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Photoionization modeling with TITAN code distance to the warm absorber in AGN.

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We present a method that allows us to estimate a distance from the source of continuum radiation located in the centre of AGN to the highly ionized gas – warm absorber (WA). We computed a set of constant total pressure photoionization models compatible with the warm absorber conditions, where a metal rich gas is irradiated by a continuum in the from of double powerlaw. The first powerlaw is hard up to 100 keV and represents radiation form an X-ray source, while the second powerlaw extends up to several eVs and illustrates radiation from an accretion disk. When the ionized continuum is dominated by the soft component, the warm absorber is heated by free-free absorption, instead of Comptonization, and the transmitted spectra show different absorption line characteristics for different values of the hydrogen number density at the cloud illuminated surface. This fact results in the possibility of deriving the number density on the cloud illuminated side from observations, and hence the distance to the warm absorber. TITAN is a photoionization code developed by *Dumont et al. 2000*.

Model assumptions:

- TITAN photoionization code is well-suited to study of both, optically thick and thin media, such as the WA.
- It computes the gas structure in thermal and ionization equilibrium in non-LTE, and radiative transfer of lines and the continuum using the ALI (accelerated lambda iteration) method.
- Our atomic data include about 10^3 lines from ions and atoms of H, He, C, N, O, Ne, Mg, Si, S, and Fe, all with cosmic abundances.
- We have shown that the assumption of constant total (gas+radiation) pressure allows the ionized gas to by naturally stratified due to illumination (Różańska et al. 2006, Gonçalves et al. 2006)
- We consider two shapes of irradiated continuum: single, hard powerlaw, and double powerlaw when soft component dominates.
- Here, we discuss the problem of distance derivation using the ionization parameter defined as: $\xi = L_{ion}/n_0 R^2$
- From observations, we are able to get the luminosity of the object, and the ionization parameter on the cloud surface. But we are still left with $n_0 R^2$ product, meaning that the distance to the WA depends on the value of the number density at the cloud illuminated surface.

Parameters:

- We consider clouds with different hydrogen density numbers at the illuminated surface: $n_0=10^5$, 10^6.. up to 10^{10} cm^{-3}.
- The ionization parameter at the cloud surface is: $\xi=10^5$.
- In all cases, the total column density is on the order of 10^{23} cm^{-2}.
- We assume turbulent velocity of the gas equal to 300 km/s.
- For a single, hard power-law irradiation, the primary continuum ranges from 0.01 keV up to 100 keV and has spectral index $\alpha=1.0$.
- In the case of double powerlaw, the parameters are:
  soft component: from 0.01 eV up to 12.24 eV , and $\alpha=0.36$,
  hard component: form 0.01 eV up to 100 keV, and $\alpha=0.78$,
- The relative normalization of both power-law components is a free parameter of our model, but we pay attention to the case when soft component dominates i.e. $L_X/L_{opt}=0.0078$. This shape of irradiation can be applied to bright quasars with a strong disk component.

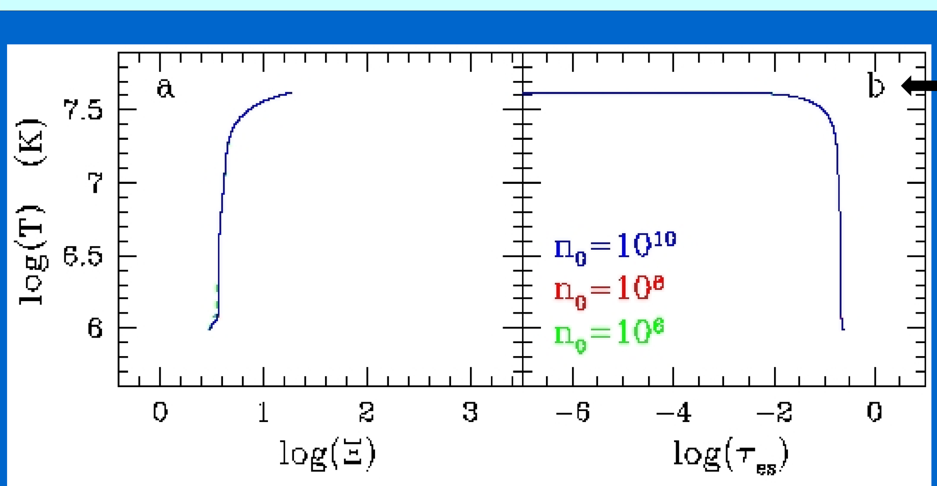


Figure 1. Ionization structure (a), and temperature structure (b), for the WA illuminated by a hard single power-law continuum for different values of n_0. : 10^6 cm^{-3} (green line), 10^8 cm^{-3} (red line), and 10^{10} cm^{-3} (blue line).

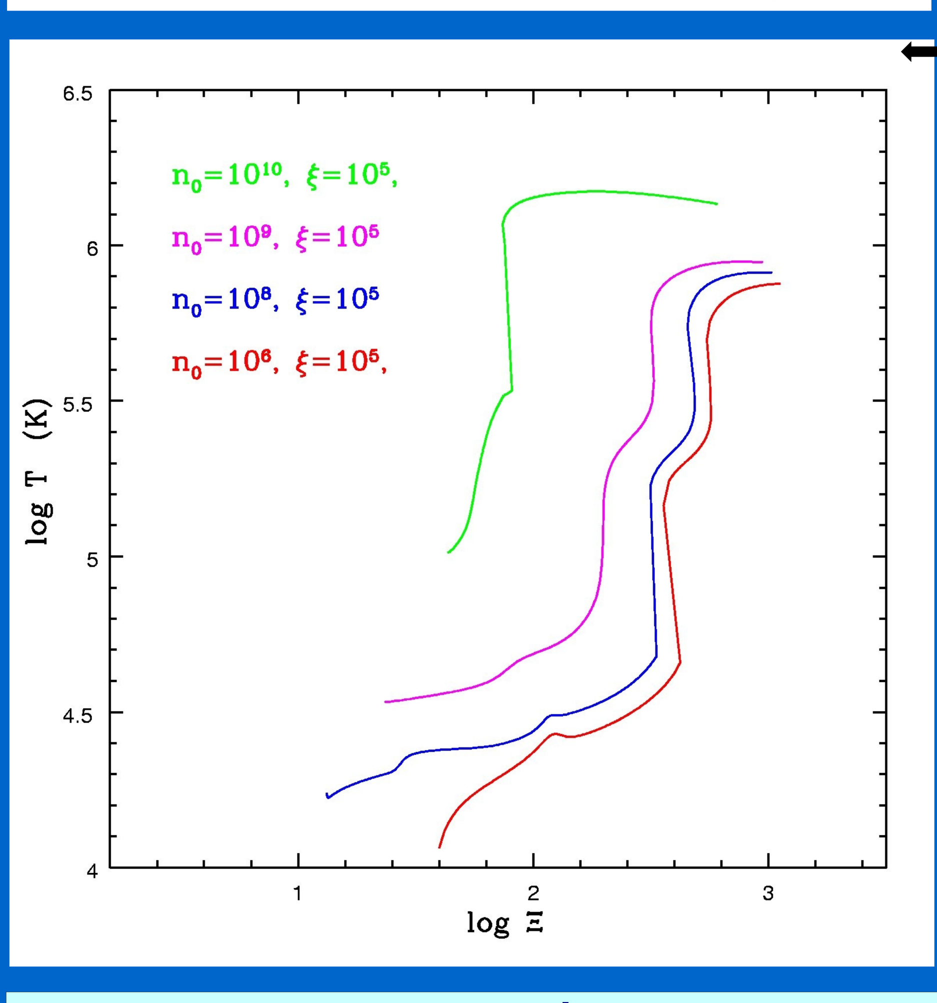


Figure 2. Ionization structure for the WA illuminated by a double power-law, with domination of the soft component: $F_X/F_{opt}=0.0078$, for four values of n_0 (listed in the figure).

References

Dumont A.-M. et al. 2000, A&A, 357,823
Różańska A. et al. 2006, A&A, 452, 1
Gonçalves A. et al. 2006, A&A, 451, L23
Różańska A. et al. 2008, A&A, 487, 895

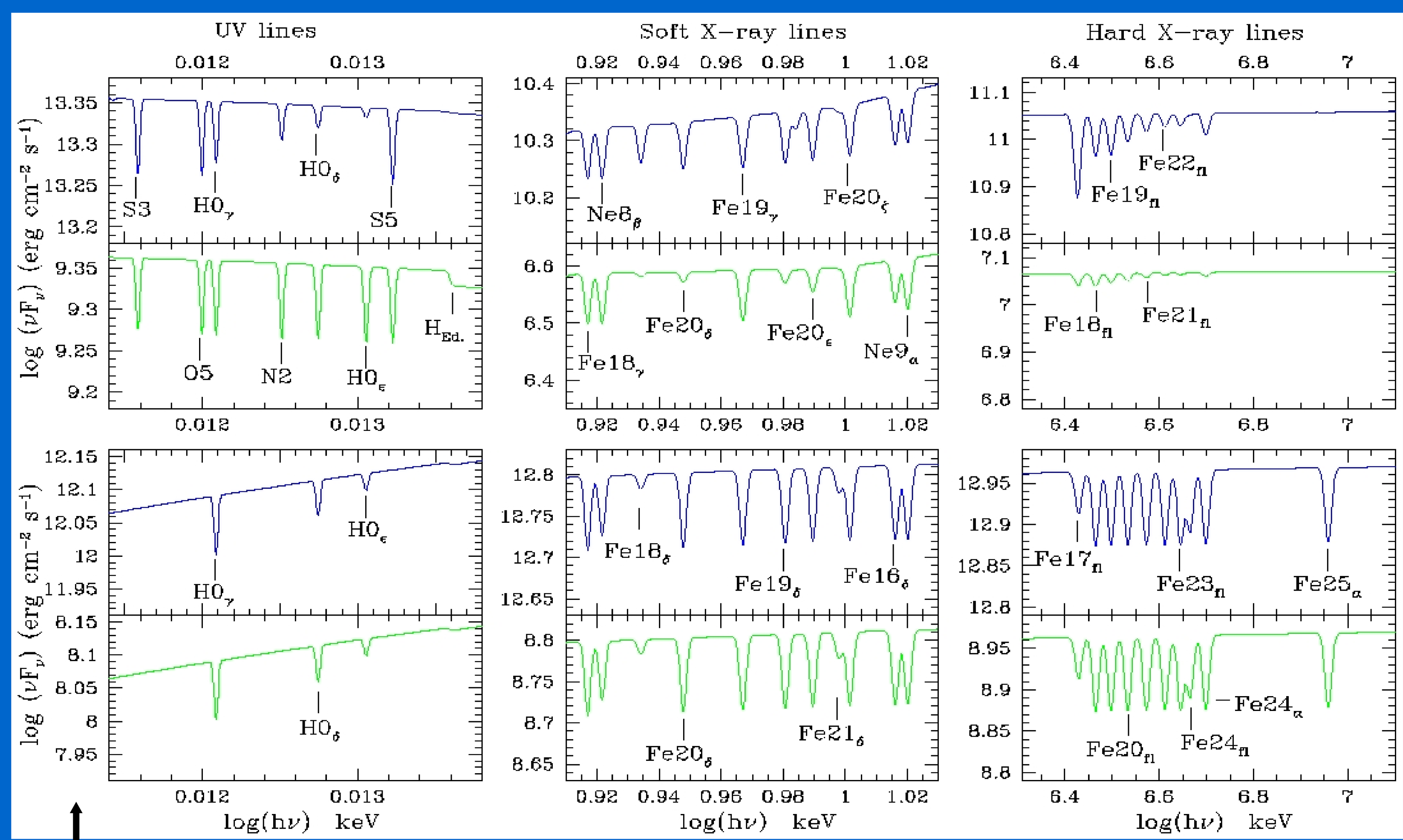
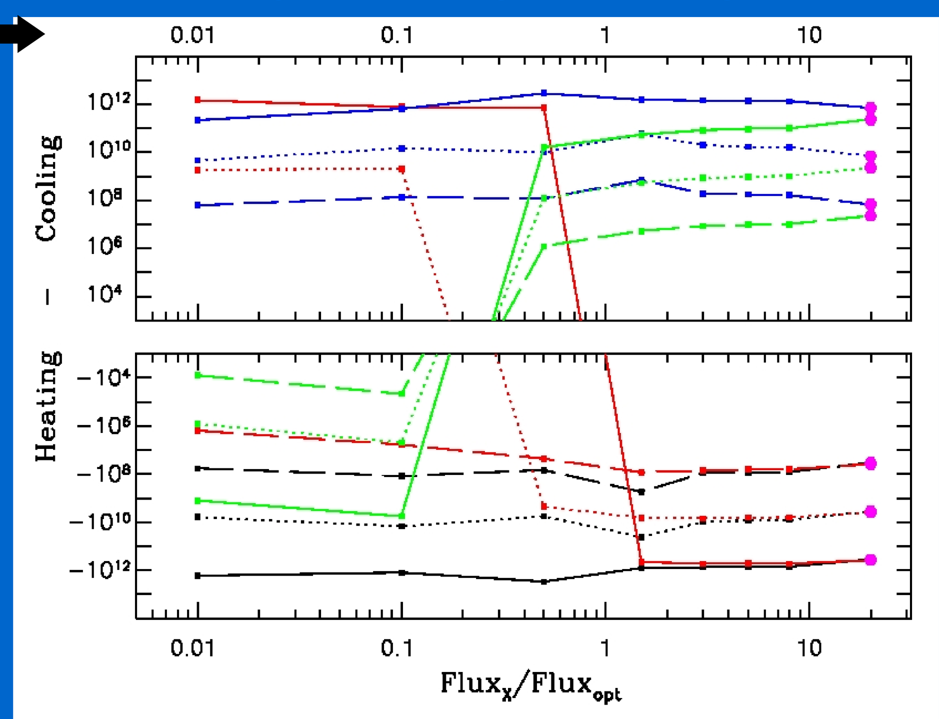


Figure 3. Comparison of spectral lines for three energy bands: UV (left panels), soft X-ray (middle panels), and hard X-ray lines (right panels). Upper panels show the case where WA is illuminated by double powerlaw with $F_X/F_{opt}=0.01$, while the bottom panels correspond to single powerlaw $F_X/F_{opt}=1$. Blue lines depict dense clouds $n_0=10^{10}$ cm^{-3}, and green lines less dense clouds $n_0=10^6$ cm^{-3}.

Figure 4. Net, i.e. Heating – Cooling gains of energy integrated over the cloud versus the ratio of hard X-rays to the soft power-law component. Net gains for Comptonization are represented by green lines, bound-free processes by blue lines, bound-bound – by black lines, and free-free – by red lines. Since axies are logarithmic, we arbitrarily assigned a minus sign to those cases where total gains are negative, i.e. cooling dominates over heating (bottom panel).There is a discontinuity between the cases where heating dominates over cooling (upper panel). For each process, solid lines represent clouds with 10^{10} cm^{-3}, dotted lines 10^8 cm^{-3}, and dashed lines 10^6 cm^{-3}. Magenta hexagons mark gains for a single, hard power-law illumination.



Results:

- Photoionized models with single, hard powerlaw, are highly degenerate in ionization and temperature structure for wide range of surface number densities. In Fig. 1 all lines are identical.
- For strongly degenerate models, absorption lines in transmitted spectra are identical in all energy bands (Fig. 3 bottom panels), and they are useless for the purpose of determining the distance to WA.
- The degeneracy breaks down when the incident continuum is in the form of double power-law with domination of the soft component (Fig. 2). The transmitted spectra look different (Fig. 3 upper panel).
- The equivalent widths of some absorption lines differ, for different n_0, giving the possibility of deriving n_0 from photoionization modeling, and hence the distance to the WA (Różańska et al. 2008).
- The degeneracy breaks down due to a switch in the radiative mechanism heating the ionized cloud when L_X/L_{opt} decreases (Fig. 4). For a single power-law, Compton heating is responsible for the hot equilibrium temperature. When L_X/L_{opt} decreases, i.e. when soft component starts to dominate, Compton heating becomes not efficient, and a hot temperature is established due to bremsstrahlung absorption. From line ratios of observed quasars, we can estimate n_0 and the distance to the WA.