Research into Missions to 1I/'Oumuamua with Passive Jupiter Encounter.

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June 2022

Do you believe in interstellar travellers visiting us from afar?

There is good news for you: a real interstellar traveller was observed by real astronomers passing through our celestial locale from late 2017 to January 2018.

Unlike a great many strange objects, captured on camera as a still or film, often claimed to be alien spacecraft and which more than likely can be attributable to drones, optical effects or possibly even bare-faced fraudulence (we shall for the moment pass over the topic of UAP – Unidentified Aerial Phenomena), this interstellar traveller was real because it was observed by telescopes independently across the globe and in space (Hubble & Spitzer).

It was designated 1I/'Oumuamua, a Hawaiian name because it was discovered by a Hawaiian observatory, PanSTARRS.

Not only was this object real, gifts continued to arrive on the desks of astronomers and other scientists in the form of unusual scientific observations and measurements, sometimes contradictory and unfathomable, yet nevertheless the only clues humans have as to the nature and origin of 1I/'Oumuamua.

It approached within 0.16 au (astronomical units – the average Sun-Earth distance) of the Earth, that's about 60 or so Earth-Moon distances, an astronomical hair's breadth. Further, it was discovered after perihelion (that's the closest approach to the sun), and so heading away from the sun at a huge speed (its speed at infinity w.r.t the sun is 26.3km/s).

There's no doubt about it, the data we have is inadequate for resolving the very many mutually paradoxical ideas as to the nature of 1I/'Oumuamua, so we need a mission in order to, at the very least, take a picture of it up close.

Rest assured the Initiative for Interstellar Studies (i4is) were quickly on the case and had initiated its Project Lyra to analyse the feasibility of spacecraft missions to intercept it. I was involved in this study as I had already developed some software which could be pertinent in quantifying the viability of such missions. I have been instrumental in many of the Project Lyra articles and a list of them can be found at the end of this note [1] [2] [3] [4] [5] [6] [7].

However, things have changed somewhat since these papers have been published in that there has been a report by Johns Hopkins University (JHU) Applied Physics Laboratory (APL) concerning the practicalities of realising a mission to the Very Local Interstellar Medium (VLISM) with a launch in the 2030s. It is the 'Interstellar Probe Concept Report' (IPCR) published in December 2021 [8]

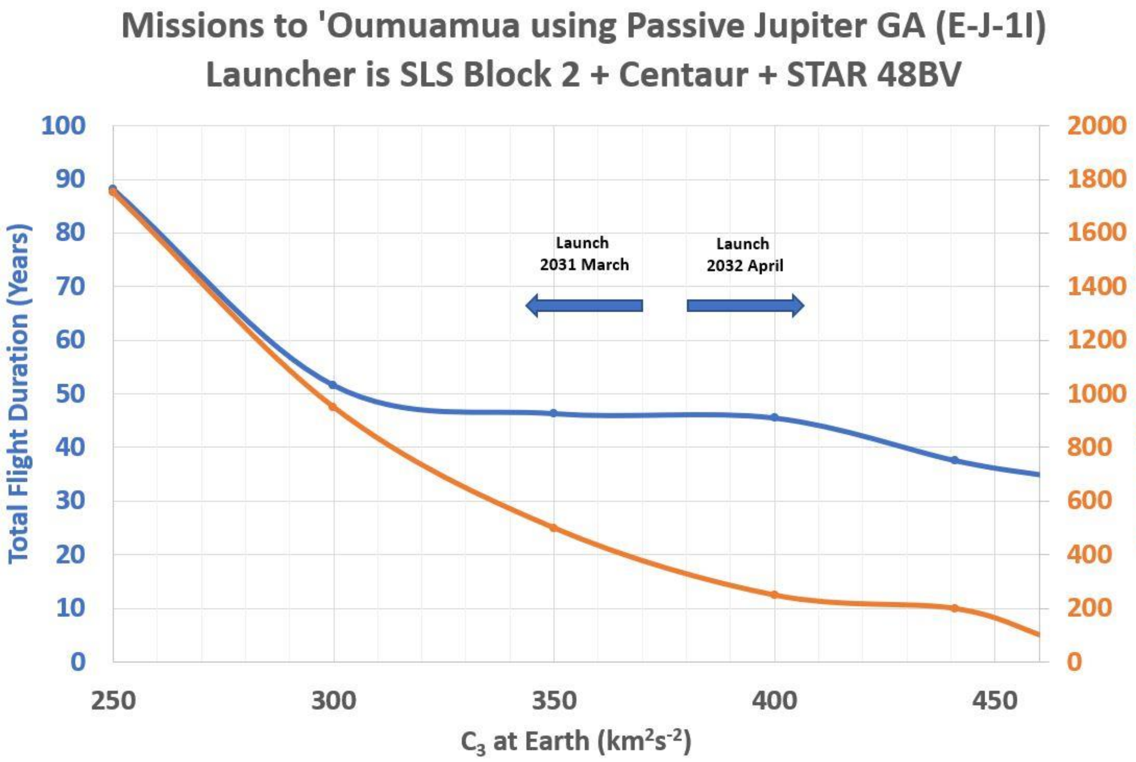
In this report emphasis has shifted from using a solar slingshot (otherwise known as a Solar Oberth Manoeuvre- SOM) whereby the spacecraft conducts a close, almost sun-grazing, passage near the sun and a rocket burn is delivered; to a passive Jupiter encounter (passive meaning no burn at peijove), the spacecraft being accelerated w.r.t. the sun by a pure, unpowered, gravitational assist of Jupiter.

The advantage of the latter is mainly its much less stringent technical demands compared to that of a SOM - the SOM has not yet even been demonstrated in a real mission and has a much lower Technical Readiness Level (TRL).

Stimulated by this change in tack, I decided to exploit my software development, *'Optimum Interplanetary Trajectory Software'* (OITS) [9], to study passive Jupiter missions to 'Oumuamua.

As in the IPCR, we assume the NASA Space Launch System (SLS) will be up-and-running by the '30s, particularly the Block 2 variant. Furthermore for extra 'oomph' a LH_2/LOX Centaur 3rd stage is adopted and a fourth stage as well – a STAR 48BV solid rocket booster.

The results can be found in the Figure below.



In this Figure the horizontal axis, C_3, is a measure of the energy per unit mass of the escape orbit from Earth. For any given launcher (in our case the SLS Block 2B + Centaur + STAR 48BV), the lower this C_3 value then the higher the payload mass delivered to the escape orbit in question.

Observe the orange line is the payload mass to 'Oumuamua (right-hand secondary vertical axis) and drops as the dynamic requirement on the launcher, C_3 increases. The blue line is the total flight duration to 'Oumuamua and varies between 35 years (on the far right of the plot) where the payload mass would be 100kg, and 88 years where the payload mass would be a considerably more hefty 1800kg.

Note the optimal launch year changes at around $C_3 = 370\ km^2s^{-2}$ from 2031 to 2032.

These results can be compared to a SOM [2] where a 22 year mission duration can be achieved and the mission with a JOM (Jupiter Oberth Manoeuvre [5]) where the mission would take 26 years.

Clearly the performance of the passive Jupiter is inferior to the two preceding candidates but there is an important point to make in that the trajectories analysed in this note are much more practically achievable using known up-and-coming technology, and the numbers here are far more realistic in this context.

1. HIBBERD, A.; PERAKIS , N.; HEIN, A. M. Sending a spacecraft to interstellar comet 2I/Borisov. **Acta Astronautica**, p. 84-592, 2021.

2. HIBBERD, A.; HEIN, A. M.; EUBANKS, T. M. Project Lyra: Catching 1I/‘Oumuamua – Mission opportunities after 2024. **Acta Astronautica**, p. 136-144, 2020.

3. HIBBERD, A.; HEIN, A. M. Project Lyra: Catching 1I/'Oumuamua--Using Laser Sailcraft in 2030. **arXiv preprint arXiv:2006.03891**, 2020.

4. HIBBERD, A.; HEIN, A. M. Project Lya: Catching 1I/'Oumuamua using Nuclear Thermal Rockets. **Acta Astronautica**, p. 594-603, 2021.

5. HIBBERD, A. et al. Project Lyra: Mission to 1I/'Oumuamua without Solar Oberth Manoeuvre. **arXiv**, January 2022.

6. HIBBERD, A. Project Lyra: Another Possible Trajectory to 1I/'Oumuamua. **arXiv**, May 2022.

7. HIBBERD, A. Intermediate Points for Missions to Interstellar Objects Using Optimum Interplanetary Trajectory Software. **arXiv**, May 2022.

8. MCNUTT JR., R. L. et al. **Interstellar Probe Conceprt Report**. JHU APL. [S.l.]. 2021.

9. HIBBERD, A. Github repository for OITS. **Github**, 2017. Disponivel em: <https://github.com/AdamHibberd/Optimum_Interplanetary_Trajectory>.