Probing Beyond COBE in the Interstellar Medium

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Introduction

The COBE satellite, with its instruments, has provided new insights into the origin and evolution of the Universe. The FIRAS (Far Infrared Absolute Spectrophotometer) has supplied the best demonstration that the Cosmic Background Radiation is a blackbody (Mather et al., 1990). The DMR (Differential Microwave Radiometer) has provided what appears to be the first measurement of the structure in the angular distribution of the background radiation (Smoot et al., 1992).

What more is there to do and how can it be done?

Beside what may be done by subsequent satellites, two important measurements can be made using interstellar thermometers. The first is to provide a precise independent check on the absolute calibration of the FIRAS spectrophotometer. The second and most interesting from a cosmological point of view is to demonstrate the homogeneity of the CBR radiation. A third possibility would be to verify the expansion of the Universe via the (1 + z) dependence of the temperature of the CBR.

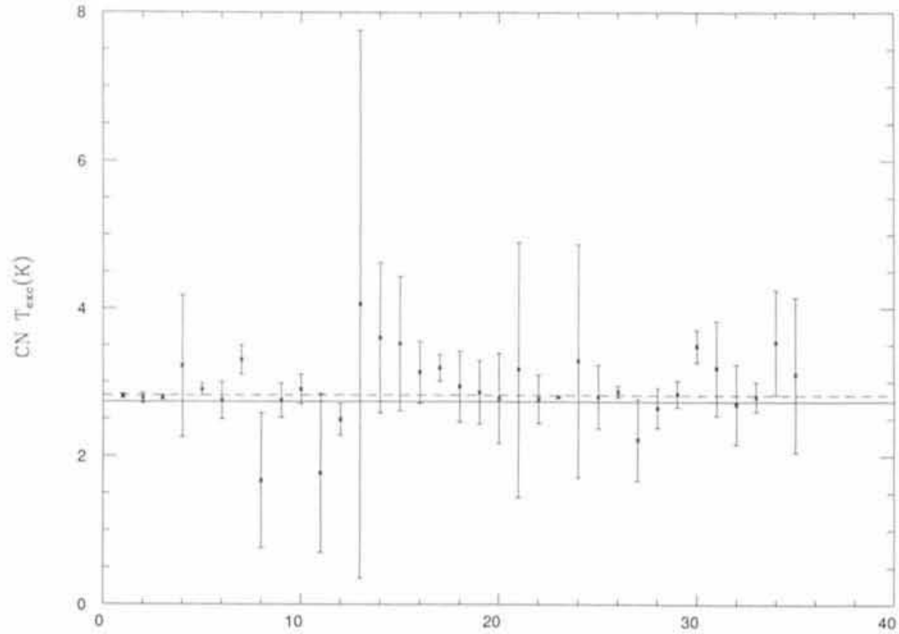

Figure 1: *Measured T_{exc}(CN) with the associated 1 σ errors vs increasing HD number of the observed stars (Palazzi et al.). The solid line represents the COBE result for T_{CBR}, T = 2.735 ± 0.06 K, the dashed line is the weighted average of the T_{exc}(CN) values, T = 2.818 ± K, the dashed line is the weighted average of the T_{exc}(CN) values, T = 2.818 ± 0.018 K.*

One of the fundamental assumptions in current cosmological models is the homogeneity of the Universe and hence of the CBR radiation. Homogeneity means that an observer anywhere in the Universe should measure the same global properties. In particluar, the temperature of the CBR should be the same.

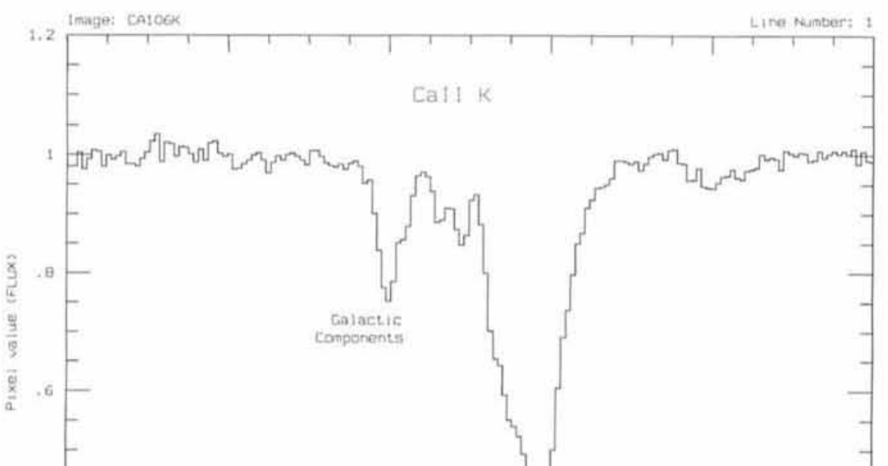

Figure 2: *Interstellar Ca II K towards the star SK 106 (SMC). Galactic components and Magellanic Cloud components are well dinstinguishable.*

Soon after the discovery of the CBR, it was recognized that the rotational excitation of interstellar CN could provide one of the best thermometers for determining the T_{CBR}. Subsequently, modern techniques have pushed the method close to the precision of the best radiometers. Although the radiometers are quite precise, they are only able to measure the CBR temperature locally (≈ 1 AU of the Sun) and they depend on sophisticated and complicated methods for calibration.

On the other hand, interstellar CN, which has been seen in several clouds within 1 Kpc, is able to report to us the intensity of the CBR radiation field in its vicinity. In addition, the actual temperature determination relies on a rather direct technique.

CN Measurements of the CBR Homogeneity within 1 Kpc

A recent compilation (Palazzi et al., 1992) of the measurements of CN excitation temperatures for bright stars has not shown any large differences in the T_{CBR} in any direction providing the largest body of data to support the homogeneity of the CBR even if only within about 1 Kpc. However, most of the CN excitation temperatures appear slightly above ($\approx 80 \pm 30$ mK) the COBE measurement of $T_{CBR} = 2.735$ K (Fig. 1). A possible explanation of this excess would be the presence of local excitation mechanisms (such as collisional excitation). None of the data necessary to quantify these mechanisms are of sufficient quality to provide a clear explanation of the observed difference. Improved observations would be needed to obtain better data on local conditions in molecular clouds and on CN absorption line measurements to show if the excess in the CN excitation temperature is really a result of collisional excitation.

Homogeneity within 50 Kpc

A very real possibility exists to determine T_{CBR} in the Magellanic Clouds if an appropriate sight line with sufficient CN column density can be found. Such a measurement is just within the possibility of the largest telescopes in the southern hemisphere.

We have initiated a programme for observing a sample of lines of sight towards bright and reddened O and B stars in the Magellanic Clouds. The observations were performed in October 1991 at the 3.6-m ESO telescope (La Silla, Chile) using the CASPEC spectrograph with the 31.6 line/mm grating plus the long camera in the wavelength range 3800Å–4500Å.

Preliminary results show that the CaII H and K interstellar lines (both galactic and Cloud components) are present in all the observed stellar spectra (Fig. 2). Molecular absorption lines of CH and CN are marginally visible (Fig. 3), representing the first detection of the CN species in the Magellanic Clouds interstellar medium. Detection of interstellar CH and CH^+ has been reported only towards supernova 1987 by Magain and Gillet (1987).

Additional observing time is needed for improving the molecular detection, in particular CN for the measurement of the T_{CBR} at 50 Kpc from us.

Homogeneity on Large Scales

It may be possible to observe the excitation of other molecular rotation or atomic fine structure lines at quite large distances (Bahcall and Wolf, 1968). Indeed a few reports (Meyer et al., 1986; Wampler, 1990) of upper limits to T_{CBR} at redshift around $z = 1.6$ and $z = 2.5$ have been reported for the excitation of CI and CII fine structure lines.

In contrast to the measurements in the Magellanic Clouds the measurements at high redshift introduce a rather large uncertainty in the local condition of the species observed, for example local excitation mechanisms such as collisional processes or local UV field are difficult to evaluate. Nevertheless, a determination of $T_{CBR}(z) < (1 + z)[T_{CBR}(z = 0)]$ at any redshift would be very difficult to explain in the context of the standard cosmological scenarios. Though they are affected by large uncertainties, the existent upper limits to $T_{CBR}(z)$ do not contradict the present theories.

In summary, exciting and important cosmological results are possible from a careful study of the interstellar thermometers available to us.

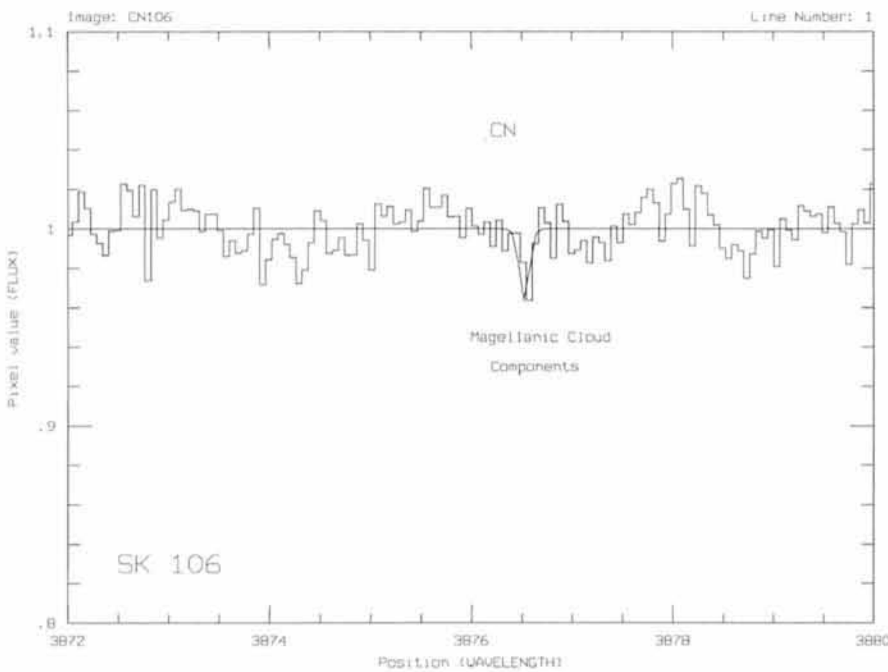

Figure 3: *Interstellar CN towards the star SK 106 (SMC). The position of the line coincides with one of the stronger components of the interstellar CaII K in the Small Magellanic Cloud. The upper limit for the CN column density is 1×10^{13} cm^{-2}.*

References

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