X-ray Measurement of the Kinetic Fluxes of 100 kpc Jets

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X-rays provide a direct means to estimate the kinetic power of jets on scales of 100's kpc. From a *Chandra* survey of radio jets, we find enthalpy fluxes typically 1–10 $\times 10^{46}$erg s,$^{-1}$ of order or larger than the bolometric radiation of the host quasar. RESULTS: Γ=6–12; B=5–40μG; θ=4°– 10°; L=100–400 kpc; $N_e \approx 10^{-8}$cm^{-3}.

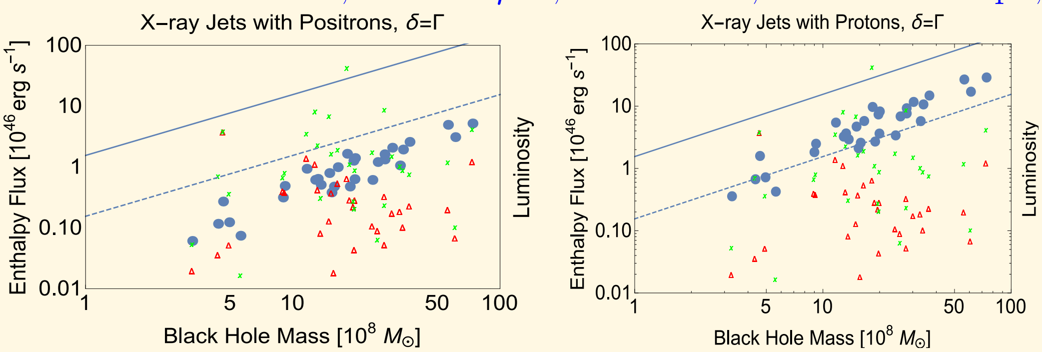

Figure 1. The blue dots show the enthalpy flux ("kinetic power") of the 31 quasar jets detected in our *Chandra* survey. The red triangles triangles show the X-ray luminosity of the host quasars, and the green x show the bolometric radiation deduced from the optical flux. Left panel assumes only positrons balance the electron charge, the right panel assumes only protons. The black hole mass is a proxy based on radio and X-ray luminosity by Gultekin et al. (2009). Solid and dashed lines indicate L_{Edd} and $0.1L_{Edd}$.

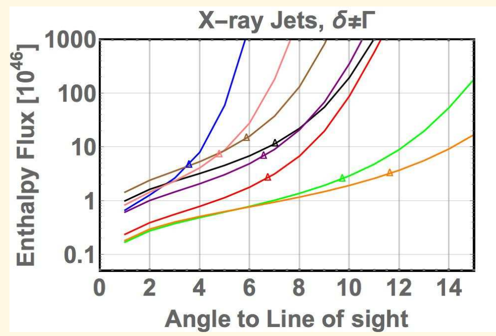

Figure 3. Without an additional assumption, such as setting the Doppler factor $\delta = 1/(\Gamma(1-\beta\cos(\theta))$ to Γ (i.e., half its asymptotic value), we can still assess the possible values of the jet parameters as a function of the unknown angle to the line of sight, θ. The solid lines above show the enthalpy flux vs θ for eight different jets. The triangle shows the value for the angle which corresponds to the $\delta = \Gamma$ assumption. This shows a reasonable compromise between small angles, which would imply very long jets and a high density of similar objects in the sky, and larger angles, which would imply diverging kinetic powers more than 100 times the Eddington luminosity in many cases. Thus while it cannot be true object by object, $\delta = \Gamma$ is reasonable for assessing the properties of a systematic collections of objects, as shown in Figure 2.

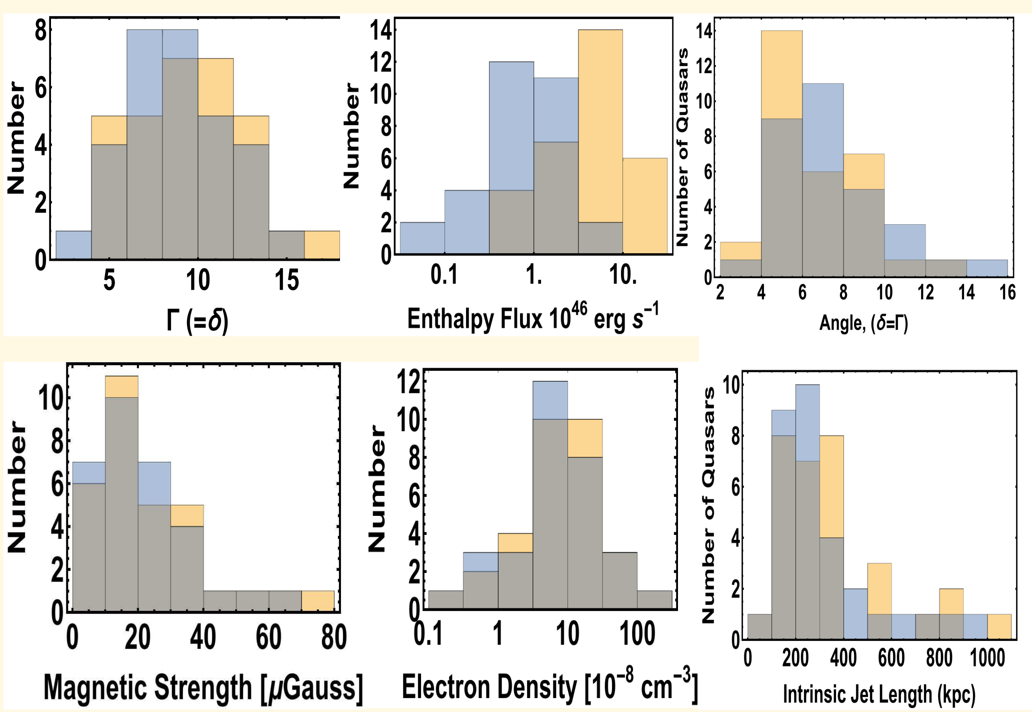

Figure 2. Distribution of parameters derived from the 31 jets detected in a *Chandra* survey of quasar jets. The calculations assume the X-rays are emitted via inverse Compton scattering of the cosmic microwave background in relativistic jets with bulk Lorentz factors Γ, observed at angles θ to our line of sight so that their Doppler factors $\delta = 1/(\Gamma(1-\beta\cos(\theta))$. We assume minimum energy in the jet rest frame, and for these plots break the (Γ, θ, δ) degeneracy by assuming that $\delta = \Gamma$, i.e., half its asymptotic maximum value. Orange histograms assume that protons balance the electron charge in the jet while blue histograms assume only positrons, and the shaded grey overlap regions show that only the enthalpy flux is very sensitive to this assumption.

Chandra Jet Survey

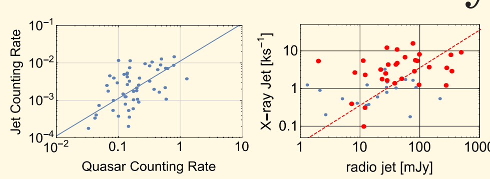

Figure 4. We have performed a snapshot survey (Marshall et al. 2005,2011) of 53 flat spectrum radio quasars, which have radio jets extended on at least 2″ scales. For 31 of these we make a signficant detection coincident with the radio jet. In this work we take the entire inner, straight portion of the radio jet, and correct the X-ray counts for scattering from the quasar, to calculate the distribution of properties of the sample. Left: Correlation of the jet X-ray counting rate (s^{-1}) to the quasar X-ray counting rate is significant with the best linear fit predicting a 1% ratio (Schwartz et al 2015). Right: Correlation of the X-ray jet count rate to the radio jet flux density. The dashed line shows the X-ray rate expected based on the observations of PKS 0637-752, and which resulted in detecting 60% of the sample in 5–10 ks snapshot observations. Both panels show the data from all 53 targets in the survey.

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