cleus and almost encircling it. Our supposition that the brightest extranuclear Hα emission is from normal HII regions is also supported by the very low values of [SII]/Hα+[NII] (Fig. 7).

Between the nucleus and the outer starburst there are regions with remarkably strong [SII] emission (Fig. 5) which most probably traces shocks from supernova remnants.

A remarkable feature is the series of 'spots' visible in the continuum and low-excitation lines (Figs. 1, 4, 5, 7 and 10) which are aligned along a chain $\simeq$ 20$''$ south of the nucleus. These are the lowest excitation objects (i.e. those with the highest [SII]/Hα+[NII] ratio) which, together with their sizes ($\simeq$ 30 pc), suggests that they are individual supernova remnants, possibly in small OB associations dominated by B stars. Additional spectroscopy and/or radio observations are needed to clarify their exact nature. As their orientation does not correspond to any obvious morphological feature we can only presume that they trace the location of a gaseous spiral feature in which starburst activity has already ceased.

Within the central $R \leq 2''$ (4 pc) the optical continuum images and the stellar absorption features observed in the optical and IR spectrum (Oliva et al. 1994, in preparation) are well fitted by a combination of late-B main-sequence stars and late K supergiants, i.e. typical of a starburst which is much older (many $\times$ 10^8 yr) than the starburst ring.

The above results are consistent with a simple model in which a starburst propagates out of the nucleus. At the outer edge we see the most massive O stars from the latest generation (those photoionizing the HII regions) while closer inside less massive (early B) stars are still producing supernovae and remnants responsible for the [SII] emission. In the central regions (nucleus excluded) the high density of late B stars is responsible for the unusually blue colours while K supergiants dominate the near IR emission.

Conclusions

Line and continuum images of the Circinus galaxy have revealed a prominent ionization cone with coronal gas ([FeXI]) close to its apex and lower excitation [OIII] emission further out which is consistent with photoionization by a power law central source. Low excitation [SII] emission observed between the [FeXI] and [OIII] peaks, however, cannot be explained by pure photoionization models. This cone originates in a nucleus whose visible and infrared positions are spatially shifted suggesting that the true nucleus suffers $A_V \simeq 20$ magnitudes of extinction. Our observations are thus consistent with the presence of a torus which both obscures the Seyfert nucleus from direct view and collimates its UV continuum emission. In addition, a starburst ring which may or may not be related to the Seyfert nucleus is also present. Older starburst activity, which is perhaps more relevant to the possible evolutionary connection between starbursts and Seyfert activity, appears to have occurred closer to the nucleus. A puzzling discovery is the chain of compact, low excitation, objects $\simeq$ 20$''$ S of the nucleus which are probably supernova remnants and associated B stars but require further study.

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Multi-Wavelength Study of ROSAT Clusters of Galaxies

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1. Clusters of Galaxies as Cosmological Probes

Among the 60,000 X-ray sources detected by the ROSAT All-Sky Survey, about one tenth are expected to be clusters of galaxies. This represents a considerable potential for cosmological studies and has motivated numerous identification campaigns, especially at ESO; we describe here such a programme together with associated observations at other wavelengths.

As the most massive bound entities known in the universe, clusters of galaxies are key objects for testing the predictions of the various cosmological scenarios. They originated from the highest peaks in the initial density fluctuations, and are expected to have evolved through characteristic processes, namely, "top-down" or "bottom-up" depending on the nature of the dark matter ("hot" or "cold"). Practically, these alternatives correspond to situations in which clusters formed either from the fragmentation of large "pancakes" or from the merging of sub-groups, and should ideally be reflected in the evolution of the cluster mass function. While the mass of a cluster is not a directly observable quantity, a number of other physical parameters can be measured directly and, therefore, provide a detailed picture of the dynamical cluster environment as a function of redshift.

2. Observational Tests

Relevant observations of clusters encompass the whole electromagnetic spectrum; a short overview includes:

- In the optical, velocity dispersions obtained through extensive spectroscopy of cluster galaxies provide mass estimates, while the presence of sub-groups in the velocity distribution may be the signature of merging events in the past history of the cluster.
- In X-rays, the cluster temperature function could in principle yield an almost direct determination of the mass function if virialization is assumed. However, temperatures are known for very few clusters, and the sensitivity of the collimators (prior to ASCA) restricts such observations to the closest objects. On the other hand, the cluster luminosity function is much easier to obtain, and evolution was detected in the Einstein Medium Sensitivity Survey sample (e.g. Henry et al. 1992 and references therein). A tight empirical correlation between X-ray luminosity and temperature then enables the shape of the initial fluctuation spectrum in CDM scenarios to be constrained (Henry & Arnaud 1991).

  Because the mean free path of the hot X-ray emitting gas in the cluster potential is considerably shorter than that of the galaxies, the X-ray morphology (and size) of clusters provides insights into subclustering and merging events which are complementary to the optical approach.
- The radio emission from a possible cluster halo or particular cluster galaxies may be also a powerful tool for investigating the physical state and motions of the hot intra-cluster medium. Since the interaction between the hot plasma and galaxy halos strongly affects the shape of the radio emission, the presence of Head-Tailed galaxies at the cluster periphery or Wide Angled-Tailed at the cluster centre (usually cDs) can constrain the properties of the gas and on the gravitational potential.
- As for the infrared emission of clusters of galaxies as such, only weak IRAS diffuse emission was detected from a small number of poor clusters, but its origin is not yet clear (Bregman 1992). Moreover, clusters are expected to be the sites where galaxy interactions are favoured, leading to enhanced star formation. This is a totally open field, and one expects exciting new results especially from the comparison between infrared and radio properties of clusters.

With the coming of large collecting area instruments, providing high spatial and spectral resolution at wavelengths far beyond the optical regime, a new era will open up, enabling the detailed study of moderately distant clusters.

3. The Cluster Sample Observed at ESO

In 1990 we started an observing programme at ESO, aiming at identifying all clusters detected by ROSAT in a single contiguous area covering about 1700 deg^2 around Hydra (a similar programme is being pursued at the AAT around the SGP). The main goals of the project are to derive the *cluster X-ray luminosity function* and study the *large-scale structures* by the spatial cluster distribution. The cluster candidates are selected by cross-correlating the X-ray source lists, issued from the ROSAT survey standard analysis, with the ROE/NRL cluster catalogue, the latter resulting from an automated analysis of the COSMOS object database derived from the scans of the UK/AAO Schmidt plates. With this method about 150 cluster candidates have been selected down to an X-ray flux limit of $\sim 5 \times 10^{-13}$ erg s^{-1} cm^{-2} in our area.

During the 1990–92 period the programme was allocated a total of 13 nights with EFOSC on the 3.6-m telescope. The strategy has been to observe the target objects in order of decreasing X-ray flux, so that at any stage the current data set is flux limited. For most clusters the multi-slit mode is used (otherwise, long slit) so that 5–12 redshifts per cluster are available, providing in some cases an estimate of the velocity dispersion. For this first identification step, the EFOSC + MOS mode – giving on average 7 redshifts per cluster – presents the ideal observing set-up, for it allows us to assess directly the membership of our cluster candidates. Unfortunately, we should mention several practical problems encountered in all runs during the fabrication of the masks, which turned out to be very time consuming: bad transmission between the computer holding the slit positions and the punching machine, punching pin breaking down several times, and overall uneven slit quality leading to unrecoverable artefacts in the sky subtraction during the subsequent data analysis. But we acknowledge here the valuable assistance of the local technical team which enabled us every night to have our masks ready in time. At present, the redshifts of some 60 clusters have been measured and a detailed optical/X-ray analysis of the 42 brightest ones is presented in Pierre et al. (1994). The most distant cluster in the sample found so far has a redshift of ~ 0.31, and the X-ray sensitivity of the area leads us to expect objects up to $z \sim 0.4$. The programme will be continued in the coming years in order to complete the identification of the sample and thus achieve our scientific goals. *For the first time, we shall have at our disposal a complete X-ray flux limited sample of clusters over a large area which will constitute a unique tool for studying luminosity and clustering evolution.*

4. Combined Observations

The analysis of the optical/X-ray properties of the clusters discovered in the Hydra region revealed some very interesting objects which motivated a more detailed multi-wavelength follow-up starting in 1992. We selected a subsample of intrinsically X-ray-bright clusters, which are therefore expected to be massive and with redshifts preferentially above 0.15. The following observing programmes are now underway:

(1) In the optical, the northernmost objects of the sample have been subsequently studied at the 3.6-m Canada-France-Hawaii telescope in 1993 and 1994. Deep B, R photometry and extensive spectrometry ($\sim$ 80 spectra per cluster) – with the MOS/SIS device using a $10' \times 10'$ CCD (2048^2 pixels) – have been obtained in collaboration with the Toulouse group.

(2) ROSAT PSPC pointings, for a few selected cases, in order to investigate the outer cluster regions, where on-going merging events are expected to be most readily detected, and to obtain a first estimate of the temperature.

(3) ROSAT HRI deep pointings, to study in detail the gas morphology and the cluster potential at the centre: substructures and correlation with the cD position (in progress).

(4) Radio observations started in 1993 in collaboration with the University of Sydney. The selected clusters are first imaged at 843 MHz with the Molonglo Observatory Synthesis Telescope (MOST; 43″ resolution); subsequently, higher resolution maps of the cluster radio sources are obtained with the Australia Telescope (AT; 1.4–5 Ghz, 2–7″ resolution).

(5) A subsample of 14 objects will be observed by the ISO satellite (1995) in the Central Programme at 7, 14 and 90 μm (29 hours are allocated to this project: Cesarsky et al.).

5. Multi-Wavelength Maps

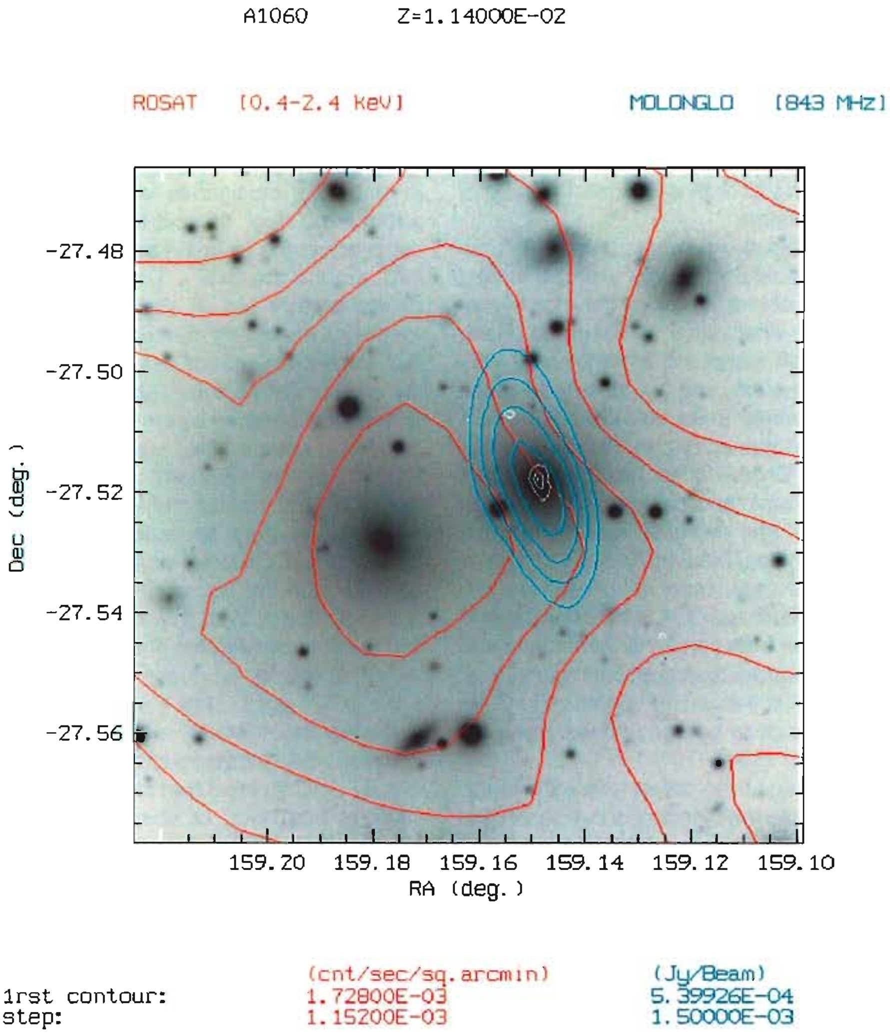
In order to exploit fully the 2-D information provided by the images obtained at different wavelengths, the ideal is to overlay them accurately so that a comprehensive picture of the cluster environment is readily available. Of special interest is any correlation amongst the optical galaxy positions, particularly the cD, the X-ray centroid of the hot ICM (and possibly other field X-ray sources), and the radio sources. This provides important clues:

(i) Radio sources can be identified and localized within the cluster;

(ii) It enables a detailed morphological study, such as a comparison of the overall shape of the cluster emission in X-rays (elongation, clumps) with the galaxy distribution in the optical (alignments, subgroups). This point is especially relevant for the investigation of the formation processes of clusters: the presence of structures in the X-ray emission associated with (velocity) sub-groups of galaxies is undoubtedly a strong argument in favour of the merging hypothesis (see Section 1). Moreover, if both X-ray and radio spatial resolutions are high enough (~ 5″), then for the nearest objects, an even more detailed study of the motions within the ICM is possible with the combined morphological analysis of interactions between the hot X-ray emitting plasma and the energetic particles producing the radio lobes (Böhringer et al. 1993);

(iii) Another interesting point to investigate is the location of the cD galaxy with respect to the X-ray centroid. In the optical, there are evidences for the existence of substructures when the cluster dominant galaxy velocity shows a significant offset with respect to the cluster's mean (Beers et al. 1991). A non-coincidence between the optical and X-ray centres (the latter is supposed to indicate the centre of the cluster potential) may be the signature of merging events in the cluster's history.

(iv) Finally, it allows flagging X-ray emitting point-like objects (stars or AGNs), which may contaminate the diffuse cluster emission (a crucial problem in the further determination of the X-ray cluster luminosity function). Such an overlay is presented in the Figure, and the procedures followed to produce this image are described on page 46 in this issue of *The Messenger.*



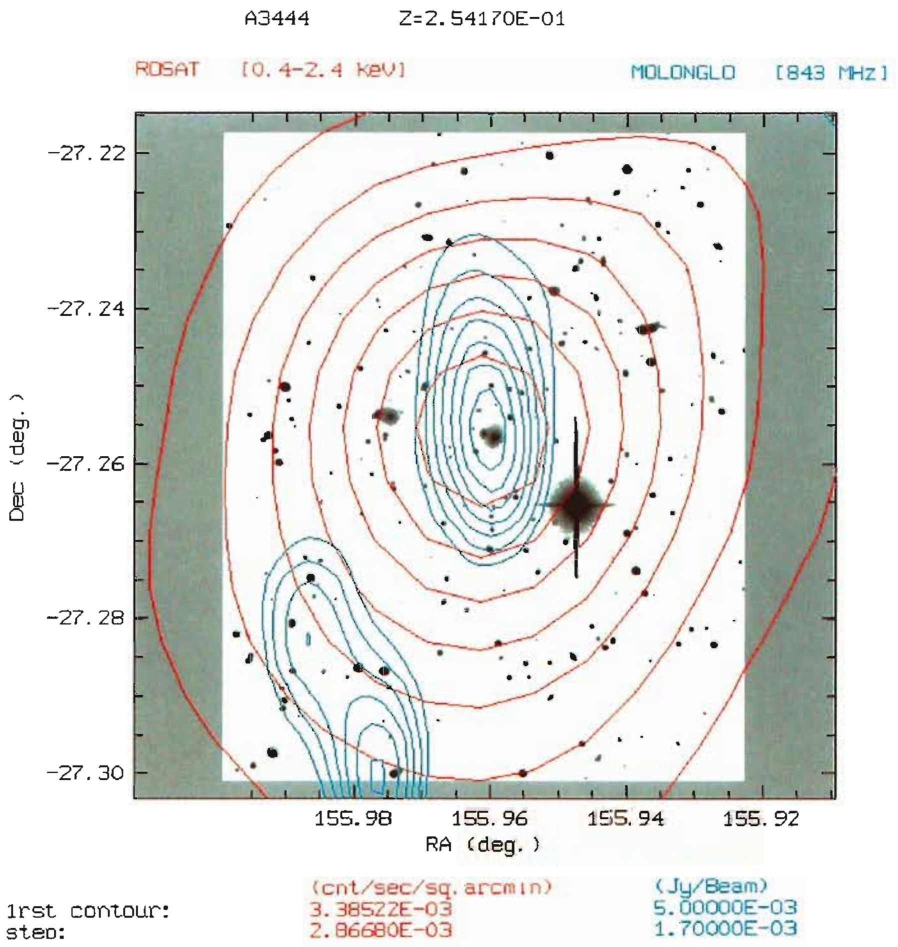
ROSAT X-ray (red) and Molonglo radio (blue) contours overlaid on the corresponding CCD optical image. The absolute instrumental positional accuracy is ~ 1–2″ in the optical and radio, and ~ 20″ in the X-ray band (1σ); the plotting accuracy is discussed on page 46 in this issue of The Messenger. First and step contours are indicated on the figures.

(Left) Abell 1060 (z = 0.0124) is a nearby cluster with low radio power (log P(W Hz^{-1}) = 22.3, H_0 = 50 km s^{-1} Mpc^{-1}) and X-ray luminosity (~ 5 × 10^{43} erg s^{-1}). In this case the number of X-ray survey photons is greater than 1000; in order to improve the angular resolution, we selected only photons falling into the inner part of the detector so that the resulting PSF has a FWHM of ~ 1′ instead of ~2′ (but the number of photons is decreased by a factor of ~5.5). Two large elliptical galaxies occupy the centre of the cluster. The radio emission clearly coincides with the brighter galaxy (NGC 3309), whereas the X-ray centroid appears to favour the other

6. Preliminary Results

Reduction of the CFH data and ROSAT pointings is in progress, as well as the processing of the AT observations. MOST and AT images have been obtained for 25 clusters so far (from $z \sim$ 0.01–0.3). A preliminary comparison between X-ray, optical and radio survey images reveals that for a high fraction of clusters there is coincidence between the X-ray centroid (or an X-ray peak) and the presence of a radio galaxy (see Pierre, Hunstead & Unewisse 1994 for more details). This is in agreement with the findings of Burns et al. (1994) who attribute this to a combination of clumped hot gas and AGN emission. We will be investigating this more closely with the high-resolution X-ray and radio images. Moreover, our sample, which possesses a significant fraction of objects at $z \geq 0.1$, suggests that the coincidence between X-ray and radio maxima is even stronger for high redshift clusters. One explanation for this effect could arise from the fact that the original sample is close to being X-ray flux limited, which means that the distant clusters are 10–100 times brighter intrinsically than the nearby ones. Consequently, we might have been selecting objects in which the X-ray flux is contaminated significantly by emission from an active galactic nucleus. Indeed, in our sample we found the second brightest BL Lac object in the sky. Detailed optical spectroscopy as well as high resolution radio observations of the galaxies concerned is now underway, in order to characterize their properties.

At the present stage it is too early to draw definitive conclusions from the X-ray/radio correlations, but if these preliminary results are confirmed with better statistics, this may have serious consequences for the practical determination of the cluster X-ray luminosity function. On the other hand, this is only one aspect of the entire programme which, once completed, should provide a unique set of data for the dynamical study of clusters up to $z \sim 0.3$. In this way, we hope to be in a position to understand better their formation process, and thus to constrain the nature and amount of dark matter present in the universe.



(NGC 3311). *The white contours are from a recent high-resolution image obtained at 13 cm with the Australia Telescope; the radio source appears, however, not to be resolved. The CCD image is a 250 s exposure obtained in B band at the AAT.*

(Right) Abell 3444 (z = 0.254) is one of the most distant clusters in the present sample. At the survey resolution, the X-ray image is point-like. The radio emission is probably slightly extended to the north (which should not be confused with the natural N-S elongation of the beam). Both X-ray and radio intensities are high: $\sim 3 \times 10^{45}$ erg s^{-1} and log $P(W Hz^{-1})$ = 24.4 respectively, and clearly centred on the cluster dominant galaxy. The exact coincidence observed here appears to occur in many of the cluster fields, especially for the high redshift clusters in the sample. The CCD image is a 3-minute EFOSC exposure in R band.

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The VLT Site at Paranal: September 1994

The centrefold of "The Messenger" shows an aerial view of Cerro Paranal, the site of ESO's Very Large Telescope. This photo was obtained in mid-September 1994 and shows the rapid developments at the time of the construction of the concrete base for the four telescope enclosures. Also visible is the complex infrastructure for the various associated laboratories. This work is being done by the Skanska/Belfi consortium. The installations for the technical equipment can be seen to the left.

The blasting work is now finished and excavations for the various connecting tunnels are clearly visible; they will be covered again when the concrete work is ready. To the right, the work on the base for Unit Telescope no. 1 is already well under way and in September reached the "floor level" on which the enclosure will be placed. The basement concrete floor on which the coudé focus for Telescope no. 2 will be installed is in place, and the concrete work will soon start in the holes for Telescopes 3 and 4.

To the extreme right and a little lower than the rest of the platform are the excavations for the control building. The platform altitude is about 2640 metres above sea level and it measures about 150 metres across. The width of the access road is no less than 12 metres, i.e. nearly equal to that of a three-lane highway; this is necessary to ensure the safe transport of all telescope parts to the top, especially the four 8.2-m fragile mirrors.

In October 1994, the first shipment of steel parts of this enclosure (manufactured by the SEBIS consortium) with a total weight of more than 100 tons left Europe for the sea journey to Chile. While the smaller parts were packed in large containers, special packing was necessary for the very large structures. The ship left the port of Marghera, Italy, and is expected to dock in Antofagasta towards the end of December 1994, after which the parts will be transported by truck to the top of Paranal.

This first shipment will be soon followed by others. It is expected that consignments of about 100 tons each will be sent to Chile over the next eight months. The enclosure erection will start in January 1995 and will be completed in about 8 weeks.

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