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Prescript

The Astrophysics Lab at U. Chicago organized a conference, a year after his death, in honor of the famous astrophysicist Subramanyan Chandrasekar,. I was visiting in Chicago in that period; my host, Louis Kauffman, offered to pay for all the expenses of the conference, provided I accompanied him and kept him from falling asleep during the more boring lectures. The format was typical : some flattering words hurriedly mumbled in honor of the great Chandra , followed by an immediate descent into an endless preoccupations with research, shop-talk and career enhancement. It's rather narrow-minded and self-centered, but everyone does it, and I'm sure that Chandra himself attended many a conference dedicated to the honored dead in which he spoke only of his own immediate research. Everything I now know about his

life and work comes from the background research I've done for this article, including the excellent biography of Kameshwar C. Wali.

It was quite otherwise at my first serious venture at conference coverage, the Einstein Centennial Symposium of March, 1979, at the Institute for Advanced Study. Then there were many scheduled talks about Einstein himself , (though only Einstein the scientist, not the writer, philosopher or political thinker) .

When I began writing up my report, I quickly found myself confronted by a dilemma: lectures and discussions had been richly scientific, but in some sense, nothing had happened, neither dramatic, admirable ,outrageous n or even embarrassing. There was little to interest anyone who was not an astrophysicist. From the viewpoint of the public , it had been a null event, which was frankly disappointing because Chandrasekar was not a null person; far from it. I could report it frankly, as a null event, just as physicists will publish the results of a null experiment; or I could make something up.

The result is strange: I dare say that these two issues may turn out to be is the strangest Ferment ever assembled. Certainly I have not fallen into the trap of allowing myself to constrained by the factual record, although I have deviated from it only to make the underlying preoccupations clearer. I present the results for what they are worth, merely adding that much of the charm of Ferment consists precisely in the fact that, lacking the resources to spend 4

months on an article, I must continually exert my imagination to make up the deficit.

Note: The series of Cambridge, Massachusetts in the winter of 1964-65 , will be continued after this account

Introduction

"Why not", I suggested, as Lou and I descended into the stairwell of the 57th Street Bookstore, "skip the banquet and just go to the reception?"

Reception and banquet were being maintained in the Quadrangle Club. We were welcome at both, the difference being that the university was asking $35 per stomach for the banquet, whereas the only requirement for the reception was a harmonious relationship with the Galaxy.

Lou wasn't all that keen on going; however, he did want to talk to Roger Penrose. People who follow the fashions on books know of Penrose as the author of The Emperor's New Mind ,one of those big coffee table books about The Everything, The Set of the Everything, and The Set of All the Everythings. Cosmologists have been developing this genre for several decades: Penrose, Hawking, Davies, Pagels, Gribbin, Rees, Tifler, Barrow, Thorne, ...

I've wondered about the title of Penrose's book: did he intend to imply that the emperor's mind is just a fiction like his new clothes? If that is the case, who is the emperor? If he considers himself the emperor - not uncommon in this paranoid age -he wrongs himself, for he possesses a mind, and a very good one

indeed. As anyone with the right qualifications - say two and a half PhD's, can discern just from reading this book!

If, as is apparently the case, he means the computer, then Penrose should have consulted the original Hans Christian Andersen fable, (a fine masterpiece of prose by the way, not like the indigestible stuff the cosmologists are giving us) . There it is the emperor himself who believes he is wearing gorgeous new clothing. If the computer is deluded in believing that it has a mind, then where is the mind in which this delusion is lodged? What the book is saying , of course, is that the computer does not even have a mind which can know that it does not have a mind.....

It wasn't an issue of such importance that I needed to discuss it with the author , but Lou had technical matters to discuss with him. Lou is another accomplished mathematician. His specialty, if that's the right term, is the Theory of Knots. Specialty might not be the right term, since Lou has applied Knot Theory to graphs, circuits, molecular biology, polymer chemistry, quantum theory, quantum field theory, elementary particle and string theories, combinatorics, statistical mechanics, models for melting ice, the analysis of complex systems, logic, algebra, and the role of the laws of form in a universe of symbol and sign.([1])

Roger Penrose's talk that afternoon had been entitled *Singularities and Cosmic Censorship*. A singularity is a situation in which some of the fundamental equations of physics break down : they have no solution, or an infinite solution, or a complex or

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[1] **That should do it**

imaginary valued solution , or, although the equation is supposed to predict a single outcome, many different solutions .

In such situations the problem consists in deciding where to fix the blame: is Nature, or the equations themselves, at fault ? People who have more faith in equations than they do in this peek-and-paw world , will tend to say that something must be going haywire in the cosmos. Those who, (the majority of humanity), hate equations, usually feel that this proves that physics is Godless nonsense and all physicists should be hanged. The truth, as the saying goes, lies somewhere in between.

Hawking and Penrose have developed a compromise position, known as the doctrine of Cosmic Censorship: it asserts that God is a prude. Note that it does not claim that He is Dead; theology has moved beyond physics in this matter. But God knows that we think that naked singularities are obscene and, so much does He love His children , that He makes sure they come covered with underwear.([2]) Whenever we uncover a singularity in His Equations, it always come packaged in a shield (known as a trapped surface), that will protect Causation from its malevolence . A Black Hole is such an evil star; its singular demon , like Lucifer, is trapped permanently in the hell of the Schwarzchild metric.([3])

Penrose honestly admitted that the theorems proven by Hawking and himself in the mid-60's gave no information about the geometrical character of Black Hole singularities: they might be anywhere in space, and not necessarily inside stars.

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[2] **, The Universe's New Clothes?**

[3] **A convenient term for the unpicturable space-time of Black Holes.**

Lou recognized his cue: perhaps another field in which knot theory could play a role! Knot Theory is closely related to Statistical Mechanics, which figures large in recent research on energy exchanges in the immediate neighborhood of Black Holes. Specifically he wanted to talk to Penrose about spin networks, which are connected to all things above.

After a quarter hour's browsing at the bookstore, Lou and I retraced our steps back to the Quadrangle Club. A very clubby place: the appurtenances of clubbiness abound on the territories of all big universities. The crowded vestibules on the ground floor were so over-charged with scientific prestige that I began to fear that some singularities of the sort described that afternoon by Penrose might spontaneously erupt ! ([4]) Unless the gathering generated enough degeneracy to counter-balance the gravity of the occasion.([5])

Once entered upon these premises, I found myself being spun about by the currents coursing through chambers, lounges, lobbies, and the staircases . In keeping with my pose as scientific gadfly, I deemed it my duty to undermine my credibility: through the arousal of appropriate levels of contempt, I might get some of the participants to drop their guard and volunteer revelations they would not give to a worthy competitor-sorry, I mean colleague.

This was no easy task, since I in fact have no credentials in astrophysics, and could not therefore pretend to pretend that I did not know what I was talking about. This led to another , oft-tested,

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[4] **Quote: "If enough stuff gets into a small enough region, then there will be a singularity".**

[5] **An astrophysical joke**

strategy: passing out reprints of a paper on a totally unrelated subject. This did not produce the forests of arched eyebrows I'd anticipated. There were enough persons there so sick to death of talking astrophysics all the time that they welcomed my odd intervention.

It was in this fashion that my perturbed orbit came to rest in a stable configuration around an Indian astrophysicist [6], by name Dr. Varadarajan. Encountering me he assumed a pose characteristic of persons of superior knowledge, staring at me between closed eyelids with amused condescension. I quickly explained to him that I myself was not an astrophysicist, but a rancorous *feuilletonist* **who clings to the fringes of science conferences.**

"So why do you want to talk to me?" he said, acknowledging my presence with something between an eye-twinkle and conjunctivitis: "You may be hoping, perhaps, that I will impart to you some *'wisdom'* **!" The experience of discovering that one has become 5 centuries of the West being put in its place is not to be missed. I forged ahead:**

"Dr. Varadarajan; could I have your opinion about the famous quarrel between Chandrasekar and Eddington?"

Varadarajan's nervous stare hardened ; his eyebrows arched like the hoods of cobras, his vermilion walrus mustache shaking like bougainvillea blasted by the monsoons.

"Don't you go writing about that!! If you take my advice, you will not say anything about Eddington! You journalists are always

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[6] **Or relativist; or cosmologist; a smooth function describes the overlap between distinct regions**

cooking up senseless controversies because you don't know any science! I very much suggest", the 'young man' was on the tip of his tongue, "that you stick to science! Science! Just write about science! Chandra and Eddington were good friends! Why, Chandra delivered two memorial lectures in honor of Eddington in 1983. Stick to science!"

The classic Chandrasekar/Eddington schism had been transformed into the Varadarajan/Lisker tiff. He could not have campaigned more effectively for getting me to write about this matter. He might as well have exhorted a cosmologist to not mention the Big Bang. Astrophysics as we know it was born from the fall-out of the Chandrasekar-Eddington falling-out: its abiding thermal entropy pervaded the conference like the 2.7° Kelvin background radiation across the Cosmos.

In 1929, at age 19, while on board the ship taking him from the intense, colorful, pungent, clamorous life of Bombay to the fraternity of the chilling bores at the high tables of Trinity College at Cambridge, Chandrasekar amused himself by producing extended calculations on the internal constitution of stars. To his amazement , that these were showing him that stars above a certain mass, about 1.4 times that of the sun and now known as the Chandrasekar limit, will not be able to maintain their volume against gravity and must contract to configurations we now identify as neutron stars and Black Holes.

Chandrasekar arrived in England eager to share this discovery with Arthur Stanley Eddington, the astronomer he had

revered from afar as the author of an important text-book on relativity published in 1923.

Eddington gave him a warm reception , though not for long. To Eddington's tidy mind, the universe could not have rips, tatters and patches. Black Holes are singular vents in the fabric of space and time. That we might live in a universe no sturdier than a homeless shelter - it beggars the imagination! If causation collapses inside a Black Hole which eventually interacts with us, then causation will collapse here. Otherwise stated, a failure in physical law anywhere in the universe implies its failure everywhere.

History had engineered a cosmic clash between two great intellectual traditions, Hindu metaphysical speculation and the English pragmatic genius. Since the Industrial Revolution, English civilization has devoted itself to the manufacture of things that work. Over two centuries it built the best instruments, invented the best machines, developed the best public medicine, laid the foundations for the most stable economies. It does not excel in imaginative metaphysics, certainly not the hyperaesthetic cosmological speculation which is the privileged province of Hinduism.

As Eddington could not dispute the calculations leading to the Chandrasekar limit, he chose the bolder expedient of impeaching the equations themselves. His strategy was carried out on two fronts. On the personal level, he did everything in his power to embarrass, denigrate, humiliate, and obstruct the career of his prize student. On the intellectual level he moved far away

from the mainstream, rejecting quantum mechanics itself and even parts of relativity. So drastically did the Black Hole infringe on his faith in cosmic law!

Recall the lectures Chandrasekar delivered in 1983 in Eddington's honor at the University of Chicago. They were entitled: *"Eddington, the most distinguished astrophysicist of his time"*. I don't believe that Chandrasekar was insincere, but he was a very fastidious individual, as circumspect with his use of words as he was with his manner of dress, his classroom delivery, his way of structuring his time and setting limits on social interactions, and many other things . When one uses the word "distinguished" in reference to a scientist, it usually means that his real contributions belong to the past. There is no question that, from the turn of the century until the early 1930's Eddington was in the first rank of astronomers. After 1932 , from about the period of his personal attacks on Chandra, his ideas ceased to be of interest to practicing scientists . It was therefore possible for him to remain on the fringes of astrophysics until his death in 1944, and still retain the *distinction of being the most distinguished* astrophysicist of his time! Chandrasekar appears to be have been rather adept at damning with faint praise; many of his recorded comments on Ramanujan carry a similar tone. The text of these lectures maintains , *sotto voce* , the ironic tone present in the title. This turns to real bitterness in some places , for which it is impossible to blame him. In consequence of Eddington's hostility Chandrasekar received no recognition for this early work until the

1960's, by which time most of it had been rediscovered by others. Kameshwar Wali has this to say:

"Physicists dare not intervene* (in defense of Chandra) *because not only was astrophysics simply not at the center of their interest, but they had stopped taking Eddington seriously....However in the astronomical community , to which Chandra's discovery should have mattered most, Eddington still enjoyed an almost mystical admiration , and his authority remained supreme.... I t took nearly 3 decades before the full significance of the discovery was recognized and the Chandrasekar limit entered the standard lexicon of physics and astrophysics.".

Which has guided me to certain unorthodox reflections : ultimately the biography of the knighted Sir Arthur Stanley Eddington is more interesting than that of Subramanyan Chandrasekar, Nobel laureate.

Chandra was a brilliant scientist who began his career with major discoveries in his 20's, then continued to do exemplary work until a few days before his death. Yet the case of Eddington presents us with the profile of the great man who, suffocated with honors heaped from floor to ceiling, *turns bad in mid-career* . Falling victim to delusions and paranoia, he uses his legitimately acquired authority to denigrate and even attempt to ruin the careers of his close associates. One might speak of a trade-off between achievement and personality. Authority is boring save in its abuse. Almost all biographies of the great achievers can be summarized in a few paragraphs:

Birth. Schooling. Early work. Middle work. Late work. Work, work, work. Controversy?(perhaps). A

scandalous love- affair?(sometimes). Divorce?(maybe). Retirement. Death! (with honor) . The End

Those who succeed in breaking out of this pattern must exhibit some special factor, like a high degree of eccentricity, youthful struggles against poverty, some unusual career change, perhaps, from circus performer to mathematician, or policeman to chemist. In the catalogue of such special factors, the manifestation of some streak of evil in mid-career is certainly one of the most effective. The reader becomes curious as to its origins; were these propensities totally unexpected, or did the subject show signs of them ,perhaps in latent form, even in childhood,? Did the false god reap the fruits of his deeds, coming to a bad end , dying in the odium of ridicule? Or gnash his teeth and laugh all the way to the cemetery? Was not society the more to be blamed than he? And so forth and so on.

The lives of great scientists tend to make dull literature. This is no doubt unavoidable: a settled, colorless, even hum-drum existence is usually a prerequisite for the steady advance of knowledge, or progress, or the wisdom of Varadarajan. The narrow constraints placed upon the life of any man who devotes his life to the registration of the slow unfolding of nature's secrets require that he be neither too bad nor too good: the world quickly takes notice of such people and puts obstacles in the way of their getting very much done.

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In defense of Eddington:

A few words on Singularities , Cosmic Angst, and Black Holes:

When dealing with shapes such as that of a taut wire, or the trajectory of a stone plummeting to earth, one can interpret their apparent straightness in two ways: one can assume that the straight line is a convenient approximation, called a 'linearization' of the real shape, which can't be perfectly straight. One might also argue that the visible shape represents the yearning of the physical world towards the ideal configuration of absolute straightness. The cosmos would aspire to perfection and it is the task of physics to discern its intentions. What are called the fundamental laws of physics, those of Newton, Maxwell, Einstein, etc..... are considered much more than artful approximations: physicists want to believe that they illuminate ideal patterns, embedded in the universe order which phenomena strive to actualize to the best of their ability, even as we, as human beings, strive to live by ideal moral codes as best we can.

Nature is everywhere interpenetrated by Idea , yet when we seek to grasp this mirage of perfection it crumbles to dust. It is at this juncture of the Actual and the Ideal that the concept of the relativistic Black Hole takes up its commanding perch . Even as hypothesis, the Black Hole percolates an unsettling anxiety down to the deepest levels of the scientific world outlook . The Black Hole as singularity shares in the attributes of pure thought.

Any singularity in a fundamental equation, in this case Einstein's equations of General Relativity, can be pictured as a kind of "substantiated mathematics" in a material universe. There is an opposing viewpoint, which says that since causation itself can be interpreted as an absolute or perfect order gleaming through the confusion of the phenomenal world, singularities can be interpreted as *conceptual violations* of ultimate categories of experience.

Although one cannot excuse Eddington's shabby treatment of Chandrasekar from the perspective of human relations, he was by no means the only major scientist to reject the disturbing implications of his calculations. Less than a year after Chandrasekar published his result in the Astrophysical Journal on November 12,1930, they were independently confirmed by the great Russian physicist Lev Landau. Landau wrote:

"For $M > M_O$, (the solar mass), there exists in the whole quantum theory no cause preventing the system from collapsing to a point.... As in reality such masses exist quietly as stars and do not show any such ridiculous (my underlining) tendencies, we must conclude that all stars greater than 1.5 M_O , certainly possess regions in which the laws of quantum mechanics are violated my italics....."

Landau, in other words, considered Black Holes so unacceptable that he was prepared to scrap quantum theory. Eddington reacted in much the same way, suggesting that one should throw out relativistic quantum mechanics and the Pauli principle.

"...Above a certain critical mass, (two or three times that of the sun, the star could never cool down, but must go on radiating and contracting until heaven knows what becomes of it. That did not worry Chandrasekar; he seemed to like the stars to behave that way, and believes that this is what really happens. But I felt the

same objections as 12 years earlier to this stellar buffoonery ; at least it was sufficiently strange to rouse my suspicions that there must be something wrong with the physical formula used." **(Harvard lecture, 1936) As we can see from this excerpt, he was not adverse to**

chucking some of the rules of basic courtesy as well.

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With the sealed promise that I would write "only about science", I left Vararajan and went looking for Lou. I knew no-one else present save by reputation and at that moment I didn't feel like talking to a reputation. However the choice would not be up to me : I discovered Lou standing by the bar in the middle of a circle that included Roger Penrose, Ed Witten, Kip Thorne, Rafael Sorkin and John Archibald Wheeler. They were thickly embroiled in some kind of argument, with invective being traded back and forth. Ed Witten and Lou were waving their arms and shouting at each other; between Penrose and Thorne the debate was perhaps more courteous, yet no less intense; while Sorkin and Wheeler remained bystanders , the former with cool disdain, the latter with his characteristic enigmatic, Buddha-like regard. Lou saw me , excused himself and came over. "I don't need to stay . We'll probably continue this conversation upstairs. Oh, by the way, I hope you don't mind." Lou reached into his coat pocket and produced two tickets for the approaching banquet. "Let's go on upstairs. Quarreling gives me an appetite."

"What was it about?"

"Oh. Well; they're all coming from differing epistemologies, but because they're physicists, or astrophysicists, you can't use a word like that. They all think they're objective ; and who can quarrel with objectivity? Rafael Sorkin does research in quantum gravity Syracuse University. He believes that continuity is a convenient fiction: the real universe is discrete. He's called the ultimate particle the "geon" ; he constructs them right out of space-time. He's hopeful that calculations using his geons may give us the kind of information about the surface and neighborhood temperatures of Black Holes that will make it possible to detect them . That's a theme going through this conference.

" Ed Witten is Mr. String Theory. As is so often the case, he didn't invent the concept of the particle-string. That was done by Scherk, Schwartz and Green. He just took over the field completely after it was launched. He's also a one-man proselytizer for strings"

I had myself observed that Ed Witten had a manner of intoning like a cantor and stretching forth his arms like a benevolent prophet. Lou continued, " Strings are continuous entities and the conceptual opposites of Sorkin's particles. Witten is now claiming that all of the different versions of string theory can be unified under something he calls 'stringy geometry' . He may well be correct; a lot of important work has been coming out recently in that field.

" Penrose doesn 't reject strings, though he isn't fond of them." Everyone knows what Penrose thinks because he's floated two big popularizers , filled with his manifold ruminations on the ultimate Everything. As a means of introducing people to the

methods and concerns of modern science, his books are better than 80% of the textbooks in use in classrooms . They're filled with wild speculative ideas that scientists aren't supposed to entertain; but they are entertaining, even if you don't agree with them. Penrose has developed his own quantum snake-oil : by a deft sleight-of-hand he connects up quantum uncertainty, his ultimate graviton, time's winged chariot , the curvature of space time, and the collapse of the wave packet.

"Kip Thorne has also written a popular tract: "Black Holes and Time Warps". He's the chief proponent of the concept of traversible wormholes. Stephen Hawking's wormholes tiny punctures in the fabric of spacetime that nothing can get into; but Thorne thinks you should be able to pick them up in your hand, enlarge them and send people down their gullet. In his book he puts his wife, Carolee, into a time-travel fantasy , whereby she goes flying off through hyperspace for 10 years on one space-time geodesic, while he and she are holding hands for 12 hours in another."

"Wouldn't they be pretty clammy by then."

"Ah, you skeptics!", Lou beamed, " Technical quibbles."

It promised to be a lively repast . Now I could appreciate the value of having taken careful notes at the lectures. If I repeated enough of the things they said back to this exalted crowd, even they might applaud my erudition.

End of Part I

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