Publ. Astron. Obs. Belgrade No. 75 (2003), 267 - 273 *Contributed paper*

ANTHROPIC - ACAUSAL APPROACH TO SOLUTION OF THE ARROW OF TIME PUZZLE

M. M. ĆIRKOVIĆ
Astronomical Observatory, Volgina 7, 11160 Belgrade – 74, Serbia and Montenegro
E–mail mcirkovic@aob.bg.ac.yu

Abstract. Recent surge of interest in the origin of the temporal asymmetry of thermodynamical systems (including the accessible part of the universe itself) put forward two possible explanatory approaches to this age-old problem. Hereby we show that there is a third possible alternative, based on the generalization of the classical ("Boltzmann-Schuetz") anthropic fluctuation picture of the origin of the perceived entropy gradient.

1. INTRODUCTION

The problem of the time-asymmetry of thermodynamics–already more than a century old in its **modern** form!–consists of the following. In our experience, systems increase in entropy in the forward direction of time. The underlying dynamical laws, which are taken to govern thermodynamical systems, however, are symmetric in time: statistical mechanics predicts that entropy is overwhelmingly likely to increase in both temporal directions. So where does the asymmetry of thermodynamics (and of our experience generally) come from? It was, of course, the great Ludwig Boltzmann who–prompted by Loschmidt, Culverwell and Burbury–asked that deep question, contingent on his statistical explanation of thermodynamical phenomena; in his words, "is the apparent irreversibility of all known natural processes consistent with the idea that all natural events are possible without restriction?" (Boltzmann 1964)

During the last decade we have been witnessing a renaissance of interest in the problem of the thermodynamical asymmetry of the world around us among physicists and philosophers alike (e.g. Zeh 1992; Price 1996; Lieb and Yngvason 1999; Albert 1994, 2000; Uffink 2001; Uffink and Brown 2001). In two recent remarkably clear and interesting papers (Price 2002a,b), Huw Price attempted to show that there are two competing projects for explanation of the perceived thermodynamical asymmetry, which he labels Causal-General and Acausal-Particular approaches. Furthermore, his intention is to show the superiority of the Acausal-Particular approach, which is in accordance with other pieces of his atemporal worldview presented, for instance, in his recent brilliant monograph on the subject of temporal asymmetries (Price 1996). The answer Price advocates relies on a low-entropy initial boundary condition: if the initial state of the universe is one of extremely low entropy, then Boltzmannian statistical considerations yield overwhelmingly likely entropy increase towards the future throughout the history of the universe. Price contrasts this account–a version of what he calls the **Acausal-Particular** approach–with those theories that derive the thermodynamic asymmetry from some underlying asymmetric causal or dynamical mechanism operating at all times (like the quantum-mechanical state reduction in quantum theories with dynamical reduction), what he calls **Causal-General** views (cf. Albert 1994, 2000). Causal-General views necessarily contradict Boltzmann's attitude toward the time-reversal asymmetry: "This one-sidedness lies uniquely and solely in the initial conditions." To Price's mind, these two kinds of account are the only serious contenders for explanation of the time-asymmetry of thermodynamics.

In this note, we would like to show that this account is lacking some important ingredients. While the desire for clarification of the common explanatory task is highly commendable, it is important that the taxonomy is kept both maximally comprehensive **and** just. The suggested taxonomy fails in one important respect: it fails to notice an alternative to both Causal-General and Acausal-Particular views. Therefore, in this note, we would like to point out that from the very preferred Price's Acausal-Particular approach bifurcates another option which deserves a separate mention in reviewing the ways toward the explanation of thermodynamical asymmetry. This third approach differs markedly from the other two in its conception of what needs to be done to solve the puzzle. In proposing this, we follow the lead of Price himself who, introducing his two proposals for explaining the thermodynamical asymmetry, points out that (Price 2002b, sec. 1.1)

> So far as I know, the distinction between these two approaches has not been drawn explicitly by other writers. Without it, it is not easy to appreciate the possibility that many familiar attempts to explain the time-asymmetry of thermodynamics might be not *mistaken* so much as *misconceived*–addressed to the wrong problem, in looking for time-asymmetry in the wrong place.

We shall see that, unfortunately, that there are several instances in which Price's own favorite proposal is misconceived, for exactly the same reason: searching for the solution of the puzzle in a wrong place.

2. ACAUSAL-ANTHROPIC APPROACH

Our first motivation is full and faithful acceptance of Price's account of the nature of explanatory task ahead (Price 2002a, section 2.2):

> First of all, let's assume that basic explanatory questions are of the form: 'Given that C, why E rather than F?' The thought here is that we never explain things in isolation. We always take something as already given, and seek to explain the target phenomena in the light of that. C represents this background, and E the target phenomenon. (C might comprise accepted laws, as well as 'boundary conditions' being treated as 'given' and unproblematic for the purposes at hand.)

Obviously, our existence as observers is part of the necessary background. Should it not be included in C? However, in the **cosmological context**, leaving observers out of the picture does not lead to happy consequences, as was first shown by Dicke and Carter in 1960s and 1970s. Especially the debate between Dirac and Dicke on the nature of explanatory projects for the "large number coincidences" is instructive in this respect, since several parallels with the projects for explaining the thermodynamical asymmetry can be drawn. The reader may recall that the famous "Dirac's hypothesis" (or the "large-number hypothesis") for explanation of the ubiquitous dimensionless number 10^{40} has been a bold suggestion that all these numerical coincidences are in fact exact equations related to the age of the universe (Dirac 1937, 1938). In other words, the relevant number is large because the universe is old. Using the completely opposite approach, Dicke (1961) has suggested that large number coincidences are **observed** only because any conceivable different values of such dimensionless quantities would be incompatible with our existence as intelligent observers (and consequently the relationships are only approximate). We can schematically compare view of the large-numbers explanandum in this case:

Dirac: "objective" coincidences (no properties of observers included in C);
Dicke: "observed" coincidences (properties of observers included in C).

The outcome of that particular duel (uncontested victory for Dicke) should warn us against dogmatism when cosmological theories are the subject of inquiry.[1]

With this in mind, we propose a novel approach to explanation of the thermodynamical asymmetry, one which could be labeled (for the reasons explained below) the **Acausal-Anthropic approach**. It represents a Dicke-like approach applied to the specific problem of the thermodynamical asymmetry and the nature (entropy-wise) of the cosmological initial conditions. To understand what this proposal encompasses, perhaps the best way is to use Price's "parsing" the natural phenomena for the different approaches (2002a, §2.3; 2002b, §3.1-3.2). Applied to the Acausal-Anthropic approach, it may look like this:

Symmetric boundary conditions–entropy high in the past
Symmetric default condition–entropy likely to be high (always)
\+ Asymmetric observational selection effect

Observed asymmetry

This should be compared with similar parsing schemes for the Causal-General:

Asymmetric boundary condition–entropy low in the past
\+ Asymmetric law-like tendency–entropy constrained to increase

---

Observed asymmetry

and Acausal-Particular views (Price 2002a):

Asymmetric boundary condition–entropy low in the past
\+ Symmetric default condition–entropy likely to be high, *ceteris paribus*

Observed asymmetry.

[1] In spite of the fact that Dirac himself emphasized the "optimistic" nature of his explanation in comparison: "On Dicke's assumption habitable planets could exist only for a limited period of time. With my assumption they could exist indefinitely in the future and life need never end." (Dirac 1961) This goes some steps toward addressing vulgar objections still heard in some quarters that anthropic explanations are anthropocentric or even "cozy" (e.g. Pagels 1998).

The basic idea of the Acausal-Anthropic approach is that, having already received from (quantum) cosmology a useful notion of the multiverse, we could as well employ it in order to account for the *prima facie* extremely improbable choice of (local) initial conditions. In other words, we imagine that everything that exists, for which we shall use the term multiverse, represents a "Grand Stage" for unfolding of–among other things–thermodynamical histories of chunks of matter. Entropy **in the multiverse** is almost everywhere high at all times ("almost" here meaning "everywhere minus possible subset of small or zero measure"). In other words, the multiverse is, formally speaking, in the state of "heat death", envisaged by the classical thermodynamics (cf. Eddington 1931; Kutrovátz 2001). Our cosmological domain ("the universe") represents a natural fluctuation–presumably of small or zero measure; but the anthropic selection effect answers the question why do we find ourselves on an upward slope of such a fluctuation. Hence what needs explaining is not that there are such fluctuations (this is entailed by the Boltzmann statistical measure); nor the fact that the local initial conditions are one of extremely low probability (this results from a distribution over all domains); but the fact that we happen to live in such an atypical region of the "grand total" which is almost always at equilibrium. And that is to be explained by showing why the observed entropy gradient is necessary for our existence as intelligent observers.

From the point of view of the present Acausal-Anthropic approach, Boltzmann (and his assisstant Dr. Shuetz to whom he gave credit for the original idea; Boltzmann 1895) was on a right track in proposing what came to be known as the "anthropic fluctuation" picture (cf. Barrow and Tipler 1986). The idea was to explain the local thermodynamical disequilibrium by appealing to the size of the universe and the conditions necessary for our existence. Remember the famous words of the Viennese master (Boltzmann 1895):

> If we assume the universe great enough, we can make the probability of one relatively small part being in any given state (however far from the state of thermal equilibrium), as great as we please. We can also make the probability great that, though the whole universe is in thermal equilibrium, our world is in its present state. It may be said that the world is so far from thermal equilibrium that we cannot imagine the improbability of such a state. But can we imagine, on the other side, how small a part of the whole universe this world is? Assuming the universe great enough, the probability that such a small part of it as our world should be in its present state, is no longer small.

In other words, in the Boltzmann-Schuetz view the world in general is in the state of maximal entropy ("heat death"). We exist within a fluctuation of low entropy (**without** reason, i.e. acausally!), which makes our existence possible. Thus, any acausal version of the explanatory project on even vaguely "Boltzmannian" grounds has to include the anthropic selection effect. Boltzmann and Schuetz thus, in our present view, were on the right track, and could not have done better under the circumstances. What they did lack was the input of modern cosmology, exemplified by the multiverse concept.[2] If we summon such help, we may truly inherit the Boltzmannian project of setting up the explanatory proposal for the observed entropy

[2]Boltzmann understood the difficulties of his position quite well; there are several examples of his regarding his cosmological thoughts as remote speculations.

asymmetry.

Note that the end result of both this and the two proposals Price describes–given by the parsing schemes above–is the same: it is an **observed asymmetry**. However, the attribute seems superfluous in both Acausal-Particular and (especially) Causal-General approaches. It has no function at all in either approach. Only in an anthropic approach advocated here it does receive the proper place in the **core** of the perceived explanandum. Is "observed" in this context the same as "objective" or it is not? By equivocating on this, Price attaches a strongly realist (indeed, essentialist) character to the two approaches he favors. Boltzmann and Schuetz spoil the essentialist fun by taking "observed" in its true and literal meaning (i.e. observed by intelligent observers possessing specific capacities, epistemic and otherwise).

Anthropic selection effect is nothing particularly new either. It was the great French physicist, mathematician and philosopher Henry Poincaré who first noted that functioning of an intelligent mind would have been impossible in an entropy-decreasing universe (Poincaré 1946). Later it was elaborated by Norbert Wiener in his celebrated *Cybernetics* (Wiener 1961). In order to immediately preempt any misgivings about the alleged anthropocentrism which undeservedly follow practically any anthropic argument, it should be explicitly stated that this property does not have any particular association with *homo sapiens* (except the trivial and temporary one that we are the only example of intelligent observers known so far; that circumstance is likely to change soon, as a result of either SETI or AI efforts).

Of course, the premise that intelligent observers select particular entropic behavior (and thus entail a temporal asymmetry) should not be taken for granted–and there we come to the crux of the explanatory task ahead. Instead of searching for strange, hitherto never seen time-asymmetric microprocesses (as in the Causal-General approach), or attempt to find a new law applying to global singularities (as in the Acausal-Particular approach), here we would like to investigate and ascertain **why** intelligent observers are dependent on the entropy gradient for their functioning. This, obviously, brings explanatory tasks mainly to the information theory, but also to the disciplines like complexity theory, cognitive and neurosciences. But this does not mean these are not physical questions! An awareness that the link between information theory and various physical theories is the **central piece** in any attempt of understanding nature has been explosively growing during the last several decades. Since the brilliant book of Brillouen (1962), physicists are gradually getting accustomed to the idea (e.g. Lloyd and Pagels 1988; Treumann 1993; Tegmark 1996), and this struck cord with the philosophers, too (for a particularly nice example, see Collier 1990). On the other hand, the working philosophy of computationalism has become the basis of the bulk of cognitive sciences (e.g. Shapiro 1995). In all quarters one may nowadays hear scholarly debates on "physical reductionism", "monism", "physicalism" and many other labels which pertain to essentially the same thing: that cognition (and various phenomena associated with it, including the apparent temporal asymmetry) is, in principle, explicable in physical terms. That we are still far from such an explanation, is certainly unnecessary to elaborate upon. Thus, the project suggested here is neither non-physical nor easy!

We notice that this still represents one-asymmetry approach, a sort of a cousin to the Acausal-Particular approach. However, the asymmetry is located in the different place from the one in Acausal-Particular approach favored by Price. **Very roughly** speaking, we need information theory and cognitive science rather than quantum gravity or even the "Theory of Everything" (which presumably, although Price remains silent on the issue, determines nature of the initial low-entropy conditions necessary for operation of the Acausal-Particular mechanism).

What are the additional benefits of this project, beyond a novel look at the explanandum of the thermodynamical asymmetry? We have already seen some of them: dropping the *ceteris paribus* clause, for instance. We are now free to state that entropy is always high in by far the predominant part of everything that exists. Thus we avoid "a surprising consequence of the one-asymmetry view" (Price 2002b): the fact that Boltzmann's statistics–being based upon temporally symmetric probabilities–implies high entropy in the past as well as in the future. And we avoid it in a natural and simple manner, which Boltzmann has endorsed himself!

However, the greatest advantage comes from possibility of connecting to cosmology, and especially contemporary currents in quantum cosmology. This is achieved without much further effort which the Acausal-Particular approach necessitates. From Bruno who argued for innumerable worlds by using a specific form of the principle of plenitude to Hume (and his "innumerable worlds botched and bungled") to Linde, Vilenkin and other modern cosmologists, as well as some respected contemporary philosophers (Nozick 1981; Smart 1989), people by and large did not take this issue so lightly and casually. There are several different approaches which all lead to the conclusion that what we perceive as our cosmological domain is just a minuscule fraction of everything that exists (cf. Linde 1986, 1990).

3. CONCLUSIONS

We conclude that a generalized Boltzmann-Schuetz or Acausal-Anthropic approach may be able to account for the perceived thermodynamical asymmetry at least in the same degree as the other approaches explicated in the recent literature.

An enormous additional benefit comes, of course, from being able to account for other anthropic coincidences (or 'fine-tunings') within the same conceptual framework received from the rapidly developing ideas of quantum cosmology. Further advantages include a connection with the latest thinking in quantum cosmology (incorporating the idea of the multiverse), dropping of the *ceteris paribus* clause in specification of the default thermodynamical condition, better accounting for thermodynamical counterfactuals and obviation of necessity to double-deal with cosmological data. At the same time, many of the virtues of the Acausal-Particular approach are retained in the Acausal-Anthropic picture.

Future behavior of the universe is rapidly becoming a recognized and legitimate target for "everyday" scientific work, and less and less an arena for wild speculation and "grand principles" (Oppy 2002). The nascent discipline of physical eschatology (Adams and Laughlin 1997) has already reached many interesting results, and it is highly misleading to present contemporary astrophysicists as ignorant about the subject as their colleagues in the time of Boltzmann or Haldane or Gold. According to unequivocal conclusion drawn from these empirical developments, the asymptotic final state of our cosmological domain (or "universe") will be one of extremely dilluted matter and extremely high entropy.

Acknowledgements. This manuscript has benefited from the technical help of Vesna Milošević-Zdjelar, Olga Latinović, Nick Bostrom, Saša Nedeljković and Milan Bogosavljević. The author acknowledges support of the Ministry of Science, Technology and Development of the Republic of Serbia through Projects #1196, "Astrophysical Spectroscopy of Extragalactic Objects" and #1468, "Structure and Kinematics of the Milky Way".

References

Adams, F.C. and Laughlin, G.: 1997, *Rev. Mod. Phys.*, **69**, 337.
Albert, D.: 1994, *Brit. J. Phil. Sci.*, **45**, 669.
Albert, D.: 2000, Time and Chance (Harvard University Press, Cambridge).
Boltzmann, L.: 1895, *Nature*, **51**, 413.
Boltzmann, L.: 1964, Lectures on gas theory, translated by S. G. Brush (University of California Press, Berkeley).
Brillouin, L.: 1962, Science and Information Theory (New York: Academic Press).
Collier, J.: 1990, in Information, Language and Cognition: Vancouver Studies in Cognitive Science, ed. by P. P. Hanson (Oxford University Press, Oxford), p. 390.
Dicke, R.H.: 1961, *Nature*, **192**, 440.
Dirac, P.A.M.: 1937, *Nature*, **139**, 323.
Dirac, P.A.M.: 1938, *Proc. R. Soc.*, **A338**, 439.
Dirac, P.A.M.: 1961, *Nature*, **192**, 441.
Eddington, A.S.: 1931, *Nature*, **127**, 447.
Kutrovátz, G.: 2001, *Open Systems and Information Dynamics*, **8**, 349.
Lieb, E. and Yngvason, J.: 1999, *Phys. Rep.*, **310**, 1.
Linde, A.D.: 1986, *Phys. Lett. B*, **175**, 395.
Linde, A.D.: 1990, Inflation and Quantum Cosmology (Academic Press, San Diego).
Lloyd, S. and Pagels, H.: 1988, *Ann. Phys.*, **188**, 186.
Nozick, R.: 1981, Philosophical Explanations (Harvard University Press, Cambridge).
Oppy, G.: 2002, *Philo*, **4**, (http://www.philoonline.com)
Pagels, H.R.: 1998, in Modern Cosmology and Philosophy, ed. by J. Leslie, (Prometheus Books, New York), p. 180.
Poincaré, H.: 1946, The Foundations of Science (Science Press, Lancaster).
Price, H.: 1996, Time's Arrow and Archimedes' Point (Oxford University Press, Oxford).
Price, H.: 2002a, *Brit. J. Phil. Sci.*, **53**, pp. 83.
Price, H.: 2002b, "Burbury's Last Case: The Mystery of the Entropic Arrow," forthcoming in Craig Callender, ed., Time, Reality and Experience (Cambridge University Press, Cambridge).
Smart, J.J.C.: 1989, Our Place in the Universe: A Metaphysical Discussion (Blackwell, Oxford).
Tegmark, M.: 1996, *Found. Phys. Lett.*, **9**, 25 (preprint quant-ph/9603008).
Treumann, R.A.: 1993, *Astrophys. Space Sci.*, **201**, 135.
Uffink, J.: 2001, *Studies in History and Philosophy of Modern Physics*, **32B**, 305.
Uffink, J. and Brown, H.: 2001, *Studies in History and Philosophy of Modern Physics*, **32B**, 525.
Wiener, N.: 1961, Cybernetics (John Wiley and Sons, New York).
Zeh, H.D.: 1992, The physical basis of the direction of time (Springer Verlag, New York).