RevMexAA (Serie de Conferencias), **17**, 198–198 (2003)

BLACK HOLE MASSES OF BL LAC OBJECTS

J.K. Kotilainen,[1] R. Falomo [2] and A. Treves[3]

The black hole (BH) mass [M(BH)] is of paramount importance in AGN models, as the dependence of M(BH) on host galaxy properties provides clues to the role of BHs in galaxy formation and evolution. The only direct dynamical method for measuring M(BH) in AGN is the time-consuming reverberation mapping of broad emission lines. Consequently, only for a few AGN M(BH) is known (e.g. Kaspi et al. 2000; Wandel 2002).

Recently, a strong correlation was found relating M(BH) with the bulge stellar velocity dispersion σ in nearby ellipticals (Ferrarese & Merritt 2000; Gebhardt et al. 2000). This relationship demonstrates a connection between BHs and bulges, and has spurred substantial theoretical effort (e.g. Adams et al. 2001). However, it requires the measurement of σ in AGN host galaxies that is difficult to obtain for high redshift and/or luminous objects. On the other hand, BL Lac objects have relatively faint nuclei, and for them this measurement can be secured with a medium-sized telescope.

We present optical spectroscopy of the host galaxies of seven nearby (z < 0.06) BL Lacs. Spectra were taken with the 2.5m NOT and ALFOSC in the spectral ranges 4800 – 5800 Å and 5700 – 8000 Å, allowing the measurement of the absorption lines of e.g. Mg I (5175 Å) and Na I (5892 Å) from the host galaxies. The spectral resolution was ∼60 – 80 km s^{-1}, adequate for the expected range of σ in luminous ellipticals (e.g. Bender et al. 1992).

We used the Fourier Quotient method (e.g. Sargent et al. 1977), in which the Fourier Transforms of the galaxy spectra were divided by those of template stars and the values of σ were computed from a χ^2 fit with Gaussian broadening function (Kuijken & Merrifield 1993). For three BL Lacs we have data in both spectral ranges. The resulting values of σ are in good agreement, ensuring homogeneity of data taken with different grisms and resolution.

We have adopted the relationship between M(BH) and σ found for nearby ellipticals (Merritt & Ferrarese 2001): M(BH) = $1.48\pm0.24 \times 10^8$ $(\sigma/200)^{4.65\pm0.48}$ [$M_\odot$]. We assume that this relationship is valid for BL Lacs, as imaging studies (e.g. Falomo & Kotilainen 1999) indicate that they are hosted by luminous ellipticals. The derived values of M(BH) span from 5 x 10^7 $M_\odot$ to 9 x 10^8 $M_\odot$.

M(BH) is also correlated (with a larger scatter) with the bulge luminosity (mass) in nearby ellipticals (e.g. Magorrian et al. 1998). M(BH) was calculated from the relationship by McLure & Dunlop (2002): log M(BH) = -0.50 ± 0.05 M_R – 2.91 ± 1.23 [$M_\odot$]. The two methods agree quite well, with average values of M(BH) derived from σ and the host luminosity: $<\log M(BH)>_\sigma = 8.62\pm0.23$ and $<\log M(BH)>_{host} = 8.66\pm0.25$.

The dynamical mass of the hosts can be estimated from (Bender et al. 1992): $M_{host}=5\sigma^2 r_e/G$, and is in the range of 1 – 4 x 10^{11} $M_\odot$. The ratio between M(BH) and M_{host} is in the range of 0.5 – 3.6×10^{-3}, with average value 1.4×10^{-3}, in good agreement with values derived for AGN and inactive galaxies (Merritt & Ferrarese 2001).

Both BL Lacs and low redshift radio galaxies (Bettoni et al. 2001) follow well the Faber & Jackson (1976) relationship between host luminosity M_R and σ. The similarity of the distributions of σ and M(BH) in BL Lacs and radio galaxies is consistent with the unified model of AGN, where BL Lacs are drawn from the population of radio galaxies according to orientation effects (Urry & Padovani 1995).

For a full discussion, see Falomo et al. (2002).

[1]Tuorla Observatory, University of Turku, Väisäläntie 20, FIN–21500 Piikkiö, Finland (jarkot@astro.utu.fi).

[2]Osservatorio Astronomico di Padova, Italy.

[3]Università dell'Insubria, Como, Italy.

REFERENCES

Adams,F.C., et al., 2001, ApJ, 551, L31
Bender,R., et al., 1992, ApJ, 399, 462
Bettoni,D., et al., 2001, A&A, 380, 471
Faber,S.M., & Jackson,R.E., 1976, ApJ, 204, 668
Falomo,R., & Kotilainen,J., 1999, A&A, 352, 85
Falomo,R., Kotilainen,J., Treves,A., 2002, ApJ, 569, L35
Ferrarese,L., & Merritt,D., 2000, ApJ, 539, L9
Gebhardt,K., et al., 2000, ApJ, 539, L13
Kaspi,S., et al., 2000, ApJ, 533, 631
Kuijken,K., & Merrifield,M.R., 1993, MNRAS, 264, 712
Magorrian,J., et al., 1998, AJ, 115, 2285
McLure,R., & Dunlop,J., 2002, MNRAS, 331, 795
Merritt,D., & Ferrarese,L., 2001, MNRAS, 320, L30
Sargent,W.L.W., et al., 1977, ApJ, 212, 362
Urry,C.M., & Padovani,P., 1995, PASP, 107, 803
Wandel,A., 2002, ApJ, 565, 762

Galaxy Evolution: Theory and Observations (Cozumel, Quintana Roo, México, 8-12 April 2002)
Editors: Vladimir Avila-Reese, Claudio Firmani, Carlos S. Frenk & Christine Allen