The ISO Data Archive - Content & Context

THE ISO DATA ARCHIVE: OVERVIEW OF SCIENTIFIC CONTENT AND USE

Alberto Salama, Christophe Arviset, John Dowson, José Hernández, Pedro Osuna, and Aurèle Venet

ISO Data Centre, European Space Agency, Villafranca del Castillo, P.O. Box 50727, 28080 Madrid, Spain.

ABSTRACT

ISO was the world's first true orbiting infrared observatory. With four highly-sophisticated scientific instruments and a pointing accuracy at the arc-second level, ISO provided a facility of unprecedented sensitivity and capabilities for exploring the Universe at infrared wavelengths from 2.5 - 240 microns. During its highly-successful in-orbit operational phase from November 1995 to May 1998, ISO made some 30,000 individual scientific observations of all types of astronomical objects, from within our own Solar System out to the most distant galaxies. The resulting database provides a treasure-trove of information for further astronomical research. All data is available to the community via the ISO Data Archive [1] and from an increasing number of suppliers of astronomical information (Virtual Observatories). An overview is given here of the ISO Data Archive functionality, content and usage.

1. INTRODUCTION

The ISO Data Archive (IDA) has been online since December 1998. It was designed and developed at the ISO Data Centre, in continuous and fruitful cooperation between users and developers, providing a unique, state-of-the art astronomical data archive.

It contains all the ISO raw and fully processed, science and calibration data as well as all ancillary data (engineering, uplink and downlink data) for a total of about 400 GBytes stored on magnetic disks. Through a powerful and user friendly Java User Interface, over 1300 registered users have already downloaded the equivalent of 7 times the total number of scientific observations in the archive, a monthly retrieval rate of around 15%.

The IDA main characteristics can be summarized as:

- Powerful and complex queries against the observations catalogue
- Configurable results display, including product visualization tools
- Customisable product retrieval via a shopping basket
- Choice for direct retrieval of products on disk
- Selection of product level for retrieval
- Product retrieval via FTP
- Tracking of publications
- Inter-operability with other archives and applications.

The IDA has been designed in an open and flexible way, which allows configurability and re-usability for other archive projects.

The IDA design was made modular and flexible, to allow easy evolution with additional user requirements. This has shown to be true. Arviset & Prusti (1999) describe the first version of the IDA, while Arviset et al. (2000, 2002a, 2002b), Salama et al. (2002) expand on the new capabilities, including those towards the integration into the Virtual Observatories (see Genova 2002).

In this paper we will give an overview of the IDA capabilities (Section 2), its contents (Section 3) and usage (Section 4).

2. ISO DATA ARCHIVE CAPABILITIES

The ISO Data Archive offers the user a self-contained, fast and powerful interface to all ISO data products. Complex queries can be made against hundreds of database parameters using friendly and modular query panels (general astronomical parameters, observer and proposal, timing constraints, list of targets, pointing and raster map constraints or even instrument details). The user is helped in the selection of observations by a clear and configurable display of results that includes quick look data browsing (static GIF icons and postcards; FITS products display), access to auxiliary and ancillary files, access to related observations in the ISO catalogue, on-line help and access to other archives (IRAS, ADS). Once logged in, the user can move this selection to his shopping basket, perform other queries, select other observations and later decide the level of processed products to download (standard datasets or user defined ones, for all or per observation). A direct download facility is also possible.

The IDA is based on a flexible and open 3-tier architecture design, the main aim of which is to separate the data and the business logic from the presentation. The overall system design was decided early 1997 and has been able to accommodate all new user and system requirements that have been raised since then.

2.1. DATA PRODUCTS AND DATABASE

The IDA contains the ISO telemetry processed by an automatic pipeline processing chain at various levels, together with an-

[1] The ISO Data Archive is available from the ISO Home Page, at `http://www.iso.vilspa.esa.es/ida`

Proceedings of the Symposium *"Exploiting the ISO Data Archive - Infrared Astronomy in the Internet Age"*,
24–27 June 2002, Sigüenza, Spain (C. Gry, S. B. Peschke, J. Matagne et al. eds., ESA SP-511)

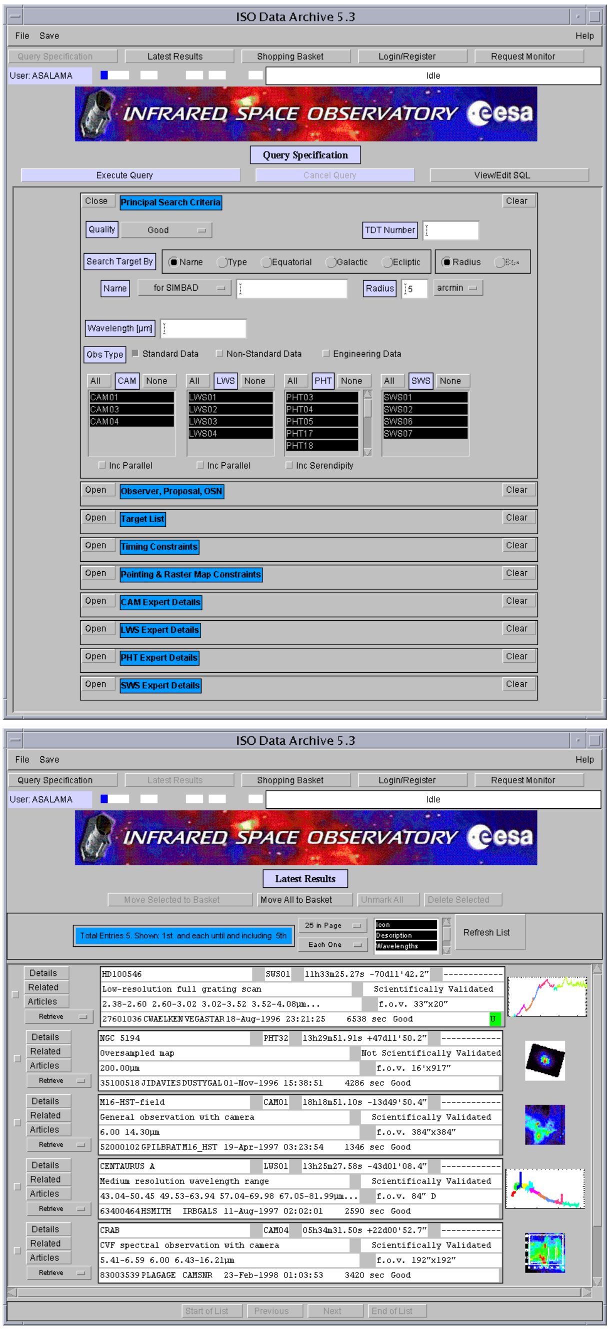


Figure 1. ISO Data Archive main and query results panels

cillary information (engineering, uplink and downlink data). Essential parameters extracted from the data are part of the database allowing complex queries to be made.

Over the years since the observations were performed, the automatic processing pipeline and associated calibration continued to be refined. All pipeline versions underwent a careful technical and scientific validation process on representative sets of data.

All standard observations were individually inspected and an assessment of the quality of the data products was made. Quality was defined in a technical sense, covering real-time operations and pipeline processing aspects. Quality information is available from the IDA.

All ISO data were reprocessed with the final version of the pipeline to produce the so-called 'Legacy Archive'. This was released at the end of February 2002 and represents the best set of products that can be generated by automatic processing.

The ISO Data Centre is now stimulating and coordinating activities to reduce selected data sets systematically by hand so as to obtain the ultimate quality data products and to capture these into the archive, the so-called "Expert Reduced Data" (XRD). This is one of the main tasks of the current phase of the ISO project, the "Active Archive Phase", which will run until December 2006. This final phase is designed to maximise the scientific exploitation of ISO's extensive infrared database and to leave behind a homogeneous archive with refined data products, as a legacy to future generations of astronomers. An important input in the selection of data sets for this manual systematic processing is given by this conference.

2.2. User Interface

In the early stages of the project in 1997, it was decided that the only way to have a powerful graphical user interface meeting all the user requirements was to opt for a Java application or applet rather than the standard approach based on cgi-bin scripts. This approach has definitely paid off, as described in Arviset et al. (1999) as the IDA offers one of the most powerful archive interfaces. Later, IDA obtained the SUN certification "100% Pure Java" which warranties that the IDA Java code is running on all platforms and meets SUN code portability standards.

2.3. Business Logic

While the pipeline calibration system produces data products and files and the user only sees the Java interface, all connections between the two other layers are made by the so called "Business Logic" or middle tier. The use of a middle tier has a number of advantages. It isolates the interface from the rest of the system and deals with most of the application business logic and complexity. This has the benefit of making the interface lighter and faster and it also means that a number of changes don't require the users to get a new version of the application. All the data transfers between the interface and the middle tier are compressed which makes the system run faster. This business logic layer is also the way other archives or applications can access the ISO data products and extra files without being required to go through the standard user interface. This has made very easy any inter-operability of the IDA in the context of the Virtual Observatories.

2.4. Re-Usability

Another great advantage has been brought by the use of Java in this open 3-tier architecture. The IDA design and code has been re-used to develop the XMM-NEWTON Science Archive

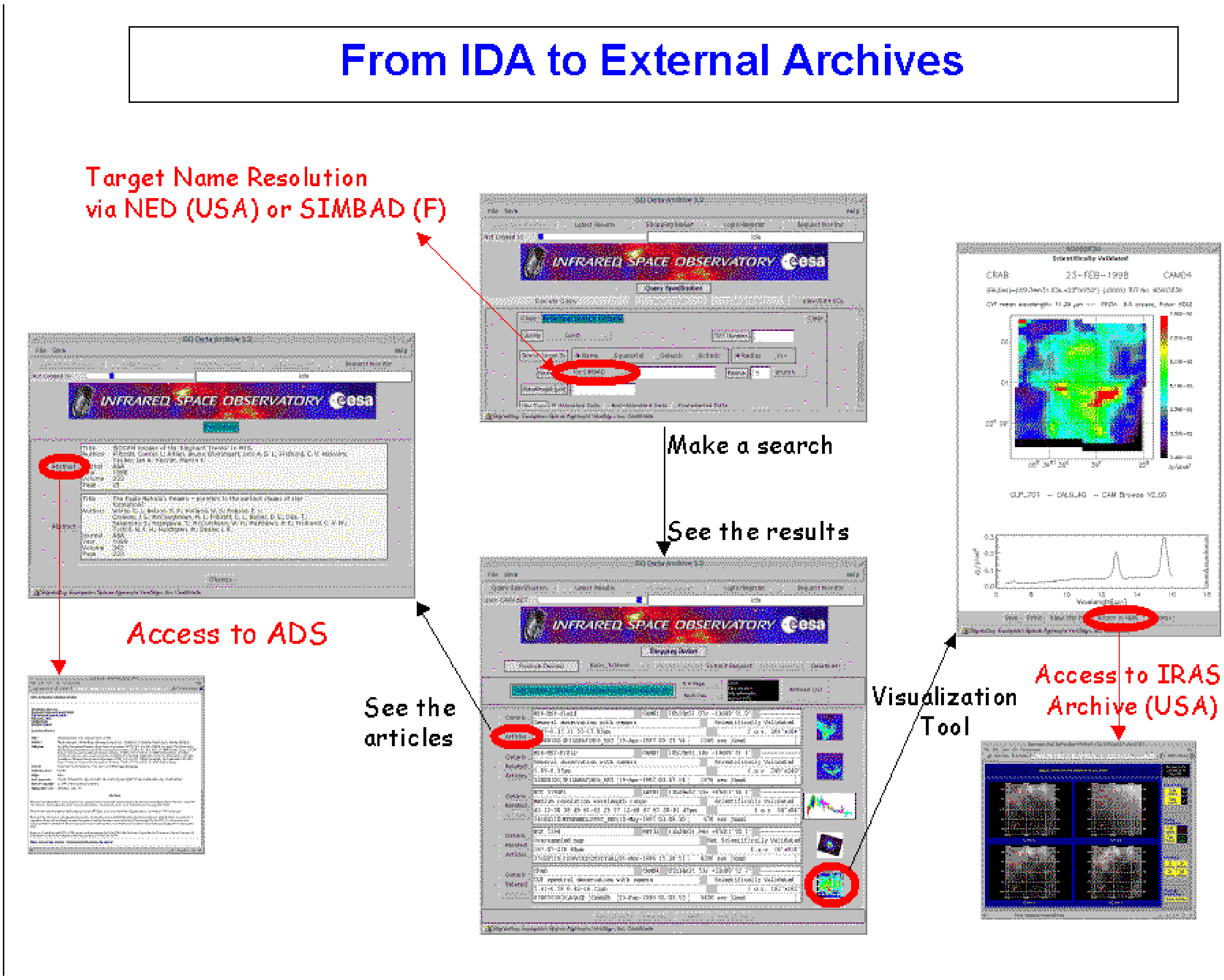


Figure 2. ISO Data Archive inter-operability – IDA and the outside world

(XSA), first released in April 2002. By doing so, development cost for the XSA has been reduced by a factor of 3 to 4 as most of the IDA code is re-usable, mainly configurable XML files had to be adapted to the new archive. Further re-usability is currently being studied for the ESA Planetary Mission and Integral archives.

2.5. Publication tracking

This service has been available from IDA 3.0, in December 1999. In cooperation with IPAC, all major astronomical journals are scanned for references to ISO. Later on, astronomers at the ISO Data Centre find the observations on which the paper is based. This process sometimes involves interaction with the paper authors, when the observations are not explicitly mentioned. The observation details are then entered into the IDA, via a dedicated web page called from the IDA itself. Paper authors can also enter directly the observations used in their paper using the same system. Further to validation by the IDC, these are entered in the IDA.

2.6. An inter-operable archive

In the last years, preparing for the Virtual Observatories, development has been focussed on improving the IDA inter-operability with other astronomical archives, through accessing other relevant archives or through providing direct access to the ISO data for external services. In particular, target name resolution via NED and SIMBAD has been available since the first version of the IDA in December 1998. Users can see the article abstracts associated with an ISO observation and a link to the ADS WWW mirror at Strasbourg, France, is also provided. On the other hand, links are provided by ADS to the ISO postcard server for the observations referenced in a given article. A link is provided from the IDA to the InfraRed Science Archive (IRSA) WWW page located at IPAC, USA. From the ISO postcard, by a simple click, the user can open a browser window that contains the IRAS data covering the region of the sky of the selected ISO observation. Direct link to the ISO data is provided by the ISO Product Server. Through calling a URL / Java Server Page (JSP) containing the ISO observation identifier (so called TDT number), it returns the ISO postcard (GIF image) of

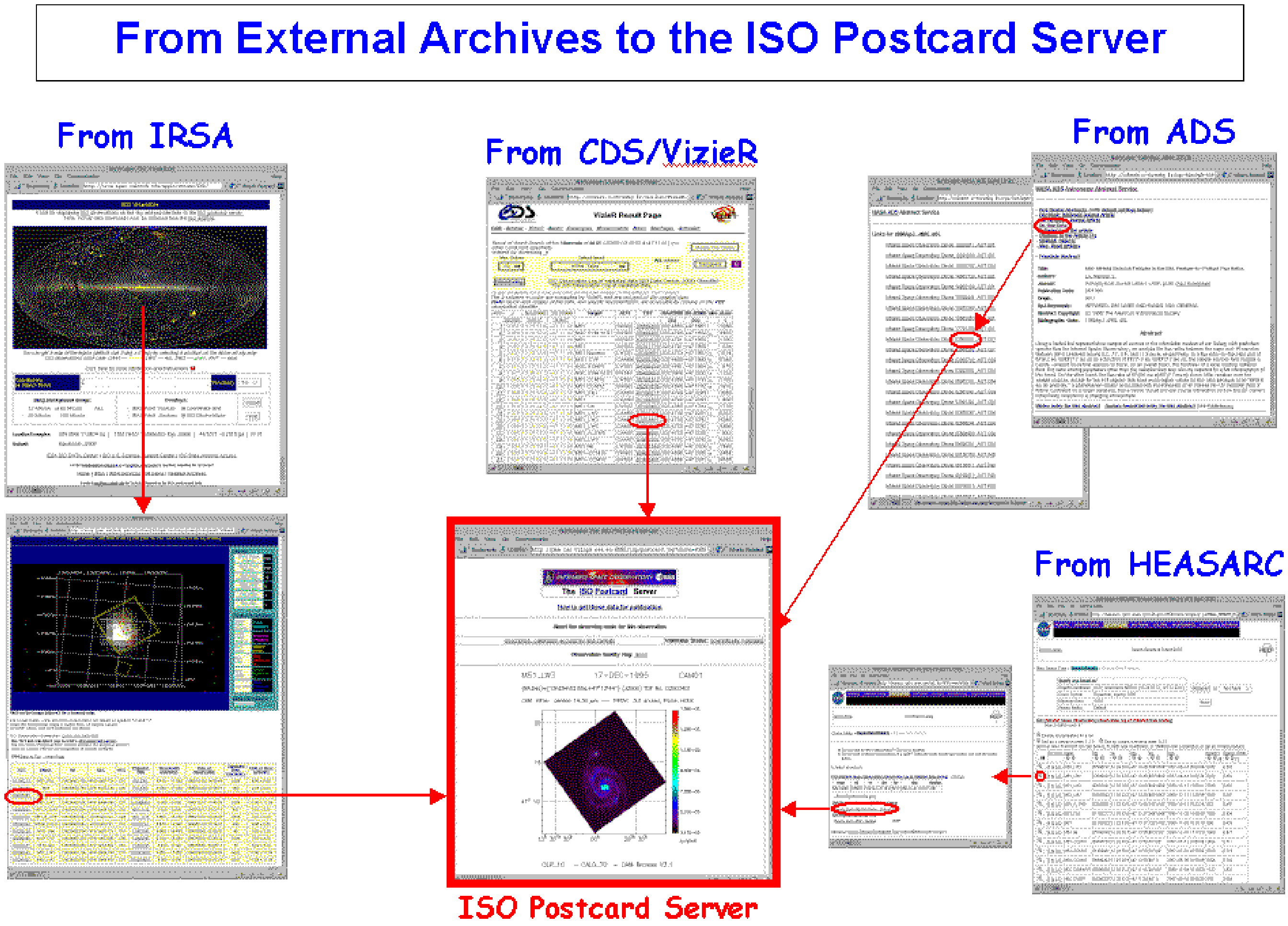


Figure 3. ISO Data Archive inter-operability – the outside world and IDA

this observation and ancillary quality and accuracy information embedded into an HTML page with appropriate documentation links. The ISO Data Centre can provide the ISO observations catalogue and the syntax for any astronomical application to be able to easily link with the ISO products without going through the standard IDA interface. This is already available through Vizier at CDS, Strasbourg, France (Genova, 2002), the NASA HEASARC archive and from ADS. IPAC/IRSA has developed a tool to visualise the ISO observations on top of IRAS images also linking observations to the ISO Postcard server (Ali et al., 2002). More detailed and technical information on the inter-operability of the IDA can be found in Arviset et al. (2000) and in Salama et al. (2002).

3. ISO Data Archive statistics

The ISO Data Archive contains ≈ 30,000 individual scientific observations and ≈ 110,000 observations performed in the ISO parallel and serendipitous modes (Kessler et al., 2002). Currently, the ISO Data Archive has 1340 registered users from over 37 countries (Matagne, 2002). In the last years, the ISO Data Archive has been accessed ≈ 1000 times per month, with ≈ 1500 queries done on average. About 60 users download every month ≈ 2000 observations.

It is of interest to report on the ISO publication statistics. At the time of the conference (June 2002), 862 ISO papers had been published in the refereed literature (at a rate of about 150 papers per year, comparable to other scientific missions) and many more as conference proceedings. In Tab. 1 the publication statistics is broken down in two components: observing time and scientific categories.

Approximately 45% of ISO's time was reserved for those parties contributing to the development and operation of the scientific instruments and the overall facility. Preparation of the programme for this Guaranteed Time (GT) started in the mid-80's and the planned observations were published to the community in April 1994. The other 55% of ISO's observing time (Open Time, OT) was distributed to the general community via two 'Calls for Observing Proposals', one pre-launch (April 1994) and one post-launch (August 1996), each followed by peer review. In total, ≈ 1000 observing proposals were carried out during the ISO lifetime.

The scientific category taken here is the one chosen by the observer in the proposal. A more homogeneous approach (statis-

Table 1. This table five the percentage of obseravtions in each category that has already been published. This is given in both, number of observations and observing time.

Scientific Category	published percentage # observations	observing time	total number of papers
Solar System GT	9	15	20
Solar System OT	34	39	42
Stellar and circumstellar GT	48	49	230
Stellar and circumstellar OT	30	36	315
Interstellar medium GT	22	39	233
Interstellar medium OT	20	30	243
Extragalactic systems GT	59	51	136
Extragalactic systems OT	16	25	159
Cosmology GT	47	59	40
Cosmology OT	31	73	62
Total GT	39	45	456
Total OT	23	34	452
Grand Total	28	36	862

tics per object type) will be possible at the completion of the cross-identification work being carried out at the CDS, Strasbourg, relating all ISO observed targets to the SIMBAD database (Genova, 2002).

4. FUTURE IMPROVEMENTS

During the ISO Active Archive Phase, the ISO Data Archive will continue to be improved with new data and information being ingested. Major tasks will be: stimulating systematic data reduction and capturing the resulting data products into the archive; ingestion of new ISO catalogues and atlases; continuing the process of increasing the inter-operability of archives by linking to other data sets; continuing the tracking of refereed ISO publications, incorporating this information; and maintaining the archive, especially the user interface to maximise its usefulness and ease of use.

REFERENCES

Ali, B., Kong, M., Salama, A., 2002, this volume

Arviset, C. & Prusti, T., 1999, ESA Bulletin 98, 133

Arviset, C. et al, 2002a, PASP 225, 165

Arviset, C., et al., 2002b, in proceedings ADASS XI, ASP Conf. Ser. 238, eds. F. R. Harnden, Jr., F. A. Primini, & H. E. Payne, [P-4] and [D-9]

Arviset, C., Guainazzi, M., Salama, A., et al., in *Toward an International Virtual Observatory*, ESO Astrophys. Symp., Springer Verlag, in press.

Genova, F., 2002, this volume

Kessler, M.F. et al. 1996, A&A 315, L27

Kessler M.F., Müller T., Leech K. et al., 2002, The ISO Handbook: Volume I, ISO - Mission & Satellite Overview, ESA SP-1262, SAI/2000-035/Dc, Version 2.0

Matagne, J., 2002, this volume

Salama, A. et al., 2002, in proceedings ADASS XI, ASP Conf. Ser. 238, eds. F. R. Harnden, Jr., F. A. Primini, & H. E. Payne, [P-52]

THE ISO CENTRAL PROGRAMME AND ITS UNEXPLORED POTENTIAL

Martin Harwit

511 H Street, SW, Washington, DC, 20024-2725, USA; also Cornell University

ABSTRACT

The ISO Central Programme covered a broad range of topics, ranging from planetary to stellar and interstellar investigations and the exploration of extragalactic sources and the cosmos. This paper concentrates on the five main classes of investigations into which the Central Programme was divided – solar system studies, stellar and interstellar observations, and extragalactic and cosmological surveys – and highlights several major accomplishments. The focus then shifts to portions of the Central Programme's accomplishments that promise to provide further astronomical insight as the archives compiled in the course of the mission are probed in greater depths.

Key words: infrared astronomy – Central Programme

1. INTRODUCTION

Even as the ISO spacecraft and instruments were being assembled in the late 1980s and early 1990s an ISO Central Programme was being compiled by the four ISO Principal Investigator (PI) teams, the five Mission Scientists and the Science Operations Team. The European Space Agency (ESA) had instructed these three teams that the guaranteed time they had been awarded was to be used to assemble a coherent program of major astronomical investigations that only ISO would be able to carry out. This program would have to first be submitted to an Observatory Time Allocation Committee (OTAC), for consideration, approval, or recommendation for revisions. Only after this procedure had been successfully completed would the resulting Central Programme be fully certified.

When ESA first revealed the thrust of this Central Programme the concept was distinctly unpopular. Many scientists who were devoting years of their lives to the ISO project felt that their guaranteed time should be dedicated to projects of their own choosing, rather than to a program ordained by a bureaucracy. Nor did these astronomers feel that their guaranteed observing time should have to undergo scrutiny by an OTAC comprised of outsiders far less familiar with the instrumentation and the capabilities of the spacecraft. Such concepts appeared to challenge the very idea of *guaranteed time*. Where had the *guarantee* gone if one was no longer free to use one's observing time as one pleased? This new way of doing things was a distinct departure from the precedent set by the US/-Dutch/British Infrared Astronomical Satellite (IRAS) mission.

Despite the grumbling, a series of workshops was held to consider the major topics that might be included in a Central Programme. As these progressed, it became clear that a vast number of attractive projects recommended themselves, and that the Central Programme offered guaranteed time holders an unparalleled opportunity to devote themselves to genuinely exciting tasks that would require large blocks of observing time. Smaller, more idiosyncratic projects that various individuals might wish to conduct were unlikely to have as great a scientific impact. In any case, small projects could always be applied for and conducted as part of the ISO Open Time (OT) program if the OTAC judged them sufficiently meritorious.

In the final years before launch, as the United States and Japan added their efforts to the ISO missions, respectively, through their space agencies NASA and ISAS, they too were awarded guaranteed time and contributed this to the ISO Central Programme.

All the observations approved to guaranteed time holders were designated "blocked" – i.e. unavailable to open time observers. The entire list of blocked observations, i.e. the entire contents of the approved guaranteed time proposals, was published as a massive document alongside the pre-launch call for proposals for open time. By these means the general astronomical community was informed about specific observations already reserved for the guaranteed time holders and the Central Programme. By default, complementing observations were then still available for inclusion in open time proposals.

It is difficult to estimate how much of the originally conceived Central Programme was actually carried out. The ISO Central Programme had been assembled on the basis of a set of expected performance figures founded on pre-flight calibrations carried out under laboratory conditions that could not adequately simulate actual conditions in flight. Once the spacecraft was launched and the performance and verification phase were well under way, it became clear that many preflight expectations had to be revised. Sensitivities in many cases were lower and noise spikes more numerous than anticipated. On the other hand, instrumental stability was considerably higher, meaning that calibrations could be more reliable. Fortunately, also, the loss of liquid helium was slower than expected. Eventually the mission life stretched to 28 months, considerably outlasting the preflight estimate of 18 months.

These competing factors meant that initially some of the weaker sources were dropped from different parts of the Central Programme in order to make sure that at least the more powerful sources would be more reliably observed. As this culling out took place, the project urged guaranteed time observers to "unblock" sources they now knew they would not observe, so that these could at least be released to open time observers who might wish to study them. Publicizing the release of these sources, however, was difficult. Most of the guaranteed time observers were reluctant to release sources when they could not know how much longer the mission life would stretch. But, as the mission clearly was drawing to an end, a concerted effort was undertaken to target important Central Programme sources that might otherwise remain unobserved. Nevertheless, as the mission ended some of these targets still remained unobserved.

2. SUCCESSES

Since the start of the ISO mission many hundreds of refereed articles based on ISO data have been published. Many of these had their origins in the ISO Central Programme or were extensions of it carried out as part of the OT program. Among so many results, and so many successes, a choice of highlights has to be quite subjective. It is inevitable that I leave out many important findings, in a short list picked almost at random.

• A number of projects mapped dark clouds, like the star-forming ρ Ophiucus region.

• Several of these clouds harbored protostars whose luminosities were determined, as in the Chameleon 1 region.

• From these observations, the initial mass function of the protostars could be deduced.

• Spectral studies of cold interstellar clouds, like the NGC 7538 region seen in absorption against IRS 9, revealed ices of various mixtures deposited on grains.

• In the shocked domains of the Orion Nebula vast quantities of water vapor were detected.

• The Orion Pk1 region exhibited an amazing array of spectral features including those of polyaromatic hydrocarbons (PAHs), ices, fine-structure transitions, and atomic and molecular hydrogen emission.

• A wealth of pure rotation lines of H_2, sometimes including the long-sought 28 μm line, established unambiguous temperatures of warm molecular regions.

• It also became clear that, in young outflows like HH54, the temperature derived from the ortho-para ratios of H_2 did not necessarily correspond to the temperature derived from population densities in excited states. Such discrepancies serve as clocks and can yield the age of an outflow.

• In comet Hale-Bopp, a similar discrepancy was found between temperatures derived from level populations and ortho-para ratios in water vapor.

• The comet also exhibited spectral features of the crystalline silicate fosterite found in the circumstellar regions of some stars.

• Other stars, like VY Canis Majoris appear to have only amorphous silicates in their outflows. The conditions which permit the annealing of amorphous grains into crystals are gradually emerging as a wider sample of sources is studied.

• A particularly useful product of ISO's spectral observations was the accurate determination of a wide range of atomic and ionic mid-infrared fine-structure spectral frequencies that are difficult to measure in the laboratory.

• These fine-structure lines were observed not only in galactic sources but in distant galaxies as well. Among other functions, they can serve as velocity indicators.

• The depth of a 35 μm absorption feature in the spectrum of the star IRC + 10420 quantitatively verified that infrared absorption pumps the star's OH masers; the same pumping mechanism was found to also account for the megamaser in the galaxy Arp 220.

• The relative strengths of the ultraviolet radiation field and of the 7 μm PAH feature in ultraluminous infrared galaxies, was found to correlate well with galaxy type. In galaxies with active nuclei (AGNs) this relative strength was universally high; in starburst galaxies it is appreciably lower.

• A number of deep cosmological surveys were undertaken, both at 170 μm and in the 15 μm region. Most of the detected sources correspond to highly luminous galaxies at red shifts $z \sim 0.7 - 1.5$.

• Observations in both these spectral ranges confirm that galaxies are strongly evolving. At the shorter wavelengths, the total flux from these sources is an appreciable proportion of the total extragalactic background inferred from observations with the Cosmic Microwave Explorer (COBE).

3. THE PROMISE OF THE ARCHIVED DATA

3.1. Unpublished Data

While these results have been gratifying, we can be optimistic that a great deal will still emerge from the ISO Central Programme archives. Two factors suggest this: Only a fraction of the data obtained has been published, while data analysis techniques have steadily improved.

Figures compiled by Alberto Salama indicate that only $\sim$ 40% of the observing time spent on the ISO Central Programme has led to refereed publications. Two or three years ago, this fraction was closer to 15%. The rate of increase suggests that there is a great deal of unpublished data that could still be mined.

Many of the results I have cited were already apparent with the initial set of ISO findings published in the Astronomy and Astrophysics Letters issue of November 1996 (Volume 315 No. 2). Others followed within a year or two. Over the years, both data-reduction software and calibrations have greatly improved, so that the archived data already in hand should, in many cases, be re-analyzed for new scientific insight.

3.2. Data Analysis and Calibration

Software approaches, both in the interactive analyses and in the steadily improved data reduction pipelines, have been able to progressively take into account what Valentijn & Thi (2000) call "cosmic weather". Valentijn & Thi were able to improve data obtained with the Short Wavelength Spectrometer (SWS) by taking advantage of the high nondestructive read-out frequency of 24 Hz at which detector voltage levels were sampled. An arbitrary set of read-out values could be compared to data sets known to be free of cosmic ray hits and, by applying several filtering techniques, detector noise could then be reduced by factors of order 3 to reveal faint spectral features otherwise lost in noise.

Coulais & Abergel (2000) have devised software methods for dealing with detector memory effects based on a model developed by Fouks and Schubert (1995), while Miville Deschênes et al. (2000) have devised techniques to deal with cleaning data obtained through raster scans. These techniques can be applied equally well to either data obtained with the ISO camera or the photometer.

In the course of the ISO mission, the method of calibration has also greatly changed. Besides the calibrations that individual proposers had initially included in their observing schedule, and calibrations routinely scheduled by the project, the stability of the spacecraft and instruments made possible a global approach to calibration. Because the performance of the instruments was so stable, essentially the full data set obtained in the course of the 28-month mission came to serve as a calibration base that could, in different ways, be tied also to well-calibrated ground-based or airborne observations. The different instruments onboard ISO could also be calibrated against each other in regions of overlap. Instrumental peculiarities could be taken into account and artifacts arising from them could be largely eliminated.

Another method, developed by Leen Decin et al. (2000), exploited an iterative process in which both accurate observations of stellar calibration sources and new modeling of these sources was involved. To obtain convergence in this process, the authors needed (1) a sample of bright stars ranging over spectral types A0 to M8 observed with the ISO-SWS, and (2) a thorough understanding of the atmospheres of these stars and of the influence of chemical composition, gravity, and effective temperature on their respective spectra. This second point required the construction of synthetic spectra obtained for a series of different stellar types. Their initial thrust was restricted to the wavelength range from 2.38 to 12 μm, the only range in which sufficiently comprehensive atomic and molecular line lists were available.

4. THE FUTURE OF THE ISO ARCHIVES

With as much work going on to obtain improved calibrations and data reduction algorithms, and with laboratory studies and theoretical modeling progressing as well, the ISO archives promise to become increasingly productive in many types of studies. Most prominent among these will be investigations that cross many wavelength bands.

• Work has already started on comparing data obtained with ISO and with the Submillimeter Wave Astronomy Satellite (SWAS), in order to obtain a better understanding of water vapor in a wide variety of sources ranging from planetary atmospheres to the general interstellar medium and the massive winds emanating from giant stars.

• A significant number of sources identified in deep cosmological studies with ISO have by now been observed at optical wavelengths, so that their red shifts are known. Many are ultraluminous galaxies at red shifts in the range of $z \sim 0.7$ to 1.5. These sources can now be examined for overlap with submillimeter sources obtained in ground-based 850 μm observations, only a fraction of which have so far been reliably identified. Some of these sources have been speculated to be galaxies at extremely high red shifts. If so, one would expect some correlation also with galaxies detected by ISO at $\sim 175\,\mu$m in the FIRBACK program (Dole et al. 2001).

• In cosmology, a particularly important activity has been the comparison of ISO source counts to the infrared background at corresponding wavelengths measured by the Cosmic Background Explorer (COBE). At mid-infrared wavelengths, the identified sources appear to account for at least a significant fraction of the directly observed extragalactic radiation.

• The recent emergence of relatively high resolution spectroscopy at X-ray frequencies, largely through the advent of Chandra and XMM-Newton, will provide a new set of analytical perspectives in the context of which ISO results will need to be re-examined and, quite probably, re-interpreted.

5. SUMMARY

With steady advances in data reduction techniques and ISO calibrations, much of the Central Programme data base might well be re-analyzed to search for significant findings that earlier could have been missed. Advances in laboratory studies and in theoretical efforts are likely to lead to further insights into the nature of the data already in hand. Work on increasingly powerful astronomical missions at many different wavelengths will require interpretation in the context of archived ISO data. With all this anticipated activity the future of the ISO archives certainly looks bright!

ACKNOWLEDGEMENTS

I would like to particularly thank Alberto Salama for sharing his compilation of, and insights on, the ISO Central Programme data base and the number of publications that have emerged from the program. My research in infrared astronomy is supported by contracts from NASA.

REFERENCES

Coulais, A. & Abergel, A., 2000, A&A Supplement 141, 533

Decin, L. et al., 2000, A&A, 364, 137

Dole, H. et al., 2001, A&A 372, 364

Fouks, B. I. & Schubert, J., 1995, Proc. SPIE 2475, 487

Miville-Deschênes, M.-A., Boulanger, F. Abergel, A. & Bernard, J.-P., 2000, A&A Supplement 146, 519

Valentijn, E. A. & Thi, W. F., 2000, Experimental Astronomy, 10, 215

ARCHIVE INTEROPERABILITY IN THE VIRTUAL OBSERVATORY

Françoise Genova

CDS, UMR 7550, Observatoire de Strasbourg, 11 rue de l'Université, 67000 Strasbourg, France

ABSTRACT

Main goals of Virtual Observatory projects are to build interoperability between astronomical on–line services, observatory archives, databases and results published in journals, and to develop tools permitting the best scientific usage from the very large data sets stored in observatory archives and produced by large surveys. The different Virtual Observatory projects collaborate to define common exchange standards, which are the key for a truly International Virtual Observatory: for instance their first common milestone has been a standard allowing exchange of tabular data, called VOTable.

The *Interoperability Work Area* of the European *Astrophysical Virtual Observatory* project aims at networking European archives, by building a prototype using the CDS VizieR and Aladin tools, and at defining basic rules to help archive providers in interoperability implementation. The prototype is accessible for scientific usage, to get user feedback (and science results!) at an early stage of the project. ISO archive participates very actively to this endeavour, and more generally to information networking. The on–going inclusion of the ISO log in SIMBAD will allow higher level links for users.

Key words: Virtual Observatory – interoperability – AVO

1. INTRODUCTION

Astronomy is at the forefront for the availability of on–line information and information networking. Information producers, such as observatories, disciplinary centers, data centers and journals, provide access to their data/information holdings. They collaborate to define exchange standards, which are used to build interoperability, i.e. to get and provide access to distributed, heterogeneous information. From a user point of view, this means being able to identify, locate, retrieve and use information of interest. From a service manager point of view, this means being able to use information from another service for one's own needs, and vice versa to provide other services with information they need.

Astronomers share a common data description, FITS (*Flexible Image Transport System*[1]), which is an early example of a very successful exchange standard: most data produced in astronomy is FITS compliant. Thus observations from any instrument can be used by any astronomer, and many generic tools for data visualization and data transformation have been developed. Another example of early interoperability tools are SIMBAD[2] and NED[3] name resolvers: observatory archives are searchable by coordinates; users are also allowed to query the archives by object names, thanks to the implementation of SIMBAD and NED name resolvers in the archive servers - the name resolvers are used to transform object names into coordinates, which are then used to search the archive.

Other disciplinary *de facto* standards have been developed, in particular for bibliographic information networking (Section 2). The recent emergence of Virtual Observatory projects, and their international coordination, are briefly described in Section 3, with emphasis on actions in the interoperability domain. The status of the *Interoperability Work Area* of the European *Astrophysical Virtual Observatory* project is assessed in Section 4. Finally, interoperability implementation in the ISO archive is described in Section 5.

2. ASTRONOMY BIBLIOGRAPHIC NETWORK

Astronomical bibliographic information has been available from electronic resources long before the advent of the World Wide Web, for instance in SIMBAD and NED. SIMBAD and NED have been exchanging bibliographic information, and for that purpose they defined a simple, human readable 19-character description of published references, the *bibcode* (e.g. 1999A&A...351.1003G for the paper published in *Astronomy and Astrophysics*, in 1999, Volume 351, page 1003; the first author is P. Guillout, hence G for the first author initial).

On-line bibliographic services have been very rapidly implemented on the Web, in particular the ADS[4] (which further developed and heavily used the *bibcode*), electronic journals, and the Web versions of SIMBAD and NED. All the actors have been working in strong partnership and have implemented links using the *bibcode*. Observatory archives have more recently joined the 'astronomy bibliographic collaboration', by checking published literature and identifying the list of papers which cite their observations. The archive server then gives access, for each observation, to the list of papers which cite this

[1] `http://fits.gsfc.nasa.gov/` and `http://www.cv.nrao.edu/fits/`

[2] `http://simbad.u-strasbg.fr/Simbad`

[3] `http://nedwww.ipac.caltech.edu/`

[4] `http://adswww.harvard.edu/index.html`

Proceedings of the Symposium *"Exploiting the ISO Data Archive - Infrared Astronomy in the Internet Age"*,
24–27 June 2002, Sigüenza, Spain (C. Gry, S. B. Peschke, J. Matagne et al. eds., ESA SP-511)

observation, with a link to the ADS for each paper, and from ADS to all the other links provided by this service (original article in the journal, scanned article, tables, objects in SIMBAD and NED,...). ADS also provides a link to the bibliographic information provided by archives (*On-line Data* link). Bibcodes have also been created for catalogues and tables included in the CDS[5] VizieR service, which can also be reached directly from the ADS through the same link.

Another recent advance in published information networking is the implementation of links between object names appearing in the text of articles published in journals and SIMBAD. This had been implemented a few years ago on a small, prototype scale, with links from objects recognized by the journal editors and checked by the data centres, in *New astronomy* (links to SIMBAD and NED) and in the *International Bulletin of Variable Stars* (links to SIMBAD). Links are now implemented on a wider scale between *Astronomy and Astrophysics* and SIMBAD: authors are invited to tag the object names in the LaTeX version of their paper, and the object names are checked by CDS to build a reliable link. For each tagged object, CDS identifies a name recognized by SIMBAD, which can be different from the name used in the article (this often happens because of the great variety of nomenclature in publications, e.g., M 1 can of course be Messier 1, but also a variable star in the field of M 16 – M 17, from a Maffei list, a star in M 31 from a catalogue from Magnier et al., a galaxy in Abell cluster 2199 from a list by Minkowski, etc[6]). These links, which come in addition to other links to CDS which already appear in *Astronomy and Astrophysics* (links to the list of objects in SIMBAD and to the tables published by CDS), have been implemented from April 2001 on, and more than 12% of *Astronomy and Astrophysics* papers display such object links.

3. VIRTUAL OBSERVATORY PROJECTS

The concept of Virtual Observatory (VO) emerged very rapidly in the last years: two founding conferences where held by mid-2000, *Virtual Observatories of the Future* in CalTech and *Mining the Sky* in Garching. VO was recognized as a priority in the USA *Decadal Survey* and by the European OPTICON network, and several projects were approved in 2001: the *Astrophysical Virtual Observatory* (AVO) in Europe, the *National Virtual Observatory* (NVO) in USA, and *Astrogrid* in UK (Astrogrid is also an AVO partner). Many other national initiatives have since then been proposed/approved, e.g. in Australia, Canada, Germany, India, Japan, Russia. A major meeting, *Toward an international Virtual Observatory*[7], held in Garching in June 2002, covered all aspects of VO: science motivation, current status and projects.

VO is a truly international endeavour, and international coordination begun very early, with teleconferences and the definition of common milestones. The *International Virtual Observatory Alliance*[8] (IVOA), which coordinates more officially all the on-going projects, was founded in June 2002 at the time of the Garching meeting; a common roadmap has been defined.

One main goal of the Virtual Observatory is the development of tools permitting the best scientific usage from the very large data sets stored in observatory archives and produced by large surveys. Interoperability is a major topic of the international virtual observatory. An *Interoperability Working Group*, first defined in the frame of the European OPTICON Network, gathers international participants from all on-going and emerging projets beyond Europe, to discuss tools, standards and metadata, which are key components of a truly international virtual observatory. It is quite significant that the first common VO milestone has been a standard, VOTable[9], an XML format for tabular data, which has been designed to be compatible with FITS. VOTable Version 1.0 has been distributed on April 15, 2002, and it is already a major tool for VO prototypes and demos.

4. AVO INTEROPERABILITY WORK AREA

The European AVO project, a RTD project funded by European Commission, begun in November 2001. AVO is a three-year, Phase A study with six partners and three work areas: ESO (PI: P. Quinn), ST-ECF/ESA (in charge of Work Area 1, Multi–wavelength science case demonstration), CDS (in charge of Work Area 2, Interoperability), AstroGrid (in charge with ESO of Work Area 3, Technology assessments and test-beds), Jodrell Bank and TERAPIX.

Basic tasks of the AVO Interoperability Work Area are, on one hand, discussion, definition and implementation of standards and metadata, in close collaboration with international VO partners and the Interoperability Working Group, and, on the other hand, federation of a set of representative space and ground–based European archives, including multi–wavelength, multi–technique observations from all the partners. This prototype uses the CDS tools VizieR, for catalogue access and federation, and Aladin, for image and catalogue integration. It allows early science usage and user feedback, evaluation of interoperability tools and standards and identification of new useful functionalities. Target archives are ISO, XMM, VLT, EIS (ESO), Wide Field INT archives, MERLIN. The archive observation lists are included in VizieR (and thus available in Aladin) and, when possible, links to the archive service are provided through VizieR and images are made directly accessible in Aladin. Another goal is to define a set of "interoperability hints" for data providers: this set of basic requirements is progressively defined through case-by-case discussions with each data provider.

[5] http://cdsweb.u-strasbg.fr

[6] This can be retrieved from the *Dictionary of Nomenclature of Celestial Objects*, Maffei list is from 1975IBVS..985....1M, Magnier et al from 1992A&AS...96..379M, Minkowski from 1961AJ.....66..558M. The *Dictionary of Nomenclature* is accessible from http://vizier.u-strasbg.fr/cgi-bin/Dic

[7] http://www.eso.org/gen-fac/meetings/vo2002/

[8] http://www.ivoa.net/

[9] VOTable documentation and discussion: http://cdsweb.u-strasbg.fr/doc/VOTable/; http://archives.us-vo.org/VOTable/

New functions to improve the multi-wavelength data usage, such as colour composition, first studied in the frame of the IDHA project (*Action Concertée incitative* ACI-GRID of the French *Ministère de la Recherche*), and contour plots, have been added in Aladin. Another important development is the implementation of *Uniform Content Descriptors*. The aim is to address common features of VO science scenarios, e.g. “Find B-band photometry of objects in a particular region of the sky”. UCDs, first studied in the frame of the *ESO-CDS Data Mining Project*, are organising hierarchically the contents of individual table columns from the CDS catalogue collection (more than 3,000 catalogues with over 100,000 columns) [10].

A UCD is attached to each VizieR table column, using the column label, description and unit. UCDs can be used to select catalogues (e.g. find all catalogues containing Johnson B magnitude data) and, together with units, for data comparison and conversion, or to check the coherence of information in a table. UCDs will be used in particular in the early 2003 AVO science demonstration to retrieve magnitude and flux measurements.

5. INTEROPERABILITY IN ISO ARCHIVE

ISO archive participates to the astronomy bibliographic network, providing links from observations to publications and to the ADS. It is also an active participant to AVO Work Area 2: the list of ISO observations has been installed in VizieR, even before the project official start (the XMM log was also installed, shortly before this meeting). Links to the ISO Postcard Server are provided from VizieR, and the feasibility to implement direct access to images from Aladin is being assessed. More advanced, value-added functionalities are in preparation, in particular the cross-identification of the list of ISO observations with SIMBAD, which will permit direct links between objects in SIMBAD and the ISO archive, search by object types in the archive, etc.

6. CONCLUSION

The advent of the WWW has revolutionized the way scientists work, and astronomers use distributed on-line resources on a daily basis, in particular to retrieve bibliographic information and data from observatory archives and compilation services. VO will allow access to more resources with an increased level of integration of information from different origins. All VO projects aim at developing an international network of resources and tools, based on a set of commonly defined standards.

ACKNOWLEDGEMENTS

The AVO and OPTICON projects are funded by European Commission.

[10] A tool to browse and query the UCD tree can be accessed from `http://cdsweb.u-strasbg.fr/UCD/`

REFERENCES

Proceedings of the conferences cited in the text are good starting points:

Virtual observatories of the future, A.S.P. Conf. Ser. 222, 2001.

Mining the Sky, ESO Astrophys. Symp., Springer Verlag, 2001.

Toward an International Virtual Observatory, ESO Astrophys. Symp., Springer Verlag, in press.

THE ISO VISUALIZER – A NEW WAY TO LOOK AT ISO DATA

Babar Ali[1]**, Mihseh Kong**[1]**, and Alberto Salama**[2]

[1]IPAC/Caltech, MC 100-22, 770 S. Wilson Ave., Pasadena, CA 91125 USA
[2]ISO Data Center, European Space Agency, Villafranca del Castillo, PO Box 50727, 28080 Madrid, Spain

ABSTRACT

The ISO Visualizer is a new web-based tool with the following aims:

- to provides, by means of an all-sky map, an overview of all ISO observations.
- to visualize the ISO observation coverage of a specified spatial region.
- to provide the relevant observing parameters and access to the original proposal abstracts.
- to provide URL link to ESA's ISO postcard server.

In this contribution, I will demonstrate these functionalities, provide the latest access statistics and the plans for future development of the ISO Visualizer and its merger with other online services.

Key words: ISO – archive: tools

1. BACKGROUND

The ISO Visualizer is a new tool jointly developed by the ISO Data Center (IDC) and the Infrared Processing and Analysis Center (IPAC). This tool is the fastest means by which to examine ISO's coverage of a particular spatial region. It was additionally motivated by the need to view the actual overlay of the observation footprint. This allows users to determine which part of the object/region was observed, and how.

The ISO Visualizer achieves the above goals by overlaying ISO observations on IRAS images. In addition to ISO instrument footprints, users can overlay all IRAS sources associated with the region of interest. The interface is described and discussed further in Section 2.

The ISO Visualizer does not provide actual ISO data. Users are directed to the ISO archive for obtaining and analyzing ISO data. The ISO visualizer provides a summary of observing parameters, in addition to the overlays, for all ISO observations overlapping the user's region of interest. The user can further access the original abstract of the proposal associated with the ISO observation. And, each observation is also linked with ESA's ISO postcard server for a quick view of the pipeline reduced data. Section 3 provides further discussion on the output and services of the ISO visualizer.

The ISO Visualizer effort was built on data tables summarizing the ISO observations, and on the visualization toolkit and relational database services developed by the InfraRed Science Archive (IRSA) at IPAC. The data tables were created and provided by the IDC.

Table 1 lists the personal involved in the design, creation and testing of the ISO visualizer. Additionally, James Brauher (LWS), Ken Ganga (CAM), Steve Lord (LWS), Nanyao Lu (PHT), and Alberto Noriega-Crespo (SWS), provided feedback during the testing phase of the development.

Table 1. The ISO Visualizer Developers & Designers.

At IPAC	At IDC
Mihseh Kong Sallie Warner-Norton Babar Ali	Alberto Salama

1.1. WHERE DOES THE ISO VISUALIZER FIT?

The ISO Visualizer provides a quick, visual access to ISO's coverage of particular spatial regions of interest. As such, we anticipate that astronomers interested in ISO data will first use the ISO Visualizer to obtain a quick look at ISO's coverage. If ISO data exists for the region of interest, the user can proceed to either ESA's ISO postcard server or to the archive to either obtain the pipe-line reduced, or the raw ISO data itself.

2. HOW TO USE THE ISO VISUALIZER?

The ISO Visualizer is available from the following internet locations:
http://irsa.ipac.caltech.edu/applications/ISO

or, by following the links to the ISO visualizer from IRSA's homepage:
http://irsa.ipac.caltech.edu

Fig. 1 shows the interface to the ISO Visualizer. The lines following the title identify the services offered by this tool. The all-sky map provides an overview of the ISO observations. Each instrument is color-coded; legend can be found just below the all-sky map.

Specifying region of interest. Users can specify a region of interest and obtain an output (with default values, see below) simply by clicking on the spatial region on the all-sky map. However, users are more likely to specify their region of interest: (i) by specifying the object name. The name resolution is

Proceedings of the Symposium *"Exploiting the ISO Data Archive - Infrared Astronomy in the Internet Age"*,
24–27 June 2002, Sigüenza, Spain (C. Gry, S. B. Peschke, J. Matagne et al. eds., ESA SP-511)

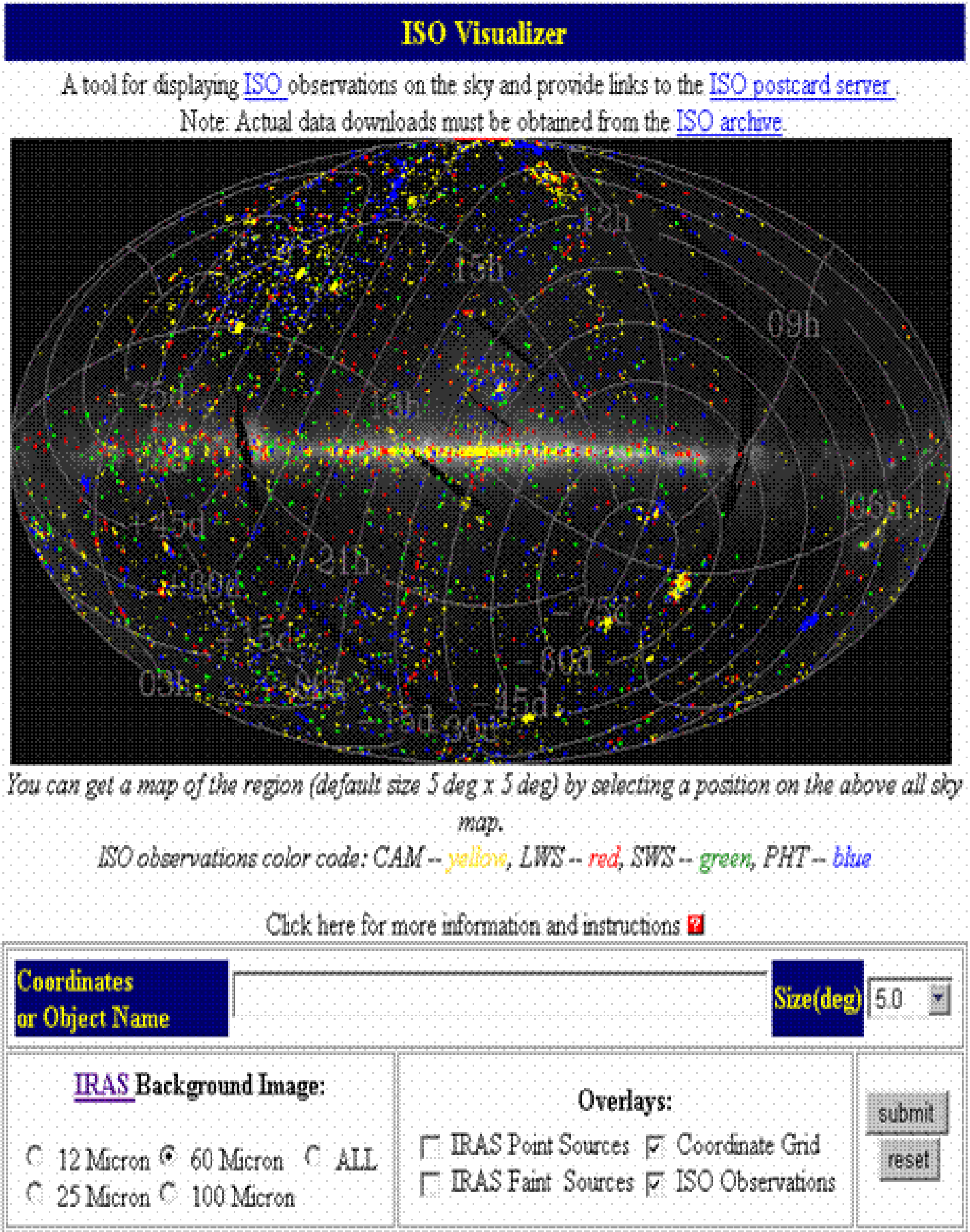


Figure 1. The ISO Visualizer main interface.

provided by SIMBAD or NED. Or, (ii) by specifying the spatial coordinates of the region. Region specification by these two methods is available from the editable fields below the all-sky image.

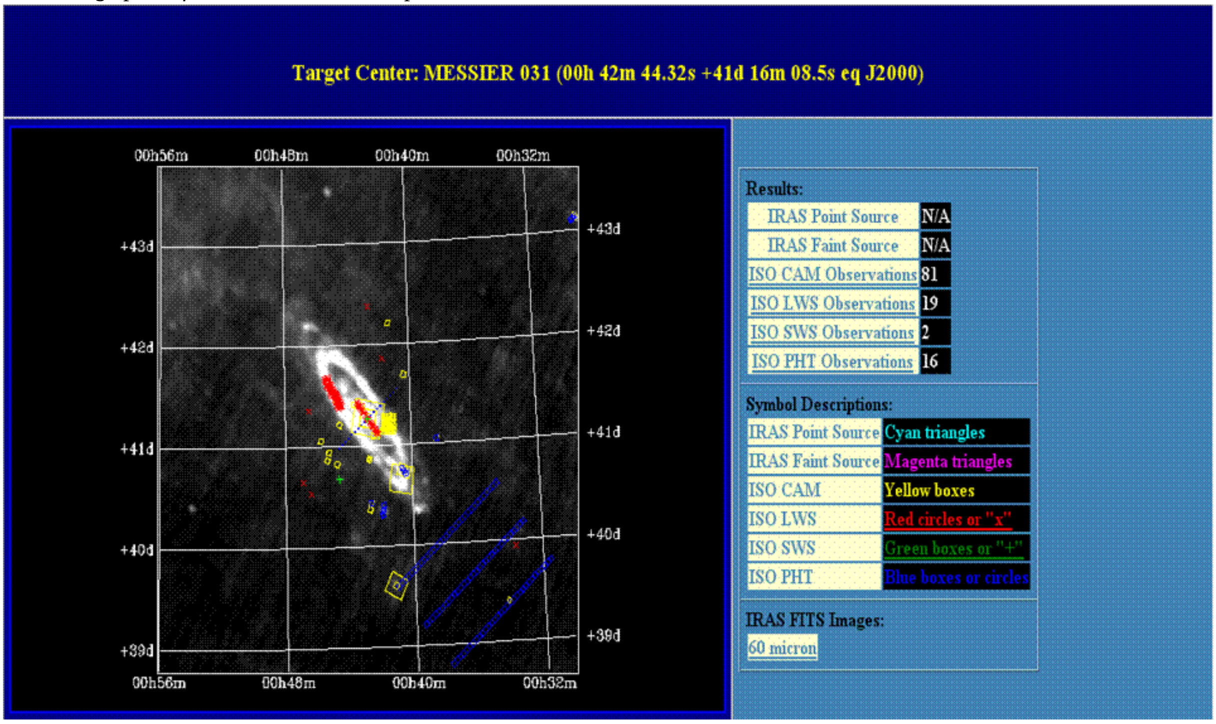
Specifying the output. The output of the visualizer is custom tailored by the following parameters:

– The background ISSA image on which to overlay the observation footprint. Users can select a single or any combi-

Figure 2. The tabular part of the ISO Visualizer output.

TDT	Object	RA	DEC	AOT	Proposal Title	Wavelength (microns)	Date of Observation	Exposure Time (seconds)	Field of View (arcmin)
39902919	NGC 205	0h40m21.96s	41d41m25.81s	C01	CAMEARLY	3.980 - 17.050	1996/12/19 23:22:26	3556	3.50 x 3.50
39903101	M31	0h41m5.79s	41d16m57.22s	C01	M31DU3_A	11.550 - 17.050	1996/12/20 01:09:06	86	3.20 x 3.20
39903102	M31	0h41m11.82s	41d16m57.22s	C01	M31DU3_A	11.550 - 17.050	1996/12/20 01:11:22	88	3.20 x 3.20
39903103	M31	0h41m17.85s	41d16m57.11s	C01	M31DU3_A	11.550 - 17.050	1996/12/20 01:13:40	86	3.20 x 3.20
39903104	M31	0h41m23.87s	41d16m56.96s	C01	M31DU3_A	11.550 - 17.050	1996/12/20 01:15:56	88	3.20 x 3.20
39903105	M31	0h41m29.90s	41d16m56.89s	C01	M31DU3_A	11.550 - 17.050	1996/12/20 01:18:14	86	3.20 x 3.20
39903106	M31	0h41m35.92s	41d16m56.89s	C01	M31DU3_A	11.550 - 17.050	1996/12/20 01:20:30	88	3.20 x 3.20

Figure 3. The image part of the ISO Visualizer output.



nation of the IRAS filters. A single 60 micron image is the default.

– What to overlay? By default all ISO observations will be overlayed. Users can optionally select a coordinate grid (selected by default), and IRAS point and faint source catalogs (not selected by default).
– The size of the output image. Currently, five choices are offered: 0.5, 1.0, 2.0, 5.0 (default) and 12.5 degrees per side.

3. THE OUTPUT

The output page of a query (Section 2) contains two main parts: (1) An ISSA derived background image of the region of interest containing the overlayed aperture footprints, and anciallary information. And, (2) a table summarizing the ISO observations obtained on the region of interest. Figs. 3 & 2 show one example of the image, and the table part of the output, respectively.

When the spatial size of individual ISO instrument aperture is smaller than the ISSA plate resolution, symbols representing the instrument are used to denote coverage rather than the actual footprint of the instrument aperture. For example, LWS

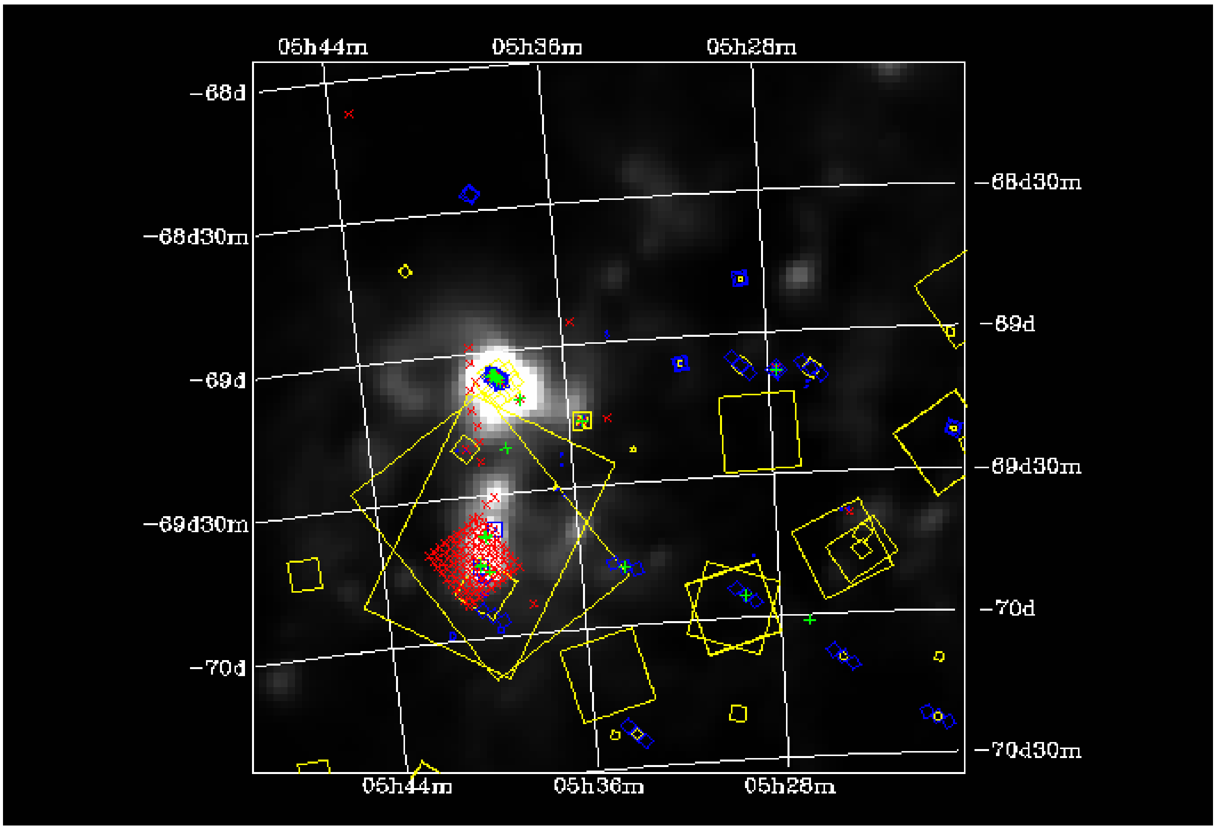


Figure 4. The ISO Visualizer output for the LMC.

observations switch from circles to the symbol, ”x”, when the output image size is selected to be 1 degree per side or larger.

In addition to the instrument apertures, IRAS sources (if requested) are also displayed on the background image. The information panel to the right of the main image summarizes both the number of ISO observations (per instrument) as well as the IRAS sources found.

The tabular part of the output (Fig. 2 summarizes observation parameters, and is organized first by instrument, and for each instrument by the TDT number of the observation. Explanations of the column titles are provided at the bottom of the page and are accessible by clicking on the column titles themselves. The listed TDTs and the proposal titles are also active links. Selecting the TDT will connect user to ESA's ISO postcard server for that particular observations. Selecting the proposal title will show the original abstract of the observation proposal as submitted by the principle investigator.

Fig. 4 show another examples of image output from the ISO Visualizer. Fig. 4 shows the output for the LMC observations.

4. FUTURE PLANS

Astute users may already have noted the “OASIS” button available with the image on the output page. OASIS stands for Online Archive Science Information Services and is a Java-based “data fusion” and interaction applet. The ISO Visualizer services have been integrated with OASIS. OASIS will allow users to fuse ISO observational coverage with other data sets. Currently, these data sets include all CDS/Vizier catalogs, GSFC SkyView image datasets, and NED image database. Additionally, an ISO meta-data coverage service will be available. Coverage information is returned as a ZIP file containing rendering directives, and coverage for each instrument as a separate GIS layer.

ACKNOWLEDGEMENTS

The authors would, once again, like to thank all the testers (see Section 1) for their advice and suggestions which greatly improved this tool.

AN ISOLWS SURVEY OF GALAXIES: AN EXAMPLE OF THE SYSTEMATIC USE OF THE ISO DATA ARCHIVE FROM CONCEPTION TO RESULTS

James Brauher

SIRTF Science Center, Caltech, Mail Code 220-6, Pasadena, CA, USA 91125

ABSTRACT

The Internet Age has revolutionized the way in which astronomers carry out research by enabling the use of publicly-available data stored in database archives. The ISO Data Archive (IDA) grew out of the need of astronomers worldwide to access the data obtained by the Infrared Space Observatory (ISO). Although many scientific papers have resulted from ISO data, the IDA still contains a vast amount of untapped scientific potential. The systematic use of the ISO Data Archive is demonstrated and its role is described in building a catalog of far-infrared fine structure lines for 227 galaxies whose data will be available from the IDA. This example provides an insight into the many opportunities the IDA offers, and the process of this project from its inception to its current results is detailed. The results from this archival research are consistent with other ISO studies and add new information to the understanding of the Interstellar Medium (ISM) of galaxies. Many new projects can be spawned through the use of this publicly-available, fully-reduced dataset that forms a foundation for observations with future observatories (SIRTF, SOPHIA, Herschel).

Key words: ISO, Galaxies

1. INTRODUCTION

The ISO Data Archive holds a vast wealth of untapped scientific data in the mid-to-far infrared wavelength regime. Early studies of the physical conditions in the interstellar medium (ISM) were carried out by the *Kuiper Airborne Observatory* (KAO). The *Infrared Astronomy Satellite* (IRAS) provided an all-sky view at 12μm, 25μm, 60μm, and 100μm. With the launch of ISO, large-scale far-infrared line studies of galaxies were possible, and these observations add new information to the understanding of the ISM.

Many neutral, ionic, and molecular lines were observed with the ISOLWS. The primary diagnostic lines of the ISM in the far-infrared are [CII] (158μm), [OI] (145μm), [NII] (122μm), [OIII] (88μm), [OI] (63μm), [NIII] (57μm), and [OIII] (52μm). [CII] (158μm) and [OI] (63μm) are the dominant cooling lines for neutral interstellar gas and with [OI] (145μm), these lines help determine the physical environment of Photo-dissociation Regions (PDRs). The ionized lines, [NII] (122μm), [OIII] (52μm, 88μm), and [NIII] (57μm), trace the conditions in HII regions. Numerous studies (Tielens & Hollenbach 1985, Wolfire et al. 1990, Kaufman et al. 1999) have prepared models, whereby, using these seven diagnostic lines, the gas temperature, density, and radiation field intensity of the ISM may be determined. In addition to the PDR and HII region lines, a suite of molecular lines such as water, hydroxyl, and carbon monoxide were measured with the LWS.

Previous ISOLWS studies using observations presented in this paper (Malhotra et al. 2001, Negishi et al. 2001, Luhman et al. 1998, Pierini et al. 1999) have only touched upon the many projects that such a large dataset may be used. Malhotra et al. (1997, 2001) first reported a drop in the [CII] (158μm) emission with increasing temperature and UV radiation field for a sample of normal galaxies, while Luhman et al. (1998) discovered an apparent lack of [CII] (158μm) emission in a small sample of ULIRGs. Malhotra et al. also showed a [CII] (158μm) correlation with [NII] (122μm) and the interplay with [OI] (63μm) as the heating environment in normal galaxies changed. Various molecular line studies determined the column density and abundance of OH, CO, and H_2O (Bradford et al. 1999, Skinner et al. 1997, Fischer et al. 1999).

The studies presented above represented smaller samples of galaxies and provide a snapshot of the varying phases of the ISM in galaxies. However, a large sample encompassing galaxies that span an extensive range of morphologies and ISM environments is needed to better understand the general properties, evolution and physical conditions of the ISM. This study was undertaken to understand whether the results from earlier research apply to galaxies as a whole and to address some of the unanswered questions about the ISM in galaxies.

2. THE SAMPLE

This sample of galaxies was initially selected by identifying galaxies in the IRAS Catalog of Galaxies and Quasars with 60μm flux densities greater than 1 Jy with ISOLWS grating observations in the ISO Data Archive and is described further in Brauher (2003). This selection criterion yielded 198 galaxies. Galaxies with IRAS 60μm flux densities less than 1 Jy or no cataloged IRAS flux density were later added to the sample. This additional set added another 29 galaxies to this sample, bringing the total number of galaxies in the sample to 227. Galaxies from other large LWS observing programs (Malhotra et al. 2001, Negishi et al. 2001, Pierini et al. 1998, Luhman et al. 1998) are subsets of this galaxy sample–the largest ever assembled far-infrared line sample for galaxies. Note that the

Proceedings of the Symposium *"Exploiting the ISO Data Archive - Infrared Astronomy in the Internet Age"*,
24–27 June 2002, Sigüenza, Spain (C. Gry, S. B. Peschke, J. Matagne et al. eds., ESA SP-511)

large, nearby galaxies M31, the Large Magellanic Cloud, and the Small Magellanic Cloud are excluded from this sample.

The galaxies in this sample span a broad range of morphology (early to late type), redshift, IRAS flux density ($<$1 - 1300 Jy), and color ($0.1<12/25\mu$m$<3.0, 0.2<60/100\mu$m<1.5). The sample has two distinct subsets–one that includes galaxies that are unresolved in the LWS beam, and one that includes galaxies resolved in the LWS beam. 181 galaxies are classified as unresolved, and 46 are considered resolved in this sample. Figure 1 plots the galaxies on an Aitoff sky projection, and it shows the distribution of this sample across the sky.

This sample consists of 465 individual observations (TDTs), incorporating approximately 95% of all galaxies observed with the LWS, 25% of all grating L01 and L02 data, 15% of all LWS data, and $\sim$ 2% of all ISO pointed observations. Over 1300 line fluxes and 600 upper limits were derived from this large dataset. In addition, 800 continuum fluxes are also estimated from this LWS dataset.

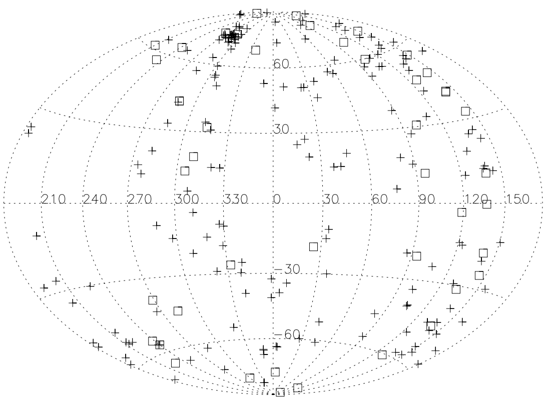


Figure 1. Aitoff projection of the galaxies in this sample. Galaxies unresolved by the LWS in the FIR are displayed with crosses. Galaxies resolved by the LWS in the FIR are shown with open squares.

3. DATA REDUCTION

The LWS grating data for all guaranteed and open time observations for 227 galaxies were extracted from the ISO Data Archive and processed through the LWS Pipeline versions 7.0 or 8.7. Between versions 7.0 and 8.7, slight improvements were made to the pipeline. A comparison of the derived line and continuum fluxes between the two pipelines reveals little difference after the data are reduced with the LWS Interactive Analysis (LIA; Hutchinson et al. 2001) and the ISO Spectral Analysis Package (ISAP; Sturm et al. 1998).

A large fraction of the galaxies in this sample are considered faint sources ($F_\nu < 50$Jy) in the $75''$LWS beam. Continuum fluxes in the LWS spectra of faint sources can be seriously affected by errors in the dark current. It is therefore necessary to accurately estimate and subtract the dark current in LIA for these faint sources. Using the routine IA_DARK in LIA,

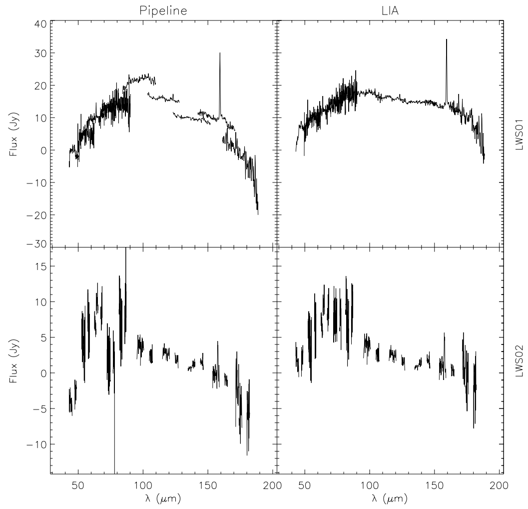


Figure 2. Two example LWS spectra representing the pipeline product L01 and L02 AOTs displayed before and after using the LIA and ISAP for data reduction. The LIA and ISAP reduced data have been fringe and glitch removed. Negative continuum fluxes and misaligned adjacent detectors have been corrected using the LIA and ISAP.

the dark currents were re-estimated and subtracted by hand for each detector for all observations. After the dark currents were removed, the absolute responsivity corrections (gain) were also re-estimated and applied by hand for each detector for all observations using the LIA routine IA_ABSCORR. The data were then flux calibrated to the LWS calibration source with the LIA routine SHORT_AAL. Bad data and faint glitches not removed by the LWS pipeline were identified and discarded with ISAP. Spectral scans were co-added and averaged using a 3σ clip in spectral bins of width 0.05μm. A sinusoidal fringe associated with internal reflection and interference within the instrument may arise for grating L01 observations. This fringe was removed using ISAP for the L01 data. Transient effects arise as the grating is scanned from one direction to another. This effect gives rise to spectral differences in the two scan directions, and it is most pronounced in the SW1, SW2, and LW2 detectors. When a strong transient effect is present, the line and continuum fluxes were individually estimated for each scan direction and averaged. For extended sources, no extended source correction was performed. Two comparison spectra before and after LIA and ISAP reduction are shown in Figure 2. The line and continuum calibration are significantly improved after the by hand reduction.

All spectral lines in this sample are unresolved ($\Delta\nu \sim 1500 km\ s^{-1}$), and the line fluxes were calculated with the assumption that the line profiles would be of the same Gaussian width as the instrumental profile. A linear baseline and Gaussian profile with FWHM=0.29μm for the short-wavelength detectors (SW1-SW5) and FWHM=0.60μm for the long-wavelength detectors (LW1-LW5) were fit to each line. The lines detected in this sample of galaxies are listed in Table 1. In addition to these extragalactic lines,

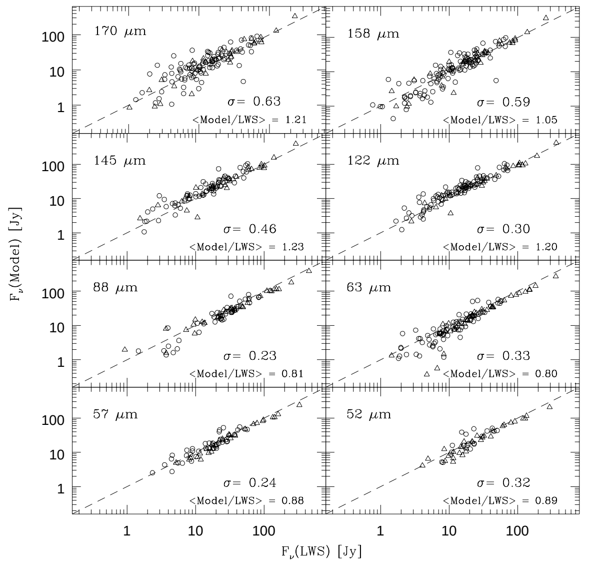


Figure 3. A comparison of LWS continuum fluxes to the Dale et al. 2002 galaxy SED model at eight wavelengths for galaxies unresolved by the LWS. There is an overall agreement between the LWS and the model to the 25% level. The dispersion increases with increasing wavelength.

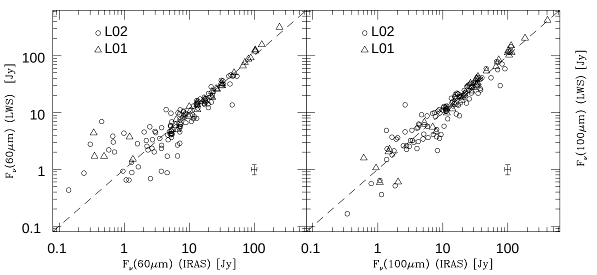


Figure 4. A comparison of the LWS continuum fluxes to IRAS 60μm and 100μm fluxes. The LIA-calibrated continuum fluxes agree with the IRAS fluxes to within a few percent over the flux density ranges shown. The dispersion increases in the low flux density limit, and the LWS becomes higher at higher fluxes.

12 serendipitous detections of Milky Way [CII](158μm) are found.

Monochromatic continuum fluxes were derived for galaxies unresolved in the LWS beam by fitting a linear baseline through a 2-5μm slice of spectra at the following eight wavelengths: 52μm, 57μm, 63μm, 88μm, 122μm, 145μm, 158μm, 170μm. The LWS fluxes are compared to a galaxy SED model (Dale et al. 2002) and are shown in Figure 3. This plot shows the overall agreement between the fluxes estimated by the LWS and the SED model to within 25%. However, the dispersion increases as wavelength increases due to the low flux levels and higher uncertainties at these wavelengths. In addition, monochromatic fluxes were derived at 60μm and 100μm and compared to IRAS Point Source Catalog fluxes as described in Brauher & Lord (2001). This comparison is shown in Figure 4. For a small cross-section of galaxies in this sample, the LWS 170μm fluxes are plotted against corresponding ISOPHOT Serendipity Survey (Stickel et al. 2000) and ISOPHOT pointed observations (Klaas et al. 2001). This comparison is shown in Figure 5. The flux densities measured by the LWS and PHOT appear to track each other although there is a large dispersion in the trend due to the uncertainties of the flux densities at this wavelength.

Table 1. Lines detected by the LWS in this sample.

Line	$\lambda(\mu$m)
[OIII]	51.82
OH	53.00
[NIII]	57.32
H_2O	58.70
[OI]	63.18
OH	65.20
H_2O	66.70
Unidentified Line	74.24
H_2O	75.38
OH	79.15
OH	84.50
[OIII]	88.36
H_2O	100.95
H_2O	108.07
OH	119.30
[NII]	121.89
[OI]	145.53
[CII]	157.71
OH	163.20

4. SCIENCE HIGHLIGHTS

4.1. [CII] (158μm)

The [CII] (158μm)/FIR ratio is plotted against the IRAS 60/-100μm and FIR/B ratios in Figure 6, and galaxies are plotted according to their morphology. From this figure, one concludes that the [CII] (158μm) emission appears to decrease with increasing 60/100μm and FIR/B ratio for all morphologies. The cause of this decrease with increasing UV radiation environment is discussed in Malhotra et al. (2001), and the likely candidate is the decreasing efficiency of the grain photoelectric heating as the temperature of the grains increase.

4.2. [CII] (158μm) AND [NII] (122μm)

The ratio of [NII] (122μm)/[CII] (158μm) were compared and no correlation was found with either 60/100μm or FIR/B. This comparison is shown in Figure 7. In past studies, [CII] emission was linked to not only PDR regions but also HII regions. The relative contributions from these regions to the [CII] (158μm) varies from galaxy to galaxy, but the most common estimate for the HII region component of [CII] (158μm) emission is $\sim$50%

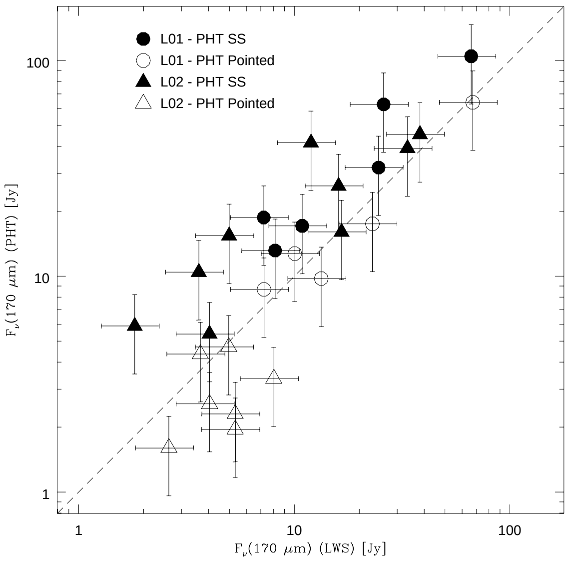


Figure 5. A comparison of LWS continuum fluxes to ISOPHOT Serendipity Survey (Stickel et al. (2000) and ISOPHOT pointed observations (Klaas et al. (2001). The uncertainties are high for both instruments at this wavelength, but the LWS and PHOT appear to broadly follow one another.

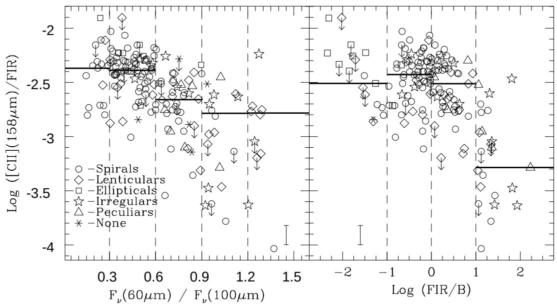


Figure 6. The ratio of [CII](158μm) to far-infrared continuum, [CII](158μm)/FIR, is plotted against the IRAS 60/100μm and FIR/B ratios for galaxies unresolved by the LWS. Spirals are plotted as open circles. Lenticulars are plotted as open diamonds. Ellipticals are plotted as open squares. Irregulars are plotted as open stars. Peculiars are plotted as open triangles. Galaxies without an RC3 classification are plotted as asterisks. Galaxies with no [CII] detection are plotted as a 3σ upper limit. Sub-bins of the data are marked by dashed lines, and the median in each bin is shown with a horizontal line. For all morphological types, the [CII](158)μm/FIR ratio decreases as the 60/100mum and FIR/B ratios decrease.

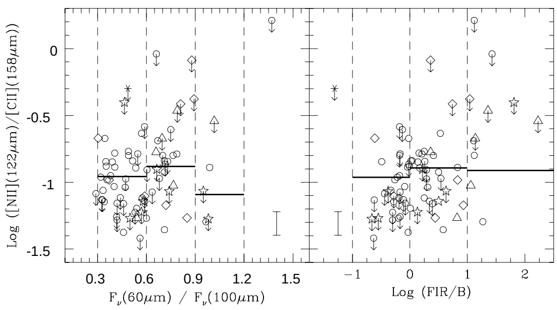


Figure 7. The ratio of [NII] (122μm)/[CII] (158μm) is plotted against the 60/100μm and FIR/B ratios for galaxies unresolved by the LWS. The ratio [NII] (122μm)/[CII] (158μm) has no correlation with 60/100μm or FIR/B, thus indicating a connection between the sources of the [NII] (122μm) and [CII] (158μm) emission. The symbols are the same as those for Figure 6.

(Petuchowski & Bennett 1993, Malhotra et al. 2001, Contursi et al. 2002).

4.3. [CII] (158μm) AND [OIII] (88μm)

The ratio [OIII] (88μm)/[CII] (158μm) were compared for varying ISM environments measured by the 60/100μm and FIR/B ratios, and this comparison is shown in Figure 8. The [OIII] (88μm)/[CII] (158μm) ratio increases with increasing 60/100μm ratio. Although [NII] (122μm) and [CII] (158μm) have similar trends when plotted against the 60/100μm and FIR/B ratios, [OIII] (88μm) does not. This implies that the ionized component of the [CII] (158μm) emission arises in the lower density, N^+ and O^+ regions rather than the higher density O^{++} regions.

5. CONCLUSIONS

The dataset presented in this paper holds many opportunities for further studies of the ISM. The following results highlight the scientific value of such a large far infrared spectral line survey of galaxies:

- Many atomic, ionic, and molecular lines exist in this spectral line survey, including serendipitous Milky Way detections of [CII] (158μm). The final database from this survey will contain over 1300 line fluxes, 600 line flux upper limits, and 800 continuum flux densities from these far infrared LWS observations of 227 galaxies. The galaxies in this study span a large range of morphologies, IRAS flux densities, and colors, thus, studies based upon these characteristics may be done.
- The LWS continuum flux densities derived for galaxies unresolved by the LWS are compared to other data and models. The LWS data agree with an SED model for galaxies to within 25% at 52μm, 57μm, 63μm, 88μm, 122μm, 145μm, 158μm, and 170μm. These reduced LWS data agree with IRAS data to within a few percent and also with ISOPHOT at 170μm, although the uncertainties of the LWS and PHOT instruments are large at 170μm. These continuum data offer many new far infrared photometry points that may be used to better understand and possibly constrain galaxy SED models.

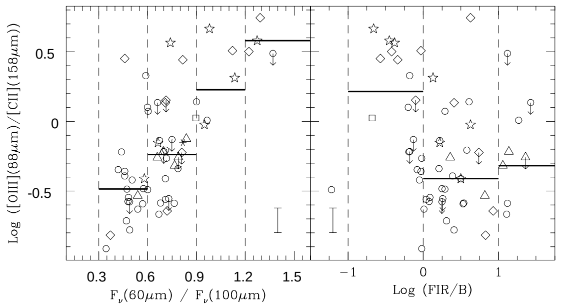


Figure 8. The ratio of [OIII] (88μm)/[CII] (158μm) is plotted against the 60/100μm and FIR/B ratios for galaxies unresolved by the LWS. The ratio [OIII] (88μm)/[CII] (158μm) increases with increasing 60/100μm, but has no correlation with FIR/B. The symbols are the same as those for Figure 6.

– The [CII] (158μm)/FIR ratio peaks for normal, star-forming galaxies with 60/100μm ratios between 0.3 and 0.6 and FIR/B ratios between 0.1 and 1, consistent with the results of Malhotra et al. (2001) and Negishi et al. (2001).
– The [CII] (158μm)/FIR ratio decreases with increasing 60/100μm and FIR/B ratio for all morphological types. This sample allows the study of the [CII] (158μm) emission across a broad range of morphologies.
– The [CII] (158μm)/FIR ratios of quiescent galaxies are similar or slightly lower than the ratios of normal galaxies. Measurements of Virgo Cluster galaxies suggest a possible drop in [CII] emission in quiescent environments, confirming the results of Leech et al. (1999).
– The [NII] (122μm)/[CII] (158μm) ratio has no correlation with either the 60/100μm or the FIR/B ratio. This indicates that a large fraction of the [CII] (158μm) emission may arise from HII regions or that ratio of PDR to diffuse ionized gas does not vary systematically with either 60/100μm or FIR/B.
– Unlike the [NII] (122μm)/[CII] (158μm) ratio, the [OIII] (88μm)/[CII] (158μm) ratio appears to increase with increasing 60/100μm ratio. This suggests that the HII region contribution to [CII] (158μm) emission comes from lower density, N^+ and O^+ regions rather than the high density O^{++} regions that produce [OIII] (88μm).

In addition to these results that will appear in Brauher (2003), this dataset is currently being used for the following studies:

– The connection between the FIR lines and the Aromatic Features in Emission (Contursi et al., this proceedings). Although [CII] (158μ)m and AFE emissions scale with one another, differences exist among galaxies of different morphologies. These differences likely arise from factors other than the the physical relationship between the AFE and atomic gas heating carrier grains.
– Detailed studies of large galaxies with extensive LWS coverage. Contursi et al. (2002) examined the relationship between individual components of the ISM in NGC 1313 and NGC 6946 using the data from this sample. To date, few of the large galaxies in the LWS Guaranteed Time Observing Program have been published. Many of these large galaxies had excellent spatial coverage with the LWS and provide an excellent source of data for in depth PDR and HII region analyses.
– Physical properties of the ISM (PDR/HII region modeling and the role of [CII], [OI], and [OIII] in the cooling of the ISM (Helou, this proceedings). A complex association between [CII], [OI], and [OIII] exists in galaxies, yet how the interplay of emission from these three lines varies from one galaxy to the next, is not well understood.
– Creating high redshift templates from current low redshift data. *The Stratospheric Observatory For Infrared Astronomy* (SOPHIA) and the Herschel Space Observatory will have instruments capable of spectroscopy in the far infrared to submillimeter wavelengths. The LWS observations of nearby galaxies can be used to simulate what these observatories may observe for higher redshift galaxies.

These data will be available for public use from the ISO Data Archive and NED.

ACKNOWLEDGEMENTS

I thank the Scientific Organizing and Local Organizing Committees for the invitation to talk at the Siguenza meeting. The ISO Spectral Analysis Package (ISAP) is a joint development by the LWS and SWS Instrument Teams and Data Centers. Contributing institutes are CESR, IAS, IPAC, MPE, RAL, and SRON. This research has made use of the NASA/IPAC Extragalactic Database (NED) that is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration (NASA). This work has also made use of the InfraRed Science Archive (IRSA) at the Infrared Processing and Analysis Center.

REFERENCES

Bradford, C.M., Stacey, G.J., Fischer, J.A., et al., 1999, ESA SP-427, 861
Brauher, J., submitted to ApJ Supplement
Brauher, J., & Lord, S., 2001, ESA SP-481
Contursi, A., Brauher, J., Helou, G., 2002, this volume
Dale, D., Helou, G., 2002, ApJ, 576, 159
Fischer, J., Lord, S.D., Unger, S.J., 1999, ESA SP-427, 817
Hutchinson, M.G., Chan, S.J., Sidher, S.D., et al., 2001, ESA SP-481
Kaufman, M.J., Wolfire, M.G., Hollenbach, D.J., Luhman, M.L., 1999, ApJ, 527, 795
Luhman, M.L., Satyapal, S., Fischer, J., et al., 1998, ApJ, 504, L11
Malhotra, S., Kaufman, M.J., Hollenbach, et al., 2001, ApJ, 561, 766
Negishi, T., Onaka, T., Chan, K.-W., et al., 2001, A&A, 375, 566
Petuchowski, S.J., & Bennett, C.L., 1993, ApJ, 405, 591
Pierini, D., Leech, K.J., Tuffs, R.J., Völk, H.J., 1999, MNRAS, 303, L29
Skinner, C.J., Smith, H.A., Sturm, E., 1997, Nature, 386, 472
Sturm, E., Bauer, O.H., Brauher, J., et al., 1998, ADASS, 7, 161
Stickel, M., Lemke, D., Klaas, U., et al., 2000, A&A, 359, 865
Tielens, A.G.G.M., & Hollenbach, D., 1985, ApJ, 291, 722
Wolfire, M.G., Tielens, A.G.G.M., Hollenbach, D., 1990, ApJ, 358, 116

THE INFRARED SPACE OBSERVATORY USERS COMMUNITY

Jean Matagne

ISO Data Centre, European Space Agency, Villafranca del Castillo, PO Box 50727, 28080 Madrid, Spain

ABSTRACT

This paper presents an overview of the Infrared Space Observatory (ISO) world-wide users community and gives a brief outline of the main services provided by the ISO Data Centre (IDC) of the European Space Agency (ESA) during the Active Archive Phase (AAP).

A snapshot of the ISO Data Archive (IDA) users registration rate and distribution per country, the number of visitors at the ISO Data Centre during the past years and the ISO World Wide Web (WWW) server access statistics are given.

Key words: Infrared Space Observatory – ISO Data Centre – Users Community

1. INTRODUCTION

The Infrared Space Observatory (ISO) was the world's first true orbiting infrared observatory (Kessler et al. 1996). Equipped with four highly sophisticated and versatile scientific instruments, it provided astronomers world-wide with a facility of unprecedented sensitivity and capabilities for a detailed exploration of the universe at infrared wavelengths between 2.5 μm and 240 μm.

The ISO scientific payload consisted of four instruments: a camera (ISOCAM), an imaging photopolarimeter (ISOPHOT), a long wavelength spectrometer (LWS) and a short wavelength spectrometer (SWS). Each instrument was built by an international consortium of scientific institutes using national funding and was delivered to ESA for in-orbit operations. The ISO spacecraft consisted mainly of a telescope with an aperture of 60 cm and the scientific instruments enclosed in a cryostat containing, at launch, over 2000 litres of liquid Helium.

The satellite was a great technical and scientific success with most of its sub-systems operating far better than their specifications and with its scientific results impacting practically all fields of astronomy (Kessler 2000).

2. THE ISO DATA CENTRE

The ISO Data Centre is based at the ESA Villafranca Tracking Station (Madrid - Spain). The IDC has built up a unique set of experience on the archive and community support together with the detailed expertise on all four instruments that is necessary to support the general ISO users community.

Retention of these core skills and knowledge will continue to enable the community to get the most out of ISO and will, additionally, build a bridge in ESA's planning towards future missions, especially Herschel.

The responsibilities of the ISO Data Centre in the Active Archive Phase can be summarised as maintaining the central archive and providing expert support to the community across all instruments.

Figure 1. The ISO Data Centre is based at the ESA Villafranca Tracking Station (Madrid - Spain).

Over the past 4 years, around 140 astronomers visited the ISO Data Centre to reduce and analyse their ISO data. The IDC visitors were supported by the staff with technical and scientific expertise on all instruments, with the latest ISO data analysis software and a wide range of knowlegde in instrument performance and calibration.

The IDC organised several conferences (7 - Including this one in Sigüenza!) and specific small "hands-on" data reduction workshops (5) with the proceedings being made widely available.

Proceedings of the Symposium *"Exploiting the ISO Data Archive - Infrared Astronomy in the Internet Age"*,
24–27 June 2002, Sigüenza, Spain (C. Gry, S. B. Peschke, J. Matagne et al. eds., ESA SP-511)

3. THE ISO WWW

Since it was started in 1995, the ISO WWW service at http://www.iso.vilspa.esa.es/ has been growing at an amazing pace. From just a few pages of information on ISO, the web server now holds more than 3000 individual HTML pages, 6000 images and 2000 documents, containing slightly more than 2 Gbytes of information.

On average it is currently visited from 4000 distinct machines/hosts each week. Fig. 2 shows the number of external accesses to HTML pages and documents (currently around 30000 per week). This number do not include the internal accesses from the ISO Data Centre and the accesses to images.

The number of accesses has been fairly growing constantly from the beginning with peaks clearly visible for example during the launch, the second call for observing proposals, the publication of a dedicated ISO issue of Astronomy and Astrophysics Letters (*A&A Volume 315 Number 2, November 1996*) or during the conference entitled "*The Universe as seen by ISO*" held at UNESCO in Paris in October 1998.

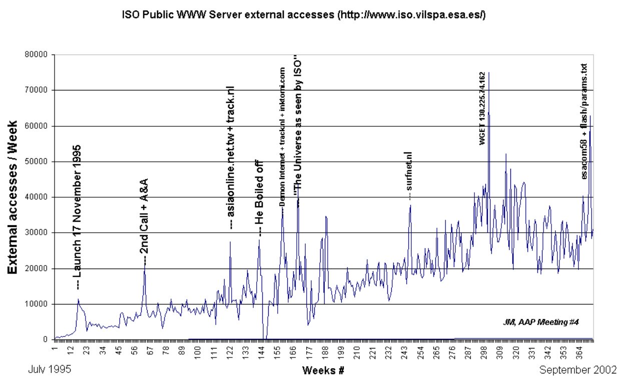


Figure 2. External weekly accesses to the ISO Public WWW server since July 1995.

The ISO homepage design was changed successively just after launch and during operations. The current layout (see Fig. 3) divided in four main sections (Data Archive, Science, Users Information and Outreach) is used since the public opening of the ISO Data Archive (IDA) in December 1998.

The site during operations was oriented towards keeping observers informed about the progress of their observations, the current one is oriented towards informing users of how to use the ISO data and gives observers an easy access to the archive.

Since 1998, the homepage graphical design was kept on purpose as simple as possible to be friendly with users reaching us over low-speed connections and to be browser-independent. During that time the state of the art in website design and navigation technologies has advanced considerably.

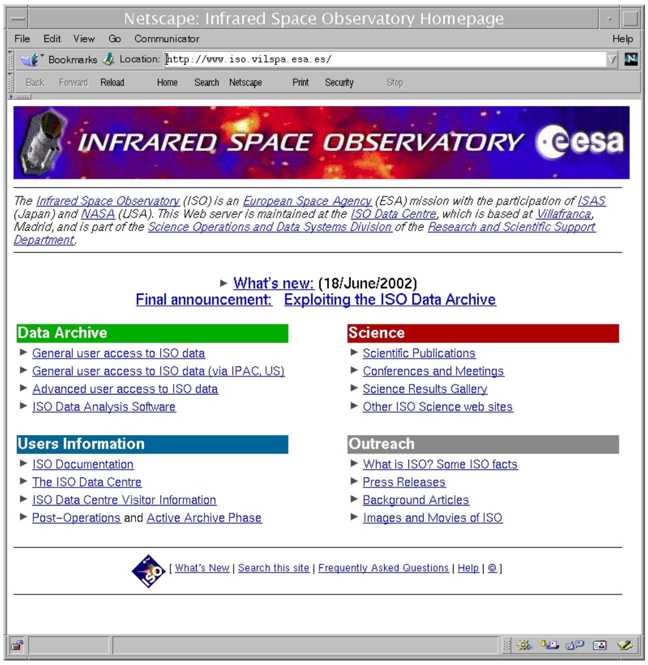


Figure 3. The Infrared Space Observatory Homepage.

During the Active Archive Phase, the ISO website will include some effort to adapt this key user interface to keep pace with rapid development of web technology in general. It is desirable to leave our web interface in the most advanced condition feasible at the end of AAP, to postpone its possible obsolescence as far as possible into the future (Metcalfe 2002).

4. THE ISO DOCUMENTATION

The goal of the ISO Explanatory Library is to provide users with a comprehensive reference source on the ISO mission and its data products. This is a guide to quickly find and access desired information on the ISO products, how they were derived and which considerations to take into account for further analysis and interpretation of the data.

The core of the Explanatory Library consists of the ISO Handbook. The Handbook is the definitive stand-alone reference document for the ISO Mission and the ISO Data Products. The structure of the ISO Handbook is such that it is composed of 5 different volumes. A first general one with an overview of the ISO Mission & Satellite and then 4 volumes, one for each instrument.

5. THE ISO HELPDESK

The ISO Help Desk (helpdesk@iso.vilspa.esa.es) - the first line support for the ISO users community- received and answered a bit more than 32500 e-mails since its creation in 1994.

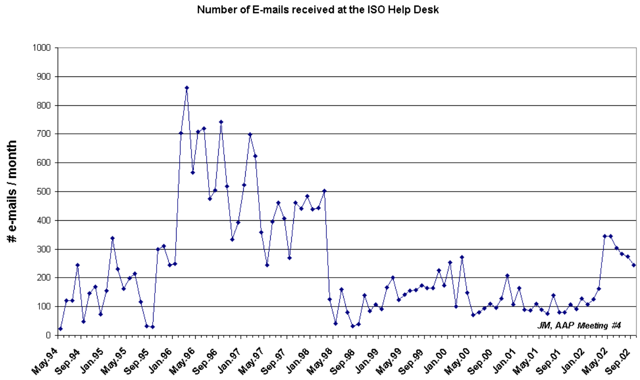


Figure 4. Number of e-mails received every month at Helpdesk since May 1994. On the above graph, the satellite operation period (November 1995 - May 1998) is clearly visible.

Helpdesk support will remain a fundamental activity for the ISO Data Centre throughout AAP. If efforts are successful to engage the Community more fully in the reduction of the ISO data then sustained, and possibly increased, helpdesk activity is to be expected (Metcalfe 2002).

6. THE ISO DATA ARCHIVE

The ISO Data Archive (IDA) was developed by the ISO Data Centre in Villafranca - Madrid, Spain (Arviset & Prusti 1999). The archive offers the astronomical community fast and easy access to all ISO data products and related information through a Java cutting-edge technology interface (Fig. 5).

It contains all the ISO raw and fully processed, science and calibration data as well as all ancillary data (engineering, uplink and downlink data) for a total of about 400 GBytes stored on magnetic disks.

Currently, 1347 users are registered with the ISO Data Archive and 297 users were "active" during 2002 (See Table 1). An "active" user is defined as a user who made at least one retrieval request during the last 12 months (Pirenne 2001).

Table 1. Registered and Active Users for different Archive Facilities

Archive Facility	Registered Users	Active Users (2002)
STScI	5401	1320
CADC	1889	N/A
ESO/ST-ECF	3244	849
IDA (ISO)	1347	297
XSA (XMM)	621	416

During the Active Archive Phase, the archive will continue to be improved with new data and information being ingested. Major tasks will be: stimulating systematic data reduction and capturing the resulting data products into the archive; tracking of refereed ISO publications and incorporating this information; ingestion of new ISO catalogues and atlases; continuing the process of increasing the inter-operability of archives by linking to other data sets; and maintaining the archive, especially the user interface to maximise its usefulness and ease of use.

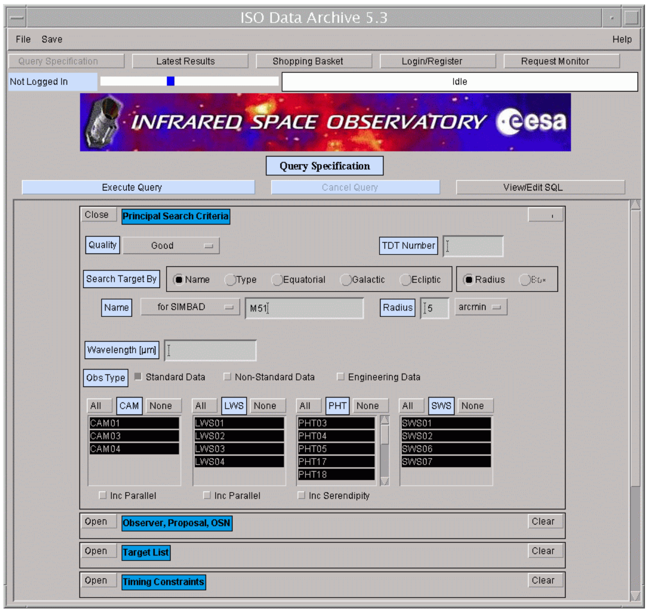


Figure 5. The ISO Data Archive query panel

7. THE ISO DATA ANALYSIS SOFTWARE

The quality of the pipeline processed data in the archive is not always sufficient for specific purposes. For further processing and analysis of ISO data the following software packages are available:

- ISOPHOT Interactive Analysis (PIA) Package
- ISOCAM Interactive Analysis (CIA) Package
- ISO Spectroscopic Analysis Package (ISAP)
- Observers SWS Interactive Analysis (OSIA)
- LWS Interactive Analysis (LIA) Package

These software packages can be downloaded from:
http://www.iso.vilspa.esa.es/archive/software/

8. SUMMARY

At the time ISO was developed there were not so many infrared astronomers in Europe. However, a world-class facility tends to create its own user community and ISO was no exception (Woltjer 1998). The number of registered users nearly

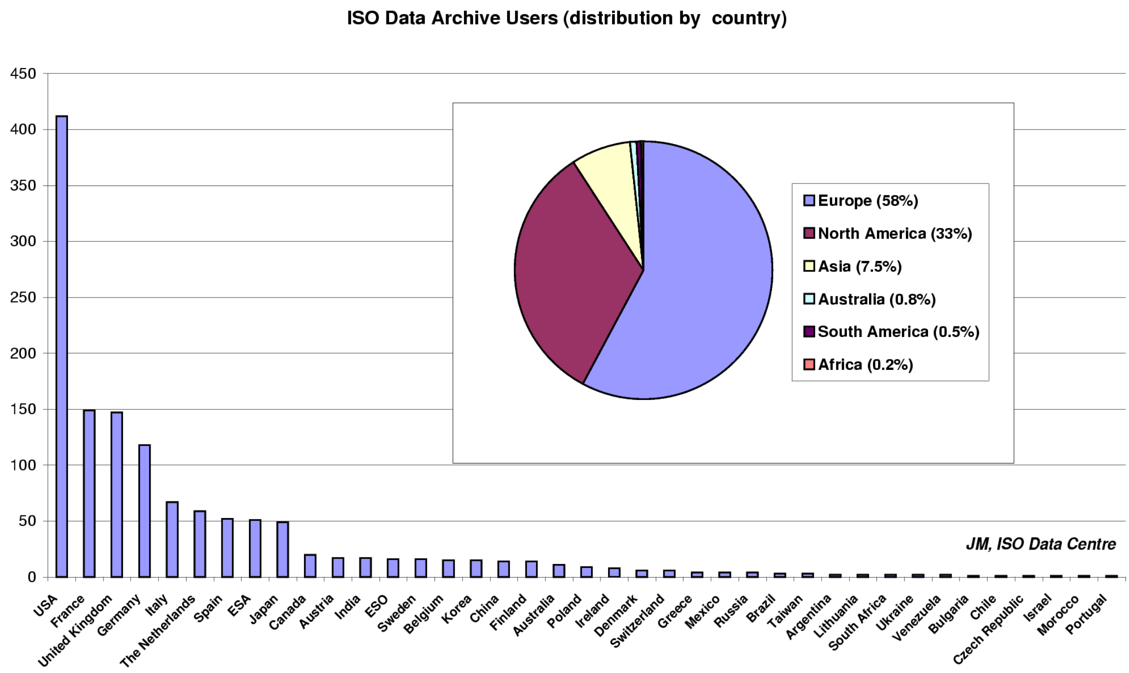


Figure 6. The ISO Data Archive Users distribution by country

triple since the public opening of the ISO Data Archive (at a rate of around 1 new user / working day).

Based on the information extracted from the ISO Data Archive users registration, the Infrared Space Observatory users community is currently distributed over 37 countries (see Fig. 6) and is mainly concentrated in Europe (58%), North America (33%) and Asia (7.5%).

For the ISO Data Centre, the main thrusts of the Active Archive Phase will be to support this community in their use of ISO data and to capture back into the archive as much as possible of the user knowledge so as to maximize the long-term value and usability of the archive.

The ISO Data Centre in collaboration with the different National Data Centres (NDCs) will continue to enable the worldwide community to get the most out of ISO and will, additionally, build a bridge towards future missions, especially Herschel but also SIRTF and ASTRO-F.

ACKNOWLEDGEMENTS

ISO is an ESA project with instruments funded by ESA Member States (especially the PI countries: France, Germany, the Netherlands and the United Kingdom) and with the participation of ISAS and NASA.

REFERENCES

Arviset C. & Prusti T., 1999, The ISO Data Archive, ESA Bulletin Nr. 98, p. 133.

Kessler M.F. et al., 1996, The Infrared Space Observatory (ISO) mission, A&A 315, L27-L31.

Kessler M.F. et al., 1998, Looking Back at ISO Operations, ESA Bulletin Nr. 95.

Kessler M.F., 2000, ISO: The mission and its results, Proc. The Promise of the Herschel Space Observatory, ESA SP-460, p. 53.

Metcalfe L., Detailed Strategy for ISO's Active Archive Phase, SAI/2001-019/Dc, Issue 1.0, June 2002.

Pirenne B., 2001, ST-ECF Users Committee Meeting presentation, December 2001.

Woltjer L., 1998, The long road towards ISO's success, Proc. The Universe as seen by ISO, ESA SP-427, Opening Address, p. 1.

HERSCHEL SPACE OBSERVATORY MISSION SUMMARY

Göran L. Pilbratt

ESA Astrophysics Missions Division, Research and Scientific Support Department,
ESTEC / SCI-SA, Keplerlaan 1, NL-2201 AZ Noordwijk, The Netherlands

ABSTRACT

The 'Herschel Space Observatory' (or simply 'Herschel' – formerly FIRST) is the fourth Cornerstone mission in the European Space Agency (ESA) science programme. It will perform imaging photometry and spectroscopy in the far infrared and submillimetre part of the spectrum, covering approximately the $57-670\ \mu$m range.

The key science objectives emphasize current questions con nected to the formation of galaxies and stars, however, having unique capabilities in several ways, Herschel will be a facility open for observing time proposals from the entire astronomical community. Because Herschel to some extent will be its own pathfinder, the issue of instrument calibration and data processing timescales has special importance. Herschel will carry a 3.5 metre diameter radiatively cooled passive monolithic telescope.

The science payload complement – two cameras/medium resolution spectrometers (PACS and SPIRE) and a very high resolution heterodyne spectrometer (HIFI) – will be housed in a superfluid helium cryostat. Herschel will be launched and placed in a transfer trajectory towards its operational orbit aroun the Earth-Sun L2 point by an Ariane 5 (shared with the ESA cosmic background mapping mission Planck) in 2007.

Once operational Herschel will offer a minimum of 3 years of routine observations; roughly 2/3 of the available observing time is open to the general astronomical community through a competitive proposal procedure.

This paper intends to provide a summary and status report, see also Pilbratt (2002) and references therein.

Key words: Space vehicles: instrumentation, cryostat; Stars: early-type, formation, late-type, pre-main sequence, winds, outflows; ISM: jets and outflows, molecules; Galaxies: evolution, formation, ISM; Infrared: galaxies, stars; Submillimetre

1. INTRODUCTION

The 'Herschel Space Observatory' (or simply 'Herschel', formerly known as the 'Far InfraRed and Submillimetre Telescope' – FIRST) is a multi-user 'observatory type' mission that targets approximately the $57-670\ \mu$m wavelength range in the far infrared and submillimetre part of the electromagnetic spectrum, providing observation opportunities for the entire astronomical community. Herschel (Fig. 1) was the fourth of the original 'Cornerstone' ($\sim$ 'flagship') missions in the ESA science 'Horizon 2000' plan, and is now being implemented as the next astronomy Cornerstone in 'Cosmic Vision 2020' – the new ESA Horizons Programme.

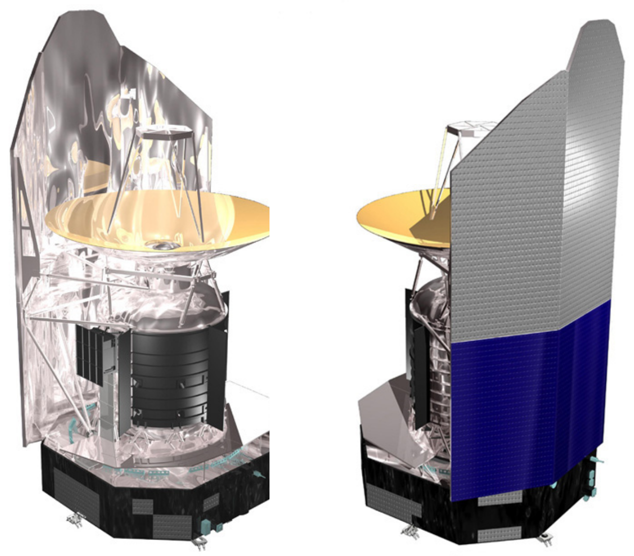


Figure 1. Current Herschel configuration, towards the end of phase B. It measures approximately 7.5 m in height, 4 m in width, and has launch mass of order 3170 kg. (Courtesy and all rights reserved Alcatel Space Industries)

Herschel is the only space facility dedicated to this part of the submillimetre and far infrared range. Its vantage point in space provides several decisive advantages. The telescope will be passively cooled, which together with a low emissivity and the total absence of atmospheric emission offers a low and stable background enabling very sensitive photometric observations. Furthermore, the absence of even residual atmospheric absorption gives full access to the entire range of this elusive part of the spectrum, which offers the capability to perform completely uninterrupted spectral surveys.

2. SCIENCE OBJECTIVES – THE 'COOL' UNIVERSE

Herschel is designed to address the 'cool' universe; it has the potential of discovering the earliest epoch proto-galaxies, re-

Proceedings of the Symposium *"Exploiting the ISO Data Archive - Infrared Astronomy in the Internet Age"*,
24–27 June 2002, Sigüenza, Spain (C. Gry, S. B. Peschke, J. Matagne et al. eds., ESA SP-511)

vealing the cosmologically evolving AGN-starburst symbiosis, and unraveling the mechanisms involved in the formation of stars and planetary system bodies.

Several major symposia have been held to discuss the scientific objectives (Rowan-Robinson et al. eds. (1997) and Pilbratt et al. eds. (2001) – also available online) and the resulting requirements on the observatory, its instrumentation and observing programmes. The key science objectives emphasize specifically the formation of stars and galaxies, and the interrelation between the two.

Herschel will complement other available facilities by offering space observatory capabilities in the far infrared and submillimetre for the first time, extending the wavelength coverage longwards from that of e.g. IRAS, ISO, SIRTF, and Astro-F and shortwards of SWAS and Odin. A major strength of Herschel is its photometric mapping capability for performing unbiased surveys related to galaxy and star formation. Redshifted ultraluminous IRAS galaxies (with spectral energy distributions (SEDs) that 'peak' in the $50-100$ μm range in their rest frames) as well as class 0 proto-star and pre-stellar object SEDs peak in the Herschel 'prime' band. Herschel is also well equipped to perform spectroscopic follow-up observations to further characterise particularly interesting individual objects.

3. TELESCOPE AND SCIENCE PAYLOAD

In order to fully exploit the favourable conditions offered by being in space Herschel will need a precise, stable, low background telescope, and a complement of appropriately capable scientific instruments. In order to maximise its size the Herschel telescope will be passively cooled, while the instrument focal plane units (FPUs) will be housed inside a superfluid helium cryostat to enable low noise high sensitivity operation.

3.1. TELESCOPE

The Herschel telescope (Sein et al. 2002) must have a total wavefront error (WFE) of less than 6 μm – corresponding to 'diffraction-limited' operation at $\sim$ 90 μm – during operations. It must also have a low emissivity to minimize the background signal, and the whole optical chain must be optimised for high straylight rejection. Protected by a fixed sunshade, in space the telescope will radiatively cool to an operational temperature in the vicinity of 80 K, with a very uniform and slowly changing temperature distribution.

The chosen optical design is a classical Cassegrain with a 3.5 m diameter primary and an 'undersized' secondary. The telescope will be constructed almost entirely of silicon carbide (SiC). The primary mirror will be made made out of 12 segments (Fig. 2) 'brazed' together to form a monolithic mirror. The secondary is made in a single piece with an integral 'scattercone' to suppress standing waves and the narcissus effect. The telescope will initially be kept warm after launch into space to prevent it acting as a cold trap while the rest of the spacecraft is cooling down. Although the Herschel telescope sets a new standard when it comes to large, high accuracy, lightweight space telescopes it is still interesting to note that the reflective aluminium layer, which is the 'working part' of the telescope, accounts for only $\sim$ 10 g of the total telescope mass of 300 kg, or about 0.003 %.

3.2. SCIENTIFIC INSTRUMENTS

The Herschel science payload complement consists of the following three instruments which will be provided by consortia led by Principal Investigators (PIs):

- The Photodetector Array Camera and Spectrometer (PACS) instrument will be built by a consortium led by A. Poglitsch, MPE, Garching, Germany.
- The Spectral and Photometric Imaging REceiver (SPIRE) instrument will be built by a consortium led by M. Griffin, University of Wales, Cardiff, UK.
- The Heterodyne Instrument for the Far Infrared (HIFI) instrument will be built by a consortium led by Th. de Graauw, SRON, Groningen, The Netherlands.

The PI consortia provide the instruments to ESA under their own funding (from ESA member states, USA, Canada, and Poland), in return for guaranteed observing time. Taken together, the payload complement enables Herschel to offer its observers large-scale imaging photometric capability in six bands with centre wavelengths from 75 to 517 μm, medium resolution spectroscopy with limited imaging capability over the entire Herschel wavelength coverage, and high to very high resolution spectroscopy over much of the coverage.

3.2.1. PACS – A CAMERA AND SPECTROMETER

PACS (Fig. 2 and Poglitsch et al. 2002 and references therein) is a camera and low to medium resolution spectrometer for wavelengths up to $\sim$ 210 μm. It employs four detector arrays, two bolometer arrays and two Ge:Ga photoconductor arrays. The bolometer arrays are dedicated for photometry, while the photoconductor arrays are to be employed exclusively for spectroscopy. PACS can be operated either as an imaging photometer, or as an integral field line spectrometer.

PACS has three photometric bands with $R \sim 2$. The short wavelength 'blue' array covers the $60-85$ and $85-130$ μm bands, while the 'red' array covers the $130-210$ μm band. In photometric mode one of the 'blue' bands and the 'red' band are observed simultaneously. The two bolometer arrays both fully sample the same $1\farcm75 \times 3\farcm5$ field of view on the sky, and provide a predicted point source detection limit of $\sim$ 3 mJy (5σ, 1 hr) in all three bands. An internal ^{3}He sorption cooler will provide the 300 mK environment needed by the bolometers.

For spectroscopy PACS covers $57-210$ μm in three contiguous bands, providing a velocity resolution in the range $150-200$ km s^{-1} and an instantaneous coverage of ~ 1500 km s^{-1}. The two Ge:Ga arrays are appropriately stressed and operated at slightly different temperatures – cooled by being 'strapped' to the liquid helium – in order to optimise sensitivity for their respective wavelength coverage. The predicted point

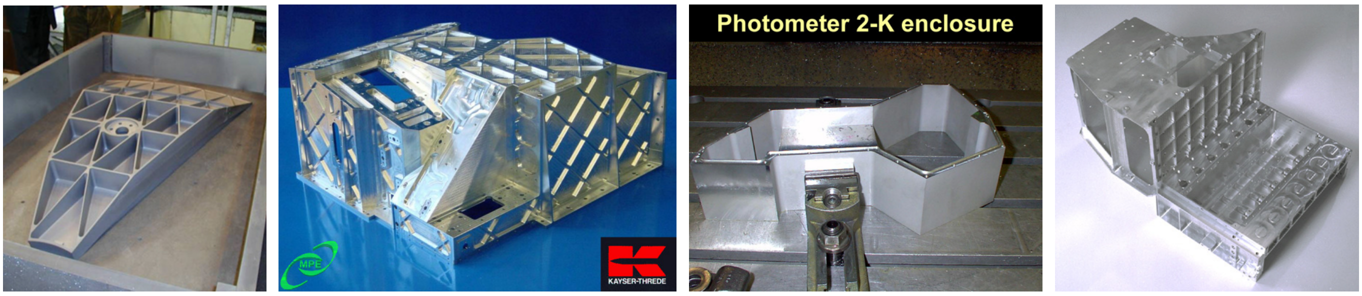


Figure 2. Herschel hardware, from left to right: a full scale SiC segment manufactured as a technology maturity demonstration in spring 2001 (Courtesy and all rights reserved Astrium-EF and Boostec), the PACS top optics part of the FPU, the SPIRE photometer 2 K enclosure, and the HIFI common optics assembly, as manufactured as of summer 2002.

source detection limit is $\sim 3\times10^{-18}\,\mathrm{Wm}^{-2}$ (5σ, 1 hr) over most of the band, rising to $\sim 8\times10^{-18}\,\mathrm{Wm}^{-2}$ for the shortest wavelengths.

3.2.2. SPIRE – A CAMERA AND SPECTROMETER

SPIRE (Fig. 2 and Griffin et al. 2002 and references therein) is a camera and low to medium resolution spectrometer for wavelengths above $\sim 200\ \mu$m. It comprises an imaging photometer and a Fourier Transform Spectrometer (FTS), both of which use bolometer detector arrays. There are a total of five arrays, three dedicated for photometry and two for spectroscopy. All employ 'spider-web' bolometers with NTD Ge temperature sensors, with each pixel being fed by a single-mode $2F\lambda$ feedhorn, and JFET readout electronics. The bolometers are cooled to 300 mK by an internal ^{3}He sorption cooler similar to the PACS one.

SPIRE has been designed to maximise mapping speed. In its broadband ($R \sim 3$) photometry mode it simultaneously images a $4' \times 8'$ field on the sky in three colours centred on 250, 363, and 517 μm. Since the telescope beam is not instantaneously fully sampled, it will be required either to scan along a preferred angle, or to 'fill in' by 'jiggling' with the internal beam steering mirror. The SPIRE point source sensitivity for mapping is predicted to be in the range $7-9$ mJy (5σ, 1 hr). Since the confusion limit for extragalactic surveys is estimated to lie in the range $10-20$ mJy, SPIRE will be able to map ~ 0.5 square degree on the sky per day to its confusion limit.

The SPIRE spectrometer is based on a Mach-Zender configuration with novel broad-band beam dividers. Both input ports are used at all times, the signal port accepts the beam from the telescope while the second port accepts a signal from a calibration source, the level of which is chosen to balance the power from the telescope in the signal beam. The two output ports have detector arrays dedicated for $200-325$ and $315-670\,\mu$m respectively. The maximum spectral resolution varies with wavelength, it will be in the range $R \sim 100-1000$ at a wavelength of 250 μm, and the field of view is $\sim 2\overset{\prime}{.}6$.

3.2.3. HIFI – A VERY HIGH RESOLUTION SPECTROMETER

HIFI (Fig. 2 and de Graauw et al. 2002 and references therein) is a very high resolution heterodyne spectrometer. It offers velocity resolution in the range $0.3-300\ \mathrm{km\,s}^{-1}$, combined with low noise detection using superconductor-insulator-superconductor (SIS) and hot electron bolometer (HEB) mixers. HIFI is not an imaging instrument, it provides a single pixel on the sky.

The focal plane unit (FPU) houses seven mixer assemblies, each one equipped with two orthogonally polarised mixers. Bands $1-5$ utilise SIS mixers that together cover approximately $500-1250$ GHz without any gaps in the frequency coverage. Bands 6L(ow) and 6H(igh) utilise HEB mixers, and together target the $1410-1910$ GHz band. The FPU also houses the optics that feeds the mixers the signal from the telescope and combines it with the appropriate local oscillator (LO) signal, as well as provides a chopper and the capability to view internal calibration loads.

The LO signal is generated by a source unit located in the spacecraft service module (SVM). By means of waveguides it is fed to the LO unit, located on the outside of the cryostat vessel, where it is amplified, multiplied and subsequently quasioptically fed to the FPU. The SVM also houses the complement of autocorrelator and acousto-optical backend spectrometers.

4. SPACECRAFT AND PAYLOAD ACCOMODATION

The Herschel spacecraft (Fig. 1) has a modular design, consisting of the 'extended payload module' (EPLM) and the 'service module' (SVM). The EPLM consists of the PLM 'proper' with a superfluid helium cryostat – based on the proven successful ISO technology – housing the Herschel optical bench (HOB) with the instrument FPUs, and supporting the telescope, the sunshield/shade, and payload associated equipment. The SVM houses 'warm' payload electronics, and provides the necessary 'infrastructure' for the satellite such as power, attitude and orbit control, the onboard data handling and command execution, communications, and safety.

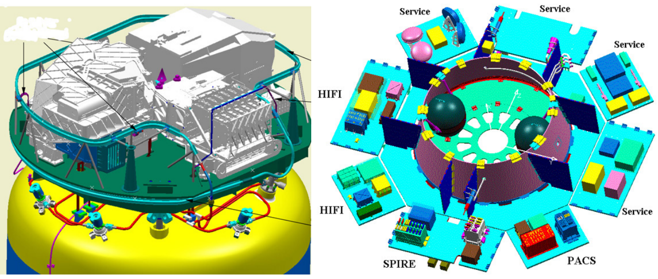


Figure 3. On the left the accommodation of the FPUs of science payload in the cryostat on the optical bench, clockwise from the left PACS, SPIRE, and HIFI. On the right the 'warm' electronics inside the service module. (Courtesy and all rights reserved Astrium-ED (left) and Alenia Spazio (right))

5. LAUNCH AND IN-ORBIT OPERATIONS

Arianespace will provide the launch services in Kourou. An Ariane 5 launcher shared by the ESA cosmic microwave background mapping mission Planck and Herschel, will inject its last stage carrying both satellites into a transfer trajectory towards the second Lagrangian point (L2) in the Sun-Earth system. First Herschel followed by Planck will then separate from the launcher, and subsequently operate independently from orbits of different size around L2 which is situated 1.5 million km away from the Earth in the anti-sunward direction. It offers a stable thermal environment with good sky visibility. Commissioning and performance verification will take place enroute towards L2. Once these crucial mission phases have been successfully accomplished, Herschel will go into routine science operations for a minimum duration of 3 years.

6. STATUS AND SCHEDULE

The current status and future schedule for the implementation of the Herschel mission are described by the ESA and industrial Prime Contractor project managers (Passvogel & Juillet 2002). Current activities are ongoing in the areas of the space segment (satellite), telescope, science payload, and operations areas. In summary:

- The industrial satellite activites commenced with the placing of a contract for Herschel (and Planck) phases B, C/D, and E1 in Apr 2001, and phase B commenced. The first major review, the System Requirements Review (SRR), took place in the autumn, and currently (Aug 2002) the Preliminary Design Review (PDR) is taking place at the end of phase B.
- The telescope activity was started in mid-2001, and the Mid-Term Review (MTR) was successfully held in Nov 2001, paving the way for the Critical Design Review (CDR) held successfully in Apr 2002.
- The instrument consortia are in the process of finalising the instrument designs and are in the process building their first test models. Their third formal review cycle, the Instrument Baseline Design Review (IBDR), took place in Feb-Mar 2002.
- The science ground segment is being developed, and will support instrument level testing commencing later in 2002.

The current planning (for more details Passvogel & Juillet 2002) envisages a series of milestones, including instrument and telescope flight model deliveries in 2004/5, to be followed by spacecraft integration and extensive system level ground testing, leading to the launch in 2007.

Additional information can be found on the Herschel web-site at `http://astro.esa.int/herschel/`.

ACKNOWLEDGEMENTS

This paper has been written on behalf of the large number of people who are working on one or more of the many aspects of the Herschel mission – in ESA and national space agencies, the instrument consortia, scientific community, and industry – or who contributed to where we are now by doing so in the past.

REFERENCES

de Graauw T., Caux E., Phillips T.G., Stutzki J., Whyborn N.D., and the HIFI Consortium, 2002, *Proc. SPIE* 4850 (in press)

Griffin M.J., Swinyard B.M., Vigroux L.G., 2002, *Proc. SPIE* 4850 (in press)

Pilbratt G.L., Cernicharo J., Heras A.M., Prusti T., Harris R. (eds), 2001, ESA SP-460; available online

Pilbratt G.L., 2002, *Proc. SPIE* 4850 (in press)

Poglitsch A., Waelkens C., Geis N., 2002, *Proc. SPIE* 4850 (in press)

Rowan-Robinson M., Pilbratt G.L., Wilson A. (eds.), 1997, ESA SP-401

Sein E., Toulemont Y., Safa F., Duran M., Deny P., 2002, *Proc. SPIE* 4850 (in press)

Passvogel T., Juillet J.-J., 2002, *Proc. SPIE* 4850 (in press)

YET ANOTHER INFRARED ARCHIVE: RELEASE OF THE INFRARED TELESCOPE IN SPACE (IRTS) ARCHIVE DATA

Issei Yamamura[1], Masahiro Tanaka[1], Hidenori Takahashi[2], Sin'itirou Makiuti[1], Takanori Hirao[3], Takafumi Ootsubo[4], Mikako Matsuura[5], Kenich Okumura[6], Daisuke Ishihara[4], Takao Nakagawa[1], Hiroshi Murakami[1], Takashi Onaka[4], and Hiroshi Shibai[3]

[1]Institute of Space and Astronautical Science (ISAS), Yoshino-dai 3-1-1, Sagamihara, Kanagawa, 229-8510, Japan
[2]National Astronomical Observatory Japan, Osawa, Mitaka, Tokyo, 181-8588, Japan
[3]Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8602, Japan
[4]Department of Astronomy, University of Tokyo, Hongo 7-3-1, Tokyo, 113-0033, Japan
[5]Department of Physics, UMIST, P.O.Box 88, Manchester M60 1QD, UK
[6]Communications Research Laboratory, Nukui-kitamachi 4-2-1, Koganei, Tokyo 184-8795, Japan

ABSTRACT

The IRTS data archive has been in public since 2002. IRTS surveyed about 7 per cent of the whole sky with four instruments, which covered from 1.4 to 700 μm. Presently the archive includes the near- and mid-infrared low resolution spectral catalogues of point sources, and image maps in five wavelength bands in the far-infrared. The point source catalogues contains over 14 000 (near-infrared) and 500 (mid-infrared) sources. The majority of detected sources are late-type stars. These large samples of uniform spectra are especially useful for statistical studies of infrared properties of stars. The far infrared image maps are obtained for the 158 μm [C II] line, and continuum bands at 155, 250, 400, and 700 μm. Radiation from the diffuse interstellar components has been studied with these data. More data products will be available in a few year time-scale. The IRTS data can be accessed via ISAS's data archive service *DARTS*, *URL: http://www.darts.isas.ac.jp/*.

Key words: Surveys: IRTS – Infrared: stars – Infrared: ISM

1. THE IRTS MISSION

Infrared Telescope in Space (IRTS) is the first Japanese space infrared mission (Murakami et al. 1996). IRTS was on board of the Space Flyer Unit (SFU) satellite, and launched in 1995 March 18 by the NASDA's H-II rocket. Survey observations were carried out from March 30 to April 24. About 7 per cent of the whole sky was covered in two stripes (Fig. 1); one (*North-scan*) scanned along the Galactic plane through near the Galactic Center, and the other (*South-scan*) observed high-galactic latitude region. SFU was retrieved by the Space Shuttle Endeavor in early 1996. Post-mission calibration measurements of the instruments were carried out and included in the calibration procedures (e.g., Murakami et al. 2002).

IRTS was equipped with a cooled 15-cm telescope and four scientific instruments, namely: The *Near-Infrared Spectrometer* (NIRS), the *Mid-Infrared Spectrometer* (MIRS), the *Far-Infrared-Line Mapper* (FILM), and the *Far-Infrared Photometer* (FIRP). The specifications of the instruments are summarized in Table 1.

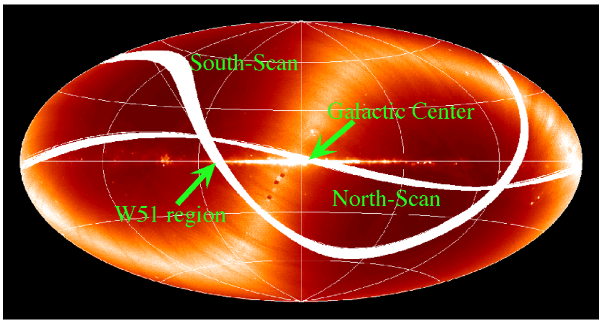


Figure 1. The IRTS scan area is overlaid on the COBE/DIRBE 12 μm image in Galactic coordinates. IRTS scanned along two stripes: North-scan *went through near the galactic center, and* South-scan *observed high-galactic latitude region. Total surveyed area is about 7 per cent of the whole sky.*

	Wavelength (μm)	Detector	Resolution ($\lambda/\Delta\lambda$)	FOV (arcmin^2)
NIRS	1.4–2.5, 2.9–4.0	2 × 12-ch InSb	12–33	8 × 8
MIRS	4.5–11.7	32-ch Si:Bi	20–30	8 × 8
FILM	63([O I]), 158([C II]), 155, 160 (cont.)	Ge:Ga, stressed-Ge:Ga	400 (lines) 130 (cont.)	8 × 13
FIRP	150, 250, 400, 700	0.3 K bolometer	3	30ϕ

Table 1. Specifications of the IRTS focal-plane instruments.

The large field-of-view (FOV) of the instruments has an advantage for observations of diffuse radiation. Interstellar and interplanetary gas and dust (Okumura et al. 1996; Makiuti et al. 2002; Ootsubo et al. 2000) as well as cosmic background radiation (Matsumoto et al. 1996) are the main targets of IRTS. In addition, the NIRS and the MIRS detected many point sources (Yamamura et al. 1996). The spectra provide information of the molecular and dust bands in the wavelengths masked by the Earth's atmosphere.

Proceedings of the Symposium *"Exploiting the ISO Data Archive - Infrared Astronomy in the Internet Age"*, 24–27 June 2002, Sigüenza, Spain (C. Gry, S. B. Peschke, J. Matagne et al. eds., ESA SP-511)

2. THE NIRS POINT SOURCE CATALOGUE

The NIRS is a low-resolution grating spectrometer that covers the wavelength ranges of 1.4–2.5 and 2.9–4.0 μm by a pair of 12 channel InSb detector arrays. Each detector pixel observes a fixed wavelength, so that the spectrum of the sky is continuously provided. The product of the NIRS observation currently available is the NIRS Point Source Catalogue (NIRS PSC, Tanaka et al. in preparation). The first version of the catalogue contains spectra of 14,223 objects confirmed by at least two detections. The catalogue is complete down to 6–7 mag (approximately 1 Jy, Figure 2). The accuracy of the flux is typically 5 per cent. Details of the NIRS calibration procedure are described in Murakami et al. (2002).

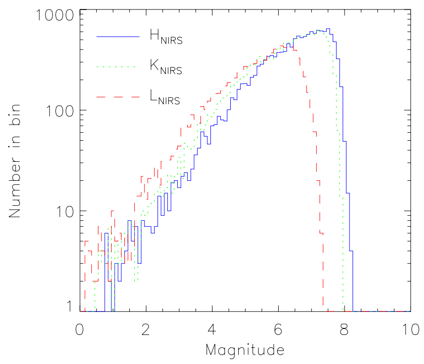


Figure 2. Magnitude–number diagram of the NIRS PSC at three wavelength channels closest to H, K, and L-band, respectively. The NIRS PSC is complete down to 6–7 mag.

The majority of sources are late-type stars; some of them show molecular absorption bands of H_2O, CO, C_2H_2, and HCN. These molecular features are indicators of chemical composition of the stars (Figure 2). Classification of the spectra using the 'key wavelength' of the features is attempted (Tanaka et al. in preparation). Figure 3 shows that M, S, and C type stars are clearly identified on the diagrams. The results of the classification of the best quality 4020 stars are listed in Table 2.

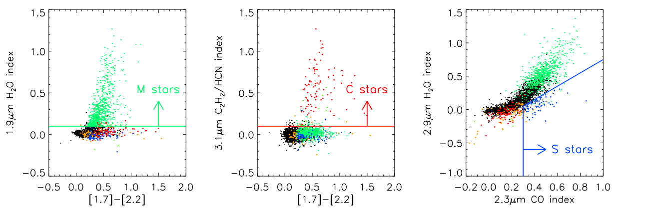


Figure 3. Color-magnitude diagrams of the NIRS point sources at different 'key wavelengths'. M-type and C-type stars are characterized by their H_2O and C_2H_2/HCN molecular absorption bands. S-type stars are defined as that they do show deep CO absorption but little or no H_2O absorption band (Tanaka et al. in preparation).

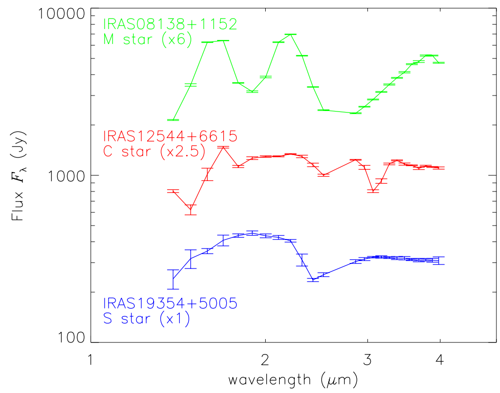


Figure 4. The typical NIRS spectra of M, C, and S-type stars, which are classified in the diagrams shown in Figure 3.

	Spectral indices	# of objects (out of 4020)
M star	w/ 1.9 μm H_2O	853
C star	w/ 3.1 μm C_2H_2/HCN	91
S star	w/ 2.3 μm CO and w/o 2.9 μm H_2O	62
UIR objects	w/ 3.3 μm band	6
Other red objects		1166
Earlier type stars		1842

Table 2. Preliminary classification of the NIRS point sources with high-quality.

The NIRS PSC is extremely useful for studies of infrared properties of the stars. Matsuura et al. (1999) reported unexpected detections of H_2O bands in the early M-type stars. The IRTS/NIRS data are also used for galactic distribution of evolved star and their contribution to the mass circulation in the Galaxy (LeBertre et al. 2001).

3. THE MIRS POINT SOURCE CATALOGUE

The MIRS is a 32-channel grating spectrometer observing a wavelength range between 4.5 and 11.7 μm simultaneously. The spectral resolution is $\Delta\lambda$ =0.23–0.36 μm. As the NIRS did, the MIRS detected a number of point sources. Many of the detected sources are mass-losing stars. It also detects the reflection nebula NGC 7023 and a few H II regions, which exhibit the UIR features. One asteroid, 01 Ceres, was observed by the MIRS for a several times and was used for the flux calibration (see, Cohen et al. 1998). The overview of the MIRS flux calibration procedures is explained in Onaka et al. (2002). The completeness level of the MIRS PSC is 10–20 Jy for the entire wavelength range (Figure 5).

The MIRS detected about one thousand point sources. The MIRS Point Source Catalogue version 1.0 contains 536 sources with relatively good quality. The objects are classified into five

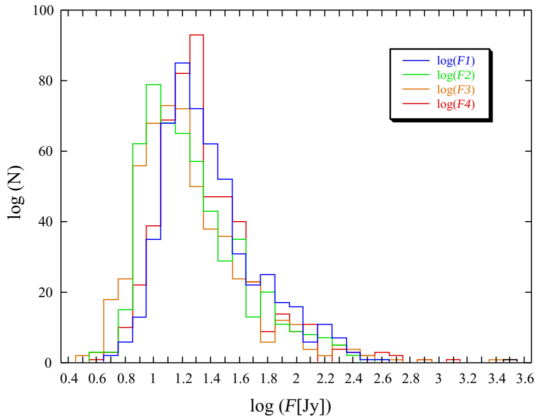


Figure 5. Flux–number diagram of the MIRS point sources at four wavelengths bands, in 4.6–6.2($F1$), 6.4–8.0($F2$), 8.2–9.8($F3$), and 10.0–11.6($F4$), respectively. The MIRS PSC contains the sources with the flux down to 10–20 Jy.

groups on the two-color diagram made from representative wavelengths at 5, 8, and 10 μm (Yamamura et al. 1996). Figure 6 shows the NIRS+MIRS spectra of representative objects. Stars earlier than K-type show almost featureless spectra. As the star becomes later, H_2O around 6 μm and SiO fundamental band at 8 μm start to appear. In carbon stars C_3 at 5.3 μm and 7 μm C_2H_2/HCN band are clearly seen. These molecular bands are dimmed as dust emission becomes stronger. H II regions are characterized by their UIR bands at 6.2, 7.7–8.6, and 11.3 μm. MIRS detected many red objects with the blackbody-like spectra of $\sim$ 300 K. Almost all of them are space debris, except one asteroid, Ceres.

Although the number of sample is not as large as the NIRS PSC, the MIRS PSC provides very unique data of mid-infrared spectra of bright objects, especially in the wavelengths inaccessible from the ground.

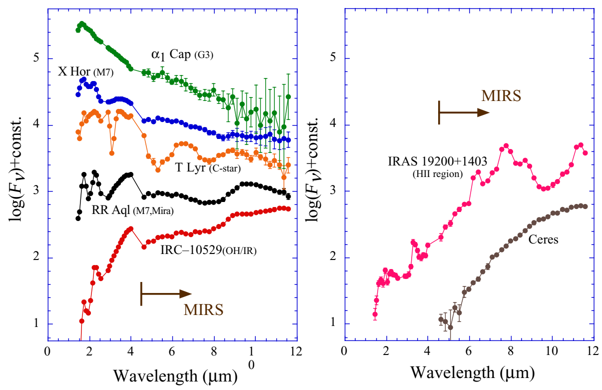


Figure 6. Examples of NIRS+MIRS spectrum of representative objects observed by the MIRS.

4. THE FILM IMAGE MAPS

The FILM is a grating spectrometer to observe the [C II] 158 μm and [O I] 63 μm line emissions as well as the far-infrared continuum emission at 155 and 160 μm. The stressed Ge:Ga detectors of the FILM performed very well, and provided high and stable (after corrected) sensitivity data. Distributions of carbon ions and cold dust in high Galactic latitude regions have been investigated using the FILM data (Makiuti et al. 2002; Okumura et al. 1996).

Image maps of the two highest performance channels, the [C II] 158 μm line and the 155 μm continuum intensities are released. The image maps are composed from the scan strip data (an aperture size of $8' \times 13'$) projected onto a $4'$ grid image plane. One image map covers 12.8×12.8 deg^2 with slight overlap with the adjacent images. No additional de-striping after image reconstruction was applied. For each region four kinds of data are provided; a raw co-add intensity map, an intensity map in which small void pixels are filled by interpolation, an error map which indicates statistical errors of the scan data at each pixel, and a map of the number of samplings participating on each pixel. The images are distributed in the FITS format. The calibration procedures are described in the explanatory documents attached to the data.

Figure 7 shows the intensity maps of the galactic plane around the H II region, W51. By comparing the 155 μm intensity with the IRAS 100 μm intensity, dust temperature is derived and is also plotted.

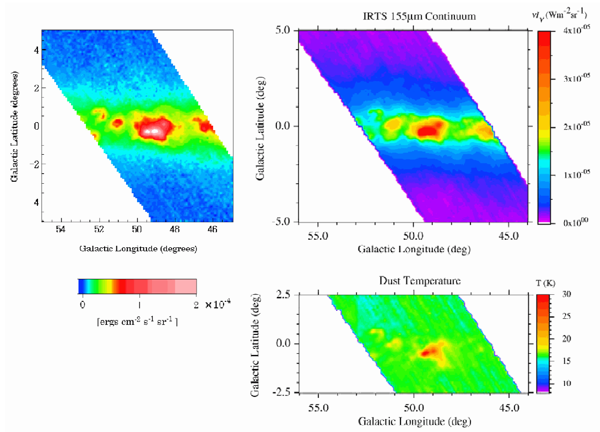


Figure 7. The W51 region image maps by the continuum and [C II] channels of the FILM. The color temperature derived from the FILM 155 μm continuum channel and the IRAS 100 μm are shown in the bottom.

5. THE FIRP IMAGE MAPS

The FIRP carried out broad-band photometry in four far-infrared wavelengths (150, 250, 400, 700 μm) operated simultaneously. The wavelength coverage of the FIRP extends beyond that of the COBE/DIRBE. The spatial resolution is also slightly better (0.5 deg). Unfortunately the system was not stable enough and some part of the data were suffered by large noises. The image maps are composed only from high-quality data in the similar manner with the FILM maps. The grid size of the maps are 8′. A raw co-add map and a sample number map are provided for each region. The 250 μm band have the best signal to noise ratio (comparable or slightly better than the COBE/DIRBE). Figure 8 shows the W51 region observed in the three channels.

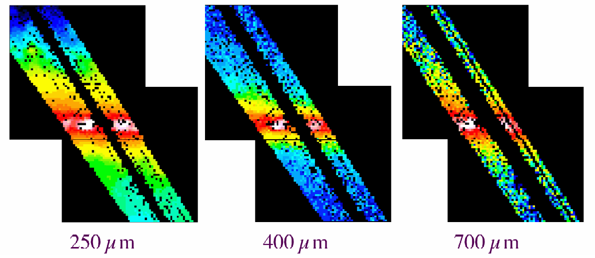


Figure 8. Image maps of the W51 region in the three channels of the FIRP.

Thanks to its unique wavelength coverage, the FIRP traces very cold dust in the galaxy (Hirao et al. 1996).

6. THE IRTS DATA ARCHIVE

The IRTS data archive system is developed as a part of ISAS's space science data archive system, *DARTS* (Data ARchive and Transmission System; *http://www.darts.isas.ac.jp/*). A simple Web interface allows the users to search, browse, and retrieve data interactively. The full data set of each product can be downloaded. Explanatory and related documents are also served. Inquires about the data are addressed to
`irts_help@ir.isas.ac.jp`.

The data will be also available from IPAC.

7. FUTURE PLAN

The data reduction activity of the IRTS still continues. Calibrated time-line data of the FILM and the FIRP will be available in near future, for those who wish more detailed analysis. Image maps of the NIRS and the MIRS survey will be released in years time scale. They are valuable especially for studies of dust and UIR bands (e.g. Onaka et al. 2000), and Zodiacal light (Ootsubo et al. in preparation).

ACKNOWLEDGEMENTS

We acknowledge all the IRTS team members for their continuous encouragement and especially Profs. H. Okuda and T. Matsumoto for their tremendous efforts in the successful IRTS project. I.Y. is supported by Grant-in-Aid for Encouragement of Young Scientists (No. 13740131) from Japan Society for the Promotion of Science.

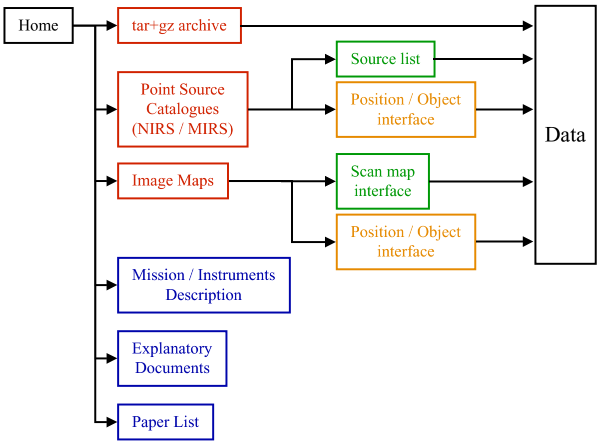


Figure 9. The structure and access flow of the IRTS data archive Web interface. Users can browse individual data by searching with object name / position or on the object list / scan map. The full data set of each product can also be retrieved in the tar+gz format.

REFERENCES

Bedding T. R., et al., 2002, MNRAS, in press
Cohen M., et al., 1998, AJ 115, 1671
Hirao T., et al., 1996, PASJ 48, L77
Le Bertre T., et al., 2001, A&A 376, 997
Makiuti S., et al., 2002, A&A 382, 600
Matsumoto T., et al., 1996, PASJ 48, L47
Matsuura M., et al., 1999, A&A 348, 579
Murakami H., et al., 1996, PASJ 48, L41
Murakami H., et al., 2002, ESA-SP 481, in press
Okumura K., et al., 1996, PASJ 48, L123
Onaka T., et al., 2000, ESA-SP 456, 55
Onaka T., et al., 2002, ESA-SP 481, in press
Ootsubo T., et al., 2000, Advances in Space Research 25, 2163
Yamamura I., et al., 1996, PASJ 48, L65