Complex Systems PhD Qualifying Exam Syllabus

References:
Chaos: An Introduction to Dynamical Systems by Alligood, Sauer, and Yorke
Critical Phenomena in Natural Sciences: Chaos, Fractals, Self-organization and Disorder: Concepts and Tools by Didier Sornette
Critical Mass: How one thing leads to another by Philip Ball

266 Topics:

- One-Dimensional Maps, Orbits, Stability, the Logistic Map

- Two-Dimensional Maps, Saddles, Sources, and Sinks

- Chaos and Lyapunov Exponents

- Fractals: Cantor, Mandelbrot, and Julia Sets

- Chaos in Two-Dimensional Maps

- Chaotic Attractors, Stable and Unstable Manifolds

- The Lorenz Attractor

300 Topics:

- Universality and accidents of history, evolutionary mechanisms, and complexification.

- Scaling phenomena including allometric scaling in biology, ecology, geophysical, informational and sociotechnical systems.

- Size distributions with heavy tails (Zipf's law, non-Gaussian statistics and power law distributions, fundamental mechanisms for generating power law distributions)

- Multiscale complex systems (hierarchies and scaling, modularity, form and context in design).

- Integrity of complex systems (generic failure mechanisms, robustness and fragility, highly optimized tolerance).

- Complex networks (generalized random networks, small-world, scale-free)

- Information (search in networked systems, search on scale-free networks, knowledge trees, metadata and tagging).

- Collective behavior and contagion in social and socio-technical systems (percolation and phase transitions, disease spreading models, Schelling's model of segregation, Granovetter's model of imitation, contagion on networks, herding phenomena, cooperation, wars and conflicts).

- Universal patterns and evolution of natural language.

- Large-scale social patterns (movement of individuals).

- Collective decision making (theories of social choice, role of randomness and chance, systems of voting, juries, success inequality)

- Complexity in abstract models (e.g., cellular automata).

- Measures of complexity (randomness and order, entropy and information theory).