OBSERVATIONS OF DIFFUSE IR BACKGROUND RADIATION BY IRTS AND IRIS

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1. Introduction

Diffuse background radiation is integrated light which is consisted of various components of intrerplanetary, stellar, interstellar, galactic and intergalactic origins as well as cosmic background radiation, the remnant of the pre-galactic phenomena in the early history of the universe.

Observations of these radiations have been made by variety of techniques in various ranges of wavelengths. Since the discovery of the microwave background radiation by Penzias & Wilson (1965), particular attention has been paid to the observations in submillimeter and millimeter ranges. These observations was culminated by the launch of COBE satellite, in which the FIRAS provided a complete and precise spectrum of the 3K emission (Mather 1994), and the DMR gave the first indication of the presence of anisotropy in the radiation (Smoot 1994), while the DIRBE has provided sky maps of various wavelength bands from near infrared to far infrared (Hauser 1994).

The observed intensties are, however, mixture of radiations of different origins and their separation is not straigtfoward but needs complicated and tedious procedures.

For better segregation of the different components and more comprehensive understanding of the diffuse background radiations, we are planning two space missions to observe the diffuse background radiations in infrared regions. Here we address briefly on the two missions, a currently ongoing mission IRTS and a future plan IRIS.

M. Kafatos and Y. Kondo (eds.), Examining the Big Bang and Diffuse Background Radiations, 117–124.

2. IRTS (Infrared Telescope in Space)

2.1. TELESCOPE AND OBSERVATIONAL INSTRUMENTS

IRTS is a small space borne telescope cryogenically cooled by liquid helium which will be dedicated for observations of diffuse emissions of galactic and extragalactic origins in infrared region. It will be launched onboard the SFU (Space Flyer Unit), a multi-purpose space platform, by the newly developed H-2 launcher in early 1995 and retrieved by Space Shuttle after the mission completes. IRTS has a telescope with an aperture of 15cm and F.O.V.s of sub-degrees. It has four types of focal plane instruments. Typical characteristics of each instrument are summarized in Table 1. NIRS (Near

TABLE 1. Major characteristics of the focal plane instruments on IRTS

	NIRS	MIRS	FILM	FIRP
Optical system	grating	grating	grating	filters
Wavelength coverage (μm)	1.4 – 4.0	4.5 – 11.7	63([O I]), 158([C II]) 155, 160 (cont.)	140, 230, 400, 700
Resolution ($\Delta\lambda/\lambda$)	15 – 30	20 – 30	400	3
Beam size	$8' \times 8'$	$8' \times 8'$	$8' \times 13'$	$30'$
Detector	InSb ×24	Si:Bi ×32	Ge:Ga ×1, stressed ×3 Ge:Ga (stressed) ×3	0.3K bol. ×4

IR Spectrometer) and MIRS (Middle IR Spectrometer) are grating spectrometers with medium resolution ($\lambda/\Delta\lambda$) of 15 ~ 30: both have a higher spatial resolution (0.1° ~ 0.2°) than COBE's DIRBE. FILM (Far IR Line Mapper) is a grating spectrometer specifically designed for measurements of [O I] (63μm) and [C II] (158μm) lines. FIRP (Far IR Photometer) is a multi-band photometer incorporated with bolometers highly sensitized by cooling down to 0.3K with a ^{3}He refrigerator. The spatial resolution is substantially higher than FIRAS and a little better than DIRBE in COBE. The technical details of the instruments are given in the series of papers published in ApJ vol.428, No 1, (Murakami *et al.* 1994).

The sensitivity limit of each instrument estimated from the laboratory calibrations are displayed in Fig 1.

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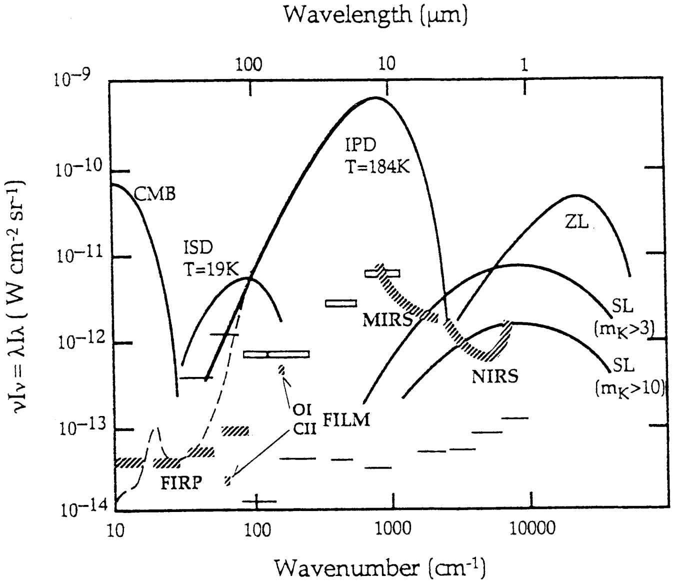

Figure 1. Observational limits of the focal plane instruments of IRTS. Those of COBE DIRBE (thin line) and FIRAS (dashed line) as sell as of IRAS (rectangular box) are also shown for comparison.

2.2. OBSERVATIONS BY IRTS

The SFU will be sent to a circular orbit with an altitude about 450km and an inclination of 28°. The telescope axis is pointed almost perpendicular to the sun's direction and rotated once a revolution of the SFU synchronized with its orbital motion so as to keep off the earth's radiation. Accordingly, it will make a continuous survey of the diffuse radiation along a great circle of the sky. The four focal plane instruments work together and provide spectroscopic information of the diffuse radiation in a wide range of wavelengths simultaneously.

The NIRS will be used for observations of spectroscopic features of diffuse emission between 1.5μm and 4.0μm. By the rocket observations, Nagoya group has detected an excessive emission in this region which is unexplanable simply by the summation of zodiacal light and integrated light of stellar component in the Galaxy (Noda *et al.* 1992). The same level of the emission has been also detected in the observation by DIRBE of COBE (Mather *et al.* 1990). The observed results by the rocket as well as by the COBE's DIRBE are shown in Fig. 2 together with the observational limits of the NIRS. The high sensitivity of the NIRS would reveal detailed characteristics of the emission features and its spatial variation.

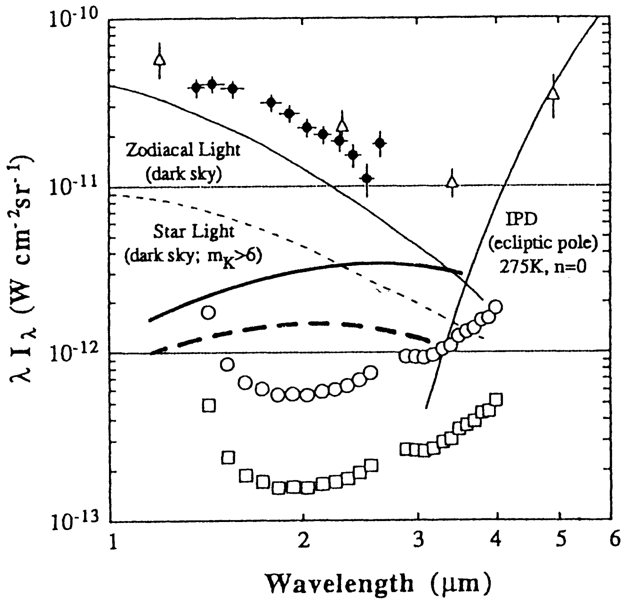

Figure 2. The observed results of near infrared diffuse radiation by the rocket (solid dots, Noda *et al.* 1992) and COBE (open triangles, Hauser 1994). The intensity levels of the theoretical prediction for integrated light of primeval galaxies (Yoshii & Takahara 1988) are also shown by thick solid line (evolutional) and dashed line (non-evolutional). The detection limits of NIRS are indicated by open circles (1F.O.V., 1σ) and by open squares (10sec, 1σ)

Whether the extragalactic component is really present or not should be subject to assessments of the foreground emissions. The better spectroscopic information would be useful for more reliable assessment of the foreground emission. The narrower beam size is certainly advantageous to remove the contribution of stellar light. Stars brighter than 10 mag can be easily removed in the observation. A great number of spectroscopic samples of the galactic stars shall be collected in the course of the survey. They will give a valuable data to estimate the average spectrum of integrated stellar light, which should help better evaluation of the contribution of stellar light.

The MIRS covers the wavelength region between 7 $\sim$ 14μm. This is the best region to study the infrared emission of dust particles, particulaly hot dust (PAH) component in interstellar space which has many characteristic peaks in mid IR region. It also covers the typical spectral band structures of silicates and silicon carbide, which should be present in the interplanetary dust emission. The MIRS will therefore provide very valuable information to assess the contribution of interstellar and interplanetary dust emissions.

The FILM will be used for observations of [O I] (63μm) and [C II] (158μm) lines, mostly of interstellar origin. It is sensitive to very low level emission as cirrus component and thus the observation would be useful for evaluation of the contribution of interstellar dust emission. This is important to check genuine features of the observed anisotropy in extragalactic background emission which is one of the major objectives of the FIRP.

The FIRP is the most relevant channel for observations of cosmic background radiation as well as low temperature component of inerstellar dust emission which has been found in the COBE FIRAS observation (Wright *et al.* 1992). The detection limit of the FIRP are considerably better than those of FIRAS and DIRBE for far IR channels. The FIRP has a much higher angular resolution than FIRAS and thus it would be able to make deeper search for anisotropies with higher harmonics. It is very interesting that the beam size is just matched for detection of the anisotropy with the similar angular scales where the recent balloon observations claim the presence of anisotropy (Lubin 1994).

The beam size of sub-degrees is a little too large for detection of Sunyaev Zeldovich effect, but could afford a possibility of its detection for relatively large clusters of galaxies or superclusters. The spectral modulation is amplified in the submillimeter region of the Wien side of 3K blackbody spectrum and hence its detection could be easier than the radio wavelength regions so far made by the balloon observations.

The wavelengh bands spreading between 100μm and 800μm are well fit for study of the low temperature dust emission. The higher spatial resoluion and the better detection limit would provide more detailed information on the low temperature dust component than the observations by COBE.

It is a little regret that due to the constraints of sharing of the mission with many other experiments on SFU, the observational period is limited in about three weekes and only about 10% of the sky shall be covered.

3. IRIS (Infrared Imaging Surveyor)

3.1. MISSION CONCEPTS

As an advanced mission following the IRTS, a full scale mission called IRIS is under planning. IRIS will be launched by the new launcher called M-V under development in ISAS. The launching capability of M-V is relatively small; about 1 ton satellite can be sent into a polar orbit at an altitude of about 700km. Under this constraint, we are planning to make survey type observations with a simple instrument and by a simple operation. Although limited in variety of functions, the simple mission could more easily achieve high efficiency and better coordination of observational programs. Moreover, we are planning to maximize its capabilities by introducing new and state of the art techniques in the mission design; mechanical coolers of two-stage Stirling type will be used for better shielding of the liquid helium tank from external heat. As a result, we could accomodate a telescope as large as 70cm in a small and light-mass cryostat. The recent progress of array detectors particularly in near and mid infrared regions would allow to use large format array detectors, which could make it easy to achieve quick and efficient survey in wide areas of the sky.

As the focal plane instrument, two types of observational instruments are under consideration. One is Near/Mid infrared camera with large F.O. V.s, but with fine spatial resolution (2" $\sim$ 5") using large format array detectors. The other is far infrared scanners with multiple bands (3 $\sim$ 4) using one dimensional composite arrays of many single detectors. The general characteristics of the focal plane instruments are summarized in Table 2. Combined with the 70cm telescope, the detection limits of the observations are estimated and illustrated in Fig. 3. They are compared with the intensity levels of some typical targets to be observed.

TABLE 2. Observational instruents on IRIS

	Near/Mid IR Camera		Far IR Scanner	
F.O.V.	$16' \times 16'$		$8' \times 8'$	
Image	2" – 5"		15" – 45"	
Detectors	InSb (3–5μm)	1024×1024	Ge:Be (40–60μm)	32×2
	SiAs (6–25μm)	$(256 \times 256) \times 3$	Ge:Ga (70–120μm)	24×2
			Ge:Ga (120–200μm) (stressed)	12×2

3.2. OBSERVATIONS BY IRIS

The IRIS is basically designed for survey works with variety of different wavelengths. The surveys are classified into two modes; one is pointing mode, fixing the telescope at a selected direction for relatively long time (maximum 15 min is available in the 900km orbit) and the other is scanning mode, drifting the telescope continuously with the orbital motion. The former is mostly applied to the Near/Mid IR observations and the latter to the Far IR observations.

The followings are typical observatons of each mode;

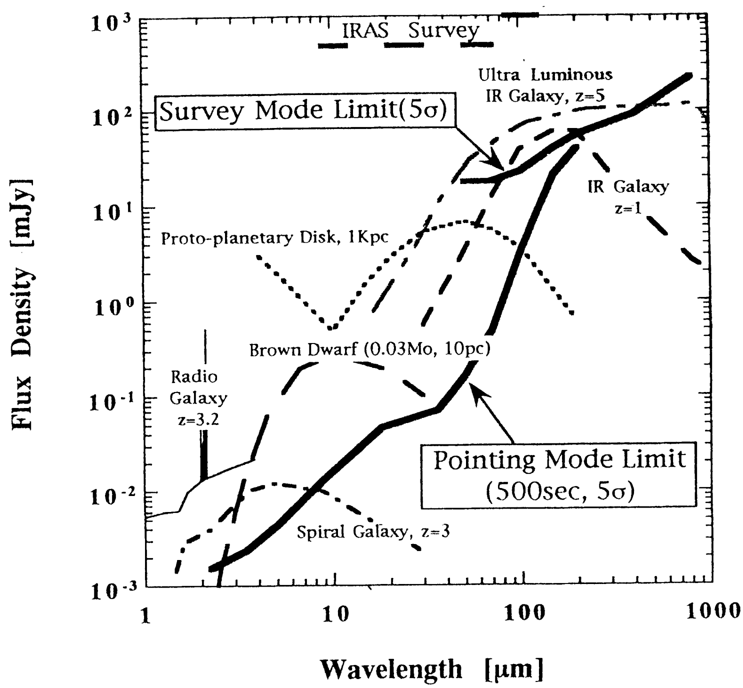

Figure 3. The detection limits of the pointing mode survey and the scanning mode survey. The intensity levels of typical target sources are given for comparison.

1) Observations by Near/Mid IR camera – pointing mode survey

One of the major objectives of the Near/Mid IR survey is a search of primeval galaxies or formation process of normal galaxies in the early history of the universe. Such surveys have been tried from the ground in optical and near infrared regions (Tyson 1988, Cowie *et al.* 1990), In spite of their extensive efforts, however, no evidence has been found yet. This may be explained as due to extinction by dust which should be strong in optical and next infrared regions. If it is the case, observaitons in longer wavelengths should be effective. It can be shown that a primeval galaxy with a moderate luminosity ($10^{12.5}L_{\odot}$) located at cosmological distrance (z$\sim$ 3) could be easily found by our survey. The wide range of the wavelength coverage would be useful to identify the observed sources. Among the detected sources, there may be contained brown dwarfs on extra-solar planetary systems. This is another objectives of our survey works with great interests. If we could make such a survey even in relatively small area of several square degrees, substantially large number of the sources should be sampled and used for statistical studies.

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2) Observations by Far IR Scanner – scanning mode survey
This observation will be made in scanning mode, that is a continuous sweeping of the sky with one-dimensional arrays. Thus the integration time should be relatively short (0.1sec), but the detecton limit would be improved by an order of magnitude compared with IRAS. The wavelength coverage will be expanded to 200μm. The observation would extend the IRAS survey to much deeper space and fainter sources in the number count of IR galaxies as made by Hacking *et al.* (1987). This would evidently distinguish different models of galaxy evolution in the early history universe.

There have been found extremely luminous object in the IR galaxies such as F10214+4724 or F15307+3252. If such objects prevail to farther distances or earlier phase of the history of the universe, many other sources could be found even at longer distances, $z = 1 \sim 5$. The total number of detectable sources would be of the order of 10^4 for z> 1 and 10^2 for z> 3 $\sim$ 4 in the full sky survey. A great number of active galaxies as Q.S.O. and Seyfert should be sampled. They would provide valuable data to trace their evolutional trend as well as large scale structure in their distribution.

Both observations by the Near/Mid IR camera and the Far IR scanner should provide cruicial information for studies of formation and evolution of normal galaxies as well as active galaxies and their genetic relation. Large and systematic samplings of the sources would provide the data to assess the contribution of discrete sources to the diffuse background radiation and check whether it is explained solely by the sum of discrete sources or genuinly diffuse component should be left.

The IRIS has been proposed for a scientific mission following the X-ray mission ASTRO-E which is scheduled to be launched in 1999. If it is successfully approved, the IRIS should be launched in early 2000's. A collaboration and coordination with SIRTF mission is under discussion with US groups.

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