SONIFICATION, MUSIFICATION AND DRAMAFICATION OF ASTRONOMICAL DATA IN THE MULTIMEDIA PRODUCTION "A SPACE JOURNEY"

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ABSTRACT

In this paper, we will discuss, in the context of a recent multimedia production at the Hamburg University of Music and Drama, the notions and concepts surrounding the musical treatment of astronomical data. We will distinguish between the three categories of sonification, musification and dramafication, forming a continuum in terms of how accurately the underlying data are represented and give examples for their application in the multimedia production.

1. INTRODUCTION

A Space Journey – Perspectives of the Unknown is a multimedia project instigated by Georg Hajdu which premiered on October 21, 2022 at the large hall (Forum) of the Hamburg University of Music and Drama (HfMT). As a collaboration between the HfMT multimedia department, its theatre academy as well as the Hamburg University astrophysics department, namely Marcus Brüggen and his team, it involved approximately 80 persons ranging from composers (teachers and doctoral students), directors (bachelor students), scientists (teachers and doctoral students), musicians, stage designers, video artists, sound designers, to actors (including a ventriloquist) and technical personnel. The idea was born out of a discussion as to how to best conclude a research and translation project which, in 2019, had already sponsored the Symphony in the St. Pauli Elbe Tunnel, a large-scale networked music performance project with 144 musicians reading animated notation [1]. Marking the end of the 5-year project, this production was to use the items acquired and installed during this period, including a 146-speaker Meyer Sound Constellation system, 60 m2 LED video wall components, nearly 50 iPads used for animated notation and a novel Bohlen-Pierce contra clarinet. Eight teams, each consisting of a composer, a theater director and an astronomer were formed during the second quarter of 2021 under the direction of the dramaturg Elise Schobeß and the director Ron Zimmering. The aim was to create a diverse yet coherent dramaturgy consisting of a sequence of eight 10-minute scenes, each on a different topic related to fundamental questions of astronomy such as black holes, the big bang, the fate and structure of the universe, exo-planets, etc. (Table 1). We soon also decided on forming a large ensemble of eleven Bohlen-Pierce instruments (Table 2) and an eight-voice mixed choir (SSAATTBB). We decided on the Bohlen-Pierce scale for mainly two reasons: Firstly, it has been studied and put into practice at the HfMT since 2007. Various instruments had been built or repurposed to this end while software had been developed to meet the challenges posed by reading and playing music in this scale [2]. Secondly, due to its alienness to the unexperienced listener it functions well as a metaphor of the extra-terrestrial. Because of its derivation from the just twelfth instead of the octave (3:1 vs. 2:1) and a set of exclusively odd-integer-ratio intervals, the study of the scale can also be seen as a viable analogy to xenobiology and the exploration of alternative hereditary material.

	Composer	Title	Music notation and delivery
1	Georg Hajdu	Solaris I	Animated notation, audio score
2	Aigerim Seilova	hidden darkness	Animated notation
3	Todd Harrop	Quarks and Queries	Static parts
4	Goran Lazarević	Call of the Void	Graphic notation
5	Georg Hajdu	Solaris II	Animated notation, audio score
6	James Cheung	Message in a boomerang	Animated notation
7	Greg Beller	UME – Unidentified Missing Encounter	Static parts
8	Xiao Fu	100 Milliarden Sonnen	Animated notation, audio score
9	Benjamin Helmer	Kein Respekt den Sternen	Static part
10	Georg Hajdu	Solaris III	Static parts, animated notation, audio score

Table 1. The order of the compositions in A Space Journey

2. HISTORICAL CONTEXT OF MUSIC RELATED TO ASTRONOMY

Since antiquity, there has been a tendency to relate the (presumed) inner workings of the universe to music. Kepler coined the term Harmonice Mundi [3] upon demonstrating a mathematical relationship between planetary motion and of musical harmony. *Music of the spheres* remained a trope throughout modernity, both in a metaphorical and a concrete sense. Gustav Holst in his suite *The Planets* (1914-16) expanded on Wagnerian harmony to create a musical language denoting the extra-terrestrial—a language that remains largely intact in Hollywood productions such as *Star Wars* (episodes created since 1977) with music by John Williams. The "apocalyptic" composers Scriabin (1871-1915) and Stockhausen (1928-2007) also had a strong affinity towards the cosmic, manifested by pieces such as *Vers la flamme* (1914), *Sternklang* (1969-71) and *Sirius* (1975-77). In contrast, composer and theorist Clarence Barlow correlates the gaps in the asteroid belt density between Mars and Jupiter to the harmonic intensity of orbital intervals obtained by his *harmonicity* formula without actually creating a musical illustration for this [4]. In 2007, Hajdu wrote the piece *Beyond the Horizon* for narrator, two Bohlen-Pierce clarinets and synthesizer on a text about the accelerated expansion of the universe due to dark energy by Scientific American authors and astronomists Lawrence M. Krauss and Robert J. Scherrer [5]. Sonification of astronomical data by NASA and others often serves a dual purpose: representing data non-visually and aestheticizing them at the same time. Prominent examples are the sounds obtained from the collision of two black holes and the sonification of the remnants of a supernova explosion, employed by Fu in her scene.

3. SONIFICATION VS. MUSIFICATION VS. DRAMAFICATION

I'm not like Stockhausen, I'm not creating music, it's already there ...

-- Morton Feldman

Sonification, musification and dramafication[1] can be conceived as approaches towards extra-musical data[2] located on a continuum but functionalizing the source materials in different ways. While sonification relies on an *auditory display* which needs to represent the original data as accurately as possible [6], musification permits adjustments and modifications of the data with the aim to represent the *structural principles* inherent in the data without necessarily having to spell them out accurately [7]. In contrast, dramafication permits the transformation and distortion of the source material subjecting it to a *musical and/or dramaturgical narrative*.

The term "sonification" was introduced in the 1990s to denote the "transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation" [6]. Thus, data sonification aims to create "an appropriate mapping between data and sound features in a sonification display". Yet, due to its very nature, a sound whether to be used to map data or not, always carry an aesthetical dimension[3], with the propensity of interfering with the perception of the sonified data [9]. To reduce unwanted effects, special care needs to be taken when creating such mappings.

In contrast to sonification, musification pays homage to the aesthetics of sound and incorporates "data features that represent more traditional elements of a musical work such as melody, harmony, and rhythm" [10].

In dramafication, finally, the connection between the original data set and the musical outcome is blurred or overridden by the dramatic effect. It ends up having the similar significance as a musical cryptogram found in the works of Olivier Messiaen and other composers [11].

	Instrument	Notation
1	BP soprano clarinet	fingering notation
2	BP tenor clarinet	fingering notation
3	BP contra clarinet	fingering notation
4	trombone	eighth-tone notation
5	violin	scordatura with tablature
6	viola	scordatura with tablature
7	cello	scordatura with tablature
8	BP 9-string electric guitar	tablature
9	fretless bass	scordatura with tablature
10	keyboard	BP keyboard notation
11	percussion: • BP glockenspiel • BP metallophone	 R clef N clef

Table 2. Instrumentation of the Bohlen-Pierce orchestra

4. GEORG HAJDU: SOLARIS

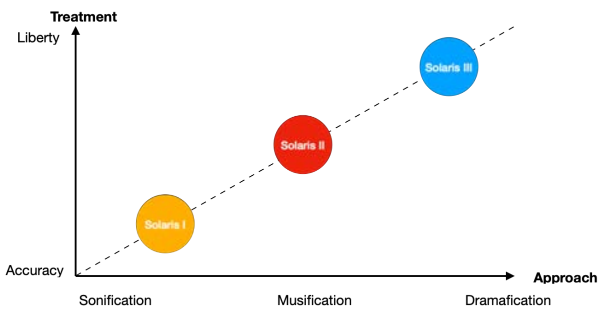

Figure 1. The three parts of Solaris treat the original astronomical data with a varying degree of artistic freedom.

[1] We are using term *dramafication* instead of *dramatisation* for two reasons: (a) to align the method linguistically with the terms sonification and musification, and (2) to distinguish it from *dramatization* which is defined as the process of adapting a novel or presenting a particular incident in a play or film while stressing that the data treatment is motivated by an overarching musical principle.

[2] The data don't need to be extra-musical: much of Lindsay Vickery's work is concerned with the (re)sonification of sonic materials.

[3] In *Doktor Faustus*, German novelist Thomas Mann ironically referred to this quality of music as "Kuhwärme" (bovine warmth).

In a team consisting of director Ron Zimmering, astronomist Kathrin Böckmann (later joined by Denis Wittor) and composer Georg Hajdu, it was decided to focus on turning the filament structure of the universe into music and use excerpts from Stanisław Lem's novel *Solaris* to be narrated alongside the music. Lem's popular work is about the failed mission to comprehend the intelligence of a large ocean covering the planet Solaris and the solipsistic nature of the human quest for alien intelligence in general.

The filament structure of the universe consisting of walls of gravitationally bound galaxy superclusters was discovered in the late 1980's. They are thought to represent the inhomogeneities of matter present during the first moments of the Big Bang. The filaments form the most complex structure in the universe, followed in complexity only by the human brain [12]. Both show a high degree of self-similarity and fractality, a quality that, to a lesser degree, can also be attributed to (tonal) music. We can therefore form a thematic triangle for which Lem's novel (excerpted by Zimmering) serves as a point of departure. Instead of a single 10-minute presentation, *Solaris* was split into three parts forming a prolog, an intermezzo and an epilog, thematically moving from the macrocosm of the filaments to mesocosm of Solaris' ocean-brain and the microcosm of neural activity, thus framing the seven other scenes.

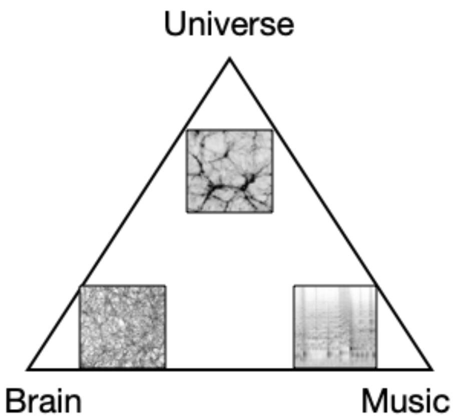

Figure 2. The universe, the brain and music are highly hierarchical and self-similar in nature and thus lend themselves to the creation of artistic analogies. The figure displays a simulation of the distribution of visible matter in the universe (top), neurons grown in a petri dish (left) and a sonogram of musical sound (right).

4.1 Workflow

The point of departure was a cross section of a simulation of the distribution of visible matter in the universe created by Wittor, consisting of a cube of 900x900x900 pixels. The x axis of the cross section was to represent ten minutes of music unfolding from left to right (Figure 3), while the y axis was mapped to a musically meaningful range of six octaves (C1 to C7).

Hajdu used software to

1. manually map the filaments to lines of varying lengths and widths and
2. isolate the largest discernible galaxy clusters and apply them to ovals with varying radii.

In a second step, the data obtained were mapped to frequency (y coordinates), loudness (width/radii) and time (x coordinates) and converted into SPEAR text format [13]. In SPEAR, the data files were transcoded to SDIF, the Description Interchange Format [14], and read into Macaque [15] allowing the conversion of the partial tracks into music notation. In the MaxScore Editor, the "approximate" feature of the n-TET Entry Tool was used to bend the pitches to the nearest Bohlen-Pierce notes [16].

```
par-text-partials-format
point-type time frequency amplitude
partials-count 373
partials-data
0 2 0. 2.
0. 2019.708 0.032 2. 2019.708 0.032
1 2 452.821 454.821
```

Table 3. SPEAR text format used to translate geometric data into partial tracks.

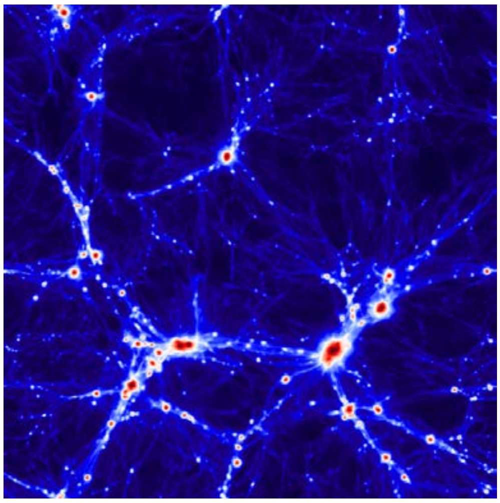

Figure 3. False-color representation of the distribution of the intra-cluster medium in the universe (image from a simulation by Denis Wittor).

Diagonal filaments were transcribed into portamenti whose rendering required a new *polybend* message to be implemented in the *MaxScore* object. To this end, a *pb* editor was added to *Picster Expressions* [15] permitting the generation of a multi-channel breakpoint functions which at runtime are translated by the *maxscore.makenote* abstraction into a sequence of *polybend* message (see 4.2.1).

4.2 The parts

4.2.1 Solaris I

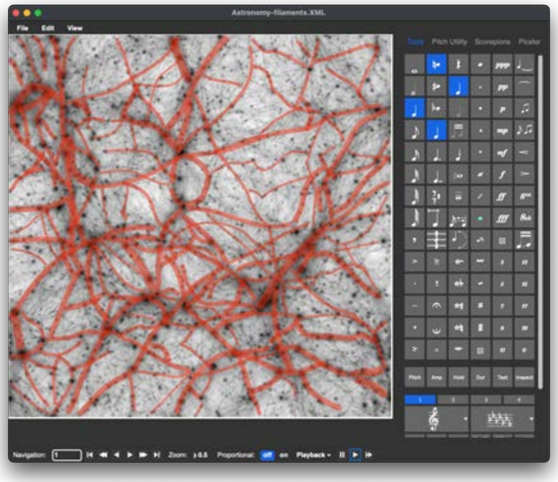

Figure 4. A map of the filaments, parsed manually in the MaxScore Editor.

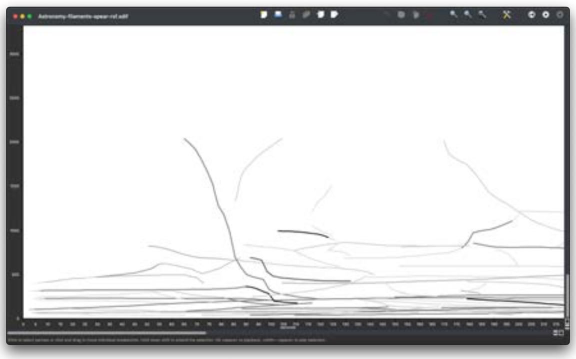

Figure 5. Translation of the filament structures shown in Figure **1** into partial tracks.

The first part, scored for narrator, eight singers and playback, has a duration of three minutes. By transcribing the filaments into partial tracks and ultimately into notation, Hajdu obtained 32 voices which were played back with glass harmonica sounds and recorded into 32 individual tracks in Ableton Live, to be spatialized on the HfMT's Meyer Sound Constellation system and played back in sync with the voices that fell into the singable range of D2 to A5 and sung by the choir.

As the score is in the Bohlen-Pierce scale, intonation posed a challenge which we met by creating a playback device in JavaScript formatting messages for drawsocket's tone.js oscillator method [17].

Figure 6. Portamenti resulting from the transcription of the filaments are rendered graphically and musically in MaxScore using Picster expressions.

For this, the maxscore.makenote object passes two types of event messages to the tonejs-osc JavaScript object (Figure 7):

- *note*, with the arguments pitch [MIDI cents], velocity, channel, e.g. "note 6025 89 29"
- *polybend*, with the arguments reference_pitch, pitch_deviation [cents], velocity deviation, channel, e.g. "polybend 6025 -100 -24 29"

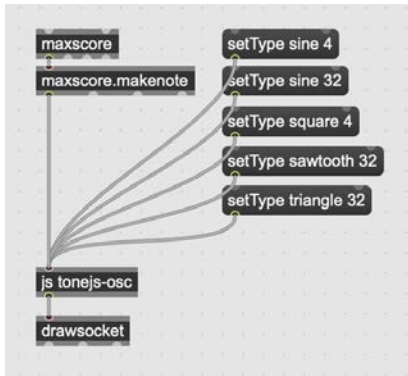

Figure 7. The js tonejs-osc object translates MaxScore event messages into dictionaries served by the drawsocket abstraction to connected browsers. The object also responds to a *setType* message setting the waveform for the synthesis performed on the browsers.

During the performance, the singers held iPads, wirelessly connected to the drawsocket server and received tone.js messages, the result of which they could via earbuds plugged into the iPads' audio jack. The score was rendered in metered proportional notation and fanned out to the performer (or groups thereof) by defining corresponding staffgroups. MaxScore now distinguishes between *metered* (barlines, flags and beams are shown) and *non-metered* (only noteheads are shown with lines extending from them to indicate the duration of the event) proportional notation.

To ensure that the singers heard their sounds well before the corresponding events hit the playhead, the score animation was offset by 500 msec ("pre-delay").

A flight through the cube (representing the universe) was prepared by the astrophysics student David Smolinski and shown on 20 individual LED screens hanging on a computer-controlled fly system. Being the first contribution to the show, the panels were slowly lowered one by one to create the sense of an introduction.

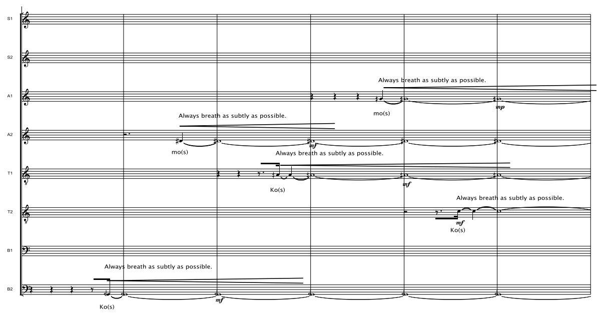

Figure 8. The opening of Solaris I in metered proportional notation. For dramaturgical reasons, the entrances of the voices were modified so they would enter one by one at nearly equal distances. A few of the pitches were adjusted to improve the resulting harmony between the voices.

Figure 9. A frame from the live stream of the premiere showing the performance of Solaris I. The eight singers holding their iPads are positioned in front of the LED video wall panels mounted on a computer-controlled fly system.

4.2.2 Solaris II

The second part lasts for 3”20” and is scored for narrator, choir and Bohlen-Pierce orchestra. In this part, Hajdu first catalogued the largest discernable objects (galaxy clusters) and translated them into a set of partial tracks with y-centers representing pitch (Figure 10). Similarly, the partial tracks were transcribed into notation and bent to the nearest Bohlen-Pierce scale tones. Using this approach, Hajdu’s intention was to create a sense for the density distribution in the universe. Dense moments (frequent attacks) would alternate with moments of low density (prevalence of sustained notes) representing the voids between the filaments—creating a sonic landscape akin to Morton Feldman’s later pieces (such as string quartet no. 2), yet not shying away from occasionally harsh wolf tones obtained by the mapping.

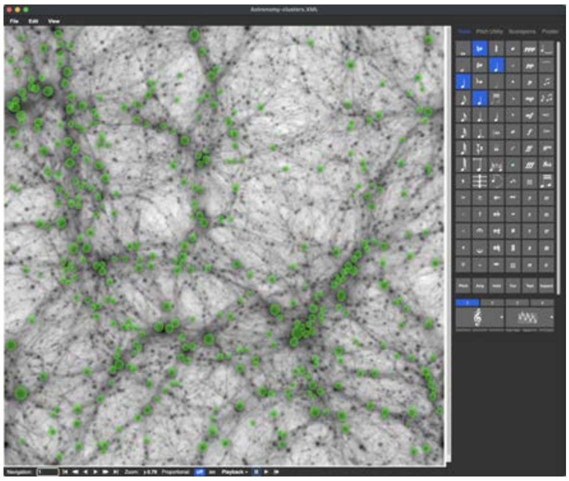

Figure 10. Major galaxy clusters were encircled and mapped to time and frequency.

Figure 11. The circles shown in Figure 10 were translated into short partial tracks and transcribed into notation (Figure 12).

Figure 12. Page 7 of the score of Solaris II.

Hajdu decided to treat dynamics and orchestration freely to highlight the inherent dramaturgy of single notes, dyads and chords resulting from the transcription. In this part, the music was displayed on the iPads of both the singers and the instrumentalists. As with the first part, the exact pitches were delivered to the singers via tone.js but this time with a pre-delay of 500 ms, just in time for their entrances.

The music was accompanied by (a) the narration about the mystery of Solaris' ocean, (b) a soundscape consisting of a multi-channel rendering of the sound of ocean waves enveloping the audience and (c) a video displaying simulations of ocean waves done by Nicolas Desmars, a doctoral student of hydrodynamics and ocean engineering at the Hamburg technical university. The flying system was programmed so that the panels individually performed smooth up and down motions, thus mimicking the behavior of waves.

Figure 13. A frame from the performance of Solaris II with the singers placed between the LED video wall panels displaying the ocean-wave simulation by Nicolas Demars.

4.2.3 Solaris III

Solaris III, 3'40" in duration and scored for narrator, choir and Bohlen-Pierce orchestra, is made of three sections with the same proportions that the Solaris parts form with each other (i.e. 9:10:11). In the first section, the music returns to the original material of the filaments but replaces the sustained notes by fast arpeggios. Hajdu developed a variable arpeggiator which steps through the frames of the SDIF file and applies patterns which Hajdu derived from Clarence Barlow's indispensability function [18]. These patterns when applied to pitch (or in this case to an index number representing a pitch within a particular frame) create interesting and aesthetically pleasing progressions which Hajdu has used in several compositions of his.

While in the first section, the patterns are being played by the guitar, bass guitar and percussion (forming a sort of rhythm group), the second section adds chords with variable lengths performed by the choir and the other instruments. These chords are derived from SDIF frame and carefully voiced to avoid highly dissonant wolf tones occurring in the Bohlen-Pierce scale. After a climax in which the clarinets play ascending and descending scales, the rhythm group performs a strong rallentando and segues into the coda consisting of four sustained fff chords representing the filament structure at specific time points. They are contrasted by repeated notes played at heart rate by the glockenspiel which also concludes the piece and thus the entire show. The music is accompanied by abstract animations created by video artists Janina Luckow alluding to neural network chatter, finally transitioning to imagery that can be interpreted as a supernovae explosion.

As the synchronicity of parts when scrolling proportional scores with very fast pulses is problematic due to small differences in response time between the browser instances within the WiFi network, we decided to use a hybrid approach: The conductor was to listen to a click track and conduct the instrumentalists while the singers would read their scrolling parts—still depending on the tones delivered with the 500 ms pre-delay. We were positively surprised about how stable and reliable this approach turned out to be.

Figure 14. Section I from Solaris III is scored for BP 9-string guitar, fretless bass with scordatura, BP glockenspiel, BP metallophone and synthesizer. The guitarist requested encircled string numbers to be written above the notes for easier orientation. This feat was automated with the *Add String Index To Tablature* Scorepion operating on tablature notation (**Figure 15**).

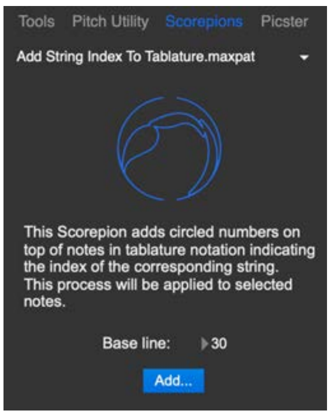

Figure 15. GUI of the *Add String Index To Tablature* Scorepion for the MaxScore Editor.

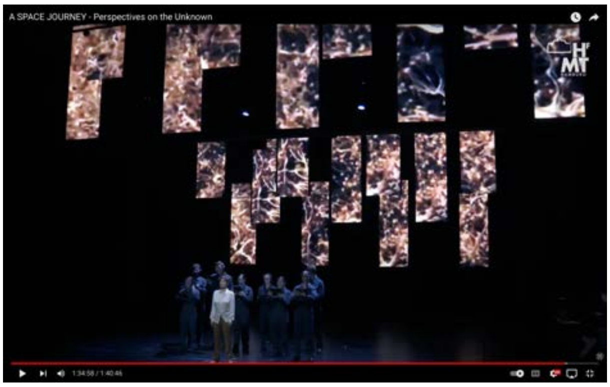

Figure 16. A moment from the dramatic ending of Solaris III with narrator and choir standing below the fly system.

5. XIAO FU: 100 MILLIARDEN SONNEN

The space - between self and the cosmos, birth and death - between each unique experience of life.
A star, a human being, a piece of sky, all live as expressions of creation, and all die as the same.
A star gathers into itself inner tension stirs transformation change explodes through its boundaries what once defined releases itself into the undefinable.

-- Sara Ezzell, choreographer

100 Milliarden Sonnen (*100 Billion Suns*) is composed in four parts: Birth, Life, Death and Sublimation and is performed by a women's choir, three BP clarinets, trombone, violin, viola, cello, percussion, tape and dancer (Sara Ezzell). It makes use of the results of the sonification project led by staff of NASA's Chandra X-ray Observatory and the Universe of Learning. She chose the sonification of Tycho's Supernova Remnant performed in the optical range (other wavelengths have also been subjected to sonification)[4].

Starting in 2012, when Fu commenced her collaboration with the architecture department of the Hamburg HafenCity University (HCU) on various space-sound installations, she developed a technique which takes a sound design as a starting point and derives the instrumental parts from it. The compositions are mostly very slow, but with a lot of subtle changes within the long tones. Stylistically, it borrows from pieces by Dutch composer Louis Andriessen: combining long tones and fast, small, moving figures. This results in an evolving harmonic movement and thus in the build-up of tension.

In *100 Milliarden Sonnen*, her point of departure was the Tycho's Supernova Remnant sonification as an *objet trouvé* which she dramafied by freely choosing and orchestrating the pitch material she obtained from it.

For this, she developed the following workflow:

1. Audio extraction
2. Audio to MIDI conversion in Ableton Live
3. MIDI import into MaxScore
4. Adjustment of the pitch material to the BP scale
5. Orchestration of select notes for the choir and BP ensemble

In the coda of her composition (approximately nine minutes into her piece), the original sonification is presented as a kind of afterthought and revelation of the source material.

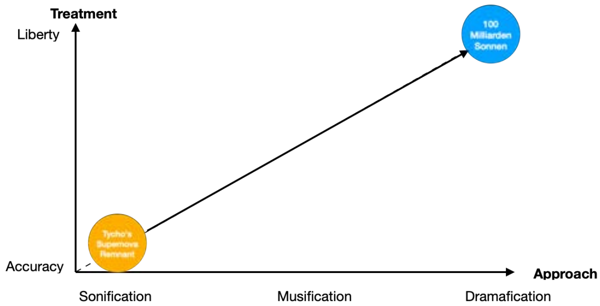

Figure 17. Path taken in *100 Milliarden Sonnen* by Xiao Fu dramafying an existing sonification obtained by NASA's Chandra X-ray observatory.

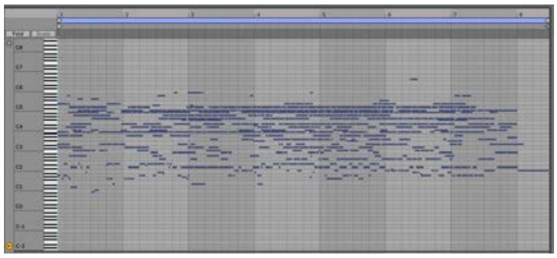

Figure 18. Display of the audio to MIDI conversion of the Tycho's Supernova Remnant (optical) sonification performed in Ableton Live.

[4] https://chandra.si.edu/photo/2021/sonify4/

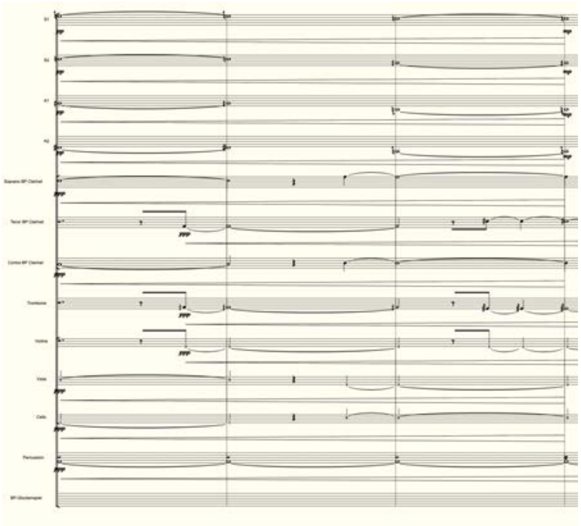

Figure 19. Score obtained from dramafication of an existing sonification.

Figure 20. Choreographer and dancer Sara Ezzell performing in front of the LED video wall.

Like Hajdu in Solaris II, Fu used the drawsocket server to distribute the parts to the performers and feed the audio score to the four singers via tone.js. The choreography was developed by Sara Ezzell while the video work was created by Janina Luckow.

6. CONCLUSION

This paper aims to present various approaches to the sonification of astronomical data. Whereas, originally, sonification aims to represent data on an auditory display as accurately as possible, we have presented several cases in which their musical transformation serves a dramatical purpose which takes them out of the original context and recontextualizes them within the framework of a large multimedia production. While the director Ron Zimmering praised the expressiveness of the sonified material, the audience response was overwhelmingly positive, which also convinced the astronomists who admitted that they had been quite skeptical at the outset of the project and now were suggesting a sequel to it.

Acknowledgments

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