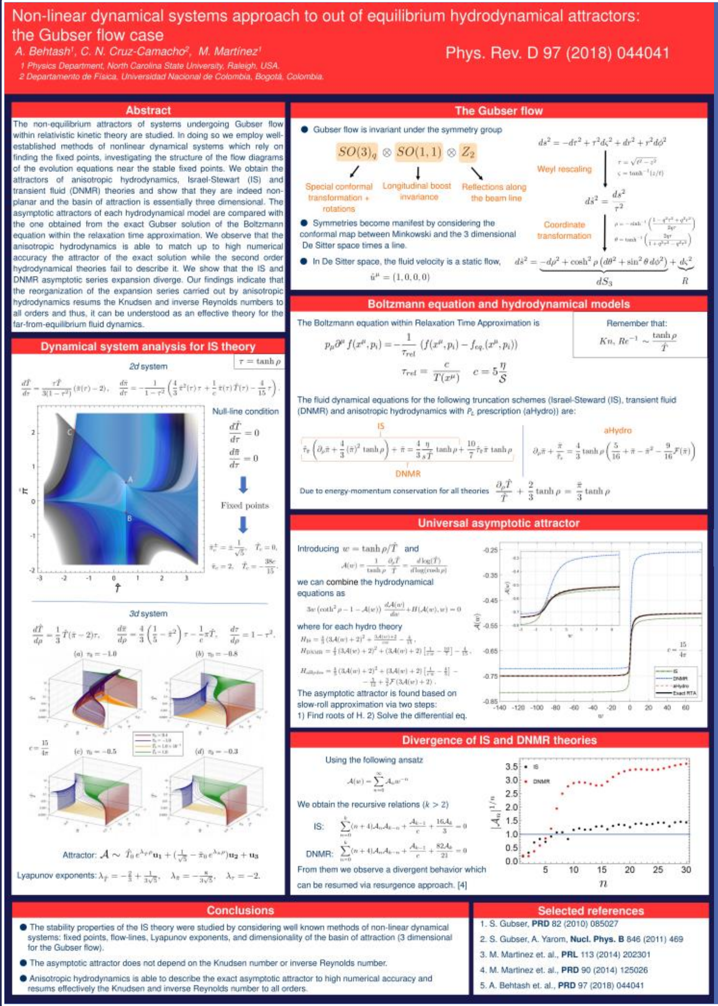


NON-LINEAR DYNAMICAL SYSTEMS APPROACH TO OUT OF EQUILIBRIUM HYDRODYNAMICAL ATTRACTORS: THE GUBSER FLOW CASE

C. Nikolás Cruz Camacho

Universidad Nacional de Colombia

Quark Matter 2018

Collaborators: A. Behtash and M. Martínez

Phys. Rev. D 97 (2018) 044041

Motivation

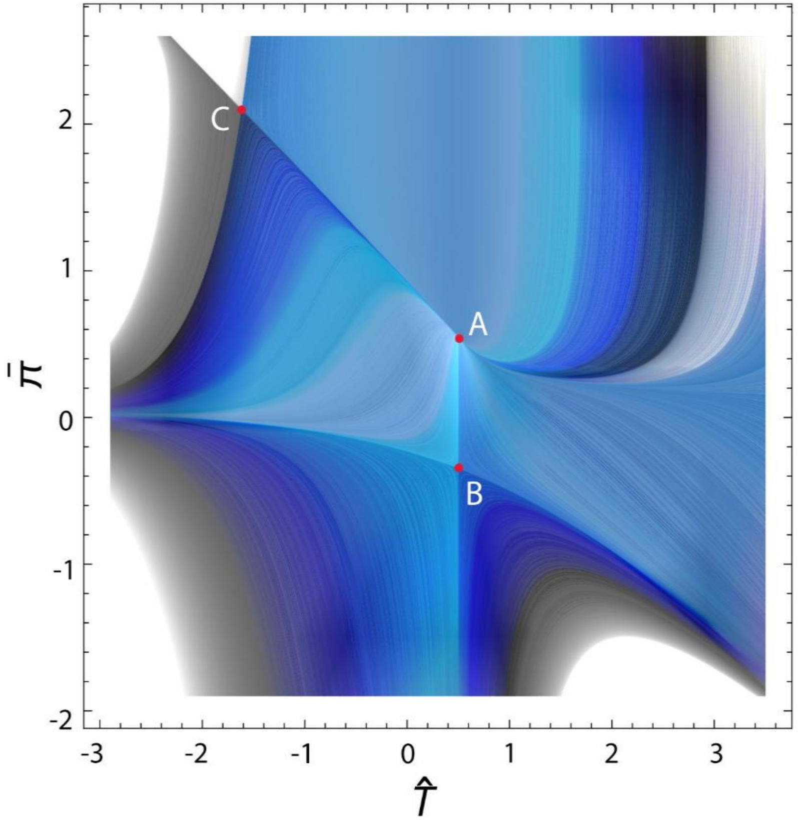
- Hydrodynamics seems to work fairly well in Pb-Pb, pA and p-p collisions. (Weller & Romatschke, Werner et. al., Bozek)

WHY?

- Theoretical models, in strong and weak coupling, indicate that hydrodynamics works in far-from-equilibrium situations.

- <u>We study far-from-equilbrium attractors for the Gubser Flow.</u>

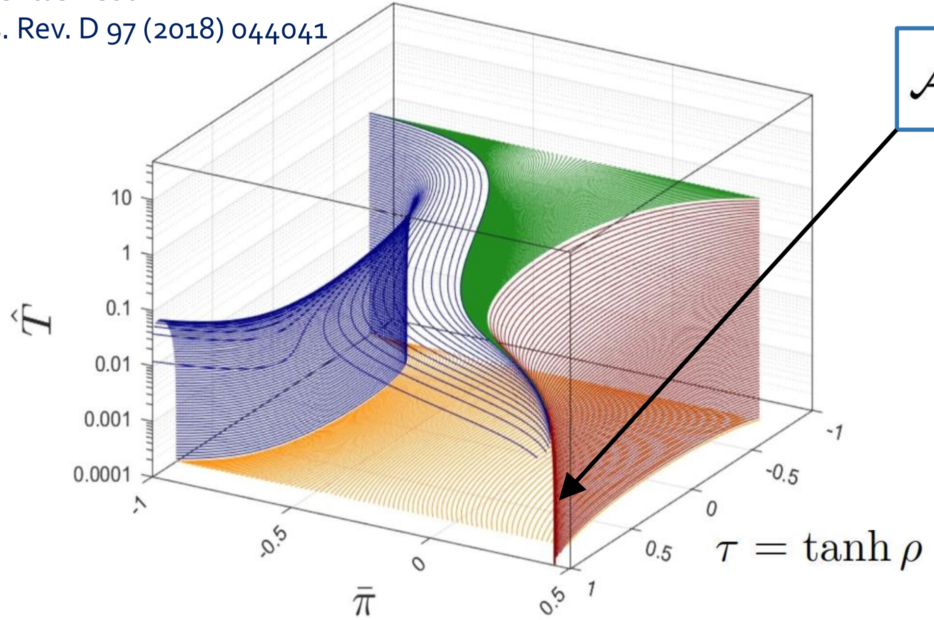
Selected for Kaleidoscope by PRD, February 2018



A. Behtash et al. Phys. Rev. D 97 (2018) 044041

Israel-Stewart case

A. Behtash et al.
Phys. Rev. D 97 (2018) 044041



- Attractor:

$$\mathcal{A} \sim \hat{T}_0\, e^{\lambda_{\hat{T}}\rho}\mathbf{u_1} + \left(\tfrac{1}{\sqrt{5}} - \bar{\pi}_0\, e^{\lambda_{\bar{\pi}}\rho}\right)\mathbf{u_2} + \mathbf{u_3}$$

- Lyapunov exponents:

$$\lambda_{\hat{T}} = -\frac{2}{3} + \frac{1}{3\sqrt{5}}, \quad \lambda_{\bar{\pi}} = -\frac{8}{3\sqrt{5}}$$

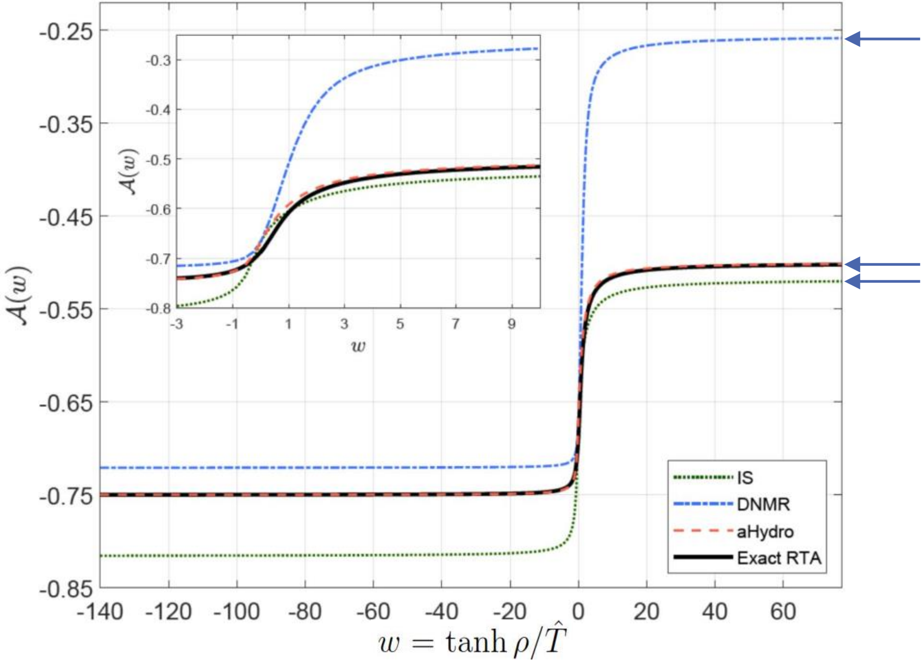
The attractor is asymptotic and it does NOT depend on the Knudsen or Reynolds numbers.

Notice that: $Kn,\, Re^{-1} \sim \dfrac{\tanh\rho}{\hat{T}}$

Similar results have been found by Denicol and Noronha. [1804.04771]

Universal asymptotic attractor

A. Behtash et al. Phys. Rev. D 97 (2018) 044041



$$\mathcal{A}(w) = \frac{d\log\left(\hat{T}\right)}{d\log\left(\cosh\rho\right)}$$

The asymptotic attractor is found based on slow-roll approximation.

Remember that: $Kn,\ Re^{-1} \sim w$

<u>Anisotropic hydrodynamics captures the exact asymptotic attractor with high numerical accuracy and effectively resums the Knudsen and inverse Reynolds number at ALL orders.</u>