# OLBERS
# AN INTERPLANETARY PROBE TO STUDY VISIBLE AND INFRARED DIFFUSE BACKGROUNDS

## *An answer to the Call for Mission Concepts for the ESA Follow-up to Horizon 2000*

F.-X. DÉSERT
*Institut d'Astrophysique Spatiale*
*Bât. 121, Université Paris XI,*
*91405 Orsay Cedex France*

**Abstract.**
The visible extragalactic background (though as yet undetected) is insufficient to explain the abundance of heavy elements in galaxies: either there should be some diffuse extragalactic light in the near infrared (from 1 to 10 $\mu$m) and/or in the far infrared ($\geq 100\,\mu$m) if dust has reprocessed the star light. We propose a new space mission to be dedicated to the search and mapping of primordial stellar light from the visible to the mid-infrared (20 $\mu$m). In this spectrum range, detectors have reached such a sensitivity that the mission should aim at being (source) photon noise limited, and not any longer background photon noise limited. For that purpose, a small passively cooled telescope with large format CCDs and CIDs could be sent beyond the zodiacal dust cloud (which is absent beyond a solar distance of about 3 AU). In that case, the only remaining foregrounds before reaching the extragalactic background, is due to the Milky Way integrated emission from stars and the diffuse galactic light due to scattering and emission by interstellar dust, which are all unavoidable. Maps of the extragalactic light could be obtained at the arcminute resolution with high signal to noise ratio. This mission is the next logical step after IRAS, COBE and ISO for the study of extragalactic IR backgrounds. It has been proposed as a possible medium-sized mission for the post-horizon 2000 ESA program that could be a piggy back of a planetary mission.

**Key words:** Visible and Infrared diffuse backgrounds

## 1. Scientific Objectives

### 1.1. INTRODUCTION

The measurement of the sky brightness has been a long standing problem. Wilhem Olbers (1758-1840), among others like de Chéseaux in 1744, noted in 1826 that it was paradoxical that the night sky was so dark. The solution of the paradox is still not completely settled though ground and space-based astronomy has put it on firm quantitative grounds. Elements of the solution include: interstellar dust clouds (blocking UV and visible light), finite size of the Milky Way, expansion, finite speed of light, and finite lifetime of the Universe as a whole (see Harrison, 1987). Indeed, modern instruments can easily pick up backgrounds from gamma to radio wavelengths. One aspect of the problem we are mainly concerned here with is the search for light

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from stars in primordial galaxies. A major question of visible and infrared extragalactic astronomy is to know how and when the heavy elements like carbon, oxygen, nitrogen, etc. (that cannot have been made in the Big Bang nucleosynthesis) got made as we can see in present galaxies. The answer so far is that the visible extragalactic background (though as yet undetected) is insufficient to explain the heavy elements: either there should be some diffuse extragalactic light in the near infrared (from 1 to 10 $\mu$m) or/and in the far infrared ($\geq$ 100 $\mu$m) if dust has reprocessed the star light.

### 1.2. GENERAL GOAL OF THE MISSION

We propose a new space mission to be dedicated to the search of primordial stellar light from the visible to the mid-infrared (20 $\mu$m ). In this spectrum range, detectors have reached such a sensitivity that the mission should aim at being (source) photon noise limited, and not any longer background photon noise limited. The IAU symposium Nr 139 shows the current knowledge on galactic and extragalactic backgrounds. The consequences of this goal are as follow: the airglow from the Earth atmosphere gives such a foreground that the mission has to be in space. Figure 1 shows the sky brightness observed from space at various wavelengths. The next foreground is due to interplanetary dust: below 5 $\mu$m it produces a strong scattering of solar light and above, it thermally emits a dominant foreground. We think that it is now within current technological possibilities to envision a small telescope being sent beyond the zodiacal dust cloud (which is absent beyond a solar distance of about 3 A.U.). In that case, the only remaining foregrounds before reaching the extragalactic background, are due to the Milky Way integrated emission from stars and to diffuse galactic light due to scattering and emission by interstellar dust, which are all unavoidable (continuous curve in Figure 1a). The study of galactic and extragalactic light is the prime target of this mission, but during the cruise from Earth to beyond 3 AU, the zodiacal light could also be studied in great detail for the first time. In order for the instrument to work at the largest throughput but with a sufficent spatial resolution to enable background fluctuations measurements, the angular resolution should be between 1 and 10 minutes of arc.

## 2. Conceptual Description

### 2.1. THE INSTRUMENT

The instrument is composed of a telescope with an estimated primary diameter of 10 to 50 centimeters. Stray ligth can be avoided by careful baffling and by using an off-axis primary mirror. A configuration with 3 mirrors like in the ground-based LITE project allows imaging of a large unaberrated field of view of several square degrees. Light is then split according to wavelength band by dichroics and/or filters and falls on various mosaics of detectors:

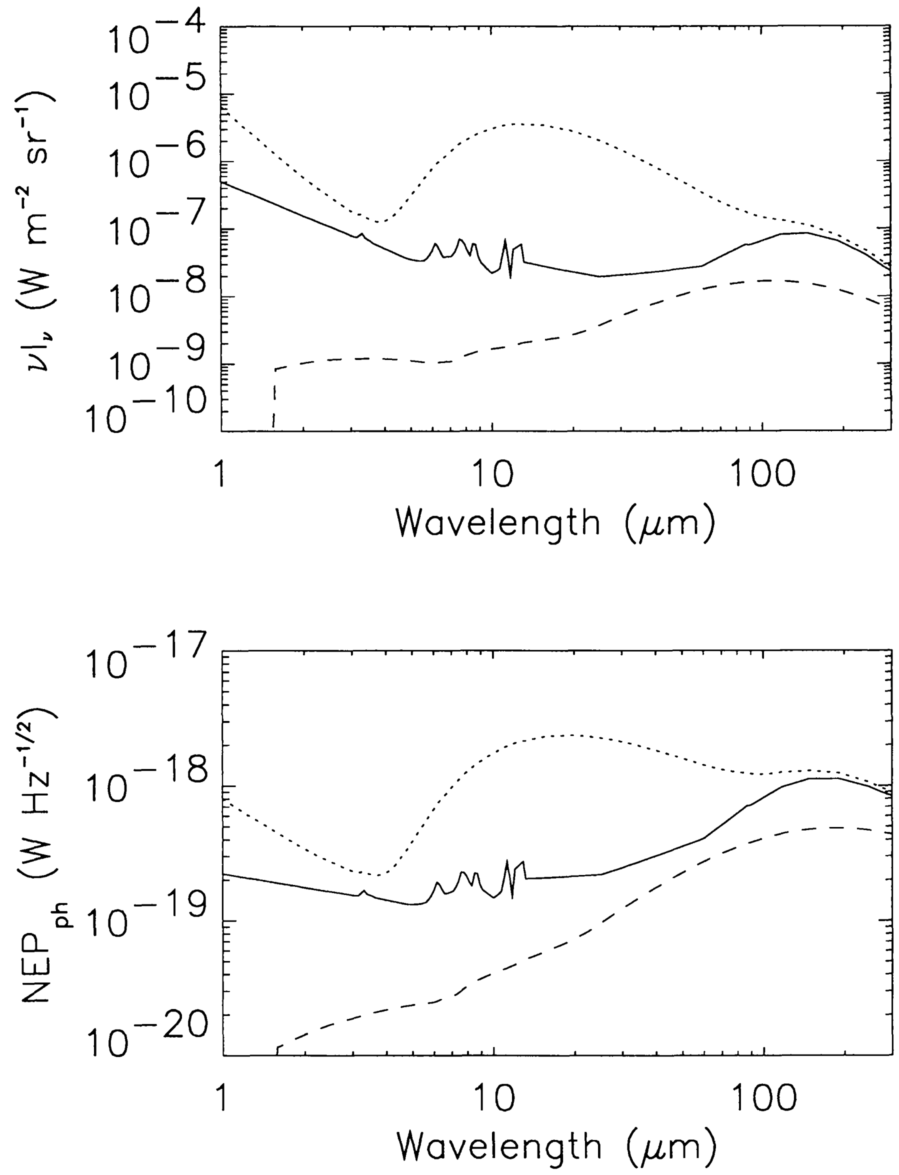

Fig. 1. a) Sky brightness at the ecliptic poles: dotted curve is the observed brightness at the distance of the Earth, continuous curve is the brightness that would be observed at a distance larger than 3 AU from the Sun, dash curve is an estimate of the sought for extragalactic background (not taken into account in the previous curves). It is expected at the $10^9$ to $10^8$ W m$^{-2}$ sr$^{-1}$ level from the visible to the mid infrared which is 10 to 100 times the expected sensitivity of the proposed instrument b) Photon noise equivalent power for an ideal detector with a spectral resolution of 4 (see Lamarre et al., this conference).

state-of-the-art detectors can have large formats (up to 512 by 512 pixels) throughout the wavelength coverage that is considered: 0.4 to about 20 $\mu$m, and which is necessary in order to subtract the galactic foregrounds and to measure the extragalactic background. One can expect that, with a careful design, passive cooling of the telescope can easily achieve 80 K just after the start of the mission, and down to 30 K or less when the distance to the Sun exceeds 3-4 AU This temperature is needed, mostly for wavelengths above 5 $\mu$m, for the telescope emission to be negligible onto the detectors. One cryocooler would allow the appropriate mid infrared detectors to work below 10 K.

### 2.2. THE VEHICLE

The studies about Rosetta (ESA third cornerstone) has shown the feasability of platforms delivering large power even at large distance from the Sun and having good pointing stability. The requirement (15 seconds of arc) is met by Rosetta and future planetary missions. The proposed instrument could therefore be added to one of the future outer solar system missions and be used during most of the cruise to the planets.

### 2.3. EXPECTED SCIENTIFIC RETURN

The mission can be programmed in two parts: a shallow survey covering most of the accessible parts of the sky and deep surveys near the ecliptic poles. Accurate and fully calibrated maps of the sky at visible and infrared wavelengths would be the starting data for a full analysis of the contributions of the various foregrounds and backgrounds. Combined with point source catalogues made by ground-based telescopes (e.g. digitised Palomar plates and K-band surveys like DENIS), one could extract the galactic and then extragalactic components from these maps. Simple calculations show that sensitivities of 0.3 to 0.03 $\mathrm{nW\,m^{-2}\,sr^{-1}}$ can be achieved for one pixel (in typically one hour, one $\sigma$) which is 10 to 100 times less than the expected extragalactic background (and 1000 times better than IRAS at 12 $\mu$m). Detailed studies of the fluctuations of this background seem therefore possible. The mid infrared part of the instrument is essential to study the interstellar dust emission in order to obtain the extragalactic NIR background by substraction. We think that the instrument should work in a survey mode (like IRAS) from a pre-defined planning by a dedicated scientific team.

## 3. Technology status

This mission can be achieved with existing space-qualified off-the-shelf technology. The modern detectors: CCDs for the visible, NIR detectors (InSb...) and BIB arrays for the longer wavelengths have now a very low readout noise (less than 50 electrons) required by the mission. They are thin enough to be the least sensitive to cosmic rays and they have low dark current levels so that integration times can be of few to 20 minutes. The main limit then comes from the photon noise as estimated in figure 1b. Cryocoolers (BAe) are now available with low weight and consumption. Passive cooling of telescopes has been thoroughly studied by space agencies and should be possible at the required level.

## 4. Relation to existing or planned space and ground systems

The "pioneering" experience similar to what is proposed here was the IPP instrument on board Pioneer 10 (Hanner et al., 1974, Soberman et al., 1974), with a field of view of about 2 degrees and 2 channels in the blue and red. It showed that the interplanetary dust is within 2.8 AU from the Sun and measured with some accuracy the brightness of the Milky Way and put some limits on the visible extragalactic background at less than 6 $\mathrm{nW}^{-2}\,\mathrm{sr}^{-1}$. Other related projects are the IRAS then COBE (DIRBE) satellites which mapped the sky in the infrared range (resp. 1 and 40 minutes of arc of resolution). The problem of giving accurate values of the background can be pinned down to the difficulty of modelling the zodiacal emission and scattering accurately enough. Even if a subtraction method can work, the end result of these missions will be an estimate of the extragalactic background with no analysis (as we propose) of the background fluctuations. The same can be said of any measurement by HST or Hipparcos. The proposed mission is a parallel of SAMBA, a proposal of a medium-sized satellite (submitted to ESA) to measure the fluctuations of the 3 K cosmic microwave background as accurately as measured by COBE on large scales: if the experiment DIRBE on COBE gives a value of the near infrared background, the next logical step is to study its structure. The Japanese team lead by T. Matsumoto has launched rockets to make a low resolution spectrum of the NIR background light. They plan longer integration observations with the IRTS telescope on the SFU Japanese satellite (1995). They will cover one modest beam of 8 $\mathrm{arcmin}^2$ at a time. Their rocket measurements are difficult to interpret because of the contribution of the zodiacal light. The near infrared catalogue of point sources that will be done with ISO and K-band ground based surveys (e.g. DENIS) will be used to remove their contribution to the diffuse backgrounds. Note that ISO and DENIS may not be able in their deepest surveys to observe objects individually if their redshift is large ($\geq 2$) but these objects may contribute substantially to the extragalactic background and its fluctuations measured by our proposed instrument (see e.g. Boughn et al., 1986).

## 5. Mission requirements

The requirement of the lowest possible foregrounds implies to put the instrument on a space probe on cruise to distant planets of the solar system. A lifetime of over 5 years would mean a large sky coverage. Stability and pointing can be achieved if the instrument is installed on a planetary mission of the Rosetta type. The power consumption is estimated at 120 W for the cryocoolers and 40 W for the electronics and detectors (Bradshaw et al. this conference). One should then include the consumption for the control of the platform attitude and the telemetry. Assuming a compression ratio of 5 and data transmission rate of 10 kbit/s (available with Deep Space Network), several 10-20 minutes integration large format images can be sent back to Earth. The instrument, if considered as a "piggy back" experience, should be well within a medium-sized mission financial envelope. The project still needs a complete feasability study. Yet it is a mission concept which is within current technological and financial possibilities. There are many European space laboratories that could collaborate on this project which is quite different from other space probes and satellites in that it would give original results unreachable with other concepts.

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