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FINAL TECHNICAL REPORT

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PART I: Ultraviolet Observations of Clusters of Wolf-Rayet Stars in the SBmIII Galaxy NGC 4214

The purpose of the grant was to obtain and analyze *IUE* (UV) and ground-based (optical) spectra of the central bar of NGC 4214, which contains several bright H II regions, in order to further explore the properties of the Wolf-Rayet stars in this galaxy. Several spatially distinct regions, with widely different equivalent widths of optical Wolf-Rayet lines, could be sampled by the large *IUE* entrance aperture. By using newly developed extraction techniques, the spectra of these H II regions could be isolated, and differences in their stellar populations would be systematically studied.

Data were obtained with *IUE* in late February and early March, 1992. Some of the shifts were successful, but a few were not — apparently the blind offset from the nearby star did not work equally well in all cases. Thus, the signal-to-noise ratio is somewhat lower than we had hoped. This necessitated a more careful extraction of the spectra of individual H II regions from the two-dimensional spectra. (A program that models the point spread function in the spatial direction was used to deblend the distinct H II regions.) The *IUE* data are currently being analyzed in conjunction with ground-based optical spectra. There appear to be obvious variations in the stellar population over

angular scales of only a few arc seconds. Later this year we expect to write up the results for publication.

Note that during part of the *IUE* shifts, Filippenko obtained data for the program entitled "International AGN Watch: Mapping the Broad-Line Region in NGC 3783" (PI: B. M. Peterson), on which he is a Co-I. The purpose was to measure the time delay in the response of the broad-line clouds to changes in the ionizing continuum. The nucleus of NGC 3783, a type 1 Seyfert galaxy, was monitored with high temporal frequency by a large consortium of observers. Interesting variations were detected, and these are being used to infer the physical conditions as a function of radial distance from the nucleus. A paper describing the results is in preparation. The grant funds were also used to support the interpretation of data from another large monitoring campaign — the BL Lac object PKS 2155-304 (PI: C. M. Urry). The results have been accepted for publication in *The Astrophysical Journal* (Urry *et al.* 1993; see Paper 5 on page 4).

PART II: Ultraviolet and Optical Observations of LINERs

This was a continuation of a long-term (several years) project that uses *IUE* (UV) and ground-based (optical) spectra to infer the physical conditions in Low-Ionization Nuclear Emission-Line Regions (LINERs). We have obtained spectra of a few key objects that cover a representative range in LINER continuum and emission-line properties. The overall goals are to (1) separate the emission into spatially distinct components, (2) establish whether the observed nuclear ultraviolet continua indicate sufficient photoionizing fluxes to account for the emission lines, (3) determine whether the nuclear emission can be explained by hot stars alone, (4) detect and measure the strengths of UV emission lines, and (5) search for systematic differences in the UV spectra of LINERs whose other properties differ in some respects.

Many interesting results have been obtained, and some of these will soon appear in technical journals. Papers 1 (Ho and Filippenko 1993) and 6 (Ho, Filippenko, and

Sargent 1993) on page 4, for example, discuss the possibility that LINERs with relatively weak [O I] λ6300 emission (relative to Hα) are actually powered by very hot O-type stars rather than by a nonstellar continuum. In this case, they are not genuine active galactic nuclei (AGNs). "Strong-[O I] LINERs," on the other hand, appear to be photoionized by nonstellar (e.g., power law) continua with a range of spectral indices and gas densities; they may, in fact, be low-luminosity AGNs. Paper 2 further examines this possibility, but also points out that LINERs with extended emission-line gas may be shock heated by supernova-driven winds, galaxy interactions, or mergers. Moreover, there is strong evidence that the line emission in some LINERs is produced by cooling flows.

Paper 3 reviews the UV spectral properties of low-luminosity AGNs, concentrating on LINERs. As above, we conclude that the LINER classification is heterogeneous; it contains objects which resemble classical AGNs in their radio, X-ray, and emission-line properties, but also objects which are clearly different. Those LINERs resembling AGNs at UV wavelengths are generally found to resemble them at other wavelengths as well. Interesting differences were found between various UV and optical emission-line profiles in M81, a well-known LINER; there appear to be at least two distinct broad-line regions, only one of which is clearly photoionized by a nonstellar continuum. A detailed analysis is currently being prepared for publication.

Finally, we have discovered a nonrandom trend in the dispersion of emission-line intensity ratios in type 2 Seyfert galaxies (Paper 4). The sense of this pattern suggests the influence of a single physical parameter, the hardness of the ionizing continuum, which controls the heating energy per ionizing photon. The observed distributions can be reproduced if the ionizing continuum is parametrized by a power law, $f_\nu \propto \nu^\alpha$, with α ranging from -1 to -2.5. Our results also suggest an inverse correlation between luminosity and continuum hardness for Seyfert 2 nuclei; if true, this trend extends a similar pattern known in quasars and type 1 Seyferts to AGNs of lower luminosity.

Publications Citing NASA Grant NAG 5-1800

1) L. C. Ho and A. V. Filippenko (1993). *Astrophys. and Space Science*, in press. "The Photoionization Mechanism of LINERs: Stellar or Nonstellar?"

2) A. V. Filippenko (1993). In *The Nearest Active Galaxies*, ed. J. Beckman (Madrid: CSIC), in press. "The Physical Nature of LINERs."

3) G. A. Reichert, E. M. Puchnarewicz, A. V. Filippenko, K. O. Mason, G. Branduardi-Raymont, and C.-C. Wu (1993). In *The Nearest Active Galaxies*, ed. J. Beckman (Madrid: CSIC), in press. "Ultraviolet Spectral Properties of Low Luminosity AGN."

4) L. C. Ho, J. C. Shields, and A. V. Filippenko (1993). *Astrophys. Jour.*, in press. "The Ionizing Radiation of Seyfert 2 Galactic Nuclei."

5) C. M. Urry, *et al.* [29 authors] (1993). *Astrophys. Jour.*, in press. "Multiwavelength Monitoring of the BL Lac Object PKS 2155-304. I. The IUE Campaign."

6) L. C. Ho, A. V. Filippenko, and W. L. W. Sargent (1993). *Astrophys. Jour.*, submitted. "A Re-evaluation of the Excitation Mechanism of LINERs."