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High-resolution X-ray spectroscopy of the Interstellar Medium

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Abstract. We present recent results on high-resolution X-ray absorption measurements of the interstellar medium. We show the results from our recent analysis of the absorption towards the Crab nebula, and discuss improvements in the absorption edge structure that have to be taken into account.

Keywords: Interstellar medium; X-rays; spectroscopy; oxygen; K-edge

PACS: 32.30.Rj, 98.38.Am, 98.38.Bn

THE RGS SPECTRUM OF THE CRAB NEBULA

The RGS spectrum of the Crab nebula has been analysed by Kaastra et al. [6]. A fit has been made using a power-law spectrum (with correction factors, see paper) with the interstellar absorption taken from the hot and slab models in SPEX (<http://www.sron.nl/spex>). Four regions have been excluded from the fit: below 7 Å, because of uncertainties in the RGS redistribution function; above 30 Å, because due to the extended nature of Crab, the lower threshold for PI selection fall below the cut-off level of the CCDs. The regions around the Fe-L and O-K edges were omitted because of the complex edge structure (our model only takes the atomic Fe I and O I into account).

TABLE 1. Interstellar abundances towards the Crab nebula

Element	N	O	Ne	Mg	Fe
Abundance	1.01 ± 0.09	1.030 ± 0.016	1.72 ± 0.11	0.85 ± 0.21	0.78 ± 0.05

From this analysis, it is possible to derive the abundances of some key elements. We find a neutral hydrogen column of $3.21 \pm 0.02 \times 10^{25} \text{ m}^{-2}$ (compare to $3.0 \pm 0.5 \times 10^{25}$ from Ly α absorption, [8]). Table 1 shows the abundances, relative to the proto-solar abundances of [7]. While most elements agree well with these proto-solar values, the Ne/O number ratio is 0.26 ± 0.02 , enhanced with respect to the proto-solar value of 0.15, but not as high (0.41) as suggested by [4]. Our values are in excellent agreement with recent measurements of the Orion Nebula (0.24 ± 0.05), [5] and B-stars in that nebula (0.26 ± 0.07), [3].

We also studied details near the main absorption edges. We obtain a good fit for Ne, but find deviations for Fe and O. This is due to the presence of dust (our model used

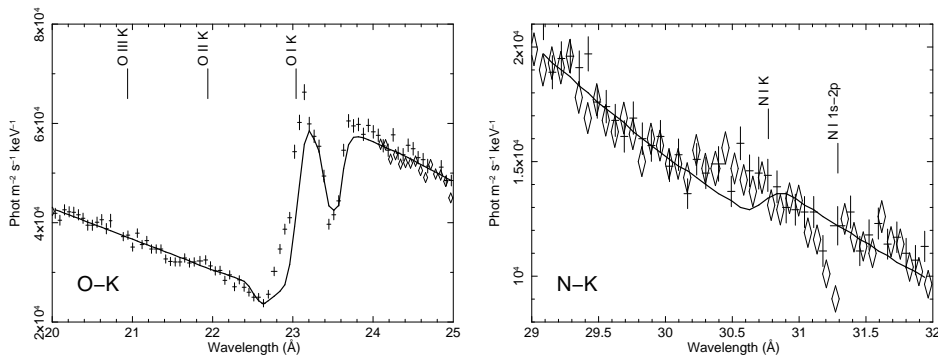


FIGURE 1. Detail of the RGS spectrum of Crab near the O I and N I edges. Crosses and diamonds correspond to the two RGS detectors. The model only accounts for atomic O and N. Differences are due to the presence of molecules.

only atomic Fe and O). Comparison with measured dust features [1, 2] suggests ferric iron may contribute significantly; but more modelling is needed.

Nitrogen edge: The Crab spectrum above shows some evidence for the presence of the N I 1s-2p absorption line, and also that the K-edge is off by $0.5 - 0.9 \text{ \AA}$! This is confirmed and seen more clearly in the RGS spectrum of Sco X-1 (de Vries et al., in prep.). The position of the nitrogen edge and line in Sco X-1, agrees extremely well with the single lab measurement available for that atom. Improvements based on these findings (and similar improvements for O I) are now incorporated in SPEX.

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