Chandra view on the active nucleus of the restarted radio galaxy CGCG 292-057

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Abstract

We present an analysis of the 90 ksec *Chandra* ACIS-I data for the galaxy CGCG 292-057 ($z = 0.054$), which is a remarkable system showing at optical wavelengths, strong evidence for a relatively recent merger event. Radio images reveal a similarly complex picture, with a pair of compact young/inner radio lobes confined to the host galaxy, and embedded within larger-scale old/outer radio lobes characterized by the X-shaped morphology. The active nucleus in the system is clearly detected in the newly obtained *Chandra* data. We model the X-ray spectrum of the core assuming various emission models, including an absorbed power-law, a power-law plus thermal emission component, and a two-temperature thermal plasma. The best fit was however obtained assuming a model consisting of a power-law emission scattered by a hot ionized gas (giving rise to the 6.7 keV iron line).

Introduction

In Active Galactic Nuclei (AGN), relativistic jets and high-energy emission of accretion disks can interact with the interstellar medium (ISM) of host galaxies by ionizing, heating, mixing, and pushing out the surrounding gas, affecting in this way the properties and structure of the hosts (e.g. Fabian 2012; Morganti et al. 2013). CGCG 292−057 is a well known post-merger starforming galaxy (Singh et al. 2015), with two pair of lobes (hereafter, outer and inner), clearly indicative of an intermittent jet activity (Fig. 1; Kozieł-Wierzbowska et al. 2012). The outer lobes are believed to have formed during the previous, long-terminated cycle of the jet activity, while the inner coaxial lobes are considered as a manifestation of a new episode of the enhanced jet production in the system, triggered by a sudden increase in the SMBH accretion rate. The inner structure of CGCG 292−057 is still confined within the host galaxy, making the source an excellent target for a detailed study of the interaction between newly-born radio jets and a post-merger ISM. The spatially resolved ($\sim 0.5''$ at the pointing center) *Chandra* observations can, in principle, help to disentangle the different contributors to the X-ray emission (e.g., reprocessed emission from corona versus shock heating of the ISM due to expanding radio lobes) in CGCG 292−057.

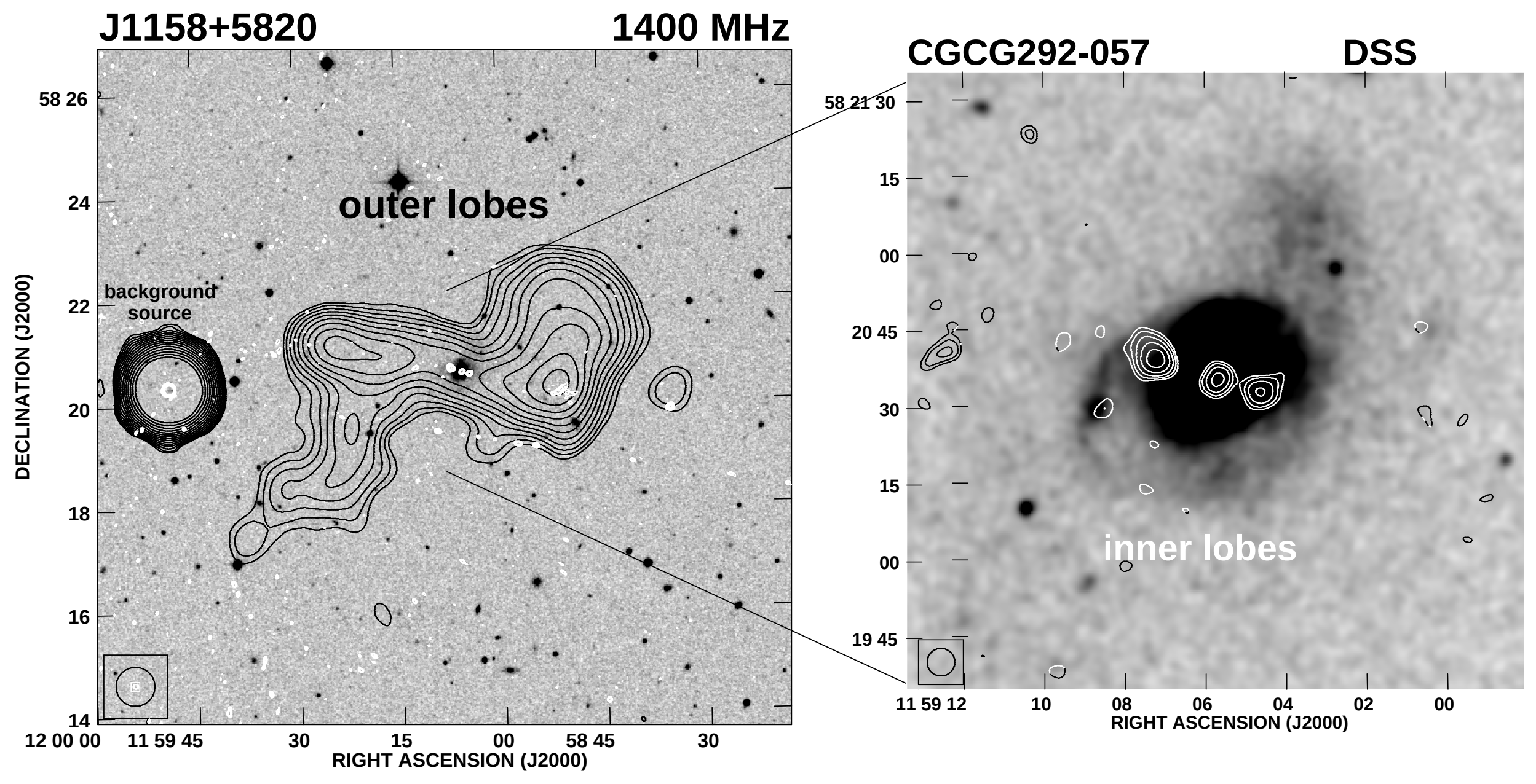

Figure 1: DSS optical image overlayed with 1.4 GHz radio contours from NVSS (black; beam size $\sim 45''$) and FIRST (white; beam size $\sim 5''$). The NVSS map of the target reveals extended radio lobes of the "X-shape morphology".

Chandra X-ray observations, data, and spectral analysis

CGCG 292−057 was imaged with the ACIS instrument onboard *Chandra* X-ray observatory for a total of 93 ks in cycle 16. The data analysis was carried out with CIAO version 4.8 software, CALDB version 4.7.2, using standard procedure. A circular region of $1''.5$ radius centered on a source position was used for spectral extraction while an annular region with inner and outer radii of $1''.8$ and $4''.4$, respectively, was used for local background extraction (Fig. 2). Spectral fitting was carried out with Sherpa using Cstat. The results of our *preliminary* analysis are presented in Table 1 and Figs 3-8.

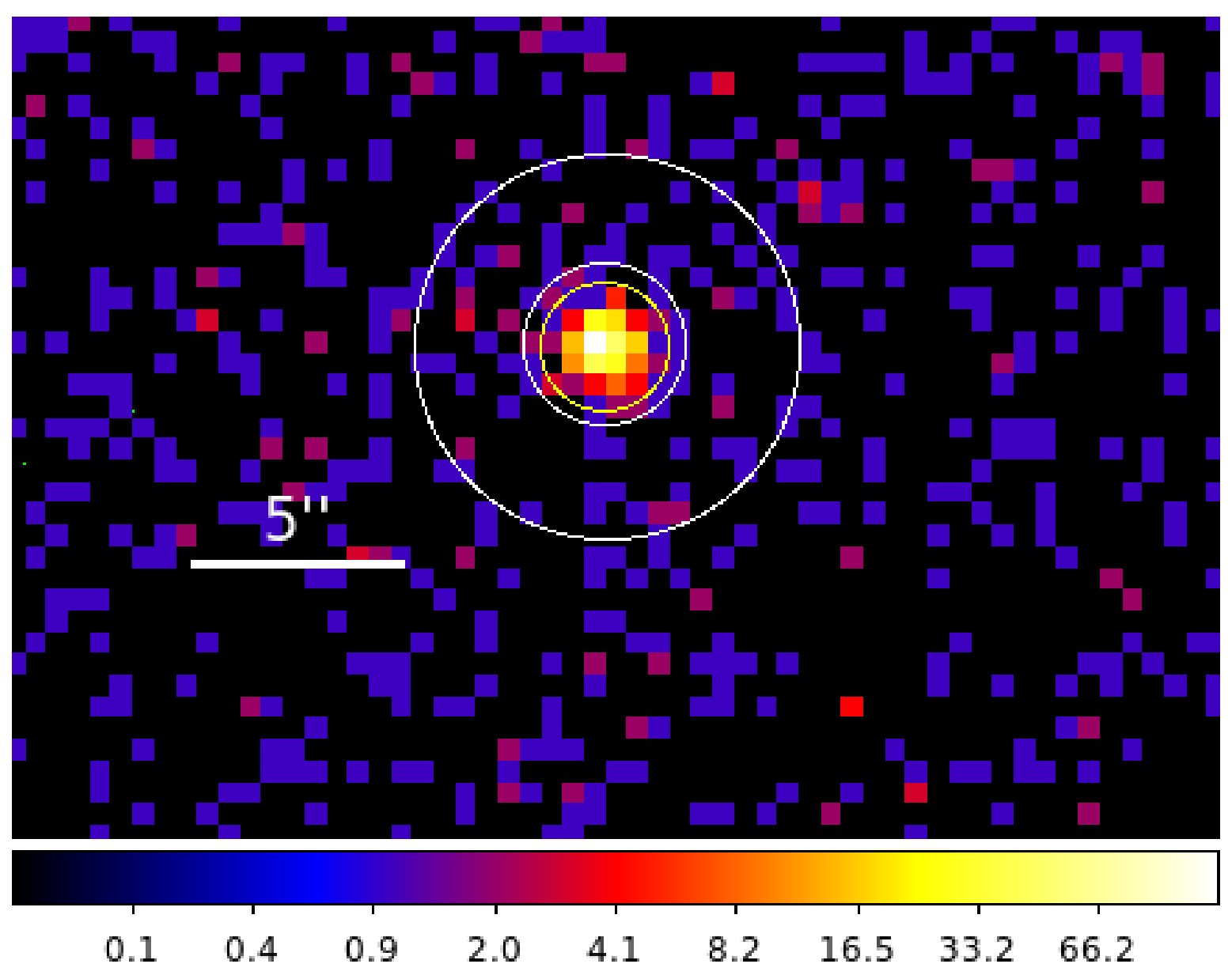

Figure 2: ACIS-S image of CGCG 292−057

Table 1: Spectral models and the model parameters for CGCG 292−057

Model (1)	$N_H^{(1)}$ [$\times 10^{22}$ cm^{-2}] (2)	$N_H^{(2)}$ [$\times 10^{22}$ cm^{-2}] (3)	$kT^{(a)}$ [keV] (4)	$kT^{(b)}$ [keV] (5)	Γ (6)	E_{line} [keV] (7)	EW_{line} [eV] (8)	Cstat/DOF (9)
A	$2.67^{+0.30}_{-0.27}$	—	—	—	$0.88^{+0.04}_{-0.04}$	—	—	669.08/886
B	$2.00^{+0.8}_{-0.45}$	—	—	—	$0.61^{+0.40}_{-0.25}$	$6.7^{+0.9}_{-0.7}$	$209^{+142.2}_{-0.06}$	663.10/884
C	$3.56^{+0.32}_{-0.28}$	—	> 10	—	—	—	—	674.60/886
D	$1.01^{+0.20}_{-0.16}$	$5.37^{+0.46}_{-0.43}$	$0.32^{+0.07}_{-0.24}$	—	$1.56^{+0.23}_{-0.05}$	—	—	636.41/883
E	$1.96^{+0.57}_{-0.52}$	$2.26^{+1.14}_{-1.99}$	> 10	$0.09^{+0.12}_{-0.02}$	—	—	—	636.07/883
F	$0.48^{+0.32}_{-0.07}$	$7.60^{+5.168}_{-2.42}$	—	—	$1.39^{+0.99}_{-0.28}$	$6.9^{+1.2}_{-0.8}$	$22.5^{+15.3}_{-7.2}$	665.11/884

Data within the range 0.5–7.0 keV; modeled using the C-stat.
Fitting optimized with levmar and neldermead methods.
Background not subtracted, but modeled (as unabsorbed power-law) simultaneously with the source.
Galactic absorption modeled with phabs assuming $N_H^{(Gal)} = 0.0143 \times 10^{22}$ cm^{-2}.

Power-law

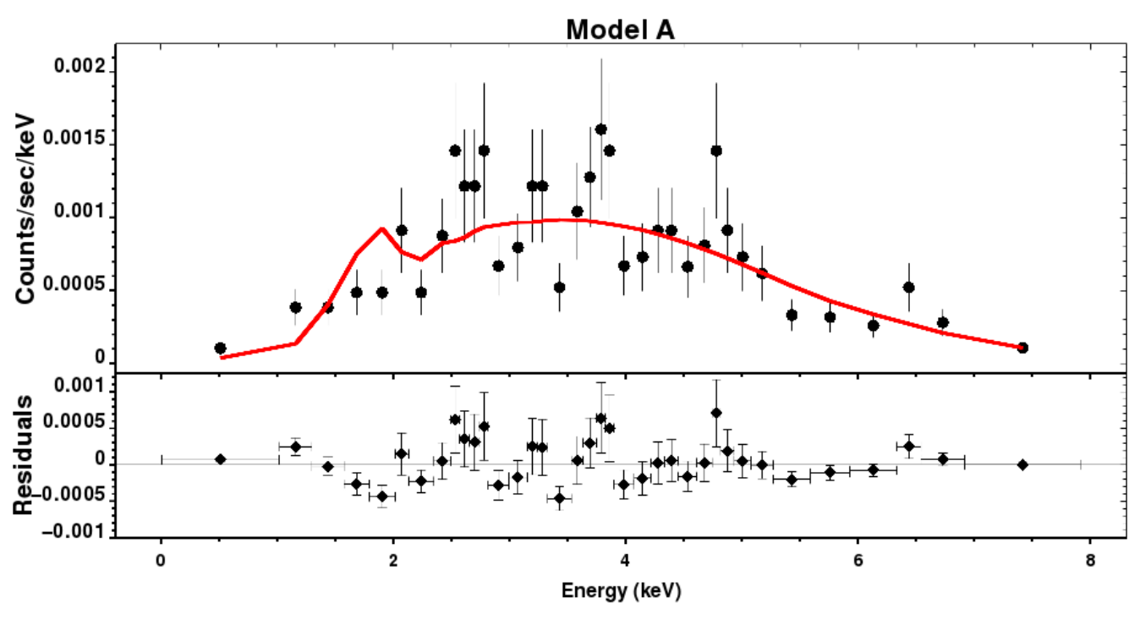

Figure 3: model **A** = zphabs*PL.

Power-law + Gauss

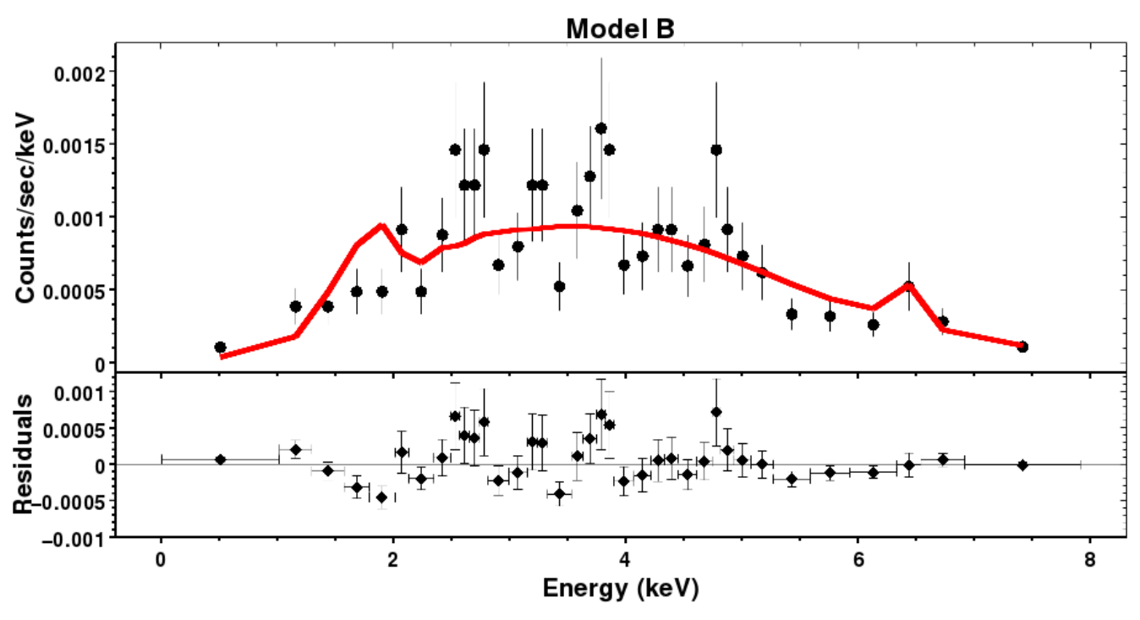

Figure 4: model **B**= zphabs*(PL + xszgauss) with σ=0.1 keV.

APEC

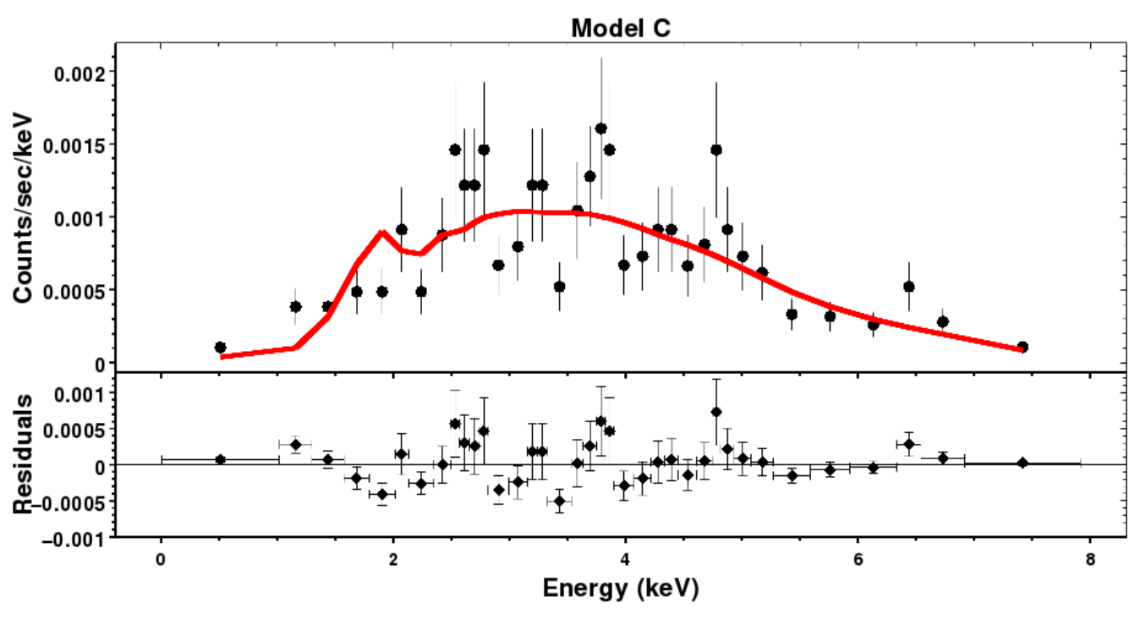

Figure 5: model **C** = zphabs*bvapec with $Z_i = Z_{\odot}$.

APEC+Power-law

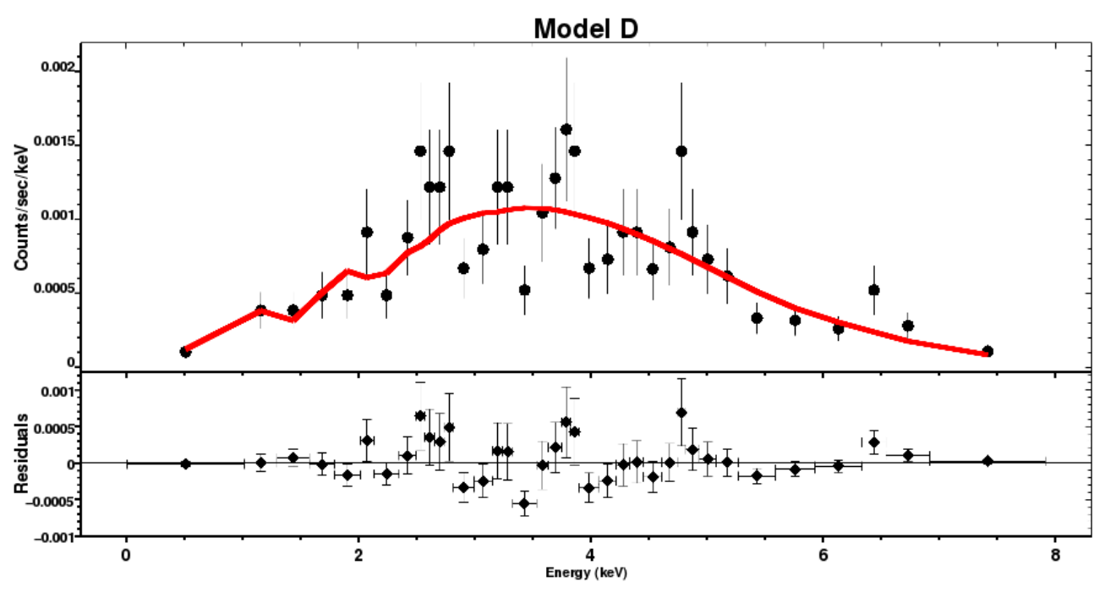

Figure 6: model **D**= zphabs(1)*bvapec+zphabs(2)*PL with $Z_i = Z_{\odot}$.

APEC+APEC

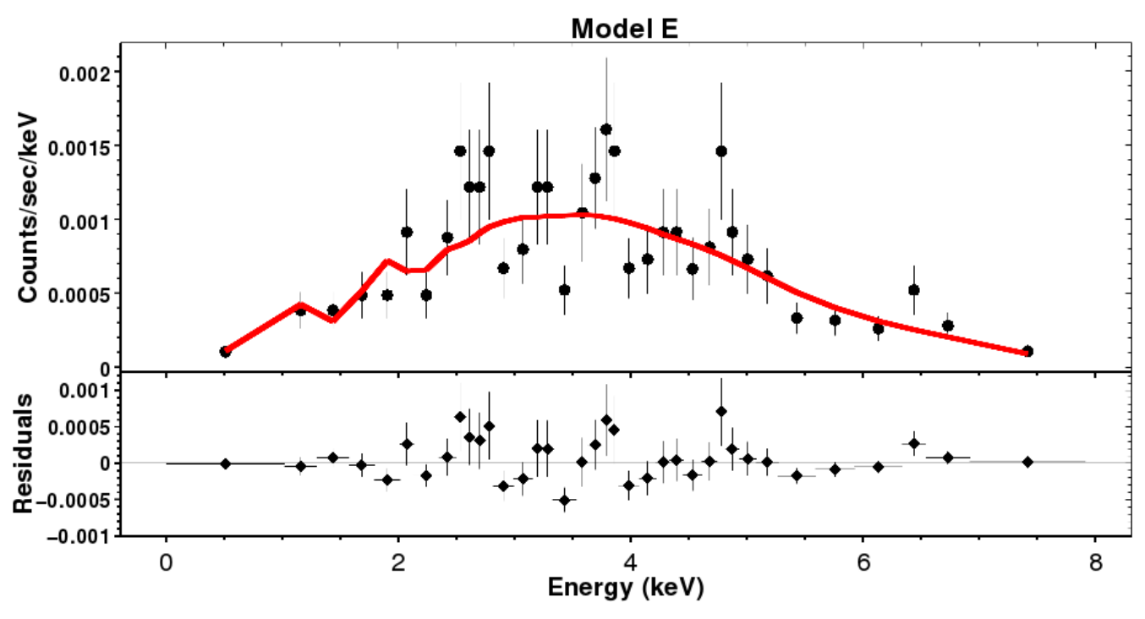

Figure 7: model **E**= zphabs(1)*bvapec(a)+zphabs(2)*bvapec(b) with $Z_i = Z_{\odot}$ except for the iron in bvapec(a) (best fit value: $Z_{Fe} \sim 1.65 \times Z_{\odot}$).

Scattered Power-law + Gauss

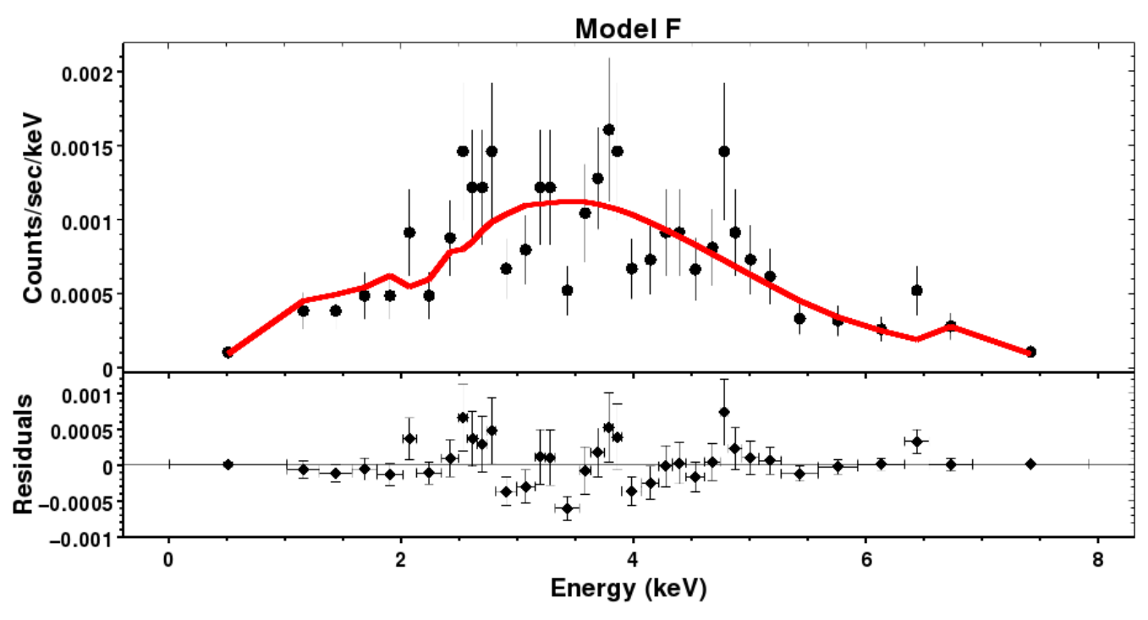

Figure 8: model **F**= zphabs*(1 - fsc)*PL+zphabs2*(fsc * PL + xszgauss) with the scattered PL fraction fsc = 0.03 and $\sigma = 0.1$ keV.

Conclusions

The main conclusions from our preliminary analysis of the X-ray core emission in CGCG 292-057: **(1)** Simple power-law fits imply rather flat photon indices ($\Gamma \leq 1$), which would rule out coronal emission, and instead suggest inner jets/compact lobes as a dominant source of the observed X-ray emission. **(2)** Simple thermal models are not favoured, because of poorly constrained very high gas temperatures implied by the fitting ($kT > 10$ keV); however, hints for a colder gas at soft X-rays ($kT < 1$keV). **(3)** Evidence for the presence of ionized iron line around ~ 6.7 keV. **(4)** Absorption at the source, at the level of $N_H \sim \text{a few} \times 10^{22}$ cm^{-2}, consistent with the ISM of a gas-rich, starforming host galaxy. **(5)** Our fits favour the model consisting of a power-law emission scattered by a hot ionized gas giving rise to the 6.7 keV iron line; for such, the implied power-law photon index $\Gamma > 1$ and the 0.5–7.0 keV luminosity of 5×10^{41} erg/s, consistent with the LINER classification of the active nucleus in CGCG 292-057.

Acknowledgments

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