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Association of Different Phases of ISM in Nearby Early Type Galaxy NGC 2434

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Abstract

This paper presents the x-ray and optical study of nearby early type galaxy NGC 2434. We present results based on systematic analysis of broad band Optical data taken from Hubble Space Telescope (HST) and X-ray data from Chandra archive data of the nearby early type galaxy NCC 2434 with total exposure of 46.69 ks (ObsID 2923). For Optical analysis of this galaxy we have used Image Reduction and Analysis Facility (IRAF) and two-dimensional fitting algorithm GALFIT, while for X-ray data analysis we have used Chandra Interactive Analysis of Observations (CIAO) v.4.6.1.1 and the corresponding calibration files CALBD v.4.6.1 provided by the Chandra X-ray Center (CXC). Color index map, extinction map and residual map obtained from optical data analysis confirms presence of dust in this galaxy. Tricolor map, surface brightness profile obtained from X-ray data analysis confirms the presence of hot gas in this galaxy. By fitting spectrum to the diffuse component of hot gas and discrete point sources present in D_{25} region of this galaxy, we have finded x-ray luminosity of diffuse gas and luminosity of point sources. In order to confirm association and origin of different phase of Interstellar Medium (ISM), we have overlaid dust extinction contours and X-ray contours on K-band near IR image.

Keywords: Optical and X-ray Analysis, NGC 2434

Introduction

Early-type galaxies i.e. ellipticals and lenticulars had long been thought as the simplest stellar systems with considerable structural regularity with a deficient of ISM. Early Type Galaxies were simplest stellar systems with no trace of substructures, interstellar medium (gas as well as dust); and exhibiting characteristic surface brightness profiles of systematically decreasing luminosity from the bright nucleus till the infinite edge. But, now a day due to availability of modern telescopes, it is confirmed that, this types of galaxies consist of gas and dust. X-ray emission in early-type galaxies partly originate from the hot interstellar medium (ISM) which is distributed throughout the galaxy, and partly from the population of point-like sources, known as low mass X-ray binaries (LMXBs) [1]. The excellent angular resolution of the Chandra X-ray telescope for the first time has made possible to spatially resolve the point sources in extragalactic environment. As hot gas distribution within a galaxy find gravitational potential of the baryonic particle, therefore, X-ray emission maps derived for external galaxies provides a powerful tool in investigating structure of the galaxy. Further, morphology and extent of the hot gas in early-type galaxies provide important input on the nature of the hot gas, metal enrichment history of the ISM of the target galaxy. In this paper we present morphology and spectral properties of hot gas and point-like sources in NGC 2434 early-type galaxy having morphology E_{0-1} [2]. We present results based on the Optical and X-ray systematic analysis of this galaxy with an objective to investigate Optical and X-ray properties.

Table 1: Global Parmeters of NGC2434

Parameter	Value
Alternate names	ESO059-G 005; ESO 073459-6910.3; WISEA J073451.18-691702.8; 2MASX J07345116-6917029
RA, DEC	07h34m51.16s,-69d17m02.9s
Morphology	E_{0-1}
Velocity(km/s)	1390
Redshift (z)	0.0046

Observations and Data Preparation

Optical Data Analysis: Optical broad brand HST images (F450w, F555w, F814w) were acquired for the this study with detector WFPC2 and aperture PC1 and were pipeline processed and cleaned properly. Further reduction and processing of the optical broadband imaging observations on this target galaxy were performed following the standard procedure discussed in Patil *et al*. (2007). The standard tasks available within Image Reduction and analysis Facility (IRAF) were used for the analysis purpose. IRAF is a software developed by the National Optical Astronomy Observatory (NOAO) for the reduction of astronomical

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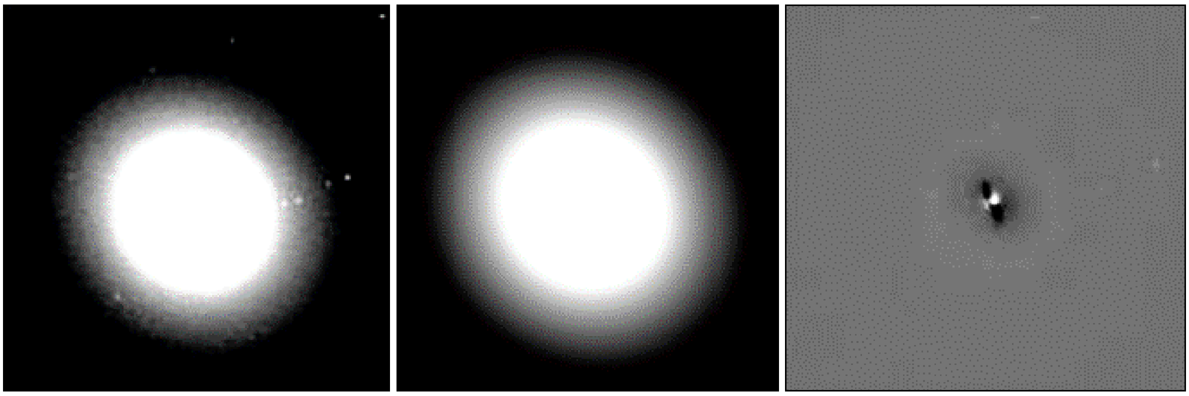
images and is a collection of several packages within it. The optical data acquired for this galaxy from HST through its archive was preprocessed i.e., bias subtracted, flat fielded, sky subtracted, cosmic ray and background corrected and were geometrically aligned. These images were used for the present study for further imaging analysis purpose i.e. for Galfit fitting, deriving smooth models, dust extinction maps and also for deriving color-index maps of the target galaxies. The extinction maps and color-index maps generated using these images acted as proxy for investigating spatial distribution of interstellar dust and other hidden features within the target galaxies. Before generating color-index maps of the target galaxies, light distribution in various broadband filters were degraded relative to one another so that PSFs of these images were matched properly.

Galfit Fitting

We have derived 2D dust free models of this galaxy using Galfit algorithm. Galfit constrains profile of target galaxy image in digital form and yield a smooth model of the target galaxy. As the target galaxies host several of the hidden features, therefore, for the present case we have made use of the simple Sersic model. This model can suitably remove all significant residuals down to the noise level. A detailed discussion on the usage of Galfit for various cases can be found in [3, 4]. Output of galfit gives us three images that is original image, smooth model image and residual map as shown in Figure 1.



(a) **(b)** **(c)**

Fig 1(a, b, c): Original (left panel), smooth model (middle panel) generated using the Galfit algorithm and residual map (right panel) derived for the NGC2434

X-ray Data Analysis

NGC2434 was observed by Laurence David with the back-illuminated Chandra ACIS-S detector on 17 October 2012 for a total exposure of 46.69 ks (ObsID 2923). We acquired the level-2 event file on this target from the archive of Chandra observatory. The data were reprocessed in a uniform manner using the standard tasks available within the Chandra Interactive Analysis of Observations (CIAO) v.4.6.1.1 and the corresponding calibration files CALBD v.4.6.1 provided by the Chandra X-ray Center (CXC). Periods of high background were verified by plotting its 0.3-10 keV light curve extracted from the chip and were filtered out using the 3σ clipping. After removal of the background flares, the clean data had a net exposure of 46 ks. X-ray background component was adequately modeled using the "blank-sky" data sets. The point source detection was performed on CCD ID 7 using CIAO wav detect task. This enabled us to detect a point sources within S3 chip. We generated exposure corrected, background subtracted 0.5-3.0 keV energy band image using dmmerge task available within CIAO 4.6.

Tricolour Map: X-ray emission originating from different sources, we extracted X-ray photons in three different energy bands namely, soft (0.5-1.0 keV), medium (1.0-2.0 keV) and hard (2.0-7.0 keV) band. These counts in three different energy bands were then used to obtain the tri-color maps of target galaxies. Adaptively smoothed tricolor images representing diffuse X-ray emission thus derived after removal of point sources for target galaxies are shown in Figure 2. The color coding in these images is red color indicates soft component (0.5-1.0 keV) of X-ray emission, green color mid band (1.0-2.0 keV), while blue color represents the hard component (2.0-7.0 keV) of X-ray emission. A careful look this tricolor map reveals that the distribution of the X-ray emitting gas in this galaxy is not symmetric about center of the galaxies but shows a wide range of morphological features like filaments, depressions in the surface brightness, etc.

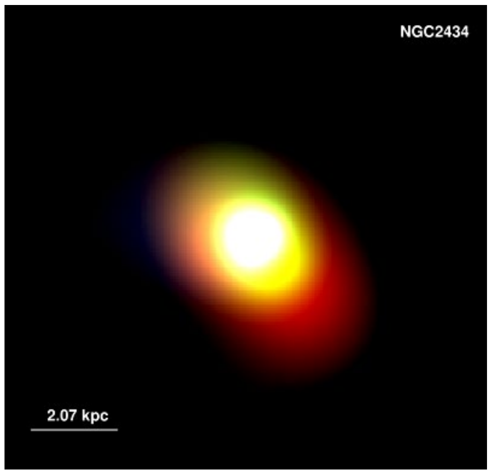


Fig 2: Tricolour image of the NGC 2434, red color represents soft component (0.5-1.0 keV), green color represents the mid band (1.0-2.0 keV), while the blue color represents the harder component (2.0-7.0 keV) of the X-ray emission.

Azimuthally Averaged Surface Brightness Profile

Azimuthally averaged surface brightness profile (red color 0-360◦) of the extended emission from NGC 2434 in the energy range (0.3-3.0 keV) was derived by extracting counts from different concentric annuli up to a radius of 30 arcsec and is shown in Figure 3. After detecting the sources and finding their positions, we extracted X-ray counts from circular regions centered on individual sources along with their local backgrounds. 1-D beta model has been widely used in the literature to investigate surface brightness distribution of hot gas in galaxies [5]. This model was primarily developed for investigating hot gas properties in galaxy clusters, however, has also been used in literature for describing the hot gas properties in individual galaxies [6, 7]. The azimuthally averaged surface brightness profile appears remarkably smooth and therefore the 1d-beta model was fitted to this profile [8].

$$\Sigma(r) = \Sigma_0 \left[1 + \left(\frac{r}{r_c}\right)^2\right]^{-3\beta+0.5}$$

Where r_c is the core radius and beta is slop parameter. The Best fitted parameters of the azimuthally average surface brightness profile are rc = 0.8066±0.324 arcsec and src.beta = 0.38±0.021. The resultant surface brightness profiles are shown in Figure 3 and show noticeable azimuthal variations.

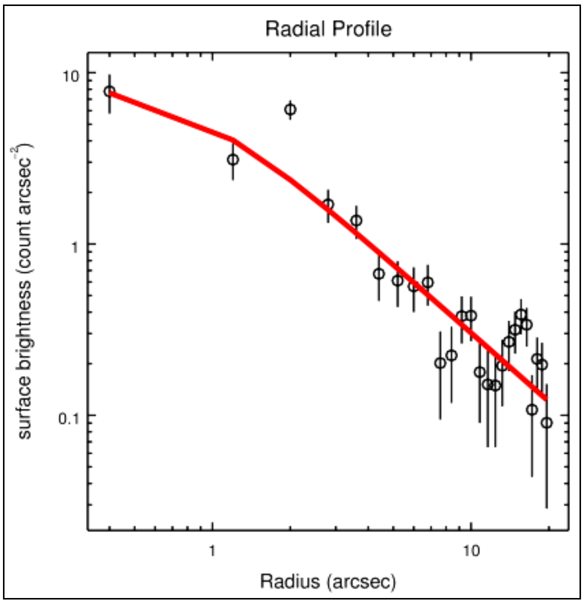


Fig 3: Surface brightness profiles of diffuse X-ray emission in NGC 2434

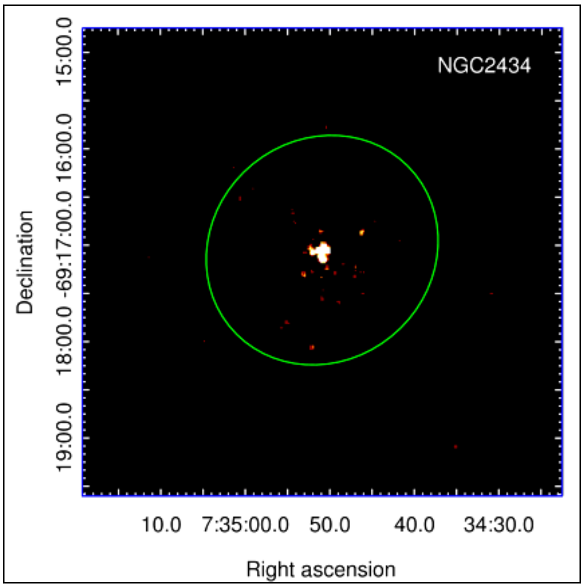


Fig 4: Csmoothed Chandra images in 0.5-3.0 keV (left panel) showing the morphology of diffuse hot gas distribution within the galaxies. Ellipse on this images indicate optical D_{25} region.

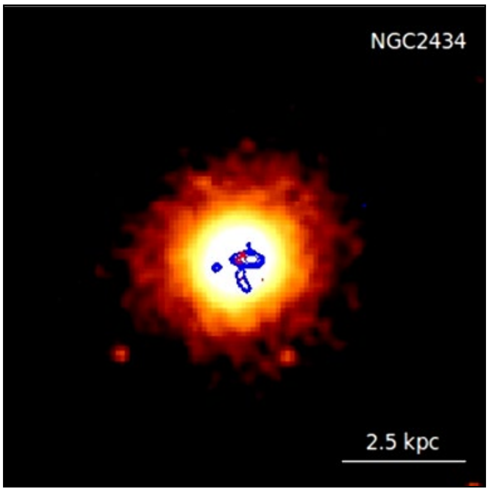


Fig 5: Optical dust contours (Red) and X-ray contours (Blue) are overlaid on near Infra-red K-band image.

Association of different Phases of ISM

In order to show association of different phases of ISM, Csmoothed Chandra image in 0.5-3.0 keV showing the morphology of diffuse hot gas distribution within the galaxy, Figure 4, ellipse on this image indicate optical D_{25} region. we have also overlay contours of the optical and X-ray emission maps on the Ks band images. As shown in Figure 5. A careful inspection of these images ravels a geometrical association of all the three phases of ISM pointing towards their common origin.

Result

V-I color map and V band extinction map derived from optical broad band images taken from HST for this galaxy revels the presence of small dust lane along its major axis. We also presented results obtained from the systematic analysis of a total of 46.69 ks of Chandra observations of a low-redshift (z= 0.0046) galaxy NGC 2434. X-ray analysis of this galaxy concludes that X-ray Luminosity of diffuse gas in D_{25} region of this galaxy is found to 6.22×10^{39} ergs/sec, while its temperature was estimated to be 0.59 ± 0.00 keV. Dust extinction contours and X-ray contours overlaid on K-band near IR image confirms the association of ISM in this galaxy.

Conclusion

We present multiwavelength imagery of NGC 2434 with an objective of studying the dust content and other phases of the ISM, and its origin in the system. The conclusions derived from this study are as follows. Color-index maps, as well as extinction maps, derived for NGC 2434 confirms presence of small nuclear dust at the center of this galaxy. Though it contains dust in the central region, we are not able to determine its mass due to less extinction in optical F450w, F555w, F814w broad bands, and an unavailability of IR, MIPS data. In X-ray analysis of NGC 2434, we find that the X-ray emitting gas is confined to the central region only. Tricolour image of this galaxy exhibits the distribution of the diffuse X-ray emission, in soft, mid and hard component and their origin. The azimuthally averaged surface brightness profile of this galaxy appears remarkably smooth distribution. The combined spectrum of the X-ray photons within the optical D_{25} region that had the point sources removed is well constrained by a double temperature together with a power law component, confirms that the contribution is from the unresolved population of sources. Dust extinction contours obtained from extinction map and X-ray contours are overlaid on K-band near IR image confirms the association of ISM in this galaxy and their common origin.

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