X-ray Spectra of Seyfert 1 Galaxies

(progress report)

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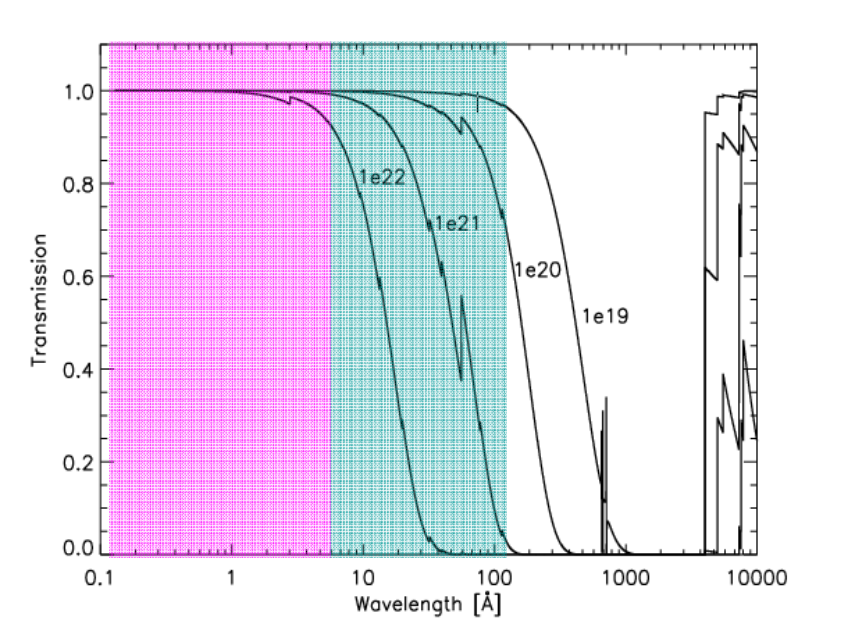
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European Space Astronomy Centre - European Space Agency

Seyfert 1 in X-rays

X-emission: inverse-Compton scattering of UV/optical continuum photons coming from the accretion disk produced in their interaction with more energetic electrons located in a corona surrounding the disk

soft X-rays	hard X-rays	γ-rays
0.1 – 2 keV	2 – 100 keV	> 100 keV

- absorption produced by Galactic material modify the X-ray spectrum



For Hydrogen column densities of about 10^{20} cm^{-2} the transmission of the neutral Galactic material decrease significantly

(Kinkhabwala, 2003)

Seyfert 1 in X-rays

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soft X-rays	hard X-rays	γ-rays
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- absorption produced by Galactic material modify the X-ray spectrum
- characteristics of the continuum radiation:
  - 2 to 20 keV most spectra can be characterised with a power law in the form

    $E^{-\Gamma}$ (photons s^{-1} keV^{-1}) $\Gamma \approx 1.9$
  - about a 50% shows an excess of the continuum emission in the soft X-rays

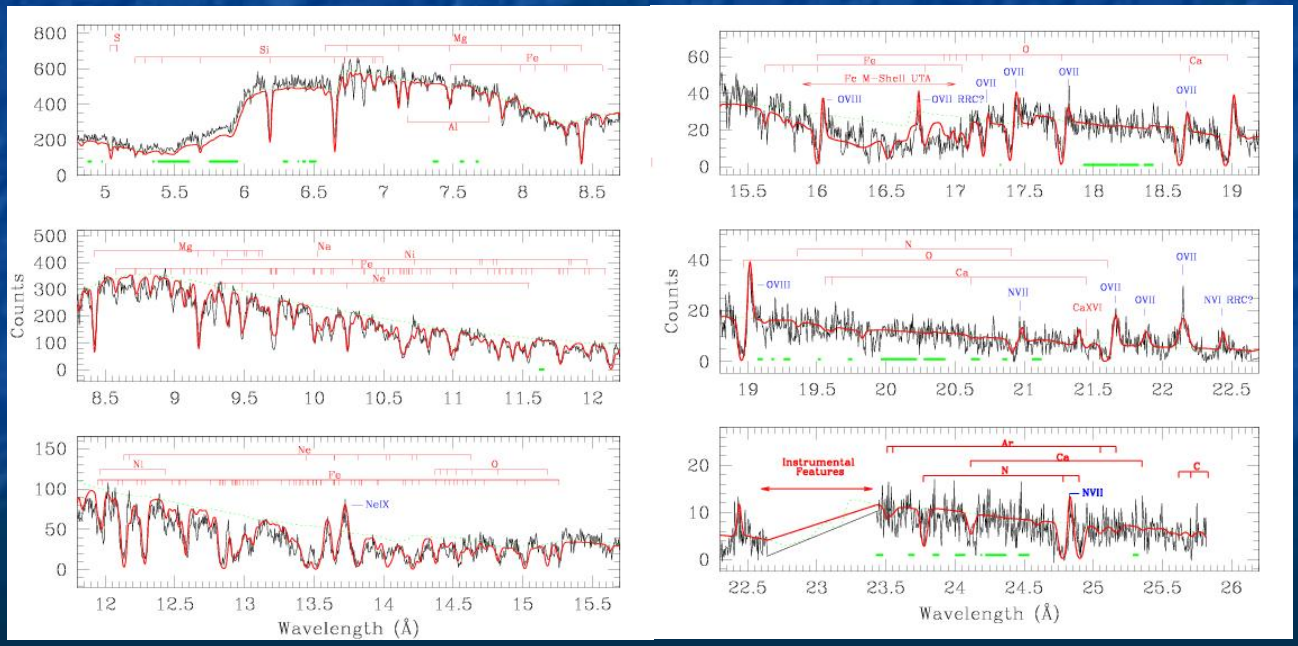
Seyfert 1 in X-rays

X-emission: inverse-Compton scattering of UV/optical continuum photons coming from the accretion disk produced in their interaction with more energetic electrons located in a corona surrounding the disk

soft X-rays	hard X-rays	γ-rays
0.1 – 2 keV	2 – 100 keV	> 100 keV

0.5 – 3 keV (4-25 Å):

transitions which involve the O, Mg, Si and S K-shell (n=1) , and the Fe and Ni L-shell (n=2)



(NGC 3783, Krongold, 2003)

Absorptions of heavy elements produced in gas clouds partially ionized (warm absorbers)

Objectives

Analyse soft X-ray spectra (6 – 30 Å) of a sample of Seyfert 1 galaxies observed with the XMM-Newton satellite

- Identify possible emission and absorption features
- Characterise the continuum emission
- To infer the physical conditions of the gas in which the absorptions and emissions are produced

Instrumentation

We have analysed data from the RSG spectrometers on board XMM-Newton satellite

- range: 5 – 38 Å (0.35 – 2 keV)
- 1st order spectral resolution: 57 – 70 mÅ
- accuracy in the wavelength calibration: ± 8 mÅ

Targets selected

HE 1143-1810 Mkn 110 CTS A08.12 ESO 359 G19

- Brights in X-rays: more than 0.85 counts/s in the ROSAT Bright Source Catalogue (Voges et al. 1999.A&A.349.389)

counts/s - ROSAT (0.1 - 2.4 keV)			
HE 1143-1810	Mkn 110	CTS A08.12	ESO 359-G19
3.29	1.69	1.70	4.08

- With low neutral Galactic Hydrogen content in the line of view ($nH \sim 10^{20}$ cm^{-2})

X-rays data

	nH (10^{20} cm^{-2})	Obs Date (2004)	z	T_{exp} (s)	counts/s RGS 1	RGS 2
HE 1143-1810	3.40	08 jun	0.033	31000	0.90 ± 0.01	0.99 ± 0.01
Mkn 110	1.42	15 nov	0.035	47000	0.78 ± 0.01	0.87 ± 0.02
CTS A08.12	4.07	30 oct	0.029	46000	0.08 ± 0.01	0.10 ± 0.01
ESO 359-G19	1.02	09 mar	0.056	24000	0.03 ± 0.01	0.03 ± 0.01

HE 1143-1810 and Mkn 110 spectra have a moderate number of counts

CTS A08.12 and ESO 359-G19 spectra have low number of counts

spectra with 3400 channels of spectral information (~60 mÅ per channel)

Spectral analysis

What we must never forget

We always observe is the source spectrum convolve with the instrumental response

Information is taken in a discrete way (and in a limited number of channels)
(we have spectra with 3400 channels of spectral information,~60 mÅ per channel)

Procedure

We propose a model for the emission of the source, convolve it with the instrumental response, and we compare it with the observed spectrum

Statistic Method

To determine how similar are the modelled and the observed spectra of the source

- merit function to minimise: chi-square
- goodness of the fit: probability that the function chi-square takes a value greater by chance than the calculated one

Models applied

Galactic absorption (xspec & Sherpa)

$$A(E) = \exp\left(- nH \times \sigma(E) \right)$$

Power law (xspec & Sherpa)

$$A_p(E) = K_p \left(\frac{E}{1\,\mathrm{keV}} \right)^{-\Gamma}$$

Intrinsic absorption (xspec)

$$A_z(E) = \exp\left(- nH \times \sigma(E[1+z]) \right)$$

Gaussians (xspec)

$$A_g(E) = K_g \, \frac{1}{\sqrt{2\pi}\,\sigma^2\,(1+z)} \, e^{-\frac{(E\,(1+z)-E_L)^2}{2\,\sigma^2}}$$

Warm absorbers (Sherpa)

PHASE Model

(Y. Krongold, private communication)

searching signatures of w.a.

We tested the presence of warm absorbers using the PHASE model (PHotoinised Absorption Spectral Engine, 2003 Krongold et al.). It is a model that reproduce UV and X-rays lines originated on ionised plasmas.

For the absorber material we obtained in all cases:

- ionization parameters: **$U \approx 0.001$ (or lowers)**
- column densities: **$nH \sim 1.8 \times 10^{19}\ cm^{-2}$ (or lowers)**

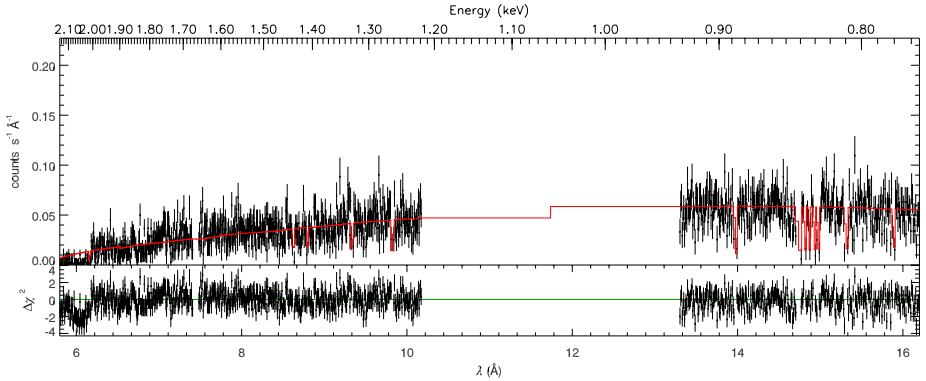
We didn't find signatures of warm absorbers in the spectra analysed

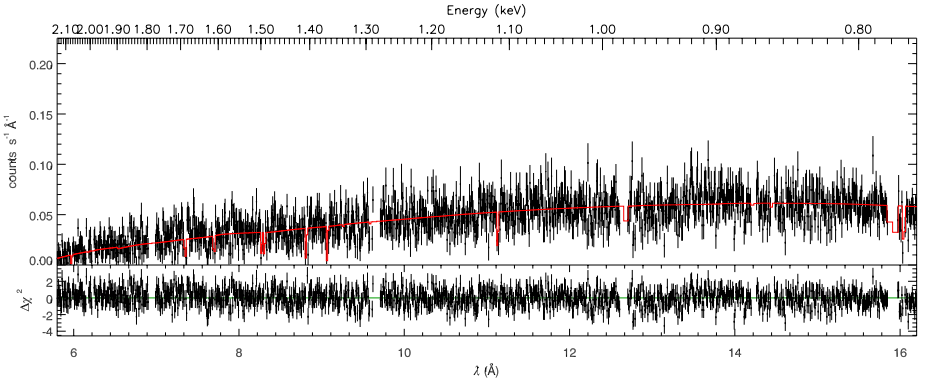
Model for HE 1143-1810

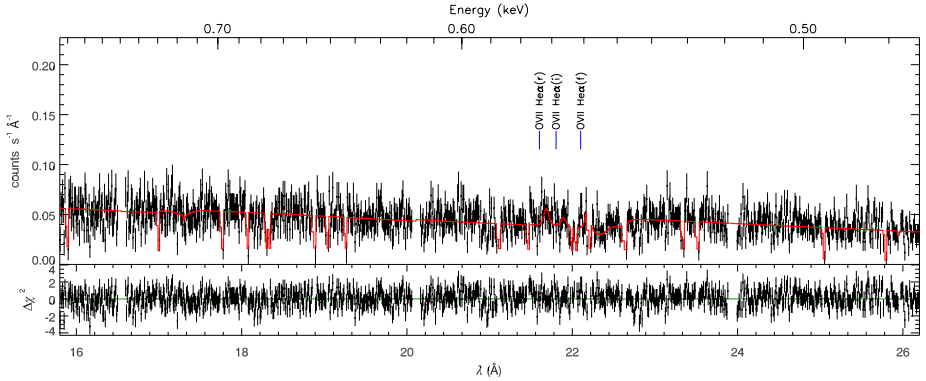
- Model A:
  Galactic absorption * power law
- Model C:
  Galactic absorption * (power law + OVII lines)

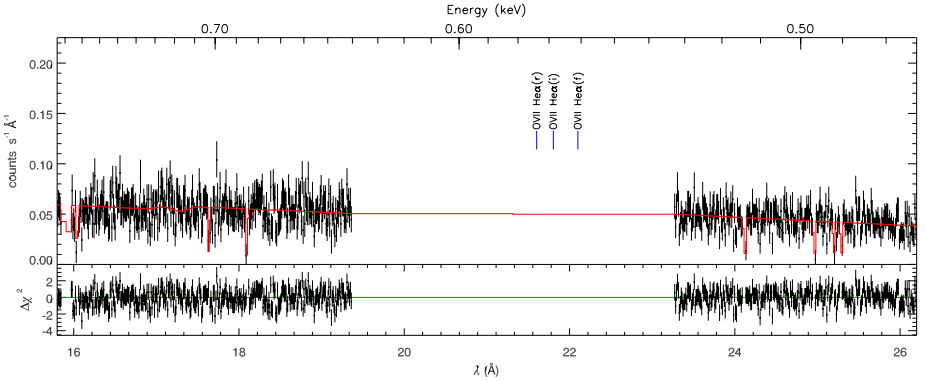
	nH_{Gal} (10^{20})	Γ	K_p (10^{-4})	nH_{intr}	χ^2/dof	$Q(\chi^2/dof)$
Model A	3.40 (fix)	2.42±0.02	120±1	---	773.8/722	0.09
Model C	3.40 (fix)	2.42 (fix)	120 (fix)	---	5074.6/5219	0.92
	OVII(r)	$K_{OVII(r)}$	OVII(i)	$K_{OVII(i)}$	OVII(f)	$K_{OVII(f)}$
	$0.5717_{\pm 0.005}$	$6.2^{+3.7}_{-2.9}$	0.5663	$3.4^{+4.0}_{-3.1}$	0.5587	$9.7^{+5.6}_{-7.2}$

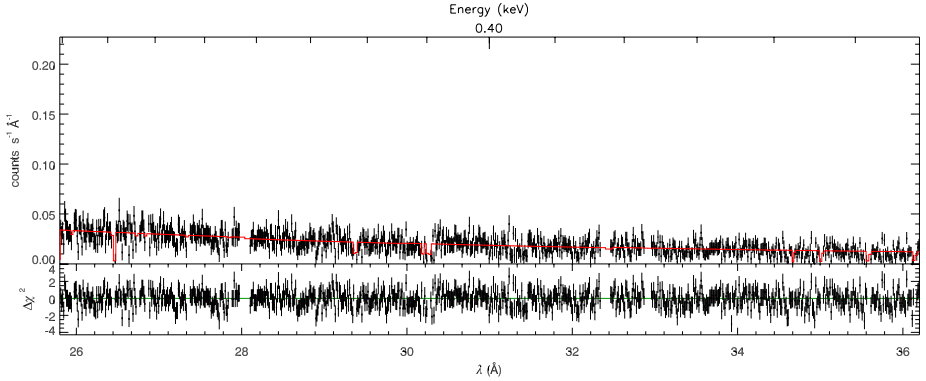
Model C & HE 1143-1810

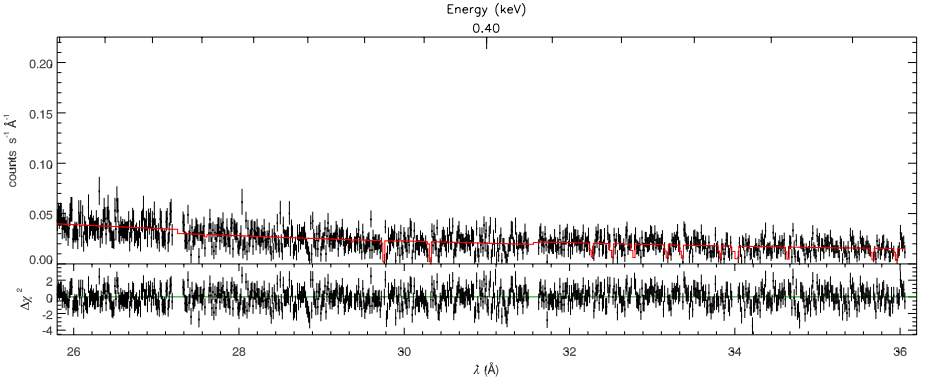










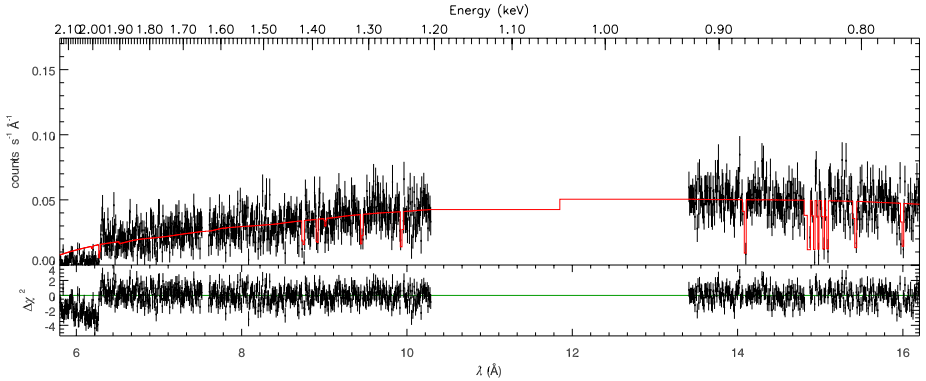


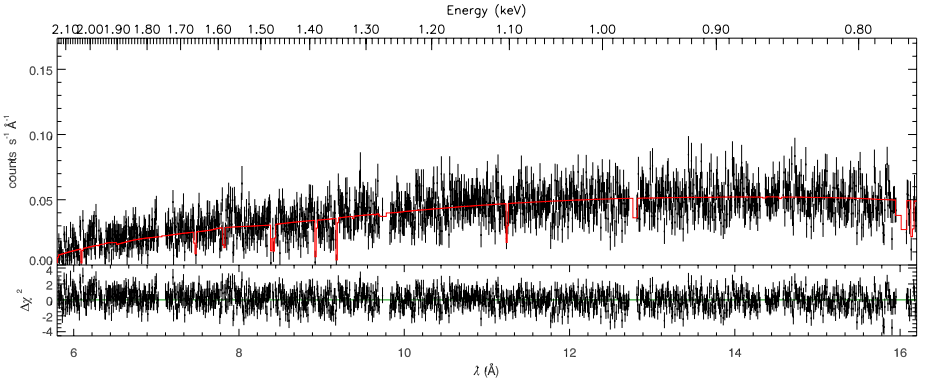
Model for Mkn 110

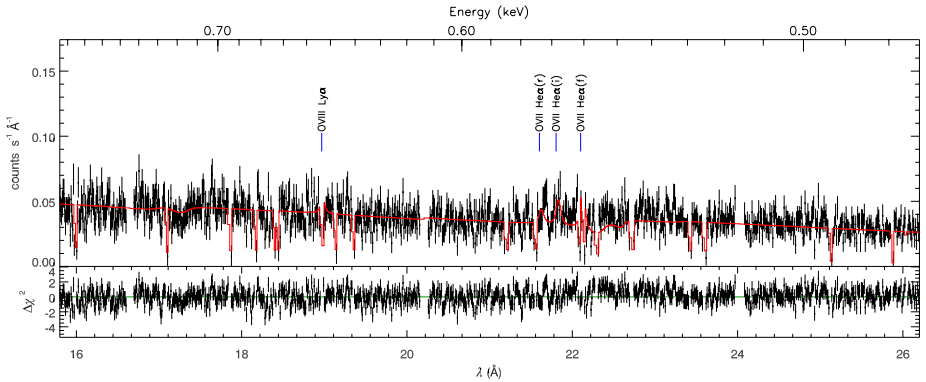
- Model B:
  Galactic absorption * intrinsic absorption * power law
- Model D:
  Gal abs * intr abs * (power law + OVII & OVIII lines)

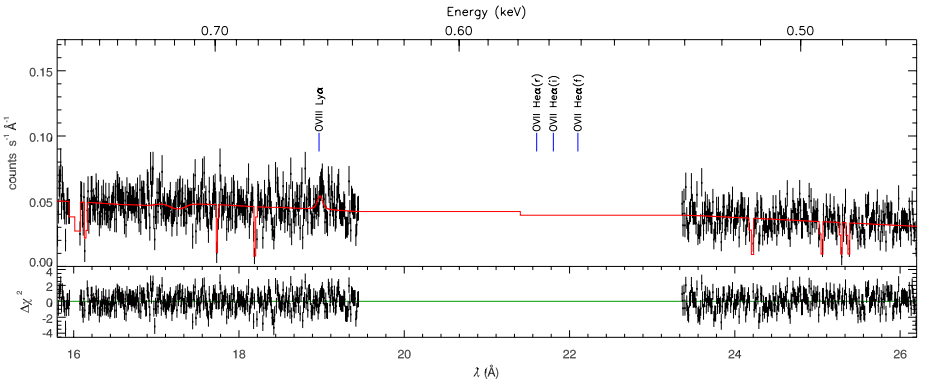
	nH_{Gal} (10^{20})	Γ	K_p (10^{-4})	nH_{intr} (10^{20})	χ^2/dof	$Q(\chi^2/dof)$
Model B	1.42 (fix)	2.25±0.02	103.6±1	1.1±0.3	3389.9/2756	$< 10^{-5}$
Model D	1.42 (fix)	2.25 (fix)	103.6 (fix)	1.1 (fix)	5074.6/5219	0.0014
	OVII(r)	$K_{OVII(r)}$	OVII(i)	$K_{OVII(i)}$	OVII(f)	$K_{OVII(f)}$
	$0.5734_{\pm 0.003}$	$3.6^{+2.7}_{-1.8}$	0.5680	$6.8^{+2.5}_{-2.3}$	0.5604	$9.2^{+2.7}_{-3.7}$
	OVIII (Lyα)	K_{OVIII}				
	$0.6530^{+0.0136}_{-0.0008}$	3.5±1.5				

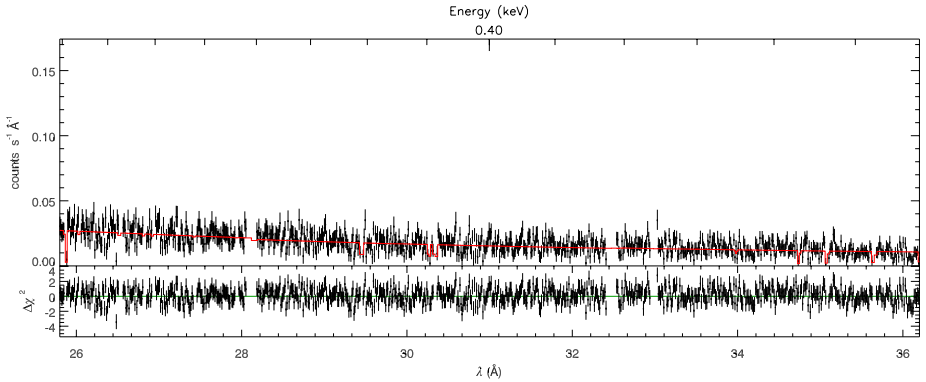
Model D & Mkn 110

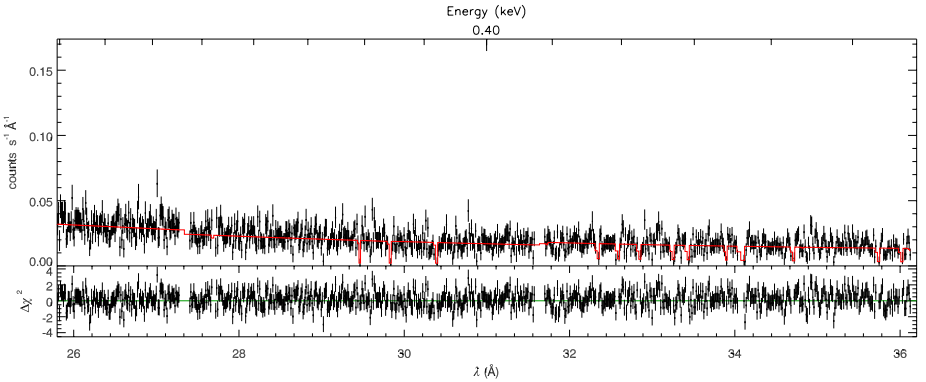












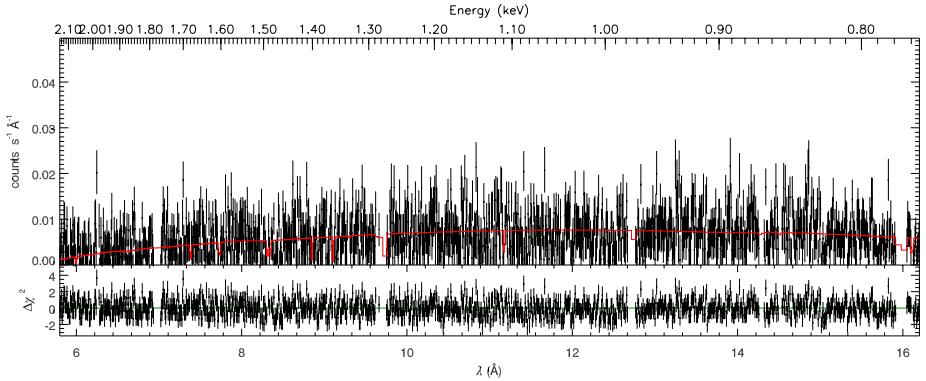
Model for CTS A08.12

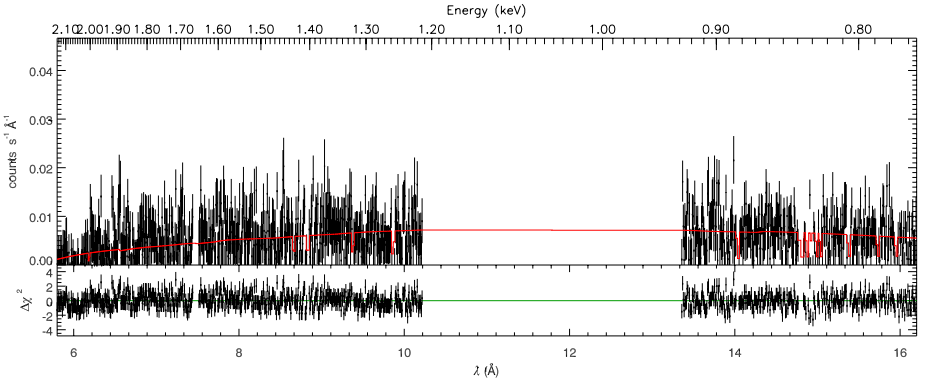
- Model B:
  Galactic absorption * intrinsic absorption * power law
- Model E:
  Galactic abs * intrinsic abs * (power law + OVIII Lyα line)

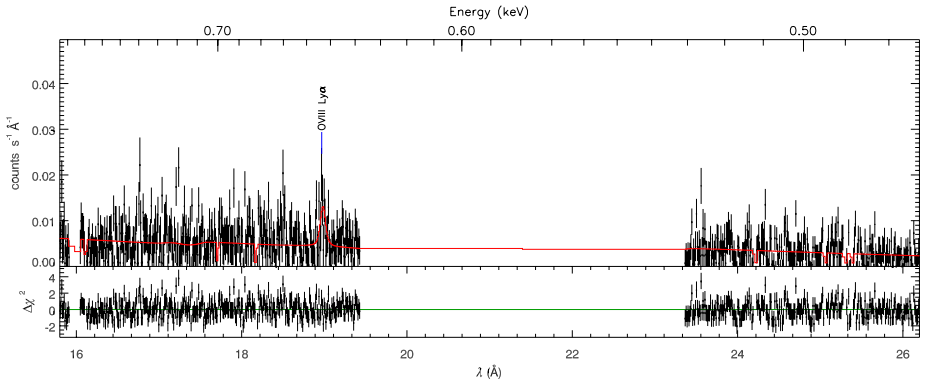
	nH_{Gal} (10^{20})	Γ	K_p (10^{-4})	nH_{intr} (10^{20})	χ^2/dof	$Q(\chi^2/dof)$
Model B	4.07 (fix)	2.39±0.17	$22.1^{+1.7}_{-1.6}$	12.2±0.2	5041.9/5192	0.93
Model E	4.07 (fix)	2.39±0.06	22.3±0.5	12.5±0.1	5010.4/5190	0.96
	OVIII (Lyα)	K_{OVIII}				
	$0.6531^{+0.0072}_{-0.0001}$	5.5±1.6				

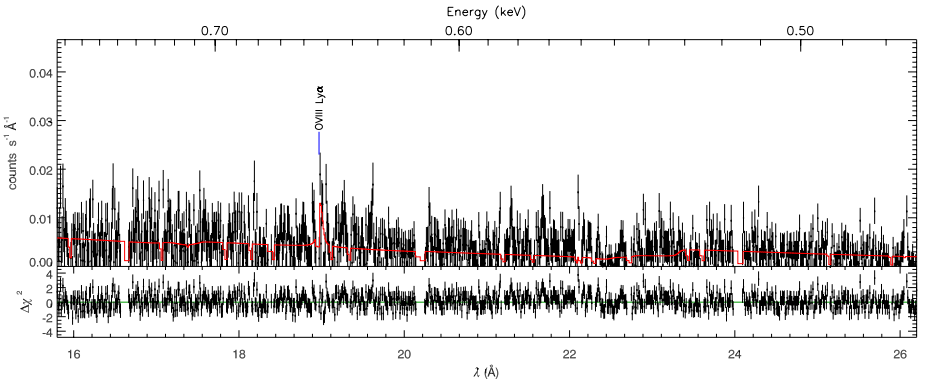
Ftest: F = 16.33 prob < 10^{-7}

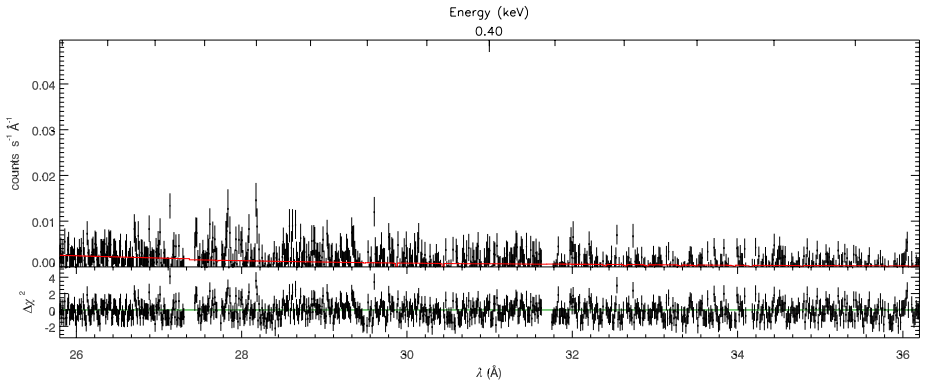
Model E & CTS A08.12

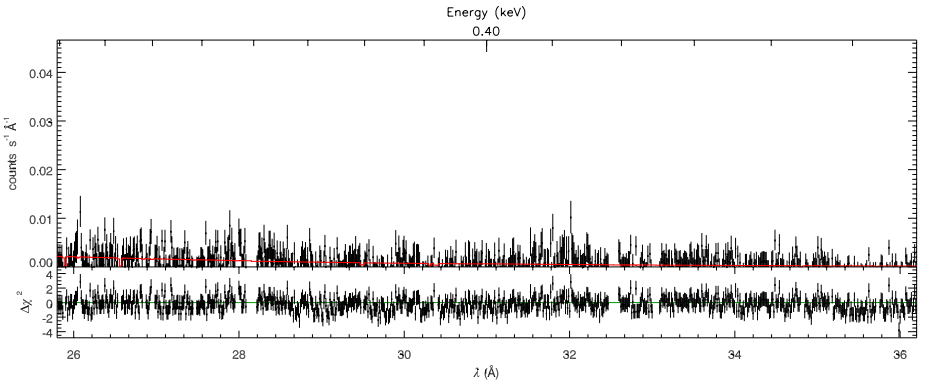












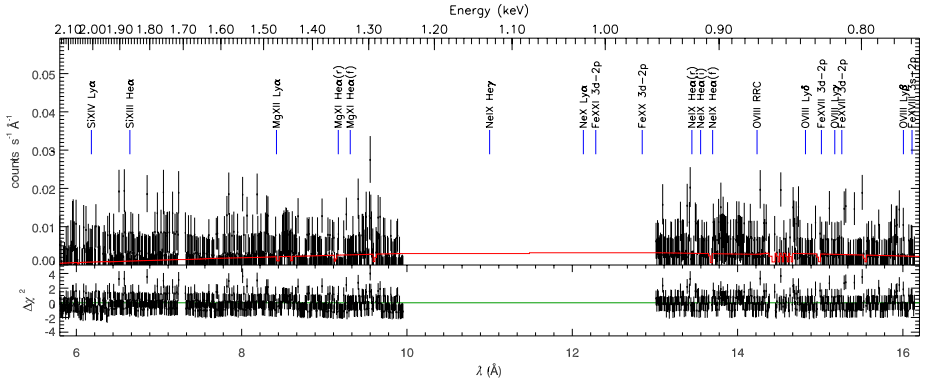
Models for ESO 359-G19

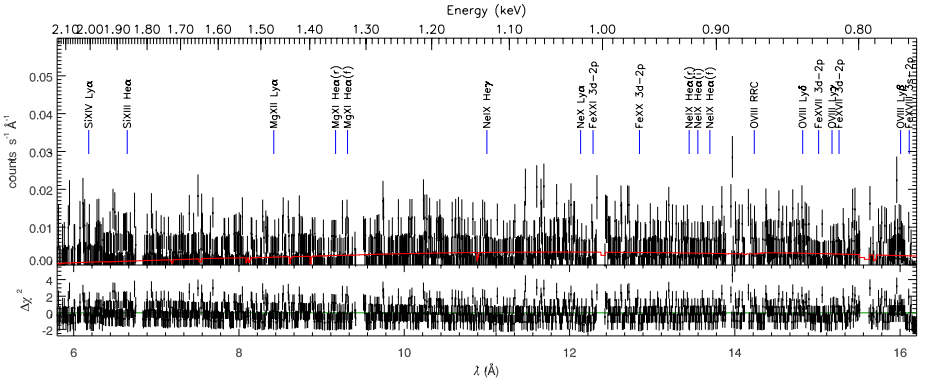
- Model A:
  Galactic absorption * power law
- Model B:
  Galactic absorption * intrinsic absorption * power law

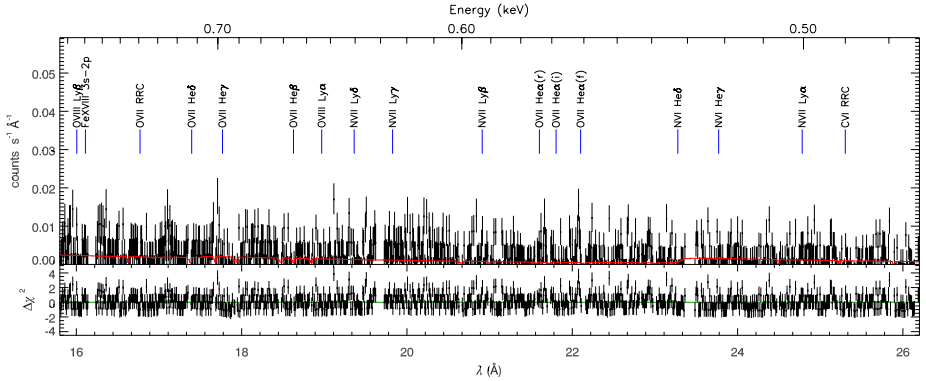
	nH_{Gal} (10^{20})	Γ	K_p (10^{-4})	nH_{intr} (10^{20})	χ^2/dof	$Q(\chi^2/dof)$
Model A	1.02 (fix)	1.21±0.14	5.6±0.4	---	5220.8/5218	0.49
Model B	1.02 (fix)	$3.75^{+0.61}_{-0.63}$	$15.2^{+4.3}_{-3.4}$	35.9±9.3	5142.1/5217	0.77

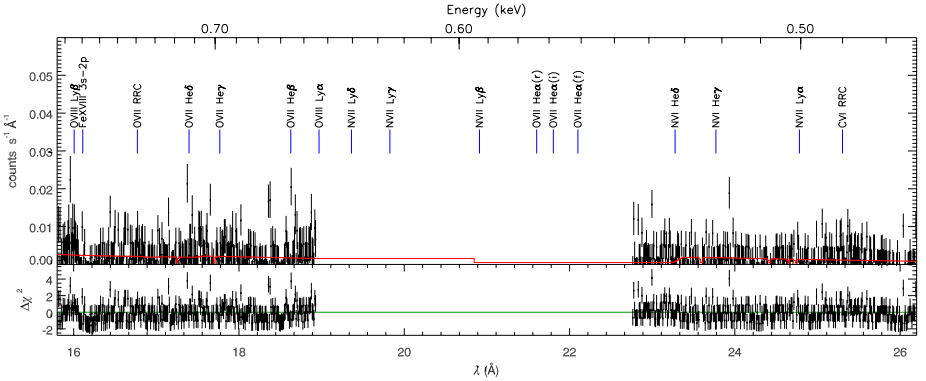
Ftest: F = 79.87 prob < 10^{-10}

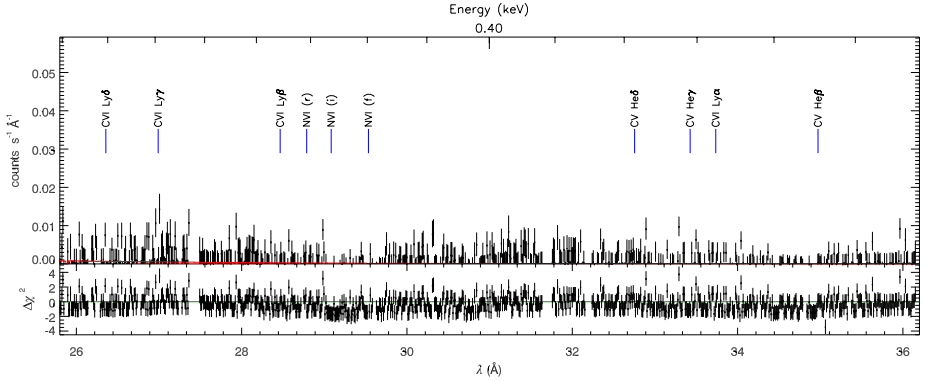
Model B & ESO 359-G19

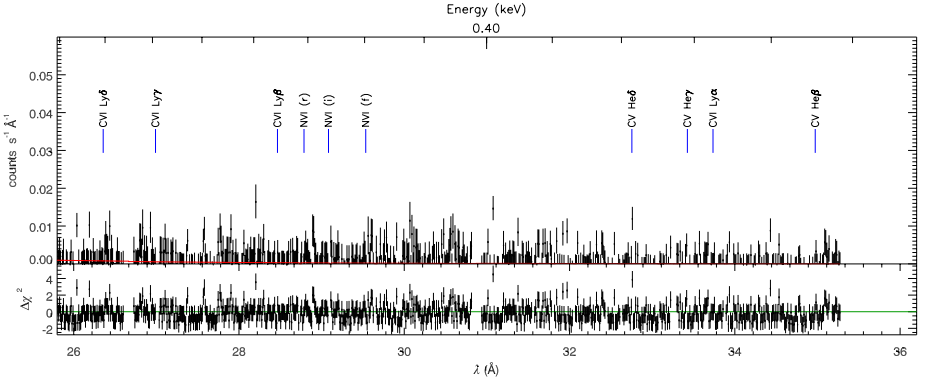












Analysis of the fittings

We have modelled the spectra adding components progressively

- continuum

A ≡ power law & Galactic absorption → HE

B ≡ A & intrinsic absorption → Mkn, CTS, ESO

index in soft X-rays:

$\Gamma_{0.35\text{-}2keV}$: 2.42 ± 0.02, 2.25 ± 0.03, 2.4 ± 0.2, 3.8 ± 0.6

Piconcelli et al.(2005): $\Gamma_{0.3\text{-}2keV}$ 2.5 y 3.4

"X-rays soft excess" (?)

Analysis of the fittings

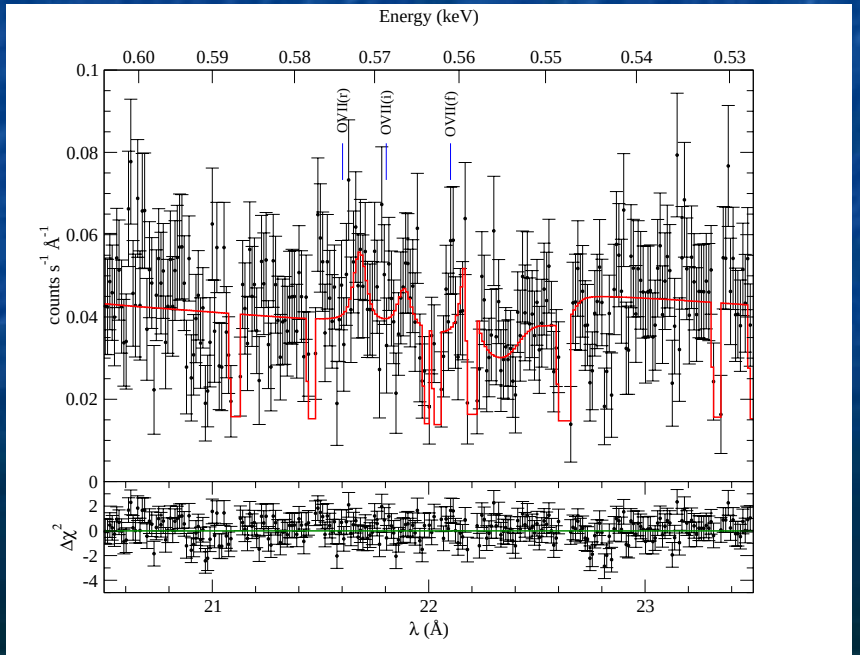
- lines

C ≡ A & OVIIT → HE 1142-1810

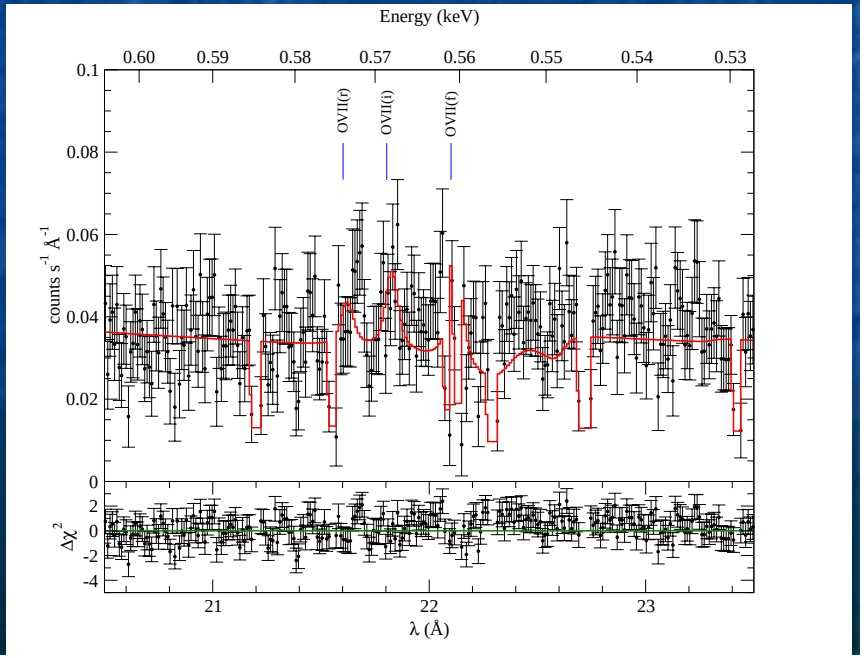
D ≡ B & OVIIT & Lyα OVIII → Mkn 110

E ≡ B & Lyα OVIII → CTS A08.12

HE 1143-1810



Mkn 110



Analysis of the results

RGS fluxes (10^{-12} erg cm^{-2} s^{-1})

	HE 1143-1810	Mkn 110	CTS A08.12	ESO 359-G19
0.35-0.5 keV	6.56±0.01	5.51 ±0.01	0.30 ±0.02	$0.12^{+0.02}_{-0.04}$
0.5-2.0 keV	29.91 ±0.08	21.36 ±0.05	3.0 ± 0.2	$1.1^{+0.2}_{-0.5}$

ROSAT fluxes (10^{-12} erg cm^{-2} s^{-1}) (Grupe et al. 2001)

	HE 1143-1810	Mkn 110	CTS A08.12	ESO 359-G19
0.2-2.0 keV		14 (Oct 1990) 55 (nov 1991)		22 (Aug 1991)
0.35-2.0 keV		29 (nov 2004)		1.3 (Mar 2004)

Intrinsic variability of the sources (?)

Analysis of the results

RGS luminosities (10^{43} erg seg^{-1})

	HE 1143-1810	Mkn 110	CTS A08.12	ESO 359-G19
0.35-0.5 keV	2.5	2.1	0.4	3.3
0.5-2.0 keV	7.0	6.7	1.0	3.5

same order than that found for the Seyfert 1 galaxies observed by ROSAT and ASCA

Rush et al. (1996) y George et al. (1998)

Analysis of the results

Line fluxes (10^{-14} erg cm^{-2} seg^{-1})

	HE 1143-1810	Mkn 110	CTS A08.12	ESO 359-G19
OVII(r)	$5.7^{+3.4}_{-2.7}$	$3.3^{+2.5}_{-1.7}$	---	---
OVII(i)	$3.1^{+3.7}_{-2.8}$	$6.2^{+2.3}_{-2.1}$	---	---
OVII(f)	$8.7^{+5.0}_{-6.4}$	$8.2^{+2.4}_{-3.3}$	---	---
OVIII(Lyα)	---	3.7 ± 1.5	5.8 ± 1.7	---

	HE 1143-1810		Mkn 110	
$R(n_e)$	2.8	$^{+2.0}_{-1.8}$	1.3	$^{+1.4}_{-1.3}$
$G(T_e)$	2.1	$^{+1.7}_{-1.6}$	4.3	$^{+3.4}_{-2.5}$

Gabriel & Jordan (1969):

$R(n_e) = (f+i)/ r$

$G(T_e) = f/ i$

Very great errors in R y G $\Rightarrow$ we cannot determine n_e y T_e

What's next?

- We will analyse the rest of the information available in the data of the XMM-Newton
- We will add more sources with similar characteristics to the sample
- We will model the spectra with some code of spectral synthesis in order to determine the physical properties of the gas and the origin of the soft X-ray radiation

Targets selected

HE 1143-1810

α_{2000}	δ_{2000}	z	D (Mpc)	m_v	B-V	U-V
$11^h\ 45^m\ 35.76^s$	-18° 27´ 28.23”	0.033	132	14.29	0.34	-0.99

Mkn 110

α_{2000}	δ_{2000}	z	D (Mpc)	m_v	B-V	U-V
$09^h\ 25^m\ 12.91^s$	+52° 17´ 12.9”	0.035	140	16.4	0.62	-0.51

CTS A08.12

α_{2000}	δ_{2000}	z	D (Mpc)	m_v	B-V	U-V
$21^h\ 31^m\ 58.55^s$	-33° 43´ 43.2”	0.029	116	15.45	0.63	---

ESO 359 G19

α_{2000}	δ_{2000}	z	D (Mpc)	m_v	B-V	U-V
$04^h\ 04^m\ 56.26^s$	-37° 11´ 36.8”	0.056	224	15.16	0.53	---