Demographics of X-ray and Optical AGNs

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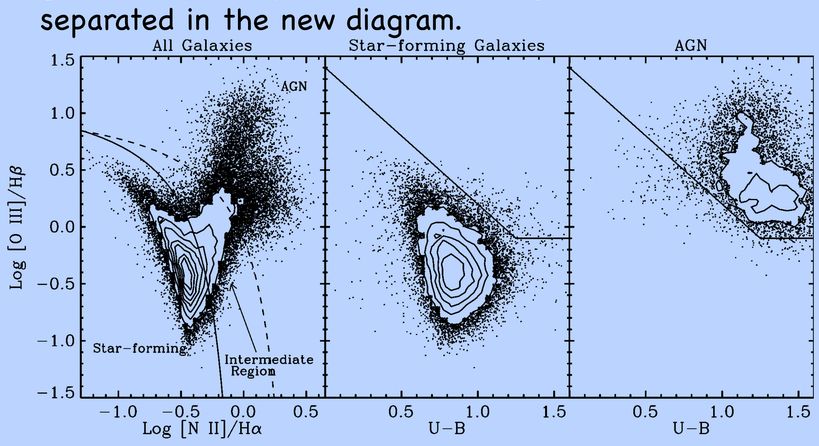
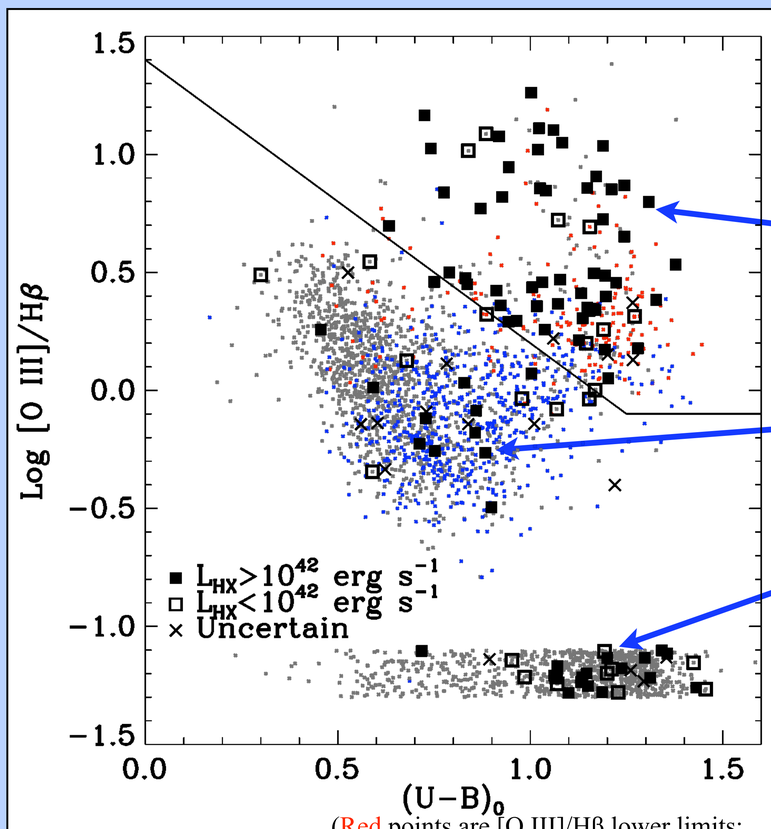
Using U-B color to replace [N II]/Hα, we established a new line ratio diagnostic diagram to classify the physical origin of optical emission lines at z>0.4. We compare the results of optical AGN selection with X-ray selection in the Extended Groth Strip using data from the DEEP2 survey (Davis et al. 2003) and the AEGIS collaboration (Davis et al. 2007). In the X-ray selected sample at 0.3 < z < 0.8 and I_{AB} < 22, only 58% are classified optically as emission-line AGNs, the rest as star-forming galaxies or absorption-dominated galaxies. The latter are also known as "X-ray bright, optically normal galaxies" (XBONGs). Analysis of the relationship between optical emission lines and X-ray properties shows that the completeness of optical AGN selection suffers from dependence on the star formation rate and the quality of observed spectra. It also shows XBONGs do not appear to be a physically distinct population from other X-ray detected, emission-line AGNs. On the other hand, X-ray AGN selection also has strong biases. About 2/3 of all optical AGNs at $L_{bol}>10^{44}$ erg/s in our sample drop below the detection threshold of 200ks Chandra images due to moderate or heavy absorption of the X-rays. For more detail, see arXiv:1007.3494.

New Optical Diagnostics

AGN identification through optical spectroscopy becomes difficult at z>0.4 when [N II] and Hα shift out of the optical window. The restframe U-B color provides a good substitute for [N II]/Ha in the standard line ratio diagnostic diagram.

The figure below demonstrates this new method using an SDSS sample. The left panel is the standard diagnostic diagram. The other two panels show the new diagrams in which the horizontal axes are replaced by the restframe U-B color. Star-forming galaxies (middle panel) and AGN (right panel) are well separated in the new diagram.





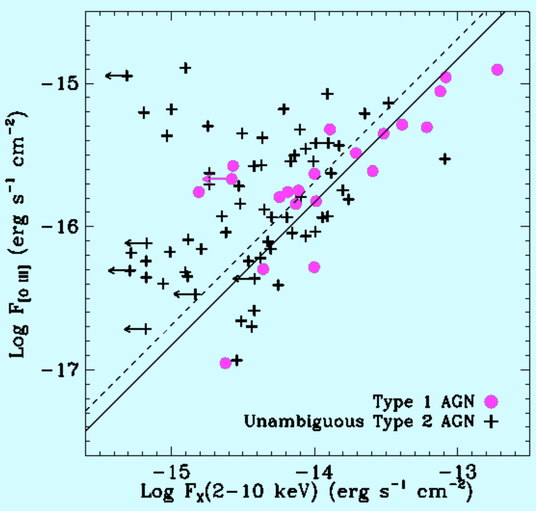
X-ray Classifications

Optical Classifications	X-ray detected	X-ray undetected
AGN	Unambiguous AGNs	Optical-only AGNs
Star-forming	X-ray-loud, Composites	
Quiescent	XBONGs (X-ray bright, optically normal galaxies)	

This figure shows our new line ratio diagnostic diagram for all DEEP2 galaxies in EGS with 0.3<z<0.8 and I_{AB}<22. The solid lines are the proposed demarcation between star-forming galaxies (below) and AGN (above). Galaxies with neither [OIII] nor Hβ detected are shown at the bottom. X-ray sources are marked as large symbols, which are found in all three classes.

Unambiguous AGNs

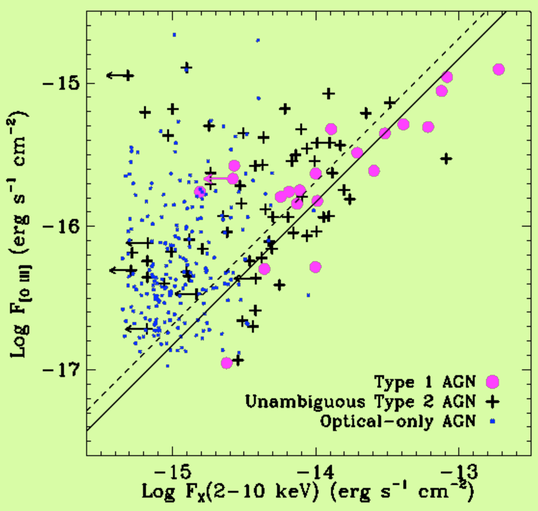
(X-ray sources that are optically classified as AGN)



- 58% of X-ray sources are classified as Optical AGNs.
- Type 1 AGN has a median Hard-X/[OIII] ratio of 1.82 dex, slightly higher than that found by Heckman et al. (2005, dashed line).
- At a given [OIII] flux, AGNs can only have X-ray flux equal to or lower than that of a Type 1 AGN of the same [OIII] flux.
- X-ray selected Type 2 AGN has a median Hard-X/[OIII] ratio of 1.42 dex, much larger than that of an [OIII]-selected AGN sample (0.68 dex, Heckman et al. 2005).

Optical-only AGNs

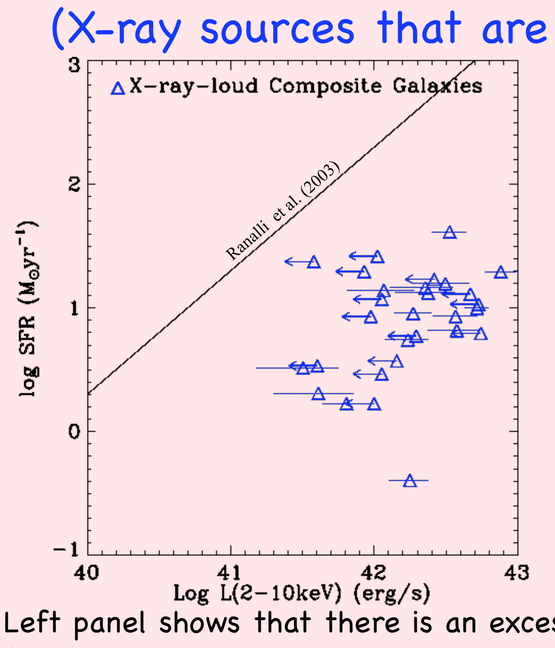
(Optical AGNs undetected in the X-ray)

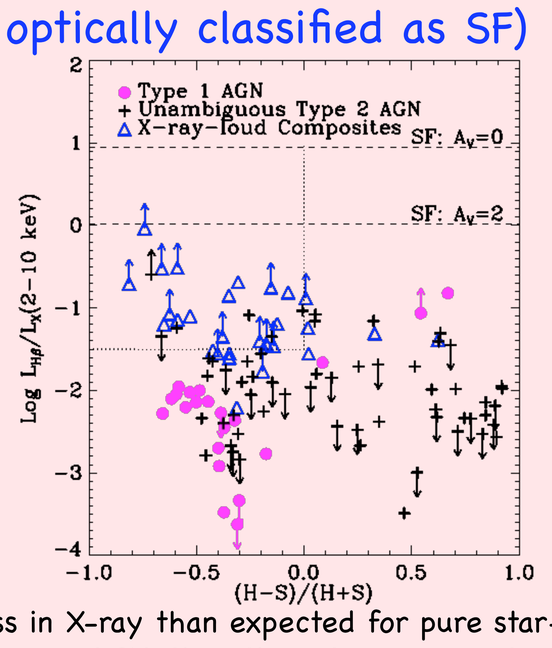


Most of the optical-only AGNs lie to the upper left of the Type 1 relation. The Hard-X/[OIII] ratios of optically-selected AGNs have a much lower median and a wider distribution than X-ray selected AGNs. This indicates that optical AGN sample include more heavily absorbed sources and possibly Compton-thick sources, which are missed by X-ray selections. At 0.3<z<0.8 and I_{AB}<22, 2/3 of all optical AGNs with $L_{bol}>10^{44}$erg/s will drop below the detection threshold of 200ks Chandra images due to absorption and/or scattering of the X-rays. For Compton-thick fraction at z~0.6, ask me.

X-ray-loud, composite galaxies

(X-ray sources that are optically classified as SF)

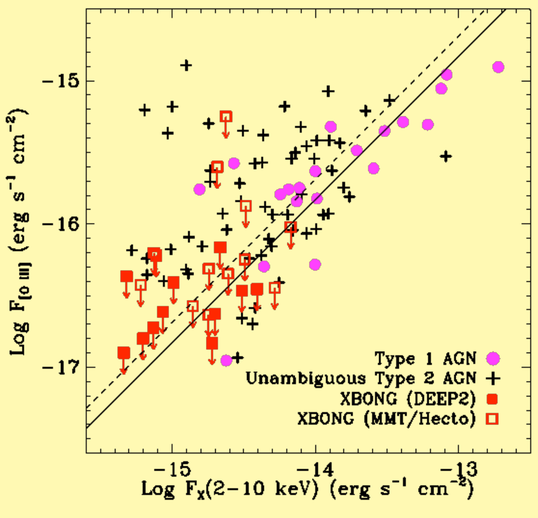




Left panel shows that there is an excess in X-ray than expected for pure star-forming galaxies. However, assuming they are AGN, then there is an excess in Hβ relative to X-ray., shown by the right panel. Therefore, they are star-forming-AGN composites with X-ray dominated by AGN and Hβ dominated by SF.

XBONGs

(X-ray sources without detectable emission lines)



The [OIII] flux upper limits of XBONGs indicate that they could have [OIII]/X-ray ratio consistent with other AGNs. They are simply near the tail of the [OIII] flux distribution at a given X-ray flux. We see no reason to postulate that they are a different type of objects.

Except in one case, the undetection of [OIII] is not due to dilution by the host galaxy light. XBONGs have the same stellar mass distribution as other AGNs with similar X-ray luminosities.

Host extinction is also not the typical cause for the undetection of emission lines. XBONGs have the same axis ratio distribution as other AGNs, and have only slightly redder color which, if due to extinction, would only dim [OIII] by 0.15 dex, which is not significant at all. Therefore, we find no evidence to suggest XBONGs are a physically distinctive class.