MODELLING OF BLACK HOLE ACCRETION INDUCED BY DYNAMICAL PERTURBATIONS

Matas Tartėnas[1], Kastytis Zubovas[1,2]

[1]Faculty of Physics, Vilnius University, Lithuania
[2]Department of Fundamental Research, Center for Physical Sciences and Technology, Vilnius, Lithuania
matas.tartenas@gmail.com

Currently, the black hole at the center of the Milky Way is inactive, but there are reasons to believe it was not always so and there were at least two activity periods in the recent past [1]. The first of these, happening a few million years ago, could be responsible for the formation of the Fermi bubbles [2]. It is suggested that such an event could be initiated by a perturbation of the molecular gas ring that surrounds the black hole by an infalling molecular cloud.

We aim to reproduce the activity period with a pair of models: a hydrodynamical Gadget-3 model of the several-parsec-wide region of the Galactic centre and a thin α accretion disc around the central black hole. The hydrodynamical model consists of three main components: the central black hole ($M_{\rm bh} = 4 \times 10^6\,{\rm M}_\odot$), the CNR-like toroidal gas ring ($M_{\rm r} = 10^4\,{\rm M}_\odot$, $R_{\rm in} = 1.5\,{\rm pc}$, $R_2 = 4\,{\rm pc}$) and the infalling molecular cloud ($M_{\rm mc} = 10^4\,{\rm M}_\odot$, $R_{\rm mc} = 1\,{\rm pc}$). The accretion disc is fed by the particles that cross a sink boundary ($r_{\rm sink} = 0.01\,{\rm pc}$) in the hydrodynamical model. Our accretion disc extends from $3\,R_{\rm s}$ to $26107\,R_{\rm s}$ and consists of 151 rings.

By varying the initial inclination angle (γ) of the orbit of the molecular cloud we change the outcome of the encounter, including the feeding rate of the central accretion disc and the morphology of resulting structures. After the accretion disc feeding rates are determined in each simulation, we use them as input parameters in the corresponding accretion disc simulations. We feed the accretion disc at five different feeding radii to investigate the effects of feeding by gas carrying different angular momenta.

We find that the feeding rate of the central accretion disc is dependent on the initial angle and reaches up to $\sim \dot{M}_{\rm Edd}$. The $\log(M_{\rm total})$ transferred to the central accretion disc (Fig. 1) can be approximated by a linear function:

$$\log M/M_0 \approx 2.34^{+0.14}_{-0.15} \times 10^{-2}\gamma - 4.34^{+0.22}_{-0.19}.$$

Also the morphology of the system is affected by the change in γ: systems with initial infall angle $\gamma \geq 60^\circ$ produce a central disk and more highly inclined initial orbits lead to a more compact and less massive resulting ring. After the most extreme collision, the energy liberated during the nuclear activity period is equal to about 4.5% of the energy required for Fermi bubble formation ($E_{\rm Fermi} \approx 3.2 \times 10^{58}\,{\rm erg}$) with initial ring mass $\sim 10^4 {\rm M}_\odot$. The highest possible ring mass ($\sim 10^6 {\rm M}_\odot$), combined with an equivalent cloud mass, would produce the required energy.

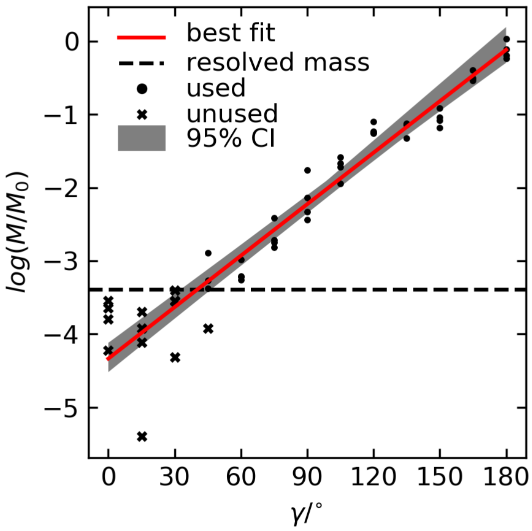

Fig. 1. The total mass transferred to the central accretion disc during the activity period (~ 0.5 Myr) with different initial collision angles γ

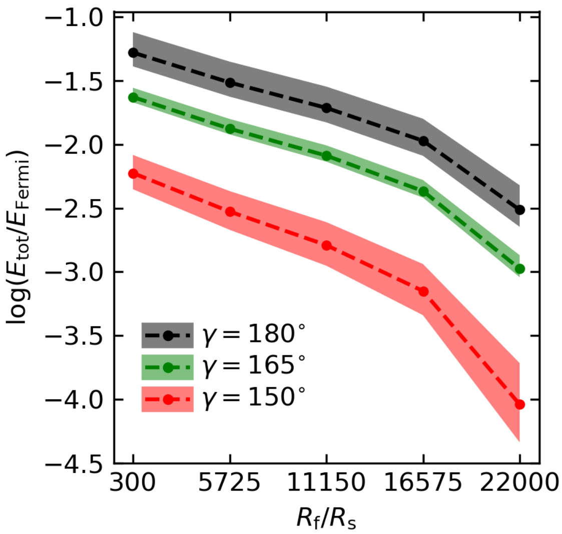

Fig. 2. The total energy released during the activity period at with different feeding radii $R_{\rm f}$ in the units of $E_{\rm Fermi}$

[1] Ponti G., Morris M. R., Terrier R., Goldwurm A., 2013, in Cosmic Rays in Star-forming Environments, edited by D. F. Torres, O. Reimer, vol. 34 of Astrophysics and Space Science Proceedings, 331.
[2] Zubovas K., Nayakshin S., 2012, MNRAS, 424, 666.