# The Photon Orbits Split Fourfold, Yet the Shadow Stays Almost a Circle

— What the spin moves is the position rather than the shape — the separator is whether what moves is the shape or the position — [Paper 1069]

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*— From thinking to syncing. —*

**Abstract**

**Around a spinning body the radius at which light can orbit splits in two, one value for each sense of circulation.The split widens with the spin and the ratio reaches fourfold.How much, then, does the shadow built from those orbits depart from a circle?This paper measures it.No new theorem or law is claimed. First, the photon circular orbits split in two under spin——at rest there is a single radius, but at maximal spin the co-rotating light sits at 1.000000000 and the counter-rotating light at 4.000000000, a ratio of 4.000000. Second, the method was checked against a published value——with the spin set near zero the fitted circle has radius 5.196152402 against the published impact parameter 5.196152422707, a gap of $2.119\times10^{-8}$, and the area is 84.822736303 against $27\pi$ at 84.823001647. Third, and this is the core. Even under spin the outline stays almost a circle——at maximal spin the largest departure from the fitted circle is 0.798736448, which is 0.157979411 of the radius. Fourth, what moves is the position rather than the shape——the centre shifts sideways by 2.249463608, reaching 0.444913883 of the radius, and at every spin the shift exceeds the departure from the circle (smallest ratio 2.816278). Fifth, the area shrinks by about a tenth——the ratio to the non-spinning case falls monotonically through 0.938271001 to 0.899135662. Sixth, the split of the orbits and the distortion of the shape differ by an order——the orbit ratio grows by 2.979424 while the shape distorts by only 0.157979. Stated plainly——the observer sits at infinity in the equatorial plane, and neither charge nor an accretion flow is included. Only the shape of the edge is counted.**

**Keywords**: spinning body, shadow edge, photon circular orbit, shape of the outline, least-squares circle, solid angle, separator.

**Scope of this paper (scope note): No new theorem or law is claimed——the spinning solution, the closed form for equatorial photon circular orbits, and the two conserved quantities of the photons that form the edge of the shadow (Bardeen 1973) are all standard.The observer sits at infinity in the equatorial plane——inclined lines of sight are not treated.Charge is not included——the treatment is limited to the purely spinning solution.Neither accretion flow nor intensity nor polarisation is included——only the shape of the edge is counted.No observational values are cited——the masses and distances of real objects are not used.The discussion does not return to the horizon——that the edge is not the horizon has been settled in an earlier paper.The dragging of polarisation is not entered——how the direction of polarisation moves in a rotating spacetime would require committing to a choice of frame, and that lies outside this paper.No theory of spinning bodies is built——numbers are produced on top of a standard solution.Numerical work is not written up as proof——what can be said is that the non-spinning limit agrees with a known value to a stated number of digits, and how much each quantity moves as the spin is raised.Relation to earlier papers：Paper 1046 showed that the edge of the shadow is not the horizon but the image of the circle where light can orbit, and its scope note said that spinning and charged solutions are not treated, that in the Kerr and Reissner-Nordstrom cases the shadow ceases to be a circle, and that only the spherically symmetric case is examined——this paper sits in the seat of that scope note and measures how far from a circle it goes. Measured, it stays almost a circle(no earlier occupant).Paper 1046 also gave the impact parameter separating capture from escape as the square root of 27——that value is used here, in the limit of near-zero spin, to check the method.Paper 1044 showed that light is gathered by a gravitational lens although the curvature of the geometry it travels in is negative——both treat how light turns, but that one concerns the sign of a curvature and this one the shape of an edge.Paper 485 showed that the radius beyond which escape fails was right for a different reason——what is measured here is not that radius but the edge seen from outside.Paper 1006 also declared in its scope note that spinning and charged solutions are not treated, and counted the interior of a bridge——of the two seats that scope note leaves open, the one taken here is the shape of the shadow.Paper 300 showed that whether two things share a root is decidable——following that discipline, the split of the orbits and the distortion of the shape are not called one effect.**What is added is：**counting how the photon circular orbits split as the spin rises, fitting a circle to the outline of the shadow and measuring the departure, showing that the shift of the centre always exceeds that departure, counting the roughly one-tenth shrinkage of the area, and placing side by side the split of the orbits and the distortion of the shape as quantities an order apart。**

## 1. The setting and the question

**Around a heavy body at rest there is a single radius at which light can orbit.The image of that circle is the edge of the shadow seen from outside.This is what Paper 1046 showed.**

**Its scope note said: spinning and charged solutions are not treated.In the Kerr and Reissner-Nordstrom cases the shadow ceases to be a circle, but only the spherically symmetric case is examined there.**

**That is the opening.It says that the shadow ceases to be a circle, but by how much was never measured.This paper produces the number.**

**The setting is as follows.The mass of the body converted to a length is set to one and the spin parameter is varied from zero to one.The observer sits at infinity in the equatorial plane.From the two conserved quantities of the photons that form the edge, the positions on the sky are obtained and the outline is drawn.**

**Four things are measured: the radii of the photon circular orbits, the departure from a circle fitted to the outline, the position of that circle's centre, and the area enclosed by the outline.**

## 2. The photon circular orbits split in two under spin

**At rest there is only one radius at which light can orbit.Under spin it splits, one radius for light circulating with the spin and another against it.**

| Spin | Co-rotating radius | Counter-rotating radius | Ratio |
|---|---|---|---|
| 0.000 | **3.000000000** | **3.000000000** | 1.000000 |
| 0.300 | **2.630025978** | **3.328854540** | 1.265712 |
| 0.600 | **2.188914020** | **3.629849697** | 1.658288 |
| 0.900 | **1.557854627** | **3.910267939** | 2.510034 |
| 0.998 | **1.073909258** | **3.998221893** | 3.723054 |
| 1.000 | **1.000000000** | **4.000000000** | 4.000000 |

**At rest the radius is three and the two coincide exactly.At maximal spin they separate into one and four, a ratio reaching four.The split widens monotonically with the spin.**

**From this alone one would expect the shadow to be distorted about as much.It is not, and that is the content of this paper.**

## 3. Drawing the outline (a check on the method)

**Before anything else, the method is checked in the limit of near-zero spin.Paper 1046 gave the impact parameter separating capture from escape as the square root of 27.That value is the reference.**

| Quantity | Value |
|---|---|
| Fitted circle radius (spin near zero) | **5.196152402** |
| Impact parameter from Paper 1046 | **5.196152422707** |
| Area enclosed by the outline | **84.822736303** |
| 27π | **84.823001647** |

**The gap in radius is $2.119\times10^{-8}$, and the area agrees with 27π to three decimals.The shift of the centre is $2.000\times10^{-4}$, which is the size of the spin that was set.The method is not broken.**

## 4. Even under spin the outline stays almost a circle

**As the spin was raised, a circle was fitted to the outline by least squares and the departure from it measured.**

| Spin | Fitted radius | Largest departure | Fraction of the radius | Shift of the centre |
|---|---|---|---|---|
| 0.00010 | **5.196152402** | 0.000000292 | 0.000000056 | 0.000200000 |
| 0.30000 | **5.187344571** | **0.018830326** | 0.003630051 | **0.603307796** |
| 0.60000 | **5.158897520** | **0.090759301** | 0.017592771 | **1.229644536** |
| 0.90000 | **5.099851390** | **0.322598520** | 0.063256455 | **1.932831465** |
| 0.99800 | **5.058983868** | **0.712379795** | 0.140814799 | **2.235716268** |
| 0.99999 | **5.055952829** | **0.798736448** | **0.157979411** | **2.249463608** |

**The departure grows with the spin.Yet even at maximal spin the fraction of the radius is only $0.157979411$.About fifteen per cent.**

**The photon circular orbits had split fourfold.The outline of the shadow built from that system departs from a circle by fifteen per cent.The splitting of the orbits does not pass through to the shape at its own size.**

## 5. What matters is the position rather than the shape

**Look at the last column of the same table.The centre of the fitted circle drifts sideways as the spin rises.**

| Spin | Shift of the centre | Departure from the circle | Shift ÷ departure |
|---|---|---|---|
| 0.00010 | 0.000200000 | 0.000000292 | **685.854804** |
| 0.30000 | **0.603307796** | **0.018830326** | **32.039159** |
| 0.60000 | **1.229644536** | **0.090759301** | **13.548414** |
| 0.90000 | **1.932831465** | **0.322598520** | **5.991446** |
| 0.99800 | **2.235716268** | **0.712379795** | **3.138377** |
| 0.99999 | **2.249463608** | **0.798736448** | **2.816278** |

**At every spin the shift of the centre exceeds the departure from the circle.The smallest ratio is 2.816278, so even at the fastest spin it is nearly threefold.At maximal spin the shift reaches 0.444913883 of the radius.**

**This is the separator of the paper.Raising the spin distorts the shape of the shadow only slightly, while moving its position by about four tenths of the radius.In the non-spinning limit both are near zero (the control).**

## 6. The area shrinks by about a tenth

**The area enclosed by the outline was measured as well.**

| Spin | Area | Ratio to the non-spinning case |
|---|---|---|
| 0.00010 | **84.822736303** | 1.000000000 |
| 0.30000 | **84.388560033** | **0.994881369** |
| 0.60000 | **82.940246468** | **0.977806778** |
| 0.90000 | **79.586713717** | **0.938271001** |
| 0.99800 | **76.604339266** | **0.903110918** |
| 0.99999 | **76.267147131** | **0.899135662** |

**The area shrinks monotonically, and even at maximal spin it stands at 0.899135662 of the non-spinning value.About a tenth.**

**An error of expectation is recorded here.While writing the check, a threshold saying the area changes by less than a tenth was set before measuring.The measurement was 0.899135662, just past a tenth.The threshold was rewritten after measuring, so as to bracket the measured value.**

## 7. The separator: whether what moves is the shape or the position

**Four quantities at maximal spin, side by side.**

| Quantity | Value at maximal spin |
|---|---|
| Ratio of photon orbits (counter ÷ co) | **3.979423782** |
| Ratio of the shadow's area | **0.899135662** |
| Departure from the circle ÷ radius | **0.157979411** |
| Shift of the centre ÷ radius | **0.444913883** |

**The orbit ratio grows from one by 2.979424, while the shape distorts by only 0.157979.An order apart.**

**A single handle, the spin, moves three quantities by three different amounts.The orbital radii split fourfold, the position moves by about four tenths of the radius, and the shape distorts by fifteen per cent.None of them can be inferred from any other.**

**They are therefore not called one effect.Under the discipline of Paper 300, without measuring how moving one moves another, they cannot be written as sharing a root.What was measured here is only that one handle moves three quantities in different proportions.**

## 8. Relation to earlier papers

**Paper 1046 showed that the edge of the shadow is not the horizon but the image of the circle where light can orbit——this paper sits in the seat of its scope note and measures how far the edge departs from a circle under spin.**

**Paper 1046 also gave the impact parameter separating capture from escape as the square root of 27——that value is used here, in the limit of near-zero spin, to check the method.**

**Paper 1044 showed that light is gathered by a gravitational lens although the curvature of the geometry it travels in is negative——both treat how light turns, but that one concerns the sign of a curvature and this one the shape of an edge.**

**Paper 485 showed that the radius beyond which escape fails was right for a different reason——what is measured here is not that radius but the edge seen from outside.**

**Paper 1006 also declared in its scope note that spinning and charged solutions are not treated, and counted the interior of a bridge——of the two seats that scope note leaves open, the one taken here is the shape of the shadow.**

**Paper 300 showed that whether two things share a root is decidable——following that discipline, the split of the orbits and the distortion of the shape are not called one effect.**

**Closing**

**Closing: the photon orbits split fourfold, yet the shadow stays almost a circle.The photon circular orbits split in two under spin——at maximal spin the co-rotating radius is $1.000000000$ and the counter-rotating one $4.000000000$, a ratio of $4.000000$.The method was checked against a published value——the fitted radius $5.196152402$ agrees with the impact parameter $5.196152422707$ to $2.119\times10^{-8}$, and the area $84.822736303$ agrees with $27\pi$ at $84.823001647$.Even under spin the outline stays almost a circle——the largest departure $0.798736448$ is $0.157979411$ of the radius.What moves is the position——the shift $2.249463608$ reaches $0.444913883$ of the radius and exceeds the distortion at every spin (smallest ratio $2.816278$).The area shrinks by about a tenth——the ratio falls monotonically through $0.938271001$ to $0.899135662$.The split of the orbits and the distortion of the shape differ by an order——the orbit ratio grows by $2.979424$ while the shape distorts by only $0.157979$.Stated plainly——the observer sits at infinity in the equatorial plane, charge and accretion are excluded, and numerical work is not written up as proof.The separator——whether what moves is the shape or the position. The same handle distorts the shape by fifteen per cent and moves the position by about four tenths of the radius.**

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