Black Holes from Stars to Galaxies – Across the Range of Masses
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The orbiting spot model gives constraints on the parameters of the supermassive black hole in the Galactic Center

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Abstract. We report on recent polarimetric observations of the 18 ± 3 min quasi-periodicity present in near-infrared flares from Sagittarius A*. Observations in the K-band allow us a detailed investigation of the flares and their interpretation within the hot spot model. The interplay of relativistic effects plays a major role. By simultaneous fitting of the lightcurve fluctuations and the time-variable polarization angle, we give constraints to the parameters of the hot spot model, in particular, the dimensionless spin parameter of the black hole and its inclination. We consider all general relativistic effects that influence the polarization lightcurves. The synchrotron mechanism is most likely responsible for the intrinsic polarization. We consider two different magnetic field configurations as approximations to the complex structure of the magnetic field in the accretion flow. Considering the quality of the fit, we suggest that the spot model is a good description of the origin for the QPOs in NIR flares.

Sagittarius A* (Sgr A*), the supermassive black hole at the Galactic center, exhibits frequent radiation outbursts, so-called flares. Near-infrared (NIR) observations with the ESO VLT in 2005 and 2006 (see Eckart *et al.* 2006b; Meyer *et al.* 2006a,2006b, and the contribution by Andreas Eckart in these proceedings) strongly support the previous evidence of 17 ± 2 min quasi-periodicity (Genzel *et al.* 2003). The emission shows significant polarization during the flares.

These QPOs manifest themselves as individual 'sub-flares'. They are seen in some NIR lightcurves with very short rise and fall timescales, suggesting a compact emission region with a size of only a few Schwarzschild radii (Eckart *et al.* 2006a). The value of ~ 17 min suggest to identify the QPOs with Keplerian motion around a Kerr black hole (BH), as this timescale is comparable to the orbital timescale near the innermost stable circular orbit (ISCO) of a spinning BH (Bardeen *et al.* 1972). Indeed, calculating the emission of confined hot spots in a circular orbit around a BH taking all relativistic effects into account (i.e. red- and blue-shifts, lensing, change of polarization angle) leads to lightcurves consistent with those that are observed (Broderick & Loeb 2005,2006; Dovčiak *et al.* 2004). Adding an underlying truncated disk/ring that accounts for the overall flare can then result in good-quality fits (Meyer *et al.* 2006a,2006b). Here we present constraints on the parameters of the Galactic BH that can be inferred from fitting the hot spot model to the observations. Details of the model and the fitting procedure can be found in Meyer *et al.* (2006a).

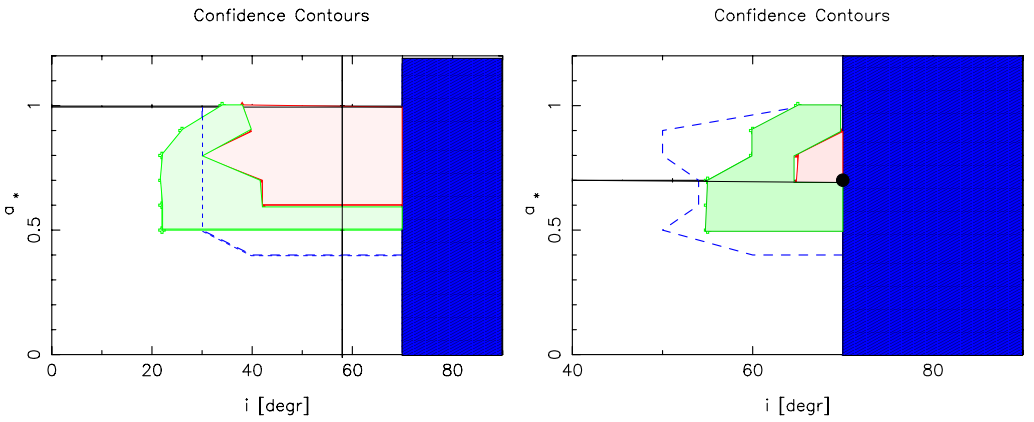

Figure 1. Confidence contours within the plane of black hole angular momentum versus inclination. We assumed two cases with different orientation of the local electric and magnetic fields: firstly, E-vector is kept constant, perpendicular to the disc plane (left), and secondly, a strictly azimuthal B vector is assumed (right). See Meyer *et al.* 2006a for details). The red (green) lines represent the analysis of the 2006 data (Meyer *et al.* 2006b) and are chosen in such a way that the projection onto one of the parameter axes gives the 1σ (3σ) limit for the corresponding parameter. The blue dashed lines indicate the 3σ contour for the 2005 data (Meyer *et al.* 2006a). The χ^2-minimum for the 2006 data is marked by the circle. The χ^2-minimum of the 2005 epoch lies at $a_\star = 1$, $i = 70°$ (left) and $a_\star = 0.5$, $i = 70°$ (right). Our analysis is limited to $i \lesssim 70°$.

Figure 1 shows the confidence contours in the dimensionless spin parameter – inclination plane (0° corresponds to face on). The left panel shows the results that assumed a magnetic field scenario that leads to a constant E-vector along the orbit of the hot spot. The results in the right panel assumed an azimuthal, i.e. toroidal, magnetic field configuration. Following the χ^2 values, the former case leads to slightly better fits. The contours show that a big part of the parameter space can be ruled out already by present data. The inclination i of the blob orbit must be $i \gtrsim 30°$ on a 3σ level, and the dimensionless spin parameter of the black hole is derived to be $a_\star > 0.5$, i.e. the BH is spinning. Future observations will allow to further tighten the possible parameter regions.

While the QPO observations seems to favour the interpretation in terms of orbiting spots, the model of relativistic plasma clouds expanding in a cone-jet geometry can also account for the flares and sub-flares of Sgr A*. The inclusion of both models offers an exciting possibility of connecting the NIR/X-ray activity to the sub-mm/radio regime.

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