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Hydrodynamic simulations of type I X-ray bursts winds

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Introduction

- Neutron stars (NSs) in low-mass X-ray binaries accrete hydrogen and helium from a companion star.
- This accreted matter can ignite on the NS surface in a thermonuclear explosion, resulting in a bright X-ray flash known as a type I X-ray burst.
- Such bursts provide crucial insights into the properties of NSs and the accretion and burning processes.

Methods

- We are carrying out the first time-dependent simulations of X-ray burst winds in full general relativity. Previous burst calculations either did not account for general relativity or assumed a time-independent wind.
- Our simulations couple two open-source codes:
  - MESA: a 1-D stellar evolution code.
  - Athena++: a general relativistic radiation-hydrodynamics code.
- MESA is used to model the accretion, thermonuclear burning, and hydrostatic regions of the atmosphere during a burst.
- Athena++ is used to model the radiation-driven wind, which ejects the outer layers of the accreted atmosphere.
- We investigate a range of burst parameters including accretion composition, accretion rate, size of reaction network, convection model, and NS radius and mass.

Results

- The energy released from the unstable thermonuclear fusion of helium heats the atmosphere to > 10^9 K.
- The luminosity becomes super-Eddington, launching a wind that drives the photosphere to >100 km above the NS surface.
- We follow the time-dependent burning, the convective and radiative heating of the atmosphere, and the launch and evolution of the optically thin radiation driven wind as the photosphere expands.
- We find that the wind can eject ashes of burning. This leaves an imprint on burst spectra that can be detectable with X-ray telescopes.
- The plots here illustrate properties of the wind profiles.

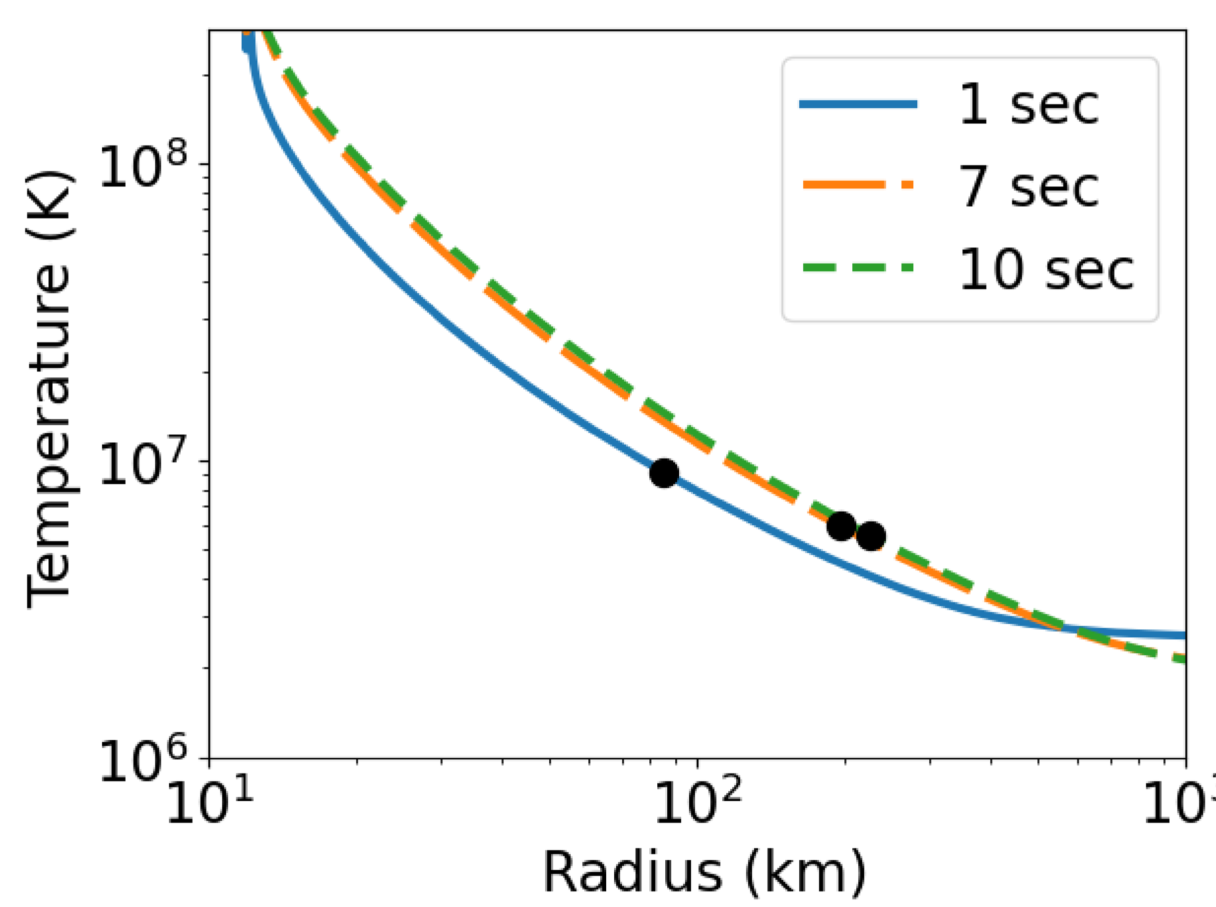

Figure 1: Temperature profile of the wind at different times using MESA. The circles indicate the location of the photosphere.

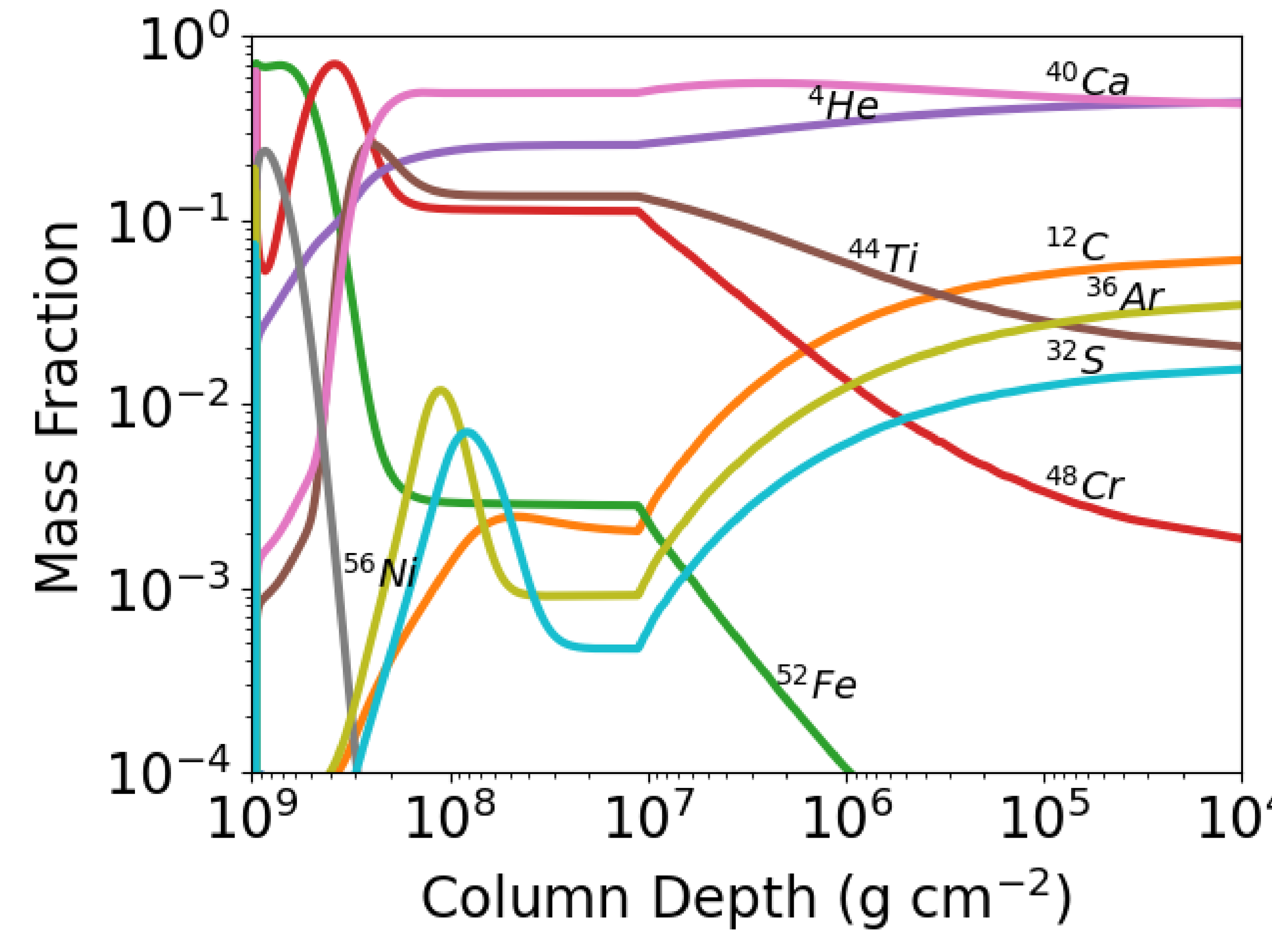

Figure 2: Composition of the wind as function of column depth at t=10 seconds when it is near steady state. Ashes of burning (e.g., ^{40}Ca) are ejected by the wind.

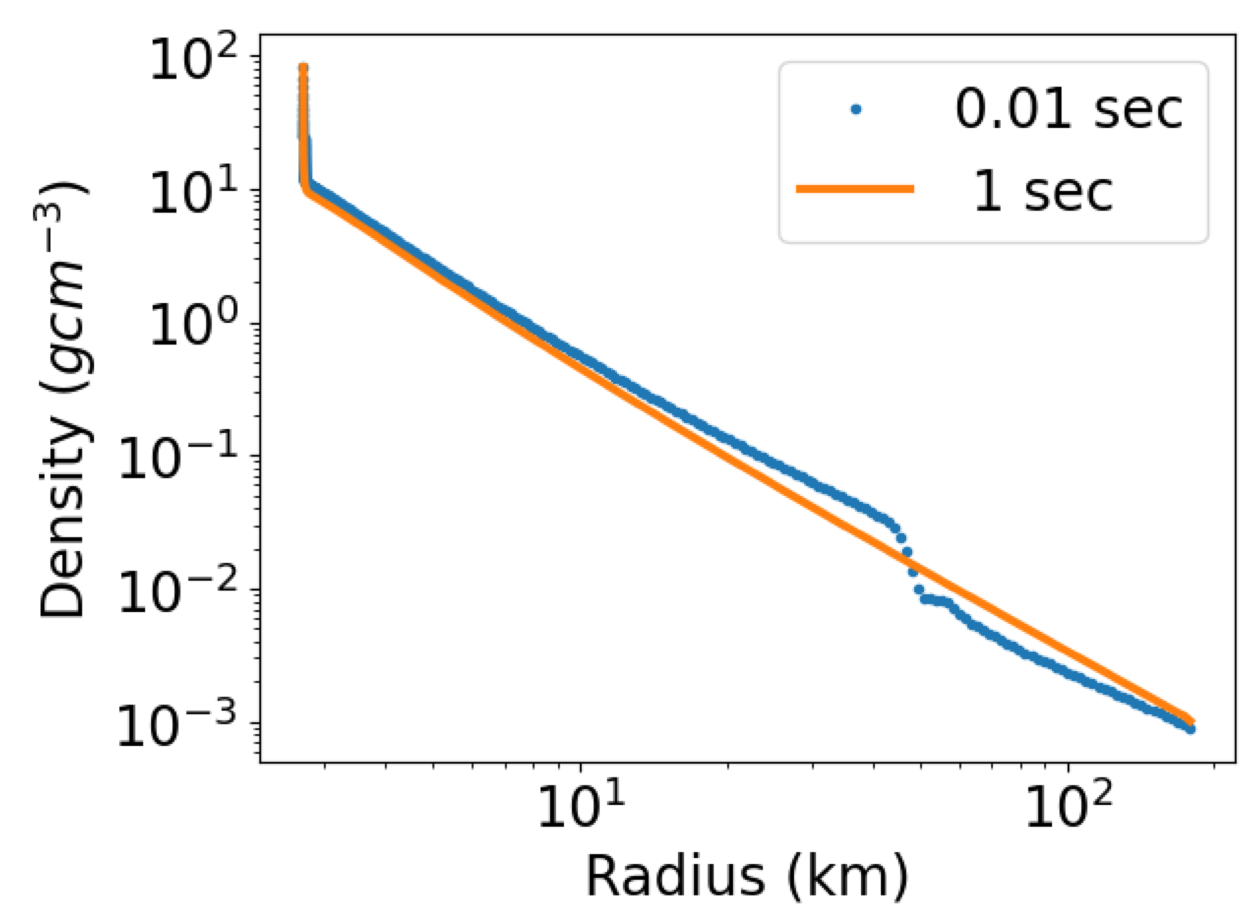

Figure 3: Density profile of the wind structure at different times using Athena++.

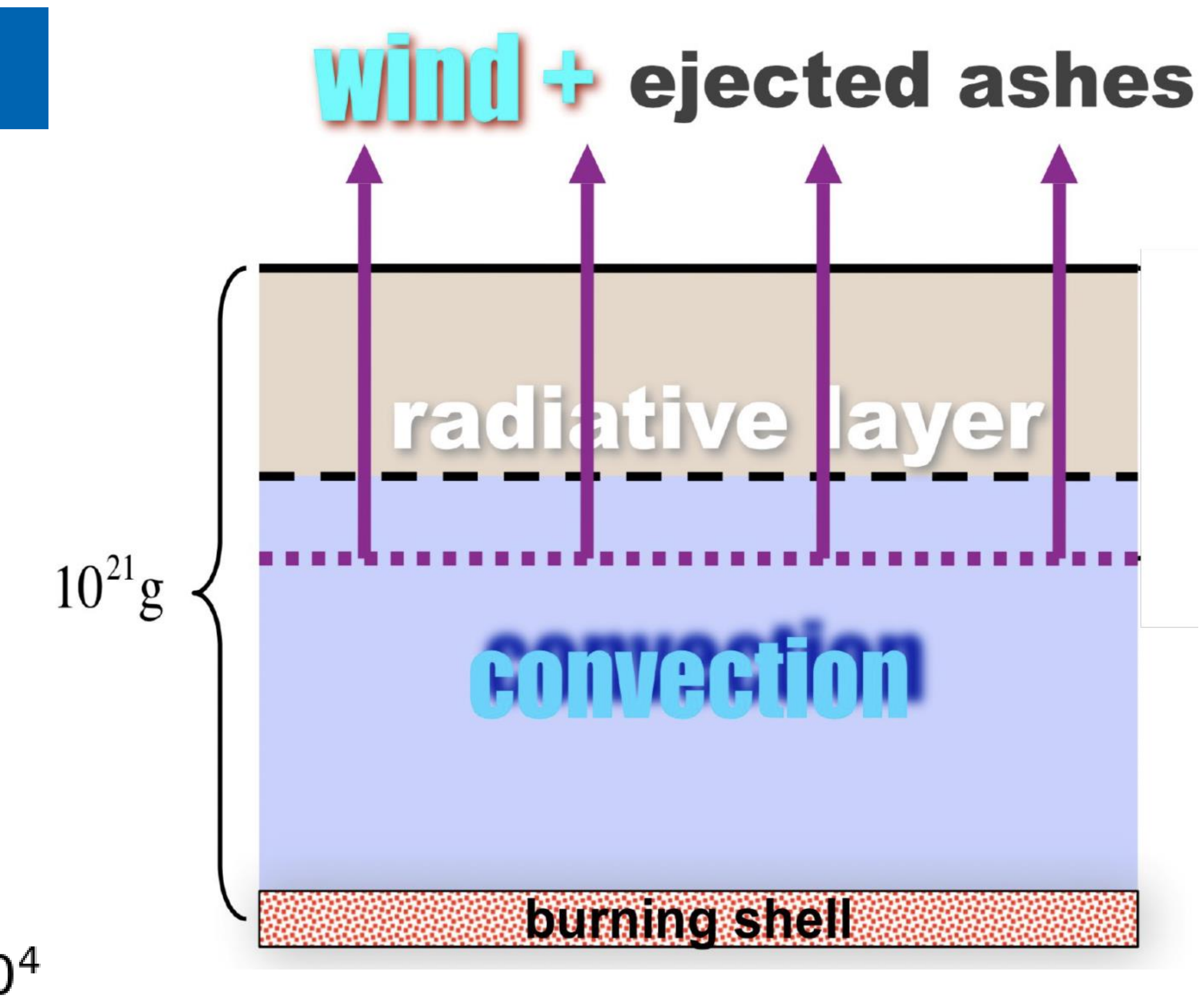

Figure 4: Illustration of a bursting atmosphere.

Conclusions

- By coupling MESA and Athena++, we carry out the first time-dependent simulations of X-ray burst winds in full general relativity.
- The wind ejects ashes of nuclear burning, including heavy elements that can leave an imprint on burst spectra.
- Comparing our models with observed bursts will provide new insights into burst and NS physics.

References

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