CNO isotopes evolution with HRMOS

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Why and where to measure CNO isotope abundances - a GCE modeler point of view

① Test stellar evolution and nucleosynthesis theory (stellar yields)

- ⌘ *Nuclear reaction rates, (extra) mixing processes, mass loss strength…*
- ⌘ *Rotating vs non-rotating stellar models*
- ⌘ *Thermonuclear runaways in nova outbursts*

② Test galaxy-wide stellar IMF (gwIMF)

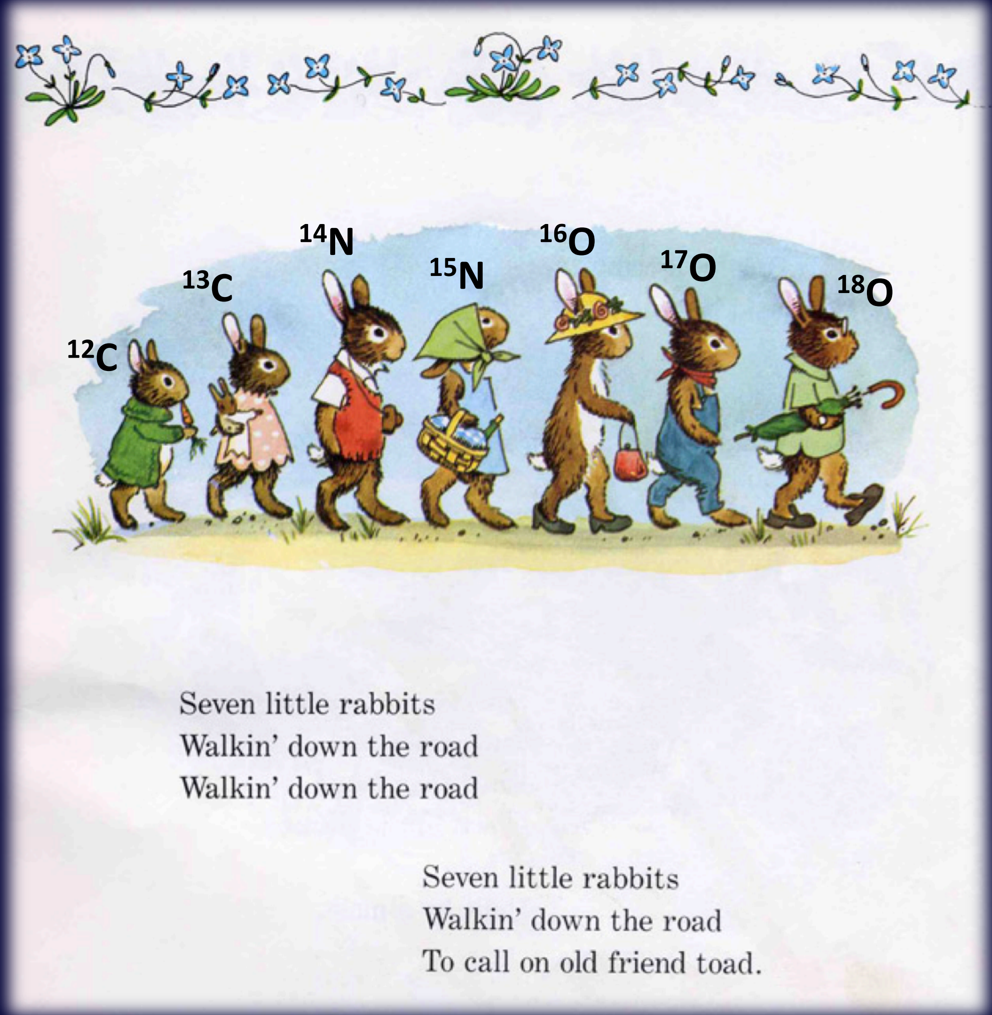
- ⌘ *Top-heavy IMF in massive (high-redshift) starbursts?*
- ⌘ *Less CC SNe in (some) low-mass galaxies?*

③ Constrain galaxy formation and evolution models

- ⌘ *Reproduce trends of abundances and abundance ratios with time/age*
- ⌘ *Reproduce galactic gradients*

Seven stable CNO isotopes

- **Gas phase:** *abundances from molecular clouds and HII regions*
  - *Probe low and high redshifts*
  - *Instantaneous picture*
- **Stars:** *secondary isotopes very difficult to measure…*
  - *Full evolutionary history (in principle)*
  - *Sample a limited volume*



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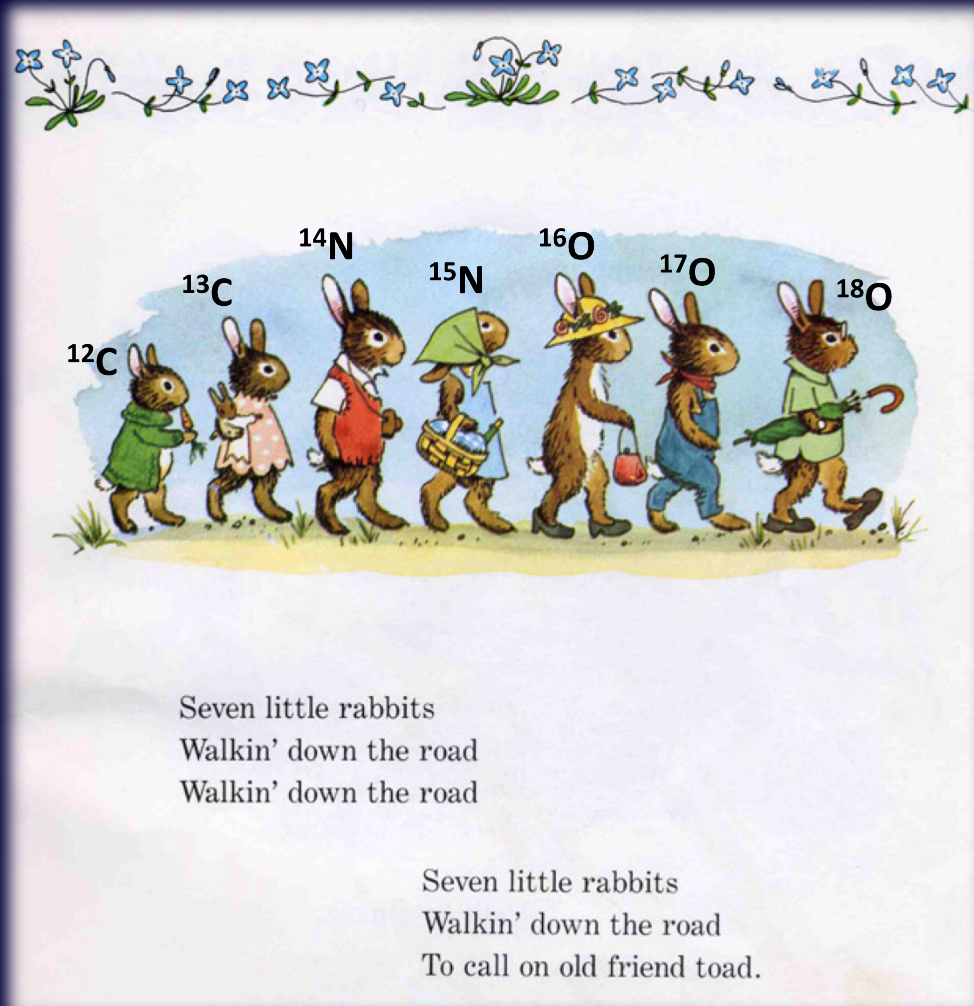
Model calibration



$^{13}C/^{18}O$: a sensitive tracer of stellar IMF

- *Standard nucleosynthesis:*
  - *– ^{13}C produced mostly in low- and intermediate-mass stars*
  - *– ^{18}O produced mostly in massive stars*
  - *(Henkel & Mauersberger 1993; Romano+ 2017, and refs therein)*
- *$^{13}C/^{18}O$ ~ 1 in a sample of four SMGs observed with ALMA implies a stellar IMF biased towards massive stars (Zhang, DR+ 2018)*

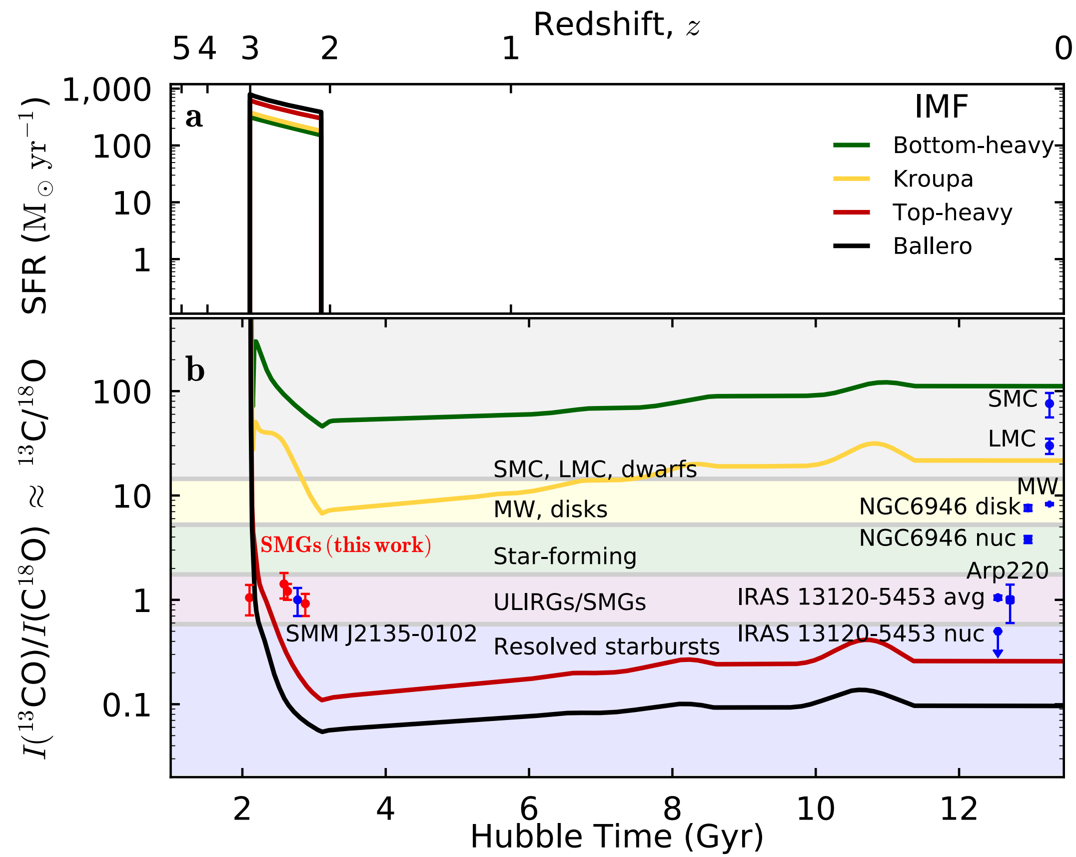
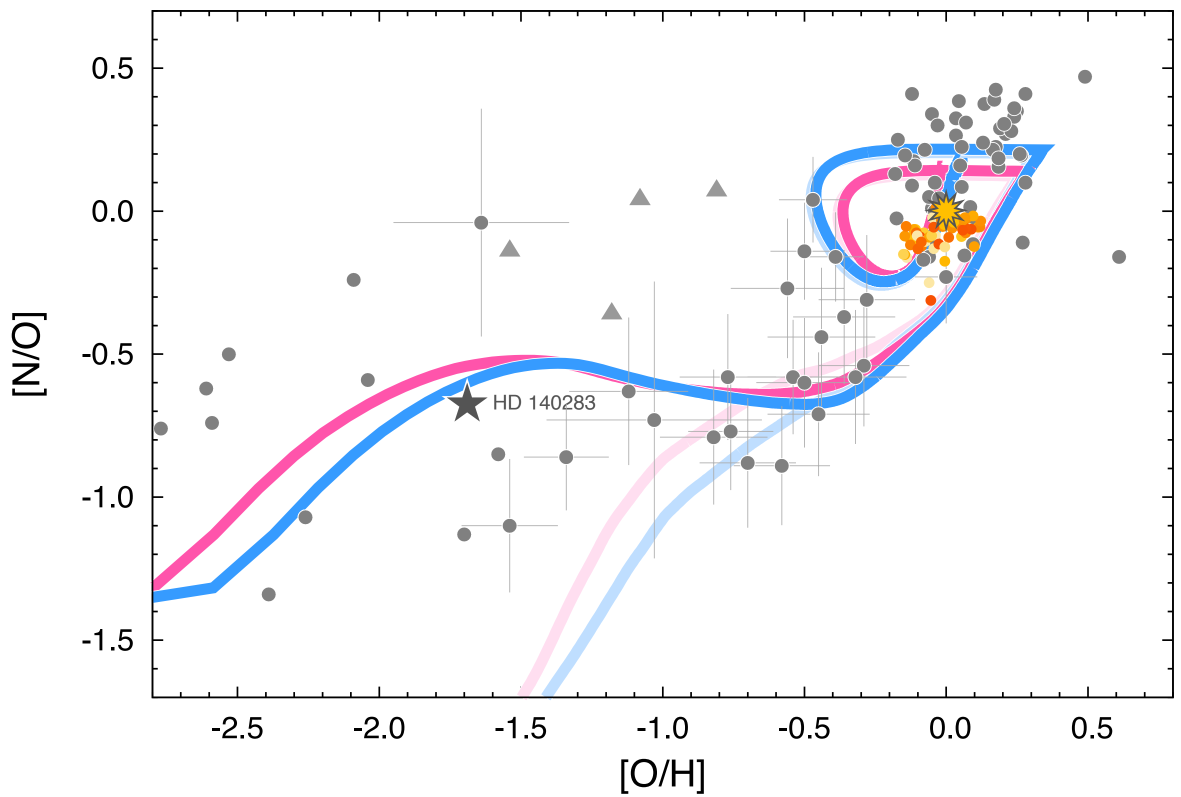


Figure from Zhang, DR+ (2018)

Primary ^{14}N from low-Z massive stars

- *Primary ^{14}N production in massive stars hypothesised long ago (Truran & Cameron 1971; Talbot & Arnett 1974)*
- *Explain observations of (N/O) in metal-poor Galactic dwarf stars and in ionized HII regions in our own and other galaxies (Sneden 1974; Smith 1975; Edmunds & Pagel 1978; Peimbert et al. 1978 + many others)*
- *Rotation trigger primary ^{14}N production (Meynet & Maeder 2002)*

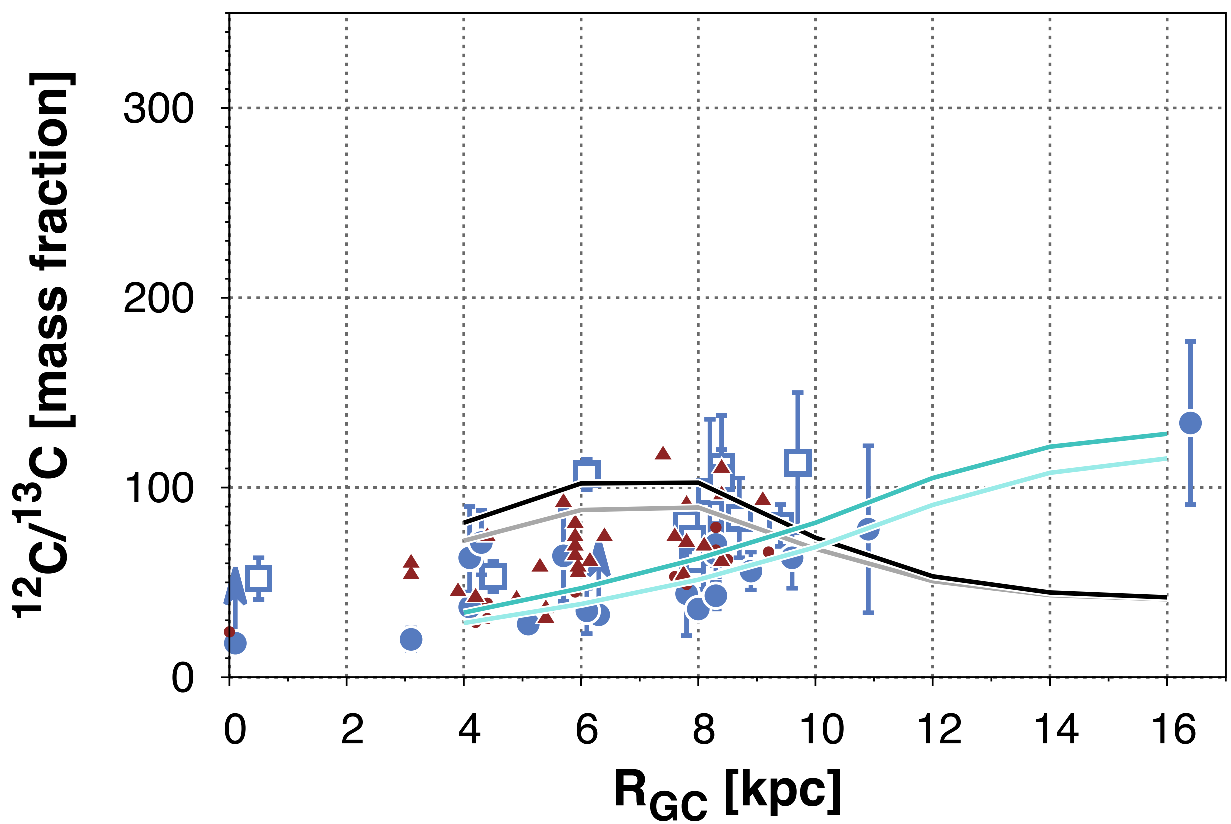


Data: Spite+ (2006); Israelian+ (2004); Roederer+ (2014); Suárez-Andrés+ (2016); Spite+ (2021); Botelho+ (2020)

Models: Romano+ (2019) updated (work in progress…)

Primary ^{13}C from low-Z massive stars

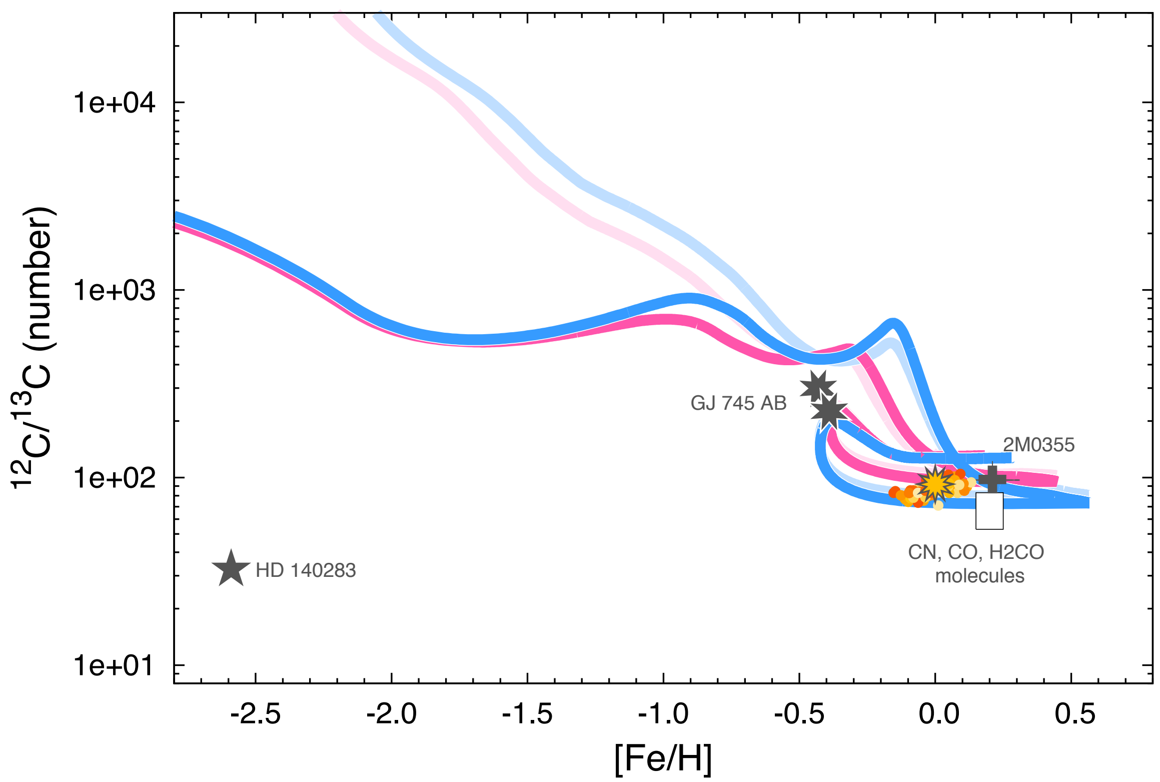
- *If rotation is at work, efficient primary ^{13}C production expected at low metallicities (Chiappini+ 2006)*
- *As a consequence, the $^{12}C/^{13}C$ gradient reverse in the outer Galaxy (Romano+ 2017)*
- *One data point at large Galactocentric distances!*
- *Can add stellar data? (HRMOS?)*



Data: Wilson & Rood (1994); Boogert+ (2000); Savage+ (2002); Milam+ (2005)
Green lines: GCE models without fast rotators
Black/grey lines: GCE models including fast rotators

Primary ^{13}C from low-Z massive stars

- *Recent, precise $^{12}C/^{13}C$ measurements in dwarf stars*



Data: Spite+ (2021); Crossfield+ (2019); Botelho+ (2020); Zhang+ (2021)
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Can HRMOS help me/us?

Work	Sample	Instrumentation	Resolution	Spectral feature(s)	Notes
Crossfield+ (2019)	2 M dwarfs	iSHELL@IRTF	70,000	CO fundamental bandheads at 5μ	Also measure $^{16}O/^{18}O$ for same stars
Botelho+ (2020)	63 solar twins	HARPS@ESO3.6m	115,000	CH A-X, CN B-X molecular electronic systems in the blue (4170-4400Å)	S/N≃800@6000Å (staked spectra)
Spite+ (2021)	1 old, metal-poor dwarf	ESPaDOnS@CFHT ESPRESSO@VLT HARPS@ESO3.6m	81,000 140,000 120,000	CH A-X, B-X and C-X transitions	S/N=1500@4200Å S/N=700@4200Å S/N=300@4200Å
Zhang+ (2021)	1 brown dwarf	NIRSPEC@Keck	27,500	K-band ($2.03-2.38\mu$)	

In the future: HIRES@ELT (R~100,000 S/N>100) for INDIVIDUAL STARS

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In a few years: $^{12}C/^{13}C$ in a significant sample of OC stars (?)