The CMBR Explained Without a Cosmological Model

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Abstract

The discovery of the Cosmological Microwave Background Radiation (CMBR) in 1964 was decisive in determining that the Big Bang Theory (BBT) is the acceptable cosmological model over its rival, the Steady State Model. However the CMBR can be explained with such notions as the escape velocity, Einstein's Equivalence Principle and some probability considerations. There is no need of a cosmological model.

1. Escape Velocity

It is known that around a spherical object, we have equipotential energy levels. Also, we have a source and a test particle in a field. It is understood that the test particle is taken to be so small that its own field compared to the source field is negligible.

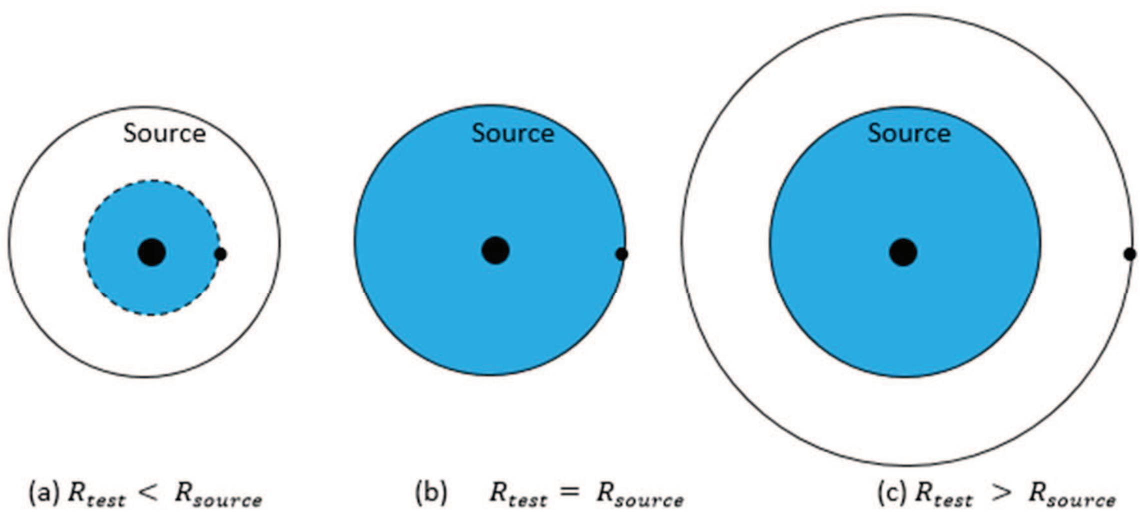


Fig. A

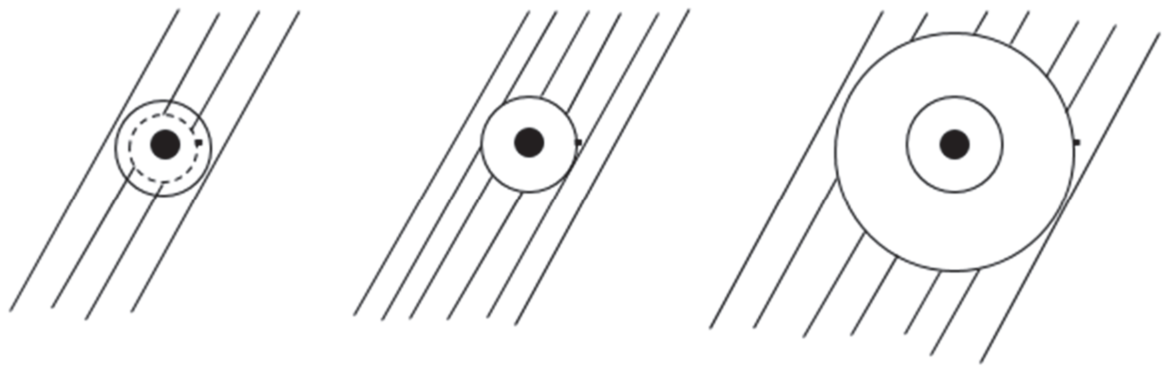
In Fig. A, we have three cases in which,

(a) The test mass is placed inside the source, $R_{test} < R_{source}$.

(b) The test mass is placed on the surface of the source, $R_{test} = R_{source}$.

(c) The test mass is placed outside the source, $R_{test} > R_{source}$.

In all cases, the test mass will experience a force of gravity as if all the mass inside the circle on which it resides is concentrated at the center. In case (a), the test mass will experience only the force due to the mass inside the dotted line, in other words, a reduced source mass .



(a) $R_{test} < R_{source}$ (b) $R_{test} = R_{source}$ (c) $R_{test} > R_{source}$

Fig. B

The good news is that we can ignore everything outside the circle of equipotential energy on which the test mass resides, even if the rest is a universe with infinite mass. For the test particle, the only thing that matters is the mass inside the sphere defined by the circle of equipotential energy. We can literally say that gravity lives on a sphere (Fig. B).

Example: The potential energy in a gravitational field.

Excluding the kinetic energy, the gravitational field applies a force of

(1) $\boldsymbol{F} = -\frac{Gm_1m_2}{r^2}\ \mathbf{e}_{\boldsymbol{r}}$

The work done by this force is,

(2) $dW = \ \boldsymbol{F}\cdot d\boldsymbol{r} = -\frac{Gm_1m_2}{r^2}\ \mathbf{e}_{\boldsymbol{r}}\cdot d\boldsymbol{r} = -\frac{Gm_1m_2}{r^2}\ dr$

Integrate to get the total work done,

(3) $W = -Gm_1m_2\int_{r_1}^{r_2}\frac{dr}{r^2} = \ -Gm_1m_2(\frac{1}{r_2} - \frac{1}{r_1})$

Consider the work done on a test particle starting at infinity to a distance r from the source of gravity, that is, we take the ground zero of potential energy to be at infinity (Fig. C).

In the case of the earth acting as the source on a test particle at a distance r from the center of the earth, we then have,

(4) $\frac{1}{r_1 = \infty} = 0, \quad \frac{1}{r_2} = \frac{1}{r}$

(5) $W = \Delta V = -\frac{GM_{earth}m_{test}}{r}$

For an object above the ground at a height h (Fig. C), $r = R_{earth} + h$. Considering the case that $R_{earth} \gg h$, we then have

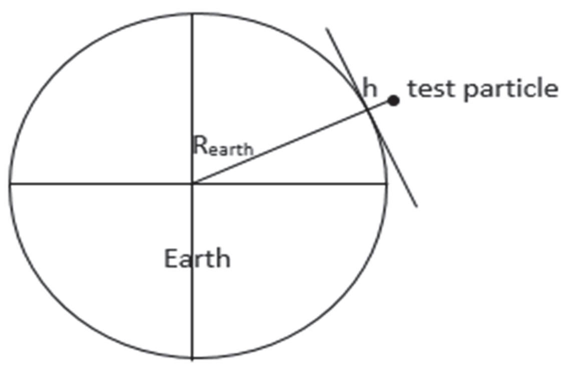


Fig. C

(6) $W = -\frac{GM_{earth}m_{test}}{R_{earth}+h} = -\frac{GM_{earth}m_{test}}{R_{earth}\,(1+\frac{h}{R_{earth}})}$

$$= -\frac{GM_{earth}m_{test}}{R_{earth}}\left(1+\frac{h}{R_{earth}}\right)^{-1}$$

$$\approx -\frac{GM_{earth}m_{test}}{R_{earth}}\left(1-\frac{h}{R_{earth}}\right)$$

$$= -\frac{GM_{earth}m_{test}}{R_{earth}} + \frac{GM_{earth}\,m_{test}}{R_{earth}^{\;2}}\,h$$

Consider the second term:

$$\frac{GM_{earth}\,m_{test}}{R_{earth}^{\;2}}\,h = \left(\frac{GM_{earth}}{R_{earth}^{\;2}}\right)m_{test}h = mgh$$

(6a) Where $g \equiv \frac{GM_{earth}}{R_{earth}^{\;2}}$.

Also we drop the subscript “test”. Now what is important is differences in potential energy, in particular between the surface of the Earth and the height h at which the test particle is located.

(7) $\Delta V = V_f - V_i$

$$= -\frac{GM_{earth}m_{test}}{R_{earth}} + mgh - (-\frac{GM_{earth}m_{test}}{R_{earth}})$$

$$= mgh$$

Another result is to calculate the escape velocity of an object from the earth's gravitational pull.

We start with the conservation of energy (kinetic energy + potential energy at two different points A and B):

(8) $T(A) + V(A) = T(B) + V(B)$

For a rocket to escape the pull of the earth, it will eventually achieve the minimum velocity required to escape the earth when we have T(B) = 0. At the same time, the rocket will no longer feel the attraction of the earth, that is, V(B) = 0. So

(9) $\frac{1}{2}m\mathrm{v}^2 - \frac{GMm}{r} = 0$

Where m is the mass of the rocket, M is the mass of the earth, and r is the distance between the rocket and the center of the earth.

Divide by m, and simplify.

(10) $\mathrm{v}^2 = \frac{2GM}{r}$

Or

(11) $\mathrm{v} = \sqrt{\frac{2GM}{r}}$

Note that this result is independent of the mass (m) of the rocket.

Taking $M_{earth} = 5.98\ x\ 10^{24}kg$, and $R_{earth} = 6.36\ x10^6m$, we get the escape velocity of a rocket of mass m taking off from the surface of the earth:

(12) $\mathrm{v} = \sqrt{\frac{2(6.674 \text{ x } 10{-}11\mathrm{m}^3\mathrm{kg}^{-1}\mathrm{s}^{-2})5.98\ x\ 10^{24}kg}{6.36\ x10^6m}}$

$$\approx 11200ms^{-1}$$

= 11.2 Km/s or 40,320 Km/hr.

2. Hubble's Law Corrected

The important result from the previous discussion is that for any test object that can escape from the pull of gravity from another body (the source) we need to consider only the mass of the source, whether that test particle is a rocket ship or a photon.

We can now show how Hubble's law can be derived from Newtonian Gravity (NG) and the Equivalence Principle (EP ≡ free falling frame).

Consider this thought experiment. Different emitters are placed at different heights from the ground. The earth plays the role of the source of gravity.

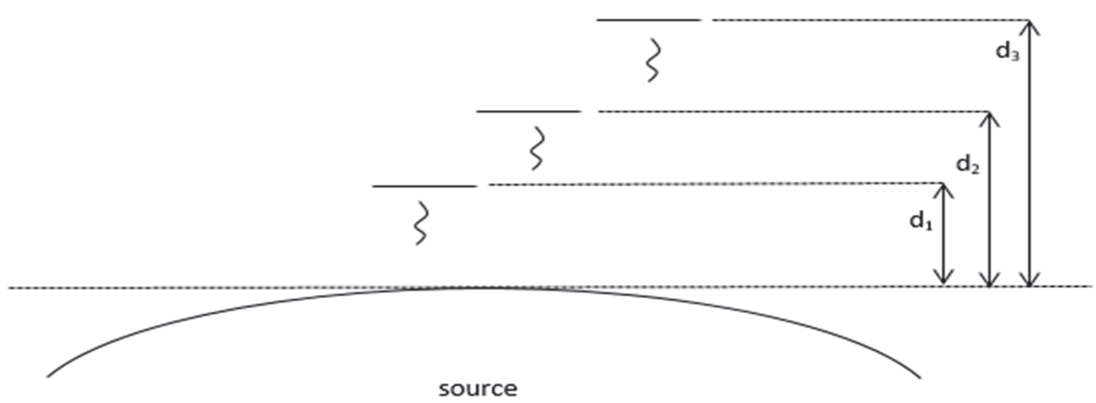


Fig. D

They emit light, which from an earth observer, would be blue-shifted. According to Einstein's Equivalence Principle: we can say that the Doppler Effect is equal to the gravitational shift.

(13) $(\Delta f/f)_{gravity} = -(\Delta f/f)_{doppler} = -\Delta v/c$

For emitter 1, we can say,

(14) $\Delta v_1 = g(d_1)\Delta t_1$

This is just the definition of acceleration, where $g(d_1)$ is the gravitational potential field g at distance d_1.

Define $g(d_1) \equiv g_1$ for simplicity, and using time = distance/velocity, and c is the speed of light.

(15) $\Delta v_1 = g_1 (d_1/c)$

However from equation 6a,

(16) $g_1 = (GM_{source}) / R_1^2$

$= (GM_{source}) (R_{source} + d_1)^{-2}$

$\approx \{(GM_{source} / R^2_{source})\} (1 - 2d_1 / R_{source})$

For $2d_1 << R_{source}$

(17) $g_1 \approx (GM_{source}) / R^2_{source}$

Substitute (17) into (15),

(18a) $\Delta v_1 = \{(GM_{source}) / cR^2_{source})\}(d_1)$

We can get the same result for emitters 2 and 3,

(18b) $\Delta v_2 = \{(GM_{source}) / cR^2_{source})\}(d_2)$

(18c) $\Delta v_3 = \{(GM_{source}) / cR^2_{source})\}(d_3)$

We can generalize equations 18 as,

(19) $\Delta v = Hd$

Where $H = (GM_{source}) / cR^2_{source}$

In case you haven't recognized this, equation 19 is Hubble's equation.

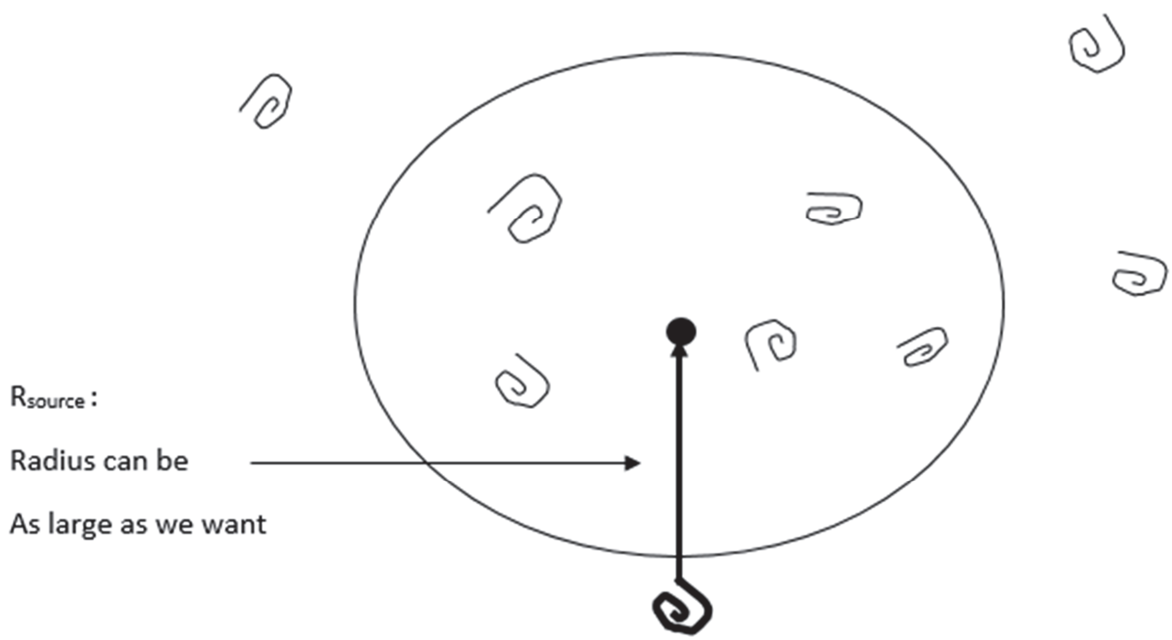


Fig. E

When Hubble discovered that all galaxies have a redshifted spectrum, Hubble concluded that all the galaxies were moving away. That is, it is the result of a Doppler Effect. However using

Einstein's Equivalence Principle, we can say that photons are red-shifted (they are moving against gravity). Note that Hubble discovered not a change in velocity proportional to the distance but just a velocity. In his days, he did not have the technology to observe such a small change in the galaxies' velocities, and it took nearly 70 years before it was discovered that galaxies are actually accelerating.

Consider one galaxy against all others (Fig. E).

According to the previous section, a galaxy would be attracted as if all the matter inside the sphere were concentrated at the center of that sphere. One can ignore all the other galaxies outside that sphere. Any object escaping that galaxy must escape the pull of gravity of all the matter in that sphere, the source. Similarly, we can argue that a photon leaving a galaxy is only influenced by the gravitational pull of the source, which has a very, very large radius in this case.

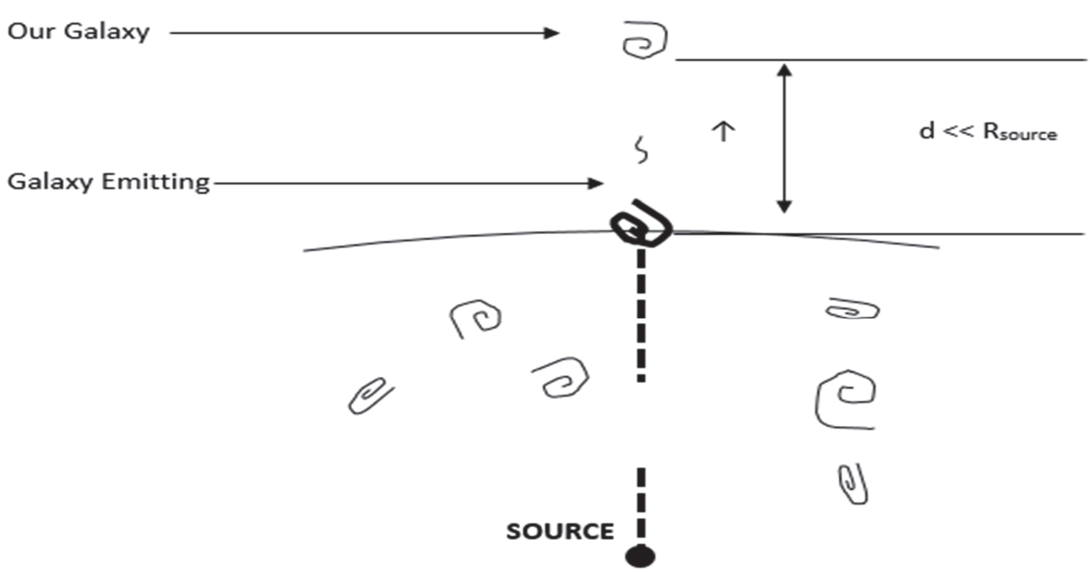


Fig. F

Ignoring scales, Fig. F illustrates what is at stakes: Equation 19 is true for every galaxy, since each one is emitting light from a source of gravity that has an infinite radius (as large as we want). Needless to say, this argument is only valid if the universe is infinite. So we have two points of view in regard to the observation of the galactic shift of photons from faraway galaxies: (1) a Doppler effect as Hubble interpreted it; (2) a gravitational shift as interpreted from the EP. Hubble's law does not distinguish these two points of view. Furthermore, interpretation (2) yields a universe that could be either accelerating or decelerating (equation 19).

3. Gravitational Redshift

One of many considerations that concerned Einstein was that gravity had to affect light. Why? He imagined this thought experiment (Fig. G). Suppose that gravity does **NOT** affect light. Then one could construct the following scheme:

One could release a particle of mass m at rest at a distance h from the ground (Fig. Ga). As it falls through the gravitational field, its potential energy (PE) is converted to kinetic energy (KE). Einstein knew that this particle could then be converted to a photon (Fig. Gb) from $E = mc^2$, and then one could send the photon to climb against gravity, reconverted to a massive particle after it has climbed the same distance h but now with $KE=\frac{1}{2} mv^2 \neq 0$. Comparing (a) and (b) we see that our particle at height h has gained kinetic energy. One could then repeat this process and create energy out of it. Einstein reasoned that the law of conservation of energy demanded that the photon, a massless particle, must lose energy when climbing up against gravity just like any other massive particle. But how, since light always travels at a constant speed c and a photon has no mass? The only way out was to use what he had already used in his seminal paper on the photoelectric effect,

$$E = \hbar\omega.$$

If E has to decrease, then the angular frequency ω must also decrease, or its wavelength increase. This is known as the gravitational redshift. Note that this phenomenon can be explained from the conservation of energy, the conversion of matter to energy back to matter ($E = mc^2$), and light in the form of a particle that can lose energy by extending its wavelength ($E = \hbar\omega$). There is no need of GR.

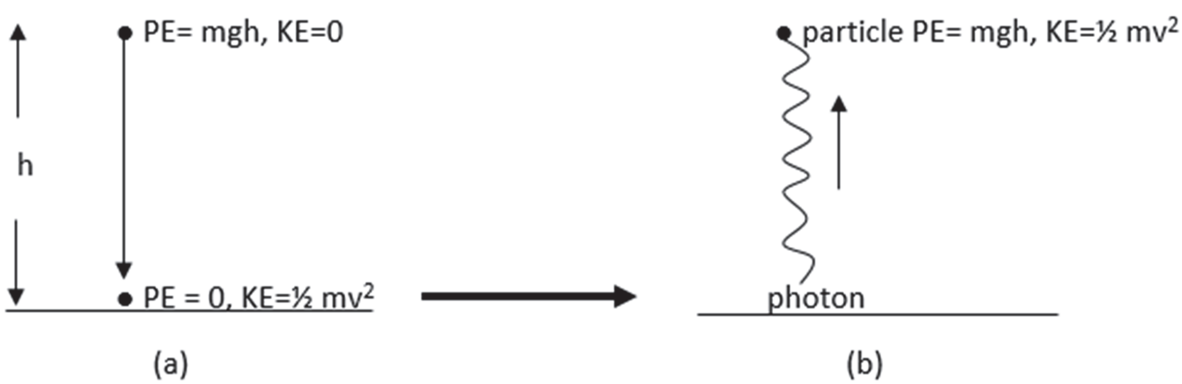


Fig. G

4. Considerations from General Relativity

The motivation behind GR was to extend the principle of Relativity from inertial frames to non-inertial frames. It is not a theory of gravity "interacting" with light as in QFT, which deals with interactions of the Yukawa type. While SR deals with inertial frames, GR deals with non-inertial ones. So it is misleading to view GR as a theory of gravity, though gravity certainly plays a central role. The main concern for Einstein was to see how light behaves in non-inertial frames. In doing so, he narrowed down to one specific non-inertial frame: the one with a free falling frame.

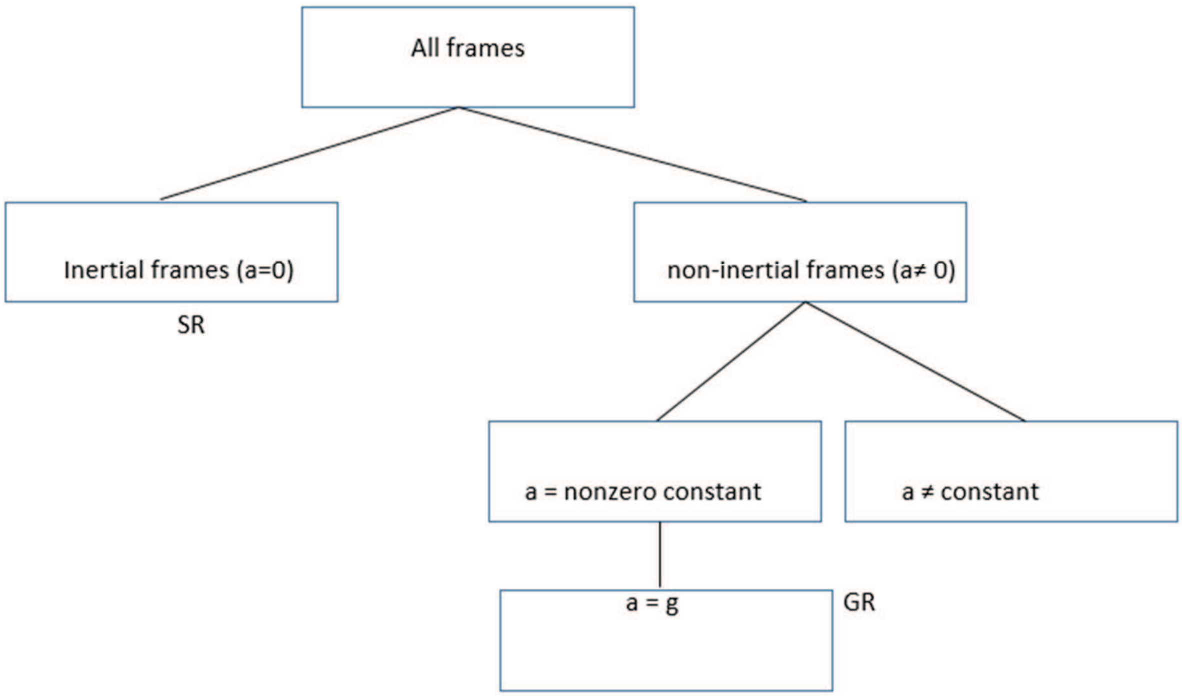


Fig. H

Consider the set of all frames, Fig. H. It contains two subsets: inertial frames (a=0), and non-inertial frames (a≠ 0). SR deals with the former. In the sets of non-inertial frames, there are two subsets: a = a nonzero constant, and a ≠ a constant. In the sets containing a = nonzero constant, there is the subset in which a = g, the acceleration due to gravity. GR deals primarily with this subset.

In gist this is what we have:

(i) Observer A in an inertial frame makes a measurement "a".

(ii) Observer B in a different inertial frame make a measurement "b" of the same event.

SR is the machinery that allows Observers A and B to compare their measurement.

With GR, we get the following:

(iii) Observer C in a non-inertial frame but free falling makes a measurement "c", but now we can use SR to relate his measurement to observers A or B.

Let met outline what this last claim is all about.

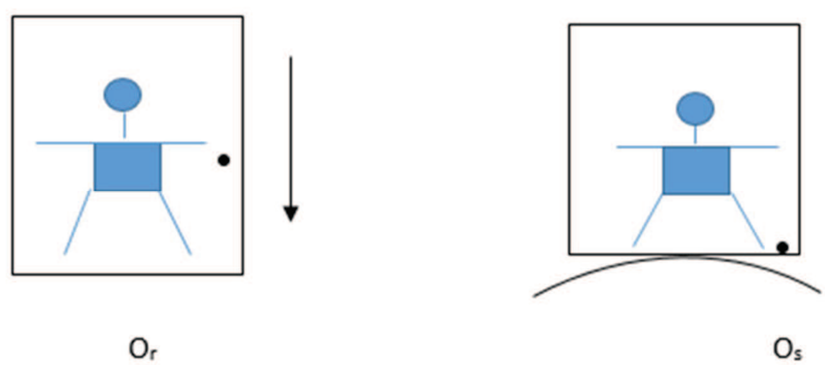


Fig. I

In GR, we construct two special reference frames (Fig. I): the first is a frame in which the observer O_R is freely falling and for whom the laws of physics (SR) are valid – the ball is at rest with the observer O_R; the second is a frame often called the "lab" frame in which the observer O_S is on the ground where the force of gravity is cancelled by the force of the ground preventing O_R from freely falling under gravity. The argument (EP) is that for observer O_r, should he be in a closed room in which he is weightless and therefore floating, and if he is pulled towards one side (the floor with respect to that observer), he wouldn't be able to tell the difference between a force pulling his room or a gravitational field pulling in the opposite direction (Fig. J below). So Einstein's field equations are formulated for these two special cases – how to transform from one set of frames (O_r) to a second set of frames (O_s).

In a rotating frame, one gets additional features such as the Coriolis force and the centrifugal force which are not present in a rectilinear motion. In GR, the additional features are the correction to Mercury's perihelion and the bending of light. In both cases, these are fictitious forces as they are not due to interactions between particles but due to a transformation of coordinate systems - when gravity is present in the case of GR. From this perspective, GR is not a theory of gravity so much different from Newtonian physics, but rather a theory that takes into considerations the effects of non-inertial frames. What was a revolution initiated by Einstein was the theory of Special Relativity (SR), in which our notion of time was turned upside down. GR contains that revolution in so far as it is an extension of SR from inertial to non-inertial frames.

There is something more to be said about the Equivalence Principle (EP). Einstein arrived as his EP with the following thought experiment. In a room without windows, one would not be able to distinguish between being pulled up by an inertial force F_i (Fig. Ja) from being pull down by a gravitational force F_g near a planet (Fig. Jb).

But is this true? Are there tidal forces that could show differences? Check Fig. K.

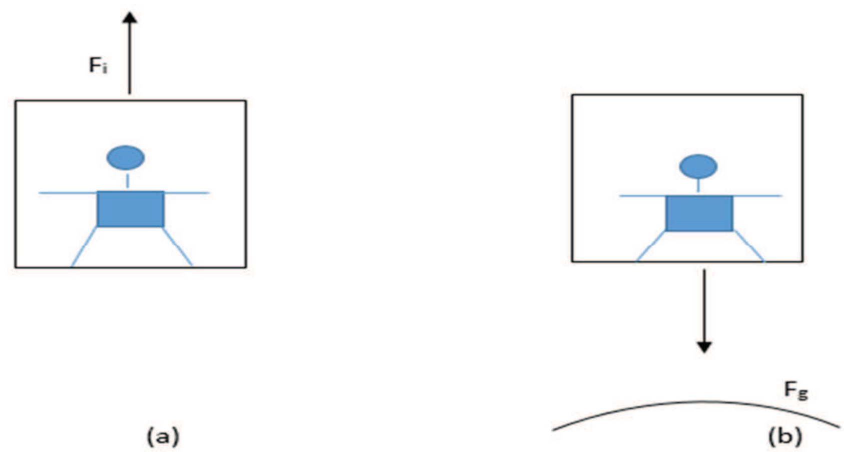


Fig. J

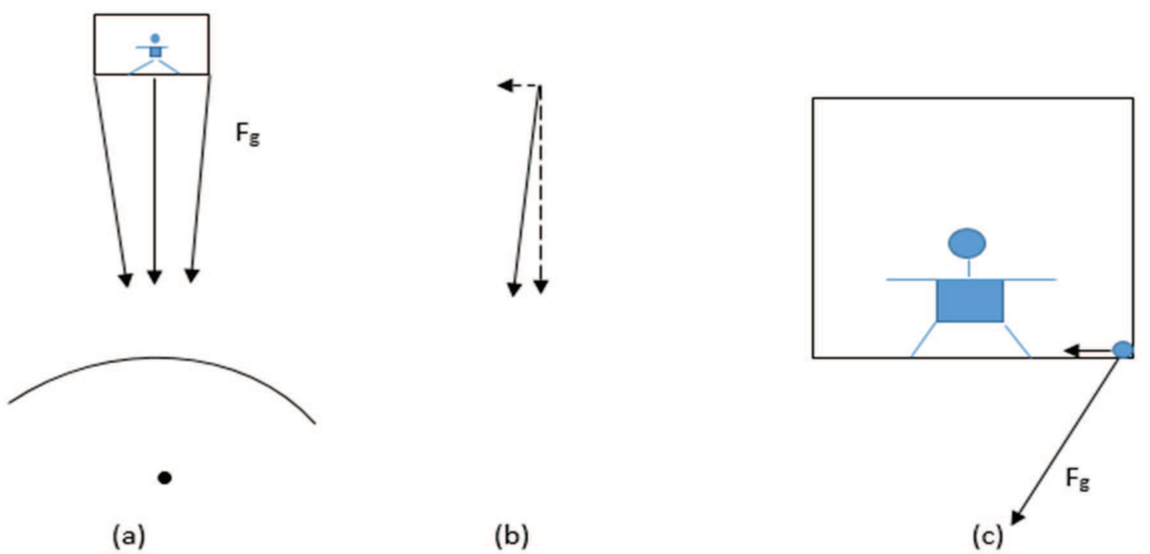


Fig. K

Acting on the frame are tidal forces as illustrated in Fig. K. What the observer would feel besides the downward pull of gravity, is a force perpendicular as illustrated in Fig. Kb. In Fig. Kc, a ball placed near a corner experiencing that tidal force would be moving towards the center of the room.

Every point on the right-hand side in that frame would feel this perpendicular force towards the left. Similarly, every point on the left would feel a force towards the right. But what about the Equivalence Principle? Does it predict also this perpendicular force in the case of an inertial force acting on the frame? To examine this question, we need to realize that an inertial force does not exist ex nihilo. What could have created this inertial force?

Consider a collision, Fig. L.

Initially you and the ball are weightless, floating in space, Fig. La. On the basis of Newton's 3rd law of motion, the frame applies a force on the colliding body, while the colliding body applies on the frame a force of equal magnitude but opposite direction. You will be pulled towards the bottom of the frame (Fig. Lb). We also see that after the collision, the floating ball in your frame after experiencing a force that has a perpendicular component, will hit the bottom and accelerate towards the left (Fig. Lc).

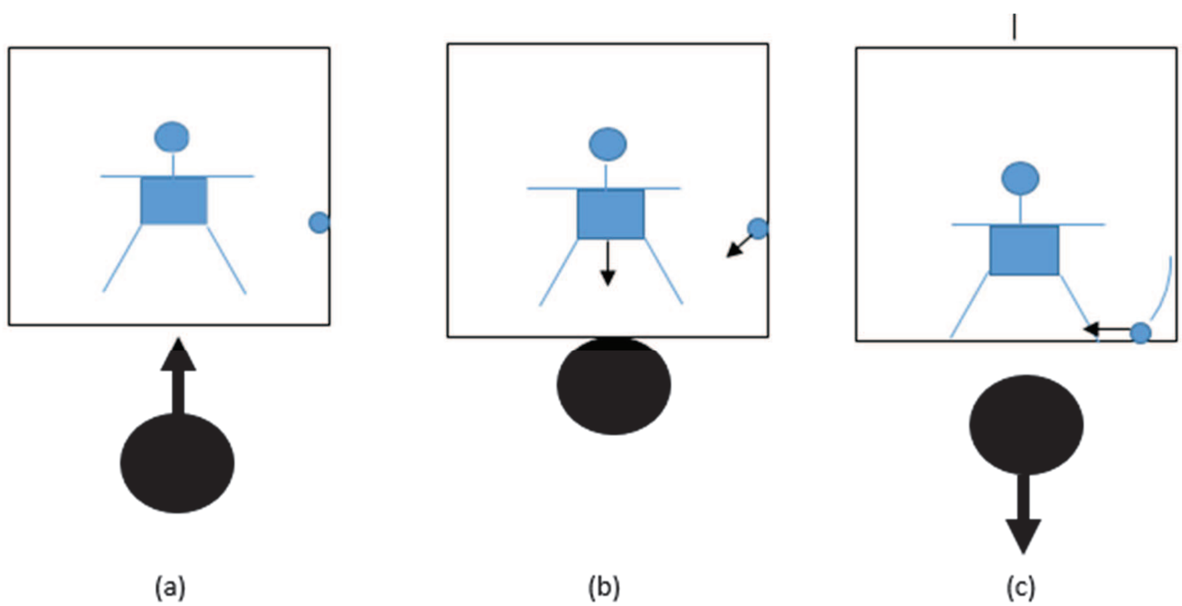


Fig. L

Now, since you are in a room without windows, you could say that:

(a) Either an inertial force acted on you as in Fig. Ja.
(b) Or you have enter a gravitational field as in Fig. Jb.

In both cases you would see the ball accelerating towards the center of the room.

The main feature of GR, which is often ignored, is that any observer, be it that she is on planet earth or in space travelling in a spaceship, or even free falling in an elevator from a broken cable, she can discover the laws of nature. The universe does not discriminate.

5. The Case of the Big Bang Theory

Now the Big Bang Theory (BBT) proposes that all matter started from a common point. It is based on Hubble's interpretation that the redshift in spectral analysis of faraway galaxies is a Doppler effect (section 2). The closest analogy is that of an explosion occurring at a single point (Fig. M where a 3-D coordinate system is at play). As different parts of matter are flying apart, "everything is matter moving through space", and given billions of years, there should be a region of an immense void created from this particular event, a void which would have been increasing in volume.

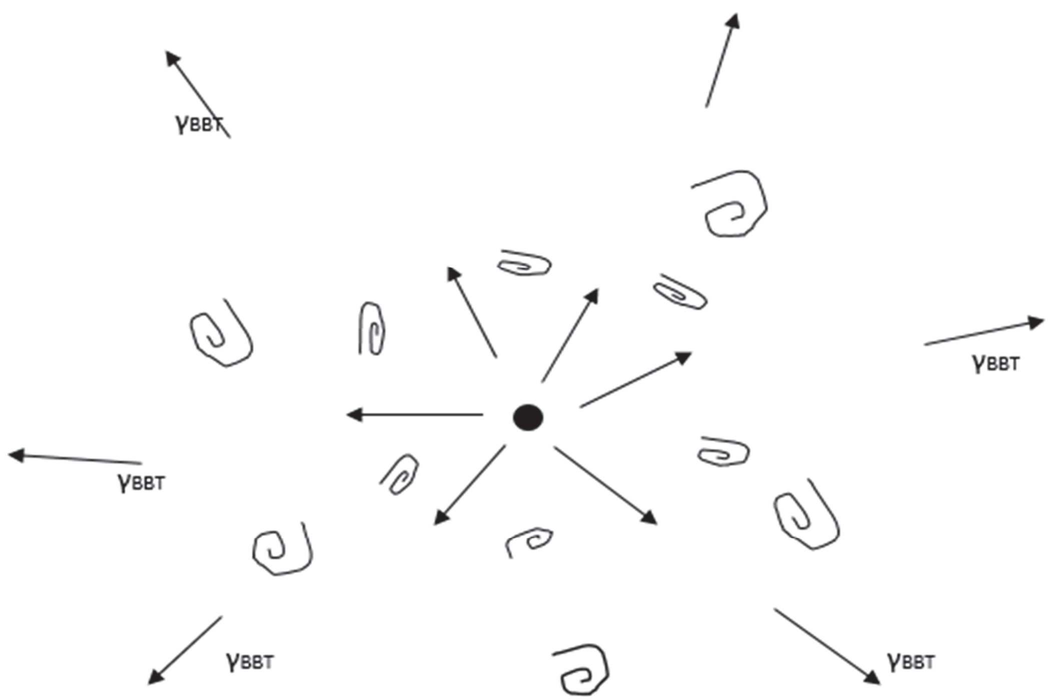


Fig. M

Note that the original photons γ_{BBT} that would be carrying images of the BBT have left our region a long time ago in this model – that is, no CMBR. Now such a universe would no longer be homogeneous and isotropic. The fact that there hasn't been any observation of this immense void so far, that there is a CMBR, and that the universe is observed as homogeneous and isotropic, constitute strong arguments against the BBT. Needless to say that any cosmological model without a complete theory of gravity is premature, and that includes the above depiction. But the BBT can be defeated using its own arguments.

Postscript: We don't observe a 4-D manifold, even though we can use that mathematical framework to work out our equations. We observe a 3-D world in which time – standardized motion [1] – depicts motion, no more and no less.

5.1 The Assumptions of the BBT

Here is a list of assumptions that underlies the BBT – the list is not meant to be exhaustive.

(i) The galaxies moving away from each other is due to a Doppler Effect. In section 2 we show that the gravitational shift can be explained otherwise.

(ii) By extrapolating backward in time, the universe started as a singularity and then expanded. Note: singularity often means the theory breaks down.

(iii) There is a 4th spatial dimension into which our 3-spatial dimensional world is expanding. There is no evidence for such a claim.

(iv) In order to solve the Einstein Field Equations to get to the Friedman equations, one must assume the universe is homogeneous and isotropic. However:

(v) To justify (iv), one must assume that the universe went through an inflationary period in the early stage. However:

(vi) To justify (v), one must assume that quantum fluctuations popped out of the vacuum some 13.7 billion years.

(vii) Since the universe is accelerating, one must assume that the universe is filled with Dark Energy, which must make up 75% of the universe in order to justify a flat space universe (As of now, the Vacuum Energy from (vi) is out of step by 122 orders of magnitude with Dark Energy).

(viii) To calculate the density of the universe, one must assume the universe is finite in size with its radius equal to its Schwarzschild radius.

(ix) In order to tie in the CMBR with the BBT, one must assume that the universe must behave like a nearly perfect idealized fluid, so that one can tie in the redshift to the scale factor in the Friedman equations (iv), which itself is tied in with temperature and time. One can then set a chronology of different reactions that would have happened at different temperatures/times, all of these requiring a number of parameters that can be fine-tuned with observation.

In conclusion, the BBT is a contrived theory which besides the number of assumptions that is needed to support it, nevertheless leaves a certain number of unanswered questions such as:

(a) What evidence do we have that a 4^{th} spatial dimension exists?

(b) If the universe didn't exist from t = -∞ to t = -13.7 billion years, what caused it to spring out of the vacuum some 13.7 billion years ago?

(c) How many more assumptions will the BBT need in order to reconcile the Vacuum Energy with Dark Energy in order to make that fit into the theory?

6. Olbers' paradox revisited

Olbers' paradox is the argument that the darkness of the night sky conflicts with the assumption of an infinite static universe.

Let n be the average number density of galaxies in the universe. Let L be the average stellar luminosity. The flux f(r) received on earth from a galaxy at a distant r is,

(20) $f(r) = L/(4\pi r^2)$

Consider now a thin spherical shell of galaxies of thickness dr. The intensity of radiation from that shell is

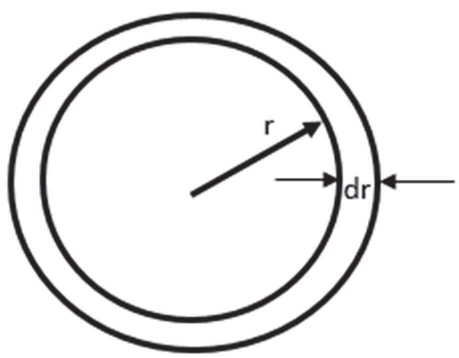


Fig. F

(21) $dJ(r)$ = flux X number of galaxies in the thin shell.

$= L/(4\pi r^2)\ X\ n\ X\ r^2dr$

$= (nL/4\pi)dr$

We can see that the intensity only depends on the thickness of the shell, and not its distance.

The total intensity is found by integrating over shells of all radii.

(22) $J = (nL/4\pi) \int_0^\infty dr = \infty$

Accordingly, the night sky should be bombarded by an infinite number of photons.

There are two possible explanations readily available (see section 2):

(i) The Doppler Effect case

The primary argument of the Olbers' paradox from the Big Bang Theory is the universe has a finite age (by extrapolating backward in time), and the galaxies beyond a finite distance, called the horizon distance, are invisible to us simply because they are moving faster than light-speed and therefore their light cannot reach us.

(ii) The Gravitational redshift case

The paradox is only an apparent contradiction. In this case, if humans had eyes that could see 7.35 cm wavelength (the Cosmic Microwave Background Radiation), then one would see the night sky being illuminated from every direction. What's missing in the above calculation is that the wavelength of light travelling intergalactic distances is shifted more and more towards the red. In terms of the wave model, the next peak would take an infinite amount of time to reach us. This is the surface of infinite redshift. What we see are the photons released from a distance slightly less than the surface of infinite redshift. Any photons released from galaxies beyond that distance will not reach us.

7. The Cosmic Microwave Background Radiation

In view of what was presented so far in this paper we can offer an alternative explanation.

If we accept that gravity is not a Yukawa type of interaction but rather a fictitious force then the Cosmic Microwave Background Radiation (CMBR) has a simple explanation.

Now consider the case of rolling a pair of sixes with a pair of even dice. In that case, the odds would be 1/36. If we would find that after 10,000 times rolling the pair of dice, our observation is 1/36 or very close to that number, no extraordinary explanation would be needed. On the other hand, should we find that our observation of rolling a pair of sixes is, say 10%, which overwhelmingly beats the odds of 1/36 (less than 3%), this would require an explanation other than the simple “all outcome are equally probable” explanation. One of those explanations could be by breaking up the die and find that one of the interior surface is coated with a heavy material. In other words, the inside of the die is not uniformly homogeneous, that is, the die is rigged. The point is: if the probability is 1/36 and the observation is 10% (much greater than the theoretical value), then we need to find more than a simple explanation provided by probability theory.

Similarly, Galileo was concerned that by releasing a 1-kg ball and a 2-kg ball from the same height, at the same time, the two balls reached the ground simultaneously. This seemed to defy the expectation as one would be inclined to think that: (1) the heavy ball should take more time as it would be slower in its motion – something we often observe from moving heavy material; or (2) the heavy ball should take less time as the force of gravity acting on it is greater, hence producing greater acceleration than the light ball. But equal time is a puzzle, which nonetheless was finally resolved by Newton with his three laws of motion and Kepler's laws for orbiting planets yielding an inverse-square law.

What about the CMB?

7.1 Thermodynamics Considerations

Consider that photons are primarily created by the stars, they are emitted in every direction. Many are absorbed by nebulae, planets, asteroids and other cosmological objects and re-radiated in every direction. But many are also never absorbed. So many are not only escaping from their source and losing energy, as we have seen in section 2, they are also distributed randomly in every direction. However that ongoing process of losing energy does not continue infinitely as energy is quantized. That is, at one point, the photon can no longer lose energy: it's either absorbed or not at all. The equilibrium temperature is at, or very near the Absolute Zero temperature. And losing the minimum quantized energy would throw them into negative energy region, which is forbidden by QM considerations. So it is no surprise that the temperature of the CMB is very close to the absolute temperature (~ 2.7 K), as the photons have the smallest amount of energy permissible without being totally absorbed.

So, shouldn't gravity be able to absorb these minimum energetic photons, in which case there would be no CMB?

7.2 QFT Considerations

As it is already known, there are two types of particles: fermions (half-integral spins) are the particles of bulk matter; and bosons (integral spins) are the force-mediating particles. If gravity is a Yukawa type of interaction, its theoretical particle, the graviton, would have spin 2 (integral spin) [2], and would now interact with photons, also particles with integral spins. Gluons can interact with themselves as they carry color charge which is necessary for strong interaction. Similarly the W bosons can interact through the electromagnetic force as they carry charge. The Z bosons interact with themselves as they carry mass. The photons however cannot interact through any of these forces as they do not have mass neither do they have charge or color charge. So by these QFT considerations, gravitons are unlikely to interact with photons, and therefore will not absorb the minimum energetic photons of the CMB – these are condemned to roam endlessly in the cosmos.

We can further argue that if gravity is not a Yukawa type of interaction – our initial assumption – and we know that photons necessarily do somehow interact with gravity (section 3, Einstein's thought experiment), then the only kind of interaction we can think of would be of the nature of a fictitious force that produce effects like the Coriolis or centrifugal forces - in the case of gravity, it can increase/decrease the photon's energy or deflect their paths. GR does that because at its core, it postulates that in a special frame – the free falling frame - photons behaves as if they follow a curved path on a manifold (gravity is switched off and replaced by an inertial force).

One final note: the CMB is observed as being homogeneous and isotropic. It's a random distribution. If the case had been otherwise, then like the rigged pair of dice, we would need an explanation other than the simple, "photons are emitted in all directions".

[1] https://vixra.org/abs/2004.0278

[2] A. Zee, Quantum Field in a Nutshell, Princeton University Press (2003), page 34.