Hinode – one satellite, three new windows to the Sun

Hinode being lauched from the Uchinoura Space Center in southern Japan by the M-V-7 launcher. (Photo credit JAXA)

With Hinode in orbit the Solar Research community has got a new way of studying the processes on the Sun. The processes affect and interect with the surroundings of Earth, and it is important to obtain new knowledge.

Early on the morning of September 23, Japanese time, an MV rocket launched the Solar B satellite into a polar orbit around the Earth. The launch was successful and as the satellite approached its final orbit and deployed its solar panels its name was, according to Japanese tradition, changed. Solar B became Hinode, 'Sunrise' in Japanese.

The Hinode mission is a follow-up to the very successful Yohkoh (Solar A) mission that Japan flew through the 1990s, but also to ESA/NASA's SOHO and NASA's TRACE projects. The prime mover behind Hinode is the Japanese Aerospace Exploration Agency (JAXA) but there are important contributions coming from the USA and Great Britain as well as from Norway and the European Space Agency (ESA). At the time of writing Hinode has opened its doors and is in the final stages of commissioning before scientific observations begin in the second week of November.

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Viggo Hansteen (born 1959) is a professor at the Institute of theoretical astrophysics, University of Oslo. Research interests include both modeling and observing the solar atmosphere. Hansteen leads the Norwegian contributions to the Hinode project; the European Data Center as well as co-operation with MSSL on the EIS instrument.

Follow up earlier sucsesses

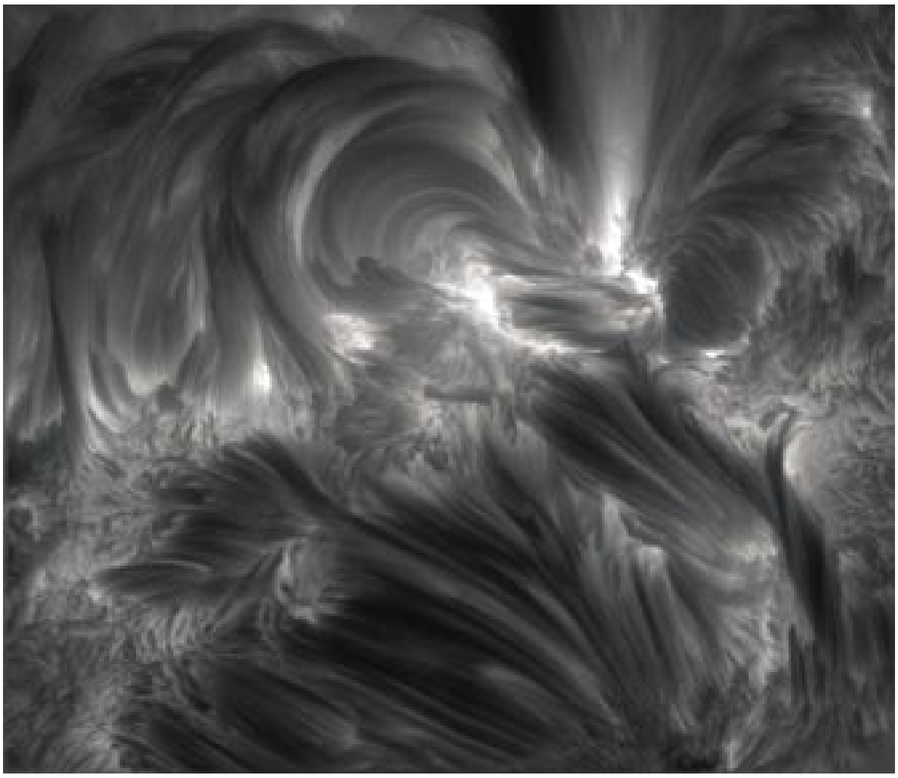
Solar Physics has taken enormous strides in the last decade as advances in numerical modeling have been matched by the high quality observations of Yohkoh, SOHO and TRACE. The outer layers of the Sun are in a state of continual ferment and the resulting high energy phenomena in the million degree solar corona power flares, coronal mass ejections, and the solar wind. The driving agent in this activity has been identified; motions just below the solar surface, in the convection zone, churn and braid the magnetic field which carries the energy flux up into the upper solar atmosphere. The primary goal of the Hinode mission is to advance the understanding of the origin of the outer solar atmosphere, and in particular the coupling between the fine magnetic structure in the photosphere and the dynamic processes occurring in the corona.

To achieve this goal Hinode carries a suite of three instruments, each designed to study certain portions of the solar atmosphere, with the hope that these instruments in collaboration will be able to solve the puzzle of how energy is carried into and dissipated in the outer solar layers; the solar crown or corona.

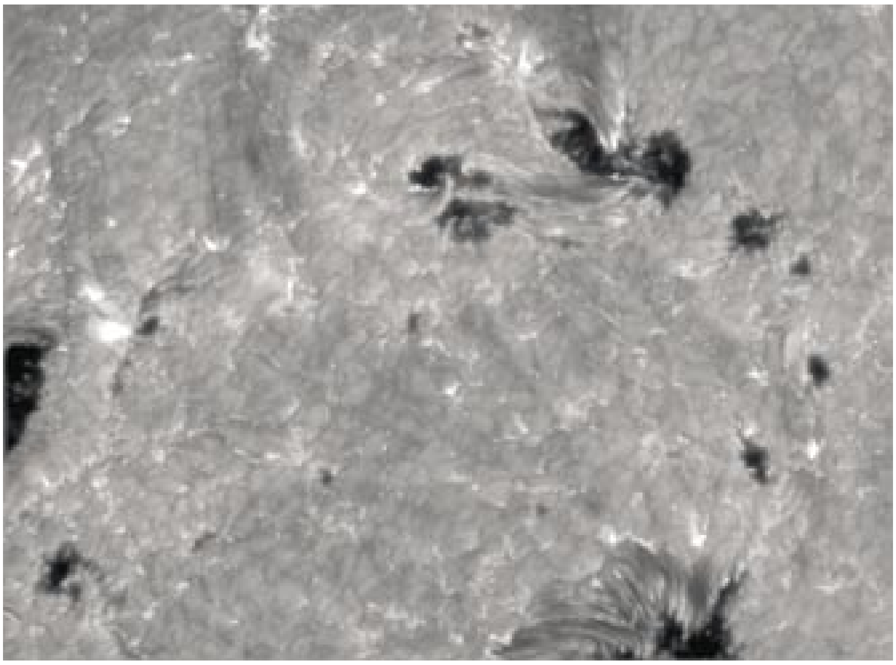
The largest solar telescope in space

The major instrument is the Solar Optical Telescope (SOT), built by the Japanese, at 50 cm aperture this is the largest optical solar telescope flown in space. Light gathered in this telescope is sent into and analyzed by the Focal Plane Package (FPP) which was constructed at Lockheed Martin Solar and Astrophysics Laboratory. The FPP can produce narrowband and broadband filtergraphs as well as measure the polarization of Sunlight. Light in the optical part of the spectrum is formed in the solar photosphere - the region we could consider the solar surface - and lower chromosphere which lies some 500 to 1000 km above the photosphere.

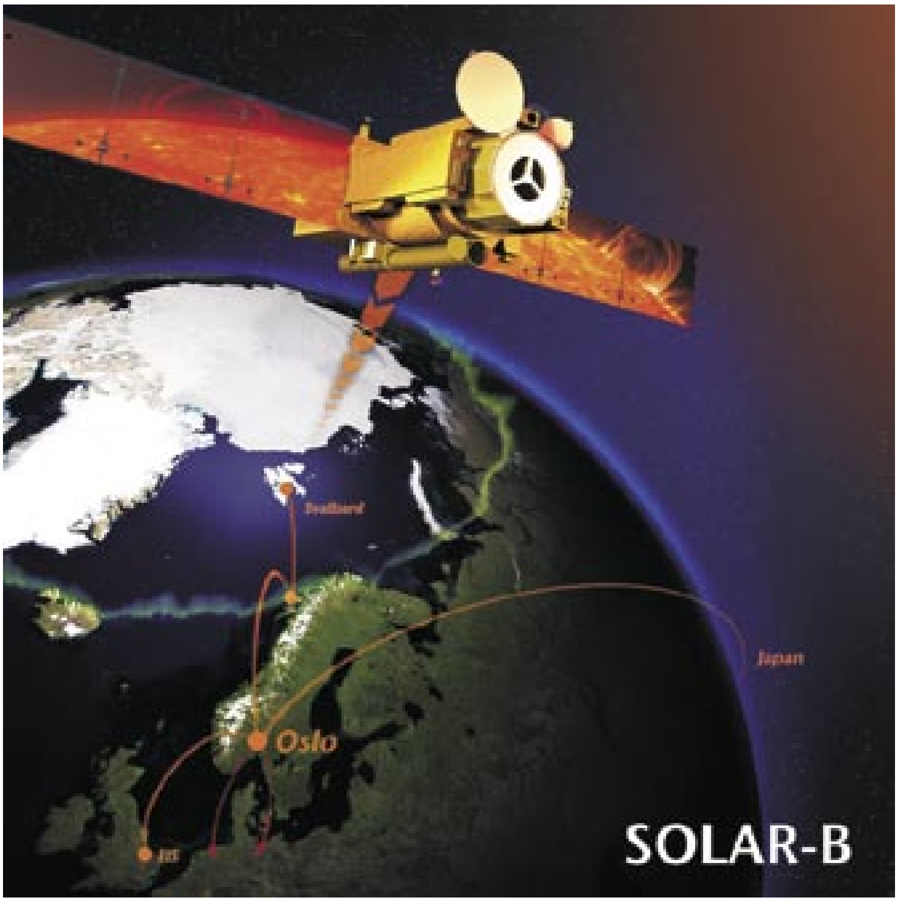
This is the region of the Sun accessible to the SOT. Filtergraphs are images of the Sun in a certain restricted wavelength range (or color). Since solar light at different colors is formed at different heights in the solar atmosphere, such images allow us to form an understanding of how the Sun varies with height. On the other hand, a magnetic field on the surface of the Sun will polarize light according to the magnetic field's strength and



The Sun as seen in the light of the core of the H(alpha) line of hydrogen. This line shows the upper chromosphere where the temperature is of order 10000 K. Just above this region lies the dramatic temperature rise to greater than 1 MK. Note how the magnetic field controls the structure of the gas. This image and the one below is taken at the Swedish Solar Telescope and shows the sort of quality that we expect to receive continuously from Hinode SOT. (Credit: SST, Luc Rouppe van der Voort)



The same region on the Sun as shown above, but in a broadband wavelength band centered on the H(alpha) line of hydrogen. In this image we see the photosphere, along with several magnetic structures such as sunspots, bright points and pores. The convective motions that drive the energetics of the outer solar layers are evident in the granular structures that permeate the quiet photosphere. (Credit: SST, Luc Rouppe van der Voort)



Hinode and the data down-link to Svalsat. Data flows from Svalbard to Japan. Reformatted data returns to Oslo where the European Science community is served. (Credit: Norwegian Space Centre)

direction. This information can be recovered from measurements of the polarization. Thus, the SOT/FPP should allow us to build up a comprehensive picture of the state of the lower solar atmosphere and in particular the state of the magnetic field which is thought to be the main driving agent behind solar coronal activity.

The 6000 K chromosphere extends some 2000 km above the photosphere before the temperature rises rapidly - perhaps in less than 1000 km - to more than 1 MK in the corona.

What drives the dynamics?

The question remaining is then how the state of the lower atmosphere drives the heating and dynamics of the outer atmosphere. Two instruments, operating in the x-ray and in the extreme ultraviolet bands of the spectrum are assigned the task of monitoring the corona. Built by the Smithsonian Astrophysical Observatory at Harvard the X-ray telescope will produce high-resolution coronal images at different temperatures, from somewhat below <1 MK all the way up to 30 MK. These images will allow us to see how coronal gas at different temperatures is produced and how it evolves with time, and by comparing with observations made with the SOT polarimeter, with magnetic field configuration.

It has become increasingly clear that the heating of the solar corona is a very dynamic affair; mass motions certainly play an important role in the dynamics and energetics of the corona. In order to study mass motions directly the Extreme Ultraviolet Imaging Spectrograph, built at Mullard Space Science Laboratory in the UK, will study spectral lines formed between 170 Å and 290 Å. Lines formed in this wavelength band stem from the region on the Sun where the temperature rises rapidly between the chromosphere and corona as well as from the corona itself. By studying the doppler shift of these lines, maps and movies of mass motions can be built up, giving important clues as to the processes driving coronal energetics.

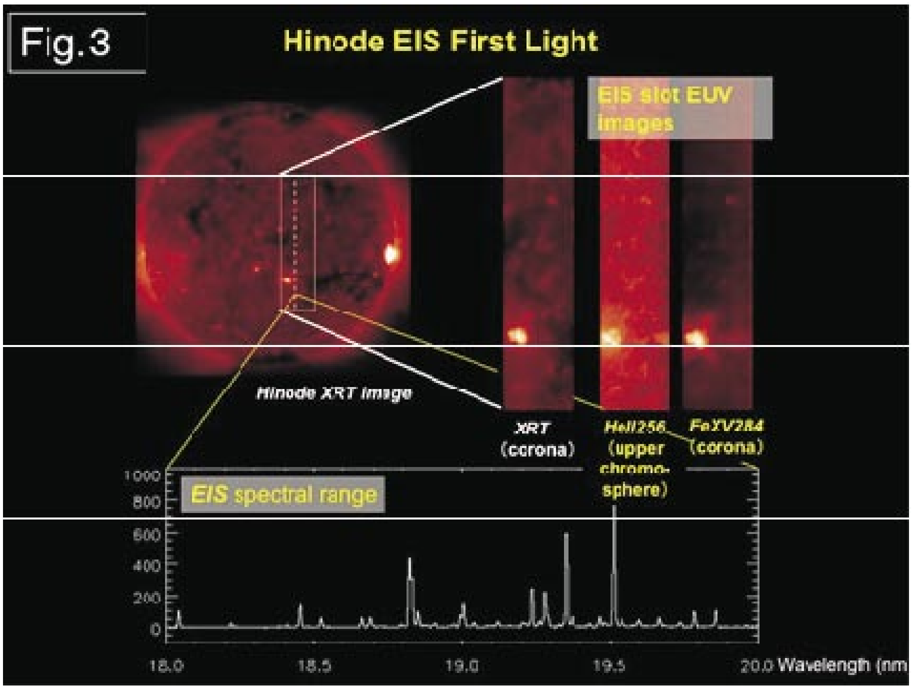
Downloading data at Svalbard

Of course dynamic implies time-dependent. A set of static images giving state of the Sun at a given instant in time is not enough. We must see how this state evolves in time, and that implies that vast quantities of data must be collected and sent down to Earth. Since Hinode is in a 90 minute polar orbit, the Japanese down-link station is only accessible two to three times per day.

A collaboration between the Norwegian Space Centre, ESA and JAXA ensures that Hinode has access to Kongsgerg Satellite Services ground station on Svalbard, which allows 15 daily passes to be down-linked - an enormous addition to the data volume. As part of this collaboration a data centre is being built up at the Institute of Theoretical Astrophysics at the University of Oslo. The data centre will contain a complete copy of the data collected by Hinode and thus ensure that European scientist have easy access to the data.

Some weeks until the operational phase starts

Another few weeks of commissioning the instruments remains. Thereafter, Hinode will commence scientific operations. Now begins the demanding and exciting task of finding out how best to use the instrument in order to gather the data crucial to understanding the Sun.



"First light" images of the Sun taken with the X-ray telescope and the EIS spectrometer. These instruments image the hot upper layers of the solar atmosphere. (Credit First Light press release, JAXA)

The first pictures from Hinode

Press release 27 November from:

Naional Astronomical Observatory of Japan (NAOJ/NINS), Institute of Space and Astronautical Science (ISAS/JAXA) and National Aeronautics and Space Afministration (NASA/USA).

After its launch on 22 September 2006, the Hinode spacecraft is working successfully. We are presenting movies of dynamic phenomena of the Sun demonstrating high performance of three telescopes on Hinode. One of the highlights is a dynamic eruption above a sunspot seen in Ca II H spectral line, which has been first discovered by Solar Optical Telescope (SOT).

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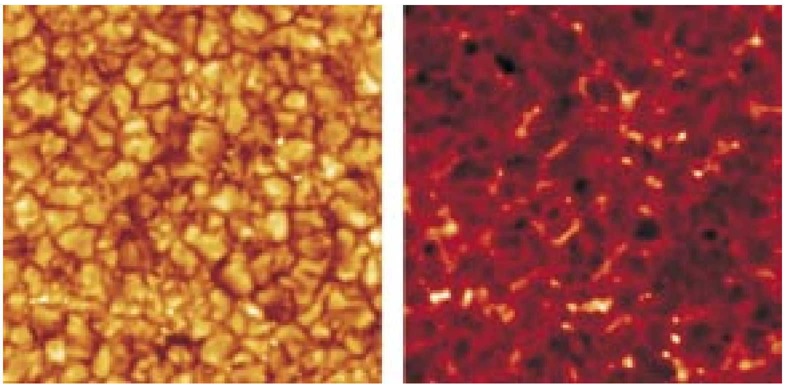
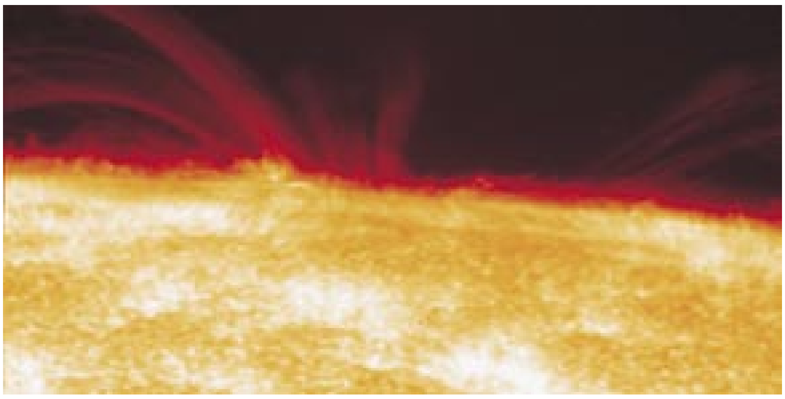


Granulation in G-band (430nm) and in Ca II H (397nm)



Eruption above the Sun spot observed in Ca II H (397nm)