Soft X-ray Excess emission from AGNs

Gulab Chand Dewangan
IUCAA

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Outline

• **Soft X-ray excess emission from AGNs**

• **Models for soft Excess emission**

• **Time lags from Akn 564 & Mrk 110**

• **Implications to the origin of soft excess emission**

• **Using wide spectral coverage to test the models for soft excess**

• **Multi-wavelength spectral modeling**
Standard Model of AGNs

- The standard model of AGNs has three components
  - Power law with high energy cutoff
  - **Compton reflection**
    - from cold torus, also produces the narrow Fe K line.
    - from accretion disk which also produces relativistically broad iron line.
  - A soft excess component, which may or may not be related to the optical/UV continuum
- **Data in the 0.3-10 keV band cannot decompose the spectral components.**
  - ASTROSAT is important.
**Soft X-ray excess emission**

- Smooth continuum Component
  Not a blend of narrow emission/absorption features
- Nearly uniform temperature \( \sim 0.1 - 0.2 \text{ keV} \) for NLS1s and quasars with a large diversity in black hole masses and luminosities
- Too hot to be the optically thick emission from standard disks around SMBHs
Three alternative models

• Thermal Comptonization in a cool (kT~0.3keV) and optically thick (τ ~ 10) medium

• Relativistically blurred reflection from an ionized accretion disk (Fabian et al. 2002; Crummy et al. 2006)

• Smeared absorption from partially ionized material (Gierliński, & Done 2004; Schurch & Done 2006)
Models Indistinguishable

• All the three models result in similar quality fits to the observed XMM-Newton data. Spectral modeling cannot distinguish between them. (Sobolewska & Done 2006)

• The ionized reflection and smeared absorption models also describe the rms variability spectra quite well. (Ponti et al 2006; Gierliński & Done 2006)

• Use other techniques, time delay between the soft excess and hard X-ray emission.
Time lags between the soft and hard band X-ray emission

Akn 564: 100ks XMM-Newton observation

(Dewangan et al. 2006)
Akn 564 - Time lag

- Simulate 5000 pairs of soft and hard band light curves and cross correlate each pair
- Measure the lag corresponding to the peak in each CCF

Time Lag = $1728 \pm 336$ s (68% level)
  $= 1728 \pm 576$ s (90%)
  $= 1728 \pm 960$ s (99%) 

Hard band lags behind the soft band
⇒ Soft excess not the reprocessed emission

Evidence for energy-dependent time delay

(Dewangan et al. 2006)

(Arevalo et al. 2006)
Mrk 110: Time lag

- ~47ks XMM-Newton observation
- Energy dependent time delay ~200s to ~4500s.
- Consistent with Comptonization process

(Dasgupta & Rao 2006)
Implications

- Relativistically blurred Ionized reflection model:
  Soft excess is mainly the blend of large number of broad emission lines

⇒ Soft excess emission cannot lead the hard X-ray emission

NOT consistent with observation of soft band lead in Akn 564 & Mrk 110

(Crummy et al. 2005)
Implications

- Smeared absorption by partially ionized matter:
  Soft excess is an artifact of deficit caused by absorption.
  \[\Rightarrow\text{Soft and hard emission arise from the same continuum component -- Comptonization}\]
  \[\Rightarrow\text{Soft photons undergo fewer scattering events than hard photons}\]

Consistent with observation of soft band lead in Akn 564 & Mrk 110

This model also has problems.
Using Broadband spectral coverage

- Shape of the Compton reflection emission changes depending on the ionization stage of the disk.
- If the soft excess is blurred reflection, it must be consistent with Compton reflection at high energies.
- In the case of smeared absorption model, hard X-ray continuum should be steep.
- The broadband X-ray spectra should be different for the three models of soft excess.
Different models for soft excess

Mrk 110: Best-fit models from XMM-Newton data

$\chi^2$/dof = 1349/1461
Γ = 2.1
Log$\xi$ = 2.74, $\sigma = 0.6$ v/c
R = -1.7

$\chi^2$/dof = 1402/1462
Γ = 1.9
log$\xi$ = 2.76, Fe/solar = 0.8
R$_{in}$ = 2.5$r_g$, $\beta$ = 4.1, $i$ = 22deg

$\chi^2$/dof = 1340/1461
Γ = 1.8
k$T_s$ = 30eV, k$T_e$ = 0.3keV
$\tau$ = 11, R = -1
Broadband X-ray spectra

- The three models predict different hard X-ray spectra above 10keV.
With Suzaku

- Spectral shape in the $\sim$8-100 keV band extrapolated to soft X-rays predicts either a deficit (smeared wind model) or an excess (ionized reflection or cool Comptonization model).

- Different spectral shapes in the hard band can distinguish the blurred reflection model from the other two models.
Broadband spectral coverage

- Soft excess as optically thick Thermal Comptonization
- Strong correlation between UV and soft X-rays is expected.
  ⇒ ASTROSAT UVIT & SXT will be useful.

- ASTROSAT with its wide spectral coverage and UVIT should be able to distinguish between the three models of soft X-ray excess.
ASTROSAT with its wide spectral coverage and UV capability should be able to distinguish between different models for the soft X-ray excess.

- Good spectral calibration of individual instruments
- Good cross calibration
- Background determination
Multi-wavelength Spectral modelling

• **Important for several classes of objects**
  – Testing disk-corona models for AGNs
  – Accretion disk emission of AGNs
  – Jet dominated AGNs

• **UVIT-SXT-CZT-LAXPC simultaneous spectral modeling**
  – Instrument response is complicated at X-ray energies
  – Direct inversion of count spectrum into fluxed spectrum is not possible in X-ray. Instrument response is used in spectral fitting process.
  – **In optical/UV, fluxed spectrum is obtained directly.**
Multi-wavelength spectral modeling

• Different ways
  – **First model the X-ray spectra, get flux and associated errors. Finally model the SED.**
    • Lose energy resolution if a few data points are derived from X-ray spectrum.
    • If a large number of points are derived, not clear if the errors are independent.
    • Best-fit X-ray model may not be consistent with UV data.
Multi-wavelength spectral fitting

- Use instrument response for optical/UV data as done in the X-ray and perform simultaneous spectral fitting of multi-instrument data.
  - Create diagonal response and use instrument effective area
  - XSPEC can handle such data
  - Simultaneous fitting of optical/UV + X-ray data

- **ISIS can handle multi-band data easily.**
  - If flux and associated errors are available at different wavelengths (radio/optical/UV/TeV gamma-rays), ISIS can be used to model the multi-wavelength spectrum.
  - ISIS automatically assumes diagonal response with $1\text{cm}^2$ effective area.
  - The fluxed-data is treated in the same way as the X-ray data.
Thank You