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The broad band spectral properties of SgrA*

The fate of the dusty object approaching the center

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Abstract. The super-massive 4 million solar mass black hole (SMBH) SgrA* shows flare emission from the millimeter to the X-ray domain. A flare analysis in the framework of a Synchrotron Self Compton (SSC) mechanism shows that a scenario in which the infrared flares are explained by synchrotron emission and the associated X-ray flares are produced via SSC emission can also explain the variability spectrum observed in the sub-millimeter radio domain. In September 2013 a dust object will pass by SgrA* giving hope for extraordinary flare events that will tell us more about the accretion and radiation mechanism close to the super massive black hole.

Key words. Galaxy:center – infrared:stars

1. Introduction

Sagittarius A* (Sgr A*) at the center of our galaxy is a highly variable radio, near-infrared (NIR) and X-ray source which is associated with a $4 \times 10^6 M_{sun}$ super-massive central black hole. Zamaninasab et al. (2010, 2011) have shown that the polarized flares show patterns of strong gravity as expected from in-spiraling material very close to the black hole's horizon. Therefore it is mainly the polarization and the strong flux variability that gives us certainty that we study the immediate vicinity of a SMBH. SgrA* is the closest SMBH and can be taken as a paradigm for low luminosity active galactic nuclei (LLAGN; see Contini 2011; Ho 2008). Hence, the exact nature of the flare emission process is essential to understand the

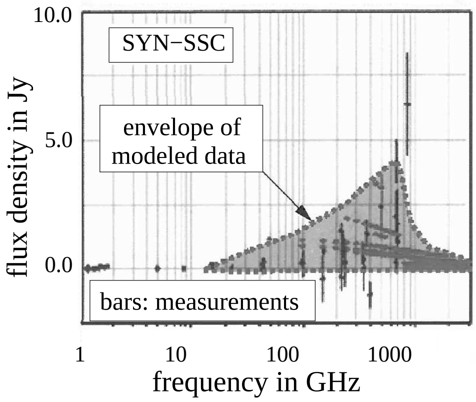

Fig. 1. NIR/X-ray prediction of the variable mm/sub-mm flux density of SgrA* (Eckart et al. 2012b).

physics close to SMBHs and SgrA* is a unique laboratory to do this. For bright high signal to noise flares relativistic spectral energy distribution (SED) modeling of the multi-wavelength data allows an analysis of the radiation mechanism (e.g. Eckart et al. 2012a and Fig.1). The dusty object (Gillessen et al. 2012a,b; Eckart et al. 2012b) that will pass by SgrA* at a distance of only 2200 Schwarzschild radii (∼176 AU) is expected to loose matter or even be completely disrupted during the periapse section of its orbit - possibly resulting in quite luminous accretion events.

2. Radio to X-ray variability of SgrA*

Eckart et al. (2012b) report on new simultaneous observations and modeling of the millimeter, near-infrared, and X-ray flare emission of the source SgrA*. The observations reveal flaring activity in all wavelength bands that can be modeled as a signal from an adiabatically expanding synchrotron self-Compton (SSC) component. At the start of the flare, the spectra of the two main components peak just short of 1 THz. Modeling of the light curves shows that the sub-mm follows the NIR emission with a delay of about three-quarters of an hour with an expansion velocity of about $v_{exp} \sim 0.009c$. The authors find source component sizes of around one Schwarzschild radius, flux densities of a few Janskys, and spectral indices α of about +1 ($S(\nu) \propto \nu^{-\alpha}$).

To statistically explain the observed variability of the (sub-)mm spectrum of SgrA*, Eckart et al. (2012b) use a sample of 8 simultaneous NIR/X-ray flare peaks and model the flares using a synchrotron and SSC mechanism. The corresponding model parameters suggest that either the adiabatically expanding source components have a bulk motion larger than v_{exp} or the expanding material contributes to a corona or disk, confined to the immediate surroundings of SgrA*. For the bulk of the synchrotron and SSC models, Eckart et al. (2012b) find synchrotron turnover frequencies in the range of 300-400 GHz. For the pure synchrotron models this results in densities of relativistic particles of the order of $10^{6.5}$cm^{-3} and for the SSC models, the median densities are about one order of magnitude higher. However, to obtain a realistic description of the frequency-dependent variability amplitude of SgrA*, models with higher turnover frequencies and even higher densities are required.

3. NIR light curves of SgrA*

In a comprehensive statistical approach and using the complete VLT NACO Ks-band data between 2002 and 2010 (Witzel et al. 2012) it was not possible to confirm the earlier claimed two states of variability (Dodds-Eden et al. 2011). We rather find that the NIR variability is represented by a single-state process forming a (straight) power-law distribution of the flux density. The turnover at low flux densities indicates the transition from a detection to a measurement and is located at the flux density of the confusion limit. At higher fluxes the statistics becomes incomplete since not too many bright NIR flares have been observed until now. Witzel et al. (2012) possibly explain the claimed bright X-ray outburst within the last 400 years (Revnivtsev et al. 2004, and references in Witzel et al. 2012) without the need for an extraordinary event. To include the expected peculiar flare activity in 2013/14 one needs to combine the (sub-)mm,

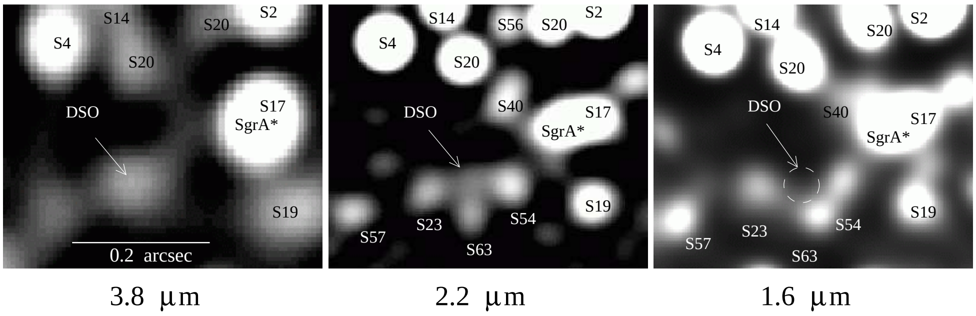

Fig. 2. Distinguishing the DSO against stars S57, S23, S54 and S63 in 2008 in L'- and K_s-band. Only an upper limit can be given in H-band (Eckart et al. 2012b).

NIR, and X-ray observations. Here particularly mm-interferometers are well suited to separate the SgrA* emission from the extended mini-spiral/circum nuclear disk complex. For flares due to enhanced accretion of matter one may expect that the entire SED will rise towards higher flux densities (e.g., Markoff et al. 2001). In order to model the flux density and polarization characteristics of the observed flares 3D relativistic disk code including radiative transport are well suited (Valencia-S., Bursa et al. 2012). Magneto-hydrodynamic models and Synchrotron/Self-Compton models with adiabatic expansion can be used to match the corresponding radio fluxes. Differences in the NIR/X-ray flare profiles can be explained by a variation in the SSC scattering efficiency (Eckart et al. 2012b). Near-infrared polarimetry shows signatures of strong gravity that are statistically significant against randomly polarized red noise (Zamaninasab et al. 2010, 2011). This allows us to derive spin and inclination information of the SMBH.

4. The dusty S-cluster object

A dusty object (DSO/G2) approaches SgrA* and will be in periapse in mid-September 2013. The expected NIR and X-ray flux density of SgrA* will increase substantially. The enhanced activity will be strong in the mm- and sub-mm part as well. To probe the accretion process and investigate geometrical aspects (outflow and disk orientation) of the enhanced activity (sub-)millimeter/radio observations around June and September 2013 in parallel with the NIR polarization observations will be essential. The exceptionally strong flare activity expected during periapse will also give an outstanding opportunity to improve the derivation of the spin and inclination of the SMBH from NIR/mm observations.

Gillessen et al. (2012a,b) interpret it as a core-less gas and dust cloud approaching SgrA* on an elliptical orbit. Eckart et al. (2012b) present the first K_s-band identifications and proper motions of the DSO (Fig. 2). Its NIR colors imply that it could rather be an IR excess star. Very compact L'-band emission is found (pointing at the presence of a star), contrasted by the broad Brγ emission (pointing at the presence of a very extended optically thin tail or envelope) reported by Gillessen et al. (2012a,b) and modeled by Burkert et al. (2012) and Schartmann et al. (2012). The presence of a star will change the expected accretion phenomena (observable through expected excess mm- NIR and X-ray flux) since a stellar Roche lobe may retain much of the material (Eckart et al. 2012b) during and after the peribothron passage (Fig. 3).

5. Conclusions

Given all the listed evidences future work needs to address the following questions: How will the close flyby of the DSO/G2 object alter the accretion characteristics of SgrA*? Does the DSO harbor a star or is it a pure gas

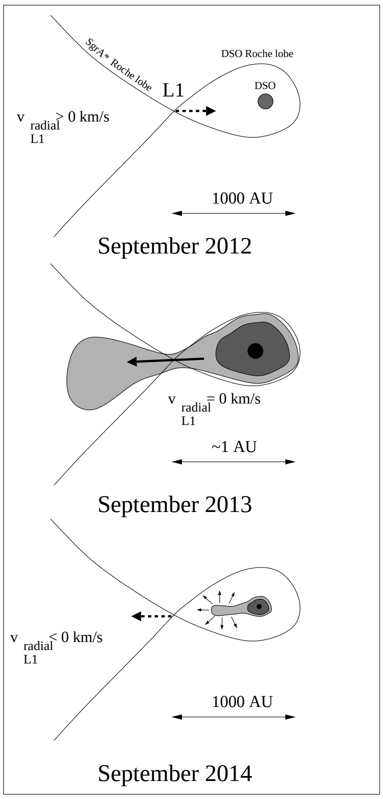

Fig. 3. Sketch of the relative position and motion of the Lagrange point L1 and the DSO (Eckart et al. 2012b).

and dust cloud only? Is the very slow moving extended 'tail' component associated with the head of the DSO/G2 source? How and where did such a cloud form? How frequent are sources like this? What consequences does the existence of such dusty sources have on our understanding of the star formation and the conditions of star formation in the central stellar cluster? Is the DSO comparable to other dusty sources in the cluster - like the infrared excess IRS13N sources (Muzic et al. 2008; Eckart et al. 2012b) or the bowshock sources X3 and X7 (Muzic et al. 2007, 2010)? Independent of the answers to these problems the DSO flyby in September 2013 will undoubtedly be a spectacular event that will reveal valuable information on the physics of the very center of the Milky Way. If future X-ray missions will provide higher angular resolution and sensitivity one will be able to better discern the flaring non-thermal from the extended non-variable Bremsstrahlung component (Baganoff et al. 2003). This will then allow us to study the variability during the faint phases of SgrA*. The possible counterparts of fainter NIR flares could be studied in their X-ray emission and a more detailed investigation of the relation between the variable NIR and X-ray emission can be performed. It is also worth mentioning that until now there is no information on X-ray line emission from SgrA*. That may in future become available for particularly bright X-ray flares.

References

Baganoff, F. K., et al.,2003, ApJ 591, 891

Burkert, A., et al., 2012, ApJ 750, 58

Contini, M., 2011, MNRAS 418, 1935

Dodds-Eden, K., Gillessen, S., Fritz, T. K., et al., 2011, ApJ 728, 37

Eckart, A., Garca-Marn, M., Vogel, S. N., et a,, 2012a, A&A 537, 52

Eckart, A., Muzic, K., et al., 2012b `arXiv1208.1907Ei`, r&A in press

Gillessen, S., Genzel, R., et al., 2012a Nature 481, 51

Gillessen, S. et al., 2012b, `arXiv1209.2272G`

Ho, L.C., 2008, ARAA 46, 475

Markoff, S., et al., 2001, A&A 379, L13

Muzic, K., Eckart, A., et al., 2007, A&A 469, 993

Muzic, K., Schödel, R., et al., 2008, A&A 482, 173

Muzic, K., Eckart, A., Schödel, R., et al., 2010, A&A 521, 13

Revnivtsev, M. G., Churazov, E. M., Sazonov, S. Y., et al., 2004, A&A, 425, L49

Schartmann, M., Burkert, A., et al., 2012, ApJ 755, 155

Valencia-S., Bursa et al., 2012, JPhCS.372a2073V

Witzel, G., Eckart, A., et al., 2012, ApJS 203, 18

Zamaninasab et al. 2010, A&A 510, 3

Zamaninasab et al. 2011, MNRAS 413, 322