X-raying the Circumnuclear Star Formation in NGC 2903

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NGC 2903 is a nearby SBc galaxy with intense circumnuclear star formation induced by a young stellar bar. We present deep *Chandra* observations of this central star forming region. The X-ray data reveal high surface brightness diffuse emission within the central 15" (650 pc) of the nucleus along with eleven point-like sources. None of the point sources coincide with the galactic center of mass, and we place stringent upper limits on the X-ray emission from any accreting compact central object (Lx $< 3 \times 10^{37}$ erg s^{-1}). Lower surface brightness emission extends to the north and west of the nucleus. X-ray temperature and column density, and pressure maps indicate a possible hot gas outflow from the circumnuclear region to the northwest; however, the rest of the hot gas is probably confined to the disk.

Star Formation & Feedback

Supernovae and massive stars heat and pressurize the surrounding interstellar medium, creating hot gas bubbles (e.g., Weaver et al., 1977) and possibly outflows (e.g., Strickland et al., 2004; Swartz et al., 2006). The hot gas is a good indicator of stellar feedback, tracing mechanical energy directly. This hot gas can be detected in starburst as well as normal galaxies in X-ray. Some barred galaxies exhibit intense star formation in a form of a circumnuclear starburst, at which infalling gas to the center stalls and stars form at an inner Lindblad Resonance. If the stellar feedback from the circumnucler star formation is effective, the gas flow at the center can be prevented, possibly slowing the growth of the nuclear black hole.

We examine the stellar feedback and its effect on the nucleus with a deep *Chandra* observation of a hot spot galaxy, NGC 2903. The galaxy is located at 8.9 Mpc, possessing a young stellar bar extended 3' from northeast to southwest. It also exhibits a prominent circumnuclear ring with a diameter of 650 pc. The *Chandra* image shows high intensity soft X-ray diffuse emission in the circumnuclear region surrounded by lower surface brightness diffuse emission (Figure 1: right panel).

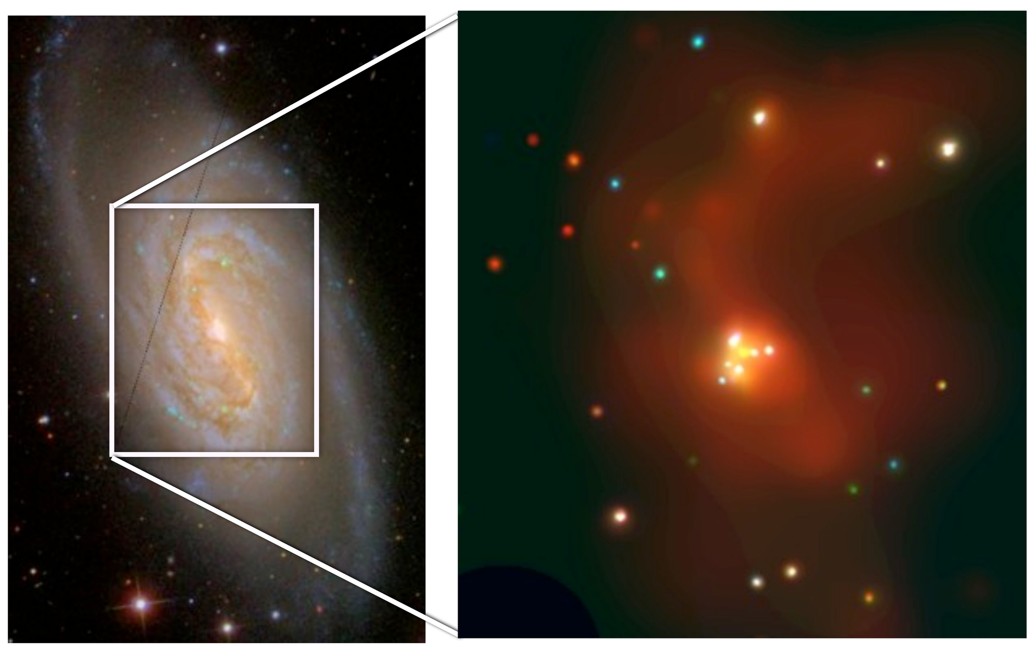

Figure 1. Left: SDSS color image of NGC 2903. Right: the *Chandra* X-ray true color image of the central region of the galaxy (red: 0.5 - 1.0 keV, green: 1.0 - 2.0 keV, blue: 2.0 - 8.0 keV). Note the many soft and hard point sources and the medium (yellow) and soft (red) diffuse emission throughout the central regions.

Maps of Thermodynamic States of Hot Gas

To characterize the morphology of the X-ray gas, maps of the thermodynamic state of the hot gas were created using an absorbed single temperature collisionally ionized thin plasma model. The measured temperature ranges from 0.1 - 0.3 keV with the highest values found in the nuclear region. This nuclear region and the dust lane crossing the east of the nuclear region indicate high absorption column density (~ 6×10^{21} cm^{-2}). The column density in the west is low indicating that the gas is above the disk; e.g., an outflow. Assuming a disk-like volume structure of the hot gas with a scale height of 200 pc, the derived electron density in the nuclear region is also higher than the surrounding region. This results in high pressure in the nuclear region.

The *HST* F814W, *Spitzer 24 μm*, and CO images exhibit a nice symmetric bar rotating counterclockwise. However, the symmetric bar is not traced in X-ray. Interestingly, only along the north side of bar shows correlations with the hot gas properties.

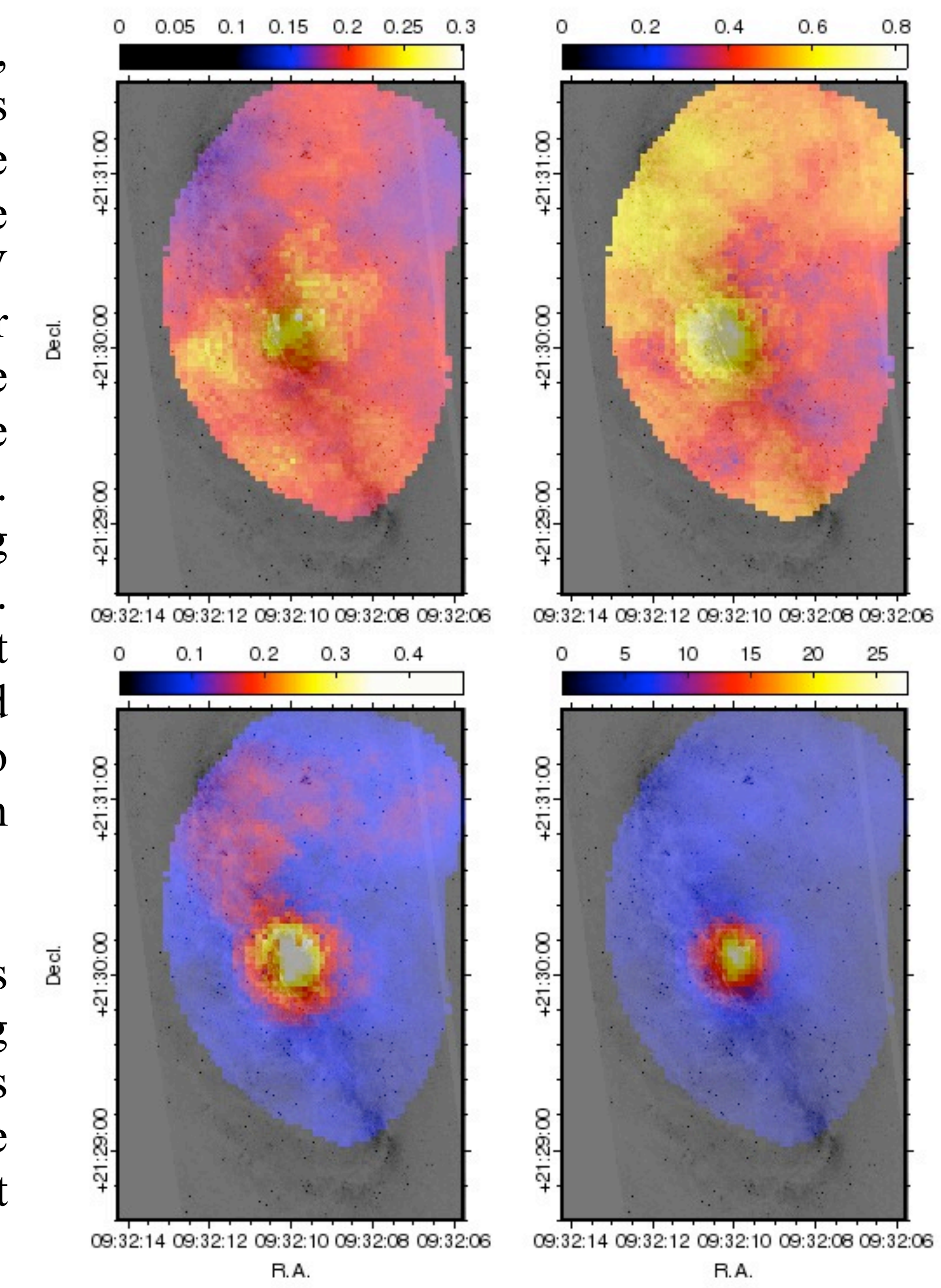

Figure 2. Clockwise from the top left: hot gas temperature, absorption column n_H, pressure (P/k), and electron density of the central 2' × 3' region. The color bars indicate the units in keV, 10^{21} cm^{-2}, 10^5 K cm^{-3}, and cm^{-3}, respectively. The *HST* F814W image is also overlaid in gray scale to indicate the galactic structures.

Circumnuclear Starburst & Nucleus

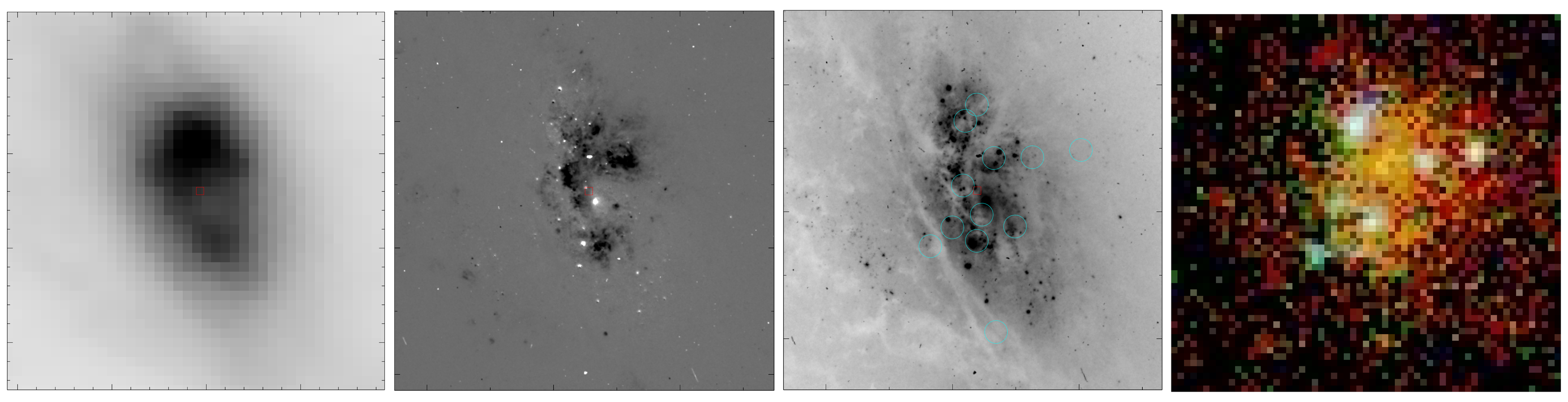

Figure 3. From left to right: close-up of the central 30" × 30" region of the *Spitzer* 8 μm, *HST/ACS* continuum-subtracted Hα, *HST/ACS* F814W, and true color (unsmoothed) X-ray images. The position of the mass center (Trachternach et al., 2008) of the galaxy is indicated with the squares. The circles indicate the X-ray detected point-like source positions (cf. Figure 1).

The nuclear starburst in the galaxy consists of numerous young (<10 Myr) massive (10^6 - 10^7 M$_\odot$; Hagele et al, 2009) star clusters and young HII regions creating a ring-like shape (Alonso-Herrero et al, 2001). The star formation rate in this region contributes 10 - 50% of that of the entire galaxy (~ 1 - 1.4 M$_\odot$ yr^{-1}).

Previously, the *XMM-Newton* observation (Perez-Ramirez et al., 2010) suggested that NGC 2903 may possess a low luminosity AGN. But the high resolution *Chandra* image of this region reveals that there are a number of point-like sources embedded in soft X-ray diffuse emission ($Lx_{(0.5\text{ - }8.0\text{ keV})} \sim 10^{39}$ erg s^{-1}). This emission is likely to be thermal in origin rather than photoionized by a nuclear source. This emission is also brighter, and the gas is hotter, denser, and more pressurized than the surrounding hot gas. The X-ray diffuse emission is more extended to the west, and the soft X-ray emission in the east, where the dust lane is visible in the optical image, is likely to be absorbed.

The detected X-ray point sources are likely to be compact objects or concentrations of hot gas. None of the X-ray point sources are coincident with the positions of the center mass of the galaxy as derived by various methods. Indeed, no evidence of AGN activity has been reported in other wavelengths. We estimate that an upper limit $Lx_{(0.5\text{ - }8.0\text{ keV})}$ of the nucleus is 3×10^{37} erg s^{-1}, assuming a power law index of 1.7 and the Galactic column density 0.3×10^{21} cm^{-2}.

Discussion & Conclusions

✓ The X-ray luminosity from the circumnuclear starburst region of NGC 2903 is ~ 10^{39} erg s^{-1}. Assuming 0.3% efficiency for conversion of mechanical luminosity to X-rays (Yukita et al. 2010) implies a nuclear SFR of 0.5 - 1 M$_\odot$ yr^{-1} which is similar to what is observed at other wavelengths.

✓ The surface brightness and the maps of thermodynamic states of hot gas suggest the properties of the hot gas associated with the circumnuclear star-forming region are different from the surrounding hot gas. Its high pressure indicates a possibility of an outflow from this region, whereas the surrounding hot gas may be confined in the disk.

✓ The diffuse emission in the central regions of NGC 2903 is best modeled as coming from hot gas rather than gas photoionized by a central source. This is consistent with the lack of any AGN signature visible at other wavelengths.

✓ There is no point-like source detected at the galactic center. We put an upper limit $Lx_{(0.5\text{ - }8.0\text{ keV})}$ of the nucleus is 3×10^{37} erg s^{-1}. Taking the lower limit mass of the nucleus as ~10^7 M$_\odot$ which is the most massive cluster found in NGC 2903, the Bondi rate of accretion of hot gas with the derived properties (kT ~ 0.2 keV, n_e ~ 0.4 cm^{-3}) is $\dot{M}_{\rm bondi}$ ~ 10^{-5} M$_\odot$ yr^{-1}. Assuming a 10% radiative efficiency and Lx/L_{bol} ~0.1 (Elvis et al., 1994), we expect $Lx_{(0.5\text{ - }8.0\text{ keV})}$ ~ 0.1 $L_{\rm bondi}$ ~ 6 × 10^{39} erg s^{-1}.

✓ CO and HCN observations indicate that there is enough cold gas available for accreting onto the nucleus. Our results suggest that the feedback from the circumnuclear starburst may be creating a hot gas outflow from the central region and preventing cold gas from accreting onto the nucleus.

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