Preliminary Observations of the Galaxy with a 7° Beam by the Cosmic Background Explorer (COBE)

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Abstract. The FIRAS instrument on COBE has mapped almost the entire sky with a 7° beam and a spectral resolution of about 1 cm^{-1}over the 1-100 cm^{-1} range. Maps showing the strengths of the three main components: dust continuum, [C II] and [N II] are presented. A mean spectrum of the galactic emission is found. These results are used to compare the Milky Way to other galaxies.

1. Introduction

This paper will summarize results that are more extensively discussed in Wright *et al.* (1991). The maps presented here include data collected during the entire ten month lifetime of the helium cryogen on COBE, while Wright *et al.* only considered the first half of the mission. However, since only six months are required to cover the sky, the increased sky coverage is from 72% to 89%. Data taken in the high spectral resolution long scan mode will fill in some of the remaining holes, leaving the total sky coverage from the FIRAS instrument at 98%. Maps of the weaker lines such as [C I] and CO only show significant signals in the inner galactic plane, while the maps of the stronger components presented here show structure over much of the sky.

2. Approach

The details of the calculation can be found in Wright *et al.*, but the basic approach is to approximate the emission from the galaxy as the product of a function of position and a function of frequency: $I_\nu(l,b) = G(l,b)g(\nu)$. The continuum map in Figure 1 is the function $G(l,b)$. The spectrum $g(\nu)$ has been modeled as a dust continuum plus lines by Wright *et al.*

The dust continuum was fit using two populations of dust with ν^2 emissivity laws: a warm component at 20.4 K and a cold component at 4.77 K with 6.7 times more opacity than the warm component.

3. CO Fitting

The four measured CO lines and the limit on the 1-0 line can be used to make a model of the CO distribution. The model that I have used is one that assumes warm and cold clouds, both optically thin and in LTE. The column density and temperature in each type of cloud give four parameters,

P. D. Singh (ed.), Astrochemistry of Cosmic Phenomena, 321–326.

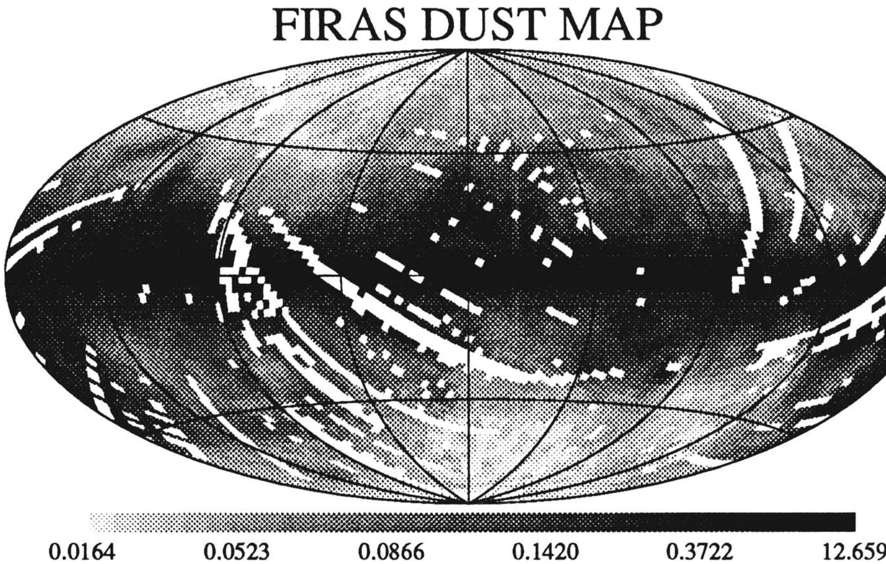

Fig. 1. A continuum map based on data from 23-50 wavenumbers.

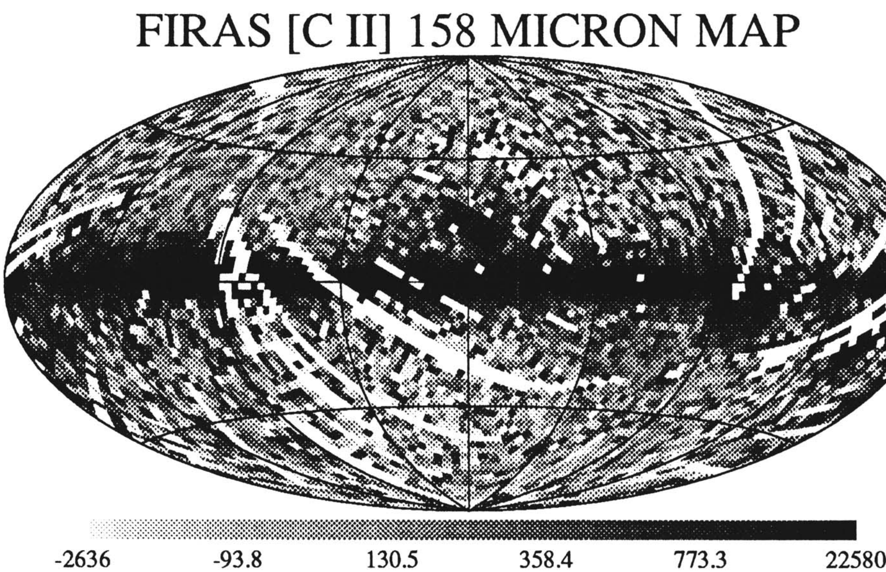

Fig. 2. Map of the [C II] 158 μm line.

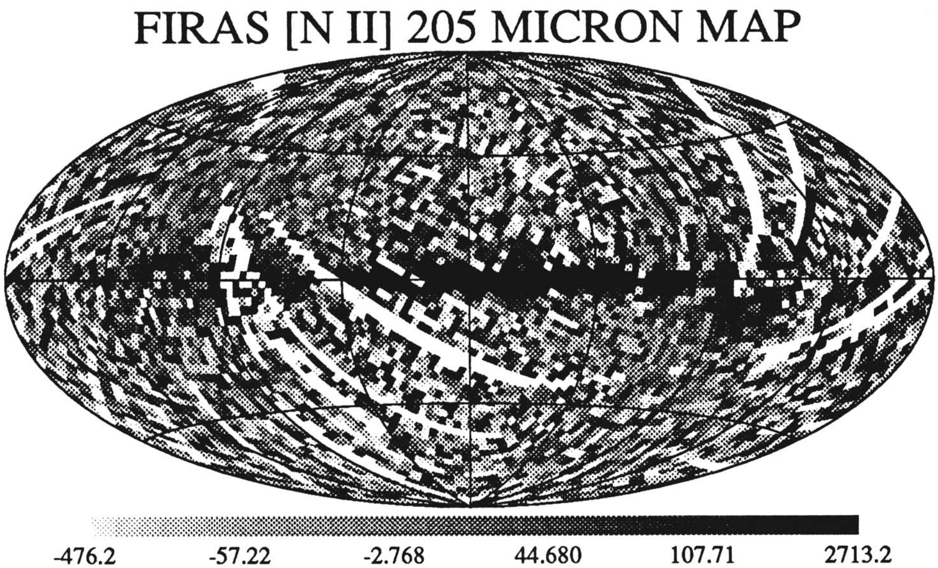

Fig. 3. Map of the [N II] 205 μm line.

and given only four measured lines, a good fit is expected even though the model is not very realistic or complete. The model has 88% of the CO at 5 K and 12% at 19 K. Figure 4 shows the line strengths and the predicted strengths from the model. This model predicts 0.5 10^{-8} erg/cm^2/sec/sr for the 1-0 line, while the CO-C$^+$ correlation from Wolfire, Hollenbach and Tielens (1989) predicts 0.4 10^{-8} erg/cm^2/sec/sr, compared to the observed (0.6 ± 0.7) 10^{-8} erg/cm^2/sec/sr.

The total CO flux from this model is 16 10^{-8} erg/cm^2/sec/sr, or 0.9% of the 158 μm flux. Note however, that the FIRAS sensitivity at short wavelengths is much worse than the sensitivity at 1 mm, so a fairly strong "hot" CO component could be present without being detected. Such a component could dominate the total CO luminosity. For example, if one includes a hot component with 1% of the total CO at T = 70 K, then the total CO luminosity doubles while χ^2 of the fit increases by only four units, even after including reasonable upper limits for the CO lines from 7-6 to 16-15.

4. [N II] Lines

The [N II] lines seen be FIRAS are quite strong relative to the [C II] lines, and cast some doubt on the idea that the [C II] line emission of galaxies is dominated by PDRs which produce no [N II] emission. Gry *et al.* (1991) have computed the [N II] and [C II] emissivities in the local ISM using

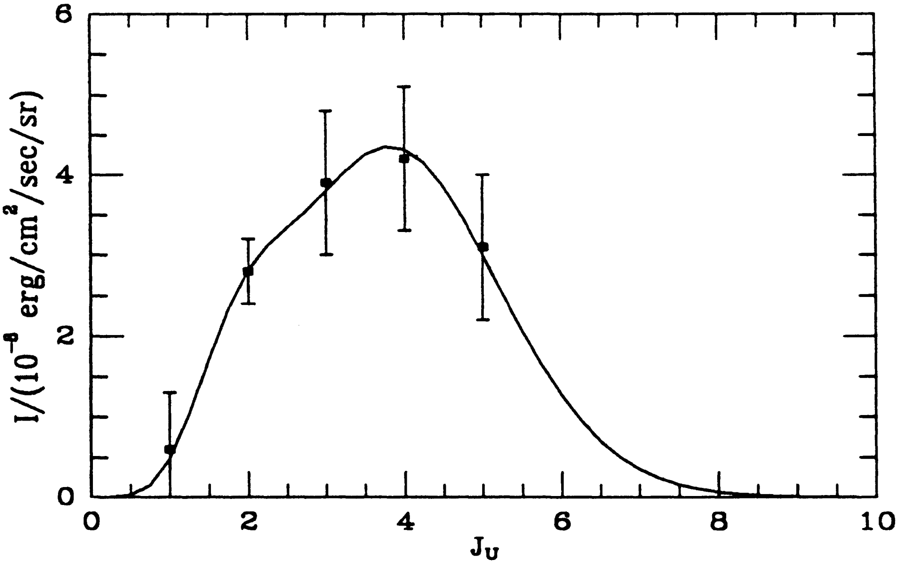

Fig. 4. Two temperature fit to the CO data.

Copernicus observations of the excited state column densities in these ions. I have taken their ratio of I(205)/I(158) for the ionized part of the local ISM and plotted it as the steeper line in Figure 5, where the points are from Wright *et al.*, while the line with the smaller slope is the ratio of the median I(205)/N_H from Gry *et al.* to the average I(158)/N_H. Note that the latter line fits the low intensity, high galactic latitude points well, while the ionized ISM value fits the higher intensity galactic plane points. This shows that a combination of the local diffuse ISM with low density H II regions can explain the observed [N II] to [C II] relation without invoking much PDR emission.

However, for a mean density of 1 H cm^{-3}, the diffuse ISM can have an opacity in the [C II] line of $\approx 1/\sin(2l)$ if all carbon is in the form of C^+ and the velocity gradient follows the galactic rotation curve. If high spectral resolution observations of distant sources such as W49 show a number of sharp absorption dips superimposed on the emission line from the source, then the true [C II] emission from the galaxy would be higher than flux measured by FIRAS, allowing for a greater contribution from PDRs to the [C II] emission.

5. Discussion

The FIRAS observations of the Milky Way show that its ratio of [C II] 158 μm line flux to the total far-infrared flux is typical of other galaxies

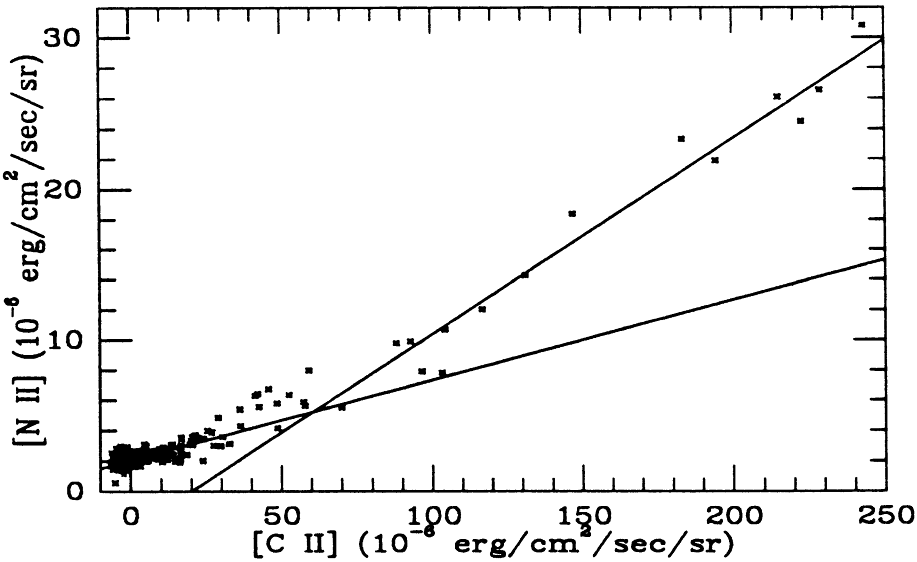

Fig. 5. N^+ *vs.* C^+. Lines show ratio for the median of 7 local lines-of-sight and the average of the local ionized ISM. Data are from Wright *et al.*.

discussed by Stacey *et al.* (1991). The species CO and [C I] each contribute about 1% as much flux as [C II], while the [N II] line at 205 μm contributes a surprisingly large 10% of the power from [C II].

Acknowledgements

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QUESTIONS AND ANSWERS

V.V.Burdysha: What is the possibility for observation of the distortion CMB in range 100 - 150 μ by COBE, which creats in the moment of the recombination of the universe?

E.L.Wright: The smallest galactic flux seen by COBE at 100 - 150 μm has about 10^{-1} times the CMB power. This is much larger than the predicted distortion in the CMB caused by the Lyman α line at recombination.

S.P.Tarafdar: You gave two temperatures for CO. Are they excitation temperature or kinetic temperature? These temperatures are very similar to two dust temperatures you obtained. Can you comment?

E.L.Wright: The temperatures are excitation temperatures. The similarity to the dust temperatures is probably coincidental.

E.van Dishoeck: Are you worried that COBE's lack of detection 557 GHs water emission will mean that the submillimeter Wave Astronomy Satellite (SWAS) will not see water?

G.Melnick: No - for three reasons. First, water emission is expected to arise predominantly in warm ($T > 30\,K$), dense ($n_{H_2} > 10^4\,cm^{-3}$) gas. Such gas comprises a very small fraction of COBE's 7 degree beam. SWAS will have a solid angle 10^4 times smaller than COBE's, which means the filling factor will favor SWAS. Second, COBE's spectral resolution, $\lambda/\Delta\lambda$, was about 100. SWAS will have a spectral resolution of 5×10^5, or 5000 times higher than COBE's. This increased spectral resolving power will aid SWAS immensely in distinguishing line emission from the (spectrally) neighboring dust continuum emission. Finally, the upper limit COBE set on the 557 GHs water emission is less than a factor of 10 lower than COBE's measurements of the lower-J CO line strengths. The known antenna temperatures produced by these CO lines for fields-of-views comparable to that of SWAS ($\sim$ 4 arcminutes) are very strong by SWAS's sensitivity expectations. Even if the 557 GHs water line strength is 10 times below COBE's upper limit, SWAS should have no problem detecting this emission.