The Interplay among Black Holes, Stars and ISM in Galactic Nuclei
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X-raying cosmic star formation history

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Abstract. Based on our previous work about a co-evolution of massive black holes (MBH) and their host spheroids, we estimate the cosmic star formation history associated with AGN accretion by ROSAT X-ray All sky surveys. We show: 1) the total amount of star formation associated with MBH growth is at least half of the net star formation at high redshift, which probably totally missed by the current UV/optical deep surveys; 2) the FIR emission from the dust heated by star formation on-going during the MBH growth could be a significant energy source for SCUBA populations; 3)the peak redshift of the massive spheroid formation in this case is around 1.5, not necessary to be at much higher redshift.

1. Introduction

A mean value of the black hole to bulge mass ratio $\mathrm{M_{bh}/M_{bulge}} \sim 10^{-3}$ and the local BH density $\rho_{\mathrm{bh}} \sim 3-5\times 10^5 \mathrm{M_\odot/Mpc^3}$ are given by different observations. This correlation implies a possible scenario where the accretion history in the inner few parsecs and the $\sim$ kpc sized star formation during spheroid formation are closely connected. Since deep X-ray surveys provide a direct probe of the AGN accretion history, we trace the BH growth and the joint star formation with soft X-ray $0.5 - 2$ keV surveys.

We adopt in the calculation: 1) a derivation of the BH mass from the AGN X-ray emission by assuming an Eddington ratio ϵ; 2) the black hole to bulge mass correlation; 3) a similar time scale for the BH growth and the intensive star formation populating finally the spheroids based on our previous work. The present day BH density and the SCUBA number counts are used as two important model constraints in the calculation, with the set of cosmological parameters $(\Omega_{\mathrm{m}}, \Omega_\Lambda) = (0.3, 0.7)$ and $\mathrm{H_0} = 50$ km/s/Mpc.

2. Model and results

Assuming an Eddington ratio $\epsilon = \frac{\eta \dot{m} c^2}{\mathrm{L_{Edd}}}$, we estimate the BH mass from the X-ray luminosity by $\mathrm{M_{bh}} = \frac{\beta\,\mathrm{L_x}}{0.013\epsilon}$. $\mathrm{L_x}$ is the AGN $0.5-2$ keV luminosity in units of 10^{40}erg s^{-1} and M_{bh} in units of $\mathrm{M_\odot}$; β is the bolometric correction ($\mathrm{L_{bol}} = \beta \mathrm{L_x}$). We adopt $\beta = 20$ based on the mean type 1 AGN SED of Elvis et al. (1994) and assume each AGN shines for a constant time scale $\mathrm{t_Q} = 5\times 10^8$yrs, close to the e-folding time. The “duty cycle” of AGN active phase is defined as $\mathrm{f_{on}} = \mathrm{t_Q}/\mathrm{t_{Hub}(z)}$, $\mathrm{t_{Hub}(z)}$ is the Hubble time. We approximate $\epsilon = 10^{\gamma\,(log\mathrm{L}\,-\,49)}$, $\gamma \approx 0.2$ is a scaling factor from various AGN observations.

Considering all AGNs in Miyaji et al. (2000) sample as unobscured type 1, the BH mass function could be derived from the observed XLF by:

$$\frac{\mathrm{d}\,\Phi(z, M_{\mathrm{bh}})}{\mathrm{d}\,M_{\mathrm{bh}}} = \frac{0.013\,\epsilon}{\beta\, f_{\mathrm{on}}}\,\frac{\mathrm{d}\,\Phi(z, L_{\mathrm{x}})}{\mathrm{d}\,L_{\mathrm{x}}} \tag{2.1}$$

The abundance ratio of type 2 and 1 AGNs is described as $\mathrm{R_{2-1}} = 4\mathrm{e}^{-\frac{\mathrm{L_x}}{\mathrm{L_s}}} + \alpha(1+\mathrm{z})^{\mathrm{p}}\,(1-\mathrm{e}^{-\frac{\mathrm{L_x}}{\mathrm{L_s}}})$. $\mathrm{L_s} = 10^{44.3}$erg s^{-1} is the e-folding luminosity. α and p are free parameters.

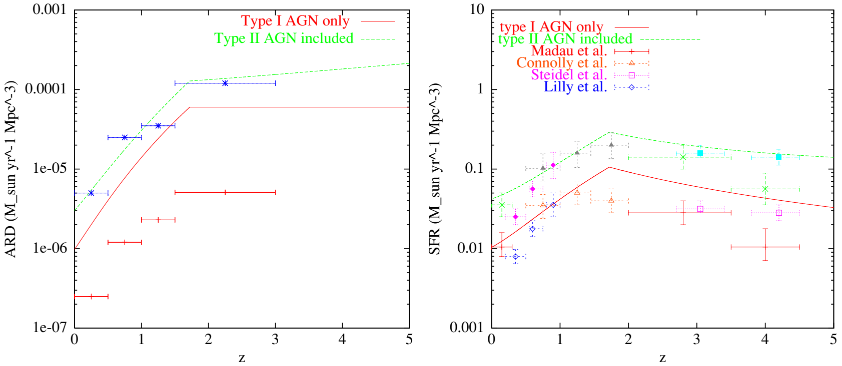

Figure 1. (*left*) ARD vs. redshift by the model (lines). The blue asterisks represent the ARD calculated from the bolometric luminosities of 69 hard X-ray selected sources; while the red crosses from their X-ray luminosities as a low limit (Barger et al. 2001). (*right*) Co-moving SFR in the host galaxies of different AGN samples (lines). The data are indicated in the Figure, the filled symbols are of dust correction (×4.7) (Steidel et al. 1999).

Based on a joint evolution scheme of the massive BHs and their spheroids, the mass function of spheroids may have a similar form to the BH mass function and is given by:

$$\frac{\mathrm{d}\,\Phi(z, M_{\rm sph})}{\mathrm{d}\,M_{\rm sph}} = \frac{\mathrm{d}\,\Phi(z, M_{\rm bh})}{\mathrm{d}\,M_{\rm bh}} \times \mathrm{R} \tag{2.2}$$

R is the black hole to bulge mass ratio, a mean value of ~ 0.002 is adopted as the first approximation (Wang & Biermann 1998; Merritt & Ferrarese 2001).

To discuss the contribution of the starburst activities associated with BH growth to the SCUBA number counts, we adopt a mean value $\mathrm{L_{FIR}/L_\odot} = 3.8\times10^9\ \mathrm{SFR(M_\odot\ yr^{-1})}$.

Similar to eq. 1, we give below the $850\mu m$ luminosity function at different redshift with a mean color ratio $\mathrm{R_c} = \mathrm{L_{FIR}/L_{850}} \sim 5\times10^3$ by Chary & Elbaz (2001) from IRAS, ISO and SCUBA surveys:

$$\frac{\mathrm{d}\,\Phi(z, L_{850})}{\mathrm{d}\,L_{850}} = f_{\widehat{\rm on}}\,\frac{\mathrm{d}\,\Phi(z, M_{\rm sph})}{\mathrm{d}\,M_{\rm sph}}\,\frac{\mathrm{d}\,M_{\rm sph}}{\mathrm{d}\,L_{850}} \tag{2.3}$$

where $\mathrm{f}_{\widehat{\rm on}} = \mathrm{t_{sf}/t_{Hub}}$ reflects the fraction of galaxies with intensive star formation ongoing. $\frac{\mathrm{d\,M_{sph}}}{\mathrm{d\,L_{850}}} = \frac{\nu\ \mathrm{R_c\ t_{sf}}}{3.8\times10^9\ L_\odot}$, $\mathrm{R_c}$ and $\mathrm{t_{sf}}$ are the parameters discussed above. $\nu = 3.5\times10^{11}$ is the frequency of $850\,\mu m$. Since the early dusty star formation could be well constrained by the far-infrared and submillimeter deep surveys, we have checked the $850\,\mu m$ number count fitting in our model and found that the amount of star formation related to the spheroid formation during the black hole growth could sufficiently heat the dust, and account for the far-infrared emission in most of the SCUBA counts.

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References

Barger, A. J., et al. 2001, AJ, 122, 2177
Chary, R., & Elbaz, D. 2001, ApJ, 556, 562
Elvis, M., et al. 1994, ApJS, 95, 1
Merritt, D., & Ferrarese, L. 2001, MNRAS, 320, L30
Miyaji, T., Hasinger, G., & Schmidt M. 2000, A&A, 353, 25
Steidel, C. C., et al. 1999, ApJ, 519, 1
Wang, Y. P., & Biermann, P. L. 1998, A&A, 334, 87