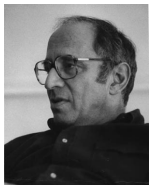


1. The Nature and Necessity of Revolutions

(A) *Are there crises and revolutions in the history of science?*

"Revolutions in science only need seem revolutionary to those whose paradigms are affected by them." (Kuhn, pg. 93.)

- *Ex.* "Discovery" of X-Rays (Röntgen 1895).
  - Notices a fluorescent effect on a screen next to shielded discharging cathode ray tube.

wife's hand!

Wilhelm Röntgen (1845-1923)

  - Led to paradigm change in expectations and procedures associated with experiments involving cathode ray tubes.

    "Paradigm procedures and applications are as necessary to science as paradigm laws and theories, and they have the same effects." (Kuhn, pg. 60.)

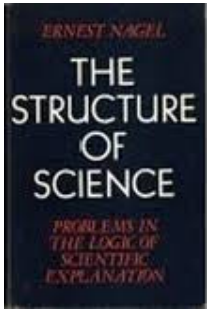
  - *But*: To astronomers, no big deal...

(B) *Must crises always lead to revolutions?*

- No!
  - "Retooling" is typically resisted.
  - Accomodation is typically the response.
- To spark revolution, in addition to crisis, there must be an extant alternative paradigm.

> <u>*But*</u>: There is no logical reason why a new paradigm replaces an old one.
>
> <u>*Moreover*</u>: There typically is *no logical connection* between new and old paradigms.

- <u>*Logical Empiricist View:*</u>
  - A new theory "reduces" to an older one in an appropriate limiting relation.
  - A new theory expands the domain of application of an old one.



Ernst Nagel
(1901-1985)

Example.

- *Newtonian dynamics*: Valid for objects at speeds $v \ll c$.
- *Relativistic dynamics*: Valid for objects at speeds $v \approx c$.

$$\text{Newtonian dyamics} = \lim_{v/c \to 0} (\text{Relativistic dynamics})$$

Newtonian momentum:

$$p_N = mv$$

Newtonian mass - constant!

Relativistic momentum:

$$p_R = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} mv$$

$$\equiv m_R v$$

Relativistic mass - varies with velocity!

Newtonian energy:

Ex: *Kinetic energy*

$$K_N = \tfrac{1}{2}mv^2$$

Relativistic energy:

Ex: *Kinetic energy*

$$K_R = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}mc^2 - mc^2$$

$$\approx \left(1+\frac{v^2}{2c^2}\right)mc^2 - mc^2, \text{ for } v \ll c.$$

Rewrite as:

$$\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}mc^2 = K_R + mc^2$$

Total energy: call it E

Energy of motion

"Rest" energy: call it E_0

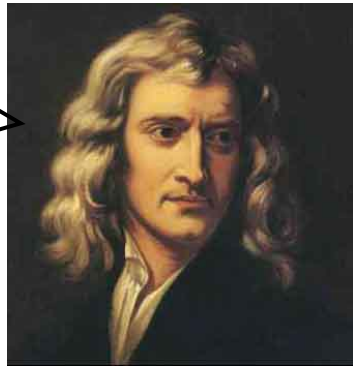
- Total Energy: $E = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}mc^2 = m_R c^2$
- Rest Energy: $E_0 = mc^2$

Energy and mass are equivalent!

Kuhn's Moral:

- The terms "mass" and "energy" appear in both the Newtonian and relativistic paradigms.
- *But*: Their referants are not the same.

By "mass" I mean something that remains constant. By "energy" my followers mean something completely distinct from "mass".



By "mass" I mean something that varies with velocity, and that is "equivalent" to energy.

Holistic Theory of Meaning

A scientific term gets its meaning from the theory it appears in.

- *Claim*: There is no neutral observation language independent of theories.
- *Consequence*: When theories change, so does the meaning of their terms.

How do scientific terms refer?

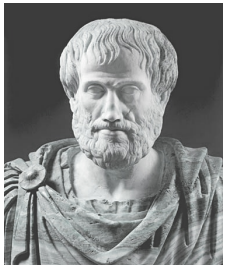
- Does the term "Newtonian mass" refer to anything in the world?
- Does the term "phlogiston" refer to anything in the world?
- Why should we think the term "relativistic mass" refers to anything in the world?

Incomensurability of Paradigms

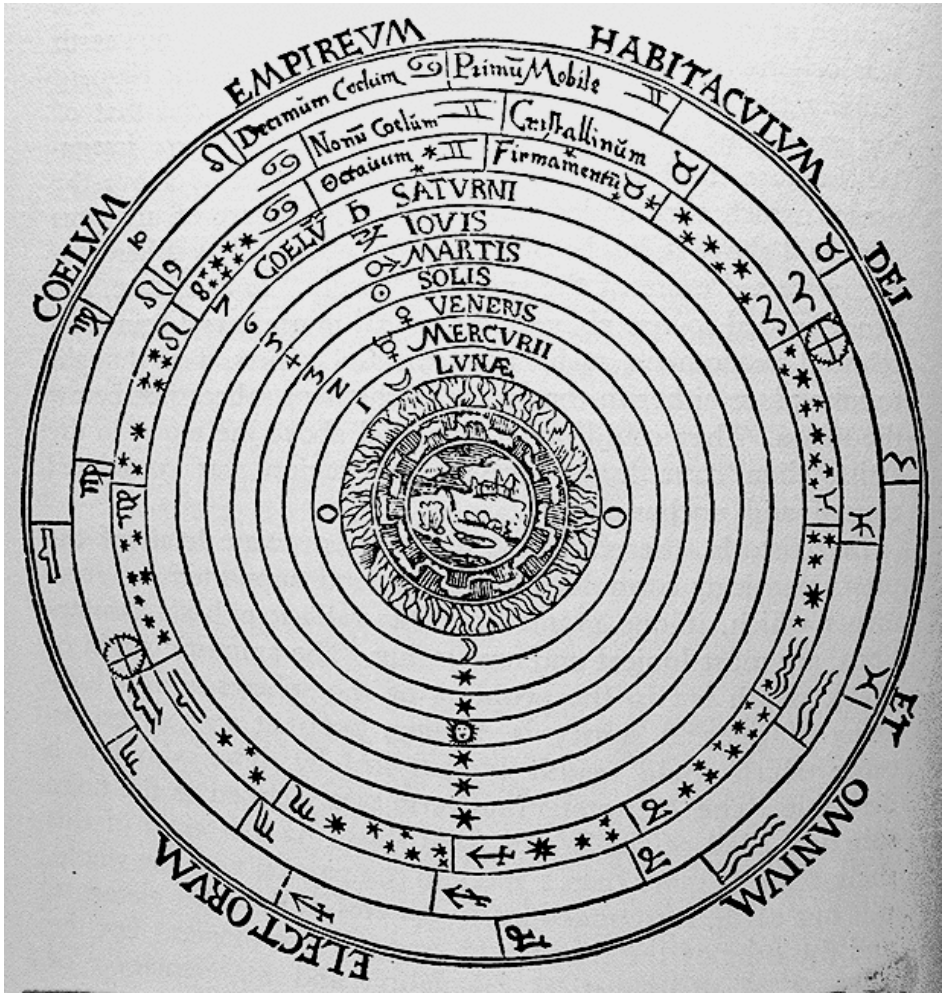
- The *terms* used by old and new paradigms to describe the world are incommensurable.
- The *standards* used by old and new paradigms to investigate the world are incommensurable.

Incomensurability of Standards

Example: Standards of explanation.



- *Aristotelian paradigm* (~300 B.C. – ~1600's):
  - Natural phenomena have "natures", "inner principles", "occult forms", *etc.*, in terms of which they are to be explained.



  - *Question*: Why does a rock fall downward?
  - *Ans*: A rock consists primarily of the element "Earth", and it is the nature of this element to move in a straight line towards the center of the cosmos.

- *Mechanical paradigm* (*e.g.*, Descartes 1600's):

  - Complete separation of *minds* ("spirits", hidden principles, occult forms, etc.) and physical *bodies*.
  - Physical bodies are to be given *mechanical explanations* in terms of cause/effect relationships mediated through contact forces.

    - <u>*One consequence*</u>: Vivisection of living (mindless) animals is permissible!

- Newton's Theory of Gravity
  - Re-introduces "occult" hidden principle!
  - Cartesians are not amused.

2. Revolutions as Changes of World View

- Inverted goggles experiment: Subjects learn to see world in a different way.
- Analogy with scientific revolutions: Scientists learn to see world in a different way.

Kuhn, Postscript, Sec. 4

- *stimuli* = common raw data of experience.
- *sensations* = processed stimuli, not necessarily common to all percievers.
- *role of paradigm* = indoctrinates practitioners into a particular way of processing stimuli (*i.e.*, of generating sensations from stimuli).

Ex1.

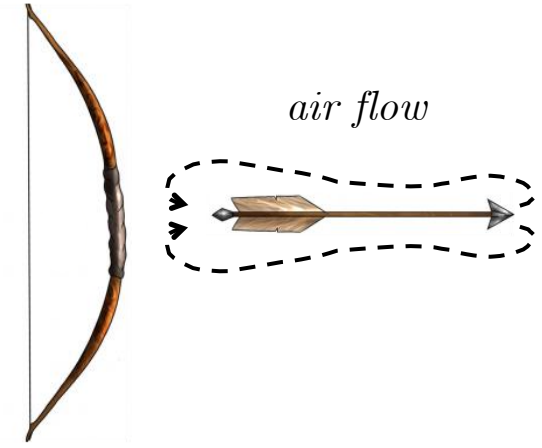
- Pre-Copernican European astronomers under Aristotelian paradigm: Did not "sense" change in the heavens.
  - *Result*: No great astronomical discoveries.

- Pre-Copernican Chinese astronomers: No Aristotelian "filters" to blind them to change in the heavens.
  - *Result*: Recorded observations of comets, lunar/solar eclipses and supernovae.

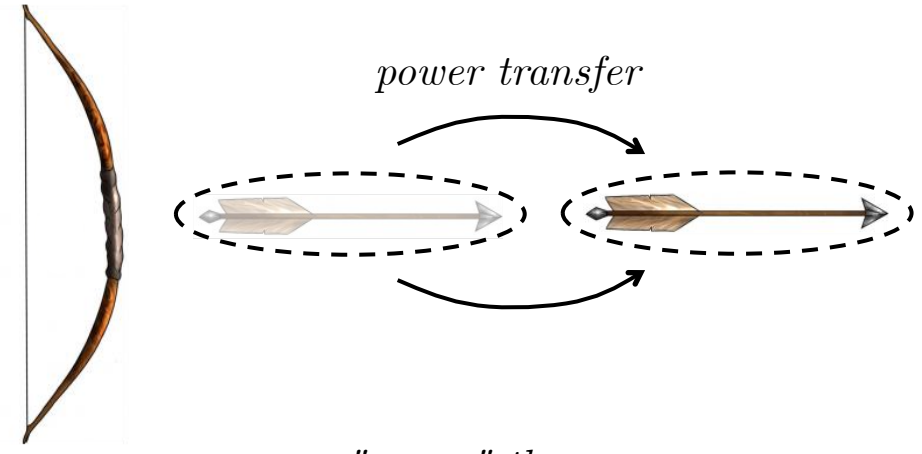
Crab nebula: Supernova recorded in 1054 A.D. China (and Arabia), but not Europe.

Ex2.

- *Aristotle's theory of motion*
  - *Claim*: All motion must have a cause in direct contact with moving object.
  - Aristotelians cannot "sense" motion without a mover.
  - *Result*: Big Research Problem: How is projectile motion explained?



"antiparistasis"



"power" theory

- *Theories of motion of Descartes and Newton*
  - *Principle of Inertia*: An object remains in uniform motion unless acted upon by external forces.
  - Cartesians and Newtonians can "sense" motion without a mover.
  - *Result*: No problem explaining projectile motion.

3. Progress Through Revolutions

- *Recall*: Progress during normal science = accumulation of solved puzzles.
- Can there be progress across scientific revolutions?
- *Trivial sense*: Victors rewrite history to make new paradigm look progressive in retrospect ("Whig history").

- *Typical View:*
  - Successful new theories are better representations of nature than older ones.
  - Scientific progress = *Convergence to the truth.*

3. Progress Through Revolutions

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- *Kuhn's View (Postscript): Evolutionary metaphor*
  - New paradigms are better adapted to their environments than old ones.

  Just like
  - New species are better adapted to their environments than older ones.

Eohippus

45 million years

$\Rightarrow$

progress?

Modern horse: closer to "truth"?