Chemical abundances in Planet Hosts

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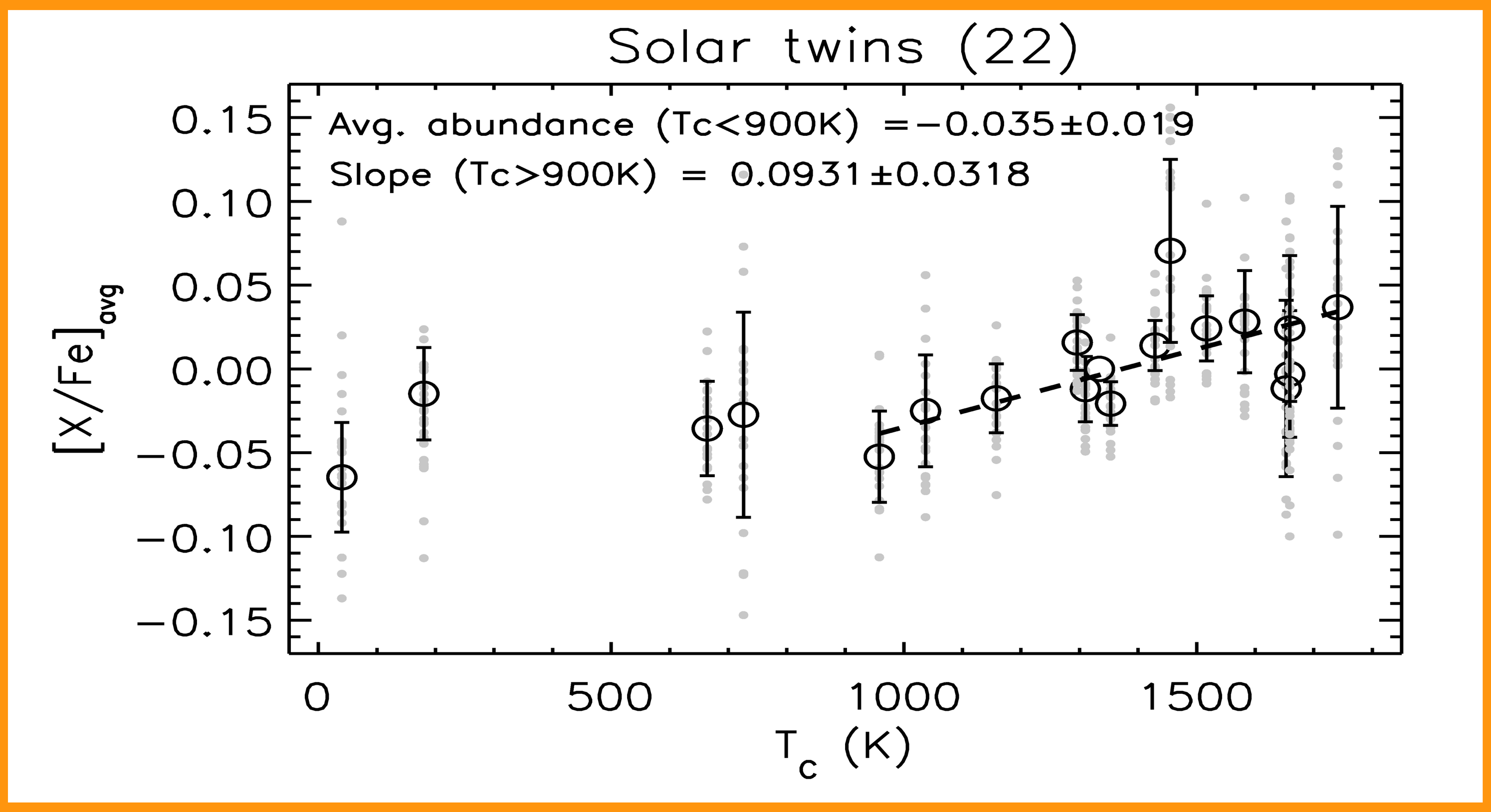
Abstract:

We examine a possible connection between the chemical composition of solar-type stars and whether those stars are hosting planets or not. In this process, we turn our attention to two different aspects of the question: on the one hand, we want to analyze the general chemical abundance patterns of solar-type stars relative to the Sun in consideration of the elements' dust condensation temperatures. We find that the Sun is depleted in high condensation temperature elements with respect to most solar twin stars, which we interpret as a signature of the formation of terrestrial planets in the solar system. On the other hand, we examine a recent claim that lithium is experiencing an extra depletion in planet-hosting stars, probably because of the interaction between the protoplanetary disk and the young host star. Instead, we find that age and metallicity biases are responsible for the apparent connection between low lithium abundance and planets.

Dust condensation temperatures:

We analyze a sample of 64 stars with basic parameters mass, metallicity, and surface gravity very similar to solar and derive precise abundances ($\sigma_{rel} \approx 0.025$ dex) for 19 different elements in those objects. When compared to the Sun, most objects show a clear overabundance in refractory elements (condensation temperature $T_{cond} \geq$ 900 K). For the 22 most solar-like stars in our sample, volatile elements ($T_{cond} \leq 900$ K) are depleted with respect to refractory elements relative to the Sun by about 20%. In addition, low T_{cond} elements appear to be on a constant level, while high T_{cond} elements show an increasing trend with condensation temperature.

This pattern seems to be a signature of the terrestrial planet formation that has taken part around the Sun but not around most of the nearby solar twins. In that process, the refractory elements that are now missing in the Sun when compared to solar twins were retained by the planets during the accretion phase. This basic idea has been fully explored on a quantitative basis, showing overall success (Melendez et al. 2009, Ramírez et al. 2009, 2010)



Conclusions:

- The elemental abundances in solar twins show a clear trend with condensation temperatures.
- An abundance pattern like that of the Sun is likely a signature of terrestrial planet formation.
- The lithium abundance in solar-type stars shows expected trends with age and indicates that the Sun is not special for a star of its mass, age, and metallicity.
- The presence of a planet does not influence the surface lithium abundance of the host star.
- Findings that indicate such a correlation are based on multiple selection biases.

References

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Israelian, I., Delgado Mena, E., Santos, N. C., et al., 2009, Nature, 462, 189

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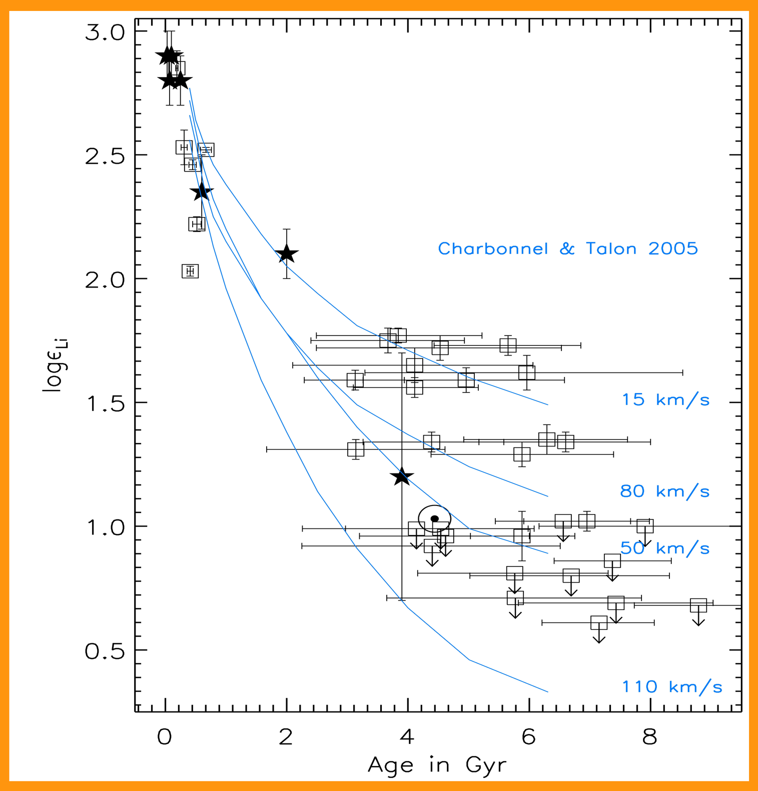
Surface lithium abundance:

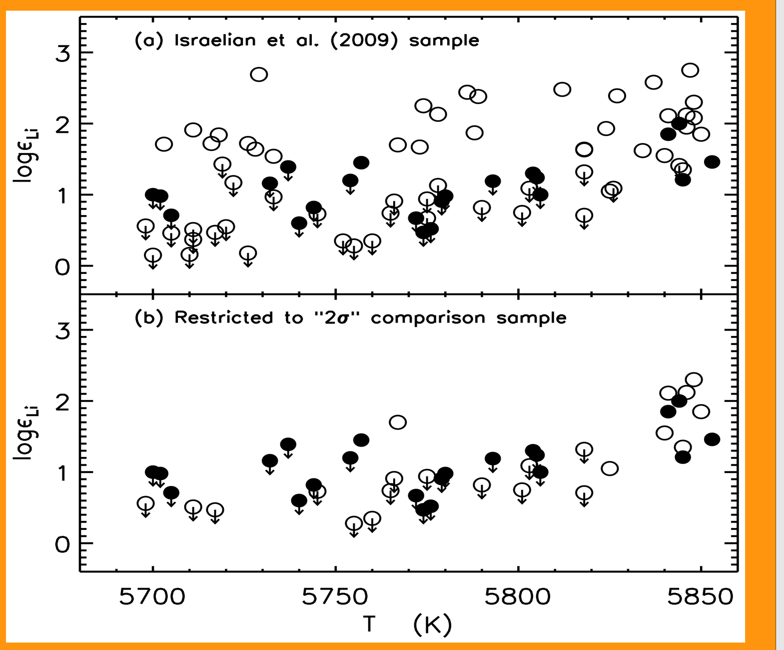
For this analysis, we examine a sample of 117 solar-type stars (mass, metallicity and surface gravity similar to solar). And derive their basic parameters. Lithium abundances were then obtained with line synthesis of the lithium doublet at 6708Å.



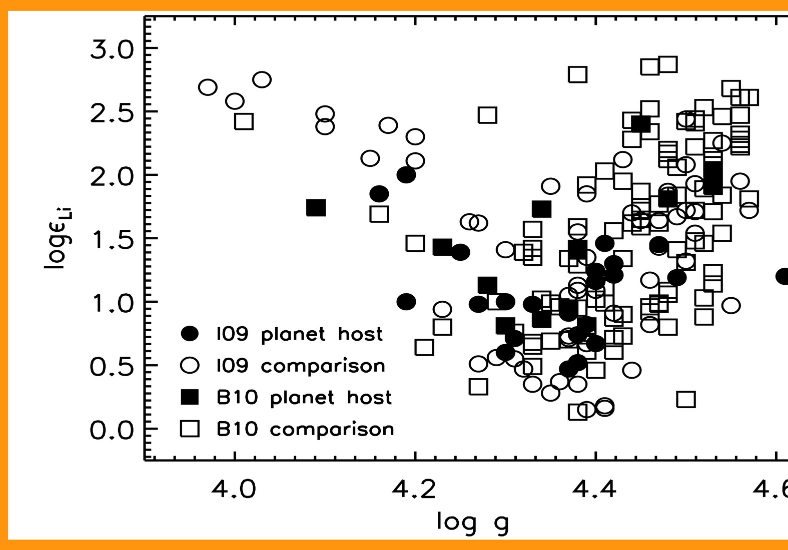
The objects in our sample follow a clear trend of surface lithium abundance with age – as predicted by non-standard models such as in Charbonnel & Talon (2005). This time-dependent depletion is caused by the fact that lithium is easily destroyed in the hot stellar interiors so the surface lithium abundance will decrease with time. This trend becomes even more apparent when we restrict the sample to solar twins, i.e. [Fe/H] = 0.0 ± 0.1 and M = (1.00 ± 0.04) Mʘ (see figure on the left) to make the comparison more self-consistent.

In the figure on the left, we added solar twins from open clusters (filled stars), because the ages of these clusters are very well determined and the fact that they follow the trend of the field solar twins suggest that the ages we derived for individual stars are reliable.

With the surface lithium abundance and planet information for every object, we can compare planet hosts to the field stars. It is obvious that they follow the same trend as the rest of the objects. The reason for the claim that lithium is more depleted in planet hosts (e.g., Israelian et al. 2009) can be explained by selection biases (right figure). The entire sample from Israelian et al. shows in general stronger lithium depletion for stars with planets. But when we restrict that sample to objects whose stellar parameters lie within 2σ around those of a planet host, this trend dissapears (lower panel). This 2σ comparison sample guarantees that we compare objects that are really similar to each other, thus minimizing biases.



The selection bias:



The fact that the sample used in Israelian 2009 (I09) is biased becomes obvious in the figure on the right, where we plot log ϵ_{Li} vs. surface gravity for our sample (B10) and the sample used in I09. Planet hosts in both samples are marked with filled symbols. The majority of the objects seem to follow one track above log g = 4.2, where no difference between planet hosts and stars without planets can be seen. On the left, there is a number of stars that appear to be sub-giants, with a high surface lithium abundance and low log g, but mostly without planets. Why those objects don't have planets but have a very high lithium abundance is unclear, but they could lead to the conclusion, that planet-hosts are in average more lithium depleted, even though they are not analog comparison objects.