Report on the FLAMES Users Workshop (FUW)

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Following the precedent set by the Potential Users of UVES (PUU) workshop held at ESO in 1998, it was decided to hold a similar-style workshop for FLAMES. FLAMES (Fibre Large Array Multi-Element Spectrograph) is the ESO VLT multi-object fibre facility which is under construction and expected to be released to the user community in 2002. FLAMES itself is a 'facility' consisting of a Nasmyth corrector for the full 25-arcmin field, the OzPoz fibre positioner, being built under contract by a consortium from the Anglo-Australian Observatory and Mount Stromlo and Siding Spring Observatory, the optical spectrometer Giraffe under construction by a team from Observatoire de Paris-Meudon (OPM) and a fibre link from the OzPoz positioner to UVES. A team from the Geneva and Lausanne observatories is providing the pipeline reduction software for Giraffe and another consortium (ITAL-FLAMES) from the observatories of Bologna, Cagliari, Palermo and Trieste is providing instrument control software and the pipeline for UVES fibre reduction. The complexity of this instrument and the need to introduce users to techniques for its full utilisation demanded an introductory workshop. The FLAMES Users Workshop (FUW) was held at ESO Garching on 9 and 10 July with a total of 60 contributors mostly from the ESO member states and including the UK and Australia. The aim was both to prepare the community for use of this complex facility and hopefully to encourage collaborations between participants as a result of the interaction.

The Workshop consisted of six sessions: an introduction to the instrument and its software; an outline of the observing plans by the instrument consortia for use of their guaranteed time; there were scientific sessions devoted to Galactic programmes, Local Group and extragalactic science; the workshop closed with a round-table discussion. We summarise the contents of the workshop and focus on a few highlights.

Instrument + Software

Luca Pasquini is the instrument scientist for FLAMES and outlined the components of the facility (see the FLAMES Web page for full details http://www.eso.org/instruments/flames/). Since the preliminary acceptance of the instrument modules will not take place before September 1 2001, then FLAMES cannot be offered for visitor or service observing in Period 69. The earliest that it will be offered will be in Period 70 with the call for proposals of March 2002. As well as the instrument capabilities, of most interest to potential observers are the constraints on observation. Owing to the need to obtain calibration data for each set-up, the number of spectrometer set-ups per night will be limited. Another limitation is the available time a given set-up can be retained without the field rotation and atmospheric refraction losses for the single object (1.2 arcsec diameter) fibres (MEDUSA mode) resulting in substantial throughput loss. A fundamental step is the fibre allocation to astronomical objects and the AAO 2dF fibre-allocation software has been adapted for FLAMES (FPOSS); Manuela Zoccali (ESO) described its use (see Fig. 1). This is an interactive tool to allow users to plan their observations. It will also be employed to set up the fibre assignments at the telescope for users in visitor mode.

Simone Zaggia described the progress made on the ESO 2.2-m WFI imaging survey of high priority fields for FLAMES. A number of fields in the Galactic Bulge and Halo, several globular and open clusters, Local Group galaxies including Sagittarius and the Magellanic Clouds have been selected. Service observations have been made and the EIS team have produced catalogues with the astrometric accuracy required to allow MEDUSA fibre assignments (typically ± 0.2 arcsec). These catalogues are publicly available and will provide for the needs of a substantial fraction of the community in their first use of this instrument. Full details can be found on the FLAMES Web page (http://www.eso.org/eis/) and also in the article on the EIS release in this edition of *The Messenger*. A first release of images and catalogues for some of the Pre-FLAMES fields has already been made.

Since many hundreds to thousands of spectra can be taken per night, then traditional interactive analysis will not be realistic and pipeline methods are mandatory. Following the example of the 2dF project, pipeline-reduced spectra will be delivered and André Blecha (Geneva) described the Geneva-Lausanne consortium Data Reduction Software (DRS). Going one step further than removal of the instrument signature, an Ancilliary Data Reduction software package (ADAS) is being written to catalogue spectra, such as providing radial velocities, line indices, etc. This task is being undertaken by a collaboration between the OPM and Geneva-Lausanne groups and Frédéric Royer outlined its scope. Andrea Modigliani (ESO), who is responsible for the UVES pipeline, described the pipeline software for extracting the eight spectra (of which one can be a simultaneous calibration fibre) when the red arm of UVES is fed by fibres from OzPoz.

The most successful wide-field multi-object spectrometer is the AAO 2dF, and Matthew Colless presented a very sobering 'Lessons Learned' talk. FLAMES is a simpler system than 2dF which has 400 fibres and a top-end configuration but it will still have to face the realities of working with fibres, such as breakages and recovery from problems with "lost" fibre buttons. Among the frequently made mistakes are too few guide stars or guide stars too faint, too few sky fibres being allowed (a good rule of thumb is (total no. fibres/2)$^{2/3}$), inadequate calibrations and over-optimism about precision of flux calibration.

Consortium Guaranteed Time Projects

The OHP team, led by François Hammer, are concentrating on a few topics on the theme of the stellar component to galaxies. From chemical abundances of individual stars in local dwarf galaxies, to globulars in nearby galaxies to kinematics in high-redshift galaxies, a variety of programmes were sketched with emphasis on using the 15 small Integral Field Units (mini-IFU's with 20 fibres and a field of 3.1 × 2.1arcsec) for collecting the light of small galaxies. Among the projects of the Geneva-Lausanne group are the presence of B stars in Magellanic Cloud clusters and velocity fields of galaxies acting as lenses to compare the lensing mass with the kinematic mass. Using the large integral field unit (ARGUS 10.4 × 7.8 arcsec field with 300 0.52-arcsec pixels) mapping of the kinematics and spatial variation of abundances in HII galaxies will be undertaken. Carla Cacciari outlined the projects of the ITAL-FLAMES consortium which cover topics from chemistry and dynamics of Galactic glob-

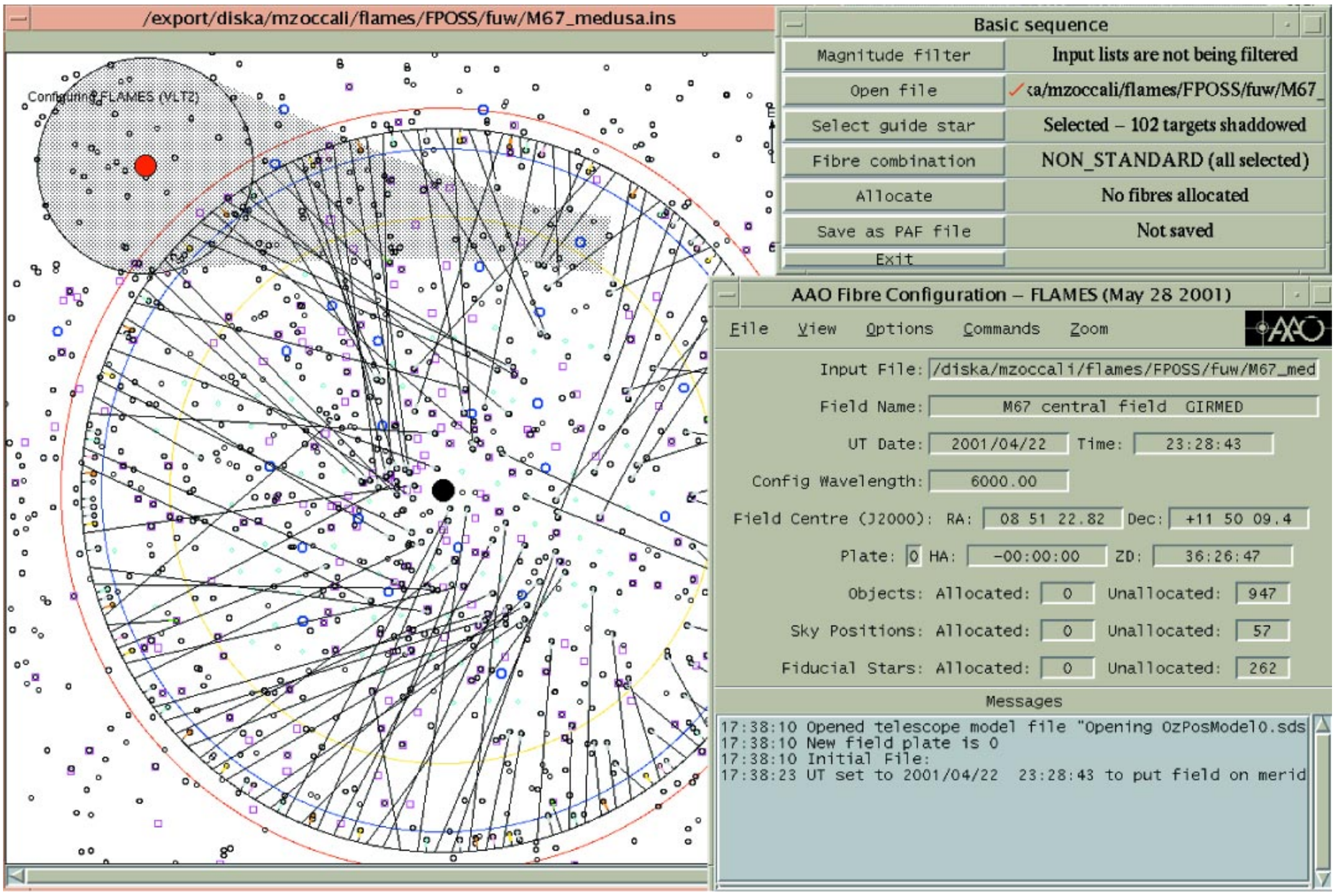

Figure 1: An example session of the FLAMES FPOSS fibre configuration software is shown. The star positions are taken from an input catalogue for the open cluster M67 and are indicated as small blue lozenges. The black circular area in the middle is the area obscured by ARGUS, and the blue circle traces the 25 arcmin diameter field. The shaded area at the top corresponds to the region obscured by the VLT guide probe. The VLT guide stars in the field are shown by large blue open circles. The catalogue stars assigned by fibres are shown as black open circles at the end of the solid lines, which represent the assigned fibres from the outer annulus. The fibres should be as close as possible to the radial direction (to minimise fibre bending). Squares correspond to positions suitable for sky fibres. The control panels can be seen to the right of the figure.

ular clusters and Local Group dwarf galaxies to the 3D mapping of the diffuse ISM from interstellar absorption lines. Many of these Guaranteed Time projects included collaborators who were at the workshop and the observations will form the foundations of large programmes.

Milky Way Projects

The power of FLAMES in its MEDUSA mode is to extend current spectroscopic studies of a few stars in particular environments to very many stars and to search for rare objects. A good example is the anomalous red giant branch detected in a WFI imaging campaign of Omega Cen (Pancino et al., *ApJ*, 534, L87, 2000) This survey has photometry of 230,000 stars and reveals a very thin anomalous red giant branch. Francesco Ferraro (Bologna) suggested that in a rather short observing time of about 20 hours the kinematics and metallicity of the ~ 700 stars in the giant and anomalous giant branches could be well characterised – a task almost inconceivable with a long-slit spectrometer. The relatively high spectral resolution of Giraffe allows accurate radial velocities of many stars to be collected, and John Danziger (Trieste) described a programme to study the internal kinematics of globular clusters in order to search for evidence for central black holes and the possible presence of dark matter. The nearby cluster NGC 6397, at 2.2 kpc, would be ideal to begin this programme. Ulli Heber (Erlangen) described a programme of spectroscopy of sub-dwarf B star binaries in the field and among globular cluster Horizontal Branch stars. Determining the stellar parameters of substantial numbers of these very hot stars would make a contribution to understanding the UV upturn in elliptical galaxies. By observing in the Galactic Bulge many spectra of these faint targets could be collected by FLAMES using the Giraffe spectrometer.

Obviously the Galactic Bulge, whose declination makes it ideally placed for Paranal, will dominate early use of FLAMES. However, only one talk concentrated on the Bulge, and Michael Rich (UCLA) made the case for large-scale studies to extend the currently available kinematics of ~ 1000 stars to much larger samples to allow full kinematic modelling of the Bulge. In addition to the kinematics, the alpha element to Fe ratio is a fundamental indicator of star-formation history and could be obtained for many K giants with FLAMES. The Magellanic Clouds is another region in which massive spectroscopy will have many benefits. Since pulsation and rotation, which regulate mass loss, in B stars is metallicity dependent, then observing in the SMC would allow the dependence on metallicity to be well determined. Dietrich Baade (ESO) advocated Giraffe observations to cover many B stars. Pierre North (Geneva) described how detached eclipsing binaries (DEB's) can provide light curves which can yield stellar masses to 1% and radii to 2%. By observing in the SMC up to 10 DEB's could be observed simultaneously (currently about 30 are known in the SMC with periods ~ 2 days); this programme would dramatically increase the small sample of about 50 stars (all in the Milky Way) with accurate masses. In addition to their role as distance indicators, stellar models can yield the ratio of enhancement of helium to metals (Delta Y/Delta Z), which is a key ingredient to Big Bang nucleosynthesis.

Local Group Projects

A number of talks concentrated on spectroscopy of Local Group dwarf galaxies. The Sagittarius dwarf, which is already well covered by the WFI pre-FLAMES survey and is well placed for the VLT, will be an obvious first target for FLAMES. Kinematics, mass-to-light ratio, abundance spread, alpha/Fe abundance ratio will yield to Giraffe spectra, and Piercarlo Bonifacio (Trieste) described a large programme to determine pipeline abundances of many elements for many stars using interpolation within grids of synthetic spectra. The UVES-fibre link would be employed to obtain R ~ 50 000 spectra to check the abundances from the lower-resolution (R ~ 10,000) Giraffe spectra. Eline Tolstoy (Groningen) showed that it is feasible to obtain spectra of every Red Giant star in LG dwarfs such as the Fornax dwarf spheroidal. Using UVES spectra of a few stars it was shown how Giraffe spectra at the Ca II triplet could be used to determine metallicities. A group of talks by Andreas Korn (Sternwarte Munich), Danny Lennon (ING, La Palma), Artemio Herrero (IAC), Norbert Przybilla (Sternwarte Munich) showed how O and B star spectra together with model atmosphere analysis can provide high quality abundances for large samples in many Local Group galaxies. The key is to extend the sample size – for example only 14 B stars outside the Galaxy have been spectroscopically well studied. In the SMC for example there are on average 70 B stars per FLAMES field, providing good multiplex advantage. The challenge will be to find techniques to side-step the very labour-intensive atmosphere modelling to allow reliable abundances of large numbers of early-type stars. The cooler stars in the Local Group were not forgotten and Vanessa Hill (ESO) showed how alpha/Fe element ratios from UVES spectra of Magellanic Cloud cluster giants had been used to constrain the star-formation history. Such studies can be extended with Giraffe spectra but using the higher-resolution UVES spectra to confirm the derived abundances.

Extra-Galactic Projects

For spectroscopy of unresolved sources in nearby galaxies (e.g. globular clusters, super-giant stars) the MEDUSA mode is usable but for more distant galaxies ARGUS is required to provide a global spectroscopic view. For high-redshift galaxies, the deployable mini-IFU's can provide full coverage of the sources. The kinematics of the globular cluster systems in galaxies to ~ 50 Mpc was outlined by Andre Blecha (Geneva). The MEDUSA mode can be used to collect spectra of hundreds of globulars in the outer regions whilst the ARGUS IFU is required for the high background and crowded central regions. A programme of Giraffe spectroscopy of emission-line dwarf galaxies was described by Véronique Cayatte (OPM) using ARGUS. Both kinematics and abundances can be derived for tidal dwarf galaxies and merger systems using the lowest resolution mode (R ~ 5000). Given a match of the IFU size to the object then many emitting clumps within larger halos can be studied. The 2dF project has had success by applying charge shuffling on the CCD together with co-ordinated telescope nodding to obtain the sky spectrum at exactly the same pixels on the detector as the object spectrum (called nod+shuffle). Whilst there is some loss due to the time spent on sky, very accurate sky subtraction can be obtained and near-optimal signal-to-noise is achievable. Piero Rosati (ESO) described the possible application of this technique to FLAMES MEDUSA mode.

Although galaxies at high redshift are small enough that spectra can be obtained with the MEDUSA mode, spatial resolution of sub-components, such as in merging systems, requires an IFU. Denis Burgarella (Marseille) described a programme to study spectra of Lyman-α emitting galaxies with FLAMES. There are as many as 100 Lyman-α emitters per unit red-shift in a single FLAMES field, making it an efficient survey device. The line profiles of the Lyman-α and other emission lines can be used to constrain the physics of the emission (infall, outflow). Daniel Thomas (Sternwarte Munich) showed that whilst dwarf galaxies dominate the galaxy statistics by number this is not reflected in observed number counts on account of the difficulties of detection. The limited number of spectra of these targets so far collected can provide ages, metallicities and formation time scale. A programme in nearby galaxy clusters was proposed using the 15 mini-IFU's to build up a large spectroscopic sample.

Panel Discussion

The Workshop closed with a one hour discussion session chaired by Danny Lennon (ING, La Palma). There was discussion about Science Verification, complementary observations, detectors and imaging surveys.

The dates for the commissioning of FLAMES are not yet fixed and there were questions whether observing time might become available in period 69. If so then this will be handled in the call for period 69 in March of 2002. Following successful commissioning of FLAMES, there will be Science Verification of all the modes with the aim to demonstrate the scientific capabilities of the instrument. This is handled by the VLT Programme Scientist (Alvio Renzini). SV data for all VLT instruments is public.

Since any given observing configuration may not allocate all MEDUSA fibres and may not use the link to UVES, the question naturally arose whether there might be set of complementary observations for standards. One suggestion was that sky spectra could be collected to form a library of template sky spectra which could be used when high signal-to-noise sky spectra are required. There is no plan to obtain extensive spectra of standards (radial velocity, spectrophotometric, etc.) during commissioning, other than that required to characterise the instrument, but this could be a possibility for SV. The suggestion was made that there could be calibration programmes which could piggy-back on service observations in order to build up libraries of standards. This was thought to be too complex in terms of scheduling and the OPC would better view proposals which were efficient in terms of using as much as possible of the FLAMES facility (e.g. Giraffe and UVES simultaneously).

Several attendees asked about the possibility of binning of the Giraffe CCD. This would aid in the detection of faint objects by reducing the readout noise penalty. Since allowing binning by one factor would entail a doubling of the number of calibration files, it may be contemplated for visitor mode. Nod and shuffle is not possible with the currently planned EEV CCD since the read-out direction is along the dispersion direction. However, there was a strong feeling that the possibility of applying nod-and-shuffle should be considered for the future in order for the facility to stay competitive. François Hammer (OPM) raised the question about installing a red sensitive CCD to allow competitive observation of high-redshift targets, since the currently selected EEV CCD is blue sensitive. This change-over is not foreseen for the early operation of the instrument but will be reviewed by the FLAMES Instrument Science Team; the current aim is to procure a CCD with high DQE in the blue and the red.

There were several calls for an extension of the Pre-FLAMES WFI imaging survey. The fields in the Magellanic Clouds are far from complete but the large area would be more efficiently covered by VST. It was clear from contributions at the Workshop that a number of groups are already embarked on imaging surveys with the aim of selecting targets for multi-object spectroscopy. The problems of performing astrometry did not appear to be problematic and there was no consensus that an astrometric pipeline be made available for WFI data. Based on experience of other observatories with input files for multi-object spectroscopy, some checking of the validity of the users' co-ordinates was recommended and could save wasted observations. There was discussion about selection of filters for VST when it replaces WFI. Although Sloan bands are broader than Johnson ones they are not much used in globular cluster photometry. A few users asked if Stromgren filters could be provided for VST but generally the Johnson set was preferred. If Sloan filters are used, then good standards must be provided to allow transformation to the standard system.

At the end of the two days of the Workshop, the conclusion was that there are many exciting observing programmes waiting to be done with FLAMES and that the user community is waiting with anticipation for the data avalanche. The Workshop was informal in the sense that no published proceedings are foreseen. However, many speakers contributed printed versions of their presentations and a bound copy is available on request from jwalsh@eso.org.

The Great Observatories Origins Deep Survey (GOODS)

R. FOSBURY and the GOODS Co-Is at ESO/ST-ECF
(J. BERGERON, C. CESARSKY, S. CRISTIANI, R. HOOK, A. RENZINI AND P. ROSATI)

What is GOODS?

In the tradition of the Hubble Deep Fields (HDF-N and HDF-S), the Great Observatories Origins Deep Survey (GOODS) is designed to push the performance of major modern observational facilities to their sensitivity limits. GOODS unites the deepest observations from ground- and space-based facilities at many wavelengths, and was selected in late 2000 as one of six Legacy programs for the Space Infrared Telescope Facility (SIRTF: the fourth of NASA's Great Observatories after Hubble, Chandra and Compton). The Legacy program is meant to "...maximise the scientific utility of SIRTF by yielding an early and long-lasting scientific heritage… producing data that will enter the public domain immediately". Under the leadership of the PI, Mark Dickinson at ST ScI, the programme will map two fields with SIRTF, one Northern one Southern, exceeding a total of 300 square arcmin. GOODS will produce the deepest observations with the SIRTF IRAC instrument at 3.6–8 microns, and at 24 microns with the MIPS instrument pending on-orbit demonstration of instrument performance relative to SIRTF Guaranteed Time observations, which will also survey these same fields at 70 and 160 microns. The depth will be such that ordinary L* galaxies will be detected in their rest-frame near-infrared light out to a redshift of 4 or beyond. Luminous starburst galaxies and AGN – even the obscured 'type 2' objects – will be seen beyond the current record redshift of ~ 6 if any lie in the fields. At the longest wavelength (24 microns), the mid-IR emission from starburst galaxies will be seen to a redshift ~ 2.5 (see Fig. 1).

The two fields selected are already amongst the most intensively studied areas of the deep 'extragalactic' sky: HDF-N (around 12.6 hr RA and +62 deg Dec) and the southern Chandra Deep Field (CDF-S: around 3.5 hr RA and –28 deg Dec). Both areas have already been imaged with the Chandra X-ray satellite with an exposure time of one million seconds, the deepest X-ray observations ever. CDF-S has been extensively observed by ESO telescopes: fairly deep optical and near-infrared imaging (SUSI2, SOFI, WFI) has been secured as part of the EIS project and further observations are planned, while several VLT programmes targeting this field have been executed (FORS deep imaging and multi-object spectroscopy and ISAAC deep imaging and spectroscopy). All these ESO data are already public or will soon be so.

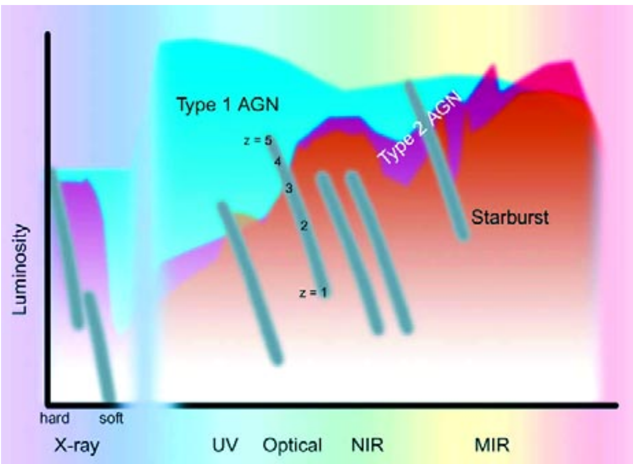

Figure 1: A schematic SED for Type 1 and Type 2 AGN and starburst galaxies showing the expected sensitivity limits as a function of redshift in a selection of GOODS bands.

In support of the SIRTF/GOODS programme, a wide range of other observations are being planned or have already been carried out which will, over the next four years, provide a public data-set covering the entire electromagnetic spectrum from X-ray to radio wavelengths at unprecedented depth. Ground-based telescopes, notably the VLT, Gemini-S and the CTIO 4-m for CDF-S, will be used to produce complementary imaging both at optical and near-infrared wavelengths. The principal role of the large telescopes, however, will be to provide follow-up spectroscopy with their new multi-object spectrographs. Time has already been allocated by ESO to begin a long-term programme using ISAAC for JHKs imaging of CDF-S. This requires some 32 pointings in each of the three filters (see Fig. 2). Some HST data are already available in these fields (most notably the HDF-N WFPC2 and NICMOS observations themselves), and new observations will be proposed for the new Advanced Camera for Surveys, scheduled to become available on HST early in 2002, for deep imaging in several filters to study galaxy morphology at a depth comparable to the HDF but over a much larger area.

To probe even higher energies than Chandra, XMM-Newton is currently being used to map the fields with its large effective collecting area and excellent spectral capabilities. The favourable K-correction and the superior high energy sensitivity of the new X-ray telescopes enables them to see most of the X-ray background as discrete sources. The combination of the spatial resolution of Chandra and the sensitivity and spectral response of XMM-Newton makes an extremely powerful diagnostic tool, even in the presence of heavy obscu-