`Great Debate' Review and History

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The Universe and the Curtis - Shapley Debate

A Mediocre Discussion?

Does it really matter that two astronomers debated each other near the beginning of this century? It is now clear that a once little-heard-of discussion was at the crux of a major change of humanity's view of our place in the universe. The events that happened in the first quarter of our century were together much more than a debate - this is a story of humanity's discovery of the vastness of our universe, a story of a seemingly small academic disagreement whose dramatic resolution staggered the world. It is a story of human drama - two champion astronomers struggling at the focus of a raging controversy who's solution represents an inspiring synthesis of old and new ideas. It is the story of monumental insight and tragic error. It is a story of an astronomical legend. Does this sound melodramatic? It s all true. And it happened this century.

In 1920 Harlow Shapley was a young ambitious astronomer. He had published a series of papers marking several fascinating astronomical discoveries - many times involving properties of stars in binary systems or globular clusters. He was a rising star himself - a golden boy of astronomy.

In 1920 Heber D. Curtis was a bit older, more established, and very well respected in his own right. He had published a series of solid papers on good astronomical results - many times on the properties of spiral nebulae. He was a `rock of clear thinking' to all that knew him. He was a hard worker usually taking the conservative view - frequently skeptical of anything new until proven to his exacting standards..

By now you know they are going to clash in a historic debate in 1920. Do you want to know who was right even before you know the issues? Was it the prodigy or the pro? OK, we'll tell you: they split. Each was right about some things and wrong about others. Shapley, the prodigy, made a monumentally correct deduction from existing astronomical data that our Sun was not at the center of our Galaxy and that our Galaxy was much larger than anyone had previously believed. Curtis vigorously opposed these views, but Shapley, like Copernicus before him, single-handedly moved the center of the universe, this time light-years from its old location. Harlow Shapley lived up to his potential. But possibly the biggest surprise came from the Curtis, the pro. Curtis was able to argue convincingly - for the first time from hard scientific data - that spiral nebulae were external galaxies and that our own Galaxy was only one of a vast number of galaxies, or `island universes'. Shapley saw this viewpoint as contrary to his large Galaxy idea. Curtis' accomplishment is impressive, representing an unprecedented redefinition of humanities concept of the universe, but he did not do it alone. He led a school of thought that had supported the island universe idea both philosophically and scientifically for more than 100 years. So Heber Curtis lived up to his reputation.

The complete scientific resolution of all the issues involved in the debate occurred slowly over the next two decades. At the time, not everybody realized what far- reaching implications the resolution of this debate would bring. In the years following the debate, Curtis was appointed Director of the Allegheny Observatory and then went on to become the Director of the Observatories at the University of Michigan. Shapley was appointed Director of the Harvard College Observatory.

In actuality, the term `Great Debate' best applies to the actual running disagreement on the nature of our Galaxy and the nature of spiral nebulae that raged from the turn of the century through the 1930s. This "debate" was between many different astronomers scattered around the globe, using data and results from many instruments, and took decades to resolve. It was truly Homeric. The term `Great Debate' is usually applied, however, to the actual meeting of Curtis and Shapley in 1920, an event which served as a focal point for the controversy.

A Brief History of the Center of the Universe

It is difficult, with the naked eye, to see anything that is not in our Milky Way Galaxy. Every individual star one can see is in our Galaxy. From Earth's Southern Hemisphere, one could see large fuzzy patches called the Large and Small Magellanic Clouds that are satellite galaxies to our own Milky Way, and in the Northern Hemisphere a dim fuzzy patch call the Andromeda Galaxy, M31, is visible if one knows where to look, but that's it - everything else visible is in our home Galaxy.

If you have a telescope or another means of seeing fainter objects, the situation changes completely. But astronomers did not always have telescopes. Humanity didn't always know the limits of our Galaxy and the existence of other galaxies - this knowledge came only this century - what was thought previously?

While it is certainly true that early civilizations had a drastically different picture of the universe, their concepts were sophisticated and completely consistent with their ability to observe the universe, just as ours are today. Early Greek civilization recorded evidence that the earth was spherical based on observations of the circular Earth shadow on the moon during a lunar eclipse. The Greek scientist Erasthothenes was able to obtain a rough estimate of the size of the earth by noting the relative lengths of shadows cast at different locations at the same time. So at that time the center of the Universe was thought to lie about 9000 km down - the distance they computed to the center of the earth.

The earth was considered the center of the universe because the leading theory about this at the time came from the Greek astronomer Claudius Ptolemy in about 140 A.D. In this theory, the earth was at the center of the universe, and the sun, the moon, the planets and stars orbited the earth.

The center of the universe remained at the center of the earth, in the view of the majority of the scientific community, until the 1500s. Occasionally there were those who suggested otherwise, the most famous of which is Aristarchus of Samos, a Greek scientist well-ahead of his time, but he, unfortunately, was not taken very seriously for very long.

The successful challenge to the earth-centered universe was begun by the Polish Astronomer Nicolaus Copernicus in 1543. In his book De Revolutionibus, he argued that the Sun was at the center of the solar system (and hence universe), and that the planets - including the earth - revolved around the sun. This heliocentric theory provided a conceptually simpler explanation for certain peculiar `retrograde' motions of the planets than the Ptolemaic geocentric theory but encountered stiff resistance from those who felt it was heretical to move humanity so far from the center of the universe.

The Italian Scientist Galileo Galilei greatly supported Copernicus's sun centered universe. In his book Sidereus Nuncius of 1610, Galileo bolstered this view with some of the first astronomical observations with a telescope. He was able to trace the motions of four bright moons as they orbited Jupiter, stunning visual proof that not all objects in the universe orbited the Earth as Ptolemy required. He was also able to see that many regions of the night sky that appeared fuzzy and nebulous to the unaided eye actually consisted of many individual stars when viewed through the telescope. Although forced to recant in his lifetime, his observations and analysis soon led to the recognition the Earth and planets orbited our sun which was one of many stars, and that the band of the Milky Way was a band of stars. In the centuries which followed, larger telescopes were used to explore the newly revealed universe of stars. By the time of the Curtis - Shapley Debate in 1920, through the arduous technique of star counts, astronomers had tried to map out the extent of the Milky Way. This work still placed the sun close to the center of a flattened universe of stars and so the center of the universe arguably remained at the center of the sun until the resolution of the Curtis - Shapley debate.

Strangely enough, acceptance of Einstein's General Theory of Relativity and popular cosmologies derived from it led to the view that each part of the Universe was expanding from all others quite similarly, so that the modern view is that there IS no unique center of the Universe. Acceptance of this did not take place until after Hubble's discovery that the universe was expanding in the 1930s.

A Brief History of the Size of the Universe

The history of the size of the universe closely follows the history of the center of the universe. With the discovery that the earth was round, the size of the universe expanded to the size of the solar system. The estimated size of the solar system also evolved as astronomical knowledge crept forward in the middle ages. The distance to the furthest planet in the solar system became separated from the size of the universe as people questioned why the stars did not move like the planets. The stars and everything else in the night sky were delegated to a great sphere that encompassed the solar system. There were no truly scientific estimates of the radius of this sphere - only folklore. Even the distance to Saturn, the most distant planet known to `pre-telescopic' astronomers, was not well determined until the time of Kepler. In truth, the distances to stars were just too large for direct trigonometric measurements (parallax) even in the 1500s.

Kepler, a contemporary of Galileo, studied data taken in the years before by Tycho Brahe and postulated three laws of motion for the planets. These laws of motion allowed an accurate estimate of the distances to the planets, hence an accurate estimate of the size of the solar system and hence that day's conception of the size of the universe.

At about the same time, the generally accepted view that everything seen in the night sky was contained in our solar system sized universe fell away. The telescopes in use from the time of Galileo caused recognition that stars were at much greater distances than even the furthest planets of our solar system.

In the mid-1700s, the English astronomer Thomas Wright suggested that two concentric spheres existed outside the solar system, and that between these spheres existed all stars and our sun and solar system. By looking along the shell we saw the band of the Milky Way, and looking perpendicular to it just the few stars between us and the boundary of the shell. The size of the shell and hence the size of the universe was not well determined in this model.

In the late 1700s Immanual Kant revised Wright's model, based partly on a misinterpretation, to suggest a Galaxy with dynamics like the solar system. In this model the stars rotated about the center of the Galaxy just as the planets revolved around the center of the sun. Kant's even suggested that the faint nebulae seen may be composed of individual stars. Although Kant considered that the sun's distance from the center may be great, he did not estimate this distance, and did not estimate the size of this universe. Kant's thoughts were not taken as scientific proof, but could be considered the start of the controversies at the heart of the Curtis - Shapley debate.

William Hershel set out to determine the size of the universe scientifically in the late 1700s. Using a new telescope with a 48-inch mirror, he counted stars in several directions, assumed a uniform star density, and hence estimated the distances needed to count so many stars in these directions. Thus, along specific directions in space he could determine the relative extent of the universe of stars. Like Galileo, Hershel also noted that some nebulous objects could be resolved into stars and believed for a while that all nebular objects could be so resolved.

Progress then had to wait for the development of larger telescopes. In the mid- 1800s, William Parsons, the Earl of Rosse, began using a 72-inch diameter telescope. He was able to resolve structure in some of the nebula as spiral structure, and thus conclude again that these were stellar systems like Kant had proposed 70 years before. Still, however, no one could estimate the distance to any of these nebulae, so the size of the universe remained unclear. The theory that spiral nebulae were separate `universes' unto themselves became known as the `island universe theory.'

At the turn of the century, the Dutch astronomer Jacobus Kapteyn used the latest data of the day to postulate a model for the Galaxy - and the universe in his eyes - that consisted of a flattened stellar system 10 kiloparsecs (30,000 light years) in diameter and 2 kiloparsecs (6,000 light years) in thickness. He placed the sun near the center of this universe. Kapteyn used the parallax method to calibrate the distance to the nearest stars, and proper motions and apparent brightnesses to estimate the distances to successively further stars. Kapteyn's extensive application of the method of star counts used by Herschel also confirmed his results for the dimensions of the Galaxy, or `Kapteyn's Universe' as it was called.

From the turn of the century to 1920, the controversy which inspired the `Great Debate' that would occur in 1920 was on. Many articles were published reporting evidence that spiral nebulae were separate galaxies like our own and at significant distances. Many discussions were held on the what new data indicated for the size of our Galaxy. Astronomers' view of the size of the universe and our place in it was in a state of flux. On the external galaxy issue, most astronomers believed that spiral nebulae were external galaxies until Harlow Shapley led one last final assault on this idea.

Shapley's View of our Galaxy and the Universe in 1920

In 1918 and 1919 Shapley published articles in the Astrophysical Journal elucidating a new model for the Galaxy. Basing his model on the asymmetric distribution of globular clusters, Shapley estimated that the diameter of our Galaxy was 100 kiloparsecs, 10 times larger that Kapteyn's value. Shapley also placed the center of the Galaxy some 20 kiloparsecs distant from the Sun, a drastic, dramatic shift in location. In his view, this large meta-Galaxy was the universe and the spiral nebulae were simply one relatively minor population of mostly gaseous objects contained within it.

Shapley was a leader in the area of observing and understanding globular clusters, but he was not the first to notice that the distribution of globular clusters on the sky is not uniform. A plot of the positions of Globular clusters on the sky shows that they are concentrated more toward one half of the sky. Shapley conjectured that this half of the sky housed the true center of our Galaxy. In 1909, another astronomer, Bohlin, suggest similar arguments which were not seriously considered. What Shapley had done that Bohlin had not was to determine approximate distances to the globular clusters, and thus give a distance of our Sun from the Galactic center. Shapley used Cepheid variables in the globular clusters to help make this distance determination.

Shapley also felt it necessary, however, to comment on the nature of spiral nebulae. Shapley thought that the Galaxy was so large it was essentially the whole universe. Shapley not only based his opinion on the distribution of globular clusters and the distances to globular clusters, but on the apparently measured rotation velocities of spiral nebulae.

In the 1910s and 1920s, Adriaan Van Maanen, an astronomer at Mount Wilson Observatory and friend of Shapley's, measured the internal rotational motion of several spiral nebulae. Measuring small motions, called proper motions, of astronomical objects was Van Maanen's task at Mount Wilson, and he was well known for having successfully measured the proper motions of nearby stars. Van Maanen measured motion in seconds of arc per year, an angular rate of motion, by comparing photographs of the same region of the sky taken years apart. Knowing the distance to the spiral nebulae would allow the conversion of his measured angular rate of rotation to a rotational velocity in kilometers per second. The distances to the spiral nebulae were not known but Shapley argued that if the nebulae were placed well outside the boundaries of the Galaxy, as Curtis and others had suggested, the rotational velocities implied would be a substantial fraction of the speed of light! This was an unreasonable result and thus he argued that the real distances to the spiral nebulae must be closer to bring their implied rotational velocities in to a physically acceptable range.

Shapley also did not believe that spiral nebulae were galaxies in their own right. At the time of the Great Debate, he thought that spiral nebula were gaseous clouds repelled by the light pressure of our Galaxy and that our Galaxy was moving through these clouds. That spirals were racing away from us was a result of the spectroscopic observations made by Slipher. Shapley thought that his postulated great extent for our Galaxy precluded spirals from being galaxies in their own right.

Curtis's View of our Galaxy and our Universe in 1920

Curtis presented a different view in his scientific publications of the 1910s and 1920s and at the debate in 1920. He followed the more traditional views of Kapteyn and believed that the diameter of our Galaxy was more nearly 10 kpc, much smaller than Shapley's estimate. This was based on star count analysis and distance estimates involving the spectral types and intrinsic brightnesses of different type stars. He also believed that our Galaxy was shaped like a flat lens with our sun very close to the center. According to Curtis, spiral nebula were systems of stars - island universes similar to our own.

Curtis followed several lines of thought to conclude that spiral nebula were galaxies. He argued that novae observed in our Galaxy were similar to novae observed in spiral nebulae, implying that the nebulae were very distant - and composed of stars. Curtis cited Slipher's spectroscopic measurements of high radial velocities for the nebulae as further evidence that they were not galactic objects which would be moving much more slowly relative to the sun. In his view, the apparent sizes of the spiral nebulae were consistent with Kapteyn's dimensions for a galaxy when the nebulae were located at extragalactic distances. Photographs of some of the spiral nebulae also revealed bands of absorbing material which Curtis interpreted as being consistent with absorbing material he believed existed at the edge of our own Galaxy.

The main reason Curtis gave for disagreeing with Shapley's model of the Galaxy was that he did not believe that Cepheid variables were good distance indicators. He therefore did not believe the distances Shapley gave for globular clusters, and hence did not believe Shapley's distance to the center of the Galaxy.

Furthermore, Curtis did not believe van Maanen's measurements of the rotations of spiral nebulae. He pointed out that these measurements involved angular motions much smaller than had ever been measured, and were unrealistically small to measure.

What was Said at the Great Debate

It has been said that the `Great Debate' of 1920 was neither `great' nor a `debate.' But wait, wasn't it said previously that it was? The actual debate between Shapley and Curtis was, in fact, not well publicized at the time, not well attended by astronomers, and did not take the form of a debate. Have we all been duped?

To be sure, what occurred was not truly a debate - each person gave a 40 minute presentation and was given one opportunity to rebut the other's remarks. After these remarks, several comments were made from the floor, including a substantial comment from Henry Norris Russell, arguably the most famous astronomer of the day, in support of Shapley.

The debate was held as a public event during the 1920 meeting of the National Academy of Sciences. It was held in the main auditorium of the Natural History Museum, then the U.S. National Museum, in Washington, D.C. on April 26. The auditorium, still in use today, is now known as the Baird Auditorium. Most of the attendees were members of the National Academy of Sciences but not astronomers, but several prominent astronomers did attend. Harlow Shapley implies in his autobiography "Through Rugged Ways to the Stars" that Albert Einstein was in attendance.

Shapley spoke first and gave a popular level lecture. Curtis followed, but gave a more technical lecture. Shapley's popular lecture was geared toward the audience of mostly non-astronomers. His approach was to educate them with the basic background material, finally using only simple arguments to support his position. Shapley concentrated on convincing the audience that his model of our Galaxy and its size were more nearly correct than Curtis'. He only briefly mentioned his views on the distances to spiral nebulae near the end of his lecture.

Curtis tried to create the best logical argument from the data, not trying to fill in all the background. He gave a more detailed presentation of the present state of research, as he saw it, and focused most strongly on the distances and nature of spiral nebulae, frequently posting comparative tables outlining how spiral nebulae made more sense as galaxies in their own right..

Who Won?

It is not really scientifically important who `won' the debate at the time. It was the underlying arguments and conclusions used by Shapley and Curtis that are held up to modern scientific scrutiny - not a hypothetical straw pole of an audience that consisted of mostly non-astronomers. Nevertheless who won is of human interest and so we will speculate on this point:

If a straw pole had been taken at the actual debate, we believe Curtis would have won. Notes from people who attended, Curtis' letter to his family about the event, and Shapley's eventual guarded characterization of the event as a `draw' all tend to support this conclusion. But who won is a subjective estimate. More importantly, how have the scientific arguments withstood the test of time? Looking back, whose arguments and conclusions were more scientifically correct?

Scientifically the debate was close to a draw. There are several popular misconceptions about this, even in the modern scientific community. The first misconception is that Shapley won. Astronomers who have not studied the debate sometimes assume this because Shapley went on to become the more famous astronomer. A second misconception is that Curtis won. Astronomers who believe this have a tendency to believe that the only scientific issue at hand was the nature of the spiral nebulae - a point which Curtis won hands-down.

But each was correct on a major point, and each was incorrect on a major point. Shapley was correct that our sun was well off from the center of our Galaxy. Let's not take this point lightly. He, like Copernicus before him, had moved humanity's place in the cosmos far away from where it was previously. As Copernicus had moved it from the Earth to the Sun, Shapley moved it, almost single-handedly, from the

Sun to the center of the Galaxy. This in itself is truly historic. Shapley was also correct that our Galaxy was much bigger than Kapteyn had hypothesized previously. Another major point where Shapley was correct was about the usefulness of Cepheid variables as distance indicators. The distance scale of the Galaxy he obtained from them was too large but not far off by astronomical standards - and Cepheids continue to be cornerstones of our knowledge of distances to further objects even today. Harlow Shapley was a great astronomer.

Curtis, however, was correct that spiral nebulae are external galaxies. This was the first time this was shown with valid scientific evidence, and this point in itself is also truly historic. In fact, there is no precedent for this - it is an accomplishment that is unique in history. So Heber Curtis was also a great astronomer. Curtis was also correct that van Maanen's measurements of the rotation of these nebulae were inaccurate. In view of his arguments against using Cepheids as distance scale indicators, it is ironic that this point was ultimately settled in his favor by Hubble's discovery of Cepheids in the Andromeda Nebula several years after the debate.

Shapley and Curtis were also wrong about some things. Shapley was completely wrong about spiral nebulae - they are exactly as Curtis had argued (and many had surmised, including Kant before him). Shapley was also somewhat incorrect on the size of our Galaxy, which he estimated to be larger than it really is. Curtis was wrong about some things too. Curtis was wrong about the Sun's place in the galaxy - it is not near the center as he estimated from star count analyses like those of Kapteyn. Curtis was wrong about Cepheids - they do indeed show a period - luminosity law somewhat similar to that Shapley had computed, and they continue to be useful distance indicators. Curtis was wrong about the size of our Galaxy - it is larger than he estimated - Shapley was more nearly correct on this point.

Oddly enough, Curtis and Shapley were BOTH wrong on some issues that they agreed upon. The most major of these points was on interstellar absorption of starlight. Both agreed that interstellar absorption was not important in determining the size of the Galaxy. Today we know interstellar absorption is extremely important. Curtis did realize that some spiral nebulae seen edge-on were dark along their leading edge - which he correctly attributed to interstellar absorption. But Curtis thought that this only occurred at the edge of galaxies, and so was not important for determining distances internal to our Galaxy. Oddly, Curtis surmised that since no globular clusters were seen in our Galactic plane, that globular clusters could not be inside our Galaxy - and used this to argue against Shapley's large Galaxy hypothesis!

It is interesting to estimate who won on the point of the title of the debate: "The Scale of the Universe." Shapley defined the universe at that time to be the local Galaxy, and his estimate of the size of our Galaxy was more nearly correct than Curtis'. Curtis would define the Universe as all that is - which includes spiral galaxies - so that the whole of the universe has much greater scale than just that of our Galaxy. So on this point Curtis, too, could be considered more correct.

Shapley did not consider the debate to be about the distances to spiral nebulae. He considered this to be a side point on the greater issue of the just how large our Galaxy was. He considered it somewhat unfair that Curtis made this such a major point. Curtis considered the distances and nature of spiral nebula to be a major point in the debate. So we see that they didn't even agree on what they were disagreeing on!

Whose arguments went on to have greater lasting impact? Shapley's placement of our sun away from the Galactic center surely is a major accomplishment, as been stated several times previously. But the discovery that spiral nebulae are galaxies just like our own is possibly without parallel. It is of dramatic importance in the big scheme of defining human existence. It is possibly the major reason why the Curtis - Shapley debate will never be forgotten. Future historians will always want to learn about the time that humanity learned there was a whole universe of galaxies out there, and so they will always be drawn to this focal point of this disagreement: the Curtis - Shapley debate. The study of galaxies in the universe continues to be a ground-breaking field in astronomy even today, and has numerous different sub-branches.

Which scientist personally had greater scientific impact? This answer is particularly subjective, but we would venture Shapley. Curtis and Shapley each represented the points of view of many astronomers, and each did contribute original research to their respective view-points. Possibly, though, Shapley contributed greater original research to the view-points he represented than did Curtis for his. There were others besides Curtis who probably could have argued most of what Heber Curtis did at the `Great Debate.' But probably nobody could have taken Shapley's place. Curtis led a movement of many astronomers who had been guessing that spiral nebulae were galaxies for more than 100 years. But Shapley was one of the first to argue that the Sun is well away from the Galactic center, and that Cepheids are valuable astronomical tools for distance estimation. Shapley won several impressive battles almost single-handedly, while Curtis led an army to win on a truly epic point.

The Resolution of the Great Debate

In 1924 Edwin Hubble located Cepheid variables in the nearest major spiral nebulae, M31. This had immediately followed a period where stars in this nebulae were being resolved. When confronted with this evidence Shapley immediately admitted he was wrong on the spiral nebulae issue - an issue that he did not consider at the heart of the 1920 debate.

During the 1920s and 1930s, evidence mounted that interstellar absorption was important and also that Cepheids were indeed good distance indicators. This allowed the astronomical community to understand why globular clusters were not visible in the galactic plane (their light was being absorbed) and allowed for a better calibration of distance indicators. These led to acceptance that the globular clusters distribution was indeed centered on the center of our Galaxy - just as Shapley had claimed. They also led to a better understanding of the size of our Galaxy which showed again that Shapley was more nearly correct.
