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Multiple accretion events as a trigger for Sagittarius A* activity

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Abstract. The Galactic center supermassive black hole is surrounded by orbiting clouds of gas. These clumps of gas may collide with each other, losing angular momentum and plunging towards the center. Observations of X-ray reflection from molecular clouds surrounding the Galactic center show evidence for enhanced activity of Sagittarius A* during the past few hundred years. These observations enable us to place constraints on the nature of past accretion events responsible for this enhanced activity. We model the source intrinsic luminosity of Sgr A* using multiple accretion events occurring at various moments in time, characterized by a range of angular momentum We also applied our scheme to the case of G2 cloud in the Galactic center.

Keywords. accretion — accretion disks — Galaxy: center

1. Introduction

The supermassive black hole at the Milky Way center has a mass ($M_\bullet$) of about $4.4 \times 10^6 M_\odot$ (Genzel *et al.* 2010), and its position coincides with the Sagittarius A* (Sgr A*) source. It presently remains in a very quiet state (Eckart *et al.* 2005; Melia 2007). The current accretion rate is very low ($10^{-9} M_\odot \mathrm{yr}^{-1}$ to $10^{-7} M_\odot \mathrm{yr}^{-1}$, Marrone *et al.* 2007). However, observations of the X-ray reflection from molecular clouds in the Galactic center using *INTEGRAL* and *XMM-Newton* imply that Sgr A* was orders of magnitude brighter a few hundred years ago (see Ponti *et al.* 2010, and references therein). Cuadra *et al.* (2008) have shown that stellar winds do not explain such an enormous change in luminosity. An inflow of clumpy material, like the G2 cloud now approaching the Galactic center (Gillessen *et al.* 2012), is a more likely explanation. We model the number, frequency and strength of such accretion events in the past, using constraints provided by the X-ray reflection from molecular clouds.

2. Modeling a single accretion event

The G2 cloud is estimated to be around three Earth masses, $M_{\mathrm{cloud}} = 3M_\oplus$. It moves along a parabolic orbit, and will reach the minimum distance from Sgr A* ($R_{\mathrm{S}} \equiv 2GM_\bullet/c^2 \simeq 3 \times 10^5\, M_\bullet/M_\odot$ cm) in early 2014. G2 has already started to get disrupted as a result of the passage. The origin, properties, and trajectory of the cloud are still not precisely determined (Eckart *et al.* 2013a,b; Phifer *et al.* 2013). We assume that the cloud will be disrupted as it nears Sgr A*, and that a fraction of the cloud will settle in a circular orbit having radius less than the value of the corresponding pericenter.

Two qualitatively different possibilities emerge from simulations: (i) a long viscous timescale of $\sim t_{\mathrm{visc},1} = 200$ yr if the material is heated and forms a thin torus ~ 0.3 of the circularization radius, or (ii) a much shorter viscous timescale of $t_{\mathrm{visc},1} = 18$ yr, if the torus is thicker, for the same circularization radius. The bolometric luminosity would double in the first case, while in the second case, it can go up by a factor of ten. The accreting cloud should possess significantly larger mass in order to produce increased amount of luminosity. The results of this simple analysis are consistent with the results in Schartmann *et al.* (2012) and Anninos *et al.* (2012).

3. Intrinsic lightcurve of Sgr A* from multiple events

We use a model consisting of multiple discrete accretion events (infalling clouds), characterized by a range of angular momentum and occurring at various moments in time. We have used data from Ryu *et al.* (2013) and Capelli *et al.* (2012). The lightcurve is characterized by a variability of about a factor of three in the last few hundred years, followed by a decline of about four orders of magnitude in the last 60 years.

We require two further assumptions to be made in modeling the viscous evolution of the accreting clumps: (i) a dependence of the radiative efficiency of the flow on the Eddington ratio, and (ii) a viscous decay timescale faster than the canonical $\propto t^{-5/3}$ profile. We are able to reproduce the overall behavior of Sgr A* over a period from about 1400 till the 1930s with these assumptions. The total accreted mass is $M_{\rm tot} \simeq 0.15 \rm M_{\odot}$, for a viscous timescale of about 3 years (corresponding to the circularization radius $R_{\rm circ} \simeq 700 R_{\rm S}$). Our model is consistent with observational constraints for the evolution of the intrinsic luminosity of Sgr A* if the clumps have roughly the same angular momentum, mass and time separation during the active period.

Next we consider reprocessing of the light signals by the Sagittarius B2 cloud, taking into account the non-negligible dimension of the cloud. We neglect the role of multiple scattering, assuming the cloud to be spherically symmetric and optically thin. We model the density distribution within the cloud in three different ways: (i) a constant density $\rho_{\rm o}$, (ii) a two-component structure (core+envelope) with two different constant values of density within the core and envelope, and (iii) a gradually decreasing density profile in the envelope enclosing a constant density core. The best representation of the data was obtained with a core of size 0.25 pc, surrounded by an outer envelope of size 3.5 pc with the density decreasing as R^{-1}. For further details, see our recent paper (Czerny *et al.* 2013).

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