Question by **Sadeem Fadhil**

Is the bending of light locally related to the equivalence principle?

The equivalence principle is locally applied in GR. At the same time light is bent due to gravity, I just want to know is there a relation between them locally?

Topics

- Quantum Mechanics
- General Relativity

- Light
- Gravity

All Answers (47)

1 2 3 4 5

- **Robert Shuler** · 30.32 · 13.83 · NASA
  Very good question, Sadeem. The point has been argued in the literature as to whether equivalence produces the bending. I will cite pivotal papers that
  - introduce the local-global terminology
  - dispute that anything other than local calculations are necessary while maintaining (and there is a long history) that neither equivalence nor flat spacetime is sufficient
  - and finally showing that indeed equivalence is sufficient to explain and calculate all bending
  - In 1996 Ehlers & Rindler published "**Local and global Light Bending in Einstein's and other Gravitational Theories**." http://link.springer.com/article/10.1023%2FA%3A1018843001842
    It is not freely downloadable so I'll quote sections: "*The present paper is writ ten in reaction to a false rumor that has a certain currency in the literature. This asserts that , since Einstein's equivalence principle is somewhat vague and heurist ic, none of it s conclusions can be fully trusted. In particular, its conclusion about light bending is held to be contradicted by Nordstrom's second theory which contains the equivalence principle and is in effect based on conformally flat spacetime: it is alleged that because of the latter there can be no light bending in that theory ... To clarify the situation, it is essential to make the distinction between two types of light bending, local and global.*"
    In this paper, "local" bending results from the light keeping pace (or falling) with a reference mass in a rocket or in a small area of a gravitational field.

    "Global" bending is not calculated, but portrayed in words describing a figure which is not drawn: "*There is ... a second contribution. We consider the bent Newtonian light path [which oddly the authors have named the local bending] to be the central line of a narrow strip which we imagine to be cut out of the plane. This strip we now glue onto what is know as Flamm's Paraboloid. This is essentially an infinite plane* *with a circular funnel-shaped hole in the middle, somewhat like the wide end of a trumpet, and it represents the* **real** *geometry of the central plane of the sun's field in which the ray lies. A little experimenting with such a curved strip will quickly convince the reader that the depression in the middle will impart an extra amount to the total deflection*"

Surely this paper with first grade paper construction explanations only got past reviewers because of the stellar reputations of the authors. But I digress...

- Moreau et. al in 1998 published "*The rate of deflection of light in an accelerated frame and a gravitational field*," available at http://users.df.uba.ar/sgil/physics_paper_doc/papers_phys/cosmo/ligt_bend.pdf . Then note "*The* **failure** *of the equivalence principle to fully account for the total deflection ... has been analyzed and discussed in this journal [Am. J. Phys.] by many authors from different points of view [11 references!]*"

  They calculate by three methods and conclude 1/3rd of the *deflection rate* is due to acceleration with respect to local inertial frames, and 2/3rd is due to spacetime curvature. There is a parameter q which if zero represents no curvature which they say confirms the "*local equivalence of accelerating frames in flat spacetime and the corresponding stationary frames in the gravitational field in the limit of zero curvature.*"

  Their comments about $q=1$ are even more interesting, as they say "*The agreement of calculations ... with $q=1$ verifies that the approximations made in the latter are valid in calculating a* **LOCAL** *quantity like the* **RATE** *of deflection [emphasis added].*" In other words, they disagree that light bending can be distinguished based on local and global. On that I would agree with them, though the rest of their argument about "flatness" is suspicious in light of the publications we will encounter later.
- In 2002 Ferraro published "*The Equivalence Principle and the bending of light*" also in Am. J. Phys. (i.e. it passed the same or similar referees) http://scitation.aip.org/content/aapt/journal/ajp/71/2/10.1119/1.1517597 (also available on ResearchGate here: https://www.researchgate.net/publication/1965658_The_equivalence_principle_and_the_bending_of_light)in which he concludes "*The use of the equivalence principle can satisfactorily account for the bending of light in the context of the weak gravitational field metric. The result from the equivalence principle corresponds to a physically meaningful quantity: it is the angle formed by the trajectory of the light ray and a direction that is parallel transported along that trajectory in 3-space. The post-Newtonian parameter does not enter the deflection angle, although it obviously affects both the trajectory and the parallel transport. In this way, any metric theory of gravity that leads to the weak field behavior of Eq. (2) contains the bending of light predicted by the equivalence principle.*"

It seems to me that Ferraro's paper represents the considered "opinion" of the "physics establishment," at least in the United States. I could find no later works rebutting Ferraro.

That leaves only finding simpler ways to explain it (Ferraro's abstract paper has no figures), and convincing the stragglers that cutting and pasting lines on funnels does not refute the completeness of equivalence in describing bending.

I offer my own simpler calculation below, with figures.

- Bending in elevator.pdf

- **Sadeem Fadhil** · 10.35 · 1.3 · Al-Nahrain University
  Thank you Robert. nice answer. So the issue is still opened.

  23 days ago

- **Alfonso Leon Guillen Gomez** · 1.04

  The principle strong of equivalence (EEP) is valid where there is no curvature (Einstein). Where there is curvature is impossible to eliminate it (Logunov) therefore EEP does not apply . And where there is no curvature EEP is false (author, see http://www.cirjap.com/ojs/index.php/jap/article/view/66N)

  23 days ago

- **Robert Shuler** · 30.32 · 13.83 · NASA
  @Gomez, that link is not to a specific article, can you correct?

  There are a lot of misunderstandings even among brilliant physicists about the equivalence principle, because it is not a statement about *a particular spacetime*. Think of it is an emulation. No SR reference frame is equivalent to curved spacetime in GR. However, for a rocket which is accelerating, there is no direct SR analysis for its frame since it is not inertial.

  What I believe Einstein was saying was that if one analyzes from the rocket viewpoint - which can done by continuously adopting instantaneously co-moving reference frames - the effect will be *as if* there were curved spacetime. But there is *no one inertial frame* in which equivalent trajectories will appear.

  23 days ago

- **Alfonso Leon Guillen Gomez** · 1.04
  I am sorry. I correct for this address.
  Thank you

  - http://www.alfonsoleonguillen.net/Critifal.pdf

  23 days ago

- **Sadeem Fadhil** · 10.35 · 1.3 · Al-Nahrain University

Robert
I read the Ferraro's paper and my coclusion in conguction with your comments in other question which is your's, as follow's
To compare what you and Charles said about the Huygens' bending and equivalence principal with Ferraro’s paper can we conclude that half of bending is due to equivalence principal and the other half is due to Huyghens' principal which is described by the bending of light in 3-space in Ferraro's paper?

22 days ago

- **Sadeem Fadhil** · 10.35 · 1.3 · Al-Nahrain University
  Gomez

  Can we consider this as a special case where the equivalence principal is inapplicable in curved space time or it refers to a general one?

  22 days ago

- **Antonio Alfonso-Faus** · 30.07 · 34.36 · Universidad Politécnica de Madrid
  I think that the essence of gravitational atraction corresponds to the property of energy in any system, What I mean is that two systems atract each other with a force in proportion to their energy. Since photons have obviously energy, a photon gas is atracted by any other energy, like the energy MC^2 of the sun. Here I do not see the need to talk about equivalence principle or curved or not curved space: of course I am thinking in Newtonean gravitational atraction, and specially in the bending of star light when passing near the sun. In short, I believe that the bending of light is locally related to the gravitational field created by an energy Mc^2.

  22 days ago

- **Alfonso Leon Guillen Gomez** · 1.04

  Fadhil

  EEP does not apply to curved spacetimes.

  22 days ago

- **Robert Shuler** · 30.32 · 13.83 · NASA
  Hmm.. who said the EEP "applies" to curved spacetimes? No one that I know. The EEP does not *apply to* a spacetime. It applies to the relationship between an accelerated reference frame in flat spacetime, and a stationary reference frame in a gravitational field (pre-GR without curvature notion), holding by *assumption* that in a small volume an observer would

find them indistinguishable *to first order* [i.e. ignoring 2nd order Taylor series terms that have to do with divergence of spherical gravity fields and non-uniformity of observations at different positions in an accelerating rocket].

Using this assumption, and some fancy mathematics, Einstein came up with the curved spacetime formulation. Tests of equivalence are routinely considered to be tests, therefore, of GR on which it is based. If a first order effect were found to be dis-similar in an accelerating setup, it would be bad news for GR. However, two things:

- Due to the difficulty of experimenting in rockets, few or no such experiments have been done.
- They can be done quite effectively as thought experiments, and only a few people find enough disagreement to propose real experiments.

Fortunately for GR, all first order effects, including the falling and bending of light, are detectable in the accelerated rocket (in thought experiments). This actually was only settled recently, really in the Ferraro paper.

Our friend Charles Francis has been kind enough to write up these results, which were somewhat hard to ferret out of the maze of papers and opinions and ways of speaking about the problem, here:

http://rqgravity.net/Gravitation#BendingOfLight

http://rqgravity.net/Gravitation#BendingFromEEP

- **Sadeem Fadhil** · 10.35 · 1.3 · Al-Nahrain University

The problem that may arise if we assumed the bending of light is due to time only, is (from my point of view at least) light has a limit velocity so logically it must have a limit of time if there is such limit. I wish I can prove it, but it's not easy at all. By all means **if there is** such time limit this means this idea will be violated. Robert and Charles, Do you agree?

1 / 0 · 21 days ago

-

Alfonso Leon Guillen Gomez · 1.04

A system accelerated, existing in a flat spacetime, applying the strong equivalence principle, we can describe it as a gravitational system at rest. A gravitational system, according to GR existing in a curved spacetime, can we describe it as an uniformly accelerated system, existing in a flat spacetime, by applying the strong principle of equivalence?

21 days ago

-

Alfonso Leon Guillen Gomez · 1.04

Does strong equivalence principle is result of relationships ....?

21 days ago

- **Antonio Alfonso-Faus** · 30.07 · 34.36 · Universidad Politécnica de Madrid

Sadeem,

As I understand, photons travelling at the speed of light have ZERO proper time (d tau) You know the "Robertson Walker Lemaitre Friedmann" metrric,

(c d (tau)^2 = (c dt)^2 - R^2 (dr)^2

for photos tau is constant, and the photon equation becomes

c dt = R (dr)

For a non expanding universe R = constant and the speed of light c is = dr/dt where r is coordinate space and t coodinate time.

So, I do not see how we can talk of time only bending light.

)

1 / 1 · 21 days ago

- **Sadeem Fadhil** · 10.35 · 1.3 · Al-Nahrain University

Dear Antonio Alfonso-Faus

I totally agree with you. That's what I'm trying to say to Charles and Robert.

0 / 1 · 21 days ago

- **Stam Nicolis** · 47.17 · 45.74 · University of Tours

The equivalence principle states that matter is affected by gravity only through the coupling of its energy-momentum tensor to the metric-which is the only field that determines spacetime properties. If one uses as energy-momentum tensor that of the electromagnetic field, one finds the result for the bending of light. If spacetime required additional fields (e.g. Brans-Dicke scalars or fields from supergravity) then the result would differ and this is one way one can imagine detecting their presence.

21 days ago

- **Robert Shuler** · 30.32 · 13.83 · NASA

In my view, time is controlled by inertia, and whatever interaction determines inertia is more likely to be akin to entanglement than to QFT. While QFT interactions are limited to lightspeed, it is well known that entanglement interactions have no regard for relativistic limits. Think of inertia as position entanglement of multiple masses.

21 days ago

- **Norbert Straumann** · 35.78 · 275.18 · University of Zurich

After so many reactions I just refer to footnote 9 of my paper: "Einstein's Zurich Notebook and his Journey to GR", arXiv:1106.0900.

As a friend of the late Juergen Ehlers I recall in this connection a lively discussion on the issue with the two authors in Munich, long before they published their paper.

1 / 0 · 21 days ago

-

Stam Nicolis · 47.17 · 45.74 · University of Tours
I think footnote 10 on p. 14 of http://arxiv.org/pdf/1106.0900v1 is what is meant, correct?

-

Robert Shuler · 30.32 · 13.83 · NASA
All falling and bending present in a gravitational field has a counterpart in an accelerated reference frame. Some of it isn't so obvious and it took us a week or two on another thread to ferret out the conclusions finally reached by physicists after 100 years of papers on the subject. See the links above provided by me to Charles' writeup. (page 1 of this thread, bottom). It really isn't feasible to repeat the discussion fresh with every newcomer. Suggest newcomers read all of this thread and Charles' links as a minimum before commenting.

- **Sadeem Fadhil** · 10.35 · 1.3 · Al-Nahrain University

The problem that you may face if you assumed only time affecting bending of light is ignoring a real physical parameter which is spacial curvature. This may lead to conflict in the case of non static gravitational potential. Because you can't generalize your theory there.

20 days ago

-

Charles Francis · 40.08 · 17.14 · Jesus College, Cambridge
To summarise the results I gave at

http://rqgravity.net/Gravitation#BendingOfLight

http://rqgravity.net/Gravitation#BendingFromEEP

The metric causes a change to the coordinate speed of light, resulting in refraction. In Schwarzschild coordinates both space and time components of the metric contribute to bending. Using the equivalence principle locally at each point along the path, only the time component causes refraction, but there is also a "falling" contribution resulting directly from the acceleration of the frame. The net result is the same for both calculations.

Btw, it is perfectly wrong to say the equivalence principle does not apply in curved spacetime. The equivalence principle applies **locally** in any spacetime.

1 / 0 · 20 days ago

-

Norbert Straumann · 35.78 · 275.18 · University of Zurich
Remark to Sadeem: The Einstein equivalence principle implies for light rays the geodesic law. See, e.g. my book "General Relativity", Springer-Verlag, 2013, especially Sects. 2.3 and 2.4, p.19--

1 / 0 · 20 days ago

-

Alfonso Leon Guillen Gomez · 1.04
Dear Charles Francis:

"According to the equivalence principle, at each point on the path of light, the geometry is locally equivalent to a frame with uniform acceleration a relative to an inertial frame".

Is there at a point curvature different to cero?

20 days ago

-

Erkki J. Brändas · 46.20 · 250.16 · Uppsala University
Dear All,

I have followed this discussion with great interest, particularly since the Einstein law for light deviation in a gravitational field has been poorly investigated and confusingly explained. I am sorry for repeating some material but since the thread has changed coordinates here we go.

The problems emerge when the argument of the Equivalence Principle is applied to photons. Here the most flagrant violation notably sticks out, i.e. that the bending of a light ray in an accelerated box will be half as large as the bending in a box at rest in a gravitational field.

The standard explanation, often given, is that the "second half" of the bending comes from the amount of space curvature, notwithstanding the fact that this space curvature should already be a consequence of the (strong) Equivalence Principle.

To me the simplest way out of this conundrum is to formulate the general physical problem as a secular like operator equation in terms of energy and momenta (cf. the Klein-Gordon or Dirac equations), adjoined with the conjugate operators in terms of time and position. The interconnected form, of the space-time- and matter-momentum formulation, therefore, in principle includes the specific tensor traits of gravitational interactions, see my RG page for more details

The physical interplay between the conjugate partners automatically takes care of the space-time "dependence". This imparts the the Einstein's law of general gravity all in commensuration with the strong equivalence principle.

The formulation in its simplicity yields Einstein relativity (note however that the "physical" interpretation becomes quite different allowing both quantum operator and classical variable representations) and thus gives a non-contradictory theory for the presently discussed light deflection in a gravitational field as well as the perihelion motion of the planet Mercury (see also the Kepler article from my RG page).

Regarding the Ferraro paper:

Here Ferraro is using an approximation to the Schwarzschild solution (Ø(r) small). He appears to have switched the components of the static metric, but that does'nt seem to influence his end result.

Second the strategy used amounts to estimating the bendings as separate contributions from the spatial and temporal parts of the metric and then comparing the results. It does not become clear in this portrait, why the force felt by a non-zero rest mass particle would be different from light as both "particles" are subject to the same gravitational field.

In my own articles I derive the Schwarzschild gauge, corresponding to an exact solution of Einstein's equations, see my RG page. From this follows the light bending, perihelion of Mercury (for details see my) etc. as direct consequences of the formulation. It does not make sense to separate the various contributions from the temporal and the spatial parts.

Antonio Alfonso-Faus: You said "that two systems attract each other with a force in proportion to their energy". This is unfortunately not true.

20 days ago

-

Alfonso Leon Guillen Gomez · 1.04
Of other hand if local is understood as a infinitisimal lapse of a curved spacetime and "the equivalence principle, if understood as the possibility of excluding the gravitational field in an infinitesimal region, is not correct since there is no way in which we can exclude the curvature of space (if it is nonzero) by selecting an appropriate reference frame, even with in a given accuracy". Logunov A and Mestvirishvili M. (1989), The Relativistic Theory of Gravitation. Mir Publisher Moscow,15-16.
Dear Charles Francis:
Is Logunov bad ?

20 days ago

-

Charles Francis · 40.08 · 17.14 · Jesus College, Cambridge
Alfonso, "locally" in this context means a region in which curvature is indistinguishable from zero up to the limit of experimental accuracy. And yes, Logunov is not even sufficiently good that he is worthy of precise criticism. One should understand gtr before thinking that one can invent one's own theory by making random assertions divorced from mathematical accuracy or empirical foundation.

20 days ago

-

Charles Francis · 40.08 · 17.14 · Jesus College, Cambridge
Erkki, there is more than one way to skin a cat, as they say. I have shown at

http://rqgravity.net/Gravitation#BendingOfLight

http://rqgravity.net/Gravitation#BendingFromEEP

that the result of using the equivalence principle is precisely the same as using the Schwarzschild geometry. There is no space curvature in each region when you use the equivalence principle, but the bending of light is the same because clocks do not keep time, and because the acceleration of the frame also causes bending. People only think there is a conflict because they forget one of those effects, but everything makes complete sense and gives agrees with the geodesic solution when a proper treatment is given.

20 days ago

- **Robert Shuler** · 30.32 · 13.83 · NASA

@Charles, is there a type in your immediately preceding post ... two occurrences of "clocks do not keep time" ... one of them should be something else?

@Alfonso Gomez, the posts between you and Charles are a bit hard to follow as to what each of you are saying. Are you questioning whether acceleration in a rocket is equivalent to remaining stationary in a gravitational field, if the rocket is also in a gravitational field? (i.e. the equivalence experiment is done with background curvature) Or are you saying that an accelerating rocket in a flat background cannot produce or explain some effect that happens with stationary objects in a gravitational field? Notice that I only said "produce or explain some effect," not that spacetime in the equivalence setup was actually curved. To an inertial observer it will not be, but to the accelerated observer, various effects combine to give *equivalent result*. It is not that spacetime structure is the same, but that effects are equivalent. The continuous change of reference frame by the acceleration mimics curved spacetime, I think is a good way to think of it.

@Erkki J. Brändas, would you care to recommend just one of your many papers for an introduction to the ideas you mentioned in your post? The least difficult one, presumably. Thanks.

20 days ago

- **Charles Francis** · 40.08 · 17.14 · Jesus College, Cambridge

Thanks Robert, I have fixed it.

19 days ago

- **Norbert Straumann** · 35.78 · 275.18 · University of Zurich

Instead of many words, I recommend to perform the following two calculations for light rays in the Earth field, say.

1. Determine the ray orbits for the Rindler wedge. (I recall that this is obtained by a coordinate transformation from the Minkowski metric.) The simplest way to do this is to look at the geodesics of the corresponding Fermat metric, which agrees with the metric of hyperbolic 3-space. Up to higher orders one obtains Einstein's result of 1907 (in Bern), which he obtained on the basis if the equivalence principle,

2. Do the same for the almost Newtonian approximation for the metric of the homogeneous Earth field. At first sight the result seems to differ by a factor 2. But this is only apparent, as can be seen with a simple coordinate transformation that has to be performed in order to compare the two results physically. (Do not misinterpret coordinates as physical lengths.)

19 days ago

- **Antonio Alfonso-Faus** · 30.07 · 34.36 · Universidad Politécnica de Madrid

Erkki, your comment:

"Antonio Alfonso-Faus: You said “that two systems attract each other with a force in proportion to their energy”. This is unfortunately not true."

In my last paper here the gravitational constant G is proportional to c^4, regardless of any time variation of either G or c. This is so for a constant lambda.

Then the gravitational atraction between two masses M and m, (Newton), is proportional to the product GMm that is proportional (to Mc^2).(mc^2), the product of their relativistic energies. I think that this is fortunate true and explains why photon gasses atract each other: a force proportional to the product of energies, not matter.

19 days ago

-

Erkki J. Brändas · 46.20 · 250.16 · Uppsala University
Dear Robert and Francis,

Thanks for your interest. Although I am a chemical physicist my scientific advisor was a theoretical physicist and I did learn early about the "problem" at least from the interpretative point of view. I will look at the papers suggested by Francis.

In the mean time I will send to both of you two very simple texts privately, since they are still under copyright, i.e. Erkki J. Brändas: Arrows of Time and Fundamental Symmetries in Chemical Physics. Int. J. Quant. Chem. 112, 173-184 (2013), and E. J. Brändas: The Relativistic Kepler Problem and Gödel's Paradox. in Quantum Systemsin Chemistry and Physics. Progress in Methods and Applications., eds. K. Nishikawa, J. Maruani, et al., Springer Verlag, Vol. 26, 3-22 (2012).

The trivial argument regarding the Equivalence Principle as applied to photons, viz. *that the bending of a light ray in an accelerated box should be half as large as the bending in a box at rest in a gravitational field*, should have a simple answer without any references to additional bendings and/or (not exclusive "or") elevators working in prior fields.

Best

erkki

19 days ago

-

Norbert Straumann · 35.78 · 275.18 · University of Zurich
Instead of many words, I recommend to perform the following two calculations for light rays in the Earth field, say.

1. Determine the ray orbits for the Rindler wedge. (I recall that this is obtained by a coordinate transformation from the Minkowski metric.) The simplest way to do this is to look at the geodesics of the corresponding Fermat metric, which agrees with the metric of hyperbolic 3-space. Up to higher orders one obtains Einstein's result of 1907 (in Bern), which he obtained on the basis if the equivalence principle,

2. Do the same for the almost Newtonian approximation for the metric of the homogeneous Earth field. At first sight the result seems to differ by a factor 2. But this is only apparent, as can be seen with a simple coordinate transformation that has to be performed in order to compare the two results physically. (Do not misinterpret coordinates as physical lengths.)

19 days ago

-

Erkki J. Brändas · 46.20 · 250.16 · Uppsala University
I am a bit confused regarding which thread to answer so here is my answer again:

Dear Robert and Francis,

Thanks for your interest. Although I am a chemical physicist my scientific advisor was a theoretical physicist and I did learn early about the "problem" at least from the interpretative point of view. I will look at the papers suggested by Francis.

In the mean time I will send to both of you two very simple texts privately, since they are still under copyright, i.e. Erkki J. Brändas: Arrows of Time and Fundamental Symmetries in Chemical Physics. Int. J. Quant. Chem. 112, 173-184 (2013), and E. J. Brändas: The Relativistic Kepler Problem and Gödel's Paradox. in Quantum Systemsin Chemistry and Physics. Progress in Methods and Applications., eds. K. Nishikawa, J. Maruani, et al., Springer Verlag, Vol. 26, 3-22 (2012).

The trivial argument regarding the Equivalence Principle as applied to photons, viz. that the bending of a light ray in an accelerated box should be half as large as the bending in a box at rest in a gravitational field, should have a simple answer without any references to additional bendings and/or (not exclusive "or") elevators working in prior fields.

Best

erkki

19 days ago

-

Norbert Straumann · 35.78 · 275.18 · University of Zurich
Instead of many words, I recommend to perform the following two calculations for light rays in the Earth field, say.

1. Determine the ray orbits for the Rindler wedge. (I recall that this is obtained by a coordinate transformation from the Minkowski metric.) The simplest way to do this is to look at the geodesics of the corresponding Fermat metric, which agrees with the metric of hyperbolic 3-space. Up to higher orders one obtains Einstein's result of 1907 (in Bern), which he obtained on the basis if the equivalence principle,

2. Do the same for the almost Newtonian approximation for the metric of the homogeneous Earth field. At first sight the result seems to differ by a factor 2. But this is only apparent, as can be seen with a simple coordinate transformation that has to be performed in order to compare the two results physically. (Do not misinterpret coordinates as physical lengths.)

19 days ago

-

Norbert Straumann · 35.78 · 275.18 · University of Zurich
Instead of many words, I recommend to perform the following two calculations for light rays in the Earth field, say.

1. Determine the ray orbits for the Rindler wedge. (I recall that this is obtained by a coordinate transformation from the Minkowski metric.) The simplest way to do this is to look at the geodesics of the corresponding Fermat metric, which agrees with the metric of hyperbolic 3-space. Up to higher orders one obtains Einstein's result of 1907 (in Bern), which he obtained on the basis if the equivalence principle,

2. Do the same for the almost Newtonian approximation for the metric of the homogeneous Earth field. At first sight the result seems to differ by a factor 2. But this is only apparent, as can be seen with a simple coordinate transformation that has to be performed in order to compare the two results physically. (Do not misinterpret coordinates as physical lengths.)

19 days ago

-

Alfonso Leon Guillen Gomez · 1.04

Dear Charles thank you

Dear Robert:

Gravitation is locally equivalent to acceleration. This is the strong principle of equivalence (EEP). I know two notions of local:
- any point of a curved spacetime and the variant of a tangent spacetime at one point (point by event) of a curved spacetime. The application of EEP to a curved spacetime to some people seems like a joke because in both cases there are no curvature (one point or in a tangent plane spacetime). Of other hand, in a point is not possible to make experiments, for example, his rocket is at Cape Canaveral and you can not put the rocket in uniform accelerated movement because its trajectory will occupy many points.
- in one infinitesimal region where the curvature has no effect on the experiments. But, to Logunov is not possible eliminate the curvature, i.e. the effect of the curvature in the experiments. For example, his rocket is in uniform accelerated movement, under action of the gravity of the Earth, within of an infinitesimal region, much as you want. In any Cape Canaveral control station it will trace trajectories of bodies initially en rest, inside rocket, that will cut at the center of masses of the Earth.

19 days ago

-

Erkki J. Brändas · 46.20 · 250.16 · Uppsala University
Dear Antonio,

The problem arises because in relativity theory the force law, the momentum law and the energy law are not compatible. In a sense this is one reason to entail tensorial descriptions.

18 days ago

-

Antonio Alfonso-Faus · 30.07 · 34.36 · Universidad Politécnica de Madrid
Dear Erkki:

Locally, at the lab system, there is total compatibility: tensorial descriptions must obey locally the special relativity theory. Otherwise it would be a WRONG THEORY. The zero covariant divergence of the tensorial Einstein field equations, div. T_mu nu = 0 ensures the conservation equations. Thank goodness¡

18 days ago

- **Erkki J. Brändas** · 46.20 · 250.16 · Uppsala University

Antonio,

The force-, momentum- and the energy laws are incompatible even in the special theory.

18 days ago

- ▫_

[**Antonio Alfonso-Faus**](#) · [30.07](#) · [34.36](#) · [Universidad Politécnica de Madrid](#)
Erkki:

Certainly I do not think so. First, the second law of Newton establishes that the rate of change of momentum dp/dt (p the momentum of a particle, t time) is equal to the force (if any) applied to this particle. Zero force, then constant momentum p. This is a relativistic relation, confirmed in special relativity theory. And as far as energy is concerned, there is a very well known relativistic equation, well confirmed too, that states E^2 = (pc)^2 + (E_o)^2 , E the total relativistic energy E = mc^2, E_o the rest energy equal to m_0 c^2, m_0 the rest mass .

Now just a bit f humor: your statement, "The force-, momentum- and the energy laws are incompatible even in the special theory." may be true in some other galaxy, if different from our Milky Way.

18 days ago

- ▫_

[**Erkki J. Brändas**](#) · [46.20](#) · [250.16](#) · [Uppsala University](#)
Antonio,

Here we go:

Energy law, case of central force: E=mc^2 (1–μ/r);   μ=GM/ c^2 [G=gravitational constant, μ=gravitational radius of the mass M].

One obtains first from the momentum law: d(mc^2)=**v**•d**p**=d**r**•(d**p**/dt) by the use of the relation m=m_0/(√1-v^2/c^2).

However the force law imparts d**r**•(d**p**/dt)=d**r**•**f** from which one obtains by using the expression for E above that dE=d**r**•**f** (1–μ/r) for all d**r**. Except for a component perpendicular to d**r** one gets a modification of the force: **f**=**n**f(mM/r^2)(1–μ/r)^(-1) with **n**=-**r**/r.

It thus appears that we get an adjustment of the force law by the extra factor above. This altered law breaks down at r= μ, which happens to be one half of the Schwarzschild value.

I am still in the Milky Way! Where are you?

18 days ago

- ▫_

[**Antonio Alfonso-Faus**](#) · [30.07](#) · [34.36](#) · [Universidad Politécnica de Madrid](#)
Erkki,

It seems to me that your maths are not right, or at least not very clear.

Let us see: Energy law, case of central force E = mc^2 - GMm/ r

This is just a computation of the total energy E: total relativistic mc^2 plus gravitational potential energy - GMm/r . This is a well known energy law. When r is very large E = m_0 c^2 and for r small enough to have E = 0 then you get a limit for r, that is the gravitational radius of M, r_g = GM/c^2 i.e. one half of the schwarzschild value as you have seen.

Now, the force law is jus the atractive force on m as - GMm/r^2 . at distance r between M and m. The work done by this field is then -GMm/r^2 . dr for a radially moving particle m approaching M. If you integrate the equation correctly, m is varying with r, then you have no discrepancy.

17 days ago

-

Erkki J. Brändas · 46.20 · 250.16 · Uppsala University
Dear Professor Alfonso-Faus,

Looking at your publications at the RG page as well as your experience and competence in the theory of general relativity, I am surprised that we have this discussion. Somehow we must have entered the wrong track and miscommunicated.

All I am trying to convey is the triviality that the three laws quoted in my previous posting are consistent with each other, or in other words compatible in the classical formulation of Newton's law.

The force law, introducing the momentum, and writing the force law in the momentum form is consistent with the energy E as a sum of kinetic and potential energies, and with the important conclusion that E is a constant of motion. Hence dE=0 gives you back the Newtonian gravitational force, which demonstrates the compatibility of a so-called privileged system. Therefore one can e.g. use all three forms in calculating the orbits of the particle (in the gravitational field associated with the large mass M), the classical Kepler problem.

As discussed in my previous posting this is not true in the relativistic case. Hence starting with the force law, as Einstein did, would not give the same result as if one had started with the energy law.

My simple demonstration, which I believe is well-known (I can give references if you want), imparts in particular that if one "take the same route" as we did above for the classical case, one ends up with an extra factor, (1–μ/r)^(-1), as a modification of the force law.

It is interesting to test the various forms in a calculation of the perihelion movement of the planet Mercury, see my RG page.

Best erkki

16 days ago

-

Antonio Alfonso-Faus · 30.07 · 34.36 · Universidad Politécnica de Madrid
Dear Professor Brändas:

Thank you very much for your kind reply. Yes, I agree with you that there has been a misunderstanding from my side: I was thinking in classical terms, may be semi-classical. I was not familiar with the different result you have pointed out for the force law. Thank you again.

Best wishes,

Antonio

1 / 0 · 16 days ago

-

Robert Shuler · 30.32 · 13.83 · NASA
That modification of the force law and various other modifications, some little known like acceleration, are derived very simply in my 2011 paper, linked below.

- Isotropy, equivalence and the laws of inertia
  Robert L. Shuler Jr

1 / 0 · 16 days ago