Evidence
Lecture 2 (4. May 2022)
Newton's Investigations on Light and Color, Part I

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1 Admin Crap

1. anyone not getting my emails?
2. revisisons to Schedule of Lectures and Readings, *inter alia*, another required reading for next week (no fear, only 2 pages)

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2 Readings and Questions

Prohibited Readings

These are works that I find so intellectually scurrilous, abusive or dishonest that good conscience requires me to try to attempt to dissuade students from reading them. If they are to be read at all, they ought to be read only *after* one has already mastered the subject to a degree that will allow one to make one's own informed decision on whether one agrees with my assessment.

Reading Newton

Newton is far more careful a writer, almost inhumanly so, than almost anyone else (including all of us) is a reader. Newton is that rarest of writers who says exactly what he means to say, nothing more and nothing less, and everything that he means to say he does actually say. One must take extraordinary care in reading him.

Study Questions

1. Review my suggested questions (http://strangebeautiful.com/lmu/lectures/evidence-study-questions-lect-02-newton-light-color-i.pdf)
2. Solicit student questions.

3 Setting the Stage

3.1 Historical Background

Coeval, Near-Universal Attitude toward Scientific investigation Hypothetic-Deductive (HD) Method in conjunction with adherence to the Mechanical Philosophy as underlying metaphysics is dominant, only game in town really:

1. the "Principles" of all scientific investigations must conform to the Mechanical Philosophy, to wit, that the only way that any physical system can act on any other physical system is by forces of direct and contiguous contact (*e.g.*, impact, percussion, pressure, *etc.*)
2. HD mandates that *what it means* to give a scientific account of a phenomenon is to pose a detailed hypothesis (or set of them) describing a specific and concrete kind or family of kinds of matter (*e.g.*, particles, continuum, plenum) with determinate properties that act on each other in a particular way conforming to the Mechanical Philosophy; and then to deduce from them testable consequences; the conformance of appropriate experimental results with the consequences provides evidential support for the hypothetical system; Huygens (1690, "Preface") gives a classic statement of HD

in particular:

1. such systems of hypotheses and their testable consequences constitute the *only possible* kind of scientific knowledge
2. observations that in some sense are in accord with conclusions deductively drawn from those hypotheses constitute the *only possible* kind of evidence for such knowledge

(we will consider this in more detail next week in lecture 3)

Received Knowledge of Light in accord with the attitude towards science:

1. wave versus corpuscular (particle) theories of light: everyone held one or the other; none of them agreed on details (*e.g.*, for a corpuscularian, on the relation between the physical properties of the particles and the phenomenal behavior of light and color, whether it was differences in particle mass, size, shape, state of motion, or something else entirely, that effected the colorificity of light in its interaction with the eye)
2. everyone agreed that, in some sense, white light (canonically, sun light) is the "natural state" of light, the physically and metaphysically simple, basic or fundamental form of light, and that different colors are produced by disturbances ("qualifications") of some kind to white light
3. known phenomena:
   a. reflection
   b. transmission through translucent media
   c. refraction
   d. propagation in straight lines (appropriately construed), as "rays"
   e. production or change of colors on transmission through and reflection off of different kinds of material media and bodies
   f. the capacity to cause bodies to increase in temperature (anachronistically put) when incident upon them
   g. Law of Reflection
   h. Snell's Law
   i. whole bunch of peculiar, individual experimental results with no understanding of how they may relate to each other in any systematic way, as regimented by an overarching theory (as Newton gestures at throughout Newton 1672a, and in his exchanges with Hooke, Huygens and Pardies)
4. $\Longrightarrow$ no systematic theory (or even loose collection of hypotheses) that could treat and explain even a small number of all known phenomena

3.2 Background to Newton's Investigations: Telescopes

1. Newton was interested in improving the resolving power of telescopes.
2. He thus began to investigate the refractive properties of glass, to determine how to minimize the sort of refraction that would impede the production of a clear, sharply delineated image of an object viewed through a telescope.
3. There is a point of deeper than mere historical interest here: for Newton, theory, experimentation and instrumentation were inextricably related.
4. The latter two are essential both for constraining the reach of theoretical certainty and for informing the proper way to understand the content of theoretical doctrine (in both metaphysical and semantical senses)—this is why he begins the Letter (Newton 1672a) with a remark on grinding lenses, and why he inserts a "Digression" on reflecting telescopes (the

idea of which he invented, as well as having constructed the first exemplars) between the litany of experiments and the statement of his Doctrine on (or, as we might say, theoretical system or framework for) light and color.

5. As such, it is *prima facie* possible that he believed the principles underlying proper approaches to the design and construction of instruments and to the planning, circumstantiation and performance of experiments were susceptible of evidential support, not only theoretical propositions.

3.3 The Instigating Observation

Newton wanted to observe "the celebrated Phænomena of Colours": white light passing through a glass prism exits as an extended distribution of spectral colors.

- A direct application of the form of Snell's Law as known at the time implied that a circular pencil of light incident on a prism should result in a circular pencil of light leaving the prism.
- This is not what Newton observed: he observed that the exiting light had the shape of an elongated capsule, *i.e.*, a narrow rectangle, the longer sides in the vertical direction, with semi-circular caps collocated at the top and bottom.
- This is what he attempted to determine the cause of. Remarkably, *no one before him* (of whom we—or Newton and his correspondents—have any clear and certain record) had noticed the discrepancy.[1]

4 The Build-Up to the *Experimentum Crucis*

From Newton's lovingly detailed description of his initial preparations and observations, and from the continuing description of how he settles down to work to isolate the cause of the aberrant phenomenon, we see a man delighted by the physical world, transported into fits of ecstasy by the opportunity to interact with and come to understand it, all so as to lead him to attend ever more closely, finely and deeply to it, his experiment not divorced from intellectual cognition and theoretical construction and elaboration but rather inextricably entrained with it.

4.1 The Initial Set Up

1. his room entirely darkened, all light blocked
2. except for a small, circular hole left in the covering of a window facing the sun, so a beam (or "pencil") of sunlight enters perpendicular to the window
3. a triangular prism placed close behind the hole to intercept the entire beam
4. the beam exiting the prism, incident on the opposing (white) wall
5. after an initial period of delight in observing the play of colors, he begins to observe "more circumspectly" and is surprised to see that the shape of the beam's image on the wall is aberrant with respect to the received laws of optics

1. The qualification "clear and certain" is required because of the fact that there is slight evidence that Thomas Harriot may have noted the discrepancy in the very early 17th Century. We cannot be sure, because Harriot never published any of his optical work, and his journals and diaries are compressed and difficult to interpret. See the discussion in Stein (unpublished, p. 10–12, footnote 21).

6. he gives a precise description of the aberrancy:
    a. the image of the light has the shape of an elongated capsule, *i.e.*, a narrow rectangle, the longer sides in the vertical direction, with semi-circular caps collocated at the top and bottom
    b. the straight edges of the rectangle are clearly delineated, the semi-circular caps less so, and he is less certain in his description of them
    c. the length is approximately 5 times the width

This raises the immediate question: is the inital observation truly in conflict with the received laws of optics, or merely an artifact of some contingent features of the observational circumstance?

4.2 Qualitative Attempts to Isolate the Cause of the Aberrancy

He begins to attempt to isolate the cause by adjusting the experimental situation and making subsequent observations all in ways describable by purely qualitative ideas:

1. different sizes of glass or disposition of ambient light and shadow?
    - passing the light through different thicknesses of glass
    - through holes in the window of different sizes
    - by placing the prism outside the window, fully immersed in sunlight, refraction occuring before passing through hole
2. inhomogeneities in the prism's glass?
    - placed 2nd prism, same shape and glass, against first: light was transformed into its original size, shape, color
    - the effect of any irregularities, however, should have been magnified, not removed

    although Newton is not explicit about it, it is nonetheless clear that the conclusion that contingent inhomogeneities could not be the cause of the aberrancy is not a deductive but a probabilistic one: there is only a *vanishingly small* probability that any two prisms selected at random will have *exactly the same* inhomogeneities as required for their respective actions to cancel each other out

None of the manipulations had any effect on the aberrancy. Thus, it does not appear to be any contingent feature of the observational circumstance that is the cause of the aberrancy.

4.3 Quantitative Attempts to Isolate the Cause in Kinematics

He continues the attempt by the application of more exact methods based on quantitative measurements (or, as one might say today, he gets quantitative on its ass): he measures angles and lengths and relative configurations of all the relevant objects and images to great precision, to see whether more refined calculations based on the received laws of refraction can account for the aberrancy. They cannot. Thus, the aberrancy truly is in conflict with the recevied laws.

4.4 Attempts to Isolate the Cause in Dynamics

He determines that the cause of the aberrancy cannot lie in any dynamical complication (*e.g.*, that the light's passage through the prism causes it to propagate curvilinearly rather than rectilinearly).

4.5 The Methodology

Note the methodology: look for the simplest possible explanations first, test them, dismiss them, both because they are easy to do and because the doing will itself suggest more complex and deeper possible explanations and tests for those in turn—he fucks with it in all ways he can think of that might effect a change in the light's behavior.

5 The *Experimentum Crucis*

The term has its origins in the *Novum Organum* of Francis Bacon, where he uses '*instantia crucis*' to mean a determining circumstance—decisive evidence—that would show that one hypothesis or theory holds true while all rivals do not. I am told (but cannot find the reference) that the term '*experimentum crucis*' was then coined by Robert Hooke, to mean the deliberate construction of a controlled situation whose observed result would provide an *instantia crucis*. But I am also told the same of Robert Boyle, so go figure.

The arrangement of Newton's *experimentum crucis* is shown in this diagram, drawn by him for Newton (1672b), his reply to the second letter by Ignatius Pardies (1672) criticizing Newton (1672a).

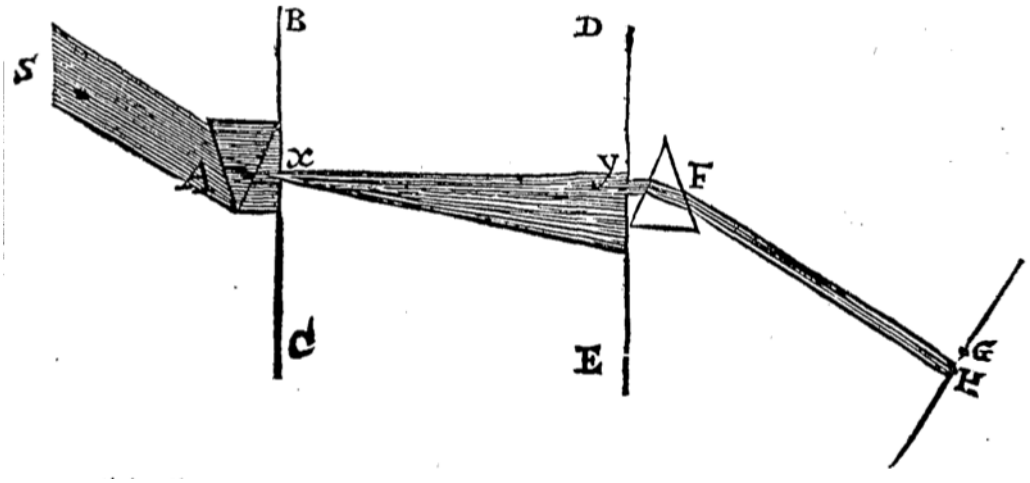

Figure 5.1: *Experimentum Crucis*

The labels in figure 5.1 denote as follows:

S the small, circular hole in the window cover allowing in only a narrow pencil of sunlight (or, perhaps, the pencil itself)

A the first prism through which the entering sunlight passes

B-C the wooden plank behind the first prism, perpendicular to the light's path, blocking almost all the light leaving the prism

X the small, circular hole in the wooden plank **B-C** allowing only a narrow, isolated ray of light leaving the prism to proceed

D-E the wooden plank in front of the second prism, perpendicular to the light's path, blocking almost all the light emanating from **X**

Y the small, circular hole in the wooden plank **D-E** allowing only a further narrowed, even more isolated ray of light to proceed through the plank to enter the second prism

F the second prism, through which the light passing through **Y** travels

G-H the small, circular image of the final ray of light leaving the second prism **F**, where it hits a smooth surface perpendicular to the direction of the ray's path

Newton (1672a, p. 51, his emphases) takes the *Experimentum Crucis* to show unequivocally that

> [white] *Light* consists of *Rays differently refrangible.*

Aside on the Duhem Thesis

Most philosophers, and perhaps many physicists, today would dismiss the possibility of a single experiment's decisively demonstrating the goodness of a theory (or theoretical account more generally), because of the Duhem Thesis: no experiment ever conclusively tests a single hypothesis or proposition in isolation, because to draw a conclusion from the hypothesis or proposition to test, one must conjoin it with "auxiliary hypotheses" (*e.g.*, principles to interpret the operational description of the experimental outcome so to bring it into substantive semantic contact with the theoretical terms used to articulate the hypothesis, claims about the appropriate isolation of the experimental arrangement from possibly confounding environmental factors, *etc.*), and so the experiment tests only the conjunction of the hypothesis and the auxiliaries *en bloc*.[2] That is as may be, but, as philosophers never seem to realize, and as Duhem himself went on to point out after laying down the Duhem Thesis, while no *single* experiment can ever do the trick, a well designed *sequence* of experiments can, by isolating in turn the possible consequences of each of the auxiliaries and alternatives, so as to dismiss their potential explanatory relevance. And that is exactly what Newton did. The *Experimentum Crucis* is the culmination of just such a sequence, and that is why, in my opinion, it does decisively and indubitably show exactly what Newton claims it does.

6 Claims Receiving Evidential Support—Contents and Kinds

1. positive qualitative existential claim about the present state of the world: "there is light that, properly circumstantiated, behaves in a particular way" (*viz.*, the "celebrated Phænomena of Colours")

2. negative qualitative modal claim about a theoretical proposition: "the properly described behavior of such circumstantiated light appears to contradict the received laws of optics"

3. negative qualitative existential claim about contingent features of the world: "no contingent feature of the observational circumstance (*e.g.*, irregularities in the glass of the prism) is the cause of the aberrancy"

2. This is often called the Duhem-Quine Thesis, or even just the Quine Thesis, but I deprecate those names, because Quine got it so badly wrong. But that's another story.

4. negative modal claim about possible law-like regularities in the world: "this possible law-like regularity (*e.g.*, the effect of the varying thickness of the prism) is not the cause"

5. positive existential claim about the present state of the world and its relation to a theoretical proposition: "the phenomenon truly is in conflict with the received laws"

6. negative universal claim about a theoretical proposition: "the recevied laws are not always true descriptions of all relevant phenomena"

7. positive modal claim about a theoretical proposition: "the received laws require modification"

8. positive existential claim about a theoretical proposition and its relation to a general phenomenon in the world: "there is a kind of light (*viz.*, white sunlight) that is truly described as having this specific composition (*viz.*, consisting of a mixture of rays differently refrangible)"

7 Invitation to a Short Essay

I invite you to write me a short discussion (no more than 2 pages, *i.e.*, no more than 1000 words) on any issue discussed in this lecture or any of this week's readings, required or suggested. You can raise further questions, propose answers or interpretations, or whatever seems of most interest to you. If you get it to me by the start of next lecture (11. May), then I will return it to you with my comments the following week.

References

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