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Constraints on the Anomalous Microwave emission with WMAP and Cosmosomas

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Abstract

The anomalous microwave emission (AME) is a dust-correlated signal that shows up in the microwave range. Strong interest in this emission has arisen since its discovery in the late 90s, due to its role as a CMB contaminant, and also because it provides a new way to explore the ISM physics. As a consequence, there has been a strong combined effort over the last decade in this regard, with several targeted observations in individual clouds, as well as different models that have been proposed to explain the origin of this emission, the most promising of which is the so-called "spinning-dust" emission. In this talk I present new observations of this phenomenon in the Pleiades reflection nebula using microwave data from the WMAP satellite and from the Cosmosomas experiment [8]. I will also discuss the implications that the AME could have as a potential contaminant of future CMB polarimeters searching for the B-mode signal from the primordial gravitational wave background (GWB).

1 Introduction

The currently known as "anomalous microwave emission" (AME) was unexpectedly first detected as a spatial correlation of COBE DMR microwave data with DIRBE maps tracing the dust emission at 140 μm [11]. This large-scale statistical correlation was confirmed by subsequent observations with similar experiments (e.g. [12]), which motivated the search for similar signals in individual regions [6]. Probably the most clear detection has been obtained in the Perseus molecular cloud with the Cosmosomas experiment [19]. However, ever since, there have been clear AME detections in different media, like different dust clouds, HII regions, and even in a star-forming region in a nearby galaxy [15].

Recent results obtained with the Planck satellite [16] have provided the most precise AME spectra measured to date in the LFI Channels (30-70 GHz), together with an accurate determination of the thermal dust spectrum thanks to the HFI channels (100–857 GHz). In [16] new results on the Perseus and in the ρ-Ophiuchi molecular clouds were presented, probably the brightest AME regions in the sky. Also, it was carried out a systematic search of new AME regions using a simple method of component separation, and two new regions were detected and studied: G173.6+2.8 and G107.1+5.2.

AME has been recognized as a new CMB contaminant in the 10-100 GHz frequency range in addition to the other three well-known mechanisms of Galactic emission: the free-free and the synchrotron, which dominate a low frequencies ($\lesssim$ 70 GHz), and the thermal dust emission, which is important at high frequencies ($\gtrsim$ 100 GHz). Although the first hypothesis for the physical mechanism generating the AME was free-free emission [12], it was soon ruled out on the basis that the high gas temperatures required to explain the observed intensities were inconsistent with the absence of significant Hα emission in the same positions. The most reliable model has become electric dipole emission from small rotating dust grains in the ISM, the so-called "spinning dust" [4]. The predicted theoretical spectra show emissivities peaking in the range $\sim 20 - 50$ GHz, and reproduce rather well the flux densities observed in the previous regions, together with the observed down-turn at frequencies $\lesssim$ 15 GHz, which is inconsistent with the flatter spectrum corresponding to the free-free emission. An alternative model proposed is the magnetic dipole radiation from hot ferromagnetic grains [5]. However, the observed polarization upper limits for the AME [13] seem to support the electric dipole hypothesis.

2 WMAP/Cosmosomas observations on the Pleiades reflection nebula

The Pleiades reflection nebula consists of a concentration of interstellar dust which is being excited by the cluster stars, located at a distance of $\sim$ 125 pc within the Taurus complex. [3] discovered infrared thermal emission around the positions of the Pleiades star. We now present the counterpart of this emission in the microwaves, which is being produced by the same population of dust grains, but through a different mechanism, most likely the spinning dust emission.

Figure 1 shows a map of the 22.8 GHz band of the WMAP satellite [10] at the position of the Pleiades reflection nebula. The infrared map of the IRAS satellite at 100 μm is represented with solid contours, indicating a clear spatial correlation between the microwave and infrared data, which is indicative of the presence of AME. The positions of the brightest exciting stars are also indicated, showing a clear correlation between these locations and the brightest infrared knots. The position of maximum infrared emission is located around 15 arcmin below 23 Tau, and corresponds to the Merope CO cloud. This position seems to approximately correspond also to the maximum microwave emission, though it is difficult to draw a firm conclusion in this regard owing to the coarse angular resolution of WMAP.

In order to confirm the presence of AME in this position it is necessary to perform a multi-frequency analysis, to subtract the contributions of other components, mainly the free-free and the thermal dust emissions, at 22.8 GHz. We built the spectral energy distribution

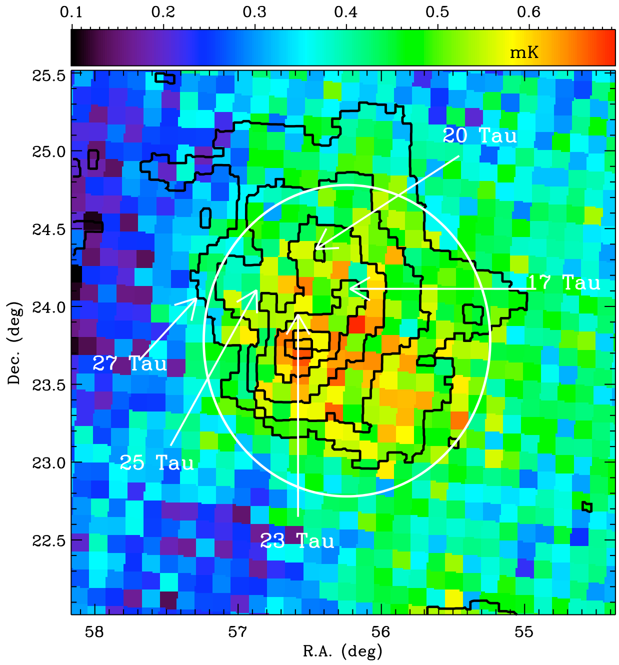

Figure 1: *WMAP K*-band (22.8 GHz) map with *IRAS* 100 μm data overplotted with contours, in the position of the Pleiades nebula. Arrows indicate the positions of the brightest star members of the Pleiades star cluster, whereas the circle indicates the 1° aperture radius we use for flux integration. A clear spatial correlation is appreciated between the microwave (AME) and infrared (thermal dust) brightness distributions.

(SED) of this region combining radio surveys at low frequency (the Haslam map at 0.408 GHz [9], the Dwingeloo map at 0.820 GHz [2] and the Reich map at 1.4 GHz [17]); microwave data from the Cosmosomas experiment and from the WMAP satellite; and infrared emission from DIRBE, an experiment on board of COBE satellite. The primordial CMB fluctuations must be considered in this case as a contaminant contribution, that could later be fitted to the SED fluxes. Instead, in this case we chose to subtract the CMB at the map level. To do this, we applied an internal-linear-combination (ILC) to the five WMAP frequency channels (between 23 and 94 GHz), to extract the CMB component that is later subtracted pixel-by-pixel to each of the WMAP maps at different frequencies.

We smoothed all the data at a common angular resolution of 1° and performed an aperture photometry integration in each of those maps. This consists on obtaining the integrated flux of the region by averaging the temperature of all the pixels within a given aperture radius and subtracting a constant background level that is estimated through the average of all pixels in an external background annulus. Here we consider an aperture radius of 1° and an external background annulus between 1.7° and 2.0°.

The final SED is shown in Figure 2. No significant emission was identified at the position

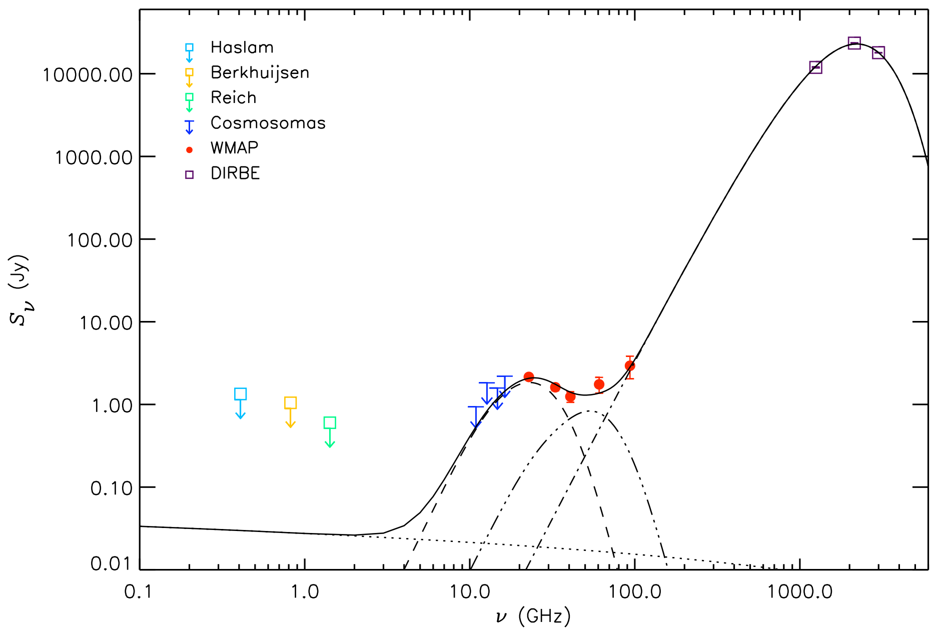

Figure 2: Final spectral energy distribution in the position of the Pleiades reflection nebula. Upper limits at the 99.7% C.L. for the radio and Cosmosomas data are shown. The dotted and dash-dotted lines correspond respectively to the fitted free-free and thermal dust spectra. The dashed and the dash-triple-dotted lines represent spinning dust spectra corresponding respectively to a molecular and to a low-density atomic gas phases.

of the Pleiades in the low-frequency maps, and therefore we placed upper limit for the fluxes at the 99.7% confidence level. The amplitude of the free-free emission was determined from the Hα map of [7] after correcting the derived Hα flux from Galactic extinction. No clear emission is visible either in the Cosmosomas maps, and we also placed upper limits using the noise on those maps. These upper limits are however crucial to trace the expected downturn of the AME spectrum at low frequencies, and also to confirm the absence of significant contribution from the free-free emission to the WMAP fluxes. The final residual flux at 22.8 GHz, which is attributed to AME and was calculated after subtracting the contributions from the free-free and thermal dust, is 2.12 ± 0.12 Jy. The WMAP data points are nicely fitted through two spinning dust spectra corresponding to two different gas phases (molecular and atomic). We calculated these spectra through the SPDUST code [1], and fitted their amplitudes to the observed data.

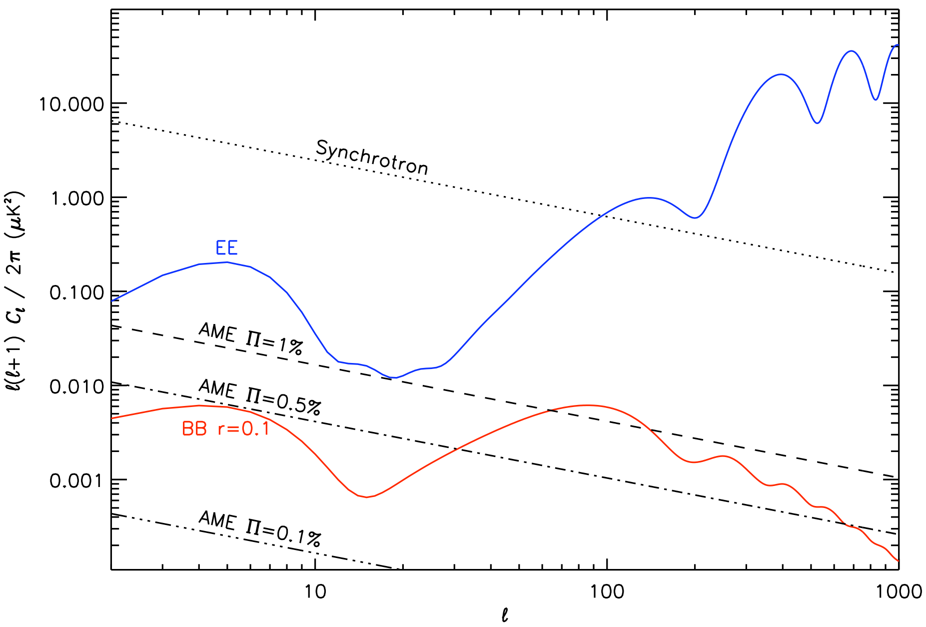

Figure 3: Power spectra of the two modes in which the polarization pattern of the CMB is decomposed: EE and BB modes. For comparison, the power spectra of the polarized synchrotron emission and of the anomalous microwave emission for different polarization fractions are also shown.

3 Constraints on the AME polarization

Observing the polarization of the AME is of strong importance because it can provide insight on the underlaying mechanism that is generating this emission, and also because it could help to assess the level of contamination that experiments observing the polarization of the CMB will suffer. Currently, one of the most important research lines in Cosmology is the study of the polarization of the CMB. The aim is to detect the B-mode signal that would have left in the CMB polarization pattern by the primordial gravitational wave background generated during the inflationary epoch. For this reason, there are many experiments, like QUIJOTE-CMB [18], that are being developed with the aim of studying the polarization of the CMB. The sought B-mode signal, which is parameterized in terms of the tensor-to-scalar ratio r, is predicted to be very weak. For this reason, it is important to have an accurate characterization of the polarized foregrounds.

Figure 3 shows the power spectra of the B-modes for r=1, in comparison with those of the polarized synchrotron and AME for different polarization fractions. Although the synchrotron emission is in principle brighter in polarization, it is clear that it is also important to assess to what level the AME is polarized. Current measurements in individual clouds like the Perseus molecular cloud have placed upper limits at the $\sim$ 1% level [13]. These measurements, which are mainly derived from the WMAP data, will be explained in more detail in other paper which is published in this same series [14]. Experiments like QUIJOTE-CMB will be able to push these current upper limits down to $\sim 0.1\%$ with relatively short observational programs.

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