Outflows from Binary AGB stars with ALMA

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Outline

• AGB stars - $A\bar{B}C$

• AGB ALMA observations

• New results: $^{12}CO/^{13}CO$–ratio

• Summary
AGB stars - ABC

- Final nuclear burning stage of low- to intermediate mass stars
- Produce a lot of carbon ($^{12}$C), nitrogen, and also some heavier elements
- Produce a lot of dust
AGB stars – ABC

• Have intense winds (<30 km/s, <10^-4 M_{sun}/yr)

• Chemical evolution driven by thermal-pulse cycle (born-again PN) and dredge-up

• Three main chemical (evolutionary?) types: M (C/O<1), S (C/O≈1), C (C/O>1)

• Few known binaries
In Cycle 0: R Sculptoris

- $^{12,13}$CO(3–2) observations with ALMA in Cycle 0
- Aim to study the detached shell
- Isotopologue ratios
- Unknown binary discovered

From Maercker et al. 2012

$^{12}$CO observations of R Scl:
AGB ALMA observations

In Cycle 0: R Sculptoris

Present-day $v_{\text{exp}}=10.5$ km/s consistent with orbital period of 350 days.

The shell:
- $R_{sh}=18.5''$ and $v_{sh}=14.5$ km/s
- Shell age $t < 1800$ yrs
- Pulse duration: 345 yrs
- Pulse mass-loss rate: $7 \times 10^{-6}$
- Present-day mass-loss rate: $3 \times 10^{-7}$

From Maercker et al. 2012

$^{12}$CO observations of R Scl:
In Cycle 1 – The small binary sample

- $^{12,13}$CO(3-2) observations with ALMA in Cycle 1
- Sample (A. Mayer’s talk): R Aqr (20 AU), Mira (60 AU), W Aql (100 AU), $\pi^{1}$ Gru (400 AU+)
- Constrain binary interaction (see Shazrene Mohamed’s talk)
- Aim to construct a reference sample
- CO isotopologue ratios
In Cycle 1 – The small binary sample

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  - Mira (60 AU),
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The $^{12}\text{C}/^{13}\text{C}$ ratio

- Isotopic ratios are crucial to constrain evolutionary models
- Constrained by observations of $^{12}\text{CO}$ and $^{13}\text{CO}$
- Mostly observed for nearby carbon stars
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The $^{12}\text{C}/^{13}\text{C}$ ratio - Two studies

Large sample, semi-detailed
- 60 stars
- All chemical types
- Constrains evolution
- Constrains nucleosynthesis

Small sample, super-detailed
- 5 binary stars (only R Scl so far)
- All chemical types
- Resolved CSE
- Constrains nucleosynthesis

- Binary fraction unknown
- Average ratio across CSE

ALMA

New results on the $^{12}\text{CO}/^{13}\text{CO}$-ratio
The $^{12}C/^{13}C$ ratio - The large sample

$^{12}CO/^{13}CO$-ratio vs. $dM/dt$:

- Low-transition (up to $J=6-5$), single-dish observations
- Detailed radiative transfer:
  1. Dust
  2. $^{12}CO$
  3. $^{13}CO$

Results:
- Dependence on $C/O$

From Ramstedt & Olofsson 2014
The $^{12}\text{C}/^{13}\text{C}$ ratio - The large sample

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From Ramstedt & Olofsson 2014

Some upper limits and J-type C-stars
The $^{12}$C/$^{13}$C ratio - The large sample

$^{12}$CO/$^{13}$CO-ratio distribution (with PNs):

- Dependence on C/O
- S-type different from M-type
- PN values are $\approx 10-20$

From Palla et al. 2000 & Balser et al. 2002
The $^{12}$C/$^{13}$C ratio - The detailed study: R Scl

- $^{12}$, $^{13}$CO(3–2) observations with ALMA in Cycle 0

$^{13}$CO observations of R Scl:

Results:
“Present-day” ratio > 60
Average shell ratio ≈ 19
(Atmospheric value = 19)

From Vlemmings et al. 2013
Summary

- Four known binary AGB stars will be observed with ALMA in Cycle 1 to constrain the gravitational effects on the wind and attain resolved isotopologue ratios.

- We have estimated $^{12}\text{C}/^{13}\text{C}$-ratios in a large mixed sample of AGB stars and find that the results support the evolutionary sequence $M \rightarrow S \rightarrow C$.

- The shell around R Scl is likely formed during a thermal pulse but the isotopologue ratios across the CSE are affected by external processes and not only influenced by the normal evolution of the star. Maybe isotopic ratios can be used to find binary companions?
To be continued...
Thanks!