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EXHAUSTIVE SEARCH OF GRAVITY ASSIST TRAJECTORIES FOR RAPID RECONNAISSANCE AND DEFLECTION OF FICTITIOUS ASTEROID PDC2025

AUTHORS AND AFFILIATION

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THE **MAIN GOAL** OF THE PRESENT WORK IS TO **EXHAUSTIVELY CHARACTERIZE** THE **MGA SOLUTION SPACE** AND **ASSESS THE MERITS** OF AN **MGA-BASED MISSION** AS OPPOSED TO A DIRECT TRANSFER APPROACH FOR **EARLY RV-RECONNAISSANCE** AND **KI-DEFLECTION** TRAJECTORIES TO ASTEROID PDC25

I. TWO-MISSION STRATEGY

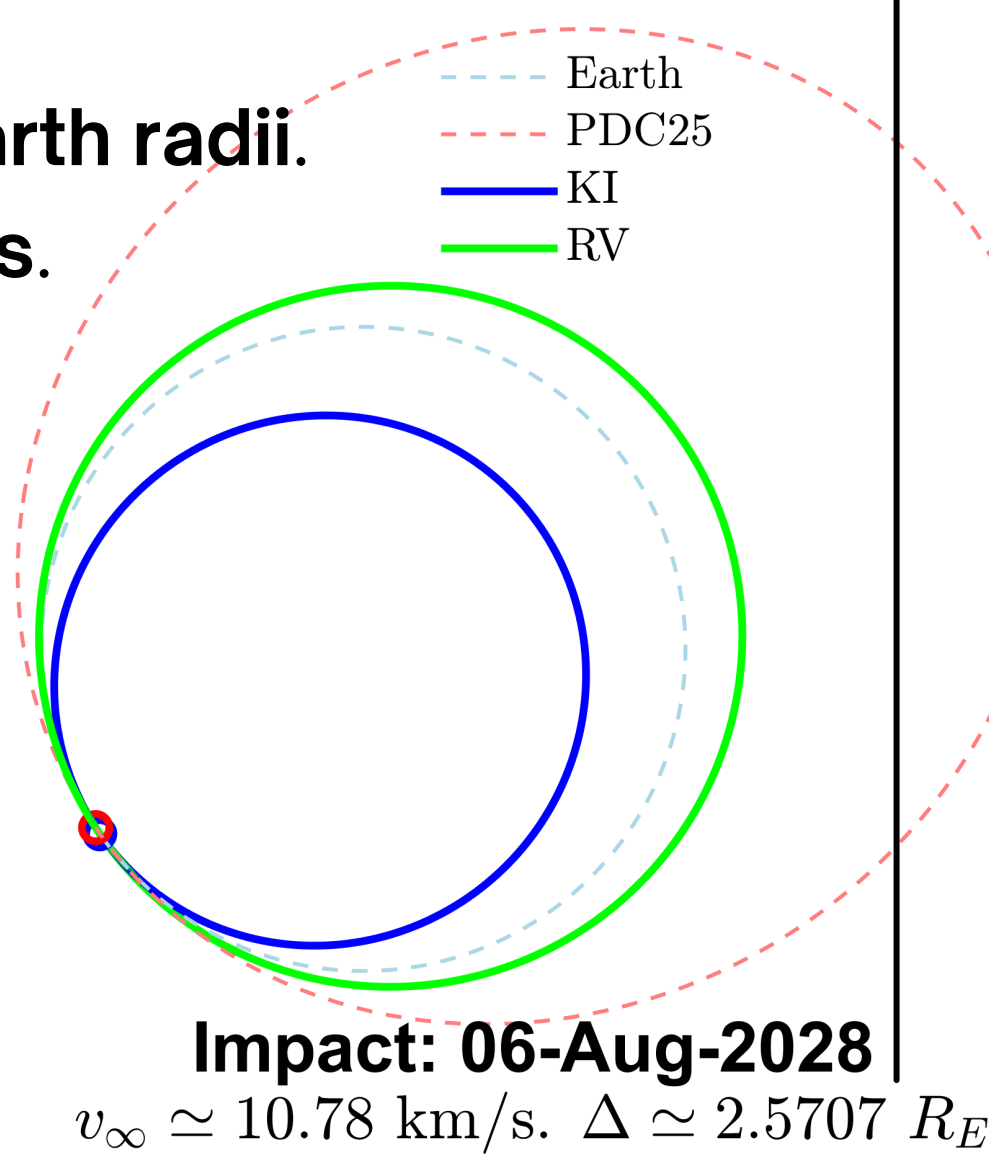
- RV** - Early rendezvous and reconnaissance mission.
- KI** - Deflection by kinetic impact mission.

“Nice-to-haves”:

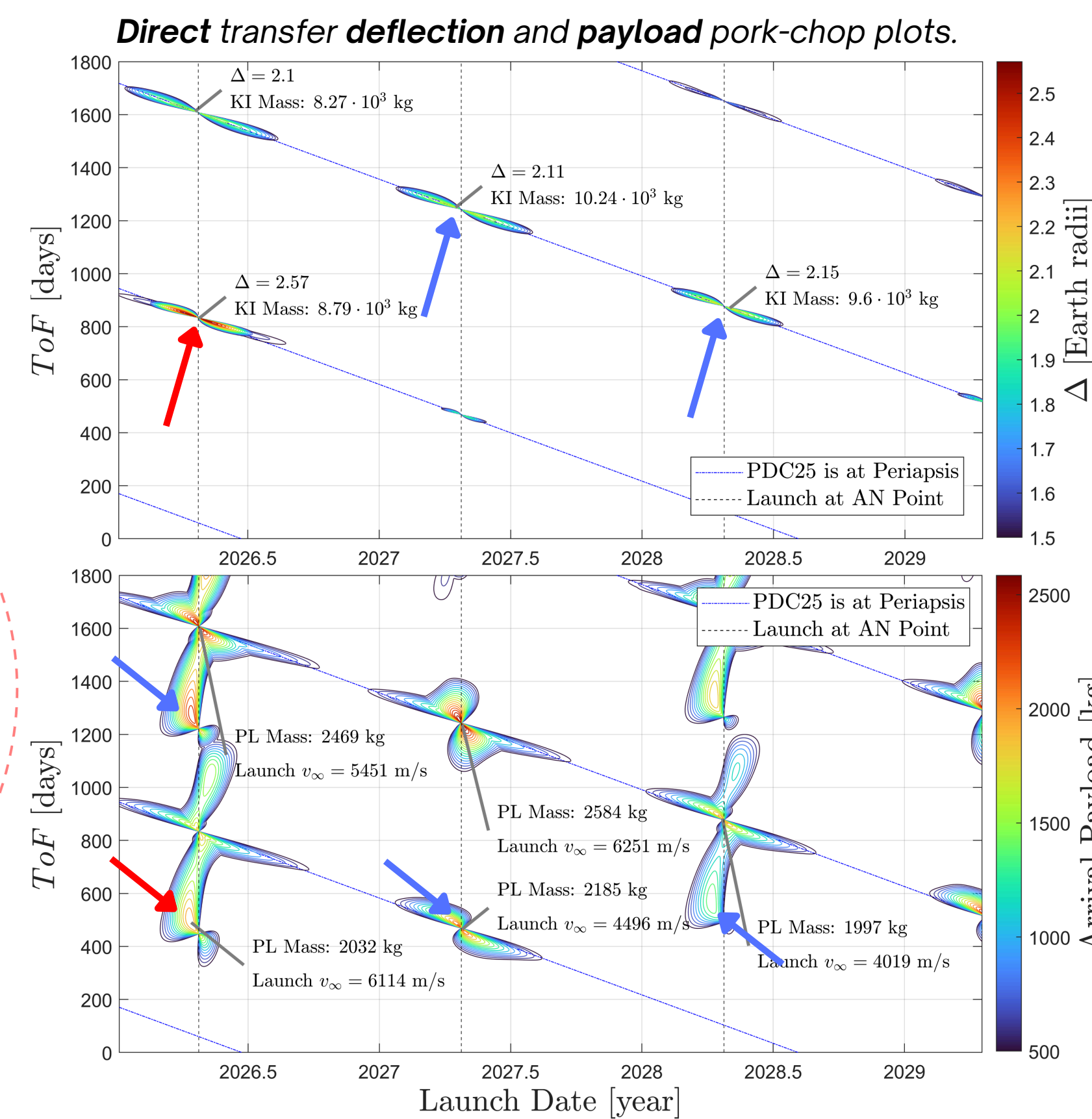
- Deflection (KI) over **2 Earth radii**.
- Flexible launch windows.
- Larger payload (RV).

What can be done with direct transfers?

- Arrival 2028
- Arrival 2030



II. DIRECT TRANSFER SOLUTION



III. WHY TAKE THE MULTIPLE GRAVITY ASSIST ROUTE?

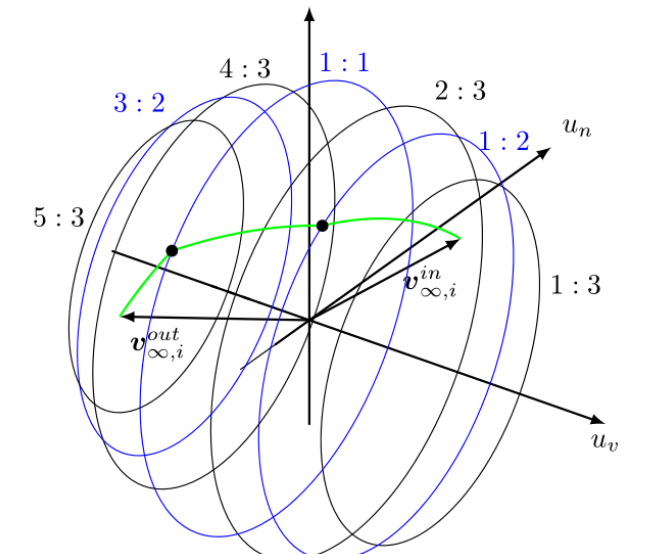
- Larger KI deflection.
- Higher RV payload mass.
- Launch and arrival date flexibility.
- Number of trajectories.

For fixed departure date and energy, even without a set flyby sequence, the number of MGA solutions is finite. We can obtain and study the entire solution space.

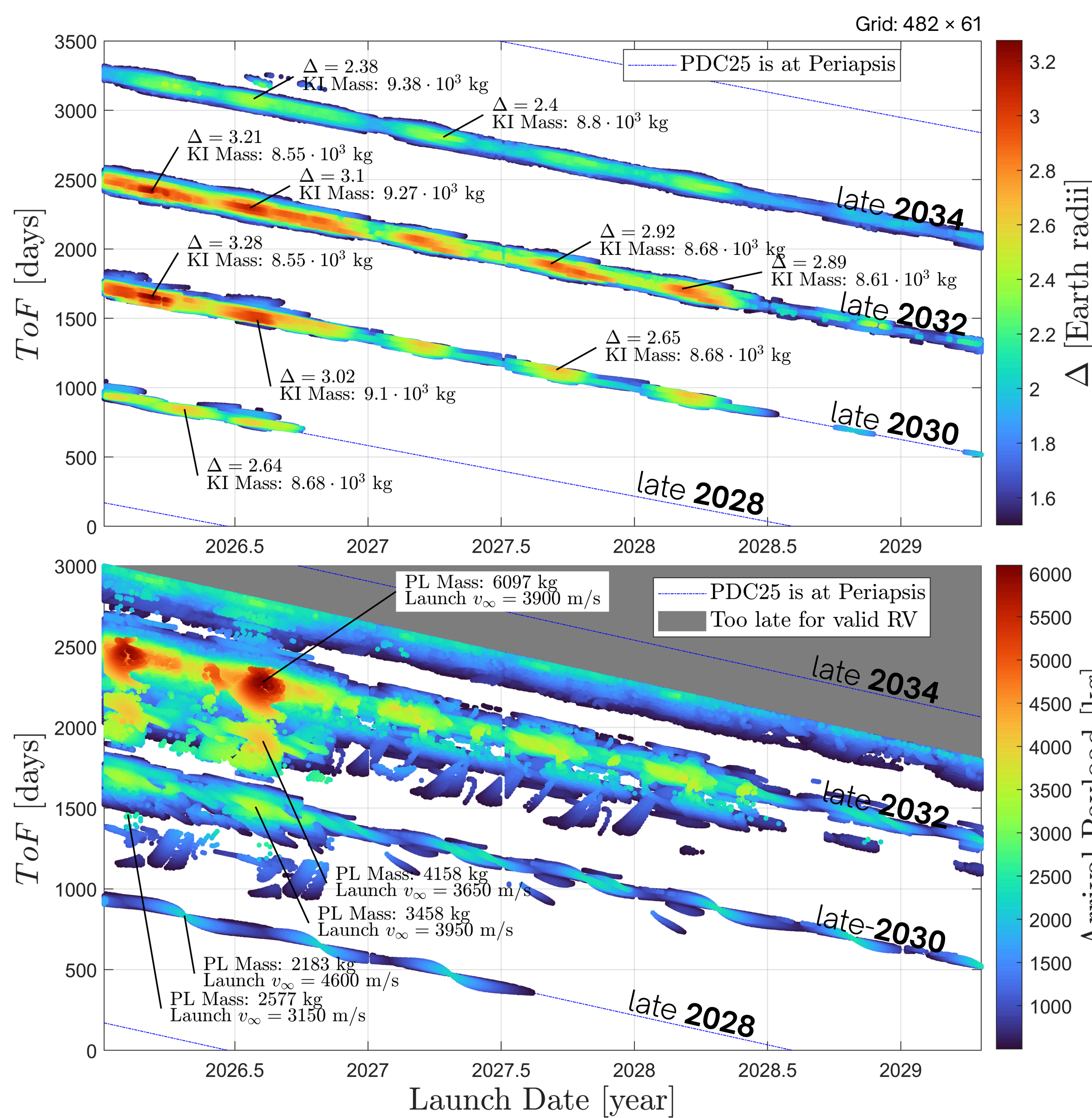
Capabilities of the new method? → Anything ballistic:

- Sequence-Independent: Venus, Earth, Mars, Jupiter.
- Resonant chains.
- Multiple revolutions.

To include resonant chains in the sequence, a v_{∞} -Sphere pathfinding algorithm is used.



IV. MAIN RESULTS: MGA SEQUENCE-INDEPENDENT PORK-CHOP PLOTS

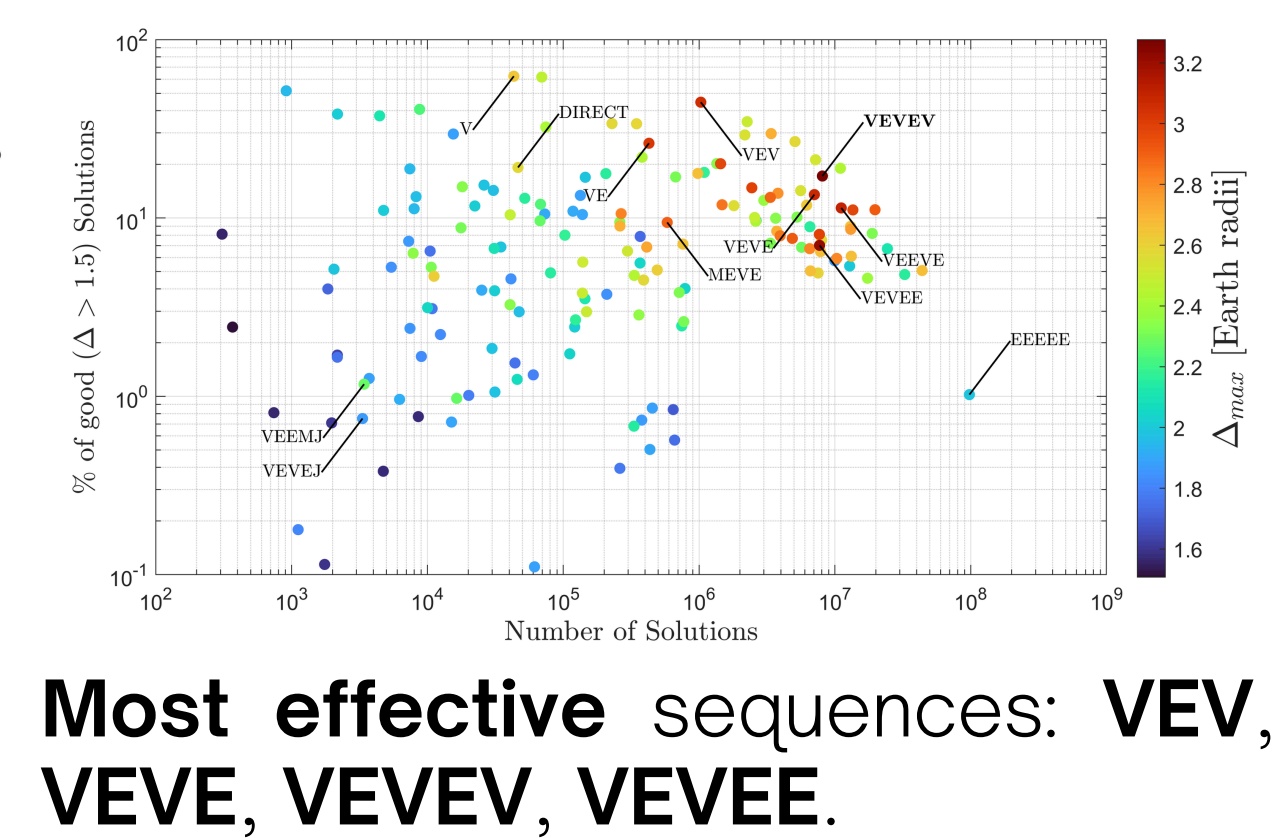


The finder tool identified over **500 million** individual MGA solutions.

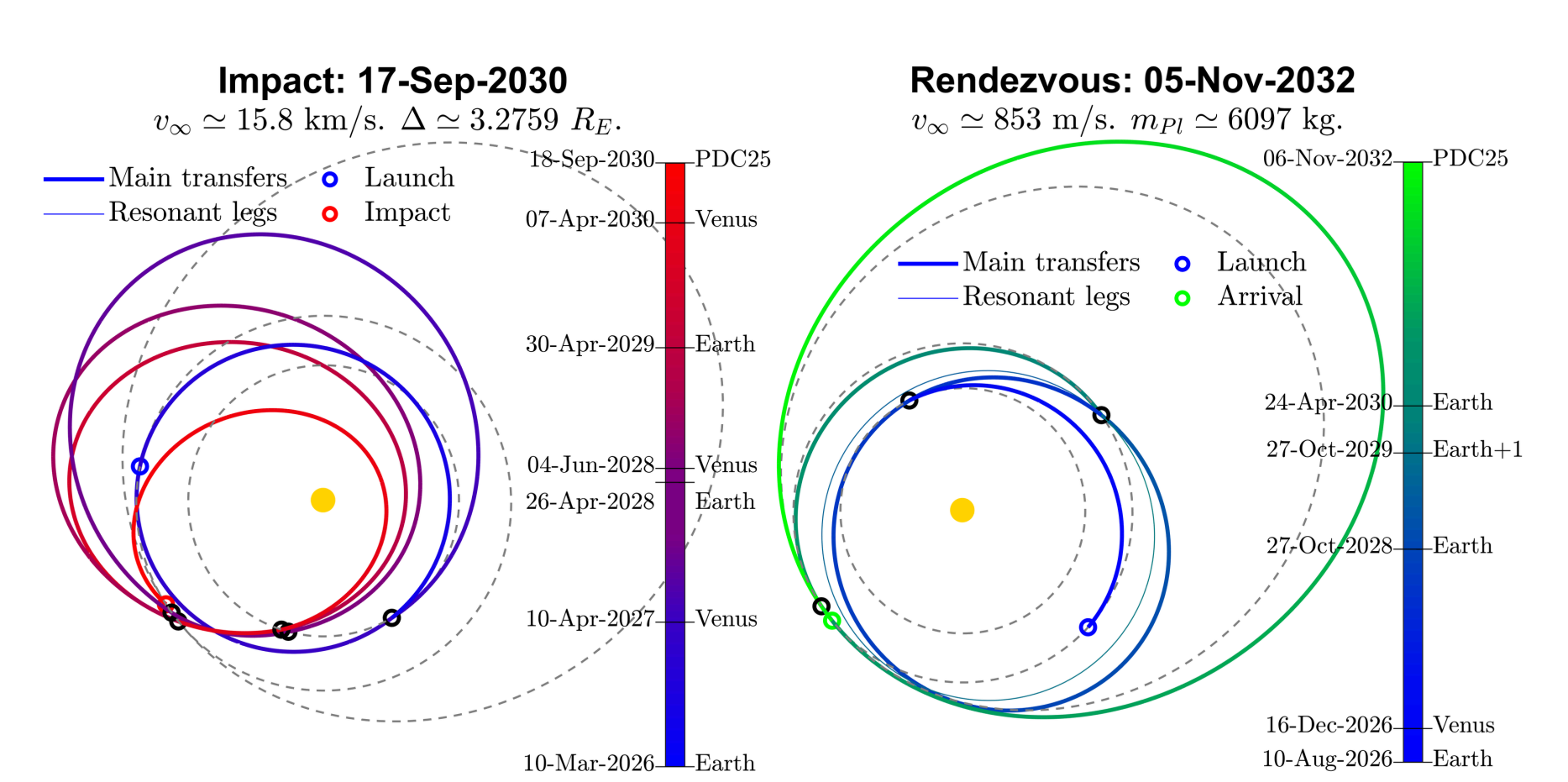
Key take-aways:

- MGA unlocks arrivals in **2032** and **2034** → + Flexibility.
- Many more options for KI and RV → + Flexibility.
- Knowledge of the solution space → Local and global optima, further constraints...
- Lower launch energy required.

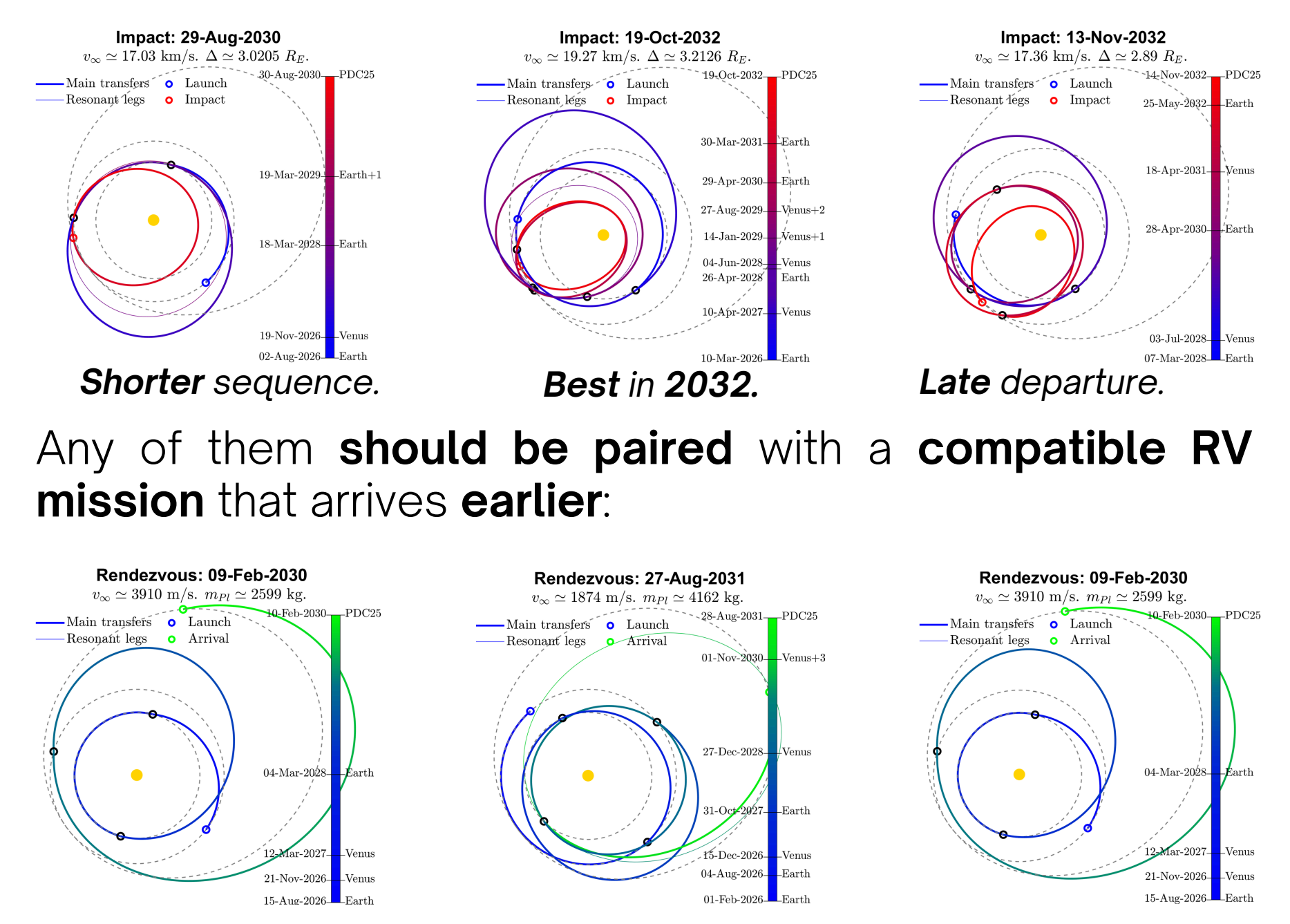
The solution space contains **249** unique sequences.



V. BEST TRAJECTORIES



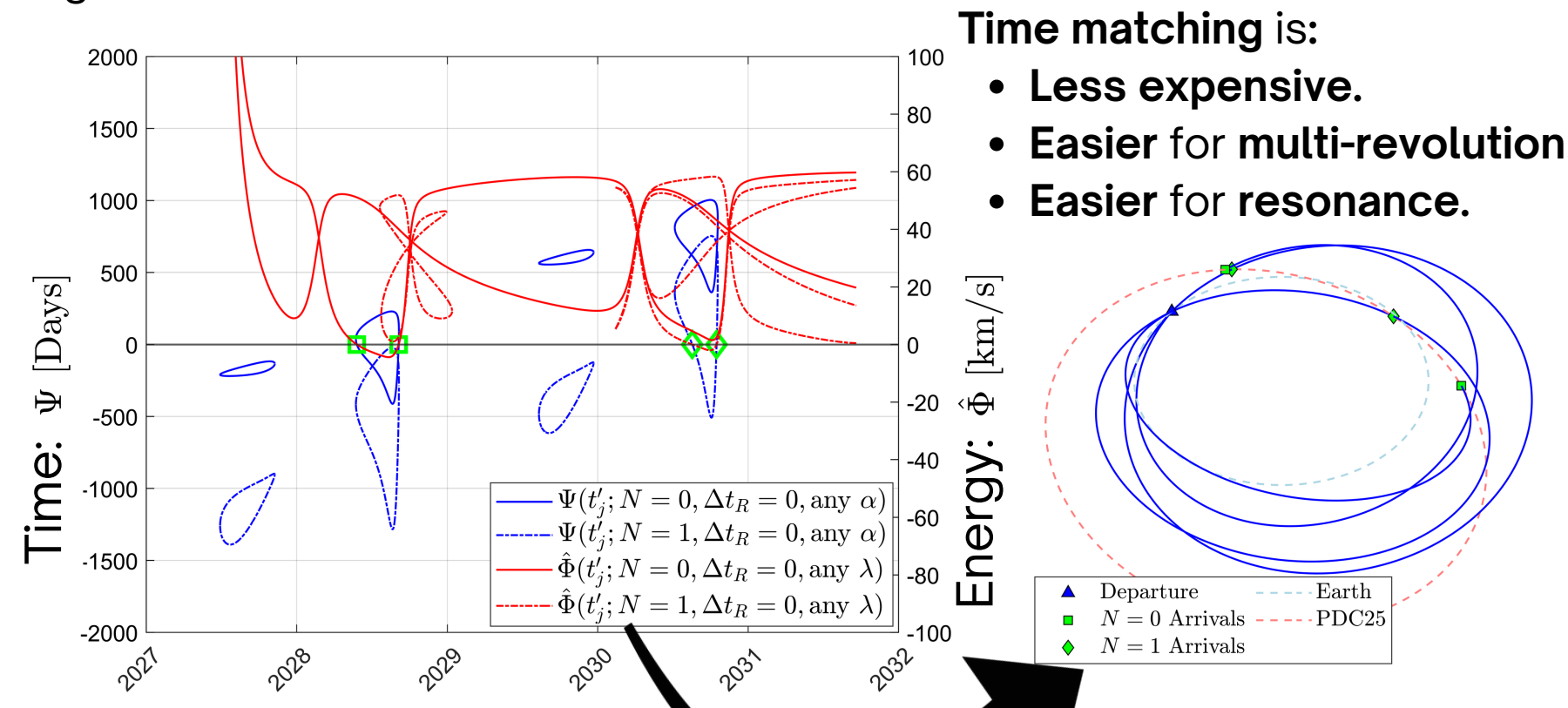
Through MGA, a **27% deflection improvement** can be achieved and **payload mass** can be **doubled**. The solution set offers other interesting alternatives:



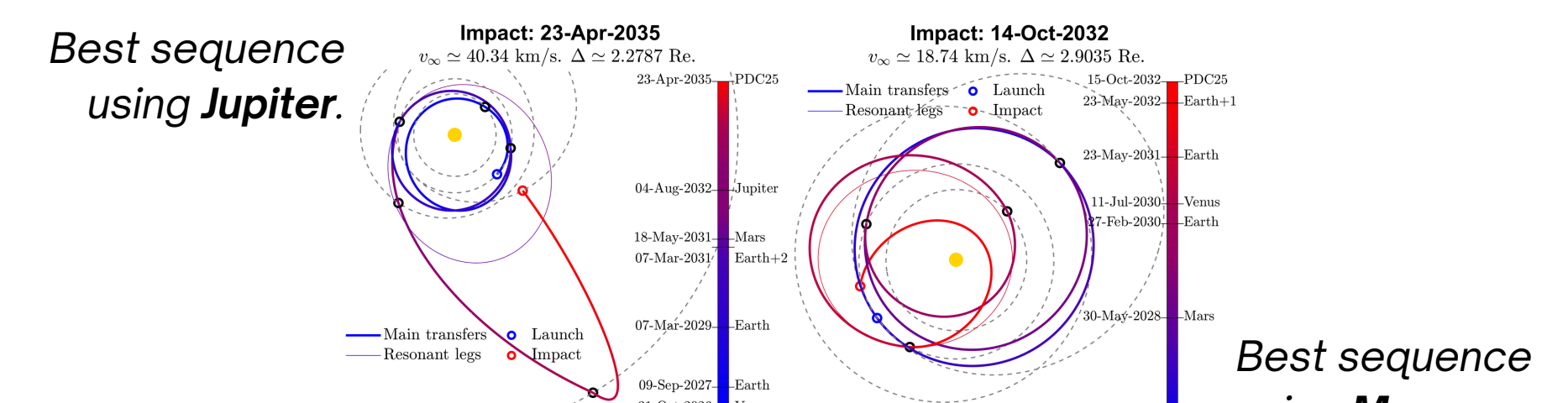
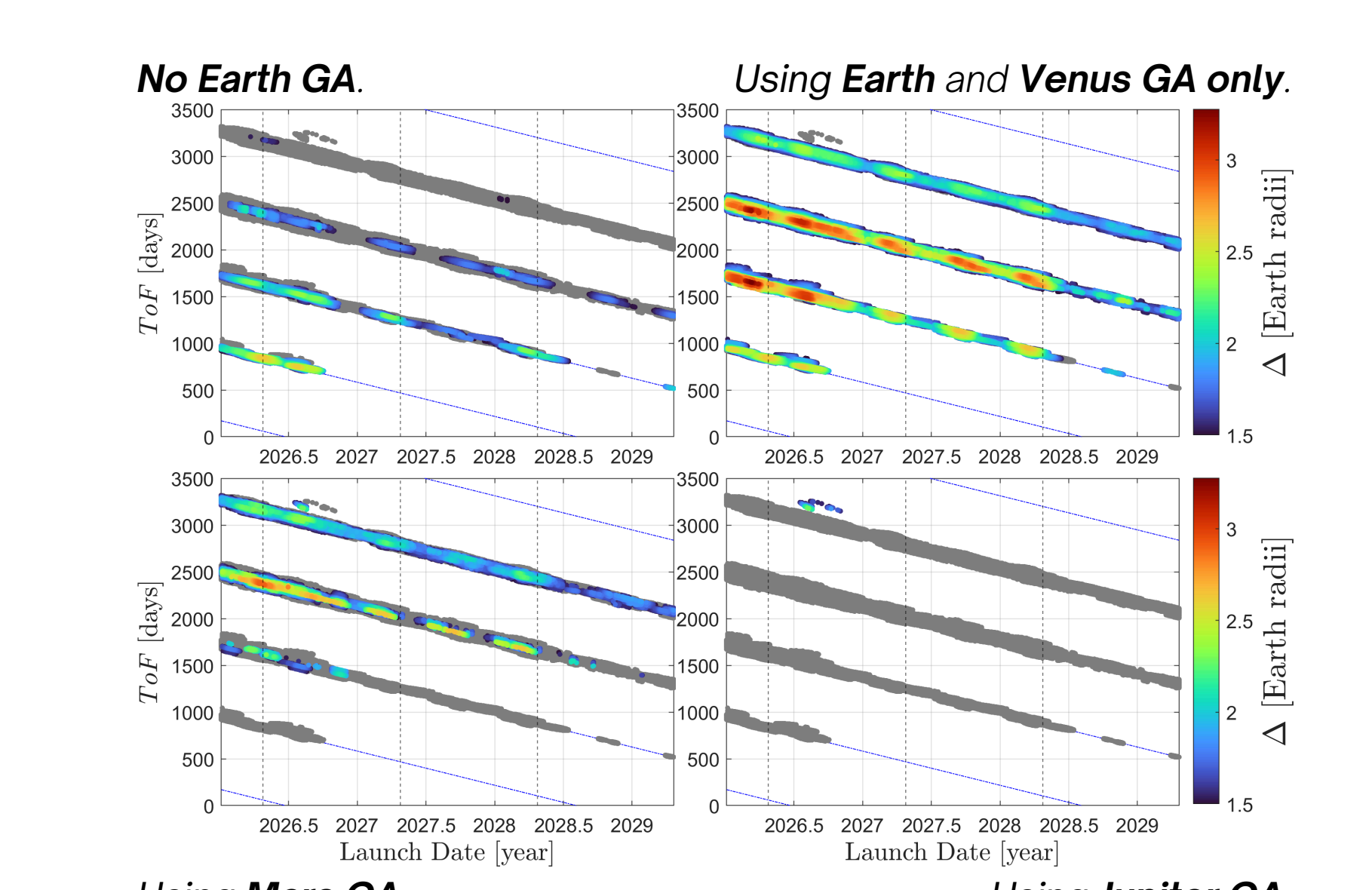
(VI). LAMBERT-FREE TRAJECTORY FINDER TOOL

For each transfer, we want to determine where on its orbit we can reach the next planet.

This requires a matching algorithm: we use Time-matching instead of Energy (C_3 -matching) to avoid Lambert's Problem. A zero of the matching algorithm means a valid transfer.



(VII). MORE RESULTS: PLANET GA INVOLVEMENT



CONCLUSIONS

The **MGA** alternative to the direct transfer is shown to offer **significant improvements (+27% deflection)**, and a more densely populated solution space, allowing **longer decision times** and **considerably more mission flexibility** for both KI and RV.

KEY REFERENCES

- M. Gavira-Aladro, C. Bombardelli, “Lambert-Free Solution of Multiple-Gravity-Assist Optimization Problem,” Journal of Guidance, Control, and Dynamics 47, 2024.
- T. Godal, “Conditions of Compatibility of Terminal Positions and Velocities,” in XIth International Astronautical Congress, Stockholm, pp. 40–44, 1960.
- J. Longuski, S. Williams, “Automated Design of Gravity-Assist Trajectories to Mars and the Outer Planets” Celestial Mechanics and Dynamical Astronomy, 1991.