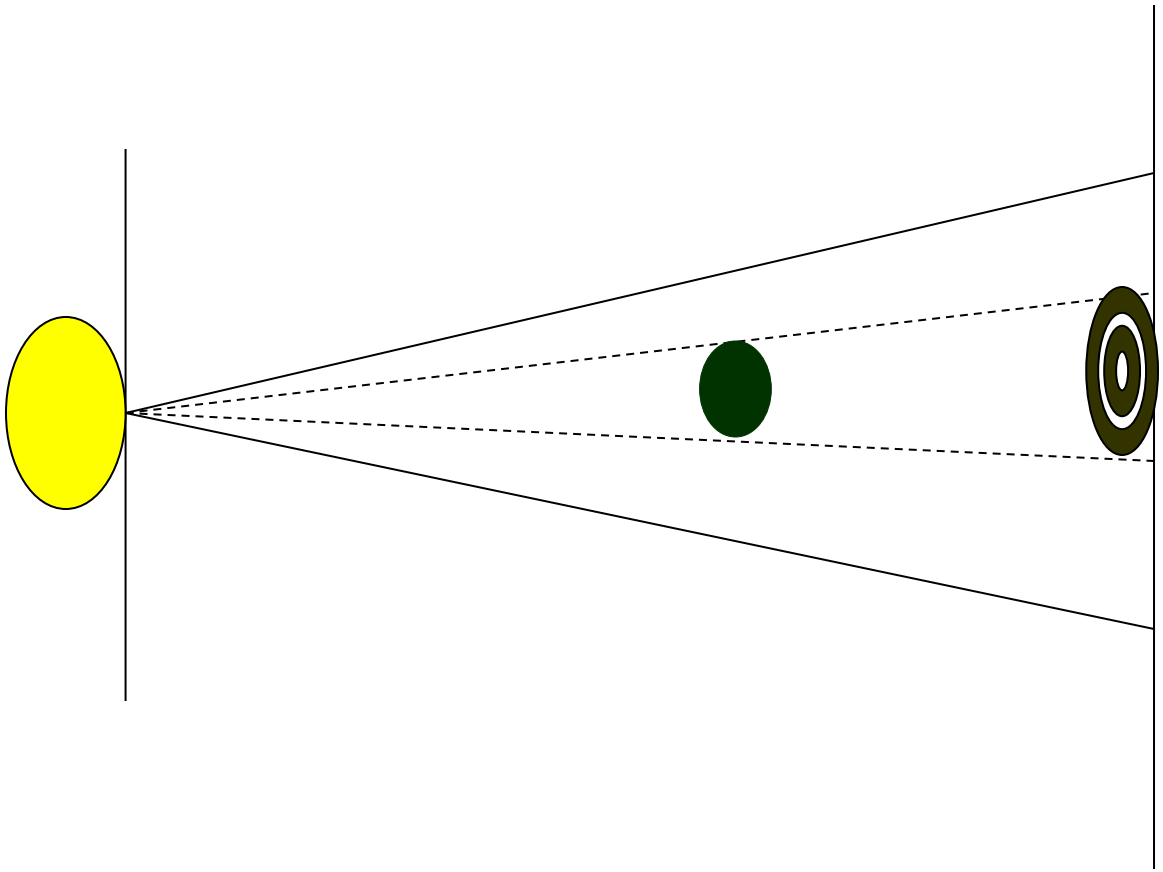
The Wave Revolution and Realism

- We just saw that the ‘wave revolution’ can be used to illustrate interesting aspects of the general issue of the rationality of theory-change in science
- It also has interesting consequences for the general issue of *scientific realism*.
- Scientific Realism is the view that our latest theories in the ‘mature’ sciences are at least approximately true descriptions of the reality underlying the phenomena.
- (or rather that that is the – uniquely – reasonable thing to believe)

The Wave Revolution and Realism

- There are two main arguments concerning scientific realism – one for and one against.
- The argument for is the ***'no miracles argument'***
- Essentially: it would be a miracle if the theories that we have in the mature sciences scored the predictive successes they do if they were not fundamentally correct (at least to a good approximation) – that is fundamentally correct in what they say is going on at the 'deep structural level' "beneath" the phenomena.
- But we should not invoke miracles, at least not when there is a non-miraculous alternative.
- In this case the non-miraculous alternative is of course exactly that the theories concerned are indeed (approximately) true.

The ‘white spot’



The Wave Revolution and Realism

- The main anti-argument is that from fundamental theory-change (aka the ***'pessimistic meta-induction***').
- Scientists of earlier epochs believed in the (approximate) truth of theories that are contradicted by theories currently accepted – they were wrong, why shouldn't we be?

The Wave Revolution and Realism

- For example, Newton's theory involved the assumptions of
- (a) action at a distance
- (b) the infinitude of space
- (c) the absoluteness of simultaneity
- All of the above are contrary to relativity theory.

The Wave Revolution and Realism

- More precisely as an inductive argument:
- ***Premise***: Except for those currently accepted, all the theories that have so far been accepted as true on the basis of the then available evidence have eventually been replaced by theories that contradict them in fundamental ways.
- ***Conclusion*** (inductive): Currently accepted theories will themselves eventually be replaced by theories that contradict them in fundamental ways (and hence show that they are not even approximately true).

The NMA (or the NM”A”?)

- Let’s look first at the pro-realist consideration
- Easy to feel the intuition but it would be nice to put it on a firmer footing by producing a proper argument.
- Some (e.g. Psillos) have seen it as an inference to the best explanation (IBE).
- So the idea is that we are in general entitled to infer to the truth of the best explanation that we have of some phenomenon or range of phenomena.
- And the NMA for realism is just an instance of this generally sound inference form.
- But this seems to me multiply-problematic.

The NMA (or the NM”A”?)

- 1. The notion of explanation (in general) is itself hardly crystal clear or undisputed
- 2. Even if it were agreed that some theory provided the best explanation of some phenomenon/a it can hardly be correct in general to infer to its truth
- [e.g at one time release of phlogiston was the best explanation of combustion]
- [general objection here the ‘best of a bad lot’ objection]

The NMA (or the NM”A”?)

- 3.In the particular case: not clear that the *approximate* truth of our theories explains their empirical success
- 4. Nor why the approximate truth of T should be a better explanation of its predictive success than T’s empirical adequacy would be

The NMA as a probabilistic argument

- A more promising route would seem to be the probabilistic one.
- So the argument is
- 1. T entails e
- 2. But e is very unlikely to be true (effectively: e is very unlikely were T to be false)
- 3. e turns out to be the case
- 4.So T is likely to be true
- Notice that 4 is what we would like to conclude intuitively not that it *is* true.

The NMA as a probabilistic argument

- 1’. $P(e/T) \approx 1$
- 2’. $P(e) \approx 0$ [$P(e/\neg T) \approx 0$]
- 3’. e
- 4’. So $P(T/e) \approx 1$

The Cabs

- There are 2 cab companies in the city
- Blue Cab drivers are incredibly reckless, the probability that any single driver will have an accident on any given night is 0.9
- Yellow Cab drivers are much more careful – probability any one of them has an accident is only .01
- You have seen an accident involving a cab but the lighting was too poor to tell whether a Blue or Yellow Cab was involved
- Which was it more likely to be: a Blue Cab or a Yellow Cab?

The “Base Rate” Fallacy

- Ans: you can’t answer without more information
- Suppose there are only 10 Blue Cabs then 9 of them will “on average” have an accident on any given night
- But there are 1000 Yellow Cabs
- then even though they have much more careful drivers (P(accident/yellow) = .01) on average 10 of them will have an accident on any given night
- So it’s actually more likely that the accident involved a yellow cab than a blue cab.
- It all depends on the *base rate* (= “prior probability”)
- Unless you know the base rate you can’t tell

The NMA as a base rate fallacy

- 1’. P(e/T) ≈ 1
- 2’. P (e) ≈ 0 [P(e/¬T) ≈ 0]
- 3’. e
- 4’. So P(T/e) ≈ 1
- Something has happened (predictive success of T) that was very unlikely to have occurred if T were not true
- ***[Something has happened (accident) that was very unlikely to occur if it was not a Blue Cab (p(accident/¬T) =0.01)]***
- So it is very likely that T is true
- ***[It is very likely that the accident involved a Blue Cab]***

Bayes Theorem

- P(T/e) = P(e/T). P(T)/P(e)
- So in trying to work out what the probability is that it was a Blue Cab (T), given the crash (e),
- doesn't just depend on P(e/T) (how safe or reckless the Blue Cab drivers are)
- but ***also on P(T)*** (basically if I draw a cab at random how likely is to be Blue?)

The No Miracles *Intuition*

- SO I think that there is no real prospect of turning this consideration into a fully fledged formal argument.
- More honest to think of this as an intuition
- A very strong one that sets the default
- But of course the default only can hold if there is no really telling counterargument
- And that is what the Pessimistic Induction threatens to be.

The Wave Revolution and Realism

- As an inductive argument:
- ***Premise***: Except for those currently accepted, all the theories that have so far been accepted as true on the basis of the then available evidence have eventually been replaced by theories that contradict them in fundamental ways.
- ***Conclusion*** (inductive): Currently accepted theories will themselves eventually be replaced by theories that contradict them in fundamental ways (and hence show that they are not even approximately true).

The Wave Revolution and Realism

- But better seen as a challenge:
- Why should ‘we’ be different?
- Some have claimed that we are (eg Lipton)
- But the differences they point to are surely only quantitative not qualitative
- If we aren’t different??
- Surely the possibility of similar changes is enough to indicate that IF realism is to remain tenable in view of theory-change we have to tell some sort of continuity story wrt to earlier ‘revolutions’

The Wave Revolution and Realism

- Notice that despite contradicting the fundamental *theoretical* claims of earlier theories, the later theory invariably explains the empirical success of those earlier theories.
- (The Newton/Einstein case is again illustrative.)

The Wave Revolution and Realism

- So the pessimistic meta-induction is generally taken to favour an anti-realist view of scientific theories
- This is the view that all that really matters for science is that our theories get the empirical phenomena correct, not that those theories themselves correctly describe an underlying reality.
- Notice that the pessimistic induction if cogent would ‘trump’ the NMA

The Wave Revolution and Realism

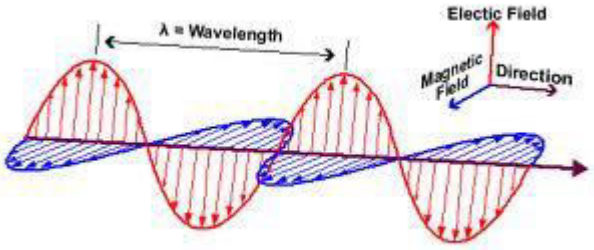
- So let's then, again, look at these general issues in the light of a particular historical case
- Let's look at the "wave revolution" from both ends – the theory that it replaced; and then the theory that it itself was replaced by.

The Wave Revolution and Realism

- 1. The acceptance of the corpuscular theory in the 18th century
- 2. Its replacement in the early 19th century by the elastic solid wave theory of light
- 3. The rejection of that theory in favour of Maxwell's electromagnetic theory in the late 19th century

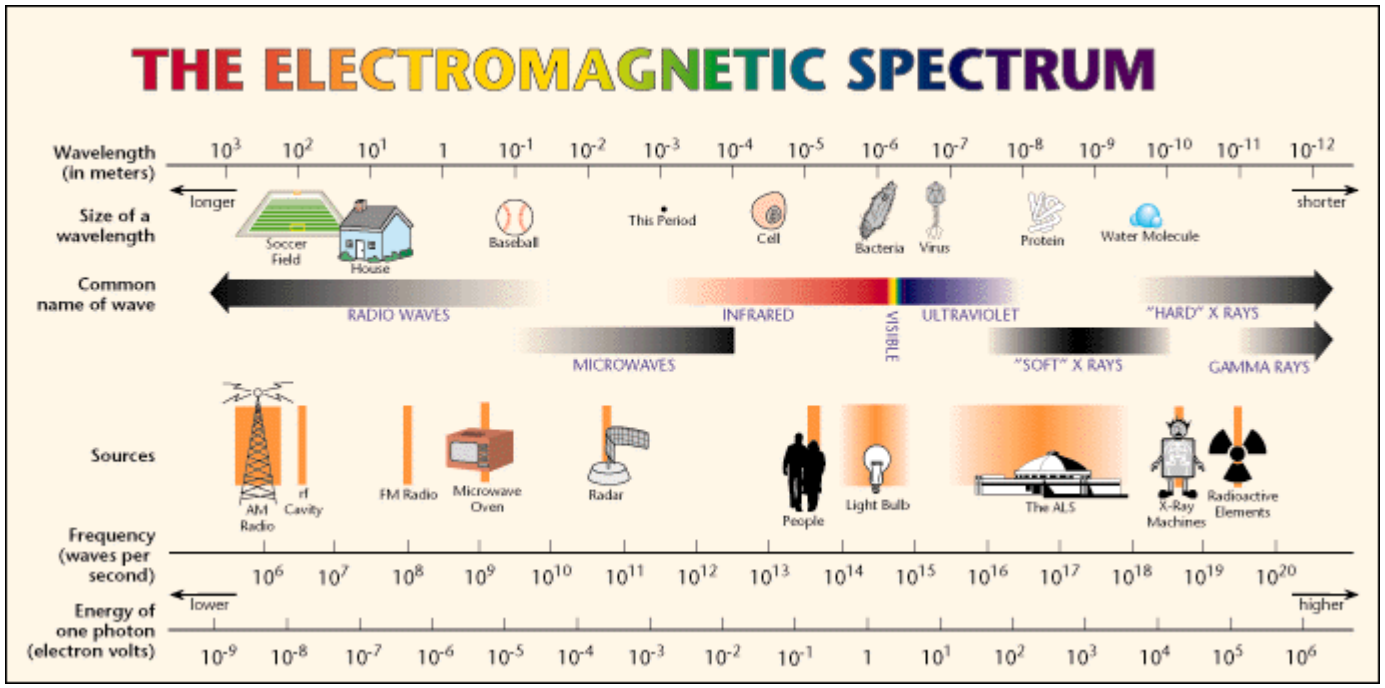
The Wave Revolution and Realism

- What the electromagnetic theory says
- Its initial and ‘mature’ forms
- http://www.olympusmicro.com/primer/java/wavebasics/index.html



The Wave Revolution and Realism

- Light is a (small) part of the overall electromagnetic spectrum



The Wave Revolution and Realism

- Is the step from 1 to 2 a persuasive instance of the "pessimistic meta-induction"?
- Or might we instead argue that the corpuscular theory continues to look at least approximately true in the light of the elastic solid wave theory?
- The only way that this could be argued, so far as I can see, is on the basis of the fact that corpuscles and waves 'do some of the same things' (e.g. get reflected by barriers)
- But this is to surrender to anti-realism

The Wave Revolution and Realism

- One suggested realist response to the pessimistic meta-induction is the ‘maturity response’
- ‘The realist does not go so far as to say that phlogiston refers’ (Putnam)
- The realist is only realist about theories in ‘mature’ science
- But what does ‘maturity’ mean?
- Sensible approach seems to be to read the definition off from the main pro-realist argument.
- A science becomes ‘mature’ when its theories make genuine new predictions (NB of new *types* of event).

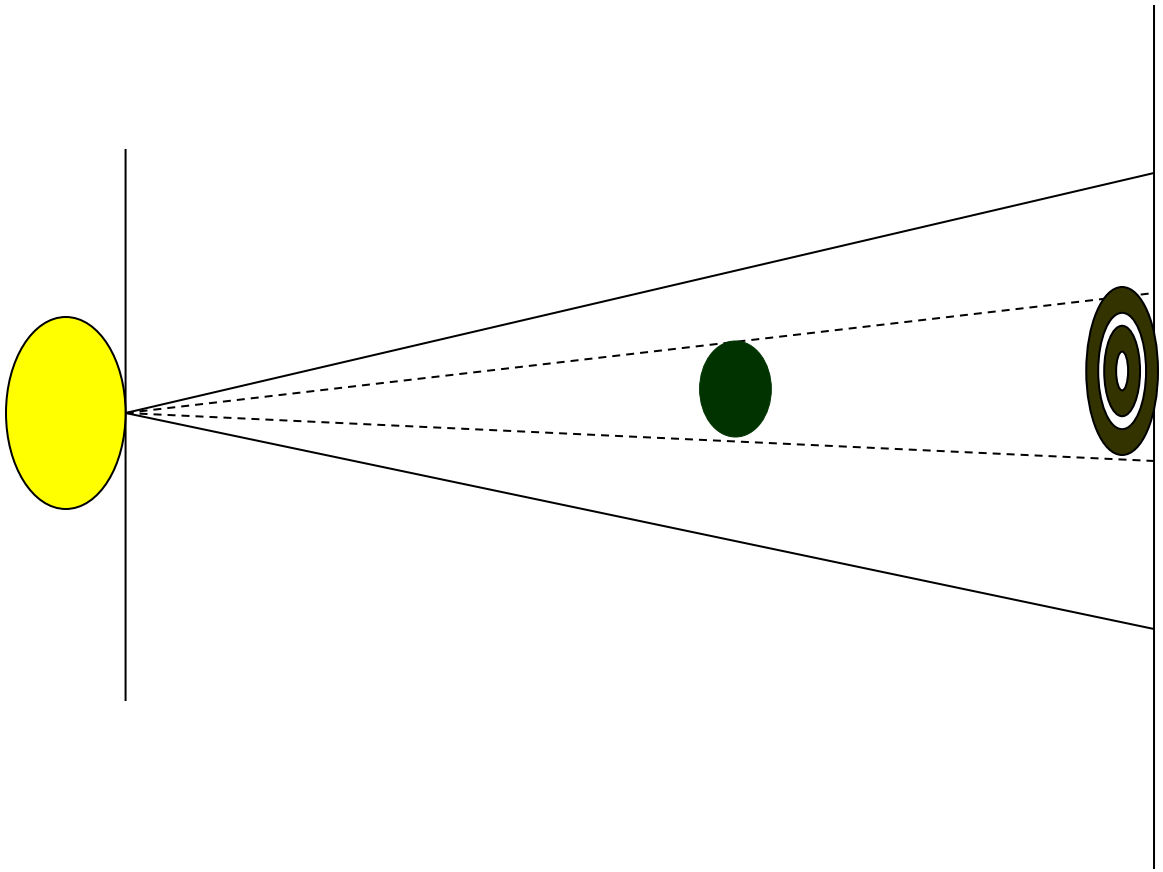
The Wave Revolution and Realism

- So the suggestion might be that optics was not ‘mature’ in the 18th century
- And so the realist does not need to worry about the theory-shift from corpuscles to waves
- Notice that for a theory to have “predictive success” it is not enough for it simply to entail correct empirical results
- Certainly nothing new from the corpuscular theory
- And of the two phenomena that it got to entail in detail, refraction is a ‘fudge’: you would not have predicted it in advance
- But the law of reflection?

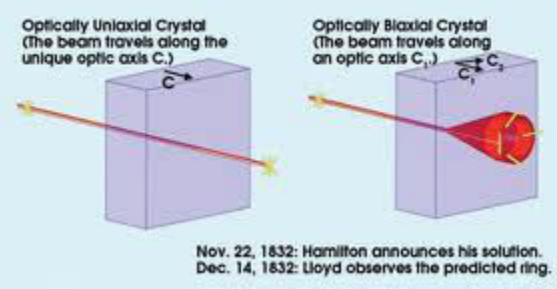
The Wave Revolution and Realism

- Whatever its merits in the case of that shift the maturity response will certainly not work for the case of the shift from Fresnel to Maxwell
- Fresnel's theory was undoubtedly predictively successful:
- A. 'white spot'
- B. conical refraction

The ‘white spot’



Conical refraction



The Wave Revolution and Realism

- How about avoiding pessimism by claiming that Fresnel's theory continues to look 'approximately true' in the light of Maxwell's theory (even the 'definitive' version)?
- The elastic solid ether is certainly unambiguously rejected by the 'definitive' version of Maxwell
- How, Laudan asks, can you claim that a theory T appears to be "approximately" true from the vantage point of later theory T′ if T′ entails that there is no such thing as the central entity postulated to exist by T??

Partial/Selective Realism?

- Perhaps this (and other ‘revolutions’) are telling us that we ought not to be ‘realist’ about the *whole* of a successful scientific theory, but only parts
- But which parts?
- Many hold that if you say ‘those parts that the later theory (more or less) endorses’ then the realism is too weak to be interesting
- In order to have an interesting version of selective or partial realism you have to identify the parts to be realist about in advance

Partial/Selective Realism?

- The suggestion is in effect to be guided by the NMA again – we should identify those parts of a scientific theory that are responsible for its empirical successes
- These are the ‘working posits’
- As opposed to the ‘presuppositional’ ones, that round out the theory explanitorily but which are not essential for its empirical successes
- Kitcher in particular claims that the ***ether*** was a non-working presupposition within Fresnel’s theory
- Whereas the notion of a ***light wave*** did work

Partial/Selective Realism?

- But this is fine: Maxwell rejects the ether, but of course accepts that there are waves of light
- So selective realism has nothing to fear from theory-change
- You should only ever be realist about ‘working parts’ of theories
- AND working parts are retained not rejected in theory-change.
- So let’s flag up the question: Was the ether a non-working posit within Fresnel’s theory?

Continuity of Reference

- Scientific realism is often taken (e.g. by Putnam) to involve 2 claims
- 1. The theoretical terms of our current theories in ‘mature science’ refer (i.e. pick out things that really exist in the world)
- 2. The claims that those theories make about the entities thus referred to are at least approximately true.
- For such realists telling a story of continuity of reference through theory change is essential to defending their position
- That is the newer theory has to say that the terms of the older theory still refer.

Continuity of Reference

- Is Fresnel's talk of a 'luminiferous ether' still referential from the point of view of Maxwell's theory?
- Hardin and Rosenberg argue that it was: when Fresnel talked about the "luminiferous ether" he was 'in fact' referring to the electromagnetic field!
- But this really means – *relative to the later theory* (we have no 'out of theory' access to the basic furniture of the world)
- And in fact this is no longer the accepted theory – instead we have photon theory and the associated quantum field theory

Continuity of Reference

- So if theory-change is unending then you'd have to say that Fresnel was referring to we know not what when he used the term 'luminiferous ether'
- Morever this view has the unattractive feature that, supposing we freeze the history of science as of now, i.e take our current theories as true, Aristotle, e.g., was referring to geodesic motion through a 4-dimensional curved space time when talking of an 'earthy body's natural motion'
- So this approach does not look plausible in the end
- Selective realism may be better?

The Wave Revolution and Realism

- What does it mean for a theoretical notion to be ‘idle’?
- If we (a) think of a theory as given by its deductive closure and (b) say that a piece of theory is ‘idle’ if it is not necessary for the derivation of empirical consequences, which could instead have been derived from some logically weaker theory, then *all* theory is idle.
- The only non-idle bit would be that given by the theory’s set of empirical consequences.

The Wave Revolution and Realism

- So it's a tricky notion but sometimes some theory elements do seem clearly idle.
- A good example is Newton's hypothesis that the centre of mass of the solar system is at rest in absolute space.
- This is because it is provable (Newton proved it) that all possible phenomena would be the same whatever value you attributed to the velocity of the centre of mass of the solar system in absolute space.
- So it does seem right to say that the success of Newton's theory gives no grounds for being realist about this particular hypothesis.

The Wave Revolution and Realism

- But not true of the assumption that there is some medium to carry the vibrations that constitute light
- Not only did this seem to be entailed by the mechanical world view (assuming that you hold the theory that light sources emit energy not matter)
- It was part of heuristic inspiration for Fresnel who took over the mathematics of material particles subjected to elastic restoring forces (in particular Hooke's law) from continuum mechanics

The Wave Revolution and Realism

- Moreover, you can't separate out the notions of (a) the ether and (b) light waves as easily as Kitcher imagines
- After all what did Fresnel mean by 'light wave'?
- Ans: an instantaneous snapshot of the distances from equilibrium occupied by the material particles making up the ether.
- So Fresnel's notion of a light wave is rejected just as sharply by 'mature' Maxwell as is the ether
- So …

The Wave Revolution and Realism

- So is there any realist position that does not succumb to pessimism?
- This, it seems to me, would have to identify some level within the theory (NB not part in the Kitcher/Psillos sense) – above the purely empirical level - at which there was accumulation in the Fresnel-to- Maxwell case?
- Poincaré suggested that there is such a level

The Wave Revolution and Realism

- *Science and Hypothesis:*
- The ephemeral nature of scientific theories takes by surprise the man of the world. Their brief period of prosperity ended, he sees them abandoned one after the other; he sees ruins piled upon ruins; he predicts that the theories in fashion today will in a short time succumb in their turn, and he concludes that they are absolutely in vain. This is what he calls the *bankruptcy of science*.

The Wave Revolution and Realism

- His scepticism is superficial; he does not take account of the object of scientific theories and the part they play, or he would understand that the ruins may still be good for something. No theory seemed established on firmer ground than Fresnel's, which attributed light to the movements of the ether. Then if Maxwell's theory is preferred today, does it mean that Fresnel's work was in vain?

The Wave Revolution and Realism

- No, for Fresnel's object was not to know whether there really is an ether, if it is or is not formed of atoms , if these atoms really move in this way or that; his object was to predict optical phenomena.
- This Fresnel's theory enables us to do today as well as it did before Maxwell's time. The differential equations are always true, they may always be integrated by the same methods and the results of this integration still preserve their value.

The Wave Revolution and Realism

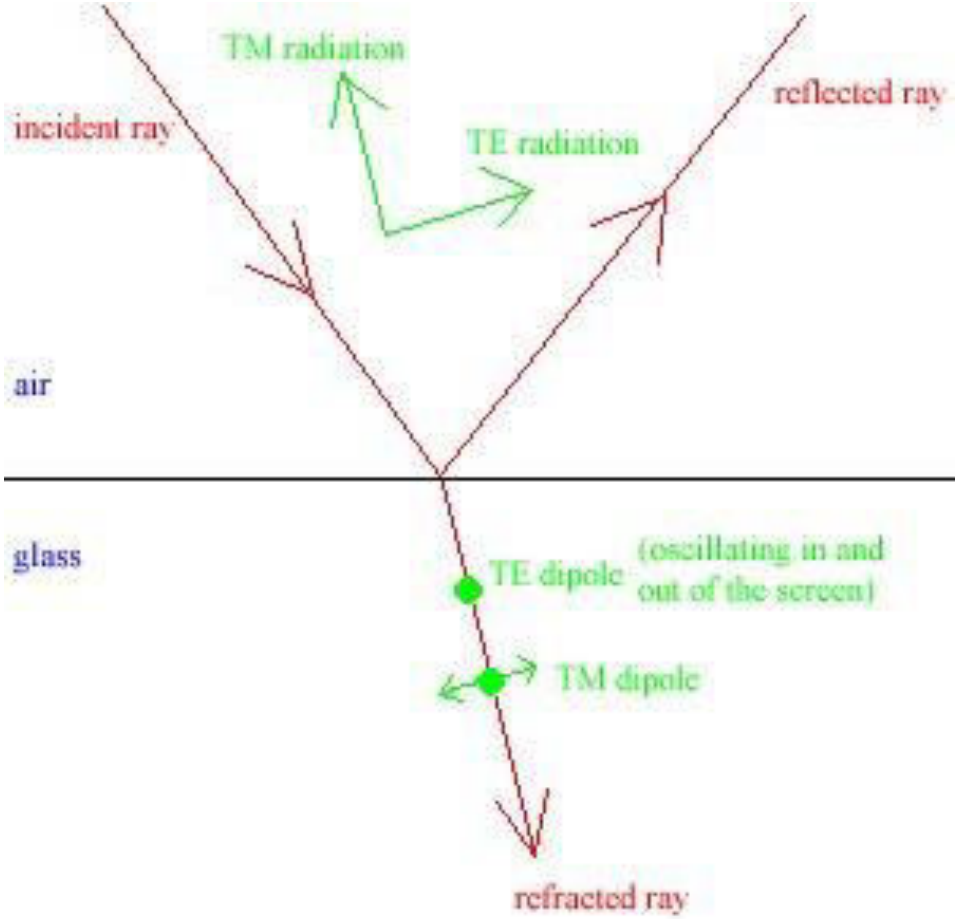
- It cannot be said that this is reducing physical theories to practical recipes; these equations express relations, and if the equations remain true, it is because the relations preserve their reality. They teach us now, as they did then, that there is such and such a relation between this thing and that; only the something which we then called *motion*, we now call *electric current.*
- But these are merely names of the images we substituted for the real objects which Nature will hide for ever from our eyes. The true relations between these real objects are the only reality we can attain ...

The Wave Revolution and Realism

- What does this mean?
- That in the light of the later theory Fresnel was right about the *structure* of optical phenomena, but not about the underlying ontology.
- He was right that optical phenomena depend on something or other that waves at right angles to the direction of propagation of light.
- “Just” wrong about *what* waves?
- Not particles and their motion, but electric and magnetic field vectors and their intensities

The Wave Revolution and Realism

- This means that Fresnel got the mathematical structure of optical phenomena correct
- (of course: ‘correct from the vantage point of Maxwell’s theory’)
- For example: suppose a light beam is incident on a plate of glass at angle *i* and is (partially) refracted into glass at angle *r*


TM radiation
incident ray
TE radiation
reflected ray
air
glass
TE dipole
(oscillating in and out of the screen)
TM dipole
refracted ray

The Wave Revolution and Realism

- Let I^2, R^2, X^2 be the intensities of the components polarised in the plane of reflection of the incident, reflected and refracted beams respectively.
- And let I'^2, R'^2, X'^2 be the intensities of the components polarised at right angles to the plane of reflection of the incident, reflected and refracted beams respectively

The Wave Revolution and Realism

- Then (Fresnel's equations)
- R/I = tan(i-r)/tan (i+r)
- R'/I' = sin (i-r)/sin(i+r)
- X/I = (2sinr.cosi)/(sin(i+r)cos(i-r))
- X'/I' = 2sinr.cosi/sin(i+r)
- These equations reappear completely in tact in Maxwell's theory

The Wave Revolution and Realism

- So, judged from the vantage point of the later theory, Fresnel's theory certainly did not achieve its empirical successes 'by accident'
- But instead because it correctly identified (some of) the structural interrelationships of optical phenomena
- It got the mathematics of light waves correct and 'just' misidentified what it is that is doing the waving in accordance with that mathematics
- That is, it (understandably) got the wrong metaphysical picture

The Wave Revolution and Realism

- So structural realism says that we have good reason to think that our scientific theories - at least approximately - reflect the correct structure of the world.
- Though not that they are true in the correspondence sense.
- Indeed we have no way of accessing whether they are true in this sense
- This is because we have no theory-independent access to an external reality to compare our theories to.

The Wave Revolution and Realism

- The claim is that Structural Realism derives support from the ‘no miracles argument’.
- And yet is immune to the ‘pessimistic meta-induction’
- And hence constitutes the ‘best of both worlds’

Criticisms of SR

- 1. The Fresnel- Maxwell case is maximally atypical
- In other cases the older theory is only recovered from the newer one modulo the ‘correspondence principle’
- (This may mean that SR is not sufficiently realist for some people.)

Criticisms of SR

- 2. Is SR “really” realism?
- It certainly doesn’t count on Putnam’s characterisation since it is not committed to continuity of reference
- (Why that’s a bad idea anyway)
- It does underwrite the NM intuition
- And it is arguably the strongest position that is compatible with the history of theory-change in science