Ion Storage Ring Measurements for Understanding Line Emission and Ionization and Thermal Structures of Photoionized Gas

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In photoionized gas ions are formed at electron temperatures far below those where they would be formed in collisional ionization equilibrium. As a result of the low electron temperature, radiative recombination (RR) and dielectronic recombination (DR) are often the dominant line formation mechanisms. RR and DR also play an extremely important role in determining the ionization and thermal structure of the photoionized gas. Storage ring measurements can aid in understanding photoionized plasmas such as planetary nebulae, H II regions, cold novae shells, AGNs, XRBs, and CVs. Ion storage rings are unique for their ability to study electron-ion recombination at low energies. DR and RR measurements are carried out by merging the stored ions with a co-linear electron beam. The merged beams arrangement allows for a low center-of-mass collision energy.

Using the heavy ion Test Storage Ring (TSR) at the Max-Planck-Institute for Nuclear Physics in Heidelberg, Germany, we have undertaken to measure the DR rates for the Fe L ions (Fe XVII to Fe XXIV). These rates play an important role in determining the thermal stability of X-ray photoionized gas. Our recent measurement of Fe XVIII to Fe XVII DR (Savin et al. 1997) has shown that at low electron temperatures, DR can proceed primarily via $2p_{1/2} \rightarrow 2p_{3/2}$ excitation of core electrons. This channel is not accounted for by LS-coupling calculations or the Burgess formula and our measured DR rate is a factor of ~ 2 times larger than predicted by previously existing theoretical calculations. Our results indicate that a reevaluation of low temperature DR rates is needed.

Our Fe XVIII results suggest that there may be a factor of ~ 2 error in the low temperature Fe L DR rates. We have used XSTAR (Kallman & Krolik 1997) to investigate the affect of such an uncertainty on the thermal instability of photoionized gas. We find that increasing the low temperature Fe L DR rates by a factor of two significantly increases the range in parameter space over which the instability exists. Correspondingly, a factor of two decrease significantly decreases the range. These results demonstrate that our understanding of the importance of thermal instabilities is limited by uncertainties in the atomic data.

References:

Savin, D. W. et al. 1997, ApJ, 489, L115
Kallman T. R. & Krolik J. H. 1997, XSTAR, A Spectral Analysis Tool

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