Low–Frequency Solar Radio Bursts from Green Bank

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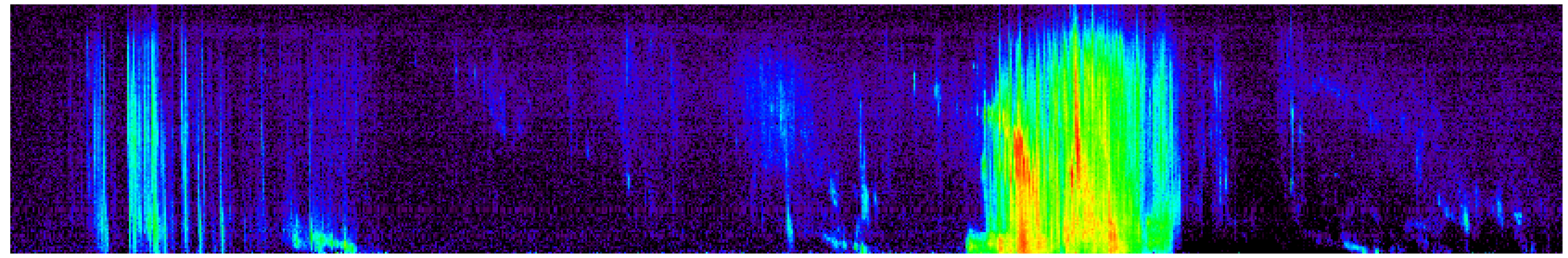

FIGURE 1: View of the Low Frequency Spectrometer (right) and the 13.7 m antenna at Green Bank, WV. Upgrades will add a 300–850 MHz feed and an 80–350 MHz log-periodic antenna on the 13.7 m antenna feeding dual polarizations to a Callisto spectrometer supplied by ETH/Zürich, and later replace the Erickson antenna with a set of four dipoles.

GBSRBS

It is a long–standing embarrassment that dynamic spectra of solar radio bursts have not been publicly available in western–hemisphere times for the study of solar phenomena. Ground–based US solar observers have not been able to compare their data directly with observations of Type II, III and IV radio bursts. To remedy this situation, funding has been received from NSF's Atmospheric Sciences division to establish a radio spectrometer, called the *Green Bank Solar Radio Burst Spectrometer (GBSRBS)*, in the radio–quiet zone at NRAO's Green Bank site. This funding is being used to develop instruments to produce high–quality dynamic spectra from 10–850 MHz that will be freely available, including real–time displays.

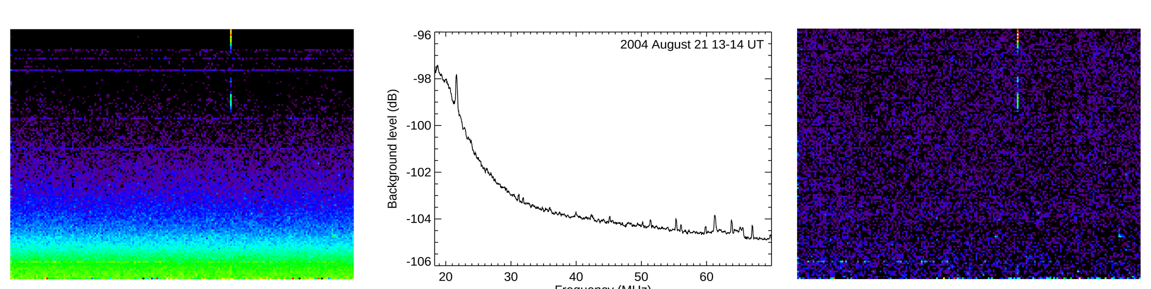

FIGURE 2: Example of a raw spectrum (left), the derived background level (middle) and the subtracted spectrum for a quiet hour of data. Presently we do not omit any channels from the spectra.

Initial development used a dipole antenna provided by NRL together with an active balun preamplifier, HP spectrum analyzer, and associated software to produce dynamic spectra in the range 18–70 MHz that are demonstrated in this poster. This setup is very similar to Bill Erickson's BIRS system in Australia, but uses an efficient low–power amplifier designed at NRAO's CDL. Future technical improvements are described in the poster by Bradley et al. The present configuration operates from approximately 1100-0000 UT each day. The frequency band from 18-70 MHz is swept once per second, linearly sampling 1700 frequency channels. Data from January 18, 2004, onwards are available at the web site `http://www.nrao.edu/astrores/gbsrbs`.

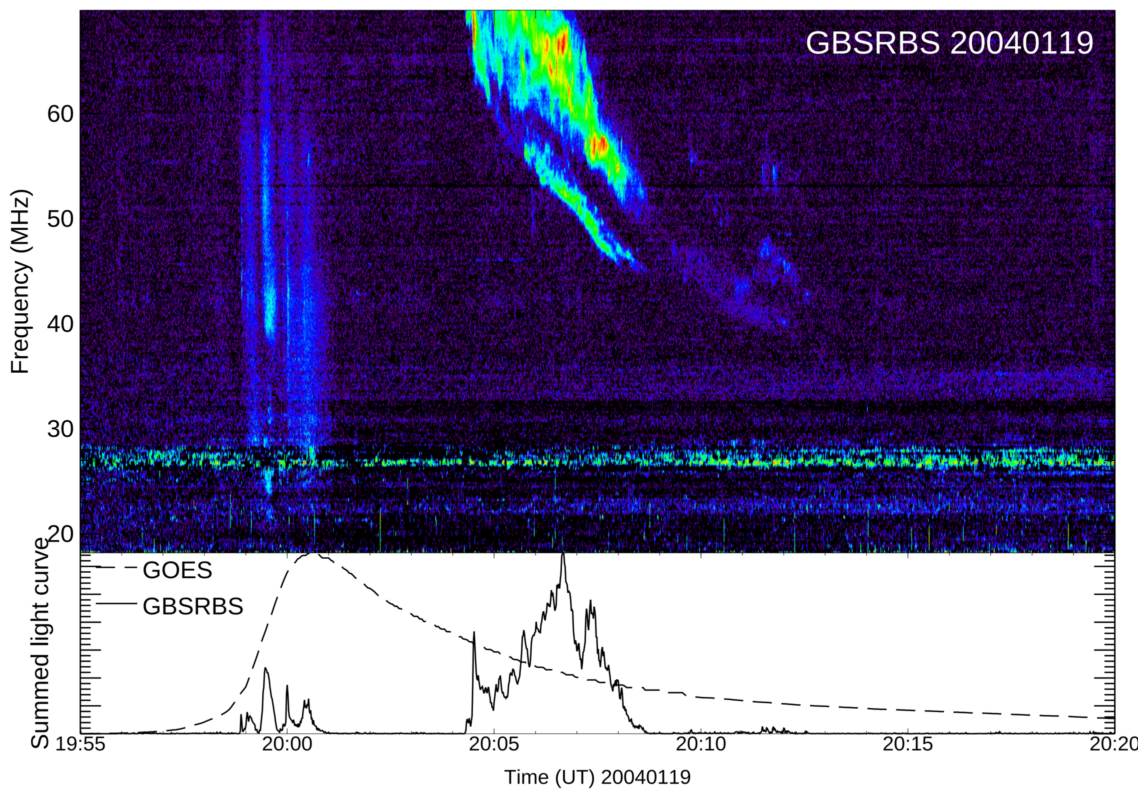

FIGURE 3: This is a classic flare event with fast–frequency–drift Type III bursts occurring during the rise of the soft X–ray emission (the GOES light curve, 0.5–4 Å soft X–rays) and a slower–drift Type II burst showing split bands of emission during the decline of the soft X–rays. The Type III bursts are attributed to beams of keV–energy electrons travelling outwards through the solar corona on open field lines, exciting electrostatic Langmuir waves at the plasma frequency that are converted into fundamental and harmonic electromagnetic waves. Type II bursts travel at speeds of order 1000 km/s, i.e., in excess of the Alfvén speed in the corona, and are attributed to shocks: whether these shocks are driven by coronal mass ejections is still a major Space Weather issue.

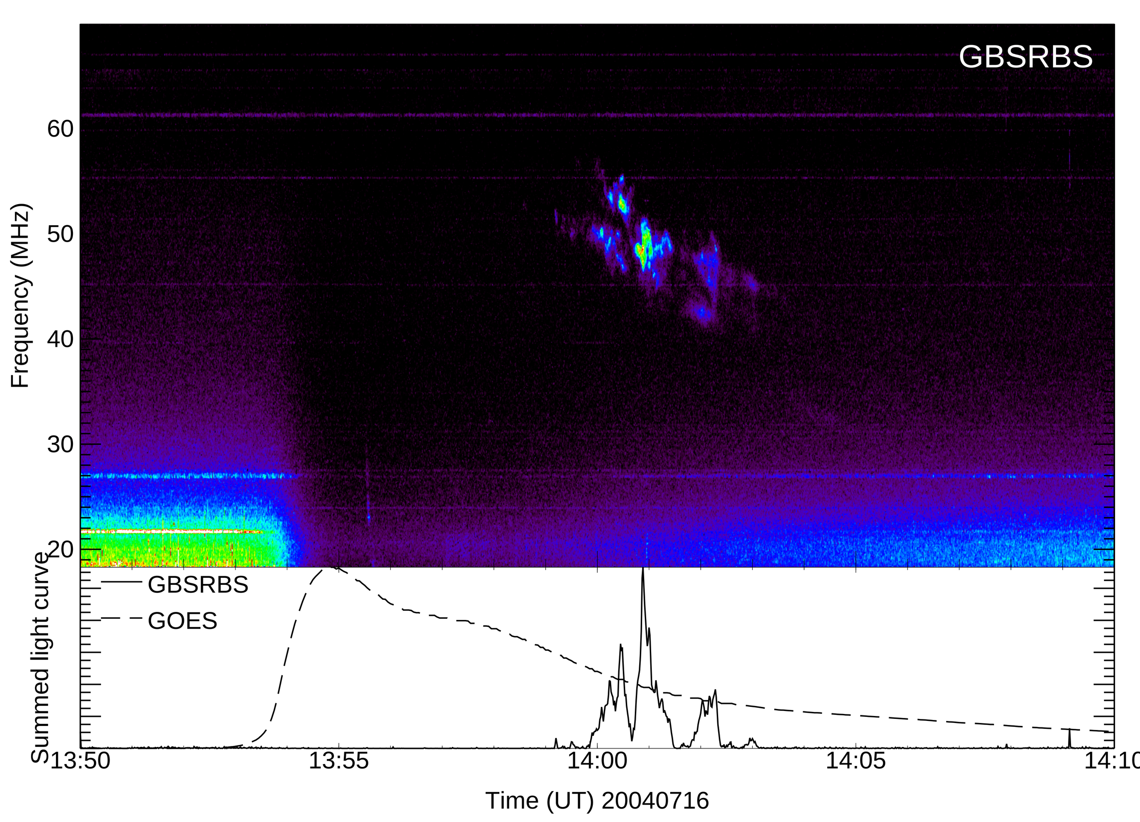

FIGURE 4: Short–wave fadeout followed by a Type II burst. In this figure the galactic background emission (the rise at low frequencies) has not been subtracted, and during the flare (indicated by the GOES soft X–ray light curve) it is seen to disappear. Solar flares produce high levels of EUV and X–ray emission that can significantly alter the Earth's ionosphere. The three main layers in the ionosphere are the D layer at about 90 km, the E layer at 110 km and the F layer above 200 km. Solar flare X–rays produce enhanced ionization and thus absorption in the D layer that affects both terrestrial HF communications as well as cosmic signals.

The Green Bank site is a big advantage for GBSRBS, as illustrated in Fig. 2. It is a very radio–quiet environment, and the small number of narrow–band interfering signals are not much above the cosmic background. In addition to these features, there is also occasional broadband interference apparently associated with high–voltage power lines, and in summer both lightning and sporadic E–layer effects (Fig. 7) are prominent.

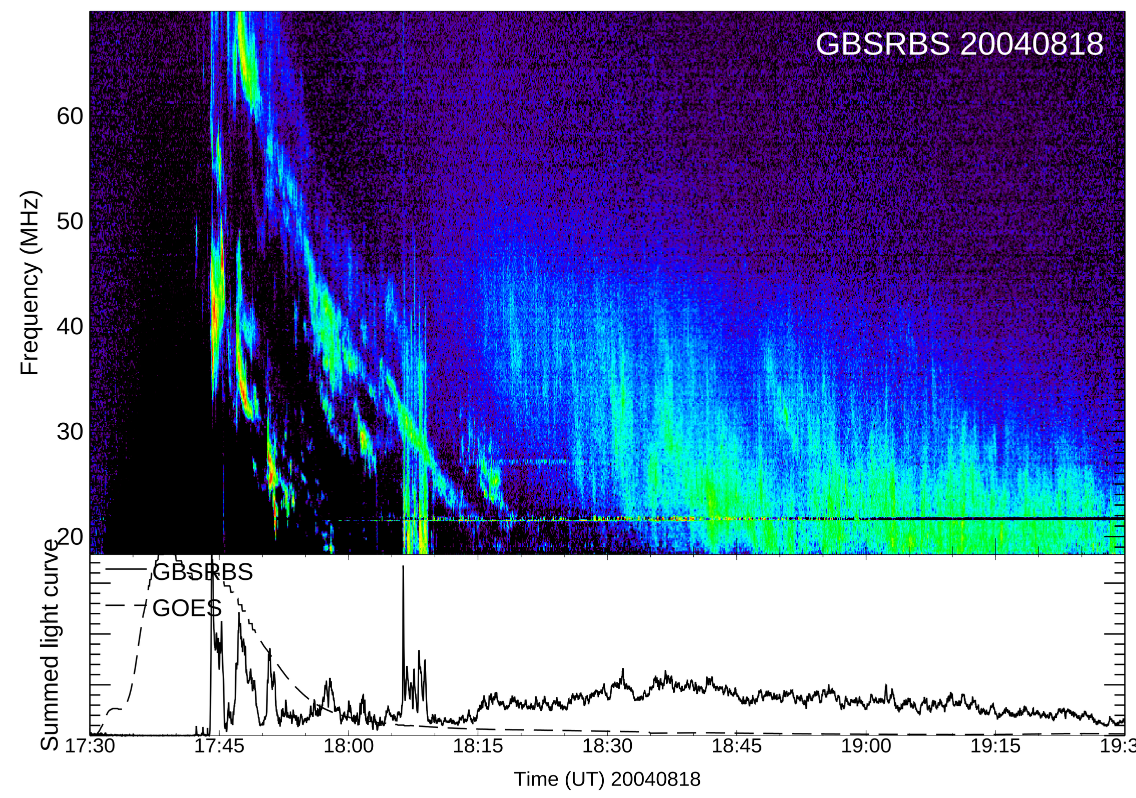

FIGURE 5: This event shows a short–wave fadeout followed by a large complex Type II event (both fundamental and harmonic bands are visible) and then Type IV emission, the broadband continuum after 18:10 UT. The Type IV emission is apparently due to long–lived energetic electrons accelerated by the flare and residing in the corona for some time afterwards.

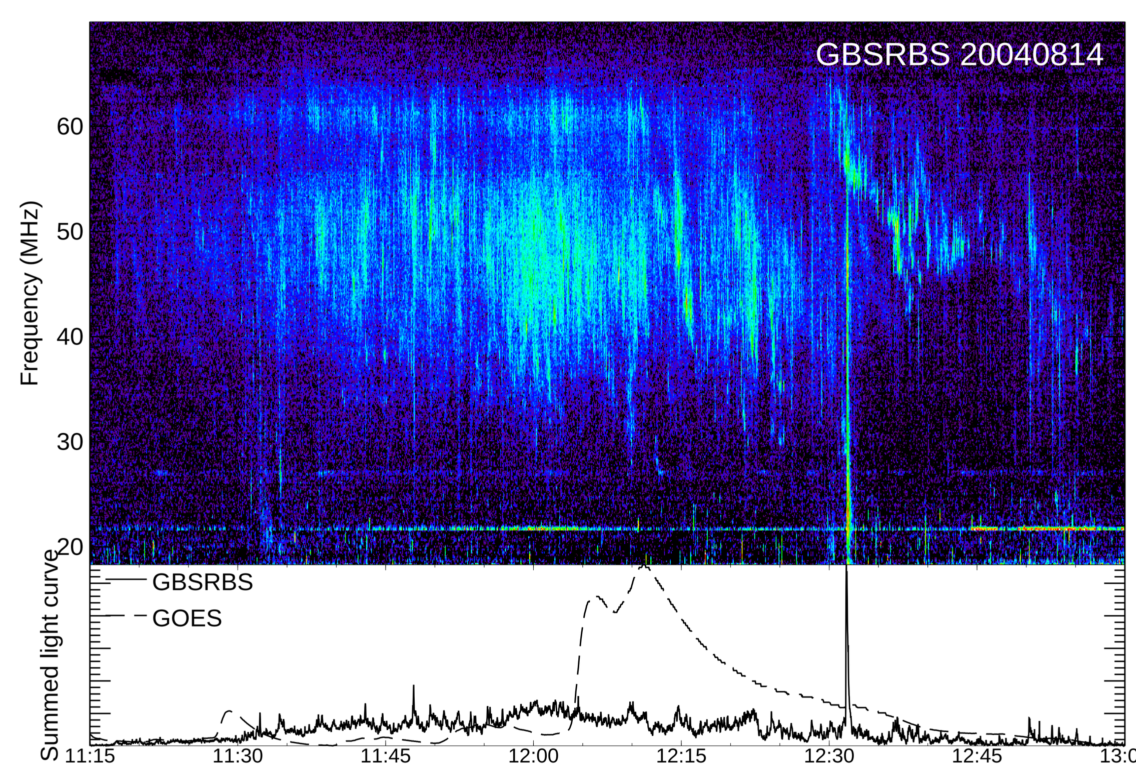

FIGURE 6: The Sun can produce radio emission even when no flares are occurring in the lower atmosphere. This is an example of "storm continuum" associated with a large flare–productive active region, but the continuum lasted for a week and was not due to flares, instead indicating the presence of a steady acceleration region somewhere high in the corona. Such "storms" can take the form shown, or can consist of many fast–drift Type III bursts.

Observing at Low Frequencies

Anyone who has tried to calibrate low–frequency data from the VLA or GMRT knows that if the Sun is anywhere within several beamwidths and is active then it causes major problems for data analysis. The quiet Sun is not particularly strong below 100 MHz, but activity makes it a very bright and rapidly varying source. Figures 3–8 illustrate some of the phenomena at low frequencies that solar astronomers study for their physical relevance, but that sidereal observers are unlikely to appreciate as much. All figures are GBSRBS data, generally processed to remove narrow interference features and the galactic background at low frequencies. For comparison, solar soft X–ray light curves from the GOES satellites are shown.

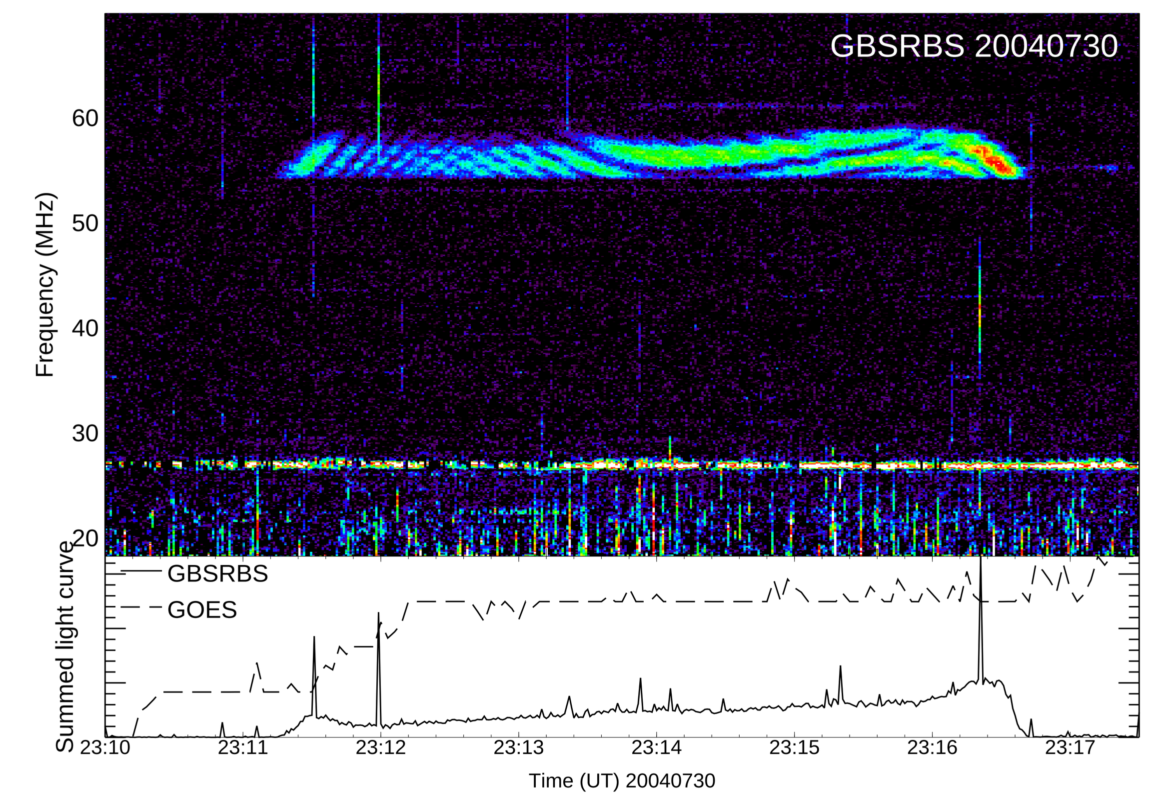

FIGURE 7: This is an example of the effects of "sporadic E–layer ionization". Sporadic–E is a still poorly understood phenomenon, but it is known to be prevalent over West Virginia during summer months. We see it as an enhancement and modulation of the 54–58 MHz carrier from a TV station in Pittsburgh (54–60 MHz is the band for channel 2; we also see channel 3 at 60–66 MHz).

Most solar radio emission below 100 MHz is due to plasma emission at the fundamental or harmonic of the electron plasma frequency, $f_p = 9000\sqrt{n_e}$ Hz, and therefore a given frequency corresponds to a certain density and a corresponding height. The frequency range 70 to 18 MHz corresponds roughly to a height range from 1.5 to 3 $R_\odot$, well above the height range where other forms of flare energy release are detected in X–rays or microwaves.

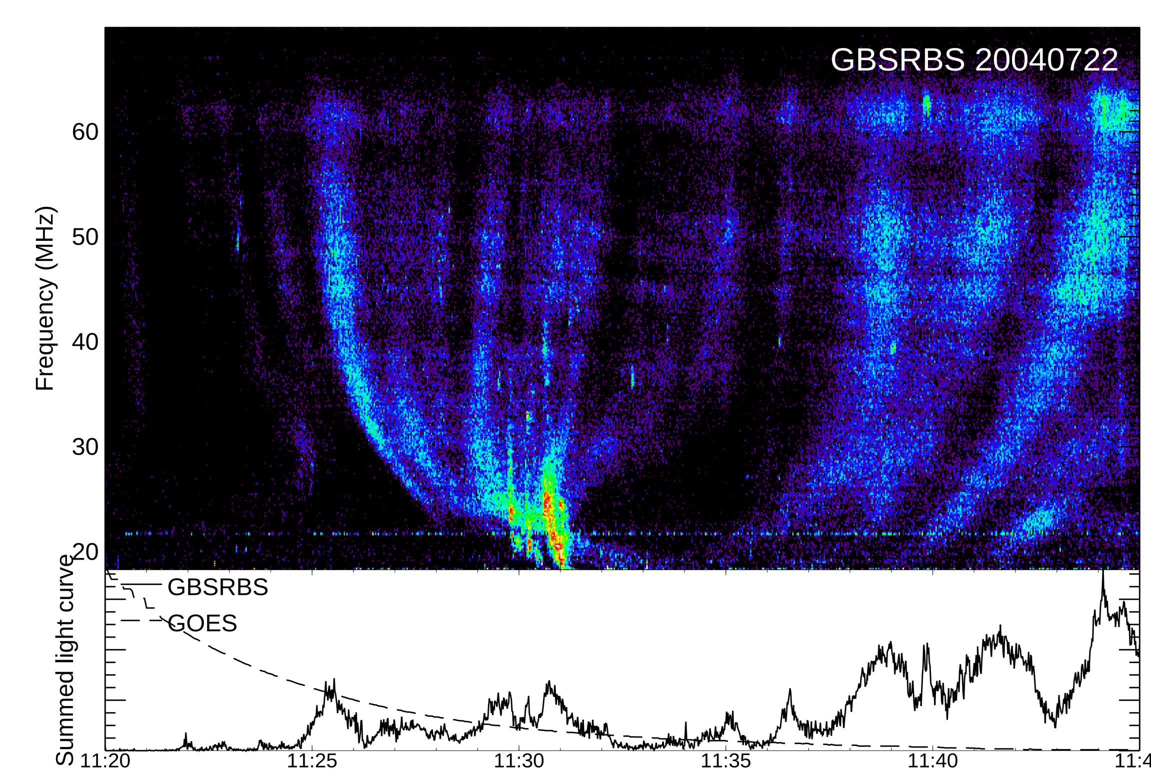

FIGURE 8: Another ionospheric feature than can be seen when there is strong solar continuum present are fringes, particularly near sunrise and sunset. These are attributed to focussing by travelling disturbances in the E layer.

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