Stars with and without planets: Where do they come from?

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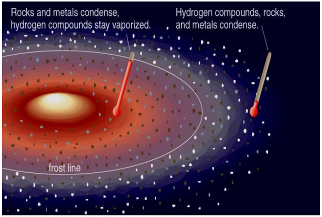
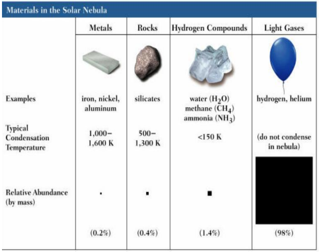
Introduction to Condensation Temperature

When the temperature in the stellar disks drops (with time or with distance from the star), the heaviest compounds (first) began to form solid/liquid droplets, a process called condensation.

The condensation temperature (Tc) for different elements is different and relates with the mass of the particles that become solid.

Low Tc elements - volatiles
High Tc elements - refractories (easily form dust)





Materials in the Solar Nebula

	Metals	Rocks	Hydrogen Compounds	Light Gases
Examples	iron, nickel, aluminum	silicates	water (H_2O) methane (CH_4) ammonia (NH_3)	hydrogen, helium
Typical Condensation Temperature	1,000–1,600 K	500–1,300 K	<150 K	(do not condense in nebula)
Relative Abundance (by mass)	(0.2%)	(0.4%)	(1.4%)	(98%)

[X/Fe] vs. Tc

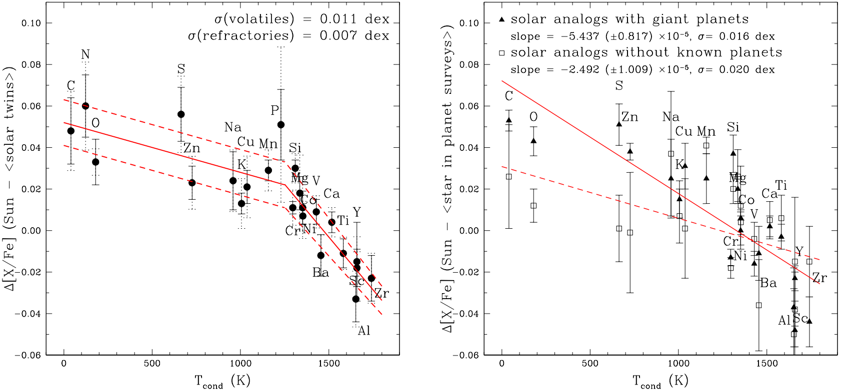


Figure: Melendéz et al. (2009).

Anomalous volatile-to-refractory ratio of the Sun when compared to solar twins.

Refractories remained in rocky planets (Ramirez et al. 2009,2010).

[X/Fe] vs. Tc

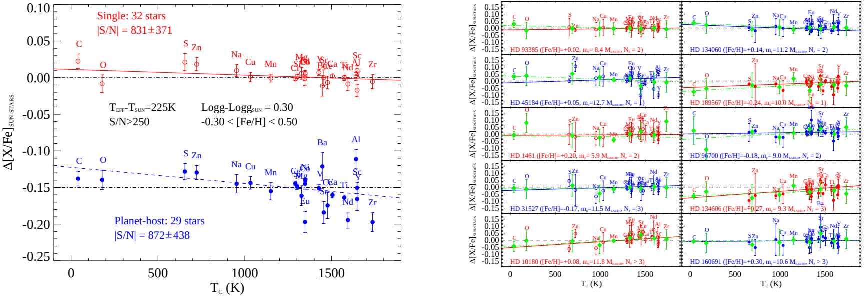


Figure: González Hernández et al. (2013).

No (significant) peculiar abundance ratio

No evidence of relation between volatile-to-refractory abundance ratio and presence of rocky planets (González Hernández et al. 2010,2013).

Contradictory results – why?

What is/are the main factor(s) responsible for the trends with Tc?

Does terrestrial planet formation leave chemical imprints in the atmospheres of their host stars?

The data is from González Hernández et al. (2010,2013)
The ages are from GCS - Casagrande et al. (2011)

Tc slope and stellar age

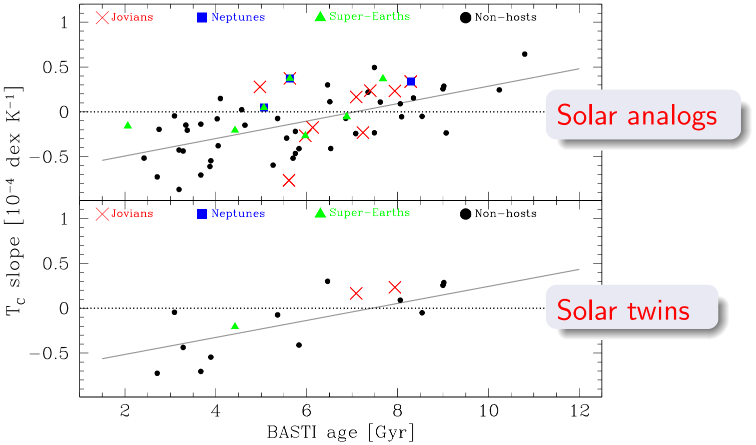


Figure: Adibekyan et al. (2014).

Tc slope strongly correlates with the stellar age

Older stars show lower refractory-to-volatile ratio **independently of the presence of planets**

Tc slope and Galactic Chemical Evolution

For FGK dwarfs chemical abundances is not a function of age

The Tc slope and age correlation is probably a reflection of the chemical evolution in the Galaxy

What else relates to Galactic chemical evolution?

The birth place: R_{mean} – mean of the apo- and pericentric distances.

Tc slope and R_{mean}

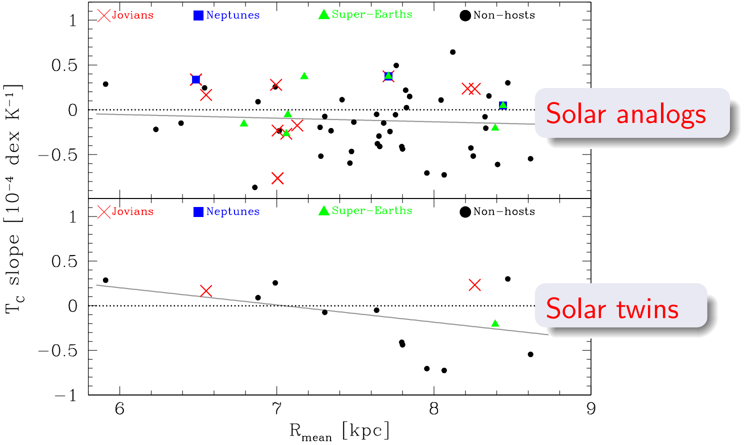


Figure: Adibekyan et al. (2014).

Tc slope correlates with R_{mean}

Stars with smaller R_{mean} show larger Tc slopes.

Tc slope and R_{mean}: Galactic abundance gradients

Tc slope correlates with galactocentric distance?
What do the other samples (data) say?

Tc slope and R_{mean}: Galactic abundance gradients

[X/Fe] vs. T_C using the Galactic abundance gradients of Galactic Cepheids from Lemasle et al. (2008, 2013).

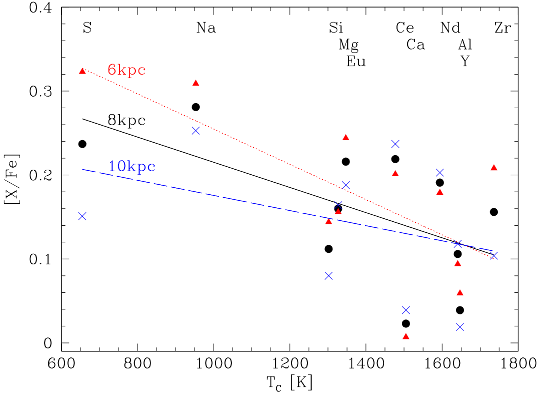
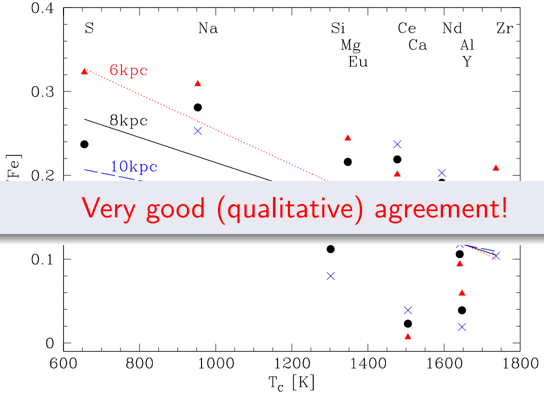


Figure: Lemasle et al. (2008, 2013).

Tc slope and R_{mean}: Galactic abundance gradients

[X/Fe] vs. T_C using the Galactic abundance gradients of Galactic Cepheids from Lemasle et al. (2008, 2013).



Very good (qualitative) agreement!

Figure: Lemasle et al. (2008, 2013).

Tc slope and planets

Tc slope depends on stellar age and galactic birth place.

What about the planets?

Tc slope and planets

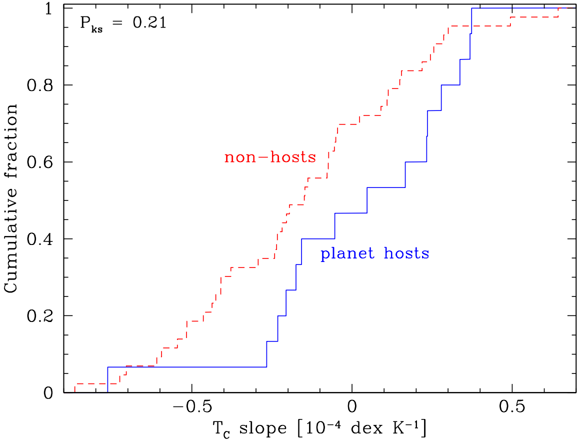


Figure: Adibekyan et al. (2014).

Solar analogues with planets show larger Tc slopes ($P_{KS} = 0.21$).

Tc slope, ages, and planets

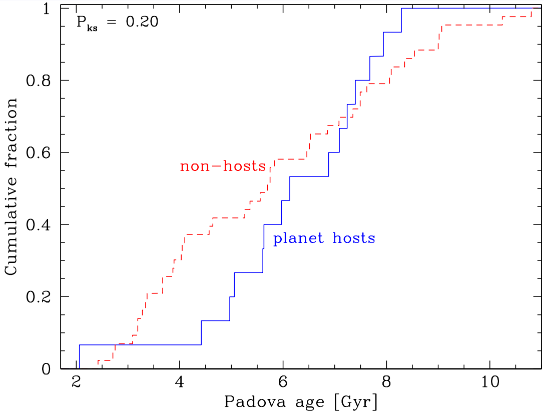


Figure: Adibekyan et al. (2014).

Solar analogues with planets have older age ($P_{KS} = 0.20$).
Should be a detection bias.

Tc slope, R_{mean}, and planets

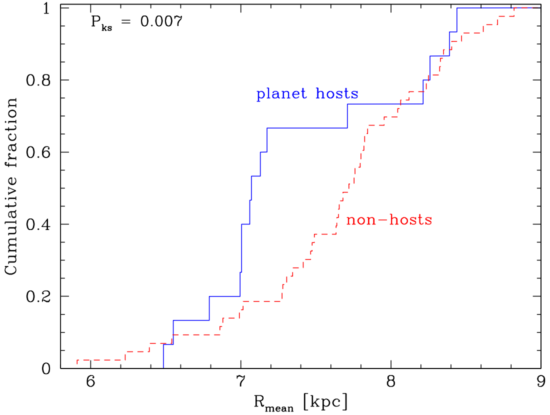
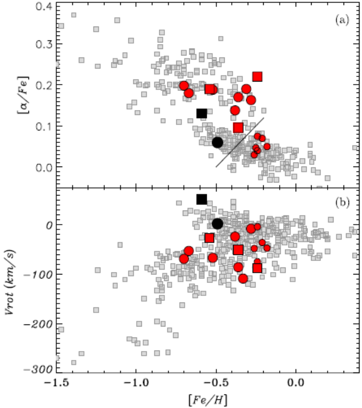


Figure: Adibekyan et al. (2014).

Solar analogues with planets show smaller R_{mean} ($P_{KS} = 0.007$).
Chemical composition (e.g. Adibekyan et al. 2014) or F(r) (Haywood 2009) ?

Planet hosts and Galactic disks



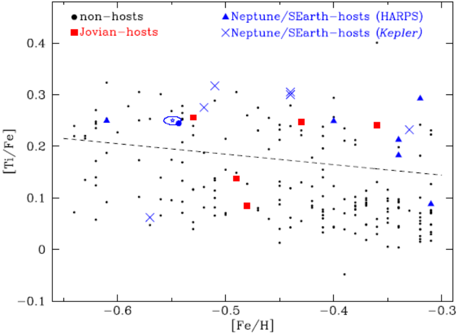


Figure: Left - Haywood 2009. Right - Adibekyan et al. 2012.

Metal-poor giant planet hosts mostly belong to the Thick disk (Haywood 2009)
Metal-poor giant and small planet hosts mostly belong to the Thick disk (Adibekyan et al. 2012)

Conclusion and open questions

The age and Galactic birth place are determinant to establish the chemical properties of each star

Solar analogues with planets mostly come from the inner Galaxy
Metal-poor planet hosts come from the Galactic Thick disk

Chemical conditions in the inner disk and thick disk are more favorable for planet formation (?)
Need to be further explored ...

Shall we search for planets around stars originated in the inner disk?

Thank you for attention!