FINAL REPORT

For The Project entitled

SPECTRAL ENERGY DISTRIBUTION OF STAR-FORMING GALAXIES

Principal Investigator: A.L. Kinney

Title: Associate Astronomer

Telephone: (410) 338-4831

Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218
Operated by the
Association of Universities for Research in Astronomy, Inc.

RESULTS

A great deal of reserach has been produced under this project, including the publication of eight papers based directly on the UV/optical spectral energy distributions (see list below). We first collected our data from satellites and from ground based facilities, and then used the database towards the following scientific questions; to evaluate the basic properties of starburst galaxies such as metallicity, age of the stellar population and star-formation rate; to study the extinction in Starbursts and to determine an extinction law for them; to create templates of quiescent and starburst galaxies used to derive K-corrections as a function of morphological type and redshift; to study the ultraviolet continuum in Seyfert 2 galaxies; to study the X-ray to radio spectral energy distributions of Seyfert 2's, Starbursts, LINER's and normal galaxies.

We performed a detailed analysis of the ultraviolet to near-infrared (λ1200-10000Å) stellar population of Seyfert 2 galaxies. This involved data which already existed in our database, new spectroscopic data, which was observed, reduced and analyzed as part of this project, as well as broad-band images.

Until recently, it was assumed that the ultraviolet continuum of Seyfert 2's was light from the hidden Seyfert 1 nucleus, reflected in our direction, and that the stellar population contribution to this waveband was negligible. However, Heckman et al. (1995) showed, comparing the ultraviolet (1200-1900Å) IUE spectra of 20 Seyfert 2's with the spectrum of Seyfert 1's, that only 20% of the Seyfert 2's UV flux could be explained as scattered nuclear light. From the comparison of the UV slopes, they suggested that the remaining 80% of the UV flux should be due to circumnuclear star formation.

Heckman et al. (1995) based their result on the analysis of the ultraviolet 1200-1900Å IUE spectra of Seyfert 2's. However, due to the low signal to noise ratio (S/N) of the individual UV spectra, their analysis had to be based on the average spectrum of 20 Seyfert 2's, and a detailed analysis of the stellar population of individual objects was not possible. This average Seyfert 2 spectrum was created weighting the individual spectra by their S/N. Doing the average in this way they gave a larger weight for galaxies with circumnuclear star-forming regions, which have a larger UV flux and better S/N, thus influencing the results.

In our analysis we study the stellar population of individual Seyfert 2 galaxies, based on spectra in the wavelength range 1200-10000Å. The analysis of the stellar population of Seyfert 2's based only on the UV spectrum (1200-3200Å) is usually not possible, due to the low S/N of the IUE spectra. However, based on the 1200-10000Å spectra, especially the visual part (3200-10000Å) which have a much better S/N, we have been able to determine the stellar population of individual Seyfert 2's. Using the equivalent widths of absorption lines in the region λ3200-10000Å, we found which galaxy template from Kinney et al. (1996) gives the best match to the observed spectrum, and, assuming that this stellar population can be extrapolated to the ultraviolet, we were to determine the stellar population contribution to the region λ1200-3200Å. The results of this study are being written up now.

Given the large aperture through which the spectra were obtained, $10'' \times 20''$, it is possible that, in some cases, the ultraviolet spectrum of these galaxies includes the contribution from young stars in the disk. In order to quantify this contribution, we are obtaining broad

band B, V and I images of this galaxies, to study in more detail the possible contribution from young stars along the galaxy disk.

SUMMARY

Our analysis allowed us to address the following points: 1) the nature of the featureless ultraviolet continuum in Seyfert 2's, in particular the amount of stellar population that contributes to this waveband; 2) the difference between Seyfert 1's and Seyfert 2's in the ratio of ultraviolet λ1400Å to soft X-rays continuum, which is larger in Seyfert 2's and apparently contradicts the Unified Model, but may be resolved if we consider the stellar population; 3) search for anisotropic radiation escaping from the nucleus of Seyfert 2's, by comparing the number of ionizing photons, estimated from the ultraviolet continuum photons, to the number of recombination photons, calculated using the Hβ line flux.

In addition, the research from this grant produced template spectra that have been used in a wide variety of applications, including the identification of high redshift galaxies in the Slone survey.

REFEREED PAPERS RESULTING FROM NAGW-3757

1. *The spectral energy distribution of Normal, Starburst and Active Galaxies*, Schmitt, H. R., **Kinney, A. L.,** Calzetti, D. & Storchi-Bergmann, T., *AJ*, 114, 592, 1997

2. *Reddening and Starformation in Starburst Galaxies*, Calzetti, D., *AJ*, 113, 162, 1997

3. *Template Ultraviolet to Near-Infrared Spectra of Star-forming Galaxies and Their Application to K-Corrections*, **Kinney, A. L.,** Calzetti, D., Bohlin, R. C., McQuade, K., Storchi-Bergmann, T. & Schmitt, H. R., *ApJ*, 467, 38, 1996

4. *Dust Obscuration in Starburst Galaxies from Near-Infrared Spectroscopy*, Calzetti, D., **Kinney, A. L.** & Storchi-Bergmann, T., *ApJ*, 458, 132, 1996

5. *The Nature of the Ultraviolet Continuum in Type 2 Seyfert Galaxies*, Heckman, T., Krolik, J., Meurer, G., Calzetti, D., **Kinney, A.,** Koratkar, A., Leitherer, C., Robert, C. & Wilson, A., *ApJ*, 452, 549, 1995

6. *Scattering Properties of the Dust in the Reflection Nebula IC435*,, Calzetti, D., Bohlin, R. C., Gordon, K. D., Witt, A. N. & Bianchi, L., *ApJ*, 446, L97, 1995

7. *Ultraviolet to Near-Infrared Spectral Distributions of Star-Forming and Seyfert 2 Galaxies*, Storchi-Bergmann, T., **Kinney, A. L.** & Challis, P., *ApJS*, 98, 103, 1995

8. *Ultraviolet to Optical Spectral Distributions of Northern Star-Forming Galaxies*, McQuade, K., Calzetti, D. & **Kinney, A. L.**, *ApJS*, 97, 331, 1995