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Directed by Dr. Alejandro Rutty, 46 pp.

Universal Density is a musical composition for digital electronic media that takes the listener on a rapid tour of the universe. It begins in the far away wastes of the Southern Local supervoid and abruptly ends at the busy edge of our own Solar system. Various celestial bodies are represented by shifting arrangements of sounds, and specific sound objects represent each body's density, temperature, electromagnetic content, and distance from Earth. Ultimately, *Universal Density* is a detailed system of musical symbols and references, constructed with the intent to provoke both an intellectual and emotional response to data about the organization of the universe. It is my hope that *Universal Density* generates a positive response from the audience, resulting in more enthusiasm for astronomy and science education as well as an interest in exploring the combined powers of science and art.

Three different pieces of media make up *Universal Density*. The first is my musical composition, presented through simple CD stereo playback. The second is a graphic score I drew, which reflects the movements of key sound objects in the music. The graphic score is a critical tool for understanding the interaction between different musical symbols and the meaning of those interactions throughout the composition. The final component of *Universal Density*, not presented in this document, is a short film comprised of NASA photographs that I had animated by Greensboro film maker Mandi Hart. While the film is not required to present *Universal Density* to an audience, I believe

it drives home the significance and wonder of the scientific information which inspired the project.

This document presents and explains the score and music portions of the *Universal Density* project. The paper examines the construction and symbolism used to create *Universal Density.* Sound samples are imbedded as they are mentioned throughout the document, and the Appendix presents the graphic score through a series of photographs and detail shots.

UNIVERSAL DENSITY: A MUSICAL REPRSENTATION OF ASTRONOMICAL OBJECTS AND CONCEPTS

by

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2012

Approved by

_____
Committee Chair

APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of The Graduate School at the University of North Carolina at Greensboro.

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Date of Acceptance by Committee

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CHAPTER I

INTRODUCTION

Universal Density is a four minute long piece of electronic music that takes the listener on a rapid tour of the universe. It begins in the far away wastes of the Southern Local supervoid and abruptly ends at the busy edge of our own Solar system. Various celestial bodies are represented by shifting arrangements of sounds, and specific sound objects represent each body's density, temperature, electromagnetic content, and distance from Earth. Ultimately, *Universal Density* is a detailed system of musical symbols and references, the interactions of which dictate the evolution of the music.

Three different pieces of media make up *Universal Density*. The first is my musical composition, presented through simple CD stereo playback. The second is a graphic score I drew, which reflects the interactions of key sound objects in the music. The third component is a short film comprised of NASA photographs that I had animated by Greensboro film maker Mandi Hart. While the film is not required to present *Universal Density* to an audience, I believe it drives home the significance and wonder of the scientific information which inspired the project.

I constructed *Universal Density* with the intent to provoke both an intellectual and emotional response to data about the organization of the universe. To learn about the astronomical environments that ultimately provide for Earth's continued existence is a

truly mind-blowing experience. Even more poignant is the emotional wonder that knowledge inspires; for me, that wonder includes a giddy thankfulness for the little planet that cradles us all, as well as deeper questions about the significance of life (and, particularly, my own life) when viewed in the context of the order and nature of the cosmos. My hope is that *Universal Density* can be used as a tool to teach a few astronomical facts. Offering information in the form of entertaining media can facilitate an enjoyable learning experience. Music is common method of provoking pathos. When combined with austere scientific data, music can become an emotional translator for the personal meaning of abstract concepts about the arrangement of the universe.

The intention of this paper is to document exactly how *Universal Density* uses musical symbolism to not only construct a sonic image of the universe, but to also provoke an emotional reaction to that picture in the listener. It is my ultimate hope that *Universal Density* will generate a positive response from its audience, resulting in more enthusiasm for astronomy and science education as well as an interest in exploring the combined powers of science and art.

I had many sources of inspiration in constructing the main sound objects in *Universal Density*. The two most prominent of these sound objects are narrating voices, which I label the Robot Voice and the Auxiliary Voice. Both of these recite astronomical information throughout the piece, but they are edited in such a way that the text is often deeply obscured. Heavily edited voices are prominently used in many electronic compositions. Tod Dockstader used pitch-shifted Gregorian chant to create an

atmosphere of "threat and despair" in his piece, *Apocalypse, Part 2* (1961). [1] In *Bye Bye, Butterfly* (1965), Pauline Oliveros used tape delay and electronic tones to obscure an excerpt from Puccini's *Madame Butterfly*.[2] Charles Dodge blurred the lines between human and mechanical voices using rhythmic and timbral manipulations in *He Destroyed Her Image* (1972).[3] In the piece *Automatic Writing* (1979), Robert Ashley used fade ins and outs to frustrate the understanding of a text, leaving only timbre and inflection to creating a convincingly ghostly voice.[4] Paul Lansky's monumental *Six Fantasies on a Poem by Thomas Campion* (1982) is a cornucopia of beautiful and disturbing variations on altered human voice. He highlighted different aspects of the reader's speech with different electronic processes, sculpting the music in much the same way as Campion used careful vowel placement to sculpt the overall sound of the original poem's reading.[5] George Todd created an entire and diverse sonic landscape of processed bits of speech in his piece, *Wordscapes* (1991). He used a harmonic spectrum analysis and re-synthesis program to process the original voice, leaving most of the resulting sounds only barely

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[1] Tod Dockstader, notes from "Apocalypse, Part 2," *OHM the Early Gurus of Electronic Music, 1948-1980*, Ellipsis Arts, 2000.

[2] Pauline Oliveros, notes from "Bye Bye, Butterfly," *OHM the Early Gurus of Electronic Music, 1948-1980*, Ellipsis Arts, 2000.

[3] Charles Dodge, notes from "He Destroyed Her Image," *OHM Early Gurus of Electronic Music, 1948-1980*, CD 3, Ellipsis Arts, 2000.

[4] Robert Ashley, "Automatic Writing" *OHM Early Gurus of Electronic Music, 1948-1980*, Ellipsis Arts, 2000.

[5] Paul Lansky, notes from "Six Fantasies on a Poem by Thomas Campion," *Fantasies and Tableaux*, New World Records, NWCR683, 1994.

recognizable as human speech.[6] Joseph L. Anderson rendered a text completely unintelligible for his piece, *In Mosaic* (1992). He used granular synthesis to create a stunning variety of vocal samples from a single short text, which he reassembled into a musical composition, much like a visual artist breaks tiles and rearranges them to make a mosaic.[7] In Jon Christopher Nelson's piece for tape and soprano, *They wash their ambassadors in Citrus and Fennel* (1994), the accompanimental track was constructed from a reading of the same text sung by soprano.[8] Elainie Lillios uses samples from the performer's voice in her piece from tape and soprano, "Earth-Body, Light-Body" from *Earth Ascending* (2000).[9] Kristi McGarity uses voices that fade in and out of intelligibility as they rise up out of synth pads and radio static in her piece *So Many Days to Be Here* (2002).[10]

The most ubiquitous sound object in my composition is the musical symbol for density. It is a wide, rolling, non-pitched sound that establishes the expansiveness of the sonic landscape. It is closer to sculpted static than it is to anything with differentiated and ordered pitches, and my main goal was to make it multifaceted so that it could be an

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[6] George Todd, notes from "Wordscapes," *Music from SEAMUS*, vol. 2, Society for Electro-Acoustic Music in the United States.

[7] Joseph L. Anderson, notes from "In Mosaic," *Music from SEAMUS*, vol. 3, Society for Electro-Acoustic Music in the United States.

[8] Jon Christopher Nelson, notes from "They wash their ambassadors in Citrus and Fennel," *Music from SEAMUS*, vol.7, Society of Electro-Acoustic Music in the United States.

[9] Elainie Lillios, "Earth Asending," *Music from SEAMUS*, vol. 11, Society of Electro-Acoustic Music in The United States, 2002.

[10] Kristi McGarity, "So many days to be here," *Music from SEAMUS*, vol. 12, Society of Electro-Acoustic Music in the United States.

evolving underpinning for everything else in the piece. There are a number of pieces in the electro-acoustic repertoire that deal with sculpting white noise—pieces that could also be described as compositions where large sections are defined by texture and timbre rather than rhythmic, harmonic, or melodic schemes. In *Projection Esemplastic for White Noise* (1964),[11] Joji Yuasa turned a rather one-dimensional, small, pitch-shifting tone into something huge and overwhelming by adding subtle washes of sound as the piece progresses. The interesting part of the metamorphosis is that, by the end of the piece, that layered tone still sounds very much like one, unified thing, not many things singing together. John Chowning's *Stria* (1977)[12] also explored an additive process to form different timbres but in a way that is very dynamic and presents a parade of many different timbers that move about as their own sound objects. He also introduced into the composition tones which modulate between sine, square, and triangle waves to create an added dialogue of texture. Bernardo Feldman's *Still Life* (1986)[13] is somehow a mix of these two approaches. He built up a static wall of sound that goes nowhere, but there are parts of that sound that are slowly revealed to be active, or running in place. Interestingly enough, the one thing that does shift throughout the composition is the panning, which—in my mind-- mimics how a viewer would move to look at a painting from different angles rather than have the painting (or its components) move around the room. Michael

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[11] Joji Yuasa, "Projection Esemplastic for White Noise," *OHM the Early Gurus of Electronic Music, 1948-1980*, CD 2, Ellipsis Arts, 2000.

[12] John Chowning, "Stria," *OHM the Early Gurus of Electronic Music, 1948- 1980*, CD 2, Ellipsis Arts, 2000.

[13] Bernardo Feldman, "Still Life," *Music from SEAMUS*, vol. 1, Society of Electro-Acoustic Music in the United States.

Pounds also used cumulative sounds to build tension in his piece *Critical Mass* (1997).[14] His sound objects are much less densely packed that Feldman's and are of a greater variety, as far as their envelope and pitch. This allowed Pounds to define the space which his music occupied in a more versatile way, allowing his composition more than one point of climax. This greater variety also allowed him to keep his audience more closely engaged, since it is more difficult to predict in what direction the sounds will evolve. Elainie Lillios also uses a variety of non-pitched sound objects in *Earth Ascending* (2000).[15] "Earth-Body, Light-Body" features sounds of something round and heavy rolling on a hard surface, which she transformed into the agitated fluttering of an army of wings. In "Wringcliff Beach," from the same work, she primarily used what sounds like tiny stones moving, fabric tearing, and a silvery fuzz of static. Here again, the interplay of sound objects with starkly different timbers and envelopes, as well as emphasis on different chunks of the harmonic spectrum, were the main focus of the tape track supporting the soprano. Lillios' *Dreams in the Desert* (2001)[16] is a masterful example of crystal-clear sampling and transformation. She turned the sound of water into dry, crunching pebbles or the crunching of icy snow. In between, interpolated harmonic sounds into everyday noise, creating a seamless tapestry of sound which is, in the strictest

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[14] Michael Pounds, "Critical Mass," *Music from SEAMUS*, vol. 8, Society of Electro-Acoustic Music in the United States.

[15] Elainie Lillios, "Earth Ascending," *Music from SEAMUS*, vol. 11, Society of Electro-Acoustic Music in the United States.

[16] Elainie Lillios, "Dreams in the Desert," *Music from SEAMUS*, vol. 13, Society of Electro-Acoustic Music in the United States.

sense, extra-ordinary. Scott A. Wyatt's *Night Visitors* (2002)[17] also transformed everyday sounds into something extraordinary. The piece was meant to represent the sound of his cats' movements at night, and features a metamorphosis of typical clattering sounds into deftly moving white noise that ranges from high, silvery fuzz to low, ominous gravelly noise.

The musical symbol I've constructed for heat is similar to the one for density, in that they are both types of white noise. However, my heat features a different timbre that is a high, silvery, sizzling, highly active mass of sound that lives in the middle and foreground of the piece. High-pitched white noise has been used by other composers as a focal point for an electronic composition. Rachel McInturff created a fertile landscape of many different middle range noises in *Origami Animae* (1997) by processing samples of sounds made by manipulating pieces of paper.[18] In *Release* (1998), Michael Pounds used a high, silvery type of static with lower-pitched fold over to represent a release of tension, along with other sounds that were "characterized by openness and motion."[19] Andrew Walters used a number of different high-pitched statics as well as more sine-like high pitches in his piece *IN→EX* (1998), which gave it an arresting textural variety. The piece itself is a meditation on the mechanical nature of cause and effect, and the high pitched

[17] Scott A. Wyatt, "Night Visitors," *Music from SEAMUS,* vol. 12, Society of Electro-Acoustic Music in the United States.

[18] Rachel McInturff, notes from "Origami Animae," *Music from SEAMUS,* vol. 8, Society of Electro-Acoustic Music in the United States.

[19] Michael Pounds, notes from "Release," *Music from SEAMUS,* vol. 9, Society of Electro-Acoustic Music in the United States.

statics were only two of many mechanical and industrial sounds featured. [20] In *The Sundering Seas* (2002),[21] Noel Paul used a vast palate mid- and high-range sounds that featured processed sound and static that sounds glassy, dully metallic, silvery, gritty, and watery.

In *Universal Density,* I represented light with clusters of bell-like sounds that were actually Tibetan singing bowls augmented by live digital processing. A number of other electronic pieces use some sort of processing to enhance an acoustic sample while leaving it recognizable as the original sound. Otto Luening turned the flute into a pulsing, ethereal, unearthly sound in *Low Speed* (1952) by manipulating "acoustic relationships" with a tape recorder. [22] Paul Koonce used granular synthesis to blur the boundary between sound samples from a piano and a synthesized chord in his piece *Whitewash* (1992). He creates continuous, glassy, glissandos and brittle, interrupted strikes that are accented by a progressively more sophisticated "whitewash," "increasingly expanding [them] toward the brink of noise."[23] Adrian Moore sampled sounds from both a piano and a harpsichord for *Superstrings* (1998), which "[colors] and [articulates]" key strokes, harmonics, and scraped strings with other sounds.[24] In *Threnos* (2002), Larry Austin elegantly augmented

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[20] Andrew Walters, notes from "IN→EX," *Music from SEAMUS,* vol. 9, Society of Electro-Acoustic Music in the United States.

[21] Noel Paul, "The Sundering Seas," *Music from SEAMUS,* vol. 13, Society of Electro-Acoustic Music in the United States.

[22] Otto Luening, notes from "Low Speed," *OHM the Early Gurus of Electronic Music, 1948-1980,* CD 1, Ellipsis Arts, 2000.

[23] Paul Koonce, notes from "Whitewash," *Music from Seamus,* vol.3, Society of Electro-Acoustic Music in the United States.

[24] Adrian Moore, notes from "Superstrings," *Music from SEAMUS,* vol. 10, Society for Electro-Acoustic

the lament of a bass clarinet with a halo of artificial tones, also derived from a bass clarinet.[25] Elainie Lillios expanded the musicality of bubbling and splashing water in *Dreams in the Desert* (2001) [26] by adding or highlighting its existing harmonic partials. In Suk-Jun Kim's piece *Gaesim* (2002),[27] I believe that (starting at about 3 minutes in) he processes the sound of a singing bowl to highlight the differences in texture between the hum of the bowl and the rubbing and striking sound of the wooden dowel used to play the bowl. In *The Sundering Seas* (2002), Noel Paul uses "spectral amplitude information distilled from water samples" to shape sound samples from "keys, bowed electric guitar, ambisonic recordings, and paper."[28]

Music in the United States.

[25] Larry Austin, notes from "Threnos," *Music from SEAMUS*, vol. 13, Society for Electro-Acoustic Music in the United States.

[26] Lillios, "Dreams in the Desert," *Music from SEAMUS*, vol. 12, Society for Electro-Acoustic Music in the United States.

[27] Suk-Jun Kim, "Gaesim," *Music from SEAMUS*, vol. 12, Society for Electro-Acoustic Music in the United States.

[28] Noel Paul, notes from "The Sundering Seas," *Music from SEAMUS*, vol. 13, Society for Electro-Acoustic Music in the United States.

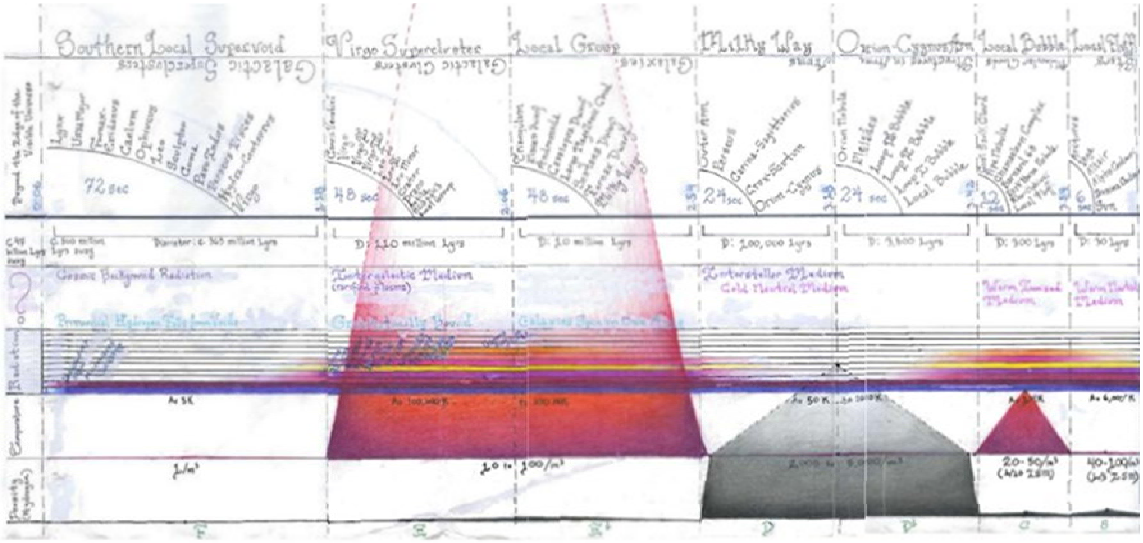
CHAPTER II

THESIS COMPOSITION

Sound Sample 1. *Universal Density*, for digital media

Click here to play embedded file:
Sound Sample 1. *Universal Density,* for digital media

Figure 1. Photo mosaic showing full graphic score for *Universal Density*



CHAPTER III

MUSICAL SECTIONS

Universal Density uses multiple layers of musical symbolism to create a sonic diorama of the universe. Among other things, it depicts the size and rough location of different astronomical structures, like galaxies, nebulae, and molecular clouds. It does this by using seven different Sections of music to represent seven different astronomical Structures and the smaller objects contained within them. The Sections are arranged so that the Structures they represent are presented from largest to smallest. This sequence also reflects how each successive Structure is, in reality, encapsulated within each previous structure. For example, Section II represents the Virgo galactic supercluster, and Section III represents the Local Group galactic cluster; in reality, the Local Group is actually one of the many galactic clusters that collectively make up the Virgo supercluster.

Figure 2. Photo mosaic of full graphic score, marked to show musical Sections and a linear representation of the listener's journey through the music and through space.

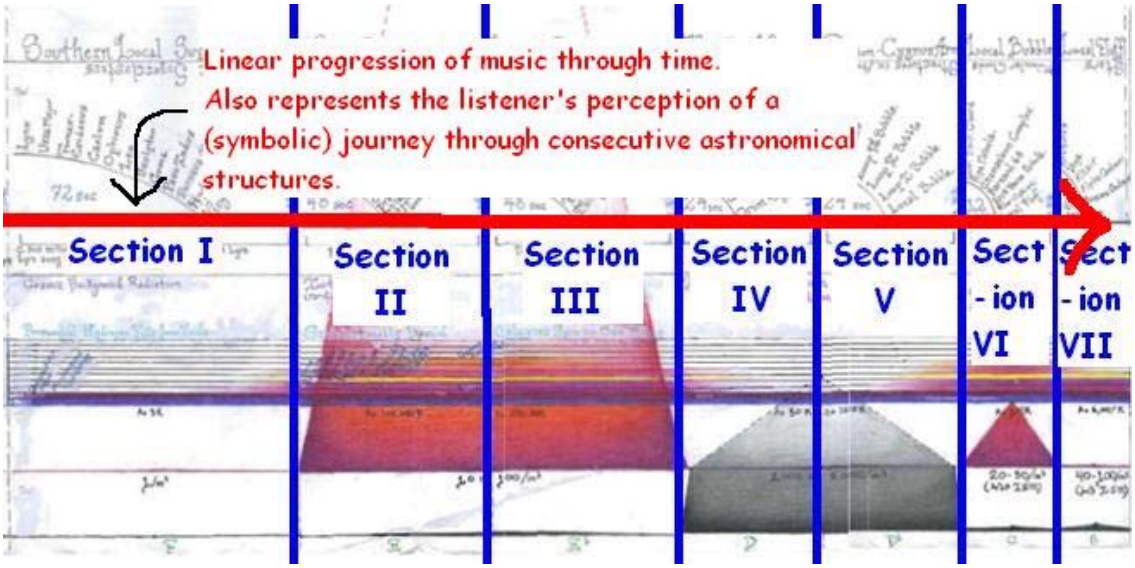
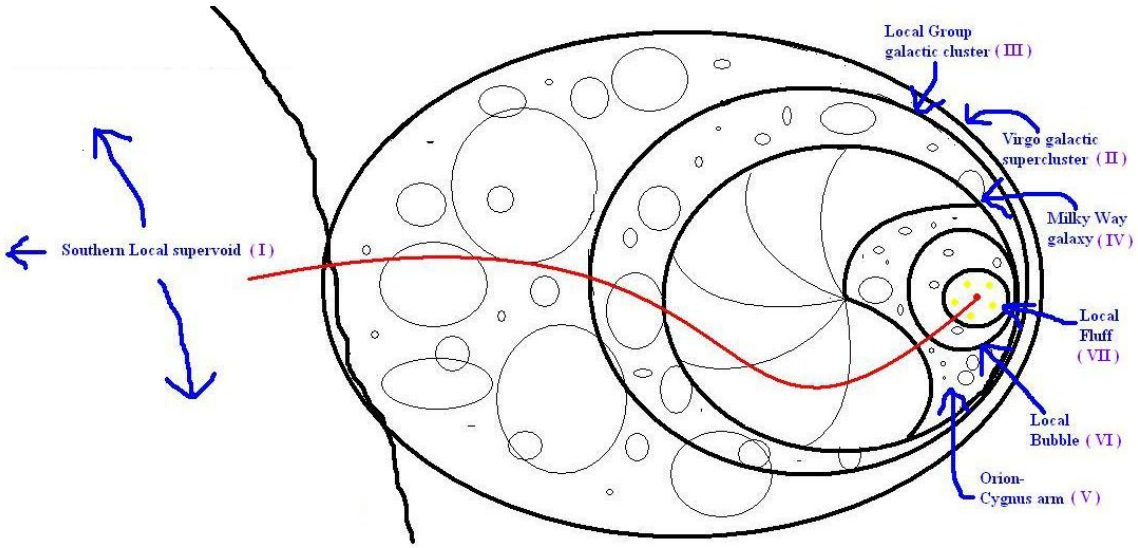


Figure 3. Table of musical Sections and their corresponding astronomical Structures, with durations

Musical Section	Astronomical Structure	Duration in Seconds
I	Southern Local supervoid	72
II	Virgo galactic supercluster	48
III	Local Group galactic cluster	48
IV	Milky Way galaxy	24
V	Orion-Cygnus arm	24
VI	Local Bubble	12
VII	Local Fluff	6

Figure 4. Illustration showing the astronomical structures represented by the musical Sections of *Universal Density*, and their nested spatial relationship.



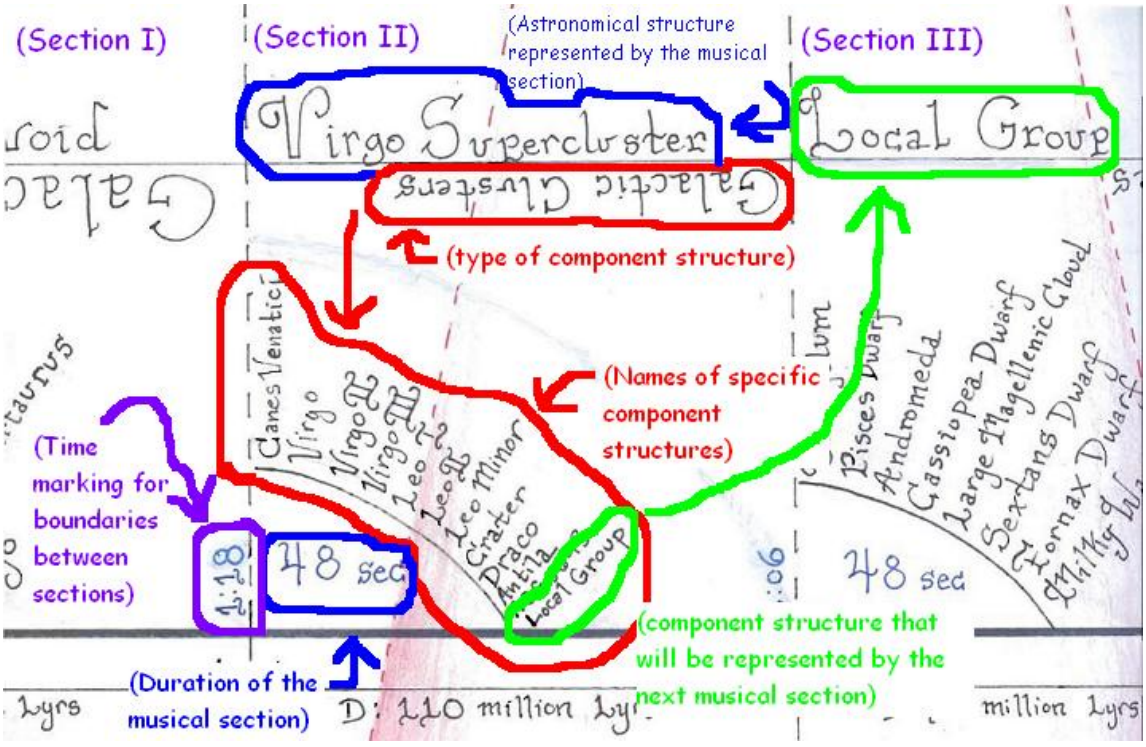
As the listener hears a musical Section, she symbolically travels through the astronomical structure it represents. At the beginning of *Universal Density* the listener is meant to feel that she is floating in the most distant astronomical structure, the Southern Local supervoid. As the music plays, the listener symbolically descends through the supervoid and into the galactic super cluster, and so on until she reaches the edge of our Solar system, represented by the end of the seventh Section.

Universal Density also uses the length of musical Sections to show the relative size of astronomical Structures. Larger Structures are represented by longer Sections of music, and smaller Structures are allotted briefer Sections of music. For example, since Section II represents the gigantic Virgo galactic supercluster, which measures one-hundred and ten million light years in diameter, it is allotted a duration of forty-eight seconds, in total. However, since Section VII represents the Local Fluff, which is only

thirty light- years in diameter, it is only allotted six seconds. By varying the relative length of musical Sections, the listener should feel like she is falling faster and faster as she approaches the end on the music.

The length of each of these musical Sections is aurally defined by a voice that continuously recites names of other astronomical objects. The recitation begins with the name of the Structure that the Section represents, followed by the names of other smaller astronomical structures found within it.

Figure 5. Graphic score detail, showing flow of information for "Robot Voice" recitation



These names symbolize some of the astronomical structures by which the listener may pass on her journey. Generally, those structures that are farther from Earth are named earlier in the recitation, and those that are closer are named later. The very last astronomical structure named in the recitation is always same as that which is represented by the next musical Section.

For example, musical Section II, which represents the Virgo galactic supercluster, occurs between the time marking 1’18” and 2’06”. For the entire forty-eight seconds that this Section lasts, a voice recites the names of the galactic clusters contained within the Virgo supercluster. The very last name recited is the Local Group, which is the astronomical Structure represented by Section III.

CHAPTER IV

NARRATING VOICES

Universal Density contains two voices that recite information about the astronomical Structures through which the listener symbolically travels. The first voice that speaks is what I call the "Robot Voice" because it sounds very metallic and has a somewhat artificial cadence. Its function is to tell the listener through which astronomical Structure she is currently travelling, and it also mentions other smaller astronomical objects by which she passes. The Robot Voice represents the human capacity to understand outer space through the raw numerical data humans have gathered via space probes, space telescopes, and mathematics. Just as astronomy tells humans the position of the earth in relation to the rest of the universe, the Robot Voice tells the listener which astronomical objects she is near.

I created the Robot Voice through digitally recording and editing my own voice using the computer program, Cubase. I used the graphic score as a script for the Robot Voice's entire recitation (see Appendix: Score Segment 1, Detail 1, which shows the beginning of the Robot Voice's recitation).

Sound Sample 2. Robot Voice: unfiltered

Click here to play embedded file:
Sound Sample 2. Robot Voice: unfiltered

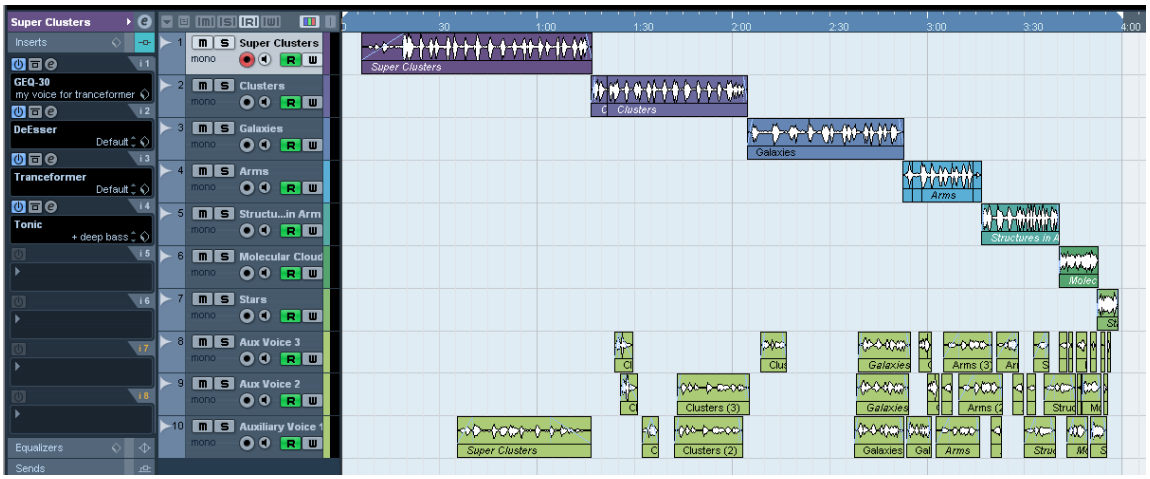
After normalizing the recording, I used a ring modulator to create new harmonics and make the Robot Voice sound metallic. I also truncated the bit depth of the audio signal to make is sound more like an old-fashioned, low-fidelity mechanical replica of a human voice. I then used a simple low frequency resonator to create what I would describe as an auditory shadow—a lower-pitched, masculine doppelganger of my female voice. To add some interesting low-frequency white noise, I used a combination of a low-frequency resonator, oscillator, and a variable low-pass filter. I finally used a volume modulator to create pops of sound that resemble static or signal clipping through a microphone. Together, these effects created a robotic voice that encounters an increasing amount of auditory turbulence as the listener nears the end of the piece.

Sound Sample 3: Robot Voice: filtered

Click here to play embedded file:
Sound Sample 3: Robot Voice: filtered

This creates an increasing instability in the Robot Voice, which leads it to break up as the listener symbolically moves closer to the Earth. This overload in the Robot Voice illustrates how human knowledge of space becomes more complex as the listener approaches Earth, to the point that it can be overwhelming.

Figure 6. Screenshot of Cubase project, showing Robot Voice for seven different musical sections (top seven rows) and the three Auxiliary Voices (bottom three rows in light green)



I call the second narrating voice in *Universal Density* the "Auxiliary Voice." It begins a little later than the Robot Voice and appears only intermittently. The Auxiliary Voice is meant to be a foil for the Robot Voice; where the Robot Voice represents a cerebral understanding of the universe based on numbers and remote measurements, the Auxiliary Voice represents an emotional understanding of the universe that hinges on a sense of community with other life forms and the transcendence of the individual. The Auxiliary Voice suggests that humans have, besides the capability for advanced logic, an intrinsic and ineffable resonance with the universe around them.

The Auxiliary Voice is different from the Robot Voice in three major ways. First, its recitation is different from the Robot Voice's. The Auxiliary Voice tells the listener how far away an astronomical Structure is from Earth, as well as the diameter of those Structures. It is aurally different from the Robot Voice in that, where the Robot Voice is

clunky and mechanical, the Auxiliary Voice is ghostly and is filled with an emotion: urgency. The Auxiliary Voice also evolves in a unique way as *Universal Density* progresses. While the Robot Voice becomes progressively buried by blossoming layers of noise, the Auxiliary Voice buds into multiple, higher-pitched voices that easily soar above the increasingly dense noise. The Auxiliary voice continues to splinter into more and higher-pitched copies as the end nears, each sounding more frantic than the last.

Sound Sample 4. Auxiliary Voice

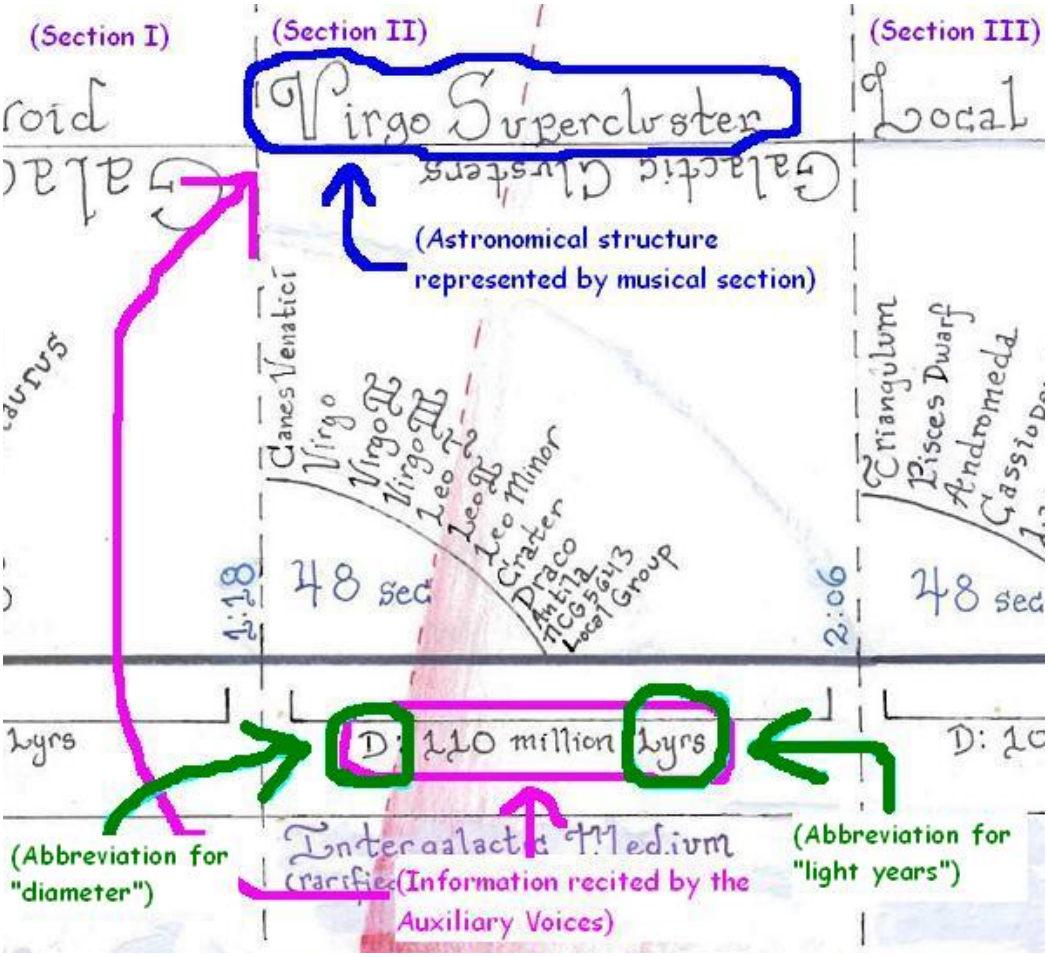
Click here to play embedded file:
Sound Sample 4. Auxiliary Voice

The excitement in the Auxiliary Voice represents a sense of homecoming as listener symbolically travels closer to the Earth. By the end of *Universal Density*, the urgency in the Auxiliary Voice is so great that the small choir of clones has evolved from angelic announcers to unnerving banshees.

Like the Robot Voice, I use a recording of myself reading from the graphic score for the source material for the Auxiliary Voice. To give the recording a ghostly, breathy sound, I used a type of reverberation simulator that incorporates a reverse-echo. As the Auxiliary Voice split into multiple layers, I transposed some clips upwards in pitch without time correction. The result is a frantic babbling of words that seems to materialize out of nowhere. To give the chatter more weight, I used increased the gain for the lower frequencies create an auditory shadow that sounds like barely audible white-noise. This weighted babbling becomes more frequent and higher pitched; by the end of

Universal Density, the Auxiliary Voice seems to be screaming in excitement while the Robot Voice is equally overwhelmed.

Figure 7: Graphic score detail, showing flow of information for "Auxiliary Voices" recitation



CHAPTER V

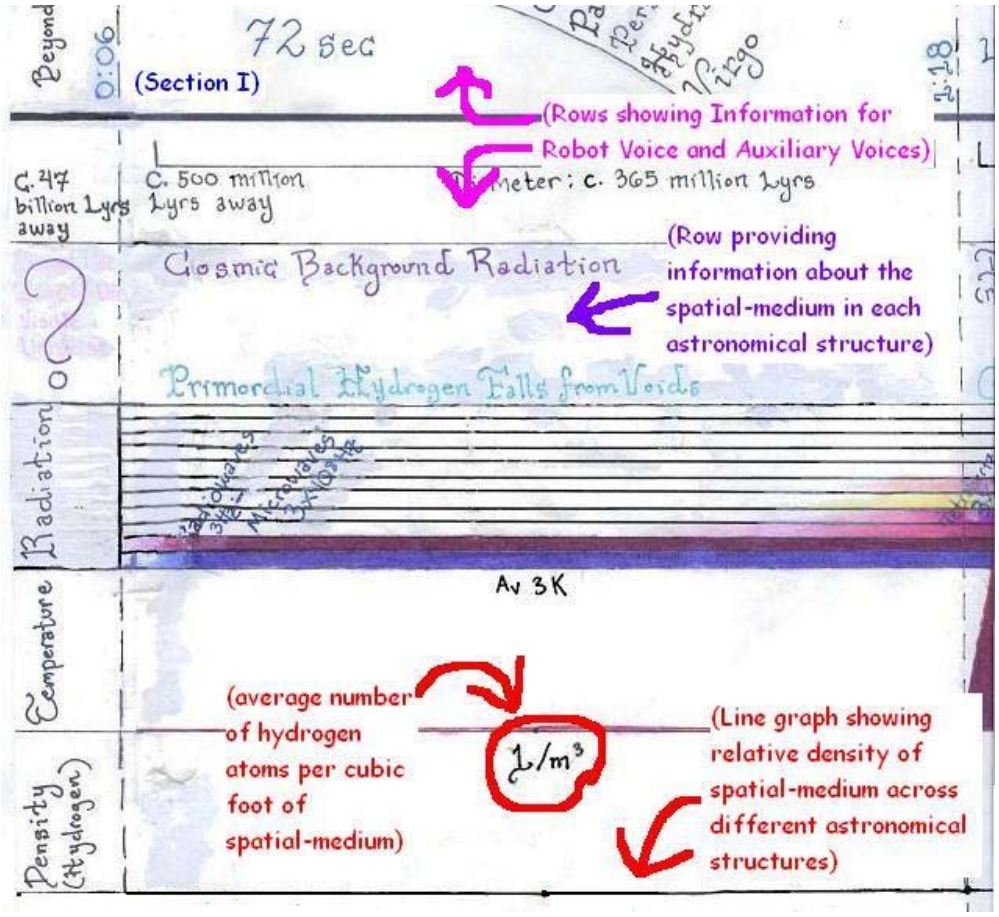
DENSITY

One of the most basic pieces of information that *Universal Density* communicates is that space is not simply a homogenous, unchanging, empty plane that stretches into eternity. Space is actually a dynamic and varied environment; it has areas of both great activity and that are packed with matter, as well as areas of miniscule movement that are filled with only extremely sparse hydrogen gas. In *Universal Density*, I have used three factors to define different areas of space: the average concentration of hydrogen atoms (or density), the average temperature created by the activity of those atoms (or heat), and the type of electro-magnetic radiation present (or light). Each of these factors is represented by its own leitmotif. As the listener makes her symbolic journey through space, these leitmotifs become louder and softer as their factors become more and less present in different areas of space.

The leitmotif that underpins all the others is the Density leitmotif. It represents the average density inside each astronomical Structure represented by a musical Section. The Density leitmotif is a wide and rolling sound, like thunder or the rush of water. To give it some depth, I sculpted it from five different audio tracks, which I call the “Density Layers.”

Each Density Layer represents a specific average density of hydrogen atoms in a cubic meter of space. Each Density Voice also corresponds to a specific spatial medium, which is the mixture of gasses, energy, and everything else that fills up space in the same way that water fills an ocean. Higher numbered Density Layers represent denser spatial mediums.

Figure 8. Graphic score detail showing location of information about the density of the spatial medium in which each astronomical structure exists



The sound source I used to create all the Density Layers is my ocean drum.

Sound Sample 5. Density and Heat source material: ocean drum, unfiltered

Click here to play embedded file:
Sound Sample 5. Density and Heat source material: ocean drum, unfiltered

I thought that ocean drum provided an excellent metaphor for density, since the many seeds inside the confined space of the drum resemble how I was measuring density by the number of hydrogen atoms in a cubic meter. However, I could not directly use the ocean drum to represent changes in density because I could not change the number of seeds inside without destroying the drum. This led me to visualize density as a change in the size of space with a static number of included particles instead of an increase of particles in a static space. I used reverberation filters to manipulate the audience's perception of the space in which the sound takes place.

By varying the extent to which reverberation was applied to different bands of frequencies, and by pitch-shifting the original recording without time correction, I was able to create progressively smaller sonic landscapes for the listener to travel through on her symbolic journey towards Earth. For Density Layer 1, which represents the sparse primordial hydrogen that fills the supervoid of musical Section I, I increased the reverberation of very high and very low bands of frequencies but muted the reverberation of the middle frequencies. This created a cavernous and slightly unreal sonic environment. For the higher numbered Density Layers, I decreased the reverberation of the highest and lowest frequencies and increased the reverberation of the middle frequencies. I also re-defined the scope of the higher, middle, and lower bands of

frequencies so the middle band was extremely narrow. This made Density Layers sound more immediate, like they were happening in a closer proximity to the listener as the music went on. In this way, as the profile of reverberation distribution evolves throughout the piece, so does the listener's idea of the environment in which the sound occurs.

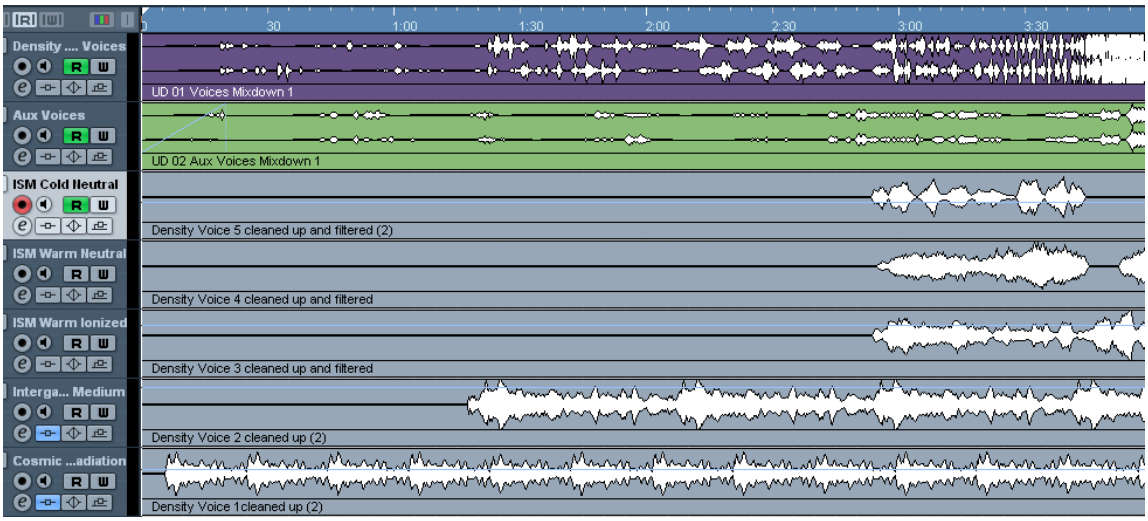
Sound Sample 6. Density leitmotif

Click here to play embedded file:
Sound Sample 6. Density leitmotif

As stated above, each Density Layer corresponds to a specific average density, or spatial medium. There are five Density Layers in all, each of which is assigned a number based on the average density it represents, with lower numbers indicating a lower density. Higher Density Layers always appear with all Density Layers with a number below theirs in tow. Density Layer 1 first appears in musical section I (see Appendix: Score Segment 1). It represents the spatial medium found inside supervoids, which is composed primordial hydrogen and cosmic background radiation left over from the Big Bang; the density of the this primordial hydrogen is about one hydrogen atom per cubic foot of space. Density Layer 1 represents this sparse medium with a very low, thunderous sound that begins as a distant rumble. This eventually swells into an over-bearing thunder, which represents the vastness of the supervoid in which the medium is found. Density Layer 2 represents a rarified plasma with an average density of ten to one-hundred hydrogen particles per cubic meter of space. Since this medium fills the space around galaxies, it is called the intergalactic medium. Accordingly, Density Layer 2 first appears in musical section II (which represents the Virgo galactic supercluster) and continues

through musical section III (which represents the Local Group galactic cluster) (see Appendix: Score Segment 2). To reflect this slightly denser medium, Density Layer 2 is slightly higher-pitched and more energetic than Density Layer 1; it sounds like the ocean waves rolling onto a beach, which is how I imagine the denser billows of the intergalactic medium meeting the edges of the supervoids. And if the intergalactic medium is an average wave breaking on the beach, the interstellar medium is a tidal wave the size of a sky-scraper. The listener would symbolically enter this new medium around the three-minute mark, in musical sections IV and V. Here, Density Layers 3, 4, and 5 enter simultaneously, representing the cold-neutral interstellar medium. This densest of all mediums fills up the inside of galaxies, the spaces between stars. Immediately upon entering musical sections IV and V, all the Density Layers rise up to meet the listener with an overwhelming rush of sound that leaves almost as quickly as it appeared. In the following musical sections, the entrances and exits of Density Layers 3, 4, and 5, reflect the different varieties of interstellar medium created from the activity of nearby stars. Density Layer 3 represents the warm-ionized variant of the interstellar medium found in the Local Bubble, which is represented by musical section VI. Density Layer 4 represents the warm-neutral variant of the interstellar medium that makes up the Local Fluff molecular cloud.

Figure 9. Screenshot of Cubase project, showing (from top row down) Robot Voice, Auxiliary Voices, Density Voice 5, Density Voice 4, Density Voice 3, Density Voice 2, and Density Voice



CHAPTER VI

HEAT

Density and heat are closely linked concepts. Because an increasingly dense cloud of gasses in space will eventually give rise to a star that radiates warmth, I wanted my leitmotifs for heat and density to also be connected in some way. I did this by using the same recording of my ocean drum as the source material for both the Density and Heat Layers. Like density, the heat leitmotif is sculpted from five Heat Layers, each associated with one of the spatial mediums. Just as each Density Layer represents a specific average density, each Heat Layer represents a specific average temperature given in degrees Kelvin.

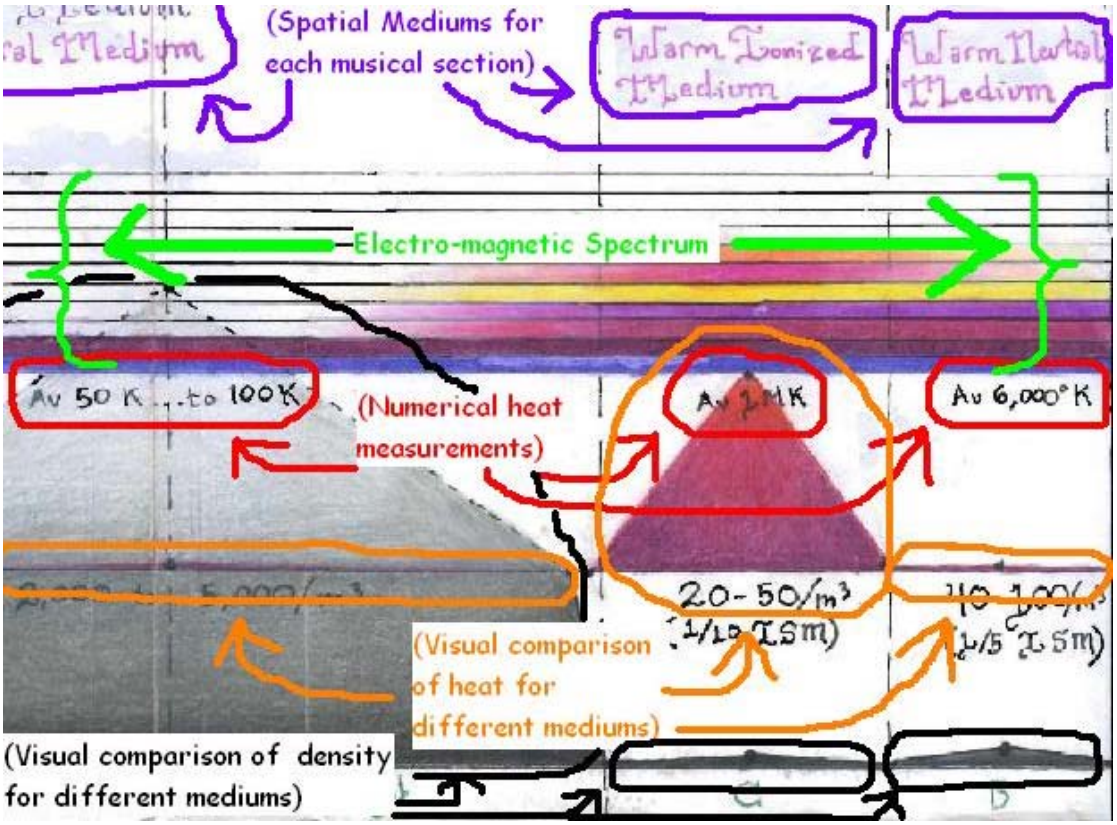
Sound Sample 7. Heat leitmotif

Click here to play embedded file:
Sound Sample 7. Heat leitmotif

The initial construction of the Heat Layers was much the same as the Density Layers. I began by normalizing the same recording of my ocean drum, giving it a little body with some light reverberation. I did not, however, construct the Heat Layers to carry

much information about the landscape in which they existed. I had an idea that the musical leitmotif for heat should be some kind of sizzling, something with a very present, dry sound. To get the fizzy sound, I pitch shifted some of the audio upwards and decreased the bit depth of the recording, which highlighted new upper frequencies as they appeared. To get a crackling sound, I modulated the volume to create clips in the track.

Figure 10. Graphic score detail marked to show visual and numerical indications of heat in different spatial mediums



The Heat Layers are numbered like the Density Layers, with the lowest numbers indicating the least hot voices. Heat Layer 1 appears first in musical section 1, the Southern Local supervoid. Here, the average temperature is only three degrees Kelvin;

accordingly, Heat Layer 1 is rather unobtrusive. It almost sounds like it is only unwanted noise from somewhere in the sound system. However, that notion is dispelled when Heat Layer 2 blooms and presents some new facets to the sound. Heat Layer 2 is the highest numbered Heat Layer in musical sections IV and V, the Milky Way and its Orion-Cygnus Arm. The cold-neutral Interstellar Medium fills these structures, and it has an average temperature of fifty to one-hundred degrees Kelvin. Heat Layer 2 communicates this lack of heat by just barely evolving the sound of Heat Layer 1 into something that falls in the Uncanny Valley between digitally altered sounds and noise. The highest Heat Layer is musical section VII, the Local Fluff, is number 3, which represents an average temperature of six-thousand degrees Kelvin. As the next hottest Heat Layer, Heat Layer 3, leaves the Uncanny Valley that Heat Layer 2 occupied and clearly sounds like an active mass of digitally filtered sound. Heat Layer 4 takes this same mass and transposes it upwards, creating some low-frequency distortions due to fold-over.

Sound Sample 8. Heat: Layer 4, showing fold-over distortions

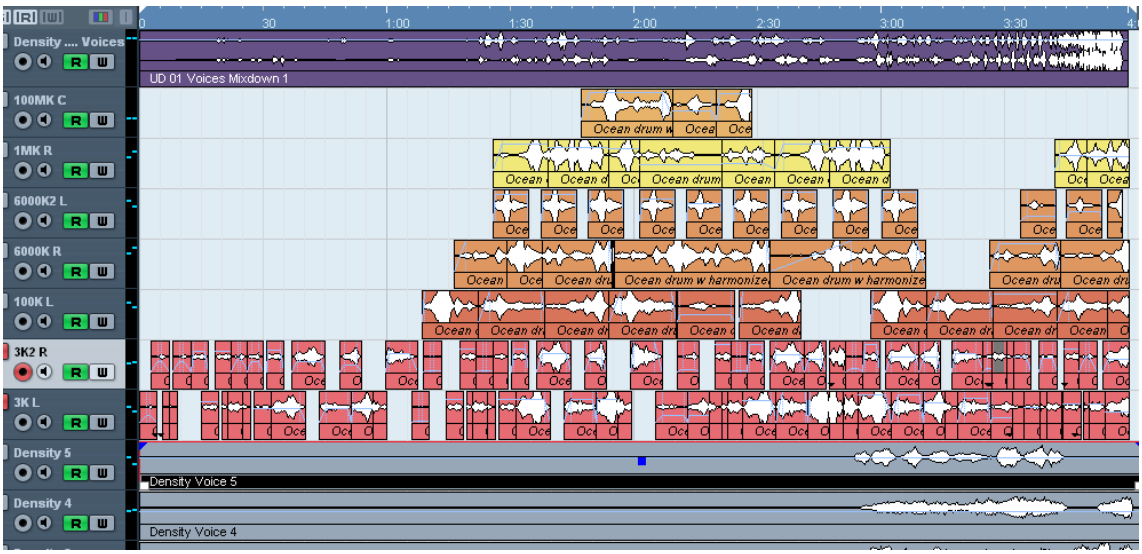
Click here to play embedded file:
Sound Sample 8. Heat: Layer 4, showing fold-over distortions

By causing fold-over and pushing the boundary of sound processing, Heat Layer 4 reflects the second hottest spatial medium: the warm-ionized Interstellar Medium of the Local Bubble, represented by musical section VI. The hottest spatial medium is the rarified plasma in the Intergalactic Medium, which fills the Virgo Supercluster and Local Group galactic cluster that are represented by musical sections II and III. Its temperature is an average of one-hundred-thousand to one-hundred-million degrees Kelvin, which is

represented by Heat Layer 5. To reflect this hottest medium, Heat Layer 5 takes the same distorted material from Heat Layer 4 and transposes it further upwards, creating an even higher-pitched fold-over

Collectively, the Heat Voices and the Density Voices create a multi-faceted backdrop for the Narrating Voices. They give depth and character to the sonic landscape in which the Narrating Voices exist, and they validate the growing sense of urgency that the Narrating Voices display as the listener symbolically falls from the edges of the universe at the beginning of *Universal Density*, to the edge of our solar system at the end of the piece.

Figure 11. Screenshot of Cubase project, showing (from top, down) Narrating Voices, Heat Voice 5, Heat Voice 4, Heat Voice 3 (left channel), Heat Voice 3 (right channel), Heat Voice 2, Heat Voice 1 (right channel), Heat Voice 1 (left channel), Density Voice 5, and Density Voice 4.



CHAPTER VII

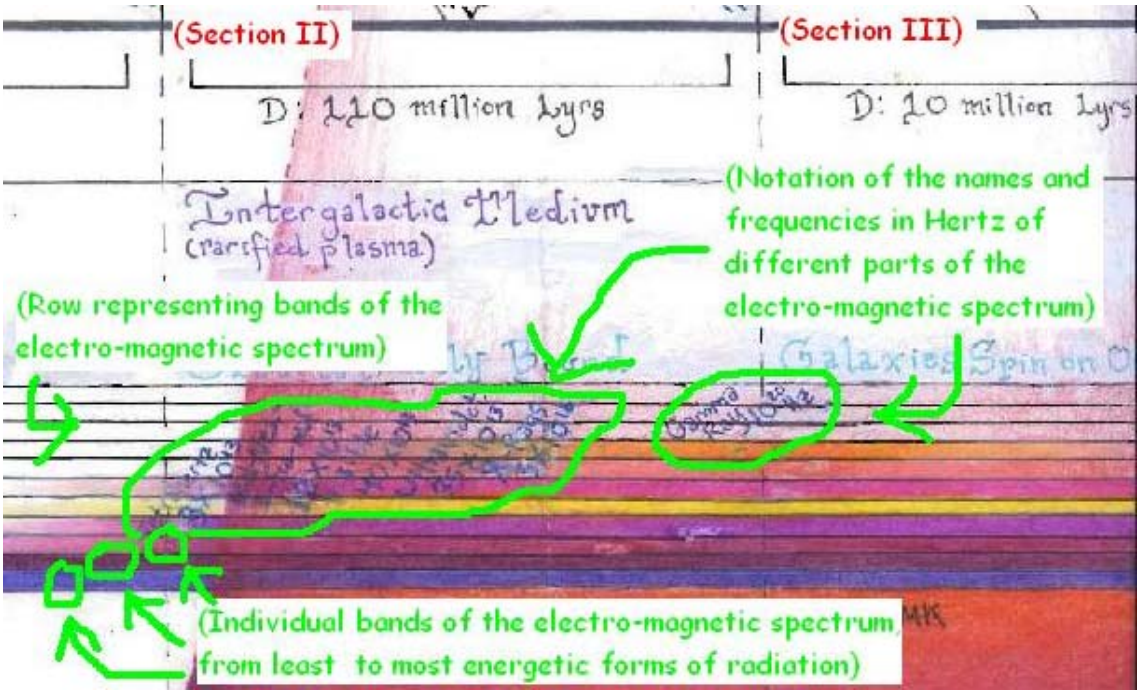
LIGHT

The final leitmotif in *Universal Density* represents electromagnetic energy, or light. Immediately after I had solidified the concept for *Universal Density,* I was particularly concerned about the appearance of light. When should the listener expect to see (and musically, hear) it? When would it become overwhelming? How did denser spatial media affect the visibility of light? The answers to these questions led me to think of light not only as the small, visible portion of the electromagnetic spectrum that humans see, but the entire electromagnetic spectrum produced by stellar nucleosynthesis. *Universal Density* accounts for radio waves, micro waves, far infra-red light, mi-near infra-red light, visible light, ultra-violet light, X-rays, and gamma rays.

Like the Density and Heat leitmotifs, the Light leitmotif is made up of multiple layers. Each musical Section is occupied by a unique collection of these layers, called a "Light Cluster." Unlike the Heat and Density Layers, which were attached to specific measurements of heat and density, specific layers in the Light Clusters do not represent specific forms of electro-magnetic radiation. Instead, the number of Layers in a Light Cluster is proportional to the variety of electro-magnetic radiation in a spatial medium. That way, as the listener progresses through the different musical Sections, the Light leitmotif changes not only in volume but also in pitch. Each entrance into a new

astronomical structure sound like someone turned the sonic kaleidoscope to reveal a new refraction of light.

Figure 12. Graphic score detail, showing different bands of the electromagnetic spectrum



Each Layer is a filtered recording of a Tibetan singing bowl. When I recorded it, I placed the first microphone about an inch away from the singing bowl and fed into a harmonizer MAX/MSP patch that worked in real time. As the resulting small tone cluster came through a speaker, I continued to play the singing bowl nearby and recorded the mixture of live and processed sound. Afterward, I divided the recording into a library of clips, which I later aggregated into the Light Clusters.

Sound Sample 9. Light Cluster source material: Tibetan singing bowl, unfiltered

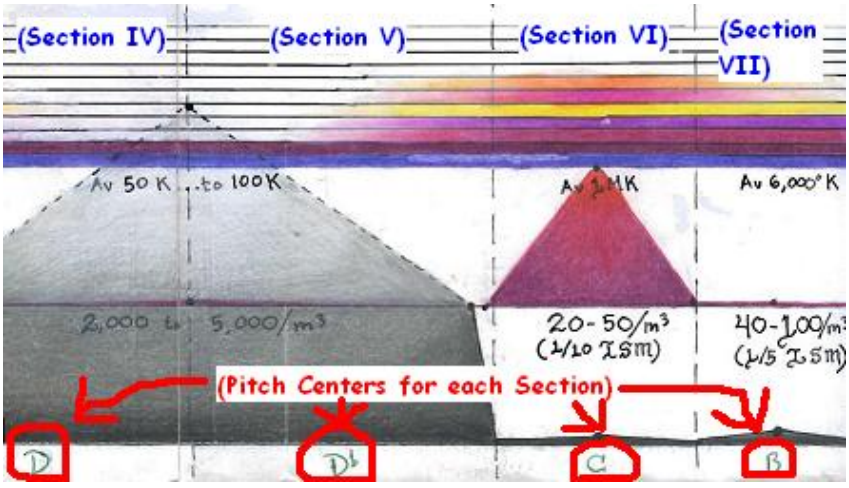
Click here to play embedded file:
Sound Sample 9. Light Clusters source material: Tibetan singing bowl, unfiltered

My method for assigning individual sound clips to a Light Cluster was based on the very high frequency pitch emitted by the ring modulator which gives the Robot Voice its metallic sound. I listened to each harmonized singing bowl clip against the pitch center for each musical section, and I used the clips to form Light Clusters that created a pattern of tension and release and the music progressed.

Sound Sample 10. Light Clusters

Click here to play embedded file:
Sound Sample 10. Light Clusters

Figure 13. Detail of graphic score, showing pitch centers for each Section notated at the bottom edge



CHAPTER VIII

CONCLUSION

Immediately after listening to *Universal Density*, I hope that the audience feels like they have been through a short but rich free-fall through various dynamic environments in the universe. I hope that my music moves the audience to emotionally connect to the great array of wonders in which our planet exists, as well as inspires them to investigate for themselves whatever they find fascinating about our astronomical home. After some review of the graphic score and some explanation of the musical symbolism in *Universal* Density, I also hope the audience enjoys the interconnectedness of the music and our knowledge of outer space. I wanted to create a logical system of reference that, once explained, could be emotionally and intellectually inhabited by the listener. I also hope that my effort to emotionally and intellectually process astronomical information through the creation of *Universal Density* inspires the audience to process the information and share it with others in their own unique way.

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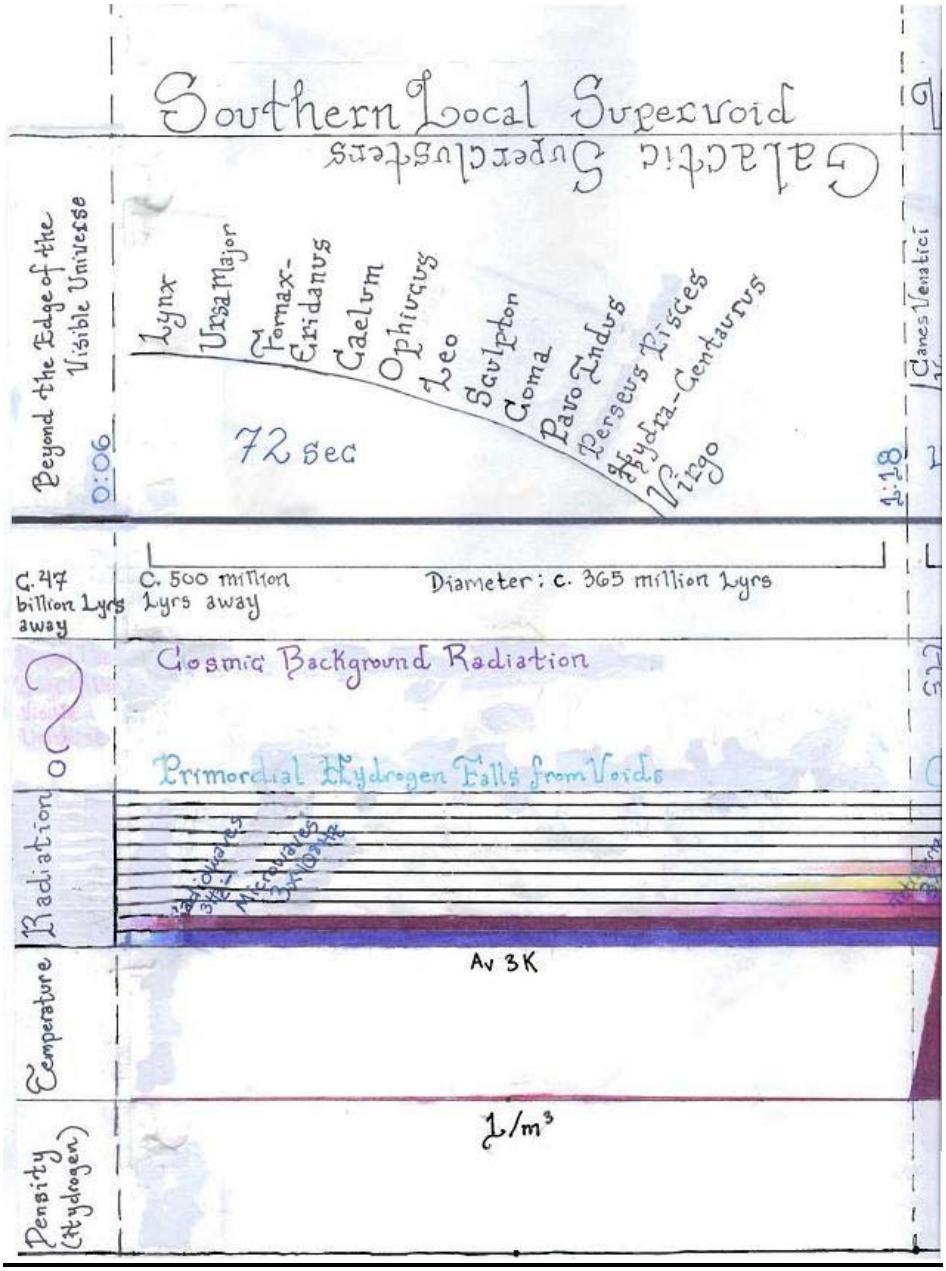
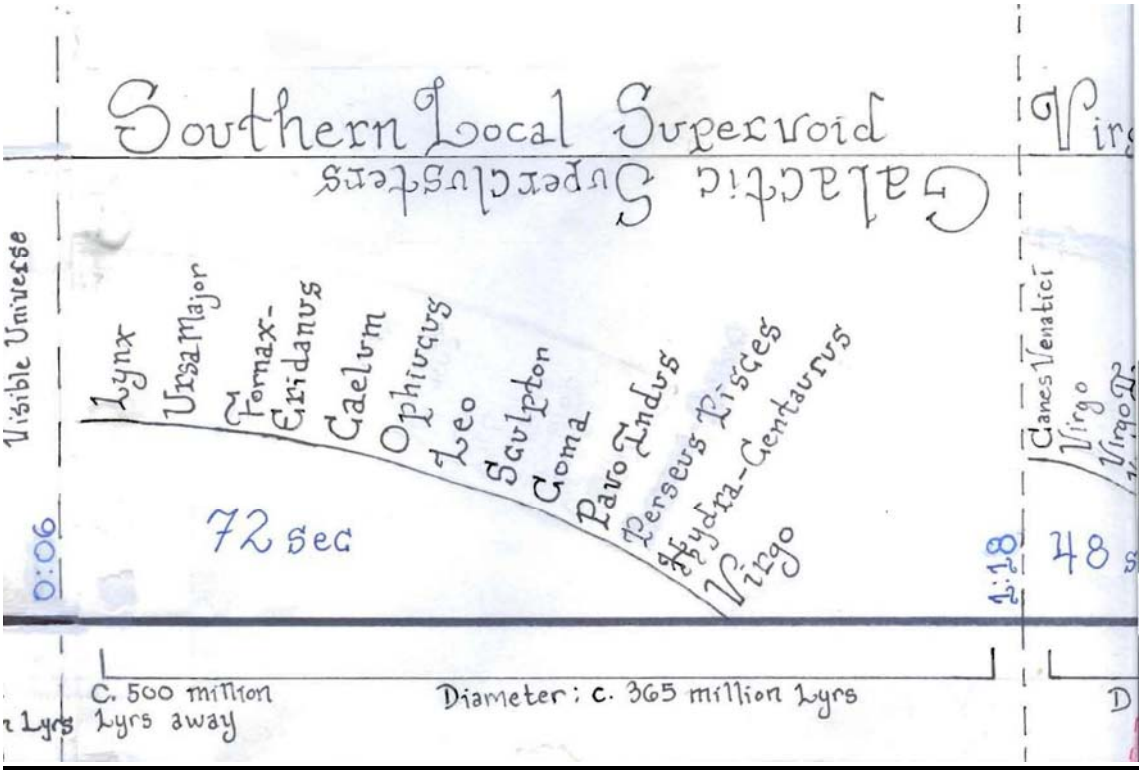
APPENDIX A

GRAPHIC SCORE

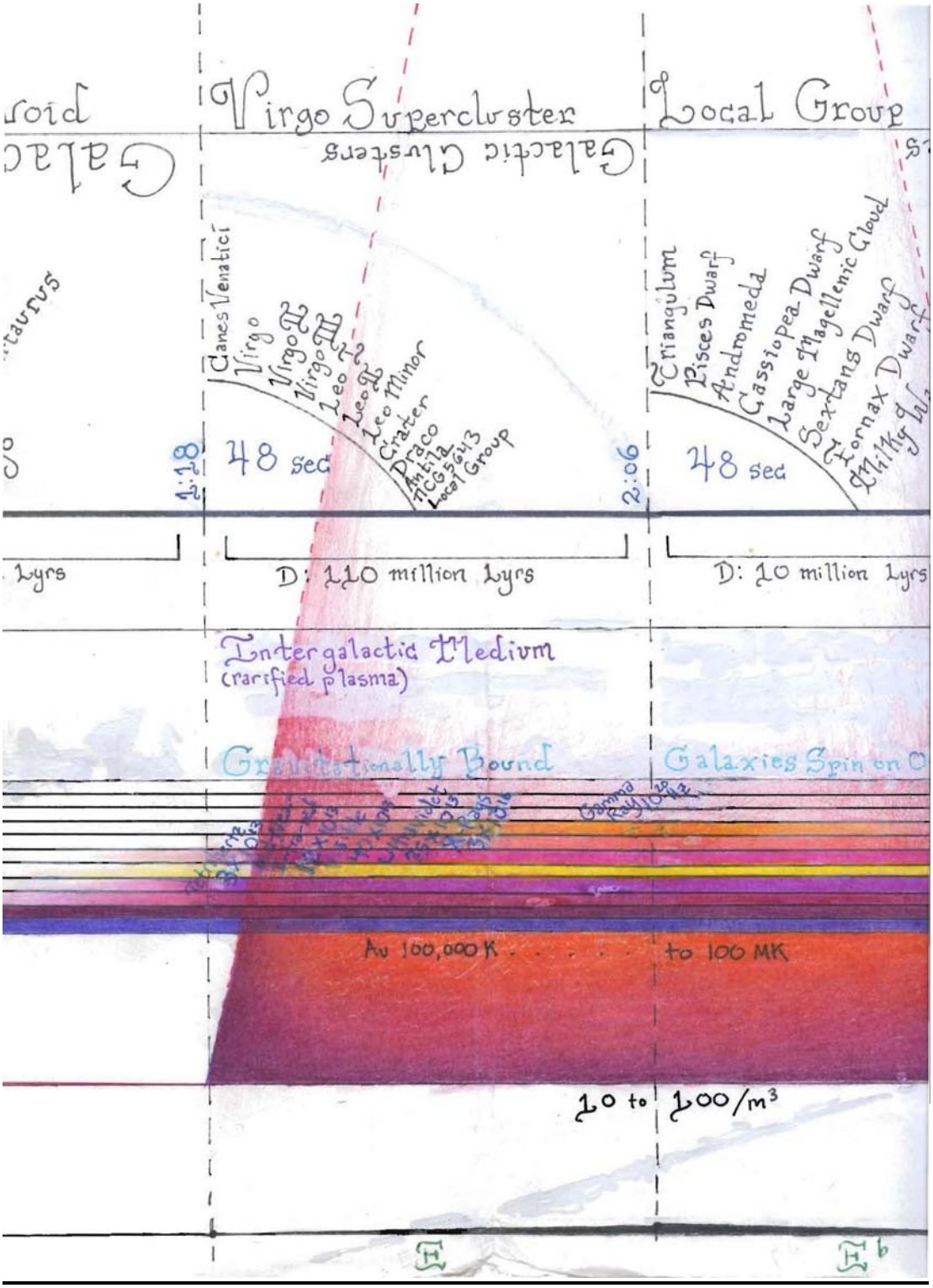
Score Segment 1:



Score Segment 1, Detail 1



Score Segment 2



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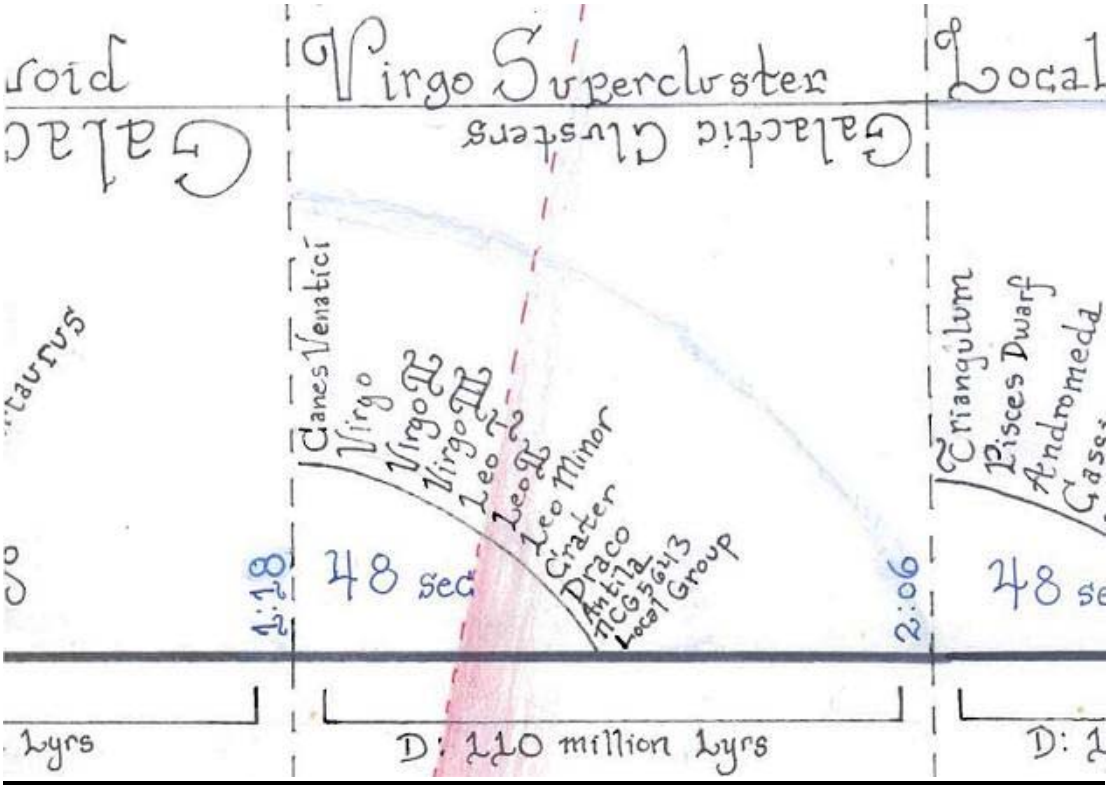
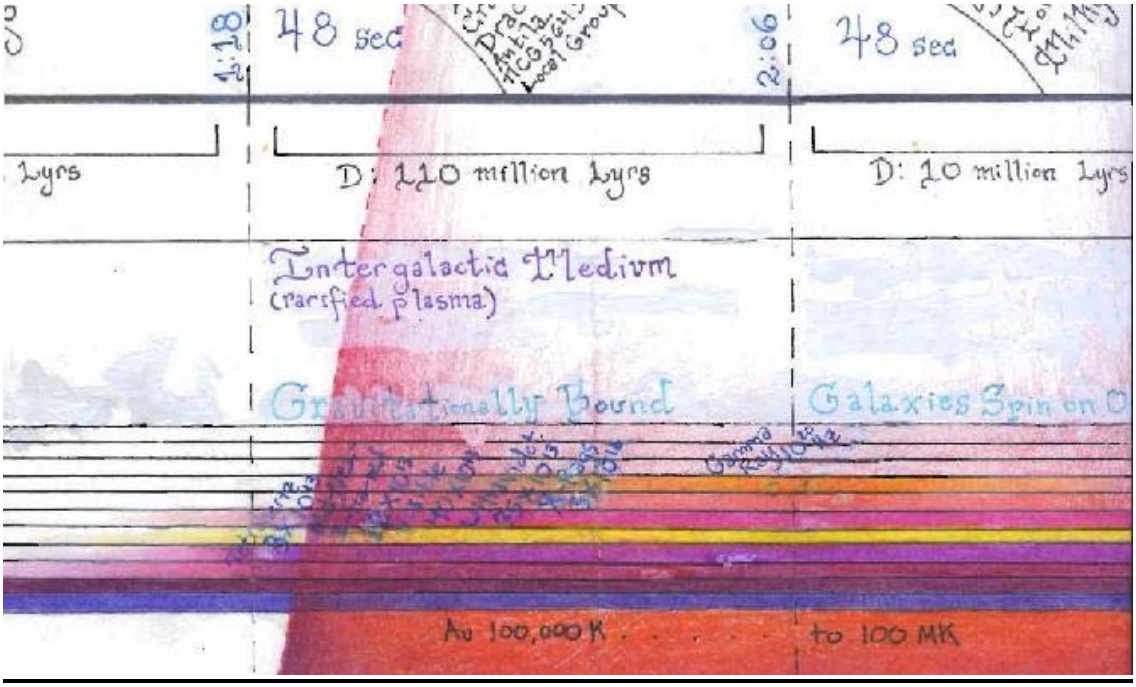
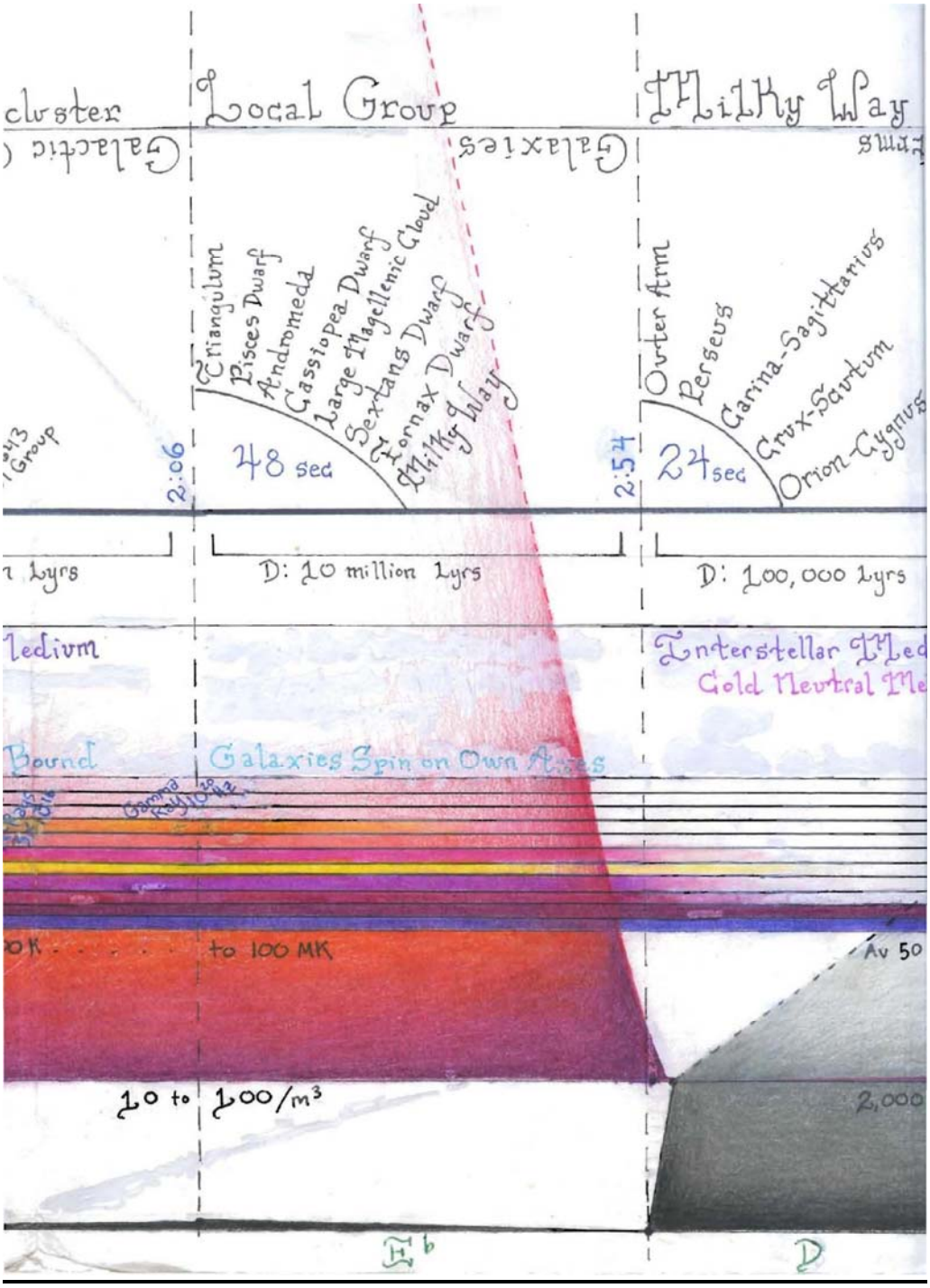


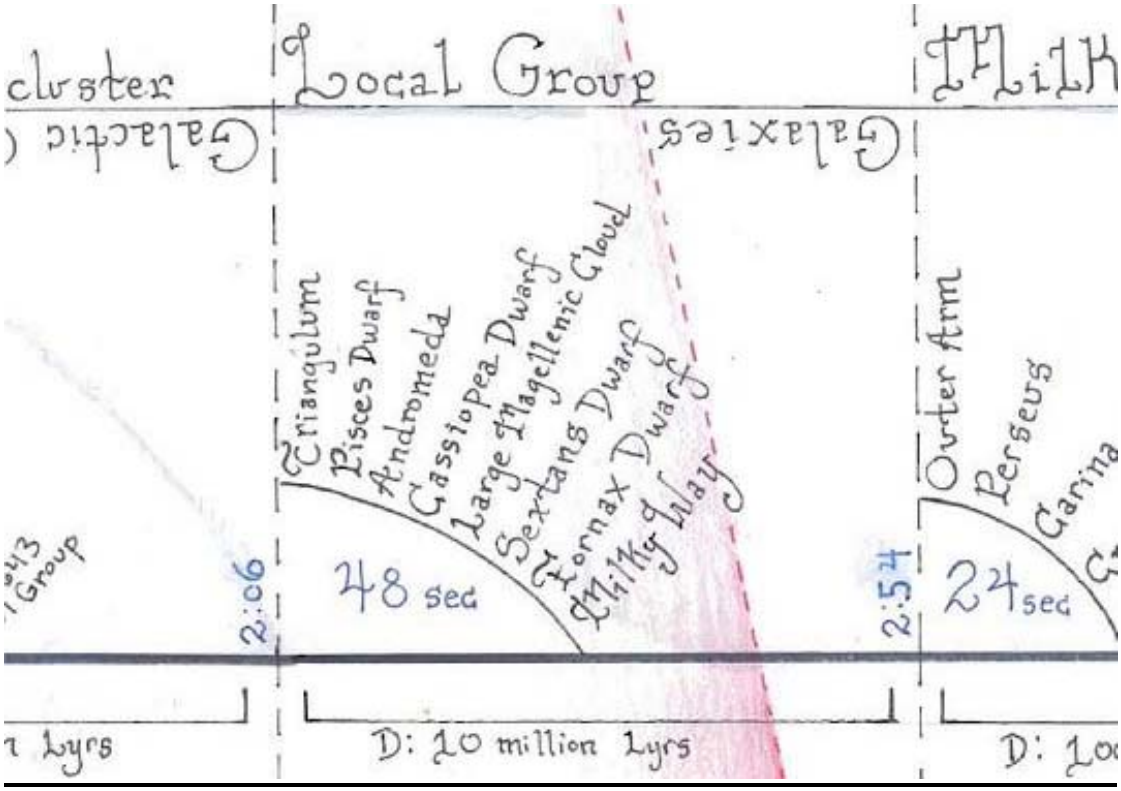
Score Segment 2, Detail 2



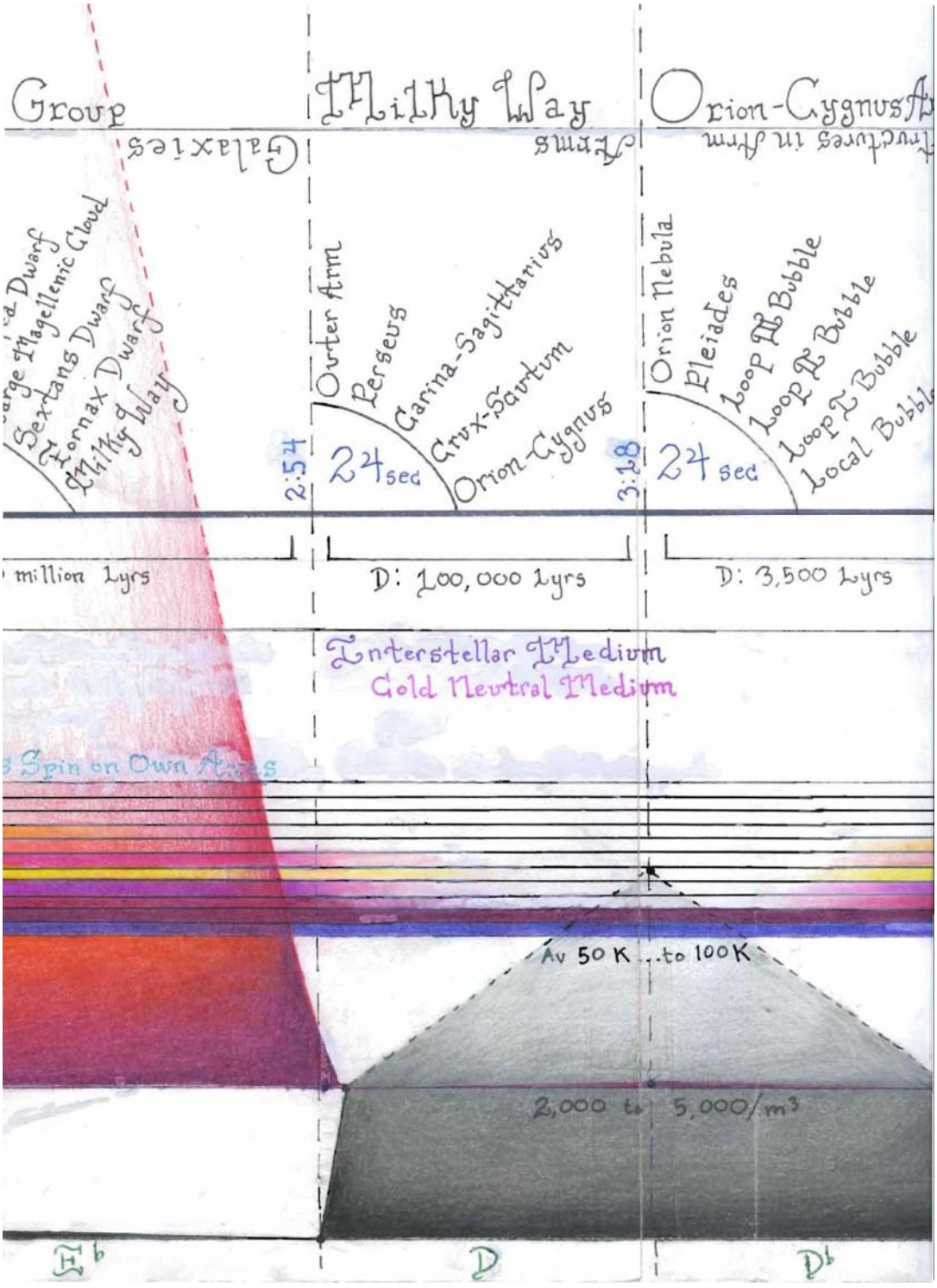
Score Segment 3



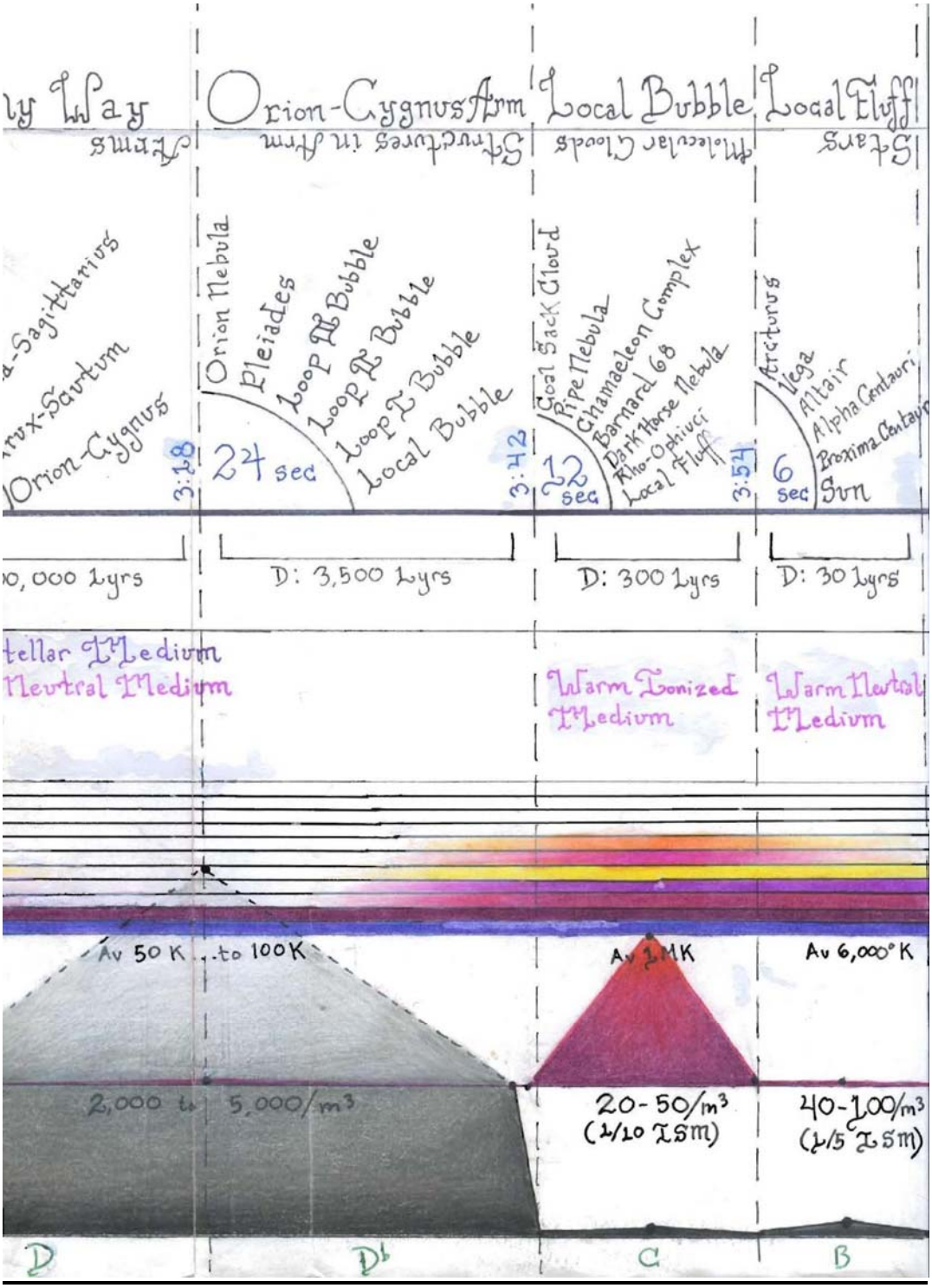
Score Segment 3, Detail 1



Score Segment 4



Score Segment 5



Score Segment 5, Detail 1