ISO'S VIEW OF SS 433 JET INTERACTIONS WITH THE INTERSTELLAR MEDIUM

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Abstract

SS 433 is a jet emitting X-ray binary surrounded by the W50 radio nebula. The SS 433/W50 system is an excellent laboratory for studying relativistic jet interaction with the surrounding interstellar medium. In this context, part of the W50 nebula has been mapped with ISOCAM at 15 µm. I will show the results particularly on the W50 west lobe, and on 2 emitting zones detected with IRAS who have also been observed in millimetre wavelength (CO(1-0) transition), and for one of them by spectroscopy with ISOLWS and ISOSWS between 2 and 200 µm.

1 Introduction

SS 433 is an X-ray binary probably composed of a high-mass star and a neutron star, with a 13 days binary period. The system emits relativistic (0.26 c) jets showing a 162.5 days precession observed at subarcsecond scale in radio till \( \sim 10^{17} \) cm from SS 433. At large scale these jets are observed in X-ray beginning at \( \sim 15' \) (14 pc) from SS 433, and they are responsible for the unusual elongated shape of W50 (\( \sim 1° \times 2° \)), the possible supernova remnant radio nebula around SS 433. We mapped at 15 µm with ISOCAM\(^2\), the infrared camera on board of the Infrared Space Observatory (ISO), a small part of the eastern lobe where an X-ray knot lies, the north-east quarter of the central circular part of W50, and nearly all the western lobe.

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2 The ISOCAM data presented in this paper was analysed using “CIA”, a joint development by the ESA Astrophysics Division and the ISOCAM Consortium. The ISOCAM Consortium is led by the ISOCAM PI, C. Cesarsky.
2 Eastern lobe observations

There is no particular 15 $\mu$m emission in the observed east parts of W50, and no correlation was found between the IR images and the corresponding ones in X-ray (with ROSAT and ASCA) and radio (at 20 cm), both for the central field and for the X-ray knot area. This is not surprising as the central part of W50 must have been swept away from its material by the supernova explosion, and the eastern lobe is described as faint in radio and less dense than the western one by Dubner et al. (1998). The X-ray knot, the brightest knot seen by ROSAT at 0.1–2.4 keV and called “c2” by Safi-Harb and Ögelman (1997), is coincident with an optical filament and is probably due to shocks with the supernova remnant (Safi-Harb and Petre 1999), but it is not visible at 15 $\mu$m with ISOCAM sensitivity.

3 Western lobe observations

The western lobe map at 14–16 $\mu$m (see Fig. 1) shows two main emitting regions aligned with the relativistic jet direction predicted by the kinematic model (Margon 1984 and references there in) based on the radio compact jets observations, and seen at large scale in X-ray (see Fig. 2). The western X-ray lobe was observed with ROSAT (0.1–2.4 keV) by Brinkmann et al. (1996), and with ROSAT and ASCA (0.5–9 keV) by Safi-Harb and Ögelman (1997) who could not conclude if its emission is thermal or not. It is only partly coincident with the nearest ISOCAM emission region from SS 433 (see Fig. 2). Its soft X-ray emission fades and its hard X-ray one disappears where the second emitting region begins. This farest IR emitting region from SS 433 coincides with the radio “ear” emission at the western edge of W50.

![Fig. 1. Left: location of the ISOCAM map in the W50 western lobe; W50 is shown at 20 cm in contours. Right: ISOCAM 14–16 $\mu$m image with a $-\sigma$ to $+2\sigma$ scale around the median flux value, and with a 6" × 6" per pixel field of view. SS 433 is the point source at the left edge of this image as indicated.](image-url)

These two ISOCAM emitting regions correspond to IR knots observed with IRAS at 12, 25, 60 and 100 $\mu$m by Band (1987), and named “knot 2” for the
ISO’s view of W50

Fig. 2. Superimposition of the western lobe X-ray ASCA emission in contours with the ISOCAM 15 μm image, showing that the IR emissions lies along the same axis as the X-ray lobe.

The nearest region from SS 433 and “knot 3” for the farest (see Fig. 3). The 6′′ × 6′′ per pixel ISOCAM spatial resolution enables to reveal their structure for the first time. The 15 μm knots emission is diffuse with punctual or not “hot spots”.

No emission from the CO(1-0) transition line at 115 GHz is observed between SS 433 and “knot 2”, as in IR at 15 μm in the ISOCAM image. Two CO(1-0) emitting regions are coincident with the two IRAS knots as shown in Fig. 3 (data kindly provided by Durouchoux, private communication). Their Doppler velocity is ~ 50 km.s⁻¹ which corresponds to the same distance as W50. Their shapes are similar to the ISOCAM shapes, so the IR and millimetre emissions are unlikely coincident by chance but must be physically linked. So the observed ISOCAM emissions are due to regions lying inside W50.

“Knot 3” was observed with ISOSWS and ISOLWS, respectively the Short and Long-Wavelength Spectrometers on board of the ISO satellite. SWS observation consists in several small wavelength-range spectra between 2 and 40 μm, which do not reveal any emission lines when the flux is not under the detection limit. The LWS continuum spectrum, between 40 and 200 μm, is consistent above 60 μm with optically thin or optically thick thermal emission from dust at ~ 30 K. Below 60 μm, the spectrum is flatter due to an additional component thermal or not.

Interpretation of the two knots emission is uncertain due to the lack of observations in near and mid-infrared wavelengths where it could be thermal or not. The observed IR emission could be due to dust regions heated by young stars still embedded in their molecular birth clouds. These regions could be crossed by the
Fig. 3. Superimposition of the CO(1–0) emitting line contours at 115 GHz (2.6 mm) with ISOCAM 15 μm image. The IRAS knots locations are indicated. “knot 2” and “knot 3” are emitting regions in both IR and millimetre with similar shapes. “knot 6” lies just at the border of W50 and was not observed at millimetre wavelengths.

relativistic western jet, which then could heat the dust with collisions between its energetic particles and the denser material of these clouds. Otherwise, the mid-infrared emission could be of synchrotron nature, coming from the very energetic particles of the jet, reaccelerated by shocks with the western lobe denser medium. These particles would lose their energy by synchrotron radiation in X-ray, then in IR as they travel further from SS 433.

More multi-wavelength observations, are planned: in near-infrared in order to reveal shocked regions or young star regions, in millimetre in order to map the whole western lobe and to know the molecular clouds limits, in X-ray with XMM-Newton to distinguish between thermal and non thermal emission and thanks to the better spatial resolution to compare precisely the X-ray images with the other wavelengths ones. These new data will help to better understand the emission mechanisms from these large scale relativistic jets, and they could also help understand extragalactic jets from AGN as there are larger scales replica.

References

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