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Doppler Effect on Durations of Events*:*

A Detailed Account of Undulatory and Ballistic Predictions

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***Abstract*:**

According to every physical theory, the Doppler effect, on the electromagnetic spectrum, must lead to shortening of measured durations of events, in all cases of approach, and inversely, to lengthening of durations of events, in all cases of recession. In this investigation, the predictions of the classical wave theory and the elastic-impact emission theory, concerning this type of effect, have been calculated and analyzed, in detail. These two theories predict the same results, in all cases of moving receivers and stationary sources; but their predictions show significant differences, in all cases of moving sources and stationary receivers. Therefore, it's, possible to distinguish, experimentally, between their predictions, in this regard. Subsequently, it has been concluded that the Doppler effect, on the durations of events, is an important first-order effect that has to be taken, always, into account, in astrometric measurements, planetary ephemerides, and space navigation.

Keywords:

Doppler effect; blue shift; red shift; event; interval of time; duration; classical wave theory; elastic-impact emission theory; light source; light receiver; apparent time compression; apparent time expansion.

Introduction:

By all accounts, the Doppler effect is, by far, one of the most instrumental and effective tools of discovery, in the entire ***16*** fields of physical sciences ***[Ref. #3]***.

Very little, or nothing, at all, could have been known, with any degree of certainty, about the composition of the universe, the dynamics of galaxies, and the structure of planets and stars, in the absence of the Doppler effect, or without any substantial help from the Doppler effect.

Historically, the Doppler effect, on the electromagnetic spectrum, played, as a matter of fact, a major and leading role, in the humiliating demise of the pessimistic and short-lived prophecy, which has been put forward, by Auguste Comte, concerning the stars, in his ***1842*** book, entitled: ***"The Positive Philosophy"***, and according to which: *"We can never learn their internal constitution, nor, in regard to some of them, how heat is absorbed by their atmosphere"* ***[Ref. #6]***.

There is, however, one essential and very important aspect of the Doppler effect, which has been widely neglected, and, rarely discussed, in the published literature, probably, due, for the most part, to its highly negative implications, for commonly held dogmas and cherished hypotheses, such as time dilation, asymmetric aging of twins in relative motion, time travel, . . . etc..

And this largely overlooked feature is the straightforward application of Doppler effect to durations of events, in particular, and time intervals, generally, as observed in all varieties of physical systems and celestial bodies, approaching, or receding from measuring observers ***[Ref. #1 & Ref. #2]***.

It's quite clear, upon close inspection of the Doppler formulas, within the framework of every physical theory, that the Doppler blue shift, as measured in the reference frame of the observer, leads, always, to apparent shortening of time intervals and durations of events, in all sorts of approaching systems. And at the same time, the Doppler red shift makes intervals of time and durations of events, in all kinds of receding systems, appear, necessarily, longer, as measured in the reference frame of the observer.

And more specifically, the exact amount of decrease and the exact amount of increase, in both cases, are directly proportional to the actual length of the time interval and the duration of the event, as well as directly proportional to the numerical value of the relative velocity between the system, in question, and the measuring observer.

For instance, if a clock is approaching, directly, an observer, with the velocity $\boldsymbol{v}$, then it must appear to be running faster than a clock, at rest in the reference frame of that observer, by an amount, directly, proportional to the numerical value of $\boldsymbol{v}$, and to the actual length of the time interval $\boldsymbol{t}$, during which the approaching clock is being observed.

And conversely, if a clock is receding, directly, from an observer, with the velocity ***v***, then it must appear to be running slower than a clock, at rest in the reference frame of that observer, by an amount, directly, proportional to the numerical value of ***v***, and to the actual length of the time interval ***t***, during which the receding clock is being observed.

And so, now, does this mean that time, itself, flows faster, throughout the approaching system, and flows slower, throughout the receding system, than what time does, throughout the system, in which the measuring observer is at rest?

The answer, of course, is no. The flow of time, in the approaching system, in the receding system, as well as in the stationary system, remains, always, identical and exactly the same.

In other words, the whole phenomenon of speeding-up clocks, in the case of approach, as well as the whole phenomenon of slowing-down clocks, in the case of recession, as seem from the reference frame of the observer, are illusory, and due, entirely, to the spatial and temporal compression of the electromagnetic signals, in the former case, and the spatial and temporal expansion of the electromagnetic signals, in the latter case.

And this seems, in all likelihood, to be the main reason why the Doppler effect, on time intervals and durations of events, has been, on the whole, so unpopular and underinvestigated, in the published literature, throughout the ***20^th^*** century, and throughout the first quarter of the present century, as well.

And that is because the Doppler effect, on intervals of time and durations of events, is first-order and much larger, by a wide margin, and much more significant than the cherished, though highly hypothetical, and second-order Doppler effect, which has been traditionally labeled as ***'time dilation'***, within the framework of Einstein's special relativity, and within the framework of the Larmor-Lorentz theory, as well.

In brief, the former effect is bound to undermine and undercut any theoretical justification for the latter effect. Since, on the face of it, after all, if the much larger, experimentally verifiable, and first-order Doppler effect, on moving clocks, is, really, illusory, then why, on Earth, shouldn't the much more minute, experimentally elusive, and second-order Doppler effect, on those same moving clocks, be deemed illusory, as well?

It should be noticed, however, that, even though it is, indeed, illusory, the first-order Doppler effect, on intervals of time and durations of events, is very crucial, and has to be taken into account, in all fields of ultraprecise measurements, especially, in the fields of astrometry, eclipse timing, axial rotation, and orbital motion; otherwise, it would, definitely, render the desired ultraprecision of the measurements, in these fields, partially or completely, illusory.

In the following investigation, the theoretical predictions of the Doppler effect, on durations of events, in particular, and on time intervals, in general, will be computed, discussed, and analyzed, in detail, within the framework of the classical wave theory, according to which the velocity of light is independent of the velocity of the light source; as well as within the framework of the elastic-impact emission theory, in accordance with which the velocity of light is dependent upon the velocity of the light source.

1. The Predictions of the Classical Wave Theory:

On the basis of the classical wave theory, within the framework of which the velocity of light is assumed to be independent of the velocity of the light source, the calculations of the Doppler effect, on time intervals and durations of events, are almost the same as the well-known calculations of the Doppler effect, on the wave periods of light; except the wave period ***T***, in the latter calculations, is replaced by the time interval ***t***, in the former calculations, in all cases of approach, as well as in all cases of recession.

For example, if a source of light is approaching, directly, at a velocity ***v***, an observer at rest, then, according to the classical wave theory, the observed wave period of its light ***T'***, as measured in the reference frame of that observer, is obtained, in accordance with the following formula:

$$T' = \frac{cT - vT}{c} = T\left(1 - \frac{v}{c}\right)$$

where ***T*** is the standard wave period, at the time of emission; and ***c*** is the speed of light.

And, in the same way, if a physical system is approaching, directly, with a velocity ***v***, an observer at rest, then the observed duration of any event or any time interval ***t***, in that approaching system, as measured in the stationary reference frame of the observer, can be calculated, through the use of the following analogous formula:

$$t' = \frac{ct - vt}{c} = t\left(1 - \frac{v}{c}\right)$$

where ***t*** is the actual time interval, at the time of emission; and ***c*** is the speed of light.

And the same procedure applies, in the case of direct recession.

For instance, if a source of light is receding, directly, with the velocity ***v***, from an observer at rest, then the observed wave period of its light ***T'***, as measured in the reference frame of the stationary observer, is computed, in accordance with the following formula:

$$T' = \frac{cT + vT}{c} = T\left(1 + \frac{v}{c}\right)$$

where ***T*** is the emitted wave period; and ***c*** is the speed of light.

And, correspondingly, if a physical system is receding, directly, with the velocity ***v***, from an observer at rest, then the observed duration of any event or any time interval ***t***, in that approaching system, as reckoned in the stationary reference frame of the observer, can be calculated, through the use of the following equivalent formula:

$$t' = \frac{ct + vt}{c} = t\left(1 + \frac{v}{c}\right)$$

where ***t*** is the actual time interval, at the time of emission; and ***c*** is the speed of light.

Within the framework of the classical wave theory, therefore, the Doppler effect, on time intervals and durations of events, is very similar, in many respects, to the Doppler effect, on waves periods of light.

In addition, as in the conventional treatment of Doppler effect, on wave periods of light, the computed predictions of Doppler effect, on time intervals and durations of events, on the basis of the aforementioned theory, produce, as well, numerical values, in all cases of moving light sources and observers at rest, which are, always, different from the numerical values, given by the predictions of the same theory, in all cases of moving observers and light sources at rest:

A. The Predictions of Temporal Doppler Effect, for Moving Light Sources:

The calculated predictions, on the basis of the classical wave theory, for moving light sources, are, always, symmetrical; i.e., for the same absolute numerical value of the velocity ***v***, the amount of decrease, in the time interval ***t***, in the case of approach, is equal to the amount of increase, in the same time interval ***t***, in the case of recession:

1. In the Special Case of Direct Approach:

As demonstrated, above, the Doppler effect, on durations of events and intervals of time, in the case of directly approaching systems, is calculated, through the use of this equation:

$$t' = \frac{ct - vt}{c} = t\left(1 - \frac{v}{c}\right)$$

where ***t'*** is the time interval, at the time of reception; ***t*** is the actual time interval, at the time of emission; ***v*** is the velocity of the approaching system; and ***c*** is the speed of light.

And it follows, therefore, that, in all cases of direct approach, the apparent time interval time ***t'***, at the time of reception, is, always, shorter, by a certain amount, than the actual time interval ***t***, at the time emission; i.e,

$$t' < t$$

for all numerical values of ***v***; except ***0***.

2. In the General Case of Approach at an Angle:

In the general case of systems approaching the stationary observer, at an angle equal to ***θ***, the Doppler effect, on durations of events and intervals of time, is obtained, by using the following equation:

$$t' = \frac{ct - vt\cos(\theta)}{c} = t\left(1 - \frac{v\cos(\theta)}{c}\right)$$

where:

$$0^o \leq \theta \leq 90^o$$

3. In the Special Case of Direct Recession:

As shown, earlier, the Doppler effect, on durations of events and intervals of time, in the case of directly receding systems, is calculated, through the use of this equation:

$$t' = \frac{ct + vt}{c} = t\left(1 + \frac{v}{c}\right)$$

where ***t'*** is the time interval, at the time of reception; ***t*** is the actual time interval, at the time of emission; ***v*** is the velocity of the receding system; and ***c*** is the speed of light.

And it follows, therefore, that, in all cases of direct recession, the time interval time ***t'***, at the time of reception, is, always, longer, by some amount, than the time interval ***t***, at the time emission; i.e.,

$$t' > t$$

for all numerical values of ***v***; except ***0***.

4. In the General Case of recession at an Angle:

In the general case of systems receding from the stationary observer, at an angle equal to ***θ***, the Doppler effect, on durations of events and intervals of time, is obtained, by using the following general equation:

$$t' = \frac{ct + v\left|\cos(\theta)\right|}{c} = t\left(1 + \frac{v\left|\cos(\theta)\right|}{c}\right)$$

where ***|cos(θ)|*** is the absolute cosine value, for each value of ***θ***, within this numerical range:

$$90^o \leq \theta \leq 180^o$$

B. The Predictions of Temporal Doppler Effect, for Moving Observers:

The computed predictions, in accordance with the classical wave theory, for moving observers, are, always, asymmetrical; i.e., for the same absolute numerical value of the velocity ***v***, the amount of decrease, in the time interval ***t***, in the case of approach, is unequal to the amount of increase, in the same time interval ***t***, in the case of recession:

1. In the Special Case of Direct Approach:

In accordance with the classical wave theory, the Doppler effect, on durations of events and intervals of time, in the special case of observers, directly, approaching systems at rest, is calculated, through the use of this formula:

$$t' = \frac{ct - vt'}{c} = t\left(1 - \frac{v}{c+v}\right)$$

where ***t'*** is the time interval, at the time of reception; ***t*** is the actual time interval, at the time of emission; ***v*** is the velocity of the approaching observer; and ***c*** is the speed of light.

And it follows, therefore, that, in all cases of direct approach, the time interval time ***t'***, at the time of reception, is, always, shorter, by a significant amount, than the time interval ***t***, at the time emission; i.e.,

$$t' < t$$

for all numerical values of *v*; except *0*.

2. In the General Case of Approach at an Angle:

In the general case of observers approaching stationary systems, at an angle equal to θ, the Doppler effect, on durations of events and intervals of time, is calculated, by using the following equation:

$$t' = \frac{ct - vt'\cos(\theta)}{c} = t\left(1 - \frac{v\cos(\theta)}{c + v\cos(\theta)}\right)$$

where:

$$0^o \leq \theta \leq 90^o$$

3. In the Special Case of Direct Recession:

Within the framework of the classical wave theory, the Doppler effect, on durations of events and intervals of time, in the case of directly receding observers, from systems at rest, is calculated, through the use of this equation:

$$t' = \frac{ct + vt'}{c} = t\left(1 + \frac{v}{c - v}\right)$$

where t' is the time interval, at the time of reception; t is the actual time interval, at the time of emission; v is the velocity of the receding observer; and c is the speed of light.

And it follows, therefore, that, in all cases of direct recession, the time interval time t', at the time of reception, is, always, longer, by a measurable amount, than the time interval t, at the time emission; i.e.,

$$t' > t$$

for all numerical values of *v*; except *0*.

4. In the General Case of recession at an Angle:

In the general case of observers receding from stationary systems, at an angle equal to ***θ***, the Doppler effect, on durations of events and intervals of time, is obtained, by using the following equation:

$$t' = \frac{ct + vt'\left|\cos(\theta)\right|}{c} = t\left(1 + \frac{v\left|\cos(\theta)\right|}{c - v\left|\cos(\theta)\right|}\right)$$

where ***|cos(θ)|*** stands for the absolute cosine value, for any value of ***θ***, within the following range:

$$90^o \le \theta \le 180^o$$

It should be pointed out, in the current context, that, within the framework of the classical wave theory, for the same value of relative velocity, the computed Doppler effect, on time intervals and durations of events, in all cases of approaching observers, is, always, less, by an amount ***Δt'***, than the computed Doppler effect, on time intervals and durations of events, in all cases of approaching systems; i.e.,

$$\Delta t' = t'_S - t'_O = t\left(\frac{\left(\frac{v\cos(\theta)}{c}\right)^2}{1 + \frac{v\cos(\theta)}{c}}\right)$$

where ***t'$_S$*** is the duration of an event, in an approaching system, as measured by a stationary observer; and ***t'$_O$*** is the duration of the same event, in a stationary system, as measured by an approaching observer.

And, conversely, the computed Doppler effect, on time intervals and durations of events, in the case of receding observers, is, always, greater, by an amount equal to ***Δt'***, than the computed Doppler effect, on time intervals and durations of events, in the case of receding systems; i.e.,

$$\Delta t' = t'_O - t'_S = t\left(\frac{\left(\frac{v\cos(\theta)}{c}\right)^2}{1 - \frac{v\cos(\theta)}{c}}\right)$$

where ***t'$_O$*** is the duration of an event, in a stationary system, as measured by a receding observer; and

t'_S is the duration of the same event, in a receding system, as measured by a stationary observer.

2. The Predictions of the Elastic-Impact Emission Theory:

In accordance with the elastic-impact emission theory, within the framework of which the velocity of light is assumed to be dependent on the velocity of the light source, the calculations of the Doppler effect, on time intervals and durations of events, are, nearly, the same as the well-known calculations of the Doppler effect, on the wave periods of light, on the basis of the same theory; except the wave period ***T***, in the latter calculations, is replaced by the time interval ***t***, in the former calculations, in all cases of approach, as well as in all cases of recession.

For instance, if a source of light is approaching, directly, at a velocity ***v***, an observer at rest, then the observed wave period of its light ***T'***, as measured in the stationary reference frame of that observer, is obtained, in accordance with the following formula:

$$T' = \frac{(c+v)T - vT}{c+v} = T\left(1 - \frac{v}{c+v}\right)$$

where ***T*** is the standard wave period, at the time emission; and ***c*** is the muzzle speed of light.

And, in the same manner, if a physical system is approaching, directly, with a velocity ***v***, an observer at rest, then the observed duration of an event or any time interval ***t'***, in that approaching system, as measured in the stationary reference frame of the observer, can be calculated, through the use of the following formula:

$$t' = \frac{(c+v)t - vt}{c+v} = t\left(1 - \frac{v}{c+v}\right)$$

where ***t*** is the actual time interval, at the time of emission; and ***c*** is the muzzle speed of light.

And the same procedure applies, in the case of direct recession.

For example, if a source of light is receding, directly, at a velocity ***v***, from an observer at rest, then, on the basis of the elastic-impact emission theory, the observed wave period of its light ***T'***, as measured in the reference frame of the stationary observer, is computed, in accordance with the following formula:

$$T' = \frac{(c-v)T + vT}{c-v} = T\left(1 + \frac{v}{c-v}\right)$$

where ***T*** is the emitted wave period; and ***c*** is the muzzle speed of light.

And, likewise, if a physical system is receding, directly, with a velocity ***v***, from an observer at rest, then the observed duration of any event or any time interval ***t'***, in that receding system, as measured in the stationary reference frame of the observer, can be calculated, through the use of the following formula:

$$t' = \frac{(c-v)t + vt}{c-v} = t\left(1 + \frac{v}{c-v}\right)$$

where ***t*** is the actual time interval, at the time of emission; and ***c*** is the muzzle speed of light.

According to the elastic-impact emission theory, therefore, the Doppler effect, on time intervals and durations of events, is very similar, in many respects, to the Doppler effect, on waves periods of light.

And furthermore, as in the well-known treatment of Doppler effect, on wave periods of light, the computed predictions of Doppler effect, on time intervals and durations of events, on the basis of the theory, under discussion, produce, exactly, the same numerical values, for the same numerical value of the relative velocity ***v***, in all cases of moving light sources, as well as, in all cases of moving observers; i.e., for the same absolute numerical value of the velocity ***v***, the amount of decrease, in the time interval ***t***, in the case of an approaching light source, is equal to the amount of decrease, in the same time interval ***t***, in the case of an approaching observer; and, at the same time, the amount of increase, in the time interval ***t***, in the case of a receding light source, is equal to the amount of increase, in the same time interval ***t***, in the case of a receding observer

A. The Predictions of Temporal Doppler Effect, for Moving Light Sources:

The calculated predictions, on the basis of the the elastic-impact emission theory, for moving light sources, are, always, asymmetrical; i.e., for the same absolute numerical value of the velocity ***v***, the amount of decrease, in the time interval ***t***, in the case of approach, is unequal to the amount of increase, in the same time interval ***t***, in the case of recession.

1. In the Special Case of Direct Approach:

As demonstrated, above, the Doppler effect, on durations of events and intervals of time, in the case of directly approaching systems, is calculated, through the use of this equation:

$$t' = \frac{(c+v)t - vt}{c+v} = t\left(1 - \frac{v}{c+v}\right)$$

where ***t'*** is the observed time interval, at the time of reception; ***t*** is the actual time interval, at the time of emission; ***v*** is the velocity of the approaching system; and ***c*** is the muzzle speed of light.

And it follows, accordingly, that, in all cases of direct approach, the time interval time ***t'***, at the time of reception, is, always, shorter, by a significant amount, than the time interval ***t***, at the time emission; i.e,

$$t' < t$$

for all numerical values of ***v***; except ***0***.

2. In the General Case of Approach at an Angle:

In the general case of systems approaching stationary observers, at an angle equal to ***θ***, the Doppler effect, on durations of events and intervals of time, is obtained, by using the following general equation:

$$t' = \frac{(c+v\cos(\theta))t - v\cos(\theta)t}{c+v\cos(\theta)} = t\left(1 - \frac{v\cos(\theta)}{c+v\cos(\theta)}\right)$$

where:

$$0^o \le \theta \le 90^o$$

3. In the Special Case of Direct Recession:

As mentioned, earlier, the Doppler effect, on durations of events and intervals of time, in the special case of directly receding systems, is calculated, through the use of this equation:

$$t' = \frac{(c-v)t + vt}{c-v} = t\left(1 + \frac{v}{c-v}\right)$$

where ***t'*** is the observed time interval, at the time of reception; ***t*** is the actual time interval, at the time of emission; ***v*** is the velocity of the receding system; and ***c*** is the muzzle speed of light.

And it follows, therefore, that, in all cases of direct recession, the time interval time ***t'***, at the time of reception, is, always, longer, by a certain amount, than the time interval ***t***, at the time emission; i.e.,

$$t' > t$$

for all numerical values of ***v***; except ***0***.

4. In the General Case of recession at an Angle:

In the general case of systems receding from stationary observers, at an angle equal to ***θ***, the Doppler effect, on durations of events and intervals of time, is obtained, by using the following equation:

$$t' = \frac{\left(c - v\left|\cos(\theta)\right|\right)t + v\left|\cos(\theta)\right|t}{c - v\left|\cos(\theta)\right|} = t\left(1 + \frac{v\left|\cos(\theta)\right|}{c - v\left|\cos(\theta)\right|}\right)$$

where ***|cos(θ)|*** is the absolute cosine value, for each value of ***θ***, within this numerical range:

$$90^o \leq \theta \leq 180^o$$

B. The Predictions of Temporal Doppler Effect, for Moving Observers:

The computed predictions, on the basis of the the elastic-impact emission theory, for moving observers, are, always, asymmetrical; i.e., for the same absolute numerical value of the velocity ***v***, the amount of decrease, in the time interval ***t***, in the case of approach, is unequal to the amount of increase, in the same time interval ***t***, in the case of recession.

1. In the Special Case of Direct Approach:

In accordance with the elastic-impact emission theory, the Doppler effect, on durations of events and intervals of time, in the special case of observers, directly, approaching systems at rest, is calculated, through the use of this formula:

$$t' = \frac{ct - vt'}{c} = t\left(1 - \frac{v}{c+v}\right)$$

where **t'** is the time interval, at the time of reception; **t** is the actual time interval, at the time of emission; **v** is the velocity of the approaching observer; and **c** is the muzzle speed of light.

And it follows, as a result, that, in all cases of direct approach, the time interval time **t'**, at the time of reception, is, always, shorter, by a certain amount, than the time interval **t**, at the time emission; i.e.,

$$t' < t$$

for all numerical values of **v**; except ***0***.

2. In the General Case of Approach at an Angle:

In the general case of observers approaching stationary systems, at an angle equal to ***θ***, the Doppler effect, on durations of events and intervals of time, **t'**, is calculated, by using this general equation:

$$t' = \frac{ct - vt'\cos(\theta)}{c} = t\left(1 - \frac{v\cos(\theta)}{c + v\cos(\theta)}\right)$$

where:

$$0^o \le \theta \le 90^o$$

3. In the Special Case of Direct Recession:

Within the framework of the elastic-impact emission theory, the Doppler effect, on durations of events and intervals of time, in the special case of directly receding observers, from systems at rest, is calculated, through the use of this equation:

$$t' = \frac{ct + vt'}{c} = t\left(1 + \frac{v}{c-v}\right)$$

where **t'** is the time interval, at the time of reception; **t** is the actual time interval, at the time of emission; **v** is the velocity of the receding observer; and **c** is the muzzle speed of light.

And it follows, as a consequence, that, within the framework of the elastic-impact emission theory, in all cases of direct recession, the time interval time ***t'***, at the time of reception, is, always, longer, by a certain amount, than the time interval ***t***, at the time emission; i.e.,

$$t' > t$$

for all numerical values of ***v***; except ***0***.

4. In the General Case of recession at an Angle:

In the general case of observers receding from stationary systems, at an angle equal to ***θ***, the Doppler effect, on durations of events and intervals of time, is obtained, by using the following general equation:

$$t' = \frac{ct + vt'\left|\cos(\theta)\right|}{c} = t\left(1 + \frac{v\left|\cos(\theta)\right|}{c - v\left|\cos(\theta)\right|}\right)$$

where ***|cos(θ)|*** denotes the absolute cosine value, for any value of ***θ***, within this numerical range:

$$90^o \leq \theta \leq 180^o$$

It follows, therefore, that, within the framework of the elastic-impact emission theory, for the same numerical value for the relative velocity ***v***, the computed Doppler effect, on time intervals and durations of events, in all cases of approaching observers, is, always, the same as the computed Doppler effect, on time intervals and durations of events, in all cases of approaching systems.

And, likewise, for the same numerical value of the relative velocity ***v***, the computed Doppler effect, on time intervals and durations of events, in all cases of receding observers, is, always, the same as the computed Doppler effect, on time intervals and durations of events, in all cases of receding systems.

3. Concluding Remarks:

As has been demonstrated, earlier, in this discussion, the numerical values of the Doppler effect, on durations of events, in particular, and intervals of time, generally, as computed, in accordance with the classical wave theory, as well as in accordance with the elastic-impact emission theory, are, directly, proportional to the numerical values of the velocity ***v***, and, at the same time, directly, proportional to the numerical values of the duration of the event or the time interval, ***t***, under investigation.

In addition, the classical wave theory and the elastic-impact emission theory lead, necessarily, to the same computed predictions of the Doppler effect, on time intervals and durations of events, in all cases, in which the physical systems, being observed, are at rest; while, the observers, carrying out the Doppler measurements, are in motion.

Nevertheless; the numerical values of the Doppler effect, on time intervals and durations of events, as calculated on the basis of the elastic-impact emission theory, are, always, less than the numerical values of the Doppler effect, on the same time intervals and durations of events, as calculated on the basis of the classical wave theory, in all cases of approaching systems and observers at rest, by an exact amount equal to $\boldsymbol{\Delta t'}$:

$$\Delta t' = \frac{\left(\frac{v\cos(\theta)}{c}\right)^2}{\left(1+\frac{v\cos(\theta)}{c}\right)}$$

where $\boldsymbol{\theta}$ is the angle, at which the physical system is approaching the stationary observer.

While, at the same time, the numerical values of the Doppler effect, on time intervals and durations of events, as calculated on the basis of the classical wave theory, are, always, less than the numerical values of the Doppler effect, on the same time intervals and durations of events, as calculated on the basis of the elastic-impact emission theory, in all cases of receding systems and observers at rest, by an exact amount equal to $\boldsymbol{\Delta t'}$:

$$\Delta t' = \frac{\left(\frac{v\cos(\theta)}{c}\right)^2}{\left(1-\frac{v\cos(\theta)}{c}\right)}$$

where $\boldsymbol{v}$ is the velocity of the receding system.

Clearly, the computed predictions, on the basis of the two theories, under discussion, have a broad range of applications, and apply, in principle, to the duration of every event and to every time interval, within any physical system in motion, relative to any observer,

A representative sample of those potentially important applications of the Doppler effect, to durations of events and intervals of time, in selected systems, is computed and, briefly, discussed, in the following concluding remarks:

I. The Doppler Effect, on Moving Clocks:

If a clock approaches, directly, at ***[30 km/s]***, an observer, at rest, then, according to the classical wave theory, for an observational duration of ***[100 hours]***, the approaching clock would appear, as compared to an identical clock in the stationary reference frame of that observer, to run faster, by an amount equal to about ***[36.0249 seconds]***. While, according to the elastic-impact emission theory, the same approaching clock would appear to run faster than the stationary clock, by an amount equal to about ***[36.0213 seconds]***.

And inversely, of course, if a clock recedes, directly, at ***[30 km/s]***, from an observer, at rest, then, according to the classical wave theory, for an observational duration of ***[100 hours]***, the receding clock would appear, in comparison to an identical clock in the stationary reference frame of that observer, to run slower, by an amount equal to about ***[36.0249 seconds]***. While, according to the elastic-impact emission theory, the same receding clock would appear to run slower than the stationary clock, by an amount equal to about ***[36.0285 seconds]***.

It should be pointed out, within this context, that the Doppler effect, on the aforementioned clocks, in both cases, is accumulative and, directly, proportional to the length of the time interval, between the start of the observation and the end of the same observation, in each case.

II. The Doppler Effect, on the Observed Rotation Period of Jupiter:

If the earth approaches, directly, at ***[29.78 km/s]***, the planet Jupiter, then, according to the classical wave theory, the actual rotation period of Jupiter – ***[9.9258 hours]*** – would appear, as measured in the moving reference frame of the earth, to be reduced, by an amount equal to about ***[3.5492 seconds]***. And likewise, according to the elastic-impact emission theory, the same rotation period would appear to be reduced, by an amount equal to about ***[3.5492 seconds]***.

And, conversely, however, if the earth recedes, directly, at ***[29.78 km/s]***, from the planet Jupiter, then, according to the classical wave theory, the rotation period of Jupiter – ***[9.9258 hours]*** – would appear, as measured in the moving reference frame of the earth, to be increased, by an mount equal to about ***[3.5499 seconds]***. And similarly, according to the elastic-impact emission theory, the same rotation period would appear to be increased, by an amount equal to about ***[3.5499 seconds]***.

III. The Doppler Effect, on the Durations of Solar Flares:

If the solar materials of a **B**-class flare, with a duration of ***[10 minutes]***, are moving, directly, towards an observer on Earth, at ***[30 km/s]***, then the duration of that solar flare would appear, as measured in the reference frame of the earth, to be reduced, by an amount equal to about ***[0.0600415 seconds]***, in accordance with the classical wave theory. While the same duration of the same solar flare would appear to be reduced, by an amount equal to about ***[0.0600355 seconds]***, according to the elastic-impact emission theory.

And, in the same manner, if the solar materials of a **C**-class flare, with a duration of ***[14 minutes]***, are moving, directly, towards an observer on Earth, at ***[30 km/s]***, then the duration of that solar flare would appear, as measured in the reference frame of the earth, to be reduced, by an amount equal to about ***[0.0840582 seconds]***, in accordance with the classical wave theory. While, at the same time, the same duration of the same solar flare would appear to be reduced, by an amount equal to about ***[0.0840497 seconds]***, according to the elastic-impact emission theory.

IV. The Doppler Effect, on Algol's Eclipses:

If the earth is moving, directly, at ***[29.78 km/s]***, towards the eclipsing binary stellar system of Algol, (***Beta Persei***), then, according to the classical wave theory, Algol's eclipse period of ***[2.867328 days]***, as well as Algol's eclipse duration of ***[10 hours]*** would both appear, as measured in the moving reference frame of the earth, to be reduced, by amounts equal to about ***[24.609 seconds]***, and ***[3.57607 seconds]***, respectively. And likewise, according to the elastic-impact emission theory, the same eclipse period and the same eclipse duration would appear to be reduced, by amounts equal to about ***[24.609 seconds]***, and ***[3.57607 seconds]***, respectively.

And inversely, however, if the earth recedes, directly, at ***[29.78 km/s]***, from the binary star system of Algol, (***Beta Persei***), then, according to the classical wave theory, Algol's eclipse period of ***[2.867328 days]***, as well as Algol's eclipse duration of ***[10 hours]*** would both appear, as measured in the moving reference frame of the earth, to be increased, by amounts equal to about ***[24.609 seconds]***, and ***[3.57607 seconds]***, respectively. And similarly, according to the elastic-impact emission theory, the same eclipse period and the same eclipse duration would appear, to observers on Earth, to be increased, by amounts equal to about ***[24.609 seconds]***, and ***[3.57607 seconds]***, respectively.

V. The Doppler Effect, on Voyager 1 Telecommunications:

If Voyager ***1 [Ref. #14]*** is receding, directly, at ***[17 km/s]***, from the ground stations, when the earth is moving with ***[29.78 km/s]***, at right angles, relative to it, then, according to the classical wave theory, a command sequence with a duration of ***[10 minutes]***, would appear, as measured in the moving reference frame of Voyager ***1***, to be increased, by an amount equal to about ***[0.0340235 seconds]***. And similarly, according to the elastic-impact emission theory, the same duration would appear to be increased, by an amount equal to about ***[0.0340235 seconds]***, as well.

However, if Voyager ***1*** is receding, directly, at ***[17 km/s]***, from the ground stations, when the earth is receding, directly, from it, with ***[29.78 km/s]***, then, according to the classical wave theory, a command sequence with a duration of ***[10 minutes]***, would appear, as measured in the moving reference frame of Voyager ***1***, to be increased, by an amount equal to about ***[0.0936247 seconds]***. While, according to the elastic-impact emission theory, the same duration would appear to be increased, by an amount equal to about ***[0.0936307 seconds]***.

And also, if Voyager ***1*** is receding, directly, at ***[17 km/s]***, from ground stations, when the earth is approaching it, directly, at ***[29.78 km/s]***, then, according to the classical wave theory, a command sequence with a duration of ***[10 minutes]***, would appear, as measured in the moving reference frame of Voyager ***1***, to be decreased, by an amount equal to about ***[0.0255777 seconds]***. While, at the same time, according to the elastic-impact emission theory, the same duration would appear to be decreased, by an amount equal to about ***[0.0255718 seconds]***.

In conclusion, therefore, the Doppler effect, on intervals of time and durations of events, is a significant and very import first-order effect, which has to be duly noted and taken into consideration, at all times, and, explicitly, specified, and included in the data reduction procedures, in all fields, in which high precision is required; especially, in astrometry, planetary ephemerides, and space communications and navigation programs.

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