Open Structure: Ontology Repair Plan based on Atomic Modeling

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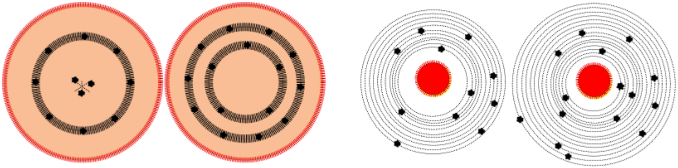
Outline

GALILEO project and Ontology Evolution in Physics

- Aim: solving contradictions between multiple ontologies.
  - Canonical case: contradictions in physics between theoretical expectations and experimental observations.
- Main results: Ontology Repair Plans (ORPs).
  - Trigger: detects contradiction between ontologies.
  - Repair: changes ontology axioms or signature.
  - Create New Axioms: propagates changes as needed.
- Methodology: turn case studies in physics history into ORPs.
  - Extract ORP's conceptual backbone from case study.
  - Represent ORP in higher-order logic.
  - Implement ORP (λProlog and beyond).
- Some ORPs and their state of development.
  - Developed and tested: Where's My Stuff?, Inconstancy, Unite.
  - Being tested: Open Structure, Close Structure.
  - Under development: Unify.

Thomson's atom (1904) and Rutherford's atom (1911)

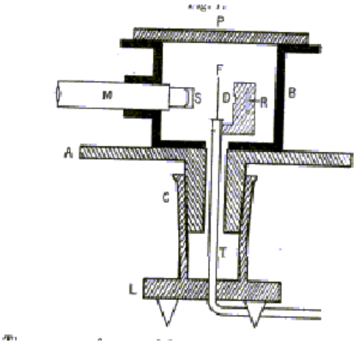


Thomson's Atom

Rutherford's Atom

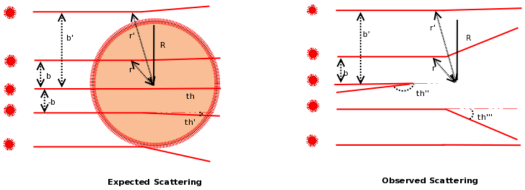
- 11 electron atom and 15 electron atom.
- Black dots and circumferences represent negative charges and their orbits/rings.
- Red circles represent positive charge (more intense where darker).
- Note that Rutherford's atom's structure is monotonic: Thomson's atom's configuration changes when electrons are added, Rutherford's atom's configuration is stable.

Rutherford's scattering apparatus (1898-1911)



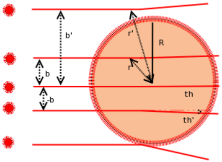
- R, fixed source of α-particles (double positive charges).
- D, collimating diaphragm.
- F, fixed foil.
- S, screen.
- M, microscope.
- Chamber is evacuated and can be rotated around F.
- Original image in (Geiger, 1913), downloaded from. http://galileo.phys.virginia.edu

Expected vs observed scattering

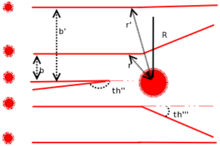


- Red spots and lines are α-particles and their paths.
- Half-dashed thin red lines are ideal undeflected paths.
- b's and $-b$'s are impact parameters ($b = 0$ for third particle).
- r's are distances between a point of the atom's electric field and the atom's center.
- R is the atom's radius.
- th's are scattering angles.
- **Expected scattering is minimal**.
- **Observed scattering is minimal, large or a complete rebound**.

The nucleus



Expected Scattering



Observed Scattering

- The nucleus explains the difference between expectations and observations.
- The nucleus entails different *deflection functions*:

  $\theta(b)_{Thomson}$ and $\theta(b)_{Rutherford}$ calculate different deflection angles for same b's.
- The nucleus also entails different *scattering potential functions*:

  $V(r)_{Thomson}$ **and** $V(r)_{Rutherford}$ **calculate different amounts of work excerted by positive electric fields when deflecting incident particles at same distance** r.

Scattering potential functions for different structures

$$V(r)_{Thomson} = \begin{cases} \frac{Q_A Q_B}{4\pi\epsilon_0}\frac{1}{r} & R \leq r \\ \frac{Q_A Q_B}{4\pi\epsilon_0}\frac{1}{2R^3}(3R^2 - r^2) & 0 \leq r \leq R \end{cases}$$

$$V(r)_{Rutherford} = \frac{Q_A Q_B}{4\pi\epsilon_0}\frac{1}{r}$$

where Q_A is the charge of incident particle, Q_B is the charge of the target atom, $1/4\pi\epsilon_0$ is the Coulomb constant, r is the distance between the incident particle and the centre of the target atom, R is the radius of the target atom.

- $V(r)_{Thomson}$ is both non-Coulombic (i.e. for values of r lower than the atom's radius R, the potential is directly proportional to r) and Coulombic (i.e. for values of r higher than R, the potential is inversely proportional to r).
- $V(r)_{Rutherford}$ is only Coulombic (R needs not to be considered).
- Formulae taken from (Zoli, 1998)

Evolution of $V(r)$ by existing ORPs

$$V(r)_{Thomson} = \begin{cases} \frac{Q_A Q_B}{4\pi\epsilon_0}\frac{1}{r} & R \leq r \\ \frac{Q_A Q_B}{4\pi\epsilon_0}\frac{1}{2R^3}(3R^2 - r^2) & 0 \leq r \leq R \end{cases}$$

$$V(r)_{Rutherford} = \frac{Q_A Q_B}{4\pi\epsilon_0}\frac{1}{r}$$

- **Where is my stuff?** would stick to Thomson's atomic structure by increasing Q_A and yielding evolution $V(r) ::= V(r)_{vis} + V(r)_{invis}$. Problem: how would the additional charge be distributed wrt R?
- **Unite**, the inverse of Where is my stuff?, would not be able to let $V(r)$ evolve.
- **Incons** too would stick to Thomson's atomic structure and let $V(r)$ evolve in such a way that the Coulomb constant $1/4\pi\epsilon_0$ would depend on distance r from the center of atom. This would yield a very complicated structure.
- **Need for an ORP that handles structural evolution as such**, rather than by pivoting on quantities.
- Formulae taken from (Zoli, 1998)

Open Structure ORP: Trigger

$$\textbf{Trigger} : O_t \vdash d_4 > d_3 \geq cop \geq d_2 > d_1 \wedge$$
$$((stuff(d_2) > stuff(d_1) \wedge stuff(d_3) > stuff(d_4)) \vee$$
$$(stuff(d_1) > stuff(d_2) \wedge stuff(d_4) > stuff(d_3))).$$
$$O_s \vdash \forall d, d' : \delta.\ d' > d \rightarrow stuff(d) > stuff(d').$$

- *stuff* represents function subject to evolution (V is *stuff*).
- *stuff* ranges over a type δ of d's (like V ranges over the type *dis* of distances r's).
- *stuff*'s domain contains a cut-off point *cop* (like V's domain contains R).
- K is constant (like all other quantities remain constant throughtout V's evolution).
- Two cases of contradiction:

  crested* vs open structure In O_t, for all arguments below cut-off point, value of *stuff* is directly proportional to argument, inversely proportional otherwise. In O_s value of *stuff* is always inversely proportional to argument.

  trenched* vs open structure In O_t, for all arguments below cut-off point, value of *stuff* is inversely proportional to the argument while, directly proportional otherwiset. O_s is the same as in the first case above.

*tentative term

Open Structure ORP: Repair & Create New Axioms

Open Structure : $\nu(stuff) ::= \lambda d : \delta.\ K/d.$

Create New Axioms :
$$Ax(\nu(O_t)) ::= Ax(O_t) \setminus$$
$$\{stuff ::= \lambda d : \delta.\ (cop > d \wedge Kd) \vee K/d\} \cup$$
$$\{\nu(stuff) ::= \lambda d : \delta.\ K/d\}.$$
$$Ax(\nu(O_s)) ::= Ax(O_s) \setminus$$
$$\{stuff ::= \lambda cop, d : \delta.\ (cop > d \wedge Kd) \vee K/d\} \cup$$
$$\{\nu(stuff) ::= \lambda d : \delta.\ K/d\}.$$

- Contradiction always repaired according to what dictated by O_s.

Application of Open Structure

$$\textbf{Substitution}: \left\{V/stuff, d_i/r_i, cop/R, K/\frac{Q_A Q_B}{4\pi\epsilon_0}\right\}$$

$$\begin{aligned}\textbf{Trigger}: O_t &\vdash r_4 > r_3 \geq R \geq r_2 > r_1 \wedge \\ &((V(r_2) > V(r_1) \wedge V(r_3) > V(r_4)) \\ O_s &\vdash \forall r, r' : dis.\ r' > r \rightarrow V(r) > V(r').\end{aligned}$$

$$\begin{aligned}\textbf{New Axioms}: Ax(\nu(O_t)) &::= Ax(O_t) \setminus \\ &\{V ::= \lambda r : dis.\ (R > r \wedge Kr) \vee K/r\} \cup \\ &\{\nu(V) ::= \lambda r : dis.\ K/r\}. \\ Ax(\nu(O_s)) &::= Ax(O_s) \setminus \\ &\{V ::= \lambda r : dis.\ (R > r \wedge Kr) \vee K/r\} \cup \\ &\{\nu(V) ::= \lambda r : dis.\ K/r\}.\end{aligned}$$

Future work

- Find other cases for application of Open Structure.
- Interpret its inverse, Close Structure, and find cases of application.
- Alternative treatment of Thomson vs Rutherford case study: modeling the evolution between the two atoms in terms of their different deflection functions.