Outflows from Binary AGB stars with ALMA

Collaborators:
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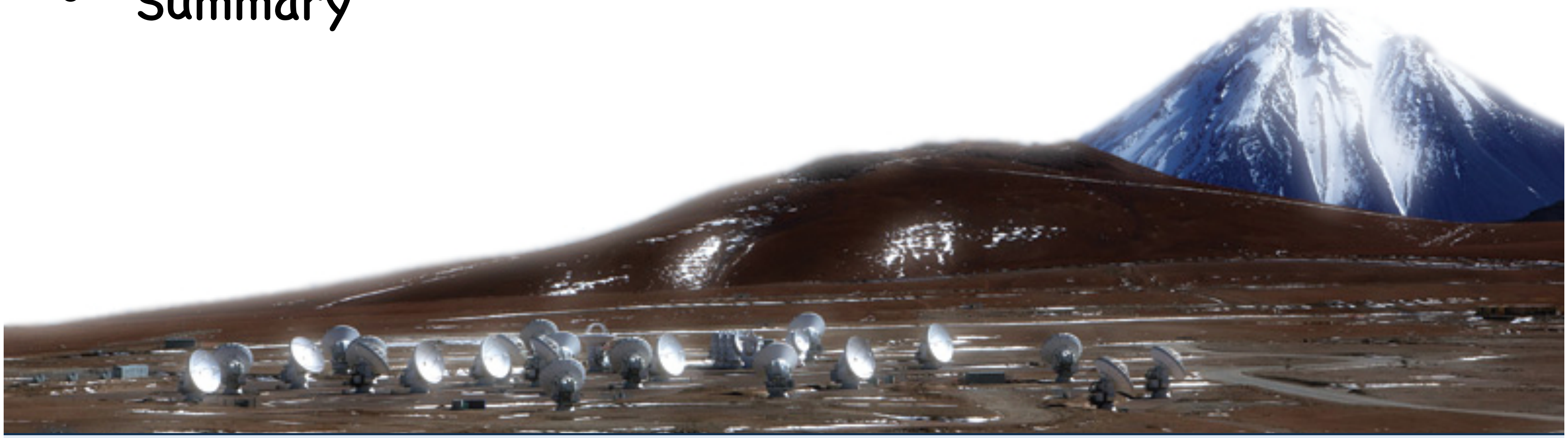
A. Mayer, R. Montez, E. Lagadec et al.

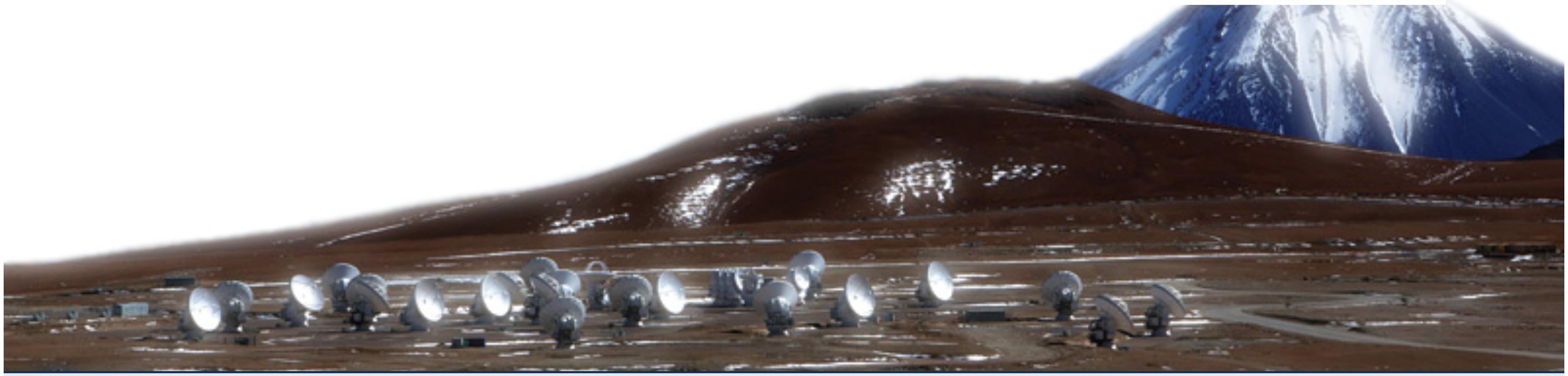
Outline

- AGB stars – $\mathcal{ABC}$
- 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

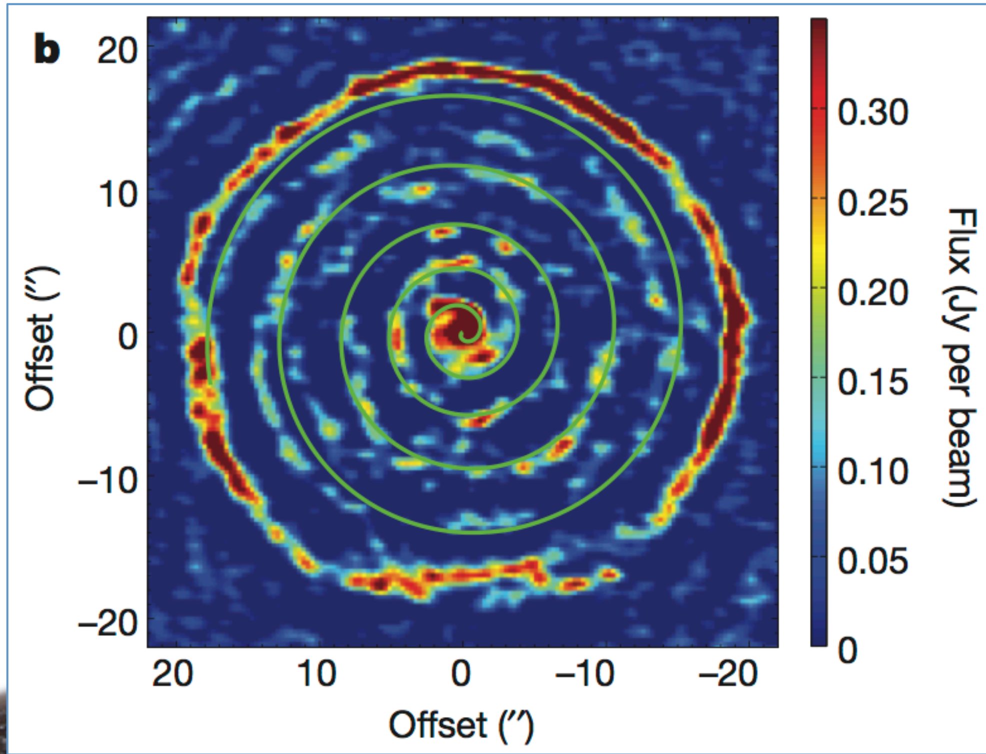
- Have intense winds (<30 km/s, $<10^{-4}$ M_{sun}/yr)
- Chemical evolution driven by thermal-pulse cycle (born-again PN) and dredge-up
- Three main chemical (evolutionary?) types: M (C/O<1), S (C/O≈1), C (C/O>1)
- Few known binaries

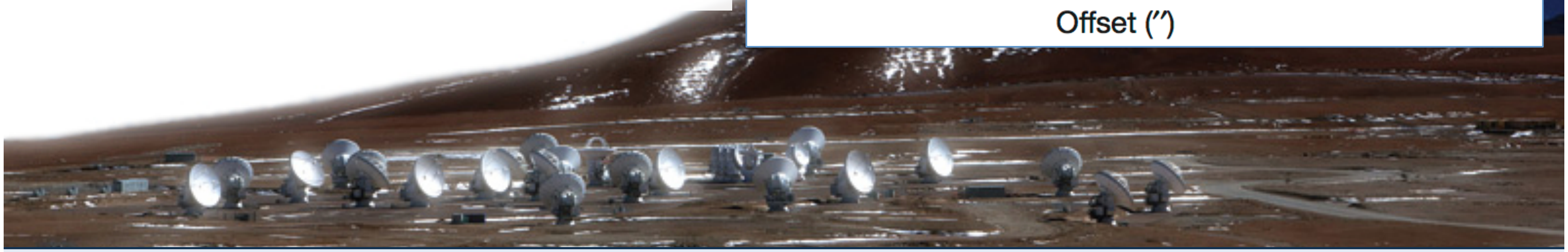
In Cycle 0: R Sculptoris

- $^{12,13}CO(3\text{-}2)$ 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:





In Cycle 0: R Sculptoris

Present-day v_{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: 7×10^{-6}
- Present-day mass-loss rate: 3×10^{-7}

From Maercker et al. 2012

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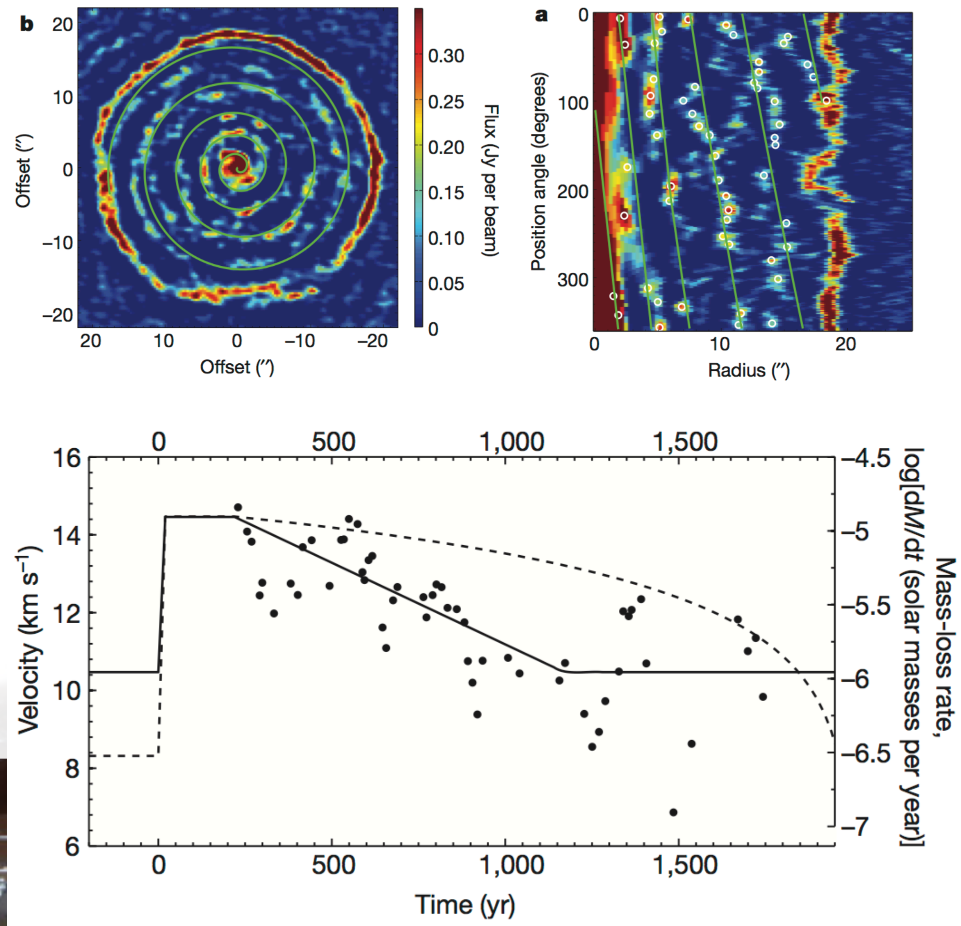
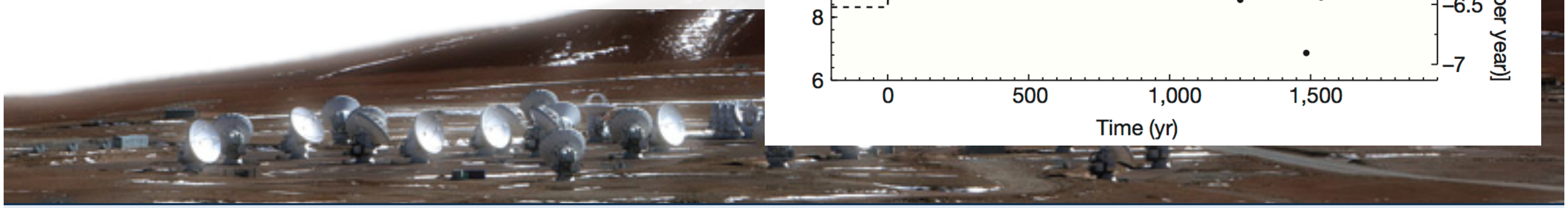
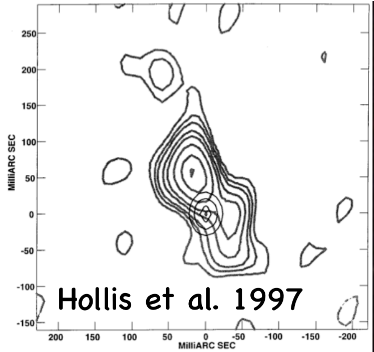




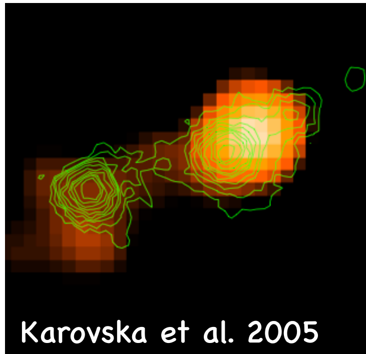
In Cycle 1 – The small binary sample

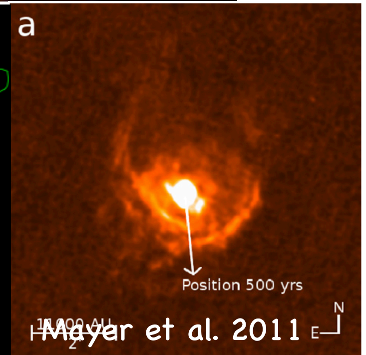
- ^{12,13}CO(3–2) observations with ALMA in Cycle 1
- Sample (A. Mayer's talk):
  R Aqr (20 AU),
  Mira (60 AU),
  W Aql (100 AU)
  π^1 Gru (400 AU+?)
- Constrain binary interaction (see Shazrene Mohamed's talk)
  Aim to construct a reference sample
- CO isotopologue ratios



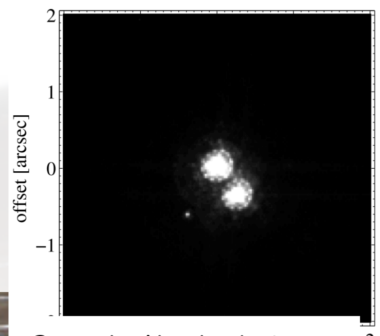
Hollis et al. 1997


Adam Block/Mount Lemmon/Uni. Arizona

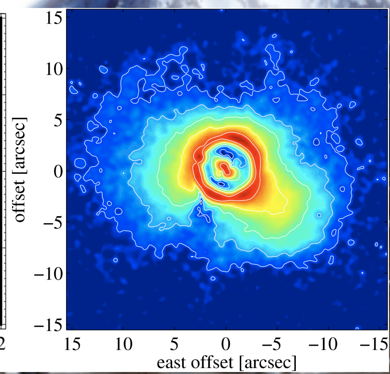

Karovska et al. 2005



Mayer et al. 2011



Ramstedt et al. 2011



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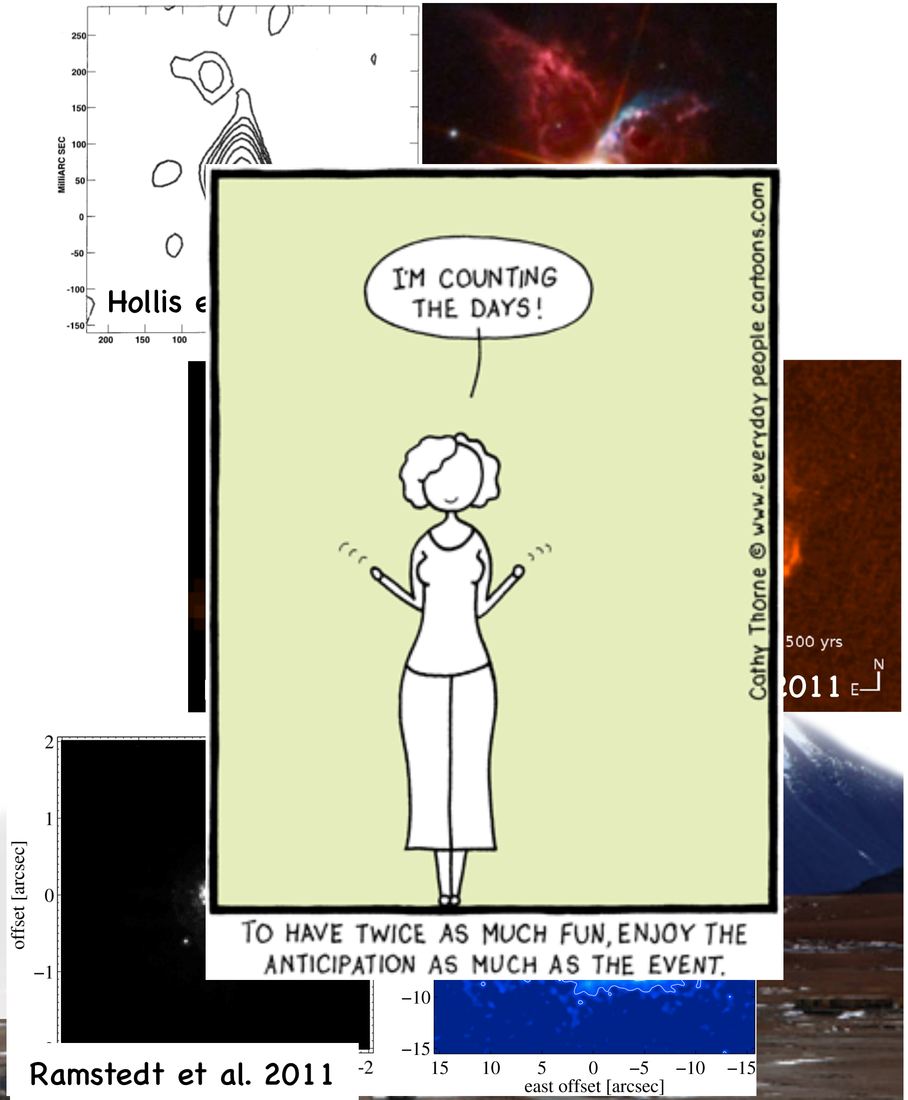

Ramstedt et al. 2011

The $^{12}C/^{13}C$ ratio

- Isotopic ratios are crucial to constrain evolutionary models
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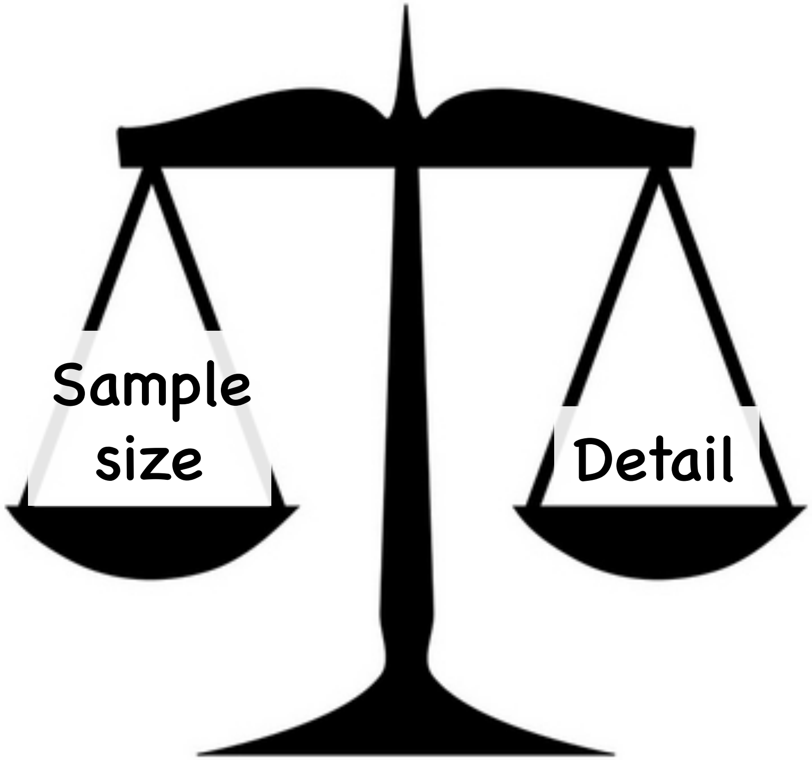


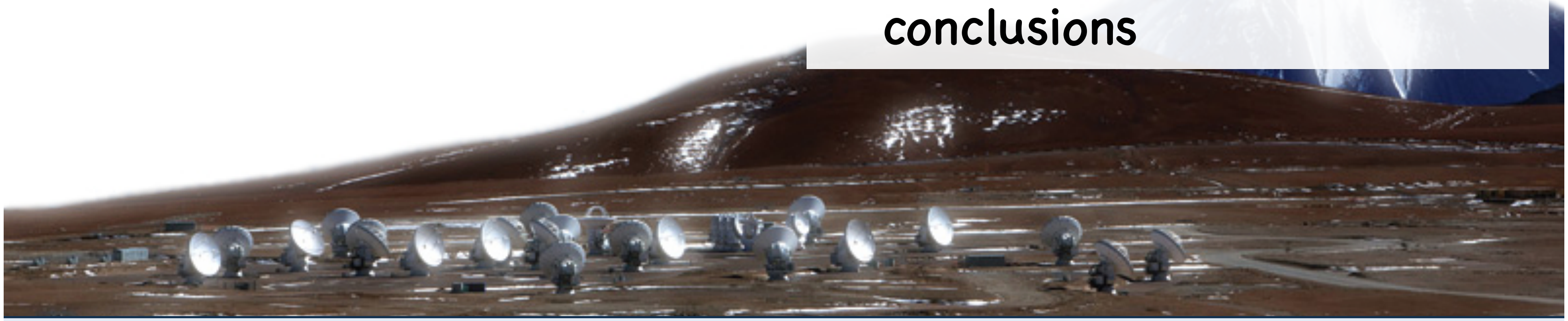
The $^{12}C/^{13}C$ ratio – Two studies

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

- Binary fraction unknown
- Average ratio across CSE

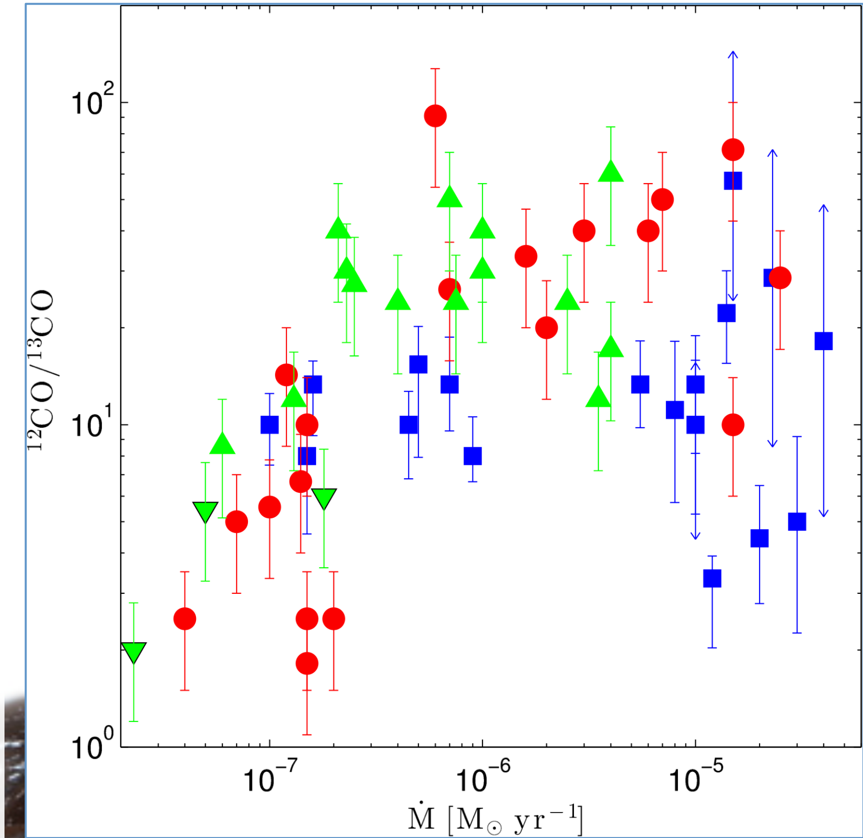
ALMA
Small sample, ~~super-detailed~~
- 5 binary stars (only R Scl so far)
- All chemical types
- Resolved CSE
- Constrains nucleosynthesis

- Difficult to disentangle
- Difficult to draw general conclusions



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

■ M-type C/O<1
▲ S-type C/O=1
● carbon stars C/O>1

From Ramstedt & Olofsson 2014

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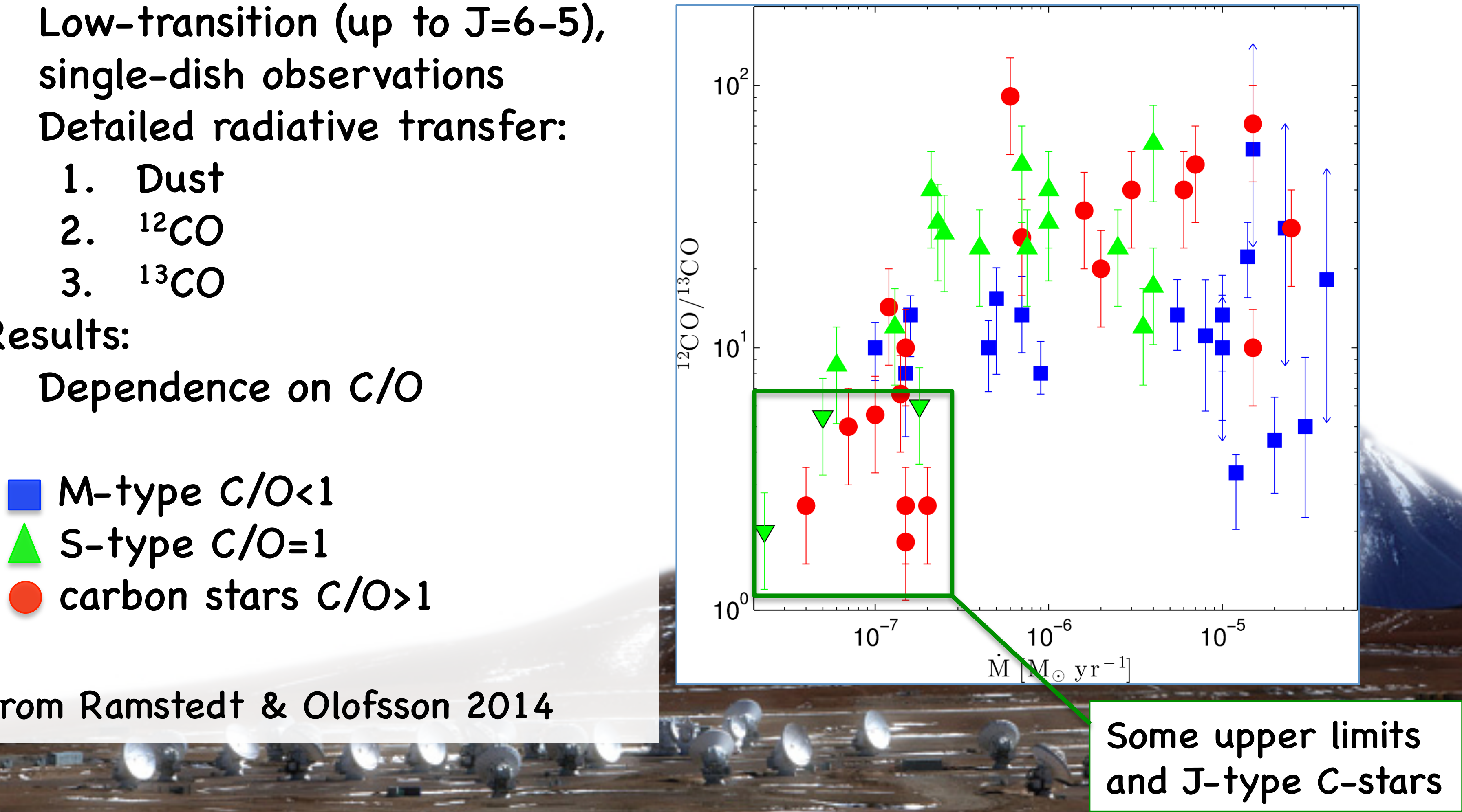


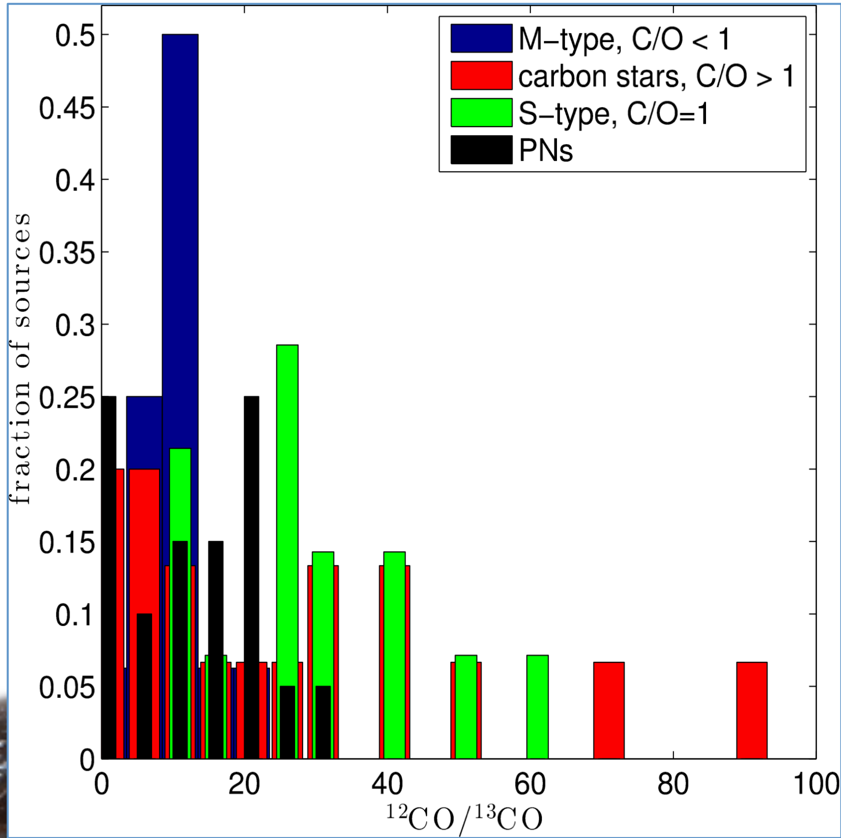
From Ramstedt & Olofsson 2014

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 ≈10-20

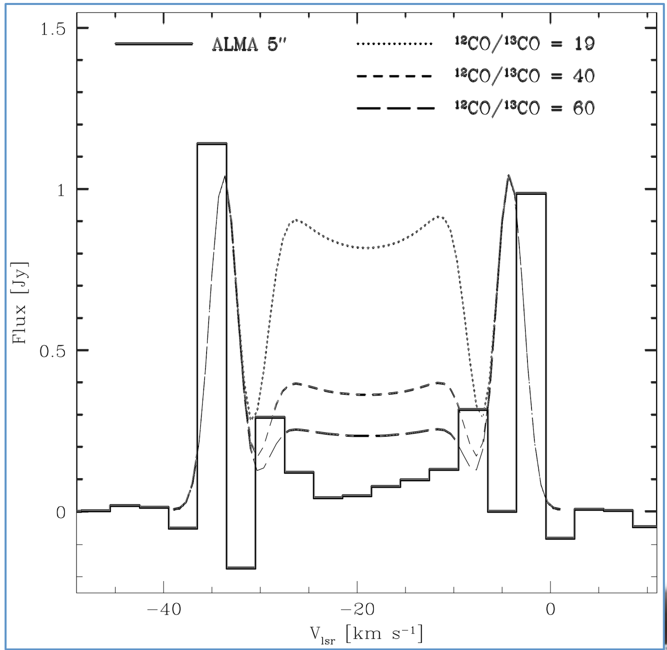
From Palla et al. 2000
& Balser et al. 2002

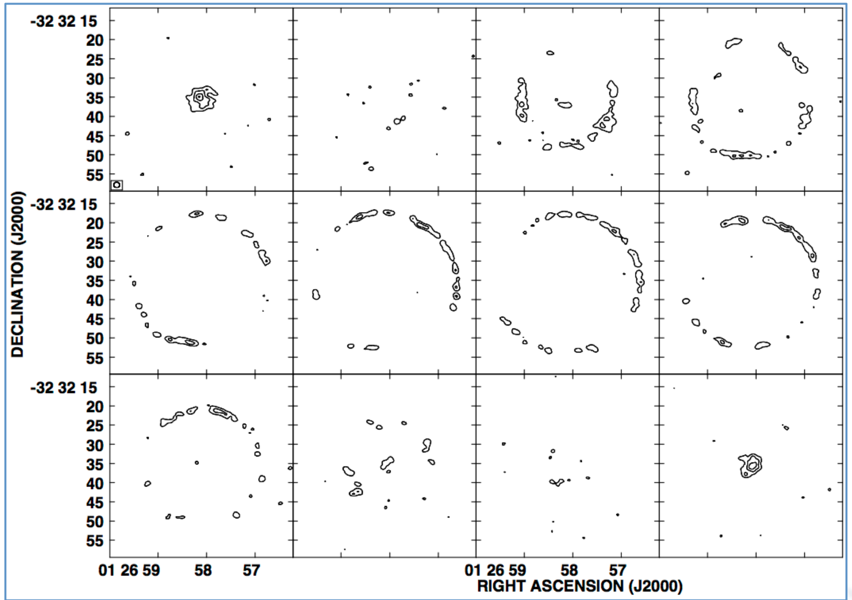


The $^{12}C/^{13}C$ ratio – The detailed study: R Scl

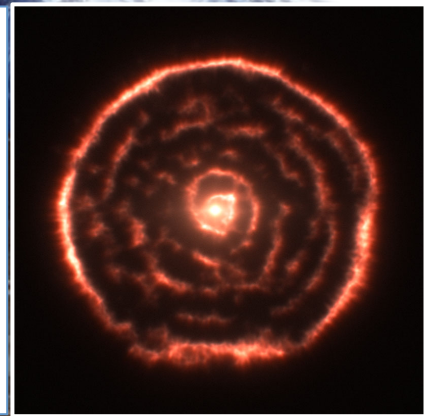
^{13}CO observations of R Scl:

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



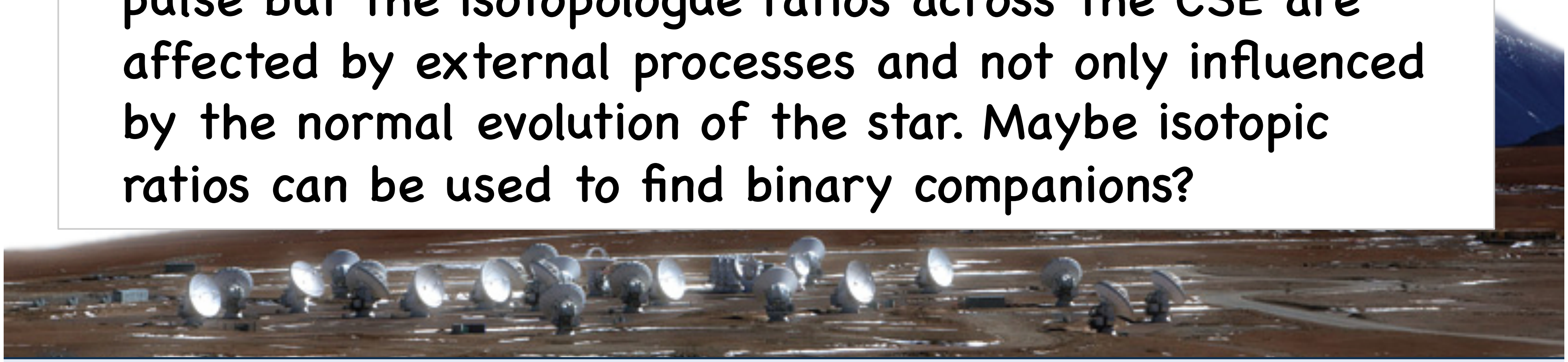


Results:
"Present-day" ratio > 60
Average shell ratio ≈ 19
(Atmospheric value = 19)
From Vlemmings et al. 2013



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 $^{12}C/^{13}C$-ratios in a large mixed sample of AGB stars and find that the results support the evolutionary sequence M → S → 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!