COSMIC STAR FORMATION HISTORY REQUIRED FROM INFRARED GALAXY NUMBER COUNT : FUTURE PROSPECT FOR INFRARED IMAGING SURVEYOR (IRIS)

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Abstract

We constructed a model of infrared and sub-mm (hereafter IR) galaxy number count and estimated history of the IR luminosity density. We treat the evolutionary change of galaxy luminosities as a stepwise nonparametric form, in order to explore the most suitable evolutionary history which reproduces the present observational results. We found the evolutionary patterns which satisfy both constraints required from Cosmic Infrared Background (CIRB) and IR galaxy number counts. One order of magnitude increase of luminosity at redshift \(z = 0.75 - 1.0\) was found in IR 60 \(\mu\)m luminosity density evolution. We also found that a large number of galaxies (\(\sim 10^7\) in the whole sky) will be detected in all-sky survey at far-infrared by Infrared Imaging Surveyor (IRIS); Japanese infrared satellite project Astro-F.

Key words: galaxies: evolution – galaxies: formation – galaxies: starburst – infrared radiation

1. Introduction

Recent infrared and sub-mm surveys revealed a very steep slope of galaxy number count compared with that expected from no evolution model, and provided a new impetus to the related field. Such excess of galaxy number count is generally understood as a consequence of strong galaxy evolution, i.e. rapid change of the star formation rate in galaxies. Now Japanese infrared satellite project Astro-F (Infrared Imaging Surveyor; IRIS) is in progress, and we calculated the expected number count by a simple empirical method (Takeuchi et al. 1999; Hirashita et al. 1999). The applied model was based on the IRAS surveys, and we need more realistic one to study the detailed observational plans and follow-up strategies. In order to construct the advanced model, we first compiled the infrared/sub-mm SEDs of galaxies obtained by ISO, SCUBA, and other facilities, and derived average SEDs for various classes of galaxies. Then, using the local luminosity function, we studied the required galaxy evolutionary history statistically.

2. Model Description

We construct the SEDs of galaxies based on the IRAS color–luminosity relation (Smith et al. 1987; Soifer & Neugebauer 1991). For the infrared – sub-mm component, we consider PAH (polycyclic aromatic hydrocarbon), graphite and silicate dust spectra (Dwek et al. 1996). Detailed PAH band emission parameters are taken from Allamandola et al. (1989). For the longer wavelength regime, power-law continuum produced by synchrotron radiation \(\propto \nu^{-\alpha}\) dominates. We set \(\alpha = 0.7\) according to Condon (1992). The SEDs are presented in Fig. 1.

![Assumed galaxy spectral energy distribution (SED) in the near infrared to radio wavelengths.](image)

Figure 1. Assumed galaxy spectral energy distribution (SED) in the near infrared to radio wavelengths.

3. Results and Discussions

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Figure 2. The double power-law form (Soifer et al. 1987) for the local luminosity function. We assumed pure luminosity evolution in this study.

3.1. Evolutionary history

We treat the evolutionary change of galaxy luminosities as a stepwise nonparametric form, in order to explore the most suitable evolutionary history which reproduces the present observational results. Furthermore, the constraint from Cosmic Infrared Background (CIRB) should be considered as another observational constraint to the models of evolutionary history.

3.1.1. CIRB

First, we searched the evolutionary pattern which satisfies the constraint required from CIRB and we found three patterns (Evolution 1−3) shown in Fig. 3. These three evolutionary patterns satisfy the constraint from CIRB (Fig. 4). In order to satisfy the high background intensity at $\sim 150 \mu m$, the high evolutionary factor at $z \sim 0.8$ is mandatory. We note that too large evolutionary factor at high $z$ would produce the excess around 1000 $\mu m$.

Figure 3. Stepwise nonparametric form of the evolutionary change of galaxy luminosities.

We obtain IR $60 \mu m$ luminosity density along with redshift (Fig. 5) from Fig. 3. Figure 5 show the rapid evolution in $\rho_L(60 \mu m)$. The increase is well described by $(1 + z)^5$! We need such a sudden rise of $\rho_L(60 \mu m)$ to reproduce the very high CIRB intensity at $\sim 150 \mu m$ mentioned before. The peak of the IR luminosity density is located at $z \sim 1$.

3.1.2. Number count

Recently, new observational results of the galaxy number counts at the mid-infrared and far-infrared (mainly by ISO), and submillimeter (SCUBA and others). We are able to compile these data as well as previously obtained IRAS data and radio data. It is obviously important to calculate multiband number count predictions and compare the multiband observations, because the response of the results to the galaxy evolutionary form varies with different wavelengths. In principle, the galaxy number count is an integrated value along with redshift $z$, and the information of the redshift is not available. But the redshift degeneracy can be solved to some extent, by treating the multiband observational results at the same time.

We check whether the three evolutionary patterns found in the previous section also satisfy the constraints from observations of number counts. We compare our number
counts with observations in Fig. 6 (infrared), and Fig. 7 (sub-mm – radio). Every pattern satisfies the constraints. When we especially focus on the sub-mm number counts, the evolution 3 is the most desirable.

3.2. Infrared Imaging Surveyor (IRIS)

Infrared Imaging Surveyor (IRIS) is a satellite which will be launched in 2003, by the M-V rocket of the ISAS (the Institute of Space and Astronautical Science in Japan). One of the main purposes of the IRIS mission is an all-sky survey at far-infrared (FIR) with a flux limit much deeper than that of IRAS. Detailed information of IRIS is available at http://koala.astro.isas.ac.jp/Astro-F/index-e.html.

In order to examine the performance of the survey, we estimated the FIR galaxy counts in two narrow bands (i.e. N60 and N170) based on models described in the previous section. We found that a large number of galaxies (∼10^7 in the whole sky) will be detected in this survey (Fig. 8).

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Figure 6. The multiband galaxy at the infrared wavelengths.

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Figure 7. The multiband galaxy at the sub-mm – radio wavelengths.

Figure 8. The galaxy number count predictions at assumed IRIS two bandpasses (N60 and N170). The dot-dashed lines denote the IRIS Far-infrared Scanner (FIS) flux detection limit at each waveband.