Residual annual and diurnal periodicities of the Pioneer 10 acceleration term resolved in absolute CMB space

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Abstract

Applying the general, classical Doppler formula (CMB-Doppler formula) of first order for two-way radio Doppler signals in the fundamental rest frame of the isotropic cosmic microwave background radiation (CMB) between earthbound Deep Space Network stations (DSN), and the Pioneer 10 space probe (P 10) resolves the phenomenon of the residual, so far unexplained annual and diurnal signal variations on top of the constant acceleration term *Anderson & Laing & Lau & et al. (2002), Anderson & Campbell & Ekelund & et al. (2008).* The anomalous annual and diurnal variations of the acceleration term vanish, if instead of the relativistic Standard-Doppler formula (SRT-Doppler formula) of first and second order the CMB-Doppler formula is used. That formula contains the absolute velocities $\mathbf{u}_{\mathrm{e}}$ of Earth, and $\mathbf{u}_{\mathrm{pio}}$ of P 10, derived from the absolute velocity $\mathbf{u}_{\mathrm{sun}}$ of the solar system barycenter in the CMB, with $u_{sun} = 369.0 \pm 0.9$ km/s, and the relative revolution velocity $\mathbf{v}_{\mathrm{e}}$ of Earth, and the relative velocity $\mathbf{v}_{\mathrm{pio}}$ of P 10 in the heliocentric frame from January 1987 until December 1996. The flyby radio Doppler and ranging data anomalies can be resolved as well by using the CMB-Doppler formula with the absolute, asymptotic velocities of the inbound and outbound maneuver flights, which have usually slightly different magnitudes, inducing the so far unexplained frequency shift, and the unexplained difference in the ranging data.

1 Introduction

For more than twenty years the conundrum of the Pioneer 10 (P 10), and Pioneer 11 P(11) acceleration anomalies induced quite many publications.
In two papers *Rievers & Lämmerzahl (2011), Francesco & Bertolami & Gil et al. (2011)*, it is shown that thermal radiation pressure is most likely the final solution to that anomalies.

Only in a few papers, the residual annual and diurnal variations (sinusoid) of the Pioneer 10 Doppler signals, in addition to the constant anomalous acceleration term, are reported as an unexplained phenomenon *Anderson & Laing & Lau & et al. (2002).*

I argue that between any two bodies, moving in the frame of the solar system, or anywhere in the rest-frame of the isotropic cosmic microwave background radiation (CMB), the classical, general Doppler formula of first order for has to be applied in case of two-way signals, while for one-way signals the general Doppler formula of first order and second order (time dilatation) has to be used. The time dilatation effect is considered to be a function of absolute velocities u in the CMB, due to two fundamental properties of photons *Pabisch (1999).*

Despite the popularity of the acceleration anomaly of P 10 and P 11, only a very few authors made attempts to resolve the residual annual and diurnal variation of the constant (former anomalous) acceleration term. The variations are obviously caused by the orbital motion of Earth and its rotation, since the Doppler residuals are distributed about zero Doppler velocity with a systematic variation of about 3.0 mm/s on a scale of about 3 months *Anderson et al. (2002)*, *Ghosh (2007)*, *Olsen (2007).* The revolution of Earth causes a significant variation of the magnitude of $\mathbf{u}_e$, since the absolute velocity vector $\mathbf{u}_{\mathrm{sun}}$ inclines the ecliptic plane with a rather small declination of $\beta = -10.60°$, an important fact for the detection of anomalies.

In one of the attempts to understand this residual annual periodic term with an amplitude of $1.6 \cdot 10^{-8}\mathrm{cms}^{-2}$ (average between 1987 and 1996, if approximated by a simple sine wave), *Anderson & et al. (2002)* suggest that the cause is most likely an error in the navigation programs determination of the direction of the space probes orbital inclination to the ecliptic plane. The residual diurnal term is explained similarly, as a misalignment of the orbits of P 10 to the equatorial plane *Anderson & Campbell & Ekelund & et al. (2008)*.

Due to the detection of the CMB *Penzias & Wilson (1965)*, and the already very exact data from the COBE, WMAP and recently Planck satellites,
the CMB dipole, as the largest anisotropy in the CMB, exhibits the absolute velocity of Earth, varying approximately between $u_{\mathrm{e}} = 340$ km s^{-1} and $u_{\mathrm{e}} = 399$ km s^{-1} during the yearly revolution. From that the absolute velocity of the solar system barycenter, $u_{sun} = 369.0 \pm 0.9$ km s^{-1} *Hinshaw & Weiland & Hill et al. (2008)* in direction of constellation Becher, follows (approximately right ascension $\alpha = 11h$ 20 and declination $\delta = -7.20°$). The latest dipole data from the Planck mission deviate only marginally from the WMAP data, hence we refer to the calculation of our paper *Pabisch & Kern (2010)*.

2 General, classical CMB-Doppler effect and absolute time dilatation effect in the rest frame of the CMB

We start with the above mentioned theoretical assumption that calculating the frequencies of one way or two way Doppler radio signals between any bodies in the CMB, especially the motions of Earth and P 10, moving at absolute velocities $\mathbf{u}_{\mathrm{e}}$, and $\mathbf{u}_{\mathrm{pio}}$, the absolute Doppler formulas of first order and second order (time dilatation) in the CMB have to be applied, instead of the relativistic Doppler formula of first and second order, using symmetric relative velocities.

The absolute velocity $\mathbf{u}_{\mathrm{pio}}$ of a space probe like P 10 in the CMB rest frame is obtained by addition of the vectors of its relative velocity $\mathbf{v}_{\mathrm{pio}}$ in the solar system, and the absolute velocity $\mathbf{u}_{\mathrm{s}}$ of the solar system barycenter in the CMB. The absolute velocity $\mathbf{u}_{\mathrm{e}}$ of Earth we derive from its relative velocity $\mathbf{v}_{\mathrm{e}}$ in the heliocentric frame, and the absolute velocity $\mathbf{u}_{\mathrm{s}}$ of the solar system barycenter in the CMB, see Fig.11.

The absolute velocity $\mathbf{u}_{\mathrm{dsn}}$ of the Deep Space Network (DSN) station, obtained by adding its relative, rotational velocity in the geocentric frame to the absolute velocity $\mathbf{u}_{e}$ of Earth, has to be applied calculating the residual diurnal term.

The CMB-Doppler-formula of first and second order for a one-way up link Doppler signal from an earthbound DSN station to P 10 is given by

$$f'_{\mathrm{up}} = f_{\mathrm{e}} \cdot \frac{c + u_{\mathrm{pio}} \cdot \cos\alpha_2}{c - u_{\mathrm{e}} \cdot \cos\alpha_1} \cdot \frac{\sqrt{1-(u_{\mathrm{e}}/c)^2}}{\sqrt{1-(u_{\mathrm{pio}}/c)^2}}, \qquad (1)$$

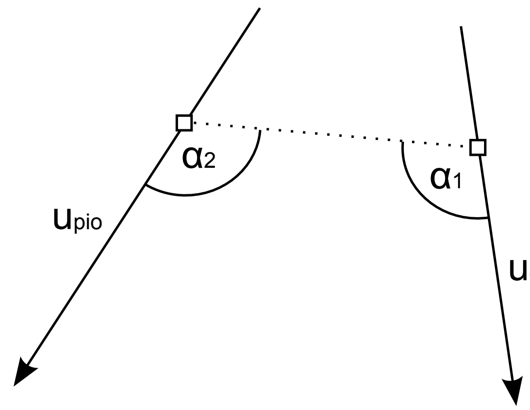

Fig. 1 Schematic visualization of the absolute velocity vectors of Earth and P 10, and the up link radio signal trajectory with the emission angle α_1 and the absorption angle α_2 in the ecliptic plane as seen from the ecliptic north pole. The dotted signal trajectory is in direction of the relative motion of P 10 towards Aldebaran.

with f_{e} denotes the sender eigen-frequency of the DSN station,
f'_{up} the frequency of the up link signal, as measured by P 10,
c the constant velocity of light in the CMB,
α_1 the angle between the vector $\mathbf{u}_{\mathrm{e}}$ and the emitted up link signal,
α_2 the angle between the vector $\mathbf{u}_{\mathrm{pio}}$ and the received up link signal, as can be seen in Fig.1, while
$\sqrt{1-(u_{\mathrm{e}}/c)^2}$ and $\sqrt{1-(u_{\mathrm{pio}}/c)^2}$
are functions of $u = [0, c[$ in the CMB. Hence, eigentime or eigen-frequency is seen as not universally invariant, but variant as a function of absolute velocities u in the CMB, derived from two fundamental properties of photons *Pabisch (1999)*.

The CMB-Doppler formula of first and second order for an one-way Doppler downlink signal from P 10 to a DSN station is given by

$$f'_{\mathrm{down}} = f_{\mathrm{pio}} \cdot \frac{c + u_{\mathrm{e}} \cdot \cos\alpha_1}{c - u_{\mathrm{pio}} \cdot \cos\alpha_2} \cdot \frac{\sqrt{1-(u_{\mathrm{pio}}/c)^2}}{\sqrt{1-(u_{\mathrm{e}}/c)^2}}, \qquad (2)$$

with f_{pio} denotes the sender eigen-frequency of P 10,
f'_{down} the frequency of the down link signal as measured by a DSN station,
c the constant velocity of light in the CMB,
α_2 the angle between the vector $\mathbf{u}_{\mathrm{pio}}$ and the emitted down link signal,
α_1 the angle between the vector $\mathbf{u}_{\mathrm{e}}$ and the received down link signal. We also use α_2 and α_1 as down link emission- and absorption angles in formula (2), for the sake of simplicity, despite the fact that they differ very slightly from the up link angles, due to the motion of Earth during the signal up and down propagation time.

Thus, the CMB-Doppler formula of first order for a two-way Doppler signal from a DSN station to P 10 and back is

$$f''_{\text{CMB}} = f_{\text{e}} \cdot \frac{c + u_{\text{pio}} \cdot \cos\alpha_2}{c - u_{\text{e}} \cdot \cos\alpha_1} \frac{c + u_{\text{e}} \cdot \cos\alpha_1}{c - u_{\text{pio}} \cdot \cos\alpha_2}, \quad (3)$$

with f''_{CMB} denotes the frequency of the two-way down link signal, as measured by the DSN station, while the standard relativistic formula (SRT-formula) is

$$f''_{\text{SRT}} = f_{\text{e}} \cdot \left(1 - \frac{v}{c}\cos\eta\right)^2 \left(\frac{1}{\sqrt{1-(v/c)^2}}\right)^2, \quad (4)$$

or more common

$$f''_{\text{SRT}} = f_{\text{e}} \cdot \frac{c + v\cos\eta}{c - v\cos\eta}. \quad (5)$$

Different to standard theory, the absolute time dilatation effect in the CMB is canceled, if two-way signals are used, since the effect is asymmetric. Only with the use of one-way Doppler down signals the absolute time delay effect of P 10, according to formula (2), would have been measurable at a DSN station.

3 Explanation of the P 10 residual annual and diurnal sinusoid of the constant acceleration term

The residual annual and diurnal terms vanish, if instead of the SRT-Doppler formula of first and second order the CMB-Doppler formula of first order is used (formula (3)). The residual annual effect is approximated as follows. Between 1987 January 1 and 1996 December 31, the relative, heliocentric velocity of P 10, and the absolute velocity of P 10 in the CMB are considered as constant, and the revolution trajectory of Earth as circular.

With $\cos\eta = \frac{\boldsymbol{v}_{\text{rel}} \cdot \boldsymbol{r}}{|\boldsymbol{v}_{\text{rel}}||\boldsymbol{r}|}$ we obtain

$$\frac{c|\boldsymbol{r}| + \boldsymbol{u}_{\text{pio}} \cdot \boldsymbol{r}}{c|\boldsymbol{r}| - \boldsymbol{u}_{\text{e}} \cdot \boldsymbol{r}} \frac{c|\boldsymbol{r}| + \boldsymbol{u}_{\text{e}} \cdot \boldsymbol{r}}{c|\boldsymbol{r}| - \boldsymbol{u}_{\text{pio}} \cdot \boldsymbol{r}} = \frac{c|\boldsymbol{v}_{\text{rel}}||\boldsymbol{r}| + v_{\text{app}} \boldsymbol{v}_{\text{rel}} \cdot \boldsymbol{r}}{c|\boldsymbol{v}_{\text{rel}}||\boldsymbol{r}| - v_{\text{app}} \boldsymbol{v}_{\text{rel}} \cdot \boldsymbol{r}}, \quad (6)$$

with v_{app} as apparent velocity, and

$$\boldsymbol{r} = \boldsymbol{r}_{\text{pio}} + \boldsymbol{v}_{\text{pio}}\ t - r_{\text{e}} \begin{pmatrix} \cos(\omega t + \varphi) \\ \sin(\omega t + \varphi) \\ 0 \end{pmatrix}, \quad (7)$$

$$\boldsymbol{v}_{\text{e}} = \omega\ r_{\text{e}} \begin{pmatrix} -\sin(\omega t + \varphi) \\ \cos(\omega t + \varphi) \\ 0 \end{pmatrix}, \quad (8)$$

Table 1 Parameters as of 1987 January 1

$\boldsymbol{v}_{\text{pio}}$	$(1.557, 13.022, 0.672)$	km s^{-1}
$\boldsymbol{r}_{\text{pio}}$	$(1.946 \cdot 10^9, 5.651 \cdot 10^9, 3.24 \cdot 10^8)$	km
r_{e}	$1.5 \cdot 10^8$	km
φ	1.752	rad
ω	$2 \cdot 10^{-7}$	rad s^{-1}

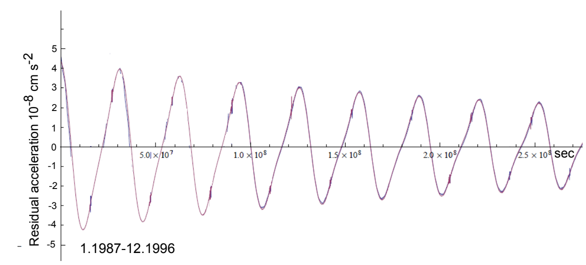

Fig. 2 The residual annual sinusoid of the P 10 constant acceleration term

with $\boldsymbol{u}_{\text{pio}} = \boldsymbol{u}_{\text{sun}} + \boldsymbol{v}_{\text{pio}}$, and $\boldsymbol{u}_{\text{e}} = \boldsymbol{u}_{\text{sun}} + \boldsymbol{v}_{\text{e}}$. The used parameters are listed in Table 1.

Considering the first derivative v_{app} as the apparent velocity

$$\frac{d}{dt}\left(v_{\text{app}} - |\boldsymbol{v}_{\text{pio}} - \boldsymbol{v}_{\text{e}}|\right), \quad (9)$$

we obtain the approximate sinusoid as plotted in Fig. 2. The first maximum of the amplitude with a magnitude of $4 \cdot 10^{-8}$cm s^{-2} we find on 1987 December 24.

Table 2 Values of extremata

	Date	Magnitude
first maximum	1987 Dec 24	$4 \cdot 10^{-8}$cm s^{-2}
first minimum	1987 Jun 27	$4.23 \cdot 10^{-8}$cm s^{-2}
last maximum	1996 Dec 26	$2 \cdot 10^{-8}$cm s^{-2}
last minimum	1996 Jun 28	$2 \cdot 10^{-8}$cm s^{-2}

The further maxima follow yearly at the same date, and a significant decrease of the maxima and minima of the amplitudes until 1996 can be seen.
For the diurnal term the so far observed magnitude is approximately $2.8 \cdot 10^{-10}$cm s^{-2}, and has an annual term maximum on 1996 December 17 *Anderson et al. (2002)*. Our calculations for 1996 show a yearly maximum on 1996 December 26, and a magnitude of $2 \cdot 10^{-10}$cm s^{-2}.

The thus only apparent residual annual term, which is derived from our theoretical method, matches closely the empirically derived formula. For the diurnal term the observed magnitude, and an annual term maximum on 1996 December 17, also fit our theoretical prediction.

4 Conclusions

4.1 Flyby Anomalies

The CMB-Doppler formula (3) of first order for two-way signals not only offers a possibility to resolve the residual annual and diurnal variations on top of the constant acceleration anomaly of P 10, but is capable to explain the unresolved flyby anomalies as well *Pabisch & Kern (2010)*. An additional analysis in the article of *Rievers & Lämmerzahl (2011)* about the resolution of the Pioneer 10 acceleration anomaly shows that thermal recoil pressure is not the cause of the Rosetta flyby anomaly. This special finding is supporting the validity of our following assumptions. The flyby anomalies, which in most cases show an apparent acceleration, some null results, and one significant deceleration are still unexplained *Anderson & Campell & Ekelund & et al. (2008)*. The total geocentric orbital energy of the spacecraft per unit mass should be the same before and after the flyby. The data indicate this is not always true.

The relative, asymptotic inbound and outbound velocities in the geocentric frame are actually equal, but the absolute, osculating asymptotic inbound and outbound velocities $\mathbf{u}_{\mathrm{in}}$ and $\mathbf{u}_{\mathrm{out}}$ in the CMB rest frame have in general slightly different magnitudes. Thus the CMB-Doppler effect is inducing the difference as measured, which in standard theory is considered as an anomalous velocity difference *Anderson & Campell & Ekelund & et al. (2008)*,

$$\frac{\Delta V_\infty}{V_\infty} = K(\cos\delta_{\mathrm{in}} - \cos\delta_{\mathrm{out}}). \qquad (10)$$

Formula (10) contains the declinations δ_{in} and δ_{out} of a spacecrafts incoming and outgoing asymptotic relative velocities in the geocentric frame. *Anderson & Campell & Ekelund & et al. (2008)* found for K the constant value $3.099 \cdot 10^{-6}$.

Using the CMB approach for two-way Doppler signals, we obtained $3.009 \cdot 10^{-6}$ for K *Pabisch & Kern (2010)*. Obviously, the different ranging data (proportional to the apparent flyby Doppler anomaly) are also caused by the different absolute velocities of the inbound and outbound flights. The different absolute velocities may cause an energy difference of second order, which is minimal compared to the first order effect, and hence neglected.

4.2 CMB-Dipole formula versus SRT-Dipole formula

In standard theory, the CMB dipole is induced by the Doppler effect of the relative motion of the satellites COBE, WMAP and Planck with respect to the CMB rest frame. The motion of an observer with velocity v relative to an isotropic Planckian radiation field produces a Lorentz-boosted temperature pattern of temperature T_0, *Planck 2015 results (2016)*,

$$\Delta T\,(\theta) = T_0 \;\sqrt{1-\left(\frac{v_{\mathrm{e}}}{c}\right)^2}\,\frac{1}{1-\frac{v_{\mathrm{e}}}{c}\cos\theta}\;. \qquad (11)$$

Formula (11) is written in most publications

$$\Delta T\,(\theta) = T_0 \left(\frac{v}{c}\cos\theta + \frac{v^2}{2c^2}\cos 2\theta + O(v^3/c^3)\right), \qquad (12)$$

thus hiding the effect of absolute time dilatation, often described as Doppler effect of second order, which is a function of velocity too, but a quite different physical effect.

The dipole is a frame dependent quantity, and we can therefor determine the absolute rest frame as that in which the dipole would be zero. Our novel CMB-dipole formula, derived from the theory behind formulas (1) and (2), has just as well two terms, whereof the linear term is the CMB-Doppler formula of first order for absolute velocities, and the second, quadratic term represents the absolute time dilatation formula *Pabisch (1999)*, *Pabisch & Kern (2010)*,

$$f'_{\mathrm{CMB}} = f_0 \;\sqrt{1-\left(\frac{u_{\mathrm{e}}}{c}\right)^2}\,\frac{c+u_e\cos\alpha_1}{c}. \qquad (13)$$

Because of (11) we can write

$$f'_{\mathrm{SRT}} = f_0 \;\sqrt{1-\left(\frac{v_{\mathrm{e}}}{c}\right)^2}\,\frac{1}{1-\frac{v_{\mathrm{e}}}{c}\cos\alpha_1}, \qquad (14)$$

and due to $v_{\mathrm{e}} = u_{\mathrm{e}}$ we obtain finally

$$\frac{f'_{\mathrm{CMB}} - f'_{\mathrm{SRT}}}{f_0} = \frac{u_{\mathrm{e}}^2\sin^2\alpha_1\sqrt{1-\left(\frac{u_{\mathrm{e}}}{c}\right)^2}}{c^2 - c\;u_{\mathrm{e}}\cos\alpha_1}. \qquad (15)$$

The difference of the low multipoles in the two formulas is significant, despite the low absolute velocity of Earth.

I conclude that the as anomalous viewed alignments of the CMB multipoles (quadrupole, octopole and all higher multipoles) among each other, and to the dipole and the ecliptic plane are not caused by physical effects or systematic errors as mostly supposed in literature *Copi & Huter & Schwarz & Starkman (2005)*. In

a recent publication it is concluded, that currently the physics behind the CMB anomalies is still unknown, and the anomalies are not consistent with the inflationary Lambda-CDM standard model of cosmology *Schwarz & Copi & Huter & and Starkman (2015)*.
They are caused solely by the use of the relativistic standard model of cosmology. Forthcoming investigations will indicate, if the now necessary novel cosmological model offers a basis for a complete explanation of all other CMB anomalies, including the cold spot anomaly and the hemispherical asymmetry.

4.3 Absolute structure of Cosmos

All the novel results considered, I conclude that:

a) the experimental proof of exact absolute velocities of inertial frames due to the Planck measurements with instruments cooled down to 0,1 Celsius above absolute zero is inconsistent with the standard assertion, that the speed of light is invariant (isotropic) in all inertial frames. That point of view will probably be supported by a very recently proposed novel experiment, designed to measure the anisotropic speed of light, emitted within a labor system on Earth. Instead of interference measurements, atomic clocks are used, to measure the anisotropy of the speed of light *Edwards (2017)*.
Thus, the possibility to measure the absolute velocity of Earth possibly inside of a labor, and definitely against the CMB radiation is contradicting the results of the famous experimentum crucis of Michelson-Morley, and all subsequent experiments up to now.

b) the firm experimental evidence of the variant eigen-time of any labor system as a function of its absolute velocity according to the quadratic term of the Dipole formula (the first term of Eq. (13)), derived from the CMB dipole data of the COBE, WMAP and Planck instruments *Planck Collaboration: Adams & et al. (2016)*, is inconsistent with the relativity principle and the equivalence principle. The effect of time dilatation is thus not dependent on relative velocities between observers, but depends exclusively on absolute velocities, obviously due to absolute properties of photons *Pabisch (1999)*. Data from millisecond pulsars during the period of a year can probably confirm further the annual variance of the Earth eigen-time.

c) using the CMB-Doppler formulas of first and/or second order between objects in the Universe, we will have the possibility to determine at least the approximate absolute velocities and positions of all observable galaxies in our Universe. A model of an universe with an absolute structure should enhance the resolution of many pending cosmological inconsistencies or unexplained phenomena, like the observation of stars in our galaxy with an age above 14 billion years, or the observation of the earliest spiral galaxy BX422, which puzzles astronomers. Similarly puzzling is the finding of astronomers from the John Hopkins University *Zheng & Postman & Zitrin et al. (2012)* about a galaxy, which started to form 200 million years after the Big Bang, due to their estimation. In such an universe, the time arrow has a positive direction only, resolving an old conundrum.

d) The P 10 acceleration anomaly should be analyzed again in the CMB-space, applying the CMB-Doppler formula for two-way signals.

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