The Initial Conditions of High Mass Star Formation: a radiative transfer model of an IRDC seen in the Hi-GAL Survey

L. A. Wilcock[1], D. Ward-Thompson[1], D. Stamatellos[1], J. M. Kirk[1], C. Battersby[2], C. Brunt[3], G. Fuller[4], S. Molinari[5], A. Whitworth[1], P. Martin[6], M. Thompson[7], J. C. Mottram[3], N. Peretto[4], R. Plume[8], H. A. Smith[9]

[1]Cardiff University, [2]University of Colorado, [3]University of Exeter, [4]University of Manchester, [5]IFSI, [6]University of Toronto, [7]University of Hertfordshire, [8]University of Calgary, [9]Harvard Smithsonian CfA

Abstract

Infrared dark clouds (IRDCs) are the earliest observable stage of high mass star formation. They have low temperatures, emitting mostly in the far-infrared and sub-millimetre. Many IRDCs contain cold, compact cores which are believed to be the high mass equivalent of protostars. Herschel offers, for the first time, high resolution far-infrared observations of not only IRDCs, but of the individual cores within. We use a 3D Monte-Carlo radiative transfer code to model the emission from two typical infrared dark cores contained within a single IRDC.

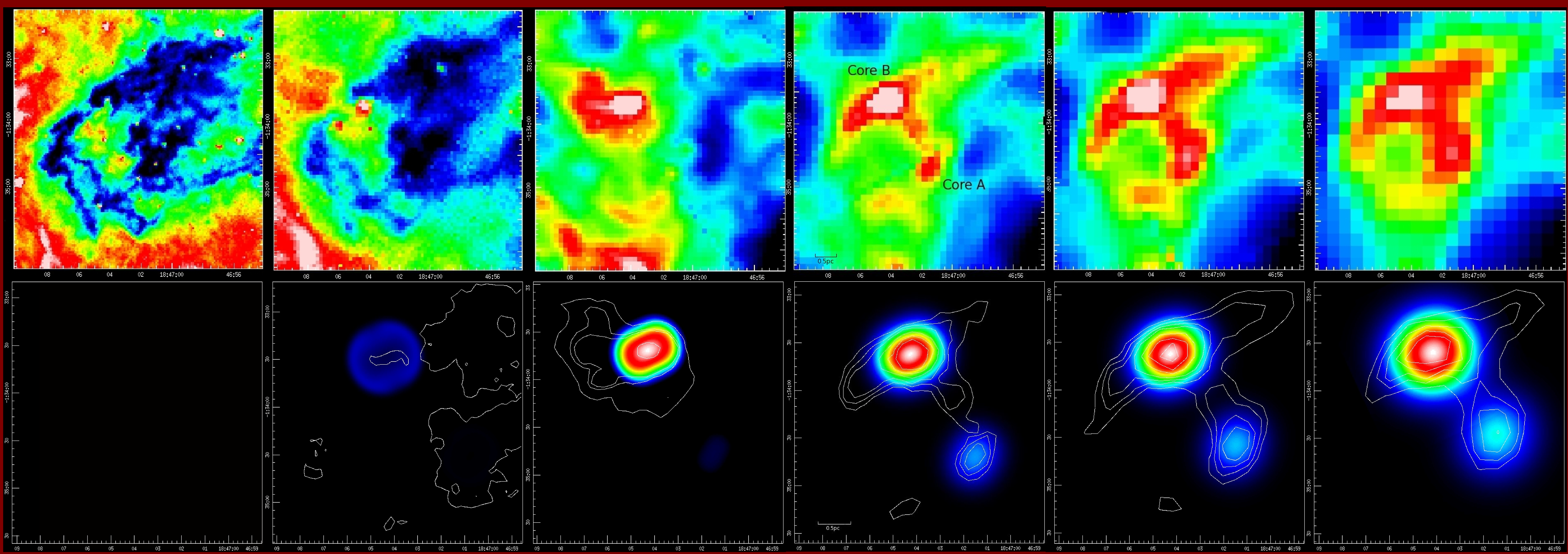

Figure 1: Top Row: G031.03+00.26 at all 6 observed wavebands (left-right: 8μm Spitzer GLIMPSE, 70μm and 170μm PACS, 250μm, 350μm and 500μm SPIRE). The positions of the two cores are shown in the 250μm image. Bottom Row: Model output for G031.03+00.26 (same wavelengths as top row). Contours are taken from observed data.

Observations of the Cores

The Simon et al. (2006) catalogue was used to identify IRDCs within the 2x2° Hi-GAL region centred around *l*=30°, *b*=0°. Each IRDC candidate was viewed at Spitzer 8μm and Herschel 70, 170, 250, 350 and 500μm. Any object showing extinction in the mid-IR but emission in the far-IR was identified as an IRDC.

One of the sources confirmed as an IRDC was G031.03+00.26. It contains two cores, designated Core A and Core B. Core B is to the north of Core A, and is the brighter and more extended of the two. Flux densities were measured in all five FIR maps for both cores. SEDs were plotted (Figure 2) and a single-temperature greybody-curve fitted from 75 to 500μm. The dust emissivity index, β, was constant at 1.85. The best fit temperatures were 14K for Core A and 17K for Core B.

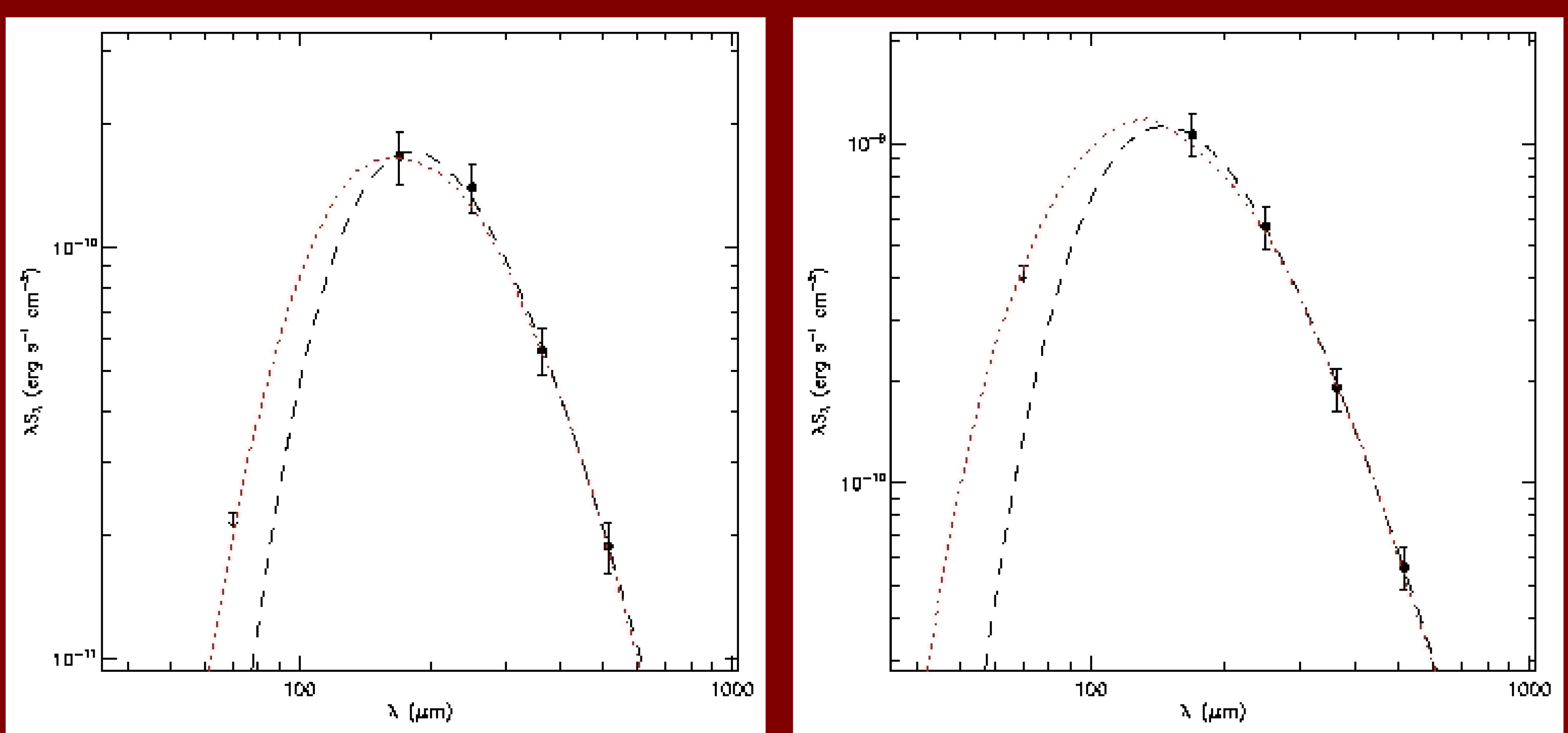

Figure 2: SED of Core A (left) and Core B (right). The dashed line shows the single-temperature greybody. The dotted line shows the Phaethon SED.

Models of the Cores

The cores were modelled using Phaethon (Stamatellos & Whitworth 2003, 2005), a Monte Carlo radiative transfer code. In the model the amount of radiation incident on the cores was allowed to vary. Output images are shown in Figure 1.

The masses of the cores were found both from the model and the 500μm flux densities (Hildebrand, 1983). The former gave masses of 165 and 290$M_\odot$, and the latter, 170 and 310$M_\odot$ for Cores A and B respectively (assuming a distance of 4.9kpc; Teyssier et al. 2002). These are in agreement with each other and with what is expected from a high mass protostar.

Phaethon models the cores as externally heated. The temperature profiles of the cores show temperatures similar to the greybody temperatures at the outer radius and lowering to approximately 10K in the centre (Figure 3).

The amount of radiation incident on Core A was found to be four times lower than that on Core B. As the modelled ISRF of Core B was consistent with measurements in the Galactic Plane, we conclude that Core A must be more deeply buried within the parent cloud than Core B.

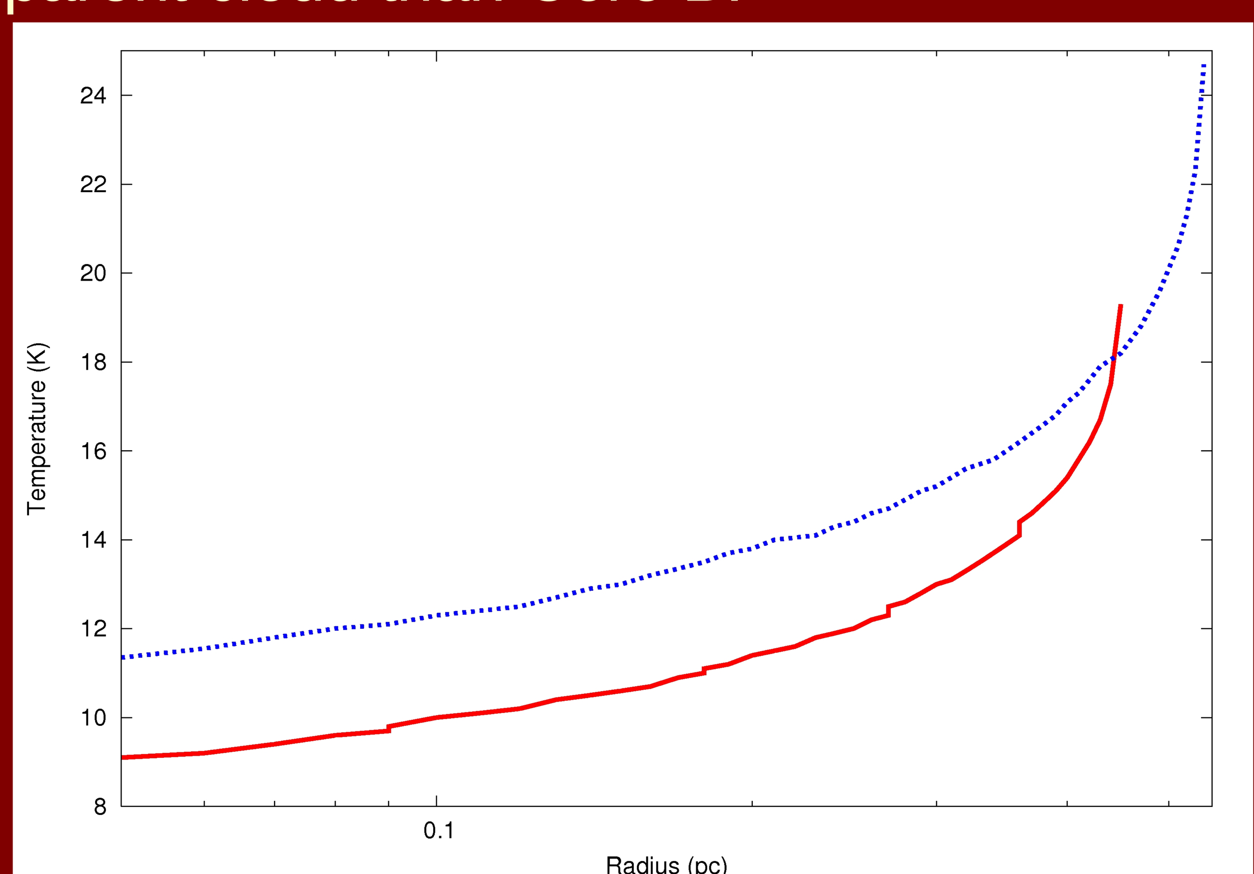

Figure 3: Model fit of temperature plotted against radius for Core A (red line) and Core B (blue line), showing that a single temperature fit is an over-simplification.

References

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