Discovery of X-ray three-ring structure around the M87 galaxy in the Core of the Virgo cluster

Hua Feng[1], Shuang-Nan Zhang[2], Yu-Qing Lou & Ti-Pei Li

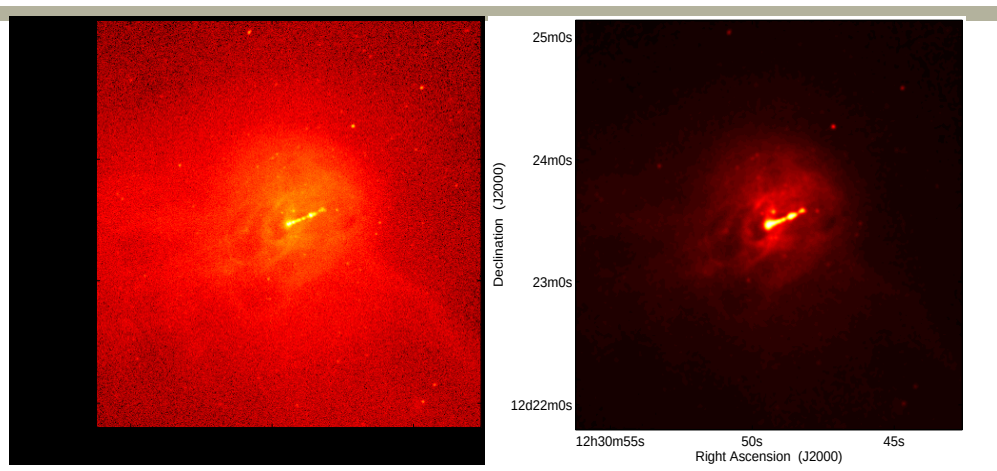
[1]fenghua01@mails.tsinghua.edu.cn
[2]zhangsn@mail.tsinghua.edu.cn (also UAH and MSFC, Huntsville, Alabama, USA)

Department of Engineering Physics
Tsinghua Center for Astrophysics
Physics Department
Tsinghua University
Beijing 100084, China

Introduction

M87 (3C 274, NGC 4486 or Virgo A), a giant elliptical galaxy, presents a variety of interesting astrophysical phenomena, as a dominant galaxy in the core the north part of Virgo cluster. M87 is famous for its highly collimated relativistic jet in X-ray, as well as optical and radio band consistently. The X-ray morphology study of the Virgo cluster from Chandra observation has been done by Young, Wilson & Mundell (2002), in which two large scales were found, namely an 'arc' from the east across the center to the southwest and two circular structures with radii of 45″ and 3′ respectively. Here we report a new discovery of a three-ring structure in the core region of the Virgo cluster which has not been noticed before.

Data reduction

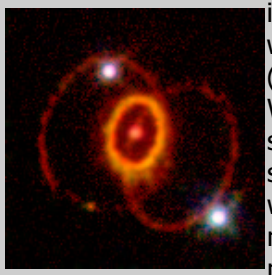


The Chandra view of the core region of the Virgo cluster, with a total exposure of 170 ks, by merging four observations with Obs-ID 2707, 352, 3717 and 1808. The large scale structures 'arc' and the small circular (Young, Wilson & Mundell, 2002) is evident. The image is shown in log scale and 1″ corresponding to 78 pc provided M87 to us is 16 Mpc.

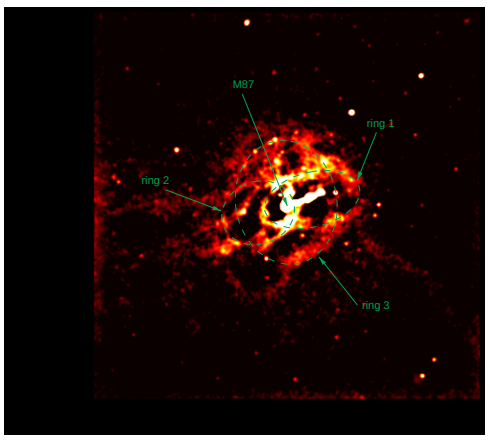
A smoothed image with the contrast adjusted to avoid the overbrightness of M87's nucleus and the jet. The image is shown in linear scale. From the image we can see some subtle structures in the core region around the jet.

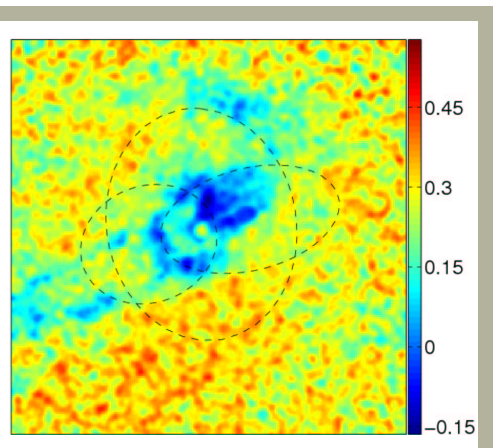
Results and discussion

The structures are markd and measured by three elliptical rings, each with five parameters shown in the right table. If the elliptical rings are projections of circular rings in the line of sight, their 3-D orientations can be reconstructed. It is noted that ring 3 is centered at M87's nucleus and almost perpendicular to the jet direction. This three-ring structure is reminiscent of the similar structure of SN 1987A, which is explained by blue super giant's 'fast wind' illuminating red giant's 'slow wind' before the explosion (Tanaka & Washimi 2002). We suggest these similar structures are dominated by similar processes, i.e. two winds, right before the formation of M87 by the merger of two SMBHs.



Forman et al (2004) suggested that the structures around ring 1 and 2 identified here are two expanding cavities around the jet and counter jet. Consequently they derived that due to different external pressures, the far front of the cavities is mildly supersonic while the inner part, close to the nucleus, thus collapsing. We argue that these two rings are indeed rings but not the projection of prolate spheres, because the expanding cavities running into each other would not allow the nested portions to be seen. Thus the morphology is more likely consisted of three rings than expanding cavities.





To reveal if subtle structures exist in the central region, a sharpening process called the unsharp-mask is applied. Three elliptical rings are revealed, two along the direction of the jet, the third one is centered at M87's nucleus across eight bright X-ray knots.

Hardness ratio map. The two energy band are 0.5-1.0 keV and 1.0-2.5 keV. Each pixel in the image is defined by H=(c2-c1)/(c2+c1), where c1 and c2 are the photon counts of this pixel in the lower and higher energy band.

	2-D Projected ellipse				3-D reconstructed circular ring	
Object	Center (RA, Dec) (degree)	a* (kpc)	b† (kpc)	θ‡ (degree)	θ′¶ (degree)	Φ§ (degree)
ring 1	187.7021, 12.3920	1.9	1.1	76	55	61
ring 2	187.7100, 12.3901	1.5	1.3	70	30	51
ring 3	187.7059, 12.3916	2.5	2.0	−10	37	9
M87 nucleus	187.7059, 12.3911	/	/	/	/	/
M87 jet	/	/	/	70	43	0

* Semi major axis.

† Semi minor axis.

‡ Angle from the major axis (or M87 jet direction) to the local hour circle line.

¶ Angle from the ring's normal direction (or M87 jet direction) to the line of sight.

§ Angle from the ring's normal direction to the M87 jet direction.