Astrophysicist explores star formation in Orion's belt

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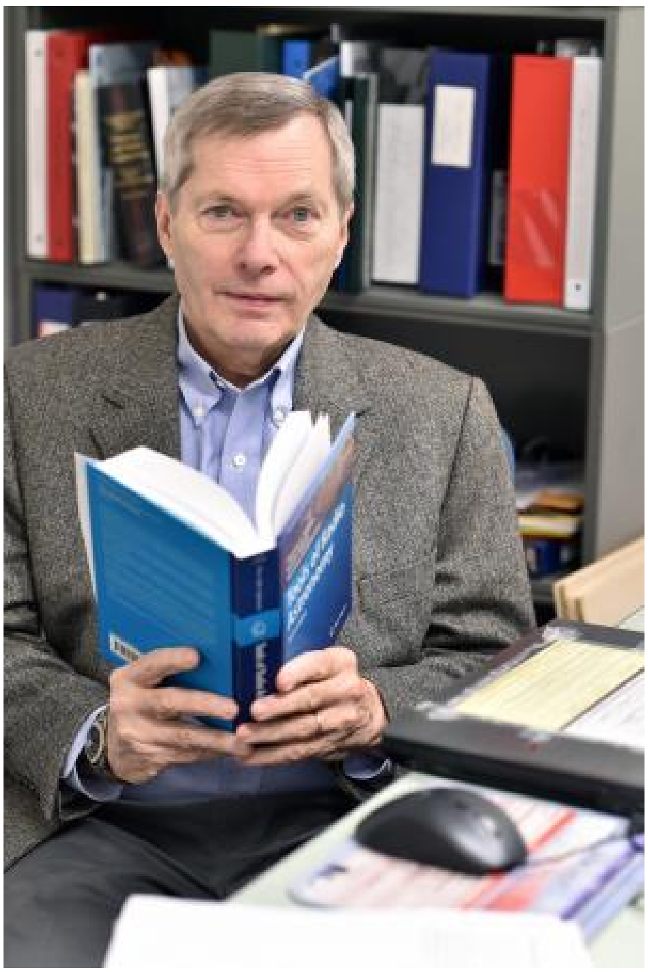

U.S. Naval Research Laboratory astrophysicist Dr. T.L. Wilson is part of a multi-national research team that has discovered an outburst in the infrared from a deeply embedded protostar. Credit: U.S. Naval Research Laboratory/Jamie Hartman

U.S. Naval Research Laboratory (NRL) astrophysicist Dr. T.L. Wilson is part of a multi-national research team that has discovered an outburst in the infrared from a deeply embedded protostar. The Herschel Orion Protostar Survey (HOPS) team's discovery, which helps resolve the discrepancy between the mass accretion rate and luminosity, furthers their understanding of the early stages of star formation. This research is published in the February 10, 2015 issue of *Astrophysical Journal*.

Star formation is a central theme of astrophysics, explains NRL's Wilson. About 45 years ago, scientists came to understand that stars form in the densest parts of cold clouds. These regions consist mostly of molecular hydrogen, helium atoms, and dust grains, and are opaque in the visible part of the spectrum.

Cold molecular hydrogen cannot produce emission lines; helium is inert and most of the trace constituents have condensed onto dust grains, but cold dust will emit small amounts of quasi-thermal radiation in the millimeter and infrared wavelengths. Unlike visible radiation, this radiation is not absorbed, so the study of the earliest phases of star formation must be carried out at infrared or sub-millimeter wavelengths. The wavelength of the maximum radiative output is determined by the temperature of the collapsing region. For the initial phase of collapse, the dust has a temperature of 20 degrees above absolute zero, the maximum emission occurs at 0.15 mm or 150 micrometers. The maximum shifts to shorter wavelengths as the collapsing region becomes warmer. That is, most of the emission falls into wavelength ranges where the earth's atmosphere is opaque, so to completely characterize the regions, the data must be taken with satellites such as the NASA Spitzer Space Telescope, the NASA Wide-Field Infrared Survey Explorer (WISE) and the European Space Agency/NASA Herschel Space Observatory. These facilities have led to a revolution in star formation studies.

Molecular clouds are supported against gravity by a combination of internal motions and magnetic fields. Sometimes small regions in a molecular cloud will collapse and form a dense core. This is the first phase of star formation. Scientists have divided a qualitative picture of star formation into four phases. In the first phase the higher density, cold core attracts nearby gas. This gas falls onto the core, causing an increase in temperature. In later phases, a star forms. This causes an outflow and a disk appears. In the final phase, the dusty disk is dispersed and a star remains. It is likely that the star is surrounded by planets.

A rather nearby cloud is in the constellation Orion, where the HOPS team has been conducting its studies at 70 and 160 micrometers. The HOPS sources were selected from the most embedded sources found in the 3.6, 4.5 and 24 micrometers wavelength survey with NASA's Spitzer satellite. The survey with Herschel measures longer wavelength dust emission in the Orion region, choosing cooler regions where earliest phases of star formation are occurring.

From observations of the number of cold condensations in molecular clouds, scientists estimate the lifetime in the initial collapse phase to be 10,000 years. The time scales of later phases of star formation are longer. However, a contradiction has appeared in the star formation scheme. Much of the luminosity of the early phase is provided by the material falling onto the core, that is, accretion; if the length of the total collapse phase is 100,000 years and if at the end of this time the mass of the core reaches one solar mass, the measured luminosity for such objects is about a factor of ten too small. This has led to a difficulty with the accretion model.

Offering a possible solution to this problem with the accretion model, the HOPS team recently found a source, HOPS 383, that shows a rapid increase in the luminosity. HOPS 383 is a deeply embedded source undergoing accretion, in other words, a star being born. This rapid increase indicates that large amounts of matter may fall onto a pre-stellar core in a short time. This source is visible at wavelengths longer than 4.5 micrometers with the NASA Spitzer satellite.

From a comparison of Spitzer data from 2004 with the data from the NASA satellite WISE, taken in 2010, scientists, including Ms. Emily Safron, Prof. S. T. Megeath (University of Toledo), and Dr. Will Fischer (Goddard space Flight Center), determined that HOPS 383 had an outburst, with an output 35 times brighter than the previous, quiescent stage. The HOPS team has confirmed this by ground-based measurements at millimeter wavelengths. These new data give support to a model in which the mass accretion onto the dense core occurs in rather short but violent episodes, as opposed to steady accretion. In the final phase of star formation, such outbursts have been found in the visible part of the spectrum. The outbursts have been observed toward other young stars, but the occurrence in early phases such as in the case of HOPS 383 is unique and shows that time-variable events are important for our understanding of star and planet formation. If this outburst discovered by the HOPS team proves to be widespread, this allows scientists to reconcile the accretion rate with luminosity.

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