

## **BIG BANG MOMENT!!**

*10<sup>-14</sup> Seconds of Rejoicing and Revel  
For the Birth of the Universe!*

### **As Scientific Theory and Celebration**

Since ancient times, most holidays have been either astronomical, military, political or religious in character, with considerable overlap in the 4 categories. New Year's Day honors the completion of a full rotation of the Earth in its orbit about the Sun; Passover and Easter are closely linked with the lunar year, the solar year, and the vernal equinox. Even Thanksgiving has its origins in the gathering of the harvest and the onset of winter.

Many of the festivals of the ancient world were linked to the planting season in Spring, and the harvesting season in October. In the days before precise clocks and calendars were available, religious feast days were determined by the observations of astronomers. The spectacular arena of Stonehenge, as well as the incredibly sophisticated structures of the Anasazi in Chaco, New Mexico, were designed both as sites for feasts, dance and ceremony, and as observatories for marking ever-recurring cosmic events.

The ancient Egyptians feted the rising of Sirius, the dog-star, in the West, signaling the flooding of the Nile, the most significant event of the agricultural year. The Mayan Indians of Guatemala and Mexico, the finest pre-Galilean astronomers in the world until the coming of Cortez in the 16th century, held fabulous celebrations every 52 years to mark the simultaneous conjunctions of all the complex religious, agricultural and astronomical cycles of the Mayan calendar.

*Big Bang Moment* commemorates the creation of the universe in  $10^{-14}$  seconds. It is hard to imagine a more appropriate candidate for a festival of feasting, rejoicing, dance and revel. Not every cosmologist is in agreement with the thesis of the "Big Bang Theory". The name was piked up and associated with the physics Jack-of-all-trades George Gamov (science popularization, quantum theory, cosmogenesis, nuclear synthesis of elements, molecular biology!) and is typical of his flamboyant and imaginative cast of mind. Well known to the general public for his many popularizations of science, such as "*One, Two Three...Infinity*"; "*Mr. Tompkins in Wonderland*"; "*The Birth and Death of the Sun*" and others. I met him over the summer of 1956 in Woods Hole, Massachusetts. He died in 1968.

By 1956, even though the *The Big Bang* theory was not universally accepted, it was already more than an idle hypothesis. In 1939 Gamov and his co-workers issued a series of papers, based on careful extrapolation from the known data. Some raised more questions than they answered, yet they were pioneering efforts in the new field of cosmogenesis. The picture of an exploding "cosmic egg" from which everything originated, due to Lemaitre, in 1927, was subsequently developed by Friedmann, Einstein and de Sitter, then brought together under the general heading of the Big Bang Theory by Gamov.

The only serious alternative to the Big Bang Theory for awhile was the *Steady State Theory* of English astronomers Bondi, Hoyle, Gold and Sciama. The basic idea of this theory is that the universe has always looked more or less the way it does *now*. Ironically it was Fred Hoyle who coined the disparaging phrase 'big bang theory' in a radio broadcast in 1949, The Steady State theory was seriously undermined in 1961 by the findings of Martin Ryle, who revealed that recent observations of the outer limit of the observable universe indicated that matter was in fact compressed more tightly together in the very distant past than it is now.

In that same year radio astronomers began receiving signals from a pervasive "background radiation" that seemed to have no identifiable source. George Gamov interpreted these signals as the vestigial "echo"

left over from the Big Bang, and most astronomers agreed with him. Even Fred Hoyle, the most celebrated remaining advocate of the Steady-State theory, discarded it.

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What, then, is the Big Bang Theory? There was a time in the summer of 1956 when I used to run into George Gamov almost daily. Sometimes in the evenings we would find ourselves sitting together around a table crowded with students, biologists and oceanographers, in the Captain Kidd Tavern in Wood's Hole, Massachusetts. While he stirred his beer with a swizel stick he would explain his cosmogenic theories to us. The swizeling of his beer was not unconnected with his explanations of the Big Bang Theory. With the stem of his pipe, he would point to the swirling brew, and say:

"Pay close attention to the angular momentum of the various parts of the stirred beer; also its tendency to foam. The shape of the flow is called a vortex. I have every reason to believe that the entire cosmos is also swirling through under the direction of the Prime Mover."

"Uh?" A student spoke up "isn't that Aristotle? He's outdated, no? Huh?"

"My young friend: Aristotle may sometimes have been mistaken, but he is never outdated! Let me continue: the foam, observe, is more gaseous than the beer. It is also colder, because it has lost heat through expansion. This corresponds to the cooling of the original cloud of hydrogen in the first few hundred thousand years. At this point my analogy breaks down. My theory asserts that, at the very beginning, and even before the beginning, matter was so concentrated that it was not even matter. It was all pure radiant energy, that is to say photons. You know: light rays, X-rays, Gamov rays!"

We had all heard this tired pun so many times, that none of us bothered even to sputter in our beer steins. Dr. Gamov went on:

*"Einstein, in his General Theory of Relativity ( at which point everyone who had not studied Relativity got up and left to take a swim in*

*Buzzard's Bay*), showed that radiant energy has a gravitational attraction. The Primordial Fireball, not more than 8 Suns in diameter, with a density of a million billion grams per cubic centimeter, was held together by this enormous force of gravity in the initial period after the explosion of the Big Bang! "

"How long a period, of time was that?" someone asked.

"Ten to the minus fourteenth seconds."

"How do you know that?" jeered a young cynic,

"Were you there with a stopwatch?"

George Gamov was equal to the challenge: "Young man", he replied, "You are working from a basic misconception. In the first one hundred thousand billionth of a second, there was not yet even any Time!"

Having put this upstart in his place, he continued:

*"The next half-hour was – the word incredible is too tame!\_ The micro-instant of the Big Bang was followed by the steady expansion and cooling of the primal Ylem! "*

"The primal What?"

"The Ylem."

"How do you spell it?"

"The way it's pronounced: Ylem!"

<sup>H</sup> But *how* do you pronounce it?"

<sup>H</sup> The way I'm saying it right now – Ylem. Don't interrupt. The primal Ylem was unbearably hot. In fact my equations seem to show that at the very beginning the temperature must have been infinite, which is impossible, but that is a detail which is easily gotten around. However, within the first hundred-thousandth of a second, it had cooled to a bit more than ten thousand billion degrees. By the end of the first second it was down to a mere 5 billion. This gave the Ylem its first rudimentary structure.

"In the beginning the Ylem was totally structureless, an unconstrained free-for-all of hadrons, photons, protons, mesons,

neutrons, leptons, baryons, bosons, fermions, quanta, neutrinos, anti-neutrinos, anti-neutrons, anti-protons, positrons, and, of course, quarks, which no-one talked about in the late 50's, but they were there."

"What about anti-quanta?" an oceanographer asked:

"The quantum has no mass", Gamov replied and quickly changed the subject,

"Let us return to the Ylem. The Ylem was not destined to remain in its state of innocence. After one second had elapsed, there was nothing left of the Ylem but electrons, positrons, and neutrinos."

"What about anti-neutrinos?" asked the same oceanographer; Dr. Gamov ignored him. The rest of us were merely amazed that something so complicated as the primal Ylem could shape up so completely in only a second.

"What happened next?" I blurted out

"Then!" George Gamov stood up and began making graphic illustrations in the air with his pipe:

"The electrons and positrons, which are related to each other as matter and anti-matter, collided at dizzying speeds, a bare millionth of a percent less than the speed of light - *and almost completely annihilated each other!*

"Try to imagine it! Billions upon billions upon billions of terratons of matter going up in mushroom clouds the size of galaxies, vanishing into pure energy, until nothing but loneliness and desolation prevailed over the vast tracts of the infinite void!" People were getting up and walking out.

"But wait!" he cried, "By a *miracle*, the universe did *not* revert to the first hundred thousand billionth of a second of pre-Ylemic Chaos! For some unaccountable reason (which does not appear to emerge anywhere from my equations) there were *more* electrons than positrons! These alone survived as matter: *and the universe was born!* In less than a hundred seconds the first helium nuclei emerged!"

A few of those who had intended to leave came back, curious in spite of themselves to know how he intended to salvage his theory. It

would have to be at least as spectacular as the way he salvaged those electrons from annihilation with anti-matter!

"From that moment on, event followed event with, one might say, an almost divine inexorability. Within the first half-hour *all* of the elements of the periodic table were created from electrons, neutrinos and photon!

"This is one of the best established parts of my theory. The details, graphs and calculations were set forth in the now classic Alpher- Bethe-Gamov paper of April 1st, 1948, in the Physical Review.

"That's an odd combination of names." someone pointed out, " It sounds like one of those college fraternities."

"The most elite fraternity in the entire academic world." Dr. Gamov conceded, "Indeed Hans Bethe had nothing to do with the paper. He allowed us to include his name because it sounds like Beta. If you read this paper, it will become clear to you, how electrons, neutrinos and photons became protons and neutrons, how protons and electrons became hydrogen atoms, how the hydrogen atoms became deuterium atoms, ( which disintegrated almost immediately, but not too fast for a small percentage of them to become helium atoms ) , how this process moved on to lithium, boron, carbon..."

"Hold on! Hold it right there!" cried a biochemist from the Marine Biological Laboratories: "What kind of malarkey are you trying to pull?" (In the 50's they spoke that way)

\* Why?" Dr. Gamov asked, "Is something wrong?"

"*You can't go from helium to lithium!* "

"And why not?" he snarled, "I can do anything I want to! I told a judge once that I was in contempt of his court, even *after* he threatened to jail me for contempt of court! "

"But you can't argue with the numbers! Helium has an atomic weight of four. Lithium has an atomic weight of six. What about five?"

" So? What about it?"

"How can your theory explain how there are elements past lithium? When the number of nucleons reaches five, the atom disintegrates instantaneously."

"So tell me", George Gamov replied, " How do you know what the universe was like fifteen billion years ago? Were you there?"<sup>1</sup>  
 Against this line of argument, the biochemist had no defense, and relinquished the floor.

However George Gamov was weary of discussing his Big Bang theory, and ordered himself and his colleagues a round of beer. By the time it arrived he was in a better mood. He proposed a contest. The person who, by popular vote, could come up with the best limerick about cosmogony and cosmogonists would receive as much free beer as he could drink for the rest of the evening.

We all set busily to work, and in a short time, each of us had a limerick to submit.

The biochemist opened the contest with the following:

*"There once was a thinker called Ryle  
 Who was totally lacking in guile  
 The steady-state theory  
 Made him terribly weary  
 So he soon proved it wrong, by a mile!"*

His limerick was voted down. It was not bad as an example of its kind, but Ryle's paper would not appear until 1961, and this gathering at the Captain Kidd took place in the late 50's.

My entry came next:

*" When Gamov, Gold, Hoyle and their peers  
 Contemplate the music of the spheres  
 They transmogrify stars  
 As graph isobars  
 And vapors more fragile than silk"*

No-one liked this poem, so the next entry was recited:

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<sup>1</sup> The difficulties associated with the transition from atomic weight 4 to 5 were resolved in a paper by Fred Hoyle, which showed how the elements were created in the interiors of stars.

*"The British cosmologist Gold  
Held ideas which he thought rather bold  
About gravitation  
And on the creation  
Of matter in empty space cold."*

And so it went. After 20 entries were recited, the prize was awarded, by universal consensus, to the following gem:

*"To Hubble the world is a bubble  
That causes us nothing but trouble  
Given speeds close to light  
Might not the world quite  
Disappear on the double, as rubble?"*

As it turned out, the prize-winner was also an incurable wino who avoided beer the way a cat shuns water. Gamov agreed to pay for his wine instead of beer, but the expense of the evening was truly astronomical. After this experience, Gamov never proposed the same sort of contest again.

By the end of the evening, under the softening effects of drink and good cheer, we were inclined to be more favorably disposed to George Gamov's theories. Although Gamov's Big Bang Theory is still full of more holes than there are Black Holes in the Local Group, it remains the best understanding we have about the way the universe began.

*Dr. Roy Lisker  
Big Bang Moment Festival  
Museum of Natural History  
New York, New York  
5 minutes and 32.0011679438132 seconds  
after 1 PM  
May 15, 1977*



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