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I. Staff

The Astronomy faculty at the University of Rochester includes W. J. Forrest, H. L. Helfer, J. L. Pipher, M. P. Savedoff, S. L. Sharpless, J. H. Thomas, H. M. Van Horn, and as of Fall 1988, D. M. Watson. Dr. Watson has been a research associate at Cal Tech and JPL, and expects to pursue a vigorous program in infrared array development and infrared astronomy at Rochester. As of July 1, Stewart Sharpless became Emeritus Professor of Astronomy and Senior Faculty Associate in the College of Arts and Science. In addition, D. D. Meisel, SUNY at Geneseo, is an Associate of the C. E. K. Mees Observatory. H. W. Fulbright, a member of the Physics faculty, has been devoting much of his teaching and research time to astronomical activity.

Zoran Ninkov completed three years as a Research Associate with the Infrared Group. While at Rochester, he extensively tested, evaluated and improved infrared arrays for SIRTF (Space Infrared Telescope Facility) experiments. In addition, he participated in several observing trips using these new arrays in the Rochester Array Camera. Zoran began a position as a Research Scientist with the Optoelectronics Division of SRL, Australia, on October 1, 1988.

James Garnett began an appointment with the Infrared Group as a Research Associate in December, 1987. Jim completed his Ph. D. in Physics at U. C., Berkeley with Eugene Cummins prior to joining the Rochester staff. He is participating in both detector array development and ground-based application of the arrays.

Gilles Chabrier completed his second year as a Research Associate in Physics and Astronomy and will return to France at the end of December, 1988. He is collaborating with Didier Saumon and Van Horn on an investigation of the equation of state of extremely dense hydrogen.

Hugh E. DeWitt spent the months of July and August 1988 as a Visiting Scientist in the Department of Physics and Astronomy, on academic leave from the Lawrence Livermore National Laboratory. He is collaborating with Chabrier, Saumon, and Van Horn in research on the problem of phase separation in binary ionic mixtures. Specific areas being investigated include C/O phase separation in white dwarfs, H/He phase separation in giant planets and brown dwarfs, and Fe/H phase separation in low mass stars.

Forrest serves as a member of the Kitt Peak User's group, and the selection committee for the IEEE 1988 Nuclear Science Symposium session on "Instrumentation for Astronomy and Space Physics."

Helfer is on the Board of Directors of the New York Astronomical Corporation.

Meisel was on sabbatical Fall 1987 and worked at Rochester on fabrication and design of a linear CCD array that will be used as a backup to the system under development by Fulbright and his students.

Pipher continues to serve on the NOAO Visiting Committee, the IAU USNC committee which oversaw organization of the successful IAU held in Baltimore this summer, the Kitt Peak Telescope Allocation Committee, the Warner/Pierce Prize Committee of the AAS and the Search Committee for an Associate Editor of the *Astrophysical Journal*. She was Chair of the Organizing Committee for the session "Infrared Astronomy from Space" held as part of Commission 44 at the IAU in August 1988. Pipher participated in the review of Radio Astronomy Centers supported by the NSF in March 1988, and was a member of the NASA Traveling Detector Team to evaluate HST second generation proposals in September 1988.

Thomas was on academic leave during 1987-88 at the University of Oxford, where he was a visiting fellow of Worcester College and a member of the Department of Theoretical Physics. He gave two invited review talks on "sunspot seismology" to the Royal Astronomical Society, and colloquia at Oxford, Cambridge, Queen Mary College, Sussex, St. Andrews, Rutherford Laboratory, Munich, Utrecht, and the Canary Islands. Thomas completed his term on the Users Committee of the National Solar Observatory and now serves on the U. S. Scientific and Technical Working Group for the proposed Large Earth-based Solar Telescope (LEST).

Van Horn continues to serve as a member of the Board of Trustees of Associated Universities, Inc., a position he has held since 1983. He also served on the Organizing Committee for the IAU Colloquium on "White Dwarfs and Cataclysmic Systems," held at Dartmouth College from 15 - 19 August 1988. Van Horn is currently a member of the International Advisory Board for the "International Workshop on Strongly Coupled Plasma Physics," to take place in Tokyo in August 1989. In collaboration with H. E. DeWitt (LLNL) and J. Callaway (LSU), he is also organizing a workshop on "Atoms and Ions in Dense Plasmas," to be held at the Institute for Theoretical Physics in Santa Barbara from September through December of 1989.

Public and special tours were conducted at the Observatory from mid-May until the end of August by graduate students, faculty and three undergraduate employees of the Observatory: Peter Owings, Ron Kohlstaedt, and Anthony Imperial. Rosemary Dow, the Astronomy group secretary, continues to be an effective public relations representative for the astronomers.

II. Undergraduate Education

The undergraduate program 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. In the 1988 summer session Astronomy 102 was offered, and taught by Meisel.

For the second time, the Departmental Award for Excellence in Teaching was presented to Sharpless. The graduating seniors in Physics and Astronomy each year select the awardee.

Meisel and Charles Recchia, a Geneseo under-

graduate student, completed the first phase of a program to bring image processing techniques into an introductory astronomy laboratory (Meisel *et al.* 1988; Meisel and Recchia 1988). Digitized images of various celestial objects as recorded from the Mees 0.6m telescope onto video tape have been used by some 300 Geneseo students in the pilot program. Work is continuing on this using a solid-state color TV camera. Reprogramming the Apple IIe software for the Apple IIGS is underway.

Meisel presented a poster paper at I.A.U. Colloquium 105- *Teaching of Astronomy* describing the Geneseo Astronomy Image Processing laboratories (Meisel *et al.* 1988).

The Advanced Physics Laboratory Course, normally taken by seniors in the Department of Physics and Astronomy, now offers students the possibility of making simple radio astronomy observations. Fulbright and past seniors have constructed a computer-controlled, steerable 8' diameter dish antenna (which was originally used for weather satellite work) along with a sensitive low-noise microwave receiver, a Dicke switch unit etc.

Fulbright and undergraduate students A. Imperial and J. Kan have recently completed construction of a CCD system for use with the visible-light Meinel spectrograph of the Mees Observatory telescope. A thermoelectrically-cooled linear CCD with 2048 elements is used. A simple sliding shutter built into the slit structure of the spectrograph allows automatic computer-controlled cyclic background subtraction. All computer programming required for device control, for monitoring and recording of data, and for wavelength calibration has been done. In preliminary tests made with the collaboration of Meisel the spectra of a variety of stars were recorded. It appears that the system should prove effective and convenient in use.

Peter Owings completed his senior thesis under the supervision of Sharpless on the determination of morphological orientation parameters spiral galaxies. These parameters are used in the study of the internal kinematics of galaxies. Michael Myers completed his senior thesis under the supervision of Pipher on the infrared properties of the radio lobe spiral galaxy NGC 3079; the infrared images of the galaxy were obtained at the request of Judith Irwin, University of Toronto, who has undertaken a case study of this galaxy for her PhD dissertation.

III. Graduate Education

Steve Solomon, Paula Comiski Turner and Uwe Peppel are graduate students working with Forrest and Pipher. Chris Moore, an incoming student Fall 1988, is a teaching assistant for the Astronomy undergraduate courses, and Shobita Satyapal, another incoming Astronomy student, is also a teaching assistant within the Department.

Theodoros Koupelis completed his Ph. D. research on "Rotation and Magnetic Fields as an Acceleration Mechanism in Astrophysical Jets." Since September 1988, he has been conducting postdoctoral research on jets with Prof. Philip Hardee at the University of Alabama. Didier Saumon, in close collaboration with Chabrier and Van Horn, is continuing his investigation of the equation of state of dense hydrogen. When completed later this year, these results will be used to construct new models of brown dwarf stars. Charles Wendell is studying the dynamics of magnetic flux tubes in the superfluid interiors of neutron stars, in order to explore the process of flux expulsion from a neutron star core. Tod Strohmayer is just beginning his thesis research to explore the coupling between non-radial oscillations of neutron stars and models for the pulsar emission process. The purpose of this research is to investigate the potential observability of neutron star oscillations. All three students are working with Van Horn.

IV. Research

A. Theoretical Astrophysics

In the past year, research in theoretical astrophysics at the University of Rochester has included studies of white dwarfs, properties of astrophysical jets and radio galaxies, equations of state for dense matter, neutron stars, high energy particles in the interstellar medium, and solar physics.

1. Solar Physics

Thomas (1988) completed the first stage of his study of steady siphon flows in isolated magnetic flux tubes, including the basic theory and numerical computations of isothermal flows. This work has applications to intense solar flux tubes and the Evershed flow in a sunspot. In collaboration with Benjamin Montesinos (University of Oxford), this work has been extended to include numerical calculations of abiabatic flows (Montesinos and Thomas 1989). Current work on this problem addresses the questions of the exact equilibrium shape of an arched flux tube containing a siphon flow and the strength and location of a standing tube shock in the downstream branch of a critical siphon flow.

Thomas and Toufik Abdelatif (Queen Mary College) have presented a comprehensive analysis of the transmission and reflection of compressive waves at a nonmagnetic-magnetic interface (Abdelatif and Thomas 1989). The results have applications to the interaction of solar p-modes with a sunspot (see Abdelatif and Thomas 1988) and to a variety of other situations involving the propagation of waves from nonmagnetic to magnetic regions in the solar (or stellar) atmosphere.

In collaboration with Alan Nye (Rochester Institute of Technology) and Bernard Roberts and David Evans (University of St. Andrews, Scotland), Thomas is studying theoretical models of the effect of photospheric and chromospheric magnetic fields on the frequencies of solar p-mode oscillations. The predicted frequency shifts, while small, are measurable with present techniques and are comparable to shifts due to other perturbing influences, such as subsurface inhomogeneities and flow, that have been proposed for detection.

2. Equations of State for Dense Matter

Chabrier (1987, 1988a,b) has carried out several calculations on the properties of mixtures of metals and molten salts. These studies are extensions to more realistic cases of prior work on the properties of the hypothetical one-component plasma. They also have provided a solid foundation for a new study of the equation of state (EOS) of dense hydrogen, which Chabrier is

pursuing in collaboration with Saumon and Van Horn. Chabrier has recently completed a calculation of the properties of fully ionized H in a responding electron background based on solutions of the so-called "hypernetted chain" (HNC) equation. His results compare very well with previous Monte Carlo calculations by Totsuji and Tokami (1984) and by Helfer and McCrory (1987). Saumon has completed a complementary calculation of the dissociation and ionization of H, using modern hard-sphere fluid perturbation theory, which he has extended by incorporating the theory of Hummer and Mihalas (1988) to treat the internal partition functions. These calculations will comprise part of Saumon's Ph. D. thesis, where they will be applied to computations of the structure and evolution of brown dwarf stars. Chabrier and Saumon (1988) are preparing a report on their calculations of the possibility that pressure-ionization may be a first-order metal-insulator phase transition, as suggested by Wigner and Huntington (1935), Friedli and Ashcroft (1977), Ross *et al.* (1983), and others. If such a phase transition exists, their calculations are expected to give the most accurate values for its parameters.

In connection with their research on the equation of state of dense, molecular hydrogen, Saumon, Chabrier, and Weis (1988) have developed a new and more accurate form of fluid perturbation theory for binary mixtures at high temperature. It is based on a new method of splitting the intermolecular potentials into a repulsive core and an attractive part, and it permits rigorous additivity of the hard sphere diameters. Comparisons with detailed Monte Carlo calculations show that the new method is accurate to a few percent even in cases where earlier forms of fluid perturbation theory are in error by as much as 50% or even fail to converge.

Lamb and Van Horn (1988) are preparing a detailed description of their calculations of the equations of state of matter at very high densities, like those occurring in the interiors of white dwarf stars.

3. White Dwarfs

In an effort to assess the reliability of the white dwarf model ages used by Winget *et al.* (1987) to determine the age of the galactic disk, Winget and Van Horn (1987) have investigated the physics of cool white dwarfs. In particular they have found that, when corrected to the same choices of input physics, all of the recent model calculations which have attempted to treat the microscopic physics accurately give ages which are mutually consistent to within about 6 percent. One set of models used in this assessment was that constructed by Wood *et al.* (1987). These have pure O cores, complementing the pure C core models constructed earlier by Winget *et al.* (cf. Winget 1981), and representing a compositional extreme which is made more plausible by recent changes in the thermonuclear reaction rates (cf. Mazzitelli and D'Antona 1986).

Koupelis and Winget (1987) have carried out new observations of the pulsations of the hot pre-white-dwarf star PG1159-035. Quite surprisingly, they found four new oscillation periods. The new modes, however, still appear to fit the form of the oscillation spectrum suggested by Kawaler (1987). Thus the mass of 0.6 $M_\odot$ inferred by Kawaler for this star remains secure.

In a short paper, Van Horn (1988) has suggested the possibility that accretion disk oscillations may be detectable in FU Orionis stars, in analogy with the case of cataclysmic variable stars. This follows the proposal by Hartman and Kenyon (1985) that accretion disks may be responsible for much of the emission from these systems.

Van Horn, Winget, and Hansen (1988) are preparing a detailed review of the current state of theory and observations of the various classes of pulsating white dwarfs.

4. Neutron Stars

McDermott *et al.* (1988) have completed work on the non-radial oscillations of non-magnetic, non-rotating, spherical neutron stars. This study, which comprises much of McDermott's (1985) Ph. D. thesis, found a wealth of adiabatic pulsation modes, including surface and core g-modes, p-modes, interfacial modes at the top and bottom surfaces of the crust, and torsional oscillation modes of the solid crust. The mode periods range from tenths of milliseconds to some tens of seconds. Van Horn *et al.* (1987) have used these results to explore the possibility that non-radial oscillations may eventually be detectable in the neutron star remnant of SN1987A.

Wendell (1987, 1988a, 1988b) has carried out a careful computation of the minimum energy configurations of magnetic flux tubes in neutron star cores, assuming that they are pinned at the base of the crust. Interestingly, he finds that the flux tubes closest to the center of the star remain trapped there, because the energy gain from buoyancy is not sufficient to overcome the magnetic tension of the pinned flux tube. However, the minimum energy state for the majority of flux tubes is that in which the pinned tube deforms and rises buoyantly until it is plastered along the underside of the crust. These results together provide a natural explanation for the recent observations which suggest that the 10^{12} gauss fields in pulsars decay on the crustal timescale to residual levels of 10^9 to 10^{10} gauss.

5. High Energy Particles in the Interstellar Medium

Helfer and Savedoff have been investigating some properties of interstellar clouds crushed by the shock fronts of expanding SNR's. Blandford and Cowie (1982) first pointed out their properties and significance for explaining the strength of the radio emission of (supernova remnants) SNR's. Helfer and Savedoff have recalculated the pion production for these clouds in which there exists a strong diffusive accelerative mechanism for primordial cosmic ray particles. They find, e.g., that pion production at 1 Gev can be enhanced by a factor of 30, leading to enhanced positron, antiproton and gamma-ray production. For a simple leaky-box model (characterized by an escape parameter of 5 g cm^{-2} of hydrogen) the $\bar{p}/p$ ratio is raised by a factor greater than ten for Gev energies. This is more than is needed to explain the observed anomalous ratio. It appears then, that allowing cosmic ray primaries to spend (no more than) a few percent of their lifetimes under the influence of strong diffusive accelerative shocks can explain some puzzling features of the observations. This work is continuing.

The investigation into the enhanced gamma ray production has lead Helfer and Savedoff into re-examination of the COS-B gamma ray data interpretation. It appears as if the present modeling is inconsistant with other data and may inadequately estimate the importance of gamma ray production by the inverse Compton effect. This work is also continuing.

6. Astrophysical Jets and Radio Galaxies

Koupelis and Van Horn (1988a), have developed a simple "helix model" for astrophysical jets. The basic concept is that the plasma in a jet is tied to a central massive object (the source of the jet flow) by the magnetic field which threads both. If the source is rotating, the magnetic field between it and the plasma blob is twisted, and the resulting gradient of $\mathbf{B}_\phi$ accelerates the plasma along the jet. For models in which the central object is a black hole or a neutron star, terminal velocities close to *c* are obtained, while for conditions typical of those in protostars the injection speed is not greatly increased. Koupelis (1988) and Koupelis and Van Horn (1988b) have further extended these calculations by considering a "narrow jet" approximation, in which the full set of MHD equations for a rotating, magnetic flow is projected onto the jet axis. The resulting system of one-dimensional equations bears a similar relation to the full magnetohydrodynamic problem as the "thin disk" approximation does to a complete accretion disk calculation. These calculations also form the basis for a "unified model" for the astrophysical jets recently proposed by Koupelis and Van Horn (1988c).

Zaninetti and Van Horn (1988) have conducted geometrical simulations of the patterns of jets emitted by moving galaxies when the source of emission is precessing, an attempt to trace the transition from C- to S-shaped sources. In particular, the effect of ram pressure bending of the jet flow has been used to investigate beam trajectories in the intracluster medium of a cluster of galaxies. Alternatively, the velocity decrease of a freely expanding jet can provide a natural way to understand the production of a "head-tail" radio jet even without the presence of a surrounding medium.

Zaninetti and Siah (1988), in work begun while both were visitors in the Department of Physics and Astronomy during the summer of 1986, explored the problem of electron acceleration in a non-homogeneous medium, as applied to the extra-galactic radio sources. In their model, the magnetic field is stronger in discrete clouds, and both Fermi acceleration and synchrotron losses affect the asymptotic spectrum.

Zaninetti (1988) has also investigated radio emission from spiral galaxies as a percolation problem. The results give encouraging consistency with observations.

B. Observational Astronomy

Forrest, Pipher, Ninkov and Garnett with their graduate students are continuing a program of astronomical imaging with the Rochester Infrared Array Camera; December 1987 was the last observing run utilizing a 32 x 32 InSb array coupled to a silicon CCD readout. On three successful runs since then, a 58 x 62 InSb array coupled to a DRO (direct read out) multiplexer was employed. For both camera systems, the InSb was sensitive from 1-5 μm. The array camera is an upgraded version of that described in Forrest *et al.* (1985). In the past year, the Infrared group has been engaged in observational programs at the NASA Infrared Telescope Facility (IRTF) and the Canada France Hawaii Telescope (CFHT) in Hawaii. Some of the scientific programs are detailed below. In addition, Forrest and Fulbright have obtained HI radio line observations of bipolar nebulae, searching for shock disassociated material. Forrest (in collaboration with Shure of the Institute for Astronomy, Hawaii, and Skrutskie, of University of Massachusetts) has obtained spectroscopic observations of the low mass stars/brown dwarfs Gliese 569B, LHS 2924, VB 10 and VB 8. The CO, H_2O, and Na features will be used to define a spectral sequence for the coolest stars, leading to better temperature estimates.

1. Brown Dwarfs and Low Mass Stars

Collaborative searches (with M. Skrutskie) for brown dwarf and low mass companions, using the Rochester infrared array camera, have been conducted. The first object found in this study, Gliese 569B was found to be a quite red object with H-K = 0.6 mag., and evidence has been compiled that indicates the system is in fact binary, and quite young (Forrest *et al.*, 1988). Age is a key factor in distinguishing between brown dwarf and low mass stars; a young age implies a brown dwarf. Other investigators confirm the red color, and Shure, Skrutskie and Forrest (1988) have obtained spectroscopy showing CO and H_2O absorption features approximately as deep as LHS 2924, the reddest main sequence star previously known. A very recent search in September 1988 provided a number of possible red companions to the primary stars searched; analysis is continuing. In this sampling, younger primary stars with reasonably well determined ages were selected, thus permitting eventual classification of the companions into the super-Jupiter/brown-dwarf/low-mass-star sequence.

2. Galactic Nebulae

Two types of bipolar nebulae have been observed with the Rochester infrared array camera, those associated with star formation regions where high velocity molecular outflow has been observed, and those associated with late type stars with high mass loss. An example of the former is L1551-IRS5, which reveals the disk collimating the bipolar flow via scattering, and in addition a partial segment of a bubble on the blue-shifted side (Moneti *et al.* 1988). The early work by our group on these objects has been expanded this summer to include imaging of Cep A in the 2.12 μm molecular hydrogen line, in collaboration with Daniel Nadeau, University of Montreal, on the CFHT. Much interesting structure on arcsecond scales was seen.

An example of a bipolar nebula associated with a late type star is OH 0739-14 (Woodward *et al.* 1988a). They show that the bipolar nebula associated with the M9III star in the source OH0739-14 is due to scattering off expelled material. Evidence for a very thick equatorial disk extending 2" north and south of the equator is given. Two moderately blue regions north and south of the disk are seen, as is one of the Herbig Haro objects identified by Cohen *et al.*

(1985). These regions are, however, redder than expected if the radiation is scattered light by a 'bare' M9III star. Possible explanations are advanced. In addition Shure *et al.* (1988) report imaging of this object at 0.42"/pixel at 1.65, 2.23, and 3.75 μm as well as through the 3.08 μm ice feature at 1% spectral resolution. The ice feature images clearly depict the extinction disk, while the high spatial 2.23 μm images show three string-like extensions from the bright northern lobe of the bipolar nebula, and terminating in the northern Herbig Haro object. Perhaps these are trails of material entrained in the flow which created the Herbig Haro object.

Infrared images in the Brα line and the 3.28 μm dust emission feature of the planetary nebula NGC 7027 show that the feature emission and the ionized hydrogen partially emanate from the same volume, but the feature emission extends beyond the ionized hydrogen boundary and does not extend within the inner gas radius (Woodward *et al.* 1988b). Thus, the small grains responsible for the feature emission are not robust very close to the central star.

Images at 3.76 μm of the HII region/molecular cloud complex near W3A were obtained at the Wyoming Infrared Telescope with the Rochester Infrared Camera, and, in combination with images obtained with other instruments at other wavelengths, allow a comprehensive model of the region to be advanced (Hayward *et al.* 1988). A new point source, IRS 2b, was found, which, in addition to IRS2 provides photons to excite the region. It may be an example of a YSO (young stellar object) in the dust clearing phase.

In collaboration with John Bally of AT&T Bell Laboratories, Forrest and Fulbright have had two observing runs at the VLA (B array) searching for 21 cm HI radiation possibly originating near sources of high-velocity outflow. Several galactic objects, which at 2 μm have recently been found to show high surface-brightness structures, some resembling unipolar bubbles, were observed. The aim was to correlate structures seen in HI with those seen in the near infrared. The objects are AFGL 2591, S 140, Cep A, MonR 2, Ori B, OH 0739-14 and S 106. The data are partially processed. Preliminary results from the first three objects listed show little if any HI radiation. The data from the other three sources remain to be processed. The possibility of improving the statistical quality of the Cep A and AFGL 2591 results by combining with them archival data from earlier observations by another investigator is being considered.

3. The Galactic Center

Imaging of the Galactic center in and out of the CO band has been initiated on the IRTF by the Infrared group both using 1% filter wheel resolution. In collaboration with Beckwith and Herbst at Cornell, the Rochester Infrared Camera has been coupled to the Cornell Fabry Perot interferometer, to make high spectral resolution observations of the CO and Brγ components of the Galactic center. The initial results were encouraging, and further observations are planned next summer with a fully stabilized Fabry Perot system. They hope to identify the background giant and supergiant components, and the extent of the anomalous blue region near IRS 16. In addition, velocity resolved imaging of the broad helium and hydrogen lines are planned at high spatial resolution (~0.35"/pixel). Occultations of the Galactic center by the Moon were observed at 2.23 μm with the Rochester array camera at the CFHT and IRTF in July and September of 1988. A 25" square region centered on IRS 16 was imaged with 0.42" pixels. Nine hundred images with 0.13 sec time resolution were obtained in July and 1200 images with 0.5 sec time resolution were obtained in September, a very slow event. In conjunction with single aperture high speed photometry they expect to obtain estimates of the sizes of sources at the Galactic center. This program was conducted in collaboration with a large group of astronomers headed by Simon of SUNY, Stonybrook.

Further images of the Galactic center in the Brα line have been obtained this summer in order to search for variability, for instance from the unusual compact Brα sources discovered by the Infrared group (Forrest *et al.* 1987). Synoptic monitoring at 2.23 μm has continued. A possible signature of an accretion disk is variability.

4. Starburst Galactic Nuclei

The prototypical starburst galaxy, M82, has been imaged in the near infrared at a spatial scale of 0.38"/pixel at the IRTF. These new observations complement earlier high resolution observations (Pipher *et al.* 1988) obtained at Kitt Peak 4-m where it was found that the infrared compact sources may either represent an infrared supernova or a cluster of supergiant and giant stars, similar to the 'blue globulars' reported in other galaxies. If the latter explanation is correct, coincidences of infrared clusters with a radio SNR can thus be expected, since the most massive stars would have undergone the supernova stage. The first possibility, that a supernova has been observed in the infrared, can be tested. Thus new temporal observations at high spatial resolution on the IRTF were obtained to investigate this possibility. These data will be reduced in the near future. The extinction (discerned from the observed H-K colors as compared to the H-K color of most stars, 0.15 mag.) is quite patchy, but substantial. There is, from preliminary 'first look' data, some evidence that there is enhanced 3.28 μm emission associated with a region reasonably devoid of stars to the west of the nucleus of M82, in a position where an HI10α recombination line source, as well as other ionized gas sources, are centered (Seaquist, Bell and Bignell 1985). Images of NGC 253, another starburst galaxy similar to M82, have been obtained at both the IRTF and CFHT. Images at J, H and K will be used to examine the stellar population and extinction pattern. Clearly, observed emission in the 3.28 μm feature in the central regions locates strong UV sources, probably related to star formation. Analysis of these data will take place in the near future.

5. Gravitational Lens Galaxies

In collaboration with Nadeau and Yee of the University of Montreal, the putative gravitational lens galaxy 2237+03 was observed at 1.25, 1.65 and 2.23 μm with the Rochester array camera on the CFHT. By imaging in the infrared, the extinction in the foreground galaxy should be minimized. In addition to the four-lobed cloverleaf pattern seen by Yee in the optical, the best infrared images

contained a definite indication of a central object. This may be the compact nucleus of the lensing galaxy, a fifth gravitational image, or something entirely new. An optical image of a **different** gravitational lens galaxy H 1413+117 (*Sky and Telescope*, October 1988) has an almost identical appearance; thus this must be a more common morphology than previously thought.

C. Instrumentation

1. Infrared Array Detector Development

Forrest and Pipher are team members of the SIRTF Imaging Team (Fazio, SAO, principal investigator), and Forrest is a team member of the SIRTF Spectroscopy Team (Houck, Cornell, principal investigator). Instrument development is under study now and technological development areas are being identified.

Forrest and Pipher have acquired several 58 x 62 InSb arrays from SBRC (Santa Barbara Research Center) with direct, switched MOSFET readout; these include a 'standard' doped array, as well as specially low doped InSb arrays for evaluation for SIRTF experiments. As well, they have acquired a Si:In array mated to the same type of readout and expect to obtain several BIT (Blocked Impurity Transducer) arrays bonded to the same type multiplexer in the near future. Testing and optimization of these arrays, as well as evaluation of alternate technologies are well under way. The best of these arrays is currently being used for ground-based Astronomy. In addition to the goal of obtaining new astronomical data with the new arrays, the Infrared Group are also studying SIRTF related issues, namely flat fielding, reimaging optics, residual charge after exposure to a bright source, linearity etc.

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