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Erratum: XMM–Newton large program on SN1006 – I. Methods and initial results of spatially resolved spectroscopy

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Key words: errata, addenda – acceleration of particles – shock waves – methods: data analysis – cosmic rays – ISM: supernova remnants – X-rays: ISM.

This is an erratum for the paper ‘XMM–Newton large program on SN1006 – I. Methods and initial results of spatially resolved spectroscopy’, published in MNRAS 453, 3953–3974 (2015). There are a few mistakes in the original scripts used to calculate the physical parameters of the hot gas from X-ray spectral analysis with a thermal plasma code, as discussed in Li & Huang (2020). We herein present erratum with the corrected text marked in red.

(i) Fig. 5 of Li et al. (2015) should be updated to Fig. 1 of this erratum. Only the scale of the vertical axis has been changed.

(ii) $n_e$ in table 4 of Li et al. (2015) should be updated to those in Table 1 of this erratum.

(iii) Fig. 9(c) and (d) of Li et al. (2015) should be updated to the left and right panels of Fig. 2 of this erratum, respectively. While the $n_e$ map (right panel) only has the scale of the colour bar changed, the $t_{ion}$ map (left panel) is further slightly changed compared to the original version, assuming a shell thickness of 0.2 shell radius, consistent with other maps in fig. 9 (see section 3.2.2 of the text for details).

(iv) The following sentence in the 2nd from the last paragraph of section 3.2.2 should be changed to:

‘As will be discussed in section 4.2.1, the maximum value of $t_{ion}$ in the SNR interior is typically $\sim 1500$ yr, consistent with the age of SN1006 ($\sim 10^3$ yr based on historical records; Stephenson 2010).’

(v) The following sentences in the last paragraph of section 4.2.1 should be changed to:

‘Except for the bright rim surrounding the SNR, which is artificial due to the low flux density of the surrounding regions, the whole SNR shell appears to have a low and smooth ionization age of $t_{ion} \lesssim 500$ year. In contrast, all the regions in the SNR interior have $t_{ion} > 500$ year, with the highest $t_{ion} \sim 1500$ year, consistent with the age of SN1006 of $\sim 10^3$ year.’

(vi) The following sentences in section 4.2.1 should be changed to:

‘Assuming no CR acceleration in this part so a compression ratio of 4, the ambient ISM density surrounding the “NW shell” should be $n_0 \sim 0.05$ cm$^{-3}$, significantly lower than the values from previous multi-wavelength estimates ($n_0 \sim 0.4$ cm$^{-3}$), which probably indicates the thickness of the SNR shell (0.2 times of the SNR radius) has been overestimated.’

‘The northern part of the ‘SNR Interior’ has a clearly lower density of $n_e \lesssim 0.1$ cm$^{-3}$, but “SNR Interior 03 and 04” may form a shell-like structure behind the SW non-thermal rim, apparently extending the ‘NW Shell’.’

‘The estimated mass of the shocked X-ray emitting plasma is $\sim 5f_1^2 M_0$, where $f$ is the volume filling factor. As discussed in section 3.2.2, the swept up ambient ISM mass is $\sim 5 M_0$. Adding the mass of the shocked ejecta, which is quite uncertain but contribute only a small fraction to the mass budget, we could roughly constrain the volume filling factor to be $f \sim 1$ under the adopted geometric model (section 3.2.2).’

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Figure 1. Derived post-shock electron number density in several outer regions versus the assumed thickness of the thermal X-ray emitting shell (in unit of the outer radius of the shell). Region names are denoted in fig. 7.

Table 1. Average value of parameters for individual regions.

| Region        | Method | $kT$  | $n_e$ | log $n_e$ | O VII K\(\delta - \zeta\) EW | O VII EW | O VIII EW | O solar | Ne solar | Mg solar | Si solar | Fe solar |
|---------------|--------|-------|-------|-----------|--------------------------------|----------|-----------|---------|----------|----------|----------|----------|
| NW Shell      | Average| 2.25  | 0.16  | 9.56      | 0.18, 23.3                      | 0.52, 12.0| 0.33, 51.9| 1.13    | 0.85     | 2.20     | 11.06    | 0.23     |
|               | Fit    | 1.58  | 0.12  | 9.32      | --                               | --       | --        | 0.92    | 0.64     | 1.05     | 4.84     | 0.05     |
| SNR Interior 01| Average| 2.10  | 0.082 | 9.50      | 0.15, 33.1                      | 0.57, 15.3| 0.33, 61.9| 1.77    | 0.49     | 3.81     | 32.38    | 0.18     |
|               | Fit    | 2.22  | 0.076 | 9.37      | --                               | --       | --        | 0.90    | 0.27     | 1.14     | 7.85     | 0.39     |
| SNR Interior 02| Average| 1.63  | 0.104 | 9.51      | 0.21, 38.3                      | 0.64, 17.8| 0.41, 74.9| 2.07    | 0.98     | 5.11     | 30.71    | 0.52     |
|               | Fit    | 1.56  | 0.098 | 9.35      | --                               | --       | --        | 1.05    | 0.44     | 1.69     | 12.36    | 0.83     |
| SNR Interior 03| Average| 2.47  | 0.108 | 9.40      | 0.17, 23.8                      | 0.60, 13.2| 0.36, 51.5| 1.44    | 0.50     | 3.42     | 6.95     | 0.25     |
|               | Fit    | 4.59  | 0.089 | 9.35      | --                               | --       | --        | 1.23    | 0.32     | 1.46     | 5.31     | 0.05     |
| SNR Interior 04| Average| 2.87  | 0.12  | 9.48      | 0.19, 27.0                      | 0.60, 10.6| 0.44, 52.3| 1.26    | 0.36     | 1.97     | 9.83     | 0.40     |
|               | Fit    | 2.30  | 0.11  | 9.40      | --                               | --       | --        | 1.01    | 0.28     | 1.53     | 7.36     | 0.36     |
| SNR Interior 05| Average| 1.30  | 0.13  | 9.65      | 0.21, 34.8                      | 0.43, 10.8| 0.37, 59.3| 1.53    | 0.62     | 3.16     | 20.23    | 0.18     |
|               | Fit    | 1.12  | 0.11  | 9.60      | --                               | --       | --        | 0.80    | 0.35     | 1.26     | 9.31     | 0.28     |
| Dark Belt     | Average| 2.06  | 0.14  | 9.49      | 0.17, 25.1                      | 0.46, 8.99| 0.33, 44.7| 1.06    | 0.39     | 1.10     | 15.33    | 0.73     |
|               | Fit    | 2.54  | 0.10  | 9.41      | --                               | --       | --        | 0.87    | 0.32     | 0.94     | 9.30     | 0.68     |
| Interior Shell 01| Average| 2.41  | 0.17  | 9.58      | 0.22, 35.9                      | 0.40, 8.43| 0.37, 50.5| 1.06    | 0.42     | 0.86     | 9.61     | 0.99     |
|               | Fit    | 2.20  | 0.14  | 9.53      | --                               | --       | --        | 0.97    | 0.38     | 0.82     | 8.86     | 0.96     |
| Interior Shell 02| Average| 2.36  | 0.17  | 9.59      | 0.20, 31.1                      | 0.37, 8.85| 0.37, 53.0| 1.23    | 0.35     | 1.62     | 13.41    | 0.34     |
|               | Fit    | 1.61  | 0.16  | 9.54      | --                               | --       | --        | 0.77    | 0.26     | 1.01     | 8.67     | 0.44     |
| O hole        | Average| 1.70  | 0.16  | 9.61      | 0.16, 31.1                      | 0.28, 5.74| 0.27, 38.7| 0.81    | 0.30     | 0.84     | 13.93    | 1.04     |
|               | Fit    | 1.65  | 0.17  | 9.61      | --                               | --       | --        | 0.43    | 0.21     | 0.47     | 5.48     | 0.63     |
| SE Shell 01   | Average| 1.89  | 0.17  | 9.53      | 0.17, 28.3                      | 0.40, 8.38| 0.37, 47.5| 1.10    | 0.27     | 1.44     | 16.56    | 0.69     |
|               | Fit    | 2.32  | 0.13  | 9.45      | --                               | --       | --        | 0.99    | 0.24     | 1.32     | 12.90    | 0.76     |
| SE Shell 02   | Average| 1.39  | 0.15  | 9.52      | 0.16, 27.5                      | 0.51, 10.0| 0.39, 53.2| 1.33    | 0.34     | 2.65     | 22.06    | 0.28     |
|               | Fit    | 1.07  | 0.13  | 9.58      | --                               | --       | --        | 1.23    | 0.31     | 1.82     | 17.61    | 0.18     |
| SE Shell 03   | Average| 1.65  | 0.101 | 9.54      | 0.22, 27.4                      | 0.64, 9.63| 0.60, 55.0| 1.45    | 0.28     | 3.21     | 15.85    | 0.10     |
|               | Fit    | 1.66  | 0.095 | 9.48      | --                               | --       | --        | 1.15    | 0.22     | 2.24     | 11.52    | 0.05     |

Notes. Average parameters of large regions enclosing some interesting features as denoted in fig. 7. For each region, the average parameters are calculated in two ways: a direct average based on the parameter images (“Average”) and the parameters obtained by fitting the MOS-1+MOS-2+PN spectra extracted from each region (e.g. fig. 8) using the model described in section 3.2.1 (“Fit”). For the former method, $kT$, log $n_e$, and $n_e$ are calculated from figs 9(a), (b), and (d). O VII, O VIII, and O VII K\(\delta - \zeta\) EWs are calculated from the linear EW maps presented in figs 12(a)–(c) (former numbers) and the 2D Spec EW maps presented in figs 12(d)–(f) (latter numbers). O, Ne, Mg, Si, and Fe abundances are calculated from the abundance maps in figs 12(g), 13(c), 14(c), 15(c) and 17(b).
Figure 2. Updated version of figs 9(c) and (d) of Li et al. (2015).