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Edgar Allan Poe's Physical Cosmology

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SUMMARY

In this paper I describe the scientific content of *Eureka*, the prose poem written by Edgar Allan Poe in 1848. In that work, starting from metaphysical assumptions, Poe claims that the Universe is finite in an infinite Space, and that it originated from a primordial Particle, whose fragmentation under the action of a repulsive force caused a diffusion of atoms in space. I will show that his subsequently collapsing universe represents a scientifically acceptable Newtonian model. In the framework of his evolving universe, Poe makes use of contemporary astronomical knowledge, deriving modern concepts such as a primordial atomic state of the universe and a common epoch of galaxy formation. Harrison found in *Eureka* the first, qualitative solution of the Olbers' paradox; I show that Poe also applies, in a modern way, the anthropic principle, trying to explain why the Universe is so large.

1 INTRODUCTION

The provocative title of this paper aims at establishing a relation between Edgar Allan Poe (1809–1849) and *physical* cosmology. It is well known that Poe was interested in science, and that in *Eureka*, his "prose poem" (**1**), he described his original, personal vision of the Universe. The question is, can we find something *scientifically* relevant in this literary work, a bizarre *mélange* of metaphysics, philosophy, and science? Indeed, Harrison (**2**) has already pointed out that Poe gives in *Eureka* a correct solution of the Olbers' paradox. I will show that this is not a lucky coincidence, and that *Eureka* has other interesting points worthy of attention.

The original premises of *Eureka* are metaphysical, quite naïve, and the more scientific, detailed discussions in *Eureka* are often vague, and sometimes wrong. This is what negative critics have stressed. But from his metaphysical speculations Poe reaches the conclusion that the Universe is evolving. From our point of view, the most interesting part of *Eureka* concerns the physical consequences of this conclusion. And this is why we can find some startling common points between his cosmology and our modern cosmology.

The idea of a dynamically evolving universe was accepted only in the 20th century; Friedmann found that it was a mathematical consequence of General Relativity, but it gained general consensus only after the compelling observational evidence presented by Hubble. Nevertheless, this evolving universe could be conceived before general relativity.

On 1848 February 3, Edgar Allan Poe gave a lecture at the Society Library of New York, entitled 'On the Cosmogony of the Universe'. *Eureka* represented an extension of that lecture, and was published in the same year.

In a letter to George W.Eveleth, Poe wrote:

> What I have propounded will (in good time) revolutionize the world of Physical & Metaphysical Science. I say this calmly—but I say it. (3)

While *Eureka* was appreciated by, among others, Charles Baudelaire (author of the first French translation of *Eureka*) and Paul Valéry, it has never been very popular.

Tipler claims that *Eureka* "is very much a metaphysical work" (4), and he quotes A.S.Eddington, as defining it a "crank-theory" (5) (it is ironic that Eddington should in his turn propose his *Fundamental Theory*). Indeed, this quotation may be misleading; Eddington expressed also his appreciation, noting that Poe seemed "to have had the mind of a mathematician". Charles O.Olivier, professor of Astronomy at the University of Pennsylvania, was also favourably impressed (5); Carol Hopkins Maddison claimed that *Eureka* was a synthesis of the most advanced thought of the 19th century (6), and more recently Bruno Bertotti wrote that Poe "was able to prophesy and prefigure modern cosmology" (7).

Anyway, Harrison has well synthesized the fate of this original work:

> *Eureka* failed to revolutionize the world of physics and metaphysics; its science was too metaphysical and its metaphysics too scientific for contemporary tastes. (2)

In particular, a serious source of confusion is represented by a presumed analogy with General Relativity, as suggested by Paul Valéry (8). He cites for example the sentence of Poe

> [...] *each law of Nature is dependent at all points upon all other laws*

and claims that the definition of the Universe from its intrinsic properties and the symmetry between the concepts of space, time, matter and gravitation are the common characteristics of Poe's and Einstein's universes:

> *C'est, en effet, une symétrie formelle qui est le caractère essentiel de la représentation de l'Univers selon Einstein.* Elle en fait la beauté.[1] (8)

Moreover, there is some reluctance to judge a literary work also from a scientific point of view. This understandable feeling is well expressed by Giorello, who writes in his introduction to the Italian edition of *Eureka*:

> Ma una lettura di *Eureka* che, alla luce delle attuali conoscenze astronomiche, fisiche, ecc., si mettesse a discriminare tra quel che Poe ha ereditato da un passato che sentiamo come sempre piú remoto e quel che ha anticipato di un futuro per lui ancora troppo lontano, ne disperderebbe tutto il fascino.[2] (9)

I am aware that *Eureka* is a complex literary work; but it is also clear that Poe attributed an enormous importance to its content.[3]

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[1] It is, in fact, a formal symmetry which constitutes the essential character of the representation of the Universe according to Einstein. This symmetry is its beauty.

[2] "But if we should read *Eureka* using our present astronomical and physical knowledge in order to discriminate between Poe's heritage from a past which is increasingly remote from us, and Poe's anticipation of a future which was too distant from him, all its fascination would be lost."

[3] It is curious to read the comments of Judith Gautier, the daughter of Théophile Gautier, who in 1864 (when she was only 15 years old) wrote an article in *Le Moniteur universel* under the pseudonym of Judith Walter about Baudelaire's recent translation of *Eureka*: "On aurait tort de croire qu'Edgar Poe en écrivant Eureka avait seulement l'idée de faire un poëme; il était bien absolument convaincu qu'il avait découvert le grand secret de l'univers, et il employait toute

He tried to build a "theory of everything", where the primordial Unity is at the origin of all things. In doing so, he adopted some metaphysical assumptions but used the physical and astronomical knowledge of his time. Therefore, I think that a separate, critical analysis of the science in *Eureka* is justified, and represents a useful complement to literary and philosophical analysis, in order fully to appreciate this prose poem in its complexity.

The purpose of this paper is to give a general description and discussion of Poe's cosmology. I want to stress the following points:

(1) the modern universe conceived by Poe is not the result of chance, but is the logical consequence of the synthesis between Poe's metaphysical principle of the "Original Unity" of matter and some of the main astronomical ideas of that epoch;

(2) while based on undeniably metaphysical premises, *Eureka* gives us a qualitative, but reasonable, Newtonian model of the Universe; and

(3) *Eureka* contains not only the correct solution of the Olbers' paradox, but also the first modern application of the anthropic cosmological principle.

2 THE UNIVERSE OF *EUREKA*

2.1 *The primordial Particle*

An exhaustive analysis of *Eureka* and its sources would require a long and detailed work; here I will deal with those issues which are most relevant to Poe's physical cosmology.

Poe had a deep interest in science and, particularly, in astronomy. In 1825, when he was 16 years old, he began to observe the Moon and the stars with a small telescope, a present from his step-father John Allan. According to Poe himself, his tale *The Unparalleled Adventure of One Hans Pfaall* (1835) had been inspired by John Herschel's *A Treatise in Astronomy*, whose American edition had been published in 1834.

Poe had also read the popular *Views of the Architecture of the Heavens* (1838) by Rev. Dr John Pringle Nichol, often quoted in *Eureka*. In 1836 Nichol had been appointed professor of practical astronomy at the University of Glasgow, and in his *Views of the Architecture of the Heavens* he described and defended the nebular hypothesis of Laplace.

Poe dedicates *Eureka* to Alexander von Humboldt, author of the famous *Kosmos, Entwurf einer physischen Weltbeschreibung*, whose first volume had been translated into English in 1845; his main references are the works of Kepler, Newton, Laplace and William Herschel. Poe synthesizes the ideas of

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la force de son talent à développer son idée" [It would be wrong to think that Edgar Poe aimed only at composing a poem when writing *Eureka*; he was absolutely convinced of having discovered the great secret of the Universe, and employed all the power of his talent to develop his idea].

About the idea of a beginning and an end of an expanding and collapsing universe, she wrote: "Là est l'idée principale d'*Eureka*, idée très belle et très neuve qui rattache le commencement à la fin, marque le point de départ dans le point d'arrivée, et, si on l'admet, jette beaucoup de clarté dans l'ensemble de l'astronomie" [Here is the main idea in *Eureka*—a very fine and new idea—which relates the beginning to the end, marks the starting point in the final point and, if accepted, represents a significant clarification of the whole of astronomy] (reprinted in Edgar Allan Poe, Eureka, Traduction de C. Baudelaire, Préface et commentaires de Jean-Louis Schefer, AGORA, les Classiques, 1990, Paris; pp. 162–167).

these great scientists in his cosmology. Newton's law of gravitation provides him with a consistent dynamical description of a finite universe; the nebular hypothesis of Laplace is generalized by Poe, becoming the basic and universal process of object formation; and the observations of Herschel constitute the essential information on the present content, structure and distance scale of the Universe.

In *Eureka* we find ideas which were well known, if not always dominant, in 1848 (**10**). What makes *Eureka* unique is the metaphysical principle assumed by Poe to explain the origin of the force of gravity (that *Eureka* is the result of Poe's speculations about the nature of gravity, is shown clearly by Poe's letter to G.W.Eveleth).

Poe presents his method in the first, satirical pages of *Eureka*, where his main hero is Kepler. According to Poe, the process of scientific discovery does not consist in deduction from arbitrary axioms, or in induction from mere empirical facts. It is essentially due to *intuition*. And from his original intuition about the nature of gravity (the primordial unity of all things), with a minimum of simple assumptions, Poe wants to derive some logical consequences; in this way he aims to develop a general theory which can explain the spiritual and material nature of the Universe, its evolution, and the form of the fundamental laws. Such a theory must be in accord with observations, and must be consistent, because

> A perfect consistency, I repeat, can be nothing but an absolute truth.

Poe states that Space is infinite. On the other hand, he claims that the Universe of Stars, i.e. the material content of the Universe, must be finite, both in space and time. Poe gives philosophical justifications (later he will add more physical reasons): the concepts of an infinite distribution of matter, and of a finite extension of space are both inconceivable. In the following it will be clear that a finite universe in an infinite space is necessary for the consistency of Poe's universe.

The main metaphysical principle, which implies an evolutionary universe, is the primordial Unity of Matter. Poe claims that this principle follows both from reasoning *a priori* and from observing the present state of matter. The force of gravity, i.e. "the fact that *each atom attracts each atom*", is considered as a universal tendency of matter to restore its 'natural' state. Therefore the universality of attraction implies that this original 'natural' state was the Unity of all matter.

This also implies that the Universe has not always been as we observe it presently, and that there was an instant when the Universe was created. What can we say about the state of the Universe at that instant? We have to assume that it was in its simplest state, and this simplest state could be nothing else than a primordial Particle. God created this Particle, and conferred to matter a repulsive force: the primordial Particle fragmented into an enormous, but not infinite, number of atoms. This Repulsion, which Poe calls Electricity, plays an important role in his metaphysics; it is the Spiritual Principle:

> To electricity—so, for the present, continuing to call it—we *may* not be wrong in referring the various physical appearances of light, heat and magnetism; but far less shall we be liable to err in attributing to this strictly spiritual principle the more important phaenomena of vitality, consciousness and *Thought*.

This phase of universal repulsion is finite; at the end of this Action, a Reaction develops: and this Reaction is the force of gravity.

If gravity were the only force in the Universe, nothing could exist; this means that atoms must develop a repulsive force to avoid a premature collapse. Only at the end of the universe, this tendency to Unity will be completely satisfied (here Poe implicitly applies the anthropic cosmological principle; in the next section I will discuss another, more interesting and explicit application).

Thus Attraction and Repulsion are the two forces that make the Universe evolve.[4] In his metaphysics Poe's universe is reminiscent of pre-Socratic cosmologies. For example, the dialectics between two forces has some analogy with the cosmology of Empedocles. Empedocles, who lived in the 5th century BC, described in his poem Περὶ Φύσεως (Peri Physeos) a universe evolving under the action of two opposing forces on the four elements; these forces are called Φιλότης (Philotes) and Νεῖκος (Neikos), i.e. Friendship and Hate. When Friendship dominates, all the matter condenses in one unique globe, the Σφαῖρος (Sphairos); Hate divides this globe, and gives origin to all things (11). But if it is true that Poe's Attraction and Repulsion play a role in his metaphysics (they are "the Body and the Soul"), they are *physical forces*, and one of them, gravitation, is mathematically well defined. Indeed the metaphysical nature of Poe's forces is extrapolated from their physical properties. On the contrary, Empedocles's universe is a uniquely metaphysical construction (a fascinating one, like many of the ideas of pre-Socratic philosophers).

Poe argues that, if the original state of matter was Unity, and given that the present state of matter is Diffusion, as implied by the distribution of stars and nebulae, then matter has been *radiated* from the original primordial Particle. At this point, Poe realizes that there is a problem. He states that a fundamental property of the Universe is its globally uniform distribution of matter. It must be so, according to him, for symmetry and simplicity, and because *observations* show a distribution of stars and nebulae which is locally irregular, but globally uniform (we would say that observations suggest an isotropic distribution, thus supporting the hypothesis that the Universe is homogeneous). Now, if Matter, under the form of a finite quantity of atoms, had been radiated in the same way as light, its surface density should decrease with the square of the distance. In modern terms, the problem Poe has to solve consists in finding how an expanding universe can conserve homogeneity. The mere fact that Poe poses this problem is truly remarkable, but his solution is disappointing.

Poe notes that a constant density in his finite, spherical universe of matter implies that the number of atoms in a shell at a distance r from the centre of radiation must be proportional to r^2. To obtain this distribution, Poe reasons

[4] Critics usually point out that the two terms of Attraction and Repulsion were applied to molecular theory by Ruggero Giuseppe Boscovich (1711–1787), who was a Dalmatian Jesuit, mathematician and astronomer (founder of the Observatory of Brera, and member of the Royal Society). He wrote an influential work about a 'unified' theory; see for example the synthetic account by J.D.Barrow in *Theories of Everything*, Clarendon Press (Oxford, 1991), p. 17. Nevertheless I do not think it is necessary to see a direct link with Poe's adoption of the two terms.

in the following way. The repulsive force F acted for a finite lapse of time; at a given instant it vanished (as a large-scale force; it continued to manifest itself as Electricity), to be replaced by the force of gravity. We can suppose that this repulsive force decreased progressively with time. Now suppose that atoms were radiated from the primordial Particle in successive expanding shells, and that the total number N of atoms in each shell was proportional to the repulsive force F exerted on each atom of the shell: $F \propto N$. Consequently, successive shells had less and less atoms, and were radiated by a proportionally less intense force, therefore reaching smaller distances from the centre. Poe writes that each shell stopped after reaching a given distance r from the centre, and that through this process the number of atoms N reaching a distance r from the centre was proportional to r^2, thus yielding, from the proportionality between F and N, the relation $F \propto r^2$.

In a footnote, Poe suggests that this process was instantaneous: "Here I describe the whole process as one instantaneous flash"; needless to say, the analogy with the Big Bang has been stressed by several critics.

The force of gravity appears to Poe as a Reaction to the Repulsive force, and, as the latter is proportional to r^2, the former will be proportional to r^{-2}; the atoms will not tend to their geometrical centre, but to their Unity, forming stars and galaxies, and at the same time pursuing the general collapse.

It is admittedly difficult to find such a symmetry as compelling as claimed by Poe. Here we are, using his own words, in the "Cloud-Land of Metaphysics"! Moreover, there are serious problems with Poe's mechanism of repulsion. Poe seems aware that the reader might not be particularly convinced by his theory, so he answers three possible objections, all of them quite natural.

First objection: why should the force of radiation be proportional to the number of radiated atoms? Poe explains that this relation is the only one which could assure the uniform distribution of the atoms in the sphere.

Second objection: if atoms are accelerated by a repulsive force, what should stop them? Poe says that at that epoch no 'principle' existed, no law of dynamics. The physical universe, with his laws, began when this repulsive force stopped.

Third objection: this mechanism of distribution of atoms in the sphere appears to be a simple (and totally arbitrary) hypothesis. But, according to Poe, it must be the truth: he claims that it is the only consistent mechanism which can explain a radiation from the centre and a uniform distribution.

Unfortunately, his explanations are not convincing.

Poe is rather vague about his mechanism. If we simply use the second law of dynamics, and we assume that the repulsive force acted during a fixed interval of time Δt, equal for all shells, his mechanism cannot give a uniform distribution. It can work with a slight correction. Suppose for example that atoms are accelerated in the radial direction with a constant acceleration a (i.e. a constant repulsive force F; Poe assumes that all atoms have the same mass). Then $r \propto a$; now we can obtain a homogeneous distribution if we assume that the force acting on each atom of a shell is proportional to the *square root* of the number N of atoms in the shell. At any time we have the relation $r \propto F \propto \sqrt{N}$, i.e. the number of atoms in a shell at a distance r from

the centre is proportional to r^2; we have also that at any time the velocity of each shell is proportional to its distance r from the centre, $v \propto r$, i.e. the Hubble law. In both the Newtonian and relativistic cosmologies, the proportionality between distance and velocity is necessary if we want the general properties of the Universe, for example the density, to be the same for all the observers at any time: it is the well-known cosmological principle. So Poe's *ad hoc* mechanism could generate a homogeneous universe. Of course, in this way we have lost the symmetry between repulsion and gravity which is so important for Poe: the force of gravity cannot be 'explained'.

The worst is that, when discussing the second objection, Poe claims that no physical law existed during the repulsive phase. This implies that we cannot apply physical reasonings. The above discussion about some plausible and simple physical model which could follow Poe's mechanism is *not* what Poe had in mind. We have to accept that atoms could stop once they reached their 'assigned' position in the sphere. We can imagine that each shell stopped where it had to stop, to give a final distribution with $N \propto r^2$. In this case, Poe's original mechanism 'works'; the drawbacks are that we have continuous fine tuning, and that the intervention of the 'Divine Volition' is heavily required. Moreover, why should we assume a given relation between the force of repulsion and the atoms radiated from the centre? Even though he claims the absence of any general law during the phase of radiation, Poe implicitly requires Newton's second law (or at least something equivalent); otherwise, why should we not believe that the Divine Volition directly put each atom in its place?

It is quite clear that Poe had a general and vague idea in mind. He was convinced that matter had been radiated from a primordial Particle; he had two forces, one repulsive, the other attractive; the latter was inversely proportional to r^2. He imagined a mechanism where Repulsion and Attraction were two symmetric forces—the result of a metaphysical analogue of the third Newtonian law, Repulsion being an Action and Attraction a Reaction—where the force of gravity was a consequence of the structure in the Universe, and where the form of this force could be predicted! He did not bother with mathematical or physical 'details'. He was satisfied with the general consistency of his mechanism. He did not realize that it was quite arbitrary. Indeed, he was aware—as he states clearly in *Eureka*—that the laws of motion would require the action of a force to stop his atoms; but probably because of a limited ability to *apply* these laws, and also for 'dogmatic' reasons, Poe did not realize what appears to us—and would have appeared to Newton himself—the obvious physical implication of his model: the radiated atoms could be stopped only by the action of an attractive force, i.e. the force of gravity.

As concerns the third point, Poe is absolutely convinced of having found the "theory of everything". It is perhaps this attitude of Poe, and his obstinacy in explaining not only the physical universe but also the fundamental physical laws through his metaphysical speculations, that partly justifies some negative opinions about *Eureka*.

The above discussion was necessary in order to understand why and how Poe reaches the concept of an evolving, collapsing universe. Now, my point is that at the end this naïve metaphysical effort allows Poe to achieve a viable

cosmological model. We have seen that, from a primordial particle, atoms are radiated in a sphere in such a way that their distribution is uniform: the physical cosmological model begins with a static, spherical and uniform distribution of atoms.

Here is the conclusion of the first part of *Eureka*:

> [...] I am fully warranted in announcing that *the Law which we call Gravity exists on account of Matter's having been radiated, at its origin, atomically, into a limited sphere of Space, from one, individual, unconditional, irrelative, and absolute Particle Proper, by the sole process in which it was possible to satisfy, at the same time, the two conditions, radiation and equable distribution throughout the sphere—that is to say, by a force varying in direct proportion with the squares of the distances between the radiated atoms, respectively, and the Particular centre of Radiation.*

2.2 *Poe's evolving universe*

In the previous section I have described how Poe conceives a universe generated by a uniform radiation of atoms from a primordial particle: the force of gravity is responsible for the subsequent collapse of the Universe, during which objects form from the growth of small density fluctuations. According to Poe, these small fluctuations originate from the different forms of atoms, which are initially homogeneously distributed in space. Hence the famous sentence:

> We thus establish the Universe on a purely *geometrical* basis.

which has clearly no relation with General Relativity[5].

Nearly a century later, Lemaître wrote:

> Le monde a procédé du condensé au diffus. [...] L'atome-univers s'est brisé en fragments [...] Nous pouvons concevoir que l'espace a commencé avec l'atome primitif et que le commencement de l'espace a marqué le commencement du temps.[6] (**12**)

Here Lemaître describes a relativistic universe where space and time begin with matter, and his primordial atom is not *in* space, while Poe describes a Newtonian universe which is *in* an infinite, pre-existing space. Poe's choice of a finite content of matter is important: it makes it possible to have a finite potential at each point of space. Poe is well aware that an infinite Newtonian universe with constant density cannot be self-consistent, as we will see later. According to him, objects begin to form only when the Universe is collapsing, while we now know that structures can form during the expansion (otherwise, we would not exist!).

It is important to bear in mind where Poe's universe differs from the correct Newtonian counterpart of a Friedmann–Lemaître closed model: it can be viewed as a collapsing cluster of galaxies, and does not follow the Hubble law.

The correct Newtonian approximation was developed only in 1934 by Milne and McCrea (**13, 14**), who showed that it could be self-consistent; a simple description is found for example in Sciama's *Modern Cosmology* (**15**).

[5] Poe writes also '[...] *no such things as axioms ever existed or can possibly exist at all*'; such a philosophical position is noteworthy but should not be over-emphasized.

[6] The world has evolved from condensation to diffusion. [...] The Universe-atom has broken into fragments [...] We can conceive that Space began with the primordial atom, and that the beginning of space marked the beginning of time.

In a closed Newtonian Universe, the radius of the Universe obeys the (Friedmann) equation:

$$\dot{R}^2 = \frac{8\pi}{3} \frac{G\rho(t_0)R^3(t_0)}{R} - kc^2 \qquad (1)$$

where $R(t)$ is the radius (the scale factor in relativity) of the Universe, ρ is the density, t_0 is the present time, c is the speed of light and the constant k is positive; the maximum radius reached by the Universe before recollapse is then:

$$R_{\max} = \frac{8}{3} \frac{\pi G\rho(t_0)}{k} \frac{R^3(t_0)}{c^2}. \qquad (2)$$

In 1955, McCrea wrote:

> Strictly Newtonian analogues of the relativistic cosmological model exist but they are bounded, though arbitrarily large, systems. (**16**)

As Ellis notes, "It is curious that it took so long for these dynamic models to be discovered after the (more complex) general relativity models were known" (**17**). As I will discuss below, the problem is that the idea of an evolutionary universe was difficult to accept.

It is important to realize not only that a Newtonian universe can be obtained as a limiting case of a relativistic one (thanks to the Birkhoff theorem), but also that the Newtonian laws before Relativity could allow a consistent cosmology: it was necessary to accept a non-static, finite universe of matter.[7] Poe became aware of that, and this seems to me one of the most important aspects of *Eureka*.

There is another, startling point in common between Poe and Friedmann, which I point out just as a curiosity. In a recent biography of Friedmann, we read:

> [...] His favourite writers were Dostoyevsky, E.T.A. Hoffmann, and Poe; he read a lot of Merezhkovsky and Fyodor Sologub. Indeed, Friedmann, as it turns out, was fond of 'the occult' in general; he claimed he could soothe pain, and once managed to do it. (**18**)

Did Friedmann read *Eureka*? It would not be serious to push this game too far.

Poe's description of the general structure and content of the Universe is extremely interesting. It is not as original as the first part; it is derived from the works of the astronomers of his time, but is more interesting from our point of view, being the most strictly scientific part, and because the astronomical knowledge of the first half of the 19th century is inserted by Poe in the framework of an evolving universe. This revolutionary and extraordinary synthesis is what gives *Eureka* a modern flavour. This is what I called Poe's physical cosmology. We can appreciate this legitimate cosmological model, independently of the various metaphysical reasons which made Poe conceive a collapsing universe.

In the 18th century, Thomas Wright and Immanuel Kant maintained the view that nebulae were systems comparable to the Milky Way. These

[7] This is true if we assume a globally uniform distribution of matter, a hypothesis which is shared by both Poe's and modern cosmology. Another possible solution is to assume a hierarchical, fractal universe (see Harrison's book, chapter 11, for the history of this concept; it is interesting to note than in 1848 it was proposed by John Herschel himself).

speculations were supported by the observations of William Herschel (with his sister Caroline), who published in 1785 an influential paper entitled 'On the construction of the heavens'—even if at the end of his life he should change his mind. In 1796, Laplace proposed the mechanism of gravitational contraction from a primordial rotating cloud (the solar nebula) to explain the formation and the observed regularities of the Solar System. Therefore it is natural that in the first half of the 19th century these ideas were well known, and that Poe could accept and use them in his work. Indeed the nebular hypothesis was very popular in America at that epoch, even if in 1848 it had received serious criticisms (**10**), so that Poe felt the need to defend it. Anyway, what is original in *Eureka* is Poe's assumption of the atomic state of matter after the primordial expansion. Laplace had considered only the origin of the Solar System; Poe imagines a primordial atomic state of the whole Universe. The part where Poe defends the nebular hypothesis is quite interesting. The problem is the following: Lord Rosse had claimed to have resolved some nebulae into stars, so that the nebular hypothesis of Laplace appeared now contradicted by observations. But Poe notices that if one could observe gaseous nebulae, they should be very nearby. In his evolving universe, the formation of stars and galaxies is a process which took place in the past, when the Universe was in an atomic state, and after it had begun to collapse; what we presently call the process of galaxy formation must have stopped a long time ago: now objects are in the same state of condensation. The nebular hypothesis is therefore applicable only to that epoch, and as a consequence we can now observe only systems of stars. While Poe, as all the scientists at the time, did not realize that different objects were classified under the name 'nebulae', it is interesting to see how his evolving model of the Universe allows him to reach in a natural way the notion of a primordial epoch of object formation.

Poe defines the Universe of Stars as a *cluster of clusters*: in modern terms, we would say that it is a system of galaxies. For him, 'cluster (of stars)' means 'galaxy', without any doubt:

> The 'clusters' of which this Universal '*cluster of clusters*' consists are merely what we have been in the practice of designating 'nebulae' and, of these 'nebulae', *one* is of paramount interest to mankind. I allude to the Galaxy, or Milky Way.
> [...]
> We have no reason to suppose the Milky Way *really* more extensive than the least of these 'nebulae'.

We read also that the form of our Galaxy has approximately ("a certain general—*very* general resemblance") to the planet Saturn:

> [...] we must picture to ourselves a lenticular star-island, or collection of stars; our Sun lying excentrically—near the shore of the island—on that side of it which is nearest the constellation of the Cross and farthest from that of Cassiopeia.

And the nearest nebulae are at distances of millions of light-years. Poe quotes the distance estimates made by William Herschel:

> [...] —yet so far removed from us are some of the 'nebulae' that even light, speeding with this velocity, could not and does not reach us, from those mysterious regions, in less than 3 *millions of years*.

On the other hand, Poe does not believe in the rotation of galaxies: he rejects the hypothesis of Mädler "that there exists, in the centre of the

Galaxy, a stupendous globe about which all systems of the cluster revolve". Poe claims that this hypothesis is in contrast with the observations of the other 'nebulae': quoting John Herschel and Nichol, he remarks that the form of these 'nebulae' is nearly circular, and this fact suggests that these systems are in a state of collapse, analogously to the Universe of Stars.

Poe describes also the fate of the Universe. The general collapse of the Universe of Stars will cause the final condensation of all matter in one globe, restoring the original Unity. Matter then will annihilate.

However, at the end of *Eureka* Poe suggests that another cycle will follow, and that this process is 'renewed forever'. Nevertheless Poe himself admits that he is 'indulging a hope', presenting the hypothesis of a cyclic universe.

This is the essential scheme of Edgar Allan Poe's cosmology. From what I have exposed, I think it is justifiable to claim that, independently of any metaphysics, the collapsing *Newtonian* universe described by Poe represents a self-consistent prerelativistic model of the Universe.

2.3 *The Olbers' paradox and the Anthropic Cosmological Principle*

I shall briefly discuss two other points, one concerning the Olbers' paradox, the other the anthropic principle.

Poe attacks the idea of an infinite Universe of Stars, using what is presently known as the Olbers' paradox (see Harrison's book [2]); nevertheless, he admits that there is a conceivable solution:

> Were the succession of stars endless, then the background of the sky would present us an uniform luminosity, like that displayed by the Galaxy—since there could be absolutely no point, in all that background, at which would not exist a star. The only mode, therefore, in which, under such a state of affairs, we could comprehend the *voids* which our telescopes find in innumerable directions, would be by supposing the distance of the invisible background so immense that no ray from it has yet been able to reach us at all.

As Harrison has found, this is a correct solution of the Olbers' paradox (the "finite age solution"). Tipler (**4**) has claimed that Poe's universe is cyclic and of infinite age, and that this fact is fatal to the finite age solution suggested by Poe himself. I think that this is not the case.

The fundamental point stressed by Poe in *Eureka* is that the Universe of Stars must be finite in an infinite Space. Poe wants to show that an infinite universe is not consistent; in the first part of *Eureka* he has adduced philosophical justifications; now he presents physical reasons. One is the Olbers' paradox, to which Poe finds only one possible solution. It is important to realize that Poe discusses the Olbers' paradox *for a static, infinite universe*, and *not* for his universe.

Indeed Poe does not believe in an infinite universe for another reason: in an infinite universe each particle would undergo the same force from each direction, and no motion would be possible. This is a naïve explanation, but it is well known that an infinite Newtonian universe is not self-consistent. In his paper of 1955, McCrea, answering some criticism by Layzer (**19**), writes:

> We may assert that an unbounded system is newtonian if the infinite integrals that give the components of newtonian attraction at any point are convergent. This is the definition most commonly adopted.

> According to this definition, a system with uniform density throughout euclidean space is not newtonian. As it is important to recognize, this means that, if the gravitational force is to be defined in the present manner, then it does not exist in the case of uniform density. Accordingly, nothing further can be inferred about this case. In particular, we may not proceed to argue, as Layzer does, that the force must be the same at every point, and thence that it must be zero. For, in order to prove that a force takes any value, in particular the value zero, the force has to exist in a mathematical sense.

We can conclude that Poe's suggested solution of the Olbers' paradox for an infinite universe is correct. But Tipler's criticism raises one more question: is the Olbers' paradox fatal to *Poe's* cyclic universe? As I have already mentioned, it is only at the end of *Eureka* that Poe suggests (as a hope) the possibility of a universe with infinite cycles; this concept is therefore an additional, last hypothesis, which is not fundamental in his physical universe. Anyway, we must recall again that Poe's universe is formed by a *finite* quantity of matter *in an infinite Space*. His Newtonian universe is not an isolated system: radiation can be diffused into infinite space. Moreover, matter is created at the beginning and annihilated at the end of the universe: in this case it is more appropriate to talk about a succession of universes and not about a single cyclic universe. Therefore the standard arguments used for relativistic cyclic universes cannot be applied here.

Tipler suggests it is natural that Poe's universe is cyclic, because most non-Christian cosmologies of the 19th century were cyclic to avoid the problems of Creation: but what is quite original is the fact that Poe admits the Creation of the Universe *and*, at the same time, suggests infinite cycles.

Now, Poe tells us that there is the Universe of Stars, and all around the infinite, absolute Newtonian Space. But is this Space completely void? According to Poe, we can imagine that an infinite number of universes exists in this Space. If we assume the existence of infinite universes which follow their cycles eternally, we will apparently face again the same problems of a single, infinite universe, for example the impossibility to define a potential, or the Olbers' paradox. But Poe clearly states that these universes do not interact. It is the logical consequence of his principle that matter interacts because of its common origin. Each universe will have its origin and its laws. A similar concept of parallel universes is presently found in quantum mechanics or inflationary cosmology (and, of course, in science-fiction, of which Poe is one of the three celebrated founders, together with Jules Verne and H.G.Wells). This final part of *Eureka*, with each universe with its God at the centre, is the most imaginative.

Another fascinating question posed by Poe is: why is the Universe so big? Why are the distances between "star and star—between cluster and cluster—" so large? Poe writes that Astronomy has no rational explanation; nevertheless, he develops an interesting argument. Poe stresses that large distances mean long times:

> [...]
> *Space and Duration are One*. That the Universe of Stars might *endure* throughout an era at all commensurate with the grandeur of its component material portions and with the high majesty of its spiritual purposes, it was necessary that the original atomic diffusion be made to so inconceivable an extent as to be only not infinite. It was required, in a word, that the stars should be gathered into visibility from invisible

> nebulosity—proceed from visibility to consolidation—and so grow grey in giving birth and death to unspeakably numerous and complex variations of vitalic development:—it was required that the stars should do all this—should have time thoroughly to accomplish all these Divine purposes—*during the period* in which all things were effecting their return into Unity with a velocity accumulating in the inverse proportion of the squares of the distances at which lay the inevitable End.

Compare the above quotation with this one by Barrow:

> [...] This state of expansion means that the size of the Universe is inextricably entwined with its age. The reason that the Visible Universe is more than 13 billion light-years in size today is that it is more than 13 billion years old. A Universe that contained just one galaxy like our own Milky Way, with its 100 billion stars, each perhaps surrounded by planetary systems, might seem a reasonable economy if one were in the universal construction business. But such a universe, with more than a 100 billion fewer galaxies than our own, could have expanded for little more than a few months. It could have produced neither stars nor biological elements. It could contain no astronomers. (**20**)

It is interesting how Poe justifies the dimension by using the Anthropic Principle (**21, 22**). He has well understood the link between dimension, age, and life, which exists in an evolving universe. Paraphrasing Eddington, we should say that Poe seems to have had the mind of a cosmologist...

I will stress just a last point about Poe's metaphysics. In *Eureka*, God is the cause of the origin of the Universe: "The Universe is a plot of God". God represents the original Unity, to which all our Spirits will return, in a strict parallelism with the matter: "That God may be all in all, each must become God".

Here again, we may wonder if it is Poe's physics which suggests his metaphysics, or the opposite.

3 THE FATE OF *EUREKA*

Why has *Eureka*'s cosmology so systematically been ignored or forgotten? For example, everywhere credit is given to Democritus for his atoms, to Aristarchus for his heliocentric system, to Kant and Wright for having considered nebulae as extra-galactic systems, and so on, but nowhere is it given to the modern universe of Poe, except for his solution of the Olbers' paradox recently pointed out by Harrison.

It is possible to list different reasons. Harrison has pointed out the main problem: metaphysics. As I have shown, a number of points in *Eureka* are well posed in rational terms, but Poe did not aim to a simple scientific cosmology. His assumptions are often arbitrary, and induce a natural scepticism in the reader.

The diffusion of *Eureka* was initially very limited: only 500 copies were published (instead of the 50000 Poe had proposed!). It was a peculiar work, "a prose poem" in the tradition of Lucretius' *De Rerum Natura*. The first pages, with an epistemological discussion and a satirical letter from the future, are quite surprising for the reader. Some parts of *Eureka* could be a good example of a popular treatise of astronomy of the 19th century; other parts are devoted to the description of an original metaphysics, both suggestive and arbitrary; everywhere Poe stresses that what he says is the

absolute Truth. It is not surprising that it was not immediately appreciated, except for the enthusiastic Baudelaire (who had quite a biased vision of Poe anyway[8]).

However, apart from the above aspects, the essential message of *Eureka* is that to have a consistent cosmology we need an evolving universe, with a beginning and an end (the parallel metaphysical message is that the spiritual universe also evolves, from Unity to Multiplicity, and from Multiplicity to Unity). The point is that there has always been a resistance to the idea of an evolving universe; and surely in 1848, the collapsing universe of Poe would appear quite visionary and even if one had believed what Poe claimed, no observational test would have been possible.

Significantly, most scientists were reluctant to accept an evolving universe, after it was predicted by relativistic models but before the discovery of the Hubble law in 1929. After all, it is Poe himself who, explaining why John Herschel was reluctant to accept the idea of the collapse of the 'nebulae', wrote:

> Simply on account of a prejudice;—merely because the supposition is at war with a preconceived and utterly baseless notion—that of the endlessness—that of the eternal stability of the Universe.

The above reasons could probably be enough to justify the oblivion of *Eureka*. Moreover, in the second half of the 19th century some of the fundamental astronomical ideas on which it was based were abandoned.

The change of vision was mainly due to the question of the nature and distance of nebulae (**23**). By 1846 Lord Rosse could claim to have resolved stars in the Orion nebula, and this appeared to be fatal to the nebular hypothesis of Laplace. In the following years, the nebular hypothesis of Laplace was confronted with the problem of the distribution of angular momentum in the Solar System: as a consequence, catastrophist theories prevailed until the 20th century.

In 1864, Huggins could obtain the spectrum of a nebula and identify three bright emission lines: he concluded that nebulae were made of gas, and not of stars. Ironically, this discovery seemed now to be at variance with the extragalactic nature of nebulae.[9]

No wonder that in 1890, in her book *The System of the Stars*, Agnes Mary Clerke could write one of the most unfortunate and most quoted sentences in the history of astronomy:

> No competent thinker, with the whole of the available evidence before him, can now, it is safe to say, maintain any single nebula to be a star system of co-ordinate rank with the Milky Way. (**24**)

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[8] French literary critics have been quite severe with Baudelaire, and in particular point out his erroneous translation of Poe's *consistency* with the French *consistance*, and his confusion between *Oneness* and *Unity*.

[9] I think that the instructive history of the problem concerning the nature of the 'nebulae', essentially due to the assumption that such objects belonged to the same and unique class, reminds us that Ockham's Razor can be misleading, especially in Cosmology. Perhaps a modern example is found in the discussion about the nature of the Dark Matter: after Hot Dark Matter models, Cold Dark Matter models gained general consensus in the last years. New data seem now to require mixed models with both Hot and Cold Dark Matter. Needless to say, this problem is far from a definitive solution.

As a consequence, for many decades most of the astronomical ideas on which *Eureka* was based became surpassed. What remained was an original, metaphysical work.

With the birth of modern cosmology, it became clear that *Eureka* contained some anticipations, but it seems that those who read this work, taking its scientific content seriously, were biased in looking for glimpses of General Relativity while, as I have stressed, Poe's universe was simply the most daring of Newtonian cosmologies.

4 CONCLUSIONS

In this paper I described Poe's general vision of the Universe and why it appears so modern in many aspects. I have chosen to analyse the 'physical cosmology' of Poe, without taking into consideration the vague analogies of his metaphysics with a modern science he could not foresee. It is the confusion between some supposedly pseudo-relativistic metaphysics (mainly contained in the first part, where Poe describes the expanding universe) and the physical, Newtonian cosmology (mainly contained in the second part, where Poe describes the collapsing universe) which has probably been an obstacle to an objective analysis of the scientific content of *Eureka.*

I have shown that Poe has not only suggested a solution of the Olbers paradox for an infinite Universe (nevertheless he claims that the Universe of Stars must be finite), but that he was also the first to conceive a Big Bang, and a universe where matter, concentrated at the beginning in one particle, expands under the action of a cosmic repulsion, generating a uniform spherical distribution of atoms. Under the action of gravity, this universe collapses, giving birth to stars, galaxies and life. According to Poe, gravity is a consequence of the tendency of matter to come back to the primordial state of Unity; the force of attraction becomes effective after the phase of repulsion, when the Universe begins to collapse. Therefore, he conceives a definite epoch of galaxy formation in the past, when matter was in an atomic state. To justify the enormous size of the Universe, he makes use of the anthropic principle.

In conclusion, I hope that this article will stimulate others to read *Eureka. Eureka* is not a crank nor a scientific theory. It offers us a fascinating vision of the Universe by an imaginative mind, which using the science of its time could conceive the most revolutionary cosmology of the 19th century. Indeed Poe, who aimed to be a modern Hesiod or Lucretius, writes in the introduction:

> *What I here propound is true*:—therefore it cannot die:—or if by any means it be now trodden down so that it die, it will 'rise again to the Life Everlasting'.
>
> Nevertheless it is as a Poem only that I wish this work to be judged after I am dead.

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