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1. 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, 1995 to September 30, 1996. The Astronomy faculty at the University of Rochester includes A. Frank (as of July 1, 1996), W. J. Forrest, H. L. Helfer (Emeritus), J. L. Pipher, M. P. Savedoff (Emeritus), S. L. Sharpless (Emeritus), J. H. Thomas, H. M. Van Horn (on leave to the NSF until June 30, 1996; resigned as of July 1, 1996), M. Wardle (resigned as of 1 Jan, 1996), and D. M. Watson. Associates of the C. E. K. Mees Observatory include D. Meisel, SUNY at Geneseo, and Z. Ninkov, Rochester Institute of Technology. [H. W. Fulbright, Emeritus Professor of Physics, remains active in the Department and at the Observatory].

Pipher assumed the position of Rochester representative to the Board of Directors of the New York Astronomical Corporation in November 1995. She continued as a member of NASA's 2MASS external review committee, and as a member of the NRAO Visiting Committee. Her term as member of the AAS council expired in June 1996. Pipher participated in an NSF review of the NOAO proposal ''Renewing NOAO,'' as well as the AURA Management plan. She chaired the NASA SOFIA Instrument proposal review, and participated in the NASA ''Origins of the Solar System Review.'' Pipher was appointed to the Advisory Committee on the AAS study ''Examining Graduate Education in Astronomy'' in May, 1996.

Thomas is serving a two-year term (1995-1997) as chair of the AAS Solar Physics Division. He continues to serve as a scientific editor of *The Astrophysical Journal* and as an affiliate scientist at the High Altitude Observatory, National Center for Atmospheric Research.

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.

Brendan Fisher resigned his postoctoral position in the Near Infrared Group [Instructor/Fellow] in May, 1996. Brendan had assumed responsibility for reduction and analysis of the several thousand Jupiter/Shoemaker-Levy9 images obtained in July 1994 in collaboration with U. Wyoming and Minnesota. He accepted an NRC fellowship at JPL and continues his collaboration with our group. Two new postdoctoral positions have been filled during this year. Babar Ali, PhD Ohio State University, has joined the Near IR group and is working on Forrest's ISO project to search for brown dwarfs. Bill Glaccum, PhD University of Chicago, joined the group this fall and will assume much responsibility for the SIRTF IRAC detector array work. Jian Wu continues as an Engineer with the Near Infrared Group. Wu's primary interest has been detector array development for space and ground-based application, and he is completing a PhD thesis under Forrest's supervision in Electrical Engineering on the development of space astronomical mid-IR HgCdTe detectors. Kevin McFadden is senior programmer/analyst with the Near IR group.

Public tours were conducted at the Observatory from mid-May until the end of August by several undergraduate employees: Jen Hoffman, Chris Holcolmb and Andi Sarafinas. We are indebted to Marilee Kaye Montanaro 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.

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

2. 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-sophomore sequence in astronomy. Pipher is the undergraduate advisor for astronomy majors.

Undergraduates Jen Hoffman and Andi Sarafinas worked with the Near IR group this summer. Jen had worked the previous year as well under the direction of postdoc Brendan Fisher on reduction of the Jupiter/Comet Levy Shoemaker 9 images. She is now reducing images on starburst and active galaxies and will complete a senior thesis in the Spring under Pipher's supervision on this topic. Andi began work under Forrest's direction on image reduction of images of brown dwarf candidates.

Undergraduates Ali and Abbas Tahir, EE majors, worked on wiring a dewar and optical ray-tracing respectively for the Near IR group, under Forrest's supervision. Abbas has nearly completed optimization of the design of a resolution 1000, cryogenic echellette spectrometer, sensitive from 1 - 2.5 μm and 3 - 5 μm, to be built in collaboration with the Universities of Wyoming and Minnesota.

Suzanne Galayda completed her undergraduate thesis, ''Analysis of Star Formation Region L988e'' under Pipher's direction. She also reported the results of this work at the *Rochester Symposium for Physics Students*, held each spring for area schools. Galayda found evidence for a cluster of stars of earliest spectral class B5. Nebulosity was associated with the earliest stars, and a bipolar flow from one of the clusters indicates that at least some of the objects have yet to reach the main sequence.

Michael Zingale completed his senior thesis on magnetohydrodynamic wave support of molecular clouds under the direction of Wardle and Thomas. His thesis was awarded the department's Stoddard Prize for the best thesis in Physics and Astronomy.

Benjamin Shaw, an undergraduate astronomy major at the University of Texas, spent the summer working on various problems in theoretical astrophysics, supervised by Thomas.

3. GRADUATE EDUCATION

Steve Solomon (in absentia), Eric Howard, Jian Wu, Jennifer Goetz, and Carl Welch have been graduate students in Forrest and Pipher's Near Infrared Group for the past year. Bob Benson has joined the group in September, 1996 as an incoming student, and is beginning to work on detector studies. David May continues a leave of absence.

Howard completed the requirements for his PhD degree in April, 1996, under Pipher's direction: his thesis is entitled ''A Multiwavelength Study of the Process of High-Mass Star Formation.'' He assumed a postdoctoral position with the 2MASS project in May, 1996.

Solomon had been active in detector development for SIRTF while in residence. He is now working at SBRC, Santa Barbara CA, on detector array development while completing his PhD thesis in absentia under Forrest's direction. His thesis will be concerned with the dual topics of 3.3 μm imaging of the reflection nebula NGC 2023 and detector physics.

Goetz has been analyzing broad-band IR and Fabry-Perot spectral images of the high mass, heavily obscured star formation region Cep A. She is currently writing her research brief, as well as a paper for publication, which develops a more complete picture of the nature of this complex source. She is incorporating radio images (of ionized hydrogen, NH_3 and CO emission, obtained from other astronomers) as well as UR IR images of the shock tracers (1.64 μm [FeII] and 2.12 μm H_2 line emission) and broad band images, which help to identify the location of the exciting source(s) and the nature of the excitation.

Carl Welch joined Pipher and Forrest's Near-Infrared Group after completing his first year of graduate studies in May 1996. Welch has been investigating impact (on Jupiter) phenomena of some of the smaller fragments of comet Shoemaker-Levy 9, particularly the V impact.

John Bloomer, Matt Guptill, 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 and millimeter-wave spectral-line imagery of galaxies. Guptill has been spear-heading the detector development at Rockwell, Anaheim with collaborator James Huffmann. Raines and Bloomer are actively involved in near IR spectral and broad band imaging of regions of high mass star formation.

Graduate students Tim Collins, Andrew Markiel, Colin Roald, Don Stanchfield, Guy Delamarter, and Anthony Perez-Miller work with the theory group.

Collins continued his research on boundary layers in cataclysmic variable stars. His studies focus particularly on incorporating the full effects of turbulent viscosity in his boundary layer models. Also, his models incorporate realistic tabulated opacities. Collins is currently in the process of writing his dissertation.

Andrew Markiel continued his thesis research with Thomas and Van Horn on the generation of magnetic fields in the Sun, white dwarfs, and other stars. In the last year he developed a 2-D code to compute dynamo models for these stars, and preliminary results were presented at the 10th European Workshop on White Dwarfs (Blanes, Spain) in June 1995.

Anthony Perez-Miller continued his reasearch with Mark Wardle extending the model of Wardle and Königl (1993) for magnetically driven winds from the disks of protostars. He left the university in August 1996 to pursue a PhD in the History and Philosophy of Science at Indiana University and will complete his master's thesis in absentia.

Colin Roald was awarded a Newkirk Fellowship by the High Altitude Observatory (HAO), National Center for Atmospheric Research, in Boulder, Colorado. He will continue his research on nonlinear stellar dynamos, supervised by Thomas, and will spend half of his time at HAO where he will work with Paul Charbonneau, Keith MacGregor, and Peter Gilman.

Stanchfield, with Thomas and B. W. Lites (HAO/NCAR), completed his analysis of observational data on the vector magnetic field, Evershed flow, and intensity in a sunspot. He presented the results of this work at a poster session at the 188th meeting of the AAS at the University of Wisconsin (Madison, WI) on 11 June 1996 (see Stanchfield, Thomas, and Lites 1997). He continues to reduce and analyze data sets from observations of dynamical phenomena in sunspots with Thomas and Lites.

Delamarter passed his PhD qualifying examination in the Fall of 1995, and continued work on C*- and J-type shock stability with Wardle. Delamarter has also started work with Frank on hydrodynamic collimation of protostellar jets, specifically towards adding more realistic ambient density distributions and cooling to models presented in Frank and Mellema (1996). Currently he is researching numerical schemes required for solving this problem, including Total Variation Diminishing (TVD) methods.

4. RESEARCH

4.1 Theoretical Astrophysics

Rochester's theoretical astrophysics group consists of A. Frank, H. L. Helfer, J. H. Thomas, and H. M. Van Horn (on leave), along with current graduate students T. Collins, G. Delamarter, A. Markiel, A. Perez-Miller, C. Roald, and D. Stanchfield. The group's research interests are mostly in the areas of astrophysical fluid dynamics and magnetohydrodynamics.

4.1.1 The Sun

Thomas is collaborating with B. Montesinos (LAEFF, Madrid) and F. Moreno-Insertis (IAC, Tenerife) on theoretical modeling of time-dependent siphon flows along solar magnetic flux tubes, with applications to the Evershed flow in sunspots and flows in emerging flux tubes. Earlier work on steady siphon flows in solar magnetic flux tubes by Thomas and collaborators is reviewed in Thomas (1996).

4.1.2 Solar and Stellar Dynamos

Roald and Thomas (1996) completed their work on a nonlinear solar dynamo model with dynamically variable α and ω effects. The bifurcation structure of the nonlinear model has been explored in considerable detail, with the results showing periodic, aperiodic, and chaotic behavior. The nonlinear quenching of the α and ω effects are shown to influence the dynamo process in dramatically different ways.

Markiel and Thomas, in collaboration with Van Horn, continued their investigation of dynamo activity in the Sun and other stars. Markiel developed a code to compute the full radial and latitudinal structure of the generated fields. A key ingredient of these models are recent determinations of the solar differential rotation from helioseismology. This new data allows improved models of the solar dynamo. Application of the model to white dwarfs confirms the previous results that dynamo processes are likely to occur in these stars.

These investigators have begun a collaboration with A. Muslimov (Goddard SFC) to investigate dynamos in the main sequence companions in X-ray binaries.

4.1.3 Accretion Disks

Collins, Van Horn and Wardle completed their study of the effects of the radial viscous force on models of accretion disk boundary layers in cataclysmic variables. They found that, for constant opacity models, its inclusion causes the radial inflow speeds to be reduced and the dynamical boundary layer becomes twice as wide. In contrast, there is essentially no effect on the thermal boundary layer or the observed spectrum. These results were presented at the Winter 1996 meeting of the AAS in San Antonio, Texas (Collins and Wardle, 1996). The detailed results are in press (Collins, 1997).

Collins, Helfer, and Van Horn have since investigated the thermal structure of the boundary layer. Disk and boundary layer models incorporating a constant opacity (equal to electron-scattering for a fully ionized gas) were compared to model using the OPAL opacity tables. The latter showed higher center-disk temperatures and lower infall speeds in the boundary layer. The effective disk thickness is increased but the emitted spectrum for these optically thick models is unchanged. These results are being prepared for submission to the Astrophysical Journal.

Currently Collins and Helfer are studying the effects of the radial viscous force and incorporation of the OPAL opacities upon the stability of the boundry layer. They plan to see if a numerical local analysis of the oscillations of the boundry layer can provide an explanation of the quasi-periodic oscillations observed in many dwarf novae (Robinson and Nather, 1979).

4.1.4 Shock Waves in Molecular Clouds

Delamarter and Wardle continued their work calculating the global stability of oblique, J- and C*-type shocks. Weak examples of these shock classes have been found which are unstable in a manner similar to C-type shocks. Work continues to extend the analysis to stronger shocks with more realistic cooling.

The steady shock structure classification and calculation module in the code is being used by Raines, who is working with Delamarter to adapt its cooling function to model shocks observed in Cep A.

4.1.5 Bipolar Outflows and Highly Collimated Jets

Frank's research focuses on bipolar outflows and highly collimated jets which are nearly ubiquitous features associated with stellar mass loss. From Young Stellar Objects (YSOs) to Luminous Blue Variables (LBVs) and Planetary Nebulae (PNe) - the stellar cradle to the grave - there exists clear evidence for collimated gaseous flows in the form of narrow high velocity streams or extended bipolar lobes. In YSOs, LBVs and PNe collimated highly supersonic outflows are observed to be transporting prodigious amounts of energy and momentum from a central star - enough to constitute a significant fraction of the total budgets of the entire system. Thus outflows and jets must play a significant dynamical role in the evolution of the parent stars.

It is remarkable that such different objects, separated by billions of years of evolution and decades of solar mass, should drive phenomena so similar. The similarity of jets and bipolar outflows across the H-R diagram must tell us something fundamental and quite general about the nature of stellar evolution as well as the interaction of stars with their environments. Indeed, because of their ubiquity and the large database of high resolution observations (most importantly those from the HST) collimated stellar outflows present a unique opportunity for astronomy. If researchers had an equally general, well tested theory for explaining outflow collimation and propagation it could serve as a powerful diagnostic tool linking the outflows to their often obscured sources.

The principal goal of Frank's research program is to develop and refine such a general theory of collimated stellar outflows by detailing the basic physics which drives the collimation process. He is also working to extend our understanding of the propagation of these outflows by incorporating more realistic physics in models such as the effect of magnetic fields and the 3-dimensional ''wandering'' of fully collimated jets. His approach to these problems relies on numerical gasdynamic and magneto-gasdynamic simulations with simultaneous calculation of the gas microphysics. Knowing the micro-state of the gas allows him produce ''synthetic'' observations of the model for detailed comparison with what is seen on the sky. Given the speed of modern computers, this is accomplished by including a self-consistent treatment of energy losses due to radiation. Tracking the radiation which leaves the systems makes synthetic observations possible. Thus the goal of his research is to produce models which can ''give the observers back their observations.''

4.2 Observational Astronomy

In the past year, observational astronomy at the University of Rochester has included studies of star formation regions, planetary nebulae, active and starburst galaxies, brown dwarf candidates, the collision of Comet Levy-Shoemaker 9 with Jupiter, and the Sun.

4.2.1 The Sun

J. H. Thomas collaborates with B. W. Lites (HAO/NCAR) in carrying out high-resolution observations of dynamical phenomena in sunspots and solar active regions using the Advanced Stokes Polarimeter (ASP) and the Vacuum Tower Telescope at the National Solar Observatory, Sacramento Peak. They had a very successful observing run with the ASP in October 1995, when they obtained several excellent data sets for studying oscillations in sunspots, sunspot seismology, and high-frequency acoustic sources and their relation to the excitation of solar p-modes. These data sets are currently being reduced and analyzed with the assistance of graduate student D. Stanchfield.

Stanchfield, Thomas, and Lites (1997) completed their analysis of observational data on the vector magnetic field, Evershed flow, and intensity in a sunspot, based on ASP data from October 1993. The results confirm the discovery by Rimmele that the Evershed flow is generally confined to narrow, elevated channels in regions of the penumbra where the magnetic field is very nearly horizontal. Although there is at most a weak relation between the Evershed flow and continuum intensity in the penumbra, there is a significant association between the Evershed flow and the darkest filamentary structures seen in core intensity in the spectral line used to measure the flow.

4.2.2 The Solar System

The Comet Shoemaker-Levy 9 impacts with Jupiter in July 1994 provided an unprecedented probe of the Jovian atmosphere. A world-wide network of observers, using a variety of techniques and instruments, were integrated together to assure complete coverage of this once-in-a-lifetime event. The Jupiter/SL9 encounter observations utilized the University of Rochester near infrared camera (described below), and observations were obtained in collaboration with our colleagues at the University of Wyoming (Woodward and Howell) and University of Minnesota (Gehrz) on the 2.3-m telescope at the Wyoming Infrared Telescope Facility (WIRO).

Our 2 – 2.5 μm dataset can be considered complementary to the large number of datasets in this band collected worldwide. Spectral images in the 3 - 4 μm waveband are crucial, and since temporal observations are extremely important, it is clear that our dataset is valuable because the worldwide coverage in this band is quite limited.

Atmospheric modeling analysis will be conducted in collaboration with Phil Nicholson's group at Cornell using a code developed by Cornell and Conrath (GSFC).

The spectra of certain impact sites as they evolved in time give crucial information concerning the chemistry from earliest acquisition of an impact site. For example, we have observed (Fisher *et al.*, in preparation) a *very* strong emission feature near 3.3–3.4 μm in the Q1 spot 3–4 hours after impact: we are studying the Q1 spot's temporal history in this band and are searching for similar emission features in other young spots.

The V impact was a very short-lived transient event for which we have a 2.2 μm light-curve. This event did not leave a visible impact site.

Postdoc Fisher wrote code for the reduction and calibration of the many images of this event, and undergraduate Hoffman has completed production of the required images for the NASA public dataset.

The structure of Saturn's mesosphere has been determined through analysis of an extensive data set of immersion and emersion lightcurves of the occultation of 28 Sgr by Saturn's atmosphere on 3 July 1989 (Hubbard *et al.* 1996, preprint). IR observations of the immersion with the Rochester first generation camera were a part of the dataset.

The last crossing of Saturn's ring plane was observed on 12 Feb. 1996 using the U. Rochester Third Generation camera at the 2.3m WIRO telescope. Since, at this time, Saturn would be observed equator-on, it was an opportunity to probe for the excess thermal emissions in the 5 μm region which are so clearly seen in Jupiter but not Saturn. These emissions arise because Jupiter has cloud- free regions (zones) and the gaseous opacity is very small, permitting viewing of the warm, deep regions in the atmosphere. The brown dwarf Gliese 229B shows similar excess emission. Images of Saturn at 1.6, 2.2 (K-band), 2.3, 3.3, and 4.7 μm were acquired. The 4.7 μm images showed no hint of the bright emission bands which are seen in Jupiter. We conclude that the cloud cover in Saturn is complete. Thus, this 5 μm emission phenomenon is not universal in giant planets and may not be universal for brown dwarfs either. The 2.3 μm images completely suppressed the planetary disk, showing faint rings and 2-3 satellites orbiting near the rings.

4.2.3 Brown Dwarfs and Low Mass Stars

The Near Infrared group continues to monitor brown dwarf candidates projected on the Taurus cloud (Forrest *et al.*, 1990) for variability. Forrest and Ali, in collaboration with Stauffer (SAO) and Leggett (Hawaii), are conducting an ISO search for Brown Dwarfs in clusters. Undergraduate student Sarafinas has begun analysis of images obtained from ground-based cameras on brown dwarf candidates in Taurus.

4.2.4 Observations of Star Formation Activity

In support of the use of the 3.29 μm dust feature as a probe of star formation in galaxies, we have extensively investigated this feature in galactic sources. The intent is to gain a better understanding of the astrophysics underlying its generation. To this end, we have imaged the well-known reflection nebulae NGC 2023 and NGC 7023 with approximately 1″ resolution. Images in the feature and the nearby continuum as well as the J,H,K bands are being analyzed for Solomon's PhD thesis. Undergraduate Hoffman will study several galaxies in this feature this year.

We have been studying massive star formation regions via: *(i.)* imaging in hydrogen recombination lines (to probe excitation and extinction); *(ii.)* imaging in lines of H_2 (to probe molecular shock excitation); *(iii.)* imaging in [FeII] lines (to probe molecular shocks); *(iv.)* imaging in the 3.28

μm PAH emission feature to explore PDR regions; and *(v.)* imaging at broadband J, H, K, L$''$, and M$'$ (to probe reflection nebulosity, thermal dust emission, and to obtain crude photometry and reddening of associated point sources). Howard *et al.* (1996) have exploited many of these techniques in detailed studies of K3-50 and S255 respectively; further observations of Orion BNKL, Cep A east and GGD37 (Cep A west), S255, NS14, NGC 7538, DR 21 and L988e are in various stages of reduction, some of which are described below.

Images of the Herbig-Haro (H-H) objects in GGD 37 show that the H_2 emission forms arcs exterior to the [Fe II] emission; the morphology is similar to that of the H_2/[S II] images of Hartigan, Carpenter, Dougados and Skrutskie (1996). The peak H_2 and [Fe II] line emissions for several of the H-H objects are clearly separated relative to one another, suggestive of multiple shocks. Raines is currently modifying Delamarter's model of the structure of C* and J shocks in H_2 to include other important coolants such as [Fe II], in order to compare the separation of the shocked emissions to those seen in GGD 37.

In Cep A ''artillery shells,'' such as those observed in Orion (Allen and Burton 1993), are observed with [FeII] emission at the tip of the shell, one side of which is outlined in H_2 emission along the string of radio continuum sources HW 7. The proposed Herbig-Haro object HW7c(ii), a radio compact source which shows a transverse motion of 300 – 400 km/s away from the exciting cluster in HW2/3, may be the Mach disk in this region (Goetz *et al.* 1996).

Images of NGC 7538 show [FeII] emission in a shell surrounding the HII region associated with IRS 2, perhaps the result of shocks driven by expansion of the HII region. Shocked molecular hydrogen is observed both adjacent to the peak [FeII] emission, as in GGD37, and in extended arcs to the north of the three embedded IR sources. Bloomer has been working on analysis of these shock features, their possible driving mechanisms, and their (non-) association with known CO outflows.

Howard, Koerner and Pipher (1996c) report HCO^+ and SiO observations of K350A obtained with the OVRO millimeter array. From these observations they have derived a self-consistent model for the region, which incorporates these radio data, earlier IR observations (Howard *et al.* 1996), as well as radio imaging by DePree *et al.* (1994). A molecular gas/dust torus surround the exciting source and compact HII region: the torus is tilted about 40^o to the line of sight, such that the near side of the torus obscures the northern part of the HII region and the northern bipolar flow is directed away from us. The SiO emission traces the shocked gas where the flow impacts molecular cloud material.

4.2.5 Observations of Active and Starburst Galaxies

Following the interesting results on the distribution of the 3.29 μm dust emission in the starburst galaxy NGC 253 described in the 1991 report, a program of observation of this feature in other starburst galaxies is being carried out using the infrared cameras of the University of Rochester equipped with 1% resolution CVFs. In a wide variety of galaxies, the 3.29 μm dust emission feature carries approximately 0.1% of the total dust luminosity, which is predominantly in the far-infrared. This feature is believed to result from extremely small grains heated temporarily to high temperatures by single ultraviolet photons. Thus, it is believed to be a good tracer for star-formation activity. With our cameras we can achieve 1$''$ resolution and locate and explore the regions of active star formation in distant galaxies. To date the (redshifted) feature has been clearly detected in images of NGC 3690, NGC 7469, M82 and NGC 1614. Spectral images of NGC 4102, NGC 4194, and NGC 1068 are being investigated for the presence of this feature. The observations have been carried out at the IRTF 3m, the MLOF 1.5m, and the WIRO 2.3m telescopes.

Greenhouse *et al.* (1996) present extinction-corrected [FeII] 1.64 μm images of M82, and conclude that the [FeII] sources trace out a supernova population considerably older than those revealed on 6-cm radiographs. The [FeII]/Brγ line ratio correlates with the age of the starburst as reflected by the photospheric emission from the stars in M82 (Satyapal *et al.* 1996). Thus, the [FeII] emission regions are colocated with a post main-sequence population.

4.3 Instrumentation

This year, infrared instrumentation development has centered on the groups' near infrared and far infrared SIRTF detector developments, improvements to the Rochester third generation ground-based camera, development of near and far IR Fabry Perot interferometers, and continued design of a near IR echellette spectrometer.

4.3.1 Near Infrared Array Detector System Development

Forrest and Pipher and their group continue to develop infrared arrays for space application using the flexible, programmable array controller utilizing DSPs described in previous reports. This year they have concentrated on 256$\times$256 InSb arrays mounted on CRC 744 multiplexers (muxes). Following Rochester tests of lot splits of bare muxes, two candidate materials were chosen. InSb arrays mounted to the best muxes exhibit very low noise at 13 – 17K (5 e^- with multiple sampling), low dark current ($<$ 0.2 e^-/s), high quantum efficiency ($>$ 85%), and as well are robust under proton and gamma ray irradiation (Wu *et al.* 1996).

In addition, Pipher and Forrest, with engineer/ graduate student Wu, are continuing work with Rockwell Science Center to develop mid-wave HgCdTe detector arrays as an alternate technology for space astronomy under a NASA grant (which expired in April 1996) and a new NSF GOALI grant (which began June 1996). There has been considerable progress in this area of research, and Pipher and Forrest have participated in the NGST study partially in order to advance this detector work.

4.3.2 Near Infrared Astronomical Instrumentation

One of the SBRC InSb CRC 463 arrays, FPA 131, is utilized in the Rochester Third Generation camera, developed under a grant from the NSF. It now has a complement of fixed filters at the J, H, K, L', 3.26 μm and M' bands, and in addition, three CVFs (circular variable filters) over the usable 1 - 5 μm waveband with $\sim$1 - 2% resolution. The Third Generation 256$\times$256 InSb array camera has been used in ever-improved form since October, 1992 at WIRO and MLOF.

For several years now, we have obtained spectral images by combining warm NRL/NASM Fabry Perot interferometers with the Rochester Third Generation camera. The resultant resolution ($\sim$ 800) has allowed our groups to obtain spectacular line emission images.

A near IR echellette spectrometer has been designed and will be built in collaboration with Universities of Wyoming and Minnesota for use at WIRO. The slit size will be $1'' \times 10''$ and the resolution will be $\sim$ 1000. The complete 1 - 2.5 μm spectrum or the complete 3 - 5 μm spectrum will fill the InSb array.

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