Probing the UV chemistry around R Scl

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Goal and motivation:

The chemistry of the circumstellar envelope (CSE) of evolved stars is strongly affected by UV photons. A schematic view of UV sources which could affect the CSE chemistry is shown in figure 1. The UV field can come from the inner part such as stellar chromospheric activity or a binary companion, or from outside such as the interstellar medium. Numerous UV-spectra indicates the presence of an active chromosphere in the outer atmosphere of carbon stars (Eaton & Johnson 1988). On the other hand, the rate of binary companions of AGB stars is unknown. R Scl is a carbon AGB star which recently revealed to be a binary (Maercker et al. 2012).

We have started a detailed study into the effect of UV photons on the CSE of R Scl, by probing carbon-bearing molecules and their photodissociation products. This work is focused on CO and HCN isotopes. The available molecular lines from single-dish data and interferometric data of R Scl are listed in table 1 and 2 respectively.

The selective photodissociation of molecular isotopes (especially ^{12}CO and ^{13}CO) is one process which improves our understanding of the effect of UV photons in astrophysical regions.

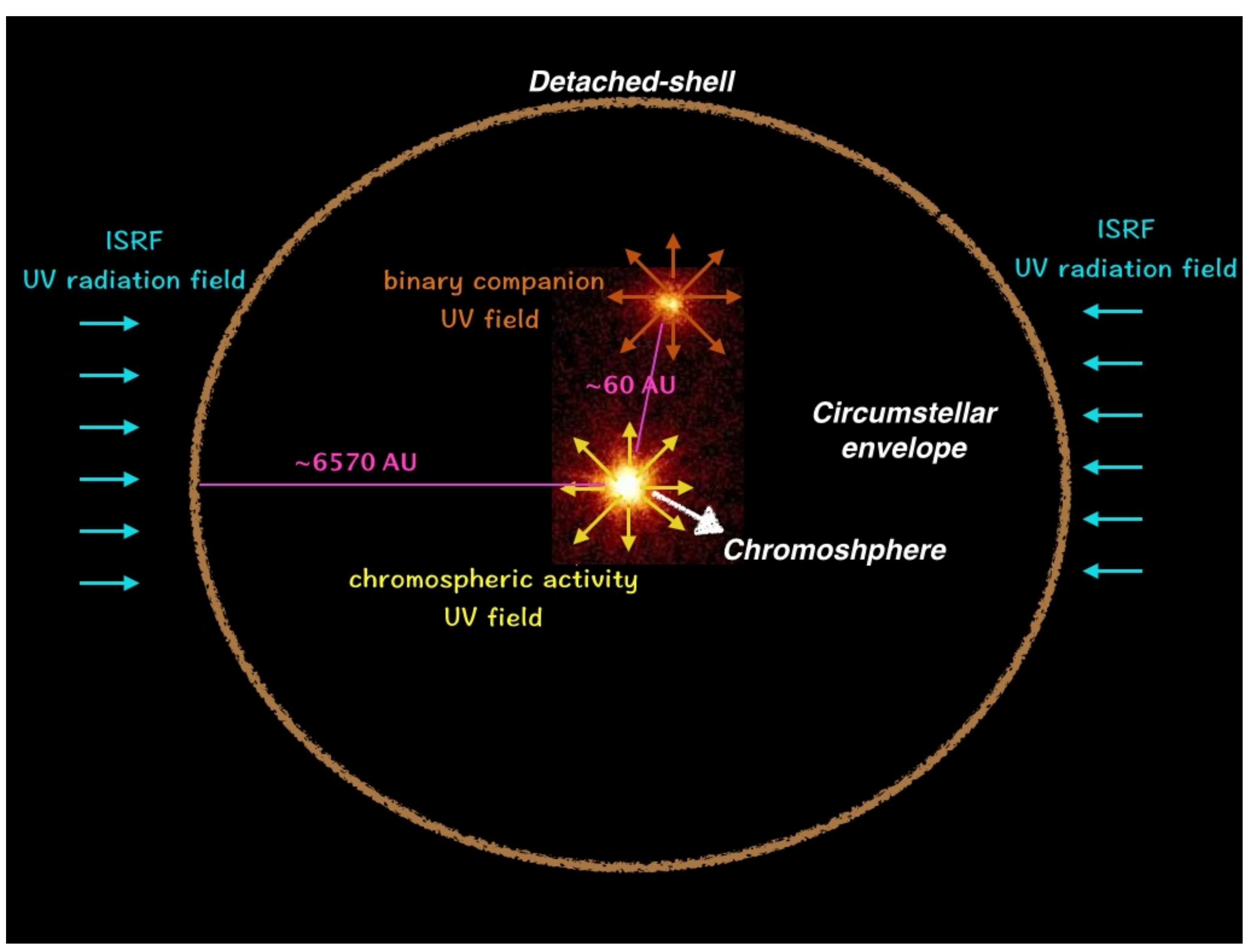

Fig1 A schematic view of an AGB star with a binary companion. Three different UV fields which could disturb the CSE chemistry are plotted: ISRF (blue), binary companion (black) and chromospheric activity (yellow).

Observational data:

Transition	Freq (GHz)	Telescope	Ref
CO(J=1-0)	115.3	SEST/ IRAM	Olofsson et al.1996/ Danilovich et al. 2015
CO(J=2-1)	230.5	SEST/ IRAM	Olofsson et al.1993a/ Danilovich et al. 2015
CO(J=5-4)	576.3	HIFI	Danilovich et al. 2015
CO(J=9-8)	1036.9	HIFI	Danilovich et al. 2015
CO(J=14-13)	1611.8	HIFI	Danilovich et al. 2015
13CO(J=1-0)	110.2	SEST/ IRAM	Olofsson et al.1993b/ Danilovich et al. 2015
13CO(J=2-1)	220.4	SEST	Olofsson et al.1993b
HCN(J=1-0)	88.6	SEST	Olofsson et al.1996
HCN(J=2-1)	177.2	APEX	Saberi et al., in prep
HCN(J=3-2)	265.9	SEST	Olofsson et al.1996
HCN(J=3-2)	265.9	HHT	Bieging 2001
HCN(J=4-3)	354.5	HHT	Bieging 2001
HCN(J=4-3)	354.5	SEST	Olofsson et al.1993b
H13CN(J=2-1)	172.6	APEX	Saberi et al., in prep
CN(J=1-0)	113.3	SEST/ IRAM	Olofsson et al.1996/ Danilovich et al. 2015
CN(J=2-1)	226.8	SEST/ IRAM	Olofsson et al.1996/ Danilovich et al. 2015
CN(J=3-2)	340.1	SEST	Olofsson et al.1996
CN(J=5-4)	565.7	HIFI	Danilovich et al. 2015
13CN(J=1-0)	108.7	SEST	Olofsson et al.1996
CS(J=3-2)	147.0	SEST	Olofsson et al.1996
SiS(J=6-5)	108.9	SEST	Olofsson et al.1996
HC3N(J=12-11)	109.2	SEST	Olofsson et al.1996
C(3P0-3P1)	492	APEX	Olofsson et al. 2015

table 1. molecular line single-dish observations of R Scl.

Transition	Freq (GHz)	Telescope	Ref
HCN(J=1-0)	88.6	ATCA	Wong et al. 2004
H13CN(J=4-3)	354.3	ALMA	Saberi et al. in prep
CO(J=1-0)	115.3	ALMA	Maercker et al. in prep
CO(J=2-1)	230.5	ALMA	Maercker et al. in prep
CO(J=3-2)	345 .7	ALMA	Maercker et al. 2012
13CO(J=3-2)	330.5	ALMA	Vlemmings et al. 2013
CS(J=7-6)	342.8	ALMA	-

table 2. interferometric observational data of R Scl.

Physical tracer of the binary companion/an extra UV field

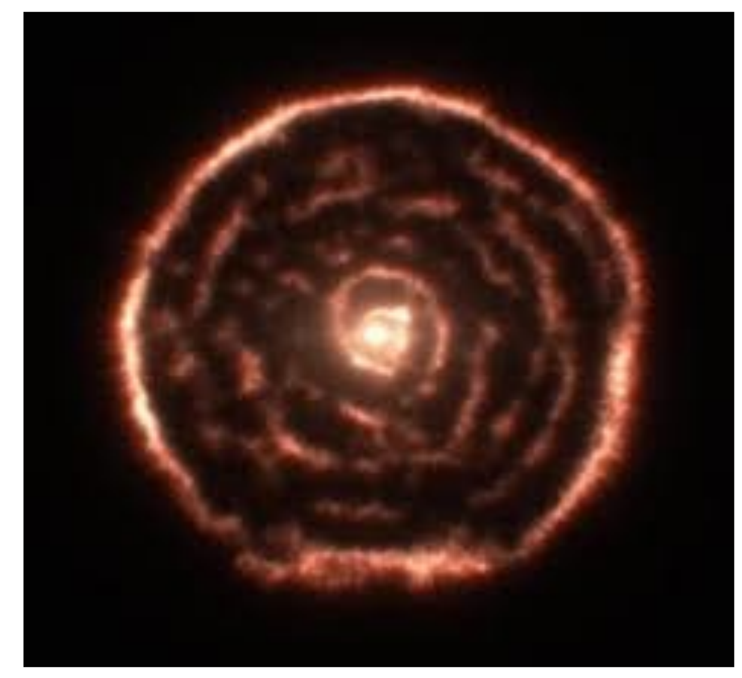

Fig2 CO (3-2) map of Carbon AGB star, R Scl at stellar velocity by ALMA, Maecker et al. 2012. The spiral arms in the outflow was the first indicator of a binary companion.

Method:

The spiral structure imprinted in the CO outflow (Fig2), detected with ALMA, was the first physical indicator of a binary companion to R Scl, Maercker et al. 2012. After that, the chemical tracer of an extra UV field in the inner part of R Scl was revealed by ALMA observations.

The ALMA observation of ^{12}CO and ^{13}CO shows a big discrepancy between $^{12}CO/^{13}CO$ ratio in the inner part (>60) and the detached shell (~19), Vlemmings et al. 2013, Fig3. An unexpectedly high $^{12}CO/^{13}CO$ in the present-day mass loss compared to the photospheric $^{12}C/^{13}C$ is likely due to the selective photodissociation of ^{13}CO.

Whereas ^{12}CO and ^{13}CO are photodissociated in well-defined bands, $H^{12}CN$ and $H^{13}CN$ are dissociated via continuum. This implies that both species would be affected by the inner UV source in the same way and that a study of the $H^{12}CN/H^{13}CN$ abundance ratio will allow us to better characterise this UV source. From a comparison of ALMA observations of $H^{13}CN$(J=4-3) to SEST observations of $H^{12}CN$(J=4-3), taking into account optical-depth effects, we derive a preliminary abundance ratio that is in agreement with the photospheric $^{12}C/^{13}C$ ratio.

Furthermore, from modelling the emission of $H^{12}CN$(J=1-0;3-2;4-3), Fig4, Wong et al. (2004) show that the $H^{12}CN$(J=3-2) emission likely traces a region of lower abundance than the other transitions. This would be in agreement with an extra source of UV dissociation rather close to the star, such as the binary companion.

Modelling HCN transition including $H^{12}CN$(J=2-1) and $H^{13}CN$(J=2-1) using the new Sepia receiver at APEX, taking into account new CO and C results (Maercker et al. 2015, Olofsson et al. 2015) would confirm the proposed scenario and help us to characterise the overall chemical imprint of the binary companion.

Chemical tracer of an extra UV field

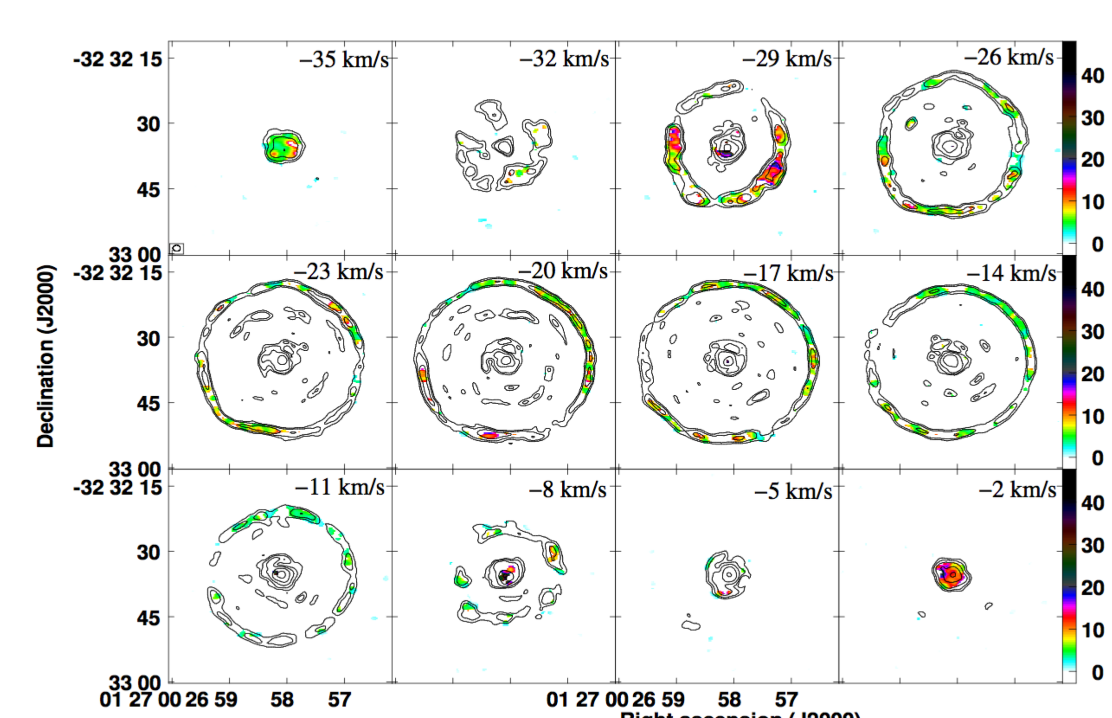

Fig3 Intensity ratio, I(12CO)/ I(13CO), (color) and 12CO(J=3-2) flux (contours) for the full velocity channel range. The channels are averaged over three km S-1 and the panels are are labeled according to their VLSR, from Vlemmings et al. 2013.

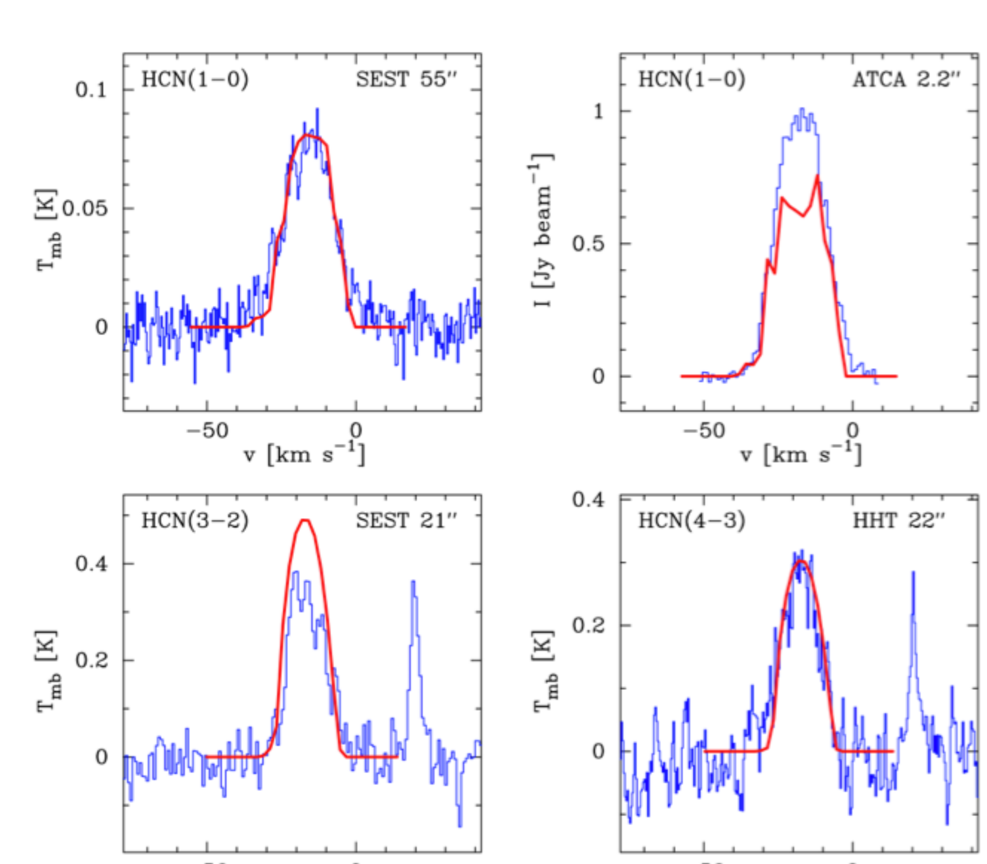

Fig4 HCN(J=1-0, 3-2, 4-3) single-dish observation of R Scl and modelling (red lines) from Wong et al. 2004.

References:

Bieging et al. 2001, ApJ, 549, 125; Eaton & Johnson 1988, ApJ, 325, 355; Danilovich et al. 2015 arXiv: 1506.09065; Olofsson et al. 1993, ApJS, 87, 267; Olofsson et al. 1993, ApJS, 87, 305; Olofsson et al. 1993, A&A, 311, 587; Olofsson et al. 2015, submitted; Lambert et al. 1986, ApJ, 62, 373; Maercker et al. 2012, Nature, 490, 232; Vlemmings et al. 2013, A&A, 556, 6; Wong et al. 2004, A&A, 413, 241