On the origin of the Fe lines in AM Herculis

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I. Intro:
   I. X-ray observations of AM Her
   II. Accretion physics & X-ray emission
II. High state data fm Chandra & Newton
   I. Chandra HETG
   II. XMM-Newton pn timing
III. Line profile modeling
IV. Results and Outlook
Regular mode
Quasi-radial one-pole accretion

*Figure 2.* Folded X-ray light curves from all four *ASCA* detectors summed in four energy bands. The hard bremsstrahlung component dominates in the lower three curves, whereas the uppermost panel contains photons mostly from the soft blackbody component. Note that the 0.4–0.6 keV curve is made from SIS data only.

*(ASCA: Ishida+97, MNRAS)*
Conditions in the accretion column

(Fischer & Beuermann 01)

Shock heating (hydro) vs particle heating

- Cooling via thermal plasma and cyclotron (RT-1D)
- Parameter: $M_{WD}$, $dm/dt$, $B$

\[ T(i^+) \quad T(e^-) \]
X-ray irradiated atmosphere: Reprocessing, Fe fluorescence and Compton reflection (v. Teeseling+96, AA)

**Fig. 1.** Solid line: energy distribution of the different spectral components from a $\log g = 8$ white-dwarf atmosphere with $T_{\text{eff}} = 200\,000\,\text{K}$ irradiated with a 40keV bremsstrahlung flux of $F_{\text{irr}} = 9 \times 10^{16}\,\text{erg}\,\text{s}^{-1}\text{cm}^{-2}$. The dotted line is the 40keV bremsstrahlung emission from the post-shock plasma, the dashed line the emission from the irradiated white dwarf.
AM Her: SED through high and low states
Figure 4. The result of a fit to the rotational maximum phase spectrum taken by the SIS with a single temperature thermal bremsstrahlung with three column densities. The parameters are $kT = 14^{+7}_{-4}$ keV, and $N_{\text{H}_1} \sim 9 \times 10^{19}$ cm$^{-2}$, $N_{\text{H}_2} \sim 2 \times 10^{22}$ cm$^{-2}$, and $N_{\text{H}_3} \sim 2 \times 10^{23}$ cm$^{-2}$ ($\chi^2 = 0.89$). The iron emission lines around 6–7 keV are represented by three Gaussians (see Section 3.3).
AM Her with Chandra and XMM-Newton (AAVSO)
Chandra and XMM-Newton
Regular mode

I. CXO/HETG
Aug 15, 2003
24600 cts in 91.4 ksec

II. XMM-Newton pn-timing
Jul 19-27 2005
(4 visits per 9 ksec)
520000 cts in 32.5 ksec
I. Orbital phase averaged spectra

II. $V(\text{Fe}26) \sim 260 \text{ km/s}$

III. $V(\text{Fe}26+\text{Ne}+\text{Mg}+\text{Si}) < 100 \text{ km/s (90\% conf)}$

$\rightarrow$ ... line emission arises predominantly from the lowest few per cent of the accretion column.
Fe XXVI maximum velocity shift of 1100 km s\(^{-1}\), close to the shock velocity expected for a 0.6 \(M_0\) WD.
Search for Doppler shifts in Chandra & XMM

I. Case for XMM-Newton?
\[ \Delta V = 1000 \text{ km/s} \ @ 7 \text{ keV (FeXXVI)} \]
\[ \rightarrow 23 \text{ eV (16\% of FWHM)} \]

II. Search strategy

I. Phase binning: 0.1, 0.2, 0.25

II. Spectral models (various combinations of either fixed and/or related parameters)
- TB+3*Gauss
- APEC+Gauss
- APEC+REFLIONX
Results Chandra

I. Mean spectrum
   FeXXVI
   $\Delta V = 340^{+150}_{-150}$ km/s

II. No significant
    phase-dependent
    Doppler shift

III. Line width 18eV
     ($=2\times$FWHM(HEG))
Results XMM-Newton

No significant phase-dependent Doppler shift
Line profile synthesis & RV predictions

I. Binary parameters
II. Accretion geometry
III. Temperature, density and velocity structure for stratified columns (Fischer & Beuermann 2001)
IV. Line profile synthesis
V. XSPEC fakeit (scaled to CXO)
VI. Doppler analysis
Line profile synthesis
RV contributions

1. Gravitational redshift & LSR (neglected)
Line profile synthesis: RV

2. Orbital motion

- NaI
- CaII

Subphotospheric heating

Chromospheric reprocessing

BeppoSAX
Line profile synthesis
RV contributions

2. Orbital motion
Binary parameters & geometry

- $M_2$ (Knigge, SpT) & $M_{wd}$ & $K_2$ (corr) $\rightarrow$ inclination
- Length of X-ray selfeclipse $\rightarrow$ latitude of column
- Combination of $i$, $\delta$ determines $\Delta V$
Stratified columns
(Fischer & Beuermann 2001)
I. Fe26!

II. Joint RV analysis of H-like ions levels out any signal
Chandra 10 Ms simulation
(10 realizations, 10 phase bins, avg spec)
Chandra 91ks simulation
(10 realizations, 10 phase bins, avg spec)
Modeling results

I. Average velocity of 350 km/s ok
II. Single 32 ks CXO observation too short to measure RV amplitude reliably
III. Column structure from lines feasible
IV. Simulated line width ~15 eV ~ok
AM Her – Kα reflection

<table>
<thead>
<tr>
<th></th>
<th>EW (eV)</th>
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<tbody>
<tr>
<td>XMM</td>
<td>&gt; 190</td>
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<tr>
<td>CXO</td>
<td>170</td>
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<tr>
<td>ASCA</td>
<td>120</td>
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XMM: Trailed X-ray spectra
AM Her – $K\alpha$ reflection

Eclipse phase:
Stream reflection

WD reflection otherwise

$i=28$, $\delta=60$
Ghisellini+94, MN
AM Her: Fe Fluorescence line

EW observed > predicted by reflection models
→ abundance?, continuum shielded?, heating?

Figure 4. The equivalent width of the iron Kα fluorescent line as a function of the temperature for different inclination angles (left panel) and as a function of the cosine of the inclination angle for different temperatures (right panel).

Fig. 4. Observed equivalent width of the iron Kα fluorescence complex from an irradiated \( F_{\text{ir}} < 10^{38} \text{ erg s}^{-1}\text{ cm}^{-2} \) \( T_{\text{eff}} = 100,000 \text{ K} \) white-dwarf atmosphere as a function of the angle between the normal of the surface plane and the line of sight. Solid lines: \( g(i) = 1 \), dashed lines: \( g(i) = \cos i \). For each geometry there are four curves for different bremsstrahlung temperatures.
Resume and outlook

I. Observations of Doppler shifts in a polar promising only in Fe26
II. Phase-resolved data inconclusive
III. Mean Doppler shift and line width in accord with column models
IV. Angular dependence of reflected lines observed for 1st time, quantitative understanding gained
V. Feasibility study for ATHENA planned (WD mass from \( z_{\text{grav}} \) of K\(\alpha \)?)