Light elements (Li and Be) in stars with exoplanets

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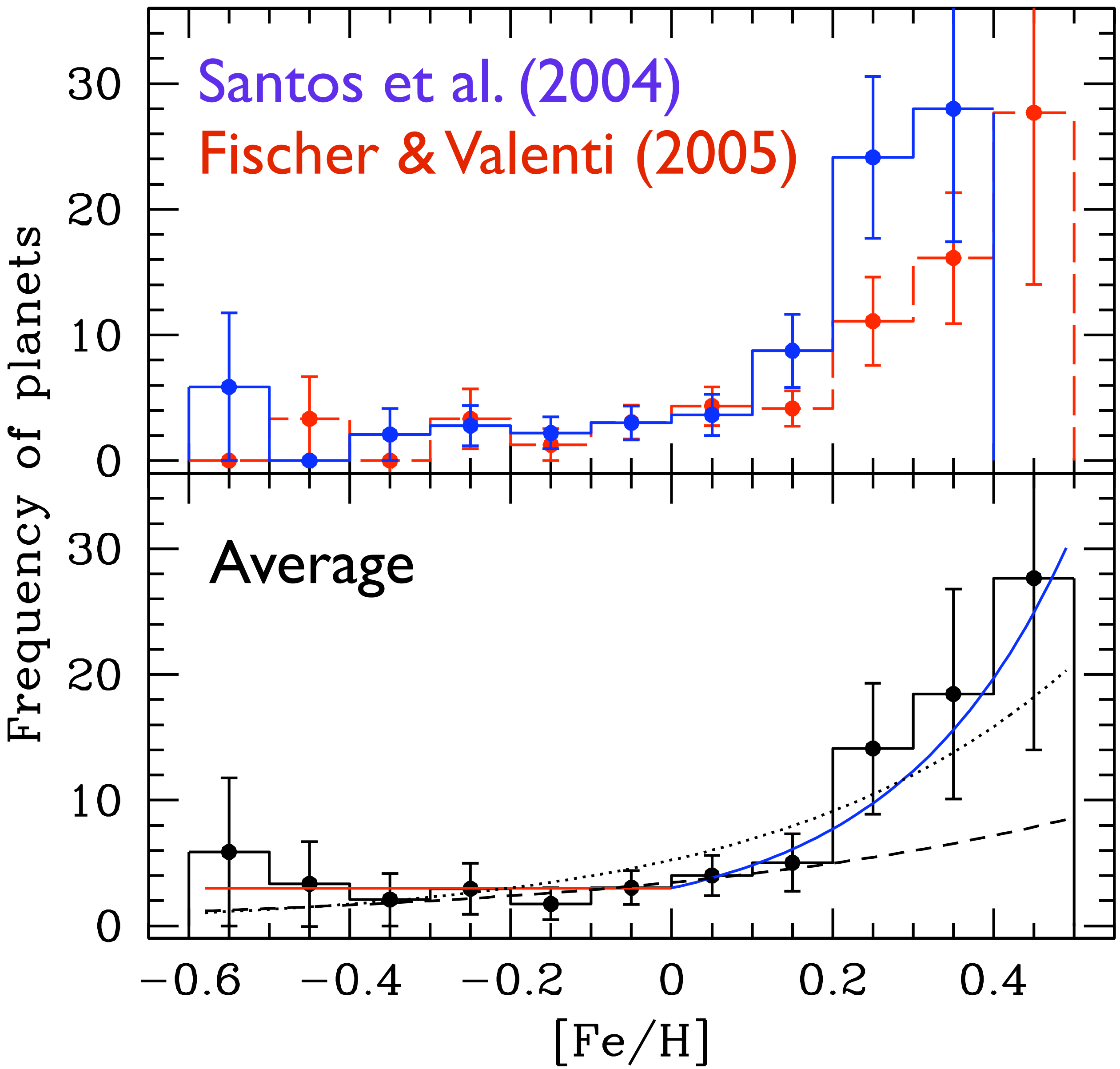
Outline of talk

- Chemical abundances of stars with planets
    - A (very) short overview
    - Why study light elements in exoplanet host stars?
- Light elements in stars with planets
    - Results on ^{6}Li, ^{7}Li, and ^{9}Be

Overview of planet searches

- More than 400 exoplanets known orbiting solar-type stars
- Simple statistics: at least 6-7% of nearby stars have planets
    - 30+ multi-planet systems
    - 50+ planets transit their host stars
    - 25+ planets with masses in range 2-20 M_{Earth}
- To understand planet formation:
    - Crucial information coming from study of planet-host stars

Metallicity distribution of stars with planets

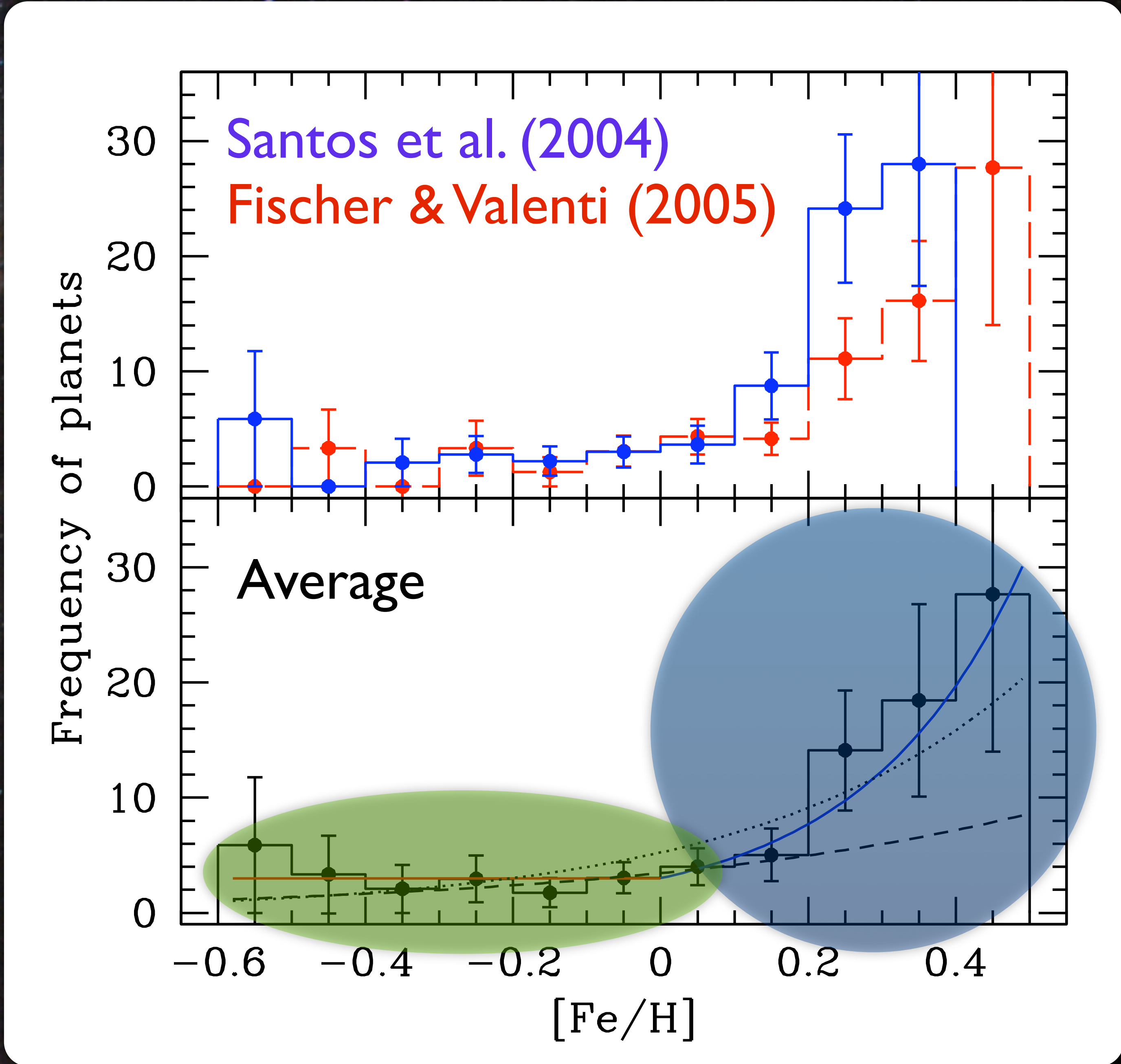


Planets more frequent around metal-rich stars

Implications for models of planet formation

- Two major giant planet formation models exist:
    - Core accretion model: planet formation dependent on dust content of disk (e.g. Pollack et al. 1996, Mordasini et al. 2009)
    - Disk instability model: not dependent of dust content (Boss 2002)
- Observations are (more) compatible with core-accretion model (but do not exclude disk instability)

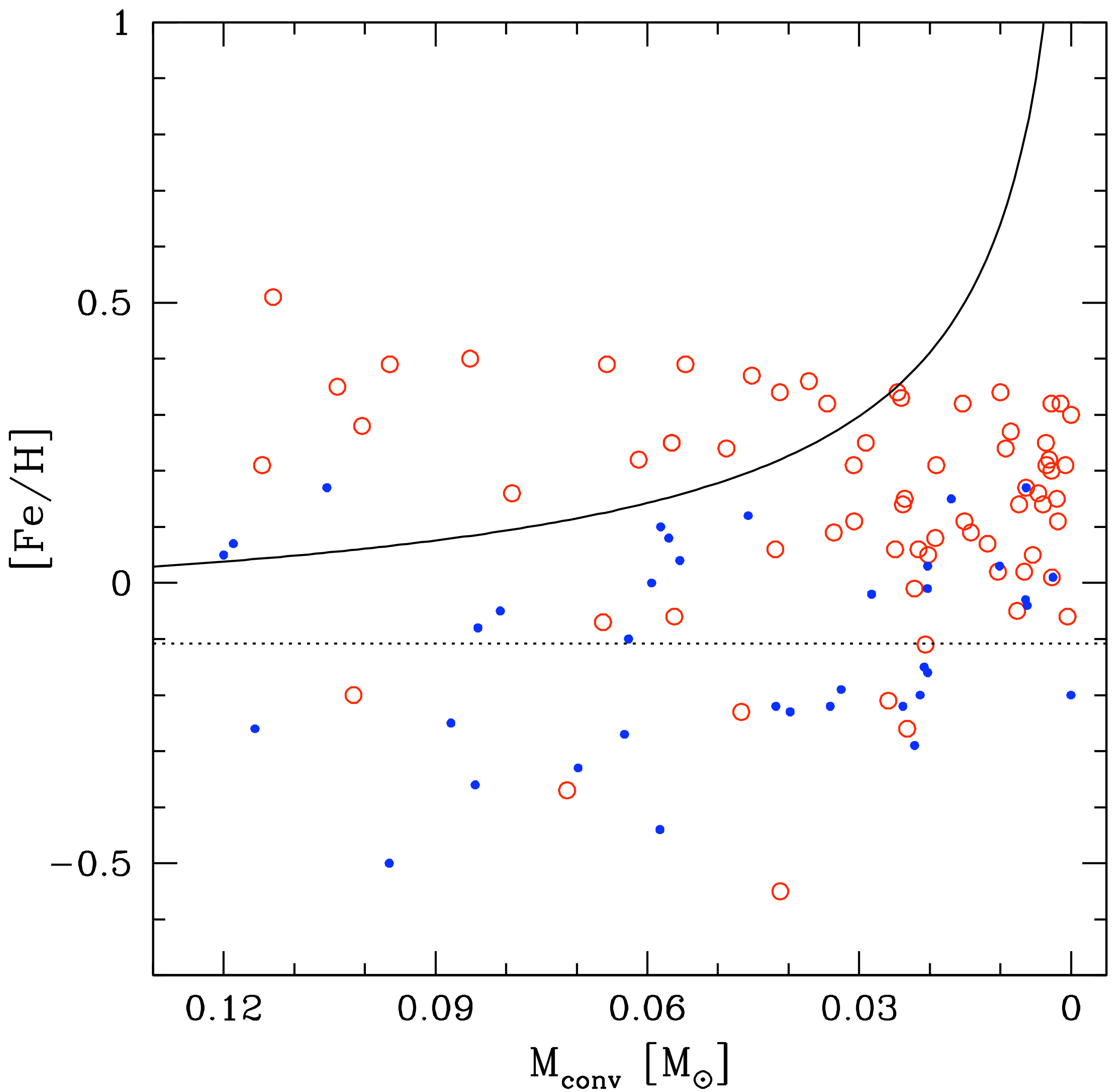
Metallicity distribution of stars with planets



Two regimes?

(Santos et al. 2004)

The origin of the metallicity excess: "primordial" vs. "pollution"



Santos et al. (2003)
Pinsonneault et al. (2001)

The explanation: primordial or pollution?

- "Against" pollution:
  - No convective envelope mass correlation (Pinsonneault et al. 2001)
  - (Too) high pollution levels needed to explain [Fe/H] in K-dwarfs
  - No metallicity dispersion in clusters (Shen et al. 2005)
  - Transit detections favor core-accretion (e.g. Guillot et al. 2007)
  - Core-accretion models fit data (Ida et al. 2004; Mordasini et al. 2009)

The explanation: primordial or pollution?

- But...:
  - Are metallicities in giants with planets the same? (Pasquini et al. 2008)
  - Dilution of initial excess in convective layer? (Vauclair 2004)
  - Cases of [Fe/H] pollution exist (though low levels) (Laws et al. 2001, Ashwell et al. 2005)
  - Li-rich giant stars exist (though post-MS accretion) (Brown et al. 1989; but see Melo et al. 2005)

Why study light element abundances in stars with planets?

- If pollution levels are "important" (important for planet formation models + chemical evolution)
  - Light elements should be particularly sensitive since they are normally depleted
  - If present in large quantities: external origin may be the best explanation (not product of stellar evolution)
- And also:
  - Light elements trace mixing in stars
  - Light element depletion dependent on rotational history
  - Are planets or planet formation affecting the abundances of light elements?

^{6}Li

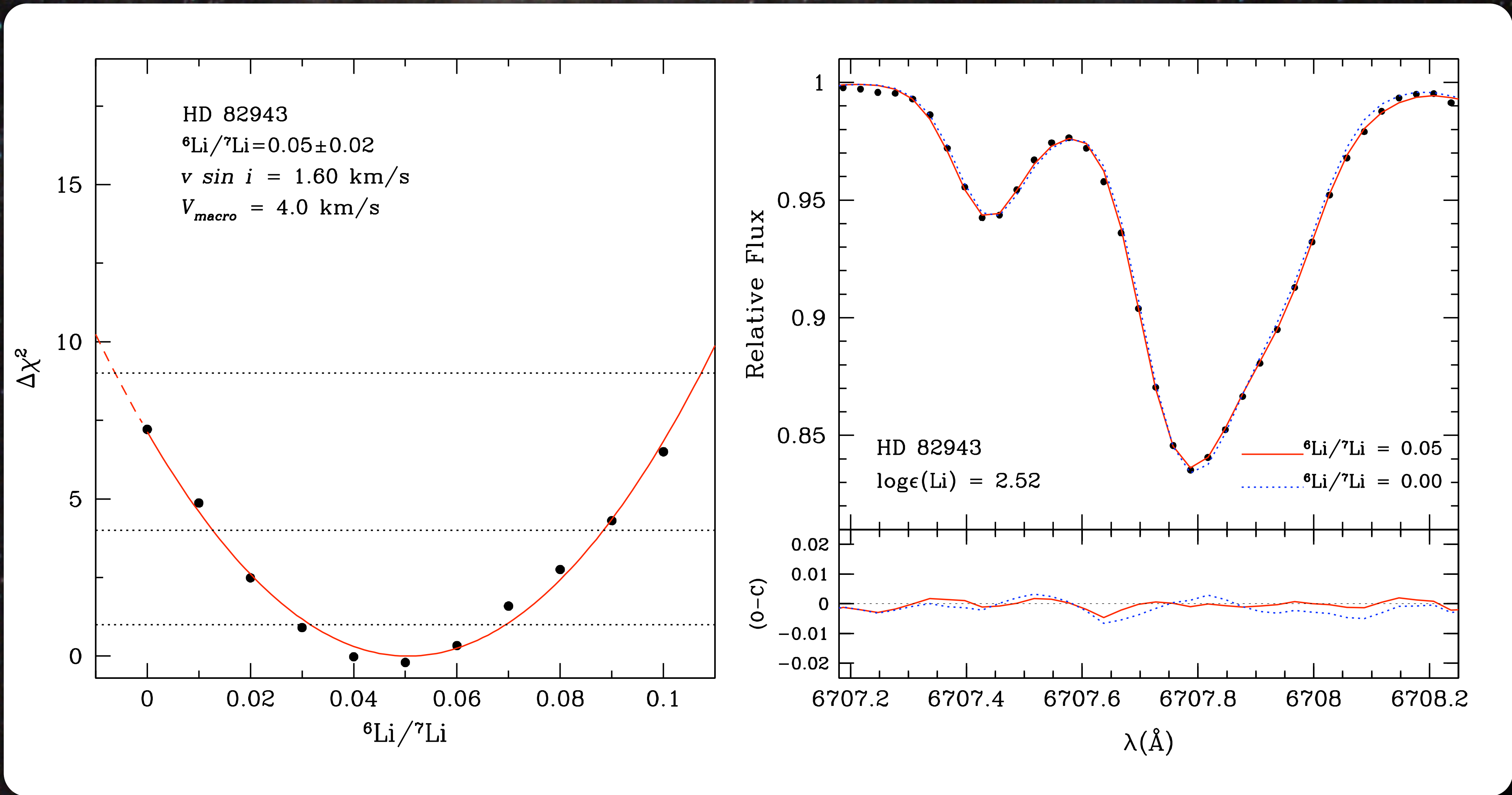
^{6}Li: tracing pollution events

- This isotope is a good tracer of pollution effects in solar-type stars (at least a bit hotter than the Sun):
  - Li-6 is not supposed to exist in solar-type stars: burned during pre-main sequence phases (Forestini et al. 1994)
  - Cannot be produced in large quantities in stellar Flares (though some is produced - Ramaty et al. 2000)
  - If added, could likely survive in Main Sequence for long periods of time (Montalban & Rebolo 2002)
  - The detection of this isotope would likely indicate an external origin: accretion of planetary-like material (e.g. Sandquist et al. 2001)

^6Li

HD82943: the first ^6Li detection

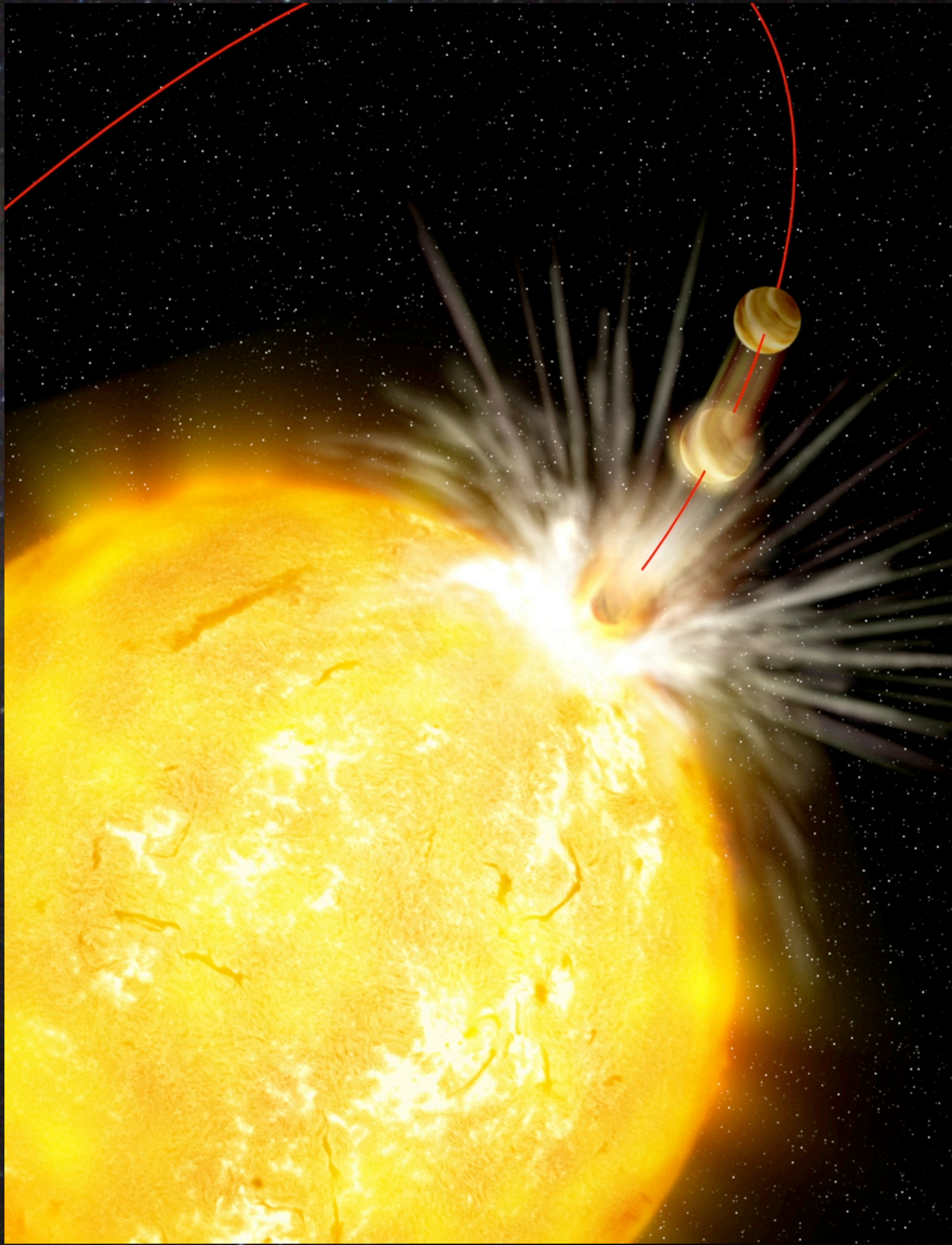
Israelian et al. (2001, 2003)



^{6}Li

HD82943

- Old (and non active) G0 dwarf (Teff = 6010 K)
- 2 planet system
- High [Fe/H]=+0.32
- Total Li abundance is high (logε(Li)~2.5)
- Best explained by infall of ~1 M_{Jup} planet (or equivalent)
- Does not significantly alter the stellar metallicity



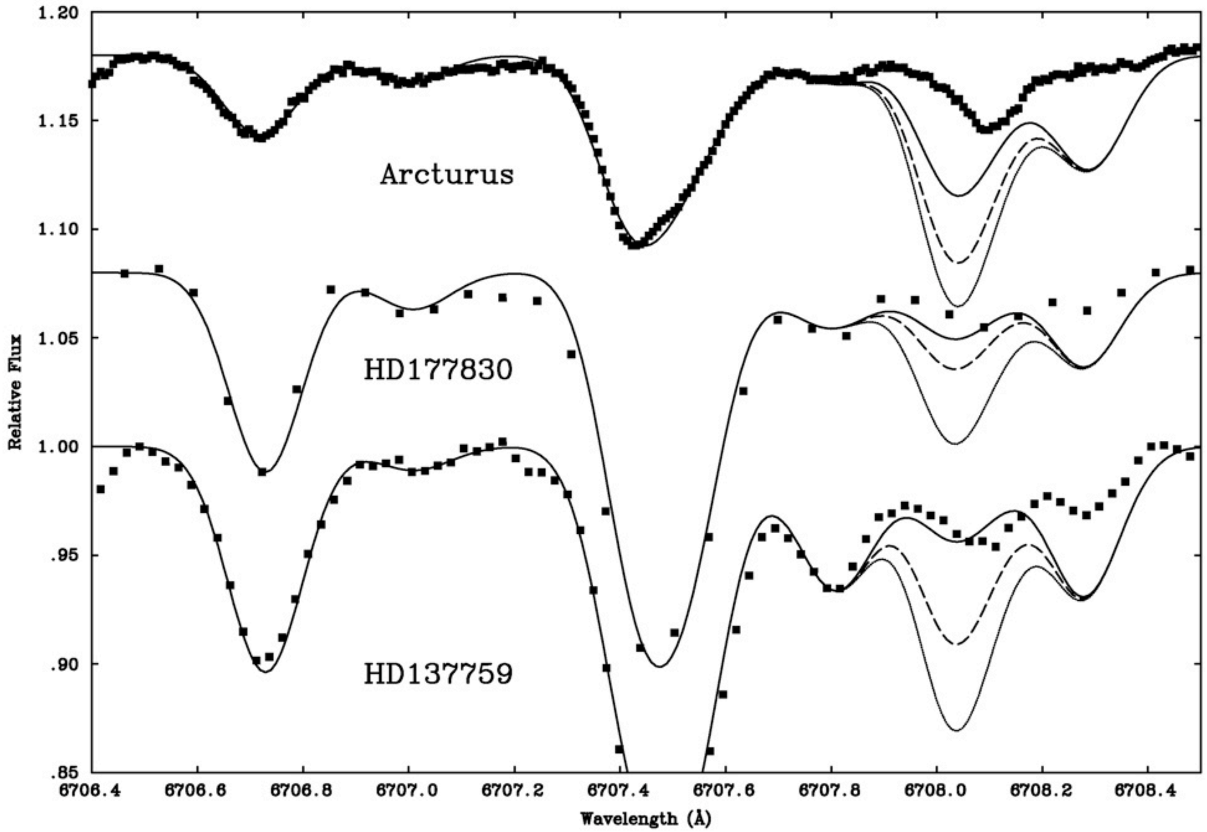
^{6}Li in HD82943: the discussion

- Reddy et al. (2002): is there really ^{6}Li on HD82943?
  - Blend with TiI line?
- Is there a problem with line-lists?
  - The detection of ^{6}Li is difficult and may be subject to line list uncertainties!
- 3-D modelling? Convection produces red asymmetries as in case of ^{6}Li (e.g. Cayrel et al. 2008, Ghezzi et al. 2009)
  - Amplitudes high enough?
- No similar detection by other authors/in other targets (Reddy et al. 2002, Mandell et al. 2004, Ghezzi et al. 2009)

HD82943: the discussion

- Line-list of Reddy et al. (2002) does not explain it... but the discussions in these domains never end!

Israelian et al. (2003)

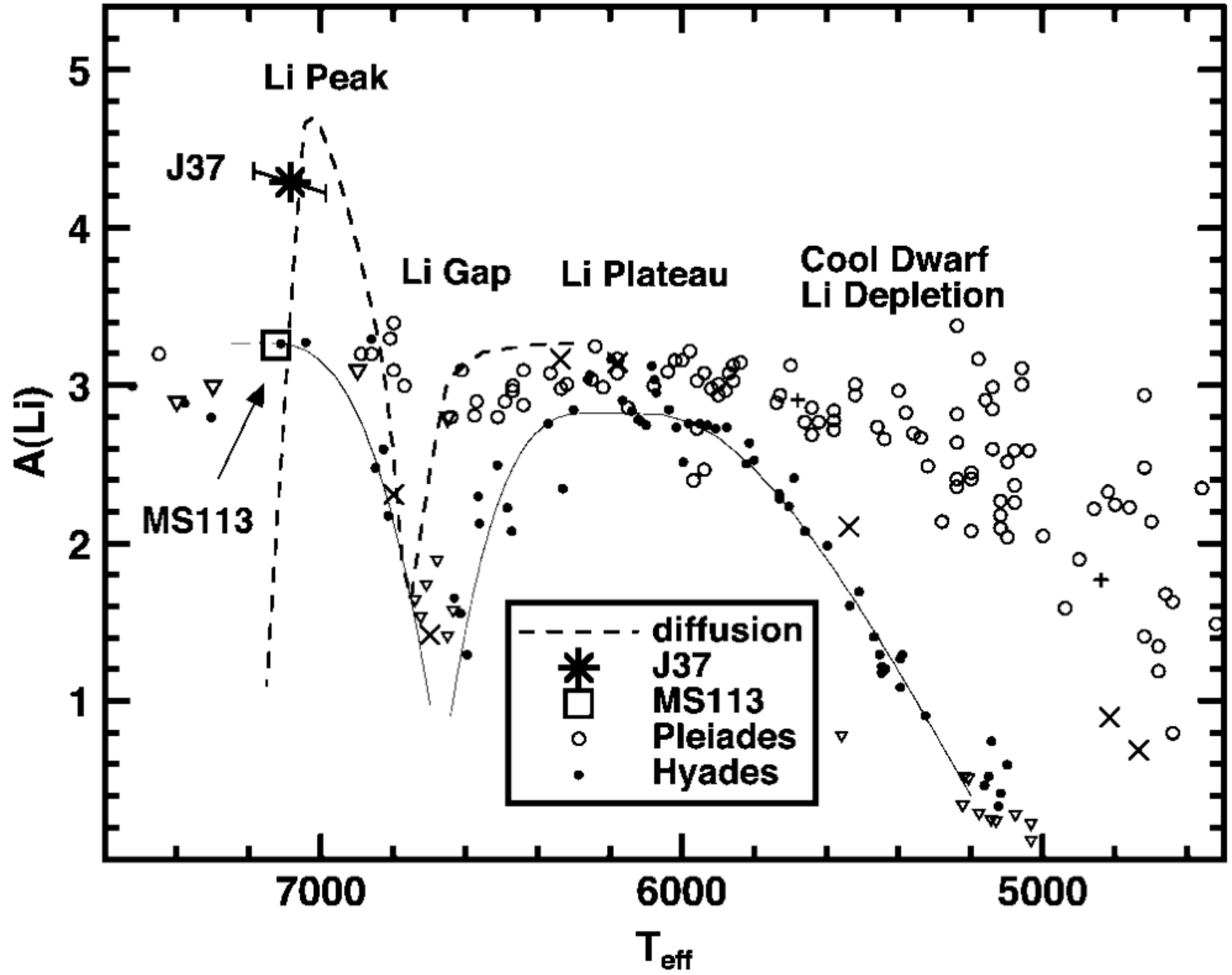


^{7}Li

^{7}Li in F stars: pollution diagnostic

- J37 (T_{eff}~7000K) in NGC6633: "gargantuan" Li abundance Deliyannis et al. (2002)
- Beryllium is also in excess (Ashwell et al. 2005)
- Other elements indicate excess abundance (Laws et al. 2003)
- Pollution evidence!

Deliyannis et al. (2002)



^7Li in stars with planets: different abundances?

- Planet-host stars have lower Li abundances in the Solar temperature region

See also:

King et al. (1997)

Cochran et al. (1997)

Gonzalez et al. (2000)

Israelian et al. (2004, 2009)

Takeda et al. (2005)

Chen et al. (2006)

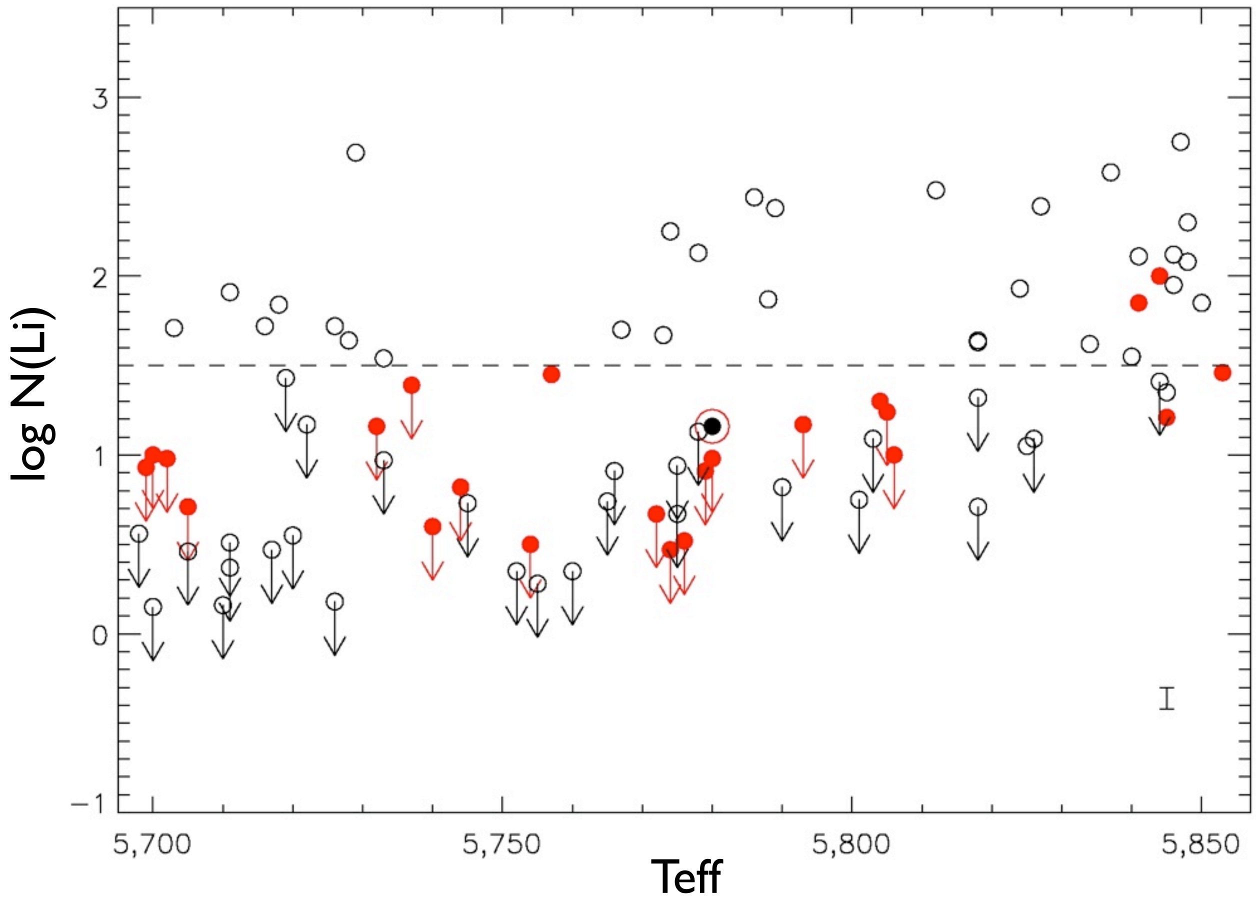
Though:

Ryan et al. (2000)

Luck et al. (2006)

Israelian et al. (2009)

Talk by G. Israelian



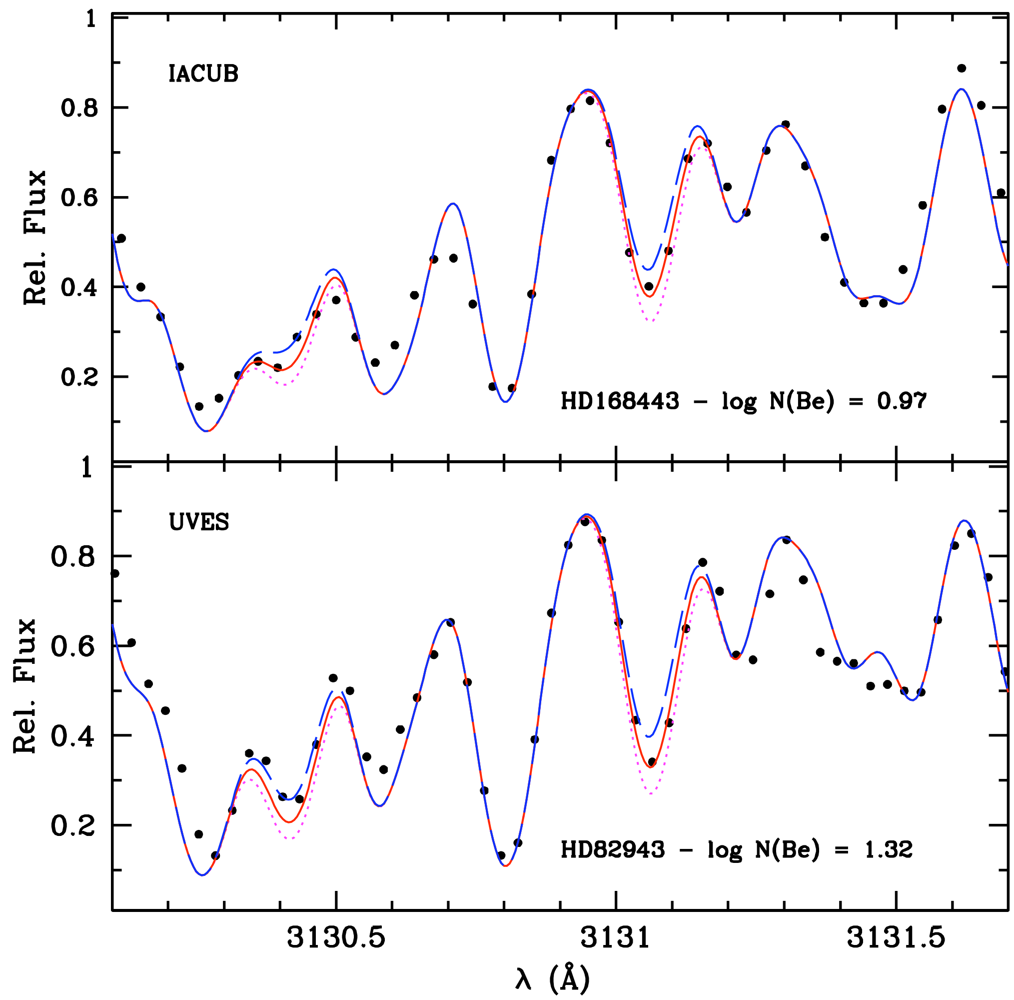
^{7}Li

^{7}Li in stars with planets: How to explain?

- Israelian et al. (2009):
  - Exclude metallicity, age, vsini, and activity effects!
- How to explain observed difference?
  - Pollution would have the opposite effect
    - This does not exclude (important) pollution effects but makes them unlikely
  - Different evolution in stars with planets?
    - Extra-mixing due to planet-star interaction (migration - e.g. Castro et al. 2009)
    - Infall of planets? (Theado et al., in prep.)
    - Disk-star interaction at play (Cochran et al. 1997; Bouvier et al. 2008): slow rotators develop strong velocity gradient at base of convective envelope

Berillium in stars with planets

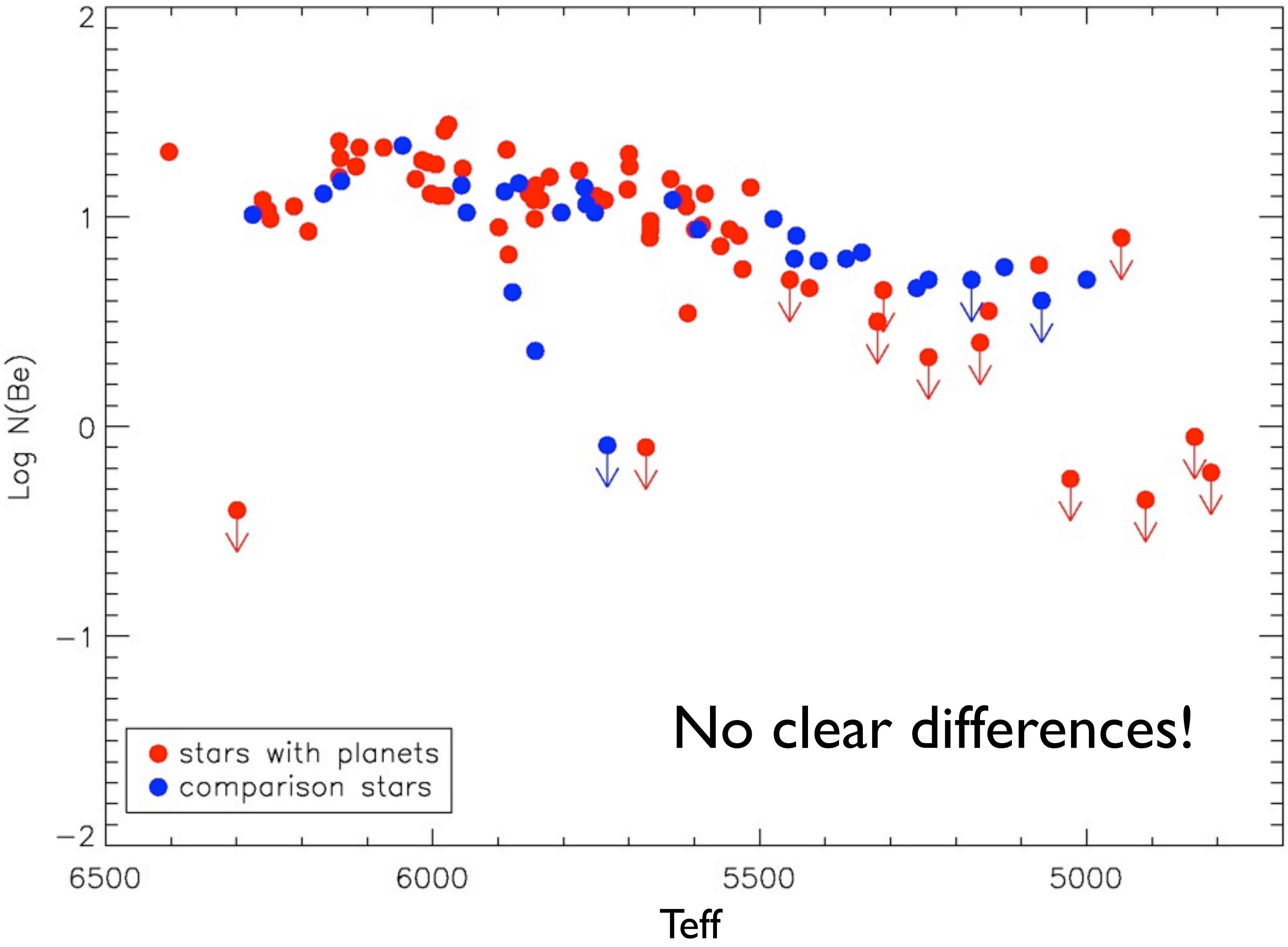
- "Complicated" element
  - Near-UV + blended region
- Not many works in the literature
  - Garcia Lopez et al. (1998) Deliyannis et al. (2000)
    - But: Very small number of stars
  - Largest samples:
    - Santos et al. (2002, 2004) Galvez et al. (2009) Delgado Mena et al. (*in prep*)



See also poster by E. Delgado Mena et al.

^{9}Be Berillium in stars with planets

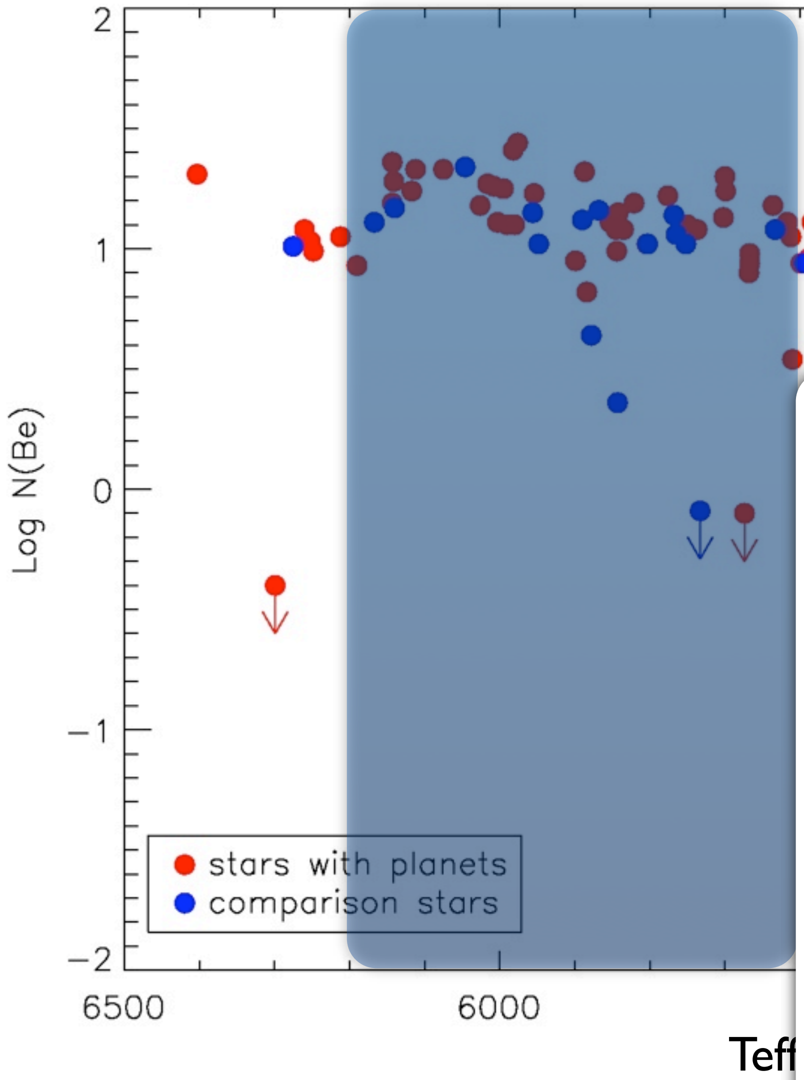
Data from: Santos et al. + Galvez et al. + Delgado Mena et al.

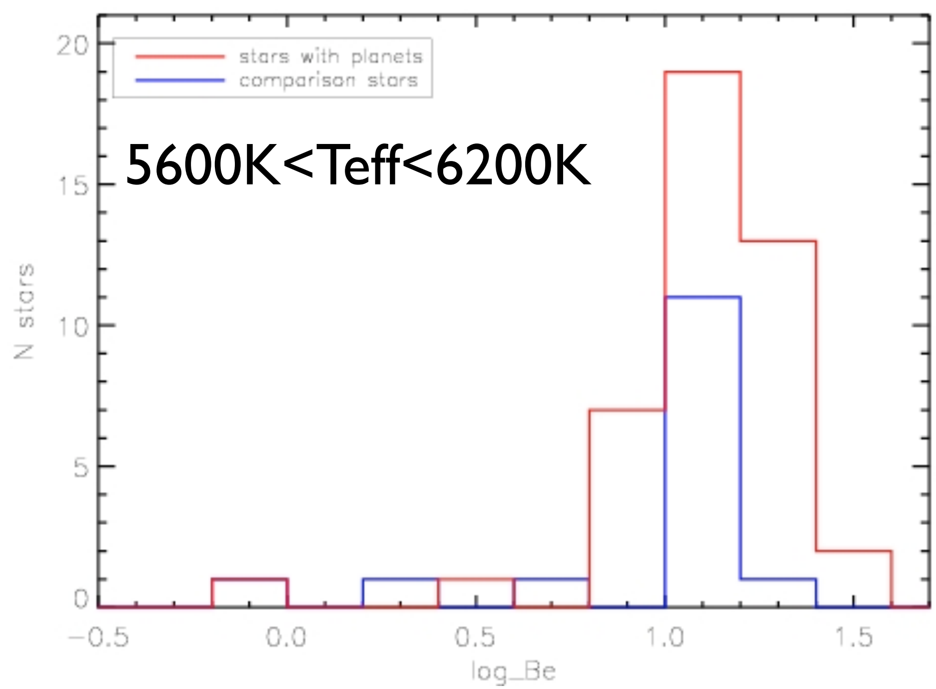


^{9}Be

Berillium in stars with planets

Data from: Santos et al. + Galvez et al. + Delgado Mena et al.

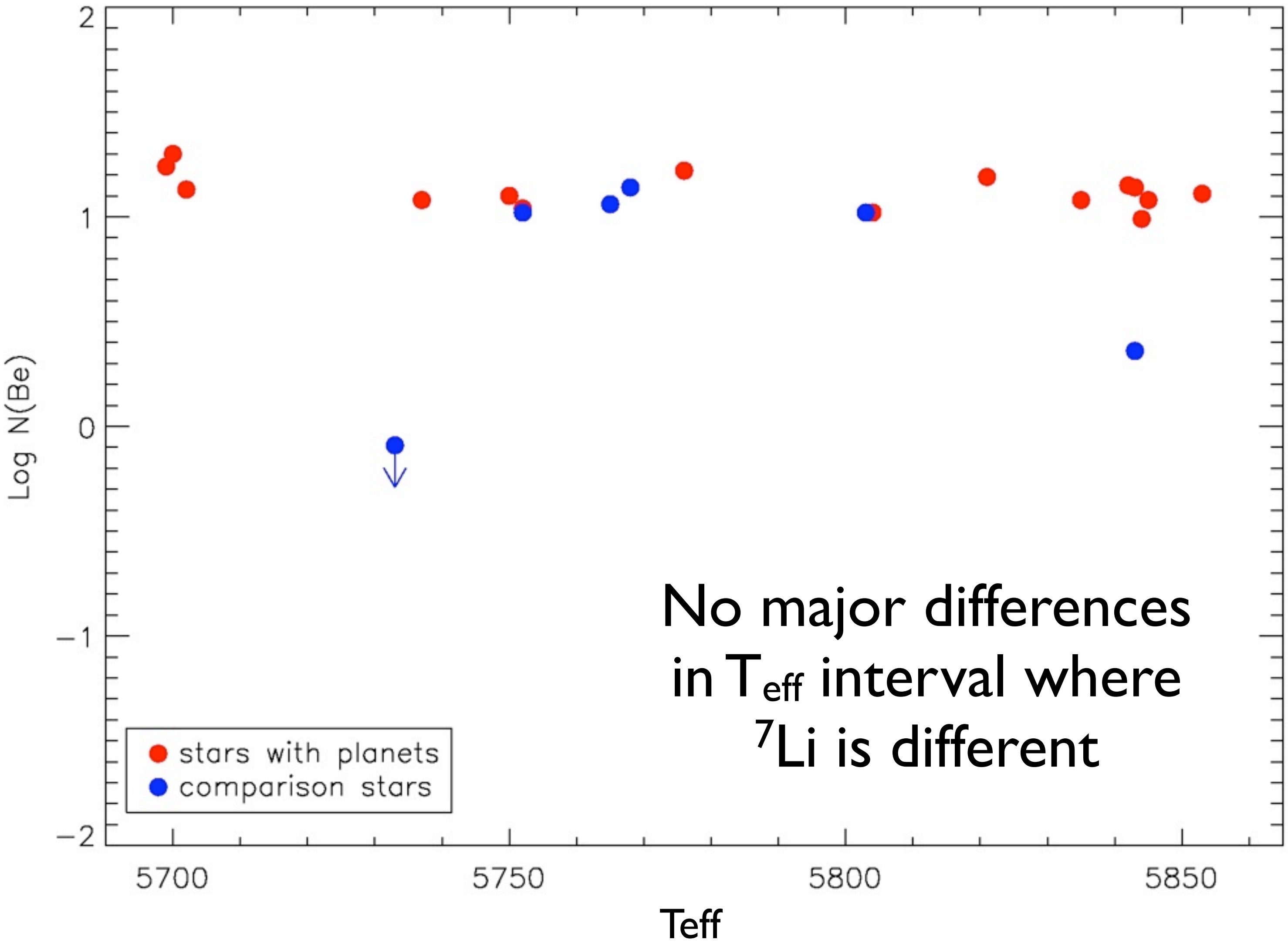




^{9}Be

The T_{eff} range where Li is anomalous

Data from: Santos et al. + Galvez et al. + Delgado Mena et al.

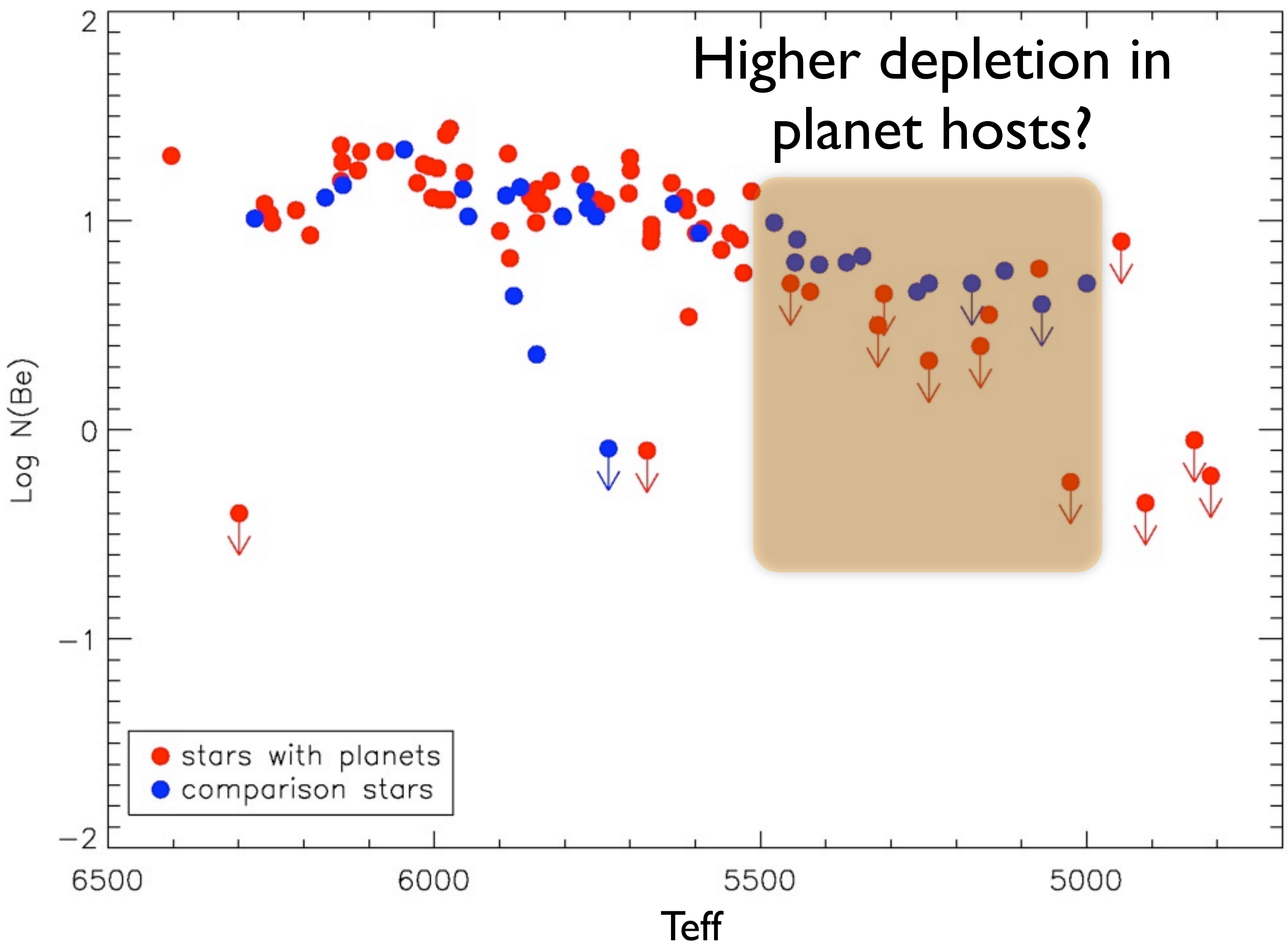


No major differences in T_{eff} interval where ^{7}Li is different

^9Be

Berillium differences?

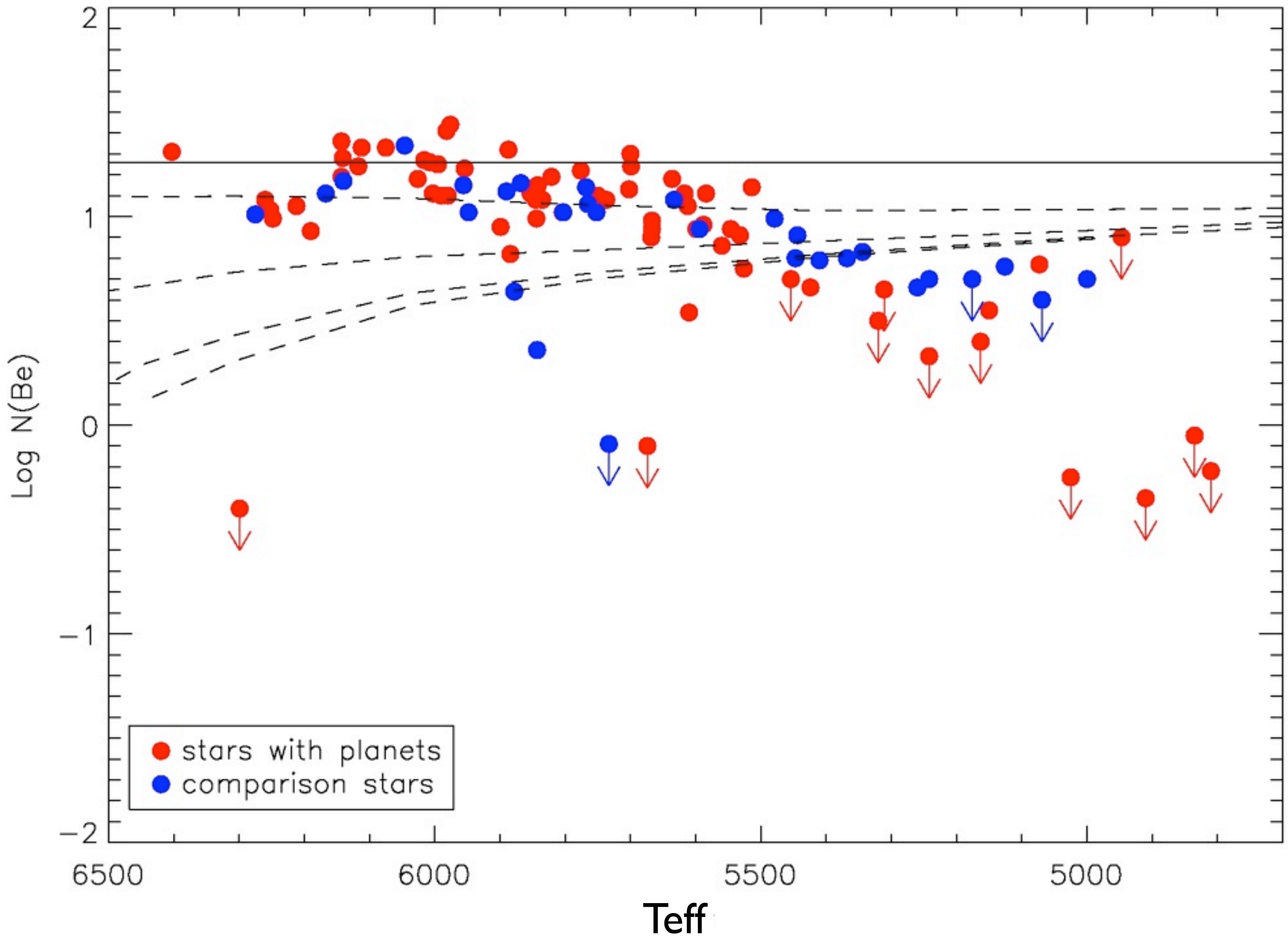
Data from: Santos et al. + Galvez et al. + Delgado Mena et al.



^{9}Be

Comparing with models

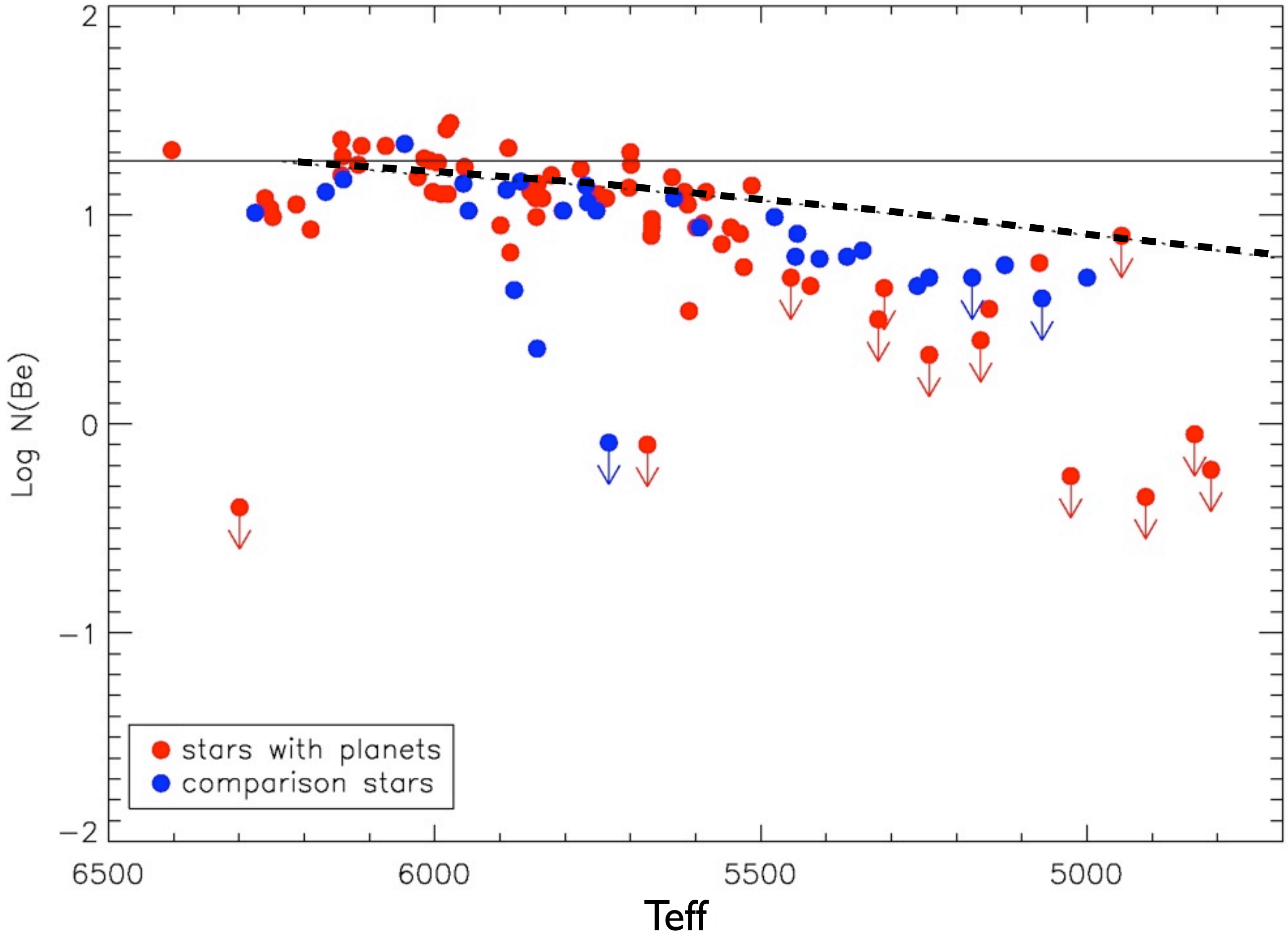
Pinsonneault et al. models (1.7Gyr, including rotational mixing)



^{9}Be

Comparing with models

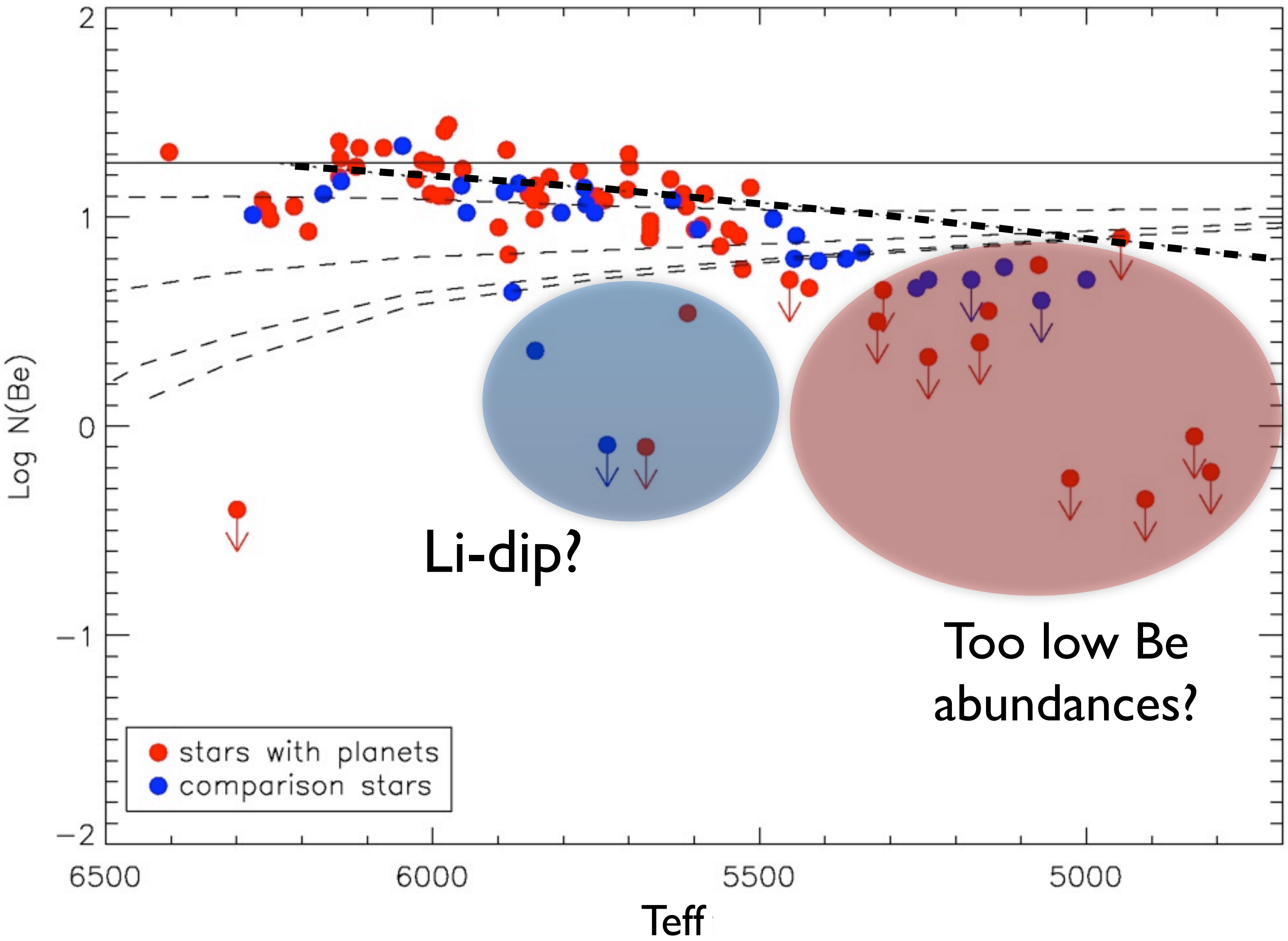
Montalban et al. models (4.5 Gyr, with internal waves)



^{9}Be

Comparing with models

See discussion in Santos et al. (2004)



Conclusions

- ^{6}Li, ^{7}Li, and ^{9}Be abundances are giving clues to planet formation and evolution
  - ^{6}Li shows evidence for pollution (but debated):
    - Is pollution a frequent event?
  - ^{7}Li more depleted in planet-hosts
    - Star-planet or Star-disk interaction?
  - Beryllium abundances do not show any clear particularity
    - More data needed to confirm some possible trends
    - But: comparison with models shows unexplained features (but not related to planets)


Thank you!
Nuno C. Santos, IAU Symp. 268 "Light Elements in the Universe", Geneva, Switzerland, 9-13 November 2009