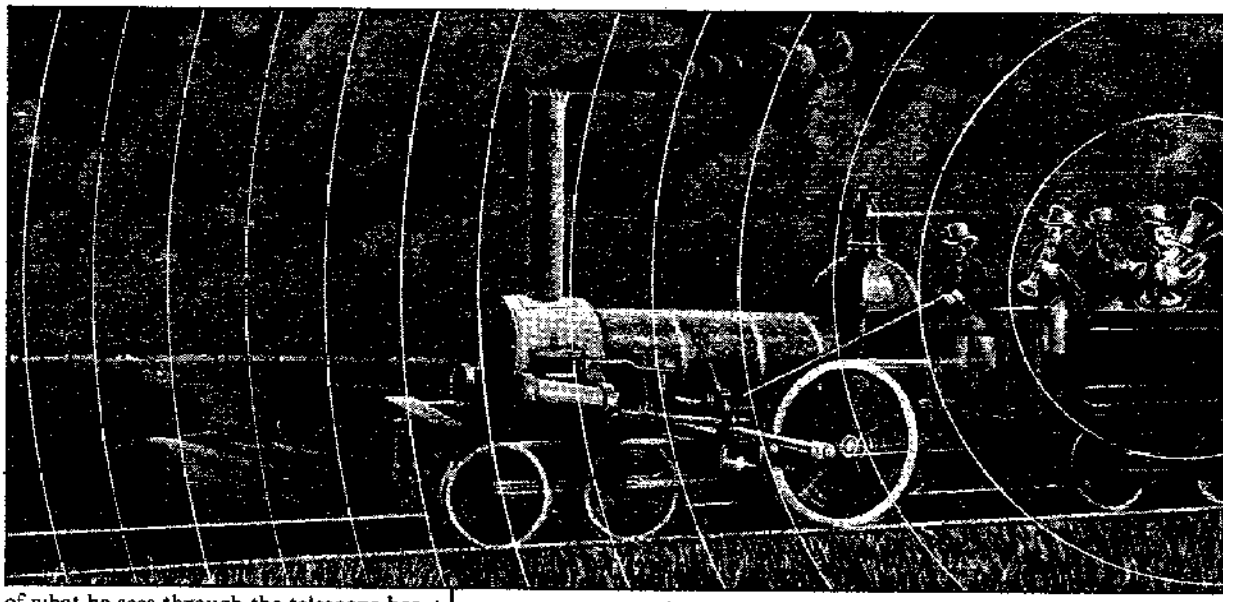
THE MOST FEARED ASTRONOMER ON EARTH

HALTON C. ARP

BY WILLIAM KAUFMANN III

This maverick believes he has a proof the Universe is *not* expanding. If he is correct, we will have to rethink almost everything we know about astronomy.

Halton Arp is a genius with a telescope. A tall, handsome, easygoing 53-year-old astronomer and former Olympic fencer, "Chip" Arp became obsessed with the mysterious celestial objects called quasars soon after they were first found in the early 1960s. Over the past two decades, his telescopic observations of quasars have presented astronomers with the first serious challenge to a law that has been basic to their science for more than half a century. Arp's interpretation



of what he sees through the telescope has also sparked one of the bitterest conflicts in memory within the small group of scientists who deal with the nature of the Universe on a cosmic scale.

If Arp is correct, if his observations are confirmed, he will have single-handedly shaken all modern astronomy to its very foundations. If he is right, one of the pillars of modern astronomy and cosmology will come crashing down in a turmoil unparalleled since Copernicus dared to suggest that the sun, not the earth, was at the center of the solar system.

The story of quasars and Dr. Halton Arp's rebellion goes back to the early 1960s. At that time, during an extensive survey of the heavens with a radio telescope, English astronomers discovered a large number of individual radio-wave sources spread across the sky. After the Englishmen carefully listed their findings in the now-famous *Third Cambridge Catalogue* (the first two versions were plagued with errors), other astronomers around the world quickly turned their ordinary optical telescopes to the positions given in the catalog to see if any visible objects might be found at the locations of the radio-wave sources.

MYSTERIOUS RADIO WAVES

Astronomers have long known that conditions inside galaxies and nebulas are often conducive to the production of radio waves. So, not unexpectedly, they found that the location of many of the radio sources coincided with visible galaxies and nebulas. They were puzzled, however, when some radio sources appeared to be associated not with galaxies or nebulas but with starlike objects; ordinary stars do not produce copious radio waves.

Detailed observations of these starlike objects only deepened the mystery. Astronomers analyze celestial objects by focusing their light onto a prismlike device called a diffraction grating that breaks the light up into a rainbow. This rainbow—called a spectrum—is often found to have thin dark lines scattered among its various colors. These so-called spectral lines are produced by the chemicals in the star or galaxy in which the light originated. Each chemical produces its own characteristic spectral lines. By knowing which lines correspond to which chemicals, astronomers can deduce the chemical composition of the object.

Spectral lines can also be used to tell how fast a star or galaxy is moving. If the light from the celestial object is coming toward you, all its spectral lines are shifted toward the blue side of the rainbow-colored spectrum. This is called a blue shift. Conversely, if a source of light is moving away from you, all its spectral lines are shifted in the opposite direction, toward the red side. This is called a red

William Kaufmann III, astrophysicist, wrote

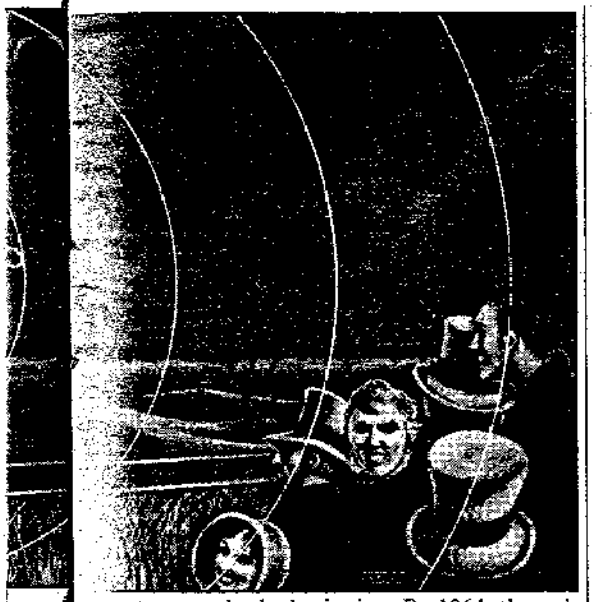
THE DOPPLER EFFECT

In the 1840s, physicist Christian Doppler staged an entertaining exper he placed a band of musicians on a moving train. While they played, with perfect pitch, stood by and listened. The notes sounded higher wh train approached and lower as it departed; the faster the train, the g the change in pitch. Doppler realized an oncoming train causes sound to compress. Though each note has its own frequency, or number of wav second, compressed waves reach the eardrum more often, thus quickeni vibration and raising the pitch. Conversely, stretched waves from a re source sound lower. What Doppler learned from sound waves, astronomers to light waves when studying the distance, brightness and movement of

ward the red or the blue end of trum is an example of the Doppl which we most commonly enc the form of a change in the pitch or fire-engine whistle as it appr recedes at high speed.

At first, the anomalous spect newly discovered starlike radio containing arrangements of spec that no one could identify, total dered the astronomers. A break 1963 when astronomer Maarten at the California Institute of Tec was examining the spectrum of radio source called 3C273 (the 2 ject listed in the *Third Cambria logue*). Schmidt thought that pe spectral lines in 3C273 looked s because they were ordinary spec that had been subject to a huge shift, placing them in unfamil tions. The spectral lines of 3C found, seemed to be shifted by a amount toward the red side of trum. If Schmidt were right, enormous extent of this apparent implied that the mysterious star

violet blue grn yel red



was only the beginning. By 1964, the red shift of another starlike radio source (3C147) suggested that it was hurtling away from us at an even higher rate: 41 percent of the speed of light. Less than a year later, 3C9 broke this record with a red shift corresponding to 80 percent of the speed of light.

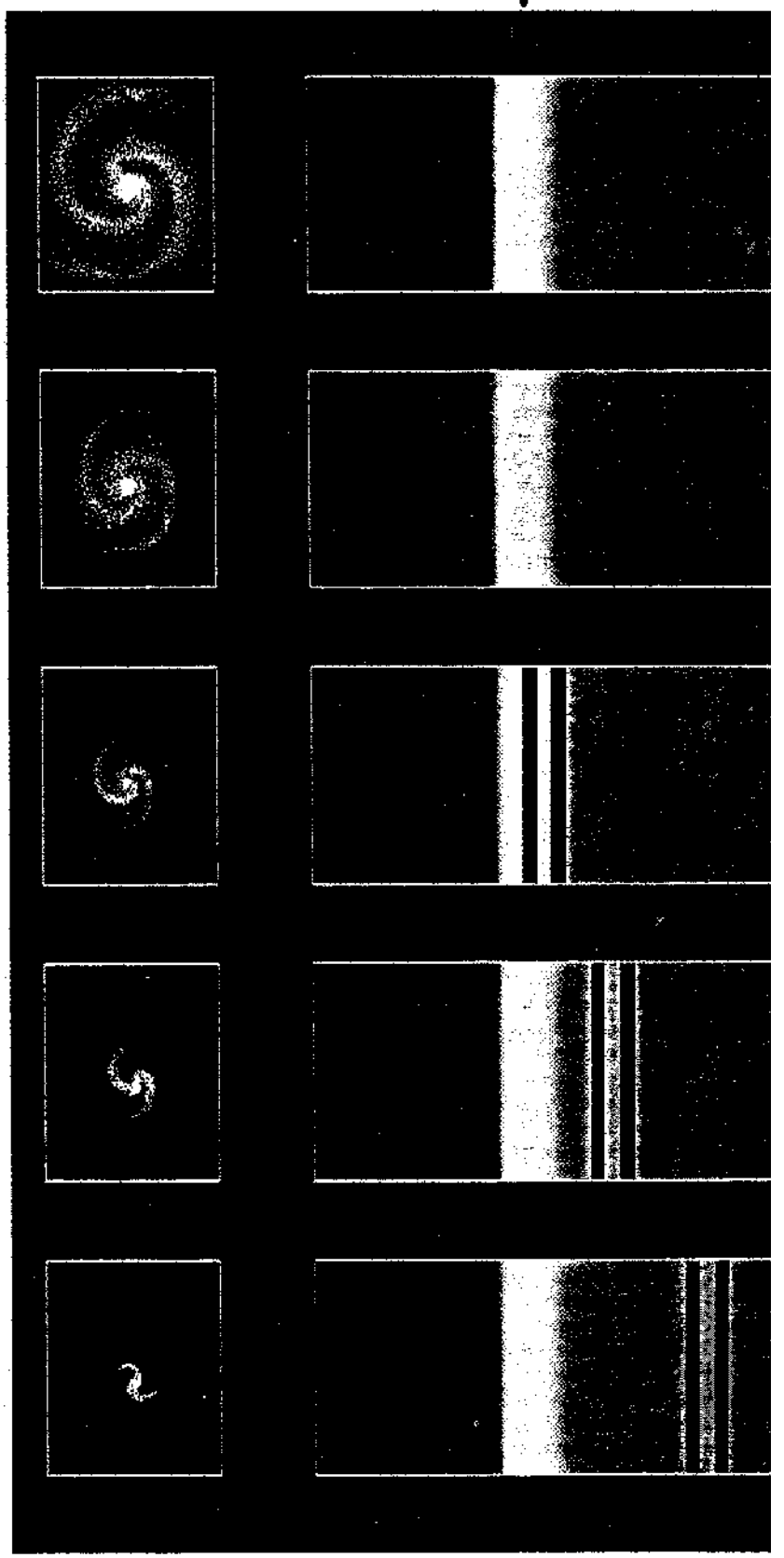
Though they look like stars, these objects were clearly not ordinary stars. They were therefore named "quasi-stellar sources," a term that was quickly shortened to *quasars*.

Hundreds of these quasars are scattered all across the heavens. Although many are not radio sources, all have large red shifts in their spectra. The red shift record is today held by one very faint quasar whose spectral lines indicate that it is rushing away from us at 91 percent of the speed of light! The only things that move that fast on earth are nuclear particles in an accelerator. To traditional astronomers the speeds of the quasars could have only one explanation: the expansion of the Universe.

FASTEST COSMIC OBJECTS?

It has been known for many years that remote galaxies exhibit red shifts in their spectra. Furthermore, the size of a galaxy's red shift is correlated not only with its speed but also with its distance from earth: the larger the red shift, the greater the distance. Thus quasars must not only be the fastest objects in the Universe but also the farthest away.

The correlation between distance and red shift has been a bastion of astronomy since the late 1920s when Edwin Hubble, at Mount Wilson Observatory in Pasadena, California, made the observations that led to what has come to be known and respected as the Hubble law. The desig-



When starlight separates into wavelengths it supplies information about dis objects. Each dark line corresponds to a unique chemical element, identifying object's composition. Most astrophysicists believe that their location within

principle. The Hubble law is the cornerstone of all modern cosmology. It is the foundation of the theory that says the Universe has been expanding since a primordial Big Bang 15 to 20 billion years ago. Any astronomer who questions the Hubble law is committing heresy.

The most straightforward interpretation of the Hubble law is that the Universe is expanding: a red shift implies not only that an object is moving, but also that it is moving *away from you*. Distant galaxies, all of which exhibit slight red shifts, are therefore all rushing from us. Moreover, according to the Hubble law, nearby galaxies must be moving away from us more slowly than those that are more distant.

The quasar's huge red shifts mean (à la Doppler effect) that these strange star-like sources of radiation are rushing away from us at enormous speeds; according to Hubble, they must be located at enormous distances from the earth, many times farther away than the typical galaxies we see scattered across the sky.

Though it all seemed to fit together

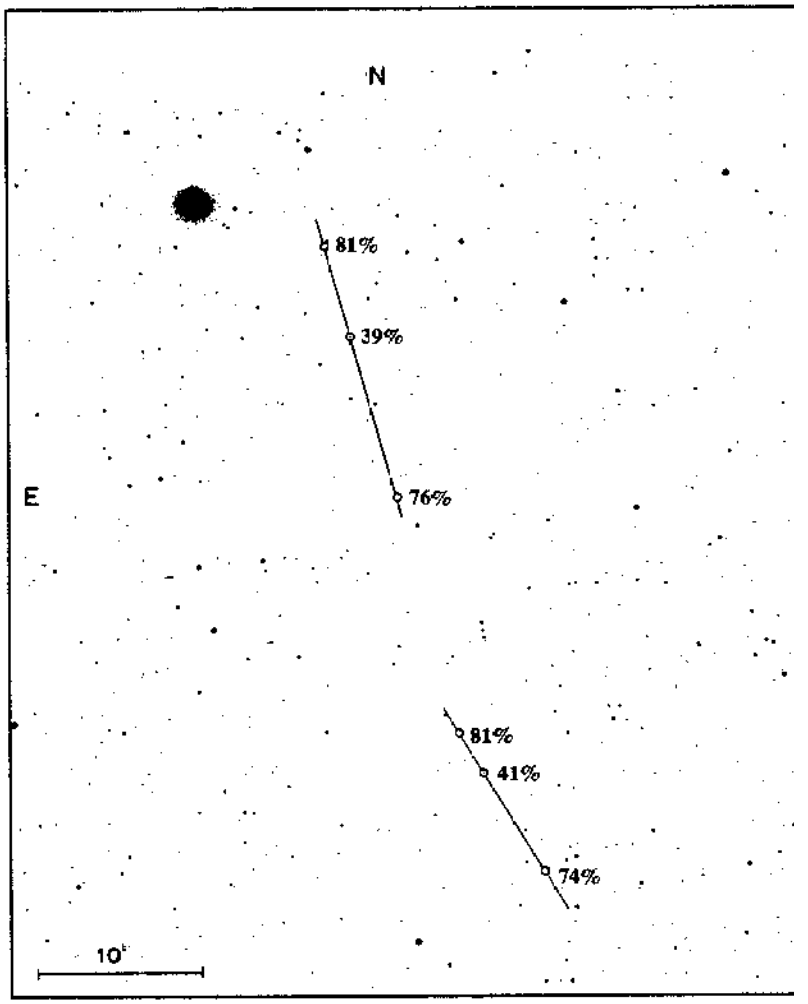
How many astronomical coincidences can science tolerate before it begins to look seriously at some of Arp's observations?

quite well, astronomers soon realized they had a big problem on their hands. If a quasar were located at such a colossal distance, its red shift and the Hubble law require that it must be shining with the brightness of 100 galaxies, each made up of billions of ordinary stars. Some quasars may even be 1,000 times brighter than our Milky Way galaxy.

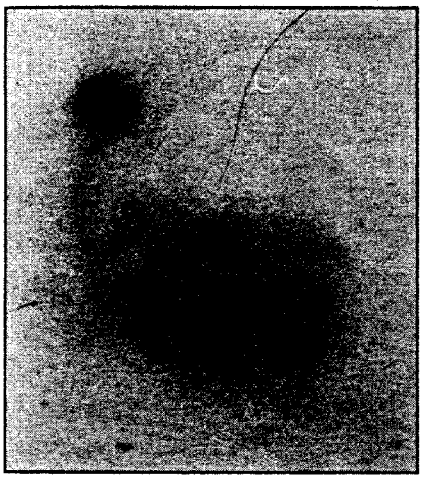
Quasars have to be this bright, or we would not be able to see them over such great distances.

How can a single object be as bright as 1,000 galaxies? This dilemma was so puzzling that some astronomers had the audacity to say the Hubble law was wrong. Perhaps, at least for quasars, red shift had nothing to do with distance? Perhaps, despite their large red shifts and in apparent violation of the Hubble law, quasars are much nearer the earth than the vast distances traditionally assigned them?

Working out of the Mount Wilson and Las Campanas observatories, Halton Arp soon emerged as the leader of the heretics. Despite his outsider's status for the past



Above: Six quasars of varying red shifts line up alongside the constellati
Below: Three quasars appear to be nestled in the arms of NGC1073, a nearby spiral galaxy in the constellation Cetus. So many quasars in one area is



According to the Hubble law, the center galaxy of low red shift is closer to the earth than its neighbor with a high red shift. Arp disagrees: the faint bridge hints that they are close to each other.

tablishment: a B.A. from Harvard and a Ph.D. in astrophysics from the California Institute of Technology; membership on Caltech faculty for 23 years; awards from the American Association for the Advancement of Science and the American Astronomical Society; dual appointments at the University of Edinburgh and the Southern European Observatory in addition to his position at Mount Wilson and Las Campanas.

Nevertheless, Arp regularly descends on scientific meetings and challenges everyone to explain the discordant red shifts in terms of conventional theory. The reactions of his colleagues range from shock to boredom to outright hostility, but "no one," points out one astrophysicist, "ever falls asleep when Chip Arp lectures." Another astrophysicist says, "I wouldn't mind being stranded on a desert island with him as long as we don't have to talk about science."

Arp believes life should be "very, very intense, competitive. But when the bout is over, you shake hands and you're friends." Echoes one of his fencing partners, "He loves to win. One thing you know when you're fencing with Arp: he's trying."

A good example of one of Arp's "impossible" observations involves the galaxy called NGC1073 (the 1073rd object listed in the *New General Catalogue*, which lists galaxies, nebulas and star clusters). Appearing face-on through the telescope, it covers an area in the sky one-hundredth the size of the full moon—remembering, of course, that the apparent area covered is a function not only of its size but of its distance from us.

NGC1073's low red shift suggests it is nearby—only 75 million light-years away. But Arp and his colleagues have discovered three quasars nestled in its spiral arms. Like all quasars, these three objects have very high red shifts, corresponding to 44 percent, 70 percent and 79 percent of the speed of light, which according to the Hubble law places them 5 billion, 8 billion and 9 billion light-years away respectively.

Says the traditional astronomer: these quasars have nothing to do with NGC1073. They are way in the background, far, far beyond the galaxy and are simply shining through it. They just happen to lie, as viewed from earth, in roughly the same part of the sky as NGC1073. It's a complete accident, an illusion, that these three quasars appear to be nestled in the galaxy's spiral arms.

Arp, on the other hand, argues that finding these quasars so closely grouped around the image of NGC1073 means that they are actually associated with the galaxy. Perhaps they are even located within its graceful spiral arms, a scant 75 million light-years from earth.

With the adroitness of an accomplished swordsman, Arp parries the traditional thrusts. Independent researchers typically find an average of only eight quasars per square degree across the sky (the diameter of the full moon covers only one-half degree of arc). Thus, Arp calmly points out, the probability of finding three quasars in an area the size of NGC173, which is one-hundredth the diameter of the full moon, is about 1 in 1,000.

"Well, he just got lucky!" is a typical response from the traditionalists.

Indeed! If it is luck, Chip Arp seems to have a limitless supply. He has found associations between low-red-shift galaxies and high-red-shift quasars all over the sky. A prolific author of scientific papers, Arp's latest work lists 22 newly discovered galaxy-quasar associations.

STRANGE CASE

Typical of Arp's recent discoveries is the strange case of NGC2859. A barred spiral galaxy in the constellation of Leo Minor, NGC2859 has spiral arms tightly wound around its nucleus and a very small red shift, corresponding to only 0.5 percent of the speed of light.

Scattered around NGC2859 are four small companion galaxies, and three of them each have a quasar nearby whose red shifts correspond to 20 percent, 72 percent and 83 percent of the speed of light respectively.

If you blindly accept the Hubble law, you must conclude that these three quasars are billions of light-years from earth. Yet NGC2859 and its low-red-shift companions are only about 70 million light-years away. Thus all three associations around NGC2859 must again be complete accidents; it is by mere chance that, as seen from earth, the nearby galaxies and the distant quasars lie in the same di-

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HERETICS TRIUMPHANT

Almost all startling advances in science must step on the toes of earlier beliefs.

Lavoisier's theory of combustion, Dalton's atomic theory, Joule's notions on the conservation of energy, Mendeleev's periodic table, Planck's quantum theory, Rutherford's nuclear atom, Einstein's relativity—all were greeted with hesitancy and doubt and denounced unsparingly by conservatives. These breakthrough scientists did not suffer for their temerity, however, and ultimately received regards and rewards in their lifetimes. Others were not so lucky.

The French chemist Auguste Laurent advanced a new theory of molecular structure in 1836 that contradicted the ideas of the aged demigod of chemistry, Berzelius. The old man denounced Laurent's notions so powerfully that Laurent's career was ruined. As Laurent died in his forties, he did not live to see his ideas accepted.

The German geologist Alfred Wegener suggested in 1912 that the continents had been drifting slowly for millions of years. He was laughed out of court and died before his idea finally won recognition.

The scientific heretics who really suffered denunciation, however, were those whose beliefs threatened dogmas *outside* of science. Then religion and popular emotion rose against them.

When Copernicus and Galileo advanced ideas that threatened the motionless, central earth of the Bible, when Darwin's evolutionary theory challenged the special creation of man, or when Hutton and Lyell presented evidence to refute the notion that earth was created 6,000 years ago, the people raged. Copernicus dared not publish until he was dying, Galileo was threatened with torture, and the others were vilified by a public that would have killed them if it could.

–Isaac Asimov

HALTON C. ARP

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rection in space. Thus do most astronomers dismiss Arp's observations.

The phenomena observed by Arp just don't make sense any other way within the standard framework of classical modern astronomy. If you believe in the Hubble law, there is no other way to explain these anomalous red shifts. As Caltech astronomer Jesse Greenstein explains, "If there is anything to Arp's observations, then everything is up for grabs!" Indeed, if Arp is right, we must admit to gaping holes in our understanding of the Universe. Needless to say, this is not a comforting prospect to the typical astronomer, who has based his life's work on ideas such as the Hubble law. "If you accept the observational evidence at its face value, you have to admit that you don't really understand this red shift in certain situations," says Geoffrey Burbidge, director of the Kitt Peak National Observatory near Tucson, Arizona. Arp's adversaries therefore have a strong psychological motivation to argue that his quasar-galaxy associations are simple accidents.

But some people do have doubts. As Burbidge inquires: "How many of these accidents can you tolerate before you believe that something is going on?"

A few choose an agnostic position, refusing to believe there is even any controversy, because, they say, Arp has not yet established his case. Furthermore, they believe that the work he has done in this area lacks clean, solid, scientific controls. "You must realize," says Allan Sandage, a longtime friend and colleague of Arp's whose devotion to carrying on Hubble's work has put the two men at scientific odds, "that there really is no controversy. There is general disbelief, but no controversy. Hardly anybody debates or talks about this work anymore."

MINOR IRRITANT

Caltech astrophysicist Wallace Sargent has acrimoniously encapsulated the history of some scientists' reactions to Arp: "The people who were antagonistic toward Arp in the past must have been afraid that he might be right. They're not, for the most part, afraid anymore. He's like a pebble in your shoe: after awhile, you don't notice the irritation anymore."

Other astronomers seem to be keeping their options open regarding Arp's findings. "There's a certain disturbing quality in a new revelation which makes it difficult to listen to because it doesn't in any way make sense," says Caltech's Jesse Greenstein. "But the fact that it's repugnant doesn't mean that it's not true."

Arp himself sees the reluctance of most of his colleagues to take his observations

"And it's mutually reinforcing," he goes on, " 'Okay,' they say, 'we're not going to give up our theoretical concepts unless the observations force us to.' And then they say, 'No observations are strong enough to give up these things we know to be true.' And *then* they say, 'We can't accept the observations until we have a theory that makes them possible.' "

Undaunted by the turmoil, Arp continues to locate strange galaxy-galaxy and quasar-quasar associations. Take, for example, the bizarre case of the six quasars on the eastern side of the constellation of Leo, the lion. The three northern quasars lie along a perfectly straight line; the three southern quasars also lie along a straight line. Even more astounding: the same pattern of red shifts appears in both sets of quasar triplets. In the northern triplet, the quasar red shifts (from north to south) indicate speeds of 81 percent, 39 percent and 76 percent of the speed of light. In the southern triplet, the quasar red shifts (from north to south) indicate speeds of 81 percent, 41 percent and 74 percent of the speed of light.

A complete accident? To make matters even more puzzling, if you take a ruler

Could quasars be the portals that allow newly created matter to gush into our Universe from other universes?

and draw a line connecting the two high-red-shift quasars (that is, the top quasar in the upper triplet and the top quasar in the bottom triplet), then a second line connecting the two middle quasars (which have nearly the same red shift) and, finally, a third line connecting the bottom two quasars (which also have nearly the same red shift), you will immediately notice that the three lines intersect in almost exactly the same place, a point very near the southern quasar of the upper triplet.

Arp and his sympathizers suggest that these quasar alignments are evidence of a common origin. Perhaps all six quasars were *ejected* in pairs from a common central source. This is one of Arp's favorite proposals, and it would explain, for example, why the quasars are located near the galaxies.

This proposal does not shed any light on the quasars' large red shifts, however. Indeed, the quasar red shifts become more mysterious than ever. If you agree with Arp that quasars are relatively near, then their red shifts cannot be due to the

ejected from nearby galaxies, then quasar red shifts cannot be due to speeds either. The reason? We are nc cated in a special place in the Univ An equal number of quasars shoul rushing toward and away from us, a dicated by an equal number of blue-s ed and red-shifted quasars. But no has ever found a single quasar w spectral lines are blue shifted. Thus, l speed ejection from a galaxy's nu cannot explain quasar red shifts.

BOLD PROPOSAL

In a similar way, you can methodi reject every single standard explan for quasar red shifts. Arp therefore b proposes that quasar red shifts have r ing to do with speed or distance bu caused by as-yet-unknown physical cesses, perhaps entailing unknown s tific principles. Such a position is no precedented. At the turn of the twen century, for example, astronomers ized that they could not explain a mon observation: the sun shines. A explanation had to wait for the inve of quantum mechanics, nuclear ph and the special theory of relativity.

Traditional astronomers are agha the idea that undiscovered laws of n might be at work in the Universe. Or triguing possibility is based on a co logical theory formulated by the Br astronomer Sir Fred Hoyle, working the Indian physicist Jayant Narlikar. Hoyle-Narlikar cosmology asserts the masses of atoms change slowly long periods. Specifically, new m freshly introduced into our Uni (from some other universe?) would sist of atoms with low mass. Spectral produced by these new low-mass a would have longer, redder wavele than usual, thereby producing a red As the matter ages, the spectral would shift toward normal. Arp co tures that quasars are therefore the tals through which newly created m is gushing into our Universe from universes.

Most astronomers would classify speculation as patently absurd. Spe for the majority, one world-renowne tronomer acrimoniously complains "We are tired and irritated that [Arp's] arguments are used on g people. I don't think they should be even on children."

Whether Arp is right or not, he ha covered a multitude of strange across the sky that clearly merit close amination. The gentle prodding of gifted astronomer has reminded us we must not shrink from questioning our most cherished beliefs. Through scrutiny, we deepen our understar and widen our horizons.