ACCRETING BINARIES OVER COSMIC TIME

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For most galaxies in the Universe, X-ray emission is not dominated by an accreting supermassive black hole (active galactic nucleus, AGN). The Milky Way is an excellent example of such a galaxy, with a very weak SMBH and many luminous accreting binaries. Indeed, the Chandra X-ray observatory has shown us, via deep X-ray studies of local galaxies and ultradeep 1-4 Ms surveys of distant galaxies, that the Universe is teeming with galaxies whose X-ray emission is dominated by a combination of accreting X-ray binaries with black holes and/or neutron stars as their donors and hot X-ray gas (Mineo et al. 2012a, MNRAS, 426, 187; Mineo et al. 2012b; MNRAS, 419, 2095, Lehmer et al. 2012; ApJ, 752, 46). We cannot study binary formation and evolution directly, due to the long timescales involved (>10^6 yrs) so it is by studying *populations* of binaries and their aggregate emission that we can test the connection between the formation and evolution of accreting binaries and galaxy properties (e.g., star formation rate, stellar masses, ages, metallicities). This is exactly the work that our group has been engaged in both from an observational and theoretical perspective.

These galaxies are faint compared to most AGN, with X-ray luminosities in the range 10^{39}-10^{42} erg s^{-1} and with Chandra we can place constraints on them to z~4 via stacking analyses where we average of the properties of multiple galaxies to secure detections (e.g., Basu-Zych et al. 2013; ApJ 762, 45). Understanding this population has important implications for our understanding of fundamental topics in physics and astrophysics. This is the progenitor population for gravitational wave sources and short gamma-ray bursts. There is a distinct possibility that *lower mass* black holes may play an important role in reionization (Mirabel et al. 2011; A&A, 528, 149, Fragos et al. 2013; ApJ, 764,41).

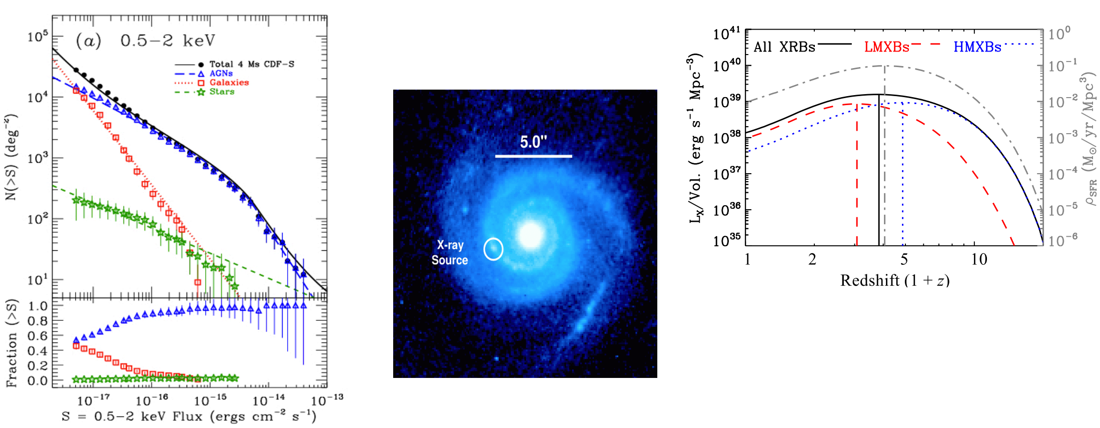

Figure 1: (LEFT) 0.5-2 keV number counts from Lehmer et al. (2012) showing that as one moves faintward in flux, the fraction of X-ray sources that are normal galaxies is increasing rapidly. 4 Ms exposures are required with the Chandra to reach the faintest X-ray fluxes shown here. Were a larger collecting area facility available, we would be able to greatly extend our knowledge of how compact objects form over a large fraction of cosmic time. (MIDDLE): The combination of Hubble (image) and Chandra imaging (used to locate the X-ray source to <1" accuracy) allows us to unambiguously identify accreting stellar-mass or intermediate mass black holes to high redshift (this galaxy at z~0.1, Hornschemeier et al. 2004; ApJ, 600, 147). Such objects are plentiful in the universe but we lack the capabilities to study them. (RIGHT): Theoretical binary population synthesis modeling has progressed immensely in recent years. Shown is the comparison of the cosmic SF history of the universe (grey) as compared with the X-ray emissivity of accreting binaries as a function of cosmic time (Fragos et al. 2013)