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Extraterrestrial music

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ABSTRACT

This paper discusses how other worlds will sound, and what we could learn by listening to them. This is illustrated by transforming a range of musical sounds (including voices) to show how they would appear on other worlds, so demonstrating the physics involved and how our understanding of that physics can allow us to make predictions about sound on other worlds.

Until now, the emphasis has been on how other worlds look, with space probes carrying sophisticated cameras, and documentary- and film-makers spending large budgets to recreate the scenery of other worlds accurately. Almost all space probes have been 'deaf', but if they had had microphones could they have heard distant storms, or been able to diagnose their malfunctioning vanes and motors by listening for 'a funny rattle'? Could a probe listen for lightning on Venus, dust storms on Mars, or ice cracking and even undersea life on Jupiter's frozen moon Europa? Could a Mars astronaut hear a rockfall behind her as she walks downhill? By demonstrating, through music, our understanding of how other worlds shape sound, this paper explores to what extent acoustics might be used to explore other worlds.

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1. INTRODUCTION

Whilst probes to other planets have carried an impressive array of sensors for imaging and chemical analysis, no probe has ever listened to the soundscape of an alien world [1-3]. With a small number of exceptions, planetary science missions have been deaf. The most successful acoustic measurements were made by the European Space Agency's 2005 *Huygens* probe to Titan, but although this probe was spectacularly successful in measuring the atmospheric sound speed and estimating the range to the ground using an acoustic signal that the probe itself emitted [4-7], we still have no measurements of sounds generated by alien worlds. Although microphones have been built for Mars [8], the *Mars Polar Lander* was lost during descent on December 3, 1999, and the *Phoenix* probe microphone was not activated (because the Mars Descent Imager system to which it belonged was deactivated because of the risk of tripping a critical landing system [9]). Instead of measuring acoustic signals that had propagated to the microphone from a distance, aerodynamic pressure fluctuations on the microphone (caused by wind on the surface of Venus in the case of the 1982 Russian *Venera* 13 and 14 probes [10, 11]; and turbulence during the parachute descent in the case of Huygens) masked the soundscape on these Venus and Titan missions. Detailed modelling of acoustic characteristics of alien worlds is vital to the design of instrumentation, the planning of the acoustical components of the missions, and the correct interpretation of the data. If the astronaut from the future is walking down a Martian hillside, looking downwards, can we design microphones to warn him of the fall of a rock dislodged behind him? How well can sound be used to confirm the opening of vanes out of camera sight, or undertake diagnostics of motors, pumps and drills? What gain, bandwidth, sensitivity and self-noise are appropriate for microphones in the atmospheres of Mars, Titan, Venus, and the planets, or hydrophones in the lakes and oceans of Titan, Europa and Enceladus? Would we be able to recognize sounds as coming from 'dust devils' on Mars [12], 'waterfalls' on Titan [13], ice cracking on Europa [14-17], or lightning on Venus? Could not film and documentary makers attempt to portray the soundscape with the same integrity they apply to the visual depiction of other worlds?

2. METHOD

Leighton and Petculescu [18, 19] demonstrated how we might begin to construct the soundscapes on other worlds, and predict not only the sounds output of natural extraterrestrial sources but also the performance of man-made sources and sensors introduced onto other worlds, by developing techniques to predict the sounds of voices and music in such environments Three extraterrestrial worlds (Mars, Venus, and Titan) are studied and compared with Earth. Its low temperature (-178^{o}C) means that, despite its small size, Saturn's moon Titan has a thick atmosphere. At ground level, the atmospheric pressure on Titan is 1.5 bar, and the sound speed is only 62% that of Earth. It is assumed, for the purpose of this exercise, that the organ contains only flue pipes, so that the note of a given organ pipe scales linearly with sound speed. Under this assumption, Bach's Toccata and Fugue in D Minor (293.66 Hz) played on Titan will automatically be transposed down to the key of ~F# minor (185 Hz). The atmospheres of Mars and Venus are both dominated by CO_2 and N_2. However, their surface temperatures are extremely different, leading to ground-level sound speeds that are, respectively, 70% and 120% of the sound speed on Earth. Thus Mars' thin and cold (7^{o}C) atmosphere transposes Bach's Toccata down to ~G# minor (207.65 Hz), whilst Venus' dense and hot (457^{o}C) atmosphere transposes it up to ~F minor (349.23 Hz) – nearly an octave above Titan's rendition at F# (185 Hz). Whilst the pitch variation for flue organ pipes is simply related to the sound speed, for reed organ pipes the sound is affected by the fluid loading on the source, which is significant in the dense atmospheres of Venus and Titan [20].

This effect also influences similar sources, such as the voice [18, 19]. The effects of the planet on timbre and resonances depend on the details of the instrument [18].

The calculated transmission losses assumed that the geometrical losses followed a spherical spreading law. Additional losses are contributed by atmospheric absorption, which are high on Mars and Venus because of the high proportions of CO_2 there. As a result, on Mars the music is barely audible merely 10 meters from the organ (suggesting that the *Mars Polar Lander* microphone, had it survived, would have had very limited range). Acoustic absorption in Titan's nitrogen-based atmosphere is less lossy than Earth's, so that the music can carry to similar distances (although, as on Earth, variations due to season and latitude, atmospheric stratification and any wind could become important, especially at very long distance propagation, e.g. of infrasound). The assumed atmospheric pressures (p), temperatures (T) and composition for each world are as follows, allowing the atmospheric sound speed (c) to be calculated: Earth (77% N_2, 21% O_2, 1% H_2O; p = 1 bar, T = 22°C, c = 340 m/s); Titan (95% N_2, 5% CH_4; p =1.5 bar, T= -178°C, c = 210 m/s); Venus (96% CO_2, 3.5% N_2, trace SO_2; p= 90 bar, T = 457°C, c = 410 m/s); Mars (95% CO_2, 2.7% N_2, 1.6% Ar, 0.13% O_2 ; p = 0.007 bar, T = 7°C, c = 240 m/s).

3. RESULTS

Multimedia audio and video files can be downloaded from the following web site: http://www.isvr.soton.ac.uk/fdag/ORGAN.HTM [21]. They demonstrate that the sounds do not travel far on either Venus or Mars, but that they travel well on Titan. The increased sound speed on Venus (compared to Earth) increases the pitch of the flue organ pipes, but the voices of the children sound as if they come from much larger humans because of the increased fluid loading generated by Venus' thick atmosphere [20]. If the calculations are redone with this fluid loading effect neglected, on Venus the children's voices sound as if they come from much smaller humans [21]. Further information can be found at [18- 22].

4. CONCLUSIONS

The ability to predict the sounds of music and voices on other worlds was demonstrated, and the observed effects were attributed to the underlying physics (absorption, sound speed and fluid loading of the source). Development of such physics should allow better microphone design for off-world exploration, and allow both qualitative (e.g. 'what made that sound?) and quantitative (e.g. 'how heavy is that ethane rain on Titan?') interpretation of any soundscapes that are recorded.

5. REFERENCES

[1] Leighton T. G., "The use of acoustics in space exploration". ISVR Technical Report 314, University of Southampton, 2007, pp. 1-34.

[2] H. Muir, "Sounds in space". New Scientist, Vol. 195(2616), 2008, pp. 28-32.

[3] Leighton T. G.,and Petculescu, A., "Sounds in space: The potential uses for acoustics in the exploration of other worlds". Hydroacoustics, vol. 11, 2008, pp. 225-238.

[4] Fulchignoni, M., et al., "In situ measurements of the physical characteristics of Titan's environment". Nature, Vol. 438, 2005, pp. 785-791.

[5] Zarnecki, J. C., et al., "A soft solid surface on Titan as revealed by the Huygens Surface Science Package". Nature vol. 438, 2005, pp. 792-795.

[6] Hagermann, A., Rosenberg, P. D., Towner, M. C., Garry, J. R. C., Svedhem, H., Leese, M. R., Hathi, B., Lorenz R. D. and Zarnecki, J. C., "Speed of sound measurements and the methane abundance in Titan's atmosphere.". Icarus, Vol. 189, 2007, pp. 538-543.

[7] Towner, M. C., Garry, J. R. C., Lorenz R. D., Hagermann, A., Hathi, B., Svedhem, H., Clark, B. C., Leese, M. R. and Zarnecki, J.C., "Physical properties of the Huygens landing site from the Surface Science Package Acoustic Properties sensor (API S)". Icarus, Vol. 185, 2006, pp. 457-465.

[8] Delory, G. T., Luhmann, J., Friedman, L. and Betts, B., "Development of the first audio microphone for use on the surface of Mars". Journal of the Acoustical Society of America, Vol. 121, 2007, pp. 3116.

[9] http://phoenix.lpl.arizona.edu/science_mardi.php

[10] Ksanfomality, L., Goroschkova, N. V. and Khondryev, V., "Wind velocity near the surface of Venus from acoustic measurements". Cosmic Research, Vol. 21, 1983, pp. 161-7.

[11] Ksanfomality, L. V., Scarf, F. L. and Taylor, W. W. L., in Venus, edited by D. M. Hunten, L. Colin, T. M. Donahue and V. I. Moroz (University of Arizona Press, Tucson, AZ, 1983), pp. 565-603.

[12] Ringrose, T. J., Towner, M. C. and Zarnecki, J. C., "Convective vortices on Mars: a reanalysis of Viking Lander 2 meteorological data, sols 1–60". Icarus, Vol. 163, 2003, pp. 78–87.

[13] Leighton T. G., White, P. R. and Finfer, D. C., "The Sounds of Seas in Space", Proceedings of the International Conference on Underwater Acoustic Measurements, Technologies and Results (J.S. Papadakis and L. Bjorno, eds.), Crete 2005, pp. 833-840.

[14] Kovach, R. L. and Chyba, C. F, "Seismic detectability of a subsurface ocean on Europa". Icarus, Vol. 150, 2001, 279-287.

[15] Lee, S., Zanolin, M., Thode, A. M., Pappalardo, R. T. and Makris, N. C., "Probing Europa's interior with natural sound sources". Icarus, Vol. 165, 2003, pp. 144-167.

[16] Lee, S., Pappalardo, R. T. and Makris, N. C., "Mechanics of tidally driven fractures in Europa's ice sheet," Icarus, Vol. 177, 2005, pp. 367-379.

[17] Leighton T. G., Finfer, D. C. and White, P. R., "The problems with acoustics on a small planet". Icarus, Vol. 193(2), 2008, 649-652.

[18] Leighton, T. G. and Petculescu, A., "The sound of music and voices in space Part 1: Theory". Acoustics Today, Vol. 5(3), 2009, pp.17-26.

[19] Leighton, T. G. and Petculescu, A., "The sound of music and voices in space Part 2: Modeling and simulation". Acoustics Today, Vol. 5(3), 2009, pp. 27-29.

[20] Leighton, T.G. "Fluid loading effects for acoustical sensors in the atmospheres of Mars, Venus, Titan and Jupiter" (JASA Express Letters DOI: 10.1121/1.3104628), *Journal of the Acoustical Society of America,* Vol. 125(5), 2009, pp. EL214-EL219.

[21] http://www.isvr.soton.ac.uk/fdag/ORGAN.HTM

[22] http://theworld.org/?q=node/22451