Herschel Space Observatory Calibration Workshop: Models and observations of astronomical calibration sources

Abstracts

1-3 December 2004, Lorentz Center, Leiden, The Netherlands

HIFI - The heterodyne instrument for the infrared calibration strategy

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Due to the absence of the atmosphere and its state-of-the-art mixers, HIFI will be the most sensitive instrument of its kind. So, although many of the same calibration principles and techniques as used on ground-based telescopes will be re-used in HIFI, its calibration is much more challenging, also because of its large instantaneous band width. HIFI will, however, be much stabler than ever achievable on ground and thus it could be the first instrument in which standing waves could be addressed in a systematic way. In order to do so, the HIFI calibration group has deviced an extensive description (the frame work), allowing to reach the calibration base-line requirement of 10%. However, the aim is to reach 3% accuracy. In order to do so, it is very crucial that excellent models of our primary calibrators, especially of Uranus, Mars and the largest asteroids, exist. This is a difficult task since there have only been few missions yet to explore the far-infrared, none at the high spatial and spectral resolutions HIFI/Herschel will reach. In this workshop we will not go into the details of the frame work, but concentrate on the calibration on astrophysical sources. We will address the needs for HIFI intensity calibration and calibration of the HIFI beams.

Solar-System Objects as Radiance Calibrators in the Far Infrared and Submillimeter

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One means to bridge the “radiance gap” between bright infrared stars and strong radio sources is the use of solar-system objects whose spectra are bright in the far infrared and submillimeter. The planet Mars was the first object used for this purpose, as it is extremely bright, although it is accompanied by the complications of atmospheric absorption features, seasonal dependencies and stochastic processes such as global dust storms which exert a significant influence on its thermal emission. Planetary satellites, such as Callisto - the outermost large satellite of Jupiter, have low-amplitude and predictable lightcurves, together with insignificant atmospheric absorption. Nonetheless, they are usually too close to correct adequately for contamination from their primaries. Large asteroids, such as Ceres and Vesta, are spherical and might fill in for this purpose. Alternatives include atmospheric bodies. For example, the spectra of cooler but larger planets, Uranus and Neptune, may be more predictable in time, but they may come with unanticipated atmospheric features at high spectral resolution. Another alternative is Venus, whose disk-averaged thermal properties are very constant in time, but whose orbit usually places it in regions of solar avoidance eschewed by spacecraft design on grounds of thermal stability and cryogen conservation. An ultimate calibration design will mostly likely involve a system of calibration which uses model and observational hybrids among solar-system objects and more traditional stellar and radio sources.

Introduction to Splinter 1 on “Mars and Giant Planets”

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Herschel depends on an excellent knowledge of the brightness temperatures of primary flux calibrators to measure the coupling of the detectors to the sky, i.e. to derive and check the beam properties. These properties can only be accurately determined in-flight. Due to the strong visibility constraints (and due to the long slewing times) of Herschel, it is mandatory to prepare for several sources. For PACS and SPIRE, Neptune and the asteroids are the best candidates, while for HIFI, Uranus, Mars, and the largest asteroids probably are the best choices. Next to photometric calibration, secondary calibrators are needed to check frequency dependent instrumental properties. I will summarize the selection criteria. Some of the questions which should be addressed at this workshop are: How well are these sources currently modelled in the submillimeter and far infrared? What has been learned from ISO? What are the open issues and what are the perspectives for improvement of the models?

Observations of Planets with SWAS: Calibration and Science

Edward Bergin
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In this talk I will present a summary of SWAS observations of Mars, Jupiter, Saturn, and Venus. I will discuss SWAS calibration observations of Mars including some of the unanticipated effects. In addition I will discuss the determination of brightness temperature of the giant planets and that Saturn's rings can contribute significantly to the flux at sub-mm wavelengths. Finally I will show the results from the long-term monitoring of Mars and the detection of water in the atmosphere of Venus.

General circulation- and submm radiative transfer modeling of the martian atmosphere at MPS

Paul Hartogh
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The talk will give an overview about our activities to model the general circulation of the martian atmosphere from ground up to 130 km. Presently we are able to get temperature and wind fields in a pure CO2 atmosphere. The implementation of a chemistry transport module is in progress and we expect first results within the next 6 month. This module will among others provide a prediction about the vertical and horizontal distribution of water vapour and other trace gases which may have a considerable contribution to the submm brightness of the martian atmosphere. Some results of the general circulation model and examples of submm spectra will be presented.

Broadband Submillimeter Measurements of the Giant Planets' Brightness Temperatures

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The giant planets have a potential interest as absolute calibrators at submillimeter wavelengths. However, reliable measurements to outline their continua and their usually broad absorption lines are difficult chiefly because of narrow frequency coverages that therefore require many settings, usually under different weather conditions and with different instruments, that turn out to be difficult to compare. We have conducted a series of measurements using a Fourier Transform Spectrometer, which has a wide frequency coverage (0.25 to 1.1 THz) and overlaps some of Herschel's frequency bands, to get around this problem. The FTS is installed on a 10m ground-based telescope (CSO) for this experiment. In the presentation I will describe the calibration peculiarities of these measurements and the first results obtained on Jupiter and Saturn.

The Observed Variability of the Uranian Atmosphere

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Observations of Uranus at visible, near-IR, and microwave wavelengths show clear variations on decadal time scales. Some of the variations are due to the viewing geometry---we see different latitudes of the planet over the course of it's 84 year orbit, and since different latitudes have a different brightness, the integrated flux changes. In addition, there is evidence for true temporal change, with the brightness of a specific region on the planet changing, sometimes over just a few years. At short centimeter wavelengths (probing the ~5 to ~50 bar pressure region), the disk-averaged variations are at least 10%, with peak brightness associated with summer solstice (which last occurred in 1985), and minima at equinox (1965 and 2007). In the visible/near-IR (probing the 0.5 to 1 bar region) variations can be larger (around 30%), but they have the same phasing as the radio data (peak brightness occurs at summer solstice). The variations with latitude and time may be due to variations in convective activity, ultimately driven by seasonal variations in sunlight. For any given epoch and wavelength, models of atmospheric structure can be made that match the observations. At this time, however, there is no complete model that describes the atmosphere for all epochs and wavelengths. Visible observations from before and after the 1985 solstice differ by about 5% (meaning the brightness is not symmetric about solstice), suggesting predictions for unobserved epochs may be uncertain by the same amount. The centimeter wavelength data are not precise enough to resolve asymmetries of that magnitude. Work is currently underway to improve models of the atmosphere, constrained by observations at additional wavelengths. Such models are necessary to estimate the variability at Herschel's wavelengths.

Calibrating the long-duration balloon flight of BLAST in 2005

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The Balloon-borne Large Aperture Sub-mm Telescope (BLAST) is a 2-m sub-mm telescope operating simultaneously at 250, 350 and 500 microns. The primary science-goal of BLAST is to conduct shallow, wide-area and deep, confusion-limited extragalactic surveys to constrain the redshift distribution, clustering properties, and star formation history of this bright population of luminous starburst galaxies in the high-redshift universe. BLAST uses identical bolometer arrays to those that will be used by SPIRE camera, and therefore BLAST can provide valuable information that may help guide the observing strategies of SPIRE. One of the greatest challenges that BLAST will encounter is the requirement to obtain accurate photometric calibration (approximately 5%) at these short sub-mm wavelengths during a long-duration balloon-flight from Kiruna (Sweden) in spring 2005. In this talk I will outline how the science-goals drive the calibration requirements for BLAST. I will also describe how we expect to achieve the required photometric accuracy at 250, 350 and 500 microns.

Establishment of asteroidal calibrators for far-infrared and sub-mm observations

Takafumi Ootsubo (Nagoya Univ.)[1], Sunao Hasegawa (ISAS/JAXA), Tomohiko Sekiguchi (NAOJ), Hideaki Fujiwara (Univ. of Tokyo), Issei Yamamura (ISAS/JAXA) and ASTRO-F Calibration team

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We will present the current activity of the ongoing preparation work on the asteroidal calibrators for ASTRO-F. Thermal radiation from asteroids can be predicted accurately by a Thermophysical model (TPM) with physical parameters, such as 3-axis size, rotation rate, spin vector, emissivity and thermal inertia. Mueller et al. are currently investigating the physical and thermal properties of about 50 asteroids. These asteroids are potential calibration standards for the ASTRO-F. To determine all TPM input parameters, we need accurate measurements of thermal radiation flux in multiple wavelength bands. We carried out SUBARU/COMICS observations to obtain accurate fluxes of the targets at several wavelengths in N- and Q-bands. We have obtained the new mid-infrared data of 5 asteroids among the 50 standard candidates so far. The data, together with already published infrared observations, will enable us to validate the TPM predictions and establish the key TPM input parameters. As a result, we can predict the far-infrared fluxes for the ASTRO-F calibration. Detailed further studies of the targets at longer wavelengths will also be possible in support for HERSCHEL, ASTE/ALMA, and other future projects.

The Asteroid Preparatory Programme for HERSCHEL, ASTRO-F and ALMA

Thomas G. Müller & members of the HERSCHEL Calibration Steering Group & members of the ASTRO-F calibration team
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We present the status of the "Asteroid Preparatory Programme" which is currently conducted together with the HERSCHEL and ASTRO-F calibration teams. We investigate the physical and thermal properties of about 50 asteroids. All of them are large, almost spherical and belong the asteroid main-belt. They cover the flux range between about 1 and several hundred Jansky at 100 micron, at 1 mm they still reach up to 10 Jy. Thermophysical model predictions (light curves, SEDs or monochromatic fluxes) are accurate on the 5-20% level, depending on the object, the wavelength, the observing and the illumination geometry. We summarize the current work on critical modelling aspects and present an overview of the ongoing observational programmes.

Stellar calibrators for HERSCHEL/SPIRE and PACS

Martin Cohen
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I will summarize the impact of the precision MSX stellar calibration experiments on absolute stellar calibration. These radiometric results support both the absolute and relative basis for the 1-35 micron products developed for ISO and MSX. These spectra were extended for ISOPHOT in the 1990s and have undergone their first test now. The extension of this all-sky network to Spitzer/IRAC and MIPS has resulted in hundreds of additional calibrators, all within the same absolute framework that MSX validates. I will report on the approximate numbers of stars currently available for FIR calibration from the brighter network of 613 K- and M-giants. Given current estimates for sensitivity of SPIRE and PACS in their various photometric bands one can estimate how many of these stars could be considered as potential HERSCHEL calibrators. The same approach is also being applied to calibrators for the all-sky FIS on ASTRO-F.

Secondary standards for ISOPHOT

Peter Abraham
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The large number of possible combinations of ISOPHOT filters, apertures, and observing modes form a huge parameter space which was only sparsely covered by dedicated calibration observations. In our approach at Konkoly Observatory we collect samples of observations which are relatively homogeneous from an instrumental point of view, and identify all - calibration or scientific- observations which could be used to check and improve the photometric calibration of the sample. These "secondary standards" are preferably normal stars (main-sequence or giant stars, lum. class III-V) which were, fortunately, observed in high number in the framework of the Vega-programmes. In this contribution I present an overview on the stellar sample measured by ISOPHOT at long wavelengths, and describe how we utilize them as secondary standards.

Secondary Calibrators at sum-mm wavelengths

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Photometric calibration at submillimeter wavelengths is very challenging. The sky is hardly ever photometric and we lack well characterized calibration sources. The emission from stellar photospheres is too faint for ground based telescopes and the calibration is tied to Mars, which adds uncertainty for absolute calibration. In this talk I review work done at JCMT to identify and establish a set of secondary calibrators for submillimeter wavelengths. The current set of secondary calibrators for SCUBA was introduced mostly as a stopgap measure and is too limited: two protoplanetaries, two AGB stars (both long period variables), one T Tauri star and one protostar. The last two are both embedded in dark clouds and not likely to be suitable as calibrators in the far infrared.

We have therefore pursued other alternatives, which can also be used at FIR wavelengths: asteroids, isolated Herbig Ae/Be stars and other dust rich stellar objects as well as galactic nuclei. The latter, although spatially compact, have significant contribution from emission lines and need to be calibrated separately for each photometric band. I present some preliminary results from this work with recommendations of what we need to do to improve the calibration accuracy in the submillimeter and far infrared.

The impact of cirrus confusion noise for Herschel/PACS

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Although cirrus confusion noise is believed to be insignificant for 3m-class IR telescopes, recent estimates based on ISO/ISOPHOT results suggest, that it still may be an important phenomenon for Herschel (being in the same order as the chopping noise due the warm mirror), especially at the longest wavelengths. In this talk I summarize the recent results based on ISOPHOT measurements and discuss the possibilities to further improve the estimates for Herschel/PACS, based on measurements of cirrus in the visual, near-infrared and/or radio domain.

SWAS Calibration Strategy

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The SWAS satellite has been operated for 5 years continuously after its launch in December 1998. This successful operation is the result of extensive testing on the ground and during its early orbit phase. In this presentation I will review the performance characterization of the SWAS heterodyne system on the ground and its on-orbit verification. The frequency calibration was verified on the ground through simulations of observations using a gas cell. The power calibration was performed using the hot-cold load measurements and nearfield beam measurements. On-orbit, the frequency and the power calibration were verified by comparing the SWAS results with ground-based observations of CI, and the SWAS beam was verified by performing map observations on Jupiter. During the on-orbit operation phase, these verification measurements were repeated in irregular intervals to track possible degradation.

ISOPHOT-related calibration work at Konkoly Observatory

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Since 2001 our group at Konkoly Observatory is involved in the systematic re-processing of selected data sets obtained with ISOPHOT, the photometer on-board the Infrared Space Observatory. We are producing far-infrared photometric catalogues as well as mid-infrared spectral atlases of compact sources. The results are available as Highly Processed Data Products on the ISO web (www.iso.vilspa.esa.es). In this contribution I summarize our work, describe the products available, and present our next plans for re-processing further ISOPHOT data sets.

Calibration strategies at JCMT

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In this talk I describe calibration strategies at JCMT for both photometry and spectroscopy. Although ground based observatories face additional challenges relative to space missions; variable atmosphere and changes in telescope efficiency due to temperature variations, most of the strategies implemented at JCMT are directly applicable to other observatories and space missions.

Calibration plan of the ASTRO-F Mission

Issei Yamamura (ISAS/JAXA) and the ASTRO-F Calibration team
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ASTRO-F is the next generation infrared survey mission. The satellite is equipped with a 68.5 cm cooled telescope and two scientific instruments, the Far-Infrared Surveyor (FIS; 50--180 micron) and the Infrared Camera (IRC; 1.8--26 micron). ASTRO-F will carry out an all sky survey in four wavelength bands by the FIS as well as two MIR-bands around 9 and 20 micron by the IRC. ASTRO-F will also perform thousands of pointed observations of selected areas. Especially intensive observations are planned in the North Ecliptic Polar region and the LMC/SMC regions.

Because of a strong visibility constraint, the astronomical calibration of ASTRO-F has to be planned very carefully. We envisage two kinds of photometric calibration sources: asteroids and stars. For the all sky survey the sources need to be distributed all over the sky, while for the pointed observations we may use stars close to the ecliptic poles. The establishment of the calibrators is ongoing in collaborations with experts on stellar and asteroid models.

We will present an the overview of the mission, the calibration strategy of the instruments, the current activity of the calibration work, and the identified problems. Main emphasis will be put on the FIS instrument. Possible contributions to calibration aspects of future missions are also discussed. Ootsubo et al. will describe the ongoing preparation work on the asteroidal calibrators for ASTRO-F.

Calibration of the Planck-HFI instrument: can it be used for Herschel?

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The High Frequency Instrument (HFI) of the Planck satellite will perform a full sky surveys in six spectral bands covering the 100 GHz-1 THz range and with an angular resolution from 5 to 10 minutes of arc. The calibration of the spectral response and polarization properties of its 52 bolometric channels will be done on the ground at the calibration facility of IAS, Orsay. The beam geometry will be obtained in orbit by observing the planets, while the Galaxy and the Dipole of the Cosmic Microwave Background will provide a permanent and accurate (percent like) photometric calibration. This will allow to propose a recalibration of the giant planets based on the CMB dipole and will provide some calibration sources available for cross checking calibration with observatories. Polarization will be available in the four low frequency channels.

Herschel Space Observatory cross-calibration strategy

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The objective of our cross-calibration activities is to assess and assist the calibration of the Herschel instruments by (i) making independent consistency checks among data from the Herschel instruments, and (ii) comparing Herschel photometry, mapping and spectrometry data to data from other ground and space facilities. We will present our initial approach to cross-calibration, in terms of requirements, selection of sources, usage of data from other facilities, and the preparation of a database. We plan to implement software utilities that will allow us to compare observations made with different observatories and instruments, taking into account their characteristics (e.g. spectral and spatial resolutions).