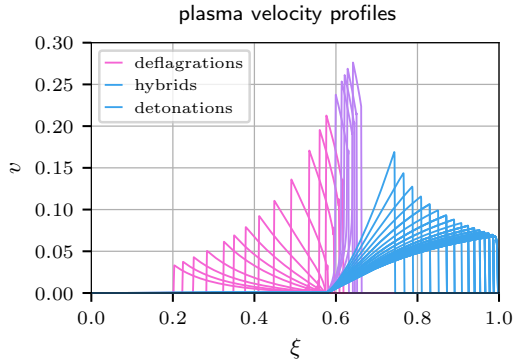
From bubble to hole

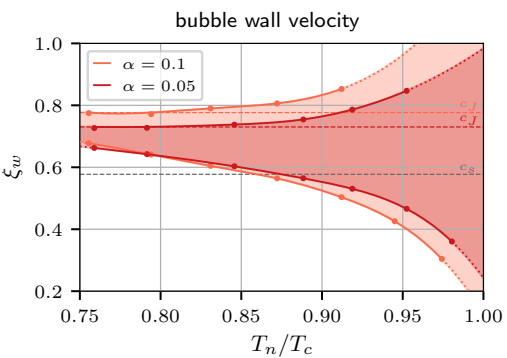
Tomasz Krajewski Nicolaus Copernicus Astronomical Center

Main results from previous year

1. "Hydrodynamical constraints on bubble wall velocity" published in Phys. Rev. D as "Editors' Suggestion".
2. Refactorization of certain parts of the KORAL code to be more robust and user friendly.
3. Extension of legacy KORAL code was developed which allow performing radiative general relativistic MHD simulations in nearly any background spacetime metric.
4. Simulations of accretion onto electrically charged compact objects (described by Reissner-Nordström spacetime metric).

Simulations of evolution of tunneling bubbles in cosmological phase transitions[1]





Our fit:

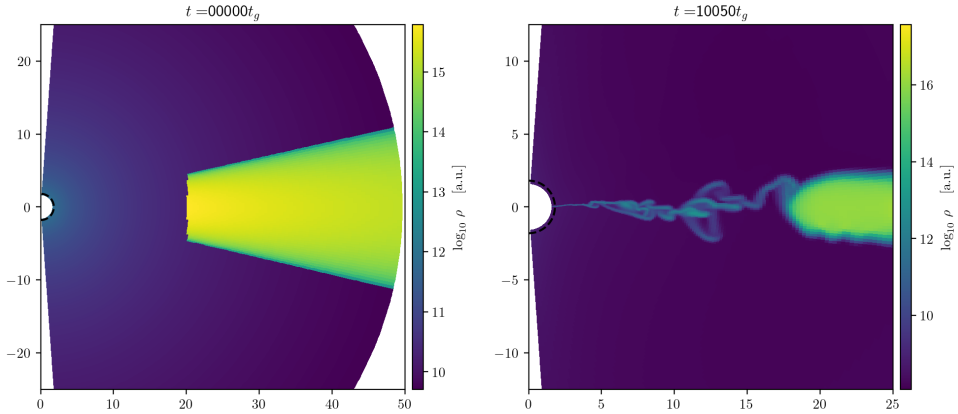
$$\xi_w^{max} = \left(1 - \frac{T_n}{T_c}\right)^k \quad \text{with} \quad k = 0.2768 \pm 0.0055$$

1. Krajewski, T. *et al. Phys. Rev. D* **108,** 103523. arXiv: 2303.18216 [astro-ph.CO] (2023).

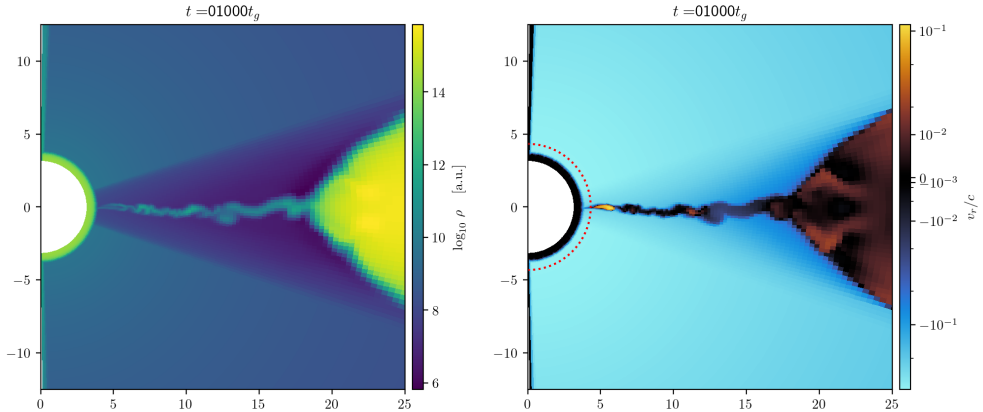
Winding road from KORAL to KORAL+$_{\times}$

- Building mechanism based on standard `autotools` framework.
- Output format and post-processing without auxiliary `sim` files (in progress).
- C++ module for metric dependent code.
- `Mathematica` framework for generating metric implementation code from human readable analytic form.
- Parts describing Kerr metric generalized to Kerr-Newman.
- Tiding up problems specification files.
- `Kconfig` based parameters specification interface.
- `pyKORAL` post-processing scripts repository (by Angelos Karakonstantakis).

Accretion onto $Q = 0.6M$ black hole



Accretion onto naked singularity $Q = 1.8M$



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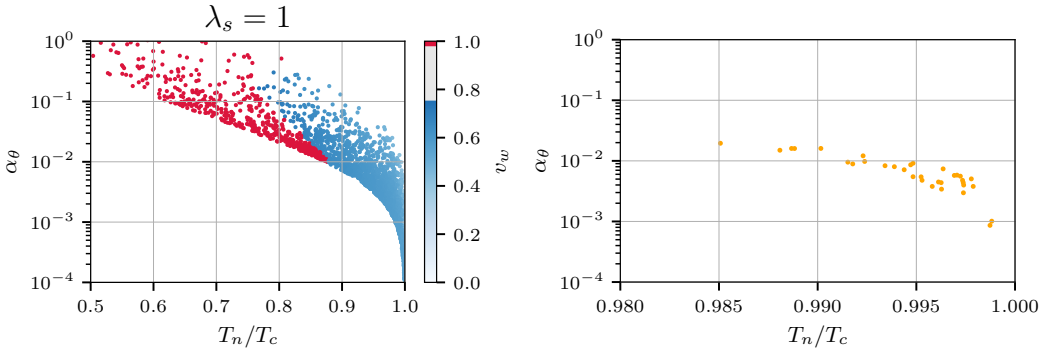
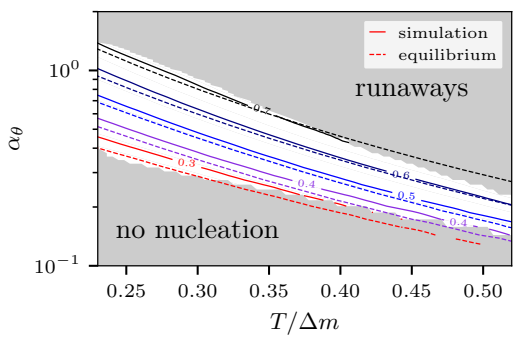
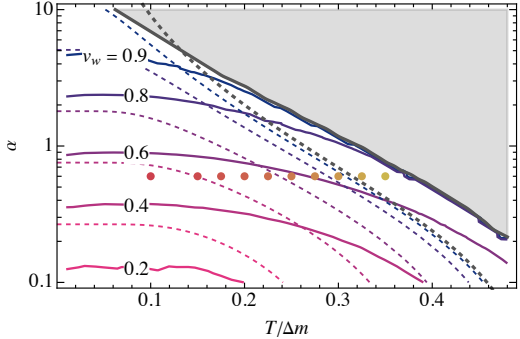
Thank you for your attention.

Bubble-wall velocity in local thermal equilibrium: hydrodynamical simulations vs analytical treatment

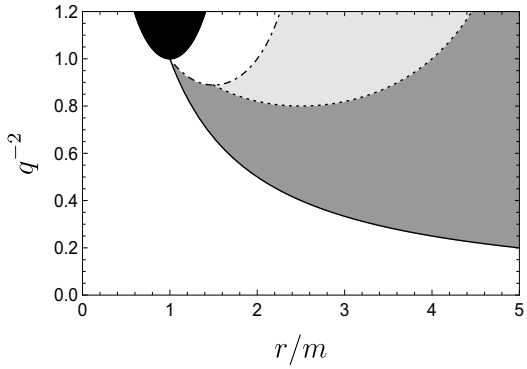


On the dynamics of growing vacuum bubbles





Stability of orbits in Reissner-Nordström spacetime



Stability diagram for Reissner-Nordström spacetime with $q \equiv Q/m$.[2].

2. Vieira, R. S. S. & Kluźniak, W. *Mon. Not. Roy. Astron. Soc.* **523,** 4615–4623. arXiv: 2304.05932 [astro-ph.HE] (2023).

Plans for current year

1. Understand accretion onto spherically symmetric naked singularities.
2. Modernize conversion from so called conserved to primitive variables in KORAL.
3. Finish research on a posteriori error estimation of nonlinear wave equation.
4. Simulate accretion onto axially symmetric naked singularities.
5. Refactorize main parts of KORAL to improve robustness and structure of the code.
6. Implement GPU accelerated versions of main computational procedures of the KORAL++.