CLUSTER OUTREACH IN A PORTABLE IMMERSIVE THEATER

P. H. Reiff [(1)], C. C. Law[(1)], R. L. Kessel[(2)], M. L. Goldstein[(2)], S. Fishman[(3)] and C. Sumners[(4)]

[(1)] *Rice University, Houston, TX 77005, USA, Email: reiff@rice.edu*
[(2)] *Goddard Space Science Center, Laboratory for Solar and Space Physics, Greenbelt, MD 20771, USA, Email: ramona.l.kessel@nasa.gov; melvyn.l.goldstein@nasa.gov*
[(3)] *Fish-I Studios, Los Angeles, CA, USA, Email: shaifishman@gmail.com*
[(4)] *Houston Museum of Natural Science, Houston TX 77303, USA, Email: csumners@hmns.org*

ABSTRACT

The four-spacecraft Cluster suite makes an excellent opportunity to teach orbital dynamics as well as Cluster science in an immersive theater. The use of single-projector fisheye systems in an inflatable projection dome can bring Cluster science to schools, museums, and even shopping centers. We present visualizations of the Cluster orbit and sonifications of Cluster data that help even visually impaired learners by providing a method of "observing" Cluster data. The Cluster data stream (magnetic fields for example) is mapped to tones, with higher tones for higher data values. Each of the Cluster spacecraft is assigned its own unique sound (e.g., guitar, piano, clarinet, flute) allowing for a true symphony in space. For samples of our sonifications and animations, see http://space.rice.edu/cluster.

1. INTRODUCTION

Spacecraft missions with spectacular imagery of far off planets are easy to inspire the public—one view of the alien shores of a Titan lake or a peek into a Martian crater is sure to create excitement. When a mission has neither imagers nor an unknown distant boundary to cross, it is more challenging to create educational materials suitable for informal science when the audience expects something interesting and unique for its precious time. On the other hand, being able to give life and interest to a data stream of measurements can at the same time create a new cadre of learners–the vision impaired, who otherwise get little from images however spectacular. New immersion techniques allow visitors to fly with the spacecraft in orbit around Earth, showing Kepler's laws in action as they fly fast at perigee and slowly at apogee. These visualizations and sonifications bring new interest to the Cluster data.

2. DATA SONIFICATION

Data sonification is nothing new–broadband plasma wave data in the audio frequency range have been transferred from radio to sounds for years. Thus "whistlers" and "chorus" are descriptive terms based on the perception of the sounds that correspond to the radio frequency data. No real shift of frequency or tone is required, just playing back the radio data in an audio system suffices.

Our approach to data sonification is rather different–we take scalar data (e.g., a component of the magnetic field, plasma density, or scalar velocity) and turn it into an audio stream, with higher pitch tones corresponding to higher magnitude data. We sonify the data using logarithmic tones–each decade of scalar values corresponding to an octave of pitch–with a median value corresponding to middle C. In this way, roughly two decades below middle C and two to three decades above middle C can be perceived, which is adequate for most data streams.

Because determining the orientation and motion of boundaries is an important task of Cluster data analysis (Fig. 1), it is fascinating that such boundaries can be identified by sound as well as the traditional method of examining a trace on a plot. The bow shock, for example, corresponds to a factor of four increase in solar wind density, readily discernable if you make the density correspond to a tone. Similarly, the magnetopause crossing generally is accompanied by a field-aligned current and thus also a change in magnetic field components. By placing the listener in the centroid of the four spacecraft in the tetrahedral orientation (with one above, one in front, and the others on the left and right), the listener can *hear* the boundaries sweep across the spacecraft, allowing a visceral perception of the motion of the boundaries. This can be done if the sound is processed in surround 2.1.1.1 format. The positions of the four spacecraft are effectively placed on the surface of the planetarium.

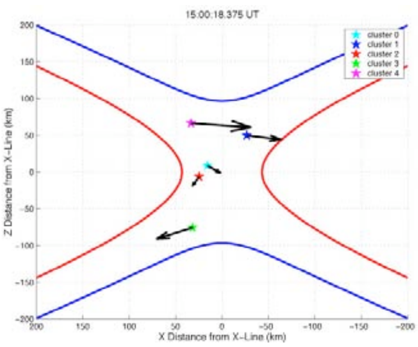

FIG. 1. Frame from the Cluster magnetopause crossing (see Wendel et al., this volume), showing an instantaneous x-line in the magnetic field data. This crossing has been sonified so that you can hear the crossings.

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Using other NASA resources, we have created a portable planetarium system, wherein the students are "immersed" in the imagery. Fig. 2 is an image from students learning about the magnetosphere at a portable planetarium show at the J. L. Burch Elementary School in San Antonio. Fulldome movies are shown using a fisheye projector in an inflatable dome. Using Cluster data we will create new visualizations and sonifications that will make this experience richer (by including immersive sound as well as immersive video).

FIG. 2. Students immersed in the magnetosphere in our portable planetarium system.

To create an immersive scene, we first render views to the inside of a cube: front, left, right, back, and top (Fig. 3). The "Front" image, combined with "Left", "Right", "Top" and "Back" frames, creates a polar "dome master", like an auroral all-sky image. This image can be projected onto a dome through a fisheye projector. Larger theaters "slice" the image into sections, with each section of the image projected by a different projector. Thirty frames per second is sufficient to create a smooth and dramatic journey, traveling with Cluster. New visualization tools can allow the fisheye projection to be created at the beginning.

We have now performed the first part of the task (devising a data sonification algorithm) and are now in the next step of creating the most effective visualizations and sonic transformations to make the boundaries most clearly audible. Note that this technique not only makes the boundaries "visible" for the first time to vision-impaired learners, but it also becomes a fascinating experience for those with normal vision as well. We are working with experts from the University of Texas Accessibility Institute and the Texas School for the Blind and Visually Impaired to create sonic tools that are effective.

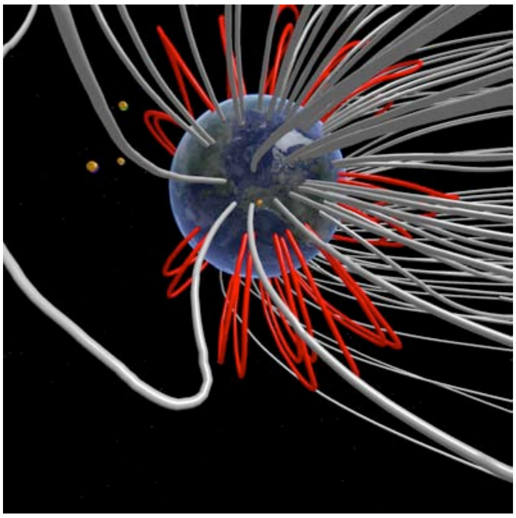

FIG. 3. "Front" Image from the in-progress Cluster movie, with the four spacecraft diving into an accurate model of Earth's magnetic field.

3. "WHAT CHANGED?" – EXPLAINING WHY FOUR SPACECRAFT ARE NEEDED TO UNFOLD SPACE AND TIME

Using sonified data from the four spacecraft in a portable theater is a terrific way for students to actually experience boundaries sweeping across them; however, it is still an experience that is limited to specific kinds of theaters using specialized equipment.

For general learners we have created a "what changed?" module (also available from our website) that teaches, using a weather analogy, why four spacecraft are needed to unfold time and space.

The unit begins with a simple linear weather analogy: Observer 1 sees rain starting at time R1, then snow starting at time S1, then clearing skies at time C1. What happened? Did the rain and snow start everywhere at once, or did a rain front, then a snow front, pass over the observer? From one site (without the benefit of weather satellites!), the observer can't tell.

Adding a second observer 2, who sees the rain starting at a different time R2 and snow at S2, the two observers can tell that the rain front is moving and that it took (T2 – T1) minutes to get from observer 1 to observer 2, but they still can't determine the orientation of the front and thus its true speed. By using four observers, the orientation and speed of the fronts in 3 dimensions can be determined.

We have created a simple flip-book activity to illustrate this effect, allowing the students to attempt to sketch a rain front and snow front whose motion is consistent with all the observations. (The movie is also available from our web site).

FIG. 4. Sequence of images from the "What changed?" activity, allowing students to determine the orientation and motion of rain front and a snow front from observing the weather at four sites over time.

4. SUMMARY

Even without the benefit of gorgeous images, or the drama of landing on a distant planet or moon, multispacecraft data can be made understandable and even dramatic to non-specialists. Students can ride the spacecraft suite through the wilds of the magnetosphere and see and hear the boundary crossings. Although this effort is still in its early stages, we anticipate that the final products will be exciting, educational, and fun.

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