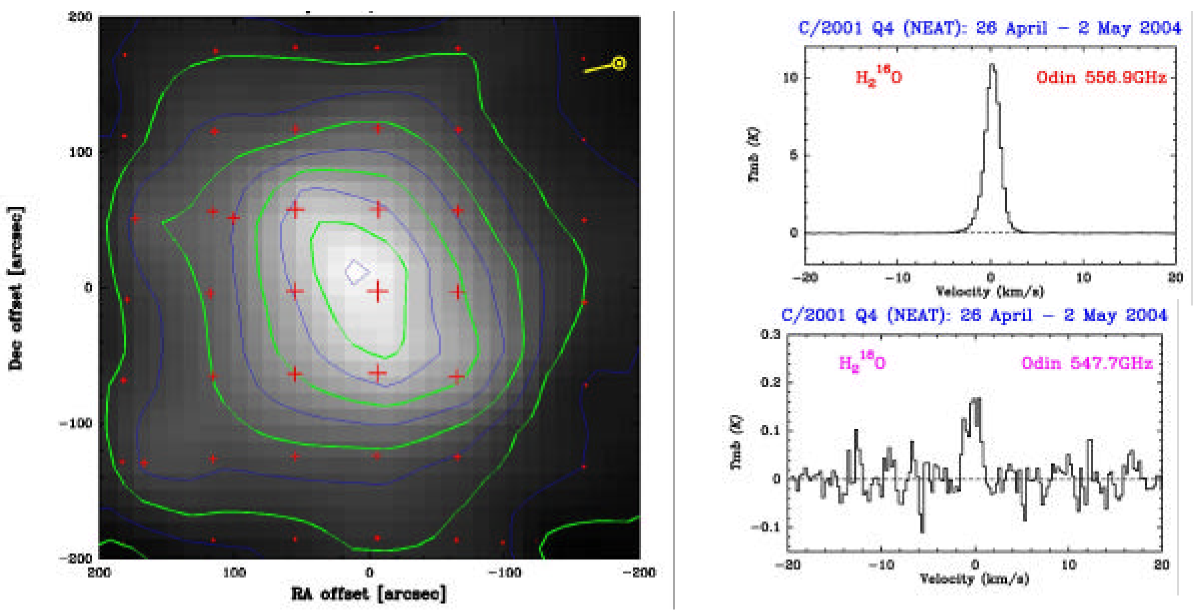
ODIN MISSION RESULTS
FACT SHEET

ASTRONOMY RESULTS

Among the remarkable astronomy results already achieved, Odin has:
- detected water (H_2O) and water isotopes in 10 comets and many galactic sources;
- made exceptionally precise measurements of H_2O in Mars' atmosphere;
- observed ammonia (NH_3) emitted from a highly carbon-rich star;
- conducted a spectral survey in the direction of Orion and the centre of the galaxy;
- revealed the very low abundance of molecular oxygen (or dioxygen, O_2), forcing scientists to reconsider current theoretical models;
- and is currently observing spectral structures against the cosmological microwave background.

The results detailed below illustrate some of Odin's most noteworthy achievements.

Searching for molecular oxygen in the Universe

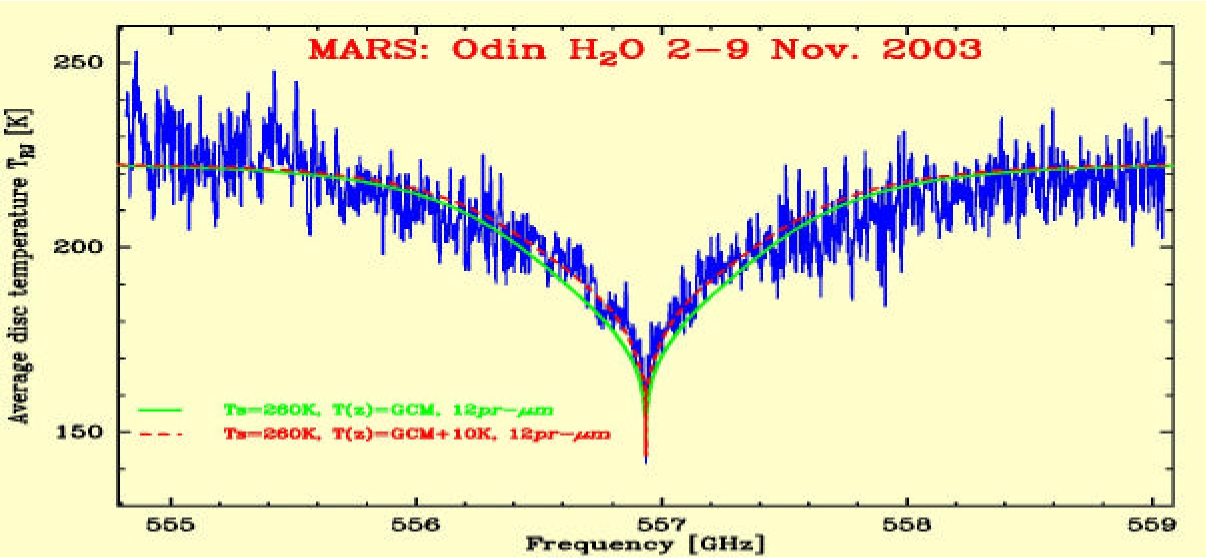


Presence of water in comet C/2001 Q4 (NEAT)

Molecular oxygen is a key component of Earth's life-sustaining atmosphere. But the vast amounts of molecular oxygen in the atmosphere obscure any attempt to look for it in the Universe. The best strategy is therefore to put a telescope in space. This is precisely what has been achieved with Odin, which is flying a payload of two instruments able to detect molecular oxygen. Odin has conducted surveys scanning many different regions of our galaxy, peering into inactive, cold molecular clouds (In the Taurus and Unicorn constellations) and into regions where massive stars form, such as the large Orion Nebula or the centre of the Galaxy. Despite deep-sky surveys, representing hundreds of hours of observations in each of these directions, not the slightest trace of oxygen has been found. Oxygen is the third most abundant chemical element in the Universe after hydrogen and helium. It exists in many forms—carbon monoxide, carbon dioxide (commonly known as carbon gas on Earth, but observed only as dry ice in space), water, methanol, ethanol (alcohol), etc.—except the form astronomers most expected to find. This mystery is still unexplained. And it will be hard to improve on Odin's observations, even with the next generation of space telescopes such as Herschel. Theoreticians now have plenty of work to explain what is going on.

Water in the Solar System

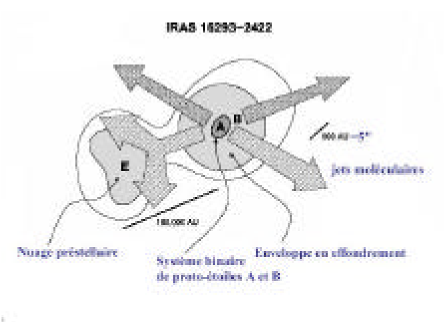
The chart above plots the intensity of the water emission line at 557 GHz in the atmosphere of comet C/2001 Q4 (NEAT), viewed by Odin on 15 May 2004. The line spectra of $H_2{}^{16}O$ and $H_2{}^{18}O$ isotopes observed in this comet at the end of April are shown alongside. Water is the chief constituent outgassed by comet nuclei and is hard to observe from the ground. Odin has so far been able to observe water outgassing from 10 comets, detecting the $H_2{}^{18}O$ isotopic species in four of them, with a $^{16}O/^{18}O$ ratio comparable to that found on Earth (approximately 500). The lines are thin, because water vapour is expelled from the nucleus at a velocity slower than one kilometre per hour. In addition to providing information on line shapes, Odin has been able to produce maps for constraining gas distribution and atmospheric models for these comets. [From Hjalmarsson et al., Adv. Sp. Res., 2005]

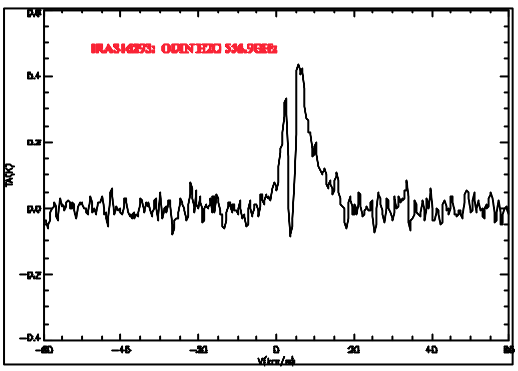


Presence of water in the Martian atmosphere

In 2003, during the closest opposition between Earth and Mars for centuries, Odin was able to measure precisely the mean quantity of water vapour (12 m³ of precipitable water) in the atmosphere of Mars by observing the spectral lines of $H_2{}^{16}O$ at 556.9 GHz and $H_2{}^{18}O$ at 547.7 GHz, among others. The water absorption line is observed in the planet's disc. Its width and shape also depend on atmospheric pressure and temperature on Mars. [From Biver et al., A&A, 2005].

Water in a star-forming region

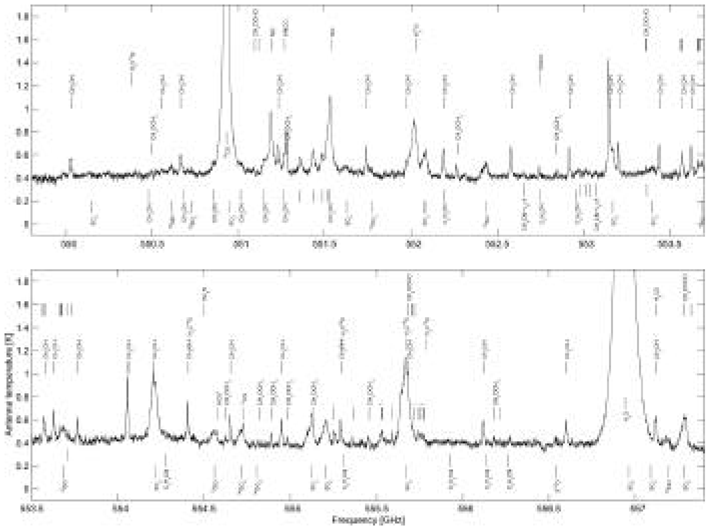




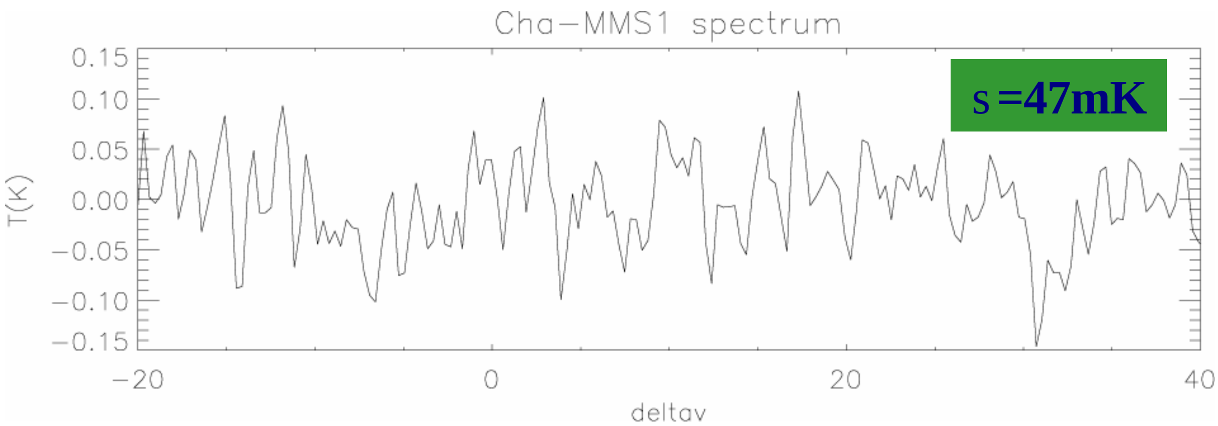
Star formation inside a molecular condensation (or cloud) in our Galaxy is governed by two opposing effects: gravity and thermal pressure. How can a cloud get rid of the heat produced as it contracts and thus fuel the formation of the protostellar nucleus? The efficient cooling process predicted by models involves the release of energy by certain "key" atoms and molecules in the cloud, namely **H_2O, O_2, CO** and **C** (Ristorcelli et al., 2005).

Left: IRAS16293 is a binary star system forming in the complex cloud near rho-Ophiuchi (160 parsecs). As they form, protostars expel powerful and diametrically opposed molecular jets, propagating shock waves at blinding speed (~ 15 kilometres per second).
Right: The spectral profile of H_2O emissions measured by Odin reveals the complex dynamics of the region, helping us to gain a closer insight into the physical and chemical processes at work. The spectrum observed by Odin can be modelled as the result of two superimposed emission sources: from water mixed with gas in the collapsing protostellar disc, and from the molecular jets. The "hollow" feature is that of auto-absorption of water present in the gas in the cold cloud surrounding the protostar.

Spectral readings in the direction of Orion



This spectral survey explored a large number of molecular transitions for the first time, highlighting a great variety of molecules in this star-forming region. The readings give us a clearer understanding of the physical conditions and the diversity of chemical reactions taking place there *(Hjalmarson et al. 2004, COSPAR)*.



Spectrum of the ortho-H_20 line at 555 GHz in the direction of the dark cloud Cha-MMS1 (α_{1950}= 11h 05 min and 7s and δ_{1950}= -77°07'18'') measured by the acousto-optical spectrometer. The upper limit of the fractional abundance of water in the direction of this object is $4\ 10^{-8}$, confirming the clear lack of water in the gaseous phase in cold and dense environments. In these environments, water has probably condensed around grains of interstellar dust to form blankets of ice, thereby altering the physical and chemical properties.

EARTH'S MIDDLE ATMOSPHERE VIEWED BY ODIN

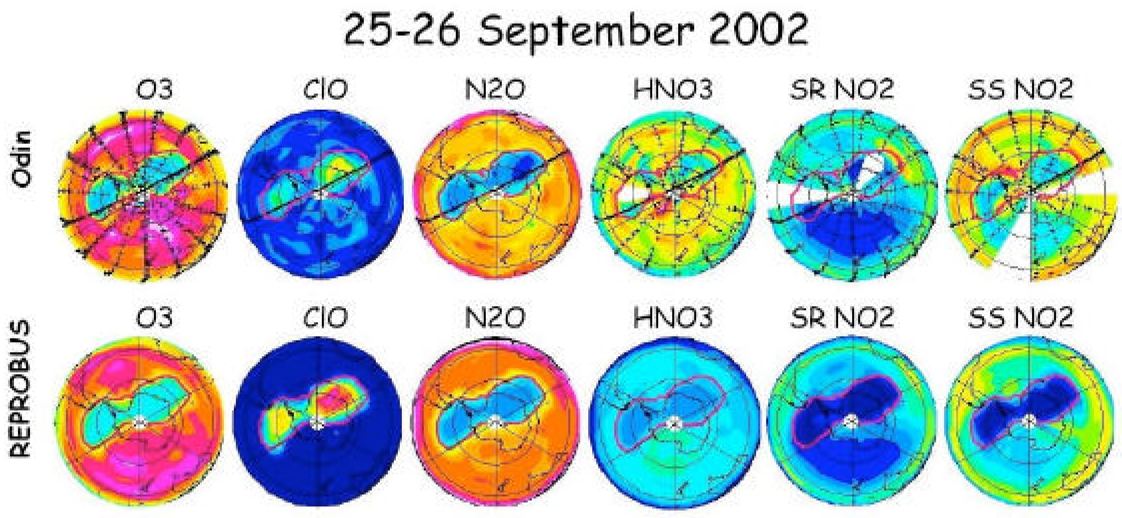
Atmospheric chemistry data produced by Odin are processed in Sweden using a Swedish algorithm, and in France using an algorithm developed by researchers at CNRS working on the national atmospheric chemistry programme and at CNES. The French algorithm is accessible over the Internet from the Ether server portal, allowing scientists to process Odin data as needed.

The Ether centre of expertise has a department dedicated to managing and producing atmospheric chemistry data. This department provides French and international scientists with satellite data and measurements from balloon-borne experiments. In all, Ether manages data from 40 experiments. The centre was developed jointly by CNES and CNRS, and is currently located at the Institut Pierre Simon Laplace (http://ether.ipsl.jussieu.fr).

Operating the SMR and OSIRIS instruments on the same satellite has yielded a wealth of science data on: 1) the physical and chemical evolution of the polar vortices and its impact on the ozone layer; and 2) dynamic coupling of middle atmosphere layers from the stratosphere to the thermosphere (15-115 km). Research work has also focused on the results of global chemistry-transport models and on data assimilation techniques designed to couple measurements and models in optimal fashion. More information can be found at http://smsc.cnes.fr/ODIN/Fr.

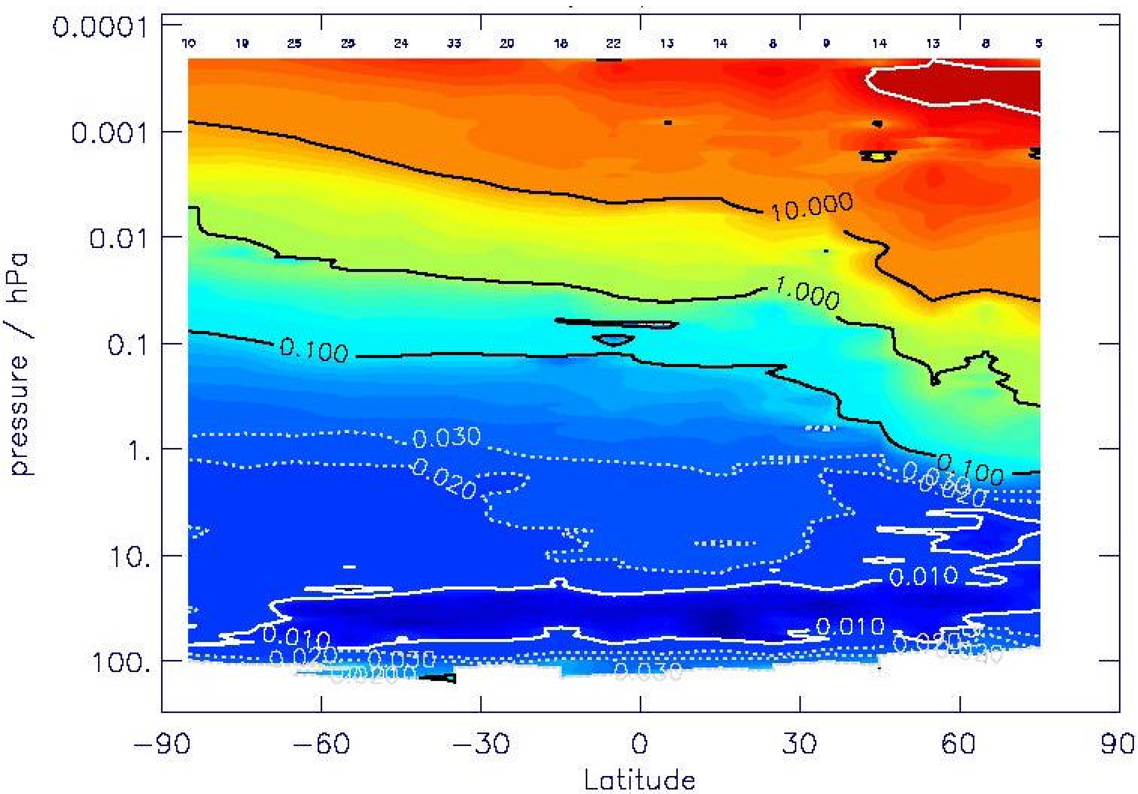
Two major results presented in this document are:

- the exceptional separation of the Antarctic polar vortex in September 2002
- the first-ever observations of latitude distribution of carbon monoxide in November 2001



Separation of the polar vortex over Antarctica

This figure shows the evolution of chemical constituents in the stratosphere at an altitude of 20 kilometres during the separation of the Antarctic polar vortex in September 2002. The top row shows the constituents measured by Odin: ozone (O_3), chlorine monoxide (ClO), nitrous oxide (N_2O) and nitric acid (HNO_3), and nitrogen dioxide (NO_2) at sunrise (SR) and sunset (SS). The bottom row shows the same constituents calculated by the REPROBUS global chemistry-transport model, developed jointly by the SA aeronomy laboratory at CNRS and the national weather service Météo-France. Chemical ozone loss is associated with an increase in ozone-depleting ClO and a decrease in nitrogen constituents (HNO_3 and NO_2) in the two lobes of the vortex (highlighted by low N_2O values). The red line traces the edge of the vortex. Blue-mauve shades indicate low values, while red-orange shades indicate high values. [From Ricaud et al., J. Geophys. Res., 2005.]



Dynamic coupling of the stratosphere, mesosphere and thermosphere

Global picture of measurements of carbon monoxide (CO) at the South Pole (left) and North Pole (right), and at 100 to 0.005 hPa (approximately 20 to 100 km altitude) on 18 November 2001. The high quantities of CO in the upper atmosphere (thermosphere/mesosphere) are produced by photodissociation of carbon gases, descending in winter inside the North polar vortex to the lowest layers of the stratosphere at around 1 hPa (approximately 30 km). Blue-mauve shades indicate low values, while red-orange shades indicate high values. [From Dupuy et al., Geophys. Res. Lett., 2004.]

Abbreviations

Adv. Sp. Res.: Advances in Space Research
A&A: Astronomy & Astrophysics
COSPAR: Committee on Space Research
J. Geophys. Res.: Journal of Geophysical Research
Geophys. Res. Lett.: Geophysical Research Letters