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This report covers the interval 1 July 1997 - 30 June 1998

1. PERSONNEL

Drs. G. C. Clayton, J. S. Drilling, J. Frank, A. U. Landolt, and J. E. Tohline made up the permanent teaching faculty in the Department of Physics and Astronomy's astronomy/ astrophysics group. Dr. G. S. Burks continued as an instructor in the department. Dr. A. K. Uomoto, The Johns Hopkins University, and Landolt continued working on the latter's CCD faint standard star project.

Dr. Karl Gordon joined the department as a postdoctoral fellow working with G. Clayton. Dr. Ken-Ichi Nishikawa was appointed to a research faculty position.

Graduate students for the year were Saied Andalib, Erik Barnes, Andrew Brunner, John Cazes, Howard Cohl, Matthew Collier, Paul Fisher, Patrick McCormick, Karl Misselt, Patrick Motl, Kenneth Taylor, Lynne Valencic, and Erik Young. McCormick and Young received their Ph.D. degrees.

Undergraduate students for the year were Peter Nelson and Craig Martin.

2. RESEARCH

Clayton, Gordon and Misselt embarked on a large program to study interstellar dust in the Local Group. They have re-analyzed the existing IUE data for the LMC and SMC (Gordon & Clayton 1998, ApJ, 500, 816; Misselt *et al.* 1999, ApJ, submitted). The behavior of the dust extinction in the Magellanic Clouds supports a dependence of dust properties on star formation activity. However, other environmental factors (such as galactic metallicity) must also be important. Dust in the LMC, where much more active star formation is present, does not share the extreme extinction properties seen in SMC dust. They are planning new observations with Hubble Space Telescope in M31, M33 and the Milky Way.

Clayton obtained UV HST/STIS spectra of an R Coronae Borealis star, RY Sgr. The spectra show evidence for CO bands. CO is thought to be instrumental in the dust formation process in RCB stars (Clayton et al. 1999, ApJ (Letters), submitted). Clayton also has discovered approximately 15 new RCB stars in the LMC using the MACHO photometric database. This is a large increase over the 3 stars previously known.

Clayton and Gordon were co-discoverers of Supernova 1998cf in NGC 3504. The supernova was discovered on IR images obtained at the NASA IRTF in Hawaii.

Clayton, Gordon, Valencic, and Misselt continued investigations of starburst galaxies through new observations and modeling. The new observations included imaging of approximately 50 galaxies in J, H, and K bands at IRTF and Mt. Laguna. In addition, investigations of starburst galaxies with UV and optical data in the HST archive were begun. The first results of such forays into the HST archive were on the dusty starburst nucleus of M33. After collecting all the available photometric and spectroscopic observations (ground-based, IUE, UIT, HST) of the nucleus of M33, the data were analyzed with a model of starburst galaxies which included stars, gas, and dust (Gordon, Hanson, Clayton, Rieke, & Misselt 1999, ApJ, submitted). The starburst model was extended to include the newest stellar evolutionary synthesis work and improved radiative transfer models. The M33 nucleus was found to be a 75 million year old burst of star formation enshrouded with a significant amount of Milky Way type dust.

Drilling has spent most of this reporting period trying to develop an MK-like system of spectral classification for hot subdwarfs using the sample of spectra described by Moehler *et al.* (1990, A & A Suppl. 86, 53 and, 1990, A & A 239, 265), Dreizler *et al.* (1990, A & A 235, 234), and Theissen et al. (1993 A & A 273, 524). He finds that a three-dimensional spectral type, consisting of a ''spectral class,'' ''luminosity class,'' and ''helium class'' is necessary to classify the sdO and sdB stars. In addition, the extremely helium-rich stars appear to form two parallel spectral sequences: one showing strong lines of CII, CIII, or CIV, and the other with these same lines weak or absent. He has also made a preliminary calibration of the new spectral types in terms of effective temperature, surface gravity, and n(He)/n(H), and has investigated the relation between the new spectral types and the natural groups defined by the PG survey.

Other work completed during the reporting period includes an ultraviolet extinction curve for circumstellar dust formed in the hydrogen-poor environment of V348 Sgr (Drilling *et al.* 1997, ApJ 476, 965), the classification of helium-rich hot subdwarfs (Jeffery *et al.* 1997, A & A Suppl. 125, 501), IRAS 17395-0841: a new, low excitation planetary nebula (Vijapurkar *et al.* 1997, AJ 114, 1573), spectral analysis of the extreme helium star LSS 3184 (Drilling *et al.* 1998, A & A 329, 1019), UV observation of the R CrB star V348 Sgr (Hecht *et al.* 1998, ApJ 501, 813), and the spectroscopic orbit of the evolved binary HD 197770 (Gordon *et al.* 1998, AJ 115, 256).

Frank was on sabbatical leave at the STScI until August 1997. With Livio and Xu (STScI) they examined the discrepancy between the number of predicted and observed isolated neutron stars and found that the near absence of detections can be understood if magnetic fields of neutron stars decay rapidly initially and then level off or decay much more slowly thereafter (1998, ApJ, 492, 298). Graduate student Patrick McCormick finished his disertation on the ''Evolutionary Effects of Irradiation in Cataclysmic Variables.'' The main results of this research were published recently in a paper by McCormick and Frank (1998, ApJ, 500, 923). The evolution of cataclysmic variables, it is argued, consists of irradiation driven cycles superimposed on a secular trend toward shorter orbital periods. Recent work supports the possibility that enhanced winds during thermal expansion of the companion also result in stronger magnetic braking. This effect may explain why there is such a scatter in the absolute

magnitudes of cataclysmic variables at a given orbital period.

Graduate student Patrick Motl (Frank and Tohline) has succeeded in putting together a numerical hydrodynamics code capable of following the mass transfer in a model binary self-consistently which will allow us to study its dynamical stability. Initially the binary components were assumed to be simple polytropes but future calculations will be generalized to more realistic star models.

Landolt continued to gather photometric data at the Cerro Tololo Inter-American and Las Campanas Observatories as he worked on the development of fainter UBVRI standard star sequences. These broadband sequences are centered at the celestial equator, around the sky, in a band several degrees wide.

Landolt did the follow-up photometry for an ultra-short period pulsating star discovered by G. W. Preston. With a period of 0.0374 days, a mean color of B-V = 0.24, and a metal-abundance Fe/H = -2.4, CS 22966-043 is very similar to the SX Phoenicis class of variable star. This star also is the primary in a spectroscopic binary system whose period is on the order of 430 days (1998, AJ 115, 2515).

Landolt contributed data toward an observational discussion of the extent on the sky of the dwarf spheroidal galaxy in Sagittarius (M. H. Siegel et. al., 1997, BAAS., 29, 1341). He also participated in the long-term monitoring of a unique class of extreme classical T Tauri stars, EXORS (G. S. Stringfellow, et. al., 1998, BAAS., 30, 934). These stars undergo outbursts of up to five magnitudes, and are believed to result from accretion of matter onto the star from a circumstellar disk.

Landolt also followed the photometric behavior of several hydrogen-deficient stars and several FU Ori stars as time permitted.

In collaboration with Kimberly New (Drexel University), Tohline has published the results of an extensive study of ''The Relative Stability against Merger of Close, Compact Binaries'' (ApJ, 490, 311, 1997). In this work, which is a principal component of the Ph.D. dissertation research that New completed while working under Tohline's direction at LSU, the stability of equal mass binary systems with polytropic, white dwarf, and neutron star equations of state has been examined. The investigation represents finite-difference, Newtonian hydrodynamic simulations of individual models constructed along equilibrium sequences of binaries with the same total mass and equation of state, but decreasing separation. Equilibrium models were introduced into the hydrodynamic code and evolved for several orbital periods in order to determine if any models on these sequences were unstable to merger on a dynamical timescale. The simulations indicate that no points of instability exist on white dwarf sequences or on polytropic sequences with polytropic indices n = 1.5 and n = 1.0. However, binary models on an n = 0.5 sequence and on sequences with realistic neutron star equations of state were found to be unstable to merger if they had sufficiently small separations. The hydrodynamic code was used to follow the evolution of a binary system with the minimum total energy and angular momentum on the n = 0.5 polytropic sequence through coalescence. At the end of the simulation, the ellipsoidal central object was encircled by spiral arms which had been ejected during the merger, and was continuously emitting low-amplitude gravitational wave radiation.

Under Tohline's direction, graduate student Andalib completed his doctoral dissertation research, producing a dissertation entitled, ''The Structure and Stability of Selected 2-D Self-Gravitating Systems.'' In this work Andalib describes the development of a new ''self-consistent-field'' technique that allows one to construct equilibrium, self-gravitating structures with compressible equations of state, nontrivial internal motions, and nontrivial surface geometries. Presently the technique is restricted to two-dimensional structures, but it offers the promise that realistic, steady-state structures with ellipsoidal (or more complicated) shapes can be constructed and their relative stability examined. Such a tool will be useful in studies of rapidly rotating protostars, galaxy disks, and compact objects that are likely to be sources of continuous wave gravitational radiation.

In connection with protostellar gas clouds, Andalib has used his new self-consistent-field technique to construct more and more rapidly rotating models that form a sequence of ellipsoidal, then dumbbell-shaped, then common-envelope binary configurations. As has been suggested by Tohline in collaboration with graduate students Cazes and Cohl, this strongly suggests that rotating protostars which contract along the Hayashi track can evolve through configurations with highly nonaxisymmetric structures and that systems which contract conserving angular momentum may ultimately ''fission'' into a common-envelope, pre-main-sequence binary system (Proceedings of Numerical Astrophysics 1998, in press).

Working with Tohline and graduate student Cazes, Christodoulou has investigated numerically the stability and temporal evolution of two-dimensional self-gravitating galaxy rings with flat rotation curves. Massless and very low-mass rings have been found to be unconditionally stable against self-gravity driven modes and convective modes. As the ring mass is increased, relative to the interior mass of the dark halo, one of three unstable modes appear. Strong unstable modes commonly are found to cause a temporal breakup of the ring and the formation of a new, lumpy but long-lived ring structure. One conclusion drawn from this study is that neither nuclear rings in barred galaxies or in active galactic nuclei, nor counter-rotating cores or polar rings in elliptical/S0 galaxies can safely accumulate matter through accretion and survive in a smooth form.

Working with Tohline, graduate student Fisher has been examining the dynamical settling of gaseous disks in normal galaxies in an effort to understand the time-evolution of systems that show sizeable warped disk structures. Using three-dimensional hydrodynamic techniques, Fisher has modeled the long-term (approximately a Hubble time) evolution of cold disks whose masses are very small compared to the mass of the dark matter halo in which they reside. Axisymmetric halos with various degrees of spheroidal flattening and disks whose angular momentum vectors are tilted at varying degrees to the symmetry axis of the halo have been considered. In all cases, the disk is observed to settle to a nonprecessing plane that is tipped at a finite angle to the

equatorial plane of the halo. Fisher has developed an analytical formula that predicts to high accuracy this final settling angle as a function of both the initial disk inclination and the quadrupole moment of the halo. These results form the foundation of Fisher's doctoral dissertation research; he expects to complete his degree within the coming calendar year.

While working to improve the accuracy and execution efficiency of the group's numerical hydrodynamic algorithms, graduate student Cohl has discovered a way of writing the solution to (self-gravitating) potential problems in terms of the cylindrical green function expansion that is much more compact than previous solutions. This solution appears not to have been previously appreciated by the astrophysics community, or even the broader physics community. The solution is in terms of well-known special functions and provides an extremely accurate and efficient means of numerically evaluating the gravitational (or electrostatic!) potential for mass distributions with complex spatial distributions. Cohl has developed a parallel (high performance) fortran algorithm to solve the gravitational Poisson equation which incorporates this new method of determining the potential on a cylindrical boundary. Coupled with the ''Parallel Implementation of a Data-Transpose Technique for the Solution of Poisson's Equation in Cylindrical Coordinates'' that he has developed in collaboration with Tohline and X.-H. Sun in LSU's Department of Computer Science, Cohl's techniques now serve as a centerpiece of Tohline's group's gravitational hydrodynamic simulations.

3. MISCELLANEOUS

Several of the faculty in the Department of Physics and Astronomy, including Burks, Landolt and Tohline contributed toward the establishment and implementation of a new public/university observatory which was built on the south edge of Baton Rouge. Information about the observatory and its operations may be found on the web at http://www.phys.lsu.edu/observatory.

Landolt continued as Secretary of the American Astronomical Society, as Secretary of the U.S. National Committee for the I.A.U., and on the Board of Governors of the American Institute of Physics. He continued to participate in the AAS Shapley Visiting Professor Program. Tohline was appointed to the advisory board of the AIP journal, *Computers in Physics*.

Arlo U. Landolt