SF2A 2023
M. N'Diaye, A. Siebert, N. Lagarde, O. Venot, K. Baillié, M. Béthermin, E. Lagadec, J. Malzac, J. Richard (eds)

DUST PROPERTIES IN THE MILLIMETER TO CENTIMETER WAVELENGTH RANGE:
ANALYSIS OF A SAMPLE OF NEARBY GALAXIES

L. Correia[1], C. Bot [1], J. Chastenet[2], A. Rymar[3] and R. Paladini[4]

Abstract. Compared to the infrared and radio domains, there are very few observations of dust emission in the millimeter to centimeter wavelength range. The naive picture is that it is the thermal Rayleigh-Jeans emission from big grains. Yet resolved sub-mm and mm observations in our Galaxy and nearby galaxies have shown possible breaks in the emission law, or excess emission at long wavelengths. Laboratory measurements of dust analogs have shown more complex spectral emission laws as well with variations in temperature.

The aim of our study is to use the diversity of environments given by nearby galaxies to study dust emission at long wavelengths thanks to archival Planck and IRAS data.

One of the difficulties for these galaxies is that other foreground and background emission sources mix and often dominate the observed emission. We have to subtract the emission of these contaminating sources to obtain the dust-only emission of our targets.

Some preliminary SEDs of the sample of nearby galaxies are presented. The SEDs were fitted with a dust, free-free and synchrotron emissions model. I will present the dust properties we obtained and we will see whether the emission is consistent with the modified blackbody spectral shape or if we observe excesses or deficits of emission. These results will also be compared to those of distant galaxies.

Keywords: (sub-)millimeter emission, nearby galaxies, dust, SED

1 Introduction

Although dust constitutes a very small fraction of the mass of galaxies, its role in their evolution is significant. Dust abundance and composition reflect the chemical history of galaxies, so it is important to measure how they varie with the environment.

Information on dust composition, mass and temperature can be obtained from the analysis of its infrared (IR) emission up to millimeter wavelength. While the IR emission of galaxies has been extensively studied over the past 20 years, with space missions in the IR and ground-based antennas in the submillimeter, the millimeter to centimeter emission remains poorly observed and studied in comparison. It is, however, an interesting range to study, and the properties of dust at these long wavelengths remain relatively unconstrained.

The thermal emission of large dust grains is usually simply modeled by a modified black body, as it provides good fits to the spectral energy distribution (SED) in the far IR, but it may be more complicated than that. Dust emissivity in the (sub)-millimeter may be flatter than previously assumed, with a number of wavelength breaks and variations in shape and intensity with environmental conditions (temperature, density, ...). This can be explained by grains of different composition and/or by variations in the optical properties of the grains. Analysis of observations at long wavelengths can therefore provide information on the evolution of dust properties that can be compared from one galaxy to another.

---

[1] Strasbourg Astronomical Observatory, France
[2] Ghent University, Belgium
[3] Université Paris-Saclay, France
[4] IPAC, Caltech

2 Sample selection

Ground-based observations of nearby galaxies in the mm to cm range provide observations with good spatial resolution but with large-scale filtering and sensitivity problems. In comparison, observations linked to the CMB such as Planck, allow to observe all the sky available, at low spatial resolution, but obtain the emission of the entire galaxy without filtering or sensitivity problems.

The IRAS and Planck satellites have mapped the entire sky, from the far-IR to microwaves. These observations give the emission of any sufficiently luminous galaxy in 10 photometric bands: 100μm for IRAS and 350μm, 550μm, 850μm, 1.3mm, 2.1mm, 3mm, 4.3mm, 6.8mm and 10mm for Planck. Some studies have exploited these data for the nearest, brightest and largest galaxies in the sky, such as the Magellanic clouds (Planck Collaboration et al. 2011) or even M33 (Tibbs et al. 2018) but a lot of nearby galaxies remain unstudied.

The sample of galaxies used in this paper is the same as the one of the IMEGIN project (Interpreting the Millimeter EMission of Galaxies *), a key project with IRAM's NIKA2 instrument, which observes 22 galaxies at higher resolution and up to 2 mm. These nearby galaxies (distance $\leq$ 30 Mpc) have a different morphological type, residing in distinct environments. In this paper, these nearby galaxies are observed at low-resolution but allow to cover a wide range of wavelengths, up to 10mm, to provide the integrated emission of these galaxies.

3 Modeling dust emission

3.1 Data processing

We start by the conversion of IRAS and Planck sky maps in the same unit (i.e. MJy/sr), the convolution of all maps over the whole sky at the same resolution (32', which is the lowest resolution in the sample, corresponding to the 10mm band) and the projection of the maps onto the same grid, at all frequencies.

Distinguishing galaxy emission in the millimeter to centimeter domain and at low resolution can be difficult: several foreground and background sources can dominate the emission of the galaxy, making it disappear. These sources, the cirrus emission from the Milky Way, the fluctuations in the cosmic microwave background, the zodiacal light and the emission from unresolved background galaxies in the field, need to be subtracted.

Figure 1 shows maps of the galaxy NGC891 in the 10 photometric bands. The central pixel surrounded in red for clarity, representing the galaxy, is completely dominated by emissions from foreground and background sources, and it is therefore necessary to subtract them.

After subtracting these emissions (see figure 2), the galaxy NGC891 is well detected, at least at shorter wavelengths, and more or less well detected at longer wavelengths.

These maps will be used to obtain galaxy fluxes in all bands in order to have the integrated spectral energy distribution for each galaxy.

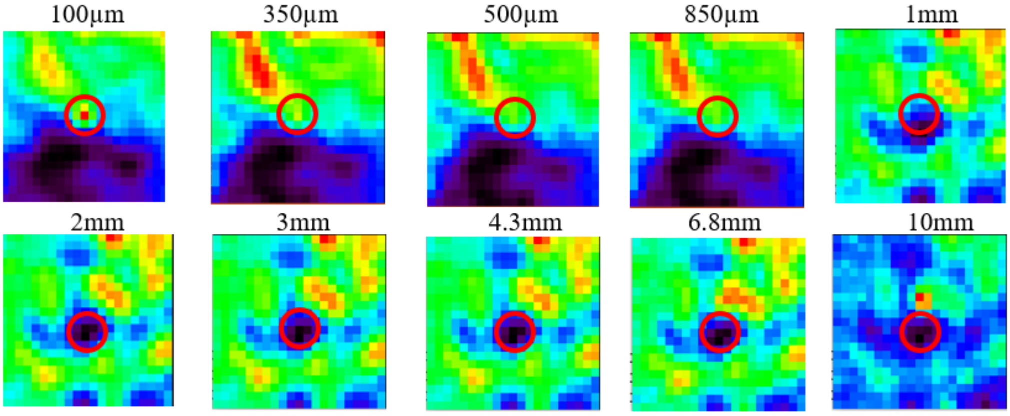

Fig. 1. Maps of NGC891 before subtraction of foreground and background emissions sources in the 10 photometric bands.

---

[*] `https://irfu.cea.fr/dap/en/Phocea/Vie_des_labos/Ast/ast_visu.php?id_ast=4645`

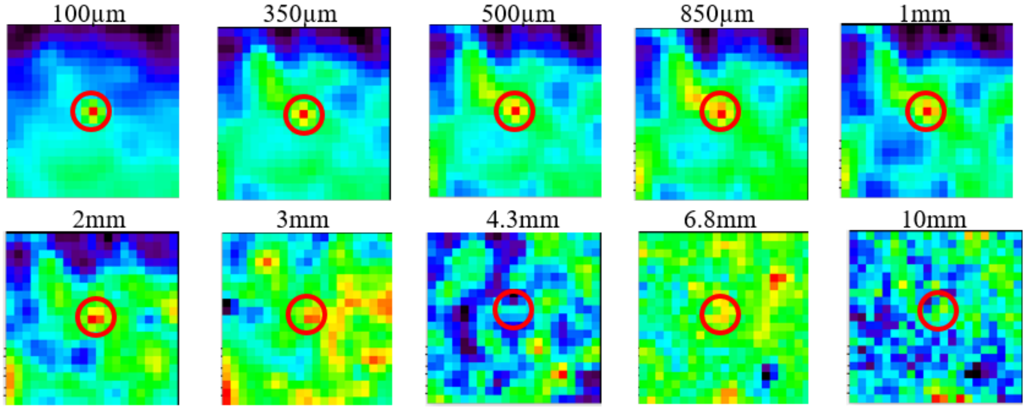

Fig. 2. Maps of NGC891 after subtraction of foreground and background emissions sources in the 10 photometric bands.

3.2 *Adjusting infrared to microwave emission*

We integrate the observed emission at the position of the galaxies and we subtract the average background emission measured in a surrounding region. The error on the galaxy flux is completely dominated by the uncertainties of the foreground and background subtractions, so the error on the measurements was measured by using the flux dispersion observed in the background region of the sky.

In the mm to cm range, the dust emission and the free-free emission of electrons from the ionized gas contribute to the total signal, which is then dominated by synchrotron emission in the radio range. Each of these components has a specific spectral shape, which is why we are able to disentangle and study them separately. To fit the SEDs of the sample of 22 nearby galaxies, we use a simplistic but phenomenological model to describe the shape and variations of dust emission, ionized gas and synchrotron emission. For that, we calculate the surface brightness S of the galaxy: $\mathrm{S_{galaxy}} = \mathrm{S_{dust}} + \mathrm{S_{free-free}} + \mathrm{S_{synchrotron}}$. In this model, the dust emission is a modified blackbody (equation 3.1Gordon et al. (2014)) and the ionized gas (equation 3.2) and synchrotron (equation 3.3) are power laws (Lequeux et al. 2004).

$$\mathrm{S_{dust}} = \kappa(\beta) \times \Sigma_{\mathrm{d}} \times \mathrm{B(T_d)} \tag{3.1}$$

$$\mathrm{S_{free-free}} = \mathrm{C_{ff}} \times \lambda^{0.1} \tag{3.2}$$

$$\mathrm{S_{synchrotron}} = \mathrm{Syn} \times \lambda^{\mathrm{C_{syn}}} \tag{3.3}$$

This model will enable us to deduce the actual physical characteristics of the dust (mass, temperature, β emissivity index) in each galaxy, and to compare them with the environment they represent (metallicity, gas mass, etc.). This modeling of the IR-cm emission will allow to see whether we reproduce the observed emission, or whether significant deviations from the model will be detected (excess or deficit).

To fit the simple model to the data, the models are integrated into the wide-band IRAS and Planck filters to best reproduce the observational data and the integrated models are fit to the data using MPFIT for each of the 22 nearby galaxy SEDs.

4 Results

Figure 3 gives two examples of SEDs observed for NGC0628 and NGC891, two galaxies of the sample, with the best model found by minimization. We superimposed radio data from SPECFIND V3.0, a radio continuum source catalogue (Stein, Y. et al. 2021) in blue. The DustPedia data corresponding to higher-resolution data for these galaxies are superimposed in green and appear to be compatible with our low resolution integrated SEDs and the best model found.

We can note that for galaxy NGC891, the SED of the galaxy can detect a small contribution of free-free emission compared to the galaxy NGC0628.

These SEDs best models give parameters of the dust, free-free and synchrotron emission, and will allow to study their properties, provide a global view of these nearby galaxies as point sources and quantify potential excesses of emission.

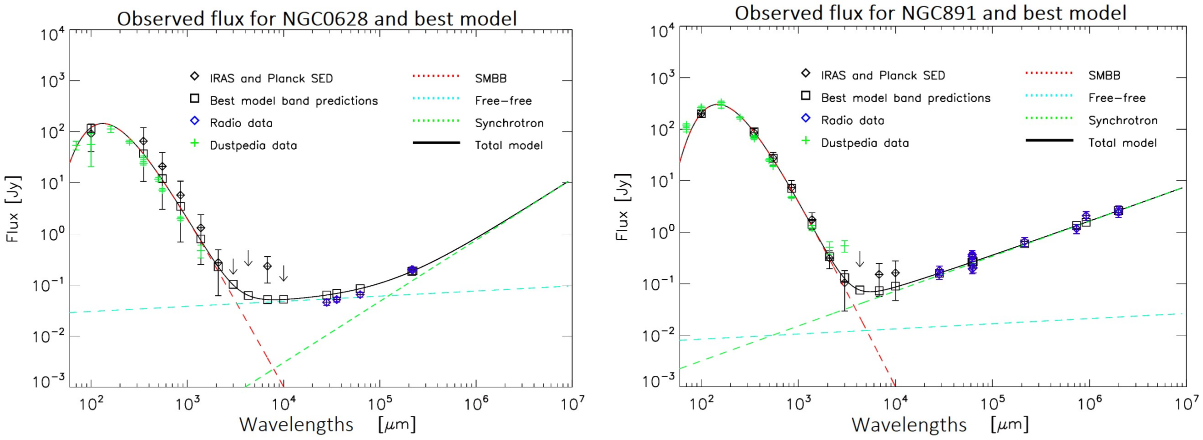

Fig. 3. Left: Spectral energy distribution of NGC0628. **Right:** Spectral energy distribution of NGC891. Black diamonds correspond to IRAS and Planck data, black squares to the best model fitting the data, blue diamonds to the radio data and green crosses to Dustpedia data. The dust model is shown in red dotted line, free-free emission in cyan dotted line, synchrotron emission in green dotted line and the total model in a blakc line.

5 Conclusions

To determine the dust properties in the millimeter to centimeter wavelegnth range, we analysed a sample of 22 nearby galaxies observed with IRAS and Planck in 10 photometric bands.
From the raw observations of these galaxies, we substrated the foreground and background emission sources that dominate the emission and prevented their detection at such low resolution.
We modeled infrared to centimeteter emission of sample of 22 nearby galaxies with a simple model of dust, ionized gas and synchrotron emission.
The next step will be to work on a potential existence of a significant excess or deficit of emission, like the one observed in the Small Magellanic Cloud (Bot et al. 2010).

References

Bot, C., Ysard, N., Paradis, D., et al. 2010, A&A, 523, A20
Gordon, K. D., Roman-Duval, J., Bot, C., et al. 2014, ApJ, 797, 85
Lequeux, J., Falgarone, E., & Ryter, C. 2004, , A&A
Planck Collaboration, Ade, P. A. R., Aghanim, N., et al. 2011, A&A, 536, A1
Stein, Y., Vollmer, B., Boch, T., et al. 2021, A&A, 655, A17
Tibbs, C. T., Israel, F. P., Laureijs, R. J., et al. 2018, MNRAS, 477, 4968