A NETWORK OF IMMINENT IMPACTOR SENTINELS

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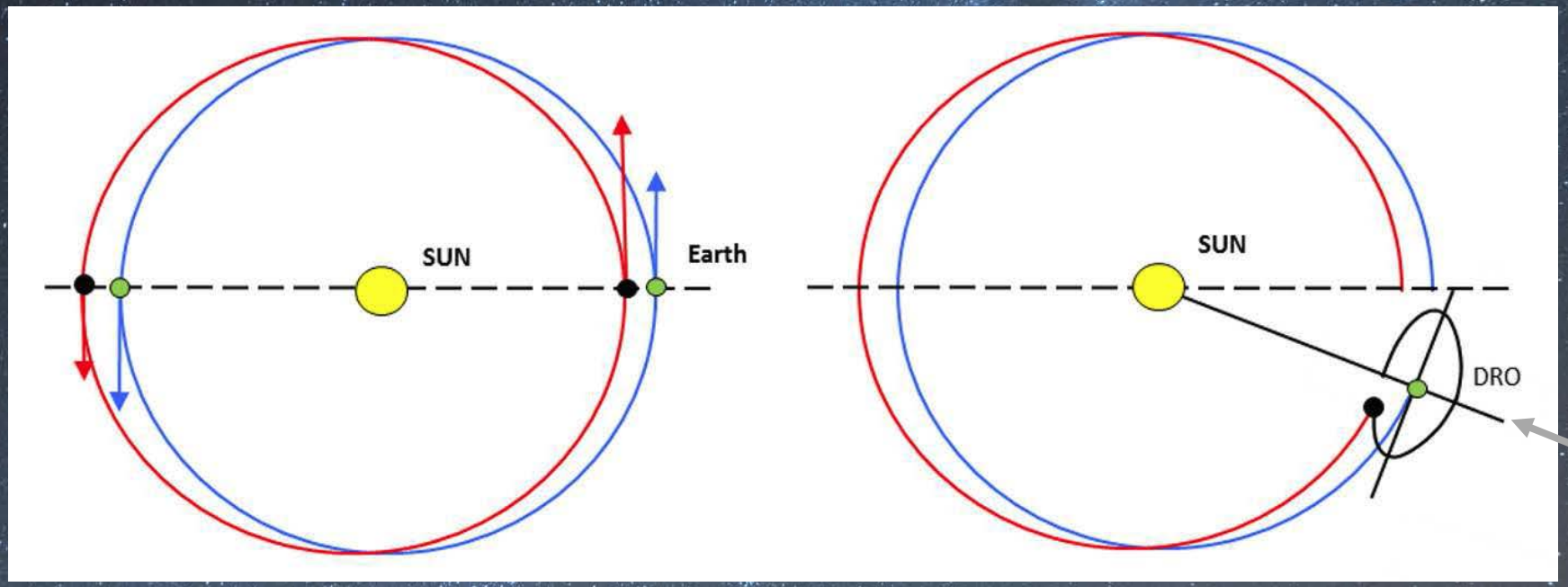
DRO - DISTANT RETROGRADE ORBITS

DRO are a family of periodic orbits in the restricted three-body problem. When applied to the Earth-Sun case these peculiar orbital configurations result from the combination of the Earth's motion around the Sun and that of a body of negligible mass having the same orbital period of the Earth but a slightly higher value of the eccentricity.

As seen from the Earth (rotating frame) the body appears then to move on a retrograde orbit around our planet.



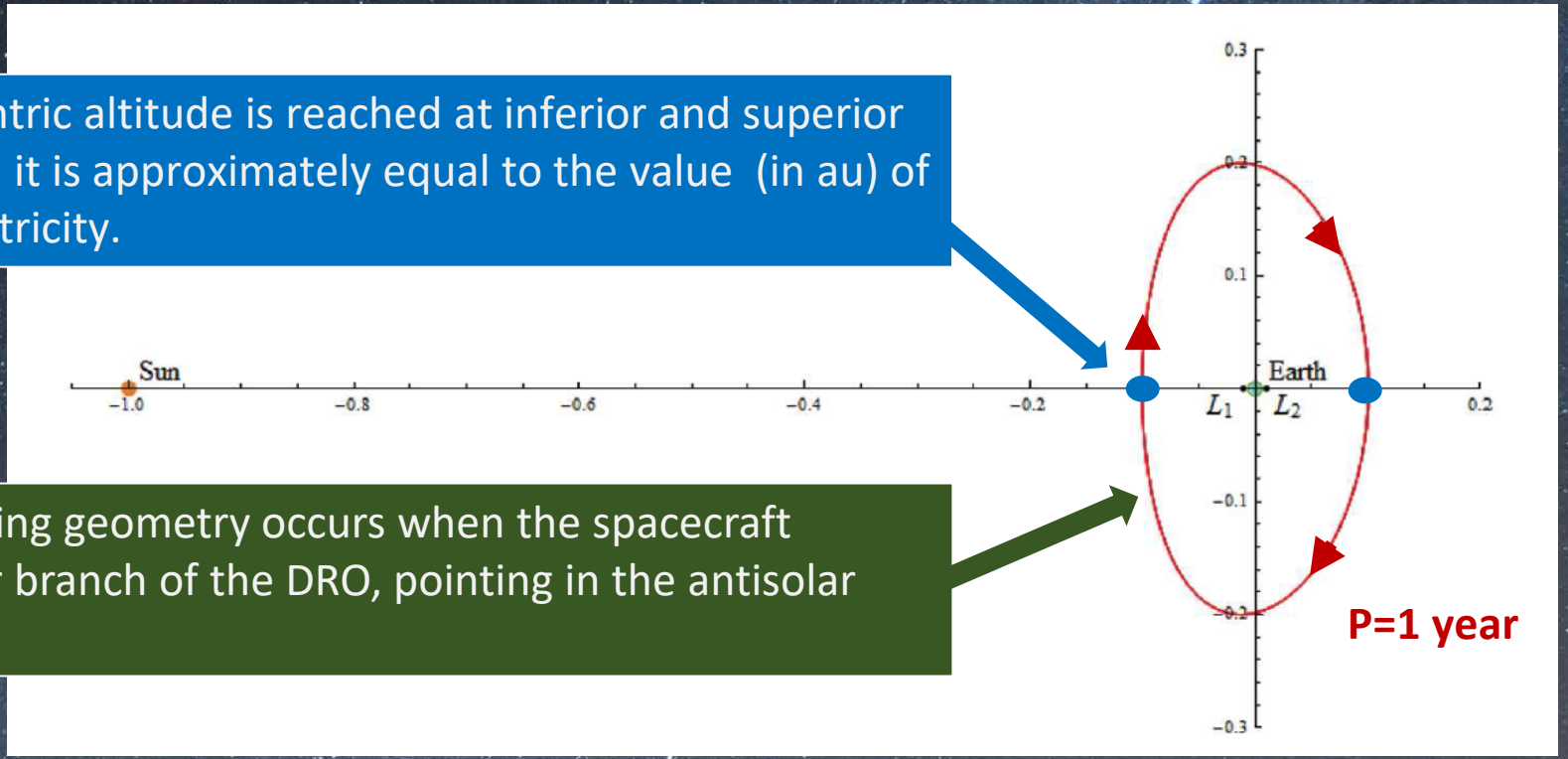
Hénon, M.: *Numerical Exploration of the Restricted Problem -Hill's Case: Periodic Orbits and Their Stability.* Astronomy and Astrophysics, 1, pp. 223–238, 1969

DRO AND PLANETARY DEFENCE

Planetary Defence could benefit of a spacecraft constellation in DRO because of the favourable phase angle when observing NEOs approaching the Earth

minimum geocentric altitude is reached at inferior and superior conjunctions and it is approximately equal to the value (in au) of the orbital eccentricity.

favurable observing geometry occurs when the spacecraft transits the inner branch of the DRO, pointing in the antisolar direction



Valsecchi G.B., Perozzi E., Rossi A.: *A space mission to detect imminent Earth impactors,* in Highlights of Astronomy, Vol. 10, issue No. H16, 2015.

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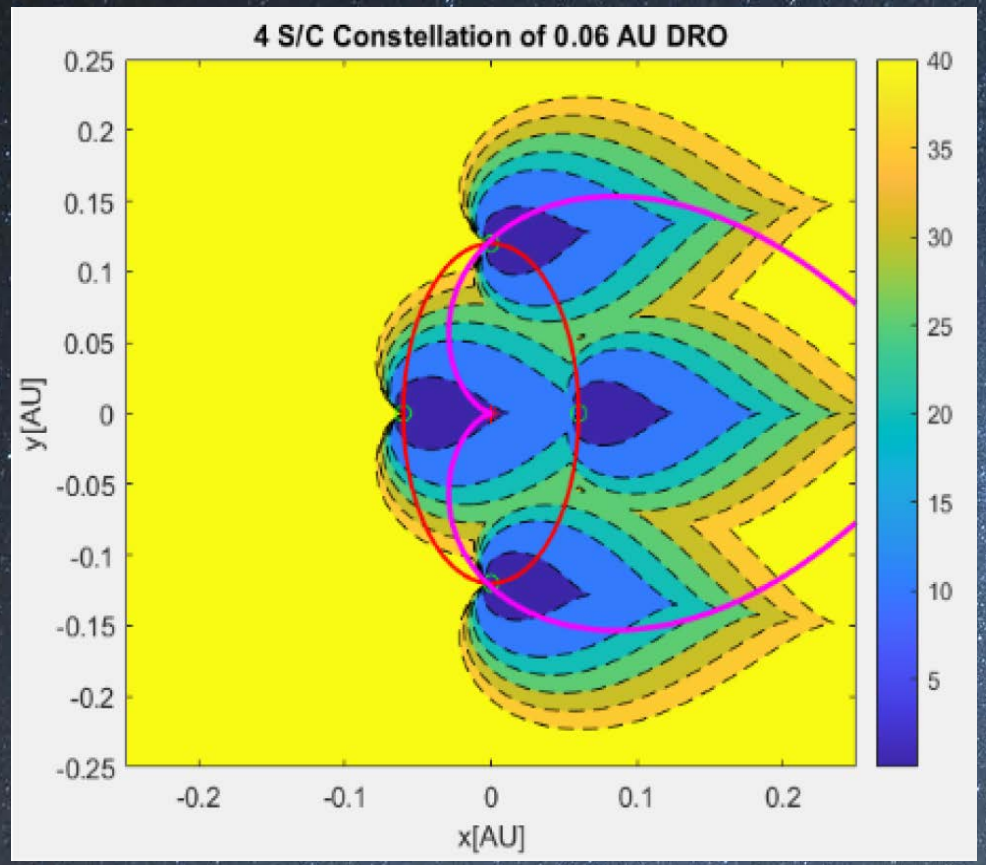
DISTANT RETROGRADE ORBITS AND IMMINENT IMPACTORS



DRO exhibit clear advantages for space missions design as they allow a spacecraft to access interplanetary space yet remaining always in the vicinity of our planet and at distances much larger than the Lagrangian points L1 and L2

Therefore DROs provide an alternative scenario for the detection from space of the “imminent impactors” i.e. small asteroids (<50m yet causing significant ground damage).

It has been shown that a 0.06au altitude DRO constellation ensures 5 days warning time, compatible with some typical civil protection alert timespan

Martinez Mata A., Perozzi E., Ceccaroni M.: *Addressing Imminent Impactors Threat From Distant Retrograde Orbits (DRO).* Paper IAC–22–D9.2.8 / ID 71048, 2022.

THE **LICIAcube** AND **ARGOMOON OPPORTUNITIES**

Credits:ASI/NASA

LICIAcube and ArgoMoon are 6U cubesats realized by Argotec under ASI contracts and represented an important in-flight test for cubesats to be employed for lunar and interplanetary missions.

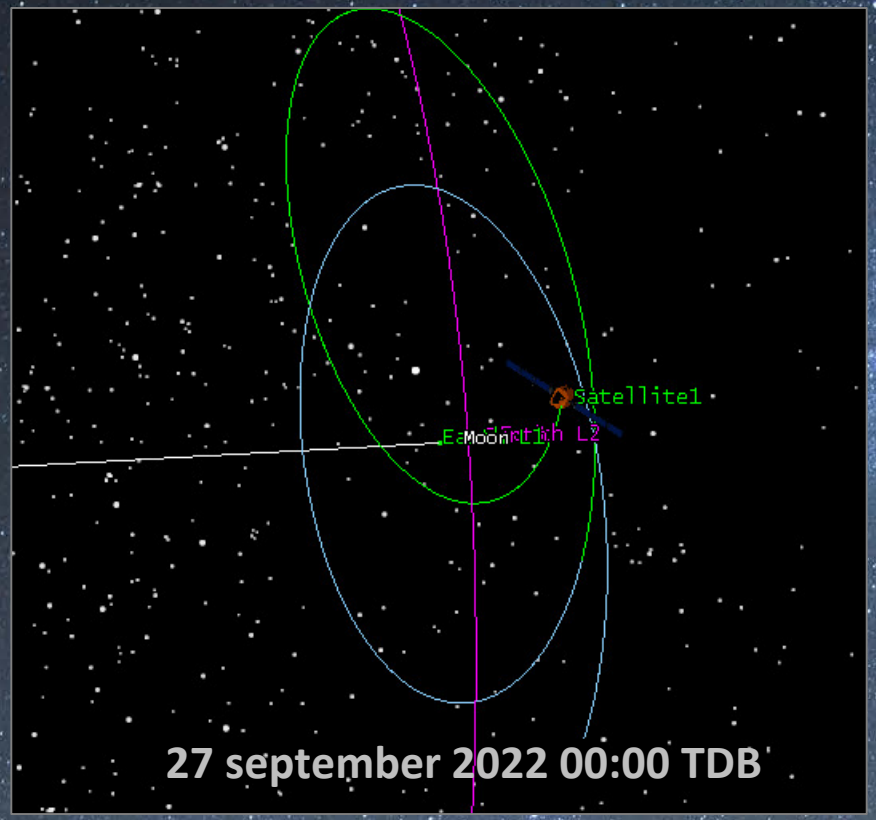
The former has successfully imaged the plume generated by the impact of the US DART spacecraft on asteroid Dimorphos, the latter has been raleased during the Artemis-1 flight and performed several lunar flybys before getting into interplanetary space.

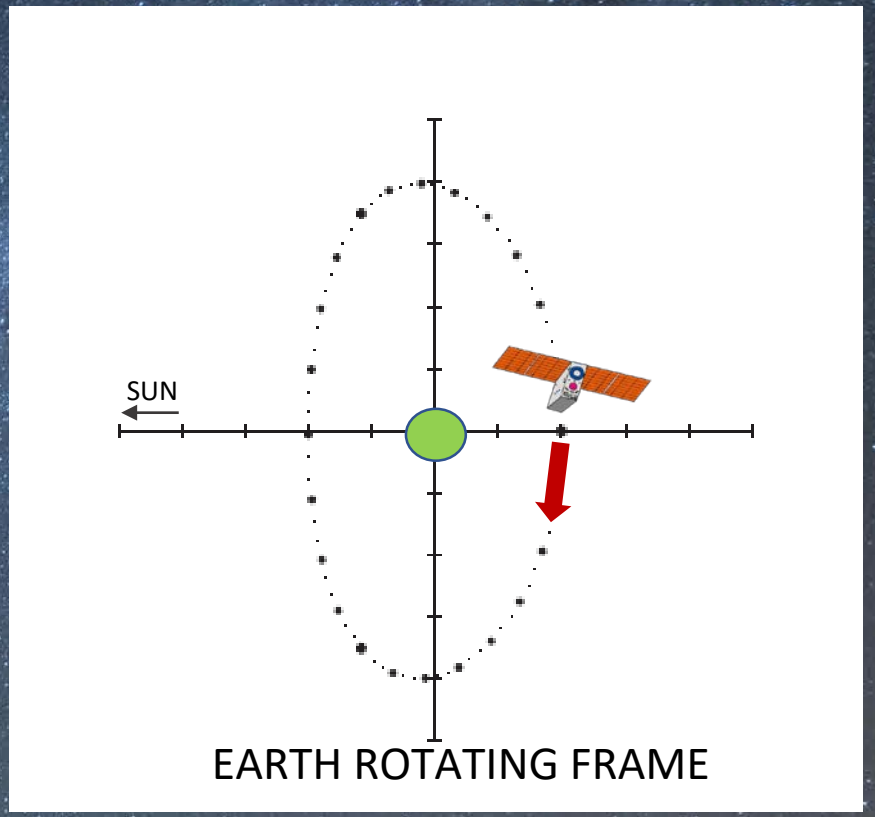
In both cases extended missions were envisaged and Planetary Defence applications were therefore taken into consideration

DISTANT RETROGRADE ORBITS AND LICIAcube

At DART impact epoch, the LICIAcube Earth phasing turned out to be compatible with a DRO configuration.

Numerical intergrations have shown that indeed LICIAcube followed an orbital path closely resembling that of a DRO.

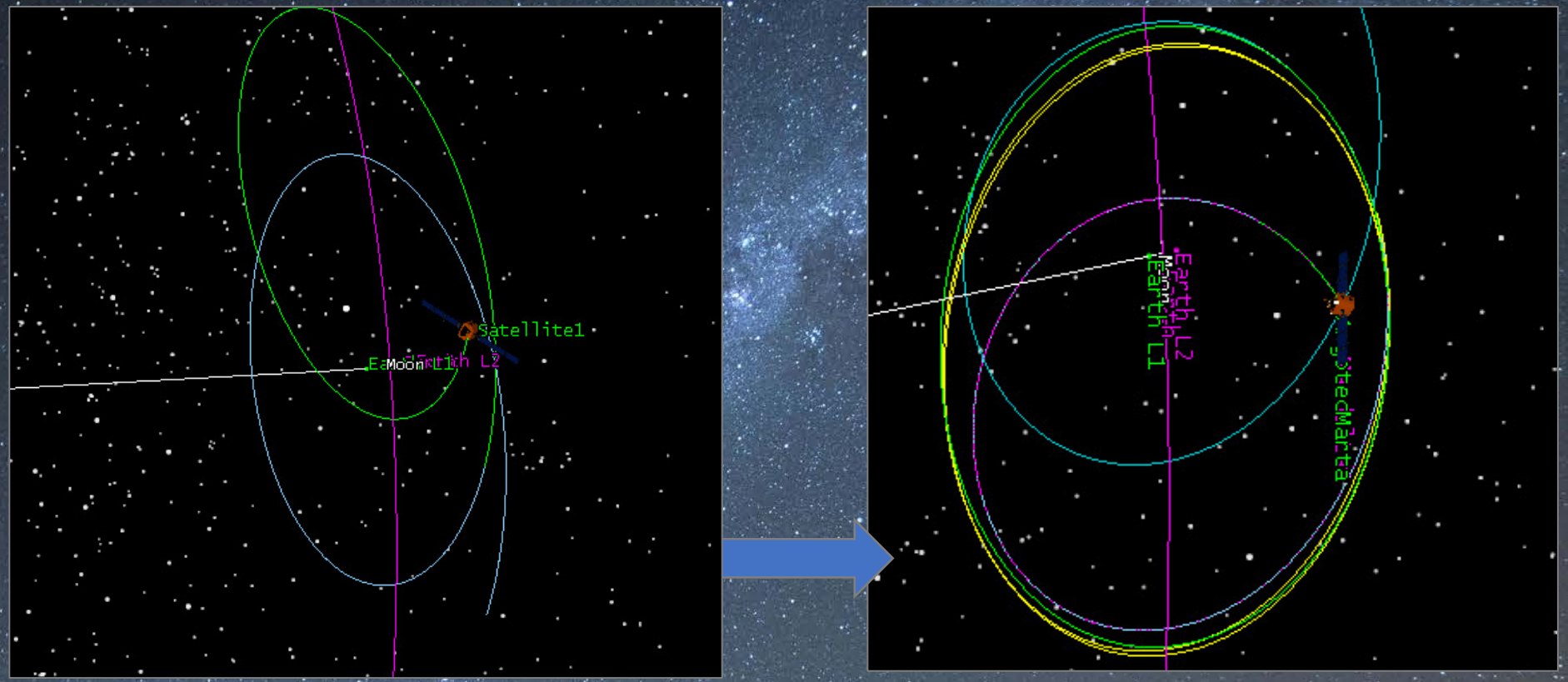




M. Ceccaroni and E. Perozzi, *The Liciacube Extended Mission as an Imminent Impactor Sentinel.* XVIII Congresso di Scienze Planetarie Abstracts, 2023.

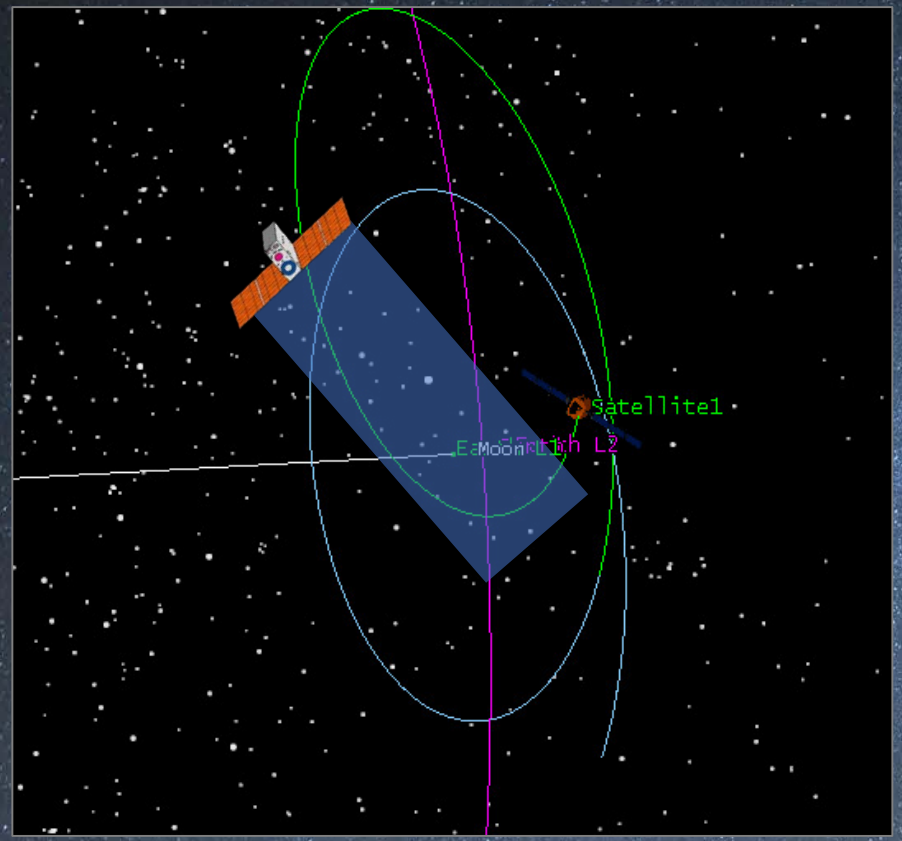
DISTANT RETROGRADE ORBITS AND LICIAcube

Due to a semimajor axis slightly different than 1, the LICIAcube trajectory drifts with respect to Earth and would need a small correction manoeuvre (order of 100 m/s) to be stabilized.



M. Ceccaroni and E. Perozzi, *The Liciacube Extended Mission as an Imminent Impactor Sentinel.* XVIII Congresso di Scienze Planetarie Abstracts, 2023.

LICIAcube AS AN IMMMINENT IMPACTOR SENTINEL



Without performing any manoeuvre, LICIAcube would be travelling for 6-months (the planned extended mission duration) along the inner DRO trajectory branch thus satisfying the planetary defence scenario for detecting imminent impactors.

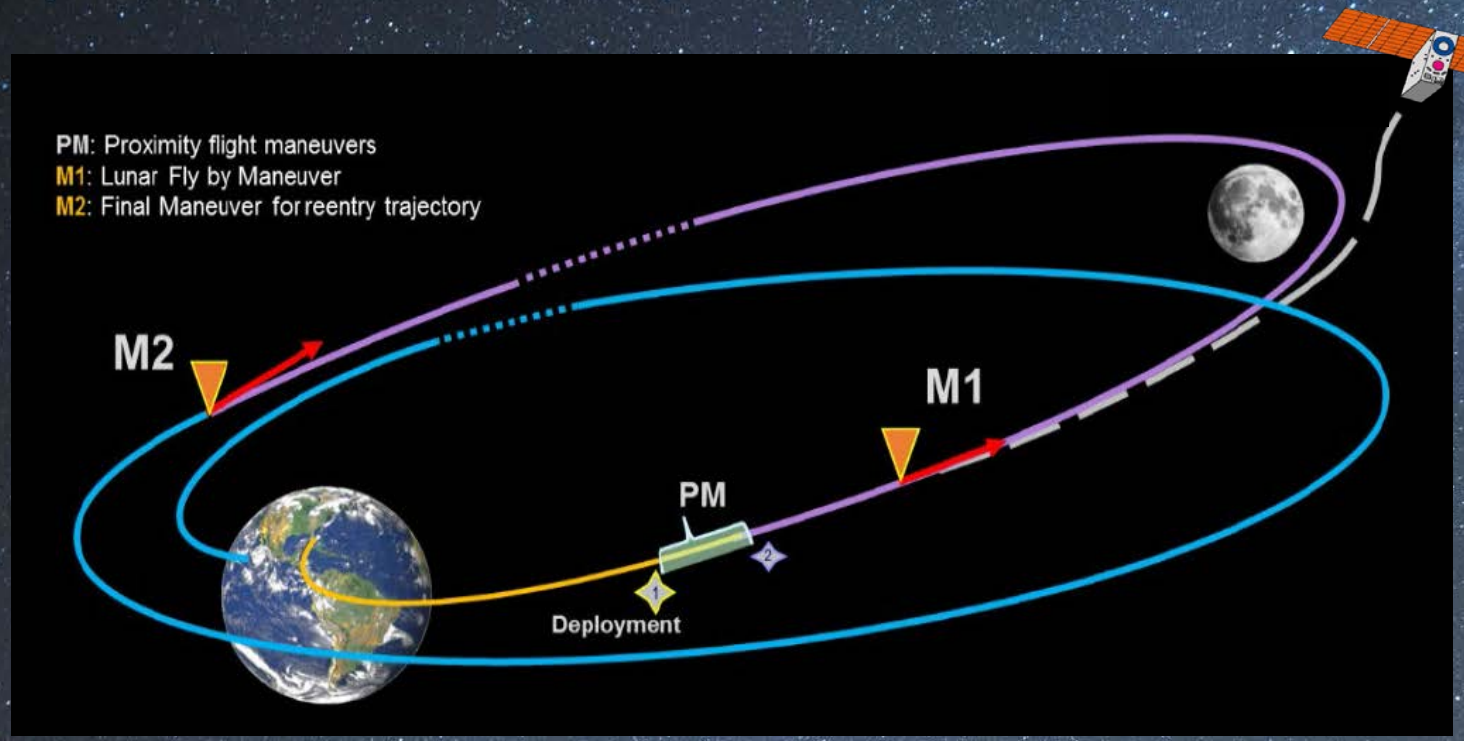
LICIAcube could then represent a precursor DRO observatory devoted to detecting imminent impactors from space.

Unfortunately about one month after the Dimorphos flyby, the radio contact with LICIAcube was lost.

M. Ceccaroni and E. Perozzi, *The Liciacube Extended Mission as an Imminent Impactor Sentinel.* XVIII Congresso di Scienze Planetarie Abstracts, 2023.

THE **argoMOON MISSION**

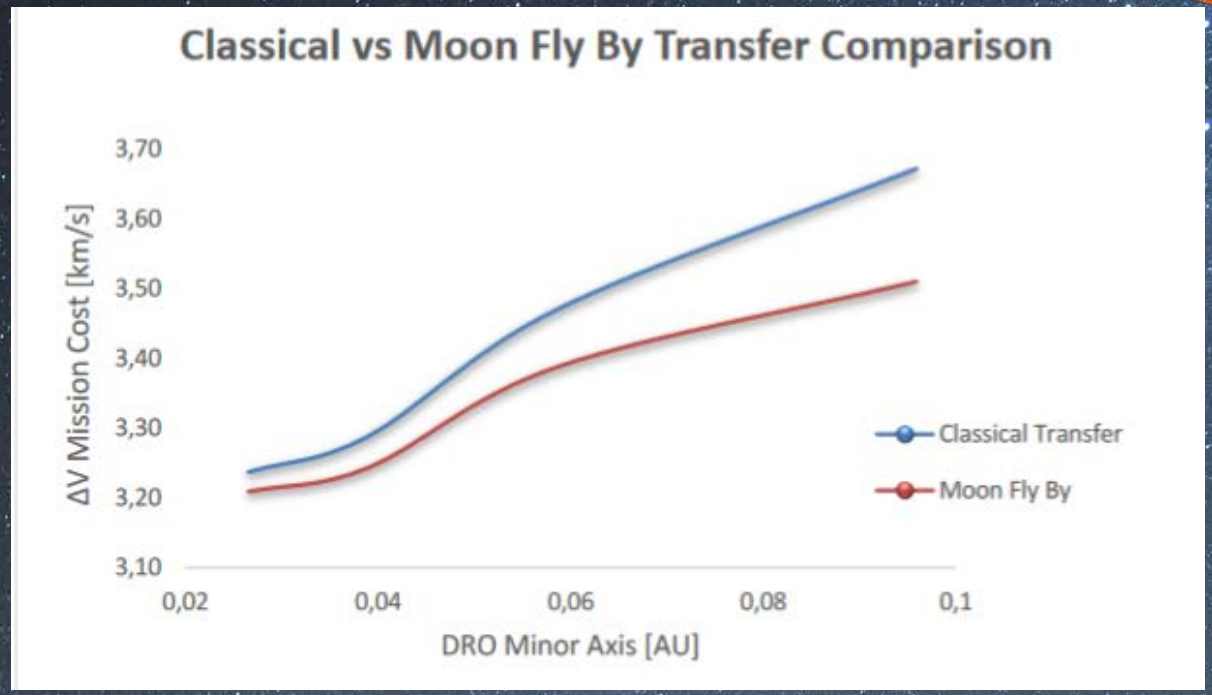
After separating from the SLS launch system in order to monitor the secondary propulsion stage , argoMOON has been travelling in an highly eccentric orbit with apogee beyond the Moon, performing several lunar flybys, imaging the lunar surface, and being eventually ejected into a heliocentric trajectory.



S. Simonetti, V. Di Tana, G. Mascetti, S. Pirrotta, E. Scorzafava: *ArgoMoon: Italian CubeSat technology to record the maiden flight of SLS towards the Moon.* 34th Annual Small Satellite Conference, SSC20-WKVII-01 , 2020.

DISTANT RETROGRADE ORBITS AND argoMOON

Numerical experiments have demonstrated that Lunar flybys are very efficient in improving the accessibility of DRO having altitudes satisfying planetary defence applications



A. Martinez Mata, E. Perozzi, M. Ceccaroni: *Addressing Imminent Impactors Threat From Distant Retrograde Orbits (DRO).* Paper IAC–22–D9.2.8 / ID 71048, 2022.

CONCLUSIONS (I)

The choice of Distant Retrograde Orbits for cubesats either for nominal or extended mission profiles offer clear advantages from the engineering point of view (e.g. telecommunication, tracking and operational requirements) since the spacecraft never leaves the surrounding of the Earth beyond a certain distance.

The LICIAcube and argoMOON extended mission studies have demonstrated that low-velocity escape into interplanetary space could easily lead to DRO-like configurations useful for planetary defence

Future cubesat missions should take this possibility into consideration already in the design phase in order to turn extended mission or end-of-life disposal strategies into imminent impactors sentinels.

CONCLUSIONS (II)

Although both LICIACube and argoMOON were lost shortly after completing their nominal mission, the near future increased utilization of cubesats within the framework of planetary and lunar exploration missions and their improved reliability could lead to the deployment of a low-cost rapid response network for timely detecting imminent impactors based on existing assets.

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