

# **The Effects of Atmosphere on Sound**

By

Erich Hauptmann

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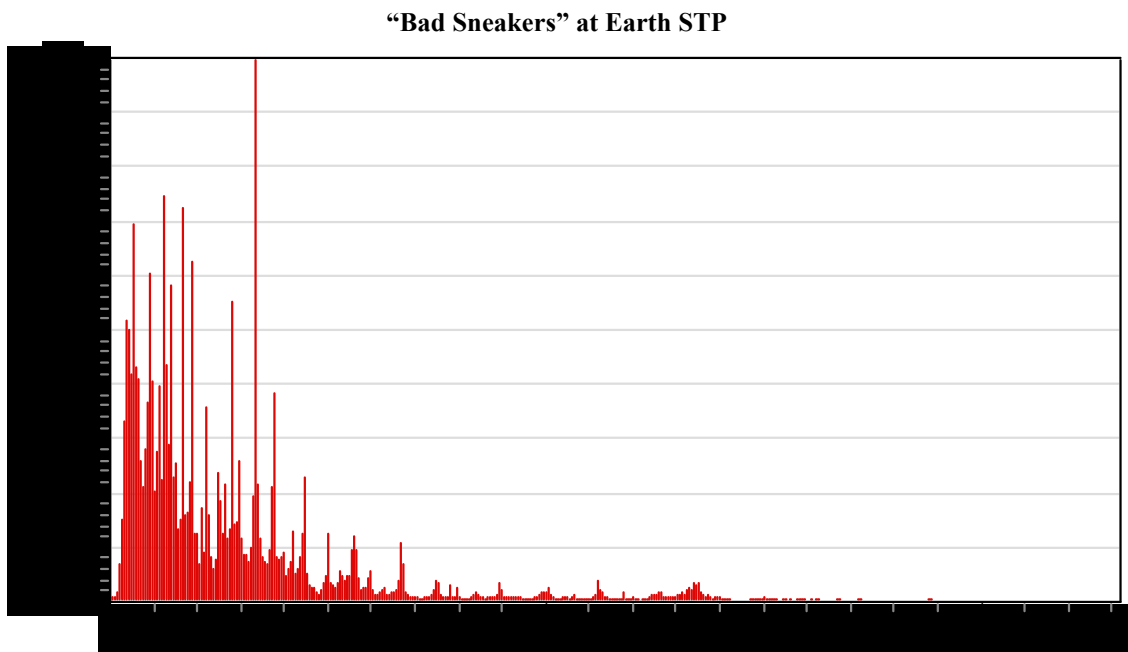
Professor Steven Errede

Any musician worth his salt knows that where music is performed matters just as much as his instruments in the quality of the sound. Just as a poor guitar can sound flat, a friend's garage often makes a poor recording studio. But whatever pitfalls are faced by musicians on Earth, they do not for the most part need to worry about the pitch of their music changing along with their location. Assuming a clumsy friend does not bump your guitar when moving it, it should stay in tune from the garage all the way to the concert hall. This is because the tuning of instruments is based strictly on quantitative values of physics that remain constants in most environments. These values do not, however, hold true for cases where the environment is not the standard atmosphere of the earth. It will be shown that should mankind be bold enough to play music on other worlds, we will have to account for a change in these factors which we currently take for granted.

Sound progresses on Earth at a speed that is determined by the pressure and density of the air, and also the gas constant of that air. Density and pressure may change somewhat depending upon temperature and altitude, but the range of their difference is negligible to the speed of sound. Speed of sound can be expressed by the equation  $c = \sqrt{(\gamma * p / \rho)}$  where  $\gamma$  is the gas constant,  $p$  is pressure and  $\rho$  is density of the environment. This becomes significant to musical performance because the velocity of wave propagation is directly related to frequency and wavelength, as expressed by the equation  $v = f * \lambda$ , where  $v$  equals the speeds of wave propagation (the speed of sound),  $f$  is the frequency of the wave and  $\lambda$  is the wavelength. In situations such as a guitar or vocal cord, wavelength is fixed, therefore frequency must change to balance the equation when the speed of sound changes. Frequency is more commonly known to musicians as pitch, and the space-faring musician with little knowledge of physics will soon find himself out of tune if he attempts to play on Mars with an earthly tuned instrument! We will examine the

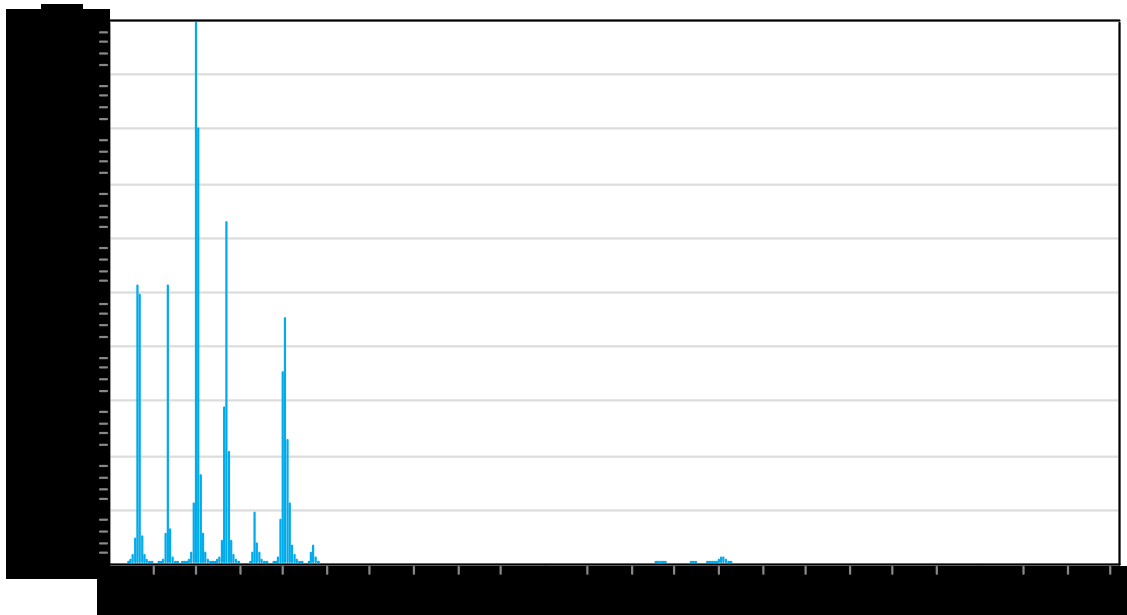
effects of atmosphere on the song “Bad Sneakers” by Steely Dan and on a vocal note in the key of C3.

As a control the samples are analyzed in their source environment, which is assumed to be Earth at Standard Temperature and Pressure.



A good point of reference for this sample will be the peak at 667.45 Hz (E5).

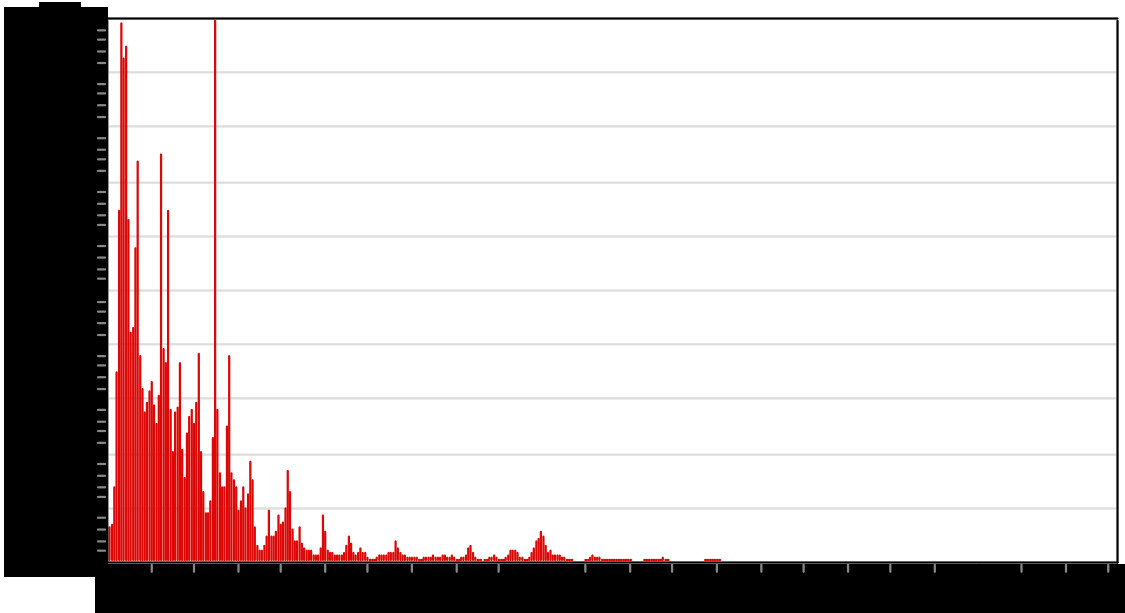
### Vocal Note at Earth STP



The vocal has a distinct note which is replicated across many harmonics. In this experiment the peak at 392 Hz will be used even though it represents a G and not the C that the performer intended.

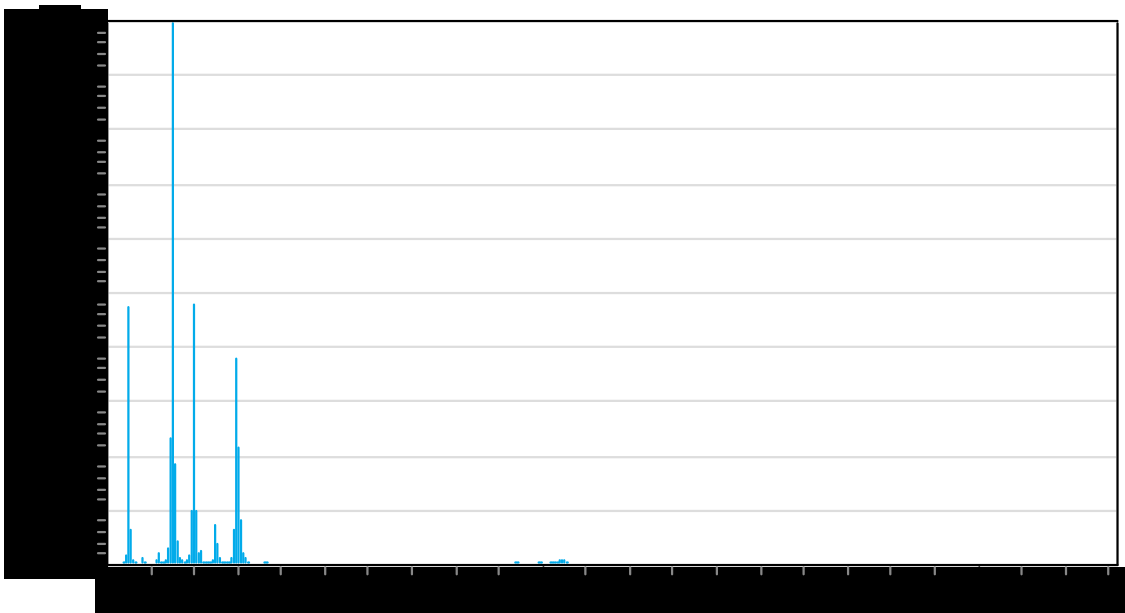
The atmosphere on Mars is composed primarily of carbon dioxide, which gives the atmosphere a gas constant  $\gamma$  of 1.2941 according to NASA. Pressure and density of the atmosphere average 700 Pa and  $.015 \text{ kg/m}^3$  respectively, from data acquired from the Mars Pathfinder probe. This gives sound on Mars a speed of 240 m/s, much slower than the 332 m/s on earth. This has the net effect of decreasing effective frequency from an instrument by 74.19%.

### “Bad Sneakers” on Mars



Accounting for some distortion occurring during the pitch change, the peak frequency has shifted to 560.10 Hz (C#5). Steely Dan is out of tune!

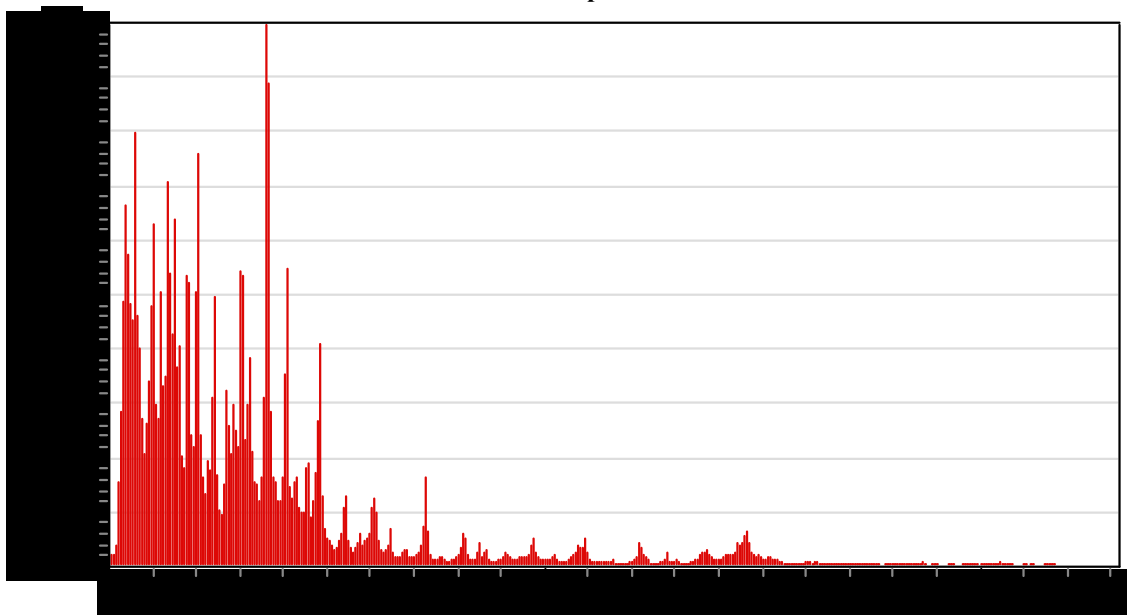
### Vocal Note on Mars



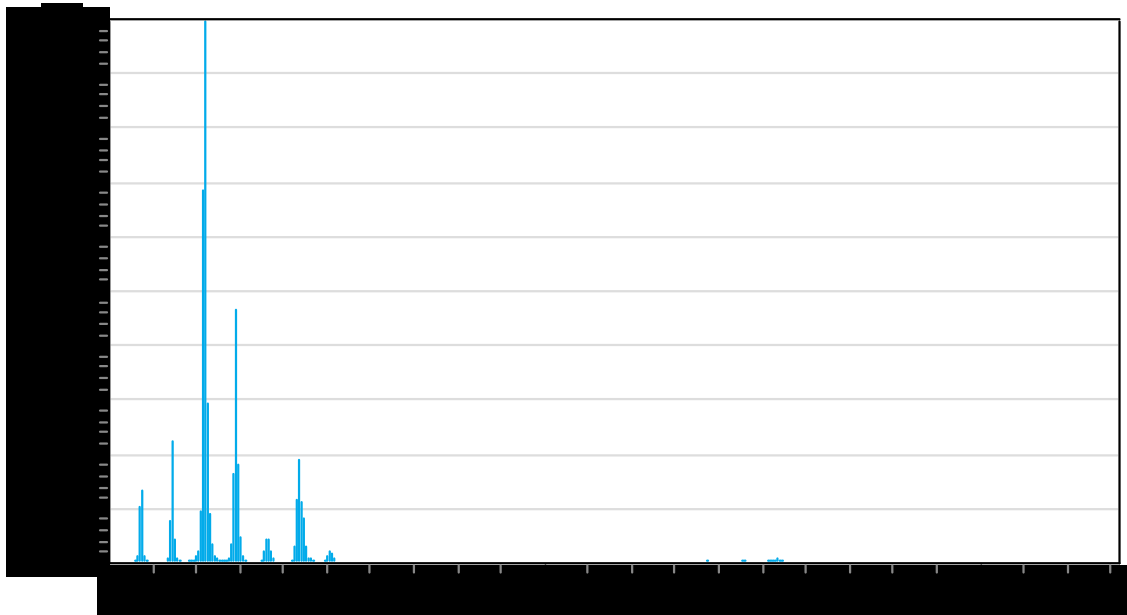
The peak frequency has shifted to 301.53 Hz (D4). While a guitar can be easily retuned, it is quite a different matter to tune one's own voice for the new environment. The singer will have to learn to use his new, deeper voice.

It is shown that a thinner atmosphere results in a shift towards lower frequencies in the spectrum. In a thicker atmosphere, such as the inner atmosphere of Jupiter, the situation changes. According to data from the Galileo space probe, Jupiter's atmosphere becomes progressively more dense towards its interior. At the pressure equivalent to Earth's sea level, the atmosphere is actually less dense than Earth so a sound similar to Mars will result. If a performer wished to operate in tolerable climate, however, he would have to be closer to the center of the gas giant. Where the temperature equals 25°C, pressure is 670,000 Pa and density of the atmosphere is 7.41772 kg/m<sup>3</sup>. The gas constant of Jupiter's (mostly helium) atmosphere is 1.4348. This makes for a speed of sound of 360 m/s, just a little faster than that on Earth.

**“Bad Sneakers” on Jupiter at 670 k-Pa**



### Vocal Note on Jupiter at 670 k-Pa



The faster speed of sound results in a slightly higher pitched tone, 442 Hz (A5) for the peak on the vocal sample and 721.33 Hz (F#5) for the song. This is of practical concern to extended duration deep-sea divers who work in a highly pressurized environment, breathing more helium gas than normal to avoid oxygen toxicity. Their vocal cords would have a similar shift towards high frequencies as would occur on Jupiter.

While it may seem odd to picture rock bands performing on a planet with toxic atmosphere, the principles of physics explored here have many practical applications as well. Should any audio recordings of foreign worlds become available, one will have to remember that sounds produced there are propagating under different physics, and in extreme environments conversion may be necessary to make sense of them. And it's also worth noting that when wavelength is not constrained, as with a speaker or microphone, the speed of sound in the environment will have the property of altering wavelength, potentially exceeding tolerances of a device designed for use on Earth. When exploring strange new worlds, it's important to

remember that every action has a strict grounding in physics, whether it concerns your guitar or scientific microphone.