Magnetic field structure in the vicinity of a super-massive black hole in low luminosity galaxies: the case of Sgr A*

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ABSTRACT

Observations of SgrA* have provided a lot of insight on low-luminosity accretion, with a handful of bright flares accompanied with orbital motion close to the horizon. It has been proposed that gas supply comes from stellar winds in the neighborhood of the supermassive black hole. We here argue that the flow at the vicinity of the black hole has a low magnetization and a structure of alternating polarity totally dictated by the well studied and long-ago proposed MRI turbulent process. This can be the case, provided that in larger distances from the black hole magnetic diffusivity is dominant and thus the magnetic field will never reach equipartition values. For SgrA*, we show the immediate consequences of this specific magnetic field geometry, which are: (i) an intermittent flow that passes from quiescent states to flaring activity, (ii) no quasi-steady-state jet, (iii) no possibility of a magnetically arrested configuration. Moreover a further distinctive feature of this geometry is the intense magnetic reconnection events, occurring as layers of opposite magnetic polarity are accreted, in the vicinity of the black hole. Finally, we argue that the absence of a jet structure in such case will be a smoking gun in 43 & 86 GHz observations.

Key words: Black hole physics, Sgr A*, Magnetohydrodynamics

1 INTRODUCTION

The supermassive black hole (BH) in the Galactic center, Sgr A*, is the closest of its kind and is the subject of several campaigns of multi-wavelength observations, since it is an excellent probe for accretion physics in the extreme gravity regime. Over the years unparalleled insight on the accretion flow in the immediate environment of the central BH has been obtained (Falcke et al. 1998; Doeleman et al. 2008). Sgr A* is one of the primary sources for the Event Horizon Telescope (EHT) and GRAVITY collaborations yielding extraordinary results the last years and more expected to come (Johnson et al. 2015; GRAVITY collaboration et al. 2018).

Multi-wavelength observations have revealed a low accretion rate with an extremely low bolometric luminosity $L_{\text{bol}} \sim 10^{-9}L_{\text{Edd}}$, where $L_{\text{Edd}}$ is the Eddington Luminosity (Baganoff et al. 2003; Bower et al. 2019), which places the accretion flow of SgrA* in the regime of a radiatively inefficient accretion flow (Yuan & Narayan 2014).

Observations have hinted that around 80 massive stars reside in a rotating disk inside the parsec neighborhood of the Galactic center (Martins et al. 2007). It has been suggested that 30 of these massive stars, identified as Wolf-Rayet (WR) magnetized stars could source the accretion flow around the Galactic center (Quataert 2004; Loeb 2004; Shcherbakov & Baganoff 2009; Ressler et al. 2020b). This scenario has been studied in a multi-scale simulation (Ressler et al. 2020a) and suggested that the accretion flow around Sgr A* is in a magnetically arrested (MAD) state, moreover, its dynamics differ significantly from the rotationally supported tori usually used in the general-relativistic magnetohydrodynamic (GRMHD) community (Porth et al. 2019).

This novel multi-scale approach assumes ideal magnetohydrodynamics, which has as a consequence, coherent magnetic field from large radii to be continuously advected, to form a MAD flow in the vicinity of the black hole (Ressler et al. 2020b).

In what follows, we present a comprehensive description of what would be different assuming a dominant magnetic diffusivity in the process of accretion generated through the stellar winds. To this end, we describe two MHD simulations, one that monitors the evolution of the magnetic field in an accretion disk where the MRI has fully developed, and another one where the magnetic field...
of different polarity is advected on the low density region above the BH and results in flaring activity, which we call the FLARE model. Estimations of the overall energy of the produced flares are presented and discussed.

This latter is organised as follows: in Section 2 we discuss in detail the different implications that follow from these assumptions, in Section 3 we present results from numerical simulations of MRI turbulence and the magnetic field structure in the close-by accretion disk. In Section 4 we present a GRMHD simulation (FLARE model) that mimics the MRI turbulent state and where plasmoids are generated above the black hole, and then compare ray-traced images from this simulation. Finally, we summarize and conclude in Section 5.

2 DIFFUSION VERSUS FLUX-FREEZING ASSUMPTION AND MAGNETIC FIELD REVERSALS

The flow generated by stellar winds around SgrA* continuously accrete magnetic field, but as the field lines are dragged, they tend to diffuse out. This may limit any effective process of magnetic field dragging (Heyvaerts et al. 1996). As the flow and magnetic field are generated far from the BH, it needs to be advected all the way to its vicinity. However, at distances of $300 - 10000 \, r_g$ a diffusive accretion disk may form as MRI is triggered. This argument will hold if the MRI linear growth time scale is smaller than the viscous advection timescale, a robust estimation of this is not easy to be calculated.

The discussion about the efficiency of the magnetic flux-freezing assumption is not new, also MRI turbulent discs and the effect of magnetic diffusion have been studied for decades. However, to interpret EHT and GRAVITY results, such discussions are not put forward as relevant. In this short study we highlight the importance of these effects and propose that such long-studied effects are crucial in interpreting SgrA* results.

In the case that turbulent viscosity is of the same order of magnetic diffusivity, then the magnetic field is not dragged effectively. This is set by the magnetic Reynolds number, in its simplest form $R_m = uL/\eta$, where $u$ is the velocity of the flow, $L$ is the length scale and $\eta$ the resistivity/magnetic diffusivity. The value of the magnetic Reynolds number can set the process along the way from the ejection of the magnetized stellar winds, all the way to the central suppermassive BH (Balbus & Henri 2008). For high $R_m$ magnetic field dragging is highly efficient, whereas for values closer to unity and below this is not the case (Contopoulos et al. 2015). A transition of $R_m$ from low to high, if it occurs at all, will occur in the inner disk regions $R_m \sim \left( \frac{L}{1000 r_g} \right) \left( \frac{u}{100 \, \text{km/s}} \right) \ll 1$ (Faghei & Mollatayefeh 2012). We need to note that in the simulations reported here, no physical resistivity was used and only numerical diffusion is present.

Thus, any flux-freezing argument will fail to produce a dynamically important magnetic field at the vicinity of the BH. The situation will be different (from the MAD configuration) with a turbulent inner-region accretion disk, which will be weakly magnetized and MRI is fully operating from the seed poloidal field that came from the stellar winds. Now if the magnetic field is not strong enough to suppress the MRI, the field reversals will occur with a predetermined period. From recent sheering box simulations we can extract that magnetic field reversals occur in around 10 local orbital periods, where local refers to $\approx 10 R_g$ (extracted from the simulation (Dhang & Sharma 2019), also see (Hogg & Reynolds 2018)). As was pointed out previously, the accretion disk could be MRI unstable from a radius of $300 - 10000 \, r_g$, however, this will not set the scale of the changing of magnetic field polarity as is shown in the simulations (Dhang & Sharma 2019; Hogg & Reynolds 2018).

This will set the length scale and the timescale of field reversals, assuming that the local orbital period is $T_{local} = \frac{2\pi (R_g/c)}{R_{local} / R_g} \approx 200 R_g / c$, and then the corresponding timescale for magnetic field reversals is $T_{mag} \approx 2 \times 10^3 R_g / c$, which to length scale of $l_{mag} \approx 10^5 R_g$ (Giannios & Uzdensky 2019). This length could hint also to the transition radius and maybe important for the particular case of SgrA* (Quataert & Narayan 1999; Xu 2013). It is important to note here that our estimations are based on the simulations of Dhang & Sharma (2019) and thus the influence of the spin of the black hole is not taken into account this could potentially affect the resulting timescale.

In order to clearly differentiate the consequences for each assumption we list them respectively, to show the important implications that each assumption leads to. At this point we take the two different assumptions (i) dragging of magnetic field is effective and the flux-freezing argument holds and (ii) that magnetic diffusivity is dominant at some point of the flow through the millions of gravitational radii that travels from the stellar winds to the BH. The discussion for the two different cases is summarized in Table 1.

For case (i) multi-scale simulations have shown that the accretion flow becomes magnetically arrested and a MAD state is established. The dynamically important magnetic field suppresses the MRI which is no longer important for the evolution of the inner-region flow (Ressler et al. 2020a). A narrow disk-like structure is produced around the central BH due to the impact of the strong magnetic field (Ressler et al. 2020b). A MAD configuration is always accompanied with a magnetized jet along the axis of the angular momentum of the BH (for a spinning BH, tilted disks excluded), MAD jets are expected to have huge power and this is yet to be observed for SgrA*. This has also a straight consequence in the

| Table 1. Consequences of the two different assumptions that (i) magnetic field dragging and flux-freezing is effective and (ii) that magnetic diffusion is dominant |
|---------------------------------|-----------------|-----------------|
| flux-freezing effective        | diffusion dominant |
| MAD suppressed                 | active MAD jet   |
| expected outflow power         | huge and steady  |
| 43 & 86 GHz image              | extended jet base|
| non-extended (when non-flaring) | maybe extended when flaring |
compact radio image of the source (Anantua et al. 2020), which however may not be so strong in the frequency that EHT is observing, the 230 GHz, but rather in 43 and 86 GHz where any extended emission from the jet base with strongly affect and enlarge the image sizes (Davlaar et al. 2018). Also a MAD configuration has certain restrictions when applied to the whole spectrum of SgrA*, in order to fit both the standard flux in quiescence and when flaring occurs (Chatterjee et al. 2020).

The last point to touch, is about the ability of a MAD state accretion for SgrA* to provide the observed flaring activity together with the characteristics, like the observed orbital motion during flares as observed by GRAVITY collaboration et al. (2018). Reconnection events and flux eruptions that periodically occur in MAD simulations were put in place to explain the flares together with their detailed characteristics (Dexter et al. 2020). The computed near-infrared (NIR) lightcurve are promising, however the flux centroid motion from the simulation NIR flares is much more restricted than the observed one. Moreover, the orbiting flux tubes that can potentially explain the flares show a sub-keplerian motion (Porth et al. 2021), whereas hot spot models of the flux centroid motion during the flares hint to a super-keplerian motion (Matsumoto et al. 2020). Another important observational feature that we could potentially distinguish models is polarization, previous results have hinted to a rather significant polarization fraction (Johnson et al. 2015), however to analyze polarization measurements from numerical simulations is not a trivial step (Gold et al. 2017).

In the second case (ii), the whole picture of the inner disc accretion flow close the central BH, is different. The magnetic field is not so strong and MRI is not suppressed, thus is active and may dictate the field accretion. A well-known and deeply studied phenomenon in accretion discs with a stratification is an oscillating mean toroidal magnetic field. Toroidal magnetic field buoyantly rises from the mid-plane to the upper coronal regions. This unique feature is commonly referred to as the butterfly diagram, and is has been seen from local (Brandenburg et al. 1995; Hawley et al. 1996) but also in global simulations (Beckwith et al. 2011; Sorathia et al. 2012).

In the scale-free simulations, the oscillating toroidal magnetic field changes sign approximately every 10 local orbits, which scaled for SgrA* yields a 6-8 hour periodicity at around \(\lesssim 20 r_g\) from the BH. However, it must be pointed out that unlike a geometrically thin disc, for a geometrical thick radiatively inefficient accretion flow (RIAF), the dynamo cycle is intermittent, both poloidal and toroidal fields flip sign irregularly (Hogg & Reynolds 2018; Dhang & Sharma 2019; Dhang et al. 2020, also see Fig. 2). These dynamo generated large-scale magnetic fields tend to be affected by the turbulent pumping (an effect which transports large-scale magnetic field from the turbulent region to the laminar region) resulting in transport of large-scale magnetic fields from the turbulent disc region to the less turbulent coronal region (Dhang et al. 2020). Hence this alternating polarity magnetic field can reconnect either inside the high \(B\) disk giving rise to heating of the inner disk, or at the low density and low \(\beta\) (highly magnetized) polar region above the BH and eventually form hot spots/ plasmoids that can become unbound and fly away from the black hole.

Reconnection in the vicinity of the black hole is operating and gives rise to plasmoid formation (Parfrey et al. 2015; Mahlmann et al. 2020; Nathanail et al. 2020; Ripperda et al. 2020). In the next Section we will present results from such a simulation and give estimates on the energy that such flares have. Such conditions could give a similar radio image in the 230GHz, but there will be a significant difference in the 43 & 86 GHZ. During a quiescent state the radio image in these frequencies will be less extended than the MAD case due to the absence of a jet. On the other, a radio image at these observed simultaneously with a flare, would be expected to have several larger scale features, which would imply an extended size, maybe similar to the MAD case. In this case models for flares accompanied with orbiting motion in horizon scales can be expected as the ones found in GRMHD simulations Nathanail et al. (2020) and will be also discussed in Section 4. These models would be similar to the plasmoid model from Ball et al. (2020).

### 3 MRI-TURBULENCE

The problem of angular momentum transport in accretion flows and the source of turbulence can be addressed through the action of the MRI which was studied by Velikhov (1959); Chandrasekhar (1960), but put into play to resolve this long-standing problem by Balbus & Hawley (1991). The linear and the non-linear regimes of the MRI have been studied in local shearing box simulations, recently also in global simulations (Beckwith et al. 2011; Hogg & Reynolds 2018; Dhang & Sharma 2019; Dhang et al. 2020) and
Table 2. Energetics of the reported flares in Fig. 3 at 4620 M in the upper panel and at 7800 M in the lower panel. The assumption on the accretion rate is reported in the first column, then the simulation time, the magnetic and total energy and the ratio between the magnetic field components.

| $m$ [M$_\odot$/year] | time [M] | magnetic energy [erg] | total energy [erg] | $B_z/B_\phi$ |
|----------------------|----------|-----------------------|-------------------|-------------|
| $10^{-7}$            | 4620     | $8.9 \times 10^{38}$  | $3 \times 10^{39}$ | 1.14        |
| $10^{-8}$            | 4620     | $8.9 \times 10^{37}$  | $3 \times 10^{38}$ | 1.14        |
| $10^{-7}$            | 7800     | $1.4 \times 10^{38}$  | $5 \times 10^{38}$ | 1.46        |
| $10^{-8}$            | 7800     | $1.4 \times 10^{37}$  | $5 \times 10^{37}$ | 1.46        |

GRMHD high resolution simulations (Liska et al. 2018). How a large-scale magnetic field is generated in an accretion flow is still debatable. The advection of the magnetic field from large radii has been proposed (Lubow et al. 1994; Lovelace et al. 2009) or the in situ production of a large scale magnetic field by a dynamo process (Brandenburg & Nordlund 2011). The production in the vicinity of the BH has been also proposed to be dictated by a battery process that has distinctive observational signatures (Contopoulos & Kazanas 1998), however for an AGN with luminosity as low as that one of SgrA* would require an extremely long timescale to build such a field (Contopoulos et al. 2015, 2018).

We are particularly interested in the generation of a large scale magnetic field by the MRI driven dynamo in a weakly magnetised RIAF (Beckwith et al. 2011). Here we will describe the results from the global 3D MHD simulation that investigates such generation of magnetic fields and the self-sustained dynamo process in a geometrically thick radiatively inefficient (RIAF) accretion disk (model M-2P of Dhang & Sharma (2019)). The simulation has an inner/outer radius of $4R_g/140R_g$ respectively and a resolution of $(r, \theta, \phi) = (296, 128, 512)$ It is important to note that to have such a high resolution in the disk and also close to the event horizon is costly and forbidden for present simulations, for this reason we employ one simulation that focuses in the disk evolution and another that focuses on the black hole activity. The simulation is initialised to an equilibrium torus (Papaloizou & Pringle 1984) threaded by the poloidal magnetic field loops of plasma $\beta \sim 800$, such that the magnetically, RIAF remains in the regime of standard and normal evolution (SANE) type of accretion disk in the quasi-stationary state.

Fig. 1 shows the evolution of the magnetic energy in the accretion flow. Time evolution follows this path: initially both poloidal ($B_r$ and $B_\theta$) and toroidal ($B_\phi$) components of the magnetic field grow exponentially. The poloidal components are amplified by the linear MRI, while shear generates the toroidal components with different sign above and below the equatorial plane. In due time the system enters the non-linear regime and parasitic instabilities become important (Goodman & Xu 1994), leading to the full development of turbulence throughout the accretion disk. Here it is to be noted that the initial zero toroidal magnetic component evolves in time to increase significantly comprising of almost eighty percent of the total magnetic energy in the quasi-steady state.

Fig. 2 shows the evolution of the azimuthally averaged radial ($\bar{B}_r$) and toroidal ($\bar{B}_\phi$) magnetic fields with latitude ($90^\circ - \theta$) and time at a radius $r = 20 R_g$. While the strong shear transforms the poloidal fields into the toroidal fields, the poloidal fields can be regenerated by an $\alpha$-effect out of the toroidal fields (Brandenburg et al. 1995; Dhang & Sharma 2019; Dhang et al. 2020). This cycle goes on resulting in large-scale magnetic fields (both poloidal and toroidal) of alternate polarity in time and develops a butterfly dia-

Figure 3. Different states during the evolution of the accretion flow with a bright flare (upper panel), a state of quiescence (middle panel) and another flare (lower panel). In both flares an orbiting plasmoid/hot spot can be identified. The time lapse from the upper to the middle panel is 10 hours and from the middle to the lower 7.5 hours (for SgrA* scales). The first column shows the magnetization $\sigma$, the middle column the criterion for unbound matter $h_u$ (where $h_u > 1$ means unbound) and the last column the toroidal magnetic field $B_\phi$. The reported snapshots are from the 2D FLARE simulation.

This is a phenomenon widely known and found in local and global simulations of accretion disks that study the MRI, moreover several studies hint to a certain periodicity, which for SgrA* would be a matter of hours (Brandenburg et al. 1995; Hawley et al. 1996; Sorathia et al. 2012; Hogg & Reynolds 2018; Dhang & Sharma 2019).
A strong turbulent pumping is present in the MRI driven dynamo giving rise to transport of the large-scale fields from the turbulent region close to the mid-plane to the less turbulent coronal region (Dhang et al. 2020). Accretion of the large-scale magnetic fields is found to be more efficient in the coronal region compared to that in the disc (Guilet & Ogilvie 2013). As these alternating polarity magnetic fields are advected onto the black hole, they reconnect and produce structures, such as plasmoids. In some cases the plasmoids fall onto the BH but they may also become energised and eventually become unbound and responsible for flaring activity.

4 THE DIFFERENT STATES OF SGR A* AND IMAGE DIFFERENCES

In this section we first discuss how the accretion of the butterfly diagram onto the BH may give rise to distinctive flaring features and present a qualitative description of the results discussed thoroughly in (Nathanail et al. 2020, 2021) called the FLARE model, and then show results of ray traced images in general relativity (GRRT) in order to show the size of the image changes for MAD models and the FLARE models we have discussed here. These features can account for the different states observed in the compact region at the center of our galaxy, SgrA*. We report high resolution, 2D (Nathanail et al. 2020) and 3D (Nathanail et al. 2021) GRMHD simulations performed with the BBAC code Porth et al. (2017), a logarithmic grid is employed with $4096 \times 2048$ in $r$ and $\theta$ for the 2D simulation, whereas an effective resolution of $1050 \times 768 \times 384$ in $r$, $\theta$ and $\phi$ for the 3D, an outer boundary at $2500 \, r_g$ and $500 \, r_g$ respectively, and a Kerr spacetime with a dimensionless spin parameter of $a = 0.9375$ for both 2D and 3D. The inner and outer radii of the torus are at $r_{\text{in}} = 6 \, r_g$ and $r_{\text{out}} = 12 \, r_g$. When the simulation reaches a steady state the average normalized magnetic flux at the horizon is $\Phi_{BH} / \sqrt{m} \approx 0.5$. This magnetic flux fluctuates, as the loops annihilate, but never approach the MAD value. The setup for the MAD simulation has an effective resolution of $384 \times 384 \times 384$ in $r$, $\theta$ and $\phi$, an outer boundary at $2500 \, r_g$, the same Kerr spacetime and inner and outer radii of the torus are at $r_{\text{in}} = 20 \, r_g$ and $r_{\text{out}} = 41 \, r_g$. Apart from the disk size, the major difference between MAD and FLARE simulations are the initial magnetic field configuration, for MAD this is a nested loop embedded in the initial torus and for FLARE the initial torus configuration is seeded with loops of alternating polarity.

In the FLARE model loops of alternating polarity are advected with the flow to the BH. This setup does not yield a persistent jet structure, but may produce striped jets (Giannios & Uzdensky 2019). The evolution of such an accretion flow together with its characteristics was presented in detail in Nathanail et al. (2020, 2021). Here, we restrict into a consideration of these simulation with a comparison to the activity of SgrA*. Our focus is to find,
during the evolution of the accretion disk and the advection of the magnetic loops, times that the whole system is radically changing behavior. At the point that two layers of different magnetic field polarity merge in the low density region above the BH, plasma gets energy and forms plasmoids through magnetic reconnection, these features become unbound and leave the BH in a spiral outward orbit, as seen in the upper panel of Fig. 3. After a major reconnection event, we usually observe a quiescent state for some time (middle panel of Fig. 3), till the flow builds a considerable magnetic flux of one polarity. This structure is subsequently annihilated by the advection of magnetic flux of different polarity and another flare (unbound plasmoids, identified through a cutoff in magnetization) is generated, as in the lower panel of Fig. 3, with a recurring timescale of ~1200 M. Flare from flare may differ in overall energy, which depends on the amount of magnetic flux that reconnects at the reconnection site. To estimate the energy of each flare we assume a mass accretion rate of \(10^{-7} - 10^{-8} M_\odot/\text{year}\), for the two boundary values of this range we estimate the energy in the flares and report them in Table 2. Since our simulations are 2D, we assume an angular size of \(\pi/10\) for the plasmoids. The resulting energetics acquire enough energy to explain bright flares from SgrA* (Bouffard et al. 2019). Another important point is that the magnetic field in the flares is predominantly poloidal, as seen in the last column of Table 2, and thus could explain the linear polarisation reported (GRAVITY collaboration et al. 2018), note that this does not hold inside the dense accretion disk where the field is mostly toroidal due to the MRI and the differential rotation.

To further compare the standard MAD GRMHD simulations (see, e.g., Cruz-Osorio et al. 2022; Fromm et al. 2021) with the ones reported in this work we performed general relativistic radiative transfer (GRRT) calculations. Given that the GRMHD simulations are scale free (except for the spin and initial magnetic field topology) we adjusted to the galactic centre during the GRRT by setting the area scale free (except for the spin and initial magnetic field topology) to avoid contamination from floor values introduced during the simulations to ensure numerical stability. The radiative transfer we exclude regions in the jet funnel with large magnetisation \(\sigma > 1\) to avoid contamination from floor values introduced during the simulations to ensure numerical stability. The radiative calculation is performed using the well tested GRRT code BHOSS (Younsi et al. 2012, 2020). Since your GRMHD simulations do not evolve the radiating electrons we need to reconstruct their properties, e.g., temperature and number density, from the ions. Therefore, we applied the so-called \(R - \beta\) model (Mościbrodzka et al. 2016) relating the ion temperature, \(T_i\) together with the plasma beta, \(\beta = p_{\text{gas}}/p_{\text{el}}\) via a free parameter labeled as \(R_{\text{high}}\) to the electron temperature:

\[
\Theta_e = \frac{p_{\text{el}}/m_e}{\rho T_{\text{ratio}}}, \quad T_i = \frac{T_p}{T_e} = \frac{1 + R_{\text{high}}\beta^2}{1 + \beta^2},
\]

with \(m_p\) and \(m_e\) the proton and electron masses, respectively. During the GRRT we assumed a thermal distribution electrons while we fixed the inclination angle to 50° and used a \(R_{\text{high}} = 5\). The result of the radiative transport can be seen in Fig. 4. The differences between the MAD model (top row) and the FLARE model (bottom row) are clearly visible and most striking one is the missing jet feature in the FLARE images. Another feature of the MAD model are bright arcs, connected to flux tubes anchored mainly in the accretion disk scale (Porth et al. 2021). In contrast, the FLARE images do not show a permanent jet\(^4\). The flux is concentrated to the innermost disk regions \(r \sim 100 \mu\text{as}\) with a steep decay with decreasing frequency as compared to the MAD model. Given these significant differences in the images and in the spectral behaviour the two models should be distinguishable in recent and future observations of the Event Horizon Telescope.

5 CONCLUSIONS

In this letter we stress out the importance of using well-studied MRI turbulent discs for the interpretation of EHT and GRAVITY results. We discuss the possibility that the magnetic field structure in the vicinity of the super massive BH at the center of our galaxy, SgrA*, may be totally dictated by the action of the MRI. This would have as a consequence that the inner accretion flow will never become magnetically arrested (MAD). We present in detail the different ways to distinguish the two scenarios, mainly by the images in 43 and 86 GHz that will uncover an extended structure at the base, close to the BH, but also the polarization signatures. These can be tested by near future observations.

Results from global simulations of the MRI in accretion disks, provide evidence for the action of the MRI and its impact to the magnetic field geometry showing an alternating polarity in an 6-8 hours periodicity. When poloidal field of different polarity is accreted, it reconnects and provides an energy release to produce plasmoid/hot spots that can further be observed as flares for SgrA*.

Lastly, we describe a specific GRMHD simulation that tries to mimic this behavior for the production of plasmoids interchanging with states of quiescence in the vicinity of the BH and we estimate the magnetic energy in the range of \(\sim 10^{35-38}\) erg for the flares, assuming a decent mass accretion rate of \(\sim 10^{-8} M_\odot/\text{year}\) for SgrA*, and that the intrinsic poloidal magnetic field in these flares can also explain the observed polarization imprint (GRAVITY collaboration et al. 2018).

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Data Availability. The data underlying this article will be shared on reasonable request to the corresponding author.

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\(^2\) The resulting mass accretion rate is consistent with the values used in Table 2.

\(^3\) The values are chosen to highlight the launched jet in the MAD models

\(^4\) as mentioned above jets are produced as transient feature in the FLARE model
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