EDGES MEMO #424

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 617-715-5533

To: EDGES group

From: Alan E.E. Rogers

Subject: Satellite reflections of FM radio may explain additional RFI in FM band

We are seeing a higher level of RFI from EDGES-3 at the MRO than we saw at the same time of day and year as we saw with EDGES-2 midband in 2018. Figure 1 shows the FM carriers reflected from the micrometeorites and satellites which may include Starlink during nighttime only on day 217 of 2023 in the top plot compared with data from day 217 of 2018 which was before Starlink was launched in 2019.

The effects of a starlink satellite reflection of a FM radio station are estimated assuming

distance dist = 550 km
radar cross-section 100 square m (uncertain some V2 already launched)
EDGES gain 6
transmitter gain 1
FM transmitter 100 kw at 100 MHz
EDGES resolution 6 kHz

from which a 35K reflection is estimated with the 6 kHz resolution of EDGES assuming an isotropic reflection over 4PI radians. Initially it was thought that the added FM channels seen in 2023 data would be much more constant but GRAVES radar station (reference 1) reports that FM reflections from a single Starlink satellite which last for several seconds. Prabu et al. report reflections of FM radio stations from the International Space Station and many other low earth orbit satellites using the MWA.

I estimate that the horizon limit of the location of a FM transmitter for a starlink reflection at 550 km altitude is about 5000 km compared with the 2000 km for FM transmitters that can be reflected by the micrometeorites which create pockets of ionization upon entry of the earth's atmosphere at about 100 km altitude.

If the locations of the FM transmitters that produced the spectrum in the upper plot of Figure 1 are farther away from the EDGES-3 antenna than those in the lower plot this would be an indication that the reflection might be from a satellite. However it is difficult to identify the location from the frequency as there are many FM stations assigned to the same channel spread across Australia.

Figures 2 and 3 show waterfall plots of the spectra from UT 18 to 19 on day 217 from EDGES-3 in 2023 and EDGES-2 midband in 2018 respectively. Based on the measurements of the bi-static radar formed by the FM stations around the MWA listed in Prabu et al. 2020 and Hennessy et al. 2022 it is very likely that the EDGES at the MRO is subject to reflections from satellites as well as from meteors but it is not possible to identify which satellites are involved as EDGES has no angular resolution of the reflections.

In summary given the increase in reflections of FM radio transmitters from satellites it is now even more important to find locations for the global 21-cm observations with relatively few FM transmitters within 5000 km. Some potential sites are discussed in memos 54, 311 ,379, 383 and 415. Wake island mentioned in memo 17 is possibly the most remote island in the world accessible by air as Wake no longer has an active FM transmitter on the island so it might be another potential new site to investigate further. While a site on the moon is a possibility it will require a large ground plane as discussed in memo 422.

References:

https://britastro.org/forums/topic/starlink-satellites-detected-by-radio-reflection

Prabu, S., Hancock, P., Zhang, X. and Tingay, S.J., 2020. A low-frequency blind survey of the low Earth orbit environment using non-coherent passive radar with the Murchison widefield array. *Publications of the Astronomical Society of Australia*, *37*, p.e052.

Prabu, S., Hancock, P.J., Zhang, X. and Tingay, S.J., 2020. The development of non-coherent passive radar techniques for space situational awareness with the Murchison Widefield Array. *Publications of the Astronomical Society of Australia*, *37*, p.e010.

Hennessy, B., Rutten, M., Young, R., Tingay, S., Summers, A., Gustainis, D., Crosse, B. and Sokolowski, M., 2022. Establishing the Capabilities of the Murchison Widefield Array as a Passive Radar for the Surveillance of Space. *Remote Sensing*, *14*(11), p.2571.

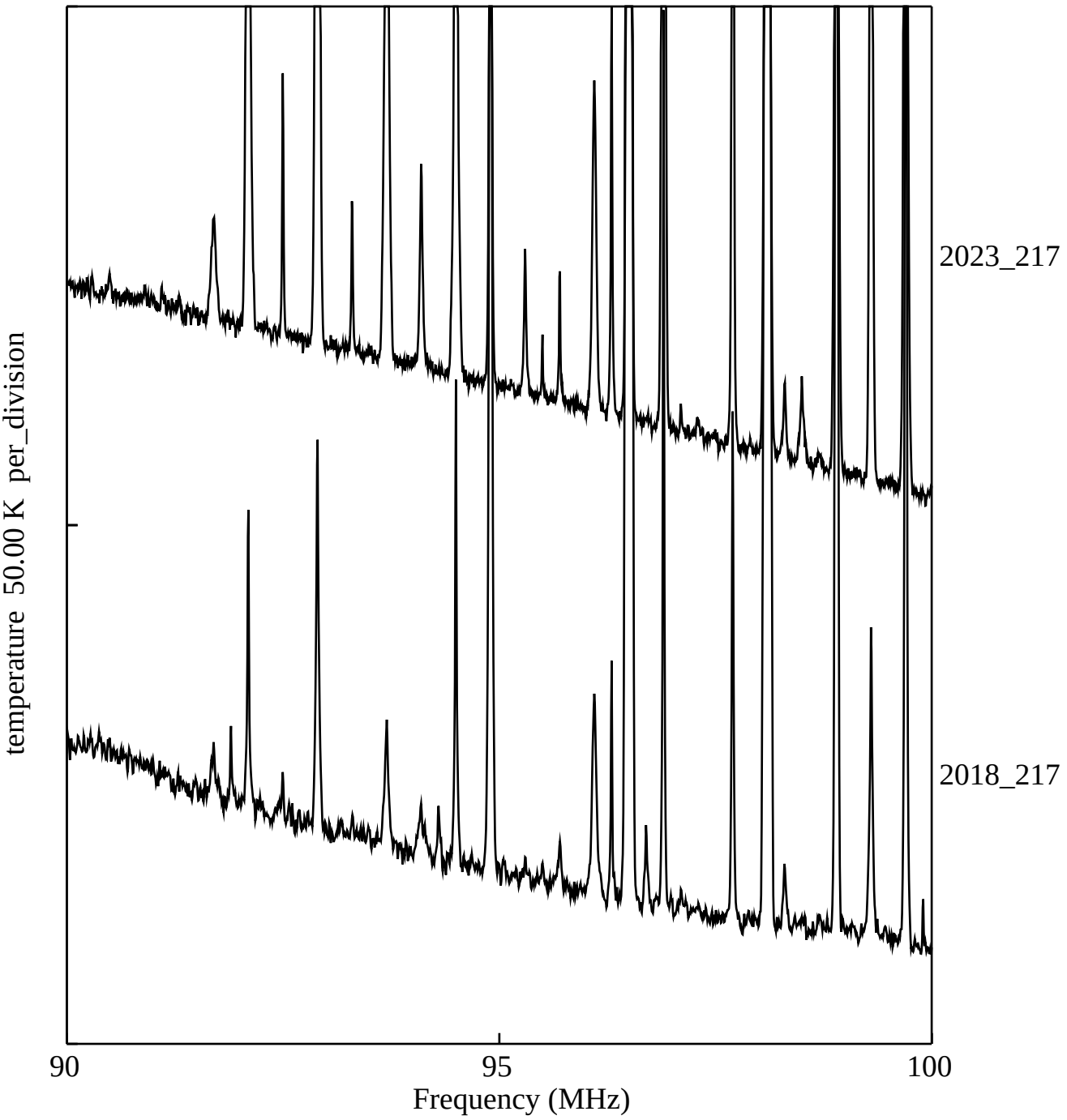

Figure 1. Spectra averages of nighttime EDGES-3 2023:217 and EDGES-2 2018:217 at the MRO.

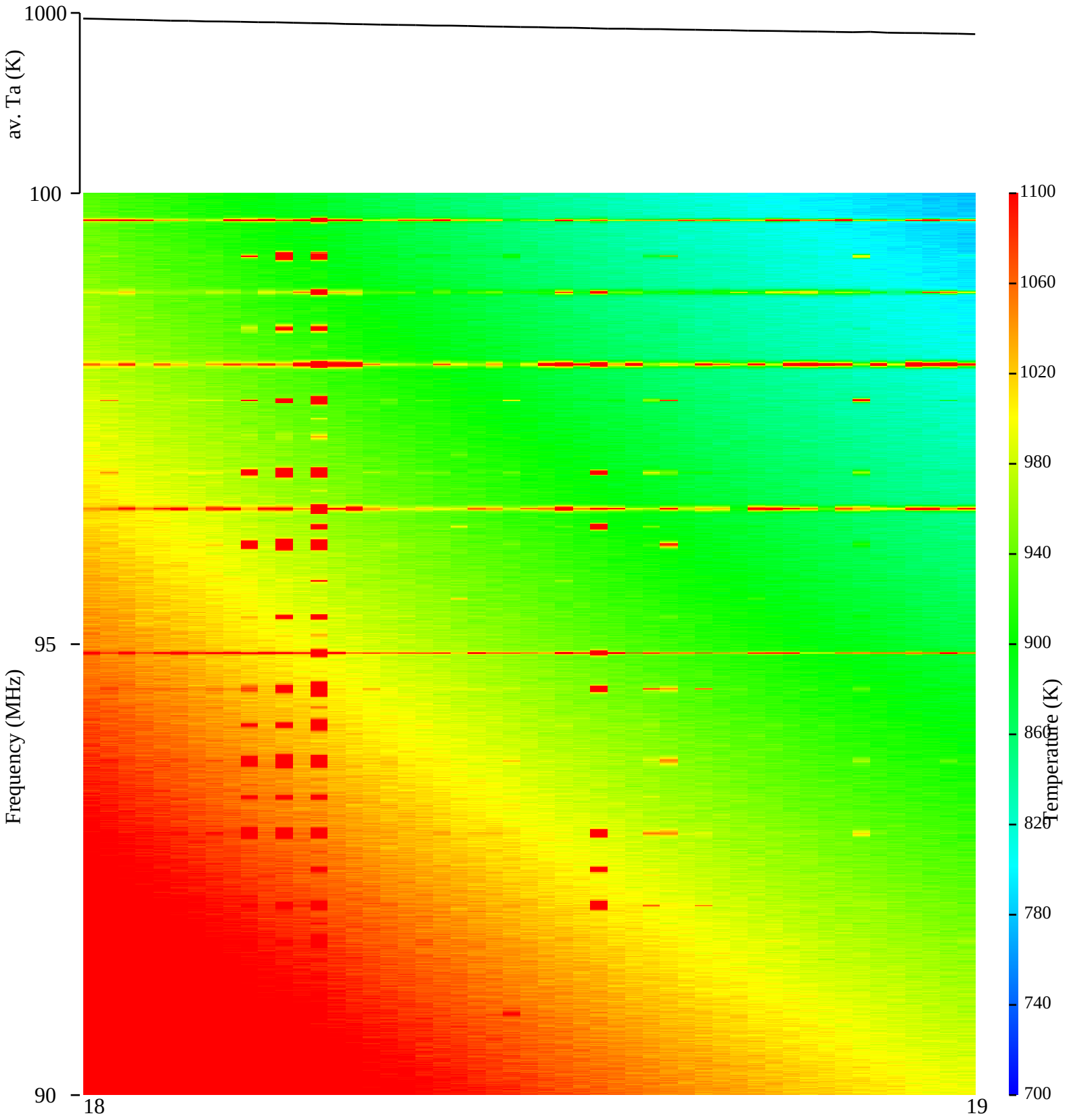

Figure 2. Waterfall plot of data from EDGES-3 2023:217 18 to 19 UT

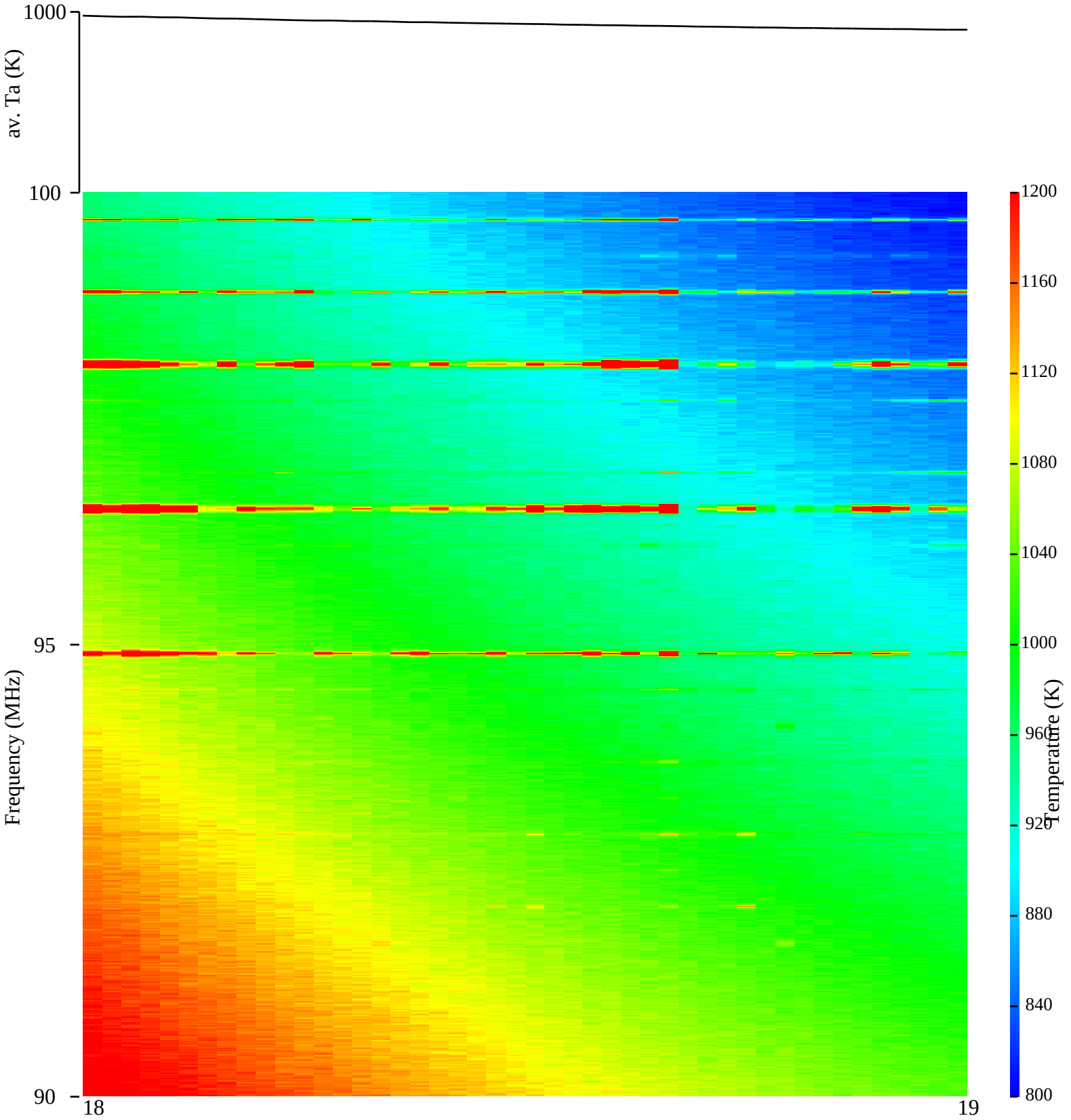

Figure 3. Waterfall plot of data from EDGES-2 midband 2018:217 18 to 19 UT