Transfers to the Outer Solar System

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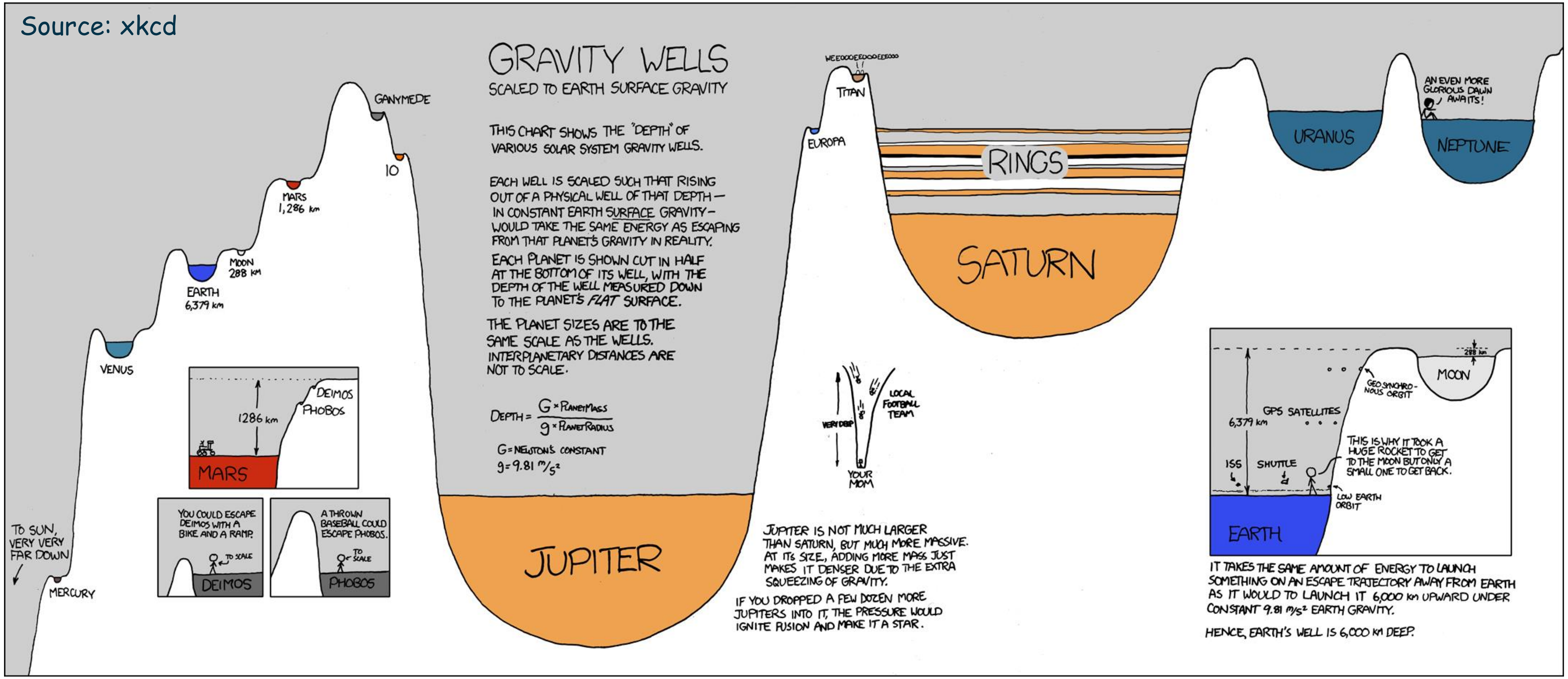
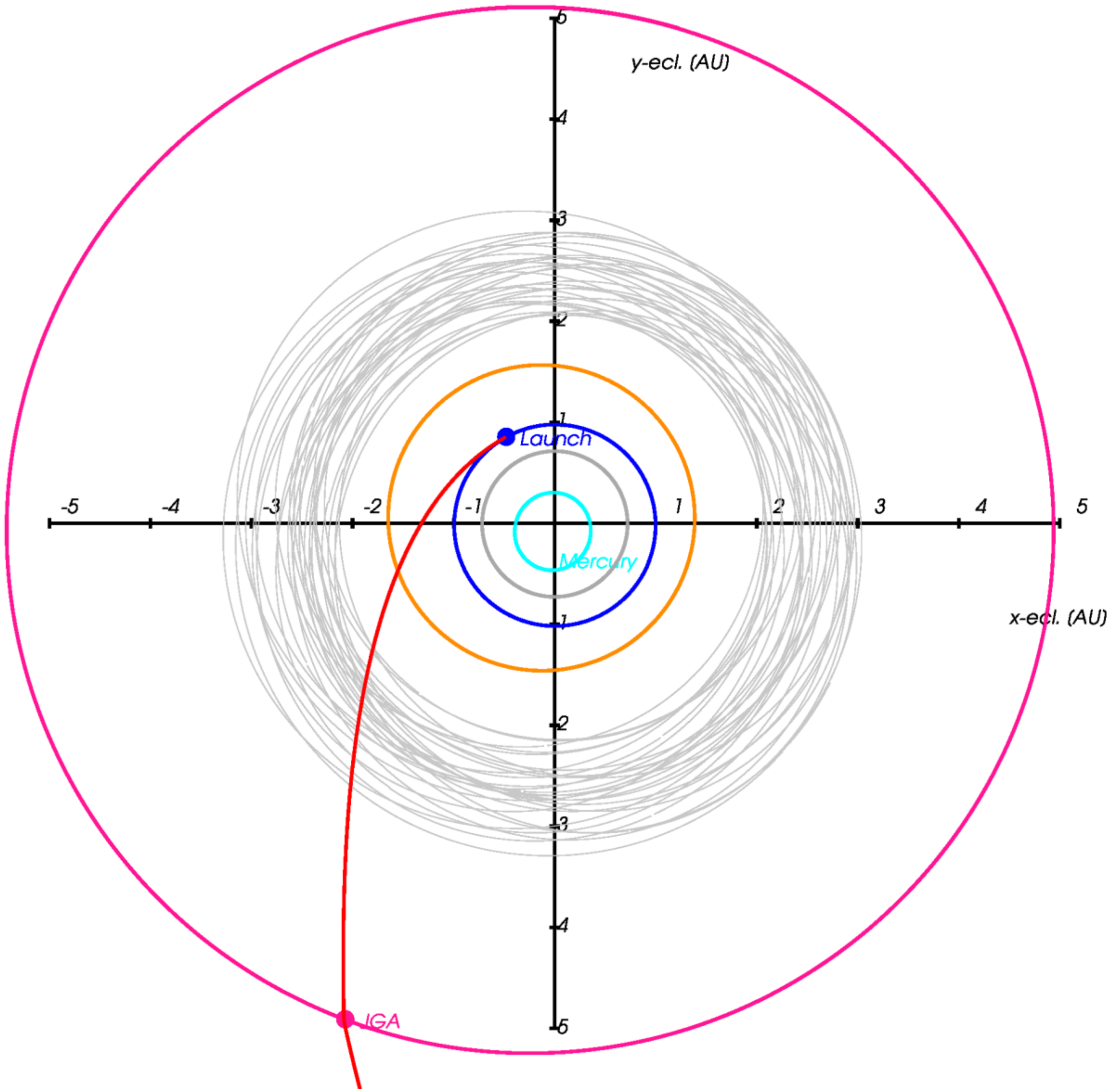
The Challenge of Reaching the Outer Solar System



Source: xkcd

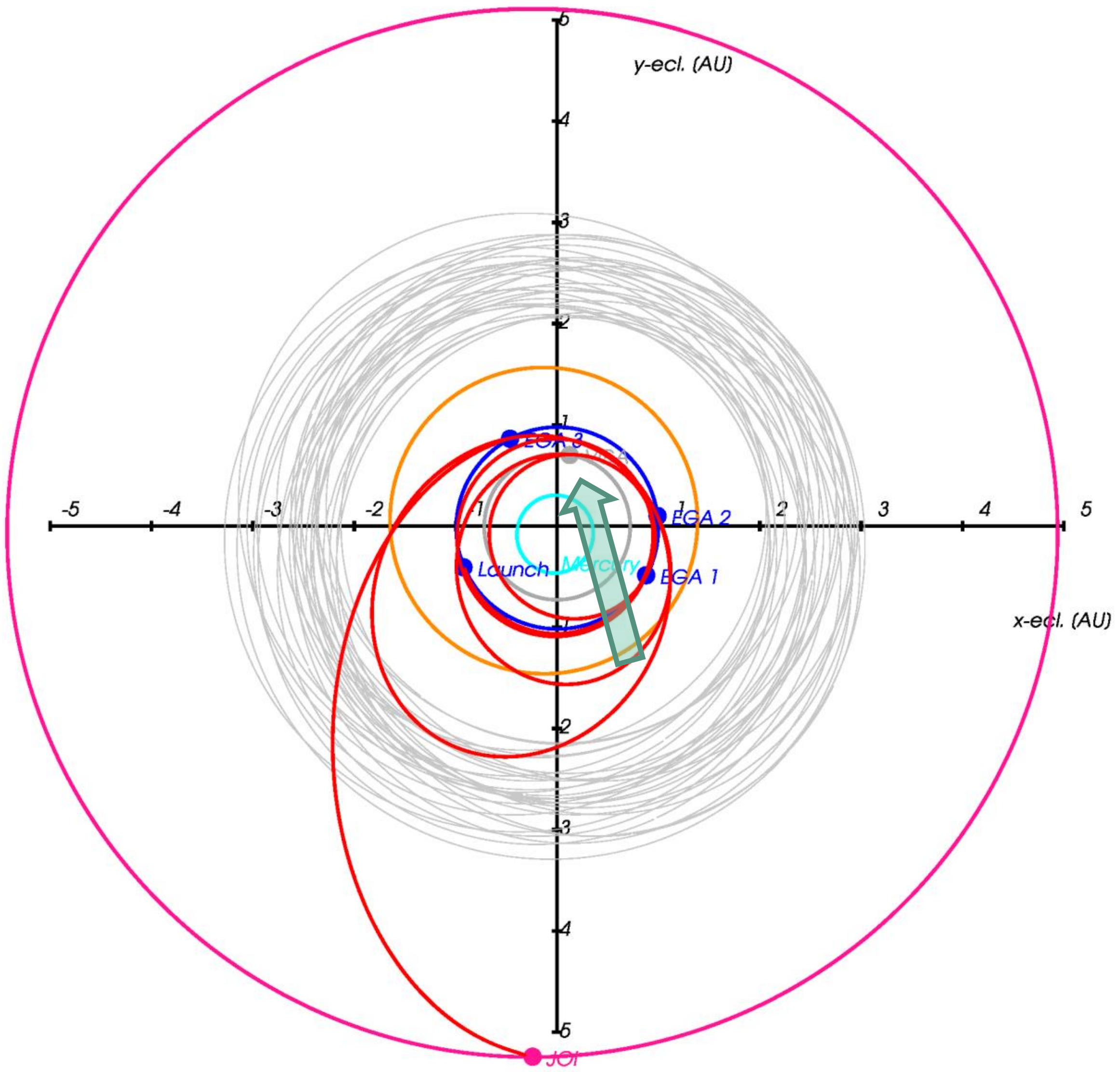
- The outer solar system is far away … Not just in actual distance – that would not matter, but in terms of energy
- There are several ways to overcome the energy difference
  - Use a large rocket and let that do the work
  - Use planetary swingbys, propulsive manoeuvres, or a combination of both

Big-Rocket Only: Example New Horizons



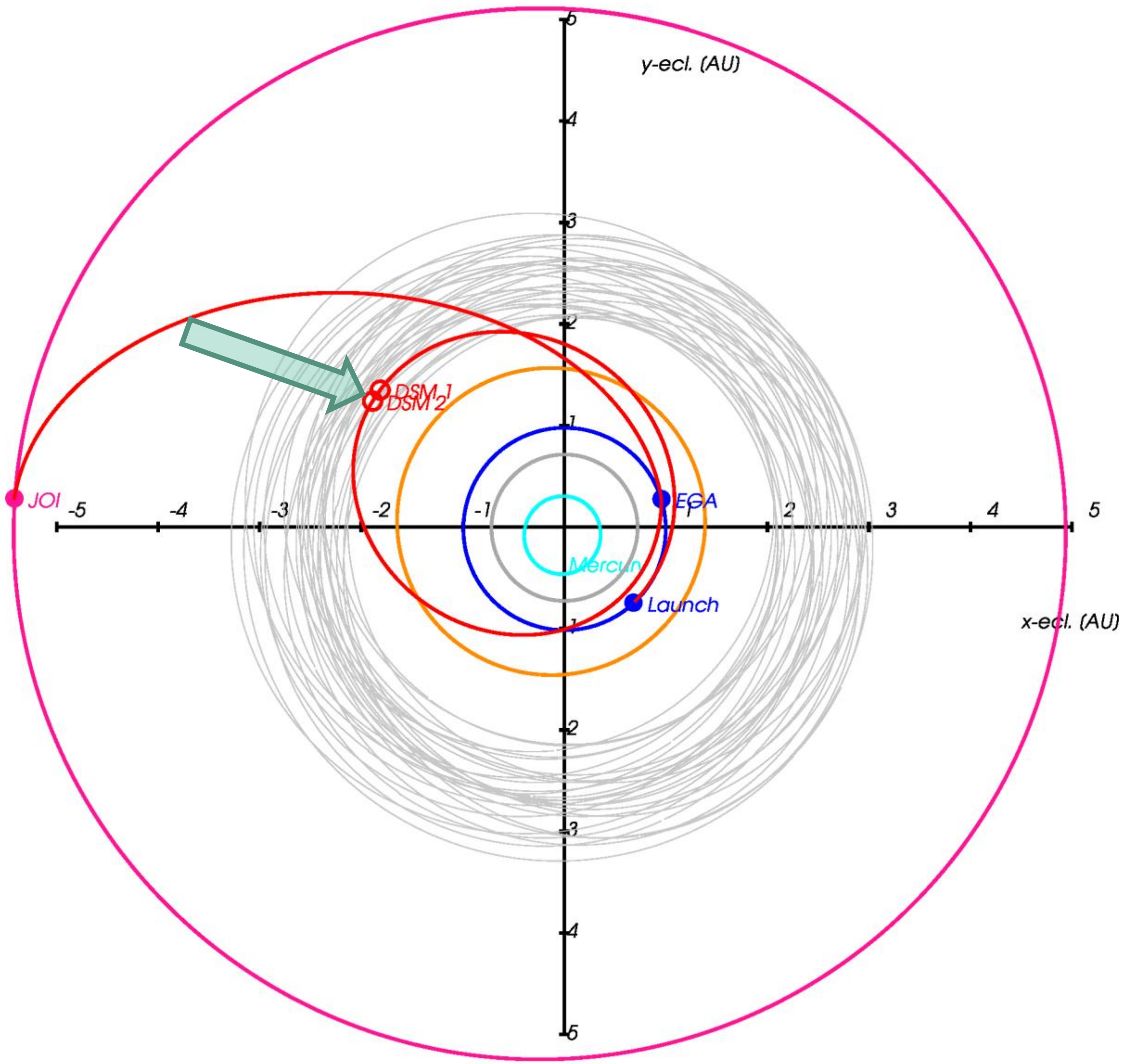
- (or Voyager 1 and 2, Pioneer 10 and 11, Ulysses)
- No gravity assist or propulsive manoeuvres
  - Typically used for a small spacecraft
  - Often with mission objectives other than or beyond Jupiter
  - This is clearly the fastest way (NH: E→J: 13.5 months

Relying on Gravity Assists: Example JUICE



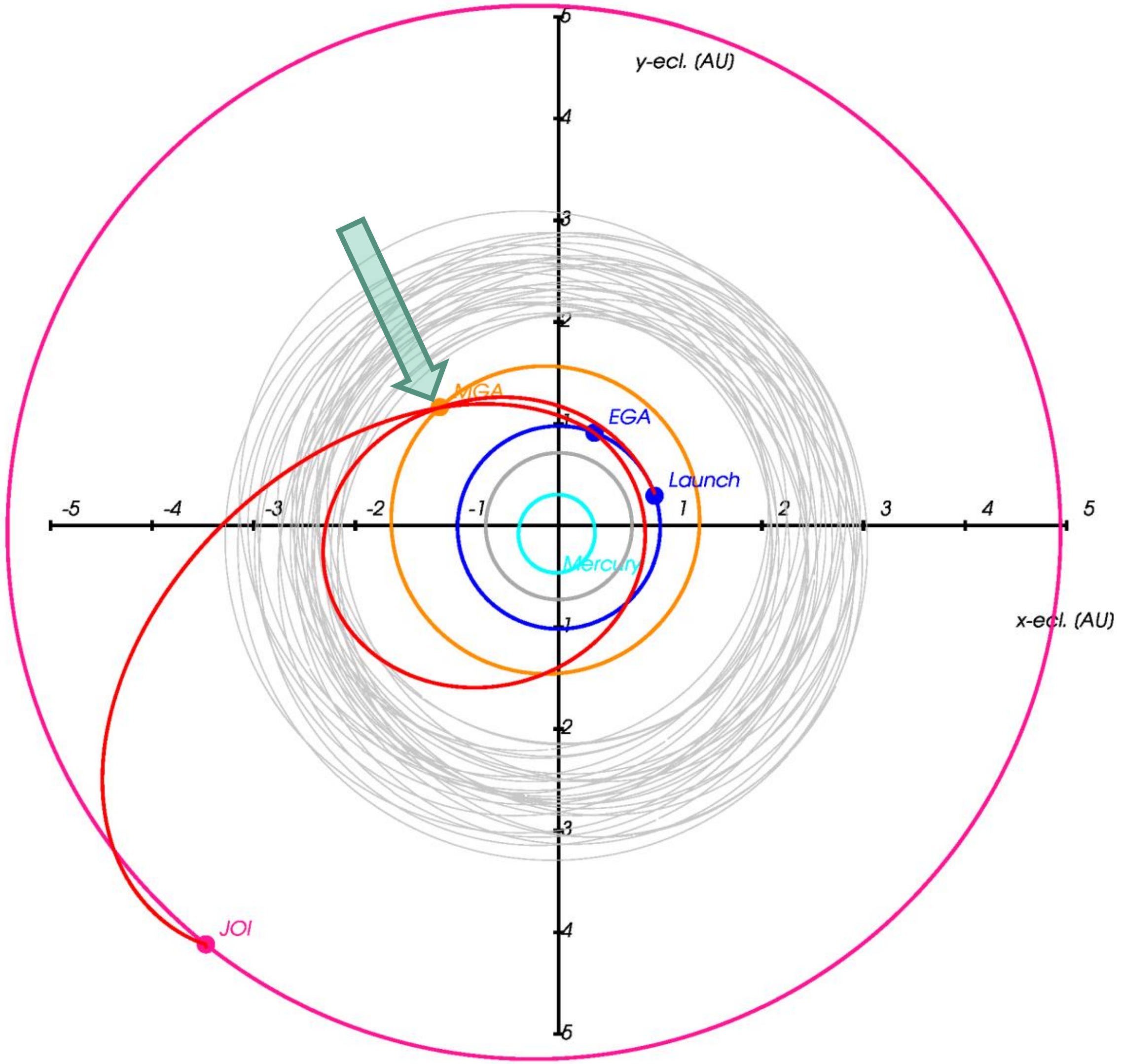
- ❑ (or Galileo or Cassini-Huygens)
- ❑ Launch vehicle requirements can be much-reduced
  - This comes at the cost of many gravity assist manoeuvres
  - The transfer duration to Jupiter for JUICE is 8 years
- ❑ At least one swingby should be at Venus
  - The spacecraft must already be built to withstand the cold, dark, radiation-intensive environment near Jupiter
  - Because of the Venus swingby it must also cope with the thermal input near Venus (2 solar constants + reflected heat)

The Modern Way: Example Juno



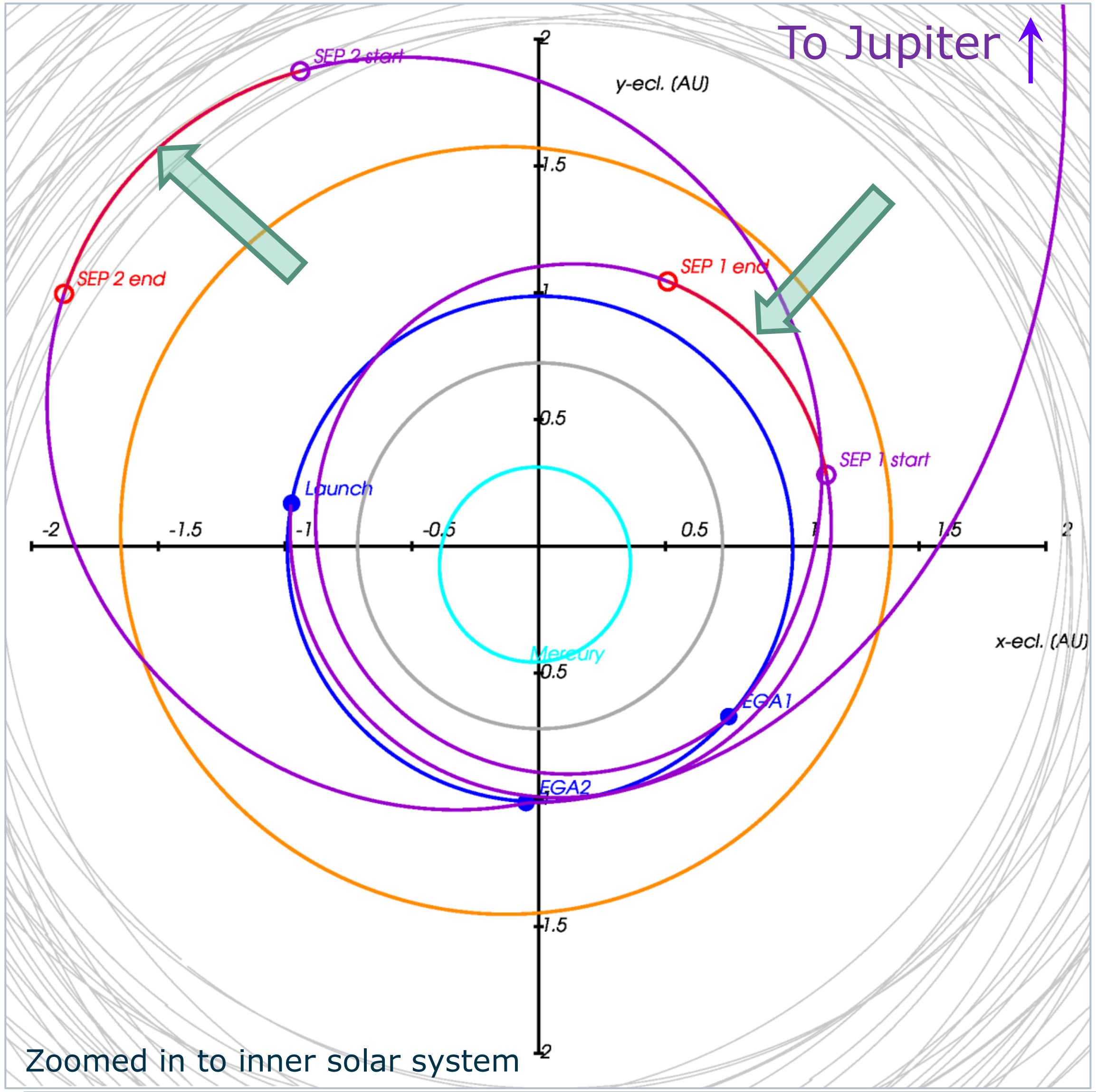
- With private launch service providers, large rockets have become affordable (though not in Europe)
  - Launch inserts payload into high orbit (though not high enough to reach Jupiter)
  - One single Earth gravity assist after two years achieves Jupiter transfer orbit
  - No more gravity assists (and especially none at Venus) are needed
  - Transfer duration for Juno: 5 years

A Lucky Break: Example Europa Clipper



- Similar to the Juno transfer, with one difference:
  - Mars is “available” for a gravity assist, so no propulsive manoeuvre is required and propellant is saved
  - Then follows the Earth gravity assist, and that is it
  - Transfer duration for Clipper: 5.5 years

The Next Step: Adding Solar Electric Ion Propulsion



- Early Jupiter missions used RTGs, i.e., nuclear power supply
- Current ones use solar arrays
  - The arrays must be large and will provide a significant power excess closer to the sun (14-20 kW@1AU)
  - The excess can power an ion drive, used before Earth gravity assists 1 and 2
- The strategy has been studied for missions to Jupiter, Saturn and the asteroid belt
  - The studies show that only two Earth gravity assists suffice
  - Transfer duration to Jupiter slightly above 6 years
  - Unlike the Juno and Clipper missions, the required Earth escape velocity is low
  - Mass penalty for the added propulsion system is small, as the arrays are available anyway

After That: Nuclear Propulsion

- Two options: nuclear thermal or nuclear electric propulsion
- Nuclear thermal
  - High-thrust, high-specific-impulse (Isp up to 900s)
  - Much higher delta-v available to mission → shorter transfers and tours
- Nuclear electric
  - Available power does not decrease with distance from sun
  - Transfer design similar to previous slide, tour design will be much different with NEP
  - Low-thrust, high-Isp propulsion also used around target body (MBA, Jupiter, Saturn …)

Thank you for your attention