Boletim da Sociedade Astronômica Brasileira, **30**, no. 1, 184-185

Star formation vs AGN black hole feedback in the evolution of galaxy outflows

W. Clavijo-Bohórquez[1], E. M. de Gouveia Dal Pino[1], C. Melioli[1]

[1] Instituto de Astronomía, Geofísica y ciências Atmosfericas (IAG)
e-mail: weclavijob@usp.br, dalpino@iag.usp.br, claudio.melioli@iag.usp.br

Abstract. Large scale, weakly collimated outflows occur in most galaxies. In complex systems, where (SF) coexists with an active galactic nucleus (AGN) it is unclear whether the SF, the AGN, or both are driving the outflows which frequently exhibit persistent high-speed cold structures. In this work we perform 3D-HD and MHD numerical simulations of the formation of these outflows considering both the feedback from the AGN wind with an opening angle of 0 and 10 supernovae (SNe) type I and II explosions. Magnetic fields are introduced too in the system because they may help to prevent the evaporation of such structures in the ISM and galactic wind. The results indicate that the inclusion of both magnetic fields and an AGN wind substantially affect the evolution of these systems and may account for high speed features, though not cold enough.

Resumo. Fluxo de material de grande escala, fracamente colimado, ocorrem na maioria das galáxias. Em sistemas complexos, onde formação estelar (SF) coexiste com um núcleo galáctico ativo (AGN), não está claro se o SF, o AGN, ou ambos estão produzindo esses fluxos de material que freqüentemente exibem estruturas persistentes densas e frias de alta velocidade. Neste trabalho, realizamos simulações numéricas hydrodynamicas e magneto-hydrodynamicas tri-dimensionais, da formação desses fluxos considerando tanto o feedback do vento AGN com um ângulo de abertura de 0 e 10, como de regiões de SF com explosões de supernova (SNe) tipo I e II. Campos magnéticos com orientações horizontais e verticais ao plano do disco são introduzidos no sistema ja que se pensa que podem ajudar a evitar a evaporação de tais estruturas no ISM e vento galáctico. Os resultados indicam que a inclusão de campos magnéticos e um vento AGN-jet afetam substancialmente a evolução desses sistemas e podem dar conta de estruturas de alta velocidade, embora não suficientemente frias.

Keywords. ISM: jets and outflows

1. Introduction

Outflows in galaxies are ubiquitus in the universe. In Seyferts galaxies and others the mechanism that accelerates the observed dense cool estructures between 10 and 10 km/s (0.1c) above the kpc scales is still a mistery. The energy and momentum feedback sources that can be responsable for these structures can be provided by radiation pressure released by gas accretion onto the central engine and by the SMBH in the center of the active galaxy (AGN wind) and/or by star formation (SF wind). Both mechanisms can be responsible for the transference of momentum and energy that carry out these clumps and clouds to kiloparsec scales. Recently observations of these outflows together with the statistical analysis of the produced data (Tombesi 2013) report a possible unified model treating them as single collimated structures covering a wide range of parametres in ionization, velocity, column density and distances from the nucleus. Some models which include magneto-centrifugal and radiation mechanisms are invoqued to explain these phenomena. Recently HD simulations (Melioli and de Gouveia Dal Pino 2015) that include feedback of winds produced by SF and by AGN-jets show that the system is almost insensitive to the passage of the collimated jet, but its presence is necessary to accelerate plasma structures to the observed velocities $\sim$ 10 km/s, and a steady flux of gas can be generated by intense SF only. Nevertheless the introduction of magnetic fields can to play an important role in the evolution of these outflows, as well as in the evolution of plasma accretion rates and the SF region. In the next, we will analize how magnetic fields perpendicular and paralell to the disc can participate in the feedback and we will compare them with previous results (Melioli and de Gouveia Dal Pino 2015) that didn't include magnetic fields.

2. Numerical model

Initial setup: we consider a model for the galaxy which includes a stellar bulge and a three-phase gas disk initially in hydrostatic equilibrium with the gravitational potential given by the dark matter halo and the bulge. The setup is appropriate for a Seyfert galaxy.

Mass and energy injection: we consider mass and energy injection by Supernovae type I and II (SNI - SNII), and a jet driven by the supermassive black hole (SMBH). The injected mass for the SNI is 10 MBH/yr and the luminosity injected by SNII is 3×10 erg/s over 300 Myr. The SMBH injects a constant luminosity (1×10 erg/s), non-relativistic collimated outflow with a speed 0.07c above and below the disk.

3. HD Model: comparison between star-formation-driven wind and the black hole Jet feedbacks

The overall evolution of the ISM of the Galaxy is almost insensitive to the passage of the narrow SMBH jet, but it is able to speed up the velocity of a very small fraction of the ISM gas that is swept by the surrounding SF-wind. The highest velocities reached are comparable to those observed in Seyfert galaxies and Ultraluminous Infrared galaxies (e.g. Melioli & de Gouveia Dal Pino 2015; Tombesi et al. 2016). Nevertheless, these high speed fetures are too hot to explain the high-speed cold clumps that are also observed in these galaxies. We find that the very small

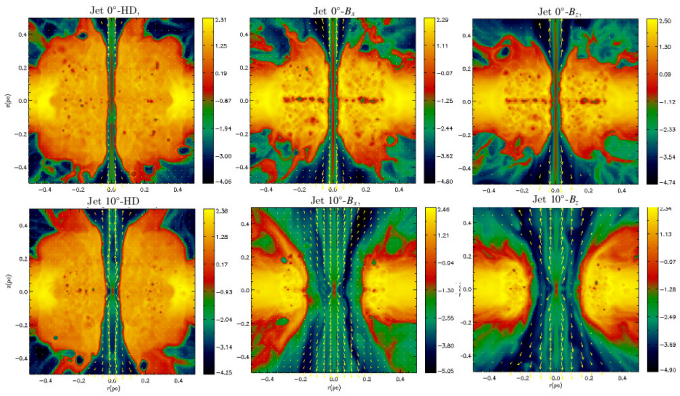

FIGURE 1. Edge on logaritmic gas density (cm^{-3}) after t = 5 Myr of evolution. Top and bottom diagrams are 0 and 10 models respectively.Left diagrams are hydrodynamical; middle diagrams have an initial horizontal magnetic field (B_x); and right have vertical magnetic field (B_z). The arrows shows the velocity field (v_x, v_z)

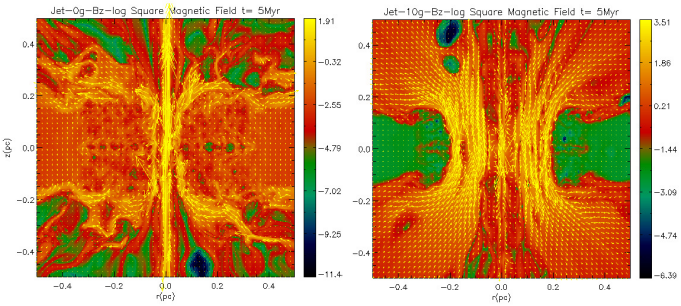

FIGURE 2. Edge-on logarithmic magnetic pressure (erg/cm^3) for models Jet 0-Bz (left) and Jet 10-Bz (right). The arrows show the magnetic field vector (B_x, B_z) in the plane.

fraction of gas that is accelerated to velocities of ∼ 10 km/s has densities between 10 and 10 cm (see Fig. 4) .

4. MHD Models

We now explore how the presence of a magnetic field in the gas with an initially $\beta = 300$ and a SMBH jet with an opening angle of 10° may affect the feedback. Figure 1 shows two-dimensional cuts (2D) of the density distribution of 6 models (HD and MHD). The results of our simulations show some important conclusions:

1. The magnetic field decreases the average temperature of the system preserving more cold structures because a fraction of energy released by the SN explosions used to heat the ISM gas is transferred to the magnetic field. (see Fig. 3 bottom left)
2. The SMBH outflow with an opening angle of 10 (Jet-10 model in Fig. 1, bottom left) clearly helps to accelerate more low density plasma increasing the velocity by one order of magnitude from 10 to 10 km/s (compare bottom left and top left in Fig. 4).
3. The comparison of MHD and HD-models with same jet-opening angle clearly shows that the presence of $\boldsymbol{B}$ helps to enhance the average outflow velocity (see Fig. 3 middle panel left and Fig. 4). This because of the combination of several effects that include the extra acceleration effect due to magnetic pressure gradient and tension forces and the less expanded (colder) surrounding ISM in the magnetized models.

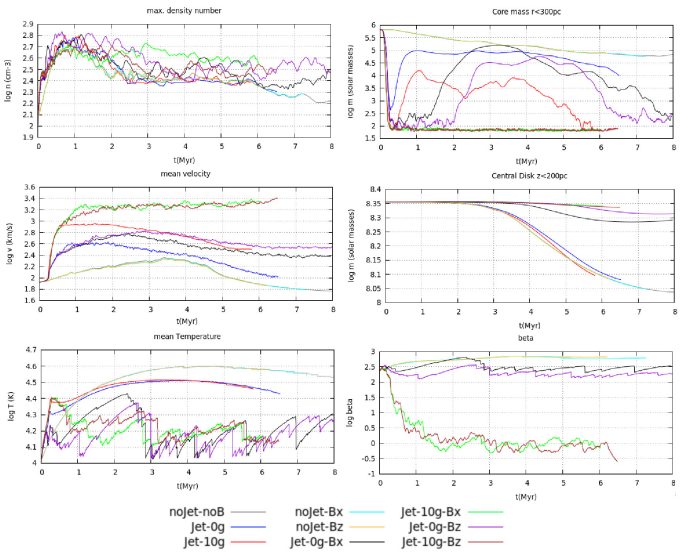

FIGURE 3. Logarithmic mean values for velocity (left-middle), central disc mass (right middle), thermal pressure (bottom-left), beta (bottom-right), central core mass (top-right). The max. number density (top-left) is the maximum value of density in one cell over all the cells in the system.

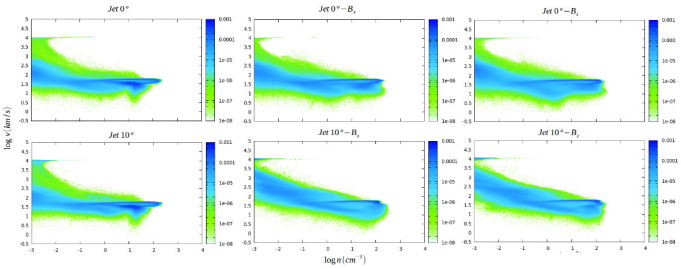

FIGURE 4. Two dimensional histogram of the vertical velocity (km/s) vs. density (cm) calculated considering every cell whithin the whole simulated system for all the models at a time $t = 5$ Myr. The color bar indicates the cell number normalized to the total number.

4. The combination of the effects of the SMBH jet and the magnetic fields together are not enough to drive the formation of high speed cold features in kpc scales expected from observations. (Fig. 4)
5. The inclusion of the magnetic field in the 10 jet model, helps to open a broader channel in the central region when compared with the HD 10 case, where the channel is confined by the thermal pressure of the gas heated by SN explosions. In fact the evolution of gas surrounding the core region ($r \leq 300$ pc, $| z |\leq 200$ pc), shows the removal of plasma in the central region that could accrete onto the SMBH possibly inhibiting the active phase of the galaxy (Fig. 3 top-right).

References

Tombesi F., et al, 2013, MNRAS 430, 1102-1117
Melioli, C., de Gouveia Dal Pino, 2015, E. M., ApJ, 812, 90