What are type 1a supernovae telling us?

Mary Beth de Repentigny

Creation scientists do not necessarily have a philosophical problem with the idea that the expansion rate of the universe might be accelerating, as the data from type 1a supernovae could be telling us. But there is an equally valid, less accepted interpretation of these same data which bolsters creationist cosmologies. In their search for a scientific explanation to the starlight and time question, two creationists have developed models which involve large-scale inhomogeneity as a required boundary condition. Although such a boundary condition is contrary to the oft-revered Cosmological Principle, a few mainstream scientists are calling for their colleagues to critically reanalyze its validity in light of the recent type 1a supernova data.

A supernova is a star that explodes as its gravitational self-attraction causes the core to collapse. These dying stars, which go out with a bang, are the brightest objects in the universe, often outshining all the other stars in their host galaxies put together (figure 1). One particular category of supernovae, referred to as type 1a supernovae (SN1a), arises when a white dwarf star explodes its degenerate matter throughout. The resultant afterglow of all SN1a explosions reaches nearly the same maximum luminosity, making this type of supernova by far the best, most luminous standard candle that astronomers have ever found to determine the distances to far-off galaxies. The general consensus among astrophysicists is that the SN1a data, which are based on the distance-luminosity relationship and redshift measurements, are showing an acceleration of galaxies' recession rates. These data were corroborated by two independent research groups and amounted to a 'cosmological furor' which came at the end of the past millenium.[1]

That the type 1a supernovae data have been almost universally interpreted as meaning that the acceleration of the universe's expansion rate stems from a philosophical bias toward the Cosmological Principle. This principal states the long-held notion that the universe is homogeneous (uniform throughout) and isotropic (invariant with respect to direction). A universe satisfying the Cosmological Principle would possess no unique center, and no edge. If large-scale inhomogeneities in the universe are discovered, then the Cosmological Principle is invalid, and the possibility of special locations does exist. To some, this possibility is unpalatable because of the anthropic implications it carries. For example, Christian doctrine tells about a plan of salvation centered upon a particular planet inhabited by a race of people descended from one particular man.

The French astrophysicist Marie-Noelle Celerier has pointed out from the beginning, however, that a straight reading of the SN1a data does not exclude the possibility of ruling out the Cosmological Principle.[2] This plausible alternate interpretation of the SN1a data implies large-scale inhomogeneity within the universe, with no constraint on the cosmological constant (the cosmological constant amounts to the universe's expansion rate). At least two creationist cosmological models have predicted inhomogeneity in the universe, with the earth near the center. Our confidence in such models can thus be encouraged as we consider with objectivity what the type 1a supernova data are telling us.

Type 1a Supernovae as standard candles

A standard candle in astronomy is a class of objects with known luminosity due to some characteristic quality. This so-called absolute magnitude can then be used as a standard of comparison for the apparent magnitudes of other shining objects of the same class. These objects' distances can then be calculated using the principle that luminosity decreases with the inverse square of their distances. In other words, the further away an object is, the less bright it will appear to be. Type 1a supernovae can be used as standard candles because they reach approximately equal luminosities as they occur under very specific initial conditions.

The model which describes these super-explosions begins with a white dwarf whose hydrogen has all been fused into heavier elements. Astronomers theorize that this particular kind of white dwarf explodes because a nearby companion star has rained hydrogen-rich material onto its surface as the companion passes through its red giant phase. The white dwarf grows denser and hotter as more material builds up on the surface, until the white dwarf's mass reaches a value of 1.44 times the sun's mass. This critical value for a white dwarf's mass is known as the Chandrasekhar limit, beyond which no white dwarf can exist. A white dwarf with mass greater than the Chandrasekar limit will either collapse under its own weight (perhaps becoming a neutron star), or set off proton fusion within its degenerate matter. When this 'blast wave' of proton fusion roars through the white dwarf, its carbon nuclei can fuse into heavier nuclei. The degenerate matter which makes up the white dwarf reacts very slowly to anything that happens nearby because its electrons are locked into place by the exclusion principle. The increased temperature due to the carbon fusion creates a resultant wave of nuclear fusion which spreads throughout the whole white dwarf before it can expand, thus blowing the entire object to bits (figure 2).

Astronomers have developed two-dimensional computer models that run on the Jaguar supercomputer at Oak Ridge National Laboratory and supercomputers at

Lawrence Berkeley National Laboratory. These models examine the influence of physical differences between type 1a supernovae on their maximum luminosities in order to determine how dependable a standard candle these astronomical objects actually provide. According to an article in *Nature* magazine's 12 August 2009 edition, these simulations show that ignition does not occur in the exact center of the star. Therefore the explosions are not spherically symmetric.[3] A source of variability comes from the fact that these asymmetric explosions look different when viewed at different angles. Another, dominant source of variability in luminosity among SN1a's is thought to come from the synthesis of new elements, especially nickel-56, which decay radioactively to heat the debris which in turn radiates light, producing the lingering afterglow of the initial explosion. These sources of variability would not produce systematic errors in luminosity measurement studies as long as large numbers of observations are used and researchers apply standard corrections for them.

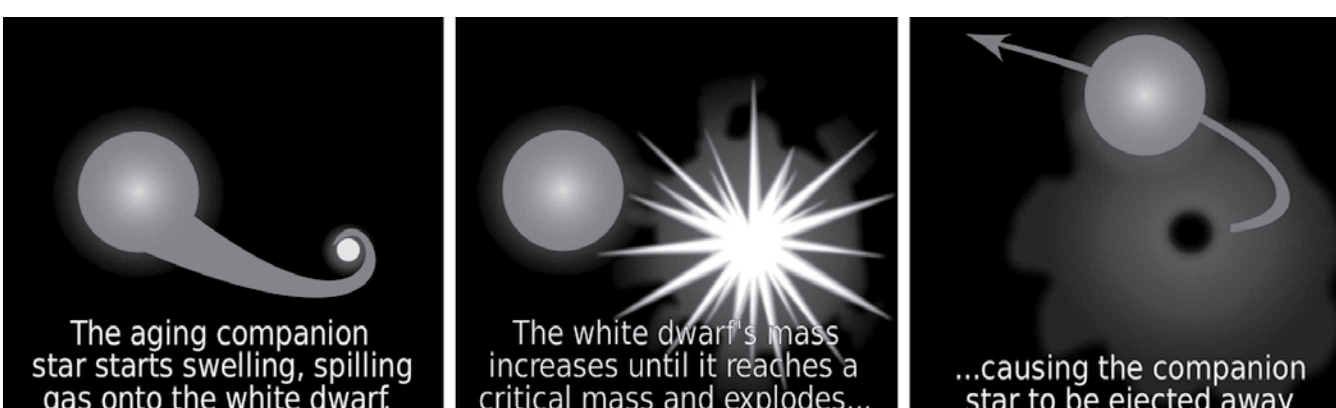
There is, however, a small effect from systematic differences in the initial chemical composition of the white dwarf stars at different distances from us. Stars that are closer to our vicinity, and thus interpreted to be younger, are likely to contain more heavy elements than the more distant stars, which are seen as being older. Calculations of this effect result in errors in distance measurements on the order of 2% or less, which does not seem like much, but future studies which wish to use type 1a supernovae as standard candles might require a precision that would make errors of 2% unacceptable.[4] All of the observational and systematic errors in the supernova data need to be accounted for so that scientists can be certain that these supernovae are not misleading them into the shocking conclusion that they presented to the world in 1998, as discussed below.

Photograph courtesy of NASA

Figure 1. The bright spot on the lower left is supernova 1994D in the NGC 4526 galaxy. By the time this image was taken, the supernova's light had already faded somewhat. At the time of its explosion, a type 1a supernova can outshine its entire host galaxy. Image by NASA, ESA, The Hubble Key Project, and The High-Z Supernova Search Team.

Is the expansion rate of the universe is increasing?

Under the influence of a positive cosmological constant, which would act, in effect, as an accelerating force on the expansion rate of space, supernovae in distant galaxies would be further away, and hence less bright, than we would expect if the cosmological constant were zero. In 1998, two supernova research teams announced that their data 'reveals' a nonzero value for the cosmological constant, meaning that the universe will continuously expand ever more rapidly as time goes by. Gravity would have slowed the expansion somewhat, but the cosmological constant's acceleration of expansion will eventually triumph, they claim. This conclusion is logical in that as galaxies theoretically separate by ever-greater distances, the pull of gravity between the galaxies would become ever-weaker. But every volume of new space that would be appearing (from nothing) would have more pushing power, which would cause the universe to expand ever more rapidly as time goes by.[5]



NASA, ESA and A. Feild (STScI); vectorisation by Chris

Figure 2. Model of the formation of type 1a supernovae.

One of the two groups of astrophysicists researching SN1a's is the High-Z Supernova Search Team at Harvard University, and the other is the Supernova Cosmology Project at Berkeley. In his book, *Runaway Universe*, Donald Goldsmith describes how the friendly rivalry between these two groups helped to advance their progress. He explains that their conclusion of a nonzero cosmological constant gained rapid acceptance because these two teams of scientists reached the same conclusion from independent sets of data. Both teams were highly experienced and both teams were suspicious that the other group had missed something important in obtaining and analyzing the data.[6]

Because SN1a's are considered to be relatively consistent standard candles, researchers can measure the apparent brightness of a highly-redshifted ('high Z') SN1a and compare that to how luminous it actually is, in order to calculate its distance. Scientists can deduce the object's recession rate by measuring its redshift with a spectroscope. In analyzing the data, it is wise to realize that a small observational error of 1% or better is involved with these redshift measurements, while the corresponding distance estimates are not as precise[7].

The observations announced in 1998 by both research teams show that very distant SN1a's are not redshifted as much as expected. To most evolutionary astrophysicists, this implies that the rate of expansion billions of years ago was less than it is today. The experts from the High-Z Supernova Team conclude in their own words as follows, "The luminosity distances of our 16 high-redshift SNe1a are, on average, 10–15% farther than expected in a low mass-density (mass density ΩM = 0.2) universe without a cosmological constant. Our analysis strongly supports eternally expanding models with positive cosmological constant and a current acceleration of the expansion."[8]

Is there large-scale inhomogeneity in the universe contrary to the Cosmological Principle?

There is another valid interpretation for the published SN1a data which has not been widely considered because of the philosophical implications it involves. Astrophysicist Michael Rowan-Robinson, in his book *Cosmology*, boldly describes the disdain among his colleagues for dissention on the issue of the Cosmological Principle saying, "It is evident that in the post-Copernican era of human history, no well-informed and rational person can imagine that the earth occupies a unique position in the universe."[9] Such staunch dogmatism is being challenged by a few scientists who are willing to look at the supernova data with uncommon objectivity. Marie-Noëlle Célérier, of the Observatoire de Paris, discusses how the claim for a strictly positive cosmological constant from SN1a data proceeds from an a priori homogeneity assumption. She points out that the Cosmological Principle plays a central role in the whole field of cosmology, but she cautions her peers to realize that it is a purely philosophical assumption that has never been verified. She then proceeds to show her colleagues that "large-scale inhomogeneity can mimic a cosmological constant in a homogeneous universe up to the precision achieved by current measurements."[10]

The observational value of the cosmological constant based on the SN1a data is off from the predicted theoretical value by 120 orders of magnitude. Theoretical physicist Leonard Susskind sums up what may very well be the worst theoretical prediction in the history of physics by saying,

> "Well, the best efforts of the best physicists, using our best theories, predict Einstein's cosmological constant incorrectly by 120 orders of magnitude! That's so bad that it's funny."[11]

Things get worse when theorists are forced to consider what natural mechanism could account for the incredible fine-tuning that cancels the repulsive effects of a positive cosmological constant to the first 119 decimal places. By reading the supernova observations within the framework of a homogeneous, isotropic universe that the Cosmological Principle asserts, one can conclude that if the laws of physics were not balanced on an incredibly sharp knife edge with this very small, but positive cosmological constant, atoms would never have had the opportunity to form in the primordial universe, much less any stars or planets. Note that the majority of physicists have been reluctant to consider that the Cosmological Principal may not be true because of the improbability of earth's being in a special place, relatively near the center of the universe. But, ironically, most have accepted the notion that the cosmological constant is so impossibly fine-tuned to allow a hospitable universe in which life could have evolved. George Ellis, who is considered to be one of the world's leading theorists in cosmology, realizes that it may be time to explore the possibility of a universal center and edge. He encourages his colleagues to do the same by pointing out the following:

> "A typical observationally viable model is one in which we live roughly centrally (within 10% of the central position) in a large void; a compensated underdense region stretching to z≈ 0.08 with δρ/ρ≈ -0.4 and size 160/h Mpc to 250/h Mpc, a jump in the Hubble constant of about 1.2 at that distance, and no dark energy or quintessence field present."[12]

Figure 3 below illustrates the model of which Ellis speaks. To be consistent with the WMAP data of the cosmic microwave background radiation, which is basically isotropic, the earth needs to be near the center of the prospective void, in violation of the Cosmological Principle. Space in the void would have less gravitational retardation and thus expand faster than space in the outer region. Objects outside the void would then be further away than they would be in a homogeneous universe. This unconventional model is competing with a probability of 10^{-120} for the cosmological constant in a FLRW (big bang) universe. "We do not have to get very high probabilities to outdo

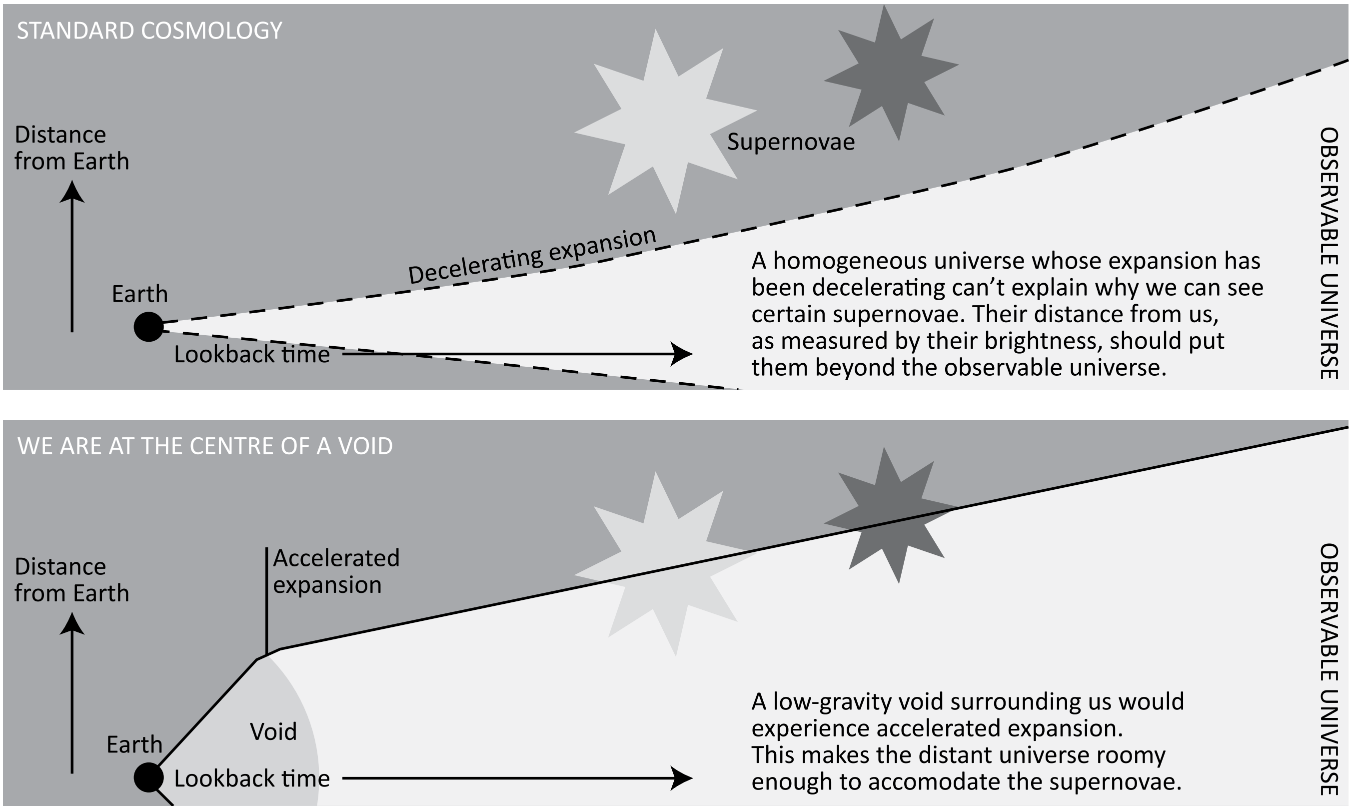


Figure 3. A viable model that fits nicely with the type 1a supernova data, has the earth near the center of an underdense void, contrary to the Cosmological Principle (after Chown ref 18).

that improbability", he says.[13] He goes on to make a plea that the Cosmological Principle's theoretical prejudices as to the universe's geometry and our place in it must bow to observational tests.[14] Scientists have more than ten years of supernova observations that are being refined in many sophisticated ways and being used to confirm the apparent acceleration of the universe. George Ellis admits that the existence of the hypothetical dark energy that supposedly propels this acceleration is a major problem for theoretical physicists, and thus he implores his colleagues to pursue the possibility of other theoretical explanations. In the *Journal of Physics: Conference Series* article, Ellis highlights the possibility that the Cosmological Principle may not be valid by stating, "The redshift-distance relation for distant supernovae may be measuring spatial inhomogeneity, rather than acceleration of a FLRW universe."[15] Célérier, too, comes to the same conclusion. In her paper entitled 'Inhomogeneities in the Universe with Exact Solutions of General Relativity', she highlights the need to examine at what point the well-worn assumption of homogeneity begins to compromise the accuracy of the models. She continues by stating,

> "Well-established physics can explain several of the observed phenomena without introducing highly speculative elements, like dark matter, dark energy, exponential expansion at densities never attained in any experiment (i.e. inflation), and the like."[16]

Certain creation cosmology models are on the right track

At least two creation science cosmology models rest upon the condition of large-scale inhomogeneity of the universe as the alternative interpretation of the type 1a supernova data may indicate. In his book *Starlight and Time*, physicist Russell Humphreys points out that unbounded and bounded cosmologies are profoundly different. Being unbounded means that the universe would have no edge and no center, in other words, it would be homogeneous. On the other hand, an inhomogeneous universe would have a center and an edge and is referred to as being bounded. As Humphreys puts it, when the unbounded assumption is used as an initial condition for Einstein's general relativity equations, big bang cosmology is a natural consequence. However, when the initial conditions of a bounded universe with the earth near the center are put into these same equations, we get an expanding universe in which clocks tick at different rates in different parts. Humphreys further gives the following explanation:

> "The physics is that of a universe-sized 'white hole' (a black hole running in reverse), with a shrinking event horizon and matter expanding out of it. At the event horizon, clocks would be momentarily stopped relative to clocks further out. At one critical moment of the expansion, the event horizon would reach the earth, and clocks there would also momentarily stop."[17]

If the event horizon arrived on the earth during the fourth day, as Humphreys proposes, billions of years would have elapsed in the distant sky as measured by clocks on the earth, giving light from galaxies many light-years away enough time to reach earth in one ordinary earth day, John Hartnett, another creationist physicist, puts forth a theory of origins based upon Moshe Carmeli's cosmological special relativity. Carmeli develops his new theory by adding a fifth dimension to Einstein's four-dimensional spacetime interval of special relativity. This new dimension is the radial velocity of the galaxies in the expanding universe.[21] The resulting universe is spherically symmetric and isotropic, but not necessarily homogeneous. Hartnett takes this work of Carmeli and extends it to the case of a finite, bounded universe with a unique center and edge. He finds that these boundary conditions are valid and yield results consistent with the high redshift type 1a supernova measurements.[21] In fact, the fit is incredibly good and needs no cosmological constant to explain the universe's acceleration. This is because in Carmeli's theory, matter density describes the geometry of spacevelocity, not only spacetime. Hartnett explains the situation as follows:

> "Since the measured matter density is less than unity, the universe is open, and it means, in the Carmeli theory, an accelerating universe which will expand forever, never collapsing back on itself. However, the Carmeli theory does not need to invent 'dark' matter and 'dark' energy."[21]

Both of these creation cosmologies have inhomogeneity as a prerequisite, a feature that until recently had no advocates in conventional evolutionary science. With the advent of type 1a supernova observations, evolutionary scientists may be starting to catch up with creationists in the field of cosmology, as some of its members are examining the creationist proposals of a bounded universe with the earth near the center. Both of the creationist models discussed here, which start with this boundary condition, dispose of the big bang cosmology with its billions of years and its *ad hoc* ideas of dark matter, dark energy, and inflation.

Conclusion

Type 1a supernova data may seem, at first, to reveal an apparent acceleration of the universe's expansion rate, and a corresponding incredible fine-tuning of the laws of physics that evolutionary scientists must explain by natural processes. But an objective handling of the data does not necessitate this interpretation. SN1a's can equally be telling us that the presumptuous assumption of the Cosmological Principle is not a certain doctrine upon which to build one's worldview. On the other hand, the Word of God, correctly interpreted, will never fail to help us understand the world that God has created.

In conclusion, let us realize that when scientists make bold announcements about new data which seem to conflict with the biblical account of creation, it is first a call to examine the facts presented, in order to see whether they are actually true. Then, we as creation scientists must consider any equally valid interpretation of the facts which will corroborate, rather than contradict, God's immutable Word.

References

1. Goldsmith, D., *The Runaway Universe- the race to find the future of the cosmos*, Perseus Books, Cambridge, MA, 2000, p.151.
2. Célérier, M.-N., Do We really See a Cosmological Constant in the Supernovae Data? *Astronomy and Astrophysics* **353**:63–71, 2000; p. 69.
3. Kasen, D., Röpke, F.K. and Woosley, S.E., The Diversity of Type 1a Supernovae from Broken Symmetries, *Nature* **460**:869–872, 13 August 2009.
4. Stephens, T., *Variability of Type 1a Supernovae Has Implications for Dark Energy Studies*, University of California Santa Cruz, 12 August 2009; news.ucsc.edu/2009/08/3137.html.
5. Goldsmith, ref. 1, p. 4.
6. Goldsmith, ref. 1, p. 138.
7. Goldsmith, ref. 1, p. 27.
8. Filippenko, A. and Riess, A.G., Results from the High-Z Supernova Search Teams, arXiv: astro-ph/ 9807008/ 1 Jul 1998.
9. Rowan-Robinson, M., *Cosmology*, Clarendon Press, Oxford, 3rd ed., p. 62, 1996.
10. Célérier, ref. 2, p. 64.
11. Susskind, L., *The Cosmic Landscape,* Little, Brown and Company, New York, p. 66, 2006.
12. Ellis, G.F.R., Dark Energy and Homogeneity, 2009, *Physics: Conference Series* **189** 012011:1–15, 28 June 2010, p. 11; iopscience.iop.org/1742-6596/189/1/012011.
13. Ellis, ref. 12, p. 12.
14. Ellis, ref. 12, p. 14.
15. Ellis, ref. 12, p. 1.
16. Célérier, M.-N., Inhomogeneities in the Universe with Exact Solutions of General Relativity, 2009, arXiv.org.physica.arXiv:0911.2597v1.
17. Humphreys, D.R., *Starlight and Time*, Master Books, Green Forest, AR, p. 83, 1994.
18. Chown, M., Our special place, *New Scientist* **2682**:32–35, 15 Nov 2008; p. 35.
19. Hartnett, J., *Starlight, Time and the New Physics,* Creation Ministries International, p. 123, 2007.
20. Hartnett, ref. 19, p. 87.
21. Hartnett, ref. 19, p. 66.

Mary Beth De Repentigny has a Bachelor of Science in Theoretical Physics from Concordia University in Montreal, Canada. After being accepted into the Master's Program in Astrophysics at the University of Vermont, she has paused her own educational pursuits in order to raise and homeschool a family of four children. Desiring to help others know and love God's Word, she has taught Bible clubs for several years.