Huw Price
"Time's Arrow
& Archimedes' Point"
NY: OUP. 1996
pp. 105 – 111

saying [illegible] the suggestion that entropy decreases toward singularities. He argues that in virtue of its commitment to temporal symmetry this view must either disallow black holes in the future, or allow for a proliferation of white holes in the past. He says that the first of these options "requires physically unacceptable teleology," while the second would conflict with the observed smoothness of the early universe.[45] However, the objection to the first option is primarily statistical: "it would have to be a seemingly remarkably improbable set of coincidences that would forbid black holes forming. The hypothesis of black holes being not allowed in the future provides 'unreasonable' constraints on what matter is allowed to do in the past."[46] And I think this means that Penrose is again invoking a double standard, in accepting the "naturalness" argument with respect to the future but not the past. Once again: the lesson of the smooth past seems to be that in that case something overrides the natural behavior of a gravitational collapse; once this possibility is admitted, however, we have no non–question-begging grounds to exclude (or even to *doubt!*) the hypothesis that the same overriding factor might operate in the future.[47]

As it stands, then, the arguments against the Gold view do not seem very convincing. Some of them involve the kind of temporal double standard which has cropped up so often in discussions we have been looking at in this and the two previous chapters. The most interesting line of argument concerned the possible interactions between the two halves of a Gold universe. In the next section I want to explore these issues a little further. As I want to show, they raise the interesting possibility that in principle, astronomers in either half of a Gold universe might be able to detect some of the features of the other half—even though those features lie in the distant future, from the astronomers' point of view.

A TELESCOPE TO LOOK INTO THE FUTURE?

Let us suppose that our universe is actually a Gold universe: it eventually recollapses, and the contracting phase (as we call it) is much like the expanding phase, with the familiar temporal asymmetries reversed. The contracting phase will contain what in our time sense look like reverse galaxies and reverse stars. These are exactly like our stars and galaxies, but with the opposite time sense. In our time sense, they are sinks for radiation, rather than sources. (Coherent radiation converges on them, rather than diverging from them.)

What happens if we point one of our telescopes in the direction of one of these reverse galaxies—in other words, if we point the telescope in what happens to be the right direction to receive some of the light which, from the standpoint of astronomers in the reverse galaxy, left their galaxy billions of years previously? What effect, if any, would this have on our telescope and its surroundings?

A useful first step is to consider matters from the reverse point of view. An astronomer in the reverse galaxy will say that light emitted from her galaxy is being collected and absorbed by the distant telescope on Earth. (She won't know that this is happening, of course, because from her point of view it is taking place far in the future. There is nothing to stop her speculating about the possibility, however.) Accordingly, she will expect certain effects to take place at the back of the telescope, due to the light's absorption. A black plate placed at the back of the telescope will be heated slightly by the incoming radiation, for example.

What does this look like from our point of view? Our temporal sense is the reverse of that of the distant astronomer, so that what she regards as absorption of radiation seems to us to be emission, and vice versa. Similarly, apparent directions of heat flow are also reversed. Thus as we point our telescope toward the distant reverse galaxy, the effect should be a sudden increase in the flow of radiation from the telescope into space; and, indirectly, an apparent *cooling* of the black plate at the rear of our telescope. Why cooling and not heating? Because heat is flowing into the plate from its surroundings, in out time sense, and then away into space as light radiation. The plate is actually hotter than its immediate environment, but it behaves in the way we normally expect of an object which is cooler than its surroundings: in other words, it takes in heat from its environment.[48]

As in normal astronomy, the size of these effects will depend on the distance and intensity of the reverse source in question. In practice, the interval between our era and the corresponding era in the contracting phase of a Gold universe might be so vast that any effects of this kind would be insignificant. These practical difficulties should not prevent us from exploring these ideas in principle, however. For one thing, we might manage to turn up some sort of logical difficulty, which would rule out the Gold universe once and for all. (Many thought experiments in physics are impossible to perform, but hardly less important on that account.)

The size of the effects aside, there seem to be theoretical difficulties in detecting them by what might seem the obvious methods. For example, it will be no use placing a photographic plate over the aperture of the telescope, hoping to record the emission of the radiation on its way to the reverse galaxy. If we consider things from the point of view of the distant reverse astronomer, it is clear that the plate would act as a shield, shading the telescope from the light from her galaxy. Thus from our point of view the light will be emitted

from the back of the plate—from the side facing away from the telescope, toward the reverse galaxy.

Let us look at the expected behavior of the telescope in a little more detail. When we shine a light at an absorbing surface we expect its temperature to increase. If the incoming light intensity is constant the temperature will soon stabilize at a higher level, as the system reaches a new equilibrium. If the light is then turned off the temperature drops exponentially to its previous value. Hence if future reverse astronomers shine a laser beam in the direction of one of our telescopes, at the back of which is an absorbing plate, the temperature change they would expect to take place in the plate is as shown in Figure 4.2a. When the telescope is opened the temperature of the plate rises due to the effect of the incoming radiation, stabilizing at a new higher value. If the telescope is then shut, so that the plate no longer absorbs radiation, its temperature drops again to the initial value.

Figure 4.2b shows what this behavior looks like from our point of view. Setting aside the issue mentioned above of the *apparent* temperature of the plate relative to its surroundings, the only change is in the temporal ordering of the relevant events. One of the striking things about this behavior is that it appears to involve what physicists call advanced effects—effects which take place *before* the event which causes them. The temperature rises before we open the telescope, and falls before we close it. This suggests that we might be able to argue that the whole setup is incoherent, using the kind of argument often used to try to show that backward causation leads to paradoxical results. (We will look at these arguments in more detail in chapter 7.) Couldn't we adopt the following policy, for example: *Open the telescope only if the temperature of the black plate has not just risen significantly above that of its surroundings?* It might seem that this entirely feasible policy generates contradictory predictions, thus providing a reductio ad absurdum of the time-reversing view.

But are the results really contradictory? Grant for the moment that while this policy is in force it will not happen that the temperature of the plate rises on an occasion on which we might have opened the telescope, but didn't actually do so. This leaves the possibility that on all relevant trials the temperature does not rise, and the telescope is opened. Is this inconsistent with the presence of radiation from the future reverse source?

I don't think so. We should keep in mind that the temperature profile depicted in these diagrams relies on statistical reasoning: it is inferred from the measured direction of heat flow, and simply represents the most likely way for the temperature of the absorbing plate to behave. But one of the lessons of our discussion has been that statistics may be overridden by boundary conditions. Here, the temperature is constant before the telescope is opened

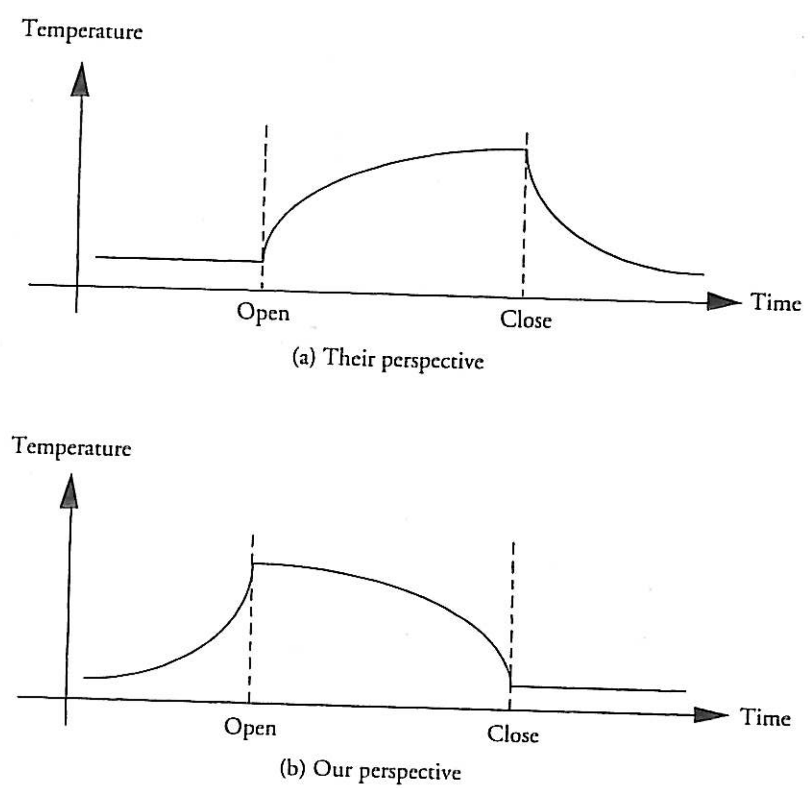

Figure 4.2. Two views of a telescope to look into the future.

because our policy has imposed this as a boundary condition. A second boundary condition is provided by the presence of the future reverse radiation source. Hence the system is statistically constrained in both temporal directions. We should not be surprised that it does not exhibit behavior predicted under the supposition that in one direction or other, it has its normal degrees of freedom. It is not clear whether this loophole will always be available, but my suspicion is that it will be. If nothing else, quantum indeterminism is likely to imply that it is impossible to sufficiently constrain the two boundary conditions to yield an outright contradiction.

A related objection to the Gold universe has recently been raised by the physicists Murray Gell-Mann and James Hartle. Gell-Mann and Hartle consider the present consequences of assuming that the universe produces stars and galaxies at both ends, in the way we have been discussing.

> Consider the radiation emitted from a particular star in the present epoch. If the universe is transparent, it is likely to reach the final epoch without being absorbed or scattered. There it may either be absorbed in the stars or proceed past them toward the final singularity. If a significant fraction of the radiation proceeds past, then by time-symmetry we should expect a corresponding amount of radiation to have been emitted from the big bang. Observation of the brightness of the night sky could therefore constrain the possibility of a final boundary condition time-symmetrically related to the initial one.[49]

In other words, the argument is that the Gold universe implies that there should be more radiation observable in the night sky than we actually see. As well as the radiation produced by the stars of our own epoch, there should be radiation which in the reverse time sense is left over from the stars of the reverse epoch. As Paul Davies and Jason Twamley describe Gell-Mann and Hartle's conclusion, "by symmetry this intense starlight background should also be present at our epoch . . . , a difficulty reminiscent of Olbers' paradox."[50]

But if there were such additional radiation of this kind in our region of the universe, could we actually detect it? Gell-Mann and Hartle overlook this issue. The problem is that the radiation concerned is "already" neatly arranged to converge on its future sources, not on our eyes or instruments. Imagine, for example, that a reverse galaxy in direction $+x$ is emitting (in its time sense) toward a distant point in direction $-x$ (see Figure 4.3). We stand at the origin, and look toward $-x$. Do we see the light which in our time sense is traveling from $-x$ toward $+x$? No, because we are standing in the way! If we are standing at the origin (at the relevant time) then the light emitted from the reverse galaxy falls on us, and never reaches what we think of as the past sky. When we look toward $-x$, looking for the radiation converging on the reverse galaxy at $+x$, then the relevant part of the radiation doesn't come from the sky in the direction $-x$ at all; it comes from the surface at the origin which faces $+x$—that is, from the back of our own head! As in the telescope case, then, we discover that the radiation associated with the opposite end of a Gold universe is not necessarily detectable by normal means.

Thus the whole issue of the consequences and consistency of the Gold view is a lot more complicated than it looks at first sight. One of the general lessons is that because our ordinary (asymmetric) ways of thinking are intimately tied up with the thermodynamic asymmetry, we cannot assume that they will be dependable in contexts in which this asymmetry is not universal. To give a simple example, suppose that an event B follows deterministically from an event A. In a Gold universe we may not be able to say that if A had not happened B would not have happened—not because there is some alternative earlier cause waiting in the wings if A fails to materialize (as happens

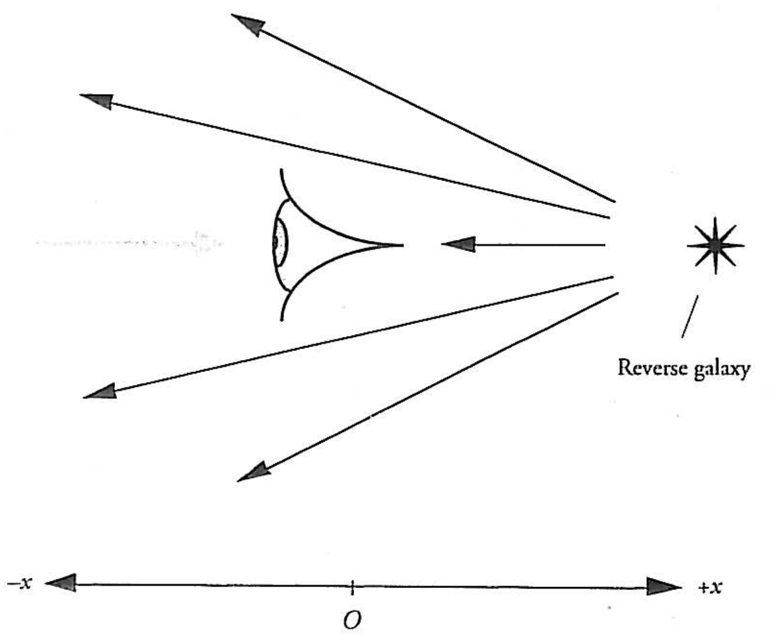

Figure 4.3. How not to see the light? If the observer looks to the sky in direction −x, hoping to see light which in her time sense would appear to be converging on the reverse galaxy in direction +x, she herself shades the sky in that direction, and so sees no light.

in cases of what philosophers call preemptive causation, for example), but simply because B is guaranteed by *later* events.

Figure 4.3 illustrates a consequence of this kind. We had a choice as to whether to interpose our head and hence our eye at the point *O*. If we had not done so, the light emitted (in the reverse time sense) by the reverse galaxy at +*x* would have reached −*x*, *in our past.* Our action thus influences the past. Because we interpose ourselves at *O*, some photons are not emitted from some surface at −*x*, whereas otherwise they would have been. Normally claims to affect the past give rise to causal loops, and hence inconsistencies. But again it is not obvious that this will happen in this case, for reasons similar to those in the telescope case.

These issues call for a lot more thought, but we can draw two rather tentative conclusions. First, the question whether Gold's view leads to some kind of inconsistency is still open (and won't be settled until we learn to think about the problem in the right way). Second, there is some prospect that the

contents of the contracting half of a Gold universe might be presently observable, at least in principle—despite the fact that they lie in what we think of as the distant future.[51] The methods involved look bizarre by ordinary standards, but in the end this is nothing more than the apparent oddity of perfectly ordinary asymmetries having the reverse of their "usual" orientation. One of the main lessons of the last three chapters is that until we have learned to disregard that sort of oddity, we will make no progress at all with the problem of explaining temporal asymmetry.

CONCLUSION

At the beginning of the chapter I noted that one of the outstanding achievements of modern cosmology has been to offer some prospect of an answer to the century-old mystery as to why entropy is so low in the past. In revealing the importance of the smooth early universe, contemporary cosmology allows Boltzmann's great puzzle to be given a concrete form: Why is the universe in this highly ordered condition, early in its history? Cosmology thus inherits the project that Boltzmann began.

When it comes to the conduct of this project, however, we have found that even some of the most able of contemporary cosmologists seem to have trouble grasping the nature of the problem. They are prone to the same temporal double standards that have always afflicted debates on time asymmetry in physics. As a result, most writers in this field have not seen the force of the basic dilemma. That is, they have not appreciated how difficult it is to explain why the universe is smooth at one end, without at the same time showing that it must be smooth at the other (so that the familiar arrows of time would reverse if the universe recontracts).

Despite the insights of modern cosmology, then, Boltzmann's project is far from completion. Until the ground rules are understood by the people who are now qualified to play, further progress seems unlikely. In this chapter I have tried to point out some of the characteristic mistakes in the game as it is currently played, in the hope of encouraging a more productive attack on the remaining mysteries of temporal asymmetry. I want to finish by summarizing the options and prospects for a satisfactory explanation of the smooth early universe, as they seem in light of the discussion earlier in the chapter.

One attractive solution would be the possibility I described in terms of the corkscrew model—in other words, a demonstration that although the laws that govern the universe are temporally symmetric, the universes that they allow are mostly asymmetric; mostly such that they possess a single temporal extremity with the ordered characteristics of what we call the big bang.