Nuclear Stellar Populations in Bright Spiral Galaxies: an Infrared Spectroscopic Perspective

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Abstract

We have used H- and K-band spectroscopy to investigate the nuclear stellar populations and star formation histories of a subsample of 41 bright spiral galaxies from an optically-selected sample (the ISO Atlas of Bright Spiral Galaxies). ~80% of the sample have spectra that are essentially identical and that exhibit only absorption features characteristic of the atmospheres of late-type stars. We present a composite near-infrared spectrum that characterizes these "quiescent" galaxies. In the other ~20% of the sample, we detect both this quiescent spectrum and emission lines from HI (Brackett γ), H_2, and [FeII] that are indicative of recent bursts of star formation. The starbursts were detected only in Sbc and later-type galaxies, and most are barred or show evidence of recent interactions. The stellar populations are most consistent with instantaneous starbursts. While only ~2% of the total nuclear stellar mass in these galaxies is due to these starbursts, we show how the nuclear stellar populations of normal spiral galaxies can be built up through a series of these bursts.

Goals

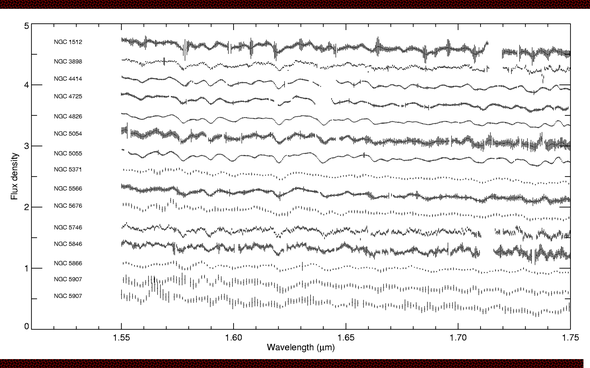
- Determine the typical stellar populations in the nuclei of spiral galaxies.
- Search for links between enhanced nuclear star formation activity and galaxy morphology, AGN activity, and environment
- Provide a baseline for comparing the stellar populations in "normal" spiral galaxies with the populations in exotic objects (such as luminous and ultraluminous infrared galaxies)

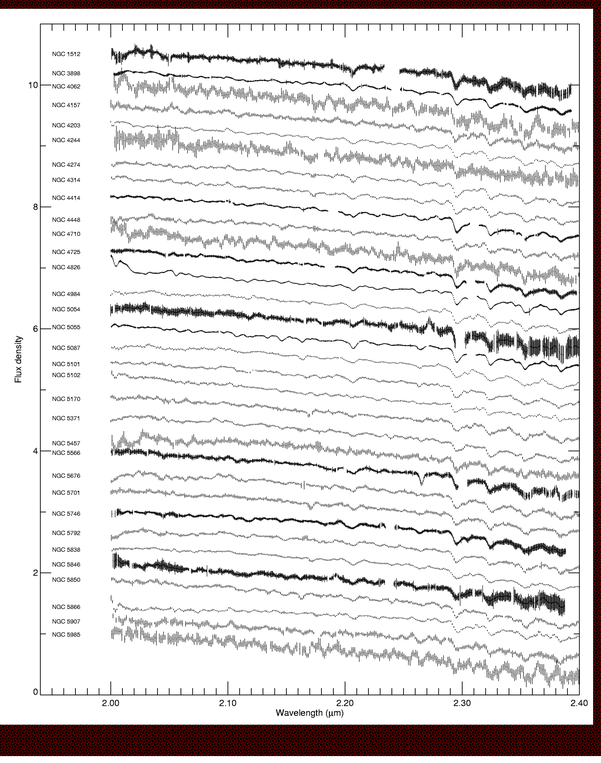
Observations

- Sample of 41 galaxies drawn from Infrared Space Observatory Atlas of Bright Spiral Galaxies sample, a representative cross-section of a optical magnitude-limited sample of spiral galaxies (Bendo et al. 2002).
  - Sample includes a range of morphological types from S0 to Sm and a mix of barred and unbarred galaxies.
  - Sample includes a range of galaxies with different kinds of nuclear activity, including two Seyferts and seven LINERS as classified by Ho, Filippenko, & Sargent (1997).
- 14 galaxies observed in H- and K-band with SPEX at the NASA IRTF with a resolution of 1200.
- 27 galaxies observed in K-band and 6 galaxies observed in H-band with CGS4 at UKIRT with a resolution of 800.

Quiescent Spectra

Individual Spectra



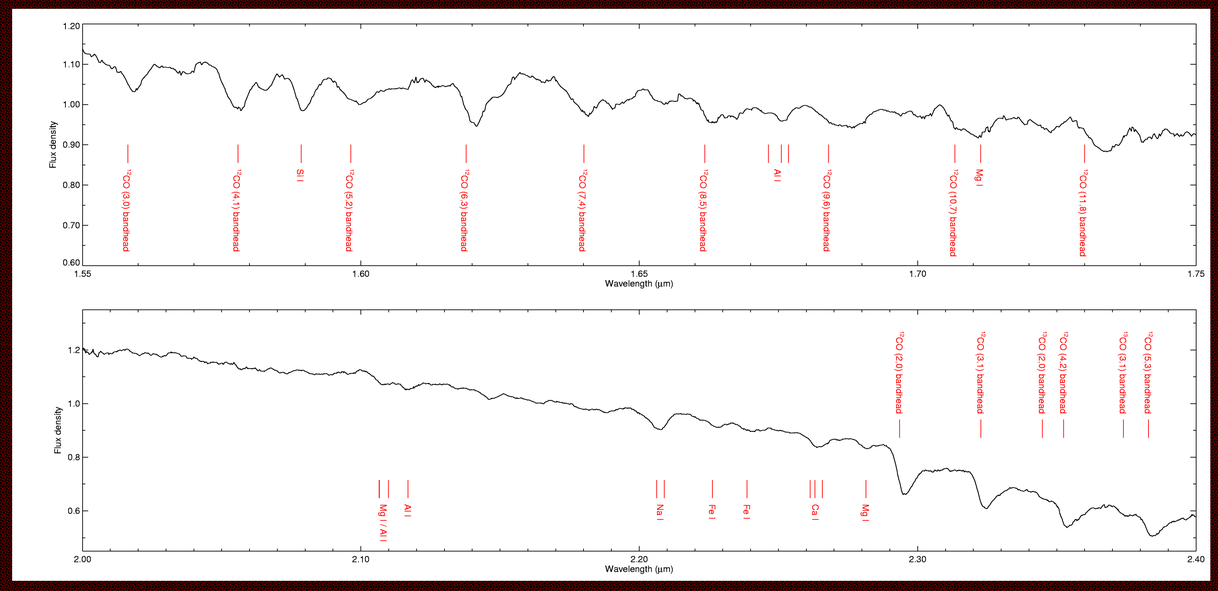


A majority of the spectra (33 of 41) were found to be quiescent spectra. The spectra all share the following features:

- CO absorption features present
- Metal absorption lines present
- Hydrogen recombination lines (Br–γ) absent
- Shock-excitation lines (H_2, [Fe II]) absent

These near-infrared spectra are clearly dominated by older, quiescent populations of red stars.

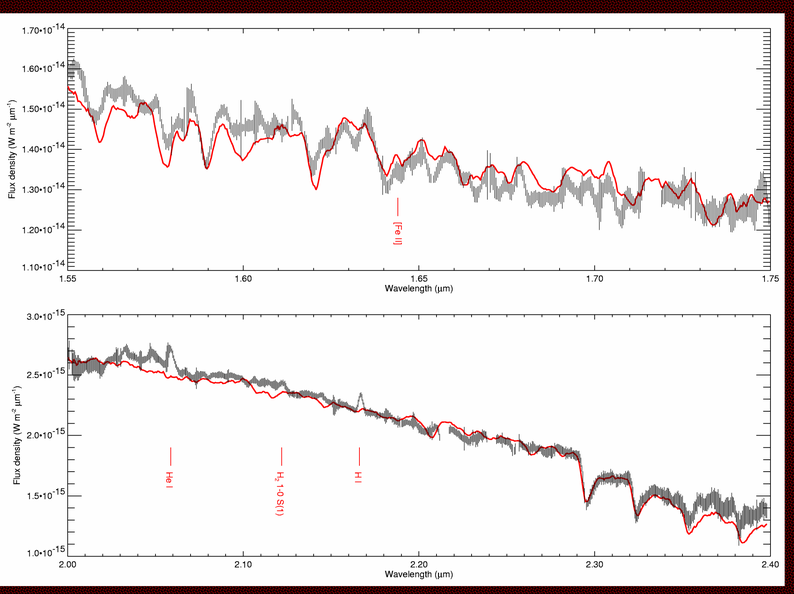
Composite Spectrum



The above normalized spectrum is a composite made from all quiescent S0 and spiral galaxies in the sample. The most prominent features include CO absorption features and metal absorption features, which indicate the dominance of evolved red stars in these galaxies' nuclei. When measurements of the absorption features are interpreted with Starburst99 (Leitherer et al. 1999), the results indicate that the population can be characterized by a single population with a Salpeter initial mass function and solar metallicity formed in an instantaneous burst 180 Myr ago. Keep in mind, however, that this is a representative age, not the true age of the entire stellar population.

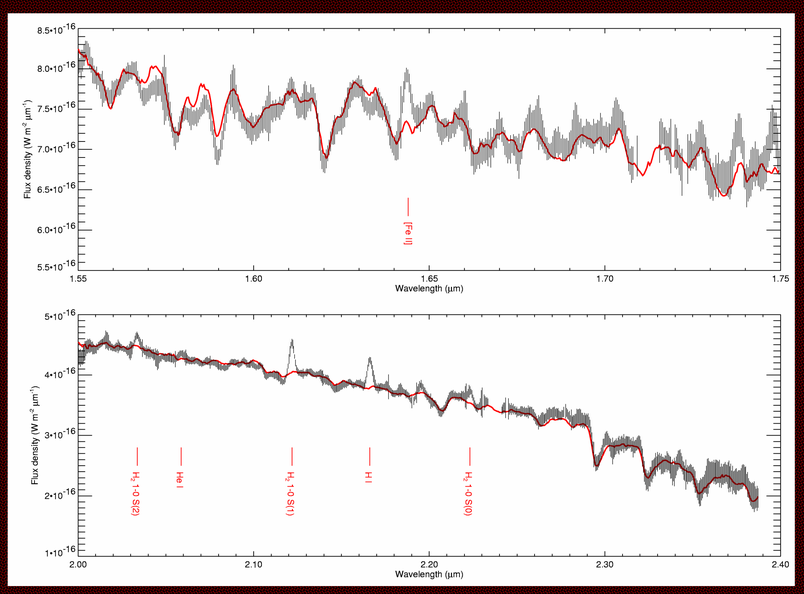
Non-Quiescent Spectra

Recombination line emission



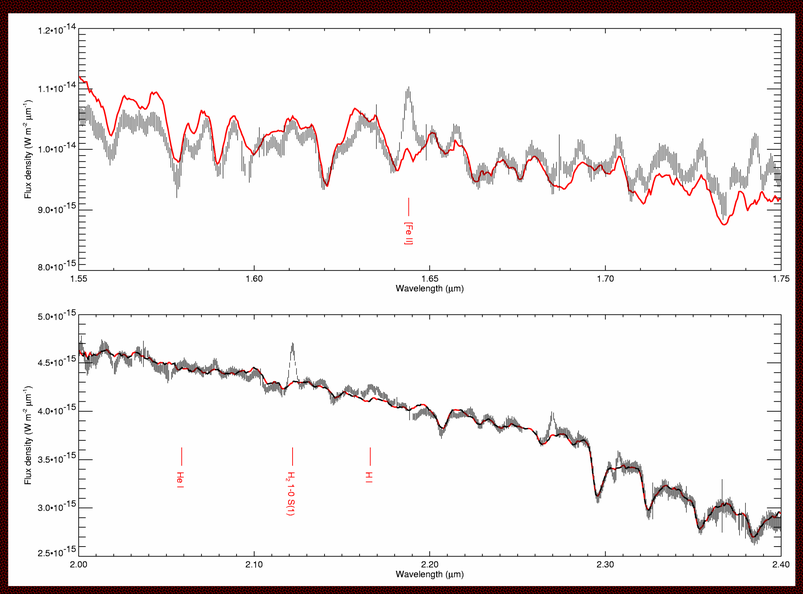
The above spectrum of the A cluster in NGC 1569 (shown with black error bars) is an example of nuclear emission that contains recombination lines (Br-γ) but no shock excitation lines ([Fe II], H_2). The match between the composite quiescent spectrum (overlaid as a thick red line) and the continuum indicates that this cluster's continuum is dominated by a population of evolved red stars similar to that in the quiescent galaxies' nuclei. The hydrogen lines show the presence of young, ionizing stars, but the absence of shock excitation lines suggests that no massive stars have evolved into supernovae. Therefore, the younger stellar population in this system must be less than 3.5 Myr old. Two other nuclear regions had similar spectra.

Recombination and shock excitation line emission



The above spectrum of the nucleus of NGC 289 (shown with black error bars) is an example of nuclear emission that includes both recombination lines (Br-γ) and shock excitation lines ([Fe II], H_2). The close match between the composite quiescent spectrum (overlaid as a thick red line) and the continuum indicates that this galaxy's continuum is dominated by the same stellar population that is present in the quiescent galaxies' nuclei. Since the recombination lines imply the presence of young, ionizing stars and the shock excitation lines imply the presence of supernovae, the younger stellar population in this system must be between 3.5 and 8.0 Myr. Two other nuclear regions had similar spectra.

Shock excitation line emission



The above spectrum of the nucleus of the Seyfert NGC 5033 (shown with black error bars) is an example of nuclear emission that contains strong shock excitation lines ([Fe II], H_2) but either weak or non-existent recombination lines (Br-γ). The composite quiescent spectrum does not match either the slope of the continuum or the depth of the CO features in the K-band, so a power-law function had been added to the continuum, which is overlaid as a thick red line. The presence of shock excitation lines indicates that supernovae may be present, but the lack of narrow recombination lines shows that all young, ionizing stars have evolved off the main sequence. Therefore, the age of the younger stellar population in this system (if the line emission is indeed from supernovae) is 8 – 36 Myr. Only one other galaxy in this sample, a LINER, had a similar spectrum.

Morphology, AGN Activity, and Environment

- All non-quiescent galaxies were late-type spirals (Sbc or later).
- 6 of 8 non-quiescent galaxies are barred, suggesting that bars caused gas infall that triggered star formation. Many quiescent galaxies, however, are also barred, so not all barred galaxies exhibit recent nuclear star formation activity.
- 6 of 8 non-quiescent galaxies are interacting, suggesting that the interactions caused gas infall that triggered star formation. As with the barred systems, though, many of the quiescent galaxies are also interacting with other galaxies, so interacting systems do not always exhibit recent nuclear star formation activity.
- One of two Seyferts in the sample showed signs of recent nuclear star formation.
- Only one of several LINERs and transition-type galaxies exhibited signs of recent star formation, suggesting that most optical LINER emission is not triggered by star formation in nearby galaxies.

Build-Up of Nuclear Stellar Populations through Instantaneous Bursts

- Stars younger than 36 Myr (the timescale during which stars from an instantaneous burst can be detected in this study) typically make up ~2% of nuclear stellar populations in non-quiescent systems.
- ~20% of galaxies are non-quiescent.
- Therefore, the average amount of stellar mass younger than 36 Myr in any galaxy nucleus is ~0.4%.
- 36 Myr divided by the timescale of the universe (14 Gyr) is 0.25 %, which is close to the average amount of stellar mass younger than 36 Myr in these systems.
- Therefore, the average mass of young stars in and galaxy' nucleus is consistent with what is expected if star formation occurs in instantaneous bursts over the age of the universe.

References

Bendo, G. J., et al. 2002, AJ, 123, 3067
Ho, L. C., Filippenko, A. V., & Sargent, W. L. W. 1997, ApJS, 112, 315
Leitherer, C., et al. 1999, ApJS, 123, 3