Mutually Incompatible Realities & the Cost of Extracting Meaning from Complex Environments

James P Crutchfield
Complexity Sciences Center
Physics Department
University of California, Davis
http://csc.ucdavis.edu/~chaos/Talks/

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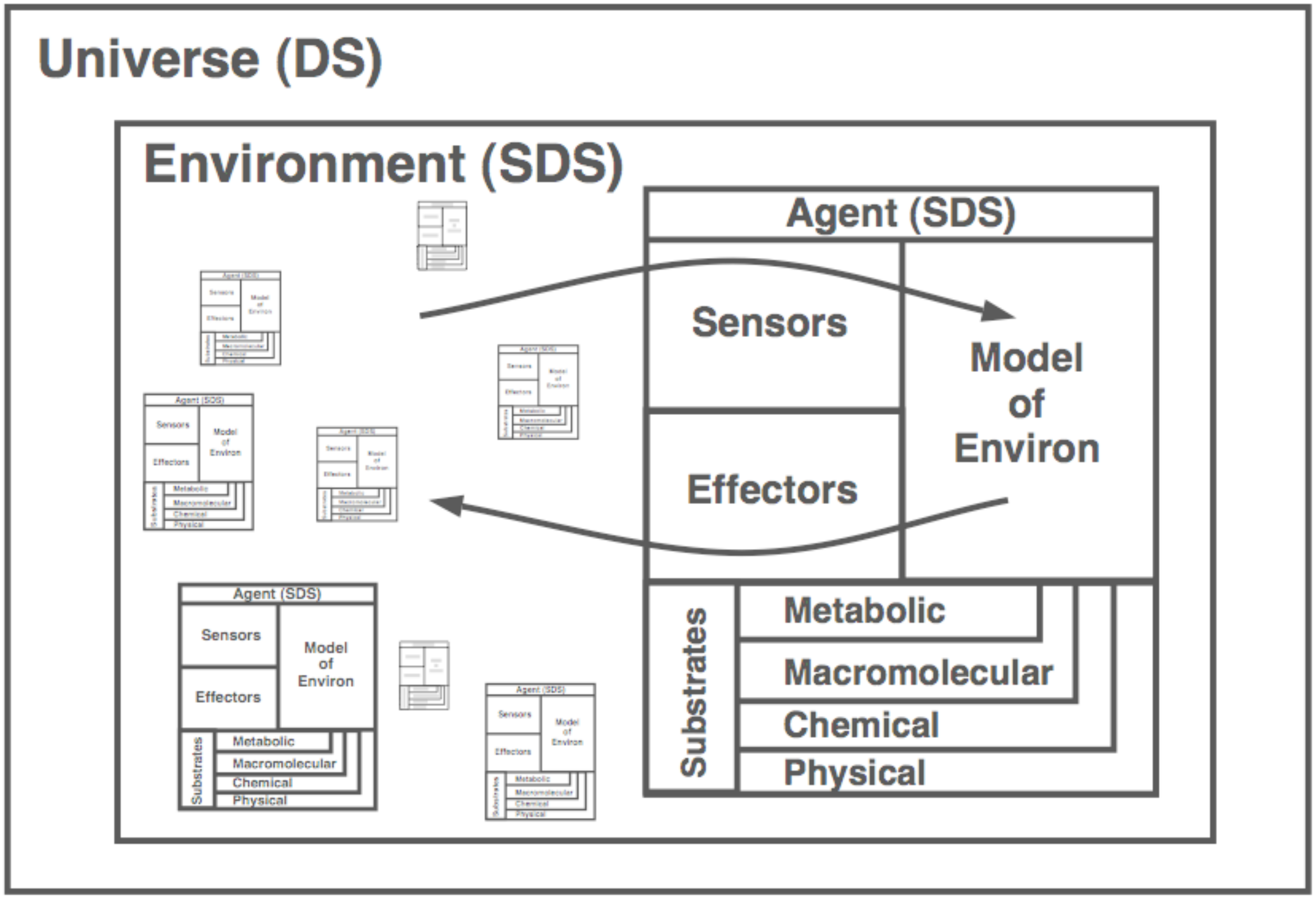
Dibyendu Mandal, John Mahoney, Josh Ruebeck

Abstract

Presumably, an intelligent agent survives in and adapts to a complex environment by employing an internal model that captures as well as possible regularities encountered in its interactions. This is expressed by the thermodynamic *Principle of Requisite Complexity*. Better models increase survival. Curiously, for a single environment there can be a multiplicity of optimal models that competing agents (i) can use to maximum benefit but that (ii) do not agree on the environment's structure. Analyzing the agents environment-interaction semantics one concludes that their worldviews are mutually incompatible—the same environmental events mean different things to each. Moreover, incompatible realities have physical consequences. The *Information Processing Second Law of Thermodynamics* applied to agent-environment interactions determines the minimal, necessary costs (energy dissipation) an agent must invest to make sense of its environment. A corollary shows that the total semantic content that can be extracted (i) by a predictive agent is the environment's statistical complexity C_μ and (ii) by a generative agent is the average memory C_g required to simulate the environment, where $C_g \leq C_\mu$. We draw out the thermodynamics of agents that operate under such semantically incompatible views of an environment. While optimality here assumes agents have correct environmental models, the semantic and thermodynamic analyses easily extend to agents employing approximate or out-right incorrect models. In this setting, both meaningful and meaningless interactions arise and their informational and thermodynamic costs can be quantified. A final result demonstrates that just as there are fluctuations in an agent's thermodynamic functioning, there are fluctuations in meaning and so in an agent's moment-by-moment reality. The result is a thermodynamics of how agents holding mutually incompatible realities can coexist in a single world.

Problem:
What is an agent?

Problem Statement



= Ecological population dynamics of structurally complex adapting agents

+ Reproduction (evolutionary population dynamics)

JP Crutchfield, "The Calculi of Emergence: Computation, Dynamics, and Induction", Physica D 75 (1994) 11-54.
In Proceedings of the Oji International Seminar:
Complex Systems—from Complex Dynamics to Artificial Reality 5 - 9 April 1993, Numazu, Japan.

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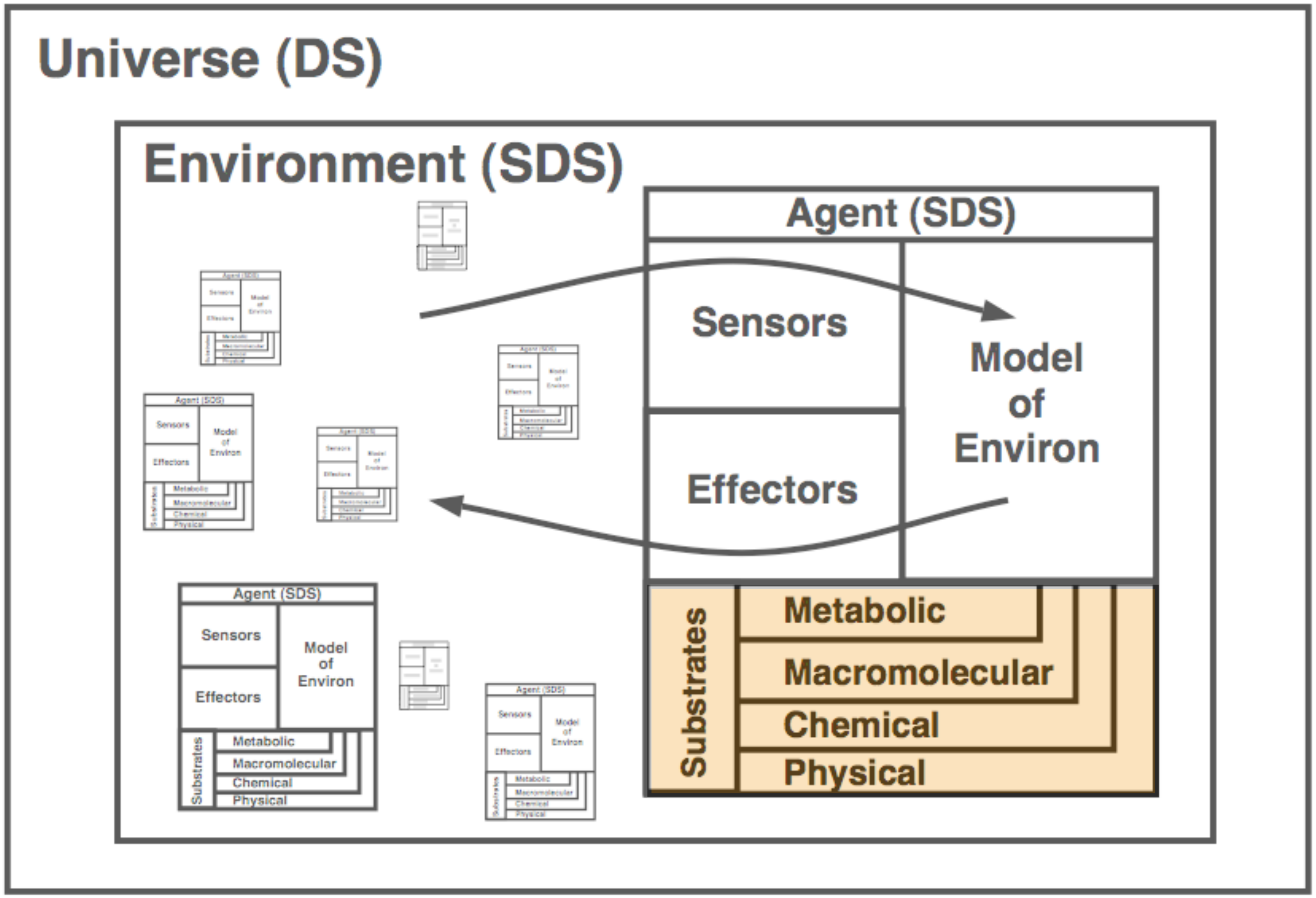

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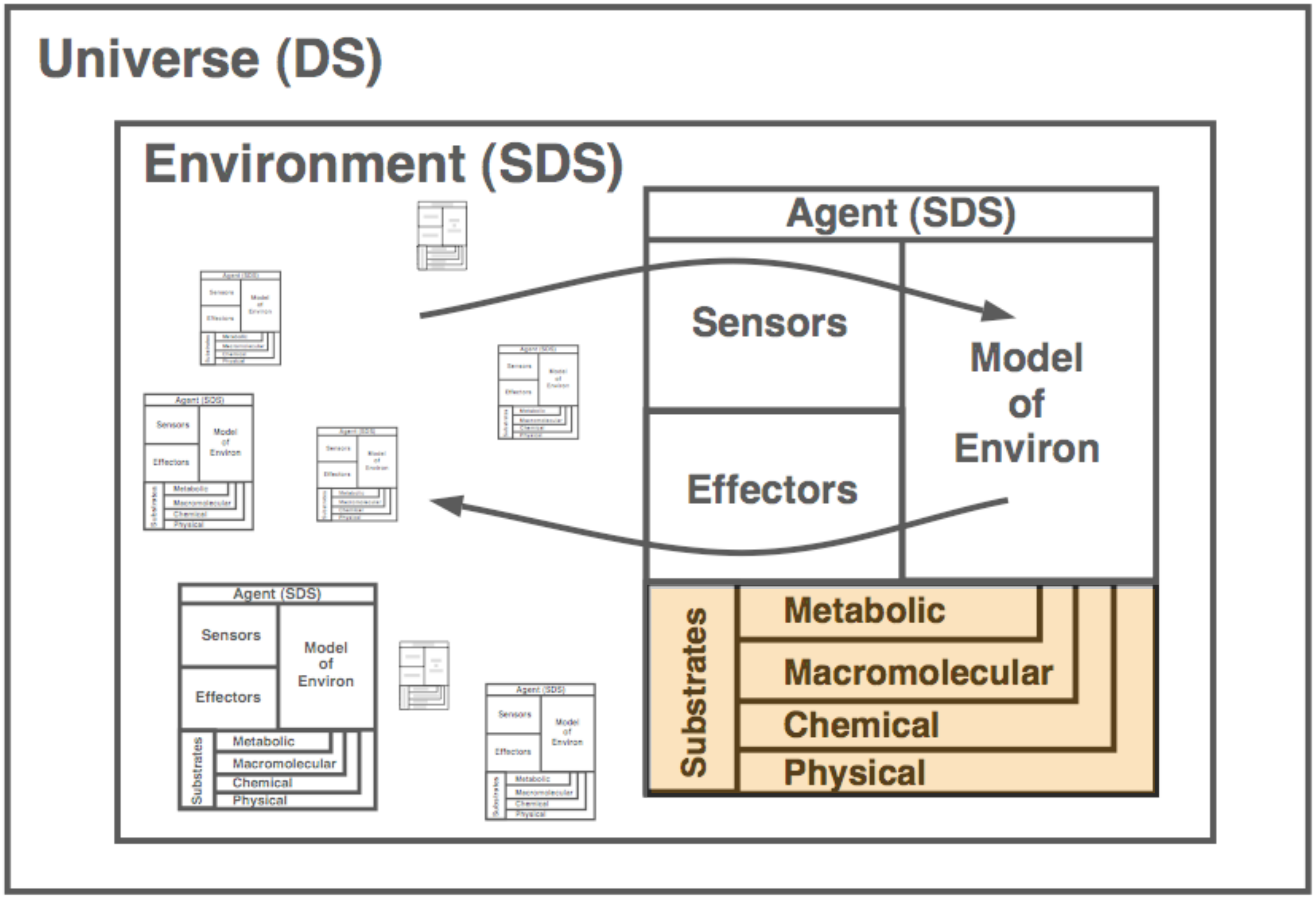
Problem Statement

How Does Agency Arise?



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Thermodynamics of Agency

Recent Bibliography (2016-2018)

- **Information Processing Second Law (IPSL)**: A.B. Boyd, D. Mandal, and J.P. Crutchfield, *Identifying Functional Thermodynamics in Autonomous Maxwellian Ratchets*, ***New Journal of Physics*** 18 (2016) 023149.
- **Principle of Requisite Complexity**: A.B. Boyd, D. Mandal, and J.P. Crutchfield, *Leveraging Environmental Correlations: Thermodynamics of Requisite Variety*, ***Journal Statistical Physics*** 167:6 (2017) 1555-1585.
- **Information creation**: C. Aghamohammadi and J.P. Crutchfield, *Thermodynamics of Random Number Generation*, ***Physical Review E*** 95:6 (2017) 062139.
- **Synchronization & error correction**: A.B. Boyd, D. Mandal, and J.P. Crutchfield, *Correlation-powered Information Engines and the Thermodynamics of Self-Correction*, ***Physical Review E*** 95:1 (2017) 012152.
- **Functional fluctuations**: J. P. Crutchfield and C. Aghamohammadi, “Not All Fluctuations are Created Equal: Spontaneous Variations in Thermodynamic Function. arxiv.org:***1609.02519***.
- **Controller structure**: A.B. Boyd, D. Mandal, and J.P. Crutchfield, *Transient Dissipation and Structural Costs of Physical Information Transduction*, ***Physical Review Letters*** 118 (2017) 220602.
- **Sensors**: S. E. Marzen and J. P. Crutchfield, *Prediction and Power in Molecular Sensors: Uncertainty and Dissipation When Conditionally Markovian Channels Are Driven by Semi-Markov Environments*, ***Physical Review E*** (2018) in press. arxiv.org:***1707.03962***. *Optimized Bacteria are Environmental Prediction Engines*, ***Physical Review E*** (2018) in press. arXiv.org:***1802.03105***.
- **Modularity**: A.B. Boyd, D. Mandal, and J.P. Crutchfield, *Above and Beyond the Landauer Bound: Thermodynamics of Modularity,* ***Physical Review X*** (2018) in press. arxiv.org:***1708.03030***.
- **Intelligent control**: A.B. Boyd and J.P. Crutchfield, *Maxwell Demon Dynamics: Deterministic Chaos, the Szilard Map, and the Intelligence of Thermodynamic Systems*, ***Physical Review Letters*** 116 (2016) 190601.
- **NESS transitions (to NEDS)**: P.M. Riechers and J.P. Crutchfield, *Fluctuations When Driving Between Nonequilibrium Steady States*, ***Journal of Statistical Physics*** 168:4 (2017) 873-918.

Thermodynamics of Agency

Recent Bibliography (2016-2018)

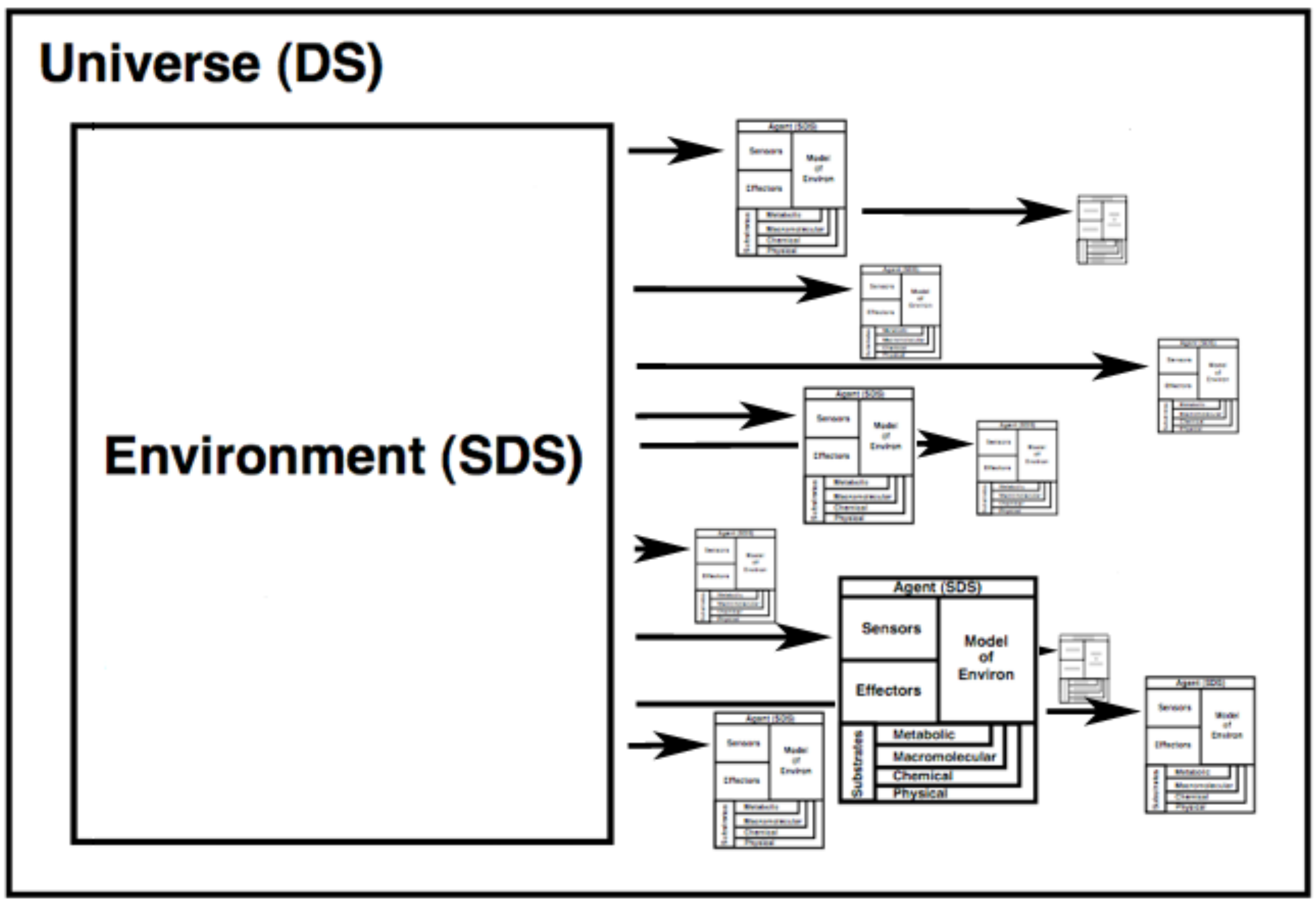
Information Processing Second Law

Principle of Requisite Complexity

Problem:
What is an agent?

A subproblem:

Noninteracting agents observe & model a given complex environment



Agenda

- Mash Up:
  - Measurement Semantics

    J. P. Crutchfield, "Semantics and Thermodynamics", in **Nonlinear Modeling and Forecasting**, SFI Studies in the Sciences of Complexity, Proc. Vol. **XII**, M. Casdagli and S. Eubank, editors, Addison-Wesley, Reading, Massachusetts (1992) 317-360.
  - Principle of Requisite Complexity

    A. B. Boyd, D. Mandal, and J. P. Crutchfield, "Leveraging Environmental Correlations: The Thermodynamics of Requisite Variety", Journal of Statistical Physics **167**:6 (2017) 1555-1585.
  - Minimal Generators

    J. Ruebeck, R. G. James, J. R. Mahoney, and J. P. Crutchfield, "Prediction and Generation of Binary Markov Processes: Can a Finite-State Fox Catch a Markov Mouse?", CHAOS **28** (2018) 013109.
- Results:
  - Mutually Incompatible Realities
  - Thermodynamic Cost of Extracting Meaning

End

Thanks!