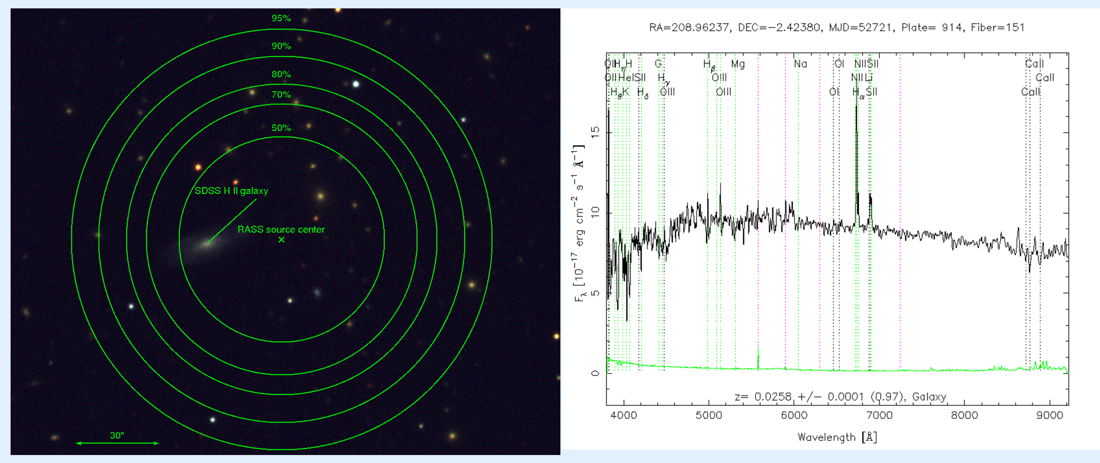
Soft X-ray Properties of "Ordinary" SDSS Galaxies

John K. Parejko[1], Anca Constantin[2], Michael S. Vogeley[1], Fiona Hoyle[3], Joseph B. Hyde[4]

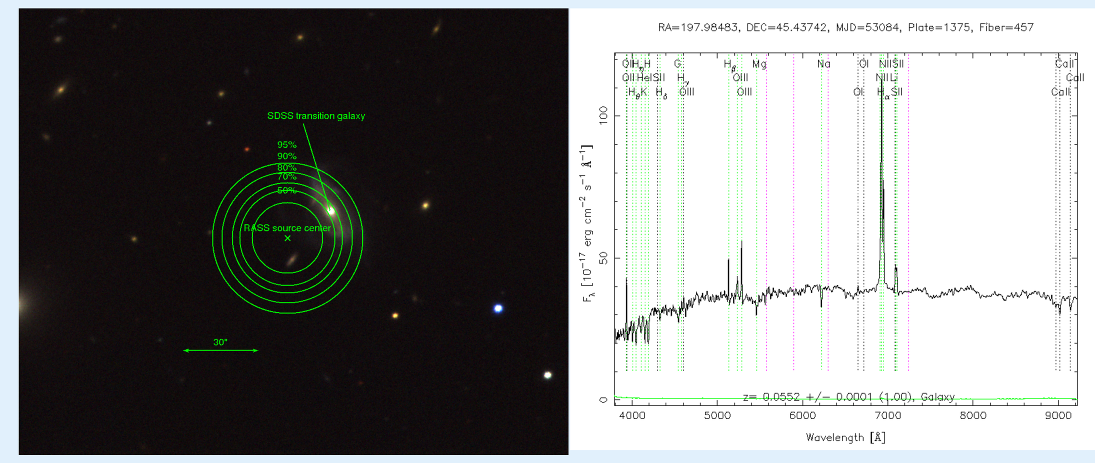
1. Drexel University, 2. Harvard-Smithsonian Center for Astrophysics, 3. Widener University, 4. University of Pennsylvania

Which of these are true matches between the optical and X-ray sources?



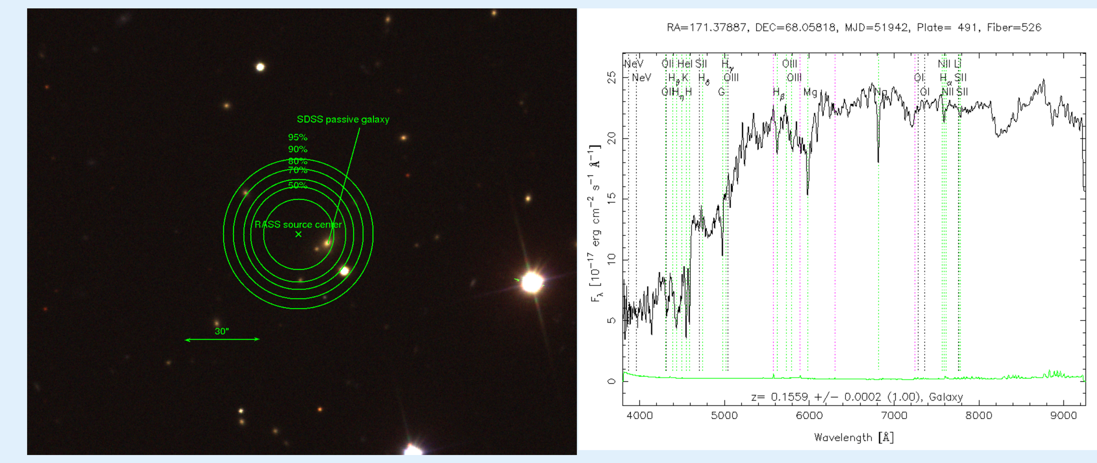
H II galaxy

No Match (11%)



Transition galaxy

Match (78%)



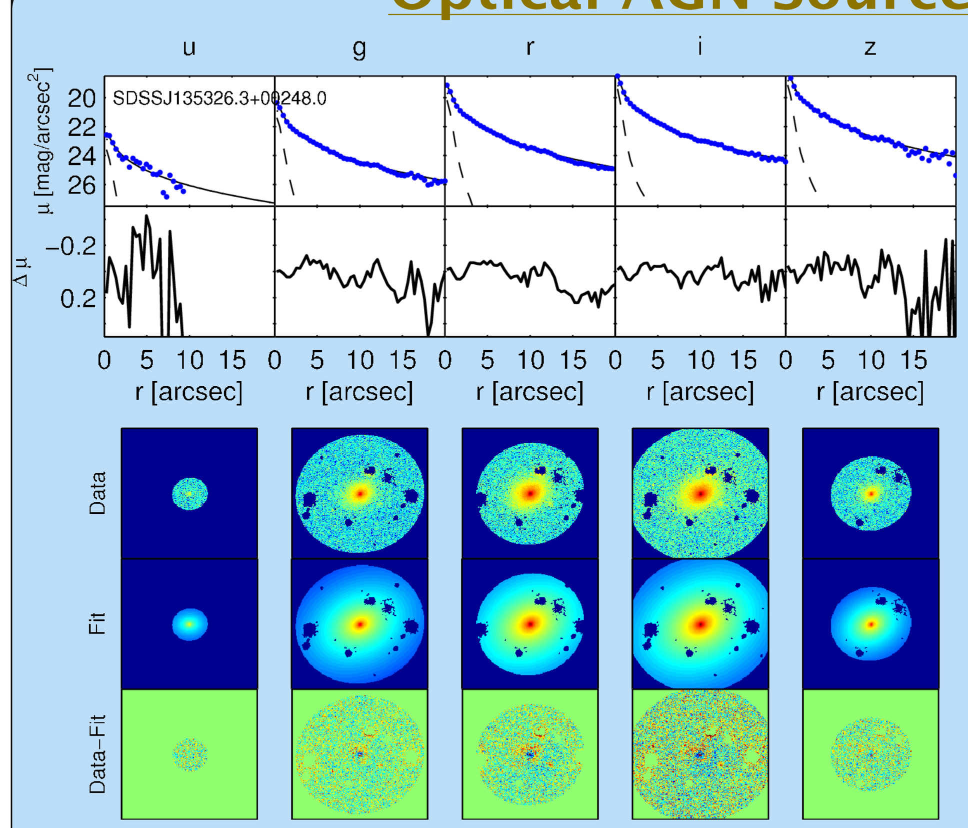
Passive galaxy

Match (85%)

Abstract

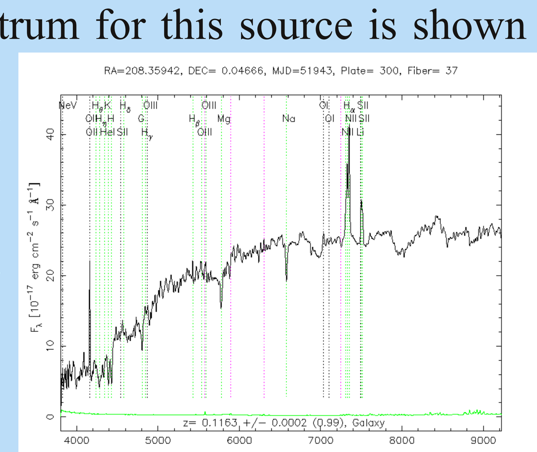
Understanding the X-ray emission of low-luminosity active galactic nuclei is important for constraining the fraction of accreting local supermassive black holes. Low-luminosity active galaxies are often weak X-ray emitters, but identifying their X-ray counterparts in large area surveys is difficult due to source confusion with brighter X-ray sources. We describe a general method for matching sources between high and low resolution surveys that relies only on the positional accuracy of each source measurement. We demonstrate the utility of this method by matching other low resolution surveys to the Sloan Digital Sky Survey (SDSS). By applying this new method to the SDSS main galaxy sample and the ROSAT All Sky Survey (RASS) we quantify the RASS detection rate for galaxies that are not hosting quasars. We provide an electronically available catalog of the match probability for more than 1800 spectroscopically classified galaxies in the SDSS. We present a detailed investigation of the X-ray properties of this catalog of weak X-ray galaxy nuclei. We find that this catalog contains a large number of potential new X-ray Bright Optically Normal Galaxies (XBONGs).

Optical AGN Source Extraction



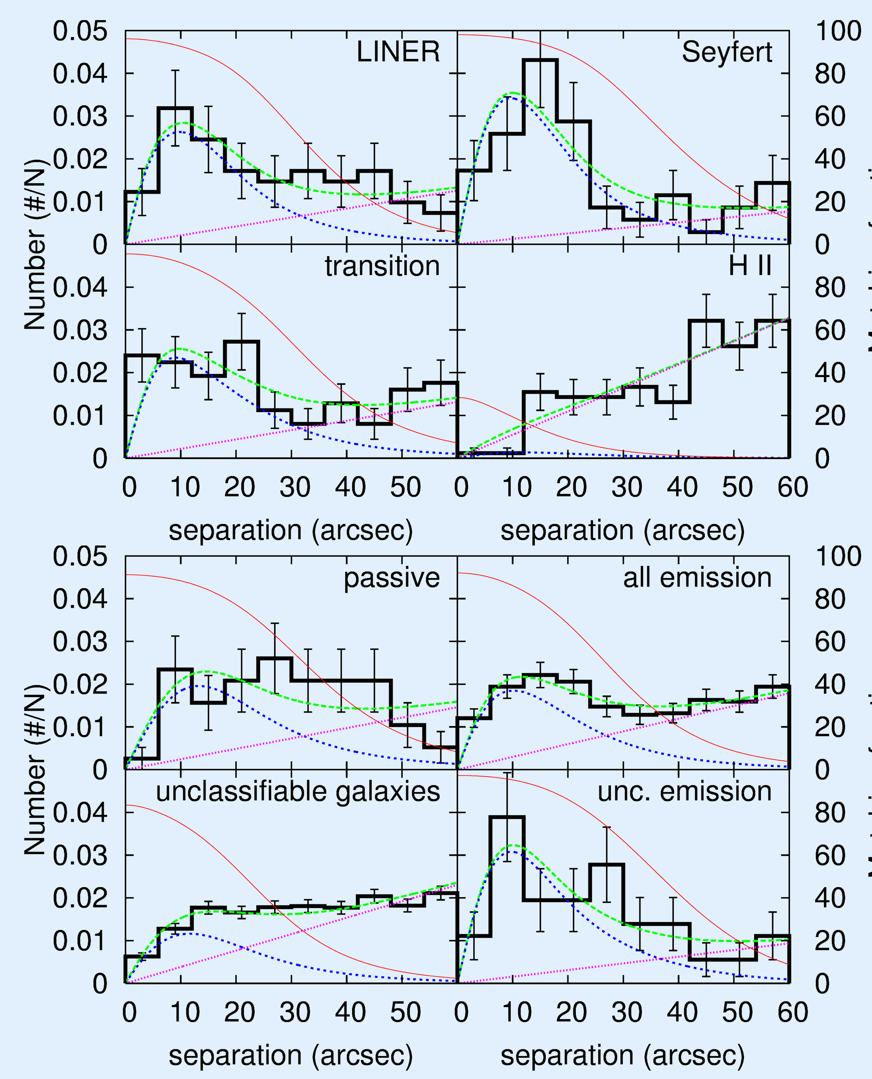
We performed a complete 2-d light profile reconstruction (central point source, deVaucouleurs/Exponential disk, with inclination and orientation) for selected SDSS galaxies that are likely to be harboring stronger active galactic nuclei, based on both emission line properties and the presence of an X-ray source.

Shown at left is an example RASS-matched LINER (SDSS J135326.26 +000247.9) from this dataset which has been fit with a point source + deVaucoulers galaxy model. The point source is found in all photometric bands with a relative strength of ~1.5% of the total galaxy's light. The SDSS spectrum for this source is shown below for reference.



The code was initially developed to compute host galaxy properties for lower-luminosity SDSS quasars. These sources have significantly higher AGN fractions than the galaxies in our sample. However, the algorithm was most reliable for small point source fractions leading us to believe that our low luminosity AGN fits are reliable. This work is ongoing; we intend to perform the fitting prodecure for all sources in this sample and thus compute α_{ox} for these galaxies.

Type-dependent matching probabilities.



Galaxies are spectroscopically classified as Seyfert, LINER, Transition, or H II by their location in three emission-line flux ratio diagrams (Constantin et al. 2008, Kewley et al. 2006). The source-separation histograms and reconstruction for RASS-SDSS matches grouped by spectral class are shown to the left. As is apparent, the "true matching fraction" (thin red line) depends strongly on spectral classification. It appears that some passive galaxies (no optical emission lines) are detected by RASS, implying that they may be XBONGs.

For each RASS/SDSS match, we generate a Rayleigh distribution —P(r)=r $\exp(r^2/2\sigma^2)/\sigma^2$—with the positional error of that RASS source as the scale parameter σ. The sum of these probability distribution functions gives the "simulated true match" curve (blue), which when combined with a linearly increasing random component (purple) gives the total source-separation histogram (green).

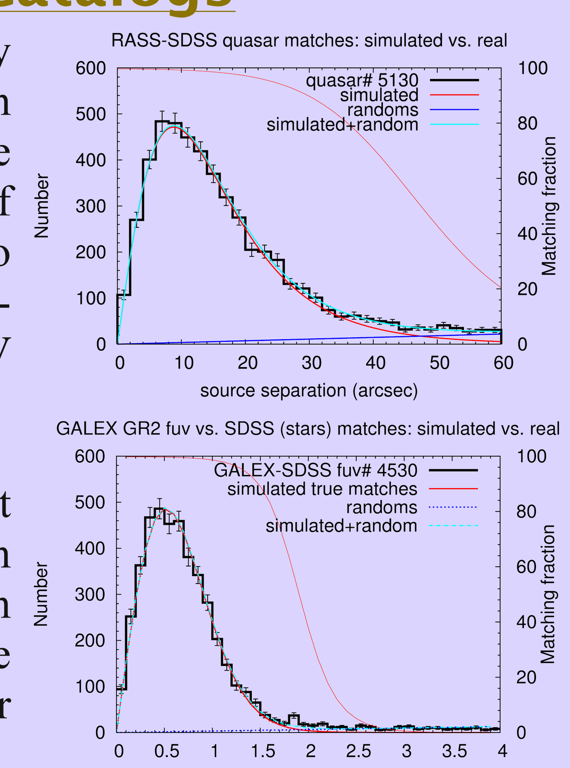
$$\mathrm{Fit}(r) = A_{\mathrm{random}} * P_{\mathrm{random}}(r) + A_{\mathrm{Rayleigh}} * \Sigma\, P_{\mathrm{Rayleigh}}(r)$$
$$\text{with } A_{\mathrm{random}} + A_{\mathrm{Rayleigh}} = 1$$

Details of the method can be found in Parejko et al. (2008).

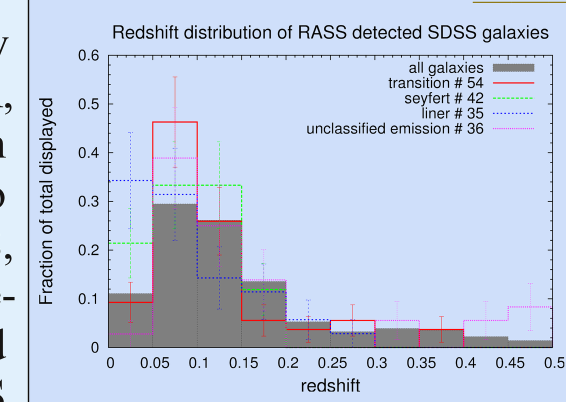
Matching with Other Catalogs

This method of computing match probabilities only requires that we know the positional error of a given measurement (and currently assumes they are the same in both directions). Thus, it can be applied to a match of any two catalogs with known positional errors. To demonstrate this, we match SDSS quasars with RASS X-ray sources and SDSS stars with GALEX far-UV sources.

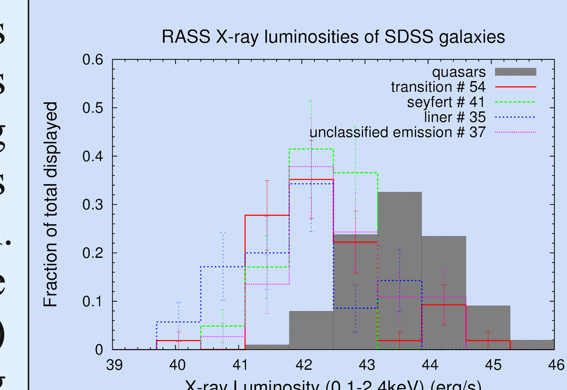
One caveat: if the centroid of a source is different at different wavelengths (e.g. strong UV H II regions in spiral arms), this will bias the source separation measurements. Thus, the method may not be reliable for matching, say, SDSS galaxies with GALEX or 2MASS.



X-ray Source Properties

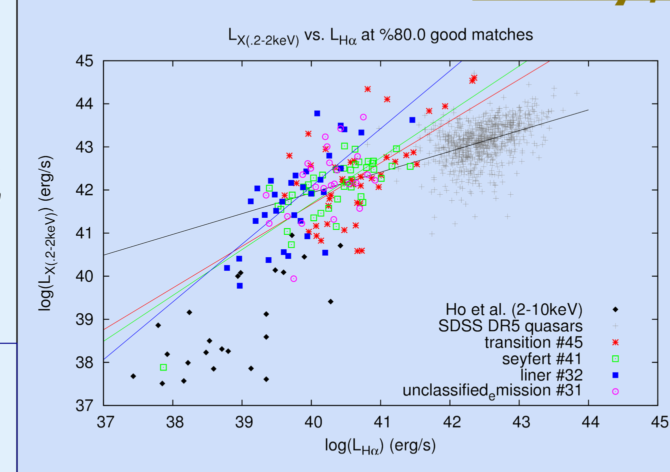


The redshift distribution of the RASS detections is skewed towards low redshift sources compared with the complete SDSS galaxy sample, as shown to the left. This is understandable, given that RASS has a relatively lower flux limit than the SDSS main galaxy sample, for this class of objects. Note: for this and all plots below, we only show sources with a match likelihood > 80%.



The X-ray luminosity distribution of SDSS galaxies is plotted, with SDSS quasars shown for reference. Note that the mean luminosity is higher in Transitions ($3.4\pm9.3\times10^{43}$ erg/s) moderate in unclassified emission-line sources ($1.9\pm4.7\times10^{43}$ erg/s) and lower in LINERs and Seyferts ($0.7\pm1.5\times10^{43}$ and $0.25\pm0.26\times10^{43}$ erg/s respectively). Note that this is not a uniform X-ray source sample.

X-ray/Hα Luminosities



Plotted here is the Hα emission-line luminosity vs soft (0.1-2 keV) X-ray luminosity for the sources in this sample (80% confidence), plus SDSS quasars with RASS detections and the data from Ho et al. (2001) plotted for comparison. Ho et al. (2001) found Chandra 2-10keV X-ray/Hα flux ratios for a number of low luminosity AGN. However, ROSAT operated at 0.1-2keV, so the results are not directly comparable. We do find a similar trend, but with higher luminosities in general. SDSS spectroscopy is done through a 3" fiber, and RASS is much lower resolution than Chandra, so the higher luminosities may be partly due to our reduced resolution. However, Ho et al. only had 24 galaxies, of various emission classes, while we have at least that many of each class.

The straight lines are simple linear regression fits to the respective points. Note the trend in slope from quasars to Transitions to Seyferts to LINERs. We find a similar trend in [O III], but with somewhat higher scatter.

References & Acknowledgments

- Parejko J. K., Constantin A., Vogeley M. S., Hoyle F., 2008, AJ, **135**, 10
- Ho L. C., et al., 2001, ApJ, **549**, 51
- Constantin A., Hoyle F., Vogeley M. S., 2008, ApJ, **673**
- Kewley L. J., Groves B., Kauffmann G., Heckman T., 2006, MNRAS, **372**, 961

This work was funded in part through NASA grant NAG5-12243 and NSF grant AST-0507647.

This poster created with Scribus.