

**Rothney Astrophysical Observatory**  
**University of Calgary**  
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[S0002-7537(99)06401-X]

The following is an RAO Report (the 6th), covering the interval 1990-1998.

## 1. FOREWORD

The Rothney Astrophysical Observatory is the principal astrophysical teaching and research facility of the Department of Physics and Astronomy of the University of Calgary. This report briefly summarizes activities since 1990, the date of our last BAAS report.

## 2. PERSONNEL

The RAO continued to be directed by T.A. Clark (Prof. Emeritus since Jan., 1995) and E. F. Milone (Prof.) of the Department of Physics & Astronomy of the University of Calgary, who are answerable to the Head of that department, currently Prof. J. S. Murphree.

The RAO has one full-time technician, F.M. Babott, supported by the department, and one part-time Resident Astronomer, P. Langill, supported partially by the department and partially by astronomy or astrophysics NSERC grant holders with the department. Management of the Astronomy Data Reduction Laboratory has been undertaken successively by Ken Lai, Glen Young, and (currently) Maurice Shevalier.

The astronomy-astrophysics professorial staff (and their areas of expertise) include: T.A. Clark (Prof. emeritus, solar physics, IR astronomy); D.J.I. Fry (Assoc. Prof.; optics, IR astronomy); D. Hobill (Assoc. Prof., black hole physics, general relativity); S. Kwok (Prof., planetary nebulae, space astronomy); P. Langill (Sessional Instructor, planetary nebulae; optical astronomy); D.A. Leahy (Prof., x-ray astronomy, space astronomy); E.F. Milone (Prof., variable stars, optical & IR astronomy); S.R. Sreenivasan (Prof., stellar evolution, theoretical astrophysics); A.R. Taylor (Prof., radio astronomy); D. Venkatesan (Prof., x-ray astronomy, space science; deceased 1996); W.J.F. Wilson (Senior Instructor, pulsating stars, theoretical astrophysics). Adjunct members of the department with an interest in astrophysics have included: A. Yau (Assoc. Prof., space science); P. Dewdney (Asst. Prof., radio astronomy), G. Garbe (Asst. Prof., space science), J. E. Penfold (Mt. Royal Coll., Calgary; extragalactic astronomy), & K. Volk (Asst. Prof., astrophysics). The department has a strong Space Sciences group which interacts with individuals in the astrophysics group.

Leahy held a Reinhardt fellowship at CITA, Toronto, Sept.-Dec. 1994, and spent his Jan-Jun 1995 sabbatical visiting for approximately 1 month periods: Max-Planck Institut für Extraterrestrische Physik in Garching, Germany; Dominion Radio Astrophysical Observatory, Penticton; Dominion Astrophysical Observatory, Victoria; and Naval Research Laboratory, Washington, D.C.

Milone spent his 1992-93 sabbatical year visiting for 2-3 month intervals: San Diego State University & UCSD; Canada-France-Hawaii Telescope headquarters, Waimea, HI;

Dominion Astrophysical Observatory, Victoria; and Ruhr Universität Bochum, Germany, where he held a DAAD fellowship.

## 2.1 Research Associates

Research fellows over this interval have included: A. G. Ananth, D. Gabuzda, S. Gibson, Dirk Terrell, K. Volk, C.-Y. Zhang. Ms. Gabuzda has accepted a position at the Sternberg Institute in Moscow. Dr. Terrell returned to Gainesville in late 1995.

## 2.2 Graduate Students

Graduate students who made use of the RAO facilities over this interval include: Mircea Athanasiu, Josephine Chan, Sean Dougherty, Kerry Kijewski, Li Lan, P.S. Li, Brenda Matthews, Michael J. Mazur (Geology), Jason R. McVean, Magdalen Normandeau, Jing Ouyang, Lisa Shadbolt, Kate Su, James van Leeuwen, Virginia (Fabro) Volk, Bradley Wallace, Stephanie Wilder, & Guojin Zhang.

## 2.3 Undergraduates

Undergraduates who have made formal use of the RAO facilities over this interval include: David Alton, Livia Bade, Jennifer Brand, Flora Chan, Jennifer Cunningham, James Day, Tyrone Deane, Kyle Degenhardt, Byron Desnoyers-Winmill, Kerri Dubray, Ingrid Eichelbaum, Danielle Fraser, Graeme Fricke, Luigi Gallo, Steven Griffiths, Leah Hannis, Clinton Harwood, Bruce Holman, Justin Jayne, Barry Johnson, Kenneth King, Andrew Kirsch, Hans Kneppers, Jean Lagace, Alice Liesman-Thaon, Nerissa Link, Thomas MacFarlane, Michael Mazur, Megan McClure, Peter Medhurst, David Paul, Lynn Raafaub, Perry Radau, David Ross, Eric Scott, Wendy Segelken, Jeremy Shaw, Warren Shaw, Kelvin Soice, Liam Stitt, Benjamin Sugars, Lance Titchkosky, Brenda Toblan, Marcelle Tremblay, David Trofimenkoff (SFU), Nicole Trenholm, Michal Urednicek, Natalie Veldhoen, Simon Warrington, Travis Whyte, Steven Weimer, Stephanie Wilder, Michael Williams, & Helge Ziegler.

## 3. VISITORS

Visitors to the department have included: J. Anosova (St. Petersburg, 1995); D. Bradstreet (St. David's College, PA, 1991); B. Hrivnak (Valparaiso U, IN, yearly); J. Kallrath (Bonn & BASF, yearly); M. Mateo (U Michigan, 1995); R.H. Nelson (New Caledonia College, BC, yearly); S.J. Schiller (South Dakota SU, 1997, 1998); A.T. Young (San Diego SU, 1991, 1995, 1998).

## 4. FACILITIES

The RAO is located in the foothills of the Canadian Rockies on a quarter section of land donated by A. R. Cross of Calgary. The plant consists of three buildings: a classroom, a

dome with attached control and chart room for the 41-cm telescope, and a large building with 13-m dome housing the 1.8-m telescope, control and chart rooms, workshop, a conference room, bedrooms, archiving room, 2-story payload workshop area, a large storage bay, and a Baker-Nunn Camera mounted in a small dome at the west end of the structure. The archiving room currently houses a seismic detector for the Geology & Geophysics Department.

The RAO's 1.8-m Angel honeycomb mirror was returned to the RAO in 1993 following its successful polishing by Norman Cole of Tucson, and its use at the Apache Point Observatory under a contract arrangement between the University of Calgary and the Astrophysics Research Consortium. Following the successful installation of a support mechanism for the 1.8-m mirror, the final phase of the 1.8-m telescope project was completed under T.A. Clark, Project Manager, in January 1996.

The RAO's instrumentation consists of the Rapid Alternate Detection System – a gated pulse-counting photoelectric chopping system, which has permitted photometry in what would be traditionally non-photometric conditions, an Astro-Computer Control CCD camera with a Kodak chip, and a Photometrics CCD camera with a Site 1024<sup>2</sup> chip, infrared detectors mounted in Infrared Labs dewars, a classification spectrograph designed by Harvey Richardson. An infrared camera with a 256<sup>2</sup> InSb detector array and an infrared spectrograph are under construction. Further details are provided at the RAO's website: <http://www.acs.ucalgary.ca/~milone/rao.html>

Access to the facility is determined by a Telescope Allocation Committee, meeting six times a year. Application forms are available through the website.

## 5. RAO SUPPORT GROUP

The RAOSG is an outgrowth of the RAO Users' Group which formally met twice a year. The RAOSG began to meet monthly in Fall, 1995. In 1997, it was recognized as an official group within the University of Calgary, and received a Group Grant in 1997-98 to promote the RAO, to support the Open House program, and to fund the 25th anniversary celebration and this report.

Reports on the status of the RAO by the co-directors, the technician, and the RA provide details about the facility to the user and wider communities at each of the meetings, and the meetings provide feedback to the co-directors.

The RAO sponsors an active Volunteer Observers program. Active amateur astronomers and interested undergraduates receive training on the instruments and in turn provide several nights of observing support for the active research programs at the RAO. In 1998, the V.P. (Research) and Faculty of Science Dean provided travel funding for the volunteers. In addition to the graduate students and undergraduates listed above, volunteers also include alumnae/alumni and active amateurs. Faithful non-university observers in recent years include Gary Billings, Tom Cameron, Jean Lagace, and Zach Linkewich.

The Open House program receives the active support of the undergraduate astrophysics majors, the Physics & Astronomy Students Association, the Dept. of Physics & As-

tronomy, and the amateur community. Speakers at the Open House events have included T.A. Clark, Alan Dyer (Calgary Science Centre), D.J.I. Fry, Grant Gussie, Phillip Langill, Sidney Lee (RASC), Alfredo Louro, Ian Lovett, E.F. Milone, A.R. Taylor, & Kevin Volk.

The Planetarium Liaison Committee works with personnel at the Calgary Science Centre to produce demonstrations for the University of Calgary's astronomy and astrophysics courses. Meetings are held three or four times of year.

## 6. CONFERENCES HELD AT THE UNIVERSITY OF CALGARY

- “*Astronomical Infrared Spectroscopy*”, June 16-19, 1992, organizer, S. Kwok.

- “*The Origins, Evolution, and Destinies of Binary Stars in Clusters*”, June 19-23, 1995, organizer, E.F. Milone.

- “*Black Holes*” June 5-7, 1997, organizer, D. Hobill.

- “*The 25th Anniversary Celebration of the Rothney Astrophysical Observatory*”, June 7, 1997, organizers, T.A. Clark & E.F. Milone. The keynote speech was given by E. M. Burbidge, 25 years and 5 months after she formally opened the RAO in 1972. For details, see: <http://www.acs.ucalgary.ca/~milone/RAO25/index.html>

- “*Science with the Square Kilometre Array*”, July 19-22, 1998, organizer, A.R. Taylor.

In addition, Milone organized a 2-session meeting on “New Generation Modeling Developments and Results for Binary Stars” at the 190th meeting of the AAS in Winston-Salem, NC, on June 10, 1997. For details, see: <http://www.acs.ucalgary.ca/~milone/AAS97/index.html>

## 7. SCIENTIFIC ACCOMPLISHMENTS

The work at the RAO is principally in support of the astrophysics teaching program of the University of Calgary, but also allows research by staff members and others through a formal application procedure. Mainly, the RAO is used for photometry of variable stars.

In Fall, 1998, the 0.41-m telescope was dedicated to asteroid projects, under the direction of M J. Mazur of the Geology & Geophysics Dept. and carried out by volunteers and by students in the Solar System Physics class. The work in this area aimed at measuring positions, improving ephemerides, and in obtaining light curves when feasible.

Much of the astrophysical work in the department also involves outside observatories and agencies.

### 7.1 Binary Stars

Milone and colleagues continued to work on improved light curve modeling programs and models. The projects carried out in this interval include:

#### a) Eclipsing Binaries in Open Clusters

- The H235 system in NGC 752 is likely to have been gradually hardened through a long series of weak encounters despite the relatively sparse nature of this intermediate-age cluster; therefore it is likely that collisions play a role in hastening the merger process in many, especially richer clusters (*cf.* Milone, *et al.*, 1995);

- NGC 6791, which is among the oldest and yet richest open clusters of the galaxy (Friel, *Annual Rev. A&A*, 33,

381, 1991), has been targeted since 1993. Our multi-passband photometry of this cluster is important for modeling the radiative properties of the eclipsing binary components; the images have been processed by summer assistants and the data are being reduced by Ms. L. Shadbolt for her MSc thesis;

- On SS Lac in NGC 7209, Milone, S. J. Schiller, & U. Munari (Asiago) have completed an extensive analysis of this dynamically interacting, former eclipsing system and determined its 'eclipse season': 1885-1937, during which the inclination varied between  $82^\circ$  and  $90^\circ$ .

#### b) Eclipsing Binaries in Globular Clusters

- BVRI images of the variables in NGC 5466 (from telescopes at DAO, Mt. Wilson, & Mt. Laguna), many of which are blue stragglers, have been reduced to improve the quality of the modeling of these systems. Kallrath, Milone, & Stagg (1992), analyzed light curves of the three eclipsing binaries obtained by Mateo *et al.*, AJ, 100, 469, 1900) and found that the components of all systems appear to be themselves blue stragglers;

- The eclipsing binaries in M71 were treated by J. McVean in his MSc thesis, and included solar and non-solar composition models; we extended the work to get optimum mass ratios (McVean, *et al.*, 1997) for each system. The system M71-V4 has been observed spectroscopically by Mateo & Yan and Milone is now analyzing the combined photometric & RV data, the first such analysis of a system near the main sequence turn-off of a globular cluster.

#### c) Field Binaries

- TY Boo was the first eclipsing binary treated with WD83K83 to have spot parameters determined on the basis of synthetic light curve trials, along with all other light curve modeled parameters (Milone, *et al.*, 1990);

- AI Phe continues to be analysed whenever light curve code and modeling improvements are made. Stagg & Milone (1993), and Milone, Stagg, & Kurucz (1992) are examples of the continuing advances made in understanding this best determined of all evolved systems;

- V728 Her, an overcontact system with little evidence of instability, contrary to expectations for a system with the very large compact parameter (0.71) found for this convective atmosphere case, the best determined solution (Nelson, *et al.*, 1995).

### 7.2 Field and Cluster Pulsating Variables

The study of regular pulsating variables has always been valuable in determining distances to clusters in which they are found. Milone, Wilson, Fry, and collaborators have applied a modified Baade-Wesselink technique to UBVRJHK and radial velocity data of dwarf cepheids or delta Scuti stars in order to obtain improved radii, or radii with more precisely determined uncertainties. The program has been extended to cepheids. The systems we have been studying include:

- EH Lib, DY Her, and DY Peg, resulting in minimum radii of  $2.62 \pm 0.19R_\odot$  for EH Lib,  $2.77 \pm 0.20R_\odot$  for DY Her, and  $2.09 \pm 0.25R_\odot$  for DY Peg (an SX Phe star). This series of papers has been dedicated to Harlan J. Smith, who first identified "dwarf cepheids" as a distinct class;

- V369 Sct, which has been observed and is being analysed by Mrs. Virginia Volk for her MSc thesis;

- SU Cas, one of the shortest period classical cepheids, and thus important for the PLRs. We find it likely to be pulsating in the overtone mode, with a mean radius of  $31.9 \pm 2.5R_\odot$ . The derived distance ( $445 \pm 35$  pcs) agrees with that from Hipparcos. We are dedicating this paper to A.J. Wesselink.

### 7.3 Infrared Photometry

In 1993, Sean Dougherty completed a PhD thesis under Taylor's direction on infrared variability of Be stars, using data from the RAO.

Milone initiated, organized, and chaired a joint meeting of IAU Commissions 25 and 9 in Baltimore in 1988 on the causes of limited infrared precision (Milone 1989). The 1988 meeting provided a consensus that the major cause of the 3% limitation in standardization precision was the strong mismatch between the atmospheric windows and existing passbands, which were not optimized to avoid water vapour absorption and which produces non-linear extinction (the Forbes effect). This led to the creation of an IAU Working Group. to redesign the passbands to be less dependent on atmospheric absorption. Young, Milone & Stagg (1994) summarizes the need, method, underlying theory, and solution. The final designs minimize the Forbes effect, have excellent transformation properties, which should be maintained from one fabrication run to another. Custom Scientific (Tucson) produced the iz, ij, ih, ik, il, and il' filters and are willing to make the rest. In the interval 1995-8, Young and Milone upgraded the study with a better telluric atmosphere model (MODTRAN 3.7) and have investigated the emission in the thermal passbands ( $\geq K$ ). They are currently preparing a paper on the improved S/N expected from these filters, and on the expected extinction curves for all the filters. Observational trials will be completed once our IR array, now under construction, is available at the RAO.

### 7.4 Light Curve Analysis Code Improvements

Milone has collaborated with J. Kallrath (Bonn & BASF), Dirk Terrell (U.Fla.), and Andrew T. Young (San Diego SU) to improve further the Wilson-Devinney synthetic light curve code that is intrinsically suited to modeling the radiative properties of stars, (Milone 1993; 1997). A further upgrade to our WD code, *WD93K93D* [which uses R.E. Wilson's 1993 upgraded program features, namely non-linear limb-darkening and better reflection treatment, and Kurucz 1993 atmospheres grids (*cf.* Kurucz in Milone 1993, pp. 93-101)], additionally now outputs 3-D plot data (residuals vs. phase vs. WL), giving the spectrum of the residuals, and thus revealing the nature of any light curve perturbations.

In July, 1995 a workshop was held at the University of Calgary which resulted in still further improvements, including:

- Kurucz' atmospheres fluxes in the atmospheres subroutine (Stagg & Milone 1993);

- a new convergence engine using damped least squares (Kallrath, *et al.*, 1998);

- a packaged front-end providing a choice of light curve modeling code; and

- automatic iteration, with a parameter constraints file to preclude exploration of non-physical regions of parameter space.

WD95 is the most powerful light curve analysis tool we have developed thus far; a WD98 version, making use of 1998 improvements by Wilson to his basic program, is currently undergoing testing.

### 7.5 Radio Astronomy

Taylor heads the Galactic Plane Survey being carried out at the Dominion Radio Astrophysical Observatory in Penticton, B.C.

### 7.6 Space Astronomy

Kwok continued his involvement with the Odin Mission.

Leahy's involvement in space satellite missions consisted of: a) Preparations for scheduling of observations of x-ray sources with the X-ray timing experiment USA on the AR-GOS satellite; b) Science planning for the ultraviolet telescope on the Russian Spektrum-X-Gamma satellite; and c) Performing a concept study for a Canadian x-ray astronomy satellite, using silicon strip detectors and coded mask.

### 7.7 X-Ray Astronomy

Leahy carried out studies of supernova remnants using X-ray imaging data and spectral data of the hot shocked gas and using radio observations of synchrotron radiation. Such studies are important to obtain information on the physics of the explosions, shock acceleration of relativistic particles, and the effects on the interstellar medium. Current projects in this area include:

- Analysis of ROSAT x-ray observations of the Cygnus Loop supernova remnant;

- DRAO 408 and 1420 MHz continuum and 1420 MHz HI line maps of the Cygnus Loop, IC443, and of supernova remnants in the Galactic Plane Survey;

- Analysis of Kitt Peak Schmidt telescope observations of supernova remnants.

Leahy is also studying X-ray binary systems. These consist of a normal type star in orbit with a neutron star, which is an intense source of X-rays, powered by the gravitational energy released by infalling matter. Current x-ray binary projects include:

- XTE and ASCA observations of the x-ray binaries HerX-1, LMC X-4 and LSI+61 303: analysis of spectra, pulse shapes, and orbital/long-cycle phase dependence;

- Observations of Her X-1 by the EUVE satellite;

- Monte Carlo calculations of X-ray radiation transfer thru matter near a neutron star;

- Calculations of pulse shape reprocessing in circumstellar matter, including propagation delays;

- Theoretical model of pulse shape formation in x-ray binary pulsars;

- Optical spectroscopic of x-ray binaries for the purpose of orbit determination;

- Theoretical calculation of second order bremsstrahlung transition rates in strong magnetic fields;

- Analysis of ROSAT x-ray observations of Her X-1.

In addition, Leahy analyzed and modelled ROSAT x-ray observations of the cluster of galaxies 3C129, Kitt Peak Schmidt telescope observations of HII regions, combined with radio and infrared observations; acquired and modelled JCMT CO line observations of the HII region Sh219; and observed and modelled symbiotic stars.

### PUBLICATIONS

Ananth, A.G., & Leahy, D.A. 1993. Infrared Observations of Symbiotic Stars, *Journal of Astrophysics and Astronomy*, 14, 37-44

Clark, T.A., & Milone, E.F. 1990, The University of Calgary Rothney Astrophysical Observatory, in *Remote Access Automated Telescopes*, eds., Hayes, D.S., & Genet, R.M., (Mesa: Fairborn Press), 125-134

Courvoisier, T.J., Orr, A., **Leahy, D.A.** *et al.* 1993. EUVITA- an extreme UV imaging telescope array with spectral capability, *Experimental Astronomy*, 4, 117-135

Damle, S., Janawalekar, S., Kothare, A., Kunte, P., Malkar, J., Naranan, S., Srekantan, B., Adarkar, H., **Leahy, D.**, & **Venkatesan, D.**, 1994. New balloon-borne telescope system TICAL-MarkII for hard x-ray astronomy, *Adv. Space Research*, 14, 101

Dougherty, S.M., & Taylor, A.R. 1994. Near-IR Variability of Be Stars, *MNRAS*, 269, 1123-1136

Kallrath, J., **Milone, E.F.**, & **Stagg, C.R.** 1992. Modeling of the Eclipsing Binaries in the Globular Cluster NGC 5466, *ApJ*, 389, 590-601

Kallrath, J., & **Milone, E. F.** 1998. *Eclipsing Binary Stars: Modeling and Analysis*, (New York: Springer).

Kallrath, J., **Milone, E.F.**, Terrell, Dirk, & Young, Andrew T. 1998. Recent Improvements to a Version of the Wilson-Devinney Program, *ApJ*, 507, 308-313

Leahy, D.A. 1990. X-Ray Pulsar Profile Analysis, *MNRAS*, 242, 188-193

Leahy, D.A. 1991. Modelling Observed X-Ray Pulsar Profiles, *MNRAS*, 251, 203-212

Leahy, D.A. 1991. Evidence for a Gas Stream in GX 301-2, *MNRAS*, 250, 310-313

Leahy, D.A. 1991. Deprojection of Emission in Axially Symmetric Transparent Systems, *A&A*, 247, 584-589

Leahy, D.A., 1991. Discovery of a non-thermal radio source associated with the Galactic Centre 511-keV annihilation-line source, *MNRAS*, 251, 22-23

Leahy, D.A. 1995. Observations of Spectral Shape Changes in Her X-1, *A&ApS*, 113, 21-29

Leahy, D.A. 1995. Five Eclipses of Her X-1 Observed by GINGA, *ApJ*, 450, 339-349

Leahy, D.A. 1996. EINSTEIN Spectral and Imaging Observations of the Supernova Remnant MSH14-63, *JRASC*, 90, 128

Leahy, D.A. 1997. Radio and Optical Observations of the HII Region Sharpless 219, *JRASC*, 91, 117

Leahy, D.A. 1997. GINGA Observations of Absorption Dips in Her X-1, *MNRAS*, 287, 622

Leahy, D.A., & Ananth, A.G. 1992. Detection of Infrared Variability in Cygnus X-1, *MNRAS*, 256, 39p-42p

Leahy, D.A., & Aschenbach, B. 1995. ROSAT PSPC Obser-

- vations of the Supernova Remnant HB9, *A&A*, 293, 853-858
- Leahy, D.A., & Aschenbach, B. 1996. ROSAT X-Ray Observations of the Supernova Remnant HB21, *A&A*, 315, 260
- Leahy, D.A., & Li, L. 1995. Including the Effect of Gravitational Light-bending in X-ray Profile Modelling, *MNRAS*, 277, 1177-1184
- Leahy, D.A., & Matsuoka, M. 1990. The Pulse Phase Dependence of the Spectrum of GX301-2, *ApJ*, 355, 627-634
- Leahy, D.A., & Matsuoka, M. 1990. Pulse Phase Studies of X-Ray Emission from GX301-2, *Advances in Space Research*, 10, 95-98.
- Leahy, D.A., & Roger, R.S. 1991. Radio Emission from the Supernova Remnant G160.9 +2.6 (HB9), *AJ*, 101, 1033-1042
- Leahy, D.A., & Roger, R.S. 1996. Radio Sources in Fields Centered Near Supernova Remnant G160.9 +2.6 (HB9), *A&ApS*, 115, 345
- Leahy, D.A., & Volk, K. 1994. Image Deprojection Applied to the Einstein Cygnus Loop X-Ray Image, *A&A*, 282, 561-566
- Leahy, D.A., & Volk, K. 1995. ROSAT PSPC Observations of the Symbiotic CH Cyg, *ApJ*, 440, 847-852
- Leahy, D.A., & Yoshida, A. 1995. Analysis of an Eclipse Ingress During a High State of Hercules X-1, *MNRAS*, 276, 607-613.
- Leahy, D.A., Fink, R., & Nousek, J. 1990. HEAO-1 A2 Low Energy Detector X-Ray Spectra of the Cygnus Loop, *ApJ*, 363, 547-553
- Leahy, D.A., Harrison, F., Yoshida, A. 1997. The ASCA X-ray Spectrum of the Unusual Binary LSI+61 303, *ApJ*, 475, 823
- Leahy, D.A., Langill, P., & Kwok, Sun 1992. High Resolution I-band Imaging of the 1E1740.7-2942 Region, *A&A*, 259, 209-210
- Leahy, D.A., Nousek, J., & Garmire, G. 1992. Discovery of X-Ray Emission Associated with the Gum Nebula, *ApJ*, 385, 561-566
- Leahy, D.A., Nousek, J., & Hamilton, A.J.S. 1991. HEAO-1 A2 LED X-Ray Spectra of the Lupus Loop and SN1006. *ApJ*, 374, 218-226
- Leahy, D.A. Roger, R.S., & Ballentyne, D. 1997. 1420 MHz Continuum and Radio Observations of the Cygnus Loop. *AJ*, 114, 2081-2094.
- Leahy, D.A., Taylor, A.R., & Young, G. 1990. HI Spectrum of the Symbiotic Nova HM SGE. *AJ*, 99, 1926-1929
- Leahy, D.A., Yoshida, A., & Matsuoka, M. 1994. Spectral Evolution During Pre-eclipse Dips in Her X-1. *ApJ*, 434, 341-348
- Leahy, D.A., Zhang, C.Y., & Kwok, S. 1994. Two Temperature X-Ray Emission from the Planetary Nebula NGC7293, *ApJ*, 422, 205-207
- Leahy, D.A., Zhang, C.Y., Volk, K., & Kwok, S. 1996. ROSAT X-Ray Observations of Four Planetary Nebula, *ApJ*, 466, 352
- Li, P.S., & Leahy, D.A. 1997. Far UV Observations with the Voyager Ultraviolet Spectrometer: New Evidence for Interacting Winds in Symbiotic Systems, *ApJ*, 484, 424
- Marshall, C.R., Leahy, D.A., & Kwok, Sun 1992. Submillimeter Observations of Circumstellar Dust, *PASP*, 104, 397-401
- McVean, J.R., & Milone, E.F. 1996. Light Curve Analyses of Eclipsing Binaries in M71, in *The Origins, Evolution, and Destinies of Binary Stars in Clusters*, eds. E.F. Milone & J.-C. Mermilliod, ASP Conference Series, 90, 220-221
- McVean, J.R., Milone, E.F., Mateo, M., & Yan, L. 1997. Analyses of the Eclipsing Binaries of the Globular Cluster M71, *ApJ* 481, 782-794
- Milone, E. F. 1993. Towards the Realization of Modelling Improvement Suggestions made at the Beijing Colloquium on Close Binary Stars, in *Pacific Rim Colloquium on New Frontiers in Binary Star Research*, eds. K. C. Leung, & I.-S. Nha. ASP Conf. Series 38, 172-180
- Milone, E. F., ed., 1993. *Light Curve Modeling of Eclipsing Binary Stars*, (New York: Springer), 202pp
- Milone, E. F. 1993. Improvement in Light Curve Modeling of Eclipsing Binaries - An Introduction, in *Light Curve Modeling of Eclipsing Binary Stars*, ed. E.F. Milone (New York: Springer), 1-6
- Milone, E. F. 1993. Concluding Remarks, in *Light Curve Modeling of Eclipsing Binary Stars*, ed. E.F. Milone (New York: Springer), 195-202
- Milone, E. F. 1994. Report of the Working Group on Infrared Astronomy, in the Commission 25 report, *Reports on Astronomy*, XXIIA, pp. 236-237.
- Milone, E.F. 1996. Opening Remarks, in *The Origins, Evolution, and Destinies of Binary Stars in Clusters*, eds. E.F. Milone, & J.-C. Mermilliod, ASP Conference Series, 90, pp. 3-11
- Milone, E.F. 1996. Concluding Postscript, in *The Origins, Evolution, and Destinies of Binary Stars in Clusters*, eds. E.F. Milone, & J.-C. Mermilliod, ASP Conference Series, 90, 504-506
- Milone, E.F., & Clark, T.A. 1990. Rothney Astrophysical Observatory, *BAAS*, 22, 974-983
- Milone, E.F., & Mermilliod, J.-C. (eds.) 1996. *The Origins, Evolution, and Destinies of Binary Stars in Clusters*, ASP Conference Series, 90. 508pp
- Milone, E.F., & Schiller, S.J. 1990. A Royal Road to Clusters and Stellar Evolution: Binaries -in-Clusters. in Janes, K., ed, *The Formation and Evolution of Star Clusters*, ed., Janes, K. (Provo: BYU Press), 427-432
- Milone, E.F., & Stagg, C.R. 1994. New Developments in Eclipsing Binary Modeling, *Experimental Astronomy*, 5, 163-169
- Milone, E.F., & Terrell, D. 1996. "Analysis of the Contact System H235 in the Open Cluster NGC 752" in *The Origins, Evolution, and Destinies of Binary Stars in Clusters*, eds. E.F. Milone, & J.-C. Mermilliod, ASP Conference Series, 90, 283-285
- Milone, E.F., & Terrell, D. 1996. Preliminary Analysis of the Contact System V7 in NGC 6971, in *The Origins, Evolution, and Destinies of Binary Stars in Clusters*, eds. E.F. Milone, & J.-C. Mermilliod, ASP Conference Series, 90, pp. 286-288
- Milone, E.F., Filhaber, J., & van Houten, C.J. 1990. Non-

- Simultaneous Photoelectric and CCD Photometry of a Variable Star: Observations of VY Crucis, in *CCDs in Astronomy II: New Methods and Applications of CCD Technology*, eds., Phillips, A.G.D., Hayes, D.S., & Adelman, S.J., (Schnectady: L. Davis Press), 149-158
- Milone, E.F., Stagg, C.R., & Kallrath, J. 1992. The Eclipsing Binaries in NGC 5466 and their Implications for System Evolution, in *Evolutionary Processes in Interacting Binary Stars*, ed. Y. Kondo, 483-486
- Milone, E.F., Stagg, C.R., & Kurucz, R.L. 1992. The Eclipsing Binary AI Phoenicis: New Results Based on an Improved Light Curve Analysis Program, *ApJS*, 79, 123-137
- Milone, E.F., Stagg, C.R., & Schiller, S.J. 1992. Constraints on the Cessation of Eclipses in SS Lacertae and their Implications for System Evolution, in *Evolutionary Processes in Interacting Binary Stars*, ed. Y. Kondo, 479-482
- Milone, E.F., Stagg, C.R., & Young, A.T. 1993. Improved IR Passbands for Ground-Based Photometry: An Aid to Calibration. in *Astronomical Infrared Spectroscopy*, ed. S. Kwok, 395-396
- Milone, E.F., Stagg, C.R., & Young, A.T. 1995. Towards Robotic IR Observatories: improved IR passbands, in *Robotic Observatories*, ed., Michael F. Bode (Chichester: John Wiley & Sons), 117-124
- Milone, E.F., Groisman, G., Fry, D.J.I., & Bradstreet, D.H. 1991. Analysis and Solution of the Light and Radial Velocity Curves of the Contact Binary TY Bootis, *AJ*, 370, 677-692
- Milone, E.F., Wilson, W.J.F., Fry, D.J.I., & Schiller, S.J. 1994. Studies of Large-Amplitude delta Scuti Variables. II. DY Herculis, *PASP*, 106, 1120-1133
- Milone, E.F., McVean, J.R., Lu, W., Schiller, S.J., & Miller, G. 1994. The Binaries-in-Clusters Program in the Age of Imaging, in *Astronomy from Wide-Field Imaging*, eds., H.T. MacGillivray, E.B. Thomson, B.M. Lasker, I.N. Read, D.F. Malin, R.M. West, & H. Lorenz, 478-480.
- Milone, E.F., Clark, T.A., Babott, F.M., Fry, D.J.I., Taylor, A.R., & Nelson, R.H. 1991, Improvements to the Infrared Telescope of the Rothney Astrophysical Observatory, in *Robotic Observatories: Present and Future*, eds., Baliunas, S. & Richard, J.L. (Mesa: Fairborn Press), 147-155
- Milone, E.F., Stagg, C.R., Kallrath, McVean, J.R., Sugars, B.J.A., & Schiller, S.J. 1992. The Contact System H235 in NGC 752, in *Evolutionary Processes in Interacting Binary Stars*, ed. Y. Kondo, 475-478
- Milone, E.F., Babott, F.M., Clark, T.A., Fry, D.J.I., Jones, B., Puetter, R.C., & Pina, R.K. 1993. A UCSD-RAO Infrared Spectrometer, in *Astronomical Infrared Spectroscopy*, ed. S. Kwok, 403-404
- Milone, E.F., Stagg, C.R., Sugars, B.J.A., McVean, J.R., Schiller, S.J., Kallrath, J., & Bradstreet, D.H. 1995. Observations and Analysis of the Contact Binary H235 in the Open Cluster NGC 752, *AJ*, 109, 359-377
- Milone, E.F., McVean, J.R., Wilson, W.J.F., Kallrath, J., Schiller, S.J., Stagg, C.R., Mateo, M., & Yan, L. 1996. Towards the Calibration of Cluster Colour-Magnitude Diagrams, *C.R. Acad. Sci. Paris*, 322, Ser. II b, 177-184
- Milone, E.F., Babott, F.M., Clark, T.A., Dougherty, S., Fry, D.J.I., Himer, J.T., Leahy, D.A., Taylor, A.R., & Ananth, A.G. 1992. Infrared Variable Star Observing from the Rothney Astrophysical Observatory, in *Automated Telescopes for Photometry and Imaging*, eds. Adelman, S.J., Dukes, R.J., & Adelman, C.J., ASP Conference Series, 28, 49-55
- Nelson, R.H., **Milone, E.F.**, Van Leeuwen, J., **Terrell, Dirk**, Penfold, J.E., and Kallrath, J. 1995. Observations and Analysis of the Field Contact Binary V728 Herculis, *AJ*, 110, 2400-2407
- Roger, R.S., & **Leahy, D.A.** 1993. HI Photodissociation Zones Around Two HII Regions in Auriga, Sh 217 and Sh 219, *AJ*, 106, 31-38
- Saraswat, P., **Leahy, D.A.**, et al. 1996. An ASCA Observation of the X-ray binary GX301-2, *ApJ*, 463, 726
- Schiller, S.J., & **Milone, E.F.** 1990. Simultaneous CCD and Photoelectric Photometry: Observations of DY Herculis, in *CCDs in Astronomy II: New Methods and Applications of CCD Technology*, Philips, A.G.D., Hayes, D.S., & Adelman, S.J., (Schnectady: L. Davis Press), pp. 159-165
- Schiller, S.J., & **Milone, E.F.** 1996. Binaries in Clusters: Exploring Binary and Cluster Evolution, in *The Origins, Evolution, and Destinies of Binary Stars in Clusters*, eds. E.F. Milone & J.-C. Mermilliod, ASP Conference Series, 90, pp. 120-130
- Schlosser, W., Schmidt-Kaler, Th., & **Milone, E. F.** 1994. (second, revised printing). *Challenges of Astronomy: Hands-On Experiments for the Sky and Laboratory*, (New York: Springer), 236pp
- Shen, Z., Wu, X., Zhang, X., Zheng, Y., Li, Z. & **Leahy, D.A.**, 1990. Radio Observation of the Supernova Remnant HB9 at 232 MHz, *ApJ*, 356, 241-242
- Stagg, C. R., & Milone, E. F. 1993. Improvements to the Wilson-Devinney Code on Computer Platforms at the University of Calgary, in *Light Curve Modeling of Eclipsing Binary Stars Modeling*, ed. E.F. Milone (New York: Springer), 75-92
- Volk, K., & Leahy, D.A. 1993. Deprojection of Planetary Nebulae Images, *AJ*, 106, 1954-1964
- Volk, K., & Leahy, D.A. 1995. Sensitivity Loss in X-ray Timing Analysis, *A&ApS*, 110, 583-585
- Wilson, W.J.F., Milone, E.F., & Fry, D.J.I. 1993. Studies of Large Amplitude delta Scuti Variables: I. A Case Study of EH Librae, *PASP*, 105, 809-820
- Wilson, W.J.F., Milone, E.F., Fry, D.J.I., & Van Leeuwen, J. 1998. Studies of Large-Amplitude delta Scuti Variables. III. DY Pegasi, *PASP*, 110, 433-450
- Young, A.T., **Milone, E.F.**, & **Stagg, C.R.** 1993. Improved Infrared Passbands, in *Stellar Photometry - Current Techniques and Future Developments*, eds., C.J. Butler and I. Elliott. (Cambridge: Univ. Press), pp. 235-241
- Young, A.T., **Milone, E.F.**, & **Stagg, C.R.** 1994. On Improving IR Photometric Passbands, *A&ApS*, 105, 259-279
- Zhang, C., Leahy, D., & Kwok, S. 1993. The ROSAT X-ray Spectrum of the Helix Nebula, *Revista Mexicana de Astronomia y Astrofisica*, 27, 219-222