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Submillimeter Space Telescope Project "Submillimetron"

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Abstract

The Submillimetron is the international project of the space telescope for full sky survey in submillimeter region 0.15 - 1.5 mm using facilities of the Russian segment of the International Space Station (ISS). A free flying module for the project is under development in corporation Energia. Periodic docking of the module to the ISS gives possibility to combine low cost with reliability, refilling, repairment and maintenance. The concept of the telescope combines a 0.6 m mirror cooled to liquid helium temperature with a novel type of microbolometers arrays developed at Chalmers University (Sweden). This combination gives unique possibility to realize background limited sensitivity about $10^{-18} W/Hz^{-1/2}$ in the spectral minimum of the extraterrestrial background near frequency 1 THz between peaks of galactic dust emission and CMB. The angular resolution of the instrument is about 1 arcmin, field of view $\sim 1^{\circ}$.

1 INTRODUCTION

The initiator of the project Submillimetron is the Astro Space Center (ASC) of the P.N. Lebedev Institute of the Russian Academy of Sciences [1, 2]. Early submillimeter research in ASC [3–9] was supported by Josif Shklovsky and Iakov Zeldovich. Great assistance to submillimeter space developments in ASC was made owing to collaboration with Guy Serra and his French colleagues. The Submillimetron, other current space projects [10, 11] and ground-based instruments [12–14] of ASC are connected by common approach in technology and science. Feasibility study of the project was conducted in S.P. Korolev Rocket Space Corporation Energia (RSCE) [15] and approved by the Russian Space Agency as international experiment. It is planned for free-flying module on the 2-d stage of ISS realization following to the deployment stage. Main part of international cooperation in the project is a development of high-sensitive detectors [16, 17] in Chalmers University of Technology, Sweden [18]. A wider participation in the project is at discussion. Particularly the use of cryogenics and optical technologies developed for similar scale infrared-submillimeter telescopes IRAS [19], ISO [20] and ODIN [21,22] should sufficiently cut down a development time. Combining this experience with unique space technologies of RSCE promises a cardinal cost reduction in comparision with other submillimeter missions of ESA and NASA.

All internet addresses referenced here are collected on page http://fy.chalmers.se/~f4agro/GS2001.htm

2 PROJECT SUBMILLIMETRON

Distinctive features of the project are: submillimeter-wave spectral region 0.15 - 1.5 mm, cryogenic telescope, antenna-coupled bolometer, and using of the International Space station (ISS) facilities. Important difference from current submillimeter ESA projects is cryogenics optics. It permits to realize background-limited sensitivity in region of minimum of extraterrestrial background. Figure 1 b shows its spectrum calculated in [23] using data COBE [26]. Radiatively cooled mirrors of telescopes Hershel [24] and Planck [25] have thermal radiation exceeding extraterrestrial background. Data for these instruments and far-infrared telescopes IRAS [27], ISO [28], SIRTF [29], and IRIS [30] are also shown on figure 1 scaled to common integration time 1 s for comparision with estimates of Submillimetron telescope sensitivity, which made for primary diameter D=0.6m, temperature T=5K and bolometer $NEP = 10^{-18} W/Hz^{-1/2}$ in [23]. This sensitivity of detectors is close to fundamental limit determined by background fluctuations [6]. It should be realized using superconducting nano-technologies [16, 17, 31]

Objects of early Universe are sufficiently redshifted, $z > 1$. So an infrared peak dominating in spectra of active galaxies is displaced into submillimeter region. As much as one third of the total luminosity is emitted in this region. Full-sky survey will provide number counts, photometric redshifts, and will find the most luminous objects in Universe. A main objective of the project is building of this general picture reflecting the most fundamental process of energy release in early Universe. High photometric sensitivity and full-sky coverage are in contradiction with high spectral and angular resolution which is necessary for investigation of individual objects using large, especially ground-based telescopes. In the same time, the survey gives a huge amount of information for many branches of astronomy: foreground data for CMB research, data on cold particles in processes of star/planetary formation and mass-loss for Galactic astronomy, data on trans-neptunian bodies in Solar system.

Engineering concept of the project is based on approach of minimum cost. The scientific tasks can be solved without expensive novel space construction, big rocket, distant orbit. The feasibility study shows that astrophysical requirements would be fulfilled with following elements: free-flying spacecraft on base of Progress cargo-ship and Soyuz launcher; service systems on base of Yamal and/or Odin developments; main payload construction (cryogenics and optics) on base of IRAS and/or ISO; deployment, maintenance, on-board testing, and repairement using docking to ISS. General view of the instrument is shown in [32]. Spacecraft dimensions permit sufficient increase of a telescope diameter if optic and cryogenics design modifications are possible.

3 DISCUSSION

An optimal choice of a spectral region and detectors permits to conduct a high sensitive survey with moderate size telescope. However, due to diffraction limit of angular resolution, a confusion problem takes place. Fig. 2 shows confusion noises with the same designations as on Fig. 1. The calculations were made using data and technique as in [33]. Confusion noises for Submillimetron telescope are in a range approximately 3-20 mJy and are comparable with statistical noises of detectors in survey mode. So, confusion doesn't change very much a detectivity of point sources. On the other hand, multiple observation of the same pixel gives possibility to separate solar-system bodies and variable sources even under confusion level. And, of course, measurements of unresolved background also supply an astrophysical information.

Therefore Submillimetron full-sky survey on its sensitivity is "background-limited" with respect to an extraterrestrial diffuse background and "confusion-limited" with respect to a background of unresolved extragalactic sources.

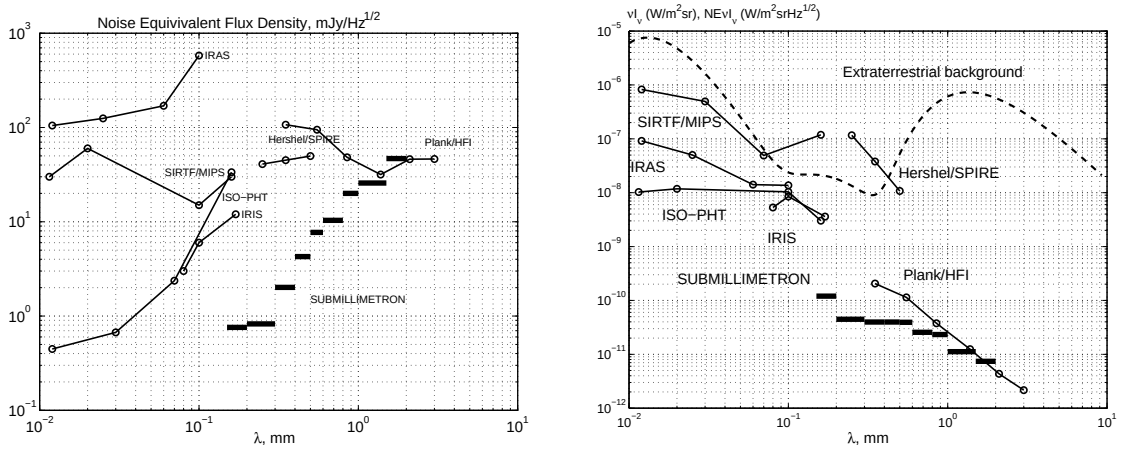

Fig. 1. Sensitivity limits determined by detector and background noise. Filled rectangles - Submillimetron project, open circles connected by lines - data for other projects (designations are given near corresponding lines). Left panel (a) – for point sources detection, right panel (b) – for extended emission measurements. Extraterrestrial background spectrum is shown by dashed line.

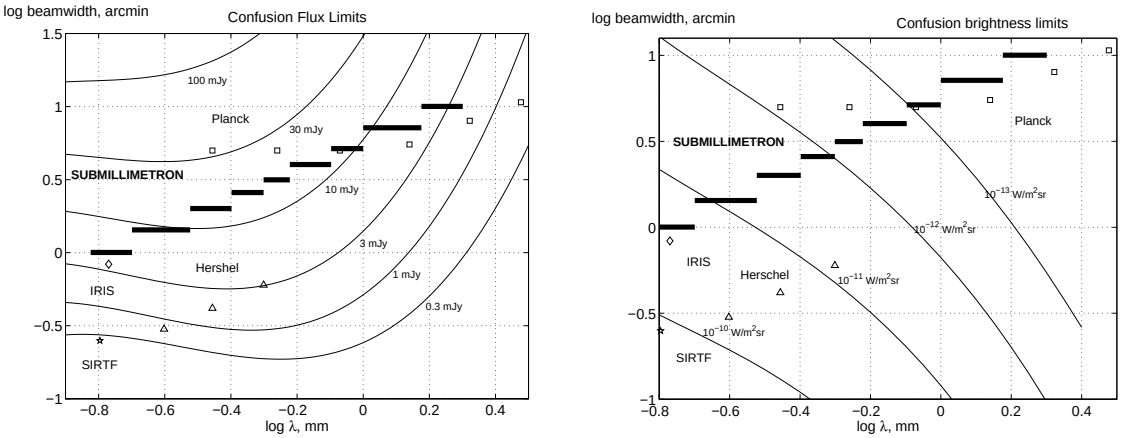

Fig. 2. Confusion noise (1σ) as function of telescope angular resolution and wavelength – solid curves. Designations of the space projects are the same as on fig. 1.

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