Applied Physics Research; Vol. 5, No. 5; 2013
ISSN 1916-9639 E-ISSN 1916-9647
Published by Canadian Center of Science and Education

Mathematical Modelling of a Gravitational Optical Phenomenon in the Milky Way Centre

Vladimir A. Leus[1]

[1] Sobolev Institute of Mathematics, 630090, Novosibirsk, Russia

Correspondence: Vladimir A. Leus, Sobolev Institute of Mathematics, Novosibirsk 630090, Russia. E-mail: vladalex@liv.ac.uk

Received: August 1, 2013 Accepted: August 13, 2013 Online Published: September 17, 2013

doi:10.5539/apr.v5n5p127 URL: http://dx.doi.org/10.5539/apr.v5n5p127

Abstract

The astronomical data obtained from the observations of an enigmatic object hidden in the centre of our Galaxy suggest possible optical phenomena due to the light bending. The existence of the gigantic collapsar (super-massive black hole) located in the centre of the Galaxy and the presence of a very dense cluster of stars all around it, allows us to propose a new approach due to the extraordinary stellar "crowd" and consequent multiple light ray deflections. Consequently, a refulgent optical aureole, which should be detectable by infrared observation, may be predicted.

Keywords: Galaxy, Galactic centre, collapsar, gravitational lensing, light bending

1. Introduction

A collapsar—"black hole" in terms of the general relativity theory (GRT)—is a massive body in which gravity prevails above all other physical forces. In 1974 the British astronomer Sir Martin Rees proposed that super-massive collapsars—ones with a million or even more solar masses—must exist within the centres of some galaxies with active nuclei that shine as brightly as tens of billions suns. Rees was speculating about black holes in active galaxies, but furthermore due to systematic observations a dawning awareness appeared that active galaxies are not the only ones to harbour such monsters at their centres. Ordinary galaxies like the Milky Way proved to have them also (Melia Fulvio, 2007).

In 1974 American radio astronomers B. Balick and R. Broun discovered a compact and variable radio source that looked much like a faint quasar but this object was only 26,000 light-years away. Because it appeared to be inside a large, extended radio source already known as Sagittarius A, they named it Sagittarius A* ("A-star"). Over the next two decades, astronomers painstakingly examined Sagittarius A* (Sgr A*) at radio, optical, and near-infrared (NIR) wavelengths, but for examination at X-ray wavelengths it would have been necessary to launch a specific X-ray telescope in orbit around the earth. In 2000 the cosmic observatory "Chandra" pinpointed a source of X-rays that coincided with Sgr A*. Due to the variable brightness of the Sgr A*, astronomers calculated that the X-ray source was only about 15 million kilometres across (c.f. the orbit of the Earth is approximately 300 million km in diameter).

The central region of our Milky Way is an extremely interesting and fascinating field of research. There, within few light years astronomers find tens of thousands of stars forming a dense cluster, and geometric centre of our Galaxy harbours a super-massive collapsar (termed here as a Collapsar) with around 4.1 million solar masses. A significant contribution in these studies has been made by astronomers of the Max-Planck Institute. Since the first NIR high-resolution observations of the Galactic centre (GC) in the beginning of the 1990s, the GC has been regularly monitored. Time resolved astrometry over a time span of the last 17 years allows a description of the proper motions of the GC stars. The observations clearly show that some stars in the immediate vicinity of Sgr A*—i.e. in distances up to around 30 light-days—move on Keplerian orbits around the central mass (Gillessen et al., 2009). From the shape of these orbits, the mass of Sgr A* and its distance from the Earth can be calculated. In order to achieve this, the astronomers of the Max-Planck Institute have observed the central parsec of the Galactic centre in near infrared wavelength at the European Southern Observatory—ESO (Chile).

Until 2003 no unambiguous NIR counterpart of Sgr A* could be detected. On the 9th of May 2003, during routine observations of the star cluster at 1.7 microns with infrared camera NAOS/CONICA they witnessed a powerful flare at the location of the black hole. Within a few minutes the flux of a faint source increased of 5-6 and disappeared again after about 30 minutes. The flare was found to have happened within a few milli-arcseconds of the position of Sgr A*. The short rise-and-decay times told astronomers that the source of the flare was located within less than 10 Schwarzschild radii of the black hole (Paumard & Perrin, 2005; Hamaus et al., 2009).

It should be noted that the wide-spread term "black hole" is not a happy choice. The Relativistic Theory of Gravity, promoted by the team of physicists in Russia (Logunov, 2001), justly asserts that a result of the collapse of a spherical mass must have a finite density irrespective of the frame of reference. But according to GRT a collapsing mass reaches infinite density during a finite period of proper time. Moreover, this final "singularity" hasn't any tangible outer boundary, and so an observer falling to it does not feel any obstacle when crossing the Schwarzschild sphere. Such fanciful properties are irreconcilable with the notion of a physical object. It was not without reason that Einstein himself wrote: "*Schwarzschild"s singularity does not exist, since matter cannot be concentrated in an arbitrary manner; otherwise clustering particles would achieve the velocity of light*" (Einstein, 1966, p. 531). In GRT, however, difficulties arose with the conservation laws of energy-momentum and angular momentum. D. Hilbert wrote in this connection: "*I claim that within general relativity theory, i.e. in the case of general invariance of the Hamiltonian function, there definitely exist no energy equation ... corresponding to the energy equations in orthogonal-invariant theories. I could even point to this circumstance as a characteristic feature of general relativity theory.*" All above is explained by the absence in Riemannian space of the ten-parameter group of motion space-time, so it is essentially impossible to introduce energy-momentum and angular momentum conservation laws, similar to those that hold valid in any other physical theory (Logunov, 2001, pp. 18-19).

Despite that "publicly transparent" statement, the erstwhile warning of the great mathematician is neglected. So, it is likely, that the "black hole" appeared as an artefact of GRT. In contrast, the novel Relativistic Theory of Gravity ascertains that "*a body of arbitrary mass cannot undergo compression indefinitely, and therefore no gravitational collapse involving the formation of a 'black hole' is possible*" (Logunov, 2001, p. 149).

Luckily for us, the phenomenon of light bending in gravitational field has the same explanation in both theories (Logunov, 2001, pp. 164-166); that is how things are in this part of physics. The existence of the Collapsar located in the centre of the Galaxy and the presence of a very dense cluster of stars all around it, allows two different (even reciprocally opposite) approaches being implemented in theoretical investigation. In (Alexander & Loeb, 2001) the authors adopt the cluster to be a new massive supplement to ability of the central Collapsar when lensing "*distant background stars*". They reasoned that "*the lensing probability is increased by factor ranging from 2 to 3*". Contrary to them, the present paper studies the role of these close stars in the central cluster as source rather than lense. This approach is based on the extraordinary stellar "crowd" and consequent multiple light ray deflections in the vicinity of the Collapsar. It consists in depicting the geometry of a three-dimensional region critical for the light bending. Thus, a refulgent optical aureole should be detectable by observation in the near infrared range if the density of stars is sufficiently high in that critical volume. The main idea behind this approach was presented at the conference on applied mathematics in February 2011, Novosibirsk (Leus & Taylor, 2011).

2. Gravitational Lensing

The effect of a light beam bending near a massive body may be interpreted as a consequence of space-refraction taking place in the vicinity of a mass, where the value of refractive index depends on the gravitational potential. Einstein was the first scientist to discuss the natural phenomenon of gravitational lensing. In 1936 he examined the possibility that the gravity-lensing effect might be detected if one star intercepts the line of sight to a more distant star. He understood that such a geometrical occurrence is extremely unlikely. Moreover, even if the case arises the effect may be undetectable due to the very small angular diameter of the image—the bright halo (Einstein ring) encircling the lensing star. Even nowadays the angular diameter of images caused by a stellar mass—so called microlensing—is too small to be resolvable by telescopes.

An observer O, a star A and a star B are arranged in the same straight line. The distance between the observer and star A is $|OA|$, the distance between the star A and star B is $|AB|$ (Figure 1). One light beam goes from the utmost down rim of the star B and another light beam goes from the utmost up rim to the star A and after being deflected there goes farther to the observer. An angle of bending $\alpha = k/b \ll 1$, where k—a constant length depending on mass of the star A, the so called impact parameter b is the distance from the ray trace to the centre of the star A.

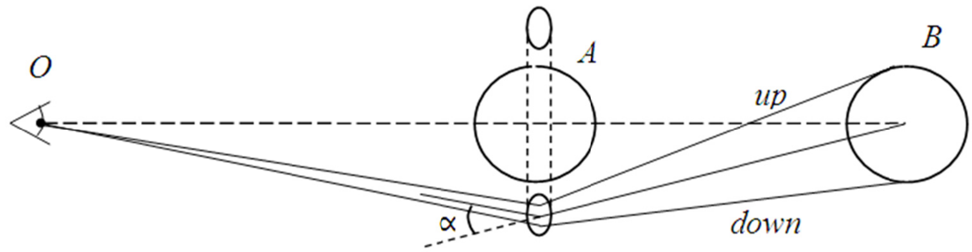

Figure 1. Schematic diagram showing microlensing seen by an observer (*O*) caused by the gravitational effect of star *A* on light from star *B*

The bending angle is approximately equal to

$$\alpha' = \frac{b}{|OA|} + \frac{b}{|AB|} = \frac{b\ |OB|}{|OA||AB|} \simeq \frac{k}{b},$$

where

$$b \simeq \sqrt{k\frac{|OA||AB|}{|OB|}}.$$

For stars similar to the Sun the value $k = 3$ kilometers, and the average distance between stars in the precinct of the Sun is equal to 10 parsec (3.1×10^{13} km). This gives $b \simeq 7 \times 10^6$ km, which is only several times bigger than the diameter $d_\odot$ of the Sun ($d_\odot = 1.4 \times 10^6$ km).

These simple estimates show that the diameter of a bending area—a torus-like region around a bending star—is in the same order of magnitude as its diameter and cannot be discerned from star image provided by a telescope. More accurate calculations, as for instance made in (Bradt, 2008), confirm the inference drawn. This is why astronomers use the "microlensing". i.e. gravitational lensing of one star by another star (Falcke & Hehl, 2003, pp. 267-269). as an optical amplifier only. When two images cannot be resolved, the spectrum and the variability of the lensed source may possibly be observed. However the more likely situation is where a distant star does not strictly lie in the line of sight with the lensing star. In this case the halo does not disappear, but splits into two arcs. A distant star, being rather weak in luminosity, becomes much more brilliant due to the so called magnification factor. In the conditions of our example (average distance—10 parsec, where the lensing star is similar to the Sun) the light flux reaching an observer through the "Einstein ring"—a circular halo around the lensing star—would be 170 times bigger than the flux obtained directly from the lensed star itself (Bogorodskij, 1962, p. 146). What is interesting to note is that at the time when Einstein was engaged in the problem of microlensing, a Russian astronomer G. A. Tikhov, who examined the microlensing independently and in parallel with Einstein, used to name the effect "a cosmic mirage" (Bogorodskij, 1962, p. 144). This was precisely the fact which called my attention to the centre of the Milky Way.

3. The Bending of a Light Ray by a Point-Mass

The bending phenomenon in a spherically symmetric gravitation field in terms of geometric ray tracing is described by the Newtonian formula:

$$\alpha = \frac{2GM}{c^2\,b},$$

where $\alpha \ll 1$ is an angle of bending for a point-mass gravitational attractor, $G = 6.7 \times 10^{-11}\ m^3\ sec^{-2}\ kg^{-1}$ is Newton's gravitation constant, M is the mass of deflecting body and the light speed $c = 3 \times 10^{10}\ cm/sec$, b is so called impact parameter—the distance from an attracting point to the straight line defined by the direction of light ray in a starting point. GRT increases this value just by factor two:

$$\alpha(b) = \frac{4GM}{c^2\,b} = \frac{2R_g}{b}, \tag{1}$$

where R_g is so called gravitational radius of deflecting body (Bogorodskij, 1962, p. 136). For the Sun with the mass $M_\odot = 2 \times 10^{30} kg$ the gravitational radius is equal to 1.5 km. A sphere of radius $r = R_g$ is named

Schwarzshield sphere. (Sometimes R_g is also referred to as the Schwarzshield radius.) For the Sun and for the majority of all normal stars the Schwarzshield sphere is buried under thick layers of the active body but another phenomenon takes place for a collapsar, whose Schwarzshield sphere is open to the outer cosmic space.

The given above formula works for the big enough values of impact parameter only. For $b < 10$ (gravitational radius taken to be unity) the error increases dramatically, and a more complicated formulae derived from the equations of motion must be used. The escape velocity enables an arbitrary body to go to infinity from the attractive centre. In a spherically symmetric gravitational field the escape velocity is $v_{esc} = \sqrt{2GM/r}$ at a distance r from the centre, both in Newtonian and Einsteinian theories. At the distance r equal to the Schwarzshield radius, i.e. on the Schwarzshield sphere of a collapsar, the escape velocity is equal to the light speed.

The trajectory of an ultra-relativistic particle (photons included) in the collapsar's neighbourhood remain also planar in GRT, but unlike the Newtonian case not every r can provide a stable circular orbit. Choosing the plane of the trajectory to be equatorial in a system of spherical coordinates (r, φ, ϑ) the equations of motion (Frolov & Novikov, 1998, p. 44) may be written in the following form:

$$\left(\frac{dr}{cdt}\right)^2 = \left(1-\frac{1}{r}\right)^2\left[1-\frac{b^2}{r^2}\left(1-\frac{1}{r}\right)\right], \qquad \frac{d\varphi}{cdt} = \left(1-\frac{1}{r}\right)\frac{b}{r^2}.$$

Here the impact parameter b and the distance r are measured in the gravitational radius units. For example, $b = 4,\ r = 3$ means $b = 4R_g,\ r = 3R_g$ respectively.

The first equation describes the rate of change for the distance from particle to the attractive centre:

$$\frac{dr}{cdt} = \pm\left(1-\frac{1}{r}\right)\sqrt{1-\frac{b^2}{r^2}\left(1-\frac{1}{r}\right)}.$$

The double sign means only two possible directions for the same trajectory. Let us find a condition for the rate to be zero. The equation

$$\left(1-\frac{1}{r}\right)\sqrt{1-\frac{b^2}{r^2}\left(1-\frac{1}{r}\right)} = 0$$

may be satisfied in two different manners. The first one $(1 - 1/r) = 0$ is trivial. More interesting is the second variant

$$1-\frac{b^2}{r^2}\left(1-\frac{1}{r}\right) = 0,$$

or $r^3 - b^2(r-1) = 0$, from which

$$b(r) = \sqrt{r^3/(r-1)} \tag{2}$$

represents an impact parameter as a function of minimal distance $r = r_{min}$ to the centre for any orbit.

The derivative of this function is

$$\frac{db}{dr} = \frac{r(2r-3)}{2\sqrt{r(r-1)^3}}.$$

It is negative at $< \frac{3}{2}$, positive at $r > \frac{3}{2}$, and zero at $r = \frac{3}{2}$. The function $b(r)$ has a minimum value $b\left(\frac{3}{2}\right) = b_0 = \frac{3\sqrt{3}}{2} = 2.598$ so that all trajectories with an impact parameter $b < b_0$ do not have a minimal value of distance to the attractive centre at all. Such a trajectory enters the Schwarzshield sphere i.e. gravitational capture occurs regardless of what momentum and energy the particle has. If the impact parameter has a value b_0, the corresponding trajectory is the closed circle of radius $r = \frac{3}{2}$ where the particle is trapped by the collapsar. If the impact parameter meets the condition $b_0 < b < b_1$, the trajectory has many revolutions with an almost closed circle but ultimately escapes to infinity in any direction (Figure 2).

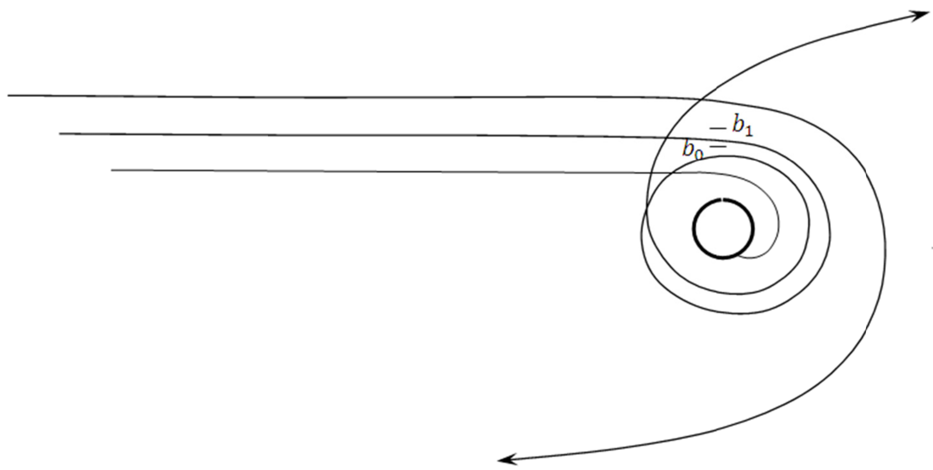

Figure 2. Different possible trajectories of a relativistic particle as a function of the impact parameter *b*

According to the above relation (2) the value $b_1 \simeq 2.75$ (Bogorodskij, 1962, p. 134) corresponds to the value $r_{min} \simeq 2$ of the minimum distance to the attractive centre. All trajectories with impact parameter $b > b_1$ do not have a full revolution over the attractive mass. These trajectories are of peculiar interest.

4. Stellar-Nourished Halo around the Galaxy Centre

Let C denotes the super-massive collapsar located in the centre of our galaxy the Milky Way. Consider a star S of luminosity $\mathcal{L}$ situated at a distance l near the Collapsar. Let D be the aperture diameter of a telescope situated on Earth at a distance L from the Collapsar (Figure 3). Conical light-flux from the star is bent by the Collapsar according to the third variant, when $b > b_1$, and then reaches the aperture of the earth telescope after passing the total distance $l + L$. The solid angle of a circular cone with planar angle 2β at its vertex is equal to $2\pi(1 - \cos\beta)$, and for a small value β it may be approximately written as $\pi\beta^2$, using the well known expansion: $\cos\beta = 1 - (\beta^2/2!) + (\beta^4/4!) - \cdots$ For the telescope viewed from the star S the planar angle $2\beta = \frac{D}{l+L}$. The full solid angle corresponding to the objective lens of the telescope has $\frac{\pi}{4}\left(\frac{D}{l+L}\right)^2$ steradian, and so the light flux impinging on the telescope is

$$\mathcal{L}^D = \frac{\pi\mathcal{L}}{4}\left(\frac{D}{l+L}\right)^2.$$

We shall estimate the total light flux impinging on the objective lens of the telescope through bending from all stars within a sphere of radius r centred on the Collapsar.

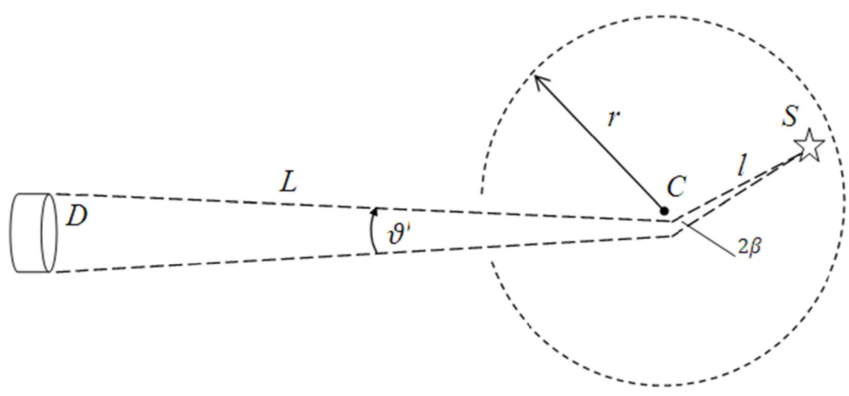

Figure 3. Light beam from star (*S*) deflected by the Collapsar (*C*), impinging upon the aperture of telescope (*D*)

Let n be an average number of stars per unit volume in the vicinity of C (so called *effective value*). The volume of a spherical layer between radii l and $l + \Delta l$ is $\Delta v = \frac{4}{3}\pi[(l + \Delta l)^3 - l^3] = \frac{4}{3}\pi(3l^2\Delta l + 3l\Delta l^2 + \Delta l^2)$.

Hence, the expression for a differentially small layer is $dv = 4\pi l^2 dl$ and the light flux on the telescope from identical stars is:

$$d\boldsymbol{\mathcal{L}^D} = n4\pi l^2 dl \frac{\pi\mathcal{L}}{4}\left(\frac{D}{l+L}\right)^2 = n\pi^2 D^2 \mathcal{L} \cdot \frac{l^2 dl}{(l+L)^2}.$$

The full flux is obtained by integration of $d\boldsymbol{\mathcal{L}^D}$ over all values of variable l between zero and r:

$$\boldsymbol{\mathcal{L}^D} = n\pi^2 D^2 \mathcal{L} \int_0^r \frac{l^2 dl}{(l+L)^2}.$$

The element of integration may be described as follows:

$$\frac{l^2 dl}{(l+L)^2} = dl - \frac{2L dl}{(l+L)} + \frac{L^2 dl}{(l+L)^2}.$$

So the integral required is

$$\int_0^r \frac{l^2 dl}{(l+L)^2} = \int_0^r dl - 2L\int_0^r \frac{dl}{(l+L)} + L^2 \int_0^r \frac{dl}{(l+L)^2} = \left[l - 2L\ln(l+L) - \frac{L^2}{(l+L)}\right]_0^r$$

$$= r + 2L\ln\frac{L}{r+L} + \frac{Lr}{r+L} = r - 2L\ln(1 + r/L) + r(1 + r/L)^{-1}.$$

We use a power series expansion:

$$\int_0^r \frac{l^2 dl}{(l+L)^2} = r - 2L\left(\frac{r}{L} - \frac{r^2}{2L^2} + \frac{r^3}{3L^3} - \frac{r^4}{4L^4} + \cdots\right) + r\left(1 - \frac{r}{L} + \frac{r^2}{L^2} - \frac{r^3}{L^3} + \cdots\right) \simeq \frac{r^3}{3L^2} - \frac{r^4}{2L^3} = \frac{r^3}{3L^2}\left(1 - \frac{3r}{2L}\right).$$

Now the total light flux impinging on the objective lens of the telescope from all stars within the sphere of radius r centred on the Collapsar may be written explicitly as follows:

$$\boldsymbol{\mathcal{L}^D} \simeq n\pi^2 D^2 \mathcal{L}\frac{r^3}{3L^2}\left(1 - \frac{3r}{2L}\right) = n\frac{4}{3}\pi r^3 \cdot \mathcal{L}\frac{\pi D^2}{4L^2} \cdot \left(1 - \frac{3r}{2L}\right).$$

Here the first multiplier is the total number of stars in the sphere under consideration; the second multiplier is the light flux impinging on the telescope from a star of luminosity $\mathcal{L}$ situated at the galaxy centre, and the third multiplier is a corrective factor taking into account the distribution of stars over the sphere of radius r centred on the Collapsar.

This estimate is too exaggerated because it ignores dispersion in a gravitational lens. Indeed, differentiation of the dependence (1) over b gives an expression

$$\frac{d\alpha}{db} = -\frac{2R_g}{b^2}.$$

A difference of impact parameters $\Delta b = (b_d - b_u)$ is not zero (Figure 1), therefore the angle $\vartheta = 2\varphi$ of light beam from a star to the telescope *D* (Figure 3) is enlarged after passing nearby the Collapsar:

$$\vartheta' \cong \vartheta + \frac{d\alpha}{db}\Delta b.$$

And what is more, the nearer to Collapsar beam passes, the wider is its divergence. For stars from the front semi-sphere (relative to an observer) trajectories with the impact parameter between b_0 and b_1 are characteristic (Figure 2), so the essentially non-linear dispersion in any direction would be typical.

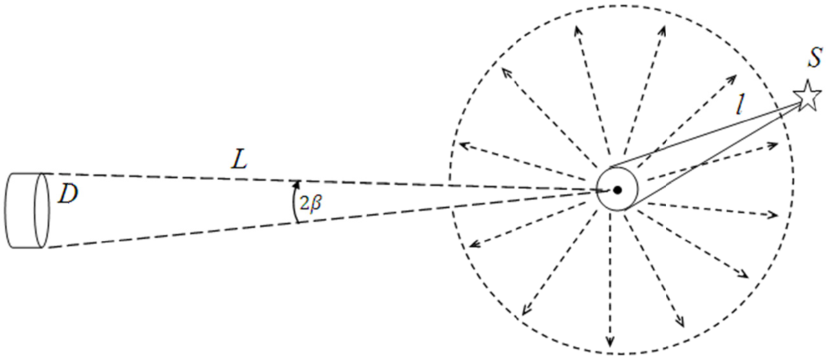

Figure 4. Light beam from star (*S*) fully dispersed by the Collapsar

Consider an another way of thinking, which would take into account the full dispersion on the spherical surface of radius mR_g (m is a whole number), encircling the Collapsar (Figure 4). Let us suppose that a uniform dispersion takes place. The light flux on the dispersive sphere from a star at distance l is equal to $\mathcal{L}\pi\left(mR_g/l\right)^2$, and after dispersion over all 4π steradians it becomes $\mathcal{L}\pi\left(mR_g/l\right)^2/4\pi$. Identical stars uniformly distributed over the spherical layer between l and $l+dl$ give $\frac{1}{4}n(l)\mathcal{L}\left(\frac{mR_g}{l}\right)^2 4\pi l^2 dl = n(l)\mathcal{L}\pi\left(mR_g\right)^2 dl$. Integration in the range between zero and r produces the light flux

$$\int_0^r n(l)\mathcal{L}\pi(mR_g)^2 dl = n\mathcal{L}\pi(mR_g)^2 r,$$

where n is an integrated average for distribution density of stars inside the sphere of radius r, encircling the Collapsar. Clearly, obtained estimate takes into account just the light of stars, incorporated in the space of a r-long bar with circular section of radius mR_g. This result approaches the truth from the "opposite side", but it underestimates the optical amplification by a gravity lensing.

As it has been remarked in the section 2, the angular diameter of star's images caused by a gravy-lens of stellar mass in the case of straight line positioning (Einstein ring) is too small to be resolvable by telescopes. Lensing in the gravitational field of the gigantic Collapsar, surely, gives much bigger circular image of a star. The angular radius of the Einstein ring is

$$\theta = \sqrt{\frac{2R_g l}{L(L+l)}},$$

where L is a distance from the observer to Collapsar, l is a distance from Collapsar to star (Bradt, 2008, p. 450). For a source at infinity Einstein radius is close to $2''$. The linear radius is

$$d = \theta(L+l) = \sqrt{\frac{2R_g l(L+l)}{L}} = \sqrt{2R_g l(1+l/L)}.$$

For $l \ll L$ we have $d = \sqrt{2R_g l}$ (Falcke & Hehl, 2003, p. 269).

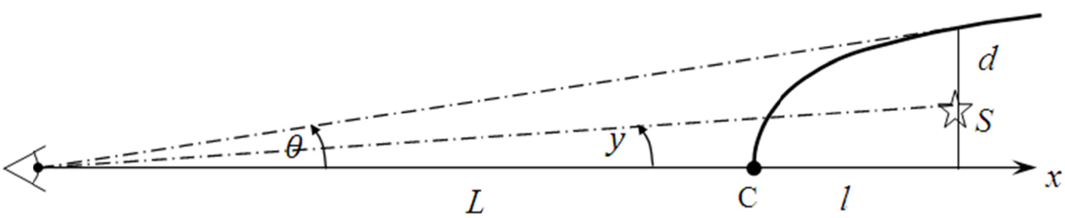

Figure 5. A lensing region in the vicinity of the Collapsar (*C*)

In Figure 5 a longitudinal cross section of the corresponding lensing region for variable values l is shown. For a star S the observer sees two images S_1—inside the Einstein ring, and S_2—outside. The primary image is always magnified with factor A_1, and the secondary image is always de-magnified with factor A_2. The total theoretical magnification therefore is: $A = (A_1 + A_2) \sim 1/y$, where y is the angle between direction to Collapsar and direction to the star (Falcke & Hehl, 2003, pp. 263-264). The volume of this lensing region of a parabolic shape is $\text{v} = \int_o^l \pi d^2 dx = \pi R_g l^2$. It would be fair to name it "Einstein paraboloid" because of its groundbreaking role in creation the optical phenomenon.

Consider a realistic example with the average spatial "density" of stars $n = 300$ per cubic light year, and $l = 300$ light years. Gravitational radius of the Collapsar with mass $4 \times 10^6 M_\odot$ is equal to 10^{-6} light years in accordance with (1). The number of stars in the limit of Einstein paraboloid is $N = n\text{v} = \pi \cdot 300 \cdot 10^{-6} \cdot 300^2 \cong 100$. The value $l/L \approx 0.01$, hence obscuration by dust within the local volume is negligible. Moreover, stars in the Galaxy centre are massive and very hot with luminosity $\mathcal{L}_S \simeq 10^3 \mathcal{L}_\odot$. So even disregarding magnification due to lensing the luminosity of this Galaxy's aureole may clearly reach $10^5 \mathcal{L}_\odot$ in every direction. Besides that in reality there are faint stars encircling the Galactic centre: "*Using positional and radial data of star S2, we found that there could exist an unobserved extended mass component of several* $10^5 M_\odot$, *forming a so-called cusp*" (Mouawad et al., 2005). These stars are too feeble in luminosity to be observed directly from the Earth, but being amplified by gravitational lensing their contribution may be appreciable. Naturally, to an observer on the Earth the light flux from the aureole is in the infrared. This is a significant trait of space near the GC collapsar which should be observable by astronomers because the separate stars are observable in the near-infrared range.

5. Conclusions

Eddington's famous phrase "...so simple a thing as a star" (from his book "Stars and Atoms") is now obsolete. However for any "black hole" there are only three physical parameters. These are: mass, angular momentum and electric charge. Even among such simple objects the Collapsar located in the centre of our Galaxy is thought to be (so far) unique: it does not rotate and is electrically neutral. However there are several riddles hitherto unsolved by astronomers. For example, there are only young blue stars in the immediate vicinity (around 0.02 parsec) whereas a mixture of young and old stars exists further away. Some astronomers admit that the nearest stars "pretend" only to be young and their up-to-date appearance is a consequence of an unusual stellar evolution. Rather puzzling is the weak radiation emanating out of the Collapsar: "*...the centre of the Galaxy is quite benign compared with activity seen in active galactic nuclei*" (Bradt, 2008, p. 41). It is this strange feebleness that gives ground to the belief that the Galactic nucleus contains a "baby" giant black hole (Falcke & Hehl, 2003, p. 307).

The mathematical model presented here adds one more item to the GC mystery list: why has not any visible radiance, circling the point Sgr A*, been discovered? What is preventing the light to reach us? It is not the accretion disk, especially if it is rather in a primitive stage: "*since the accretion disk in Sgr A* is so faint and the accretion rate so uncertain, we cannot actually derive an accretion disk luminosity or accretion power*" (Falcke & Hehl, 2003, p. 338). Theoretically speaking, several models predict the synchrotron emission of gas falling into the black hole from immediate vicinity of order $15\, R_g$. Would it or not be transparent for the visible light? If the latter, the halo will lose a significant part of its luminosity. At distances bigger than $15\, R_g$ the bending angle α becomes less than 0.15Rad and so only these stars which fall out of the α-conical segment make a contribution to the halo brightness. In that way the most efficient volume of Einstein paraboloid becomes idle for the amplification process.

Another cause might be not internal absorption but an external shielding. Far away ($> 100\, R_g$) where gravitational bending vanishes, clouds of dust are supposedly orbiting the Collapsar along all kinds of non-Keplerian trajectories. The question "of what origin?" naturally occurs. Trying to figure out what they might be made of, it is possible to suppose an existence of remnants of once collided stars. The density of stars has a cusp-like dependence on the distance to Collapsar and such a catastrophic event indeed may occur. After such a catastrophe debris are spreading along the orbit in the form of a diffuse wisp. The light from an outer source has to cross twice this natural "smoke-screen" of previously collided stars. This point is a subject for further discussion. In any case, an authentic "cosmic mirage"—the invisibility of the gravitational optical aureole in the Galactic centre—represents a serious observational challenge for modern astronomy. It is likely that astronomers working with specific telescopes (functioning in infrared range) will in due course be able to provide answers from direct observations to the questions raised in this paper.

Acknowledgements

The author thanks Professor Stephen Taylor, at the University of Liverpool, for the fruitful discussion on the topic.

References

Alexander, T., & Loeb, A. (2001). Enhanced microlensing by stars around the black hole in galactic center. *Astrophysical Journal, 551*, 223-230. http://dx.doi.org/10.1086/320052

Bogorodskij, A. F. (1962). *Equations of Einstein's field and its implementation in astronomy*. Russian: Edition Kiev University.

Bradt, H. (2008). *Astrophysics Processes*. New York: Cambrige University Press

Einstein, A. (1966). *Collection of scientific works* (Vol. 2). Moscow: Nauka

Falcke, H., & Hehl, F. W. (2003). *The Galactic Black Hole*. Bodmin, Cornwall, UK: MPG Books Ltd.

Frolov, V. P., & Novikov, I. D. (1998). *Black Hole Physics*. London: Kluwer Academic Publishers

Gillessen, S., Eisenhauer, F., Trippe, S., Alexander, T., Genzel, R., Martins, F., & Ott, F. (2009). Monitoring stellar orbits around the Massive Black Hole in the Galactic Center. *Astrophysical Journal, 692*, 1075-1109. http://dx.doi.org/10.1088/0004-637X/692/2/1075

Hamaus, N., Paumard, T., Muller, T., Gillessen, S., Eisenhauer, F., Trippe, S., & Genzel, R. (2009). Prospects for testing the nature of Sgr A* 's NIR flares on the basis of current VLT—and future VLTI observations. *Astrophysical Journal, 692*, 902-916. http://dx.doi.org/10.1088/0004-637X/692/1/902

Leus, V., & Taylor, S. (2011). Mathematical modelling of a gravitational optical phenomenon in the Milky Way centre. *Methods of Spline-Functions Conference*, Institute of Mathematics, Novosibirsk. ISBN 978-5-86134-180-6

Logunov, A. A. (2001). *The Theory of Gravity*. Moscow: Nauka

Melia, Fulvio. (2007). *The Galactic Supermassive Black Hole*. USA: Princeton University Press

Mouawad, N., Eckart, A., Pfalzner, S., Shödel, R., Moultaka, J. & Spurrem, R. (2005). Weighting the cusp at the Galactic centre. *Astronomische Nachrichten, 326*, 2, 83-95. http://dx.doi.org/10.1002/asna.200410351

Paumard, T., & Perrin, G. (2005). Scientific prospects for VLTI in the Galactic centre: Getting to the Schwarzschild radius. *Astronomische Nachrichten, 326,* 7, 559-573. http://dx.doi.org/10.1002/asna.200585004

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/3.0/).