Figure 8 The universe as a batch of dough being folded over and over, the raisins, sesame seeds and yeast flow in the enfolding process just as stars, planets and atoms flow in the universe.

A mathematical formulation of this view [9], [10], [11], manifests the ideas of Bohm. The model exposes an interconnected web of integer relations that can be visualised to appreciate the underlying patterns, complexity and relationships among components of a complex system. Components that only have access to local information form together with other components to exhibit global phenomena and behaviour that was not available to the components.

Figure 9 Three snapshots of windows looking into a small portion of structural space based on the Thue-Morse sequence [9, 10, 11].

In this view "the dough" is a space of integer relations and integer patterns called structural space. To illustrate, consider looking through some windows at a slice of this dough (Figure 9). It is not like a piece of toast that is rigid but still has the sense of movement like the ultrasound.

The integer relations are the patterns of integers that form together to equal zero on each successive level with a corresponding increment of exponents. The sign (positive or negative) of each integer is determined by the integer's corresponding position in the sequence (see bottom line of Figure 10). Here zero in the sequence determines a positive sign and one in the sequence gives a negative sign. The second bottom line of Figure 10 shows the translated sequence

The integer patterns are the boxes with integers in them along the bottom of each snapshot in Figure 9. They are areas under a step function that is specified by the translated sequence shown as the second last line in Figure 10. Under the process of integration the patterns form together to form new patterns on the next level. The area of the integer pattern in some way represents the energy of the pattern.

The arrows show how the patterns and relations are linked together in a kind of enfolding process. The sequence that is considered in each successive window is twice as long as in the preceding window. Also each integer relation in each successive level is twice as long as in the preceding level.

Each successive window also reveals a new level of formation. The number of levels that can be constructed from a given sequence is the called the structural complexity of the sequence. Figure 10 portrays the next successive window constructed from 16 elements of the Thue-Morse sequence and exhibits five hierarchical levels. So this subsequence has a structural complexity of 5.

The example shown in Figure 9 and Figure 10 is a small part of the infinite structure that is revealed by the Thue-Morse sequence. It is believed that this sequence is the most compact example chosen from an infinite number of sequences that possess the qualities demonstrated by structural space.

Certain sequences when regarded separately exhibit no visible properties but when depicted together reveal visible patterns that demonstrate structural complexity. These sequences are therefore related in the web of relationships. Visualisation plays an important part appreciating the interconnectedness of these sequences.

Complexity is viewed from the point of view of understanding the world as a dynamic web of relations. The process of formalisation is realised by the encoding of phenomena as a mapping onto the set of integers in a structural space where complexity is measured by the isomorphism between exponentiation and integration. The example with the Thue-Morse (TM) sequence over 16 integers as shown in Figure 9 and Figure 10 visually demonstrates this process.

There is a kind of symmetry in the TM sequence that captures the notion of enfoldment. Just as DNA folds certain molecules together into enzymes and amino acids. Enzymes fold amino acids together into proteins. Proteins are folded into cells. Cells into organs and systems. Which are folded into creatures and creatures into ecosystems, which are folded into the biosphere.

It is suggested that certain sequences and their corresponding structural complexity, encapsulate the interconnectedness of complex systems. Consider this simplified illustration from information technology: for some particular sequence that “enfolds” the interrelatedness of the Internet, the bottom level, (structural level 1) would represent the component building blocks, individual computers. These are linked up to a local network, LAN, (structural level 2). Various LANs are connected to WEB servers (structural level 3), and the whole thing is called the Internet (structural level 4).

Under the structural complexity approach a measure of complexity is proposed in order to formalise a system for describing the universe in global terms as a web of relations rather than in reductionist terms as the interaction of independent and separable parts. This measure provides a formal framework for investigating the problems exhibiting complex adaptive phenomena such as human decision making,

robots cooperating as teams, data communications, national economies, and ecosystems, etc.

Figure 10 Structural complexity of the TM sequence over 16 integers. Components form together on ascending structural levels under exponentiation and integration [9, 10, 11].

4.1 Thue-Morse Sequence

Schroeder [16] describes the TM sequence, a binary aperiodic sequence with amazing properties. It can be constructed in several ways:

1) Taking the parity of the binary representation of each element of the non-negative integers.

2) Recursively by appending to each subsequence the complemented subsequence.

3) Self generating by starting with 0 and having each term have a complimentary baby

0
0 1
0 1 1 0
0 1 1 0 1 0 0 1

4) It also has a self-similar property in that striking out every second term reproduces the sequence:

0 ~~1~~ 1 ~~0~~ 1 ~~0~~ 0 ~~1~~ 1 ~~0~~ 0 ~~1~~ 0 ~~1~~ 1 ~~0~~
0 1 1 0 1 0 0 1

Self-generating sequences mimic the self-organisation of matter. For example the signs of the Rudin-Shapiro polynomial, which form a periodic sequence, mimic in one dimension the growth of crystals [16]. The TM sequence, which is aperiodic, imitates a newly discovered solidification process. The Fibonnacci sequence, another self-similar aperiodic sequence, is related to the ten-fold symmetry found in electron diffraction patterns of an aluminium manganese alloy [16]. This evidence gives

impetus to the theory that some sequence or union of sequences may depict the interconnectedness of complex systems.

4.2 Fourier Amplitude Spectrum (FAS)

The Fourier Amplitude Spectrum (FAS) is a tool for investigating periodic behaviour of sequences. It is found by taking the modulus of the Fourier transform of a portion of a sequence. To create these graphs, the author used the macro and data analysis features of Microsoft excel. In Figure 11 the FAS has been taken for 4 simple sequences. It is seen that as the length of the repeating section of the sequence is increased, the number of spikes increase.

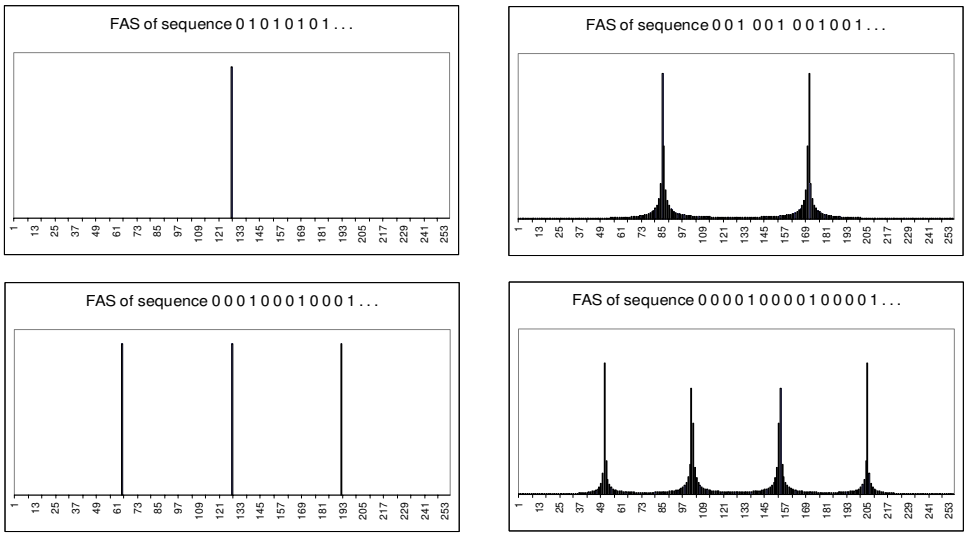

Figure 11 Fourier Amplitude Spectrum (FAS) for 4 simple sequences. This illustrates how the FAS is a measure of the periodic behaviour of a sequence.

Figure 12 shows the Fourier amplitude spectrum of the self-similar TM sequence (see section 4.1) for the first 256 elements as shown in [16]. The Thue-Morse sequence is an aperiodic sequence. That means it never repeats itself. What is interesting is that the FAS of the Thue-Morse sequence shows regular high spikes. This indicates there is some long-range order in the Thue-Morse sequence. Each element of the sequence seems to know its place much like electrons know their position so they don't crash into each other.