

A Pattern Of Resistance

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IN questions of science the authority of a thousand is not worth the humble reasoning of a single individual. So wrote Galileo back in the early part of the seventeenth century. In more modern times Sir Peter Medawar had this to say: *I cannot give any scientist of any age better advice than this, the intensity of the conviction that a hypothesis is true has no bearing on whether it is true or not.*

The common sentiment voiced by two highly creative scientists separated by more than three and a half centuries calls for objectivity in the practice of science. After all isn't the phrase "scientific temper" born out of the very same objectivity that is supposed to be followed in science? Yet, the history of science speaks otherwise despite its Galileos and Medawars. Indeed, there have been many occasions when dogma shared by a large majority had forced scientific development to stray from the path of truth. A few notable instances from astronomy will underscore this fact.

The telescope: illusion or witchcraft?

Take the example of the telescope which is today the bread and butter of astronomy. In 1609 when Galileo initiated its use for observing the heavens his findings evoked a hostile reception. When his telescope discovered the craters on the Moon and dark spots on the Sun, he was disbelieved. Why? Because these results indicated "defects" in divine creation which was believed to be perfect. Even his discovery of the four innermost moons of Jupiter was unwelcome,

for, the prevailing belief was that the whole cosmos revolves around the Earth. How could therefore four moons go round Jupiter?

So the intelligentsia advised that Galileo's telescope was a source of illusions, or, worse, witchcraft to be avoided at all cost. Galileo himself was subjected to the rigours of inquisition. Think of the decades lost by observational astronomy because of this hostility.

The treatment meted out to Galileo was the natural and predictable reaction of an Establishment that felt threatened by the influx of new ideas. Galileo was a strong supporter of the Copernican theory that the Sun and not the Earth forms the centrepiece of what we today know as the Solar System. The Copernican ideas took nearly a century to take root. After all they were seeking to displace an established order of more than fifteen centuries.

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Catering to the human ego

It could be argued that consciously or unconsciously it was the human ego that came in the way of this revolution. The humans were being asked to relinquish their claim of being at the privileged location of the centre of the universe! But as their observing capabilities prospered (thanks to the improvements in the very same much maligned telescope) their ego took a further beating.

In the late eighteenth century William Herschel attempted a map of our Milky Way Galaxy. This was based on the estimates of stellar distances which were just becoming possible to measure observationally. In Herschel's map our Sun and the Solar System appears at the centre of the Galaxy.

The astronomical techniques continued to improve through the nineteenth century but even as late as 1917 Herschel's view of our Galaxy continued to prevail. There were some indications that went against this view and a small minority of astronomers was voicing the opinion that our Galaxy might be a lot bigger than subscribed to by the popular belief and that the Sun was in fact far away from the Galactic Centre. This view was strongly resisted until Harlow Shapley conclusively demonstrated that the minority view was correct. Today we estimate that the Sun may be about thirty thousand light years away from the centre of the Galaxy, that is, the light from the Galactic Centre would take thirty thousand years to travel to us.

The mistake of the earlier astronomers, as it turned out, was that they had not properly allowed for the obscuration of the distant stars in the Galaxy caused by interstellar dust. The dark regions of the Milky Way that were believed to be devoid of stars did in fact contain stars obscured by dust enroute, much like the city smog that obscures the view of distant buildings. Thus Shapley dealt the second blow to the human ego by displacing our Solar System from the centrepont of our galactic habitat.

But the saga does not end here. The very same Shapley turned out to be wrong when it came to deciding what exactly does the Milky Way contain. For, during the nineteenth century, astronomers were beginning to photograph faint cloudlike objects quite unlike stars, and these became subjects of controversy. Some of these *nebulae* (as they came to be known) could be related to gas ejected by stars and were therefore local to the Milky Way; but some were thought by a minority of astronomers to be quite distant, being galaxies in their own right lying well beyond the Milky Way.

The majority firmly ridiculed this interpretation arguing that all nebulae were part of our Galaxy. (Again human ego wanting "our" Galaxy to be the sole and important object in the universe?) However, before the second decade of this century was over the minority opinion was vindicated by the better telescopes like the new Mount Wilson Telescope. By 1929 Edwin Hubble had published his epoch-making findings that in the vast extragalactic universe these other galaxies are found to be receding from us according to a set pattern that soon came to be known as the Hubble Law. The universal recession of galaxies gave rise to the concept of the *expanding universe* which in turn led to the popular big bang models of the universe wherein the universe is believed to have originated in a primordial explosion, the "big bang". We will have occasion to refer to Hubble's Law and to the big bang universe later in this article.

A controversy in radio astronomy

The advent of radioastronomy in the

post-World War II era brought in another controversy. Radio telescopes were picking up sources of radio emission practically from all directions in the sky. At Cambridge, Martin Ryle, leader of one of the pioneering radioastronomy groups believed that these sources were radio stars in our Galaxy and his colleagues felt likewise. Tommy Gold, a theoretician believed otherwise. According to Gold, the majority of the sources were extragalactic, being very far away. The arguments got fiercer and uglier and finally Gold was banned from attending Ryle's seminars in the Cavendish Laboratory.

The controversy was finally resolved as more and more radio sources were optically identified, that is, the optical astronomers could visually "see" objects located at the positions of the radio sources. And it turned out that Gold was correct! The vast majority of radiosources observed by Ryle & Co. and by other radioastronomers in England and Australia turned out to lie far beyond the confines of our Milky Way.

THE bottom line of such studies is that the Milky Way, large though it is by human and terrestrial standards, is but a drop in the cosmic ocean. Time and again man has underestimated the vastness of the cosmos.

J.B.S. Haldane had cautioned: *The universe is not only queerer than we suppose but it is queerer than what we can suppose.* Nowhere more so than in astronomy do we come across evidence that this is indeed the case.

The discovery of quasars

By the early 1960s astrophysicists had more or less solved the puzzle of what makes the stars shine. A star like the Sun is producing all its energy through nuclear fusion which converts hydrogen into helium, the very same process that produces the explosive energy of a hydrogen bomb. The star naturally changes in its chemical composition as it ages and this in turn produces changes in its size and appearance. The science of stellar evolu-

tion studies the various stages in a star's life and relates them to the stars actually observed by astronomers.

The success of this subject had thus created the general impression that thermonuclear fusion is the main source of energy of cosmic sources. In 1963, however, thanks to the cooperative efforts of radio and optical astronomers a new class of sources began to be discovered. Known as quasi stellar objects (QSOs) or more popularly as *quasars*, these sources of radiation appear to be very small in extent, being almost pointlike so that they were initially mistaken for stars. However, they produce energy at such a rate that the nuclear fusion process proves inadequate to explain it.

Theoreticians are still grappling with the energy problem. The majority consensus is that a quasar is powered by a massive black hole at its centre. A black hole is an idealized object whose gravity is so strong that it pulls back any radiation that may try to escape from its surface. It is argued that the strong pull of a black hole churns the surroundings and generates the violent activity and radiation found in a typical quasar. An alternative minority view is that quasars are sites of creation of new matter, a process which causes its explosive ejection along with radiation. More astronomical observations are needed to tell us which, if any, of these views is correct.

How far are the quasars?

One crucial information relevant to the energy problem of quasars is their distance. Astronomers do not have a direct means of telling just how far away from us the quasar is. It is customary to use Hubble's law of 1929 to estimate the distance of a quasar. The law is basically a simple one to interpret and is used in practice as follows.

The spectrum of a source analyses its total light according to colours just as the sunlight is distributed in seven rainbow colours. The physicist knows that light waves with different wavelengths appear in different colours with the red end corresponding to the longest waves and violet end the shortest ones. Over and above these colour bands in the spectrum there are dark and

bright lines which arise from the emission or absorption of light by elements. Each element has its own signature in the sense that the wavelength of each such line can be identified with a specific element with the help of atomic physics.

In the case of light sources from outside our Galaxy the spectra systematically show a peculiar feature. These well identified lines do not appear at their usual wavelengths but are shifted towards the red end. This effect is commonly known as red-shift. The extent of shift may differ from source to source but Hubble's law tells us that *the farther away the source the larger the shift of its spectral lines towards the red end.*

The 1929 studies of Hubble were limited to nearby galaxies. But over six decades the subsequent observations have shown it to be valid for galaxies more than a hundred times farther away. Indeed the confidence generated by the applicability of Hubble's law has led to a firm belief in the mathematical models of the large scale structure of the universe in particular the big bang model.

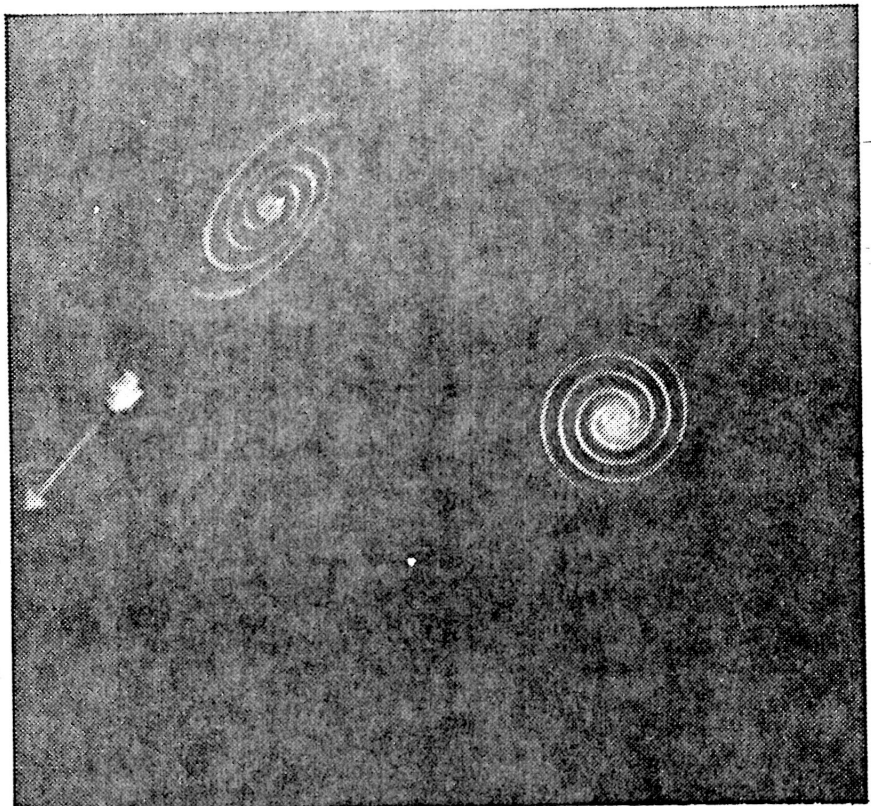
To return to quasars, their spectra generally show very large redshifts, several times larger than the redshifts of typical galaxies observed by the astronomer. Thus, if we assume that Hubble's law applies to quasars then we have to conclude that the typical quasar is considerably farther away than a typical galaxy. This is the consensus prevalent in astronomy.

However, while the astronomer is able to estimate the distance of a galaxy at least approximately there is no direct measurement of the distance of a quasar. Thus one can say that the Hubble law can be directly verified for galaxies but not for quasars.

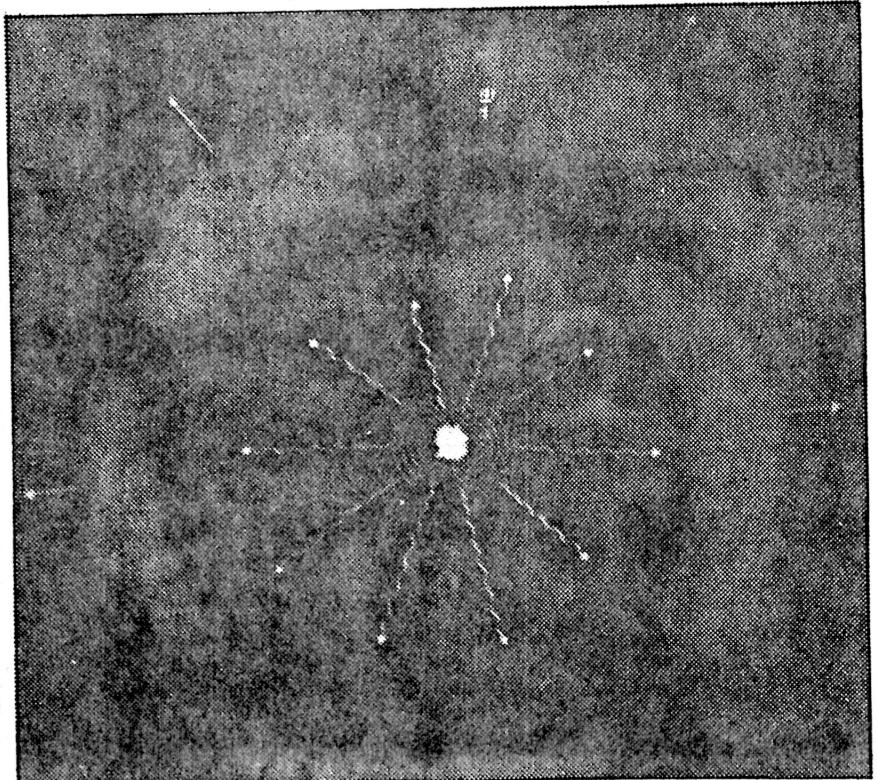
In the absence of direct verification quasar astronomers simply assume that the law does hold for quasars and proceed with that assumption to interpret their data. And this belief therefore goes unchecked.

Arp vs the establishment

However, in the late sixties Walter (Chip) Arp a distinguished astronomer from the Mount Wilson and Palomar Observatories began to question this belief. Himself a



Some scientists believe that quasars are galaxies that travel faster than the speed of light



The core of the quasar which contains electrons or protons trapped in a magnetic field

meticulous observer, Chip Arp has many achievements to his credit including an atlas of galaxies which many workers in the field refer to as a standard reference source. However, Arp's observations turned up evidence that seemed to go against the cherished belief in Hubble's law.

A typical example of such anomalous evidence is the finding of one or more quasars in directions very close to the direction of a galaxy. If the large redshifts of quasars are indicative of their large distances then the only possible interpretation is that the galaxy (because of its low redshift) is in the foreground and that the background quasars happen to lie in its direction. In the solar system this type of situation is not unknown; in a typical occultation the Moon and a planet come in the same direction although the planet is physically behind the Moon and much farther away.

The quasars, however, are comparatively rare set of objects and if one were to ask the question about the probability that the above special distribution comes about by chance, then the answer is very small, much less than a per-cent. Statisticians call such occurrences "significant", i.e., indicating that the assumption of the background quasars coming by chance in the direction of the foreground galaxy may be somewhat shaky.

An isolated observation of this kind may still be dismissed or ignored and this was the fate of some of Arp's earlier data. He was told that these are freaks that cannot be taken as generic cases; that in any case unless more such cases are discovered by him nobody will worry about them.

As it happened, in the ensuing years Arp did just that. He began to look for and report more and more anomalous cases of various kinds. In some cases he could even demonstrate filamentary connections between two objects of very different redshifts. Normally, two galaxies which are close neighbours have a tidal gravitational interaction in which material is pulled out of one galaxy in the form of a filament that extends towards the other. The adjective "tidal" is used from the analogy of a similar interaction between the Earth and the

Moon that causes tides in the oceans as the ocean water rises towards the Moon.

In Arp's cases there are filaments linking two galaxies with one large galaxy and the other, smaller, companion galaxy. Nobody would object to the picture as an example of interacting galaxies until the redshifts of the pair are disclosed. They are vastly different! If Hubble's law is to apply to them then the smaller galaxy would have to be a background object much farther away and

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therefore having no connection with the foreground big galaxy. But then is it a coincidence that the filament from one appears to connect the other? It is becoming harder and harder for the Establishment to argue away the cases as freaks.

It is an illustration of how disturbed the Establishment has become by the steady accumulation of such cases that over the last decade Arp has been denied access to the best observatories. He left the United States and moved to Europe where the hostility towards anti-Establishment ideas is not so severe. Working without direct

access to some of the best telescopes in the world, he and a few others are still able to find more cases that cast doubt on the universality of Hubble's law. In a book published a few years ago (*Quasars, Redshifts and Controversies*, publisher, Interstellar Media, Berkeley) Arp has given a blow by blow account of how such evidence has accumulated despite scorn, criticism and resistance by the astronomical community.

In conclusion ...

The Arp episode is not an isolated example. In cosmology itself the idea of big bang has become so well rooted as to become a religious dogma which cannot be challenged, as Fred Hoyle, Geoffrey Burbidge and I have found to our cost. While proposing an alternative to the big bang cosmology we encounter the very same hostility that Arp finds towards his observational results. Indeed the resistance to new ideas today is just as strong as it was four centuries ago, but for different sociological reasons.

In the days of Copernicus and Galileo their discoveries were seen as threat to the established religious order which in turn was powerful politically. Today the place of organized religion is taken by organized science which wields power. New ideas are seen as a threat to that power. Further, scientific research has become a big-money proposition and there is severe competition for the limited funds from the various government agencies in different countries. The evaluation of project proposals is carried out by peer-review committees and these experts being conscious of their responsibility of selecting a few out of many take a cautious approach and always opt for the ideas that are already established and therefore considered safe for further exploration. This filtering process automatically eliminates any new and daring or outlandish idea even though it comes from scientists of established credentials.

This of course does not augur well for astronomy or for science in general, for putting stress on conformism will deprive us of fresh new thoughts which alone have been responsible for the dramatic strides of progress in the past.