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ACCRETION OF STELLAR WINDS IN THE GALACTIC CENTRE

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RESUMEN

Sgr A* está identificado como el hoyo negro supermasivo $M_{\rm BH} \sim 3.5 \times 10^6$ M$_\odot$ en el centro de la Galaxia (SMBH). Por su proximidad, Sgr A* puede jugar un papel clave en la comprensión de los núcleos activos de galaxias (AGN).

ABSTRACT

Sgr A* is identified with the $M_{\rm BH} \sim 3.5 \times 10^6M_\odot$ super-massive black hole (SMBH) at the centre of our Galaxy. By virtue of its proximity, Sgr A* may play a key role in the understanding of Active Galactic Nuclei (AGN). Indeed, this is the only AGN where observations detail the origin of the gas in the vicinity of the SMBH. This information is absolutely necessary for the accretion problem to be modelled self-consistently.

Key Words: **ACCRETION, ACCRETION DISCS — GALAXY: CENTER — STARS: WINDS, OUTFLOWS**

1. INTRODUCTION

One of Sgr A* puzzles is its low luminosity with respect to estimates of the accretion rate. From *Chandra* observations, one can measure the gas density and temperature around the inner arcsecond[4] and then estimate the Bondi accretion rate (Baganoff et al. 2003). However, hot gas is continuously created in shocked winds expelled by tens of young massive stars near Sgr A*, so the situation is far more complex than in the idealised, symmetric and steady state, Bondi model.

An alternative approach is to model the gas dynamics of stellar winds, assuming that the properties of the wind sources are known (Coker & Melia 1997; Rockefeller et al. 2004; Quataert 2004). Here we present the first numerical simulations of wind accretion onto Sgr A* that include optically thin radiative cooling and allow the wind-producing stars to be on Keplerian orbits.

2. METHOD AND INITIAL CONDITIONS

A full account of our numerical method along with validation tests was presented elsewhere (Cuadra et al. 2005b). Here we describe only briefly the method. We use the SPH/N-body code GADGET-2 (Springel 2005) to simulate the dynamics of stars and gas in the gravitational field of the SMBH. The SMBH itself is modelled as a "sink" particle (Springel et al. 2004), with all the gas passing within a given distance from it (0.07″ in the present simulation) disappearing from the computational domain. To model the stellar winds, new gas particles are continously created around the stars.

The initial conditions are chosen to broadly reproduce the observed stellar population and dynamics (Paumard et al. 2001; Genzel et al. 2003). We introduce two stellar types: luminous blue variable candidates (LBVs) with wind velocity $v_{\rm w} = 300$ km s^{-1}, and Wolf-Rayet stars (WRs) with $v_{\rm w} = 1000$ km s^{-1}. We distribute the stars in two perpendicular discs, with radial extents 2–5″ and 4–8″. We use 20 wind sources, 6 LBVs and 2 WRs stars in the inner disc, plus 3 LBVs and 9 WRs in the outer disc. Each star has the same mass loss rate of $\dot{M}_* = 4 \times 10^{-5}M_\odot$yr^{-1}.

3. RESULTS

Two-phase gas. Figure 1 shows the resulting morphology of the gas 2450 yr into the simulation. Cool dense regions in the gas distribution are mainly produced by winds from LBVs. When shocked, these winds attain a temperature of only around 10^6 K, and, given the high pressure environment of the inner parsec of the GC, quickly cool radiatively (Cuadra et al. 2005a). LBV winds form bound clouds of gas, often flattened into filaments due to the SMBH potential. As more filaments are formed in the inner region, they start overlapping and eventually form a disc at $R \sim 1''$. This disc appears to be inconsistent with current observations. The most likely reason for this discrepancy may be ascribed to the specific initial conditions we used. In particular, placing many LBVs in the same plane at a short distance from

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[4] 1″ corresponds to $\sim 10^{17}$cm or $\sim 10^5 R_{\rm S}$ for Sgr A*.

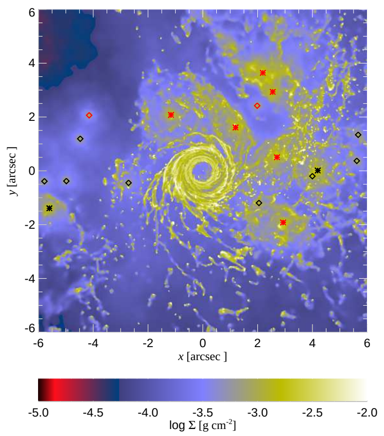

Fig. 1. Column density of gas in the inner $6''$ of the computational domain. Stars of the inner disc are shown as red symbols, while the ones on the outer disc appear in black. Asterisks mark LBVs, whereas diamonds mark WRs. The inner stellar disc is face-on, while the outer one is seen edge-on.

the SMBH is particularly favourable for the development of a disc. Newer observations show that LBVs and WRs are more evenly distributed between both discs (Paumard et al. 2006). We also ran simulations where the stellar orbits are oriented randomly (Cuadra et al. 2005b). In this case there is no preference for a particular plane and no disc was formed.

Variable accretion. Figure 2 shows the accretion rate onto the SMBH as a function of time. The accretion of hot gas proceeds at a fairly constant rate, at a value $\dot{M}_{\rm BH} \approx 3 \times 10^{-6} {\rm M}_\odot\ {\rm yr}^{-1}$, consistent with the *Chandra* estimates (Baganoff et al. 2003). In addition to this component, the accretion of cold clumps occurs in short bursts. The actual rate of accretion onto the SMBH has still to be determined by the accretion flow physics that we cannot resolve here, but it is expected to maintain most of the variability in time-scales longer than ~ 100 yr. In the extreme sub-Eddington regime of Sgr A* accretion, the dependence of the luminosity on the accretion rate is very non-linear (e.g., Yuan et al. 2002). Thus, even small changes in the accretion rate could result in a strongly enhanced X-ray emission.

4. CONCLUSIONS

We presented our new numerical simulations of wind accretion onto Sgr A*. Compared with previous works, our methodology includes a treatment of stellar orbits and of optically thin radiative cooling. While the results depend on the assumptions about stellar mass loss rates, orbits, and wind velocities, some relatively robust conclusions can be made.

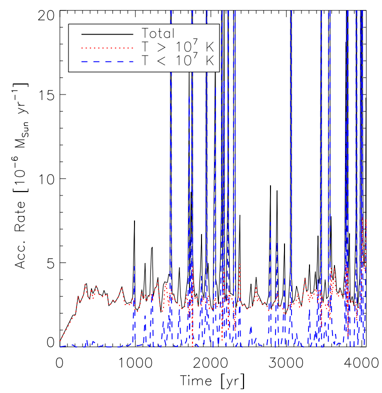

Fig. 2. Accretion rate onto the SMBH as a function of time (black line). This rate is then divided into that of hot gas (red) and that of low temperature gas (blue).

We find that the gas at $r \sim 1''$ distances from Sgr A* has a two-phase structure, with cold filaments immersed into hot X-ray emitting gas. Depending on the orbital distribution of the mass-loosing stars, the cold gas may be settling into a coherent structure such as a disc, or be torn apart and heated to X-ray emitting temperatures in collisions. The accretion rate we obtain is consistent with the *Chandra* estimates. The accretion of cooler gas proceeds via clump infall and is highly intermittent, although the average accretion rate is dominated by the quasi-constant inflow of hot gas.

The variable accretion rate implies that the current very low luminosity state of Sgr A* may be the result of a relatively unusual quiescent state. The role of Sgr A* for the energy balance of the inner region of the Galaxy may therefore be far more important than its current meager energy output would suggest. Observations of γ-ray/X-ray echos of past activity of Sgr A* (Revnivtsev et al. 2004) seem to confirm these suggestions from our simulations.

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