The loopy face of Sgr A*

Exploring the polarisation signatures of the Milky Way's central black hole

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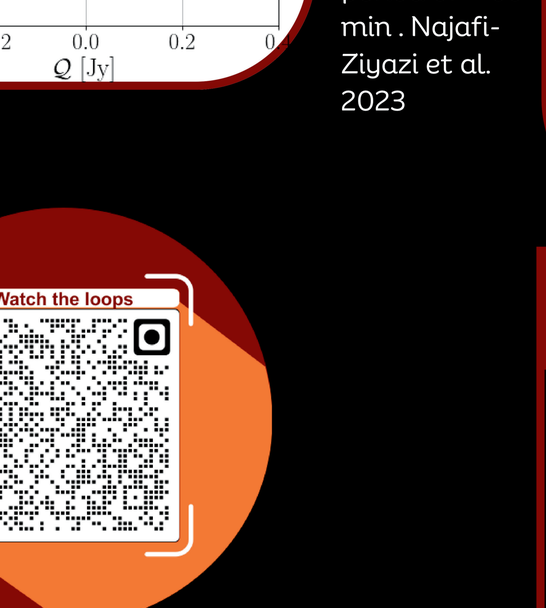
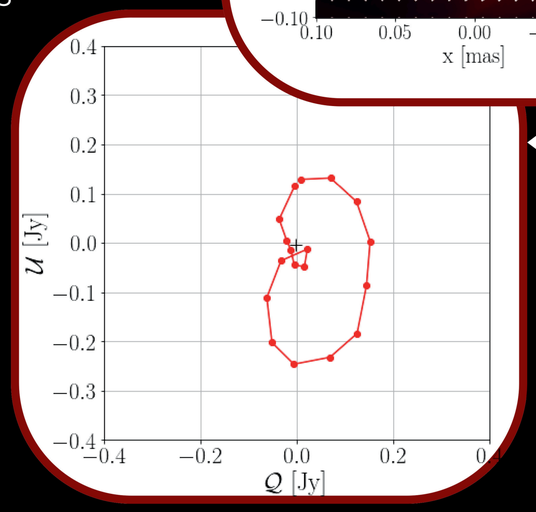
Introduction

The Milky Way's supermassive black hole known as Sagittarius A* (Sgr A*) shows daily flaring activities registered in various wavelengths. This emission is polarised in nature and can be recorded by detectors on Earth. The observations have shown that after a flaring event, a coherent pattern emerges in the linear polarisation plane of the emission (as seen in IR and sub-mm). These patterns represent loops with a period ~1 hour.



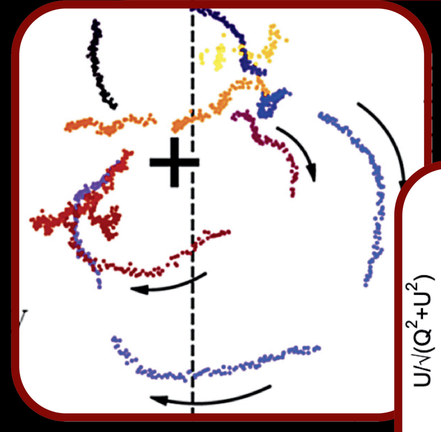
A snapshot of an orbiting flux bundle forming in a MAD disk perturbing the background polarisation. The white ticks are the instantaneous electric vectors while the red ticks are the background electric vectors. Najafi-Ziyazi et al. 2023



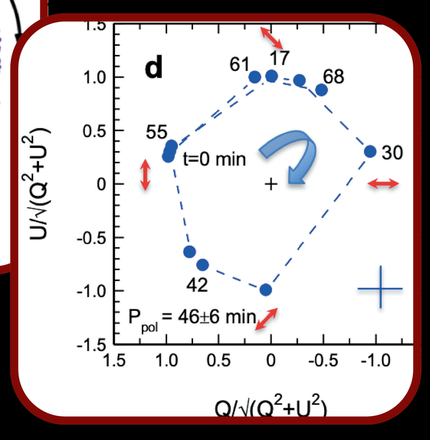
A loop formed in the linear polarisation plane as result of orbiting flux bundle for a period of ~ 60 min . Najafi-Ziyazi et al. 2023

GRMHD models

The general relativistic magnetohydrodynamic (GRMHD) simulations have shown that some of the features of the flaring events can be recovered by the flux bundles that naturally occur in highly magnetised accretion disks known as magnetically arrested disks (MADs). We looked at the post-processed synthetic thermal emission of these simulations, and saw that each eruption is assciated with a loop!



sub-mm loops in the Q-U plane. Wielguss et al. 2022

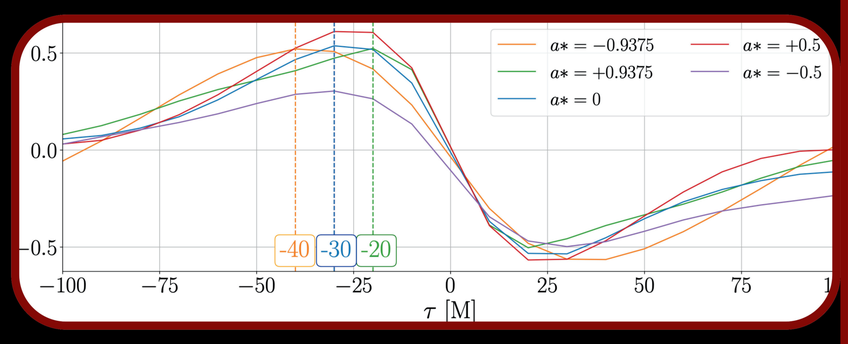


IR loops in the Q-U plane. GRAVITY collab 2018

Watch the loops

Loop Periods

The periods of the loops can be inferred from the cross-correlation between Q(t) and U(t). We have found that the periods of the loops are spin-dependent, where the spin a*= +0.9375 generates a loop with a period of ~ 27 minutes and the counter-rotating spin a* = -0.9375 generates a loop of 54 minutes, which is twice longer. Therefore, our model shows that if we measure the period of the loops we can predict the mass of the black hole within factor of two.

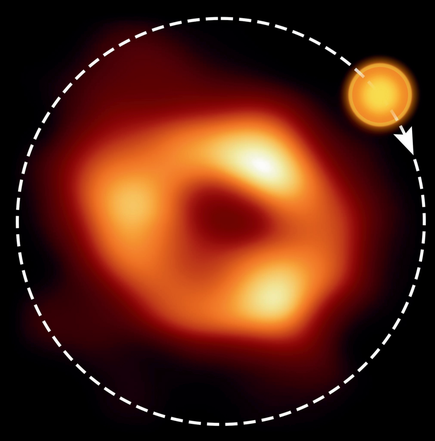


The normalized cross-correlation between Q(t) and U(t) is displayed for various spins of the black hole (a*) where the x-axis is the time-delay (τ). Najafi-Ziyazi et al. 2023

Hot spot model

The loops are the indication of the periodic change in the time series of the linear polarisation components Q(t) and U(t). A model is proposed to explain this periodic variation known as the 'hot spot' model. According to this scheme, a blob of emission is orbiting in the accretion disk of the black hole close to the event horizon, which results in the periodic disturbance of the background polarisation. This periodicity takes form as a loopy feature in the linear plaorsiation plane.

The 'hot spot' model illustration. EHT Collaboration, ESO/M. Kornmesser



Conclusion

The loops contain information about the properties of the black hole such as magnetic profile, spin, and inclination. Our analysis of these loops has shown that a MAD disk is a favourite candidate for Sgr A*, and the counter-rotating spin seems to generate loops with periods similar to the observations.