OTELO :

Deep X-Ray and Optical Observations of the Groth Field

Miguel Sánchez-Portal[7], Jordi Cepa[1,2], Emilio Alfaro[3], Héctor Castañeda[1], Jesús Gallego[4], Jesús J. González[5], J. Ignacio González-Serrano[6], Ana Pérez-García[1],

and the OTELO collaboration

1: Instituto de Astrofísica de Canarias, La Laguna, Spain, 2: Departamento de Astrofísica, Universidad de La Laguna, Spain,
3: Instituto de Astrofísica de Andalucía, Granada, Spain, 4: Departamento de Astrofísica, Universidad Complutense de Madrid, Spain,
5: Instituto de Astronomía, Universidad Nacional Autónoma de México, México, 6: Instituto de Física de Cantabria (CSIC-Universidad de Cantabria, Spain,
7: Herschel Science Centre - INSA/ESAC, Madrid, Spain.

OTELO, the key OSIRIS science project, is a deep emission line object survey to be performed with the OSIRIS Tunable Filters, in selected atmospheric windows relatively free of sky emission lines. The observing strategy will allow studying a clearly defined volume of the Universe at a known flux limit. The total survey sky area is about 1 square degree, distributed in different low extinction fields with adequate angular separations. The survey will result in 3D data cubes covering 150+180 Å wavelength intervals at spectral resolution of ~700, from which spectra of the different sources will be retrieved. OTELO is not only unbiased, but its 5σ depth of 1×10^{-18} erg/cm²/s will make OTELO the deepest emission line survey to date.

SUMMARY

We present a preliminary analysis of public, deep (200 ksec.) Chandra/ACIS observations of three fields comprising the original Groth-Westphal strip (GWS), gathered from the Chandra Data Archive, combined with optical BVRI data from our broadband survey carried out with the 4.2m WHT at La Palma. Several distance-independent diagnostic tools are applied, including the X-ray to optical flux ratio (X/O) and hardness ratios (HR). We find that hardness ratios are mostly consistent with varyingly absorbed power laws, with photon index raging from Γ=1 to Γ=2. Based on X/O vs. HR diagnostics, around 40% of the X-ray sources with unique optical counterpart can be tentative classified as broad-line AGNs. Optical colors are consistent with those of early-type and spiral galaxies. Many sources present large V-I colors compatible with passively evolving elliptical model.

DATA PROCESSING

We processed the data Using the Chandra Interactive Analysis of Observations (CIAO) (http://cxc.harvard.edu/ciao/), v3.3.0.1 and Calibration Data Base (CALDB) v3.2.2.
Following the prescriptions from Nandra et al. (2005), we have applied the following steps:

1. Creation of a new Level 1 (L1) events file, removing the afterglow correction when appropriate and applying the `run_hotpix` tool to create a new bad pixel file. The L1 events file was then built using the `acis_process_events` procedure.
2. Filter for bad event grades (keeping only ASCA grades 0, 2, 3, 4, 6 and status=0) and apply Good Time Intervals (GTI) supplied by the pipeline process to generate a new Level 2 (L2) events file.
3. Run the `destreak` procedure to remove streak events.
4. The L2 files were filtered to restrict events with energy in the 0.5-8 keV range, since outside this interval the background is quite high relative to any source signal.
5. Periods of high background were removed analysing the light curves by means of the `analyze_ltcrv` script. Putative sources were previously removed running the `celldetect` script on each individual L2 file.
6. L2 events files corresponding to the same field were co-added by means of the `merge_all` script. Only chips 0, 1, 2, 3 were used, since ACIS-S detectors (chips 6 & 7) are far off-axis and separated from the FoV of the optical observations.
7. The resulting files were filtered to create several energy band events files: Full (0.5-7 keV), Soft (0.5-2 keV), Hard (2-7 keV), Vhard (4-7 keV). An additional band, Hard2 (2-4.5 keV) has been also computed to allow our data to be compared with our previous XMM-Newton results (Sanchez-Portal et al., 2006).
8. Unbinned effective exposure maps at a single energy representative of each band were created using the `merge_all` procedure: 2.5 keV (full), 1 keV (soft), 4 keV (hard), 3 keV (hard2) 5.5 keV (vhard).

PROPERTIES OF THE SOURCES

Since photometric redshifts are not currently available our analysis should limit to distance-independent parameters. A diagnostic that has revealed very promising to perform a rough classification of X-ray emitters (see for instance Della Ceca 2004) is depicted in the figure below (left), where the HR1' ratio is combined with the 0.5-4.5 keV to optical R-band flux ratio. A set of 119 Chandra sources with unique optical counterpart and HR1' ≠ 0 have been depicted. A set of 43 XMM-Newton sources have been also included for comparison. The dashed-dotted line corresponds to X/0=0.1, typical of coronal-emitting stars, normal galaxies and heavily absorbed AGNs. 3 (5) of Chandra (XMM) sources lie below this line, being likely either normal galaxies or Compton-thick AGNs (one of them is probably a star since its stellarity index as given by Sextractor is nearly 1). The dashed-line rectangular box encloses the region containing 85% of the optically classified broad-line AGNs in the XMM-Newton Bright Source Sample (BSS;Della Ceca 2004). 49, i.e. 41% (29, 67.4%) of the Chandra (XMM) sources fall within this area and can be roughly classified as QSO1/Sy1. Objects with harder HR and high X/O can be tentative classified as QSO2/Sy2.

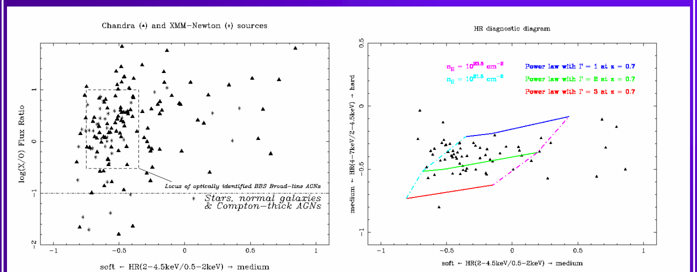
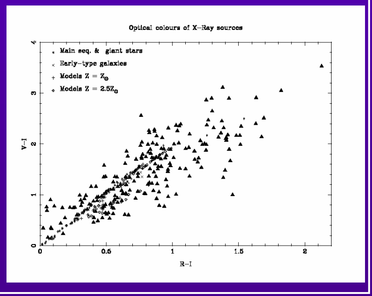


Figure above (right) shows the HR1' vs. HR2' diagnostic diagram, along with a control grid built varying the power law photon index and the absorption n_H column density. It can be seen that most sources can be properly fitted by a power law with photon index between 1 and 2 and different absorption values.

The optical colours of the X-ray sources are depicted in the right figure . Generally, there is a good agreement between these colors and those of stars, early-type and spiral galaxies . There is a large number of sources with V - I > 2, compatible with those of a passively - evolving elliptical model (Kodama & Arimoto, 1997) with z >~ 0.6



OBSERVATIONS

Chandra has observed three consecutive fields centered at the original HST GWS using the ACIS-I instrument. All datasets have been gathered from the Chandra Data Archive (http://asc.harvard.edu/cda/) using the Chaser tool. PI of all the retrieved observations is K. Nandra. Total exposure time in each field is about 200 ksec. Field size covered by ACIS-I chips 0,1,2 & is 16.9'×16.9'. Center-of-field coordinates are (α=14:15:22.5, δ=+52:08:26.4), (α=14:16:24.5, δ=+52:20:02.6), (α=14:17:43.6, δ=+52:28:41.2).

SOURCE DETECTION

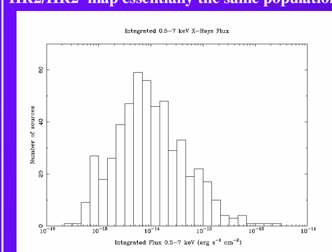
We have applied the CIAO `wavdetect` Mexican-Hat wavelet source detection program to all bands (full, soft, hard, hard2 and vhard) in the three fields. A significance threshold of 1×10^{-6} has been used in the full and soft bands and 2×10^{-6} in the hard, hard2 and vhard bands. According to the CIAO documentation,we expect no more than 1 (2) spurious detections per ACIS chip in the full/soft (hard/hard2/vhard) bands. Different wavelet scales, ranging from 1 to 16 pixels were applied.

The source detection procedure yields nearly 700 X-ray emitters and is summarized in the table on the right.
We have computed a set of hardness ratios:

```
HR1  = (hard - soft)/(hard + soft)
HR1' = (hard2 - soft)/(hard2 + soft)
HR2  = (vhard - hard)/(vhard + hard)
HR2' = (vhard - hard2)/(vhard + hard2)
```

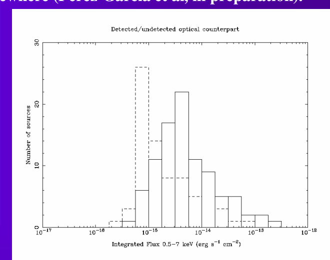
It has been found that the sets HR1/HR1' and HR2/HR2' map essentially the same populations.

Condition	# sources
Detected in soft, hard & vhard bands	108
Detected only in soft & hard bands	103
Detected only in hard & vhard bands	27
Detected only in soft & vhard bands	1
Detected only in soft band	299
Detected only in hard band	64
Detected only in vhard band	13
Detected only in full band	70
Total	685

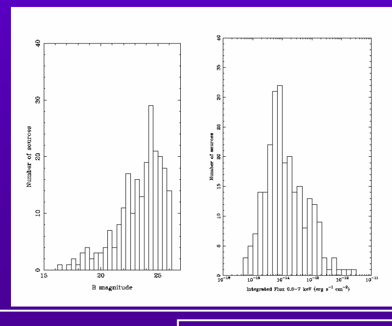


From the table above we can conclude that nearly 75% of the total sources are detected in the soft band (75%) while only 15% of the X-ray emitters are detected only in the hard or vhard bands. The remaining 10% is only detected in the full band. The source flux distribution is shown in the left plot.

Optical source detection is described elsewhere (Perez-Garcia et al, in preparation).



The X-ray source catalog has been matched against our WHT optical source catalog using a circular 2" search box. 280 unique detections and 51 multiple detections are achieved. Therefore, an optical counterpart is not found for about half of the X-ray sources. This can be at least partially explained by observing the flux distribution of sources with and without optical counterpart (solid and dashed lines in the right plot, respectively). The median flux value of the later distribution is 1.2×10^{-15} erg/s/cm². Assuming X/O ≈ 1, R ≈ 24 mag. At that magnitude our optical sample is possibly not complete. This could be also suggested by the shape of the magnitude distribution of optical counterparts depicted in the left plot on the figure below:



Left: Magnitude distribution of the optical counterparts.
Right: X-ray flux of the sources with optical counterpart

REFERENCES
Della Ceca, R., et al. 2004 A&A 428, 383
Kodama, T. & Arimoto, N. 1997 A&A 320, 41
Nandra, K., et al. 2005 MNRAS 356, 568
Pérez-García, et al., 2006 in preparation
Sánchez-Portal et al., 2006, ESA SP-604, 841