Interplanetary Trajectory design for Rosetta and other ESA missions

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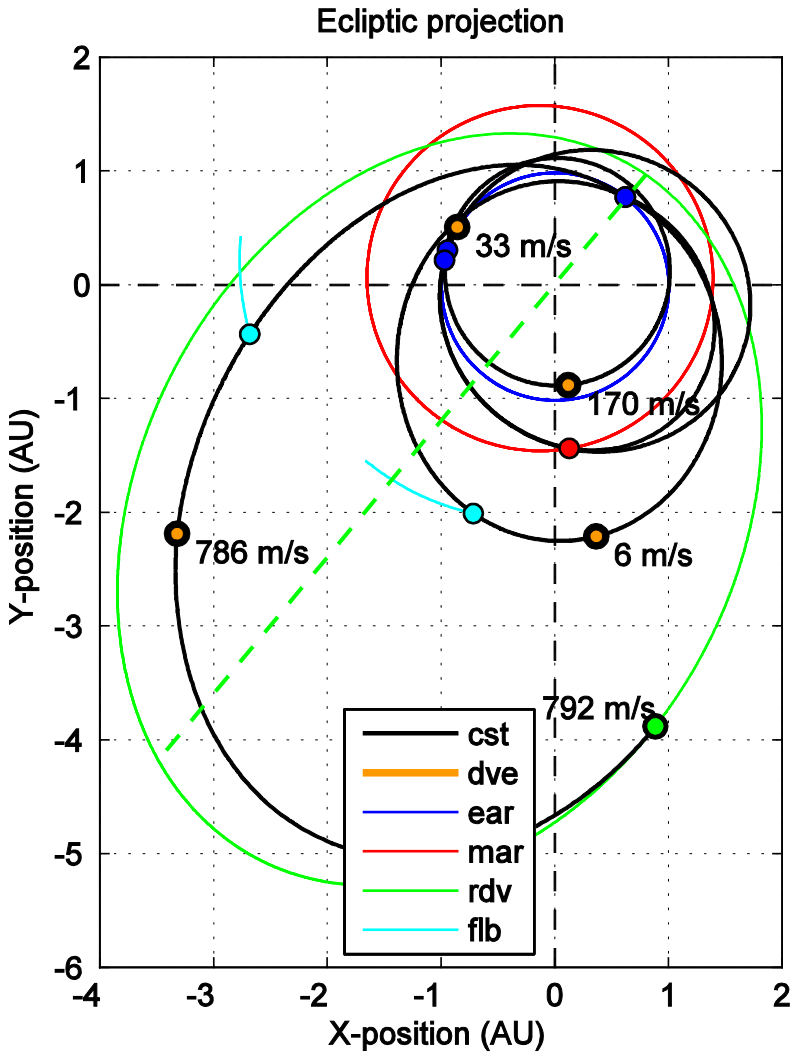
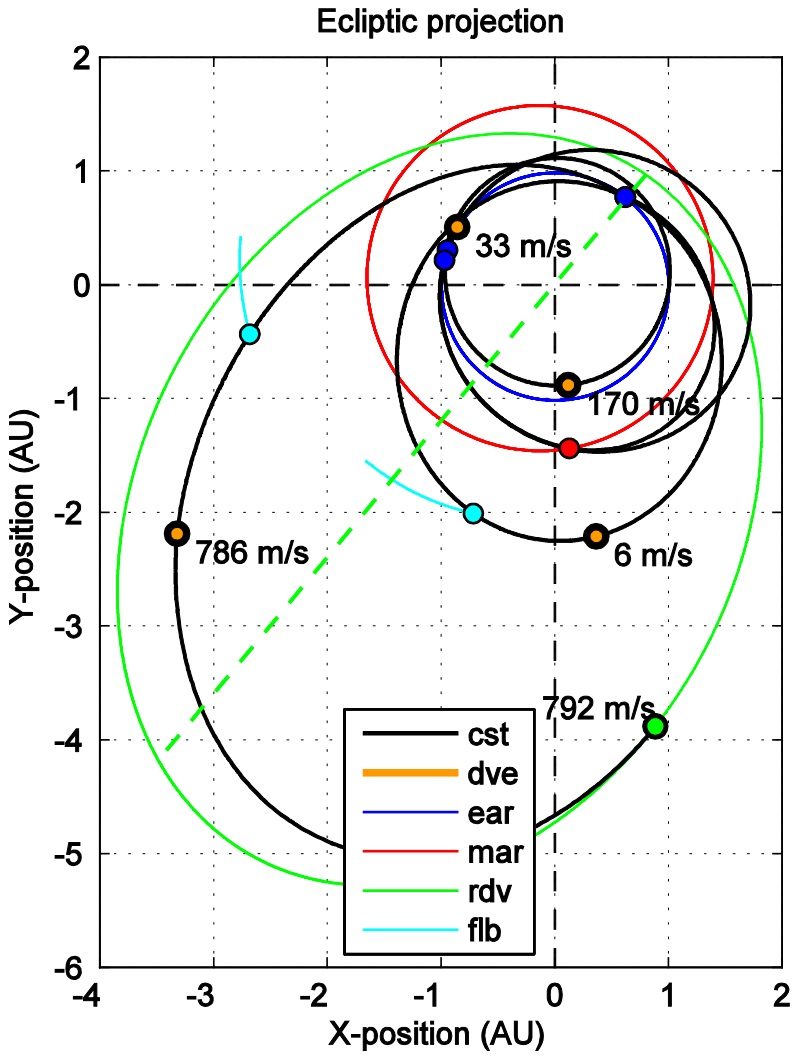
Introduction

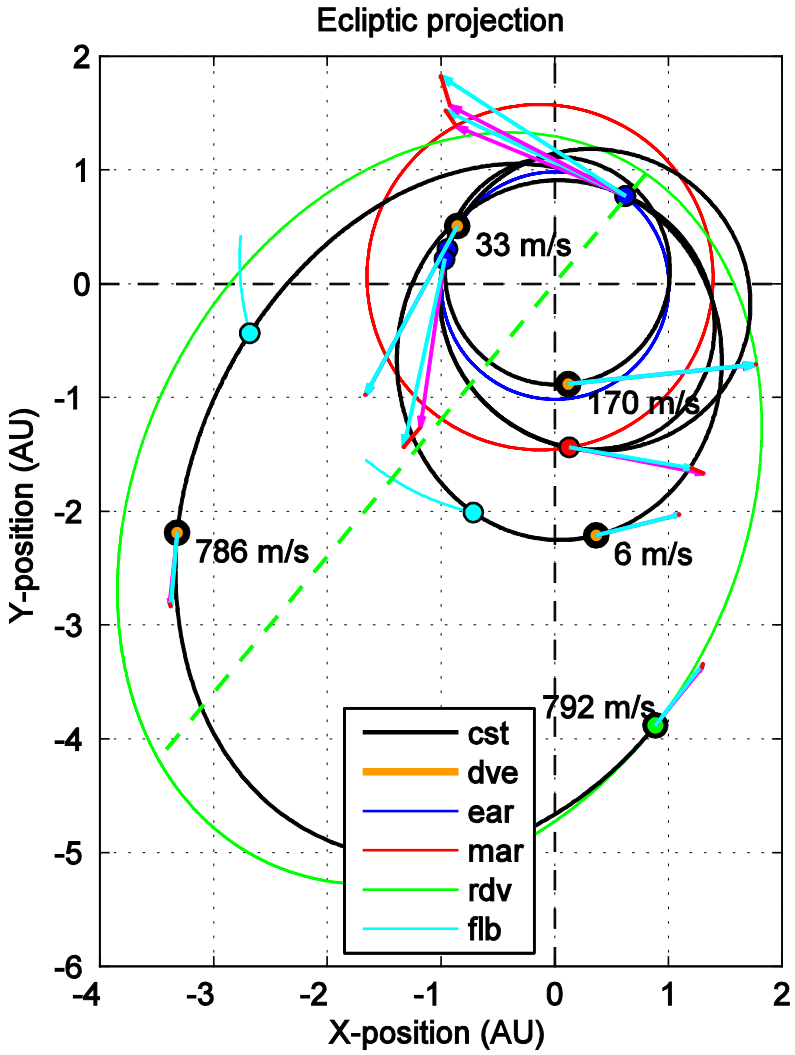


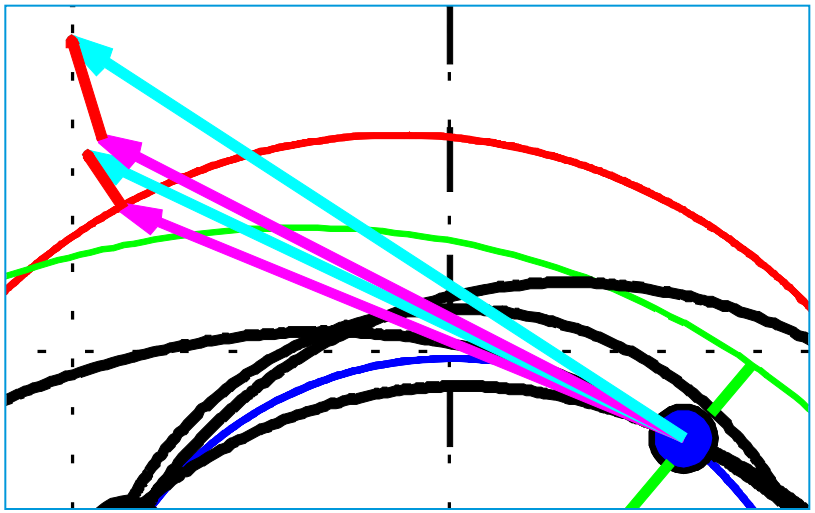
Outline

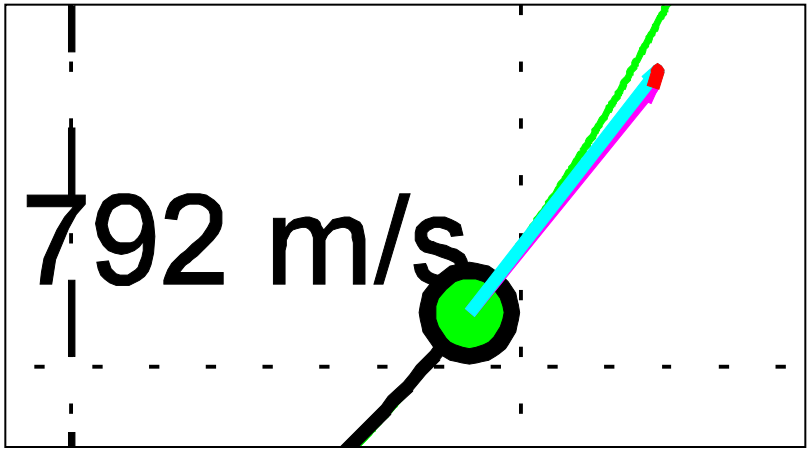


- Patched conics model
- Tisserand graph
- Swing-by's
- Resonant orbits
- Delta-V gravity assists
- Rosetta
- Solar Orbiter
- Juice
- Bepi-Colombo

Patched Conics Model: Swing-by







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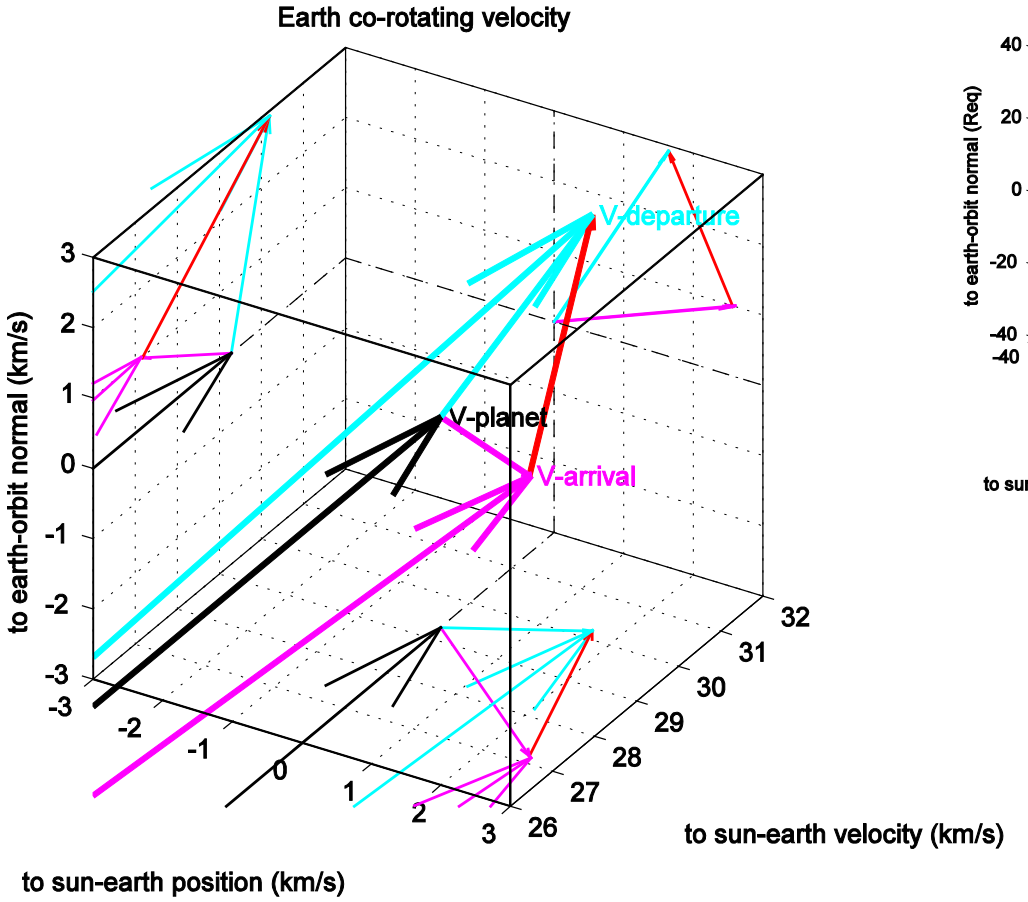
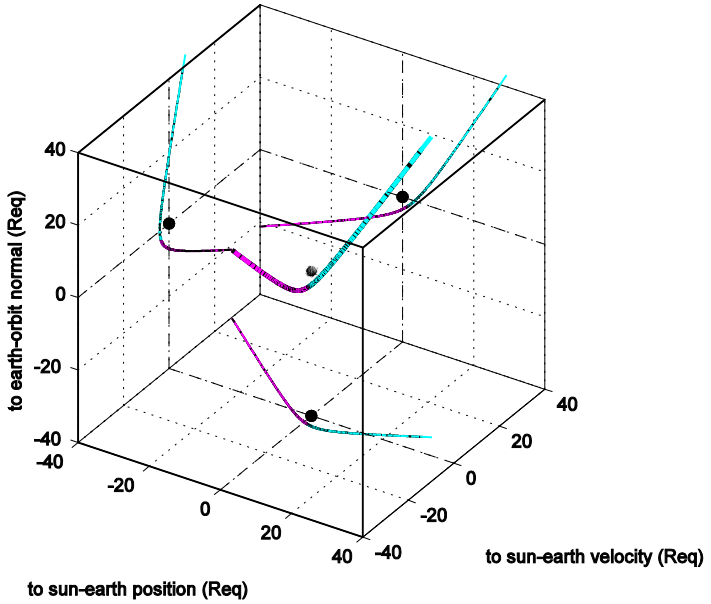
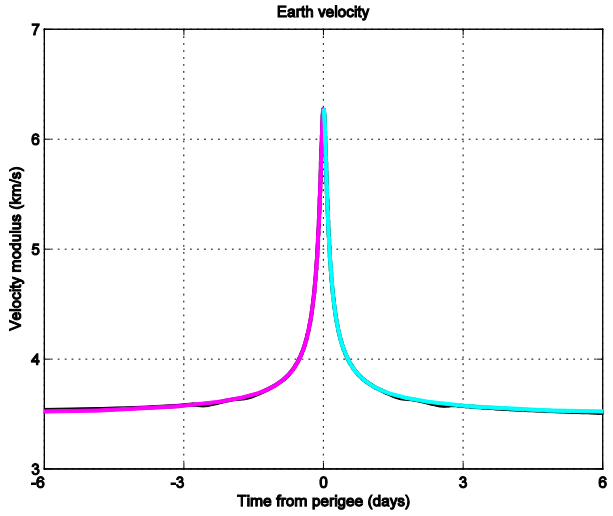
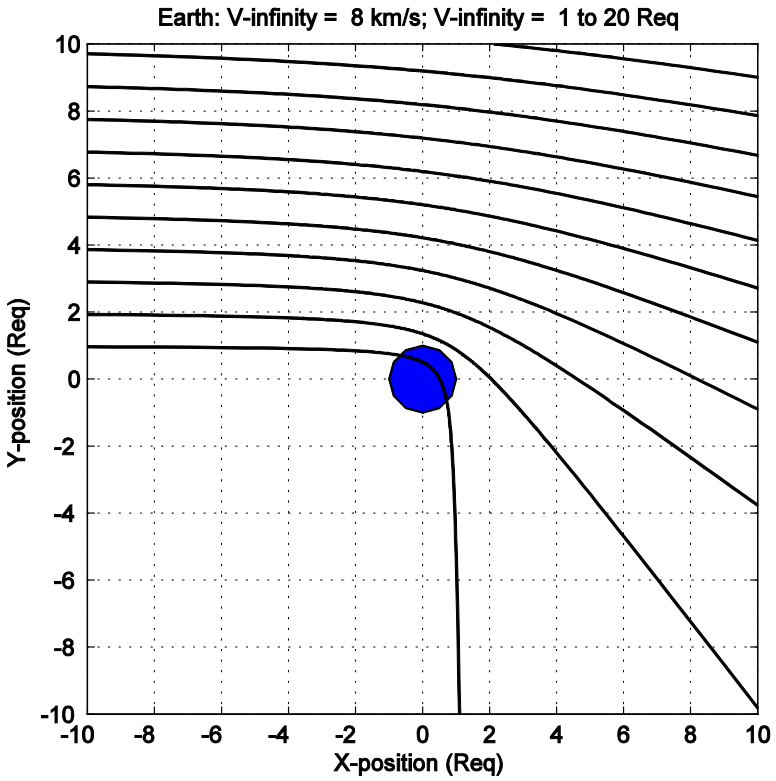


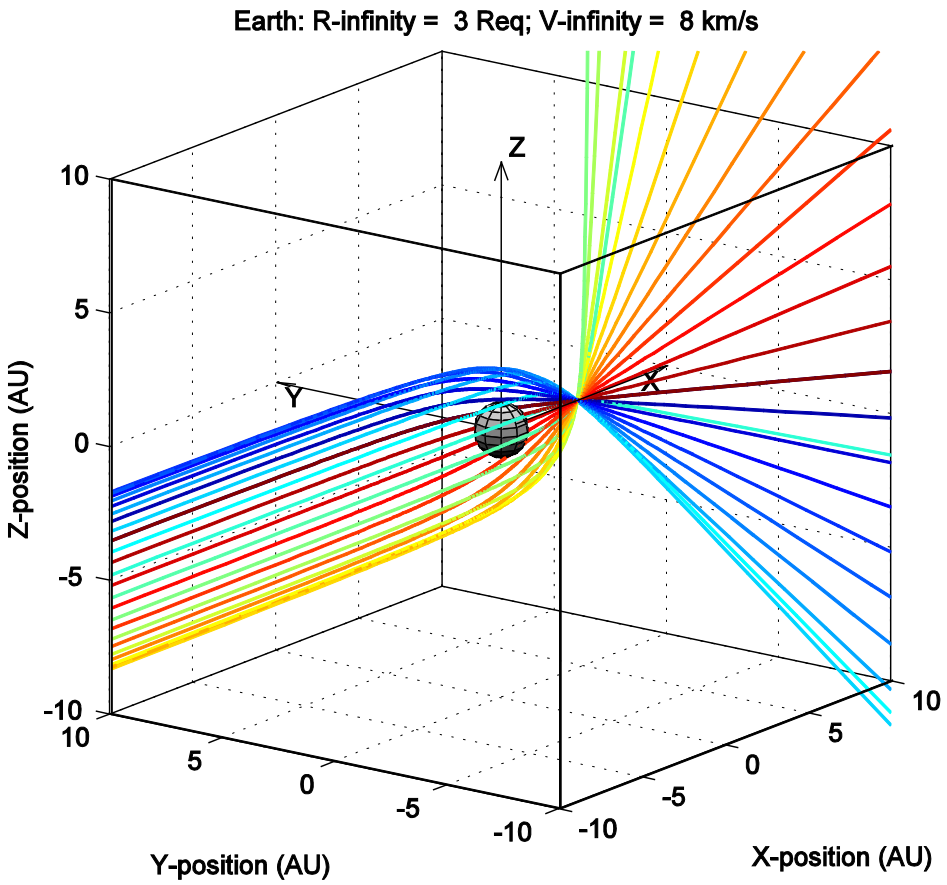




Patched Conics Model: Hyperbola

1 m/s at -10 days =>
1000 km change in approach point

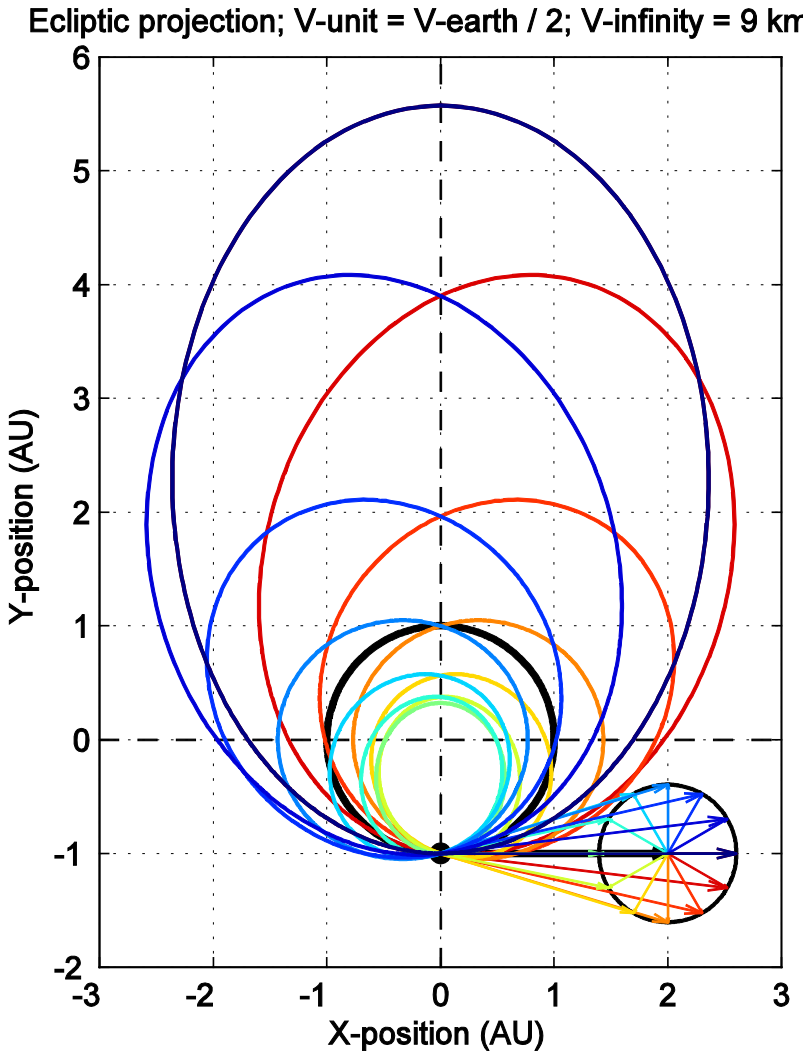


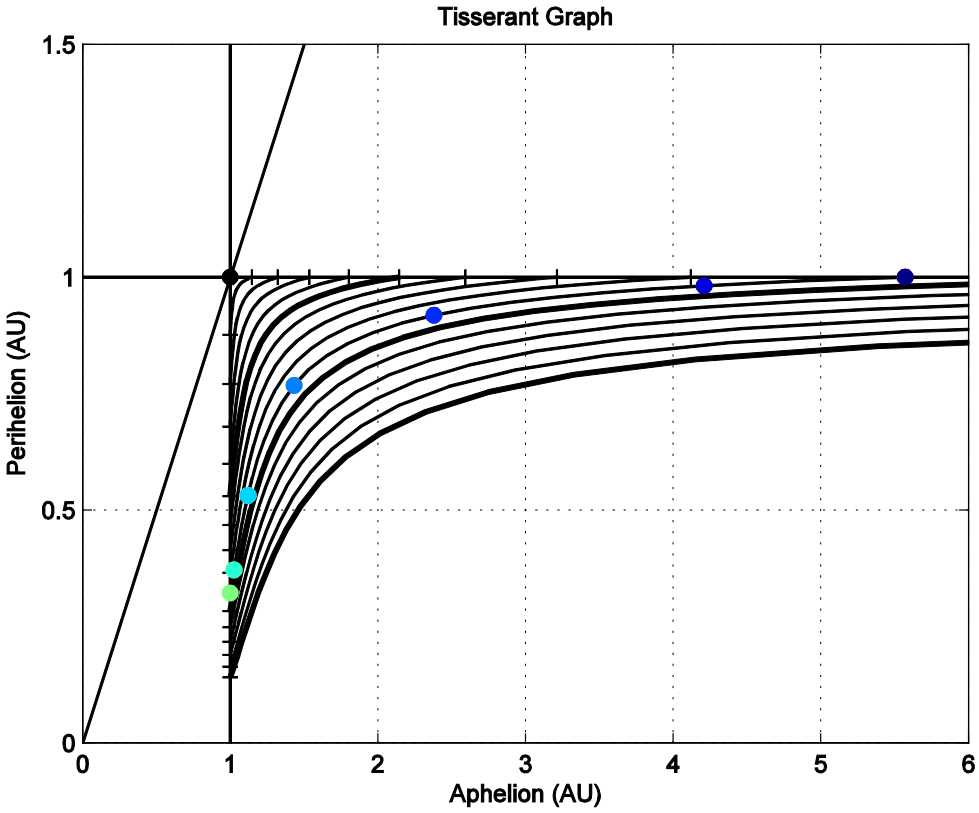


Patched conics model: Summary

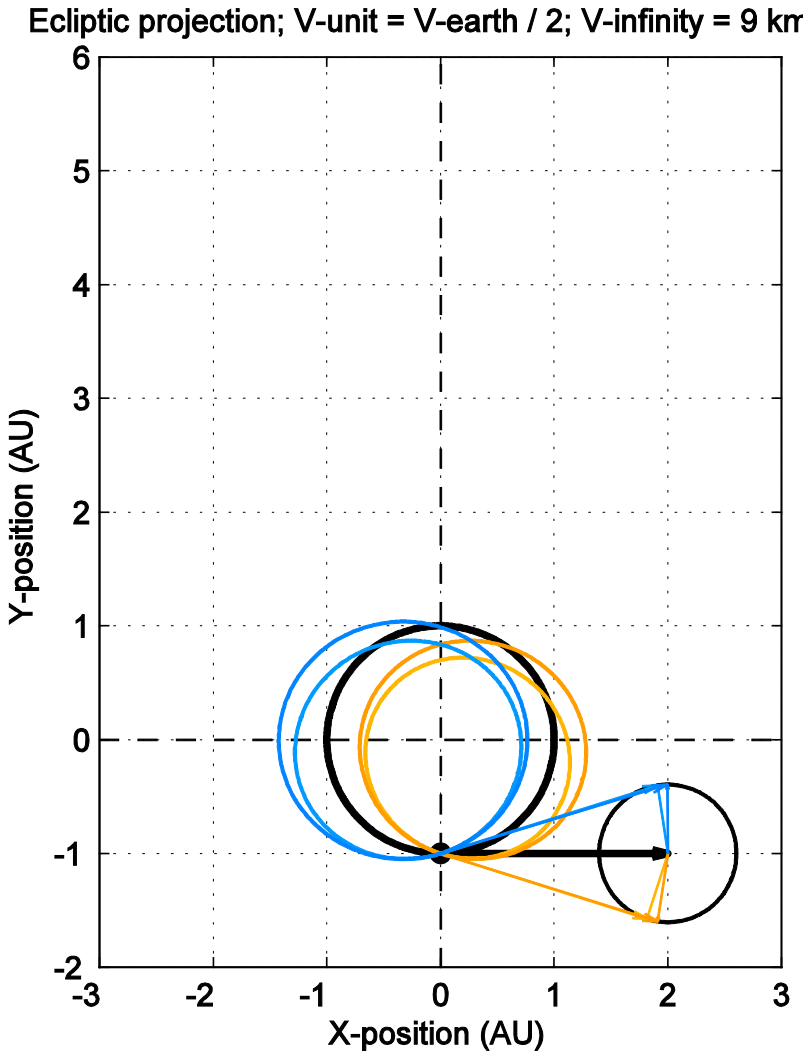
- **Motion relative to sun modelled by ellipse segment:**
  - Starting and ending at the centre of a planet or DSM location
  - Start time of next segment = End time of previous segment
- **Motion relative to planet modelled by hyperbola:**
  - Infinity arrival velocity vector of hyperbola = Final velocity vector of preceding ellipse segment - Planet velocity vector
  - Infinity departure velocity magnitude = Infinity arrival velocity magnitude
  - Control of deflection magnitude and direction by small adjustments of arrival conditions (few m/s)
  - Deflection magnitude limited by minimum peri-centre radius
  - Initial velocity vector of following ellipse segment = Planet velocity vector + Infinity departure velocity vector of hyperbola
- **Motion relative to asteroid or comet:**
  - Straight line
  - Rendez-vous Delta-V vector = - Infinity arrival velocity vector
- **Deep space manoeuvre:**
  - Delta-V vector = Initial velocity vector of following ellipse segment - Final velocity vector of preceding ellipse segment

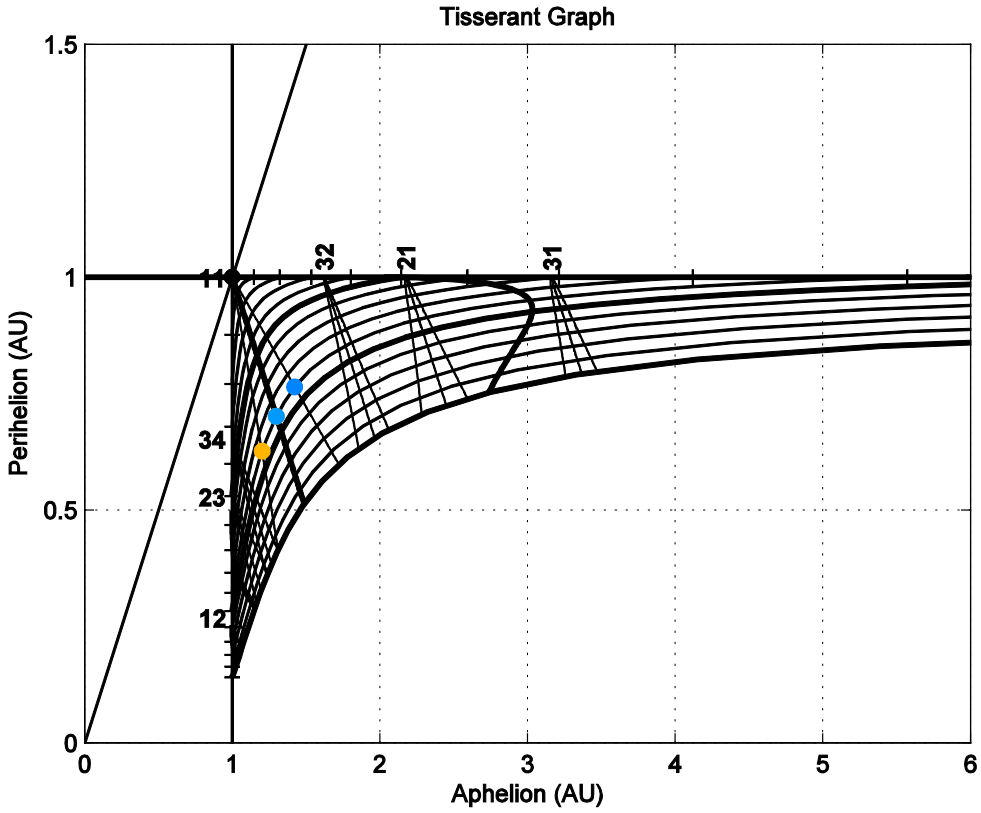
Tisserand graph: V-infinity lines



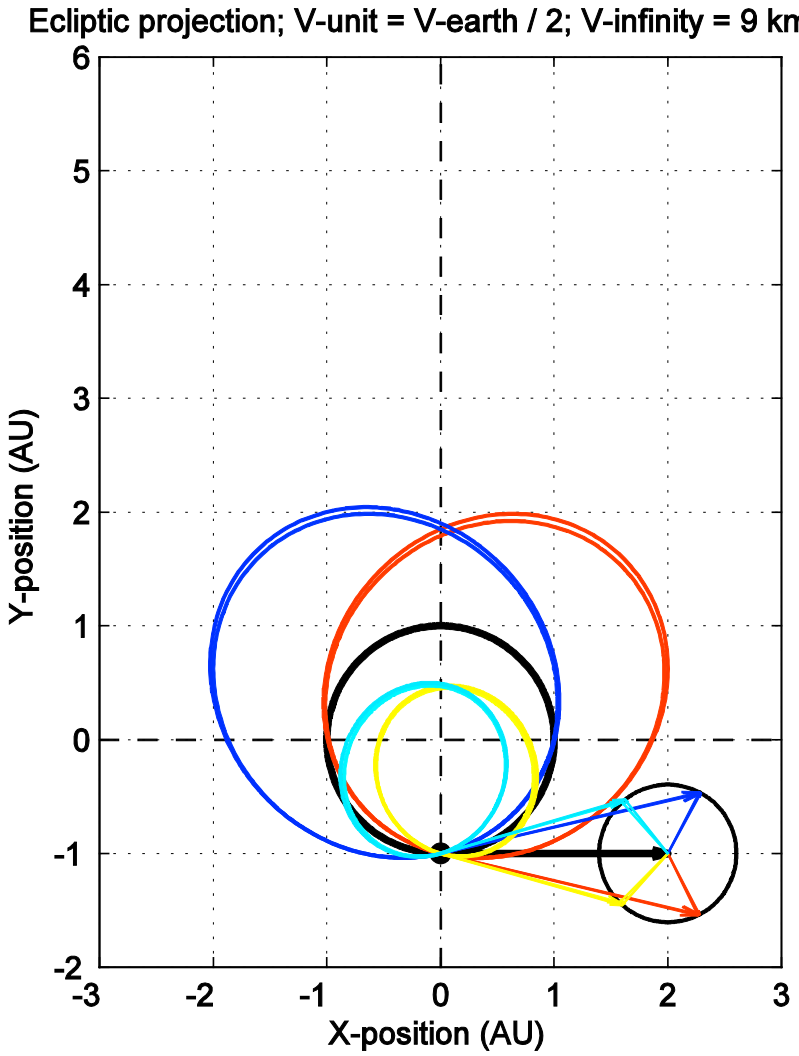


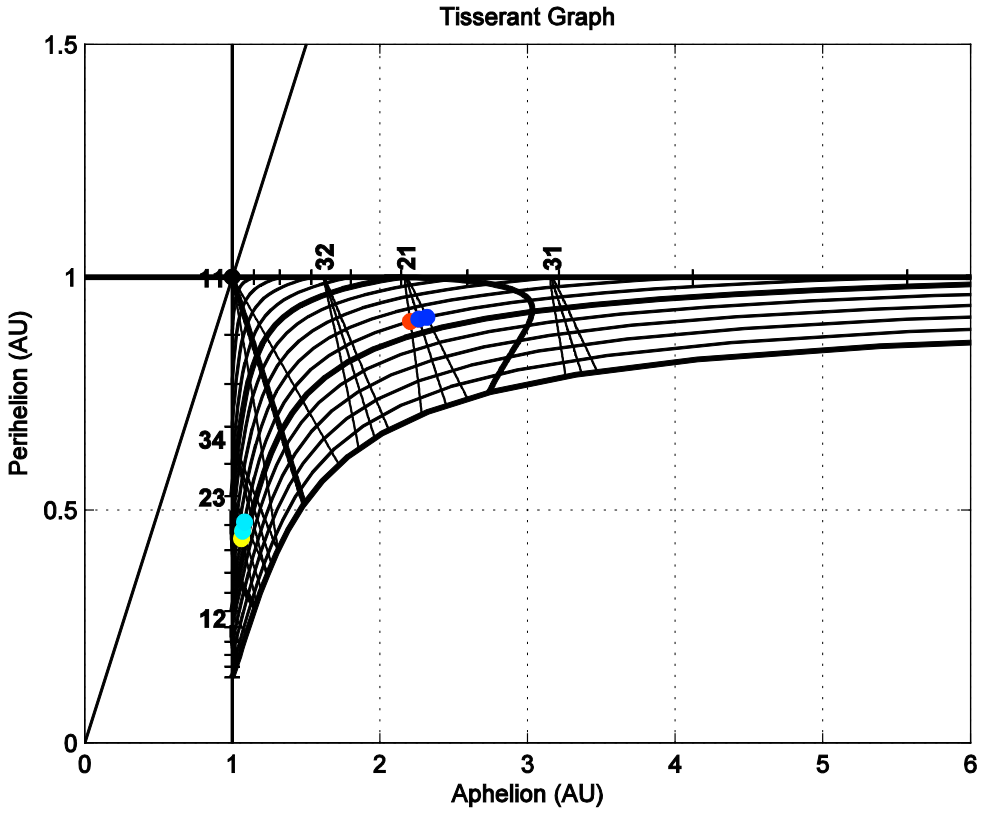
Tisserand graph: Resonant orbits



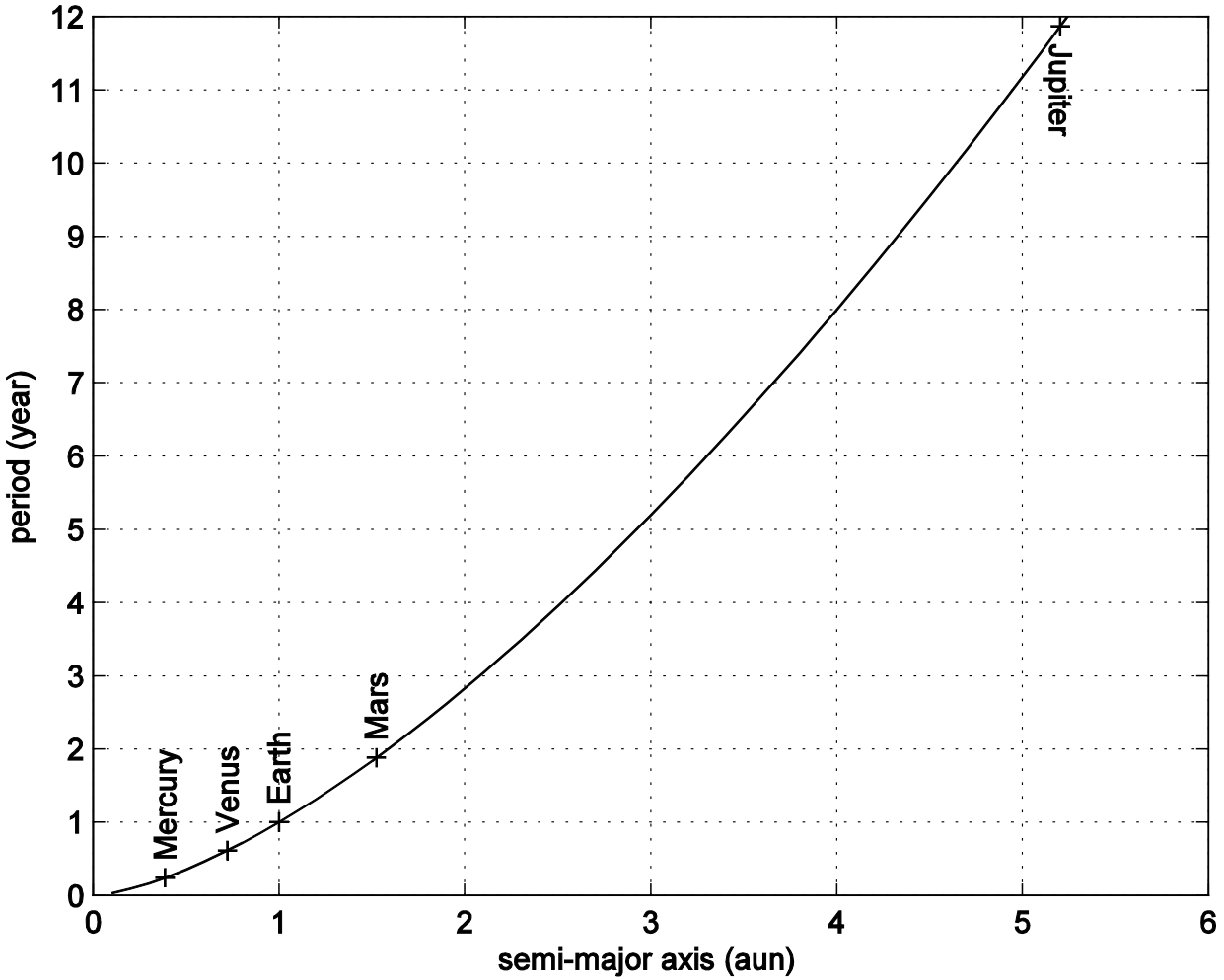


Tisserand graph: Resonant orbits



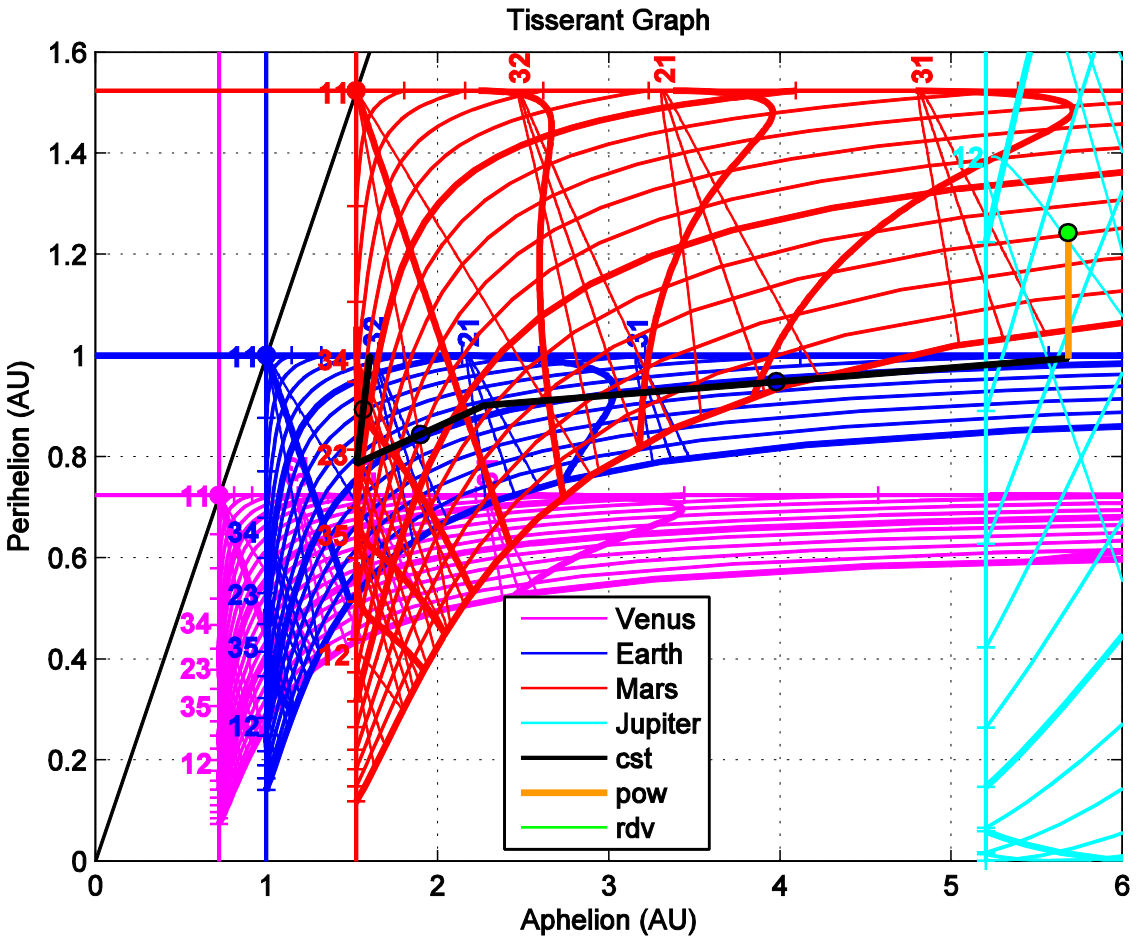


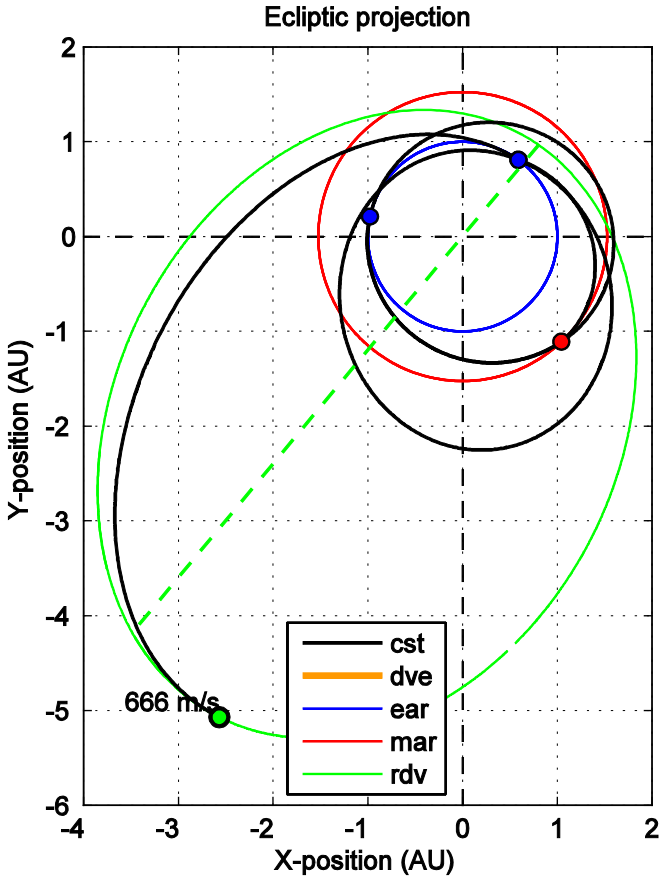
Tisserand graph: Resonant orbits



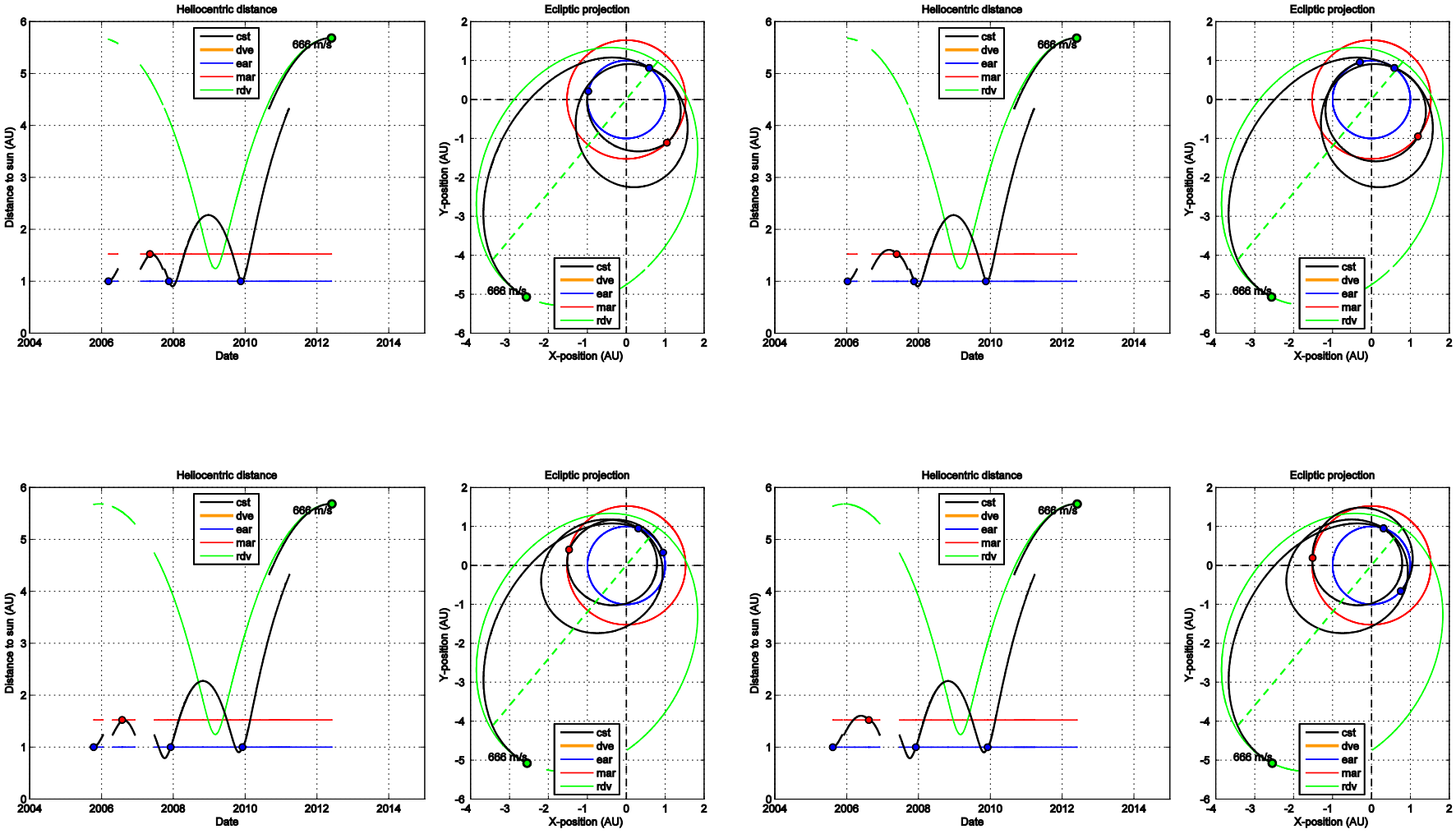
Tisserand graph: Rosetta

Rendez-Vous with Comet Churyumov-Gerasimenko

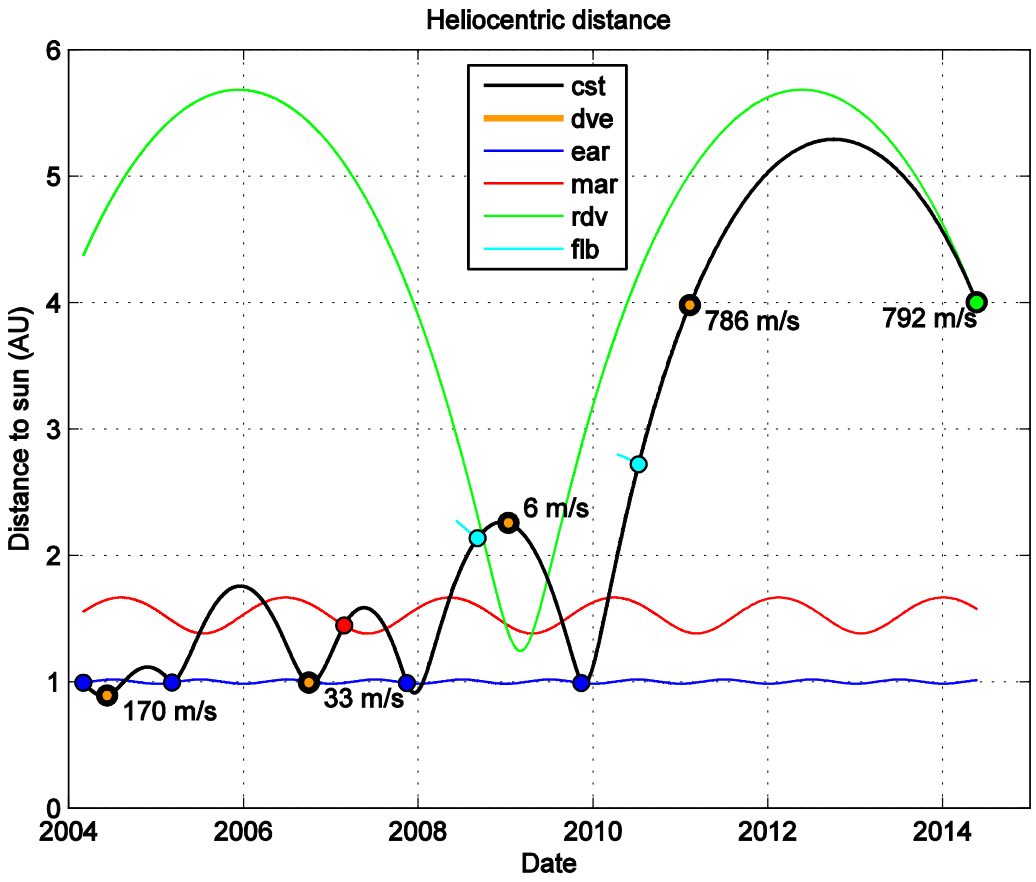


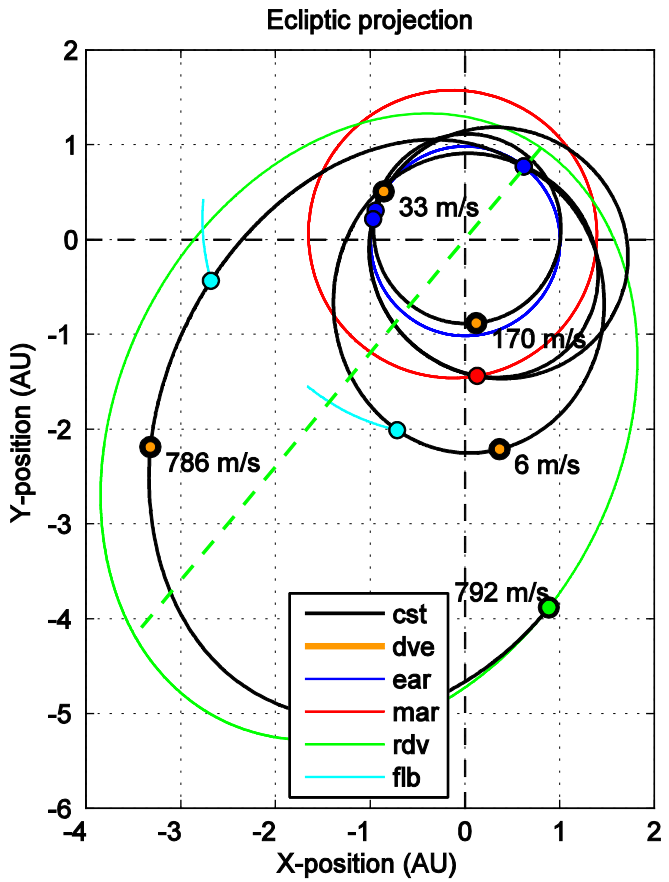


Tisserand graph: Solution types

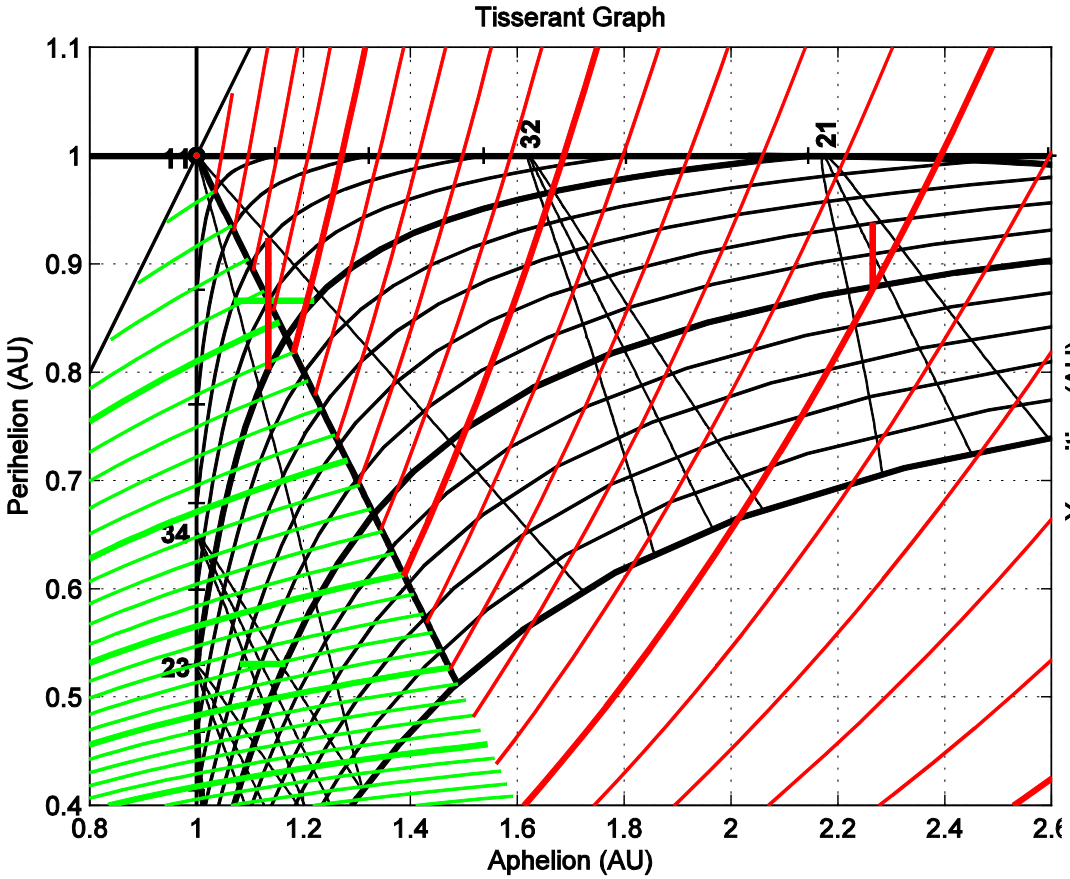


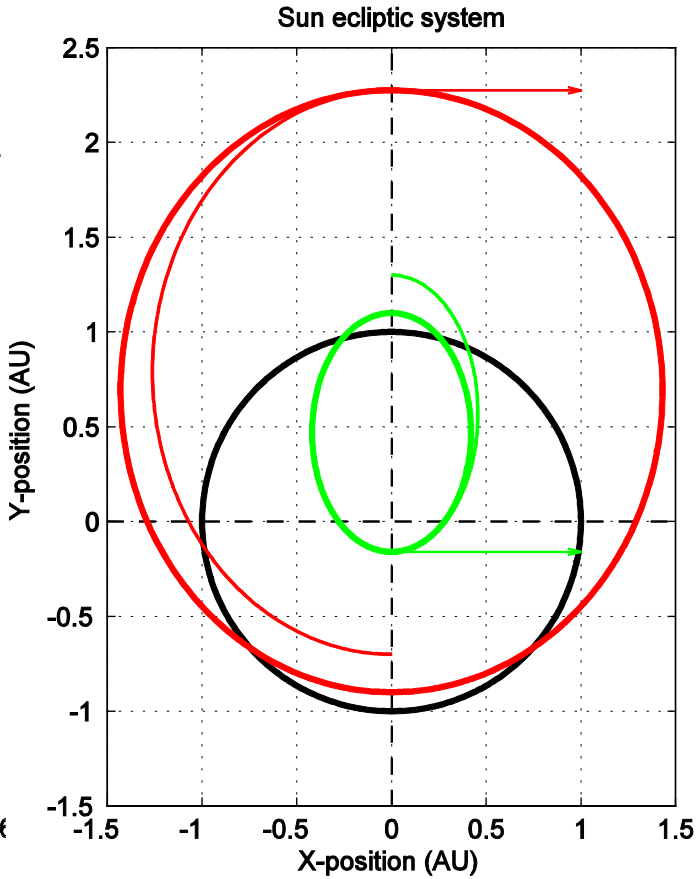
Tisserand graph: Rosetta



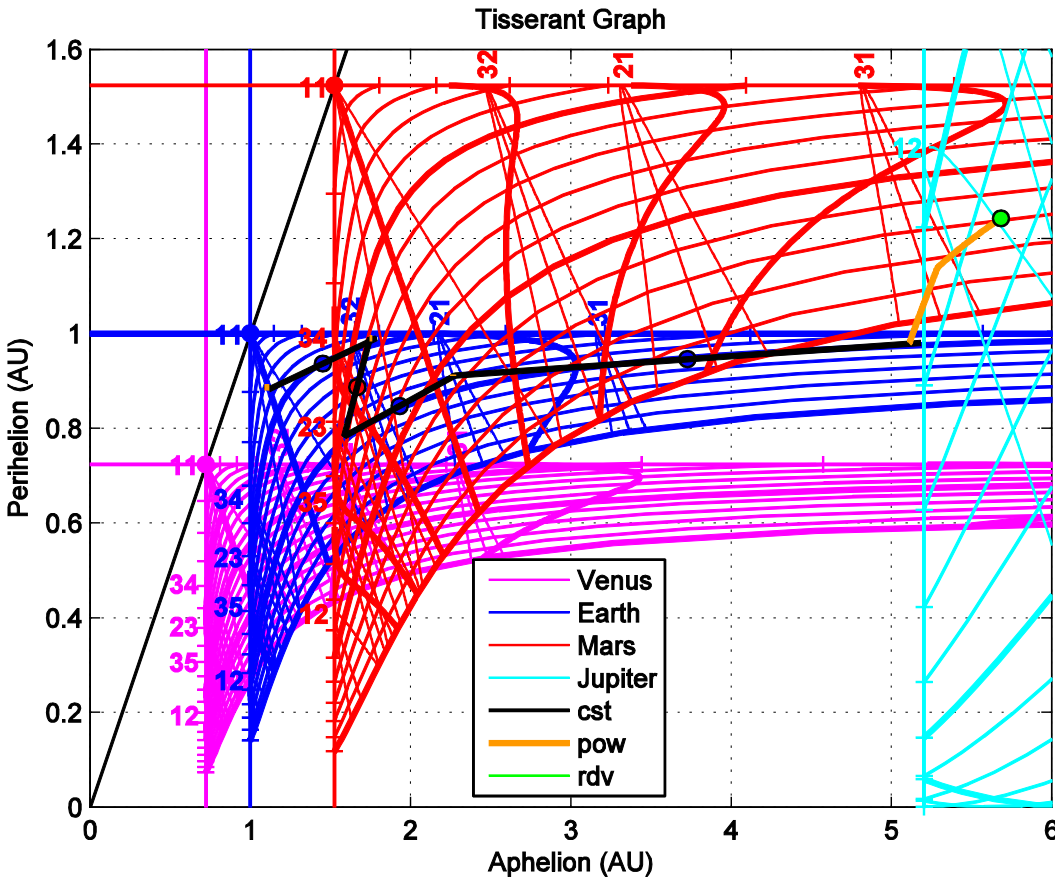


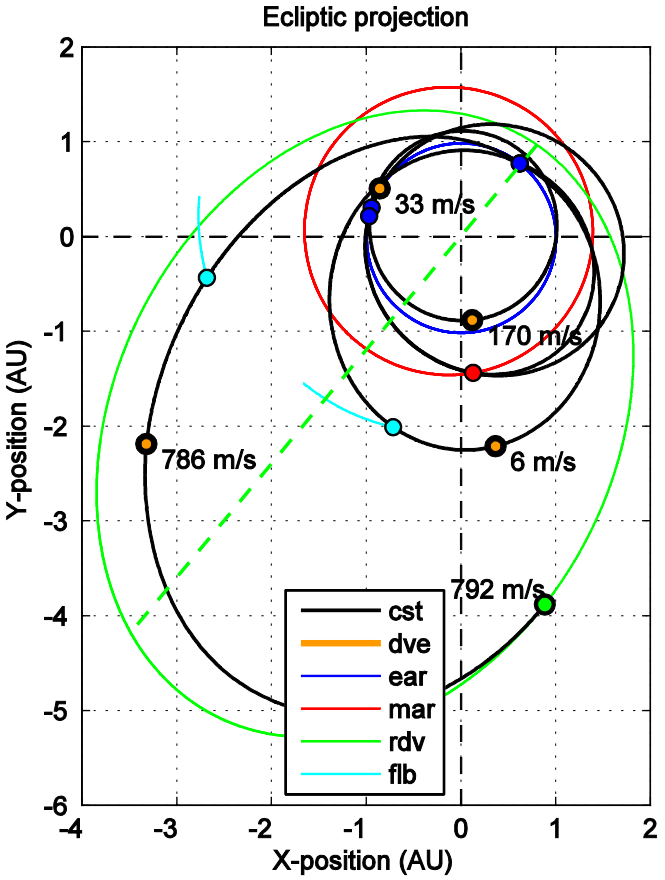
Tisserand graph: DV Gravity assist





Tisserand graph: Rosetta

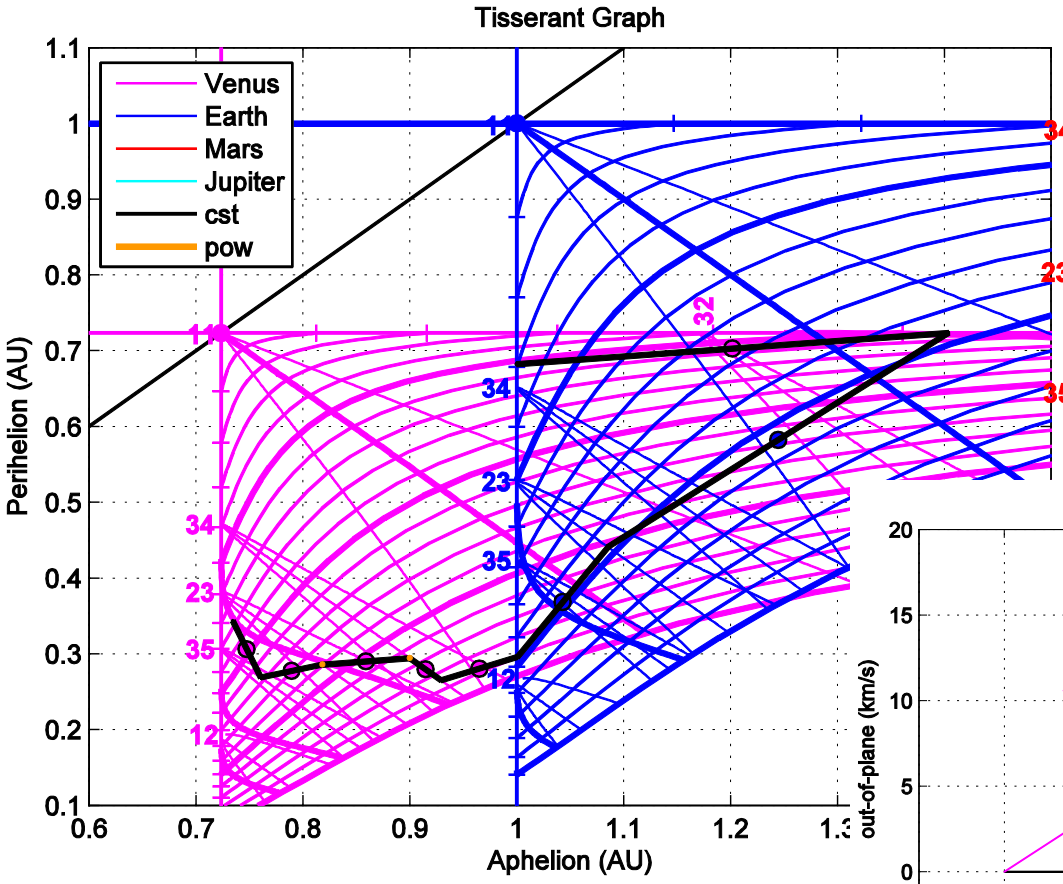


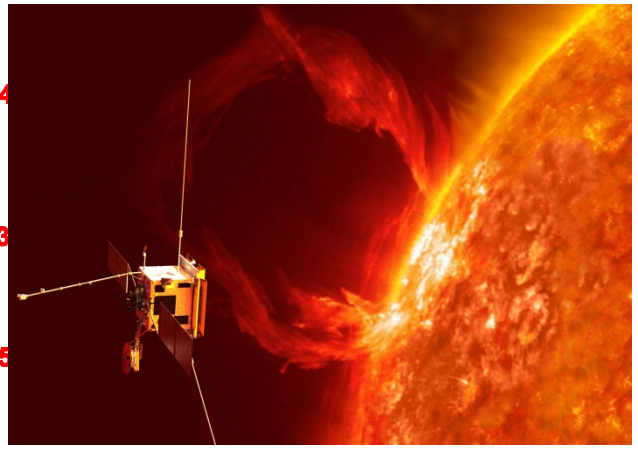


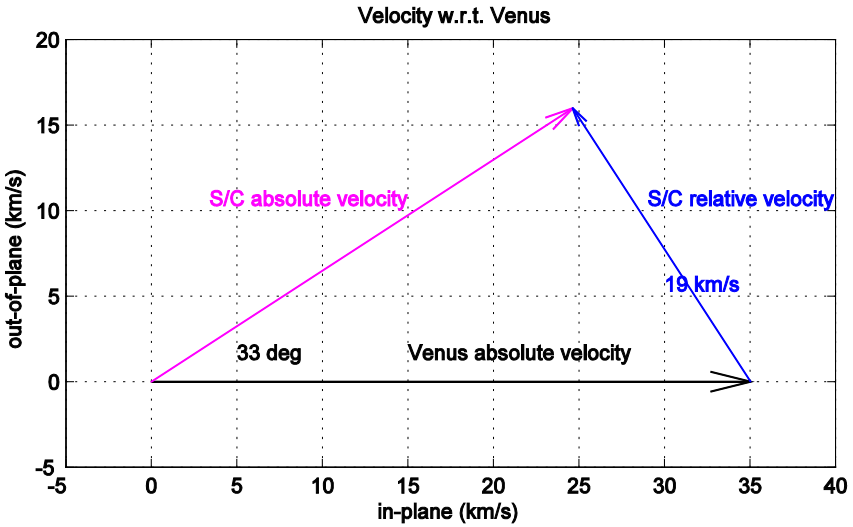
Tisserand graph: Summary

- **2-D plot of pericentre radius versus apocentre radius**
- **Simplifications**
  - Planar motion
  - Circular planet orbits
  - Timing ignored
- **Content**
  - Equal V-infinity lines
  - Lines of full and pseudo resonances
  - Lines of maximum deflection of V-infinity
  - Lines of constant pericentre and apocentre velocity => DV gravity assist
- **Purpose**
  - Identify possible sequences of swing-by's and resonances
  - Identify associated solution types (inward and outward)
- **Time gaps solved by**
  - Shifting swing-by's by one or more planer revolutions
  - Adding intermediate revolutions
  - Closing residual time gap by local optimisation of given solution type

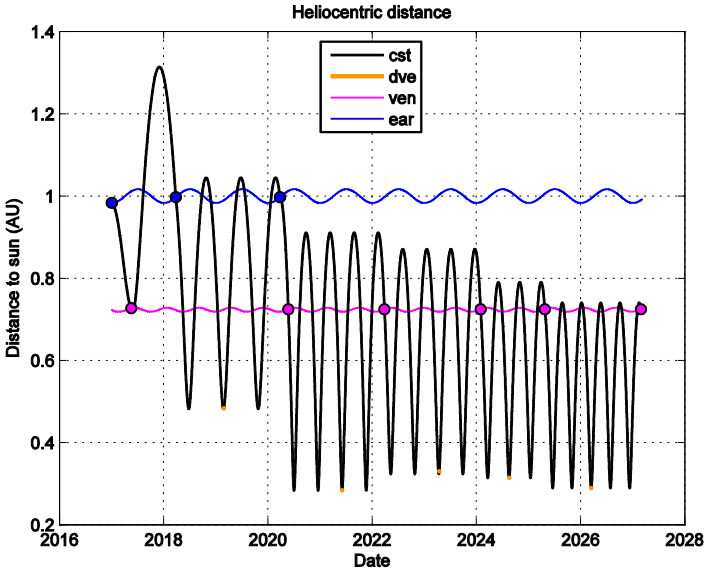
Close and high latitude solar observatory mission

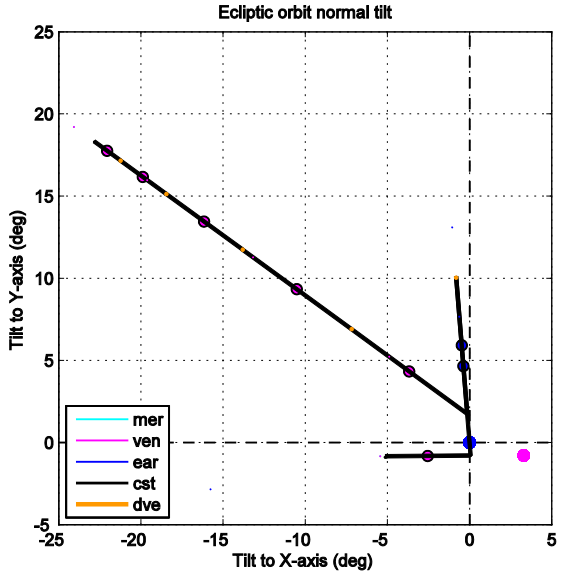


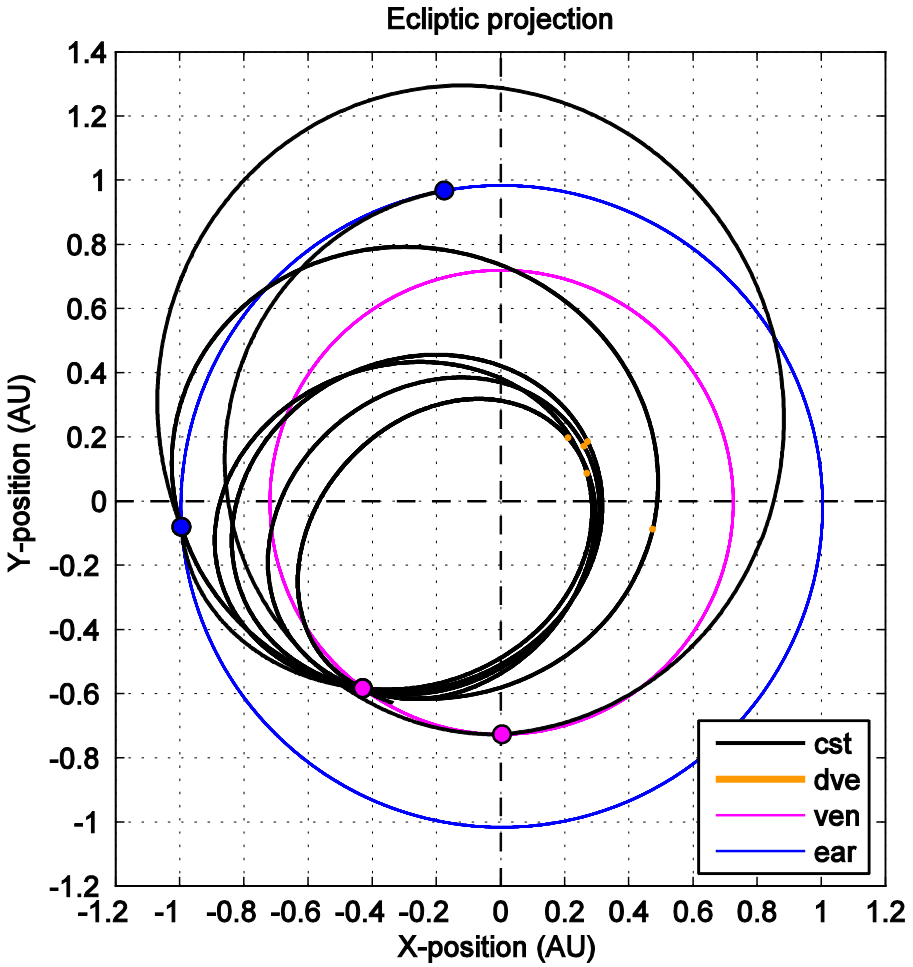




Inner solar system transfer: Solo

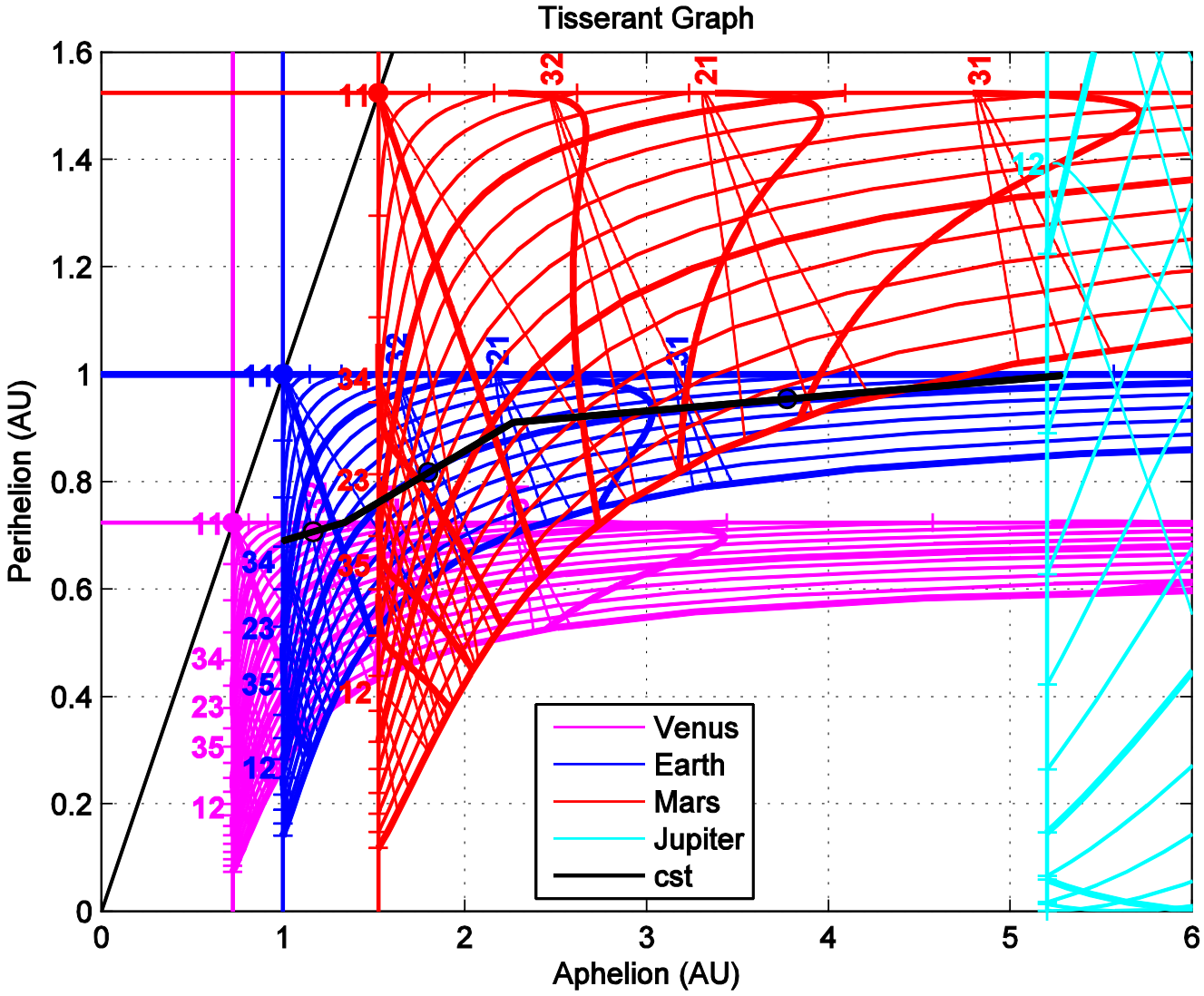


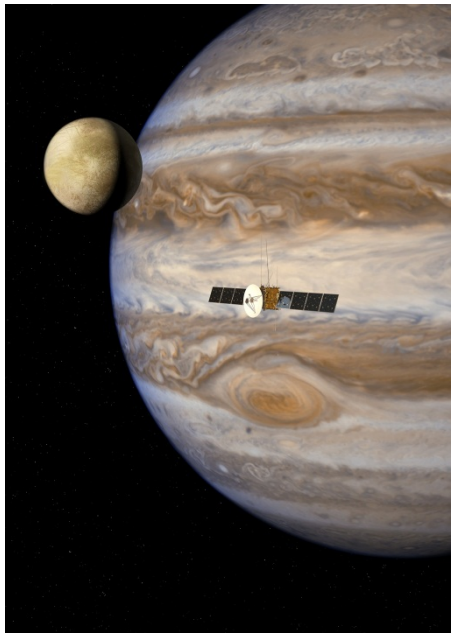




Outer solar system transfer: Juice

Mission to Jovian moons Europa and Ganymede





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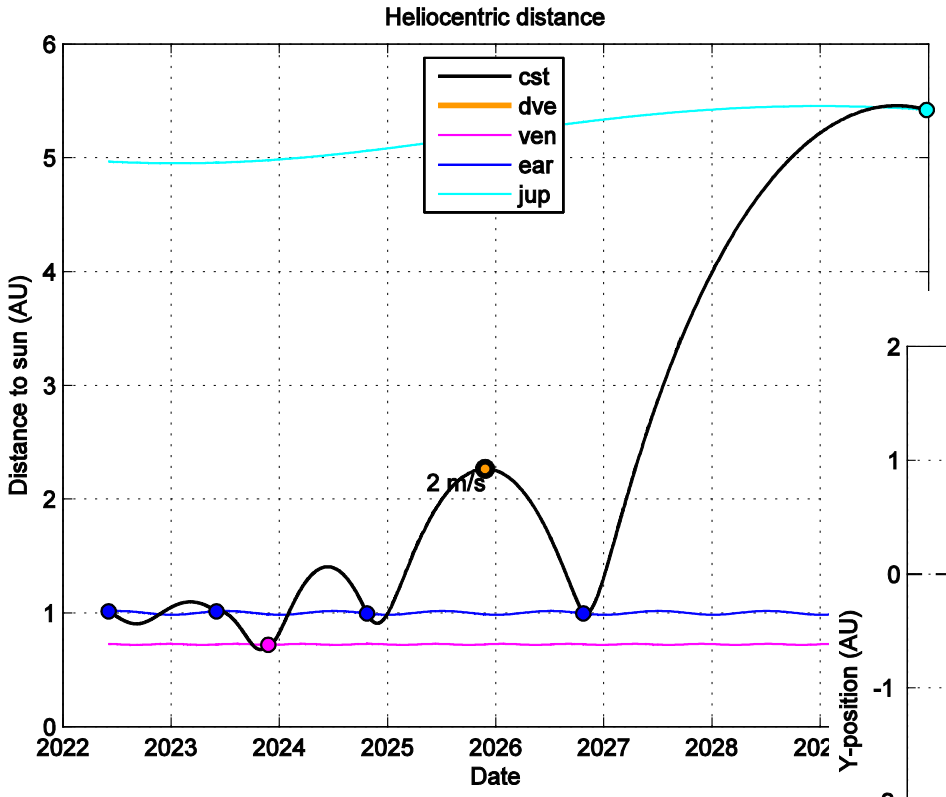
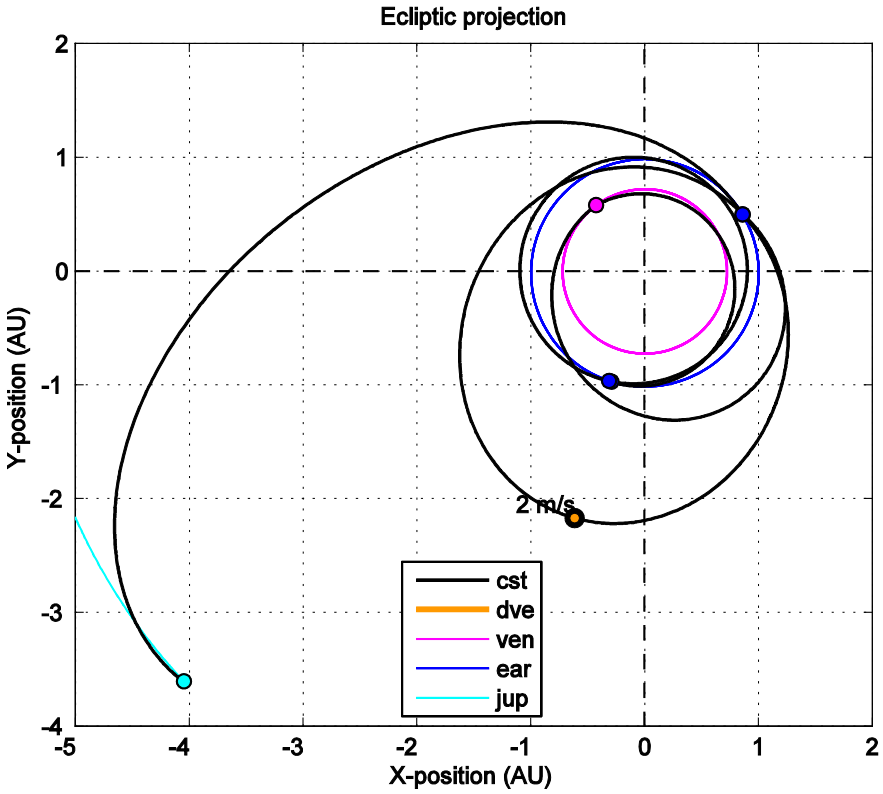
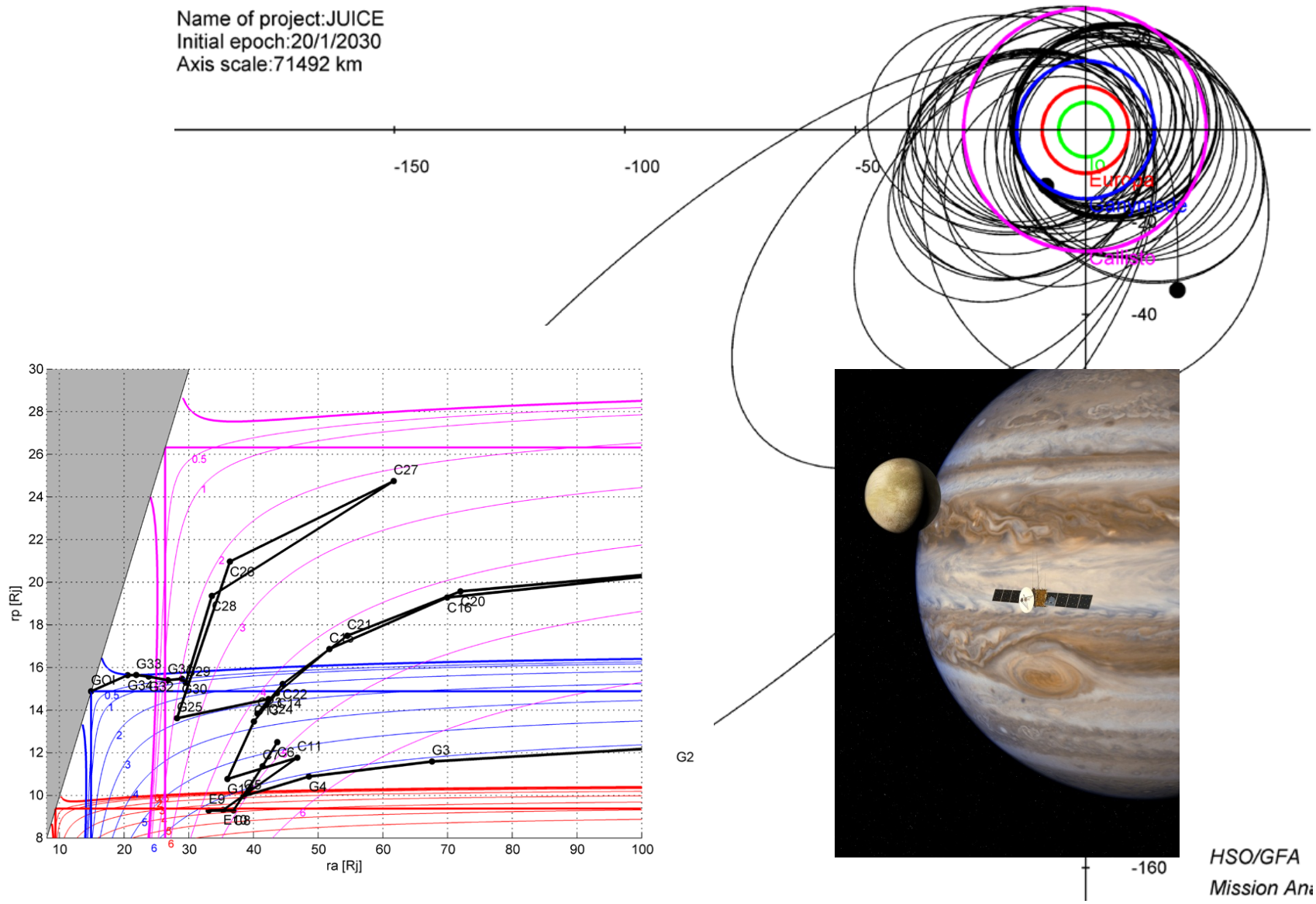


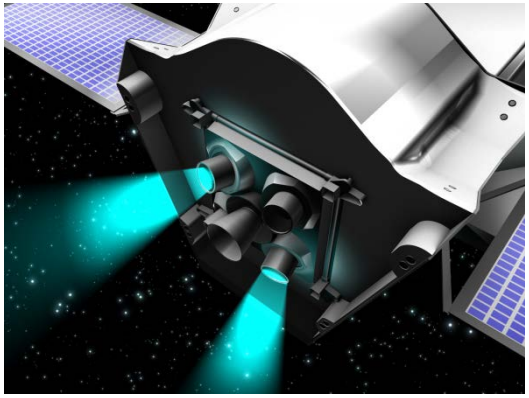


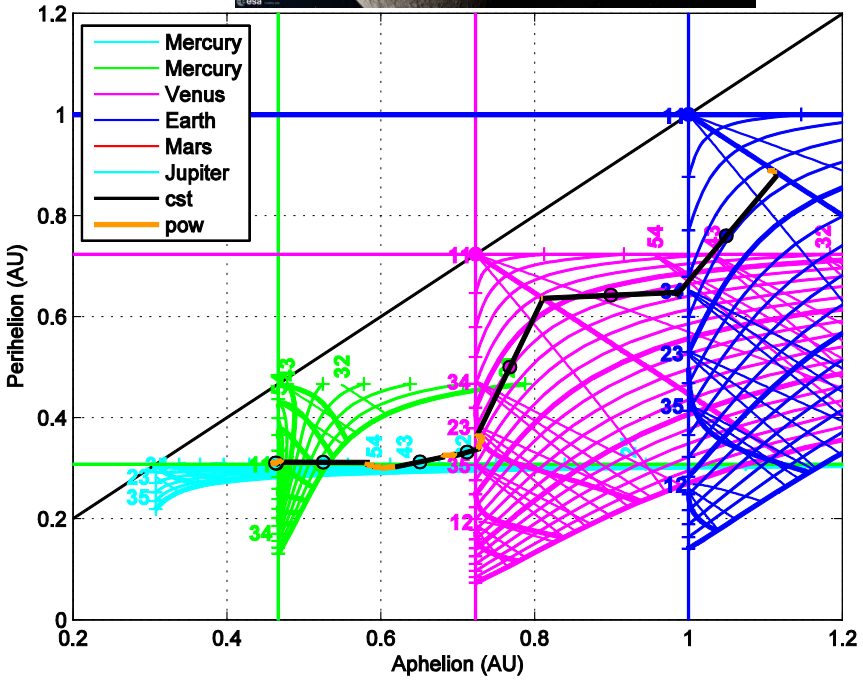
Jupiter tour

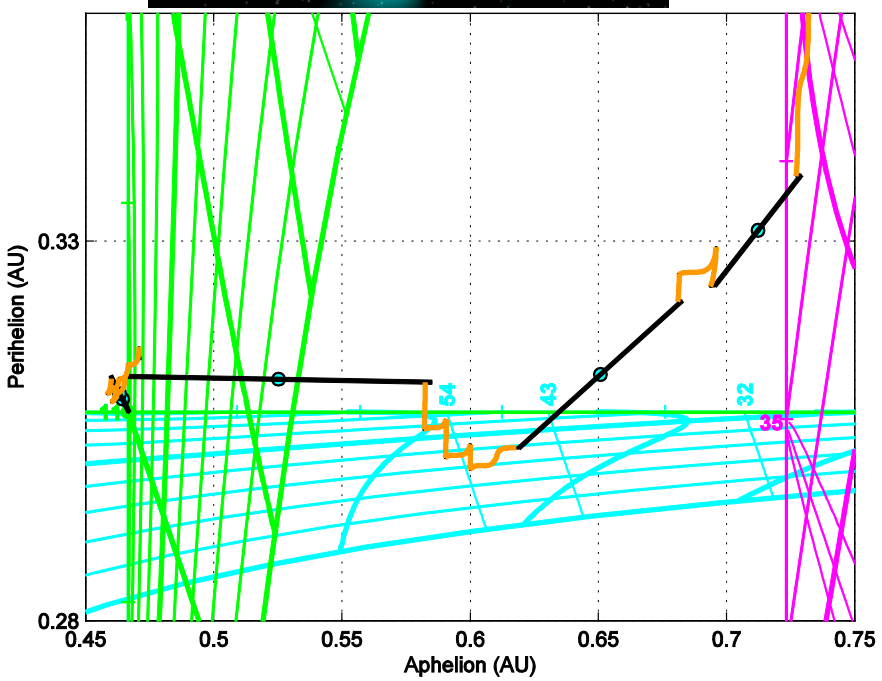


SEP transfer: Bepi-Colombo

Mercury orbiter mission with solar electric propulsion transfer







SEP transfer: Bepi-Colombo