Abundance trends in planet hosts. What can we learn from evolved stars?

Jesús Maldonado

INAF - Osservatorio Astronomico di Palermo

jmaldonado@astropa.inaf.it

Planetary Systems beyond the Main-Sequence II

Outline

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What stellar properties influence planet formation?

Gas-giant planets and stellar metallicity (PMC) $\Rightarrow$ Perhaps the only one well established trend

Controversial claims:

"Deficit" of refractory elements in the Sun

- Related to the formation of terrestrial planets?
- Effects of Galactic Chemical Evolution?
- Age/Galactic origin of planet hosts

Most detailed studies based on MS stars:

Unclear if PMC holds for evolved stars!

- Maldonado et al. 2013, only on giants with $M_\star > 1.5\ M_\odot$
- Similar results by Mortier et al. 2013
- Jofré et al. 2015, no PMC
- Reffert et al. 2015, only among "secure" planet hosts

The opportunity of evolved stars !

- **Planet formation and evolution as a function of stellar mass**
- **Origin of chemical trends in planet hosts**

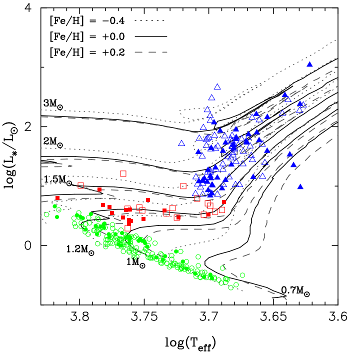
Outline

Notation/Observations

In this study:

Chemical abundances of:

1. **Giants**
   43 planet hosts (67 comparison)
2. **Subgiants**
   16 planets (17 comparison)
3. **Main-Sequence**
   41 planets (157 comparison)



Spectroscopic Analysis

- **Stellar parameters, code TGVIT (Takeda et al. 2005)**
  Iron ionisation and excitation conditions, match of the curve of growth
- **MOOG code (Sneden 1973) + ATLAS9 models**
  C, O, Na, Mg, Al, Si, S, Ca, Sc, Ti I, Ti II, V, Cr I, Cr II, Mn, Co, Ni, Zn

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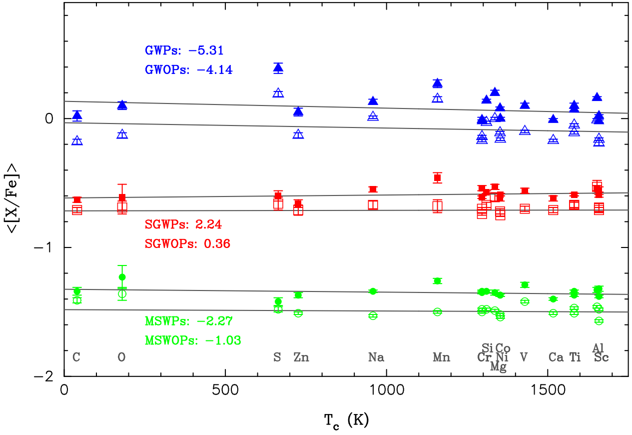
No differences planet hosts / comparison samples

All elements

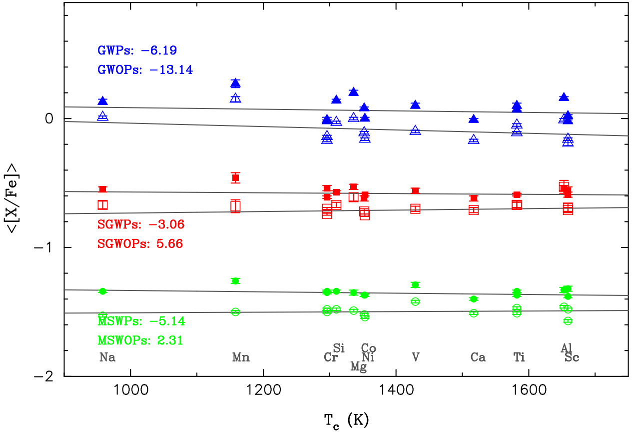


- **Independently of the evolutionary stage**
- **Giants: significant < 0 slopes**

<[X/Fe]>-T_C slope trends

Abundances of volatiles not as reliable as refractories' ones

Only $T_C > 900$ K



- **Main-Sequence and Subgiants: planet hosts < 0 slopes, comparison > 0 slopes**
- **Giants: planet hosts and comparison < 0 slopes**

Possible different trend planet/non-planet hosts. Only for MS and subgiant stars:

- Do the abundance trends correlate with the evolutionary parameters?

- **Correlations with** log g**, stellar mass, and age**
- Even after correcting for GCE ([Fe/H])

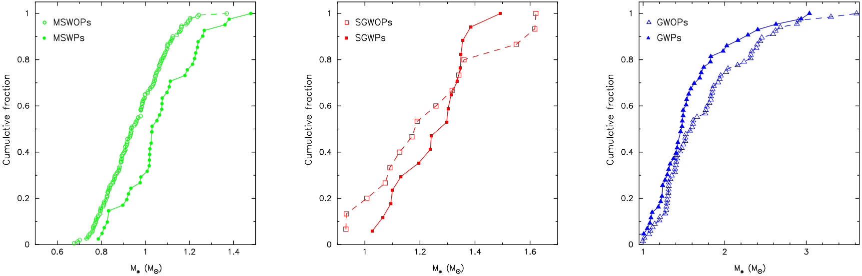
	All elements		**Only refractory**	
Parameter	SR	p	SR	p
[Fe/H]	0.31	$\sim 10^{-8}$	-0.37	$\sim 10^{-12}$
logg	-0.18	$\sim 10^{-3}$	0.28	$\sim 10^{-7}$
$M_\star$	0.36	$\sim 10^{-11}$	-0.45	$\sim 10^{-17}$
Age	-0.14	~ 0.01	0.31	$\sim 10^{-8}$
$R_\star$	0.25	$\sim 10^{-6}$	-0.33	$\sim 10^{-9}$

- **Less massive and older stars: Show more $+$ T_C^{ref} and more $-$ T_C^{all}**

Less massive and older stars: Show more $+\,\mathrm{T_C^{ref}}$ and more $-\,\mathrm{T_C^{all}}$

- Do planet/non-planet hosts differ in terms of mass?

MS and subgiant NON planet hosts: **Slightly smaller masses and older ages**



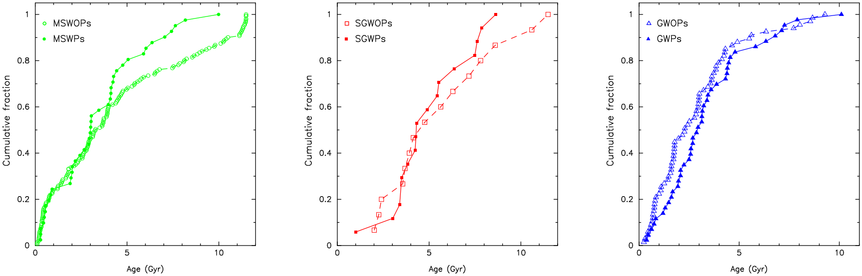
Giants:

- **Comparison sample: Slightly younger and massive than planet hosts**

Less massive and older stars: Show more $+\,T_C^{ref}$ and more $-\,T_C^{all}$

- Do planet/non-planet hosts differ in terms of age?

MS and subgiant NON planet hosts: **Slightly smaller masses and older ages**



Giants:

- **Comparison sample:** **Slightly younger and massive than planet hosts**

Outline

Haywood (2009): Possible inner disc origin of planet hosts
Radial mixing: secular process, older stars migrate further, come from a region with different abundances

- **MS non planet hosts:** older, less massive, more contaminated by stars from the outer disc, $\Rightarrow \Downarrow$ [Fe/H], $\Uparrow$ [X/Fe], $\Rightarrow + \mathrm{T}_{\mathrm{C}}^{\mathrm{ref}}$
- **Giants:** giants with/without planets are younger and less contaminated by radial mixing

MS non-planet hosts less massive and older than MS with planets: **biases in exoplanet searches**

Do the <[X/Fe]>-T_C trends fit in the ME09 hypothesis?

- **Meléndez et al. 2009:** Deficit of refractory in the Sun with respect to other solar twins. Related to the formation of low-mass planets
- **González Hernández et al. 2012, 2013; Adibekyan et al. 2014:** Galactic chemical evolution effects, age/Galactic birth place explanation

- Chemical trends in MS gas-giant planet hosts (no low-mass planets), but ME09 may still holds for gas-giants (formation of a rocky core)
- **As the star evolves off the MS:** Chemical fingerprint gets erased
- **However,** the sample of stars that show hints of changing its chemical behaviour is the one **without planets**:
  - **MS** and **subgiant** non-planet hosts: **POSITIVE** ref slopes
  - **Giants** non-planet hosts: **NEGATIVE** ref slopes
  - **Planet hosts:** always **NEGATIVE** ref slopes

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Summary

Ref: Maldonado & Villaver 2016, A&A, 588, A98

Detailed chemical analysis of a large sample of evolved stars

- **[X/Fe]-T_C trends**
  - **All elements:** no differences in T_C between planet and non-planet hosts
  - **Only refractories:** different slope planet hosts/comparison for Main-Sequence and Subgiant stars, NOT for giants!
- **Correlations with evolutionary parameters**
  - Less massive and older stars show more $+ T_C^{ref}$ and more $- T_C^{all}$
  - Main-Sequence and subgiant non planet hosts: less massive and older
- **Chemical depletions: Radial mixing**
  - **Giants:** more massive and younger, less contaminated by stars from the outer disc, no chemical differences planet/non-planet hosts
  - **Main-Sequence:** comparison sample less massive and older, chemical trends
- **Chemical depletions: Planet formation?**
  - General trends do not exclude particular cases


thank you
danke
謝謝
ngiyabonga
teşekkür ederim
gracias
merci
obrigado
bedankt
dziękuję
go raibh maith agat
sukriya
kop khun krap
terima kasih
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рахмат
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