THE MYSTERIOUS UNIVERSE

A documentary on some of the controversial issues in modern astronomy and cosmology.

Script by:

Michael Cremo and
Richard Thompson

Scientific advisor:

Richard Thompson

Outline of main topics covered:

Theme music [synthesizer music a la Brian Eno].

Theme image of night sky with moon and stars moving majestically.

NARRATOR [OFF CAMERA]: Gazing at the moon and stars in the night sky, people have always wondered about the origins and nature of the universe.

SPECIAL EFFECT: The motion of the moon and stars, etc. is accelerated so that they move majestically at a clearly visible rate.

NARRATOR [ON CAMERA]: Where did it all come from? These days most people will answer with some version of the Big Bang theory.

Sun rises majestically in theme image. Narrator on camera in forest location, possibly with Mt. Palomar or Mt. Wilson observatory in background, or perhaps the Goldstone deep space dish. This is the standard setting.

STUDENTS and PROFESSORS explain their idea of the origin of the universe by the big bang, in accordance with physical laws and chance.

Students and professors in university setting. These professors are not professional astronomers; they show that the big bang theory has been asccepted as truth by many intellectuals.

NARRATOR [ON CAMERA]: What exactly is the Big Bang theory?

Narrator in standard setting.

NARRATOR [OFF CAMERA]: Basically it's the idea, put forward by many scientists, that in the beginning, or before the beginning, if you will, all matter in the universe was concentrated into an infinitly small volume at an infinitly high temperature and pressure. And then, according to the story, it

SPECIAL EFFECT: Graphic presentation of the big bang. First a brilliant sphere of white light expands. Then the light winks out, revealing a mass of glowing specks flying apart from each other. Zoom in on the specks. We see that they are diffuse clouds forming into galaxies of the pinwheel type. Show stars exploded with tremendous force. From this explosion rushed a super-heated ionized gas or plasma. This plasma expanded uniformly until it cooled sufficiently to form ordinary gas. Within this cooling cloud of expanding gas formed galaxies, and within the galaxies took birth generations of stars. In turn planets such as our own earth formed around the stars.

forming in galaxies and planets forming around stars.

NARRATOR [ON CAMERA]: The big bang theory seems to have captured the minds of people everywhere. Why? One possible reason is that its supporters have unleashed an unprecedented explosion of big bang propaganda in the form of high tech television programs, flashy magazine articles, and well-illustrated popular books. In classrooms around the world teachers present the big bang as the only possible explanation of how the universe and everything in it came to be.

Narrator in standard setting.

Then SPECIAL EFFECTS:
(1) Clips from tv shows on big bang spiraling in.
(2) Motion graphics of magazine articles about the big bang, spiraling in from a distance, becoming larger, leaving a trail of images.

NARRATOR [ON CAMERA]: The message comes across loud and clear. The universe is expanding, and everything must have been together at one point in the beginning.

Narrator in standard setting.

INTRODUCTION TO THE IDEA OF THE EXPANDING UNIVERSE.

NARRATOR [OFF CAMARA]: But here's a fact few people realize. Even with the most powerful telescopes it is not possible to actually see stars and galaxies moving away from us. The images we see are static, and scientists would not expect them to show visible motion, even if

SPECIAL EFFECT: Display the theme image with accelerated motion of stars and the moon, and then zoom in on a region of the sky to show some galaxies. Whereas the movement of the moon and stars was clearly noticable, the picture of the galaxies will be static.

observations could go on for centuries.

NARRATOR [OFF CAMARA]: So how do we really know the universe is expanding? All we have to go on is the light and other kinds of radiation that travel to us from across the reaches of interstellar space. Images formed from this radiation do not directly show universal expansion, but subtle features of the radiation have convinced scientists that this expansion is taking place. What scientists do is first assume that the earthly laws of physics apply without change throughout the universe. They then try to figure out how processes obeying these laws could produce the observed light.

SPECIAL EFFECT: First a cartoon-like image of a person on the earth looking up at incoming light that seems to originate just above his head. Then a model of the structures producing the light appears overhead. This model might be in dotted lines to emphasize its theoretical nature.

NARRATOR [ON CAMERA]: To understand how scientists have used this way of analyzing light to conclude that the universe is expanding, we go back into the history of astronomy and astrophysics.

Narrator in standard setting.

NARRATOR [ON CAMERA] Examining the heavens, astronomers long ago observed that in addition to individual stars and planets there were many faintly glowing bodies in the sky. They called them nebulae, a Latin word meaning "clouds," and later on, as their conceptions evolved, they called them galaxies.

Early pictures of spiral nebulae.

NARRATOR [OFF CAMARA]: Larger than the full moon in the night sky, yet hardly visible to the unaided eye because it is so dim, is the

Focus on the cloudy patch of sky that is the Andromeda galaxy and increase the intensity of it for visual effect, near the moon if nearby galaxy Andromeda. In the early part of this century, astronomers turned powerful new telescopes on this and other galaxies, and found they appeared to be vast islands of billions of stars.

possible. This will develop into an elliptical patch of light about six times as long as the diameter of the full moon.

Then gradually begin to magnify the image until it becomes a spiral island of billions of stars.

NARRATOR [OFF CAMARA]: At further distances are found entire clusters of galaxies.

Until the discovery of stars in Andromeda, it was generally thought that all celestial bodies were located within the boundaries of our local Milky Way galaxy. But with this development and the discovery of other more distant galaxies all that was changed. The dimensions of the universe expanded beyond comprehension.

Photo of galaxy clusters.

NARRATOR [OFF CAMARA]: This photo shows the galaxies that have been discovered in the northern galactic hemisphere. It is estimated that detectable galaxies may number in the hundreds of billions.

The standard map of the galaxies in the northern hemisphere.

NARRATOR [ON CAMERA]: Up until the early part of this century, scientists believed the basic objects in the universe to be static in relation to each other.

Narrator in standard setting.

NARRATOR [OFF CAMARA]: Then in 1913, the American astronomer Vesto Melvin Slipher came to study the spectra of light coming from a dozen prominent nebulae and concluded that they were moving away from the earth at speeds of up two million miles per hour.

Photo of Slipher. [Did he do his work at Lowell Observatory in Flagstaff Arizona? If so we could shoot there.]

NARRATOR [OFF CAMARA]: How did Slipher reach this astonishing conclusion? For some time astronomers had been using spectrographic analysis to determine the elements present in the stars. A spectroscope is a device that contains a prism or diffraction grating. We're all familiar with the fact that sunlight focused through a prism will divide into a spectrum of colors like the rainbow. This happens because the prism is separating the white light into its various wavelengths.

Prism dividing light into different colors.

NARRATOR [ON CAMERA]: A spectroscope operates on the same principle. Each element leaves a particular characteristic set of lines in the spectrum. In this example the light lines at the top represent the spectral lines of iron. The corresponding dark lines in the spectrum below show the presence of iron in this particular star.

Narrator in classroom with spectroscope and charts representing the spectra of iron.

INTRODUCTION TO THE IDEA OF COSMIC RED SHIFTS.

NARRATOR: Slipher noticed that in the spectra of galaxies he studied, the lines for certain elements were shifted toward the red part of the spectrum. This curious phenomenon is called a "red shift." These spectra are from two different stars. In this first example we have used an arrow to mark the position of the two readily identifiable lines for calcium. Notice how in the spectrum for the second star, there is a similar pair of

Spectra showing a red shift for calcium.

lines, but they are shifted towards the right.

NARRATOR [ON CAMERA]: Slipher interpreted the red shift as a Doppler effect indicating the galaxies were moving away. This was the first major step toward the idea that the entire universe is expanding. If the lines in the spectrum had been shifted toward the blue end of the spectrum, that would have indicated the galaxies were moving toward the observer.

Narrator in standard setting.

NARRATOR [ON CAMERA]: What exactly is a Doppler effect? It can best be understood by listening to the whistle of a passing train. [noise of approaching train whistle]

Narrator walking along railroad tracks in forest setting. Footage of train rushing past.

NARRATOR [ON CAMERA]: Did you notice how the sound of the whistle dropped in pitch as the train passed us? This phenomenon was first scientifically explained by Christian Johann Doppler, an Austrian physicist, in 1842. He proposed that the intervals between the sound waves emitted from an object moving toward a listener are compressed, causing the sound to be higher pitched. Similarly, the intervals between sound waves reaching a listener from a source moving away are elongated, and thus the sound is of lower pitch.

Narrator by tracks.

NARRATOR [OFF CAMARA]: Here the source is stationary. [sound] Here it is moving toward the listener. [sound higher pitched] And here the source is moving past and away from the listener. [sound

Moving graphics depicting sound waves from stationary and moving sources.

lower pitched]

NARRATOR [ON CAMERA]: After formulating his equations, Doppler tested them by placing trumpet players on a flatcar drawn by a locomotive. Musicians with perfect pitch listened carefully as the trumpet players moved by them and confirmed Doppler's analysis. [trumpet sound]

Narrator on tracks. Railroad car with trumpet player in 19th century costume rolls by in background.

NARRATOR [ON CAMERA]: Doppler predicted a similar effect for light waves. For light, an increase in wavelength corresponds to a shift towards the red end of the spectrum. Therefore the spectrum of an object moving way from an observer would tend to be shifted toward the red. Slipher chose to interpret his observations of galaxies in this way, as a Doppler effect. He noted a red shift, and decided the galaxies must be moving away.

Narrator by tracks

NARRATOR: Another step toward belief in an expanding universe took place in 1917, with Einstein's publishing of his theory of general relativity.

Stock footage of Einstein in period as close to 1917 as possible.

NARRATOR: Before Einstein, scientists had always assumed that space extended to infinity in all directions and that the geometry of space was Euclidean and three dimensional. But Einstein proposed that space could have a different kind of geometry--four dimensional curved space-time, in which space could curve back on itself.

There are many different forms that space could take

Computer graphics to represent Euclidean space and the two varieties of Einstein's four-dimensional space-time.

according to Einstein's theory. One is a closed space without a boundary, like the surface of a sphere; another is a negatively curved space that extends to infinity in all directions.

NARRATOR: Einstein himself thought the universe should be static, and adjusted his equations to insure this outcome. But almost immediately Willem de Sitter, a Dutch astronomer, found solutions to Einstein's equations that predicted a rapidly expanding universe. The geometry of space would change with time.

Photo of De Sitter.

NARRATOR: De Sitter's work caused a stir among astronomers around the world. One of them was Edwin Hubble. Hubble had been present when Slipher had announced his original findings about the motion of galaxies to a meeting of the American Astronomical Society in 1914. In the world of science, a good theory needs good evidence to back it up, and good evidence needs a good theory to explain it. Hubble set to work bringing De Sitter's theory of an expanding universe and Slipher's observations of receding galaxies together.

Photo(s) of Hubble.

NARRATOR [ON CAMERA]: This is the Mt. Wilson observatory, in the mountains just north of Los Angeles. Here Hubble began his work on the expanding universe problem in 1928.

Narrator at Mt. Wilson.

NARRATOR: Hubble was assisted by Milton Humason, an

Photo of Humason.

self-taught astronomer who had once worked as a janitor and mule-team driver at Mt. Wilson.

NARRATOR: Hubble used the 100 inch telescope here to try to measure distances.

Narrator by the telescope on location, or photograph of Hubble using the telescope.

NARRATOR: Humason used a spectroscope to analyze red shifts and calculate the speeds at which the galaxies should be receding.

Narrator at Mt. Wilson spectroscope, or photo of Humason using spectroscope.

NARRATOR [ON CAMERA]: Hubble reasoned like this: In an expanding universe you would expect the galaxies to be moving apart from each other. And the further apart from each other they were, the faster they should be moving apart from each other.

Narrator at Mt. Wilson, walking and talking.

NARRATOR: Let's consider an example. In an explosion, fragments are flying out from the center. But now let's stop the picture. All the fragments began moving at the same time. So now it's obvious that the faster fragments are at the greatest distance from the center. The faster they are traveling the further out they are, and the further out they are, the faster they are are traveling.

Special effect animation of explosion, very slow motion. Stop it to show positions of fragments at various distances from center. Then resume it, in slow motion.

NARRATOR [ON CAMERA]: In an ordinary explosion, of course, everything is flying out from one center. But in the expanding universe theory, the galaxies are not expanding from a central point into preexisting space. Rather all the galaxies are moving apart from each other in an environment in which space

Narrator walking and talking at Mt. Wilson itself is expanding. Thus there is no center to the expansion.

NARRATOR [ON CAMERA]: According to this model, the universe can be thought of as being like an expanding balloon.

Narrator at Mt. Wilson, blowing up balloon, after delivering line at left.

NARRATOR [ON CAMERA]: Any one of the dots on the surface of the balloon can be seen as the center of the expansion.

Narrator blows up balloon some more after delivering line.

NARRATOR: And the further away any spot is from another, the faster it is moving away from it on the surface of the expanding balloon.

Close up of expanding balloon.

NARRATOR [ON CAMERA]: That would mean that from any point, including the earth, an observer should see that all other galaxies are moving away and that on the average , the further away a galaxy is the faster it should be moving away.

Narrator walking and talking at Mt. Wilson.

THE MEASUREMENT OF GALACTIC DISTANCES.

NARRATOR: Hubble set out to see if this were true and discovered that there seemed to be a proportional relationship between the distance of galaxies and the degree of their redshifts. Most galaxies, he observed, had red shifts, and the greater the distance, the greater the red shift.

Narrator, walking and talking. Cut in a photo of Hubble.

This raises a vexing questions-- how did Hubble know how far away any given galaxy was? That was a very difficult problem for Hubble, and remains so even for today's astronomers. After

Narrator at Mt. Wilson, toward sunset.

all, there are no measuring rods that can reach to the stars. But the basic idea is this: if we can identify a class of galaxies that are somewhat similar in intrinsic luminosity, or brightness, then on the average their apparent luminosity will be a function of their distance. This is according to the inverse square law.

NARRATOR [ON CAMERA]: Let's suppose these flashlights represent galaxies. They're all made by the same manufacturer and are all the same size.

Narrator with bag of flashlights, surrounded by some volunteers.

NARRATOR [ON CAMERA]: Now let's have our volunteers spread out across this darkened field. When they reach their assigned positions, they are going to turn on their lights.

Narrator hands flashlights to volunteers, who singly depart into the night.

NARRATOR [ON CAMERA]: There they are, the lights are starting to come on.

Narrator alone.

NARRATOR: You could safely say that the lights that are bigger and brighter are closer, and that those that are dimmer and smaller are further away. The light shining to our right appears to be close to us. That one there appears to be far away.

Lights shining from field. Focus on a bright one, then a dim one.

NARRATOR [ON CAMERA]: Now here's another bag of flashlights. As you see, some are big, some are small, some are in between. Let's give them to our volunteers and send them on their way.

Narrator gives lights to volunteers.

NARRATOR [ON CAMERA]: Now

Narrator in field, talking

what if you didn't know that the flashlights were of different sizes and you tried to analyze the distance of the lights as we did just a little while ago.

to camera.

NARRATOR: You might think, well, there's a small, dim light. It must be further away. And there's a bigger, brighter light. It must be closer.

Dim light, bright light.

NARRATOR [ON CAMERA]: But now let's have a look.

Narrator sets off across field.

NARRATOR [ON CAMERA]: As you can, see, all the flashlights are being held by our volunteers, at the exact same distance.

Narrator with volunteers in line.

NARRATOR [ON CAMERA]: So the point is this--we should be a little cautious about placing absolute faith in the estimates scientists like Hubble give about the distances of galaxies and other celestial objects. Of course scientists themselves are aware of these problems; they use many sophisticated observational methods and statistical techniques to estimate the actual brightness of galaxies, and improve the chances their guesses about distance are right. But in the end, they can never be quite sure.

Narrator at Mt. Wilson, walking and talking.

NARRATOR [ON CAMERA]: In any case, Hubble, using his methods of approximating distance, established a proportion between degree of red shift and distance for galaxies. He believed he had clearly shown that the

Narrator at Mt. Wilson.

galaxies most distant from us had the biggest red shifts, and were thus receding from us at the fastest rates of speed. This he took as ample evidence the universe is expanding.

Eventually this idea became so solidly established that astronomers began to apply it in reverse: If distance is proportional to redshift then one can measure the distance of galaxies simply by measuring their redshifts.

NARRATOR: Geoffrey Burbidge is professor of astrophysics at the University of California at San Diego.

G. Burbidge in his office.

INTERVIEW WITH G. BURBIDGE. Suggested points: He discusses the standard view that astronomers have developed, pointing out that astronomers are convinced that the universe is expanding, and that redshifts can reliably be used to measure the distances of remote objects.

G. Burbidge in his office.

NARRATOR: But as we have seen, Hubble's distance figures don't really refer to direct, accurate measurements of how far away galaxies actually are. Rather they are derived indirectly from the apparent brightness of the galaxies. The problem is twofold. The brightness and dimness of stars could quite possibly be caused by something other than how far away they are, and thus the distance figures derived from them could be flawed. And secondly, it is possible that the red shift might not be connected to velocity. A

The night sky
theme image of galaxies.

number of astronomers are convinced that some red shifts are not caused by a Doppler effect. And some even go so far as to question the very concept of an expanding universe.

GALAXIES AND QUASARS WITH ANOMALOUS RED SHIFTS--THE OBSERVATIONS OF HALTON ARP.

NARRATOR: Halton Arp has been a member of the staff of the Hale Observatory at Mt. Palomar and is currently doing research at the Max Planck Institute near Munich, West Germany. He has done much of his most important work here at Palomar.	Shot of place where Arp works.
NARRATOR [ON CAMERA]: Arp points out specific examples of discordant red shifts that do not follow the Hubble Law. Arp's analysis suggests to him that the red shift is due to something other than a Doppler effect.	Narrator at Palomar
NARRATOR [ON CAMERA]: Why do scientists say that the red shift is a Doppler effect? It may be true that a Doppler effect produces a red shift, but how do we know that a red shift must be due to a Doppler effect? One of the main reasons for this is that, as far as physics is concerned, the only phenomenon other than a Doppler effect that will produce a pronounced red shift is a powerful gravitational field.	Narrator at Palomar.
NARRATOR: If light is going up against a gravitational field, it loses energy and produces a red shift. However, astronomers don't find this	Show photons in a gravity field turning red as they move up against the field.

explanation applicable in the cases they observe, because the fields would have to be of incredible strength to produce the observed red shift.

NARRATOR [ON CAMERA]: Arp argues that he has found objects with high and low red shifts in close proximity with each other. According to the standard theory, an object with a small red shift should be relatively nearby, and an object with a large red shift should be far away. Thus, two objects that are relatively close to one another should have similar red shifts.

But Arp gives the following example.

Narrator at Palomar.

INTERVIEW WITH H. ARP. Suggested discussion: Arp maintains that the spiral galaxy NGC 7603 is connected to a companion galaxy by a luminous bridge. Yet the companion galaxy has a red shift of 8,000 kilometers per second higher than the spiral galaxy, and thus they should be at vastly differnent distances. The companion should be about 478 million light years further away. This is strange, since the two galaxies seem to be close enough together to be physically connected. For comparisons sake, our own galaxy, the Milky Way is just 2 million light years from its nearest neighbor, the galaxy Andromeda.

Arp on camera with pictures of Galaxy NGC 7603 and its companion.

NARRATOR [ON CAMERA]: But there are some defenders of the standard view who strongly disagree with Arp's interpretation. John N.

Narrator at Princeton.

Bahcal, from Princeton's Institute of Advanced Studies, maintains there is no reason to suppose they are connected. The objects are actually distant from each other, and just appear to be closely associated. The so-called luminous bridge is there, but the more distant galaxy just happens to be lined up behind it from our point of view. Bahcal gives this specific rebuttal.

INTERVIEW WITH J. BAHCAL. Suggested discussion: Bahcal strongly criticizes the idea that objects of significantly different red shift have been shown to be physically connected. He shows a photograph of a star within our own Milky Way galaxy apparently connected to a distant galaxy by what appears to be a luminous bridge. Are they connected? This is clearly impossible because the star is in our own galaxy, but the distant galaxy is 44 million light years away.

Bahcal on camera with cutaway to picture of Galaxy NGC 7741 and star.

NARRATOR: But what does Arp have to say about this?

Arp on camera.

INTERVIEW WITH ARP: Arp would reply that Bahcall is just being frivolous. The galaxy he shows is not in any way unusual. The luminous bridge to the star is simply one of the normal spiral arms. But in the example he himself has chosen, the bridge is an unusual structure, not normally found in such galaxies. The likelihood that two galaxies of this type could be found in such a relationship is far less than the likelihood that a star in the Milky Way will be lined up with an ordinary galaxy.

NARRATOR [ON CAMERA]: Arp has found many other examples that seem to violate the traditional understanding of the red shift. He now explains one of he most controversial.

Narrator at Palomar.

INTERVIEW WITH ARP: Near the spiral galaxy NGC 4319 is a quasar, Makarian 205, apparently connected to the galaxy by a luminous bridge. The galaxy has a red shift of 1800 km per sec, giving it a distance of about 107 million light years. The quasar has a red shift of 21,000 km per second, which should mean that it is located 1.24 billion light years distant. But Arp suggests that they are definitely connected and that this shows the standard interpretation of the red shift is wrong in this case. We may note, by the way, that the very fact astronomers express red shifts in terms of kilometer per second recession speeds shows how thoroughly committed they are to the idea that the red shifts are Doppler effects. Whether this absolute faith is warranted, however, is open to question.

Arp on camera and picture of spiral galaxy NGC 4319 and quasar Markarian 205.

NARRATOR [ON CAMERA]: Arp's picture was developed over a period of four hours. Critics took similar photographs, and claimed not to have found the connecting bridge shown in Arp's picture. Others said the bridge was a "spurious photographic effect." But recently, Jack M. Sulentic, of the University of Alambama at

Narrator at Palomar

University, did extensive photometric studies of the two objects and concluded that the connecting bridge is real.

INTERVIEW WITH J. SULENTIC. Suggested discussion: Sulentic describes how he has shown that a luminous bridge linking NGC 4319 and MRK 205 actually exists. He discusses some of the controversial points.

Sulentic on camera and Sulentic's picture of the bridge between NGC 4319 and MRK 205.

NARRATOR: Another example of discordant red shifts noted by Arp is found in this highly unusual chain of galaxies called Vorontsov-Velyaminov 172, after its Russian discoverers. The smaller, more compact member of the chain, second from the top, has a red shift twice as great as the others.

the Vorontsov-Velyaminov 172 chain of galaxies.

NARRATOR: Arp then points out something even stranger--it appears that quasars and galaxies can eject other quasars and galaxies.

Narrator at Palomar.

INTERVIEW WITH ARP: Here are some examples. The exploding galaxy NGC 520 has a red shift of .007. Located along a straight line running to the southwest from the galaxy are 4 quasars of the faint type. Arp says that these faint quasars are the only ones in this region. Could it simply be an accident that they are arranged almost exactly on a straight line from the galaxy? Arp says the chances of this are extremely remoted. This suggests that the quasars were ejected from the exploding galaxy. Strangely enough, however, the quasars have much larger red

Arp on camera with cutaways to NGC 520 and companions.

shifts than the galaxy that seems to be their parent. This is remarkable, since according to the standard theory of the red shift, the quasars should be much further away than the galaxy.

NARRATOR [ON CAMERA]: Some scientists question whether it is really possible for galaxies to eject other massive objects such as galaxies or quasars. In response, Arp offers this striking example.

Narrator at Palomar

INTERVIEW WITH ARP: This photograph shows the giant spherical galaxy M87 ejecting a body of material. When we look at the galaxies of the elliptical type in the region around galaxy M87, which is also elliptical, we find they all fall on a line drawn in the direction of the jet of ejected material. This suggests to Arp that these galaxies have been ejected by M87.

Arp on camera and picture of Galaxy M87 and ejected object.

NARRATOR [ON CAMERA] How is it that a galaxy can emit another galaxy? If a galaxy is an "island universe" consisting of a vast aggregate of stars and gas, how can it emit another galaxy, which is a similar aggregate of stars and gas.?

Radioastronomy may provide a clue. In recent times radioastronomers have agreed that vast radio emission areas can be ejected from galaxies. These emission areas exist in pairs on either side of galaxies. To explain this astronomers have postulated gigantic spinning black holes

Narrator at Palomar. Radio pictures of galaxies with lobes. Follow with visual of black holes sucking in stars and spitting out streams of luminous matter.

in the center of galaxies that gobble up nearby stars and spit out material in both directions along their axis of spin. However, if Arp's analysis is correct, one has not only to explain the radiating emission regions, which may be composed of a thin gas, but also how entire galaxies or precursors of galaxies might come flying out.

NARRATOR [ON CAMERA]: Regarding the red shifts of such ejected galaxies and quasars, Arp has found the following:

Narrator on camera at Palomar.

INTERVIEW WITH ARP: Arp finds that the ejected objects, although in close proximity to the parent objects, have much higher red shifts. This can only be taken to mean that their red shifts are not Doppler red shifts. That is, they do not measure the speed at which the object is receding. Rather the red shift has something to do with the actual physical state of the object. But the present laws of physics provide no explanation for how an object could be in such a state.

Arp on camera.

INTERVIEW WITH ARP: A galaxy is composed of many individual stars and extensive clouds of dust and gas, so what qualities could they have that would result in a red shift that is not due to velocity or gravitation? This cannot be explained in terms of known physical principles.

A cloud of stars and gas swirling about.

NARRATOR: This seems to call for new physics. But

Narrator at Palomar.

that opens up a whole Pandora's box, because modern cosmology is completely committed to the assumption that everything we see in the universe can be explained by the known laws of physics.

Arp's findings are of course very controversial, and many astronomers doubt that the associations between galaxies and quasars he speaks of could actually be real. But this is only one line of evidence that suggests that the standard interpretation of galactic red shifts might be in need of revision.

DISCUSSION OF HUBBLE'S CONSTANT.

NARRATOR: Some astronomers have drawn attention to a problem with Hubble's constant, which is the very heart of the expanding universe model. As we have seen, according to the big bang model, the further away a galaxy is, the faster it should be going.

Show a graph with two axes, the horizontal labeled distance, and the vertical axis labeled velocity.

NARRATOR: Let us suppose that a galaxy is located at a certain distance and is moving away from us at a certain velocity. This situation can be represented by putting a point on our graph. The position of the point horizontally represents how far away it is, and the position above the horizontal axis represents its speed. If an object is twice as far away from us, it should be going twice as fast. (A point will appear in the appropriate place.) And if the object is three times as far away, it will be going three times as

Points appear on the graph as they are mentioned, and a line representing Hubble's law appears, passing through them.

fast. In this way, we notice the points all lie on a straight line. The steepness of this line tells how fast things are moving away. The figure representing the steepness of the line is Hubble's constant, named after Hubble, who first calculated its value. The steeper the line is, the bigger Hubble's constant is.

NARRATOR [ON CAMERA]: In the graph that establishes the Hubble constant, the distance of galaxies, as we have seen, is derived from their brightness. The speed of the galaxies' recession is derived from measurements of their red shifts. By use of the Hubble constant it becomes possible for astronomers to caculate the distance of galaxies simply from their red shifts. Find the red shift on the chart. Draw a line up to the line representing the Hubble constant--and now you have the distance.

Narrator with chart, showing how it works.

NARRATOR [ON CAMERA]: The constant also gives astronomers the size of the universe. They can measure the red shift of the most distant celestial object and use the Hubble constant to figure its distance. The Hubble constant is therefore an extremely crucial number. For example,If you double the constant you double the estimated size of the universe. Over the years, however, different scientists have obtained many different values for Hubble's constant.

Narrator at Palomar.

NARRATOR [ON CAMERA]: These graphs show the values for

Use a graph with an abruptly jumping line to show successive years. The constant is expressed in kilometers per second per megaparsec. (A megaparsec is a cosmic distance unit equal to 3.3 million light years.) In 1929 the value of Hubble's constant was 500, in 1931 550. In 1936 it was 520 or 526. In 1950 it was given as 260, down somewhat. By 1956 it dropped to 176 or 180. In 1958 it fell much further down, to 75, but in 1968 bounced back up to 98. In 1972 it ranged from 50 all way up to 130. Today, the Hubble Constant is pegged at 55. All this change led one astronomer with a sense of humor to say that perhaps the Hubble constant should better be called the Hubble variable.

how the line representing Hubble's law changes over the years.

NARRATOR: Of course, these changes over the decades can be explained by the fact that scientists have improved their methods and refined their calculations. But even so, something appears to be amiss.

Chart keeps jumping.

J.P. VIGIER'S OBSERVATIONS AND HIS TIRED LIGHT THEORY.

This brings us to the work of Jean Pierre Vigier, a French astrophysicist at the Institut Henri Poincare.

Scenes of France, and the Institut Henri Poincare.

INTERVIEW WITH VIGIER. Suggested discussion: Vigier points out that even today different observers obtain different values for Hubble's Constant.

Tammann and Sandage, give 55 plus or minus five. Abell and Eastmond arrived at 47, plus or minus 5. Then there is van den Bergh, who calculates a value between 93

Vigier on camera. Cutaway to chart. As each figure is announced, put a new line on a graph corresponding to that value of Hubble's constant.

and 111. Heidmann got 100 for his figure. De Vaucouleurs came up with 100 plus or minus 10.

NARRATOR [ON CAMERA]: If the universe is expanding according to some uniform physical principle, how is it that so many observers obtain so many greatly different values for the rate of expansion?

Narrator at Palomar.

VIGIER INTERVIEW: Vigier says that when astronomers take measurements in different directions, they find different rates of expansion.

Vigier on camera.

VIGIER INTERVIEW: He then points out that an even stranger thing occurs. The sky can be divided into two sets of directions. The first is the set of directions in which many galaxies lie in front of more distant galaxies. The second is the set of directions in which there are distant galaxies without foreground galaxies. Call the first set area A, the second set area B.

Vigier on camera, with cutaways to animation of different parts of sky with and without foreground galaxies, and cutaways to charts showing different values of the Hubble constant.

Vigier found that if you restrict yourself to the distant galaxies in area A and calculate Hubble's constant you get one value, and in area B you get a significantly different one. This suggests that the rate of expansion varies depending on whether we measure galaxies with or without foreground galaxies. If the universe is expanding, what could these foreground galaxies possibly have to do with the rate of expansion? Vigier suggests that in fact the measured red shifts of the distant galaxies are not caused by the expansion of the universe at all. Rather they are caused by something quite different--something called a tired light mechanism.

VIGIER INTERVIEW: According to Vigier, as light moves through space it becomes red shifted simply from traveling a certain distance. This happens in accordance with physical laws, just like any other phenomenon. There is a law requiring that as light travels, it shifts toward the red. The effect is so small it can't be readily measured in laboratories on earth, but as light moves the vast distances between galaxies, the effect becomes apparent.

Show rays of light starting from a source, gradually shifting to a reddish color--from blue to green to yellow to red. There could be a man formed of light, and he could be blue and running fast in the beginning and become red and tired in the end.

NARRATOR [ON CAMERA]: This is called the tired light hypothesis because the light loses energy as it moves through space. And the more tired it becomes, the redder it becomes. Red shift is therefore proportional to distance, but not to the velocity of the object. Vigier pictures the universe as not expanding. All the galaxies are more or less stationary. The red shift is not a Doppler effect; it has nothing to do with the velocity of the light's source. The red shift is caused by an inherent property of the light itself, namely that it becomes tired after traveling long distances.

Narrator walking and talking at Palomar.

Most astronomers reject the idea of tired light. In the words of Joseph Silk of the

University of California at Berkeley: "Tired light cosmologies are unsatisfactory because they invoke a new law of physics."

But Vigier presents his tired light theory in a way that does not require radically new physics.

VIGIER INTERVIEW: He proposes that there is a kind of particle in intergalactic space that interacts with light in such a way as to steal energy from it. In the vicinity of massive objects, there are more of these particles than elsehwere.

Vigier with cutaways to animation showing particles in space around massive celestial objects. Show photons of light turning red as they go through the other particles.

So Vigier explains the different red shifts for the A and B regions in this way. The light passing through foreground galaxies encounters more of these particles and therefore loses more energy than light not passing through regions with foreground galaxies. Thus there is a greater red shift for the light going through regions with foreground galaxies, and this accounts for the different values found for the Hubble constant.

NARRATOR [ON CAMERA]: In short, Vigier explains the red shift in terms of a nonexpanding universe in which light behaves somewhat differently than it is normally supposed to behave. Vigier claims that his model fits the astronomical data better than the standard expanding universe model, which cannot explain the widely different values

Narrator at Palomar.

obtained for the Hubble constant.

NARRATOR: Vigier cites more evidence for nonvelocity red shifts. For example, when the light from stars is measured when passing near the sun, it displays a higher red shift than when measured in a different area of the sky. Such measurements can only be made during total eclipses of the sun, when stars near the solar disc become visible in the darkness.

Narrator with cutaway to stars near sun during a total eclipse.

NARRATOR [ON CAMERA]: According to Vigier, nonvelocity red shifts may be a general feature of the universe, The universe could very well be static, and thus there would be no reason for the big bang theory.

Narrator at Palomar.

QUASARS.

NARRATOR [ON CAMERA]: The tired light theory leaves cosmic distances the same while abolishing the expanding universe. But if there is something wrong with the standard interpretation of the red shift, then it is it quite possible that many objects, such as quasars, which are generally thought to be at extremely vast distances because of their high red shifts, may actually be quite close.

Narrator with cutaways to images of quasars.

Quasars look like stars but have very big red shifts, and are thus considered the most distant objects in the universe, more distant than the most distant galaxies.

NARRATOR [ON CAMERA]: We have already seen that Halton Arp belives some quasars are cosmologically close to us even though they have high red shifts.

Narrator at Palomar.

ARP INTERVIEW: Arp has noted that quasars tend to be located in the same vicinity of the sky as a large group of galaxies relatively close to our own. This suggests to him that the quasars may associated in some fashion with these local galaxies and thus be at the same distance.

Arp on camera with cutaways to charts showing distribution of quasars relative to galaxies.

NARRATOR [ON CAMERA]: This raises a question. If some quasars are actually close, and thus have large nonvelocity red shifts, why couldn't that be true of quasars in general?

Narrator at Palomar.

In fact it has long been observed that there are severe difficulties with the idea that quasars are at their cosmological distances, that is, that they are at the distance obtained by applying the Hubble constant to their extremely large red shifts.

NARRATOR: The big problem is that quasars are very bright. If they are in fact extremely far away, that means that many quasars are putting out hundreds of times more energy than the brightest galaxies, which are composed of hundreds of billions of stars. If quasars were as big as galaxies, that would not be implausible. But it turns out that quasars can vary in their light intensity in periods as short as days. This

Radio images and optical images of quasars and galaxies.

observation suggests to astronomers that they are very small compared to galaxies. No one can understand how such a small object can generate so much energy, at least by presently known physical laws.

One solution is that perhaps the quasars are not so far away, but that leaves the problem of accounting for their big red shifts. Big red shifts should mean big distances.

ANOMALOUS FEATURES OF QUASARS--THE OBSERVATIONS OF Y.P. VARSHNI.

NARRATOR: Y.P. Varshni is a physicist at the University of Ottawa in Canada.	Footage identifying Varshni.
INTERVIEW WITH Y.P. VARSHNI. Suggested discussion: Normally you would expect celestial objects like quasars to have a wide variety of red shifts with no discernable pattern, as we see in this chart. But Varshni finds that if you look in different directions of the sky and measure the red shifts of quasars, the red shift measurements from quasars the different directions will fall into definite groups. Very few quasars have red shifts that would place them outside the major groupings. This clustering of red shifts is very difficult to explain.	Varshni with cutaways to a graph with quasars listed along the x axis (identified by letters). On the vertical axis the red shift is plotted. Suppose the quasars are not plotted in any particular order and the points are scattered over the graph. We rotate the graph, sighting parallel to the x axis, and see that the red shift values fall into definite groupings. Re-sort the points into a new graph, with quasars of the same red shift grouped together.
NARRATOR: A similar phenomenon was also noted by the astronomer Geoffrey Burbidge.	Burbidge on camera.

BURBIDGE INTERVIEW: He notes that an unexpectly great percentage of quasars have red shifts grouped closely around 1.95.

VARSHNI INTERVIEW: Let us apply the standard cosmological interpretation to the distance of the quasars. All of the quasars with the same red shift should be at the same distance. This means that the quasars lie on a series of spherical shells centered on the earth. This conclusion is unacceptable to modern cosmological thinking because it places the earth in a special central position in the universe.

Show series of shells around earth, with quasars located on each shell.

NARRATOR [ON CAMERA]: Here's what astronomers mean by special position. If the quasars are arranged in shells, then if we move to a vantage point away from the earth and conduct the same observation, the quasars would no longer be arrayed on the shells. Rather they would be scattered in all directions at varying distances, no longer grouped in a concentric pattern.

Narrator at Palomar.

NARRATOR: How this is true is shown in this picture. First we establish a central point and draw a circle around it. The points on the circle can represent the quasars. Draw radii from points to the center. All radii are equal. But if you take a new point and measure the distances, they are no longer equal.

Computer graphics: Several points on a circle with lines drawn to the center. When the center is shifted to one side, the lines no longer have the same length.

NARRATOR [ON CAMERA]: The odds that this arrangement in

Narrator walking and talking at Palomar, with shells could happen by chance are next to nothing. Varshni therefore argues that the conclusion that the earth really is at the center of concentric shells of quasars is not acceptable. Therefore the red shifts of the quasars must be due to something other than the Doppler shift as described in the expanding universe model. If they are not due to the Doppler effect, they do not represent distance, and if they don't represent distance, it is no longer necessary to suppose the quasars are arranged in shells.

cutaways to repeats of the computer graphics.

VARSHNI INTERVIEW: Varshni believes that quasars generate light in a different way, a way that gives the appearance of red shifted light. According to Varshini, laser effects in the quasars give light inherently different characteristics that have nothing to do with velocity. Varshni believes scientists have mistaken the spectral lines in this type of light for red shifted spectral lines in ordinary ionized gas. So according to Varshni, the quasars are close by, and the idea that they are far away results from misinterpreting their laser generated light as red shifted ordinary light.

Varshni, with cutaway to star emitting red shifted laser effect light.

QUANTIZED RED SHIFTS--THE OBSERVATIONS OF WILLIAM TIFFT.

NARRATOR: William G. Tifft is an astronomer at Steward Observatory at the University of Arizona at Tucson. His conclusions have perhaps the most disturbing implications of all for the expanding

Shots of Steward Observatory and Tifft.

universe model.

INTERVIEW WITH W. TIFFT. Suggested discussion: Tifft has observed that the red shifts associated with galaxies tend to be quantized. What this means is that red shifts do not tend to be just any numbers, but tend to be multiples of a certain basic unit of about 72 kilometers per second.

Tifft on camera, preferably walking near the observatory at sunrise or sunset, or some other visually interesting place.

In general his studies show that red shifts of galaxies are grouped at 72 kps, 144 kps, 216 kps, and 288 kps and so on.

NARRATOR: Let us consider a pair of galaxies close to each other in space. According to ordinary theory, these galaxies should be attracting each other gravitationally. Thus they should be orbiting around each other.

Show two galaxies orbiting around each other to slow waltz music.

NARRATOR: Tifft examined the relative red shift of pairs of galaxies. This, according to standard theory, would represent not the speed at which the pair is receding from the earth, but rather the speed at which one is moving in orbit around the other, measured along the line of sight from the earth. Simply put, it is calculated like this. The observer measures the red shift of each of the pair of galaxies. For example one may have a red shift of 7,500 kps and the other may have one of 7,000 kps. This means that one galaxy is at that time moving relative to the other at a speed of 7,000 kps along the line of sight.

Narrator at Steward Observatory with cutaway to picture of two galaxies slowly orbiting around one another. The relative motion along the line of sight is shown by a bar that expands and contracts in length.

But because this is a relative speed it will vary according to the positions of the galaxies at different points in time. For example, when they are moving perpendicular to the line of sight, the relative motion will be zero, because they will have exactly the same red shift at that point.

NARRATOR: So if the two galaxies are in fact moving in orbit, the relative red shift will vary smoothly with a definite range of values. Of course, it is not possible to measure this variation for a single pair of galaxies. They would not display any visible motion or change of red shift within the lifetime of the observer. Therefore it is necessary to observe hundreds of pairs of galaxies and calculate the relative red shifts. In the chart we are now looking at, the pairs of dots represent pairs of galaxies, and the particular shades of red represent their relative red shifts. According to the standard theory, the relative red shifts should indicate orbital movement. One would expect a nearly continuous spread of values, because we would be catching them for measurement at a variety of different positions relative to our line of sight.

Sky scene. Show static pairs of galaxies, with different shades of red indicating relative motion. We take it that we are looking at galaxies that are orbiting and the red shift represents orbital movement. Have music, slow and somber.

NARRATOR: But Tifft has found this is not the case.

TIFFT INTERVIEW: The red shifts are grouped in multiples of a basic unit--72 kilometers per second. This indicates to Tifft that the red shift is a

Tifft on location, with cutaways to animation of a galaxy changing by steps to different degrees of redness (like an atom changing energy levels). Then a scene of galaxies either orbiting or falling in toward each other.

nonvelocity red shift and that the pairs are actually not orbiting each other. If we were actually catching them in different orbital positions, we should expect smooth variation over the entire range of values rather than the kind of clustering Tifft finds.

Tifft's findings apply not only to galaxies moving in pairs, but to whole groups of galaxies. This poses two questions that modern physics cannot answer. The first is: how is it possible for galaxies to have a nonvelocity red shift? Tifft says it caused by the nature of the galaxies themselves. They produce light that is red shifted because of internal properties having to do with some as yet unknown law of nature.

The second question is: If the red shift is not due to motion, then what is the motion of the galaxies? If they are orbiting, then there should be a continuous range of Doppler shifts whatever the internal properties of the galaxies might be. Could it be that they are not orbiting? Then, according to the Newton's or Einstein's laws of gravity, they should be falling together. They should still be moving--either orbiting each other or falling in towards each other. The indication is that they are doing neither. Therefore, according to Tifft, new princples of gravitation are necessary.

NARRATOR [ON CAMERA]: There is already evidence that might be interpreted as indicating Newton's laws may have to be revised, especially in relation to galaxies. For many years scientists have found great difficulty in acconting for the dynamics of galactic motion in terms of the law of gravity. For example, it may be seen that certain galaxies appear to be orbiting in a cluster, but the dynamics of mass and gravity suggest they should not be arranged in that way. For this they would have to be much more massive. But rather than sacrifice the laws of gravity, astronomers have posited the existence of great quantities of invisible dark matter to account for the missing mass. Some say 90% of the mass of the universe is missing.

Narrator walking and talking at Steward. Then show cluster of orbiting galaxies, and add missing mass as a dark cloud around them.

NARRATOR [ON CAMERA]: But another way to deal with this issue is to say the laws of gravity need revision, and Tifft is suggesting this based on his research. With new laws of gravity, the need to posit missing mass disappears. Is Tifft right or wrong? As of now, it isn't possible to say. But his ideas do show how scientists, operating with the very limited data they have been able to acquire, are running into all kinds of contradictions in their attempt to comprehend the universe.

Narrator walking and talking at Steward Observatory.

Thus far we have discussed pairs and groups of galaxies. We have seen how their red shifts representing movement relative to each other along an observer's line of sight should vary smoothly through a wide range of values. But Tifft has found they are quantized in multipiles of a constnat unit and concludes they are not moving at all relative to each other.

But what about their absolute movement away from us? Is it possible that the galaxies are also standing still in relation to us, that they are not moving away as the expanding universe model tells us they should be?

TIFFT INTERVIEW: Tifft believes the answer is that they are not moving. If they are moving due to expansion of the universe, their red shifts should span a wide range, covering all possible intermediate values. But Tifft proposes that these red shifts are also quantized.

Tifft on camera.

Normal measurements do not show this. But Tifft points out that when the effect of solar motion is subtracted, the quantization of the red shifts becomes unmistakably clear. The red shifts do not vary smoothly, but instead come in multiples of a constant number.

NARRATOR: Let's take a closer look at this problem. If the red shifts are quantized, as Tifft says they are, the sun, because of its motion, adds a Doppler effect to those quantized red shifts. What you add will depend on the angle of the distant galaxy's motion to the sun's motion. If the galaxy is

Show picture with the earth and sun surrounded by galaxies, all at a fixed distance and with equal bars representing equal red shifts. Then show how the sun's motion changes the red shifts, making all the bars uneven.

moving perpendicular to the sun's path, the sun's movement will not add anything. At 0 degrees there would be a negative red shift that would be subtracted. At 180 degrees you add a positive red shift. At points in between you get other values. By adding these values you break up the quantized nature of the red shifts. To detect the quantization, you have to subtract the red shift due to the sun's motion from the observed red shift values. Tifft says he has done just that.

NARRATOR: An example may help us understand what Tifft is talking about. Suppose a scientist is flying above a city trying to measure the heights of various buildings by using radar. He has a theory that the buildings are all multiples of a single story building, the height of which is 25 feet. He is flying at 500 feet and is measuring the distance between the plane and the tops of the buildings. Therefore as he surveys hundreds of buildings, he should be getting readings such as 475, 450, 400, 475, and so on. But this is only true if he is flying completely level. If he is flying at an angle, the numbers will display no apparent pattern. So if he discovers this is the case, he has two choices. He can try to repeat the experiment. Or he can try subtracting sets of numbers depending on his possible angle of flight. If he comes up with an angle that results in the heights

Narrator on camera for a little in beginning and end. Animation of the plane flying above different buildings on a tilted path. Show the varying altitudes as lines above each building. Then correct them for tilt, and show that they are now in multiples of 25.

displaying multiples of 25, he can assume his hypothesis was correct with a great deal of certaintly.

This is more or less what Tifft has done to uncover the quantization of galactic red shifts. When he subtracted values representing the sun's motion from his figures, he found all the galaxies had red shifts arranged in multiples of 72 kilometers per second. Thus he concludes they are nonvelocity red shifts, and he posits a static universe.

TIFFT INTERVIEW: Tifft says, "In view of all the implications which inevitably follow from the discrete redshift hypothesis, it is not surprising hat that the idea has met extreme resistance." Tifft might explain the nature of this resistance. He might also discuss the fate of other researchers, such as Arp, who have advocated controversial views.

Tifft on camera.

NARRATOR [ON CAMERA]: Halton Arp, however, independently confirms some of Tifft's findings, and this in turn lends greater weight to Arp's own anomalous observations.

Narrator on camera at Steward or Palomar.

Arp observes that in groups of galaxies, one member is generally brighter and bigger. This galaxy tends to have a lower red shift than its smaller companion galaxies. Arp suggests they are all in the same region, at the same general distance from us; therefore the red shifts are not giving velocity effects and distances, but indicate something else. As in

Vigier's case, Arp's suggestion has also met with resistance from astronomers committed to the standard expanding universe model.

ARP INTERVIEW: Arp says, "This important result has largely been ignored because it does not fit within the current theoretical framework." Have him go more into detail.

Arp on camera.

NARRATOR [ON CAMERA]: Arp believes that young galaxies ejected from other galaxies naturally have higher red shifts. In other words, the red shift is related to the age of the object and not its velocity. If we look at the whole group of objects Arp suggests are being ejected from a particular parent galaxiy, we find they all have greater red shifts than their parent. According to standard red shift theory, this means they have all been ejected in a direction away from the earth. This seems to give the earth a special position, which, as we have seen, is not a very popular idea with astronomers.

If the red shift is related to movement, it seems some of the ejected objects should be showing smaller red shifts than their parent, indicating movement toward the earth and not away from it. But if the red shifts are simply a characteristic of young, recently created celestial objects, the difficulty does not occur. Whether they are coming or going or standing still, they would have a higher red shift

Narrator on camera. Cutaway to pictures of parent and ejected objects on all sides of the earth. Then some animation showing ejected objects moving away on lines of sight from earth, with arrows indicating movement. All the arrows point away from the earth.

relative to their parent object.

NARRATOR [ON CAMERA]: There are, however, some possible objections to Arp's examples. Are the celestial objects he studies really really physically associated? Some scientists claim their apparent proximity to each other could be just a projection effect. The reason the dominant galaxy is bigger and brighter is that it is closer. And the reason that the smaller ones have big red shifts and are dimmer is that they are further away. There is no paradox.

Narrator on camera, with cutaway to picture of one of Arp's examples.

But not only do these smaller galaxies have positive red shifts relative to their parent galaxies, but these red shifts are quantized, just the way Tifft indicates they should be in his studies.

Narrator on camera, at Palomar.

ARP INTERVIEW: Arp finds peaks at 70, 140, and 210; this agrees well with Tifft's findings of quantization in multiples of 72 kps. As we have seen, this means that they are nonvelocity red shifts. And that fact that the quantization is in relation to the dominant galaxy in the group indicates there is some physical association. Why would the quantization be there is if the association is simply coincidental? The fact it is there indicates the association is real.

So here we have an example in which we see dim galaxies in close proximity to bright galaxies, although by standard cosmological ideas they should

Arp on camera, with cutaway to chart showing quantization of red shifts.

be vastly further away. This raises questions about the whole procedure of calculating distance according to brightness, as well as raising questions about the interpretation of red shifts.

NARRATOR [ON CAMERA] One of Arp's peaks for red shift differences among groups of galaxies is in the 136-144 kilometers per second range, as we can see from this chart. This is highly unusual. If these groups are involved in orbital motion we would expect to be finding them at different points in their orbits--some galaxies should be coming toward us, and others moving away from us. Thus we would expect a spread much greater than in this peak. This suggests that the orbital velocities, if present, are very small, too small for the galaxies to be actually orbiting each other according to present physical laws and estimates for the masses of the galaxies.

Tifft's ideas about the need for new laws of gravity seem to be confirmed.

Narrator at Palomar, walking and talking.

NARRATOR: Let's take a closer look at the problem Arp is dealing with. Suppose the central galaxy in this picture has a red shift of 400 kilometers per second and the companion has a red shift of 544 kilometers per second. The red shift difference is 144 kilometers per second. That puts it in the group Arp is considering. But now suppose the companion is orbiting the main galaxy at 30 kilometers per second. Therefore the 144

Animation of orbiting galaxy. Have a number box at the side of the orbiting galaxies. As they orbit, have it give readings of numbers. Also cutaways to the chart, showing how the peak should spread and disappear. Narrator comes on camera at end.

kilometer relative red shift should have values between plus and minus 30 added to it. That is it should have relative red shift values ranging between 114 and 174 at different points of its orbit, relative to us. Of course, we don't see this in a single example. The galaxies are moving too slowly. But when we sample large numbers of galaxy groups, we can and expect to catch them at different points in their orbits, with the appropriate orbital speed already added to their relative red shift. Therefore you would not expect the relative red shifts for galaxy groups to come out in the 136-144 range in so many cases. That is unless he orbital speed is no greater than 4 kps plus or or minus. Then given all the different orbital positions, the red shift differences, even with this orbital velocity added or subtracted would still be in the 136 - 144 range.

Given the ways galaxies should behave according to the Newtonian laws of gravity and the estimated masses of galaxies, this is too slow. Arp therefore concludes, along with Tifft, that they are not orbiting.

NARRATOR [ON CAMERA]: Arp also concludes that missing mass is not necessary. It was originally proposed to account for mysterious orbital motions based on calculations from red shifts interpreted as Doppler effects, but if there is no orbital motion, there is no need to posit missing mass.

Narrator at Palomar.

SECTION ON RADIOASTRONOMY.

NARRATOR [ON CAMERA]: Thus far we have been considering evidence gathered by optical telescopes and spectroscopes. Now let us turn to evidence from the field of radioastronomy. The silent discs of the radiotelescopes turned upward to the heavens are one of the most impressive images of the modern age.

Narrator on camera at Goldstone deep space dish. Cutaway to images of radio telescopes with appropriate music.

The history of radio astronomy begins in the 1930s with K.G. Jansky, who built the first crude prototypes at the Bell Telephone Laboratories. Then just after the Second World War, radio waves were bounced off the moon, giving an accurate measure of distance.

Jansky's original antenna; radio waves bouncing off moon.

Since then, great progress has been made, culminating in modern radiotelescopes using the techniques of very long base line interferometry.

Show modern radiotelescopes.

NARRATOR [ON CAMERA]: By combining the signals from radiotelescopes in different places on the earth, one can resolve structures in the sky smaller in angular diameter than those that can be seen by the most powerful optical telescopes.

Narrator at Goldstone, cutaway to radiotelescope images of galaxies in false color.

But have the discoveries made with radiotelescopes confirmed the standard expanding universe theory, or have they led to greater mysteries?

K.I. KELLERMAN ON SOME OF THE LIMITATIONS OF RADIOASTRONOMY.

NARRATOR: To answer this question, we turn to

West Virginia radiotelescopes.

radioastronomer K.I. Kellerman of the National Radio Astronomy Observatory at Green Bank, West Virginia.

INTERVIEW WITH K. KELLERMAN. Suggested discussion: He points out that despite the great promise of radioastronomy, it has not made very many contribuions to modern theories. Kellerman says we can't get Hubble's Law from radioastronomy.

Kellerman walking and talking by West Virginia radiotelescope array, with cutaways to radio images of galaxies, radioastronomers at work, etc.

Kellerman says: "Why have radio sources made so little contribution to observational cosmology?. There are in fact two important and fundamental reasons. The first is that since there are no sharp features in the radio spectra of galaxies and quasars, here is no way to determine their distance from radio measurements alone. Second the origin and evolution of radio sources is not well understood . . . So while we radio astronomers may claim to be able to see further out in the unverse than anyone, unfortunately we don't know where we are looking and we don't know what we are looking at."

Kellerman also says: "I have discussed several types of radio observations that might be expected to be relevant to observational cosmology. These are the radio number counts, the spectral index-distance relation, the angular size-disatance relation, and apparent motions of expanding sources . . . . in each case it appears that unless there is some close and subtle connection between the properties of the radio sources and their red shift, or that the entire class of general relativisitc cosmologies is inappropriate to our particular universe, it is difficult to reconcile the observed red shifts with the apparent lack of any other distance indicator. It is indeed disappointing, and perhaps cause for concern, that so far it has not been possible to detect the expected effect of the red shift on the observed intensity, angular size, or spectra of the extragalactic radio sources. If the large observed red shifts are of cosmological origin, then it appears that the only way we can in which we can save our accepted models of the universe is by introducing somewhat abrbitrary systematic changes with distance in the density or luminosity, in the spectra, and in the linear dimensions of radio sources. The question is, "Are we drawing too many epicycles?"

Kellerman concludes: " . . . the more we learn about the universe, the more confusing and complex the picture becomes."

THE BIG BANG AND THE COSMIC BACKGROUND RADIATION.

NARRATOR [ON CAMERA]: Thus far we have been discussing red shifts as evidence for an expanding universe. Now let us turn to another kind of evidence, one that many scientists consider to be the strongest proof for the big bang theory. They call it the

Narrator at Goldstone.

cosmic background radiation. In 1948, Ralph Alpher and Robert Herman predicted that scientists would eventually discover the remnants of the cosmic fireball of radiation ignited by the big bang. Over billions of years, this radiation, spreading outward with the expansion of the universe, would have cooled down considerably. But it should still be detectable as what scientist call a black body radiation.

NARRATOR: In 1965 Arno Penzias and Robert Wilson of Bell Laboratories were testing a radiotelescope. To their surprise they detected a faint unexplained radio signal coming in from all directions of the sky. It conformed to a black body radiation at 3 degrees Kelvin. It seemed that they had discovered the cosmic background radiation predicted by the big bang theorists.

Stock footage or photos of Penzias and Wilson and their apparatus.

NARRATOR [ON CAMERA]: But for some scientists the cosmic background radiation is not a confirmation of the big bang. Rather it simply adds to our difficulties in understanding the nature of the universe.

Narrator at Goldstone; cutaway to animation to show isotropy. Have wavy, uneven concentric circles of radio energy converging on the earth. Then have the circles become almost perfectly round to show isotropy.

After subtracting out the influence of solar motion, the cosmic background radiation is supposed to be incredibly isotropic. That is to say, its strength is almost exactly the same in all directions, varying only one part in three thousand. The uniformity of the cosmic background radiation implies that the universe was uniform to the same extent at the time the background radiation was released into independent existence.

NARRATOR: Here is what is supposed to have happened: the big bang goes off, and the universe is filled with a glaring white hot soup of subatomic particles. This is called a plasma. There are no atoms yet because the ionized plasma is so hot that free electrons cannot connect with nuclei.

Animation showing big bang, plasma, free electrons interacting with photons, trapping them, formation of atoms, and free light, passing through the electrically neutral atoms.

In a plasma light and other kinds of electromagnetic radiation interact strongly with the charged particles they encounter. So a plasma is not transparent; it doesn't allow free passage of light. A candle flame, for example is not transparent. Once the plasma expands and cools somewhat, electrons combine with nuclei to form atoms, which are neutral in charge. The plasma has become a gas, and the gas is transparent. For the very first time, light now freely travels in straight lines without appreciably interacting with matter.

NARRATOR [COMING ON CAMERA]: This radiation, when measured billions of years later, appears as the cosmic background radiation. It is a piece of cosmic history. We see it just as it left the plasma when it turned into a gas, except the expansion of the universe has red shifted the radiation. Therefore its temperature has dropped from many thousands of degrees to 3 degrees Kelvin.

Keep animation on for a little while, then cutaway to narrator at Goldstone.

NARRATOR: Because this cosmic background radiation is uniform in all directions to a high degree (one part in 3,000) then the whole universe at the time of the formation of atoms must have been uniform to that same degree. So it is hard to understand how the matter in our present universe is distributed in such a thoroughly nonuniform way. A uniform distribution would yield a universe consisting of nothing more than a cloud of gas. But we actually observe matter in clumps such as galaxies, and even these are unevenly distributed. Why are there big clusters of galaxies in one area and few in another? This is a complete mystery. Therefore the uniformity of the cosmic background radiation is not really a confirmation of the Big Bang theory, but instead adds problems to the picture of the universe it gives us.

Repeat uniform background radiation animation. Visual showing a clear sphere and a second sphere, full of variegatedness, galaxies, planets etc. Use theme sky image to show unequal distribution of galaxies.

THE PARADOX OF ANISOTROPY.

NARRATOR [ON CAMERA]: R.A. Muller and his colleaques at the Lawrence Berkeley Laboratory and Space Sciences Laboratory at UC Berekeley have pointed out another mystery resulting from study of the cosmic background radiation.

Narrator at Space Sciences Laboratory, Berkeley.

NARRATOR [ON CAMERA]: Apparently the Milky Way has a movement that is not attributable to the expansion of the universe. Muller and his coworkers determined this by their measurements of anisotropy, or inequalty, in

Chart of red shift anisotropy of background radiation. The sky is divided into different ovals, some red, some blue.

the cosmic background radiation. The finding is that the uncorrected background radiation is blue shifted in one part of the sky and red shifted in another, indicating that our galaxy, the Milky Way, is moving against the background radiation in what is called a peculiar motion.

NARRATOR: In the ideal situation the cosmic background radiation should be of the exact same intensity in all directions. Let's look again at our expanding balloon model. Pick a dot on the surface of the expanding balloon. All the other dots at any particular distance are expanding from it in all directions at the same speed. But if the dot begins moving in on the surface, then the dots in the direction of movement will have a blue shift and the dots away from the direction of movement will have a corresponding red shift. This is exactly the effect noted by Muller in his measurements of the red shift of the cosmic background radiation.

Expanding balloon model. Pick a center dot, color it green. Pick out a circle of dots at the same radius from it. When the green dot moves, color dots in direction of movement blue, dots opposite direction of movement red, in various shades. Those perpindicular to the movement don't change in color.

NARRATOR [ON CAMERA]: In this way, Muller and his colleagues have calculated the rate of motion of the Milky Way galaxy. They estimate the galaxy must be moviing at 600 kilometers per second in a certain direction against the background. This is what is called a peculiar motion, namely a motion distinct from the overall expansion of the universe.

Narrator at Berkeley Space Science Lab.

But there's more. It has also been shown from red shift measurements that the nearby cluster of galaxies, the Virgo cluster, must also be moving in that direction, since relative to us, it appears to have no motion.

NARRATOR: Here's an example to show what we mean. Say you are moving in your car on a freeway at 50 miles per hour. If a car next to you has no motion, you can assume it is also moving at 50 mph.

Car is driving down highway at certain speed. Driver looks out and sees car next to him. This could be turned into something humorous by changing speed of the car to 70, and have the driver look out and see a policeman moving next to him at the same speed. Then fade.

NARRATOR [ON CAMERA]: Using our car example, imagine you are going 50 miles per hour and a car begins moving past you at 10 miles per hour. It must be moving at 60 miles per hour. By a similar technique, astronomers Rubin and Ford have measured rates of motion relative to us for a large collection of local galaxies within a sphere having a radius of 100 million light years. When they added this figure to our own motion, they found that the galaxy group group has a motion of 800 kilometers per second against the background.

Narrator at Berkely Space Lab; cutaway to graphics of Milky Way, B Virgo Group, and Rubin-Ford galaxies moving against the back ground radiation.

NARRATOR [ON CAMERA]: What is it that's causing this widely distributed collection of galaxies to be moving against the background radiation in that way?. One would expect only a small movement or no movement in a case like this.

Narrator at Berkeley Space Science Lab.

NARRATOR: Here is the crucial concern. If something is moving in an explosion

Figure showing increase of motion going back in time.

faster than the speed of the material around it, it will tend to catch up with material further out that is moving faster. That is to say, in the future its movement relative to the expansion will decrease. But if we look into the past, we would find its motion increasing.

What this means is that the motion of the Rubin-Ford galaxies would have been much greater in the past. For example, at 10 billion years ago, the supercluster would be moving at roughly 1,600 kilometers per second. This leads to a big contradiction, for it indicates that as we move closer to the time of the big bang, the rates motion of large groups of galaxies relative to the expansion of the universe become greater and greater. This violates the principle of homogeneity and isotropy in the early stages of the expanding universe model.

NARRATOR [ON CAMERA]: We have thus encountered in the cosmic background radiation some fundamental paradoxes. The first is connected with its isotropy. Because the background radiation is uniform in all directions, this suggests that the early stages of the expansion of the universe were also uniform. But if that is true, why do we have such a variegated distribution of matter in our present universe? Second, studies of the cosmic background radiation reveal that some regions of the universe have large peculiar motions, which when projected

Narrator at Berkeley Space Science Lab, with cutaways to brief repeats of previous graphics on isotropy of background radiation and unequal distribution of matter in universe.

back in time, become even larger, indicating greater and greater chaos as we approach the supposedly homogeneous starting point.

NARRATOR: Regarding the first point, Muller says, "It is not obvious how to reconcile the featureless nature of the background radiation with the high degree of local turbulence."

Narrator at Berkely Space Science Lab, cutaway to radiotelescope images superimposed on theme sky.

And in a more general comment he says: "Perhaps the most perceptive criticism of the homogeneous isotropic big bang model is that it is far too simple to represent reality. One is easily tempted to assume that the unknown is simple."

ALTERNATIVE EXPLANATIONS FOR THE COSMIC BLACK BODY RADIATION.

NARRATOR [ON CAMERA]: Many scientists take it for granted that the cosmic background radiation can only be understood in terms of the big bang expanding universe model. But in fact there are other explanations of this background radiation. Let's consider the one offered by Vigier.

Narrator at Palomar.

NARRATOR: The starting point for his understanding of the background radiation is the frequently mentioned observation that the energy level of the cosmic background radiation is about the same as the energy level of starlight. As we can see from this painting by Vincent Van Gogh stars do have an energy. One thought that comes to mind is this: could the cosmic

Van Gogh night sky painting.

background radiation be starlight that has been diffused and reaches with almost uniform intensity from all directions? Vigier points out that his tired light model predicts just such a thing will happen.	
NARRATOR: In Vigier's model the universe is static; there is no expansion, so there is no red shift caused by velocity. But as light moves through intergalactic space it loses energy from interacting with certain subatomic particles. The interaction robs the light of energy, and thus its spectrum gradually shifts toward the red. This explains the Hubble Law, because the further the light goes, the further it shifts.	Repeat graphics of photons bumping into particles and turning red.
NARRATOR: Each time light bumps into the particles that absorb its energy, it is slightly deflected. Over vast distances the effect of the deflections is to obscure the sources of light.	Continue graphics.
NARRATOR [ON CAMERA]: Something like this happens on a foggy day. On a very foggy day you can't even tell where the sun is because the light is coming at you in an isotropic fashion, at the same intensity from all directions. If the fog is somewhat less dense, you can see further, but beyond a certain distance everything is still a blank, a uniform grey tone.	Ideally have the narrator walking and talking on foggy day; otherwise, just foggy day footage with voice superimposed.
NARRATOR [ON CAMERA]: Similarly, according to Vigier and his associates, the light from very distant galaxies	Animation. Show earth surrounded by distant galaxies. Show photons emerge from distant

becomes diffused to form a uniform background of light in which no details can be discerned. This light is coming from distant galaxies, which have the characteristics of black bodies with a high radiation temperature. But by the time the light reaches us it will be red shifted by the tired light effect down to a very low black body temperature. In this way, Vigier's theory predicts a background radiation of low temperature with a black body spectrum, just as the big bang theory does.

galaxies, encounter particles, get deflected, and merge into a blur; meanwhile distant galaxies fade. Photons from nearer galaxies reach earth in straight lines, however, and the galaxies remain visible.

CONCLUSION.

NARRATOR: So the simple observation that there is an isotropic background radiation with a black body spectrum does not mean the big bang theory is true. There are other theories that can or could account for it. Perhaps the correct theory is one not even thought of yet.

Narrator at Palomar.

Therefore we should be cautious in accepting the the big bang model as the final word in cosmology. Geoffrey Burbidge, after studying all available evidence supporting an expanding universe, gives this warning.

BURBIDGE INTERVIEW: He wrote:"I believe that if one attempts to evaluate this evidence objectively there is still no really conclusive evidence in favour of such a universe."

Burbidge on camera at UCSD.

Burbidge also says: "Was there really a big bang? I believe that the answer clearly must be that we do not know, and that if we are ever to find an answer much more effort must be devoted to cosmological tests, with a much more openminded approach, and that much more original thinking must be done to attempt to explain the large amount of observational material, and not only that material that can be used in a narrow sense to fit preconceived ideas."

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