Astrophysical Phenomena Revealed by Space VLBI
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A Next-Generation Space VLBI Observatory Assembled in Orbit

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Abstract

A concept for an SVLBI-2 mission with a 25-30 m orbital radio telescope assembled in space is briefly outlined. The International Space Station (ISS), a permanent multi-purpose orbital manned facility, is considered as a base for the telescope assembly.

1 Introduction

This Symposium proves that the first letter in the acronym VLBI, so familiar to the readers of these Proceedings, means **Very** indeed: owing to VSOP, the interferometer baselines are no longer limited by the Earth's diameter. VSOP is the brightest event in the history of Space VLBI (SVLBI) which has begun with several missions proposed in Europe, the USA and the USSR in the 70's and 80's (see Ulvestad et al. 1997 and Davis 1998 for a brief review). One of the earlier proposed missions, RadioAstron (Kardashev 1997), is hoped to become operational this decade and, alongside with VSOP, forms the first generation of SVLBI missions. The technical feasibility of SVLBI was demonstrated by observations conducted with the communication satellite TDRSE in 1986 (Levy et al. 1986). VSOP moves on by testing many new features compulsory for a robust SVLBI observatory. But VSOP is only the beginning of the extraterrestrial era in VLBI. It is clear that the next steps in SVLBI (SVLBI-2 hereafter) will move toward even higher angular resolution, broader frequency coverage and better sensitivity. Of these three main SVLBI-2 characteristics, the latter seems to be of paramount importance.

There are three means of improving VLBI sensitivity:

- to decrease the system temperatures of the telescopes;
- to increase the data rate of the signal recorded;
- to increase the collecting area of each VLBI telescope.

The first option is being actively investigated, with the goal of reaching a system temperature $T_{\rm sys} \approx 10 - 20$ K for most operational frequencies of the ARISE mission (Ulvestad et al. 1997). This development is matched by similar target values for the ground-based radio telescopes. However, further improvement of VLBI sensitivity due to decrease of $T_{\rm sys}$ is becoming asymptotically difficult as the values of system temperature reach single digits in Kelvin.

The second option is also being actively pursued. It is foreseen that a data rate of 1 Gbit/s will become available in a few years (Whitney 1999, Cannon 2000). However, further increase of the data rate might become problematic due to the need to overhaul the entire set of VLBI instrumentation, from the IF electronics to the data processing hard- and software. There is also a practical limit on the width of the signal: the bandwidth must not exceed a reasonable fraction of the sky frequency of the observations. In addition, a major drawback of this venue for sensitivity improvement is its irrelevance to spectral line VLBI.

The remaining option, increase of the collecting area of each element of the VLBI array, remains the only option that is practically unlimited and equally efficient for both continuum and spectral line VLBI observations. Thus, we arrive at the necessity to build a space-borne SVLBI-2 element with as large an antenna as feasible.

2 How and Where To Build a Large SVLBI-2 Antenna

The first generation SVLBI missions, VSOP and RadioAstron, are characterized by 10-m class parabolic reflector antennas. It is reasonable to aim at 25–30 m as the diameter of an SVLBI-2 orbital antenna. To be operational at wavelengths as short as 3 mm (e.g., the target requirement for the ARISE mission, Marscher, these Proceedings), the reflector antenna must have an rms accuracy of ~ 0.2 mm.

Traditionally, SVLBI is considered as a single launch mission with no in-orbit assembly operations. Three possible technologies have been investigated for forming the reflecting surface – mesh, inflatable, or solid material structure. All three options require in-orbit deployment of the antenna. A brief overview of these options and their pros and cons is given in Gurvits (2000). I reiterate here that the two contradictory requirements – overall size in excess of 25 m and sub-millimeter rms accuracy – makes any of these three options extremely challenging.

An alternative to the single launch concept is a mission using a multiple launch and in-orbit assembly of its large payload. This concept makes it possible to accommodate an antenna of considerably larger mass, and therefore larger diameter and better surface accuracy. The multiple launch concept could be combined with all three antenna designs above. However, the most obvious advantages of the multiple launch scheme are for the solid petal antenna. Since the assembly is likely to require manned operations, it is logical to consider the International Space Station (ISS) as the base for such an SVLBI-2 mission. In general, it is imperative for the ISS to become an assembling facility for future large orbital or interplanetary missions.

The SVLBI-2 spacecraft module should have the ability to function in a free-flying regime as well as docked to the ISS. It can reach the ISS in autonomous flight or be delivered to the ISS by a Space Shuttle or other transport spacecraft. In the former case, the module must be equipped with a full set of systems for autonomous flight, rendezvous, proximity operations and docking. Most of these could be utilized for autonomous flight after assembling the radio telescope. The set of antenna elements (petals) could be delivered to the ISS by a Space Shuttle or other transport vehicle involved in the ISS logistics.

The main requirements for the module spacecraft of an SVLBI-2 mission and the overall mission operational issues are similar to those of several other applications (e.g. astrophysical and Earth science missions) that do not need to be permanently located at the station. A very high level of commonality in major mission requirements could be reached between the SVLBI-2 concept described here and the X-ray Evolving Universe Spectroscopy mission (XEUS, Bavdaz et al. 1999).

The assembly of the radio telescope would be carried out in the docked position (Figure 1). It would utilize the available robotic mechanisms on the ISS (e.g., the European Robotic Arm, ERA, and the Canadian Space Robotic Mechanisms) and would require some extravehicular activity by the station crew. A possible scenario for an SVLBI-2 radio observatory assembled in Space is described in Gurvits (2000). Here I underline two important items of this scenario: *(i)* the SVLBI-2 radio telescope occupies one of the ISS docking ports for a very limited time (approximately one month) and leaves the ISS low orbit after completion of assembly and test operations; *(ii)* the in-orbit checkout of the telescope starts while the SVLBI-2 spacecraft is docked at the ISS. The latter provides the opportunity to fix most possible problems with the SVLBI-2 spacecraft before it goes into autonomous flight.

Multiple launch and in-orbit assembly of an SVLBI-2 mission could bring technical, budgetary and logistical advantages over traditional single-launch in-orbit deployment schemes. The in-orbit assembly con-

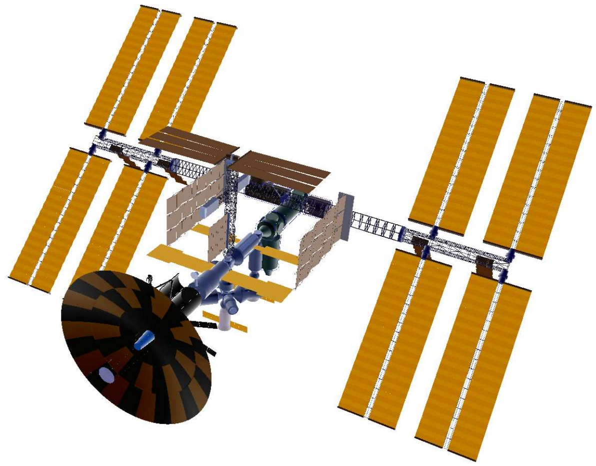

Figure 1: A 30-m radio telescope of an SVLBI-2 module assembled on the International Space Station (a concept, courtesy Aerospatiale). This configuration is temporary: after completion of the assembly and tests, the SVLBI-2 module leaves ISS for a high apogee operational orbit.

cept should therefore be explored at the earliest stages of the SVLBI-2 mission design studies. Such a scheme could also bring additional benefits (in the form of decrease in per-mission cost) by sharing substantial parts of its overall cost with other ISS applications.

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