The Spectral Energy Distributions of Normal and Weakly-Active Galaxies

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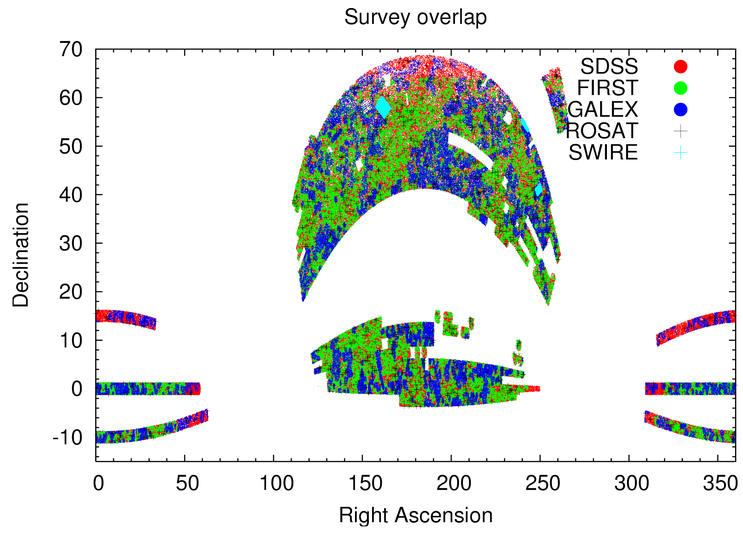
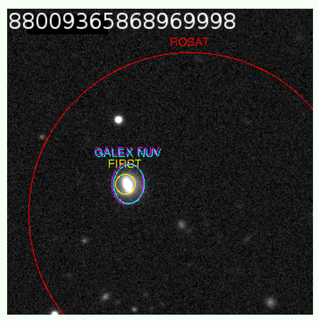
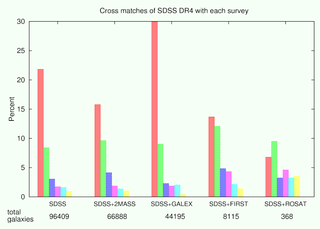
We present radio to X-ray spectral energy distributions (SEDs) of over 1000 galaxies, which constitutes the largest (by at least a factor of 4) and most uniform multi-wavelength sample yet produced. We perform cross-matching of spectroscopically observed SDSS galaxies with surveys from radio (FIRST), IR (2MASS), UV (GALEX) and X-ray (ROSAT All-Sky Survey) that produce firm detections in FIRST, 2MASS and GALEX for 1155 galaxies. We do not include data in the FIR because Spitzer coverage is small and the IRAS flux limits are much to high. We provide a statistical analysis of the validity of the SDSS-RASS matches. Active galaxies were identified based on the presence of strong emission lines in SDSS spectra, and sub-classified as H II, Seyfert, LINER or transition systems according to line flux ratios. The resulting multi-wavelength dataset contains an order of magnitude more actively line-emitting galaxies than any previous sample. We present individual and composite galaxy SEDs. For systems that show evidence for an accreting nucleus, we attempt to correct their bolometric luminosities for the contamination by the host galaxy based on active galaxy SEDs measured at high spatial resolution (Ho 1999). We then compute the bolometric luminosity of the central sources and estimate the corresponding accretion rates.

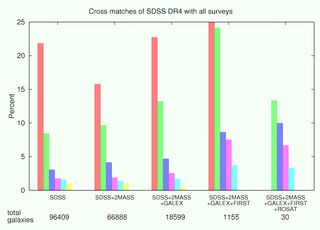


Data and Processing

The baseline dataset for this study is the SDSS DR4 main galaxy spectroscopic sample. We present here only the matches within the area observed by GALEX and FIRST. Matching is done within each survey's 2-sigma error circle. Duplicate matches are not included.





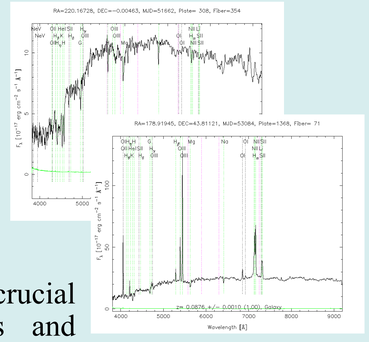


The bars are normalized to the total number of galaxies with each given match.

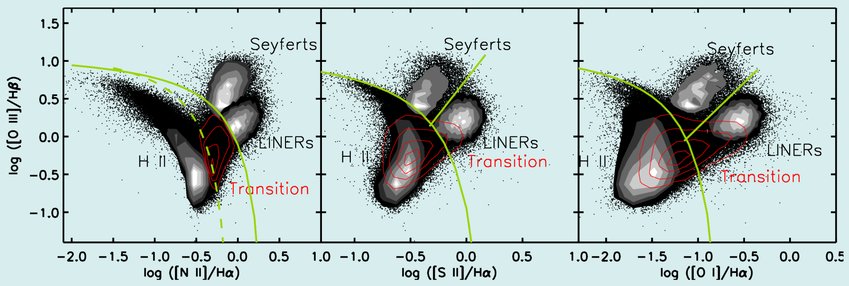
- This bar chart shows the result of cross-matching SDSS with each individual survey in turn.
- Different types of of objects are shown in different colors.
- This bar chart show the result of an intersection between SDSS and 2MASS, GALEX, FIRST and RASS adding one at a time.

Classification of Galaxies

Using emission-line measurements from SDSS optical spectra, we classify galaxies into H II, Seyfert, LINER and Transition objects based on classification criteria from Kewley et al. (2006) as illustrated in the diagnostic diagram.



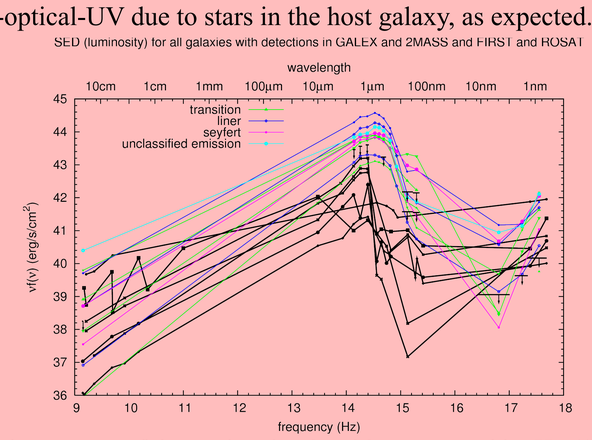
Note that [S II]/Ha and [O I]/Ha are crucial in distinguishing between Seyferts and LINERs, and in revealing the strong stellar contamination in Ts.



- Passive galaxies are identified as objects with no emission lines.
- "Unclassifiable" galaxies are those with possible emission activity, which is not detected at a 2-sigma level.
- "Unclassified emission" galaxies are objects that are in different regions in different diagrams.

Spectral Energy Distributions

There are 10 galaxies that are detected in all surveys considered in this study and we present their SEDs in this plot. For comparison we show each survey's upper-limits as black arrows and the Ho (1999) nuclear SEDs as black lines. The colored SEDs show a substantial contribution at NIR-optical-UV due to stars in the host galaxy, as expected.

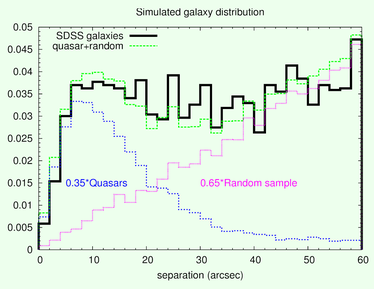


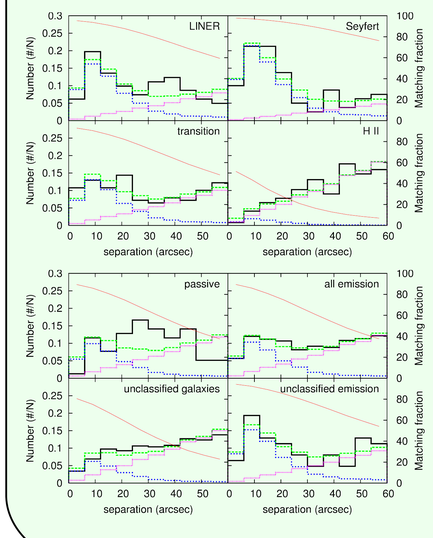
We use the average of the nuclear luminosities measured by Ho (1999) to find the mean amount of stellar emission. This quantity is then used to obtain the bolometric luminosities of the nuclei of these 10 galaxies (L_{corr}). We calculate black hole masses based on stellar velocity dispersions and combine them with L_{corr} to estimate the corresponding Eddington ratios.

Class	L_{bol} $(erg\,s^{-1}\,cm^{-2})$	L_{corr}	M_{BH} $(10^6 M_\odot)$	L_{edd}	L_{bol}/L_{edd}
Seyfert	5.37×10^{43}	1.45×10^{42}	209	2.63×10^{46}	5.5×10^{-5}
Seyfert	8.40×10^{43}	2.26×10^{42}	155	1.95×10^{46}	1.1×10^{-4}
transition	7.44×10^{43}	2.0×10^{42}	253	3.17×10^{46}	6.3×10^{-5}
transition	6.27×10^{43}	1.69×10^{42}	20.7	2.59×10^{45}	6.5×10^{-4}
transition	9.50×10^{42}	2.56×10^{41}	8.8	1.11×10^{45}	2.3×10^{-4}
transition	7.21×10^{43}	1.94×10^{42}	74.4	9.35×10^{45}	2.1×10^{-4}
unclassified	1.14×10^{44}	3.06×10^{42}	187	2.35×10^{46}	1.3×10^{-4}
LINER	1.34×10^{44}	3.61×10^{42}	356	4.48×10^{46}	8.0×10^{-5}
LINER	2.93×10^{44}	7.88×10^{42}	852	1.07×10^{47}	7.4×10^{-5}
LINER	1.62×10^{43}	4.35×10^{41}	49.4	6.21×10^{45}	7.0×10^{-5}

Matching SDSS with RASS

The distribution of matching radii between the ROSAT All Sky Survey (RASS) and the SDSS main galaxy sample is well modeled by a combination of a log-normal distribution (corresponding to SDSS quasar/RASS matches) and a random distribution. This implies that there is a significant "bad match" fraction for the RASS/SDSS galaxy matches, which we investigate here for the first time.





- No H II galaxies are detected in RASS as X-ray sources.
- At a 30" matching radius, ~90% of Seyferts, ~80% of LINERs and 70% of Transition objects represent real RASS sources.
- 75% of the "unclassified emission" galaxies are real RASS sources: can ambiguous optical classification be clarified by X-ray identification?
- 60% of passive galaxies appear to be found by RASS: does this represent a reliable method for finding XBONGs?
- Essentially no "unclassifiable" galaxies are RASS sources.

These plots show SEDs of all SDSS main sample line-emitting galaxies detected in 2MASS, GALEX and FIRST. Different panels show different object types and are shown in order of decreasing UV emission. The colors of each SED correspond to different g-r colors. The last panel shows the average SEDs per object type, normalized to a K-band flux of 10^{43} erg/s/cm^2.

- The sequence in UV flux corresponds surprisingly well with an H II -- Seyfert -- Transition -- LINER sequence.
- This sequence also corresponds to an increase in radio emission.
- H IIs are generally blue in g-r, and have the lowest average radio fluxes.
- Seyferts have relatively blue g-r colors and have the third highest average radio flux.
- Transition galaxies span a wide range of colors and show UV and radio emission similar to Seyferts.
- Unclassified emission galaxies are generally redder and show the second highest radio emission.
- LINERs have the reddest host galaxies and are the most radio loud.
- This plot shows that the 2MASS fluxes can be predicted from SDSS, consistent with Obric et al. (2006) .
- Based on the uncorrected optical fluxes, none of these galaxies would be classified as "radio-loud."
- There is no sign of a "big blue bump."