A deep HETGS observation of MCG-6-30-15: a narrow view of the broad iron line

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Outline

- Introduction to MCG-6-30-15
- Absorption lines from highly ionized outflows
- The robustness of the broad iron emission line
MCG-6-30-15

- Nearby ($z=0.008$) Seyfert 1.2 galaxy
- Borderline member of the NLS1 class
- Intensively studied because of its warm absorber and relativistic broad iron emission line

Fabian et al. (2002)
The deep HETGS observation

- Motivation
  - Detailed study of well-known warm absorber
  - First high s/n, high-resolution study of iron-band region of spectrum... assess role of absorption in confusing broad line studies

- Performed 19-27th May 2004
- 522ks good exposure time
- Will just discuss hard band (>2keV) results here.

Binned spectrum

Can recover broad iron line (but not extreme red-wing)

0.067Å bins; powerlaw fitted from 2.25-2.5keV to 7-7.5keV

HETGS & EPIC-pn
Full resolution spectrum

 Flux (photons s^{-1} cm^{-2} keV^{-1})

 Energy (keV)

 ΔX

 Fe K α  Hα-like Fe  H-like Fe
Other signatures of the same flow... SiXIV and SXVI
The highly ionized WA

- $18 \pm 6 \text{eV Fe}^{25}$ line; $21 \pm 10 \text{eV Fe}^{26}$ line
- Column densities and velocities...
  - $N_{\text{Fe}^{25}} = 3 \times 10^{17} - 3 \times 10^{18} / \text{cm}^2$ ($b=500-100 \text{km/s}$)
  - $N_{\text{Fe}^{26}} = 6 \times 10^{17} - 4 \times 10^{19} / \text{cm}^2$ ($b=500-100 \text{km/s}$)
  - Ionization parameter; $\log(\xi) = 3.6$
  - Equiv-H column $N_\text{H} = 1.6 \times 10^{23} \text{ cm}^{-2}$
  - Outflow; $V = 2.0 \pm 0.8 \times 10^3 \text{ km/s}$
  - [or, kinematically consistent with being local $z=0$ material; ala McKernan et al. 2004]
Physical properties of the highly ionized WA…

- Constraints on location…
  \[ \xi = \frac{L_{\text{ion}}}{n r^2} = \frac{L_{\text{ion}}}{N r} \left( \frac{\Delta r}{r} \right) \]
  
  - Must be close to central engine; \( R < 0.02 \text{pc} \)

- Constraints on mass outflow rate
  \[ \dot{M} = \Omega r^2 n u m_p = \Omega \left( \frac{L_{\text{ion}}}{\xi} \right) v m_p \]
  
  - Mass flow rate = 0.3 \((\Omega/4\pi) M_{\text{sun}}/\text{yr}\)

- Kinetic energy = \(4 \times 10^{41} (\Omega/4\pi) \text{ erg/s}\)
All mass and energy fluxes are for $\Omega = 4\pi$

<table>
<thead>
<tr>
<th>log($\xi$)=3.6</th>
<th>Maximum Radius (pc)</th>
<th>Mass Flux ($M_{\text{sun}}/\text{yr}$)</th>
<th>Energy Flux (erg/s)</th>
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<tbody>
<tr>
<td>V=2000km/s</td>
<td>0.02</td>
<td>0.16</td>
<td>$2 \times 10^{41}$</td>
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<td>log(x)=3.4</td>
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<td>log(x)=2.1</td>
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<td>log(x)=0.2</td>
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Last three rows from McKernan, Yaqoob & CSR, submitted
Full resolution spectrum
$N_W = 2.7 \times 10^{21}, \log(\xi) = 2.42$

$N_W = 1.4 \times 10^{21}, \log(\xi) = 0.71$

$\chi^2 = 5497/1413$
$N_W = 3.2e21, \log(\xi) = 2.46$

$N_W = 1.5e21, \log(\xi) = 0.73$

$\chi^2 = 6026/1413$

Ignore 3-8keV in fit...
Fitting 3-6keV and 8-10keV band, can reproduce “red-wing” curvature from iron-L absorption (Kinkhabwala 2003; PhD thesis)

Generic prediction - significant iron K line absorption from FeXVII-FeXXIII (~6.4-6.6 keV)
We clearly do not see the iron resonance absorption lines created by the species required to mimic the extended red-wing of the iron line.
Consistent with XMM spectral variability…

Difference spectrum
Conclusions

- Presented results from a deep (522ks) Chandra grating observation of MCG-6-30-15
- Reveals signatures of a highly ionized wind, possibly carrying significant energy flux
- Rules out presence of a “broad Fe line mimicking warm absorber”… predicted resonance absorption lines are plainly absent.
- Highlights importance of DEEP AGN spectroscopy
Dusty warm absorbers

Lee et al. (2001)