Space VLBI; the VSOP Mission

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Abstract. The space VLBI mission VSOP will be launched in 1996. A brief summary of the mission is given, with an emphasis on the possibilities for stellar astronomy. The relevant starting points to get further information are listed.

1. Characteristics of the VSOP mission

The VSOP acronym stands for VLBI Space Observatory Programme. The mission is run by the Japanese organizations ISAS & NAO, with participation by many other organizations world–wide, which provide ground telescopes, tracking stations, correlators and user facilities.

The projected launch date is September 1996. After in orbit check outs, astronomical observations are anticipated to start early 1997. The satellite has an estimated lifetime of 3 years. The first proposals are due November 17, 1995; a possible second proposal round is planned for early 1997.

The spacecraft consists of a deployable mesh antenna, equivalent in size to an 8m antenna. It is equipped with receivers for 1.6, 5 and 22 GHz. A small antenna is used to send the data down to a tracking station, without any internal storage stage. As the spacecraft does not carry a maser frequency standard, the same ground station will also provide a reference signal.

2. Orbit & Operations

The orbit will be eccentric with an apogee height of 22,000 km, and perigee at 1000 km, which results in a 6.6 hr orbit. A typical astronomy experiment will involve a number of normal ground telescopes. The resulting resolution can be estimated as $\theta \approx 2(\frac{\nu}{\mathrm{GHz}})^{-1}$ mas. The inclined orbit will give optimal U–V coverage for specific parts of the sky at a certain date. But as the orbit precesses the areas of the sky with best U–V coverage will evolve during the mission.

The above constraints for scheduling are further complicated by a number of others: The satellite cannot observe closer than 70° from sun. With the low perigee, the Earth can fill a large part of the sky, which can block the target sources or the sun, which is needed to power the spacecraft. Furthermore, the satellite needs to be in contact with one of the five ground stations (Madrid, Green Bank, Usuda, Goldstone, Tidbinbilla), for data and reference signal links. This results in a complex set of constraints, which also involve the desired U–V coverage and hence will depend on which ground telescopes will participate.

3. Sensitivity

The sensitivity depends on the selected ground telescopes in a specific experiment, as well as the VSOP size, efficiency and receiver quality. The expected values for this are give in Table 1.

Table 1. Predicted VSOP sensitivity

	Observing Band		
	1.6 GHz (20 cm)	5 GHz (6 cm)	22 GHz (1.35 cm)
Frequency Range (GHz)	1.60–1.73	4.7–5.0	22.0–22.3
Polarization	LCP only	LCP only	LCP only
Aperture Efficiency	38%	54%	47%
Aperture Sensitivity (mK Jy^{-1})	69	98	85
System Temperature (K)	100	120	200
SEFD (Jy)	14500	12200	23500

Most major ground telescopes have committed to a certain amount of observing time in conjunction with VSOP. Considerations of which ground telescopes are to be used in a particular experiment include sensitivity, observing band, U–V coverage and availability. This will have to be specified in a general sense by the P.I. in the proposal. Finally, the compatibility of VSOP modes and the ground telescopes need to be considered. The possible VSOP modes are listed in Table 2.

Table 2. VSOP bandwidth & recorder modes

Mode properties			Recorder compatibility	
N channels	Bandwidth per channel	Sampling quantisat.	VLBA/MkIV/S2 compatible	VSOP compatible
Two	16 MHz	2 bit	yes	yes
Two	32 MHz	1 bit	no	yes
One	32 MHz	2 bit	no	yes

These recorder modes must be compatible with the selected ground telescope and correlator for a certain experiment. Only limited copy facilities are available for VLBA→VSOP and S2→VSOP at the VSOP correlator in Mitaka. This 8 station processing facility will be ready in 1996. VLBA/MkIV stations will have 1 mode compatible with VSOP. This will be generally available at European and U.S. telescopes and can be processed at the VLBA correlator in Socorro. The EVN/JIVE MkIV correlator in Dwingeloo, the Netherlands, is planned for 1997.

4. (Circum)Stellar Astronomy with VSOP

Many of the observations will concentrate on AGN's and interstellar masers. Some stellar astronomy projects might be feasible. First the detection of continuum emission from stars is considered. Sensitive baselines can detect $\approx$ 50 mJy of correlated flux at 5 GHz. Here it was assumed that the coherence time $\tau = 350$ s. This is equivalent to $T_{\rm b} = 2 \times 10^{11}$ K at 5 GHz. We have limited knowledge whether the stellar emission mechanisms operate in this brightness regime, but it may be possible that R CVn's and dMe's reach these high brightness temperatures during outburst. The VSOP mission supports proposals for Target of Opportunity observations at any time during the mission, although one should be aware that scheduling on short notice is fairly complicated. Another category of continuum sources of interest are X–ray binaries. Most likely these will be too weak for VSOP. However, the brightest pulsars should be detectable with VSOP.

Masers around evolved stars is another phenomenon in stellar astronomy which can be studied by VLBI. For OH at 1.6 GHz the detection limit for VSOP is $T_{\rm b} \approx 10^{13}$ ($\tau = 650$ s). It seems unlikely that circumstellar OH masers reach this value, especially in view of interstellar scattering, which limits the resolution and hence the brightness temperature. Note that for OH masers VSOP will only have 3 km/s resolution when the VLBA correlator is used. For H_2O at 22 GHz the situation is more promising. With 1 km/s spectral resolution (obtainable with the VLBA correlator for this transition), the detection threshold lies at 4 Jy (/km/s), and $T_{\rm b} = 2 \times 10^{13}$ ($\tau = 150$s).

5. Writing a proposal and getting help

The Announcement of Opportunity (AO) is available and comes with a detailed Proposer's Guide. It can be obtained for instance at the following anonymous ftp sites: `ftp.vsop.isas.ac.jp:/pub/doc`, `sgra.jpl.nasa.gov:/pub` or `ftp.nfra.nl:/jive/vsop/docs`. Or accessed over the World Wide Web at `http://www.vsop.isas.ac.jp/`, `http://sgra.jpl.nasa.gov/` or finally at `http://www.nfra.nl/home_jive.html`. Further help is made available from regional contact points. The e–mail addresses for these can be found in the Proposer's Guide and Announcement of Opportunity. Three Space VLBI software packages are available that can be helpful when writing a proposal. How to get these is also described in the above documents.

Acknowledgments. Thanks to Russ Taylor and Leonid Gurvits for helping me set up this contribution. Most of the information for this paper was obtained from the Proposer's Guide by D.W. Murphy.