THE SEARCH FOR ELECTROSTATIC DISCHARGES ON MARS. N. O. Renno[1] and C. S. Ruf[2], [1]Department of Atmospheric, Oceanic, and Space Sciences (Ann Arbor, MI 48109, e-mail: renno@alum.mit.edu), [2]Department of Atmospheric, Oceanic, and Space Sciences (Ann Arbor, MI 48109, e-mail: cruf@umich.edu).

Introduction: Ruf *et al.* (2009) used the Deep Space Network (DSN) to search for electrostatic discharges on Mars and found evidence for it in the form of non-thermal radiation modulated by Schumann Resonances. They hypothesized that this signal was caused by electrostatic discharges in a deep convective dust storm that developed during their measurements. Anderson *et al.* (2012) followed up on this finding and used the Allen Telescope Array (ATA) to search for similar events, but did not find evidence for it. Unfortunately, the ATA search was not conducted during the dust storm season when deep convective storms are likely to occur. The ubiquitous dust devils and small dust storms that were instead present during the ATA observations are shown to be too shallow to excite Schumann Resonances and the modulated non-thermal radiation observed by Ruf *et al.* (2009).

Inspection of the spectral and temporal behavior of the DSN and ATA data confirm that Ruf *et al.* (2009) detected evidence of the emission on non-thermal radiation by Mars, and that Anderson *et al.* (2012) detected man-made pulse modulated telecommunication signals. Ruf *et al.* (2009) found evidence for many 'discharge events' during a 35-km deep dust storm on 8 June 2006. The simple spectral peak at 10 Hz found in man-made signal deteted by the ATA (Anderson *et al.*, 2012) does not adequately characterize the events detected by the DSN. The DSN signal is characterized by spectral peaks at several modes of the martian Schumann Resonances (SR) as well as at harmonics that provide evidence for a trigger mechanism (Ruf *et al.*, 2009).

The Excitation of Schumann Resonances: The maximum charge moment of a dust devil or dust storm is $M_{Max} = zA\varepsilon E_{Max}$, where z is the depth of the dust devil or dust storm, A is the area covered by the dust plume, $\varepsilon \approx 8.85\times10^{-12}$ F/m is the electric permittivity of the martian air (~free space), and E_{Max} is the maximum electric field in the dust storm, taken as the nearly critical (close to the breakdown value) electric field amplitude $E_{\max} \sim 20$ kV/m. Ruf et al. (2009) estimated $M_{Max} \approx 10^9$ C m for the 8 June 2006 dust storm. For a typical dust devil, less than 1 km deep with dust cloud area smaller than 1 km^2, we find $M_{Max} << 10^2$ C m. Ruf *et al.* (2009) calculate the maximum forcing of the SR by assuming that the dust storm would be completely discharged during the minute long bursts seen in the kurtosis. In this case the averaged rate of charge transfer squared would be 10^{16} (C m)^2/s for the 8 June 2006 dust storm and less than 1 (C m)^2/s for typical dust devils. Thus, the forcing of SR by a typical dust devil is at least 10^{16} times smaller than that of the June 2006 dust storm. Typical dust storms are shallow, no more than a few km deep and much less likely to produce charge separation as large as storms with rapid vertical development such as the 8 June 2006 dust storm; therefore they produce charge moment at least an order of magnitude smaller than the 8 June 2006 dust storm. For this reason, the forcing of SR by typically shallow dust storm of similar area is at least ~10^2 times smaller that of the 8 June 2006 dust storm. Shallower dust storms of larger areas are not uncommon, but it is unlikely that the entire dust storm would be electrically active. Convective dust storms of large vertical growth and capable of being strongly electrified, like terrestrial thunderstorms and similar to the June 2006 storm, are more rare. Therefore, the 8 June 2006 convective dust storm is not at all the typical event suggested by Anderson et al. (2012).

Data Analysis: Here we show that a careful data analysis indicates that the signals detected by the ATA resemble man-made pulse modulated telecommunication signals. In contrast, it indicates that the signals detected by the DSN during the 8 June 2006 deep convective dust storm do not resemble man-made signals.

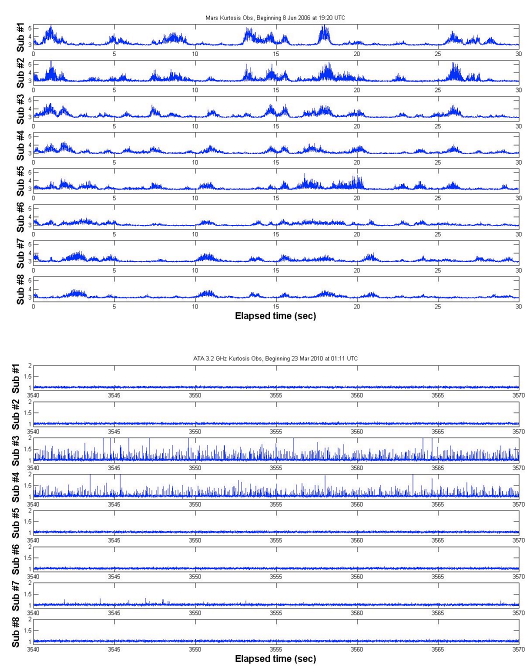

Fig. 1. Comparison between Ruf *et al.* (2009) and Anderson *et al.* (2012) observations of non-thermal signals while viewing Mars. **(top)** Observations of kurtosis at 8 spectral bands on 8 June 2006. **(bottom)** Observations of spectral kurtosis at 8 spectral bands on 23 March 2010. Deviations from 3 (top) and 1 (bottom) indicate the presence of a signal with non-gaussian amplitude distribution.

The Anderson *et al.* (2012) statement that “The frequency structure and timescales of the signals seen in the kurtstrum [i.e. spectral kurtosis] strongly resemble those detected by Ruf et al. (2009) during the 8 June 2006 large-scale dust storm event” is incorrect. The temporal and spectral dependencies of the signals are dissimilar in important ways that suggest very different sources for the two signals. The Anderson *et al.* (2012) observations were made with finer temporal and spectral resolution (1.25 ms and 0.102 MHz, respectively) than were those in Ruf *et al.* (2009), which were 4.2 ms and 2.5 MHz. The resolution of the Anderson *et al.* (2012) observations has been degraded by averaging to 3.75 ms and 2.46 MHz in order to more directly compare them with those of Ruf *et al.* (2009). A 30 s time interval of both observations in each of 8 contiguous spectral bands is shown in Fig. 1 for periods when strong non-thermal signals are present. Two significant differences are apparent between the two observations. The spectrum of the Ruf *et al.* (2009) observations extends over all 8 sub-bands, whereas the Anderson *et al.* (2012) observations are limited to just sub-bands 2 and 3.

Signals with sharply restricted spectral extent are a common characteristic of man-made telecommunications. The time dependencies of the signals detected by and Ruf *et al.* (2009) and Anderson *et al.* (2012) are quite different. In the case of Ruf *et al.*, the non-thermal events tend to persist for several seconds or more. The Anderson *et al.* non-thermal events, on the other hand, occur in brief bursts. The non-thermal events in the two cases have very different time dependence. In the case of the Anderson *et al.* (2012) observations, there are clear intervals of time between the short non-thermal bursts in which no signal is present. This is also a common characteristic of man-made pulse modulated telecommunication signals. The Ruf *et al.* (2009) observations, on the other hand, do not resemble any common type of telecommunication signal.

The Anderson *et al.* (2012) statement that “10 Hz variations in the kurtstrum are consistent with the expectations for electrostatic discharges as described by Ruf *et al.* (2009)” is not supported by a careful examination of the observations. In fact, the spectral composition of the two signals is quite different. Power spectra derived from 10 s segments of each of the two signals from Fig. 1. As shown in Fig. 2 the Ruf *et al.* spectrum contains frequency components at three SR frequencies (9.6, 27.8 and 31.6 Hz) and at a number of exact integer multiples of those frequencies (9.6x2, x4, x5, x7, x10; 27.8x2, x4; and 31.6x3). As discussed by Ruf *et al.* (2009), the presence of these harmonics is evidence of a trigger mechanism by the SR modes. Apart from these frequency components, there is very little spectral content in the Ruf *et al.* (2009) signal. The power spectrum of the Anderson *et al.* (2012) signal shown in Fig. 3, on the other hand, contains one prominent spectral feature at 11.2 Hz plus a large number of additional spectral components. Notably, the spectrum does not appear to contain integer harmonics of the 11.2 Hz component or of any other of its larger spectral features. In fact, the Anderson *et al.* (2012) spectrum has the dense spectral distribution common to many spread spectrum-type communication protocols.

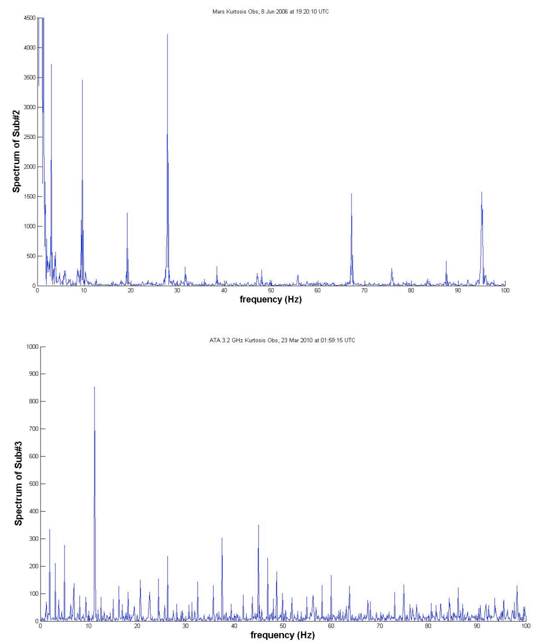

Fig. 2. Comparison between power spectra derived from 10 s time records for Ruf et al. (2009) and Anderson et al. (2012) observations of non-thermal signals while viewing Mars. **(top)** Observations of kurtosis at 8472.5-8475MHz on 8 June 2006. **(bottom)** Observations of spectral kurtosis at 3195-3197.3 on 23 March 2010.

Colclusions: Detailed analysis of the spectral and temporal behavior of the signals detected by Anderson *et al.* (2012) suggests that they originated from man-made pulse modulated telecommunication signals rather than martian electric discharge. In contrast, an identical analysis of the signals detected by Ruf *et al.* (2009) during the 8 June 2006 convective dust storm reveals features that are markedly different from common man-made signals. The analysis indicates that the signals detected by Ruf *et al.* (2009) were most likely modulated by martian Schumann Resonances, as originally hypothesized. The hypothesis proposed by Ruf *et al.* (2009) should be tested by measurementsduring the martian dust storm season when deep convective dust storms are more likely to occur.

References: [1] Ruf, C. S. (2009), *Geophys. Res. Lett.*, **36**, L13202. [2] Anderson, M. et al. (2012), ApJ, 744, 1.