The UV (GALEX) and FIR (ASTRO-F) All Sky Surveys: the measure of the dust extinction in the local universe

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Abstract

Before the end of 2002 will be launched the GALEX satellite (a NASA/SMEX project) which will observe all the sky in Ultraviolet (UV) through filters at 1500 and 2300 Å down to m(AB)~21. In 2004 will be launched the ASTRO-F satellite which will perform an all sky survey at Far-Infrared (FIR) wavelengths. The cross-correlation of both surveys will lead to very large samples of galaxies for which FIR and UV fluxes are available. Using the FIR to UV flux ratio as a quantitative tracer of the dust extinction we will be able to measure the extinction in the nearby universe (z<0.2) and to perform a statistically significant analysis of the extinction as a function of galactic properties. Of particular interest is the construction of pure FIR and UV selected samples for which the extinction will be measured as templates for the observation of high redshift galaxies.

1 Introduction

The problem of the dust extinction in galaxies is crucial for the study of galaxy formation and evolution. Indeed the light emitted by the stars is partially absorbed by the dust before escaping galaxies: the determination of the true stellar content and of the star formation activity inside galaxies can only be done once the amount of extinction is known. The situation is dramatic at ultraviolet wavelengths which are observed in the visible at high redshift and where the extinction is particularly severe (e.g. Meurer et al. 1999, Steidel et al. 1999).

2 How to estimate the UV dust extinction

Our knowledge of the UV dust extinction by the study internal to galaxies comes from the studies of very limited samples of galaxies in the nearby universe. Two major methods have been proposed based on the analysis of

1. the shape of the UV continuum between 1200 and 2500 Å (Calzetti et al. 1994)

2. the $F_{\text{FIR}}/F_{\text{UV}}$ ratio and an energetic budget (Buat & Xu 1996, Meurer et al. 1999)

2.1 Using the shape of the UV continuum

This method has been built for central starbursts in galaxies observed by IUE (Kinney et al. 1993). It is based on the fact that the UV energy distributions for young starbursts are very similar. They can be fitted by a power-law of the form $F_{\lambda} = \lambda^\beta$ (Leitherer & Heckman 1995) and changes in the exponent $\beta$ is attributed to reddening (Calzetti et al. 1994, Meurer et al. 1995). The method was originally calibrated with the measure of the Balmer decrement (Calzetti et al. 1994) and new calibrations account for the far-infrared emission of the galaxies (Calzetti et al. 2000). Several recipes to estimate the extinction in the UV range have been deduced from this approach (Meurer et al. 1999, Calzetti et al. 2000). Recent studies have criticized the universality of the link between the slope $\beta$ and the dust extinction: theoretical studies explain the close link between the extinction and the slope $\beta$ for starburst galaxies only under restrictive conditions (Witt & Gordon 2000); moreover the $\beta$-$F_{\text{FIR}}/F_{\text{UV}}$ relation observed for starburst galaxies does not hold for Ultra Luminous Infra Red Galaxies (ULIRGs, Goldader et al. 2002) or normal spirals (Bell 2002).

2.2 Performing an energetic budget

The principle of this approach is very simple: the stellar emission is absorbed by the dust which re-emits the energy in the far-infrared. Since the UV non ionizing flux (912 Å $< \lambda < 3000$ Å) is the main source of dust heating in galaxies forming stars actively the $F_{\text{FIR}}/F_{\text{UV}}$ ratio is a powerful tracer of the dust extinction (Buat & Xu 1996, Meurer et al. 1999, Witt & Gordon 2000). Indeed the $F_{\text{FIR}}/F_{\text{UV}}$ ratio can be calibrated quantitatively in terms of extinction: it is relatively insensitive to the geometry of the dust versus that of the stars, to the dust properties and to the details of the star formation history (Gordon et al. 2000).

In order to apply this method one must estimate the total dust emission from the mid-infrared to the sub-mm. A good estimate of this total dust emission for normal galaxies needs observations at long wavelengths ($\lambda > 60 \mu\text{m}$, Dale et al. 2001).

3 The UV and FIR observations

3.1 The existing data

Until now the UV data are relatively scarce: wide field imagers ($\lambda \sim 150–200$ nms) have only covered limited sky areas (Donas et al. 1987 (SCAP), Milliard et al. 1994 (FOCA), Deharveng et al. 1994 (FAUST), Stecher et al. 1997(UIT)) and the infrared data for statistical studies came essentially from IRAS. The low sensitivity of IRAS has limited the sample of galaxies with photometric data in FIR and UV to few hundreds objects: only 5% of the galaxies detected in the UV survey of the FOCA experiment of 70 deg$^2$ have a FIR counterpart and the resulting sample contains only 80 galaxies (Buat et al. 1999).

The situation is even worse for UV spectroscopy since we still rely on the observations of the IUE satellite (Kinney et al. 1993) complemented with some data from HUT (Leitherer et al. 2002). The comparison with IRAS data is very difficult given the small aperture of the IUE telescope (10 arcsec x 20 arcsec) as compared to the optical size of the galaxies often as large as several arcmins (Meurer et al. 1999, Buat et al. 2002).

If visible spectroscopy is needed in complement to UV and FIR observations the samples are reduced to few tens of galaxies (Meurer et al. 1999, Buat et al. 2002).

3.2 Future observations

The situation will be greatly improved with the launch of all sky surveyors in UV (GALEX) and FIR (ASTRO-F): we expect several millions of galaxies with both FIR and UV data. The launch of the UV satellite GALEX is scheduled for the end of 2002: it will perform a full sky imaging survey at a limiting flux of 5$\mu$Jy at 1500 Å and 8.5$\mu$Jy at 2300 Å. A deeper survey covering 160 deg$^2$ will reach 0.1 $\mu$Jy in both bands. Moreover, the GALEX survey will provide low resolution (R=100) UV spectra of thousands of galaxies from 1350 to 3000 Å.

The ASTRO-F All Sky Survey scheduled for 2004 is expected to be ten times deeper than the IRAS one. The limiting flux of 80 $\mu$m (FIS instrument wide-S filter) will reach 16 mJy [http://www.ir.isas.ac.jp/ASTRO-F]. The performances of both surveys can be compared in figure 1. In this figure we have plotted the FIR flux versus the UV one. Both fluxes are defined as $\nu \cdot F_{\nu}$. The expected limits for GALEX at 1500 Å(FUV) and 2300 Å (NUV) are reported as vertical dashed lines and right arrows. The limiting flux at 80 $\mu$m of ASTRO-F is represented as an horizontal dashed line and arrows up. For comparison we have also reported the limit of IRAS Point Source Catalog at 60 microns. Observed data for existing samples of galaxies are also plotted (see the legend of the figure for details). Diagonal dotted lines represent the locus of constant $F_{\text{FIR}}/F_{\text{UV}}$. Most of the galaxies in the nearby universe have a $F_{\text{FIR}}/F_{\text{UV}}$ ratio comprised between 0.1 and 100 (Buat & Xu 1996, Buat et al. 1999).

3.3 Statistical analyses with the future GALEX and ASTRO-F data

A first look to the figure 1 leads to the conclusion that the two surveys are very well suited: the full cross-correlated GALEX–ASTRO-F sample is expected to be not strongly biased against or towards galaxies with a low or high extinction. Therefore
Figure 1: The expected limits of the all sky surveys of ASTRO-F and GALEX. The IRAS-FSC/FOCA sample (Buat et al. 1999) is plotted with black dots; the IUE sample and the sample of nearby galaxies with visible spectroscopy are plotted with red stars and blue triangles respectively (Buat et al. 2002); 3 ULIRGs (Trentham et al. 1999) are plotted with green filled circles. The diagonal dotted lines are the locus of constant FIR to UV flux ratio (log($F_{\text{FIR}}/F_{\text{UV}}$) = −1, 0, 1, 2). The detection limit of ASTRO-F and IRAS/FSC are indicated by horizontal dashed lines and arrows up, the detection limits of GALEX are indicated by vertical dashed lines and right arrows.

This full sample can be used for statistical studies of the FIR and UV properties of the galaxies in the local universe in terms of dust properties, extinction or star formation. Here are some examples of the topics which might be addressed with these data.

1. The process of dust heating by the UV photons will be studied. The dust temperature will be estimated with the ASTRO-F observations at 80 and 155 μm.

2. For each type of galaxies, we will compare both indicators of dust extinction: the slope β of the UV continuum (with the two bands of GALEX at 1600 and 2300 Å) and the $F_{\text{FIR}}/F_{\text{UV}}$ ratio. Complementary data in the visible will be available from the large surveys SDSS or 6dF.

3. The high sensitivity of ASTRO-F will provide us with a wide range of luminosity of galaxies in the local universe. Hence, we will obtain a large sample of dwarf galaxies, whose FIR properties have been still only poorly understood. Dwarfs generally have low metallicities, so it also means that we will be able to study the dust extinction of low-metallicity objects unobserved in FIR until now.

4. The biases induced by the adoption of UV or FIR selection criteria in observations of galaxies at any redshift will be properly analysed and understood by studying the statistical properties of galaxies in pure UV and FIR selected subsamples drawn from the GALEX–ASTRO-F sample. For example from the Figure 1 we can build a UV selected sample for which a FIR detection with ASTRO-F is very likely (and for which a non detection will put a strong constraint) by truncating the GALEX All Sky Survey at log($f_{\text{uv}}$) ∼ −14.5 (equivalent to m(AB) ∼ 18). We expect ∼ 400000 objects for such a sample.

5. An estimate of the total star formation rate from the observed UV and FIR emissions: $SFR(\text{total}) = SFR(\text{UV}) + SFR(\text{FIR})$ (Flores et al. 1998, Buat et al. 1999)

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