Formation and Evolution of Galaxy Bulges
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Chemical evolution of Seyfert galaxies

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Abstract. We computed the chemical evolution of Seyfert galaxies, residing in spiral bulges, based on an updated model for the Milky Way bulge with updated calculations of the Galactic potential and of the feedback from the central supermassive black hole (BH) in a spherical approximation. We followed the evolution of bulges of masses $2 \times 10^9 - 10^{11} M_\odot$ by scaling the star-formation efficiency and the bulge scalelenght as in the inverse-wind scenario for ellipticals. We successfully reproduced the observed relation between the BH mass and that of the host bulge, and the observed peak nuclear bolometric luminosity. The observed metal overabundances are easily achieved, as well as the constancy of chemical abundances with the redshift.

Keywords. Galaxy: bulge, galaxies: abundances, galaxies: evolution, galaxies: Seyfert

1. The evolution model

We based our analysis on the model by Ballero *et al.* (2007), which holds for a bulge of $M_b = 2 \times 10^{10} M_\odot$. In order to analyse bulges of different masses, we chose to keep the IMF and infall timescales constant and to scale the effective radius and the star-formation efficiency following the inverse-wind scenario of Matteucci (1994); therefore, for bulges of 2×10^9 and $10^{11} M_\odot$ we adopted a star-formation efficiency of 11 and 50 Gyr^{-1} and an effective radius of 1 and 4 kpc, respectively.

We define a displacement radius r_t where the gas contained at $r < r_t$ is carried by the wind, and we adopt $r_t = 3R_e$. The gas binding energy ΔE_b is made up by the contribution of three components, a Hernquist (1990) distribution for the bulge stellar component, an isothermal dark matter halo with circular velocity v_c and a razor-thin exponential disk. These components are represented by the terms at the r.h.s. of the equation:

$$\Delta E_b = \frac{GM_g M_b}{r_b} \times \Delta \tilde{f}_b(\delta) + M_g v_c^2 \times \Delta \tilde{f}_{DM}(\delta) + \frac{GM_g M_d}{r_d} \times \Delta \tilde{f}_d(\delta, r_d) \tag{1.1}$$

where M_g is the bulge gas mass, r_d is the disk scalelenght, $r_b = R_e/1.8$ and $\delta = r_t/r_b$.

The supernova feedback is calculated as in Pipino *et al.* (2002). We consider a spherically accreting BH, at a rate $\dot{M}_{BH}$ given by the minimum between the Bondi and Eddington rate (Sazonov *et al.* 2005). The bolometric luminosity emitted by the BH is then $L_{bol} = \eta c^2 \dot{M}_{BH}$ ($\eta = 0.1$, Yu & Tremaine 2002) and we assume that the energy released is a fraction $f = 0.05$ (Di Matteo *et al.* 2005) of L_{bol} integrated over the timestep.

2. Results

We showed that the BH feedback is in most cases not significant in triggering the galactic wind with respect to the supernova feedback. The predicted BH masses are in agreement with measurements of BH masses inside Seyferts (e.g. Peterson 2003) and reproduce fairly well the relations of McLure & Dunlop (2002) and Marconi *et al.* (2003).

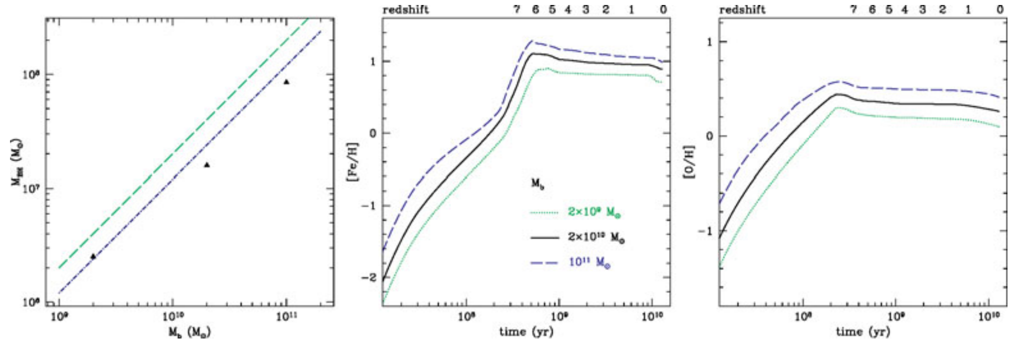

Figure 1. *Left panel*: predicted M_{BH} *vs.* M_b relation compared with the observations of Marconi & Hunt (2003, dashed-dotted line) and McLure & Dunlop (2002, long-dashed line). *Middle and right panel*: Evolution with time and redshift z of the [Fe/H] and [O/H] abundance ratios; z is derived for a ΛCDM cosmology with $H_0 = 65$ km s^{-1} Mpc^{-1}, $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$, and $z_f \simeq 10$.

The predicted bolometric luminosities lie in the range $10^{42} - 10^{44}$ ergs s^{-1}, in agreement with recent estimates (e.g. Wang & Wu 2005), although we could not reproduce a true quiescence after the peak due to the lack of a hydrodynamical treatment.

Solar metallicity is reached in a very short time ($\lesssim 10^8$ yr). The huge metallicities inferred from observations (Fields *et al.* 2005b) are thus easily achieved, with more massive bulges giving rise to higher metallicities (up to 7 times solar). After the first $\sim 3 \times 10^8$ years, the bulge ISM reaches overabundances of up to 10 times solar for N, Fe, Si, 5 times solar for Mg and 3 times solar for C, O, roughly consistent with the estimates for Fe, N and O in the broad and intrinsic narrow line regions of Seyferts (e.g. Storchi-Bergmann *et al.* 1996; Ivanov *et al.* 2003). The slightly supersolar [Fe/Mg] and its weak dependence on the bulge luminosity (mass) are recovered (Dietrich *et al.* 2003). The mean value of the [N/C] ratio is very sensitive on the bulge mass, due to its sensitivity on metallicity. The predicted values (N/C $\sim 1.5 - 4$(N/C)$_\odot$) agree with the estimates of Fields *et al.* (2005a).

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