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The following report covers the Department activities from July 2001 through June 2002.

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 Margaret Hanson, whose major research interest centers primarily around near-IR studies of young, massive stars and their circumstellar and nebular environment, and Michael Sitko, who works largely in the field of dusty disks surrounding young intermediate-mass and low-mass stars. Dr. Matthew Kenworthy has recently joined the group, in November 2001, hired under the auspices of Hanson's NSF CAREER award. Kenworthy's expertise lies in adaptive optics, infrared photometry, and astronomical software and hardware.

During the past year Hanson has supervised research by graduate student Sriyani Jayatilleke. Ms. Jayatilleke is studying the young, massive galactic clusters found at the center of our galaxy using near-infared spectra taken with the Very Large Telescope (VLT) in Chile.

Amanda Bauer completed her undergraduate degree, and is now in graduate school at the University of Texas at Austin. While at Cincinnati, she spent time investigating the photometric characteristics of an SBIG ST-8 CCD camera that had been shipped from Cincinnati to the Perth Observatory in Australia, reduced photometric data from this camera of selected Herbig Ae/Be stars and T Tauri stars, and spent two summers working on spectral classification for the Sloan Digital Sky Survey at Fermilab [the SDSS work supervised by Dan Vanden Berk].

Undergraduate, Lara Mercurio completed her work in August 2001 with Hanson on near-infrared spectra of CI Cam, and the project is now being continued by a new master's student in the astronomy program, Badra De Silva. She will be looking at how the emission lines in CI Cam have evolved since a high energy outburst occurred 2 years ago, and investigate if in studying the changing conditions of CI Cam, she can discern the nature of the compact object.

In the summer of 2001, Carolyn Eglet and Melodie Fickenscher joined Hanson's massive stars group. Melodie is analyzing some recently obtained spectra of SS 433, while Carolyn has begun a project studying the young star forming region M17 in red-optical spectra.

2. RESEARCH

2.1 Young Stars & Their Environments

Hanson's long awaited near-infrared survey of ultracompact HII regions, in collaboration with K. Luhman (Harvard, CfA) and G. Rieke (Steward Observatory) was published in The Astrophysical Journal, Supplements, January 2002. This survey of 63 radio selected regions is the first of its kind to have studied a significant number of sources in a systematic way to make statistical claims about the detection limit of such sources, and the utility of developing near-infrared nebular analysis for such sources. Approximately half of the radio-selected sources were detected in Brγ emission, and of those, nearly half were detected in He I, allowing the temperature of the central ionizing object to be estimated. In three sources, the central ionizing source was directly revealed using follow up high-resolution near-infrared spectroscopy at the Multiple Mirror Telescope.

Hanson is finishing up a 2-year collaboration with T. Wilson, director of the Sub-Millimeter Telescope Observatory, to study the extensive molecular cloud associated with the young star forming region, M17. In this study, Hanson and Wilson have mapped a $13' \times 23'$ region adjacent to the central OB cluster of M17, in $C^{18}O$ J=2-1 and CS J=3-2 and J=5-4. The study concentrated on two large molecular clouds, Cloud A to the north, and Cloud B to the southwest. Over 40 cloud cores have been identified. Most have never been previously cataloged. The effect of the local OB cluster is heating and strongly compressing Cloud B, reflected in the large number of very young massive stars being formed within. Cloud A, while less effected, may have some associated star formation. This paper is currently in press.

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], C. Grady [Eureka Scientific] in a survey of the mid-IR (3-14 μm) spectral characteristics of dusty protostellar disks. The spectral features observed provide valuable clues about the chemical composition and thermal history of the dust grains in these disks, as well as their geometrical structure. Because of their generally higher brightness levels, the project has previously focused mainly on Herbig Ae stars (intermediate-mass PMS stars), but is now beginning to push to the fainter IR flux densities typical of the T Tauri stars (lower-mass PMS stars). Observations are being obtained using the Aerospace Corporation's Broad-band Array Spectrograph System (BASS) on NASA's Infrared Telescope Facility (IRTF). Although the survey is not yet complete, some of the data have already been analyzed and published.

Sitko worked with N. Calvet and her collaborators at the Harvard-Smithsonian Center for Astrophysics to investigate the structure of the disk surrounding TW Hya using a sophisticated model that includes the effects of both internal viscous heating and external irradiation from the star. 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. The data indicate 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 at 4 AU may indicate the presence of planet-building within that region.

In January, mid-IR spectra of numerous T Tauri stars in the Taurus-Auriga complex were obtained, along with data on Hen 3-600, another member of the TW Hydrae Association. As was done for TW Hya itself, Calvet *et al.* plan to combine the BASS spectra with data at other wavelengths in order to investigate the structure of the inner accretion disk that surrounds one component of this binary star system.

Kenworthy has previously worked on the orbital determination of the multiple brown dwarf system, Gliese 569B, producing orbital parameters agreeing with other groups' data. A significant discrepancy in the reported photometries of the 0.1 arcsecond separation binary, however, coupled with a recent finding of radio flaring in young brown dwarfs, has prompted Kenworthy to begin investigation as to whether the system is variable. Data are being taken at the end of July 2002 to investigate possible correlations of near infra-red variability with the radio flaring seen in these brown dwarfs.

As part of a team headed by M. Gagne [West Chester University], Kenworthy is collaborating with N. Tothill [University of St Mary's, Halifax] and M. McCaughrean [AIP] on X-ray observations of M8 (Lagoon Nebula). Using data to be taken with the Chandra X-ray satellite in late 2003, this project promises new insight into both high mass stellar X-ray variability and the detection of many low-mass embedded young stars in this nebula.

2.2 Solar System

Sitko is collaborating with J. Bradley [Lawrence Livermore National Lab] and Frank Molster [ESA/ESTEC] in a project to study the spectroscopic properties of interplanetary dust particles (IDPs) of presumed cometary origin. Laboratory studies of these particles provide a degree of "ground truth" in our understanding of the chemical composition of the protosolar nebula, and by inference, young protostellar disks. X-ray spectroscopy of the particles provides an inventory of the atomic species present in the IDPs, from which the grain mineralogy can be deduced. IR spectra are then obtained in order to connect the mineralogy to a spectral signature. One of the great outstanding problems related to both IDPs comet dust, and the dust in protostellar disks is the origin of the crystalline silicates. They are present in both IDPs some comets, and some protostellar disks, but their presence is not detected in spectra of the interstellar medium. The IDP spectra suggest three different sources of crystalline material production. One is direct condensation from the gaseous state in the early solar nebula. A second is reprocessing of protosolar grains. A third source is pre-solar grains embedded within primitive IDPs. These grains may represent heavily damaged interstellar particles which formed in a largely crystalline state in the outflows of evolved stars, but whose crystal structure has been destroyed in the outer layers through long-term exposure to cosmic rays, leaving only a small amount of crystalline material in their cores. The large outer rim of non-crystalline material would seem to be masking any hint of the crystalline core when observed spectroscopically along interstellar lines-of-sight.

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 IRAS07077+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 C_2, CN, and CO, while the 11.3 μm feature of SiC is present in the mid-infrared.

Along with K. Werner, S. Dreisler [Institut fur Astronomie und Astrophysik, Tubingen], and J. Kruk (Johns Hopkins University], Sitko was also involved with a study of two DO white dwarfs, HS0713+3958 and HE0504-2408, using the Far-Ultraviolet Spectroscopic Explorer (FUSE). Although the FUSE spectra of these two hot stars are relatively flat, the source of the opacity remains a mystery. The lack of any 2200 Å feature, the weakness of H_2 lines, and absence of CO lines indicate that interstellar extinction cannot be the source of the spectral flatness. Numerous lines from the iron group elements may be responsible, but they were not detected with the relatively low signal-to-noise data obtained.

Hanson is continuing her collaboration with Joachim Puls (University of Munich) to develop a method for quantitative spectral analysis for massive stars which depends solely on near-infrared spectra. The motivation for this program, which is sponsored by an NSF CAREER award, is to allow them to quantitatively study massive stars throughout the entire Galaxy, with extinction as high as tens of magnitudes in the optical. Puls has extended his highly sophisticated, non-LTE, unified model atmospheres developed for the UV and optical to the near-infrared. Hanson has obtained very high-resolution, near-infrared spectra of well-known, optically visible stars, to use as the first standards and to calibrate the method. Data for this program have been obtained at the 8.2-m VLT2 using the ISAAC spectrometer and most recently at the 8-m Suburu telescope using IRCS, in collaboration with Rolf-Peter Kudritzki. During data reduction of these spectra, Kenworthy has also been investigating the wavelength calibration issues that such high dispersion infrared spectra present.

2.4 X-ray Binaries and Variable Stars

Hanson has continued her studies of variable stars and binaries in the past year. M. Krauss (Harvard-Smithsonian, CfA) and Hanson completed a comparative near-infrared analysis of the newly identified central blue star found at the center of the spherical radio remnant, G79.29+0.46. The nature of this star has been difficult to surmise because of the high line of sight extinction, $A_V \approx 14$. The nebular morphology of G79.29+0.46 suggests it was cast off by the central star, suggesting it to be a Luminous Blue Variable (LBV). They obtained high-resolution $H-$ and $K-$band spectra of G79.29+0.46 star, along with identical spectra of the prototypical spherical winded LBV, P Cygni, and the non-spherical, flat-winded emission line object, MWC 349. Spectral similarities of G79.29+0.46 star were found with both P Cygni and MWC 349, as well as the LBV HR Car. While spectral similarities are not appropriate for use in identifying LBV stars, G79.29+0.46 star appears to be one of this very unique class.

Hanson has recently completed a multi-year observational campaign to observe the slow variation of spectral and continuum features of the outburst star, CI Cam, also known as XTE J0421+560. This transient X-ray source was first detected by RXTE on 1998 March 31, and it was soon confirmed that the B[e] star CI Cam is the optical counterpart, probably the mass donor for a compact object. High-resolution near-infrared spectra obtained in October 1999 and October 2000 found the strong spectral lines seen at outburst to have been entirely engulfed in excess infrared emission. Also seen is a clear steepening of the near-infrared continuum through the $H-$ and $K-$band. It appears that the entire binary system has now become enshrouded in an expanding dust shell. Kenworthy is complementing Hanson's CI Cam data in a collaboration with Mark Wagner [University of Arizona] and is proceeding to reduce the IR data.

Hanson and R. Fender (U. Amsterdam) are analyzing near-infrared spectra taken of the well known X-ray binary system, SS 433. They obtained unprecedented observations in June 2000: high-resolution, near-infrared spectroscopy of SS 433 for a continuous 13 nights at the University of Arizona's Bok telescope. This covered the entire orbital period of the binary system. While the analysis has only begun, working with M. Stills (GSFC/NASA) they find strong evidence of sinusoidal motion in the trailed spectra, indicating they may be detecting the orbital motion of the binary system.

Sitko worked with D. Lynch and R. Russell [The Aerospace Corporation] in their project of obtaining and analyzing BASS spectra of Nova V455 Pup. The spectrum revealed only a smooth, featureless continuum that decreased monotonically with increasing wavelengths between 3 and 13.6 μm. Its slope was much shallower than the Rayleigh-Jeans tail of a black body. The spectrum was consistent with thermal emission from gray (constant)-emissivity dust whose temperatures ranged from around 280 K to upwards of 1300 K. The presence of such strong IR continuum emission so early after the nova's outburst may suggest that this object has undergone previous outbursts.

2.5 Extragalactic

Working with a team led by D. Hines, Sitko continued his (now infrequent) research activities in extragalactic astronomy with a spectropolarimetric study of the two IRAS-selected QSOs, IRAS 13349+2438 and the BALQSO IRAS 14026+4341. These two objects were observed using the HST Faint Object Spectrograph in the polarimetric mode at ultraviolet wavelengths, complemented at longer wavelengths with ground-based spectropolarimetry. The polarization of both objects rises rapidly toward the blue, peaks near 3000 Å in the rest frame, and remains nearly constant for shorter wavelengths. The rest frame optical polarized flux density spectra also increase rapidly toward the blue, but then decrease dramatically below 3000 Å. This distinctive wavelength dependence of polarized flux shows that the polarization is produced by dust scattering. The lower polarization of the [O III] λλ4959,5007 lines in IRAS 13349+2438 compared to the continuum suggests that the scattering grains are interior to, or mixed with, the narrow line gas.

PUBLICATIONS

The publication list includes all papers published or submitted between July 2001 and June 2002 by the staff.

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