The ALMA view on W Aquilae:
Observations and Modelling of Molecules in the Circumstellar Envelope

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Introduction

Asymptotic Giant Branch (AGB) stars suffer strong mass-loss and enrich the ISM with heavy elements. Their C/O ratio classifies them as M, S or C-type, where S-type marks the transition from O- to C-rich chemistry. They are perfect targets to study the varying chemical composition of evolved stars.

W Aquilae (W Aql) is an S-type AGB star with a binary companion at a distance of 0.46" [1] (190 AU for D=395 pc; [2]). We present new ALMA observations and radiative transfer modelling results for several spectral lines observed in the circumstellar envelope (CSE) of W Aql. The extent of the line emission is analyzed and modelled, improving abundance estimates, stellar parameters, mass-loss rates and properties of the CSE.

Methods

ALMA Band 7 mosaic data of the whole CSE around W Aql were taken in March & April 2014, and reduced, imaged and analysed with the Common Astronomy Software Application (CASA). Building on previous work of Danilovich et al. (2014) [3], accelerated lambda iteration (ALI) radiative transfer modelling of the observed spectral lines was carried out, including the new data.

ALMA Data Results

8 molecular lines, consisting of 4 different species, different isotopes and vibrationally excited states, were observed in the present-day mass-loss of W Aql. Images of the lines in the vibrational ground state at stellar velocity (-23 km/s) are given in Figure 1, spectra in Figure 2.

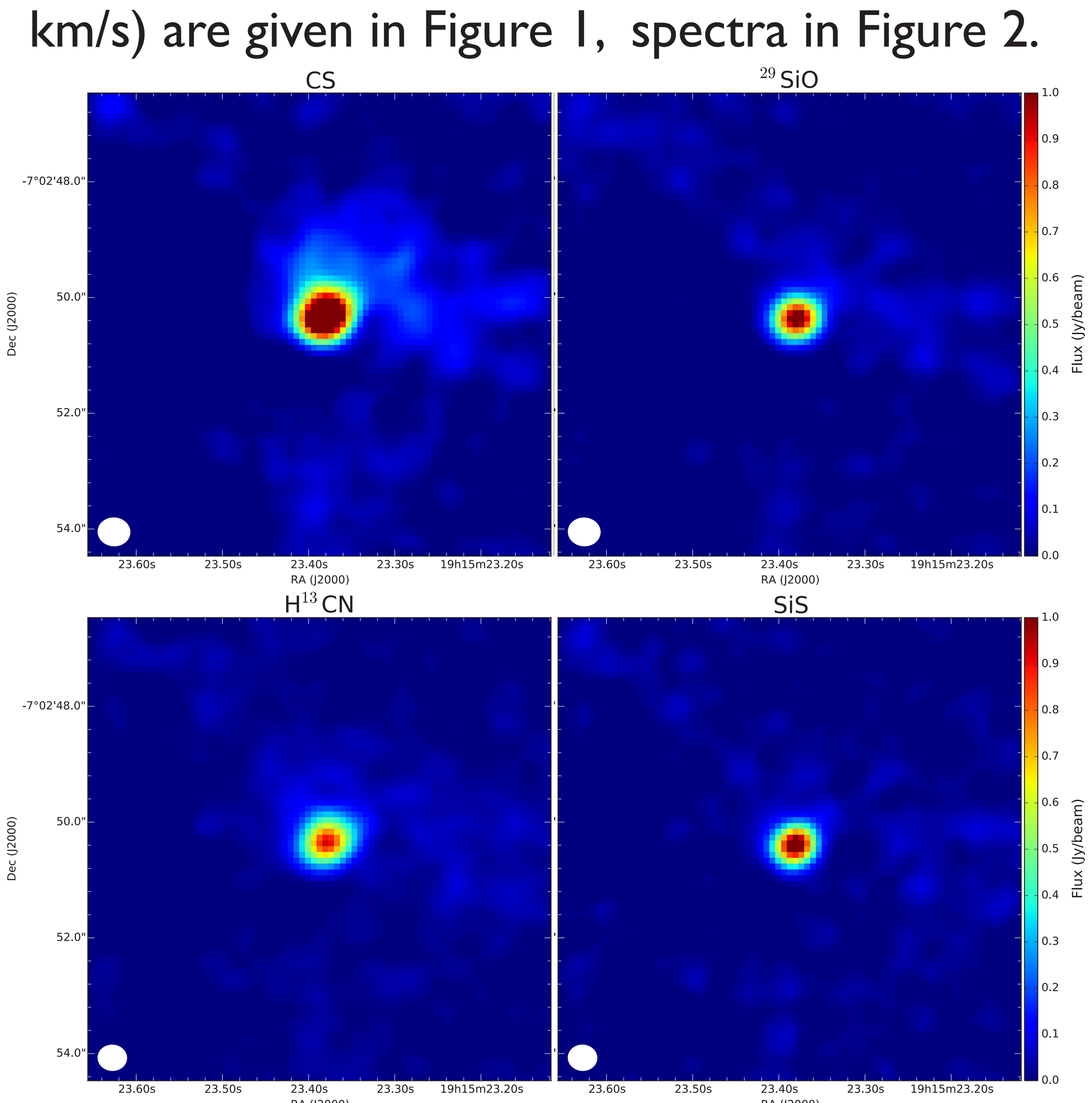

Figure 1: ALMA observations of the molecular emission of CS(7-6), ^{29}SiO(8-7), $H^{13}CN$(4-3) and SiS(19-18) around W Aql (ALMA beam given in lower left corner).

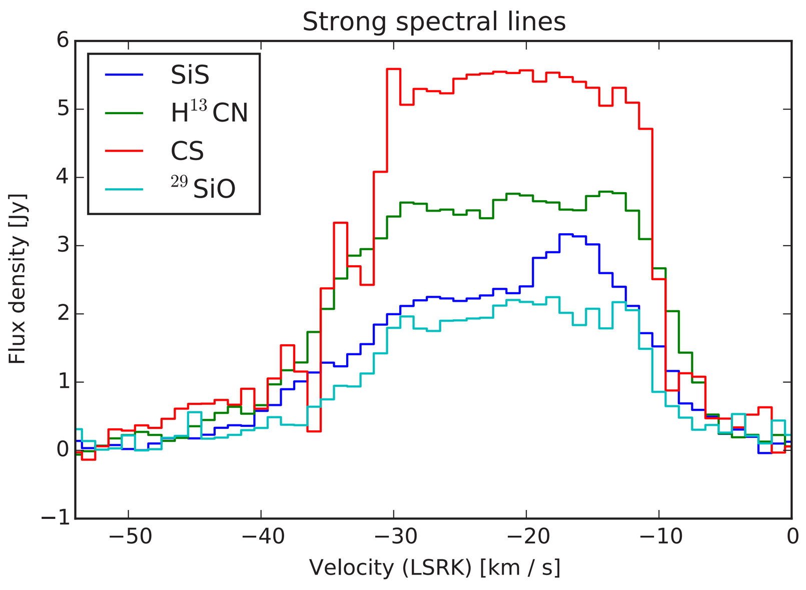

Figure 2: Spectra of strong molecular lines presented in Figure 1; extracted with centered, 4 " circular beam.

Modelling Results

The results of radiative transfer modelling of the 4 strong molecular lines in ground vibrational state are presented in Figures 3 to 6. Radial intensity profiles and spectral line models are shown for the ALMA data in comparison with HIFI, IRAM or APEX spectral line data. Abundances and model-dependent parameters are given in Table 1. For this preliminary analysis, the radial profiles were extracted in North direction, covering the most extended parts of emission.

Model parameters W Aquilae		Molecule	Abundance f_0	e-folding radius R_e [cm]
Distance	395 pc	CS	9.00×10^{-7}	9.50×10^{15}
Effective Temperature	2300 K	SiS	3.10×10^{-6}	1.00×10^{15}
Dust/gas mass ratio	2×10^{-3}	$H^{13}CN$	1.50×10^{-7}	4.00×10^{15}
Luminosity	7500 $L_\odot$	^{29}SiO	2.40×10^{-7}	2.00×10^{15}
Stellar mass	1 $M_\odot$			
Gas expansion velocity	16.5 km/s			

Table 1: Radiative transfer model parameters and resulting abundances for the observed molecules.

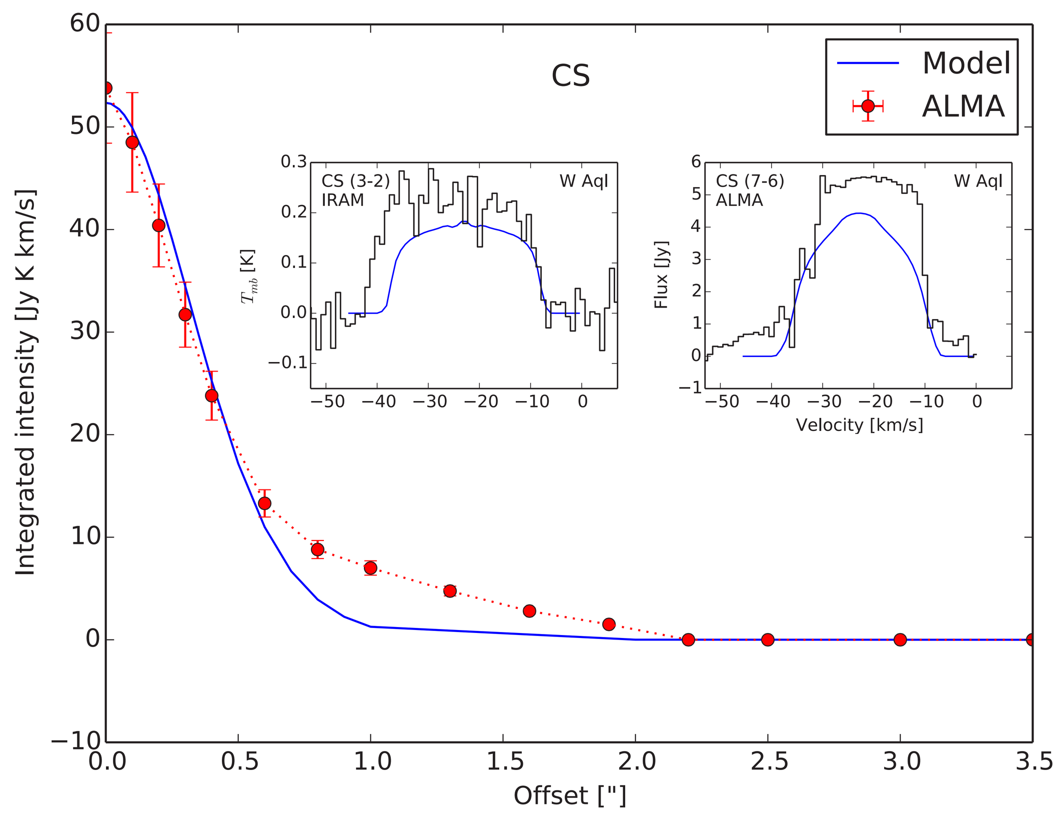

Figure 3: Modelling results for CS(7-6); Radial integrated intensity profile and modelled spectral lines in comparison with IRAM and ALMA data.

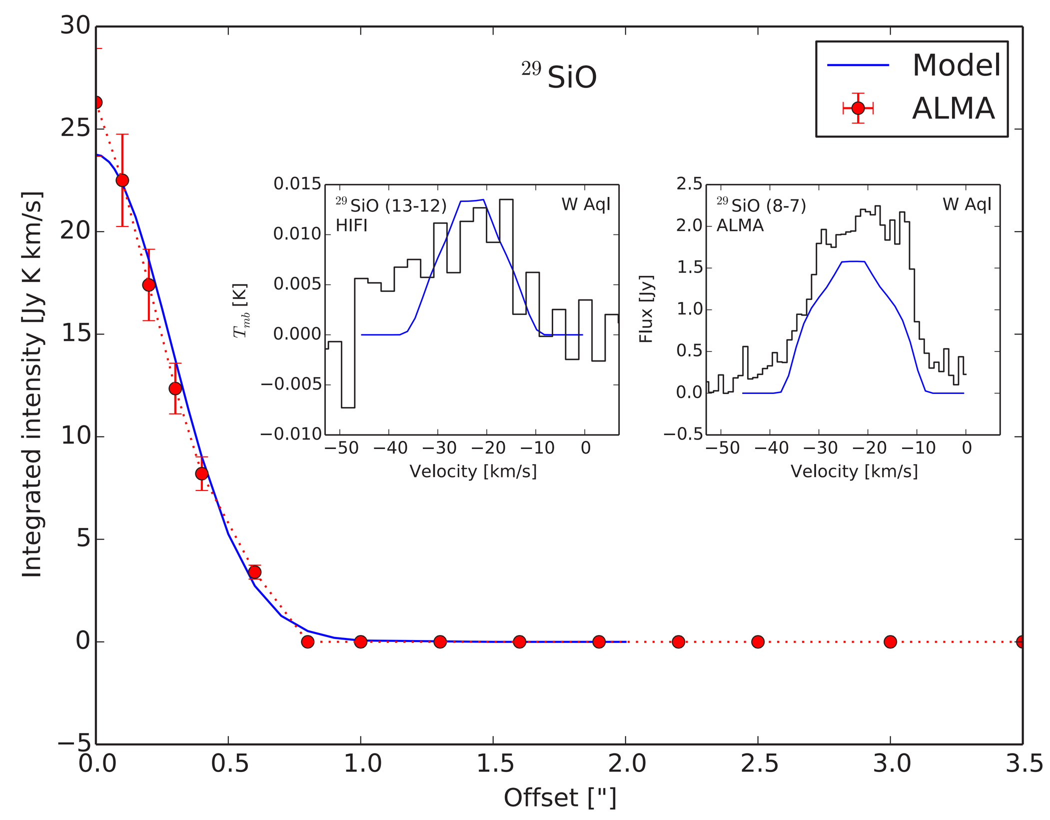

Figure 4: Modelling results for ^{29}SiO(8-7); Radial integrated intensity profile and modelled spectral lines in comparison with HIFI and ALMA data.

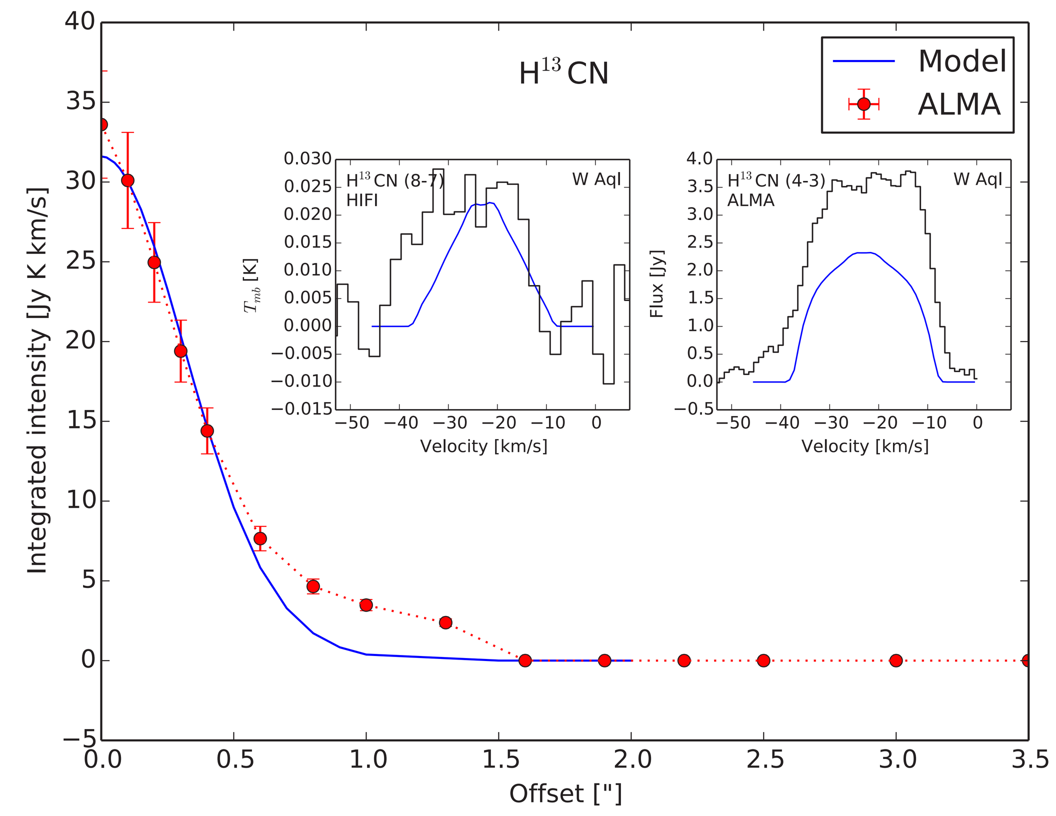

Figure 5: Modelling results for $H^{13}CN$(4-3); Radial integrated intensity profile and modelled spectral lines in comparison with HIFI and ALMA data.

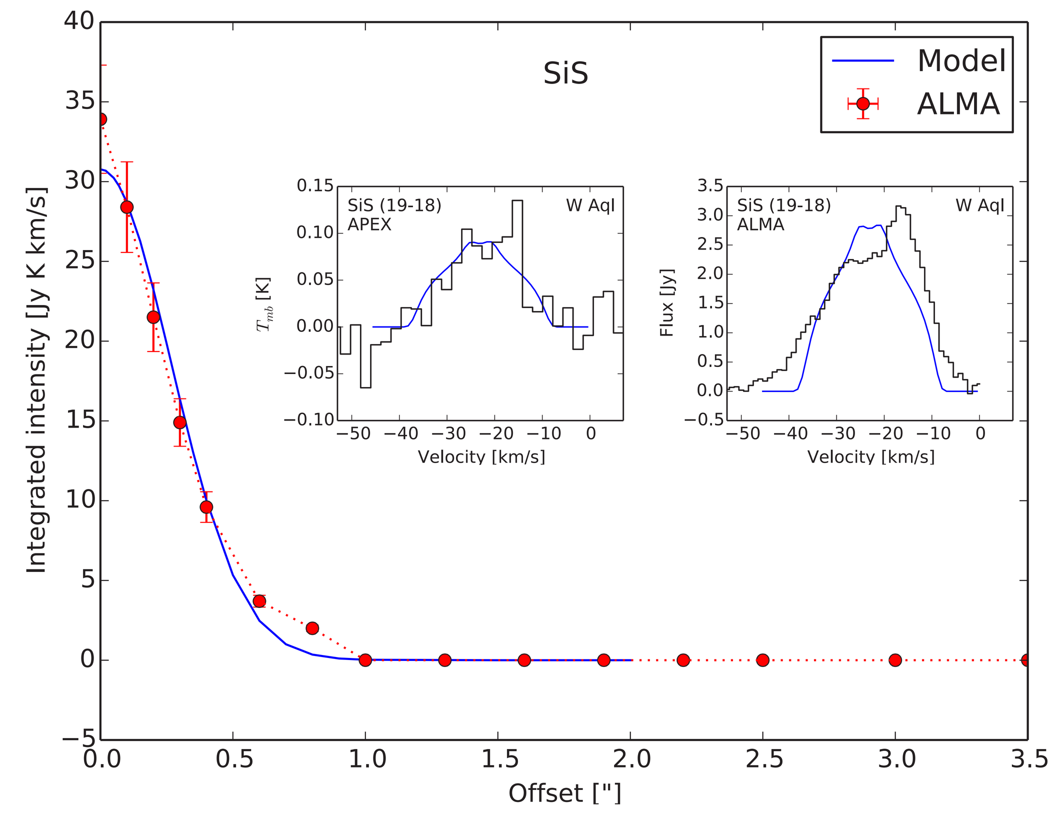

Figure 6: Modelling results for SiS(19-18); Radial integrated intensity profile and modelled spectral lines in comparison with APEX and ALMA data.

Discussion

The detected molecular emission is concentrated in the present-day mass-loss close to the star, with a faint, broader emission component, possibly linked to the large scale morphology seen in the Herschel dust emission [4]. The spectral lines show excess emission on the blue shifted side (at about -35 km/s), also seen in the complex CO gas distribution (Ramstedt et al. in prep).

As can be seen in the brightness profiles, the radiative transfer models slightly underestimate the central flux of all lines and do not fit the extended emission from 0.5" outwards. This probably contributes to the under-prediction of some of the line profiles. Additional results, also covering the weak molecular lines, will be discussed in an upcoming paper.

References

[1] Ramstedt, S., Maercker, M., Olofsson, G., et al. 2011, A&A, 531, A148
[2] Whitelock, P.A., Feast, M.W., & van Leeuwen, F. 2008, MNRAS, 386, 313
[3] Danilovich, T., Bergman, P., Justtanont, K., et al. 2014, A&A, 569, A76
[4] Mayer, A., Jorissen, A., Kerschbaum, F., et al. 2013, A&A, 549, A69

This poster makes use of the following ALMA data:
ADS/JAO.ALMA#2012.1.00524.S (PI: Sofia Ramstedt)

Contact me!

I am happy to talk to you about this project in more detail and answer your questions.
You can also send me an email!

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