Hot spots in the XMM sky

Cosmology from X-ray to Radio

Book of abstracts

Mykonos, 15-18 June 2016

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PREFACE

Hot spots in the XMM sky: Cosmology from X-ray to Radio

Mykonos island, Greece, 15-18 June 2016

Galaxy clusters and AGN are luminous sources of energetic X-ray photons and X-ray observations provide a highly effective means of identifying such sources. Since the launch of the Chandra and XMM-Newton space observatories in 1999, our knowledge of clusters and AGN, out to cosmological distances, has increased immensely. This period has also witnessed great advances in the scale and complexity of numerical simulations of galaxy clusters and supermassive black holes - from the details of individual systems to their cosmological context. The community is currently facing the challenge of using large surveys of galaxy clusters and AGN to probe with precision our cosmological model.

Considering the probable extension of the XMM mission for another twelve years, the meeting aims at: (1) a review of the state-of-the art studies of the cosmic web, as revealed in X-rays in partnership with observations across the entire electromagnetic spectrum; (2) providing a framework to discuss holistic pictures of structure formation with the aid of numerical simulations; (3) exploring the scientific potential and feasibility of future extra-large, community-based surveys with XMM.

One of the meeting highlights will be the presentation of recent results from the XXL survey, the largest XMM program undertaken to date (6 Ms 2x25 sq. deg. - with some 500 clusters of galaxies and 25,000 AGN).

Scientific Committee:

C. Adami (LAM/Pytheas), M. Birkinshaw (Univ. Bristol), A. Evrard (Univ. Michigan), C. Horellou (Obs.Onsala), A. Iovino (INAF-OAB, Brera), C. Lidman (AAO, Epping), S. Maurogordato (Obs. Nice), L. Moscardini (Univ. Bologna), S. Paltani (Univ. Geneva), M. Pierre (CEA Saclay), M. Plionis (Univ. Thessaloniki), H. Rottgering (Obs. Leiden), V. Smolcic (Zagreb Univ.), J. Surdej (Univ. Liege), C. Vignali (Univ. Bologna), J. Willis (Univ. Victoria)

Local Organizing Committee:

A. Akylas, S. Basilakos, I. Georgantopoulos , E. Koulouridis, M. Plionis (Chair), T. Sabidekova, A. Theodorakakos

Invited speakers:

D. Alexander, A. Finoguenov, I. Georgantopoulos, R. Hickox, M.Jarvis, I. McCarthy, A. Mantz, J.B. Melin, Y. Mellier, A. Muzzin, E. Rozo

INVITED SPEAKERS

Retrospects and prospects of X-ray cluster surveys

Alexis Finoguenov

I will present an introduction to galaxy cluster surveys using X-ray telescopes, showing how performance of the surveys developed in the recent decades. I will discuss the achievements of the ultra deep surveys and present the plans to conduct the new all-sky survey with eROSITA.

Black holes in the cosmic web: The big picture of AGN & LSS

Ryan Hickox

Large multiwavelength surveys have revolutionized our understanding of the growth of super-massive black holes through AGN activity in the context of cosmological structure formation. In particular, studies of spatial clustering allow us to measure how black holes growing in different modes populate their host dark matter halos, placing constraints on the drivers of accretion, AGN lifetimes, and the effects of AGN feedback. I will review recent clustering results for AGN detected in different wavebands (including X-rays, optical, infrared, and radio) and will interpret the results in terms of the larger picture of galaxy and large-scale structure evolution. I will highlight advances in techniques such as HOD modeling and CMB lensing, and will look to the future of even larger-scale surveys of AGN.

Calibrating Cluster Masses

Eduardo Rozo

Mass calibration continues to be the main source of systematic uncertainty in cosmological studies of cluster abundances. I will discuss efforts to calibrate the masses of the photometrically selected redmapper clusters, and place them in their broader context.

Cosmological simulations and the interpretation of large surveys

Ian McCarthy

I will give a review of "Cosmological simulations and the interpretation of large surveys".

Cluster scaling relations and cosmology

Adam Mantz

I will review the current status of cosmological tests using galaxy clusters, and the related astrophysics of cluster scaling relations. Recent years have been extremely productive on both fronts, largely due to advances in weak gravitational lensing analysis, the availability of large lensing and X-ray follow-up data sets, and the completion of the first large-area Sunyaev-Zel'dovich cluster searches. An impressive degree of concordance has been reached among independent cluster cosmological tests, yet there are plenty of cosmological and astrophysical questions remaining, which our rapidly improving census of the cluster population as a function of wavelength, mass, and redshift can address.

SZ cosmology. Status & future directions

Jean - Baptiste Melin

In this talk, I will review recent cosmological results from the Planck, SPT and ACT experiments. I will discuss consistency between them and propose possible paths for improvement with current and future datasets.

Obscured AGN

Ioannis Georgantopoulos

I will review our current knowledge of heavily obscured AGN as revealed by X-ray (and IR surveys). X-ray surveys provide the most efficient way to find AGN. Still at very high column densities even X-rays have difficulties in detecting AGN. Chandra and XMM probed very deep fluxes in the 2-10 keV band, where obscured AGN are very abundant, yielding for the first time the AGN luminosity function and its evolution as a function of obscuration. The BAT detector (14-195 keV) onboard SWIFT made a leap forward in detecting heavily obscured AGN in the local Universe. At the same time NUSTAR owing to its superb angular resolution probed at least two orders of magnitude deeper than SWIFT. Finally, synergies with other wavelengths (IR and sub-mm) will be reviewed.

Current and future radio surveys: from galaxies to cosmology

Matt Jarvis

I will provide an overview of the current and future extragalactic surveys that will be undertaken with both existing and future radio facilities. In particular, I will focus on the deep-field science that is enabled by the leap in survey speed and sensitivity provided by LOFAR, which is now fully operational and is about to enter a period of delivering rapid science results. I will then provide and update on the science that will be achieved with the MeerKAT telescope in South Africa, which begins early science this year, and full operation in 2017. Finally, I will discuss the scientific opportunities that the SKA will bring post 2023.

The connection between AGN activity and star formation

David Alexander

I will review the connection between AGN activity and star formation. My talk will mostly focus on Spitzer, Herschel, and ALMA results obtained for distant X-ray detected AGN; however, I will also include results from more local AGN to place these distant systems into context. I will discuss results that constrain the average star-formation properties of AGN as a function of AGN luminosity and redshift, highlighting the importance of providing reliable star-formation rate measurements that are (mostly) uncontaminated by AGN activity. I will also discuss

the more detailed star-formation constraints for individual AGN that are emerging from sensitive ALMA studies. Lastly, I will discuss how these results allow us to understand the physical connection between AGN activity and star formation.

IR - Selected Clusters at z > 1: Current Status and Future Prospects

Adam Muzzin

Optically-based cluster detection methods have been successfully discovering clusters at z < 1 for approximately 60 years. In the last decade we have seen the first generation of IR-based searches for clusters. These IR-based surveys have detected hundreds of clusters at z > 1, with 10 - 20 now confirmed in the 1.5 < z < 2.0 range. In this talk I will review progress on the detection of very high redshift clusters, as well as what we have learned about z > 1 clusters and cluster galaxies from IR surveys. Lastly, I will discuss future prospects for IR-selection and potential synergies with other wavelengths such as X-rays and SZ.

EUCLID Overview

Yannick Mellier

CLUSTERS

An overview of XXL

Marguerite Pierre

We present the overview of the observations, of the processing and of the first series of results from the XXL survey (the brightest 100 clusters and 1000 AGN). We discuss the challenging issues raised by the cosmological analysis of the complete samples, due by the end of 2018. We describe the release plan of XXL legacy data products.

The XXL 100 brightest galaxy cluster sample

Florian Pacaud

With a total geometric area of 50deg^2, XXL is the largest contiguous survey undertaken by the XMM-Newton satellite. The final survey catalogues are expected to contain 25000 AGNs down to a flux limit of 3e-15 erg/s/cm^2 and 500 groups and clusters of galaxies up to a redshift of z~1.5. In this contribution, I will present the first scaling relation and cosmology results obtained from the recently released sample of 100 bright galaxy clusters in the XXL survey. I will then draw some updated perspectives for the analysis of the complete XXL galaxy cluster sample.

Cosmological constraints from the brightest clusters in the sky

Thomas Reiprich

High quality observations of well-defined cluster samples are key for robust constraints on scaling relations and cosmology. New results based on >6 Ms Chandra observations of the nearby HIFLUGCS clusters are presented. Results from extensions to the galaxy group regime and also an outlook for eHIFLUGCS are provided. New weak lensing results for the distant (z ~ 0.5) 400d cluster sample are described. Galaxy group outskirts as well as forecasts for eROSITA are discussed.

HICOSMO - X - ray analysis of a complete sample of galaxy clusters

Gerrit Schellenberger

Galaxy clusters are known to be the largest virialized objects in the Universe. Based on the theory of structure formation one can use them as cosmological probes, since they originate from collapsed overdensities in the early Universe and witness its history. The X-ray regime provides the unique possibility to measure in detail the most massive visible component, the intra cluster medium.
Using Chandra observations of a local sample of 64 bright cluster (HIFLUGCS) I provide total and gas mass estimates of each cluster individually. The cosmological analysis involving a likelihood estimation of a halo mass function with a Markov Chain Monte Carlo algorithm results in Ω_m= 0.17 ± 0.02 and $\sigma 8$ = 0.90 ± 0.05 for a flat LCDM Universe (purely statistical uncertainties). The gas mass fraction of each galaxy cluster is also compared with simulations, which constrain Ω_m = 0.246 ± 0.007 . Several tests to understand the systematics involved are performed, like creating subsamples and adding a hydrostatic bias on the mass estimates. Also galaxy groups seem to influence results. Since also the gas mass fraction suggests an insufficient modeling of low mass systems by the simulations, this aspect needs to be studied in more detail in future hydrodynamic simulations.

SPIDERS: the spectroscopic follow-up of X-ray selected clusters of galaxies in SDSS-IV

Nicolas Clerc

The distribution of galaxy clusters puts stringent and independent constraints on cosmological models and on the formation of large-scale structure across cosmic times. Observations of wide sky areas in the X-ray band provide the large samples necessary to studying the population of halos as a function of their mass, in space and in time. Optical spectroscopy of their member galaxies unambiguously confirms the nature of these systems, their distance to us and provide independent information on their mass distribution. Combining large X-ray surveys to intensive spectroscopic follow-up campaigns therefore leads to the well-controlled, pure and complete samples of galaxy clusters necessary for precision cosmology studies.
SPIDERS (SPectroscopic IDentification of ERosita Sources) is conducted as part of the six-year SDSS-IV project. It currently performs the optical spectroscopy of X-ray

selected, massive (~10^{14} to 10^{15} $M_{\odot}$) galaxy clusters discovered in ROSAT and XMM-Newton data, before data from the eROSITA all-sky survey are available. SPIDERS will determine precise (delta-z ~ 0.001) redshifts for 4,000 to 5,000 of these systems out to z ~ 0.6 in the Northern hemisphere. I will present the cluster samples selected for follow-up and I will show the efficiency of our methods at selecting targets in SDSS imaging data based on a robust red-sequence finder and a prioritization scheme that identifies galaxies most likely to belong to an X-ray cluster. Based on first results from the program, I will demonstrate the ability of the algorithms to deliver catalogues of spectroscopically confirmed galaxy clusters and discuss the relevance of cluster dynamical mass estimators for further cosmological applications. The uniquely large catalogue of spectroscopically confirmed X-ray clusters outcome of the program will serve a variety of science goals ranging from galaxy evolution to cosmological studies.

Evolution of the real-space correlation function from next generation cluster surveys

Srivatsan Sridhar

Galaxy clusters being the largest gravitationally bound objects in the Universe, can play a vital role in constraining cosmological parameters. One can use large scale simulations to study how galaxies cluster in time and compare the same with observed data. Photometric redshift surveys are crippled by the uncertainties that exist in the measurement of redshifts, which destroy the clustering signal. We see how well one can recover the clustering signal using the method of deprojection from photometric catalogues with different redshift uncertainties.

Angular correlation studies of the cosmic X-ray background – A new frontier of large-scale structure studies with X-ray surveys

Alexander Kolodzig

Angular correlation analysis of the cosmic X-ray background (CXB) is becoming a new frontier of large-scale structure (LSS) studies in X-rays. Fluctuations of the CXB surface brightness carry unique information about faint and low luminosity source populations, which are inaccessible for conventional LSS studies based on resolved sources. We demonstrate this by presenting the first full description of CXB fluctuations on the angular scales below ~17 arcmin. It is the result of our extensive

study of the fluctuations of unresolved CXB in XBOOTES, which is currently the largest continuous extragalactic survey by Chandra covering the area of ~9deg². It enabled us to conduct the most accurate measurement to date of power spectrum of CXB fluctuations below ~17 arcmin. We find that at angular scales smaller than ~2 arcmin the power spectrum is adequately described by the AGN shot noise, without much need for any significant contribution from the AGN one-halo term at the given accuracy of ~30%. This is consistent with the theoretical expectation that low luminosity AGN reside alone in their dark matter halos. However, at larger angular scales we found a significant excess power, which is much stronger than what can be plausibly explained by the correlation signal from AGN. We demonstrate in several independent tests that the observed excess power is produced by the clusters of galaxies, and, in particular, is related to the internal structure of their X-ray halos (i.e. one-halo term). The shape of the power spectrum of CXB fluctuations can be used to characterize the spatial structure of their IGM, while its amplitude can constrain the volume density of faint (L_X ~ 10^{42}-10^{43} erg/s) clusters of galaxies located at the redshift of z ~ 0.4.

Looking for Baryon Acoustic Oscillations of Galaxy Clusters

Lauro Moscardini

Baryon Acoustic Oscillations (BAO) are currently one the most powerful cosmological probe. They exploit the technique of the standard ruler to map the distance-redshift relation to get cosmological constraints. Usually BAO are investigated using wide surveys of galaxies. Here I present the first results of their application to the largest spectroscopic samples of galaxy clusters to date reaching z=0.5.

Cosmology with the new XCLASS cluster sample

Lorenzo Faccioli

We present an updated version of the XCLASS (Clerc et al. 2012) sample of clusters selected from a complete processing of the XMM archive up to August 2015 and preliminary results from its cosmological analysis. The cosmological analysis is based entirely on measured instrumental variables (count rate, hardness ratio and apparent core radius) as presented in (Pierre et al. 2016) and bypasses the need to estimate masses for the clusters in the sample, thus considerably speeding up the analysis The work builds upon the previously published XCLASS sample both by including XMM observations from 2010 to 2015 and by using an improved version

of the analysis which includes apparent core radius as an additional variable.

The mass in galaxy clusters from X-ray/SZ observables

Stefano Ettori

The key tool to use galaxy clusters as astrophysical laboratories and cosmological probes is the knowledge of the distribution of the their gravitating and baryonic mass.
I'll discuss the current status in reconstructing the gas and total cluster mass profiles from observations via X-rays and the Sunyeav-Zeldovich effect, highlighting the present limitations and biases, in particular in the clusters' outskirts and at high-redshift, where we have obtained the first constraint on the concentration-mass relation at z>0.7 from X-ray analysis. I'll show how the use of generalized scaling relations can help to reduce the scatter in obtaining the total mass and to constrain the physics responsible for the observed deviations from the self-similar model. I'll elucidate how Athena, the next-generation X-ray observatory and ESA-L2 mission, will address these issues.

Hydrostatic and Caustic Mass Profiles of Galaxy Clusters

Ben Maughan

The calibration of galaxy cluster mass estimators is essential for cluster cosmology, but the different techniques used for measuring masses all suffer from different systematics. This motivates the comparison of multiple techniques across large samples of clusters. I will present the results of a comparison between cluster mass profiles determined from galaxy dynamics using the caustic technique, and from X-ray data assuming hydrostatic equilibrium. We find a large scatter but good average agreement between the techniques. Our results suggest that the so-called hydrostatic bias cannot be large enough to explain the discrepancy between cosmological constraints from cluster number counts and cosmic microwave background anisotropies.

Cluster selection functions for next - generation surveys

Begoña Ascaso

The advent of next-generation surveys will provide a large number of cluster detections that will serve the basis for constraining cosmological parameters using cluster counts. I will present robust cluster selection functions for three of these surveys: Euclid, LSST and J-PAS and compare them with other future X-ray and SZ selection functions. Moreover, I will discuss the importance of the mass-richness calibration, the use of realistic simulations and the model of systematic errors to obtain an accurate final Figure of Merit.

Calibrating the galaxy cluster mass scale for cosmology

Stefania Amodeo

The potential of galaxy clusters as cosmological probes critically depends on the capability to obtain accurate estimates of their mass. This will be a key measurement for the next generation of cosmological surveys, such as Euclid.
The disturbing discrepancy between the cosmological parameters determined from anisotropies in the cosmic microwave background and those derived from cluster abundance measurements from the Planck satellite calls for careful evaluation of the reliability of cluster mass measurements and potential systematic biases. For this purpose, it is crucial to use independent techniques based on different physical properties, like analysis of the thermal emission of the intracluster medium (ICM), observed either in the X-rays or through the Sunyaev-Zeldovich (SZ) effect, dynamics of member galaxies or gravitational lensing.
We will present results published in two recent papers, the goal of which is to calibrate the galaxy cluster mass scale.
Firstly, we will discuss possible bias in the Planck SZ mass proxy, which is based on X-ray observations. Using optical spectroscopy from the Gemini Multi-Object Spectrograph of eleven Planck SZ-selected clusters, we will present new estimates of the cluster mass calibrated on the velocity dispersion of the member galaxies and independently of the ICM properties. We find a mass bias of 0.95, with an uncertainty of 20%.
Secondly, we will show results on the total mass profiles of a large sample of X-ray galaxy clusters observed with Chandra assumed to be in the hydrostatic equilibrium. In particular, we will investigate the relation between halo mass and dark matter concentration and its evolution with redshift.

Photometric redshifts from multi-chromatic optical imaging of X-ray galaxy clusters for precision cosmology

Jethro Ridl

The number density of clusters as a function of mass and redshift depends strongly on fundamental cosmological parameters such as Ω_m and $\sigma 8$ which can thus be constrained by large cluster surveys. In order to use cluster samples for cosmological analyses, the sample should span a wide range of masses and redshifts and a precise understanding of the selection function of the clusters is necessary. Building large, well-selected cosmological samples of galaxy clusters is thus crucial to constraining cosmological parameters with cluster observations.

Inferring the mass of galaxy clusters based on their X-ray emission is challenging. A large amount of information relating to the clusters' mass and redshift is contained in purely X-ray instrumental observables. By self-consistently modeling the cosmology, scaling relations, the selection function and instrumental responses one can predict an expected distribution in the count rate - hardness ratio (CR-HR) space which can be directly compared with the observational data. Such an analysis has already been successfully performed on the XMM Cluster Archive Super Survey (X-CLASS). Theoretical forecasts predict that knowledge of the individual cluster redshifts increases the reliability of this method.

The huge number of observations performed by XMM-Newton since it began its operation provides a large area of sky with relatively deep X-ray data from which cosmological samples of clusters can be created. X-CLASS, a serendipitous, X-ray selected cluster catalogue, containing 850 galaxy clusters is one such survey taking advantage of this. From these clusters a high signal-to-noise cosmological sample is extracted, benefiting from a uniquely well-controlled selection function over 90 deg2. In order to build on the previous analysis using the CR-HR method, these clusters have been followed up with GROND, a seven-channel (g'r'i'z'JHKs), simultaneous imager on the MPG/ESO 2.2m telescope at La Silla. By making use of an algorithm designed to take advantage of both the XMM and GROND data this provides an efficient tool for the determination of cluster photometric redshifts to an accuracy ~2%. This catalogue will be used for a cosmological analysis, making use of the CR-HR-z method. These observations will assist with the refining of observational and analytical strategies for future eRosita cluster studies, particularly in areas not covered by large surveys such as SDSS or DES.

Mass-Richness relations for Xray- and SZE-selected Clusters at 0.4 < z <2.0 as seen by Spitzer at 4.5 um

Alessandro Rettura

We study the Mass-Richness relation of 116 spectroscopically confirmed massive clusters at 0.4 < z < 2. We homogeneously measure IRAC [4.5] um galaxy richness for our cluster sample within a fixed aperture of 2 arcmin radius. We have two subsamples, based on a) literature X-ray masses or b) literature Sunyaev-Zeldovich Effect masses. We find the associated errors in mass at fixed richness to be 0.2 dex for both subsamples, and the scatter to be independent of cluster redshift. We study the dependance of these relations with central galaxy concentration. We find that at fixed aperture radius the scatter increases for clusters with higher central concentration. We study the dependance of our richness estimates with IRAC depth and find that reaching an image depth of at least [4.5]= 21.5 AB is sufficient to derive robust mass estimates, which can be attained with just 90s exposure. As Spitzer continues its Warm Mission, these results make robust richness-based cluster mass estimates available for very large samples at a very low observational cost, playing a crucial synergic role to the upcoming Euclid and WFIRST large scale surveys.

The dynamical and cool-core state of Planck SZ-selected clusters

Mariachiara Rossetti

Selection effects and observational biases should be carefully taken into account when inferring the properties of a population of objects detected in a survey. Clusters of galaxies are no exception to this rule and indeed X-ray surveys of galaxy clusters have been shown to be biased in favor of cool-core relaxed objects, because of the prominent surface brightness peak usually found in these systems. SZ surveys are expected to be less biased basing on simulations because of the weaker dependence of SZ quantities on the details of the cluster physics. I will present some recent work (Rossetti et al. 2016, Rossetti et al. in prep.) where we tested this prediction by measuring the dynamical and cool core state of a representative sample of Planck SZ clusters and comparing it to X-ray selected samples. The distribution of our dynamical indicator (the offset between the X-ray peak and the BCG) in the Planck sample is significantly different from the one in X-ray selected samples, with a smaller fraction of relaxed objects in Planck (52% vs 74%). The difference is even more apparent when we use an indicator which directly measures the presence of a clear surface brightness peak, such as the concentration parameter: only 30% of the clusters in the Planck sample are cool core while the

fraction almost doubles (59%) in the X-ray selected sample MACS. In both cases the differences between the distributions, tested with the KS test, are highly significant, even when comparing subsamples with similar mass and redshift properties. We can thus conclude that the difference is due to the selection method: SZ vs X-rays. I will discuss this result in the context of present and future surveys of galaxy clusters, both in SZ and X-rays, with a focus on XXL.

Cluster Science with WFIRST

Megan Donahue

I will review some of the synergies between the WFIRST science goals and X-ray cluster science. I will describe the WFIRST program in context with testing models for galaxy evolution and cluster cosmology.

Exploring the Intracluster Magnetic Fields through Radio and X-ray Observations

Motokazu Takizawa

Observations of polarized radio sources within galaxy clusters provide us with crucial information about the intracluster magnetic field though the Faraday Rotation Measure (RM), depolarization, and Faraday tomography techniques. In this presentation, we will introduce polarimetry results of merging cluster Abell 2256, relaxed cluster Abell 1367 and cool core cluster Abell 2199 with JVLA. We obtained a spatially-resolved RM maps for radio sources within these clusters and investigate the magnetic field structures combined with X-ray data . As for Abell 2199, the fractional polarization of the radio relic decreases from ~ 35 % to ~ 20 % around 3 GHz as the frequency increases and nearly constant between 1.37 and 3GHz. We perform depolarization modeling and Faraday tomography for these results, which imply the existence of multiple depolarization components toward the relic.

A Catalogue of Relics and Halos from the MWA GLEAM Survey

Melanie Johnston - Hollitt

The Murchison Widefield Array (MWA) GLEAM Survey covers the sky south of +30 in 20 frequency bands spanning 72-231 MHz. Due to the MWA's superb sensitivity, GLEAM is the ideal survey to search for relics and halos in galaxy clusters. Here we present a new catalogue of relics and halos across the MWA accessible sky. In particular we present a number of new detections as well as considerable increases in the size of previously known diffuse cluster sources. In several cases we find evidence for halos filling the entire cluster volume, not just the central X-ray parts. We will discuss how this new sample affects the present cluster halo scaling relations in the literature.

Shocks in galaxy cluster outskirts: the case of A3667

Emma Storm

The latest stages of hierarchical structure formation result in the collisions of massive galaxy clusters. These collisions drive turbulence and shocks throughout the cluster environment. The outskirt regions of galaxy clusters are particularly rich environments to study structure formation and merger dynamics. The observation of diffuse radio emission in the form of radio relics indicates the existence of cosmic rays that are likely accelerated by shocks in these regions. X-ray observations of cluster outskirts have revealed such shocks in a few objects, often spatially coincident with radio relics. A3667 is a classic example of a cluster that experienced a major merger. A3667 hosts a cold front in its core and a pair of radio relics in the outskirts. X-ray observations of the northern region of the cluster previously revealed an X-ray shock associated with the northern relic. However, the southern region of the cluster remains relatively unexplored. We use new XMM observations of the southern outskirt of A3667 to investigate the nature of the southern component of the radio relic and a potential second shock.

Joint X-ray and Subaru/HSC Weak-lensing Analysis of Very Nearby Galaxy Clusters

Nobuhiro Okabe

We carry out weak-lensing analysis of galaxy clusters at z<0.06 using a new prime focus camera, Hyper Suprime-Cam (HSC), of the Subaru telescope. Weak-lensing (WL) analysis is a powerful and unique tool to derive cluster masses without any assumptions of dynamical states, which is complementary to X-ray analysis to estimate hydrostatic equilibrium masses. A joint WL and X-ray analysis of the Subaru/HSC and the XMM and Suzaku satellites enables us to conduct a mass comparison from cluster cores to the viral radii and indirectly constrain the non-thermal pressure. Our target clusters are significantly overlapped with Hitomi primary targets to directly measure gas dynamics. Our project of very nearby clusters will build an essential bridge from previous studies to next, cluster based, cosmological studies based on the eROSITA, XXL, and the HSC SSP survey.

Comparison of X-ray and optical clusters/groups from XXL and GAMA

Paul Giles

The XXL survey is the largest homogeneous survey undertaken by XMM. Covering an area of 50 deg² (split between two 25 deg² areas), the survey contains several hundreds of clusters out to a redshift of ~2. The galaxy and mass assembly (GAMA) spectroscopic survey covers an area of ~280 deg², with the aim of studying structures on scales of 1 kpc to 1 Mpc. The GAMA survey overlaps with one of the XXL regions, therefore offering a unique opportunity to study cluster/group samples drawn from two selection methods. We will present the samples drawn from these two selection methods. We will show how GAMA may help with understanding the X-ray selection methods employed to detect sources in XXL.

X - ray morphological study of galaxy cluster catalogues

Jessica Democles

Context : The intra-cluster medium distribution as probed by X-ray morphology based analysis gives good indication of the system dynamical state. In the race for the determination of precise scaling relations and understanding their scatter, the

dynamical state offers valuable information.
Method : We develop the analysis of the centroid-shift so that it can be applied to characterize galaxy cluster surveys such as the XXL survey or high redshift cluster samples. We use it together with the surface brightness concentration parameter and the offset between X-ray peak and brightest cluster galaxy in the context of the XXL bright cluster sample (Pacaud et al. 2015) and a set of high redshift massive clusters detected by Planck and SPT and observed by both XMM-Newton and Chandra observatories.
Results : Using the wide redshift coverage of the XXL sample, we see no trend between the dynamical state of the systems with the redshift.

Weak Lensing Study of 16 DAFT/FADA Clusters: Substructures and Filaments

Nicolas Martinet

The current model for the growth of structures places clusters at the nodes of a filament network, and allows prediction of the abundance of clusters, which is used for constraining cosmology. The detection of filaments around galaxy clusters is therefore important to validate the use of the latter cosmological probe, and remains challenging at redshifts above 0.4.
I will present our search for filaments at medium-high redshift (0.4<z<0.9) around 16 galaxy clusters with large field of view optical data from the DAFT/FADA survey. Detections are made in weak lensing (WL) mass maps, and secured through noise resampling and simulations, before being compared with X-ray maps, derived from XMM-Newton data, and optical galaxy density maps. In addition, we measure WL masses of clusters and compare them with masses derived from X-rays, contributing to the calibration of the observable-mass relation required for cluster abundance cosmological studies.

Detection of filaments and large scale structures around the DAFT/FADA clusters up to redshift ~1

Florence Durret

Based on numerical simulations of the formation of large scale structures in the universe, galaxy clusters are believed to be at the intersection of cosmic filaments, and to be continuously accreting galaxies or groups along these directions. However, due to their relatively low contrast with respect to the field, these

filaments are difficult to detect unambiguously, particularly at high redshift. We have searched for such large scale optical filaments around 30 clusters with large field images (CFHT/Megacam or Subaru/SuprimeCam) taken from the DAFT/FADA survey of massive clusters in the redshift range 0.4<z<0.9. By selecting galaxies along the red sequence in a colour-magnitude diagram and drawing density maps of these samples with an adaptive kernel technique, we have detected elongated structures in at least 12 clusters. In most cases they match well the matter distribution derived from our weak lensing mass reconstruction and/or with the X-ray emission (when available).

Searching for high- redshift galaxy clusters with Planck/Herschel

Bruno Altieri

Searching for z>1.5 clusters/protoclusters is an active field in cosmology, and quite successful using wide near-infrared surveys (e.g. Spitzer). We present a new approach by selecting highly star forming high-z cluster candidates over the whole sky using Planck, taking benefit of the redshifted far-infrared peak into the Planck submillimetre channels and a clean component separation (among which Galactic cirrus & CMB).
Out of more than 1000 Planck high-z candidates, about 230 were confirmed by a Herschel/SPIRE follow-up, as significant overdensities of red sources, confirming their high-z spectral energy distribution and high star formation rates (typically 700 $M_{\odot}$ /yr per SPIRE source, and >5000 $M_{\odot}$ /yr for each structure). These overdensities could be protoclusters in their intense star formation phase. Few targets have spectroscopic redshift (in the NIR and mm) confirmations, all in the range 1.7-2.3, while photometric analysis indicates z>2 for all the Planck counterparts. Forty fields were followed-up by Spitzer down to 1uJy 5sigma, and show unambiguous presence of galaxy overdensities compatible with z~2 based on color analysis on 4 band photometry (J, K, 3.6 and 4.5um).
This new window on the high-z (z>1.5) protocluster may yield powerful constraints on structure formation (eg., SFR vs environnement at high-z, z>1.5 mass assembly in clusters, bias). Furthermore, these objects will allow to better quantify the prediction for clusters to be detected by Euclid. Finally, these clusters will help us extending the current search for high-z clusters, in nice complementarity with current selections in X-rays (eg. XDCS, XXL surveys), the near-infrared (dominated by stellar mass) and the millimeter (dominated by hot gas and SZ effect), using the far-infrared and submillimetre (dominated by star formation).

Next Generation Cosmology: Constraints from the Euclid Galaxy Cluster Survey

Barbara Sartoris

We build a cosmological pipeline to study the characteristics of the galaxy cluster samples expected from the European Space Agency's Euclid satellite.
*We explore the strength and the peculiarity of Euclid cluster samples with the aim of optimizing the performance and the constraining power of the final sample. We present the forecast constraints on parameters describing a variety of cosmological models, including ΛCDM, primordial non-Gaussianity, quintessence, modified gravity and neutrino density, making use of the photometric sample of ~ 2 *10^6 objects, with about one fifth of hem at z≥1.*
Our results have been obtained from the Fisher Matrix analysis including the information from the cluster mass function and its evolution, and from the power spectrum, the bias between the matter and the haloes distribution, including the redshift space distortions contribution.
The calibration of the observable mass scaling relation over the largest possible redshift range is known to be crucial to constrain cosmological parameters from cluster catalogue. The Euclid mission with its imaging and spectroscopic data will enable internal mass calibration at least up to z=1.5, with ~< 10 and ~<30 per cent accuracy, using the weak lensing and spectroscopic surveys. This information will be further complemented by wide-area multi-wavelength external cluster surveys like eRosita.

Suzaku Observations of the Galaxy Cluster 1RXS J0603.3+4214

Madoka Itahana

We present the results of Suzaku observations of the galaxy cluster 1RXS J0603.3+4214 with "toothbrush" radio relic. Although the shock with Mach number M≈3 is expected at the outer edge of the relic from the radio observation, our temperature measurements of the intracluster medium indicate weaker temperature difference than what is expected. The Mach number estimated from the temperature difference is ~1.6, which is significantly lower than the value estimated from the radio data even considering both statistical and systematic errors. This suggests a simple diffusive shock acceleration theory, which is assumed in the Mach number estimation from the radio data, seems to be invalid for this relic.
*We searched for the non-thermal inverse Compton component in the relic region and the resultant upper limit on the flux is 2.2 * 10^{-13} erg cm^{-2} s^{-1} in the 0.3-10 keV*

band. The lower limit of the magnetic field strength becomes 1.7 μG, which means that magnetic energy density could be more than a few % of the thermal energy.

Baryonic Properties Evolution within Galaxy Clusters

Elena Rasia

The total mass of galaxy cluster regulates global properties such as X-ray luminosity, SZ signal mass, temperature, or mass of the cluster baryonic component. However, the kpc-to-Mpc distribution of the gas properties is mostly linked to a series of astrophysical phenomena including radiative cooling, feedback by stars and active-galactic-nuclei (AGN), and merging events. By analyzing state-of-the-art simulations, which have produced a realistic description of the gas profiles in the cluster central regions, we will focus on the evolution of the ICM pressure, metallicity, and entropy in relation to the history of the cluster.

Chemical enrichment of the ICM

Peter Thomas

We present an analysis of the iron abundance in the hot gas surrounding galaxy groups and clusters.
To do this, we first compile and homogenise a large dataset of 79 low-redshift systems (159 individual measurements) from the literature. We then compare this dataset to groups and clusters in the Munich semi-analytic model of galaxy evolution, L-Galaxies.
Our homogenised dataset reveals a tight T -ZFe relation for clusters, with a scatter in ZFe of only 0.10 dex and a slight negative gradient. Our galaxy evolution model suggests greater accretion of hydrogen in the hottest systems, via stripping of gas from infalling satellites, as a cause. At lower temperatures, our model over-estimates ZFe in groups, indicating that metal-rich gas removal (via e.g. AGN feedback) is required.
L-Galaxies provides a reasonable match to the observed ZFe in the intracluster medium (ICM) of the hottest clusters from at least z ~ 1.3 to 0.3. However, the ZFe in intermediate-T clusters appears to be under-estimated in our model. The merits and problems with modifying the ICM enrichment modelling to correct this are discussed.

Probing the Bow-Tie Density Distribution of Hot Baryons in and around the Milky Way

Fabrizio Nicastro

We present strong evidence that a large amount of metal enriched hot (T~ 1e6 K) baryonic matter permeates the Milky way and deploys radially from the center up to the Galaxy virial radius and possibly beyond. This medium is characterized by a peculiar density distribution, whose peak is shifted radially from the Galaxy's center by ~7 kpc. We speculate that this peculiar bow-tie density distribution results from the expansion of a central bubble of hot matter driven either by a short period of AGN activity or a powerful burst of star formation, and note that the time needed for a shell of hot material traveling at v=1000 km/s (typical velocities of AGN-driven outflows) to propagate from the Galaxy center to a radial distance of 7 kpc equals the age of the two young star disks present in the central parsec of the Galaxy.
The mass of this large baryon reservoir is comparable to the total mass of the known baryonic components of the Galaxy (stars and cold gas and molecules), and therefore significantly alleviates the Galaxy missing baryon problem.

Clusters Forward modeling of clusters number counts

Arya Farahi

Relating observations of cluster galaxies or the gas component to the total mass of the system is a key challenge in the current cluster cosmology community. In Evrard et al. (2014), we develop a convenient and powerful mathematical framework for modeling counts and conditional statistics in a space of multiple observable properties and total mass. The model make explicit how counts and scaling relations are sensitive to covariance between pairs of observable properties.
In the first part of this talk, I discuss a forward likelihood model to constrain the scaling relation properties, including covariance, of a cluster sample using a cosmological mass function prior. I then present results of this method applied to multi-wavelength data from the LoCuSS survey sample.
A related challenge for cosmological analysis of cluster counts, is good understanding of the systematics and the selection function of survey. Cosmological N-body simulations can be thought of as a way to characterise systematics and the selection of given survey. We have developed a flexible simulation method designed to enable testing of X-ray survey selection (Farahi et al. (in prep)). For the second part, we discuss lessons we learned so far and the potential prospects for future analysis, like the interesting and observationally unconfirmed strong anti-correlation between galaxies and hot gas inside clusters (Wu et al. 2015).

Population Statistics of Galaxy Cluster Samples

August Evrard

The composition of clusters — dark matter and baryons in multiple phases evolving within a cosmic network of massive halos — is being scrutinized observationally across the electromagnetic spectrum and with increasingly sophisticated numerical simulations. This body of work informs a phenomenological framework for cluster cosmology derived from cluster counts as a function of redshift and some observable property (aka, a mass proxy). After briefly reviewing the state of the art, I will argue for a relatively simple model for predicting multi-wavelength population statistics, including counts and conditional statistics, then discuss opportunities and challenges for application to large, ongoing surveys in X-ray, optical-IR and millimeter/radio wavelengths.

Evolution of the Cluster Scaling Relations with MACSIS

David Barnes

Galaxy clusters form from the largest primordial density fluctuations and their distribution, as a function of mass and redshift, is a sensitive probe of cosmological parameters. However, we must infer a cluster's mass from its observable properties and the mass-observable relations contain scatter and bias due to the differing formation histories of clusters. Many studies have shown that the scatter is reduced for massive, relaxed clusters. Therefore, to probe cosmology with clusters we require a sample of massive clusters with well-understood scaling relations. We present the MAssive ClusterS Interclusters Structures (MACSIS) project (Barnes+ in prep.), a set of 390 clusters with MFOF > 10^{15} $M_{\odot}$ simulated with full gas physics using the BAHAMAS code (McCarthy+ 2016). We present the scaling relations and how their slope and normalisation evolves from z=0 to z=1.5. We select a massive subset, T > 5keV, and a relaxed massive subset of clusters to understand the impact of these selection criteria on the scaling relations and their evolution.

On the nature of hydrostatic equilibrium in simulated galaxy clusters

Veronica Biffi

We present results on the level of hydrostatic equilibrium (HE) in the intra-cluster medium (ICM) of simulated galaxy clusters, which is one of the fundamental assumptions at the base of X-ray mass reconstructions and scaling relations. The study sample has been extracted from state-of-the-art cosmological simulations performed with the Smoothed-Particle Hydrodynamic code GADGET-3, including star formation, chemical enrichment, feedback from both stellar sources and AGNs, and an improved hydrodynamical scheme. Evaluating the radial balance between the gravitational and hydrodynamical forces, via the gas accelerations generated, we effectively examine the deviation of the gas from HE, its dependence on the radial distance from the center and on the classification of the cluster in terms of either cool-coreness or dynamical state. Furthermore, we explore its relation to the hydrostatic mass bias and to temperature inhomogeneities, for the different subsets of cool core/non-cool-core and regular/disturbed systems. The connection between mass bias and deviation from HE has also been investigated in light of the amount of non-thermal motions of the gas, that can contribute to the pressure support in addition to the thermal ones.

Scaling Relations of High-Redshift Simulated Clusters of Galaxies

Nhut Truong

Current and planned future X-ray and Sunyaev-Zeldovich (SZ) galaxy clusters surveys will furnish a large amount of data for cosmological and astrophysical studies. By analyzing state-of-the-art cosmological re-simulations of galaxy clusters, we studied various scaling relations from redshift 0 to redshift ~2: M-Mgas, M-Tsl, M-Yx, L-T, and L-M. After comparing our low-z simulated results with observations of the local universe, I will review our most important results on the evolution of the slope, the normalization, and the intrinsic scatters of those scaling relations.
(Authors: Nhut Truong, Elena Rasia, Pasquale Mazzotta, Stefano Borgani, Susana Planelles, Veronica Biffi, Giuseppe Murante)

Coherent motions of ICM and dark matter in synthetic clusters of galaxies and their impact on kinetic SZ maps

Marco De Petris

Dynamical properties of Intra-Cluster Medium (ICM) and Dark Matter (DM) are studied by the gasdynamical simulations of the MUSIC project selecting massive synthetic clusters of galaxies with $M_{vir} > 10^{15} h^{-1} M_{\odot}$ at z=0.
In order to investigate the presence of coherent motions inside the clusters, we select relaxed clusters (59% of the objects in MUSIC-2 catalog), avoiding to include disturbed halos with possible ongoing merging processes. The rotational state of each cluster is quantified through the spin parameter value. A simple model based on solid body rotation is clearly not suitable to describe the specific angular momentum radial pattern, both for ICM and for DM, mainly because of the non-negligible contribution of turbulence. The tangential and the turbulent components of ICM and DM velocity radial profiles highlight the dominant role of turbulence in the case of DM for the rotating clusters. The gas tangential velocity field can be well modelled with a modified profile of the ICM circular velocity derived from a Navarro-Frenk-White DM density distribution. In general, different models applied to describe the baryon physical processes in the simulations do not have significant impact on the dynamical behaviours confirming that the DM contribution plays a dominant role in clusters dynamics.
We find that 40% of clusters shows evidences of co-rotation of ICM and DM, allowing to infer the DM rotational state by ICM observations.
Motions of the diffuse ICM could be indeed detected by a variety of observational techniques such as X-ray spectroscopy or surface brightness mapping. We explore the observations of clusters rotation by kinetic Sunyaev-Zel'dovich effect.

The physical impact of baryonic feedback and neutrino free-streaming on the abundances and internal structures of simulated cluster haloes

Benjamin Mummery

With initial conditions based on high redshift geometric observations, the heirarchical formation paradigm of ΛCDM overpredicts the degree of observed local structure. Both baryonic feedback from AGN and the free-streaming of massive neutrinos have been invoked to resolve this discrepancy, however the magnitude of the their effects is not well constrained, and they are at least partially degenerate. Using the Cosmo-OWLS and BAHAMAS suites of large, hydrodynamic cosmological simulations we investigate the individual effects of each mechanism, with varying

values for the AGN heating and summed neutrino mass respectively. Abundances, clustering, density profiles and mass concentration relations are examined for simulated haloes of mass $10^{12} < M_{200,\,crit} / M_{\odot} < 10^{16}$. In each case we also examine the necessity of simultaneously evolving both the baryonic and neutrino physics in simulations by comparing the results of such to a simple multiplicative treatment of the effects in isolation.

Code performances in subsonic flows of an SPH scheme based on a matrix approach (Integral Approximation)

Ricardo Valdarnini

We present results from a suite of hydrodynamical problems aimed at verifying the code behavior of a new SPH scheme. In the new formulations gradients are derived through a matrix inversion based on an integral approach. We compare results against those obtained using standard SPH and the corresponding ones previously obtained using codes based on other numerical methods, such as a moving-mesh code.

We find that the new IA-SPH formulation outperforms standard SPH and in terms of accuracy yields results in good accord with those produced using other numerical schemes recently proposed.

We conclude that the new scheme can be successfully applied to many astrophysical problems for which standard SPH simulations are inadequate and are present subsonic flows, such as subsonic turbulence in galaxy clusters.

AGN

Chandra COSMOS - Legacy: clustering of moderate luminosity X - ray AGN at 2.9 < z<5.5

Viola Allevato

AGN clustering measurements provide a unique way to put constraints on the BH/galaxy formation and co-evolution and their connections to the large-scale structure. In the cold dark matter dominated Universe AGN are believed to populate the collapsed dark matter halos. Their distribution within halos is described by the halo occupation and the large scale clustering is described by the 2pcf. By matching the 2pcf at large scale to detailed outputs of dark matter numerical simulations, one can infer the typical environment where AGN live in, through the so called AGN bias. This in turn can provide new insights into the physical mechanisms responsible for triggering AGN activity, since diverse BH triggering models predict different typical masses of the hosting halos as a function of redshift and luminosity, as well as a different AGN halo occupation.
I'll present here a study on the clustering properties of Chandra COSMOS-Legacy AGN. This new catalog is the largest available sample of X-ray selected AGN for clustering studies. The 2pcf has been measured at z>3 for the first time using X-ray data with high accuracy, using new techniques based on photometric redshift in the form of probability distribution functions in addition to any available spectroscopy. The results will be compared to previous studies using optically selected quasars and interpreted in terms of AGN triggering mechanisms.

The BH mass - LK relation in type 2 AGN

Fabio La Franca

According to the current models of galaxy evolution in a hierarchical cosmology, low mass Black Holes (<10^7 $M_\odot$) at low redshift contain clues about the formation of the first Black Holes and Galaxies.
Moreover, as they extend the dynamic range of the BH-mass/galaxy scaling relations to extreme values, they are extremely useful in constraining AGN/galaxy co-evolution models.
In the past years, in the framework of the verification of the AGN unified model, there have been several attempts to detect faint broad emission lines in type 2 AGN with both NIR and polarised spectroscopy.

We here present the new results from a systematic study performed using deep NIR (VLT and LBT) spectroscopy of a sample of ~40 low-z AGN2, drawn from a complete hard X-ray selected sample. Thanks to our single epoch relation calibrated on unbiased quantities (hard X-ray luminosity and Pabeta line width), we have been able to directly measure in a virial way the BH mass of these AGN2.
Our recent findings allowed us to measure for the first time the Eddington ratio distribution and the local Black Hole mass - K-bulge luminosity relation of AGN2. The results will be discussed in the framework of the AGN/galaxy coevolutionary scenarios.

Constraining the UV emissivity of AGN throughout cosmic time via X-ray surveys

Federica Ricci

The cosmological process of hydrogen reionization in the intergalactic medium is thought to be driven by UV photons emitted by star-forming galaxies and ionizing AGN. The contribution of QSOs to hydrogen reionization at z>4 has been traditionally believed to be quite modest, due to the steadily decreasing number density of AGN at z>3. Recently this view has been challenged by new estimates of a higher faint-end UV luminosity function (LF). However, these measures are still poorly constrained, because of the difficulties related to the UV/optical AGN selection at high redshifts. To set firmer constraints on the role of AGN in the hydrogen reionization, we use complete X--ray selected AGN samples, as the X--ray selection provides a better handle on the AGN LF faint end since it is not biased toward obscuration. Thanks to the heritage of X--ray astronomy, a big part of which gained through XMM-Newton observations and surveys (SXDS,LH/XMM,HELLAS2XMM,XBS..) and to new deep Chandra and COSMOS Legacy data, we constrain the AGN XLF up to redshift about 6. We find good agreement between the unabsorbed (logNH<21-22 cm^{-2}) XLF and the UV/optically-selected QSO LF (in line with traditional AGN unified models) and therefore the unabsorbed XLF is an unbiased proxy to estimate the density of ionizing AGN. The use of the unabsorbed XLF allows us to measure the 1 ryd comoving QSO emissivity up to z about 5-6 without any luminosity extrapolation, exceeding the current flux limits probed by optical surveys.
Finally, we quantify the role of AGN comparing the photon emission rate with the critical value needed to keep the Universe ionized. We find that the contribution of ionizing AGN at z=6 is little (i.e., 1% - 7%) and in any case very unlikely to be greater than 30%, thus excluding an AGN-dominated scenario as instead recently suggested by other studies.

The WISSH Quasars project: Probing the AGN/galaxy co-evolution in the most luminous quasars

Federica Duras

The WISE/SDSS selected hyper-luminous (WISSH) quasars survey is an extensive multiband observing program (from millimeter wavelengths to hard X rays) to investigate the role of nuclear activity in SMBH-galaxy self-regulated growth via extended outflows.
Our ongoing project is designed to accurately constrain both AGN and host galaxy ISM properties in a large sample of ~ 90 broad-line quasars at the brightest end of the AGN luminosity function (L_{bol} > 1e14 $L_{\odot}$) and at the peak of their number density (z ~ 2 – 4).
I will review the most relevant results obtained to date with emphasis on the nuclear and galaxy physical parameters derived through multi-component SED fitting method, and the discovery of extremely powerful (up to ~ 4% of L_{bol}) ionized outflow.

A benchmark study of Active Galactic Nuclei: Decoupling luminosity and evolution in the SEDs of AGN

Eleni Kalfountzou

In recent years the study of active galactic nuclei (AGN) has undergone a renaissance. This is due to the fact that AGN activity is now widely believed to be an important phase in the evolution of every massive galaxy in the Universe. However, the picture is still not clear, with investigations at different wavelengths producing many differences of opinion as to the amount of radiation that is absorbed and reprocessed by dust, how this is related to the host galaxy and whether the triggering mechanism behind the AGN activity is also responsible for massive star-formation activity. Moreover, it is also unclear how these processes depend on luminosity, radio-loudness and orientation.
A drawback of all previous surveys is that they are fundamentally limited by the degeneracy between redshift and luminosity in flux-density limited samples. We have constructed well-defined samples of radio-quiet and radio-loud quasars, along with radio galaxies. These samples are defined to span a factor of >100 in both optical and radio luminosity, with each subsample composed of objects with matched luminosity distributions, at a single cosmic epoch (0.9 < z < 1.1). Combining multi-wavelength observations and surveys (e.g. XMM-Newton, UKIRT, Spitzer, Herschel, SDSS, VLA), we aim to create a detailed picture of how the full SEDs of AGN change as a function of luminosity, orientation, radio-loudness and redshift which is crucial for improving our understanding of virtually all aspects of

the AGN phenomenon. At the same time, it will also provide a benchmark sample from which other AGN surveys will benefit, in particular when computing bolometric luminosities and accretion rates.
Our results, extracted from the full SEDs, optical spectra and wide-field photometric observations, will be discussed in terms of the fundamental questions such as: Do AGN feedback quench the star formation in their hosts, or do black holes and stellar bulges form in parallel? Is star formation different in the host galaxies of radio-loud and radio-quiet AGN and whether all radio-loud AGN are the same in this respect? Which are the dust properties of AGN over the epoch of activity and the unification picture? What is the evolutionary status of the clusters forming around the z~1 AGN and whether this depends on the central mass of the AGN host galaxy/black hole, the radio-loudness, or on the fraction of massive galaxies in the cluster?

NGC5506: variations on the Title of AGN obscuration

ShangYu Sun

NGC 5506 is a nearby narrow-line Seyfert I galaxy. Although it is moderately obscured in X-ray, it is bright enough to be a proper source for studying in detail the structures and activities near an active supermassive black hole (SMBH). We present the X-ray spectra from Chandra, XMM-Newton, Suzaku, and NuSTAR in 2000-2014, which together resolve the time evolution of the SMBH and the surrounding that might obscure it. To describe these multi-epoch spectra from soft X-ray to hard X-ray, more than one obscuring components are needed: one directly obscures the central nuclear emission in the line of sight, the other is a torus, which obscures the emission depending on the orientation of the AGN, and reflects it based on scattering angles. Detailed obscuration information can be extracted out from modeling all the spectra simultaneously. The knowledge of AGN obscuration will be improved through this study.

Quasars as standard candles

Guido Risaliti

The well known non-linear correlation between X-ray and UV emission in quasars can be used as a distance indicator. Until a few years ago, the small number of quasars with both UV and X-ray measurements, and the large dispersion of the correlation, made it impossible to use this method as a cosmological probe. The situation has radically changed today: (1) thanks to large optical and X-ray surveys, the X-ray to UV relation can be studied for thousands of quasars; (2) we

found that most of the observed dispersion is due to measurement errors, while the intrinsic dispersion is lower than 0.2 dex, making quasars effective '' standard candles'' for the determination of cosmological parameters. I present a Hubble Diagram of quasars up to z~6, which provides significant new constraints on the ΛCDM model, and on the possible extensions in the dark energy sector. I show how a combination of Chandra/XMM-Newton shallow surveys and pointed observations of z>3 quasars can significantly improve the present measurements, indeed opening a new branch of observational cosmology at high redshift.

The search for heavily obscured AGN in the Chandra deep fields

Cristian Vignali

Among the possible methods to select heavily obscured AGN, I will present one which combines the strength of SED fitting with deep X-ray spectroscopy in the Chandra deep fields. In the sample of sources characterized by powerful mid-infrared AGN emission and relatively faint X-rays we discovered nine heavily obscured AGN, some of which having a column density above 10^{24} cm^{-2}.
Prospects for forthcoming X-ray and mid-IR facilities will be also highlighted.

The 12k AGN luminosity function

Sotiria Fotopoulou

Understanding the growth and triggering mechanisms of active galactic nuclei (AGN) requires a consensus of the AGN population not only across luminosities and redshifts but also across different environments. The XXL survey covers two fields of 25deg^2 each, with a flux limit of F[2-10keV]=5e-15 erg/s/cm^2, providing a unique X-ray sample of 12 000 sources the majority of which are AGN. This is the largest X-ray detected AGN sample ever used to constrain the shape of the AGN luminosity function to date. Additionally, by mapping the large scale structure in the same field, we are in position to identify which AGN reside in X-ray detected clusters and thus decompose for the first time the luminosity function of AGN as a function of their environment, up to redshift of one.

AGN host galaxy mass function of the XMM-COSMOS sample. Is AGN feedback responsible for the mass-quenching of galaxies?

Angela Bongiorno

Supermassive black hole growth, nuclear activity, and galaxy evolution have been found to be closely related. To understand the role of black hole activity in galaxy evolution it is fundamental to have a accurate and unbiased census of the AGN population and its relation to the properties of their host galaxies.
Starting from the XMM-COSMOS sample, we investigate the role of supermassive black holes in the global context of galaxy evolution by measuring the host galaxy stellar mass function (HGMF) and the specific accretion rate distribution function (SARDF), up to z~2.5. Using a maximum likelihood approach, we jointly fit the stellar mass function and specific accretion rate distribution function, with the X-ray luminosity function as an additional constraint. I will present the results of this work also in the perspective of AGN feedback as possible responsible mechanism for galaxy quenching.

The unabsorbed 2-10 keV luminosity function of AGN from the XMM-LSS, CDFS and COSMOS surveys

Piero Ranalli

The XMM-Newton LSS, CDFS, and COSMOS surveys probe complementaryregions of the flux-redshift plane, and together they provide one of the largest samples of AGN available to study their luminosity function (LF). I will present the redshift-dependent 2-10 keV LF, estimated using different methods: a binned LF, and a Bayesian analysis using the LDDE and LADE models for its evolution. Both methods account for uncertainties about absorption and photometric redshifts by considering their complete probability distributions. I will then introduce the Bayesian framework for model comparison, focusing on posterior-based metrics such as the Widely-Applicable Information Criterion (WAIC). The LF will be compared to previous determinations and models. Finally, I will present LFTools, a publicly released toolset for computing Lfs.

The ATCA XXL-S 2.1 GHz Radio Survey: First results and preliminary AGN luminosity functions

Minh Huynh

The XXL is the largest survey ever with the XMM-Newton X-Ray telescope, comprising 6.9 MS spread over two 25 deg² fields, the XMM-LSS field (XXL-N RA=2:18, Dec=-5:17) and the BCS-XMM field (XXL-S at RA=23:30, Dec=-54:30). One of the main goals of the XXL project is to study galaxy evolution with a large sample of AGN. As part of the ongoing multiwavelength followup to achieve the science goals, radio observations at 2.1 GHz were obtained on the Australia Telescope Compact Array covering the full 25 sq deg of the XXL-S, reaching an rms noise of ~40 microJy and a resolution of ~5 arcsec. This is the largest radio survey ever at these flux density levels. We identify ~6000 radio sources down to 5 sigma. We use the multiwavelength data in this field to characterise the radio sources and present preliminary AGN radio luminosity functions from the XXL-S.

A realistic simulated X-ray AGN catalogue up to z=3: The when and the how AGN affect the X-ray selection of the XXL galaxy clusters

Elias Koulouridis

We compile a catalogue of X-ray AGN from the output black-holes of the cosmo-OWLS hydro-simulations. The sources comply with the observed luminosity function, logN-logS and correlation function of AGN. Our aim is to determine how the black hole X-ray emission affects the X-ray cluster selection. Especially for the unexplored population of galaxy clusters above z=1, our results are a valuable not only for the deciphering of the observations, but also for the hunt of high redshift galaxy clusters. We will present the AGN catalogue and instructive results from the cosmo-OWLS simulations.

Xray and numerical models of AGN jets in galaxy clusters

Salvatore Cielo

The hot circumgalactic medium in some of the most massive galaxy clusters needs steady central energy injections, in order to compensate or prevent effective radiative cooling, especially in the central few 10s of kiloparsec. Models in which

this energy is provided by the mechanical feedback from central AGN jets have been proposed and studied, and are supported by Xray observations, as jets reproduce also the observed CGM cavities. Jets/cavities of the observed power should be active continuously throughout the cluster lifetime in order to provide sufficient energy. Jets are also expected to re-orient their main axis to originate the multiple pairs of cavities we observe.
We explore this model by 3D hydrodynamic simulations of rapidly re-orienting jets in a massive galaxy cluster environment. We produce synthetic Xray maps of the hot gas and cavities, as integrated thermal+line emissivity in the soft ([0.5, 2] keV) and hard ([2, 10] keV) Xray bands, or directly as mock observations by current (XXM, Chandra) and next generation (Athena) telescopes (preliminary!).
The simulations, and the comparison between synthetic and real Xray maps, allow us to to characterize in detail the energetics of the system. We calculate the fraction of the initial jet power that is converted into mechanical work performed by the cavities on the gas, and how in turn this energy is split in mechanical (potential, kinetic and turbulent) and internal energy of the gas. In addition, the Xray maps show short-lived interaction with a cold gas component, allowing us also to study jet-induced positive feedback.

AGN feeding and feedback: beyond sub-grid physics

Andrea Negri

AGNs are among the most luminous X-ray sources in the universe. Black hole (BH) accretion models and hydrodynamical cosmological simulations have proved to be an invaluable tool to study how AGN evolve in the Universe. However, the interplay between AGN and the large scale structure is challenging to study due to the large dynamical range and complex physics involved. The spatial scale where the BH dominates the hydrodynamical processes (the Bondi radius) is usually unresolved, and different approximate Bondi-Hoyle accretion rates are adopted to estimate both BH accretion and feedback. We analyse a galaxy simulation that includes cooling, star formation, Type Ia and Type II supernovae, BH accretion and a realistic model for AGN feedback (radiation pressure, Compton heating/cooling and broad absorption line isotropic/conical winds). Our standard simulation has sub-parsec resolution and estimates BH accretion directly though mass flux. We "degrade" the resolution and physical approach to mimic the sub-grid physics used in large scale simulations. We find that the approximated Bondi formalism leads to an overestimate of the BH growth, due to the complex interplay between AGN feedback and BH accretion. At low resolution the mechanical feedback is less effective in evacuating the BH surroundings, thus producing an enhanced and almost continuous BH accretion and high luminosity. Instead, in high resolution runs the galaxy central regions are depleted of gas by BH winds, leading to a chaotic, intermittent BH accretion, and an extremely variable luminosity.

POSTERS

Super-Eddington growth of the first black holes

Edwige Pezzulli

The formation and growth of the first super massive black holes (SMBHs) at z ~ 6 is a subject of intense debate. If black holes grow at their Eddington rates, they must start from high-mass seeds, (M_{seed} ~10^4 -10^5 $M_\odot$), formed by direct collapse of gas. Here I will consider an alternative scenario where remnant of population III stars, (M ~ 100 $M_\odot$), can grow at super-Eddington rates via radiatively inefficient slim accretion disks. In Pezzulli et al., (MNRAS 2016), we use an improved version of the cosmological, data-constrained semi-analytic model GAMETE/QSODUST. We follow, for each progenitor present in the simulation, the evolution of nuclear BH, gas cooling, disk and bulge formation of their host galaxies together with the star formation, SNe/AGN feedback and chemical and dust enrichment.
By adopting SDSS J1148+5251 at z=6.4 as a prototype of luminous z=6 quasars, we find that ~ 80% of the SMBH mass of J1148 is provided by super-Eddington gas accretion, which can be sustained down to z ~ 10 in dense, gas-rich environments, and the BH progenitors of the final SMBH evolve in symbiosis with their host galaxies.
We reproduce all the observed quantities of J1148, also predicting an AGN-driven mass outflow rate at z=6.4 broadly consistent with the radial profile inferred from CII observation by Cicone et al. 2015. Interestingly, we find that ~20% of J1148 progenitors at z=7.1 have BH luminosities and masses comparable to ULAS J1120, suggesting that the most distant quasar ever observed may be one of the progenitors of J1148.

Galaxy cluster rotation

Maria Manolopoulou

We study the possible rotation of galaxy-members in clusters, developing, testing and applying a novel algorithm. Finding rotational modes in galaxy clusters would lead to the necessity of correcting the dynamical cluster mass calculation. To validate our algorithms we construct realistic Monte-Carlo mock clusters in order to confirm whether our method provides robust indications of rotation. We also compare our method to that of other studies found in the literature. We then apply our methodology on a sample of Abell clusters with z<=0.1, selected such that their

richness class is 1 or 2 and their distance class is 4 or 5. We select their galaxy members using the SDSS DR10 spectroscopic database. We then apply our algorithm to determine its rotation or not, its rotational centre, rotation axis orientation, rotational velocity amplitude and, finally, the clockwise or counterclockwise direction of rotation on the plane of the sky. We find that between ~ 35% and ~ 48% of the clusters are rotating either within 1.5 or 2.5 h^{-1}_{70} *Mpc radius from the cluster centre. In an attempt to identify the causes of cluster rotation we correlate our rotation indicators with the cluster dynamical state provided either by their Bautz-Morgan type or by their X-ray isophotal shape. For those clusters that show indications of rotation we find that the significance and strength of rotation is strongly correlated to dynamical youth but only for the 1.5* h^{-1}_{70} *Mpc radius case. The lack of significant such correlations for the 2.5* h^{-1}_{70} *Mpc radius 70 case points towards a different mechanism being responsible for the rotation of the inner and outer cluster region. The outer cluster rotation could possibly be related to coherent motions of infalling substructures.*

Modeling the cluster physics in the L-Galaxies SAM : Hot gas properties and AGN feedback

Benoît Fournier

Semi-analytical models (SAMs) combine dark matter only simulations of structure formation with analytical prescriptions of the various physical processes responsible for shaping the formation and evolution of galaxies.
The latest version of L-Galaxies (Henriques 2015) successfully reproduced various observational properties, such as the stellar mass function, luminosity function, …, from z = 0 up to z = 3. However, the current model is unable to reproduce the ICM properties of cluster : higher fractions of baryons, hot gas and metallicities than observations, no X-ray predictions available, … .
The new model we implemented has 3 major components :

- *Physically motivated baryon fraction correction;*
- *A new cooling model leading to x-ray predictions;*
- *A more detailed AGN feedback mechanism (quasar + radio modes).*

We present our preliminary results and compare them with the latest observational data.
Collaborators: Peter Thomas (Sussex), Steve Wilkins (Sussex), Bruno Henriques (ETH Zurich), Rob Yates (MPE, Munich).

Clusters of galaxies in the cosmic web

Florian Sarron

Numerical simulations of the formation of large scale structures in the universe paint the picture of galaxy clusters being located at the intersection of cosmic filaments and accreting galaxies and groups of galaxies along these preferred directions throughout cosmic time.
These filaments have proven to be hard to detect due to their intrinsic low density contrast with respect to the field. Detection of such structure has been limited to relatively low redshifts ($z < \sim 0.3$) and usually through the use of spectroscopic redshifts. Since clusters of galaxies are thought to form around redhifts of $z \sim 1$, being able to study their environment up to such a range of redshifts is of critical importance to put constraints on their formation and evolution scenarios.
We are searching for such filaments around the thousands of clusters detected in the Canada France Hawaii Telescope Legacy Survey (up to redshift $z=1.5$ in the Deep fields, $z=1.2$ in the Wide fields) through the use of photometric redshifts. For this, we draw 2D galaxy density maps in redshift slices, applying an adaptive kernel technique. This allows us to detect the structures in the physical environment of each cluster. We are currently developing tools to study the characteristics of such structures, and quantify a possible evolution of these with cluster redshift and mass/richness, and will present preliminary results.

NGC741: Mergers and AGN feedback at the galaxy group scale

Gerrit Schellenberger

Low mass systems play an essential role in upcoming cosmological studies like eROSITA. Though the effects of AGNs and merging processes are of special importance to quantify biases like selection effects or deviation from hydrostatic equilibrium, they are poorly understood on the galaxy group scale. We present an analysis of recent deep Chandra and XMM integrations of NGC 741, which provides an excellent example of a group with multiple concurrent phenomena: both an old central radio galaxy and a spectacular infalling head-tail source, strongly-bent jets, a 100kpc radio trail, intriguing narrow X-ray filaments, and gas sloshing features. Supported principally by X-ray and radio continuum data, we address the merging history of the group, the nature of the X-ray filaments, the extent of gas stripping from NGC 742, the character of cavities in the group, and the roles of the central AGN and infalling galaxy in heating the intra-group medium.

A comprehensive catalogue of X-ray detected nearby galaxies from the X-CLASS survey

Tatyana Sadibekova

We present a thorough study of the sample of nearby galaxies detected as extended X-ray sources in the X-CLASS survey. Our aim is to better determine a relation between the mass of the dark matter halo and the super-massive black hole at the centre of galaxies. To this end, we compiled a comprehensive catalogue of their multi-wavelength properties. Being well known and well resolved in X-ray and optical wavelengths, with a typical apparent size of X-ray halo R=1-3' (XMM-Newton PSF~6"), these galaxies allow for the decomposition of the extended X-ray emission into its various components, mainly the hot gas halo and the AGN. We present preliminary results of early-type galaxies that, being less contaminated by star-forming activity, significantly simplify the halo measurements.

Star formation at z = 1.9 in an XXL cluster of galaxies: the far-infrared to submillimeter view

Cathy Horellou

Clusters of galaxies at z > 1 are rare, and studying their properties provides insights into early structure formation and galaxy evolution. Observations in the submillimeter (submm) part of the spectrum are required to probe dusty, gas-rich star-forming galaxies that are largely obscured at other wavelengths. The galaxy cluster XLSSU J021744.1–034536 at a photometric redshift of 1.9 is the most distant cluster detected both via its X-ray emission and the Sunyaev-Zeldovich effect (Willis et al. 2013; Mantz et al. 2014).

We present far-infrared and submm observations of the field around this cluster. We used two bolometer cameras, Artemis and LABOCA, on the Atacama Pathfinder EXperiment (APEX) to image this field at 350 and 870 microns. We also used Herschel SPIRE images 250, 350 and 500 microns to estimate the photometric redshifts and star-formation rates of the detected sources. Out of 15 secure LABOCA detections, two are in the area of the cluster and one has a concordant redshift. The inferred star-formation rate of that probable cluster member is greater than 1000 solar masses per year.

Constraining the evolution of the CMB temperature with SZ and distance measurements

Gemma Luzzi

The CMB temperature-redshift relation, $T_{CMB}(z)=T_0(1+z)$, is a key prediction of the standard cosmology, but is violated in many non standard models. Constraining possible deviations this law is an effective way to test the ΛCDM paradigm. We put tight constraints on the redshift evolution of CMB temperature up to redshift 1. We do so by using the spectral signature of the SZ effect for 103 clusters selected from the Planck SZ cluster catalog. Our results are compatible with previous measurements and allow an improvement on the bounds.
After combining all currently available direct and indirect measurements of $T_{CMB}(z)$ we constrain the common phenomenological parametrization $T_{CMB}(z)=T_0(1+z)^{(1-\beta)}$ and obtain the first sub-percent constraint on the temperature growth index $1-\beta$ (Avgoustidis et al. 2016). We find $\beta = (7.6 \pm 8.0) * 10^{-3}$ at the 68% confidence level.

Giant Radio Halos and Relics in ACT Clusters.

Sinenhlanhla Sikhosana

Galaxy clusters are the largest gravitationally bound structures in the universe. They act as the universe largest laboratory and are extremely interesting objects to study. In previous decades the most prominent cluster studies were focused on thermal processes in the Intra Cluster Medium (ICM). However recent studies have shown that non- thermal studies bring a different perspective on ICM processes.
The study of radio halos and relics has a number of open questions such as the observed bimodality in the radio power vs X-ray luminosity. Partially the cause has been the use of cluster samples without well-defined selection function to search for the radio halos and relics.
We aim to study radio halos and relics in a sample of clusters selected via the Sunyaev- Zel'dovich (SZ) effect by the Atacama Cosmology Telescope (ACT) project. We begin by doing a study on the giant radio halo found in the SZ selected merging galaxy cluster ACT CL J0256.5+0006, observed with the Giant Metrewave Radio Telescope (GMRT).