Ohio University

Department of Physics and Astronomy

Athens, Ohio 45701

The following report covers the period November 2002 through October 2003.

1 INTRODUCTION

Ohio University was the first institution of higher education in the Old Northwest, and is part of the state university system of Ohio, with a current enrollment of approximately 20,000 students. Ohio's Department of Physics & Astronomy has 28 faculty active in research in areas including nuclear physics, biophysics, condensed matter and surface physics, nanoscience, and astrophysics. The Department offers a Ph.D. in physics, with a current graduate enrollment of approximately 60 students. Additional information about the Department can be found at the WWW site `http://www.phy.ohiou.edu`.

2 PERSONNEL

Astrophysics faculty in the Department include Markus Böttcher, Brian McNamara, Joseph Shields, Thomas Statler, Emeritus Professor James Dilley, and Instructors George Eberts and Tom O'Grady. Additional faculty in the Department engaged in astrophysics-related research include Carl Brune and Daniel Phillips. Felix (Jay) Lockman of the National Radio Astronomy Observatory, Green Bank, was appointed an Adjunct Professor. Mangala Sharma continued as a Postdoctoral Research Associate under McNamara's supervision. Statler completed a year-long sabbatical in August, and Shields began a year-long sabbatical in September.

During the past year Böttcher supervised research by graduate students Justin Finke, Manasvita Joshi, and Swati Gupta; McNamara supervised research by graduate students Laura Birzan, David Rafferty, and Rocco Samuele, and undergraduates Tim Lester and Jack Steiner; Shields supervised research by graduate students Anca Constantin, Yurii Pidopryhora, and Zachary Heinen; and Statler supervised research by graduate students Steven Diehl and Robert Salow and undergraduate Daniel Wik. Wik completed a bachelors degree in astrophysics in June, and held a summer research position at the Harvard-Smithsonian Center for Astrophysics. At the June Commencement, Ohio University presented an honorary D.Sc. to Donald Osterbrock, Ohio native and Professor Emeritus at the University of California, Santa Cruz.

Böttcher received new and continuing funding from the *Chandra X-ray Observatory* (*CXO*) and NASA, including support for INTEGRAL GO observations. McNamara received new and continuing funding from NASA, the Department of Energy, and the *CXO*, including a NASA Long Term Space Astrophysics grant for projects related to X-ray emission in clusters and the optical and radio properties of giant central cluster galaxies. He continued as a member of the Telescope Allocation Committee for the National Optical Astronomy Observatory (NOAO), was appointed to a two-year term as a VLA/VLBA Proposal Reviewer, and chaired CXO Cycle 5 Proposal Review and Cost Review panels. McNamara also served on the Scientific Organizing Committee for the conference "The Riddle of Cooling Flows in Galaxies and Clusters of Galaxies," held in Charlottesville, VA in June, and was appointed to the Constellation-X Facility Science Team Panel on ISM/IGM.

Shields received new and continuing funding from the Space Telescope Science Institute (STScI) and the *CXO* for studies of active galaxies. He continued his service as Scientific Editor for the *Astrophysical Journal*, and was a member of the NOAO Telescope Allocation Committee in May. He also served on the Scientific Organizing Committee for the conference "Active Galactic Nuclei Physics with the Sloan Digital Sky Survey," held in Princeton, NJ, in July. Statler's research on the structure and evolution of elliptical galaxies received continuing support from STScI and the *CXO*. Statler completed his term as a member of the Committee of the AAS Division on Dynamical Astronomy.

3 RESEARCH

3.1 Normal Galaxies

Salow is completing his doctoral dissertation on the double nucleus of M31, under Statler's supervision. Salow has extended his previous work on weakly self-gravitating, finite dispersion eccentric disk models (Salow & Statler 2001) to include the proper radial extent to fully model the nucleus. A multi-dimensional Downhill Simplex Method (see Press et al. 1992) is used to minimize the reduced χ^2 value between a given model and the best-available photometric and kinematic nuclear data for M31. A grid of 24 models has been computed to quantify some of the possible systematic effects, covering three sets of kinematic and photometric data, two bulge models, two eccentricity distributions, and fixed or free inclination. The key result of this modeling effort is that the mass of the black hole in the center of M31 is $56.2 \pm 0.7 \times 10^6 M_\odot$. This value is the most accurate to date, since it is found by fitting only recent high-resolution one- and two-dimensional kinematic and photometric data.

A 25-orbit *HST*/STIS spectrum of M31's nucleus will be obtained in Cycle 12, in a program led by E. Emsellem [Lyon] and Statler, along with R. Bacon [Lyon], F. Combes and M. de Oliveira [Paris], N. Sambhus [Basel], and Salow. The mass of the central black hole (BH) will be determined to $< 20\%$ accuracy, using the spectrum of the UV peak, a 0.4 pc stellar cluster associated with the BH, and the line of sight velocity distributions (LOSVDs) of the underlying nucleus. The expected velocity dispersion of the UV cluster is > 550 km s^{-1} and will be measured with an accuracy of 10% from the Balmer lines. The spectrum obtained simultaneously in the 4500–5500 Å region will yield the full LOSVDs of the nuclear disk in the region where the dispersion is high. The LOSVDs, in turn, will constrain dynamical models of eccentric ($m = 1$) disk modes.

Statler is collaborating with the SAURON group (T. de Zeeuw [Leiden], R. Davies [Oxford], R. Bacon [Lyon], et al.) to model the elliptical galaxies observed using the SAURON integral field spectrograph. The objective is to use the 2-dimensional kinematic maps together with Statler's dynamical modeling approach both to constrain the intrinsic shapes and viewing geometries of the individual objects, as a prelude to more careful modeling by Schwarzschild's Method, and to obtain the intrinsic shape distribution of elliptical galaxies. Results for the "standard elliptical" NGC 3379 are consistent with the previous results obtained from long-slit kinematic data. NGC 4365, a galaxy with skew rotation and a kinematically decoupled core, is found to be highly triaxial and somewhat flatter than it appears. The old age of the stellar population implies that this shape has persisted for many hundreds of dynamical times. This rules out black holes $> 3 \times 10^9$ $M_\odot$, which numerical simulations indicate would either have globally axisymmetrized the galaxy or rendered the inner several arcseconds spherical. It is also possible to constrain the rate of figure rotation (tumbling) about the short axis. The required populations of long-axis tube orbits, combined with the small isophotal twist, places corotation at > 8 effective radii. Work is continuing to model the remaining SAURON ellipticals and to determine the elliptical galaxy shape distribution.

A major systematic uncertainty in modeling elliptical galaxy shapes is the present inability to constrain their internal orbital structure on theoretical grounds. However, a huge archive of N-body merger simulations exists, few of which have ever been carefully analyzed in terms of their internal kinematics. Statler is developing tools to mine this archive, in collaboration with E. Athanassoula [Marseille]. A quick analysis of a set of simulations of small, merging groups of dissipationless, spherical systems performed by Athanassoula shows, quite surprisingly, that all of the merger remnants are rapidly tumbling bars. Tools to extract and visualize the internal kinematic fields will be developed in the coming year.

Statler is beginning work on hydrodynamical simulations of the formation of giant cooling disks in elliptical galaxies, in collaboration with M. Ruszkowski [Colorado]. This work is motivated by *Chandra*/ACIS-S observations of NGC 1700 conducted by Statler and McNamara in 2000. The results showed highly flattened X-ray isophotes, flatter, and with a shallower radial profile, than the starlight. The flattening is so extreme that the gas cannot be in hydrostatic equilibrium in any plausible potential, and therefore probably has significant rotational support. A simple rotating model can reproduce the isophotal profile, with a cooling time that matches the time since the last major merger. The most likely scenario is a merger of a spiral with a pre-existing elliptical with a hot ISM. Preliminary 2-D simulations, in which a spherical blob of gas is dumped into a static potential on an eccentric orbit, show that it is possible to create large, slowly cooling, rotationally supported disks of approximately the observed density and temperature. More sophisticated simulations in 3 dimensions are planned for the near future.

Diehl and Statler are continuing their archival survey of *Chandra* X-ray data from ~ 80 early-type galaxies. The spectra of resolved point sources are analyzed and their luminosity function is derived with an iterative Bayesian algorithm, where incompleteness effects are taken into account. The contribution of unresolved point sources to the diffuse emission is derived by extrapolation of the luminosity function to lower luminosities under *Chandra*'s detection limit. Removal of this point source contribution reveals the emission of the hot gas only. Comparison of the optical and corrected X-ray isophotes will uncover the importance of rotational support for the hot gas in elliptical galaxies. If angular momentum generally plays an important role, this could have major consequences for dark halo mass estimates which are mostly based on the common assumption of hydrostatic equilibrium.

Statler is collaborating with L. Young [New Mexico Tech] to study the stellar and gas kinematics of CO-rich ellipticals and investigate the dynamical connection between the stars, ionized gas, and molecular gas. Multi-position-angle long-slit spectroscopy in V band of the well-behaved galaxy NGC 807 and the young merger remnant NGC 3656 was obtained at the MMT in 2003 January, in clear but not photometric conditions. Data reduction is progressing.

Wik completed an undergraduate thesis, under Statler's supervision, consisting of an observational study of the shell galaxy NGC 2634 and a numerical study of the time evolution of Fisher Information in phase mixing. BVR imaging data from the 2.4 m Hiltner telescope at MDM Observatory shows an extensive set of at least 7 shells in NGC 2634. The shell spacing is consistent with a standard isothermal halo mass profile, and an age > 1.2 Gyr. From the numerical work, the Fisher Information of the coarse-grained distribution function is seen to change non-monotonically with time as a 1-dimensional system phase-wraps. As such, it may be a better measure of the smoothness of a distribution than the classical Boltzmann entropy. However, the usefulness of Fisher Information is limited by the fact that, unlike entropy, it is not canonically invariant.

Shields is continuing his collaboration with a team led by T. Böker [ESA] in a study of nuclei in bulgeless, late-type galaxies. Work currently focuses on following up on an *HST* imaging snapshot survey of 77 objects that revealed nuclear star clusters in the majority of cases. Analysis of the images indicates that the clusters are on average 4 magnitudes brighter than Galactic globular clusters, but have comparable sizes, with a median effective radius of 3.5 pc. A related effort led by C. J. Walcher [MPIA] involves the analysis of VLT UVES spectra, which allows measurement of the cluster stellar populations and velocity dispersions, which in turn yield estimates of cluster mass. The spectra indicate that most of the clusters have a significant young component, although older populations dominate the mass. Star formation has evidently occurred over multiple epochs in these clusters, which further distinguishes them from globular clusters in other environments.

Pidopryhora, in consultation with Shields and Lockman, has initiated dissertation research that will use the Green Bank Telescope (GBT) and other facilities to study the nature of HI clouds in the Milky Way halo. The existence of this cloud population was revealed only recently in early observations with the GBT by Lockman. The nature of these clouds is of considerable interest for comparison with theoretical models for the cold and warm neutral medium in the Galaxy. Measurements of the clouds may also provide diagnostics of physical conditions in the Milky Way halo.

3.2 Active Galactic Nuclei

Böttcher has established a rigorous program of coordinated multiwavelength observations and theoretical modeling of broadband spectra and spectral variability of blazars (i.e. gamma-ray loud quasars and BL Lac objects). An intensive multiwavelength campaign on BL Lacertae had been carried out in the second half of 2000. The final data analysis was completed in the summer of 2003. The campaign revealed significant optical and X-ray variability on ~ 1.5 hr time scales, with remarkable spectral variability in both the optical and the X-ray regime. At optical and hard X-ray frequencies, a general trend of spectral hardening during flares was uncovered, while the soft X-ray variability appears to be associated with spectral softening during flares. In work currently in progress, this spectral variability is being modelled with time-dependent leptonic and hadronic jet models for blazars (e.g., Böttcher & Chiang 2002, Böttcher, Mukherjee & Reimer 2002). Preliminary results of this modelling indicates that leptonic models are well suited to reproduce the observed spectral energy distributions and spectral variability if flaring activity is primarily related to a hardening of the energy spectra of electrons injected/accelerated near the base of the jet.

A large international collaboration led by Böttcher is currently (Sept. – Dec. 2003) conducting a coordinated multiwavelength monitoring campaign on the BL Lac object 3C 66A. This involves radio monitoring by the University of Michigan and the Metsähovi (Finland) radio observatories, 9 epochs of VLBA observations, optical observations by the Whole Earth Blazar Telescope (WEBT) collaboration (Böttcher is the WEBT campaign manager of this project), 20 monitoring observations by the Rossi X-ray Timing Explorer (RXTE), and ground-based Very-High-Energy γ-ray observations by the STACEE and VERITAS Atmospheric Cherenkov Telescope facilities.

Böttcher was also part of two collaborations organizing multiwavelength observations of the prominent quasars 3C273 and 3C279. The centerpiece of these campaigns was AO-1 observations of these quasars with the European INTEGRAL γ-ray satellite. 3C273 (PI: T. Courvoisier, ISDC, Geneva) was clearly detected by all four instruments on board INTEGRAL, and a high-quality spectrum in the ~ 2 – 500 keV could be extracted. The spectrum is consistent with a pure power-law with photon index $\Gamma \sim 1.7$, as expected for an inverse-Compton dominated X-ray spectrum. In the preliminary analysis done so far, no significant X-ray and γ-ray variability could be seen, whereas the optical (V band) light curve does show evidence for microvariability on time scales of a few hours. 3C 273's "sister" source 3C 279 was not detected during the INTEGRAL observations in June 2003 (PI: W. Collmar, MPE, Garching).

Shields is continuing his collaboration with H.-W. Rix [MPIA-Heidelberg], L. Ho [OCIW], A. Filippenko [UC-Berkeley], M. Sarzi [Oxford U.], G. Rudnick [MPA-Garching], D. McIntosh [U. Mass.], and A. Barth and W. Sargent [Caltech], in studying the spectroscopic properties of nearby, weakly active nuclei as measured through small apertures (median radius ~ 8 pc) with *HST* and STIS. In a study led by Sarzi, the nuclear stellar populations for a sample of 23 galaxies were analyzed by fitting of Bruzual & Charlot (2003) spectral templates. The results indicate that the stars are predominantly old, with single-age templates yielding a median age of $\sim 8 - 10$ Gyr. Analysis with multiple templates indicates that at least half of the nuclei show evidence for more than one episode of star formation.

In a related study, R. Pogge and D. Fields [Ohio State U.], Shields, and P. Martini [CfA] are continuing their analysis of *HST* STIS spectra for a sample of 18 nearby Seyfert 2 nuclei. This project takes advantage of *HST*'s spatial resolution to study the emission-line and continuum properties of these systems on small scales, with minimal circumnuclear contamination. Efforts are underway to quantify whether star formation is enhanced on these scales, as reported in other Seyfert 2s observed through larger apertures.

Constantin and Shields have completed a detailed analysis of the UV-optical properties of Narrow-Line Seyfert 1 (NLS1) galaxies. The study employs archival *HST* spectra of 22 objects, and detailed analysis of composite spectra. The results indicate that NLS1s have redder continua than typically measured in QSOs. Among the sample, the objects with UV line absorption show redder spectra, suggesting that dust is important in modifying the continuum shapes. The continuum slopes are also found to be redder in lower luminosity sources, in agreement with other AGN studies, and suggest that interstellar reddening is luminosity-dependent. The data permit a detailed investigation of a proposed link between NLS1s and $z \gtrsim 4$ quasars. Direct comparison of their composite spectra, as well as a Principal Component Analysis, suggest that high-z QSOs do not show a strong preference toward NLS1 behavior.

Motivated by the findings of the NLS1 study, Constantin and Shields have initiated a more general investigation of the possible relationship between reddening, luminosity, and continuum shape in AGNs. This new project involves simple Monte Carlo simulations of dust reddening of quasars, in a scheme in which the inner radius of the absorbing material scales with the intrinsic luminosity of the central source (a variant of the "receding torus" picture), consistent with expectations that grains will evaporate above a certain radiation density. Preliminary results produce qualitative agreement with the observed luminosity-continuum slope correlation. This simple picture can also be used to generate predictions of the fraction of obscured AGNs, and the resulting estimates appear consistent with recent x-ray observations of the extragalactic point source population.

Shields continues as part of a large team investigating the nature of UV and X-ray absorption in the Seyfert 1 galaxy NGC 3783, as constrained by multi-epoch observations. Analysis of *HST* spectra led by J. Gabel [Catholic U.] has led to the discovery for the first time of evolution in the outflow velocity of a component in the UV absorber. *Chandra* observations have been analyzed in an effort led by H. Netzer [Tel Aviv U.], and reveal that the X-ray absorber can be described by three components that are consistent with coexistence in pressure equilibrium.

Shields and McNamara, along with investigators at SAO and NOAO, are part of a team that recently carried out *Chandra* observations of the 9 square-degree Bootes field of the NOAO Deep Wide-Field Survey. Initial analysis efforts are underway, and follow-up spectroscopy is planned. The substantial multi-wavelength database for this field will enable detailed studies of AGN behavior as a function of environment.

3.3 Galaxy Clusters

McNamara and colleagues were awarded several *Chandra* Cycle 5 programs to investigate galaxy clusters with bright, X-ray cores ("cooling flows"). The programs address the cycle of cooling, accretion-driven star formation, and reheating of the intracluster gas by radio jets, supernova explosions, and thermal conduction. High resolution *Chandra* images of clusters have revealed complex structures created by interactions between powerful radio sources and the gaseous medium surrounding them. McNamara and colleagues have shown that giant, galaxy-sized cavities or bubbles in the X-ray emission are created during these interactions. Birzan, Rafferty, and McNamara, with M. Wise [MIT] and P. Nulsen [SAO], are investigating the systematic properties of cavities in a large sample of clusters taken from the *Chandra* archive. X-ray measurements of bubble sizes, surrounding pressures, and demographics have provided reliable estimates of the kinetic power of radio jets, bubble ages, advance speeds, and radio duty cycles. The results indicate that the total energy per cavity scales proportionally to the central cluster X-ray luminosity. In addition, the central cooling time of the keV gas and rate of bubble production are roughly matched on a $\sim 10^8$ yr timescale. These properties suggest, remarkably, that cooling is regulated to some degree by radio sources. These new findings have significant implications for understanding the general problem of self-regulated galaxy formation, particularly during the growth of galaxy halos and supermassive black holes, which appear to be causally linked.

McNamara continues his collaboration with Hui Li, Phil Kronberg, Sterling Colgate, and others from Los Alamos National Laboratory studying the origin and dynamics of magnetic fields in the intra- and intercluster media.

A study of the Abell 1068 cluster of galaxies was completed by McNamara, S. Murray [SAO], and Wise. They found that Abell 1068 behaves as a classical cooling flow with a cooling rate of $140 M_\odot$ yr^{-1}. The X-ray cooling rate matches the star formation rate $\sim 70 M_\odot$ yr^{-1} to within the measurement uncertainties. The team investigated the significance of reheating of the cooling gas by the radio source, thermal conduction, and supernova explosions associated with the starburst. Heating luminosities from the radio source and conduction represent a negligible fraction of the cooling luminosity. Instead, heating is dominated by supernova explosions, but at the level of only $\sim 20\%$ of the cooling luminosity.

In collaboration with E. Blanton, C. Sarazin, and T. E. Clarke [U. Virginia], McNamara is examining the X-ray and optical properties of the Abell 262 cluster. The cluster harbors twin X-ray cavities straddling the nucleus of the cD galaxy. The cD has a prominent central dust lane but otherwise little evidence for accretion and little star formation. An analysis similar to that described above for Abell 1068 is in progress.

Sharma, McNamara, and colleagues are analyzing *Chandra* images of the bright cluster Abell 1991. The cluster has inwardly decreasing temperature and cooling time profiles, and a low temperature core, as are found in other cooling flow clusters. The cluster core contains cool, dense lumps of gas within the halo of the cD galaxy that are not clearly related to the weak central radio source. The origin of these lumps of gas and their possible relationship to star formation is being considered.

Abell 1835 is the subject of an optical and X-ray study by McNamara, Steiner, and undergraduate alumnus Russell Ryan [Arizona State U.]. Abell 1835 has been observed spectroscopically with XMM-*Newton*'s Reflection Grating Spectrometer and with *Chandra*'s ACIS camera. It was the first cluster shown to be absent the low energy emission lines predicted by the classical cooling paradigm. At the same time, its central cD galaxy hosts a massive central starburst. McNamara and his team are testing the cooling paradigm by measuring and comparing the cooling rate and the star formation rate for consistency. They are performing similar analyses on two additional clusters being observed with *Chandra* in Cycle 4.

McNamara continued his long-term collaboration on the "160 Square Degree Rosat Cluster Survey" with A. Vikhlinin [CfA], C. Mullis [ESO] and others. The team has obtained redshifts for essentially all clusters and has published the final cluster catalog. The luminosity function has been derived, allowing comparison between the local and distant cluster luminosity functions. Clusters with luminosities above $\sim 10^{44}$ erg s^{-1} are rarer at redshifts $z > 0.6$ than in the nearby universe, demonstrating the existence of luminosity evolution in clusters at greater than 3σ confidence. The team was able to constrain Ω and Λ using the gas-mass fraction of distant clusters from this survey.

Samuele, McNamara, and colleagues are using [O II]$\lambda3727$ emission from cD galaxies in the 160 degree survey to search for warm interstellar media. Nebular emission is a sensitive tracer of cooling flows. The current project uses the line equivalent width to search for evolution in the strength and number of cooling flows as a function of redshift and cluster X-ray luminosity.

3.4 X-Ray Binaries

Using a coupled Monte-Carlo/Fokker-Planck code for time-dependent radiation transfer and electron dynamics in two spatial dimensions, Böttcher and Finke are currently simulating the X-ray spectral variability signatures resulting from various flaring scenarios in an accretion-disk corona configuration with a realistic radial and vertical profile of the corona and a Shakura-Sunyaev-type radial profile of the accretion disk emission. The work aims at modelling the recently reported powerful millisecond flaring activity of Cyg X-1 (Gierlinski & Zdziarski 2003), during which spectral information could be extracted on millisecond time scales. Preliminary results indicate that the high-state flaring activity of Cyg X-1 reported by Gierlinski & Zdziarski may be successfully reproduced by a powerful energy release (e.g., through magnetic reconnection) localized in a tenuous, hot corona atop a cool, optically thick accretion disk.

Böttcher and Gupta are currently investigating time-dependent spectral and variability signatures of mildly relativistic jet outflows from X-ray binaries. A possible application of the results from this study may be the ultraluminous X-ray sources (X-ray sources exceeding the Eddington luminosity of black holes of a few solar masses) discovered in many nearby galaxies.

I. A. Smith [Rice U.] and Böttcher are leading a collaboration to monitor the ultraluminous X-ray sources in the nearby spiral galaxy NGC 1313. A series of pointings by the *XMM-Newton* X-ray observatory are currently (Oct. 2003 – Jan. 2004) being carried out and are co-ordinated with ground-based radio (ATNF; PI: S. Ryder) and optical (VLT; PI: M. Pakull) observations. These observations are intended to extract useful X-ray spectra from the individual X-ray sources in NGC 1313, to identify their optical and radio counterparts, and to monitor their variability on time scales from weeks to months.

3.5 Nuclear Astrophysics

Brune is pursuing a better understanding of the ^{12}C$(\alpha,\gamma)^{16}$O reaction at low energies. The rate of this reaction determines the ^{12}C/^{16}O ratio produced by helium burning, and consequently has very significant effects on the subsequent structure and nucleosynthesis, as well as the final outcome of the evolution. Calculation of the reaction rate in helium-burning conditions requires the cross section be known for energies of ~ 300 keV; unfortunately, at this energy the cross section is too small to measure with presently available accelerator technology. One must thus rely on indirect methods and extrapolations of measurements performed at higher energies. Work on this project is proceeding on several fronts. Brune and graduate student Catalin Matei are measuring the γ-ray branching ratios for states in ^{16}O which impact the reaction cross section. They are additionally collaborating with scientists at Argonne National Laboratory to make improved measurements of the ^{16}N β-delayed α particle spectrum which help to constrain the cross section. Brune and Matei are also part of a collaboration to make improved direct measurements of the ^{12}C$(\alpha,\gamma)^{16}$O cross section at the TRIUMF facility (Vancouver, BC).

Efforts to use radioactive beams to study reactions relevant to nucleosynthesis in stellar explosions continue through Brune's collaboration with scientists at Oak Ridge National Laboratory (ORNL). The team has completed measurements of the proton-transfer reaction ^{14}N(^{17}F,^{18} Ne) and analysis is underway. This cross section helps to constrain the rate of the proton capture reaction ^{17}F$(p,\gamma)^{18}$Ne. In the future it is hoped that sufficient ^{17}F beam intensity can be developed so that the ^{17}F(p,γ) reaction can be measured directly. The proton-capture reactions on ^{17}F are critical for estimating the quantity of ^{18}F produced by novae, an isotope whose β^+ decay may produce an observable flux of γ rays with energies up to 511 keV. These reactions also have important effects on the yields of heavier nuclei produced in novae and x-ray bursts.

Brune and collaborators are also initiating a new program to study the nuclear structure of nuclei far from stability. Experiments are being planned to measure the nuclear level densities in neutron-rich Cs isotopes at ORNL. This information is crucial for determining (n,γ) rates in the rapid neutron capture process (r process).

For non-universal gaugino masses, collider experiments do not provide any lower bound on the mass of the lightest neutralino. Phillips, working with H. Dreiner [Bonn U.], C. Hanhart [FZ-Julich], and U. Langenfeld [Bonn U.], has reviewed the supersymmetric parameter space which leads to light neutralinos, and finds that such neutralinos are almost pure bino in character. In light of this, the neutralino lower mass bound obtained from supernova 1987A (SN1987A) was examined. The analysis considers the production of binos in both electron-positron annihilation and nucleon-nucleon binostrahlung. For electron-positron annihilation, the calculation takes into account the radial and temporal dependence of the temperature and degeneracy of the supernova core. For the case of bino production in NN collisions, the Raffelt criterion and recent work concerning the strong-interaction part of the calculation are used to gauge the impact of bino radiation on the SN1987A neutrino signal. Considering these two bino production channels allows determination of separate and combined limits on the neutralino mass as a function of the selectron and squark masses. Values of the selectron mass between 300 and 900 GeV are inconsistent with the supernova neutrino signal. On the other hand, in contrast to previous works, this study finds that SN1987A provides almost no bound on the squark masses: only a small window of values around 300 GeV can be excluded.

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