Gyroscopic Paradox of Motion: Validation of Mach's Principle?

--PART 1

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A discussion of angular momentum conservation, in the context of the long-standing controversy over Absolute vs. Relative space, introduces concerns about an aspect of Newtonian mechanics in situations involving compound rotational dynamics. Historical review of anomalistic behavior, those noted by Laithwaite in particular, is followed by description of apparent paradoxes involving gyroscopic precession in both gravitating systems and accelerating systems. Difficulties in conformance to the classical law of angular momentum conservation are encountered in the attempt to reconcile some of the cited experimental claims with the quantification of centrifugal force and gyroscopic torque. A Machian-style interaction is considered to account for reported anomalies; however, difficulties in conforming angular momentum conservation to such interaction are also noted. The need for experimental evidence and further investigation is stressed in a tentative conclusion.

"Sometimes I've believed as many as six impossible things before breakfast" – Lewis Carroll

1. Introduction

One thing more: The ultimate paired and balanced angular momentum system is the angular momentum quantum $h/2\pi$, known to quantum physics as $\hbar$, where h is Planck's constant, the quantum of *action*. The two masses involved in this angular momentum coupling, into which all angular momentum systems ultimately reduce, are those which have been conventionally called the 'electron' and 'proton'. In the Angular Momentum Synthesis, however, the conventional 'charge' on these particles in coulombs is cashed-out in equivalent terms of spin *kinetic energy* in joules, where the spin is that ascribed to the 'electron' by Uhlenbeck and Goudsmit. Due to the conservation of angular momentum, when one atom loses a quantum of angular momentum, another, somewhere else, has to gain that lost amount in a resonant interaction which begs no question of how and by what means that action, in units h, is conveyed. In Normal Realism, these quantum interactions, in statistical numbers, are what is called light. This present account is, perforce, somewhat sketchy and condensed, but is fully explained in the POAMS books and papers. For this complete paper see www.vivpope.org

Newtonian mechanics for compound rotational systems, though often a vexation for physics and engineering students, is nevertheless apt to be considered a 'solved science' among senior physicists. Difficulties with centrifugal forces, gyroscopic torque vectors, and overall angular momentum conservation for complex systems of rotation are theoretically eliminated by rigorous application of the laws of mechanics: there are no discrepancies in the generation of torques and forces with the Third Law of Motion. Angular momentum, despite initial appearances, is always conserved. Nevertheless, occasional objections to these conventions enter the literature of science: attendant to the controversy over whether the 'centrifugal force' is to be treated as a *real force* or a *fictitious force*, is the case of Dr. Robert Goddard, 20th century physicist and rocket scientist, whose youthful explorations included the following scheme:

> "As I looked toward the fields in the east I imagined how wonderful it would be to make some device which had even the possibility of ascending to Mars, and how it would look on a small scale if sent up from the meadow at my feet. It seemed to me that a weight whirling around a horizontal shaft, moving more rapidly above than below, could furnish lift by virtue of the greater centrifugal force at the top of the path. I was a different boy when I descended the tree from when I ascended, for existence at last seemed very purposive." [1]

A few years later, after some study, Goddard recognized the fallacy in this conception:

> "I began to realize that there might be something after all to Newton's Laws." [2]

Such events in the annals of science, while confirming nothing about possible selective direction of the centrifugal force, nevertheless demonstrate recurrent preoccupation with the subject. Another such episode concerns the so-called "Dean Drive", developed in the 1950s, in which a device composed of various rotors, springs, and pendulums was supposed to demonstrate a local violation of the third law of motion. Its inventor proved to be rather secretive, however, and no independent laboratory confirmation has yet been documented [3].

Others have attempted to claim minute "Machian" effects from various devices, but again, no independent agreement has been forthcoming from the scientific community on the true causes of whatever effects might be obtained [4].

2. The Case Laithwaite

Finally, there is the notorious affair involving the British engineer, Eric Laithwaite, professor of heavy electrical engineering at London's Imperial College of Science and Technology, who claimed that simple gyroscopic motion produced marked effects not in agreement with Newton's Laws. Without discussing the research and demonstrations in technical detail, suffice it to say that Prof. Laithwaite asserted experimental findings that indicated apparent loss of weight, rotation not about center of mass, and most notably, deficiency of centrifugal force in various gyroscopic systems. His presentation before the Royal Institution of Great Britain [5] constitutes something of a scandal in British Science: he was summarily dismissed from further exposition of his ideas, and was granted the singular distinction of being the only presenter before that distinguished body whose demonstration notes were *not* included in the official record. The prejudice is understandable: claims of violations of Newton's Laws in the very institution founded upon Newton's accomplishments, in Newton's native land, would be very hard to tolerate. But then at least a thorough refutation of Laithwaite's claims should have been expected, in which all observations were properly reconciled with physical law.

The affair is particularly intriguing in that Laithwaite was no mere crank, outsider, or professional failure. A fully accomplished electrical engineer, who had done notable work on transportation systems for the British government, Laithwaite cannot so easily be dismissed. How could a fully qualified graduate of British scientific education, a full professor, distinguished inventor and engineer pass through the system with such a poor understanding of basic Newtonian mechanics? Physicists yet maintain interest in the 'Laithwaite effects' [6, 7].

These controversies aside for the time being, the general problem may be approached after a brief descriptive review, for the purpose of orientation, of gyroscopic phenomena.

3. The Gyroscope and the Planet

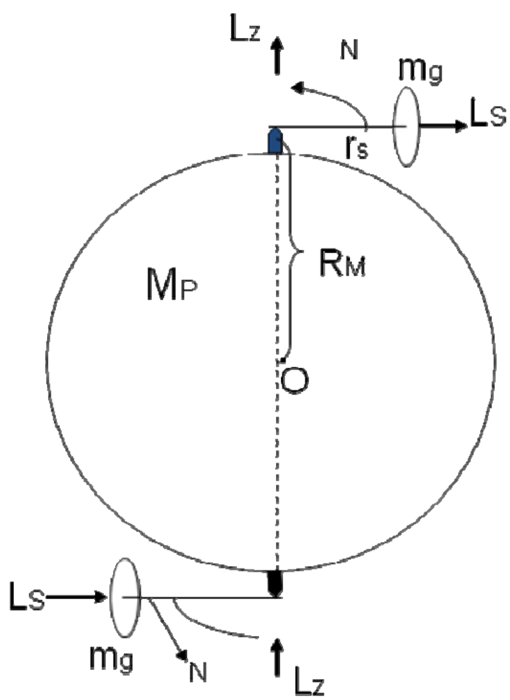

Fig. 1. Gyroscope and planet arrangement

Let M_P be the mass of large gravitating body (planet), m_g the mass of a large spinning gyroscope, mounted to revolve in precessional fashion (at the 'north' pole) about vertical z-axis through the gravitating body; R is radius of M_P (to point of support of spin axis of m_g) and r_s is radius of revolving spin axis. If m is presumed to be concentrated in a thin ring, then its radius r_g shall be the radius of gyration of the spin angular momentum of the gyroscope. For balance, let another such gyroscope, spin vector pointing inward, be mounted opposite the original gyroscope (at the 'south' pole), and revolve in precessional fashion also about the z-axis (Fig. 1).

For angular momentum (AM) to be conserved, all the various torques and change rates of AM which arise must at all times sum to zero. Let $\mathbf{L}_S$ be the 'spin' AMof each gyroscope; let $\mathbf{L}_z$ be the AM about the vertical axis of the system; another AM quantity may be identified from the cross product of the instantaneous linear momentum of m (in the N direction, which is normal to both instantaneous S and z), and the moment R. This latter is recognizable as a form of 'off-diagonal' component of an inertia tensor multiplied by an angular velocity, i.e., $I_{sz}\omega_z$, and shall be identified as L_{cin}, meaning 'cinematic' AM, since its value depends upon the perspective of the viewer. (For an observer turning *with* the precessing frame of the gyroscope, this term appears to vanish.)

$$\begin{aligned}\mathbf{L}_S &= M_G r_g^2 \boldsymbol{\omega}_S \\ \mathbf{L}_{cin} &= M_G\left(\mathbf{R}_z \times \mathbf{v}_N\right)\end{aligned} \tag{1}$$

Torques are to be associated with the changes in these quantities. In addition, torques arise from dynamical considerations: a 'gyroscopic torque' from the changing orientation of the spin axis, and a 'centrifugal torque' supposedly from crossing of the centrifugal force on the revolving M by the radius vector R. If motional 'torques' are identified as τ_{kin}, 'kinematic torque' (change of angular orientation of spin AM about z); τ_{cen}, above-mentioned 'centrifugal torque'; τ_{gyr}, 'gyroscopic torque' (tendency to pivot the spin axis about N); and 'cinematic torque' τ_{cin}, the rate of rotation revolution of L_{cin}; then of necessity (claims of Laithwaite notwithstanding), the third law of motion will be satisfied when all such torques sum to zero

$$\boldsymbol{\tau}_{kin} + \boldsymbol{\tau}_{cen} + \boldsymbol{\tau}_{gyr} + \boldsymbol{\tau}_{cin} = 0 \tag{2}$$

This condition holds true since the magnitudes of the cinematic torque and the centrifugal torque are mathematically identical and opposite (assuming, again, that there are no discrepancies in quantifying the centrifugal forces), where the magnitude of the gyroscopic torque is itself actually determined by the rate of change of orientation of the spin AM as each gyroscope revolves through its horizontal plane. The gravitational torque components, acting respectively on M_P and m_g about axes parallel to instantaneous N, must axiomatically cancel, since their resultants comprise centrally acting forces which have no moment.

A type of paradox is discernible in all this, nonetheless, in answering the question: What holds the gyroscope 'up'? Because a torque is experienced about the center of mass of the gyroscope m_g, its weight is transferred to its point of support at the 'north' pole of M_P. This opposes the z component of gravitational force on the planet, while the 'lift' on m_g relieves the downward z-axis gravitational component on it. This leaves the horizontal component of gravity on m_g to cross R_M, to produce a torque on M_P in opposition to the centrifugal torque on it. Ordinarily, the centrifugal torque quantitatively opposes the cinematic torque, and the gyroscopic torque opposes the kinematic torque; but paradoxically, a sufficiently rapid spin rate and slow precession rate will render the centrifugal force *exactly* equal (and opposite) to the horizontal component of the gravitational force: the cinematic torque is now opposed exclusively by the kinematic torque. This assumes, again, that there is no defect in the centrifugal force, or additional *centripetal force* produced by the action—hence the need for *experimental* verification or falsification of Laithwaite's claim.

4. The Gyroscope and the Rocket

Gyroscopes have well-known uses in rocket stability; however a problem is posed by the following arrangement: Let a standard spinning gyroscope be pivoted with one end of its spin axis on the front tip of an accelerating rocket, and precessing at a regular rate in the plane perpendicular to the direction of acceleration. Does the rocket body maintain a straight course, or does it describe a helix about an axis parallel to the acceleration direction? On one hand, the 'weight' of the gyroscope is transferred from its position at the extremity of the S-axis to the pivot point where it is 'felt' at the tip of the rocket, where the rocket might find it indistinguishable from an ordinary mass so situated. On the other hand, the third law of motion requires that a system rotate about its mass center, between the rocket and the gyroscope . Thus, a paradox arises for Newtonian mechanics, (and possibly for the Equivalence Principle of GRT). *An experimental resolution of the issue is hereby necessitated:* this could be accomplished in a zero-g environment, e.g. in an orbiting space station, or perhaps in the cabin of an aeroplane laboratory in parabolic 'free-fall' trajectory. A massive precessing gyroscope, driven by a small rocket motor, could be launched from a track fixed within the laboratory. The subsequent free pathway of the mass center of the entire projectile system would then be carefully monitored for any observable trajectory deviation.

5. The Gyroscope and the Roundabout

Let the end of the spin axis of a gyroscope be pivoted in a small framework mounted against the inside vertical wall of a massive, rotating, right circular cylindrical shell. How is angular momentum conserved? The situation poses additional problems concerning the quantification of rotational inertia; but as a solution would also pose a serious calculative challenge, no attempt will be undertaken to resolve it here—the example merely draws attention to the difficulties.

A closer investigation of the precise nature of the motions and forces involved in rotating systems is recommended, pursuant to the preceding examples. A precise understanding of the nature and origin of the various torques is to be sought. A foundation may be laid in which the necessary quantifications are reduced to examination of the behavior of individual 'point-mass' concentrations: essentially a 'dumbbell'-shaped mass, variously mounted and spinning about a revolving shaft. Only a very simple construction will be analyzed at this point.

6. A Revolving Ponderable Dipole

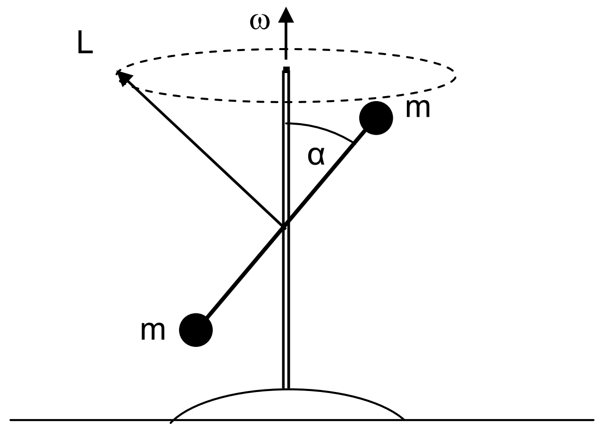

Fig. 2. Revolving Ponderable Dipole System

A common textbook example depicts a dumbbell-shaped object, secured at its mid-point to a rotating vertical shaft, at a fixed angle α to the horizontal (Fig. 2). The system is customarily described to possess a constant angular velocity ω_z, with a precessing AM vector L, which describes a right circular cone about the vertical axis. Though kinematically descriptive of the dipole itself, the physical reality of the whole situation is just the converse: the total AM vector cannot change, while the angular velocity vector must precess about a narrow cone: this is because the vertical shaft, anchored in a massive laboratory, must transmit a torque to the surrounding mass, which torque is produced by the centrifugal force on the dipole lobes crossing their respective vertical moments.

$$\tau_{\text{cen}} = R_{\text{vertical}} \times mr\omega^2{}_{\text{horizontal}} \tag{3}$$

Thus, the total AM vector remains constant in both amplitude and direction, where the z axis is carried about by the slightly gyrating laboratory. The positions of the lobes form products of inertia, e.g., $I_{xz} = mr_x R_z$, which when multiplied by ω_z, produce an instantaneous L_x which vectorially combines with L_z to yield the total $\vec{L}$ of the dipole. The change of orientation of this vector is accompanied by the changing AM of the laboratory: as before, the 'cinematic' torque is exactly opposed by a 'centrifugal' torque. Though this phenomenon is fully supported by Newtonian mechanics, the rotation of the product of inertia immediately poses a problem for any proposed Machian interaction. If the centrifugal force actually results from *interaction* with distant matter, rather than with 'absolute space', then the necessary response of the distant matter will itself answer the torque applied to the lab. The local 'cinematic' torques and angular momenta become redundant, and the *total* AM is no longer conserved. While on one hand, this might be regarded as *prima facia* evidence for Absolute Space, on the other hand it exposes a certain artificiality in the 'cinematic' quantities—they lack true dynamic expression ('torque' would not compress a torsion spring) and are in this sense merely a consequence of the observer's perspective. The dilemma for Machian mechanics, then, is to find a rule for angular momentum conservation (AMC), which accommodates these phenomena; otherwise AM itself would have to be redimensioned.

7. Conclusion

The proximate purpose of the preceding exposition has been to elucidate certain aspects of the science of mechanics through the introduction of apparent paradoxes in gyroscopic behavior. The ultimate purpose has been to raise again the controversy of Absolute Space vs. Relative Space [8, 9]. Though several lines of reasoning *suggest* a possibility of discrepancy in AMC in a local system, *no* such departure from classical mechanics has yet been *proven*. This paper serves as but an introduction to a more rigorous analytical treatment in a sequel—Part 2—in which the quest to prove the Machian interaction will be resumed.

The need for basic experimentation cannot be over-stressed. The "gyroscope and rocket" experiment, proposed in section 4. could effectively settle the Laithwaite controversy: a confirmed observation of revolution of such a system about its center of mass would largely dispel any notion of lack of centrifugal force. Off-center revolution, would, however, herald a 'revolution' in the science of mechanics—and Laithwaite would in great measure be vindicated, even celebrated as discoverer of new relations in dynamics. Other, perhaps more elaborate, experimental arrangements ought well to be explored, in pursuit of this most elusive of physical phenomena. The weight of scientific consensus will probably remain against such a possibility, but detection of a local imbalance of torques would, needless to say, be of extraordinary significance, as it would virtually prove the need for a Machian interaction to balance AMC.

8. Epilogue

The *hypothetical* possibility of a quantitative defect in local rotational dynamics is not likely to be received with great enthusiasm among the physics community—any more than was Laithwaite's claim of *experimental* anomalies with the conventional laws of motion. Nevertheless, such possibilities cannot simply be dismissed, and the quest to discover a measurable local anomaly in AMC should not prematurely be abandoned. Discreditation of such possibilities requires thorough experimental falsification, along with sound theoretical argument, particularly when attempting to assert Absolute Space over Relative Space. Negatives by nature tend to be unprovable, such as the impossibility of some subtle effect in rotational dynamics which might measurably conflict with local angular momentum conservation, and certainly the issue of other documented, [10] though sporadic, reports of experimental anomalies remains unresolved. A brief (and fanciful) 'story' may be told to illustrate a possibility:

9. A Tale of Two Scientists

Future scientists have grown up in a large, spherical interstellar space station (fully self-sufficient), after having been orphaned by some calamity, which sealed all ports to outer space, and erased all record of an outside universe. Having access to the basic laws of physics, however, (including the very weak gravitation between laboratory objects) one scientist makes a startling observation, and is eager to announce discovery of a new phenomenon: in the central zero-gravity lab, a long dumbbell-shaped mass is seen to turn unaccountably about a particular axis—in violation of local angular momentum conservation. Another scientist, certain of observational error, rejects the notion: no such violation of ancient Newtonian mechanics is permissible within the 'known' universe contained by the impenetrable wall of the space colony. (Talk of "beyond" the wall only raises eyebrows.) After much reflection, the one scientist finally postulates the existence of a massive *external body*, whose tidal gravity field is responsible for the torque on the dumbbell, whereby angular momentum is conserved in a minute reaction of the external mass…

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