Iowa State University

Department of Physics and Astronomy
Erwin W. Fick Observatory

Ames, Iowa 50011

This report covers the period from September 2003 through August 2004. We limit the research descriptions in this report to brief summaries, along with specific internet addresses, and selected publications. For more information on facilities, personnel, and research programs, see our group website:

http://www.public.iastate.edu/∼astro

1 Personnel and Education

G. H. Bowen (emeritus), D. Carter-Lewis, J. Eitter (Observatory Manager), G. Gonzalez, S. Kawaler, C. Kerton, F. Krennrich, R. Lamb (emeritus, resident in Pasadena, CA), M. Pohl, C. Struck & L. A. Willson.

Graduate students in astronomy included J. Brown, S. Hostler, A. Imran, B. Behera, M. Vuckovic, & Q. Wang. During this period, S. Hostler completed a Masters degree and took a position with the SAO Submillimeter Array on Mauna Kea, and J. Brown completed a Masters degree and entered the graduate program at the University of New Mexico. D. Oesper progressed on a Masters program that included astronomical pedagogy.

Stephane Lebohec completed his senior postdoctoral fellowship working on SGARFACE and VERITAS, and in August 2004 joined the faculty at the University of Utah. Michael Daniel continues as a postdoctoral fellow working on VERITAS and analysis of Whipple telescope data. He is based in Ames, but makes frequent trips to Arizona to observe or work on the VERITAS prototype telescope. Dirk Pützfeld is a postdoctoral scholar working with M. Pohl.

Undergraduates involved in astronomical research included ISU students G. Knoke, K. Marasinghe, A. Marshall, and E. Potter; I. Radtke (Minnesota State University, Mankato) joined us for summer research.

Kawaler continues as AURA member representative for ISU and Director of the Whole Earth Telescope (WET) collaboration. He also is serving a three-year term as vice-president of I.A.U. Commission #27, and serves on the AURA Solar Observatories Council. Reed Riddle continued as Associate Director of Whole Earth Telescope Operations, and in August moved to Caltech where he is part of the TMT project. Pohl continues as NASA Interdisciplinary Scientist for the GLAST mission. Willson serves Ex-President of the American Association of Variable Star Observers (AAVSO).

Willson, with several undergraduate and graduate students, continue developing a series of web based astronomy modules (the Polaris Project). Aimed at the freshman non-scientist, several modules have been tested by students with backgrounds ranging from none to senior in physics or astronomy. The presentation material is open for use by anyone:

http://www.polaris.iastate.edu

Kerton presented a talk at a special education session of the May 2004 CASCA meeting. The talk detailed the undergraduate lab course developed at ISU for non-science students taking introductory astronomy classes.

Gonzalez and graduate student David Oesper have signed a contract with Cambridge University Press to revise the textbook *Observational Astronomy*, by D. Scott Birney. This project will be Oester's Masters thesis project. It is scheduled for completion in May 2005. Prior to going out of print a few years ago, this was a popular textbook for upper level undergraduate courses on observational astronomy.

2 Facilities

Gonzalez (with Eitter and Kerton) continued construction of a precision radial velocity spectrograph (m/s resolution). The spectrograph is based on the "Externally Dispersed Interferometer" design of J. Ge and D. Erskine. It will eventually be used with the Mather Telescope at Fick Observatory to obtain high precision radial velocities to study giant planets around Sun-like stars.

CCD imaging and photometry at Fick Observatory, with imaging on 84 nights over this period, and high-speed time series photometry of variable stars on 28 additional nights. These observations have employed the Andor CCD camera; we are also developing a new system using a high-speed CCD photometer (based on the Apogee AP-7) with custom software (designed by Riddle and Radtke) to allow nearly real-time light curve analysis.

A new roof was installed on the movable roof of the observatory. A new 8 1/2 foot Clear Skys Inc. dome was installed around the 14" Celestron telescope used for tours and the observing classes. A SBIG spectrometer and CCD was also obtained for use with these classes.

3 Research Programs

3.1 Galaxies & ISM

Kerton, along with C. Brunt (UMass/FCRAO) and L.B.G. Knee (HIA/NRC Canada) continued his studies of propagating star formation around small HII regions. In October 2003 he obtained new submm observations of a number of HII regions using SCUBA on JCMT. The science program is now moving towards using deep NIR imaging to investigate the embedded stellar content in more detail while awaiting the arrival of the SCUBA2 instrument on JCMT to continue the submm

survey observations. A poster reviewing the JCMT observations was presented at the Canadian Astronomical Society (CASCA) annual meeting in May 2004.

Kerton continues his studies on the ISM as part of the International Galactic Plane Survey (IGPS). From May-August 2004 two undergraduate students worked on IGPS related projects. J. Wahl (UNI) constructed an observational database of the Cepheus star-forming region and S. Dennis (ISU) worked on a catalog of extended 1420 MHz emission features seen in IGPS data. Kerton is investigating HI self-absorption features seen in the IGPS data and is particularly interested in the rare cases where the cold HI is seen both in emission and absorption.

As part of his involvment with the Galactic Arecibo L-Band Feed Array (GALFA) consortium Kerton is looking at high velocity HI features seen in IGPS data with the goal of characterizing their frequency and association with known massive star forming regions. Such low intensity, high-velocity wings seen in older HI surveys are thought to be associated with old supernova remnants and are a proposed target for future ALFA observations.

Kerton continues to work on the creation of high-resolution IRAS-based maps of the Galactic plane. These maps are integrated into the IGPS data base and provide information on the dust component of the ISM at a comparable resolution to the radio wavelength surveys. The final data products are also being made available through the Infrared Science Archive (IRSA) ATLAS web site

C. Struck continued work on models of star–gas dynamics and induced star formation in pre-merger stages of galaxy collisions. This work focuses on modeling specific well observed systems. A talk on the importance of detailed studies of specific systems (given at IAU Symposium 217) was published in this period. A Chandra Observatory X-ray study of the classic starburst system Arp 284, reporting the discovery of an incipient wind and several ultraluminous sources associated with tidal structures, has been submitted for publication in the AJ. Guest observer time was obtained with a number of collaborators to study systems with bridges and tails with the Spitzer Space Telescope and GALEX, and to study ring galaxies with GALEX. These observations should give unprecedented information about star formation in collisionally induced waves in galaxies. See

http://www.public.iastate.edu/∼curt.

3.2 Stars and Planets

Gonzalez continues a long-term program, started in late 1995, to derive the basic properties of stars with planets. This is the Ph.D. thesis topic of C. Laws (U. Washington), which he expects to complete in December 2004. Work with G. Wallerstein (U. Washington) and S. Giridhar (Indian Inst. of Astrophysics) on the abundances of very metal-poor cool giants continues; the work is based on observations obtained in 2000 and 2001 with the KPNO 4-m and Apache Point 3.5-m telescopes. In collaboration with J. Armstrong (Weber State), Gonzalez continues a study of the Moon as a source for evidence of early life on Earth, exploring the possibility of re-seeding the Earth following a sterilizing impact, and search strategies for Terran meteorites on the Moon.

Struck, Willson and Cohanim (former undergrad.) completed work on the effects of accretion onto giant planets and brown dwarfs orbiting in the extended atmospheres and winds of stars like the Sun in their late evolutionary stages (AGB, Mira phase). A grid of two-dimensional numerical models highlighting the bow shock, wake and accretion hydrodynamics of such systems, was published in the MNRAS. Related material can be found at;

http://www.public.iastate.edu/∼lwillson

Struck, Willson, Bowen and former graduate students D. C. Smith and G. Turner also completed and published analytic models of the self-similar structure of the winds of long-period variables. In the case of pulsationally driven winds the models are based on non-barotropic, Reynolds-type equations, like those used in turbulence studies. The work also suggests that dust-driven winds are self-regulated.

Willson spent the academic year on "faculty professional development assignment," visiting the astronomy department at the University of Minnesota, the Harvard-Smithsonian Center for Astrophysics, Uppsala University, and UC Berkeley. Her research focused on (a) understanding the implications of the realization that Miras are surrounded by material with a large amount of water vapor near two stellar radii (Traub et al. in prep); (b) considering possible explanations for variations in the periods of Miras over decadal timescales (Templeton et al in prep); and (c) exploring with C. Struck the effects of episodic mass loss on orbits. Her main project for the year was beginning to write a new textbook, Essential Physics of Stellar and Planetary Atmospheres, under contract with Cambridge U. Press. In conjunction with that project she gave a seminar series at the University of Minnesota. She also gave talks at all the above listed institutions plus the University of Washington and Stockholm University on her research. Finally, she spent some time at the American Association of Variable Star Observers while director Janet Mattei was ill, and served on the search committee for a new director.

A new flare star, discovered by Eitter, is being monitored which was first seen on some wide field observations of comet Ikeya-Zhang in 2002. Observations of a 21.45 hour eclipsing binary discovered by Mike McClure are being taken. Mike is a ISU physics alumnus who is an amateur astronomer searching for new variable stars.

Under Kawaler's direction, the Whole Earth Telescope continued reduction and analysis of data from prior campaigns, including the August 2003 campaign on the pulsating sdB star KPD 1930. With undergraduate L. Potter, Kawaler and the collaboration completed analysis of the pulsating hot white dwarf PG 1707+427. In addition, the WET collaboration began preparations for the 24th WET campaign, scheduled for October 2004. Graduate student S. Hostler completed her Masters research project with analysis of 20+ years

of data on the pulsating white dwarf G29-38, including data from the 23rd WET campaign and data taken locally at Fick Observatory.

On the theoretical side, Kawaler and graduate student Hostler completed their initial study of the evolution of angular momentum within stars as the evolved from the main sequence to the white dwarf (and hot subdwarf) phases. Results of these studies suggest new ways of analyzing the pulsating members of those classes to look for evidence of rapid core rotation. Other theoretical studies include collaborative work on the influence of neutrinos on the evolution of DB white dwarfs, and topics in pulsations of Miras and semiregular variables.

For more details about work in these areas, as well as links to the Whole Earth Telescope project and Kawaler's teaching activities, see

http://www.public.iastate.edu/∼sdk

3.3 Particle Astrophysics

Faculty members Frank Krennrich and David Carter-Lewis work entirely in this area. Martin Pohl divides his time between GLAST (satellite/GeV energies) and VERITAS (ground-based/TeV energies).

3.3.1 TeV Gamma-ray Astronomy

Ground-based gamma-ray astronomy has opened up a new observational window for observing TeV (10^{12} eV) photons from active galactic nuclei (AGN), supernova remnants and pulsars. Our group, as part of the Whipple collaboration has pioneered the technique of detecting gamma-rays from using large (Whipple 10 m), ground-based optical telescopes.

Astrophysics at TeV energies is about to undergo a revolution as the next generation Cherenkov telescopes (VERITAS, HESS, MAGIC, CANGAROO) come on line. The existence of several types of cosmic accelerators emitting TeV gamma rays is well established; the underlying physics is not. These new arrays will have 1-2 orders of magnitude better sensitivity, increased angular resolution and sensitivity extending to dramatically lower energies. In addition the GLAST satellite will give unprecedented sensitivity at GeV energies overlapping (or almost overlapping) with the low energies of the Cherenkov arrays.

The VERITAS array (Very Energetic Radiation Imaging Telescope Array System) is the successor of the Whipple telescope and will have dramatically improved sensitivity, energy threshold, and angular and energy resolution. At ISU, we have designed and are building the focus boxes and focal plane instrumentation for this array. The first telescope is now functioning with a subset of pixels at Whipple Observatory basecamp near Amado Arizona. (The VERITAS array will eventually be located at KPNO.) The remaining photomultiplier-tube/preamp assemblies for the first telescope have now been completed at ISU, and the camera will soon have a full complement of 499 pixels.

With Stephan LeBohec (Utah) and Charles Duke (Grinnell), we are presently investigating analysis methods for best utilizing this array, particularly in regard to obtaining the lowest energy threshold. This work utilizes Monte Carlo code largely developed here.

TeV science issues being addressed at ISU include the measurement of energy spectra of AGN, the implications for particle acceleration in the vicinity of supermassive black holes, and implications for extra-galactic background light. Primary science results from last year include a significant new analysis of joint constraints on blazar TeV and EBL by Dwek and Krennrich, spectral analysis of the blazars H1426+426 and 1ES1959+650 and a search for TeV gamma rays from M87. Details are summarized in the publication list below.

In addition we have developed a unique trigger system (SGARFACE) now attached to the Whipple telescope to search for burst phenomena on timescales of 10 nanoseconds to 10 microseconds. Frank Krennrich, Stephan Lebohec and Bagmeet Beherra are working on the first data and developing data analysis techniques. SGARFACE will eventually be expanded and moved to VERITAS.

3.3.2 High Energy Astrophysics

Pohl continues his investigations of high–energy phenomena in supernova remnants, AGNs, and the Universe.

An origin of cosmic rays in supernova remnants (SNR) would have profound consequences for how these particles would be distributed in the Galaxy, and consequently how the local cosmic-ray measurements have to be interpreted. The effects are possibly visible in the spectra of diffuse galactic γ-ray emission, where they could account for observed excess emission at a few GeV. In particular the flux of high-energy electrons would have a highly inhomogeneous distribution in the galactic disk, and it would also display temporal variations. The typical correlation length for the spatial fluctuations in the electron flux is approximately 200 pc at an electron energy of 100 GeV or higher. The distribution of cosmic-ray nucleons would show fluctuation at the 20% level with occasional spikes of much higher amplitude, which would only be observed for primary cosmic rays. Therefore the commonly used method of determining CR propagation parameters by fitting secondary-to-primary ratios appears flawed on account of the variations that these ratios would show throughout the Galaxy.

Three shell-type SNRs have been detected at TeV-scale γ-ray energies to date, all of which show non-thermal X-ray emission, which presumably is synchrotron radiation. A large fraction of the non-thermal X-ray emission originates from very thin filaments, which are probably magnetic structures at the contact discontinuity between the ejecta and the circumstellar material, suggesting that the radiating relativistic electrons are not accelerated at the forward shock and hence not produced by the commonly assumed process of diffusive shock acceleration.

Active galactic nuclei (AGNs) are powerful sources with relativistic outflows that can emit the bulk of their

luminosity in the form of gamma rays, the flux of which displays variability on time scales so short that, on account of causality, the emission regions can not be larger than a few light hours.

Relativistic collision fronts in the jets of AGN make excellent candidates for hosting the very rapid acceleration processes, that are required to explain the fast variability observed from AGN. A kinetic treatment of the relativistic collision fronts is desirable on account of the collisionless nature of astrophysical plasmas. We have developed the "relativistic pick-up model", in the framework of which the individual TeV flares can be explained as the consequence of the collisionless interaction of a single massive outflow component with an inhomogeneous ambient medium.

The predicted radiation reproduces the observed multi-band spectra and the lightcurves of gamma-ray blazars while making definite predictions for the neutrino emission. Corresponding calculations are being made for outflows consisting of an e^+/e^- pair plasma, which is possibly the case in gamma-ray bursts.

A host of data is available to date that allows tests of cosmological models. We investigate possible extensions and generalizations of the simple Friedmann-Lemâitre universes by using statistical tests on a sample of radio galaxies and galaxy clusters. We find that one class of non-Riemannian structure can not contribute more than 5% of the critical mass in the universe.

For further information about Pohl's research programs, see

http://cherenkov.physics.iastate.edu/∼mkpohl

PUBLICATIONS

F. Aharonian, et al. (including **M. Pohl**) 2004, "H.E.S.S. observations of PKS 2155-304," A&A, submitted

F. Aharonian, et al. (including **M. Pohl**) 2004, "Calibration of cameras of the H.E.S.S. detector," Astropart. Phys., in press

F. Aharonian, et al. (including **M. Pohl**) 2004, "Very high energy gamma-rays from the direction of Sagittarius A*," A&A 425, L13

C. Akerlof, et al. (including **D. A. Carter-Lewis & F. Krennrich**) 2003, "A search for correleations of TeV gamma-rays with ultra-high energy cosmic rays," ApJ, 586, 1232.

C. Arbeiter, **M. Pohl**, & R. Schlickeiser 2004, "Synchrotron-self-comptonization in a relativistic collision front model," ApJ, submitted

I. Büsching, A. Kopp, **M. Pohl**, R. Schlickeiser, C. Perrot, & I. Grenier 2004 "Cosmic-ray propagation properties for an origin in SNRs," ApJ, in press

Y.M. Butt, P. Benaglia, J.A. Combi, M. Corcoran, T.M. Dame, J. Drake, M. Kaufman Bernadó, P. Milne, F. Miniati, F., **M. Pohl**, O. Reimer, G.E. Romero, & M. Rupen, 2003, "CHANDRA/VLA follow-up of TeV J2032+4131, the only unidentified TeV gamma-ray source," ApJ, 597, 494.

B.G. Castanheira, et al. (including **S.D. Kawaler**) (the WET collaboration) 2004, "Observations of the Pulsating White Dwarf G 185-32," A&A, 413, 623.

M.K. Daniel, et al., (including **D. A. Carter-Lewis, F. Krennrich**, & **S. LeBohec**) 2004, "The energy spectrum of the BL Lac object 1ES1959+650," ApJ, in press.

I.C. De La Calle Perez, et al. (including **D.A. Carter-Lewis, M.K. Daniel, F. Krennrich, & S. Le Bohec**) 2004, "Search for high energy gamma rays from an X-Ray selected blazar sample," ApJ, 599, 909.

E. Dwek & **F. Krennrich** 2004, "Simultaneous constraints on the spectrum of the extragalactic background light and the intrinsic TeV spectra of Mrk 421, Mrk 501 and H1426+428," ApJ, in press.

A. Falcone, et al., (including **D. A. Carter-Lewis, F. Krennrich, & S. LeBohec**) 2004, "A search for TeV gamma-Ray emission from high-peaked flat spectrum radio quasars using the Whipple air-Cherenkov telescope," ApJ, in press.

D. Geisler, V. V. Smith, G. Wallerstein, **G. Gonzalez**, & C. Charbonnel, 2004, "'Sculptor'-ing the Galaxy? The chemical compositions of red giants in the Sculptor dwarf spheroidal galaxy," AJ, in press.

T.A. Hall, et al. (including **D.A. Carter-Lewis, F. Krennrich, & S. Le Bohec**) 2003, "Search for TeV emissions from pulsars in binary systems," ApJ, 583, 853.

J. Holder, et al. (including **D.A. Carter-Lewis, F. Krennrich, S. Le Bohec, & D. Petry**) 2003, "TeV gamma rays from the BL Lacertae Object 1ES 1959+650 with the Whipple 10 Meter Telescope," ApJ, 583, L9.

D. Horan, et al. (including **D.A. Carter-Lewis, M.K. Daniel, F. Krennrich, & S. Le Bohec**) 2004, "Constraints on the Very High Energy Emission from BL Lacertae Objects," ApJ, 603, 51.

U. Hwang et al. (including **M. Pohl**) 2004, "A million second Chandra view of Cassiopeia A," ApJ, submitted

I. I. Ivans, C. Sneden, G. Wallerstein, R. P. Kraft, J. E. Norris, J. P. Fulbright, & **G. Gonzalez** 2004, "On the Question of a Metallicity Spread in Globular Cluster M22 (NGC 6656)," MnSAI, 75, 286.

S.D. Kawaler, **E. Potter**, M. Vuckovic, et al. (the WET collaboration) 2004, "Whole Earth Telescope observations of the pulsating hot white dwarf PG 1707+427," A&A, in press.

S. D. Kawaler & **S.R. Hostler** 2004, "Internal Rotation of Subdwarf B Stars: Limiting Cases and Asteroseismological Consequences," ApJ, submitted.

C.R. Kerton 2004, "A direct determination of the spin temperature of an HI self-absorption feature," ApJ, in press

C.R. Kerton, C.M. Brunt, & L.B.G. Knee 2003, "High Spatial Dynamic Range HI Surveys of Nearby Molecular Cloud Complexes," in Milky Way Surveys: The Structure and Evolution of Our Galaxy, ASP Conf. Ser. 317 (available October 2004)

C.R. Kerton, C.M. Brunt, & and R. Kothes 2004, "The overlooked HII region DA 568," AJ, 127, 1059

C. R. Kerton, C.M. Brunt, C.E. Jones, & S. Basu 2003, "On the intrinsic shape of molecular clouds," A&A, 411, 149

C. R. Kerton, G. Cameron, D. Oesper, & L.A. Willson 2004, "Integrating a Lab Experience with an Astro 101 Class," in Physics in Canada, Vol. 60, No. 3, May-June 2004, 58 (abstract)

C.R. Kerton, L.B.G. Knee, & C.M. Brunt 2004, "Propagating Star Formation Around Single O star HII Regions," in Physics in Canada, Vol. 60, No. 3, May-June 2004, 132 (abstract)

D. Kilkenny, M.D. Reed, D. O'Donoghue, **S.D. Kawaler** et al. (the WET collab.) 2003 "A Whole Earth Telescope campaign on the pulsating subdwarf B binary system PG 1336-018 (NY Vir)", MNRAS, 345, 834.

F. Krennrich, et al. (including **D. A. Carter-Lewis, M. K. Daniel, & S. LeBohec** 2004, "VERITAS: the Very Energetic Radiation Imaging Telescope Array System," New Astronomy Reviews, 48, 345.

K. Kosak, et al. (including **D.A. Carter-Lewis, M.K. Daniel, F. Krennrich, & S. Le Bohec**) 2004, "TeV Gamma-Ray Observations of the Galactic Center," ApJ, 608, L97.

C. Laws, **G. Gonzalez** , et al., 2003, "Fossils in the Photosphere: Condensation Temperature Trends in the Chemical Abundances of Stars with Radial-Velocity Companions," BAAS, 203, #6.07.

S. Le Bohec, et al. (including **D. A. Carter-Lewis, M.K. Daniel, & F. Krennrich**) 2004, "Observations of M87 at E ¿ 400 GeV with the Whipple 10m Telescope," ApJ, 610, 156.

M. Lyutikov & **M. Pohl** 2004, "The origin of nonthermal X-ray filaments and TeV emission in young SNRs," ApJ, 609, 785

T.S. Metcalfe, M.H. Montgomery, & **S. D. Kawaler** 2003 , "Probing the envelope structure of DBV white dwarfs", MNRAS, 344, L88.

A. Mukudam, et al. (the WET collaboration, including S.D. Kawaler) 2004, "Constraining the Evolution of ZZ Ceti", ApJ, 594, 961.

M. Pohl, C. Perrot, I. Grenier, & S. Digel 2003, "The imprint of Gould's Belt on the local cosmic-ray electron spectrum," A&A, 409, 581

D. Pützfeld, M. Pohl, & Z.-H. Zhu, Z.-H. 2004, "Complementary constraints from FR IIb radio galaxies and X-ray gas mass fractions in clusters on non-standard cosmological models," ApJ, submitted

M.D. Reed, **S.D. Kawaler**, et al. (the WET collaboration) 2004, "The long term pulsational stability of the pulsating sdB star Feige 48", MNRAS, 348, 1164.

O. Reimer, **M. Pohl**, P. Sreekumar, & J.R. Mattox 2003, "EGRET upper limits on the high-energy gamma-ray emission of galaxy clusters," ApJ, 588, 155

R. Schlickeiser, **M. Pohl**, & R. Vainio 2003, "The influence of electron impact ionisation in the relativistic pick-up of interstellar neutrals," ApJ, 596, 840

M. Siewert, **M. Pohl**, & R. Schlickeiser, R. 2004, "The impact of thermal gas in AGN jets on the low-frequency emission," A&A 425, 405

B. J. Smith, **C. Struck**, & M. Nowak 2004, "Chandra X-ray Imaging of the Interacting Starburst Galaxy System NGC 7714/15: Tidal ULXs, Emergent Wind, and Resolved HII Regions,", AJ, submitted.

C. Struck 2004, "Case Studies of Mass Transfer and Star Formation in Galaxy Collisions," in *Recycling Intergalactic and Interstellar Matter: IAU Symposium Series, Vol. 217*, eds. P.-A. Duc, J. Braine, & E. Brinks (San Francisco: ASP), p 400.

C. Struck, B. E. Cohanim, & **L. A. Willson** 2004, "Continuous and Burst-like Accretion on to Substellar Companions in Mira Winds," MNRAS, 347, 173.

C. Struck, D. C. Smith, L. A. Willson, G. Turner, & G. H. Bowen 2004, "The Self-Regulated Winds of Long-Period Variable Stars," MNRAS, 353, 559.

G. Tautvaisiene, G. Wallerstein, D. Geisler, **G. Gonzalez**, & C. Charbonnel 2004, "Elemental abundances of three red giants in Terz. 7, a globular cluster associated with the Sagittarius galaxy," AJ, 127, 373.

R. Vainio, **M. Pohl**, & R. Schlickeiser 2004, "Conversion of bulk kinetic energy into radiation in AGNs and GRBs: particle transport effects," A&A, 414, 463

D.E. Winget, D.J. Sullivan, T.S. Metcalfe, **S.D. Kawaler**, & M.H. Montgomery 2004, "A strong test of electroweak theory using pulsating DB white dwarf stars as plasmon neutrino detectors," ApJ, 602, L109.

P.R. Wood, E.A. Olivier, & **S. D. Kawaler** 2004, "Long Secondary Periods in Pulsating Asymptotic Giant Branch Stars: An Investigation of their Origin", ApJ, 604, 800.

Steven D. Kawaler