XMM XXL Survey Workshop 2008

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Normal/Starburst Galaxies

Key Issues

1.The X-ray/SFR and X-ray/mass correlations

The X-ray emission of normal/starburst galaxies is due to hot ISM (kT ~ 0.2-1 keV, with low temperatures in the halo and high temperatures in the inner regions of disks in spirals and virial temperatures in the case of ellipticals), low-mass and high-mass X-ray birnaries (LMXB and HMXB), and in some cases also individual supernovae. Hot ISM and HMXB in spirals should be proportional to the recent star-formation rate since HMXB are expected to have evolutionary time scales that are short relative to the Hubble time (i.e., comparable to high-mass stars), and SN due to high-mass stars drive the heating of the ISM. LMXB in all galaxy types should be proportional to the galaxy stellar mass since they have long evolutionary time scales. However, it would not be surprising if the actual scaling turned out to be non-linear and if breaks are present in these correlations (e.g., due to different source types dominating in different SFR and/or mass regimes and the detailed response of stellar evolution to star-formation episodes). Since normal/starburst galaxies rarely exceed X-ray luminosities of 10^{42} ergs s^{-1}, they are relatively faint X-ray sources. As a result the best X-ray data for galaxies are the targets of pointed observations. Since there is a large scatter in the amount of X-ray emission for a given recent SFR and stellar mass, the current correlations may be biased. This is because sources will tend to be selected from the high X-ray/SFR and X-ray/mass end of the correlation in order to minimize the amount of exposure time needed. Figure 1 shows the results to date of a program to observed optically-selected galaxies with XMM (from Ptak et al. 2008), along with a sample of normal galaxies detected in a correlation of Chandra observations with the SDSS (Hornschemeier et al. 2005). In both cases there were less than ten X-ray detections of normal galaxies. These results imply that the correlations may not be simple, but only a large sample of normal/starburst galaxies observed in an unbiased fashion would determine the true correlations.

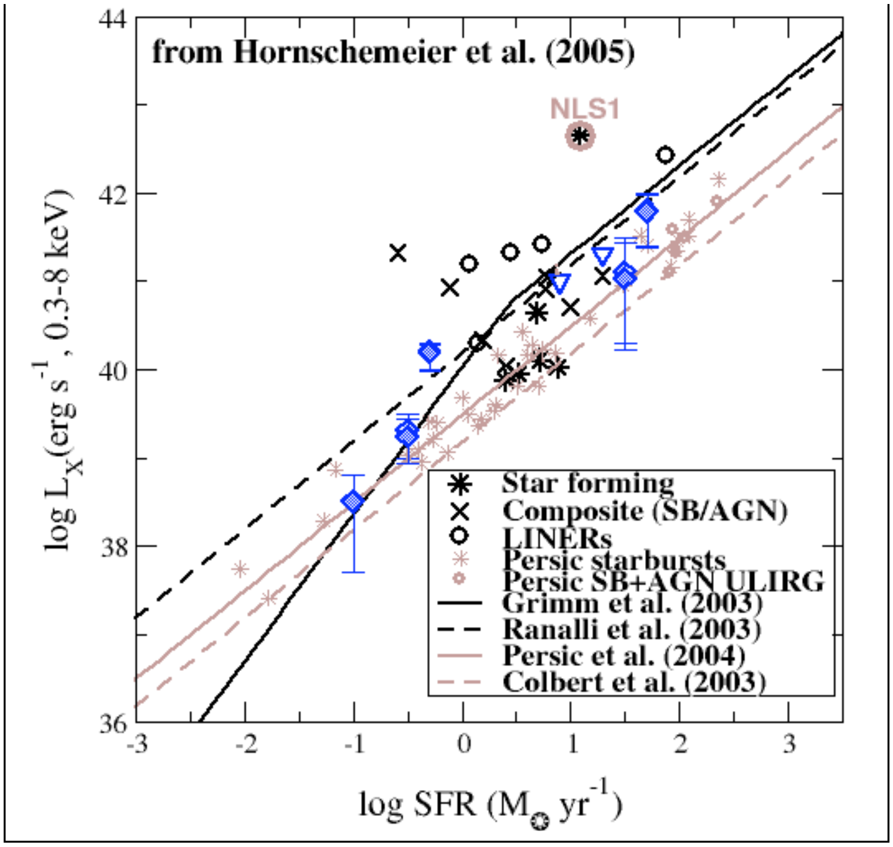

Figure 1. The X-ray/SFR rate correlation from Hornschemeier et al. (2005) with X-ray observations of the Nearby Field Galaxy Sample also shown as blue diamonds and upper-limits shown as blue triangles (see Ptak et al. 2008, XMM Nearby Galaxy Workshop procedings).

2. ISM Energetics and Stellar Feedback

Current models of galaxy evolution require "feedback" mechanisms that regulate star formation. At high galaxy masses AGN outflows should dominate but at low galaxy masses superwinds are expected to be the dominate mechanism. This should be observable by detecting hot ISM over a wide range of galaxy mass and type, and determining the total energetics of the heating of the ISM. A key question would be if sufficient energy input is present to provide the required feedback, which in turn requires that sufficient counts be detected from a sample of galaxies to determine the (spatially-averaged) temperature. The soft X-ray luminosity function of normal/starburst galaxies would also be a constraint on the energetics of SN-heated ISM on average.

3. X-ray Binary Duty Cycles and Stellar Captures

The X-ray luminosity of high-SFR galaxies is dominated by the brightest X-ray binaries. With an appropriate cadence, multiple observations of galaxies over a 1-2 year time scale would then be probing the long-term variability of these XRB. Of particular interest would be the frequency and persistence of the brightest ultra-luminous X-ray binaries (ULXs, or sources with $L_X > 10^{39}$ ergs s^{-1}). While many ULXs are likely to be stellar-mass black holes at the high end of the X-ray binary mass function, the highest luminosity ULXs are more likely to be intermediate-mass black holes (IMBH). Determining how persistent these sources are would argue to would help to determine if they are due to IMBH as opposed to super-Eddington accretion onto stellar-mass black holes. In addition the tidal capture of stars by dormant supermassive black holes would likely be observed (at a rate to be determined).

Expected Numbers in an XXL XMM Survey

Georgantopoulos et al. (2005) correlated the SDSS with XMM observations to create the "Needles in a Haystack Survey (NHS)". This resulted in the detection of 28 galaxies in 11 deg^2 down to a limiting 0.5-8.0 keV flux of ~ 2 x 10^{-15} ergs s^{-1} cm^{-2} (0.5-2.0 keV flux of ~ 1 x 10^{-15} ergs s^{-1} cm^{-2}, assuming a power-law spectrum with $\Gamma \sim 2$). Georgakakis et al (2006) report the detection of 23 galaxies in ~ 6 deg^2 down to a limiting flux of ~ 10^{-15} ergs s^{-1} cm^{-2} in the xmm1 serendipitous source catalog. Kim et al. (2005) report finding 23 normal galaxies in ~ 2 deg^2 down to a limiting 0.5-8 keV flux of ~ 10^{-15} ergs s^{-1} cm^{-2}. The logN-logS of normal galaxies as derived by Ranalli et al. (2006) is shown in Figure 2. These results imply that a ~ 100 deg^2 survey would detect several hundred galaxies if the limiting flux were also on the order of ~ 1 x 10^{-15} ergs s^{-1} cm^{-2}. Scaling from COSMOS suggests that total exposures on the order of 20-25 Ms would be required.

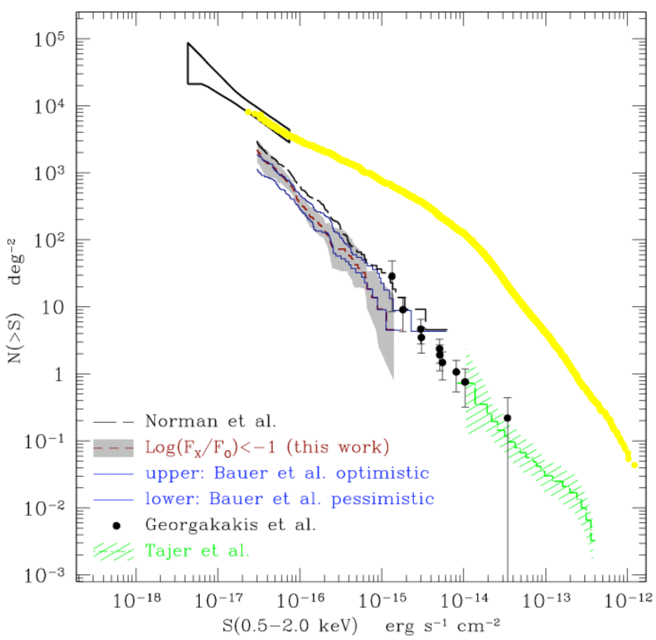

Figure 2: The logN-logS relation for normal galaxies determined from Ranalli et al. (2005).

As is also shown in Figure 2, at fluxes of order 10^{-16} or higher the X-ray number counts will be completely dominated by AGN. Therefore the science goals of any XLL XMM survey would be driven by AGN and cluster science with galaxies being a secondary science goal. However since $F_X/F_{Opt} < 10^{-2}$ for galaxies and $F_X/F_{Opt} > 10^{-2}$ for AGN, any XXL XMM survey optimized for AGN, namely including good optical/NIR coverage for optical identification and photometric redshifts, would correspondingly be suitable for galaxy science since the optical counterparts will be brighter on average. The optical/NIR photometry and, if available, spectroscopy would also serve to derive galaxy types and stellar masses. Particularly when optical spectra are not available, UV and/or FIR coverage would be desirable to derive unobscured and obscured star-formation rates.

Future Work

- Determination of the number of galaxies expected from current surveys such as COSMOS, XMM2 and the XMM slew survey.
- Determine more precisely what exposure times and sensitivities are realistic, and the corresponding number of detections and sources with sufficient counts for hardness ratios or simple spectral modeling (probably on the order of 10-100).
- Optimize field selection, although this will almost certainly be dominated by cluster and AGN science.
- Simulation of the expected local normal galaxy luminosity function, including segregation by spectral type (i.e., via the R-K color). Evolution would not be observed directly since most galaxy detected at fluxes of 10^{-15} or greater will be at redshift of < 0.1, however this sample will serve as the baseline for determining the amount of evolution observed in deep fields.