A Galaxy Cluster Near NGC 720

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ABSTRACT

The galaxy cluster RXJ 0152.7-1357 is emitting X-rays at the high rate of 148 counts ks$^{-1}$. It would be one of the most luminous X-ray clusters known if it is at its redshift distance of $z = .8325$. It is conspicuously elongated, however, toward the bright, X-ray active galaxy NGC 720 about 14 arcmin away. At the same distance on the other side of NGC 720, and almost perfectly aligned, is an X-ray BSO of 5.8 cts/ks. It is reported here that the redshift of this quasar is $z = .8312$.

1. Introduction

The ESO Messenger (Rosati et al. 2000) carried a color picture of the powerful X-ray cluster of galaxies RXJ 0152.7-1357 at $z = .83$. (Reproduced here in Fig. 1). Because the cluster was linearly extended by a ratio of about 3 to 1 Arp looked along the direction of the line to see if there was any nearby active galaxy. In fact there was a very bright Shapley Ames galaxy, NGC 720 ($B_T = 11.15, z = .0057$). NGC 720 is strongly active with an X-ray filament extending from the nucleus and curving southward as it emerges (Buote and Canizares 1996).

The configuration was compelling enough to motivate searching a field of 30' radius around NGC 720 for additional active objects. The results are shown here in Fig. 2 (adapted from a picture published in the Catalogue of Discordant Redshift Associations, Arp 2003). The most conspicuous additional object in the field is the rather bright ($r, b = 19$ mag.) blue stellar object (BSO) which coincides with the ROSAT PSPC X-ray source of 5.8 cts/ks. This X-ray BSO is just 14.5' from NGC 720. The X-ray galaxy cluster is 14.2' from NGC 720 and the two are almost exactly aligned with each other across the galaxy.

The search for telescope time to obtain the spectrum of the candidate BSO was solved by E. Margaret Burbidge who enabled a 5 minute exposure to be obtained with the Keck Telescope. The optical spectrum of 2XRP was obtained with the Low Resolution Imaging Spectrograph (LRIS) (Oke, Cohen et al. 1995) attached to the Keck I 10m telescope on Mauna Kea. We show the spectrum in Figs. 3 and 4 which identify the major emission lines. This X-ray/BSO is clearly a QSO with an emission redshift of $z = .8312$.

The spectrum as shown here in Figs. 3 and 4. is marked by strong emission MgII and [CIII] in the blue and extraordinarily strong $H\beta, H\gamma, H\delta, H\epsilon$ in the red. The latter lines remind one of strongly star forming galaxies and may contain interesting information about the structure of this particular quasar.
Fig. 1.— An optical image, with X-ray contours superposed, of the cluster RXJ0152.7-1357 at z = .833 (Rosati et al. 2000). Frame is 4.7' x 4.7'. At its redshift distance it would be one of the most X-ray luminous clusters known. It points, however, nearly at the strong X-ray E galaxy NGC 720. (See next Figure.)

Fig. 2.— Field of 30' radius around the X-ray ejecting NGC 720 (Arp 2003). The strong X-ray cluster with z = .833 in Fig.1 is shown schematically to the SW. The spectrum of the X-ray blue stellar object (2XRP) to the NE is shown in the next figure to have z = .831.
2. Probability

The space density of galaxies brighter than $B_T = 11.15$ in the general region of NGC 720 is about 0.009 sq.deg. To find a galaxy as bright as NGC 720 within 14' of the X-ray cluster has a probability of about $P = 0.002$. But then we have to decrease this by at least an order of magnitude in order to find a galaxy as active as NGC 720. Moreover there is the additional improbability that the cluster is elongated within about 20 deg. back toward NGC 720 and that an X-ray filament extends from the nucleus of NGC 720 and curves around toward the south as it exits the galaxy (Buote and Canizares 1996).

But now with the strong X-ray/quasar aligned with the strong X-ray cluster within a few degrees across NGC 720, and the pair accurately centered, the improbability of the configuration decreases even more drastically. Finally the redshifts of the two paired objects are both $z = 0.83$ where a random redshift would be expected somewhere between $z = 0.3$ and $z = 2.6$.

We can estimate the probability of the configuration accidentally fulfilling the prototypical pattern of: active galaxy near bright object, pair of objects aligned and centered across active galaxy, and similarity of redshifts of paired objects:

$$2 \times 10^{-4} \times 2 \times 10^{-2} \times 5 \times 10^{-3} = 10^{-8}$$

Since for each of these properties $p = 0.5$ would signify an average random result, we divide by $0.5^4 = 0.0625$ giving a final value of:

$$P = 1.6 \times 10^{-7}$$

that the configuration accidentally fulfills the empirical criteria for ejected objects.

3. Precedent for Alignment and Ejection

It is sometimes objected that alignments of quasars and other high red shift objects across galaxies are not meaningful because the probability estimates are a posteriori. The answer is that the first alignment is a posteriori. Each subsequent alignment is confirmation of an a priori prediction. Moreover the improbabilities compound as each new case is discovered. The stated characteristics are closeness of bright objects, their alignment, their centering and the similarity of the aligned objects. These are all properties expected of objects ejected from active galaxies.

The tendency for paired quasars across galaxies to have similar redshifts is well documented (e.g. Arp 2003). A previous example of a pair of almost identical redshift quasars closely paired across an active galaxy is Arp 220 where the quasar redshifts were $z = 1.25$ and $z = 1.26$ (Arp et al. 2001).

The first alignments were established by strong radio quasars (usually Parks or 3C sources) across peculiar (usually morphologically disturbed or active nuclei galaxies (Arp 1967; 2003). Because radio sources had been by then accepted as ejected from galaxy nuclei the aligned high redshift objects were strongly indicated to be ejecta from the central galaxy.

One of the reasons we know radio sources are ejected is that we observe radio emitting gas moving outward in jets that terminate on extended clouds of radio emission (e.g. Zensus 1997). Since the advent of
Fig. 3.— A 5 minute spectrum with the Keck telescope on the 2XRP object 14’ north of NGC 720. The CIII] line is measured at $\lambda3485.44$. 
Fig. 4.— An enlargement of the red section of Fig. 3 showing the strong Balmer emission lines in the 2XRP quasar.

X-ray astronomy we can also observe X-ray winds and jets emerging from active galaxies, some as a narrow cores to the radio ejections. In the case of pairs and lines of X-ray sources ejected from active galaxies, however, almost every point X-ray source can be established as a high redshift quasar. The question is then posed: Why do many radio sources appear as blank fields with no optical object?

In the past it has been suggested that radio quasars on their way out of the inner regions of galaxies or through the intergalactic medium are stripped of their outer layer of lower density, radio emitting gas. (Arp 2001a). In any case the more compact X-ray sources are almost always optically identified, form an even more consistent pattern of pairing across active galaxies and empirically support the picture of ejection of high red objects. (See samples of the many cases as reviewed in Arp (1987; 1998) and Catalog of Discordant Redshift Associations (Arp 2003.)

4. Evidence for Association of Galaxy Clusters with Low Redshift Galaxies

It is almost universally believed that galaxy clusters are distant aggregates of normal, luminous galaxies and that they could not possibly be associated with nearby, low redshift progenitors. There is, however, considerable empirical evidence that the latter is the case. For example the very bright, nearby, radio and X-ray ejecting galaxy, Cen A (NGC 5128) was shown to have a cone of higher redshift galaxy clusters extending 15 - 20 deg. northward along the direction of its radio ejection (Arp 1998, p147). Later a pair of X-ray clusters was shown across the X-ray galaxy ESO 185-54. The SE of this pair, A3667 was a very strong in X-rays at 2440 cts/ks. It was elongated back toward the central galaxy and the low and high redshift galaxies were intermixed along the connection. Moreover high resolution Chandra observations captured a bow shock at the head of A3667 which showed the it was moving with 1400 km/sec directly away from the low redshift, central, X-ray galaxy down the extended line of mixed redshift galaxies (Arp 2003)
Further evidence for a number of cases of Abell clusters physically associated with bright, low redshift, nearby galaxies was presented by Arp and Russell (2001). One point made in that publication was that at the nearer distances for these clusters, the galaxies would be moderately to somewhat underluminous but at their conventional redshift distance they would be unprecedentedly over luminous.

5. Are proto Clusters of Galaxies Ejected like quasars?

If we accept that both quasars and galaxy clusters have their origin in ejections from low redshift galaxies we must face the question of what is their relation to each other. We start with the question of what gives the quasars their intrinsic redshifts. Here we invoke the variable mass hypothesis of Narlikar (1977) and Narlikar and Arp (1993). In that solution of the general relativistic field equations the particle masses of new matter start out at or near zero mass and grow with time. Because the electrons making orbital transitions in radiating atoms are initially small the emitted photons are initially redshifted and decrease their intrinsic redshift with time. The quasars are then viewed as being composed of young matter which evolves toward normal matter and normal galaxies with time.

In the initially ejected proto quasars the particles grow in mass and slow down in order to conserve momentum so the particles cool and increasingly gravitate toward a young galaxy (no dark matter needed). The initial plasmoid, however, has low mass ions which have large cross sections and are more strongly frozen in by magnetic fields (Arp 1963). In order to have the time to evolve intrinsic redshifts into the range of older galaxies like our own they must be slowed down or stopped by the passage through the internal regions of the parent galaxies or meeting clouds in the medium exterior to the galaxy. They should be fragile and observations suggest that some quasars are split into two’s or three’s (Arp and Russell 2001, p548; Arp 1999). In practice it is suggested that sometimes they can run into a medium of cloudlets and be divided into many small proto galaxies. i.e. a cluster of proto galaxies on its way to evolving into a cluster of galaxies.

It is worth noting that active galaxies, quasars and clusters of galaxies are the three principle kinds of extra galactic X-ray sources that exist. In the above picture each are subunits of the former. The processes in galaxy nuclei which give rise to the quasars furnish the energy to fission or explode some quasars into smaller pieces which evolve into galaxy clusters particularly in interaction with a galaxy/extra galactic environment. An example of a group of X-ray quasars which should evolve into a galaxy cluster are those roughly aligned across 3C345 (Arp 1997).

Aside from discussions about overluminous galaxies at conventional distances versus underluminous galaxies in nearby clusters, there are the large cluster distances calculated on the assumptions of the Sunyaev-Zeldovich effect. But as discussed in the Moriond presentation Arp (2001b) the non-equilibrium physical state of low particle mass plasmas may give much different predictions in the S-Z analysis than in the present models.

6. Summary

The preceding qualitative discussion of theory is intended to suggest a physically plausible model which could explain the empirical evidence for the relation between quasars and galaxy clusters of various redshifts. The overriding important point, however is that the NGC 720 case reported here confirms at a very high level of significance the previous evidence for ejection of much higher redshift objects from active galaxy
nuclei. It would seem that the recognition of this evidence should necessitate a reconsideration of the fundamental assumptions about extragalactic redshifts.

A more conventional interpretation of this unusual grouping of X-ray sources is in press in the Publ. Astron. Soc. Pacific (E.M. Burbidge, H.C. Arp 2005).

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