How good is dust emission as a tracer of star forming regions in molecular clouds?

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Abstract

A molecular cloud was simulated using RADMC-3D (Dullemond et al. n.d.) using bespoke input files generated in Python. This simulation was performed across the 3 SPIRE (Griffin et al. 2010) wavebands centered on 250 μm, 350 μm and 500 μm. This data was then 'degraded' by accounting for SPIRE's transmission curve to better simulate a molecular cloud observed by Herschel. This data was then analysed by performing weighted averages in each of the wavebands, subsequently plotting Spectral Energy Distributions (SEDs) on a pixel by pixel basis to recover the column density N and temperature T at each pixel.

Contents

I. Introduction

A star is defined as a spherical object of ionised plasma bound by its own gravity. A star is not itself a static object as nuclear fusion actively changes the composition of the star throughout its lifetime.

I. Star Formation

The star forming process is one of the most important processes in the cosmos, as star formation (and the subsequent evolution of the star) poses an unequivocal factor driving the evolution of the Universe forward.

Stars are essentially chemical foundaries, acting as the primary source of elements heavier than ^{2}He in the Universe. The production of ^{1}H, and ^{2}He, occured within the first few seconds after the Big Bang (Olive and Peacock 2011). Whilst further production of ^{2}He can occur via the first fusion process, the proton-proton (pp) reaction described by Equation 1 (Burbidge et al. 1957), ^{1}H cannot be produced via a fusion process.

$$^{1}\mathrm{H} + {}^{1}\mathrm{H} \longrightarrow {}^{2}\mathrm{He} + \mathrm{e}^{+} + \mathrm{v_e} + 0.42\,\mathrm{MeV} \tag{1}$$

That being said, ^{1}H is still the most abundant element in the Universe, amounting to roughly 72% by mass according to Suess and Urey (1956). As a result of the ^{1}H synthesis during the Big Bang, its abundance can be used as an indicator of an object's age.

^{56}Fe cannot be fused to create any heavier elements as this fusion requires more energy to fuse than the fusion would produce, thus acting as a net loss of energy.

II. Molecular clouds

Molecular clouds themselves are dense regions of the Interstellar Medium (ISM), composed primarily of molecular Hydrogren (H_2) at temperatures $< 20\ K$ (Hildebrand 1983). Much like the ISM, they are composed of gas and cosmic dust, however a molecular cloud differs from the ISM in that significantly greater densities are found within a molecular cloud than that of the ISM. The dust density in a molecular cloud is around $10^5\,g\,cm^{-3}$, whilst the dust density in the surrounding ISM is around $10^2\,g\,cm^{-3}$. The molecular cloud is also colder than the surrounding ISM: the temperature is approximately 15 K in the ISM whilst the temperature in the molecular cloud is approximately 10 K. This results in a temperature gradient that increases with radius. The ISM essentially bathes the molecular cloud, heating it from the outside.

Dust is a relatively small fraction of the total ISM mass, estimated as being only 1% according to Shetty et al. (2009). Whilst the dust mass accounts for such a small mass component, it still presents an important role in forming stars.

Dust radiates as a modified black body approximated by Equation 2.

$$S_\nu = N\Omega\kappa_0\left(\frac{\nu}{\nu_0}\right)^{\beta} B_\nu(T) \tag{2}$$

In Equation 2 S_ν is the flux density, N is the column density, Ω is the solid angle subtended by the beam, κ_0 is a reference dust opacity, ν is the frequency of the image, ν_0 is a reference frequency at which the reference opacity κ_0 was evaluated at, β is the dust spectral index and $B_\nu(T)$ is the frequency dependent Planck function.

Dust properties such as the spectral index β and temperature T have an effect on dust emission and therefore the ability to detect radiation from within a molecular cloud due to, for example, a prestellar core and therefore understand the processes governing its formation and evolution.

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