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Feedback from AGN.
The kinetic/radio luminosity function

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CONTEXT: Virtually all massive galaxies, including our own, host central black holes ranging in mass from millions to billions of solar masses. The growth of these black holes releases vast amounts of energy that powers quasars and other weaker active galactic nuclei. A tiny fraction of this energy, if absorbed by the host galaxy, could halt star formation by heating and ejecting ambient gas. A central question in galaxy evolution is the degree to which this process has caused the decline of star formation in large elliptical galaxies, which typically have little cold gas and few young stars, unlike spiral galaxies (see Cattaneo et al. 2009 for a review).
All previous estimates of the contribution of the AGN radio activity to the heating of the ambient gas have been based on the measure of the AGN radio luminosity function. These estimates however reflects mainly the contribution of the radio loud population, while the contribution of the radio-quiet population is still scarcely known (see e.g. Shankar et al. 2008; Kording et al. 2008; Merloni & Heinz 2008; Smolcic et al. 2009; Cattaneo & Best 2009).

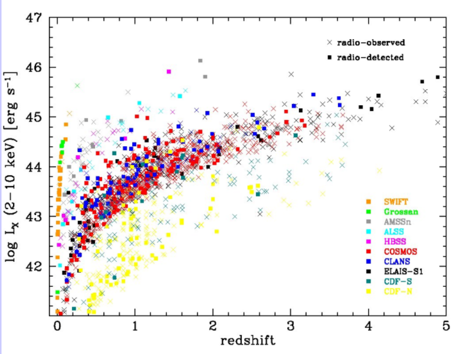

Fig. 1 - X-ray intrinsic luminosity as a function of redshift of our complete sample of ~1600 AGN for which 1.4 GHz radio observations are available. Radio detections are represented by squares while crosses represent sources with radio flux upper limits.

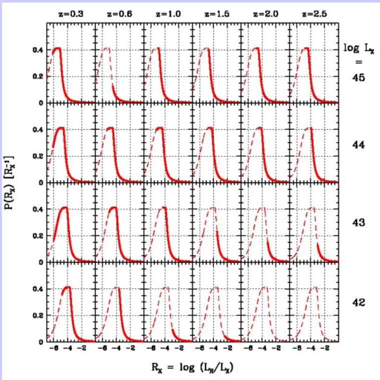

Fig. 2 – Best fit probability distribution of the ratio R=log(L_R/L_X) as a function of intrinsic 2-10 keV X-ray luminosity and redshift. The continuous lines indicate the parts of the distribution probed by the data, while the dashed lines show the parts which have been extrapolated.

AIMS: We wish to measure the distribution P(R) of the ratio R=log(L_R/L_X) of the radio to X-ray intrinsic (absorption corrected) luminosity of AGN as a function of the X-ray luminosity and redshift, probing also the radio quiet population. The knowledge of the distribution of R=log(L_R/L_X) (once convolved with: a) the X-ray AGN luminosity function, and b) the conversion of the radio luminosity into kinetic luminosity) will be used to derive the AGN kinetic luminosity density.

METHODS: We have measured (via χ^2 fitting) the distribution P(R) of the ratio R=log(L_R/L_X) as a function of the X-ray intrinsic (absorption corrected) luminosity and redshift from a compilation of complete hard (2-10 keV) X-ray selected samples of AGN, all observed in the radio (1.4 GHz). A total of about 1600 AGN have been used (see Fig. 1). In order to avoid FRII sources whose radio lobe emission belongs to million of years older epochs than the nuclear X-ray emission, a radio-optical (maximum likelihood) cross-correlation has been carried out within 5 arcsec of radius (~40 kpc at z~2). A total of 375 AGN have been detected in the radio. For a complete sub-sample of ~50 X-ray bright AGN it was possible to reach a ~80% level of radio detections, and therefore, for the first time it was possible to derive the complete probability distribution function of the ratio R=log(L_R/L_X), probing the radio quiet population down to R=-6 .

RESULTS:

1) Our best fit estimate of the probability distribution of the ratio R=log(L_R/L_X) is shown in Fig. 2. It roughly spans over 6 decades (-7<R<-1) and has an average value of R~-4.2 which depends from both the X-ray luminosity and redshift.

2) The convolution of our measured distribution of the ratio R=log(L_R/L_X) with the hard X-ray luminosity function of La Franca et al. (2005) and Brusa et al. (2009) fairly reproduces both the radio 1.4 GHz luminosity function (see comparison with Smolcic et al. 2009; Fig. 3) and the 1.4 GHz counts (once the contribution from Wilman et al. 2008 of the FRII radio sources is added). See Fig. 4.

3) In Figure 5 (bottom) we show our estimate of the AGN mechanical (kinetic) luminosity density as a function of redshift (red continuous line). It has been obtained by convolving our measure of the distribution of the ratio R=log(L_R/L_X) with the X-ray AGN luminosity function (La Franca et al. 2005 and Brusa et al. 2009) and the conversion of the radio luminosity into kinetic luminosity from Best et al. (2006) at low luminosities and from Willott et al. (2001) at high luminosities.
Using the above described X-ray luminosity function and the X-ray bolometric correction from Marconi et al. (2004) we have also derived the AGN radiative bolometric luminosity density (green continuous line).

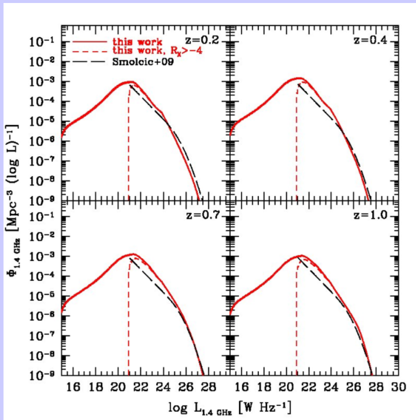

Fig. 3 – Our predicted 1.4 GHz luminosity function at four redshifts (red continuos line) from our fit of the R=log(L_R/L_X) distribution. The measure from Smolcic et al. (2009) is shown by a dashed black line. Our fit fairly well reproduces the measure from Smolcic et al. (2009) once only the radio loud population (with R>-4) is used.

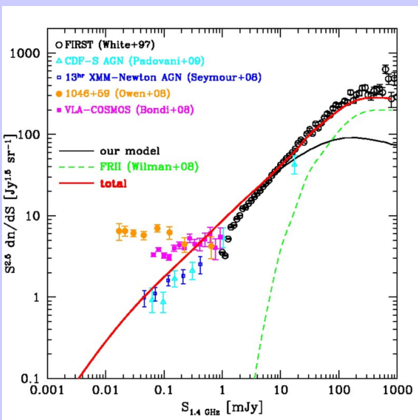

Fig. 4 – Differential radio counts at 1.4 GHz. The counts are fairly well reproduced from our fit of the R=log(L_R/L_X) distribution once the FRII population (which has been excluded from our analysis) is added. The sum of our predicted counts (black line) and the contribution from FRII sources (from Wilman et al. 2008, green line) is shown by the red continuous line.

COMMENTS AND CONCLUSIONS:

1) The knowledge of the P(R) distribution is necessary to estimate the AGN radio feedback, by allowing to couple it with the luminous (accreting) phases of the AGN activity.

2) The average value of R=log(L_R/L_X) increases with decreasing X-ray luminosity and increasing redshift. No statistically significant difference between the radio properties of X-ray absorbed (N_H>10^{22} cm^{-2}) and un-absorbed AGN is observed.

3) The AGN mechanical (kinetic) luminosity density decreases of a factor of 5 below z<0.5, at variance with what assumed in many galaxy formation and evolution models (see Fig. 5). The ratio of the kinetic to the radiative power increases with decreasing redshift (see Fig. 5 top).

4) The exclusion of the radio-quiet population would result in a underestimation of the kinetic power of a factor larger than 2. See comparison of the red dashed and continuous lines in Fig. 5 (bottom).

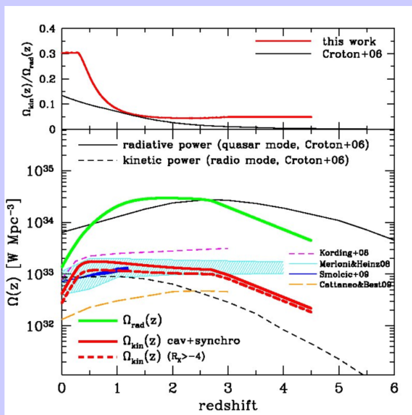

Fig. 5 – *Bottom*. Mechanical (kinetic) and radiative luminosity density as a function of redshift. Red continuous and dashed lines are our kinetic power predictions for the whole AGN population and excluding the radio quiet AGN, respectively. The green continuous line shows our estimate of the radiative bolometric luminosity density. The expectations from Croton et al. (2006) are represented by black lines. The estimates from other authors are also shown. *Top*. Our estimate (red line) of the ratio of the kinetic to the radiative power. The expectations from Croton et al. (2006) are shown by a black line.