AGN Jets - Assassins or Patrons of Star Formation?

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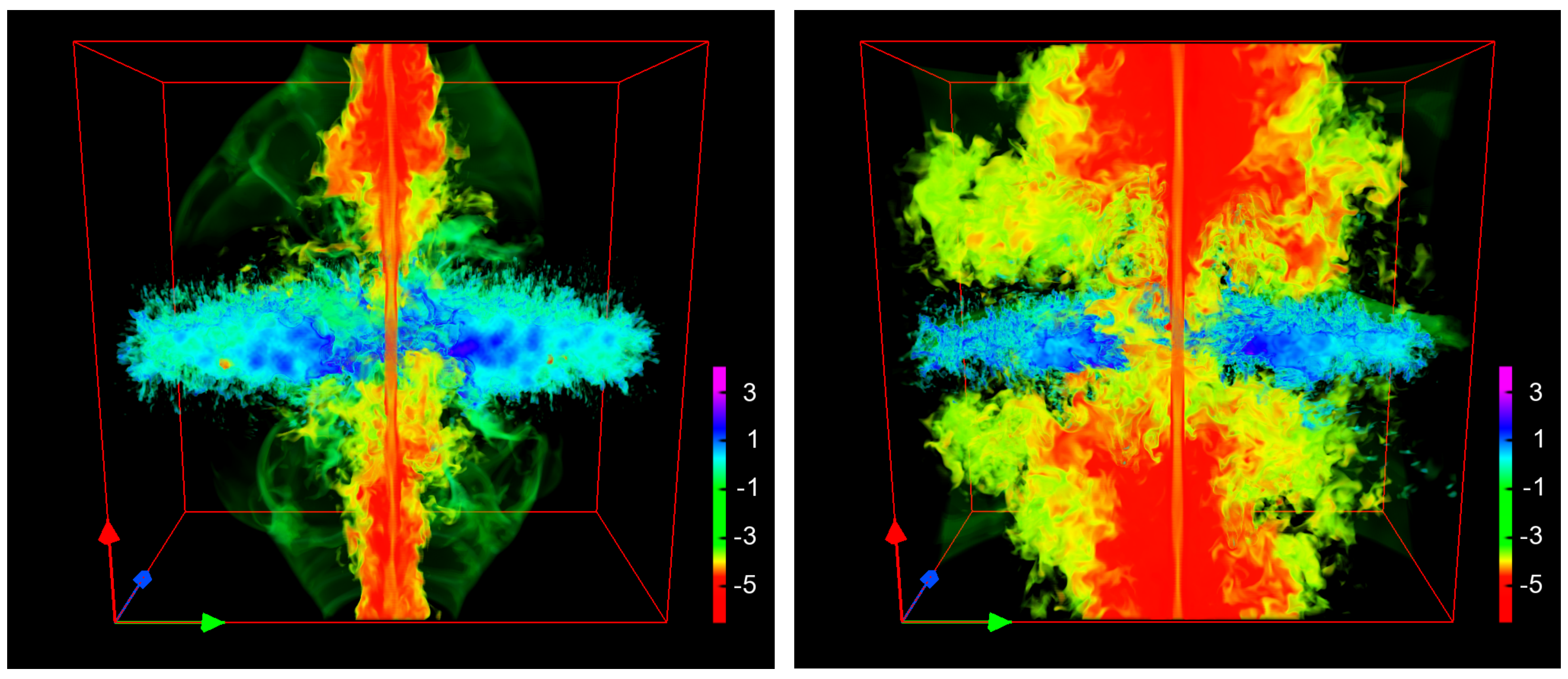
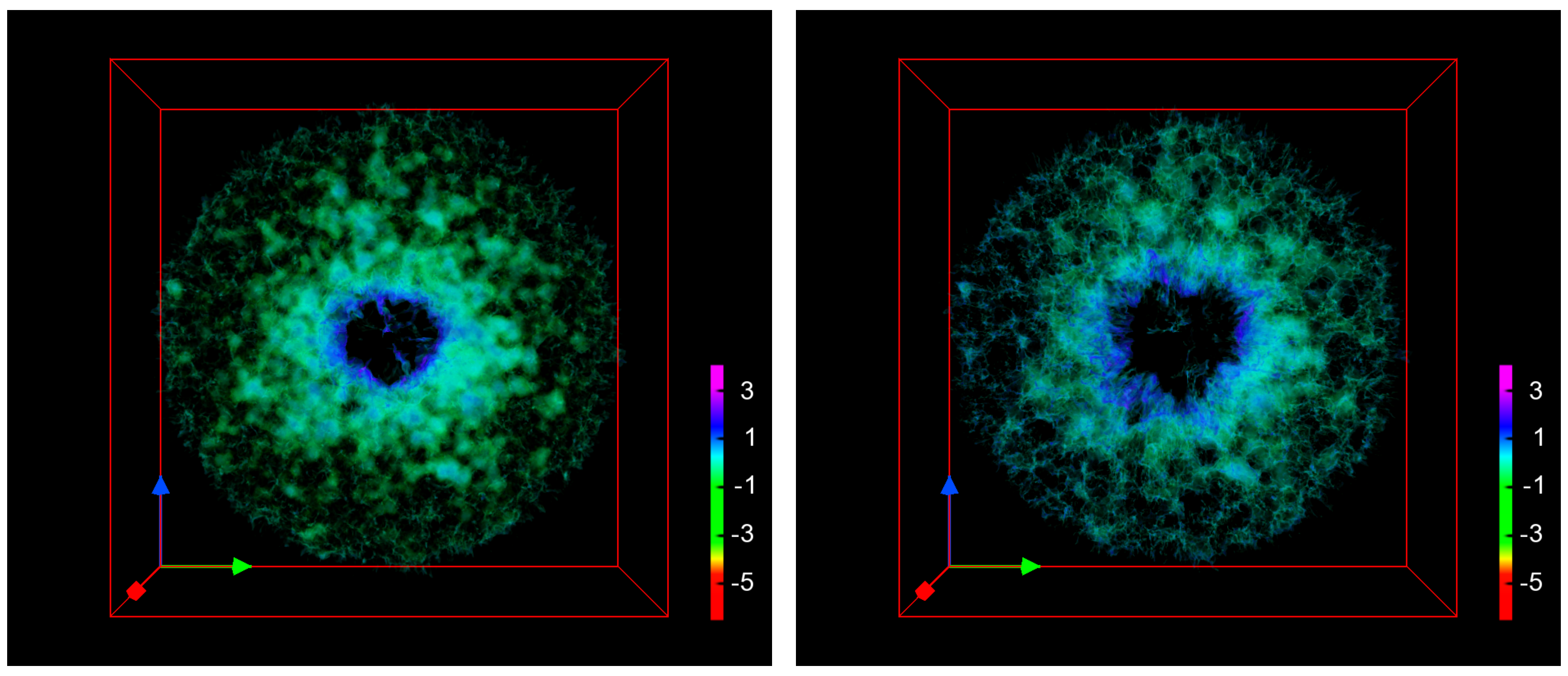
Abstract

Feedback from active galactic nuclei (AGN) has become a major component in simulations of galaxy evolution, in particular for massive galaxies. AGN jets have been shown to provide a large amount of energy and are capable of quenching cooling flows. Their impact on the host galaxy, however, is still not understood. Subgrid models of AGN activity in a galaxy evolution context so far have been mostly focused on the quenching of star formation. To shed more light on the actual physics of the "radio mode" part of AGN activity, we have performed simulations of the interaction of a powerful AGN jet with the massive gaseous disc (10^{11} solar masses) of a high-redshift galaxy. We spatially resolve both the jet and the clumpy, multi-phase interstellar medium (ISM) and include an explicit star formation model in the simulation. Following the system over more than 10^7 years, we find that the jet activity excavates the central region, but overall causes a significant change to the shape of the density probability distribution function and hence the star formation rate due to the formation of a blast wave with strong compression and cooling in the ISM. This results in a ring- or disc-shaped population of young stars. At later times, the increase in star formation rate also occurs in the disc regions further out since the jet cocoon pressurizes the ISM. The total mass of the additionally formed stars may be up to 10^{10} solar masses for one duty cycle. We discuss the details of this jet-induced star formation (positive feedback) and its potential consequences for galaxy evolution and observable signatures.

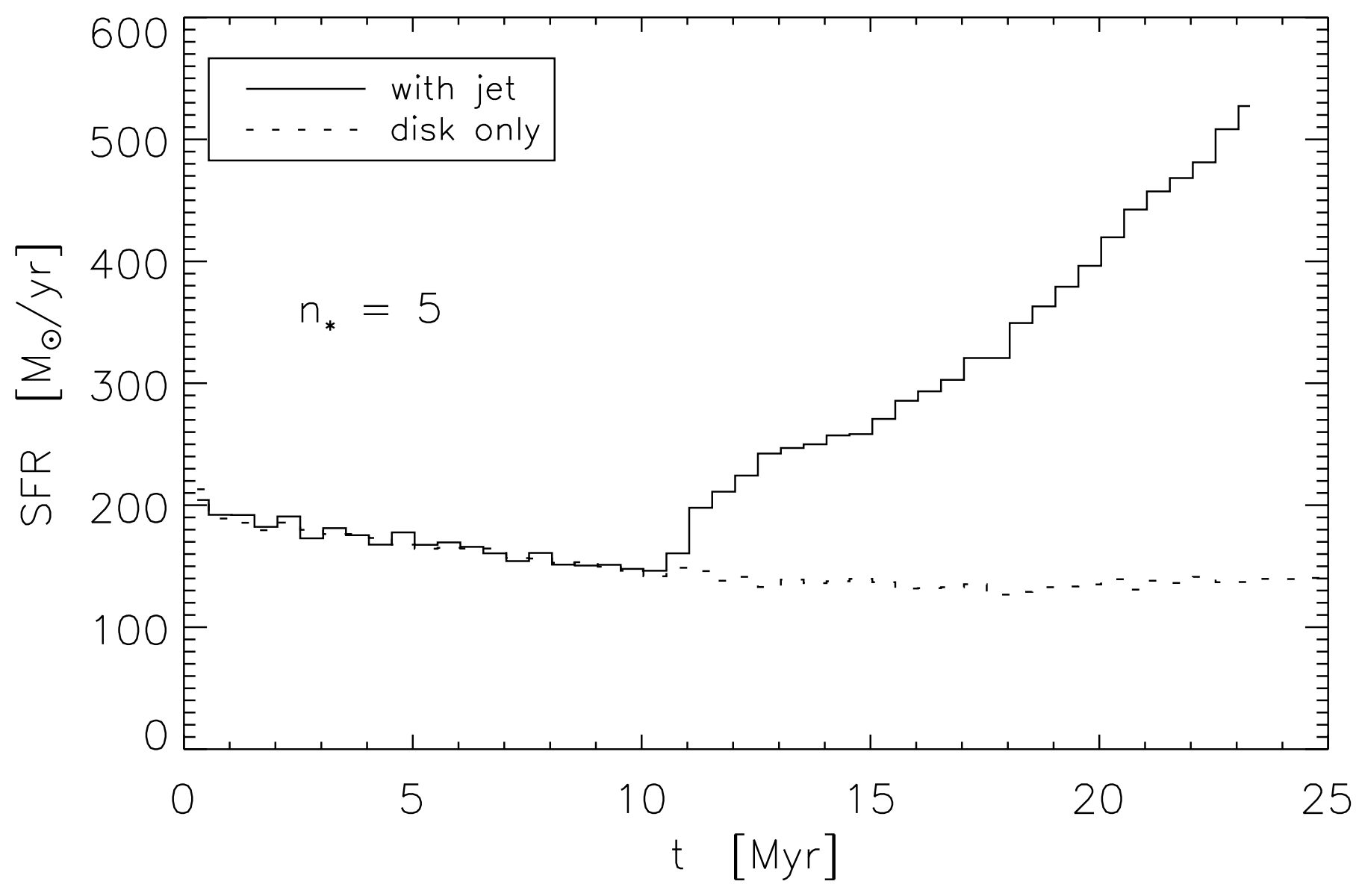
more details: arXiv:1111.4478, MNRAS in press.



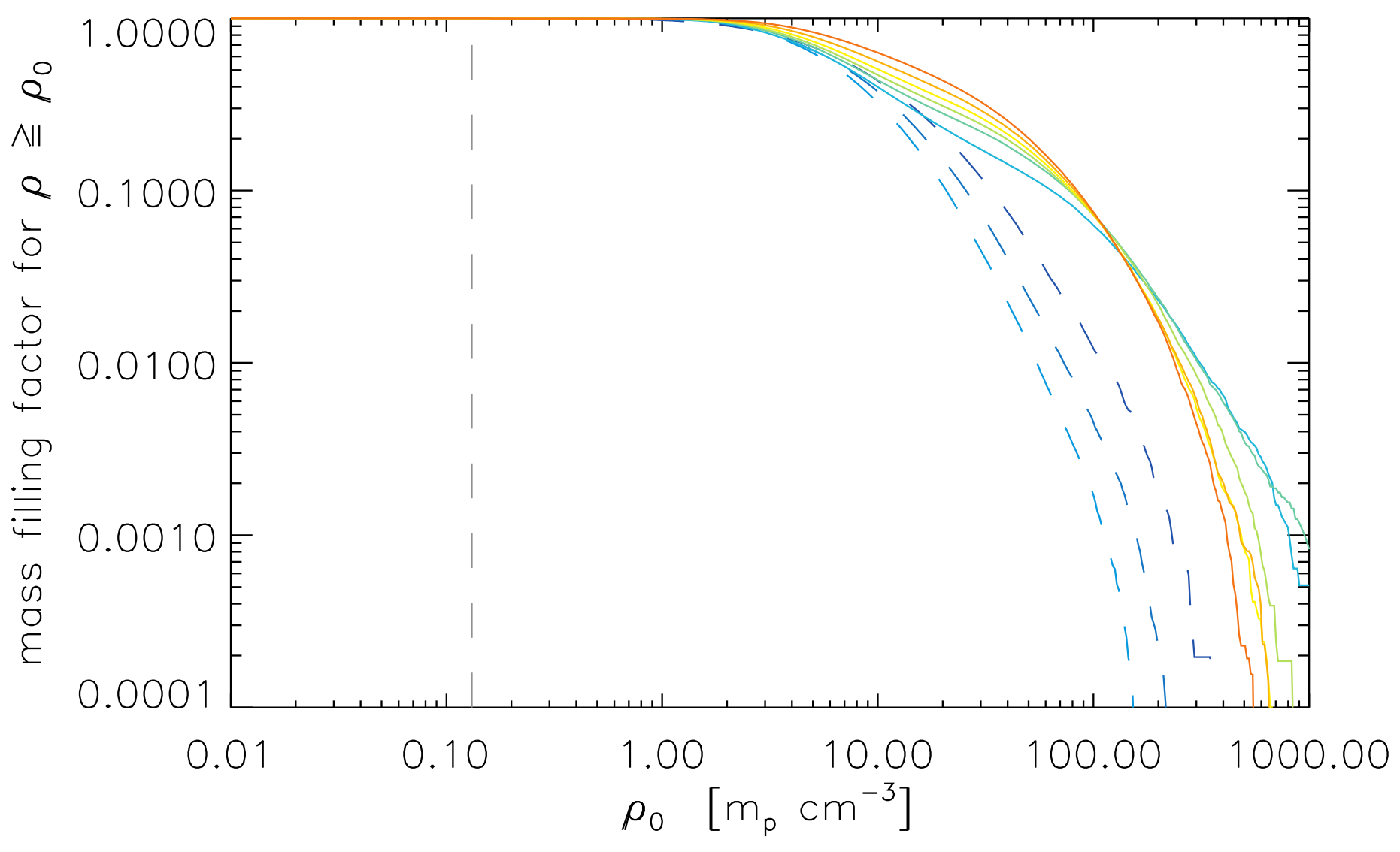
Density volume rendering of the central part of the domain (32 kpc box length) at t = 14 (left) and t = 22 Myr (right). The jet became active at t = 10 Myr. Only the z > 0 half is shown and densities close to the ambient X-ray gas are transparent to give a tomographic view. The colour bars show log density in units of m_p/cm^3.



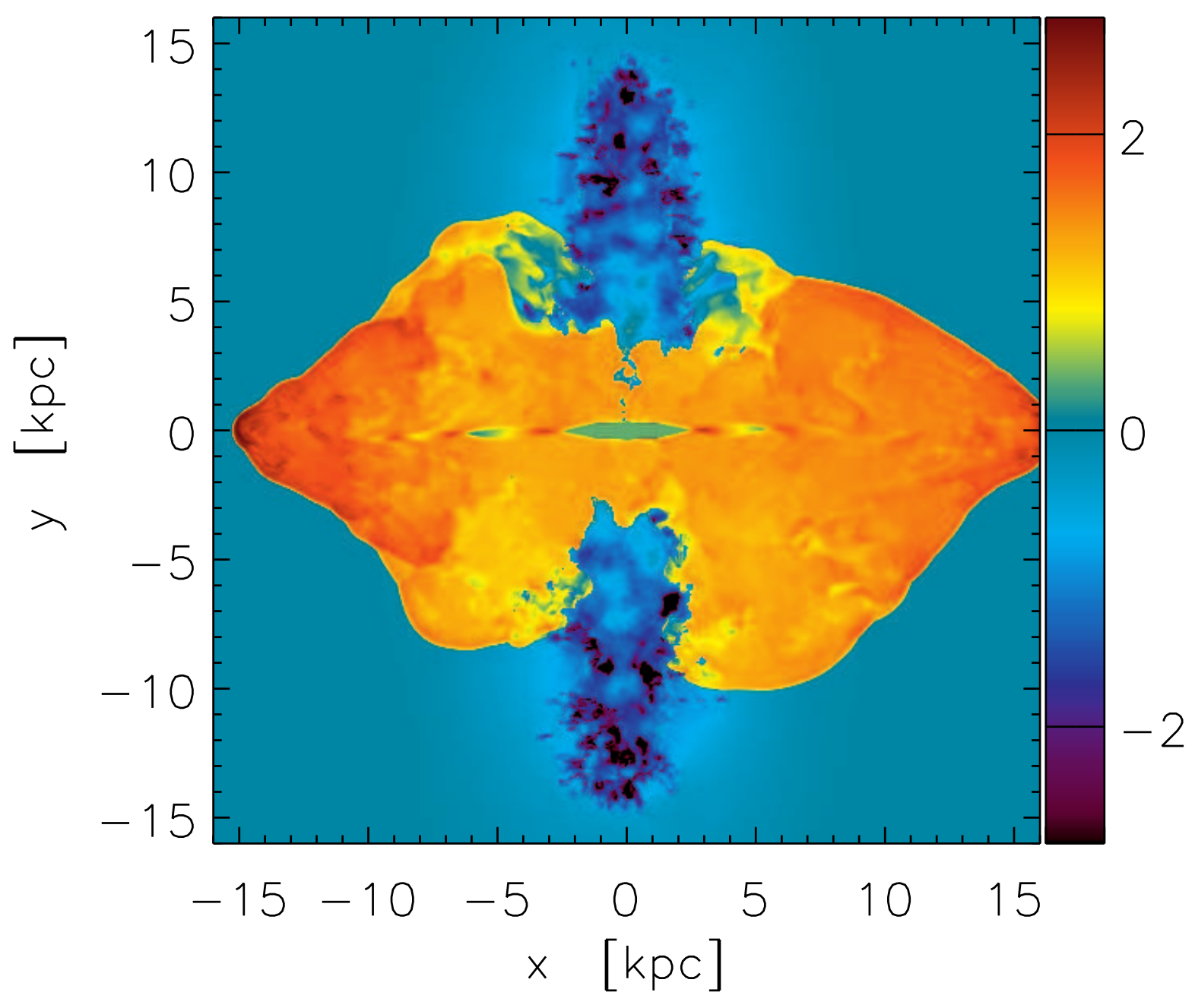
Density volume rendering of the high density gas in the disc (face-on view) at t = 14 (left) and t = 22 Myr (right). The box length is 32 kpc, lower density regions are transparent and the colour scale is the same as in figure above.



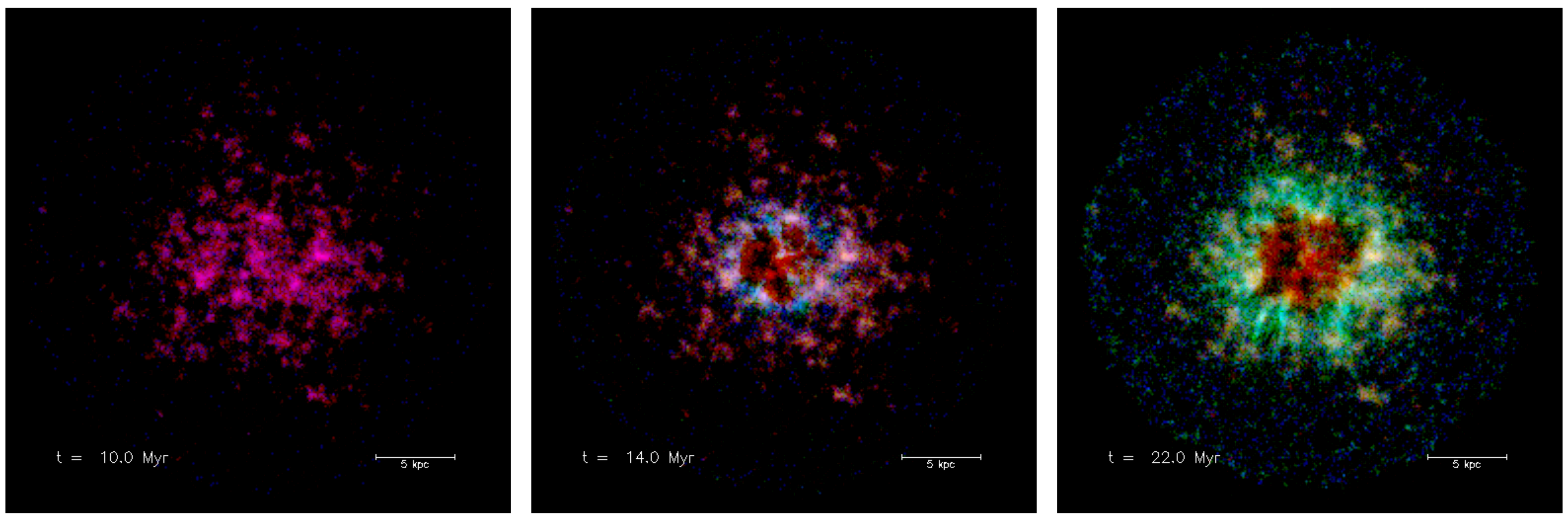
Total star formation rate for star formation thresholds of $n_* = 5$ cm^{-3}. The jet is started at t = 10 Myr. The dotted line shows the control simulation without a jet.



Evolution of the mass filling factors of the disc. Time evolution by colour: going from blue via green and yellow to red. Early evolution without jet: dashed (0, 5, 10 Myr), filling factor decreases. With active jet: solid (12, 14, 16, 18, 20, 22 Myr), quick increase, then decrease at high densities.



Pressure slices through z = 0 at t = 13 (left) and t = 22 Myr (right), showing log p normalized to the ambient pressure.



Pseudo-colour star formation maps for t = 10 Myr (top), t = 14 Myr (middle) and t = 22 Myr (bottom row) as RGB composite of the face-on view. Newly formed stars (formed within the last 1 Myr) are shown in blue, all other are shown either in red (stars formed at t < 10 Myr, in the undisturbed disc) or green (stars formed at t > 10 Myr, jet was active). The images refer to the simulation with the high density threshold ($n_* = 5$ cm^{-3}), a scale bar with 5 kpc length is given.

Feedback - Negative and Positive?

Observational evidence points toward early enrichment and formation of the stellar population of the most massive elliptical galaxies. At the same time observations indicate that the activity of the most luminous quasars peaks at earlier times than that of less luminous ones. How can the fast growth of stellar mass be paralleled by a fast growth in BH mass if feedback from AGNs is only negative? Can early **positive feedback** enhance star formation and enrichment in the ISM? Does the AGN drive out a large fraction of metals or are they trapped within the galaxy? How does **negative feedback** effect the host galaxy and could it be more important at low redshifts?

Background image: Mare Nostrum Simulation, Pichon, Teyssier