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The Herschel Data Processing System — HIPE and Pipelines — Up and Running Since the Start of the Mission

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Abstract. The Herschel Space Observatory is the fourth cornerstone mission in the ESA science programme and performs photometry and spectroscopy in the 55 - 672 micron range. The development of the Herschel Data Processing System started in 2002 to support the data analysis for Instrument Level Tests. The Herschel Data Processing System was used for the pre-flight characterisation of the instruments, and during various ground segment test campaigns. Following the successful launch of Herschel 14th of May 2009 the Herschel Data Processing System demonstrated its maturity when the first PACS preview observation of M51 was processed within 30 minutes of reception of the first science data after launch. Also the first HIFI observations on DR21 were successfully reduced to high quality spectra, followed by SPIRE observations on M66 and M74. A fast turn-around cycle between data retrieval and the production of science-ready products was demonstrated during the Herschel Science Demonstration Phase Initial Results Workshop held 7 months after launch, which is a clear proof that the system has reached a good level of maturity.

We will summarise the scope, the management and development methodology of the Herschel Data Processing system, present some key software elements and give an overview about the current status and future development milestones.

1 Introduction

The Herschel Space Observatory, the fourth cornerstone mission in the ESA science programme, was successfully launched 14th of May 2009. With a 3.5 m Cassegrain telescope it is the largest space telescope ever launched (Pilbratt et al., 2008). Herschel's three instruments (HIFI, PACS and SPIRE) perform photometry and spectroscopy in the 55 - 672 micron range and will deliver exciting science for the astronomical community during at least three years of routine observations (de Graauw et al., 2008, Poglitsch et al., 2008, Griffin et al., 2008). One month after launch, on its way to its operational orbit around L2, the Lagrange point located 1.5 million kilometres away from the Earth, the cryostat lid was opened, and the first observational tests were conducted. Most of Herschel's performance verification and science demonstration phase activities have been completed for SPIRE and PACS, and both instruments will commence routine operations before 2009 ends.

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http://herschel.esac.esa.int/DpHipeContributors.shtml

2 Scope, Management and Development Methodology of the Herschel Data Processing System

The development of the Herschel Data Processing System started in 2002 to support the data analysis for Instrument Level Tests with the final goal to provide an integrated, easy to use, well tested and documented data processing system to the astronomical community free of charge. Subsequently the Herschel Data Processing System was used for the pre-flight characterisation of the instruments, and exercised during various ground segment test campaigns. The system combines for the first time data retrieval, pipeline execution and scientific analysis in one single environment. All tools for data reduction and analysis, e.g. also the expert applications for Instrument Calibration, Trend Analysis and Quality Control systems are part of the Herschel Data Processing System. Therefore the community has access to the same system as the instrument experts. Also the Standard Product Generation (SPG) software which automatically generate data products are a subset of the Herschel Data Processing System.

The Herschel Data Processing system is coded in Java/Jython to be license free and portable for different operating systems. Its source code is freely available under the GNU lesser general public license and is already accessible to Herschel Key Programme users.

Developing the Herschel Data Processing system is a major project, with over 200 contributors and currently 60 full-time equivalents working on calibration, coding, documentation, quality control, testing and tutoring. The Herschel Science Centre (ESA), the Instrument Control Centres (HIFI, PACS and SPIRE) and the NASA Herschel Science Center (NHSC) jointly manage and contribute to the Herschel Data Processing System.

3 Key Software Elements of the Herschel Data Processing System

Installers are available for a variety of operating systems and formal support is provided for Windows XP, Vista, Linux, Mac OS X 10.5 ("Leopard") for both user and developer versions of the Herschel Data Processing System. Formal support of Windows 7 and Mac OS X 10.6 ("Snow Leopard") will be provided in the future.

The Herschel Interactive Processing Environment (HIPE) was introduced as the user friendly face of the Herschel Data Processing System. It provides both a script driven, command line based environment suited to developers' and experts' needs and a GUI based end user-oriented environment. This interface is more data-centric than language-centric, providing astronomers who are not experienced in Java a state of the art interface to process Herschel data. It also has the great advantage that the same framework can be used to download, reprocess, analyse and compare data from all three instruments in Herschel simultaneously.

HIPE is rich in features: Drag 'n Drop, command-line echoing, access to functionality by menu, toolbar, pop-up menus, and keyboard short-cuts. It allows to analyse the same data in different ways and to compare similar types of data easily. It features a user controllable layout, permitting to organise the views the way the user wants it, add/remove them, and to dock and undock

views. HIPE allows the user to execute the official pipeline and to adapt it to their own scientific needs within the same environment.

Another advanced feature of the Herschel Data Processing system is the Product Access Layer, an interface to store, query and load Herschel data in/from different types of specialised Products pools, the documentation generation system, and the direct access to the Herschel Science Archive, which allows users to retrieve the raw data from the HSA directly in batch mode. The Product Access Layer also permits to share data between collaborators.

A state of the art documentation system for the framework and all instruments which includes context-sensitive search functionality is provided as part of the Herschel Data Processing System.

4 Operational Use of the Herschel Data Processing System

The data processing pipelines which automatically generate data products are executed on the European Space Astronomy Centre (ESAC) computing grid to produce Herschel Products to different reduction levels:

Level 0 products Raw telemetry data as measured by the instrument. They might be minimally formatted

Level 1 products Detector readouts calibrated and converted to physical units, in principle instrument and observatory independent

Level 2 products Level-1 data further processed to absolutely calibrated images, spectral cubes and spectra so that scientific analysis can be performed

The data products are ingested into the Herschel Science Archive (HSA) and made available to the data owners through a user interface similar to those of existing ISO and XMM archives, usually on the same day of reception of the data from the satellite.

Data quality control is performed for all Herschel scientific observations by the observatory's Technical Assistants and Instrument Calibration Scientists. This data quality control is a combination of automatic screening and manual inspection. Quality control reports are electronically distributed to experts and usually takes a few days. A summary of these findings is contained in the quality control summary that is made available as part of the Herschel data products.

5 Handling of Herschel Data During Its Early Operational Days

Herschel opened its eyes on 14 June 2009, precisely one month after the launch from Kourou, as the cryocover, the cryostat lid, was commanded to open. During the remainder of the operational day Herschel carried out test observations labelled a 'sneak preview'. Within 30 minutes following the reception of these data from the first PACS observation of the whirlpool galaxy M51 a fantastic image was generated within HIPE, followed by the operational pre-launch pipeline. Also spectra showing CO and H_2O lines of HIFI's first light observation of the star forming region DR21 were generated both in the interactive environment and in the standard pipeline. Finally SPIRE's first light observations of M66 and M74 were successfully handled by both HIPE and pipeline. Other early results were the handling of PACS imaging spectroscopy on the Cat's Eye' nebula

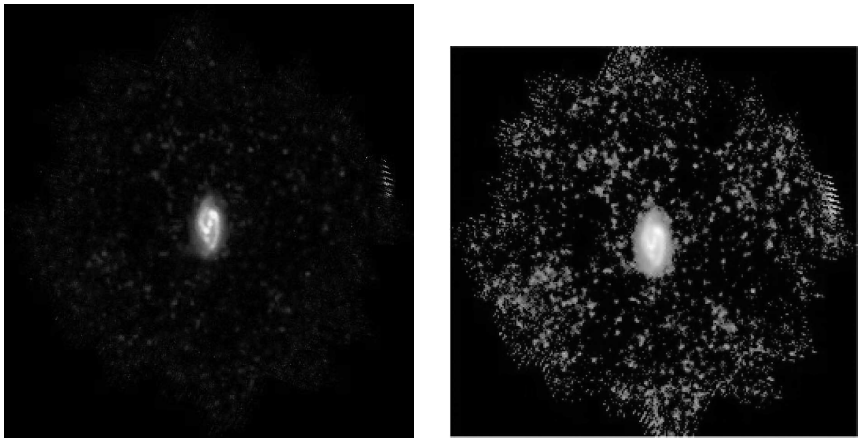

Figure 1. SPIRE first light observation on M66 reduced by HIPE (left) and the current operational pipeline (right).

NGC6543 and of the PACS/SPIRE parallel mode that revealed new details in the Milky Way.

6 Current Status and Future Development Milestones

HIPE 1.1 (Performance Verification Phase version) was made available to the Herschel Key Program teams. This version was also used to perform the first bulk reprocessing exercise of Herschel data. The first Science Demonstration Phase observations were conducted in September 2009 and data products were provided to the observers using an early version of HIPE 1.2. As of end 2009 HIPE 1.2 (Science Demonstration Phase version) is operational. HIPE 2.0 (Science Routine Phase version) is currently under testing. An early version of HIPE 2.0 was made available to the participants of the Herschel Science Demonstration Phase Data Processing Workshop. HIPE 2.0 will be made available to the Herschel community early next year. It is foreseen that future HIPE versions will be released regularly; during the following year around each three months.

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Herschel's 'sneak preview', 'first-light' and PACS/SPIRE parallel mode results,
http://herschel.esac.esa.int/SneakPreview.shtml
http://herschel.esac.esa.int/FirstLight.shtml
http://herschel.esac.esa.int/FirstParallelModeImages.shtml

Herschel Science Demonstration Phase Initial Results Workshop,
http://herschel.esac.esa.int/SDP_IR_wkshop.shtml