Charting Circumstellar Chemistry of Carbon-rich AGB Stars

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AGB stars are major contributors to the chemical enrichment of the ISM through nucleosynthesis and extensive mass loss. Most of our current knowledge of AGB circumstellar chemistry, in particular in a C-rich environment, is based on observations of the carbon star IRC +10 216, which is often attributed the status of an archetypal carbon star. In this work, we aim to observationally verify if IRC +10216 is indeed an archetypal carbon star.

Aims

+Obtain a more generalized understanding of the chemistry in C-rich AGB CSEs by studying a sample of three carbon stars:

IRAS 15194−5115, IRAS 15082−4808, and IRAS 07454−7112.

+Test whether IRC +10216 is a representative C-type AGB star.

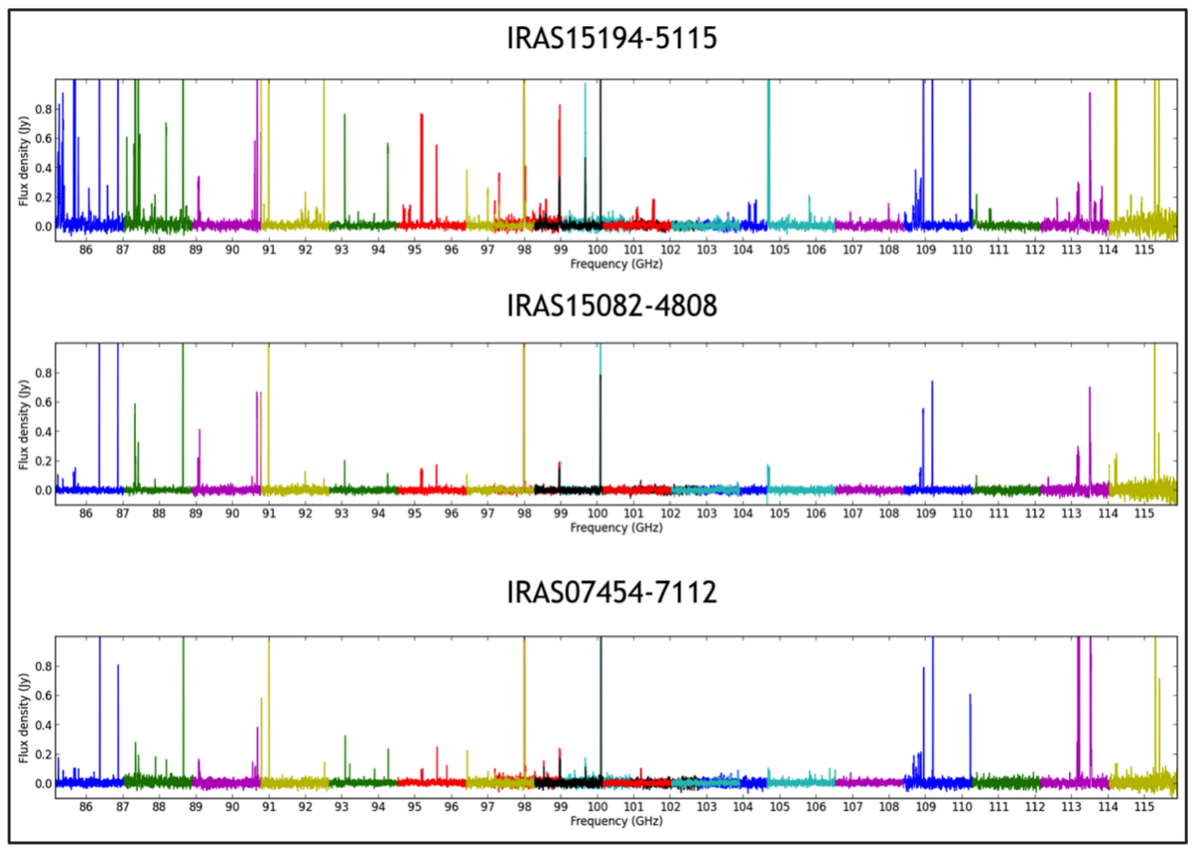
Observations

+ ALMA: Band 3 (85 - 116 GHz) - spectral survey of three C-type AGB CSEs.

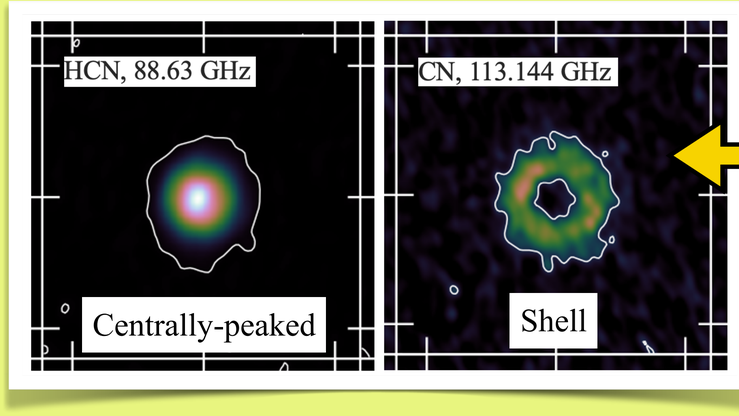
+ APEX: 159 - 270 GHz spectral surveys of the sample, and 272 - 376 GHz survey of IRAS 15194-5115.

Source	Distance (pc)[(1)]	Mass-loss rate[(2)] ($M_\odot$/yr)	$^{12}C/^{13}C$[(2)]	V_{exp}[(2)] (km/s)
IRAS 15194-5115	696 (-93/+129)	1.6e-5	6	21.5
IRAS 15082-4808	1050 (-60/+60)	2.7e-5	35	19.5
IRAS 07454-7112	583 (-56/+70)	3.4e-6	17	13.0
IRC+10 216	190 (-20/+20)	3.0e-5	45[(3)]	14.5[(3)]

1. Overview of the ALMA Band 3 spectra



2. Types of Morphologies



+The maps show molecular line emission at the systemic velocity

+Two major emission morphologies found:

+**Centrally-peaked** (HCN, SiO, SiS, CS)

+**Hollow spherical shell** (e.g. CN, HNC)

Complex morphology in IRAS 15194-5115 and IRAS 15082-4808

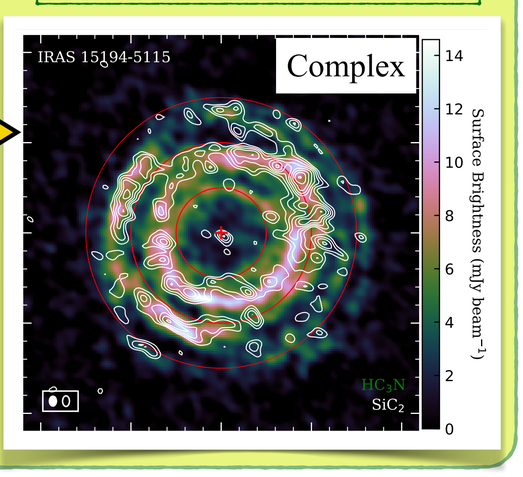
+HC_3N (color), SiC_2 (contour)

+Both centrally-peaked and shell components.

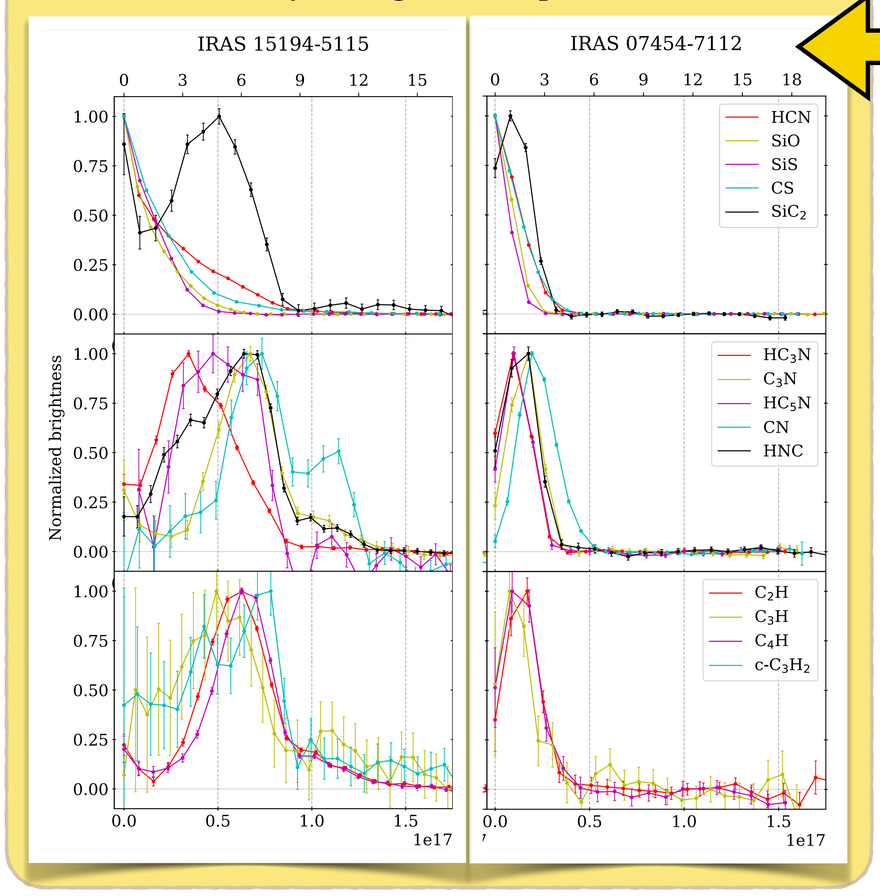
+Distinct arcs within the emitting shells.

+Similar morphology also observed towards IRC +10216.

+Possible binary companion.



3. Azimuthally averaged radial profiles (AARPs)



+Normalized AARPs produced by azimuthally averaging the stacked systemic velocity emission from the detected lines of each species.

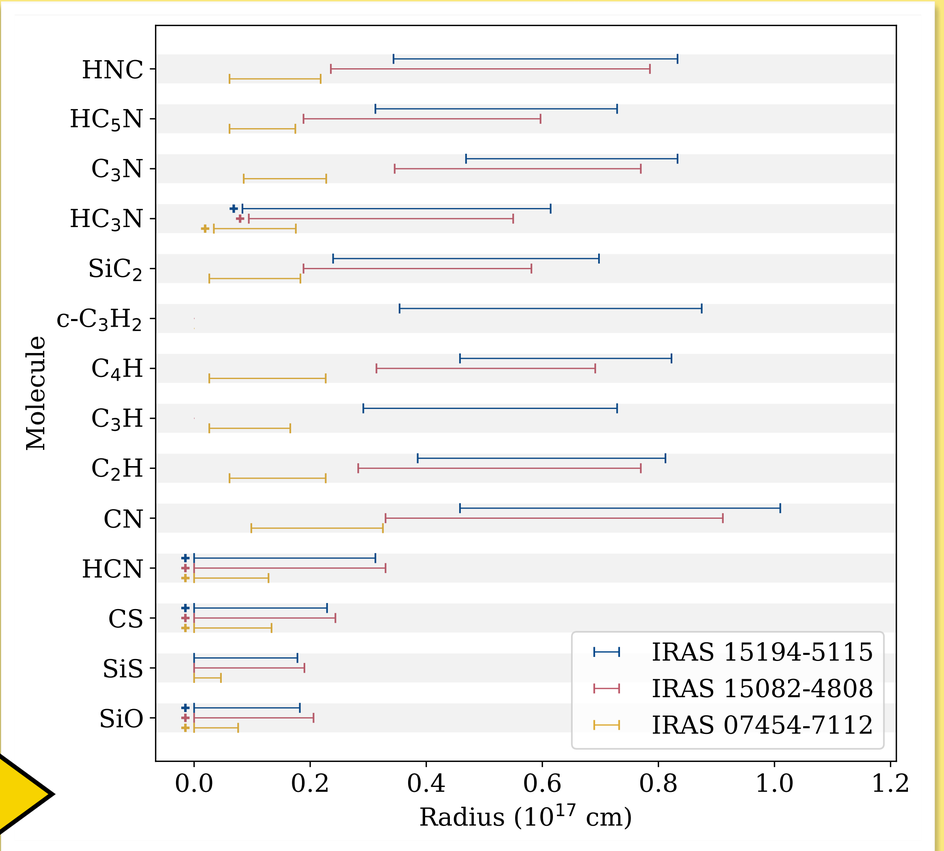
+Gives an overview of the radial emission region sizes of each species.

+Emission region size estimates obtained by fitting Gaussians to the AARPs of each species.

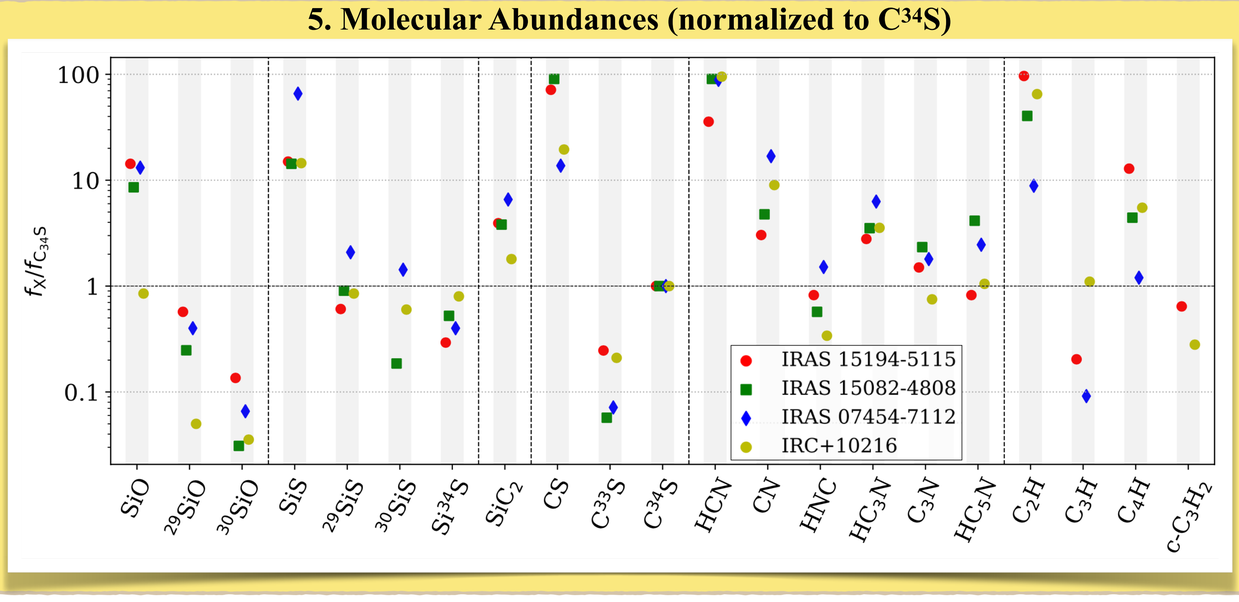
+Used in abundance calculations.

+IRAS 07454-7112 has the smallest CSE in the sample.

4. Sizes of molecular emitting regions



5. Molecular Abundances (normalized to $C^{34}S$)



Results

+Detected 132 rotational transitions of 49 molecular species.

+Deviations from smooth, spherically symmetric CSE model detected towards IRAS 15194−5115 and IRAS 15082−4808: density enhancements.

+Similar circumstellar chemistry observed across the stars, both in terms of relative location of emitting regions, and molecular abundances.

+IRC +10216 serves reasonably well as an archetypal carbon star, at least for modelling the CSE chemistry of stars with MLRs within an order of magnitude.

Future work

Detailed radiative transfer analysis to obtain more rigorous estimates of the molecular abundances, and the physical parameters of the CSE.

References: (1)Andriantsaralaza et al. (2022), (2)Woods et al. (2003), (3)Cernicharo et al. (2000)

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