Constraints on the Polarization of the Anomalous Microwave Emission in the Perseus Molecular Complex from 7-year WMAP data

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Abstract

We have used the seven year *Wilkinson Microwave Anisotropy Probe* (WMAP) data in order to update the measurements of the intensity signal in the G159.6-18.5 region (within the Perseus Molecular Complex), and to set constraints on the polarization level of the anomalous microwave emission in the frequency range where this emission is dominant (20-30 GHz). At 23, 33 and 41 GHz, we obtain upper limits on the fractional linear polarization of 1.0, 1.8 and 2.7 % respectively (with 95% confidence level). These measurements rule out a significant number of models based on magnetic dipole emission of grains that consist of a simple domain (Draine & Lazarian 1999) as responsible of the anomalous emission. When combining our results with the measurement in the region obtained with the COSMOSOMAS experiment at 11 GHz (Battistelli et al. 2006), we find consistency with the predictions of the electric dipole and resonance relaxation theory (Lazarian & Draine 2000) at this frequency range.

1. Anomalous Emission

It is an emission process in the microwave frequency range which is spatially correlated with the far-infrared emission, but can not be explained in terms of the three known physical mechanisms of diffuse emission in the Galaxy: Free-Free, synchrotron and thermal (vibrational) dust emission.

Due to the importance that it may have on the detection of the polarization in the maps of the Cosmic Microwave Bacground (CMB), we need to understand both the properties of this emission, especially its polarization, as well as the physical mechanism that generates it.

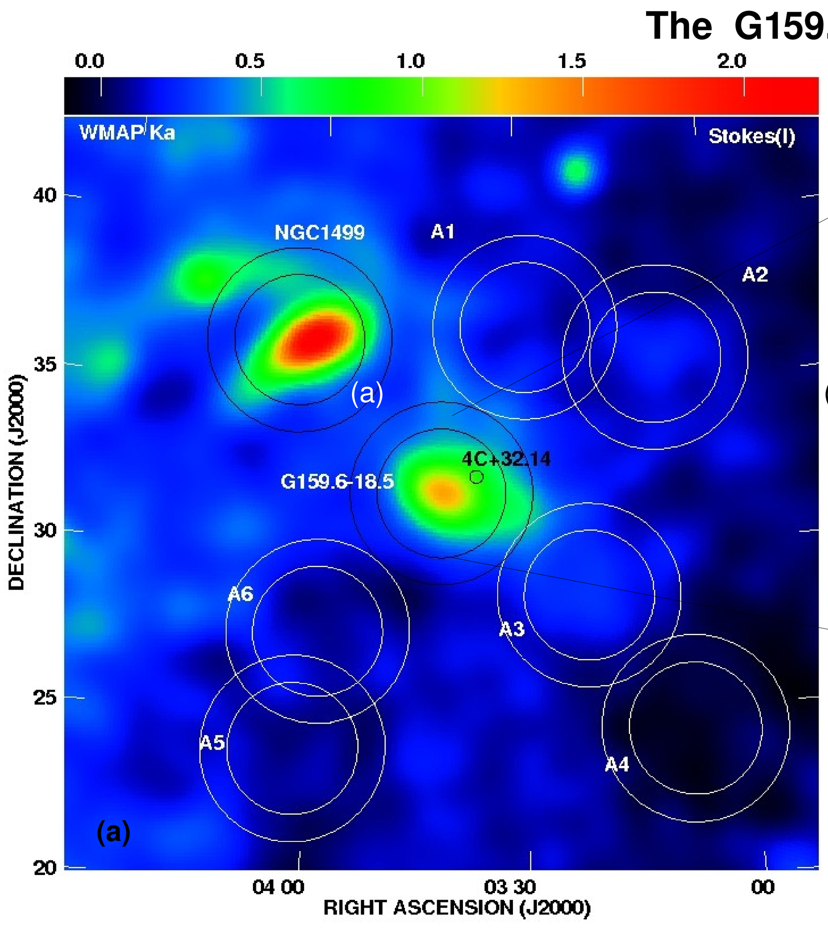
2. The G159.6-18.5 Region

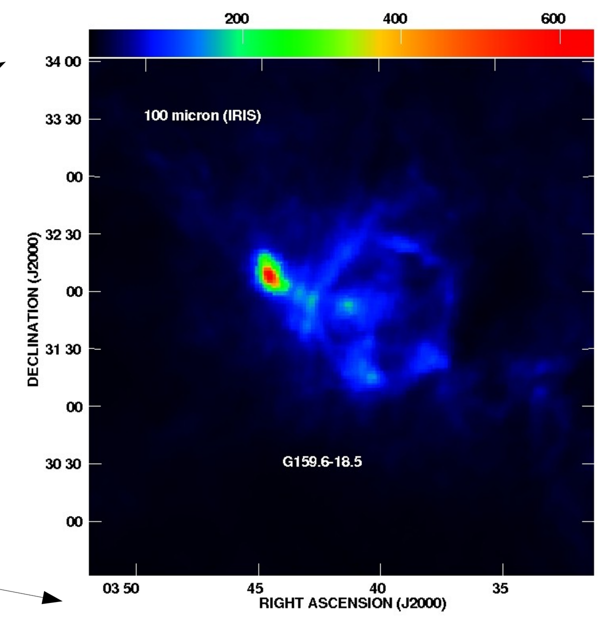
It is a dust feature within the Perseus Molecular Complex, located at a distance of 260 pc, with coordinates in R.A=55.4^0 and Dec.=+31.8^0.

Watson et al. (2005, hereafter W05) carried out a detailed study of the SED in a wide frequency range (408 MHz-3000 GHz). They used the WMAP and COSMOSOMAS data to show that an adequate fit to the SED should include the contribution of an additional component peaking around 20 GHz.

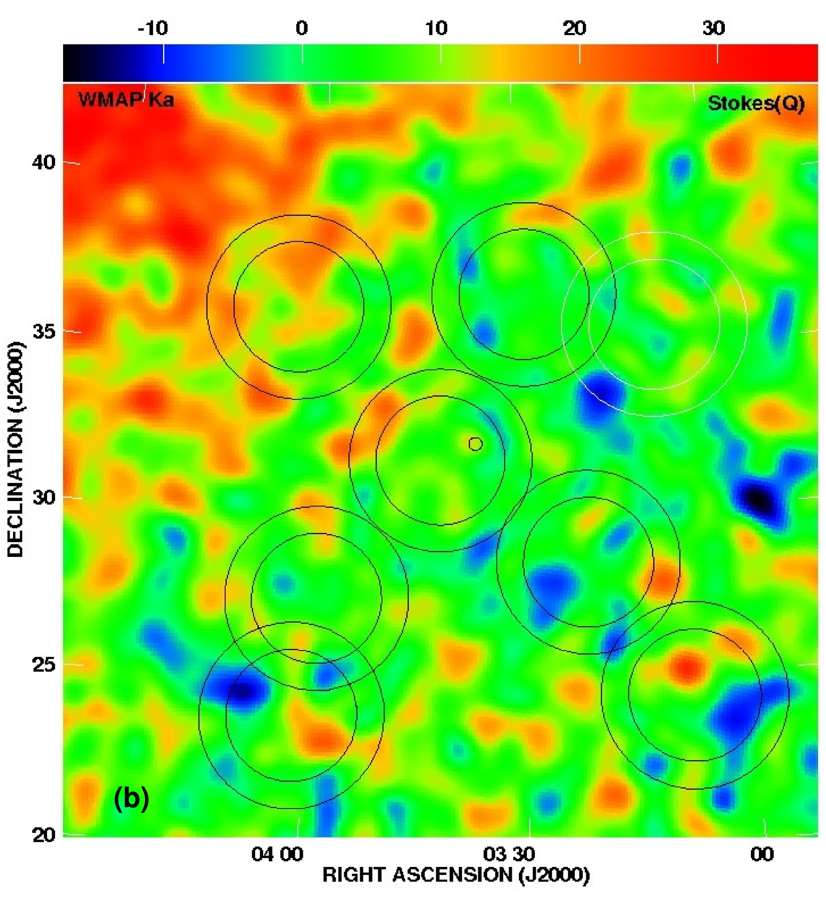
Battistelli et al. (2006), using the COSMOSOMAS data at 11 GHz, presented the only measurement up-to-date of the polarization level Π=3.4$^{+1.5}_{-1.9}$ % (with 95% c.l.). This low level of polarization favors the spinning dust model (Lazarian & Draine 2000).

The G159.6-18.5 Region





Close view of G159.6-18.5 as seen by IRIS at 100 µm, where Perseus appears as a slightly broken ring with a diameter ~1.5°.



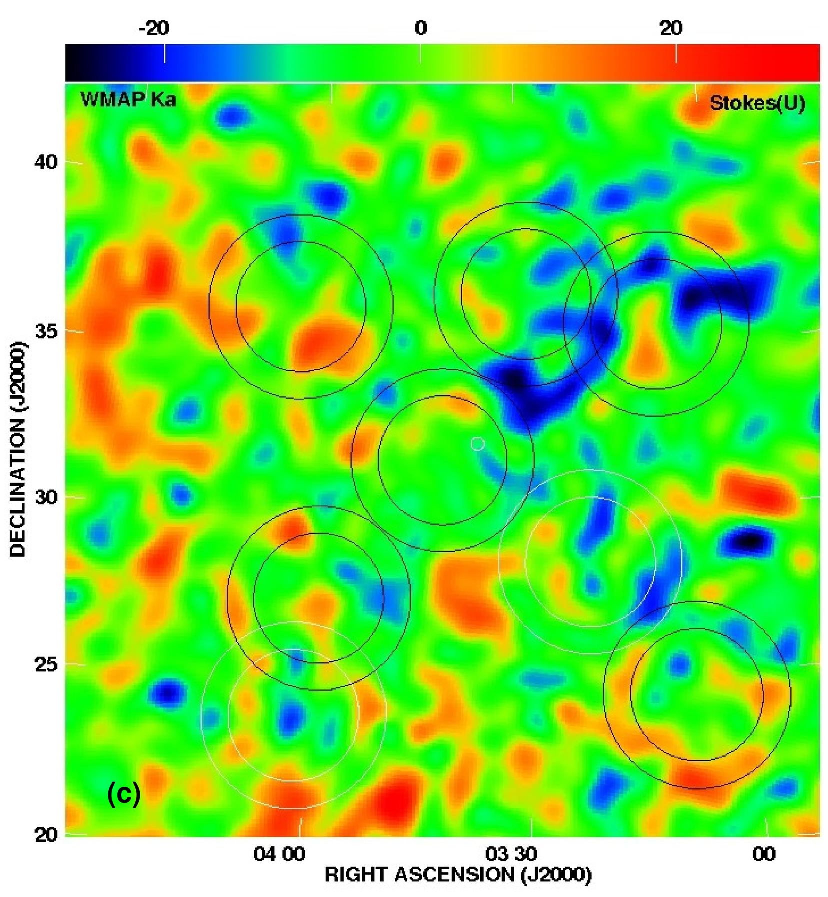


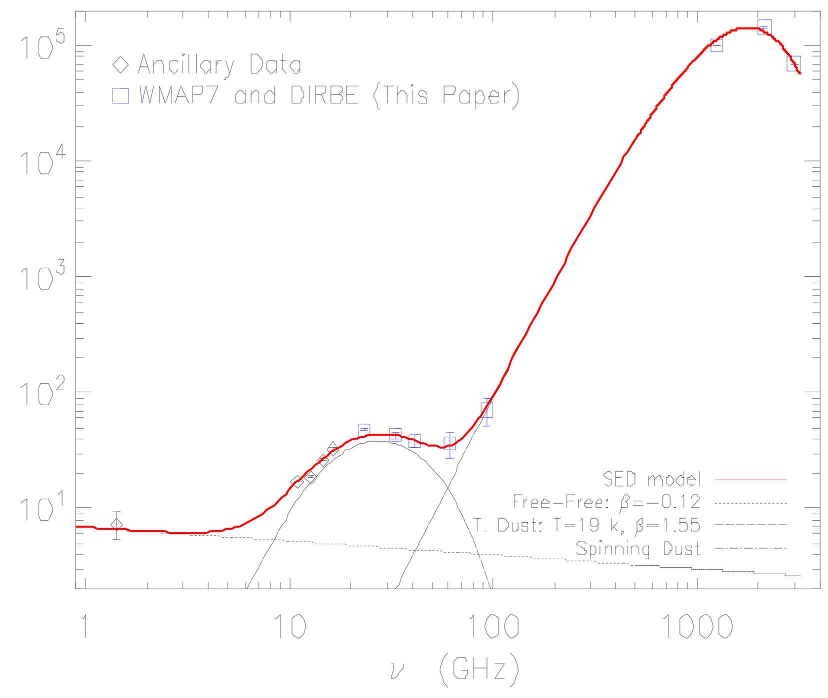
Figure 1. Neighborhood of the Perseus Molecular Complex as seen by WMAP-7 at 33 GHz (Ka band), with a field of view of 23^{0}x23^0 centered in the G159.6-18.5 region. The (a), (b) and (c) images (I, Q and U respectively) are smoothed to 1^0 resolution, and in units of mK (thermodynamic).
The black circles define the circular apertures around the G159.6-18.5 region, six control regions for the characterization of the diffuse background emission, and the HII region NGC1499 which is used as a comparison region with no polarization. The small aperture at the northwest of the center of G159.6-18.5 is the quasar 4C+32.14; those pixels were not considered in our flux estimation.

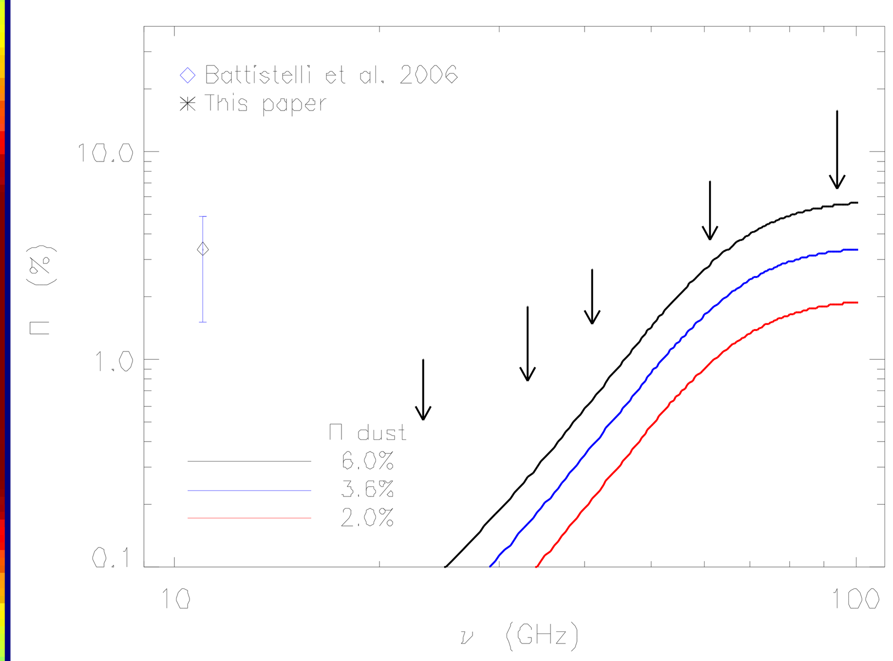
3. Data and Methodology

- We use the seven-year WMAP data (Jarosik et al. 2010). The I, Q and U maps, for each of the five frequency bands at 23, 33, 43, 61 and 94 GHz, are degraded to a common resolution of 1^0.
- To obtain the flux measurements (for intensity and polarization), we adopt a direct aperture integration or "ring analysis". The error bar takes into account the pure instrumental noise and the CMB contribution, in both cases considering the correlation terms.
- We apply a maximum likelihood approach to obtain the upper limits on the total and fractional observed linear polarization .

4. Results and Discussion

Intensity: SED for G159.6-18.5. The blue squares and black diamond are our measurements and the ancillary data used(COSMOSOMAS and HASLAM). The SED is fitted with three contributions: i) free-free, using spectral index β_{ff}=-0.12. ii) the thermal dust, with β_{dust}=1.55 and T_{dust} =19 K. iii) the spinning dust due to the electric dipole emission from two Draine & Lazarian (1998) models: warm neutral medium and molecular cloud (0.85 WNM + 0.35 MC).

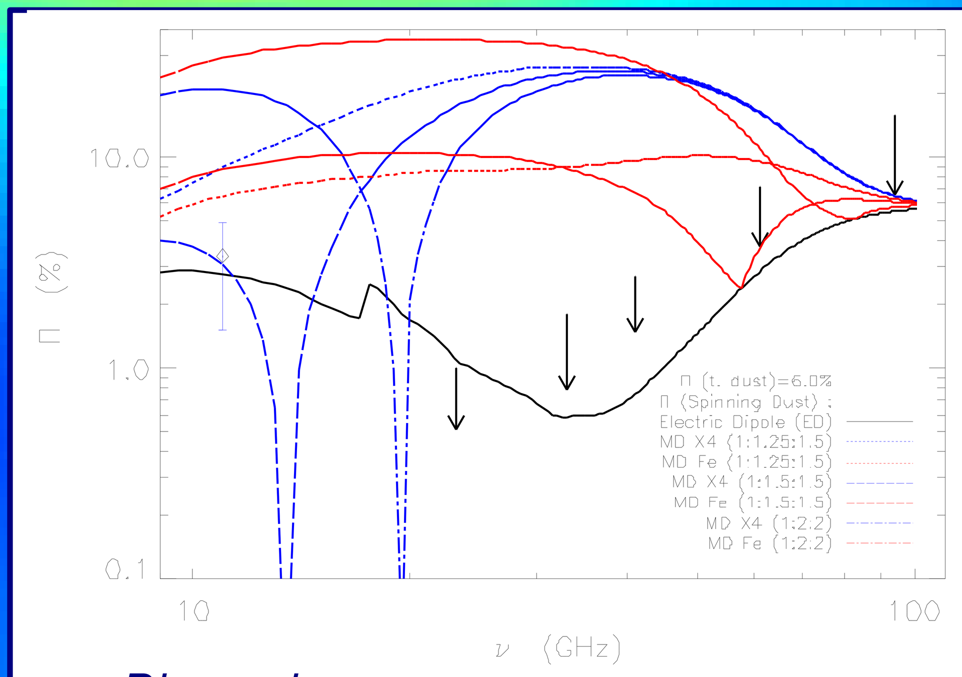


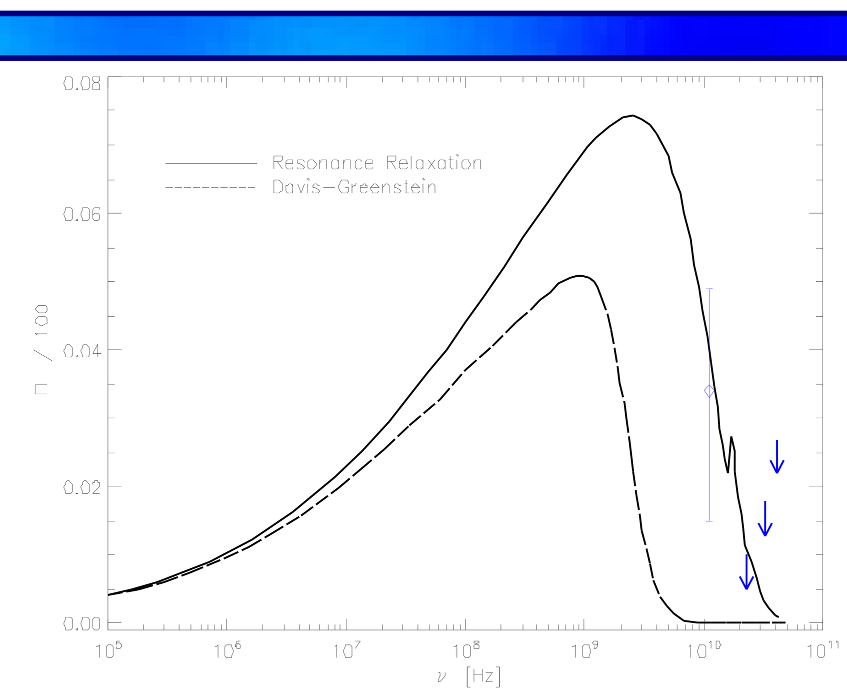


Polarization: The figure shows our upper limits on the total fractional linear polarization Π (black arrows) and the Π=3.4$^{+1.5}_{-1.9}$% measurement at 11 GHz from Battistelli et al. (2006).

The solid lines are the predicted fractional polarization due to the thermal dust (Π_{dust}).

The upper limits at 23 and 33 GHz constitute the most stringent constraints on the polarization of the anomalous microwave emission.





Discussion: Solid lines represent different spinning dust models: i)the electric dipole emission from Lazarian and Draine 2000 (black line). ii) the magnetic dipole emission from Draine and Lazarian 1999 (depending on the composition and shape of grains). All curves include the thermal dust contribution (with Π_{dust} = 6.0 %).

Our results exclude the magnetic dipole emission as the physical process responsible of the observed polarization. Moreover, the constraints are in agreement with the predictions of the electric dipole emission and resonance relaxation theory at this frequency range.

5. Conclusions

- In intensity, the results confirm the presence of anomalous emission.
- We present the first constraints on the polarization properties of the anomalous microwave emission in Perseus at high frequencies, from 23 to 94 GHz.
- The upper limits allow to exclude a significant number of models based on the magnetic dipole emission of dust grain as the physical process responsible of the observed emission.
- Our constraints in the range 23-94 GHz together with the COSMOSOMAS measurement at 11 GHz are consistent with the expected linear polarization arising from the electric dipole model with resonance relaxation.

6. Referencias

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