



Sounds in the Martian Atmosphere

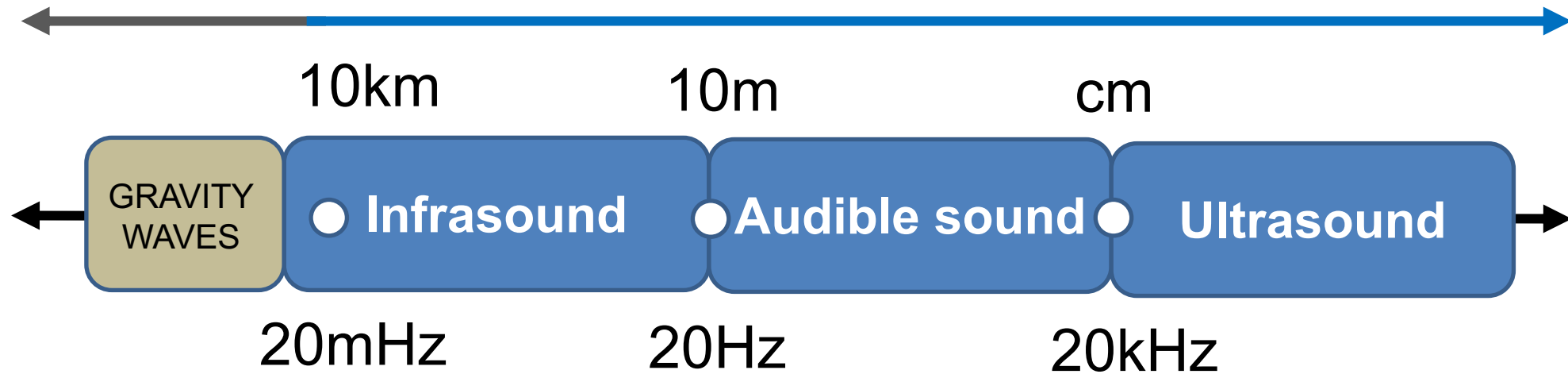
Lucie ROLLAND
Physicienne Adjointe OCA/Géoazur
InSight Science Team member
Atmospheres and Impact Working Groups

InSight@School2020 Centre International de Valbonne

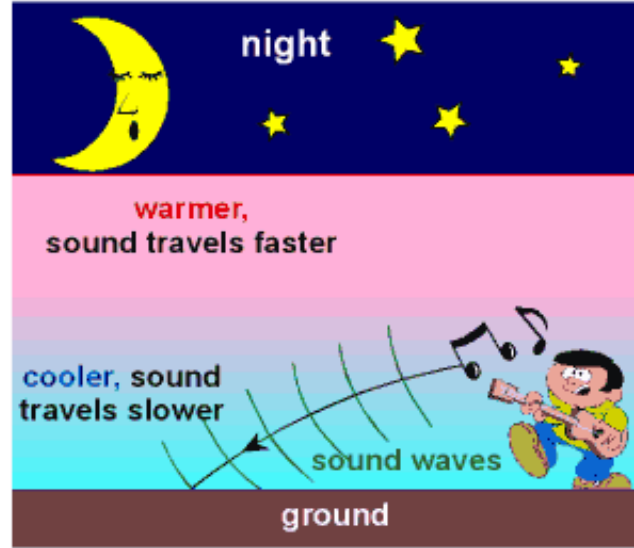
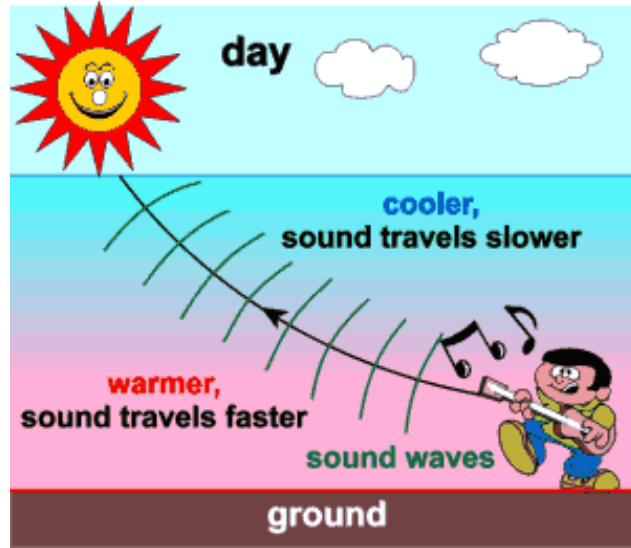




ACOUSTIC WAVES



Infrasound can propagate over long distances



Source: <http://www.hk-phy.org>

Acoustic waveguides

Ground: a perfectly rigid reflector

- Thermal ducts

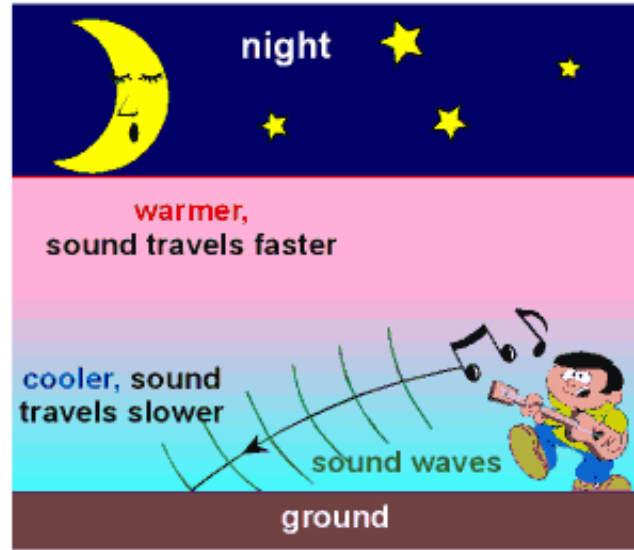
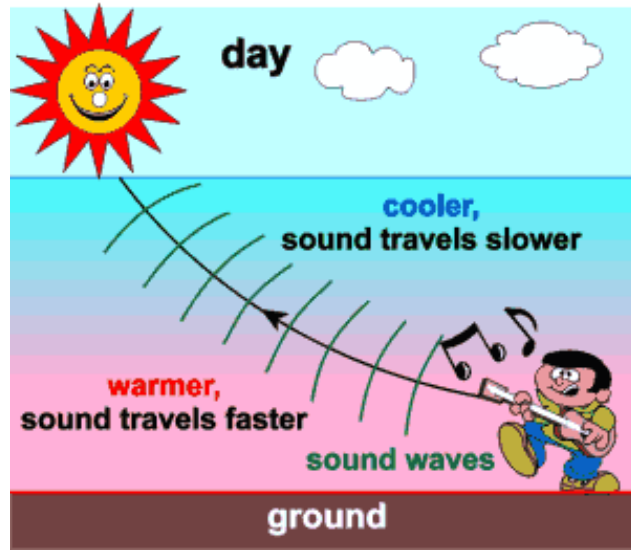
Sound speed c is proportional to Temperature^{1/2}

Refraction of acoustic waves toward **slower (colder) zones**

Day: temperature decreases with height

Night: radiative cooling of the ground

Consequence: sound propagates better at night in all directions



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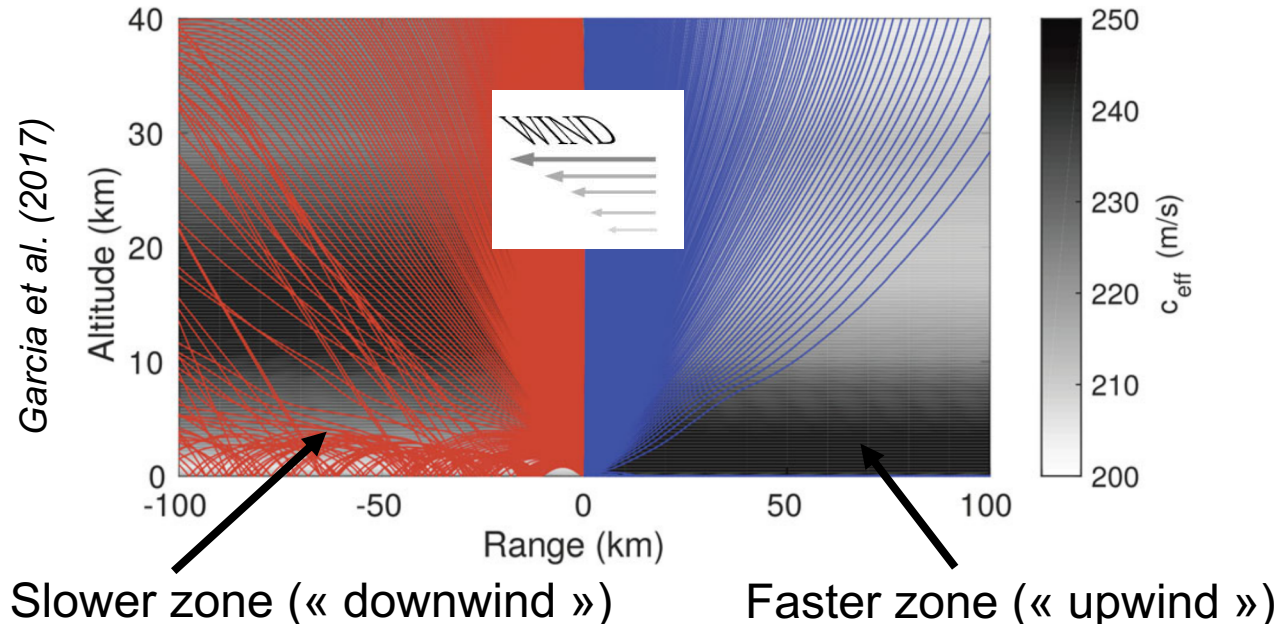
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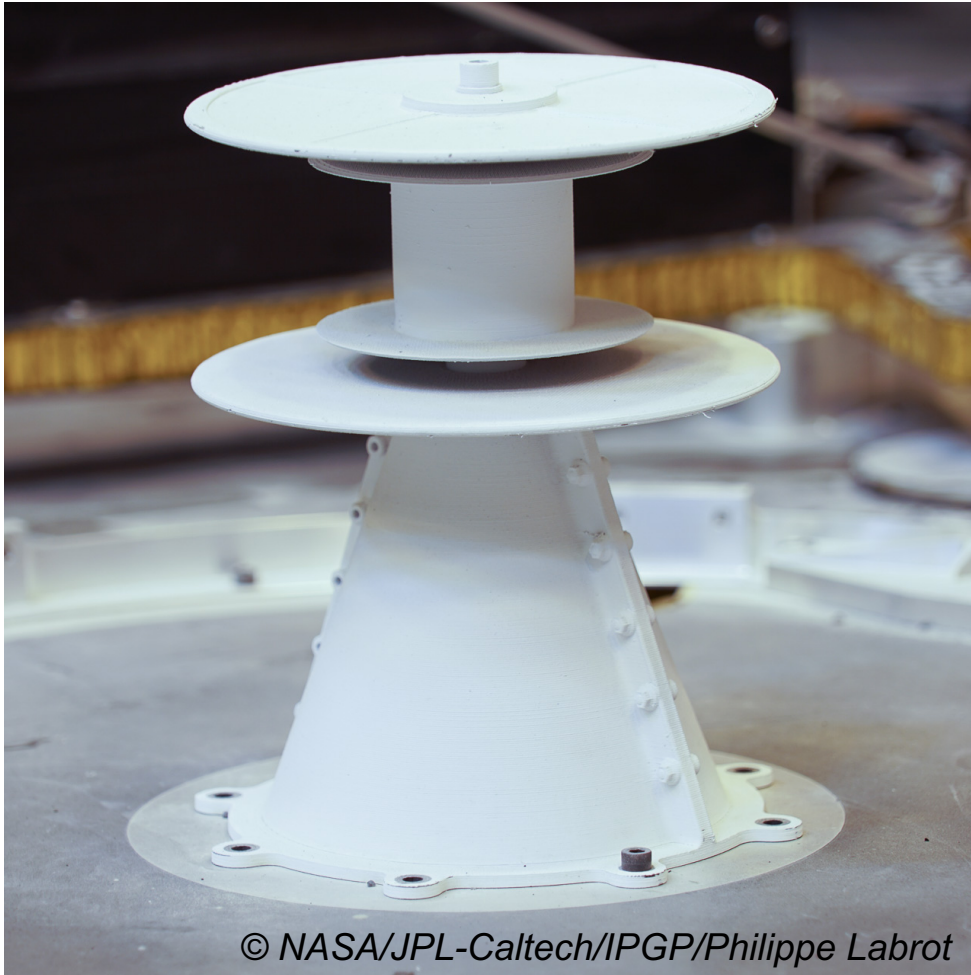
- Wind ducts

Effective sound speed: $c_{\text{eff}} = c + \mathbf{w} \cdot \mathbf{k}$

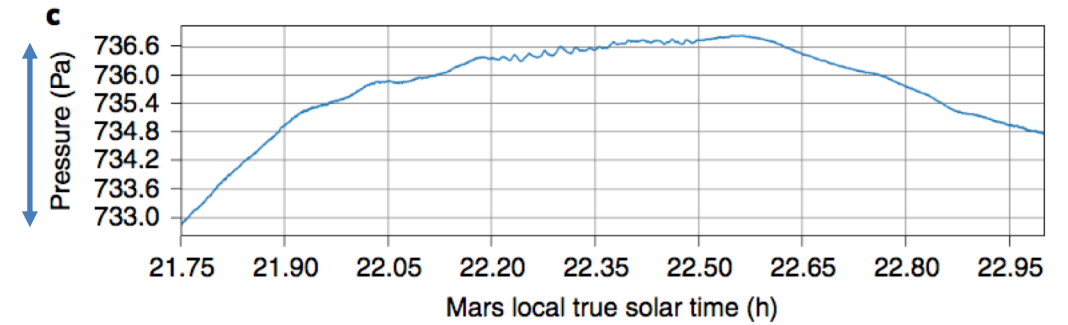
Consequence: sound propagates better downwind, preferential direction changes with season



InSight's ultra-sensitive barometer ($10\mu\text{Pa}$)



3.6 Pa

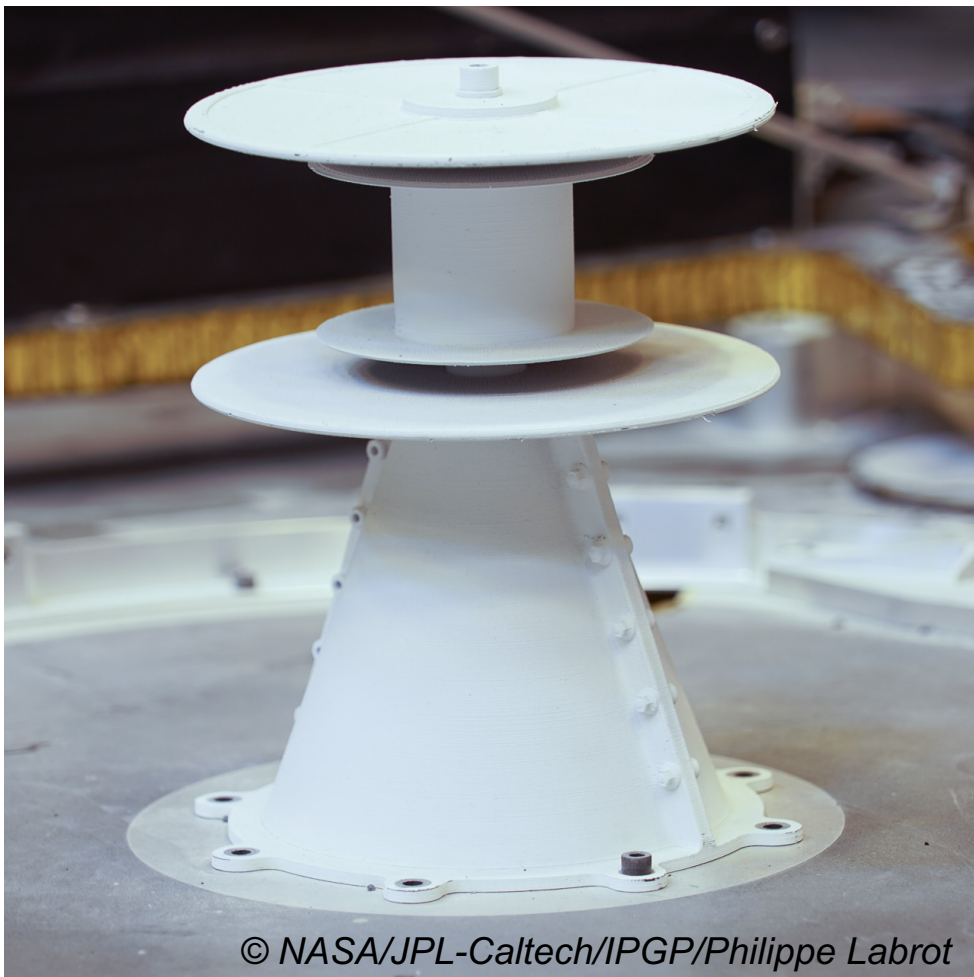


Banfield, Spiga et al. (2020)



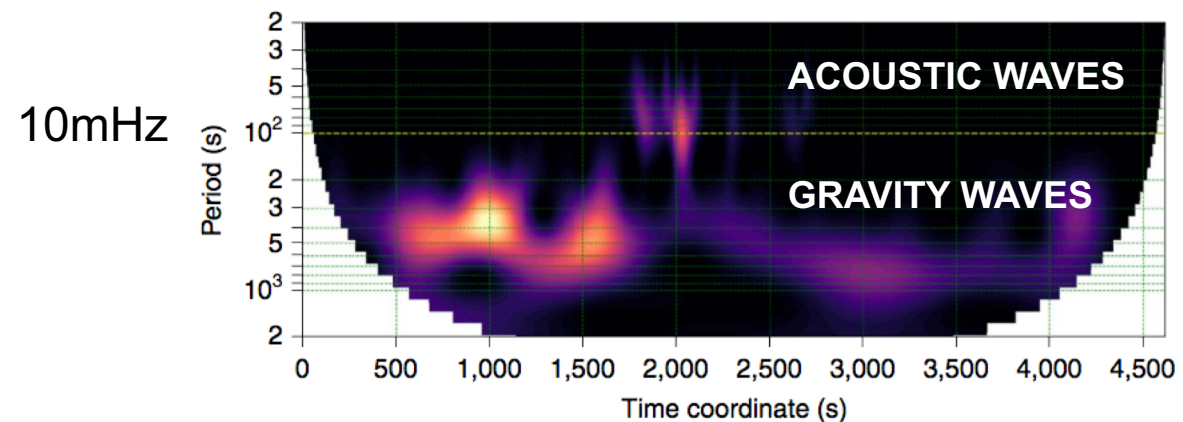
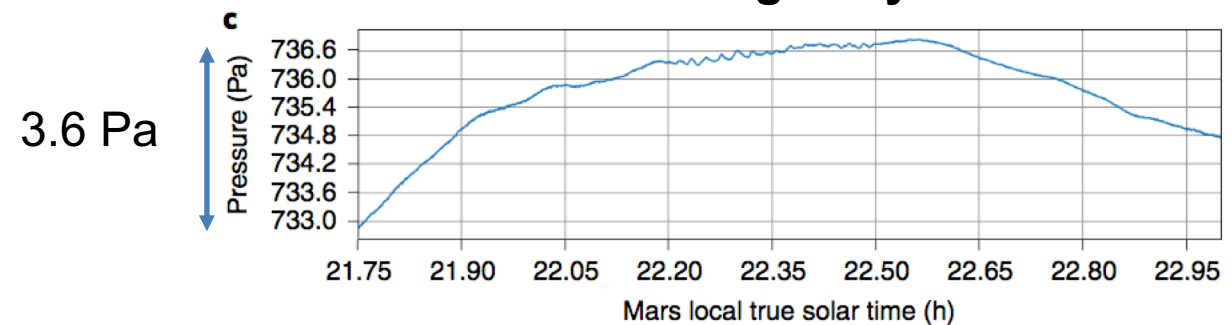
InSight's infrasound sensor

InSight's ultra-sensitive barometer ($10\mu\text{Pa}$)



© NASA/JPL-Caltech/IPGP/Philippe Labrot

Acoustic-gravity waves

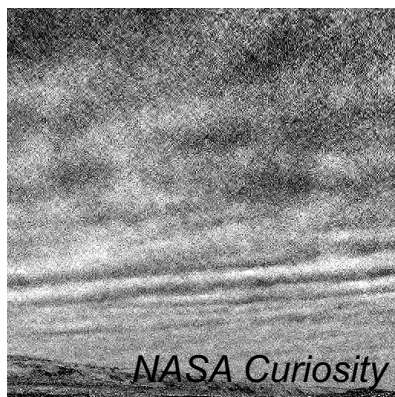
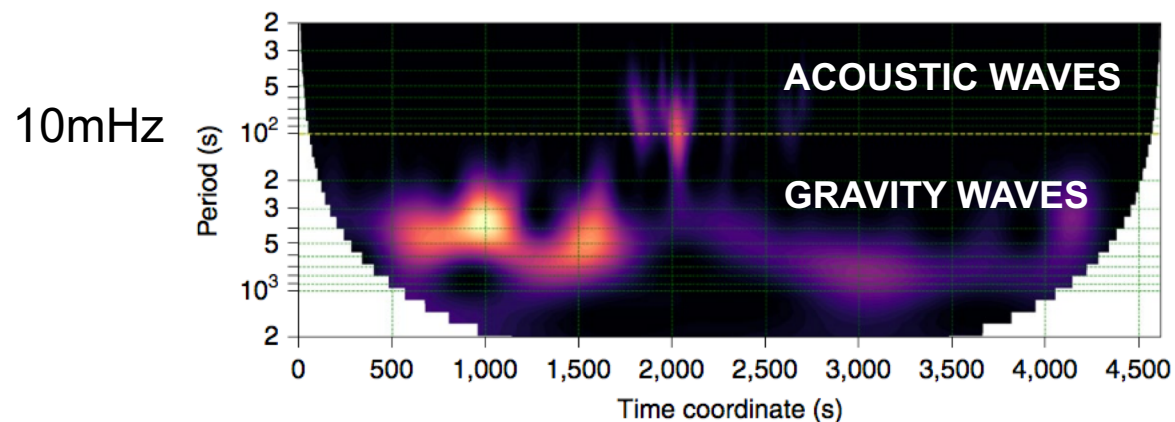
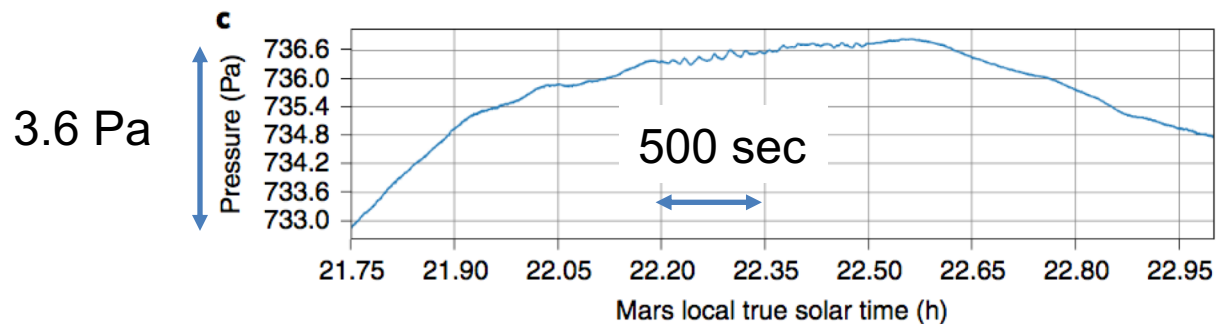


Banfield, Spiga et al. (2020)



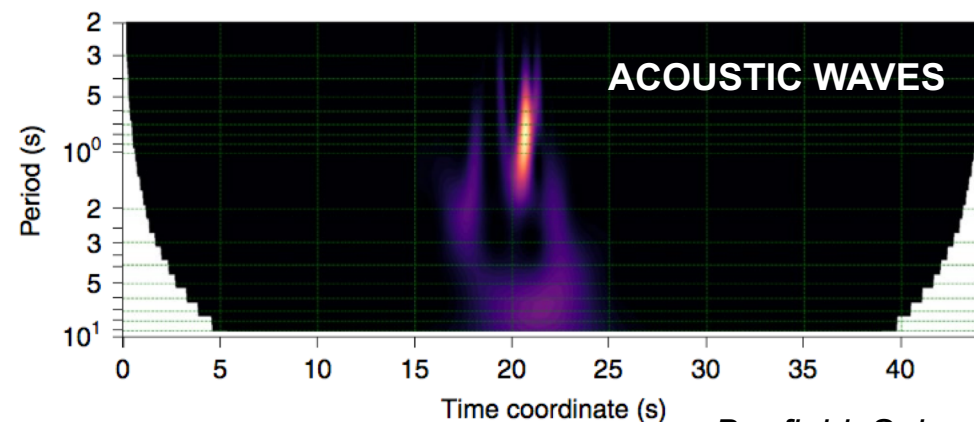
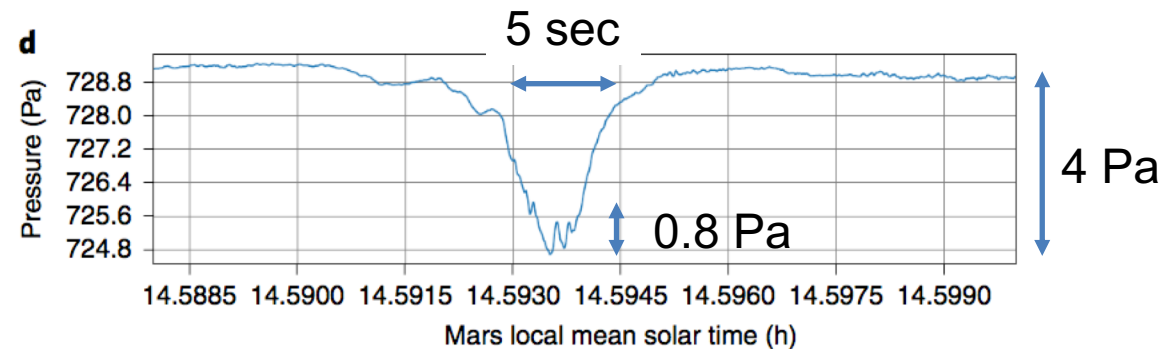
2 types of infrasound detected on Mars with InSight so far

Acoustic-gravity waves



NASA Curiosity

The sound of a dust devil

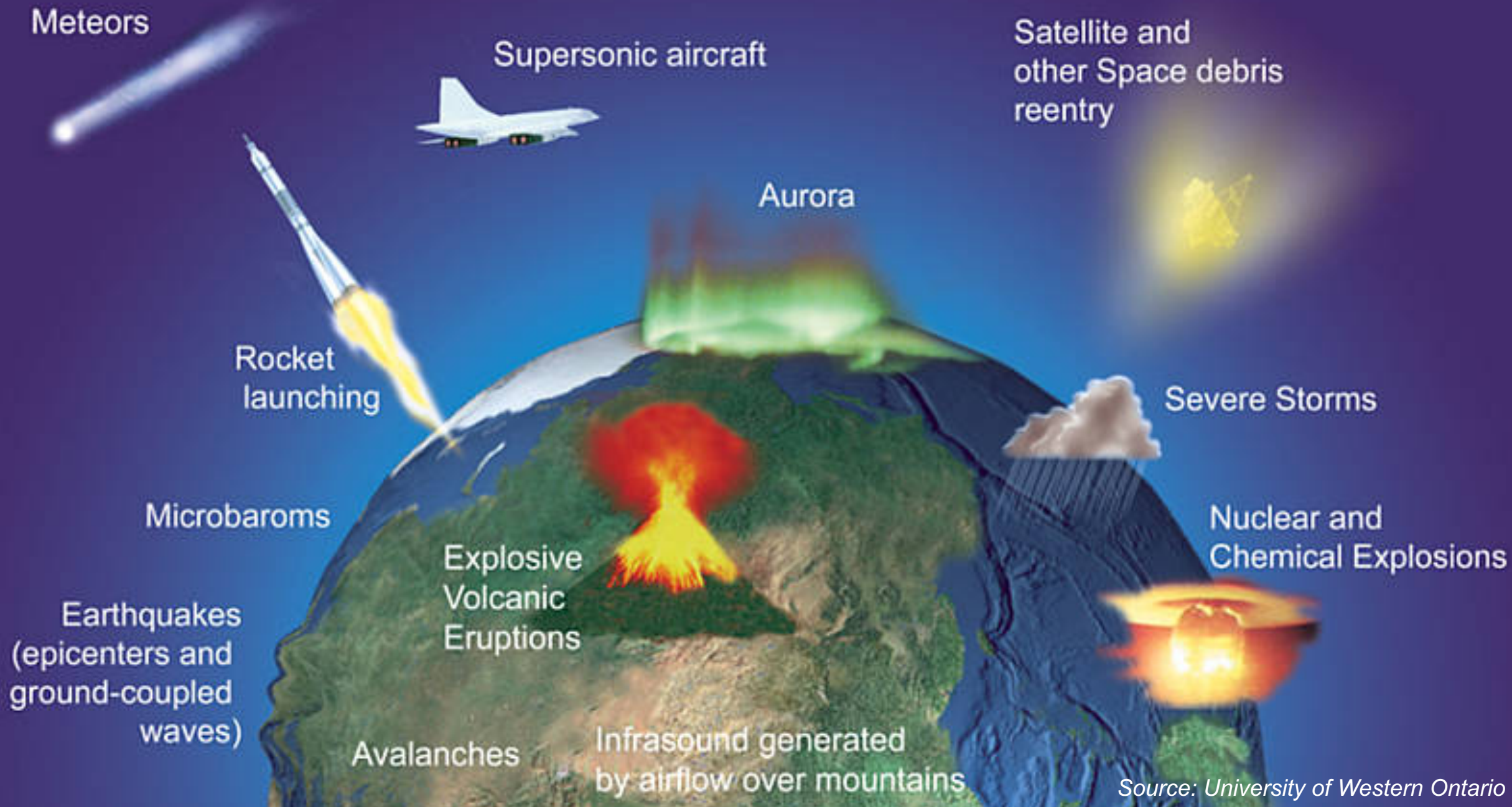


Banfield, Spiga et al. (2020)

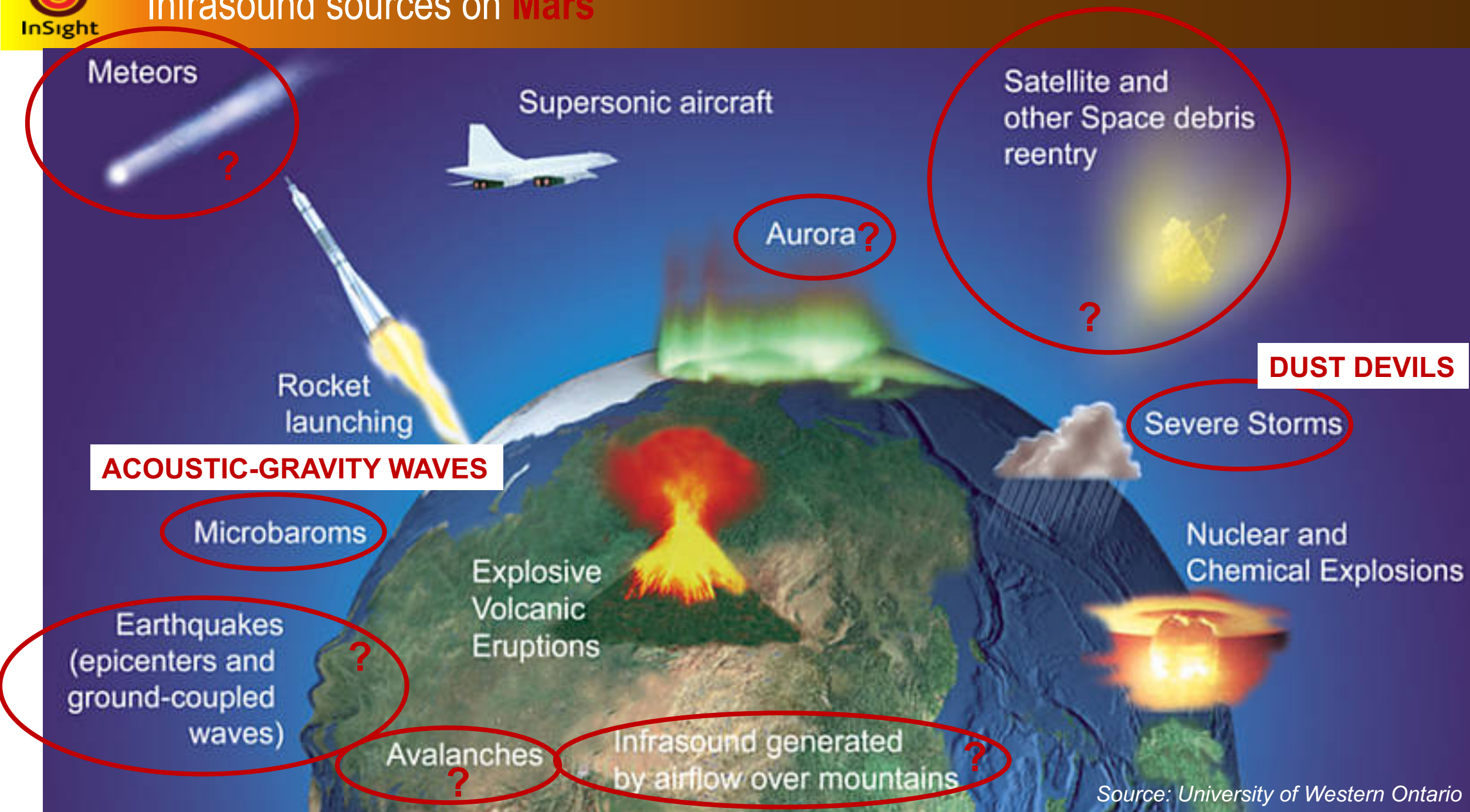


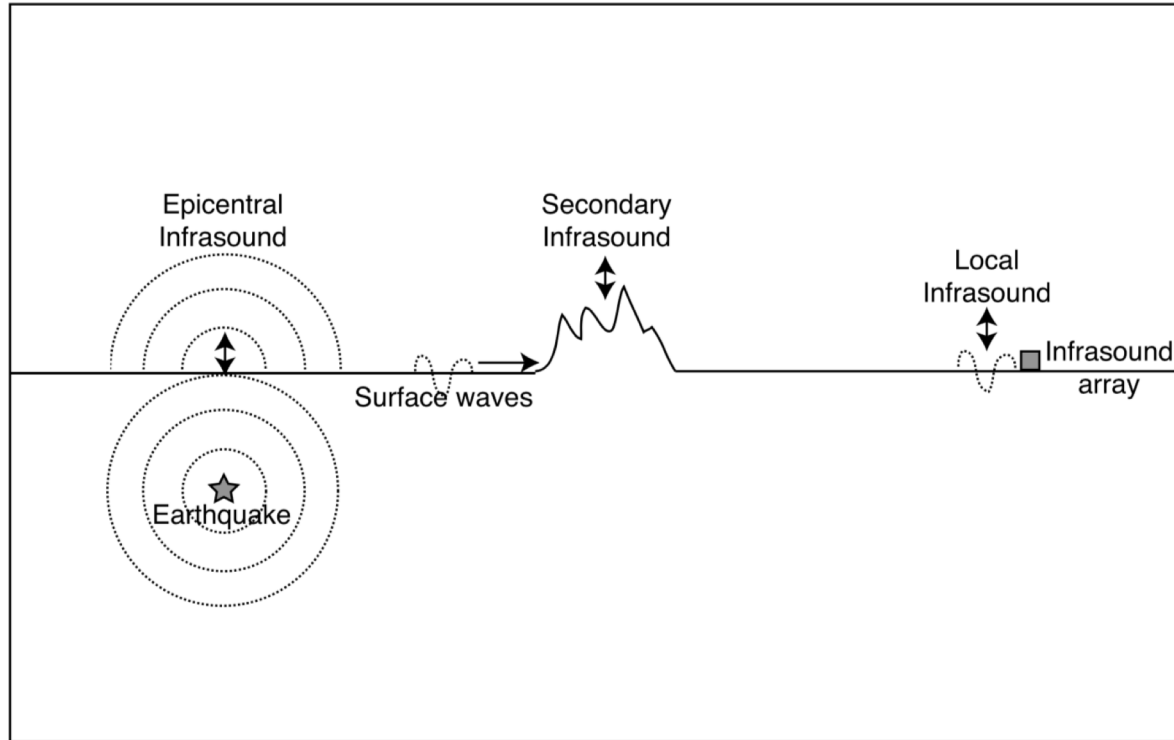
NASA Spirit

Infrasound sources on Earth



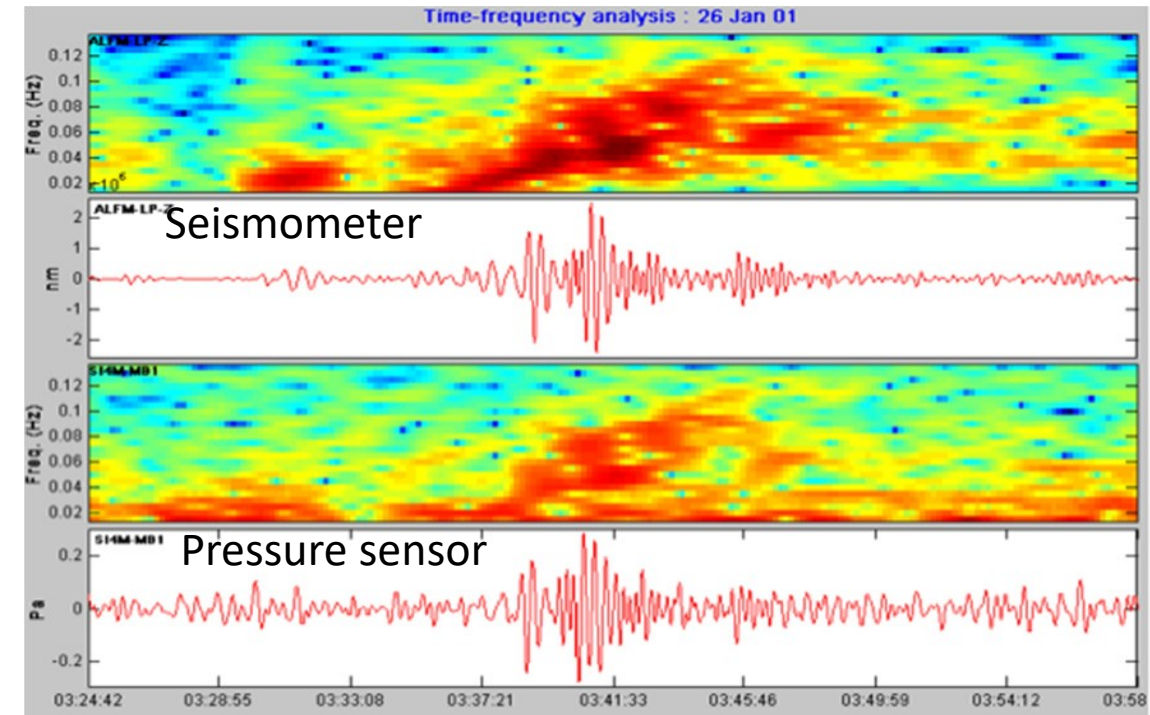
Infrasound sources on Mars





Arrowsmith et al. (2010)

Earthquake in India, measured in Mongolia



T. Farges (CEA)

The atmosphere is sensitive to ground shaking

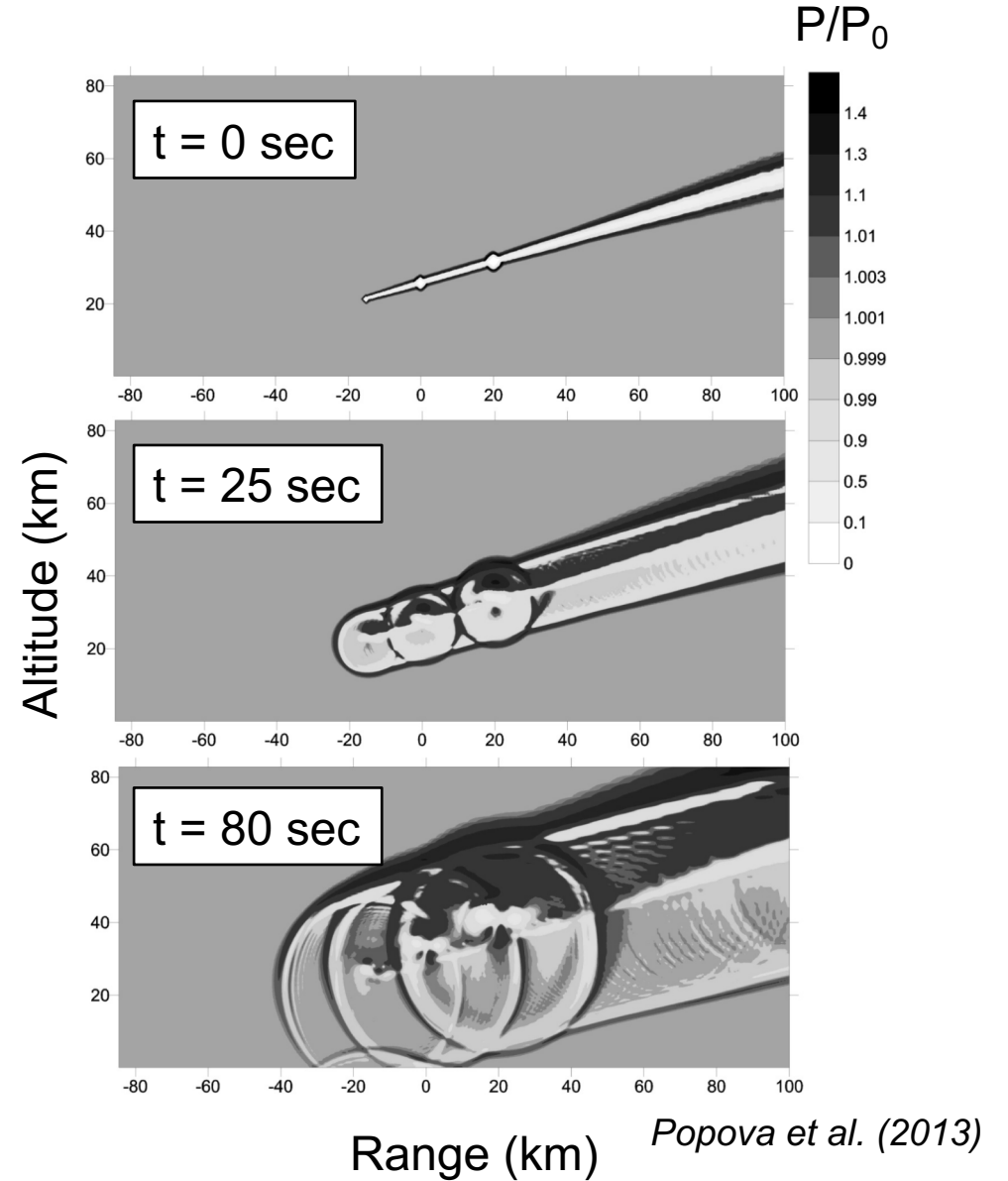
Chelyabinsk, February 15, 2013

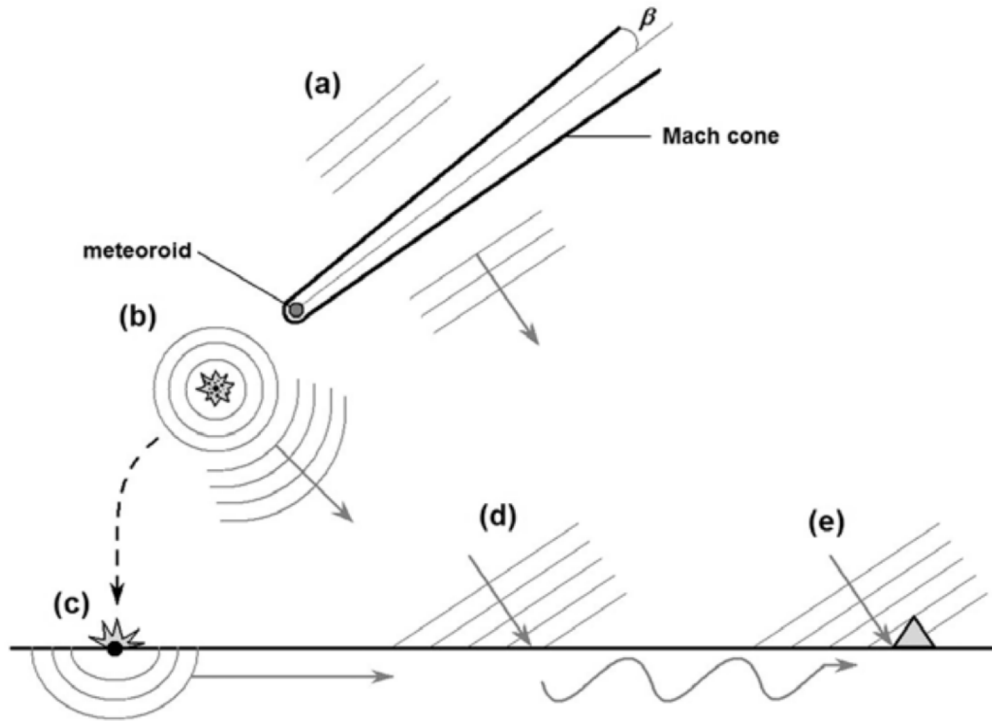


A ~15 meters asteroid @ ~20 000 m/s
Fragmentation in the atmosphere



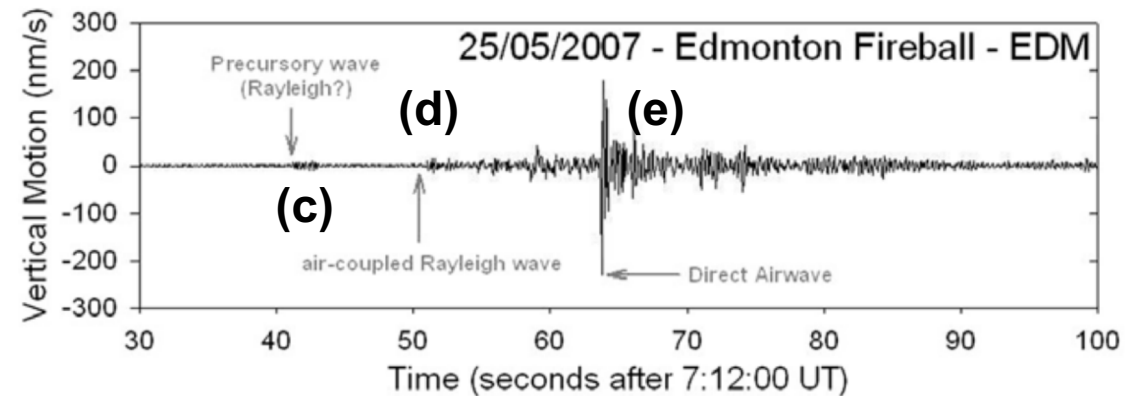
Sonic booms

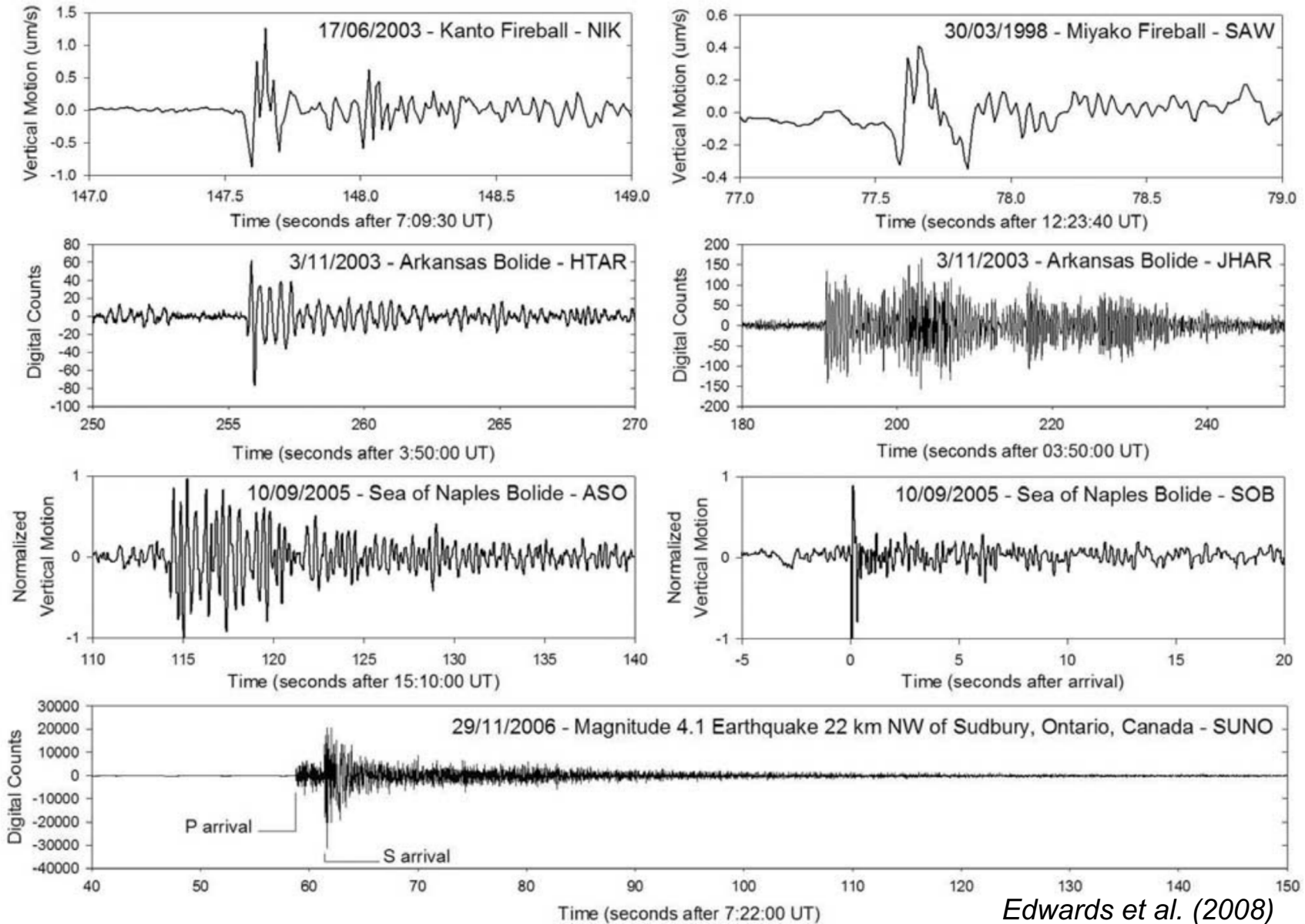




Edwards et al. (2008)

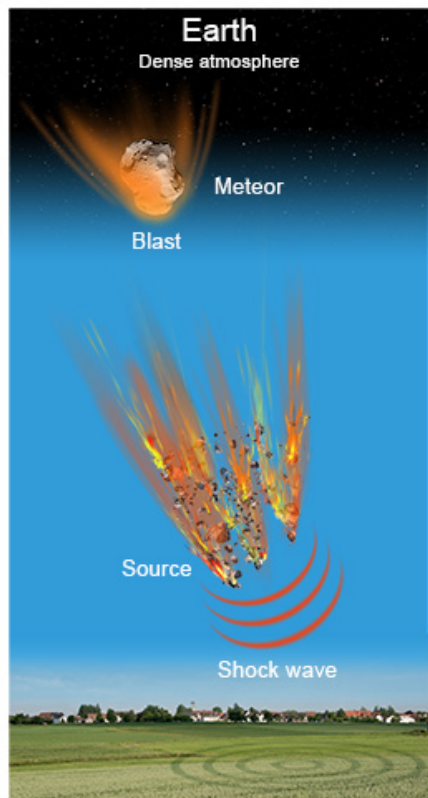
- Pressure fluctuations induces a seismic signature (higher pressure push on the ground, lower pull)
- A way to discriminate between an impact and a marsquake
- First: impact related seismo-acoustic wave (c)
- Second: Rayleigh wave (d)
- Third: direct acoustic shock wave (e)



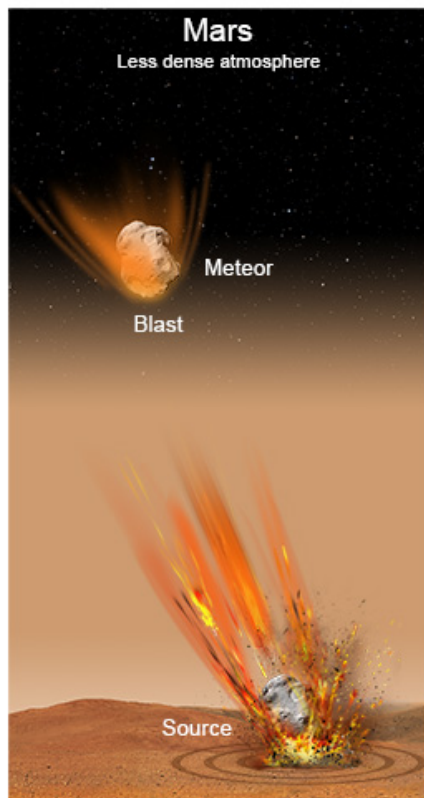


Edwards et al. (2008)

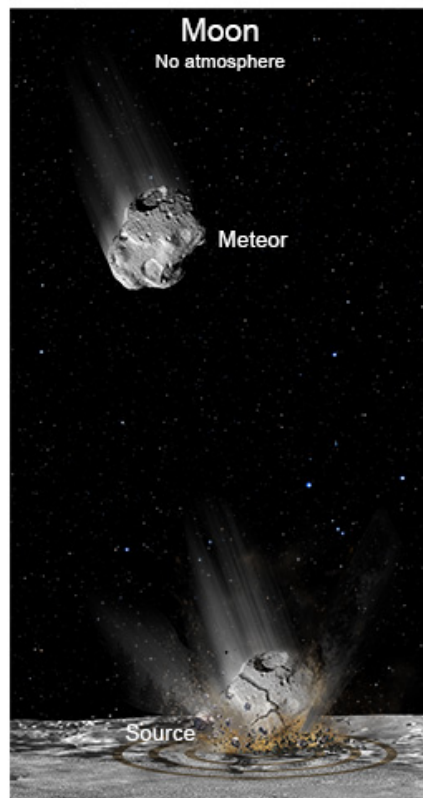
Comparative meteor entry on Earth, Mars and the Moon



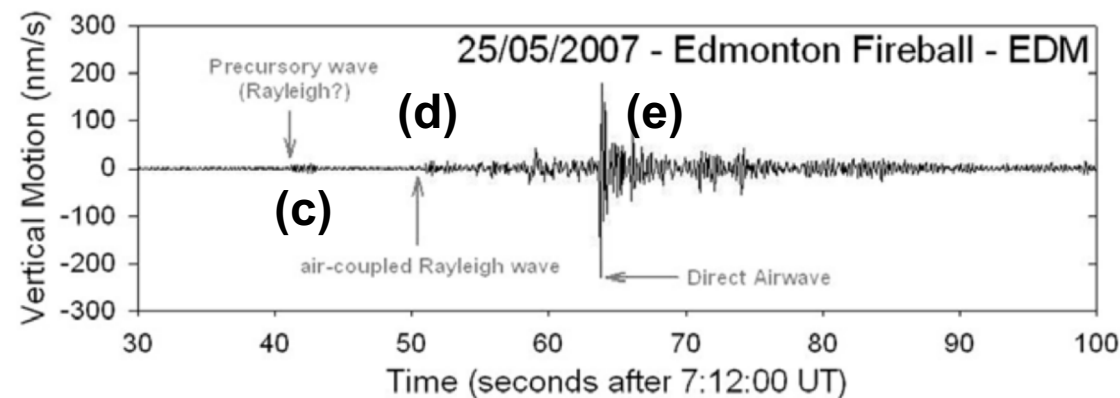
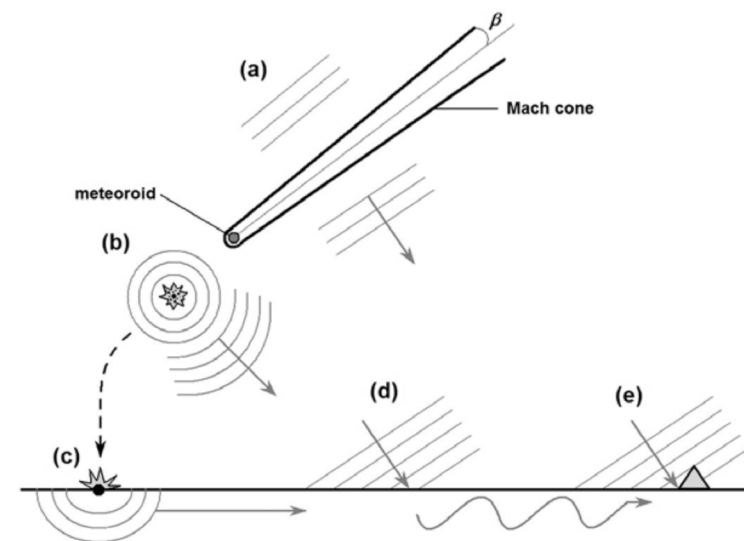
(d),(e)



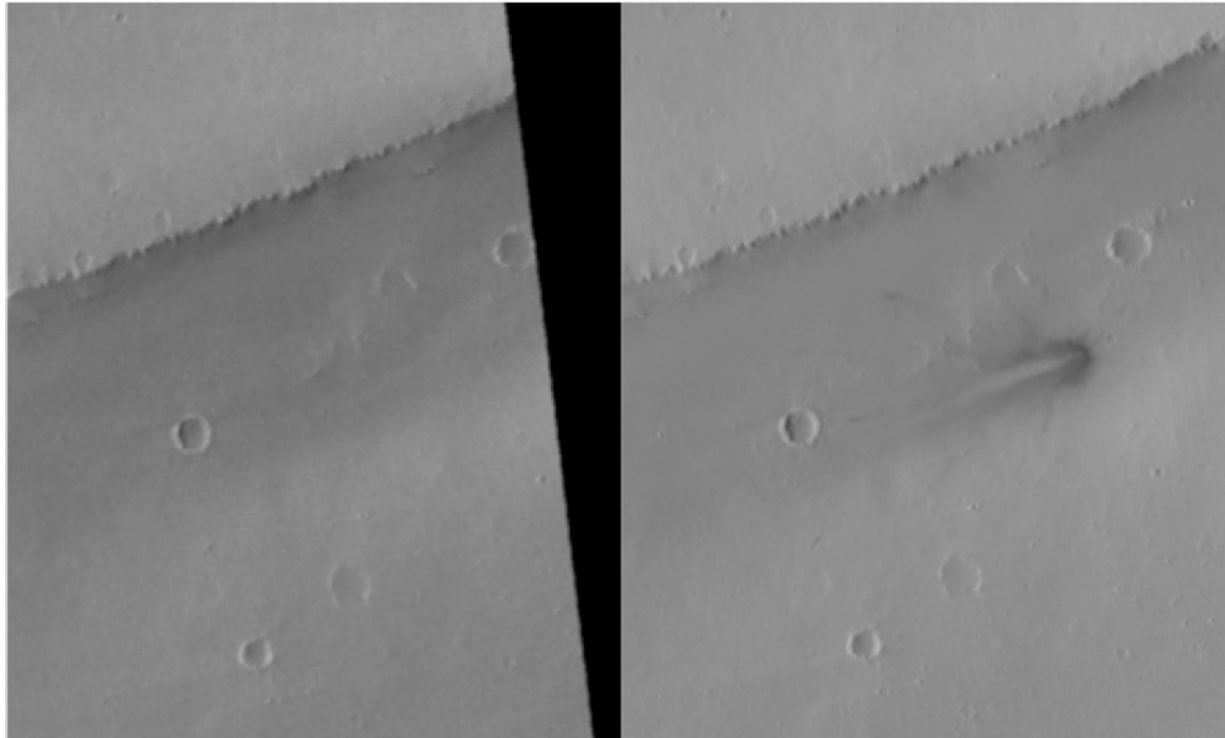
(c),(d),(e)



(c)



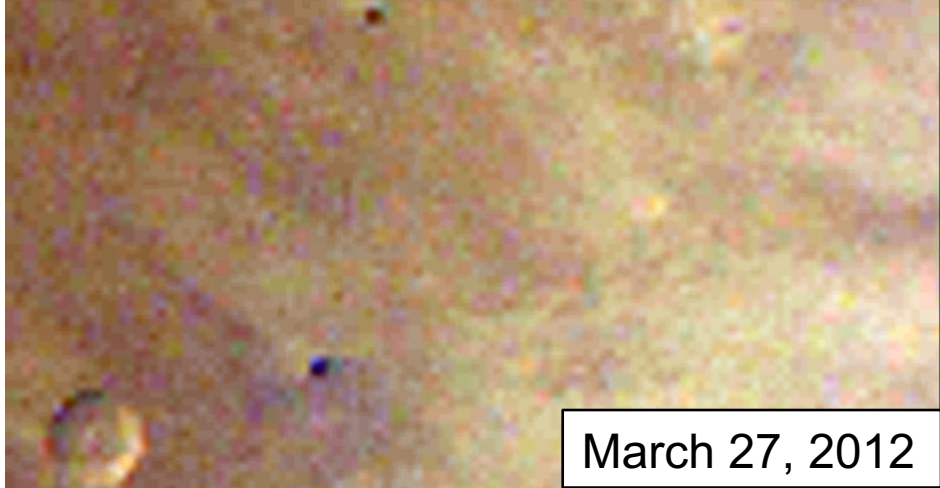
SEIS is our best chance to detect a meteor entry !



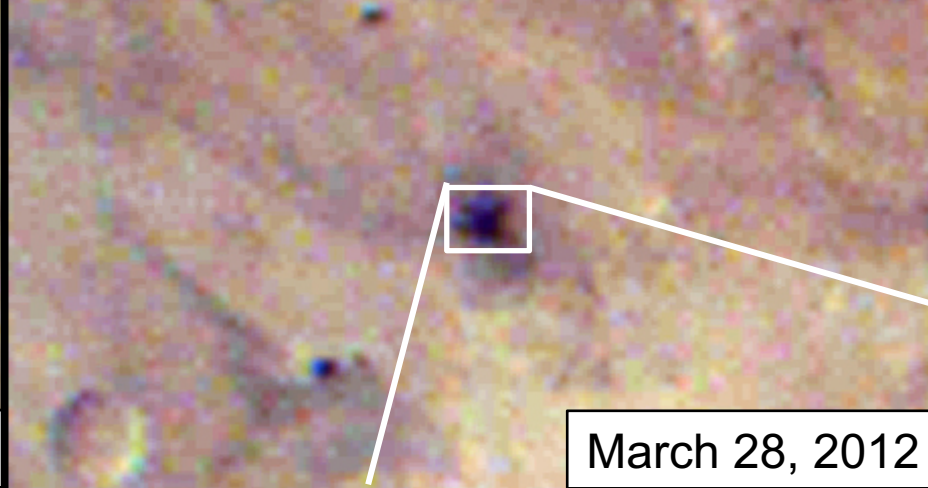
18 Feb. 2017
20 March 2019



Gif by P. Gringrod



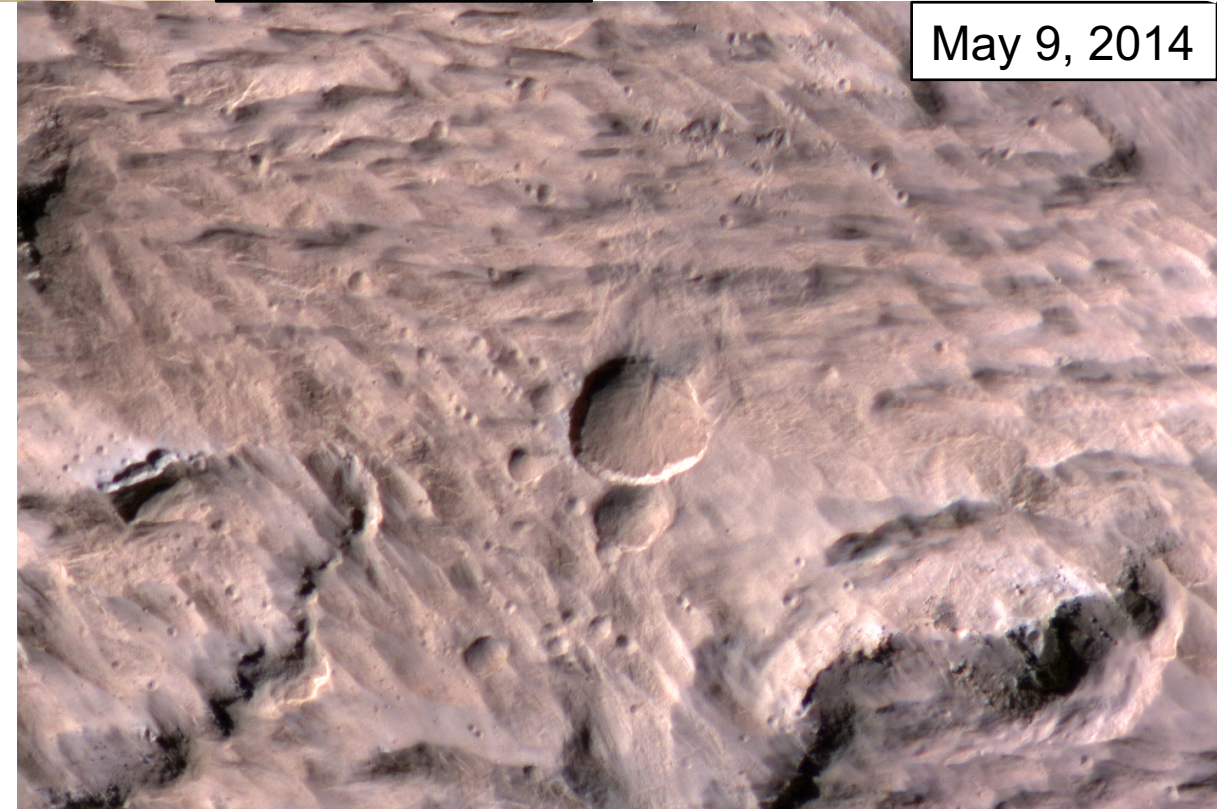
March 27, 2012



March 28, 2012

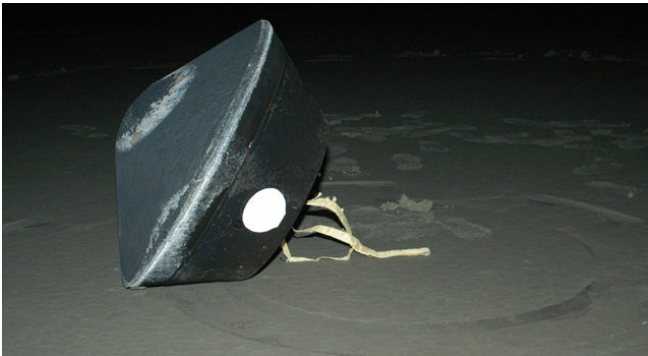
MARCI Image NASA/MRO

48.5m wide crater
About 500 craters identified in before-after images

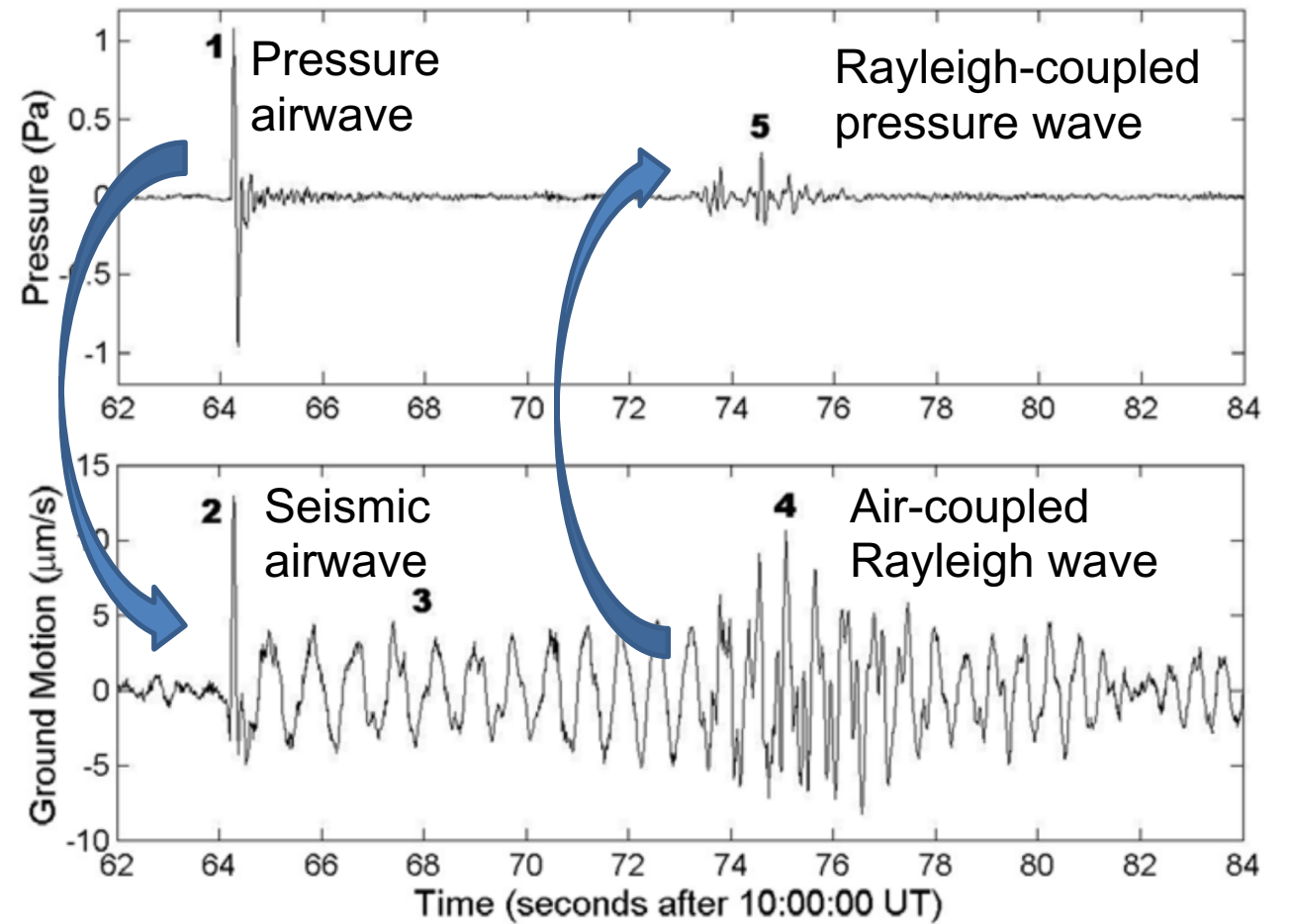


May 9, 2014

HiRise Image NASA/MRO

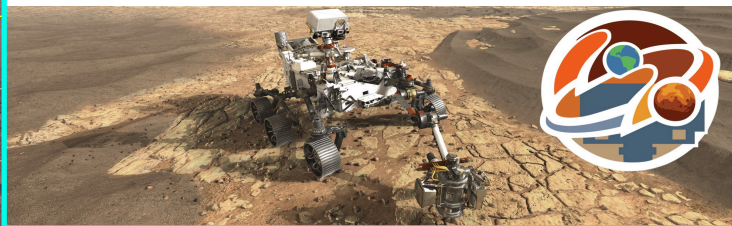


Co-located infrasound and seismic station records



Phoenix •

Feb 18, 2021 Mars 2020 (NASA)



Viking 2 •

Viking 1 •

Pathfinder •

• ExoMars

Mars 2020 •

Beagle 2 •

InSight •

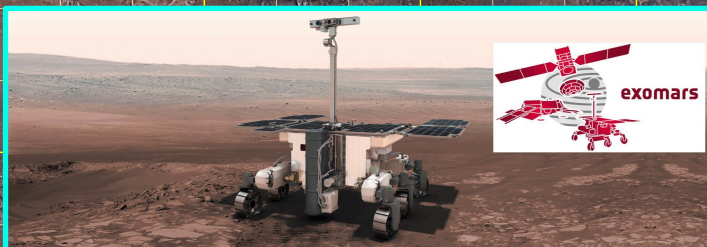
Opportunity •

Schiaparelli

Curiosity •

Spirit •

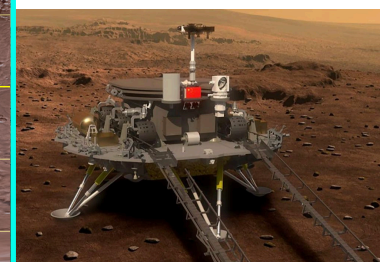
Mars 3 •



Mar 19, 2021 ExoMars(ESA)

Mars 2 •

Apr 23, 2021
HX-1 (CNSA)



Mars Polar Lander •

**Merci !
Thank you !**

