Absolute Frame in Physics

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Abstract: In this paper we investigate the concept of "absolute frame of reference" in contemporary physics as well as its properties, instances (or potential instances), types, conceptualizations, evidence, problems, controversies, and so on. This investigation is essentially epistemological in nature and hence we do not discuss or investigate any technical formulation related to this subject.

Keywords: Absolute frame, frame of reference, epistemology of science, philosophy of science, contemporary physics, fundamental physics, modern physics, epistemology of contemporary physics.

Contents

1 Introduction

In [1] we identified "the existence of absolute frame" as one of the main epistemological[1] features of classical mechanics (and its Newtonian formulation in particular). Absolute frame actually enjoys a central position and plays an essential role in the conceptual and theoretical framework of classical mechanics from both the formal and epistemological perspectives. In fact, its existence (or supposed existence) characterizes other branches of classical physics (especially classical electrodynamics) and hence it can be seen as a characteristic feature of classical physics in general and not only classical mechanics. This is inline with the fact that classical physics is essentially based on the classical philosophical heritage with regard to "space" and "time" whose roots come from intuition and common sense, and hence classical physics can be regarded as a continuation to the natural philosophy of the ancient and middle ages.

The existence of absolute frame was generally "obvious" in the mind of classical physicists (or at least the majority of them who represent the main stream of classical physics), and apparently there was no serious question marks about its existence (in some shape or form) although many details about it and its instantiations and realizations remained unclear or/and controversial. The absoluteness of rotation (as indicated and demonstrated by Newton's bucket experiment for instance) was an obvious indication or evidence (or at least that is what is seen by classical physicists) for its existence. In fact, the concept of inertial frame (which is central to classical mechanics), let alone the concepts of absolute space and absolute time of Newton (as stated in his book "The Mathematical Principles of Natural Philosophy" or *Principia*), was an implicit (if not explicit) admission and acceptance of the notion of absolute frame and its physical existence (or at least this was the dominant view and understanding among the classical physicists).

However, serious suspicions and question marks about the existence of absolute frame were raised at the end of the nineteenth century following a number of investigations and experiments whose objectives were generally to prove or/and identify the absolute frame within some of its supposed instantiations and physical realizations (where in this regard we refer particularly to the Michelson and Michelson-Morley and Morley-Miller experiments[2] whose objective was to establish and measure the speed of Earth relative

[1] In fact, it is also a formal feature since the formalism of classical mechanics depends implicitly on the existence of absolute frame due to the intimate relationship between "inertial frame" (which is fundamental to the formalism of classical mechanics) and absolute frame (see § 9).

[2] In fact, there are many question marks on these experiments and their validity and significance (see for instance [2]). We should also refer in this regard to the Miller ether drift experiment (see [3, 4]).

to the ether which is one of the potential instantiations and physical realizations of absolute frame, i.e. the electrodynamical instantiation of absolute frame).[3] These suspicions led eventually to the emergence of the Lorentzian transformations and Lorentz mechanics and its special relativistic version (or rather interpretation) in particular which is based on the denial of the existence of ether (and hence the denial of the existence of absolute frame). In fact, this development (in addition to the emergence of quantum mechanics) marks the transition from classical physics to modern physics and can be regarded as one of the main milestones in the birth and development of contemporary physics. This should highlight the pivotal role (at least from a historical perspective) that "absolute frame" played in the transition from classical physics to modern physics and the birth of contemporary physics (and even contemporary science in general).

Anyway, absolute frame should be seen as a necessity to classical mechanics (which is a branch of contemporary physics) even though it is generally denied within other branches of contemporary physics (i.e. the more modern branches of contemporary physics). This (i.e. being a necessity to classical mechanics) is due to the fact that the classification of frames of reference in classical mechanics to inertial and non-inertial and the distinction between them physically necessitates the existence of "absolute frame" in some shape and form although the details of such a frame and its characteristic features, instances, properties (... etc.) generally differ and can be subject to debates and disputes.

In this context it is worth noting that the (implicit or explicit) admission of "absolute frame" in contemporary physics (i.e. within classical mechanics) may be regarded as an element or source of inconsistency in contemporary physics (especially from an epistemological perspective) because absolute frame is accepted (or must be accepted) in certain branches of contemporary physics (namely classical mechanics) while it is denied in other branches of contemporary physics (namely the relativity theories). Nevertheless, we should note that "absolute frame" enjoys more acceptance among physicists in recent times as compared to earlier times when the relativity theories (following their emergence) were more influential and dominant. In fact, many respected physicists these days accept not only the existence of absolute frame but even some "ancient" paradigms of absolute frame like the "luminiferous ether" (which was seen a few decades ago as a bizarre idea and as a relic from the old and obsolete physics of the nineteenth century). This (more accep-

[3] Actually, the ether itself may not have been seen as an absolute frame (or an instance of absolute frame) but due to its supposed relationship to the Newtonian absolute frame (i.e. the ether was generally believed to be at rest in this absolute frame) it is identified with (or linked to) the absolute frame of classical physics. See § 5.3.

tance) is generally due to the theoretical and experimental failures (or supposed failures) of the relativity theories. The acceptance of Mach's proposal (or principle)[4] by some physicists may be another factor for the acceptance (or more acceptance) of the existence of absolute frame due to the fact that the "overall distribution of matter in the Universe" should represent an ideal physical realization to "absolute frame" since it is actually more physical and "materialized" than the Newtonian space-time or the "luminiferous ether" for instance.

Anyway, absolute frame may be referred to or indicated in the literature of contemporary physics by different names and labels (such as "absolute rest" and "absolute motion" as well as more explicit identifications).[5] Very often, absolute frame is referred to implicitly (rather than explicitly) where it can be "felt" or seen "hiding" in the background and within the hidden and undeclared assumptions and axioms of certain physical theories and formulations. This is particularly true in the literature of modern physics where this "implicit" (or "hidden" or "undeclared") acceptance is due to the relativistic "phobia" of this concept because of its clash with the relativity theories. We should also find differences in the instantiation, conceptualization, and characterization of "absolute frame" (as well as many other differences like these). Some of these differences will be investigated or identified, explicitly or implicitly, in the due course of the present paper, while some others will be investigated in forthcoming papers.

The present study comes to meet a need and demand for this investigation because we believe that the issue of absolute frame (or at least some essential aspects of it) is not investigated properly and sufficiently in the literature of contemporary physics (and in the literature of its epistemology and philosophy in particular) although it historically was a central issue in the classical physics (especially before and during the emergence of the relativity theories). In fact, the overwhelming acceptance of the relativity theories among the mainstream physicists may have contributed to this lack of interest and deficiency in this investigation because these theories are generally based on the denial of the existence of absolute frame (or at least commonly understood to be so since "absolute frame" seems opposite to "relativity").

It is worth noting in the end of this Introduction that the present paper (as well as other upcoming papers) is a continuation to our series "The Epistemology of Contemporary

[4] We prefer "proposal" because it lacks the characteristics of "principle". The commonly used labels in the literature are "Mach's principle" or "Machian principle" (whose origin can be found in the writings of Moritz Schlick).

[5] Absolute rest and motion of an object are rest and motion defined and determined without reference to any other (localized) object.

Physics" where we will use in this series (from now on) specific titles to highlight the main subject of each paper and attract attention to its contents. The monotonous title "The Epistemology of Contemporary Physics" seems uninteresting to many readers and is rather boring and uninformative and hence we decided to use more specific titles which reflect the contents of each paper in this series.

2 Definition of Absolute Frame

We may define "absolute frame" as a frame that is physically distinct from all other frames of reference where the origin of this distinction is the global or cosmological structure of the Universe, i.e. the space-time of the Universe or its physical constituents such as the overall matter in it (inline with Mach's proposal) or a type of radiation (such as the Cosmic Microwave Background Radiation or CMBR) or a certain medium (such as the luminiferous ether). In fact, this definition embeds the essential properties or characteristic features of absolute frame which will be investigated next (see § 3).

In this regard it is important to note that "inertial frame" was defined by some physicists[6] as: a frame in which space is homogeneous and isotropic and time is homogeneous. This seems to be the most strange definition of "inertial frame". For example, this definition may be criticized for being conceptually and practically more abstract and ambiguous than the defined term (i.e. "inertial frame"). However, if this is really a definition to a certain type of frame of reference then it may be more appropriate to be a definition to "absolute frame" since it represents certain intrinsic physical properties that distinguish such a frame (see § 10). In fact, this could justify this definition and may even make it a natural and logical definition not only to "absolute frame" but even to "inertial frames" due to the strong link between "absolute frame" and "inertial frames" (see § 9).

Accordingly, there should be no contradiction or clash between this as a definition to absolute frame and as a definition to inertial frame (if it is accepted as such) due to the intimate relationship between inertial frames and absolute frame (as indicated already) although it may not be an ideal definition (due for instance to the aforementioned criticism or because it is more appropriate to be a characterization rather than a definition). In fact, even the issue of uniqueness of absolute frame should not contradict the non-uniqueness

[6] According to Landau and Lifshitz (see page 5 of [5]): It is found, however, that a frame of reference can always be chosen in which space is homogeneous and isotropic and time is homogeneous. This is called an inertial frame. In particular, in such a frame a free body which is at rest at some instant remains always at rest. (End of quote)

of inertial frames when we note that the uniqueness of absolute frame can be interpreted as being representative to a specific class of frames rather than a single individual frame (see § 7.2).

However, this definition may not be appropriate if it is supposed to be a definition to "inertial frame" as used commonly in physics and by physicists (especially in classical mechanics and as suggested by "is called") rather than being a characterization or a convention of these physicists (i.e. Landau and Lifshitz) which is very unlikely to be true. But this matter is not of central importance to the scope and objectives of the current investigation. We should also note that this definition may be based on a relativistic view (or similar controversial view) where an inertial observer "sees" time and space as such (and hence inertial frame is defined by his vision and conception rather than the other way around as it should be or as it is the more natural way to be a definition). These issues may be pursued further in forthcoming papers of this series.

We should also note that we may also propose other (and more practical) definitions of "absolute frame" where such a frame is identified by certain physical objects and structures and used as "empirical definitions" which are essentially approximations and instantiations of the concept of "absolute frame". We can consider in this category the use of the frame of "fixed stars"[7] as an absolute frame which is generally seen as a good approximation and a practical choice for referencing physical events and processes. In fact, we may label these definitions as "practical" or "operational" as opposite to "theoretical" or "conceptual" definitions that may be attached to the previous definitions (as well as other similar definitions). However, we should note that these practical definitions should be ultimately based on certain theoretical criteria and qualifications. For instance, the frame of "fixed stars" may be identified with (or seen as an associate to or marker on) the Machian frame or the CMBR frame (and so on; see § 5).

Anyway, although these (theoretical and practical) definitions (or most of them as well as other potential definitions) may not be very useful practically and empirically or even not very sensible conceptually and theoretically (e.g. by being too abstract or ambiguous or difficult to identify in reality) as individuals, each one of them could give some idea about "absolute frame". Hence, they (or a number of them) as a whole could provide reasonably-technical and clear definition of "absolute frame" by identifying a number of

[7] We can (and will) use "fixed stars" or "distant stars" (which are traditional and historical terms) to refer to the large material structure of the Universe at astronomical (and even cosmological) scale where these stars should be seen as markers to this large scale structure. This structure at this very large scale is supposedly stable and constant (or "static") as a whole (possibly within certain temporal limits) although local changes are continuously happening in all of its parts and constituents.

its properties and attributes (and even potential physical instances). In fact, this "overall" definition of "absolute frame" is what legitimizes the use of this concept and paradigm as one of the main foundations or characteristics of classical mechanics despite the many problems about the paradigms of "frames" (or "inertial frames") in general and "absolute frame" in particular. So in brief, these definitions (and their alike) should characterize (in their totality) the paradigm of "absolute frame" conceptually and practically in a rather clear and technical manner (although this should not remove all the theoretical and practical difficulties that surround the definition and identification of "absolute frame" in physical terms and with regard to the reality of physical world).

3 Characteristics of Absolute Frame

We outline in the following points the main characteristic features or properties of absolute frame (according to our view):

1. Physicality: absolute frame is not an artificial or conventional frame but it has a physical origin in the structure of the Universe (see the definition of absolute frame in § 2). In fact, this is the main property of absolute frame that makes it distinct from all other frames because it is the only frame that is "built" into the structure of the physical world and hence it has real physical existence and properties. One of these physical properties (as an example) is its inertiality (which will be discussed in point 3).
2. Globality (i.e. being cosmological in scale): absolute frame is generally perceived to be global or cosmological (i.e. it extends to the scale of the entire Universe). This property can also be inferred from the definition of absolute frame as given in § 2. In fact, globality should be essential for the frame to be absolute because local frames of certain physical properties (which are shared with the properties of absolute frame such as inertiality) are not necessarily absolute since these physical properties can originate from local factors (or structures or circumstances or ... etc.) rather than from the global structure of the Universe. For example, local frames can be inertial (i.e. they demonstrate inertial properties) at local level although they are not actually inertial (i.e. at a global level). However, globality (at cosmological scale) may be difficult to prove physically (by experiment and observation) but this should not be a big problem because it can be assumed (or postulated or axiomatized) and hence any theory that is based on such assumption should get its validation and endorsement from the overall success of the theory within the overall experimental and observational evidence on its

behalf.

3. Inertiality: although "absolute frame" can (in principle) be of any type (i.e. inertial or non-inertial) it is commonly understood that the absolute frame (assuming its existence) is the ultimate reference to all inertial frames and hence it is inertial. In fact, if the absolute frame is non-inertial then this should be the death of classical mechanics since Newton's laws should lose their physical justification and rationale. Anyway, the inertiality of absolute frame should imply that all inertial frames equally belong (or affiliate) to the absolute frame, and hence all inertial frames can be seen as representatives and instances of the "ideal" (or "ultimate" or "true") absolute frame. This means that the "absoluteness" of frame may have a loose (or rather extensive) meaning in the sense that "absolute frame" can be seen as a class of frames rather than a single, individual and "unique" frame (noting that "unique" may also be loosen or extended to accommodate the looseness and extension of absoluteness). However, this issue is related to the issue of uniqueness of absolute frame (as indicated already) and the absoluteness of rest and motion. These issues will be investigated further later on (see for instance § 7).

   We should also note that "inertiality" may be thought as appropriate for absolute frames of mechanical nature and type such as the Newtonian space-time and the Machian-type frames (see § 5.1 and § 5.2), and hence for the absolute frames of other types (such as the luminiferous ether which is of electrodynamic type; see § 5.3) we should adjust and adapt the concept of inertiality or adopt another property to suit their types and reflect their specific nature. However, we think "inertiality" even in its basic mechanical sense can extend to these non-mechanical frames. For example, "inertiality" for the ether frame should mean the ability of the frame of ether (by virtue of its intrinsic inertness) to define an absolute state of rest and motion and hence it is capable of being a reference for any inertial frame. This means that it has the property of "inertiality" in the above sense although the frame itself is not of mechanical nature and type since it belongs to electrodynamics and is identified and conceptualized by its phenomena (also see footnote [3]).

   We may also say (differently) that "inertiality" should represent the characteristic physical property of absolute frame from a mechanical perspective (i.e. with respect to the state of rest and motion), and hence we may need (necessarily or preferentially) to identify or define other characteristic physical properties of absolute frame from the non-mechanical perspectives such as having certain characteristic speed of light for the absolute frame in electrodynamics. Whether these characteristic physical properties identify the same frame in reality or not should depend on the uniqueness and mul-

tiplicity of these absolute frames in reality (see § 7) and whether these characteristic physical properties coincide in reality or not (i.e. by identifying the same physical entity or not). These issues should be investigated in the due course of this paper.

Anyway, in our view this is not a big issue as long as we understand that absolute frame is characterized (mainly by virtue of its physicality; see point 1) by certain physical property(s) where "inertiality" (due mainly to historical reasons) represents the primary and the most prominent characteristic physical property although other properties may also be used to characterize absolute frame (for different purposes or perspectives or branches) alternately or collectively (although this should be inline with the details and considerations about the issue of uniqueness which will be discussed mostly in § 7).

4 Absolute Frame in the Branches of Physics

We briefly investigate in this section the main branches of contemporary physics that accommodate (or should accommodate) the paradigm of absolute frame of reference and use it (or based on it or deal with it) in its formalism or/and epistemology (and hence these branches can be regarded as proper or natural "venues" for the paradigm of "absolute frame" and its investigations). We also investigate in some cases whether this paradigm is a need (or necessity) to these branches or not.

4.1 Classical Mechanics

Classical mechanics (in the form of Newton's laws of motion) is the natural venue for the paradigm of absolute frame, noting that this paradigm was born, developed and elaborated within classical mechanics. In fact, most of the details and issues about absolute frame were investigated historically (from the perspective of philosophy as well as from the perspective of physics) within the venues and contexts of classical mechanics. This situation continues in large part until these days although the relativity theories (and special relativity in particular) share this position with classical mechanics since their appearance on the stage (which is justified by the intimate link between classical mechanics and the relativity theories especially from the perspective of "absolute frame" which sounds and suggests the opposite of "relativity").

The existence of absolute frame is a necessity to classical mechanics (or at least it seems so) noting that historically it was seen so because all the philosophical and epistemological views about absolute frame within the framework of classical mechanics are based either

on explicit or implicit acceptance of absolute frame or at least on non-denial of its existence and this situation continues until these days. This is due to the strong association between the paradigm of absolute frame and the paradigms of inertial and non-inertial frames which are central to classical mechanics formally and epistemologically (see § 9). In fact, classical mechanics is unique in this regard since it seems to be the only branch of physics that is based on the paradigm of absolute frame and it needs it in its formalism (implicitly) and in its epistemology (explicitly).

4.2 Classical Electrodynamics

Classical electrodynamics emerged (and was developed almost entirely) during the nineteenth century where classical mechanics was the main and dominant branch of physics, and hence all the other branches of physics were generally following the footsteps of classical mechanics in many aspects and details and borrowing or imitating or customizing its paradigms and ideas to meet their needs and suit their frameworks where and when this was possible. In fact, classical mechanics was the first and main reference to most branches of physics at that time as well as being their source of inspiration and resource of ideas, and this is actually inline with the fact that classical mechanics is the mother of all contemporary physics (see for instance [1]).

So, it is logical to expect classical electrodynamics to be another venue for absolute frame in some shape and form. In fact, this is what actually happened during the first stages of development of classical electrodynamics where absolute frame was strongly present in the form of "luminiferous ether" (see § 5.3) which is a from of (or associated with) absolute frame. However, this situation did not last long as inconsistencies and lack of experimental evidence on the existence of such a frame (or rather alleged inconsistencies and lack of evidence) have emerged soon and thus resulted in the emergence and development of the Lorentzian transformations and Lorenz mechanics which were interpreted and understood by some (especially within the interpretation of special theory of relativity) as contradictory to the existence of absolute frame (particularly in its "luminiferous ether" form).

However, "absolute frame" remained a subject of deliberation and debate within the framework of classical electrodynamics on both sides of the divide, and hence it was *present* (i.e. either by assuming its existence or by denying its existence) in classical electrodynamics. In fact, this situation continues until these days noting that the strong rejection of "luminiferous ether" following the emergence of the relativity theories has been moder-

ated and reduced in ferocity in more recent times where electrodynamic theories based on "luminiferous ether" (or similar hypothetical entities) were proposed and developed (and actually are still being proposed and developed although they are mostly not within the mainstream physics).

So, we can say that although classical electrodynamics is a venue to "absolute frame" (where absolute frame is present in it either by affirming its existence or by denying this existence), absolute frame is not a necessity to classical electrodynamics (unlike classical mechanics) since classical electrodynamics has been conceptualized and epistemologized both within theories based on the existence of absolute frame and within theories based on the denial of absolute frame.

We should also note another difference in this regard between classical mechanics and classical electrodynamics that is: in classical mechanics absolute frame is present (in some shape and form) both in the formalism and epistemology, while in classical electrodynamics absolute frame is *present* (i.e. either by assuming its existence or by denying its existence) mainly and essentially in the epistemology where the formalism mostly seems neutral towards this issue.[8]

In short, the situation in classical electrodynamics is different to that in classical mechanics as there are classical electrodynamic theories which are based on both views, i.e. we have classical electrodynamic theories which are based on the existence of absolute frame (usually in the form or instance of ether) and other classical electrodynamic theories which are based on the denial of absolute frame. Moreover, absolute frame is a formal and epistemological issue in classical mechanics while it is essentially an epistemological issue in classical electrodynamics. Hence, we can say that the existence of absolute frame is not a necessity in classical electrodynamics (unlike classical mechanics) although classical electrodynamics is one of its venues in physics.

4.3 Lorentz Mechanics

Lorentz mechanics (i.e. the mechanics that is based on the Lorentzian transformations of space and time) is the birthplace of the theory of special relativity (which in our view is no more than an interpretation of Lorentz mechanics that was originally proposed by Henri

[8] We should note in this regard that while the motion in classical mechanics has a single model (i.e. particles moving in space noting that classical mechanics is a mechanics of particles) the "motion" in classical electrodynamics is more diverse in modeling since the dynamics of electromagnetism may be modeled as a mechanics of particles (or projectiles) or as a mechanics of waves (classical or non-classical) and hence electrodynamics seems to have more options with regard to the "absolute frame".

Poincare and developed further later on by a number of other physicists; see [2, 6, 7]) and hence it is a *natural venue* (i.e. in the negative sense) for the paradigm of absolute frame (noting that "absolute frame" is generally perceived to contradict "relativity" at least in its special relativistic sense and interpretation).

In fact, due to the dominance of special relativity (since the early stages of its appearance and development)[9] the paradigm of absolute frame was rejected by the majority of the mainstream physicists, and this rejection was extended (among the mainstream physicists) to other branches of physics (or rather to all other branches of physics since the non-existence of absolute frame was seen as a physical fact that is independent of special relativity and any other theory). In fact, even classical mechanics (which is an essential part of contemporary physics) was affected by this rejection to a certain degree despite the pivotal role and central position of "absolute frame" in its framework (see § 4.1). Accordingly, "absolute frame" is taught in classical mechanics (if it is given any attention at all) as a historical relic from the Newtonian mechanics (rather than a physical fact as required by classical mechanics). Alternately, the issue of "absolute frame" is ignored[10] or marginalized especially within the classical mechanical investigations of practical nature where classical mechanics is seen and treated as a useful tool and an inexact theory of "local" nature rather than a realistic and exact scientific theory that have serious epistemological and philosophical consequences and implications at cosmological scale (as "absolute frame" should suggest and imply).

So in brief, special relativity should be given the credit for the general rejection of "absolute frame" in recent times although the iron grip of special relativity is rather weakening in the last few decades and hence "absolute frame" becomes more accepted (or less rejected) by physicists. However, this should not affect the central position of "absolute

[9] The dominance of special relativity reached its climax with the alleged confirmation of general relativity by Eddington and his team (in the famous solar eclipse expeditions of 1919) which granted the relativity theories overwhelming support among physicists (as well as among the general public!!! thanks to the huge propaganda that associated this event whose harmful consequences invaded physics and science ever since). This situation continued until now although skepticism and criticisms to the relativity theories increased in the recent decades due to theoretical and experimental inconsistencies and question marks about the validity of these theories (such as paradoxes and logical inconsistencies in these theories as well as experimental results and implications from quantum mechanics which were seen to challenge these theories).

[10] For example, important physics textbooks do not refer to or investigate the issue of absolute frame (see for instance [8, 9]). Although "absolute frame" may be regarded as mainly an epistemological and philosophical issue, it is central to classical mechanics and it is related directly to its formalism (due to the strong link between absolute frame and inertial and non-inertial frames). Anyway, it has an important educational value and hence it should be part of any comprehensive curriculum of contemporary physics.

frame" in Lorentz mechanics in general (whether by accepting or rejecting its existence) and hence Lorentz mechanics should also be seen as a natural venue for the paradigm of absolute frame.

In fact, the presumed inertiality of the frames of reference in Lorentz mechanics (and in special relativity in particular) should make "absolute frame" as central to Lorentz mechanics as to classical mechanics from this perspective (due to the intimate relationship between the paradigms of "inertial frames" and "absolute frame"; see § 9) although the paradigm of "absolute frame" may not be as intrinsic and central to Lorentz mechanics as to classical mechanics (especially from an epistemological perspective) due mainly to historical reasons and the controversy about it in Lorentz mechanics.

Anyway, if we accept special relativity (ignoring its rejection to "absolute frame") and consider it as a "special case" of general relativity and it is of local nature (and hence the inertiality of frame is not global) then we may accept the view that Lorentz mechanics (which is the scientific essence and foundation of special relativity) in itself and within its formalism can in principle accept (unlike classical mechanics) both views, i.e. the existence and non-existence of absolute frame. This should also reflect the historical debate about this issue within the field of Lorentz mechanics where we find theories and views within the field of Lorentz mechanics that reject the paradigm of absolute frame and other theories and views that accept this paradigm (whether in its Newtonian or Machian or ether forms and instances or some other forms and instances; see § 5). For example, special relativity rejects absolute frame while the interpretation of Hendrik Lorentz to Lorentz mechanics (which may also be dubbed as Lorentz relativity theory) embraces the idea of absolute frame in the form of ether (or at least this is what some of his writings and views suggest). In fact, there are many details about these issues some of which are discussed in [2, 10] (and hence the interested reader should refer to these books).

In this regard we should also pay attention to the strong link between classical electrodynamics and Lorentz mechanics (noting that the latter has emerged from the former). As we noticed in § 4.2, classical electrodynamics is a venue to absolute frame although there are classical electrodynamic theories which are based on both views (i.e. accepting and rejecting absolute frame), and hence it is not strange that this situation is reflected in the field of Lorentz mechanics.

4.4 Gravitation

The subject of gravitation may not seem a logical venue for the paradigm of absolute frame noting that gravity (in its basic and classic conceptualization) is a force and hence gravity in itself has nothing to do with absolute frame. However, there are several reasons and factors that oppose this and hence they make the subject of gravitation another venue (and even a natural venue) for the paradigm of absolute frame in physics. The main of these reasons and factors are outlined in the following points:

1. The subject of gravitation was historically an essential part of the classical (or Newtonian) mechanics in its extended sense (i.e. beyond Newton's laws of motion which represent the main or "real" classical mechanics). This is largely due to the emergence and development of classical mechanics during the seventeenth century where it was dominated by Newton's work (which is largely presented and documented in his *Principia*) with the law of gravity being one of the main themes and novel theories in this work alongside the "real" mechanical substance and content of this work (i.e. Newton's laws of motion). Moreover, gravity as a force is generally linked to the subject of mechanics (which is the science of motion and rest which are caused and influenced by forces) especially within the Newtonian formulation of classical mechanics which is based on the concept of force (see [1]).
2. Another factor is the dominance of the theory of general relativity (since the time of its appearance) on the investigations and studies of gravitation. Now, because general relativity is a natural venue for the investigations of "frames" and "absolute frame"[11] it is logical to expect a strong interrelationship and interaction between the subjects of gravitation and absolute frame in the modern investigations of gravity, and this is actually what happened (and is still happening) in the mainstream physics (and even beyond the mainstream physics in part). However, in our view the issue of absolute frame is not properly and thoroughly investigated within the literature of general relativity in general.
3. Another factor is the Machian proposal about the origin of inertia which played (and is still playing) an important role in the development of contemporary physics. In fact, the role of this proposal seems to be increasing in recent times as more theories and opinions emerge these days which are based on this proposal or deal with it not only in its philosophical and historical context (especially regarding its influence on

[11] Since general relativity is essentially a geometric theory about space and time (or rather spacetime), we can legitimately describe it as a "theory of frames" (which should naturally include "absolute frame" regardless of the acceptance or denial of general relativity to the existence of such a frame).

the development of general relativity) but in its capacity as a potential (and physically more sensible) physical reason and origin of inertia. Now, Mach's proposal in itself (i.e. as proposed by Mach) does not seem to suggest a specific reason for the overall structure of the Universe to be the source and origin of inertia and inertial forces in general. So, to rationalize this proposal a number of theories (which may not be seen as mainstream theories) have tried to conceptualize and theoretize this proposal through gravitation (see for instance [11] and the associated literature related to the so-called relational mechanics). Now, if we note that Mach's proposal is essentially a proposal about "absolute frame" (see § 5.2) then any Machian-related gravitational theory (or rather any theory that makes a connection between Mach's proposal and gravity in any shape or form) should make gravitation a reasonable venue for "absolute frame".

4.5 General Relativity

The issue of absolute frame with regard to the theory of general relativity was referred to within the context of gravitation (see § 4.4). However, general relativity is supposedly not only a gravitation theory but it is a "General Theory" (see [10]) where the latter is supposed to be an extension to the special theory of relativity and hence it is essentially a theory about spacetime (and thus a theory about frames). In fact, this issue is lengthy and complex and hence it is out of scope and size of the present paper. However, we investigated this issue in detail in our book [10] which the interested reader should refer to.

Accordingly, the theory of general relativity (or rather the general theory of relativity to indicate its generality with respect to the special theory of relativity) is another natural venue for the investigation of absolute frame in physics. However, as indicated earlier we believe that the issue of absolute frame is not investigated properly and thoroughly within the literature of general relativity (i.e. neither within its capacity as a "Gravity Theory" nor within its capacity as a "General Theory").

4.6 Quantum Mechanics

Due to the association of the issue of absolute frame with the issue of states of rest and motion (which are the primary subject of investigation of the science of mechanics) any branch of mechanics can in principle be a potential venue for "absolute frame" although this may depend on the domain of the particular type of mechanics and its specific subject

of investigation (such as the aspects of rest and motion that to be investigated, the specific type of the system under investigation, and so on).

Accordingly, it is logical (although it may seem strange) to consider quantum mechanics as a potential venue for the investigations of absolute frame (to assess, for instance, the potential consequences and implications of the existence and non-existence of absolute frame on the formalism and epistemology of quantum mechanics or to assess the implications of some quantum mechanical phenomena on the issues of space-time and absolute frame and our notions about them).

However, it may be thought that because the quantum phenomena are very tiny (since the quantum objects belong to the microscopic and sub-microscopic scales) and they take place in a very limited and tiny space, the issue of absolute frame (which is an issue of cosmological scale; see § 3) is irrelevant. But this thought should be rejected for at least three reasons:

1. The size of the objects and space of the physical phenomena is irrelevant to the necessity of existence (or non-existence) of absolute frame, because otherwise the issue of absolute frame will be irrelevant even in classical mechanics where the size of the objects and space is also tiny and limited in comparison to the cosmological scale of absolute frame. In fact, the potential (or possibly obvious) link between "inertia" and the existence of absolute frame (especially in its Machian form; see § 3, § 5.2 and § 9) is a simple demonstration of the fact that cosmological issues can have (or should have) a direct link to "tiny" issues and influence on them (and vice versa since the Cosmos is made of tiny objects, such as atoms, and hence the cosmological characteristics and attributes of the Universe should be influenced by the physical effects, contributions and properties of these tiny objects).[12]
2. Quantum phenomena and quantum-related phenomena can take place at any scale as demonstrated (for instance) by quantum entanglement (where the quantum objects "interact" over an extensive scale at least in comparison to the quantum scale). Accordingly, the issue of absolute frame can be investigated appropriately and relevantly within quantum mechanics, and hence quantum mechanics is a potential venue for "absolute frame". In fact, quantum entanglement should demonstrate the potential impact of "tiny" issues on large scale (and even cosmological) issues because quantum entanglement has serious consequences and implications on the concepts of space and time (or rather space-time or spacetime) and our notion about them.[13] In fact, the theoretical revolution caused

[12] Actually, this should reflect the "dialectic" between the whole and its parts.

[13] We should note that quantum entanglement is not the only quantum phenomenon that necessitates the

by quantum entanglement (as represented by Bell's theorem and related experimental investigations such as those of Aspect and co-workers; see for instance [12–14]) should demonstrate vividly this strong interaction and interrelation between "tiny" issues and "big" issues. Huge amounts of studies and investigations have emerged as a result of quantum entanglement where these studies are related to and impacted not only quantum mechanics and its natural extensions and branches but even other subjects and branches of physics (as well as epistemology, philosophy, philosophy of sciences, etc.) which are not directly related to quantum mechanics (such as the relativity theories and cosmology). All this should make clear that quantum mechanics should be seen as a proper venue (or even natural venue) for the investigations of absolute frame despite the huge difference in scale between the quantum world and the cosmological entity of absolute frame.

3. As indicated already, absolute frame is essentially a mechanical issue (i.e. it is related to the states of rest and motion) and hence any branch of mechanics (which is the science of rest and motion) can in principle be a proper venue for absolute frame. So, quantum mechanics is a potential venue for the investigations of absolute frame, although this important issue is usually ignored or marginalized in the literature of quantum physics as if "absolute frame" is irrelevant to quantum mechanics.[14]

So in short, the tiny scale of the quantum objects does not affect the entitlement and qualification (in principle) of quantum mechanics to be a proper or natural venue for absolute frame and its investigations. In fact, we believe that a number of quantum phenomena and quantum-related phenomena necessitate the inclusion of these investigations within the branch of quantum mechanics. The obvious example (which we indicated already) is quantum entanglement and its implications and significance with regard to the issue of absolute frame (as well as many other important issues in physics especially with regard to the nature of space and time in the physical world and our notion or understanding of them where these issues have formal or/and epistemological consequences and dimensions that impact many branches and aspects of physics). However, as indicated already no

consideration of absolute frame (and actually from various aspects and considerations). For example, any non-local occurrence (such as the instantaneous collapse of wavefunction on a global scale) should also necessitate the consideration of absolute frame (although possibly from a different aspect to that of inertia for example).

[14] It is important to note that "absolute frame" is a bigger issue than a mechanical issue in the basic meaning of "rest and motion". This also applies to the science of mechanics which is a bigger subject than "the science of rest and motion" in the basic meaning of this. This similarly applies to quantum *mechanics* which is bigger than "rest and motion". However, we use simplistic language for ease and clarity (relying on the wit of the reader to understand our real intention and deep meanings).

sufficient attention is paid to the issue of absolute frame within most of the investigations of quantum mechanics and related literature of physics.

We should finally note that even if quantum mechanics in itself (i.e. in its original version and basic formulation or what we may call "classical quantum mechanics") is not a proper venue for absolute frame, the involvement of other subjects (which are proper or natural venues to absolute frame) in some of the versions or formulations of quantum mechanics and its extensions and generalizations should make it a proper venue. For example, relativistic quantum mechanics should be a proper venue for absolute frame even if we assume that quantum mechanics in itself is not. This should similarly apply to interdisciplinary (or multidisciplinary) subjects that involve quantum theory such as quantum gravity (as well as related subjects and disciplines) since quantum gravity is generally theoretized and investigated within the framework of general relativity which is a proper venue for absolute frame (see § 4.5).[15]

4.7 Cosmology

Strictly speaking, cosmology is not a branch of physics although it is strongly related to physics. In fact, we will not investigate absolute frame in cosmology in any detail in this subsection,[16] so the inclusion of cosmology in this section is due to the importance of cosmology as a venue for the investigation of "absolute frame" especially with regard to the cosmic microwave background radiation which is cosmological in nature (see § 5.4).[17] However, we will refer to cosmology in some suitable contexts when this is useful or necessary for the main purpose of this paper (see for instance § 8).

[15] In fact, this should apply even if quantum gravity was investigated within a classical gravitation framework (or a framework other than general relativity and classical gravitation); see § 4.4.

[16] In fact, our plan is to investigate cosmology and its issues (including "absolute frame" which is central to cosmology) in forthcoming papers of this series.

[17] In our view, cosmology is not a really scientific subject or purely physical discipline although it is strongly related to science (and physics in particular). This is because science (and physics in particular) is essentially about the Universe as it is while cosmology is largely about the origin of the Universe, its chronological development, and its past as well as its present and future. In fact, the theoretical framework of cosmology (whether in its old philosophical form or in its modern and largely scientific form) contains strong elements of philosophy (as well as elements of science and physics in its modern form). Also, some of the themes and issues of cosmology are out of reach of science and its observational and experimental methods of inspection and verification and hence they essentially represent philosophical and epistemological contemplations rather than real scientific knowledge. In fact, cosmology should be regarded as an interdisciplinary (or multidisciplinary) subject which combines science (or physics in its extended meaning that includes for instance chemistry) with other branches of knowledge (as well as knowledge-based contemplations).

5 Types of Absolute Frame

We can find in the literature of physics a number of proposed (or potential) types or instances of absolute frame. Actually, these are physical structures and entities (or hypothetical physical structures and entities) that can form a basis for absolute frame and determine its physical nature. In the following subsections we list and discuss briefly the four main types of these candidates of "absolute frame".

5.1 Newtonian Space-Time

This is the first type or instance of absolute frame from a theoretical or conceptual perspective since it consists of "space" and "time" which represent the foundation for the concept of "frame" explicitly and directly. It is also the first type or instance of absolute frame from a historical perspective since it is proposed by Isaac Newton (who is one of the founding fathers of classical mechanics and contemporary physics) in his *Principia*.[18] Most readers of the literature of classical mechanics should have come across the famous passages of Newton in his *Principia*: "Absolute space, in its own nature, without regard to anything external, remains always similar and immovable ..." and "Absolute, true, and mathematical time, of itself, and from its own nature flows equably without regard to anything external ...". This reflects the classical view of the world where the space and time are two independent, absolute and passive entities in which the physical objects do exist and the physical events take place.

In fact, the concepts of absolute space and time (as described here and as conceptualized to be a basis for this type of absolute frame) are inherited from the cultural and philosophical heritage of the old civilizations and were formulated (though may not be as explicit and eloquent as in the above passages of Newton) in the Aristotelian philosophy which was the dominant school of thought in the Mediterranean civilizations during the medieval ages. Accordingly, the space as we know is strictly described by the Euclidean geometry and the inert and regular flow of time can be measured in an absolute sense by any recurrent physical process such as the repetitive swing of a free pendulum. This classical view of the physical world in its spatial and temporal dimensions is based on the common sense and direct experiences which are gathered from everyday life and hence it

[18] It is worth noting that this type of absolute frame (or rather "absolute space and time" which underlie this type of "absolute frame") is not the creation of Newton or his brainchild but it represents the common understanding among the natural philosophers of that time. In fact, the roots of this go back to the classical philosophy and even further back in human culture and human history (as will be explained next).

(in its basic and intuitive or instinctive form) can be seen as part of the cultural heritage of the human species.

Anyway, the Newtonian space-time may be challenged (at least from the perspective of being a reasonable foundation for absolute frame) by claiming that it is a philosophical rather than physical entity and hence it is not a proper physical foundation for absolute frame which is a physical entity (see § 3). The general conception seems to envisage space-time as an abstract geometric construction synthesized and conceptualized by the human mind rather than a physical entity of its own with certain physical properties (unlike for instance Mach's structure or CMBR which are physical entities; see § 5.2 and § 5.4). However, it is reasonable and sensible to envisage space-time as a physical entity with certain physical properties (such as the inertia of classical mechanics or the absolute permittivity and permeability of electrodynamics or the characteristic speed of light in vacuum).

5.2 Machian-Type Frame

This type of absolute frame is based on Mach's proposal[19] about the origin of inertia and the nature of inertial and accelerating motion (which essentially defines inertial frames and hence absolute frame) where the overall matter in the Universe and its distribution (which we may call "the large scale structure of the Universe") have direct influence on local physical events and phenomena (and the inertial properties and behavior of material objects in particular). This large scale structure of the Universe is the foundation of a truly physical absolute frame by which even the states of absolute rest and motion can be defined and identified (at least theoretically and in principle).

In fact, Machian-type frame is the most explicit and accessible type of absolute frame from the perspective of physicality (see § 3) since Mach's structure is material and subject to direct observation and inspection. With regard to the actual identification and direct accessibility to this absolute frame (especially for practical purposes such as identifying inertial frames) we can use specific physical objects of large-scale (such as the "fixed stars" or "distant stars") which can be seen as fixed marks in the large scale structure of the Universe. For example, we can define and identify inertial frames practically as those frames which are at rest or moving uniformly and rectilinearly relative to the "fixed stars" which identify the large scale structure of the Universe.

[19] In fact, Mach's proposal is understood and interpreted in various ways in the literature. The following represents one of these understandings and interpretations.

It is noteworthy that Mach's structure defines only the spatial part of this type of absolute frame and hence we should assume (following Mach, as can be understood from some of his writings) that the temporal part of this frame is the same as the Newtonian absolute time (see § 5.1).

5.3 Luminiferous Ether

This is another type of absolute frame of reference (or at least a potential absolute frame). While the frames of Newtonian space-time and Machian structure (see § 5.1 § 5.2) are more related (theoretically as well as historically) to mechanics (and classical mechanics in particular), the frame of luminiferous ether is more related to electrodynamics (and classical electrodynamics in particular) due to its nature (or supposed nature) as a medium for the propagation of electromagnetic waves and the determination of the characteristic speed of light in *vacuum* (i.e. c).[20]

The belief in the existence of ether apparently dominated classical electrodynamics in the nineteenth century due to the properties and behavior of light as a wave which classically requires a medium for its propagation[21] and this necessitated (in the view of classical physicists) the existence of this medium which is supposedly a physical "substance" of cosmological extension and scale and has the ability (by virtue of its intrinsic inertness) to define a state of absolute rest and motion (and hence it meets the main characteristics of absolute frame; see § 3). However, this belief has receded (but did not disappear) for some decades following the emergence of Lorenz mechanics (thanks to the dominance of special relativistic interpretation of Lorentz mechanics in particular which explicitly dismisses ether and makes it redundant).

Nevertheless, the existence of ether and its status as an absolute frame of reference (or rather a basis for defining such a frame) have seen some revival in the recent decades following the identification of a number of theoretical cracks and inconsistencies in special relativity as well as the emergence of certain experimental evidence that challenges special

[20] About the nature of ether and its physical properties (as well as its role in the propagation of light) according to classical electrodynamics, we refer the readers to [2] (see in particular exercise 6 of § 2.5 of [2] where the solution can be found in the solutions book). We should also note that "ether" as an absolute frame may extend to branches of physics other than electrodynamics such as gravitation where ether can play the role of the medium for the transmission of gravitational interactions (or the transmission of gravitational waves if such waves do exist; see [10]).

[21] In fact, this should demonstrate the strong influence of classical mechanics at that time which was the main and dominant branch of physics and hence other branches and subjects of physics (such as the wave theory of electrodynamics) were generally conceptualized and theoretized on the style of classical mechanics by using its concepts and ideas and following its methods and approaches.

relativity or some of its postulates and implications. This motivated some physicists to go back to the old theories and ideas of electrodynamics (and related fields of physics) to address these difficulties.

It is worth noting that the luminiferous ether itself may not be seen by the classical physicists who believe in it as an absolute frame (or an instance of absolute frame or a basis for it) but due to its supposed relationship to the Newtonian absolute frame (i.e. the ether was generally believed to be at rest in this absolute frame) it is identified with (or linked to) the Newtonian absolute frame and hence it can be seen as an absolute frame (at least from an empirical perspective). This issue will be investigated further later on (see for instance § 7).

We should also note (as we noted earlier with regard to the Machian-type frame; see § 5.2) that luminiferous ether defines only the spatial part of this type of absolute frame and hence we should assume that the temporal part of this frame is the same as the Newtonian absolute time (see § 5.1). We also note that the existence of luminiferous ether is hypothetical (unlike the Machian structure and the cosmic microwave background radiation) which is one of its weaknesses from theoretical and practical viewpoints (for instance its physicality may be questioned; see § 3). In fact, it has some resemblance to the Newtonian space-time from this perspective although "hypothetical" should be understood differently in these cases (i.e. Newtonian space-time and ether).

5.4 Cosmic Microwave Background Radiation (CMBR)

This is another type of absolute frame (or a potential absolute frame). Its strength (theoretically and practically) is that its existence is verified empirically by direct observation (and hence it is like the Machian structure and unlike the luminiferous ether in this respect). It is worth noting (as we noted in § 5.2 and § 5.3) that the CMBR defines only the spatial part of this type of absolute frame and hence we should assume that the temporal part of this frame is the same as the Newtonian absolute time (see § 5.1). Also see § 8.

6 Comparison between the Types of Absolute Frame

In this section we compare briefly between the types of absolute frame (which were investigated in § 5) from various perspectives. In fact, some of these comparisons have been discussed earlier and hence we include them here for the purpose of further clarity and thoroughness (by gathering all of them in the same place). We outline these comparisons

in the following points:

1. The Newtonian space-time frame is rather philosophical (or hypothetical in some sense), and the Machian and CMBR frames are empirical (or observational), while the ether frame is hypothetical. Hence, the Machian and CMBR frames are the strongest types from the perspective of physicality (see § 3).
2. The Newtonian space-time and Machian frames primarily belong to mechanics, and the ether frame primarily belongs to electrodynamics, while the CMBR frame does not seem to belong to a specific field or subject of physics (although it seems more appropriate to belong to cosmology; see § 4.7).
3. The Newtonian space-time and Machian frames identify absolute frame directly, while the ether and CMBR frames are bases or foundations for identifying and defining absolute frame.[22]
4. These frames (excluding the Newtonian space-time) are spatial in nature as they lack an explicit temporal dimension and hence absolute time should be added to them (as indicated earlier).
5. Mach's proposal about absolute frame may seem more sensible as well as more physical than the abstract Newtonian proposal (where its sensibility may originate from its physicality). This may also apply to the other proposals (i.e. ether and CMBR) which actually represent (according to point 3) bases or foundations for identifying and defining absolute frame and hence Mach's proposal seems more sensible than them from this perspective. Mach's proposal may also be more appropriate (and even more useful) than the other proposals as potentially providing a basis for explaining certain physical phenomena and answering some perplexing physical questions such as the origin of inertia and inertial effects (and inertial frames of reference).

In fact, a thorough and fair comparison between these types of absolute frame requires a rather extensive study which is beyond the scope and size of the present paper. However, in the following subsections of this section we will draw the attention to some important aspects and issues that should be considered and investigated in the context of comparison between these types of absolute frame (and even other potential types).

[22] In fact, some may reject this distinction (especially with regard to the difference between the Machian on one side and the ether and CMBR on the other side). However, this is a trivial issue. Also see footnote [26].

6.1 Distinction in Reality between the Types of Absolute Frame

In this regard we ask the following question: is there any physical mean (such as experimental tests or astronomical observations) by which we can find out which type of the above types of absolute frame (and potentially other types) is *the* really existing absolute frame, i.e. whether the existing absolute frame (as indicated or evidenced by its effects and influences) originates from the Newtonian space-time or from the Machian structure (or from one of the other types)?[23]

In fact, we can find in the literature of physics and philosophy of science some basic proposals of tests or effects or signs (or ... etc.) that can be applied or used to distinguish between these types or to identify a certain type regardless of the other types (assuming that these types are not mutually exclusive, i.e. we can have more than one type at the same time; see for instance § 7). For example, it is proposed that the Machian-type frame can be distinguished (from other types) or identified (in itself regardless of other types) by the effect of a big lump of matter in the neighborhood of a test object where tiny inertial effects on the test object may be detected due to the existence of this lump (in comparison to the absence of these inertial effects by the absence of the lump). This proposed test supposedly indicates (if its result is positive) that the absolute frame is of Machian type since the inertial effects in the Machian type originate from the material structure of the Universe (noting in this regard the relationship between the inertial effects and absolute frame; see § 9).[24]

However, these proposed tests (or whatever else) are generally hypothetical and not of any practical use even if we accept their validity in principle and from a purely theoretical perspective (noting that these proposed tests are mostly questionable even theoretically). Nevertheless, we cannot rule out the possibility of the existence of some theoretically-valid and empirically-viable tests which we are not aware of or which will emerge in the future. Meanwhile, it is reasonable to assume that the difference and distinction in reality between

[23] This question seems to suggest the uniqueness of absolute frame in a rather specific sense (even though this is not necessarily the case). However, this issue will be dealt with and clarified in the due course of this paper (noting that the italic "*the*" in the text is supposed to indicate this).

[24] In fact, we may add to this what is proposed by Mach himself with regard to Newton's bucket experiment (which, i.e. the proposal, may be considered as a basis for some modern experimental tests due to the huge experimental and observational capabilities at the hand of contemporary or future scientists) that is: "No one is competent to say how the experiment would turn out if the sides of the vessel increased in thickness and mass till they were ultimately several leagues thick". In our view this proposed test may not prove Mach's principle due to the presence of contact forces and the possibility of the effect of other short range forces. In fact, other challenges and questions can be posed but this is not a primary subject of interest to us in the present paper.

these types (or rather some of these types) is of philosophical rather than scientific nature since we are supposedly unable to establish by any scientific means (i.e. experiment and observation) which type of frame is the actual absolute frame (even though the existence of absolute frame in some shape or form is supposedly certain and unquestionable).

So, from the perspective of absolute frame and its real type and nature the difference (for instance) between the Newtonian space-time and the Machian structure is essentially philosophical as long as we are unable to identify the actual type of absolute frame and whether the existing absolute frame is in reality the space-time of Newton or the large scale material structure of the Universe of Mach.[25] For example, we cannot remove the matter from the Universe to see if the inertial effects will continue to exist (and hence the absolute frame is Newtonian) or will cease to exist (and hence the absolute frame is Machian). This may also apply (in a similar rather than identical manner) to some of the other types of absolute frame.

6.2 Types of Absolute Frame in Relation to Various Branches of Physics

It may be thought that our classification of the types of absolute frame from the perspective of their relationship to the branches or subjects of physics (or rather science in general) is of trivial significance and it is essentially of educational and didactic nature. However, this classification is based in our view on a deeper and wider understanding of the role(s) of absolute frame in theory and in reality, i.e. as conceptualized and theoretized in physics (and related branches of science like cosmology and philosophy of science) and as demonstrated and indicated through its effects and influences in the reality of the physical world.

The common understanding (according to our reading of the literature) is that the paradigm of absolute frame is essentially about mechanics since absolute frame is commonly associated with mechanical issues like the state of absolute rest and motion, inertia, fictitious forces, and so on.[26] However, in our view the paradigm of absolute frame may be

[25] Actually, the difference between the Newtonian and Machian frames can be philosophical from some perspectives but not from all perspectives (and hence we could have some differences of physical and scientific nature). This should also apply to other correspondences between types (e.g. Newtonian versus ether).

[26] In fact, even in classical electrodynamics (which is the second important venue for absolute frame) the need for ether is primarily as a medium for the transmission of electromagnetic interactions and waves and not as an absolute frame although it can serve as an absolute frame. This should partly justify and clarify our view that we expressed in point 3 of § 6.

required beyond mechanics and hence we may have a "mechanical absolute frame" (i.e. an absolute frame for the mechanical physical effects which essentially belong to the science of mechanics) and an "electrodynamic absolute frame" (i.e. an absolute frame for the electrodynamic physical effects[27] which essentially belong to the science of electrodynamics), and so on.

This does not necessarily mean that these absolute frames are physically (and from the perspective of their reality in the physical world and their physical foundations) different. For example, we may not need to assume that the Newtonian space-time or Machian structure is the physical foundation for the mechanical effects of absolute frame while the luminiferous ether is the physical foundation for the electrodynamic effects of absolute frame (and hence we have two existing types of absolute frame in parallel: one mechanical and one electrodynamic). Instead, we may have a single absolute frame (such as the Newtonian space-time) that demonstrates itself through mechanical effects and electrodynamic effects simultaneously and is based on the same physical foundation.

So, different types of absolute frame can in reality be no more than different demonstrations of a single absolute frame which physically underlies all these demonstrations. On the other hand, different types of absolute frame can in reality be physically different in their bases and foundations (e.g. the Machian structure underlies the mechanical absolute frame while the luminiferous ether underlies the electrodynamic absolute frame) and hence we have multiple absolute frames where each one of these absolute frames serves a specific purpose and demonstrates itself through specific types of physical effects and influences. Accordingly, specific types of absolute frame may provide limited explanations and applications and have restricted physical scope due to their specificity with regard to the subject of investigation. This issue will be investigated further next (see § 7).

7 Uniqueness of Absolute Frame

"Absolute frame" seems to suggest that it is intrinsically unique. However, we think we need first to investigate the potential meaning(s) of being unique, and second to investigate if "absolute frame" should be unique according to the specific meaning (as identified first). In our view there are two main meanings or conceptualizations of uniqueness with regard to "absolute frame": being unique with respect to the type of frame (as investigated earlier

[27] Examples of electrodynamic physical effects for the presumed "electrodynamic absolute frame" may include the electric permittivity and magnetic permeability of free space and the characteristic speed of light in vacuum (i.e. c).

in § 5 and discussed further in § 6 and § 6.2 in particular), and being unique as a single entity in the reality of the physical world (for a particular type).[28] These meanings (and related issues) will be investigated in the following subsections.

7.1 Uniqueness with Regard to Type of Frame

The essence of this issue was largely (but briefly) investigated in § 6.2 where we reached the conclusion that absolute frame can be unique and can be multiple from the perspective of the types of absolute frame and the physical branches to which they belong. To summarize, absolute frame is not necessarily unique (or non-unique) from the perspective of type, and therefore we may have a single absolute frame (whether it is representing a single type or multiple types but as demonstrations to the same reality) and we may have multiple absolute frames from the perspective of their types (e.g. a mechanical absolute frame and an electrodynamic absolute frame and even a cosmological[29] absolute frame).

In fact, we can add to this another detail (or rather a further clarification to what we indicted already and earlier in § 6.2) that is: the multiplicity of absolute frame (when it is assumed) may be considered with respect to the physical reality (i.e. of different types) and may be considered with respect to conceptualization and theoretization (even though the physical reality may be single). This means that the presumed multiple absolute frames can (on one hand) have different physical reality (with different bases and foundations), and can (on another hand) have a single physical reality (with a single base and foundation) although they are conceptualized and theoretized (in our physical and non-physical theories) as different and distinct frames.[30]

[28] It is important to note that static translation of the origin of space-time coordinates or static rotation of the spatial coordinates (as well as similar static adjustments like scaling of coordinates) should not be considered as a factor that determines the uniqueness of frame and hence this sort of transformations should not affect the uniqueness. This is because what we are considering here is the uniqueness from a physical perspective (rather than mathematical or geometric perspective).

[29] "Cosmological" here means "related to the field of cosmology" and hence it should not be confused with "cosmological" within the context of the characteristics of absolute frame which were investigated in § 3.

[30] We should also refer the reader to 2.2.2 of [1] for some indications and discussions related to the issues of the present subsection. As indicated there, multiple absolute frames can be envisaged in many different ways and with regards to several perspectives (such as type, physical reality, theoretization, and so on).

7.2 Uniqueness with Regard to Physical Reality

This kind of uniqueness is essentially about the necessity of conceptualizing the absolute frame as an individual frame or as a class (or set) of frames which have certain property(s) with regard to certain physical effects, phenomena and attributes. This issue has several sides and dimensions and can be related to a number of branches of physics and science. Moreover, it is essentially about conceptualization, theoretization and epistemologization and hence it is largely contemplative in nature.

We do not want to go far in this sort of theoretization and contemplation and hence we focus our attention on a single issue in this regard, that is the uniqueness of absolute frame (as an individual frame or as a class of frames) from the perspective of the relationship between absoluteness and inertiality of frames of reference. In fact, this is the main issue of the uniqueness of absolute frame as an individual frame or as a class of frames although other issues may also be investigated in the future.

In short, the presumed uniqueness of absolute frame in physical reality may not mean necessarily its uniqueness as a single individual frame, but may mean its uniqueness as a class (or set or collection) of frames that have the physical characteristic and the theoretical and practical ability to be a basis and foundation for defining and identifying inertia and inertial effects and hence defining and identifying inertial frames of reference as a physically distinct type of frames (i.e. the uniqueness actually belongs to this class of frames which includes an infinite number of individual frames).

As well as its obvious relationship to the issue of inertial frames (as demonstrations and individual realizations of absolute frame), this kind of uniqueness of absolute frame is intimately related to the issue of the state of absolute rest and (rectilinear uniform) motion and if it is physically sensible and real or not (regardless of the issue that such a presumed state can or cannot be identified in practice and regardless of the issue of whether or not a presumed state of absolute rest is physically distinct from the state or states of absolute rectilinear uniform motion by some hypothetical physical sign or test or formulation). It should be obvious that if the presumed absolute frame is unique as an individual frame then we should have a state of absolute rest that is distinct from any other state of rectilinear uniform motion (although this does not mean that it has distinct physical consequences that distinguish it from other inertial frames or it can be identified practically), but if the absolute frame is unique as a class of frames then such a state of absolute rest may not be sensible to define in theory or viable to identify in practice (since such a state does not exist).

Accordingly, the existence of absolute frame of reference does not necessarily mean the existence of a state of absolute rest as opposite to uniform rectilinear motion (noting that accelerated motion is distinct from both). In fact, this should depend on the nature of this absolute frame and its actual physical realization as a unique individual frame or as a unique class of frames. For example, if the absolute frame is realized through an infinite Newtonian-type frame (i.e. infinite absolute space-time) then a state of absolute rest as opposite to uniform rectilinear motion may not be possible to define sensibly because this absolute frame is unique as a class of frames. On the other hand, if the absolute frame is realized through a Machian-type frame then such a state may be defined sensibly (regardless of being possible to identify practically or not and regardless of even having distinct physical effects and signs in comparison to the state of uniform rectilinear motion) because this absolute frame is unique as an individual frame.

It is useful to note in this context that some of the confusion and absurdity in special relativity may originate from the lack of proper distinction between the existence of absolute frame of reference and the existence of a state of absolute rest and uniform rectilinear motion which is related partly to the issue of this kind of uniqueness of absolute frame (i.e. as an individual single frame or as a class and collection of frames with certain properties originating from a certain physical basis and foundation).[31]

8 Evidence for the Existence of Absolute Frame

We believe that there are a number of indications (and possibly some evidence) on the existence of absolute frame in some shape and form. We present in the following list some of these indications:[32]

[31] More generally, many of the misconceptions and confusions about absolute frame in the literature of physics (and in the literature of special relativity in particular and because of it) originate from the belief that the existence of absolute frame requires or implies having special laws (or special forms of laws or states or ... etc.) for this frame and hence it should be detectable by these special laws as marks that distinguish the absolute frame from all other frames. However, this is not necessarily the case because for instance we can have (with no logical inconsistency) an absolute frame that is indistinguishable and undetectable from other inertial frames. In fact, this is logically consistent from formal and epistemological viewpoints. Moreover, the existence of absolute frame in this case can have very important epistemological and interpretative role(s) even though it may not have a formal role. In fact, it may be legitimate to even assume (hypothetically) the existence of such a frame for legitimate epistemological and interpretative role(s) if this proved to be sensible, useful and consistent. Also see point 2 of § 11.

[32] The items in this list largely represent various demonstrations of the same or similar things. Also, the items in this list are mostly based on inference rather than direct experimental or observational evidence and hence it may seem more appropriate to regard them as indications rather than conclusive

1. The obvious existence of inertial and non-inertial frames as two physically distinct types of frame. For example, astronauts can distinguish between a state in which they are pushed or pulled to one side or another (i.e. when they are in a non-inertial frame) and a state in which they do not feel such push and pull (i.e. when they are in an inertial or approximately inertial frame).[33] No sensible explanation and justification (from theoretical and practical perspectives) for the distinction between inertial and non-inertial frames seem to exist without the assumption of the existence of some form of absolute frame.
2. The validity of Newton's laws of motion in a particular type of frames (i.e. inertial frames) but not in another type (i.e. non-inertial frames). This may also be extended to other laws and principles that belong to other fields of physics (such as Lorentz mechanics) whose validity is restricted to inertial frames (or non-inertial frames).
3. The absoluteness of acceleration in general since acceleration implies a frame of reference to which this acceleration is referred and defined, and hence the absoluteness of acceleration implies the absoluteness of this frame of reference or some related frame which this frame is ultimately referred to (see § 2.2.2 of [1]).
4. The absoluteness of rotation in particular (as a form of acceleration). There are clear evidence for the absoluteness of rotation such as Newton's bucket experiment[34] (and this is one reason for the special importance of absoluteness of rotation and its particularity as a strong indication to the existence of absolute frame). There are also tentative evidence for the absoluteness of rotation such as the Sagnac effect.[35]
5. The principles of conservation of momentum and angular momentum since these principles cannot be rationally explained without the existence of an absolute space (and hence an absolute frame of reference) because the conservation requires definite and absolute meaning of direction and orientation. This may also be extended to the conservation of

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evidence.

[33] We actually consider the distinction between these two states from a purely kinematic perspective and as entirely dependent on the state of motion. This can by identified and distinguished by the astronauts from the states of the engine of their space vehicle (i.e. on or off) although this may require further justification and clarification (noting that any doubt should not affect this as an indication rather than evidence especially when it is considered alongside other indications and evidence).

[34] Other evidence may include Newton's rotating spheres experiment (or argument) and Foucault pendulum experiment. In fact, we may include even the determination of the peculiar velocity of the Earth (or the solar system) from the dipole anisotropy in the cosmic microwave background radiation as evidence for the absoluteness of rotation (or absoluteness of acceleration or even absoluteness of motion).

[35] We may also refer in this regard to the Miller ether drift experiment (see [3, 4]) as potential tentative evidence for the absoluteness of motion or acceleration.

energy in its relation to time.[36]

6. The existence of the cosmic microwave background radiation (CMBR) whose isotropy in a certain frame (or a type of frames) indicates the existence of an underlying absolute frame.
7. Having "free space" properties and quantities (such as the absolute permittivity ε_0 and absolute permeability μ_0 or the characteristic speed of light in vacuum c) since these properties and quantities indicate that "free space" has some reality and hence it is appropriate to have an absolute frame that represents this reality and justifies these properties and quantities. It is irrelevant to question these properties and quantities as attributes to the "free space" in itself (rather than being, for instance, generated by and originate from the material structure of the Universe inline with Mach's proposal or any other proposal) because this issue does not affect the above logic about the existence of absolute frame (even though it may affect other physical issues). In other words, we are not obliged to consider these attributes as actually belonging to "free space" (i.e. space in itself) or consider the underlying absolute frame as necessarily being of Newtonian type.[37]
8. The cosmological expansion of the Universe (for those who believe in the Big Bang theory) may also be seen as an indirect admission of the reality of space (and hence the logical sensibility of the existence of absolute frame for this real space). In fact, the existence of things like cosmic time, fundamental observers and co-moving frames and coordinates in modern cosmology is an implicit admission of the necessity of the existence of absolute frame (although it is not necessarily in the classical sense).

We should finally refer the reader to some of our books (e.g. [2, 10]) and papers (e.g. [1]) for further discussions and deliberations about absolute frame and the evidence (or indications) about its existence (see for example exercises 6, 7 and 10 of § 6.5 of [10] and § 2.2.2 of [1]).

[36] In fact, the homogeneity and isotropy of space and the homogeneity of time (which are commonly regarded as properties of space and time in general and which are seen as the basis for the conservation principles) may more appropriately be considered as properties of space and time from the perspective of absolute frame. This should be inline with the fact that these properties may be considered as properties of space and time in inertial frames (and hence inertial frames are defined by these properties; see footnote [6]) noting the obvious and strong relationship between absolute frame and inertial frames (see § 2, § 9 and § 10).

[37] Something like this may be said about "space" in point 5.

9 Relationship between Absolute Frame and Inertial Frames

As indicated earlier, "absolute frame" and "inertial frames" are strongly linked conceptually, theoretically and realistically.[38] In brief, the mere existence of the paradigms of inertial and non-inertial frames is based on (and cannot be justified without) an implicit assumption of the existence of some kind of absolute frame of reference. In fact, the existence of absolute frame is what makes the distinction (in physical reality as well as in theory) between inertial frames and non-inertial frames sensible and explicable, i.e. inertial frames are those frames which are at rest or in uniform rectilinear motion relative to absolute frame (and hence non-inertial frames are those which are not).[39]

This can be seen as the fundamental definition or characterization of inertial frames (and non-inertial frames) since it is based (supposedly) on the actual physical relationship between absoluteness and inertiality of frames which intrinsically reflects the physical reality and nature of these frames. In fact, there are many other definitions and characterizations of inertial frames (see for instance [15]), but most of them should be seen as "symptomatic" definitions and characterizations rather than fundamental and intrinsic (like this one).

It is worth noting that this fundamental definition (or characterization) is mechanical in essence and nature although it may apply to non-mechanical applications and branches of science, or at least it can be used (with some adaptation) as a basis or a start for non-mechanical definitions and characterizations. However, this should depend on the issue of uniqueness of absolute frame (see § 7) where in some cases and situations of multiplicity of absolute frame we may need different definitions and characterizations for different applications and branches of science (also see § 2 and § 3 with particular attention to point 3 of § 3).[40]

Anyway, the relationship between "absolute frame" and "inertial frames" is deep and intrinsic and it provides the physical basis for the definition and characterization of inertial

[38] We should note that the "inertiality" as one of the characteristics of absolute frame (see § 3) should reflect this intrinsic link between "absolute frame" and "inertial frames".

[39] This definition or characterization should apply (with some modification and attention) even to the conceptualization of absolute frame as a class of frames (see § 7.2).

[40] In fact, we may even need some other adaptations to reflect the actual or supposed relationship between "absolute frame" and "inertial frames". For example, the absolute frame of electrodynamics (i.e. luminiferous ether) should require the choice of a specific inertial frame (see for instance [16]) which may not be required for the absolute frame of mechanics as a unique class of frames rather than a unique individual frame (see § 7.2).

frames and non-inertial frames (as well as other physical concepts and paradigms), and can in principle provide reasonable explanations and justifications for many aspects of the physical world (especially with regard to the aspects of mechanics although mechanics is not the only field that benefits from this or impacted by this).[41]

We should finally note that the issue of the relationship between "absolute frame" and "inertial frames" (such as the definitions and characterizations which are based on this relationship) is a big subject and has several aspects and dimensions (i.e. scientific, philosophical and epistemological) and hence it cannot be investigated fairly in this paper. Hence, we refer the interested readers to our books and papers (see for instance [1, 2, 10]) as well as the literature of physics and the philosophy and history of science in general (see for instance [15]).

10 Absolute Frame and the Properties of Space-Time

Absolute frame obviously coordinates, and hence represents, some kind of space-time (regardless of whether absolute frame is physically originating from and founded on this space-time according to the Newtonian view or not). So, there should be some relationship between the absolute frame and the properties of space-time. In other words, we are trying to answer the following question: a space-time of which properties is more appropriate (or perhaps even necessary) to be represented by the presumed absolute frame (apart from the property of absoluteness of space-time in some sense which is obvious because we are talking about *absolute* frame)?

So, in this section we briefly discuss the relationship between absolute frame and the space-time which absolute frame (ideally and possibly necessarily) refers to from the perspective of the properties of this space-time. We address this issue from two aspects (representing two types of properties of space-time) which are:

1. The geometric properties of space-time: absolute frame seems to require (or at least prefer) Euclidean geometry (or rather flat geometry) of the space-time. It seems natural and logical to assume that absolute frame represents a flat space-time as it is the more natural and intuitive geometry for the space-time that is represented by absolute frame. In fact, the birth of the concept of absolute frame of space-time within the classical mechanics of the Renaissance era (whose instinctive and intuitive roots go back in time to the old natural philosophy and even to the ancient philosophies and beliefs) should

[41] We should also refer the reader to point 3 of § 3.

indicate the flat nature of this space-time. The intimate relationship between absolute frame and inertial frames (as discussed for instance in § 9) should also suggest such a flat space-time due, for instance, to the "rectilinearity" and "uniformity" of motion of inertial frames relative to absolute frame (see § 9).[42] In fact, we do not need to find or propose a specific reason for choosing or justifying the flat nature of space-time here other than there is no reason to choose non-flat space-time because flat space-time is the simplest and most intuitive and hence it is the most natural geometry to choose and use (noting that we are referring in this regard to the epistemological principles of science and the principles of economy and intuitivity in particular; see § 5 of [17] and § 5.4 and § 5.5 of [17] in particular).[43]

2. The symmetry properties of space-time (i.e. the homogeneity and isotropy of space and the homogeneity of time): in this regard we refer to footnotes [6] and [36] (and the related texts). In brief, we consider these symmetry properties as belonging to the space-time that is referred to by the absolute frame (or inertial frames in general) and hence the space-time that is represented by absolute frame is homogeneous and isotropic (as stated already). We may repeat some of the arguments of the previous point (related to the geometric properties of space-time) to support our claim (e.g. we do not need to find or propose a specific reason ... etc.). In fact, we may even claim that the flatness of space-time (which we supposedly established in the previous point) and its homogeneity and isotropy (which we want to establish in this point) are interconnected and intrinsically related in the sense that they imply each other (or at least they suggest each other) noting that there is a strong affinity and resemblance between the flatness of space-time and its "homo-isotropy".[44] Anyway, as indicated already the "homo-isotropy" of space-time is the simplest and most intuitive and hence it is the most natural property to attribute to the space-time of absolute frame (with no need for any specific reason to justify this).

[42] Actually, inertial frames are naturally associated in the literature of physics (and the literature of relativity theories in particular) with flat space-time.

[43] As indicated, the inertiality of absolute frame (see § 3 and § 9) should also suggest flatness due for instance to the rectilinearity and uniformity of free motion in inertial frames. We may even claim that the conservation principles of energy and momentum cannot be rationalized properly without the assumption of flatness (noting that this is also related to the next point, i.e. the symmetry properties of space-time which are related, according to the mainstream physics, to the conservation principles).

[44] In fact, this is very logical from a purely geometric perspective because flat *space* is naturally homogeneous and isotropic.

11 Criticisms and Challenges to Absolute Frame

There are many criticisms and challenges to the paradigm of absolute frame in physics (and science in general). For instance:

1. "Absolute frame" may be seen as a philosophical or metaphysical issue and hence it does not belong to physics. However, even though we accept that absolute frame is philosophical and contemplative[45] (which may make it look like metaphysical) it is a useful physical paradigm (e.g. in explaining and justifying inertial frames and their distinct physical properties and behavior in comparison to non-inertial frames) and hence it is physical as well and thus it belongs to physics (as well as to philosophy and epistemology). Moreover, some types of absolute frame (such as the Machian and CMBR frames) are physical (or rather being based and founded on observable physical structures).[46]
2. "Absolute frame" may be criticized by the lack of evidence (or test or sign or ... etc.) in support of the existence of a state of absolute rest (as required even by classical or Galilean relativity) which seems to be a natural consequence of the existence of absolute frame. However, this criticism may be revoked by the conceptualization of uniqueness of absolute frame as a class of frames rather than as an individual frame (see § 7.2). Moreover, even if we conceptualized absolute frame as a single and individual frame it is not necessarily that the state of rest should physically differ in its effects and consequences from the state of rectilinear uniform motion (i.e. unaccelerated motion) because such a difference in effects and consequences may depend on the order of the temporal rate of change of displacement (e.g. second or third order) and hence only accelerated or higher order temporal changes can make such a difference in effects and consequences. Also see footnote [31] and the related text.
3. There are problems and criticisms related to "inertial frames" (see for instance [15]) and these problems and criticisms (or at least some of them) should extend to "absolute frame" due to the strong and intrinsic link between "inertial frames" and "absolute frame" (see for instance § 9). However, we are planning to investigate "frames of reference" (and "inertial frames" in particular) and the issues and problems related to them in a forthcoming paper (so please wait!).

[45] It is "contemplative" because its existence is generally based on inference rather than direct experimental or observational evidence (see footnote [32]).

[46] In fact, they are observable in some sense (although they may not be observable in their totality and globality). Moreover, they are not observable as such (i.e. as absolute frames or foundations to absolute frame). However, these should not affect our argument in the text substantially.

Anyway, the main challenges to the paradigm of absolute frame seemingly come from the relativity theories which unfortunately are not within the scope and size of the present paper (see § 12). So, we refer the readers to the references and promises that we made in § 12.

12 Absolute Frame and the Relativity Theories

As indicated earlier (see § 4.3 and § 4.5) the relativity theories are some of the most natural scientific fields and venues for the discussion and investigation of absolute frame. In fact, the word "relativity" has strong suggestion about the issue of absolute frame. In short, absolute frame is one of the central issues in the special and general theories of relativity. However, "absolute frame" is too big to be investigated in this paper from the perspective of the relativity theories although we touched on some of its aspects earlier on (see for instance § 4.3 and § 4.5). We have also discussed this issue in many contexts and from various aspects in our books about the relativity theories (see [2, 10]). Moreover, we are planning to investigate this issue further in forthcoming papers about the relativity theories and related subjects (so please wait!).

13 Conclusion

The paradigm of absolute frame of reference is not investigated properly in the literature of physics (and science in general). In this paper we highlighted some aspects and details that require further attention and inspection by the researchers and investigators in various branches of physics and science (such as classical mechanics, electrodynamics, gravitation, relativity theories, quantum physics, cosmology, and so on).

Future investigations should address important philosophical and epistemological issues, as well as formal issues, where "absolute frame" plays (or should play) a role in the conceptualizations and applications (especially in the aforementioned branches and fields). They should also try to put an end to certain disputes and reach some conclusions or compromises about long standing questions in this regard by dedicating more resources and expending more efforts on experimental and observational projects, as well as theoretical work, to achieve these goals.

This should contribute positively and immensely to the progress and advancement of contemporary physics and will rid physical sciences of chronic illnesses and dilemmas that

infected modern physics thanks to the unjustified dominance of certain theories and the embracement of some dogmatic views in the mainstream physics. This should also put modern science on the right track and orient it in the right direction for the foreseeable future and beyond.

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