Explaining anomalous forces in dielectric EM drives

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Abstract: The authors report some encouraging results with basis on their calculations to forecast the magnitude of anomalous thrust forces measured in resonant microwave cavities with dielectrics, for two configurations known as Cannae-Drive and Tapered Drive, when operating for high values of power. Despite of the weakness of the forces, both devices could provide us with a novel future propulsion technology by means of a thrust without ejecting propellant. In the calculations, they applied their theoretical model based on the dipole-environment interaction via generalised quantum entanglements (GQE) ensuring the momentum conservation principle. They obtain good agreement with the experimental measurements, although the anomalous forces have weak magnitude. The control and enhancement of the effect can be accomplished by applying GQE hypothesis in order to allow the future viability of a new technology based on quantum electromagnetic propulsion of aircrafts and vehicles.

1 Introduction

In recent years, it has been developed intense research on the existence of anomalous thrust effects in a resonant microwave cavity [1–9]. The investigation for understanding and enhancing the phenomenon can mean the advent of a remarkable new space propulsion technology named electromagnetic drive (EM-Drive) [5–9]. Such drives were for the first time proposed in 2001 by Roger Shawyer as a device formed by a conical cavity which had the function of converting electrical energy into microwaves which at last provided thrust to move a rocket or an airship. Fig. 1 exhibits a scheme of an EM-Drive, as shown in [10]. Although the effect is very weak, those vehicles could travel through space because the thrust would go on over time, so that the speed would increase very much. However, so the thrust measured in the device as the Shawyer's hypothesis for explaining it are still very controversial and many researchers believe that it cannot exist. The reason would be that the effect could violate Newton's third law, as it would be creating thrust without expelling fuel, needed for the reaction force described in the third law.

Since its invention, the device has been continuously improved in design. For instance, in other recent work [11], it was reported successful theoretical and experimental results for the electromagnetic thrust generated by a microwave thruster system. Basically, the microwave thruster system described can convert microwave power directly to thrust without a gas propellant. The net electromagnetic thrust for that device was experimentally measured in the interval [70, 720] μN when the microwave output power was in [80, 2500] W.

The generation of a weak anomalous thrust in such devices was also reported in other works [2, 12]. For instance, in [2] a low-thrust torsion pendulum was measured by considering radio-frequency (RF) resonant cavities and without the need of propellant or other medium which allowed exchanging momentum. As example of the effect weakness, the thrust measured in [2] was 40 μN in an RF resonant cavity (Cannae) for 935 MHz and 28 W; and in a tapered cavity it was measured a thrust of 91 μN for 1933 MHz and 17 W.

As known, conventional space plasma thrusters are basically Hall thrusters and ion thrusters. Those engines are space propulsion devices of high performance and long life duration [13, 14]. So, the EM-Drive is a new type of thruster, that is a microwave thruster. The basic component of the thruster is a cylindrical tapered resonant cavity, which can also be pushed by microwave radiation, with the microwave source and the tapered resonant cavity integrated together. Hence, in relation to other thruster devices the microwave thruster is more compact, highly efficient, and easy to control the thrust level [11].

From that original idea of Shawyer-based on magnetrons, other types of design were developed in order to generate forces or thrusts, known as Tapered Drive or Cannae-Drive. Basically the Cannae-Drive corresponds to a device in a pillbox shape or formed by an asymmetric capacitor with an internal dielectric. The Cannae-Drive was invented by Guido Fetta [4] as a new shape of drive to generate thrust [1, 4]. In Fig. 2, one can see a basic scheme of that configuration, as shown in [10]. It is a little different in the concept and arrangement. Basically, it is like a device formed by an asymmetric capacitor working in AC regime (RF), so that the thrust effect can be understood by the same principle earlier analysed in our research works based on anomalous effects in symmetrical [15, 16] or asymmetrical capacitors [17]. That type of drive also corresponds to a propulsion technology that does not demand on-board propellant to generate thrust but Lorentz Force imbalances created by thrusters to generate propulsion. It has also since his initial report improved so in the design as in performance, with more and more increasing in the magnitude of the thrust obtained.

As described by Cannae Corporation [18] – that has been founded to commercialise Cannae-Drive devices for propulsion...
technologies that provide improved performance for space applications – the system can be used for deep-space applications and can outperform propellant-driven systems by orders of magnitude. Besides, the Cannae-Drive technology can allow new deep-space missions that up to date would be impossible [18].

In this work, we present our calculations based on GQE formalism applied to the EM-drives with dielectrics which can produce weak anomalous thrust forces. In next section, we describe in a summarised way the theoretical framework. In the following, we show our theoretical model to the physical system in order to compare with the experimental results obtained from literature. Finally, we present our main conclusions and final remarks.

2 Theoretical description

2.1 Generalised quantum entanglement

The theoretical framework that leads us to a macroscopic description of our system is based on the generalised quantum entanglement (GQE) hypothesis [19]. Basically, our model for the calculation of anomalous forces in EM-Drives considers that in some physical conditions the state of GQE among the microscopic constituents of a physical system can manifest itself in macroscopic scale and the effect can be observed by means of the measurements of macroscopic observables, as the anomalous thrust in drives. In addition, we also assert that the magnitude of the macroscopic observables can be determined by means of classical calculations, with basis on the idea of quantum witness reported in [20–24], as explained in [19].

In case of the works related to the symmetric [15, 16] and asymmetric capacitors [17], the equations for the force calculation have also applied a classical quantity such as the electric susceptibility $\chi_e$ and some analogy with the magnetic susceptibility $\chi_m$ can be taken in place accordingly. In other words, the electric susceptibility $\chi_e$ can be considered as an entanglement witness [20].

We now propose a similar theoretical framework for our cavity system. The device analysed corresponds to a drive in which it is used any cavity filled by dielectrics whose anomalies are explainable by considering it as an asymmetrical capacitor. Such a case can involve both the Cannae-Drive and the Tapered Drive.

2.2 Model for Cannae-Drives

One of the devices used by NASA [2] is the so-called Cannae-Drive, as seen in Fig. 2. Basically, it is constituted by a metallic RF cavity in a pillbox shape and with beam pipes in its symmetry axis in each of both sides. In NASA experiments, it was measured by means a torsion pendulum an average anomalous force of magnitude about 40 μN along the symmetry axis of the cavity when it was subjected to an RF signal with $\sim$28 W for the power and a frequency 935 MHz, corresponding to 0.322 m for the wavelength $\lambda$. In those NASA experiments, the measurements were obtained for two different configurations of the device, that is one with internal slots and another without slots and no significant variations were found. The inventor of the device reported that the anomalous force was a consequence of the internal electromagnetic unbalance caused by the slots [25]. As the cavity is resonant, the RF signal injected is controlled by a phase-locked loop (PLL) circuit. As known, it is a control system that produces an output signal whose phase is related to the phase of an input signal. Such an electronic circuit used for frequency control can constantly adjust the current in order to match the phase of the frequency of an input signal, so that it is always maintained fixed. The signal of the force changes from positive to negative according to the position of the cavity rotating in 180°.

A cylindrical dielectric of Polytetrafluoroethylene (PTFE) leaked by an internal axial electric conductor acts as a resonator of wave guide in which the RF signal is injected in the cavity and propagates. In [2], it is indicated the possibility of using that element installed in the interior of the metallic tube of the cavity with one-fourth of wavelength $\lambda$. According to that NASA work, it is in that dielectric that the thrust must occur being the RF cavity (pillbox) nothing else than an element of connection (matching network) of those elements. The maximum value of the electric field is $4.72 \times 10^4$ V/m, as reported in the same article according to a computational simulation.

The fixed phase (standing wave) of the electric field in the axial conductor placed in the centre of the dielectric whose length is exactly one-fourth of the wavelength $\lambda$ of the signal, that is 0.0805 m. The nodes and anti-nodes of the electric field are distributed along the conductor as shown in the upper diagram of Fig. 3. In the scheme, we see at right the drawing created by NASA of the cavity Cannae in the format pillbox, with the simulation of the electric field magnitude and directions of the internal dipoles.

The electric field is maximum in one extremity of the dielectric while in the other one is minimum. Such an asymmetry induces a convergence of the electric forces in the electric dipole of the dielectric which point from the large electrode (tube) to the smaller electrode (conductor or axial cylinder).

The electric field is maximum in one extremity of the internal axial conductor while in the other one is minimum. Such an asymmetry induces a convergence of the electric forces in the electric dipole of the dielectric along the direction of the length of the internal conductor, as shown in the bottom diagram of Fig. 3.

According to those conditions described, we propose a model in which the setup is constituted by the tube of the resonant cavity, the internal conductor where the RF signal is injected and the cylindrical dielectric. Hence, the dielectric is equivalent to an asymmetric capacitor in which the larger electrode is represented by the external area or border of the cylinder and the smaller electrode is represented by the cylindrical area of the internal conductor placed in the centre of the dielectric.

The area $A_1$ of the larger electrode is calculated simply in the following form:

$$A_1 = \frac{1}{4} \lambda$$

Fig. 2 Setup of a basic Cannae-Drive device (NASA setup). In the device, we see indicated the diameter of the small axial cylinder corresponding to the length of 1/4 of the wavelength $\lambda$, the smaller diameter of the cylinder $2r$ and the higher diameter of the pillbox $2R$.

Fig. 3 Diagram of drawings created by NASA of the cavity Cannae-Drive and its simulations of the electric field magnitude and directions of the internal dipoles.
in which $A_1$ is the cylindrical area of the larger electrode, $A_2$ is the area of the cylinder constituted by the smaller electrode, $R$ is the radius of the cylindrical dielectric and $h$ is the length of the dielectric. Those parameters are not precisely indicated in NASA paper, hence we consider some approximations by comparing with the geometric proportions of the diameter of the resonant cavity (11 in) indicated in the figures in [2], so we have $h=0.05$ cm (one-fourth of the wavelength) and $R=2.413$ cm. We also consider the internal conductor has gauge 22 as indicated in the scheme of the electric connections of that reference so that the value of its radius is 0.38 mm. Therefore its cylindrical lateral area is $A_2=1.927 \times 10^{-4}$ m$^2$. By considering those data, by means of (1) we have $A_1=0.013841425$ m$^2$.

Based on those parameters and the maximum value of the electric field $E=4.72 \times 10^4$ V/m given in [2] we can calculate the dipole force $F$ using the formula valid to asymmetric capacitors reported in our earlier article given in [17]:

$$F = \frac{0.102 \epsilon_r - 1}{16 \epsilon_r + 2} A_1 E^2,$$  

in which $F$ is calculated in units of kgf, $A_1$ is the area of the smaller electrode, $A_2$ is the area of the larger electrode, $\epsilon_r$ is the relative permittivity which in the case of the dielectric material used Polytetrafluorethylene (PTFE) is 2.2. $\epsilon_r$ is the dielectric constant of the vacuum and $E$ is the electric field in the dielectric bulk. By analysing that equation, we can realise that the term at right side of anomalous thrust one can use dielectrics with higher values of order to act as a resonator dielectric.

Because we do not get to explain it in terms of current theories. The factor tends to unity for totally due to the relative permittivity, that is, to the nature of the dielectric used in the physical system. The factor tends to unity for very high values of relative permittivity, as we can check in the plot of Fig. 4. As the plot suggests, in order to obtain higher values of anomalous thrust one can use dielectrics with higher values of relative permittivity, but as the value of that factor cannot overcome the unity it is a wise choice to use dielectrics with values as closer as possible to 1.

The value of the force calculated by that formula is given in Table 1 and it is consistent with the average of the experimental measurements (with a relative error about 10.5%), even if we consider the lack in accuracy of the values of the parameters.

The phenomenon described involves the principle of momentum conservation and by means of that GQF model we obtained good agreement so qualitative as quantitative when comparing it with the experimental result. That agreement leads us to believe that the phenomenon is really of dipole nature.

### 2.3 Model for tapered cavity TM212

In [26], NASA researchers measured magnitude of forces in a conic electromagnetic cavity made by copper with larger diameter 27.9 cm, smaller diameter 15.9 cm and an axial length 22.9 cm. A disk of plastic material HDPE of 5.44 cm thickness and 15.67 diameter was internally coupled to the circular smaller face in order to act as a resonator dielectric.

A powerful RF signal of magnitude 1937 MHz was injected into the cavity through a loop antenna so that the cavity operated in resonant mode TM212 with four stationary nodes in the azimuth direction and two nodes in the longitudinal direction. Such a mode was guaranteed by means of another antenna placed inside the cavity in order to provide ‘feedback’ to the circuit of external control PLL; so, it was maintained the cavity tuning and the stability of the nodes.

The conical cavity was supported in a torsion pendulum with its axis in the horizontal position. So, by means of that setup, NASA group was successful in the measurements of an anomalous impulse (force) parallel to the axis of the cavity and in the direction of the smaller circular face. The impulse is called anomalous because we do not get to explain it in terms of current theories. The most significant controversy refers to the principle of momentum conservation: in order to respect it we need to conclude that the physical system must in any way have an interaction with the external environment. In a Shawyer’s work [27], the pioneer in experiments with that kind of conic cavity, it was reported that the anomalous force is the result of the asymmetry in the electromagnetic fields which oscillates forward and backward inside the cavity in asymmetric boundary conditions, as the space in the interior of the cavity decreases from the larger circular face to the smaller one. The result is a non-null resultant force that points to the smaller circular face of the cavity. The controversy is in the fact that in a closed system and only considering the internal fields of the cavity, the force should be zero due to the principle of momentum conservation.

The group of NASA researchers in [26] presented other explanation to the anomaly that is the creation of a plasma of virtual particles emerging from quantum vacuum inside the cavity due to (i) the intense stationary electromagnetic fields and (ii) the ejection is in direction in the larger circular face, that is backwards. As occurs in rockets, the ejection of virtual plasma generates an impulse backwards and as consequence the cavity dislocates forward due to the reaction force in the opposite direction to the thrust. There is some controversy in that explanation as the transient duration of the particles of the quantum vacuum according to the principle of uncertainty, so that there is an impossibility of manipulation of them and the quantum vacuum is considered neutral.

As alternative, in order to explain the anomalous forces, we propose a model that considers the set of the conic cavity made of copper with its internal dielectric developing the role of an asymmetric capacitor. As seen in our earlier papers [15–17], both symmetric and asymmetric capacitors present very weak forces when energised due to the orientation of the internal electric dipoles in their dielectrics and their interactions which are not local with the environment, so that the force raised in the system can be justified by the principle of momentum conservation.

By considering a possible condition that exists in the mode TM212, in the internal volume of the conic cavity near to the smaller circular face there are four circular regions (static nodes) where occur the concentration of the electric field gradient in maximum magnitude that we consider having each a diameter corresponding to one-eighth of the wavelength $\lambda$ of the RF signal injected in the cavity, as shown in Fig. 5. In that figure, we see a diagramatic scheme of drawings and simulations reported by NASA. At left and at right, the diagrams represent the electromagnetic fields of the conic cavity in the mode TM212.

\[
A_1 = 2\pi Rh + \pi R^2 - A_2, \quad (1)
\]

\[
F = \frac{0.102 \epsilon_r - 1}{16 \epsilon_r + 2} A_1 E^2, \quad (2)
\]

![Fig. 4](image_url)
The dielectric dipoles guided by central forces
higher concentration of the electric field gradient inside the dielectric disk
computer simulations
field in the region of the smaller circular face of the conic cavity performed by computer simulations. In our model, they are considered adequate tuning of the cavity. In our model, they are considered equivalent to small electrodes with circular areas of an asymmetric capacitor while the single larger electrode is represented by the lateral area of cylindrical boundary of the dielectric, as shown in Fig. 6. At left frame of that figure, it is shown the possible position of the four regions which are symmetrically distributed and of higher concentration of the electric field gradient inside the dielectric disk. That drawing refers to the part of the conic cavity of smaller circular face. At right one, a didactic drawing shows a cross-sectional view of the smaller circular face where are visible two circular regions (equivalent to smaller electrodes) and a part of the dielectric dipoles around them (small lozenges) guided by central forces. All of those elements are immersed inside the dielectric (rectangle) so that its lateral defines the dimension of the larger electrode. It is also shown – but qualitatively and not in scale – the thrust and the reaction force vectors.

Hence, due to the gradient of the electric field which remains stationary inside the cavity, the dielectric dipoles constituting the dielectric (even in non-polar case and with total dipole momentum approximately null) are subjected to alignment forces which are concentrated from large electrode (lateral areas of the cylinder made by the dielectric) towards the four small electrodes (nodes).

Rather due to the gradient of the electric field, by considering both extremities of the dipoles (the polarisation of the plastic dielectric is electronic, that is under an electric field there is a larger gap between electronic clouds and nucleus of the atoms), they tend to align towards the nodes and their opposite extremities tend to align towards opposite directions, that is outer the dielectric, so that there is a collective net force from inside to outside of the dielectric in the spatial configuration of change in the dipole momentum of the system, as shown in Fig. 6.

The physical boundary conditions restrict so mechanically as electrically the dielectric disk in one of their circular faces which is connected to the small circular face and that prevents the expansion in that side. On the other hand, the other circular face of the dielectric is free and then the expansion occurs in its side.

The preexistent state of GQE in the system of electric dipoles that constitute the dielectric with the environment was earlier reported in our recent works for many physical systems [15–17]. Such entanglement states indicate that the thrust in the direction of the larger face of the cavity implies in a reaction force towards to the smaller circular face aligned to the symmetry axis of the cavity, according to the predicted by the principle of momentum conservation. Such a force was experimentally measured by NASA.

The impulse driven from the larger face to the smaller one of the cavity would be a reaction force (vide Fig. 6) as other model also supposes, as discussed in [26]. However, in the latter case, there is the hypothesis of existence of a propellent plasma flow of virtual particles in vacuum in the direction from the dielectric disk towards to the larger circular face of the cavity. Such a reaction also occurs when the symmetric capacitors are placed with their circular faces in the horizontal position supported in a surface so that the force always point out upwards, as we showed in our article in [15]. In the situation described of the symmetric capacitors does not exist any cavity in a clear way but only a solid dielectric placed between two circular symmetric electrodes. So, due to the similar physical configurations, our model can be applied to both devices and the phenomenon can be related to the electric dipoles adequately guided through intense electric fields. It is worth to remember that interaction between the electric dipoles and the environment is fundamental in order to an explanation type cause–effect for the thrust if we take into account the principle of momentum conservation for the resonant electromagnetic cavities.

Anomalous forces are also measured in some empty resonant electromagnetic cavities which do not have resonant dielectrics. In that case, the same interactions earlier reported in the context of laser diodes [28] involving charge carriers that flow in the cavities and in the circuits are equivalent to ones here described for dipoles. We intend to analyse such an issue, that is the simultaneous description of different physical systems by taking into account the same model, in a more profound way in future works.

By means of dipole force (2) described in our earlier works [15–17] related to anomalous forces in symmetric and asymmetric capacitors, we can calculate the magnitude of the force for each of the four identical small electrodes immersed in the dielectric, being the total force in the cavity TM212 four times higher.

The calculation of the force considers the lateral area of the cylindrical dielectric (larger electrode) and the area of one of the smaller electrodes corresponding to a circular region delimited (node of the electric field) with diameter one-eighth of the wavelength λ.

The area of the larger electrode is calculated as
\[ A_1 = 2\pi rh + 2\pi r^2, \]
in which \( r \) is the radius of the cylindrical dielectric with value 0.07835 m and \( h \) is the length of value 0.0544 m. So, the value of the area is \( A_1 = 0.0653512 \text{ m}^2 \). The area \( A_2 \) is the sum of the four circular areas of the small electrodes and it can be calculated according to \( A_2 = 4\pi r^2 = 0.001164 \text{ m}^2 \) in which \( r \) is the radius of the circular region or node with diameter (1/8)λ, whose value is 0.009625 m. By considering the areas \( A_1 \) and \( A_2 \) and the value of the dielectric constant \( \epsilon_r = 2.26 \) for the dielectric cylinder made by Polyethylene HDPE, we can calculate the force between the larger electrode and one of the smaller electrodes by means of the dipole force (2).

In order to complete the calculations, it is needed to determine the value of the electric field \( E \) which can be determined if we know the average value of the voltage \( V \) of the RF signal applied in
the device by dividing that value by the value of the distance between both electrodes, that is (1/8)μ. The magnitude of the electric field calculated in our model is consistent with the value reported in NASA simulations here shown in Fig. 5. By analysing the graphs in [26], we obtained the values of the tension of the RF signal applied to the device, that is 433.34 V for a power of 60 W, 244.45 V for power 40 W and 346.15 V for power 80 W.

Based on that information, the values of the total dipole force calculated by means of formula (1) and for the powers 40 and 80 W applied on the cavity, they were very consistent with the average values that were experimentally measured with error smaller than 10% and only the value for power 60 W presented an error higher, due to problems that occurred during the experimental measurements described.

Table 2 shows a summary of the experimental and theoretical values. In the experimental setup, the average values of force measurements were performed with the cavity physically placed in a certain position of the torsion pendulum (forward) and in the inverted position (reverse).

The first column at left shows the three values of power of the RF signal applied on the cavity. For each values exists the correspondent value of average force measured by a torsion pendulum, as shown in the central column. The theoretical values are shown in the column at right and as one can see the values are in good agreement with the experimental ones. The model of asymmetric capacitor for the EM-Drives also seems to explain so qualitatively as quantitatively the force considered anomalous that occur in conic cavities.

Here, it is interesting to compare both theoretical calculations presented in Tables 1 and 2. The dipolar force for asymmetric capacitors provides for the Cannae-Drive reported in [2] a result with relative error 11.3%. In the second case, the same equation also provides good results, with best value for the case of power 40 W, with relative error about 6.0%. For the higher power, we obtained ~8.7% and only for 60 W the relative error is higher than 10%. However, as it has been reported this case presented the higher experimental error, what can explain the discrepancy. It is remarkable that there is a high error (63 μN) for the measurements related to the forward thrust setup in comparison than reverse thrust setup concerning the 60 W power band when one compare the other bands like 40 W (0 μN) and 80 W (2 μN). According to the graphics of the NASA's article, the average of force measured was 84.84 μN (±6 μN), but the range varied between a minimum of 43 μN (±6 μN) and a maximum of 106 μN (±6 μN). It corresponds, respectively, to the signal voltage applied between 296.55 and 731.03 V. Considering those values of signal voltage, the respective theoretical values of the force varied between a minimum of 57.74 μN and a maximum of 350.83 μN. This analysis indicates that the experimental range is partially covered by the theoretical range.

In summary, in our study case involving either the Cannae-Drive or Tapered Drive, the engine is basically an asymmetric capacitor. So, the effect of anomalous forces that raise due to high-voltage capacitors [29–33] shows close similarity, so that we can use the same formulation for the cases of both drives, mainly considering works related with the same asymmetric capacitors [34–38] when they are subjected to high voltage.

3 Conclusions

In this work, we present our study and analysis concerning to the existence of a weak-induced force or thrust in microwave cavities in devices formed by dielectric in two shapes: Cannae-Drive and Tapered Drive. We investigated theoretically the operation of such EMs with dielectrics by applying the theoretical framework called GQE formalism, as considered in our early works for other systems as symmetric capacitors [15, 16] and asymmetric ones [17]. Our calculations confirmed with good accuracy the experimental results earlier reported in the literature concerning to the presence of weak anomalous forces in a dielectric cavity.

In order to test our model, we supposed as main idea that Cannae- and Tapered Drives can be associated to asymmetric capacitors so that we can apply the formula of dipole force generated in such devices to the drives. The results presented show that there is a clear good agreement between experiments and theory and the magnitude of forces raised in those systems can be described within the error range by GQE framework. This reinforces our hypothesis related to the non-local interaction between micro and macro systems (quantum witness) from a preexisting state of GQE among all particles, revealed by the operation of the devices subjected to high fields. As described in literature, from GQE hypothesis we can describe the physical systems by some macroscopic observables considering them as manifestations of quantum entanglements between magnetic or electric dipoles, so that it is worth to calculate the magnitude of the forces generated in the cavity via equations using classical calculations.

As the anomalous thrusts are still very weak, in order to obtain industrial applications, we need to enhance the effect so that it can be more efficient. One possible way would be to find new dielectric materials with higher values of electric permittivity (as earlier explained, with the term of Clausius–Mossotti closer to 1), a higher asymmetry of areas (up to an acceptable geometry) and a high magnitude of electric field (or power) to obtain higher values of the anomalous force. However, such an increasing in the parameters is not so direct and simple and must be carefully calculated in order to avoid the destruction of the dielectric materials. We intend in a next step to study new materials or other possible configurations with the devices analysed or new setup possibilities which could enhance the interaction so that one can use them in technological applications as electric propulsion systems.

In summary, from the exposed discussion, we conclude that the anomalous forces can be qualitatively explained by GQE hypothesis in the case of drives with dielectrics, independently if we use pillbox or conic shapes as electromagnetic drives. We can also explain in quantitative terms and good agreement the magnitude of the anomalous forces generated in both types of drives with dielectrics, just associating them to asymmetric capacitors.

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