THE COLOURS OF THE INTERSTELLAR MEDIUM

(Letter to the Editor)

PETER MÜLLER AND WOLFGANG KUNDT
Astrophysikalische Institute der Universität, Bonn, F.R.G.

(Received 5 January, 1989)

Abstract. On the basis of I−I plots, we find that the ISM radiates preferentially at two pairs of far-infrared frequencies which correspond to (scattered) black-body temperatures of (23 ± 1, 187 ± 5) K and (39 ± 1, 104 ± 5) K. The first pair is emitted by the cold matrix, the second pair by H II regions and supernova shells.

1. I−I Plots

Whereas galaxies are usually mapped by the visible radiation of their stars, the medium between the stars is a poor emitter at optical frequencies. Instead, the interstellar medium (= ISM) radiates predominantly at far-infrared and submm wavelengths, in the form of thermal radiation from dust, at temperatures between 20 and 200 K.

The temperature of a dust grain should depend on both the gas temperature of its environment and on the albedo (absorptivity) and thermal emissivity of its surface. These properties can be different for grains of different chemical composition, like graphite and silicate, as well as for grains of different sizes (see Hildebrand, 1983; and Draine and Lee, 1984).

It, therefore, comes as a surprise that IRAS observations of the ISM find essentially two radiation temperatures, namely 23 K for the cold, unperturbed ISM and 39 K for locally re-heated regions, like H II regions and supernova shells. On top of these, there is a 30% admixture of radiation corresponding to temperatures of ≤ 190 K and ≥ 100 K, respectively. More precisely, the infrared colours of the ISM correspond to $T = (23 \pm 1, 187 \pm 5)$ K for the unperturbed cold matrix and $T = (39 \pm 1, 104 \pm 5)$ K for localized warm regions whereby only some 25% of the total power are emitted at the higher temperature.

These properties would be obvious if high-resolution IR spectra were available (cf. Cox et al., 1986). Instead, the uniformity of the radiation spectra can be inferred from so-called I−I plots, or T−T plots, in which the pointwise intensities $I_\lambda(v)$ of digitized maps at two different frequencies $v_\lambda$ are plotted against each other (see Hirth et al., 1987). Such I−I plots are scatter diagrams unless all gridpoints have the same intensity ratio at $v_1$ and $v_2$, a property which is implied by identical radiation temperatures. Identical radiation temperatures (colours) yield straight-line I−I plots.

Remarkably, the IRAS maps at wavelengths of 100, 60, 25, and 12 μm can be decomposed into 'background' and 'localized sources' such that for the two components, the I−I plots are straight lines, indicating uniform colours. Figure 1 demon-
Fig. 1. Intensity–intensity plots for a 1.3° × 5° field centered on the H II region S 54; plotted are spectral intensities $I_v$ in units of MJy ster$^{-1}$ for the IRAS grid of 40 times 151 pixels. (a) $I_v$ (60 µm) versus $I_v$ (100 µm). The bottom boundary corresponds to the cold background of $T_{cb} = (22.8 \pm 1)$ K. The broad strip of 3.2 times steeper slope corresponds to the cold local source of $T_{cl} = 38.7$ K. (b) $I_v$ (12 µm) versus $I_v$ (25 µm). The warm background component, of $T_{wb} = (187 \pm 5)$ K, is clearly indicated as the left-hand boundary. (c) After subtraction of the cold background according to Equations (1) and (2), the cold local source reveals its uniform temperature of $T_{cl} = (38.7 \pm 0.5)$ K. (d) After subtraction of the warm background according to Equations (1) and (2), the temperature of the warm local source is found as $T_{wl} = (105 \pm 5)$ K.

strates this fact for the galactic H II region S 54. The first, $I_v$ (60 µm) versus $I_v$ (100 µm), manifests the cold background temperature $T_{cb} = (22.8 \pm 1)$ K as a sharp lower boundary from which the warmer 'localized' $T_{cl} = 39$ K branches off as a broad strip of steeper slope. The second, $I_v$ (12 µm) versus $I_v$ (25 µm), manifests the warm background temperature $T_{wb} = (187 \pm 5)$ K as the left-hand boundary from which the (cooler) warm 'localized' temperature $T_{wl} = 104$ K branches off with a flatter slope. In both cases, the first temperature can be found with an uncertainty of order 1% (under the assumption of scattered black-body radiation) whereupon the second temperature