

Galaxy S-Stars Exhibit Orbital Angular Momentum Quantization per Unit Mass

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The innermost stars of our Galaxy, called S-stars, are in Keplerian orbits. Quantum celestial mechanics (QCM) predicts orbital angular momentum quantization *per unit mass* for each of them. I determine the quantization integers for the 27 well-measured S-stars and the total angular momentum of this nearly isolated QCM system within the Galactic bulge.

1 Introduction

The innermost stars of our Galaxy, called S-stars, are in Keplerian orbits about a proposed [1] black hole of mass 4.3 ± 0.3 million solar masses. Their orbital planes appear to have random orientations, their orbital eccentricities range from 0.131 to 0.963 with no apparent pattern, and their origins of formation remain an issue. The star labelled S0-2 has the smallest semi-major axis of about 1020 AU and has been monitored for one complete revolution of its orbit, thereby allowing a determination of the position of the Galactic center Sgr A* at a distance of 8.33 ± 0.36 kpc.

In this brief report I use the orbital distances of the 27 well-measured S-stars revolving about the Galactic Center as a test of the orbital angular momentum quantization *per unit mass* predicted by the quantum celestial mechanics (QCM) introduced by H.G. Preston and F. Potter in 2003 [2, 3]. For the derivation of QCM from the general relativistic Hamilton-Jacobi equation, see the published articles online [2, 4].

In a Schwarzschild metric approximation, their proposed gravitational wave equation (GWE) reduces to a Schrödinger-like equation in the r -coordinate while the angular coordinates (θ, ϕ) dictate the angular momentum quantization per unit mass. In particular, a body of mass μ orbiting a central mass M has an orbital angular momentum L that obeys

$$\frac{L}{\mu} = m c H, \quad (1)$$

where m is the quantization integer and c is the speed of light. We assume that over millions of years the orbit has reached a QCM equilibrium distance r that agrees in angular momentum value with its Newtonian value $L = \mu \sqrt{GM}r$.

H is the Preston gravitational distance, a different constant for each separate gravitationally bound system, equal to the system's total angular momentum L_T divided by its total mass M_T

$$H = \frac{L_T}{M_T c}. \quad (2)$$

Note that H is not a universal constant, unlike \hbar , and that QCM is not quantum gravity. Also recall that the GWE in the free particle limit becomes the standard Schrödinger equation of quantum mechanics.

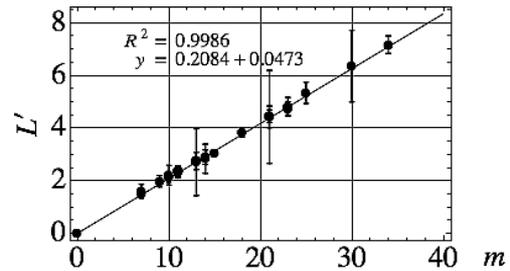


Fig. 1: QCM fit of S-stars at the Galactic Center.

2 S-star Orbital Quantization

The pertinent orbital parameters [5] for the 27 S-stars are listed in Table 1. Note that some uncertainties in both the semi-major axis column and in the eccentricity column are quite a large percentage of the mean values. These uncertainties will become smaller as more of these stars complete their orbits in the decades to come. More than an additional 100 S-stars are being studied in order to determine their orbital parameters. S0-16, whose orbital parameters are still being determined, has come the closest [1] to the Galactic Center Sgr A* at 45 AU (6.75×10^{12} m) with a tangential velocity of 1.2×10^7 m/sec!

I assume that each S-star is in a QCM equilibrium orbit in order to use the Newtonian values for the plot of $L' = L/\mu c$ versus m in Figure 1. The linear regression measure $R^2 = 0.9986$ indicates an excellent fit. I did not take the proposed black hole mass for M but used one solar mass instead as a reference. The slope $H = 6.59 \times 10^7$ meters for one solar mass, which becomes $H_{BH} = 1.30 \times 10^{11}$ meters (0.87 AU) for the proposed central black hole mass. For comparison, the Schwarzschild radius for this BH is 1.27×10^{10} meters.

Stars having the same QCM values for m , such as the six stars with $m = 11$, have orbits in different planes. I.e., their orbital angular momentum vectors point in different directions. There might be orbital resonances among stars with different m values even though their orbital planes have quite different orientations. With much more S-star orbital data to be determined, future fits to the QCM angular momentum quantization constraint should be very interesting.

| S-star | m | a ["] | ϵ |
|--------|-----|-------------------|-------------------|
| S0-2 | 7 | 0.123 ± 0.001 | 0.880 ± 0.003 |
| S0-38 | 7 | 0.139 ± 0.041 | 0.802 ± 0.041 |
| S0-21 | 9 | 0.213 ± 0.041 | 0.784 ± 0.028 |
| S0-5 | 10 | 0.250 ± 0.042 | 0.842 ± 0.017 |
| S0-14 | 10 | 0.256 ± 0.010 | 0.963 ± 0.006 |
| S0-18 | 10 | 0.265 ± 0.080 | 0.759 ± 0.052 |
| S0-9 | 11 | 0.293 ± 0.050 | 0.825 ± 0.020 |
| S0-13 | 11 | 0.297 ± 0.012 | 0.490 ± 0.023 |
| S0-4 | 11 | 0.298 ± 0.019 | 0.406 ± 0.022 |
| S0-31 | 11 | 0.298 ± 0.044 | 0.934 ± 0.007 |
| S0-12 | 11 | 0.308 ± 0.008 | 0.900 ± 0.003 |
| S0-17 | 11 | 0.311 ± 0.004 | 0.364 ± 0.015 |
| S0-29 | 13 | 0.397 ± 0.335 | 0.916 ± 0.048 |
| S0-33 | 13 | 0.410 ± 0.088 | 0.731 ± 0.039 |
| S0-8 | 13 | 0.411 ± 0.004 | 0.824 ± 0.014 |
| S0-6 | 14 | 0.436 ± 0.153 | 0.886 ± 0.026 |
| S0-27 | 14 | 0.454 ± 0.078 | 0.952 ± 0.006 |
| S0-1 | 15 | 0.508 ± 0.028 | 0.496 ± 0.028 |
| S0-19 | 18 | 0.798 ± 0.064 | 0.844 ± 0.062 |
| S0-24 | 21 | 1.060 ± 0.178 | 0.933 ± 0.010 |
| S0-71 | 21 | 1.061 ± 0.765 | 0.844 ± 0.075 |
| S0-67 | 21 | 1.095 ± 0.102 | 0.368 ± 0.041 |
| S0-66 | 23 | 1.210 ± 0.126 | 0.178 ± 0.039 |
| S0-87 | 23 | 1.260 ± 0.001 | 0.880 ± 0.003 |
| S0-96 | 25 | 1.545 ± 0.209 | 0.131 ± 0.054 |
| S0-97 | 30 | 2.186 ± 0.844 | 0.302 ± 0.308 |
| S0-83 | 34 | 2.785 ± 0.234 | 0.657 ± 0.096 |

Table 1: Galaxy Center S-star orbital parameters.

3 Total Angular Momentum

If there exists the BH at the center, from the value of H_{BH} we calculate the predicted QCM total angular momentum L_T of this system to be about 3.35×10^{56} kg m²/s. The rotating BH can contribute a maximum angular momentum of $J = GM^2/c$, about 1.64×10^{55} kg m²/s, meaning that the orbiting stars dominate the angular momentum of this system.

Spectroscopic measurements to determine S-star types indicate that their masses lie between 10 and 30 solar masses, so assuming about 100 such stars randomly distributed within 10 times the orbital radius of S0-83, one estimates an average total contribution of about 1.4×10^{56} kg m²/s, large enough to accommodate the QCM predicted total angular momentum value. Therefore, most of the system angular momentum is in the orbital motion of the S-stars.

Just how big radially is this gravitationally bound system involving the S-stars according to the QCM fit? Obviously, the angular momentum totals indicate that this gravitationally bound system does not extend significantly into the Galactic bulge, otherwise, the system's predicted H value will increase by many orders of magnitude with increases in radial dis-

tance. The Preston gravitational distance for the Galaxy, $H_{Gal} = 1.2 \times 10^{17}$ meters, may be the partition distance between this nearly isolated inner system and the rest of the Galaxy.

Therefore, this S-star system behaves as a nearly isolated system obeying QCM in the larger system called the Galaxy (or perhaps the Galaxy Bulge). Such QCM smaller systems within larger QCM systems already exist in the Solar System, e.g., the satellite systems of the planets [2], including the Jovian systems and the moons of Pluto [6]. Our Solar System [6] is a QCM system out on one spiral arm of the Galaxy, which is itself a QCM system requiring a different metric [4]. This hierarchy of QCM systems even applies to clusters of galaxies [7] and the Universe [8].

4 Final Comments

QCM predicts the orbital angular momentum quantization exhibited by the 27 S-stars nearest the Galactic Center. The result does not disagree with the proposed black hole mass of about 4.3 million solar masses there. The consequence is that the S-stars seem to be in their own nearly isolated QCM gravitationally bound system within the larger system of the Galaxy and the Galaxy bulge.

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