Ohio University
Department of Physics and Astronomy
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The following report covers Departmental activities in astronomy from September 1995 through October 1996. Additional information about the Department can be found at the WWW site http://www.phy.ohiou.edu.

1. FOREWORD

Ohio University was the first institution of higher education in the Old Northwest, and is part of the state university system for Ohio, with a current enrollment of approximately 20,000 students. OU's Department of Physics and Astronomy has for many years been active in research in areas including nuclear, solid state, and surface physics. The Department inaugurated a new program in astrophysics in September 1995.

2. PERSONNEL

Thomas Statler moved from the University of North Carolina to join the OU faculty as an Assistant Professor in September 1995, and hired postdoctoral fellow Suvendra Dutta (formerly of Oxford University). During the past year Statler has supervised research by graduate student Jakob Bak and undergraduates Chad Myers and John Day. Joseph Shields arrived from the University of Arizona to join the OU Department as an Assistant Professor in September 1996. Shields is currently supervising research by undergraduate Richard Waters. These personnel represent astrophysics within the Department, which has a total of 20 full-time faculty and graduate enrollment of 53 students.

3. FACILITIES

The Department has made a substantial commitment of resources in support of the astrophysics group. Over the past year three Sun workstations and supporting peripherals have been purchased by the group, augmented by a large existing network of workstations within the Department as well as by computers brought by Statler and Shields. Part of this equipment has been used to establish the OU Laboratory for Astronomical Image Reduction (LAIR), housed in Clippinger Graduate Research Laboratories.

The OU library has also undertaken a significant effort to upgrade its holdings related to astronomy. This work has been aided by generous donations of journals by Drs. Stephane Courteau [NOAO], Robert O'Connell [U. Virginia], Catherine Pilachowski [NOAO], William Saslaw [U. Virginia], and Donald Terndrup [Ohio State U.].

For astronomical observations, the group makes use of national facilities and other telescopes. Both Statler and Shields have active research projects based on observations from the Multiple Mirror Telescope, and Shields has approved programs with the *Hubble Space Telescope*,*ISO*, and *ROSAT* observatories.

4. RESEARCH

4.1 Early-Type Galaxies

Statler's work has focused on the determination of the three- dimensional mass distributions in elliptical galaxies, by fitting dynamical models to observations of the surface brightness distributions and the mean radial velocity fields. Although small compared to the random motions, the mean velocity field in effect shows the locations of critical points associated with orbit family boundaries, which reveal the shape of the potential; this is why the velocity field can be a shape diagnostic.

Bak and **Statler** have used these methods to model nine galaxies from the Davies & Birkinshaw (1988) sample of radio ellipticals, obtaining radially averaged shapes for each. Using an iterative technique, a nonparametric estimate of the parent shape distribution is obtained for the sample. The distribution is weakly bimodal, with peaks at the oblate and prolate ends. There is thus an indication that radio ellipticals may tend toward axisymmetry, but not necessarily toward oblateness. Methods for further constraining the parent distribution of dynamical parameters are being explored.

The above result is limited by small sample size and data quality. **Statler**, collaborating with T. Smecker-Hane [UC Irvine], G. Cecil [UNC], J. Bland-Hawthorn [AAO], and M. Merrifield [U. Southampton], has initiated a program to map the stellar kinematic fields of elliptical galaxies with high accuracy to large radii and at multiple position angles. Complete 4-position-angle observations have been completed at the MMT for NGC 1700 and NGC 3379, with partial coverage for NGC 3377; partial mapping has also been done at the AAT of NGC 4697 and NGC 7144.

The NGC 1700 data are highly symmetric with respect to the morphological axes, indicating that the galaxy is nearly oblate for $r \lesssim 2.5 r_e$; careful dynamical modeling gives the middle-to-long axis ratio $b/a > 0.9$ with 2σ confidence. The velocity distribution in the counterrotating core argues against a central stellar disk (and therefore against a gas-rich merger), and is consistent with the accretion of a low-mass stellar companion in a retrograde orbit. Photometric fine structure at large radii is also indicative of a merger; but rapid prograde rotation implies that this was not the same event that made the counterrotating core. Dynamical timing arguments suggest a merger of 3 or more stellar systems 2 – $4 h^{-1} Gyr$ ago. Additional dynamical modeling by **Statler** and H. Dejonghe [U. Gent] shows NGC 1700 to be one of the best cases, based on integrated light, for an elliptical with a dark halo.

Statler has previously modeled the ''standard elliptical'' NGC 3379 using data from the literature, with the result that oblate or fairly round triaxial shapes were preferred. New data, however, obtained with Smecker-Hane and Cecil, show, in addition to weak minor-axis rotation not detectable in earlier studies, unusual sharp kinks in the rotation profiles, near which locations the skewness of the line of sight velocity distribution changes sign. Profiles for S0 galaxies obtained by D. Fisher [U. Groningen] reveal strikingly similar features; major axis profiles of NGC 3379 are nearly identical to those of the edge-on S0 NGC 3115. This suggests a kinematic way to search for hidden disks in ellipticals.

Statler, **Dutta**, **Myers**, and **Day** performed a photometric study of galaxies in the Hubble Deep Field (HDF), and devised filtering strategies to identify the ellipticals. *Bona fide* ellipticals are rare, amounting to $<3\%$ of all objects in the HDF. The apparent ellipticity distribution is found to be flatter than that for $z\approx 0$ ellipticals; furthermore the fainter, bluer half of the sample is apparently flatter than the brighter, redder half. This may be a sign of slow shape evolution, ellipticals growing gradually rounder with time. However, the filtering strategy must be tested on simulated deep fields to rule out selection effects.

Dutta and **Statler**, with M. Weil [Oxford U.], have been analyzing results of numerical simulations of mergers of spiral galaxies to limit the set of dynamical models such mergers result in. The orbit structure and mean motions of stars in the merged object are used to constrain the dynamical model of the system. Particle orbits are calculated for initial conditions given by the instanteneous position and velocity of all the particles in the simulation. These orbits move in the smooth potential calculated by first producing a density field in a spherical polar grid, then expanding in orthogonal functions which are combinations of powers of radii and associated Legendre functions. By analyzing the average angular momentum of an orbit and its symmetry the orbits can be classified. One can distinguish between boxlets and boxes and the two types of long axis tube orbits, as well as recover the turning points of the orbit.

Dutta and **Statler** have also investigated the average streaming motion of stars in the merger simulations. Each particle orbit is integrated until it crosses the X-Z plane. The mean of the velocity in the Y-direction of all orbits crossing the X-Z plane near to that point contributes to the mean streaming velocity. The nature of the streaming motions on the X-Z plane constrains the dynamical characteristics of the merger remnant. By comparing these characteristics with observations one can make statements on the effectiveness of mechanisms like major mergers in producing objects that are like observed elliptical galaxies.

Dutta has recently completed a study of scattering and capture of orbits in different potentials with N. Evans [Oxford U.] and J. Collett [Oxford U.]. The study investigated the capture of orbits into resonances in barred potentials and its implications on the shapes of galaxies. They are presently engaged in studying the formation of elliptical galaxies by the gradual merger and collapse of smaller compact ellipticals.

Shields and **Waters** are investigating optimal techniques for removal of background starlight in narrow-band imaging studies of optical nebulosity in early-type galaxies. Most existing observational studies rely on narrow-band images of the stellar continuum for this purpose, but recent work has attempted to employ broad-band images instead, which has the advantage of reducing the required exposure time per image. The broad-band method remains unproven, however, in that broad bandpasses may be more susceptible to radial gradients in metallicity and spectral morphology than narrow bandpasses, which may lead to errors in the emission-line image after subtraction of the continuum. In the current program, long-slit optical spectra of early-type galaxies acquired with the Steward 2.3-m telescope are being used to simulate the stellar continuum subtraction method employed with direct images, in order to test the relative validity of narrow- and broad-band measures of the continuum.

4.2 Spiral Galaxies

Dutta has been working with J. Binney [Oxford U.] and I. Jiang [Oxford U.] on the modelling of warps in disks of spiral galaxies. A very large fraction of spiral galaxies appear to have severe warps in their disks. Attempts have been made to understand this in terms of different orientations of the disk and halo making up the galaxy. **Dutta** and coworkers are attempting to tackle this problem through numerical simulations. It is important to model the halo's reaction to the disk because there can be considerable exchange of energy from one to the other. To this end they are performing self-consistent simulations of a disk inside a halo to test different scenarios under which one could obtain a sufficiently long-lived warp.

4.3 Active Galactic Nuclei

Shields, F. Hamann [UCSD], C. Foltz [MMT Observatory], and F. Chaffee [Keck Observatory] have been conducting a program of observations with the Multiple Mirror Telescope in order to study the rest-frame ultraviolet spectra of known QSOs with redshift $z>4$. The goal of this effort is to quantify emission-line properties in these extreme objects for comparison with lower-redshift samples, and in particular to measure the strength of the N V λ1240 line for use as a diagnostic of abundance. The sample now includes 25 objects. Preliminary results indicate that the emission lines in the high-redshift QSOs are on average narrower and described by higher line-to-continuum peak flux ratios than lines of lower-redshift sources. This trend may arise in part from selection effects stemming from correlations between line profile and equivalent width, however. Emission in the N V feature remains strong, suggesting a degree of (high) enrichment in these sources similar to that found previously in QSOs at $z=2-3$.

Shields and Hamann have completed an analysis of absorption seen in ultraviolet and X-ray spectra of the Seyfert 1 galaxy NGC 3783 in the years 1992 – 1994. There is disagreement at the present time as to whether absorption in the two bandpasses in AGNs arises in general from a common medium, and also whether the absorbing matter resides on compact or extended scales with respect to the broad emission-line region. In NGC 3783 the measured absorbing column densities of multiple ions are consistent with those of a single-phase medium that is photoionized by the active nucleus, with equal shadowing of the UV and X-ray continuum sources; more complicated scenarios cannot be excluded, however. Variability in the UV absorber suggests that this material has an electron density of at least ~300 cm^{-3}, and a location within ~10 pc of the central engine. The absorber is sufficiently ionized, however, that it is unlikely to trace a component of the broad-line region that is important for emission of the observed UV and optical emission lines.

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