TEMPORARY SATELLITE CAPTURE OF SHORT-PERIOD JUPITER FAMILY COMETS FROM THE PERSPECTIVE OF DYNAMICAL SYSTEMS

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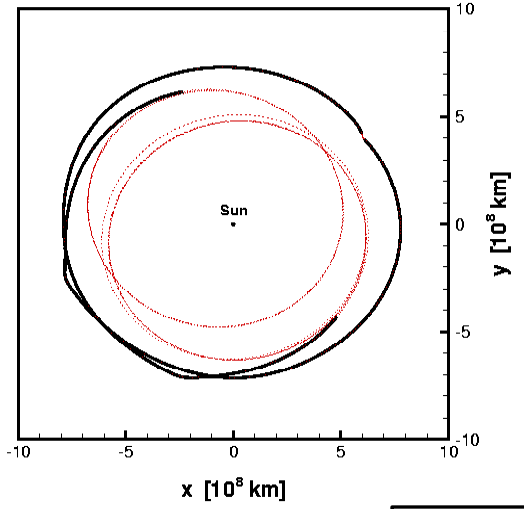
Capture of Comets by H

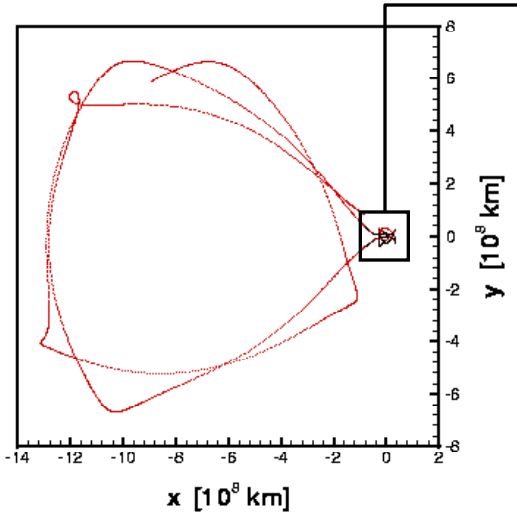
Helin-Roman-Crockett

(1943-2019)

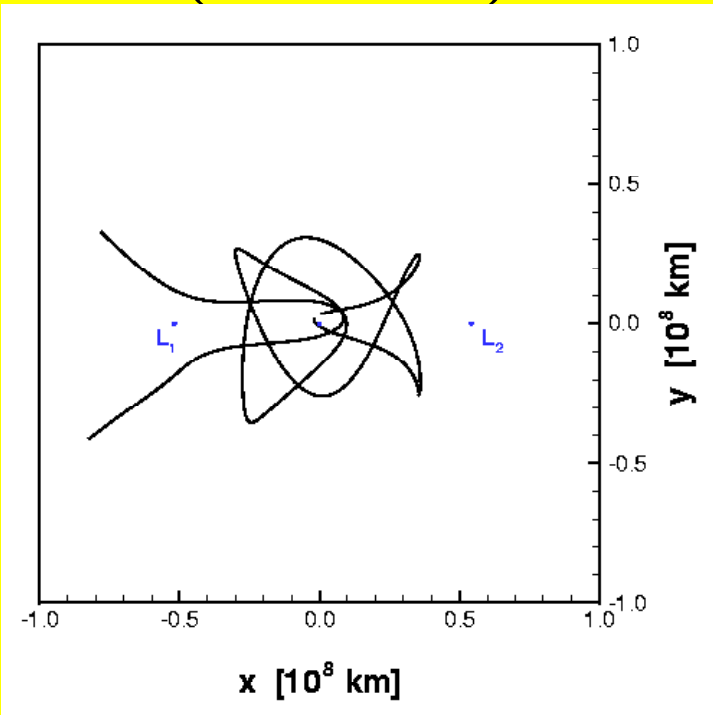
Heliocentric Inertial Frame



Joviocentric Synodic Frame



Temporary Satellite Capture (1966-1985)

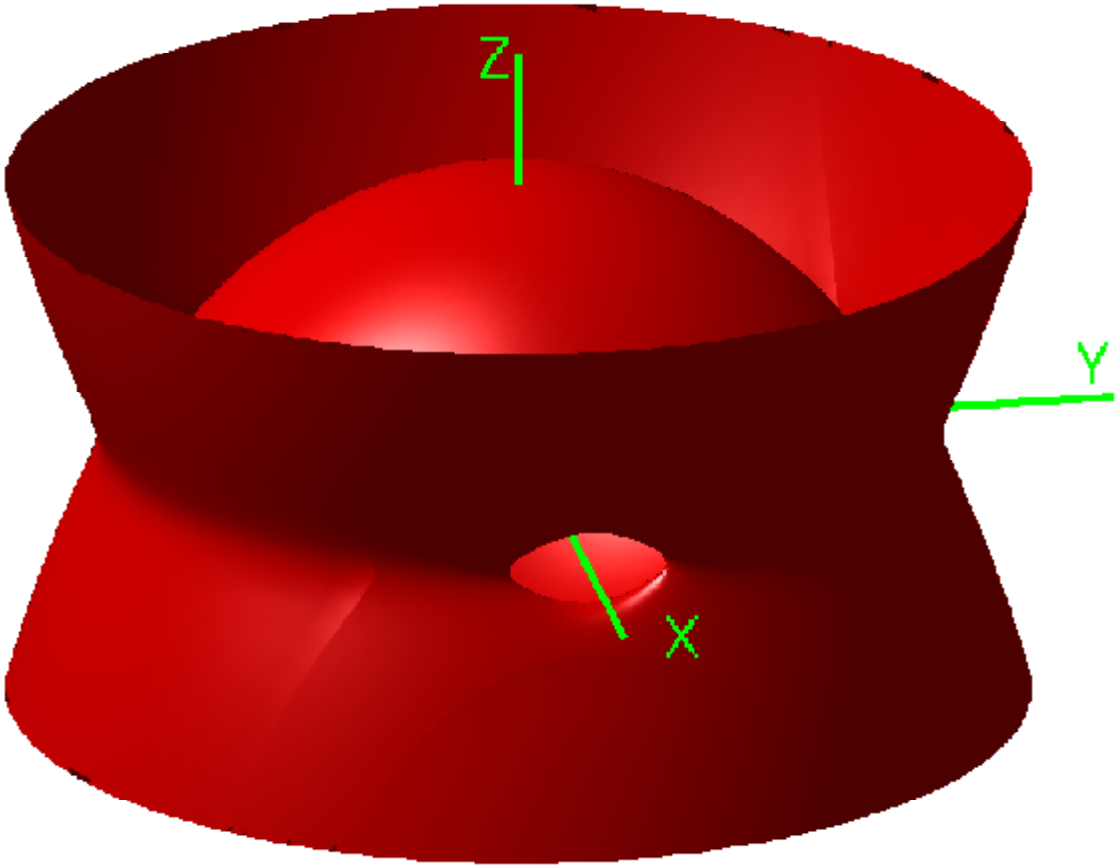


Modeling TSC

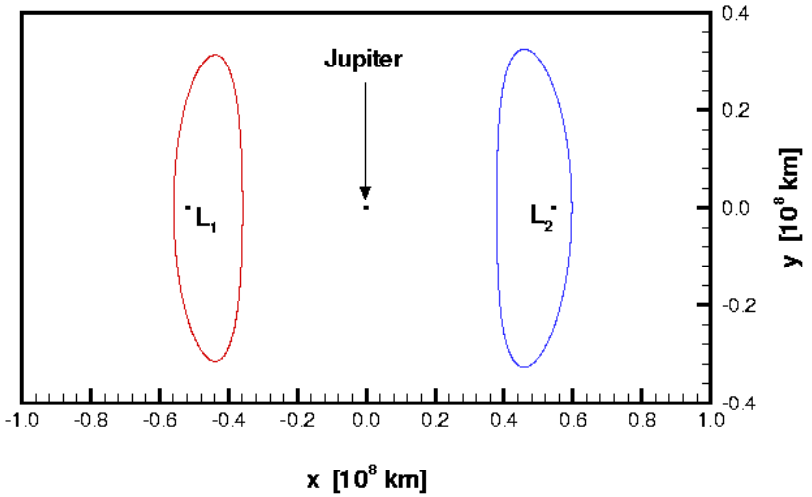
- Modeling Approach
  - Initially use CR3BP
    - *Three*-Dimensional Regions of Exclusion
    - Types of Solutions Available (3D-Periodic)
    - Application of DS Perspective
      - Compute Trajectories on Stable/Unstable Manifold
      - Numerical Analysis $\Longrightarrow$ Insight into geometry of phase space
    - Analytical Symmetry of Solutions
    - Numerically Observed Symmetries

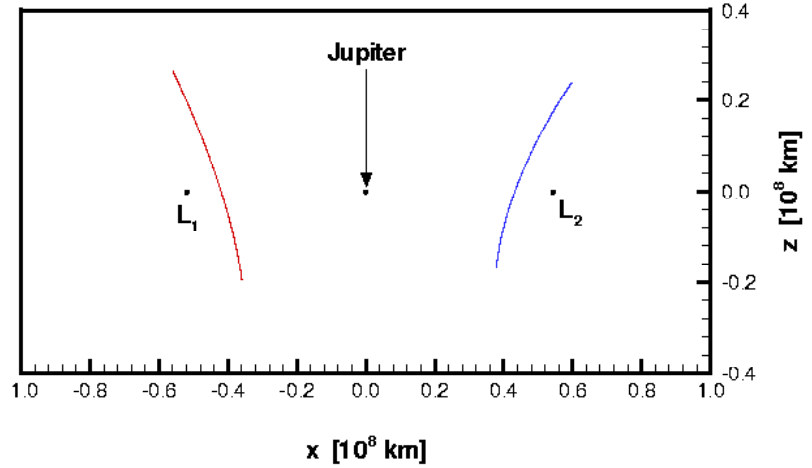
3D Regions of Exclusion

Sun-Jupiter System: Zero Velocity Surface for *C (Jacobi Constant) = 3.0058*

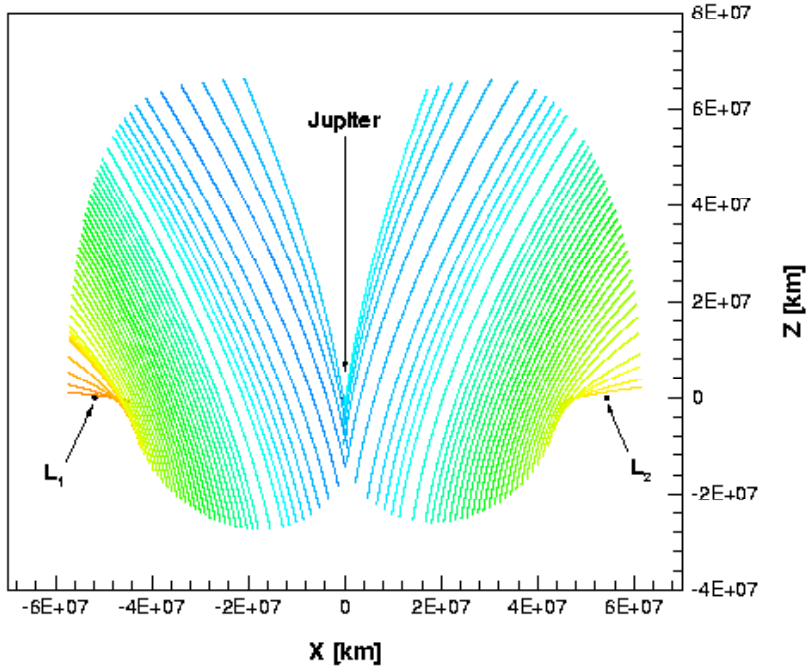


Periodic Solutions



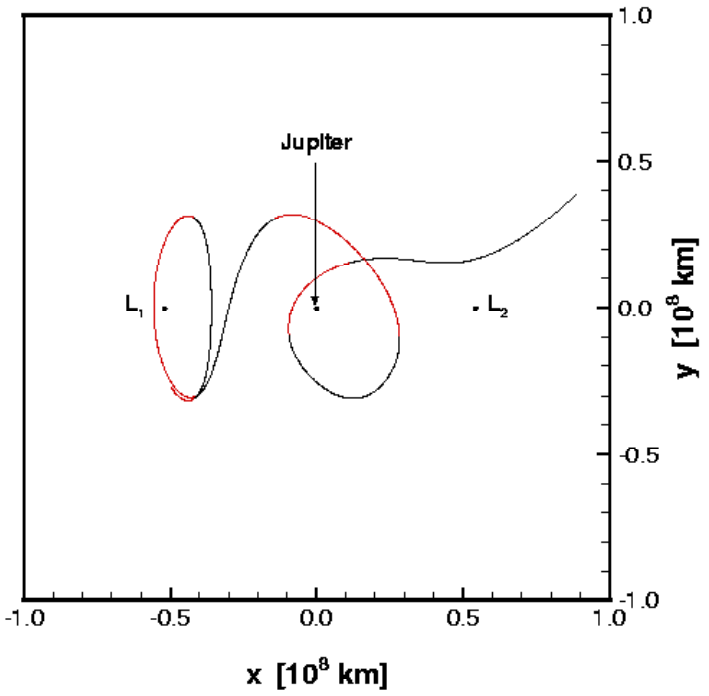


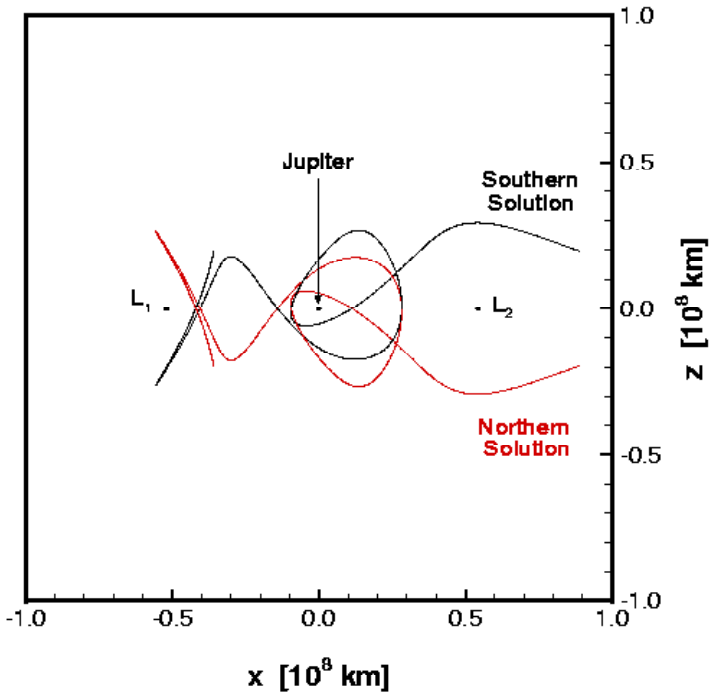
Sun-Jupiter
L_1 and L_2 Families
of Periodic Halo Orbits



Northern/Southern Symmetry

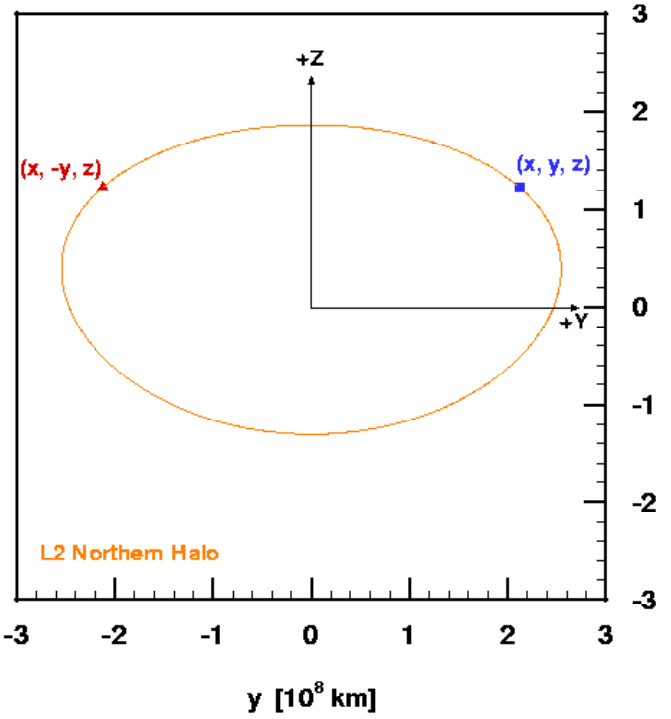
For every solution $[x(t), y(t), z(t), \dot{x}(t), \dot{y}(t), \dot{z}(t)]^T$ there exists a second solution of the form $[x(t), y(t), -z(t), \dot{x}(t), \dot{y}(t), -\dot{z}(t)]^T$.

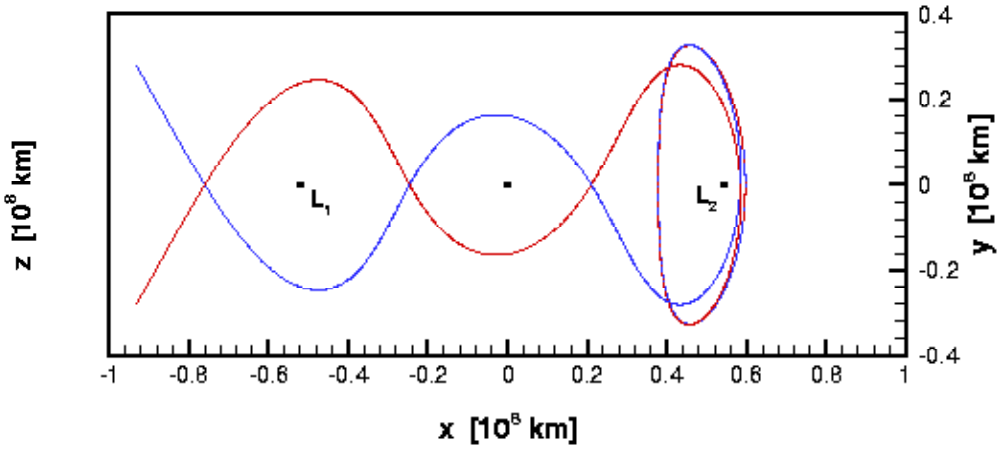




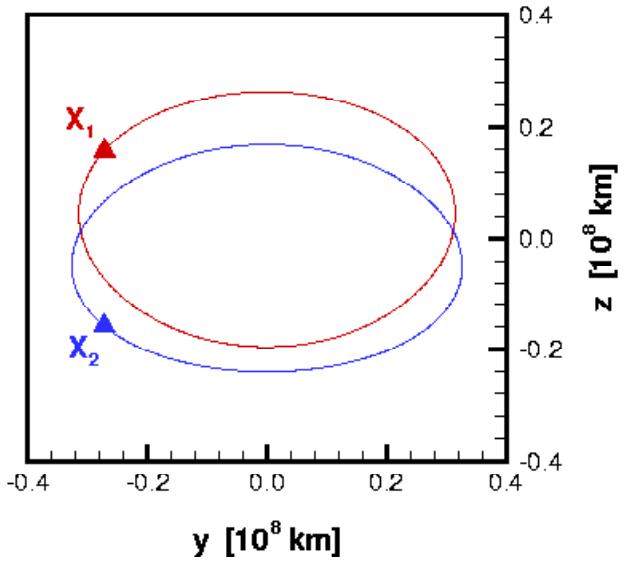
Symmetry Due to Time Invariance

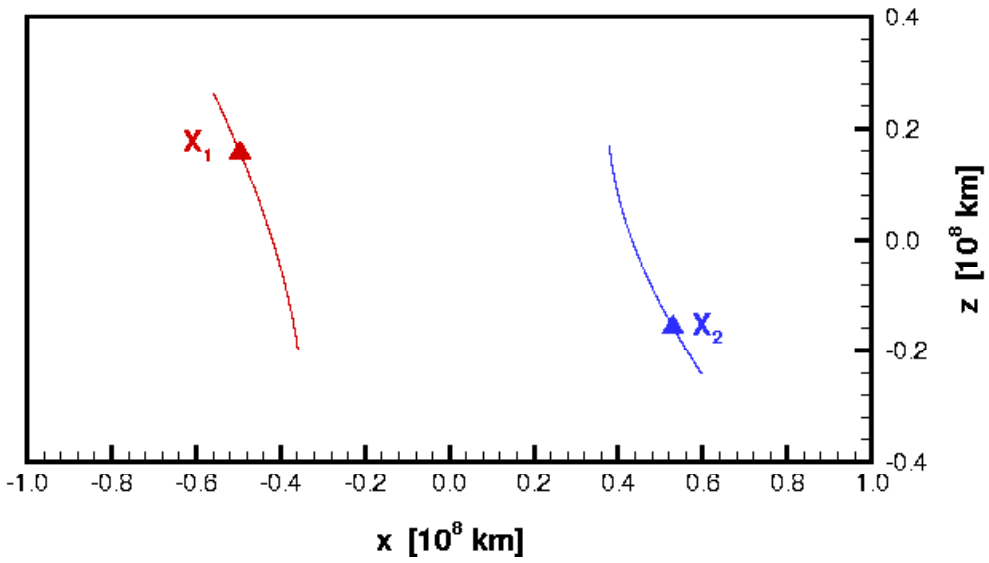
The ***stable*** manifold, associated with the state $[x, y, z, \dot{x}, \dot{y}, \dot{z}]^T$ on a halo orbit, is a mirror image about the XZ plane of the ***unstable*** manifold associated with the state $[x, -y, z, -\dot{x}, \dot{y}, -\dot{z}]^T$ on the orbit.





Numerical Near Symmetry (I)

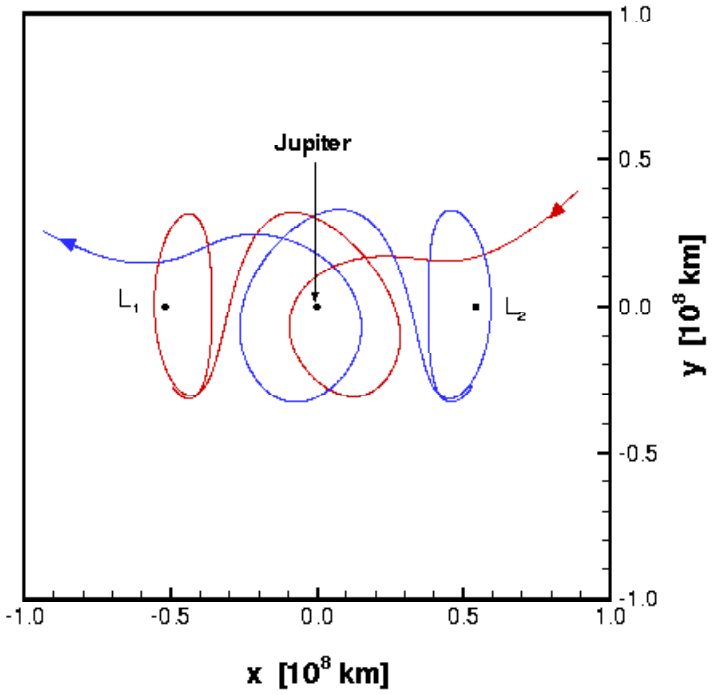


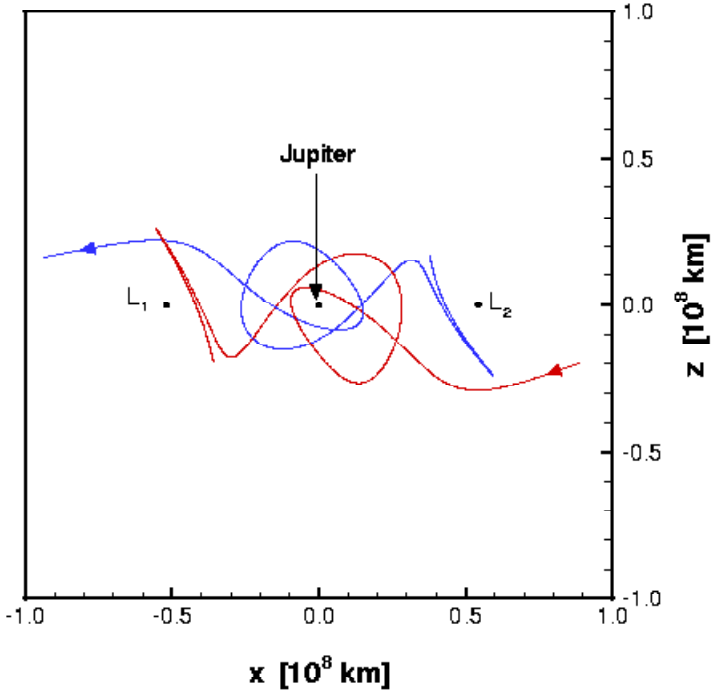


The ***stable*** manifold associated with a state $\bar{X}_1 = [x_1 \quad y_1 \quad z_1 \quad \dot{x}_1 \quad \dot{y}_1 \quad \dot{z}_1]^T$ on a northern L_1 halo exhibits features that are similar to those of the ***unstable*** manifold associated with a state $\bar{X}_2 = [x_2 \quad y_2 \quad z_2 \quad \dot{x}_2 \quad \dot{y}_2 \quad \dot{z}_2]^T$ on a southern L_2 halo for $y_1 \approx y_2$ and $z_1 \approx -z_2$.

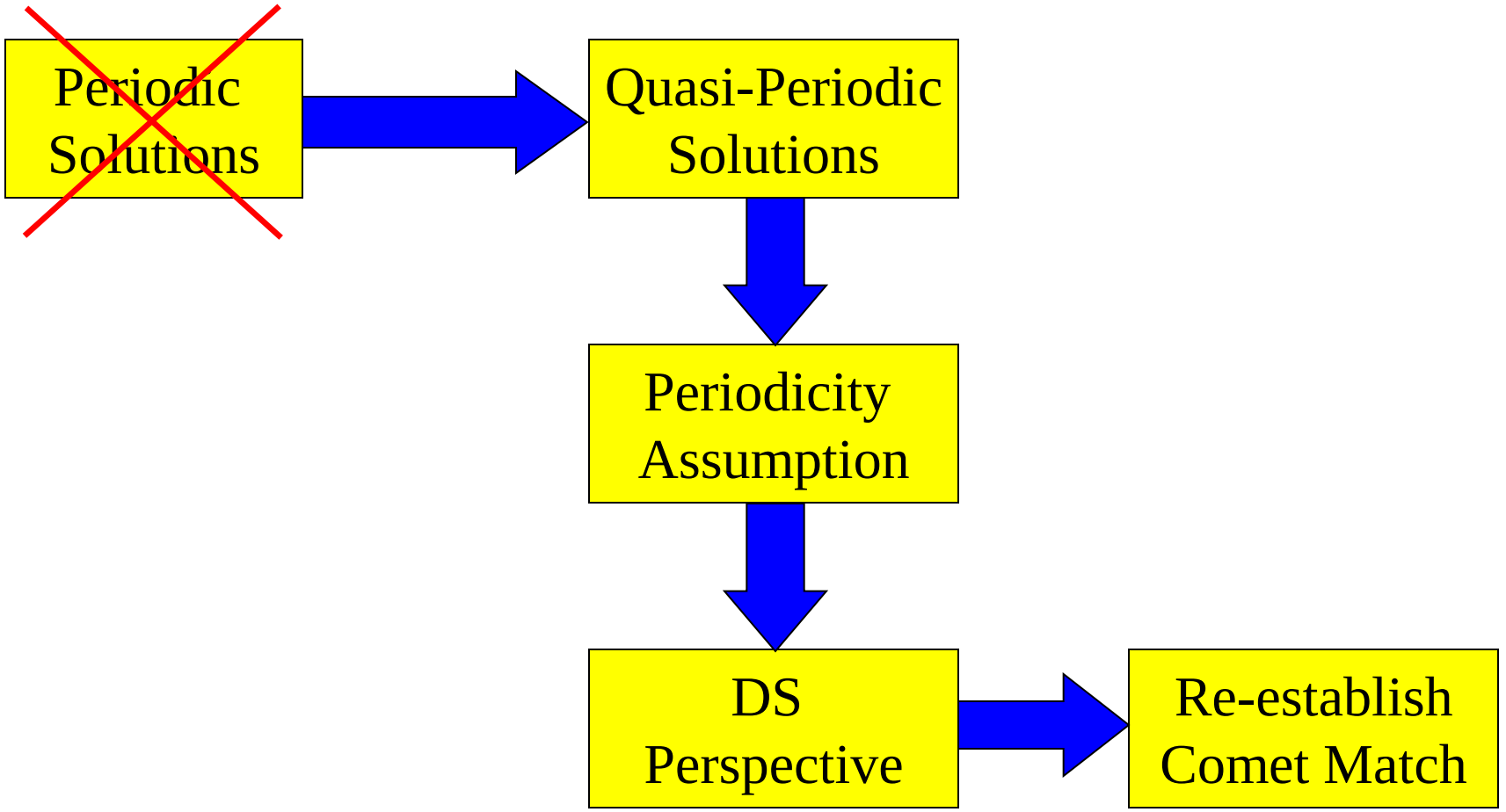
Numerical Near Symmetry (II)

A numerical inverse (***Z***) near mirror (*XY*-plane) symmetry exists between the stable/unstable manifold solutions associated with L_1 northern/southern halo orbits and the unstable/stable manifold solutions associated with L_2 southern/northern halo orbits.



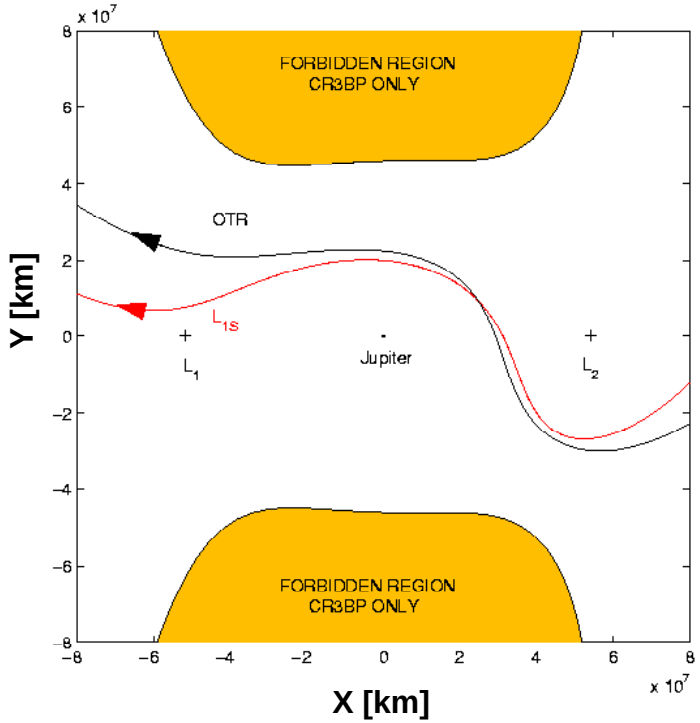


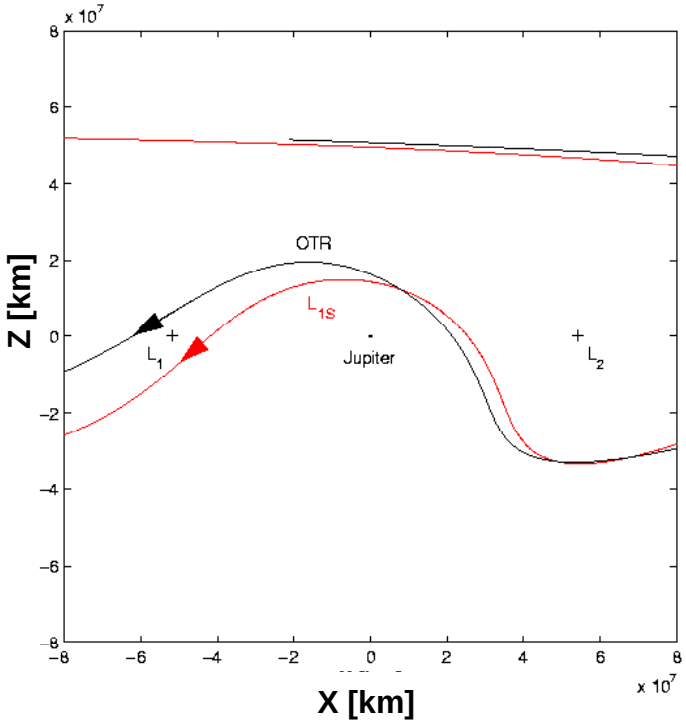
Ephemeris Model Solution



Numerically Integrated 3-D Trajectories
3BP Ephemeris Model

Dynamic Behavior of Oterma (OTR) Follows Stable (**S**) Manifold Trajectory Associated with a Sun-Jupiter L_1 Northern Quasi-Periodic Orbit.

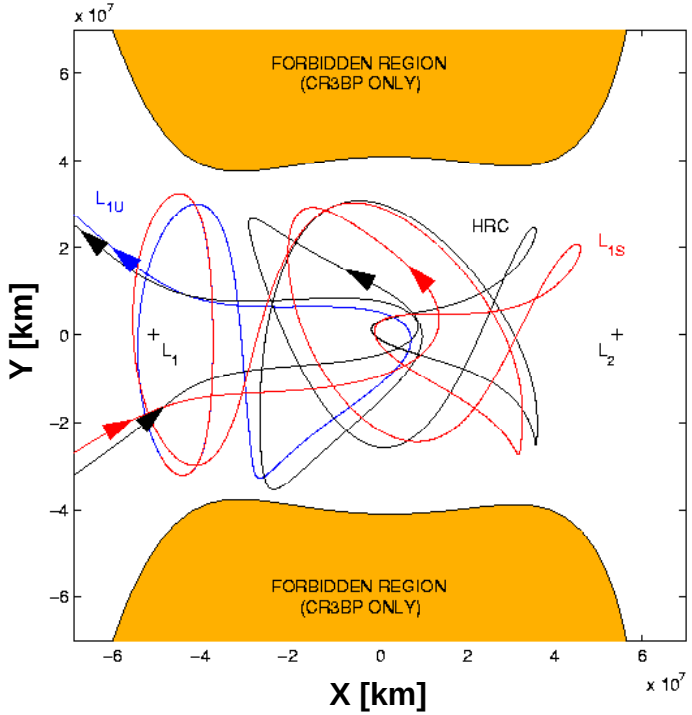


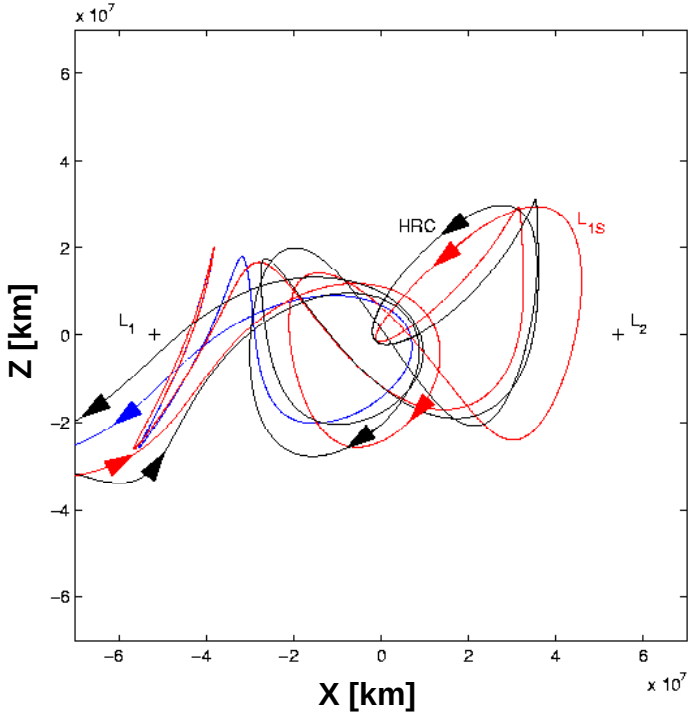


TSC Trajectory of Comet Oterma

Numerically Integrated 3-D Trajectories
3BP Ephemeris Model

Dynamic Behavior of Helin-Roman-Crockett (HRC) Follows Stable (**S**) and Unstable (**U**) Manifold Trajectories Associated with a Sun-Jupiter L_1 Southern Quasi-Periodic Orbit.





TSC Trajectory of Comet Helin-Roman-Crockett

Summary

- Modeling TSC w/ R3BP (Sun-Jupiter-Comet)
- Characterizing the solution space of the CR3BP
  - 3D Regions of Exclusion
  - Types of Solutions
  - DS $\Longrightarrow$ Stable/Unstable Manifold Flow
    - Analytical symmetries
    - Numerical near symmetries
- Applications
  - Modeling of natural bodies
  - S/C Mission Design