Astrophysical Phenomena Revealed by Space VLBI
H. Hirabayashi, P.G. Edwards and D.W. Murphy (eds.)

VSOP and Chandra Observations of 0836+710

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Abstract

In this paper we describe the radio observations that form part of co-ordinated Chandra, HALCA+VLBA, and VLBA-only observations of the gamma-ray loud quasar 0836+710. The radio observations were at 6 frequencies (1.6, 5, 8, 15, 22, and 43 GHz) with the two lower frequency observations being undertaken with HALCA co-observing with the VLBA. The aim of the radio observations is to determine the peak brightness temperature of each of the VLBI components and hence provide better constraints on predicted X-ray emission than has previously been possible.

1 Introduction

There is much interest in relating the radio properties of AGN with their high energy X-ray and gamma-ray properties. With the simultaneous operation of both the HALCA spacecraft and the Chandra mission it becomes feasible to test the popular Synchrotron-Self Compton (SSC) model with the current generation of both VLBI and X-ray facilities. We undertook co-ordinated observations of the high redshift (z=2.17) superluminal gamma-ray and X-ray loud, core-dominated radio quasar 0836+710, with the VLBI observations taking place on 7 October 1999 followed by the Chandra observations on 16 October 1999.

2 VLBI Observations of 0836+710

Our VLBI observations of 0836+710 were a target of opportunity proposal since the X-ray observations were scheduled earlier in the lifetime of the Chandra mission than we had previously envisioned. HALCA co-observed for about 11 hours with the VLBA at both 1.6 GHz and

5 GHz followed by 3 hours of VLBA-only data where several snapshots were undertaken at 8, 15, 22, and 43 GHz. The HALCA observations used the unusual observing mode with one 16 MHz channel observing at 1.6 GHz and the other at 5 GHz. During this time the VLBA switched between observing at 1.6 GHz or 5 GHz on a roughly 10-minute timescale. Figure 1 shows the (u, v)-coverages and images from our 1.6 and 5 GHz HALCA+VLBA observations. At 5 GHz, 0836+710 is the subject of a VSOP monitoring campaign by Lobanov and 5 GHz VSOP images have already been published (Lobanov et al. 1998).

3 X-Ray Flux Density and Radio Brightness Temperature

To a first approximation, the X-ray flux density (at ν_x) due to SSC scattering in a VLBI component is given by:

$$\frac{S_x}{\mu Jy} \approx (\frac{S_m}{1Jy})(\frac{\nu_m}{1\,GHz})^{\alpha+2}(\frac{T_m}{2.6\times10^{12}K})^{2\alpha+3}(\frac{1+z}{\delta})^{2\alpha+4}(\frac{\nu_x}{1KeV})^{-\alpha}$$

where S_m, T_m, ν_m are the component's observed turnover flux density, brightness temperature, and frequency respectively. α and δ are the component's optically thin spectral index and Doppler factor while z is the source redshift

X-ray observations give the overall source X-ray flux density and multi-frequency VLBI observations allow us to measure the properties of the individual VLBI components which make up the source (hopefully S_m, T_m, ν_m, and α for every component). Combining the X-ray data with the VLBI data then allows the Doppler factor (or at least a lower limit on it) to be determined. From the above formula it can be seen that only those VLBI components with intrinsic brightness temperatures near 10^{12} K are able to produce substantial X-ray flux density.

In Figure 2 we show the observed brightness temperatures of the VLBI components which make up the VLBI jet on 0836+710. For this preliminary analysis we choose to consider the jet to be made up of 4 components which are labeled in Figure 1 (d). From Figure 2 it can be seen only components C0 and C1, i.e., the core and the strong jet component near the core (C1), have brightness temperatures which allow them to produce substantial X-ray emission. This result is similar to that found for the quasar 3C345 (Unwin et al. 1997) and indicates that there might be a universal mechanism which limits component brightness temperatures for components far away from the core i.e., strong shocks

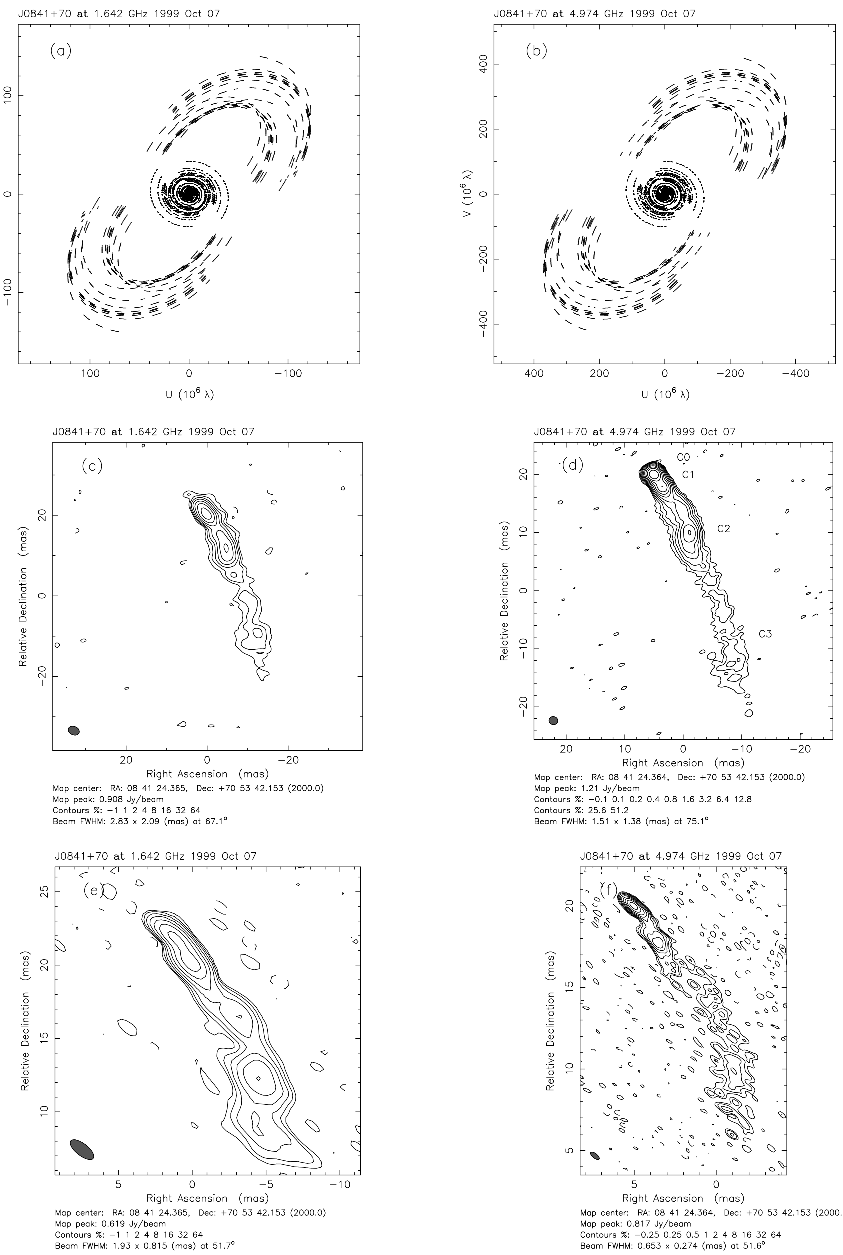

Figure 1: 1.6 GHz and 5 GHz HALCA+VLBA observations: (a) 1.6 GHz (u,v)-coverage (b) 5 GHz (u,v)-coverage (c) 1.6 GHz image (50 Mλ taper) (d) 5 GHz image (100 Mλ taper) (e) 1.6 GHz image (no taper) (f) 5 GHz image (no taper).

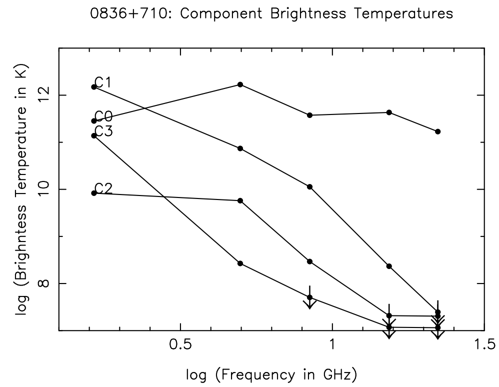

Figure 2: Component brightness temperatures

and *in situ* particle acceleration by themselves seem unable to produce substantial X-ray emission. In should be pointed out that only high resolution 1.6 GHz HALCA+VSOP observations enabled the C0 and C1 properties to be determined at this frequency since the VLBA-only image shows these two components blended into one.

4 Conclusions

The preliminary results above have shown that it is productive to undertake co-ordinated VSOP and Chandra observations. Furthermore the simultaneous 1.6/5 GHz HALCA observing mode with the VLBA switching frequencies is a very efficient mode for strong sources. A small extra amount of VLBA-only time also provides a large increase in the science return since multi-frequency analyses can be undertaken. So far, we have shown that the X-ray emission from 0836+710 is dominated by the emission from the core and 2-mas component. We will extend our analysis when the calibrated Chandra data becomes available.

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References

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