C/O ratios for planet hosts: comparing two oxygen indicators

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Outline

- Introduction
- Observations
- Standard analysis-solar abundances
- Results
- Summary

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C/O ratios can help us to:

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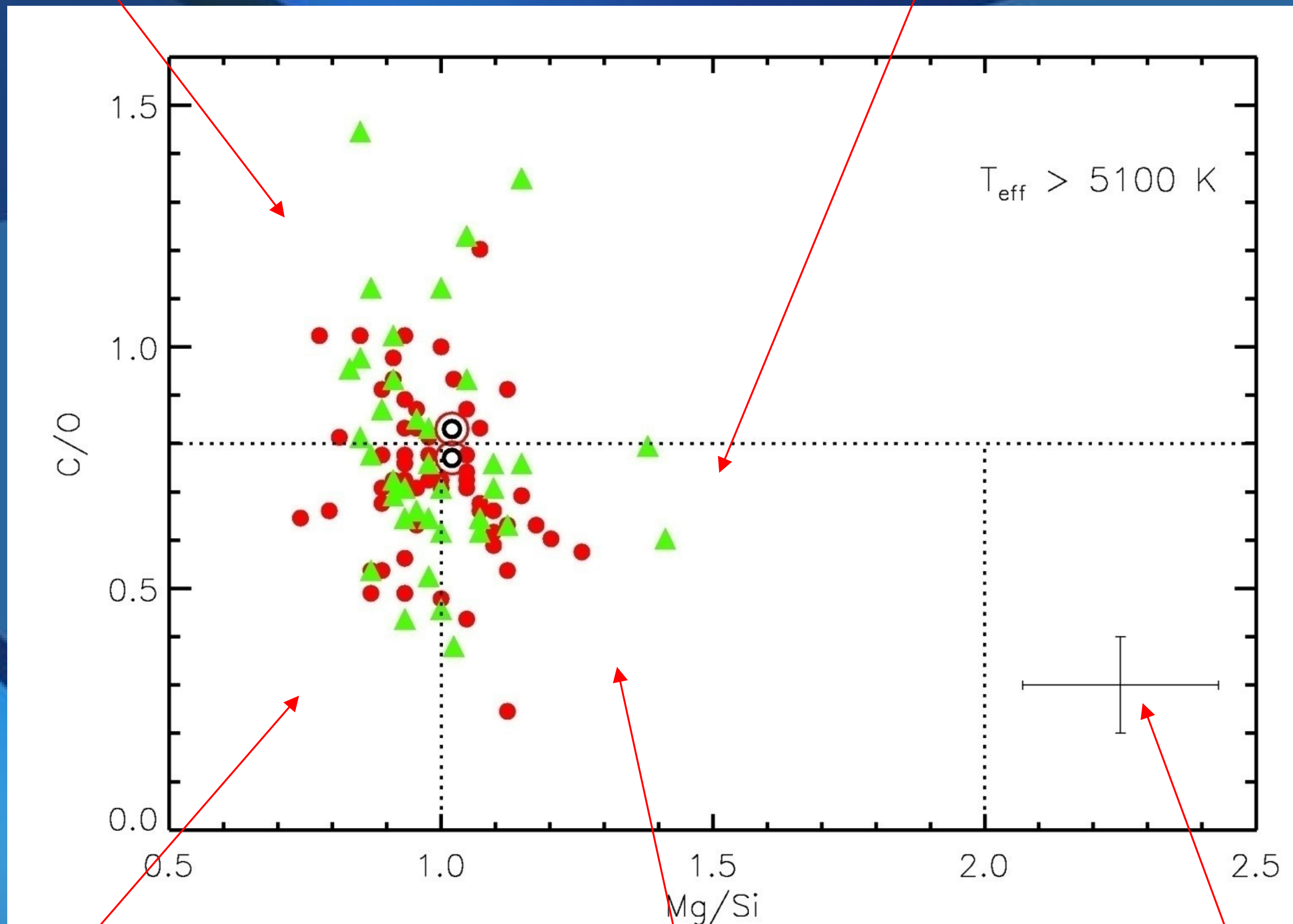
C-rich phases such as graphite, SiC and TiC

Si mainly present as SiO2



Mg as pyroxene (MgSiO3) and excess Si as feldspars

Mg mainly distributed as olivine and pyroxene

All Si as olivine (Mg2SiO4), MgO

Delgado Mena et al. 2010, Bond et al. 2010

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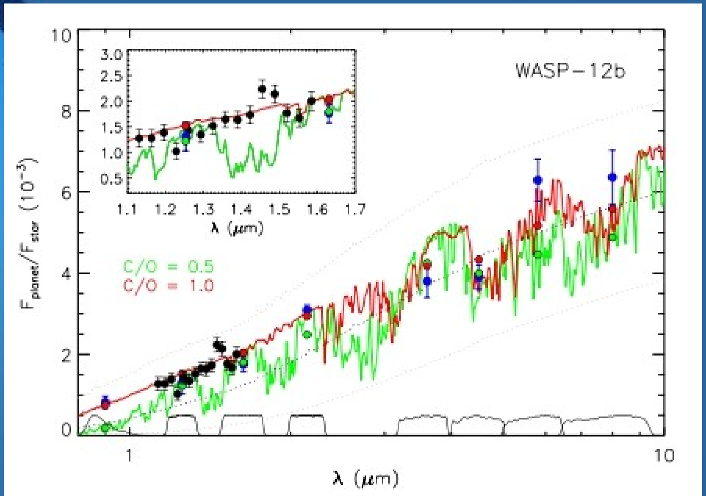
- Learn about galactic chemical evolution and constrain the production sites for these elements (SNII, SNIa, CNO cycle...)
- Constrain the bulk composition of planets: distribution of silicates and carbides (Bond et al. 2010)
- Regulate atmospheric chemistry of hot Jupiters (e.g. Oberg et al. 2011, Madhusudhan et al. 2012)



Observations and model spectra of dayside thermal emission from the hot Jupiter WASP-12b (Madhusudhan et al. 2012)

...but it's difficult to measure them

- Early studies of C/O in planet hosts yielded very high C/O ratios (Delgado Mena et al. 2010, Petigura & Marcy 2011) --> see discussions by Fortney (2012), Nissen (2013) and Teske et al. (2014)

- No agreement for high C/O found in WASP-12 atmosphere (Madhusudhan et al 2012, Swain et al. 2013; Kreidberg et al. 2015)

Stars, disks and planets share the same C/O ratios? (e.g. Oberg et al. 2011, Thiabaud et al. 2015)

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The sample

HARPS GTO sample (R=115000):
134 stars with planets
993 stars without detected planets
4500K < Teff < 6500K -1,35 < [Fe/H] < 0.45

Other planet hosts:
UVES/VLT spectrograph (*R*=80000/110000)
FIES/NOT (*R*=67000)
FEROS/2.2ESO (R=48000)

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Carbon lines:

- High excitation optical lines at 5052A and 5380A, negligible NLTE effect for solar type stars (Nissen 2014, Takeda & Honda 2005)
- CH band ~4300 A (see talk by Lucía Suárez Andrés in tomorrow session of Sat. Meeting 8)
- [CI] line at NIR
- C2 electronic lines (less reliable, Asplund et al. 2005)

Oxygen lines:

- OH lines in near UV
- [OI] lines at 6300A and 6363A: different abundances for the Sun and other dwarf stars, not for giants (Caffau et al. 2013)
- OI high excitation line at 6158A
- O NIR triplet --> strong but severely affected by NLTE

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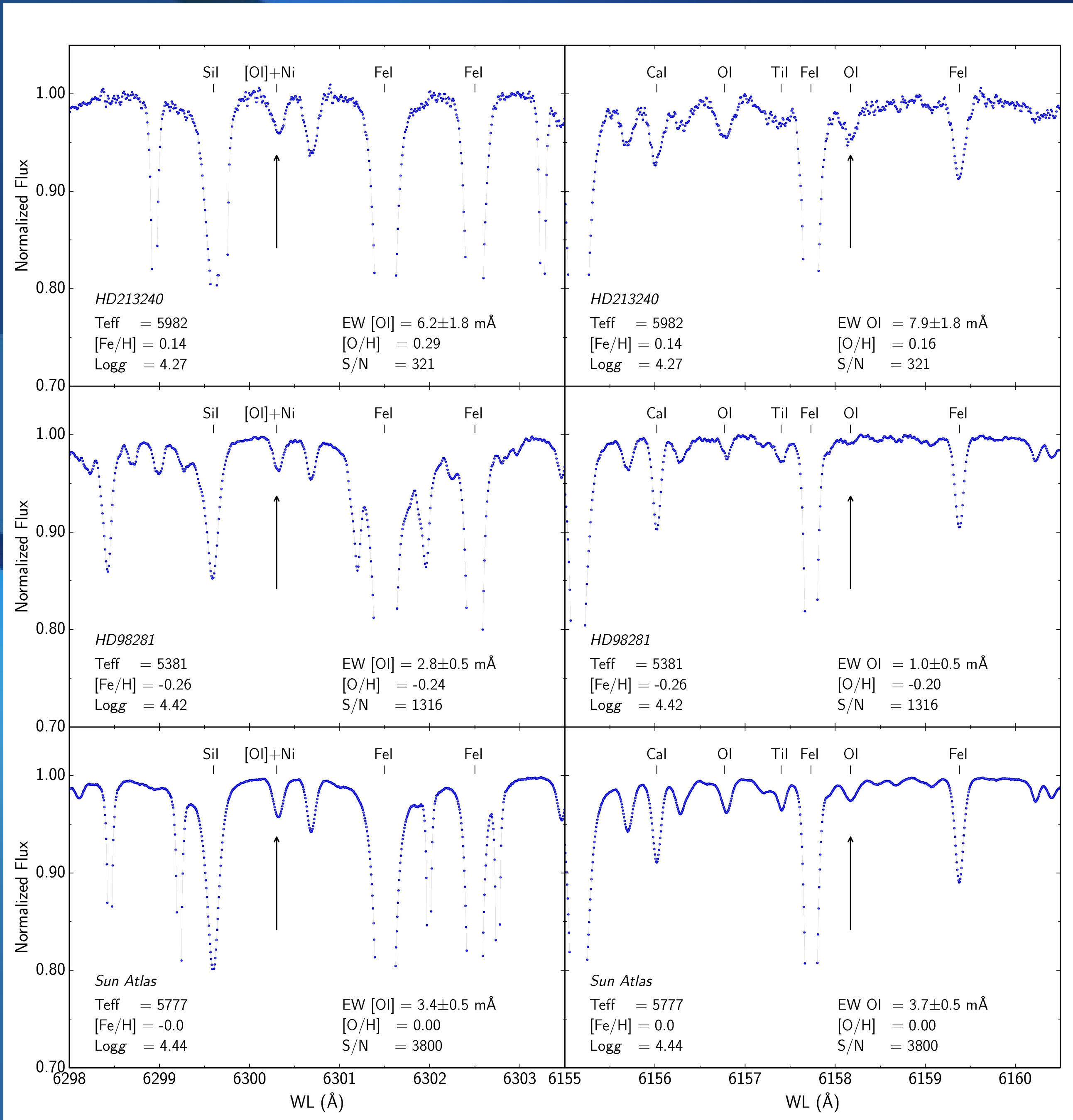
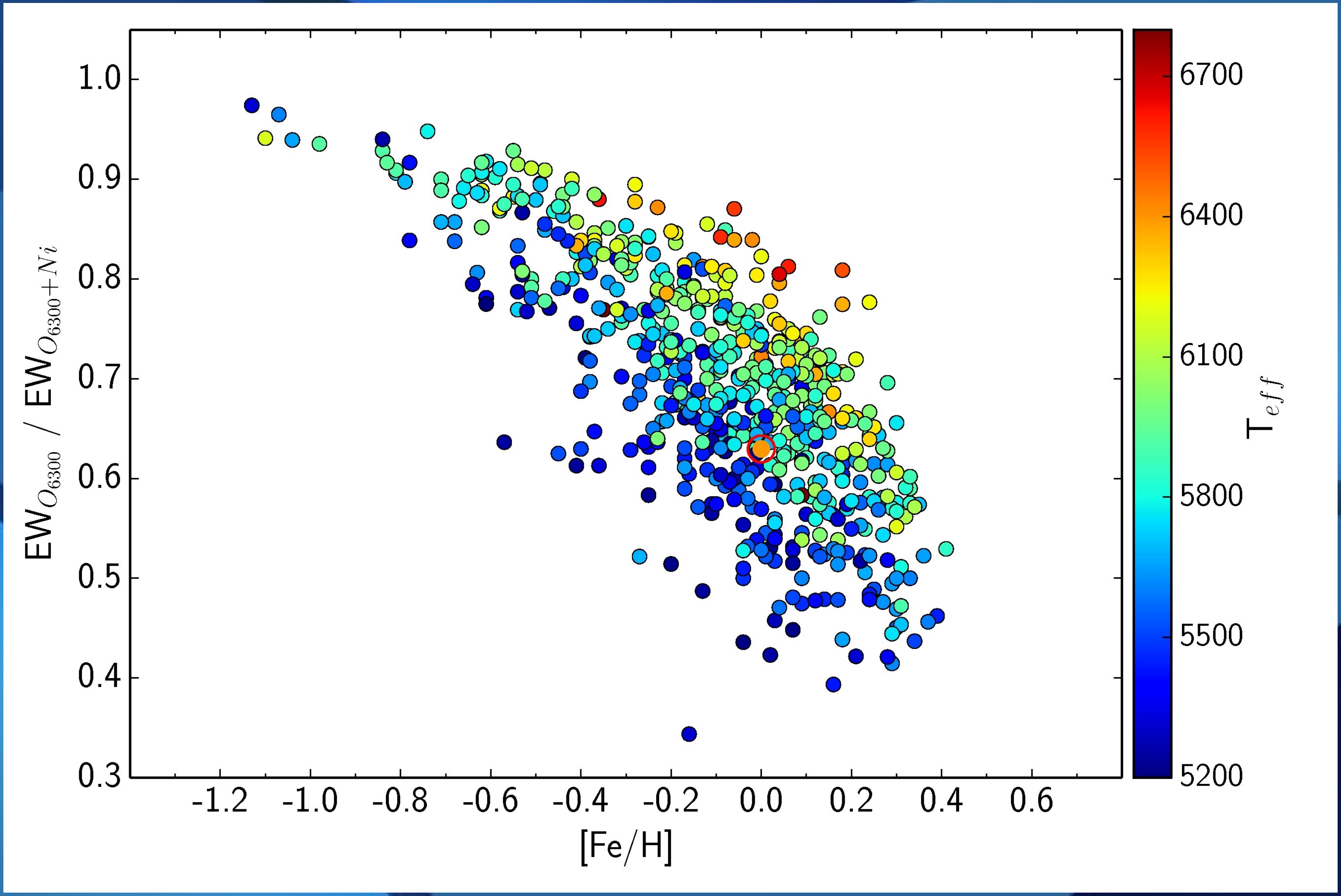
LTE analysis with MOOG code (2013) and kurucz model atmospheres

Standard analysis



Different stars analyzed by Bertrán de Lis et. al. (2015)

Standard analysis



Effect of Ni blend on [OI] line (Bertrán de Lis et. al. 2015)

Solar reference approach

Chemical abundances studies take usually solar abundances as a reference --> differential analysis

• Choose a literature solar abundance

• Choose a literature solar abundance and calibrate the log gf's to match a given set of EW's (measured by the authors)

• Consider laboratory log gf's and obtain your own solar abundances with your own EW's measurements

Solar abundances

	Asplund 2004,2009 3D mod	Caffau 2008, 3D mod	Delgado Mena 2010, 1D KURUCZ models	This work/Bertran de Lis 2015, 1D KURUCZ models	This work 1D MARCS models
Log C	8,43	8,50	8,56 (Anders & Grevesse 89)	8,48	8,37
Log O	8,69	8,76	8,74 (Nissen 02)	----	----
Log O 6300	8,69	8,69	8,60 (harps solar spectrum)	8,65	8,61
Log O 6158	8,62	8,64	----	8,71	8,61
C/O	0,55	0,55	0,66/0,83	0,67/0,59	0,57

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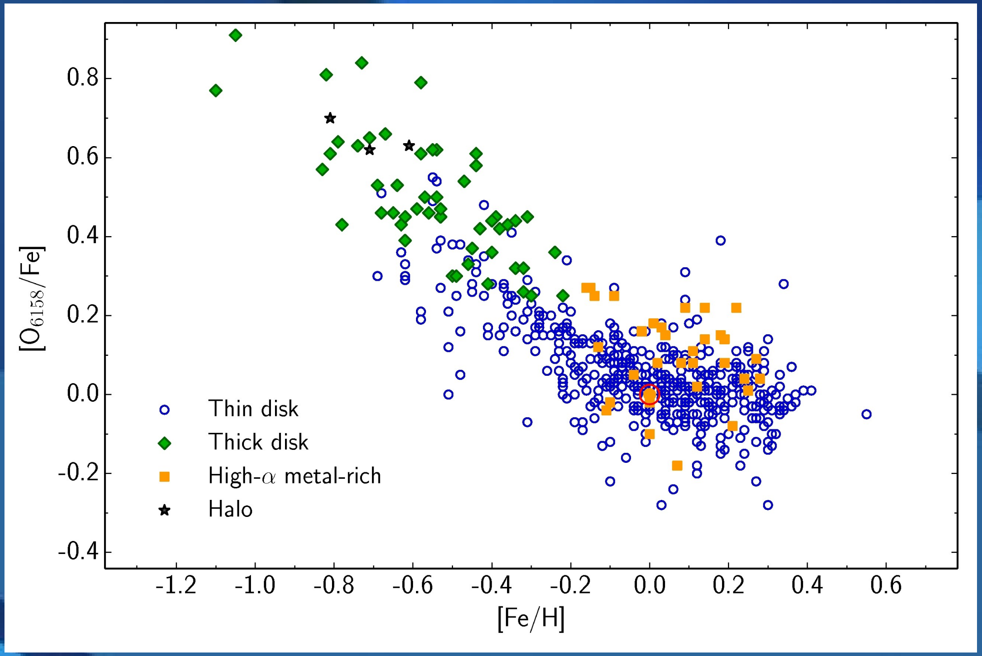
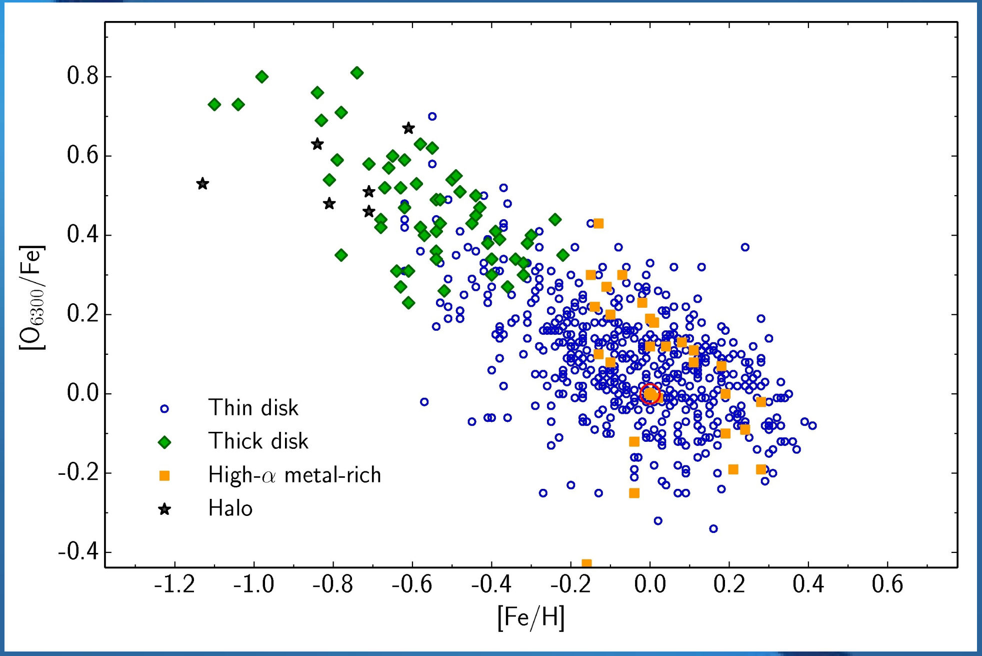




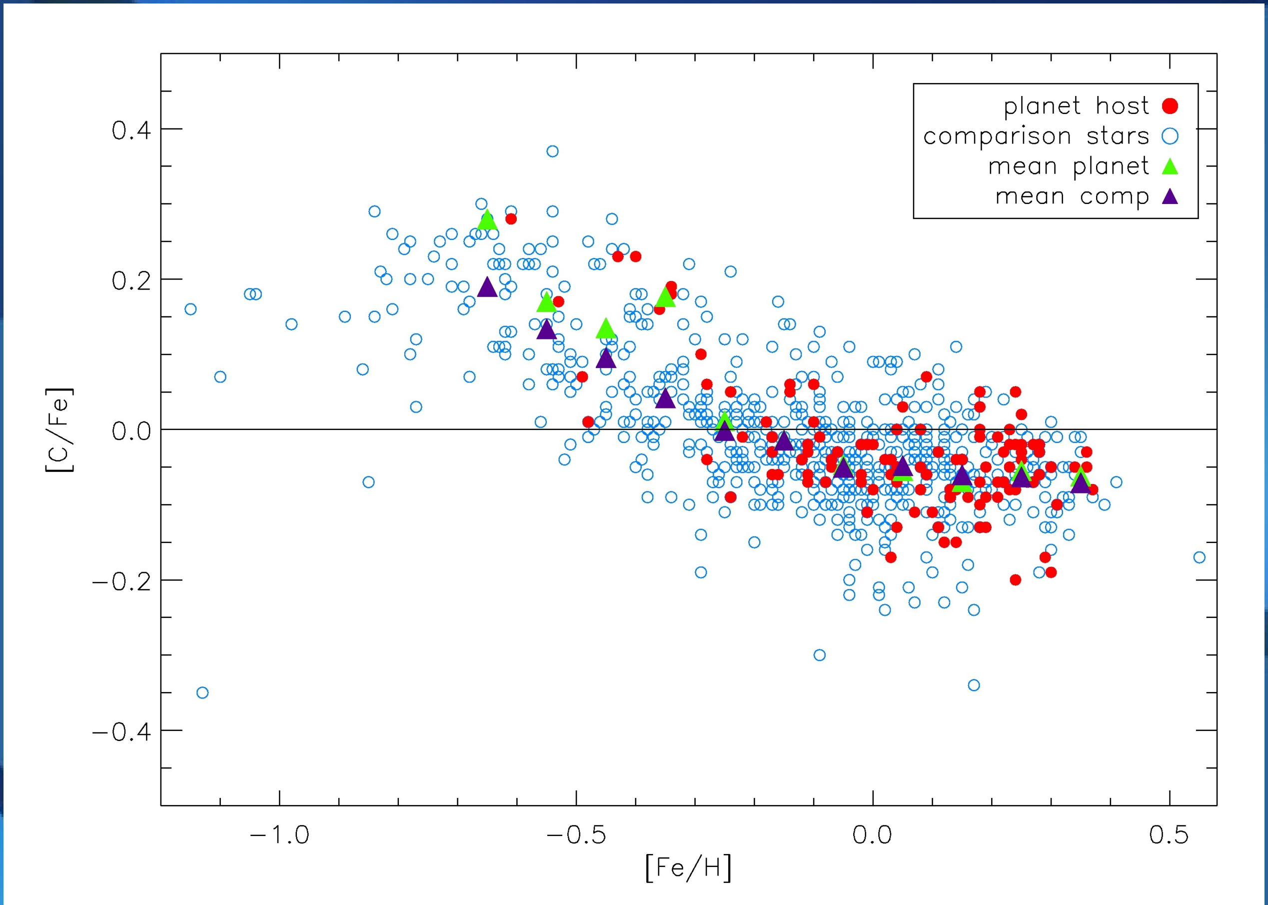
Oxygen abundances from Bertran de Lis (2015) using same spectra and same stellar parameters than this work

6158A: 98 PH+437CS
6300A: 96 PH+512CS

O6158 is 0.024dex higher on average than O6300 (0.05dex for high S/N)

Oxygen is a pure alpha element, produced in the explosion of SNII. Galactic populations based on chemical criteria by Adibekyan (2011)

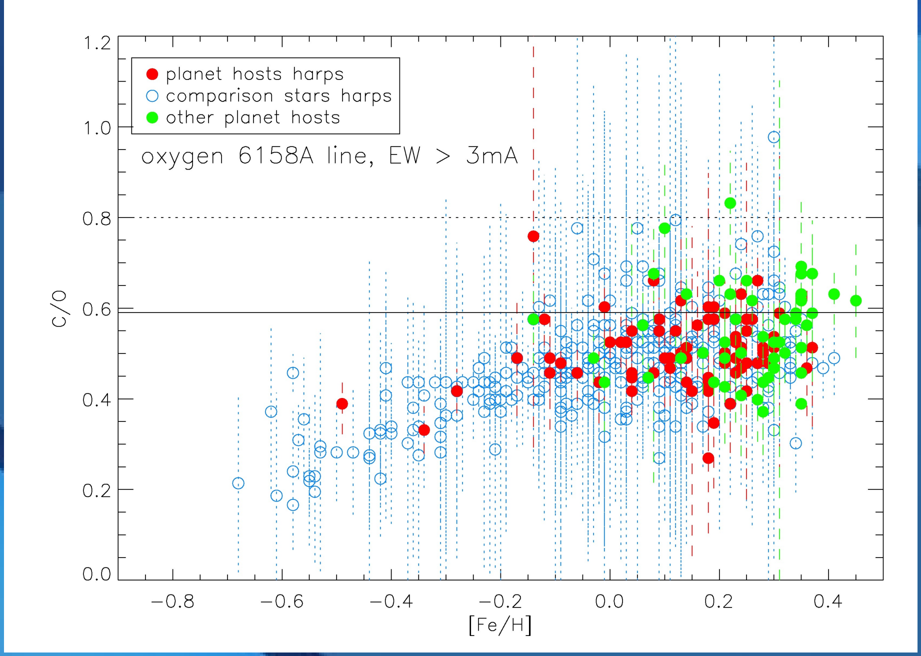
Results

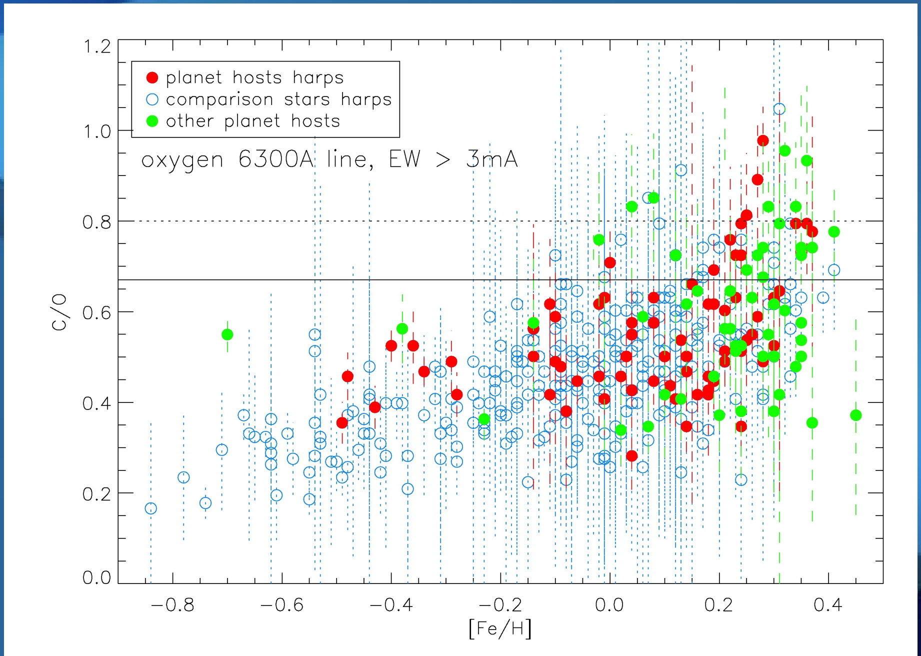


Delgado Mena et al. 2015 (in preparation)

110 planet hosts and 648 stars with no detected planets (Teff > 5200K)
Carbon behaves in a similar way as alpha elements but it's also created in SNIa and CNO cycle. Important for planet formation?
[C/Fe] are 0.07 dex higher for metal poor planet hosts--> higher differences for stars hosting smaller planets

C/O from both oxygen lines





C/O ratios show very high errors, differences up to 0.53 dex between both lines

Less dispersion with 6158A line, only 1% of stars show C/O > 0.8 (full sample)

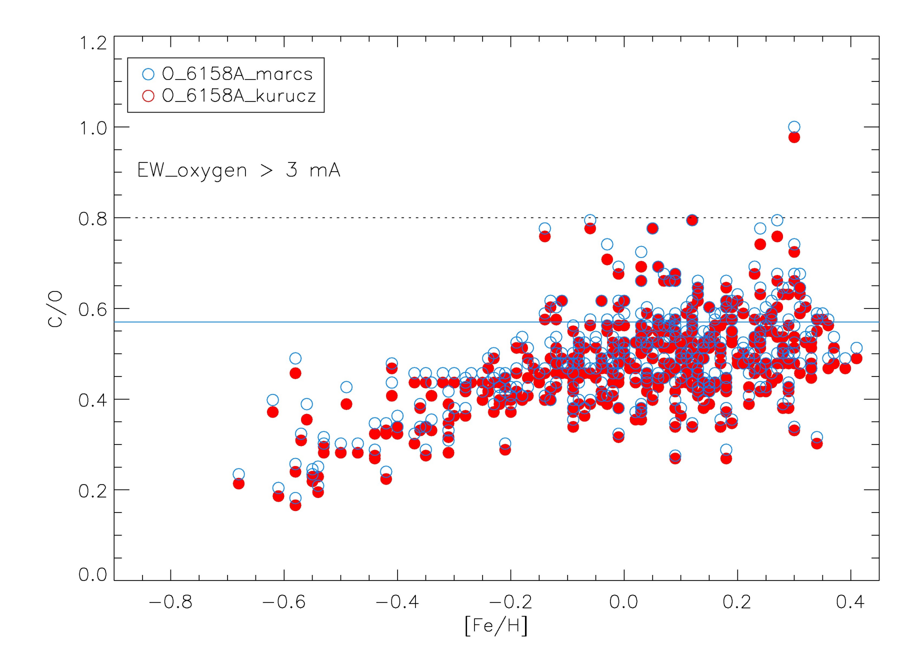
For the forbidden line 8% of stars show high C/O (full sample)

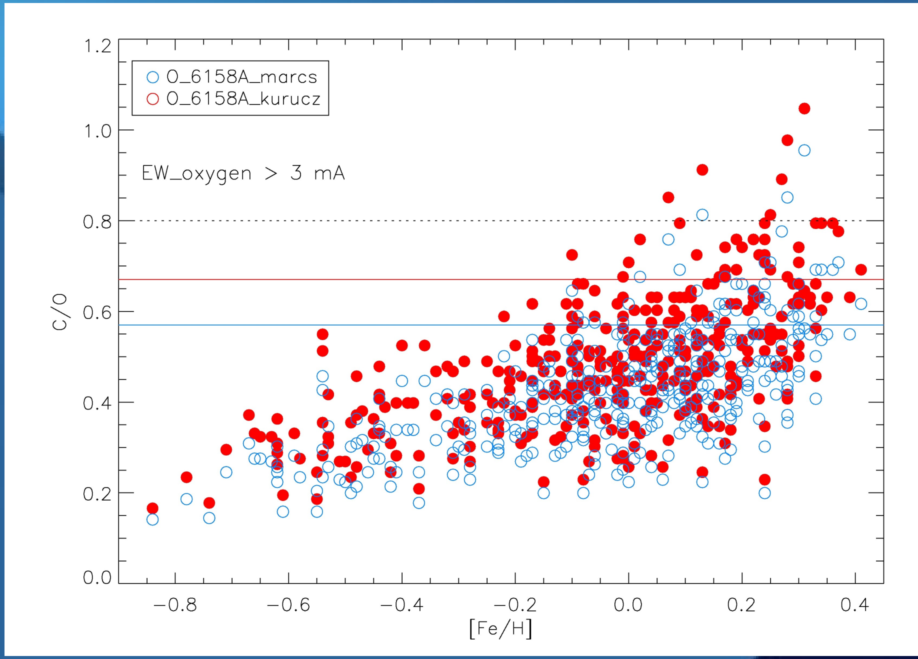
Discard very weak lines

55 Cnc: C/O=0.43-0.75

WASP-12: C/O=0.32-0.50

MARCS vs KURUCZ models





Carbon with MARCS models: 0.08-0.12 dex lower, increase diff. with [Fe/H]
Oxygen 6158 with MARCS: 0.09-0.15 dex lower, no effect of [Fe/H]
Oxygen 6300 with MARCS: 0.00-0.06 dex lower, increase diff with [Fe/H]

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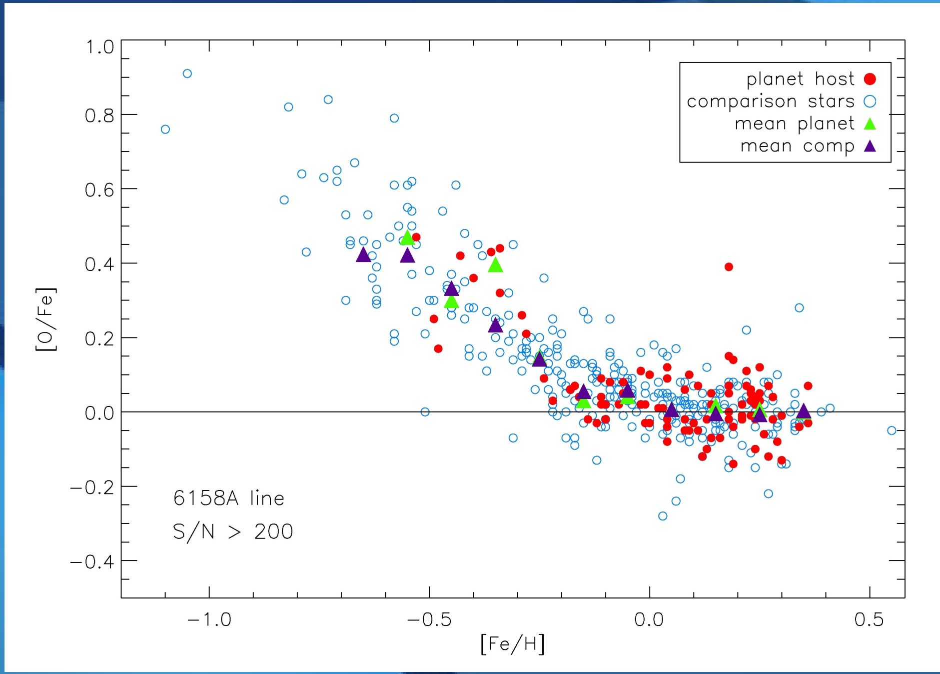
C/O ratios are important to understand the formation, evolution and composition of stars, disks and planets:

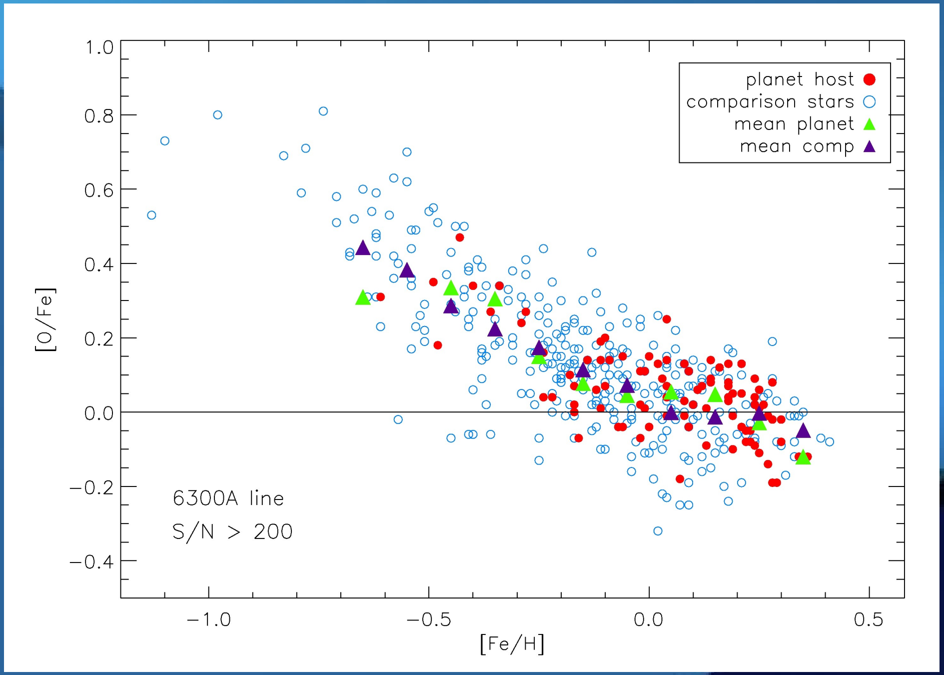
- O abundances are affected by important uncertainties, difficult to determine even for the Sun
- The C/O ratios are strongly affected by errors in oxygen abundances and reference solar abundance (don't mix C/O ratios from different authors)
- Our new analysis shows a much lower number of systems with high C/O. Better to use 6158A line when it's not very weak


Thanks


Thanks

Results





Oxygen is a pure alpha element, produced in the explosion of SNII.
Difficult determination of abundances.