Variable and Broad Iron Lines around Black Holes

**ESAC/XMM-Newton Science Operations Center Workshop** 

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## "Broad" Iron Line ~20 years ago Cyg X-1



Gas Scintillation prop. Counter: best energy resolution at that time



## **Iron K-line profile** near a black hole

## Fabian et al. 1989

General Relativity: **Gravitational Redshift** 

**Disk Emissivity** 



# Fe K emission

- Most prominent feature in X-ray spectrum of reprocessed (reflected) emission
- Important diagnostics of illuminating source & illuminated matter
- Sensitive probe of central region under extreme physical conditions
- Potential of determining BH Mass & Spin [Fabian] [Matt] [Miniutti]

~10 yrs ago

#### with ASCA



K. Nandra

### Era of XMM-Newton, Chandra & Suzaku higher sensitivity and/or higher energy resolution

- Presence of broad Fe lines confirmed and more are found
- Also from Galactic BHBs
- More complex spectral & time-variability features / properties discovered
- Interpretations developed

# Relativistic Lines in Galactic BHs little

affected by continuum model [Miller]



Broad Fe line in ~20 systems: [J.Miller]

# Is the relativistic broad Fe line robust? POTENTIAL COMPLICATIONS

- Narrow components
- Blueshifted & redshifted lines [Cappi]
- Compton reflection
- High ionization / high column absorbers may mimic broad red wing [Reeves]
  [Turner]
- Determination of correct continuum crucial
- Break degeneracy (e.g. hard X spectrum)

#### Light bending model: Miniutti & Fabian 2004 [Miniutti]

observe

PLC

r in

RDC

- Maximally rotating black hole
- Primary source lifted up above the disk
- Compact illuminated spot at r < 2rg</li>
- Most radiation bent towards the disk plane
- Outgoing beam reduced



 For the primary source, possibility of magnetic flares, and/or high-energy electrons discussed [Karas][Goosmann][de Castro]

rout

MCG-6-30-15 [Fabian] [Miniutti] [Larsson]





## **Relativistic broad Fe lines are robust**

BROAD LINE HALL OF FAME [Nandra]

Δχ2>10 cf. blend/absorber Rbreak <20 Rg

MCG-5-23-16 MCG-6-30-15 Mrk 766 NGC 2992 NGC 3516 NGC 3783 NGC 4051 NGC 4151



Iron line parameters are no longer degenerate with simultaneous measure of reflection component and high-energy continuum [Reeves] [Markowitz] • Both broad (redshifted) and narrow components of the Fe line are required and reflection is seen in HXD,

## Suzaku NGC3516



•several soft X-ray lines are also detected.

A new feature is also observed, due to an absorption edge near 7.6 keV in the rest frame, which is detected in both XIS and RXTE. This could be due to an ionized absorber or ionized reflection,

## **Redshifted absorption features**



## **Transient / energy-shifted line emission**

A number of examples have been obtained thanks to high sensitivity of XMM-Newton

Variations on ~dynamical timescales of the inner part of accretion disk [Cappi][De Marco][Turner]



#### Time variable line shifts: Mkn 766 [Turner]



#### "Edge" shift in NLS1 [Boller]



# Dominating reflection from Ionized disk & LightBending Model:Fabian et al.; Miniutti & Fabian 2004



Ionized disk reflection vs Partial covering outflow [Boller] [Ponti] [Crummy] High statistics could solve it!

#### Time Variabilities of Soft and Hard Excesses above Power-law

IRAS 13224-3809

1H 0707-495 AO2



Between high-flux and low-flux periods

- Hard excess changes much less than soft excess
- No change in Tbb of soft excess

#### MCG-6-30-15: Suzaku

Strong iron K line and disk reflection

No variations in Fe-line /reflection

Gravitational light bending around a Kerr BH? (Miniutti & Fabian 2004)



# **NGC 4051- Spectral Variability**



#### **Towards the Future: Fe-line ubiquitous**



Streblyanska et al. 2005

1.412 1.4x = 0.71.2 1.4 s-0.0-1. 13 1.4 ratio 1.1 = 21.2 1.41.21 1.41.2 1 1.4 1.2 3 õ в  $\hat{z}$ 4 E (keV)Brusa et al. 2005

#### 1 Ms XEUS view of a Laor line



XEUS Science: Hasinger et al.



To study Black Holes on intrinsic variability light crossing inner orbital period

⇒ effective collecting area at 6 keV of 2 m<sup>2</sup>!

Relativistic Fe line physics remains extremely important for the next-generation missions

It is important to clear up skepticism? on the reality of relativistic broad Fe lines.