Constraining HJ Compositions via Host Star Abundances of Planet-Building Elements

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Carnegie DTM/OCIW

collaborating with

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Jonathan Fortney (UCSC)

Towards Other Earths II
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Travel partially funded by AAS Travel Grant

How do we learn about exoplanet composition?

me, skydiving

my mom, not skydiving

To understand the child, one must consider the parent(s)

What can the host star tell us?

Why is C/O interesting?

How is this a cautionary tale?

What is the frequency of C-rich host stars?

How can we relate stellar abundances to planet composition?

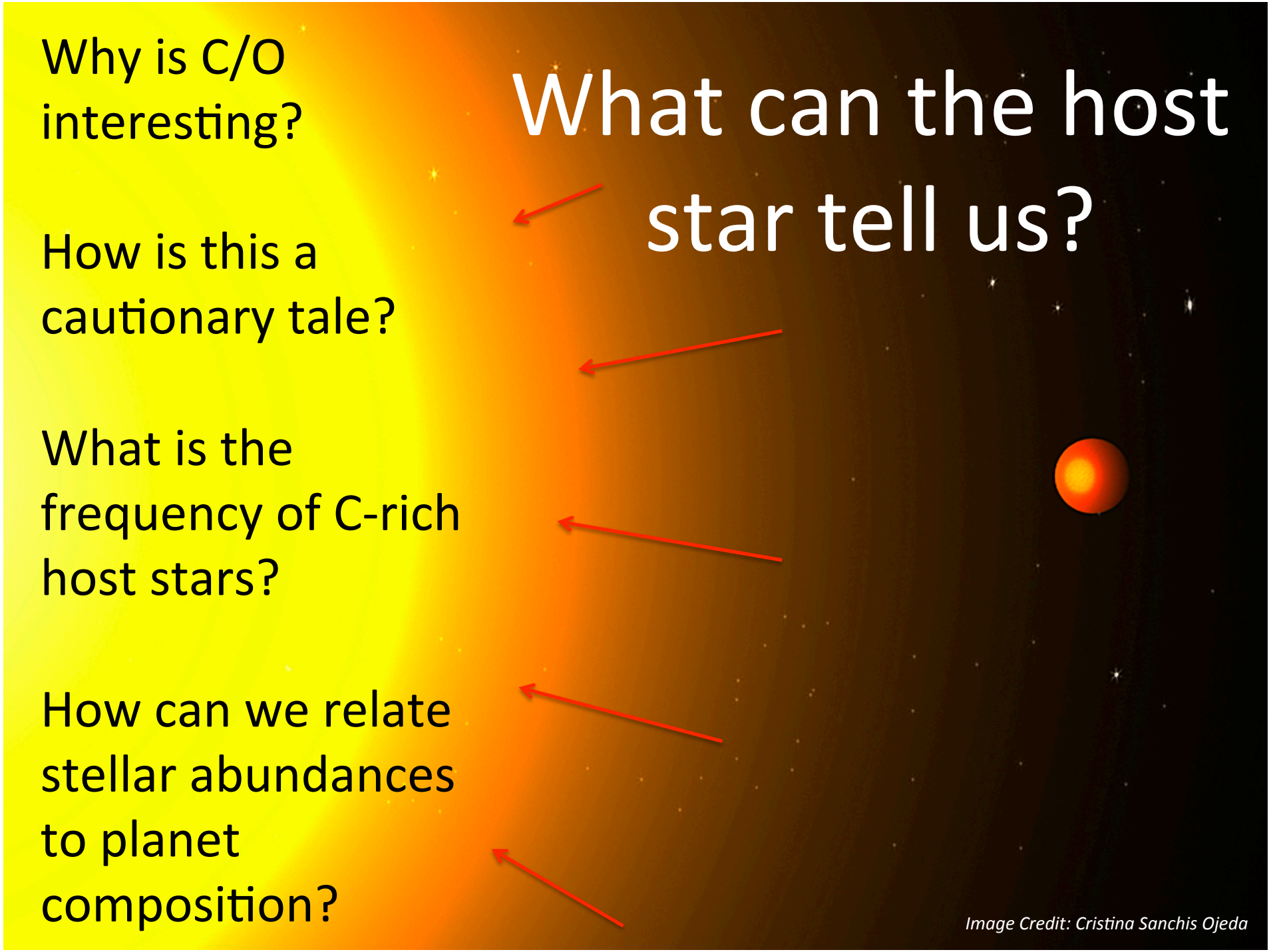
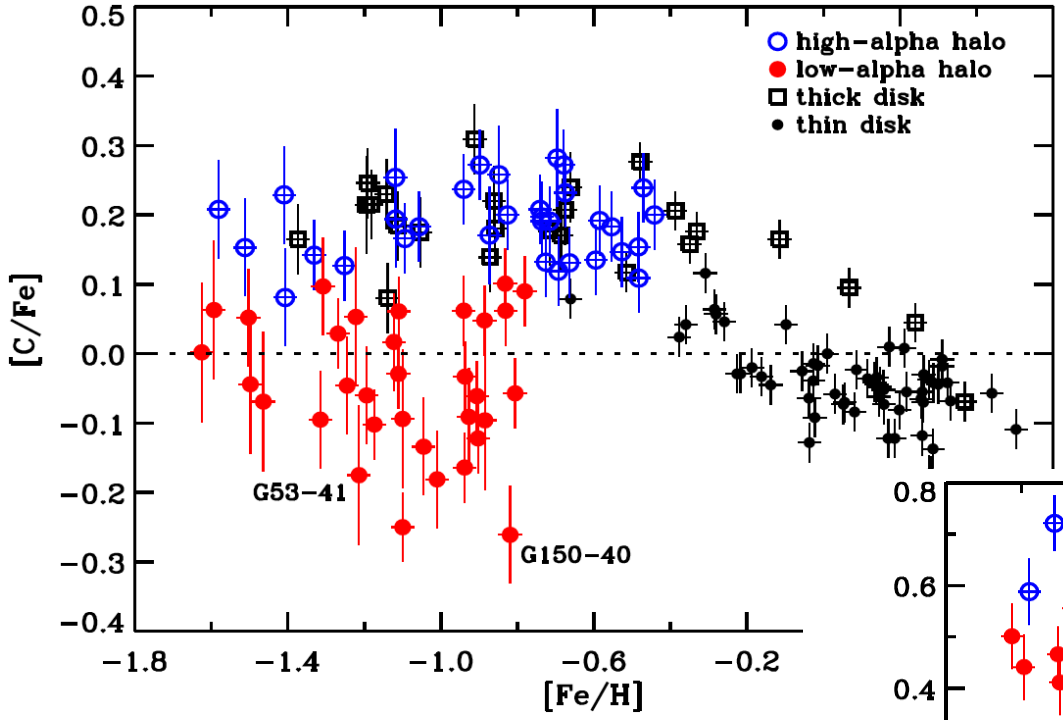


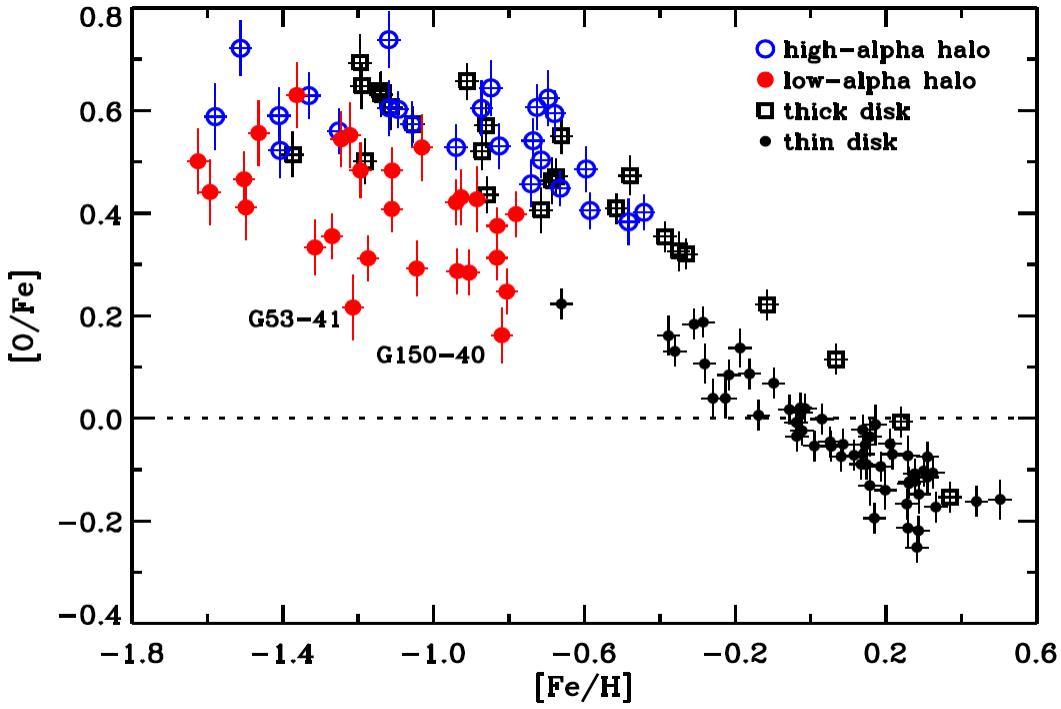
Image Credit: Cristina Sanchis Ojeda

Why is C/O interesting
in stars?



Galactic chemical evolution

Increasing C/O with [Fe/H]

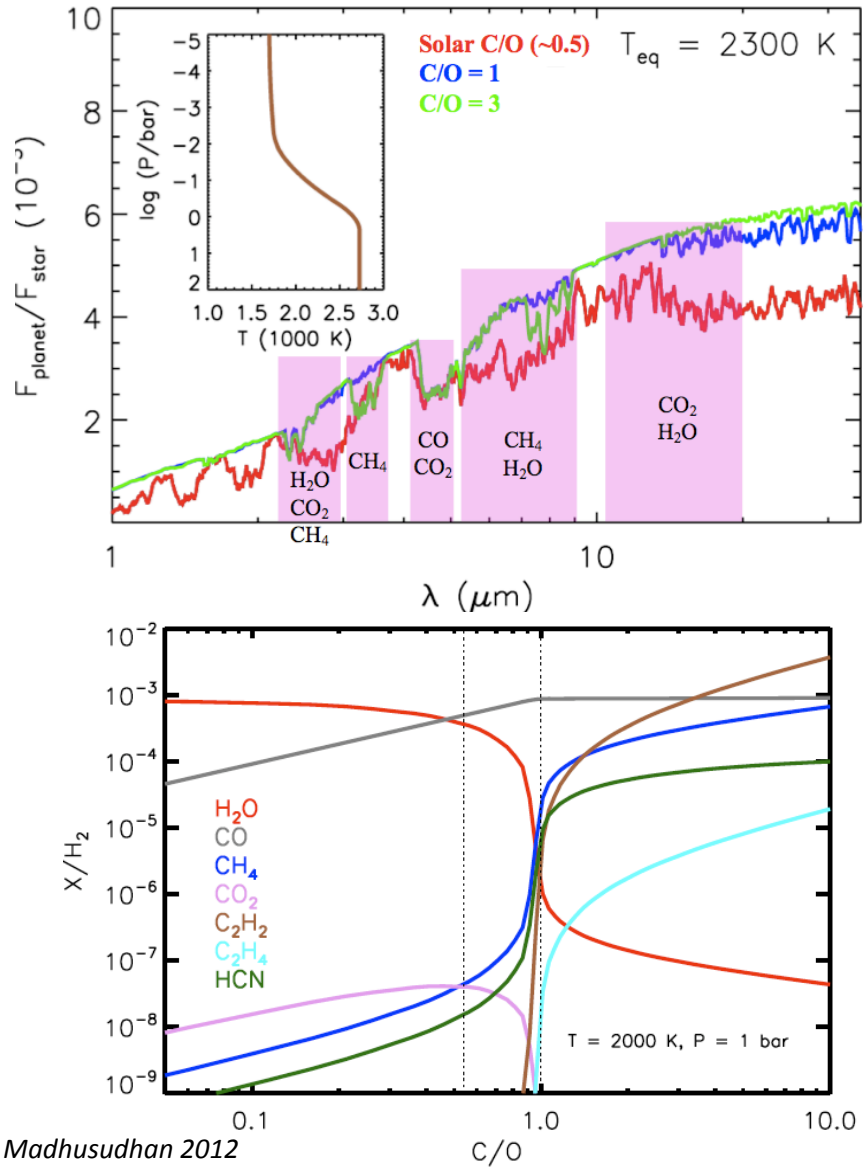


Nissen et al. 2014

($C/O_{\odot}$ 0.54)
($Mg/Si_{\odot}$ 1.07)

Why is C/O interesting

in hot Jupiters?

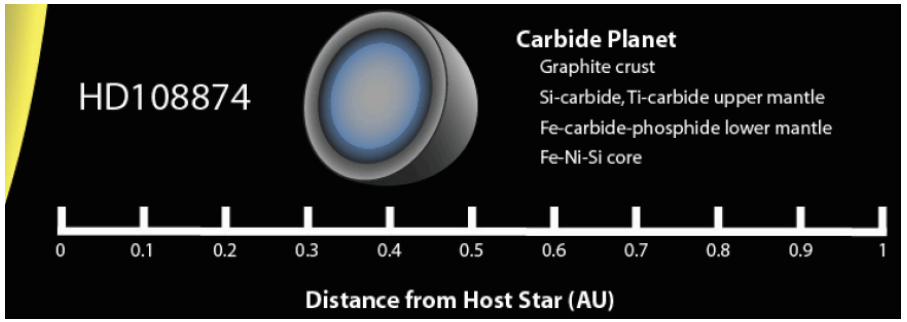


Madhusudhan et al. 2011

Madhusudhan 2012

in terrestrial planets?

C/O 1.35, Mg/Si 1.45



Bond et al. 2010

Oceans of tar?

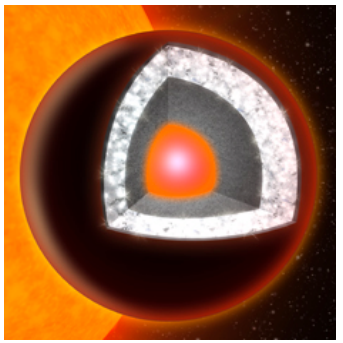
Lower probability of plate tectonics?

Habitability decreased?

Diamond interior?

55 Cnc

C/O 1.12, Mg/Si 0.87



Haven Giguere

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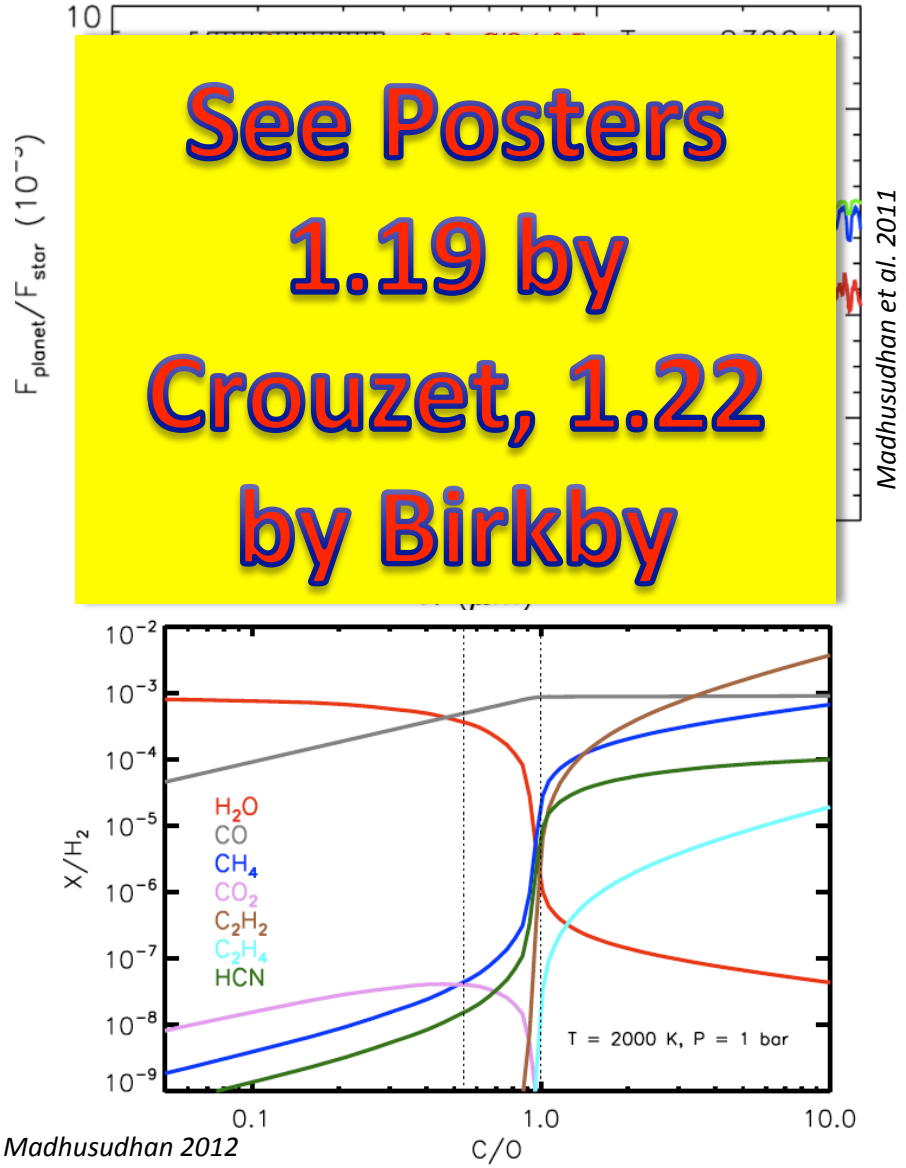

Madhusudhan 2012

See Posters 1.19 by Crouzet, 1.22 by Birkby

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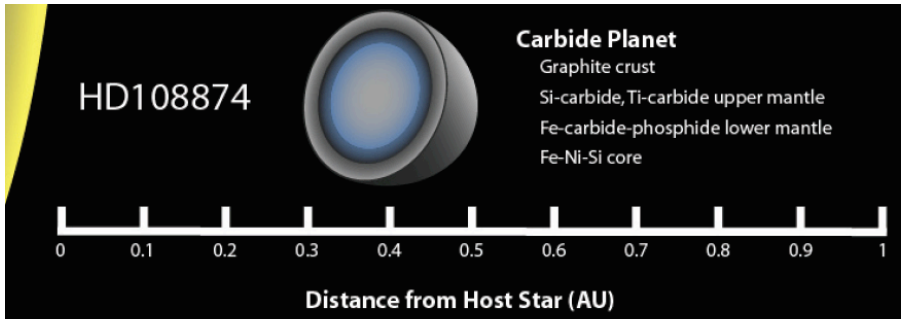

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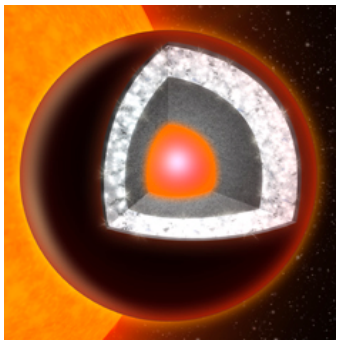

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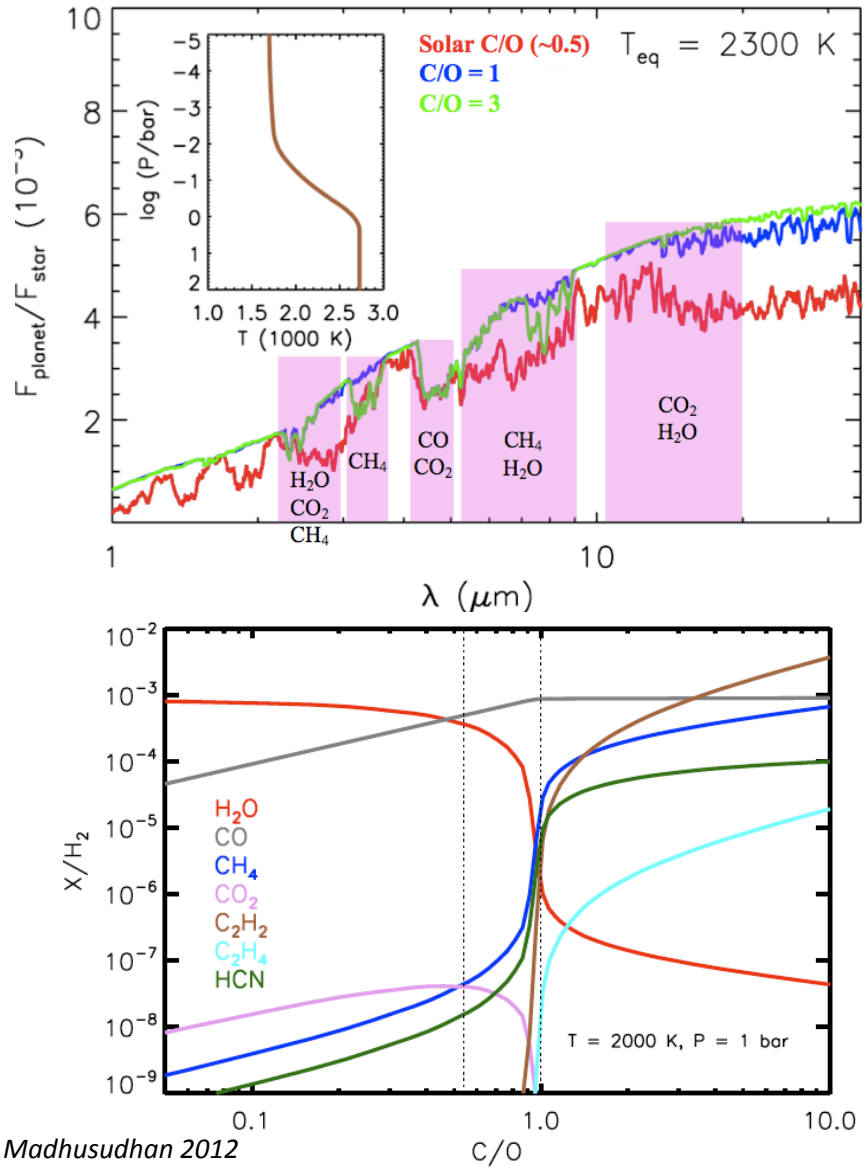

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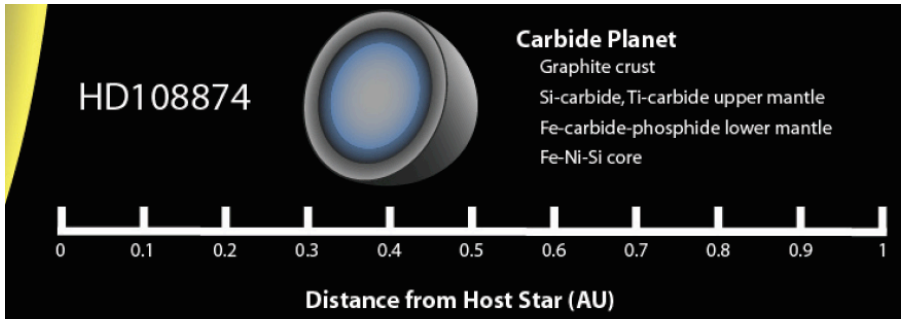

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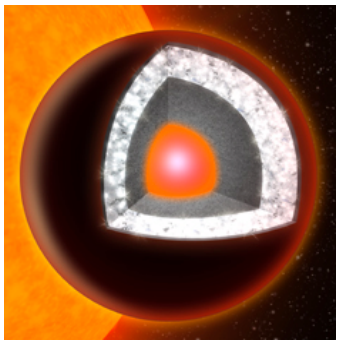

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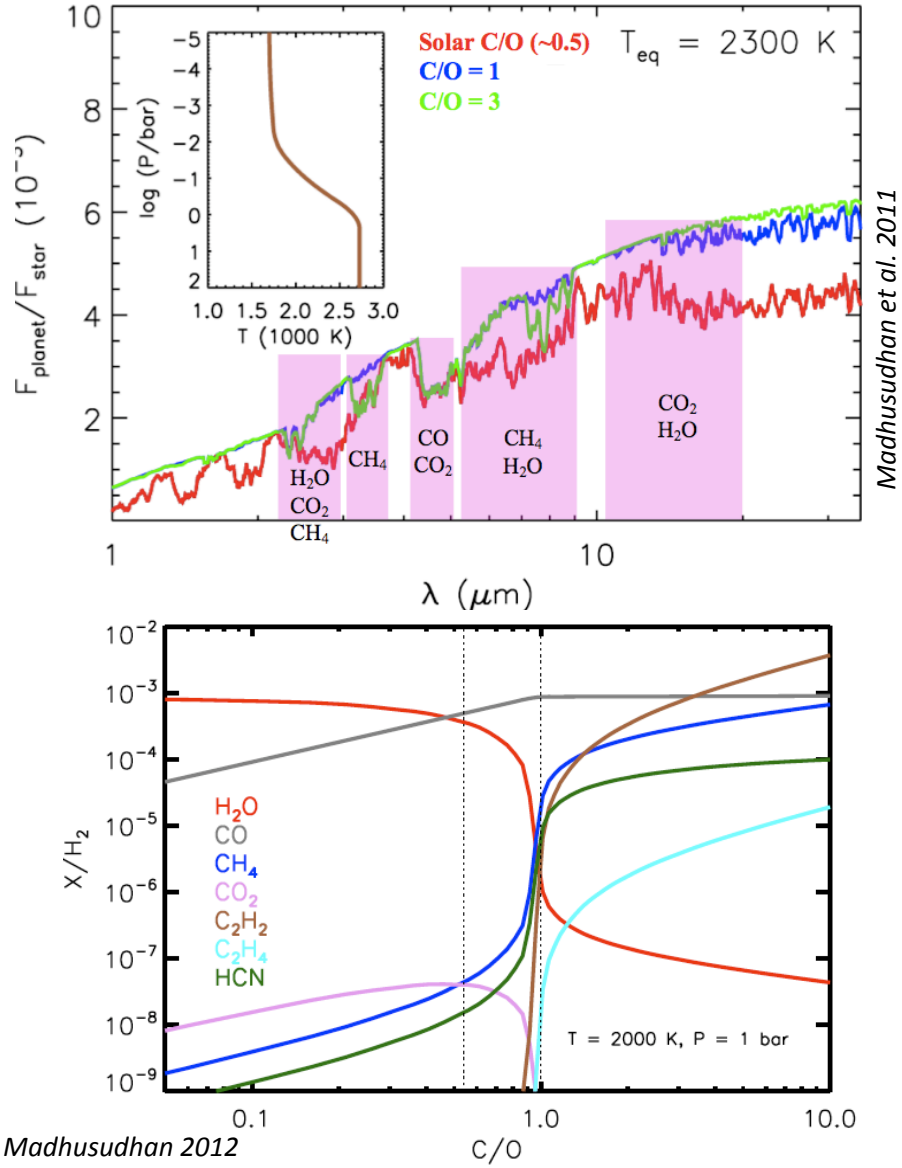

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See Poster 3.5 by Jay Farihi

O… 2010

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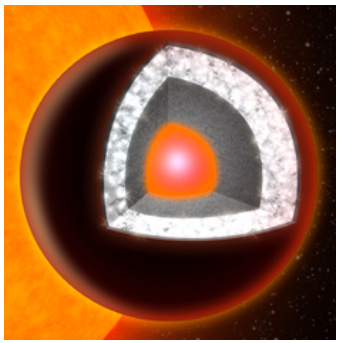
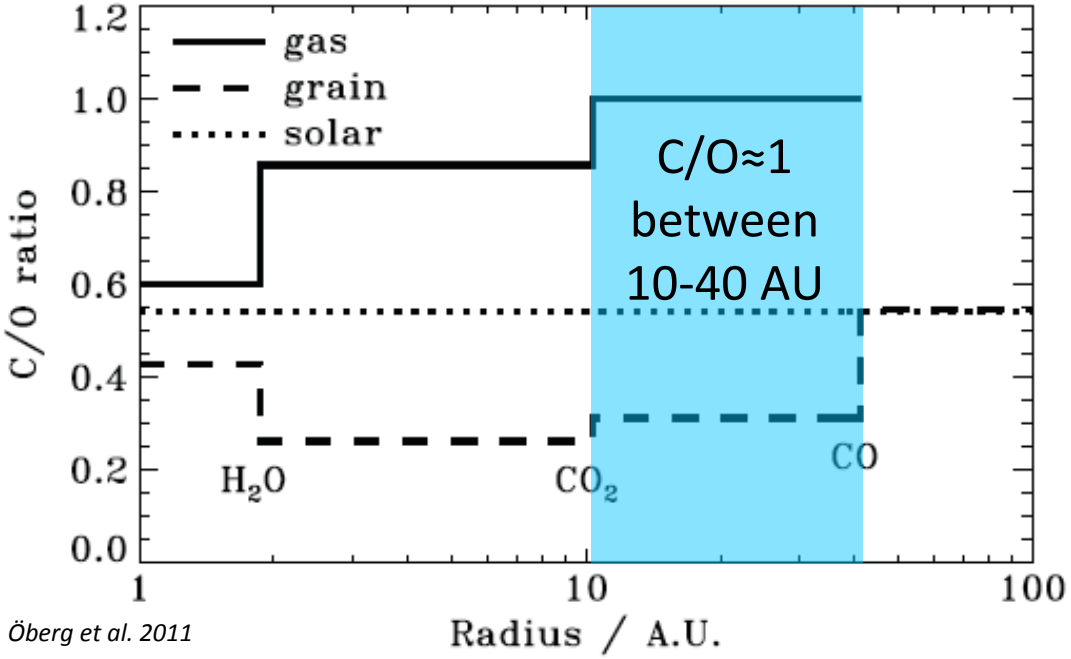
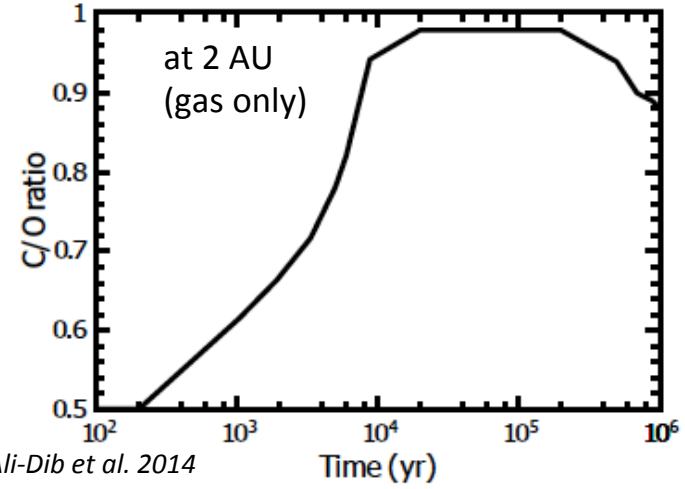


Haven Giguere

Why is C/O interesting
in disks (wrt planet-formation)?



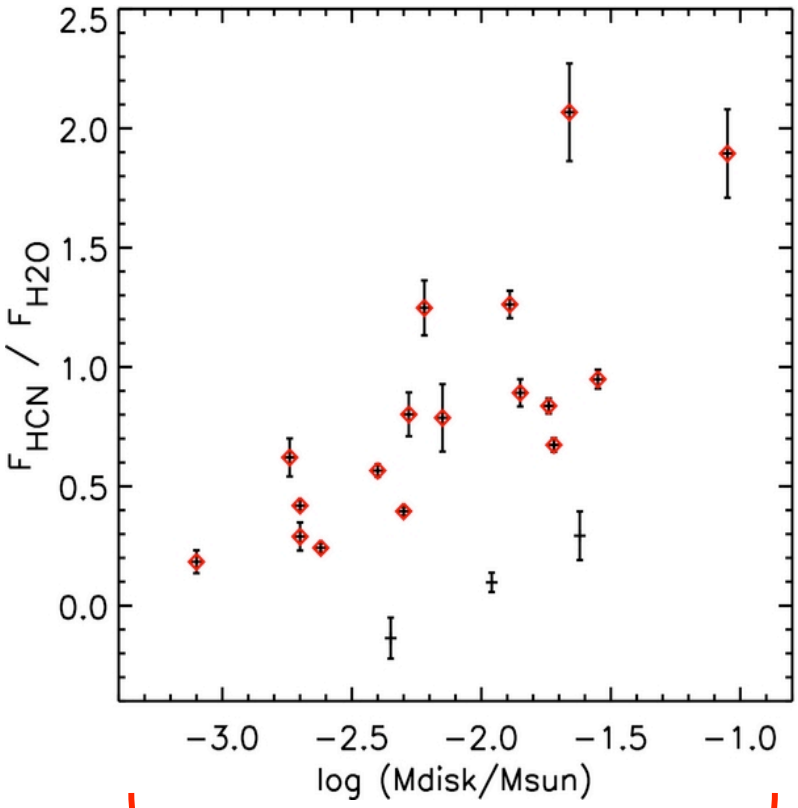
Öberg et al. 2011



Ali-Dib et al. 2014

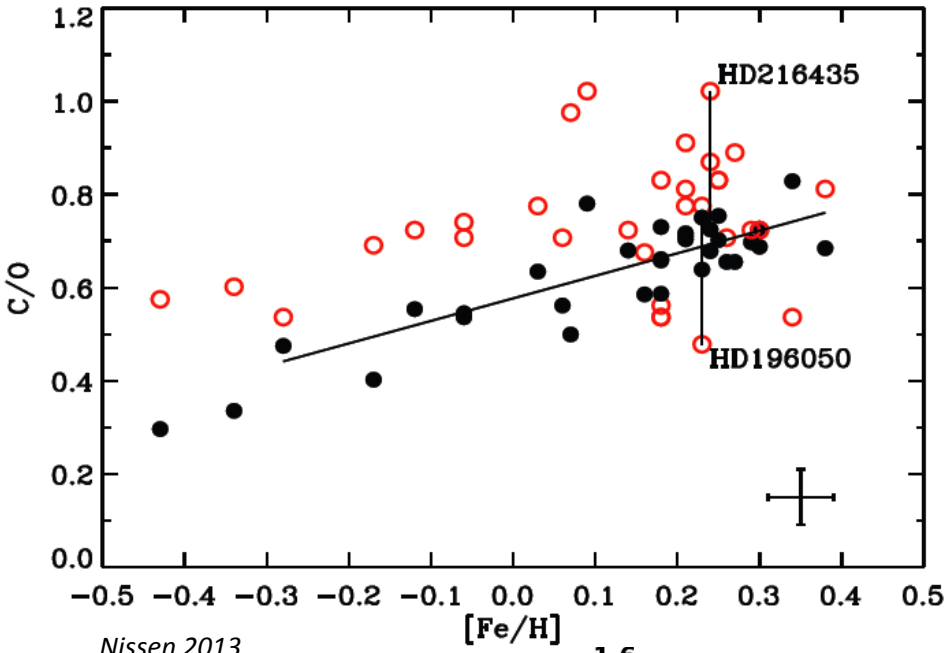
Disk C/O changes with time

Najita et al. 2013

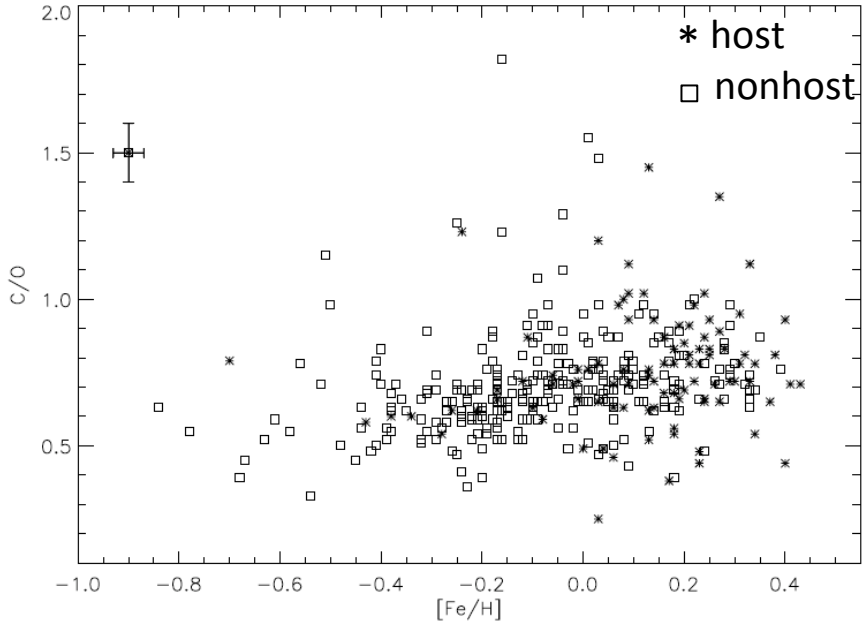


More massive disks
= more icy solids trapped
= higher C/O in inner planet-forming region

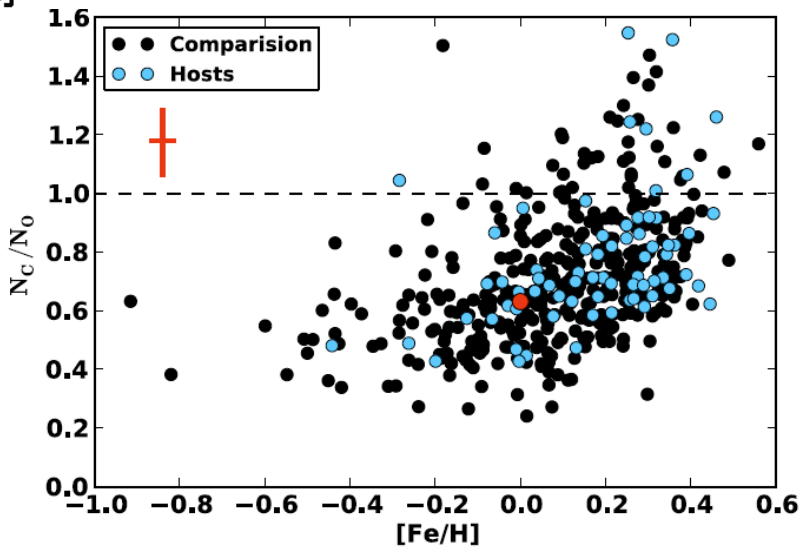
We can measure $C/O_{host\ star}$ (more) reliably and for a large sample, spanning many types of stars and planets.



Nissen 2013

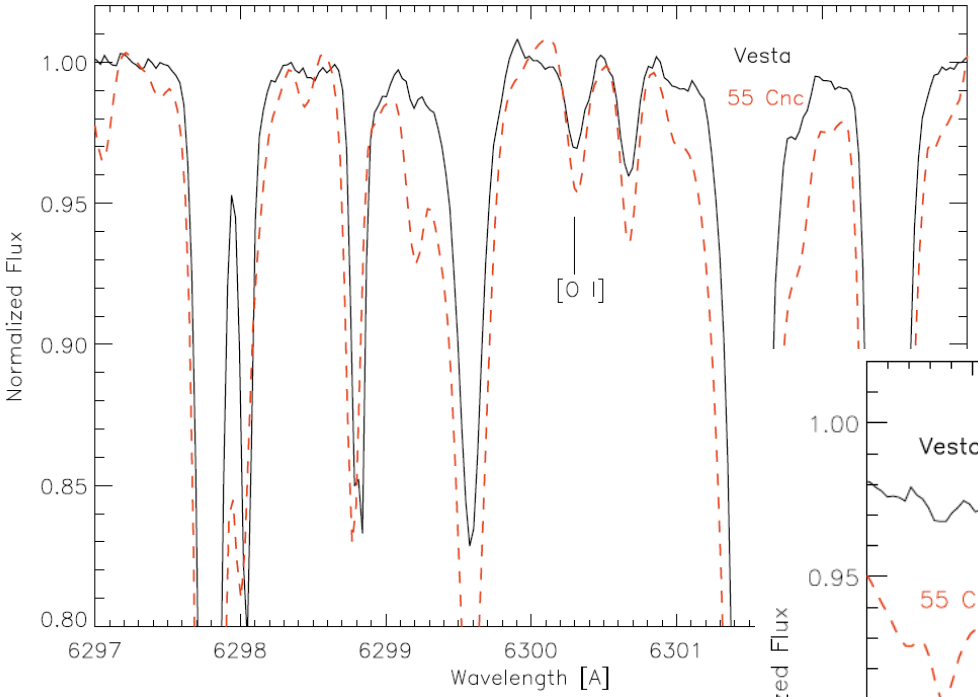


Delgado Mena et al. 2010 (plotted by me)



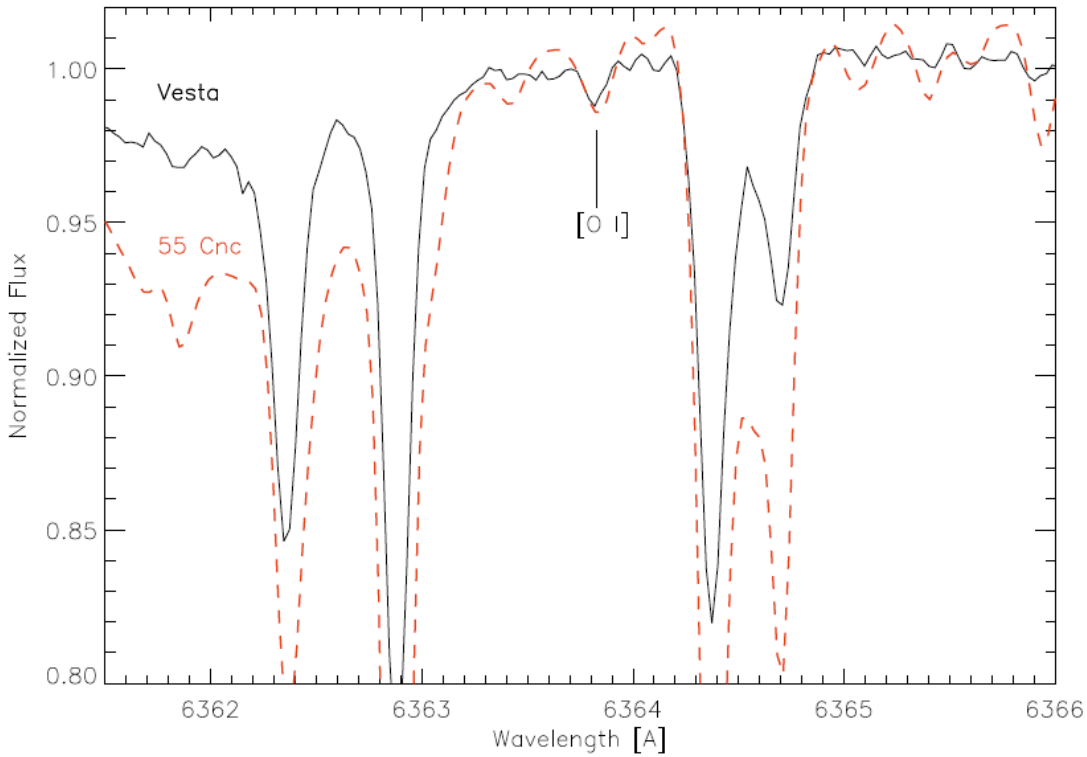
Petigura & Marcy 2011

Measuring [O/H] is tricky, especially when it comes cool, metal-rich stars…



[OI] 6300 Å line

[OI] 6363 Å line



Spectra from Keck/HIRES archive

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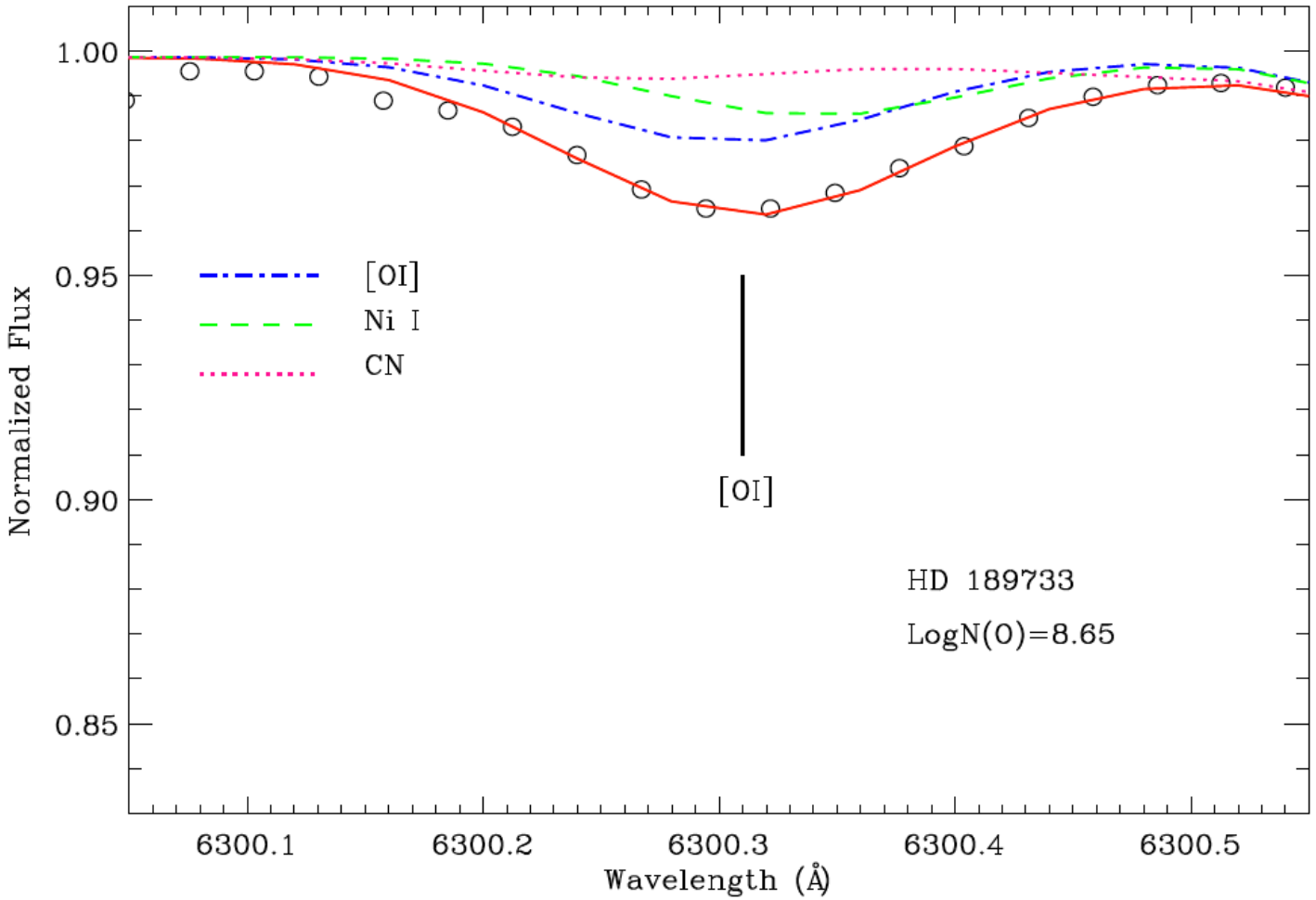

Teske et al. 2014

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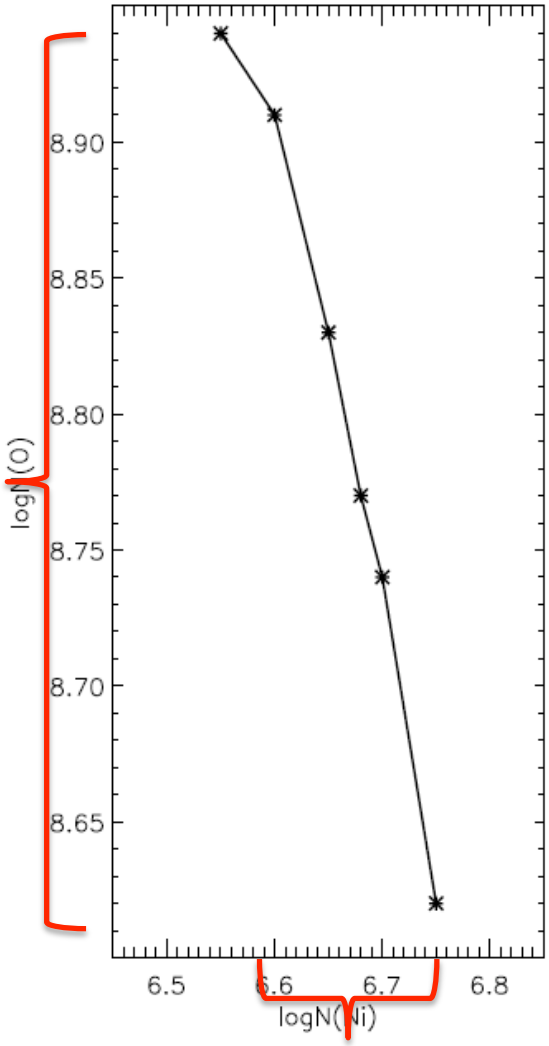

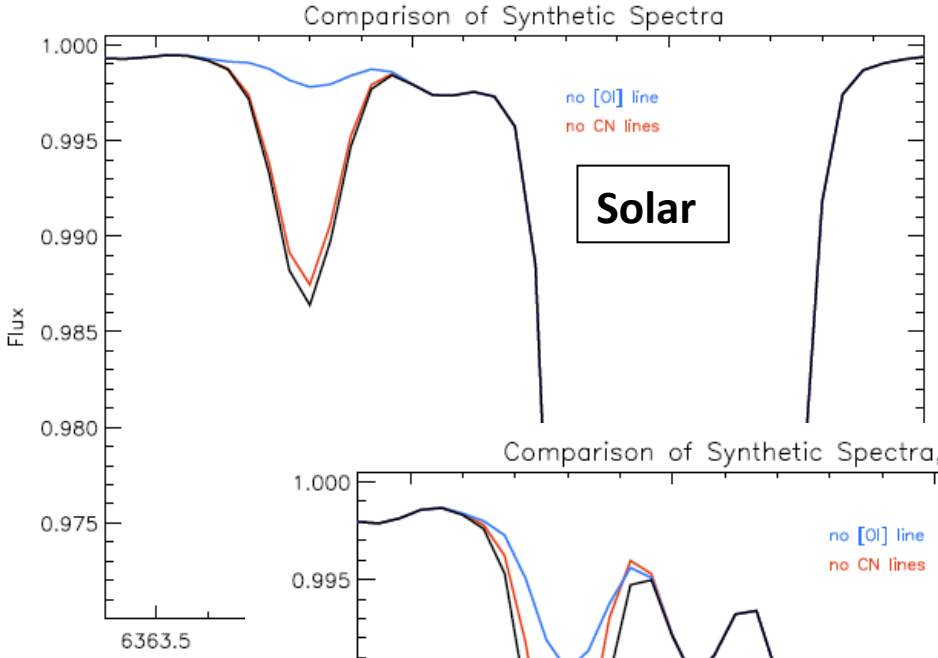

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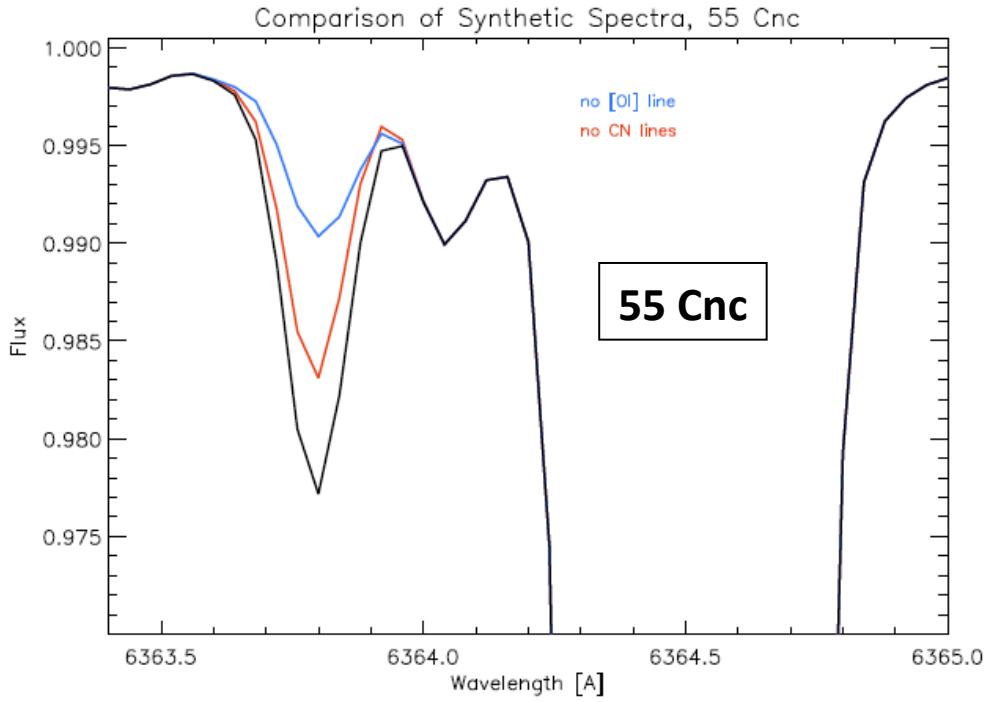

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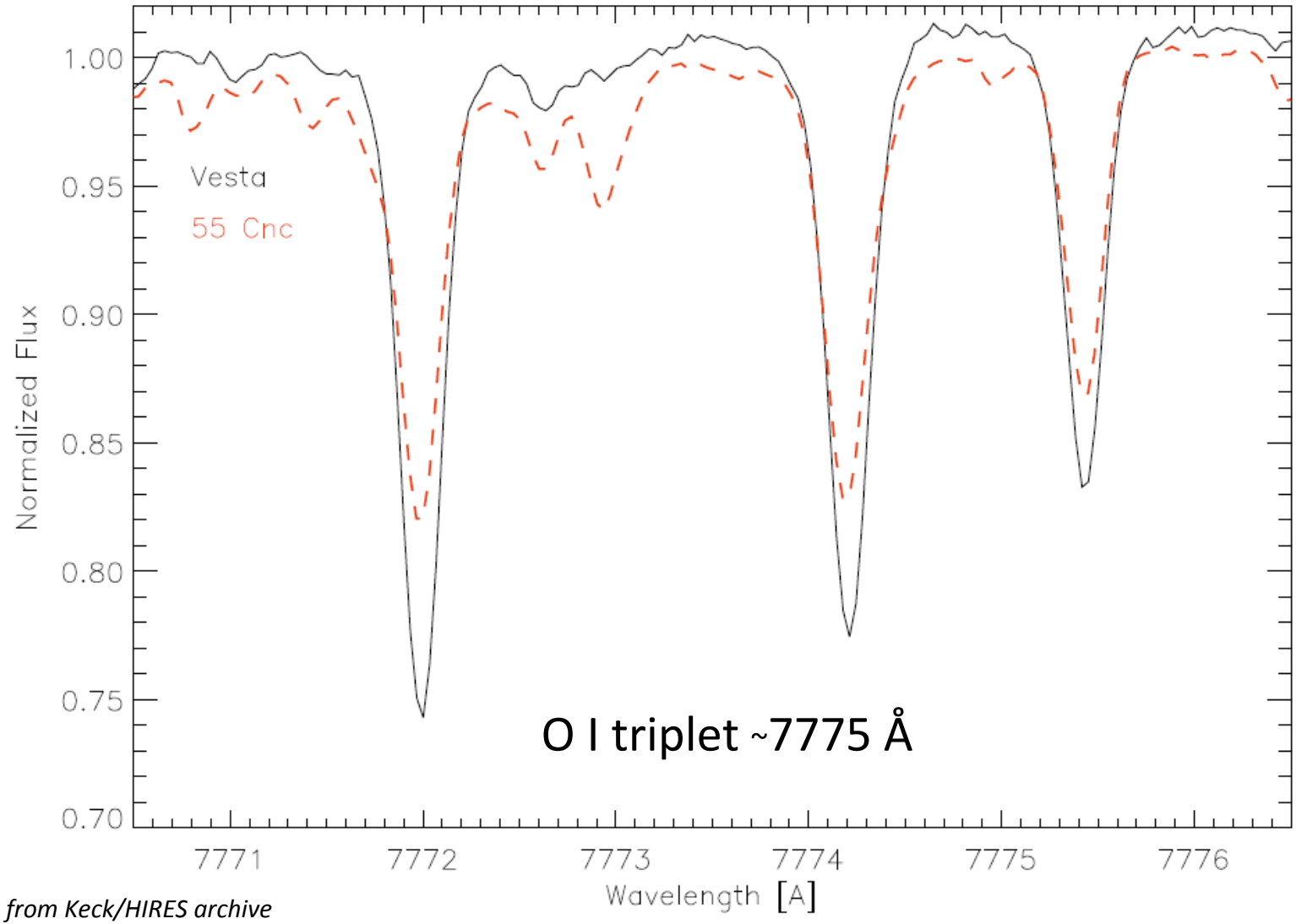

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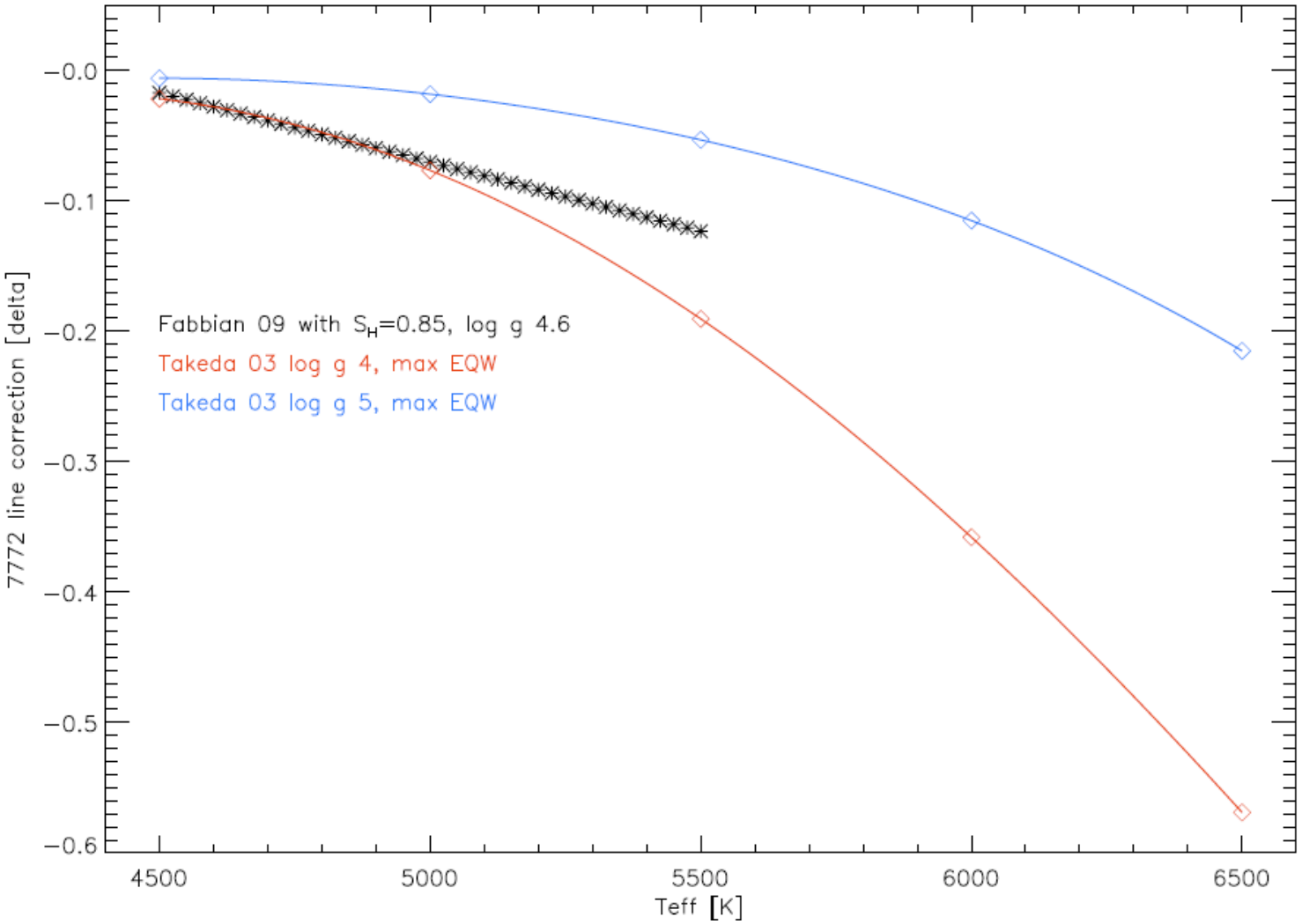

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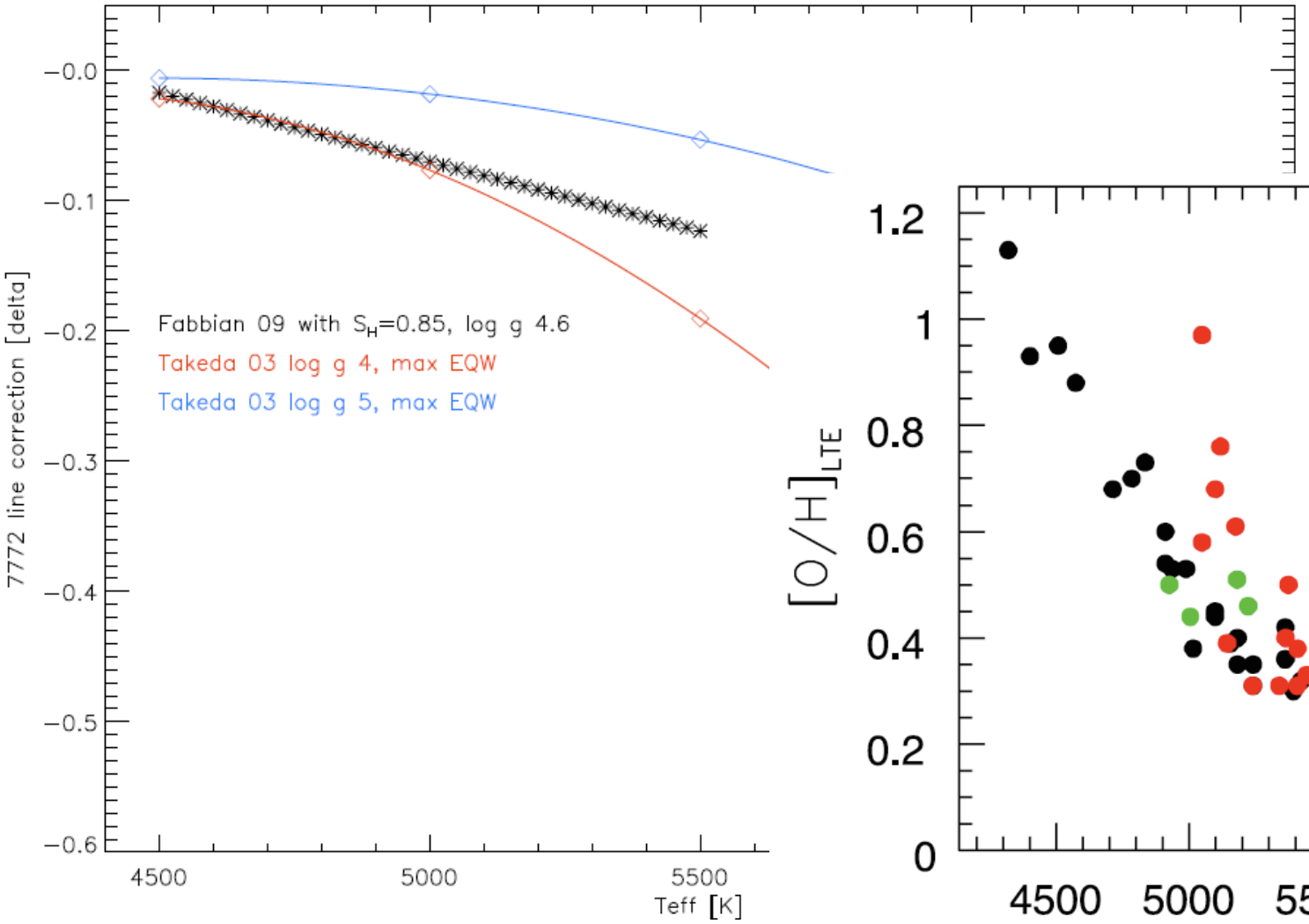
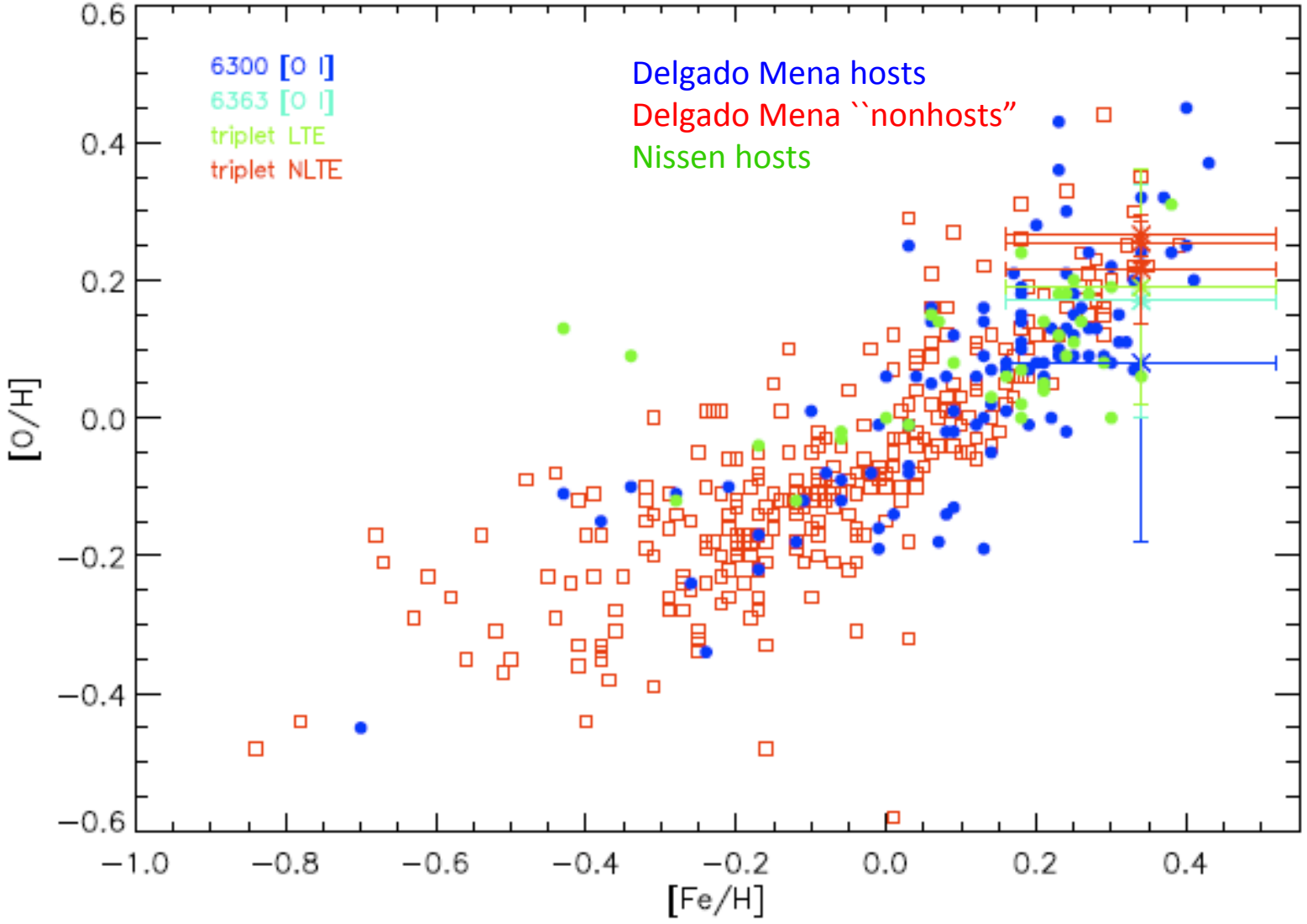


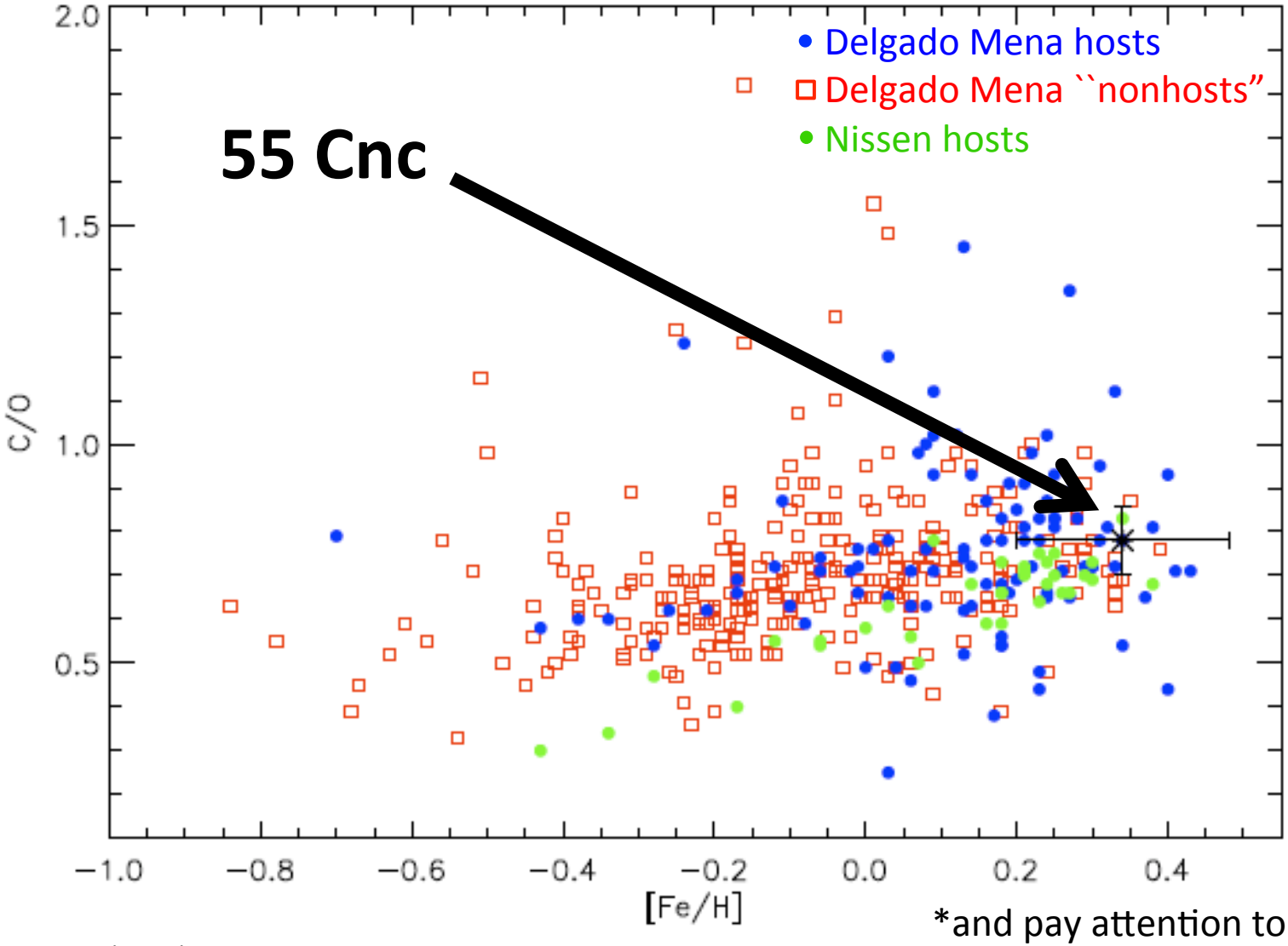
Schuler et al. 2006

Derived C/O Ratios Can Depend on Abundance Indicators



Teske et al. 2013

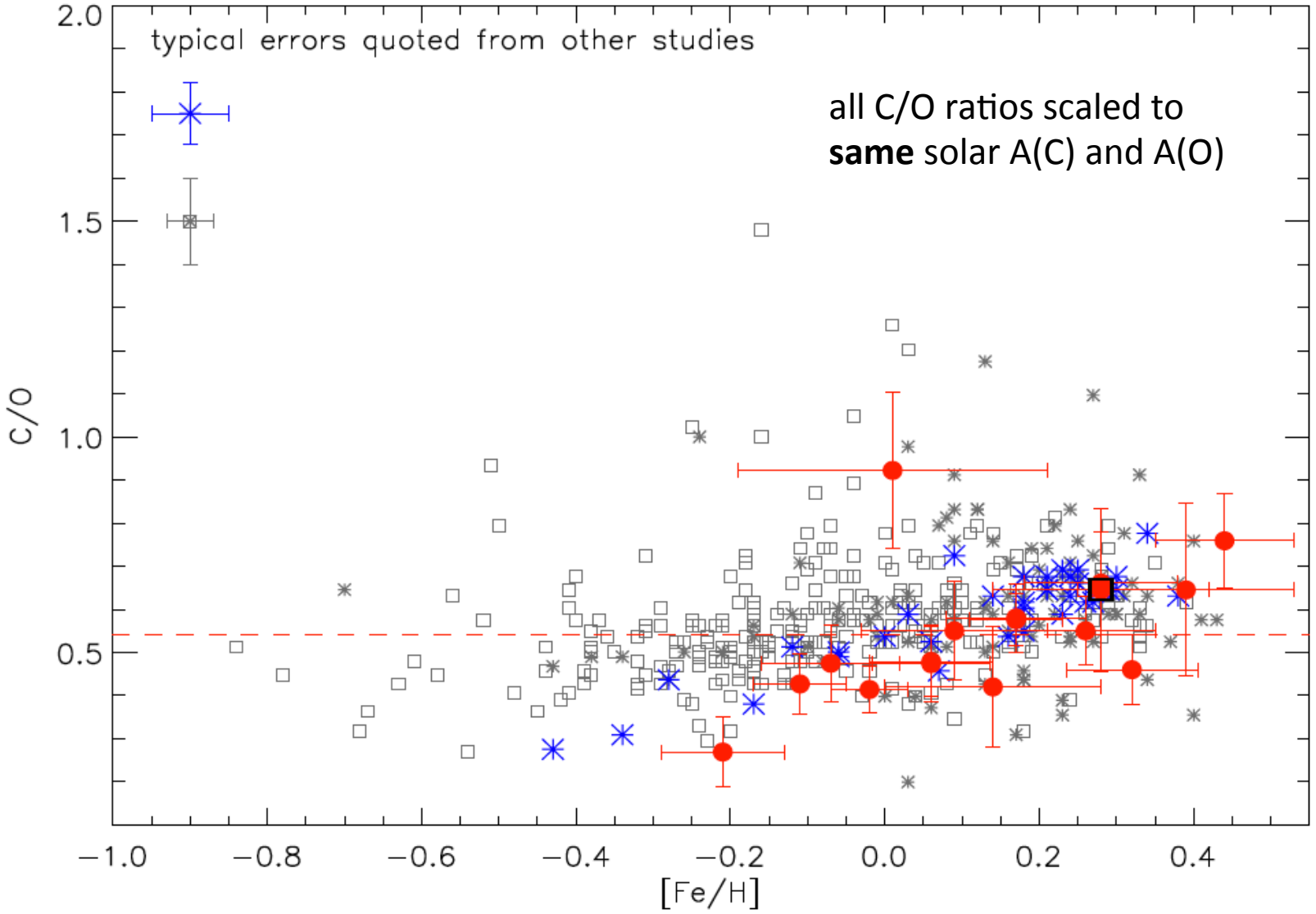
Moral of the Tale:
Gather As Much Information as Possible*



*and pay attention to details

Teske et al. 2013

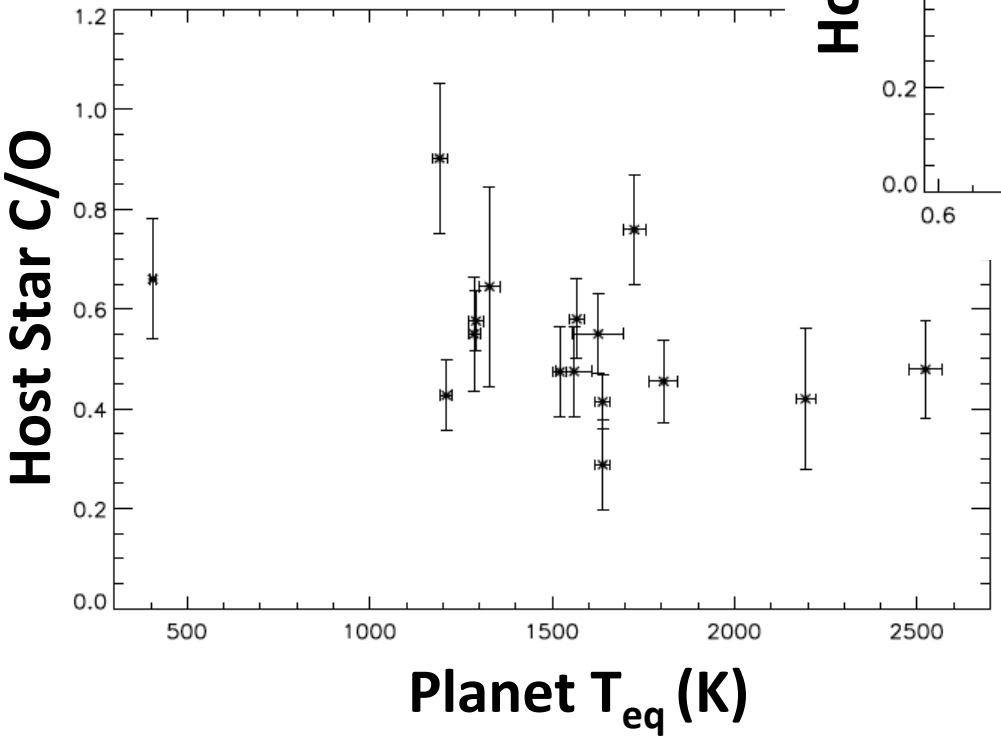
We can measure $C/O_{host\ star}$ (more) reliably and for a large sample, spanning many types of stars and planets.

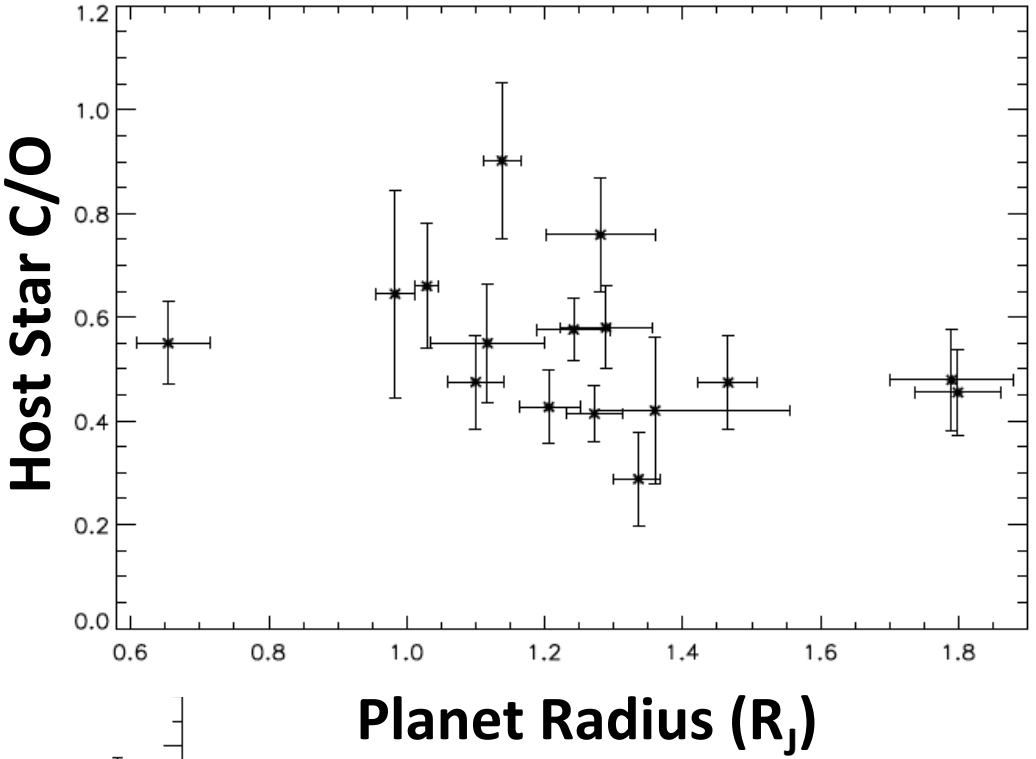


Teske et al. 2014

Comparing planets to stars…

maybe?





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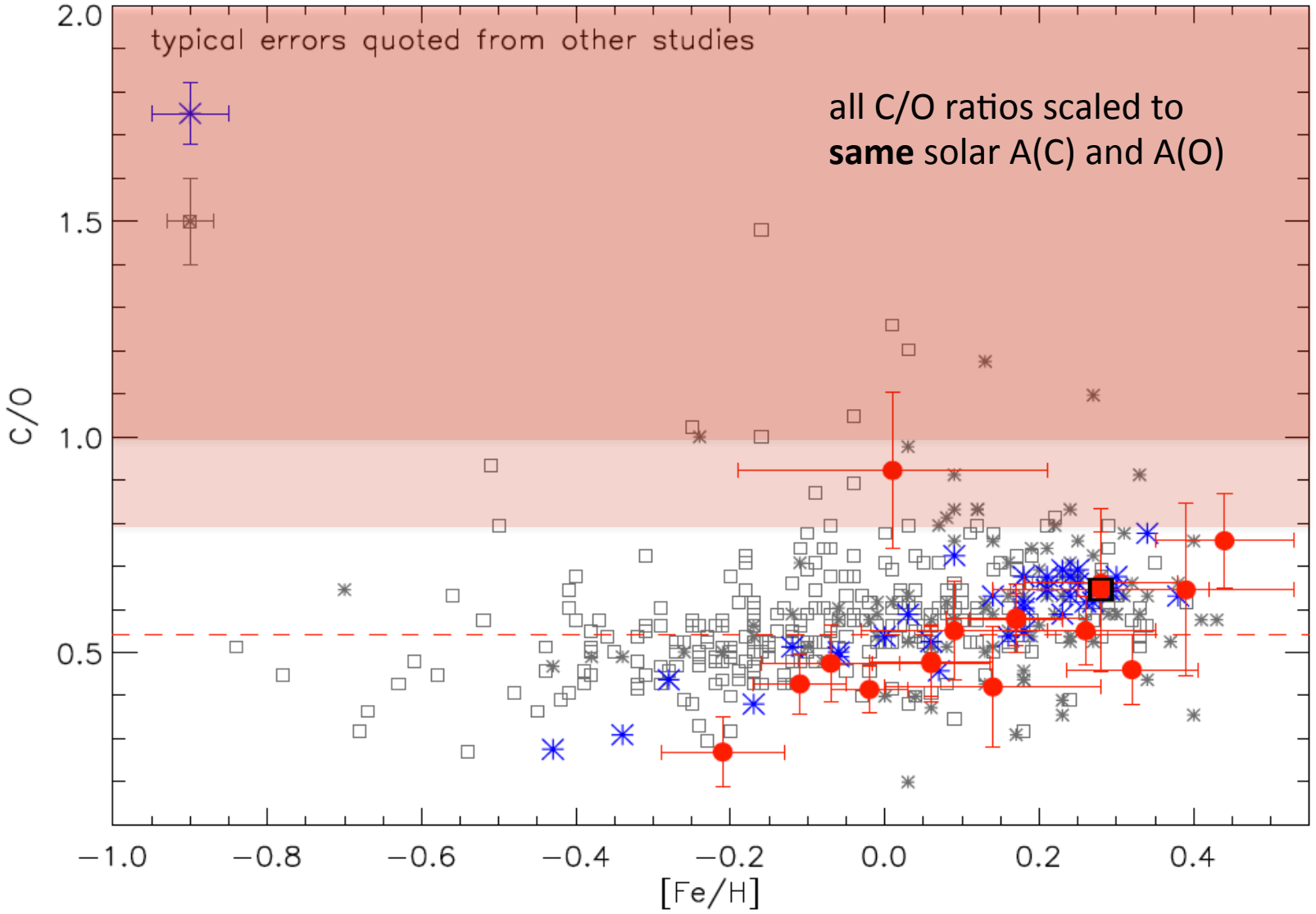
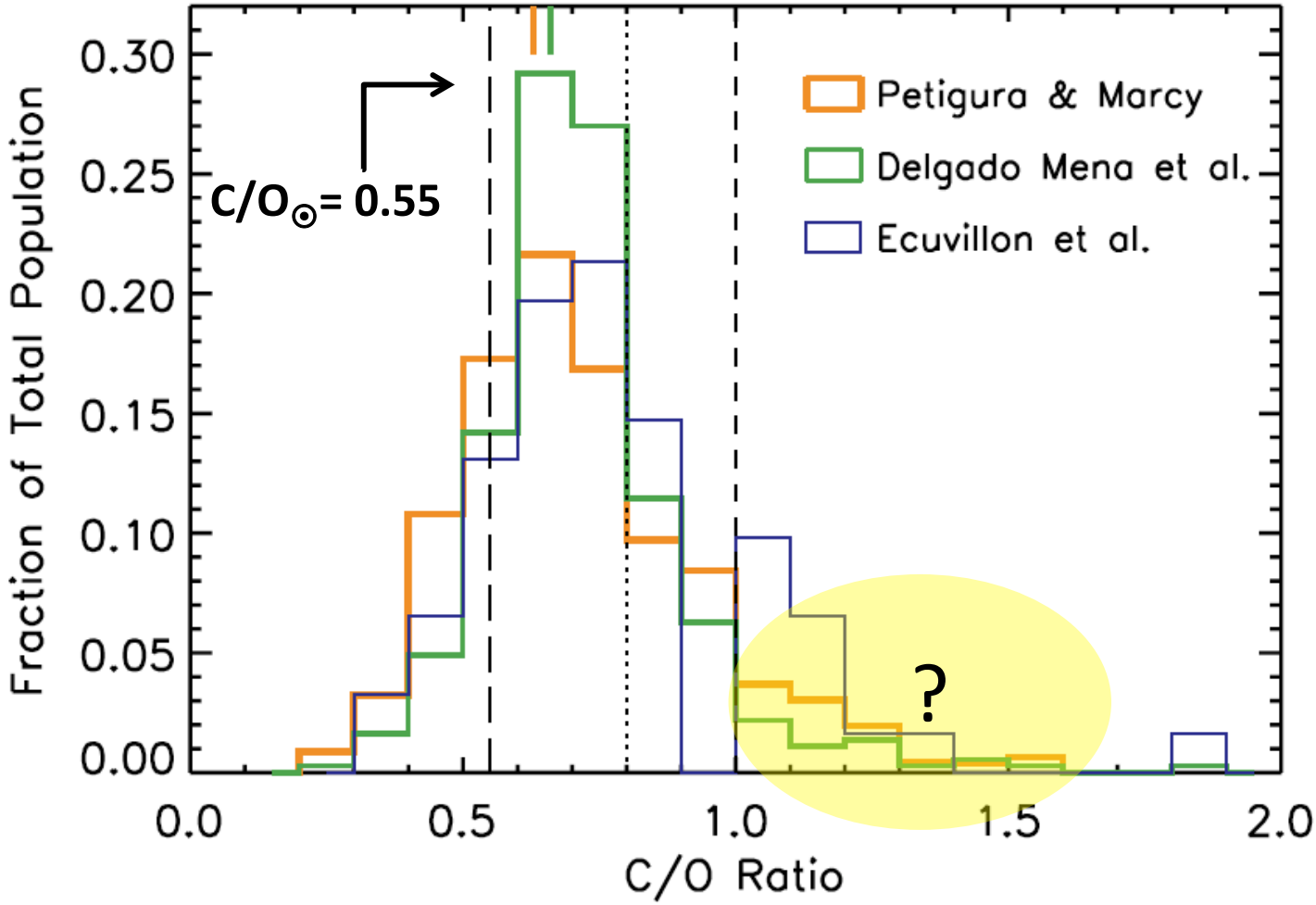


Teske et al. 2014

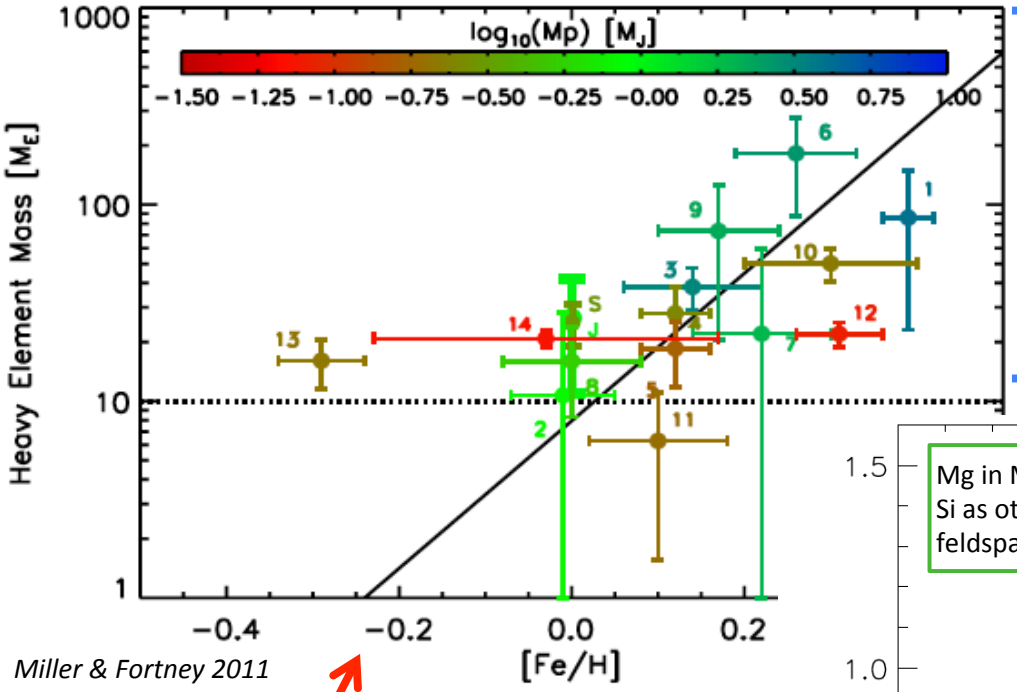
We do not find high C/O host stars.



From large SDSS surveys, frequency of carbon-rich M dwarfs is ~10^{-3}-10^{-5}

Fortney 2012

Stellar Abundances and Cool Giant Planet Bulk Metal Enrichments

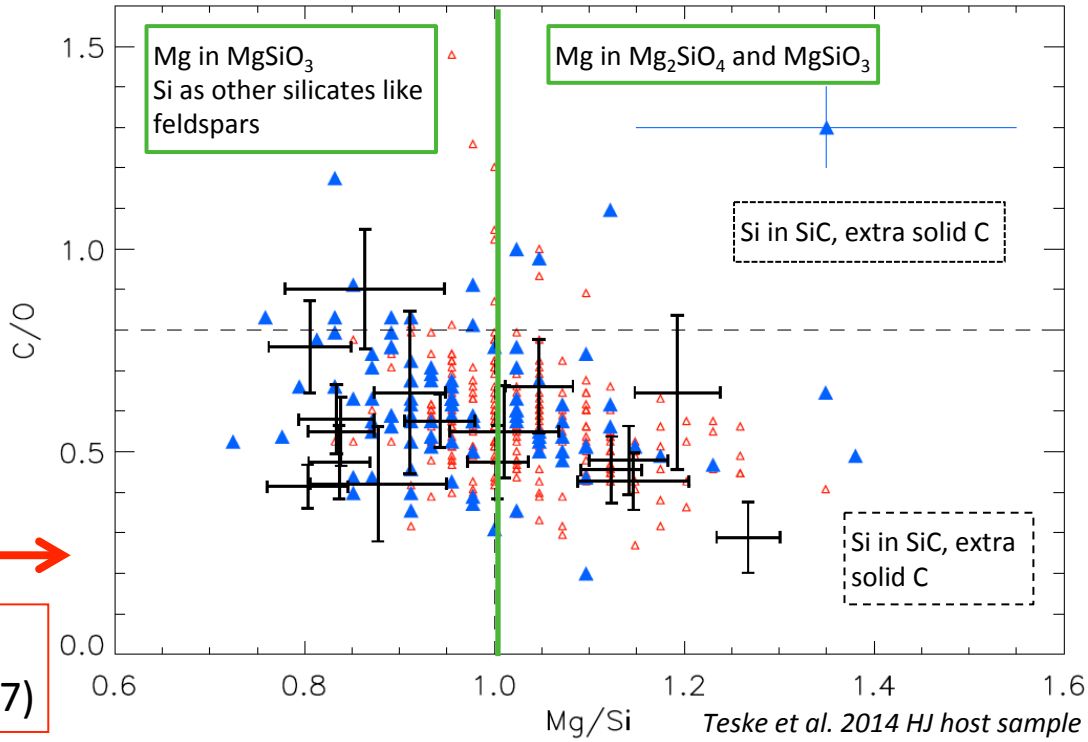


Miller & Fortney 2011

More Fe-rich stars make more metal-rich planets

Non-inflated giants are all over-dense compared to planet models matching their host star [Fe/H]

How do this trend and planetary interior models compare to host star C, O, Mg, Si abundances?



Teske et al. 2014 HJ host sample

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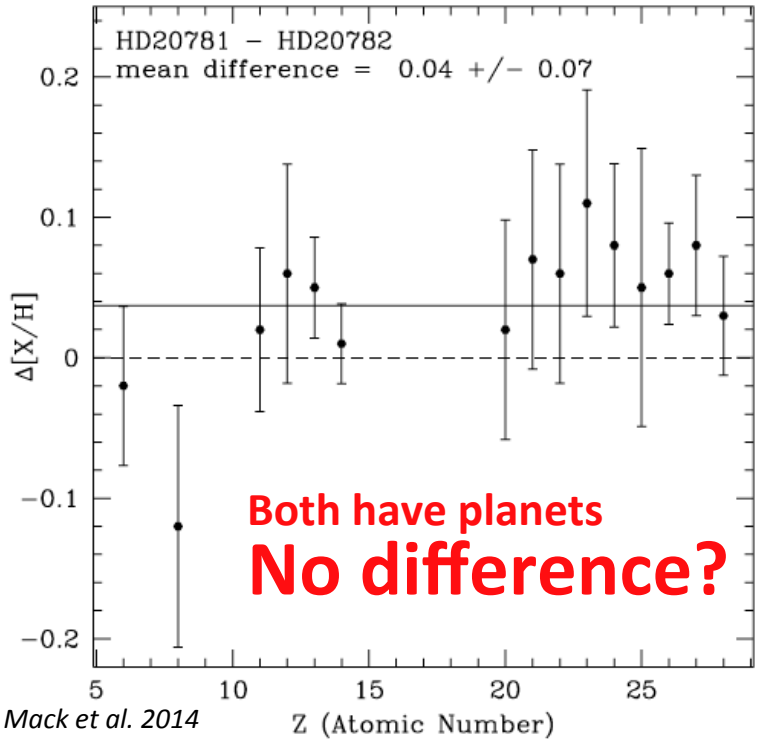
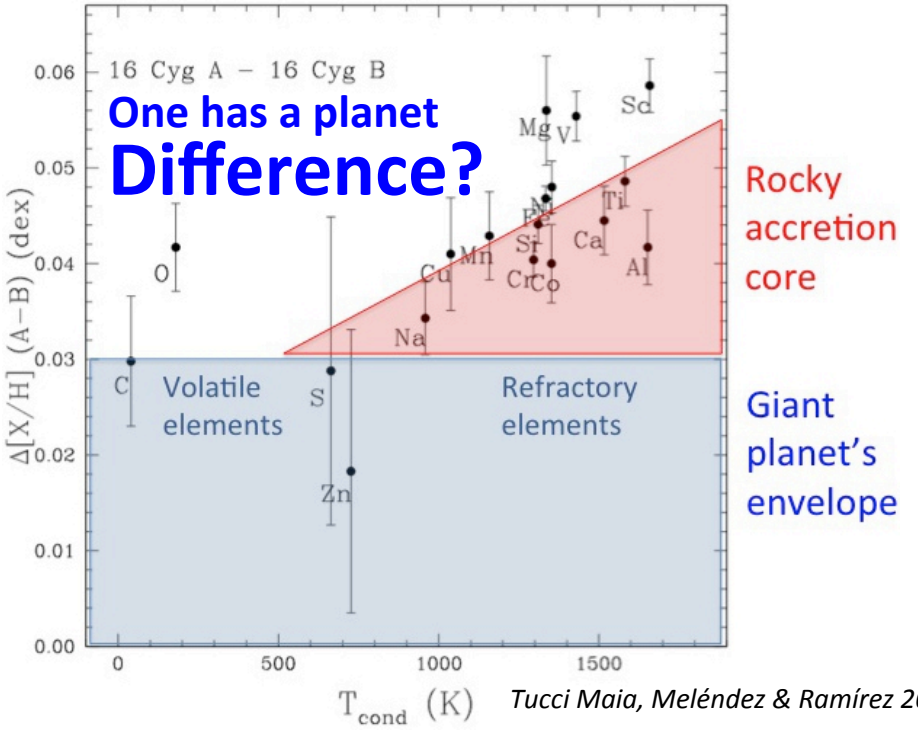
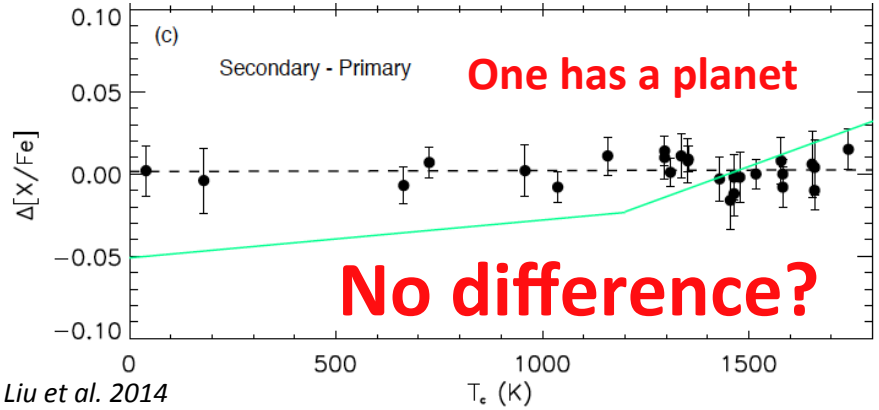
Host Star Binary Systems = Important Tests of Planet Formation Effects



Mack et al. 2014



Tucci Maia, Meléndez & Ramírez 2014



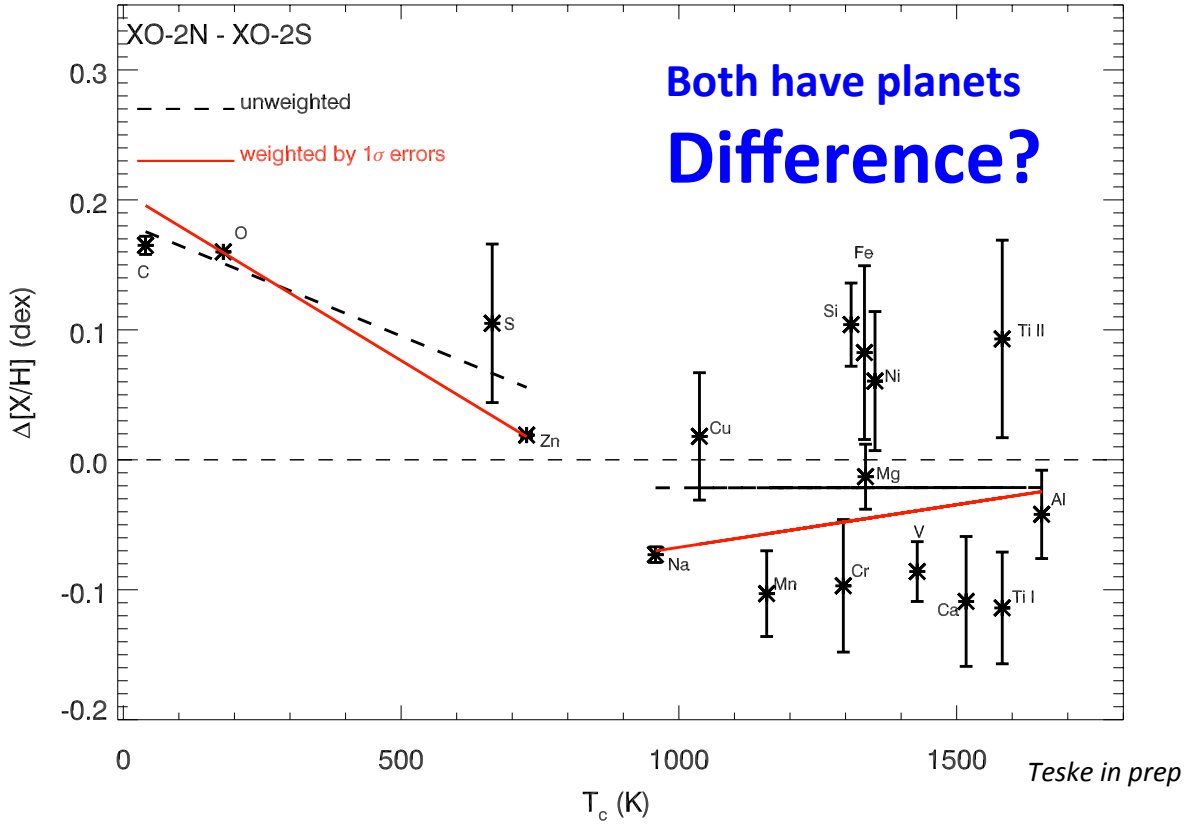
Liu et al. 2014

Binary stars expected to have = compositions

If they don't → signature of planet formation?

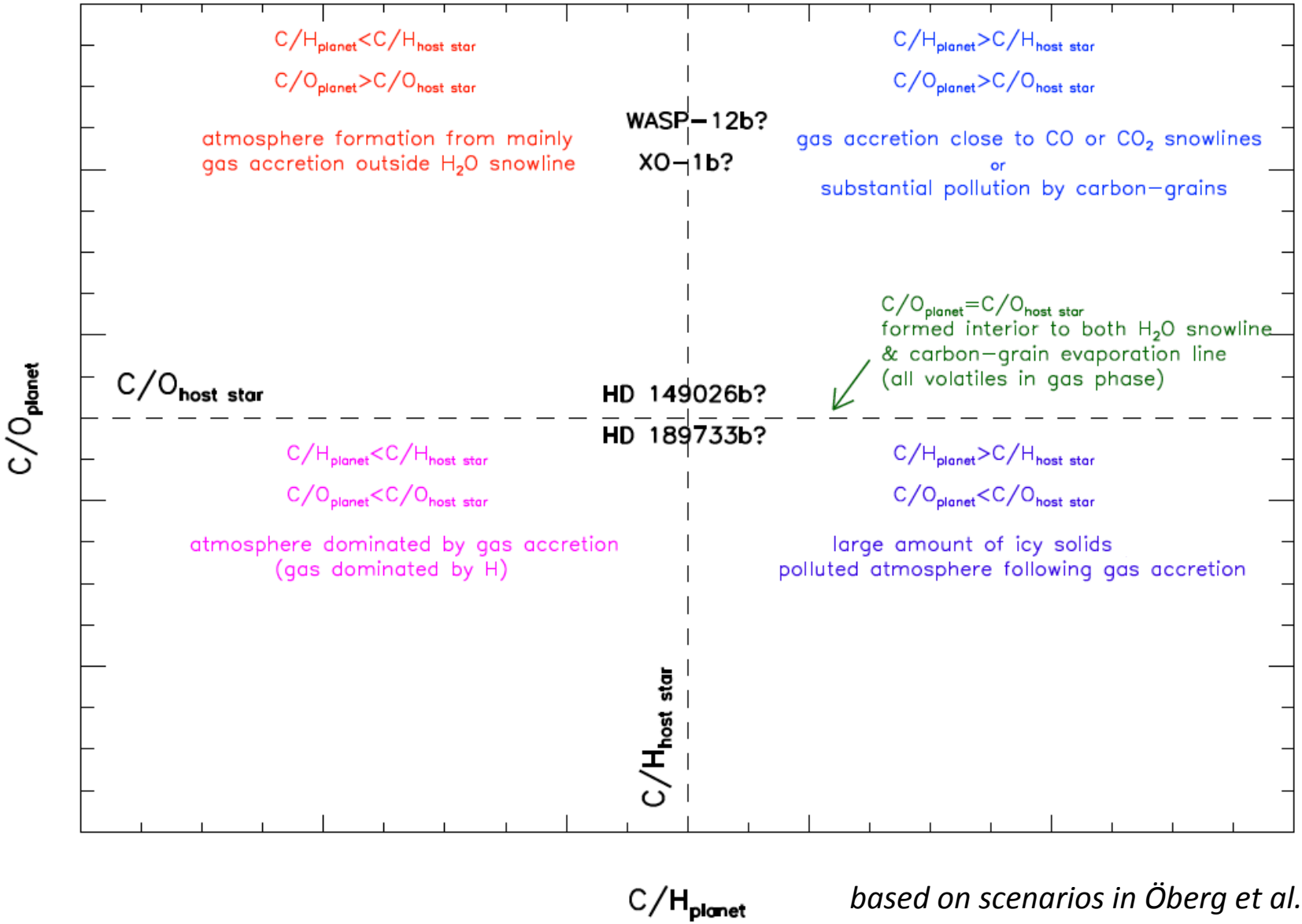
Is material "missing" (giant planet cores, terrestrial planets) or added (pollution by giant planet migration, pl-pl scattering)?

Host Star Binary Systems = Important Tests of Planet Formation Effects



See Posters 3.8 by Tucci Maia, 3.10 by Liu, 3.6 by me

Constraining Atmosphere Formation Location via C/O_{star} vs. C/O_{planet}



based on scenarios in Öberg et al. 2011

Constraining HJ Compositions via Host Star Abundances of Planet-Building Elements

- The relative amounts of C and O are important in stars, planets, and protoplanetary disks
- Determining C and O abundances in stars is more precise than in planet atmospheres (and interiors), but can still be hard, and requires multiple indicators and high-quality data
- We do not find high C/O ratio host stars (in general)
- Host star abundances can be compared to planet properties to constrain when/where/from what material in the disk the planets formed

Talk Tweet

"@johannateske Stellar C/O tricky but doable. Must gather all info, pay attn 2 deets. No high C/O HJH. C/O = probe of plnt frmn #toe2014"