Star clusters and black holes in galaxies across cosmic time
Proceedings IAU Symposium No. 312, 2014
Y. Meiron, S. Li, F.-K. Liu & R. Spurzem, eds.

doi:10.1017/S1743921315007711

The *Fermi* bubbles inflated by winds from the accretion flow in Sgr A*

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Abstract. By performing three-dimensional hydrodynamical simulations, we show that the *Fermi* bubbles could be inflated by winds launched from the "past" hot accretion flow in Sgr A*. The parameters of the accretion flow required in the model are consistent with those obtained independently from other observational constraints. The wind parameters are taken from small scale MHD numerical simulations of hot accretion flows.

Keywords. accretion, black hole physics, jets, hydrodynamics

A pair of giant gamma-ray bubbles which extend 50 degrees above and below the Galactic plane with a width of 40 degrees are revealed by the *Fermi* Gamma-ray Space Telescope (Su *et al.* 2010). The formation mechanism of the bubbles is still under debate.

Many observations have strongly indicated that the activity of the supermassive black hole located in the Galactic center, Sgr A*, is likely much stronger than the present time (Totani 2006), and the *Fermi* bubbles may be the result of this activity. Specifically, the previous independent quantitative studies to the past activity show that while Sgr A* was also in a hot accretion regime, the accretion rate should be $3 \sim 4$ orders of magnitude higher than the present value and last for 10^7 yr.

One of the most important features of hot accretion flow is the existence of strong wind (Yuan *et al.* 2012; see review in Yuan & Narayan 2014). The main properties of winds such as mass flux and velocity have been obtained from the analysis to the MHD numerical simulation data (Yuan *et al.* 2012).

Based on these knowledge and constraints, we have performed three-dimensional hydrodynamical numerical simulations to study the formation of the *Fermi* bubbles. The properties of wind such as the mass flux and velocity are not free parameters but are obtained from previous works on MHD numerical simulations of hot accretion flows once the mass accretion rate is given. The power of wind is $P_w = 2 \times 10^{41}$ erg s^{-1}. The supersonic winds blow into the ISM in the galactic halo, and produce shock. The contact discontinuity separating the shocked ISM and the shocked winds is the boundary of the *Fermi* bubbles. We find that this process can well explain the observed morphology of the *Fermi* bubbles. The active phases is required to last for about 10 million years and the later quiescent state should last for no more than 0.2 million years. Disc-like and massive Central Molecular Zone (CMZ), which are located along the galactic plane around Sgr A*, changes the wind orientation to be approximately towards Galactic poles. This is the reason why we obtain a narrow waist of the *Fermi* bubbles near the galactic plane. Viscosity suppresses the Rayleigh-Taylor (RT) instability and Kelvin-Helmholtz (KH) instability, inducing a smooth edge of the bubble. The observed ROSAT X-ray features can be interpreted by the shocked interstellar medium (ISM) and the interaction region between wind and CMZ gas. We find that the temperature in the shocked ISM at high

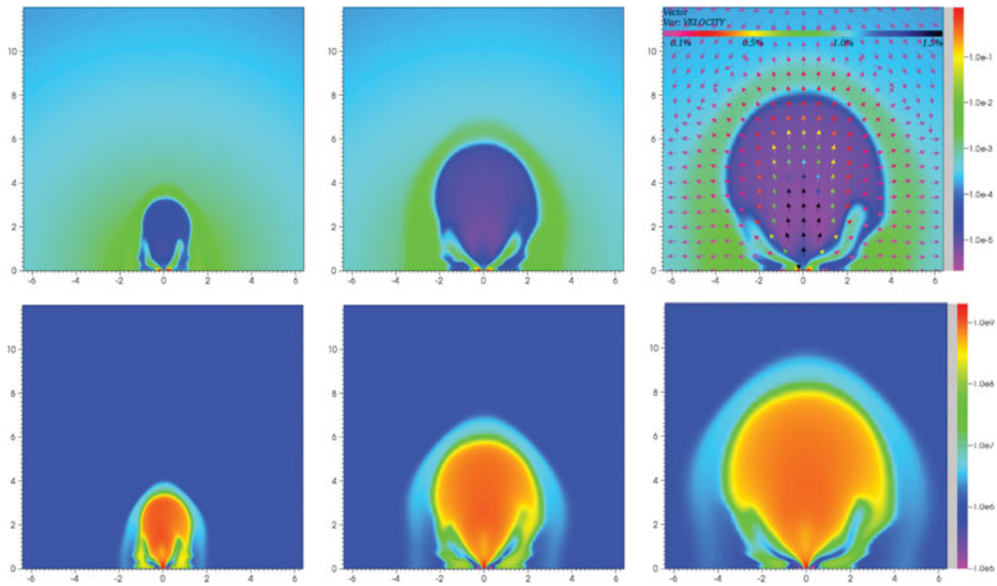

Figure 1. Evolution of electron number density (top) and temperature (bottom) distributions in the X-Z slice. Taken from Mou *et al.* (2014). From left to right, the plots correspond to $t = 4$, 8, and 12.3 Myr, respectively. The velocity field is added in the top right panel with values in units of the light speed.

latitude ($\geqslant +40°$) is about 0.4 keV, and the thermal pressure is 1.2×10^{12} dyn/cm^2. These values are in very good consistency with the results of 0.3 keV and 2×10^{12} dyn/cm^2 obtained in the recent Suzaku observations (Kataoka *et al.* 2013). We leave the study of the production of γ-ray photons and the explanation of the spectrum to our next work (Mou *et al.* 2015, in preparation.).

References

Kataoka, J., Tahara, M., Totani, T., *et al.* 2013, *ApJ*, 779, 57
Mou, G., Yuan,F., Bu, D., Sun, M. & Su, M., *ApJ*, 790, 109
Su, M., Slatyer, T. R., & Finkbeiner, D. P. 2010, *ApJ*, 724, 1044
Totani, T. 2006, *PASJ*, 58, 965
Yuan, F., Bu, D., & Wu, M. 2012, *ApJ*, 761, 130
Yuan, F. & Narayan, R. 2014, *ARA&A*, 52, 529

https://doi.org/10.1017/S1743921315007711 Published online by Cambridge University Press