Thermal stability of Warm Absorber in AGN

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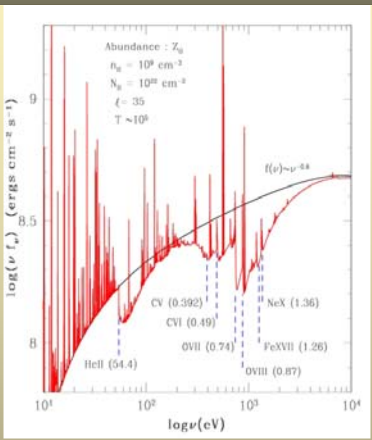


Warm Absorber

Absorption Edges and lines in Soft X-ray Spectra

- Edges

CV	CVI	OVII	OVIII	FeXVII	NeX
392	490	740	870	1260	1360

- Lines
  C (V & VI)   O (V - VIII)   Fe (XVII - XXII)
  Ne (IX & X) Mg (XI & XII) Si (XIII - XVI)

Properties

- Partially ionized gas in our line of sight to AGN
- Distance from the central engine is ~ 0.001 – 10 pc as interpreted from observations of different objects
- Column Density (N_H) ~ $10^{22\pm1}$ cm^{-2}
- Density (n_H) ~ 10^6 - 10^{12} cm-3
- ξ ~ 10 – 100 erg cm s^{-1} for 10^5 K gas
- Temperature ~ 10^5 – $10^{6.5}$ K

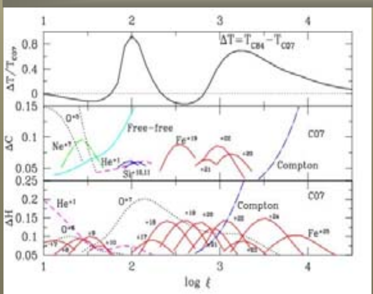
Current Issues

- Absorption features are blue shifted relative to optical emission lines, indicating outflow
- Mass loss rate is a substantial fraction of the accretion rate, or exceeds it.
- The X-ray warm absorber could coexist with a UV absorber, but it is still difficult to connect them.
- Is gas in thermal equilibrium the best explanation for warm absorber? If so, does the gas have multiphase nature?

Theoretical tool for systematic study

- A stability curve is a T- P phase diagram
- The ionization parameter $\xi = L/n_H r^2$ gives the ratio of photon flux to particle flux
- $\xi/T \sim (p_{Rad})_{ion}/p$
- ξ ~ 100 for warm gas at 10^5 K

Dielectronic recombination and stability of warm gas in AGN



The Problem

- Using same set of parameters the current version of CLOUDY, C07 gives different results from version C84 used by Reynolds & Fabian in 1995
- $\Delta\log(\xi/T)$ at 10^5 K increases from 0.05 back then to 0.22 now. Probability of thermally stable warm gas at 10^5 K is increased.
- $(T_{C84} - T_{C07}) / T_{C07}$ shows maximum value at ξ ~ 100, relevant for warm absorbers.

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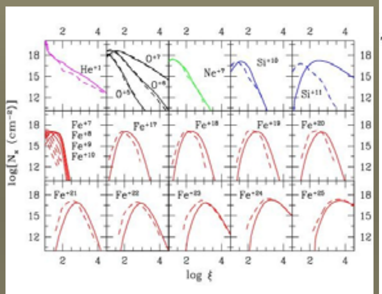
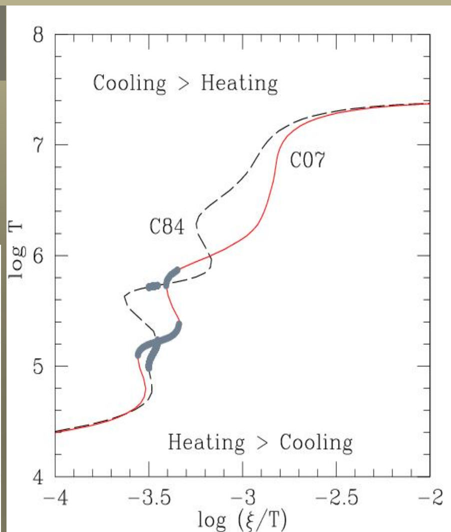
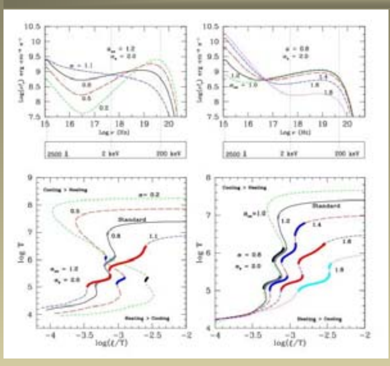




The Solution

- The dominant cooling and heating agents were identified as a function of ξ and their column densities calculated using both C07 and C84.
- Column densities of prominent cooling agents He+1, Si(+10 & +11) & Fe(+21 to+ 23) was found to vary significantly from C84 to C07.
- The cooling at warm absorber temperatures is brought about mainly by radiative and dielectronic recombination. Hence the predicted temperatures in such simulations are dependant on the estimation of the recombination rate coefficients.
- The atomic data base of dielectronic recombination rate coefficients have been exhaustively updated and expanded by Badnell and co-workers in the last decade which have helped in better estimates of the cooling in C07.

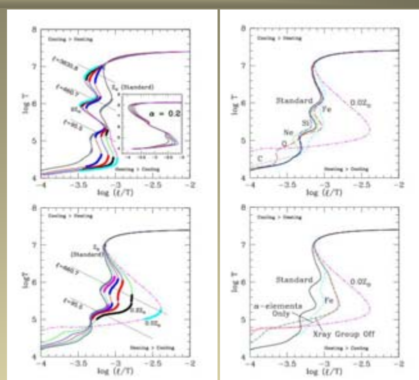
Properties of warm absorbers in active galaxies: a systematic stability curve analysis

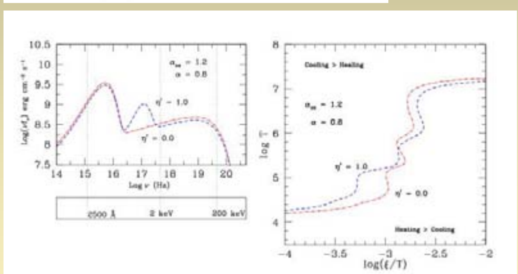


The stability curve is most affected by the shape of the incident ionizing continuum and the chemical composition of the absorbing gas. We systematically study their effect on the nature of the warm absorber.

The Continuum

- The 1 kev spectra is well fitted with $f_\nu \sim \nu^{-\alpha}$ with α ~ 0.8 for most Seyfert 1 galaxies. In addition there is the 'Ultraviolet excess' which can be parametrised using α_{OX}, the slope of the join between flux at 2500 A and 2 keV. We have varied the soft X-ray slope α and the EUV to X-ray slope α_{OX}.
- Although a two powerlaw continuum with appropriate α and α_{OX} represents the overall shape of the continuum, between 2500 A and 2 keV, it fail to bring out the detailed features like the effect of "Disk Blackbody" from the accretion disk and the "Soft Excess" seen at ~ 500 eV. Hence as the next step of understanding we have studied the effect of the "Disk Blackbody" (model in Xspec) at lower energies (~ 10 eV) and a thermal blackbody model with T_{SE} = 150 eV as the "Soft Excess".





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Chemical Composition

- The chemical abundance near the central engine of AGN is predicted to be super Solar by Hamann and Ferland which motivates to investigate a warm absorber with high metallicity.
- AGN, however, also illuminate low density gas on large scales which has low abundances, especially at high redshift. Sub-Solar chemical composition are relevant for such line of sight absorbing systems. Hence we also examine the effects of sub-Solar abundance on the stability curve.
- Interaction between gas and radiation is sensitive to the ionization potentials of various ions of elements like C, O, Fe and Ne indicating that the WA states are likely to be affected not only by the overall abundance of the absorber, but also by specific elements and groups of elements. These effects have been systematically examined for X-ray group (O, C, Ne, Fe) and α-elements (Ne, Mg, Si, S, Ar, Ca, Ti) as a group and also for the individual elements.

Results

- No stable warm absorber if α < 0.2
- Multiphase WA if α ~ 0.8. Interesting, because majority of Seyfert 1's have such X-ray slope.
- For α > 1.1, no unstable states, but no pressure balance either.
- For a given α_{OX}, the "Disk Blackbody" does not add any new effect compared to a 'two powerlaw' continuum.
- Continuum having significant "Soft Excess" enhances WA stability at 10^5 K.
- Z_0 - Classical S-curve. Primordial gas with only H and He has no WA.
- $Z > Z_{sol}$ enhances multiphase because it gives extended stable state at 10^6 K
- $Z < Z_{sol}$ reduces multiphase
- α-elements are 1st elements formed in the Universe through SN type II. Interestingly gas with only α-elements does not have WA.
- X-ray Group : Most effective group
- Oxygen : Most effective element at 10^5 K.
- Iron : most effective element at 10^6 K. It formed at T_{UNIV} = 1 Gyrs. WA before and after that will be different.

- A combination of Soft Excess and Super Solar metallicity gives the best description of WA as gas in thermal equilibrium
Enhanced stability at 10^5 K and multiphase scenario with 10^5 K & 10^6 K in pressure equilibrium