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The following report covers the Department activities from July 2002 through June 2003.

1. PERSONNEL

At the University of Cincinnati, research in astrophysics can be broadly characterized as the investigation of young stellar systems and their environment, primarily at infrared wavelengths. The astrophysics faculty consists of associate professor Margaret Hanson, whose major research interest centers primarily around near-IR studies of young, massive stars and the massive clusters they form in, and full professor Michael Sitko, who works largely in the field of dust in comets and disks surrounding young intermediate-mass and low-mass stars. Dr. Matthew Kenworthy, a post-doctoral fellow working under the auspices of Prof. Hanson's NSF CAREER Grant, works in the area of infrared studies of young clusters, brown dwarfs and extrasolar planets, and the development of instrumentation and sophisticated spectroscopic observing methods. In addition, a number faculty in the Particle Physics group (Philip Argyres, Paul Esposito, Peter Suranyi, Rohana Wijewardhana, and Louis Witten) are actively pursuing theoretical research in areas related to black holes and cosmology.

2. RESEARCH

2.1 Young Stars & their Environments

As part of a program supported by a grant from NASA's Origins of Solar Systems program, Sitko is collaborating with D. Lynch and R. Russell (The Aerospace Corporation) and C. Grady (Eureka Scientific) in a survey of the mid-IR (3-14 μm) spectral characteristics of dusty protostellar disks. The mid-IR data were obtained over the course of 8 years using the Aerospace Corporation's Broad-band Array Spectrograph System (BASS). The purpose of the program is to investigate the evolution of the grains during the epochs when planetary systems are developing. In all, over 40 pre-main sequence stars (Herbig Ae/Be stars and T Tauri stars) were observed. In many cases, multi-epoch observations have been obtained, in order to investigate the time-dependent changes in the structure of the innermost regions of the disks. To unravel the geometry of the disks, and the distribution of the dust within them, theoretical models are being applied to these and other available data.

Sitko is working with N. Calvet and her collaborators at the Harvard-Smithsonian Center for Astrophysics to investigate the structure of the disks surrounding the T Tauri stars, as they did previously with TW Hya. In these investigations a sophisticated model that includes the effects of both internal viscous heating and external irradiation from the star is used. By combining the spectral energy distribution of the star with high resolution imaging at millimeter wavelengths, it was possible to place significant constraints on the nature

of the surrounding disk. For TW Hya, the data indicated that an optically and geometrically thick disk extends to at least 140 AU from the star, and the dust within it must have grown to sizes on the order of 1 cm. Inside 4 AU, the disk is optically and geometrically thin, but this region must contain a sufficient population of grains on the order of 1 μm in size in order to produce the observed 10 μm silicate emission band. The abrupt change in disk properties at 4 AU may indicate the presence of planet-building within that region. Similar modeling is now under way for other objects (GW Ori, GM Aur, DM Tau, Lick Ca 15, etc.).

Sitko and a graduate student, William J. Carpenter, have begun a program to model the global characteristics of the entire sample of objects. For handling such a large group of objects, the publicly-available DUSTY code (University of Kentucky) is being used. In a few cases, these results will be compared with those using Monte Carlo methods. As part of a program led by D. H. Wooden (NASA Ames), Sitko has been monitoring the infrared spectral signature of the highly variable T Tauri star DG Tau. This unusual object has exhibited a silicate profile that has changed from emission to absorption and back again. Features consistent with the presence of crystalline grains are present.

Hanson and collaborators have completed two studies published early in 2003 based on earlier VLT spectroscopic studies in the near-infrared on the ultra-compact HII region G29.96-0.02, and the young star forming region NGC 2024. In the former, and with the help of lead author Leticia Martin-Hernandez (Kapteyn Institute, NL), they performed a near-infrared nebular analysis on the ionized gas. In the latter study, lead author Arjan Bik (U. of Amsterdam, NL) used stellar spectroscopy of IRS2b in NGC 2024 to show this source to be the main source ionization for the entire HII region.

Hanson, Tom Wilson and Dirk Muders (both of Max-Planck-Institut Bonn, Germany) published their study of the mm line-emission from the M17 star forming region. In this study, they mapped out the northern quiescent molecular cloud and the south-western star forming molecular cloud to compare kinematic, chemical and ionizing properties. This allowed them to delineate a number of important star formation tracers within the mm-line properties of the two clouds, which can be used to help identify star forming sites in other giant molecular clouds.

Kenworthy and collaborators completed the first paper in a series of studies on M8, the Lagoon Nebula. This first paper, lead by Nick Tothill (Smithsonian Observatory), presents new high resolution submillimeter and millimeter-wave maps of the molecular gas and dust around the edge of the HII region. Further work, lead by Kenworthy, on the near-infrared stellar sources in the M8 field, is soon to be completed.

2.2 Solar System

For the past few years, Sitko has been collaborating with D. Lynch and R. Russell (The Aerospace Corporation) on the investigation of the nature of cometary dust using BASS. Some of these objects, such as comets C/1999 T1 (McNaught-Hartley) and C/2002 V1 (NEAT) exhibit a significant (15 percent above continuum) silicate emission feature near 10 μm , while in other objects such as C/2002 X5 (Kudo-Fujikawa) it is weak or absent. The entire corpus of BASS spectra, stretching back over the past decade, is being analyzed for possible trends in silicate band strength and excess grain temperature (over that expected for a blackbody in equilibrium) with orbital parameters.

Sitko also contributed to two “white papers” submitted from the astronomical community to the National Research Council’s Solar System Exploration Decadal Survey. One dealt with Dust Astronomy, and the other with the related topic of Comets.

2.3 Stellar Astrophysics

Working with R. Rudy, D. Lynch, R. Russell (The Aerospace Corporation) and others, Sitko was involved in an investigation of the nature of IRAS 07077+1536 using contemporaneous near-infrared (0.8-2.5 μm) and mid-infrared (3-14 μm) spectroscopy. This previously uncharacterized source was discovered to be a carbon star embedded in a circumstellar dust envelope. The near-infrared spectrum displays molecular absorption features of C₂, CN, and CO, while the 11.3 μm feature of SiC is present in the mid-infrared.

Hanson has recently completed a new spectroscopic atlas of hot massive stars to update the one she published in 1996. The new atlas includes over 3 dozen O and early-B stars, observed at high signal-to-noise (S/N \sim 150) and resolution (R \sim 9000) in the H and K near-infrared bands. Besides improving upon the 1996 atlas paper on massive stars, these high quality spectra allow direct fits of the stellar profiles, allowing for the first tests of new atmospheric models being developed with collaborator Joachim Puls (U. Munich, Germany) for quantitative analysis of hot massive stars in the near-infrared. The atlas will be published in 2004, and the model results will soon follow. In order to put together this high resolution atlas, Kenworthy played a crucial role in the reduction of much of the near-infrared spectra, and in developing sophisticated methods for removing strong telluric (Earth) absorption features.

Kenworthy and collaborator Phil Hinz (U. of Arizona) completed a high precision, spectroscopic study of the star HD 209458. HD 209458, which harbors an extrasolar planet, was observed just before, during and after secondary occultation to search for reflected light originating from the planet. While their observations were unsuccessful to detect the reflected light from the planet, their observations and reductions were able to achieve exceedingly small levels of reflected light, about 0.1%. Such light levels are not high enough to detect extrasolar planets, but would be high

enough for a number of other applications, such as short-period binary systems with large brightness ratios (exceeding 6 magnitudes).

Two graduate students, Badra De Silva and Sriyani Jayatileke, completed their projects with Hanson in the summer of 2003, while a third new graduate student, Yara Beshara (BS, Louisiana State U), arrived to begin her project with Hanson, organizing a spectroscopic study of the LBV candidate star G79.29+0.46. Also, in June 2003, Melodie Frickenscher (BS, Northern Kentucky U.) began an appointment as Hanson’s new research assistant.

2.4 Variable Stars

Sitko collaborated with a number of Aerospace Corporation personnel (D.K. Lynch, R.J. Rudy, R.W. Russell, S. Mazuk, C.C. Venturini, and W. Dimpfl) who undertook both near-IR (0.8-4.6 μm) and mid-IR (3-13.5 μm) spectra of the unusual nova V838 Mon. This now-famous object has exhibited a plethora of unusual features during the course of its evolution. Among these are numerous molecular bands due to metal oxides, and a feature near 10 μm that is most easily interpreted as a silicate emission band with a self-absorbed core. The mass of the ejected material is estimated at 0.04 solar masses.

PUBLICATIONS

The publication list includes all papers published or submitted between July 2002 and June 2003 by the staff.

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