Parsec-scale Radio Imaging of the nearby X-ray bright Seyfert NGC 6764

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NGC 6764 is a nearby (32 Mpc for H_0 = 71 km/sec/Mpc; 1" = 154 parsec) S-shaped barred spiral galaxy (SBb), classified as a LINER and a Seyfert 2, with signatures of recent massive star formation. Spectral synthesis models suggest two starburst episodes in the nuclear regions (~3") that occurred 3 - 5 Myr and 15 - 50 Myr ago (*Schinnerer et al., 2000, ApJ, 545, 205*).

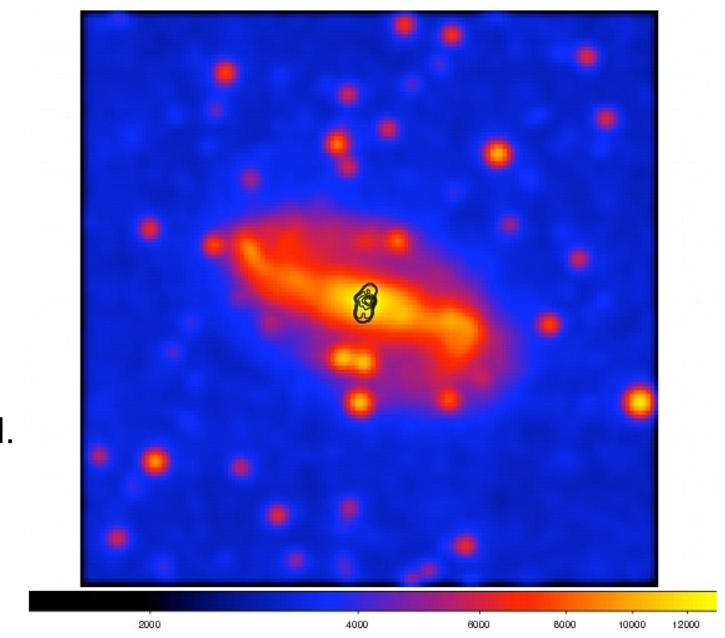

Fig. 1. The optical image of NGC 6764 from the Digitized Sky Survey, with 1.4 GHz VLA radio contours superimposed.

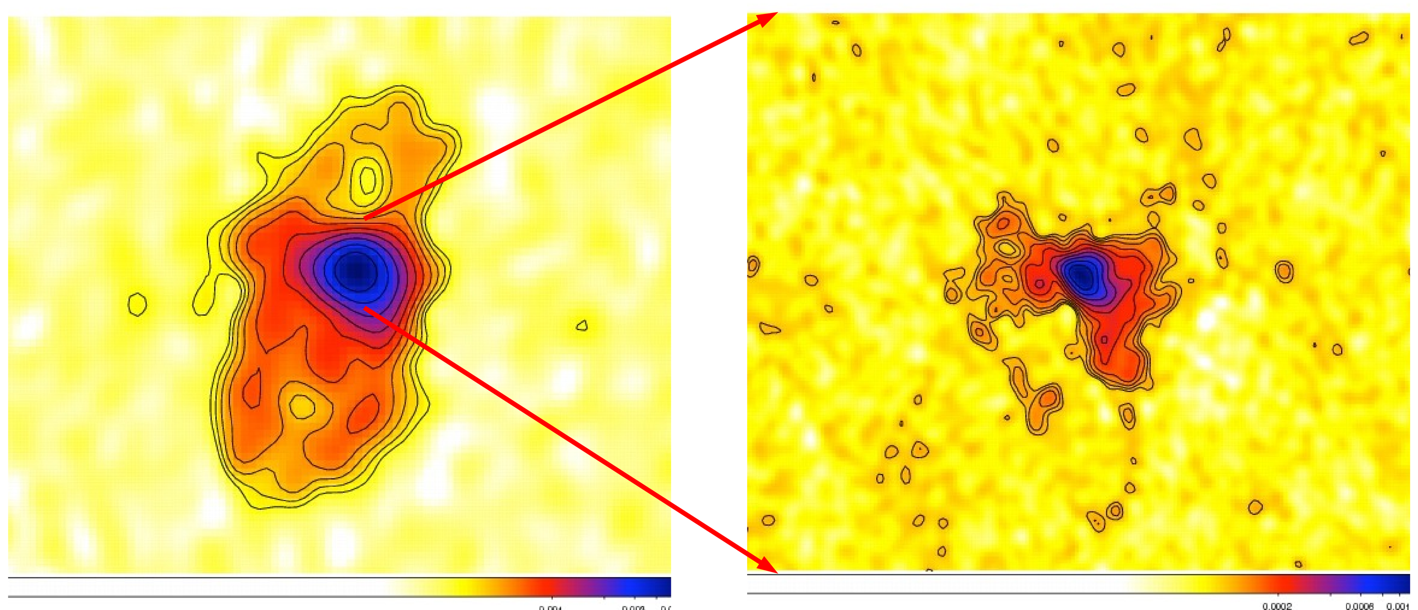

Fig. 2A (Left). The VLA B-array configuration image at 4.9 GHz showing the bipolar radio bubbles (northern bubble is ~1.1 kpc and southern bubble is ~1.5 kpc in extent). Fig. 2B (Right). The higher resolution VLA A-array configuration image at 4.9 GHz showing the east-west radio bright region.

Kpc-scale radio observations with the Very Large Array (VLA) reveal ~1 kpc bipolar bubbles of non-thermal radio emission along the minor axis of the spiral host (Fig. 1, Fig. 2A). The higher resolution 5 GHz VLA image (Fig. 2B) reveals a region of bright radio emission extending roughly in the east-west direction (*Hota & Saikia 2006, MNRAS, 371, 945*). Similar radio bubbles have been observed in other Seyfert galaxies, like Markarian 6 (*Kharb et al., 2006, ApJ, 652, 177*), NGC 3079, and others. That there are no convincing examples of radio bubble galaxies without an AGN, strongly suggests that the bubbles are driven by an active nucleus (*see Hota & Saikia, 2006*).

We observed NGC 6764 with the **Chandra X-ray telescope (ACIS-S)** for 20 ks in January 2008 (*Croston et al., 2008, ApJ, 688, 190*). These observations showed extended X-ray emission exactly coincident with the radio bubbles (Fig. 3A), with the brighter X-ray emission in the center coinciding with the region of high surface brightness radio emission in the east-west direction (Fig. 3B).

X-ray spectral fitting of the north-south bubbles and the east-west extension showed that the X-ray data is best fit by a hot thermal gas model with a temperature of kT = 0.75 keV and 0.93 keV for the north-south and east-west regions, respectively. A powerlaw model is not a good fit to the X-ray emission in these regions. The total energy stored in the hot gas is high ~10^{56} ergs, which cannot be accounted solely by starburst activity (*see Croston et al., 2008*).

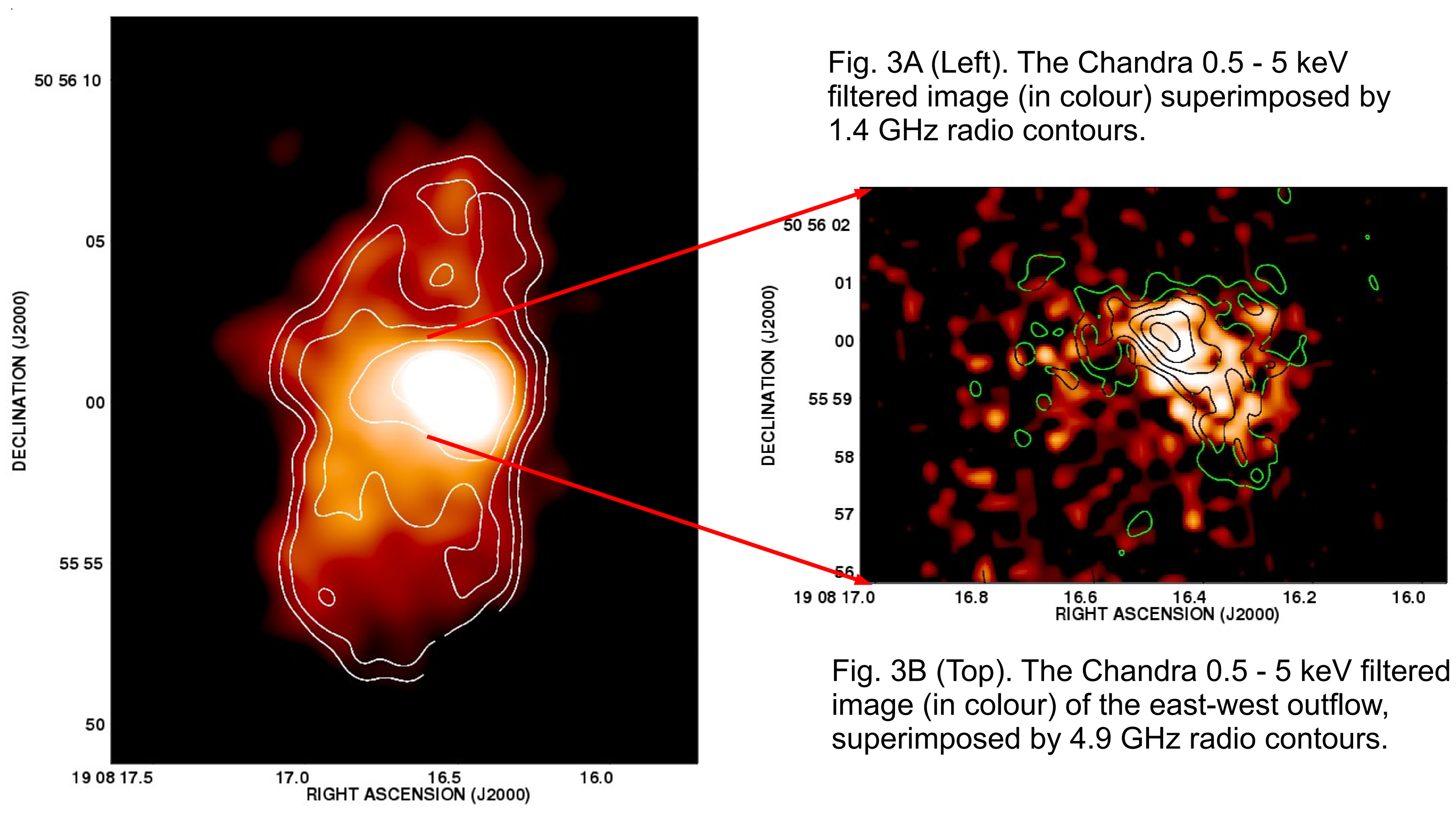

Fig. 3A (Left). The Chandra 0.5 - 5 keV filtered image (in colour) superimposed by 1.4 GHz radio contours.

Fig. 3B (Top). The Chandra 0.5 - 5 keV filtered image (in colour) of the east-west outflow, superimposed by 4.9 GHz radio contours.

The X-ray hardness ratio maps (using the 1.0 - 5.0 keV and 0.4 - 1.0 keV filtered images) reveal that the western edge of the kpc-scale bubbles has harder X-ray emission. Radio spectral index maps (using the 1.4 - 4.9 GHz VLA images and 1.4 - 8.4 GHz Giant Meterwave Radio telescope images, *see Hota & Saikia 2006*) reveal this edge to have a flatter radio spectrum. These results suggest that the AGN outflow may be shock heating the Interstellar medium (ISM), leading to an increase in the X-ray temperature, and a flattening of the radio spectrum due to localized particle acceleration.

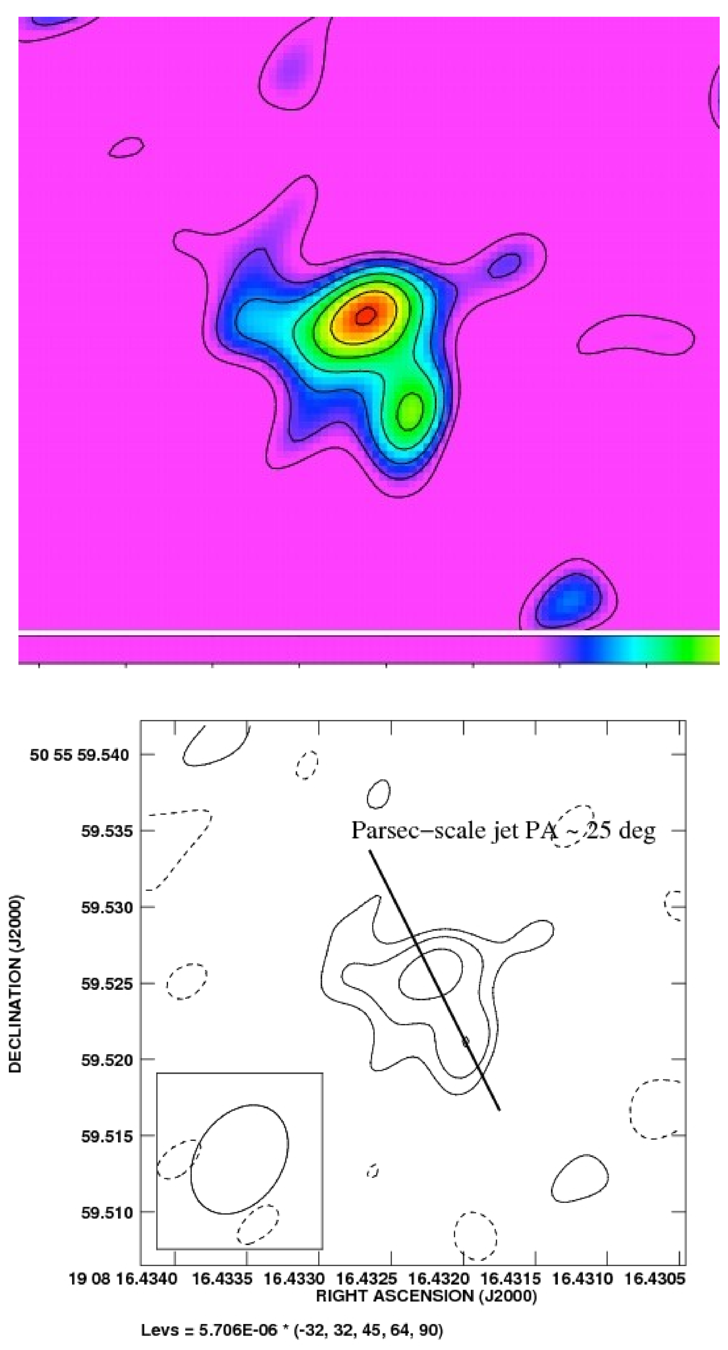

Fig. 4A (Top) & 4B (Bottom). The VLBA 1.6 GHz radio image of NGC 6764.

New Parsec-scale Radio Observations

We observed NGC 6764 with the ten elements of the **Very Large Baseline Array (VLBA)** on November 13, 2008, at 4.9 and 1.6 GHz, in a phase-referencing experiment. A faint, diffuse jet-like structure was detected at 1.6 GHz, but not at 4.9 GHz. The position of the peak radio emission is at RA 19h 08m 16.432s, DEC 50d 55m 59.525s. The optical host galaxy position is at RA 19h 08m 16.370s, DEC 50d 55m 59.58s (*Clements, 1981, MNRAS, 197, 829*). The peak surface brightness and total radio emission is only ~0.5 mJy/beam and ~0.8 mJy, respectively. The RMS noise in the map is ~0.1 mJy/beam. There appear to be two components present, 0.8 parsec apart, inside more diffuse emission (Fig. 4A, 4B). Assuming that the 4.9 GHz core flux is less than 3 times the RMS noise, the spectral index at the 1.6 GHz peak is steeper than -0.4.

Preliminary Findings

1. The parsec-scale jet position angle is around 25 degrees. The jet in NGC 6764 is therefore pointing towards the southern bubble (specifically towards its western edge). This puts the idea that the north-south bubbles have an AGN-related origin, rather than a galactic-wind-origin, (as deduced from our X-ray observations), on a firmer footing.

2. The steep radio spectrum parsec-scale jet supports the idea of strong jet-ISM interaction, which makes the synchotron-emitting electrons rapidly loose energy. This is consistent with the "frustrated jet" model picture suggested through our X-ray observations.

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