Reopening the Book on Black Holes[1]

The ugly specter of a black hole is somehow quite enchanting to physicists in this new millennium, in part I suppose this is because they mirror conditions perceived by many as pertinent to our ultimate womb and doom – a narcissistic perspective that has seemed to beckon physicists for well over forty years now. That the geniuses of Hawking and Penrose have been greeted with such enthusiasm is due in large part to priorities they have assigned to these elusive objects of their unique insights – insights involving the inner workings of what have been perceived as seething vortexes of matter. But the most salient features of black holes can easily be understood by virtually anyone – even those with minimal backgrounds in the sciences. Black holes had been anticipated hundreds of years ago by a member of the clergy who stated in his paper presented to the Royal Society back in 1783 that escape velocities from an extremely massive object could exceed the speed of light under prescribed conditions. Thus, a lowly holy man augured prophetically that "all light emitted from such a body would be made to return towards it."[2]

For a particle of mass *m* to escape from a more massive body of mass *M*, the kinetic energy imparted to it must involve a velocity larger than the 'escape velocity' v_s in order to overcome negative gravitational potential energy so that:

$$\tfrac{1}{2}\, m\, v_s^2 \geq \mathrm{G}\, M\, m \,/\, r,$$

where G is the gravitational constant 6.7 x 10^{-8} erg-cm/gm^2, *r* the distance of *m* from the center of gravity of the object of mass M when it possesses the velocity v_s. Since the upper limit on achievable velocities is that of light, we have:

$$r_s = 2\, \mathrm{G}\, M \,/\, \mathrm{c}^2.$$

where, c is the speed of light, 3.0 x 10^{10} cm/sec, and r_s the *Schwarzschild radius* to the 'event horizon' from within which even photons of light could not escape. This formula derives from classical analyses as shown, but is compatible with Einstein's gravitational model. Thus, if an object were sufficiently dense, it would be invisible. That is, if it were smaller than its Schwarzschild radius r_s, it could not be observed other than by external effects of matter being dragged to its doom and a minor associated effervescence. Let us ignore for now the ability to 'observe' it by means of its gravitational 'field,' i. e., how do these fields escape if electromagnetic ones cannot? How fast do gravitons move? Etc..

Thus, Newton's formulation of gravity in which forces act through the center of mass of an object reduces the complexity of calculating the Schwarzschild

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2 Although John Mitchell was indeed a member of the clergy he was also a polymath of no mean talent who had given up a post as professor of geology in Cambridge in 1764. (Gribbon, 2002, p. 293.)

radius of an event horizon from beneath which no light can escape to mere child's play. The minimum mass that is required by evolving stellar masses if they would attain unto this status is similarly easy to determine as we will see. It is about two solar masses. We now know also from Hawking's and Penrose's extensive work that there are no particular subtleties with respect to black holes; they must all be 'standard' inasmuch as distinguishing characteristics outside their 'event horizons' can only be their unique mass and angular momentum – net charge not being much of a possibility. (Thus, "Black holes have no hair" is every bit as sophisticated as, but certainly no more so than, the statement, "There is no free lunch.")

But despite such dispassionate determinations of their simplicity there is still a tremendous amount of conjecture pertaining to internal structures – or lack thereof – with popularized conceptions promoted by those who should know better dictating an associated spacetime singularity. That general relativity, whose equations cannot even be solved for trivial planar cases, implies that spacetime may be "pinched off" in the vicinity of a black hole is a factal of which I will deny myself other than an amused awareness (for reasons to be discussed in more detail below). From the outside, however dark, a black hole is just an object. There persists this notion that having once sunk beneath its Schwarzschild radius all its mass would have been swallowed into a single mathematical point never to return, although we have been told by the same individuals that our current universe emerged (or is just about to emerge) from beneath just such a shroud. It's hard for me to distinguish just what should be believed before breakfast. From such fanciful theorizings come fantasies of "worm holes," Einstein-Rosen Bridges, "quantum foam," and time machines. Notwithstanding these absurd (Oh, did I say "absurd?") presumptions, Hawking has shown that given 10^{85} years (regrettably somewhat less than a picturesque googol) black holes would eventually effervesce back into visible matter. And as usual, I'm skeptical – not of the effectuality of his effervescence which seems reasonable mind you, but of a need for it in this case.

We are all aware of the frequent news flashes claiming repeatedly to have confirmed the existence of black holes. It is claimed that there are giant black holes at the centers of many distant galaxies and even our own Milky Way. The galaxy M87 is thought to possess a black hole at its center with a gravitational pull three billion times that of our sun. These "messy eaters" have become the engines of choice for the prodigious energies generated by quasars, etc. Statistical estimates place the number of black holes resulting from collapsed neutron stars at as many as 100 million in our Milky Way galaxy alone. With respect to the news flashes, there is considerable reason to believe that black holes do indeed exist. But on logical grounds I currently have very serious doubts – outside the scope of mathematical games played with general relativity – about their being associated with singularities in spacetime as popularly envisioned. Let us consider that notion.

There is, of course, the minimum mass requirement for astronomical objects that proceed down the thermonuclear ash ladder based on thermodynamic pressures and simple gravitational collapse considerations. There are observationally confirmed stopping off places in the collapse of matter into its densest states. In a penultimate state, an entire massive star may be comprised of a single nuclear blob of juxtaposed protons and neutrons surrounded by an atmosphere of electrons. This structure is known as a "white Dwarf." Quantum solutions for such high Z (proton count) "Hartree atoms" would provide an extremely wide range of orbits for degenerate (as in Pauli exclusion principle) electrons. The inner shells would be constrained well within even their own Schwarzschild radii while the outer shells would be virtually free of gravitational attachments altogether. Such stars are thought to be particularly stable because electron degeneracy that precludes the particles occupying the same angular-momentum-space-spin attributes, would preclude their being packed more tightly such that they would then have to share mutually exclusive allotments as in the shell structures of their more mundane atomic counterparts. Neutron stars are those that fall through this rung on the downward spiral staircase by virtue of exceeding the Chandrasekar threshold of 1.4 solar masses. Exceeding this limit suffices to allow gravity-induced pressures to exceed electron degeneracy forces by increasing temperatures such that thermonuclear reactions that merge electrons and protons into neutrons occur, so that the star plunges to the next rung on the ladder. If the stellar mass is less than about 2.0 solar masses the surface of the neutron star will remain above its Schwarzschild radius. Such neutron stars are now well-known as "pulsars." Those that have been observed have radii of about ten kilometers just safely larger than their Schwarzschild radius of approximately five kilometers. However, stars more massive than this threshold, will eventually disappear. Their collapse is envisioned by many, however, as hounding them like Bill Clinton's tireless detractors even beyond their new-found obscurity. But how can that happen when the mass density must now be determined by neutron degeneracy? It is conventionally thought that processes similar to those whereby electron degeneracy is overcome by gravitational pressures would eventually force neutron stars also to succumb. But this would not occur as soon as the neutron star sank beneath its event horizon – these two phenomena are certainly not directly coupled.

For modeling purposes calculations of gravitational collapse phenomena can be simplified by unrealistic assumptions involving constant densities such that any macroscopic region of a neutron star would have the same density. As compaction proceeds in search of a new compressed equilibrium under such (unrealistic) assumptions, the object would more or less continuously reach higher and higher densities. This process is perceived as proceeding "beyond" the neutron star stage once a black hole is created with an associated abandonment of the conservation of baryons as the trapped heat from the increasing pressure cannot be released. Assumptions appropriate to a neutrino-quark gas are what are inferred and in this form the indivisibility of major atomic components is seen as having finally been lost. In this case the density profile is intuited to proceed down the path to singularity. Collapse would force density toward infinity more rapidly than the radius tends toward zero. The tremendous gravity would turn surface mountains into submicroscopic ripples, smoothness, then oblivion. One might argue thus that for matter comprised of point particles distributed evenly as in a gas in a spherical gravitational well there is no reason why, if degeneracy gives way to the ineluctable pressures of gravity, sufficient matter should not collapse indefinitely. So singularity might seem to be inevitable such that black holes would become point particles of extremely large mass – the big bang happening in reverse! Such fantasies of thought engage even the brightest notwithstanding the established facts to the effect that whether black holes collapse to singular points or hover forever just beneath their event horizons could never be scientifically distinguished unless there were some possible consequence that could be observed – that there isn't. But singularities are the stuff of dreams for string theorists who anticipate so many large point particles they don't know what to do with them all. That the truth might forever be shrouded from falsifiability by experimental and even theoretical means has never been an obstacle to such theorists; it may even subconsciously be acknowledged as an advantage. But let's just consider the simplified model of matter involving uniform distributions of infinitesimally small point particles. How legitimate is it?

It is true that the divergence theorem legitimizes the assumption of all symmetric mass distributions acting *as though* (but certainly not *as in actual fact*) operating through a *single point* at the center of mass of the distributed body for gravitational consideration. It is also true that the Schrödinger equation that nailed down the behavior of electronic matter did assume *point particles*, but that treatment used little more than broad analogies. It turns out that solution of these equations involving the very same *point particles* results in their inevitably being *smeared out* as mere probability clouds with absolutely no credentials for existence at a single point at any particular time. The validation of these solutions by experiment is legend. But despite success in the laboratory, the derivation of the equation itself and the assumptions that went into it remain entangled in hocus-pocus. Notice also in this regard that although it assumed that attractive forces of the nucleus act through a single point this is *only* in the sense of the divergence theorem, and that in cases with more than a single proton it obviously cannot actually *be* a single point other than as the abstracted center of mass. So… so much for those lame arguments. If particles are, in fact, as most theorists maintain, *point* particles, one might ask why protons and neutrons do not ultimately just collapse into their own gravitational potential wells. Their Schwarzschild radii are on the order of $r_s = 5 \times 10^{-19}$ cm, but that is one hell of a lot bigger than a *point* particle and would provide a very dangerous environment for a particle that dashes about violently within strict confines! It would be like a man in an Edgar Allan Poe nightmare with a manhole-sized abyss in the middle of his dark cell – simply a matter of time. The answer to this dilemma is simple if one accepts data from the real world. The theoretically and experimentally inferred radii of their associated clouds exceed 10^{-13} cm. They are alas, despite theoretical arguments to the contrary, like neutron stars of less than several solar masses, everyday planets, people, baseballs, and M&M's, just too damn big to fit within any such confinement as their own event horizon!

Mass and charge are concepts that are not all that well defined other than with respect to their effects on apples and cat's fur, and I will not make conjectures here other than in that same time-honored tradition. In figure C1 there is a set of curves representing the density of nuclear charge as a function of radius for a few garden variety atomic nuclei as determined by electron scattering methods appropriate to this endeavor. You will notice that all these nuclei are too big to fit into their Schwarzschild radii and I would wager that there is little danger of component quarks falling into theirs either. It is inherently reasonable to assume there are nearly identical distributions of mass and charge in such cases. There is, of course, the slight increase in the percentage of the uncharged neutrons relative to protons with increasing atomic number, but otherwise the curves in figure C1 are much more like what one should expect for mass distribution of elementary nuclear particles than for the soup model described above. But again, when dealing with units of miles or kilometers such fuzziness about the edges would have been on the order of 10^{-20} smaller – in fact the mere "ripples" of which we spoke earlier.

But before we talk too glibly of singularities, for which such fuzziness becomes huge, let's consider effects of such fuzziness on the ultimate collapse of matter into the abyss of its own black hole.

When electron degeneracy breaks down in the collapse into a neutron star and in proceedings thereafter (if there is, in fact, a thereafter), is it reasonable to assume that the generic aspect of a probability distribution associated with the building blocks of matter would be drastically altered also? And if the structure were to be so altered,who is to say it would be to a distribution along the lines of a simplistic soupy model? Does it seem reason-able to anyone capable of coherent thought on the subject that Quantum organization would be abandoned at this point? Would God have thrown up his hands at that point and said, "Oh, I never thought about that?" I don't think so. Be aware that no one knows correct answers to such metaphysical questions since we have no snap shots from the supposed *bang*, sometime after which neutrino degeneracy is praised, but I don't think that matter in black holes would turn to soup. Occam's Razor would surely take a swipe at that assumption, and I see no reason to fight such a weapon myself. There is a continuous record of soupy models of matter having repeatedly been replaced by previously unsuspected models involving a more organized structure as heady endeavors provided additional information about phenomena associated with submicroscopic matter. In particular there would have been every reason to believe that a stable hydrogen atom would prove to be an utter impossibility. But nature has vehemently insisted on particle indivisibility that precluded an electron soup from spiraling into a proton soup and their two charges dissipating in a sayonara swan song as they disappeared altogether into however romantic a unity in an electromagnetic vortex. The forces were there for exactly that eventuality, but… it turns out that there are *other* forces than electromagnetism and gravitation that have precluded that. How could tiny nuclei contain multiple protons whose inverse square repulsion would skyrocket these juxtaposed objects to the opposite ends of the universe? But of course the nuclear attractive and repellent forces involving lower levels of fundamental particles enforce comfort distances using forces of much higher order than an inverse square relationship to preclude such disasters. No one could have anticipated the nature of these additional forces until sufficient data was available. Now there's a concept! All the high-powered deductive reasoning on then current models was laughably insufficient to scale these peaks of knowledge. It has been our scientific heritage that by employing inductive methods we do systematically scale such peaks, and ultimately smile down on our former ignorance. But there seems currently to be little inclination to such humility on that account or patience for just plain "finding out!"

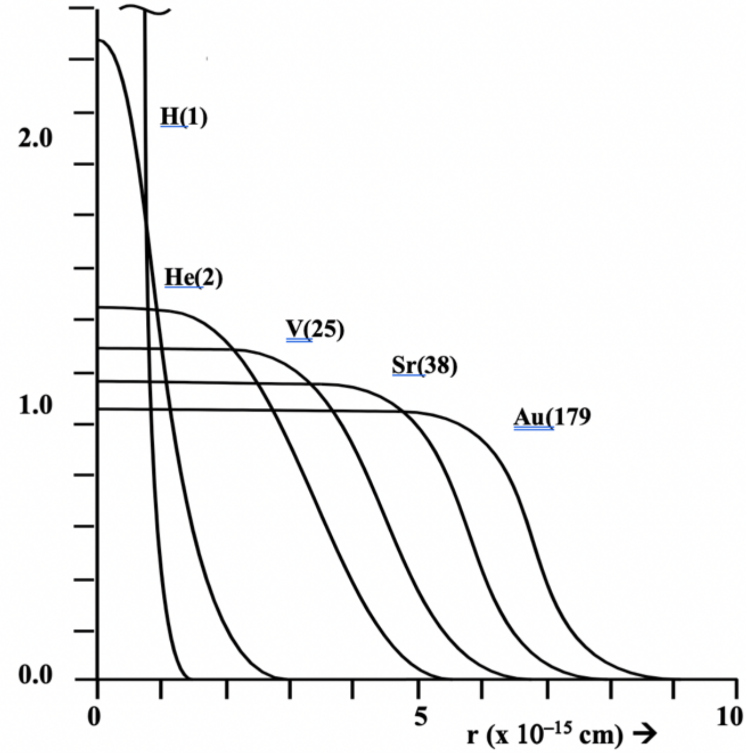

Figure C1: Nuclear charge densities

It should be noted that nuclear forces although symmetric do not involve inverse square relationships and that, therefore, the divergence theorem that is so essential in the context of black holes no longer even applies in that domain. Certainly as a neutron star becomes more massive by accretion, more significant gravitational forces become increasingly pertinent to any quantum solution. However, it seems a bit rash to predict that a tiny force, that in domains for which we have actual data pertaining to it being smaller by a factor of less than 10^{-40} than another, should prematurely be declared the victor based on interpolations from an ultimate dearth of data. Never mind the fact that G. W. Bush achieved as much in Florida – that was third world politics not heady science.

To assume that an inverse square law attractive force could suck objects into a singularity in the real world when those same objects repel each other by much more extreme forces is a bit…well…extreme! Much more likely it seems to me is the possibility that increasingly massive stars would go quietly to that good night behind the curtains of their event horizons. As a neutron star's mass attained several solar masses, whether initially or eventually through gradual accretion, whatever associated increase in volume it achieved by adding particulate matter would be dwarfed by more dramatic cubic increases in the volume increases due to its increased Schwarzschild radius. So it would seem reasonable to assume that the object might indeed eventually sink beneath its event horizon. But it seems unlikely without further evidence that it would proceed from such a gradual demise directly to the hidden singularity too often propounded as a necessary consequence. Why would it? No one now, nor will anyone *ever*, have empirical evidence of what happens beneath an event horizon other than that of our segment of the universe, because alternative inner workings of black holes must forever remain moot points in accordance with the findings of Hawking and Penrose. But one thing seems certain and that is that there is so far no adequate justification to conclude that they must proceed in one fell swoop to a mathematical point rather than the externally equivalent alternative! As mentioned, their radii and all other features are fixed independent of their internal workings so why is it scientific to presume such an impossible situation when all possibility of evidence for that eventuality is foregone? This gets back to the meaning of the divergence theorem and the equivalence of any symmetric distribution to one in which all mass is concentrated at a point: That equivalence applies to inverse square law forces and even in that case does not confuse anyone with regard to our sun, earth, and moon possibly thereby being merely mathematical points assigned the given masses. Why is this so-related point so hard to understand?

The neutron star rung in the matter ladder may ultimately arrest collapse altogether – perhaps it's the basement floor itself or the trampoline beneath the trapeze of being! An object's surface may immerse into and beneath an event horizon, but the internal workings of the associated object itself need not undergo transmogrification on that account. It is my guess that it will remain the embodiment of the very same generic rung on the ladder notwithstanding its understandable new shyness. It is obvious that we know too little about neutron stars other than pulsar radiations we attribute to them. What is the structure of a neutron star – whether it involves 1.0, 1.4 or 5.0 solar masses? Whatever it is, it must involve a lump of neutrons whose organization is determined by quantum considerations pertinent to a fermi gas trapped in a tremendous gravitational well. Complementarity suggests that classical expressions for energy of a neutron added to such an object of radius r must bear some resemblance to the corresponding quantum mechanically determined value. So $E \approx 4/3\ \pi\ G\ m_n\ \rho\, r^2$, where $m_n=1.67\text{x}10^{-24}$ gm is the mass of a neutron with density $1.67\text{x}10^{15}$ gm cm^{-3}, which is not much more dense than typical neutron stars as one might expect. But now let's consider how a distribution of fermions is affected by increasing temperatures that would accompany additional gravitational pressure. As is typical of quantum solutions, the distribution becomes much broader by skipping energy levels and hopping into extended orbits as implied in figure C2. Only at the temperature of absolute zero Kelvin would such a gas be completely compacted within its minimum radius determined by E_f (the highest compacted energy level). At 10,000 K the distribution would be totally out of any bounds we could associate with complete compaction in any way similar to a soupy model restricted within an event horizon let alone presume it to have collapsed to a mathematical point. At hundreds of millions of degrees – reasonable temperatures for such ensembles – associated neutrons would exist throughout a vast cloud much larger than the event horizon. Nor would this involve impossibilities of faster than light travel; in quantum solutions there is no sense in which probabilities of being here or a light-year away involve the concept of 'escape velocity'. And since a high-energy neutron has a definite propensity for disintegrating and/or interacting with other matter no matter where it is found in the vicissitudes of its 'travels', this scenario involves something totally *other* than being 'confined to a black hole'. These real-world considerations are why the contents of such objects cannot be dismissed like debris shoved down a garbage disposal. High-energy neutrons light years away from the center of the neutron star or black hole would disassociate atoms, create deuterium in collision with plasma protons, and ultimately create helium and traces of heavier elements far removed from the hole itself. In short, this would ape big bang behavior. The pertinent question is, "How could this *not* happen?"

Being compressed to a Schwarzschild radius is *not* like reaching *Mach one* or *the boiling point*! There is no qualitative new torture awaiting matter at this coincidental (as against universal) threshold as popular thought insists. (For example, scientists are having one hell of a time determining whether our entire universe is beneath or has somehow crawled out from underneath such a shroud. If it made such a tremendous difference, why could we not tell? And if our entire universe escaped its own event horizon as data increasingly suggests to most that it must have a long time ago now according to the standard cosmological model, *how* did it get out?) Internal phenomena might very well reach a state (even if one anticipates some method of circumventing fermi gas restrictions) in which it becomes sufficiently energetic whereby internal eruptions (the next up the Richter scale from supernova) associated with quantum distribution phenomena occur. We may already have observed this at the centers of active galaxies – quasars or gamma ray bursts – about which we have had plenty of Jungian *inflationary* dreams concerning primordial origins. There is no reason to presume that such once-obscured matter might not reappear as a result of internal reorganizations that swells it first back beyond its Schwarzschild radius in a process that might afterwards explode the entire now visible contents back into luminous interaction. Such a process could free all of the trapped matter with no violation of any physical law – freeing the hot neutrons in one gigantic (although not *that*!) big bang from which the rest of all we know about the universe proceeds. There is nothing magical here. This would not involve the spewing forth of iron, gold, Europium, Americanum, or the various other heavy elements of a supernova, but the basic building blocks that have naively been assumed as only *initial* primordial prerequisites of the universe. "Cosmocentrism" propounded by Frank Luger (2000) may be actualized by such rising phoenixes – not everywhere all at once, but all black holes at some point in their maturity so as to maintain an infinite and eternal equilibrium between these sources and sinks of all material existence. It is enough to titillate and frustrate the fantasies of creationists of all ages and scientific persuasions.

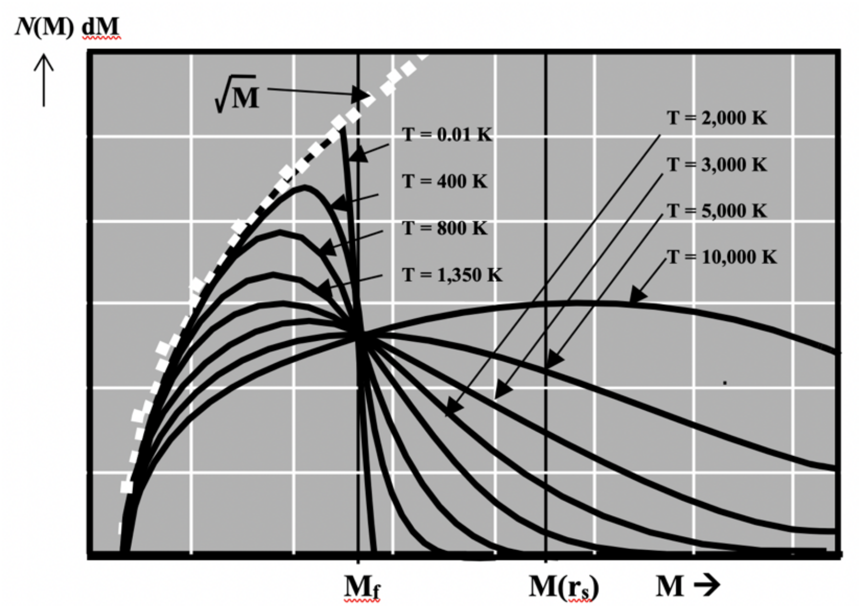

Figure C2: Significance of fuzziness in the mass distribution in a 'fermion gas' of neutrons as would be realized in a collapsed neutron star

I wish I could flap my lips to produce the mellifluous sounds of a Carl Sagan on one of those old Public Broadcasting System *Nova* programs my children used to deplore when I say the following because it expresses the awe-inspiring religious sense in which I feel it. Anyway, getting away from this epiphany, and whether with eloquence or a more characteristic bombasity, here goes: "Nothing says that a book, a mind, or even a black hole, having once been closed, cannot be re-opened."

Afterward:

There would seem to be some level of hypocrisy for those propounding the origin of the universe from what they consider to be a singularity with a "big bang" when these same cosmologists insist on the penultimate death of the material universe into just such singularities. For example, Ed Seidel (NCSA and University of Illinois) states with regard to what he considers to be cosmic "decency laws" that what happens beneath Event horizons must in essence forever remain no one's business such that:

"All singularities within the universe must therefore be 'clothed.'

"But inside what? The event horizon, of course! Cosmic censorship is thus enforced. Not so, however, for that ultimate cosmic singularity that gave rise to the Big Bang."

That is not the introduction to an explanation, but the end of one. And this ultimately is the hypocritical lie to be told – where we find that what is good for the goose in *not*, in fact, good for the gander!

I was recently accosted by an individual who claimed that the universe could not possibly exist in a stationary state because of the multiple levels of fundamental particles, and indeed the 'standard' models of fundamental particles and cosmology have been very purposely, but the author believes illegitimately, linked. I asked the accoster just how he conceived that such a logical structure could imply a temporal origin to the universe. I was told in essence that many, if not indeed *most*, of these particles would have no role if it were not for the big bang where they could conceivably have had some play. It was as though my critic had perceived the universe as a staged production being somehow *directed*; and why would a playwright write a play with specified actors for some of whom there were no parts written. A theatre group that hired actors for which there were no roles would be a madhouse. In such case there should as likely be roles for which there were no actors.

I understood his point. I could tell from whence he came.

However, what did he not understand about the similarity presented by the possibility that black holes might ultimately spew forth matter back into the useful universe just as what is envisioned as having happened with an even bigger bang?

Certainly the high-energy conditions under which these lower levels of fundamental particles have been discovered are realized inside black holes. So just maybe these neutron lumps transform to heavier but similarly structured matter as a next rung on the ladder of material being that retards the ultimate collapse – until it also reaches its own analogy to a supernova. Who knows?

There is a lot we do not know about gamma ray bursts other than that they seem to occur even at the extremities of the visible universe and to be associated with optical galaxies. Very possibly these are the evidence of black holes erupting.