X-ray Reflection from Inhomogeneous Accretion Disks: I. Toy Models and Photon Bubbles

D. R. Ballantyne1,2, N. J. Turner3 and O. M. Blaes3
1Canadian Institute for Theoretical Astrophysics, McLennan Labs, 60 St. George Street, Toronto, Ontario, Canada M5S 3H8; ballantyne@cita.utoronto.ca
2Kavli Institute for Theoretical Physics, Kohn Hall, University of California, Santa Barbara, CA 93106
3Department of Physics, University of California, Santa Barbara, CA 93106; neal, blaes@physics.ucsb.edu

abstract Numerical simulations of the interiors of radiation dominated accretion disks show that significant density inhomogeneities can be generated in the gas. Here, we present the first results of our study on X-ray reflection spectra from such heterogeneous density structures. We consider two cases: first, we produce a number of toy models where a sharp increase or decrease in density of variable width is placed at different depths in a uniform slab. Comparing the resulting reflection spectra to those from an unaltered slab shows that the inhomogeneity can affect the emission features, in particular the $\alpha$ and Ly$\alpha$ lines. The magnitude of any differences depends on both the parameters of the density change and the ionizing power of the illuminating radiation, but the inhomogeneity is required to be within $\sim 2$ Thomson depths of the surface to cause an effect. However, only relatively small variations in density (on the order of a few) are necessary for significant changes in the reflection features to be possible. Our second test was to compute reflection spectra from the density structure predicted by a simulation of the non-linear outcome of the photon bubble instability. The resulting spectra also exhibited differences from the constant density models, caused primarily by a strong 6.7 keV iron line. Nevertheless, constant density models can provide a good fit to simulated spectra, albeit with a low reflection fraction, between 2 and 10%. Below 2 keV, differences in the predicted soft X-ray line emission result in very poor fits with a constant density ionized disk model. The results indicate that density inhomogeneities may further complicate the relationship between the equivalent width and the X-ray continuum. Calculations are still needed to verify that density variations of sufficient magnitude will occur within a few Thomson depths of the disk photosphere.