Iron Line Diagnostics in Compact objects
What do we learn with XMM?

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Why the Iron lines?

X-ray source

absorption

reflection

Cold optically thick material

Iron is the element with the highest production yield

Fluorescence yield

Abundance

Observed for the first time in Seyfert galaxies with Ginga

(Pounds et al. 1990; Piro et al. 1990)

EPIC-XMM-Newton consortium meeting: Five years of Science with XMM-Newton
What did we know before XMM?

Observations of iron line with ASCA showed that relativistic iron lines appeared to be common in AGNs (Nandra et al. 1997, Reynolds 1997)

(Fig. from J. Reeves)
Signature of gravitational effects produced by a compact object

Special and general relativity effects modify the line profile
(e.g. Fabian et al. 1989, Laor 1991, Matt et al. 1992)

Measure of the black-hole spin!
The Famous case of MCG-6-30-15

First AGN where a broad line was detected (Tanaka et al 1995)

Confirmed by SAX (which cover the 0.1-200 keV band) a few years latter

Observations in a low state of the source request a rotating black-hole

Iwasawa et al. (1996)
The XMM-Newton Era

The XMM-Newton/EPIC sensitivity allow unprecedent detailed studies of the line complex in AGNs and GBHC

An important literature

- ADS with “XMM + Iron + line” in the abstract 259 articles in refereed journal (91 with “XMM + Iron + Kα”)

I will not be able to present all the results!
Seyfert 1

- All objects show a iron line complex (e.g. Pounds & Reeves 2002; Bianchi et al. 2004)
- Broad emission lines NOT observed in ALL objects (~1/3)
- Observations of Narrow cores and/or Blue and/or Red wings

Narrow neutral lines

The narrow (i.e. unresolved by XMM) lines are consistent with reflection off remote Compton-thick material covering ~π str.

(Figs. from J. Reeves)
An X-ray Baldwin effect in Type I AGNs?

After Ginga (Iwasawa & Taniguchi 1993) and ASCA (Nandra et al. 1997), also observed with XMM, an anti-correlation between the narrow core of the line and luminosity (and Eddington ratio) is confirmed:

- 51 objects: $\text{EW} \propto L^{-0.17 \pm 0.08}$
- 66 objects: $\text{EW} \propto L^{-0.19 \pm 0.04}$

Zhou & Wang (2005)

See also (Jiménez-Bailón et al. 2005)

In agreement with a decrease of the covering factor of the emitting material (dusty torus?) for increasing luminosity
Seyfert 1
Blue wings

Presence of ionized material, other elements (Ni,...), ...

(Figs. from J. Reeves)
Seyfert 1

Red wings

(Figs. from J. Reeves)

Spinning black holes in Radio-Quiet AGNs (i.e without jet) ....
What about MCG-6-30-15?


- Spinning black hole with $a > 0.93$
- Steep disc emissivity (within ~10 Rg)


Lampost model including relativistic effects....

MCG-6-30-15: The Line Variability

Part of the lines have different variability behaviors compared to the continuum.

The line follows the continuum in the low state of 2000, but no correlation in the mean state of 2001.

Does it depend on the flux state?

...produced by different regions.
Importance of the light bending effects

Light bending effects between a moving up-and-down X-ray source and the disc may explain the lack of variability of the line and reflection hump while the continuum does (Fabian & Vaughan 2003)

Miniutti et al. (2003); Miniutti & Fabian (2004)
Similar behavior seen in other objects

**AGN**

- Steep disc emissivity to fit the broad profile

**GBHC**

- No linear correlation between line and continuum flux

Huge reflection may be due to bending effects (Fabian et al. 2004; Malzac et al. 1998)

**NGC 4051, 1H0419-577** (Pounds talk)
A lot of other interesting objects/studies...

• Iron line properties in quasars not strongly different from Seyfert (e.g. Porquet et al. 2004, Page et al. 2004, Piconcelli et al. 2004, Jimenez-bailon 2005)

  - narrow lines generally present (from BLR, torus?)

  - broad lines relatively rare (due to high luminosity?)
  
  (Nayakshin et al. 2000)

• All objects do not easily fit in the “light bending” framework

  Other physical processes may be important (non-axisymmetric disc structure disc warping, spiral arms (Hartnoll & Blackman 2000, 2002), absorbers (Inoue & Matsumoto 2003, Reeves et al. 2004), etc...)
Mapping the in-flow/out-flow environment close to the central engine

**Outflows**

Observations of strongly ionized outflows carrying a significant proportion of the total power (Pounds and O’ Brien talks)

**Inflows**

- Nandra et al. (1999) for redshifted abs. line in NGC 3516 with ASCA.

- Some indications in the XMM obs. of Mkn 335 (Longinotti et al. in preparation)
  Q0056-363 (Matt et al. 2005)

See also Dadina's talk for transient redshifted and blueshifted absorption lines in Mkn 509
Mapping the in-flow/out-flow environment close to the central engine

Redshifted narrow emission line

Signature of a rotating hot spot?

See also Guainazzi (2003) for ESO 198-G24, Yaqoob et al. (2003) for NGC 7314, Longinotti et al. (2004) on Mkn 841

(Dovciak et al. 2004, Iwasawa et al. 2004)
X-ray primary source = lamppost model
(e.g. aborted jet Henri & Petrucci 1997; Ghisellini et al. 2004 jet basis,...)

Outflows

Inflows

Disc hotspots

Flare

Reflection components (Fe line, hump)
In the Universe

770 ks XMM-Newton survey of the Lockman Hole

The average rest-frame spectra of AGNs type I and II show:

- A strong fluorescent line with relativistic (Laor) profile ➔ the average supermassive black hole has a significant spin
In the Milky Way

Cumulative exposure on the Galactic central region

The iron line concentration near Sgr A East is due to an abundance gradient (Sakano et al. 2002).
A two-component model

The continuum seems to be the combination of two components: a strongly variable one (~ power law) and a roughly constant one (reflection hump).
This effect is not seen in a large sample of quasars but is consistent within the errors (Jiménez-Bailón et al. 2005)
**Individual objects**

**AX J0447-0627**
Della Ceca et al. (2005)
Iron complex and large EW

**Circinus**
Molendi et al. (2003)
Ni line, Compton shoulder

**PG 1402+261**
Reeves et al. (2004)
Strong blueshifted line