22: Origins and Profound Ramifications of Irreversibility

"...we described some difficulties in the microscopic theory of irreversible processes. Its relation with dynamics, either classical or quantum, cannot be simple, in the sense that irreversibility and its concomitant increase of entropy cannot be a general consequence of dynamics. A microscopic theory of irreversible processes will require additional, more specific conditions. We must accept a pluralistic world in which reversible and irreversible processes coexist. Yet such a pluralistic world is not easy to accept."[28]

"There can be no doubt that irreversibility exists on the macroscopic level and has an important constructive role, as we have shown... Therefore there must be something in the microscopic world of which macroscopic irreversibility is the manifestation."[29]

We have considered the previous attempts to explain the origin of irreversibility. They have all failed. But we persisted because we knew there had to be a "manifestation" at the submicroscopic level.

Boltzmann's investigations considered all possible collisions of molecules in a gas. From this he was sure that his 'H theorem' proved that a distribution of molecular velocities would ineluctably be driven to the Maxwell-Boltzmann distribution. But in fact he had only shown that this distribution is indeed associated with equilibrium conditions.

The number of molecules with component velocities in each of three-dimensional directions remains unchanged after each collision except that they are reversed – the epitome of a reversible interaction. There is no number of completely elastic collisions that changes the distribution of relative velocities of molecules in a gas by one iota. Nor did he shed light on how thermal radiation arises in a thermodynamic system.

Einstein's derivation of the Planck distribution of blackbody radiation associated with thermodynamic systems in equilibrium failed in a similar way to shed light on irreversibility. Although demonstrating that the resulting distribution would remain compatible with the Maxwell-Boltzmann distribution by means of momentum transfers to the kinetic motions of the molecules in the system, he did not use his own relativistic Doppler formula in this endeavor, and because of that simplification he failed to identify a source of irreversibility.

Statistical mechanics addresses the combinatorics of permutations that are inevitable concomitants of random distributions. Clearly there is an irreversible tendency to distribute an increasing amount of the total energy among more and more component particles. Clearly there are many more ways for particles to possess small portions of the total amount of energy than there are for them to possess larger portions of the total amount. But this does not in any way suggest mechanisms by which these tendencies arise. The discipline is based exclusively on likelihood and is left vulnerable to suppositions of possibilities that, for example, all of the molecules of air in a room could end up in one corner of that room defying the conservation laws. There is physically no way for that to occur.

root causes of irreversibility at the submicroscopic level

Virtual 'reversible' behavior is associated with slow motion. There is very nearly complete reversibility when pistons move slowly enough. With rapid motion second order effects begin to become apparent and with them, irreversibility becomes a measurable reality.

There is a time-honored adage that all of the laws of physics at the submicroscopic level are reversible. They aren't. With the advent of Einstein's relativity and quantum mechanics, any excuse for believing that went away. The development of those theories at the beginning of the 20th century began what is denominated 'modern physics'. And with it the laws that describe submicroscopic behavior changed forever. Whenever particles and radiation interact, that interaction is irreversible. The impact is miniscule on a single interaction, but it is unilateral and cumulative. The interactions between particles and radiation provide the mechanism whereby the redistribution of energy is increasingly spread among more and more of the constituent particles of a thermodynamic system.

We have seen that there is incompatibility of the conservation laws for kinematic interactions of particles and those same laws associated with radiational interactions. The expression for the conservation of energy of a particle is nonlinear with respect to the expression for the conservation of momentum of those particles. There is on the other hand a linear relationship between conservation expressions for a photon of radiation and that difference is the root cause of irreversibility. An interaction be-tween particulate matter and ra-diation inevitably results in irreversible behavior on that account.

entropy at the submicroscopic level

The descriptive facts of entropy link it directly to the concept of irreversibility. Now since we have identified irreversible interactions that occur at the submicroscopic level of our reality, we must show that this behavior is in fact the reduction of entropy to the submicroscopic level in order to satisfy our scientific reductionist agenda.

First of all entropy demands that energy flow from the higher to the lower energy segment of a system or combined systems. It is only through the mediated or scattering interactions of radiation with the particulate aspect of systems that that happens. Elastic collisions of particles can never transfer energy out of the particulate segment of a system, nor can they even change the distribution of permutations of the energy among the component particles. One particle takes on the energy of another with no significant change whatsoever in the total distribution of energy in the system nor of its permutations.

However, with the mediated interactions resulting from radiation exchanges, the excessive energy of one molecule relative to that of another is reduced in the exchange. This results in the two molecules having more nearly similar amounts of energy and both of them having less than that of the emitting molecule. This sharing of energy does, in fact, produce the increase in permutations involving smaller amounts of the total energy just as statistical mechanics has suggested must be the case with an associated increase in entropy. Thus we have identified the specific mechanism for bringing this about.

The mathematical combinatorics of statistical mechanics merely describes the results of irreversible redistribution of permutations of the allowed energy allocations among particles. But again there is in that discipline no attempt to explore the mechanisms by which the redistribution occurs.

Einstein's treatment of the quantum theory of radiation elaborates how energy stored in molecules is transferred to the radiation segment so that rather than being locked up within the particulate segment, it is redistributed in transit to the radiation distribution. But there is no demonstration of irreversibility here. The photons of radiation emitted by either of his defined methods are assumed to be capable of adhering to particulate matter again with only a reversible classical momentum exchange between segments. The treatment is probabilistic so that the mechanisms whereby exchanges occur are obscured from scrutiny.

This is where clarification of Einstein's disagreement with Walter Ritz concerning the origin of irreversibility could have had a significant impact on his treatment. Ritz saw the distinction between retarded and advanced wave solutions to Maxwell's equations as a cause of irreversibility. He was close. So in the end, although having made a major step forward, Einstein left the issue of irreversibility unresolved. It is resolved by the details of the mechanism whereby only certain exchanges are allowed, and these happen to be irreversible.

heat at the submicroscopic level

Exclusive attribution of 'heat' to molecular motions is misguided in as much as being hit by a fast particle would not feel 'hot'. It would probably hurt like being hit with a small rock at high speed. Being irradiated by high frequency radiation burns – like being burnt by fire. So why is radiation not a major part of the answer to "What is heat?" It is in fact the major aspect of any correct answer in this regard.

We acknowledge that entropy is associated with the transfer of heat' from a system with the most heat to the one with the least heat; it is radiation that does that, not particle collisions. What occurs at the submicroscopic level traces directly to 'heat' it should.

closing loops in the models of submicroscopic behavior

We mentioned that the major attempts to model submicroscopic behavior failed to close all the loops so that the veracity of every attempt was in question. In closing those loops there is the transfer of energy across boundaries of molecules (particles in general) transferring energy and momentum to radiation. This occurs in the mediated exchanges of photons of radiation between molecules. This, and not elastic collisions is what brings about the Maxwell/Boltzmann distribution of particulate energies. Elastic collisions only maintain it.

The transfer of energy and momentum to particles happens as a result of scattering of radiation by charged particles as well. In this way the energy of high frequency radiation is transferred to particles as a part of the process of redshifting in thermal media. This is the process of thermalization that brings the thermal radiation to the stable blackbody form.

Figure 22.1 illustrates the mechanisms that produce the necessary and sufficient conditions for the respective distributions of energy. If they are not matched, then an adjustment occurs naturally as a part of the loop closure that initially introduces and thereafter maintains a system in equilibrium.

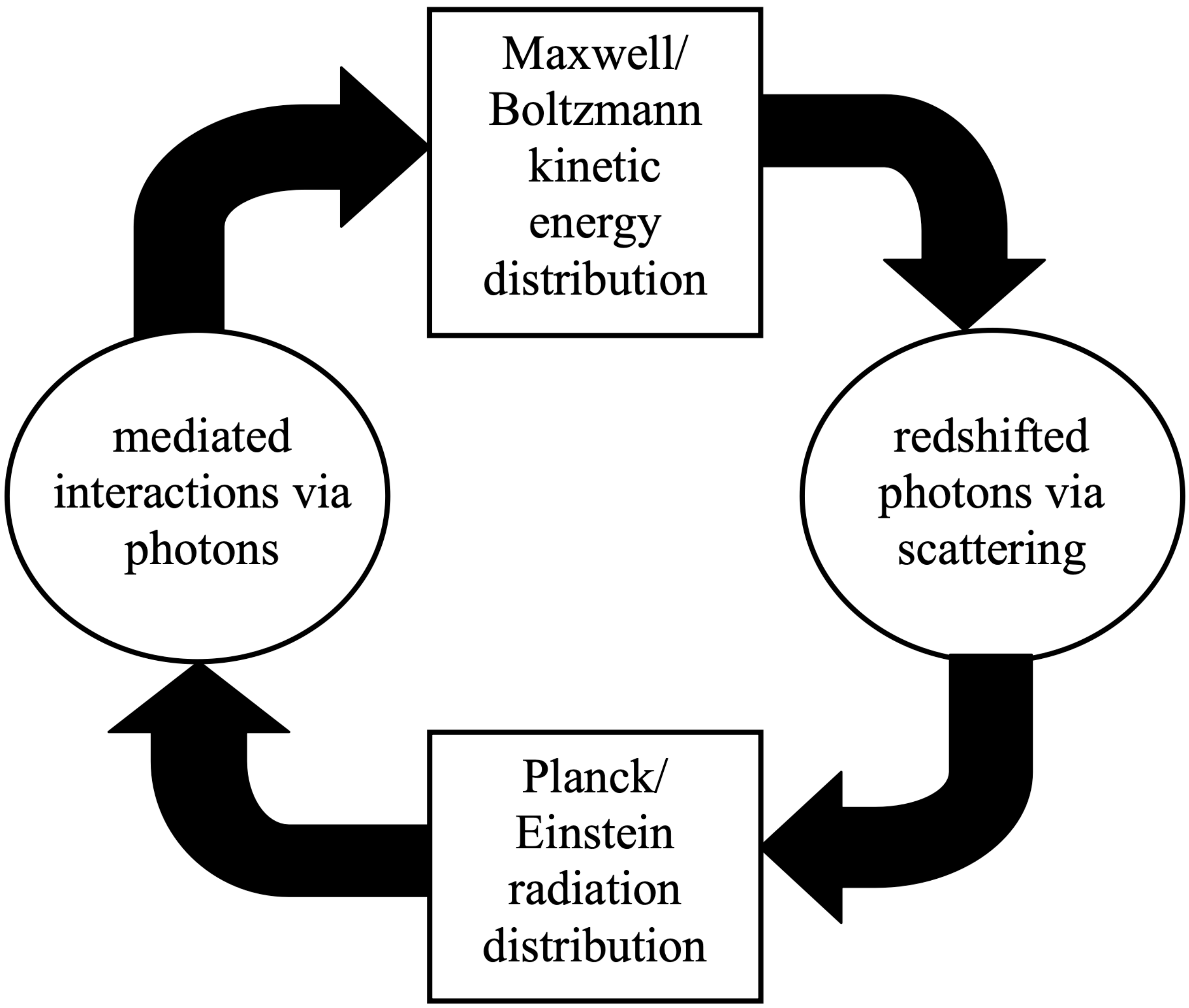

Figure 22.1: Energy distributions being equalized by irreversible processes that drive a system to equilibrium

closing loops at the top level of our universe

But we have not addressed the whole story. There is a universe ‘out there’ that is in a dynamic stasis maintained by the opposing forces of gravity and thermodynamics. Rejecting the ‘astro-physical trend’ as an origin of irreversibility does not eliminate high level macroscopic processes from consideration in discussions of thermodynamics.

Entropy is sometimes interpreted as the level of disorder of a system, or that part of a system that cannot be used to produce physical work. In another sense, entropy is concerned with the amount of information required to describe a system. A disorganized system requires more information to describe it accurately than does an orderly one. The affirmation that entropy can never decrease implies that the requisite physical description of a system cannot be reduced, i. e., information cannot be destroyed.

And yet, black holes for which there is undeniable evidence seem to do just that. An adage that is on a par with the no free lunch maxim associated with the second law of thermodynamics is that ‘black holes have no hair’. This is because a black hole involves no subtleties of description; there is their mass, their electronic charge, and their rotation – nothing more. What this means is that if a thermodynamic system with considerable entropy were to be swallowed by a black hole, the entropy of that system would virtually disappear and entropy of the global system that includes the black hole would decrease.

The thermodynamics of black holes is a subject of some interest to the physics community on this account. We will not proceed further into this area of discussion, but it is an interesting area the reader may wish to investigate further. A way out of this dilemma as it has been presented has seemed to be Hawking radiation by which a black hole could eventually effervesce itself away over a period of time of on the order of 10^{85} years. But... during the hiatus?

Be that as it may, we now know of gamma ray bursts with energies so great that they recreate conditions that emulate what has been attributed to a ‘big bang’ origin of the entire universe. More recently even more direct evidence of black hole eruptions has been obtained.[30] It seems reasonable to assume that these eruptions are indeed that of black holes, spewing forth the primordial hydrogenous plasma of the intergalactic medium. At the temperatures prevalent during gamma ray bursts thermonuclear processes occur whereby the 24% helium by mass is maintained as a ubiquitous constant in mass distributions throughout our universe.

The conversion of hydrogen into helium results in the generation of high energy radiation as a part of balancing conservation equations. In fact, as described by Bonn, this amount of hydrogen conversion would produce a radiation energy density throughout the universe of ρ_{rad} as follows:

$$\rho_{rad} = 4.169 \times 10^{-13} \text{ ergs per cm}^3$$

This is precisely the amount of energy per cm^3 that is currently observed in the microwave background radiation. This cannot be a coincidence. These are simply the manifestly observed facts of our universe.[31] In figure 22.2 we reproduce a diagram from Bonn (2011) illustrating the loop closures of phenomena at the highest levels of a complete description of our universe. This universe is obviously not static, nor can it be represented by an the invalidated ‘steady state universe’ model. But it is in a ‘stationary state’, meaning that at the highest-level nothing changes. People come and go, planets come and go, even stars come and go, and galaxies, and even black holes but the universe is here for the long haul. There is no ‘astrophysical trend’ as a demise of the universe as a whole.

the big picture with regard to irreversibility and entropy

Irreversibility and entropy are major concepts concerning the phenomena we observe in the universe we inhabit. They are inextricably linked. One implies the other, but they are not

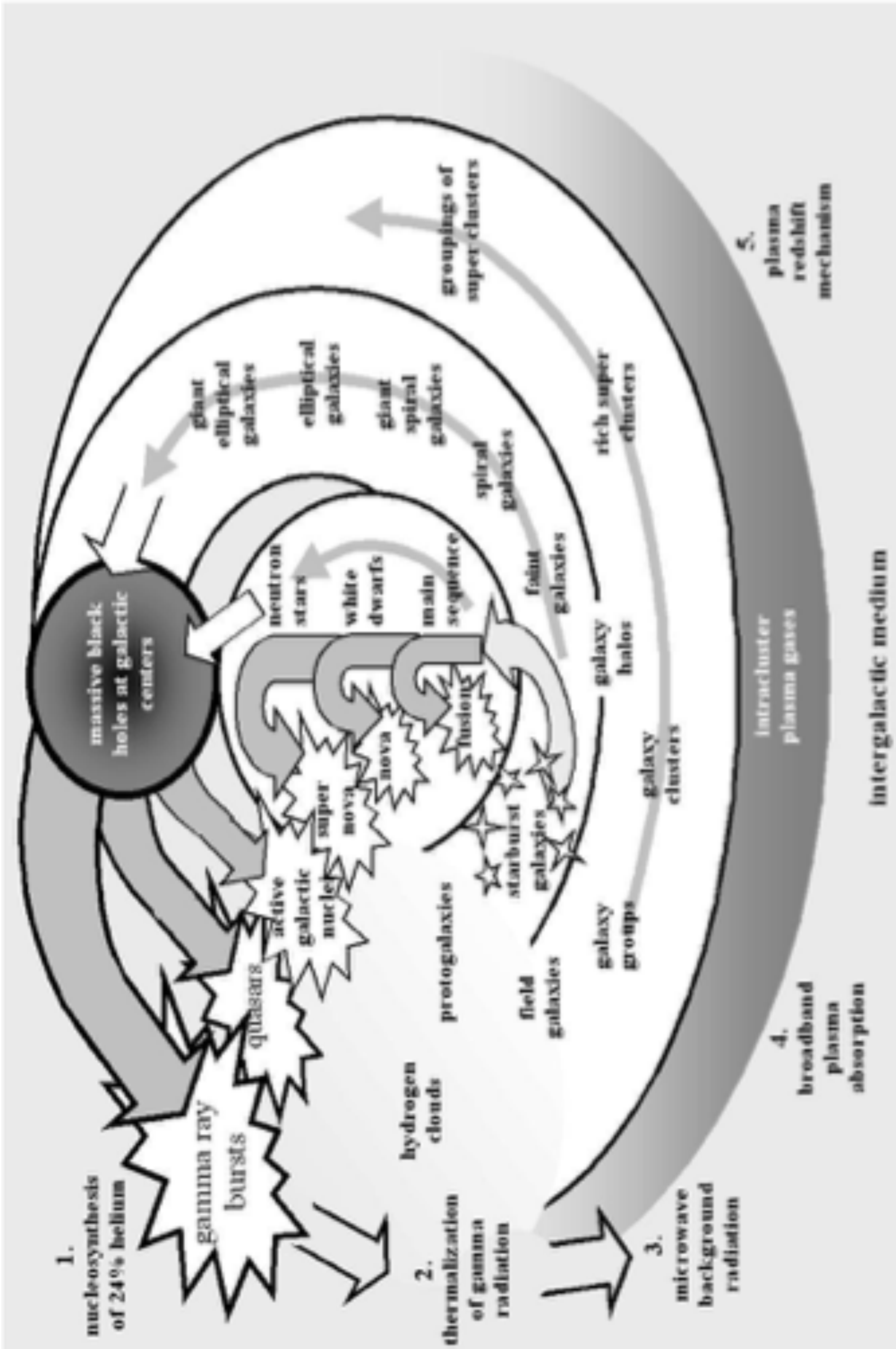

Figure 22.2: The universe whose stasis is maintained by loop closures

equivalent. Irreversibility is a low-level concept that most accurately applies to individual interactions; interactions can either be reversed or they cannot. Entropy on the other hand applies most specifically to thermodynamic systems as a whole. We have discussed the individual interactions whereby irreversible behavior makes its entry. But what is the associated story for entropy from a perspective of what occurs at the highest level of our universe?

The entropy of any system must somehow drop to near zero if it is swallowed by a black hole. But then what happens with the subsequent eruption of that black hole, whether a primordial universe-in-a-pinhead gigantic blackhole with a one-time-big-bang or with a gamma ray burst that signals a somewhat smaller event, entropy proceeds to (once again) continuously increase. Facts now seem to reveal exactly that latter scenario, where from a universal perspective overall entropy decreases significantly in a first phase but, may very likely once again re-instigate continuous increases per expectation. All of this is a direct affront to what has been accepted as the undeniable facts associated with the second law of thermodynamics with entropy never decreasing. Of course the entropy of any system we could observe in our mundane world would always continuously increase.

The submicroscopic processes associated with gravitation whereby entropy might actually decrease when a system collapses into a black hole are not addressed here, because that has not been a concern of ours. Nor will we concern ourselves with it here. But those phenomena, whatever they might be, are the means whereby the outer loop is closed in any model of a stationary state universe. Entropy, like everything else, has its ebb and flow. A similar explanation is required of any consistent explanation of the standard cosmological model.

In any case we have solved the mystery of the origin of irreversibility and the ineluctable increases in entropy. That origin is in the irreversible submicroscopic processes that do in actual fact occur as we have shown. The ramifications of the tiny effects associated with irreversible behavior are indeed profound.