The peculiar X-ray properties of the low-redshift quasar MR 2251-178 and its environment: some surprises

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Abstract. MR 2251-178 was the first quasar initially discovered in X-rays, and the first one found to host a warm absorber. Despite its many outstanding multi-wavelength properties, MR 2251-178 has not yet been studied in detail with recent X-ray observatories. Here, we present results from an analysis of the X-ray spectral, temporal, and spatial properties of this source and its environment based on deep observations carried out with the X-ray satellite ROSAT. The derived mean soft X-ray luminosity of MR 2251-178, \( L_{\text{soft}} \approx 10^{45} \) erg/s, places the quasar among the most X-ray luminous AGN in the local universe.

1. Introduction

MR 2251-178 at redshift \( z=0.064 \) was the first quasar initially discovered by X-ray observations (Ricker et al. 1978), and the first one found to host an ionized absorber (Halpern 1984). The quasar turned out to be outstanding in many respects. It has a high ratio of \( L_x/L_{\text{opt}} \), is surrounded by the largest quasar emission line nebula known, and is located in the outskirts of a cluster of galaxies (e.g., Bergeron et al. 1983). Our analysis of the ROSAT PSPC observations of this source and its environment revealed a number of surprises, summarized below.

2. X-ray results: some surprises

Results presented here are based on the analysis of two ROSAT PSPC observations of MR 2251-178, carried out in Nov. 1990 (all-sky survey) and Nov. 1993 (18.3 ksec duration). Details of the data analysis and the discussion of results is presented by Komossa (2001). The following results were obtained:

X-ray variability. There is evidence for an X-ray flaring event with variability by a factor ~2 within 10 ksec during the ROSAT all-sky survey; rarely observed in such a luminous source, but similar to PDS 456 (Reeves et al. 2000) and PKS 0558-504 (Wang et al. 2001).

The source was a factor ~3 brighter during the later pointed ROSAT observation. The mean observed soft X-ray luminosity at that epoch, \( L_{(0.1-2.4)\text{keV}} \approx 10^{45} \) erg/s, places the quasar among the most X-ray luminous AGN in the local universe.
X-ray spectrum. Remarkably, we do not detect any excess X-ray cold absorption expected to originate from the giant [OIII] gas nebula surrounding MR 2251-178. This finding excludes the presence of a huge HI extent of the HII emission line gas (along the line-of-sight), and constrains some formation scenarios (e.g., Shopbell et al. 2000) of the gas nebula.

On the other hand, we do find that the X-ray spectrum is modified by lots of amounts of gas along the line of sight - but this material is highly ionized. As indicated by some, but not all, earlier X-ray observations of MR2251-178, a single powerlaw does not provide an acceptable spectral fit ($\chi^2_{\text{red}} = 5.4$). The presence of an ionized absorber markedly improves the fit. We find an ionization parameter $\log U = 0.5$ and a column density $\log N_{\text{w}} = 22.6$ of the ionized material (see Komossa 1999 for a general review on warm absorbers). The presence of highly ionized material along the line of sight is consistent with the detection of absorption lines in the UV spectrum of MR 2251-178 (Monier et al. 2001). Our best-fit warm-absorber model still leaves some residuals at the low-energy part of the spectrum, suggesting the presence of a very soft excess.

Surrounding sources. None of the other optically bright member galaxies of the cluster to which MR 2251-178 belongs, are detected in X-rays. However, east of the quasar there is a significant excess of X-ray sources (a factor of 4 compared to the log N – log S distribution of Hasinger et al. 1994), several of them without optical counterparts on the UK Schmidt plates.

Intra-cluster gas emission: The X-ray emission from the intra-cluster medium is weak or absent. We derive an upper limit on the X-ray luminosity of $L_x \leq 2 \times 10^{42}$ erg/s from the direction of the optical center of the cluster, weaker than other clusters of comparable richness. This may indicate that what appears as one single cluster could be just a chance projection of several poorer clusters or groups. Alternatively, the cluster X-ray emission might be off-set from the optical center.

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