NUMERICAL SIMULATIONS OF JET-INTERSTELLAR MEDIUM INTERACTIONS

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ABSTRACT: ***The physical system formed by a very young star and its accretion disc is a scaled version of the compact object+accretion disc scenario observed in AGNs. For young stars with accretion discs (e.g. classical T Tauri stars), dense gas coming from the disc is collimated into a jet as explained in the context of the theory of magneto-centrifugal launching. We aim at studying the jet propagation and its interaction with the ambient medium. In particular, we are interested in determining the properties of the jet material in terms of density and temperature. Our objective is to understand the morphology of the jet at different wavelengths and the appearance of distinct structures such as blobs and Herbig-Haro objects and their relation with initial conditions. We performed a set of numerical model simulations of supersonic jet ramming into uniform ambient medium using the PLUTO code.***

INTRODUCTION

We study the particular case of the jet HH 248, situated at the base of the Horsehead Nebula, in a well-known young star-forming region (see Fig. 1). This jet seems to impact against a much denser molecular region, causing X-ray emission from the shock by hydrodynamical processes.

We propose a scenario in which a supersonic jet that is denser than the ambient reaches a denser molecular cloud becoming lighter than the surrounding medium. We study the jet-ambient interaction in terms of density and temperature, specially when the jet reaches the denser region (see Fig. 2).

We perform a set of HD numerical simulations of a jet propagating in a uniform medium that reaches a denser wall. The calculations were performed using PLUTO (Mignone et al. 2007), a modular, Godunov-type code for astrophysical plasmas (http://plutocode.ph.unito.it/).

Fig. 1.— Deep IRAC/Spitzer observation in the 3.6 micron band of NGC 2023 and its proximities. HH 248 is situated to the South-East of the cTTS V615 Ori, at the base of the Horsehead Nebula and to the South of the NGC 2023 nebula.

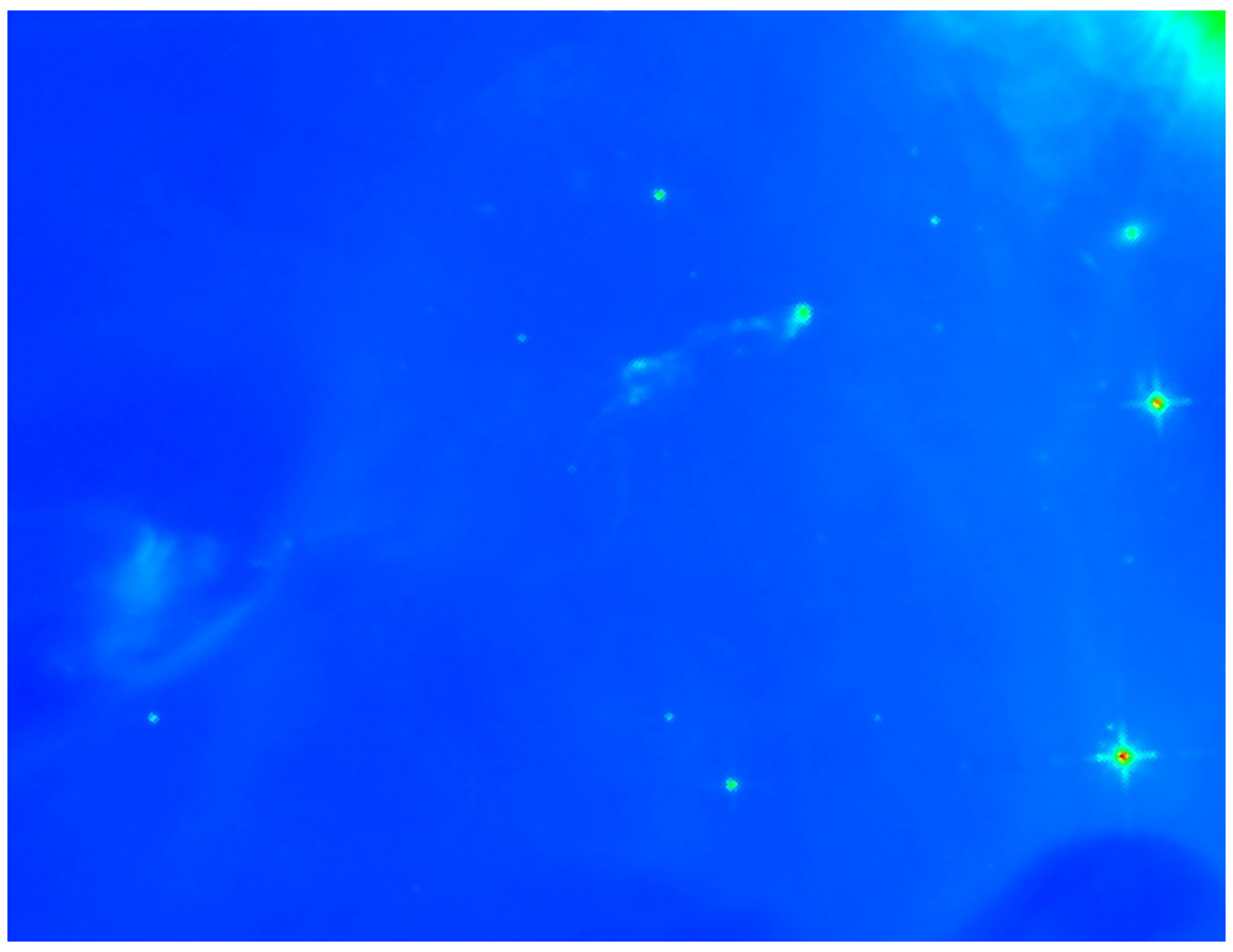

Fig. 2.— High-contrast HST/WFC3 H band image centered at HH 248. V615 Ori is the saturated source at the upper right corner.

THE MODEL

We model the propagation of a continuously driven protostellar jet through an isothermal and homogeneous ambient medium, that reaches a denser wall at the end of domain (see Fig. 3, first panel). We use a smooth function in the limit between the two zones of the domain. We assume that the fluid is fully ionized and that it can be regarded as a perfect gas with a ratio of specific heats γ= 5/3 and that magnetic fields are negligible (HD equations).

The jet evolution is described by the fluid equations for mass, momentum and energy conservation, taking into account the effects of radiative losses and thermal conduction.
We use the HD module of PLUTO code. Multiwavelength analysis was performed to fit the initial conditions of the simulation, based on measurements of the density in the surroundings of the Horsehead Nebula, where HH 248 is located.

NUMERICAL SETUP

We adopt a 2D cylindrical (r, z) coordinate system, with the jet axis coincident with the z-axis (see Fig. 3). The computational grid size is 1500 AU in the r direction and 15000 AU in the z direction, achieving a maximum spatial resolution of 2 AU (in both the r and z directions).

The jet density is ρ_j = 1.05e-21 gr/cm^3, while the ambient and wall densities are ρ_a/ρ_j = 0.1 and ρ_w/ρ_j = 10 respectively. The higher density region (wall) is included at 10000 AU from the base of the domain. We assume an initial temperature of 10^4 K for the jet, 10^5 K for the ambient and 10^3 K for the wall. These values are imposed only to maintain the pressure equilibrium and have no physical meaning. The Mach number, M = v_j/c_a = 30, where c_a is the ambient sound speed.

Reflective boundary conditions are imposed along the jet axis, inflow boundary conditions are imposed at z = 0 and r ≤ rj, and outflow boundary conditions (zero gradient) are assumed elsewhere.

SOME RESULTS

We follow the jet/ambient medium interaction for 32 years aproximately. The evolution of the jet's density and temperature are shown below (see Fig. 3). Each figure corresponds to a time delay of eight years. The jet enters the molecular cloud in the second panel creating a cocoon, experiencing a temperature increase.

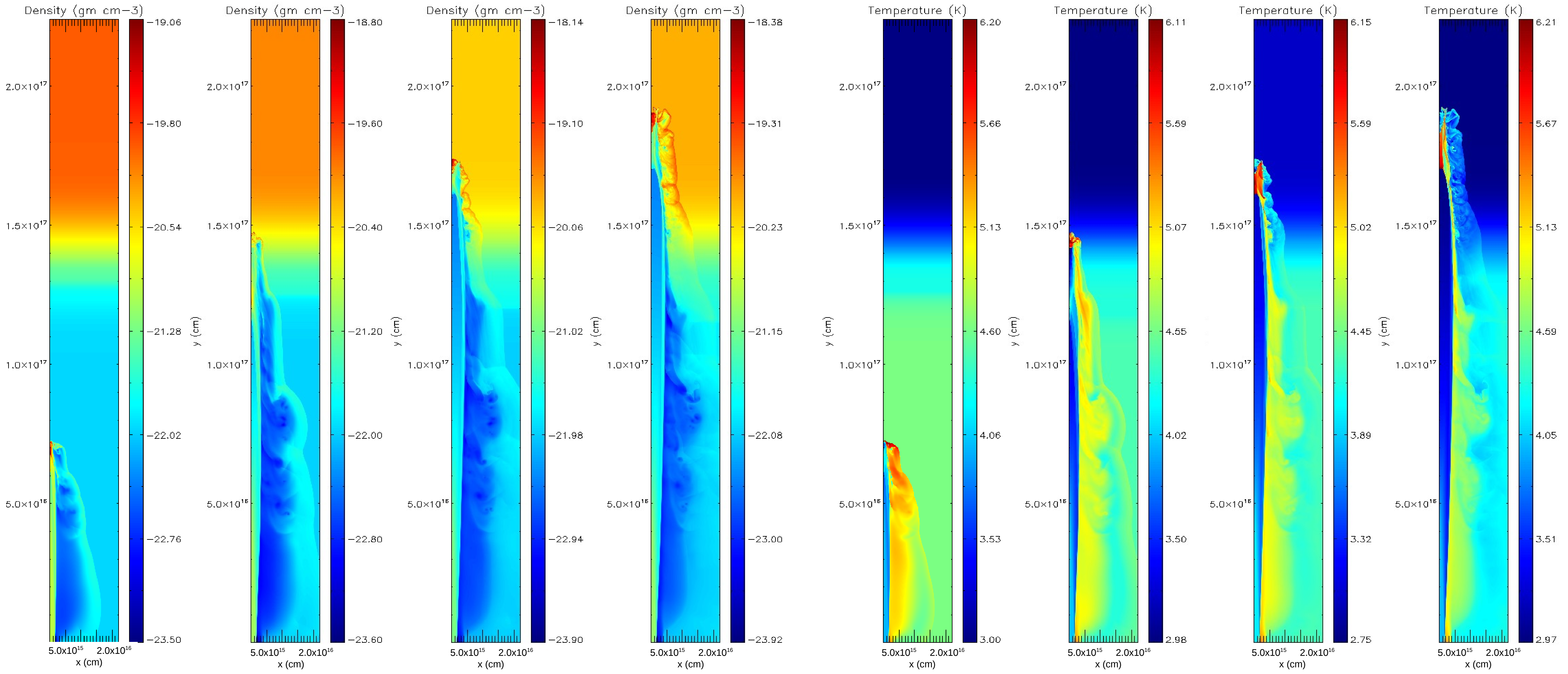

Fig. 3.— Evolution of jet's logarithmic density (gr cm^{3}) and temperature (K). We show four panels for density and temperature, corresponding to 8, 16, 24 and 32 years since the beginning of the simulation.

Bibliography: Mignone et al. (2007); Bonito et al. (2007); Habart et al. 2005; Gómez de Castro & von Rekowski (2011); Martí et al. (1993).

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