# Models, Measurement, and Simulation: The Changing Face of Experiment

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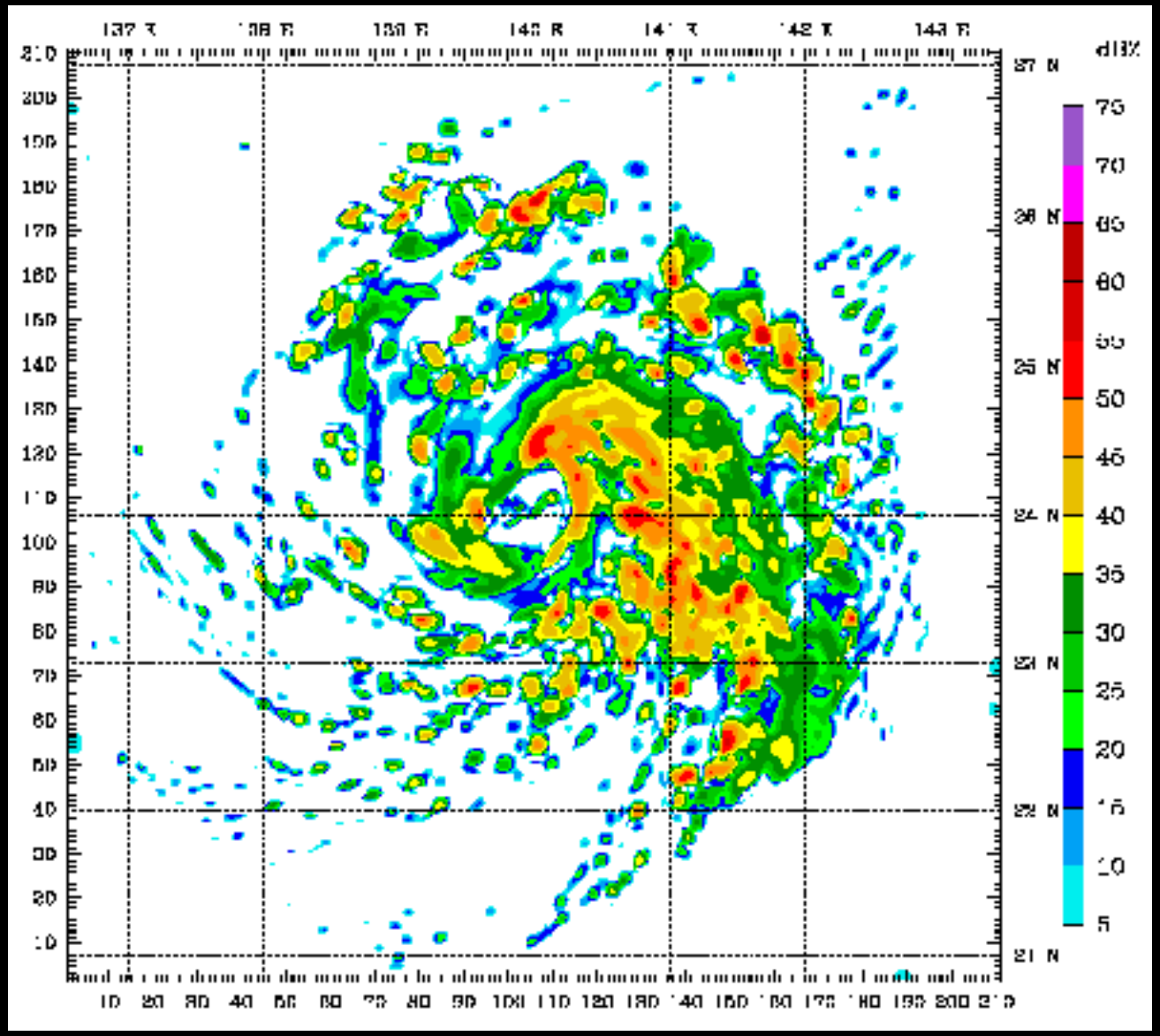



A 48-hour computer simulation of Typhoon Mawar using the Weather Research and Forecasting model

Main Claim: Computer simulations have the same epistemic status as experimental measurement.

Models play a role in experimental activity by functioning as measuring instruments

Models constitute both the *object of inquiry* and the *experimental tool*

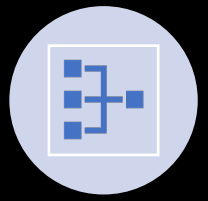
Simulation systems are like models

This connection explains why simulation is a kind of experimental activity

# What would it mean to characterize the product of a simulation as a measurement and the simulation itself an experiment?

Focus on the *process* of measurement.

# The Semantic Games



Model: Abstract representation of the physical world

Experiment: Directly engage the physical/material world

Measurement: C*ausal interaction* with the material world

Calculation: Mathematical activity involving inputs and outputs

Simulation: Using numerical methods to find approximate solutions to mathematical models

# Kelvin's Philosophy of Science

"I never satisfy myself until I can make a mechanical model of a thing. If I can make a mechanical model I can understand it. As long as I cannot make a mechanical model all the way through I cannot understand; and that is why I cannot get the electromagnetic theory. I firmly believe in an electro-magnetic theory of light, and that when we understand electricity and magnetism and light we shall see them all together as parts of a whole (Kelvin, 1884, pp. 6, 132, 270–271).

"I often say that when you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot express it in numbers your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science whatever the matter may be (Kelvin, 1891, pp. 80–81).

**Are there sciences which do not measure numerically?**

**Are there sciences whose empirical content get lowered by trying to measure? E.g. psychophysics/mathematical psychology or the adoption of "The "more math-y it is, the more science-y it is" in psychology**

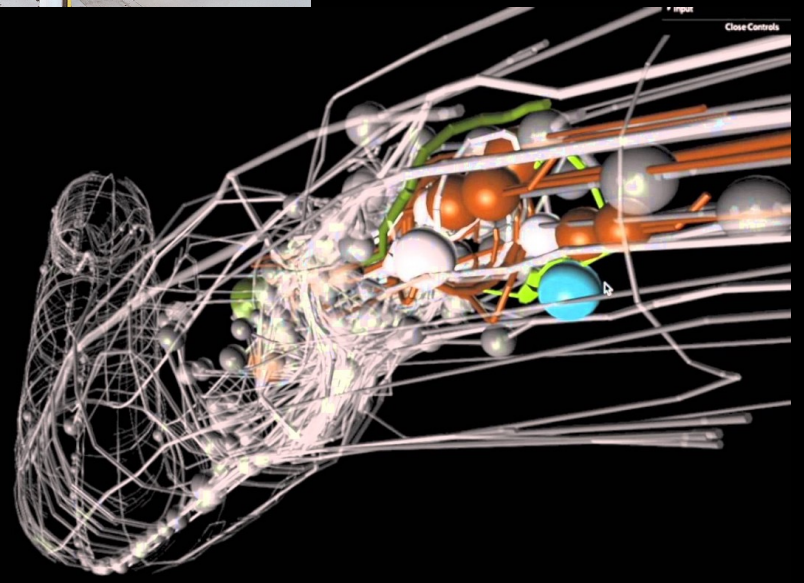
# Kelvin's Philosophy of Science

- Models as material structures
- Mechanical models as experimental demonstrations
- Mechanical models and measurement
  - "what was physically realizable was what could be mechanically constructed and what was mechanically constructed could be measured"

# What are computer simulations?

- Simulation: one type of system is used to represent or mimic the behaviour of another. E.g., wind tunnels mimic aerodynamical features of flight.

- Computer simulation: computer program mimics processes of a phenomena.
  - Evolution of a system
  - Measurement of values of specific properties

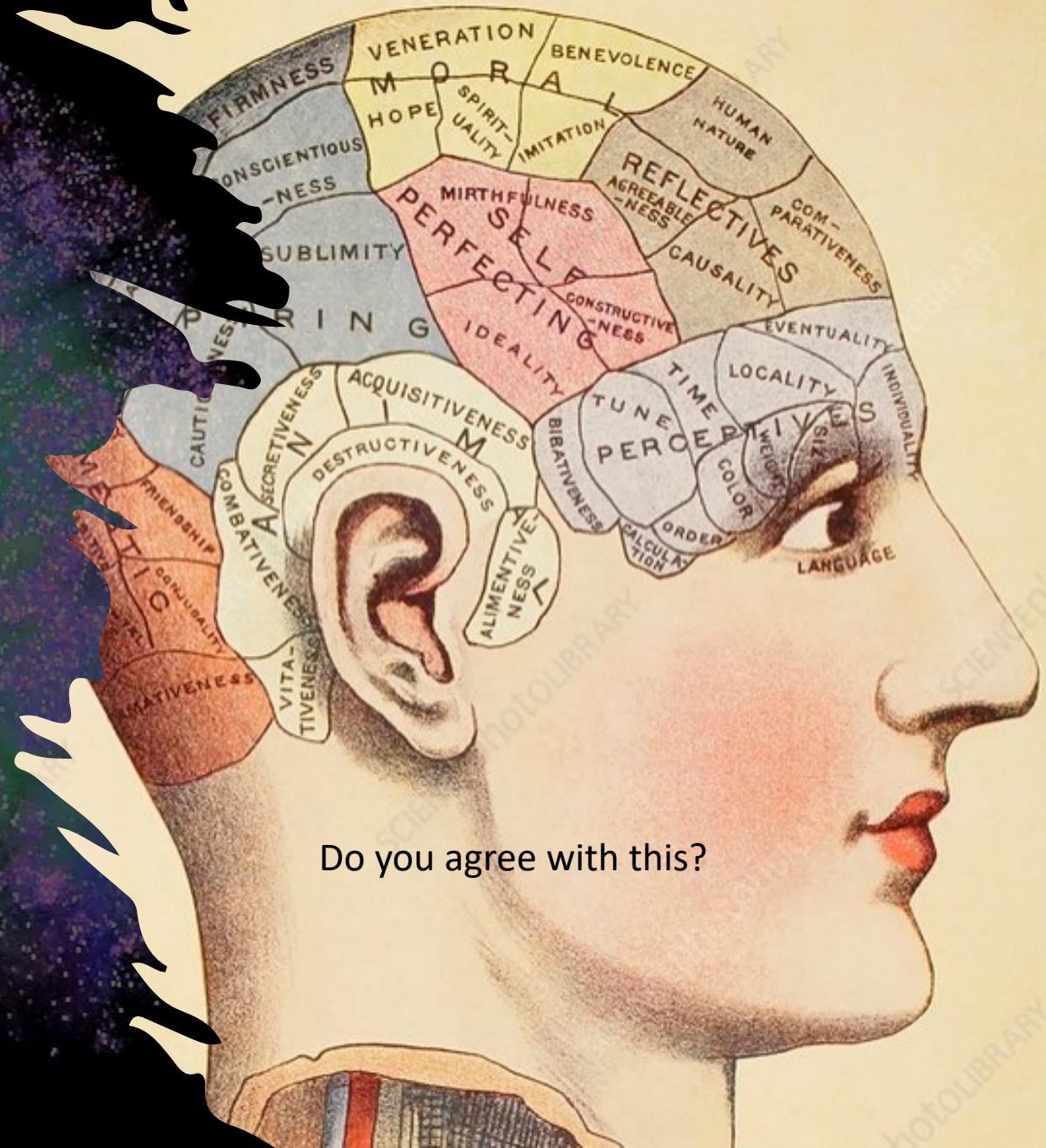



C. Elegans, a microscopic worm with its entire neural network of 302 neurons virtually respresented

# Arguments for epistemic inferiority of computer simulations from experiments

- Experimenting with the object of interest vs experimenting with the model
- Material manipulation and epistemic power
- External validity (simulation) vs internal validity (experiment)

- “in experiment we are interested in modelling ‘‘the object’’ under study rather than the target system and hence the model building principles are used to justify the internal validity of the experiment.In simulation we are interested in the target system and its relation to the outside world, hence external validity is what we are concerned with ”




Do you agree with this?

# “Simulation system” (Morisson)

- Computer simulation using particles
  - Traces the motion of tens of thousands of particles
  - Tracks temporal evolution
  - Represents target system in terms of an appropriate mathematical model
  - Particle method discretizes the mathematical method for cases in which we have a corpuscular system

- Parts of the simulation system
  1) Computer
  2) Program
  3) Simulation model

# Simulation systems as a (computer) experiment

- Simulation system is both the *apparatus* and *material under investigation*

- Apparatus – computer + program
- Material under investigation – Simulation model

- Materiality not in the computer but the simulation system

# Models as measuring instruments: How do models measure?

- Straightforward conception: Physical models of the British Field Theorists
  - Dialectical notion of measurement
- Not-as-straightforward conception: Physical plane pendulum which measures local gravitational acceleration
  - Direct measurement

- Modelling isn’t calculation
  - Calculation: manipulating mathematical symbols
  - Modelling: *causal connection* to instruments that generate data from some physical source

- **Without models, there is no measurement!**

# Putting it all together

- Models function both as 1) the object of investigation and 2) type of experimental tool
- Simulation systems functions both 1) the object of investigation and 2) type of experimental tool
- Models function as measuring instruments in experimental inquiry and simulations (as a form of modelling) can do the same
- Simulations have the same epistemic status as experiments/experimental measurement

# Gems & Coals

Centering a (historical) scientist as inspiration for her account of experiments, measurements, models, and simulations.

Explicating preexisting accounts of simulation and explaining why her account differs.

Too caught up in semantic games.

Accounts of simulation only applies to particles models.

# Questions

- How much internal and external validity do experiments and simulations have and how does bear on their ability to represent the model system?

- Investigative research typically involves a variety of scientific methods such as computer simulation, experiment without a hypothesis etc. How should we classify investigative research in this framework?

- Morisson's examples are primarily from physics. Are these sciences in which models (and/or simulations) would not count as the object of investigation because they possess a different material relation to the target system?

- How important do you think the semantics of models, measurements, simulation, and experiment are to scientific activity and practice? What do scientists gain by understanding this distinction? How does it change their scientific practice?