GENERAL FRAMEWORK

The coupled formation and evolution of structures ranging from Coma-size clusters to galaxies to super-massive black holes (SMBH) in the context of the large scale structure (LSS) in which they reside is a key scientific quest in cosmology. X-ray surveys are the most efficient way to trace the energetically dominant population of accreting obscured SMBH, to estimate the history of accretion processes over the cosmic time and to study the relation of AGN to the surrounding large scale environment. High-energy surveys need to be complemented by longer wavelengths (radio, IR, optical) follow-up observations which are fundamental to address the issues described above.

There are several observational evidences pointing to a tight link between nuclear SMBH and galaxy evolution. The comoving number density of high-luminosity quasars rises rapidly up to z about 2–3 without evidences of a decline up to z=4–5, while the evolution of lower luminosity AGN is slower and their number density starts to drop above redshift one. The former is probably related to the evolution of massive spheroids as witnessed by the tight correlation between black hole masses and bulge properties of their hosts, the latter is similar to the cosmic evolution of the star formation rate which is required to fit the mid–infrared source counts. While high-luminosity massive systems can form and feed efficiently in the early Universe, the bulk of AGN population has to wait much longer. Cold Dark Matter models for the formation and growth of the structures in the Universe, linked with the changing accretion rates of cold gas onto the central SMBH, are able to reproduce, at least qualitatively, this anti-hierarchical growth. The comparison of these models with the evolving AGN luminosity functions can allow us to investigate and understand the role of relative feedbacks and delays between nuclear activity, star formation and galaxy evolution.

X-ray selected AGN are highly biased tracers of LSS as shown by the significant signal in the correlation function, the field-to-field source counts variance and the presence of spikes in the AGN redshift distribution. The AGN clustering redshift evolution and the comparison with that of galaxy populations gives important clues on the role of the environment and the type of dark matter halos in triggering the nuclear activity.

The study of SMBH physics and the evolution within the cosmic web requires an unbiased census of the high-redshift obscured AGN population which can be efficiently obtained combining hard X-ray surveys with specifically designed multiwavelength observations, especially in the infrared bands.

HERITAGE

HELLAS

The HELLAS collaboration includes scientists from several INAF Observatories and Institutes and from the Universities of Bologna and Roma Tre. The collaboration started in 1997, pioneering X-ray surveys in the hard 5-10 keV band using *BeppoSAX*. After the launch of *Chandra* and XMM-*Newton*, the collaboration used their data to study the faint X-ray source population, obtaining, in just 3 years, the first sizeable survey of XMM-*Newton* serendipitous sources with nearly complete optical identification down to a 2–10 keV flux limit of 6×10^{-15} erg cm^{-2} s^{-1}, the HELLAS2XMM survey (232 X-ray sources over 1.5 square degrees, 153 spectroscopic redshifts to date). The results obtained together with the HELLAS collaboration are due to an aggressive strategy, that included first the exploitation of the *Chandra* and XMM-*Newton* archives, and then the prompt identification of the optical counterparts of the X-ray sources, through small but well focused programs. A parallel program was devoted to a detailed study of accretion processes in nearby AGN making use of *Chandra* and XMM-*Newton* observations and archival data. The goal is to characterize the emission and absorption properties of AGN circumnuclear matter.

ELAIS COSMOS

In order to extend the HELLAS survey, since 2003 we started to work on two large international projects aimed at the study of the X-ray selected AGN clustering and evolution: the XMM-*Newton*

survey of the ELAIS S1 field and the XMM-*Newton* survey of the COSMOS field. These surveys cover contiguous areas of 0.5 and 2 square degrees, respectively. The search for high-redshift obscured AGN, the comparison of AGN clustering, galaxy clustering and theoretical models for the evolution of the LSS are the key scientific goals of these projects. More specifically, we want to understand whether AGNs trace higher density peaks or higher mass haloes and how active sources are correlated with the environment. The COSMOS project is a truly multiwavelength collaboration and some of the scientific objectives of the present project are overlapping with those of the zCOSMOS project (a major redshift survey in the COSMOS field; PI: M. Scodeggio).

DEEP FIELDS

Since 1999, in collaboration with the John Hopkins University and ESO, we studied the properties of the sources detected in the *Chandra* Deep Field South (CDFS), including Type I and Type II AGN, QSO, QSOII, optically normal/X-ray bright galaxies and star forming galaxies. The goal of this pencil-beam survey is to trace the evolution of both obscured and unobscured AGN down to the highest redshifts, as well as the cosmic star formation history through X-ray up to $z \approx 1$. The wide range of redshift probed so far ($z \approx 0$–5) allowed us to detect significant large scale structures traced by the AGN and to measure with good accuracy their 3D correlation function. The detailed analysis of the X-ray spectral properties of the AGN sample is almost completed, with particular emphasis on the distribution of intrinsic absorption among the different classes of AGN as a function of epoch and intrinsic luminosity. The CDFS survey is also a multiwavelength survey included in the GOODS project.

XMM-BSS

With the aim of complementing the results obtained by medium-deep XMM-*Newton* and *Chandra* surveys, we have built "The XMM-*Newton* Bright Serendipitous Source Sample" (hereafter XMM BSS), a large (400 objects) sample of bright serendipitous XMM-*Newton* sources at high galactic latitude. The XMM BSS, a project lead by the Osservatorio Astronomico di Brera in collaboration with the XMM-*Newton* Survey Science Center (see http://xmmssc-www.star.le.ac.uk), consists of two flux-limited samples: the XMM BSS sample having a flux limit of $7{\times}10^{-14}$ erg cm^{-2} s^{-1} in the 0.5–4.5 keV energy band and the XMM HBSS sample having a flux limit of $\approx 7{\times}10^{-14}$ erg cm^{-2} s^{-1} in the 4.5–7.5 keV energy band. We have already spectroscopically identified about 70% of the sources using observing time already allocated to this project at TNG, ESO and Calar Alto, as well as data from the literature. The main aim here is to fully identify and classify this source sample, as well as to characterize the X-ray source properties, in order to:
1) study the ratio between the different kind of AGNs (Type 1 vs. Type 2 AGN; Absorbed vs. Unabsorbed AGN; RQ vs. RL AGN) at a flux limit of $\approx 10^{-13}$ erg cm^{-2} s^{-1} and to investigate in detail their physical nature. A major advantage of the BSS sample, when compared to samples selected by deeper surveys, is that the majority of the X-ray sources have enough statistics in the discovery data to determine, on a source-by-source basis, the amount of absorption, the spectral shape and the presence of reprocessed features (e.g. Fe K line). Combining the X-ray data with high-quality optical spectra, we will be able to study in detail the physical properties of X-ray selected sources.
2) complement other medium and deep XMM-*Newton* and *Chandra* surveys having fluxes 10 to 100 times fainter but covering a much smaller area of the sky. The XMM BSS will provide a larger baseline for all evolutionary studies and will allow us to investigate the differences in the X-ray source population as a function of the energy selection band and absorption properties and define statistical identification procedures to select rare and interesting populations of X-ray sources.

FUTURE DEVELOPMENTS

The 4 *Chandra* pointings of the Extended CDFS (to be completed within December 2004) will bring the total surveyed area to ≈ 0.3 square degrees. The completion of the optical (photometric

and spectroscopic) follow-up for the Extended-CDFS catalog will provide a final sample of roughly 800 X-ray sources with known redshift. This will allow us not only to investigate the distribution of properties of faint X-ray sources relying on a much larger statistical sample, but also to significantly improve the study of the 3D correlation function of AGN.

The first half of the XMM-*Newton* COSMOS survey will be available at the beginning of 2005. We plan to carry out a systematic analysis of the X-ray data (detection and spectral analysis of point-like and extended sources) of the optical counterparts (which will be observed spectroscopically within the zCOSMOS project) along with an extensive use of the multicolor photo-z catalogue already available.

During 2005 we should be able to obtain hundreds of redshifts for the X-ray sources in the ELAIS-S1 and COSMOS samples. This should allow us to study AGN spatial clustering in boxes of the order of 10–40 Mpc (angular size), making an order of magnitude improvement with respect to studies based on the GOODS survey, which sample a volume which is still not representative at redshifts of the order of unity, the epoch where the action is, i.e., the time when galaxy, star and cluster formation and quasar activity peaks.

Even medium deep surveys like ELAIS-S1 and COSMOS are just starting to sample volumes which may be considered a fair representation of the Universe. In fact, according to cosmological simulations, only at scales of the order of 100 Mpc side all mass overdensities relative to the mean will be sampled at their "true" occurrence rates. These linear scales translate to boxes of 4 and 3.3 degrees side at z=0.5–1, respectively (assuming a "concordance" cosmology).

An X-ray follow-up of the LBC survey, by probing the 100 Mpc scales, will provide unique data to explore and constrain the coupled evolution of galaxies and their nuclei. In particular, it will be essential in linking galaxies and AGN evolution into their full environmental context. The comparison between AGN clustering, galaxy clustering and theoretical models for the evolution of the large scale structure of the Universe can allow us to understand whether AGNs trace higher density peaks or higher mass haloes and how active sources are correlated with the environment. By identifying a statistically similar region to the observed environment in a simulation, and rewinding that simulation back in time, we can gain knowledge of the history of the environment of observed galaxies and AGNs over several Gyr.

The scientific aims of the present project will greatly benefit from the foreseen collaborations with the LBT (PI: E. Giallongo) and galaxy evolution (GMASS, PI: A. Cimatti) programs. On a much longer timescale, the scientific objectives will be pursued with *ALMA* and *XEUS/Constellation-X*.

We also plan to apply for *Spitzer* and *SCUBA* observations of well defined subsamples of hard X-ray sources. The main scientific objective is to obtain a robust estimate of the bolometric output of obscured AGN. This information is extremely important to properly compute the SMBH growth rate and mass density.

The above mentioned activities will be complemented by detailed studies on the properties of the obscuring/reflecting matter in individual, bright AGN. This activity is of course essential to properly interpret the results from the surveys.

WORK PACKAGES

The most important activities of each group are summarized by the following keywords:

- OABo: HELLAS2XMM, COSMOS, AGN clustering, AGN evolution, clusters
- UniBO: Spitzer/SWIRE, obscured AGN
- OAR: HELLAS2XMM, ELAIS-S1, AGN clustering, AGN evolution, obscured AGN
- OAA: GOODS, AGN clustering, SMBH models
- OATS: AGN clustering, clusters
- Roma Tre: AGN physics, obscuration, AGN luminosity functions
- OABrera: BSS, AGN evolution, AGN luminosity function
- OAMerate: COSMOS, clusters

• IASF/MI: HELLAS2XMM 7-11 survey, clusters

PRODUCTS

A detailed management plan will be worked out in a due time. Here we anticipate that the research products will be timely published on referred journals and presented at international conferences. We also plan to make publicly available the multiwavelength catalogues on a dedicated web page. An example is given at www.bo.astro.it/∼marfield/HELLAS2XMM/sample.html, where we collect products from the HELLAS2XMM survey.

BUDGET

One of the most important outcomes of our project has been the training of a dozen Ph.D. students since 1999. However, only a few of them could find post doc. or permanent positions in Italy to continue the collaboration with our groups so far, due to the shortage of funds and positions dedicated to high-energy astrophysics. As a consequence, a sizable fraction of the know-how and expertise built in the last five years can be lost, jeopardizing our ability to fully exploit the large amount of multiwavelength data that will be available in 2005–2007; this in turn would strongly reduce our ability to participate, promote, and possibly have a leading role in large international observational campaigns, which will be at the basis of our activity in the following 3–5 years. For this reason the requested financial support is mainly in terms of man-power (post-docs and tenure tracks for young researcher). The available resources for 2005 are reported. Further resources are expected from the ASI-INAF data analysis grant.

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