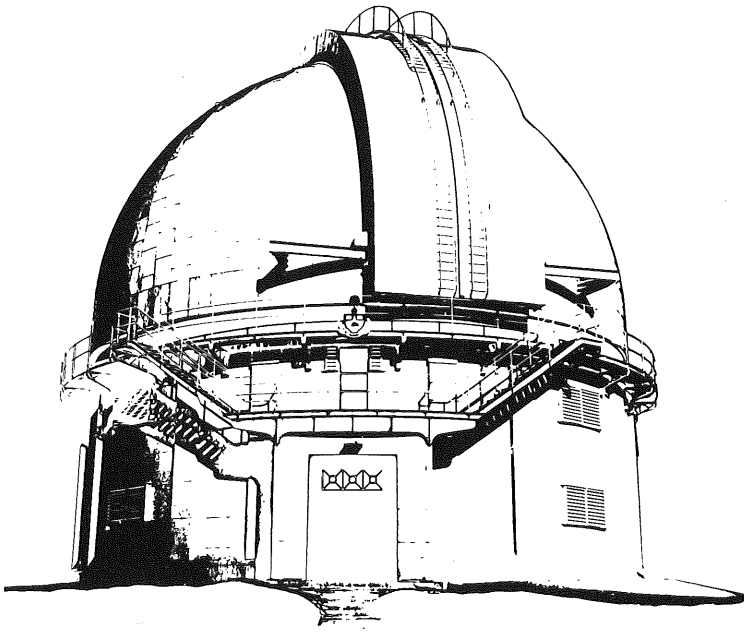
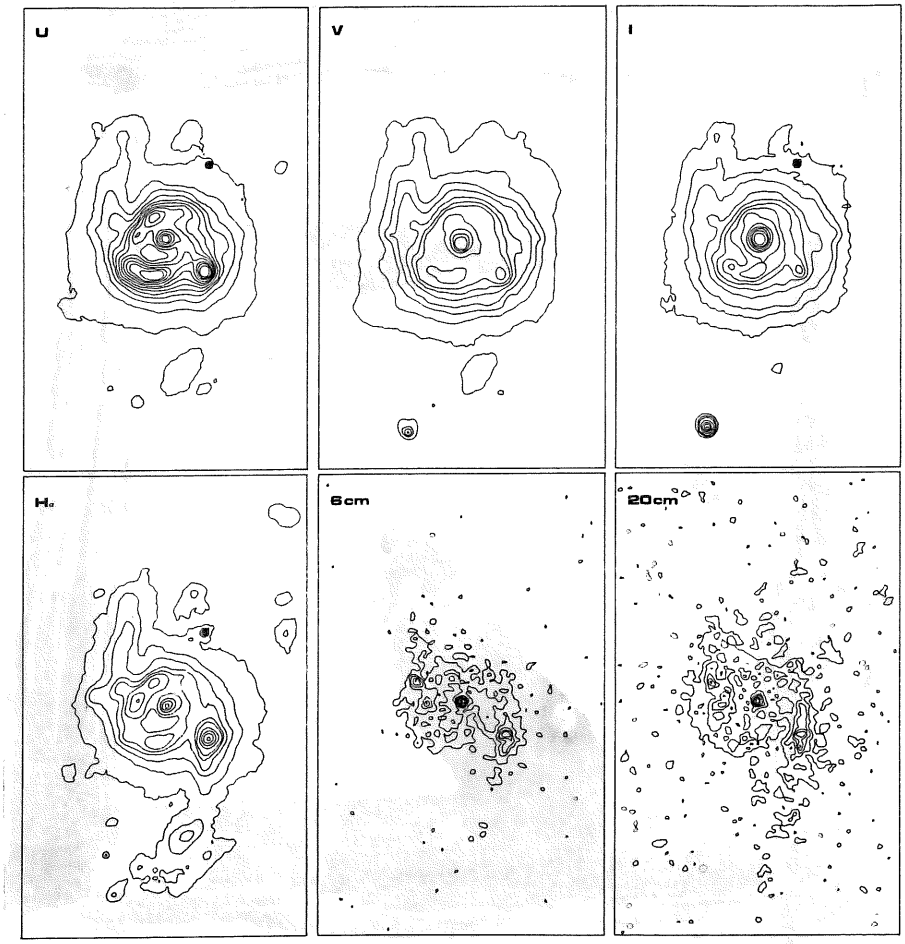


THE DAVID DUNLAP DOINGS

Vol. 16, No. 6 4 Nov. 1983

THE MANY FACES OF NGC 3310



Cover Story p.3

C O N G R A T U L A T I O N S

To Allan Busch, *who recently completed his voluminous master's thesis entitled "Companions to SO Galaxies - A Morphological Study". Allan was working with Barry Madore during the past two years; he has now moved downstairs a few floors to work with Lynn Trainor in biophysics. The abstract to Al's thesis is to be found at the end of this issue.*

To Edwin Zukowski *and* Petrusia Kowalsky *who successfully passed their oral general exams. Petrusia is working with John Lester and Edwin is continuing on with Phil Kronberg.*

To Kwang-Tae Kim *who (just before press time) also passed his general exam. Kwang-Tae is working with Phil Kronberg.*

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COVER STORY

On the Origin of Cosmic Rays in Spiral Galaxies

The origin of cosmic rays in the disks of spiral galaxies is a long-standing and fundamental problem in astrophysics. Previous attempts to address this problem were made by comparing distributions of synchrotron radio emission and optical radiation. These studies led to contradictory results which could probably be attributed to the limited resolution of radio telescopes and the inability of radio interferometers to map all scale lengths of emission. With the development of the VLA, the opportunity arose to study galaxies in the radio at a resolution comparable or even better than that in the optical.

With this in mind, Ernie Seaquist and I, along with Pat Crane, Carl Bignell (NRAO) and Lindsey Davis (KPNO) began a project to study a candidate galaxy at a resolution close to $\sim$1". The best, available galaxy, given the restrictions imposed by the VLA and CCD camera fields of view, was NGC 3310. The many faces of NGC 3310, shown on the title page, were used to study the relationship between the radio continuum emission and the optical radiation.

Inspection of the data revealed that the synchrotron radiation (and therefore cosmic ray electrons) correlated best with the Hα emission, both spatially and in intensity, leading to the conclusion that the CR electrons were associated mainly with the gaseous spiral arms of the galaxy and possibly with the extreme Pop I objects. Discrete sources of CRs such as supernova remnants and pulsars are unlikely to account for much of the observed synchrotron emission because (a) more than 10^5 of them are required and (b) they cannot account for the extended emission along the arms since the speeds at which cosmic rays can propagate in dense, star forming regions are limited to less than $\sim$10 pc/10^6 yrs.

In M51, enhanced emission along the arms is attributed to a compression of the ISM by the shock front associated with the density wave and is therefore a global phenomenon. In NGC 3310, the arm to disk enhancement of synchrotron radiation is $\gtrsim$100, much greater than what is observed in M51. We have tried to model this large enhancement with an M51 type compression using magnetohydrodynamic (MHD) shock calculations. It appears, from our results, that compression alone cannot account for all of the emission. In such a case, therefore, one must consider particle acceleration in the shock. This is nothing new theoretically and the idea has been applied to SNRs extensively. We have taken this idea and adapted it to the shock front associated with the density wave in NGC 3310. The actual acceleration mechanism is due to turbulent scattering of particles and predicts that the synchrotron emissivity is a power law function of the shock velocity which is also a function of galactocentric radius. The variation of synchrotron emissivity along the arms (as observed) is easily duplicated by the model. In addition, the lack of observable polarization in our data indicates that magnetic field lines may be tangled thus lending support to the turbulence picture.

In conclusion, we find that supernova related objects are not likely sources of most of the CR electrons produced and that the observed enhancement is probably associated with the global, density wave shock. The data seems to favour particle acceleration (along the shock) over compression although we are still working on modelling the latter. In any case, the possibility of density wave-induced CR production is, to us, exciting for it may help us make some headway in solving the fundamental but evasive problem of the origin of cosmic rays.

Neb Duric

COMINGS AND GOINGS

Nancy Evans, as of October 1, 1983 took up the position of Support Astronomer at the IUE in Greenbelt, Maryland. Nancy, who is originally from the United States, is returning after some fifteen years in Toronto. She obtained her M.Sc. and Ph.D. from U. of T., spending a year in England before completing her doctorate. Thereafter she held a research associateship, collaborating with John Percy while simultaneously bringing up a young family. Last year Nancy taught at Erindale College during John's sabbatical and most recently co-edited the DDD.

Ever active in cepheid research Nancy has initiated a number of collaborative projects with others at Toronto. This work and the up-coming IAU Cepheid Colloquium in Toronto in 1984 will bring here back often we trust.

Our best wishes to Nancy and may the IUE gyros last for many more years.

Bernard Bois currently in the Master's programme working with Stefan Mochnacki has planned to move to the Electrical Engineering Department for a second M.Sc. We wish Bernard well with his newly chosen career and his young family.

Gerry Grieve who completed his doctoral degree this summer with Barry Madore has accepted a position in Ottawa working with the Canadian Centre for Remote Sensing. He joins more than a decade's worth of U of T Astronomy graduates including Dave Goodenough, Phil Teillet and Bob Gauthier.

Pamela Sullivan, after six years as senior departmental secretary on the St. George Campus, left the Astronomy Department on Oct. 1. We shall all miss Pamela but wish her well in her new home in Australia.

NEW ARRIVALS

This year the Department of Astronomy welcomes new graduate students. Entering the Master's programme are

Dale Frail, from Acadia University will be working with Ernie Seaquist.

Brian Glendenning, from the Univ. of Prince Edward Island will be working with Phil Kronberg.

John Harper, from U of T is continuing his studies with Charles Dyer, and

Michel Bouchard, transferring up from Physics will be working with Peter Martin.

and beginning her doctoral degree is

Judith Irwin, who obtained her Master's degree from the Univ. of Victoria and most recently worked at the Edmonton Planetarium. Judith is working with Ernie Seaquist.

P O T P O U R R I

Stefan Mochnacki was a visitor at the Institute of Astronomy, Cambridge, in July and August. He gave an invited review at the NATO Advanced Study Institute on Interacting Binaries. In early September he attended the 8th Symposium on Photoelectronic Image Devices at Imperial College, London.

Barry Madore and Wendy Freedman were also in Cambridge for a good part of summer using the APM (see Wendy's report below) and competing for VAX time into the wee hours.

Earlier Barry Madore participated in the Aspen Astrophysics Summer Workshop in June and gave an invited seminar on extragalactic globular clusters.

After a brief September stop-over in Toronto Barry and Wendy flew to Tucson for an observing run at the Kitt Peak 4m. The project is a collaboration with Lindsey Davis (KPNO) and Chris McAlary (Steward Obs.) and is a long-term CCD investigation of the Cepheids in M33. The time at KPNO was enormously successful despite a very late departure of the monsoon. Sandwiched between the Kitt Peak observing were two ill-fated nights at the CFHT which were totally lost to equipment failure

At the end of September Barry then swung over to California to meet Doug Welch for a three night run on the Palomar 5m. This time the Pacific (?) storms got the best of them but the first night was photometric until low-level fog swallowed the mountain. The project was to finish up the infrared work on the M31 and M33 Cepheids which was to have been finished up last year but was closed out due to high winds. "Third time is a charm" so they say.

Ray Carlberg spent a good part of this summer in Victoria using their computer facilities, getting fresh ideas from their staff and seriously hurting his back mountain climbing.

John (Noah) Percy was at Kitt Peak observing (during) the maelstrom of 1983.

John Percy and Rick Crowe attended the Fall Meeting of the American Association of Variable Star Observers, held Oct. 20-23 at Nantucket to mark the 75th anniversary of the Maria Mitchell Observatory. John serves as a member of the Council of the AAVSO, and as editor of the AAVSO Photoelectric Newsletter. At the meeting, he reported on the progress of the AAVSO's new photoelectric photometry observing program [illegible] while Rick reported on and discussed his work on Mira variables.

Armando Arellano visited the Department from Mexico City. Armando is collaborating with Barry Madore and was reducing IUE spectra of intermediate supergiants in search of hot companions.

On 28th and 29th of June, Phil Kronberg attended the Herstmonceux Conference on Observational Cosmology at the Royal Greenwich Observatory, and gave a talk on the detection of magnetic fields in distant extragalactic objects. While in England, he also visited the Nuffield Radio Astronomy Laboratories at Jodrell Bank. During a brief period in May and later in early July he visited the Max-Planck-Institut fur Radioastronomie at Bonn, working on a paper with Garry Welter at the Astronomische Institute der Bonn, and with Judith Perry at the Max-Planck-Institut fur Radioastronomie, and also with R. Wielebinski, D. Graham, W. Sieber, and P. Biermann on various ongoing projects. Graduate student Edwin Zukowski joined him in mid-July and spent a further few weeks at the MPI both observing and reducing observations of linear polarization in radio galaxies and quasars.

Phil Kronberg has been appointed chairman of a newly instituted Steering Committee to advise the Herzberg Institute on the creation of a new millimeter wave telescope facility at ARO.

Dr. John Dreher of MIT spent most of the week of 5th to 9th September analyzing VLA data on the AIPS terminal with Phil Kronberg. The AIPS work station has also attracted other visitors to our department recently; namely Dr. David Routledge of University of Alberta and Dr. Serge Pineault of Universite Laval who were here together in August, and in September, Dr. V.A. Hughes from Queen's University.

The October Mini-Campaign on Be Stars
by Chris Stagg

Four members of the department took part in the recent mini-campaign on Be stars involving spectroscopic and photometric observers on three continents. The five bright northern Be stars with rapid variability (omicron And, KX And, KY And, LQ And, and EW Lac) were studied from stations at widely differing longitudes. This should mean fewer gaps in the data and a more accurate determination of the periods or timescales of variability. It is also hoped that simultaneous spectroscopic and photometric observations will provide valuable information on the pulsational behaviour of these stars.

John Percy's arrival in south-eastern Arizona coincided with the region being declared a disaster area because of heavy rains and floods. He nonetheless returned without webbed feet and with one and a half nights of photometric observations from his ten night run at Kitt Peak. Meanwhile, back at the DDO, Kodak delivered our spectroscopic plates at the twelfth hour, and I went on to get four and a half clear nights during my two week run on the 74". At the same time *Alex Fullerton* and *Fred Schmidt* obtained two good nights of observations on the twin photometer.

In the next few weeks the photometric data should start rolling in from the other stations: China, India, Russia, Yugoslavia, Czechoslovakia, and Texas. I shall be subjecting these observations to rigorous period analysis whilst PDS'ing my fifty or so plates to look for line profile and radial velocity variations. At least I won't have to worry about clouds!

Wendy Freedman Reports:

This summer has been an extremely busy and productive one, reducing data for my thesis. At the start of July, Barry Madore and I set off for Cambridge, England continuing to use the Automatic Plate Measuring (APM) machine that I began using last summer. This fast laser-scanning machine is fully automated and can scan an entire 10" x 10" CFHT plate in about 8 hours. The machine has special purpose hardware which allows much on-line reduction such as computation of and subtraction of background and calculation of image parameters to be done as the machine is scanning. It is therefore enormously faster than conventional PDS scanners, both in actual scan time and in the later reduction stages, since the user may specify a threshold limit of detection for the machine. Thus if one is interested in the stars or galaxies on a plate then one may reduce (by at least an order of magnitude) the amount of material to be stored on tape, by eliminating blank areas of the plate.

Over the course of two summers, 35 CFHT plates of the galaxies M33, NGC 2403, M81, M101 and several 4m Tololo plates of NGC 300 have been scanned and are now reduced.

The motivation for the project was to investigate the high mass end of the luminosity function in near-by resolved spiral galaxies, the aim being to determine rates of star formation, determine difference if any, in the high mass end of the luminosity function between galaxies, or within galaxies (e.g. arm/interarm, radial gradients, etc.). The aim was also to acquire stellar data at the same high resolution as the HI maps available for these galaxies and to map out the distribution of O and B supergiants to see where the high-mass star formation is occurring.

The summer in Cambridge was enormously productive; the APM was working extremely well and in between scans I began writing some software to analyze the data. Preliminary results indicate that the high-mass end of the luminosity function in M33 is similar to the Miller and Scalo luminosity function for the galaxy as well as to that of the LMC, determined by Linda Stryker.

The distribution of O and B supergiants is well correlated with the distribution of HII regions in M33, particularly with the distribution of the fainter HII regions. The young blue stars are also not confined solely to spiral arm regions, but are formed in the interarm regions as well, which implies that stars also form outside of spiral arms since these stars are too blue and too young to have migrated out of the arms.

Just as the results were beginning to get intriguing, it was time to leave Cambridge. Back in Toronto for two days (!) before heading out to Tucson for a Kitt Peak 4m prime focus CCD run with Lindsey Davis, Chris McAlary, Barry Madore and myself to study the Cepheids in M33. We had three excellent nights, spared three days apart. In between, Barry and I whisked off for a 2-night CCD run at the CFHT. Unfortunately we had technical problems that run.

Back in Tucson, the last three weeks were spent reducing the data from the 4m run using the Kitt Peak RICHFLD Photometry Software for crowded fields. In addition to measuring all the Cepheids in the fields, I measured three thousand stars in BVRI for additional data on the lumiosity function. While the APM is fast and accurate in uncrowded fields, it does not yet have the software to deconvolve very crowded images. This is in fact what RICHFLD was designed to do. [I might mention however that RICHFLD takes ∿1 CPU minute per star! For comparison the APM can scan ∿40,000 images in 7 hours.]

The photometry from RICHFLD will provide a more accurate luminosity function for the crowded regions and should allow a quantitative estimate of the numbers of stars missed by the APM.

All in all, it's been an extremely profitable summer. Now with all this data in hand, it's time to get down and do the real work for this thesis.

DIAL "M" FOR MMT

by Doug Welch

I recently journeyed down to Tucson for two observing runs: one on the 61-inch at Mt. Lemmon and one on the 4.5m at Mt. Hopkins. As the first was rained out I shall restrict my discussion to the MMT. Chris McAlary and I were the investigators on both runs.

It was an unconventional trip to an unconventional telescope. The journey began innocently enough -- an hour's drive from Tucson to Amado where the headquarters for the MMT is located. Normally one would cross the river a few hundred meters down the road. The "Flood of '83" had changed all that. The bridge across the river had been ripped to pieces by raging torrents earlier in October. Fortunately, a 5-hour detour was no longer necessary. Instead, we were handed a map showing the most recent route to Mt. Hopkins. Where our path was to cross the river lay the cryptic warning "Drive slowly -- don't flood the engine". Sure enough, our four-wheel drive vehicle crossed the 2-foot deep Santa Cruz river without the benefit of a bridge.

The hour-long drive from the river to the mountain was no less interesting. The road to the summit was very poor. By comparison, the summit road on Mauna Kea looks like a four-lane highway. The last kilometer of the access road is paved. This is fortunate, as the section leading to the telescope has a 25% grade!

The summit on Mt. Hopkins is quite picturesque and has a view unrivaled by any observatory I have visited. The lodge and common building are both new and very comfortable, but the observatory itself is most interesting. The "dome" in this case IS the building. The first thing one notices upon arriving at the summit is a sign stating "Warning - Building Rotates". Indeed, inside the observing room one often has the impression that one is at sea, as the building tries to keep pace with the telescope. The scope itself is comprised of six 72-inch systems. The structure holding these together resembles an enormous "jungle gym". Indeed, the observer must climb around INSIDE to fill the dewar with nitrogen or to raise and lower equipment. The mounting is alt-azimuth and as the building rotates with the scope, the telescope chamber is very compact.

Our first night on the mountain was scheduled for engineering. This was necessary because the infrared dewar had recently been drop-kicked and alignment problems were possible. As it turned out, the dewar was fine and after 3 hours of checking things out and aligning the telescopes, the MMT was turned over to us. Chris was scheduled for one night observing Seyferts prior to our 3 nights for M33 Cepheids. However, we observed Cepheids on both nights prior to the Official run in return for a few hours on Seyferts when M33 was too low. As a result of this arrangement, we observed Cepheids on 4 nights out of 5 -- the last being cloudy.

The observations were of very high quality and a good S/N was obtained very quickly. As it turns out, M33 passes within 1 degree of the zenith at Mt. Hopkins. Anyone familiar with alt-azimuth mounts knows that tracking near the zenith is very difficult as the scope must swing through a large azimuth angle very quickly to follow the object. Nevertheless, the MMT performed beautifully.

Background contamination is a bit of a problem in M33. Normally the solution is to rotate the chopping angle to obtain empty comparison beams. This is no trivial undertaking with the MMT and generally the telescope is left chopping in elevation. On most objects then, the MMT solution is to wait until the position angle of the chop on the sky has changed due to diurnal motion. Could this be done with the M33? Of course not! It turns out that the position angle of the chop is ±80 ±2 degrees for the entire time M33 is observable except for 10 minutes either side of transit.

Our measurements showed that one particularly bright Cepheid had contamination in its reference beam both before and after transit. We decided to follow it through transit and were delighted as the normally negative readings became strongly positive for 5 minutes during transit and then returned to their previous state thereafter!

The run was a tremendous success and we observed 17 Cepheids in M33, 4 in NGC 6822, and 2 in NGC 2403. The local distance scale is no doubt more secure after this run!

The Ups and Downs of Periodograms and Statistics

Over the summer, both Fullerton (Fln) and Gies (Gis) encountered serious problems interpreting 'power spectra' obtained with the well known Deeming routine. Fln seemed to be finding many significant periodicities in short strings of radial velocity data, while Gis was having difficulty setting an upper limit on the amplitude in his null detection of a radial velocity variation associated with the 294 day periodicity of Cyg X-1. The outcome of these difficulties was the creation of a new periodogram routine based on the statistically 'clean' formulation of Scargle (1982) Ap.J., 263, 835.

Until recently, we used the Deeming power spectrum to obtain periods from a data string, but estimated amplitudes from a least squares fit of sinusoids to the data. An F test was used to assess the statistical significance of the fit. In contrast, Scargle's approach is to estimate all three quantities directly from the periodogram. Our troubles intensified when we applied Scargle's precepts to the Deeming power spectrum. There was some justification for assuming that all results would carry over, but (of course!), upon comparison with our other numbers, we found considerable disagreement. This was particularly disturbing since Scargle demonstrated that his periodogram approach is exactly equivalent to a least squares fitting approach.

As a remedy, we hurriedly coded Scargle's periodogram and ran a series of tests with it. We think we now understand the origins of our difficulties: while the least squares approach and the Scargle approach reduce to each other, mixing them up part way through (as we were doing!) complicates the interpretation enormously. In particular, mixing the methods does not take account of the 'statistical penalty' for searching many frequencies. This was probably the origin of the exaggerated significances Fln was finding.

But why are we bothering to broadcast our research headaches? (Surely a dangerous precedent for these pages!) Our purpose in writing this article was partly to inform other users of the Deeming routine of our problems, and partly to advertise the availability of the Scargle periodogram routine. We strongly advocate the use of the Scargle formulation because the statistical analysis is possible, and indeed, straightforward. Extensive documentation, including a discussion of the statistical interpretation of the results (detection thresholds, error bars, and upper limits) has been prepared and is available from Fln. See either Fln or Gis for a demonstration; a VT100 terminal with graphics is required. We're interested in hearing about any bugs in the program or flaws in the documentation, and to receive any general comments.

LIBRARY NEWS

Library Move

All went well with the library move in August. The movers packed up the library on Wednesday the 10th, moved everything down to the Department on the 11th, and unpacked on the 12th. During the weekend, Bill Weller and Rick Crowe helped me move the Reference Room from DA to DDO. Special thanks goes to both of them for donating their personal time and brawn. It was appreciated! The new library was open for business at 9 a.m. on Monday the 15th.

We are pleased to report that the library's use within the department has increased as predicted. To date, the dreaded undergraduate problem has not developed into one. The undergrads that do use the facilities are generally from 3rd and 4th year astronomy courses.

DDO Library has suffered somewhat in the move. Materials have been reclassed from the old DA system to the Library of Congress classification scheme. A card catalogue should be completed within the month. The library does have a new look. A couch and a rug have been added which we hope will prove to be more comfortable for everyone.

Physics Library & Astronomy Library Cooperation

Now that we are in the same building, cooperation between the Physics Library and Astronomy Library has increased. Physics Library has agreed to donate their astronomy monograph collection to the department. This will solve Physics Library's selving problems and help build the DDO Library collection.

Physics Library has a new circulation policy concerning journals. Journals do not circulate. We do hope to arrange a mutual photocopying agreement so that staff and students may photocopy materials in either library using the auditron rather than the coin-operated facility.

Book Sale

On Wednesday October 18, we held a book sale in the new library. Items for sale included old textbooks, duplicate (or triplicate) monographs and dated physics texts.

At 50¢ an item, we sold 75 books in a matter of a few hours. All the proceeds will go toward the purchase of a book truck for the library.

Address and Telephone Number

The new address and telephone number for the new library are:

Astronomy Library
University of Toronto
Room 1306
60 St. George Street
Toronto, Ontario
M5S 1A7 (416) 978-4268

Library hours: Monday to Friday 9 to 5.

LaC & RD

COLLOQUIA AND G2000 SEMINARS

This year John Lester, our new graduate secretary, has plunged G2000 into yet another format. Every five years or so, either the staff or students or both find that the student seminars are not serving the best interests of those who participate. The new format, of directed, lunch-time discussions of current research, is to be provisionally divided into stellar and extragalactic interests. Meeting every Wednesday over lunch, both staff and students are expected to participate more actively, discussing their current endeavours and interests in a more relaxed atmosphere. Tom Bolton and John Percy are co-ordinating the stellar sessions, Ray Carlberg and Barry Madore are responsible for the extragalactic topics.

This change of venue has opened up all of the regular G2000 slots on alternate Wednesday afternoons for more formal colloquia. The budget for such purposes has not doubled so it is hoped that the spots will be filled by staff talks and by our graduating doctoral students. The Colloquium Chairman is still trying to find John Lester.

The slate of talks this fall, past and planned is given below.

October 5	*Doug Welch and Alex Fullerton, U. of Toronto, G2000 Current Literature Seminar*
October 12	*Dr. Hugh Harris, McMaster University, "Abundance Gradients in the Galaxy"*
October 19	*Drs. S. Mochnacki and C.T. Bolton, U. of Toronto, "The Status of the STARLAB Project"*
October 26	*Dr. Russ Taylor, U. of Toronto, "6-cm Patrol of the Northern Milky Way"*
November 2	*Stellar and Galactic Discussion Group Meeting, "The Most Luminous Stars: Nature, Evolution and Stability"*

November 2	*Dr. J.S. Mathis, University of Wisconsin, "What We Learn from Models of HII Regions"*
November 23	*Dr. Jerry Sellwood, Cambridge University, "Grand-Design Spirals: Transient or Mode?"*

AAS Announces 1983 Winners of the Henri Chretien Award

Barry Madore has been selected by the American Astronomical Society as one of this year's recipients of the recently established Henri Chretien Award. Set up in 1982 to honour the name of the French Professor of Optics and originator of the Ritchey-Chretien telescope design, the award is given annually to individuals and groups so as to further observational astronomy on an international basis.

PAPERS SUBMITTED

P.P. Kronberg	Faraday Rotation and Magnetic Fields in QSO Absorption Line Clouds
J.D. Fernie	Relationships Between Johnson and Kron-Cousins VRI Photometric Systems
D.A. Fraquelli	The RS CVn Phenomena I: Hα Emission in HR 1099
R.F. Garrison R.E. Schild W.A. Hiltner W. Krzeminski	CPD -48°1577: The Brightest Known Catacylsmic Variable
D.R. Gies C.T. Bolton	The Optical Spectrum of HDE 226868=Cygnus X-1. II. The Search for Periods Longer than 5.6 Days
N.R. Evans	X Cygni: Duplicity Period Stability and Atmospheric Velocity Structure
K.W. Kamper S. van den Bergh	Recent Observations of Cassiopeia A
G.L. Welter J.J. Perry P.P. Kronberg	The Rotation Measure Distribution of QSO's and of Intervening Clouds: Magnetic Fields and N_e
M.C. Lane J.B. Lester	Effective Temperatures and Surface Gravities of Metallic-Line A Stars
C.W. McAlary B.F. Madore L.E. Davis	The Distance to IC 1613 From Infrared Photometry of Cepheids
J.D. Fernie	Cepheid Period Changes and Stellar Evolution
E.R. Seaquist A.R. Taylor S. Button	A Radio Survey of Symbiotic Stars
J.D. Fernie	A Survey of Cepheid Sizes
S.W. Mochnacki	Accurate Integrations of the Roche Model

F. Bertola
C. Casini
D. Beltari
G. Galletta
L. Noreau
P.P. Kronberg

NGC 3448 Revisited : A Combined Optical, Radio and UV Investigation

D.L. Welch
F. Wieland
C.W. McAlary
R. McGonegal
B.F. Madore
R.A. McLaren
G. Neugebauer

JHK Observations of Classical Cepheids

THESIS ABSTRACT

Companions to SO Galaxies
by Allan E. Busch

Fields of 141 kpc radius centered on SO and SBO galaxies were examined for physical companions. SO/SBO galaxies were chosen for this preliminary study as they were not entirely included in previous studies (Holmberg, 1969; Bothun and Sullivan, 1977). A total of 127 SO and SBO galaxies with radial velocities 500 km/s<V_r<3000 km/s were taken from A Revised Shapley-Ames Catalog of Bright Galaxies. The positions, morphology, and relative surface brightnesses of all non-stellar objects with sizes greater than 1 kpc (H_o=100 km/s/Mpc) projected to the distance of the parent SO/SBO, were recorded.

A Physical Companion (PC) coding system based on morphological classification and relative surface brightness values, was created to reflect the probable association of the objects to the parents.

There are several advantages to this approach over straight galaxy counts. Firstly, it has allowed us to qualify the types of galaxies most likely to be found as physical companions to SO/SBOs. From our Local Group and other near-by systems, our expectations were that the most likely candidates for physical companions would be dwarfs. Thus we designed the coding system to differentiate the dwarf irregulars and dwarf spheroidals by placing them alone in one category. A second advantage is the preservation of the positional information on each companion. This is allowed for the determination of the projected distribution of the physical companions, and hence a comparison to the covariance function.

Using radial fall-off plots, we calculated upper and lower limits of 1.56 and 0.42 dwarf companions per parent. The form of the radial fall-of of the physical companions yields a γ for the covariance function of 1.60±0.10. This agrees with the value of 1.52±0.19 calculated by Lake and Tremaine (1980). From the plots, we also find differences in the number of physical companions of SBOs versus SOs. This may be due to either blocking of background galaxies by large opaque halos, or a biasing in the PC code assignment.

In constrast to the result of Holmberg (1969) for spiral galaxies, we find no significant preferential alignment of physical companions around nearly edge-on parents.

This preliminary study lays down the groundwork for further analysis concerning the importance of companions in the formation and evolution of SO and SBO galaxies.