Multi-planet Exosystems All Obey Orbital Angular Momentum Quantization per Unit Mass predicted by Quantum Celestial Mechanics (QCM)

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Quantum celestial mechanics (QCM) predicts that all orbiting bodies in gravitationally bound systems exhibit the quantization of orbital angular momentum *per unit mass*. I show that the 15 known multi-planet systems with four or more planets obey this QCM prediction. This angular momentum constraint could be the explanation for their orbital stability for billions of years, suggesting that viable models of the formation and evolution of gravitational systems must include QCM.

1 Introduction

According to recent calculations, our Solar System is unstable [1] and should have existed for only a few 100 million years! However, the Solar System has existed for more than 4.5 billion years. Obviously, some fundamental physics concept is missing. H. G. Preston and I have proposed [2] that the missing constraint is the quantization of orbital angular momentum *per unit mass* for all orbiting bodies in gravitationally bound systems. Herein I establish that all 15 known multi-planetary systems with four or more planets exhibit this constraint.

In several previous papers [2–4] we derived Quantum Celestial Mechanics (QCM) from the general theory of relativity and successfully applied QCM to numerous gravitationally bound systems, including the planets of the Solar System, the moons of the Jovian Planets, the five moons of Pluto, the Galaxy rotation velocity, gravitational lensing, clusters of galaxies, the cosmological redshift of the Universe, the circumbinary planet Kepler-16, and the S-stars at our Galaxy center.

QCM predicts that a body of mass μ orbiting a central massive object in a gravitationally bound system obeys the angular momentum L per unit mass quantization condition

$$\frac{L}{\mu} = mcH \tag{1}$$

with m an integer and c the speed of light. The Preston gravitational distance H requires only two physical parameters to determine all the possible QCM states in the system, the system's total angular momentum L_T and its total mass M_T:

$$H = \frac{L_T}{M_T c}. \tag{2}$$

In order to use this restriction, one assumes that the orbiting body is at or near its QCM equilibrium orbital radius r and that the orbital eccentricity ϵ is low so that our nearly circular orbit approximation leading to these particular equations holds true. Therefore, the L of the orbiting body will agree with its Newtonian value $L = \mu\sqrt{GM_T r(1-\epsilon^2)}$.

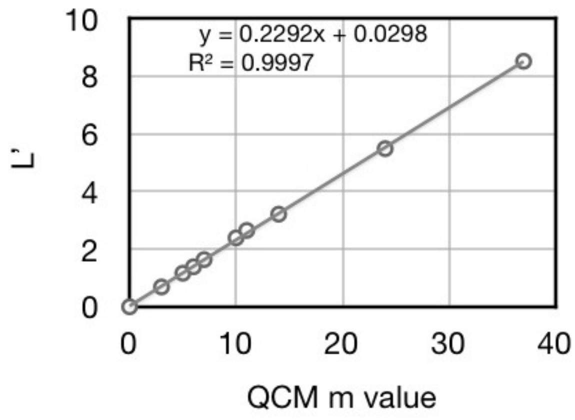

Fig. 1: The HD10180 System fit to QCM.

Every Newtonian orbit is an equilibrium orbit, but not so for QCM orbits. For a body not at the QCM equilibrium orbital radius for the QCM state or for particles near the QCM equilibrium orbital radius that could collect into a massive body, there exists a small QCM acceleration. Usually a time frame of tens or hundreds of millions of years are needed to achieve dynamic QCM equilibrium with its extremely small remnant radial oscillations. Therefore, QCM is expected to play an important role in the formation and eventual stability of multi-planetary systems over billions of years.

For circular orbits or nearly circular orbits there is a principal number $n = m + 1$ associated with the energy *per unit mass* quantization for a QCM state

$$\frac{E_n}{\mu} = -\frac{r_g^2 c^2}{8n^2 H^2} = -\frac{G^2 M_T^2}{2n^2 L_T^2} \tag{3}$$

with r_g the Schwarzschild radius of the system. The derived Schrodinger-like gravitational wave equation dictates all the physics via solutions that are hydrogen-like wave functions.

The QCM fit to the orbital parameters of all known planets of a multi-planet system determines the total angular momentum of that system, a value which can be used to predict whether more planets can be expected and/or whether the equivalent of an Oort cloud is required. Recall that for our own Solar System the Oort Cloud dominates the total angular momentum, being a factor of at least 50 greater than the total planetary orbital momentum. Without the Oort Cloud angular momentum, QCM predicts that all the planetary orbital radii would be within the radius of the Sun! By including the angular momentum of the Oort Cloud, QCM suggests that the planets formed near to their present orbital radii.

Many exoplanetary systems have their Jupiter size planets at extremely small orbital radii, within about 1.5 AU from the star, with many more smaller planets even closer. There is the question of why such massive planets are so close to their star. One possible answer is that the system total angular momentum value is low compared to the QCM value needed to "push" the system further out. That is, QCM predicts that a larger total angular momentum for the system means larger QCM orbital spacings.

2 Multi-planetary results

Multi-planet systems are in the database called the Exoplanets Data Explorer [5], but complete data sets for HD 10180 [6], HD 40307 [7], Tau Ceti [8], GJ 676A [9], and Upsilon Andromedae [10] are only in research articles. There are hundreds of two and three planet systems which I choose to exclude herein even though they also exhibit the QCM constraint. As more planets orbiting these systems are identified, their fits to the QCM prediction can be determined.

In Table 1 are listed the host star, the star mass in solar units, the number of planets N, their QCM m values, and the slope b for $L/\mu = bx + a$ in the plot of $L' = L/\mu$ versus m for all the planets of the particular system. The plot for HD10180 is shown as an example, with the uncertainty bars for L' within the circle data points. By using both the semi-major axis and the orbital period as constraints, one obtains a linear regression fit with $R^2 > 0.999$. The system's predicted total angular momentum $L_T = b\,M_T$ multiplied by 10^{15} kg m^2/s.

From the QCM predicted L_T values, one learns that these 15 multi-planet systems have more angular momentum which is to be contributed by additional orbiting bodies such as planets and/or the equivalent of the Oort Cloud.

Table 1: QCM Multi-Planet m Values

System	Mass	N	m Values	b
HD 10180	1.055	9	3,5,6,7,10,11,14,24,37	0.23
Sun	1	8	3,4,5,6,12,17,25,31	0.77
HD 40307	0.752	6	8,11,14,17,20,29	0.10
Kepler-11	0.954	6	10,11,13,15,17,23	0.13
Kepler-20	0.912	5	14,17,21,25,40	0.06
Kepler-33	1.291	5	8,11,13,15,16	0.16
Kepler-62	0.690	5	6,8,9,17,22	0.14
Tau Ceti	0.783	5	8,11,16,19,30	0.15
55 Cancri	1.026	5	4,10,16,27,76	0.13
GJ 581	0.311	4	7,9,12,21	0.05
GJ 676A	0.71	4	3,6,20,34	0.25
GJ 876	0.334	4	5,13,17,22	0.07
HR 8799	1.472	4	12,16,20,27	1.65
Mu Arae	1.077	4	4,12,15,29	0.38
Ups Andr	1.01	4	2,10,18,27	0.42

3 Conclusions

All the 15 analyzed multi-planet systems obey the QCM orbital angular momentum per unit mass quantization condition. The integers for the m values are not sequential, implying that the history of each system plays an important role in which orbital states are occupied. For example, mass depletion in a region caused by the faster formation of a large planet might not leave enough mass for another planet to form at a nearby QCM equilibrium orbital radius.

The resulting fits are evidence that the quantization of orbital angular momentum per unit mass is an important physical factor in planetary systems and should not be ignored in studies of their formation, stability, and evolution.

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