The properties of pre-stellar cores

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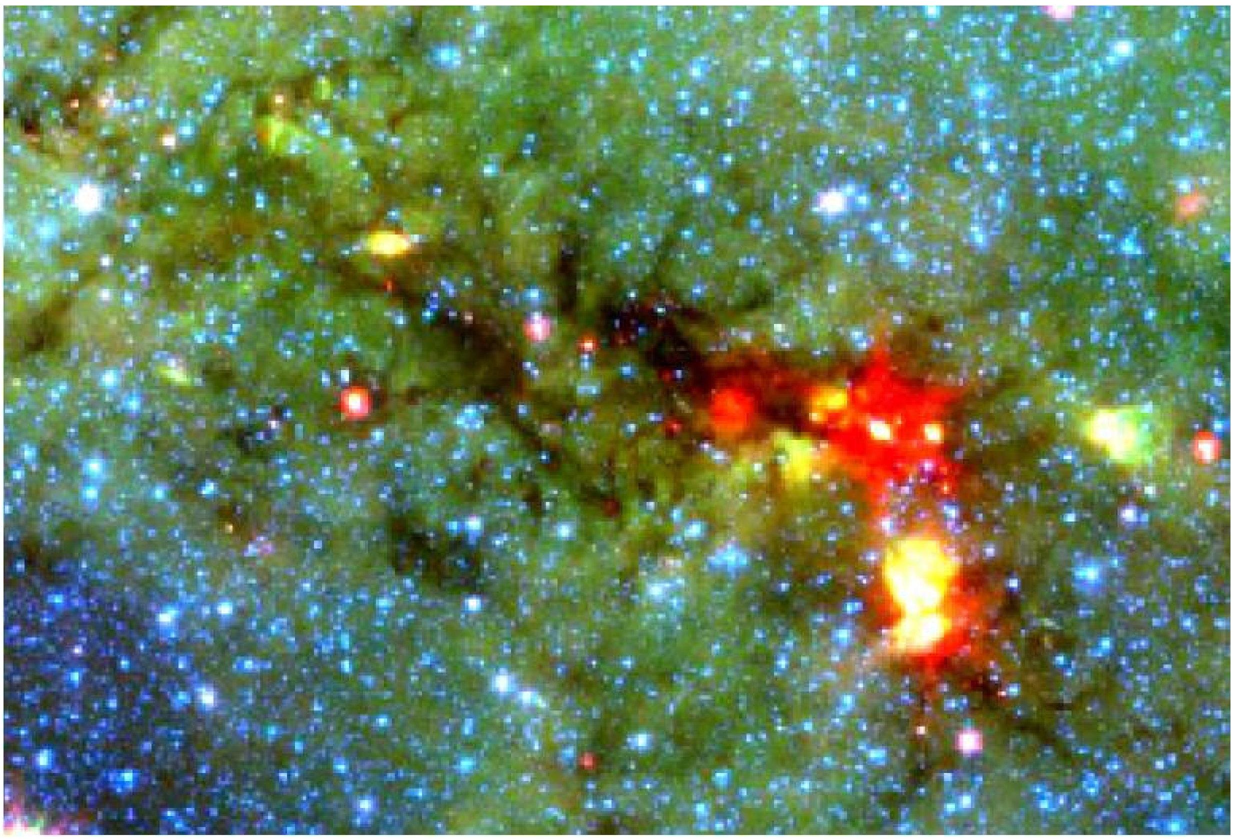

A false-color infrared image of a young, star-forming dust cloud with several embedded cores (identified in red). A new infrared study of 3218 cores in various stages of development has enabled astronomers to categorize the temperatures, densities, and evolutionary characters of young stellar nurseries. Credit: NASA/Spitzer and P. Myers

Stars like the Sun begin their lives as cold, dense cores of dust and gas that collapse under the influence of gravity until nuclear fusion is ignited. These cores contain hundreds to thousands of solar-masses of material and have gas densities about a thousand times greater than typical interstellar regions (the typical value is about one molecule per cubic centimeter). How the collapse process occurs in these embryos in poorly understood, from the number of stars that form to the factors that determine their ultimate masses, as well as the detailed timescale for stellar birth. Material, for example, might simply fall freely to the center of the core, but in most realistic scenarios the infall is inhibited by pressure from warm gas, turbulent motions, magnetic fields, or some combination of them.

Astronomers are actively studying these issues by observing young stars in the process of being born. The dust in these natal cores (or clumps), however, makes them opaque in the optical, thus requiring observations at other wavelengths, in particular infrared, submillimeter, and radio. In the early stages of star formation, an embryonic star heats the surrounding dust cloud to temperatures between about ten and thirty degrees kelvin before stellar winds and radiation blow the material away and expose the newborn star. CfA astronomers Andres Guzman and Howard Smith, together with their colleagues, have completed an analysis of 3246 star-forming cores, the largest sample ever done. The cold cores themselves were discovered with the APEX submillimeter-wavelength sky survey and then observed in sixteen submillimeter spectral lines; the spectral information enabled the astronomers to determine the distance to each core as well as to probe its chemistry and internal gas motions. The new paper combines these results with far-infrared measurements taken by Herschel Space Observatory surveys. The Herschel data allow the scientists to calculate the dust density, mass, and temperature of each core; the large dataset then permits useful statistical comparisons between cores with varyious parameters.

Sources in the sample fall generically into four categories: quiescent clumps, which have the coldest temperatures (16.8K) and the least infrared emission, protostellar clumps, which are sources with the youngest identifiable stellar objects, ionized hydrogen regions, which are cores within which the stars have ionized some of the surrounding gas, and "photo-dissociation" cores, the warmest of the set, which have dust temperatures around 28K, are slightly more evolved and brighter than the ionized hydrogen cores. Although the groups overlap in their properties, the large sample enables the scientists to conclude that, on average, in the quiescent clumps the dust temperature increases towards the outer regions, whereas the temperatures in protostellar and ionized hydrogen cores increase towards the inner region, consistent with the idea that they are being internally heated. The latter also tend to have dust densities that increase more steeply than the quiescent cores. This study has also identified a population of particularly cold and infrared-dark objects that are probably still in the stages of contraction, or else for some reason have had their star formation aborted. The new paper and its catalog are just the beginning: now that the dust in all these cores has been well characterized, astronomers can associate chemistry with dust temperature, for example, and study subgroups that might represent different stellar masses in gestation.

More information: Far-Infrared Dust Temperatures and Column Densities of the MALT90 Molecular Clump Sample. arxiv.org/abs/1511.00762

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