Hard X-ray View of HCG 16 (Arp 318)

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Abstract

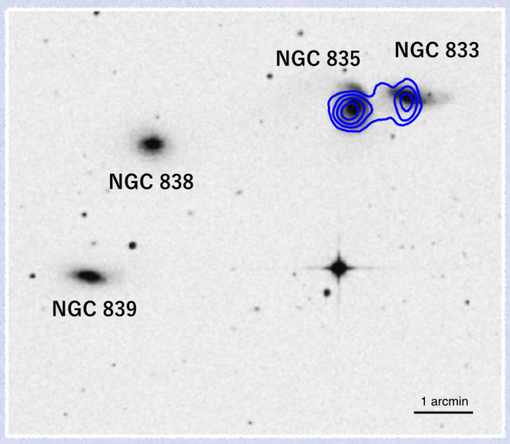
We report the hard X-ray (3-50 keV) view of the compact group HCG 16 (Arp 318) observed with Nuclear Spectroscopic Telescope Array (NuSTAR). NGC 838 and NGC 839 are undetected at energies above 8 keV, showing no evidence of heavily obscured active galactic nuclei (AGNs). This confirms that these are starburst-dominant galaxies as previously suggested. We perform a comprehensive broadband (0.3-50 keV) X-ray spectral analysis of the interacting galaxies NGC 833 and NGC 835, using data of NuSTAR, Chandra, and XMM-Newton observed on multiple epochs from 2000 to 2015. NuSTAR detects the transmitted continua of low-luminosity active galactic nuclei (LLAGNs) in NGC 833 and NGC 835 with line-of-sight column densities of $\sim 3 \times 10^{23}\ \mathrm{cm}^{-2}$ and intrinsic 2-10 keV luminosities of $\sim 3 \times 10^{41}\ \mathrm{erg\ s}^{-1}$. The iron-K$\alpha$ to hard X-ray luminosity ratios of NGC 833 and NGC 835 suggest that their tori are moderately developed, which may have been triggered by the galaxy-galaxy interaction. We find that NGC 835 underwent long-term variability in both intrinsic luminosity (by a factor of 5) and absorption (by $\Delta N_{\mathrm{H}} \approx 2 \times 10^{23}\ \mathrm{cm}^{-2}$). We discuss the relation between the X-ray and total infrared luminosities in local LLAGNs hosted by spiral galaxies. The large diversity in their ratios is consistent with the general idea that the mass accretion process in the nucleus and the star forming activity in the disk are not strongly coupled, regardless of the galaxy environment.

1. Introduction

- A key mechanism of co-evolution between galactic bulges and supermassive black holes (SMBHs) would be major mergers, which cause vigorous starburst activity together with rapid mass accretion onto SMBHs observed as active galactic nuclei (AGNs).
- To detect hidden AGNs in merging galaxies, hard X-ray observations at energies above 10 keV are a promising approach least biased against heavy obscuration.

2. Object and Observations

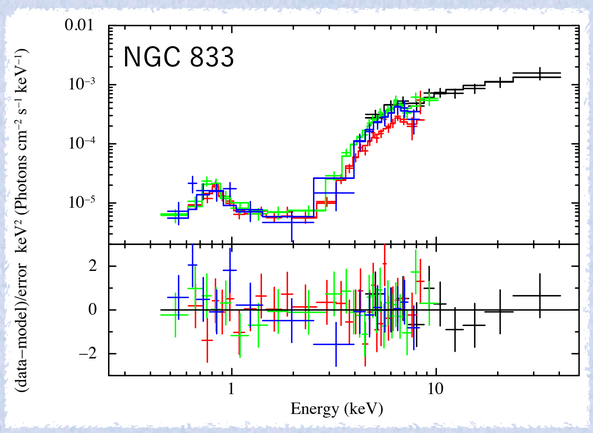
- **HCG 16,** also known as **Arp 318**, is one of the nearest compact groups of galaxies and hence an ideal target to study galaxy-galaxy interaction and its influences on AGN activities. It consists of seven member galaxies, which include the central four spiral galaxies, NGC 833, NGC 835, NGC 838, and NGC 839.
- We have obtained the tightest upper limits of the hard X-ray flux above 10 keV for NGC 838 and NGC 839, supporting the previous arguments by Turner et al. (2001) and O'Sullivan et al. (2014) that they are both starburst dominant galaxies without luminous AGNs ($L_{2-10} < 3 \times 10^{42}\ \mathrm{erg\ s}^{-1}$ even assuming a column density of $N_{\mathrm{H}} = 10^{25}\ \mathrm{cm}^{-2}$).

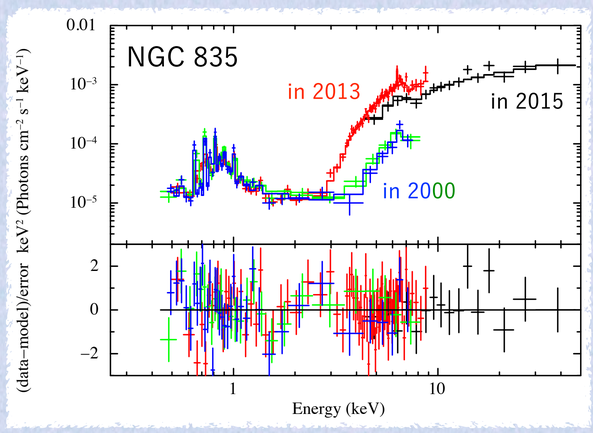


DSS2 R-band image
+ Hard X-ray contours
of the NuSTAR 3-24 keV image

3. Spectral Analysis of NGC 833 and NGC 835

- Strong signals are detected by NuSTAR (black) from NGC 833 and NGC 835, for which we perform detailed broadband spectral analysis combining the Chandra (red) and XMM-Newton (green and blue) data.
- To consider a realistic geometry of the torus, we use a Monte-Carlo based numerical spectral model by Ikeda et al. (2009).
- The model consists of five components: the transmitted component from the AGN, the torus reflection component, the fluorescence iron-Kα emission line, the scattered component, and the optically-thin thermal component.

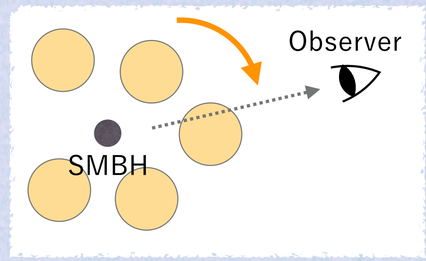




- We have confirmed that both NGC 833 and NGC 835 contain obscured LLAGNs with intrinsic 2-10 keV luminosities of $\sim 3 \times 10^{41}\ \mathrm{erg\ s}^{-1}$ and line-of-sight column densities of $\sim 3 \times 10^{23}\ \mathrm{cm}^{-2}$.

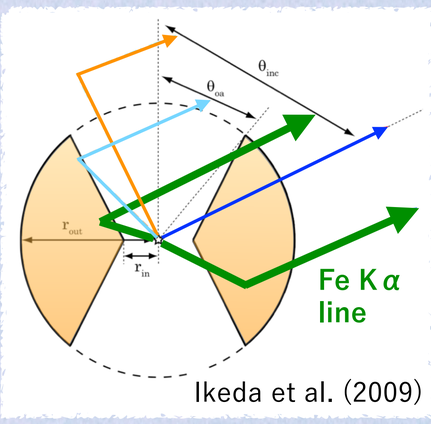
4.1. Origin of Flux Variability of NGC 835

- We have revealed that NGC 835 underwent long-term variability in both intrinsic luminosity and absorption. The line-of-sight column density was changed from $\approx 5 \times 10^{23}\ \mathrm{cm}^{-2}$ in 2000 to $\approx 3 \times 10^{23}\ \mathrm{cm}^{-2}$ in 2013/2015. This can be interpreted as a transit of clouds as expected in the clumpy torus.



4.2. Torus Structure

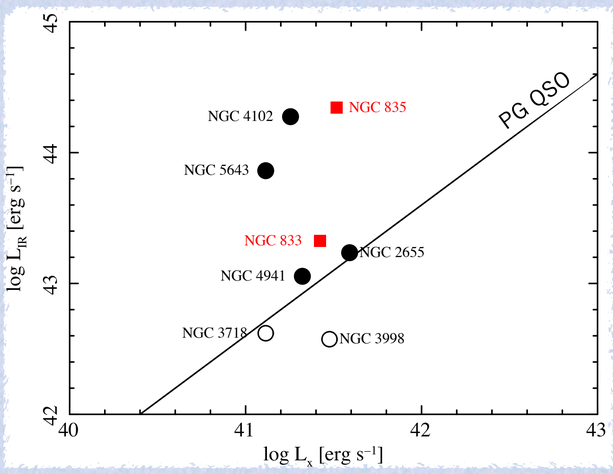
- The luminosity ratio of the iron-Kα line to the hard X-ray (10-50 keV) continuum is a good indicator of the torus covering fraction (Ricci et al. 2014; Kawamuro et al. 2016).
- The ratios are found to be $\sim 2 \times 10^{-3}$ for NGC 833 and NGC 835, locating both LLAGNs around the transition region between the well-developed tori at high λ_{Edd} and underdeveloped ones at low λ_{Edd}. It indicates that the tori are moderately developed in both objects.



Ikeda et al. (2009)

4.3. Infrared to X-ray Luminosity Relation of Local LLAGNs

- The X-ray and total infrared luminosities are indicators of the mass accretion rate and star forming rate in the host galaxy, respectively.
- There is large diversity in the L_{X} versus L_{IR} relation in local LLAGNs, regardless of their environments (in interacting systems or not). This is consistent with the general idea that the mass accretion process in the nucleus and the star forming activity in the disk are not strongly coupled.



5. References

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