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Structure and Properties of AGN Cores from VLBI and Total Flux Density Variations

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Abstract. By combining VLBI and total flux density data it is possible to get an indirect "look" at the innermost, unresolved core regions of AGN and to estimate physical parameters such as the intrinsic brightness temperatures, Lorentz factors and viewing angles, unobtainable by either VLBI or multi-frequency flux monitoring alone.

1. Introduction

It is well known that the total flux density spectrum and its variations correspond closely to the source structure and its changes. The radio "core" is usually the dominant flux density component at the highest frequencies, while the fluxes of individual VLBI components dominate at lower frequencies, peaking in approximate age order. This is no surprise, since the ejected VLBI components are the same shocks which are known to cause all the major total flux density variations (for a review, see, e. g., Valtaoja 1994).

One might therefore think that due to this close correspondence the total flux density variations, lacking spatial information, are just poor substitutes to be used only when no VLBI data are available. However, this is far from the case. Total flux density (TFD in the following) variations can be used to study the source structure below the resolution obtainable with VLBI. Furthermore, by joining TFD and VLBI data one can estimate basic source parameters unobtainable by either method alone.

Both uses require millimeter data. The simple reason is that at longer wavelengths many components are visible (and blend together) in the VLBI maps. The TFD spectrum and variations also have a corresponding number of contributors, making a unique spectral decomposition impossible. Only above 22 GHz is the number of strong components sufficiently reduced for comparing the components' VLBI and TFD properties and evolution.

2. Unresolved "Cores"

Reports about changes in the point-like VLBI "core" flux are common, but it is uncertain what is really changing. Since the "core" is presumed to be the apex of the jet, the luminosity of the underlying jet itself may be changing. Alternatively, we may have insufficient resolution and a newly created shock component blends together with the core in VLBI maps. (It is useful to remember that at the most common VLBI frequency 5 GHz, a typical $z = 0.5, v/c = 5$ source is seen with a linear resolution of 20 l.y. and with a "time resolution" of 5 years, while TFD variations show typical shock variability and evolution timescales of less than a year; see Valtaoja 1997). It is also possible that a completely new phenomenon is responsible for the core flux variations. These alternatives can be tested with multi-frequency monitoring.

The TFD variations at 22 and 37 GHz can be modeled surprisingly well with a small number of self-similar exponential flares (Valtaoja 1996). For the few sources with good 22 GHz VLBI monitoring, the individual TFD flare fluxcurves correspond very well to the ejected VLBI component fluxcurves. However, there are some cases where the VLBI "core" brightens and dims without a subsequent ejection of a new VLBI component, while the corresponding TFD variations appear similar to other events clearly related with the creation of new VLBI components (e.g., 3C 345 and 3C 395; see Valtaoja 1996, 1997). If these core brightenings were caused by new shocks, why did they never emerge from the core as the others did? Is there a class of shocks which never propagate far along the jet, perhaps due to small speed? Or, if the core brightenings were not caused by shocks, why did the underlying jet's luminosity variations mimic the shock-induced variations so closely? More cases are needed to choose between the possibilities, but in any case it is clear that the "core" is not as simple a component as it may appear on VLBI maps.

3. Determining the Main Source Parameters from VLBI and TFD Data

We can do even better than just complement VLBI data with TFD data: we can actually estimate the main source parameters from such comparisons, arguably more accurately than with any other method. The key idea is that the observed VLBI and TFD parameters have different dependences on the Doppler boosting D and the intrinsic brightness temperature $T_{b,int}$. In the first approximation, the VLBI size of the shock component is unaffected by Doppler boosting (which only produces rotation), while the observed TFD light travel time size does depend on D. Similarly, $T_{b,obs}$(TFD) and $T_{b,obs}$(VLBI) depend differently on D and T_{int}. Simultaneous TFD and VLBI data can thus be combined in various ways to obtain estimates of D and T_{int}; see Wiik & Valtaoja (these proceedings, p. 151).

The obtained values of T_{int} can be used to estimate the true limiting brightness temperature (Lähteenmäki & Valtaoja, these proceedings, p. 135). The calculated values for D are arguably more reliable than the commonly used SSC-derived ones, and can together with VLBI expansion speeds be used to obtain better estimates for the most important jet parameters, the intrinsic Lorentz factor Γ and the viewing angle Θ (Valtaoja & Teräsranta 1994; Lähteenmäki & Valtaoja 1997).

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