ISO INFO

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Newsletter on the Infrared Space Observatory

Introduction

Welcome to the second issue of ISO INFO. During the last year, much progress has been made on all aspects of *ISO*. Concerning the satellite itself, the industrial phase B (detailed system design) study started in December 1986. As a result of this and other studies, there have been some changes to the *ISO* design. An impression of the appearance of the entire satellite is given in figure 1. In order to increase significantly the scientific return of the mission, a new higher orbit with a period of 24-hours has been adopted. Design and development work has continued on the four focal plane instruments. Later sections of this newsletter return to all these topics however the main purpose of this issue is to provide more details on the design and status of the scientific instruments.

Recently, NASA made a proposal to ESA that *ISO* and their *SIRTF* (Space Infrared Telescope Facility) project should be considered as an "co-ordinated international programme in infrared astronomy" and suggested a number of possible contributions from one project to the other. ESA is currently reviewing the proposal.

Due to the tragic loss of the shuttle *Challenger*, the launch of the *Ulysses* mission (scheduled for May 1986) has been postponed. This delay has made it impossible for the jobs of project manager for *ISO* and *Ulysses* to be handled by the same person. Therefore, Derek Eaton, the project manager on *Ulysses* who had taken on the *ISO* project's management as *Ulysses* was approaching its launch, will stay on as manager of the *Ulysses* project and J.A. (Hans) Steinz has been appointed manager of the *ISO* project as of 1st January, 1987. At their December meeting, the ISO Science Team passed a unanimous vote of thanks to Derek Eaton for his work on *ISO* and wished him success with *Ulysses*.

Satellite Design

It was anticipated, during the phase A study (1981-82), that *ISO* would be launched by an Ariane 2. However, now this version will have been phased out before the time of *ISO's* launch and thus *ISO* will use an Ariane 4. This vehicle is larger and more powerful and permits some improvements and simplifications in the design. Some of the main results can be seen in figure 1. The deployable wings of the old design carrying the solar array have been removed and the solar array has been placed on an enlarged sun shield (in an IRAS-type configuration). This increase in diameter was not possible with Ariane 2 due to the size of the fairing. Ariane 4's larger fairing also allows the use of fixed rather than deployable antennas. The elimination of these mechanisms reduces the cost and increases the reliability of the satellite.

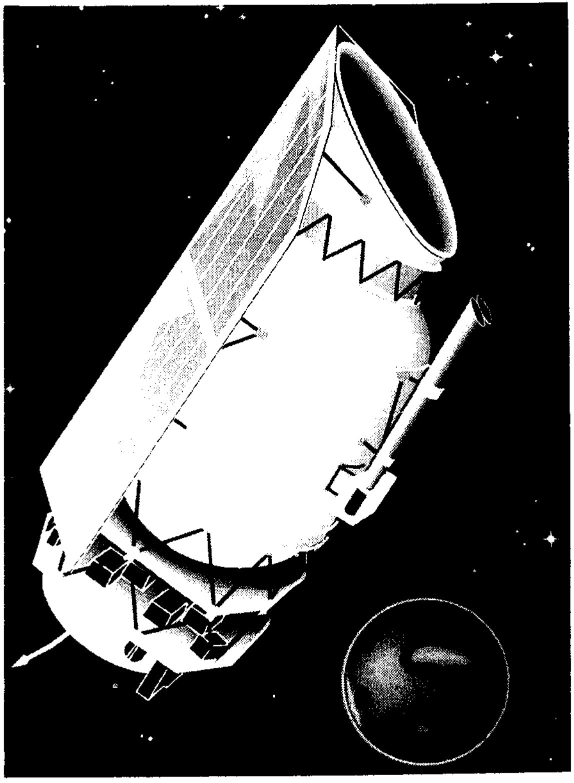

Fig. 1: Impression of ISO in orbit

The star trackers have also been moved from their phase-A location on the service module onto the side of the payload module. This leads to an improvement in the pointing accuracy of the satellite

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at the cost, however, of a slightly reduced lifetime. After endorsement by the ISO Science Team, it was decided in January 1987 to make this change.

A schematic view of the current payload module design is shown in figure 2. A small tank of normal liquid helium has been added to provide the cooling needed by the satellite during a period of up to 3 days immediately prior to launch when access to *ISO* is no longer possible after closure of the Ariane fairing. The helium tank in the cryostat cover has been deleted; the radiation shields in the cover are now cooled passively by contact to the radiation shields and main baffle in the main cryostat. For ground tests where a low photon background is needed, the cryo cover radiation shields will be further cooled by a liquid-helium flush. Two optical windows have been added to the cryo cover to permit verification of the alignment of the telescope and instruments even after they are at cryogenic temperatures.

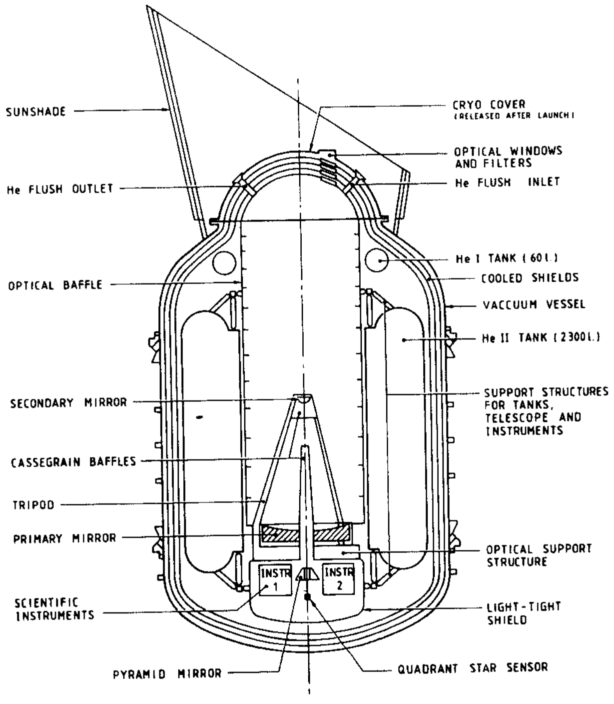

Fig 2: Schematic view of payload module

Phase B Study

The objective of the Phase B study is to define the satellite including its interfaces to the Ariane launcher in detail, to a level that will permit the commencement of hardware development and testing (Phase C/D) at the beginning of 1988. In order to be able to optimise the overall project schedule for minimum technical and financial risk, ESA decided to remove the requirement to launch *ISO* in October 1992. The launch date is now one of the parameters in this optimisation. Currently a date between late 1992 and mid-1993 is foreseen.

The Industrial Consortium for Phase-B is headed by Aerospatiale (F) as prime contractor and also responsible for the optical sub-system and sunshield. There are six co-contractors: CASA (E) for the service module structure, thermal subsystem and harness; ETCA (B) for power ; Fokker (NL) for the attitude and orbit control and measurement subsystem; MBB/ERNO (D) for the payload module; Marconi Space Systems (GB) for the reaction control sub-system; and Selenia Spazio (I) for radio frequency, data handling and service module integration. There are also seven sub-contractors: AEG (D), CAPTEC (IRL), Linde (D), ORS (A), REOSC (F), Saab (S) and Vevey (CH).

The ISO Orbit

A new, higher orbit was adopted for *ISO* in May 1987. The parameters of this orbit are: apogee, 70 000km; perigee 1 000km; inclination 5deg; and period, 24 hrs. The major advantage of this orbit is that *ISO* will spend nearly three-quarters of its time outside the Earth's radiation belts. During this time, the IR detectors will be virtually free of effects induced by the trapped protons and electrons and their sensitivity will be increased, by up to an order of magnitude in some cases. The disadvantage of the 24-hour orbit is that it requires a dedicated, and hence more expensive, Ariane 4 launcher rather than the shared Ariane 4 previously envisaged. Thus, for financial reasons, it has been decided to operate *ISO* only for the best 14 hours of each orbit using a single ground station. Due to the increased performance of the instruments, operation during these 14 hours per day will give a substantially better scientific return from the mission than from 20 hours per day of operations in the old 12-hour orbit. However, ESA is actively seeking an international collaboration to supply a second ground station so that an additional 8 hours per day of good quality data may be retrieved.

Overview of Scientific Instruments

ISO's instrument complement consists of two spectrometers (SWS, LWS), an imaging photopolarimeter (ISOPHOT) and a camera (ISOCAM). Each instrument is being built by an international consortium of scientific institutes using national funding and will be delivered to ESA for in-orbit operation. Each of the consortia is headed by a single Principal Investigator (PI), who is the formal point of contact between ESA and the instrument team. The four instruments will view separate areas on the sky and switching between them will be accomplished by repointing the satellite. In keeping with the observatory nature of *ISO*, the individual instruments are being optimised to form a complete, complementary and versatile package and two-thirds of the observing time will be available to the general astronomical community.

The next four sections concentrate on the design and status of each of the scientific instruments. The overall scientific aims of the mission and the expected instrument sensitivities in the old 12-hour orbit were given in ISO INFO No. 1. Improved sensitivity figures, resulting from the change to a 24-hour orbit will be given in a later issue.

ISOCAM

PI: C. Cesarsky, Saclay, F

The ISO camera (ISOCAM) is an instrument designed to map selected areas of the sky in the spectral region from 2.5 to 17 μm at various spatial and spectral resolutions. Polarisation mapping will also be possible. The sensitivity limitation will be mainly that imposed by the astronomical background, in particular by the photon noise of the zodiacal light. Spatial resolution will be limited by diffraction in the telescope and by the satellite pointing.

A very wide range of astrophysical problems can be tackled with ISOCAM. Examples of current interest include: a systematic search for and survey of circumstellar disks or proto-planetary clouds; a probe for dark matter in the form of low mass stars; the nature and distribution of the emitters of the "unidentified" (PAH?) infrared features; the low mass end of the initial mass function in star-forming regions; mapping interacting and starburst galaxies; and finally, there is great potential for discovery, e.g. of galaxies at high redshifts.

ISOCAM will provide imaging capability across a 3 arc min field of view with two arrays of 32 x 32 infrared detectors. Each array is mounted in one optical channel: the short wavelength channel operates in the 2.5 to 5.5 μm wavelength range with an InSb CID array, made by Sociètè Anonyme des Tèlècommunications; the long wavelength channel operates from 4 to-17 μm, with a Si:Ga direct read out array (DRO) made by LETI-LIR. Figure 3 shows the layout of the camera.

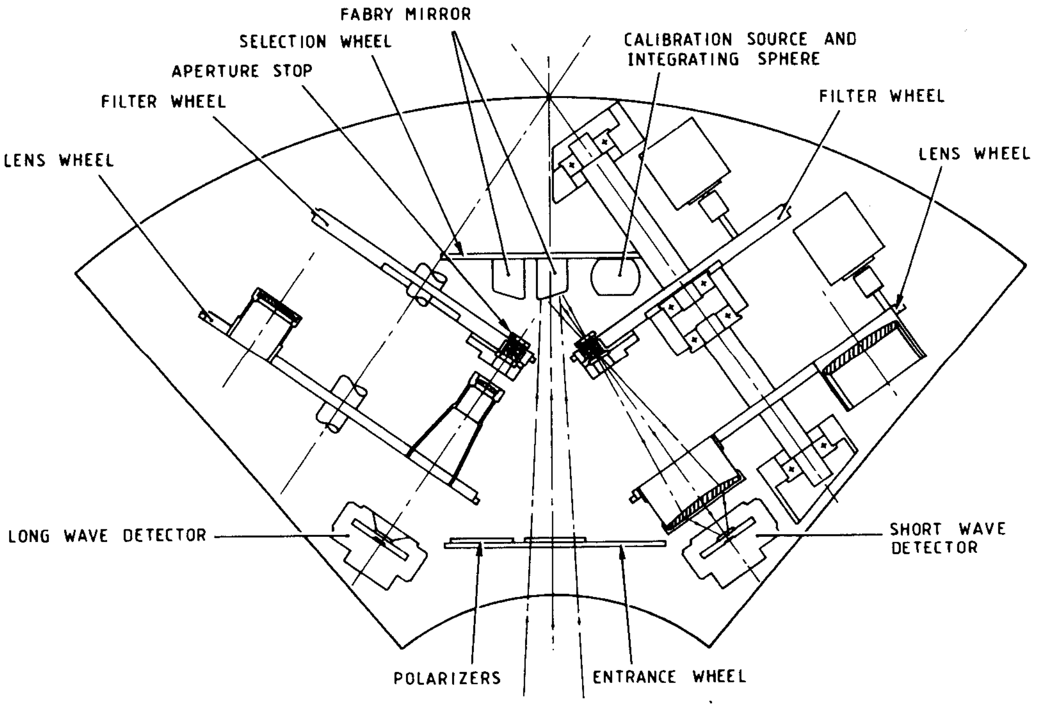

Fig. 3: Schematic of ISOCAM

Selection between the channels is achieved by two off-axis Fabry mirrors mounted on a wheel. When one mirror is in position, it reflects the telescope beam into one of the channels. The other mirror has a symmetric off-axis angle and is used for the other channel. Only one channel operates at a time. In each channel a lens reimages the telescope focal plane onto the array. Different magnification factors for matching the fixed pixel size to the desired pixel field of view on the sky are provided by four different lenses, which are mounted on a wheel. Choices of 1.5, 3, 6 or 12 arc secs are possible, thereby determining the spatial resolution of the camera.

The spectral range of the observations can be selected in each channel by a set of about 10 fixed band-pass filters and a Continuous Variable Filter (CVF), all mounted on a wheel. The spectral resolution is about 50 for the CVF, and ranges from 2 to 100 for the filters.

Three polarising grids are mounted on a wheel ahead of the Fabry mirror in the telescope beam, and provide the possibility of polarisation measurements in either channel.

The in-flight operation of the camera requires periodic checking of the response of the detectors with a calibrated flux. The relative response of the detectors will be measured using a uniform source, namely the output aperture of an integrating sphere illuminated with a small thermal source. The sphere is mounted on the same wheel as the Fabry mirrors; in operation, its aperture matches the field of view of the camera in the telescope focal plane. The absolute calibration will rely on observations of selected standard stellar sources.

The on-board electronics controls the readout of the arrays and the configuration of the camera: including selection of channel, filter, pixel field of view and flat fielding source. When the camera operates as the prime instrument, all the frames of data, or pictures, will be transmitted to the ground where the image processing is performed.

The camera will also be used, in one fixed configuration, to observe in parallel when another instrument is being operated in one of its prime modes.

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ISOPHOT

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The scientific targets of the imaging photopolarimeter include solar system objects, like distant comets before activity has developed, the search for invisible matter, and the most distant galaxies in the universe. Spectrophotometry, polarimetry and mapping will be used to investigate the origin, composition and distribution of interstellar dust grains. The diffraction-limited resolution attainable at all wavelengths will help to study the formation of low mass stars as well as the search for planetary-like rings around other stars. The investigation of interacting galaxies, star bursts in galaxies and active galactic nuclei will be possible with the unprecedented sensitivity, wavelength coverage and polarimetric capability of ISOPHOT.

ISOPHOT is composed of 4 subsystems optimised for certain modes of photometry. These are:

> ISOPHOT-P, a multiband, multiaperture photopolarimeter for the range 3 - 110 μm,
>
> ISOPHOT-C, a photometric camera for the range 30 - 200 μm,
>
> ISOPHOT-A, three linear arrays for photometric mapping in the range 3 - 30 μm,
>
> ISOPHOT-S, two grating spectrophotometers for the range 2.5 - 12 μm.

This modular subsystem concept allows a minimum of mechanisms, a compact and rigid design, and an easier interface between components developed at different institutes. By appropriate setting of only three wheels (see figure 4) a certain mode of a certain subsystem can be selected from a very large choice of useful combinations of wavelengths and apertures. ISOPHOT has a total of 215 high performance detectors, including 4 stressed Ge:Ga detectors for the unexplored 200 μm region.

The industrial development of the instrument started in December 1986. In this phase B there are two competing industrial consortia: (i) Dornier as prime contractor with Battelle and IMEC and (ii) MBB as prime with SBRC. The subcontractors will develop the Si:X-detector arrays and the cold read-out electronics. After 1 year a choice will be made between the consortia and the phase C/D will have only one contractor. In phase B both contractors will deliver a complete instrument design, the specifications and some critical hardware parts.

Doped Germanium detectors for the long wavelength camera (ISOPHOT-C) are undergoing tests and all perform as well as or better than stated in ISO INFO No. 1. Recent measurement on a stressed Ge:Ga detector (200μm camera) subjected to a simulation of the high level of ionizing radiation in the radiation belts showed large responsivity shifts. Several counter-measures are now under investigation, including (i) curing by flashing with IR laser diodes, (ii) bias boosts, (iii) more frequent calibrations. These responsivity drifts are smaller in other Ge:X detectors and are minor in the Si:X material. All detectors will be minimised in size in order to make them less vulnerable to spike noise.

ISOPHOT-P, the multiaperture, multicolour photopolarimeter has now an extended wavelength range (3 - 110 μm) gained by replacing the Si:In detector by a Ge:Ga element. The aperture of the spectrophotometer (ISOPHOT-S) has been increased to 25 arc secs in order to improve its sensitivity for extended objects while maintaining its resolution of nearly 100. A differential focal plane chopper with a beam separation of up to 3 arcmin and square wave modulation up to 10 Hz is now being studied in phase B.

ISOPHOT-C's 200μm camera will be used in a serendipity mode during large slews of the satellite. It can be expected that up to 60% of the sky will be covered with a limiting magnitude of 1 Jy, thus complementing the IRAS 100μm survey.

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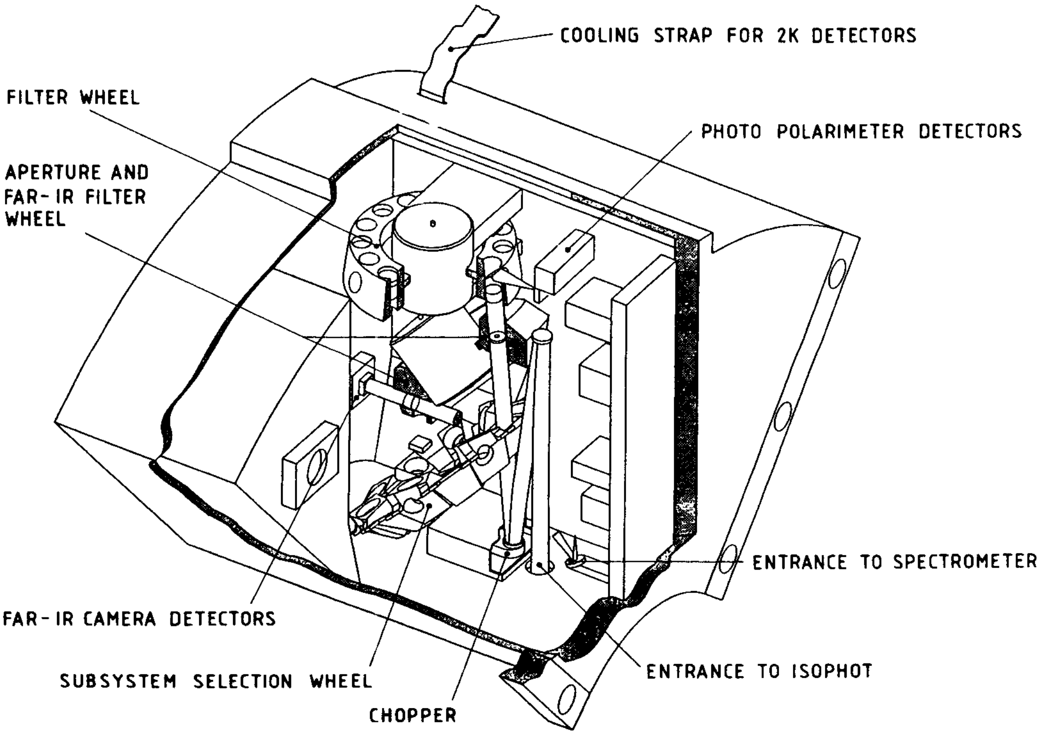

Fig. 4: Schematic of ISOPHOT

SWS

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The SWS wavelength range (2.3 - 45μm) includes numerous atomic, ionic and molecular transitions as well as diffuse features. These provide unique and excellent tools for studies of the physical and chemical processes in the universe, especially of those regions optically hidden by interstellar dust. The SWS resolving power allows probing of kinematic processes in a variety of objects ranging from nuclei of galaxies to planetary atmospheres. With the SWS sensitivity, line studies of extragalactic objects, out to distances of the Virgo cluster, can be carried out. An ultimate attempt can be made for direct observation of ground state molecular hydrogen in the interstellar medium. With the SWS over 100,000 objects are within reach for detailed spectroscopic studies including many galaxies.

The SWS is a grating spectrometer that covers the wavelengths between 2.3 and 45 μm at a spectral resolution of 1,000. A Fabry-Pérot interferometer can be used behind the grating section, to raise the spectral resolution to 20,000 in the wavelength range 15-35 μm.

The grating instrument consists of two nearly independent sections, each with its own grating. The gratings are used in their first, second and third orders. The required order separation is achieved by using three different input slits, each with its own filters, and two different detector arrays, also each with its own filter, in both spectrometer sections. For wavelengths less than 28μm, the width of the entrance slit is 14 arcsec on the sky and for wavelengths greater than 28μm, 20 arcsec.

Figure 5 gives an impression of the layout of the SWS. The IR radiation is reflected radially into the instrument by a pyramid mirror on the telescope's optical axis. The input unit contains the three entrance slits with their dichroics and spectral filters and the shutter system. Two light-paths are drawn in the long wavelength section of the instrument, one to the detector block of the grating instrument and one through one of the two Fabry-Pérot etalons. The wavelengths are scanned by rotating a flat mirror close to the grating. The scanning mirror is mounted on flexural pivots and driven by a coil in the field of a fixed magnet. The scanner design achieves an accuracy of 3 arcsec over a total range of 12 degrees. The maximum dissipation in the motor is 1 mW. The Fabry-Pérots are mounted on a pair of parallel plates. Their distance and parallelism can be varied by changing the currents in three pull coils.

The SWS will have the following detectors for the grating section:
12Si:In for 2.4-7μm   12Si:P for 12-28μm
12Si:Ga for 7-13μm   8Ge:Be for 28-45μm
and for the Fabry-Pérot section:
2Si:P for 15-25μm   2Ge:Be for 25-35μm

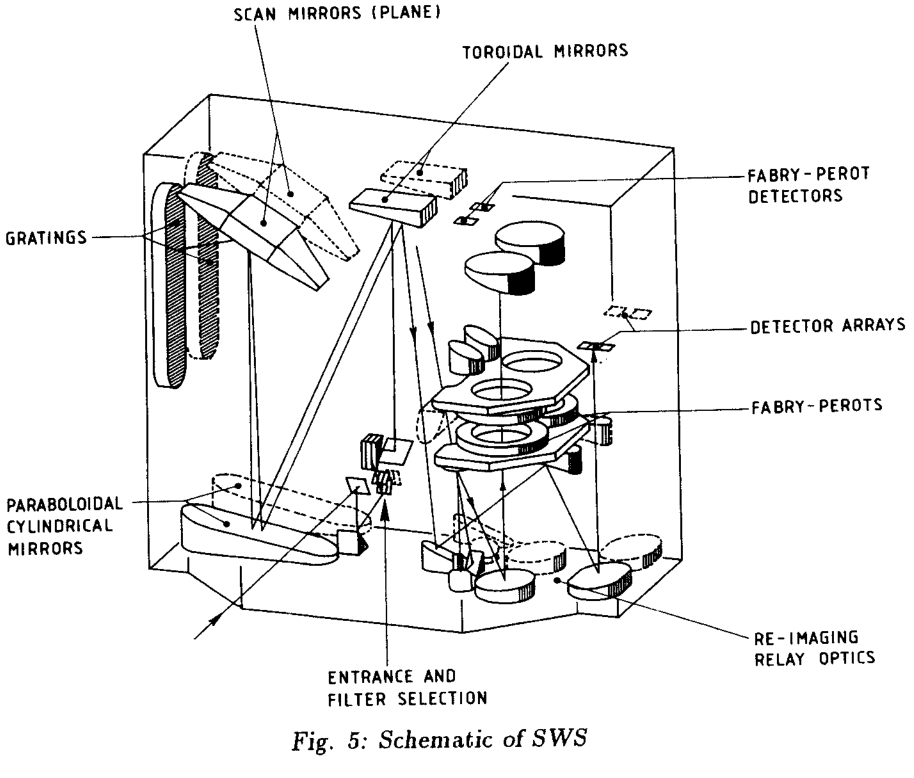

Fig. 5: Schematic of SWS

The silicon detectors may be heated to a few degrees above their 3.5K environment; the germanium detectors will be cooled by a thermal conductor to the 2 K cryostat heat sink. The likely supplier of the detectors is the Batelle Institute in Germany. The detectors will be delivered as arrays without read-out circuitry. The detectors will be used with integrating pre-amplifiers with non-destructive read-out, employing heated JFET's.

The general status of the instrument development is very satisfactory. Read-out noise levels as low as 15 electrons have been achieved so far. The overall structure is already being cut with a numerically controlled milling machine. The detailed design of the mechanisms, calibration sources, Fabry-Pérot etalons, detector block etc. will be presented at a design review meeting in September 1987. Particularly encouraging are the results of the vibration tests of the grating scanner mechanisms with flexural pivots.

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The Long-Wavelength Spectrometer (LWS)

PI: P. Clegg, Queen Mary College, London; GB

The LWS covers the wavelength range 45 – 180μm in which the bulk of the energy emitted by interstellar and protostellar clouds is radiated. This energy is emitted (i) in the form of continuum radiation from dust particles whose Planck maxima correspond to temperatures in the range of about 20-100K; and (ii) in the form of discrete emission lines from atoms, ions and molecules whose energy levels can be easily excited at the gas kinetic temperatures characteristic of the cool, shocked or ionised phases of such material. LWS far-infrared spectroscopy is a unique probe of the bulk of interstellar and protostellar matter, which is cool and often highly obscured at shorter wavelengths. The instrument will be used to study: the processes by which stars are formed and evolve; the dynamical and physical properties of the interstellar medium; the global interactions between these two components and the way they determine the properties and structures of galaxies.

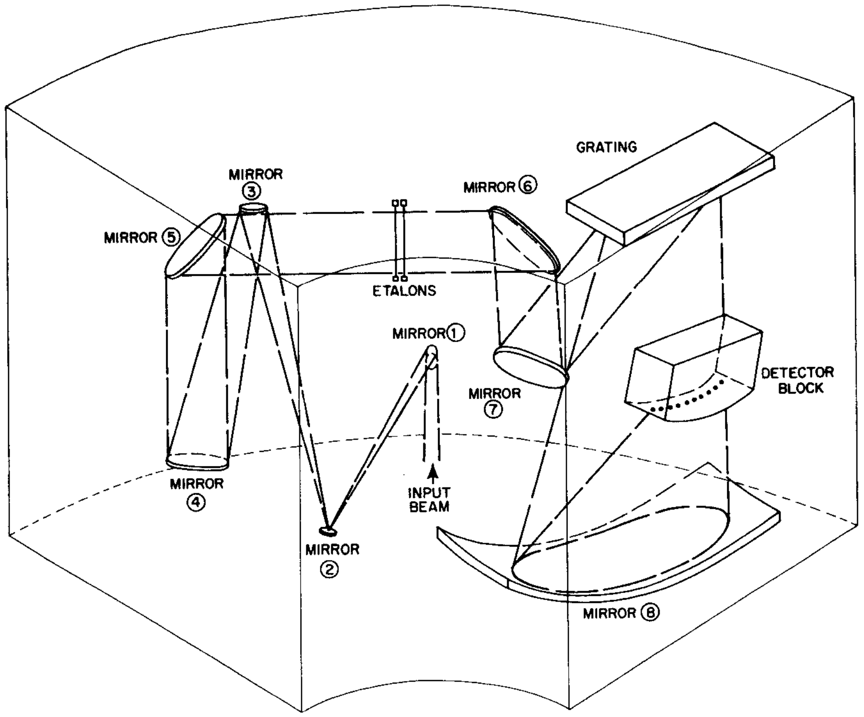

Fig. 6: Schematic of LWS

Essentially the LWS (figure 6) is a grating spectrometer providing a spectral resolving power of about 200 from 45 μm to 180 μm. Fabry-Pérot Interferometers can be inserted into the optical train to boost the resolution to 10,000 across this entire wavelength range. In the lower resolution mode, the input beam from the telescope encounters folding and collimating optics (mirrors M1 to M6), with the FP assembly set so that the beam passes through a clear aperture to illuminate the plane grating. The grating is used both in first and second orders. The infrared is brought to a focus along a line matching the surface of the detector assembly via the refocusing mirror M8. Detector apertures are placed along this focal surface with filters to separate the two grating orders, so that each detector samples a limited range of wavelengths. In all, there are 10 detectors so that the spectral range is sampled at 10 wavelengths forming a crude spectrum. In practice, a more detailed spectrum is obtained by sampling the outputs from the various detectors with the grating rotated in steps through a few degrees. A complete spectrum is given when the spectral range falling on one detector just overlaps with that of its neighbours. The high resolution mode is established when the F-P assembly is rotated so that F-P1 or F-P2 intercepts the collimated beam. F-P1 is optimised for wavelengths 45 to 90μm and uses the grating in 2nd order, whilst F-P2 covers 90-180μm in conjunction with the grating in 1st order.

The LWS can be operated under software control in a variety of modes. Two main modes of operation are envisaged: firstly, Fabry-Pérot mode in which a high resolution spectrum is obtained by using the F-P/grating combination and secondly, grating mode which gives a medium resolution spectrum using only the grating. Within these modes, various selections can be made depending on the way that the detected signal is modulated. These choices include: "rapid scanning", in which a spectrum, or part of the spectrum will be scanned sufficiently fast that the information in the continuum spectrum is preserved; and "frequency switching", in which the instrument will be switched rapidly between two spectral points, for example between the centre of a line and the nearby continuum. The difference between these two signals will be taken on the ground. This will certainly be possible in the Fabry-Pérot mode and may be possible in the Grating mode.

It is expected that the LWS (which uses detectors with an intrinsic NEP close to 10^{-17} W/$\sqrt{Hz}$) will only be photon-noise limited when the very brightest astronomical sources are examined, and then only in the 'grating mode'.

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Vacant Scientific Positions with ISO

For *ISO*, ESA is seeking scientists with Ph.D or equivalent in physics or astronomy with experience in instrument development and/or observational astronomy, preferably but not essentially at infrared wavelengths. Such staff would, under the direction of the ESA project scientist, support the development and use of *ISO*'s scientific instruments. During the development and test phases, they will liaise with the PI-led instrument teams to help ensure that the instruments fulfil their scientific objectives and also meet the needs of the astronomical user community. During the operational phase, such staff will be members of the scientific team at the operations centre and will be involved in all aspects of the *ISO* observational programme, including data reduction, calibration and analysis. Further details may be obtained from the project scientist, Martin Kessler, either by phone (1719 83623) or at the address below.

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