Mon. Not. R. Astron. Soc. **343,** L15–L19 (2003)

Close stars and an inactive accretion disc in Sgr A*: eclipses and flares

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Accepted 2003 May 22. Received 2003 May 22; in original form 2003 February 5

ABSTRACT

A cold neutral and extremely dim accretion disc may be present as a remnant of past vigorous activity around the black hole at our Galactic Centre (GC). Here we discuss ways to detect such a disc through its interaction with numerous stars present in the central 0.01 pc of the Galaxy. The first major effect expected is X-ray and near-infrared (NIR) flares arising when stars pass through the disc. The second is eclipses of the stars by the disc. We point out conditions under which the properties of the expected X-ray flares are similar to those discovered by Baganoff et al. The combination of the expected flares and eclipses offers an invaluable tool for constraining the disc density, size, plane and even direction of rotation. The winds of the O-type stars are optically thick to free–free absorption in radio frequencies. If present near the Sgr A* core, these stellar winds can modulate and even occult the radio source.

Key words: accretion, accretion discs – Galaxy: centre.

1 INTRODUCTION

The centre of our Galaxy appears to host a very massive black hole (e.g. Genzel et al. 2003; Ghez et al. 2003) identified with the compact radio source Sgr A* (e.g. Reid et al. 1999), with $M_{\rm BH} \simeq 3 \times 10^6\ {\rm M}_{\odot}$. One mystery of Sgr A* is the fact that its bolometric (mostly radio) luminosity is very low, i.e. $\sim 10^{-9}$ of the corresponding Eddington luminosity $L_{\rm Edd} = 1.3 \times 10^{44}$ erg s^{-1} $(M_{\rm BH}/10^6\ {\rm M}_{\odot})$ whereas its quiescent X-ray emission is even dimmer than radio: $L_{\rm x} \sim 10^{-11} L_{\rm Edd}$ (Baganoff et at. 2003a; for a review of Sgr A* see Melia & Falcke 2001 and Markoff et al. 2003 on the role of the jet). This is puzzling because there is enough hot gas observed at $\sim$0.04 pc from Sgr A* core to let the black hole radiate some $\sim$4 orders of magnitude more (Baganoff et al. 2003a). The current favourite explanation of this aspect of Sgr A* are accretion flow solutions (Narayan & Yi 1994; Narayan 2002) that radiate extremely little compared with the standard discs (Shakura & Sunyaev 1973).

However for 'our' black hole to grow so massive there should have been a much more vigorous accretion activity in the past. Such an activity is usually assumed to proceed via the thin standard disc and cease when the supply of matter ends. Note that because matter in the standard disc flows in and out, the disc always develops over a broad range of radii (Kolykhalov & Sunyaev 1980). A 'light' and very cold ($T \sim 10^2$ K) inactive disc may remain there essentially indefinitely because its viscosity is extremely low. Nayakshin (2003) recently suggested that there is such a disc in Sgr A* and that it is draining the heat from the hot gas by thermal conduction. Instead of flowing into the black hole, the hot gas in this model settles down (condenses) on to the inactive disc at large distances. The accretion of the hot gas is thus delayed in this picture which then explains the *present-day* low luminosity of Sgr A*.

Sgr A* is believed to be closely related to the low-luminosity active galactic nucleus (AGN) (LLAGN; e.g. Ho 1999). Most if not all of these sources have cold discs that are seen through water maser emission (e.g. Miyoshi et al. 1995), and double-peaked emission-line profiles (see Ho 2003). Unfortunately our GC is an extremely 'low-luminosity' LLAGN and an inactive disc there can be very hard to detect via its *quiescent* emission (see Nayakshin, Cuadra & Sunyaev 2003, hereafter N03).

However there are as many as $\sim 10^4$ stars in the central arcsec (1 arcsec $\simeq$ 0.039 pc $\simeq 1.2 \times 10^{17}$ cm) of the Galaxy (Genzel et al. 2003). The orbits of the brightest of these stars (B and O types; Gezari et al. 2002) are now being precisely mapped (e.g. Schödel et al. 2002; Ghez et al. 2003). These stars may be eclipsed by the disc if it is optically thick. In addition, even much smaller and much less luminous solar-type stars will produce X-ray and near-infrared flares when passing through the disc. In this Letter we present a concise and (we hope) clear overview of our ongoing work on the star-disc interactions near GC (N03 and Cuadra, Nayakshin & Sunyaev 2003, hereafter C03).

2 STAR–DISC ECLIPSES AND CROSSINGS

A star can be eclipsed when it moves into the area shadowed by the disc as seen from our line of sight. If the star moves 'far' behind the disc then this type of eclipses is completely analogous to the eclipses of Sun by the Moon and can be referred to as a 'blocking eclipse'. The star may instead strike the disc, pass through it, and become eclipsed because it moved from the front/visible side of the

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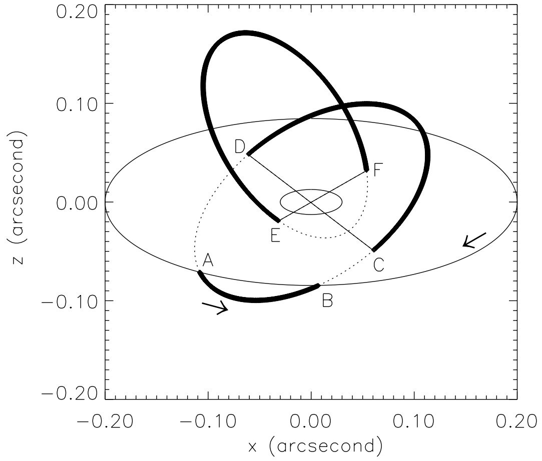

Figure 1. Two examples of star–disc eclipses and flares. Visible and eclipsed parts of trajectories of stars are shown with thick solid and dotted curves, respectively.

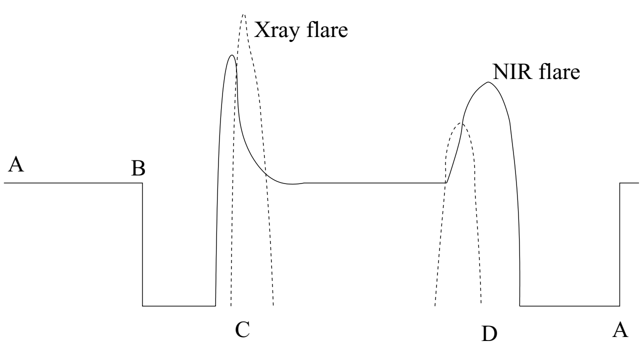

Figure 2. Schematic light curve of the star-disc eclipses and flares corresponding to the orbit ABCD in Fig. 1. Flares, shown not to scale, are shorter by about a factor of 10^3 than eclipses. Their duration and amplitude can be used to constrain disc properties.

disc to its back/invisible side. This type of eclipses may be referred to as an 'impact eclipse'.

In Fig. 1 we show two stellar trajectories interesting in terms of eclipses and flares. The star moving along the ABCD path is eclipsed by the disc twice per orbit. In point B the star does not physically intercept the disc but only its shadow, and hence this is the beginning of a blocking eclipse. Owing to the star's finite size and (most likely) a gradual rather than an abrupt nature of the disc edge on both the inner and the outer boundaries, partial eclipses could be observed for hours to months (see Fig. 4 later). The eclipse ends at point C when the star goes through the disc, from its back to its front side. A NIR and an X-ray flare will be emitted (see Fig. 2). *If the disc is optically thick* to X-rays, then NIR flare will precede the X-ray flare. The CD part of the trajectory is an 'unremarkable' quiescent star emission, which terminates when the star hits the disc for the second time. This time the X-ray flare should be emitted first. The eclipsed part DA ends when the star emerges from the disc shadow without a flare.

To date, there is only one star whose orbit is nearly completely known, i.e. the star S2 (Schödel et al. 2002). The orbit is highly elliptical (eccentricity $e = 0.87$), inclined at $i_* = \pm 46^\circ$ (we picked the + sign here, but see below), and the period is 15.2 yr. We plot (Fig. 3) the orbit of S2 and a disc that does *not* eclipse any of the

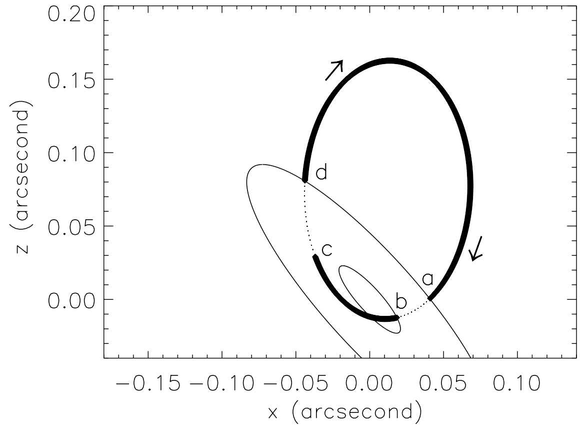

Figure 3. Eclipses and a flare for star S2 (Schödel et al. 2002) and a disc inclined at $i = 75^\circ$ with $R_\mathrm{d} = 0.12$ arcsec ($\sim 1.4 \times 10^{16}$ cm) and inner radius $R_i = 0.03$ arcsec. Highly elongated orbits are excellent probes of the inner disc structure.

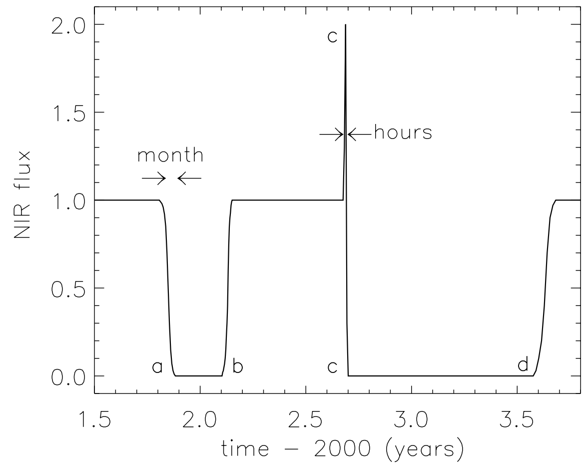

Figure 4. Light curve for the star–disc system shown in Fig. 3. Note the large difference in time-scales of flares and duration of eclipses.

measured positions (fig. 1 in Schödel et al. 2002). Note that the disc can in principle still exist beyond R_i or R_d but it cannot be optically thick there. Fig. 4 shows the expected light curve of the star (the passage of the pericentre radius for S2 occurred at 2002.3). The eclipse *ab* ($t \sim 2002.0$) is of the blocking type and therefore there is no flare associated with it, whereas the second eclipse (point *c*) begins with a flare. Figs 3 and 4 are only examples.

Ghez et al. (2003) very recently showed that i_* for S2 is actually negative. Using this now *completely* constrained orbit, C03 found that the disc eclipses can only be avoided if the disc has a relatively large inner hole, $R_i \gtrsim$ few $\times 10^{-2}$ arcsec. In addition, C03 showed that the optically thick disc *reprocesses* the optical–UV continuum of S2 into the near-infrared band very efficiently. This requires the disc optical depth at 2.2 μm to be smaller than ~ 0.01 to satisfy the K_s-band spectral constraints for S2. These new results show that the eclipses of close stars that we discussed here *may only be partial*. With the column depth required by star–disc interpretation of X-ray flares (which seems to be in the range 10^{22}–10^{24} hydrogen nuclei per cm^2), the dust grain size in the disc should satisfy $a \gtrsim 30$ μm. Such a large a appears to be consistent with the very rapid rate of grain growth expected for gas densities of order 10^{10}–10^{12} cm^{-3}.

Information that can be gained from observations of stellar eclipses and flares:

(i) Coordinates of star's trajectories are three-dimensional; therefore, star-disc crossing points (e.g. D or C) yield 3D coordinate of a point in the disc. Together with the known coordinates of Sgr A* itself, any such crossing yields a line in the disc plane. Therefore, knowledge of 3D coordinates of points D and F, for example, (and Sgr A^*) is sufficient to determine the plane of the disc rotation.

(ii) If the plane of the disc is known, then two blocking points (A and B) uniquely determine the outer disc radius.

(iii) The maximum luminosity of a flare is a strong function of the angle between the star and the disc velocity at the point of impact (Section 3), θ_r. Hence one may tell whether the disc is rotating clockwise or counterclockwise in Fig. 1.

(iv) If the dust opacity is reasonably large, then the flare is mainly due to *reprocessing of the optical/UV stellar radiation* into NIR and would last $\sim$ months (C03).

(v) However, if the dust opacity is negligible, the NIR flare is emitted only during the star passage through the disc when *the gas* is heated to high temperatures. Such flares should be as short as X-ray flares, i.e. $\lesssim$ minutes to hours.

3 STAR–DISC FLARES

At a distance R from the black hole, let a star with mass $M_* = m_*$ $\mathrm{M}_\odot$ and radius $R_* = r_*\, \mathrm{R}_\odot$ move with velocity v_* that makes angle θ_r with the disc circular Keplerian velocity, v_K. We also define for convenience $r_4 = R/10^4 R_\mathrm{S}$. The relative velocity of the disc and the star, v_rel, is essential for the problem. In general $v_\mathrm{rel}^2 = v_\mathrm{K}^2 + v_*^2 - 2v_*\, v_\mathrm{K} \cos\theta_r$, and one needs to carry out calculations for arbitrary v_* and θ_r and then integrate over the star's 3D velocity distribution. In what follows we simply assume that $v_* \simeq v_\mathrm{K}$. Under the assumption of an isotropic star cluster the 'average' angle θ_r is equal to $\pi/2$, so $v_\mathrm{rel} = \sqrt{2} v_\mathrm{K}$. However we shall keep in mind the importance of the actual v_* and θ_r for exact results (cf. point iii above).

The star's internal density is very much larger than that of the disc and we can consider the star to be a rigid solid body (see Syer, Clarke & Rees 1991). We neglect tidal effects and accretion of gas on to the stellar surface because the corresponding Bondi radius is much smaller than $R_* (R_\mathrm{B} = GM_*/v_\mathrm{rel}^2 = 1.5 \times 10^9 m_*\, r_4 \ll 7 \times 10^{10} r_*)$. The Mach number of the star in the disc is about $v_\mathrm{rel}/\sqrt{(kT_\mathrm{d}/m_\mathrm{p})} \sim 10^4$. Thus the star drills a narrow hole in the disc (Syer et al. 1991) Note also that $R_* \ll H$. The star is essentially a piston moving into the gas and the rate at which the star makes work on the gas in the disc is approximately $L_\mathrm{w} \sim \pi\, R_*^2 m_\mathrm{p} n_\mathrm{d}\, v_\mathrm{rel}^3$, where n_d is the midplane density of hydrogen nuclei.

X-ray continuum spectrum. The characteristic temperature to which the gas is heated in the shock wave is

$$T_\mathrm{char} = \frac{2}{3}\frac{\mu v_\mathrm{rel}^2}{2k} = 1.8 \times 10^8 r_4^{-1}\ \mathrm{K}, \tag{1}$$

where we set $\mu \simeq m_\mathrm{p}/2$. For T_char as high as 10^8 K, optically thin X-ray spectra are dominated by bremsstrahlung emission. The photon spectral index in the $2 \lesssim E \lesssim 8$ keV energy range is $\Gamma \sim 1.5$ and is in agreement with the observed values of $\Gamma \simeq 1 \pm 0.7$ (Baganoff et al. 2001; Goldwurm et al. 2003). However, in the wake of the star, the gas is cooler than T_char. The integrated (i.e. time-averaged) spectrum of the flare is thus a superposition of separate optically thin (mainly) bremsstrahlung spectra with $T \leqslant T_\mathrm{char}$. If the radiative energy losses are less important than adiabatic ones, then the wake of the shock will make an important contribution to the spectra, and thus Γ may be significantly softer than the pure free–free value. Hence $\Gamma \gtrsim 1.5$ in general. In the soft X-ray range, i.e. $E \lesssim 1$ keV, the spectrum is dominated by atomic lines and should eventually become harder than it is in the $E \gtrsim 1$ keV energy range.

Atomic features in the X-ray spectrum. Depending on R, R_*, θ_r, the disc column depth $\Sigma(R)$, and also on the properties of the stellar wind and corona, there will be a large variety in the gas temperatures and the spectra of the resulting flares. If the emission measure of the shocked gas is dominated by hot gas with $T \gtrsim 10^8$ K, then the Fe Kα line is weak. For lower temperatures a highly ionized Fe Kα line will be emitted. In addition, a weak X-ray reflection feature (off the cold disc or stellar surface) may be expected. Absorption of soft X-rays in the disc photosphere could be significant unless the X-rays from the shock photoionize the disc material enough to 'hide' this absorption (see N03). Despite all these uncertainties, the *possible* Fe Kα line and an excess soft X-ray absorption during flares are distinctive signatures of the flares taking place near cold gas and at 'large' distances from the black hole.

X-ray luminosity. Consider first an optically thin case. If the cooling time of the shocked gas, t_c, is shorter than R_*/v_*, then the X-ray luminosity, L_xe, should be about L_w. On the other hand, if adiabatic losses dominate cooling of the hot gas, then $L_\mathrm{xe} \sim L_\mathrm{w}(R_*/v_* t_\mathrm{c}) \ll L_\mathrm{w}$. We find that the latter case is more appropriate for Sgr A* flares, and obtain

$$L_\mathrm{xe} \sim 4.1 \times 10^{33} n_{11}^2 r_*^3 r_4^{-1/2}\ \mathrm{erg\ s^{-1}}, \tag{2}$$

where $n_{11} = n_\mathrm{d}/10^{11}\ \mathrm{cm^{-3}}$. If the disc is optically thick to photoabsorption, then X-ray emission becomes observable only when the star reaches the disc photosphere, i.e. when $\tau = (\cos i)^{-1} \sigma_\mathrm{eff} H n_\mathrm{p} \simeq 1$, where i is the disc inclination angle, H is disc half-thickness, $\sigma_\mathrm{eff} = b\sigma_\mathrm{T}$ is the effective X-ray total cross-section ($b \sim$ few), and n_p is the local density. This moment defines the maximum in the X-ray light curve: inside the disc X-rays cannot escape to the observer; in the disc photosphere, on the other hand, the gas density is too small.

Using the $\tau = 1$ condition we then obtain the density $n_\mathrm{max} \sim \cos i/(b\sigma_\mathrm{T} H)$ at which the maximum X-ray luminosity, L_max, is emitted. L_max is clearly given by the optically thin luminosity (equation 2), calculated with n_max instead of n_d, times exp $[-1]$:

$$L_\mathrm{max} \sim 2 \times 10^{34} \left[\frac{\cos i}{b}\right]^2 T_2^{-1} r_*^3 r_4^{-7/2}\ \mathrm{erg\ s^{-1}}. \tag{3}$$

Flare duration. The disc half thickness, H, is

$$H = \sqrt{\frac{kT_\mathrm{d} R^3}{GM_\mathrm{BH} m_\mathrm{p}}} = 3.9 \times 10^{12} T_2^{1/2} r_4^{3/2}\ \mathrm{cm}, \tag{4}$$

where $T_2 = T_\mathrm{d}/100$ K, and we assumed that the gas is mainly molecular hydrogen. The flare duration for an optically thick disc is $t_\mathrm{dur} \sim (H + 2R_*)/v_*$:

$$t_\mathrm{dur} \simeq 2.5 \times 10^4 T_2^{1/2} r_4^2 + 670\, r_* r_4^{1/2}\ \mathrm{s}, \tag{5}$$

which is in accord with observations if $R \sim 10^3$–10^4 R_S.

Mass of the disc. The disc surface density $\Sigma \simeq 2Hn_\mathrm{d}m_\mathrm{p} = 1.3 n_{11} r_4^{3/2} T_2^{1/2}$ g cm^{-2}. The mass of the accretion disc, calculated for density and temperature independent of radius, is $M_\mathrm{d} \sim 0.1\ \mathrm{M}_\odot\ n_{11} r_4^{7/2} T_2^{1/2}$. Such a 'light' disc is neither globally nor locally self-gravitating (e.g. Kolykhalov & Sunyaev 1980).

NIR luminosity. Consider optically thick case, $\Sigma \gtrsim 1$ g cm^{-2}. Deep inside the disc X-rays are absorbed and re-emitted as blackbody emission in the near infrared. Assuming $L_{\rm w} \sim \sigma_{\rm B}\, T_{\rm ir}^4 \times 2(2H)^2$, we get $T_{\rm ir} \simeq 1.5 \times 10^3$ K $[n_{11} r_*^2/T_2]^{1/4} r_4^{-9/8}$. The predicted NIR luminosity is then $\nu L_\nu = (4\pi)4H^2 \cos i\, \nu B_\nu(T_{\rm ir})$:

$$\nu L_\nu = 5.7 \times 10^{35} \cos i\; T_2 r_4^3 \frac{\bar{\nu}^4}{e^x - 1}\ \mathrm{erg\ s^{-1}}, \qquad (6)$$

where $\bar{\nu} \equiv \nu/1.5 \times 10^{14}$, and $x \equiv h\nu/kT_{\rm ir}$; we assumed the distance to the GC $D = 8.0$ kpc. In the optically thin case (which seems to be very likely in view of recent results of C03), the NIR flare luminosity will be reduced. On the other hand reprocessing of the *stellar radiation* into the NIR may significantly increase corresponding flare luminosity.

Rate of star–disc flaring. The recent results of Genzel et al. (2003) finally settle the issue of the stellar cusp in Sgr A*. Namely, these authors find that within $R < R_b$, where $R_b = 10$ arcsec, the stellar mass density follows the law $\rho_*(R) = \rho_{*0}(R/R_{\rm b})^{-p}$, where $\rho_{*0} = 1.2 \times 10^6\ \mathrm{M_\odot\ pc^{-3}} = 70\ \mathrm{M_\odot\ arcsec^{-3}}$, and $p = 1.4 \pm 0.1$. Within our very simple model where the stars are on circular Keplerian orbits around the black hole, and with $p = 1.5$, the rate at which they cross a disc with inner radius R_i and outer radius $R_{\rm d}$ is (see N03 for more detail)

$$\dot{N}(R_{\rm d}, R_i) = 0.5 \ln(R_{\rm d}/R_i) m_*^{-1}\ \mathrm{d}^{-1}, \qquad (7)$$

For example, with $R_{\rm d} = 10^4\ R_{\rm S}$, and $R_{\rm i} = 20 R_{\rm S}$ (tidal radius for a 1-M$_\odot$ star), we have $\dot{N} \simeq 3$ flare per day, while with $R_{\rm i} = 10^3\ R_{\rm S}$ (see below), we have $\dot{N} \simeq 1$ flare per day. The observed event rate is about 1 flare per day.

Inner hole in the disc. The star–disc interactions can remove the disc angular momentum and yield some accretion. For parameters appropriate here, the time to remove all disc angular momentum is shorter than 10^6 yr for radii less than $\sim 2 \times 10^3 R_{\rm S}$ (see N03). The disc viscous time at $r_3 = R/10^3 R_{\rm S}$ is $t_{\rm visc} \sim 5 \times 10^5 \alpha^{-1} T_2^{-1} r_3^{1/2}$ yr, where $\alpha < 1$ is viscosity parameter (Shakura & Sunyaev 1973). Clearly the disc inner hole cannot be refilled by accretion of material from larger radii for $R \lesssim 10^3 R_{\rm S}$. Thus most likely $R_i \sim 10^3 R_{\rm S}$. (Note that this result may also be relevant for the inner edges of LLAGN discs in general; e.g. Quataert et al. 1999 and Ho 2003.)

We plot the flare properties in Fig. 5 for two values of the star's radius, $R_* = \mathrm{R_\odot}$ (thin curves) and $R_* = 5\ \mathrm{R_\odot}$ (thick). Conclusions from Fig. 5 are as follows.

(i) Flare X-ray luminosity is a strong function of radius. Flares even from large stars are too dim to be detected for $R \gtrsim 2 \times 10^4\ R_{\rm S}$. Stronger flares are produced by larger stars.

(ii) To date no flares from Sgr A* much in excess of $L_{\rm x} \sim 10^{35}$ erg s^{-1} were observed by *Chandra* or *XMM*. This requires that the disc midplane density be $n_{\rm d} \lesssim 10^{11}$ cm^{-3}. Thus the column depth of the disc is $N_{\rm H} \sim 10^{22}$–10^{24} hydrogen atom cm^{-2} (depending on radius R). The larger values may yield observable cold gas absorption *additional to the usual* interstellar absorption for Sgr A*.

(iii) The disc cannot be exactly edge-on to us or else X-ray flares would be too weak (see equation 3).

(iv) The maximum NIR 2-μm luminosity during flares calculated as in equation (6) is 'only' ∼1–100 times solar luminosity (L$_\odot$) even for the largest stars. At the same time, reprocessing of the visible/UV stellar radiation in the disc into the NIR band may yield up to $\sim 10^5\ \mathrm{L_\odot}$ into NIR (C03).

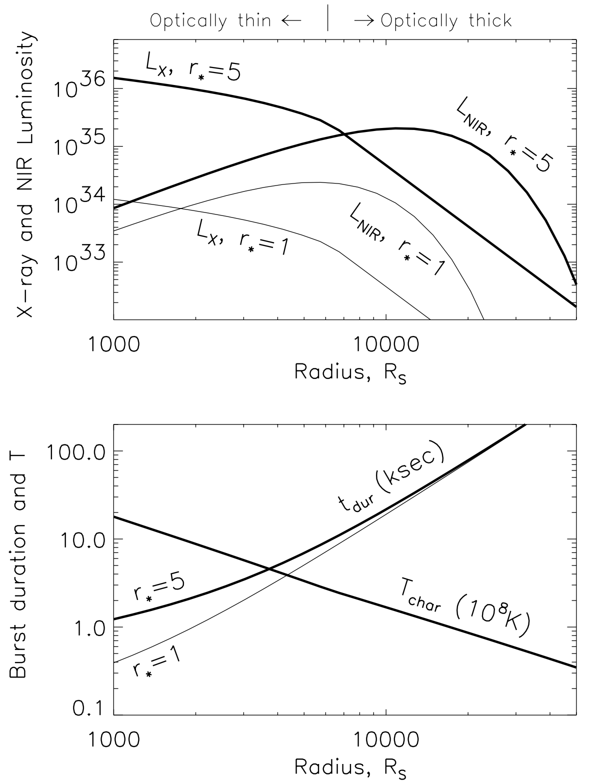

Figure 5. Dependence of flare characteristics on the radial distance from the black hole. The disc has a constant midplane density $n_{\rm d} = 10^{11}$ cm^{-3} and is inclined at $i = 75°$. The disc region with $R \lesssim 7 \times 10^3 R_{\rm S}$ is optically thin along the line of sight whereas for $R \gtrsim 7 \times 10^3 R_{\rm S}$ it is optically thick in the sense explained in the text after equation (2). Two values for the star radius, $r_* = R_*/\mathrm{R_\odot}$ are considered. $b = 2$ for all the curves. Top panel: maximum X-ray and near infrared (NIR) luminosities achieved during bursts (but see Section 5). Note the break in the slope of $L_{\rm x}$ where the disc becomes optically thin. Star-disc collisions at $R \gtrsim$ few $\times\ 10^4\ R_{\rm S}$ produce X-ray flares too weak to observe. Lower panel: flare duration and characteristic temperature. Note that the predicted duration is in the range from ∼1 to tens of thousand seconds, which compares well with the observations.

(v) We have not covered here the formation of ionization fronts in the disc owing to both stellar and the shock radiation. Emission from these layers in the NIR may significantly exceed the simple estimate (equation 6), and hence give rise to detectable NIR flares (not yet observed: Hornstein et al. 2002).

(vi) X-ray flares *due to* star–disc interactions in more distant LLAGN are harder to detect. However this may become possible in the future (see N03).

(vii) Radio emission from the shocked gas is very weak (compared with Sgr A* radio luminosities) since it is completely self-absorbed. This may explain why there is no radio flares correlated with X-ray outbursts in Sgr A*.

4 MODULATION OF SGR A* RADIO EMISSION BY STAR PASSAGES

The luminous stars produce powerful winds with mass loss rates as high as $\dot{M}_{\rm w} = 10^{-5}\ \mathrm{M_\odot}$ per year. The optical depth to free–free absorption in radio frequencies, $\tau_{\rm ff}(\nu)$, can be significant. Estimating density in the wind a distance $\tilde{R}$ from the star as $n_{\rm H} \sim \dot{M}_{\rm w}/4\pi\tilde{R}^2 v_{\rm w} m_{\rm p}$, we obtain

$$\tau_{\rm ff} \sim 2\dot{M}_6^2 v_3^{-2} T_4^{-3/2} [\nu/10^{11}\ {\rm Hz}]^{-2} [\tilde{R}/10^{13}\ {\rm cm}]^{-3}, \quad (8)$$

where T_4 is wind temperature in units of 10^4 K, and $v_3 \equiv v_{\rm w}/10^3$ km s^{-1}, and $\dot{M}_6 = \dot{M}_{\rm w}/10^{-6}\ {\rm M}_{\odot}$ per year. Therefore such powerful stellar winds may eclipse jet radio emission at low enough frequencies.

Another effect is a star passing through or close to the jet. The emission of relativistic electrons in the jet can be either enhanced (via providing seed photons for Comptonization) or reduced (via too strong cooling of the jet electrons). The rate of these 'jet-crossing' events is roughly θ_j/π times smaller than that for the star–disc crossings, where θ_j is the jet opening angle. However, only the brightest stars are likely to cause the jet disturbance. The duration of the event is much longer than that of X-ray flares, i.e. $t_{\rm dur} \sim \theta_j R/v_*$ i.e. weeks to years depending on the distance R. Zhao, Bower & Goss (2001) reported a 106-d periodicity in the radio emission of Sgr A*, which could be related to the jet–star interactions.

5 DISCUSSION

We have shown that the presence of close stars and a cold thin disc near Sgr A* will produce two potentially observable effects: eclipses and flares. Sgr A* does produce X-ray flares (Baganoff et al. 2001, 2003b; Goldwurm et al. 2003; Porquet et al. 2003). We have shown that if the disc density is $\sim 10^{11}$ hydrogen nuclei per cm^3, then the flare luminosities and spectra, duration, number of evens per day and absence of radio counterparts agree quite well with the observed properties of the flares. Depending on parameters, the X-ray spectra may show a Fe Kα line and *additional* X-ray absorption. Such extra absorption is reported by Porquet et al. (2003) in the *XMM* spectrum of a particularly bright X-ray flare. In addition, Genzel et al. (2003) report an excess in the $\lambda = 3.8\ \mu$m (NIR L'-band) spectrum of star S2 in 2002. We find (this will be reported elsewhere) that this excess may be explained by the dust and free–free emission of the disc. Therefore several lines of evidence for the inactive disc presence in Sgr A* (just as in most LLAGN; Ho 2003) emerge, and thus the role of such discs in the structure of accretion flows in low-luminosity objects should be studied.

In this Letter we considered the properties of flares under the simplest assumptions. In reality, owing to a great range in the properties of stars (radius, mass loss rate, luminosity), and also a possible presence of compact objects in Sgr A* star cluster, the respective range in the expected flare characteristics is immense and will be a subject of future studies.

ACKNOWLEDGMENTS

Useful discussions with P. Predehl, R. Genzel, R. Schödel, T. Ott, K. Dullemond, D. Porquet, A. Ghez, A. Goldwurm, and especially J. Cuadra, are greatly appreciated.

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