MAX-PLANCK-INSTITUT
FÜR PLASMAPHYSIK

Is stochasticity a threat for the stellarator-reactor island divertor?

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Motivation

- In W-7x, for high I_{cc}, a substantial field line chaos is observed.
- How stochastic transport the size of the islands in the future stellarator-reactor?
- When Scrape-off layer (SOL) flows become affected by the stochasticity (when stochastic transport become dominant)?
- Relax limitation of existing coils –> synthetic magnetic configuration

Hamiltonian systems to study stochasticity

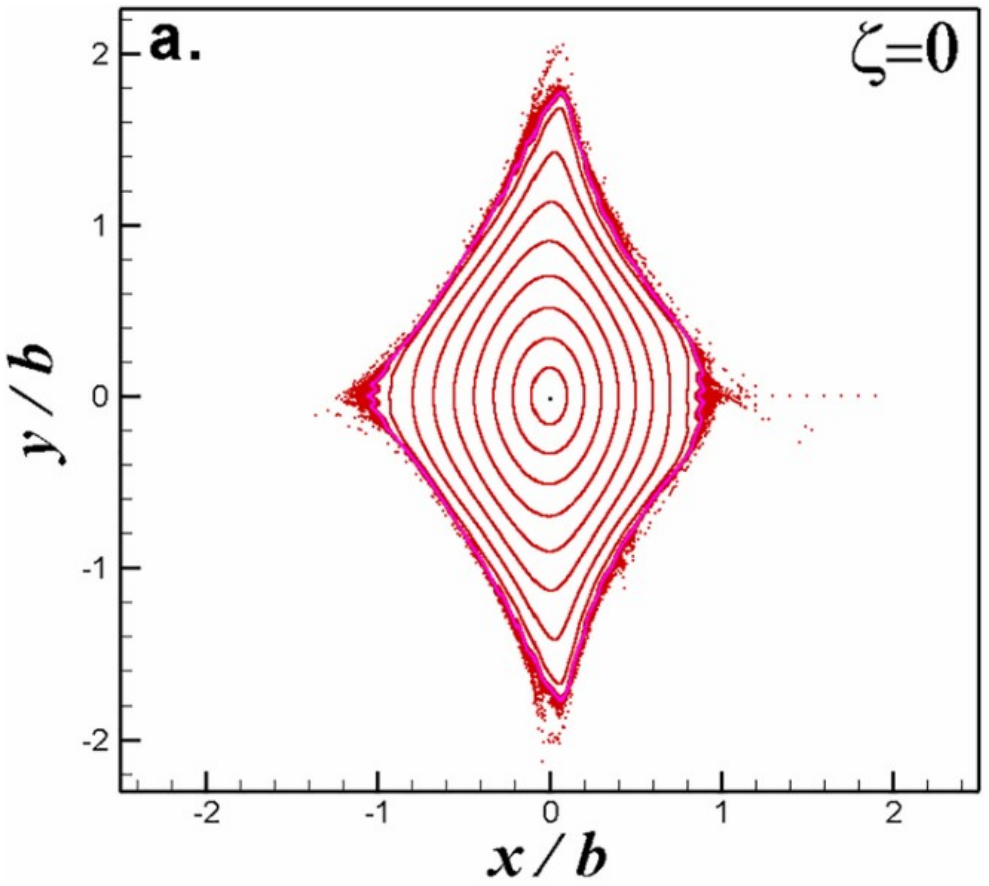
$$\frac{d\psi}{d\phi} = -\frac{\partial \chi}{\partial \theta} \qquad \frac{d\theta}{d\phi} = \frac{\partial \chi}{\partial \psi}$$

- Synthetic magentic configurations
  [Alkesh Punjabi and Allen H. Boozer Phys. Plasmas, (2020)]

- Idea: create two island chains and overlap

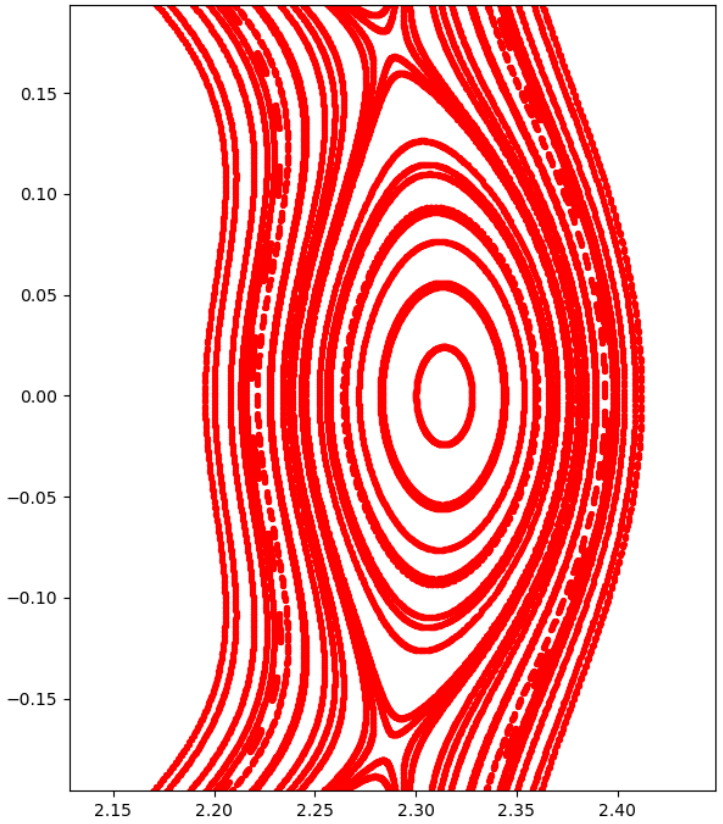
$$\chi = \psi\,(\frac{\iota_a}{2}\psi + \iota_b) + A_1 \cos(m_1\theta - n_1\phi) + A_2 \cos(m_2\theta - n_2\phi)$$

$$r = \sqrt{\frac{\psi}{\pi B_0}} \qquad \frac{d\chi_0}{d\psi} = \iota(\psi) = \iota_a\psi + \iota_b$$

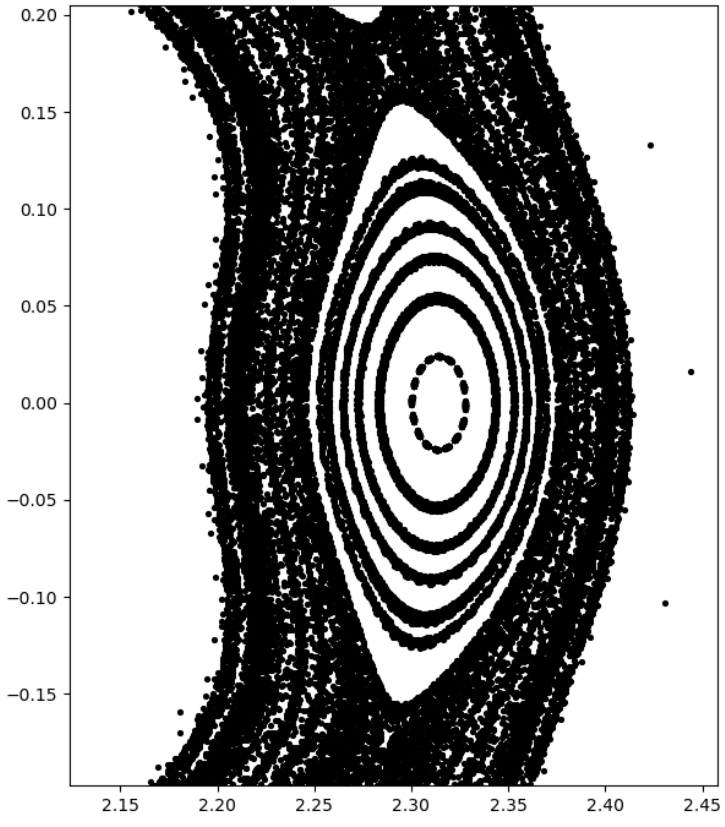


Time independent (TI) Hamiltonian

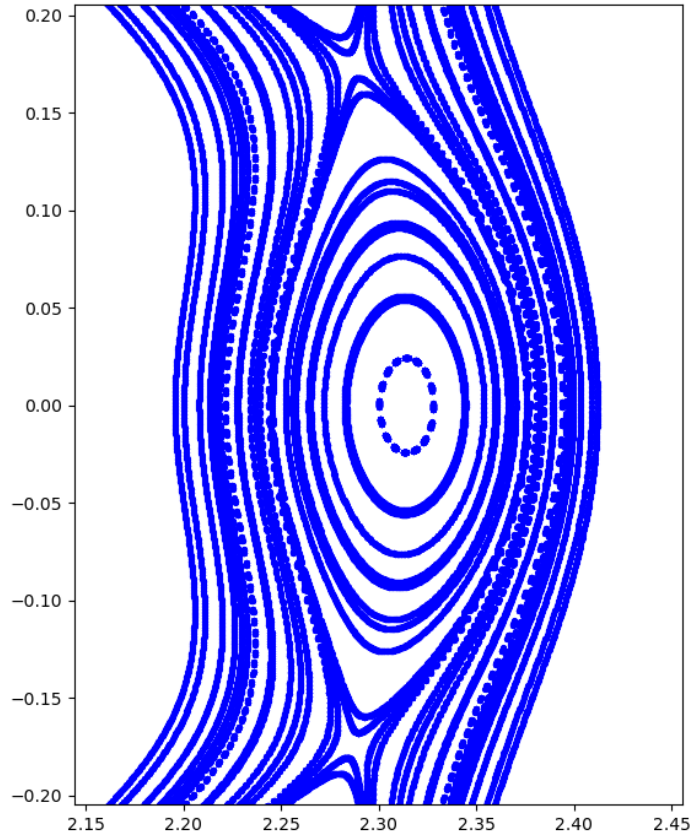
Pendulum



Runge-Kutta



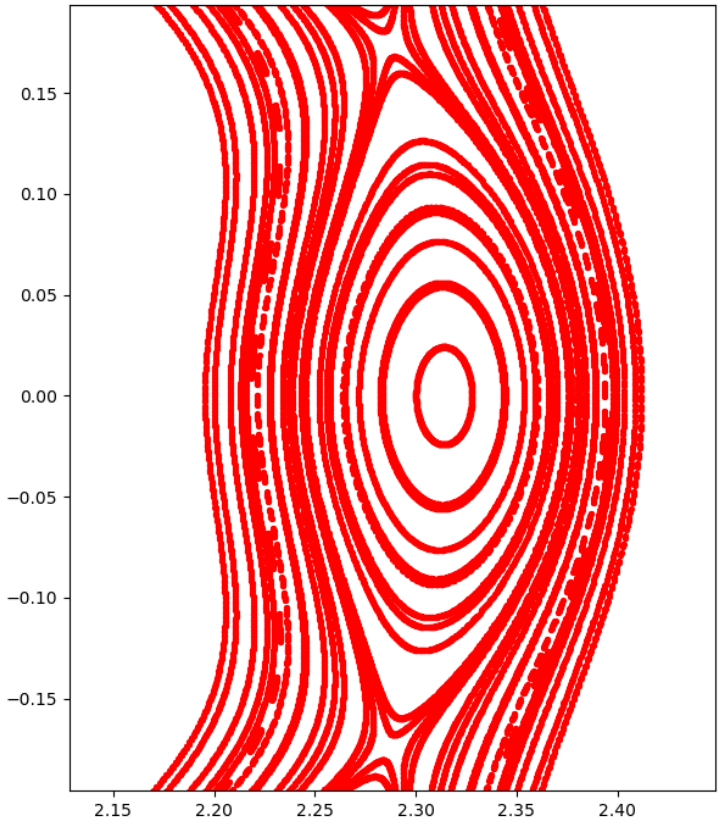
Störmer-Verlet



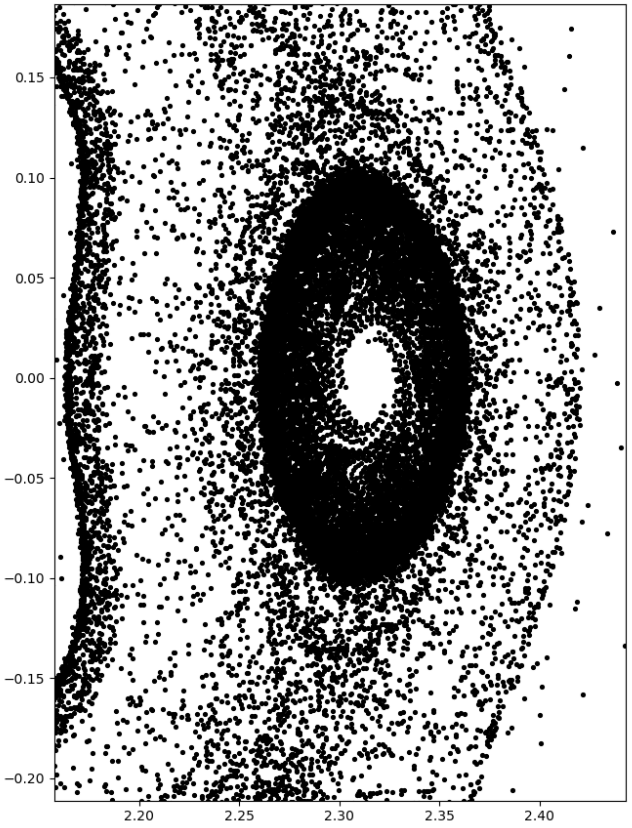
- Runge-Kutta **does not preserve energy** → creates an artificial stochasticity
- The energy preserving Störmer-Verlet scheme is more stable

Time dependent (TD) Hamiltonian

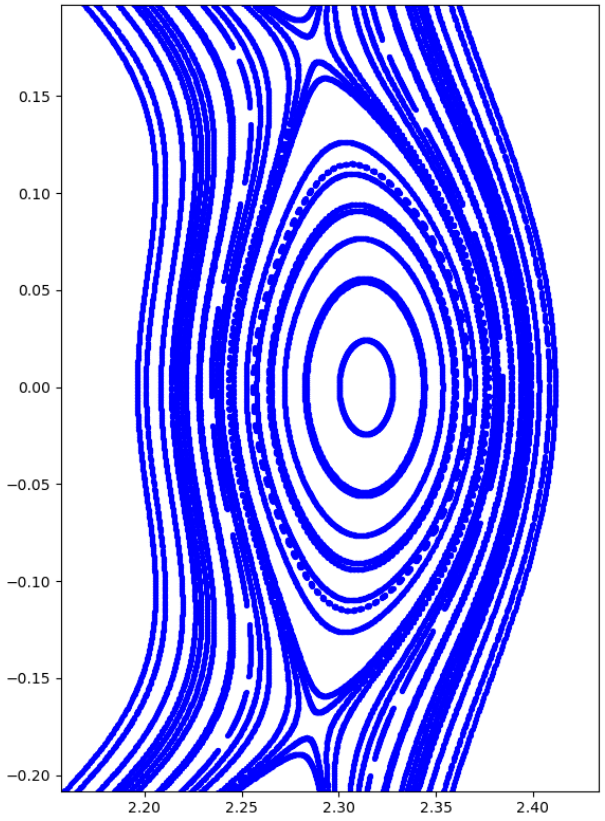
Pendulum



Runge-Kutta

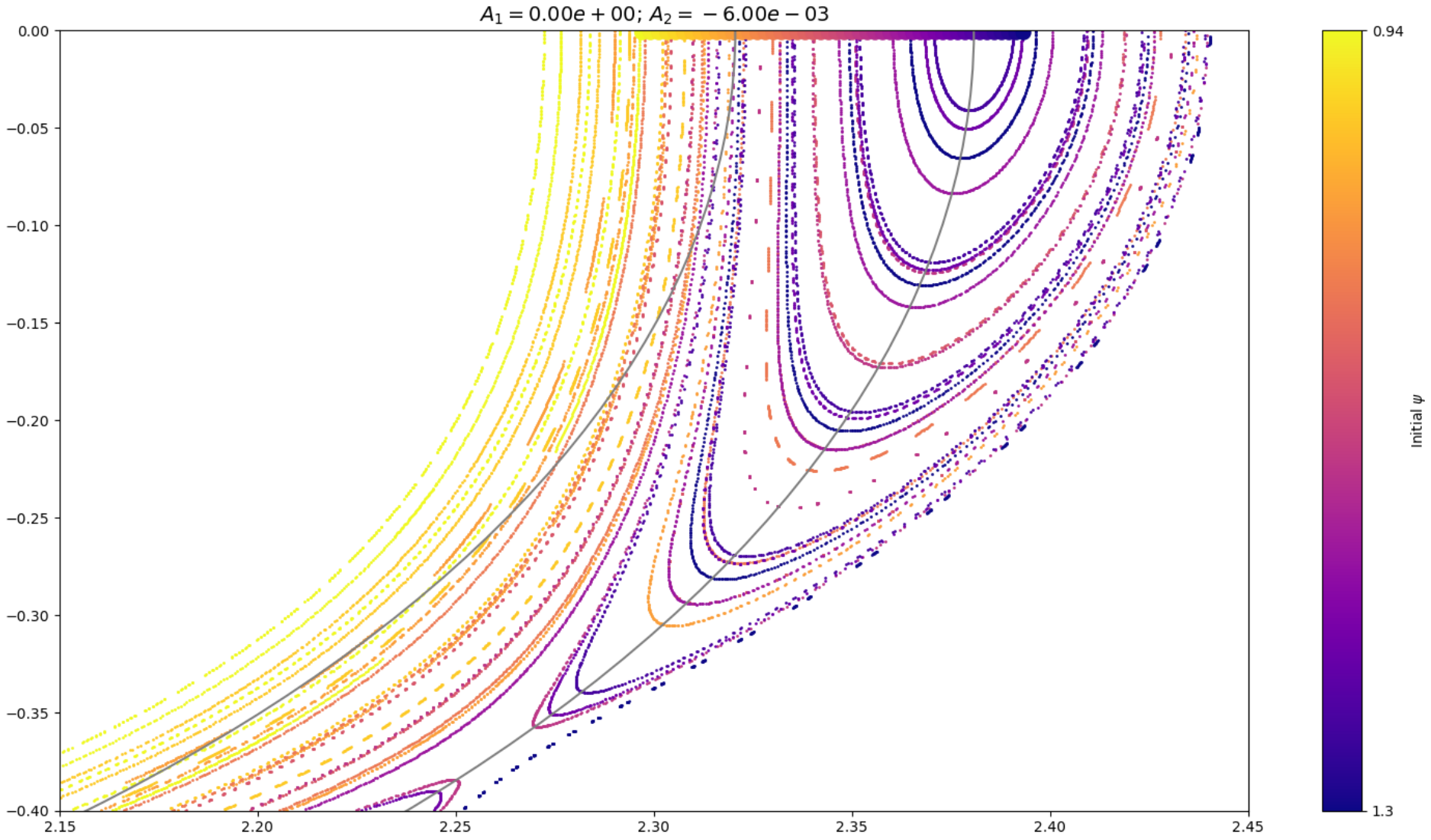


Störmer-Verlet



- The energy preserving schemes should be used for stochasticity studies
- Similar scheme (semi-implicit Euler) is used in [Alkesh Punjabi and Allen H. Boozer Phys. Plasmas, (2020)]

Two islands Störmer-Verlet: 5/5 large + 10/11 small islands



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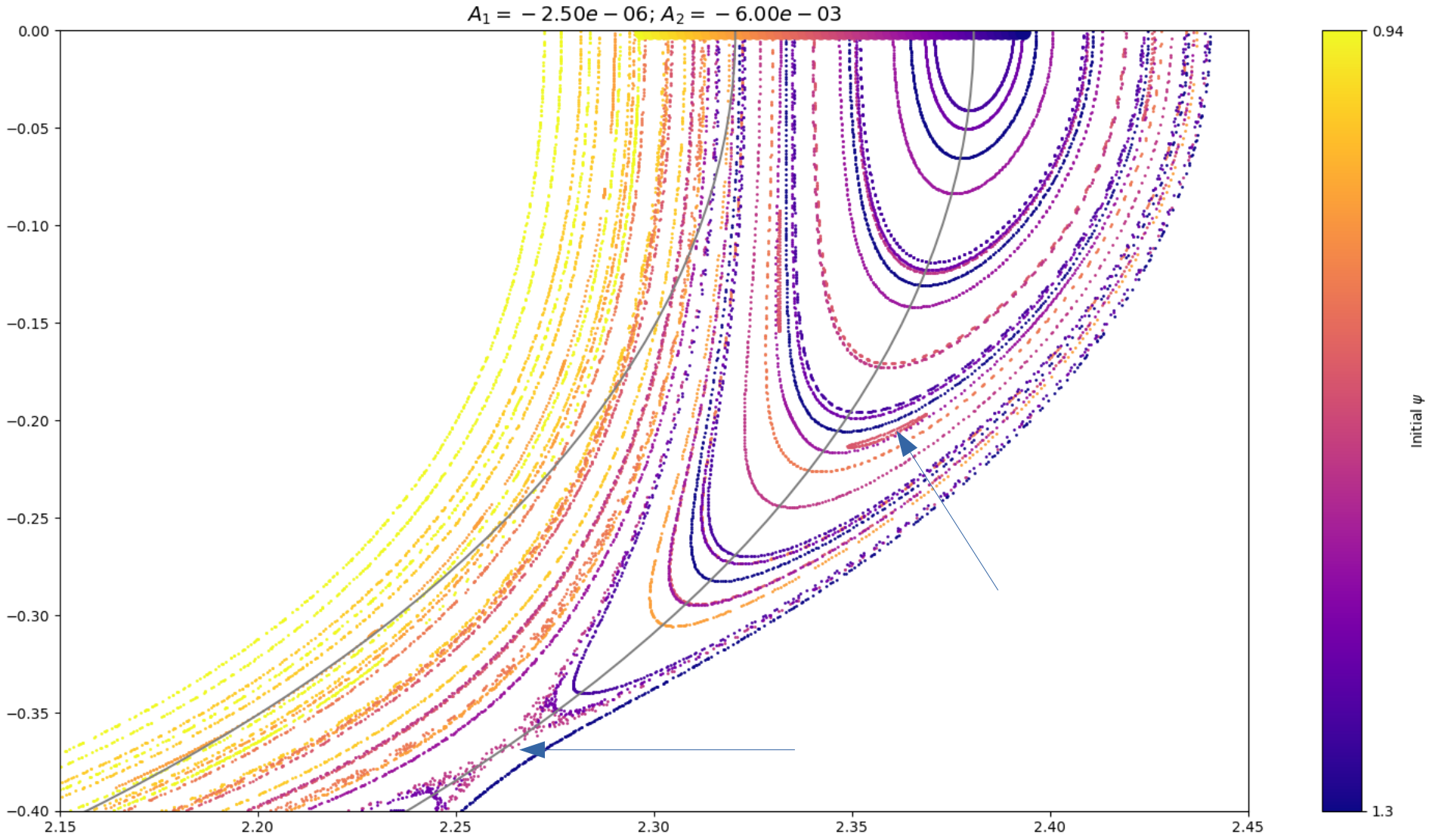

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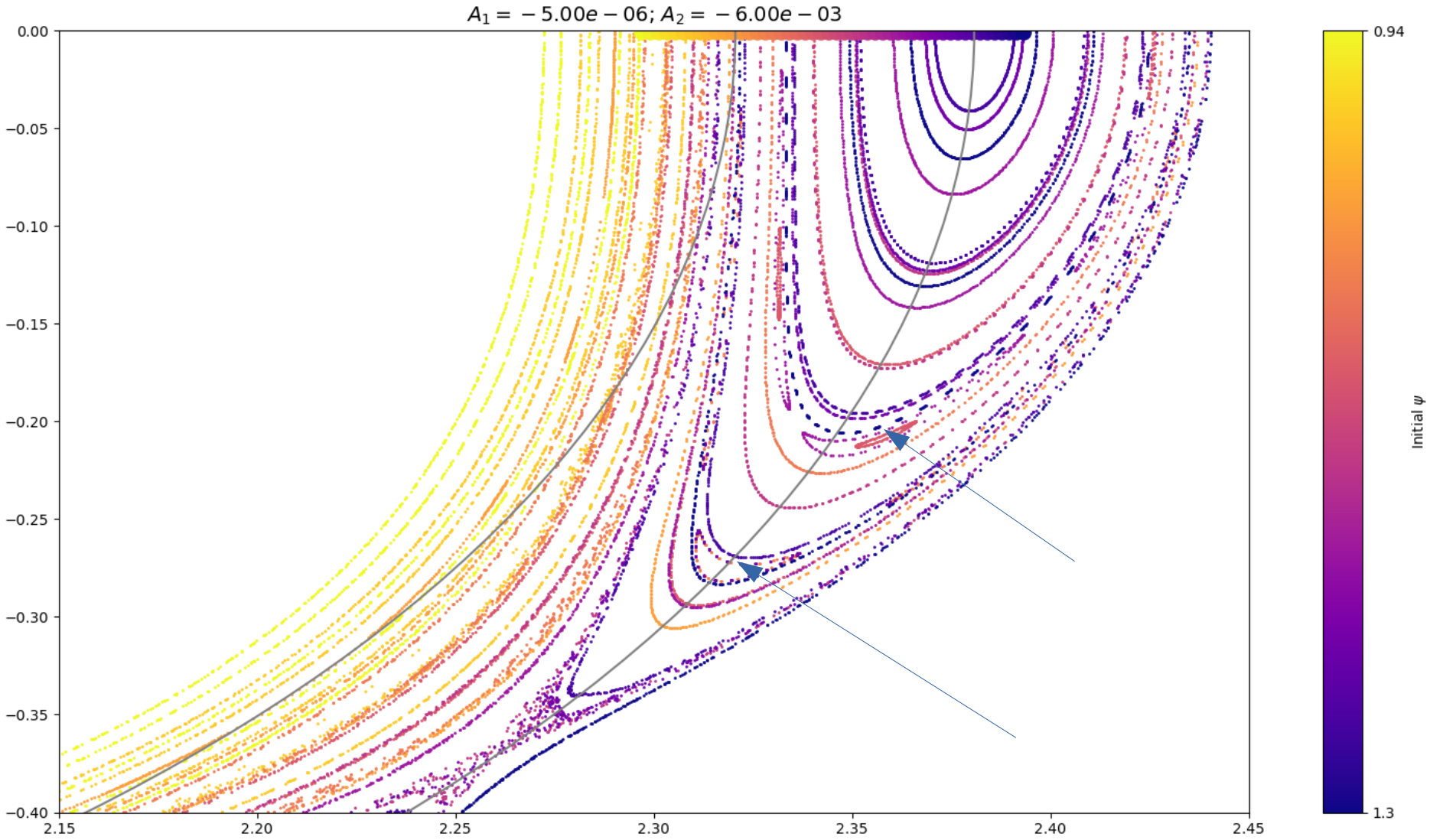

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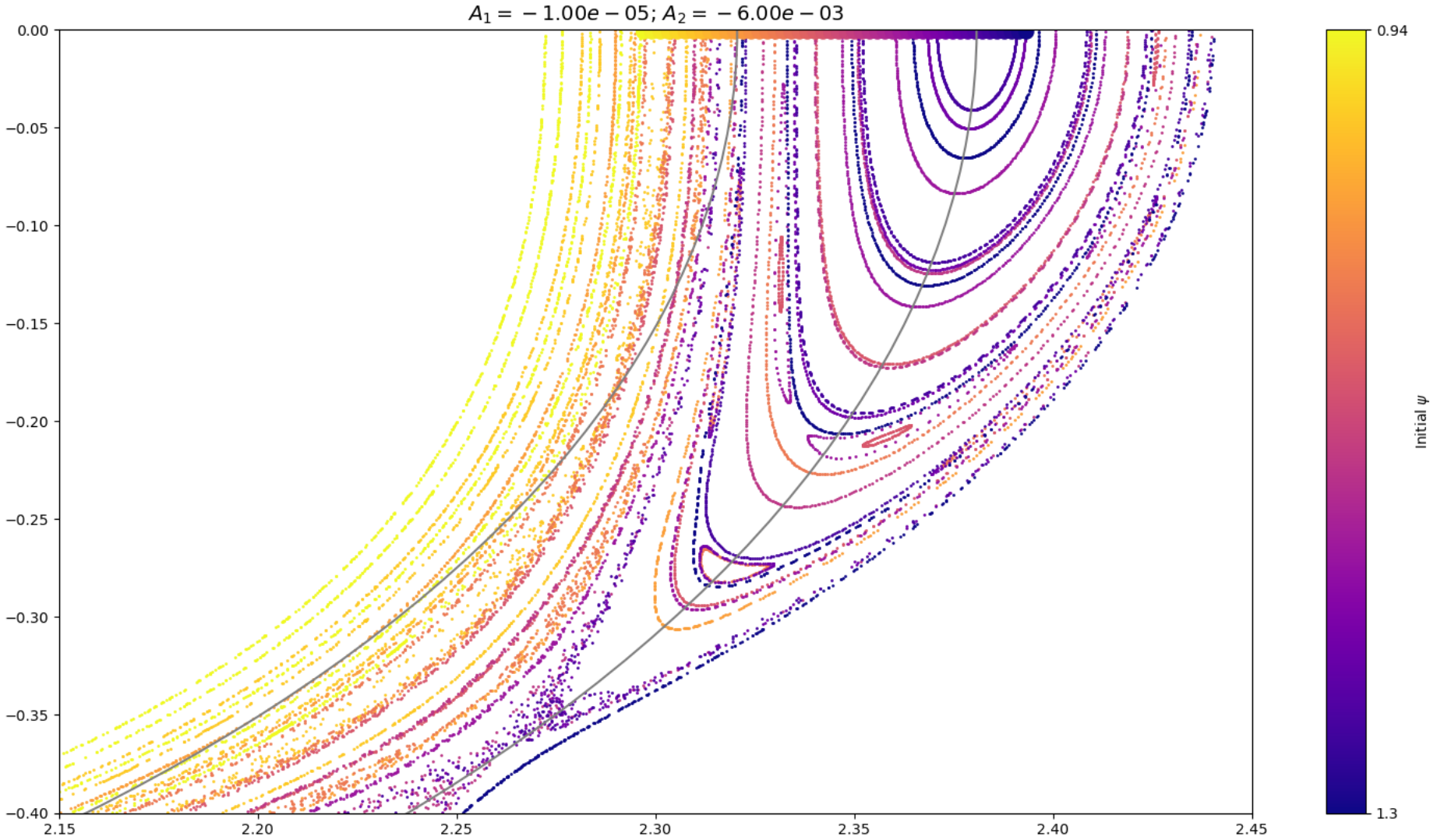

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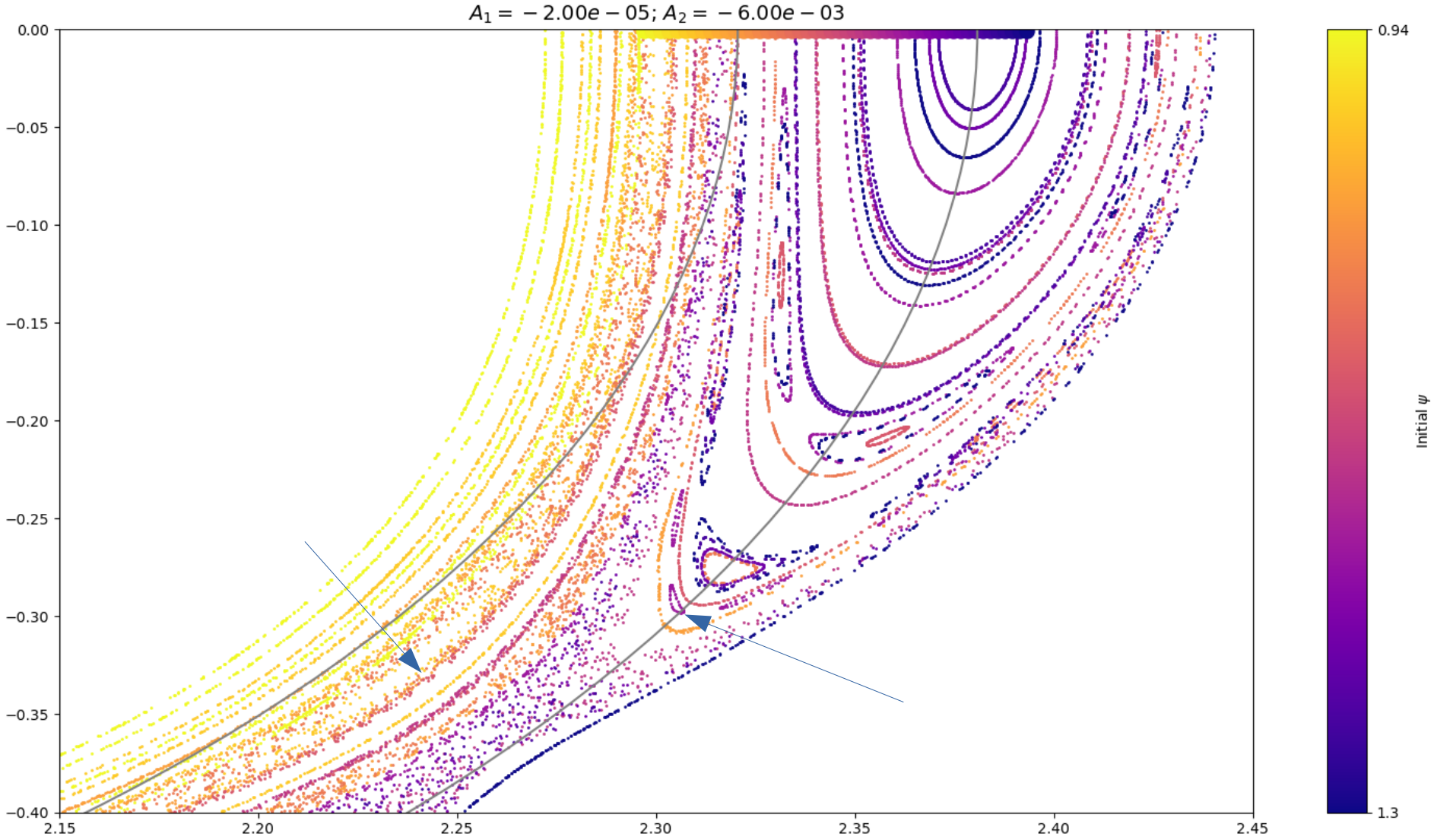

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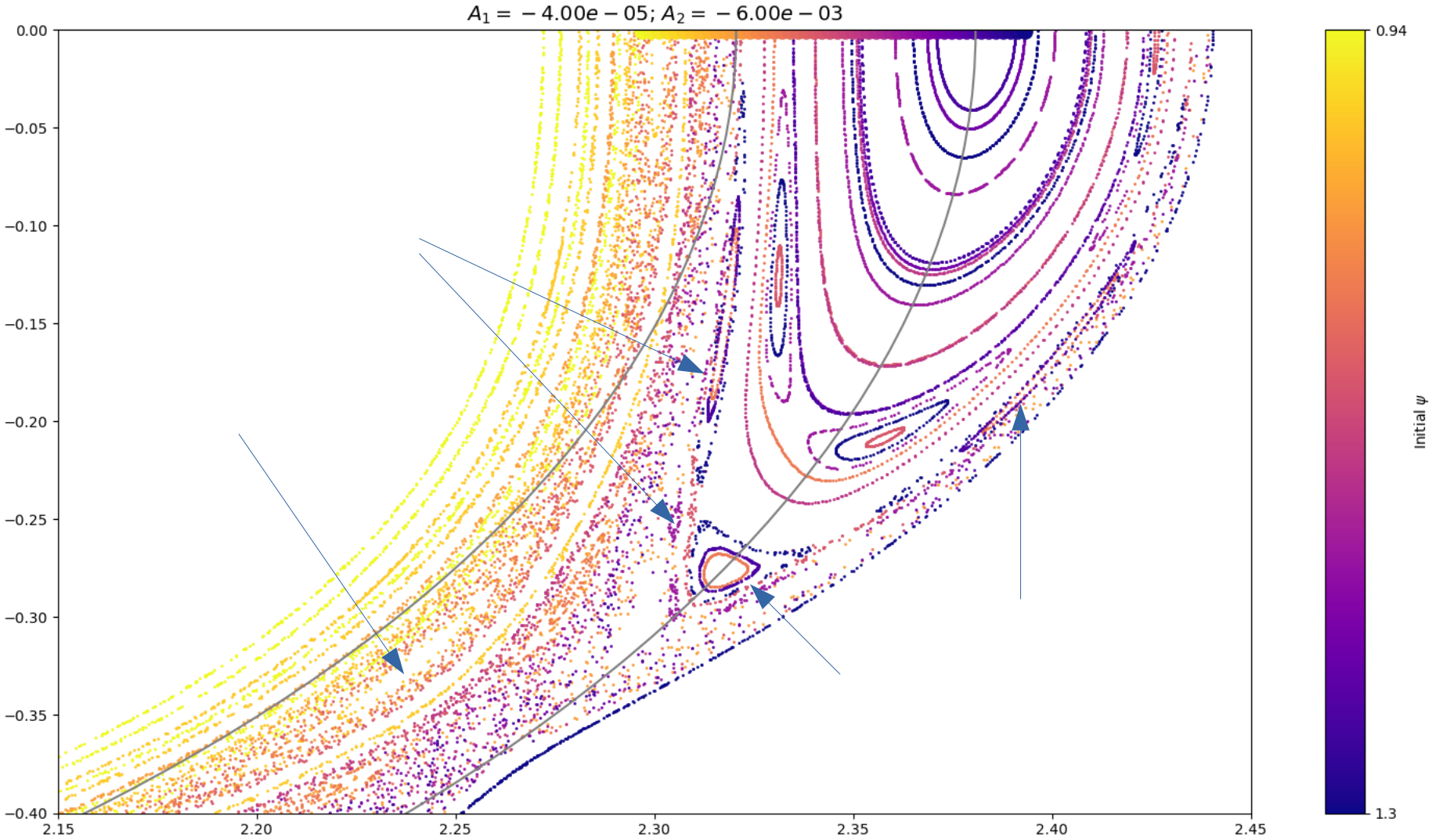

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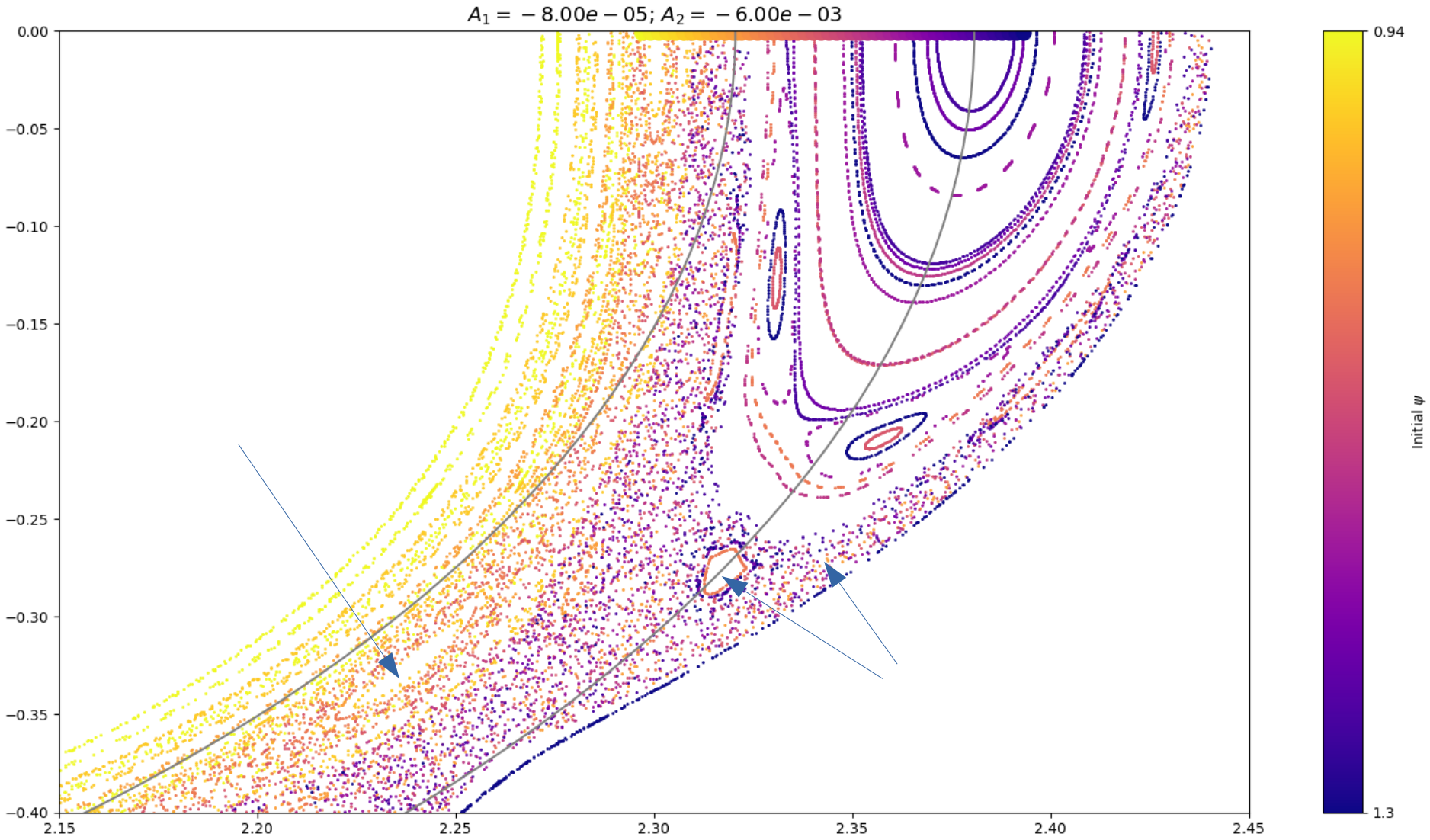
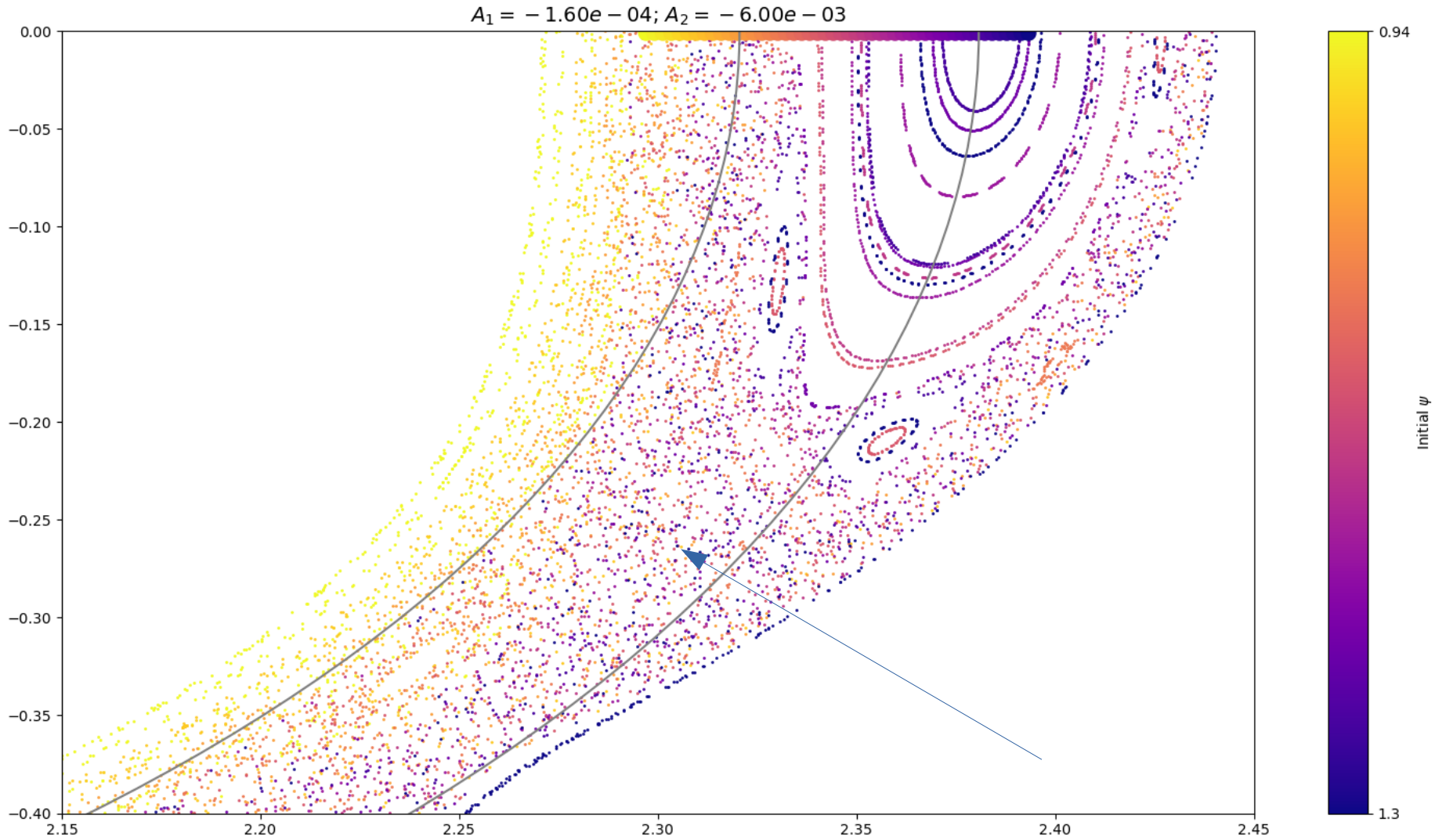


Two islands Störmer-Verlet: 5/5 large + 10/11 small islands



Bob’s method (Core/PFR): 5/5 large, no chaos

https://youtu.be/VtarxtkdGps

Bob’s method (Core/PFR): 5/5 large + 10/11 small islands, with chaos

https://youtu.be/i8nZStd3r5U

Bob’s method (Core/SOL): 5/5 large + 10/11 small islands, with chaos

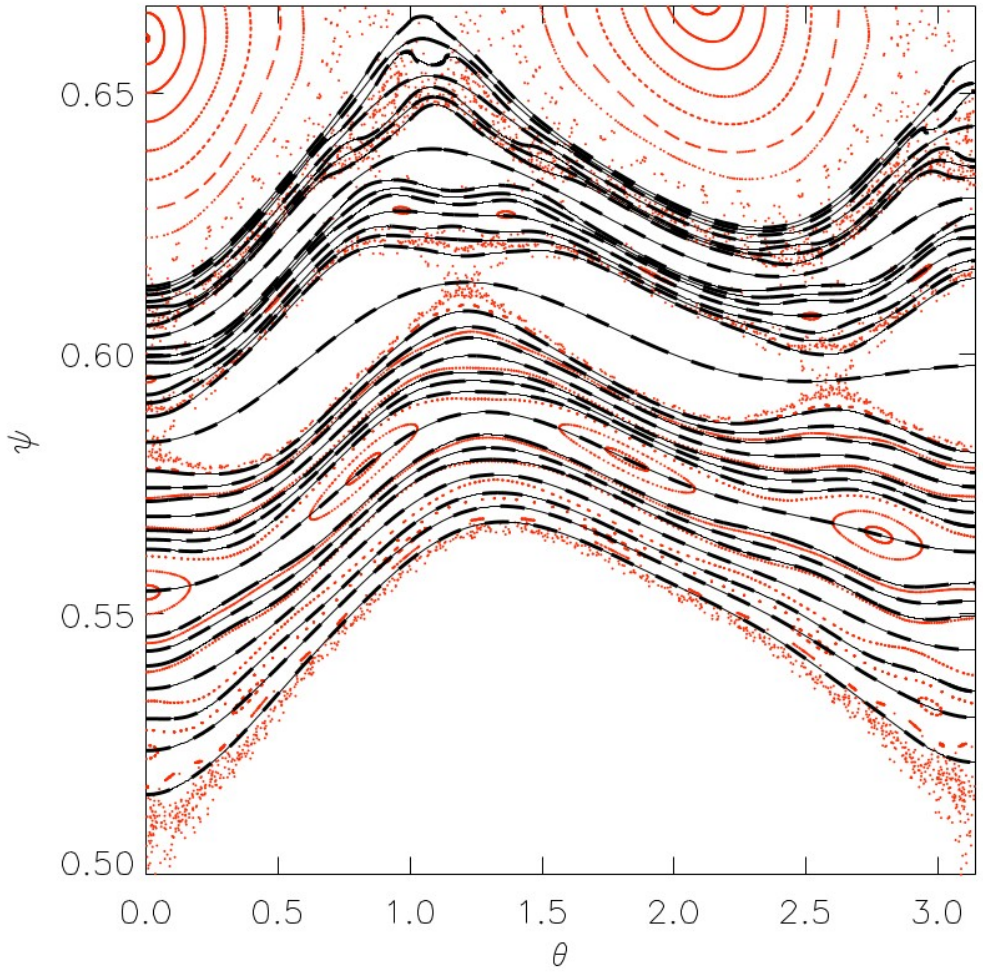
https://youtu.be/N0POPTlWch0

Future work

- Quadratic-flux-minimizing (QFMin) (quantify stochastic transport)

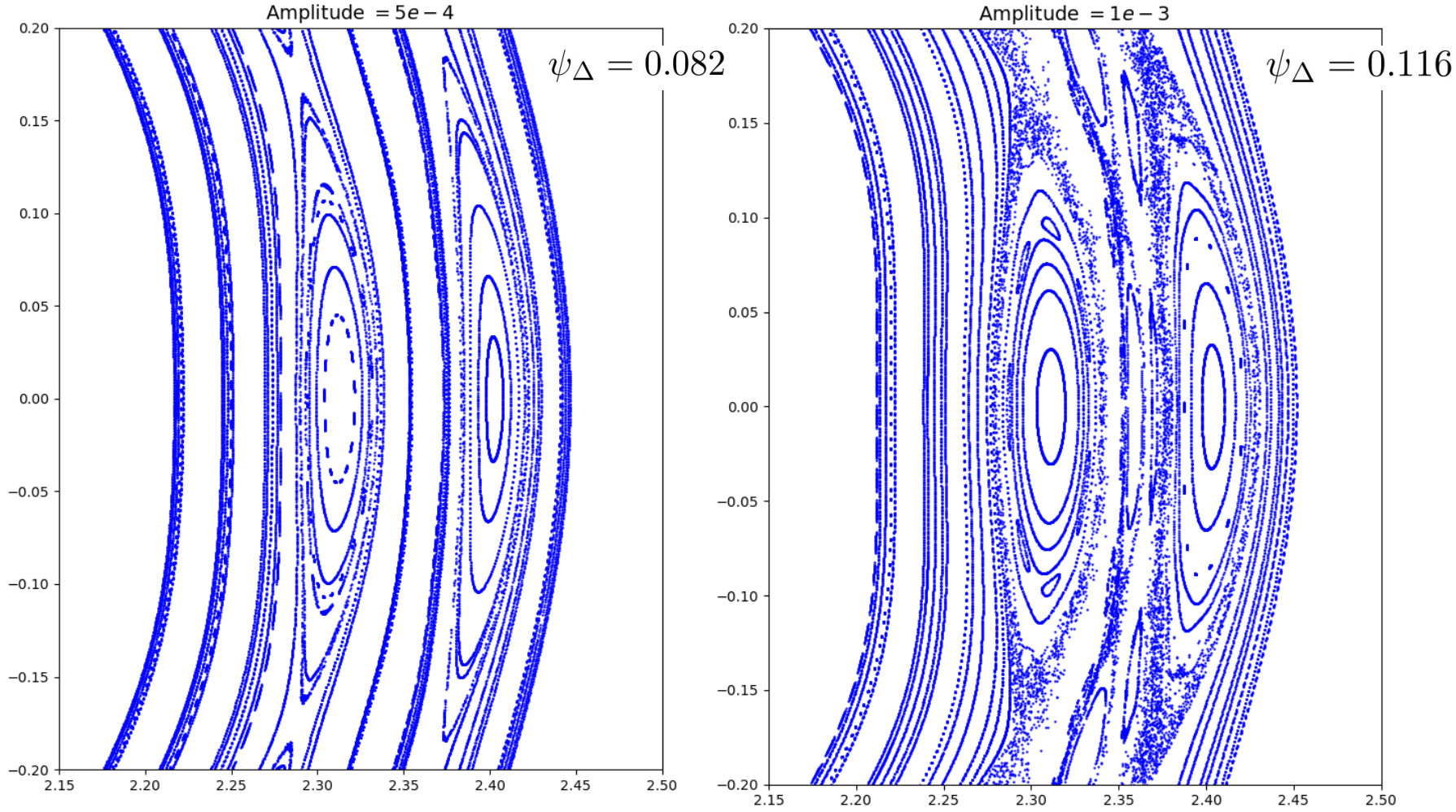
  [S.R. Hudson and R.L. Dewar (2010)]

- EMC3-EIRENE: at what level at stochasticity the SOL flows keeps island structure?



Two islands Störmer-Verlet: Amplitude 5e-4 and 1e-3

$$\psi_\Delta = 2\sqrt{\frac{A}{\iota'}} \qquad \psi_0^{(2)} - \psi_0^{(1)} = 0.33.. \quad A^{overlap} = -2.08e-3 \qquad \begin{matrix} m_1 = 10 & m_2 = 10 \\ n_1 = 10 & n_2 = 11 \end{matrix}$$



Two islands Störmer-Verlet: Amplitude 2e-3 and 4e-3

$$\psi_\Delta = 2\sqrt{\frac{A}{\iota'}} \qquad \psi_0^{(2)} - \psi_0^{(1)} = 0.33.. \quad A^{overlap} = -2.08e-3 \quad \begin{matrix} m_1 = 10 & m_2 = 10 \\ n_1 = 10 & n_2 = 11 \end{matrix}$$