Seasonal Variations of Seismic Activity on Mars? M. Knapmeyer[1], S.C. Stähler[2], M. van Driel[2], J.F. Clinton[2], W. Banerdt[3], M. Böse[2], S. Ceylan[2], C. Charalambous[4], R. Garcia[5], A. Horleston[6], T. Kawamura[7], A. Khan[2], P. Lognonne[7], M. Panning[3], T. Pike[4], J.-R. Scholz[8], R.C. Weber[9]; [1]Rutherfordstr. 2, 12489 Berlin, Germany, martin.knapmeyer@dlr.de, [2]Institute of Geophysics, ETH Zürich, Sonneggstrasse 5, 8092 Zürich, Switzerland, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA, [4]Department of Electrical and Electronic Engineering, Imperial College London, South Kensington Campus, London, SW7 2AZ, United Kingdom, [5]Institut Supérieur de l'Aéronautique et de l'Espace SUPAERO, 10 Avenue Edouard Belin, 31400 Toulouse, France, [6]School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol BS8 1RJ, UK, [7]Université de Paris, Institut de physique du globe de Paris, CNRS, F-75005 Paris, France, [8]Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany, [9]NASA MSFC, NSSTC Mail Code ST13, 320 Sparkman Drive, Huntsville, AL 35805, USA

Introduction: We analyze the sequence of seismic events of different types as recorded by the SEIS instrument of the InSight mission [1,2]. After several weeks without any detection, event counts started to increase at the end of May 2019. The majority of recorded events belongs to the class of 2.4 Hz events, which prominently excite a continuously observed natural resonance frequency. Comparison with expected event counts from a constant-rate Poisson process shows a repeated, stepwise increase of the event rate with time. At the same time, event amplitudes, and hence magnitudes, are found to increase as well.

Event Types: The observed types of events subdivide into two main families [3,4]: Family 1 consists of Broadband and Low Frequency events, with signal frequencies mainly below 1 Hz. These events are most likely of tectonic origin. Family 2 basically contains all other events, which sometimes have signal frequencies up to the Nyquist frequency. The origin and mechanism of these events is not well understood. Family 2 events show a clear evolution in time which cannot explained by observer biases alone.

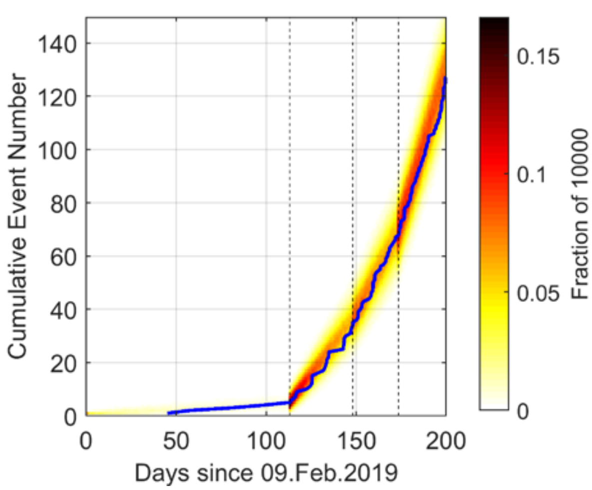

Figure 1 Cumulative event rate of combined HF, VF, and 2.4 Hz events (blue), vs. synthetic sequences (red/yellow shades). Vertical lines indicate times of rate increases.

Event Rates: Estimating event rates as if events are the result of a constant-rate Poisson process leads to contradictions with the statistical properties of those, either in the cumulative event count or in the lag time distribution. These contradictions can be overcome by assuming a step-wise increase of the event rate.

After a sudden onset of seismic detections by the end of May 2019 (about sol 180, $L_S \approx 32°$), especially the combined event rate of the High Frequency, Very High Frequency, and 2.4 Hz family of events increased from 3.6 events/sol in June 2019 to more than 9 events/sol until late August 2019, i.e. increased by a factor of about 3. Figure 1 compares the actual cumulative event rates until the end of August 2019 with the output of 10000 synthetic sequences resulting from a Poisson process with a stepwise increasing event rate.

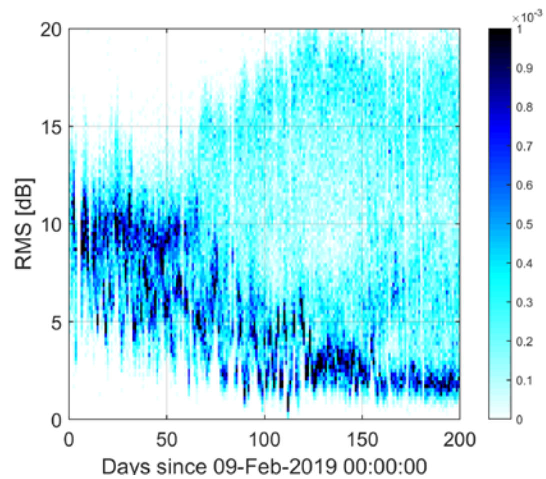

Figure 2 Evolution of the background noise: time-dependent PDF of the displacement noise RMS amplitude, in dB with respect to the lowest value observed up to the end of August 2019, namely 3.2×10^{-12} *m*.

Amplitudes: Although the background noise during the first about 125 sols was considerably higher than afterwards, likely preventing the detection of most events, the rate increase in the later parts of the mission cannot be attributed to an improved signal-to-noise ratio: The typical RMS value as well as the maximum value attained each sol basically remained constant (Figure 2, [5]).

The event magnitudes are estimated to be between 1.3 and 2.3 [2], with epicentral distances of a few tens of degrees. The sources are thus of a significant size.

Conclusions: The statistically significant rate increase during the few months of registration shown in Figure 1 is an observational fact, but at least one complete revolution of Mars, possibly more, is necessary to obtain a firm correlation with possible external forces.

Any deviation from a purely random occurrence of quakes, in both time and space, requires a mechanism to suppress or support the source process. Seismologists on Earth are used to connect seismic activity to plate boundaries, while distinguishing source times from random is challenging. The seismic activity of the Moon is mainly controlled by tidal deformation, at least in terms of source time. What controls the event rate of martian high frequency events is currently elusive.

Mars and Moon are the only extraterrestrial bodies on which extensive listening to natural seismic activity was conducted. Unexpected types of seismic events were found on both. More new science can probably be expected from seismology on other worlds.

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The event catalog used in this study is based on the data recorded by the SEIS instrument on Mars [5]. Noise RMS amplitudes and event catalog [4] are based on waveform data which is released to the public via the NASA Planetary Data System (https://pds.nasa.gov/) and IRIS (https://www.iris.edu/hq/sis/insight) several times a year [5].

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