Observation and Growth in Scientific Knowledge

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1. How Some Physicists Talk About What They Observe

The first published paper on pulsars was entitled, by its five co-authors, "Observation of a Rapidly Pulsating Radio Source". (Hewish, et al. 1968). The publication of this paper preceded by some months the coining of the word 'pulsar' to refer to such pulsating radio sources. Does it seem odd to talk of observing pulsars? It might seem so since much effort has subsequently gone into identifying pulsars with optically visible stars using conventional light, not radio, telescopes.[1] We can say that the moons of Jupiter are observable since either we can see them through a telescope or, at some future date, astronauts will be able to travel close enough to Jupiter to see its moons without visual aids. However, our five co-authors remained on Earth for their observations; nor did they visually identify their pulsar with some object which they could view through an optical telescope. Perhaps many would agree that it is too restricting to confine what we can observe to what is immediately visible (or audible, or touchable, etc). Only a committed phenomenalist or logical positivist would take such a severe approach. But perhaps not all philosophers would feel comfortable with astronomers who talk freely of observing what we cannot see either with the naked eye or with aids such as optical telescopes. This paper will advocate an epistemological theory which should enable philosophers to feel comfortable with such talk.

Particle physicists seem unconstrained in their talk of what they can observe. In the index of Harald Fritzsch's Quarks we find the entry "Gluons, observation of" and a reference to all of Chapter 16 which is entitled "How to 'See' Gluons". The inverted commas in the title may suggest some unease about the use of the word 'see', but in the course of the chapter Fritzsch becomes more relaxed sometimes dropping them when he uses perceptual terms. Thus we find: "One way of looking for gluons is to study the force between quarks, which is supposedly generated by gluons." (Fritzsch 1984, p.164, my emphasis); "If QCD [Quantum Chromodynamics] is the correct theory of hadrons, it must be possible to observe gluons indirectly by looking for gluon jets." (Fritzsch 1984, p.174, my emphasis); and so on. The qualifier 'indirectly' as applied to perceptual terms seems to have the same force as the use of inverted commas around them.

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Still one can find unqualified uses of perceptual terms as in: "Finally, we observe three hadron jets: a quark jet, an antiquark jet and a jet originating from the gluon. We can estimate how often we should observe such three-jet events at high energies." (Fritzsch 1984, p.173). Another entry in the index, "Quarks, visibility of" takes us to Chapter 14 entitled "A Surprise at PETRA: Quarks Become 'Visible'". In this chapter we find remarks such as: "It was observed that, at energies of the order of 15 GeV per beam, the final hadrons are distributed in the form of narrow jets. For the first time, physicists were able to 'see' quarks, at least indirectly". (Fritzsch 1984, p.150). Other examples of the use of perceptual terms, with or without qualifiers, can be culled from Fritzsch's book.

P.C.W. Davies heads Chapter 5 of his book The Search for Gravity Waves with the title "Have they been seen?" presupposing that whether we have seen them or not the question makes good sense. Davies, however, is not as profligate with his use of perceptual terms as Fritzsch and prefers more often to talk of the detection of gravity waves rather than seeing or observing them; still, talk of seeing or observing gravity waves is not totally shunned by Davies. In contrast, the physicist Gerald Feinberg is not as coy as Davies in his use of perceptual terms. In his recent book there is a section entitled "Seeing Gravity" in which Feinberg tells us: "There is, at present, a group of remarkable experimental techniques under development for the observation of gravity waves." Owing to the extreme delicacy of experiments involving gravity wave detectors Feinberg alleges that gravity waves are observable items, but they have not yet been observed: "The difference is that while light waves have been observed since there were human beings, and radio waves for the past century, we have not yet observed gravity waves." (Feinberg 1985, p.138). Newton, and others who hold a particle view of light, would demur from the claim that we could ever observe light waves and, instead, might prefer the safer claim that we humans have always observed light. Still, if light really is a wave phenomenon then it follows, by substitution of identically referring general terms, that we humans have observed light waves. The same goes for radio waves. These points aside, the significant aspect of Feinberg's views is that gravity waves are alleged to be observable.

As a final case consider the following remarks made by Millikan in his Nobel Lecture for the 1923 Nobel Prize for Physics:

> He who has seen that experiment [i.e., the oil-drop experiment], and hundreds of investigators have observed it, has literally seen the electron. ...
> But the electron itself, which man has measured ... is neither an uncertainty nor an hypothesis. It is a new experimental fact that this generation in which we live has for the first time seen, but which anyone who wills may henceforth see. (Millikan 1924, pp.58-9; emphasis in the original).

Millikan did not have extraordinary powers of vision enabling him to see what others cannot see. Perhaps he might have more cautiously said that he had detected electrons, in which case most philosophers would have no quibble with him. But it would be rash to say that Millikan in his Nobel Lecture had thrown caution to the winds; his words were deliberately intended since he had gone to the trouble of italicizing them. Millikan's

use of perceptual terms, like their use by scientists cited above (and many others), is standard in scientific circles.

In reaction to rather narrow phenomenalist or positivist analyses of observation philosophers such as Ryle, Hanson, Kuhn and Feyerabend have spoken of the theory-ladenness of observation in order to give an account of the theoretical loading apparent in perceptual claims of the kind cited above. But the word 'ladenness' was laden with too much of the burden of explaining what connections there were between theory and observation, a burden which it has not been able to carry satisfactorily. Recently Shapere (see Shapere 1982) has discussed talk of "observing the centre of the sun" and of "observing solar neutrinos" by physicists involved in the solar neutrino experiment. He propounds a theory of observation which is a step in the right direction away from the vagaries of claims about the theory-ladenness of observation. Somewhat earlier Dretske (see Dretske 1969) had proposed a theory about observation, and seeing in particular, which can serve equally well to account for most of the uses of perceptual terms, such as those cited above, which may seem to some to be philosophically suspect. This paper will be concerned with, first, developing Dretske's theory of observation for cases like those cited, and, second, extending this to the account of observation suggested by Shapere.

2. The Dretske-Jackson Theory of Non-Epistemic and Epistemic Seeing

Dretske's theory of observation is set out in his book Seeing and Knowing with a wealth of detail; only a sketch will be provided here sufficient to develop the main points of the paper. He distinguishes two kinds of seeing-that (labelled 'primary' and 'secondary') both of which are belief-entailing but both of which involve a notion of non-epistemic seeing, viz., seeing objects. For our purposes secondary seeing-that is important but its analysis involves both non-epistemic seeing and primary seeing-that. Consider the claim that person P sees that a is A, where 'a' names some item in P's field of vision and 'A' names a property of the item. Then P primarily sees that a is A if and only if:

(i) a is A (i.e., the truth-condition)

(ii) P $sees_n$ a. $Seeing_n$ is a non-epistemic kind of seeing in which the claim that P sees a does not entail that P believes that q, for any particular proposition q. More positively, for P to see a it is required that a be visually differentiated from its immediate environment by P. In this sense a dog, a baby and an astronomer can see, say, the sun. 'P $sees_n$ a' is a visual relation holding between P and a, the term 'a' being replaceable by any co-referring term unlike the 'a' in 'P sees that a is A'.[2]

(iii) The conditions under which P $sees_n$ a are such that a would not look the way it now looks to P unless it was A.

(iv) P, believing the conditions are as described in (iii), takes a to be A.

Whether or not these four conditions capture fully the notion of primary seeing-that is not germane to our purpose.[3] However they do provide the main features of an analysis of claims such as: P sees that the ink on this page is black; Q sees that the ammeter needle points to 5 amps; and so on. We could offer a similar analysis for 'primarily hears that' as

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in 'R hears that the patient has a heavy cough'. Since 'observes' is a general perceptual term including seeing, hearing, touching, etc., we also have at hand a partial analysis of observing-that as in 'R observes that the patient has a heavy cough'. Note as well that 'observes' can replace the word 'sees' in the previous two examples without difficulty.

Not all cases of seeing-that can be captured by the above schema. Thus we say: 'P sees that the petrol tank is empty'. What P sees (i.e., $sees_n$) is not the inside of P's petrol tank but a petrol gauge of which we can make the report 'P sees that the gauge registers zero'. If P believes that the gauge registers zero because the tank is empty, we can then make the report, when P looks at the gauge with the ignition switched on, 'P sees that the tank is empty'. There are countless cases of secondary seeing that such-and-such is the case which arise from our primarily seeing that so-and-so is the case. We (secondarily) see that the water in the kettle is boiling by (primarily) seeing that steam is issuing from the kettle spout; only rarely do we primarily see that the water is boiling by looking into the kettle. We (secondarily) observe, or see, that we are consuming electric power by (primarily) observing, or seeing, or hearing, that our electric meter is ticking over. We observe that radio-activity is present by hearing that the geiger-counter is emitting clicking noises. A doctor observes that an accident victim is still alive by hearing, with a stethoscope, that the victim's heart is still beating. And so on, for countless such ordinary cases. Given the examples cited in the first section of this paper we can also say: Millikan (secondarily) observed, or saw, that an electron had hopped onto an oil drop by (primarily) observing, or seeing, that an oil drop changed its motion; Joseph Weber (an early researcher into gravity waves) secondarily saw that a gravity wave had rippled passed by primarily observing that his gravity-wave detecting machine had registered particular vibrations; and so on.

In these examples we have moved from indisputable cases of secondarily observing (or seeing) in the case of kettles boiling to more disputable cases of secondarily observing (or seeing) in the case of electrons jumping onto oil drops or gravity waves rippling by. Yet the structure of these cases is much the same, as can be seen from the analysis of secondary seeing-that. Instead of Dretske's analysis, a slightly modified version suggested by Jackson[4] will be employed. P sees, in a secondary manner, that b is B if and only if:

(1) b is B
(2) P believes that b is B
(3) There is some a and A such that P primarily sees that a is A
(4) The circumstances are such that P's belief that a is A is a sufficient ground for the knowledge claim by P that b is B, and P believes this.

(This account assumes that P does not primarily see that b is B in any way.)

This is not the place to defend the Dretske-Jackson analysis of seeing. Rather, it will be applied to some cases. The virtues of the analysis can, in part, be judged by the account it gives of these cases. Consider the claim that P primarily sees that the petrol gauge of P's car registers zero. This entails, by the definition of primary seeing-that, that P believes that the petrol gauge registers zero. Given this primary visual

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belief, then, providing the circumstances are right, P has sufficient grounds to claim that the petrol tank is empty. The right circumstances (or background conditions, as they will subsequently be called) may include a large number of things of which P may not necessarily be, and is ordinarily not, aware. This would include, for example, the well-functioning of the gauge and the flotation system in the petrol tank, the battery being sufficiently charged to work the electric circuitry, the ignition being on, etc. Note that the grounds referred to in (4) are only sufficient for the knowledge claim; this leaves open the possibility that P may come to believe that P's petrol tank is empty on grounds other than seeing that the gauge registers zero. However if we are to claim that P sees that his petrol tank is empty then there must be some primary visual belief which is sufficient for this claim. Moreover P must believe that his primary visual belief (in this case that the gauge registers zero) is sufficient for the claim that the tank is empty; without this P cannot advance beyond his mere primary visual belief.

Cases of perceptual relativity can arise between those who satisfy condition (4) and those who do not. Consider another person, Q, who can read gauges but who does not believe that the primary visual belief that the gauge registers zero is sufficient for the claim that the petrol tank is empty. Then, even though P and Q both primarily observe that the gauge registers zero, only P can be said to observe that the petrol tank is empty; Q can make no such secondary observation-that claim. It could be said that P's observation is "theory-laden" while Q's is not; however the precise import of this remark is best spelled out in the above manner in terms of primary and secondary observation-that.

The cases of geiger-counters and gravity-wave detectors are on a continuum with petrol gauges, but they are far more complex. All three devices can be set up so that anyone untutored in advanced physics can make correct secondary observation-that reports. If P merely hears the clicks on a geiger-counter then, providing P satisfies condition (4) (viz., P believes circumstances are such that P's aurally acquired primary beliefs are sufficient for the claim that radio-activity is present), we may claim that P (secondarily) observes that radio-active material is present. Merely knowing what is the function of geiger counters, without knowing any theory of sub-atomic physics or theory behind the construction of the geiger-counter, is sufficient grounds for making secondary observation-that claims. These claims may be expressed in language that could contain highly theoretical terms; however such theory-ladenness of the secondary observation-that report arises in a quite natural manner that presupposes no great knowledge of physics on the part of the person making the report.

Gravity wave detectors exhibit even more complexity but still no difference in kind. In his book The Search for Gravity Waves Davies discusses the theory of such waves as it arose from Einstein's theory of relativity and also possible sources of gravity waves such as ripples from the earliest moments after the big bang, black holes, the interiors of quasars, the turbulence of star clusters, and so on. These waves, as they pass us, could convey information about such items: "An analysis of this radiation would provide information of incomparable value about these highly inaccessible and remote locations of the cosmos, and would tell us something about the behaviour of spacetime and matter under the most extreme conditions." (Davies 1980, p.93). In terms of the views

of Shapere (to be mentioned shortly) we have a "theory of the source" of these waves and a "theory of the transmission" of the waves bearing information from that source free of any interference between the source and our reception of them. Finally we have a "theory of a receptor" (in fact several theories of several different kinds of receptors) which can detect the presence of, and the information conveyed by, these waves as they ripple through the matter out of which the receptor is constructed. The output of the receptor could be any method for recording vibrations, from moveable pen recorders to computer print-outs. From these we acquire our primary observations that such-and-such a kind of vibration has occurred in the detector. Perhaps these are not so primary in that what we primarily observe may well be, say, that a pen has traced a particular sort of wavy line on a moving sheet of paper calibrated in a particular way. On the basis of these primary observations we make the secondary observation that the detector has been subject to such-and-such vibrations; then we make the further secondary observation that a gravity wave of such-and-such an intensity has rippled by. Making such secondary observation-that claims does not require that a person have mastered all the background theory of the nature, source, transmission and reception of gravity waves. But such background theory licences the claim of clause (4) that when a person acquires certain primary perceptually-based beliefs (e.g., by looking at a record of vibrations of the wave detector) then there are sufficient grounds, in those circumstances, for the claim that a gravity wave has rippled by.

3. Observing What We Cannot See

Does clause (4) open the floodgates for what counts as observable? Not quite. What has been defined is a notion of secondary seeing-that. In so far as we can replace the verb 'see' by the word 'observe' (as has been done in some cases above) then we have a notion of secondary observing-that. The notion of secondary observing-that is well established in our ordinary talk of observing, say, that water has boiled or that the petrol tank is empty; the more recherché examples have been got from science merely by extension. For those who would resist any notion of secondary observing-that there is always the notion of primary observing-that upon which to fall back. However this is to avoid many of our ordinary uses of 'seeing', 'hearing', 'observing', which, as has been argued, have found a place in the discourse of practicing scientists most of whom have remained uncorrupted by epistemological theories. What clause (4) sanctions is that if we acquire certain visually-based beliefs by primarily seeing or observing that a is A then, given the conditions under which we see, or observe, there is a sufficient ground for the claim that b is B, and we believe this. We may fail to secondarily see, or observe, that b is B in lots of ways; we may come to know that b is B by failing to primarily see, for any a and A, that a is A; we may fail to believe that the conditions under which we see that a is A are sufficient for the claim that b is B; the sufficiency requirement just mentioned may not be fulfilled due to the faulty nature of our background theories backing the sufficiency claim; and so on.

Having introduced two kinds of observing that, viz., primary and secondary seeing-that, we can now introduce what it is for some item to be observable, whether the item be an object, event, process or state of affairs. 'Observable' means 'can be observed'. What the modal 'can' means can be left open since there are a number of plausible contenders

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for what it can stand for; a favourite might be 'what is possible for us to observe given the laws of nature which hold in our world'. Initially we can say that an object X can be observed if we can see X in the non-epistemic sense of 'see' briefly sketched in the definition of primary seeing-that, i.e., X is an item in our field of vision which we can visually differentiate from its environment. Thus I would fail to see_n X if it were too far away from me, if it were too small to detect no matter how close I got, if it were to merge imperceptibly with the landscape, and so on. In this sense we do not see_n pulsars (unless some have been visually identified using light telescopes) or see_n electrons. If $seeing_n$ X were also necessary for observing X then observing would be co-extensive with $seeing_n$. (We might need to consider perceptual relations other than seeing, e.g., hearing, feeling, touching etc., to fill out the other ways in which observation can be carried out - but this is a minor modification to any proposal concerning the notion of observation.) Those of a phenomenalist or positivist persuasion would want to leave the matter at this point. However we can proceed further and say: if 'X' is a sentence which designates an event, state of affairs, or process, then that X is the case is an observable event (state of affairs, process) if it can be seen that X in either a primary or secondary way. Thus, that the petrol tank is empty is an observable state of affairs as much the claim that a gravity wave rippled by at 2:05 a.m. today is an observable event (albeit an event observable in only a secondary way). This does not quite give us the sense in which some objects are alleged to be observable, e.g., the sense in which astronomers say that they observe pulsars or Millikan said that he saw electrons.

Observing is an activity which can take place over a long period of time. Ethologists observe animal behaviour for hours, days or years. In much the same way police observe, say, a building during a stake-out. Their observing may issue in observation reports such as 'person Q entered the building at 3:17 a.m. and left at 3:23 a.m.' Such reports would be primary when based on direct visual experience; they could be secondary when based on the viewing of screens connected to closed-circuit TV cameras or the playing of videos or films (as is often the case with ethologists observing bird behaviour). The basic idea behind observing is that of keeping some item or items under surveillance over a period of time. What we keep under surveillance can range from buildings and animals to planets and stars. If we cannot see them (in the non-epistemic sense of 'see_n') then this does not necessarily count against their being kept under surveillance by us, and therefore being observed by us. All that is required is that we be able, from time to time, to come up with a number of observational reports about them. Such reports can be either primary observing-that reports or secondary observing-that reports.

Hewish *et al.* who entitled their paper "Observation of a Rapidly Pulsating Source" kept their newly discovered pulsar CP1919 (as they called it) under surveillance each day for as long as it came within the sweep of their radio telescope (which was fixed on the ground but moving with the Earth's diurnal rotation). What they observed primarily were literally thousands of feet of strips of chart paper on which pen traces were drawn, calibrated, for example, to measure quantities such as radio signal pulse amplitude against time. The story of how pulsars were first discovered is an interesting one that cannot be gone into here. Suffice to mention that what their discoverer, Jocelyn Bell, first noticed was what she called a "patch of scruff" i.e., a distinctive bit of tracing-pen squiggle which reappeared from time to time on the

hundreds of feet of chart paper she looked at weekly.[5] Observing the "patch of scruff" gave Jocelyn Bell her primary observation reports. From these a number of secondary observation reports arose. For example, Jocelyn Bell had to discover the portion of sky occupied by the source which caused the patch of scruff on the chart paper. Of this the authors of the paper say: "Soon after the instrument [i.e., their radio telescope] was brought into operation it was noticed that the signals which appeared at first to be weak sporadic interference were repeatedly observed at a fixed declination and right ascension; this result showed that the source could not be terrestrial in origin." (Hewish et al. 1968, p.5). To observe, as the authors say, that the signal comes from a fixed declination and right ascension, is to make a secondary observation-that claim which presupposes a theory about how one gets from pen traces on chart paper to the position in the sky of a radio signal. Further, the authors noted that there was a repetition period of pulsing of about 1.337 seconds. Of this the authors say: "Further observations have shown that the true period is constant to better than one part in 10^7 ..." . (Hewish et al. 1968, p.5). Again, to observe that the period of pulsing is constant, or observe that it is constant to 1 part in 10^7, is to make a secondary observation-that claim, this being an inference from what one can primarily observe about the pen tracings on the chart paper.

In sum, since a host of observe-that claims, mainly secondary, can be made about pulsar CP1919 there is a good sense in which we can say that the astronomers were observing the pulsar and, therefore, that the pulsar is an observable item even though the astronomers could not see_n the pulsar. (Incidentally the authors tell us that their radio telescope was the first built which could have possibly detected such pulsars; it was actually built to detect interplanetary scintillation and only accidentally picked up signals from pulsars. This suggests another sense of 'can' in 'can be observed'; what we can observe is dependent on times, on the availability of instruments, detectors and other bits of apparatus as well as an adequate theory of the operation of these.)

Consider now Millikan's claim that he could see electrons. If 'see' in these contexts means 'see_n' then electrons are simply not items which, when positioned in front of Millikan, could ever be seen by him, or anyone else. However Millikan had a strong sense of the reality of electrons when he performed his oil-drop experiment. Simply by spraying electrons onto oil droplets moving in an electric field Millikan could watch the changing motions of the droplets. As electrons hopped on, descending oil drops would slow down, become stationary or move upwards; as electrons hopped off, the reverse would happen. In Ian Hacking's phrase: "if you can spray them, then they are real". (Hacking 1983, p.22). Familiarity with the experiment, Millikan said to the audience at his Nobel lecture, enabled him to even count the number of electrons on an oil drop. (Millikan 1924, p.59). None of this constitutes $seeing_n$ an electron. But Millikan does primarily see that ..., where the blank is filled by descriptions of the behaviour of the oil drops in his experimental apparatus. Given these primary visual beliefs Millikan has sufficient grounds, and also believes that he has these grounds, to make knowledge claims about the behaviour of electrons. Thus he can, with good justification, say that he sees (secondarily) that an electron has hopped onto an oil drop, or that he sees (secondarily) that a particular

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oil drop has seven electrons on it. Given that he is able to keep some of the features of electrons under surveillance we can say that Millikan observed electrons and thus that electrons are observable. But such a locution can only be understood in terms of the theory of secondary seeing-that. We must keep in mind the clear sense in which any epistemologist would baulk at Millikan's claim to have seen an electron, i.e., to have $seen_n$ electrons in the sense that they are visually discriminable items in Millikan's field of vision. Presumably, Millikan would not want to claim that he could see electrons in this quite special sense of 'see' once it had been made clear to him. Otherwise, if he could literally see electrons (in the sense of 'see_n') why did he bother with the oil-drop experiment at all?

4. Shapere's Account of Observation

Dudley Shapere has recently considered the uses which astrophysicists have made of perceptual terms when they talk of "seeing into a stellar interior" or of "observing solar neutrinos". He proposes the following sufficient condition for what it is to observe an object X:

> X is directly observed (observable) if:
>
> (1) information is received (can be received) by an appropriate receptor; and
>
> (2) that information is (can be) transmitted directly, i.e., without interference, to the receptor from that entity X (which is the source of the information). (Shapere 1982, p.492).

These jointly sufficient conditions are schematic in that terms like 'source of the information', 'information', 'transmission of information', 'receptor (of the information)' need to be filled out in the light of our current scientific theory about the information source, our theory of the receptor which picks up the information from the source and our theory of the nature of the information and its transmission from source to receptor relatively free of interference and alteration. Such a view of observation, it will be argued, is consonant with the account given in the previous section of what it is for objects to be observable.

Shapere illustrates his schematic conditions by describing in detail the solar neutrino experiment designed to observe, as it is said, features of the sun's interior. Similar illustrations could be given using the example of gravity-wave detectors or of geiger-counters; for simplicity the example of petrol tanks and gauges will be used once more. The source of the information is clearly the petrol in the tank, the information itself being that there is such-and-such an amount of petrol. The receptor is the gauge on the dashboard suitably calibrated. The information about the amount of petrol is transmitted electrically through the employment of the tank's flotation system and the electrical circuit with its battery. Is the amount of petrol in the tank an observable item? Yes, but the manner in which Shapere's schematic conditions are satisfied can be set out in terms of the theory of observation developed in the previous two sections.

In order to do this two features of clause (4) of the definition of secondary seeing-(observing-)that need to be spelled out in greater

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detail. First, there are quite specific conditions which must obtain when P observes that a is A (i.e., that the gauge registers zero) if P is successfully to observe that b is B (i.e., that the tank is empty). These include: the well-functioning of the battery, the circuit and the flotation system; the ignition being on; and so on. Call these the background conditions. Second, there is an inferential link between P's primary visual belief that a is A and P's secondary observational belief that b is B. This inferential link can be expressed in the form of a conditional: if a is A, in background conditions C, then b is B. Call this the background conditional.

By clause (4) P must believe that there is such a background conditional and rely on its truth if P is successfully to observe (secondarily) that b is B. P is not required to know that such a background conditional is true, while relying on its truth. Nor is P required to know what the background conditions C are. P is required to believe only that there is something which makes P's belief that a is A a sufficient ground for P's knowledge claim that b is B in the background conditions, whatever they be, that prevail.

However the truth of such a background conditional needs to be established in some way. Thus, if anyone is ever successfully to believe, and secondarily observe, that their petrol tank contains n litres of petrol by seeing that their petrol gauge registers n litres then a background conditional of the following sort must be true: in the conditions in which the petrol gauge registers n litres, the petrol tank contains n litres of petrol. That such a background conditional is true may simply be a matter of common experience. However, when petrol gauges were first introduced more scientifically based tests employing some physics may have been used to establish the truth of such conditionals.

The second alternative must be the case for more complex detectors whose reliability has to be established. In fact much complex physics must be used to establish that solar neutrino detectors, gravity wave detectors and radio telescopes for observing pulsars do genuinely detect the items scientists allege they detect. Before P can make a successful claim to have (secondarily) observed, say, that some solar neutrinos have been captured, there must be a background conditional upon which P can rely. Such a background conditional would be: if such-and-such a receptor registers in a particular way under conditions C then a neutrino from the sun has been detected. The conditional is necessarily vague in certain respects. A detailed description of the receptor and the way it operates needs to be given; this, of course, will involve much physics and chemistry. In addition, to show that it is a solar neutrino which has been captured we must employ a current theory about the nature of the thermonuclear reactions going on in the sun and a theory about the neutrinos that it emits. Call all the theory employed to show that the background conditional is worth relying upon 'the background theory'.

Given the controversial character of the solar neutrino experiments, and more so the experiments designed to detect gravity waves, whether or not experimenters have made successful secondary observations-that concerning solar neutrinos or gravity waves depends crucially on the background theory. Doubts about the background theory cast doubts on any

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observation-that claims about solar neutrinos or gravity waves. However, setting these doubts aside, we have a good sense in which we can say that many observation-that claims in science are secondary observations-that and that they depend, in the way set out, for their truth on background theory to establish the reliability of an appropriate background conditional. Call this the theory-dependence of observation if you wish. However, the character of that dependence has been spelled out in ways which depend crucially on the theory of secondary observation-that; such a theory can help us avoid some of the difficulties that have beset many accounts of the theory-ladenness of observation (especially some of the more dubious claims that lead to relativism).[6]

By employing the notion of background conditionals and background theory in the way just suggested, aspects of the theory of observation outlined in the previous two sections have been highlighted to provide a setting for Shapere's theory-dependent schema for what it is for some object to be observed (or observable). Background conditionals and background theory underpin our secondary observation-that claims; in turn, such secondary observation-that claims underpin our claims that certain objects are observable (as was argued in section 3). Thus there is a good sense in which we can say that we have observed gravity waves or solar neutrinos when we look at the behaviour of certain detectors.

5. Growth in Observation Reports with Growth in Science

In the move from primary observation-that claims to secondary observation-that claims our observations are sensitive to the growth in scientific knowledge that has taken place. It is not that our primary observation-that claims have any secure foundation of the sort to which a phenomenalist or a classical foundationalist in the theory of knowledge would have aspired. Rather, given the wide acceptance that our primary observation-that claims have and given the knowledge we have acquired about how the world works, either based on common observation or highly theoretical scientific investigation, we can make the incremental shift to secondary observation-that claims. In talking about the world we endeavour to use our best theory of it. Such talk ultimately gets round to what we observe. So it is no accident that the reports of what we observe are expressed in the language of that theory. And of course new theory brings new ways of reporting what we observe. Paradoxically put, often what we observe is what we cannot see. But if the distinctions drawn in this paper between non-epistemic seeing and the primary and secondary kinds of seeing-that are preserved, along with the variety of ways in which it may be said that some item is observable, this is no paradox at all.

Notes

[1]See some of the papers in Pulsating Stars: A Nature Reprint (1968), especially papers 19 to 26.

[2]The nature of non-epistemic seeing is discussed more fully in Chapter II of Dretske (1969).

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[3]The analysis of primary seeing-that given in the text is that suggested by Dretske in Chapter III §1 of Dretske (1969); see the rest of the chapter for a full defence of his analysis. See Jackson (1977) Chapter 7 §4-7 for improvements to the conditions for primary seeing-that proposed by Dretske. These improvements have no direct bearing on the points developed in the paper.

[4]See Jackson (1977), Chapter 7 §8. Dretske's conditions for secondary seeing-that can be found in §2 of Chapter IV of Dretske (1969).

[5]For her story see Burnell (1978). (S. Jocelyn Bell is now S. Jocelyn Bell Burnell.)

[6]Some of these are spelled out in Shapere (1982) § IV, especially pp.514-6.

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