Numerical simulations of wind accretion onto compact objects

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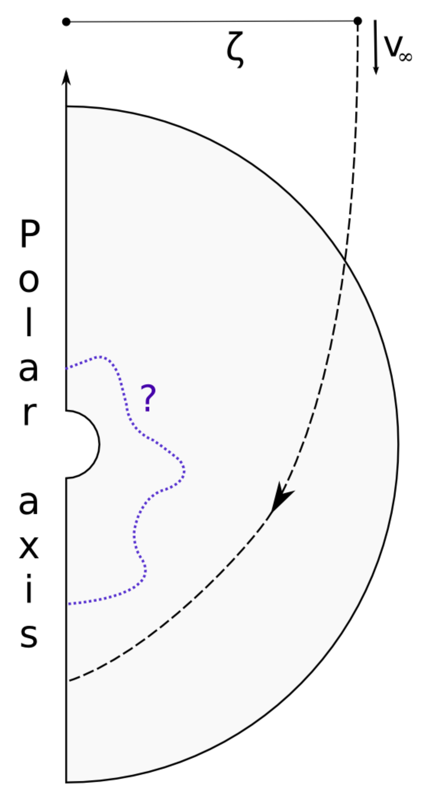
Abstract

We designed hydrodynamical (HD) numerical simulations of gas being accreted onto compact objects to investigate the case of the wind accreting Supergiant X-ray binaries (SgXB). Contrary to the Roche lobe overflow mechanism, predominant in the low mass X-ray binaries, wind accretion does not necessarily give birth to an accretion disc. To identify the conditions favourable to the formation of a wind-capture disc, we first developed a numerical setup based on the Bondi-Hoyle-Lyttleton (BHL) axisymmetric case which confirmed the topology of the sonic surface and enabled us to characterize the structure of the stationary flow, from the large scale of the accretion radius down to the vicinity of the compact accretor. We then extend the analysis to non axisymmetric incoming flows originated from a stellar wind in a Roche potential.

Theoretical overview



$$\zeta < \zeta_{\rm HL} = \frac{2GM}{v_\infty^2}$$

$$\dot{M}_{\rm HL} = \pi \zeta_{\rm HL}^2 \rho_\infty v_\infty$$

$$\frac{\zeta_{\rm HL}}{R_{\rm Schw}} = \left(\frac{c}{v_\infty}\right)^2$$

▶ **Assumptions**

- Supersonic
- Axysymmetric
- Small accretor

▶ **Steady-state flow**

- Accretion radius $\zeta_{\rm HL}$
- Stagnation line / tail [3]
- Anchored sonic surface [6]
- Mass accretion rate [6]

▶ **Physical objects of interest**

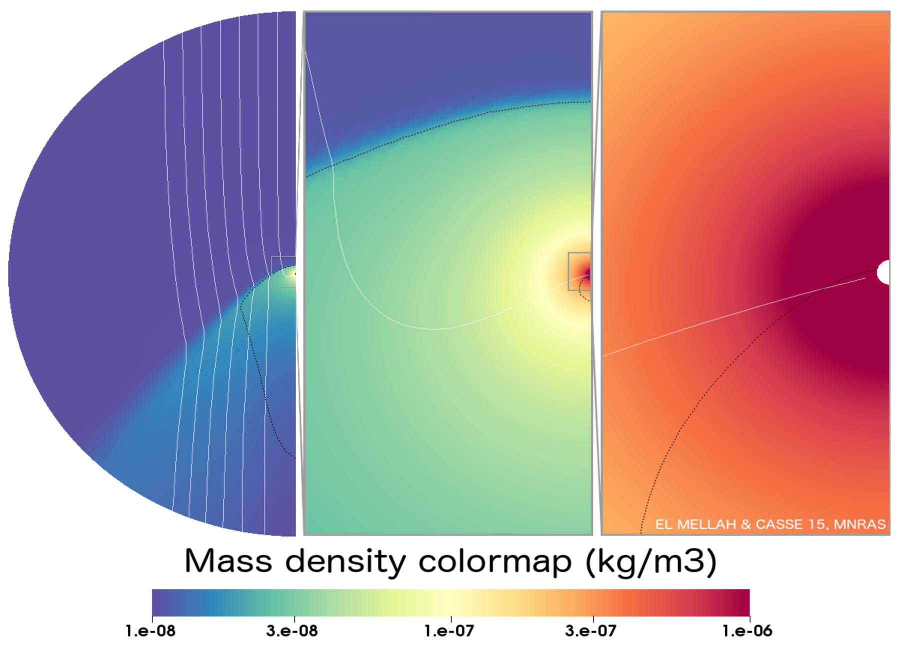
- Supergiant X-ray binaries [10]
- Symbiotic binaries [2]
- Runaway neutron stars

Structure of the flow?
Sonic surface?
Mass accretion rate?
Influence of the accretor size? [9]
Stability of the wake? [5, 1]

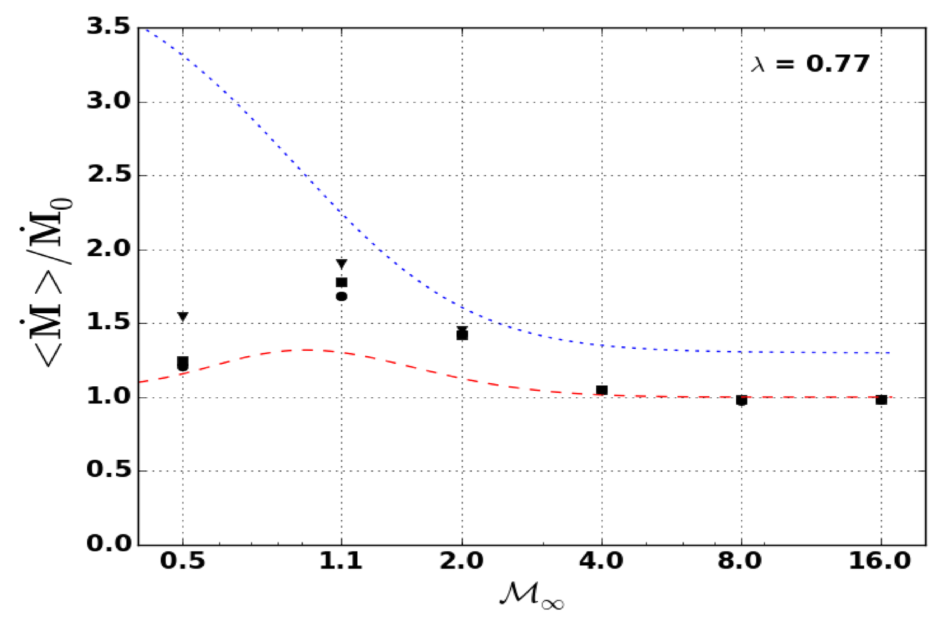
Numerical setup

- Spherical 2.5D grid
- Logarithmically stretched
- OpenMPI parallelized - MPI-AMRVAC [8]
- Spans up to 5 orders of magnitude

▶ **Boundary conditions**
▶ **Free parameters**
▶ **Solvers & diffusivity**



Mass accretion rate & topology of the flow

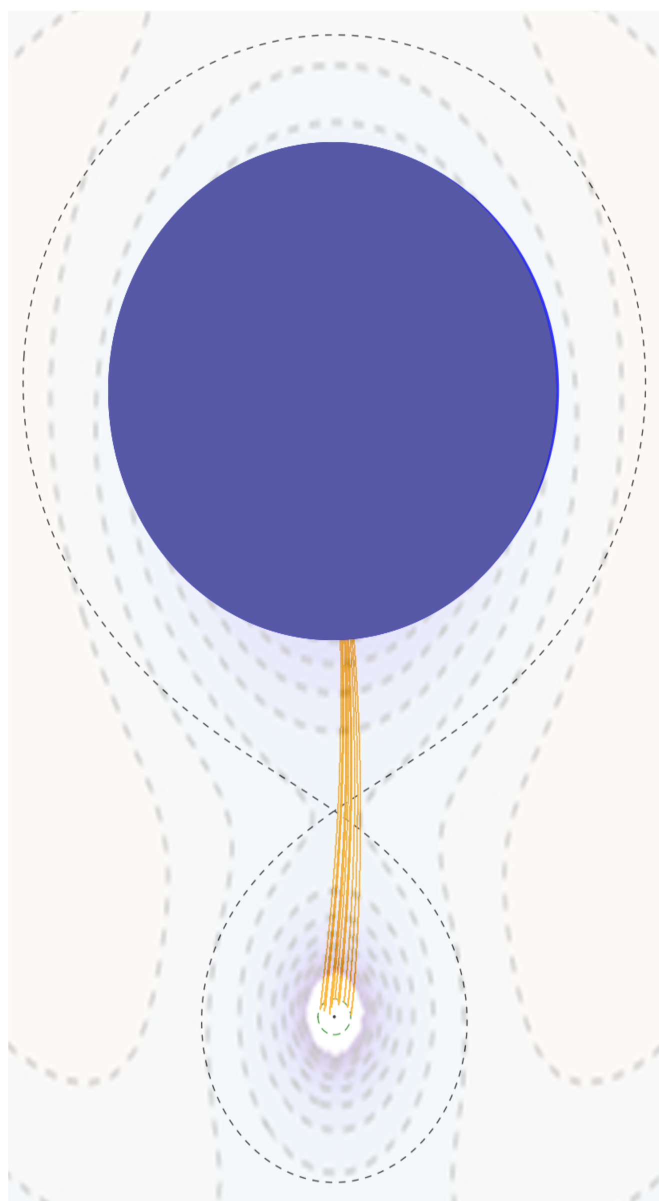


▶ **Structure of the shock**
detached, hollow and stable

▶ **Sonic surface**
anchored for any supersonic wind

▶ **Mass accretion rate**
no longer dependent on accretor size

Wind-capture discs in Supergiant X-ray Binaries?



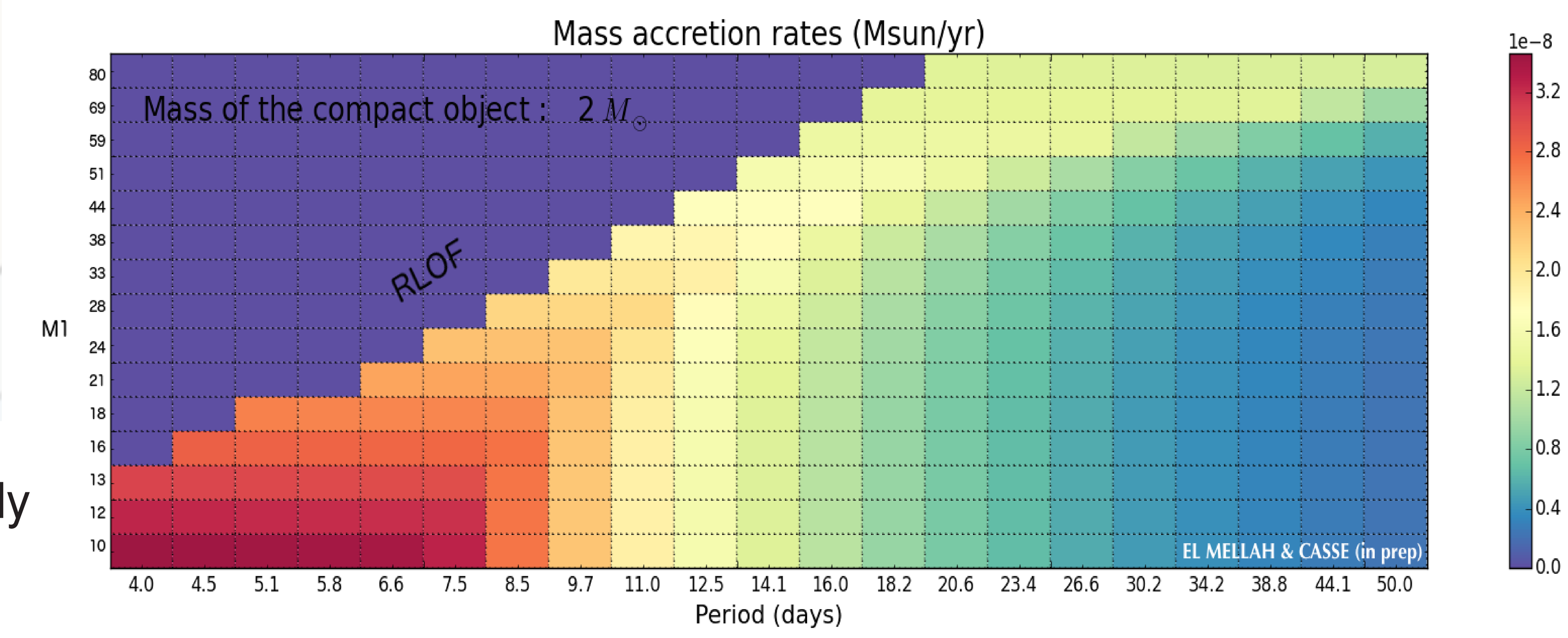
Ballistic streamlines of a steady wind in a Roche potential

▶ **Massive stars winds**

- The beta-law for an isolated star
- Modified in a binary system
- Parameters to explore : mostly filling factor, mass ratio, line absorption acceleration and clumpiness

▶ **Results**

- Upper limits on mass accretion rates
- Angular momentum accretion rate and disc formation
- Physically motivated outer boundary conditions



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Conclusion & perspectives

Thanks to the use of a center stretched grid in a parallelized code, we reached a dynamical range which includes the two physically relevant scales of wind accretion onto compact objects. We disentangle the orbital and the accretion scales in Sgxb where the dense and fast wind is provided by a massive evolved companion. It enables us to identify the favourable large scale configurations to witness the formation of a disc around the accretor, relying on the numerical setup we initially developed for BHL flows.