Fe K and ejecta emission in SNR G15.9+0.2 with XMM-Newton

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Abstract: We present a study of the Galactic supernova remnant SNR G15.9+0.2 with archival XMM-Newton observations. Using EPICs collective power, we report for the first time the detection of Fe K line emission from SNR G15.9+0.2. We measure the line properties (e.g. centroid energy and width) and find evidence for spatial variations. We discuss how SNR G15.9+0.2 fits within the current sample of SNRs with detected Fe K emission and find that it is the core-collapse SNR with the lowest Fe centroid energy. We also present some caveats to the use of Fe K line centroid energies as typing tools for SNRs.

We analyse the emission-line rich X-ray spectra extracted from various regions. The abundances of Mg, Si, S, Ar, and Ca are super-solar and their ratios strongly suggests that the progenitor of SNR G15.9+0.2 was a massive star, strengthening the physical association to a candidate Central Compact Object detected with Chandra.

Using the absorption column density and ambient medium density constrained by the X-ray spectral analysis, we revise the measures of the age and distance to the SNR.

1) Introduction

SNR G15.9+0.2 was discovered in radio by Clark et al. (1973, ICLPA). The SNR is relatively bright in X-rays, as found in Chandra data by Reynolds et al. (2006, hereafter R06). Although 300 SNRs are now known in the Milky Way, SNR G15.9+0.2 is an interesting target for an in-depth analysis with XMM-Newton for several reasons:

- It is likely young (~10^5 yr), as suggested by R06. Adding G15.9 to the sample of SNRs less than 2000 yr would reduce the number of SNR in the observed and expected number of young SNRs.
- It hosts a candidate central compact object (CCO). There are only 7 confirmed CCOs and 7 candidates (including G15.9+0.2).
- In young age and plasma conditions should produce detectable Fe K emission. Yamaguchi et al. (2014) found that the Fe K energy emission is an effective tool to distinguish type II SNRs (Fe K ~ 6.7 keV) and core-collapse SNRs (Fe K ~ 6.95 keV). Fe K emission can be detected, we will obtain independent clues to the origin of the remnant.

II) Observations and X-ray Image

SNR G15.9+0.2 was serendipitously observed twice at off-axis angles of ~15° and ~22°. Exposed exposures times are ~200 ks and ~400 ks. The spectrum of the energy band (200 eV) to its spectrum (600 eV). The detection and background-subtracted images from the two exposures were added, smoothed, and divided by the corresponding (copper) exposure map.

The composite x-ray image of SNR 15.9+0.2 is shown in Fig. 1. The central regions at high energy (3-10 keV) are straight emission, speckled to the SB. The position of the CCO candidate, which is detected with lower signal-to-noise ratio, is marked by a blue circle.

The source exhibits a well-defined shell morphology, with the central and southern-west edges particularly bright. In contrast, the north-western part of the shell is much flatter and soiler. This contrast that was not detected with Chandra complements the X-ray shell. The shell is a slightly overlapping ellipse, with major and minor axes of 6.2 and 5.2. The CCO candidate is offset ~10" from the visual centre.

III) Spectral Analysis

We extracted X-ray spectra from various regions of the remnant, as shown in Fig. 2 (centre). We used the method described in Maggi et al. (2016). We performed fits for the source and background with a mixture of an instrument model, astrophysical, and continuum contributions to the background explicitly modeled. The source spectrum (Fig. 2) is thermal with many strong lines from Mg, Si, S, Ar, and Ca. In severely cut-off at soft energy, indicating a high absorption. The spectra are well fit with an ionized plasma plus Compton model. Abundance must be super-solar to reproduce the strong lines, betraying an ejecta origin.

V) Summary

- SNR G15.9+0.2 exhibits a shell morphology with the brightest regions in the east and south-west, and the faintest and softest to the north-west.
- Analysis of the spectra abundance pattern establishes SNR G15.9+0.2 as a core-collapse SNR, strengthening the physical association with the candidate CCO detected in its interior.
- We report for the first detection of Fe K emission from SNR G15.9+0.2, with signal at both the high and low-temperature end of the line. The overall trend is lowest at the lowest of any core-collapse SNR.
- Comparing the X-ray derived absorption with HI and CO data, we set a conservative lower limit of 5 kpc for the distance towards the source. For such large distances, the SNR is likely older than 2000 years.

4) Results and Discussion

The X-ray emission is significantly detected in G15.9. The "shell region" is the inner ring in best agreement with a Gaussian fit (in the middle panel of Fig. 4, right), and the other Gaussian in 6.4-6.7 keV central (inset below G15.9). We simulated the spectral centroid of a pure-iron lamba in this region (Fig. 5, bottom panel) to illustrate the sharpness of the Fe K line between a k ~ 10^-10 and a low 10^-14, corresponding to an age of 10^-4-5000 yr for an ambient medium density of 1 cm^-3.

The CHD model (8 cm^-3) is fit to SNR, and Fe K is shown to be super-solar to reproduce the strong lines, betraying an ejecta origin.

The spectrum of the X-ray lines from the SNR is shown in Fig. 5 (top panel), using results of Yamaguchi et al. (2014), Maggi et al. (2016). The model G15.9+0.2 as in the CC SNR with the lowest central energy. The distributions of SNR of different type as function of central energy (Fig. 6, middle panel) has a valley at 6.7 keV due to the rapid transition between a roughly 6.4 keV central (iron above the Fe K line) and a 6.6-7 keV central (iron below Fe K line).

We simulated the spectral centroid of a pure-iron lamba in this region (Fig. 5, bottom panel) to illustrate the sharpness of the Fe K line between a k ~ 10^-10 and a low 10^-14, corresponding to an age of 10^-4-5000 yr for an ambient medium density of 1 cm^-3.

The CHD model (8 cm^-3) is fit to SNR, and Fe K is shown to be super-solar to reproduce the strong lines, betraying an ejecta origin.

For a given ejecta mass and expansion energy, the age and (Fe K) radius are constrained by the abundance density G in the region least affected by X-rays (base 100). The CHD models provide a simple way to model the Fe K line profile of SNR, compared to more complex models.

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References

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