Orbital stability in the Solar System for arbitrary inclinations and eccentricities.

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1 GOAL

To study the **orbital stability** of test particles in the Solar System in the space (a,e,i) defined by 0 < a < 38 au, 0 < e < 0.9 and **0 < i < 180**.

2 WHY?

Minor bodies are in the midst of a struggle between random destructive **planetary perturbations** and the synchronized **resonant** ones. Sometimes, for some region in the space (a,e,i) resonances dominate providing predictive behavior. And sometimes it is just the chaos. Our maps are the result of that struggle.

TWO NOTABLE FACTS:

1) Resonances exist even for **retrograde** orbits (Namouni and Morais 2015, Gallardo 2019a, Li et al. 2019)

2) Sometimes only retrograde resonant orbits survive while direct ones are destroyed (Fernández et al. 2016)

3 METHOD

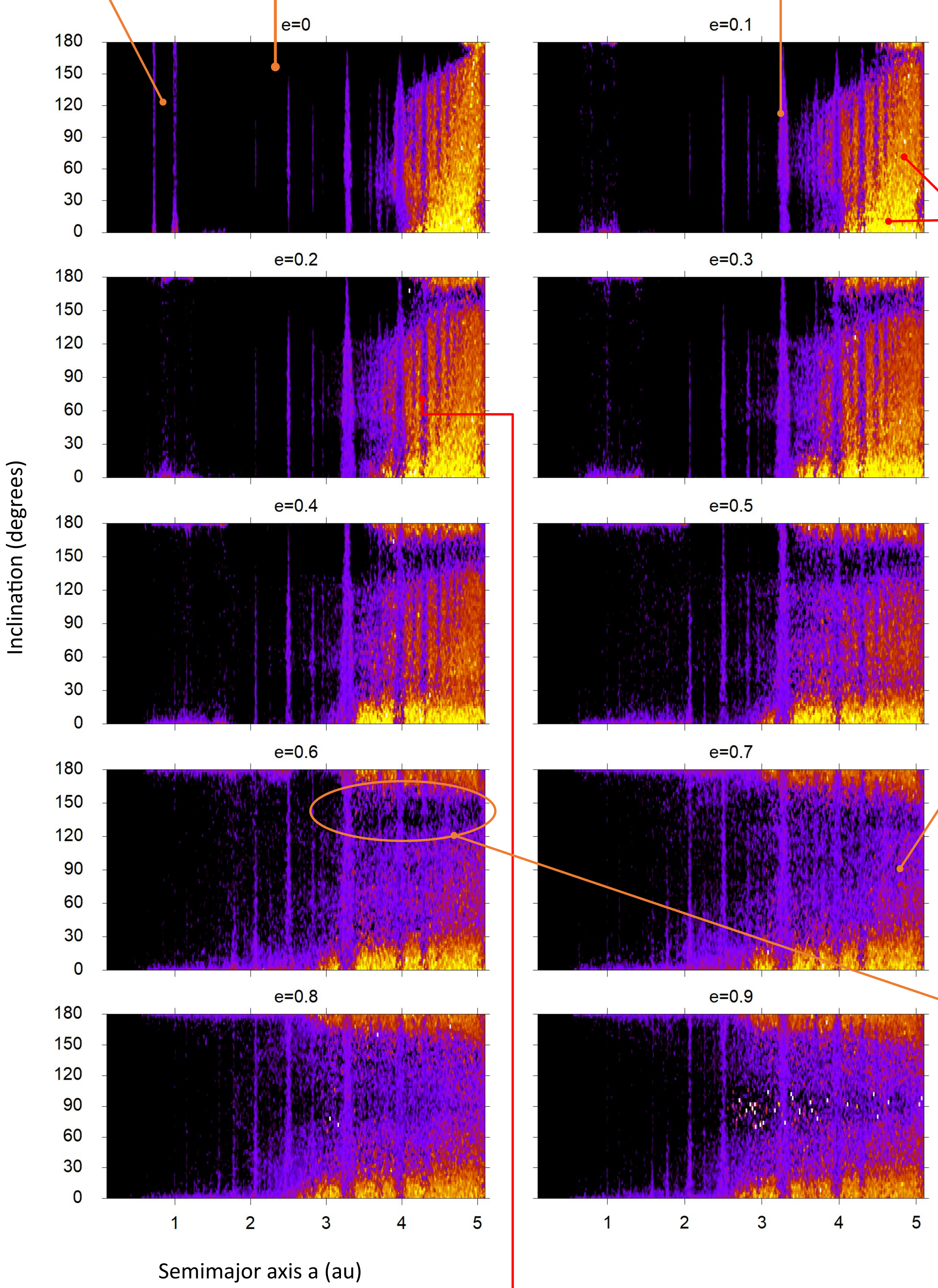
Dynamical maps obtained with numerical integrations of test particles inside a grid in the space (a,i) with initial e=0, 0.1,... 0.9 and random initial Ω, ω, M. The maximum Δa/a detected after 1000 orbital revolutions is plotted in color code.

Dark: Δa/a ~ 0.001
very small Δa typical of stable secular evolution
SECULAR

Pale tone: Δa/a ~ 0.01
small Δa typical of resonant evolution
RESONANT

Bright: Δa/a>0.1
large Δa typical of chaotic evolution
CHAOS

Venus and Earth's coorbitals



4 Results: INNER SOLAR SYSTEM

LOW eccentricity **chaotic** orbits
and
HIGH eccentricity more **stable** orbits

Tip: encounter probability with Jupiter

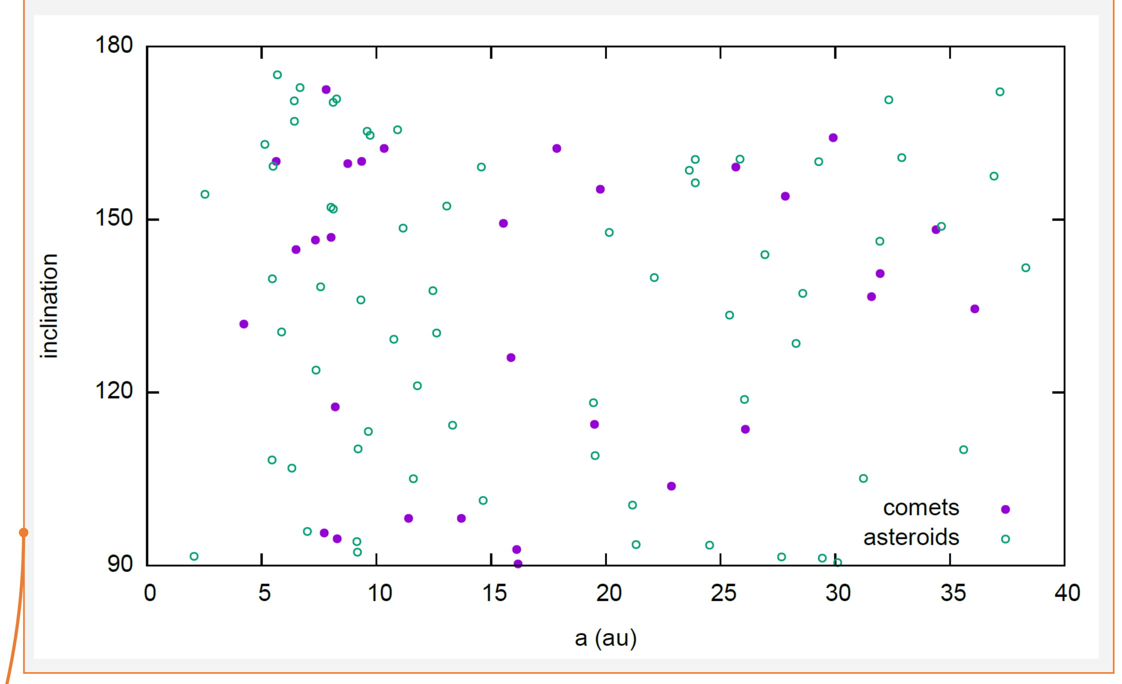
Stable (darker) stripes around 150 degrees

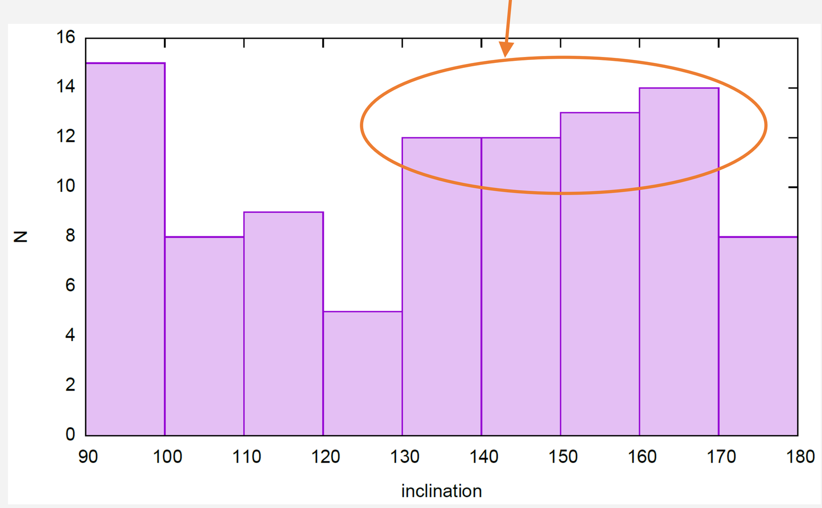
Stable resonances (direct and retrograde) inside chaotic regions

Some direct and retrograde surviving resonances

Resonance	a (au)
1:1V	0.72
1:1E	1.00
4:1J	2.06
3:1J	2.50
2:1J	3.28
3:2J	3.97
4:3J	4.29
1:1J	5.2
2:3J	6.8
1:2J	8.2
1:3J	10.8
1:4J	13.1
1:5J	15.2
1:2S	15.2

The **known population** of retrograde objects with a<40 au.





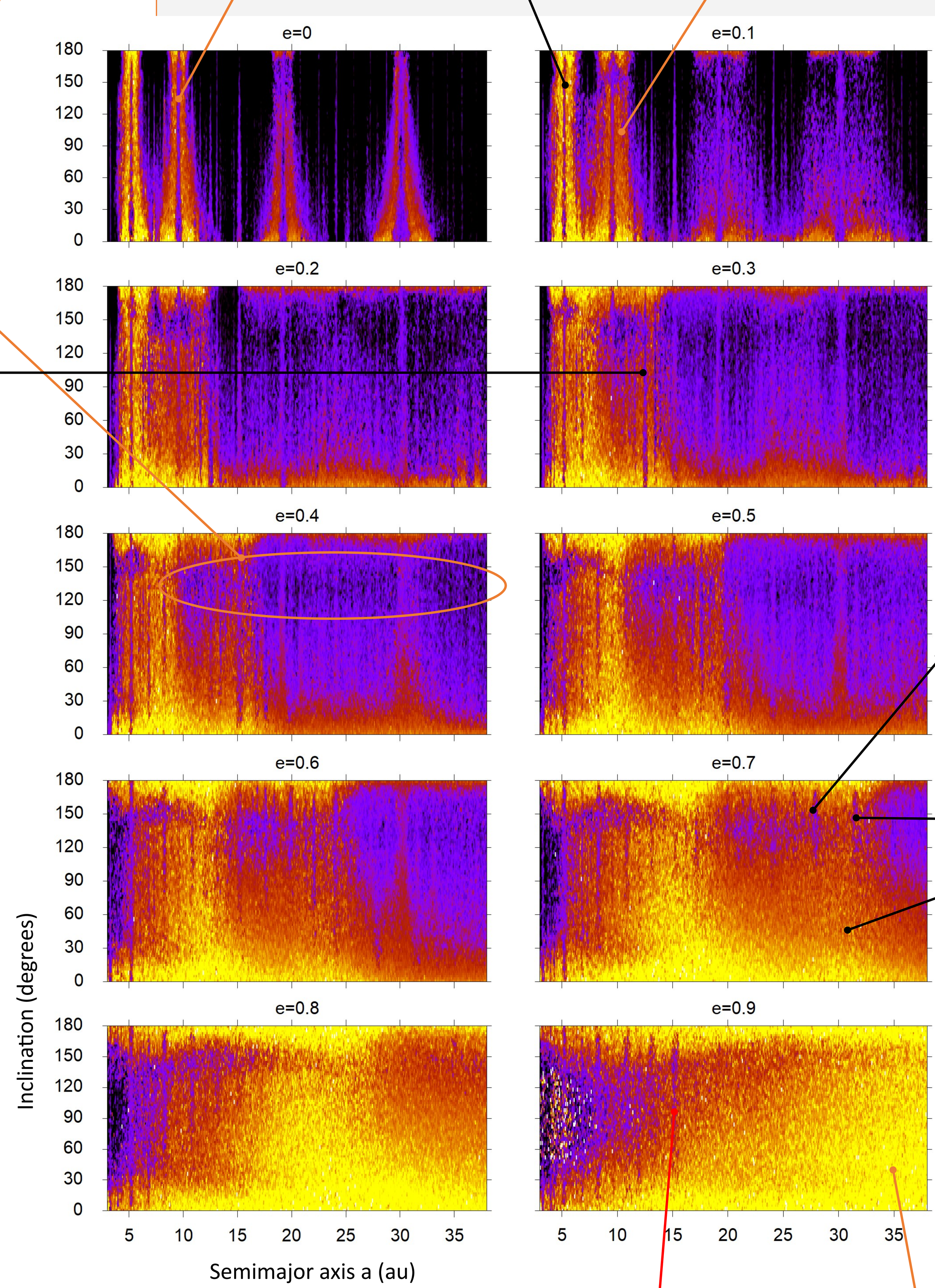
The **known population** concentrates in the stable inclination strip.

Tip: encounter probability and velocity with planets (Öpik theory)

5 Results: OUTER SOLAR SYSTEM

Stable RETROGRADE coorbitals

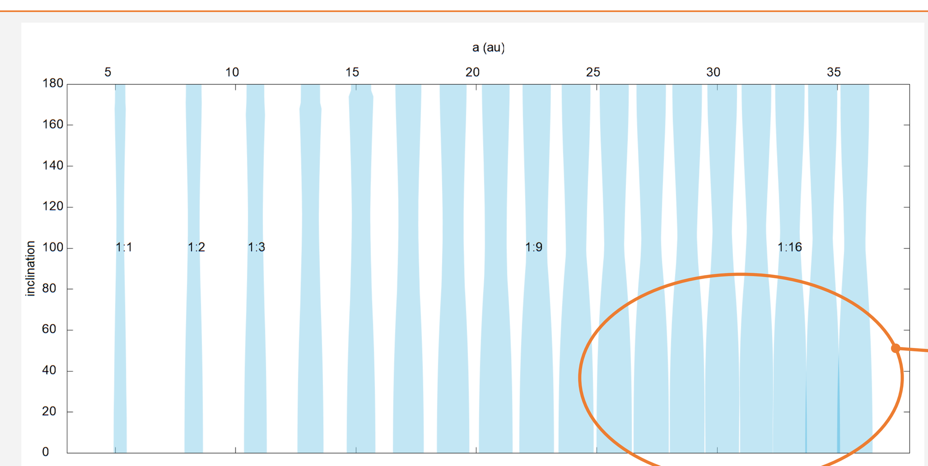
Unstable regions near coorbitals



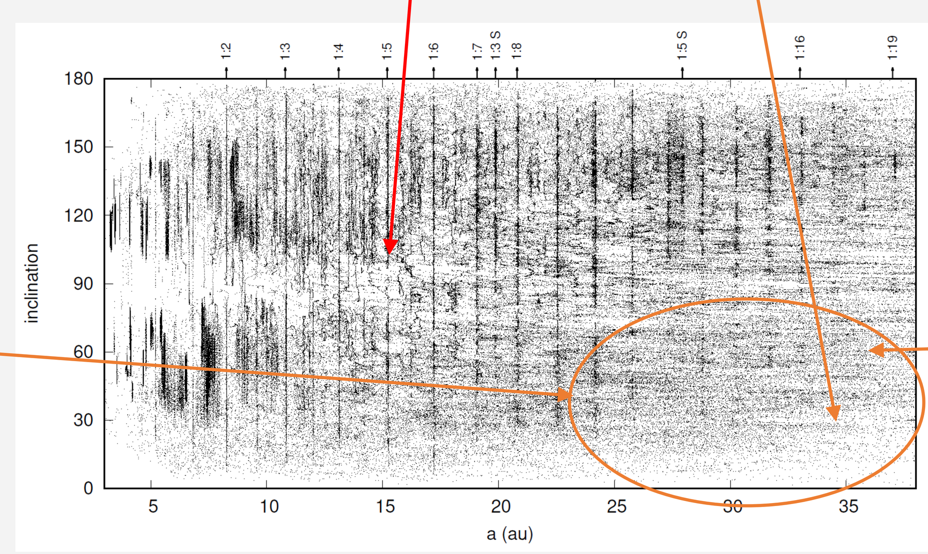
Exterior resonances 1:N with Jupiter, up to 1:15

Retrograde resonances survive, but direct ones do not.

Tip: planetary perturbations



Widths of exterior resonances 1:N with Jupiter in the space (a,i) for e=0.9 following the **model** by Gallardo 2019c. Direct resonances are **stronger** and wider but **more perturbed** by the other planets.



No direct resonances survive.

Points are orbital states of high eccentricity **test particles** integrated by 2 Myr. Vertical lines are due to concentrations of resonant orbital states, mainly 1:N with Jupiter. Note the captures in retrograde resonances where perturbations are weaker (Gallardo 2019b).

6 CONCLUSIONS

Son ustedes quienes deben encontrarlas.

Tip: planetary perturbations + resonances strengths

REFERENCES

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