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****disclaimer for peer reviewer: getting closer to final results, just a little bit of work left before the final discussion can be written but the introduction & methods are mostly complete up until this point. the methods may expand depending on the what addition analysis we do**

Working Title: Setting Our Sights on Mars: Using InSight to Take a Closer Look at the Seismicity of The Red Planet

Abstract:

Two years ago, NASA's Insight mission team successfully installed the first seismometer on the surface of Mars capable of detecting seismic waves. By looking at the characteristics of these waveform signals, seismologists hope to gain a better understanding of the structural features and chemical composition below the visible surface of the planet. The mission's goal is to answer questions about the early formation processes of Mars as well as the ongoing processes affecting the planet today, either on the surface or deep within. We created a visual catalog of the waveform data and used it to identify common features among them. Based on previously reported events, we analyzed these waveforms with the goal of constraining the location of the event and the possible processes contributing to these signals. (MAJOR FINDING)

Introduction:

On November 26, 2018, NASA's Mars InSight mission team successfully installed the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) lander on the surface of Mars. The lander is outfitted with many instruments hoping to answer the major questions surrounding the formation and current structure of Earth's most interesting neighbor. One of these instruments, the Seismic Experiment for Interior Structure (SEIS), is the first seismometer on the surface of Mars capable of detecting seismic signals (Banerdt 2020). Using this data, seismologists can begin to investigate the early formation processes of the rocky planets of our inner solar system as well as gain a better understanding of the current processes shaping the red planet (Knapmeyer-Endrun 2020).

Characteristics of the seismic signals can aid in constraining the current models of the structure of Mars as well as provide information about the source of the event. This project will focus on analyzing the body waves which travel through the interior of the planet. Body waves include primary waves, or P-waves, which are longitudinal and secondary waves, or S-waves,

which are transverse. The P-waves cause motion in the direction of propagation and tracing that motion can be used to estimate the direction of the origin event relative to the lander. S-waves propagate slower than P-waves and therefore the delay in arrival time at the seismometer can be used to estimate the epicentral distance. Since S-waves can only move through solids, they can be used to look at the characteristics of the interior of Mars by determining the depth of possible liquid components (Knapmeyer-Endrun 2020). ****ADD CITATIONS****

Unlike Earth, Mars's crust is composed of a single tectonic plate and therefore intraplate tectonics, such as faulting, and impacts are expected to be the major contributors to the seismicity of the planet. (Clinton 2018)(Longnonne 2019). The lander is located about 1600km west of the Cerberus Fossae region, which is hypothesized to be an active tectonic structure and a major contributor to Mars' seismicity (Banerdt 2020). This region has already contributed two of the clearest signals collected by InSight thus far (Giardini 2020). We choose these two events, S0173a and S0235b, as references to compare other signals against.

In this paper, we will catalog and characterize the seismic events detected and reported by the Mars Quake Service (MQS) in order to expand our understanding of Mars. By using events S0173a and S0235b as reference, we will attempt to constrain the location of other reported events through polarization analysis of the waveforms and calculated particle motion. Additionally, we will begin to hypothesize about the phenomena associated with these seismic signals by....

Observations & Data Reduction & Methods:

This project took advantage of the waveform data in Mars Seismic Catalog provided by the Insight Marsquake Service (MQS). It was downloaded directly from the Incorporated Research Institutions for Seismology (IRIS) database using a function of the python package ObsPy. The instrument of interest for this project is the very broadband (VBB) seismometer, which is a part of the seismometer package, Seismic Experiment for Internal Structure (SEIS). The Insight mission successfully installed the geophysical observatory on 26 November 2019 and the data used for this analysis extends from 1 January 2019 to 31 December 19 (InSight Marsquake Service). Each event was then categorized based on their frequency content and those containing a possible seismic signal were tagged as candidates for further analysis. These tagged events were next filtered over four different frequency ranges, 2-8Hz, 1-4Hz, 0.125-0.1Hz, and 0.03-0.125Hz which helped us to look more closely at the wavetrains before

performing a polarization analysis. In order to perform this analysis, the three data streams from the different components of the seismometer needed to be recombined using a specific equation pulled from (Suemoto 2020). Using Equation 1, we reorientated the data such that each data stream now pointed in the north, east and azimuthal direction.

(INSERT MATRIX EQUATION)

Three new data streams were then extracted and used to plot the particle motion at the seismometer of the arriving P and S waves. These results were used to estimate the location of the origin event and hypothesize about the possible source mechanisms. ****INCLUDE CALCULATIONS FROM TTBOX OR AN EQUATION FOR SOURCE MECHANISM ANALYSIS****

Analysis & Results:

After analyzing the candidates in different frequency spaces, we identified one event as likely having seismic origin in addition to our two previously stated references. The event, now known as S0325a, occurred on 26 October 19 with the P-wave arriving at 06:58:58 UTC and the S-wave arriving at 07:02:56 UTC.

- TTBox explanation
- BAz calculations
- mention the glitch in 173a / appeared in other possible events

Discussion:

The particle motion of S0325a was plotted on two different cross sections and as a mapview for the arrival window of each waveform. Based on the intrinsic characteristics of longitudinal and transverse waves, we were able to determine that the event originated slightly south of due east. We also estimate that the epicentral distance is farther than that of the two reference events based on the longer separation between the P and S wave arrival shown in the seismogram. This was confirmed by...

The polarization analysis as well as the distance of ____ indicate that event S0235a likely originated from Cerberus Fossae which is consistent with expectations predicted by …. (Longonne paper?)(Clinton paper?). Because of its proximity to S0173a and S0235b, this event most likely was triggered by a similar source mechanism like….(Lognonne? Banerdt?).

- ➢ Include what the BAz + distance means
    - compare to the reference events to constrain the event location
- ➢ TTBox + S-wave characteristics shows about the internal structure or source mechanism

Conclusion:

Using SEIS, we were able to create a catalog of seismic events occurring on Mars between 1 January 2019 and 31 December 20. We focused specifically on an event named S0325a and attempted to gather as much information as possible from the waveform data. By specifically focusing on the body waves we were able to conclude that the event originated in Cerberus Fossae about _____km away. Based on this we can assume that the source mechanism was _____.

As the mission continues more data will become available that can provide a more complete picture of the seismicity of Mars. By also gaining a better understanding of seismology using a single instrument, we can begin to develop better technology and data processing techniques that can be applied to InSight data as well as data from future missions. These updated methods can then be used to investigate the interior of other small bodies in our solar system, like Europa or Titan. Both(?) are hypothesized to be seismically active due to tidal forces from Jupiter and Saturn respectively.