

Exploring the Diffuse X-ray Emission of Supernova Remnant Kesteven 69 with *XMM-Newton*

Kyoung-Ae Seo[†], Chung Yue Hui

Department of Astronomy and Space Science, Chungnam National University, Daejeon 305-764, Korea

We have investigated the X-ray emission from the shock-heated plasma of the Galactic supernova remnant Kesteven 69 with *XMM-Newton*. Assuming the plasma is at collisional ionization equilibrium, a plasma temperature and a column absorption are found to be $kT \sim 0.62$ keV and $N_H \sim 2.85 \times 10^{22} \text{ cm}^{-2}$ respectively by imaging spectroscopy. Together with the deduced emission measure, we place constraints on its Sedov parameters.

Keywords: supernova remnants, X-rays, Kes 69

1. INTRODUCTION

A series of multiwavelength observations has been devoted for investigating Galactic supernova remnant (SNR) Kesteven 69 (Kes 69). Millimeter band observations of CO and HCO⁺ lines towards Kes 69 provided strong evidence for the association between Kes 69 and the molecular cloud (Zhou et al. 2009). An extended OH (1,720 MHz) emission region further indicates the presence of shocked molecular gas in Kes 69 (Hewitt et al. 2009). With HI observation, the kinematic distance for Kes 69 has been determined for a range from 5.5 kpc to 11.2 kpc (Tian & Leahy 2008).

In X-ray regime, it has an irregular morphology as observed by *ROSAT*, which shows correlation with an incomplete radio shell (Yusef-Zadeh et al. 2003). The analysis of the X-ray energy spectrum obtained by the *ROSAT* Position Sensitive Proportional Counter inferred a temperature and interstellar absorption of $kT \sim 1.6$ keV and $N_H \sim 2.4 \times 10^{22} \text{ cm}^{-2}$. Because of the limited photon statistics and energy range provided by *ROSAT*, a more detailed analysis of the remnant emission was not allowed (Yusef-Zadeh et al. 2003). This has motivated a dedicated *XMM-Newton* observation of Kes 69 (Obs ID: 0605480101 PI: Miceli). For searching the evidence of fast ejecta propagating in a dense environment, a recent study has revealed 18 hard

X-ray point sources in the field of Kes 69 with this *XMM-Newton* observation (Bocchino et al. 2012). Investigations of their source nature suggest these hard X-ray sources can possibly be fast ejecta fragments or cataclysmic variables (CVs). Through a detailed timing analysis of the bright source detected in this field, XGPS-I J183251-100106/2XMM J183251.4-100106, a periodic signal of ~ 1.5 hours has been discovered with the same *XMM-Newton* data (Hui et al. 2012a). Its phase-averaged X-ray spectrum can be well modeled with a thermal bremsstrahlung temperature of $kT \sim 50$ keV. Both the X-ray spectral and temporal behavior of this system suggests that it is a nearby eclipsing magnetic CV (Hui et al. 2012a). This study has excluded any possible association between this bright source and the SNR.

While the aforementioned studies are focused on the point source population detected in the field of Kes 69, in this paper we report a detailed analysis of diffuse emission with *XMM-Newton* data and provide constraints on its dynamical properties. In Section 2, the details of this observation and the procedures of data reduction are described. The results and the physical inferences are given in Section 3.

© This is an open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Received Nov 30, 2012 Revised Dec 25, 2012 Accepted Dec 31, 2012

[†]Corresponding Author

E-mail: miriamseo@naver.com

Tel: +82-42-821-5461, Fax: +82-42-821-8891

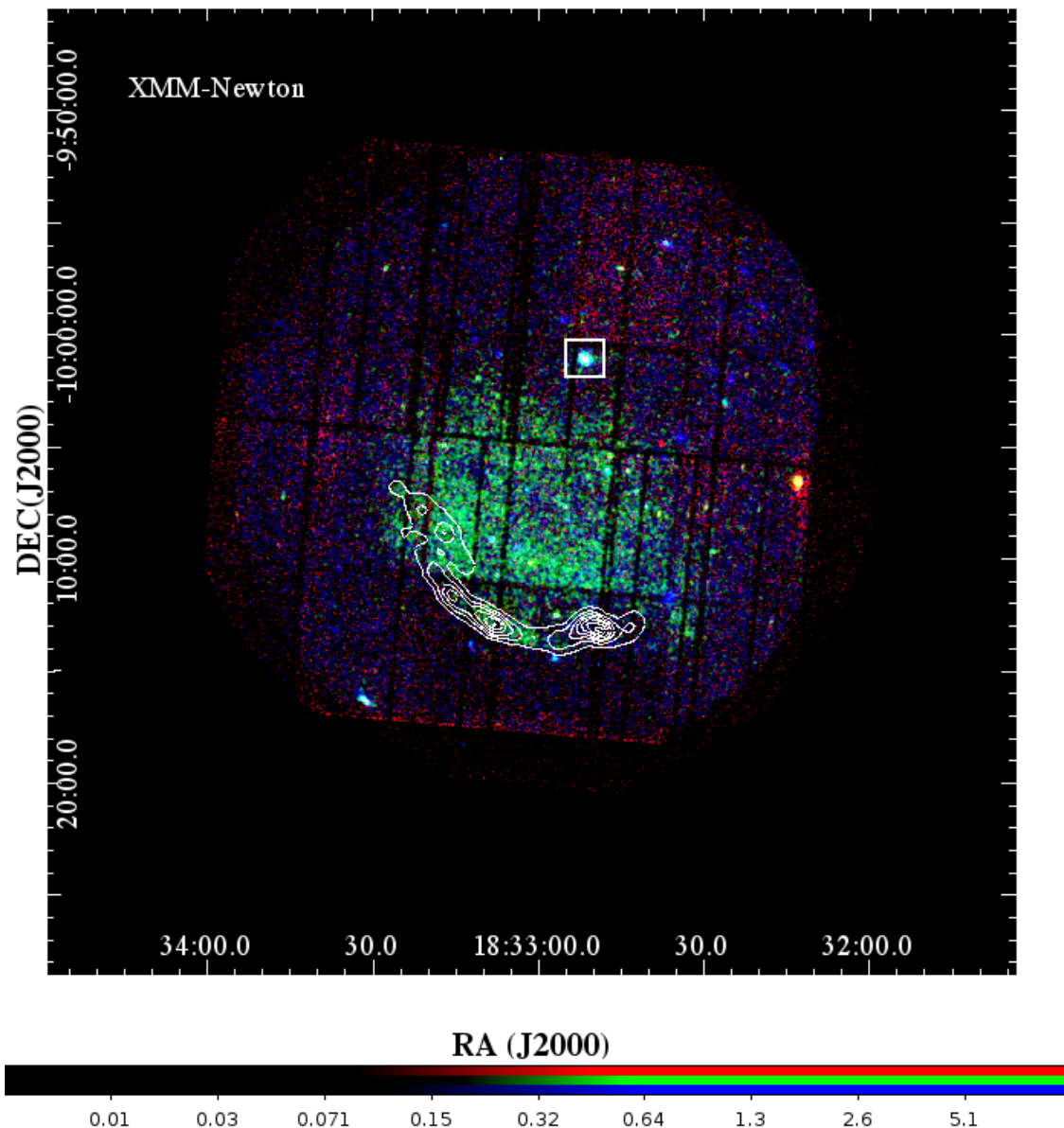


Fig. 1. X-ray color image of a 25'x25' FoV toward the supernova remnant Kes 69 with MOS1/2 and PN data merged (red: 0.3–1 keV, green: 1 – 2 keV, blue: 2 – 12 keV). Radio contours as observed by Very Large Array (VLA) at 1.4 GHz are overlaid for comparison. The X-ray emission is well correlated with the radio shell on south edge. The bright source as highlighted by the white box is XGPS-I J183251-100106/2XMM J183251.4-100106 which is found to be a serendipitous magnetic CV detected in this field (Hui et al. 2012a).

2. OBSERVATION AND DATA REDUCTION

Kes 69 was observed on 2009 October 8-9 with the European Photon Imaging Camera (EPIC) on board *XMM-Newton* which consists of two metal oxide semiconductor CCD detectors (MOS1 and MOS2) and a PN CCD detector. The aim point is R.A. = 18:32:57.01, DEC = -10:05:41 (J2000). MOS1/2 and PN were operated at full frame mode (frame time = 2.6 s) and extended full frame mode (frame time = 199.1 ms) respectively. Medium filters were used to block

optical stray light in all EPIC instruments. We used the tasks *emproc* and *epproc* of the XMM Science Analysis Software (XMMSAS version 11.0.0) for reprocessing all the EPIC data with the updated instrumental calibration. We selected events with the pattern in the range of 0-12 for both MOS cameras and 0-4 for the PN camera in 0.3-12 keV. We have taken the data by accepting only the good time intervals when the sky background was low for the whole camera ($< 2.4 \text{ counts s}^{-1}$, $< 2.8 \text{ counts s}^{-1}$, and $< 5.7 \text{ counts s}^{-1}$ for MOS1, MOS2, and PN, respectively). After removing all events

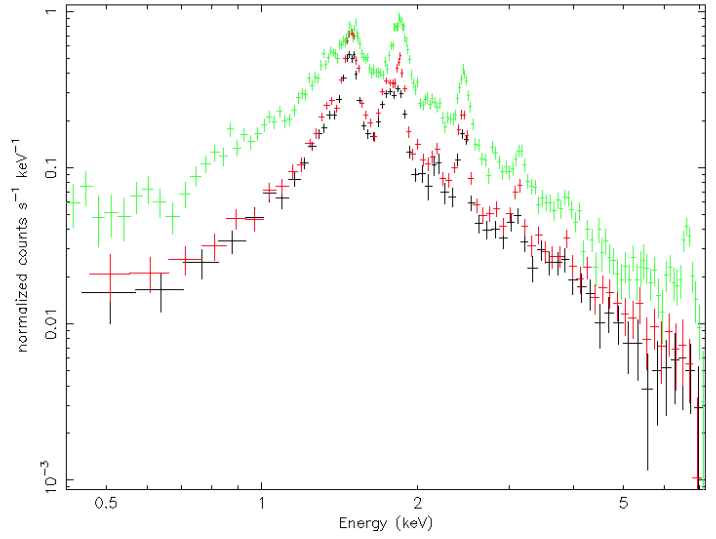
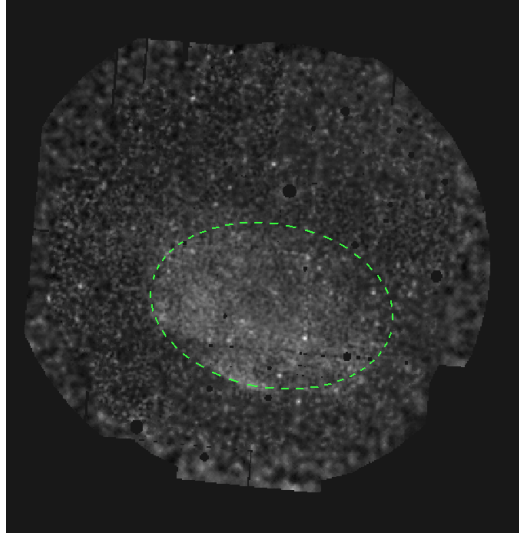


Fig. 2. (Left panel) Adaptively smoothed image with all EPIC data merged. All the resolved point sources have been subtracted from the data in accordance with the point spread function width at their off-axis angles and peak energies. The extracted region for X-ray spectrum of the remnant emission is illustrated by the green ellipse. (Right panel) Energy spectrum of Kes 69 remnant emission as observed with MOS1 (black symbols), MOS2 (red symbols) and PN (green symbols).

which were potentially contaminated by bad pixels, effective exposures were found to be 55.9 ks, 56.6 ks, and 41.3 ks for MOS1, MOS2, and PN, respectively.

3. DATA ANALYSIS

The X-ray color image of the field around Kes 69 is shown in Fig. 1. With source detection performed on all EPIC data in the energy range of 0.3–12 keV, we have revealed a population of point sources in this field. Since we concerned only diffuse emission from the SNR, all these resolved point sources were subsequently subtracted in accordance with the point spread function width at their off-axis angles and peak energies. In the left panel of Fig. 2, the adaptively smoothed “cheese” image after point source subtraction is shown. The energy spectra of the SNR were then extracted from individual camera within the elliptical region as illustrated in the left panel of Fig. 2. Response files were computed by using XMMSAS. The energy spectra as seen by individual camera are shown in the right panel of Fig. 2. In order to obtain a tight constraint on the emission properties, we fitted the data obtained from all three cameras simultaneously.

For the spectral fitting, we used XSPEC (version 12.6.0) with χ^2 statistics. We followed the method described by Snowden & Kuntz (2011) for modeling the background. Assuming the SNR has already reached the condition

for collisional ionization equilibrium (CIE), we fitted the observed spectrum with the XSPEC model *VEQUIL*. This yields a goodness-of-fit of $\chi^2 = 173.1$ for 184 degrees of freedom with the best-fitted column density, plasma temperature and the model normalization of $N_H \sim 2.85 \times 10^{22} \text{ cm}^{-2}$, $kT \sim 0.62 \text{ keV}$ and $\sim 0.02 \text{ cm}^{-5}$. For properly constraining the spectral parameters, we have computed the confidence contours which are shown in Fig. 3.

Following Hui et al. (2012b), we discuss the properties of Kes 69. Assuming the shocked densities of hydrogen n_H and electrons n_e are uniform in the extraction region, the normalization of the CIE model can be approximated by $10^{-14} n_H n_e V / 4\pi D^2$, where D is the distance to Kes 69 in cm and V is the volume of interest in units of cm^3 . In this analysis, we adopt a remnant distance of 5.5 kpc (cf. Tian & Leahy 2008). Assuming a fully ionized plasma with $\sim 10\%$ helium ($n_e \sim 1.2 n_H$) and Kes 69 is in a Sedov phase, the shock temperature can be estimated by $T_s \sim 8.1 \times 10^6 E_{51}^{2/5} n_{\text{ISM}-1}^{-2/5} t_4^{-6/5} \text{ K}$, where t_4 , E_{51} , and $n_{\text{ISM}-1}$ are the time after the explosion in units of 10^4 years, the released kinetic energy in units of 10^{51} erg, and the ISM density in units of 0.1 cm^{-3} , respectively. Assuming it is a strong shock, n_{ISM} is estimated to be $0.25 n_H$. With $E_{51} = 1$, the age of Kes 69 is estimated as $\sim 2.5 \times 10^4$ years.

ACKNOWLEDGMENTS

K. A. Seo and C. Y. Hui are supported by the National

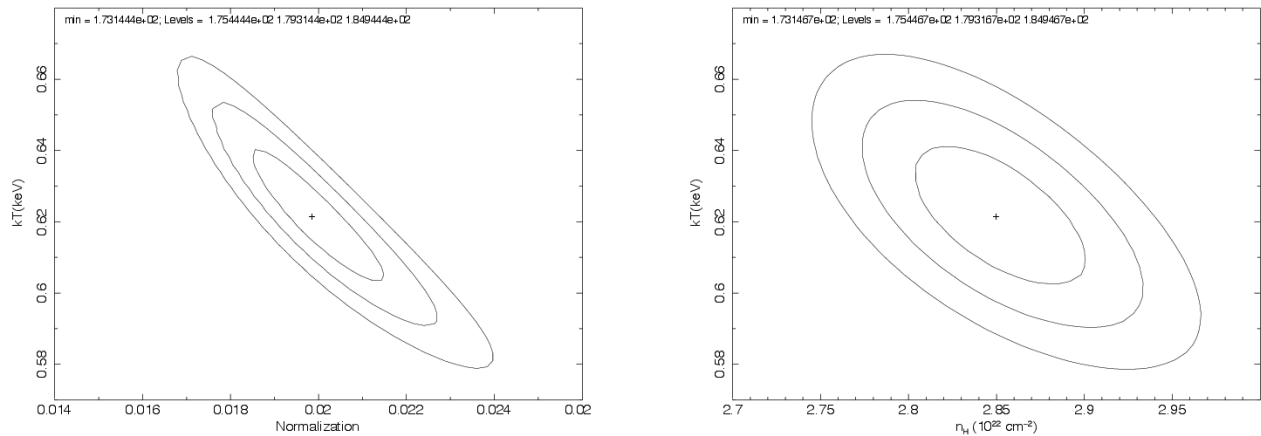


Fig. 3. Confidence contours for CIE plasma model fitted to the X-ray spectrum of diffuse emission of Kes 69. (left panel: plasma temperature vs. model normalization; right panel: plasma temperature vs. column density). The χ^2 values for the minimum and each contour are given at the top of each plot.

Research Foundation of Korea through grant 2011-0023383.

REFERENCES

- Bocchino F, Bykov AM, Chen Y, Krassilchtchikov AM, Levenfish KP, et al., A population of isolated hard X-ray sources near the supernova remnant Kes 69, *A&A*, 541, A152 (2012). <http://dx.doi.org/10.1051/0004-6361/201219005>
- Hewitt JW, Rho J, Andersen M, Reach WT, Spitzer Observations of Molecular Hydrogen in Interacting Supernova Remnants, *ApJ*, 694, 1,266-1,280 (2009). <http://dx.doi.org/10.1088/0004-637X/694/2/1266>
- Hui CY, Seo KA, Hu CP, Lin LCC, Chou Y, Detection of X-Ray Periodicity from a New Eclipsing Polar Candidate XGPS-I J183251-100106, *ApJ*, 759, 109 (2012a). <http://dx.doi.org/10.1088/0004-637X/759/2/109>
- Hui CY, Seo KA, Huang RHH, Trepl L, Woo YJ, Identification Campaign of Supernova Remnant Candidates in the Milky Way. I. Chandra Observation of G308.3-1.4, *ApJ*, 750, 7 (2012b). <http://dx.doi.org/10.1088/0004-637X/750/1/7>
- Snowden SL, Kuntz KD, Cookbook for Analysis Procedures for XMM-Newton EPIC MOS Observations of Extended Objects and The Diffuse Background, version 4.3 (2011).
- Tian WW, Leahy DA, The distances of supernova remnants Kes 69 and G21.5-0.9 from HI and 13CO spectra, *MNRAS*, 391, L54-L58 (2008). <http://dx.doi.org/10.1111/j.1745-3933.2008.00557.x>
- Yusef-Zadeh F, Wardle M, Rho J, Sakano M, OH (1720 MHz) Masers and Mixed-Morphology Supernova Remnants, *ApJ*, 585, 319-323 (2003). <http://dx.doi.org/10.1086/345932>
- Zhou X, Chen Y, Su Y, Yang J, Discovery of Molecular Shells Associated with Supernova Remnants. I. Kesteven 69, *ApJ*, 691, 516-524 (2009). <http://dx.doi.org/10.1088/0004-637X/691/1/516>