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Interstellar radiation and dust

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The Sun shines down on the Earth breathing life into everything around us. A myriad of other stars likewise illuminate their own neighborhoods. However, those distant stars are often much less benevolent to their local environments than the Sun is to its own back yard. The sum of these stellar illuminations is the interstellar radiation field (ISRF), which is made up of photons originating from a large number of stars with very different colors, activity levels, and ages. One should, of course, add the extragalactic and cosmological contributions to this radiation.

The photons of the ISRF are responsible for warming the cold interstellar medium through the heating of the gas and dust. They can, when particularly energetic, lead to the destruction of that gas and dust by "photo-dissociation". Some important effects of the ISRF on the interstellar medium include the heating of the gas by the energetic photo-electrons ejected from grains following ultraviolet photon absorption, the forces exerted on dust by photons that then drive mass movements, and the thermal energy re-radiated by dust at mid-infrared to millimeter wavelengths that can heat dust in the interiors of dense cores that are opaque to stellar visible and ultraviolet photons.

A detailed knowledge of the combined contribution of the stars to the ISRF is one of the keys to interstellar medium studies of the gas and dust physics. Earlier ISRF studies mainly focused on the shorter wavelength, stellar part of the ISRF (e.g. Habing 1968; Draine 1978, online). John Mathis, Peter Mezger, and Nino Panagia built upon these foundations in their 1983 paper, which was itself based on the soon-to-be eclipsed companion paper (Mezger et al. 1982, with >200 citations), and laid out a four-component stellar radiation field model and an associated dust emission model to explain the existing observations of the ISRF from the ultraviolet to the mm wavelength domain. The utility of their approach has clearly been attested to over the years by the almost 600 SAO/NASA Astrophysics Data System (ADS) citations to the paper.

This is a seminal piece of work in the many areas of interstellar medium physics that it tackles, including the stellar input to the ISRF, the dust heating in GMCs and dense cloud interiors, and radiative transfer effects in interstellar clouds. The scope of the paper couples some of the extremes of astrophysics, i.e., encompassing studies of the big (stars) and the small (dust grains), and leads the reader to a series of analytical equations that provide a complete and self-consistent description of the ISRF and the dust temperatures in the interstellar medium.

An important element that this work brought to interstellar medium studies was the calculation of the three-dimensional variations in the Galactic ISRF, principally as a function of galacto-centric distance (D_G). This was based on a simple geometric model of the Galaxy, omitting spiral structure and the clumpiness of the ISM. In particular, Mathis, Mezger, and Panagia showed that the ISRF total energy density decreases by almost an order of magnitude between D_G = 5 and 10 kpc. They showed that ISRF is dominated by starlight in the 0.09–8 μm wavelength region (peaking at about 1 μm) and at 8–1000 μm wavelengths (peaking at about 150 μm) by the re-emission of the large fraction of that starlight that is absorbed by galactic dust. At wavelengths longer than about 1000 μm, the cosmic microwave background makes up the major contribution to the ISRF. They were able to show that the emission from the dust associated with the diffuse interstellar medium contributes almost half of the galactic far infrared/sub-mm emission. They also calculated the radiation field inside giant molecular clouds arising from the heating of dust by stellar photons and also by the FIR/sub-mm emission from the dust itself. Interestingly, they predicted that the dust at the center of "very opaque clouds", heated by an enhanced far-infrared radiation field coming from the warmer dust at the cloud surface, should have temperatures in the range 5–8 K. Thus, the stellar photon energy that is absorbed by dust at the cloud surface is re-radiated at far-infrared wavelengths into the denser, opaque regions and is able to keep the dust in the cloud interior at temperatures above the 2.9 K background. Such emission may already have been detected in the Milky Way and in dwarf galaxies (e.g. Reach et al. 1995; Galliano et al. 2003, respectively).

One of the major predictions that came out of this work now seems so commonplace and so obvious with, of course, the added value of more that 20 years of observations and improved instrumental developments. Mathis, Mezger, and Panagia proposed that the thermal radiation from the cold dust in dense cores ($n_H = 10^6$–10^9 cm^{-3}) within GMCs ought to provide a means of probing these sites of eventual star formation with the then "next generation" of mm/sub-mm radiotelescopes. As we now know, this was certainly the case and these sites of star formation have indeed been thoroughly studied by those "new" facilities (e.g. Mezger et al. 1990, online) and, much more recently at shorter wavelengths, by space-borne telescopes (e.g., Bacmann et al. 2000). These dense star-forming regions will shortly receive the focused attention of the *Herschel* and *Planck* missions, and we will, for the first time, be able to examine the physics of some of the coldest and densest regions of the interstellar medium and the initial stages of star formation in fine detail.

Since the initial rapid rise in the citations to this work it has achieved an annual average citation rate of about 15–25 citations per year since 1986. That the citation rate has remained roughly constant over more than the last 20 years attests to its quality and longstanding utility. The papers that have referred to this work over the years include the many fields of astrophysics pertaining to the gas and dust physics in the interstellar medium of the Milky Way but also come from the extragalactic domain (e.g. Silva et al. 1998; Calzetti et al. 2000, online). Obviously, in the area of galactic interstellar medium studies, this paper has achieved wide utility, and the methodology has been used as an essential element of diffuse interstellar cloud studies (e.g., van Dishoeck & Black 1986; Boulanger & Perault 1988); carbon and silicate dust thermal emission models (e.g. Draine & Lee 1984; Dwek et al. 1997; Désert et al. 1990; Draine & Li 2001b, online); small grain and "PAH" stochastic thermal emission (e.g. Puget & Léger 1989; Draine & Li 2001a, online); understanding the large-scale distribution of the extended red emission (ERE, e.g. Gordon et al. 1998, online); grain alignment, polarization, and spinning dust studies (e.g., Draine & Lazarian 1998); the photoelectric heating of the gas (e.g., Weingartner & Draine 2001); the photon irradiation of ice mantle materials (e.g., Gerakines et al. 1996; Ehrenfreund & Charnley 2000); the study of interstellar ions, radicals, and molecules and their photo-dissociation and ionization (e.g., van Dishoeck & Black 1988; Draine & Bertholdi 1996); interstellar clouds and photon-dominated regions (e.g. Wolfire et al. 2003; Hollenbach et al. 1991, online); and radiative transfer codes (e.g. Boissé 1990, online).

What makes this such an outstanding and well-cited piece of work? This is clearly due to its applicability to fundamental areas of interstellar medium astrophysics. Such an astute application of the work and its full-value exploitation by the authors is remarkable, making this paper a "classic" in interstellar medium studies.

I would like to end by thanking John Mathis, Peter Mezger, and Nino Panagia, on behalf of all the users of their work, for having provided the astronomical community with the ideas and tools that have allowed us to significantly advance our studies of interstellar medium physics.

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