accelerate them (Fig. 14). The high-pressure energy bubble progresses more slowly, shearing and accelerating the filamentary fragments, creating fast radial outflows (~500 km s\(^{-1}\)) for \(P_{\text{jet}} = 10^{45}\) ergs\(^{-1}\)). The shocks driven by the energy bubble create a multiphase ISM of mildly hot (\(T \sim 10^5\) K) gas in the outer layer of the forward shock. The forward shock is followed by an adiabatically expanding hot energy bubble (\(T \sim 10^6\)–\(10^7\) K). Observational evidence of such shocked multiphase ISM have been obtained from extended X-ray emission from radio-loud galaxies (Kraft et al. 2003; Croston, Kraft & Hardcastle 2007; Mingo et al. 2011; Wang et al. 2012). Clouds trapped in the energy bubble are shredded with their outer layers flowing out in fast, hot, low-density outflows (with \(T > 10^6\) K, \(n < 10\) cm\(^{-3}\), \(v_r \sim 1000\) km s\(^{-1}\)). The dense central cores are radially accelerated to velocities of ~500 km s\(^{-1}\). Such velocities are in agreement with observations of jet-driven outflows (see for example WBU12; Collet et al. 2016, and references therein).

(iii) Feedback from low-power jets:

a significant result from this work is the effect of low-power jets on the ISM of the host galaxy. High-power jets, although more effective in launching faster outflows, are less destructive of the ISM since they efficiently drill through the ISM. Low-power jets lack sufficient momentum to readily pierce the ISM and remain trapped for a longer time. This results in a more lateral spreading of the trapped energy bubble which causes enhanced shearing of the ISM filaments (as shown in Figs 16 and 17). Such persistent coupling of a trapped jet with the ambient ISM will result in constant stirring of the turbulent ISM, inhibiting star formation in the process. This agrees with recent suggestions of suppressed star formation in some systems with a weak radio jet, such as NGC 1266 (Nyland et al. 2013; Alatalo et al. 2015) and some molecular hydrogen emission galaxies with weak radio jets (Ogle et al. 2007, 2010; Lanz et al. 2015a).

As noted in Section 1, the radio luminosity function implies that the distribution of 1.4 GHz radio power, \(P_{\text{1.4}}\), peaks at around the FRI/FRII break at \(10^{24.6}\) W Hz\(^{-1}\) (Mauch & Sadler 2007). Approximately this corresponds to \(P_{\text{jet}} \sim 10^{42–43}\) erg s\(^{-1}\). Thus, given our results from the simulation with \(P_{\text{jet}} = 10^{43}\) erg s\(^{-1}\), we expect that low-powered jets with \(P_{\text{jet}} \lesssim 10^{42}\) erg s\(^{-1}\) should play a significant role in affecting the evolution of the ISM and star formation in the host galaxy.

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**Figure 18.** 2D PDF for Sim. D with \(P_{\text{jet}} = 10^{43}\) ergs\(^{-1}\) at ~9 Myr. The evolution of the ISM is significantly different from that of the high-power jets, as inferred by comparing similar plots presented in Figs 12–14. A significant amount of the gas remains in the mildly hot phase (\(\sim 10^5\) K) from the forward shock. The temperature–velocity plot shows very little outward radial acceleration of the gas.

**Figure 19.** The evolution of the kinetic energy of the dense ISM (\(\rho > 1\) cm\(^{-3}\)) with time. The top panel shows the fractional increase of the kinetic energy of the ISM from its initial value. The lower panel plots the kinetic energy at a given time normalized to the total energy injected by jet till that time, indicating the efficiency of coupling of the jet.

**Figure 20.** The figure shows the maximum radial distance a gas with a given velocity may reach under the influence of gravity, expressed as a fraction of the total ISM mass.
The velocity dispersion map at the $E_1$ cm being the kinetic energy of the dense gas ($\sigma$ being the mean of the dispersion of the three velocity components ($\sigma^2 = \sum_{i=1}^{3} \sigma_i^2 / 3$).

(iv) Efficiency of feedback:
the jet significantly couples to the ISM within the central few kpc before it breaks out into the ambient halo. From Fig. 19, we see that nearly ~30 per cent of the jet energy is transferred as kinetic energy to the ISM for high-power jets. This measure of coupling efficiency $^{4}$ is independent of jet power and density, as long as the jet creates a sufficiently overpressured bubble. This agrees with previous results of WBU12.

(v) Small net mass-loss:
only a few per cent of the dense gas mass is ejected from the galaxy to large distances (see Fig. 20). Most of the mass affected by the energy bubble is expected to rain back down into the galaxy’s potential on free-fall time-scales – typically of the order of a few tens of Myr. This supports the galactic fountain scenario of jet-driven feedback (similar to Oppenheimer et al. 2010; Davé et al. 2012). The jets may cause temporary quenching of star formation by launching local outflows and making the ISM turbulent, but the ejected mass will fall back and may be available for star formation after a few tens of Myr. The effect of such repeated cyclic explosive episodes and its connection to the AGN duty cycle needs to be explored in future work.

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$^{4}$ $E_{\text{kin}} / P_{\text{jet}}$, $E_{\text{kin}}$ being the kinetic energy of the dense gas ($n > 1 \text{ cm}^{-3}$).
The lognormal distribution has proven to provide excellent description of the density pPDF for simulations of isothermal turbulence (Li, Klessen & Mac Low 2003; Kritsuk et al. 2007; Federrath et al. 2010). The distribution is defined as a Gaussian in $s = \ln \rho$ with a mean $-\sigma_s^2/2$ and variance $\sigma_s^2$:

$$P_V(s) = \frac{1}{\sigma_s \sqrt{2\pi}} \exp \left[ -\frac{(s + \sigma_s^2/2)^2}{2\sigma_s^2} \right]$$  \hspace{1cm} (A1)$$

The subscript $V$ refers to volume-weighted PDF, which is considered primarily in this work while describing the 1D density PDFs. The above definition of the PDF satisfies the following two conditions of normalizations:

$$\int_{-\infty}^{\infty} P_V(\ln \rho) d \ln \rho = 1$$  \hspace{1cm} (A2)$$

$$\int_{-\infty}^{\infty} \rho P_V(\ln \rho) = \bar{\rho} \text{ (mean density).}$$  \hspace{1cm} (A3)$$

The mean of the distribution is

$$\langle \ln \rho \rangle = -\frac{\sigma_s^2}{2}$$  \hspace{1cm} (A4)$$

and the variance in $\rho$ is

$$\sigma_\rho^2 = \bar{\rho}^2 \left[ \exp \left( \sigma_s^2 \right) - 1 \right].$$  \hspace{1cm} (A5)$$

In the presence of strong shocks, the density PDF shows significant departure from a true lognormal, especially in the high- and low-density tails. An improved function proposed by Hopkins (2013) gives a better description of the density PDF in the presence of intermittency:

$$P_V(s) = I_1 \left( 2 \sqrt{\lambda u(s)} \right) \exp \left[ -1 - u(s) \right] \sqrt{\frac{\lambda}{u(s)^2}}$$

$$u(s) = \lambda \left( \frac{1}{1+\eta} + \frac{s}{\eta} \right) \left( u \geq 0 \right); \ s = \ln \left( \rho/\bar{\rho} \right)$$

$$\lambda = \sigma_s^2 \left( \bar{\rho}^2 \right)$$  \hspace{1cm} (A7)$$

Here, $I_1$ is the modified Bessel function of the first kind. The PDF in equation (A7) is defined by three parameters: the mean density $\bar{\rho}$ which is defined by $A_2$, the dispersion ($\sigma_s$) and a parameter $\eta$ defining the degree of departure from a lognormality.

For $\eta = 0$, $\bar{\rho}_s$ is

$$\bar{\rho}_s = \frac{1}{3} \left( \frac{1}{2} + \sqrt{1 + \frac{4}{9}} \right) \left( 1 + \frac{1}{2} \right)$$

$$u(s) = 3 \left( \frac{1}{1+\eta} + \frac{s}{\eta} \right) \left( u \geq 0 \right); \ s = \ln \left( \rho/\bar{\rho} \right)$$

$$\lambda = \sigma_s^2 \left( \bar{\rho}^2 \right)$$  \hspace{1cm} (A7)$$

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$$\lambda = \sigma_s^2 \left( \bar{\rho}^2 \right)$$  \hspace{1cm} (A7)$$

Here, $I_1$ is the modified Bessel function of the first kind. The PDF in equation (A7) is defined by three parameters: the mean density $\bar{\rho}$ which is defined by $A_2$, the dispersion ($\sigma_s$) and a parameter $\eta$ defining the degree of departure from a lognormality.
equation (A7) reduces to the standard expression of a lognormal distribution (equation A1). The mean density of the improved function is same as in equation (A4) above. The variance in $\rho$ is given by

$$\sigma^2_{\rho} = \bar{\rho}^2 \left[ \exp \left( \frac{\sigma^2_{\rho}}{1 + 3\eta + 2\eta^2} \right) - 1 \right]. \quad (A8)$$

**APPENDIX B: ADIABATIC EXPANSION OF AN ENERGY BUBBLE**

For a spherical bubble with radius $R_B$, expanding with uniform pressure ($p_B$), driven by a constant input energy flux from a jet or wind ($P_j$), the energy equation can be written as

$$\frac{d}{dt} \left[ \frac{4\pi}{3} p_B R_B^3 - \gamma - 1 \right] + 4\pi R_B^2 p_B \frac{dR_B}{dt} = P_j - L_{cool} \quad (B1)$$

$$\frac{d}{dr} \left[ p_B R^3 \gamma \right] = \frac{3(\gamma - 1)}{4\pi} P_j R_B^{3(\gamma - 1)}, \quad (B2)$$

where $\gamma$ is the adiabatic index and $L_{cool}$ is energy loss from atomic cooling. The first term in the left hand side of equation (B1) is the change of internal energy inside the volume, while the second term is the work done by the expanding bubble. Since we are considering an adiabatically expanding bubble, we do not consider the cooling losses in equation (B2). If the radius expands as $R_B \propto t^\alpha$, following equation (B2), we find that the pressure to evolve as

$$p_B \propto t^{1-3\alpha}. \quad (B3)$$

For a self-similarly expanding bubble in an ISM of constant density ($\rho_0$), the radius and pressure evolve as (Castor et al. 1975; Weaver et al. 1977)

$$R_B \propto \left( \frac{P_j}{\rho_0} \right)^{1/5} t^{3/5}; \quad p_B \propto t^{-4/5}. \quad (B4)$$

However, in a multiphase ISM the bubble expansion is slower than the adiabatic case due to cooling losses and turbulent mixing (e.g. Rosen et al. 2014). For Fig. 11, we find the radius to evolve as $R_B \propto t^{0.55}$. For an adiabatically expanding bubble, this implies (following equation B3) that the pressure should vary as $p_B \propto t^{-0.65}$. This approximately agrees with the initial evolution of the mean pressure of the bubble (shown in Fig. 10), for the simulations with high-power jets ($P_{jet} \geq 10^{44} \text{ ergs}^{-1}$). This indicates that for jets with higher power, an overpressured bubble is formed which initially evolves as an adiabatically expanding spherical bubble till jet break out.

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