FIVE YEARS OF THE VLBI SPACE OBSERVATORY PROGRAMME

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ABSTRACT

The radio astronomy satellite HALCA was launched by the Institute of Space and Astronautical Science in February 1997 to participate in Very Long Baseline Interferometry (VLBI) observations with arrays of ground radio telescopes. HALCA is the main element of the VLBI Space Observatory Programme (VSOP), an international endeavor involving over 25 radio telescopes from 14 countries. Simultaneous observations with HALCA's 8-m diameter radio telescope and ground radio telescopes enable imaging VLBI observations on baselines over three times longer than those achievable on Earth: the highest resolution 1.6 GHz and 5 GHz images ever made.

INTRODUCTION

The radio astronomy satellite HALCA is the main element of the VLBI Space Observatory Programme (VSOP), an international endeavor involving over 25 radio telescopes, five real-time data-link stations, four recording formats, three correlators, two orbit determination teams, and one commanding and telemetry station [1]. HALCA's orbit has an apogee height above the Earth's surface of 21,400 km, a perigee height of 560 km, and an orbital period of 6.3 hours. Simultaneous observations with HALCA's 8-m diameter radio telescope and ground radio telescopes enable imaging VLBI observations on baselines over three times longer than those achievable on Earth [2].

By the fifth anniversary of HALCA's launch, over 700 VSOP observations will have been carried out at 1.6 and 5 GHz, predominantly, but not exclusively, of the relativistic jets and accretion disks surrounding supermassive black holes in active galactic nuclei. The sub–milli-arcsecond resolution achieved by the VSOP observations probes the parsec-scale structure at the core of the AGN.

TECHNICAL ACHIEVEMENTS

The technical achievements of the mission include: deployment in-orbit of the 8 m diameter antenna and its tension-truss support structure; the round-trip phase transfer from ground based frequency standards to the spacecraft; down-linking of the science data at 128 mega-bits per second in real-time; precise orbit determination; the application in the correlators of rapidly varying spacecraft positions and timing corrections derived from the open-loop phase transfer process; and the global co-ordination of all of the disparate elements required by this complex mission.

HALCA is also equipped with a 22 GHz receiver, although this has not been available for routine scientific observing. The detection at 22 GHz of an Orion-KL water vapor maser during an outburst in 1998 was a crucial test of the whole space VLBI system, from satellite attitude control to correlation. These all performed to expectation, indicating that the proposed inclusion of higher observing frequencies on future space VLBI missions is perfectly feasible.

SCIENTIFIC OBSERVATIONS

The majority of VSOP observations are made as part of General Observing Time, selected from peer-reviewed proposals submitted by the world's astronomical community. A VSOP observation, involving the HALCA satellite, an array of ground radio telescopes, and several data-link stations, lasts typically 12 hours, with another 12–24 hours required to slew the satellite and its large antenna to the target source and make calibration measurements [1]. Twenty-five percent of the scientific time of the mission is devoted to the VSOP Survey Program [3], which entails observations of 289 bright, compact extra-galactic radio sources at 5 GHz, using fewer ground telescopes and shorter observations. The major goals of the Survey Program are statistical in nature: to provide a source list for use with future space VLBI missions; to compare radio properties with data from other wavelengths; and to determine the approximate structure and brightness temperature of the sources.

Scientific highlights of the mission to date include: the measurement of brightness temperatures significantly in excess of theoretical limits, supporting the belief that relativistic Doppler boosting plays an important role in bright, compact, radio sources [4]; high-resolution information on the strength and orientation of the magnetic fields in the cores and jets of selected active galactic nuclei, including the first observational evidence for the theoretically predicted "flip" in polarization angle between the optically thick and optically thin regimes [5]; observations of "free-free" absorption at these relatively low frequencies, where the longest possible baselines are needed to provide adequate angular resolution [6]; and observations of the spectral lines of OH masers, where again VSOP provides the only way to gain improved resolution [7].

THE FUTURE

Before launch, the mission lifetime was expected to be 5 years, with cosmic-ray degradation of the solar panels providing the main limitation on the lifetime. After three years in orbit it had become clear that the solar panel degradation was not as severe as had been anticipated, and that sufficient power will be available for several more years of operation. The mission lifetime may, instead, be determined by other factors: only a small amount of hydrazine thruster fuel remains, and one of four reaction wheels has been taken out of operation.

In February 2002 the mission switched from predominantly General Observing Time to predominantly VSOP Survey Program observations, with the aim of completing observations of all 289 sources by February 2003.

The successes of the VSOP mission have paved the way for a next generation space VLBI mission. Planning in Japan for such a mission, VSOP-2, is described elsewhere in these proceedings [8].

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