Can we see the Milky Way with LWA antenna and Callisto spectrometer?

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Following the experiments of Karl G. Jansky, which he published in Feb. 24 1932 [1], I was wondering if it would be possible to demonstrate the same experiment 82 years later with modern hardware but with much worse conditions caused by strong man made radio frequency interference (RFI). At the time of Jansky's experiments there was almost no manmade RFI, so he did not have to deal with it and could collect all photons from the outside of the Earth. For my experiments I used the Long Wavelength Array (LWA) antenna shown in figure 1 and the Callisto solar radio spectrometer.

Figure 1 ~ An LWA antenna installed at the observatory site in Bleien, Switzerland. Chicken wire mesh on the ground functions as ground reflector to improve antenna gain and its beam pattern. The blue plastic tube contains two coaxial cables (one per linear polarization) going to the observatory. I am not allowed to cut the nearby bushes because the antenna site is in the center of a protected natural zone for birds.

The LWA antenna already has proved to provide perfect conditions for meteor detection and solar radio burst observations; see SARA journals issue Jan-Feb 2014 (S. Nelson), pages 37-43 and issue May-June 2014 (C. Monstein), pages 75-79. Now, I wanted to test if the system is sensitive enough [2] and stable enough to observe galactic radio emission at low frequencies. Observations during 10 days in June showed some periodic structure in the light curves with a frequency of about 1/24h; see figure 2.

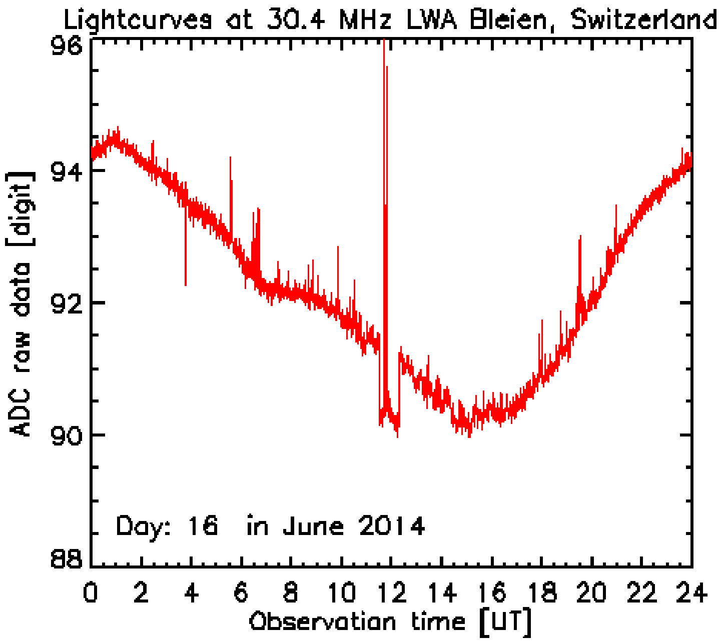

Figure 2 ~ Callisto light curve observed for a 24 h period on June 16 2014 at 30.4 MHz with 300 KHz radiometric bandwidth and 80 ms integration time. Positive peaks are due to lightning strokes, strong RFI and solar radio bursts. Negative peaks are due to rainfall and/or saturation due to very strong local RFI which compresses the system gain. The peak amplitude of the light curve is around 01:00 UT.

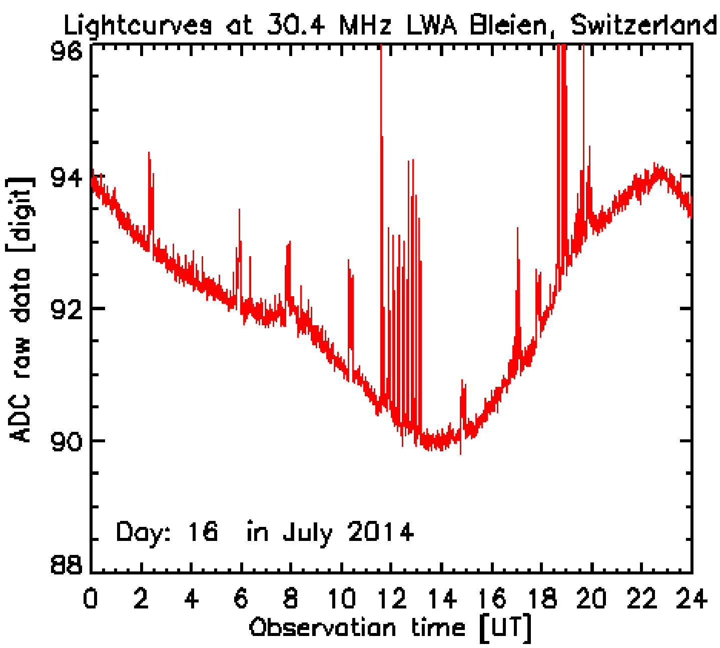

Figure 3 ~ Similar light curve as shown in figure 2 observed one month later on July 16 2014 with the same conditions of 30.4 MHz with 300 KHz radiometric bandwidth and 80 ms integration time. As before, positive peaks are due to lightning strokes, strong RFI and solar radio bursts. Negative peaks are due to rainfall and/or saturation due to very strong local RFI which compresses system gain. The peak amplitude of the light curve is now earlier at around 23:00 UT.

My first idea was that the periodic structure may be caused by some daily temperature drift of the low noise amplifier or spectrometer. I then decided to append all data in time (figure 4) and to conduct a time analysis to find precise information about its period. This analysis could be done by Fourier-Transform of the light curves with a read out of the frequency with the peak amplitude. However, this analysis is much easier with a special function called *periodogram()*, which was originally developed for the SOHO solar satellite to find periods in solar phenomena. This function directly produced a probability plot of the period as shown in figure 5. It also produced a numerical value for the period on the order of 23 h 56 min, thus demonstrating the source to be of sidereal origin. To be on the safe side the observations were reproduced one month later, from which we can see that the peak of the light curve is now 2 hours earlier (figure 3). A sidereal day is about 4 minutes shorter than a solar day. A rough calculation gives 30 days x 4 min/day = 2 h earlier. The peak shift from 01:00 UT in June back to 23:00 UT in July is exactly that amount, so any manmade or terrestrial source for the periodic signal can be ruled out and it can be concluded that the source is the Milky Way.

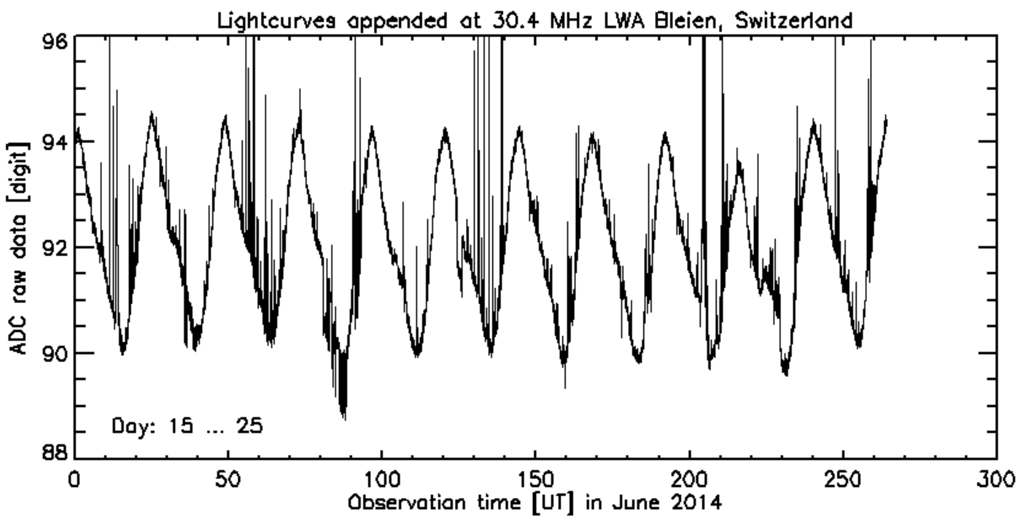

Figure 4 ~ Several consecutive light curves appended in time to allow a time series analysis. The plot is obviously periodic, but is it of terrestrial origin (temperature drift or local RFI) or does it have a sidereal period?

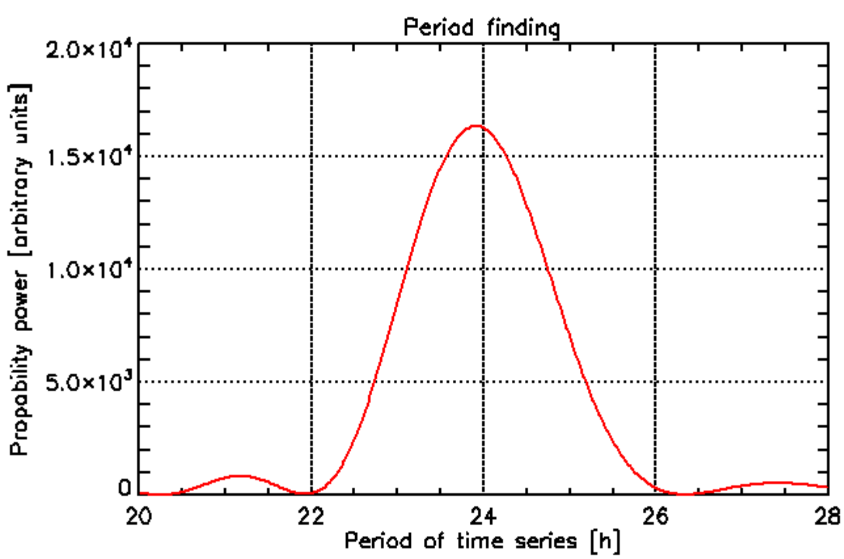

Figure 5 ~ Period analysis conducted with an IDL function called *power=periodogram()*. It uses the method of Horne and Baliuna (Ap.J. 1986) to calculate the periodogram within a user-set frequency or period limits in a time series of data. It was originally designed for the solar satellite SOHO - CDS. The peak of the probability plot is a few minutes below 24 hours proving, that the signal is of sidereal origin.

Conclusion

Historic observations can be reproduced with modern and cheap equipment despite bad conditions due to RFI. This is a nice and simple students experiment to demonstrate the sidereal period of the Milky Way.

Further information and reading:

[1] K. Kellermann and B. Sheets, Serendipitous Discoveries In Radio Astronomy, NRAO, Green Bank, 1983
[2] John D. Kraus, Radio Astronomy, 2nd Ed., Powell, OH, Cygnus-Quasar Books, 1986

More information about the instrument Callisto and the network e-Callisto can be found here:
http://e-callisto.org/

More information about the LWA can be found here:
http://www.reeve.com/RadioScience/Antennas/ActiveCrossed-Dipole/ActiveBalunOrderInfo.htm