Chapter 8
Bipolar Quantum Linear Algebra (BQLA) and Bipolar Quantum Cellular Automata (BQCA)

ABSTRACT
This chapter brings bipolar relativity from the logical and relational levels to the algebraic level. Following a brief review on traditional cellular automata and linear algebra, bipolar quantum linear algebra (BQLA) and bipolar quantum cellular automata (BQCA) are presented. Three families of YinYang-N-Element bipolar cellular networks (BCNs) are developed, compared, and analyzed; YinYang bipolar dynamic equations are derived for YinYang-N-Element BQCA. Global (system level) and local (element level) energy equilibrium and non-equilibrium conditions are established and axiomatically proved for all three families of cellular structures that lead to the concept of collective bipolar equilibrium-based adaptivity. The unifying nature of bipolar relativity in the context of BQCA is illustrated. The background independence nature of YinYang bipolar geometry is demonstrated with BQLA and BQCA. Under the unifying theory, it is shown that the bipolar dimensional view, cellular view, and bipolar interactive view are logically consistent. The algebraic trajectories of bipolar agents in YinYang bipolar geometry are illustrated with simulations. Bipolar cellular processes in cosmology, brain, and life sciences are hypothesized and discussed.

INTRODUCTION
Bipolar relativity now consists of the theories of bipolar sets, bipolar dynamic logic (BDL), bipolar quantum lattice (BQL), bipolar dynamic fuzzy logic (BDFL), bipolar agents, bipolar causality, bipolar strings, and bipolar quantum theory. Following the arrival of bipolar agents, the emergence of space and time has become a natural process. A completely background independent quantum theory of
bipolar relativity has been achieved. However, the theory so far is a logical theory. One unanswered question is whether the logical foundation is leading to bipolar mathematical extension. This chapter is to make up this gap by introducing bipolar quantum linear algebra (BQLA) and YinYang-N-Element bipolar quantum cellular automata (BQCA) characterized with bipolar dynamic equations. With limited mathematical depth BQLA and BQCA are intended to be a starting point for further quantization and mathematical development.

YinYang is about equilibrium, harmony, symmetry, and stability which are all fundamental concepts in physical, socioeconomic, and bioeconomics systems. The current computation and modeling tools for physical, socio- and biosystem processes such as growing, aging, degenerating, equilibrium, and non-equilibrium processes in molecular and gene regulation networks, however, are based on classical truth-based mathematical abstraction where the Yin (such as genomic repression ability) and Yang (such as genomic activation ability) as well as their bipolar interaction, oscillation, local and global equilibria cannot be explicitly captured for holistic visualization and analysis. For instance, the YinYang1 (YY1) ubiquitous regulator protein (Shi et al., 1991) exhibits both repressor and activator behaviors in gene expression regulation, but classical mathematical abstraction do not support holistic YinYang bipolarity. A YinYang mathematical model is needed for simulating the repression and activation abilities with explicit bipolar interaction, oscillation, quantum entanglement, equilibrium, and non-equilibrium.

As a universal computational architecture, cellular automata find applications in all scientific fields. There are many possible generalizations and extensions of cellular automata. Among all the different varieties, holistic nature is a common property of cellular automata. The holistic nature makes cellular automation an excellent candidate for computing with equilibrium or non-equilibrium-based bipolar relativity. While mainstream cellular automation has been rooted in classical truth-based mathematical abstraction, YinYang bipolar mathematical abstraction provides a theoretical foundation for a bipolar quantum linear algebra (BQLA) and a theory of YinYang-N-Element bipolar quantum cellular automation (BQCA).

In this chapter we present BQLA and BQCA. It is shown that BQLA makes it possible to describe YinYang bipolar relativity as a unifying mathematical physics theory in the context of YinYang-N-Element BQCA. It is shown that the dimensional view, bipolar logical view, and cellular view are semantically consistent under the unifying theory. Therefore, bipolar set theory, bipolar dynamic logic, bipolar quantum linear algebra, bipolar agents, bipolar causality, and BQCA are all unified under bipolar relativity. The algebraic trajectory of bipolar agents in YinYang bipolar geometry is illustrated with simulated data. The background independent nature of bipolar relativity is demonstrated with bipolar algebraic YinYang bipolar geometry.

The remaining presentations and discussions of this chapter are organized in the following sections:

- **Background Review.** This section presents a brief review on related concepts in cellular automaton and linear algebra.
- **Bipolar Quantum Linear Algebra (BQLA) and Bipolar Quantum Cellular Automata (BQCA).** This section presents: (1) the definitions of BQCA; (2) Bipolar Quantum Linear Algebra (BQLA); (3) YinYang-N-Element Bipolar Cellular Networks (BCNs); (4) YinYang-N-Element Dynamic Equations; (5) Non-Classical vs. Classical YinYang-N-Element Cellular Networks; (6) YinYang-N-Element Cellular Combinatorics. In general, three families of BCNs are developed, compared, and analyzed: one family has predefined nourishing and regulating cycles following the classical YinYang-5-Element protocol in traditional Chinese medicine (TCM); another family has
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