

Deep Chandra Observations of the Arches and Quintuplet Clusters at the Galactic Center

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Abstract

We present a deep *Chandra* ACIS-I observation of the Arches and Quintuplet clusters at the Galactic Center. We detect several bright point-like sources that are clearly associated with the clusters. Some of the sources are positionally coincident with known radio sources with strong stellar winds. The sources have similar X-ray spectra, which are dominantly thermal and show an unusually strong 6.7 keV emission line, indicating that they are most likely the colliding wind close binaries of very massive stars. The spectra of the diffuse X-ray emission are significantly flatter than that of point-like sources. The luminosity, spectrum, and spatial distribution of the diffuse emission suggest that it arises primarily in cluster winds. Away from the Arches cluster, an enhanced diffuse X-ray feature shows a strong 6.4-keV emission line, but is not associated with any dense molecular cloud. The nature of this feature is still unknown.

1. Introduction

The massive stellar clusters, Arches and Quintuplet, in the Galactic center provide excellent local test-beds for our understanding of the interaction between star formation and galactic nuclear environment. We have obtained an 100 ks *Chandra* ACIS-I observation of these two clusters. Figure 1 shows this observation, combined with available archival data of the region.

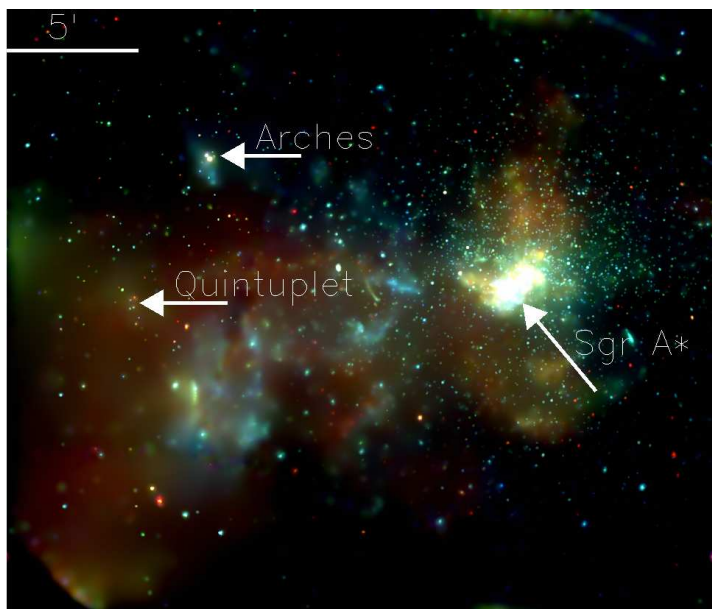


Figure 1. *Chandra* exposure-corrected true-color image of the Galactic Center (Red: 1-4 keV, Green: 4-6 keV, Blue: 6-9 keV). The image is plotted in Galactic coordinate.

2. Point sources

We detect various point sources in both Quintuplet and Arches clusters in the 0.3-8 keV luminosity range of 2×10^{32} - 1×10^{34} ergs s⁻¹ (Fig. 2). The spectra of these sources typically show a strong 6.7-keV emission line and can be well characterized by an optically-thin thermal plasma with a temperature of 3×10^7 K. No strong variability ($\geq 30\%$) is detected. The strongest X-ray sources all have radio counterparts. These results suggest that the sources most likely represent massive colliding-wind close binaries.

In contrast, the brightest near-infrared star, the Pistol, is not detected, with a 3σ luminosity upper limit of 5×10^{31} ergs s⁻¹.

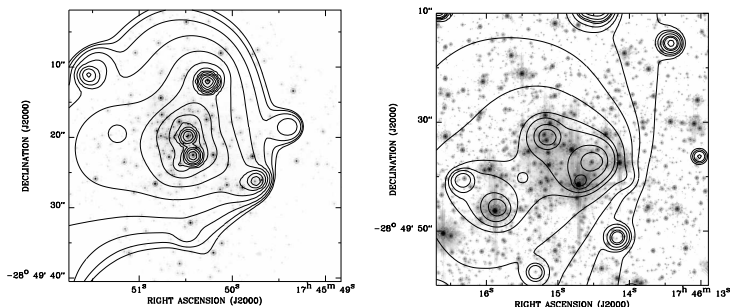


Figure 2. ACIS-I 1.0-9.0 keV intensity contours of Arches (left panel) and Quintuplet (right panel) on near-IR grey scaled images^[1].

3. Diffuse emission

Fig. 3 shows the distributions of the diffuse X-ray intensity (with detected point-like sources removed) in the Quintuplet and Arches fields.

The diffuse emission has a spectrum that is substantially harder than that of the point-like sources. In the core region (e.g. $\leq 15''$, for Arches). The potential contamination of faint undetected point-like sources could be up to $\sim 65\%$, but mostly at energies ≤ 4 keV. The remaining diffuse emission can be characterized by a plasma with a temperature of $\sim 5 \times 10^7$ K. The 0.3-8 keV luminosity of the emission is 1.6×10^{33} ergs s⁻¹ for Quintuplet and 7.7×10^{33} ergs s⁻¹ for Arches. The luminosity, spectrum, and radial surface brightness are consistent with the predictions of the cluster wind simulations^[2].

A fraction of the diffuse emission might originate in young stellar objects (YSOs)^[3]. We estimate their potential contribution (2-8 keV) to be $\sim 4.0 \times 10^{33}$ ergs s⁻¹ for Quintuplet and 7.7×10^{33} ergs s⁻¹ for Arches, assuming the Salpeter initial mass function and the mean spectrum of YSOs observed in the Orion nebula^[4]. The contribution is about three times greater than the observed values and should primarily be in the outer regions of the clusters. Therefore, we conclude that substantially fewer YSOs are present in the clusters than the expected.

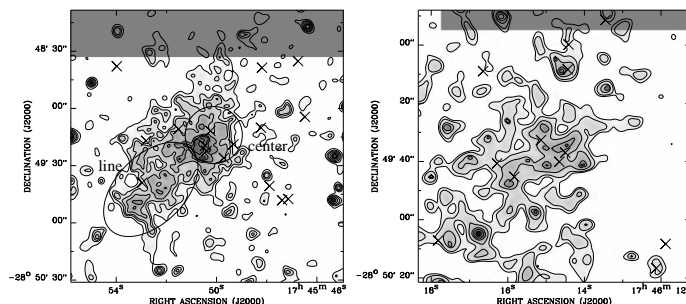


Figure 3. Arches (left panel): 1.0-9.0 keV image of the diffuse emission. The circle encloses the cluster region and the ellipse outlines the southeast extension which shows strong 6.4-keV Fe K α line emission. Quintuplet (right panel): 1.0-9.0 keV image of the diffuse emission. The positions of the detected point sources are marked by crosses.

4. The 6.4-keV Fe line feature

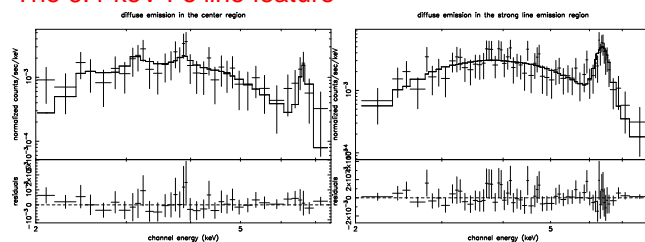


Figure 4. Spectra of diffuse emission in the Arches cluster (left panel) and in the southeast extension (right panel). See also Fig. 3 left panel

The diffuse emission enhancement southeast to the Arches cluster (Fig. 3, left panel) has a hard spectrum with a strong 6.4-keV line (Fig. 4, right panel). This region shows no indication of a dense molecular cloud or any other distinct radio/infrared features. The spectrum of the emission can be well fitted with a power law of a photon index of 1.1 (0.7-2.4) plus a Gaussian line with an equivalent width of ~ 1 keV and at 6.38 (6.34-6.43) keV (90% confidence uncertainty intervals). There is no indication for any 6.7-keV line emission in the spectrum. Any interpretation of the emission needs to explain the high luminosity ($\sim 4 \times 10^{33}$ ergs s⁻¹), the flat spectral shape, and the strong 6.4-keV line as well as the lack of the association with a dense molecular cloud.

5. Summary

- Most of the point-like X-ray sources are massive colliding-wind close binary.
- The diffuse emission in the clusters is apparently produced by cluster winds.
- The origin of the strong 6.4-keV neutral iron line emission, southeast to the Arches cluster, is unknown.

6. References

- [1]Figer, D.F. et al 1999, ApJ, 525, 759
- [2]Rockefeller, G. et. al 2005, ApJ, 623, 171
- [3]Feigelson, E.D. et al, 1999 ARA&A, 37, 363
- [4]Feigelson, E.D. et al, astro-ph/0506503