

Is SNR 0506-68 overionised?

S. Broersen, J. Vink, J. Kaastra and J. Raymond

A&A submitted

s.broersen@astro-uu.nl



#### Introduction

Using the Reflection Grating Spectrometer (RGS) on board the XMM-Newton satellite, we observed the mature supernova remnant SNR 0506-68 which is situated in the Large Magellanic Cloud. This remnant, which is the result of a core collapse supernova explosion, shows several signs of overionisation, which suggests that the remnant is cooling rapidly. This overionisation has been observed in multiple SNRs, most particularly in remnants of the mixed-morphology type.

# The evidence

## Cooling model

Remarkably, the total spectrum of SNR 0506-68 is best-fit by a cooling model. This is an inverted non-ionisation equilibrium (NEI) model in which the initial temperature is higher than the final temperature. The figure below, which shows part of the EPIC MOS spectrum, shows that the cooling model (labelled "Model B") significantly decreases the C-statistic, among others due to presence of the Fe XVII recombination edge at 1.26 keV.



#### Line ratios

High resolution spectra of SNRs, obtained with e.g. the RGS, hold detailed information about the ionisation state and temperature of the plasma. One important plasma diagnostic is the so-called G-ratio of OVII. The figure below shows the OVII triplet of the 2000 and 2002 observation of SNR 0506-68. The G-ratio of the 2002 observation of SNR 0506-68 equals 1.13±0.09, indicating an overionised state of the OVII plasma, while the 2000 observation suggests it is in ionisation equilibrium.





### **Cooling rates**

The above figure shows a comparison of the OVII recombination timescale  $\tau_{rec}$  to the total cooling timescale  $\tau_{cool}$ , for different densities.  $\tau_{cool}$  is calculated by adding the adiabatic and radiative cooling timescales. When the curve is above 1, cooling rate exceeds the recombination rate, causing overionisation. This is more likely to happen at high temperatures and at lower densities. As is clear from the figure, overionisation for OVII can occur over a large range of temperatures and densities. However, a shocked plasma starts out underionised, so a remnant needs to be sufficiently mature for overionisation to occur. For SNR 0506-68, the cooling rate is about equal to the recombination rate

## he verdict

To summarize:

- the best-fit models to both the RGS and MOS spectra are cooling models
- the G-ratio of 2002 suggests that the OVII plasma is overionised
- an adiabatically expanding plasma can reach an overionised state at a large range of temperatures and densities.

The overall spectral modelling gives statistically significant evidence that the remnant is indeed overionised. The detailed line spectroscopy, however, gives no conclusive confirmation.