

PIONEER ANOMALY

According to 'MATTER (Re-examined)'

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Abstract: Observed locations of Pioneer 10 and 11 spacecrafts, after they left the solar system, are displaced from their predicted positions in space, and the discrepancy, which could not be explained by current physical laws, is termed the 'Pioneer anomaly'. This article attempts to show that the noticed discrepancy is an apparent phenomenon, produced by faulty geometry used in the contemporary laws of planetary motion. In reality, the spacecrafts and external efforts on them behave normally. There is no cause for the assumption of strange 'forces' or mysterious effects on these spacecrafts.

Keywords: Pioneer anomaly, planetary orbits.

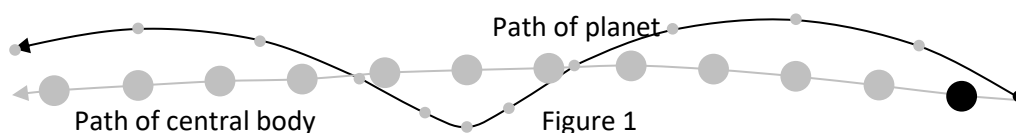
Introduction:

Upon completion of their assigned roles, both spacecraft, Pioneer 10 and Pioneer 11, were set sailing farther into space, away from the solar system. They had sufficient impetus to carry themselves away from the solar system, against deceleration by gravitational attraction, towards other macrobodies in the solar system. Calculations to determine their current locations are based on existing laws of gravitation and planetary motion. On establishing their present locations on various occasions, certain progressive but unaccounted discrepancies were noticed. Retardations of both spacecraft were found to exceed the predicted values. This phenomenon gave rise to numerous speculations and exotic theories. However, none of them could, so far, logically explain the anomaly satisfactorily.

Contemporary laws on planetary motions are derived from empirical data collected about the relative positions of a few planets in the solar system, with respect to the assumed static state of the Sun. Therefore, they can be true only to determine the relative positions of macrobodies in a planetary system with respect to their static central body. Relative positions of a planet, moving in a stable orbital path about a central body, may be predicted by contemporary laws of planetary motion. Using these laws to determine other parameters of macrobodies in the solar system is not right. All conclusions expressed in this article are from an alternative concept presented in the book, 'MATTER (Re-examined)' [1]. For details, kindly refer to the same. Figures are drawn not to scale. They are depicted only as an illustration of the phenomena described.

Planetary orbits:

All textbooks (and other literature) teach that the shape of a planetary orbital path is elliptical (or circular) around its central body. At the same time, simple mechanics tells us that no free macrobody can orbit around another moving macrobody in a closed geometrical path. An elliptical (or circular) orbital path, around a central body is an apparent structure that suits observation, related to a static central body. This is not the real path of a planetary body in space. Unfeasibility to find a static macro body in space confirms the impracticality of a real circular/elliptical orbit around a central body. (Only stable galaxies remain stationary in space) [1]. With respect to absolute reference, the real orbital path of a planet is wave-like about the central body's path, with the planet periodically moving to the front and to the rear of the central body, as shown in Figure 1. In this article, we shall ignore the eccentricity of apparent planetary orbits and consider them as circular.



In Figure 1, the arrow in black wavy-line shows planet's real orbital path in space. Unevenness of curvatures and magnitudes of departure of the path on either side of the central body's path (in the figure) are due to different scales used for linear and radial displacements. The path of the central body is shown by an arrow in a grey line. This curved path, also is wavy to a smaller extent, curving in the same direction as the path

of the planet. The path of the planet's satellite is wavy-line about the planet's path. The central body and planet are shown by black circles, and their future positions are shown by grey circles. In this sense, it can be seen that a planet (or a satellite) orbits around the centre of the central body's curved path, and the wave pattern in its path is caused by the presence of the central body. Such changes in the path of a free macro body may be attributed to perturbations caused by the presence of nearby macrobodies. These perturbations look like orbital motion around a central body, only when they are referred to the assumed static state of the central body in a relatively small system of macrobodies.

Figure 2 compares the real and apparent orbital paths of a planet. The blue arrow on the centre line shows the linear (curvature ignored) path of the central body. The central body (in its present position) is depicted by a large black circle in the centre of the planet's apparent orbital path, shown by a red circle in dotted line. Large grey circles show the future and past positions of the central body. The planet is shown in its present position by a small black circle, and small grey circles show the planet's future positions. The real orbital path of the planet is shown by a black curved line with an arrow in the direction of its motion.

The real orbital path of the planet may be divided into four quarters as shown in the figure, separated by vertical dotted lines. Unevenness in the width of quarters is due to different scales used in the figure for vertical and horizontal measurements. The large circle in a dashed red line shows the apparent orbit of the planet around the central body, in its present position. The planet's apparent orbit is along with the central body in its path. It is an imaginary path

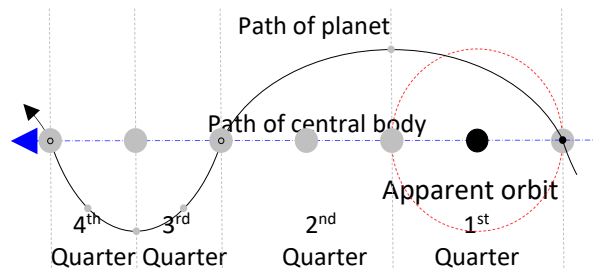


Figure 2

around the central body, on which every point is equidistant from the central body (for a circular apparent orbit). In order to obtain an apparent orbital path, we need to split the real orbital path into two curved paths, one on either side of the central body's path, and recombine them by changing the direction of the planet's motion into one curved path. Apparent orbital path gives accurate information on the relative positions of central and planetary bodies and no other orbital parameters. According to the concept in reference [1];

Circular/elliptical orbital paths of planets are apparent orbits around another free macrobody, which the observer assumes is static in space.

A planetary system can develop and sustain only (nearly) in the plane of the central body's curved path.

All planets enter into their orbital path from external space. The entry of a planet into its stable orbital path is a one-time process. There is no gradual development of a stable orbital path for a macrobody or development of a macrobody in its stable orbital path.

Every planet has an ideal 'datum orbital path' about its central body. Datum orbital path is a circular apparent orbit around a central body, assumed in a static state. Parameters of datum orbital path depend on the 3D matter-contents of central and planetary bodies, the angle of approach, and the linear speed of the planetary body.

A planetary body may enter into its stable orbital path only through two small conical windows in space, on the datum orbit, facing rear on the outer or inner sides of the linear path of the central body.

Five-eighths of the 'central force' on a planet is utilised for its orbital motion, and the rest, three-eighths of the 'central force,' is utilised for its spin motion.

(Datum) point(s) at which a planet attains its highest/lowest linear speed need not coincide with perigee/apogee of its (elliptical) apparent orbital path.

Equation (16/13), in reference [1], $-\alpha = \sin^{-1} \frac{u}{V}$, gives limit of drifting rate at the point of entry (from within datum orbit) for macro bodies, which may form successful stable orbits about a central body. [Where, α is angular drifting rate (rate of change of \angle TbE in figure 3) between planetary body's current direction of absolute linear motion and tangent to orbital path, u is magnitude of planetary body's radial velocity towards central body by part of 'central force' and V is planetary body's absolute linear speed]. Datum orbit is the smallest (circular) apparent orbital path corresponding to the parameters of central and planetary bodies.

Macrobodies, approaching the datum orbit from within, with higher (negative/clockwise) drifting rate, ($-\alpha$), than the value, given by the above equation, flies away from the central body. This is the current states of both spacecrafts, Pioneer 10 and Pioneer 11. They are moving away from the solar system. At the instant when the spacecrafts left the surface of earth, they had their absolute linear speed, inherited from the motion of the

Earth. While they were inside the solar system, within and without Earth's influence, their absolute linear speed increased due to various impetuses. Their datum (apparent) orbital paths, around the Sun continued to enlarge due to increases in absolute linear speeds, angles of approach to the datum orbits, and increases in the distance from the Sun. By the time spacecrafts reached the limit of the solar system, their absolute linear speeds could overcompensate for their displacements due to gravitational attraction towards the Sun.

Once outside the solar system, there are no external influences on the spacecrafts that could increase their absolute linear speed. From then onwards, absolute linear speeds of the spacecrafts are continuously reduced by gravitational attraction towards the Sun. As distances from the sun increase, gravitational attractions on the spacecrafts gradually reduce. If their absolute linear motions survive even after gravitational attraction towards the Sun becomes negligible, they will become wholly free from the solar system and be free macrobodies in the galaxy. We shall limit the discussion only to the parameters of one of the spacecrafts.

Spacecraft, leaving solar system:

Before the spacecraft reached the outskirts of the solar system, it was moving in a (sort of) unstable orbital path, constantly under the control of various external efforts that guided its motion. Any discrepancy in displacement was readily corrected by the guiding efforts. An anomaly in the spacecraft's displacement was noticed after it passed about 20 au on its way out of the solar system. At this distance, spacecraft had no guiding influences other than gravitational attraction towards the solar system (the Sun). From its part of space, the whole 3D matter-content of the solar system could be considered as concentrated at the centre of the Sun.

When the spacecraft is at this distance, it is under two separate impetuses.

1. Additional work associated with its 3D matter-content and additional work gained from the motion of the solar system (and Earth), before the spacecraft was launched, tends to move it along with the solar system in the direction of the motion of the Sun. During the spacecraft's travel through the solar system, additional work is modified by various efforts that guide the spacecraft away from the solar system. Additional work associated with the spacecraft tends to move it at a constant linear speed in a straight-line path, deflecting outward from the Sun's path. The path of a spacecraft, at any instant, is a part of its (unstable) real orbital path.
2. Simultaneously, gravitational attraction towards the solar system tends to accelerate the spacecraft towards the Sun (decelerate its outward motion).

The action of (deceleration) gravitational attraction is always towards the sun. However, the direction of motion due to associated additional work depends on the curvature of the (unstable) real orbital path at its current location. The location of this point is bound to make considerable variation in the resultant actions on it. In current theories, the direction of linear motion of the spacecraft, along its apparent orbital path, is ignored. Only the displacement of spacecraft in the direction away from the central body is considered.

A spacecraft, when on Earth, shares Earth's absolute linear speed. Once it leaves earth's influence, it becomes an independent macrobody, flying towards and trying to enter into its datum apparent orbit around the Sun. However, in the case of any spacecraft designed to fly away from the solar system, it becomes an independent macrobody only after all external influences on it cease.

For simpler explanations, we shall consider a spacecraft rocketed from a central body in a two-body planetary system consisting of the spacecraft and its central body (representing the solar system). If the spacecraft's linear speed is greater than the escape velocity from the central body and its direction of motion is right, it will move towards its datum apparent orbit around the central body. Since the datum apparent orbit is around and away from the central body, the spacecraft is approaching the datum apparent orbit from within. A macro body, trying to enter its datum apparent orbit, has to do so through any of the two windows at the rear of its (future) real orbital path [1]. Therefore, a spacecraft, designed to leave the solar system, has to enter its datum apparent orbit, somewhere in the first or third quadrant of its real orbital path (as shown in figure 2), preferably nearer to the second or fourth quadrant.

Pioneer Anomaly:

The establishment of a stable orbital path by a spacecraft depends on its parameters. For a stable orbital path, magnitude of drifting rate of orbital path, $-\alpha$, should be between that given by equation (16/13), $-\alpha = \sin^{-1} \frac{u}{v}$, and equation (16/7), $-\alpha = \sin^{-1} \frac{u}{2v}$, in the book 'MATTER (Re-examined)' [1]. If it is designed to leave solar system, magnitude of drifting rate of orbital path, $-\alpha$, should exceed value given by equation (16/13), $-\alpha = \sin^{-1} \frac{u}{v}$. Drifting rate, $-\alpha$, may be increased either by increase in spacecraft's radial speed, u , towards solar system or by a reduction

in its absolute linear speed, V . Since spacecraft is moving away from sun, magnitude of gravitational attraction between them gradually reduces. Hence, radial velocity, u , cannot increase. It can only diminish in magnitude.

Other option, left to increase drifting rate, $-\alpha$, is to reduce spacecraft's absolute linear speed. This is achieved by its gradual and diminishing deceleration by gravitational attraction towards the solar system. Because of higher drifting rate ($\angle TbE$ in figure 3) and larger deflection angle ($\angle HBE$ in figure 3), spacecraft slows down its linear motion. Spacecraft moves away from the solar system and continuously loses additional work derived from its parent macrobody's motion and received from other sources during its travel within the solar system. As the spacecraft is destined to leave the solar system, its absolute linear speed is not reduced to such an extent as to provide a drifting rate suitable for a stable real orbital path. Nevertheless, the attempt continues until the influence of the solar system on the spacecraft becomes negligible.

The magnitude of the spacecraft's deceleration is directly related to the magnitude of gravitational attraction towards the solar system, an approximate value of which is given by an equation in Newtonian gravitational laws. This equation needs a slight modification to reflect a reduction in the gravitational attraction in proportion to the distance between the spacecraft and the solar system. Only five-eighths of the 'central force' is utilised for the spacecraft's acceleration towards the solar system. Rest, three-eighth part of the 'central force', is used to spin the spacecraft about an axis perpendicular to its orbital plane [1]. The radial speed of the spacecraft towards the solar system is combined with the absolute linear speed to get its resultant speed in space. The magnitude of the resultant speed depends not only on the magnitudes of constituent speeds but also on the angular difference between them.

Anomalies in the parameters of Pioneer spacecrafts were noticed when they were more than 20 au farther from the boundaries of the solar system. As this distance is too large compared to the distribution of large macrobodies in the solar system, it is convenient to assume the whole of the solar system's 3D matter-content is concentrated at the centre of the Sun. Sun travels in a circular path around the galactic centre. Since the period considered is too small (less than 100 years) compared to the time required for the Sun to travel through one full circle, we may consider the Sun's path (a small part of a circular path) as a straight line. The distance between the observer on Earth and the spacecraft may be taken as the distance between the spacecraft and the centre of the Sun.

Figure 3 represents the general layout of a planetary system that has the solar system (represented by the sun) as the central body and a spacecraft (leaving the solar system) as its planetary body. Blue arrow XX shows the linear path of the sun (a small part of its curved path). A is one of its past positions, C is one of its future positions, and B is its current position. a , b and c are positions of the spacecraft corresponding to positions A , B and C of the sun. The curve SS in red dashed line shows part of the apparent orbital path of the spacecraft, corresponding to the current position of the sun at B and the spacecraft at b . Line TT in red shows the tangent at point b to apparent orbit SS .

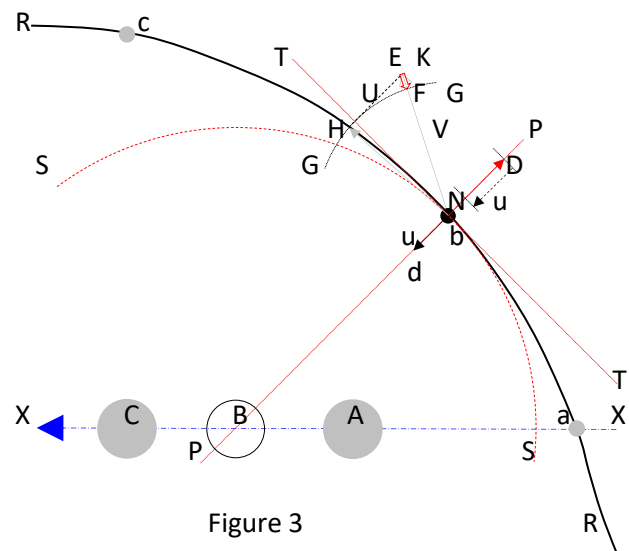


Figure 3

Considering the motion of the spacecraft in relation to its apparent orbital path, it is situated at b on its apparent orbital path SS . It has radial velocity, u , represented by arrow bd towards the sun. At the same time, the spacecraft is moving away from the sun, under centrifugal action (provided by the outward deflection of its linear motion). The magnitude of the spacecraft's outward deflection is represented by red arrow bD . $bD = EH$. Taking the resultant of these two motions (in opposite directions), the spacecraft has a resultant (rate of) outward displacement equal to bN , away from the sun. As the distance between the Sun and the spacecraft increases, the magnitude of gravitational attraction between them and hence the spacecraft's radial velocity towards the Sun decreases. As long as the spacecraft's outward displacement is more than its radial displacement due to gravitational attraction towards the Sun, it should continue to move away from the solar system at a rate corresponding to the resultant of inward and outward velocities. However, in the case of pioneer spacecrafts, their inward velocity appeared to over-compensate and effectively reduce their outward velocity. This brings about an unaccounted apparent radial acceleration towards the sun.

Calculations to determine the parameters of the spacecraft's motion, on this basis, do not allow any discrepancy in magnitudes of its displacements. Ultimately, the spacecraft may enter into a stable apparent orbit around the sun, unless the outward impetus that drives it away from the sun lasts until gravitational attraction between the two has become negligible. Even today, the Pioneer spacecraft is under the influence of gravitational attraction towards the Sun. However, the magnitude of gravitational attraction is not sufficient to move it along a stable orbital path. As long as this state of affairs continues, the apparent orbit of the spacecraft around the sun gradually enlarges to move it away from the sun. Parameters of its motion always adhere to calculations made in this regard. Nevertheless, a discrepancy is noticed in distances from the sun, determined by direct observation. The spacecraft is found nearer to the Sun than the distance determined by calculation, and this discrepancy is termed the 'Pioneer anomaly'. In reality, there is neither an external effort on the spacecraft nor does it have any additional acceleration towards the central body. An additional reduction (not corresponding to the calculation) in the linear speed of the spacecraft is assumed as a result of unaccounted inward acceleration.

When the displacement of the spacecraft is determined as per current laws on planetary motion, it is assumed to move in an apparent elliptical orbital path around a central body. Its present instantaneous linear speed and its future instantaneous linear speeds are approximately equal. As the spacecraft moves away from the central body, its apparent orbital path expands at a steady rate. This means that the spacecraft should be moving away from the central body at a certain linear speed.

However, by considering the real orbital path of the spacecraft, as shown above with respect to figure 3, in order to move away from the central body, the present instantaneous linear speed, b_E , of the spacecraft is maintained slightly greater than its future instantaneous linear speed, b_H . The difference in these linear speeds is not accounted for when the apparent orbital path is used. Excess magnitude, EF , of the present instantaneous linear speed over the future instantaneous linear speed appears only when we consider the real orbital path of the spacecraft. Future instantaneous linear speed is always less than the present instantaneous linear speed of the spacecraft. This difference is reflected in the displacement of the spacecraft from the central body. Real distance travelled by the spacecraft, determined by using future instantaneous linear speed, is less than apparent distance, determined by using present instantaneous linear speed.

As the spacecraft has not travelled through the apparent distance, determined by the present instantaneous linear speed, a discrepancy is assigned to various phantom phenomena that may produce additional retardation of the spacecraft in its motion, away from the central body. This difference appears as a result of an unknown acceleration towards the Sun and causes the 'Pioneer anomaly'.

The magnitude of the reduction in the spacecraft's absolute linear speed also depends on its position with respect to the Sun in the first/third quarter of its real orbital path. Hence, the magnitude of the anomaly depends on the relative positions of the sun and spacecraft in their real orbital paths. It is variable.

In the case of apparent orbits, the inward radial velocity of a planetary body, due to mutual gravitational attraction, is assumed to act always perpendicular to the planetary body's linear motion. Linear motion of a planetary body is assumed along tangents to the apparent orbits. Changes in distance between central and planetary bodies are affected only by deflection of the direction of the planetary body's linear motion. In the case of real orbital paths, depending on the relative positions of the planetary and central bodies, the angle between the absolute linear motion of the planetary body and its radial velocity towards the central body changes through a full circle. Absolute linear motion of a planetary body is taken in its true direction in space. Therefore, a component of radial inward motion directly reduces the planetary body's absolute linear motion, in addition to deflecting the planetary body's direction of absolute linear motion. This additional reduction in absolute linear speed of spacecraft accounts for discrepancies, currently noticed as the 'Pioneer anomaly'.

Conclusion:

'Pioneer anomaly' is the result of using the geometry of the apparent orbital path of spacecraft around the solar system instead of the geometry of their real orbital path (in space) about the solar system. Additional retardation to the absolute linear motion of a planetary body, as seen in the real orbital motion of a planetary body in certain parts of its real orbital path, can account for this anomaly.

Reference:

- [1] Nainan K. Varghese: *MATTER (Re-examined)*, <https://www.matterdoc.in/>

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