# AE 502: Homework Project 1

Due Date: February 26, 2023, 11:59pm CT

## Problem

Interstellar objects passing through our Solar System have been one of the most amazing scientific discoveries of the last decade. Interstellar objects originate beyond our Solar System and travel on hyperbolic trajectories with respect to our Sun. 1I/'Oumouamoua (Figure 1) was the first interstellar object to be discovered by Robert Weryk on October 19, 2017 [Meech et al., 2017]. In 2019, Comet 2I/Borisov was the second object discovered to be on a hyperbolic trajectory through our Solar System [Opitom et al., 2019]. Getting a closer look at those objects would yield invaluable scientific insights into how asteroids and comets form around other suns. As future trajectory design engineers it now falls to you to determine whether a rendez-vous or fly-by mission to such objects is feasible! To this end you have to

1. (20 points) Write your own Universal Variable two-body orbit propagator (e.g., Curtis' Algorithms 3.3 and 3.4 [Curtis, 2013])!

2. (20 points) Write your own Lambert-Solver, based on e.g., Curtis' Algorithm 5.2, or Gooding [1990] or even better Izzo [2015].

3. (20 points) Generate two pork chop plots [e.g. Bombardelli et al., 2018] with departure dates from Earth in the range of January 2017 - December 2017 vs arrival dates in August 2017 - January 2019 vs total $\Delta V$ color coded) for rendez-vous ($\Delta V < 50$km/s) and fly-by missions ($\Delta V < 20$km/s) to 1I/'Oumouamoua, respectively.

4. (20 points) Generate two pork chop plots with departure dates from Earth in the range of January 2017 - July 2020 vs arrival dates in June 2019 - January 2022 vs total $\Delta V$ color coded) for rendez-vous ($\Delta V < 60$km/s) and fly-by missions ($\Delta V < 20$km/s) to 2I/Borisov, respectively.

5. (10 points) Convert the initial state vectors to suitable orbital elements and show that those objects are indeed interstellar!

6. (10 points) How realistic are those mission scenarios? If you had to pick one, which one would it be?

Initial state vectors for the epoch of 2017-Jan-01 00:00:00.0000 UTC
i.e. JD 2457754.5., are in units of au and au/day:

$$
\begin{aligned}
r_{1I} &= [3.515868886595499 \times 10^{-2}, -3.162046390773074, 4.493983111703389] \\
v_{1I} &= [-2.317577766980901 \times 10^{-3}, 9.843360903693031 \times 10^{-3}, -1.541856855538041 \times 10^{-2}],
\end{aligned}
$$

$$
\begin{aligned}
r_{2I} &= [7.249472033259724, 14.61063037906177, 14.24274452216359] \\
v_{2I} &= [-8.241709369476881 \times 10^{-3}, -1.156219024581502 \times 10^{-2}, -1.317135977481448 \times 10^{-2}],
\end{aligned}
$$

and the initial state vector for the Earth is

$$
\begin{aligned}
r_E &= [-1.796136509111975 \times 10^{-1}, 9.667949206859814 \times 10^{-1}, -3.668681017942158 \times 10^{-5}] \\
v_E &= [-1.720038360888334 \times 10^{-2}, -3.211186197806460 \times 10^{-3}, 7.927736735960840 \times 10^{-7}].
\end{aligned}
$$

Assume two-body motion with respect to the the Sun! Please upload your code to your own GitHub repository! Good hunting!

# References


Karen J Meech, Robert Weryk, Marco Micheli, Jan T Kleyna, Olivier R Hainaut, Robert Jedicke, Richard J Wainscoat, Kenneth C Chambers, Jacqueline V Keane, Andreea Petric, et al. A brief visit from a red and extremely elongated interstellar asteroid. *Nature*, 552(7685):378–381, 2017.

Cyrielle Opitom, Alan Fitzsimmons, Emmanuel Jehin, Youssef Moulane, Olivier Hainaut, Karen J Meech, Bin Yang, Colin Snodgrass, Marco Micheli, Jacqueline V Keane, et al. 2i/borisov: A c2-depleted interstellar comet. *Astronomy & Astrophysics*, 631:L8, 2019.

Howard Curtis. *Orbital mechanics for engineering students*. Butterworth-Heinemann, 2013.

Robert H Gooding. A procedure for the solution of lambert's orbital boundary-value problem. *Celestial Mechanics and Dynamical Astronomy*, 48(2):145–165, 1990.

Dario Izzo. Revisiting lambert's problem. *Celestial Mechanics and Dynamical Astronomy*, 121:1–15, 2015.

Claudio Bombardelli, Juan Luis Gonzalo, and Javier Roa. Approximate analytical solution of the multiple revolution lambert's targeting problem. *Journal of Guidance, Control, and Dynamics*, 41(3):792–801, 2018. doi: 10.2514/1.G002887. URL https://doi.org/10.2514/1.G002887.

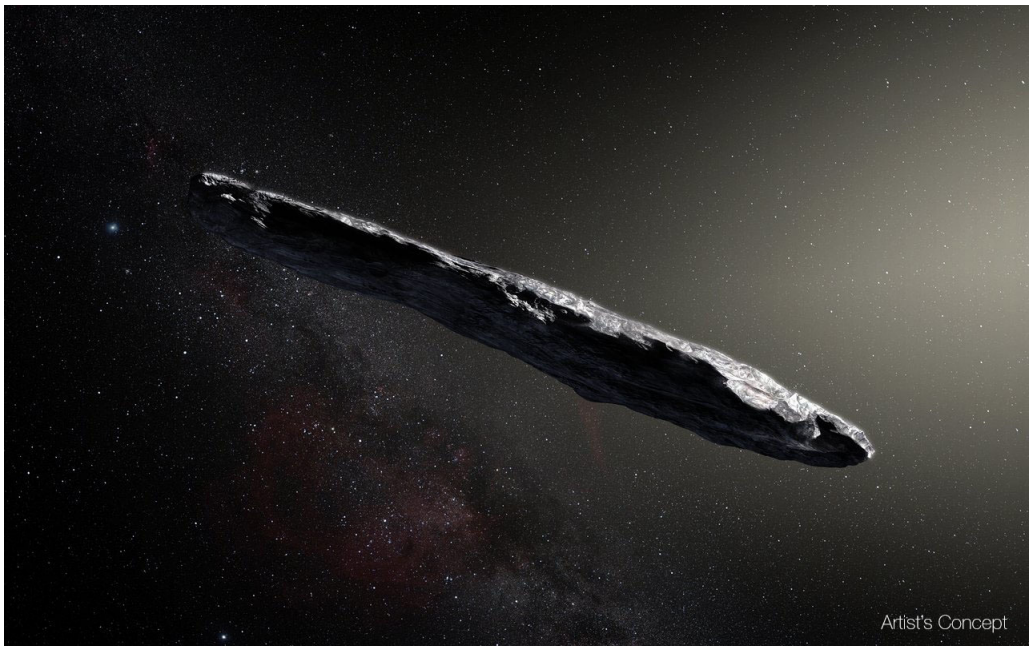


Figure 1: Artist rendering of 1I/'Oumouamoua, source: ESA.