Flyby Radio Doppler and Ranging Data Anomalies are due to different inbound and outbound velocities in the CMB rest frame

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Abstract

The COBE, WMAP, and Planck data analyses exhibit that the CMB restframe can be seen as a fundamental, absolute space, the CMB-space. All Earth flyby radio Doppler data anomalies can be resolved by applying the general, classical Doppler formula (CMB-Doppler formula) of first order for two-way signals between earthbound Deep Space Network stations and a spacecraft during an Earth flyby. For that purpose, the annually varying absolute velocity vector $\vec{u}_e$ of Earth is used, derived from the absolute velocity vector of the solar system barycenter, $\vec{u}_{sun}$, magnitude $u_{sun} = 369.82 \pm 0.11 km\ s^{-1}$, in direction of constellation Crater, near Leo. Together with the relative, asymptotic inbound and outbound velocity vectors $\vec{v}_{in}$ and $\vec{v}_{out}$ in the equatorial frame, we obtain the absolute inbound and outbound velocity vectors $\vec{u}_{in}$ and $\vec{u}_{out}$ in the equatorial frame. The relative, asymptotic inbound and outbound velocities are actually equal ($v_{in} = v_{out}$), while the magnitudes of the absolute inbound and outbound velocities $\vec{u}_{in}$ and $\vec{u}_{out}$ of a spacecraft are in general different ($u_{in} \neq u_{out}$), leading to the apparent anomaly. Thus the use of the CMB-Doppler formula explains the so far as residual considered positive or negative differences in energy. The measured, different absolute velocities in the CMB rest frame explain the supposed radar ranging data residuals as well.

Keywords: Earth flyby anomalies, absolute velocities in the CMB rest frame, general classical Doppler formula of first and second order in the CMB rest frame

1 Theoretically derived formula is reproducing the empirically devised prediction formula

The flyby anomalies, which in most cases show an apparent acceleration, some null results and one significant deceleration between the inbound and outbound flights, are still unexplained *Anderson & Campell & Ekelund & et al.* [1], *Acedo* [2]. The total geocentric orbital energy per unit mass should be the same before and after the flyby. The data indicate this is not always true.
To predict further flyby anomalies, 14 years ago *Anderson & Campell & Ekelund & et al.* [1] published an empirically devised formula from previous flyby anomaly data,

which involves the incoming and outgoing geocentric latitudes of the relative, asymptotic velocity vectors,

$$\frac{\Delta V_\infty}{V_\infty} = K(\cos\delta_{in} - \cos\delta_{out}), \tag{1}$$

where ΔV_∞ is the apparent anomalous difference in velocity, V_∞ is the asymptotic relative velocity, δ_{in} is the asymptotic, geocentric latitude of the inward flight trajectory, δ_{out} is the asymptotic, geocentric latitude of the outward flight trajectory, and K has the constant value $3.099 \cdot 10^{-6}$.

Using the CMB-Doppler formula approach for two-way tracking signals, we obtain $K_{CMB} = 3.059$ *Pabisch & Kern* [3]. Obviously, the ranging data anomaly is also caused by the different absolute velocities of the inbound and outbound flights, see figure 1, and again the CMB-approach will explain accelerations, decelerations and null results as well.

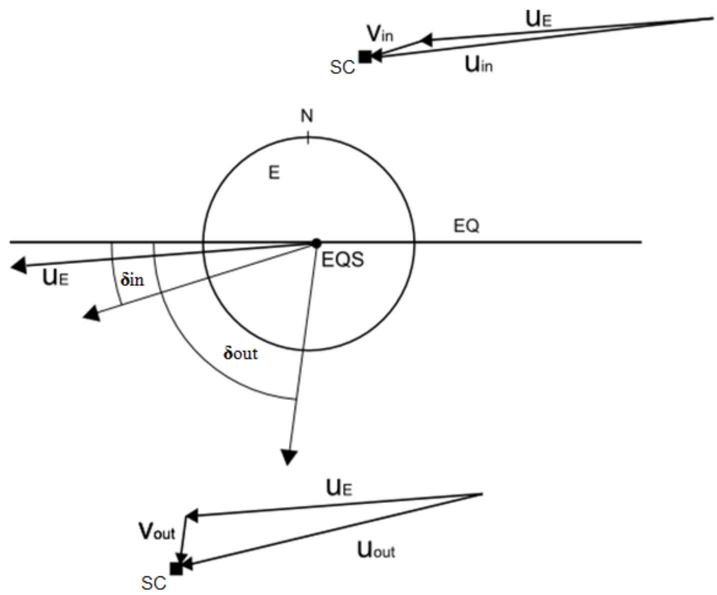

Figure 1: Schematic visualization of the absolute velocity vector $\vec{u}_e$ of Earth and the relative, asymptotic pre-encounter velocity vector $\vec{v}_{in}$, the relative, asymptotic post-encounter velocity vector $\vec{v}_{out}$ of a spacecraft (SC) in the equatorial frame (EQS), their declination angles δ_{in} and δ_{out}, and the derived absolute asymptotic pre-encounter and post-encounter velocity vectors $\vec{u}_{in}$ and $\vec{u}_{out}$ of a spacecraft during a gravity assisted flyby manoeuvre.

The latest Planck dipole data analyses Planck Collaboration I [4] indicate a peculiar velocity of the solar system of $369.82 \pm 0.11 km \cdot s^{-1}$ in direction of constellation Crater near Leo, at $\alpha = 167° \cdot 94$ and $\delta = -6° \cdot 90$. The absolute velocity of Earth in the CMB restframe varies between $u_e = 340 km \cdot s^{-1}$ around mid June and $u_e = 400 km \cdot s^{-1}$ around mid December during the yearly revolution, while the velocity at mid March or mid September is $u_e = 371 km \cdot s^{-1}$. From that velocity the value $K_{CMB} = 3.059 \cdot 10^{-6}$ follows.

We now assert, that calculating the frequencies of two way signals between any two moving bodies in the universe, especially in the solar system, the CMB-Doppler formula of first order in the absolute space of the CMB rest frame has to be applied, instead of the relativistic Doppler formula of first order. The absolute velocity $\vec{u}_{sc}$ of a spacecraft (SC) is derived by addition of its relative velocity $\vec{v}_{sc}$ in the geocentric frame together with the absolute velocity $\vec{u}_e$ of Earth, see fig. 1. The absolute velocity $\vec{u}_{dsn}$ of the Deep Space Network stations (DSN) is calculated by adding its rotational velocity in the geocentric frame and the absolute velocity $\vec{u}_e$ of Earth.
We neglect the rotational velocity in our formula for simplicity because of the minimal effect, hence $\vec{u}_{dsn} = \vec{u}_e$. The time dilatation effect as a function of absolute velocities in the CMB rest frame *Pabisch* [5] is neglected too, for reasons we discussed in *Pabisch & Kern* [3], and in a more recent paper *Pabisch* [6]. All vectors are defined in the equatorial frame of Earth.

The CMB-Doppler formula of first order for an uplink signal reads

$$f'_{sc} = f_{dsn} \frac{c + u_{sc} \cdot \cos \alpha_2}{c - u_{dsn} \cdot \cos \alpha_1}, \tag{2}$$

where f_{dsn} denotes the frequency of the uplink signal emitted by a DSN station,
f'_{sc} the frequency of the uplink signal received and measured by a spacecraft SC,
c the constant velocity of light in the CMB rest frame,
α_1 the angle between the vector $\vec{u}_{dsn} = \vec{u}_e$ and the vector $\vec{c}_{up}$ of the uplink signal,
α_2 the angle between the vector $\vec{u}_{sc}$ and the vector $\vec{c}_{down}$ of the downlink signal.

The CMB-Doppler formula of first order for a downlink signal reads

$$f''_{dsn} = f'_{sc} \frac{c + u_{dsn} \cdot \cos \alpha_1}{c - u_{sc} \cdot \cos \alpha_2}, \tag{3}$$

where f''_{dsn} denotes the frequency of the downlink signal, as received and measured by a DSN station.

The difference ΔQ of the two quotients $\left(\frac{f''_{inDSN}}{f_{inDSN}}\right)$ and $\left(\frac{f''_{outDSN}}{f_{outDSN}}\right)$, where $\left(\frac{f''_{inDSN}}{f_{inDSN}}\right) = \frac{c+\cos\vartheta\ u_e}{c-\cos\vartheta\ u_e}\frac{c-\cos\eta\ u_{in}}{c+\cos\eta\ u_{in}}$ and $\left(\frac{f''_{outDSN}}{f_{outDSN}}\right) = \frac{c+\cos\gamma\ u_e}{c-\cos\gamma\ u_e}\frac{c-\cos\varepsilon\ u_{out}}{c+\cos\varepsilon\ u_{out}}$, can be expressed as

$$\Delta Q = \frac{c+\frac{\vec{u}_e\cdot\vec{v}_{in}}{v_{in}}}{c-\frac{\vec{u}_e\cdot\vec{v}_{in}}{v_{in}}}\ \frac{c-\frac{\vec{u}_{in}\cdot\vec{v}_{in}}{v_{in}}}{c+\frac{\vec{u}_{in}\cdot\vec{v}_{in}}{v_{in}}} - \frac{c+\frac{\vec{u}_e\cdot\vec{v}_{out}}{v_{in}}}{c-\frac{\vec{u}_e\cdot\vec{v}_{out}}{v_{in}}}\ \frac{c-\frac{\vec{u}_{out}\cdot\vec{v}_{out}}{v_{in}}}{c+\frac{\vec{u}_{out}\cdot\vec{v}_{out}}{v_{in}}}. \tag{4}$$

We assume that in the geocentric frame the condition $v_{in} = v_{out}$ is valid, despite the apparent flyby anomaly, and the relative and absolute velocity vectors of formula (4) are defined as

$\vec{v}_{in} = \begin{pmatrix} v_{in}\cos\delta_{in}\sin\alpha_{in} \\ v_{in}\cos\delta_{in}\cos\alpha_{in} \\ v_{in}\sin\delta_{in} \end{pmatrix}$ is the relative, asymptotic velocity vector of the incoming spacecraft, as calculated in the equatorial frame,

$\vec{u}_e = \begin{pmatrix} u_e\cos\delta_e\sin\alpha_e \\ u_e\cos\delta_e\cos\alpha_e \\ u_e\sin\delta_e \end{pmatrix}$ is the absolute velocity vector of Earth in the equatorial frame,

$\vec{u}_{in} = \begin{pmatrix} v_{in}\cos\delta_{in}\sin\alpha_{in} + u_e\cos\delta_e\sin\alpha_e \\ v_{in}\cos\delta_{in}\cos\alpha_{in} + u_e\cos\delta_e\cos\alpha_e \\ v_{in}\sin\delta_{in} + u_e\sin\delta_e \end{pmatrix}$, where $\vec{u}_{in} = \vec{v}_{in} + \vec{u}_e$ is the absolute, asymptotic velocity vector of the incoming spacecraft in the equatorial frame,

$\vec{v}_{out} = \begin{pmatrix} v_{out}\cos\delta_{out}\sin\alpha_{out} \\ v_{out}\cos\delta_{out}\cos\alpha_{out} \\ v_{out}\sin\delta_{out} \end{pmatrix}$ is the relative, asymptotic velocity vector of the outgoing spacecraft, as calculated in the equatorial frame, and

$$\vec{u}_{out} = \begin{pmatrix} v_{out}\cos\delta_{out}\sin\alpha_{out} + u_e\cos\delta_e\sin\alpha_e \\ v_{out}\cos\delta_{out}\cos\alpha_{out} + u_e\cos\delta_e\cos\alpha_e \\ v_{out}\sin\delta_{out} + u_e\sin\delta_e \end{pmatrix},$$

where $\vec{u}_{out} = \vec{v}_{out} + \vec{u}_e$ is the absolute, asymptotic velocity vector of the outgoing spacecraft in the equatorial frame.

Each of these vectors is defined in the equatorial frame of Earth by means of its declination δ and right ascension α and its magnitude relative to the center of Earth. Furthermore ϑ is the angle between the absolute velocity vector $\vec{u}_e$ of the geocentric, and the relative, asymptotic velocity vector $\vec{v}_{in}$ of the incoming spacecraft, as calculated in the equatorial frame,

where $\cos\vartheta = \frac{\vec{u}_e \cdot \vec{v}_{in}}{u_e v_{in}}$,

η denotes the angle between the absolute, asymptotic velocity vector $\vec{u}_{in}$ of the incoming spacecraft, and the relative, asymptotic velocity vector $\vec{v}_{in}$ of the spacecraft, as calculated in the equatorial frame,

where $\cos\eta = \frac{\vec{u}_{in} \cdot \vec{v}_{in}}{u_{in} v_{in}}$,

γ denotes the angle between the absolute velocity vector $\vec{u}_e$, and the relative, asymptotic velocity vector $\vec{v}_{out}$ of the outgoing spacecraft in the equatorial frame,

where $\cos\gamma = \frac{\vec{u}_e \cdot \vec{v}_{out}}{u_e v_{out}}$,

ε denotes the angle between the absolute, asymptotic velocity vector $\vec{u}_{out}$ of the outgoing spacecraft, and the relative, asymptotic velocity vector $\vec{v}_{out}$ of the outgoing spacecraft in the equatorial frame,

where $\cos\varepsilon = \frac{\vec{u}_{out} \cdot \vec{v}_{out}}{u_{out} v_{out}}$.

From formula (4) we now obtain formula (5)

$$\Delta Q = \frac{c + u_e \cos\delta_e \sin\alpha_e \cos\delta_{in} \sin\alpha_{in} + u_e \cos\delta_e \cos\alpha_e \cos\delta_{in} \cos\alpha_{in} + u_e \sin\delta_e \sin\delta_{in}}{c - (u_e \cos\delta_e \sin\alpha_e \cos\delta_{in} \sin\alpha_{in} + u_e \cos\delta_e \cos\alpha_e \cos\delta_{in} \cos\alpha_{in} + u_e \sin\delta_e \sin\delta_{in})}$$

$$\frac{c - ((v_{in} \cos\delta_{in} \sin\alpha_{in} + u_e \cos\delta_e \sin\alpha_e) \cos\delta_{in} \sin\alpha_{in} + (v_{in} \cos\delta_{in} \cos\alpha_{in} + u_e \cos\delta_e \cos\alpha_e) \cos\delta_{in} \cos\alpha_{in} + (v_{in} \sin\delta_{in} + u_e \sin\delta_e) \sin\delta_{in})}{c + (v_{in} \cos\delta_{in} \sin\alpha_{in} + u_e \cos\delta_e \sin\alpha_e \cos\delta_{in} \sin\alpha_{in} + (v_{in} \cos\delta_{in} \cos\alpha_{in} + u_e \cos\delta_e \cos\alpha_e) \cos\delta_{in} \cos\alpha_{in} + (v_{in} \sin\delta_{in} + u_e \sin\delta_e) \sin\delta_{in})}$$

$$- \frac{c + u_e \cos\delta_e \sin\alpha_e v_{out} \cos\delta_{out} \sin\alpha_{out} + u_e \cos\delta_e \cos\alpha_e v_{out} \cos\delta_{out} \cos\alpha_{out} + u_e \sin\delta_e v_{out} \sin\delta_{out}}{c - (u_e \cos\delta_e \sin\alpha_e v_{out} \cos\delta_{out} \sin\alpha_{out} + u_e \cos\delta_e \cos\alpha_e v_{out} \cos\delta_{out} \cos\alpha_{out} + u_e \sin\delta_e v_{out} \sin\delta_{out})}$$

$$\frac{c - ((v_{out} \cos\delta_{out} \sin\alpha_{out} + u_e \cos\delta_e \sin\alpha_e) \cos\delta_{out} \sin\alpha_{out} + (v_{out} \cos\delta_{out} \cos\alpha_{out} + u_e \cos\delta_e \cos\alpha_e) \cos\delta_{out} \cos\alpha_{out} + (v_{out} \sin\delta_{out} + u_e \sin\delta_e) \sin\delta_{out})}{c + (v_{out} \cos\delta_{out} \sin\alpha_{out} + u_e \cos\delta_e \sin\alpha_e) \cos\delta_{out} \sin\alpha_{out} + (v_{out} \cos\delta_{out} \cos\alpha_{out} + u_e \cos\delta_e \cos\alpha_e) \cos\delta_{out} \cos\alpha_{out} + (v_{out} \sin\delta_{out} + u_e \sin\delta_e) \sin\delta_{out}}.$$

Since the asymptotic inward flight right ascension angle α_{in}, and the asymptotic outward flight right ascension angle α_{out} do have a negligible effect on the quotient ΔQ of formula (5), we approximate further, and by equating $\alpha_{in} = \alpha_{out} = \alpha_e = \delta_e = 0$ we obtain with

$$c\Delta Q = -\frac{2c^2 u_e v_{out}(\cos\delta_{in} - \cos\delta_{out})(v_{out} + u_e(\cos\delta_{in} + \cos\delta_{out}))}{(c - u_e\cos\delta_{in})(c - u_e\cos\delta_{out})(c + v_{out} + u_e\cos\delta_{in})(c + v_{out} + u_e\cos\delta_{out})}. \tag{6}$$

Using $v_{out} + u_e(\cos\delta_{in} + \cos\delta_{out}) \approx u_e(\cos\delta_{in} + \cos\delta_{out})$, and
$(c - u_e\cos\delta_{in})(c - u_e\cos\delta_{out}) \approx c^2$,
we get $c\Delta Q = -\frac{2u_e^2 v_{out}(\cos\delta_{in} - \cos\delta_{out})(\cos\delta_{in} + \cos\delta_{out})}{(c + v_{out} + u_e\cos\delta_{in})(c + v_{out} + u_e\cos\delta_{out})}$, and approximating further

$$(c + v_{out} + u_e\cos\delta_{in})(c + v_{out} + u_e\cos\delta_{out}) \approx c^2,$$

we obtain

$$c\Delta Q = -\frac{2u_e^2 v_{out}}{c^2}(\cos^2\delta_{in} - \cos^2\delta_{out}). \tag{7}$$

If we consider $\Delta V_\infty = \frac{c\Delta Q}{2}$ as difference in velocity, we get

$$\frac{\Delta V_\infty}{v_{out}} = -\frac{u_e^2}{c^2}(\cos^2\delta_{in} - \cos^2\delta_{out}), \tag{8}$$

and finally

$$\frac{\Delta V_\infty}{v_{out}} = -\frac{2u_e^2}{c^2}(\cos\delta_{in} - \cos\delta_{out}). \tag{9}$$

The term $\frac{2u_e^2}{c^2}$ yields $3.059 \cdot 10^{-6}$ for the factor K_{CMB}, if the velocity of Earth $u_e = u_{dsn} = 371 km \cdot s^{-1}$ around mid March is inserted. Due to the CMB-approach, the value of $3.059 \cdot 10^{-6}$ is not constant, but varies as a consequence of the annual variation of the absolute velocity of Earth between $u_e = 340 km \cdot s^{-1}$ and $u_e = 400 km \cdot s^{-1}$. Around mid June $K_{CMB} = 2.57 \cdot 10^{-6}$ results, and around mid December $K_{CMB} = 3.55 \cdot 10^{-6}$. The negative sign of our factor K_{CMB} stems from the difference of the absolute inbound velocity minus absolute outbound velocity as can be seen in formula (4). The other way around a positive value results.

Cahill [7] derived a formula on equivalent theoretical reasoning. He asserted, that the speed of light is not invariant, and is isotropic only with respect to the CMB restframe. For some reason he then applies a shibboleth absolute velocity of the solar system to calculate the flyby effects, which deviates significantly in direction and magnitude from the latest Planck values.

Note that the formula by *Anderson et al.* [1], and hence our theoretically derived formula as well, gives wrong, not null anomaly predictions for the second and third Rosetta flybys, and for the Juno flyby of October 2013, *Acedo* [2]. The deviation sometimes arises when the inbound frequency, in fact due to the absolute inbound velocity u_{in}, leads to

a misleading value of the relative inbound velocity v_{in}, which results from the standard Doppler formula of first order and the varying factor K_{CMB} may be a reason, too.
The difference between the inbound angles of the relativistic Doppler formula and the CMB-Doppler formula should not be overlooked also, see figure 1.

2 Conclusions and Predictions

2.1

The dipole Doppler term of 1^{st} order is the result of the motion of our solar system through space. It is a frame dependent quantity, and we can determine the absolute restframe as that in which the dipole would be zero. We conclude from formula (9), and the resulting factor K_{CMB}, that the use of the CMB-Doppler formulas (2) and (3) does yield frequencies which will match all measured positive or negative deviations during Earth flyby maneuvers, despite $v_{in} = v_{out}$ is valid in the geocentric frame. A renewed evaluation of the independently observed ranging data, using the absolute, asymptotic inbound and outbound velocity vectors, and the absolute velocity vector of Earth will exhibit velocity differences which explain the seemingly anomalies, measured during some flyby manoeuvres. Several other successful applications of the CMB approach make a random match of formula (9) with the empirically found formula (1) vastly improbable.

2.2

The motion of an observer with velocity v relative to the isotropic Planckian radiation field produces a temperature pattern *Planck Collaboration R. Adam & et al.* [10], *Scott & Smoot* [11] of

$$\Delta T = T_0 \left(\sqrt{1 - \left(\frac{v_e}{c}\right)^2} \frac{1}{1 - \frac{v_e}{c}\cos\theta} \right). \tag{10}$$

Formula (10) is written in most publications

$$\Delta T = T_0 \left(\frac{v}{c}\cos\theta + \frac{v^2}{2c^2}\cos 2\theta + O(v^3/c^3) \right), \tag{11}$$

thus hiding the effect of time dilatation in CMB-space, often described as Doppler effect of 2^{nd} order which is a function of velocity too, but a quite different physical effect compared to the 1^{st} order effect. The value of the quadratic term of the CMB dipol formula (10), the inverse γ-Faktor, precisely confirms the purely kinematic origin of the first order effect. That concordance indicates we have to interpret the time dilatation effect as an asymmetric function of absolute velocities u in the CMB restframe *Pabisch* [5]. Due to $v_e = v_u$ in formulas (10) and (11), Earth eigentime is obviously not invariant since it varies annually $\approx \pm 110 ns/s$ around a time dilatation value of $765 ns/s$ at mid March or mid September. Clocks at Earth are delayed less than one microsecond per second versus a clock at rest in the CMB-restframe, the SI-second is not invariant. Only against the absolute temperature variations, due to the absolute motion of Earth that asymmetric effect can be measured, not within any laboratory on Earth, at least until now *Sanner & Huntemann* [12].

2.3

The CMB Doppler formulas of 1^{st} order not only allow to calculate the, in general slightly different, absolute inbound and outbound velocities of flyby manoeuvres, thus resolving the flyby anomalies. The quite different phenomenon of the annual and diurnal signal residuals *Anderson J. D. & et al.* [8] on top of the resolved Pioneer 10 acceleration term *Rievers B., Lämmerzahl C.* [9] is as well resolved by applying the CMB Doppler formula of 1^{st} order *Pabisch* [6].

2.4

The CMB multipol anomaly can be resolved in CMB-space as well. The observed alignment of the low multipoles (quadrupole and octopole) with one another and their perpendicular orientation to the Ecliptic is not a mysterious property of the presumptive background radiation *Dominik Schwarz & et al.* [13], *Dominik J. Schwarz & Glenn D. Starkman & Dragan Huterer, & Craig J. Copi* [14], *Dragan Huterer* [15]. That in standard physics unexplained phenomenon is caused by the annual motion of Earth, and the fortunate random fact, that the absolute vector of the solar systems velocity runs nearly parallel to the Ecliptic, near to the equinoxes.

2.5

Summarizing, we have several independent indications that the CMB basic approach is new physics:

- We can exactly measure absolute velocities and absolute directions of bodies, stars and galaxies, at least in our cosmic neighbourhood.
- The application of the classical Doppler formula of 1st order in the CMB-space (CMB Doppler formula) resolves several different, so far unexplained deviations from the standard Doppler formula of 1^{st} order.
- Absolute velocities of bodies cause physical effects like time dilatation. That supports the assumption of an inertial mass of photons [5], [6].
- The solar system is not cosmically aligned, as argued in 2.4, and the CMB anomaly of the north-south hemispheric asymmetry, the preference of odd parity, and the cold spot are all resolved in an anisotropic and inhomogeneous cosmos.

2.6

We predict, the forthcoming data and images from the James Webb Space Telescope (JWST) will show that the expected structures and traces of an infant universe, according to the ΛCDM model are not to find in the outermost regions. Instead, at least some massive galaxies and quasars will show up in the data. Possibly the region beyond a distance of 13.7 billion ly is not the assumed edge of our Universe. The presumptive age of our cosmos of 13.8 billion years is challenged, just a several other components of the ΛCDM model. The reasons, supporting those predictions, will follow in another publication.

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