MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

Carbon, Nitrogen and the isotopic ratio $^{12}C/^{13}C$ in solar twins

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et al.

CAPES

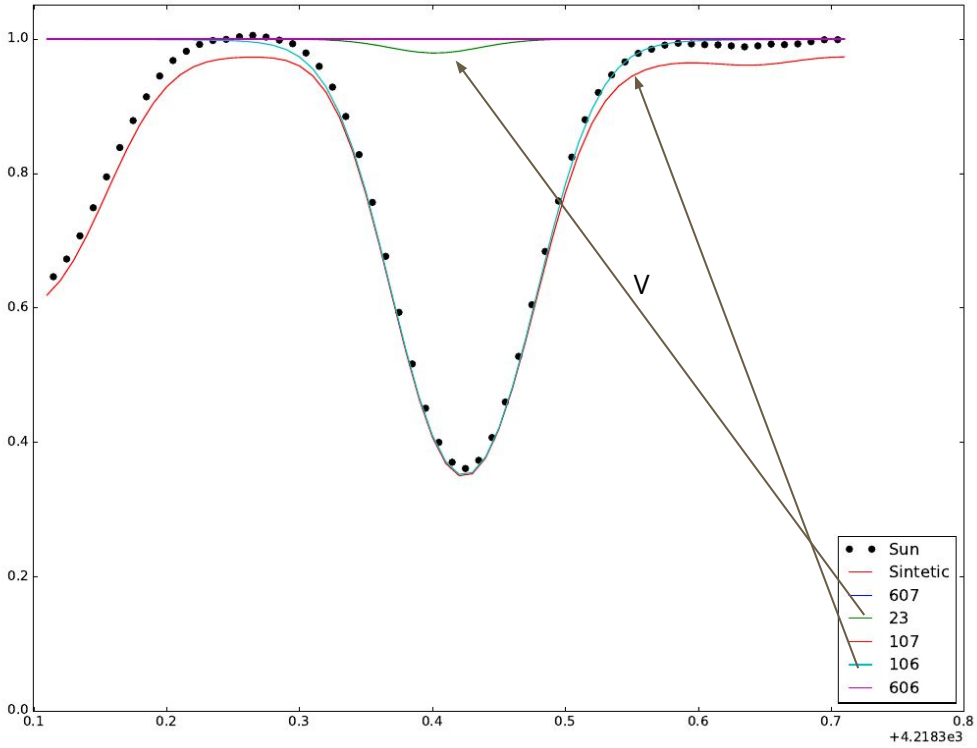
Motivation: connection to planet formation

- C, N and O are essential to life like we know
- They also play a role in the formation of giant planets
  - whose seeds are built beyond the snowline in proto-planetary discs through coagulations of dust particles, growth of cm-sized objects to km-sized planetesimals and collision/accretion of planetesimals to planetary embryos, in which ices of CNO act as efficient stickers (referencia)
- High precision CNO characterization in solar-type stars can help us to understand the planet formation: what about well-analysed solar twins?
- What would the C and N abundances and their isotopic ratios be in nearby solar twins along the Galaxy disc evolution?
- Were nearby solar twins born with a uniform $^{12}C/^{13}C$ ratio, or even a uniform chemical composition?
- Are the solar twins also solar siblings?

Sample: HARPS solar twins

- 66 stars + Sun
- Photospheric parameters, age, mass, Sr, Y, Zr, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd e Dy by Spina et al. (2018)
- **C**, **O**, Na, Mg, Al, Si, S, Ca, Sc, Ti, V, Cr, Mn, Co, Ni, Cu, e Zn by Bedell et al. (2018)
- HARPS: λλ3780 − 6910 Å, R=115.000
- T_{eff}: 5678 to 5912 K
- log *g*: 4.275 to 4.540 dex
- [Fe/H]: -0.126 to 0.132 dex
- Age: 0.5 to 8.4 Gyr
- Mass: 0.96 to 1.08 M_o
- V_{macro} & v.sin(i): dos Santos et al. (2016)

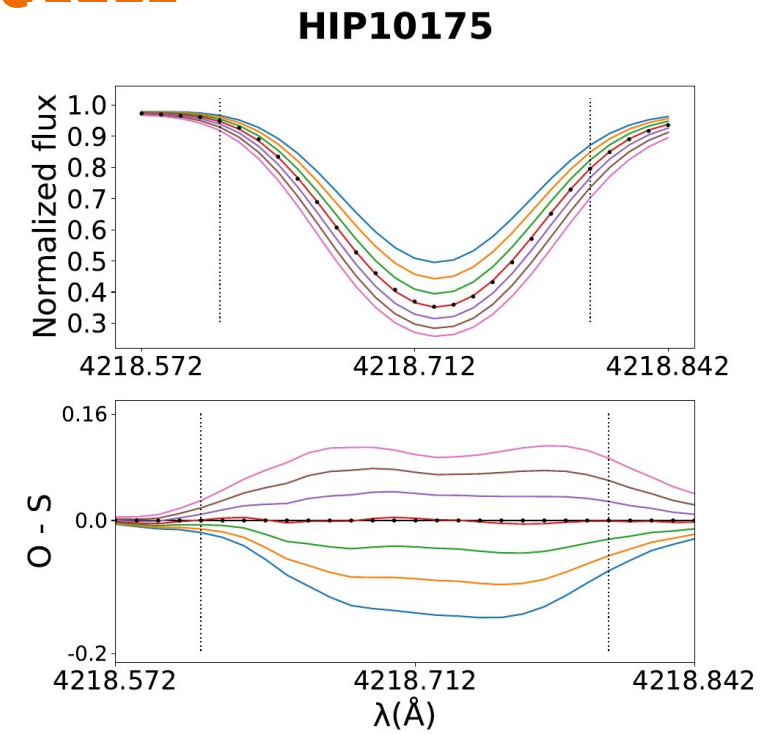
Lines

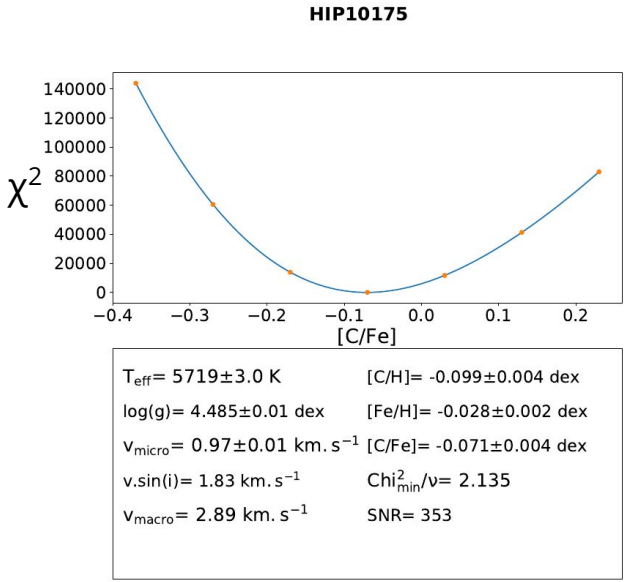


CH A-X lines	CN B-X lines	^{13}CH A-X lines
λ4211.0 Å	λ4180.0 Å	λ4297.1 Å
λ4212.6 Å	λ4193.0 Å	λ4298.1 Å
λ4216.6 Å	λ4193.4 Å	λ4299.4 Å
λ4217.2 Å	λ4195.9 Å	λ4299.7 Å
λ4218.7 Å	λ4212.2 Å	λ4300.6 Å
λ4248.8 Å		λ4303.3 Å
λ4255.2 Å		
λ4278.9 Å		
λ4281.9 Å		
λ4288.7 Å		
λ4378.2 Å		
λ4387.0 Å		

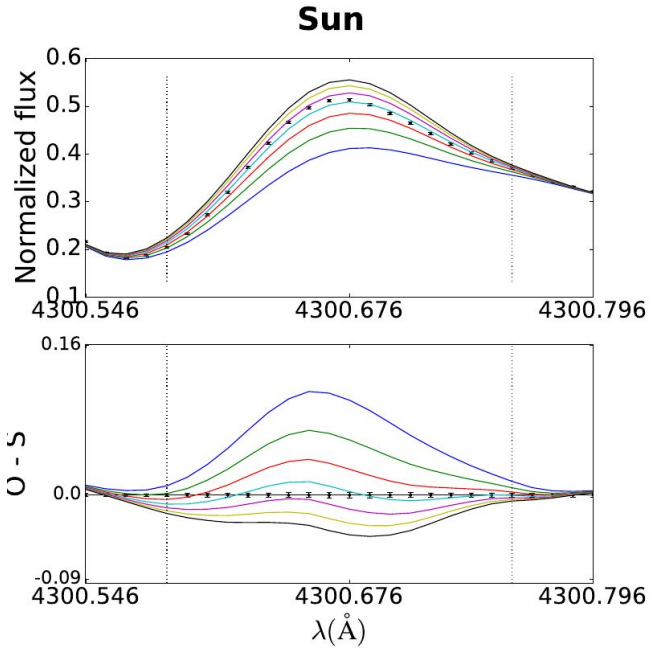
Synthesis Process

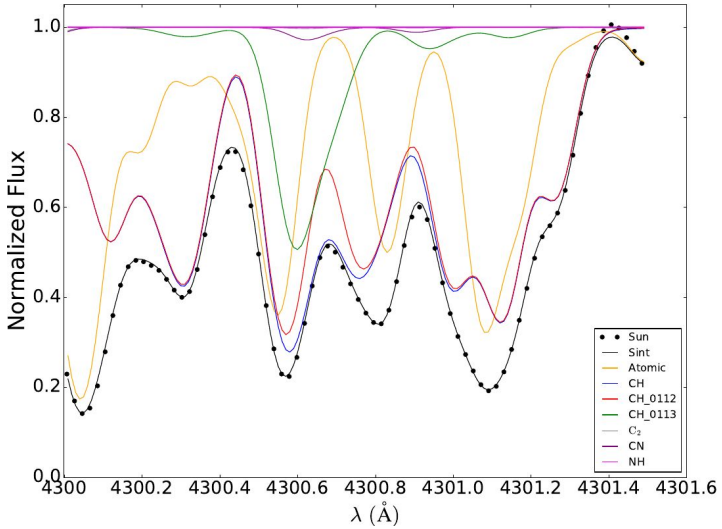
- 7 synthetic spectra
- step : 0.01 dex
- χ^2 minimization
- abundance error is due to the synthesis and error parameters propagation

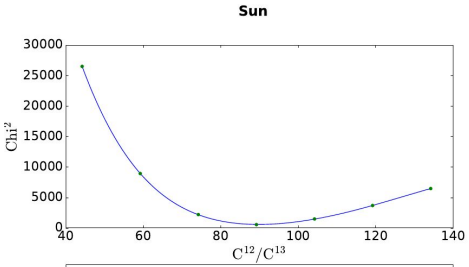




- 7 synthetic spectra
- step : 15
- Solar = 89.4

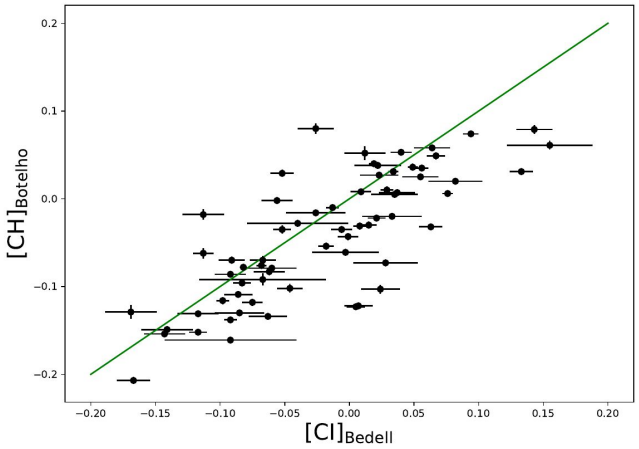


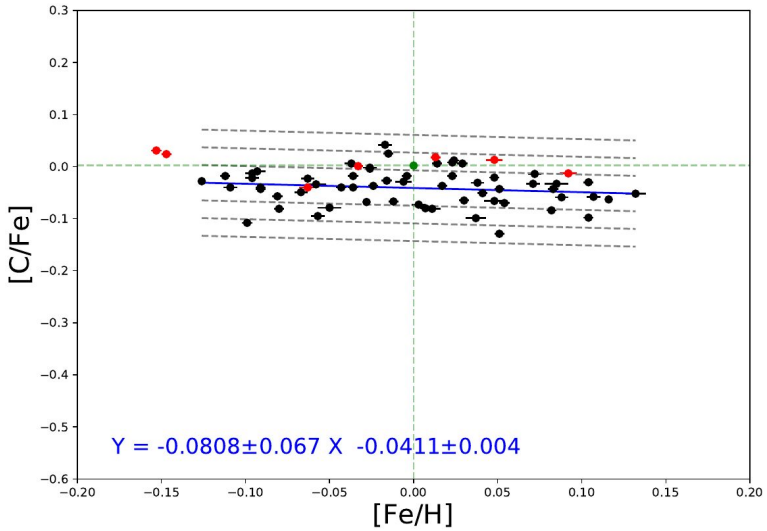




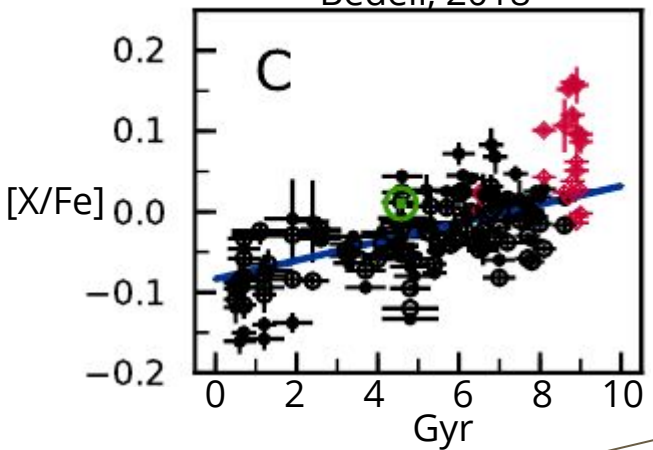
T_{eff}= 5777±0.0 K
C^{12}/C^{13}= 89.763±0.001
log(g)= 4.44±0.0 dex
[Fe/H]= 0.0±0.0 dex
v_{micro}= 1.0±0.0 km.s^{-1}
Chi^2_{min}/ν= 34.363
v.sin(i)= 2.04 km.s^{-1}
SNR= 266
v_{macro}= 3.2 km.s^{-1}

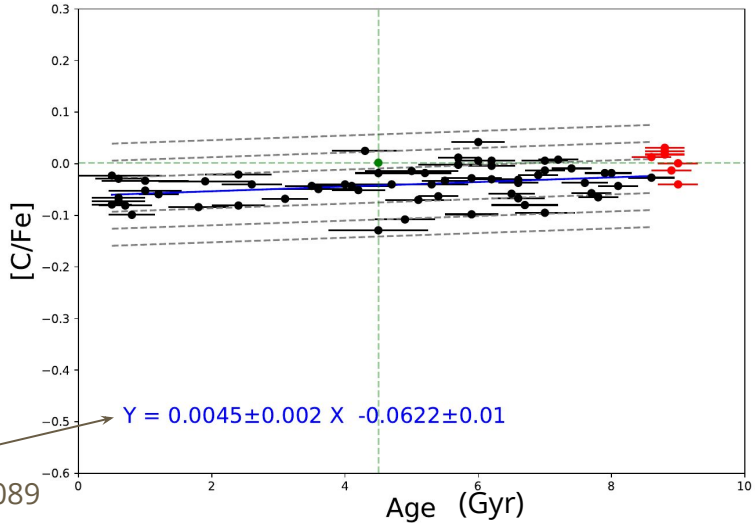
Carbon





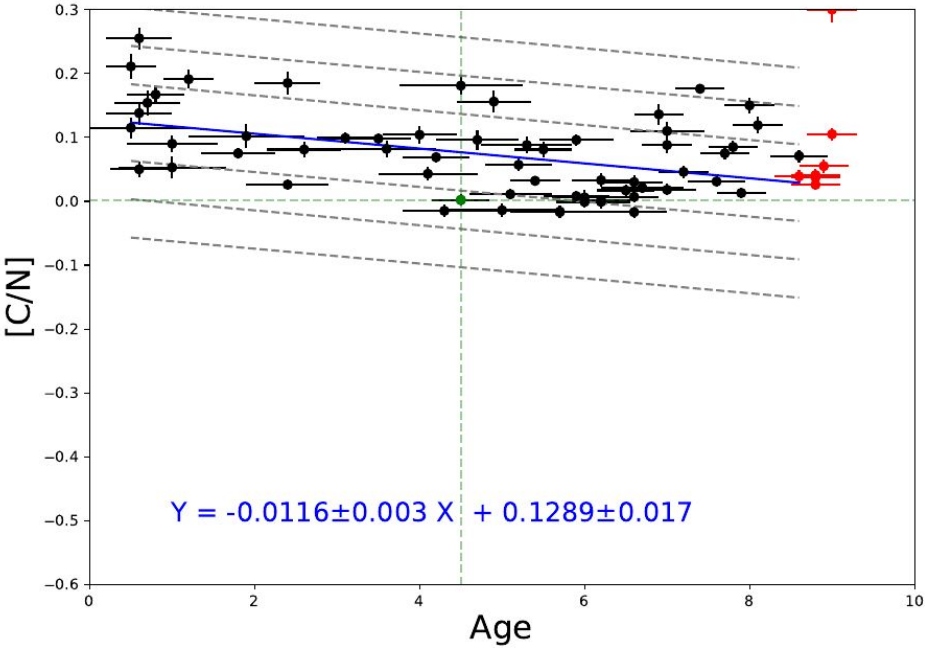
Bedell, 2018

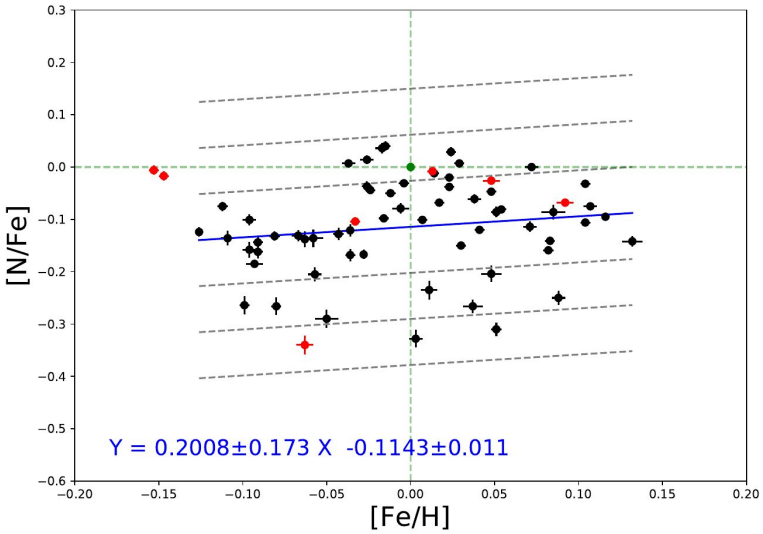


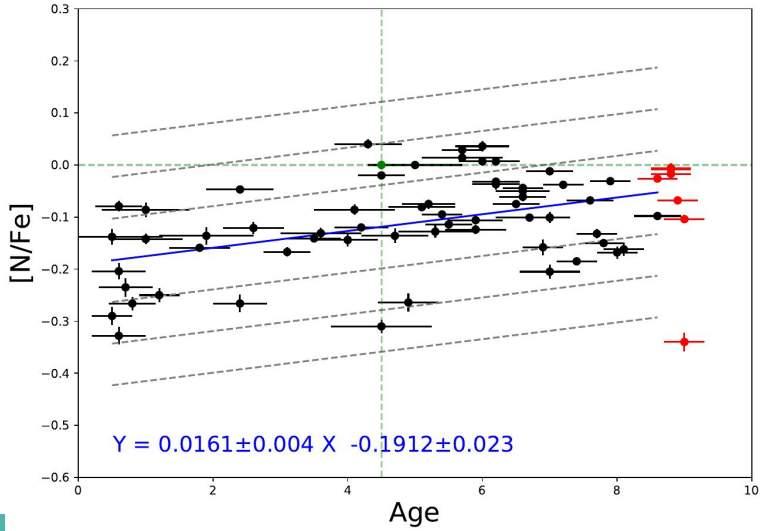


Y = 0.0115 ± 0.0014 X −0.0836 ± 0.0089

Nitrogen


[C/N]
Age
Y = -0.0116±0.003 X + 0.1289±0.017


[N/Fe]
[Fe/H]
Y = 0.2008±0.173 X -0.1143±0.011


[N/Fe]
Age
Y = 0.0161±0.004 X -0.1912±0.023

Isotopic ratio

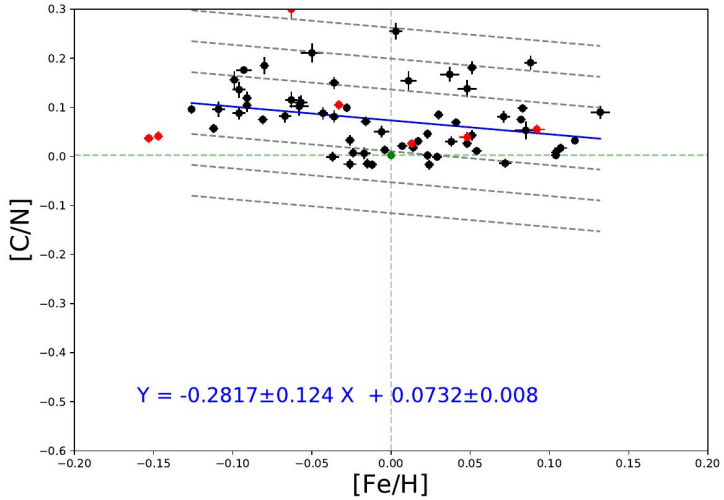
^{12}C ↓

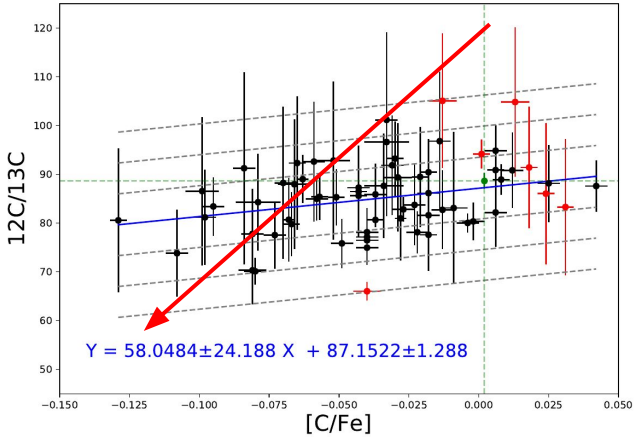
^{13}C ↑

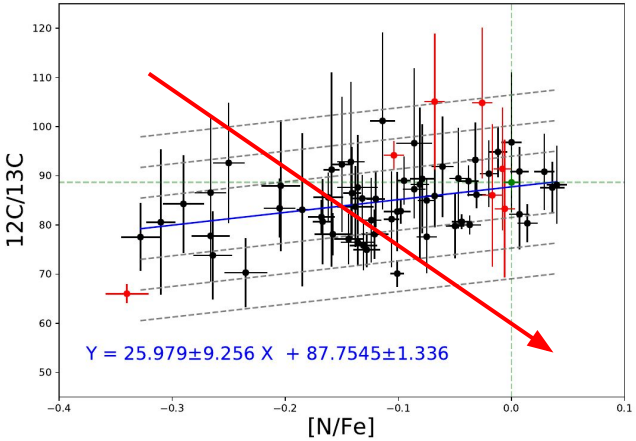
^{14}N ↑

^{15}N ↓

Core





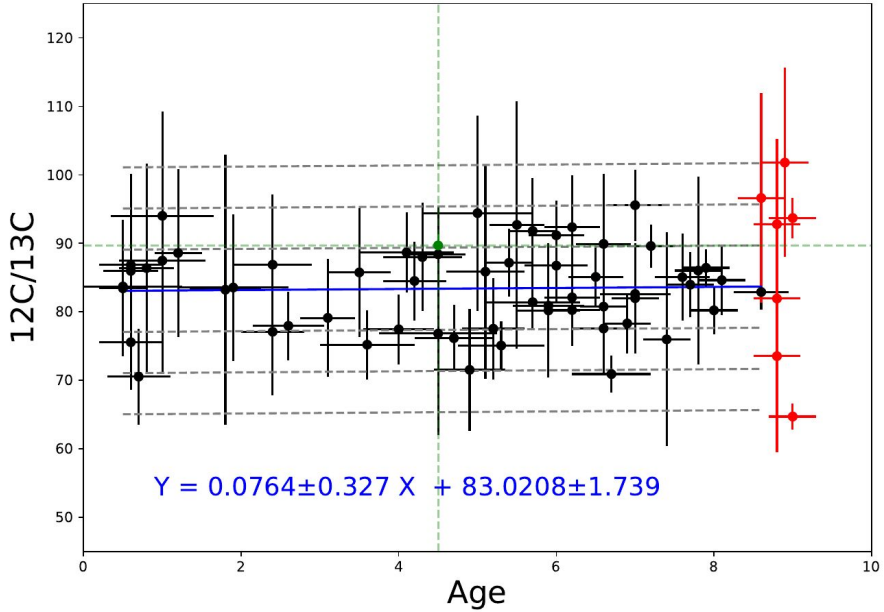


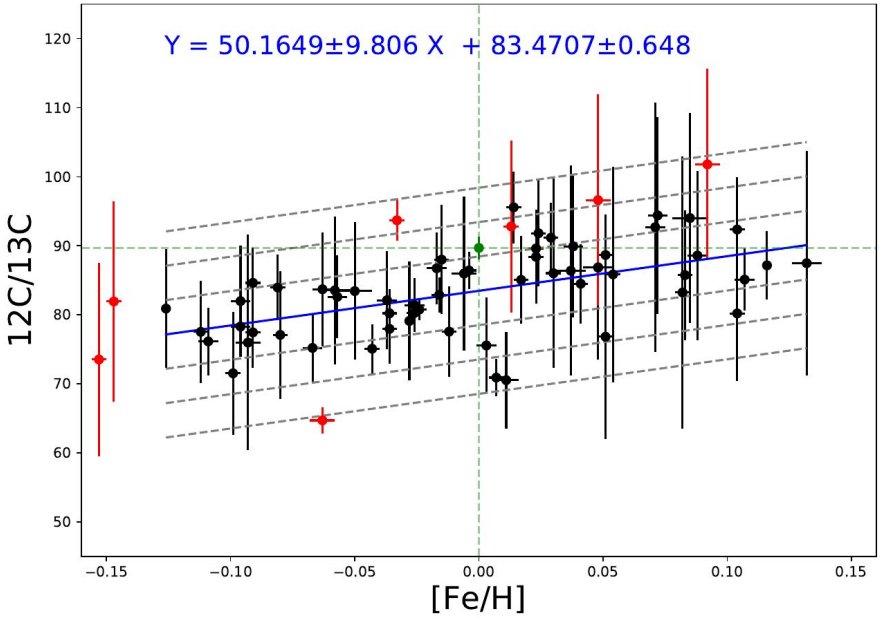
$^{12}C/^{13}C$ ↓

$^{14}N/^{15}N$ ↑

Photosphere

Isotopic ratio





Conclusions

- The volatiles C and N are slightly enhanced in the Sun relative to the refractory Fe in comparison with solar twins.
- Solar twins seem to be solar siblings indeed
  - $^{12}C/^{13}C$ ratio is uniformly solar across the age scale of solar twins
- There is a correlation between $^{12}C/^{13}C$ and [Fe/H] <=> Galactic chemical evolution in the solar neighborhood
- [C/Fe] is uniformly undersolar against [Fe/H] and age
- [N/Fe] is uniformly undersolar over [Fe/H], but it has a correlation with age
- [N/C] increases with age <=> Galactic chemical evolution in the solar neighborhood
  - N seems to be produced in more massive stars than C

Thanks