The Ohio State University
Astronomy Department

Columbus, Ohio 43210

This annual report covers the period 2003 September through 2004 August.

1 PERSONNEL

During the period covered by the report, the regular academic faculty of the Department of Astronomy included Richard Boyd, Darren DePoy, Jay Frogel, Andrew Gould, Eric Herbst, Christopher Kochanek, Smita Mathur, Jordi Miralda-Escudé, Gerald Newsom, Patrick Osmer (chairman), Bradley Peterson, Marc Pinsonneault, Richard Pogge, Anil Pradhan, Barbara Ryden, Kristen Sellgren, Gary Steigman, Donald Terndrup, Terrance Walker, and David Weinberg. James Beatty and John Beacom (OSU Physics) have courtesy appointments in the Astronomy department, effective July 2004. Frogel completed two years as an IPA at NASA headquarters as Program Scientist for Spitzer and for Herschel; he is currently on leave from OSU at AURA, Inc. where he is Vice President for Science. Boyd was on leave as a Program Director at the National Science Foundation.

Sultana Nahar held an appointment as Research Scientist, and David Ennis served as a Lecturer. Cheongho Han was a Visiting Scholar during the 2004 calendar year. Emeritus professors in the Astronomy department are Eugene Capriotti, George Collins II, Stanley Czyzak, Geoffrey Keller, William Protheroe, Robert Wing, and (effective October 2004) Gerald Newsom.

The staff of the Imaging Sciences Laboratory (ISL) included Bruce Atwood, Ralph Belville, David Brewer, Paul Byard, Mark Derwent, Jerry Mason, Thomas O'Brien, Daniel Pappalardo, David Steinbrecher, and Edward Teiga. Michael Savage was computer network administrator.

In Tucson, Mark Wagner was a Research Scientist, and Ray Bertram was a Research Associate. Wagner and Bertram were working full-time on the Large Binocular Telescope (LBT) project. Wagner is Instrumentation Scientist for the LBT, coordinating the instrumentation efforts of the LBT partners and developing instrument support on the mountain.

Postdoctoral researchers in the Astronomy Department during this period were Dirk Grupe, Eric Monier, Nick Morgan, and Marianne Vestergaard. Matthias Dietrich, Xinyu Dai, and Oleg Gnedin arrived as postdocs in fall 2004.

Graduate students in the Astronomy department during the academic year included Deokkeun An, Nikolay Andronov, Misty Bentz, Christopher Burke, Julio Chanamé, Guo-Xin Chen, Franck Delahaye, Dale Fields, Stephan Frank, Himel Ghosh, Guangfei Jiang, Susan Kassin, Juna Kollmeier, Jennifer Marshall, Christopher Morgan, Grant Newsham, Christopher Onken, Josh Pepper, James Pizagno, Adam Steed, Jeremy Tinker, Rik Williams, Jaiyul Yoo, and Zheng Zheng. Frank, Morgan, and Newsham received masters degrees. Guo-Xin Chen received his doctorate and accepted a postdoctoral fellowship at the Harvard-Smithsonian Center for Astrophysics in the Institute of Theoretical Atomic and Molecular Physics. Susan Kassin received her doctorate and is now a postdoctoral researcher with the Deep Project at UC Santa Cruz. Zheng Zheng received his doctorate and was awarded a Hubble Fellowship; his host institution is the Institute for Advanced Study.

Steigman won the 2004 William Fowler Award of the Ohio Section of the American Physical Society. Beacom was elected a member of the Executive Committee of the Division of Astrophysics within the American Physical Society.

2 TELESCOPES AND INSTRUMENTATION

OSU has a one-quarter share of the observing time at the 2.4m and 1.3m telescopes of MDM Observatory on Kitt Peak. The other MDM partners are Dartmouth University, Columbia University, and the University of Michigan. OSU is also a partner in the Large Binocular Telescope (LBT), which is under construction at the Mount Graham International Observatory in Arizona; OSU will have a one-sixth share of the observing time. Other partners in the LBT project are the University of Arizona, astronomical consortia in Italy and Germany, and the Research Corporation.

The LBT, with twin 8.4m mirrors, will be the world's largest optical/IR telescope on a single mount, and will have a 22.8m baseline for interferometric observations. During the last year, the first primary mirror and its cell were transported to Mt. Graham and installed on the telescope. The first Large Binocular Camera (LBC) was completed in Italy, shipped to Arizona, and successfully mounted on the telescope. Extensive work was done in parallel on finishing the enclosure, installing and testing the mount control system, and doing initial work on the alignment of the telescope. By the end of the reporting period, first test images of Polaris with the LBC and uncoated primary had been obtained.

In Columbus, extensive testing and development work was carried out on the aluminizing system that OSU is providing as an in-kind contribution to the LBT. All 28 boron nitride crucible units were installed and operated with the control system; twelve test firing runs were carried out in the rented hangar space at Rickenbacker Airport. This work was completed in 2004 June; the system was then disassembled and shipped to Airzona, where the equipment arrived by the end of August.

The vacuum bell jar and mirror cell were transported to the LBT in September, where they will be reassembled for testing prior to the first aluminization of the mirror, planned for early 2005.

Highlights of the Multi-Object Double Spectrograph (MODS) project, carried out by OSU for the LBT, included an award of \$2.6M from the NSF-funded Telescope System Instrumentation Program (TSIP). This award will enable the construction of the second MODS for LBT. TSIP is a cooperative program in which recipients provide observing time to the community in return for funding to build instruments for large telescopes. During the year, the MODS structure was completed and progress continued on the polishing of the optics and on the design and fabrication of the acquisition and guiding unit and the slit mask assemblies for the spectrographs.

The two "Buckeye" Filter Wheels, 12-position remote-operated filter wheels that can accommodate up to 4-inch filters, were designed by Marshall, Kollmeier, and Derwent. Pogge designed the control system. The first Buckeye Filter Wheel was deployed at the MDM 1.3m telescope in December 2003. The second Buckeye Filter Wheel was deployed at the CTIO Yale 1m telescope in March 2004 with an Apogee AP7B CCD camera. This instrument has been in use by the SMARTS consortium since April 2004 for regular nightly operations. A web-based queue/service observing preparation system, based on our existing ANDICAM system for SMARTS, was developed by Pogge for use by all SMARTS partner astronomers assigned queue/service time on the CTIO 1m. With this work, SMARTS now has all 4 small- and medium-aperture telescopes at CTIO (0.9m, 1.0m, 1.3m, and 1.5m) in nightly operation.

A science-quality image camera (named "RETROCAM") was completed for the MDM 2.4m telescope. This camera was supervised by Morgan and is continuously available for monitoring projects, since it can be rapidly inserted into the beam of the telescope. RETROCAM is currently being used to monitor lensed QSOs (Morgan & Kochanek) and to monitor M31 for microlensing events (Gould). The Kilo-square-degree Extremely Little Telescope (KELT) started operation in September 2004. KELT, built by DePoy, Gould, Pepper, and Pogge, is a 4096×4096 commercial CCD (Apogee AP14E) camera and medium-format camera lens (Mamiya 645 format) that will be used to monitor most northern sky bright stars for planetary transits.

3 LENSING

Gould is continuing his work on microlensing, including detection of planets, microlensing observations toward M31, development of new methods to extract additional information about individual lensing events, investigation of the relation between star counts and microlensing, and measurement of the masses of nearby stars using astrometric microlensing. Gould is PI on a SIM Microlensing Key Project whose primary aim is to measure the mass function of both dark and luminous objects in the Galactic bulge.

DePoy, Dong, Gould, and Pogge are working on the μFUN collaboration to search for extra-solar planets by intensive follow-up observations of ongoing microlensing events. μFUN has substantial observing time on the SMARTS 1.3m and 1.0m, as well as time on the Wise 1m and the Palomar 1.5m.

Kochanek is PI of a large *HST* program to obtain images of 45 multiply-imaged gravitational lenses. The largest segment of the collaboration, known as CASTLES, consists of Kochanek, E. Falco (SAO), C. Impey (Steward), C. Keeton (Chicago), B. McLeod (SAO), J. Munoz (Valencia), C. Peng (Steward), H.-W. Rix (MPIA), D. Rusin (U. Penn), and J. Winn (Harvard). Recent applications of these data and their earlier *HST* imaging surveys have been to use the fundamental plane of gravitational lenses to determine the rate at which the stellar population of early-type galaxies evolve between $z = 1$ and now, and to estimate the mean mass distribution of early-type galaxies. Kochanek and collaborators are currently working on determining the deviations of galaxy potentials from ellipsoidal and the detection of high-mass substructures in the lens galaxy.

Kochanek and collaborators have started a large-scale gravitational lens monitoring program. In the South, this uses the SMARTS 1.3m; in the North, it uses a network of telescopes. They are presently monitoring roughly 25 lenses and have measured two new time delays and have observed quasar microlensing variability in a significant fraction of the systems. They will be using the data to study the halo structure of early-type galaxies, mean stellar masses, and the sizes of quasar accretion disks. The *HST* images provide the basic astrometric data needed to interpret the time delays.

With A. Dey (NOAO), W. Forman (CfA), B. Januzzi (NOAO), C. Jones (CfA), A. Kenter (CfA), and B. McNamara (Ohio U.), Kochanek and his CASTLES collaborators have obtained a 5 ksec *Chandra* image of the northern NOAO Deep Wide Field Survey (NDWFS) field, identifying 3200 X-ray point sources and 42 extended sources. In 2004, they will obtain redshifts of most of these sources as well as a large sample of galaxies in the field. The data will be used to study the nature of the X-ray sources, to measure the correlation function of AGNs near $z = 1$, and to measure the accretion and star formation history of the universe. Using the MMT and the 300 fiber Hectospec spectrograph, the ANG and Galaxy Evolution Survey (AGES) has measured 9000 galaxy and 800 quasar redshifts in the Boötes field of the NDWFS. There are well-defined samples at wavelengths from 24 microns to the X-ray region. Among the projects making use of the data are analyses of galaxy luminosity functions at all these wavelengths and studies of quasar spectral energy distributions.

4 STARS

An, Terndrup, and Pinsonneault have been engaged in a major effort to provide improved empirical calibrations of the color-temperature relations and bolometric corrections used in Pinsonneault's YREC models.

They showed in two preliminary papers that the models are well calibrated in "theory space" (that is, luminosity and effective temperature), but that the available color-temperature relations do a poor job in matching the detailed morphology of the main sequence, even in well-studied clusters. The resulting systematic errors in main-sequence fitting limit our ability to improve the Pop I and II distance scales and thereby obtain better ages for globular and open clusters. An, Terndrup, and Pinsonneault are resolving many of the difficulties by an extensive analysis of field (sub)dwarfs with good parallaxes and spectroscopic determinations of temperature and metallicity. Much of this work is being done in collaboration with R. Hanson (UCO/Lick) and J. Stauffer (IPAC/Caltech).

Delahaye and Pinsonneault are including microdiffusion processes (radiative acceleration, detailed gravitational settling) in a stellar evolution code. As a preliminary step, they have studied the impact of different sources of atomic data on radiative acceleration. They will take advantage of the new astrophysical opacities from the Opacity Project to extend the comparison with other sources of opacity data. As an application, they will study the effect of radiative levitation on horizontal branch stars and the resulting impact on the horizontal branch morphology of globular clusters.

Terndrup has continued his work on hot horizontal-branch stars in the bulge and in the local field. With Pinsonneault and other collaborators, Terndrup is engaged in new observational efforts to map the pulsation spectrum of HB pulsators, which are potentially valuable targets for the asteroseismology of evolved stars. Students Abby Daane and Naomi Brown have participated in this work.

New astrophysical opacities from the Opacity Project have been computed by M. Seaton (UCL), Delahaye, and collaborators. These incorporate inner-shell excitation data and extend into the stellar interiors. Delahaye and Pinsonneault are using the new opacities to compute radiative accelerations of elements in metal-poor halo stars, to explain anomalous abundances. These opacities and accelerations are generally applicable to stellar models. An important problem that may be at least partially solved by the new opacities is the discrepancy in element abundances in the Sun derived from non-LTE stellar atmosphere models, and those obtained by Bahcall and Pinsonneault consistent with helioseismology.

Pinsonneault, with J. Bahcall (IAS), investigated the impact of proposed new solar abundances on the properties of solar models. The new solar abundances of light metals derived from 3D hydrodynamic model atmospheres are significantly lower than previous values, which leads to a modest reduction in solar neutrinos. However, a metal-poor solar model is in poor agreement with the seismically measured depth of the solar surface convection zone. In two subsequent papers, including collaborators A. Serenelli (IAS) and S. Basu (Yale), the helioseismic properties of solar models with different heavy element abundances were examined. Low metallicity solar models combined with current input physics were found to be incompatible with seismology. Either the new abundances are in error, or there are implausibly large errors in the radiative opacities in current solar models.

Wing has used CCD imaging observations from the CTIO/SMARTS 0.9m telescope to establish a set of standard stars for his 6–color system of narrow-band classification photometry.

5 STAR CLUSTERS

Terndrup and Pinsonneault are following up on a recent demonstration that the strongly spotted stars in young clusters often have anomalous colors, particularly in the blue, that can affect the morphology of the main sequence. This suggests that the ages of some important calibrating clusters may be in error. With undergraduates Thomas Scaife and Abby Daane (now at Clemson U.), Terndrup has completed the observational phase of a program to obtain multicolor (BVRI) photometry of spotted, rapidly rotating stars in Alpha Persei. The goal is to determine correlations between rotation rates and color excursions, thereby providing a way to translate the colors of spotted stars to the right location on the main sequence.

In collaboration with R. Wyse and I. Platais (JHU) and N. Suntzeff (NOAO/CTIO), Terndrup is starting an extensive astrometric analysis of wide-field images of the globular cluster (or accreted satellite) ω Centauri. The goal will be to resolve the internal motion of subpopulations within the cluster, thus providing information on the formation of the system. To do this, they are using ground-based data to transform the extensive WF/PC2 imaging onto an all-sky reference frame; this will provide, along the way, improved calibrations of the time-dependent distortions in the *HST* WF/PC archive.

Frogel and A. Stephens (Gemini) have completed the second part of their near-IR spectroscopic survey of globular cluster giant stars. They obtained medium resolution infrared K-band spectra of 44 giants in seven heavily reddened clusters in the Galactic bulge, as well as 12 giants in ω Centauri. The heavily reddened clusters have been little studied, but knowledge of their physical characteristics is important for understanding the chemical evolution of the bulge of the Milky Way. From the equivalent widths of the Na doublet, the Ca triplet, and the CO band head, they determined the metallicity of each star and thus an average metallicity for each cluster. The average metallicities range from [Fe/H] = –1.62 for Terzan 4 to [Fe/H] = –0.36 for Liller 1.

6 INTERSTELLAR MEDIUM

Herbst is continuing his joint research programs in laboratory molecular spectroscopy and theoretical astrochemistry. With F. De Lucia (OSU physics), postdoctoral associates, and students, Herbst studies the submillimeter-wave rotational spectra of known and likely interstellar molecules. In addition, a long-running collaboration with the Cologne group is continuing in an effort to study rotational spectra in the THz region, in preparation for *SOFIA* and *Herschel*. In the past year, Herbst and De Lucia studied the spectrum of the prebiotic molecule oxiranecarbonitrile, which can now be searched for at submillimeter wavelengths in hot molecular cores. In addition, they measured and analyzed spectral lines of deuterated isotopomers of methanol, which is enabling astronomers to detect and study these species in the protostellar source IRAS 16293–2422. With the Cologne group, Herbst analyzed the THz spectrum of the simple free radical methylene (CH_2), which is likely to be abundant in an assortment of interstellar regions.

Herbst's program of modeling the gas-phase and grain-surface chemistry of interstellar clouds continues, with an emphasis on star formation regions. With postdoctoral associate Helen Roberts, Herbst has recently developed a shell model of prestellar cores that reproduces the deuterium fractionation detected in such sources. In addition, they have made the bold prediction that the triatomic molecular ion D_3^+ is the most abundant ion at the center of prestellar cores despite the fact that the elemental D/H ratio is 10^{-5}. The prediction, originally derided, is now well received since the ion HD_2^+ has already been detected and found to be of high abundance.

Based on both theoretical and experimental research, Herbst and collaborators have shown that the standard synthesis of the abundant species methyl formate in hot molecular cores is erroneous. This discovery is troubling, because our understanding of chemical processes in hot cores has been used to determine their ages. In a related study, Herbst collaborated with European investigators to show that the sulfur chemistry in hot cores, used as a clock, is not as good an indicator of age as previously supposed. Herbst, in collaboration with Le Petit and Roueff, showed that the surprisingly high abundance of the ion H_3^+ along the line of sight to ζ Persei can be explained in terms of a moderately high cosmic ray ionization rate. In collaboration with student Q. Chang (OSU physics) and the chemist I. Smith, Herbst published a new network of chemical reactions (osu.2003) to be used for modeling the gas-phase chemistry of cold interstellar regions.

With graduate student T. Stantcheva (OSU physics), Herbst utilized a detailed stochastic procedure, known as the direct master equation approach, to model surface chemistry on interstellar grains. This procedure can now be used in large gas-grain chemical models of dense cold sources. Looking more carefully at the formation of molecular hydrogen on grains in diffuse clouds, Herbst and Chang have developed a Monte Carlo procedure that allows them to study the reaction on realistic irregular and highly heterogeneous surfaces. The somewhat surprising result is that the efficiency of the process is increased when compared with simple pristine models of the surface.

Sellgren concentrated her research efforts on mid-IR spectroscopy from the newly launched *Spitzer Space Telescope*. Her first *Spitzer* paper, written in collaboration mainly with M. Werner (JPL) and K. Uchida (Cornell), is on the photodissociation region NGC 7023. This paper presents long-slit spectroscopy that shows spatial variations in the strengths and widths of the aromatic emission features and discovers new emission features, due to either tiny dust grains or large aromatic molecules. Sellgren is currently working on a follow-up paper, concentrating on the contrast between features at 16.4 μm, apparently emitted by a non-equilibrium process such as tiny grain emission or molecular fluorescence, and the new 19.0 μm feature, which appears to be in thermal equilibrium with the stellar radiation field.

Sellgren and Yoo are analyzing ground-based narrowband images at 2.2, 3.3, and 3.6 μm of NGC 7023. The goal is to interpolate between continuum images at 2.2 and 3.6 μm to obtain a more accurate continuum image at 3.3 μm, to be compared to the 3.3 μm image of the 3.3 μm aromatic emission feature plus its underlying continuum. Variations in [2.2 μm] – [3.6 μm] and the 3.3 μm feature-to-continuum ratio are currently being analyzed.

7 MILKY WAY

Sellgren is part of a team headed by S. Stolovy (Spitzer Science Center/Caltech) that will image several square degrees toward the Galactic Center, using the IRAC mid-infrared camera on *Spitzer Space Telescope*. Observations are scheduled for spring 2005. Sellgren's interest is in the stellar populations in the Galactic Center, and searching for mid-infrared excess emission over the stellar photosphere. Observations have been obtained of the central parsec of the Galaxy, aimed a searching for mid-infrared flare activity from Sgr A*, the counterpart to the several million solar mass black hole at the center of the Galaxy. These observations, scheduled to be simultaneous with *Chandra* and *HST*/NICMOS observations, are being analyzed. If a flare is detected, this will provide the first mid-infrared energy distribution of Sgr A* activity, which in turn will constrain the emission mechanism.

Gould is continuing his studies of Galactic structure, primarily focusing on using the Gould & Kollmeier "SDSS $\cap$ USNO-B" proper motion catalog to probe the stellar halo.

8 GALAXIES

Kassin completed her dissertation study of the stellar and dark matter content of 40 nearby spiral galaxies, using optical and near-IR images acquired as part of the OSU Bright Spiral Galaxies Survey. This work was done in collaboration with R. deJong (STScI) and Pogge. For each galaxy, she used the color relations of Bell & deJong to convert K-band surface brightness into a stellar mass density, constructing azimuthally averaged mass-density profiles for the galaxies. Integrating these with disk and bulge models produced the stellar-mass component of the rotation curve; comparison with the observed gas rotation curve resulted in an empirical estimate of the radial distribution of dark matter.

Yoo and Miralda-Escudé have been developing a code for computing the evolution of substructure in dark matter halos. With Morgan, they are applying this code to the dynamical evolution of hypothetical black holes formed in halo centers as these halos merge. A particular goal is to determine the largest black hole masses we should observe at present in the most massive halos (that is, the center of a rich cluster of galaxies). Miralda-Escudé is participating in a related project with L. Ferrarese (Herzberg Institute), in which *HST* STIS spectra of four central cluster galaxies were acquired to measure the velocity profiles in their nuclear emission-line disks. These galaxies are good candidates for containing the most massive black holes.

With undergraduate student R. Vincent (OSU physics), Ryden has investigated the dependence of intrinsic galaxy shape on both luminosity and surface brightness profile type. Using a sample of over 70,000 galaxies from the Sloan Digital Sky Survey (SDSS), they have found that in their inner regions, galaxies with de Vaucouleurs profiles are rounder than exponential galaxies of the same luminosity. However, when the shape is estimated from the axis ratio of the 25 mag/arcsec^2 isophote, the de Vaucouleurs galaxies, at this low surface brightness, are flatter than exponential galaxies of the same luminosity. For a given surface brightness profile type, bright galaxies are rounder than faint galaxies.

Ryden and graduate student F. Kuehn (OSU physics) are using SDSS data to investigate the morphology–density relation for galaxies. Preliminary results indicate that although de Vaucouleurs galaxies tend to be rounder in locally overdense regions, no such tendency is seen for galaxies with more nearly exponential profiles.

Ryden is continuing her study of the intrinsic shapes of galactic disks by analyzing shape information from the 2MASS Large Galaxy Atlas. Late-type spirals have a distribution which is consistent with their being thin, perfectly axisymmetric disks; early-type spirals have much thicker, nonaxisymmetric disks.

9 AGN & QUASARS

Onken, Peterson, and Pogge are working with L. Ferrarese (Herzberg Institute), M. Malkan (UCLA), D. Merritt (RIT), M. Vestergaard (Steward), A. Wandel (Hebrew U.) and H. Netzer, D. Maoz, and S. Kaspi (Tel Aviv U.) to improve measurements of the masses of black holes in AGNs through reverberation techniques. They have reduced the random component of the measurement to about the 30% level. They have also shown that active galaxies show the same strong correlation between bulge velocity dispersion and black hole mass that is found in quiescent galaxies, and they use this correlation to calibrate the reverberation mapping based mass scale. Scatter about this relationship shows that the reverberation-based masses have systematic uncertainties smaller than a factor of three. The new results are being used in additional recalibration of the broad-line region radius/luminosity relation and the AGN mass/luminosity relation.

Bentz, Peterson, Pogge, and Vestergaard are working on an *HST* and ground-based project to image reverberation-mapped AGNs, with the purpose of determining the host galaxy contribution to their optical fluxes.

As part of his dissertation work, Onken is working with Peterson, Pogge, and collaborators on *HST* and ground-based long-slit spectroscopy of the Ca II triplet lines in NGC 4151. These data are being modeled with stellar dynamical codes in an effort to measure the central black hole mass. The goal of this project is to compare directly the black hole mass obtained by stellar dynamical methods with that obtained by reverberation mapping techniques. As a complement to this work, undergraduate student K. Metzroth is working with Peterson and Onken on a thorough reanalysis of archival reverberation data on NGC 4151, in an attempt to improve the reverberation-based black hole mass measurement for this galaxy. Another undergraduate, C. Kuehn, is working with Peterson to quantify systematic errors that can affect reverberation-based black hole mass estimates.

Bentz, Onken, Peterson, Pogge, and collaborators are working with A. Laor (Technion, project PI) on a combined *HST* and ground-based reverberation program on the very low luminosity Seyfert 1 galaxy NGC 4395. The data from this large program are currently being analyzed.

Denney, Onken, and Peterson are analyzing data obtained in a 10-night reverberation mapping pilot study. The goals are (1) to determine quality and repeatability of the data obtained with the available CCD spectrograph on the MDM 1.3m telescope and (2) to determine whether a sample of low luminosity AGNs shows sufficient short-term variability that a long program with nightly resolution is likely to be successful.

Vestergaard and Peterson are examining archival UV and optical spectra of NGC 5548 in order to determine the characteristics of Fe II in this source. They find that Fe II varies in response to continuum variations, with an amplitude approximately the same as that of the Hβ emission line.

Grupe and Mathur worked on the analysis of *XMM* X-ray data of high redshift quasars. They found that in radio-loud $z = 4$ quasars, the intrinsic absorption is a factor of 10 less than that previously derived from ASCA observations.

Grupe and Mathur found that the Narrow Line Seyfert 1 (NLS1) galaxies in the soft-X-ray selected sample of Grupe et al. deviate from the $M(BH) - \sigma$ relation relation found in nearby galaxies and AGN; the NLS1 galaxies have larger bulge stellar velocity dispersions than expected for their black hole mass. The NLS1 galaxies with the largest deviation are those with the highest Eddington ratio $L/L(Edd)$, and hence the fastest black hole growth rate. This result supports the hypothesis that NLS1 galaxies are active galaxies in an early state of their development.

Grupe has studied the statistical properties of a sample of soft-X-ray selected AGN. Half of these sources are Narrow Line Seyfert 1 galaxies characterized by relatively narrow Hβ lines, strong Fe II emission, weak [O III] emission, and steep soft X-ray spectra. Principal component analysis indicates that the observed properties of these sources are governed by the Eddington ratio.

Pogge, Ghosh, Mathur, P. Martini (OCIW/CfA), and J. Shields (Ohio U.) are working on a 40 ksec *Chandra* program to investigate the X-ray properties of a sample of Seyfert 2 galaxies that have no hidden or direct-light broad Hα emission lines and no spectroscopic evidence of dust extinction toward the nucleus on 100 pc scales. This experiment is intended to test whether these active nuclei are strongly soft-X-ray absorbed or even Compton thick, or if they are in fact unabsorbed in X-rays. If they are unabsorbed, these could be candidates for true Seyfert 2 nuclei: *viz.*, objects with little or no broad-line region, not because the broad lines are obscured but because they are absent altogether. Initial data have been acquired; analysis and modeling are in progress.

Grupe and Mathur, in collaboration with S. Komossa (MPE Garching), studied the *XMM* X-ray data of the Narrow Line Seyfert 1 galaxy Mkn 1239, a highly optically polarized AGN with an unusual X-ray spectrum. They found that Mkn 1239 has an exceptionally steep soft X-ray spectrum. It also has a very strong Ne IX X-ray emission line; this line is strongly detected because of the highly absorbed continuum. Most likely, the direct light path to the X-ray source is blocked, but the X-rays we observe are scattered light from matter above the absorber, a picture that is supported by the high wavelength-dependent optical polarization.

Mathur and Fields are using coordinated *Chandra*, *HST*, and *FUSE* data to determine metallicity in a Narrow Line Seyfert 1 galaxy.

Pogge, along with M. Kadler (MPIfR) and colleagues, studied the radio, optical, and X-ray emission from the nuclear jet in the nearby elliptical galaxy NGC 1052, using *Merlin*, *Hubble*, and *Chandra* data. The bright knots seen in all three wavebands from the jet are inconsistent with synchrotron emission, instead showing a hot (0.5 keV) thermal X-ray spectrum. The X-ray knots are offset and apparently surround the compact radio knots, while the optical emission is roughly cospatial with the inner part of the X-ray emission, consistent with these coming from hot working surfaces where the radio-emitting plasma is impacting the surrounding ISM of the host galaxy.

Steed and Weinberg completed a paper presenting a theoretical framework for calculating the joint evolution of quasar and supermassive black hole populations. The central actor in this framework is the accretion rate distribution, the probability $p(\dot{m}|M,z)$ that a black hole of mass M is accreting at a rate $\dot{m}$, in Eddington units, at redshift z. Modeling the observed optical luminosity evolution shows that either the typical value of $\dot{m}$ has declined toward low redshift or p has evolved in a way that preferentially suppresses accretion onto massive black holes at low redshift. Future modeling that starts from the present day black hole mass function and works backward, with constraints from the observed luminosity function, should be a powerful method for discriminating among scenarios for black hole and quasar evolution.

Frank and Osmer are using data from the CDFN 2 megasecond survey and related multi-wavelength observations to investigate the nature of the intrinsic SEDs of AGNs, how they vary with redshift and luminosity, and how the data may be affected by obscuration and contributions from starbursts. Their goal is to find a simple, effective way to use multi-wavelength data to characterize the intrinsic SEDs of AGNs. Shifting the observational data to the emitted frame of the AGN provides a direct way to visualize the effects of obscuration and possible changes in the underlying SED from object to object. This will assist in understanding the evolution of AGNs and their contribution to the X-ray background. Their preliminary findings show that four classes of SEDs are apparent: 1) luminous unobscured AGNs, 2) red, X-ray flat AGNs, 3) red, X-ray steep AGNs, and 4) "normal" galaxies. The first group has more objects at $z > 1.2$ than at $z < 1.2$, while the three other groups are predominantly at $z < 1.2$.

Kollmeier and Miralda-Escudé developed a model to explain the quasar phenomenon based on supplying matter to an accretion disk around a black hole from stars that are perturbed into radial orbits and collide with the disk. The stars are gradually slowed until they are embedded within the disk and are destroyed, making their matter available for accretion. This model may be able to explain the observed correlation between the black hole mass and the velocity dispersion of the stellar system around it. Several processes may cause a quasar to switch off after a strong nuclear starburst near the quasar: evolution of the stellar population, depletion of the loss-cone, or a gradual decrease in the rate of stellar captures by the accretion disk as the black hole grows in mass, eventually causing a switch form a thin accretion disk to a low-efficiency advection disk.

When the Lyα forest is observed on a line of sight passing near a quasar, the Lyα absorption at the quasar's redshift could be either decreased owing to the quasar flux or increased due to an enhanced intergalactic gas density near the quasar. The decrease in absorption due to the quasar flux could be reduced if the quasar radiation is anisotropic or strongly time variable. Miralda-Escudé and Jiang are analyzing simulations to measure the increased Lyα absorption near halos of fixed mass as a function of impact parameter and redshift difference. The results can be used to estimate the expected effect from the increased gas density if quasars are assumed to be located in halos of a certain mass.

Pradhan, Nahar, and A. Sigut (U. Western Ontario) have computed theoretical iron emission line strengths for physical conditions typical of AGN with Broad Line Regions. The non-LTE models include a new extensive treatment of radiative transfer in the Fe III ion, complementing the Fe II emission line strengths predicted in their earlier work. The new results satisfactorily reproduce the empirical UV Fe III emission line template of

Vestergaard & Wilkes for the prototypical Narrow Line Seyfert 1 galaxy I Zw 1. They also study the role of Fe–H charge exchange and of variations in turbulent velocities and iron abundance, and they carry out Monte Carlo simulations in order to demonstrate the effect of uncertainties in atomic data on the computed spectra.

Pradhan and collaborators used near-infrared spectroscopy to correlate the kinematics and excitation mechanisms of H_2 and [Fe II] gas in a sample of mostly Seyfert 1 galaxies. They deduced that a combination of X-ray heating, shocks driven by the radio jet, and circumnuclear star formation contributes, in different proportions, to the H_2 and [Fe II] lines observed. This work helps to explore the starburst–AGN connection via stellar and non-stellar origins of emission lines.

10 LARGE–SCALE STRUCTURE & COSMOLOGY

Miralda-Escudé and N. Gnedin (U. Colorado) are continuing work on the expansion of ionized bubbles during the reionization of the universe, using simulations of very large box size. They are developing a method to treat the density fluctuations responsible for the Lyα forest statistically, in order to work with large box simulations to follow the evolution of the large-scale ionized regions.

Mathur and Williams have been working on understanding the low redshift warm-hot intergalactic medium using high resolution spectroscopy with *Chandra* and *FUSE*.

Weinberg, Zheng, Tinker, and Yoo, with various collaborators, investigated numerous aspects of galaxy clustering. These studies included an analysis of theoretical predictions of the Halo Occupation Distribution (HOD), focused on the distinction between the central galaxies of dark matter halos and their satellites; determination of HODs as a function of galaxy luminosity and color, from measurements of the galaxy correlation function in the SDSS; development of accurate numerical and analytic methods for predicting redshift-space distortions and galaxy-galaxy lensing given specified cosmological parameters and HODs; and investigation of the ability of these and other clustering measurements to constrain separately galaxy bias and cosmological parameters. The correlation function modeling is the first step of a broader program of applying these methods to SDSS data.

Weinberg, in collaboration with D. Keres and N. Katz (U. Mass.) and R. Davé (Arizona), investigated the physics of gas accretion by galaxies in hydrodynamic cosmological simulations. They showed that, in contrast to conventional analytic models, a large fraction of gas in simulations accretes onto galaxies without ever being shock heated to the virial temperature of the host dark matter halos. Virial shocks and hot gas halos develop only around relatively massive galaxies, and cooling in these hot halos may be suppressed by AGN feedback or thermal conduction (neither of which is included in the simulations). If hot accretion is suppressed in the real universe, it would remove many of the main discrepancies between current theories of galaxy formation and observed properties of galaxies.

11 ATOMIC ASTROPHYSICS

The atomic astrophysics group at OSU, including Pradhan, Nahar, Chen, Delahaye, and J. Oelgoetz (OSU chemical physics), is part of the international Iron Project (IP) team, with members from the UK, Germany, France, Canada, Venezuela, and the US. The IP team produces results on collisional excitation, photoionization, and fine structure bound-bound transitions for analysis of astrophysical spectra of iron-peak elements. The IP complements and improves on the work of the earlier Opacity Project, by implementing relativistic effects in Breit-Pauli approximations with an R-matrix approach. This allows highly accurate and large-scale calculations for both atomic radiative and collisional processes.

An extensive set of transition probabilities for Fe IV has been submitted by Nahar and Pradhan. Fe IV is a difficult ion to study because of its strong electron-electron correlation effects. Calculations were carried out in LS coupling that yielded 1798 LS bound states with $n \leq 11$ and $\ell \leq 9$ and 138,121 dipole allowed transitions. Algebraic transformation of the LS multiplets resulted in a total of 712,120 dipole allowed fine structure transitions for Fe IV affecting the features of monochromatic opacity.

After finding the importance of core excitations to highly excited states in photoionization of Fe XVII, the atomic astrophysics group has carried out an extensive new calculation using a large wavefunction expansion including 60 fine structure levels of the core ion. Computation is near completion with Fe XVII levels going up to $J = 5$.

Nahar calculated photoionization cross sections of the highly charged ion Ar XIII, showing strong features at very high energies where the core can be excited to $n = 3$ states. The resonant features are much more extensive than those at lower energies, affecting the photoionization rate considerably at high energies. Such features were unexpected before the calculations since there is a large energy gap between the $n = 3$ and $n = 2$ states, indicating possible weak coupling. Two other isoelectronic ions, Ca XVII and Fe XXI, are being studied in detail.

Nahar is calculating total and level-specific recombination rate coefficients, as well as photoionization cross sections, of He- and Li-like atoms, going up to nickel. Relativistic effects are included for these ions. These data are needed to analyze X-ray results from *Chandra* and *XMM–Newton*.

Nahar is continuing her collaboration with the experimental group of R. Phaneuf at Reno/Berkeley, measuring precise photoionization cross sections at the Advanced Light Source in Berkeley. The experimental group presented the comparison of their measured photoionization cross sections with her results, finding reasonably good agreement.

The unified treatment of Nahar and Pradhan, which accounts for both the radiative recombination (RR) and dielectronic radiation (DR) in a unified manner, is being used for calculations of the highly charged and complex ions Ca XV and Fe XXI. This follows from the study of Ar XIII, performed by Nahar, which shows a unique feature not seen before. Typically, the total recombination rate coefficient is high at low temperatures due to RR, and decreases monotonically with temperature; at high temperatures the total rate rises again to form a DR "bump", then decays exponentially. However, if autoionizing resonances are present, there could be a low-temperature bump. Instead of one or two bumps, Ar XIII exhibits four, two at low and two at high temperatures. Recombination of Fe XXI is of interest since the cross sections have been measured recently at the Heidelberg ion storage ring. Preliminary calculations indicate relativistic effects will be important in the low energy regime.

The atomic astrophysics group has been involved in computing extensive sets of transition probabilities using the relativistic Breit–Pauli approximation. The Breit–Pauli R–matrix (BPRM) method, developed under the Iron Project, is the only currently available method to consider large numbers of transitions in an *ab initio* manner to yield many energy eigenvalues of the Hamiltonian matrix with consistent accuracy. In addition, the atomic structure code SUPERSTRUCTURE was extended considerably to include forbidden transitions of the electric quadrupole, electric octupole, magnetic dipole, and magnetic quadrupole type. Nahar's work is in progress to obtain forbidden transition probabilities of Fe IV.

Extensive new code development was done during the past year by Chen. Inclusion of the full two-body Breit interactions in the BPRM code is near completion, in collaboration with W. Eissner (Stuttgart). Although the interactions are often weak, they can make significant contributions to transitions in heavy atomic systems and highly charged ions; for instance, the intercombination transitions. Considerable efforts have been made to include these contributions in calculations in the close coupling approximation.

Oelgoetz and Pradhan developed a new code to simulate time-dependent X-ray spectra of He-like ions in order to study transient plasmas such as flares in accretion disks, stellar coronae, and laboratory fusion devices. Spectral simulations may be carried out as a function of temperature, density, and ionization structure, with or without a radiation field.

12 PARTICLE ASTROPHYSICS

Steigman continued his research using primordial nucleosynthesis to constrain nonstandard models of particle physics and cosmology. In work done with J. Keller (NCSU), he presented simple but accurate analytic fits to the BBN predictions. These fits can be used to test new models in which the universal expansion rate and/or the universal lepton asymmetry depart from the predictions of the standard model.

Steigman, Walker, and former OSU physics student M. Kaplinghat (now at UC Irvine) calculated the background of relic neutrinos from Type II supernovae. The SuperK collaboration has provided a new observational upper bound to this flux which is very close to the predicted value. Steigman, Walker, Kaplinghat, and L. Strigari (OSU physics) are extending the earlier work, using very recent results on the magnitude and evolution of the universal star formation rate to calculate the fluxes and event rates expected at SuperK and KamLAND. They conclude that SuperK is on the verge of detecting the supernova relic neutrino background, and that the event rate is within the reach of the KamLAND detector. Further, they show that the nondetection (so far) of these relic neutrinos leads to a reduction in the range of star formation rates allowed by the SDSS data.

Beacom, with N. Bell (Fermilab), D. Hooper (Wisconsin), S. Pakvasa (Hawaii), and T. Weiler (Vanderbilt), has considered how well the flavor ratios of astrophysical neutrino fluxes can be measured. These ratios, comparing the electron neutrino, muon neutrino, and tau neutrino components of the total flux, will be measurable in future neutrino detectors. In a crude sense, these flavor ratios are analogous to polarizations of electromagnetic radiation, and they also reveal more about sources than just intensities. Typical expected astrophysical sources (for example, AGNs and GRBs) should produce neutrinos in the flavor ratios $1:2:0$. Recent terrestrial measurements of neutrino oscillation parameters imply that oscillations will quickly transform those ratios into $1:1:1$. However, in scenarios with new physics, these flavor ratios can be altered. Beacom and collaborators have shown that a wide variety of neutrino decay scenarios would lead to flavor ratios of either $0:1:1$ or $5:1:1$, depending on the sense of the neutrino mass hierarchy. Such strong deviations from the standard value would be easily detectable, and if not seen, would improve the limits on the neutrino lifetime by about eight orders of magnitude. More subtle alterations of the flavor ratios may arise in another new-physics scenario, in which sterile neutrinos are coupled to the standard-model neutrinos by very tiny mass-squared splittings.

PUBLICATIONS

Abazajian, K., et al. (153 authors including **D. H. Weinberg**) 2004, "The Second Data Release of the Sloan Digtal Sky Survey," AJ, 128, 502

Abe, F., et al. (33 authors including **D. M. Terndrup**) 2003, "Probing the Atmosphere of a Solar-Like Star by Galactic Microlensing at High Magnification," A&A, 411, L493

Aldcroft, T. L., Siemiginowska, A., Elvis, M., **Mathur, S.**, Nicastro, F. & Murray, S. S. 2003, "*Chandra* Observation of 3C 212: A New Look at the X–Ray and Ultraviolet Absorbers," ApJ, 597, 751

An, J. H. & **Sellgren, K.** 2003, "Spatial Separation of the 3.29 Micron Emission Feature and Associated 2 Micron Continuum in NGC 7023," ApJ, 599, 312

An, J. H., et al. (16 authors including **A. Gould**) 2004, "The Anomaly in the Candidate Microlensing Event PA–99–N2," ApJ, 601, 845

An, J. H., et al. (16 authors including **A. Gould**) 2004, "The POINT–AGAPE Survey – I. The Variable Stars in M31," MNRAS, 351, 1071

Anderson, S. F., et al. (28 authors including **D. H. Weinberg**) 2003, "A Large, Uniform Sample of X-Ray–Emitting AGNs: Selection Approach and an Initial Catalog from the *Rosat* All–Sky and Sloan Digital Sky Surveys," AJ, 126, 2209

Andronov, N. & **Pinsonneault, M. H.** 2004, "Stellar Models of Evolved Secondaries in Cataclysmic Variables," ApJ, 614, 326

Andronov, N., **Pinsonneault, M.** & **Terndrup, D.** 2003, "Formation of Blue Stragglers in Open Clusters," AAS 203.85.04 (abstract), BAAS, 35, 1343

Bahcall, J. N. & **Pinsonneault, M. H.** 2004, "What Do We (Not) Know Theoretically about Solar Neutrino Fluxes?" Phys Rev Lett, 92, 121301

Bahcall, J. N., Serenelli, A. M. & **Pinsonneault, M. H.** 2004, "How Accurately Can We Calculate the Depth of the Solar Convective Zone?" ApJ, 614, 464

Beacom, J. 2004, "Neutrinos in Cosmology and Astrophysics" (abstract), APS Apr04, L4 005

Beacom, J. F., Bell, N. F. & Dodelson, S. 2004, "Neutrinoless Univese," Phys Rev Lett, 93, 121302

Beacom, J. F., Bell, N. F., Hooper, D., Learned, J. G., Pakvasa, S. & Weiler, T. J. 2004, "Pseudo–Dirac Neutrinos: A Challenge for Neutrino Telescopes," Phys Rev Lett, 92, 011101

Beacom, J. F., Bell, N. F., Hooper, D., Pakvasa, S. & Weiler, T. J. 2003, "Measuring Flavor Ratios of High-Energy Astrophysical Neutrinos," Phys Rev D, 68, 093005

Beacom, J. F., Bell, N. F., Hooper, D., Pakvasa, S. & Weiler, T. J. 2004, "Sensitivity to θ_{13} and δ in the Decaying Astrophysical Neutrino Scenario," Phys Rev D, 69, 017303

Behnke, M., Medvedev, I., Winnewisser, M., De Lucia, F. C. & **Herbst, E.** 2004, "The Millimeter– and Submillimeter–Wave Spectrum of Oxiranecarbonitrile," ApJS, 152, 97

Bennett, D. P., et al. (22 authors including **A. Gould**) 2004, "The Microlensing Planet Finder," AAS 204. 11.06 (abstract), BAAS, 36, 675

Bentz, M. C., Hall, P. B. & **Osmer, P. S.** 2004, "Nitrogen–Enriched Quasars in the Sloan Digital Sky Survey First Data Release," AJ, 128, 561

Bentz, M. & **Osmer, P.** 2004, "A Search for Nitrogen Enriched Quasars in the SDSS Early Data Release," in *AGN Physics with the Sloan Digital Sky Survey*, ed. G.T. Richards & P.B. Hall, ASP Conf. Ser., 311, 289

Bentz, M. C. & **Osmer, P. S.** 2004, "A Search for Nitrogen–Enriched Quasars in the Sloan Digital Sky Survey Early Data Release," AJ, 127, 576

Bentz, M. C., **Osmer, P. S.** & **Weinberg, D. H.** 2004, "Bright Lyman Break Galaxy Candidates in the Sloan Digital Sky Survey First Data Release," ApJ, 600, L19

Blanc, G., et al. (61 authors including **A. Gould** & **D. Graff**) 2004, "Type Ia Supernova Rate at a Redshift of ~ 0.1," A&A, 423, 881

Blum, R. D., Ramírez, S. V., **Sellgren, K.** & Olsen, K. 2003, "Really Cool Stars and the Star Formation History at the Galactic Center," in *Galactic Center Workshop 2002 – The Central 300 Parsecs of the Milky Way*, AN Supp, 324, 247

Blum, R. D., Ramírez, S. V., **Sellgren, K.** & Olsen, K. 2003, "Really Cool Stars and the Star Formation History at the Galactic Center," ApJ, 597, 323

Bond, H. E., Henden, A., Levay, Z. G., Panagia, N., Sparks, W. B., Starrfield, S., **Wagner, R. M.**, Corradi, R.L.M. & Munari, U. 2004, "*Hubble Space Telescope* Observations of the Light Echoes around V838 Monocerotis," in *Asymmetrical Planetary Nebulae III: Wings, Structure and the Thunderbird*, ed. M. Meixner, J.H. Kastner, B. Balick & N. Soker, ASP Conf. Ser., 313, 543

Boyd, R. N., Rauscher, T., Reitzner, S. D. & Vogel, P. 2003, "Observing Nucleon Decay in Lead Perchlorate," Phys Rev D, 68, 074014

Brand, K., et al. (18 authors including **C. Kochanek** & **C. R. Watson**) 2004, "Tracing the Accretion History of the Universe Using X–Rays from the Red Galaxy Population in the Bootes Field," AAS 204.48.12 (abstract), BAAS, 36, 747

Bruenken, S., Michael, E. A., Lewen, F., Giesen, Th., Ozeki, H., Winnewisser, G., Jensen, P. & **Herbst, E.** 2004, "High–Resolution Terahertz Spectrum of CH_2: Low J Rotational Transitions near 2 THz," Can J Chem, 82, 676

Burke, C. J., Gaudi, B. S., **DePoy, D. L.**, **Pogge, R. W.** & **Pinsonneault, M. H.** 2004, "Survey for Transiting Extrasolar Planets in Stellar Systems. I. Fundamental Parameters of the Open Cluster NGC 1245," AJ, 127, 2382

Burke, C. J., **Pinsonneault, M. H.** & Sills, A. 2004, "Theoretical Examination of the Lithium Depletion Boundary," ApJ, 604, 272

Chanamé, J. & **Gould, A.** 2004, "Disk and Halo Wide Binaries from the Revised Luyten Catalog: Probes of Star Formation and MACHO Dark Matter," ApJ, 601, 289

Chen, G.-X. & Eissner, W. 2004, "On the Development of a Full Breit–Pauli R–Matrix Code" (abstract), Bull APS, DAMOP 35, D1 109

Chen, X. & **Miralda–Escudé, J.** 2004, "The Spin–Kinetic Temperature Coupling and the Heating Rate Due to Lyα Scattering before Reionization: Predictions for 21 Centimeter Emission and Absorption," ApJ, 602, 1

Cohn, J. D. & **Kochanek, C. S.** 2004, "The Effects of Massive Substructures on Image Multiplicities in Gravitational Lenses," ApJ, 608, 25

Dalal, N. & **Kochanek, C. S.** 2003, "Detection of CDM Substructure," Nuc Phys B Supp, 124, 144

Darnley, M. J., et al. (19 authors including **A. Gould**) 2004, "Classical Novae from the POINT–AGAPE Microlensing Survey of M31 – I. The Nova Catalogue," MNRAS, 353, 571

de Jong, R. S., **Kassin, S.**, Bell, E. F. & Courteau, S. 2003, "Properties of Dark Matter Halos in Disk Galaxies," in IAU Symp. 220: *Dark Matter in Galaxies*, ed. S.D. Ryder, D.J. Pisano, M.A. Walker & K.C. Freeman (Astron. Soc. Pacific), p. 281

Delahaye, F., **Chen, G.**, **Nahar, S.**, **Oelgoetz, J.**, **Pradhan, A.**, Eissner, W., Sigut, A. & Zhang, H. 2004, "The Iron Project and the RMAX Project: Collisional and Radiative Atomic Processes in Fe–Peak Elements and Astrophysics Applications" (abstract), Bull APS, DAMOP 35, J1 038

Delahaye, F., **Nahar, S. N.**, **Pradhan, A. K.** & Zhang, H. L. 2004, "Resolution and Accuracy of Resonances in R–Matrix Cross Sections," J Phys B, 37, 2585

Delahaye, F. & **Pinsonneault, M. H.** 2003, "Comparison of Radiative Accelerations Obtained with Atomic Data from OP and OPAL," AAS 203.85.05 (abstract), BAAS, 35, 1343

Delahaye, F. & **Pradhan, A. K.** 2003, "Relativistic and Resonance Effects in Excitation and X–Ray Spectra of He–Like Ions," AAS 203.87.05 (abstract), BAAS, 35, 1347

D'Elia, V., Fiore, F., Elvis, M., Cappi, M., **Mathur, S.**, Mazzotta, P., Falco, E. & Cocchia, F. 2004, "The Faint X-Ray Source Population near 3C 295," A&A, 422, 11

DePoy, D.L., **Atwood, B.**, **Belville, S.R.**, **Brewer, D.**, **Byard, P.L.**, **Derwent, M.**, **Marshall, J.L.**, **Mason, J.**, **Morgan, C.**, **O'Brien, T.P.**, **Osmer, P.S.**, **Pappalardo, D.P.**, **Pogge, R.W.**, **Steinbrecher, D.**, **Teiga, E.** & **Weinberg, D.H.** 2004, "A Multi–Object Double Spectrograph for the Large Binocular Telescope," in *Ground-Based Instrumentation for Astronomy*, ed. A.F.M. Moorwood & M. Iye, SPIE, 5492, 452

Dietrich, M., Hamann, F., Appenzeller, I., **Vestergaard, M.** & Wagner, S. 2004, "High–Redshift Quasars and Early Star Formation," in *Origin and Evolution of the Elements*, ed. A. McWilliam & M. Rauch (Carnegie Observatories: www.ociw.edu)

Dietrich, M., Hamann, F. & **Vestergaard, M.** 2004, "High Redshift Quasars as Probes of Early Star Formation," in *AGN Physics with the Sloan Digital Sky Survey*, ed. G.T. Richards & P.B. Hall, ASP Conf. Ser., 311, 403

Dijkstra, M., Haiman, Z., Rees, M. J. & **Weinberg, D. H.** 2004, "Photoionization Feedback in Low–Mass Galaxies at High Redshift," ApJ, 601, 666

Gallo, L. C., Boller, Th., Brandt, W. N., Fabian, A. C. & **Grupe, D.** 2004, "An Intense Soft Excess and Evidence for Light Bending in the Luminous Narrow–Line Quasar PHL 1092," MNRAS, 352, 744

Gaudi, B. S. & **Han, C.** 2004, "The Many Possible Interpretations of Microlensing Event Ogle 2002–BLG–055," ApJ, 611, 528

Gezari, S., Halpern, J. P., Komossa, S., **Grupe, D.** & Leighly, K. M. 2004, "Erratum: "Follow-up *Hubble Space Telescope*/Space Telescope Imaging Spectroscopy of Three Candidate Tidal Disruption Events (ApJ, 592, 42 [2003])," ApJ, 601, 1159

Gezari, S., Halpern, J., Komossa, S., **Grupe, D.** & Leighly, K. 2004, "Follow-Up STIS Spectroscopy of Three Candidate Tidal Disruption Events," in *Coevolution of Black Holes and Galaxies*, ed. L.C. Ho (Carnegie Observatories: www.ociw.edu)

Gould, A. 2004, "Resolution of the MACHO–LMC–5 Puzzle: The Jerk–Parallax Microlens Degeneracy," ApJ, 606, 319

Gould, A. 2004, "Erratum: "Stellar Halo Parameters from 4588 Subdwarfs" (ApJ, 583, 765 [2003])," ApJ, 607, 653

Gould, A., Bennett, D. P. & Alves, D. R. 2004, "The Mass of the MACHO–LMC–5 Lens Star," ApJ, 614, 404

Gould, A. & **Chanamé, J.** 2004, "New *Hipparcos*–Based Parallaxes for 424 Faint Stars," ApJS, 150, 455

Gould, A. & **Kollmeier, J. A.** 2004, "Proper–Motion Catalog from SDSS $\cap$ USNO–B," ApJS, 152, 103

Green, P. J., Aldcroft, T. L., Silverman, J. D., Kim, D.-W., Barkhouse, W. A., Cameron, R. A., **Ghosh, H.**, Jannuzi, B., Mossman, A. & Wilkes, B. J. 2003, "Optical vs. X–Ray Evidence for Absorption in the ChaMP," AAS 203.63.01 (abstract), BAAS, 35, 1309

Green, P. J., et al. (33 authors including **H. Ghosh** & **S. Mathur**) 2004, "The *Chandra* Multiwavelength Project: Optical Follow-Up of Serendipitous *Chandra* Sources," ApJS, 150, 43

Grupe, D. 2004, "Multiwavelength Studies of AGN," in *Toward an International Virtual Observatory*. ed. P.J. Quinn & K.M. Gorski (Springer), p. 283

Grupe, D. 2004, "A Complete Sample of Soft X-Ray–Selected AGNs. II. Statistical Analysis," AJ, 127, 1799

Grupe, D., Leighly, K. M., Burwitz, V., Predehl, P. & **Mathur, S.** 2004, "*Chandra* Observations of he Narrow–Line Seyfert 1 Galaxy RX J2217.9–5941," AJ, 128, 1524

Grupe, D. & **Mathur, S.** 2004, "$M_{\rm BH} - \sigma$ Relation for a Complete Sample of Soft X-Ray–Selected Active Galactic Nuclei," ApJ, 606, L41

Grupe, D., **Mathur, S.** & Komossa, S. 2004, "Markarian 1239: A Highly Polarized Narrow–Line Seyfert 1 Galaxy with a Steep X–Ray Spectrum and Strong Ne IX Emission," AJ, 127, 3161

Grupe, D., **Mathur, S.**, Wilkes, B. & Elvis, M. 2004, "*XMM–Newton* Observations of Two High–Redshift Quasars: RX J1028–0844 and BR 0351–1034," AJ, 127, 1

Grupe, D., Wills, B. J., Leighly, K. M. & Meusinger, H. 2004, "A Complete Sample of Soft X-Ray–Selected AGNs. I. The Data," AJ, 127, 156

Harmon, R. O., Cademartori, E. A. & **Terndrup, D. M.** 2003, "Starspots on AP 063 and AP 117 Imaged via Matrix Light–Curve Inversion," AAS 203.83.09 (abstract), BAAS, 35, 1339

Herbst, E. & Roberts, H. 2004, "How Well Do We Understand the Chemistry in Hot Molecular Cores?" Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 184

Horn, A., Møllendal, H., Sekiguchi, O., Uggerud, E., Roberts, H., **Herbst, E.**, Viggiano, A. A. & Fridgen, T. D. 2004, "The Gas–Phase Formation of Methyl Formate in Hot Molecular Cores," ApJ, 611, 605

Horne, K., **Peterson, B. M.**, **Collier, S. J.** & Netzer, H. 2004, "Observational Requirements for High–Fidelity Reverberation Mapping," PASP, 116, 465

Hradecky, V., **Kochanek, C. S.**, Pahre, M. A., Hartman, M. A., Falco, E. E. & Huchra, J. P. 2003, "The Velocity Function of Local Galaxies," AAS 203.91.10 (abstract), BAAS, 35, 1353

Hynes, R. I., et al. (14 authors including **R. M. Wagner**) 2004, "Correlated X–Ray and Optical Variability in V404 Cygni in Quiescence," ApJ, 611, L125

Kadler, M., Kerp, J., Ros, E., Falcke, H., **Pogge, R. W.** & Zensus, J. A. 2004, "Jet Emission in NGC 1052 at Radio, Optical, and X–Ray Frequencies," A&A, 420, 467

Kassin, S. A. 2003, "Radial Distributions of Dark and Luminous Matter in Spirals," AAS 203.32.02 (abstract), BAAS, 35, 1255

Kassin, S. A., de Jong, R. S. & **Pogge, R. W.** 2004, "Radial Distributions of Dark and Luminous Matter in Bright Spiral Galaxies," in IAU Symp. 220: *Dark Matter in Galaxies*, ed. S.D. Ryder, D.J. Pisano, M.A. Walker & K.C. Freeman (Astron. Soc. Pacific), p. 307

Keenan, F. P., Katsiyannis, A. C., Reid, R.H.G., **Pradhan, A. K.** & Zhang, H. L. 2003, "Extreme Ultraviolet Emission Lines of Ar XIV in Solar Active Region and Flare Spectra," MNRAS, 346, 58

Kenter, A. T., et al. (12 authors including **C. Kochanek**) 2003, "*Chandra* Observations of the Bootes 9 Square Degree Field," AAS 203.90.08 (abstract), BAAS, 35, 1351

Kenter, A. T., et al. (18 authors including **C.S. Kochanek** & **C.R. Watson**) 2004, "*Chandra* Results from the Boötes 9 Square Degree Field," AAS 204.43.15 (abstract), BAAS, 36, 730

Kerins, E., et al. (13 authors including **J. An** & **A. Gould**) 2003, "Theory of Pixel Lensing toward M31. II. The Velocity Anisotropy and Flattening of the MACHO Distribution," ApJ, 598, 993

King, J. R., Hobbs, L. M., Schuler, S. C. & **Pinsonneault, M. H.** 2003, "Lithium in the Pleiades Revisited," AAS 203.14.02 (abstract), BAAS, 35, 1227

Kisiel, Z., Pszczółkowski, L., De Lucia, F. C., **Herbst, E.**, Medvedev, I. & Winnewisser, M. 2004, "Assignment of the Lowest Excited Vibrational States in *tt*–Diethyl Ether," Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 246

Kneller, J. P. & **Steigman, G.** 2004, "BBN for Pedestrians," New J Phys, 6, 117

Kochanek, C. 2004, "Where's the Dark Matter? Current Problems in Halo Structure" (abstract), APS, Ohio Section Sp04, A2.001

Kochanek, C. S. 2004, "Quantitative Interpretation of Quasar Microlensing Light Curves," ApJ, 605, 58

Kochanek, C. S. & Dalal, N. 2004, "Tests for Substructure in Gravitational Lenses," ApJ, 610, 69

Kochanek, C. S. & Schechter, P. L. 2004, "The Hubble Constant from Gravitational Lens Time Delays," in *Measuring and Modeling the Universe*, ed. W.L. Freedman (Cambridge), p. 117

Kochanek, C.S., Schneider, P. & Wambsganss, J. 2004, "*The Saas Fee Lectures on Strong Gravitational Lensing*, Part 2 of *Gravitational Lensing: Strong, Weak & Micro*, ed. G. Meylan, P. Jetzer & P. North (Springer)

Koushiappas, S. M., Zentner, A. R. & **Walker, T. P.** 2004, "Observability of Gamma Rays from Neutralino Annihilations in the Milky Way Substructure," Phys Rev D, 69, 043501

Krisciunas, K., et al. (23 authors including **D. L. DePoy**) 2004, "Optical and Infrared Photometry of the Nearby Type Ia Supernovae 1999ee, 2000bh, 2000ca, and 2001ba," AJ, 127, 1664

Krongold, Y., Nicastro, F., Brickhouse, N. S., Elvis, M., Liedahl, D. A. & **Mathur, S.** 2003, "Toward a Self–Consistent Model of the Ionized Absorber in NGC 3783," ApJ, 597, 832

Krongold, Y., Nicastro, F., Elvis, M., Brickhouse, N. S., **Mathur, S.** & Liedahl, D. 2004, "High Resolution X–Ray Spectroscopic Analysis of the Ubiquitous Multi–Phase Wind of AGNs," AAS 204.50.01 (abstract), BAAS, 36, 751

Kuraszkiewicz, J. K., Green, P. J., Crenshaw, D. M., Dunn, J., Forster, K., **Vestergaard, M.** & Aldcroft, T. L. 2003, "Emission Line Properties of AGN from a Post–COSTAR FOS *HST* Spectral Atlas," AAS 203.55.10 (abstract), BAAS, 35, 1297

Kuraszkiewicz, J. K., Green, P. J., Crenshaw, D. M., Dunn, J., Forster, K., **Vestergaard, M.** & Aldcroft, T. L. 2004, "Emission Line Properties of Active Galactic Nuclei from a Post–COSTAR *Hubble Space Telescope* Faint Object Spectrograph Spectral Atlas," ApJS, 150, 165

Laws, C., Gonzalez, G., **Walker, K. M.**, Tyagi, S., Dodsworth, J., Snider, K. & Suntzeff, N. B. 2003, "Fossils in the Photosphere: Condensation Temperature Trends in the Chemical Abundances of Stars with Radial–Velocity Companions," AAS 203.6.07 (abstract), BAAS, 35, 1213

Le Petit, F., Roueff, E. & **Herbst, E.** 2004, "H_3^+ and Other Species in the Diffuse Cloud towards ζ Persei: A New Detailed Model," A&A, 417, 993

Lipshtat, A., Biham, O. & **Herbst, E.** 2004, "Enhanced Production of HD and D_2 Molecules on Small Dust Grains in Diffuse Clouds," MNRAS, 348, 1055

Marshall, J.L., **Atwood, B.**, **Byard, P.L.**, **DePoy, D.L.**, **O'Brien, T.P.** & **Pogge, R.W.** 2004, "An Image Motion Compensation System for the Multi–Object Double Spectrograph," in *Ground-Based Instrumentation for Astronomy*, ed. A.F.M. Moorwood & M. Iye, SPIE, 5492, 739

Mathur, S., Nicastro, F. & **Williams, R. J.** 2004, "Probing the z = 0 Warm–Hot IGM with *Chandra* and *FUSE*," HEAD 8.2.22 (abstract), BAAS, 36, 906

McDonald, P., **Miralda–Escudé, J.**, Rauch, M., Sargent, W.L.W., Barlow, T. A. & Cen, R. 2003, "Erratum: "A Measurement of the Temperature–Density Relation in the Intergalactic Medium using a New Lyα Absorption Line Fitting Method" (ApJ, 562, 52 [2001])," ApJ, 598, 712

Medvedev, I., Winnewisser, M., De Lucia, F. C. & **Herbst, E.**) 2004, "Computer Aided Assignment of Asymmetric Rotor Spectra (CAAARS)," Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 119

Medvedev, I., Winnewisser, M., De Lucia, F. C., **Herbst, E.**, Białkowska–Jaworska, E., Pszczołkowski, L. & Kisiel, Z. 2004, "The Millimeter– and Submillimeter–Wave Spectrum of Trans–Gauche Diethyl Ether ($C_2H_5OC_2H_5$)," Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 245

Miralda–Escudé, J. 2003, "On the Evolution of the Ionizing Emissivity of Galaxies and Quasars Required by the Hydrogen Reionization," ApJ, 597, 66

Morata, O. & **Herbst, E.** 2004, "What Molecules are Produced in Dense PDRs?" Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 268

Mukhopadhyay, I., De Lucia, F. C., **Herbst, E.** & Duan, Y.-B. 2004, "Millimeter Wave FASSST Spectrum of Methanol–D_4," Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 135

Muñoz, J. A., Falco, E. E., **Kochanek, C. S.**, McLeod, B. A. & Mediavilla, E. 2004, "The Extinction Law in High–Redshift Galaxies," ApJ, 605, 614

Murray, S. S., et al. (17 authors including **C. Kochanek**) 2003, "X–Ray Boötes 3 Dimensional Survey (XB3dS)," AAS 203.61.03 (abstract), BAAS, 35, 1307

Murray, S. S., et al. (17 authors including **C. Kochanek**) 2004, "Initial Results from the *Chanda* Shallow X–Ray Survey in the NDWFS in Bootes," AAS 204.48.10 (abstract), BAAS, 36, 747

Nahar, S. N. 2004, "Atomic Data from the Iron Project. LIV. Relativistic Calculations for Allowed and Forbidden Fine Structure Transitions in Fe XX," A&A, 413, 779

Nahar, S. N. 2004, "Photoionization Cross Sections of O II, O III, O IV, and O V: Benchmarking R–Matrix Theory and Experiments," Phys Rev A, 69, 042714

Nahar, S. 2004, "Unified and Self-Consistent Treatment of Photoionization and Recombination: New Features in Ar XIII" (abstract), Bull APS, DAMOP 35, M3 003

Nahar, S. N. & **Pradhan, A. K.** 2003, "Electron–Ion Recombination Rate Coefficients and Photoionization Cross Sections for Astrophysically Abundant Elements. VII. Relativistic Calculations for O VI and O VII for Ultraviolet and X–Ray Modeling," ApJS, 149, 239

Nahar, S.N. & **Pradhan, A.K.** 2004, "Self-Consistent R–Matrix Approach to Photoionization and Unified Electron–Ion Recombination," Rad Phys Chem, 70, 323

Nava, A., Maddox, L. A., Matsumoto, C., Leighly, K. M. & **Grupe, D.** 2003, "An *XMM–Newton* Observation of the Bright Seyfert 2 Galaxy NGC 6300," RevMexAA (Ser. de Conf.), 18, 72

Netzer, H., et al. (15 authors including **B. M. Peterson**) 2003, "The Ionized Gas and Nuclear Environment in NGC 3783. IV. Variability and Modeling of the 900 Kilosecond *Chandra* Spectrum," ApJ, 599, 933

Oelgoetz, J., **Delahaye, F.**, **Nahar, S. N.** & **Pradhan, A. K.** 2004, "Time Dependent Spectra of He–

Like Ions in Transient X–Ray Plasmas" (abstract), Bull APS, DAMOP 35, D1 006

Onken, C. A. & **Miralda–Escudé, J.** 2004, "History of Hydrogen Reionization in the Cold Dark Matter Model," ApJ, 610, 1

Osamura, Y., Roberts, H. & **Herbst, E.** 2004, "On the Possible Interconversion between Pairs of Deuterated Isotopomers of Methanol, its Ion, and its Protonated Ion in Star–Forming Regions," A&A, 421, 1101

Osmer, P. S. 2004, "The Evolution of Quasars," in *Coevolution of Black Holes and Galaxies*, ed. L.C. Ho (Cambridge), p. 325

Parise, B., Castets, A., **Herbst, E.**, Caux, E., Ceccarelli, C., Mukhopadhyay, I. & Tielens, A.G.G.M. 2004, "First Detection of Triply–Deuterated Methanol," A&A, 416, 159

Park, B.-G., et al. (28 authors including **D. L. DePoy**, **A. Gould**, **C. Han** & **R. W. Pogge**) 2004, "MOA 2003–BLG–37: A Bulge Jerk–Parallax Microlens Degeneracy," ApJ, 609, 166

Peng, C. Y., Impey, C. D., Falco, E. E., Keeton, C. R., **Kochanek, C. S.**, Lehár, J., McLeod, B., Muñoz, J., Rix, H.-W. & Rusin, D. 2004, "Lensed Quasar Host Galaxies," in *Coevolution of Black Holes and Galaxies*, ed. L.C. Ho (Carnegie Observatories: www.ociw.edu)

Peng, C. Y., Impey, C. D., Rix, H.-W., **Kochanek, C. S.**, Falco, E. E., Lehar, J., McLeod, B. A. & Keeton, C. R. 2004, "Possible Supernova Associated with Q0957+561," IAU Circ. No. 8298

Pepper, J., **Gould, A.** & **DePoy, D. L.** 2003, "Using All–Sky Surveys to Find Planetary Transits," Acta Astronomica, 53, 213

Pepper, J., **Gould, A.** & **DePoy, D. L.** 2004, "KELT: The Kilodegree Extremely Little Telescope," in *The Search for Other Worlds*, AIP Conf Proc, 713, 185

Peterson, B. M. & Horne, K. 2004, "Echo Mapping of Active Galactic Nuclei," AN, 325, 248

Peterson, B. M. & **Onken, C. A.** 2004, "Zero–Point Calibration for AGN Black–Hole Mass Estimates," in *AGN Physics with the Sloan Digital Sky Survey*, ed. G.T. Richards & P.B. Hall, ASP Conf. Ser., 311, 75

Peterson, B. M., Polidan, R. S. & Horne, K. 2004, "*Kronos*: A Satellite for Astrotomography," AN, 325, 257

Peterson, B. M., et al. (12 authors including **K.M. Gilbert**, **C.A. Onken**, **R.W. Pogge** & **M. Vestergaard**) 2004, "Central Masses and Broad–Line Region Sizes of Active Galactic Nuclei. II. A Homogeneous Analysis of a Large Reverberation–Mapping Database," ApJ, 613, 682

Pinsonneault, M. H., **Terndrup, D. M.**, Hanson, R. B. & Stauffer, J. R. 2003, "The Distances to Open Clusters from Main–Sequence Fitting. I. New Models and a Comparison with the Properties of the Hyades Eclipsing Binary VB 22," ApJ, 598, 588

Pinsonneault, M. H., **Terndrup, D. M.**, Hanson, R. B. & Stauffer, J. R. 2004, "The Distances to Open Clusters as Derived from Main–Sequence Fitting. II. Construction of Empirically Calibrated Isochrones," ApJ, 600, 946

Pogge, R. 2004, "Narrow-Line Seyfert 1s and SDSS: What Can We Learn?" in *AGN Physics with the Sloan Digital Sky Survey*, ed. G.T. Richards & P.B. Hall, ASP Conf. Ser., 311, 257

Pope, A. C., et al. (26 authors including **D. H. Weinberg**) 2004, "Cosmological Parameters from Eigenmode Analysis of Sloan Digital Sky Survey Galaxy Redshifts," ApJ, 607, 655

Pradhan, A., **Nahar, S.**, **Oelgoetz, J.**, Burke, P., Burke, V., Sunderland, A. & Noble, C. 2004, "R–Matrix II Approach to Electron Correlations in Heavy Atomic Systems" (abstract), Bull APS, DAMOP 35, F4 011

Ramírez, S. V., **Sellgren, K.**, Blum, R. & **Terndrup, D. M.** 2003, "CNO Abundances in the Quintuplet Cluster M Supergiant 5–7," in *Galactic Center Workshop 2002 – The Central 300 Parsecs of the Milky Way*, AN Supp, 324, 299

Reitzner, S. D., **Boyd, R. N.**, Rauscher, T. & Vogel, P. 2004, "Simulation of Nucleon Decay in Lead Perchlorate" (abstract), APS, Apr04, W9.013

Roberts, H., **Herbst, E.** & Millar, T. J. 2004, "The Effect of CO Depletion on the D_2CO/H_2CO Ratio in Prestellar Cores," Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 221

Roberts, H., **Herbst, E.** & Millar, T. J. 2004, "The Chemistry of Multiply Deuterated Species in Cold, Dense Interstellar Cores," A&A, 424, 905

Rodríguez-Ardila, A., Pastoriza, M. G., Viegas, S., Sigut, T.A.A. & **Pradhan, A. K.** 2004, "Molecular Hydrogen and [Fe II] in Active Galactic Nuclei," A&A, 425, 457

Romano, P., et al. (14 authors including **S. Mathur**, **B. M. Peterson** & **R. W. Pogge**) 2004, "The Spectral Energy Distribution and Emission–Line Properties of the Narrow–Line Seyfert 1 Galaxy Arakelian 564," ApJ, 602, 635

Ryden, B. S. 2004, "The Ellipticity of the Disks of Spiral Galaxies," ApJ, 601, 214

Schirber, M., **Miralda–Escudé, J.** & McDonald, P. 2004, "The Transverse Proximity Effect: A Probe to the Environment, Anisotropy, and Megayear Variability of QSOs," ApJ, 610, 105

Schuler, S. C., King, J. R., Hobbs, L. M. & **Pinsonneault, M. H.** 2003, "Oxygen in Open Cluster

Dwarfs: Pleiades and M34," AAS 203.14.03 (abstract), BAAS, 35, 1228

Schuler, S. C., King, J. R., Hobbs, L. M. & **Pinsonneault, M. H.** 2004, "Oxygen in Open Cluster Dwarfs: Pleiades and M34," ApJ, 602, L117

Schwarz, G., Karam, A., **Wagner, R. M.**, Rohrbach, J. G. & Starrfield, S. 2004, "Supernova 2004cv in MCG +03–41–120," IAU Circ. No. 8364

Semenov, D., Pavlyuchenkov, Ya., Henning, Th., **Herbst, E.** & van Dishoeck, E. 2004, "On the Feasibility of Chemical Modeling of a Proplanetary Disk," Baltic Astron., 13, 454

Sigut, T.A.A., **Pradhan, A. K.** & **Nahar, S. N.** 2004, "Theoretical Fe I–III Emission–Line Strengths from Active Galactic Nuclei with Broad–Line Regions," ApJ, 611, 81

Smith, I.W.M., **Herbst, E.** & Chang, Q. 2004, "Rapid Neutral–Neutral Reactions at Low Temperatures: A New Network and First Results for TMC–1," MNRAS, 350, 323

Soderblom, D. R., et al. (12 authors including **M. Pinsonneault**) 2004, "The Distance to the Pleiades from *HST*/FGS Measurements," AAS 204.45.07 (abstract), BAAS, 36, 735

Stantcheva, T. & **Herbst, E.** 2004, "Models of Gas–Grain Chemistry in Interstellar Cloud Cores with a Stochastic Approach to Surface Chemistry," A&A, 423, 241

Steigman, G. 2003, "Probing Baryons, Neutrinos, and Nonstandard Physics with BBN and the CBR" (abstract), APS, DNP03, 5WB.002

Steigman, G. 2004, "Big Bang Nucleosynthesis: Probing the First 20 Minutes," in *Measuring and Modeling the Universe*, ed. W.L. Freedman (Cambridge), p. 169

Steigman, G. 2004, "Tracking the Baryon Density from the Big Bang to the Present," in *The Dark Universe: Matter, Energy and Gravity*, ed. M. Livio, STScI Symp. 15, p. 46

Steigman, G. 2004, "Primordial Alchemy: From the Big Bang to the Present Universe," in *Cosmochemistry: The Melting Pot of the Elements*, ed. C. Esteban, R.J. García López, A. Herrero & F. Sánchez (Cambridge), p. 1

Stephens, A. W. & **Frogel, J. A.** 2004, "An Infrared Spectroscopic Study of Eight Galactic Globular Clusters," AJ, 127, 925

Strigari, L. E., Kaplinghat, M., **Steigman, G.** & **Walker, T. P.** 2004, "The Supernova Relic Neutrino Backgrounds at KamLAND and Super-Kamiokande," J Cosmology and Astroparticle Physics, 3, 7

Tegmark, M., et al. (67 authors including **D. H. Weinberg**) 2004, "Cosmological Parameters from SDSS and WMAP," Phys Rev D, 69, 103501

Tegmark, M., et al. (65 authors including **D. H. Weinberg**) 2004, "The Three–Dimensional Power Spectrum of Galaxies from the Sloan Digital Sky Survey," ApJ, 606, 702

Tinker, J., **Pinsonneault, M.** & **Terndrup, D.** 2003, "Angular Momentum Evolution of Stars in the Orion Nebula Cluster," in *The Future of Cool–Star Astrophysics: 12th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun*, ed. A. Brown, G.M. Harper & T.R. Ayres (U. Colorado), p. 769

Tisserand, P., et al. (45 authors including **A. Gould**) 2004, "EROS 2 Photometry of Probable R Coronae Borealis Stars in the Small Magellanic Cloud," A&A, 424, 245

Turnshek, D. A., Rao, S. M., Nestor, D. B., VanDen Berk, D., Belfort–Mihalyi, M. & **Monier, E. M.** 2004, "Double–Damped Lyα Absorption: A Possible Large Neutral Hydrogen Gas Filament near Redshift $z = 1$," ApJ, 609, L53

Vestergaard, M. 2003, "Occurrence and Global Properties of Narrow C IV λ1549 Å Absorption Lines in Moderate–Redshift Quasars," ApJ, 599, 116

Vestergaard, M. 2004, "Black–Hole Mass Measurements," in *AGN Physics with the Sloan Digital Sky Survey*, ed. G.T. Richards & P.B. Hall, ASP Conf. Ser., 311, 69

Vestergaard, M. 2004, "Evidence for Early or Efficient Black–Hole Growth," in *AGN Physics with the Sloan Digital Sky Survey*, ed. G.T. Richards & P.B. Hall, ASP Conf. Ser., 311, 87

Vestergaard, M. 2004, "Evidence for Early Black Hole Growth," in *Coevolution of Black Holes and Galaxies*, ed. L.C. Ho (Carnegie Observatories: www.ociw.edu)

Vestergaard, M. 2004, "Early Growth and Efficient Accretion of Massive Black Holes at High Redshift," ApJ, 601, 676

Wagner, R. M. 2004, "An Overview of Instrumentation for the Large Binocular Telescope," in *Ground-Based Instrumentation for Astronomy*, ed. A.F.M. Moorwood & M. Iye, SPIE, 5492, 108

Wagner, R. M., et al. (18 authors) 2004, "Discovery and Evolution of an Unusual Luminous Variable Star in NGC 3432 (Supernova 2000ch)," PASP, 116, 326

Wakelam, V., Caselli, P., Ceccarelli, C., **Herbst, E.** & Castets, A. 2004, "Resetting Chemical Clocks of Hot Cores Based on Sulphur–Bearing Species," Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 212

Wakelam, V., Caselli, P., Ceccarelli, C., **Herbst, E.** & Castets, A. 2004, "Resetting Chemical Clocks of Hot Cores Based on S–Bearing Molecules," A&A, 422, 159

Watson, C. R., et al. (18 authors including **C. S. Kochanek**) 2004, "X–Ray Emission from Low Redshift 2MASS–Selected Galaxies in the Bootes Field and Implications for Star Formation," AAS 204.48.13 (abstract), BAAS, 36, 747

Weinberg, D. H., Davé, R., Katz, N. & Hernquist, L. 2004, "Galaxy Clustering and Galaxy Bias in a ΛCDM Universe," ApJ, 601, 1

Werner, M. W., Uchida, K. I., **Sellgren, K.**, Marengo, M., Gordon, K. D., Morris, P. W., Houck, J. R. & Stansberry, J. A. 2004, "New Infrared Emission Features and Spectral Variations in NGC 7023," ApJS, 154, 309

Wilkes, B. J., Risaliti, G., **Ghosh, H.**, Cutri, R., Gilli, R. & Nelson, B. 2003, "The Contribution of Red 2MASS AGN to the Cosmic X–Ray Background," AAS 203.63.04 (abstract), BAAS, 35, 1310

Williams, R., **Mathur, S.**, & **Pogge, R.** 2004, "Are All Narrow–Line Seyfert 1s Ultrasoft and X–Ray Bright?" in *AGN Physics with the Sloan Digital Sky Survey*, ed. G.T. Richards & P.B. Hall, ASP Conf. Ser., 311, 261

Williams, R. J., **Mathur, S.** & **Pogge, R. W.** 2004, "*Chandra* Observations of X-Ray–Weak Narrow–Line Seyfert 1 Galaxies," ApJ, 610, 737

Wing, R. F. & Jørgensen, U. G. 2003, "Stellar Spectra in the H Band," JAAVSO, 31, 110

Wing, R. F., **Walker, K. M.**, Costa, E., Houdashelt, M. L. & MacConnell, D. J. 2003, "Narrow–Band Photometry of Red Supergiants in the Small Magellanic Cloud," AAS 203.49.01 (abstract), BAAS, 35, 1284

Wing, R. F., **Walker, K. M.**, MacConnell, D. J. & Costa, E. 2004, "Red Supergiants in the Small Magellanic Cloud: The Effects of Metallicity on Narrow–Band Classification Indices," in *Variable Stars in the Local Group*, eds. D.W. Kurtz & K.R. Pollard, ASP Conf. Ser., 310, 317

Winn, J. N., Rusin, D. & **Kochanek, C. S.** 2003, "A Central Image of a Gravitationally Lensed Quasar," AAS 203.68.04 (abstract), BAAS, 35, 1314

Winn, J. N., Rusin, D. & **Kochanek, C. S.** 2004, "The Central Image of a Gravitationally Lensed Quasar," Nature, 427, 613

Winnewisser, M., Medvedev, I., De Lucia, F. C., **Herbst, E.** & Christiansen, J. J. 2004, "The Millimeter– and Submillimeter–Wave Spectrum of Cyanoformamide Revisied," Abstract Book, 59th Ohio State University International Symposium on Molecular Spectroscopy, p. 208

Witherick, D. K., Prinja, R. K., Howell, S. B. & **Wagner, R. M.** 2003, "Balmer Absorption Variability and the Disc Wind of V592 Cassiopeiae," MNRAS, 346, 861

Yoo, J., **Chanamé, J.** & **Gould, A.** 2004, "The End of the MACHO Era: Limits on Halo Dark Matter from Stellar Halo Wide Binaries," ApJ, 601, 311

Yoo, J., et al. (19 authors including **D. L. DePoy**, **A. Gould** & **R. W. Pogge**) 2004, "OGLE–2003–BLG–262: Finite–Source Effects from a Point–Mass Lens," ApJ, 603, 139

Yoo, J. & **Miralda–Escudé, J.** 2004, "Formation of the Black Holes in the Highest Redshift Quasars," ApJ, 614, L25

Zehavi, I., et al. (28 authors including **D. H. Weinberg** & **Z. Zheng**) 2004, "On Departures from a Power Law in the Galaxy Correlation Function," ApJ, 608, 16

Zhang, P. & **Beacom, J. F.** 2004, "Angular Correlations of the MeV Cosmic Gamma–Ray Background," ApJ, 614, 37

Zheng, Z. 2004, "Interpreting the Observed Clustering of Red Galaxies at $z \sim 3$," ApJ, 610, 61

Zheng, Z. 2004, "Projected Three–Point Correlation Functions and Galaxy Bias," ApJ, 614, 527

Zheng, Z., Flynn, C., **Gould, A.**, Bahcall, J. N. & Salim, S. 2004, "M Dwarfs from *Hubble Space Telescope* Star Counts. V. The I–Band Luminosity Function," ApJ, 601, 500

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