X-Ray Signatures of Radio Source Interaction with the ISM

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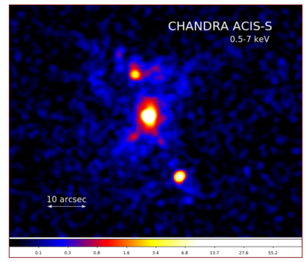
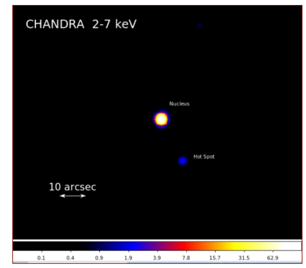
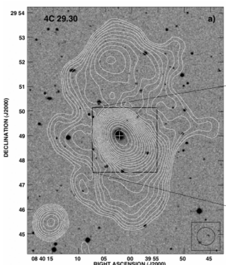
ABSTRACT: Growing observational evidence relates the AGN feedback to a black hole radio-mode (e.g. large cavities observed in X-ray clusters, evolution of radio sources). The physical process involved is not well understood, although it must play a major role during the primary epoch of galaxy formation at high redshifts. X-rays give information about a distribution of hot thermal gas and a possible presence of shocks associated with a radio source growing within the host galaxy environment. However, due to resolution constraints X-ray signatures of the radio source impact on the host galaxy environment can only be studied in nearby galaxies. Here, we present results of a deep Chandra observation of a low redshift radio galaxy where the complexity of the interactions between the radio plasma and ISM is uniquely displayed, allowing a direct mapping of the radio source growth and its immediate impact onto the galaxy. Chandra X-ray morphology shows a direct correspondence to the radio one, and we detect X-ray emission associated with a relativistic jet, knots, hot spots and lobes. We discuss the source X-ray properties.





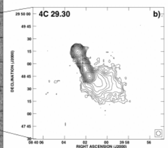
4C+29.30: 300 ksec Chandra ACIS-S observation.
The Images has been smoothed with 1.3 arcsec Gaussian.

4C+29.30 Restarted Radio Source - Elliptical Galaxy



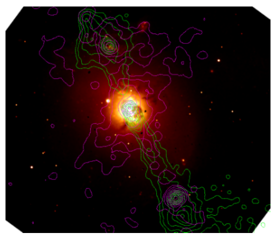
1.4GHz VLA D-array contour overlayed on DSS optical image. The size of the radio source is ~8 arcmin.

VLA Maps



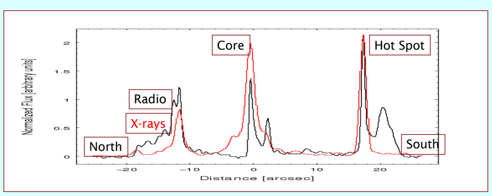
1.4GHz VLA B-array map of the central ~50 arcsec radio structure

Low redshift galaxy z=0.067

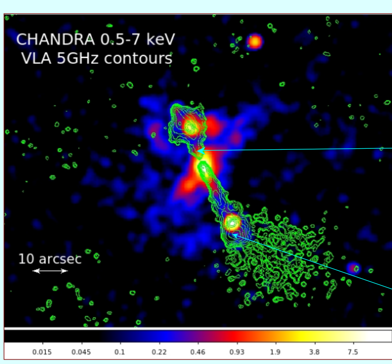


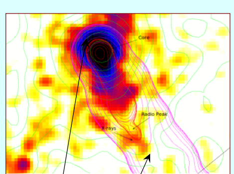
HST/ACS image with radio (green) and X-ray (magenta) contours showing the corresponding morphologies. The dust line crosses the nuclear region.

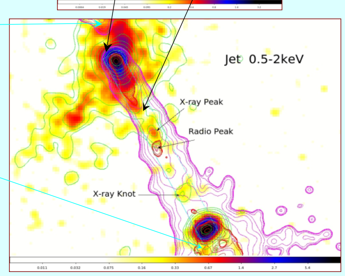
Radio and X-ray Emission Properties



- Radio features occur in pairs;
- X-ray peaks occur as single features;
- The Southern Hot Spot is the brightest feature in radio and X-rays.
- Radio and X-rays peaks are offsets in secondary features, while the strongest emission sites are aligned.







X-ray Properties

The soft 0.5-2 keV X-ray emission spreads over the entire radio source with several emission regions: Central diffuse emission, Southern jet, Hot Spot and some diffuse emission related to the Southern Lobe. To the North the strong diffuse X-rays correspond to the Northern Radio Lobe and Hot Spot.

Nucleus is highly absorbed and dominates the hard (2-7 keV) emission. We measure N_H = 3.95 (0.27/-0.33) x 10^{23} cm^{-2} and a power law slope of Γ=1.70 (+0.38/-0.36) with the hard unabsorbed X-ray luminosity equal to L_x(2-10keV) = 5.0±0.5 x10^{43} erg/s

The X-ray emission of the Northern Hot spot is very soft and well fit by a thermal model with kT=0.54±0.5 keV. The HS is also absorbed with NH ~10^{21} cm^{-2} and the unabsorbed luminosity is equal to L_x(0.5-2keV) = 1.7x10^{41} erg/s. The HS emission disappears in the hard band. The origin of this hot spot is most likely related to the jet interaction and heating of large amount of gas there.

The X-ray emission of the Southern Hot Spot is extremely bright in X-rays. It is also hard in contrast to the Northern HS. The total luminosity of this HS is equal to Lx(0.5-10keV) = 1.3x10^{41} erg/s.

X-ray Jet emission is detected to the South, although the emission is not continuous, but in form of enhancements along the radio jet. The continues emission is only visible in the central region but it is hard to disentangle it from the diffuse thermal emission of the hot gas there.

Summary and Conclusions

- X-ray emission identifies the sites of interactions between the radio source and the ISM.
- There is a strong morphological correspondence between the main radio source components and the detected X-ray emission features suggesting that the radio source heats up the gas and dissipate the initial jet energy.
- An absorbed AGN nucleus is powering the jet. It is relatively powerful with the unabsorbed luminosity > 5x10^{43} erg/s, but the accretion state of the central BH is still not clear, as the optical emission is buried within the dust.

Acknowledgments

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