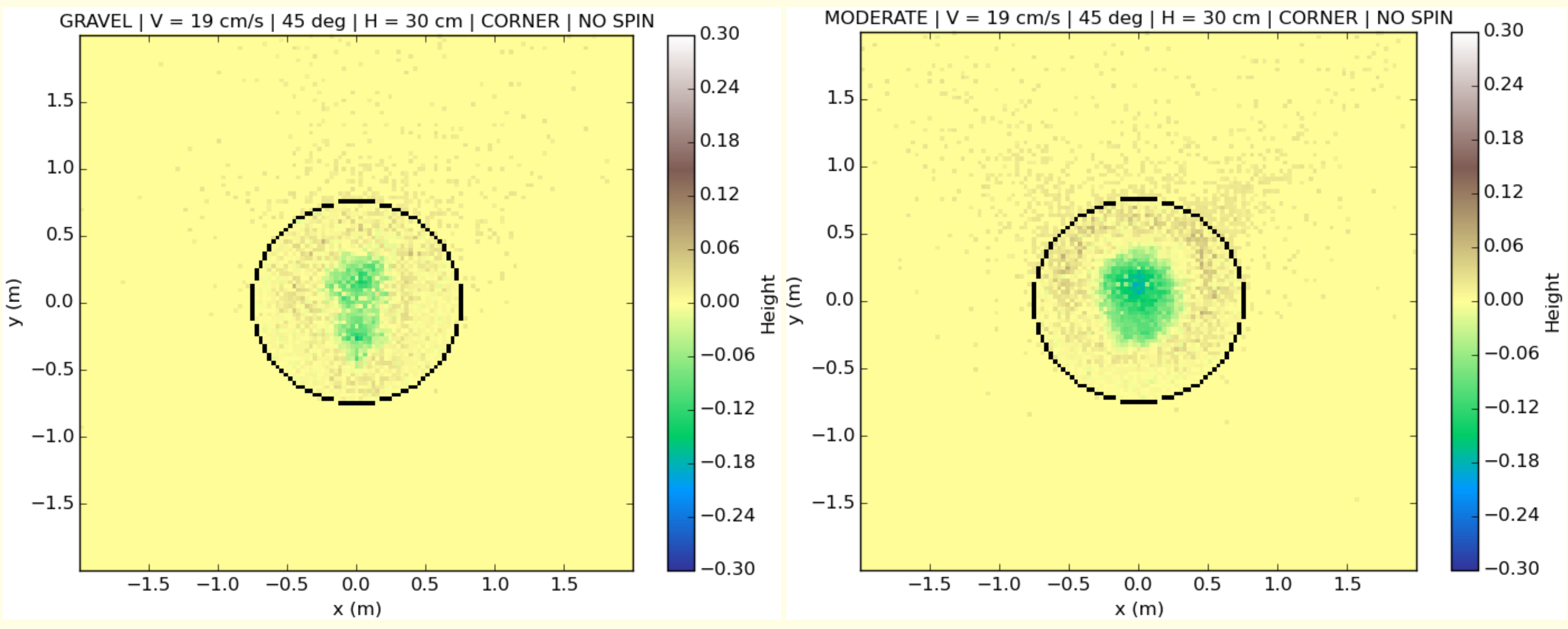

Figure 3: Traces left by MASCOT in the regolith after the first impact, for gravel-like (left) and moderate friction (right) parameters

METHOD

- Simulations are performed with the *N*-body code ***pkdgrav***, using the soft-sphere discrete element method (**SSDEM**) [2].

Parameters	Values
Uniform Gravity	2.5×10^{-4} m/s²
Impact Speed	16 cm/s
Grain Size Distribution	Gaussian (1-cm mean)
Friction Parameters	Gravel-like or Moderate
Granular Bed Depth	15, 30 or 40 cm
Impact Angle	0, 15, 30, 45 or 60°
MASCOT's Orientation	On a Flat face or a Corner
MASCOT's Coefficient of Restitution	0.4, 0.6 or 0.8

Table 1: Simulation parameters

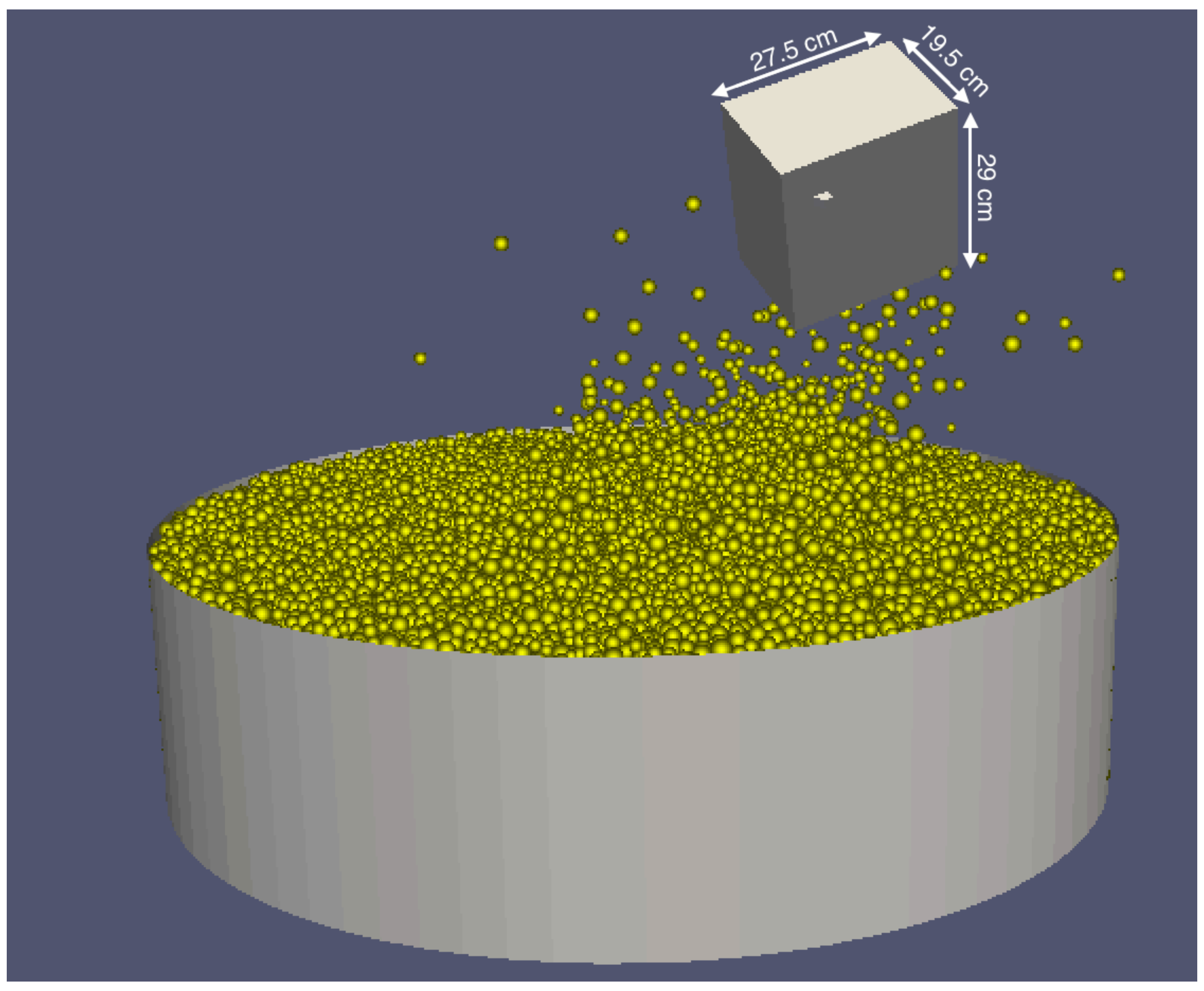

Figure 1: Snapshot of a simulation of MASCOT interacting with the regolith

MAIN OUTCOMES

- A 33%-difference on MASCOT's structural coefficient of restitution has little impact on MASCOT's behavior.
- **The more grazing the first impact, the larger the distance MASCOT travels** and **the longer the time between the two first impacts**. The largest distances and times are obtained with a 15-cm depth and MASCOT landing on a corner.

	15 cm	30 cm	40 cm
Traveled distance	40-50 m	25 m	25-30 m
Time	750 s	400-450 s	450-500 s

Table 2: Maximum distance traveled by MASCOT and time between the two first impacts as a function of regolith bed's depth

- **The strongest bounces are obtained with a gravel-like regolith**. In this case, **traces** left in the regolith bed are **smaller and shallower**, and the **quantity of ejecta is lower**.
- This kind of simulations can be used for asteroid deflection methods including the deployment of a lander on the target, as was originally planned in the Asteroid Impact Mission (AIM) studied at ESA.

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References: [1] Ho, T.M. et al. (2016) Space Sci. Rev., doi:10.1007/s11214-016-0251-6. [2] Schwartz, S. R. et al. (2012) Granular Matter, 14, 363-380.