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Fountain-driven gas accretion by the Milky Way

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Abstract. Accretion of fresh gas at a rate of $\sim 1\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ is necessary in star-forming disc galaxies, such as the Milky Way, in order to sustain their star-formation rates. In this work we present the results of a new hydrodynamic simulation supporting the scenario in which the gas required for star formation is drawn from the hot corona that surrounds the star-forming disc. In particular, the cooling of this hot gas and its accretion on to the disc are caused by the passage of cold galactic fountain clouds through the corona.

1. INTRODUCTION

Each year a star-forming galaxy like the Milky Way converts $\sim 1\,\mathrm{M}_\odot$ of gas into stars and has done so at a fairly constant rate for nearly a Hubble time [1]. In addition, the gas content of these galaxies has remained approximately unchanged throughout the Hubble time [2]. Typically, the mass of gas contained in the thin disc can sustain the process of star formation for a few Gyrs only and thus, at any given cosmic epoch, Milky Way type galaxies need external gas to be brought into the disc at a rate that compensates the conversion of gas into stars [3]. A plausible reservoir of baryons available to star-forming galaxies, which can sustain such an accretion rate for a Hubble time, is the virial-temperature corona in which they are embedded. In this work we present a new hydrodynamic simulation showing that the interaction between the cold galactic fountain clouds (clouds ejected from the mid-plane of the galaxy by supernova explosions [4]) and the hot corona leads to the cooling and the accretion of the latter on to the star-forming disc at a rate comparable to that at which gas is transformed into stars.

2. HOW CORONAL GAS IS ACCRETED

Our previous numerical simulations (see [5] for further details and [6] for the dynamical consequences of the interaction) indicate that the galactic fountain clouds effect the transfer of gas from the hot corona to the thin disc through the following steps: (i) the Kelvin-Helmholtz instability strips gas from fountain clouds, (ii) in their turbulent wakes, the stripped high-metallicity gas mixes with comparable amounts

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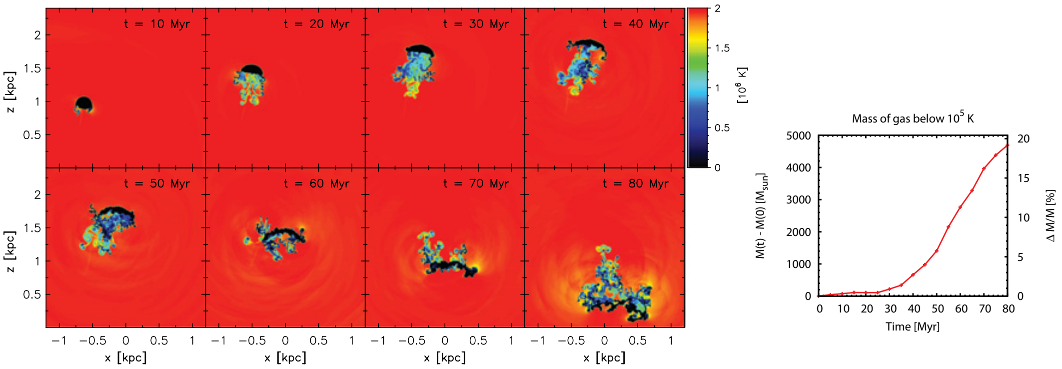

Figure 1. *Left*: Temperature snapshots for a typical fountain cloud moving through a hot hydrostatic corona ($T_{cor} = 2 \times 10^6$ K) in the vertical gravitational field of the Milky Way at the solar circle. Note the formation of a turbulent wake containing knots of cold gas. *Right*: Evolution of the mass of cold ($T < 10^5$ K) gas for the same simulation. The mass of cold gas increases throughout the simulated time due to the condensation of the corona.

of low-metallicity coronal gas and the cooling time of the engulfed coronal gas becomes shorter than the cloud's orbital time, (iii) knots of cold gas form and accrete on to the disc in a dynamical time.

This situation is illustrated in Fig. 1 (left panel), which presents temperature snapshots of a new 2D simulation of a typical fountain cloud moving through a hot isothermal corona in hydrostatic equilibrium with the vertical gravitational field of the Milky Way at the solar circle. The cloud is shot from the bottom edge of the computational domain (where the star-forming disc is supposedly located) with an initial velocity $v_0 = 75\,\mathrm{km\,s^{-1}}$, at an angle of 10° with respect to the vertical direction. Due to the presence of the gravitational field, the cloud describes approximately a parabolic orbit and in ~ 80 Myr falls back to the disc. Knots of cold gas cooling from the corona form in the cloud's wake and closely follow the motion of the main body of the cloud. Note that the gas below 10^5 K is mostly located within ≈ 1 kpc or less of the leading edge of the cloud. This suggests that the cooled gas can be accreted on to the disc in a cloud's dynamical time to feed the star formation. To estimate the global accretion rate on to the disc, we computed the evolution of the mass of gas below 10^5 K (Fig. 1, right panel). As a consequence of the condensation of the coronal gas, this mass increases with time throughout the simulation. When this behaviour is extrapolated to the whole Milky Way halo, a global accretion rate of $\sim 1\,M_\odot\,\mathrm{yr}^{-1}$ is obtained, in agreement with our earlier results (see also [7]).

Therefore, we propose that positive feedback from supernovae, which drive the galactic fountain, is the mechanism that sustains star formation in galaxies like the Milky Way, at least for redshifts $z \lesssim 1$ [8]. This scenario also explains how star-forming galaxies can accrete gas from the hot intergalactic medium, represented by virial-temperature coronae, notwithstanding the thermal stability of these structures [9].

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