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AGB CIRCUMSTELLAR ENVIRONMENTS PROBED THROUGH THE 21 CM ATOMIC HYDROGEN LINE EMISSION. A PROGRAMME FOR THE SKA ?

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Abstract. Red giant stars are responsible for 70% of the recycling of stellar matter in the local interstellar medium (ISM) through mass loss, mainly along the AGB sequence. Most of the matter in circumstellar shells is hydrogen in atomic (or molecular form). However, up to now, atomic hydrogen has remained largely undetected due to the weakness of its emission, the merging of circumstellar matter with the ambient ISM and the confusion from foreground and background interstellar hydrogen along the same line of sight. With the upgraded Nançay Radiotelescope, we have started a new search for H I at 21 cm towards AGB stars and post-AGBs, including PNs. We illustrate our results on one case, EP Aqr, which shows that the contamination by interstellar emission must be treated with great care and discuss the prospects with the SKA. In order to sort out the genuine circumstellar H I emission from the interstellar one, it is necessary to map large areas of the sky (at all angular scales from sub-arcsec to degrees) with high spectral resolution, high sensitivity and a large dynamical range.

1 Introduction

Most of the matter in circumstellar shells (CS) around red giants should be in hydrogen, atomic or molecular. For stellar effective temperature larger than 2500 K, hydrogen is expected to be mainly atomic (Glassgold & Huggins 1983). Otherwise molecular hydrogen should be photo-dissociated within the shells at distances $\sim 10^{16} - 10^{17}$ cm from the central star depending on the mass loss rate, expansion velocity, etc. The H I line at 21 cm should therefore be a useful probe of CSs in all cases.

However, in most galactic directions, the spectrum is dominated by the interstellar emission. In Fig. 1 (left panel) we show the 21 cm spectrum obtained with the Nançay Radiotelescope (NRT) in the direction of the semi-regular variable EP Aqr ($T_{\rm eff}\sim$ 3200 K). The horizontal bar represents the velocity extent ($V_{\rm lsr}\pm V_{\rm exp}$) expected from the CO (1-0) and (2-1) lines obtained with the IRAM 30-m by Winters et al. (2003).

Although the source is located away from the galactic plane ($b^{\rm II} = -39°$), the H I emission in that direction is dominated by local interstellar emission around 0 $\rm km\,s^{-1}$ (LSR). Fortunately the signal from the source is offset with respect to the peak of H I interstellar emission. Nevertheless the source signal is much weaker and a careful position-switch procedure adapted to single-dish observations of extended sources with low surface brightness was necessary to map the emission from EP Aqr with the NRT (Fig. 1, right panel; Le Bertre & Gérard 2004).

The emission is extended ($\sim 1°$) and shows complex spatial and dynamic structures. We note in particular that the spectral profile varies radially and azimuthally.

With the NRT, we have now detected about 20 H I sources associated with red giants (Gérard & Le Bertre 2006). The emissions are generally spatially resolved, i.e. larger than the NRT beam, $4'$ in the East-West direction, for sources up to 1 kpc. Such informations on the neutral gas kinematics at large distance from the central star come at the right time as new satellites (Spitzer, Akari) start mapping the dust distribution with high sensitivity in many AGB sources (Ueta et al. 2006; Wareing et al. 2006).

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2 Prospects, in particular with the SKA

The confusion by interstellar H I is a serious problem, even at high galactic latitude and large radial (LSR) velocity. In order to isolate CS emission, one needs to map H I over a field larger than the source. Therefore a field of view of $\sim 1^\circ$ is necessary if one wants to image the nearest sources that are obviously those for which the most detailed informations can be obtained.

We already found very extended H I emission around AGB stars ($\sim$ 1 pc). The envelopes may not be spherical due to the effect of the mass loss phenomenon itself, or of the ISM ram pressure. To study these effects one needs spatial, as well as velocity (≤ 1 km s^{-1}), resolution. Thanks to the high spectral resolution provided by the heterodyne technique, the H I line can give unique informations on the kinematics in the external parts of CSs, where they interact with the ISM, and on the past history of mass loss.

With a large field of view, high spectral resolution and high sensitivity, together with a large dynamical range (to correct for the ISM background), and high spatial resolution, the new generation of radiotelescopes, ATA (Allen Telescope Array), E-VLA (Expanded VLA), and, above all, SKA (Square Kilometer Array), will be ideally suited to study the mass loss history of AGB stars within the Galaxy, and the interaction of circumstellar outflows with the surrounding ISM. AGB CSs that are in the Magellanic Clouds are expected to be a few arcsec in H I and thus might even be within reach of the SKA !

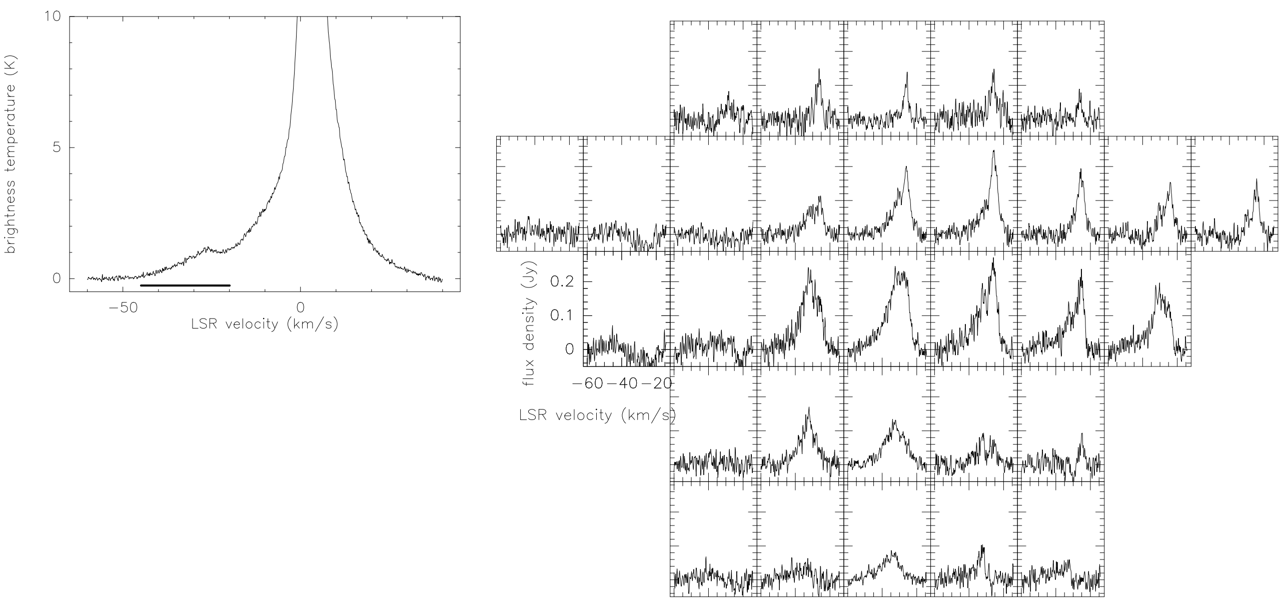

Fig. 1. Left panel: On-source spectrum obtained in the frequency-switch mode in the direction of EP Aqr ($l^{II} = 54^\circ$, $b^{II} = -39^\circ$; $V_{lsr} = -33$ km s^{-1}). The emission comes essentially from interstellar atomic hydrogen on the line of sight. **Right panel**: Map of the 21 cm H I emission from the EP Aqr circumstellar envelope. The central position in the second row from the top corresponds to the star; the steps are 4′ in right ascension and 11′ in declination. North is up and East to the left. No signal was detected in the rows at 22′ North and 44′ South of EP Aqr.

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