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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 October 1, 1990 to September 30, 1991. The Astronomy faculty at the University of Rochester includes W. J. Forrest, H. L. Helfer, J. L. Pipher, M. P. Savedoff, S. L. Sharpless (emeritus), J. H. Thomas, H. M. Van Horn, and D. M. Watson. In addition, D. D. Meisel, SUNY at Geneseo, is an Associate of the C. E. K. Mees Observatory. M. P. Savedoff became emeritus Professor of Astrophysics on 1 July. He maintains an active interest in astrophysical research within the department, particulary in cosmic rays, white dwarfs, and applications of coherence theory. H. W. Fulbright, emeritus Professor of Physics, remains active in the Department and at the Observatory.

James Garnett, Research Associate in the Near Infrared Group since December, 1987, left the University in late August to enter Law School at Case Western Reserve University. Hao Chen is in his third year as an Engineer with the Near Infrared Group: he received his "green card" this past summer. Garnett and Chen's primary interest has been in detector array development for space and ground-based application. Nat Cowen continues as programmer/analyst with the Near IR group; he has been crucial in the Array Controller development program of the group.

Pipher began terms on the Kuiper Airborne Observatory and on the Origins of the Solar System Proposal Review Committees, and continues in a three year term as a member of the Board of Editors of the PASP. She also continues as Chair of the New York Astronomical Corporation Student Prize Committees. She participated in the review of the second generation HST experiment NIC (formerly NICMOS). Pipher gave invited talks at the International Astronomical 21st Union (IAU) General Assembly, held in Buenos Aires, Argentina, 22 July-2 August, 1991.

Watson serves 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.

Thomas was a visiting professor at the new Research Centre for Theoretical Astrophysics at the University of Sydney, Australia, during January and February of 1991. He holds a joint appointment as an affiliate scientist at the High Altitude Observatory, National Center for Atmospheric Research, in Boulder, Colorado. He is a member of the U. S. Scientific and Technical Working Group for the Large Earth-based Solar Telescope (LEST) and an associate scientist for the Coordinated Instrument Package for the NASA Orbiting Solar Laboratory.

Thomas and N. O. Weiss (University of Cambridge) are co-directors of a NATO Advanced Research Workshop on "The Theory of Sunspots," to be held in Cambridge 22-27 September 1991.

In January 1991, Thomas and Van Horn received one of the competitive NASA Theory Grants to conduct research on "The Seismology of Rotating, Magnetic Stars." This research program will include investigations of oscillations of the Sun, giant planets, "brown dwarfs," white dwarfs, accretion and "excretion" disks, and neutron stars. In July 1991, Umin Lee, previously from the Astronomy Department at the University of Tokyo, joined the new group as a Research Associate. He will be investigating the high- and low-frequency global oscillations of Jupiter, excretion disks around rapidly rotating early-type stars, angular momentum transfer by low-frequency oscillations in rotating stars, rotational effects on the low-frequency modes of neutron stars – including the so-called r-modes – and solar seismology. Also as a participant in this research program, Benjamin Montesinos of the Department of Physics at Oxford University was a Visiting Scientist in our theory group during July and August 1991. He collaborated with Thomas on studies of siphon flows in isolated magnetic flux tubes and with Thomas and Van Horn on problems associated with possible dynamo generation of magnetic fields in white dwarfs. In August, 1991, Theo Koupelis returned to Rochester as a Visiting Scientist with the theory group. He will continue his research on the acceleration of narrow astrophysical jets by the combined action of rotation and magnetic fields. In September 1991, Shuji Ogata also joined the group for a three-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 is the first scientist to visit Rochester for an extended period as part of the collaborative research program organized by Ichimaru and Van Horn to study phase transitions in dense astrophysical plasmas. Ichimaru himself visited Rochester for a two-week period in September 1991. This program is supported by grants from NSF and from the Japan Society for the Promotion of Science.

Van Horn continues to serve on the Board of Trustees of Associated Universities, Inc., an organization of which he has been a member since 1983. In the past year he also served as a member of the Visiting Committees for the Department of Physics and Astronomy and for the Bartol Research Institute, both at the University of Delaware, responsibilities he assumed in 1984 and 1987, respectively. In addition, he served as chairman of the Visiting Committee for the Physics Department at Case Western Reserve University. He has also been a consultant to Lawrence Livermore National Laboratory since 1985, and he is a member of the AXAF Senior Review Board established by the Eastman Kodak Company, one of the three members of the industrial team that is building the Advanced X-ray Astrophysics Facility. In addition, he served the second year of a five-year term as a member of the Annie J. Cannon Award Advisory Committee for the American Astronomical Society (AAS). Also during 1991 he was named a Fellow of the American Association for the Advancement of Science, and he was elected to the Publications Board of the AAS. Van Horn also served as a panelist during the May 1991 AAS Meeting in Seattle to participate in a discussion of the topic "How to Write a Winning Grant Proposal." He is chairman of the Scientific Organizing Committee for the next International Conference on the Physics of Strongly Coupled Plasmas, which will be held at the University of Rochester in August 1992.

Savedoff served this year both on the NRC Associate Review Panel and on the panel for the Fullam Awards.

Helfer served as the Chair of the Executive Committee of the University of Rochester's Faculty Senate and completed his term as faculty representative of the University's Priorities Committee. He is also on the Board of Directors of the New York Astronomical Corporation.

Meisel attended the 21st General Assembly of the IAU in Buenos Aires Argentina where he participated mainly in meetings of Commissions 15 (comets), 22 (meteors), 29 (working group on Be stars), 5 (IAU circulars), and 46 (teaching). At the commission 22 meetings, he presented the report of the Professional-Amateur Cooperation Committee of which he was chairman. During July, Meisel headed an expedition of amateur astronomers which successfully observed the total solar eclipse from Hawaii. He also presented public lectures on eclipses prior to the event in Honolulu and Hilo.

Public tours were conducted at the Observatory from mid-May until the end of August by four undergraduate employees, Chad Engelbracht, Kevin McFadden, Christopher Mason, and Mike Thrapp. We are indebted to Barbara Warren for her excellent handling of tour arrangements and public relations for the Observatory, and to Kurt Holmes, carrying on in his father's fine tradition as Observatory Supervisor. The Observatory grounds were badly damaged by the infamous "ice storm" of 1991: Holmes stayed on the grounds throughout the crisis, and single-handedly took care of the many problems.

Marilee 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 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.

Undergraduate Bruce Pirger continued to work with the Near Infrared Group until his graduation in May. He completed a senior thesis under the direction of Pipher, entitled "Near Infrared Images of Markarian 231". Chad Engelbracht joined the Near IR Group this spring, taking over many functions formerly handled by Pirger. He will begin a senior thesis on IR imaging of M82 under Pipher's direction in September.

During summer 1991, Richard Charles from Queens College of CUNY participated in research with the astrophysics theory group, with support from the SURF program at the University of Rochester. His project was designed to investigate the effects of pressure-broadened hydrogen lines on the opacity of hydrogen at high densities.

Van Horn and Meisel continued to serve as the Harlow Shapley Visiting Lecturers for the American Astronomical Society. In January, 1991 Van Horn visited Western Piedmont Community College in North Carolina, where he presented a talk entitled "Exploration of the Solar System." Meisel visited the Elizabeth City State University at Elizabeth City, North Carolina. A number of talks including microcomputer demonstrations were given.

Meisel with K. Kinsey (SUNY) continues to develop Macintosh HyperCard modules for use in introductory astronomy courses and laboratories. A progress report was presented at the AAS meeting in January 1991 in Philadelphia. The development efforts have now moved to HyperCard 2.0 and there are now over twenty modules available for free distribution to the astronomical community.

Meisel has been experimenting with using the Santa Barbara Instrument Group ST- 4 array system in the introductory astronomy course at Geneseo. The initial results were presented at the Astronomical Society of New York (ASNY) meeting at Colgate University in April 1991.

III. GRADUATE EDUCATION

Steve Solomon, Paula Turner, Scott Libonate and Eric Howard are graduate students in Forrest and Pipher's Near Infrared Group. Solomon and Libonate expect to complete their Admission to Candidacy Exams in Fall 1991, with research topics centering on IR imaging of the galaxy NGC 253, and Brackett α imaging of the Galactic Center, respectively. Solomon and Libonate have been active in detector development for SIRTF: Solomon was granted a NASA Traineeship for his work characterizing trapping in near IR detector array materials.

Shobita Satyapal, Uwe Peppel, Matt Guptill, Mark Swain and Nick Raines 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 spectral-line imagery of starburst galaxy nuclei.

Incoming graduate students Melanie Swain and Alexi Helmbock joined the Astrophysics group this September.

Charles Wendell completed his Ph.D. thesis in December, 1990, on the dynamics of magnetic flux tubes in the superfluid interiors of neutron stars. Wendell (1990) has shown that the combined effect of flux tube buoyancy in the core and ohmic dissipation in the rigid crust allows flux tubes to be expelled from the core in a time short compared to the crustal dissipation timescale. He is currently a Research Associate at the Goddard Institute for Space Studies, in New York City.

Tod Strohmayer continued his own thesis research, supervised jointly by Van Horn, J. M. Cordes (Cornell), and Thomas, on theoretical and observational investigations of non-radial oscillations of neutron stars. The purpose of his research is to investigate the potential observability of neutron star oscillations. Strohmayer's work is being supported for a second year by one of the highly competetive NASA Graduate Student Researchers grants, which was awarded for his proposal entitled "Neutron Stars in Low-Mass X-Ray Binaries and Pulsars." Gordon Brown also continued his investigation of a model for irradiation-driven accretion disk oscillations as a possible explanation for the so-called normal branch quasi-periodic oscillations (QPOs) observed in bright, low-mass X-ray binaries. He gave a talk on this subject at the spring meeting of the Astronomical Society of New York (Brown 1991). He has recently left Rochester to pursue an industrial career.

Zhi We Xu is continuing his investigation of phase transitions in degenerate stars and planets and of the evolution of pure hydrogen models for "brown dwarf" stars. This work will constitute a part of the collaboration with Prof. Ichimaru's group from the University of Tokyo. Ravi Sankrit joined the group in spring 1991 and computed cooling models of low-mass He white dwarfs, with the goal of refining the age estimate for PSR 1855+09 (*cf.* Kulkarni *et al.* 1991). He also computed models of the convective He envelope of the white dwarf GD 358, in an effort to help determine whether magnetic fields, which are suspected from the observations (Winget 1991), can be generated by a dynamo mechanism operating in the thin convection zone in this star. He has recently transfered to Arizona State University, where he will continue to work toward his Ph.D. degree.

Tim Collins joined the group in summer 1991, and he is beginning a study of the effects of superfluidity on the spheroidal oscillations of neutron stars, in collaboration with Van Horn and Richard Epstein (Los Alamos).

IV. RESEARCH

A. Theoretical Astrophysics

In the past year, research in theoretical astrophysics at the University of Rochester has included studies of solar and planetary physics, phase transitions in dense astrophysical plasmas, white dwarfs, neutron stars, cosmic ray physics, and coherence effects in Astronomy.

1. Solar Physics and Planetary Physics

J. H. Thomas and Benjamin Montesinos (University of Oxford), have extended their theoretical studies of siphon flows in isolated magnetic flux tubes to include calculations of the strength and position of standing "tube shocks" in critical siphon flows (Thomas and Montesinos 1991) and the effects of radiative transfer between the flux tube and the surrounding atmosphere. These siphon flows offer a possible mechanism for producing intense magnetic flux concentrations in the solar photosphere and for the Evershed flow in a sunspot penumbra.

Saumon *et al.* (1990) have recently applied their new equation of state for dense hydrogen to investigate the evolution of the giant planets. If the so-called "plasma phase transition" actually exists, the thermal energy content of Jupiter and Saturn may be large enough so that H/He phase separation is not needed to account for the age of Saturn.

Helfer is constructing simple models of an evolving Martian atmosphere to see if the transition from a dense to a rarefied atmosphere could have occurred in ~ 1 Gyr. Previous work (Helfer, 1990) suggested that such a rapid transition was needed.

2. Properties of Dense Matter

Van Horn (1991) prepared an invited review article on dense astrophysical plasmas for a special issue of *Science* which was devoted to astrophysical plasmas. The review described the physical conditions in dense stars and planets and summarized our current understanding of the equation of state, opacity, and nuclear reaction rates at high densities.

3. White Dwarfs

In the past four years, the cooling times of the white dwarfs have given us a new estimate of the age of the disk of our Galaxy. The result, ~ 9 Gyr, is much shorter than the $11 - 17$ Gyr ages of the globular clusters. If correct, this result suggests a need for a new theory of galaxy formation. Alternatively, there may be some additional energy source that prolongs the cooling times of the white dwarfs, thus lengthening their ages. One possibility that has been suggested is separation of C from O or of heavier elements from C/O in the core of a white dwarf.

Xu (1991) and Xu and Van Horn (1991) have computed the energy released in a postulated separation of primordial Fe from C. They have shown that this process alone can only lengthen the cooling times by ~ 0.6 Gyr but that three-component calculations are necessary in order to determine whether C/O, Ne/(C+O), and Fe/(C+O) can occur sequentially, a sequence that *would* significantly lengthen the ages.

In another project, Verdon *et al.* (1991) have begun to explore the hypothesis that the UV radiation from white dwarfs may act to inhibit accretion of hydrogen from the interstellar medium by these stars. The existence of trace elements in the surface layers of cool white dwarfs demonstrates the occurrence of accretion from interstellar clouds. However, the nearly complete absence of H from the surface layers of the cool, He-atmosphere white dwarfs shows that something interferes with the accretion of H. In preliminary hydrodynamic calculations of this process, Verdon *et al.* have found that UV radiation can indeed suppress accretion of H, although they have not yet found suppression factors as large as those observed. These calculations are continuing.

Van Horn, Winget, and Hansen (1991) are currently finishing a detailed review of the current state of theory and observations of the various classes of pulsating white dwarfs. In addition, Van Horn and J. W. Liebert are preparing a book about the white dwarf stars, which they hope to complete within the coming year.

4. *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) have now 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. T. Collins has just begun to work with Van Horn and Epstein to extend this study to include the effects of superfluidity on global spheroidal oscillation modes as well.

Strohmayer (1991a, b) has employed a perturbation method to investigate the effects of rotation on the nonradial oscillations of neutron stars. He finds that it is often necessary to include as many as 30 to 50 overtones in order for this technique to yield "converged" results for the eigenfunctions, depending upon the mode being corrected. The Coriolis force also couples modes with spherical harmonic index l to those with index $l \pm 1$. For those modes which were purely toroidal in the non-rotating star, this rotational coupling produces non-vanishing radial components, the existence of which modifies both the neutrino- and electromagnetic-damping rates for these modes.

Ogata and Ichimaru (1990) have recently carried out the first *ab initio* calculations of the shear modulus of a neutron star crust, and Strohmayer *et al.* (1991) have conducted a preliminary study of the effects of the new shear modulus on neutron star oscillations. It is generally believed that the crust of a neutron star is a *bcc* crystalline solid. Because neutron stars cool very rapidly, however, it is possible that the crust may be glassy instead. The new shear modulus calculations by Strohmayer *et al.* have been computed for both crystalline and glassy crusts. Except near the surface of the solid crust, where thermal effects are large, the results are quite similar, although both are significantly less than the Fuchs value used previously. Not surprisingly, those oscillation modes which are most sensitive to the crustal properties – such as the toroidal oscillation modes – have significantly shorter periods when calculated using the new shear moduli.

Strohmayer (1991c) has investigated the light curves that can be produced by a rotating, oscillating neutron star whose emission is confined to circular magnetic polar cap regions, as might be produced in pulsars and x-ray binaries. The theory includes the effects of general relativity on the photon trajectories and assumes homogeneous emission from the neutron star surface. Non-isotropic emission is allowed for through the use of a beaming function (Pechenick *et al.* 1986). A gaussian beaming function is used to simulate the narrow pulse profiles of pulsars, and to investigate a simple model of subpulse drift in pulsars. Simulations of x-ray observations with AXAF and XTE are used to estimate the sensitivity for detecting neutron star oscillations in x-ray burst sources and x-ray pulsars with these observatories.

5. *High Energy Particles in the Interstellar Medium*

Helfer and Savedoff are continuing to investigate the consequences of acceleration of cosmic ray protons in shocked interstellar clouds (the DAS process). One can represent the observed $\bar{p}$ flux by a model in which they are produced in shocked clouds with a volume filling factor $\leq 1\%$ of that for all clouds; this implies that the porosity factor Q of Cox and Smith is ≤ 0.2. A leaky-box diffusion-advection model was shown to be consistent with these observations with no necessity to assume the existence of an old CR population. The $\bar{p}$ work is in press (Helfer and Savedoff, 1991). The investigation of pion production in shocked clouds is in progress. There is an upper limit to the energy of positrons produced in such clouds imposed by synchrotron losses, which could serve to establish observational limits on the degree of compression of such clouds.

6. *Coherence Effects in Astronomy*

D. F. V. James, in association with E. Wolf, continues investigation of coherence and correlation effects with astronomical applications. James (1990) has shown that interferometric measurements of radii may be underestimated by the order of 10% for highly spatially coherent masers as represented by a heuristic model.

A second study by D. F. V. James and E. Wolf (1991) treats a possible new method of interferometry based on measurements of spectra rather than fringe visibilities with two elements.

B. Observational Astronomy

In the past year, observational astronomy at the University of Rochester has included studies of nebulae, active and gravitational lens galaxies, pulsars, brown dwarf candidates, and the Sun.

Z. Ninkov, R. Eastland, J. Kern (all Rochester Institute of Technology), Fulbright, Meisel and their students have been testing several CCD arrays at the Mees telescope for the visible and near IR study of comets, nebulae and early-type stars.

1. *The Sun*

Thomas is continuing his collaboration with Bruce Lites, Timothy Brown, and Thomas Bogdan (all at the High Altitude Observatory, NCAR) in a program of observations of the interaction of solar p-modes with sunspots as a means of determining the subsurface structure of the sunspots ("sunspot seismology"). Current efforts are concentrated on interpreting a high-quality set of observations made simultaneously with the vacuum tower telescope at NSO/Sunspot and the HAO/NSO Fourier tachometer in Tucson.

2. Pulsars

Strohmayer *et al.* (1990) and Strohmayer, Cordes, and Van Horn (1991a, b) have recently examined the coherence of microstructure in PSR 2016+28 in an attempt to determine whether or not the quasiperiodic micropulses, first observed by Boriakoff, (1976) can be attributed to oscillations of the underlying neutron star. A Fourier cross spectral analysis of 2000 consecutive pulses from this pulsar confirms that the micropulse quasiperiods are *not* coherent across individual pulses of this pulsar. A Q-value of ≈ 6 is deduced from the width of the quasiperiodic micropulse feature which is seen in the average power spectrum of the individual pulses. Identical analysis of fully random, simulated pulsar signals supports the notion that the quasiperiodicities are probably *not* associated with high-Q oscillations of the star. In contrast, the drifting subpulses which are seen in this pulsar (Backer 1973) do show evidence for coherence across several pulse periods. Analysis of the cross spectrum in the subpulse separation feature (P_2) indicates coherence across 4 - 5 pulse periods and a Q-value of ≈ 90.

Analysis of simulated pulses indicates that these results are consistent with a model which allows for variable subpulse drift about a mean drift rate.

3. Brown Dwarfs and Low Mass Stars

The Near Infrared group continues to monitor brown dwarf candidates in the Taurus cloud (Forrest *et al.*, 1990) for variability.

3. Galactic Nebulae

Woodward *et al.* (1991) present optical (H α, R [6500 A], and I [8290 A] and Infrared (H [1.65 μm], K [2.23 μm]), L′ [3.75 μm] and 3.3 μm) observations of the planetary nebula NGC 7027. They have used these data to investigate the spatial distribution of the dust both internal to the nebula, and that providing the extinction.

4. The Galactic Center

Scott Libonate (1991) is reducing a second epoch of Brackett α observations of the Galactic center to search for variability of the unusual Brackett α sources (with no corresponding free-free radio emission) discovered by Forrest *et al.* (1987), and to attempt to identify other unusual Brackett line-emitting sources. These unusual sources were suggested by Forrest *et al.* (1987) to be wind sources, resembling Wolf-Rayet stars, Be stars, or O supergiant/LBV stars. Herbst *et al.* (1991) followed up on this earlier work to obtain velocity-resolved Brackett γ observations of the central parsec of the Galaxy, utilizing the Rochester Array Camera and the Cornell Fabry-Perot Spectrometer. In addition to characterizing the overall dynamics at the Galactic Center, stellar wind sources were identified. These include the brightest of the the unusual Brackett α sources, and most notably, IRS 1 and IRS 13, located on either side of the non-thermal radio source SgrA*, and of IRS 16, the complex close to the dynamic center and SgrA*. Simon *et al.* (1990), in lunar occultation observations of the Galactic Center with the Rochester Array Camera, had identified two stellar components to each of these sources IRS 1 and 13. Subsequently, Libonate, Forrest, and Pipher obtained long-slit, near- infrared spectra of the central regions of the Galactic Center using the 2.1- m telescope at the Kitt Peak National Observatory, as well as the CRSP facility spectrometer. These observations will complement those of Krabbe *et al.* (1991), who have investigated the He I emission from stars at the Galactic Center. There is substantial evidence that wind sources are prominent at the Galactic Center, may dominate the energetics, and even affect the dynamics. Rieke, Rieke, and Paul (1989) have suggested that unresolved clusters of hot stars may dominate the IRS 16 complex. Further high spatial/spectral resolution spectroscopic studies are planned, since the ***starburst vs. black hole*** controversy of the Galactic Center excitation seems to be close to resolution.

5. Extragalactic Objects

Turner *et al.* (1991a) report near infrared images of the central regions of the Galaxy NGC 5128, Centaurus A. It is a double-lobed radio source, with two optical components—a luminous giant elliptical bisected by a warped dark lane of gas, dust, younger stars and HII regions, suggesting a probable merger. The infrared observations identify a red, variable compact object (the probable nucleus) and show that the optical hotspot is not the nucleus but rather a hole in the extinction.

Nadeau *et al.* (1991) present infrared and visible images of the gravitational lens system 2237+030. In addition to identifying extinction in the distant galaxy, and the energy distribution of the quasar emission, the data constrain the suggested microlensing event of August-September 1988 to a timescale of 100 days, implying a mass of planetary size for the microlens. Forrest and collaborators W. B. Weaver and C. Alcock plan to monitor at optical wavelengths the gravitational lens systems Q2237 and Q1413.

Steve Solomon (1991) is analysing infrared images of the starburst galaxy NGC 253; the near infrared group has previously worked on the prototypical starburst galaxy, M82, as well as other starburst galaxies. He has discovered bubble-like structures in the 3.3 μm feature emission, which he attributes to mass-loss from very massive objects in the galaxy. He is able to identify the nucleus uniquely, and to identify several other sources with the VLA radio maps of NGC 253 by Antonnucci & Ulvestad *et al.* (1988).

Satyapal and Watson, along with J. R. Graham, B. T. Soifer and K. Matthews (Caltech) are analyzing spectral line images of M82 and NGC 253. High-resolution images of the nuclear regions of these galaxies have been produced for Brγ, Brα and H_2 $v = 1 \rightarrow 0$ S(1), as well as in broad band filters at 1.2, 1.6 and 2.2 μm. Among other things, this work is expected to yield more reliable luminosity functions for the star clusters in these galaxy nuclei.

C. Instrumentation

This year, infrared instrumentation development has centered on the groups' near infrared and far infrared

SIRTF detector developments.

Meisel with Z. Ninkov, R. Eastland, J. Kern (all of RIT) and Fulbright (U of R) continue to work on the development of very near infrared CCD detectors for the Vaughan Fabry-Perot interferometer at the Mees Observatory.

1. Near Infrared Array Detector System Development

Forrest and Pipher and their group continue to develop infrared arrays for two SIRTF experiments, IRAC (the Infrared Array Camera) and IRS (Infrared Spectrometer). They have been concentrating in the past year on further testing of composite arrays bonded to a CRC228 multiplexer, developed by Santa Barbara Research Center (SBRC) for SIRTF, in order to ascertain appropriate detector material selection, the effects of lateral collection, octagonal *vs.* square diode junctions, and variable gate overlap. Noise reduction schemes have been implemented, and the effects of charged particle radiation (gamma radiation and protons) have been evaluated. In addition, the occurrences of latent images, and a droop in signal rate at low signal levels have been studied. The group has been working with SBRC on the development of 256×256 InSb arrays. SBRC has delivered several arrays for evaluation: the new 256×256 multiplexer, CRC463, has excellent noise at a temperature of 28K (namely 50 e-), and the other properties of the arrays are also quite good. In addition, SBRC has loaned the University of Rochester several arrays with a new front surface passivation, that does not require metal gates to control the surface potential. The gateless structure leads to reduced nodal capacitance, hence reduced read noise. Evaluation on those arrays is continuing. A study of passivations on SIRTF detector materials will take place this year: the detector arrays will be bonded to the new low-noise SBRC/Hughes multiplexer being developed, the CRC590A. At the same time, a flexible, programmable, array controller and signal processor has been developed by the Near Infrared Group for use with arrays of various formats and readouts. The controller/processor has been developed with the assistance of Prof. Dan Briotta, Ithaca College and Cayuga Microprocessor Services, and George Gull, Electromechanical Design, and Russell Wallace, Wallace Instruments. Nat Cowen (programmer/analyst) and Bruce Pirger and Chad Engelbracht (undergraduates) have been heavily involved in the program, as have Jim Garnett and Hao Chen. Scott Libonate designed, had built, then tested fast, quiet A/D boards for the system. Bill Forrest has directed the program. Other arrays tested this year include devices from Cincinnati Electronics, with InSb detector arrays. Rochester will receive a Cincinnati Electronics InSb array coupled to the newly developed Valley Oak multiplexer this year. In addition, Pipher and Forrest have begun work with Rockwell Science Center to develop mid-wave HgCdTe detector arrays as an alternate technology for SIRTF, under a NASA contract. The group continues to use their state-of-the-art InSb arrays for ground-based Astronomy.

2. Far-Infrared Detector Array Development

A great deal of progress has been made during the past year on the development of Ge:Ga blocked-impurity-band (BIB) detector arrays, which will be of benefit to the SIRTF instruments and to instruments intended for airborne and ground-based applications. Watson, Guptill, Raines and Satyapal, with J.E. Huffman (Rockwell) and T. N. Krabach (JPL) have produced modest-sized (3, 5, 2×8, 6×6) monolithic arrays with performance comparable to the SIRTF/IRS goals over the 80 - 200 μm wavelength range peak responsivity over 10 A/W, peak quantum efficiency over 10%, dark current below 100 e/s. The physical processes which lead to beneficial long-wavelength (>115 μm) response have been identified; processes which inhibit response at shorter wavelengths (< 80μm) have been identified and eliminated, improving the detectors' performance. The first "fully-epitaxial" Ge:Ga BIB arrays have been successfully fabricated and operated. Low responsivity in the initial devices — a factor of 20 down from other devices — is traced to a donor "spike" at the blocker-absorber epilayer interface, which can be eliminated. Initial results indicate that a silox-based surface passivation and gold-tungsten circuitry may meet our dark-current long-term stability requirements. Yield on latest devices is 100% so far. Crucial semiconductor analysis tools — cryogenic spreading resistance analysis (Rockwell), photothermal ionization spectroscopy (UR), cryogenic C-V (UR) — are operating robustly. During the coming year the principal development issues are improved overall quantum efficiency, improved response for $\lambda = 35 - 100$ μm, development of compatible multiplexers, and fabrication of back-illuminated Ge:Ga BIB structures.

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