Deep Chandra Images of the X–ray Jets in PKS 0208–512 and PKS 1202–262

D.A. Schwartz (CfA), E. S. Perlman, M. Georganopoulos, (UMBC), H.L. Marshall, J. Gelbord, (MIT),D.M. Worrall,, M. Birkinshaw (U Bristol), J.E.J. Lovell, D.L. Jauncey (CSIRO),Bicknell, G. V., Godfrey, L. (MSO/ANU), D.W. Murphy, R.A. Preston (JPL)

PKS 0208-512

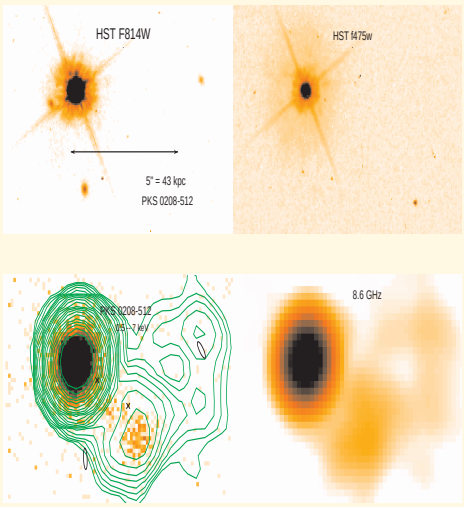

Figure 1. Images of PKS 0208-512, all to same scale. Clockwise from upper left: HST F814W, HST F475W, ATCA 8.6 GHz, Chandra 0.5 – 7 keV. The red f841w image shows two spots, indicated as "X's" on the X-ray image, possibly associated with the jet, and two galaxies, indicated as ellipses on the X-ray image, which may be relevant to the jet dynamics. These are not visible on the F475W image. The 8.6 GHz contours, in factors of $\sqrt{2}$ starting at 1 mJy, are superposed on the X-ray image.

Abstract

We have followed up the discovery of X-ray jets in the quasars PKS 0208-512 at z=0.999, and PKS 1202-262 at z=0.789, (Marshall et al. 2005), with deeper *Chandra* images. We interpret the overall SED in terms of inverse Compton scattering on the cosmic microwave background, in relativistic jets directed close to our line of sight.

We acknowledge the support of NASA contract NAS8 39073 to SAO, SAO contract SAO SV1-61010 to MIT, CXC grants G02-3151 and G04-5107X, HST grant STGO-10002.01, and NASA grant NAG5-9997

Discussion

The broadband SED's (cf. Figs 5 & 6) do not allow a single power law electron distribution to produce both the radio and X-ray emission via synchrotron radiation. Under the hypothesis of minimum energy, the X-rays can be made from the same electron population by inverse Compton scattering off the cosmic microwave background (IC/CMB). We deduce that the PKS 0208-512 jet is moving with bulk Lorentz factor $\Gamma \approx 6$ and PKS 1202-262 has $\Gamma \approx 10$, and that their internal magnetic fields are $\approx 10\ \mu$ G.

With the deeper observations shown here we can study the spatial structure in more detail. We note that the X-rays carry the bulk of the radiated power from the jet (Figs 3 & 4, right panels). The relative constancy of the x-ray to radio ratio (Figs 3 & 4, left panels) supports the IC/CMB picture, in which both radio and X-rays arise from relatively low energy electrons, with long lifetimes (Fig 7), while synchroton X-rays would arise from electrons with very short lifetimes (Fig 8).

X-ray emission in both jets terminates abruptly where the radio image has a large angle bend.

PKS 1202-262

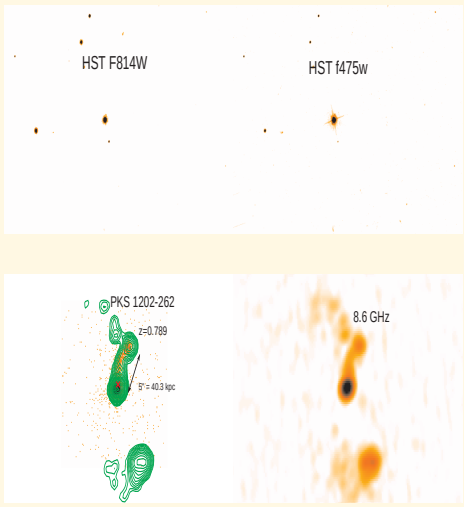

Figure 2. Images of PKS 1202-262, all to same scale. Clockwise from upper left: HST F814W, HST F475W, ATCA 8.6 GHz, Chandra 0.5 – 7 keV. Both HST images show a spot, indicated as a red "X" on the X-ray image, probably associated with the jet. The 8.6 GHz contours, in factors of $\sqrt{2}$ starting at 1 mJy, are superposed in green on the X-ray image. Note the abrupt termination of X-rays where the radio bends steeply to the NE.

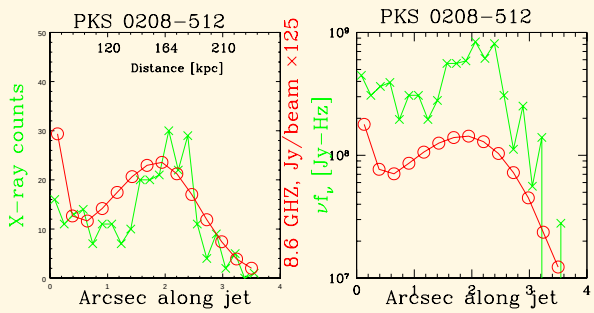

Figure 3. X-ray (green) and 8.6 GHz radio (red) profiles along the jet of PKS 0208-512. The projection starts about 1.″5 from the quasar, and is 4″ wide perpendicular to the jet. The left panel is observed data, with the radio data arbitrarily normalized. In the right panel, we present the energy flux profile for each band. On the top horizontal scale we give the distance from the quasar core, considering our modelled angle to the line of sight.

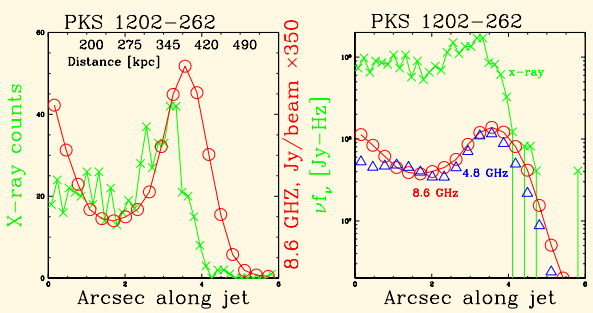

Figure 4. X-ray (green), 8.6 GHz radio (red), and 4.8 GHz (blue triangles) profiles along the jet of PKS 1202-262. The projection starts about 1.″8 from the quasar, and is 3″ arcsec wide perpendicular to the jet. The left panel is observed data, with the radio data arbitrarily normalized. In the right panel, we present the energy flux profile for each band. On the top horizontal scale we give the distance from the quasar core, considering our modelled angle to the line of sight.

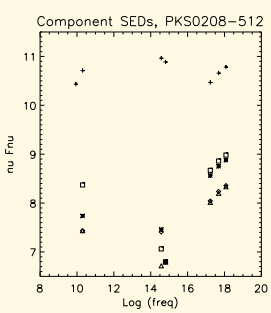

Figure 5. Spectral energy distribution of distinct spatial regions of the PKS 0208-512 jet.

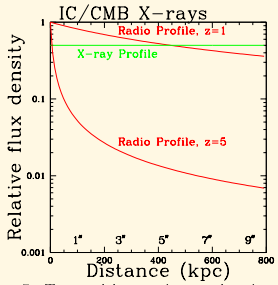

Figure 7. Toy model assuming acceleration at a point, radio synchrotron with B=10 μ G, and bulk motion with $\Gamma = 10$. Angular scale assumes z=1 and that jet is 0.1 radian from our line of sight.

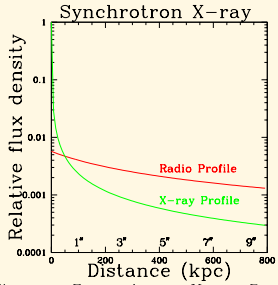

Figure 8. For synchrotron X-rays, B must be larger, and Γ smaller. The lifetime of X-ray emitting electrons is much shorter, and therefore the X-ray profile falls very steeply relative to the radio.

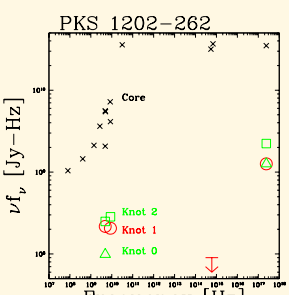

Figure 6. Spectral energy distribution of distinct spatial regions of the PKS 1202-262 jet.