Pioneer 6 Anomalous Redshift near the Sun

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Abstract: Not only spectral lines in the optical range, even radio signals with significantly lower frequencies are red shifted when they the corona close to the sun. A possible explanation is the energy loss of electromagnetic waves, when the electric component accelerates unbound electrons in the thin plasma surrounding the sun. A reexamination of the radio signals that were recorded, when Pioneer 6 was occulted by the sun, corroborates the predicted redshift of electromagnetic waves. This allows to determine the number of free electrons in the neighborhood of the sun.

Introduction

Since 1907, it is an established but unexplained fact that the wavelengths of the Fraunhofer lines depend on the point of observation an the solar disk[1 2]. This systematic deviation from the predictions of the theory of relativity is amazing and can not be caused by turbulence of the plasma. The explanation[3] of the observed redshift as energy loss in the plasma suggests that this frequency reduction can be measured in *each* spectral band of the electromagnetic waves, even at low frequencies of the radio waves. Amazingly, the red shift of satellite signals was measured already 46 years ago and was so far ignored. The effect was examined several times[4 5 6 7].

Pioneer 6 still circles around the sun, the smallest distance (0.81 AU) is about 173 times greater than the radius of the sun. Any direct influence of the satellite by the sun, for example, by sun eruptions, is excluded.

Whenever the earth, sun and Pioneer 6 are almost lined up, the radio signals from the transmitter (2295 MHz) have to cross the Corona and enable conclusions on the composition. Since Pioneer 6 was briefly obscured by the sun on November 23, 1968, the carrier frequency was repeatedly measured and recorded[8] daily during the period from 31 October to 8 December. Surprisingly, only the received power and the bandwidth were analyzed, while the striking frequency shift was ignored and not evaluated. Mystery remains, what Goldstein may have meant by the following sentence: "*The second is a background bandwidth of about 1 Hz, due to frequency instabilities of the system, which appeared when Pioneer 6 was far from the sun. This component increased slowly as the rays penetrated more deeply into the corona.*" Pioneer 6 was *never* close to the sun, the distance changed between 0.81 AU and 0.98 AU! And why should the transmitter get unstable and modify its frequency when a small part of its radiated energy penetrates the corona more than 120 million kilometers away? Pertubations from such a great distance are unknown and contradict to the laws of wave propagation in the far field.

The reason for this omission could be that (according to the rules of quantum mechanics) the frequency of photons must not change. Measurements without theoretical justification are to be ignored!

Unfortunately, the report gives no information on how the daily average frequency was determined, although the picture shows a rapid and striking change in frequency. It also lack error bars. A detailed knowledge of all the recorded spectra would facilitate the analysis.

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Enigmatic Frequency Shift

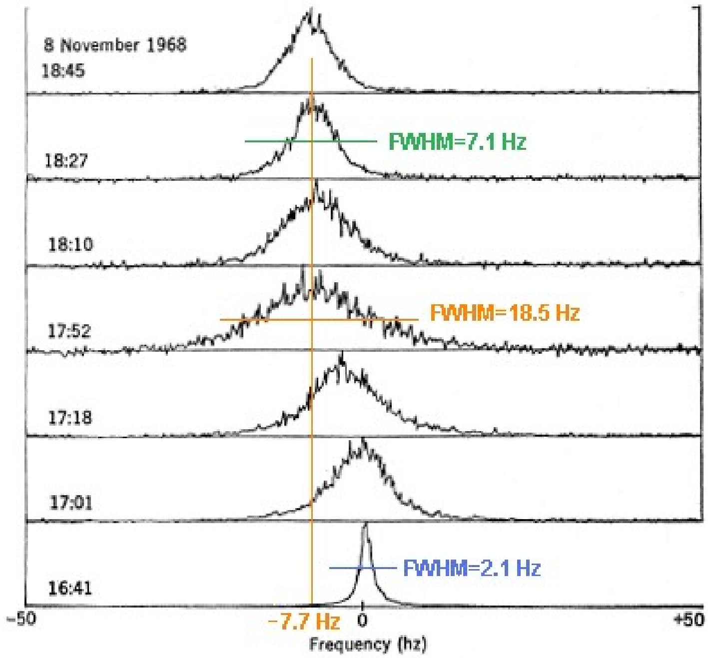


Fig. 3. Sample spectrograms taken on 8 November 1968, showing the effects of a solar event. Each spectrogram is the result of 15 minutes of averaging time.

One example of a fast frequency deviation is shown in the picture. Pioneer's transmitter is extremely narrow-banded, has a drift of about 13.4 Hz per day and sometimes spontaneous frequency jumps (in both directions!) of 1 or 2 Hz per 15 minutes, not too much for a center frequency of 2295 MHz. But on November 8, over a period of only 50 minutes, the frequency decreased gradually by 7.7 Hz and then remained constant. Presumably this is just one of several images of similar redshift.

Frequency shift can be produced by the Doppler effect. To achieve the above values, the satellite would have to increase its radial velocity (within 50 minutes) by 1 m/s (and decrease it later again by the same amount, in order not to leave the trajectory). A solar flare, about $120 \cdot 10^6$ km away, can not cause this change in velocity that would have influenced Venus and Mercury even stronger.

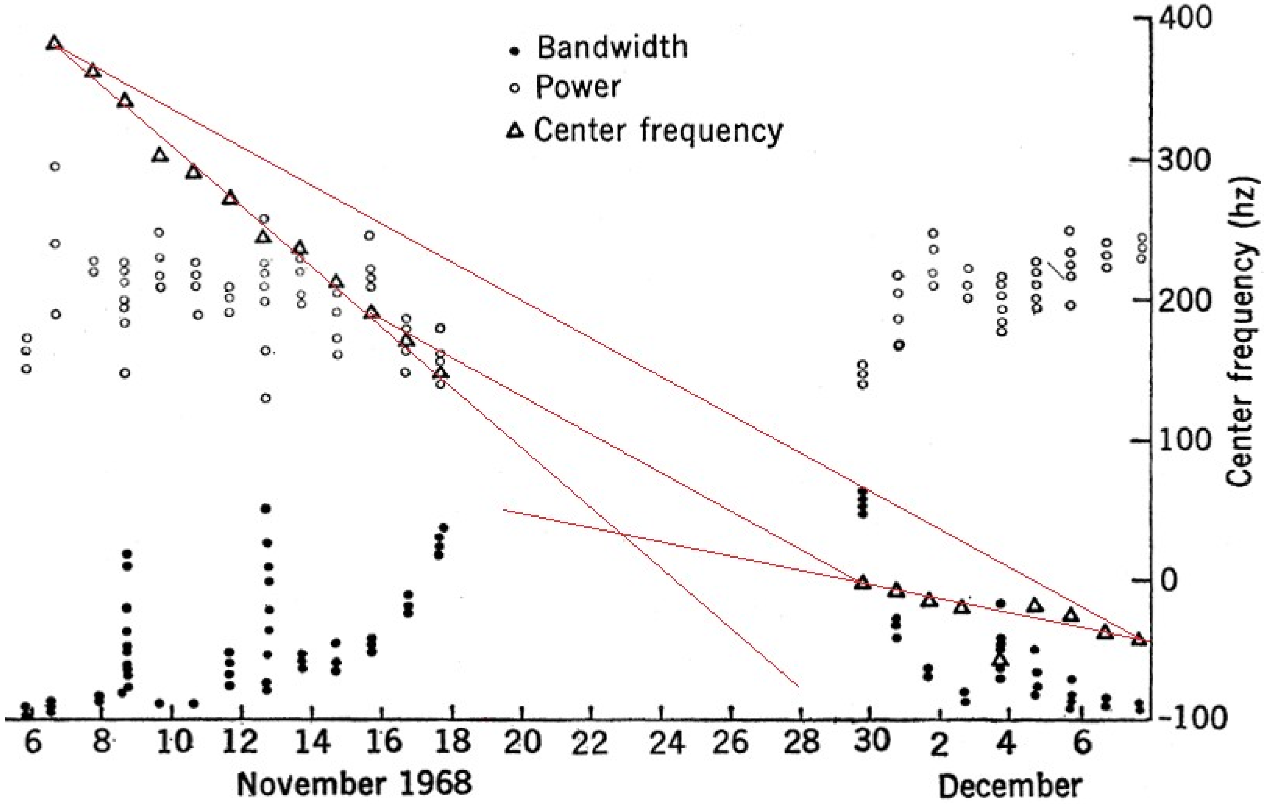
Oddly enough, the anomalous redshifts are not mentioned in the report, the investigator Goldstein was interested only in the increase in bandwidth, which was caused by solar flares. Both changes (bandwith and frequency shift) are caused neither by Pioneer 6 nor by the gravitational field of the sun. They are caused by the unbound electrons in the plasma along the radio path. It would be very interesting to know whether ever comparable fast blue shifts were observed, with a simultaneous increase in the bandwidth.

Goldstein's intention was to measure the *Spectral Broadening.* Subsequently only the *shift* of the center frequency will be analyzed.

In order to explain a frequency change of an electromagnetic wave, so far only the Compton effect has been taken into consideration. This explanation applies at frequencies above 10^{16} Hz, perhaps even in UV light. In visible light, the Compton effect is no longer detectable. At 2295 MHz, any explanation with Compton effect is nonsense because the rest mass of the electron is much too large. Quantum mechanics offers no explanation, but with the proven methods of classical mechanics, the frequency change can be described without problems[9]. Goldstein and Chen[10] have detected this frequency reduction and both tests should be reproducible at any time.

Goldstein's Data

Goldstein did not publish the 450 spectrograms, which he had taken. The picture shows the main results after the data reduction. The data of the period 10/31 till 11/5 and 12/8 have been omitted for unknown reasons.



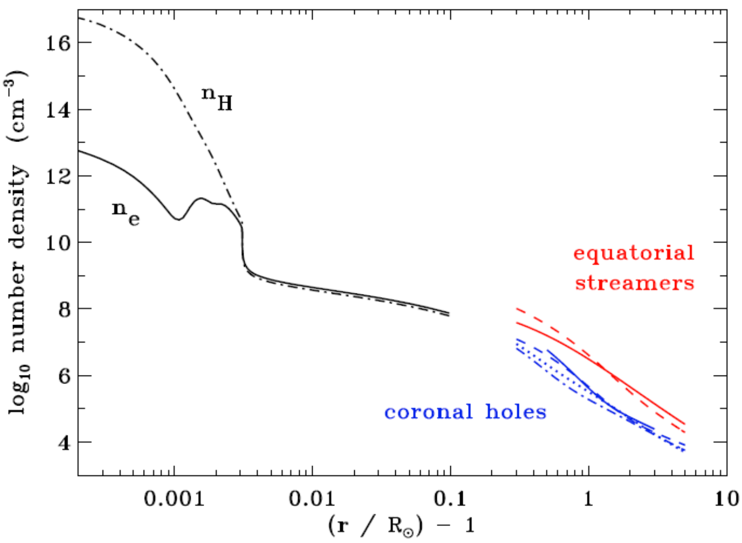
Bandwidth, center frequency, and power of the Pioneer 6 signals as a function of date.

Although the transmission frequency is characterized by a very high spectral purity, an additional variable noise modulation is received (referred to as bandwidth), which can only be generated by the plasma along the transmission path. It is known that electromagnetic waves are strongly affected in the ionosphere of the earth, but so far a frequency reduction could not be detected, because the path length is much shorter than in the corona of the sun. As can be seen in the picture, the change in the bandwidth does not affect the central frequency, indicating different causes. The only exception on December 3, is probably an error of the analysis, which can be solved only with reference to the original spectra.

The connection of the daily *center frequencies* of 6 November and 7 December is parallel to the connection of 17 November and 29 November. Both correspond to the long-term drift of 13.4 Hz per day of the transmitter in the satellite. Since all *center frequencies* are regularly lined up below the upper (red) connection, a redshift of unknown cause must be assumed. During the first half of November, the frequencies decrease approximately linearly, in early December they rise approximately linearly. Both lines intersect on November 23. On this day the sun is roughly in the middle between Pioneer 6 and the earth and obscures the satellite. The optical cover does not affect the technology of the satellite and it can not change the transmission frequency. Such a long-range effect over a distance of $120 \cdot 10^6$ km can be excluded.

The most likely cause of the observed Redshift is an energy loss of the radio waves when they pass through the plasma of the corona. The smaller the distance between the *line-of-sight* and the Sun is, the denser plasma is penetrated. Every unbound electron (the plasma is 100% ionized) slightly reduces the energy of traversing electromagnetic waves. According to classical physics, the energy loss can not be avoided, it is described here[11] in detail. According to quantum mechanics, there is no loss of energy because Photons never reduce their frequency when they pass through thin plasma.

The light path near the solar limb

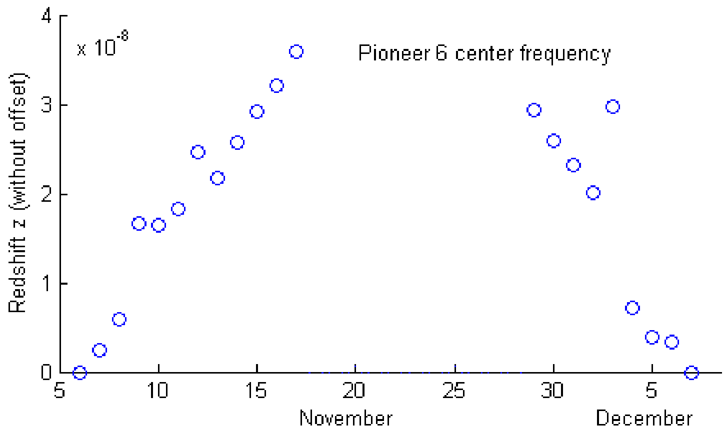


The sun is surrounded by a thin plasma, whose electron density (ED) decreases with increasing distance. Far outside, the ED is not well known, the estimates differ by more than an order of magnitude[12 13] as shown in the picture. As explained, every electron is accelerated by the electromagnetic wave and therefore radiates like a dipole antenna *without* preferred direction. Since this secondary radiation is not directed to the observer, the law of conservation of energy requires that the original electromagnetic wave loses a tiny amount of energy and therefore reduces its frequency[B]. With a single electron, the loss will be hard to detect. But if the length of the light path in the plasma is long enough, a density of $n_e = 10^5\, cm^{-3}$ or less produces a measurable drop in energy.

Here[11] is shown, that the redshift z can be calculated by $z = w \int_0^D n_e\, ds$ with

$$w = \frac{3\, q_e^4\, \mu_0^2}{512\, \pi\, m_e^2} = 2.33 \cdot 10^{-30}\, m^2$$

Modeling of the Redshift



To extract the redshift from Goldstein's data, the difference frequency between the daily *center frequencies* and the connection of the outmost points (6 November and 7 December) is calculated. This removes the slow frequency drift of Pioneer's transmitter (13.4 Hz / day). As a result, the two outer measurement points obtain the provisional (and wrong!) redshift z=0. The true *z-offset* is determined by an optimization calculation and added.

Since the exact transmitting frequency of Pioneer 6 is unknown and will surely differ from the value that was measured before Pioneer 6 was launched, a value called *z-offset* can be chosen arbitrarily so that the calculated redshift fits to Goldstein's data. As shown below, the best match was found at *z-offset* = $3.9 \cdot 10^{-8}$. The gravitational redshift caused by the sun may be neglected, because it is of the order 10^{-10}.

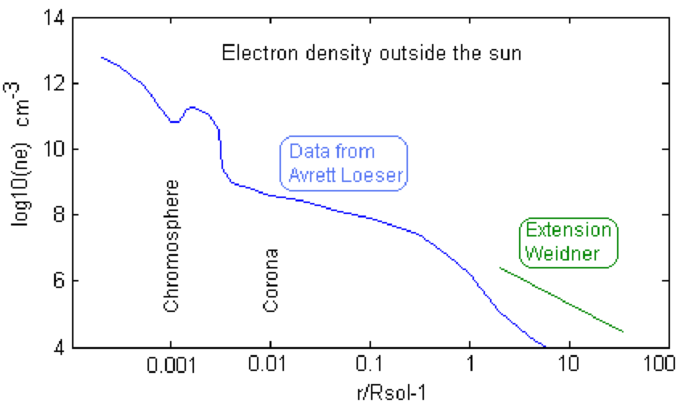
(B) For a detailed discussion, see [9] and [11]

In the period from 6 November to 7 December 1968, the shortest distance of the *line-of-sight* between Pioneer 6 and the earth from the center of the sun was always in the range $3 \cdot R_{Sun} < r < 11 \cdot R_{Sun}$. Since the electron density and thus the redshift decrease with increasing distance from the sun, the energy loss of the electromagnetic wave in the plasma was calculated only within a radius of $50 \cdot R_{Sun}$ around the sun. The energy loss of the remaining distance to the earth changes the redshift barely and is ignored.

The electron density at distances greater than $3 \cdot R_{Sun}$ is unknown and may be chosen arbitrarily. The selected values strongly influence the calculated energy loss and thus the redshift. As a first step, the ED is chosen at the end points of the range $3 \cdot R_{Sun} \rightarrow 50 \cdot R_{Sun}$. The local values for the ED are linearly interpolated between the two end points.

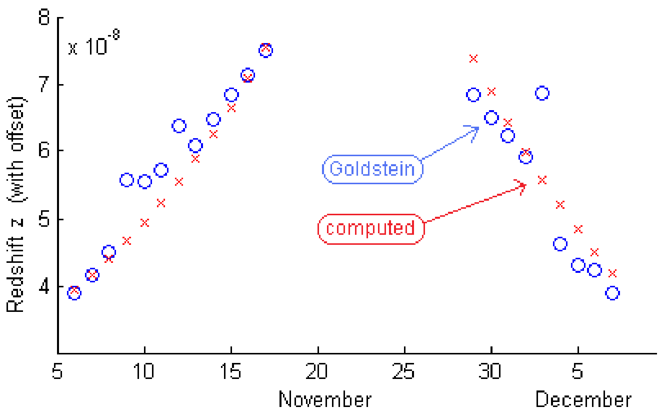
Distance from the center of the sun	$\log10(n_e)$ (cm^{-3})
$3 \cdot R_{Sun}$	6.39
$50 \cdot R_{Sun}$	4.44

These estimates may be changed, they are stored in table *nex* (program lines 8 and 9). The consequences of the change will be displayed graphically. The optimal result is shown in the picture.



The left part of the blue-colored curve shows the electron density, which is based on the model of Avrett and Loeser[13], the values are considered to be backed up. The right part of the blue curve is estimated and hardly substantiated by measurements. Large uncertainties must be expected. Using numerical integration in the program *Pioneer6*, the green-colored straight line near the right edge shows the result for best match between measured and calculated data for the redshift.

The lower picture shows the best fit of the model to Goldstein's data. The good agreement indicates that the energy loss of the electro-magnetic wave in the plasma is the sole cause of the redshift. The match was achieved by varying only three parameters in the program *Pioneer6* listed below.



A more detailed inspection requires more measurement points, which can only be obtained by a repetition of Goldstein's experiment. It is questionable whether Pioneer 6 can be re-activated. The test with a new satellite could include several complete orbits and cover different frequency ranges, an occultation of the satellite from the sun is not necessary. With the data, the structure and the electron density of the corona could be determined. The frequency data should be distinguished whether they were received with strong or weak noise modulation. This can be reconstructed from the records of Pioneer 6 if they are published by NASA (Spectral Broadening (1965-105A-09)).

Appendix: Programs for MATLAB

The file “Pioneer6.zip” contains the program “Pioneer6” and the neccessary data.
It may be requested by mail from herbertweidner@gmx.de

```
%Pioneer6, Herbert Weidner
%occulted by the sun: 596/366 (23 November 1968)
fe=[-100 36;400 486]; %calibration of frequency
load gold %ne %contains data from Avrett Loeser 2008
%ne(:,1) %=r/Rsol-1, r=height over photosphere
%x=ne(:,2); %=log10(r/Rsol-1)
%y=ne(:,3); %=log10(ne) %local density
nex(1,1)=3; nex(1,2)=log10(nex(1,1)-1); nex(1,3)=6.39; %guessed
nex(2,1)=50; nex(2,2)=log10(nex(2,1)-1); nex(2,3)=4.44; %guessed
plot(ne(:,2),ne(:,3),nex(:,2),nex(:,3))
xlabel('log10(r/Rsol-1)')
ylabel('log10(ne)'), title('Electron density outside the sun')
offset=3.9e-8; %offset for Goldstein-data (guessed)
% gold(1,1:2) und gold(21,1:2) define ref-line
x=[gold(1,1) gold(21,1)];
y=[gold(1,2) gold(21,2)];
gold(:,3)=gold(:,2)-interp1(x,y,gold(:,1));
figure(1)
scatter(gold(:,1),gold(:,3)) %raw differences from ref-line
gold(:,4)=-gold(:,3)*(fe(1,1)-fe(2,1))/(fe(1,2)-fe(2,2));
gold(:,5)=-gold(:,4)/2296e6; %f(send)=2295 MHz
gold(24:32,:)=gold(13:21,:); %we need place for..
gold(13:23,:)=0;%..missing data
gold(1:25,6)=6:30; %date November
gold(26:32,6)=1:7; %date Dezember
gold(1:32,7)=6:37; %continuous count of days for graphs
scatter(gold(:,7),offset+gold(:,5)) %z relative to ref-line
title('Pioneer 6 center frequency')
xlabel('November / December')
ylabel('Redshift z (without offset)')
fprintf('dzG=%g ?=? ',1e8*gold(12,5)); %equal?
%coordinates from picture angle_date.png
save gold1 %shortest distance to sun->gold(:,12)
gold(:,8)=interp1(angle(:,1),angle(:,2),gold(:,7)); %p-asc
gold(:,9)=interp1(angle(:,1),angle(:,3),gold(:,7)); %p-dec
gold(:,10)=interp1(angle(1:2,5),angle(1:2,4),gold(:,8)); %ascension
gold(:,11)=interp1(angle(4:5,6),angle(4:5,4),gold(:,9)); %declination
gold(:,12)=sqrt(gold(:,10).^2+gold(:,11).^2); %angle to sun
Rsol=696.34e6; AE=149.6e9; %[m]
gold(:,13)=AE*sin(gold(:,12)*pi/180); %smallest angle
gold(:,14)=gold(:,13)/Rsol; %..as multiple of Rsol
w=2.33e-30; %[m²]
for x=1:size(gold,1)
    if gold(x,1)>0
        y=gold(x,14):0.05:nex(2,1); %divide into small pieces
        nem = interp1(nex(:,1),nex(:,3),y); %local density
        z=2*sum(w*1e6*10.^nem.*(y(1,2)-y(1,1))*Rsol); %cm³->m³, Hin+Rückweg
        gold(x,15)=z;
    end
end
gold(13:23,15)=offset;
figure(2), scatter(gold(:,7),gold(:,15),'r','x')
xlabel('Date'), ylabel('Redshift z'), title('computed Redshift')
fprintf('dzc=%g\n',1e8*(gold(12,15)-gold(1,15)));
%finito
```

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[11] H. Weidner, The Hubble constant H0 is not constant, but proportional to the density of free electrons, http://vixra.org/abs/1405.0209
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