University of Rochester
C.E.K. Mees Observatory
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I. STAFF

This year's "Report of the C.E.K. Mees Observatory" covers activities of the faculty, staff and students at the University of Rochester, as well as of the Mees Associates, during the period 1 October 1992 to 30 September 1993. The Astronomy faculty at the University of Rochester includes W. J. Forrest, H. L. Helfer (Emeritus and Faculty Associate), J. L. Pipher, M. P. Savedoff (Emeritus), S. L. Sharpless (Emeritus), J. H. Thomas, H. M. Van Horn, and D. M. Watson. H. Fulbright, Emeritus Professor of Physics, remains involved in the Observatory.

During the 1992-93 academic year, the Department of Physics and Astronomy conducted an international search for a new Assistant Professor in the area of theoretical astrophysics. Dr. Mark J. Wardle, then a visiting faculty member at Northwestern University accepted our offer of appointment effective 1 July 1993. Dr. Wardle's research interests include dynamical processes in the interstellar medium, magnetohydrodynamics, and the galactic center. He has recently been collaborating with Prof. A. Königl at the University of Chicago to investigate the physics of magnetic fields and ambipolar diffusion in realistic models for protostellar accretion disks. In addition, he is interested in the stability of and ionization balance in molecular clouds.

Dr. Kaiyou Chen began a 2-year visiting appointment in the Department of Physics and Astronomy 1 September 1993. Dr. Chen's research interests include origins of millisecond pulsars, accretion disks in high gravity environments, and neutron star structure.

D. Meisel, SUNY at Geneseo, and Z. Ninkov, Rochester Institute of Technology, are Associates of the C. E. K. Mees Observatory. Meisel acts as Associate Director of the Observatory. Pipher, Director of the C.E.K. Mees Observatory, began Academic Leave 1 July 1993. Forrest assumed Acting Directorship of the C.E.K. Mees Observatory 1 July, 1993.

Pipher continues as a member of the Board of Editors of the PASP, and chaired the New York Astronomical Corporation Student Prize Committees until 1 June 1993. Pipher is in the second year of a three year term on NASA's IR/SubMM/ Radio Management and Operations Working Group. She was elected to the AAS Council for a three year term beginning in June 1993, and became a member of the Space Studies Board of the National Research Council in January 1993. Her duties on this Board include membership on the Joint Committee on Technology for Space Science and Application, and an *Ad Hoc* Panel reviewing COMPLEX (Committee on Planetary and Lunar Exploration) research strategy. She was invited to give the opening talk at the UCLA meeting "Infrared Arrays, The Next Generation" in July 1993.

Watson continues to serve on the NSF/NRC Graduate Fellowship Review Panel.

Forrest, Pipher and Watson are members of instrument teams for the NASA Space Infrared Telescope Facility (SIRTF), and are responsible for a substantial amount of the detector array development for these experiments. Forrest and Pipher are members of the SIRTF Infrared Array Camera (IRAC) team, and Forrest and Watson belong to the SIRTF Infrared Spectrograph (IRS) consortium.

James Garnett, Research Associate, and Hao Chen, Senior Engineer, both with the Near Infrared Group, left the University in the summer of 1993 to work in Industry. Bradley Marazas is in his second year as Engineer with the Near Infrared Group. François Piché joined the group as a Research Associate in November 1992. Kevin McFadden is in his second year as Programmer/Analyst with the Near IR group. Jian Wu joined the group in August as a half-time Engineer.

Following the annual meeting of the American Association for the Advancement of Science (AAAS) in February 1993, Van Horn became the Chair of the AAAS Section on Astronomy. He was also elected to chair the Publications Board of the American Astronomical Society (AAS), assuming this position following the June 1993, meeting of the AAS. In July 1993, he completed his one-year term as Acting Chair of the Department of Physics and Astronomy and took a two-year leave of absence to begin an appointment as Director of the Division of Astronomical Sciences at the National Science Foundation, in Washington, DC. In addition, he continued to serve as one of the Harlow Shapley Visiting Lecturers for the American Astronomical Society. In March 1993, he visited Miami University in Ohio, where he presented a talk entitled "Exploration of the Solar System." With Prof. S. Ichimaru of the University of Tokyo he also edited the proceedings of the International Conference on the Physics of Strongly Coupled Plasmas, which was held at the University of Rochester from 17-21 August 1992; the proceedings have just been published by the University of Rochester Press. In addition, he served the fourth year of a five-year term as a member of the Annie J. Cannon Award Advisory Committee for the AAS.

Van Horn also presented several invited lectures in 1992-93. He spoke about "Physical Properties of Dense

Astrophysical Plasmas" at the 4th International Toki Conference at the National Institute for Fusion Science in Toki City, Japan, on 19 November 1992 (Van Horn 1993a). He discussed "Equations of State in Stellar Structure and Evolution" at IAU Colloquium 147 in St. Malo, France, on 14 June 1993 (Van Horn 1993b). He discussed "The Physics of White Dwarfs" at the 9th APS Topical Conference on Atomic Processes in Plasmas in San Antonio, Texas, on 20 September 1993 (Van Horn 1993c).

Thomas and Van Horn continued in the third year of their NASA Theory Grant, on "The Seismology of Rotating, Magnetic Stars," which supports the research of their joint astrophysics theory group. The research program of this group includes investigations of oscillations and other physical properties of the Sun, giant planets, "brown dwarfs," white dwarfs, accretion and "excretion" disks, neutron stars, and astrophysical jets.

In July 1993, Umin Lee began his third year as a Research Associate with the group. During the past year, Lee has investigated the high- and low-frequency global oscillations of Jupiter. Currently, he is also interested in forced oscillations of massive main-sequence stars in close binary systems. Because of radiative dissipation near the surface of the star, the forced oscillations may play a role in exchanging angular momentum between orbital motion and the stellar rotation. In addition, Lee is interested in calculating nonadiabatic oscillations of white dwarfs, in order to determine the locations of the blue edges of the pulsational instability strip. Dr. Lee has accepted a position in the Ecole Normale Superieure, in Lyon, France, beginning in November 1993.

Also in July 1993, Alexander G. Muslimov, began his second year with the group as an Instructor/Fellow in Astronomy. He is supported by a grant from NSF, and he is studying the effects of cooling on the evolution of magnetic fields in neutron stars. He is also investigating the oscillations of low-mass stars in binary systems and the evolution of low-mass binaries with neutron stars.

In September 1992, Shuji Ogata also joined the group for a 2 1/2-month period as a Visiting Scientist. A member of Prof. S. Ichimaru's research group in the Physics Department at the University of Tokyo, Ogata visited Rochester as part of the collaborative research program organized by Ichimaru and Van Horn to study phase transitions in dense astrophysical plasmas. This program is supported by grants from NSF and from the Japan Society for the Promotion of Science. Van Horn spent two weeks in Japan in November 1992, conducting research with Ichimaru's group and attending a plasma astrophysics workshop at the Japanese National Institute for Fusion Science. Ichimaru and Van Horn's collaborative research grant has now been expanded by a two-year grant to Prof. Ichimaru from the Monbusho organization. The expanded program now includes J. H. Thomas (Rochester) and W. B. Hubbard (Arizona), in addition to Van Horn, from the U.S. side, and Y. Osaki (Tokyo) and H. Iyetomi (Tokyo), in addition to Ichimaru, from the Japanese side.

Dr. Marek Sarna, from the N. Copernicus Astronomical Center, in Warsaw, visited for a period of one month in the spring of 1993 to participate in research with the astrophysics theory group. He collaborated principally with Dr. A. G. Muslimov in research on the evolution of low-mass binaries with neutron stars.

Dr. Yuri K. Kurilenkov, of the Institute for High Temperatures in Moscow, spent three months during the spring of 1993 as a Visiting Scientist with the astrophysics theory group. During this period, he continued work on a book on plasma physics, and he and Van Horn began a collaboration to conduct research on radiative transfer and opacities in dense plasmas.

Thomas was appointed to a three-year term as an associate editor of *The Astrophysical Journal* in March 1993. He served as a Shapley lecturer for the AAS during 1992-93. He holds a joint appointment as an affiliate scientist at the High Altitude Observatory, National Center for Atmospheric Research, in Boulder, Colorado. Thomas is on academic leave in 1993-94 with the support of a Guggenheim Fellowship.

In his role as a Shapley lecturer for the American Astronomical Society, Meisel visited Stockton State College in New Jersey where he gave three lecture demonstrations on technology in astronomy.

Meisel served as Geneseo's representative on the board of directors of the Astronomical Society of New York (ASNY). During the spring 1993 semester, the semi-annual meeting of ASNY was held at Geneseo with Meisel serving as meeting coordinator. Meisel again served as executive director of the American Meteor Society.

At the 181st meeting of the American Astronomical Society in Phoenix, Arizona, Meisel presented one invited oral presentation on Macintosh software, one oral presentation on the NSF ILI CCD project, and one poster paper with student R. Schulitz and Z. Ninkov [RIT] and Marc Lacasse [Smithsonian Center for Astrophysics] on their continuing research on Hubble's Variable Nebula.

During spring 1993, Meisel worked with the Geneseo BOCES "PROBE" program by presenting talks and telescope viewing for students in the upper primary and junior high grades. He also made a presentation on astronomy at the inner city Rochester School #5 to a class of special education students.

Helfer officially retired as of 1 July 1992 but remains active in the Department. He served as Rochester's representative on the Board of Directors of the New York Astronomical Corporation.

Public tours were conducted at the Observatory from mid-May until the end of August by several undergraduate employees: Craig McMurtry, Bernie Sklanka, Michael Reuter. We are indebted to Barbara Warren and Mary Beth Vogel for their excellent handling of tour arrangements and public relations for the Obser-

vatory, and to Kurt Holmes, carrying on in his father's fine tradition as Observatory Supervisor.

Marilee Kaye Montanaro, Administrative Research Coordinator for Astronomy, has handled efficiently the many administrative tasks for the group.

II. UNDERGRADUATE EDUCATION

The undergraduate program at the University of Rochester includes the option of both a B.A. and a B.S. in Physics and Astronomy. A flexible advanced program is offered, in addition to the two-semester introductory freshman sequence in astronomy. Helfer is the undergraduate advisor for majors.

Leah Buchholz worked with the Far-IR group this year, and wrote a senior thesis entitled "CO Emission from the Polar Ring of NGC 2685" under Watson's direction. She won the ASNY undergraduate prize for this work, and will present her prize-winning lecture at the fall meeting.

Andrea LaBarbera continued to work with the Near-IR group. Her senior thesis concerned a search for IR supernovae in M82, under the direction of Pipher.

Undergraduates Craig McMurtry, Bernie Sklanka, Heidi Van Tassell, and Nageswari Shanmugalingam worked for the Near-IR group this year. Heidi accepted a summer position with the University of Wyoming, and the others continued working with the group over the summer.

Undergraduates Tracey Buettgens and James Muzerolle joined Watson's group in 1992, Buettgens is principally involved, along with graduate students Shobita Satyapal and John Bloomer, in the construction of a near-infrared Fabry-Perot interferometer to go with the UR third-generation near-infrared camera. She spent the past summer as an intern in the NOAO summer program in Tucson, and is planning a senior thesis on spectroscopic observations of starburst galaxies, under Watson's direction. Muzerolle spent the summer as a research assistant at the University of Georgia, involved in a project on combined molecular, atomic and IRAS observations of high-latitude interstellar clouds. He has begun a senior thesis on imaging spectroscopic observations of molecular hydrogen in galactic star-formation regions, also under Watson's direction, and has become heavily involved in far-infrared detector array characterization, with graduate student Nick Raines.

Don Stanchfield completed a very successful senior year as President of the Society of Physics Students and graduated in May 1993. For his senior thesis, he completed a project under the direction of Thomas on the statistical distribution of sunspot areas based on data from the Mt. Wilson white-light plates. He participated in the summer student program at the National Solar Observatory in summer 1993, and he is now a graduate student in theoretical astrophysics at Rochester.

Graduating senior Mike Thrapp resigned his position as computer system manager for the astrophysics theory group and has accepted a another position. Graduate student Colin Roald took over these responsibilities.

Meisel finished work on the 27 astronomy Macintosh Hypercard modules that have been used in the Geneseo Introductory Astronomy Lab over the last three years.

Meisel obtained an NSF ILI grant to build and use CCD camera systems in introductory astronomy. This grant runs two years and started in Fall 1992. He also received one of three 1993 Geneseo Summer Faculty Development Grants and a Departmental Planning Grant from the Geneseo College Planning Council in further support of this project. Full scale testing of 12 portable cameras for use by introductory astronomy students started with a class of 130 in September 1993.

Meisel, along with Geneseo student Rick Schulitz, attended the Fall 1992 ASNY meeting at Union College. Schulitz presented a paper, "Using NIH Image as an Astronomical Image Processing Program."

At the spring 1993 ASNY meeting held at Geneseo, four Geneseo students, Bill Abe, Bridget Emerling, Mark Greenfield, and Michele Lang, presented a poster paper describing CCD research they carried out under Meisel's direction. These students, along with Schulitz also presented their results orally at the Geneseo Undergraduate Symposium in April 1993.

III. GRADUATE EDUCATION

Tod Strohmayer, who received his Ph.D. for research completed with the Rochester theory group in 1992 and who has since held a postdoctoral position at Los Alamos National Laboratory, returned in April 1993 to present the Graduate Student Prize Lecture for the Astronomical Society of New York. Strohmayer won the 1992 Prize for his paper entitled "Light Curves of Rotating, Oscillating Neutron Stars" (Strohmayer 1992).

Tim Collins passed his qualifying exam in February 1993, and continued his research on the effects of superfluidity on nonradial spheroidal oscillations of neutron stars, in collaboration with Van Horn, Umin Lee, and Richard Epstein (Los Alamos). A paper describing these results is under revision (Collins, *et al.* 1993). He also began his Ph.D. thesis research, investigating models for quasiperiodic oscillations in cataclysmic variables. He is modeling the boundary layer between accretion disks and white dwarfs in cataclysmic variables and has also been investigating a new mechanism for relaxation oscillations in cataclysmic variables proposed by Van Horn.

Guy Delamarter joined the astrophysics theory group in the summer of 1993. He collaborated with Van Horn on a project to study the process of core formation in the terrestrial planets and the moons of the giant planets. A paper describing these results is in preparation (Delamarter and Van Horn 1993).

J. Andrew Markiel joined the group in summer 1992. With Thomas and Van Horn, he is studying models of time-dependent dynamos operating in the convective He envelopes of white dwarfs, in an effort to determine whether this process can generate magnetic fields with the strength and variability timescale which are suspected from the observations of GD 358 (Winget *et al.* 1993). The preliminary results appear very promising, and the three investigators have submitted a short paper describing their results to the *Astrophysical Journal* (Markiel, Thomas, & Van Horn 1993) as a companion to the observational paper by the Texas group of Winget, *et al.*

Colin Roald joined the group in summer 1993. With Thomas, he is examining several possible ways to include nonlinear effects in a simple model of solar and stellar dynamos to produce aperiodic oscillations of the magnetic fields. Effects being considered include quenching of the alpha-effect, losses from magnetic buoyancy, and modification of the velocity shear resulting from torques exerted by the Lorentz force. This work is still in an early stage.

Mark Swain is conducting his Ph.D. thesis research on high resolution radio observations of the radio galaxy 3C 253 under the direction of Dr. Alan Bridle at the Charlottesville, Virginia, headquarters of the National Radio Astronomy Observatory. His internal advisers are Van Horn and Watson.

Tony Perez-Miller entered the astronomy program in September 1993, and is a teaching assistant in the astronomy undergraduate laboratory course.

Steve Solomon, Paula Turner, Scott Libonate, Eric Howard, Diana Coppenbarger and Alexei Helmbock are graduate students in Forrest and Pipher's Near Infrared Group.

Solomon has been active in the near IR group's detector development program for SIRTF; Solomon completed his second year of a NASA Traineeship for his work characterizing trapping in near IR detector array materials. He left Rochester to accept a position at Santa Barbara Research Center this summer, and he is writing his Ph.D. thesis *in absentia* on both his detector studies and on his study of the physical conditions leading to excitation of the 3.28 μm dust emission feature in galactic and extragalactic objects.

Turner is also writing her Ph.D. thesis *in absentia*, on the topic of galaxy-galaxy interactions: she is Assistant Professor of Astronomy at Kenyon College.

Howard passed his qualifying exam this year. He submitted a paper to the *Astrophysical Journal* on infrared imaging of the high luminosity bipolar outflow source MonR2, and is currently working on other outflow objects. He has presented papers at several professional meetings on MonR2. Howard is also System Manager for the Near Infrared Group's Sun network.

Libonate is continuing his analysis of near IR spectra of galactic center sources. His major concentration is on the unusual Brackett α sources discovered by Forrest *et al.* (1987). These were recognized as stars with winds, and subsequent work has revealed that there may be dozens of wind sources at the galactic center. Libonate has been characterizing these objects through spectroscopy, and has submitted one paper, is working on a second, and has presented talks on these objects at several professional meetings.

Coppenbarger completed work on the low mass secondary of Ross 614 (submitted to AJ) and began work on the analysis of 256 $\times$ 256 images of M82. She finds that the 3.28 μm dust feature emission regions closely correspond to Brackett γ emission regions. Helmbock is beginning a study of gamma irradiation of gateless InSb arrays, and has been involved in writing clocking programs for the arrays.

John Bloomer, Matt Guptill, Nick Raines and Shobita Satyapal are graduate students in the Far Infrared Group, working with Watson on far-infrared detector development for SIRTF, imaging far-infrared spectrometer development, and infrared and millimeter wave spectral-line imagery of galaxies.

Rochester Institute of Technology graduate students, supervised by Ninkov and involved with optical CCD observations at the C.E.K. Mees Observatory, are David Bretz (O star systems), Chen Tang (monitoring He I 10830 line), Brian Backer (CID Imaging) and Ultan Carroll.

IV. RESEARCH

A. Theoretical Astrophysics

1. Solar Physics

Thomas and Dr. B. Montesinos (University of Oxford) are continuing their work on the theory of siphon flows in isolated magnetic flux tubes. The calculations of siphon flows have now been extended to include the effects of variable ionization and radiative transfer between the flux tube and its surroundings (Montesinos and Thomas 1993). In collaboration with D. Degenhardt (Goettingen) and S. K. Solanki (Zurich), they have used their siphon flow models to produce synthetic spectral line profiles which compare favorably with observed profiles of possible siphon flows in photospheric magnetic elements, and which indicate the presence of standing tube shocks in the observed flows. In related work, Thomas and Montesinos (1993) have produced a siphon-flow model of the photospheric Evershed flow in a sunspot. Further work on this model is in progress.

2. Planetary Physics

As noted above, Delamarter and Van Horn (1993) have investigated the process of core formation in the terrestrial planets and the moons of the giant planets. Their preliminary results suggest that spontaneous core formation, driven by the gravitational energy released during the process, can occur above a certain

critical mass, but that this mass may be too large to be of interest for cosmogony.

Motivated by the recent detections of several kinds of global oscillations of Jupiter, Lee has been working on theoretical studies of Jovian oscillations. Lee, Strohmayer, and Van Horn (1992) investigated the properties of inertial mode oscillations of Jupiter. Inertial waves which propagate in isentropic regions of stars are produced by the effects of rapid rotation. Since Jupiter is rapidly rotating and believed to be fully convective, Jupiter is likely to sustain inertial modes. Lee (1993a) also studied the effects of rapid rotation on acoustic modes of Jupiter by taking into account the deformation of the equilibrium structure of Jupiter due to rotation. Although deformation is a second-order effect of rotation, it was shown that it is important for high frequency acoustic modes.

Lee and Van Horn (1993) extended earlier calculations by Lee and his collaborators on the global oscillation spectrum of Jupiter to estimate the oscillation amplitudes that may be excited by the collision of Comet Shoemaker-Levy 9 with Jupiter in July 1994. They found that high frequency acoustic modes may reach observable amplitudes.

3. Stellar Oscillations

Lee and Bradley (1993) devised an improved method of calculation for nonadiabatic oscillations of stars. They applied this method to white dwarf stars, since in the interior of white dwarf stars the thermal time scale is much longer than the oscillation time scale.

Lee, Collins, Epstein and Van Horn (1993) calculated spheroidal oscillations of neutron stars by taking account of the effects of neutron superfluidity in the inner crust. They found that the neutron superfluid in the inner crust affects the frequency spectrum of neutron stars, and that it is particularly important for shear modes and acoustic modes. They also found two f-modes associated with the solid crust and the superfluid sphere, respectively.

Saio and Lee (1993) investigated the effects of rotation on the stability of low radial order g- and p-modes of massive main sequence stars. During the evolution in the main sequence stage, a μ gradient zone develops around the convective core. This μ gradient zone affects the frequency spectrum of low order radial modes and causes interference between the modes when the effects of rotation are taken into account. If a stable mode comes to be in resonance with an unstable mode, it can become unstable as a result of the resonance. Saio and Lee suggested that detailed observation of low order radial modes would bring information of the region near the outer edge of the convective core of rotating massive main sequence stars.

4. Massive and Close Binary Stars

Lee has been interested in the mechanisms of angular momentum transfer in rotating stars. Lee and Saio (1993) discussed the efficiency of angular momentum transfer by nonradial oscillations in rapidly rotating massive main sequence stars. In this paper, they considered low frequency oscillation modes excited by overstable convection modes in the core of the star. They found that these low frequency modes can transfer angular momentum from the core to the envelope, and that this mechanism keeps differential rotation between the core and envelope weak during the course of the evolution from the main sequence stage. Lee (1993b) also studied the case where low frequency oscillations of a massive main sequence star in a binary system are excited by tidal forces exerted by the companion. Because of strong nonadiabatic effects associated with low frequency oscillations in the outer envelope, a considerable amount of angular momentum from the orbital motion is shown to be deposited onto the outer layers. They applied this mechanism to high mass X-ray binary systems with Be stars and showed that the angular momentum deposition from the orbital motion is large enough to expel the matter in the outer most envelope to form an excretion disc around the star. Lee is now interested in modeling excretions discs around rotating stars. Sarna, Lee and Muslimov (1993) discussed the properties of oscillations of low mass stars in close binary systems. They also calculated tidal oscillations of low mass stars in binary systems and suggested that the tidally forced oscillations can be a mechanism which leads to mass loss from the dwarf star to the compact companion object.

5. Properties of Dense Matter

Van Horn and Kurilenkov have begun a collaboration to apply the results of laboratory investigations of the optical properties of dense matter to astrophysical applications. Several poster papers have already been presented (Kurilenkov and Van Horn 1993a, b; Kurilenkov, Van Horn, and Skowronek 1993), and a number of longer papers are currently in preparation (Van Horn and Kurilenkov 1993). The goal of this work is to investigate the effects of plasma dispersion upon the transfer of radiation in dense plasmas, to calculate the Rosseland mean opacity under conditions where $\hbar\omega_p/kT > 1$, and to include the effects of the modified atomic energy level structures in dense plasmas upon the Rosseland mean opacity.

New calculations have also been performed for nuclear reaction rates at high densities. Ichimaru, Ogata, and Van Horn (1992) have recently extended the calculation of pycnonuclear (density-induced, $T = 0$) reaction rates to the case where the reacting ions are of different species. Such a mixture is termed a "binary ionic mixture" (BIM). The formula obtained by Ichimaru *et al.* generalizes the previous expression obtained by Ogata *et al.* (1991) for C-O pycnonuclear reactions to arbitrary mixtures. Still more recently, Ogata, Iyetomi, Ichimaru, and Van Horn (1992) have similarly extended the results of Ogata *et al.* (1991)

to the general calculation of strong screening of thermonuclear reaction rates in BIMs. The detailed Monte Carlo calculations on which these new rates are based show that the enhancement of nuclear reaction rates may be significantly larger or smaller than previous results, depending upon the relative concentrations of the ions with larger and with smaller nuclear charges.

Ogata *et al.* (1993a, b) have also computed new phase diagrams for dense, multi-ionic matter. This work was motivated by an interest in the energetic consequences of phase separation for the ages of the coolest white dwarf stars. Without the energy released during phase separation, the best estimates for the ages of these stars are $\sim$ 9 Gyr, much less than other estimates for the age of the Milky Way Galaxy. The new calculations indicate that phase separation, especially of Ne from C in the dense core of a white dwarf, can prolong the cooling time by as much as $\sim$ 6 Gyr. Whether this large an increase can occur in the multi-ionic plasma within a real white dwarf remains to be seen.

6. *White Dwarfs*

Winget *et al.* (1993) have discovered that the oscillation spectrum of the prototypical He-atmosphere white dwarf GD 358 exhibits evidence for weak, $\sim 10^3$ G magnetic fields, which appear to vary on a timescale on the order of months. This clearly suggests that a dynamo process may be operating in the surface convection zone of this star. Markiel, Thomas & Van Horn (1993) have recently demonstrated that a time-dependent dynamo can indeed operate in a white-dwarf convection zone, producing fields strengths as large as $\sim 10^4$ G, with a dynamo cycle period $\sim$ years. Their analysis is based on local, nonlinear dynamo equations and detailed models of the surface convection zone in a white dwarf. The manuscripts describing the observational and theoretical results have been submitted as companion papers to the *Astrophysical Journal*, and a more extensive theoretical investigation is currently in progress.

Collins and Van Horn have begun a study of the boundary layer between white dwarfs and their accretion disks in cataclysmic variables. They are also investigating a new mechanism for relaxation oscillations in cataclysmic binaries.

7. *Neutron Stars*

Epstein (1988) has previously discussed the effects of superfluidity upon the oscillations of neutron stars, using a short-wavelength approximation for his calculations. Van Horn and Epstein (1990) subsequently extended this work to include the global nonradial toroidal oscillation modes, which are generalizations of Epstein's transverse waves. Superfluidity increases the propagation speed of transverse waves, and this increases the toroidal oscillation frequencies significantly over the results obtained neglecting superfluidity. Lee *et al.* (1993) and Collins *et al.* (1993) have now extended these results to include the effects of superfluidity on the global spheroidal oscillation modes of neutron stars.

Haensel, Urpin, and Yakovlev (1990) showed that in the high magnetic fields **B** at the surfaces of pulsars, the generalized "Ohm's Law" that governs fields decay depends nonlinearly on **B**. As a result, the timescale for field dissipation may be only $\sim 10^6$ years, rather than exceeding the Hubble time. Muslimov and Van Horn (1993) have recently explored this process using a more detailed model than that employed by Haensel *et al.* They find that the combination of the nonlinear field-dependence and the temperature sensitivity of the transport coefficients indeed leads to rapid dissipation of toroidal magnetic fields, with a timescale $\sim 10^5$ yr, if the rapid cooling produced by the direct Urca process actually occurs.

Muslimov calculated the evolution of the magnetic field in a neutron star crust with allowance for the Hall effect (Muslimov 1993). He has shown that the coupling of low-order poloidal and toroidal modes may strongly affect the evolution of poloidal modes after $\sim 10^8\ yr$. Muslimov and Van Horn suggested a simple model for the evolution of a poloidal magnetic field initially trapped in a region containing normal *npe* matter within the outer liquid core of a neutron star (Muslimov & Van Horn 1993). They showed that an initially quasi–homogeneous magnetic field of strength $B = 10^{12}\ G$ declines during the first $\sim 1\ Myr$.

Muslimov and Sarna are continuing their work on the evolution of low–mass binaries with neutron stars (1993a). One of the interesting issues they recently investigated (1993b) was the regime of episodic mass loss, approximately at the Eddington rate, by the donor star, commencing at the late stage of evolution before the donor star reached the minimum mass $\sim 0.2\ M_\odot$ and contracted within its Roche lobe.

Sarna, Lee and Muslimov (1993) investigated pulsations of the red–dwarf companion of the neutron star (NS) in a low–mass binary (LMB). They demonstrated that for donor stars of mass $\sim 0.2\ M_\odot$ the spectrum of free oscillations becomes qualitatively different from the spectrum of the ZAMS star of the same mass.

They also considered tidally forced g-modes and performed a linear analysis of these oscillations for different degrees of the non–synchronization between the orbital rotation and spin rotation of the red-dwarf component.

8. *Perturbations of the Oort Cloud of Comets*

Helfer considered the effect of distant stellar encounters upon the Oort cloud by using a simplified model of the solar neighborhood in which space is divided into cubes for which at any one time only one star is within each cube. It was found that in 4.5×10^9

years, the random walk velocity change for a comet caused by stars more distant than 0.5 pc amounts to $\sim 0.03\xi_4\,\mathrm{km\,s^{-1}}$ where ξ_4 is the comet's semi-major axis measured in units of 10^4 AU. Consideration of less distant stellar collisions, those with impact parameters between 500 AU and 0.5 pc make it unlikely that the Oort cloud could be larger than $\sim 5 \times 10^4$ AU.

9. Magnetic Field Decay in Cold Interstellar Clouds

The usual treatment of the decay of magnetic fields in partially ionized clouds is that of Kulsrun & Pearce (1969). They used Braginskii's (1965) approach in which the neutral and hydromagnetic fluids are coupled together by momentum transfer by collisions between the two fluids. This approximation is not appropriate in many low ionization clouds because the neglected non-linear inertial term (and possibly the viscosity term) is larger than the momentum exchange term in the equation of motion of the neutral fluid. To a consistent level of approximation, one may ignore the response of the neutral fluid to fluctuations in the plasma. Helfer examined the electron-ion plasma fluctuations in the presence of a large scale magnetic field, and found that while short scale length fluctuations in the currents and their associated magnetic fields decay in the very short time scale found by Kulsrud & Pearce, longer wavelength modes decay with a characteristic time scale much smaller than that inferred from the electrical conductivity. The results imply that in a cold interstellar cloud, with no neutral fluid motions, all initial magnetic field structure with scales less than 1 pc should decay within the lifetime of the cloud.

B. Observational Astronomy

1. The Sun

Thomas continues his collaboration with Bruce Lites, Timothy Brown, and Thomas Bogdan (all at the High Altitude Observatory, NCAR) on observations of the interaction of solar p-modes with sunspots ("sunspot seismology"). Their observations confirm the absorption of p-modes by sunspots discovered by Braun, Duvall, and LaBonte (1987), but with some significant differences concerning the dependence of the absorption on wavenumber (Bogdan, Brown, Lites, and Thomas 1993). The high signal-to-noise ratio of the data allow a determination of the absorption as a function of mode degree along individual p-mode power ridges. The absorption shows a sinusoidal modulation along the ridges, which provides important clues about the absorption mechanism and the subsurface structure of a sunspot.

2. Meteors

Meisel is continuing research on the chaotic behavior of meteor orbits in collaboration with R. Desourdes, Jr. of SAIC, Massachusetts. Work on fireball spectra is continuing with V. Getman of the Tadjik Astrophysics Institute and with J. Mathews of Penn State, Department of Electrical Engineering.

In October 1992, the American Meteor Society under Meisel's direction received a $100,000 bequest from the estate of Clinton B. Ford, a well-know supporter of amateur astronomy projects. The AMS has been supported for nearly twenty four years in part by funds from the Geneseo Physics and Astronomy department. The AMS is now incorporated as a not-for-profit scientific organization in the State of New York as the American Meteor Society Ltd. and will retain its address at Geneseo with reimbursement for annual expenses to the department. Under a special arrangement of investment of the principal in the Geneseo Foundation, projects supported under this bequest will include a world-wide radiometeor network.

Meisel was a joint author on the book "Meteoritos y Grandes Extinctiones" in Spanish with R. Desourdes, Jr., C. Amengual, C. de Torres, and C. Lopez. The book included a diskette with PC programs was published by Infortec, Barcelona Spain.

3. Brown Dwarfs and Low Mass Stars

Forrest is working on a program with Bruce Weaver (MIRA) and Charles Alcock (LLNL) to monitor the 4 images of the quasar Q2237 for microlensing events. Frequent observations with good image quality are required to produce high quality light curves. The data will eventually be used to characterize the mass spectrum of bodies in the intervening galaxy and also to resolve the quasar emitting region. The one event seen in 1988 indicated a sub-stellar micro-lensing mass. The MIRA site has been found to have superior seeing for the project. Tests are underway to measure and improve the image quality of the MIRA 0.9 m telescope. Forrest collaborated with Ninkov, Bretz, and Weaver to equip the MIRA 0.9 m with a 2k×2k Kodak CCD camera in July-August 1993. After some work on the telescope mount, the images were very close to the required quality, $0.9 \times 1.2''$. Further improvement in the telescope tracking was achieved by use of an offset guider and SBIG ST-4 guide CCD.

4. Observations of Star Formation Regions and Nebulae

Work is continuing on several research projects. First, the Hubble Variable Nebula project started with Rick Schulitz, Zoran Ninkov, and Marc Lacasse and using the RIT large format Kodak CCD array will continue during the 1993-94 winter observing season. Student Michele Lang will use the new Geneseo ST-6 array on the University of Rochester 0.6 m Mees telescope to follow the changes in the nebula throughout the year. Of particular interest are images taken through filters centered on the hydrogen Balmer alpha and the SII lines. A preliminary image was obtained

in the 1992-93 season using the RIT array and though underexposed, several interesting features were identified. The new Geneseo array is a very low noise device and should be capable of exposures of an hour or more. This work should be ready for publication during 1994.

François Piché has continued his work on the star forming region NGC 2264. His work has concentrated on determining the luminosity function of the cluster and interpreting it in terms of the underlying initial mass function. Furthermore, he has demonstrated the advantage of combining infrared and optical photometry in identifying young stars with infrared excess. He has also started work on determining the excitation mechanism of the molecular hydrogen emission in the young outflow L1448. Preliminary results seem to confirm shock excitation.

Broad-band and 3.28 μm images of several Young Stellar Objects (YSOs) and reflection nebulae have been obtained with the new 256 × 256 InSb camera at WIRO in the past year, including the CepA complex, the S158 complex (NGC 7358), L1551 and NGC 7023. In addition, H_2 images of the HH object GGD37 in CepA in the $v = 1-0$ S(1) line of H_2 at 2.12 μm and in [FeII] at 1.64 μm were obtained. The latter observations utilized the NASM Fabry Perot Interferometer with the Rochester camera. Similar line observations of the region of explosive ejection in Orion (Allen and Burton 1993) were obtained with the NRL K-Band Fabry Perot Interferometer, and the NASNM H-band Fabry Perot Interferometer. In this study, unlike that of Allen and Burton, the stellar images are removed, so that the ejecta detail is enhanced. The 3.28 μm dust feature emission was studied along a ridge of enhanced reflection nebulosity in the N7023 reflection nebula. The dust feature emission is enhanced along the ridge, which exhibits cooler [H-K] color temperature than the surrounding reflection nebulosity.

5. The Galactic Center

Libonate is continuing his analysis of near IR spectra of galactic center sources as discussed earlier. He collaborated with Cornell astronomers to obtain high resolution H-band spectra of the key sources with CRSP at KPNO to confirm the spectral classification based on earlier low resolution H-K spectra and high resolution K-band spectra.

6. Extragalactic Objects

Satyapal, with Watson, Forrest, Piche and Pipher (Rochester), Greenhouse (NASM), Fischer, Thompson (NRL) and Woodward (WIRO), has acquired high spectral and spatial resolution images of the central arcminute of the starburst galaxy M82, using the third-generation Rochester near-IR camera, the NASM and NRL Fabry-Perot spectrometers, and the 2.3 m WIRO telescope. Images in the Paschen Beta (1.25 μm) and Brackett Gamma (2.16 μm) hydrogen recombination lines have yielded a high-resolution image of the extinction toward the central starburst region of this galaxy. The extinction is quite patchy but seems not to exceed a visual extinction of 12 magnitudes, significantly smaller that that inferred or assumed in previous studies. The extinction image has been used to deredden high-resolution broadband images of the starburst region, resulting in true colors and luminosities of a large number of young star clusters. The analysis of the properties of these clusters will comprise yet another stern test of models of the stellar initial mass function of starburst galaxies.

Heidi Van Tassel has worked on the [FeII] 1.64 μm Fabry-Perot images of M82 obtained with the Rochester 256 × 256 camera and the NASM FP at the WIRO observatory. She started this work during a summer undergraduate internship at U. Wyoming under the supervision of C. Woodward. The 1.64 μm [FeII] line emission is distributed quite differently than the hydrogen line emission. It is believed to trace supernova activity in the nuclear region.

Dan Watson and Matt Guptill, with Leah Buchholz (formerly UR, now UCLA) have used the Caltech Submillimeter Observatory to detect, and partially to map, seven polar-ring galaxies out of a sample of ten in the $J = 2 - 1$ line of carbon monoxide. In each case the molecular component of the polar ring is substantial, comprising $1 - 20 \times 10^8$ solar masses; in three cases the mass in molecular form exceeds the atomic hydrogen mass. Comparison of the CO results to those of IRAS reveals that all of the galaxies detected have low to moderate star formation efficiency (0.1 - 10 $L_\odot/M_\odot$), much lower than that of other galaxy-interaction remnants such as starburst galaxies (typically 200 $L_\odot/M_\odot$). The observed low star formation rate and high molecular-to-atomic gas ratio of a few of these galaxies is difficult to reconcile with the standard picture of the formation of polar rings by the accretion of dwarf galaxies or tidal capture of outer disk material from spirals. The total mass of interstellar gas in each ring is a substantial fraction of the total mass of the system, and so will be important in the dynamics and evolution of each object. Initial results from this program will appear in print soon (Watson, Guptill & Buchholz 1993).

C. Instrumentation

1. Ge:Ga IBC Detectors and Imaging Spectrometer

Dan Watson and his group, with J.E. Huffman (Rockwell) and T.N. Krabach (JPL), continue to develop germanium blocked-impurity-band detector arrays for use in the 50-200 micron channels of the SIRTF spectrometers and photometers. Currently 6 × 6 arrays are produced, and achieve peak quantum efficiencies up to 20% and dark currents below 100 e/s, suiting the scientific requirements of the SIRTF Infrared Spectrograph. Details of the performance can be found in

papers that appeared this year (Watson *et al.* 1993; Watson 1993). An imaging far-infrared Fabry-Perot spectrometer that will use these arrays is also under construction at UR by Matt Guptill, Nick Raines and Dan Watson; it will be complete early next year.

2. Fabry-Perot Cameras

The third-generation Rochester near-infrared camera has been integrated successfully with the near-infrared Fabry-Perot spectrometers of the National Air and Space Museum (NASM) and the Naval Research Laboratory (NRL), and the combinations used for observations with the 2.3 m telescope of the Wyoming Infrared Observatory (WIRO). This project has resulted in the acquisition of high-resolution infrared spectral-line images of starburst galaxies and Galactic star formation regions with 1″ spatial resolution. It involves the efforts of Forrest, Howard, Libonate, Piche, Pipher, Raines, Satyapal, and Watson (UR), M.A. Greenhouse, H.A. Smith and M. Whitis (NASM), J.L. Fischer and K. Thompson (NRL) and C.A. Woodward (U. Wyoming).

Experience with the UR camera - NASM/NRL spectrometer combination has also been valuable in the design and construction of a second-generation imaging Fabry-Perot spectrometer for these cameras, soon to be completed at UR by Satyapal, Bloomer and Watson.

3. Near Infrared Array Development

The near IR group continues to test 256 × 256 InSb arrays from SBRC in the lab and at the telescope for suitability for low-background space observations. The latest gateless arrays from SBRC have been excellent, with 80-90% QE, less than 1 e^-/s dark current, and excellent cosmetics. Using Fowler-style multiple sampling, 15 e^- read noise is achieved, somewhat higher than in previous arrays. Consistent, low-level latent images have been observed, but these can be eliminated through multiple resetting. The arrays are close to meeting SIRTF specifications when operated at 30K.

Piché has ray-traced the re-imaging optics for use with the 256 × 256 InSb camera on the Mt. Lemmon Observing Facility 1.5 m telescope. He found that the our re-imaging optics actually *improved* the wide-field image quality of this Dall-Kirkham telescope. The first 256 × 256 InSb camera run on the Mt. Lemmon Observing Facility is scheduled for December 1993.

4. 256 × 256 Si:As IBC arrays

The near IR group tested a 256×256 Si:As IBC array from Hughes Technology Center for possible use in space experiments. The array cosmetics were excellent, with a handful of dead pixels, an extremely flat field, and good imaging properties. The device showed large photoconductive gain without attendent extra noise up to 3 V of bias. The detective QE ranged from 20% at 4.5 μm to 36% at 11.5 μm. The dark current was 10-20 e^-/s at 5.5 K with 2 V of bias (PC gain about 1.6). This performance is close to meeting SIRTF specifications in these areas. Testing of an Aerojet 20×64 Si:As IBC also showed strong promise, but this company has since left the field.

5. Optical Instrumentation

Work on the germanium diode detector for the Vaughn Fabry-Perot by Meisel and Fulbright is continuing. Use of the Geneseo ST-6 array with the Mees spectrograph is currently being considered.

Meisel with B. Ristow, Geneseo Associate Provost, is experimenting with astronomical uses of Kodak PhotoCD technology both for research and education. The first films digitized were Meisel's extensive collection of solar eclipse films and slides. The PhotoCD technique is most valuable for archiving images obtained prior to the wide-spread use of CCD cameras which present their images in already digitized form.

Video capture of monochrome and color astronomical images from a variety of sources (CD-ROM, videodisk, and videotape) has been made possible through a grant from the Geneseo foundation for the purchase of a Videospigot (tm) board for the Macintosh computer. These images, including Quicktime (tm) movies, can be used for both instruction and research. The main research interest for this equipment is a continuation of solar activity research started by former Geneseo students Fred Huebner and Louis Serpe. Other projects include movies of chaotic behavior in physical and astronomical environments.

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