**Synthetic observation generation codes and libraries description**

**Libraries:**

* **synthetic\_obs\_l (SOL):** Contains the basic skeleton of the observation generation and propagation, providing the 2-body and 3-body (perturbed) propagations, the function to generate the ra-dec observations and the generation of files. Also, the function to get the orbital elements from state vectors.  
  The 3-body propagator has also a *rough* function that gives a preliminary value of the closest approach distance b/w the 2 bodies.
* **Equations\_of\_motion (EOM):** Contains the equations of motion (to be integrated in SOL by a RK5 algorithm) for the 2 body and 3 body propagation. Moreover, contains the function to include the perturbations (for the moment just third body perturbation). Contains the information (as a struct) of the third bodies that can be included: planets and cpv. Teir position are read from ephemerides\_libr.
* **ephemerides\_libr (EPHLIB):** Contains the functions to access to the SPICE repository of the desired ephemerides for planets and cpv. Provided in Solar System barycentre in J2000 ecliptic reference frame are based on:
  + **de430.bsp** for planets (which has to be downloaded from the proper sources)
  + **naif0012.tls** for the leapsecond kernel and time frame information
  + **codes\_300ast\_20100725.bsp** for the asteroid (usual Jim Baer’s 300 asteroid ephemerides)
  + **codes\_300ast\_20100725.tf** necessary options file to read the asteroid ephemeris.

These files must be loaded at the beginning of every **main** file.  
In here, the correction at -67 second (the inferred leapsecond from the analyses) is applied

* **ephem\_generation\_lib (EGL):** This library allows to generate the ephemerides of the perturbing asteroid. It can be done in 2 ways: (**long)** from the whole 1799-2200 propagation time of the Baer’s ephemerides file, or (**short**) just for the time step interested in the main propagation. Since the latter has been proved that this version works as well as the other but is significantly *faster*, we can opt just for this one. It then performs the 2-body propagation for the perturbing body and generates the ephemerides for the time steps for the Baer’s ephem (40 days of time span).Then it overwrites the asteroid ephem file in order to modify (433) Eros orbital parameters with this new one. Why Eros? Because it is the smallest one and NEO, so unlikely to perturb anyway our MBA. Other choices can be done. If one wants to put the hands on find\_orb, it is techinally possible to modify the proper file to Include 301 asteroids. Since it is impossible for the desktop application, I’ll skip this operation for now.  
  The library also overwrites mu1.txt file with the new mass of the perturbing asteroid, in place of that of Eros.  
  It does this operation in “Ast\_ephem” subfolder, where there is the file “asteroid\_ephemeris\_original.txt” that is copied to generate the new “asteroid\_ephemeris.txt” file to be used. Moreover, the newly generated file is copied in “asteroid\_ephemeris\_{num\_peeturbeing\_ast}.txt” for posterity. To use them in the desktop version of Find\_orb, it is needed to modify the environ.dat file in Find\_orb folder in order to address the asteroid perturbing ephemerides file folder to the newly generated ephemerides file. Moreover, the files bc-405must be deleted, because they refer the old ephemerides. They will be re-generated at the first inclusion of the asteroid perturbes in the solution.
* **replicate\_obs\_file\_l (ROFL):** More updated version of SOL, allows for an enhanced set of functionalities, among which replicate patterns of actual asteroid .rwo observation files to match the synthetic observations with the actual observations. Plotting function of the observation distribution and a magnitude simulator based on the distance of the observed are also here implemented. It also has important functions to refine the setting of initial state vectors based on visibility conditions, if required.
* **Topocentric observations (TO):** Functions that provide the topocentric positions on Earth surface of ground observatories.

**Main files:**

* **residual\_simulation\_3\_body\_both\_files:** This includes two asteroids: a perturbed and a perturbing. We define the SV at encounter epoch of the perturbing, and relatively the perturbed with the Broucke parameters (see [**https://doi.org/10.3390/aerospace11080647**](https://doi.org/10.3390/aerospace11080647)). Then propagation and synthetic observations of the perturbed and unperturbed solutions, saved as ADES\_3B\_pert\_m\_{mu:.4e}.txt and ADES\_3B\_unpert\_m\_{mu:.4e}.txt. In the unperturbed the mass of the perturbing body is set as 0. Noise can be set and applied to the solution to resemble real-life observation errors. No ephemerides of the perturbing body are created. Just to propagate and compare the files.
* **synth\_obs\_def** It allows for the simulation and observation generation for a flyby among two asteroids. It collects almost all the available options of initial and boundary condition definition, which can be accessed and selected through proper flags at the beginning of the code. They include:
  + Level of noise in the observations, to simulate random astrometric errors,
  + Geographical origin of the observations.
  + Generation of the ephemerides of the perturbing body.
  + Number of observations desired.
  + Mass of the perturbing body.
  + Select the other gravitational perturbers (planets and cpv).
  + Define the initial conditions:
    - If selecting a flyby between 2 existing bodies, the date0 will be the date when the propagation starts, and Deltat the total time of propagation in years. The asteroids can be selected by inputting their number/name in lines 113 and 114.
    - If selecting 2 new bodies, then date0 is the epoch at which the flyby takes place, and Deltat is the years to propagate before and after that epoch. The initial state vectors are defined: line 163 for the heliocentric position of the perturbing body, and line 169 for the heliocentric velocity (can be done also according to a reference distance/velocity). The position at the moment of flyby of the perturbed body is done between lines 189 and 195 with the definition of approach geometry, distance and relative velocity.
* **residual\_simulation\_3\_body\_optimum\_obs\_distribution:** The definition of the perturbing body’s state vectors can be done both inputting the desired state vectors, or you can define the desired orbital parameters, and ROFL will generate the state vectors matching these conditions, and visibility of the close encounter from Earth. Also, the observations are provided only if and where the stations have visibility. Information on the magnitude is provided as well. Can plot the distance over time and the observation distribution per week over the observation period.