Astrophysical Phenomena Revealed by Space VLBI
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VSOP Current Status

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Abstract

HALCA was launched on 12 February 1997. The current status of the VLBI Space Observatory Programme (VSOP) mission is described.

1 Introduction

The Institute of Space and Astronautical Science (ISAS) launched the first space VLBI (Very Long Baseline Interferometry) satellite, HALCA, on 1997 February 12. After completing a series of engineering experiments to verify space VLBI observations, the first VLBI fringes and images were obtained in May and June 1997, respectively. HALCA is being operated for science observations at 1.6 and 5 GHz for the VSOP (VLBI Space Observatory Programme) project in cooperation with many organizations and radio telescopes around the world. HALCA's status earlier in the mission has been reviewed by Hirabayashi (1998), Hirabayashi et al. (1998), Lovell et al. (1999) and Hirabayashi and Hirosawa (2000): in this paper more recent science activities of the mission are described.

2 The HALCA Satellite

HALCA's orbit has an apogee height of 21,400 km, perigee height of 560 km, inclination angle of 31°, and orbital period of 6.3 hours. The 8 m main reflector and the sub-reflector supporting structure were deployed in orbit. The satellite as it appears after full deployment in orbit is shown in Figure 1.

The on-board radio astronomy subsystem is composed of low-noise amplifiers for three frequency bands, 1.60–1.73 GHz, 4.7–5.0 GHz and 22.0–22.3 GHz, down-converters, two video converters, two high speed samplers, a formatter, two frequency-synthesizers, and a calibration signal generator (Hirosawa and Hirabayashi 1997, Hirabayashi et al. 2000).

The HALCA radio-telescope has typical system temperatures of 75 K at 1.6 GHz and 95 K at 5 GHz, with an antenna aperture efficiency

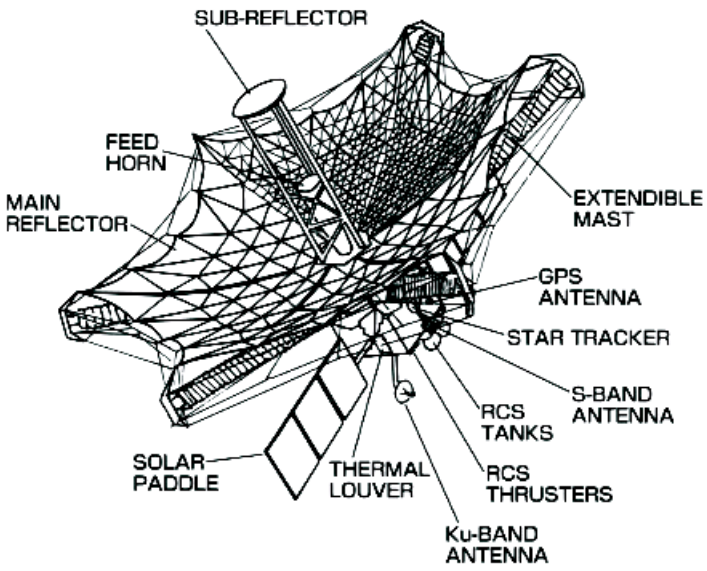

Figure 1: The fully deployed HALCA satellite.

of about 30% at 1.6 GHz. The 22 GHz system temperature is unexpectedly high, and it is believed that the 22 GHz waveguide connecting the feed horn and the front-end was possibly impaired due to heavy vibrations during launch.

3 In-Orbit Checkout

After a series of experiments as an engineering satellite — deployment of the 8 meter antenna, precise attitude control of spacecraft with a large antenna, transfer of phase reference signal, high data rate telemetry, etc. — the Usuda 64 m antenna and HALCA, via Usuda 10m tracking antenna, observed the quasar PKS 1519−273 at 1.6 GHz on 1997 May 7. The tapes were processed with the VSOP correlator at the National Astronomical Observatory (NAO), Mitaka, and the first HALCA-ground fringes were found on May 13. Subsequent three station interferometry with HALCA, the Usuda 64 m antenna and the Kashima 34 m showed stable closure phases confirming the success of the observations and paving the way for the imaging experiments.

In June 1997, the Canadian correlator at the Dominion Radio As-

trophysical Observatory (DRAO), Penticton, and the VLBA (Very Long Baseline Array) correlator of the National Radio Astronomy Observatory (NRAO), Socorro, detected fringes at 1.6 GHz. In July 1997, fringes at 5 GHz were first detected at Socorro, then at Penticton and at Mitaka. In mid-June 1997, the first 1.6 GHz images were generated and in July the first 5 GHz images were produced and an angular resolution of $\sim$0.3 mas achieved.

In April 1998, 22 GHz fringes to HALCA were first detected at Socorro for the bursting water maser in Orion-KL (Kobayashi et al., these proceedings). Imaging at 22 GHz has only been possible for this source because of the sensitivity problems, with little HALCA contribution because of the extended maser size.

HALCA has had some operational problems resulting in a observing being stopped because of telemetry signal loss, attitude control loss, etc. However, as far as electric power is concerned, it seems HALCA will be able to operated for at least five years from launch (Murata, these proceedings).

4 VSOP International Operation

HALCA is commanded from the Sagamihara Operations Center at ISAS six times a week by 2.1 GHz telemetry through the Kagoshima Space Center. For VLBI observations real-time two-way telemetry support is required with uplink at 15.3 GHz and data downlinked at 14.2 GHz at 128 mega-bits per second. Five 15 GHz-band tracking stations are employed: at Usuda (Japan), operated by ISAS; Green Bank (USA), operated by NRAO; and Goldstone (USA), Madrid (Spain), and Tidbinbilla (Australia) operated by NASA/JPL. Range-rate data from this ground telemetry network is also used for ISAS and JPL orbit determination.

A number of ground radio telescopes have committed time for simultaneous observations with VSOP. Commitments of ground radio telescope time for the mission have been negotiated through the Global VLBI Working Group (GVWG), formed under URSI Commission J. Participating telescopes include those of the Very Long Baseline Array (VLBA), the European VLBI Network (EVN), the Asia-Pacific Telescope (APT), and individual telescopes.

The recording format of the VLBI data is dependent upon the ground facilities involved. Three different tape formats are used: S2, VSOPT and VLBA/MkIV. Depending on the participating ground tele-

scopes, VSOP observations are correlated at the 10-station VSOP correlator in Mitaka, the 20-station VLBA correlator in Socorro, the 6-station S2 correlator in Penticton. Experiments involving two or more formats require conversion of some tapes at Mitaka, which has two S2/VSOPT and two VLBA/VSOPT bi-directional copiers.

5 Science Activities of VSOP

Scientific observations are classified into two categories; the peer reviewed General Observing Time Program and the mission-led Survey Program. The first Announcement of Opportunity covered observations for the 17 month period to the end of 1998, and the second Announcement of Opportunity solicited proposals for the calendar year 1999. The VSOP World Wide Web site (http://www.vsop.isas.ac.jp/) contains additional information and pictures of mission activities.

Observations of 4–7 hours are used for Survey Program observations. The Survey Program deals with a statistical sample of nearly 300 sources to be observed at 5 GHz with typically 3–4 ground telescopes, and is described in more detail in the papers in these proceedings by Fomalont et al., Moellenbrock et al, and Lovell et al.

Table 1: Summary of VSOP Observations to January 2000

Year	GOT observations	Survey observations	Test observations	Total
1997	49	20	25	94
1998	109	65	9	183
1999	183	45	9	237
Total	341	130	43	514

Scientific observations are being routinely undertaken at 1.6 and 5 GHz. A summary of VSOP observing to date is given in Tables 1 and 2. About fifty Survey Program observations have been extracted from GOT observations, and so the grand total of observed Survey sources is now 180 sources (Fomalont et al. these proceedings). Of the GOT observations, 131.5 were made at 1.6 GHz and and 209.5 at 5 GHz (with one observation conducted simultaneously at 1.6 and 5 GHz – see Murphy et

Table 2: Summary of observations by correlator

Correlator	GOT observations	Survey observations
Socorro	229	–
Penticton	88	105
Mitaka	24	25

al., these proceedings). Approximately 200 AO1 observations and 140 A02 observation have been made, with some ambiguity in these numbers due to shares, mergers and continuing programs.

6 VSOP Historical Notes

The year of HALCA's launch was half a century after the first detection by the so-called cliff-top interferometer in Sydney (Bolton and Stanley 1948). The first successful VLBI experiments in Canada and soon after in the USA were done in 1967, thirty years before HALCA's launch. The first space VLBI experiment with TDRSS was successful in 1986 (Levy et al. 1986), paving the way for dedicated imaging space VLBI to come 10 years later. The idea of space VLBI had been talked about, and concepts developed, by many people related to various missions like QUASAT, RadioAstron, and IVS before HALCA was finally launched.

In the year VSOP was budgeted, we had a space VLBI symposium here at ISAS, and this was 10 years and 2 months before this symposium. To make the VSOP mission successful, we had worked together with international colleagues with lots of efforts. We shared the ten years and we are now ten years older!

HALCA is now 3 years old. She had observed so many varieties of AGN features. But as Shakespeare stated as for the beauty of Cleopatra in *Antonio and Cleopatra*, "AGE (AGN?) cannot wither her, nor custom stale Her infinite variety."

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