The Odin Satellite

Steve Torchinsky, Kevin Volk, Sun Kwok
Space Astronomy Laboratory, University of Calgary

Introduction

Odin is a millimetre to sub-millimetre wave astronomy/aeronomy missionwith Sweden, Canada, France, and Finland as partners. Canada has a 20% share in both aspects of the mission with support provided by the Canadian Space Agency and NSERC. The major scientific goal of the mission is to study the interstellar chemistry of oxygen and water by observing the rotational transitions of those molecules. Since Odin is the first submillimetre-wave astronomy satellite to have tunable receivers, many other molecular and atomic lines of astronomical interest will be accessible for the first time. The members of the Space Astronomy Laboratory at the University of Calgary participated in the design and construction of Odin, and we continue to play an active role in the operation of the satellite. Odin's payload consists of 4 submillimetre (495, 548, 555 and 571GHz) receivers, 1 millimetre (119 GHz) receiver, and three separate spectrometers; the acousto-optical spectrometer (AOS) and two digital auto-correlators. The spatial resolution is ~2 arc min at sub-millimetre wavelengths and ~9 arc min at 119GHz. Odin was successfully launched on February 20, 2001 by a Russian START-1 rocket, and is now into its second year of operations.

Fig. 1 (left) Odin was launched on 08:48 UT, February 20, 2001 by a START-1 rocket from Russia into a 600-km sun synchronous polar orbit (above right). The image above is a composite showing Odin at 600km above the Earth.

Odin Millimetre/Submillimetre Radiometer Design, Integration, and Testing

Canadian hardware contributions include the design, integration and test of the millimetre/submillimetre radiometer. This was done through a close collaboration with Chalmers University of Technology. The radiometer optical design was carried out using Quasi-Optical ray tracing and CAD software developed for this purpose, but the software can also be used for general applications. All mirror surface specifications, and lens designs were part of the Canadian contribution, as well as much of the mechanical design associated with the support of optical elements. An example of a novel design for a lens is shown in Figure 4.

The Canadian support of the radiometer instrument also includes the testing, trouble shooting, and integration of the system. In particular, the integration and test of the spectrometers became a Canadian responsibility, which resulted in the development of a software suite used for extraction and display of the scientific data from satellite telemetry. Our support of *Odin* at the system level continued with participation in the comprehensive performance tests, including telescope beam measurements, and satellite command and data analysis during flight simulation.

Fig. 2 (left) The main optics plate of the *Odin* radiometer just before integration into the satellite.

Fig. 3 (below) A CAD drawing of the *Odin* radiometer platform showing the 3-dimensional quasi-optical ray tracing that was used to help design and analyse the system.

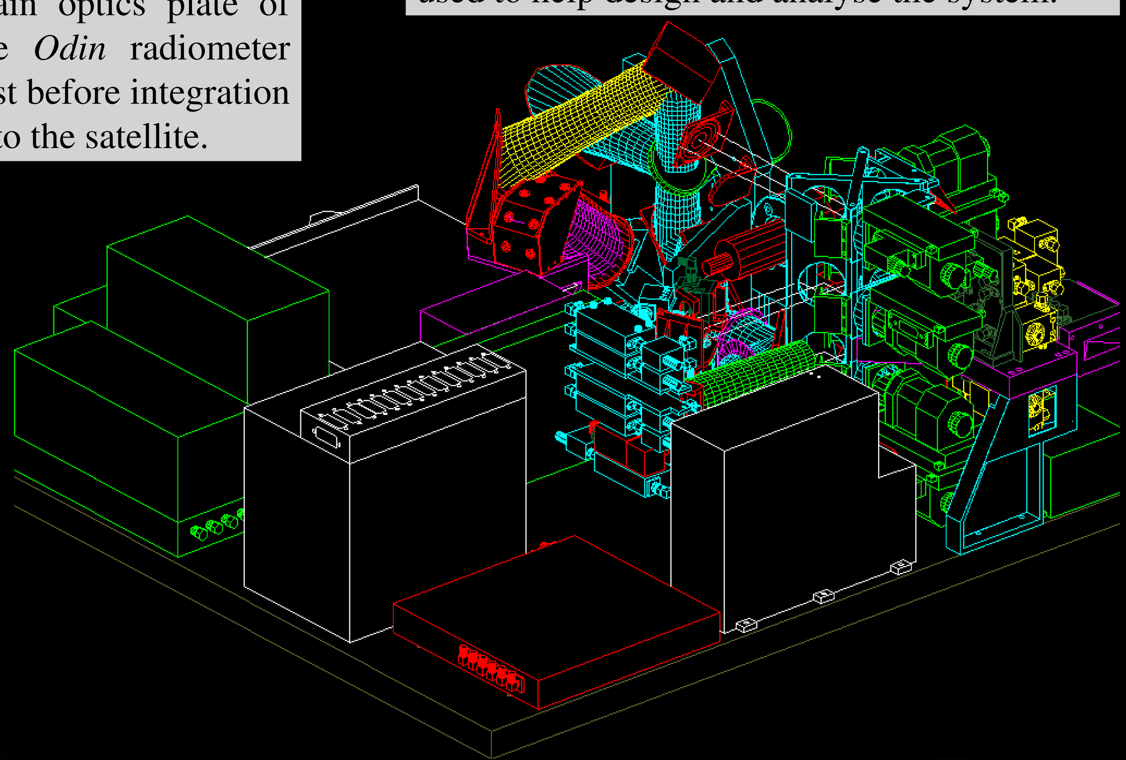
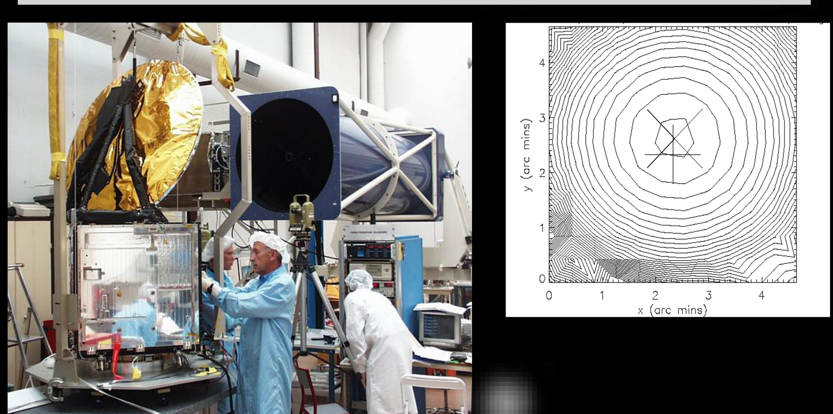


Fig. 4 (left) A teflon lens for the 119GHz receiver has linear matching grooves to eliminate reflections

Fig 5 (below left) Odin beam measurements were done at the telescope testing facility at the Centre d'Etudes Spatiale de Rayonnement, Toulouse, France. The beam map produced **(below right)** shows that Odin's beam is circular and Gaussian to a high degree.



Odin Operations Support

Since the launch of Odin on February 20th, 2001, Canada provides support to Odin operations in a number of areas. At the Space Astronomy Laboratory of the University of Calgary we are responsible for satellite scheduling, and for telecommanding of the radiometer backend spectrometers. SAL members also participate in the Odin Data Evaluation Group which monitors data quality and involves data processing of raw data from Odin science and hardware telemetry.

Extensive software development has been carried out in the Space Astronomy Laboratory for the Odin operations support.

Telemetry commanding software has been provided to the Swedish Space Corporation. This tool generates the command sequence required for the many different observing modes of the Odin radiometer.

The combined Astronomy/Aeronomy nature of the Odin mission, and the radiometer's great versatility create a complex system which requires extensive scheduling tools. These have been provided to the Swedish Space Corporation and are an essential part of the Ground Operations. (see figures 6 and 7 below).

A data reduction tool has been developed to deal specifically with Odin's observing modes and system parameters. This optimized tool combines standard data reduction techniques with the specific needs of Odin raw and calibrated data. (see figure 8 below).

Recent Results

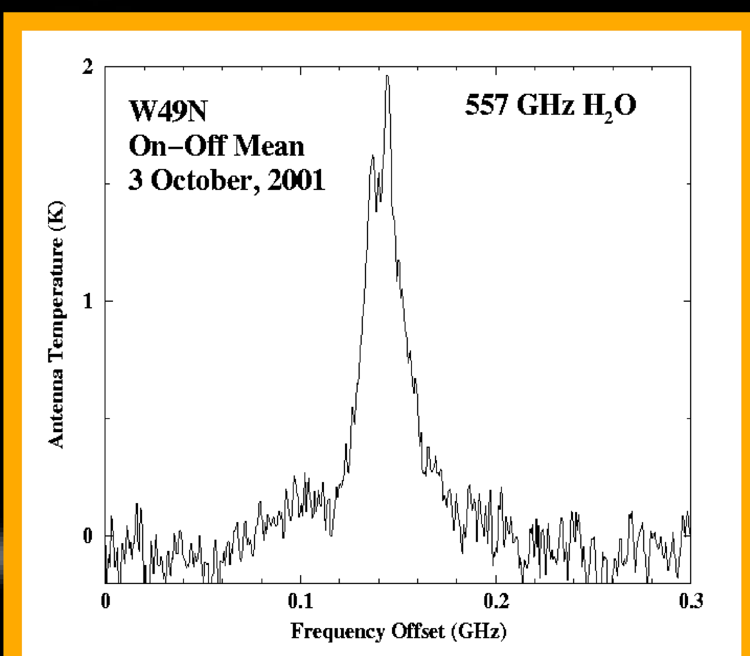


Fig 9 (above) This is 40 minute integration showing the spectrum of W49N centred at the 557GHz transition of water. One can clearly see self absorption. The acousto-optic spectrometer was used for this observation.

Fig. 6. (left) The sky beam visualisation tool allows the user to examine the status of the Odin sky beams for different targets. The sky beam directions are determined by the spacecraft attitude, the target position, and the spacecraft roll angle which is set to produce maximum solar panel illumination. The main panel in the window shows the sky in galactic coordinates with a 7 degree smoothed CO intensity map. The target is marked in red,the two sky beams are marked in purple, the Sun is marked by the yellow ellipse with the black border, and the moon is marked by the grey circle. With this tool, one can track the solar, lunar and galactic plane constraints on the sky beams over time.

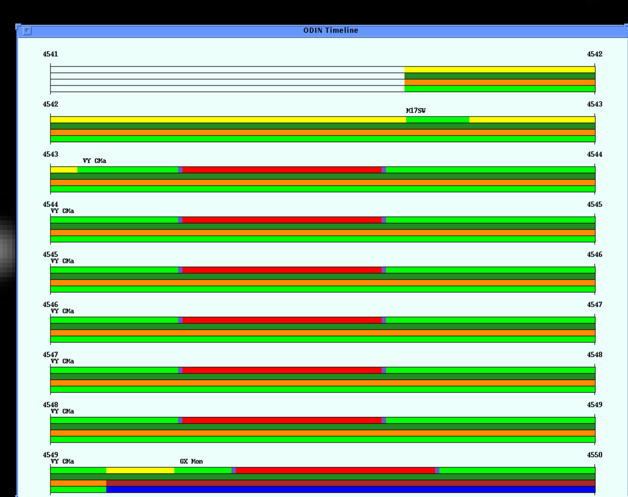


Fig. 7 (left) A graphical summary of the major events in each orbit. Each colour represents a different Astronomy programme, for example: Stars, Interstellar Medium, Molecular Clouds, Shocks. System events are also indicated by different colours. These include target rise and set times, calibration events, switching of receiver modes, star tracker orientations, and slew times.

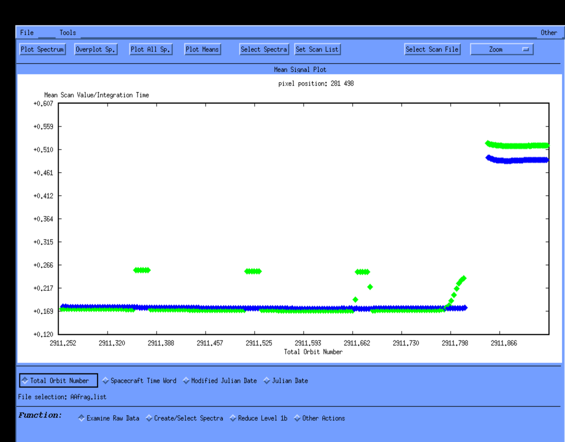


Fig. 8 (left) In the data reduction tool, one can plot the mean values of consecutive spectra. Here, Odin was using the "Sky Switching" observing mode. Alternate blue and green points show the "on" and "off" positions. The three clusters of high green points are the integrations in the internal calibration load. At the end of the sequence, Odin begins to observe the Earth's atmosphere.