



MAX-PLANCK-GESELLSCHAFT

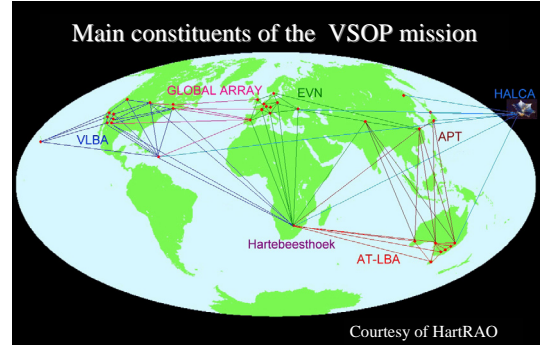


Space VLBI studies of extragalactic jets

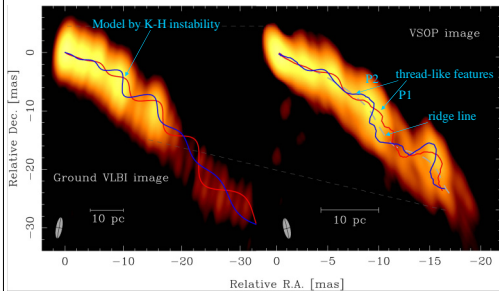
Overview of the VSOP mission

Space VLBI era has begun in the mid 1980-s, with trial experiments using a TDRSS satellite and ground telescopes in Japan and Australia. In the following two decades, several international space VLBI projects were proposed and put under development. The VLBI Space Observatory Programme (VSOP) has been the most successful space VLBI effort so far, employing an 8-meter antenna on board of the Japanese satellite HALCA launched on 12 February 1997. The VSOP mission had continued through 30 November 2005. A large number of ground-

-based radio telescopes took part in VSOP observations at 1.6GHz and 5GHz, turning it into a superb instrument for imaging compact radio sources and studying in detail internal structure and physical properties of extragalactic jets. Studies of the jets in the quasars 0836+710 and 3C273 briefly described below exemplify the excellent scientific capabilities of the VSOP. Following up the scientific outcome of the VSOP, a successor project, named VSOP-2, has been proposed. More information can be found at www.vsop.isas.jaxa.jp/vsop2/



Courtesy of HartRAO

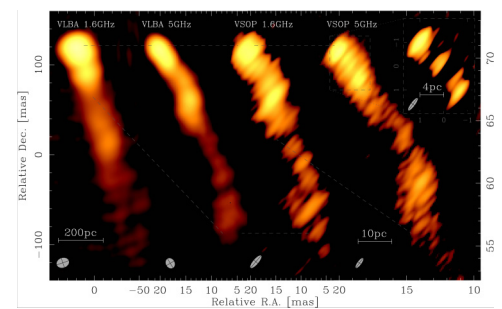


Ground VLBI and VSOP images of 3C273 at 5 GHz. Two thread-like features (red and blue solid lines) are identified in the VSOP image. These features are winding around the mean ridge line of the jet. They are most likely reflecting the development of Kelvin-Helmholtz instability in the relativistic flow.

Jet structure in 3C273

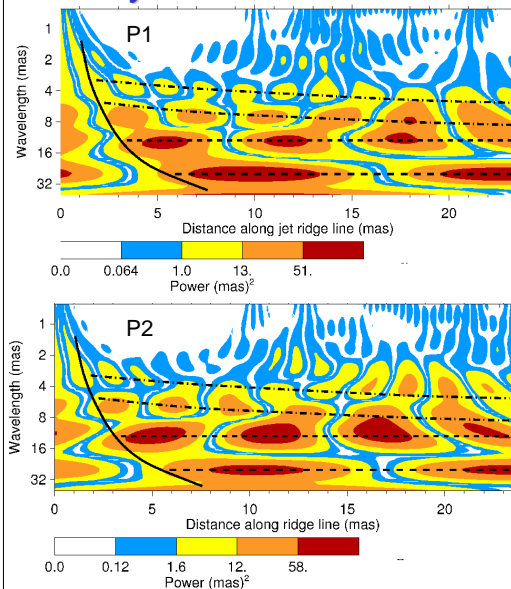
VSOP observations of the quasar 3C273 have yielded an image in which the emission across the jet is resolved, revealing two thread-like patterns which form a double helix inside the jet. This double helical structure can be reconciled with Kelvin-Helmholtz instability, and at least 4 different instability modes can be identified and modeled by a light jet with a Lorentz factor of 2.1 and a Mach number of 3.5. The model reproduces in detail the internal structure of the jet on scales of up to 30 milliarcseconds (~300 parsecs), and is consistent with the general morphology of the jet on scales of up to 1 kiloparsec.

Plasma flow in 0836+710



Collage of four VLBA and VSOP images at 1.6 GHz and 5 GHz. Dashed lines indicate similar scales in different images. Ellipses mark the synthesized beams of each individual image, plotted to the respective scales. The areas covered by the synthesised beams in VLBA image at 5 GHz and the VSOP image at 1.6 GHz are comparable, and these images can be used for mapping the spectral index distribution in the jet.

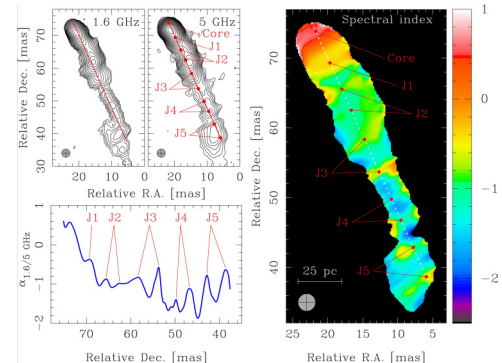
Physics of the relativistic jet plasma in 3C273



Detailed wavelet analysis of the oscillations of the thread-like features detected in 3C273 enables in depth studies to be made of the physical properties of the plasma flowing in the jet of this object. In both thread-like features, the wavelengths of the two shortest modes increase with distance, while the two longer modes keep their wavelengths constant. This implies strongly that the two shorter wavelengths are produced by body modes of Kelvin-Helmholtz instability, while the longer wavelengths are resulting from helical and elliptical surface modes of the instability.

This identification enables a detailed model of the jet flow to be made, and it yields the most accurate to date determination of physical properties of the flowing plasma. This shows that the observed structures are generated in an underdense flow propagating at a moderate Lorentz factor and they represent not likely the outer layers of a stratified relativistic outflow.

Wavelet transforms of the apparent positions of the two thread-like features in the jet in 3C273. Four oscillatory modes are present.



Spectral index distribution in 0836+710. The distribution is derived from the images shown in the top left. Dotted line marks the run of a slice presented in the bottom left panel. Dots indicate the locations of individual peaks identified in the slice. The edges of all distinct regions of enhanced emission (marked with a letter "J" and successive numbers) are emphasized by peaks of the spectral index. The peaks are spaced at quasi-regular intervals, with an average separation of ~4.8 mas. This regularity is indicative of shocks or instabilities developing in the jet plasma.

References:

- A.P. Lobanov, J.A. Zensus, *Science*, 294, 128, 2001
- A.P. Lobanov, T.P. Krichbaum, A. Witzel, J.A. Zensus, *PASJ*, 2006 (in press)