Cosmological Inferences

"Cosmologists are often in error, but never in doubt." – Lev Landau

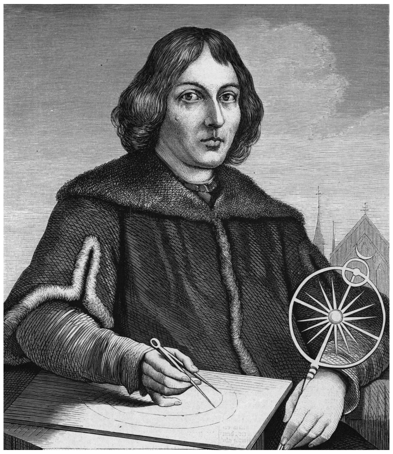
by R. F. Vaughan

Man has probably always strived to understand the cosmos – why would he not? Asking 'why?' is what we do as a species. Once our senses mature to the point that an external world seems undeniable, we seek to find our proper context within it – a family, a tribe, a locale, a country, a continent, the world, the solar system, the Milky Way, a galaxy group, a cluster, supercluster, and universe. The sun, moon, planets, and stars befuddled the endeavor until Copernicus simplified that for us. Emanual Kant went a step further by reducing the significance of our sun to but another star in the Milky Way galaxy. Edwin Hubble was next to expand our universe. Expansion has occurred at every step in the succession of understanding our reduced significance to the universe. It is always the last in the sequence that we are after, even knowing that infinite series exist, whose sum although finite, are without a final term. But we insist on knowing what's next, and so for some it is a 'multiverse' even while admitting they can know nothing beyond this universe.

What Hubble did was discover a 'standard candle' for looking out into the vast universe with which one could infer distance. It was the similarity of galaxy types whose spectral features and inherent brightness formed a basis for identifying them as similar. For the closer galaxies, a difference in observed brightness indicated a difference in distance. He noticed that a unilateral shift in the spectra $\Delta\lambda$ of the galaxies was correlated with their distances d. Thus, 'redshift' became the indicator of cosmological distance by defining the relationship, $z = \Delta\lambda/\lambda_e = H_o d$, between distance d and the unitless redshift parameter z. The constant of proportionality was H_o. Here $\Delta\lambda$ was the difference between the observed wavelength of radiation and the wavelength of that which was emitted divided by the emitted wavelength λ_e. There were caveats on caveats, of course, there always are, but the trend was undeniable. Our Milky Way galaxy is not the center of the universe. Eventually measurements determined H_o with sufficient accuracy to proceed with the exploration of the universe beyond the immediate environs of the Milky Way.

But we ask 'why?" Our species always has, always will. And when the answer "God said so" is not enough, the ripened fruit of the Tree of Knowledge beckons, and Pandora's box is opened – again – to mix a couple of metaphors.

As early as Hubble's first discoveries, conjectures arose concerning possibilities of alternative causes of the redshifting of



Nicolas Copernicus

Immanuel Kant

Edwin Hubble

galaxy spectra. Perhaps the loss of photon energy in propagating billions of light years through an intergalactic medium facilitated the direct distance-dependence of redshift, which is after all what is observed. Hubble seemed to have considered the possibility that we looked out into the universe wearing rose colored glasses much longer than his peers. But a consensus emerged that the Doppler effect of recessional relative velocities, known to cause a redshift of mundane sources of radiation, was also the cause of this cosmological redshift.

$z = \Delta\lambda / \lambda_e = v/c$

Here v/c is the recessional velocity of the source of the radiation divided by the speed of light. It seemed like the veritable definition of redshift, neat and clean as a formula with no more mystery as to its cause. But it has no bearing on what is observed; $z = H_o d$ is what is observed.

Scientists seem to have this penchant for ‘neat and clean’ when new data fits an old formula – new cloth on an old garment. That is what gave rise to an ecstatic comment when the cosmic microwave background data was shown to precisely fit the Planck formula for blackbody radiation at a temperature for 2.7 K. The data was provided to the public with a capitalized bold font statement, “THEORY AND OBSERVATION AGREE” printed on the plot. It’s a bald-faced lie that anyone predicted that cosmic microwave radiation would have a temperature of 2.7 K. The fact that it happens to be blackbody radiation is perhaps another proof of Planck’s theory, but if so it came decades after agreement with theory had been demonstrated. When George Smoot and colleagues announced that they had found and mapped a pattern of tiny temperature fluctuations in the CMB, he emoted, "If you're religious, it's like seeing the face of God." These ‘tiny fluctuations’ are differences of ten to the minus fifth! God must have very shallow eye sockets and a very flat nose. C’mon guys, act like you’ve been here before.

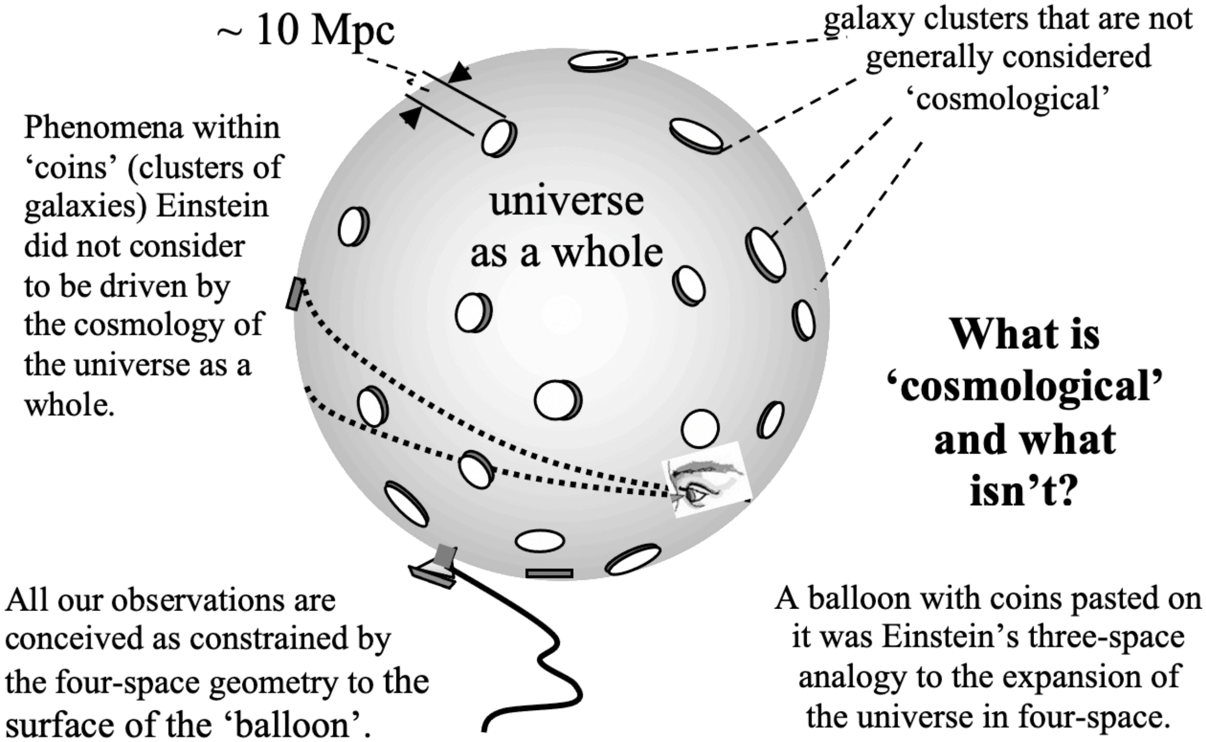

George Smoot

Meanwhile, sixty years before Smoot humiliated himself to a Nobel prize, acceptance of the Doppler interpretation of galaxy redshift was not without unimaginably difficult implications requiring the creation of the universe from nothing, unprecedented expansion at speeds far greater than the speed of light, and ultimately acceptance of invisible matter and energy. And finally with Smoot, reinterpretation of the inevitable radiation of any – however large – thermodynamic system.


Yakov Borosovich Zel’dovich

All these were antithetical to the mere suggestion that there might be a previously unknown form of scattering by observed matter in intergalactic regions that results in the redshift of radiation passing through it. In retrospect, would it have been better to embrace a universe emerging from nothing, escaping from its own black hole, and invisible unexplained matter and energy, or search for a previously undiscovered interactive process of known radiation and matter? That is what was at issue when an assertive Yakov Zel'dovich known for having said, "Without publicity, there is not prosperity," placed his influential finger on the scale, proclaiming any such interaction would be utterly impossible and thus anathema to the study of cosmology as a serious science. He demonstrated the statement of his mentor, Lev Landau, stated above.

Whereas it is easy enough to realize that what appears to be a linear relationship for relatively small distances and values of redshift, may actually be an approximation to a nonlinear functional relationship such as the natural log with no hidden meaning or change in the factuality of there being a correlation between distance and redshift. But with the Doppler relationship an endless stream of questions with bad options arises. Are galaxies speeding away from us at the same rate in all directions? Yes. Then are we at the center of an exploding universe? Unlikely, to such an extent that Einstein introduced the four-space possibility shown in figure 1, which seems more tenable. A nonlinear relationship between redshift and velocity would have been seen as a good thing if velocities were not to exceed c, which is taboo.



Whether the universe would continue to expand or deflate became a preoccupation. With an inflationary initial period and now with Reiss's claim of a more recent acceleration, it is as though additional breath had been required of the creator.

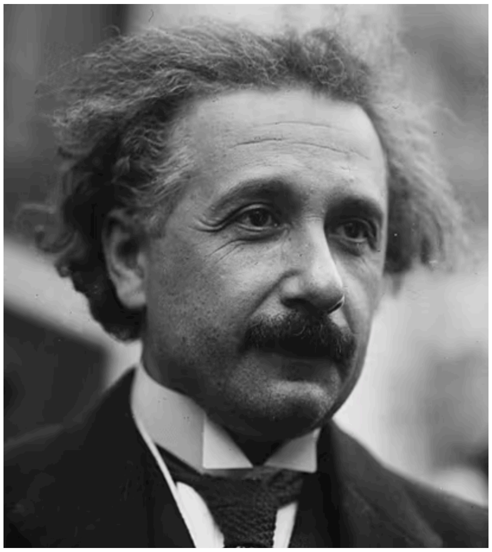
Figure 1: Einstein's early conception of a four-space universe with galaxy clusters as nonexpanding coins on an expanding surface

Certainly theorists had their work set out for them. Long ago Newton had concluded that although a finite universe would collapse under its own weight, an infinite one would not. That became a major issue for Albert Einstein, later joined by Steven Hawking. This obsession led to what Einstein considered to have been his most egregious error in doubting Poisson's universally accepted equation. Hubble's discovery and interpreting it as confirming recessional galaxy velocities brought Einstein to his senses with regard to the legitimacy of Poisson's equation. But he and Hawking still engaged in the misapplication of that formula as follows.

In consideration of his general theory of relativity Einstein was primarily concerned with mass density in his attempt to disprove viability of the infinite extent of Newton's universe. Naively, Einstein and Hawking envisioned an infinite universe as an indefinitely enlarged spherical region of uniform density. Using Poisson's equation, they demonstrated that such a universe would collapse. That totally invalid depiction, despite continued acquiescence to legitimacy of Poisson's equation, has not been relinquished by cosmologists. In fact even a lambda fudge term that Einstein had incorrectly added to the Poisson equation to keep a universe from collapsing, he later acknowledged as having been his most egregious error, has been requisitioned as the density of supposed dark energy. But they were wrong – not just in adding an unjustified term to Poisson's equation, but much more significantly in their characterization of an infinitely extended universe. Any three-dimensional model of the universe, whether finite or infinite, as an expanded sphere of a given density implies an illogical 'outside' of the universe with an outer surface at which any collapse must inevitably begin. In this simplistic characterization, we would be at the non-Copernican center of the universe as it collapses around us. Alleviating the unjustified aspect of the depiction is quite straight-forward. There is no outside of the universe. No one comes in to shave the barber who shaves everyone in town.

It is Einstein's and Hawking's model, not Poisson's equation, that is incorrect. However large the three-dimensional sphere one chooses (refer to the one on the left in figure 2), there is an equally large sphere adjacent to it, which is still a part of an infinite universe. All the rest of the universe (both inside and outside the larger sphere) is completely symmetric with regard to the point in question, so all gravitational forces cancel at every such point on the surface of the smaller sphere that Einstein and Hawking used as the model of an infinite universe. There could be no collapse. And forced to imagine observation in four dimensions is a bit of an imposition.


Sir Isaac Newton


Albert Einstein


Steven Hawking

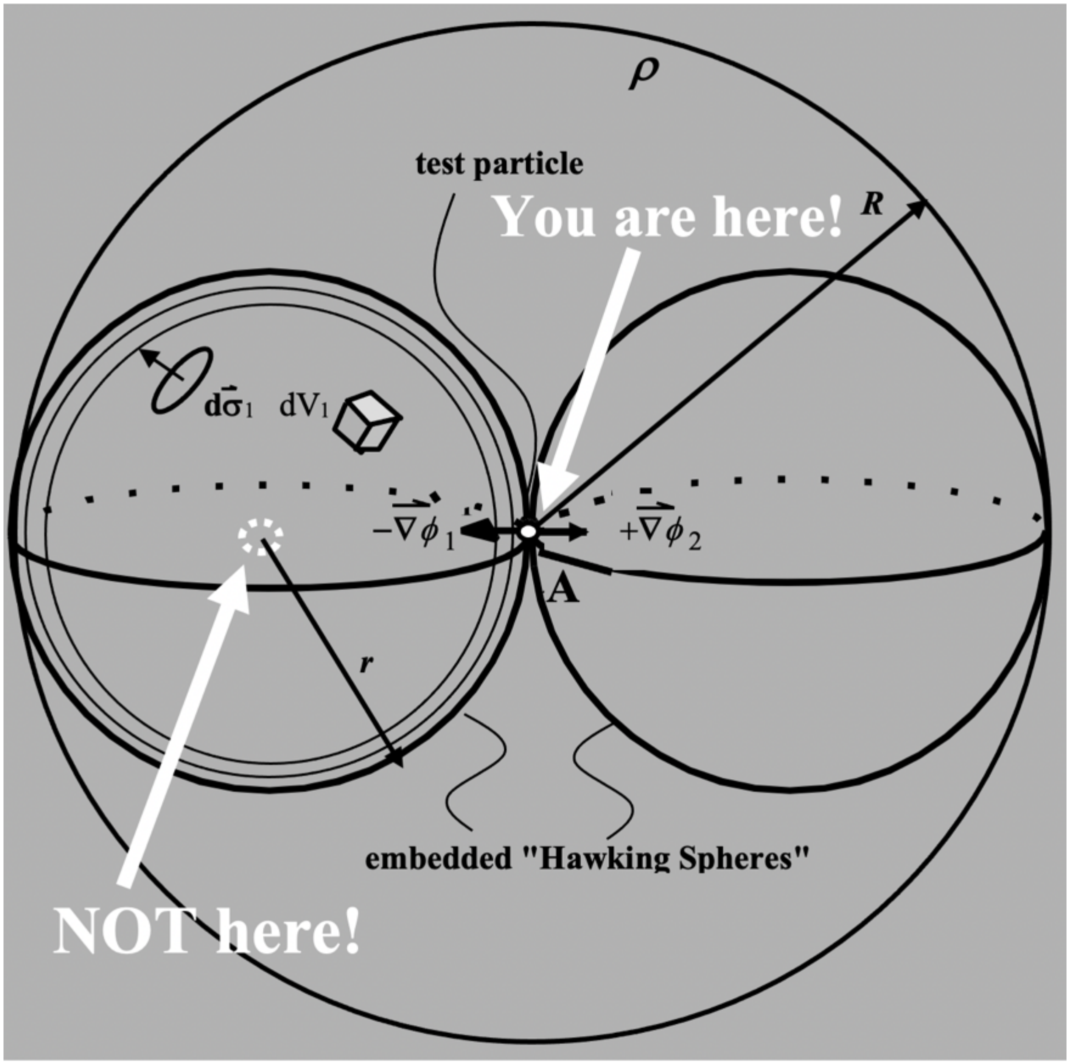


Figure 2: Using the Poisson equation to model a stable uniform-density infinite universe

If the left-hand sphere in figure 2 were somehow to have been filled with a higher total density of matter without affecting the surrounding uniform density, it and regions surrounding it would begin to collapse inward forcing a larger and larger exception to uniformity. If instead, that sphere had been empty without affecting the surrounding uniformity, then the hole would expand indefinitely outward. This is due to outward gravitational force on the particles at the boundary that would increase the size of the hole. But in a stationary state universe there would always be a level at which the universe can be considered uniformly dense.

Of course, uniformity at the detailed local level of our universe is unrealistic, to say the least. Random variations are required of a realistic dynamic model of the universe; that would produce clumps and holes in the uniformity. One of the more egregious of Einstein's errors was in depicting an exclusively gravitational universe. Any adequate model of the universe must include thermodynamic considerations with its ideal gas law for which a stable uniform mass density would be associated with uniform temperature and pressure. In the (only realistic) situation of higher temperatures and pressure in the denser clump, pressure would limit infalling matter from its outer regions, stability ultimately resulting. A void would be filled in by diffusion due to pressure from the outside until a spherical declivity was filled in enough to counter the outward gravitational force. Unless matter were to have been inserted or extracted from the general uniformity, hydrostatic equilibrium would be maintained with uniformity established at a higher level of granularity. In either of these cases, there will be a gravitational clumping toward the center of a left-most spherical region surrounded by a less dense region out to where the uniform density is realized at the interface to the sphere of counter gravitational force. This is because all symmetrically organized forces external to the two smaller spherical regions nullify each other. This is shown in figure 3 with typical functionalities of density, temperature, and pressure shown in figure 4. Variable density regions will expand and be extended until average density is equilibrated to the average uniform density and pressure values with cancelation of forces at the boundaries of the deviation. The average of temperature and pressure will follow the mass density.

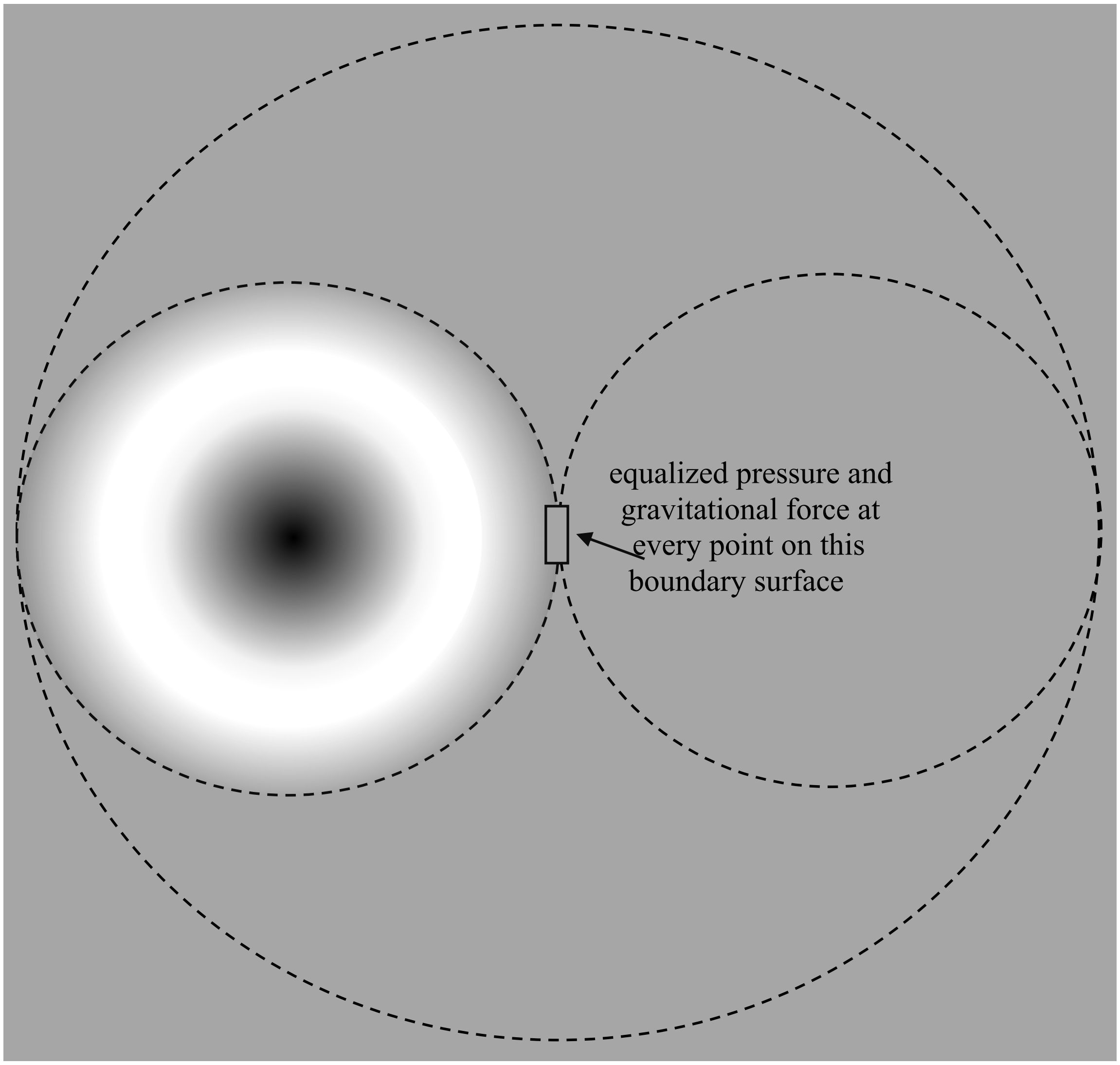


Figure 3: Poisson equation applied to stationary state model of varied uniform density

Long after dark matter was firmly affixed in lexicons, X-ray background radiation and finally cosmic microwave background (CMB) radiation were discovered and given names, bringing them to the forefront of cosmological consideration. However, this discovery was not predicted by the standard cosmological model. The CMB was discovered by explaining anomalous measurement from an antenna that had been attributed to pigeon feces. For this bit of fortuity, Penzias and Wilson received the Nobel prize.

These radiations originate in plasma gases in intergalactic regions whose thermodynamic properties, including a density that greatly exceeds that of all the stars in all of the galaxies combined, and temperatures generating high energy Xrays (see figure 3), and the extreme hydrostatic pressure. All this was unknown when Zel'dovich closed the debate on the profound implications of redshift. Thermodynamic effects had been overshadowed by the emphasis on gravitational effects. Fortunately, the nature of the intergalactic plasma gases is now quite well understood.

Robert Wilson and Arno Penzias

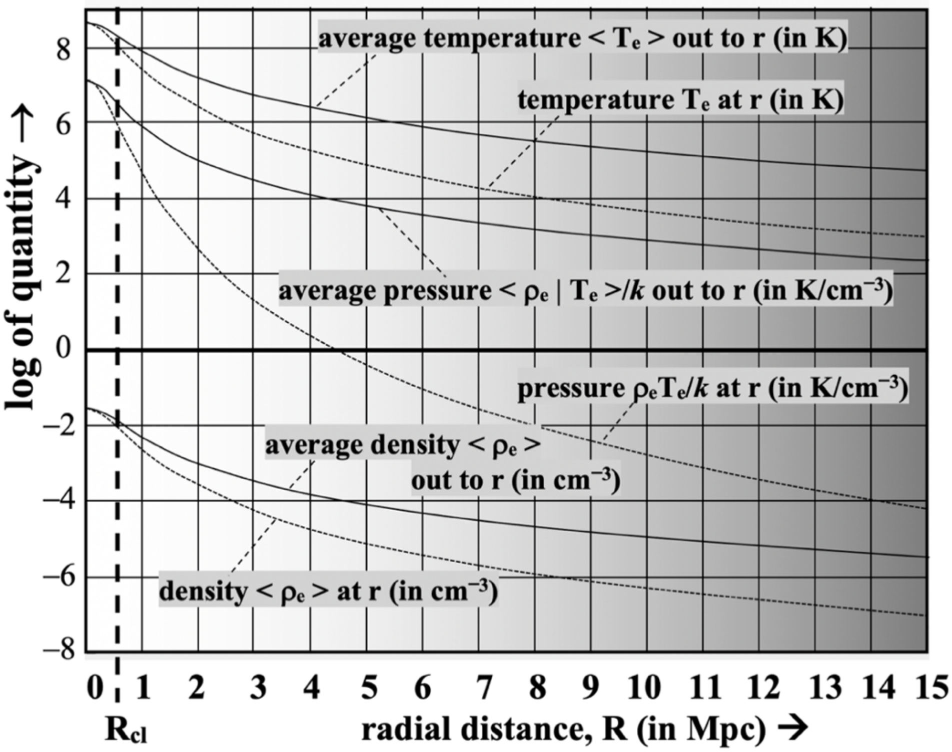


Figure 2: Typical temperature, density, and pressure of intergalactic plasma gases in a galaxy cluster cell as functions of the distance from the centers of the cells

Excuses proliferate for the fact that these intergalactic plasma gases exist, counter to accepted prognostications and presumptions of a cold empty space whose effectuality would be nil. These major misconceptions have persisted regarding the vast regions between galaxies for much longer

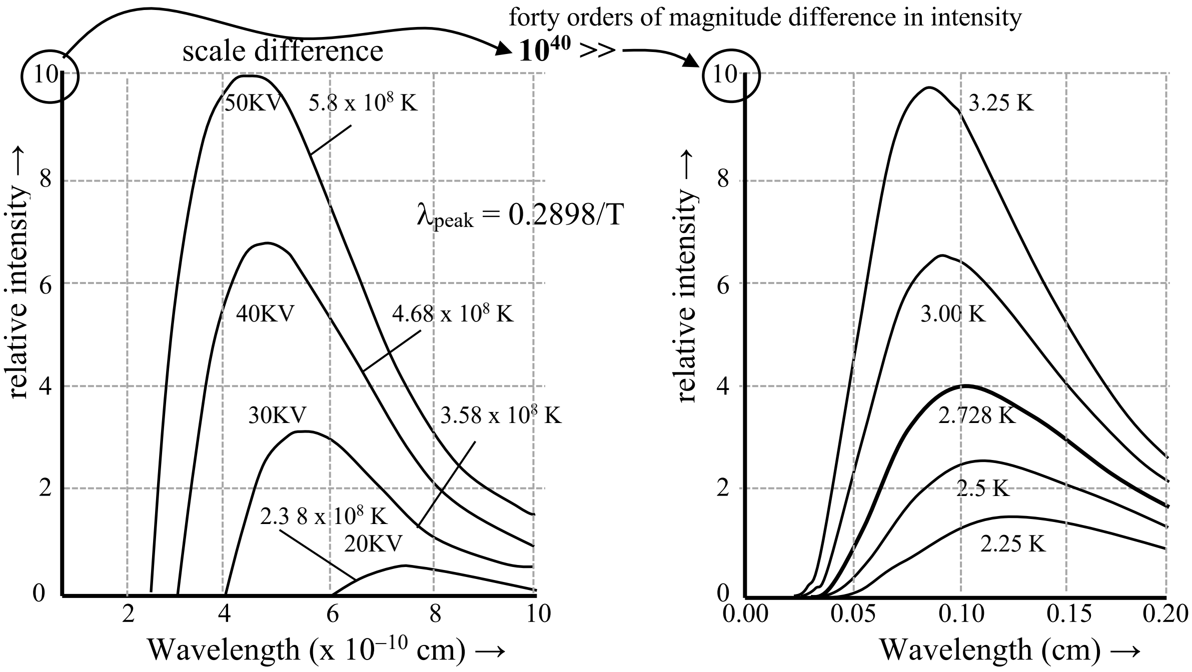


Figure 3: Thermal radiation from free electrons in cluster cells – intense Bremsstrahlung Xray radiation from cluster core region, weak microwave radiation from surrounding regions

than they should have and by persons who had to know better. For example, in 1998 Riess et al. stated the following: "…there are huge contrasts between the stars with their blazing surfaces (and still hotter centers) and the sky between them, which is almost at the 'absolute zero' of temperature – not quite, of course, because it is warmed to 2.7 degrees [in Kelvin (K), but –454 degrees on the Fahrenheit scale!] by the microwave 'echoes' from the big bang." Their theoretical motivation is captured by the statement, but facts must remain factual. It is not empty 'sky', it is hydrogenous plasma which in total dwarfs all other baryonic mass in the universe. And its temperature ranges from somewhat less that 10^4 K at which hydrogen clouds form between clusters that produce Lyman-alpha forests to as high as 10^9 K at the centers of galaxy clusters that generate the continuous X-ray background radiation. At its lower range of temperatures (still with nearly complete ionization) between clusters, the plasma is virtually invisible. Galaxy clusters are predominantly hydrostatically maintained regions of hot plasma gases, whose characteristics were illustrated in figure 2. The thermodynamic energy of the gas near cluster centers generates Bremsstrahlung radiation as shown at left in figure 3. "Stars with their blazing surfaces (and still hotter centers)" could more accurately be contrasted with the temperatures between galaxies in the *opposite* sense to that specified by Riess et al. who received a Nobel prize for showing that the consensus model does not fit the SN1A supernova luminosity data without a further adjustment requiring the acceleration update at some point in time since the big bang.

Adam Riess

Luminous matter has taken on a more specific meaning than was available when dark matter was first introduced as its opposite. Stars and their emanations are of much less significance than was known at that time. It was the last decades of the 20th century before all that is shown in figure 2, 3, and 4 had been discovered. We will discuss the cosmic microwave background spectrum, CMB and how its presence is accounted in the alternative approach to cosmology elsewhere.

There have been considerable changes to acknowledged ratios of mass to luminosity of astronomical objects obtained over the last half century. Loewenstein (2003) provides then-current data on these ratios. (The table included below is taken from his article.) Changes to these ratios continue, but do not diminish, the significance of intergalactic plasma gases to that of stars.

Mass-to-Luminosity Ratios and Mass Fractions

parameters	universe as a whole	galaxy clusters
$\langle M_{total} / L_{total} \rangle$	270	300
$\langle M_{stars} / L_{stars} \rangle$	3.5	4
$\langle M_{gas} / L_{gas} \rangle$	41	35
mass fraction in baryons	0.17	0.13
mass fraction in stars	0.013	0.013
mass fraction in gas	0.15	0.12
stars/gas ratio	1/12	1/9

Loewenstein (2003)

It goes without saying that if galaxies are moving away from us at velocities approaching the speed of light there must have been one hell of a big bang at a calculable time and distance in the past. And as for the future… well figure 5 illustrates the options we are given by one version or another of the standard cosmological model. Robert Frost's poem is as explicit. The fascination with a Big Bang and a "let there be light" origin following "darkness on the face of the deep" has taken hold with its biblical scope and mathematical challenges embedding it more firmly into our ancient cultural heritage and emerging scientific aspirations. It is time to reconsider the alternative.

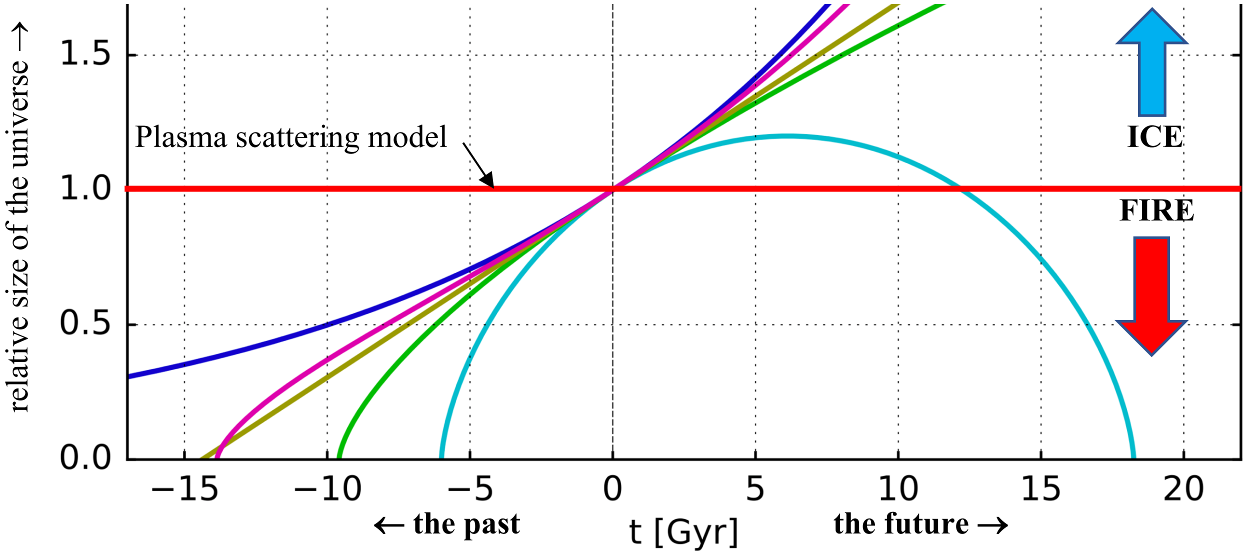
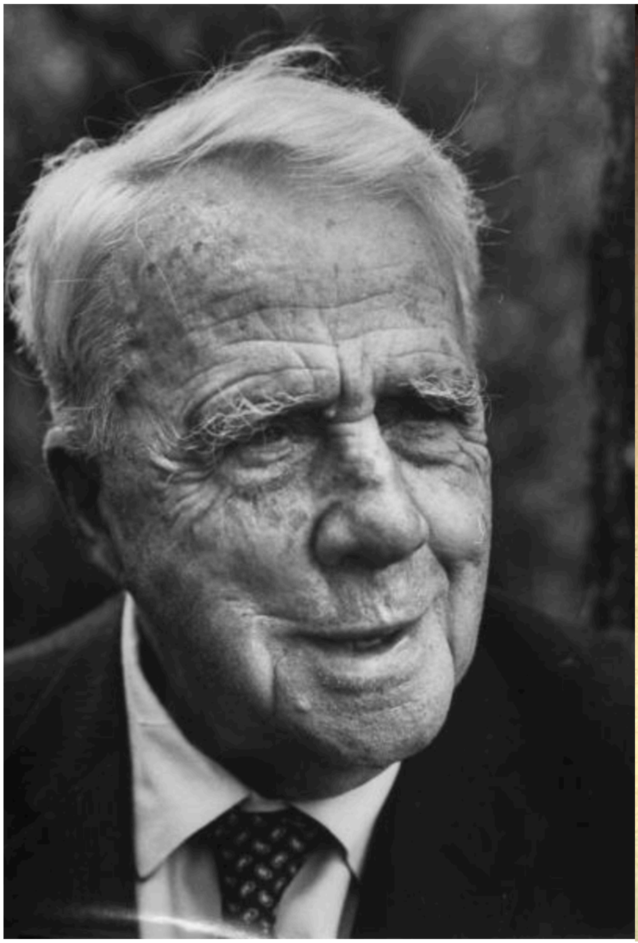
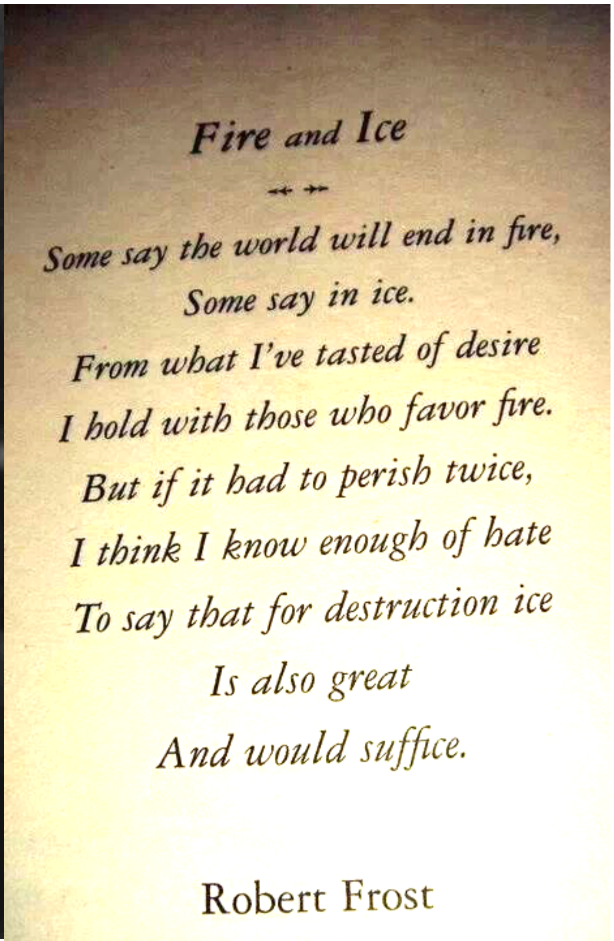


Figure 4: The far-flung implications of cosmological inferences



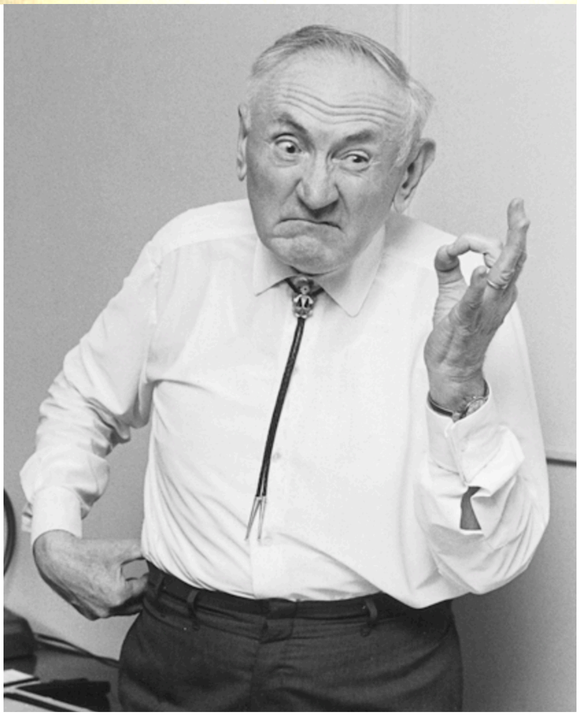


Fire and Ice

Some say the world will end in fire,
Some say in ice.
From what I've tasted of desire
I hold with those who favor fire.
But if it had to perish twice,
I think I know enough of hate
To say that for destruction ice
Is also great
And would suffice.

Robert Frost

As an aspect of Hubble's precaution that the redshift-distance relation only holds for distances greater that several hundred mega parsecs, what transpires within those lesser regions is of note. Galaxies are densely concentrated near the centers of clusters with the same general distribution as the mass of the plasma gases – many orders of magnitude greater numbers near the center than at the outer edges. Thus, even though tightly bound spatially, cluster galaxies appear to be distributed in lines in redshift surveys. See figure 5. These dense rays of galaxies are what are called the 'fingers of god' phenomena. Fritz Zwicky seems to be responsible for the term and used the virial theorem to try to explain them as the Doppler effect of the orbiting velocities of the galaxies. That ultimately gave rise to what he termed 'dark matter' because of the additional mass that would be required to result in such a tremendous spread in galaxy orbital velocities if a first-order Doppler



Fritz Zwicky

line of sight velocity effect was responsible for the redshift. There are velocity variations due to centripetal acceleration caused by the gravitational effect of baryonic matter in the cluster to be sure, but that is typically less than 10% of the variation that is observed. That was the rationale for introducing the hypothesis that there had to be excessive amounts of unseen (dark) matter distributed in and around the cluster cores. Although Zwicky tried harder than most to come up with a 'tired light' version to account for cosmological redshift, even considering the effect of free electrons. Ultimately, he gave up, assuming with Zel'dovich that any such scattering would alter the direction of the scattered light. Dark matter was here to stay.

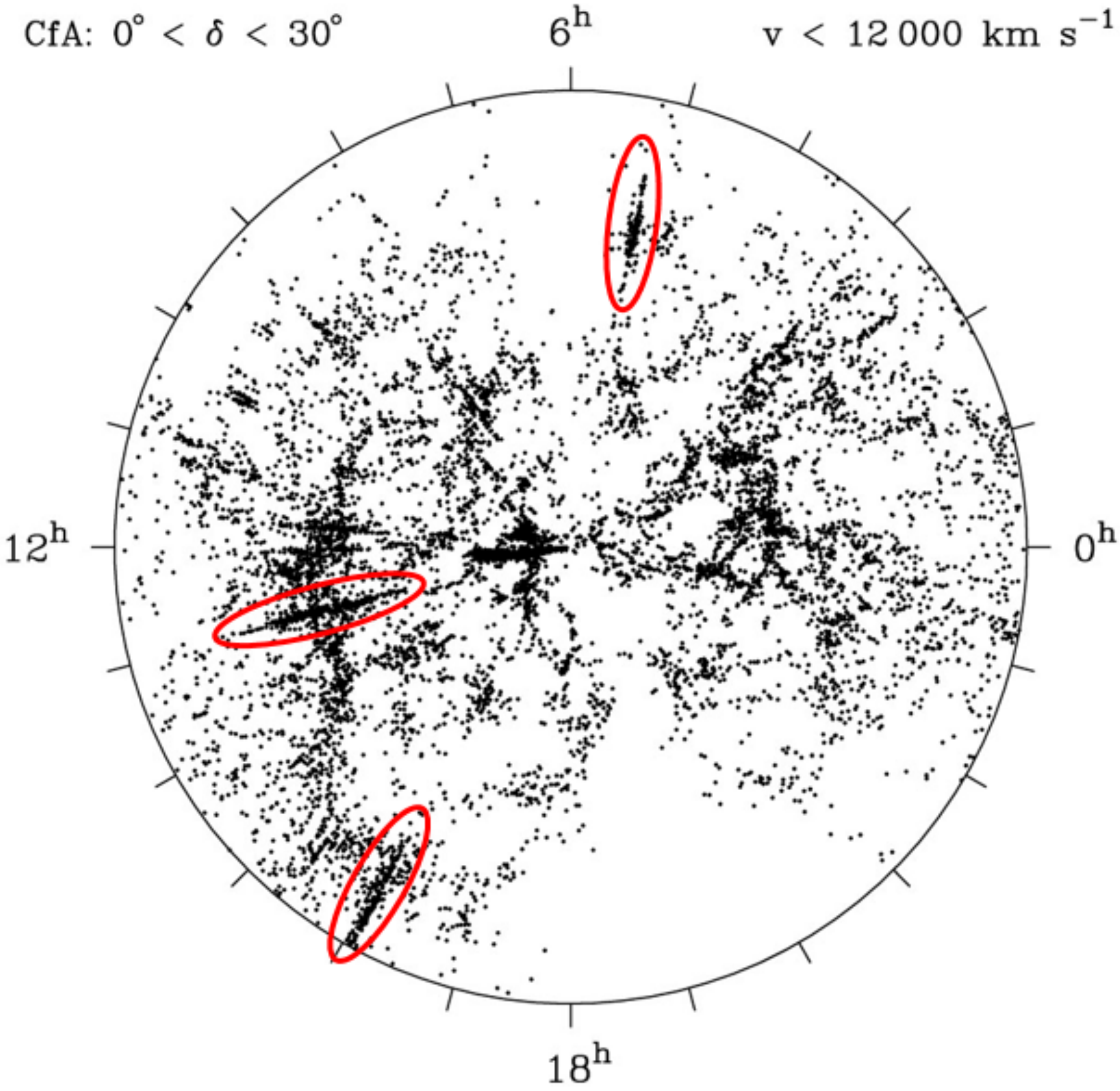


Figure 5: The 'fingers of God' phenomena in galaxy surveys

Zwicky also discovered and coined the term 'supernova', which because of their extreme luminosity could be observed at greater distances (redshift) than galaxies. It was Riess, et al. who demonstrated that no standard model curve could be made to fit the data for the SN1A supernovas without the introduction of a mid-course acceleration to the expansion of the universe.