A DANGEROUS PASSION

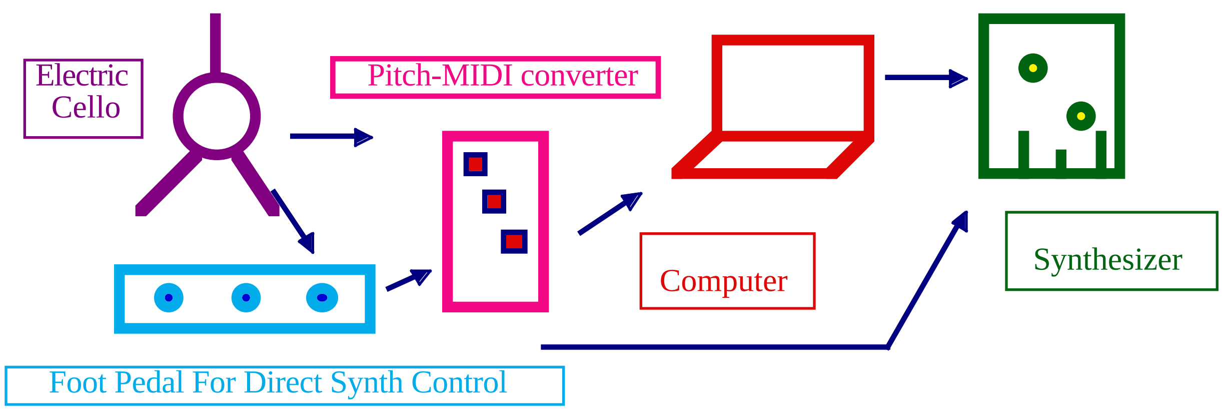
by Ami Radunskaya

An interactive duet for electric cello and Synthesizer, with a Macintosh interface implemented in MAX

Recorded at ***Studio Nadine***, Caremont, CA by Chris Darrow.
Performed by Ami Radunskaya. Time: 4'46". Please listen to the enclosed cassette tape.

This is and example of a piece which uses a dynamical system as a musical source and as a gestural/musical interface. In recent years I have tried to articulate the connection between mathematics and music that has always been in my consciousness. I have performed and written music, I have collaborated with graphic artists and other mathematicians, I worked with a water sculptor in designing an interactive fountain, I have given lectures, participated in open discussions, and I designed and co-taught a course at Pomona College called "mathematical and musical processes". In the following paqes I have compiled a list of frequently asked questions about my work, focusing on the excerpt presented on the enclosed cassette. This music is intended to be played live, and to be appreciated as a real-time duet between a machine and a human. Therefore, I made the recording in one pass - I hope that the listener can imagine her/himself present at the session.

To help the listener visualize the live performance here is a diagram of the typical stage set-up:



FAQ

Frequently Asked Questions about the Music

[Q1]: We've just listened to an excerpt from "*A Dangerous Passion*"**.** I only saw you playing, along with some electronics. What gives the orchestral fullness of the sounds we heard?

[AR]: The main instrument which you heard, the solo voice, is an electric cello. Mine is a custom-built instrument, made of hand-carved teak wood by inventor/designer Don Buchla of Buchla Associates. He built it for me 20 years ago, and it has gone through a few transformations since then. It is currently equipped with two ouputs: one which sends the signal directly to an amplifier and reverb unit, and the other which sends signals from each separate string to a pitch-to-MIDI converter built by ZETA. Through this interface, the cello can communicate to the Macintosh laptop which in turn controls the Yamaha synthesizer you see in the black case. The orchestral accompaniament is performed real-time on the Yamaha TG77 by the Macintosh - there are no pre-recorded sounds, loops, or sequences, so that this piece is truly a duet. In this particular work, I have chosen a group of 16 instruments for the orchestra. Some of them are conventional, such as a grand piano, a fretless bass, a marimba, and a full range of percussions instruments. A few others are designed by myself, known in the trade as "custom sounds". These include Bird Lips, Brux Choir, New Sitar, Peace Bells, and Peace Glass. The Macintosh can only select from these instruments, but it has some "freedom of choice" in deciding which will play at which instant.

[Q2]: Tell me about your musical background: how did you get into this type of creative endeavor, and where have you performed recently?

[AR]: I've been performing and writing music since I was a young girl, but my experience combining acoustic and electronic sounds began in the '70's when I was a member of the contemporary chamber group, the Arch Ensemble, in the San Francisco Bay Area. This was an experimental group which often included electronic instruments and sound processors. I have always enjoyed participating in the *process* of music creation, both as a performer and as an audience member, and so my work focuses on live combinations of acoustic and electric instruments. As hybrid and digital instruments came of age, I continued to explore the performance possibilities of the technology, evolving a compositional style I call 'technoclectic' since it combines many old styles with the newest technological innovations. This particular piece was premiered at the Starbird Lecture series at Pomona College in 1996, where I presented it as an example of the interweaving of mathematical and musical processes, and it has subsequently been performed in Palo Alto, on television - on the SciFi Channel, and in Italy. I use similar techniques when performing with my group, MIMI and the Illuminati, in which we add visual music to the palette. With this trio and our Mathematically Illuminated Musical Instrument (MIMI) we attempt to bring to life through sound and color the beautiful patterns and structures which mathematicians have enjoyed since Poincare discovered dynamical systems. We recently played at the San Francisco Art Institute at a special event for the G2 institute.

[Q3]: How are you combining the disciplines of music and art with the "hard" discipline of mathmatics?

[AR]: The computer has allowed the new digital instruments to directly comminicate with the world of mathematics by interpreting numbers as a musical language. In fact, the vocabulary of mathematics has been used since the beginning of recorded history as a way to describe musical forms, from Pythagoras, through Bach, Mozart, and into the present century with such luminaries as Strauss, Scriabin, Schoenberg, and Xenakis. Before digital instruments, however, the formal mathematical rules, once executed, needed to be transcribed into standard musical notation, and then copied out for each performer in the orchestra in order to be heard. Now most music when reproduced or synthesized is represented digitally, as a list of numbers, so that the mathematical language can be spoken directly to the orchestra (in this case, the Yamaha synthesizer). With the standardization of musical data formats such as MIDI, composers can write programs which can communicate with any instrument or computer, and instruments can in the same fashion communicate with each other, with computers, or with any digitally controlled medium, such as video, lights, or pyrotechnics. The computer has also revolutionized the study of dynamical systems by enabling us to visualize the evolution of processes described by any invented laws of motion or change. The complicated orbit structures imagined by Poincare in the last centruy, and sketched by hand by Julia are now available in millions of colors on screen-savers and postcards around the world. Thus the computer allows us to take an abstract process, an artifact of our imagination or some simulation of the real world, and to portray it as colors and sound, in real time. Through any number of interfaces, we can interact with these virtual environments and life-forms and watch them grow, metamorphose, shift states, or die away. I hope to communicate the aesthetic pleasures born in the world of numbers without definitions and formulas, but rather with music.

[Q4]: Could you explain a bit more about your perfomer/instrument real-time interface?

[AR]: In the early days of electronic instruments, we would create interactive performances by linking together various analog devices with wires, controlling the amplitudes or frequencies of oscillators by changing voltages. One such an attempt is a piece called "Silicon Cello", where various analog modules respond to the cellist through envelope detectors and filters. In another piece, "Consensus Conductus", the audience controlled the pitch, loudness and timbre of the electronic orchestra by shining light which was reflected onto photo-voltaic sensors. Electrical signals could also be used to produce controlling voltages, as in our pieces for amlified brain-waves. While we sometimes feel nostalgic for the organic quality of these pieces, the digital revolution has given us precise control at so many levels that we can now truly create a dialog on stage with our electronic music-makers.

The problem we face when structuring an interactive performace is designing the mapping between a performer's gesture and the response of the computer-controlled instrument. In this piece we have the cellist's notes as gestures, which will be mapped to musical aspects of the orchestral accompaniament. With the Zeta interface, the notes can be broken down into MIDI messages, each containing a note number, representing the pitch of the note, a volume, and a long list of control parameters. With the help of the computer, these messages can be parsed and sorted, so that very specific commands can be given through single notes or melodies. Some of the aspects of the orchestra we control in this piece are melody, loudness, harmonic content, start and stop commands, tempo, and instrumentation. For this musical piece I have chosen as controlling gestures certain pitch sequences: for example, a high A (MIDI note number 81) will start the dynamical system which in turn starts the orchestra, while a low C (MIDI note number 36) stops the system and the orchestra. Repeated open D's (MIDI note number 50) will cause the orchestra to vary its dynamics, which a low D (MIDI note number 38) temporarily disconnects the interface. The orchestra has been instructed to try to follow the tempo of the cellist, unless this interface is disconnected. Other commands will direct new instruments to enter the ensemble, and will control the evolution of the harmonies. The possibilities are enormous, and you will hear only a few of them in this short work.

[Q5]: How does the mathematics help in the design of this interface?

[AR]: To answer this question, we'll need to review some of the concepts behind chaotic dyamics. The study of dynamical systems actually involves looking at an entire <u>family</u> of processes. This family is often described by a single equation, where each member of the family is uniquely determined by the value of one 'parameter' in this equation. As an example, consider a pot of water heating on the stove. The family of processes in question will describe the motion of a single molecule of water in the pot. The parameter will be the heat put out by the burner under the pot. At a low levels of this parameter, the burner is on low: water molecules at the bottom of the pot are heated, rise to the surface, cool off, and then descend again, resulting in a circular pattern which repeats itself over and over again. As the burner is turned up, that is, as the parameter value is increased, the molecules at the bottom gain more thermal energy. Again, they rise to the top, cool off and descend, but because of the addtional energy they don't go back to the same place they started: they descend at a different spot, rise to the surface again, and then finally return to their original positions. They have completed two up-and-down circuits before repeating the pattern again. If the heat is turned up even more, the patterns traced by the water molecules become increasingly more complicated, until, at high heat, we see the water moving in a rolling boil. At this point, where the motion is turbulent, we have what is known as "chaotic motion". Mathematically, we are just as interested in the way the system steps through this family of motions to get to turbulence as we are in the nature of the turbulent motion, and it is a characteristic feature of these families that very small changes in the value of the control parameter will result in drastically different types of motion.

I use this feature in my music by mapping performance gestures to one or more of these control parameters of a dynamical system. The mathematical process is then mapped to a musical one played by the synthesizer: the numbers may be interpreted as pitch, tempo, volume or harmonic structures. In this way, by changing a parameter value, the <u>composition</u> itself changes qualitatively. At an extreme change, the computer's performance may go from a Philip Glass imitation to Cecil Taylor at his most manic, or from a nursery rhyme to a Charles Ives symphony.

[Q6]: Are you using a chaotic system in this piece?

[AR]: Yes, I chose a very simple-looking family of functions as the basis for the orchestral accompaniament to *"A Dangerous Passion".* I wanted to illustrate the power of the configuration as well as the tendency for simple, natural processes to "run away" with themselves. I can describe it to you if you wish:

This chaotic family is given by the equations:

$$f_a(x) = ax^3 + (1 - a)x$$

where **a** is the control parameter, and is allowed to range from 1 to 4. For every value of the parameter, a, we can generate source material for the music. A sequence of numbers, or **orbit,** is generated as follows: the computer is given a starting point, or number, which we will call **x0.** In the examples below, x0 is .2. This number is fed into the equation above, and the next orbit point is calculated:

$$x1 = f(x0) = ax0^3 + (1 - a)x0$$

Similarly, x2 is calculated by plugging x1 into the function:

$$x2 = f(x1) = ax1^3 + (1 - a)x1$$

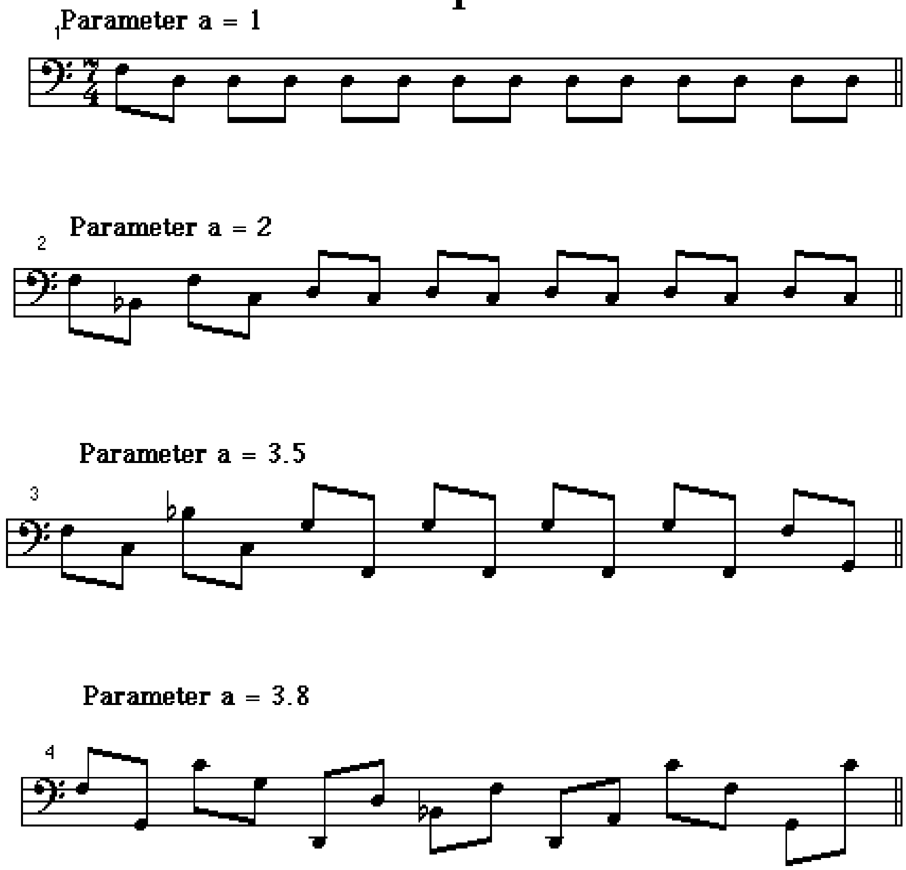
This process is continued as long as one wishes to create a sequence of numbers:

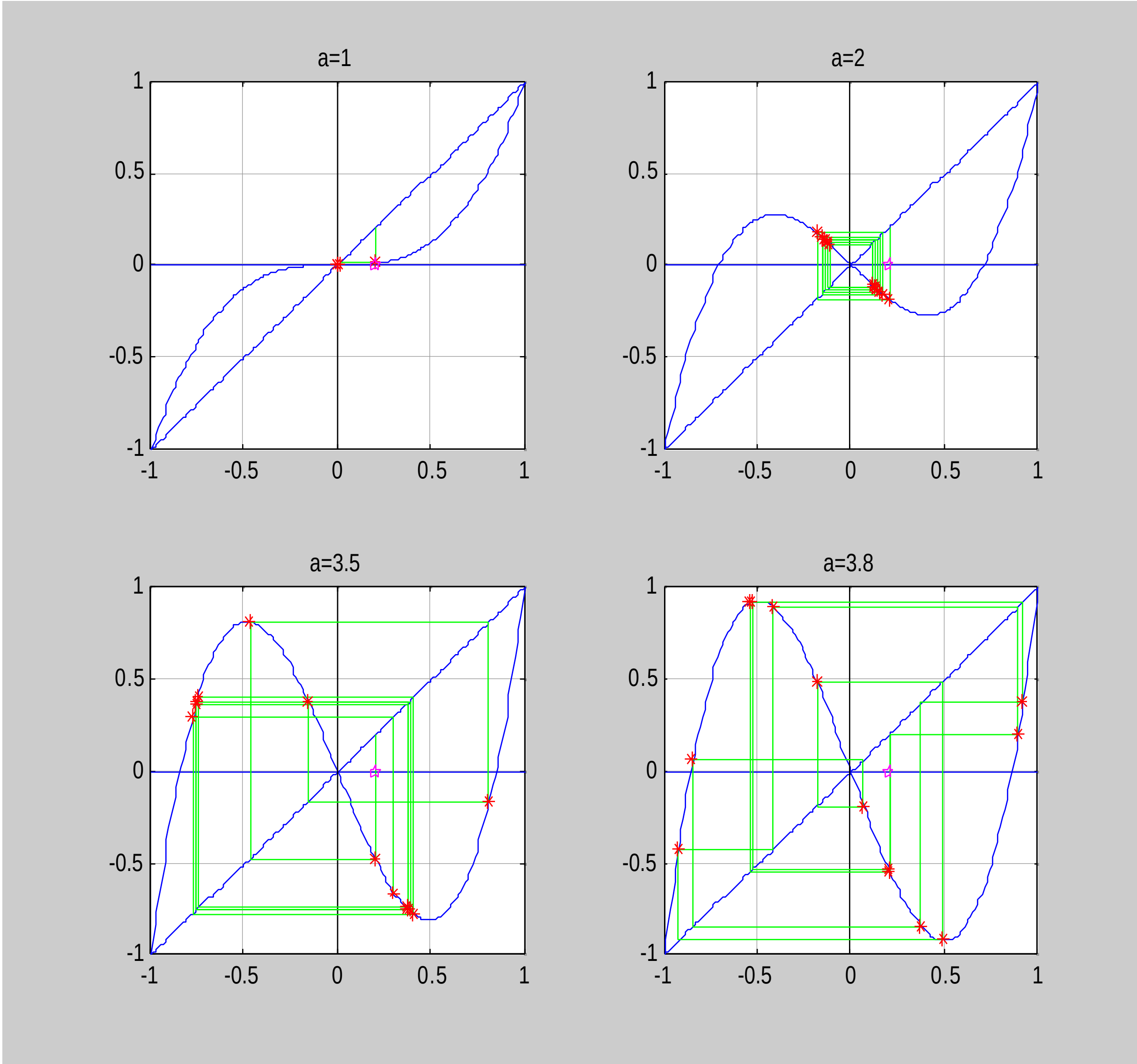
$$x0,\ x1,\ x2,\ x3,\ \ldots\ xN$$

I chose this family because, in addition to exhibiting exemplary metamorphosis from the simple to the chaotic, it has two additional properties which are very nice for musical purposes. The first is that, if an x value between -1 and 1 is entered into the equation, a number between -1 and 1 is produced. It is important in many musical applications to know that the numbers will be bounded: we don't want pitches which are too low or too high to hear, for example. The other nice property of this family is that, for any parameter value greater than 1, we will get oscillating patterns: successive x-values which alternate between negative and positive values. These oscillations create very natural rhythms and melodies. To clarify the process, here are a few examples. For each example, I have represented an orbit of 14 points as a graph, as a list of numbers in a chart, and as a sequence of musical pitches. Notice that the lowest parameter value causes the numbers to settle down quickly to zero, and you can verify that the same thing would happen no matter which value was chosen as the starting point, x0. As the parameter value is increased, the orbit becomes more complex. At a = 2 we see the orbit settle down to an oscillation between two values, .3798 and -.7578 which, under this particular mapping, become the pitches D and C. At a = 3.5 the orbit is a bit more wild, but it preserves a regular jumping up and down movement, visible on the graph as a large rectangle. Finally, at a = 3.8 we are in the chaotic regime: the orbit moves apparently randomly through the available notes.

	a=1	a=2	a=3.5	a=3.8
X0	0.2	0.2	0.2	0.2
X1=f(X0)	0.008	-0.184	-0.472	-0.5296
X2=f(X1)	0.000000512	0.171540992	0.811960832	0.918427338
X3=f(X2)	0	-0.161445355	-0.156317583	0.372269222
X4=f(X3)	0	0.153029337	0.377425186	-0.846309174
X5=f(X4)	0	-0.145862061	-0.755388505	0.066258369
X6=f(X5)	0	0.139655414	0.379853699	-0.184418068
X7=f(X6)	0	-0.134207838	-0.757803983	0.492536752
X8=f(X7)	0	0.129373204	0.371373913	-0.925057252
X9=f(X8)	0	-0.125042455	-0.749167009	-0.417920045
X10=f(X9)	0	0.121132223	0.401269413	0.892803752
X11=f(X10)	0	-0.117577473	-0.777034143	0.204429251
X12=f(X11)	0	0.114326583	0.300527893	-0.539937105
X13=f(X12)	0	-0.111337956	-0.656319995	

Sample Orbits




a=1
a=2
a=3.5
a=3.8
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1

[Q7]: Did you have any idea what it will sound like ahead of time?

[AR]: Actually that's the beauty of using these chaotic processes. While I don't know exactly which pitches will come out, I have a very good idea based on the mathematical analysis of the system. For example, if I have set a = 2, as in the second example above, I know that the orchestra will settle down to the repeating pattern: D-C-D-C-D-C ...
The composer sets up the boundaries of the orchestral performance, by programming the reactions to the signals received by the computer and the palette of the computer's choices, and also by sending, via the live performer, parameter values and starting positions as the piece evolves. However, within these boundaries, the computer can explore an infinite number of possibilities.

[Q8]: How do you know what to play on the cello to make it not sound discordant?

[AR]: This is the real job of the composer. First, choose a scale system, sounds, and harmonies so that the piece has a well-defined harmonic form. . The harmonic cohesion is acheived by careful preselection of the computer's pitch set, which makes it possible for the orchestra and cellist to play in the same key. Secondly, the piece must always be <u>shaped</u> by the composer: in this case, the computer is programmed to respond to cues from the cello, as we discussed previously. The cellist has complete control over when the orchestra starts and stops, and its tempo. The performer, therefore, directs the orchestra, following the composition's prescribed form. As the cello plays, the computer changes the parameter value and initial points based on the pitches (in the form of MIDI note numbers) received from the performer. In this way the cellist has control of the melodic evolution of the piece and the texture of the composition, while maintaining the excitement of real-time performance. There is still an element of mystery, a counterplay between the computer's orchestra and the cellist's phrases. In order for the composer to make informed choices, she must have knowledge of the structures involved. In some cases this might mean understanding the rules of counterpoint or how fugues are structured. In this case, the composer must know the structure of the dynamical system, and this involves knowing the math: what functions have any particular desired properties, which parameter values are interesting, how does the system behave qualitatively for different parameter values, and where do the bifurcation points occur. For me, it is also inspiring to know if the system arises as a model of a real process and, if so, how are all the variables interpreted as physical quantities.

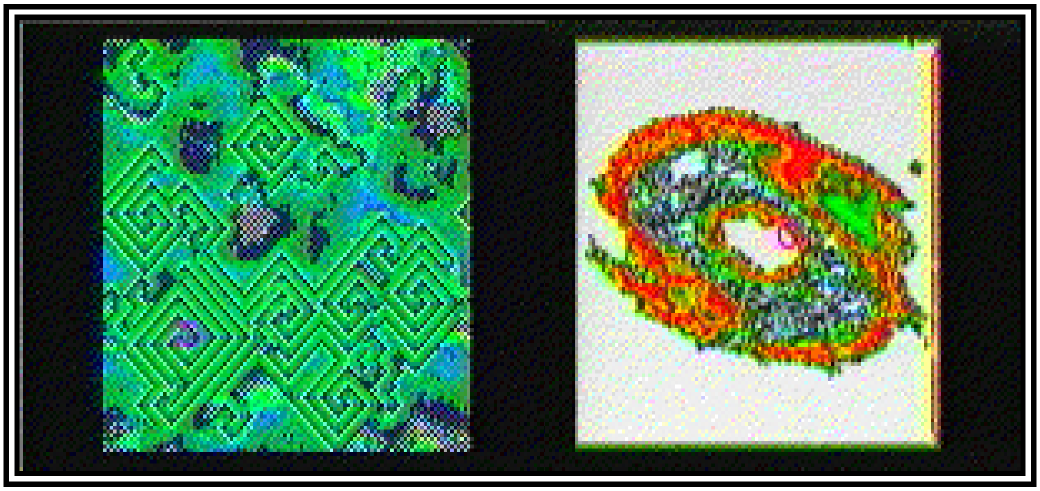
[Q9]: How different will another dynamical system sound, and how difficult would it be to program in another dynamical system?

[AR]: Each dynamical system has its own personality. At this point, the programming of the equations into the performance screens is an easy matter of changing a few numbers. However, the qualitative features of each system suggest different mappings between gesture and number, and between number and musical attribute. The cubic family used in "*A Dangerous Passion"* is, by its oscillitory nature, jaunty and rythmic. Another system which evolves more slowly, such as the Brusselator, a model of chemical morphogenesis, produces oozing patterns which metamorphose slowly from one to the other. This model suggests long sustained chords with high obbligato lines: a mapping of numbers to pitches in this case would result in a tedious drone, and wouldn't capture the essential dynamics of the system. As a result, using the Brusselator I wrote a piece called *Brux Hymn* in which the numbers produced by the system were sampled over an entire two-dimensional grid, and then interpreted as a *frame entropy,* a measurement of the diversity in the virtual body-mass. This entropy was then mapped to the harmonic dissonance of the evolving music, rather than to a melodic line. In short, the compositional process involves looking, listening, and experimenting with each dynamical system in order to extract its salient personality traits. A mathematical analysis of the *bifurcation points,* the sensitive parameter hot spots, also helps in the structuring of the score: the performer must know how to stimulate the system to provoke a desired response during the course of a performance.

A Few Other Dyanamical Systems

from MIMI and the Illuminati, April, 1998

FIREFLY FANDANGO



SCROLLS *GALAXY*

[Q10]: The works of the great composers such as Bach, Mozart and Beethoven are inspiring but perhaps not always accessible to the layman. Do you think that all music can be understood as mathematics, and would knowing mathematics help us understand music?

[AR]: Studying the relationship between math and music, facilitated by high-speed computers gives the layman a key to unlock some of the mysteries of the creative process. As we study this relationship, our understanding of music can be enhanced by extracting patterns describably in the vocabulary of mathematics. However, a computer, while occasionally surprising us with innovative `creations' will never BE a mind, and numbers, while able to capture some of the vertical and horizontal structures of music, will never be musical in and of themselves. For me a live performance is one of the most exciting media of communication, and through it we can speak of everything: mathematics, music, and the mysteries of creation.