THE UNIVERSE

ASTROPHYSICS AND SPACE SCIENCE LIBRARY

VOLUME 244

THE UNIVERSE

Visions and Perspectives

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SPRINGER-SCIENCE+BUSINESS MEDIA, B.V.

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN 978-94-010-5784-4 ISBN 978-94-011-4050-8 (eBook)
DOI 10.1007/978-94-011-4050-8

Courtesy of Prof. W.J. Couch, The University of New South Wales.

Printed on acid-free paper

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Preface

It is with great joy that we present a collection of essays written in honour of Jayant Vishnu Narlikar, who completed 60 years of age on July 19, 1998, by his friends and colleagues, including several of his former students. Jayant has had a long research career in astrophysics and cosmology, which he began at Cambridge in 1960, as a student of Sir Fred Hoyle. He started his work with a big bang, expounding on the steady state theory of the Universe and creating a new theory of gravity inspired by Mach's principle. He also worked on action-at-a-distance electrodynamics, inspired by the explorations of Wheeler, Feynman and Hogarth in that direction. This body of work established Jayant's reputation as a bold and imaginative physicist who was ever willing to take a fresh look at fundamental issues, undeterred by conventional wisdom. This trait, undoubtedly inherited from his teacher and mentor, has always remained with Jayant. It is now most evident in his untiring efforts to understand anomalies in quasar astronomy, and to develop the quasi-steady state cosmology, along with a group of highly distinguished astronomers including Halton Arp, Geoffrey Burbidge and Fred Hoyle. In spite of all this iconoclastic activity, Jayant remains a part of the mainstream; he appreciates as well as encourages good work along conventional lines by his students and colleagues. This is clear from the range of essays included in this volume, and the variety and distribution of the essayists.

After a long stay in Cambridge, Jayant moved to the Tata Institute of Fundamental Research in Mumbai (then Bombay) in 1972. There he inspired several research students to work in gravitational theory and its many classical and quantum applications to cosmology and astrophysics, and established collaborations with his peers, which led to a fine body of work over the next 15 years. But perhaps his most enduring contribution of this period was to forge a link between distinguished senior relativists in India, and the younger generation of aspiring researchers. This has led to the formation of a warm and congenial community, spread throughout the country, working in relativity, cosmology and theoretical astrophysics. During this period Jayant also worked hard at the popularization of science, through the press, television and most importantly through talks to ever increasing audiences. This not only exposed people to good science, but it also helped to establish Jayant as one of the public figures of science in India. Jayant has used his formidable reputation and influence, developed during this period, for the advancement of science in India, always in a very quiet manner.

In 1988, inspired and aided by Professor Yashpal, then Chairman of the University Grants Commission, Jayant set up the Inter-University Centre for Astronomy and Astrophysics at Pune. Through this centre he has been able to open up for the university community avenues for excellent research in these areas. Jayant's broad vision, and his readiness to encourage every shade of opinion and to bring out the best in his colleagues, has enabled IUCAA to develop an international reputation. The centre is now seen as an example of how the energies of the research institutes and universities in India, usually considered disparate, could be harnessed together to excellent effect.

It is the general practice to list, in a volume of this kind, the scientific and other works of the person it seeks to honour. The list in the present case would have been rather unusually long, and we have therefore decided, in consultation with Jayant, that we will enumerate only his scientific books. These expose much of the work he has presented elsewhere in the form of research papers and review articles. They also present highly readable and often pedagogic accounts of modern astrophysics, and will surely continue to be read for a long time to come. Amongst the works that we will leave unlisted will be his contributions to the annals of science fiction, which have helped much to endear him to the general public. In this matter too Jayant has followed in the steps of Fred Hoyle.

Naresh Dadhich
Ajit Kembhavi

Acknowledgments

We wish to thank Professor K. S. V. S. Narasimhan for a careful reading of the manuscript.

Chapter 1

OBSERVATIONS AND THEORY[1]

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1. INTRODUCTION

The most predictable observation concerning theories is that they will probably always turn out to be wrong. From Ptolemy to phlogisten these excercises have wasted untold model calculations and obsoleted endless sermons. Nevertheless, for the last 77 years, eschewing all humility, orthodox science has insisted on the theory that the entire universe was created instantaneously out of nothing. Observations for the last 33 years have shown this to be wrong - but these basic facts of science have been rejected on the grounds there was no theory to "explain" them.

Since 1977, however, there has not even been this feeble excuse for abandoning empiricism. That was the year in which Jayant Narlikar published a short paper in Annals of Physics (107, p325). The paper outlined how a more general solution of the equations of general relativity permitted matter to be "created" i. e. enter a black hole and remerge somewhere from a white hole without passing through a singularity where physics just broke down. This was not just another play with words because it turned out that the newly created matter would have to have a high intrinsic redshift. The latter is just what observations with optical and radio telescopes had been requiring since 1966!

As contradictory cases mounted over the years, the Big Bang theory had to be rescued by postulating an ever increasing number of adjustable parameters. As a consequence there is today a giant tsunami of evidence cresting above the Big Bang. It demonstrates continual creation of galaxies and evolution of intrinsic redshift in an indefinitely old and

[1]Editors' note: Dr. Halton Arp has requested that his contribution be presented as two separate articles, which we do in this chapter and the next.

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large universe. By now we can start anywhere with this evidence so let us start with new results on a class of objects called active galaxies.

2. ACTIVE GALAXIES

In the preceding paper, preliminary investigation of two Ultra Luminous Infrared Galaxies (ULIRG"s) are reported. It is clear that these very disturbed objects are being torn apart during the process of ejecting high redshift quasars. Empirical evolutionary sequences show that the ULIRG's themselves are very active galaxies recently evolved from quasars. Therefore they also possess an appreciable component of intrinsic redshift. Conventionally this redshift gives too large a distance and this is why these objects are considered to be so "overluminous". As we shall comment later, however, they do not look at all like the most luminous galaxies of which we have certain knowledge. Instead they resemble small, active companion galaxies to larger, older parent galaxies. For example, Markarian 273 is an obvious companion to the large, nearby spiral, Messier 101.

The defining characteristic of active galaxies is that they show enormous concentrations of energy inside very small nuclei. They also show optical, radio and X-ray jets and plumes of material emerging from their centers. The latter is not surprising since the concentrated energy must expand and escape somehow. It has been accepted for about 40 years that active galaxies eject radio material so it is difficult to understand why the ejections associated with quasars are not recognized. But the expulsion of material is clearly responsible for the disrupted appearance of the active galaxies. Why then does conventional astronomy make an enormous industry out of a completely different, ad hoc explanation for morphologically disturbed galaxies - namely mergers!

3. MERGERS?

What is the conventional view of disturbed galaxies and ULIRG's? It is that two independent galaxies are merging. One galaxy sees another and heads directly for it. In its excitement it forgets about angular momentum and unerringly scores a direct hit. To judge how reasonable this is one could ask how many comets are perturbed into the solar system and proceed to plunge directly into the sun?

In all honesty, however, I must admit that my long term scorn for the merger scenario has been tempered by recent evidence on ejection from active galaxies. For many years it was clear that there was a tendency for galaxies to eject along their minor axes. But recently there have been some cases where ejection has been aligned with striking accuracy along the minor axis (6 quasars from NGC3516 , Chu et al. 1998, and five Quasars and four companion galaxies from NGC5985, Arp 1999). It is clear that proto galaxies ejected exactly out along the minor axis, and evolving into companion galaxies as they eventually fall back (Arp 1997;1998) will have little or no angular momentum and therefore move on plunging orbits. Their chances of colliding with the parent galaxy are therefore much greater than if they were field galaxies. So maybe there is some usefulness after all to those many detailed calculations which have been carried out on colliding galaxies.

But when the ejection of protogalactic material takes place in the plane or tries to exit through the substance of the parent galaxy then an entirely different scenario develops. Using the low mass creation theory, one can now begin to connect these events with previously uninterpretable observations.

4. SUPERFLUID

In 1957 the famous Armenian astronomer Ambartsumian concluded from looking at survey photographs that galaxies were formed by ejection from other galaxies. As an accomplished astrophysicist he realized that would require ejection in an initially non-solid form form but with properties different from a normal plasma. He called it "superfluid". In spite of general agreement that Ambartsumian was a great scientist his important conclusion about the formation of galaxies has been ignored.

But now the Hoyle-Narlikar variable mass theory is required to explain the high intrinsic redshifts of the quasars ejected from galaxies. The creation of mass in the centers of galaxies with this same variable mass theory then also solves the major problem which must have caused Ambartsumian to use the term "superfluid", namely that a normal, hot plasma expanding from the small dimensions of a galaxy nucleus would not have been able to condense into a new galaxy. In contrast, as the particles in the newly created plasma age they gain mass and, in order to conserve momentum, must slow their velocity. This means the plasma cools as it ages and also its self gravitation increases - both factors working in the direction of condensing the material into a proto galaxy.

The second major obstacle overcome by starting the particles off with near zero mass is the initial velocity of ejection. Observations have shown examples of ejected material in jets approaching closer and closer to the speed of light. Physicists believe that as a particle approaches the speed of light its mass must approach infinity. In other words one has to pump an enormous amount of energy into a huge number of particles to get the velocities (gamma factors) which are implied by the observations. If the particles are initially near zero mass, however, they are almost all energy and are emerging naturally with near the signal velocity, c.

In M87, the very strong radio galaxy in the Virgo Cluster, knots in the jet have been measured by their proper motion to have apparent outgoing velocities of 5 to 6 c. But further out along this jet we find quasars and companion galaxies which the knots must evolve into. Now, however, all the calculations based on the assumption that the knots consist of normal plasma will have to be redone with a low mass plasma, e.g. the calculations of supposed shock fronts and containment envelopes. (See Arp 1998,1999)

5. EXPLODING GALAXIES

There is a strong (and in some cases almost perfect) tendency for quasars to be initially ejected out along the minor axis and also ordered in descending redshift with angular separation. Nevertheless there are some cases where quasars are found close to their galaxy of origin but not ordered in redshift. The key to understanding this situation lies in the observation that the nearby galaxy of origin is usually spectacularly disrupted. What could cause this disruption? The obvious inference is that the process of ejection has, somehow, fragmented the galaxy when the ejection is not out along the minor axis.

At this particular point the usefulness of the variable mass theory becomes especially apparent. We are able to visualize a cloud of low particle mass material pushing out against the material of the galaxy, initially with velocity c. Low mass particle cross sections are large and eject and entrain the material of the galaxy into long, emerging jets. The initial pulse of energy concentrated at the center of the galaxy plus the sudden decentralization of mass explodes and tears asunder the parent galaxy. Moreover, the new material is retarded and fragmented so that it develops into many smaller new proto galaxies much closer to the, by now, thoroughly disrupted galaxy. This is the case where the new material does not exit along the minor axis.This is exactly what is observed as shown here in Figures 1 and 2.

Here the disrupted galaxy is 53W003 (a blue, radio, galaxy). As the picture shows it has been disrupted into at least three pieces. A pair of almost perfectly aligned quasars of z = 2.389 and z = 2.392 have apparently come out fairly unimpeded. (There are, as expected, brighter quasars of z = 1.09 and z = 1.13 about 7 arcmin further along in this direction). The rest of the quasars, about 18 similarly high redshift objects, have wound up in a cloud only about 1.5 arcmin from the disrupted

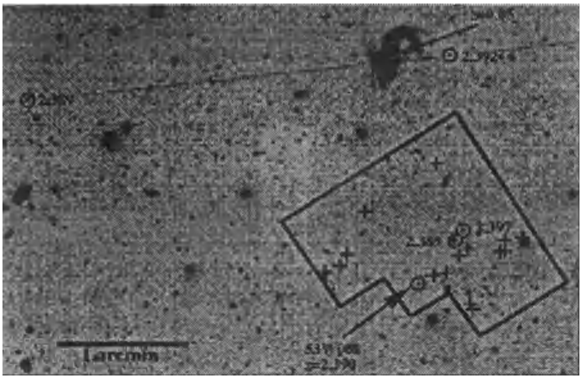

Figure 1.1 Part of a 4m PF-CCD field in the F410M filter (4150A, filter width 150A). The WFPC2 search fields are outlined - plus signs show non-AGN Ly α emitters. Quasars in the cluster are circled with z marked. From Keel et al. 1998.

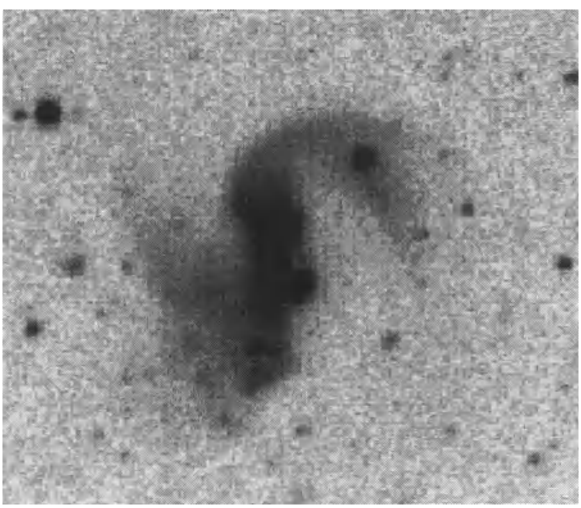

Figure 1.2 Enlargement of z = .05 galaxy in Fig.1. Note how this blue radio galaxy, 53W003, has multiple components. Image courtesy W. Keel.

galaxy. Evidently they represent some low mass plasma that was broken up into smaller clouds in its violent exit from the galaxy. In support of this scenario, high resolution, Hubble Telescope images of these high redshift objects show them to be blue and irregular. At their conventional redshift distance they would have absolute magnitudes of M = -24 mag. - well into the supposed quasar range of luminosity. Yet they have an extended morphology, whereas, in general, brighter quasars of the same redshift are point-like.

More broadly, this leads me to comment that the faint images in the famous Hubble Deep Field exposure which have such large redshifts are of predominantly blue, irregular morphology. At their conventional redshift distance they should be enormously luminous. But all our experience with genuinely luminous galaxies indicates such galaxies should be massive, relaxed, equilibrium forms - like E galaxies, or at least Sb's. These Hubble Deep Field objects have ragged, irregular looking dwarf morphology. Instead of a new kind of object suddenly discovered in the universe would it not be plausible that they are really relatively nearby dwarfs but simply have high redshifts because they are young?

6. A USEFUL THEORY

Speaking for myself, the Narlikar general solution of the relativistic field equations has been a salvation. It has opened up possibilities of understanding the observational facts - facts which must be accounted for if we are to have a science. In the dogma of current astronomy, evidence no matter how many times confirmed, cannot be accepted if it does not fit Big Bang assumptions. With the the variable mass theory, however, essentially all the salient observational facts can be related to each other in a physically understandable, reasonable way. Even if it is only a stepping stone to a future, deeper theory - I must say, thank you Jayant.

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Chapter 2

EJECTION FROM ULTRALUMINOUS INFRARED GALAXIES

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Abstract

Active galaxies, particularly Seyferts, have been shown to eject material in various forms including quasars with high intrinsic redshifts. A class of active galaxy which has so far not been analyzed from this standpoint is the so called Ultra Luminous Infrared Galaxies (ULRIG's). Here we report the very beginning of an analysis of the three most luminous examples of such galaxies. Aided by the availability of the new VLA all sky radio surveys it is clear that these ULRIG's show especially strong evidence for ejection in optical, radio and X-ray wavelengths . These ejections are strikingly connected with adjacent quasars, both with those of known redshifts and those which are candidate quasars waiting to be confirmed.

1. MARKARIAN 273

This is a torn apart galaxy with a brilliant, long optical jet. At a conventional distance corresponding to its redshift (z = .038) it is one of the most luminous galaxies known in red wavelengths. Hence it is called an Ultra Luminous Infrared Galaxy (ULIRG). When observed in X-rays the galaxy has an active center. Only 1.3 arcmin NE, right at the end of a broad optical filament, lies another X-ray source (see Figure 2.1). When the spectrum of this companion (Mark273x) was taken it was reported as z = .038, the same as the central galaxy. Naturally this was interpreted as showing that Mark273x was a "dwarf" Seyfert interacting with Mark273. Fortunately the investigators checked the spectrum (Xia et al. [2], [3]). They found they had accidentally measured an HII region

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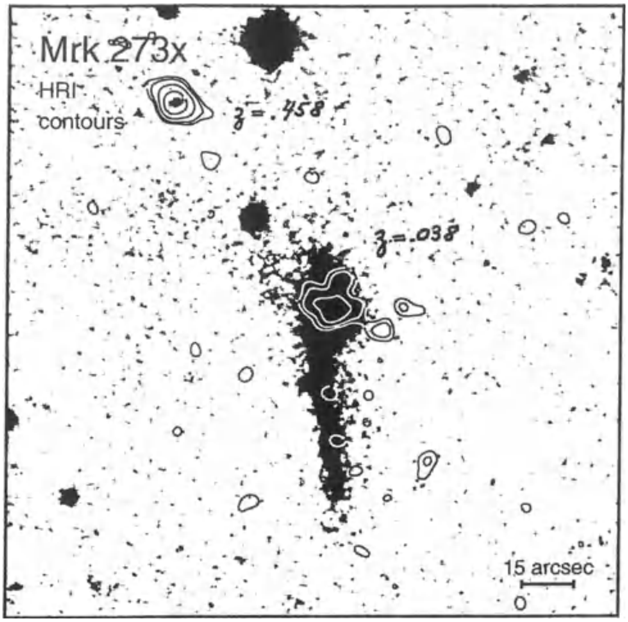

Figure 2.1 Copy of R film from POSSII. The X-ray contours around Mark273x (upper left) and Mark273 (center) are from Xia et al. [2]. Redshifts of each object as measured by Xia et al. [3]. Photographs to fainter surface brightnesses show luminous material extending in the direction of, and almost to, Mark273x.

in Mark273 and that Mark273x was actually a high redshift object of z = .458.

As in untold numbers of similar cases, as soon as the high redshift of the companion was discovered it was relegated to the background as an unassociated object. But, embarassingly, in this case it had already been claimed to be associated at the same distance. Tracking down the X-ray map of this system revealed at a glance that the z = .038 galaxy and the z = .458 companion were elongated toward each other! Moreover there was a significant excess of X-ray sources around the active central galaxy indicating further physically associated X-ray sources. Two of the brightest lay only 6.2 and 6.6 arcmin to the SE. The first was a catalogued quasar of z = .941 and the second an obvious quasar candidate whose redshift needs to be measured. As shown in Figure 2.2 there are both X-ray and radio jets emanating from Mark273 in the direction of these two additional quasars. Moreover the fainter radio emissions form two separate filaments leading directly to the two quasars. On a deep optical plate one can see the beginning of these two filaments starting SE from the strong optical jet which dominates

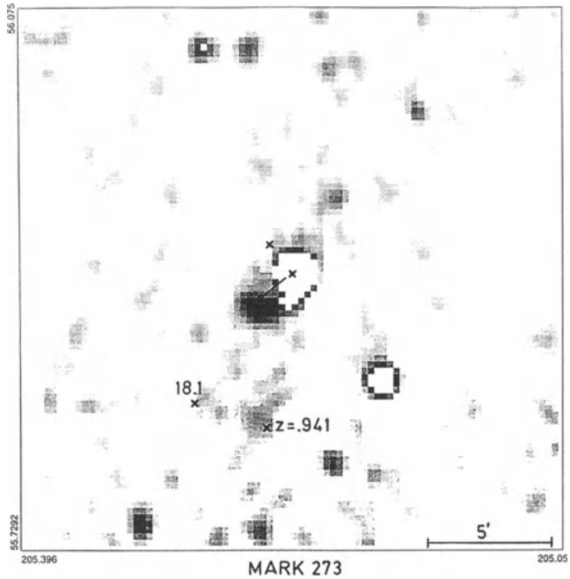

Figure 2.2 Radio map from the NRAO VLA Sky Survey (NVSS). The four brightest X-ray sources in the region are marked with X's. The direction of the X-ray jet from Mark273 is indicated by an arrow. Faint radio filaments lead southeastward to the quasar (z = 0.941) and the the quasar candidate (V = 18.1 mag.). This is generally along the line of the main radio and X-ray extensions from Mark273. Note also the exact alignment of Mark273x and the strong radio source to the SW across Mark273.

Mark273. (See deep R photograph of Mark 273 on web page of John Hibbard, www.cv.nrao.edu/ jhibbard)

This active galaxy appears to be ejecting optical, X-ray and radio material in two roughly orthogonal directions. (Note the exact alignment of 273x with the strong radio source to the SW of Mark273.) Associated with these ejections are high redshift quasars and quasar-like objects. Although all of these kinds of ejections have been observed many time before (see Arp [1] for a review), the ULIRG galaxies seem to be especially active. The authors of the original paper measuring Mark273x (Xia et al. [2]) report that in correlating ROSAT X-ray sources with ULIRG's: "...we find that some ULIRG's have soft X-ray companions within a few arcminutes of each source" and "This phenomenon was first mentioned by Turner, Urry and Mushotzky (1993)...". Later (Xia et al. [3]) state: "It is interesting to note in passing that the X-ray companions of the three nearest ULIGs (Arp 220, Mrk 273 and Mrk 231) are all background sources...".

Just a glance at two of the other most luminous ULIRG's (Mark231 and Arp220) shows similar evidence for ejection from these enormously

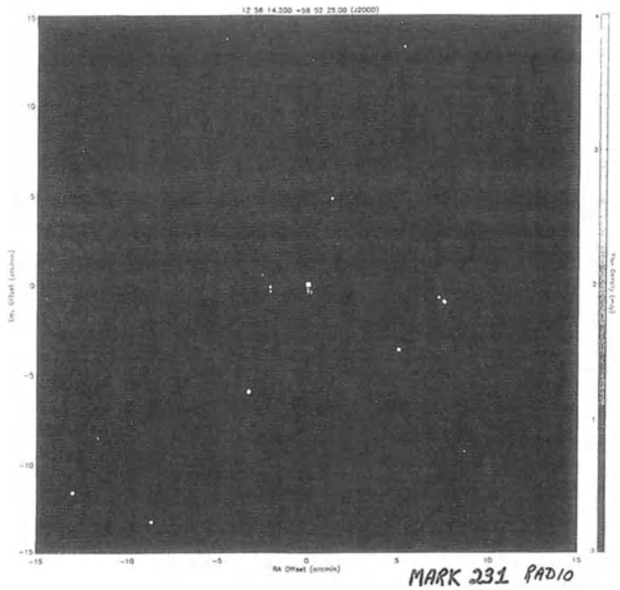

Figure 2.3 High resolution radio map centered on Mark231 (at 20 cm from VLA FIRST). Note puff of radio material just below the ULIRG and double nature of radio sources paired across Mark231.

disturbed galaxies. I will show now some preliminary evidence for Mark231 but it is already clear that there appear to be strong X-ray sources, radio ejections and physically associated high redshift objects connected to all three of these ULIRG's.

2. MARKARIAN 231

Figure 2.3shows a 30x30 arcmin radio map around Mark231. The images are high resolution 20cm from the VLA FIRST survey (www.nrao.edu). The brightest object in the center is Mark231. There is a puff of radio material immediately below the galaxy. Forming a striking pair across Mark231 are radio sources both of which are close doubles. The multiplicity of these flanking sources is unusual and suggests secondary ejection. At the least these radio sources are strongly indicated to be associated with the central, active galaxy.

Figure 2.4 shows an approximately 19x19 arcmin continuum radio map at lower resolution but fainter surface brightness. Here we see a continuous radio extension to the East of Mark231 including the multiple source seen previously on the higher resolution map. In addition we see a radio extension to the West, in the direction of the strong, close double source. There is also a string of small sources extending northward