

**Ohio University**  
**Department of Physics and Astronomy**  
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The following report covers the period November 1996 through October 1997.

## 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. OU's Department of Physics & Astronomy has 20 faculty active in research in areas including nuclear physics, chaos and nonlinear dynamics, condensed matter and surface physics, and astrophysics. The Department offers a Ph.D. in physics, with a current graduate enrollment of approximately 50 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 Assistant Professors Joseph Shields and Thomas Statler, and Emeritus Professor James Dilley. Suvendra Dutta continued as a Post-doctoral Research Associate under Statler's supervision, and also served as an Adjunct Assistant Professor during the fall quarter. During the past year Statler has supervised research by graduate student Jakob Bak and undergraduate Chad Myers, and Shields has supervised research by graduate student Mansie Iyer and undergraduate Richard Waters. Waters completed a bachelors degree in physics in June, and entered the graduate program in astronomy at the University of California at Santa Cruz in September.

Statler was chosen to receive a Faculty Early Career Development (CAREER) Award by the National Science Foundation. Funding provided by this award will be used to support Statler's research into the structure and evolution of elliptical galaxies, as well as a summer internship program, Science Teachers Active in Real Science (STARS), for K-12 educators. Statler and Shields also received continued funding from NASA for theoretical and observational studies of normal and active galaxies. Shields began a three-year term on the Publications Committee for the Astronomical Society of the Pacific.

## 3. FACILITIES

The astrophysics group continued to enlarge its research infrastructure with the acquisition of new workstations and peripheral hardware. OU's library holdings in astronomy were also augmented by generous donations of journals by Drs. Jay Frogel [Ohio State U.] and Ivan King [UC-Berkeley]. Planning was initiated for an on-campus teaching observatory, in parallel with the start of regular "Star Walks" and public viewing nights with portable telescopes.

The astrophysics group continued to make use of national facilities and other telescopes for research. Statler completed observing runs in 1997 at the Multiple Mirror Telescope and

Kitt Peak National Observatory, and Shields collected data at the MMT and Keck Observatories. Shields continued to make active use of space-based telescopes, including the *Hubble Space Telescope*, *ISO*, and *ROSAT* observatories. Dutta received a Major Research Grant of computer time on the Cray-YMP8E at the Ohio Supercomputer Center.

## 4. RESEARCH

### 4.1 Stars

Shields and A. Filippenko [UC-Berkeley] have used infrared (JHK) images from the Keck I telescope to study the site of supernova 1961V in the galaxy NGC 1058. This transient source is the prototype of the supernova Type V class defined by Zwicky. Goodrich *et al.* (1989, ApJ, 342, 908) and Filippenko *et al.* (1995, AJ, 110, 2261) have previously argued that SN 1961V was not, in fact, a true supernova, but instead was the eruption of a massive, evolved star, similar to the luminous blue variable  $\eta$  Carinae. A prediction of this scenario is that the star is still present, rather than having been obliterated in an explosion, and that the star in its present state is probably highly reddened by circumstellar dust that formed in ejecta accompanying the outburst. The Keck results reveal the presence of a point source at the location of SN 1961V, consistent with identification as a highly reddened luminous blue variable star, thus confirming that SN 1961V was probably not a true supernova.

### 4.2 Normal Galaxies

Dutta has developed a code to simulate very flattened stellar systems (*viz.* disk galaxies). Along with N. W. Evans [Oxford Univ.] and J. L. Collett [Univ. of Hartfordshire] he intends to use this code to understand and categorize the instabilities of power law disks both with and without dark halos. On the longer term they plan to use this code to understand the evolution of stellar disks under small perturbations such as due to fly-bys of companion galaxies.

Dutta & Statler continue to work with M. Weil [Columbia Univ.] to understand the orbital characteristics of remnants in galaxy merger simulations. They are using a two-pronged approach to the problem. On one hand they are using the data to constrain and verify the dynamical models used by Statler (1994) in his method to estimate the intrinsic shapes of galaxies. On the other hand they are trying to understand the dynamical behaviour of the merger remnants through the characteristics of the orbits making up the remnants.

Dutta has also been working with J. L. Collett on the merger of elliptical galaxies. A subset of Hickson groups of galaxies contain four or five galaxies with a low spiral fraction. The spiral-poor Hickson groups are also systematically denser than average. These systems may thus represent environments where we may observe the merger of several elliptical galaxies. The current work will test whether the

merger of elliptical galaxies can leave a remnant with characteristics (like the central density profile, triaxiality, rotation etc.) significantly different from those of the initial galaxies. If so, this evolutionary path would be a possible way of creating the observed dichotomy of elliptical galaxies, with the more massive elliptical galaxies having different central density profiles and triaxiality than the less massive elliptical galaxies.

Statler is continuing observational studies of the stellar kinematics of elliptical galaxies, in collaborations with T. Smecker-Hane [UC Irvine] and M. Merrifield [U. Southampton]. High-accuracy mapping of the kinematic fields can be used with dynamical models to constrain the three-dimensional mass distributions in these systems. The observational program seeks to obtain mean velocities with  $\sim 10$  km/s accuracy on four position angles per galaxy out to  $> 1.5$  effective radii. New data for NGC 3377, NGC 2768, and NGC 4472 obtained at the MMT and the KPNO Mayall 4m are presently being reduced. Dynamical modeling of previously obtained data for NGC 1700 shows it to be very nearly axisymmetric in the inner 3 effective radii despite being disturbed in the outer parts; further models contributed by H. Dejonghe [U. Gent] indicate that the mass-to-light ratio must increase radially outwards, even if velocity anisotropy is included. NGC 3379 and NGC 3377, leading candidates for harboring central supermassive black holes, are both seen to exhibit slow rotation on their minor axes of  $\sim 5$  km/s amplitude. NGC 3379, long regarded as a dynamically ordinary elliptical rotating slowly about its apparent minor axis, shows clear signs of slight triaxiality, as well as dynamical resemblance to edge-on S0 galaxies, perhaps suggesting the presence of a hidden disk.

Statler and R. Anderson [UNC-Chapel Hill] completed a study of the mean orbital motions of stars in realistic triaxial potentials, to test the conjecture that these motions can be accurately represented by confocal streamlines. It was found that most orbits at a given energy can be fitted by nearly identical confocal systems. The fitted streamline parameters reproduce, to high accuracy, the boundary between short axis and outer long axis tubes, which is a direct measure of the triaxiality of the potential. These results support the efforts described above to measure triaxiality from kinematic data using reasonably simple velocity field models.

Statler is collaborating with I. King [UC-Berkeley], P. Crane [ESO] and R. Jędrzejewski to study the nuclear kinematics of M31. The M31 nucleus has long been known to be strange; the off-center brightness peak originally detected by *Stratoscope* was later resolved into two peaks by *HST*. A 7-orbit spectrum has been secured with the  $f/48$  long-slit spectrograph of the *HST* Faint Object Camera, with the slit laid across the two nuclei. The total peak-to-peak rotation amplitude is more than 500 km/s. The rotation curve itself is highly asymmetric, and the center of rotation coincides with neither brightness peak. The dispersion profile, which is still highly uncertain, appears comparably asymmetric. Full dynamical modeling is planned for the near future.

Statler is beginning a collaboration with B. Ryden, D. Terndrup, and R. Pogge [Ohio State U.] to study the stellar populations of dwarf ellipticals in the Virgo cluster using

surface brightness fluctuations. Time has been scheduled on the MDM Hiltner 2.4m to begin *BVRI* surface photometry of selected objects.

Bak is engaged in Ph.D. dissertation work, under Statler's supervision, on the formation of counterrotating cores in elliptical galaxies. The goal is to simulate counterrotating core formation by a variety of processes and determine if the formation mechanism leaves an identifiable signature in the observables. A dissipationless tree code is being used to simulate accretion of small stellar systems by a pre-existing giant elliptical. Penalized-likelihood methods are employed to extract the final core line-of-sight velocity distributions. At a later stage, major merger simulations are planned with an explicit attempt to generate counterrotating cores through the initial conditions. Eventually hydrodynamics and heuristic star formation may be included.

Waters and Shields investigated analysis methods for narrow-band imaging of elliptical galaxies employed for measurement of interstellar nebulosity. Simulations employing spectra acquired with the Steward Observatory 2.3-m Bok telescope indicate that broad-band images (e.g. in the *R* bandpass) can yield accuracy comparable to that of narrow-band images for purposes of subtracting the stellar continuum from narrow-band images centered on  $H\alpha$ . For both bandpasses, measurement of nebular emission at equivalent widths less than  $\sim 1 \text{ \AA}$  is susceptible to systematic errors arising from gradients in  $H\alpha$  absorption strength, as well as other continuum features.

### 4.3 Active Galactic Nuclei

Shields, F. Hamann [UCSD], C. Foltz [MMT Observatory], and F. Chaffee [Keck Observatory] continued their study of the emission properties of QSOs at redshifts  $z > 4$ , with new observations collected at the MMT and Keck Observatories.

Shields has studied the ultraviolet spectral properties of low-ionization nuclear emission regions (LINERs) as part of several collaborations with A. Barth and A. Filippenko [UC-Berkeley], L. Ho [CfA], A. Koratkar [STScI], D. Maoz [Tel Aviv U.], K. Nicholson, K. Mason, and E. Puchnarewicz [Mullard SSL], and G. Reichert [GSFC]. UV spectra of seven LINERs are now available from *HST*. These sources appear heterogeneous in terms of emission line strengths. Evidence is present for hot stars contributing significantly to the continuum in several of the objects; the observed recombination emission suggests that a hard continuum component extending into the X-ray region plays an important role in photoionizing the emission-line plasma. Line ratios are generally incompatible with ionization by fast shocks.

Shields, in collaboration with F. Hamann, R. Cohen, M. Burbidge, and V. Junkkarinen [UCSD], and M. Crenshaw [GSFC], have analyzed new *HST* spectra of QSOs in order to measure the strength of Ne VIII  $\lambda 774$  emission. This work confirms preliminary findings by the same group suggesting that Ne VIII emission is often strong, and traces a high-ionization extension of the broad emission-line region that covers at least 30% of the sky as seen from the central continuum source. This medium is essentially identical in its

characteristics to the “warm absorbers” frequently observed in soft X-ray spectra of AGNs.

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