ON ALIGHTING DAINTILY AT JUPITER: INNOVATIVE METHODS FOR EFFICIENTLY ACHIEVING JOVIAN ORBIT

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Introduction and Outline

Focused on missions to Galilean satellites

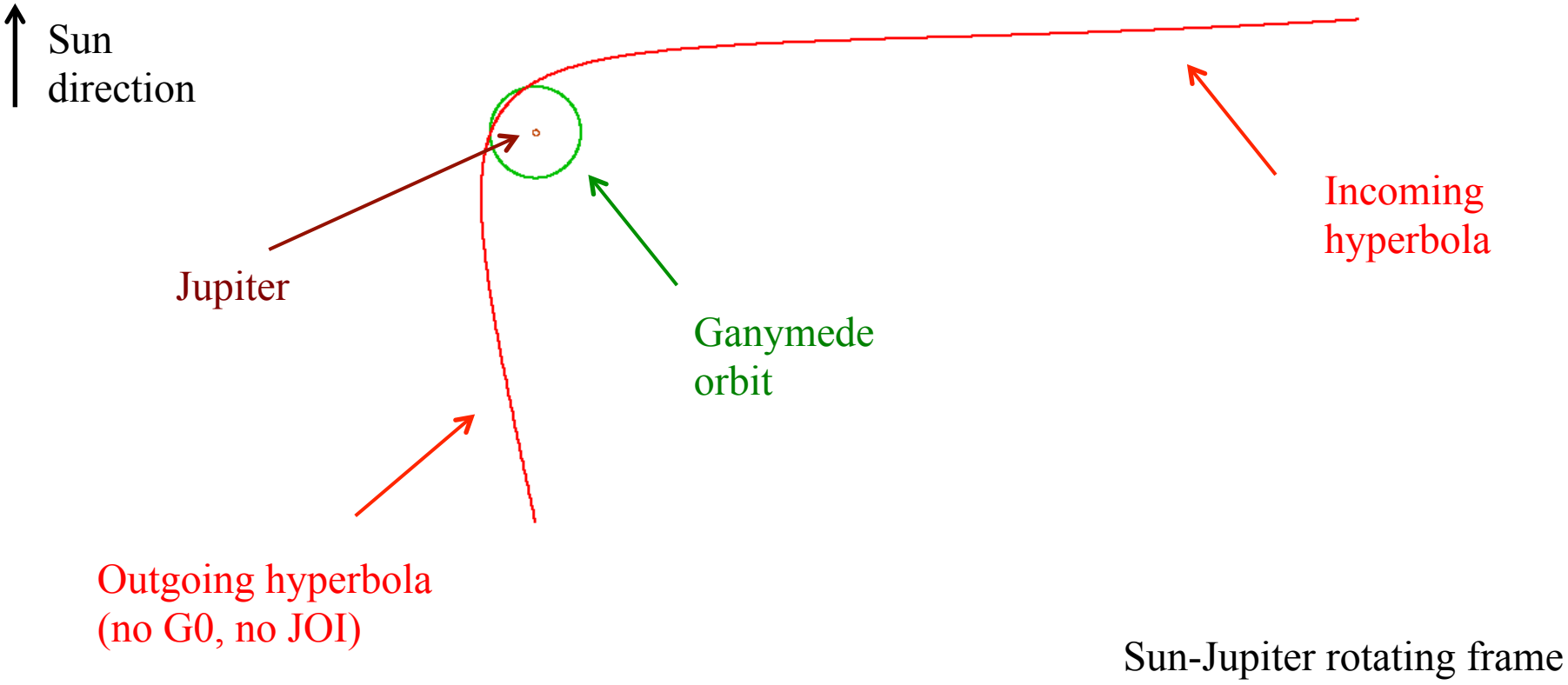
- Particularly Europa and Ganymede

Orbit capture topics:

- Nominal capture elements
- Single flyby
  - Extended pump-down
- Double flyby
  - Satellite alignments
- Navigation
- Solar Electric Propulsion (SEP) assistance
- Retrograde, “cloudtops”
  - With ΔV-EGA

Summary and conclusions

Nominal Capture Elements



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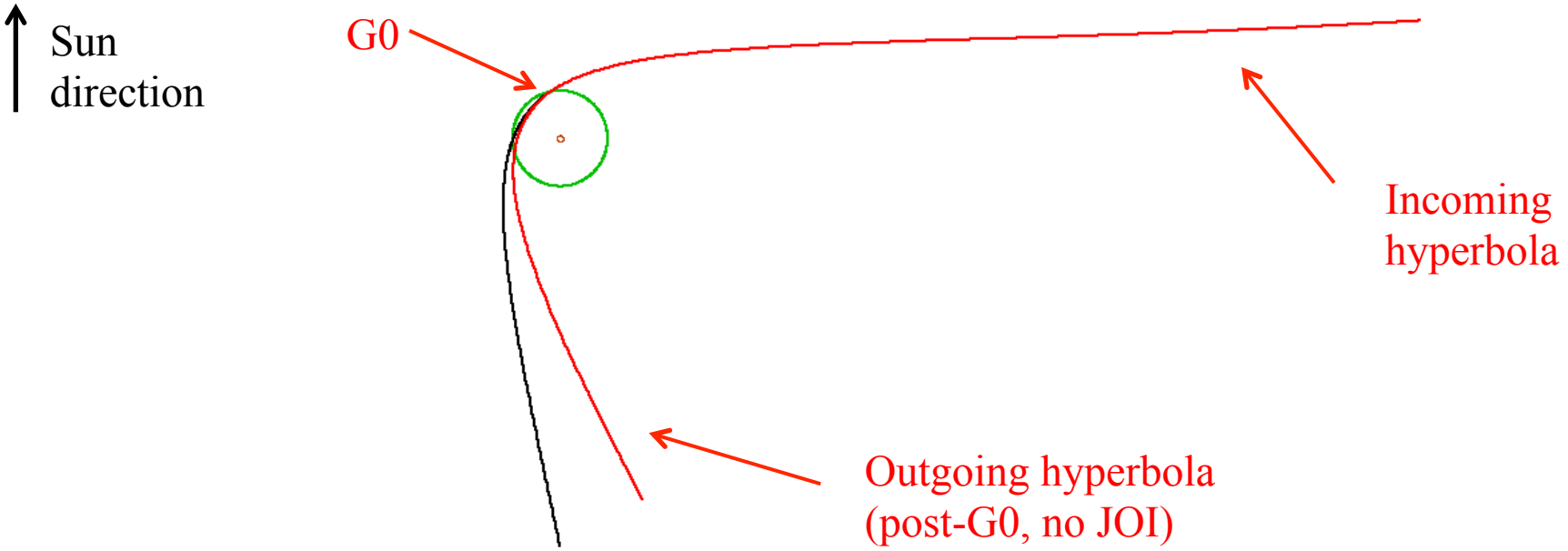
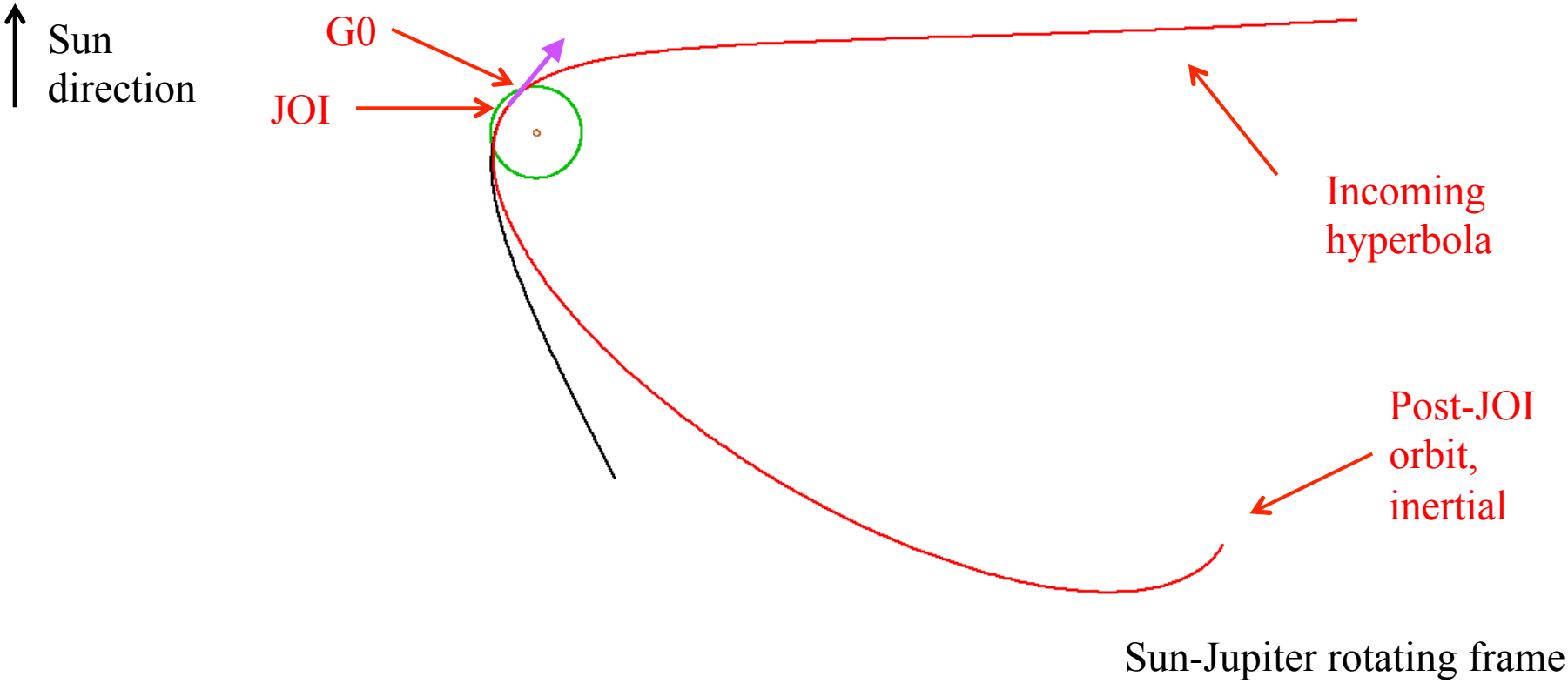


Sun-Jupiter rotating frame

Nominal Capture Elements



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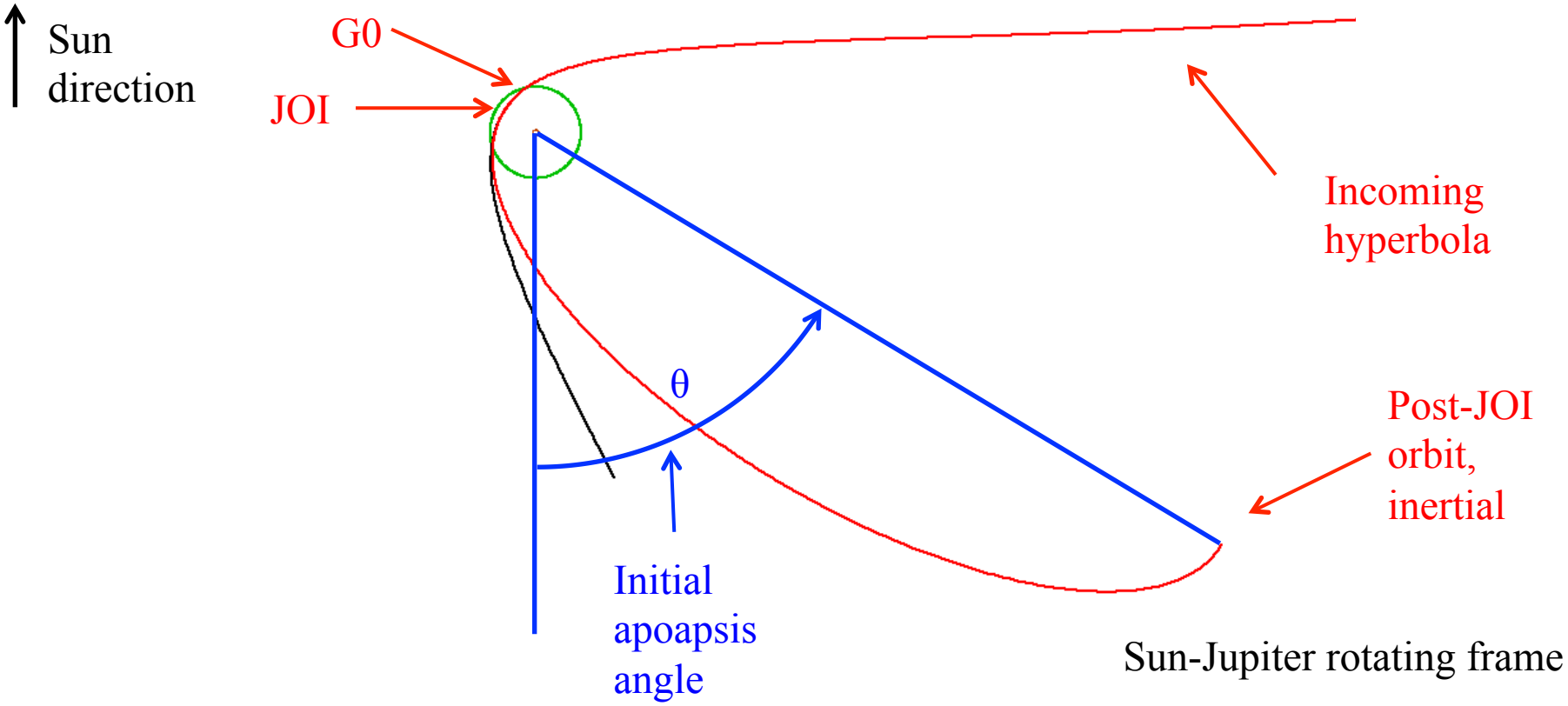

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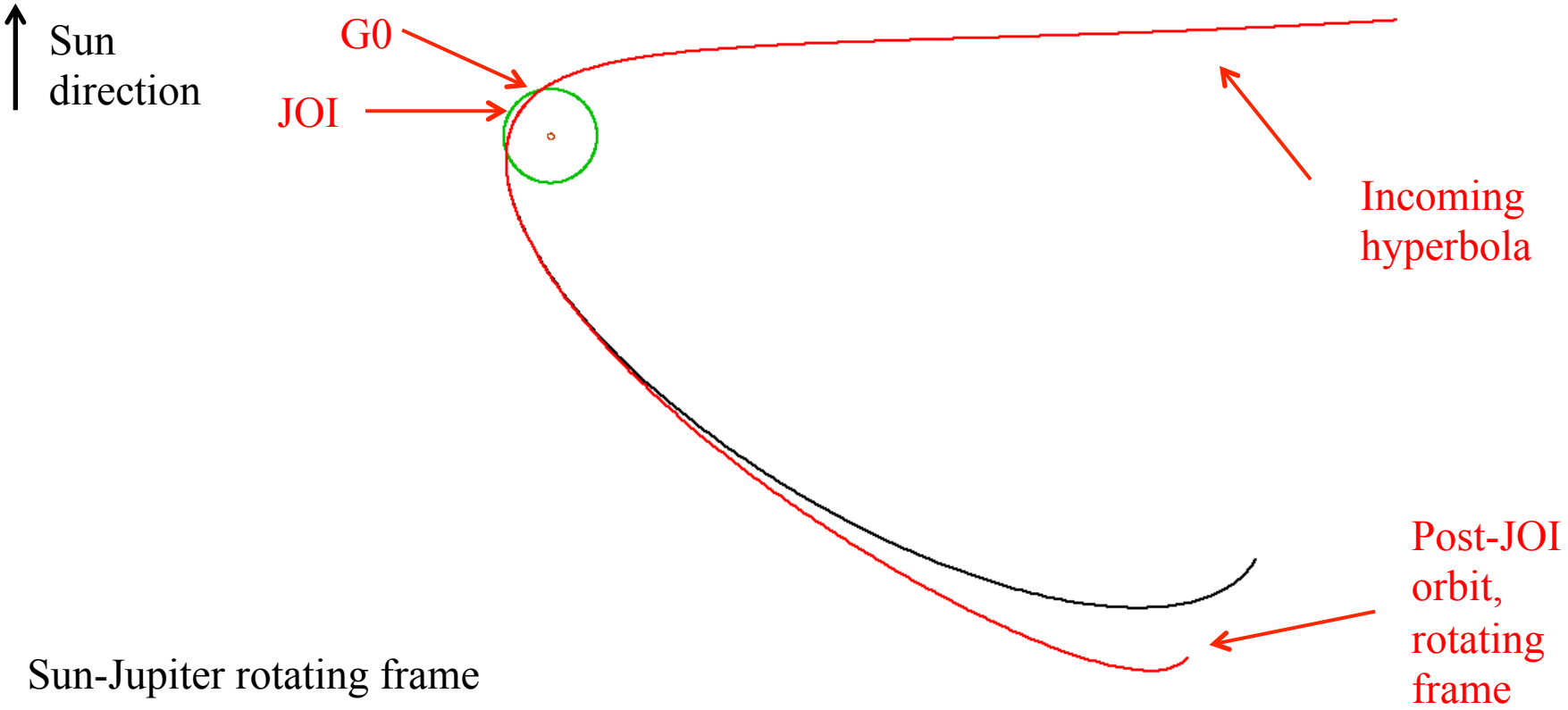

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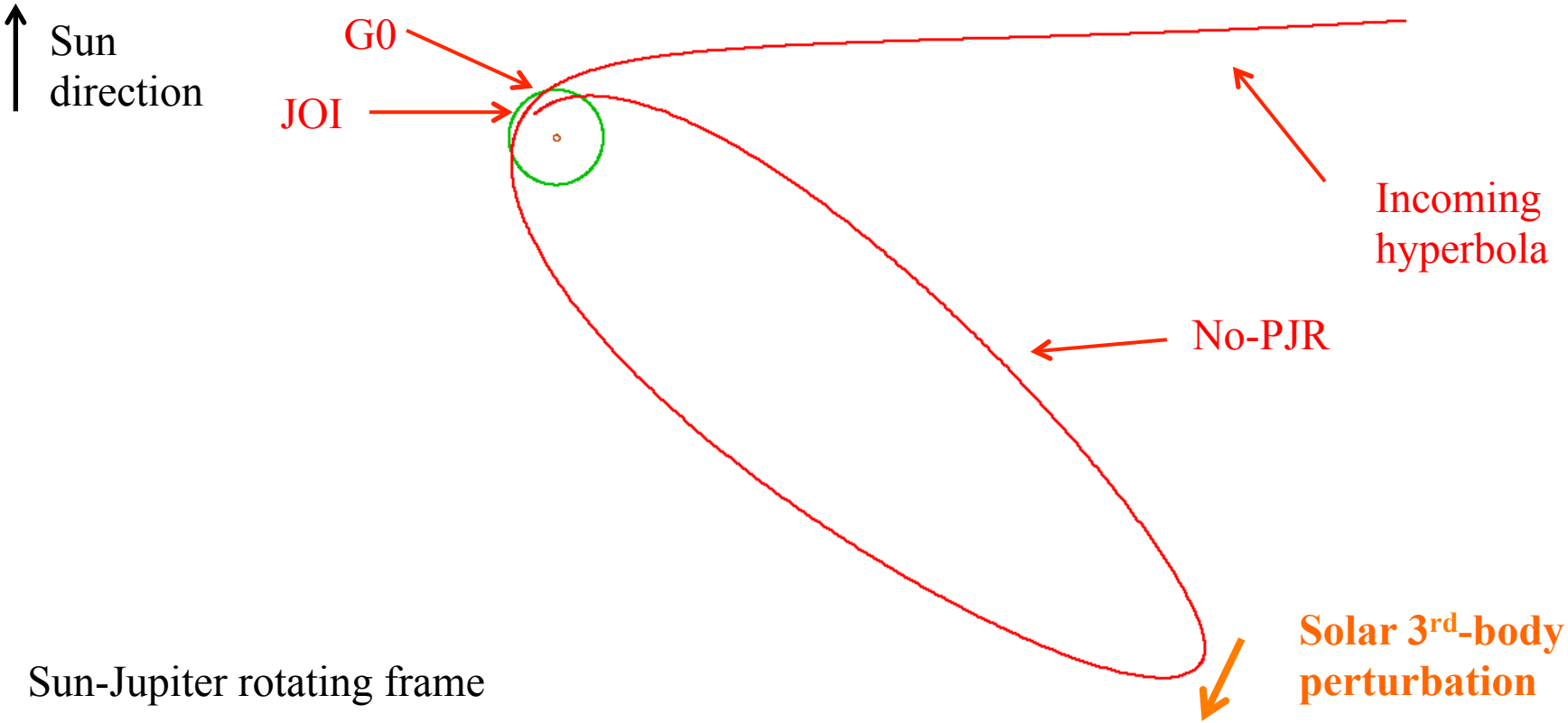

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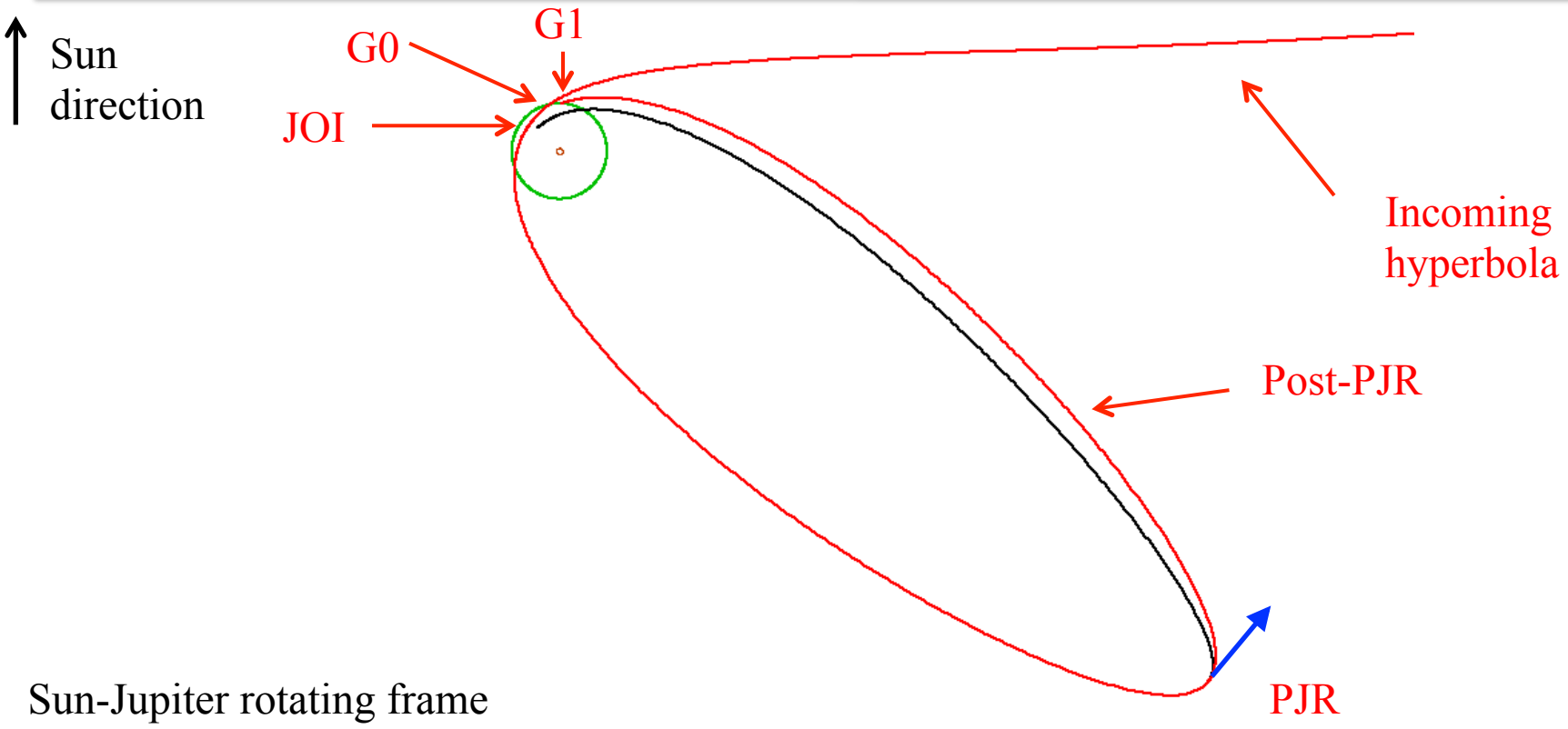

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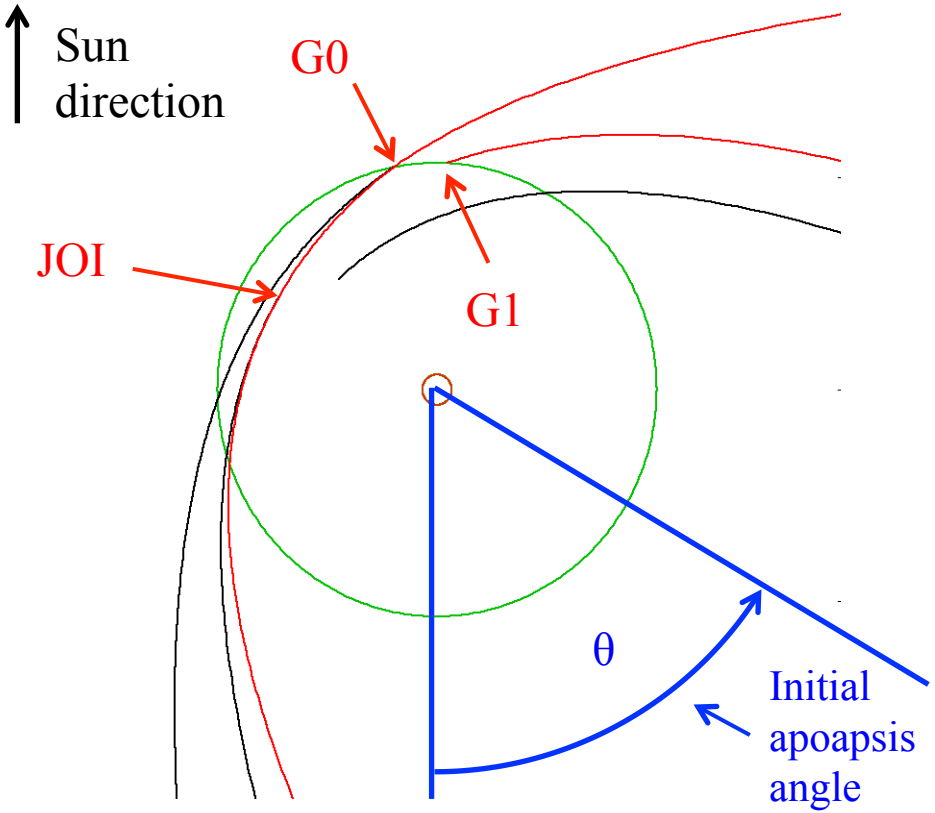

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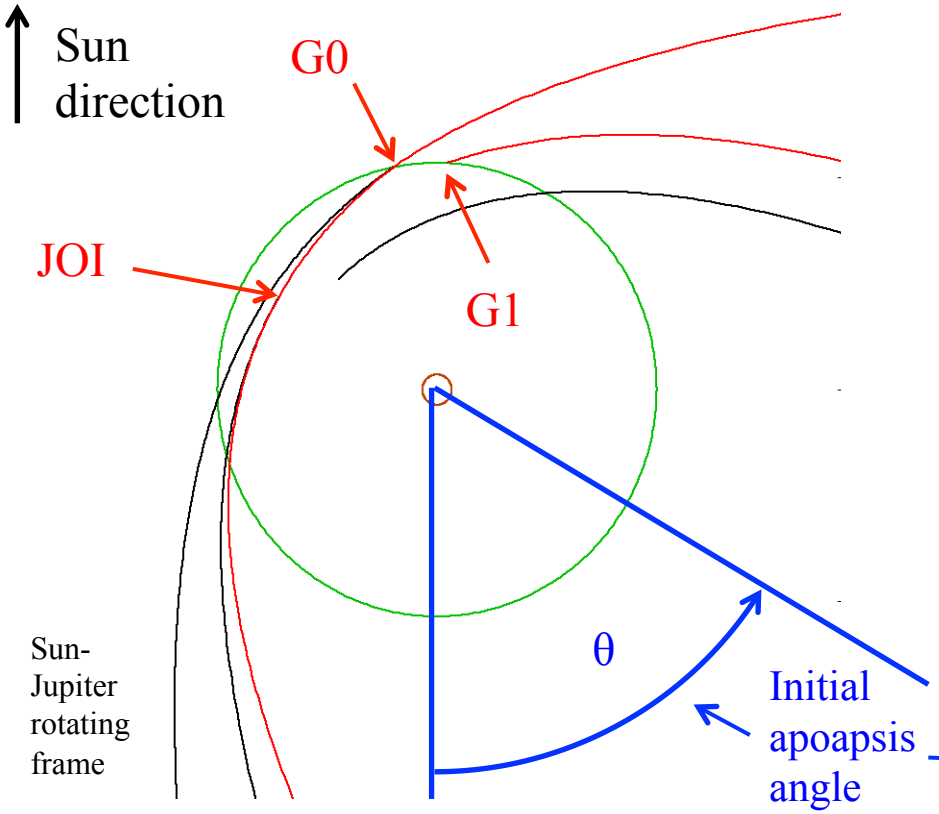
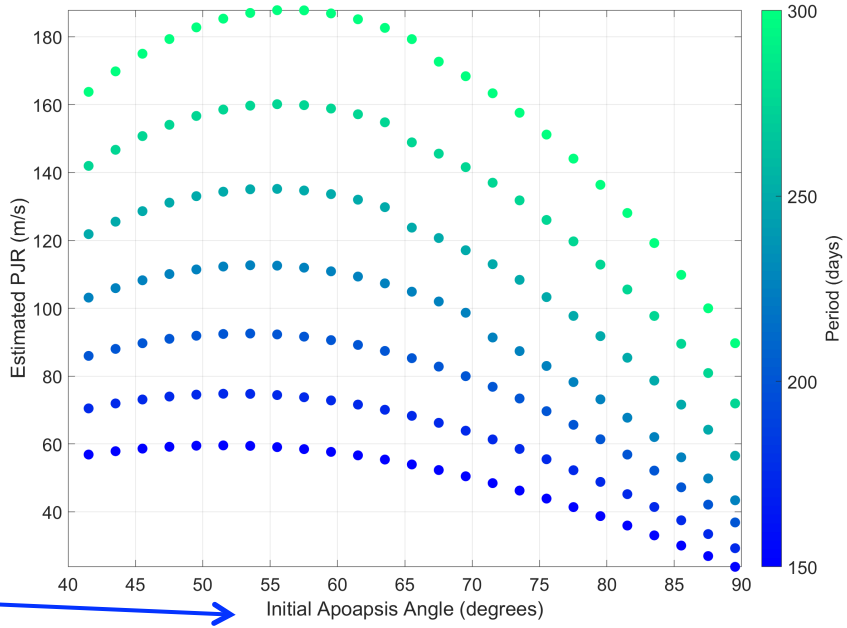


PJR cost due to solar perturbation (additional cost due to conic periapsis raise)



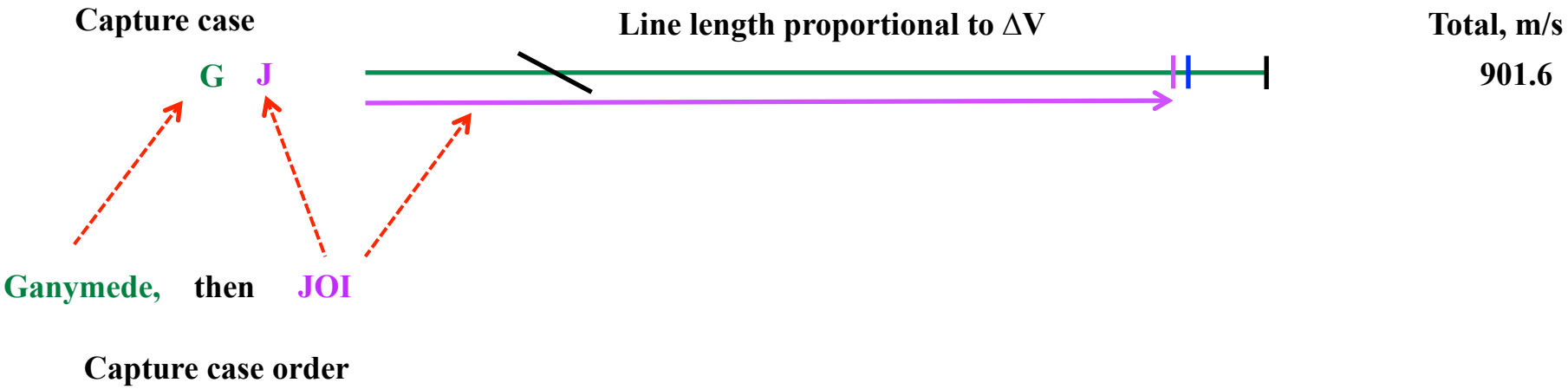
Single-flyby Capture

Capture case **Total, m/s**

G J **901.6**

What is this?

Single-flyby Capture



Jupiter V_∞ 5.6 km/s
Arrival solar phase 90°
Flyby alt 100 km
200-day initial period
G1 V_∞ 6.27 km/s

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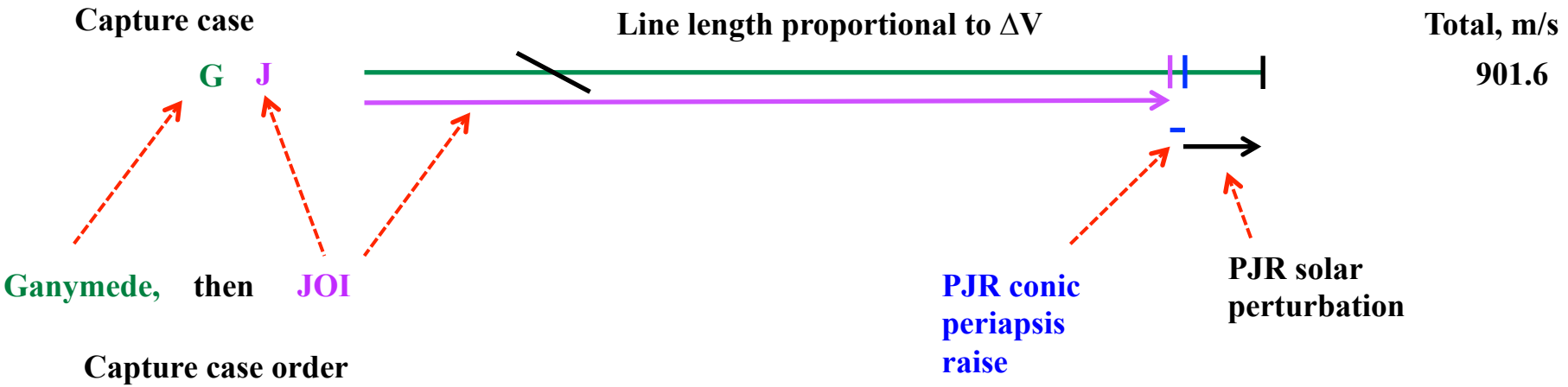

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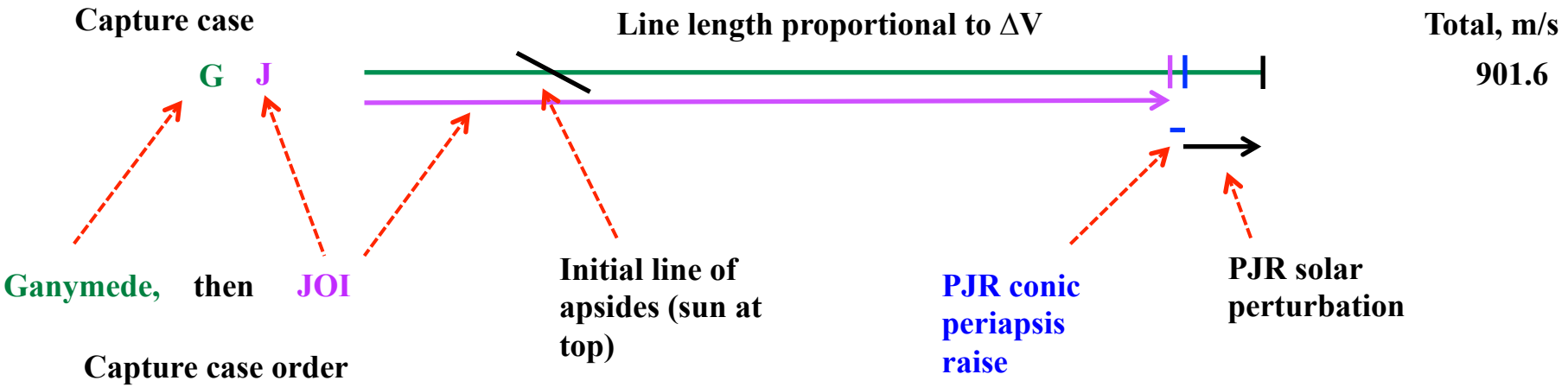

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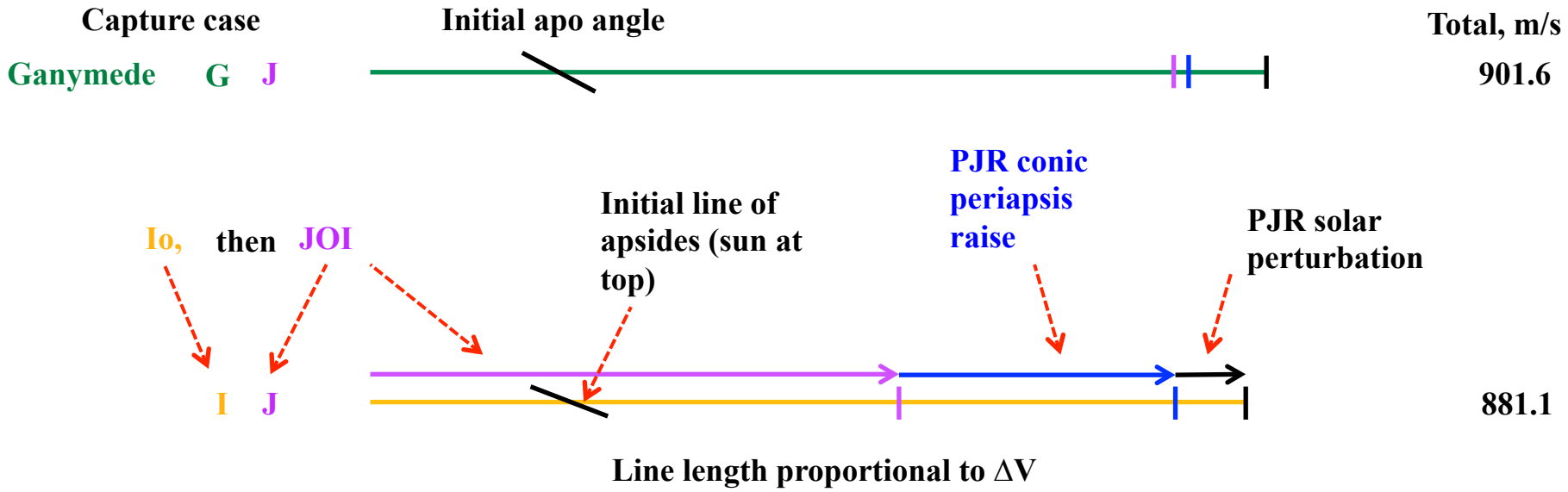

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Capture case			Initial apo angle	Total, m/s
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Io	I	J		881.1

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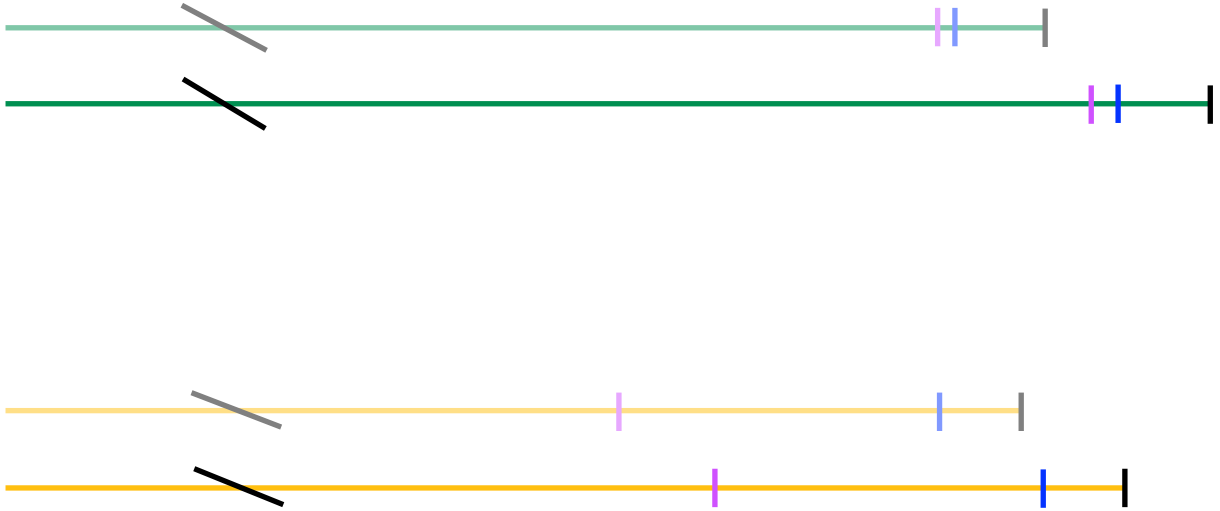
V_∞= 6 km/s	G	J		1045.3
Io	I	J		881.1
V_∞= 6 km/s	I	J		972.4



Pre-Decisional Information — For Planning and Discussion Purposes Only

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JOI first		**J**	**G**		**827.1**
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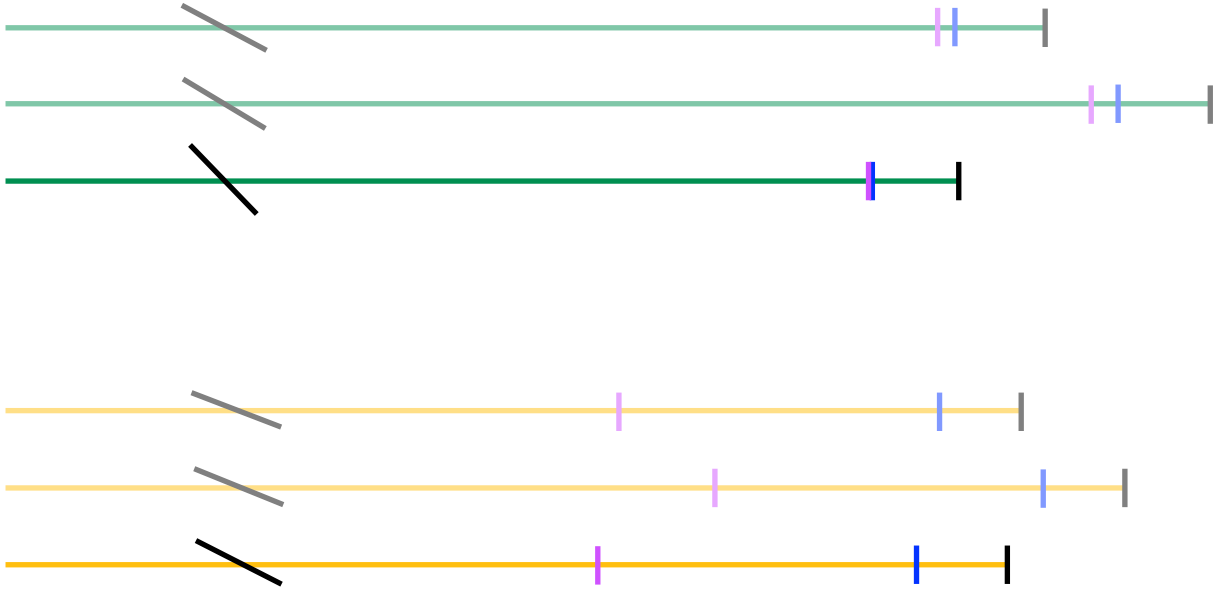

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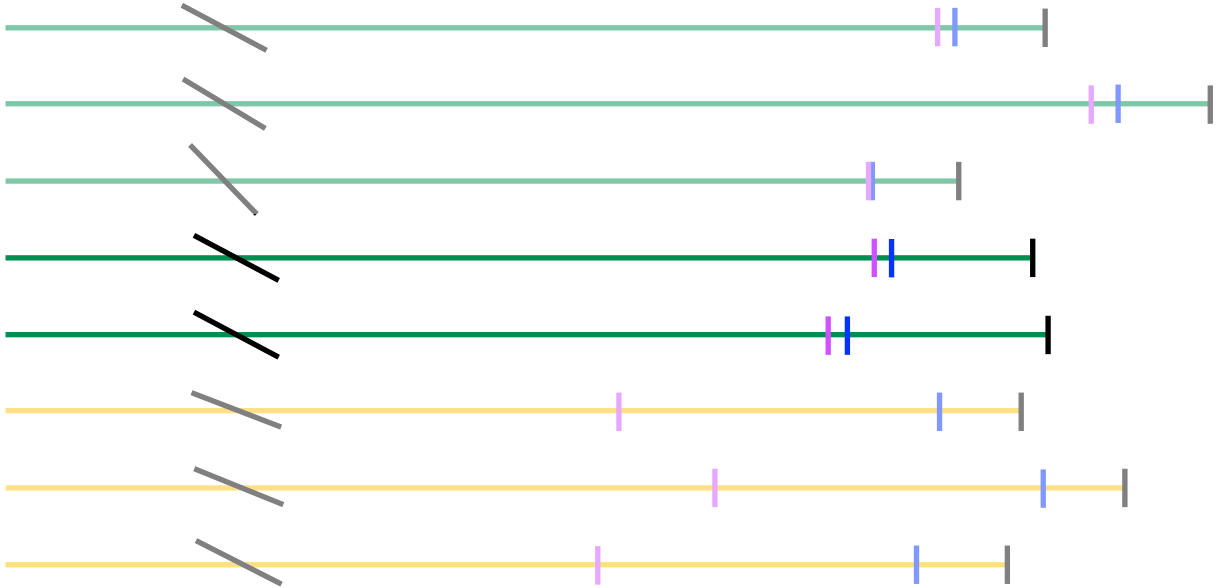
Ganymede	G	J		901.6
V_∞= 6 km/s	G	J		1045.3
JOI first		J	G	827.1
250d period	**G**	**J**		**891.2**
300d period	**G**	**J**		**904.5**
Io	I	J		881.1
V_∞= 6 km/s	I	J		972.4
JOI first		J	I	867.5



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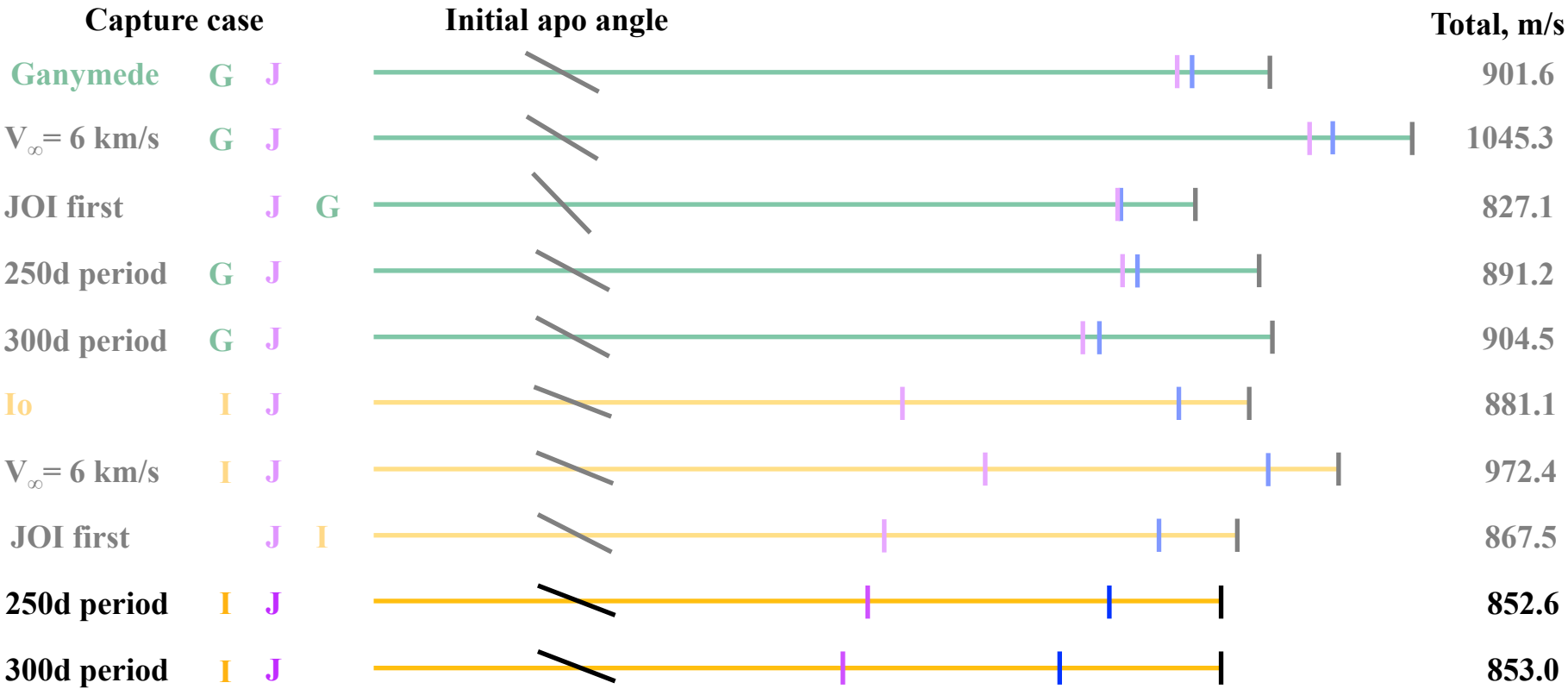

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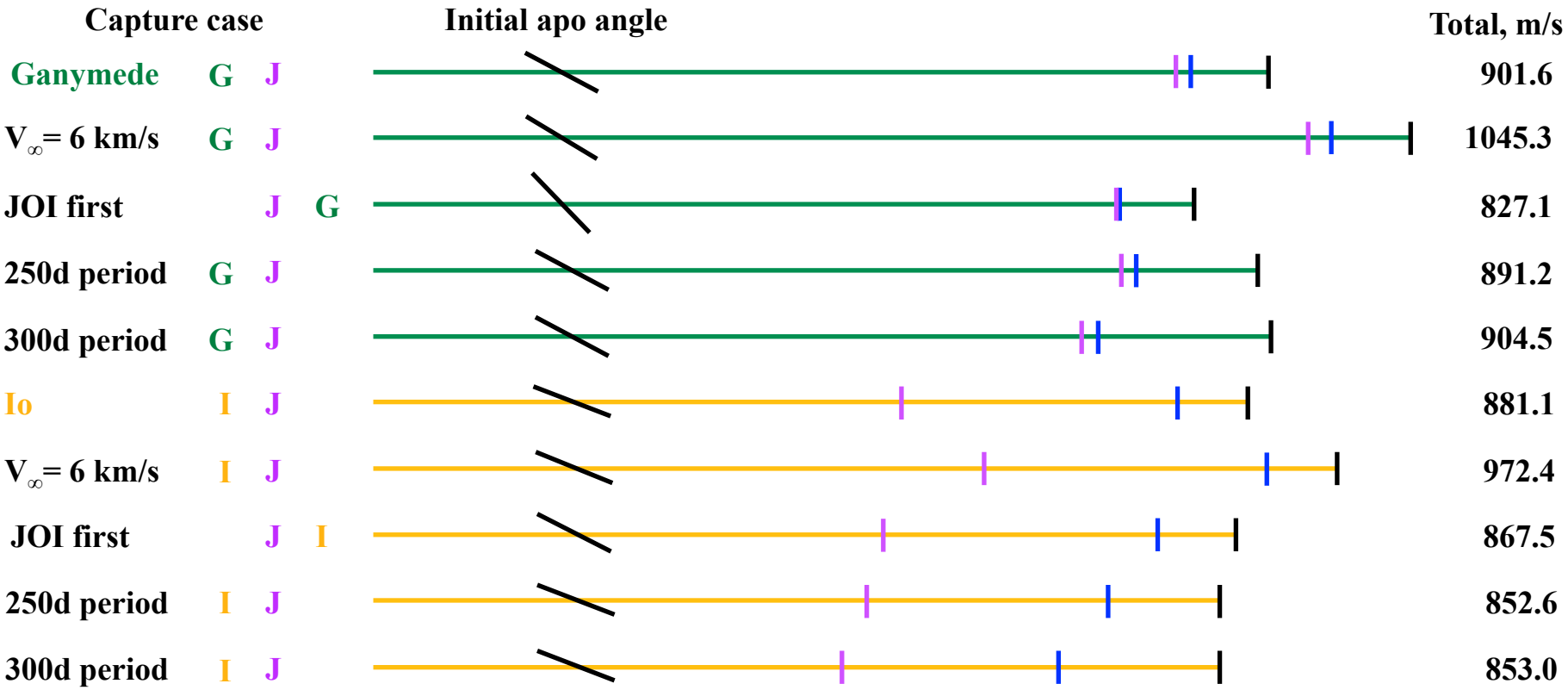

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Extended Pumpdown

Relaxing G1 V_∞ to 9.5 or 10 km/s reduces JOI+PJR ΔV

- Longer tour used to reduce V_∞ at Ganymede
  - Including more Callisto flybys
- Trades longer time-of-flight (TOF) and higher radiation Total Ionizing Dose (TID) against ΔV
- Details in paper AAS 19-295 this afternoon

Example Extended Pump-Down Results*

Value	Lower TID case	Lower TOF case
ΔV savings (m/s)	111.7	122.9
TID penalty (krad)	376.1	521.6
TOF penalty (days)	208.7	114.7
Final Ganymede V_∞	5.0	5.0

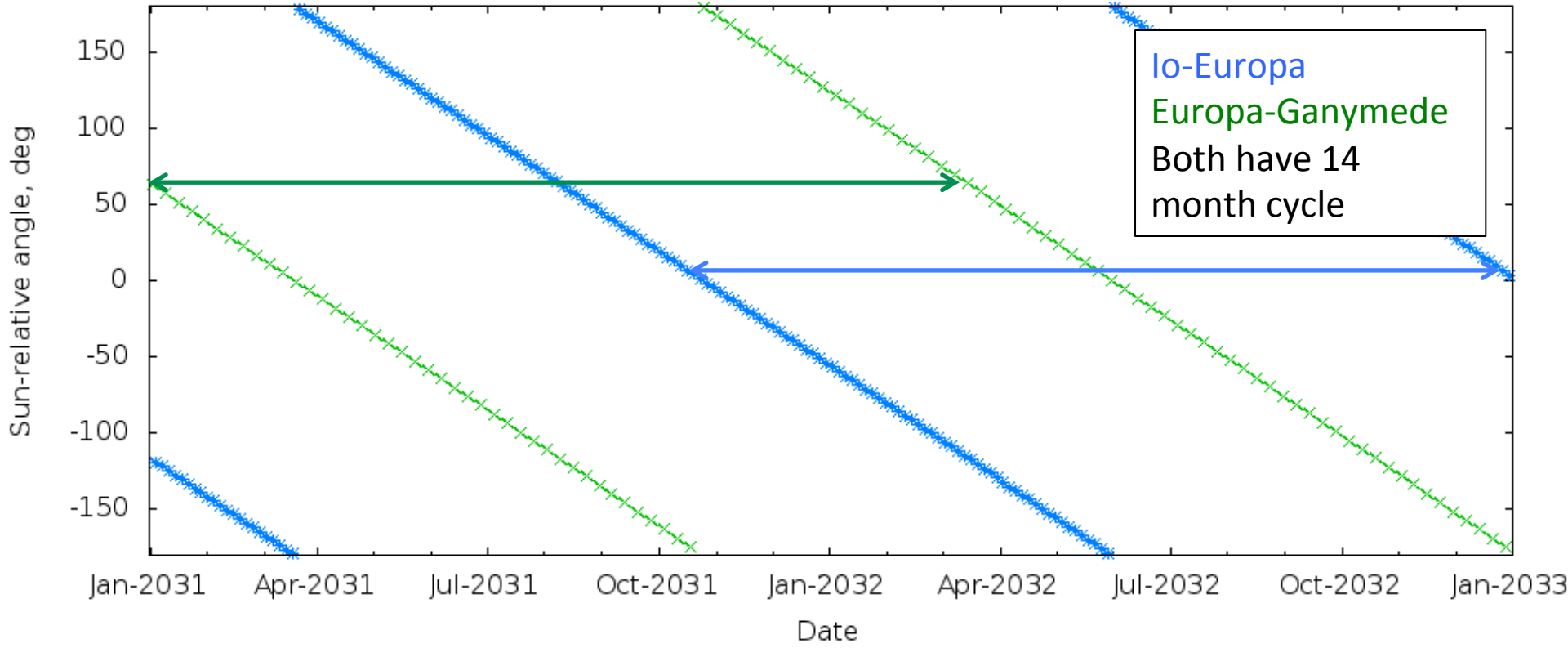
* For G1 V_∞ 9.5 km/s

Double Flybys: Satellite Alignments

To use two satellite flybys, they have to be lined up appropriately

➔How often does that happen?

Double Flybys: Satellite Alignments



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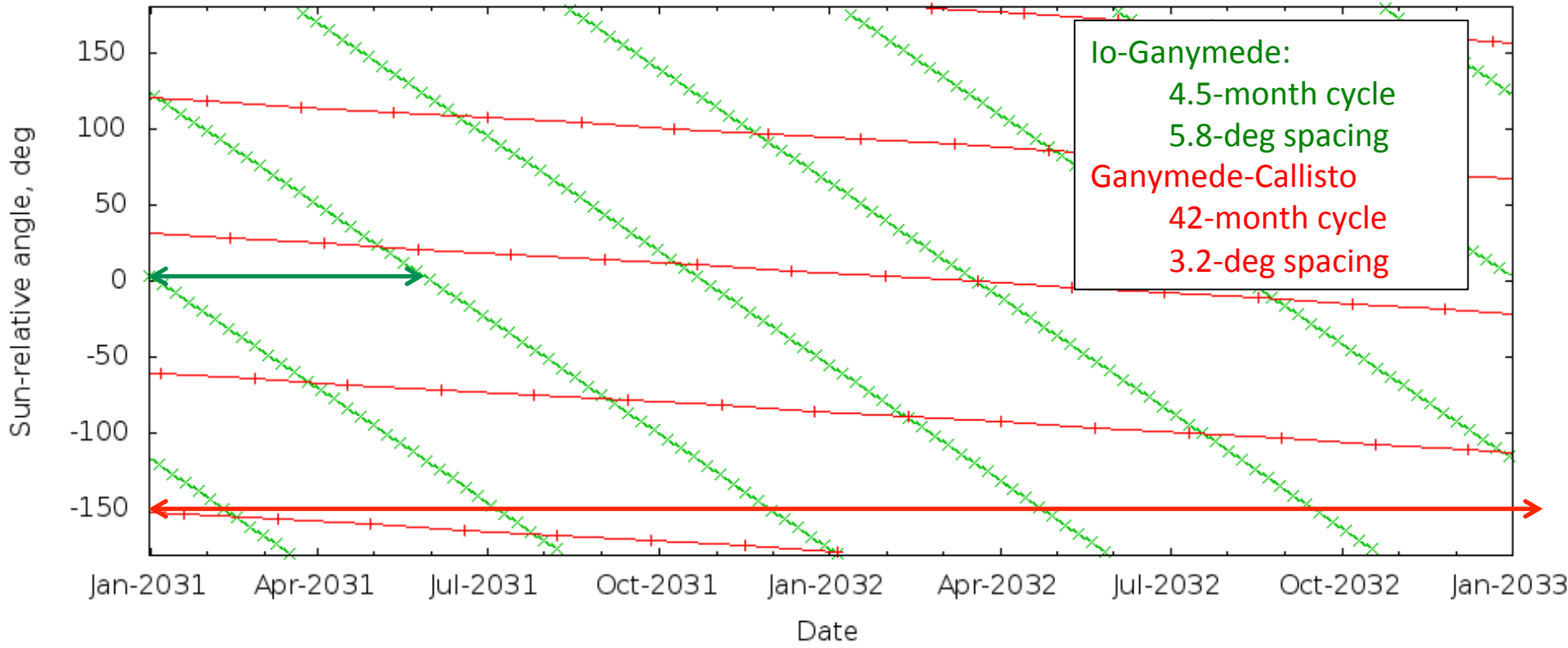

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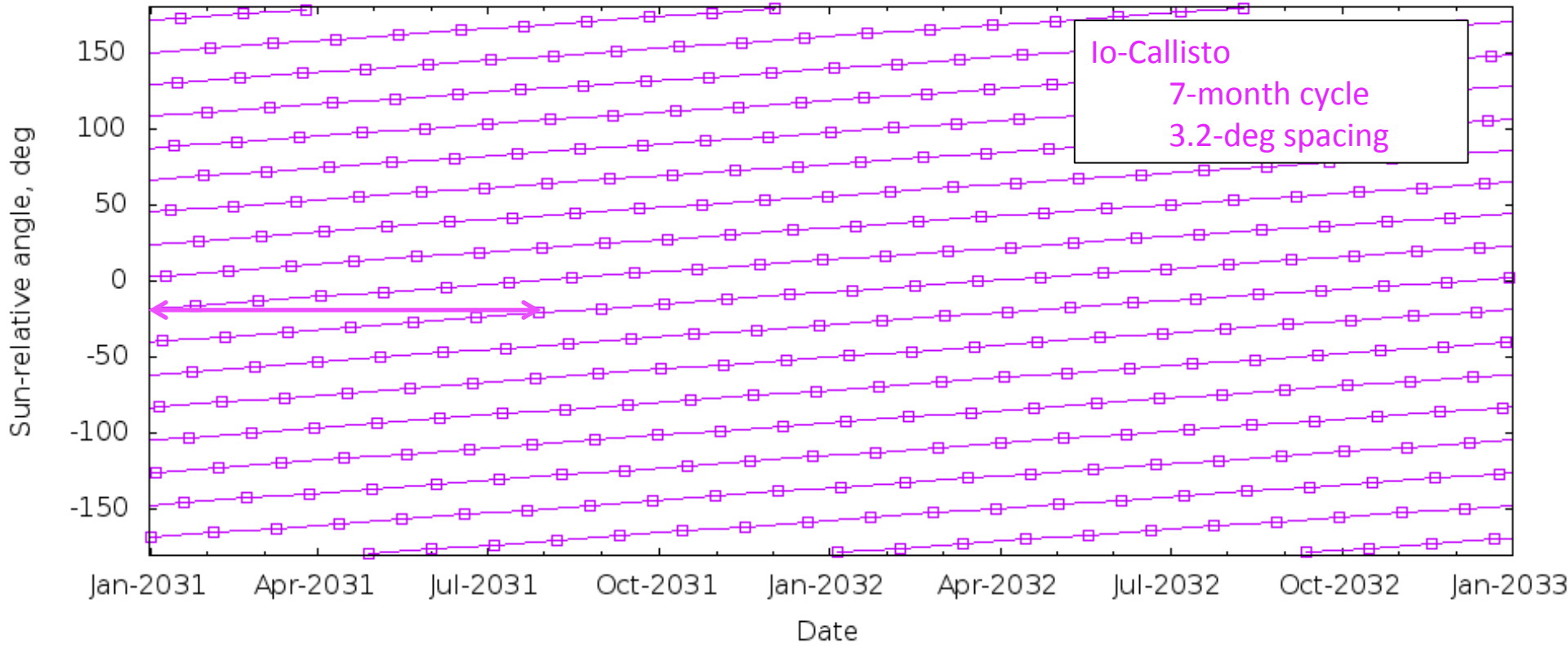

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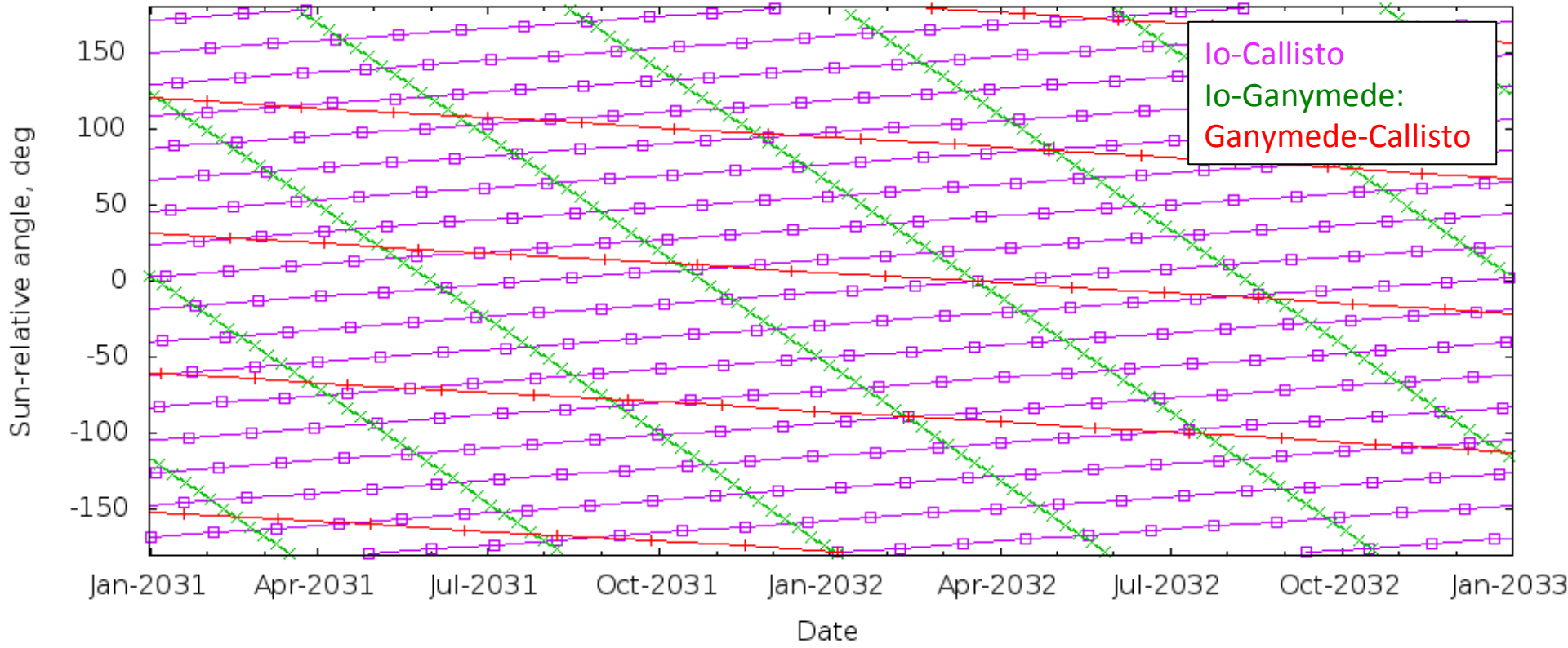

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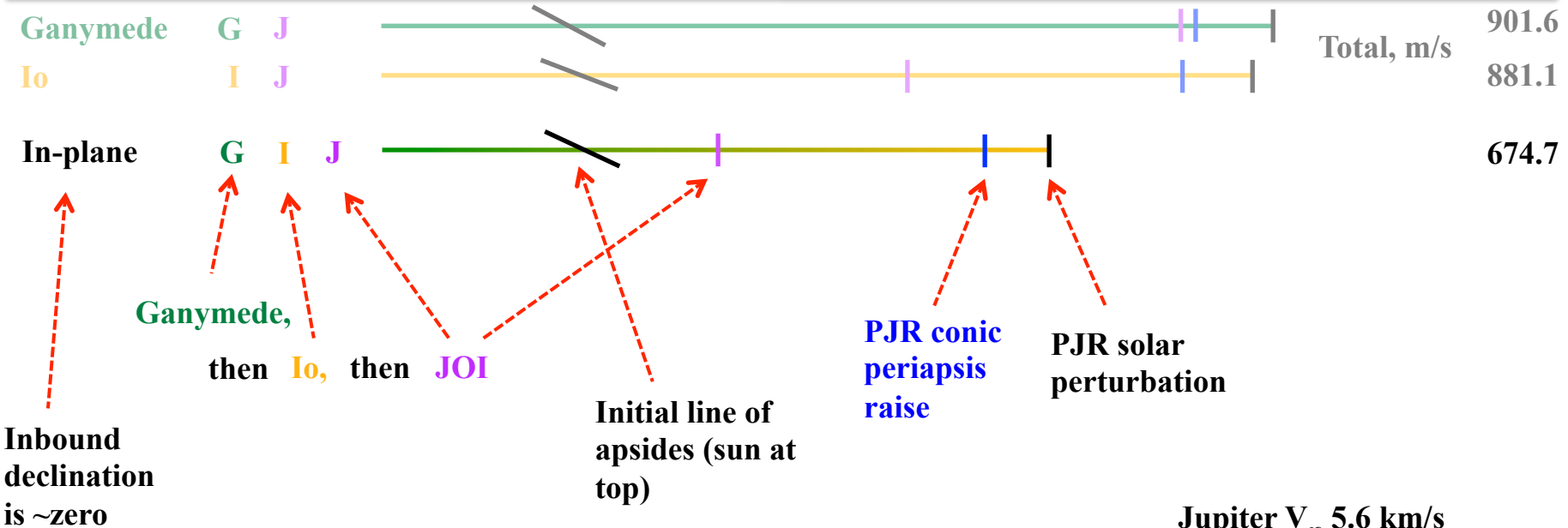

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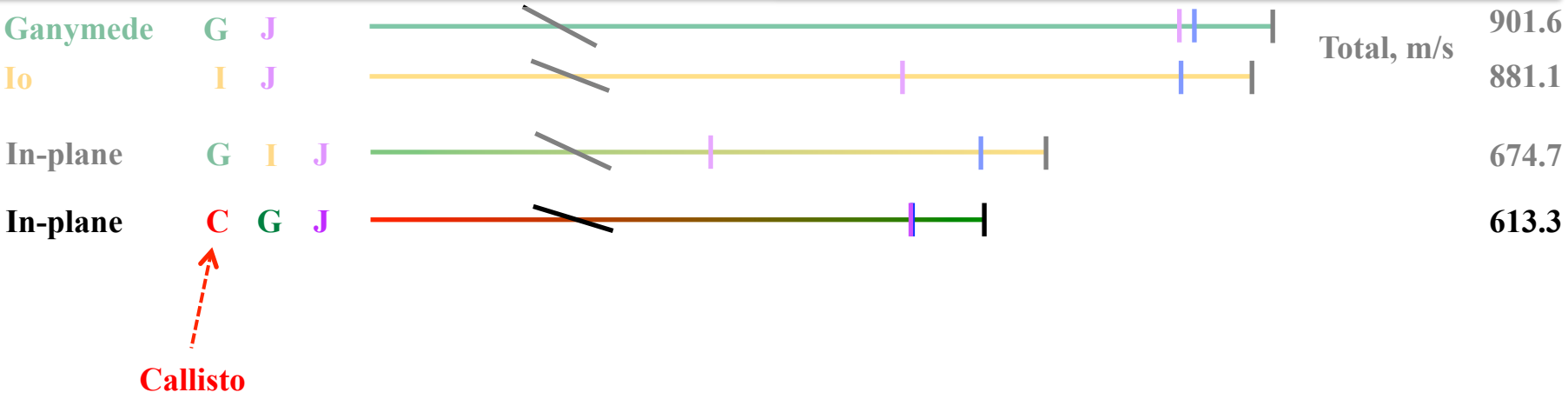

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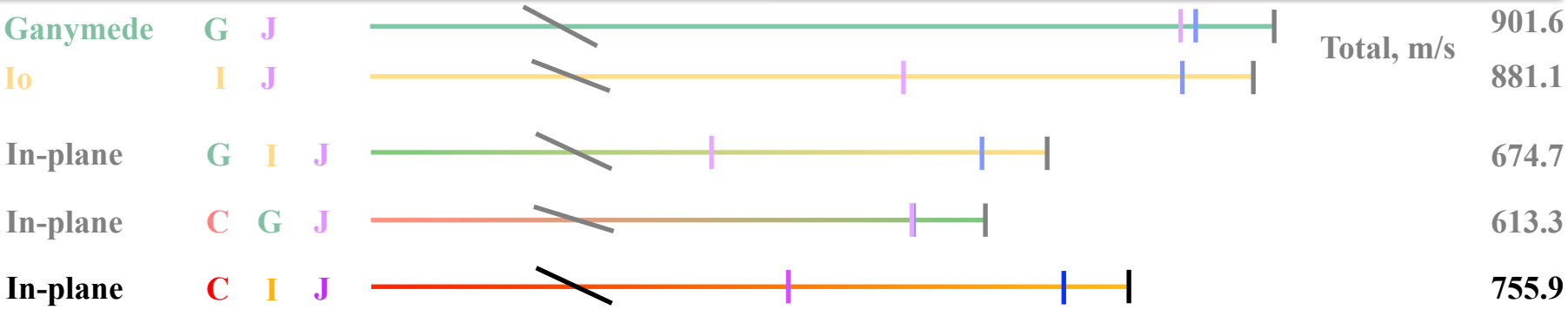

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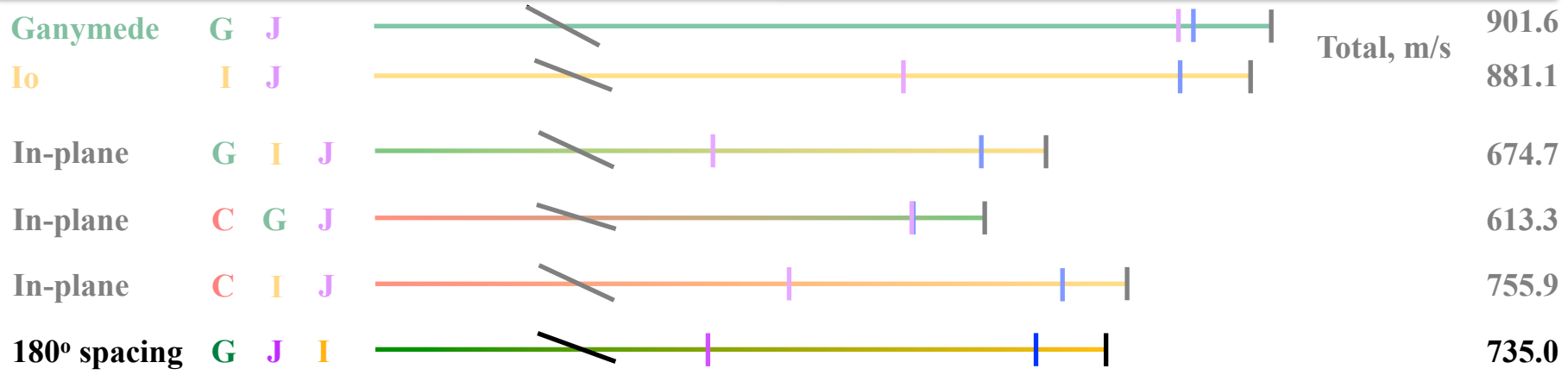

Inbound declination can be up to 8º, flybys happen at nodes

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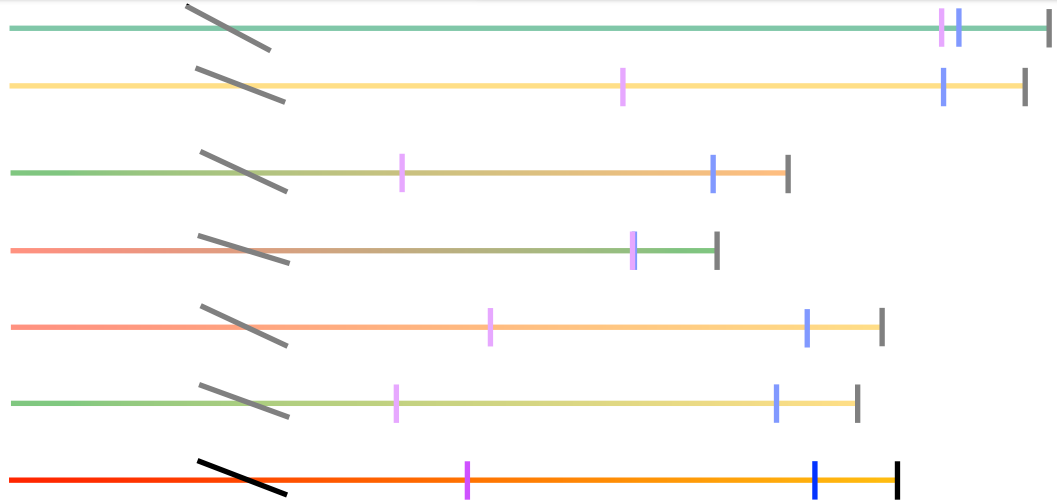

				Total, m/s
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Io	I	J		881.1
In-plane	G	I	J	674.7
In-plane	C	G	J	613.3
In-plane	C	I	J	755.9
180º spacing	G	J	I	735.0
180º spacing	**C**	**J**	**I**	**770.4**

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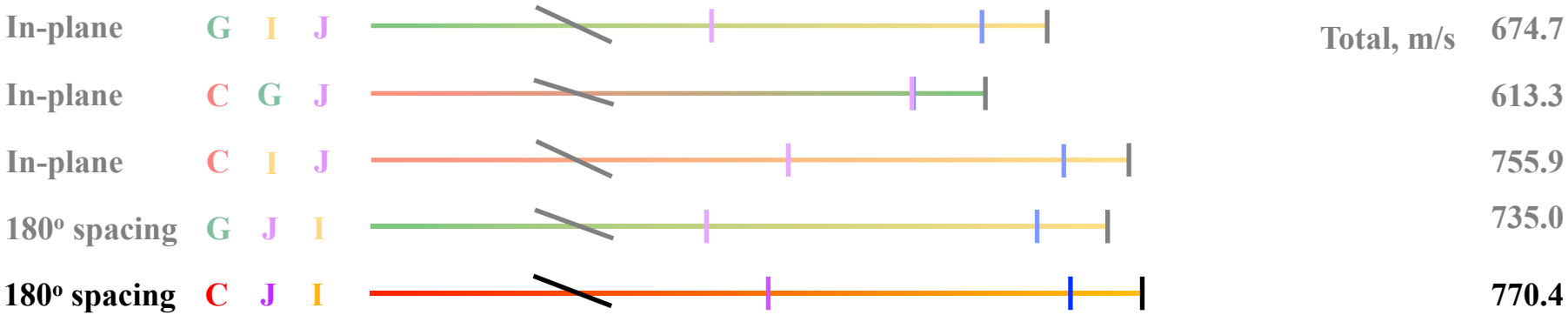
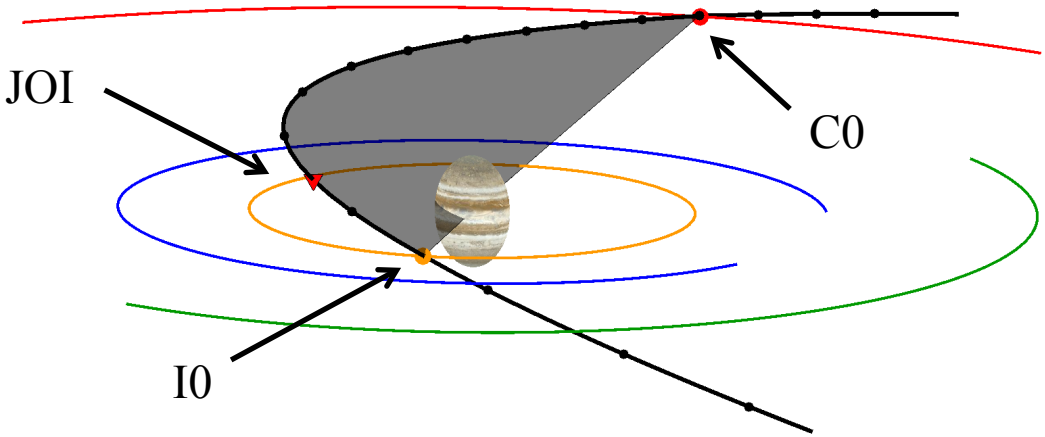


Example Callisto-JOI-Io capture case in high-fidelity

- Inbound declination 7.5°
- 4-hour time tics



Navigation

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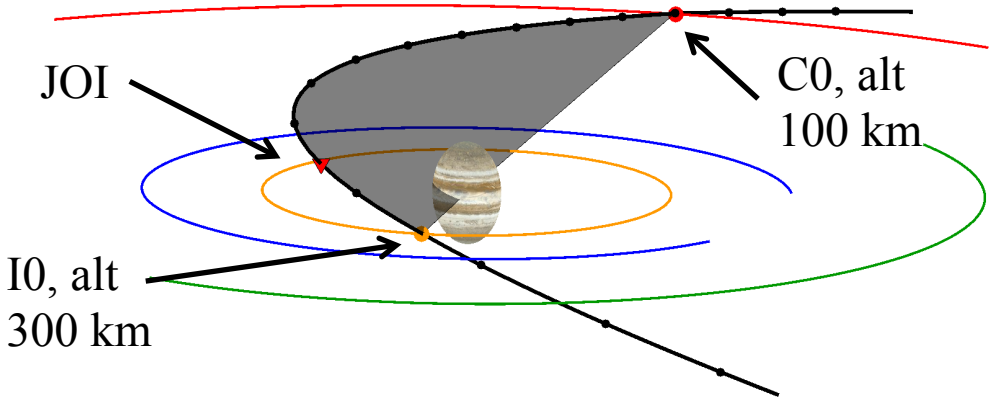

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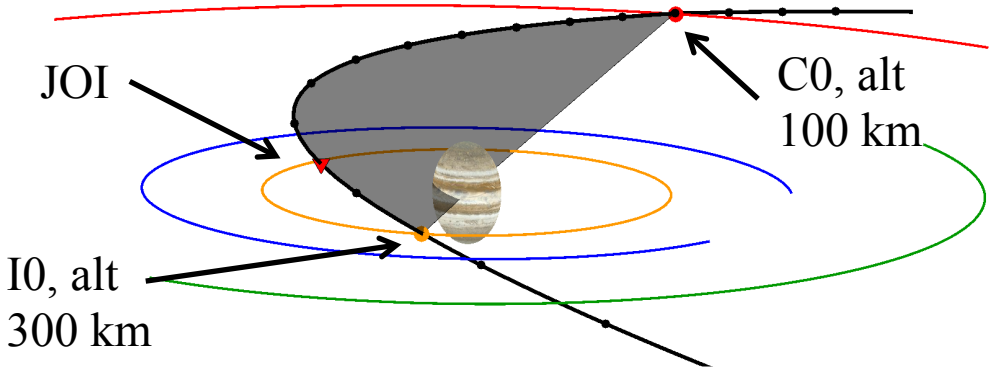
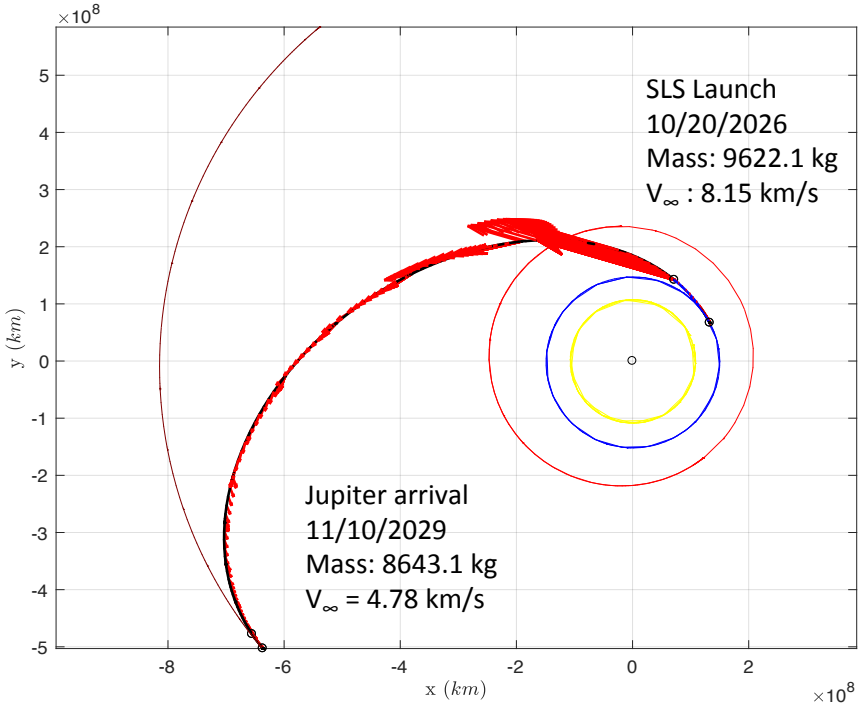


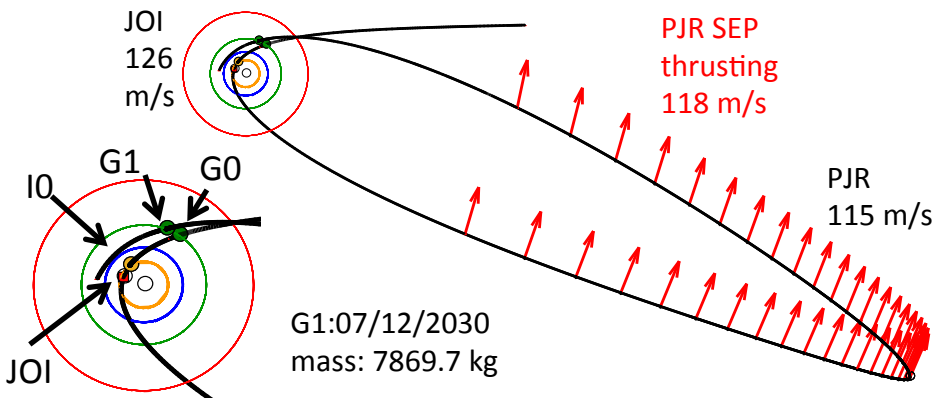
Parameter	Delta	Io-0 Δalt (km)	Δperiod (days)
JOI mag	0.5%	8.3	1.26
JOI pointing	0.5°	55.5	11.0
JOI epoch	86.4s	21.3	2.64
C0 altitude	5 km	233.8	34.6
C0 alt + JOI ptg	5km, 2°	12.7	7.29

SEP Assisted Capture Example



SEP systems are a reasonably good match for solar-powered Jupiter missions

- Allows more efficient trajectories
  - Lower TOF
  - Double-flyby capture
- Limits chemical propulsion system size



Cloudtops Arrival

Jupiter is frustrating:

- Low JOI is really effective, but
- Periapsis raise is expensive, and
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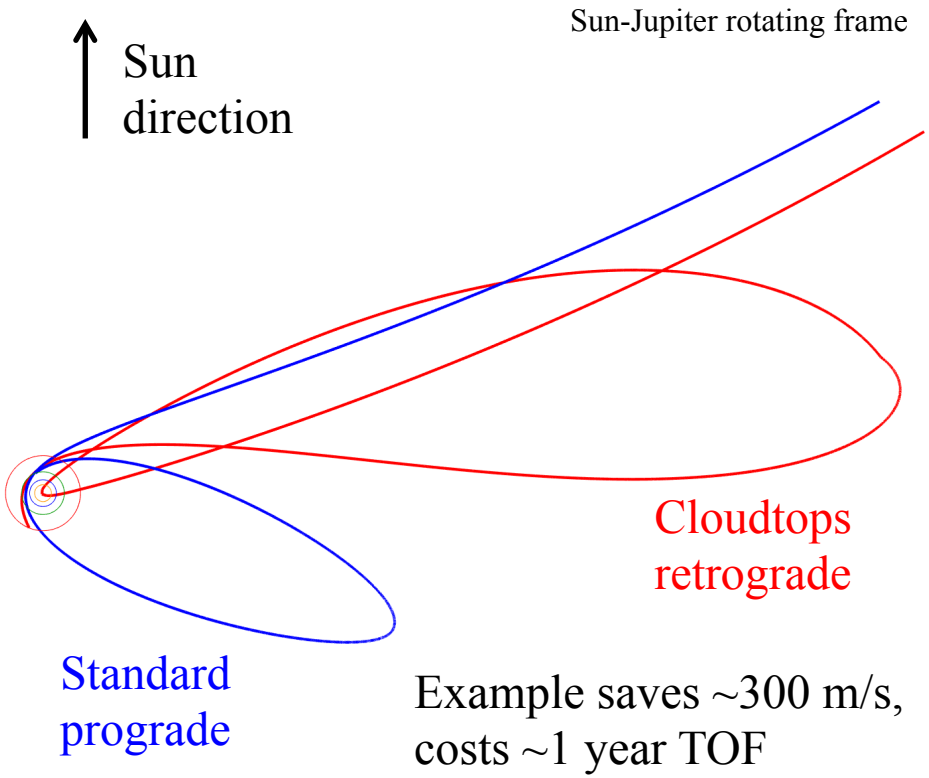

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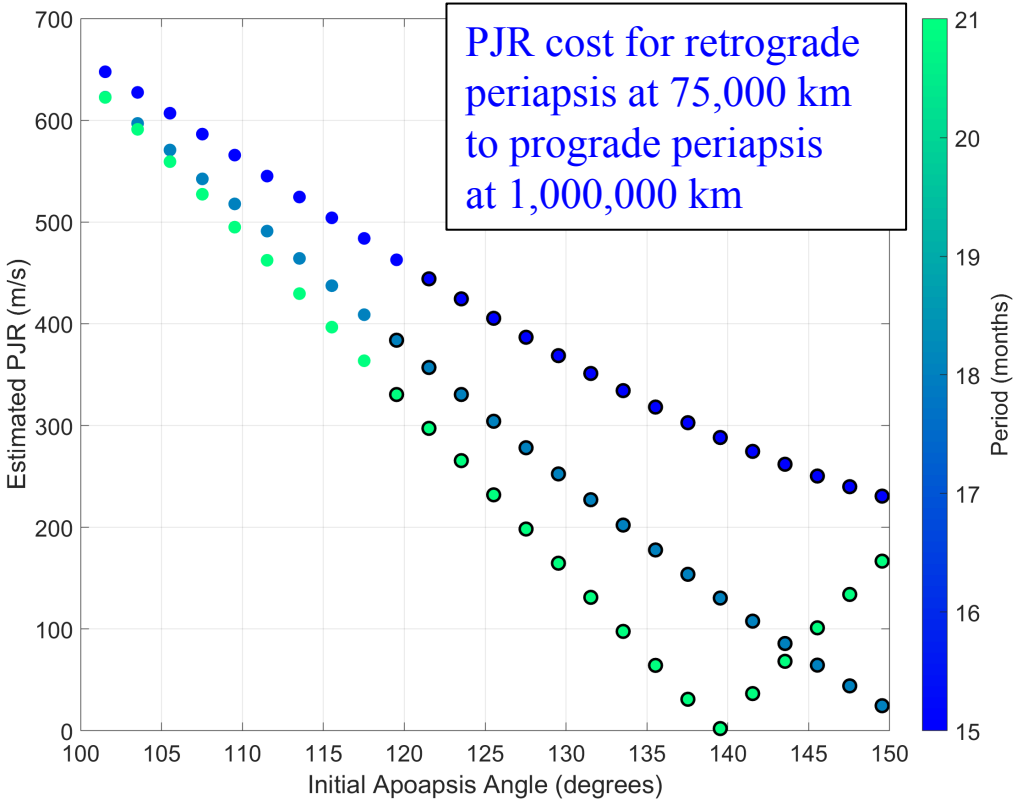

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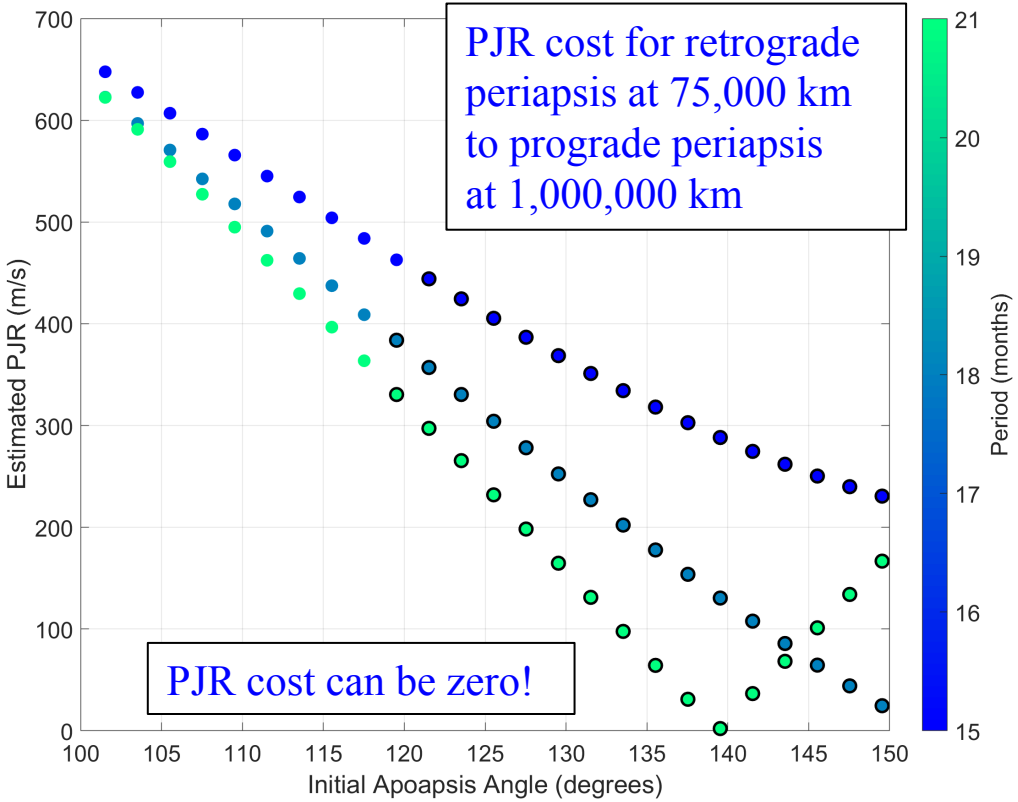
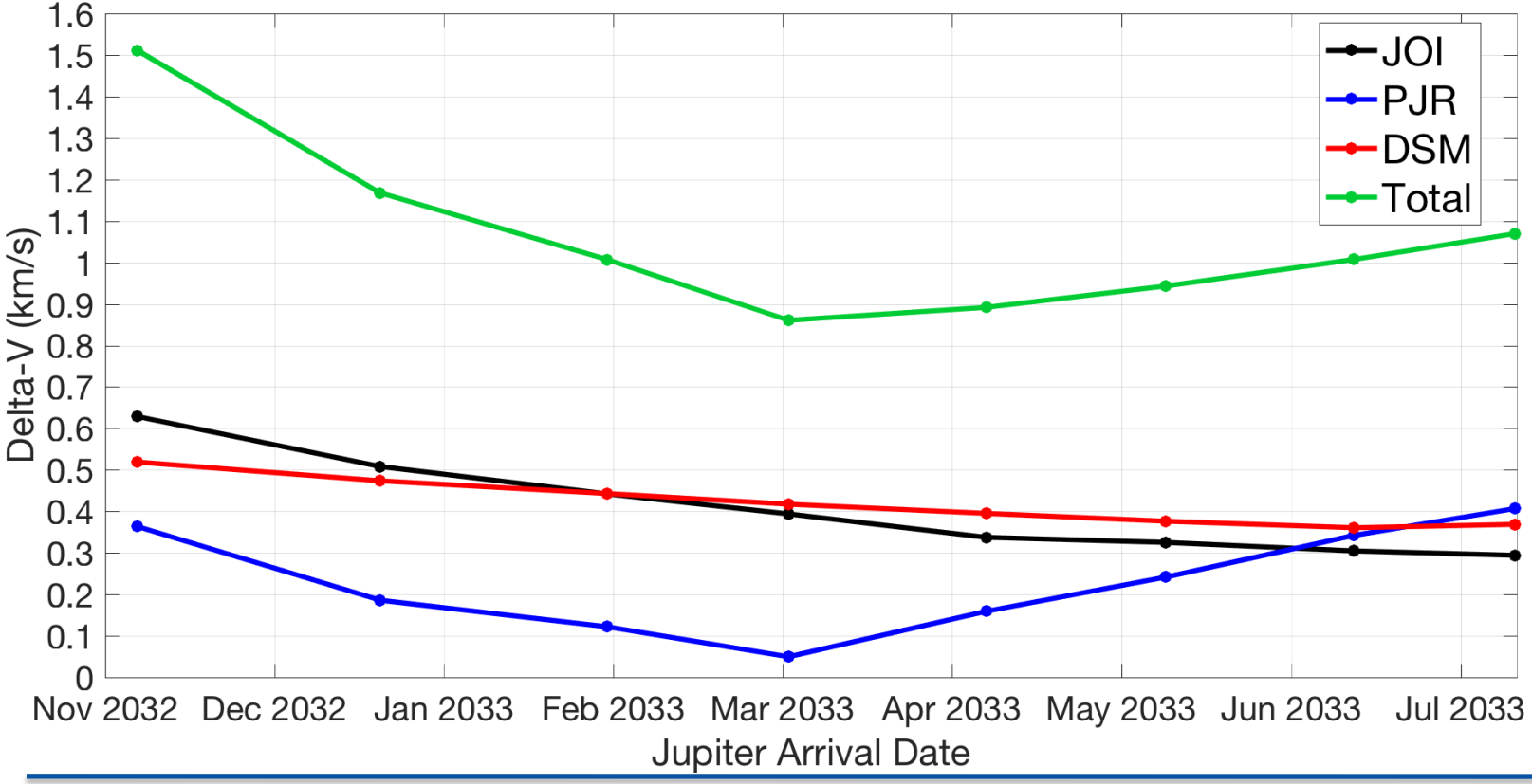
How can we make ΔV even better?

➔Move apoapsis towards the Sun!

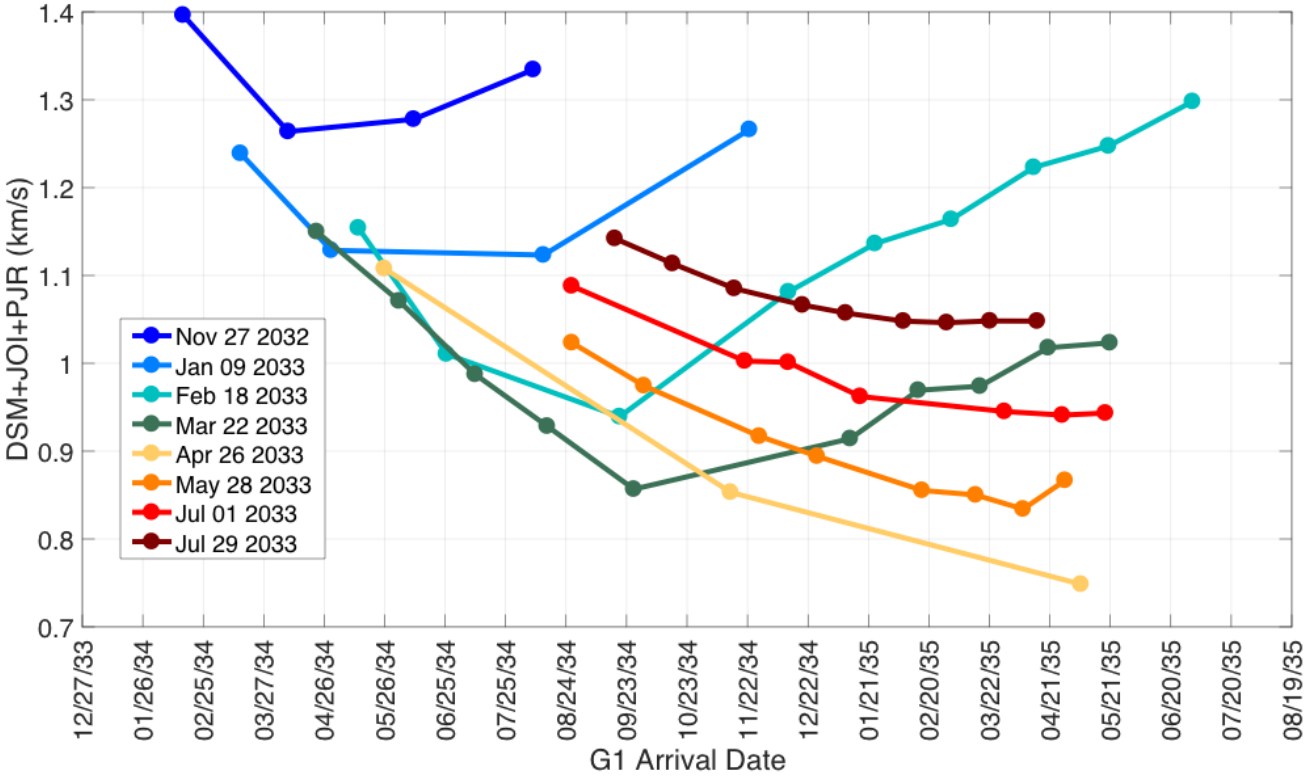


Cloudtops: ΔV Components vs. Arrival Date



For 2028 ΔV-EMGA trajectory, 18-month initial period

Cloudtops: Total ΔV vs. G1 date

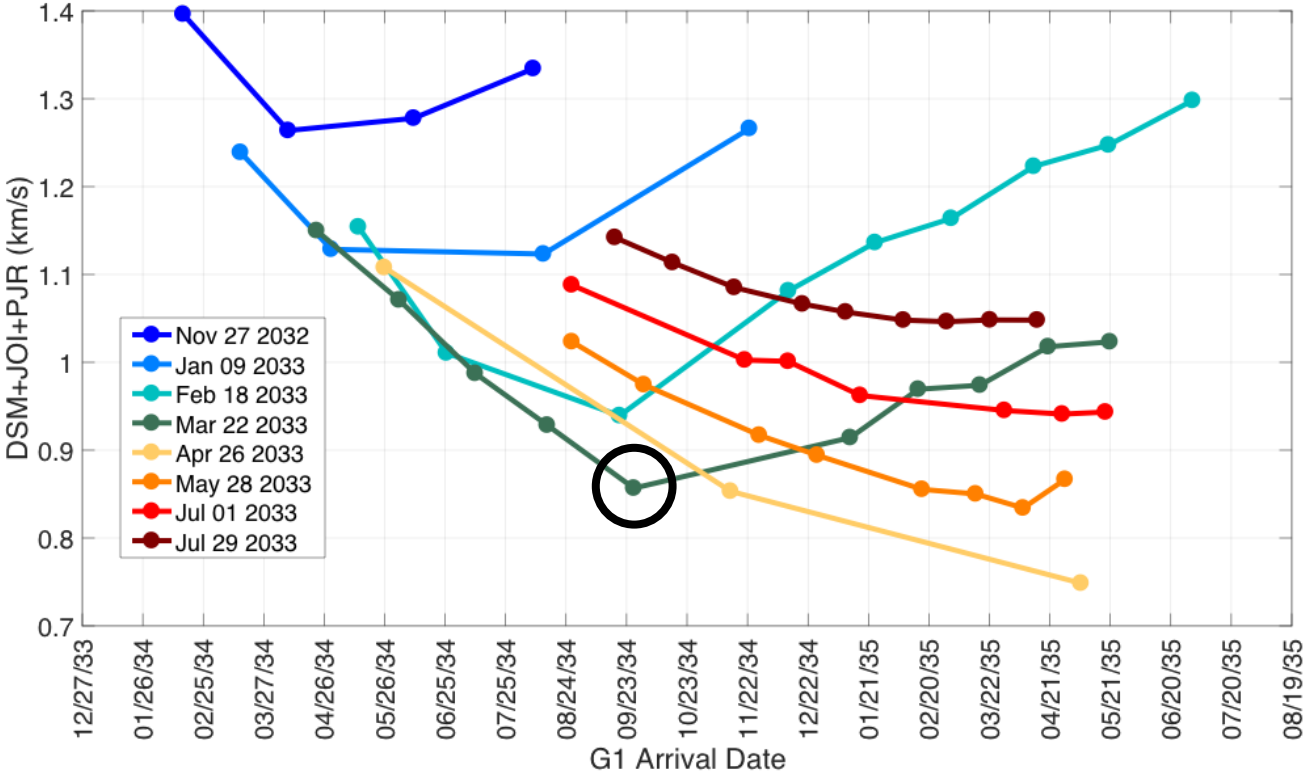


For 2028 ΔV-EMGA trajectory

ΔV-EGA curves are similar shape, but ~250 m/s higher

Standard prograde G1 date is 2/13/2034

Cloudtops: Total ΔV vs. G1 date



For 2028 ΔV-EMGA trajectory

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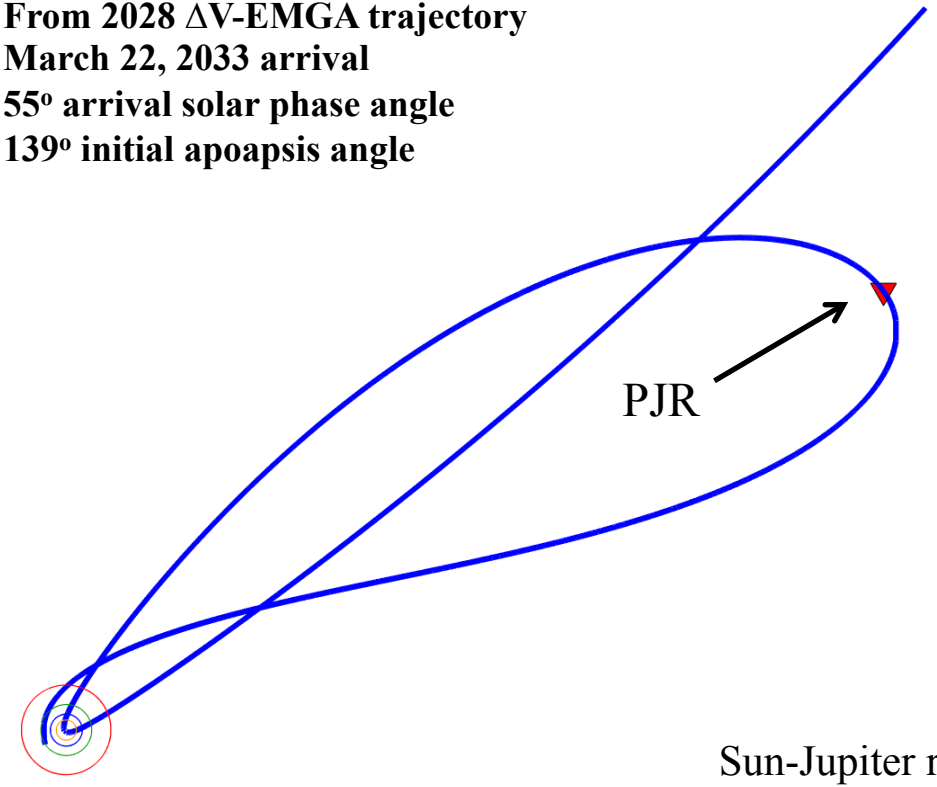
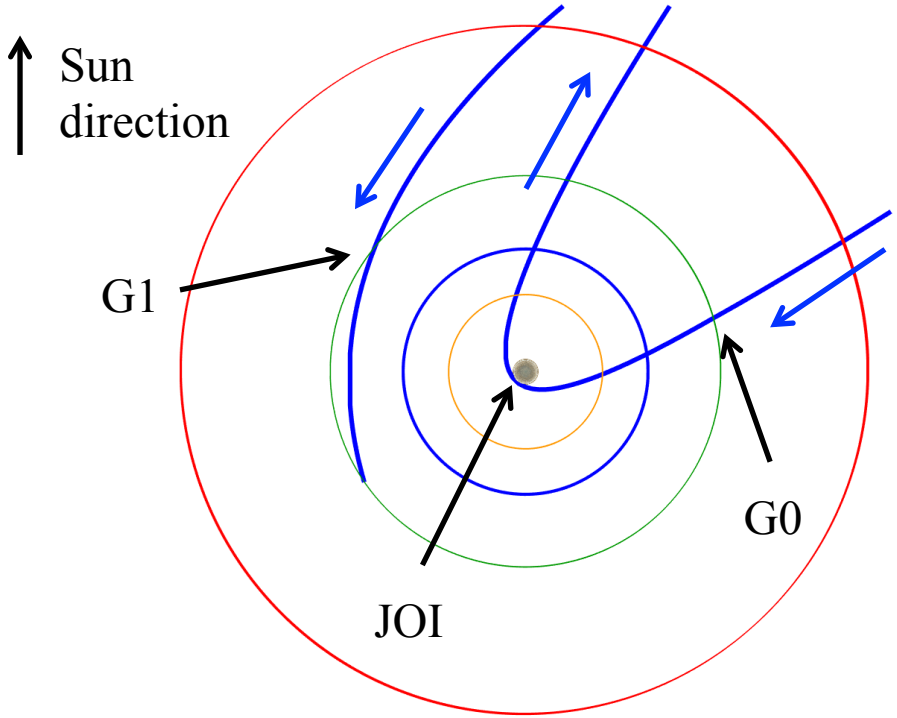
Standard prograde G1 date is 2/13/2034

Cloudtops: Jupiter Arrival Example

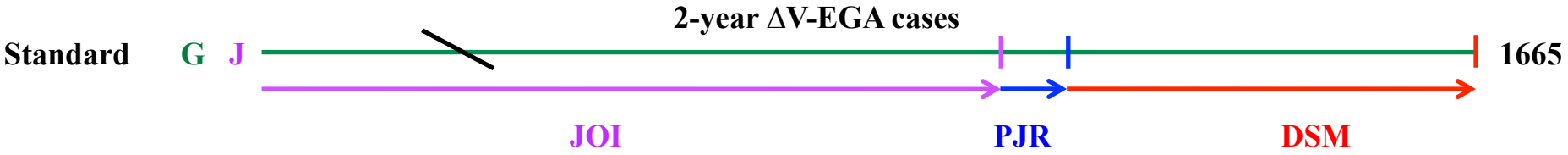
From 2028 ΔV-EMGA trajectory
March 22, 2033 arrival
55° arrival solar phase angle
139° initial apoapsis angle





Sun-Jupiter rotating frame

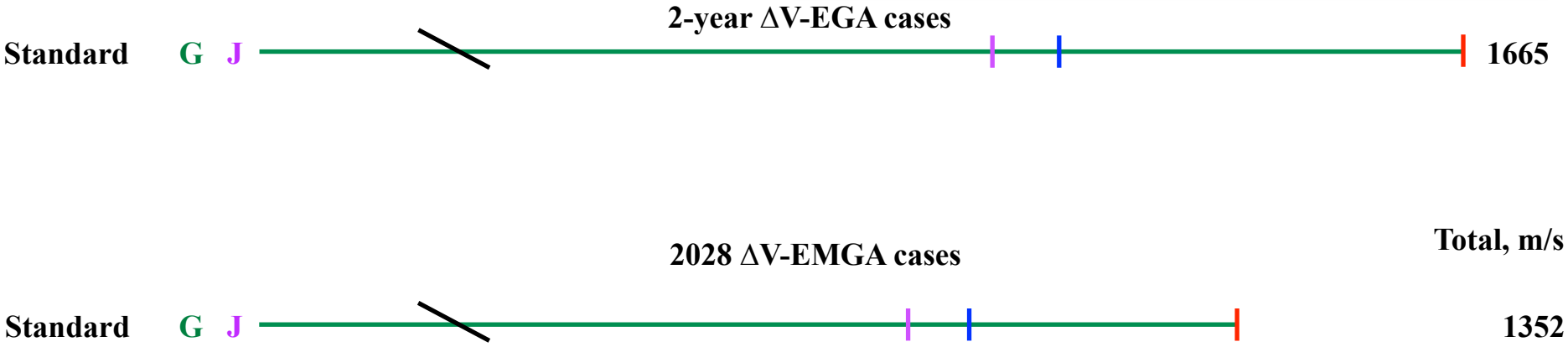
Cloudtops vs. Standard ΔVs



Total, m/s

G0 flyby alt 500 km
200-day initial period
for standard cases
G1 V_∞ 6.27 km/s

Cloudtops vs. Standard ΔVs



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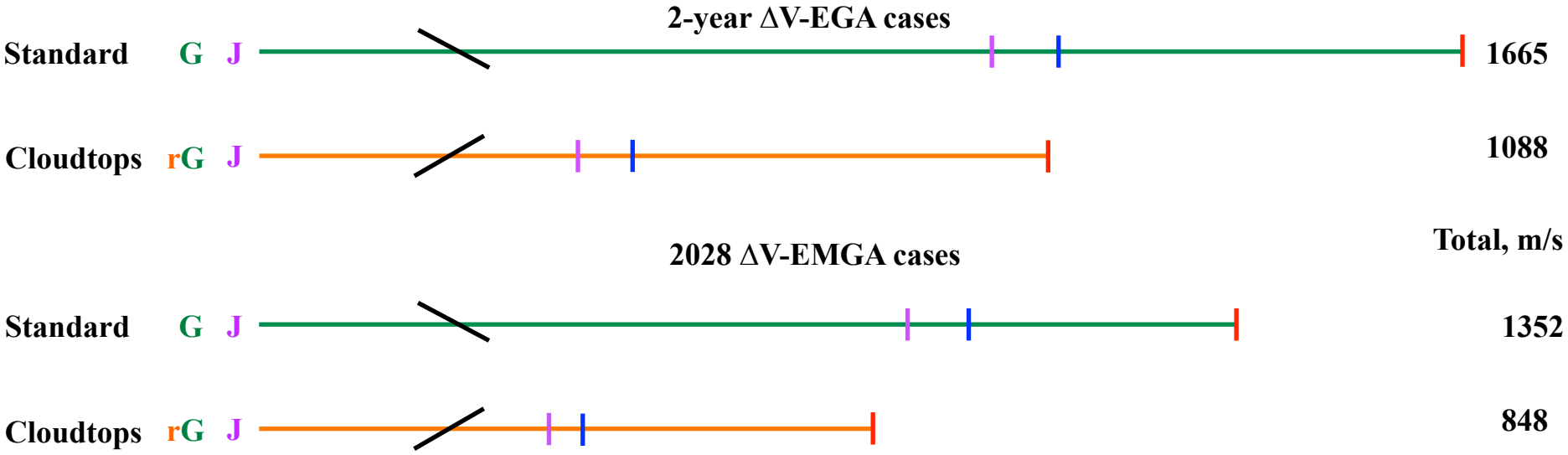
Cloudtops vs. Standard ΔVs



G0 flyby alt 500 km
G1 V_∞ 6.27 km/s
200-day initial period for standard cases
Cloudtops JOI at 75,000km

Only 8-month TOF increase for cloudtops arrivals

Summary and Conclusions

Many ways to capture into equatorial orbit at Jupiter

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  - Inclined double flybys possibly more useful
- Navigation for double flybys and flybys after JOI is challenging but not impossible
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Retrograde, "cloudtops" arrivals:

- Save over 500 m/s with ΔV-EGAs
- No insurmountable difficulties
- Let's fly one!