INFLUENCE OF STELLAR COMPONENT ON THE CONDITIONS FOR THERMAL INSTABILITY IN THE GALACTIC CENTER MINISPIRAL REGION

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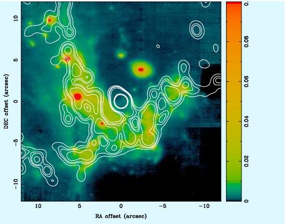
Previously we demonstrated that collisions between clumps of gas in the Circum-Nuclear Disc can reduce their angular momentum and set some of the clumps on a plunging trajectory towards the supermassive black hole. If the central luminosity is determined by the gas accretion mechanism, then there exists a certain range of accretion rate and efficiency that allow the thermal instability to sustain the mass inflow through the two-temperature medium. Here we explore the stellar component of the nuclear star cluster which acts as an additional source of heating and contributes an additional energy input into the gaseous environment in the Galactic center Minispiral region.



Mini-spiral as a source of material for Sgr A*
(**Kunneriath et al. 2012**)

Introduction

Field (1965) showed that a thermal instability can arise in the interstellar medium for certain ranges of parameters, leading to the formation of a two-phase medium where cold, denser matter coexists with a rarified hot medium in pressure equilibrium. The circumnuclear region of Sgr A* contains a dense nuclear star cluster, in addition to a reservoir of partially ionised cold clumps ($T \sim 10^4 K, n_e \sim 10^4 cm^{-3}$) in the mini-spiral, surrounded by the hot ionized plasma ($T \sim 10^7 K, n_e \sim 30 cm^{-3}$). The two media appear to be in mutual contact and the pressure equilibrium can be established.

Observations of an X-ray echo from the large molecular clouds surrounding Sgr A* indicate that it was highly active a few hundred years ago **(Sunyaev et al. 1993, Koyama et al. 1996, Ponti et al. 2010)**. **Czerny et al. (2013)** suggested that accretion of relatively dense gas from the mini-spiral passing through a transient accretion ring at about 10^4 gravitational radii of the supermassive black hole provides a viable scenario to trigger the bright phase of the Galactic center.

Model

Różańska et al. (2014) considered the effect of thermal instability in supporting the scenario of **Czerny et al. (2013)** for the enhanced accretion of clouds during the past active period of Sgr A*. In this work, we extend the previous analysis to include the energy input of the nuclear stellar cluster by radiative heating and wind outflows.

We use Cloudy photoionisation code (**Ferland et al. 2013**) to set up a simplified model of the two-phase ISM in the GC, using photoionisation calculations with a proper treatment of all cooling and heating mechanisms operating in the region for three cases:
(i) radiative heating by the accreting central black hole (**Różańska et al. (2014)**),
(ii) with additional radiative heating by the stellar cluster, and
(iii) with additional mechanical heating by stellar winds.
A similar operation of Thermal Instability can be seen in numerical simulations of **Barai et al. (2012)**.

Results

Thermal instability for different states of luminosity

We consider a broad range of the possible bolometric luminosities of Sgr A* from **Moscibrodzka et al. (2012)** as described in **Różańska et al. (2014)**. We describe the stellar light using the spectral template for stars of solar metallicity and age 6 Myr from Starburst99 (**Leitherer et al. 1999**). Assuming a stellar mass input of $10^{-8} M_\odot \mathrm{yr}^{-1}$ and wind velocity 1000 km s^{-1} at a distance of $0.2''$ from the nucleus, and stellar mass input of $3 \times 10^{-8} M_\odot \mathrm{yr}^{-1}$ and wind velocity 1200 km s^{-1} at a distance of $5''$ (**Shcherbakov & Baganoff 2010**), we calculate a heat input of

$$Q_\star = 1.0 \times 10^{-19} \mathrm{erg\,s^{-1}cm^{-3}} \ \text{at} \ \ r = 0.2'', \qquad (1)$$

$$Q_\star = 3.0 \times 10^{-17} \mathrm{erg\,s^{-1}cm^{-3}} \ \text{at} \ \ r = 5''. \qquad (2)$$

for the nuclear stellar cluster.

We see that addition of stellar light to the radiative heating by a central source results in a decrease of the temperature of the irradiated medium, especially in the case of lower luminosities of Sgr A*. Since the central emission has the strong X-ray component, the addition of a blue light lowers the Inverse Compton temperature of the incident radiation. **Furthermore, the inclusion of the mechanical heating by the shocked stellar winds changes the picture dramatically.** We were not able to cover the low density range for the case of Sgr A* high states. Even for the displayed range, densities from $\log(n/cm^{-3}) = 2.5$ to $\log(n/cm^{-3}) = 6.25$ show unrealistic extreme temperatures.

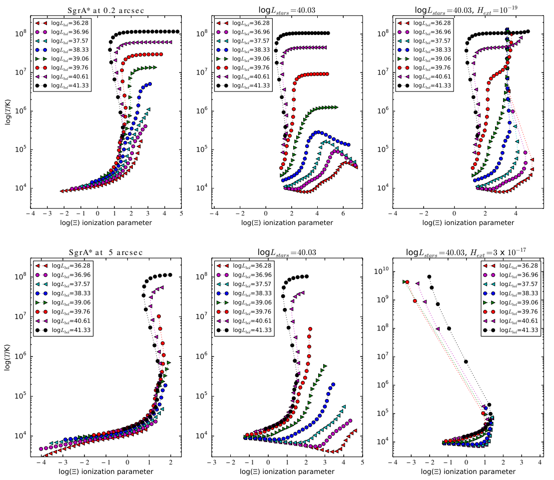


Figure 1: Instability curves, i.e. log(T) versus log(Ξ), for clouds located at $0.2''$ (top) and $5''$ (bottom), for three cases: radiative heating only by Sgr A* (left), radiative heating by Sgr A* and the stellar cluster (middle), and the radiative heating by Sgr A* and stars, along with heating by stellar winds (right).

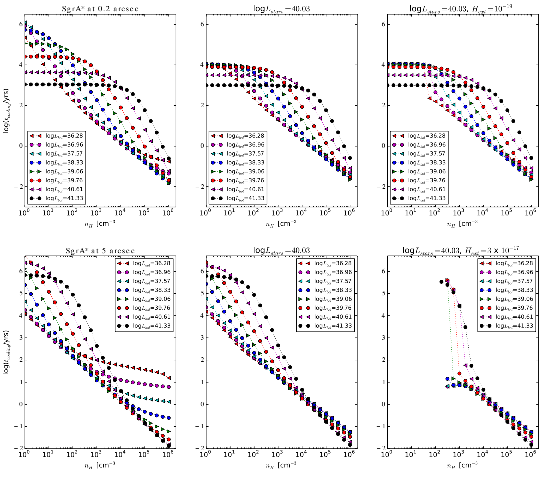


Figure 2: Dependence of cooling time on the cloud number density for clouds located at $0.2''$ (top) and $5''$ (bottom), for three cases: radiative heating only by Sgr A* (left), radiative heating by Sgr A* and the stellar cluster (middle), and the radiative heating by Sgr A* and stars, along with heating by stellar winds (right).

Two-phase medium around Sgr A*

For the Bondi accretion flow starting roughly at the capture radius, we computed density and gas pressure profiles around Sgr A*, for an outer temperature $T_\mathrm{e}^\mathrm{out} = 3.5\,\mathrm{keV}$, and two different values of outer number density, $n_\mathrm{e}^\mathrm{out} = 18.3\,\mathrm{cm}^{-3}$ and $n_\mathrm{e}^\mathrm{out} = 1\,\mathrm{cm}^{-3}$. The regions of instability are shown in Fig. 3 in the form of strips. For all gas above the red contour, only hot phase can exist at a given luminosity while below the blue contour, only cold clouds can exist. **There are several distance ranges where two-phase medium can co-exist.** For Bondi flow with $n_\mathrm{e}^\mathrm{out} = 18.3\,\mathrm{cm}^{-3}$ (left panel of Fig. 3) it appears only for the two highest luminosities and quite close to Sgr A* within 0.4 pc, while for $n_\mathrm{e}^\mathrm{out} = 1\,\mathrm{cm}^{-3}$ the two-phase medium can be sustained up to 1.4 pc (right panel of Fig. 3). Thermal Instability is suppressed by the feedback from the Nuclear Star Cluster but it can still contribute to the mass accretion under certain conditions in the center of Sgr A*.

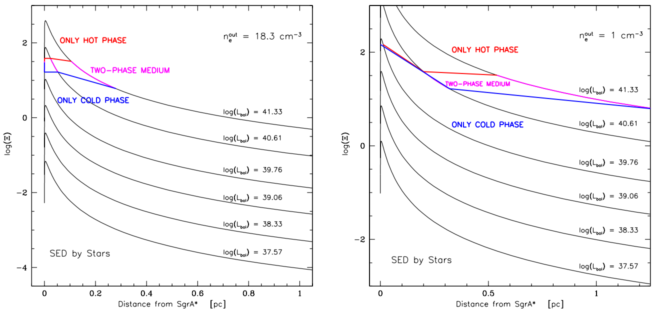


Figure 3: Instability strips for the different luminosity states in case of Bondi accretion flow onto Sgr A* for outer temperature $T_\mathrm{e}^\mathrm{out} = 3.5\,\mathrm{keV}$ and outer number density $n_\mathrm{e}^\mathrm{out} = 18.3\,\mathrm{cm}^{-3}$ (left) and $n_\mathrm{e}^\mathrm{out} = 1\,\mathrm{cm}^{-3}$ (right).

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Poster #A11, 'Spectral Components (AGN)'