Manuscript Date: 26 April 2007
Preprint typeset using LaTeX style emulateapj v. 08/13/06

A MICRO-SPIRAL OF LIGHT-MONTHS AROUND SGRA* AT THE GALACTIC CENTER

A. Rej
Bygdøy Allé 51B, 0265 Oslo, Norway
anup.rej@c2i.net
Manuscript Date: 26 April 2007

ABSTRACT

It has become a common practice these days to explain the activities at the centers of galaxies by assuming the existence of black holes with masses ranging between 10^6 and 10^9 solar masses. The observations of the orbital motions of young stars, moving within a couple of light-months from the center, have been argued as the conclusive evidence behind the existence of a black hole. The variable flares seen in X-rays and Infrared wavelengths, occurring close to the galactic center, have further emboldened this view. We have reanalyzed the motions of these stars, and studied the data in X-rays and Infrared wavelengths using different image processing techniques. Here we report the existence of a micro-spiral structure of a few light-months in size, whose center lies about a light-month South-East of the compact radio source SgrA*, and also show that there exists a structure at the very position around which the star S2 moves in orbit like its binary companion. Several stars in the region are attracted towards the center of the micro-spiral. Some stars may even follow helical paths as they coil towards the center. The phenomenon reported here is unknown before, and points to a mechanism which may have relations to strong magnetic fields at the heart of the galaxy, which one will need to explore in the future. Moreover, we anticipate that the structure of hierarchically embedded spirals, as observed within a few pc of the Milky Way center, could be a generic phenomenon occurring in many galaxies of different morphological classes and, in fact, such spirals could be driving the activities at the centers of most galaxies.

Subject headings:

1. INTRODUCTION

The galaxies which possess active nuclei are expected to harbor supermassive black holes (SMBH) at their centers (Ferrarese & Ford 2005). The activities at the center are believed to be driven by the dynamics of these black hole. The nearest place to study such a black hole is the center of our own Milky Way galaxy. Since the discovery of the compact radio source known as Sagittarius A*(SgrA*) in 1974, the speculation about the existence of the black hole in the galactic center have intensified. The observations of the orbital motions of young stars (Schödel et al. 2002; Ghez et al. 2005), moving within a couple of light-months from the center, have been argued as the conclusive evidence behind the existence of a black hole. A black hole will be surrounded by a disk, and accrete matter from it while generating X-rays. The observations by Chandra X-ray satellite have confirmed the X-ray emissions from the galactic center (Baganoff et al. 2003). Apart from the observations of variabilities in flares both in X-rays (Baganoff et al. 2001; Goldwurm et al. 2003; Eckart et al. 2006) and Infrared (Genzel et al. 2003), simultaneous detections of X-ray and Infrared flares have also been made. The X-ray observations show a few hot spots immersed in a background of diffuse emission. The strongest hot spots lie within 2 light-years of SgrA*. It has been argued that one of these X-ray hot spots could be associated with the SgrA*.

The major problem of the black hole model has been the presence of young supermassive Wolf-Rayet stars, and blue O-B stars at the immediate vicinity of SgrA*(Eckart et al. 2004; Figer 2003). The formation of such young stars inside the sphere of influence of the black hole remains difficult to explain. Moreover, there exist two stellar clusters near SgrA*. These clusters (IRS16 and IRS13) show motions in the opposite directions (Paumard et al. 2006). How could such clusters form so near the black hole, or if they were formed originally outside the sphere of influence of the black hole, how could they migrate towards the black hole and still stick together as co-moving stars without being torn apart? They could be the remnants of ruptured accretion discs (Levin & Belobordov 2003) where the young stars once formed. The intermediate mass black holes may have formed inside these clusters (Maillard et al. 2004; Schödel et al. 2005), which hold the stellar groups together against the disrupting forces of the SMBH. However, one needs to invoke two counter-rotating accretion discs to explain the motions of the stars. Furthermore, the variability of the nearby stars (DePoy et al. 2004; Martins et al. 2006) seen in different wavelengths raises problems. The strong variability observed in x-rays has given rise to the idea that a swarm of black holes could be roaming around the galactic center (Roy & Watzke 2005). These black holes may capture one of the stars from a binary system and eject the other. One also needs to understand how the filaments seen around these clusters (Moultaka et al. 2004), which are possibly created by shock generated by material streaming out from the center and impinging on the dense surrounding medium, could be compatible with the black hole scenario.

While many bewildering questions are being raised, orbital motions of young massive stars around SgrA* have been observed. Particularly a star named S2 has been observed to trace an orbit of semi-major axis of 5.5 light days with an orbital period 15.2 yr (Schödel et al. 2002). It has also been speculated that the curved paths

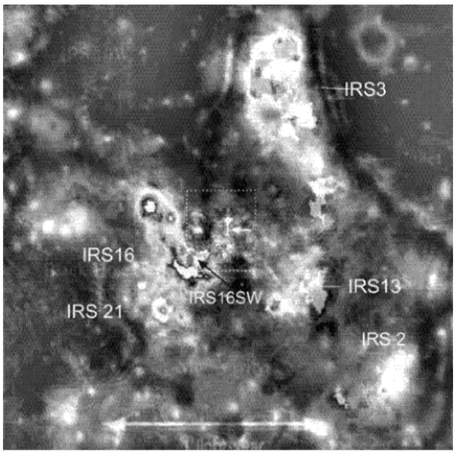

FIG. 1.— X-ray image of 2 lyrs on each side overlaid over the Infrared image of the center of the Milky Way galaxy. Lighter areas, showing the jet like structures, are the most X-ray intense regions inside the galactic core. The position of SgrA* in the picture is marked by two arrows at the center of the image. The X-ray picture is based on the Chandra X-ray data. The structure exhibiting X-ray emission features may be viewed as comprised of two interacting spirals - one to the left and the other to the right of SgrA* position. The Northern arm of the left spiral contains IRS 16SW-E, S2-4, S2-5, S2-6, IRS 16NE and IRS 16CC, while the southern arm embeds IRS 21, and the arm moving towards SgrA* contains IRS 16SW. The Northern arm of the right spiral is closely associated with IRS 13 and IRS 3, while the X-ray emission from the Southern arm could be related to IRS 2. One observes the formation of a micro-spiral of a few light months in size in the center where the inner moving arms of the two above spirals of about an order of magnitude larger in size have met.

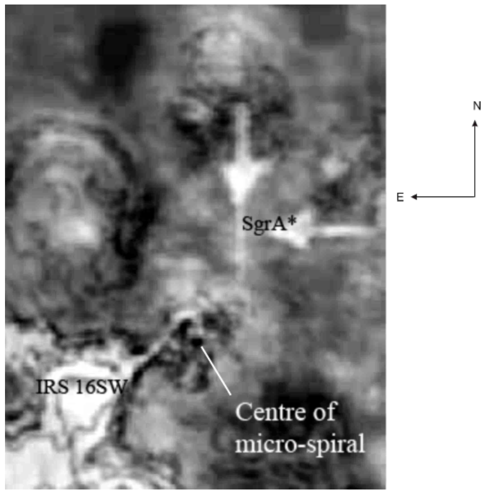

FIG. 2.— The region of approximately 3.5 x 4.5 light months (dotted rectangle in fig 1) encompassing SgrA* and the central mouth of the micro-spiral. The micro-spiral structure is obtained by image processing different infrared images, and overlaying the enhanced images over each other. Several image enhancement and filtering techniques, together with the ways to avoid loosing resolution as one magnifies the images, which are available with several graphic software have been used to extract deeper information from the digital data. The radio source SgrA* lies encoiled inside the Northern arm of this micro-spiral.

of six more stars could be portions of the Keplerian orbits (Ghez et al. 2005) around the SMBH. The motions of these stars have been put forth as the conclusive evidence for the existence of a black hole.

A reanalysis of the different Infra-red and X-ray images of the inner few light years of the galactic center, and the motions of the stars observed by the ESO Telescopes at near-infrared, form the basis of the results presented in this letter. The Chandra X-ray images (Chandra website 2003), as well as the Infra-red images of the Galactic Center (Max-Planck Galactic Center Group 2006) are studied by using different image enhancement methods. The result of the analysis reveals a new picture of what may be happening at the galactic center, which is unknown before.

The X-ray images of the inner 2 light years (Fig.1) show that the most intense x-ray emitting regions form a spiral structure, and the major X-ray hot spots coincide with the IRS clusters. The X-ray variability seen close to IRS 16SW and IRS 21 could be due to the violent winds, blowing from the massive young stars, that collide with the dense surrounding medium. The spiral structure seen in X-ray may be tracing the collisions of winds in denser medium. The center of this spiral structure is close to IRS 13. However, the most interesting observation of this report is the existence of a micro-spiral structure of a few light months in size (Fig.2). The center of this micro-spiral lies about the midpoint between SgrA* and the IRS 16SW. The SgrA*, which shows very little X-ray features, remains encoiled inside the northern arm of the micro-spiral, which coils inward like a vortex (Fig.2). A spiral hierarchy, where a larger spiral (the so called mini-spiral of about 10 light years) embeds a smaller spiral (2 light years) at its heart, which in turn embeds an even smaller spiral (light months), seem to exist in the galactic center.

Among the O/B stars moving close to SgrA* only S2 has been seen to complete two-third of its Keplerian orbit around SgrA* (Schödel et al. 2002). The Keplerian orbits of the other stars are more a matter of guess. Apart from S2, the star S12 is observed to be clearly deflected by SgrA* as one would expect from an orbiting object in its perihelion passage. At best three stars are accelerated as they come close to SgrA*, while several other stars move towards the center of the micro-spiral (Fig.3). The paths followed by the stars falling in the mouth of the micro-spiral could be zigzag, or helical. While a few stars spiral inside the micro-spiral center, some appear to be ejected from it. The IRS 16SW forms a bridge between the IRS 16 complex and the center of the micro-spiral, where several spring like helical structures can be observed. In fact, the co-moving group of stars, of which IRS 16SW is a member, itself could be a part of a spiral formation (Fig.1). One arm of this spiral is connected to the center of the micro-spiral lying about one light-month North-West of IRS 16SW. The group of helium stars co-moving with IRS 16SW as a cluster show motions (Lu et al. 2005) away from the center of the micro-spiral towards the North-East. Similarly, the motions of the co-moving stars in IRS 13 cluster indicate movements away from this micro-spiral mouth in the Westward direction. A scenario of ejections mediated by the micro-spiral formation would be compatible with the filamentary structures seen around IRS16 and IRS13.

The next interesting point of this report is the existence of a structure at the very position of SgrA*(Fig.4). The star S2 rotates around this structure like its binary companion. As S2 rotates, the structure appears to undergo deformations. The structure could be a knotted object made of filamentary ropes which coil and twist

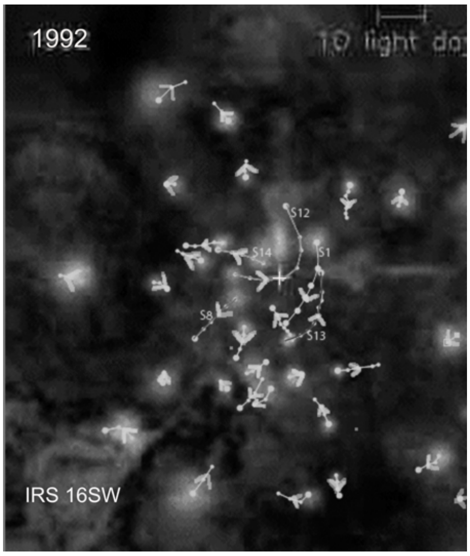

Fig. 3.— The directions and the paths of motions of the stars forming SgrA* star cluster as observed with SHARP camera on the ESO NTT during 1992-2002. The motions of S1, S2, S8, S12, S13 and S14, which are labelled, have been presently argued as case for a convincing evidence for the existence of a black hole (residing at the position of the cross). Apart from the orbit of S2 (not shown in the figure), which appears to be bound to SgrA*, only the orbit of S12, which moves in the counter-direction of S2, makes a swing around SgrA*. The paths of 33 stars are shown by lines with dots, and their directions of motions are indicated by arrows. Except S12, all stars lying left of the SgrA* move away from the presumed black hole. Instead, the directions of S1, S8 and S9, as well as the majority of stars lying in the lower half of the picture appear to be heading towards the mouth of the micro-spiral. S13 and a few stars lying closest to it (referring to the position in 1992) and just south of it, can be seen to be moving away from the micro-spiral mouth. The X-ray source IRS 16SW, which is situated at the left lower corner of the image, also shows movement away from the spiral mouth. The paths of some stars show some amount of zigzag motions. They could be affected by the motions of the other stars passing close by. In such a dense stellar environment one should expect snatching of material from each other, causing quakes and flares in X-rays and infrared. Given the present observational situation it would be dubious to speculate that these stars could be tracing Keplerian orbits around a black hole.
See Mpeg movie:
http://cosmology.in/structureformation/GC/microspiral/movie.swf

around each other. The X-ray and Infrared flares observed from SgrA* could result from the tightening of these ropes (might be turbulent plasma?), which could be driven by magnetic processes, and then relaxation of these ropes by releasing magnetic energies as wind and ejecta. Electron acceleration by plasma wave turbulence can explain the spectral nature of the observed flares (Liu et al. 2004). Though the flares could be caused by magnetically driven plasma ejection, one needs to understand the nature of the SgrA* object and the dynamics that has generated the compact radio source. If gravity is the only force driving the dynamics at the galactic center then the object has to be enormously massive, and one would need to understand what kind of matter could constitute such a cosmic object. However, if one abandons such an assumption and looks for windows of understanding that incorporates turbulence and magnetic field as major players in the structure formation in the universe it may open a new era of understanding the cosmos (Rej 2006).

We have here pointed out the significance of an alternative, or a supplementary dynamics to that driven

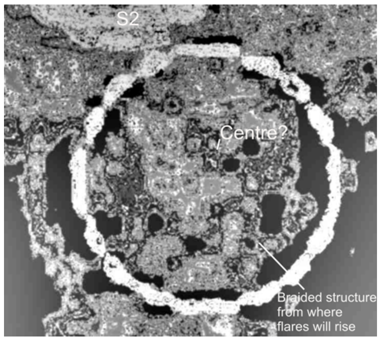

Fig. 4.— A structure is revealed at the position of SgrA*. The area inside the white ring has been envisaged as the place where a black hole hides. To the upper left side above the ring, the southern portion of the star S2, which is bound to the SgrA*-object, is barely visible. Instead of a black hole a structure, which possesses twisted rope-looking filamentary forms in its southern part, exists. The image is obtained by image enhancing the SINFONI Infrared data (ref 20), which are taken at the time of no flare. The flares occurring at the same position, after a short time, could be associated with the braided structure that appears in the southern part of this enigmatic object, and might be the results of ejections of material rather than any accretion process. The release of magnetic energies, while the twisted filaments relax, could be the cause of the flares one observes. In such a scenario one should be able to detect ejecta associated with the flares, which will move away from the SgrA*-object. The star S2 revolves around this enigmatic object like its binary companion. The exact position of the radio source could be a little above the centre of the ring.

by a black hole, in explaining the observed structure at the galactic center mediated by the presence of a hierarchically embedded spiral formation. We have also shown that there exists an enigmatic structure at the SgrA*, where magnetic braiding of plasma loops may have formed, whose tightening and relaxation could result in intermittent flares, which outpour large amount of energies in different wavelengths. The X-ray emissions observed within the 2 light years area around SgrA* may be explained as the results of heating of the turbulent winds blown from the supermassive young stars (Rockefelleret al. 2005) (but, no supernova) when the winds collide with each other, or as results of shocks generated by plasma, ejected from the centers of violently churning young stars, that impinge on the dense surrounding medium. We have also demonstrated the presence of a micro-spiral structure in the scale of light-months, which devour and eject stellar structures at the same time. We anticipate that this mechanism of recycling by accretion and outflow going on at the same time, driven by spiral dynamics, could be a generic phenomenon in the centers of many galaxies belonging to different morphological classes. One observes such spirals at the centers of many galaxies - for example, the Whirlpool galaxy M51 (Grillmair et al. 1997), the giant elliptical galaxy M87 (Tsvetanov et al. 1999), spiral galaxy NGC 5248 (Laine et al. 2001). Moreover, the present study envisages the possibilities which magnetic fields and turbulence (Haverkorn et al. 2004) may play in the star formation as well as the accretion and ejection of material from the galactic centers.

I thank Prof. Finn Ingebretsen and Prof. Øyvind Grøn for carefully reading the paper and giving their comments and suggestions.

REFERENCES

Baganoff, F. K., Bautz, M. W., Brandt, W. N., Chartas, G., Feigelson, E. D., Garmire, G. P., Maeda, Y., Morris, M., Ricker, G. R., Townsley, L. K., Walter, F. 2001, Nature, 413, 45

Baganoff, F. K., Maeda, Y., Morris, M., Bautz, M.W., Brandt, W. N., Cui, W., Doty, J. P., Feigelson, E. D., Garmire, G. P., Pravdo, S. H., Ricker, G. R., Townsley, L. K. 2003, ApJ, 591, 891

Chandra Website for Sagittaruis A* 2003, http://chandra.harvard.edu/photo/2003/2003long

DePoy, D. L. et al. 2004, ApJ, 617, 1127

Eckart, A., Moultaka, J., Viehmann, T., Straubmeier, C. & Mouawad, N. 2004, ApJ, 602, 760

Eckart et al. 2006, A&A, 450, 535

Ferrarese, L. & Ford, H. 2005, Space Sci. Rev., 116, 523

Figer, D. F. 2003, Astron. Nachr. Suppl., 324, 255

Genzel, R., Schödel,R., Ott, T., Eckart, A., Alexander, T., Lacombe, F., Rouan, D., Aschenbach, B. 2003, Nature, 425, 934

Ghez, A., Salim, S., Hornstein, S. D., Tanner, A., Lu, J. R., Morris, M., Becklin, & E.E., Duchêne, G. 2005, ApJ, 620, 744

Goldwurm, A., Brion, E., Goldoni, P., Ferrando, P., Daigne, F., Decourchelle, A., Warwick, R. S. & Predehl, P. 2003, ApJ, 584, 751

Grillmair, C. J. et al. 1997, AJ, 113, 225

Haverkorn, M., Gaensler, B. M., McClure-Griffiths, N. M., Dickey, J. M. & Green, J. 2004, ApJ, 609, 776

Laine, S., Knapen, J. H., Perez-Ramirez, D., Doyon, R. & Nadeau, D. 2001,Ap&SS, 276, 475

Levin, Y. & Belobordov, A. M. 2003, ApJ, 590, L33

Liu, S., Petrosian, V. & Melia. F. 2004, ApJ, 611, L101

Lu, J. R. et al. 2005, ApJ, 625, L51

Maillard, J. -P., Paumard, T., Stolovy, S. R. & Rigaut, F. 2004, A&A, 423, 155

Martins, F. et al. 2006, ApJ, 649,L103

Max-Planck-Institut für extraterrestrische physik-Infrared/submillimeter Astronomy- Galactic Centre Research 2006, http://www.mpe.mpg.de/ir/GC

Moultaka, J. et al. 2004, Proceeding of IAU Symposium (eds Storchii-Bergmann, T., Ho, L. C. & Schmitt, H.R.) 222, 141

Paumard, T. et al. 2006, J. Phys.: Conf. Ser., 54, 199

Rej, A. 2006, http://www.cosmology.in/structureformation

Rockefeller, G., Fryer, C. L.,Baganoff, F. K., & Melia, F. 2005,ApJ, 635, L141

Roy, S. & Watzke, M. 2005, http://chandra.harvard.edu/press

Schödel, R. et al. 2002, Nature, 419, 694

Schödel, R., Eckart, A. & Iserhole, C. 2005, ApJ, 625, L111

Tsvetanov, Z. I., Allen, M. G., Ford, H. C., & Harms, R. J. 1999, Proceedings of the M87 workshop, Ringberg Castle (eds Röser, H.-F., & Meisenheimer,K.)p301