THE LITHIUM ISOTOPIC RATIO OF THE METAL-POOR BINARY CS22876-032: THE COSMOLOGICAL LI PROBLEM

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Stellar Archaeology as a Time Machine to the First Stars

Lecture Hall – Kavli IPMU

Tokyo, Kashiwa-shi, Chiba, 3rd December 2018

COLLABORATORS

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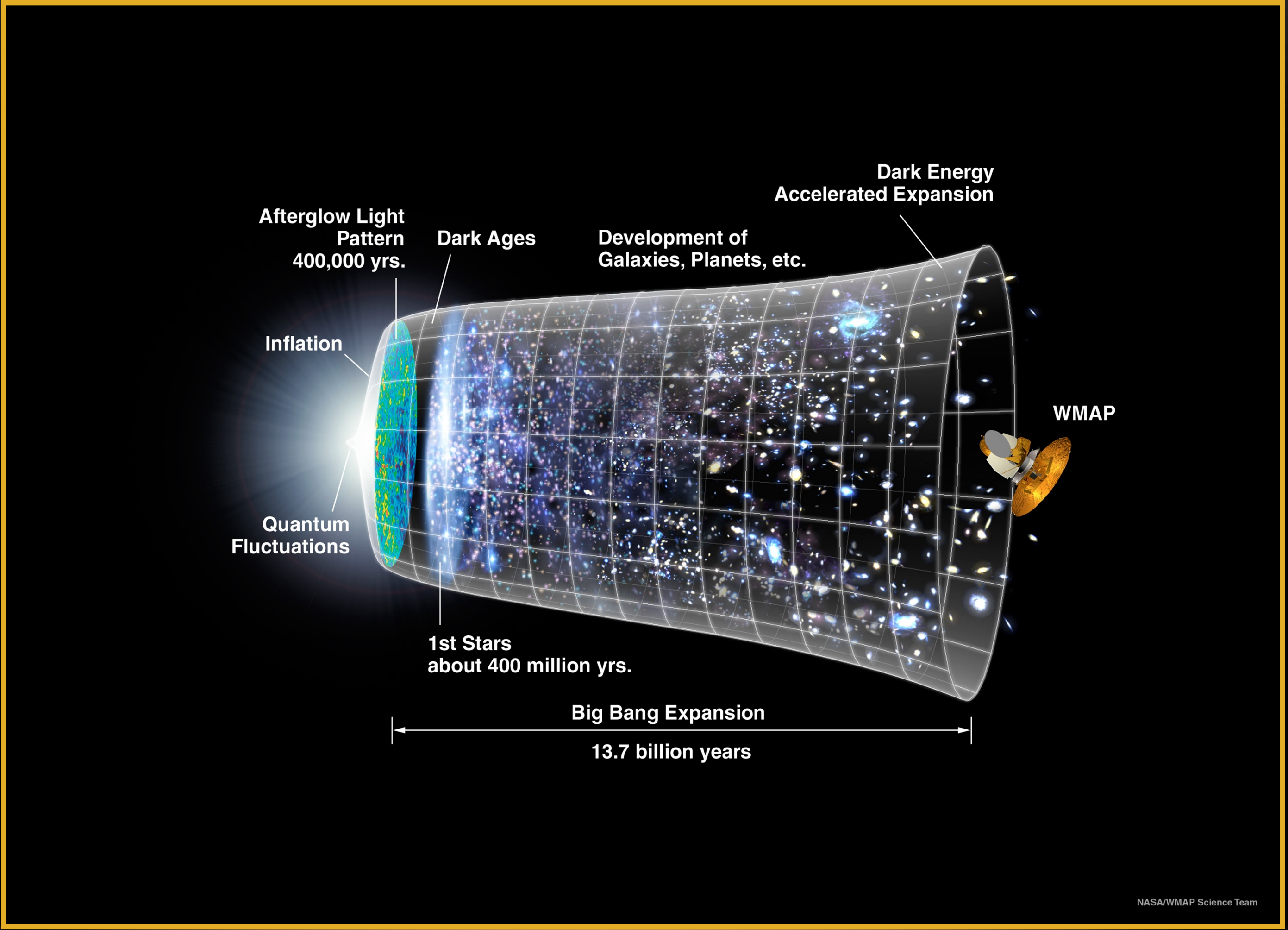
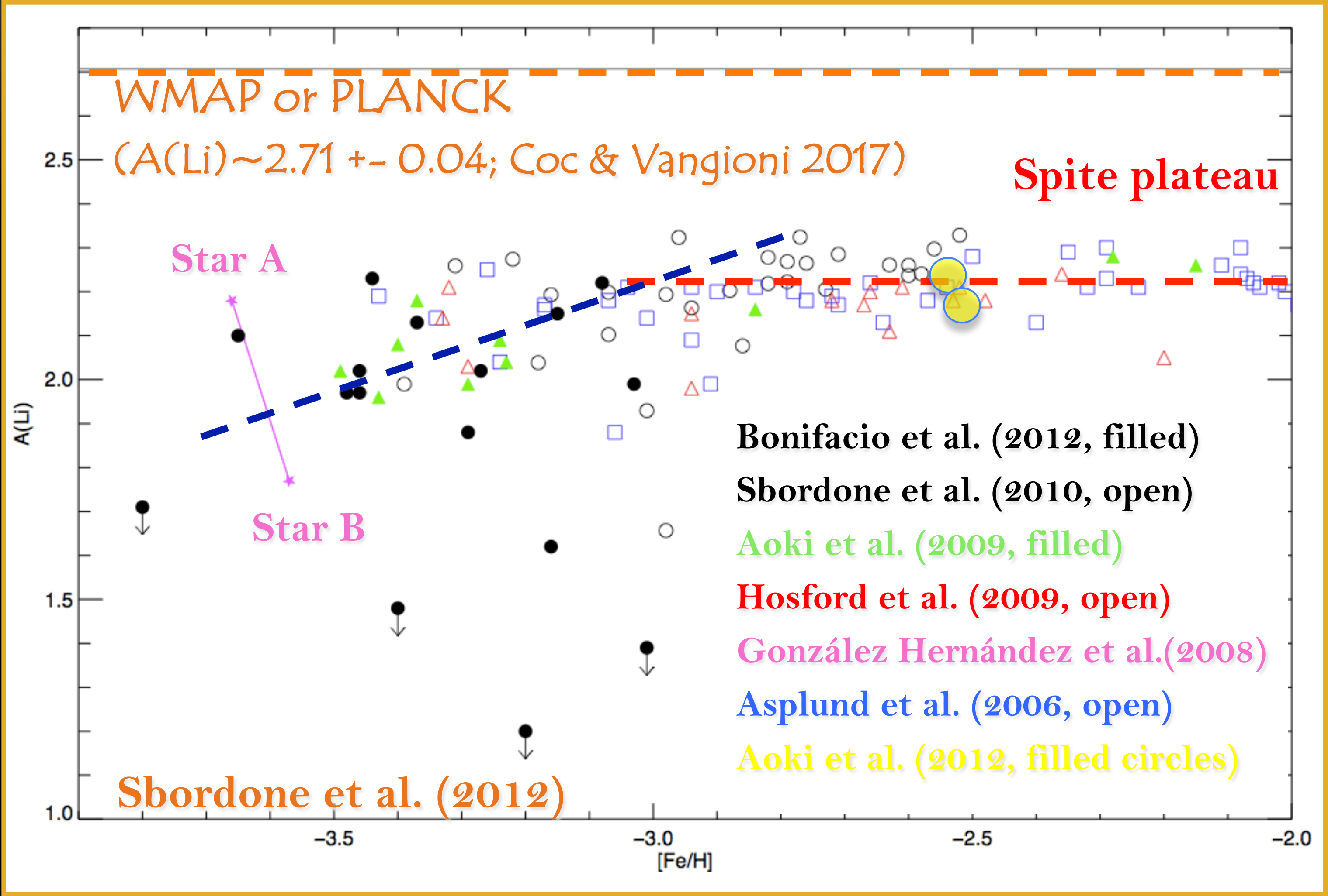
- Elisabetta Caffau
- Hans Ludwig
- Matthias Steffen
- Lorenzo Monaco
- Roger Cayrel

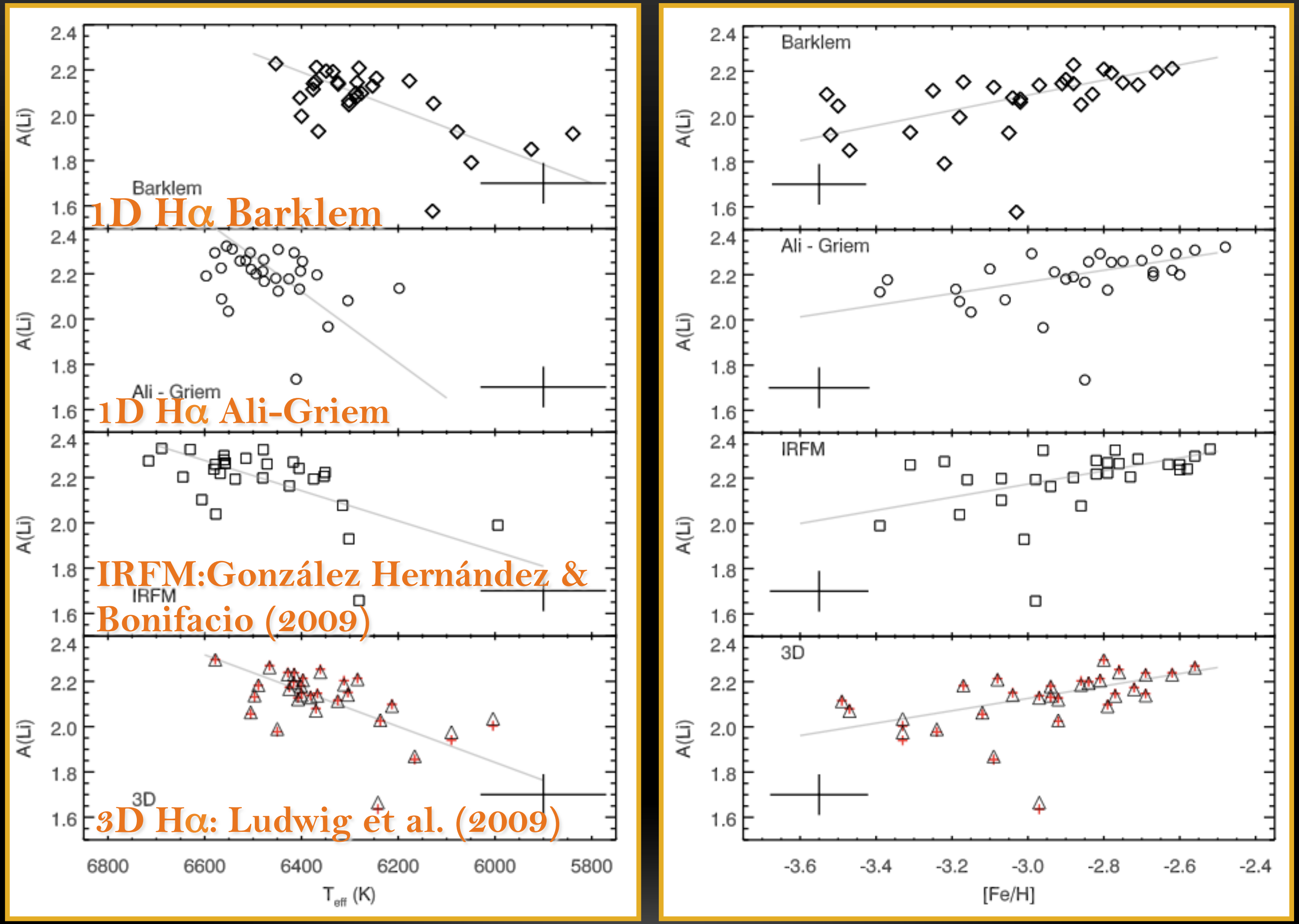
Cosmological Li Problem



Lithium in Metal Poor Stars



Lithium in Metal Poor Stars



Sbordone et al. (2010)

Lithium Discrepancy

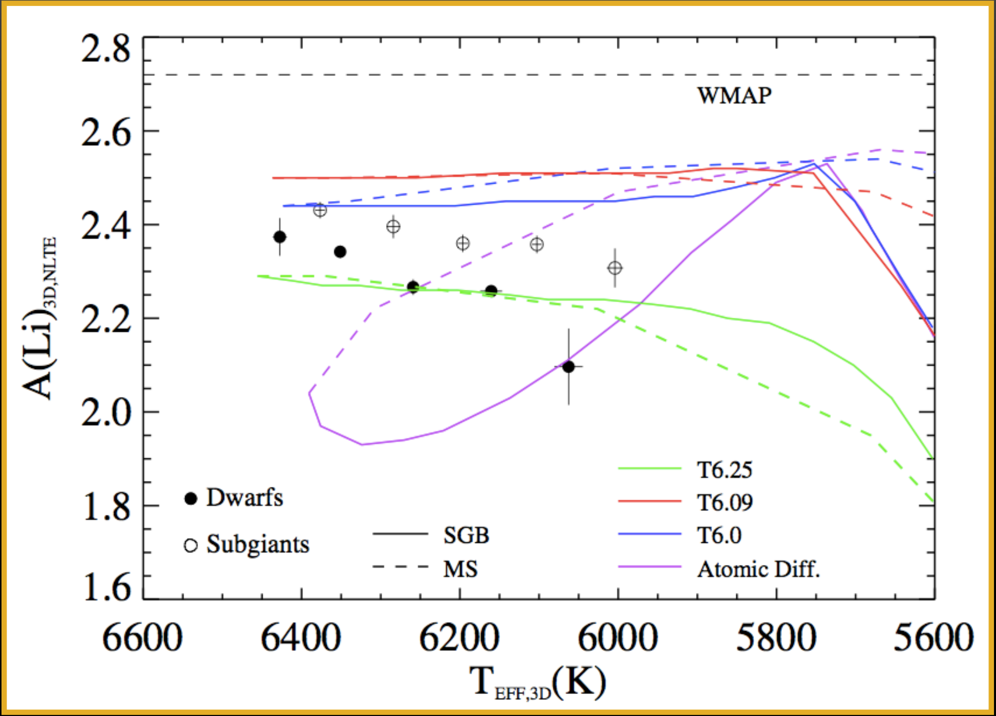
The 0.4-0.5 dex of difference between the Spite plateau and WMAP & PLANCK results may be explained by:

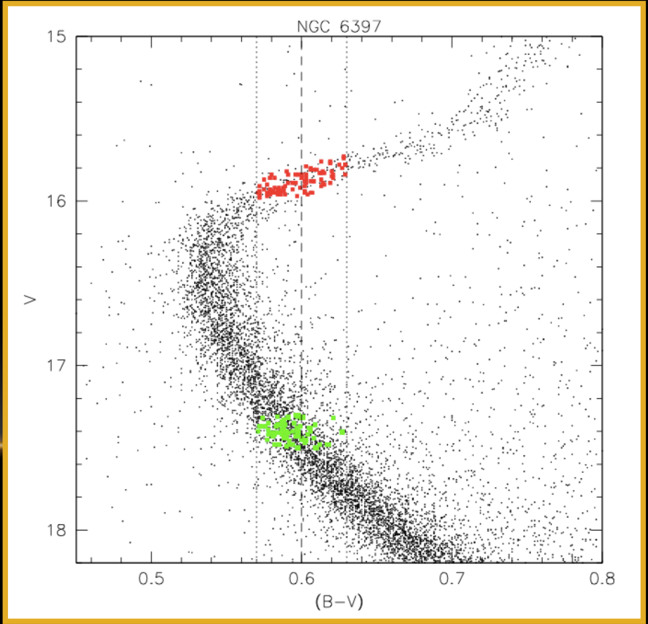
- Diffusion with turbulence (Richard et al. 2005)
- Gravity waves in stellar interiors (Charbonnel & Talon 2005)
- Pre-galactic Li processing by massive Pop III stars (Piau et al. 2006)
- Tachocline mixing (Piau et al. 2008)
- Mass dependence Li depletion (Meléndez et al. 2010)
- Pre-main sequence depletion + accretion (Molaro et al. 2012)
- Non-standard BBN (Jedamzik 2006; Hisano 2009)

…

NGC 6397: SG & MS

- Li surface abundance changes with evolutionary status.
- The Li abundance pattern seen in the globular cluster NGC 6397 has not been observed so far in field stars.
- The cosmological lithium problem still awaits a solution
- Our observations call for new investigations into the stellar physics, including gravity waves, atomic diffusion, winds and turbulent mixing





González Hernández et al. (2009)

Lithium Discrepancy

- BBN produces insignificant amout of ^{6}Li

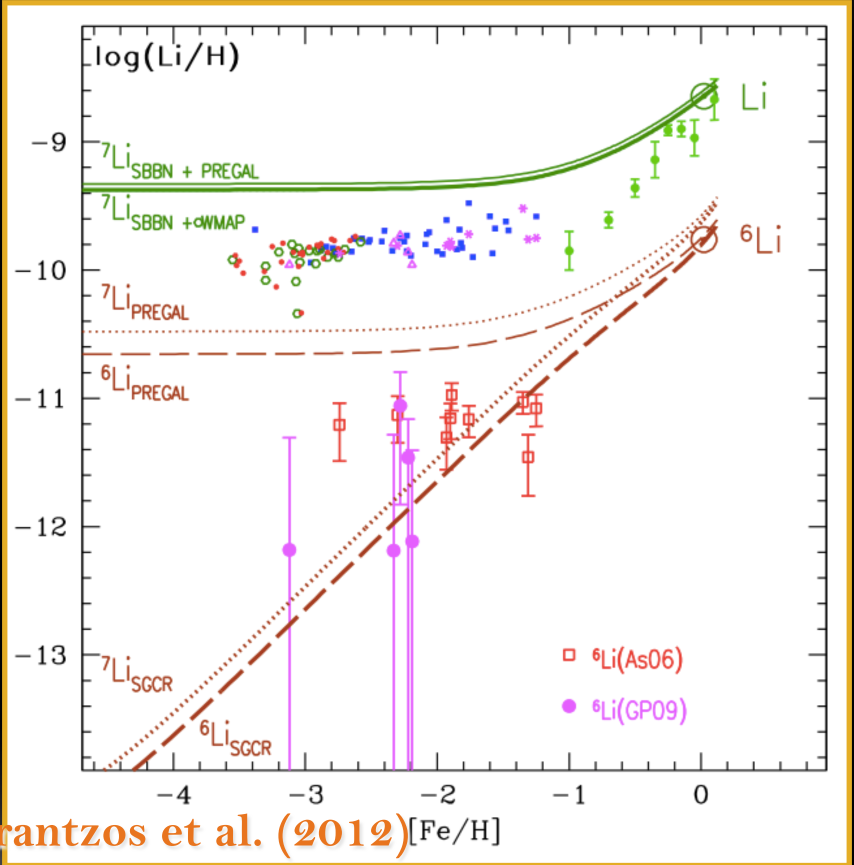
- ^{6}Li in the Galaxy possibly created by spallation reactions with galactic cosmic rays (GCRs)

- At [Fe/H] < -2, the predicted level of ^{6}Li/^{7}Li < 1%

- Detecting ^{6}Li in metal-poor stars may suggest other production channels:

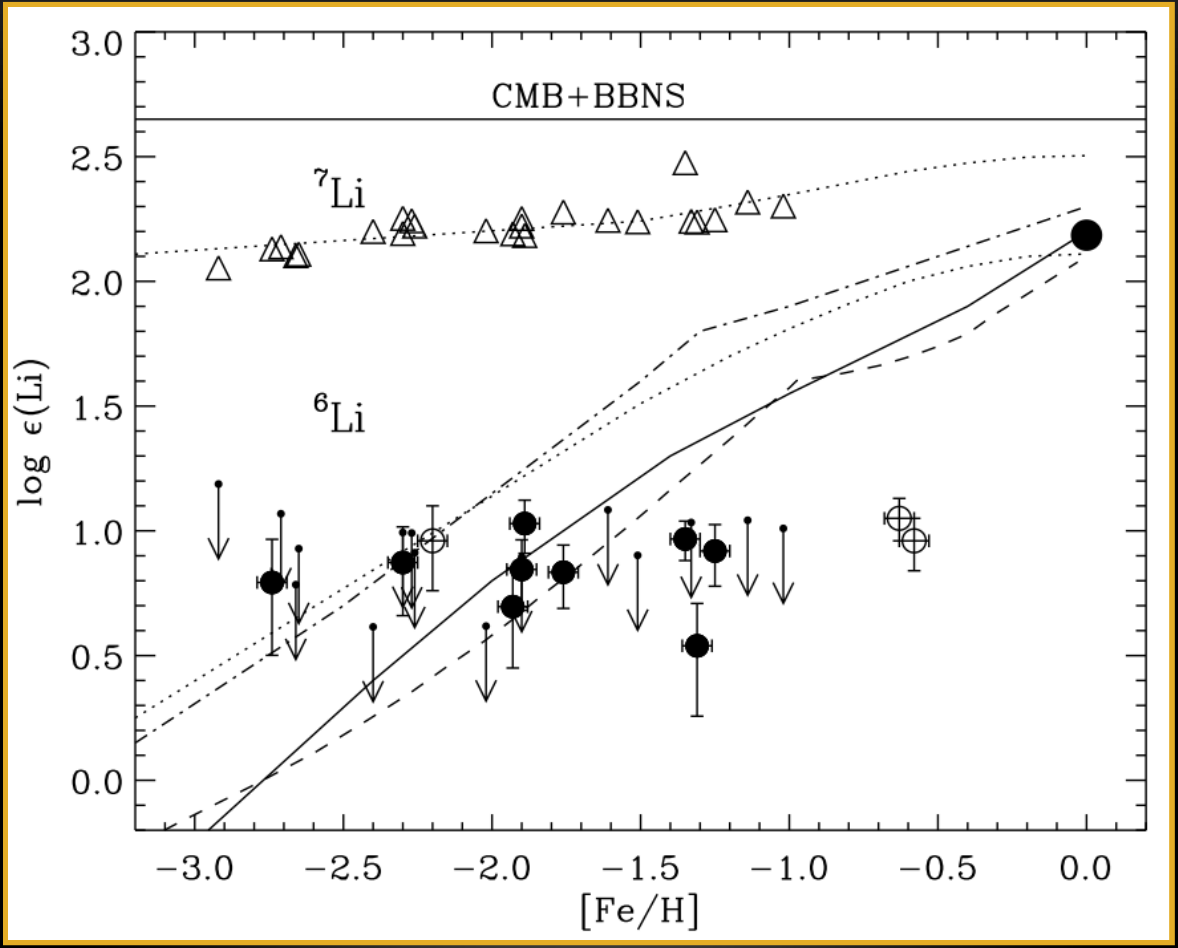
    - non-standard physics (Jedamzik & Pospelov 2009)

    - pre-galactic origin (e.g. Rollinde et al. 2006)



Prantzos et al. (2012)

Lithium in Metal Poor Stars



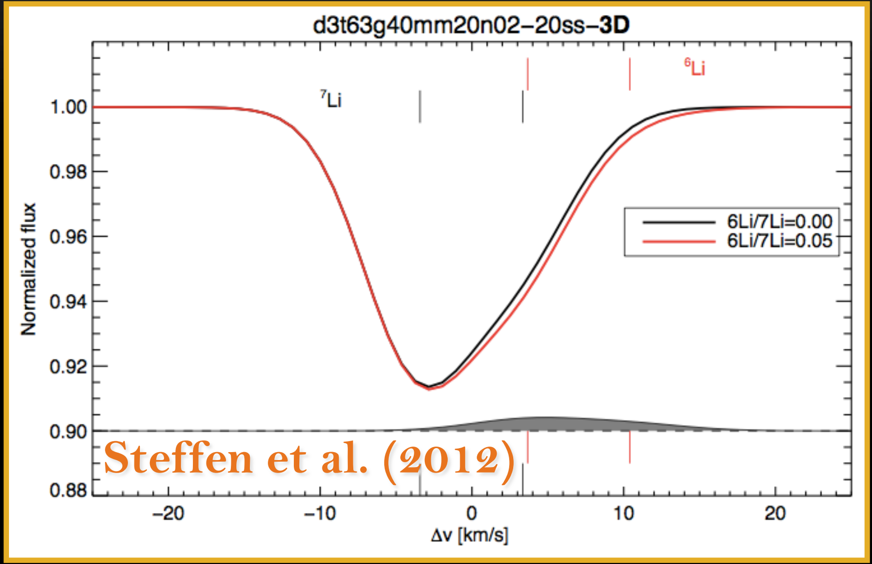
Asplund et al. (2006)

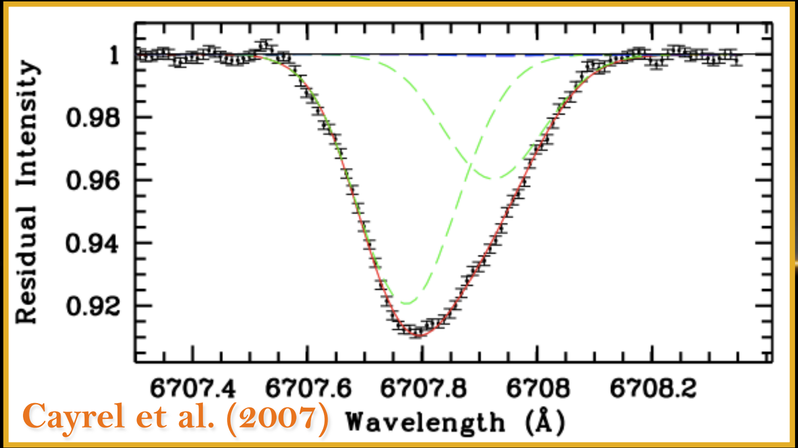
^{6}Li Measurement

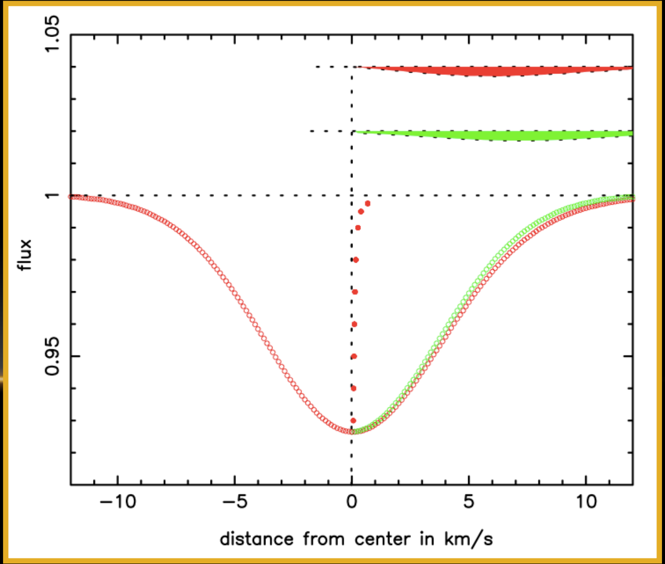
- ^{6}Li/^{7}Li is measured from the asymmentry in the red wing of the Li 6708A doublet

- ^{6}Li/^{7}Li in metal-poor stars needs to be done using 3D hydrodynamical simulations of atmospheres and using NLTE line computation

- After this, it was demonstrated that most of the stars show no ^{6}Li (Cayrel et al. (2007); Steffen et al. (2012); Lind et al. (2013)







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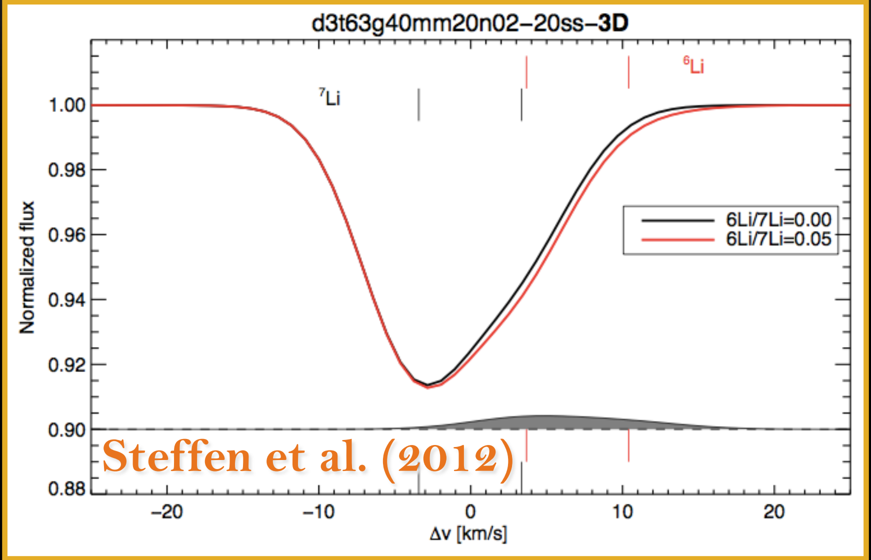
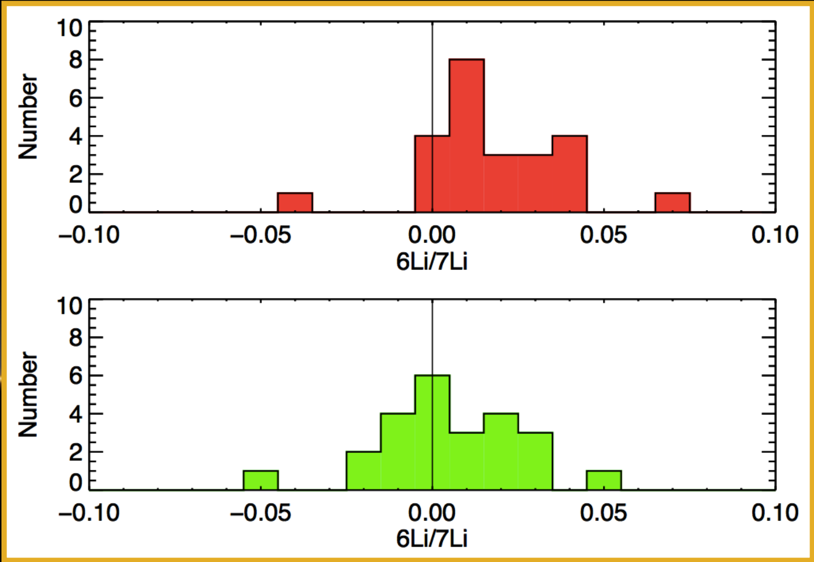
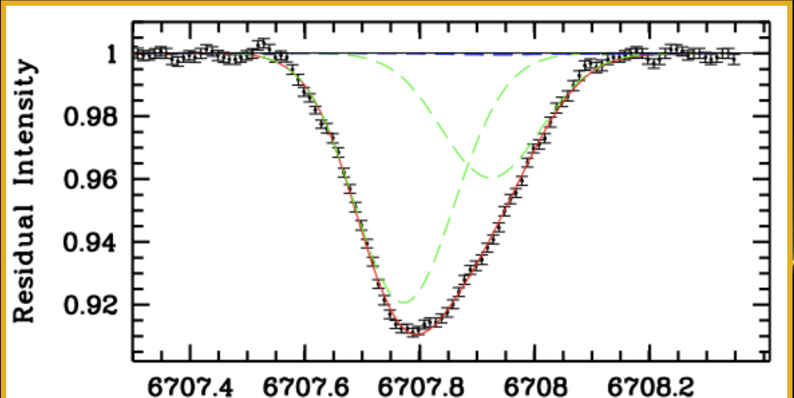


Steffen et al. (2012)





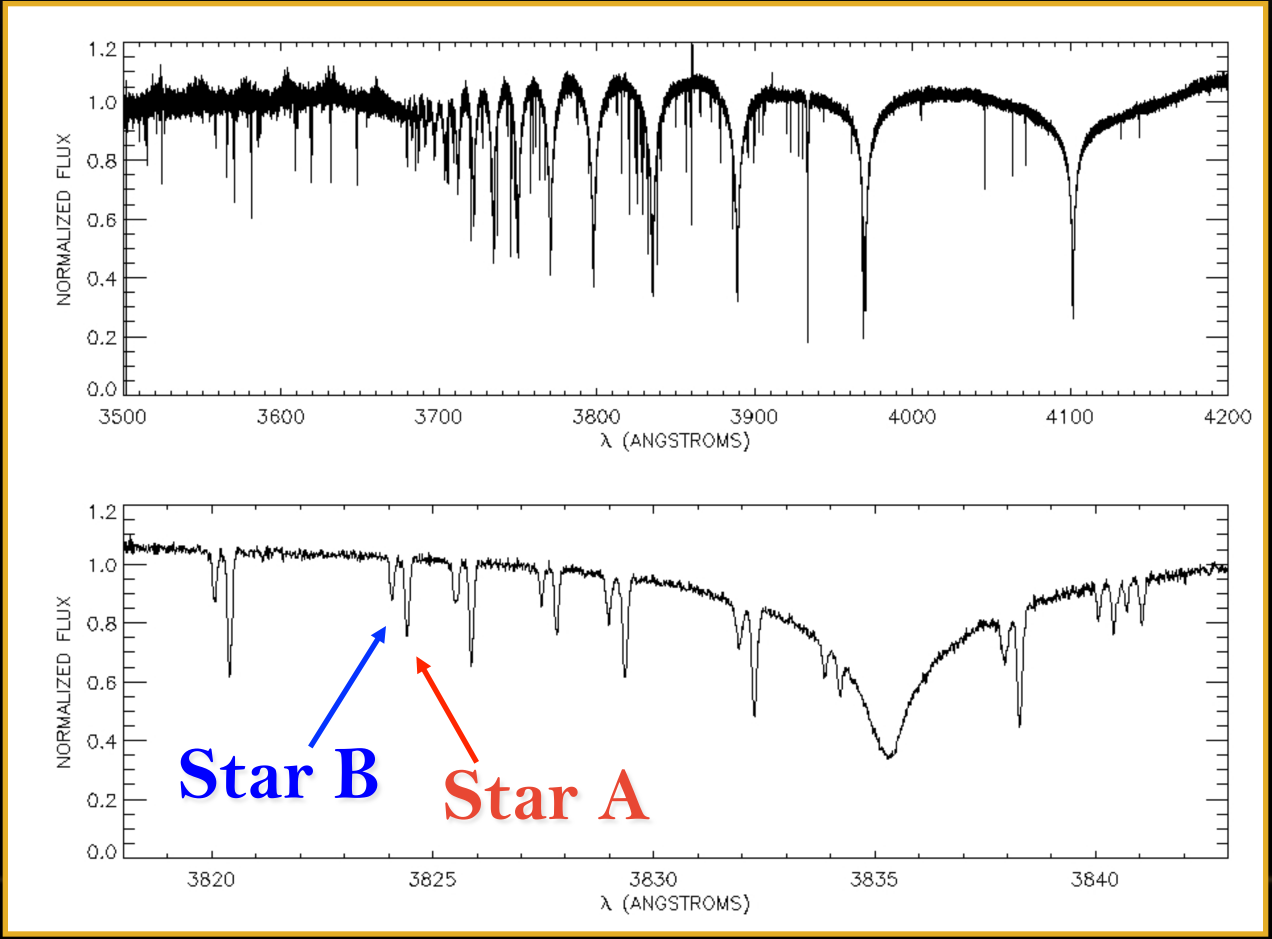
Cayrel et al. (2007)

OBSERVATIONS: CS 22876-032

- Spectroscopy with VLT/UVES with IS#3
- Spectral region 500-680 nm
- $\lambda/d\lambda \sim 110{,}000$
- 28 useful spectra of ~3000 s

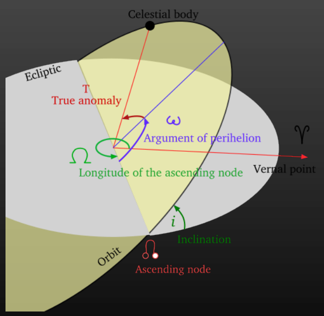
Chemical Analysis

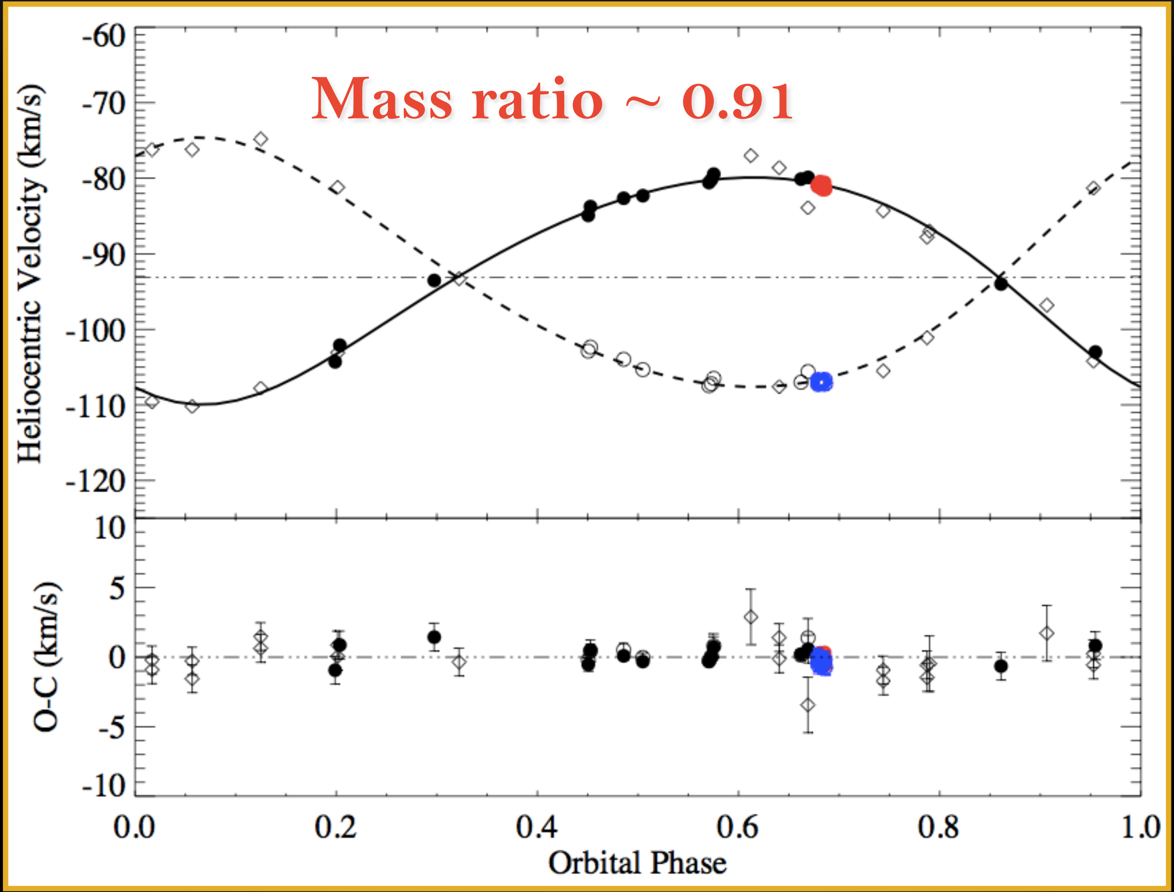
UVES/VLT spectrum shows a [Fe/H]~ -3.7



González Hernández et al. (2008)

Orbital Elements

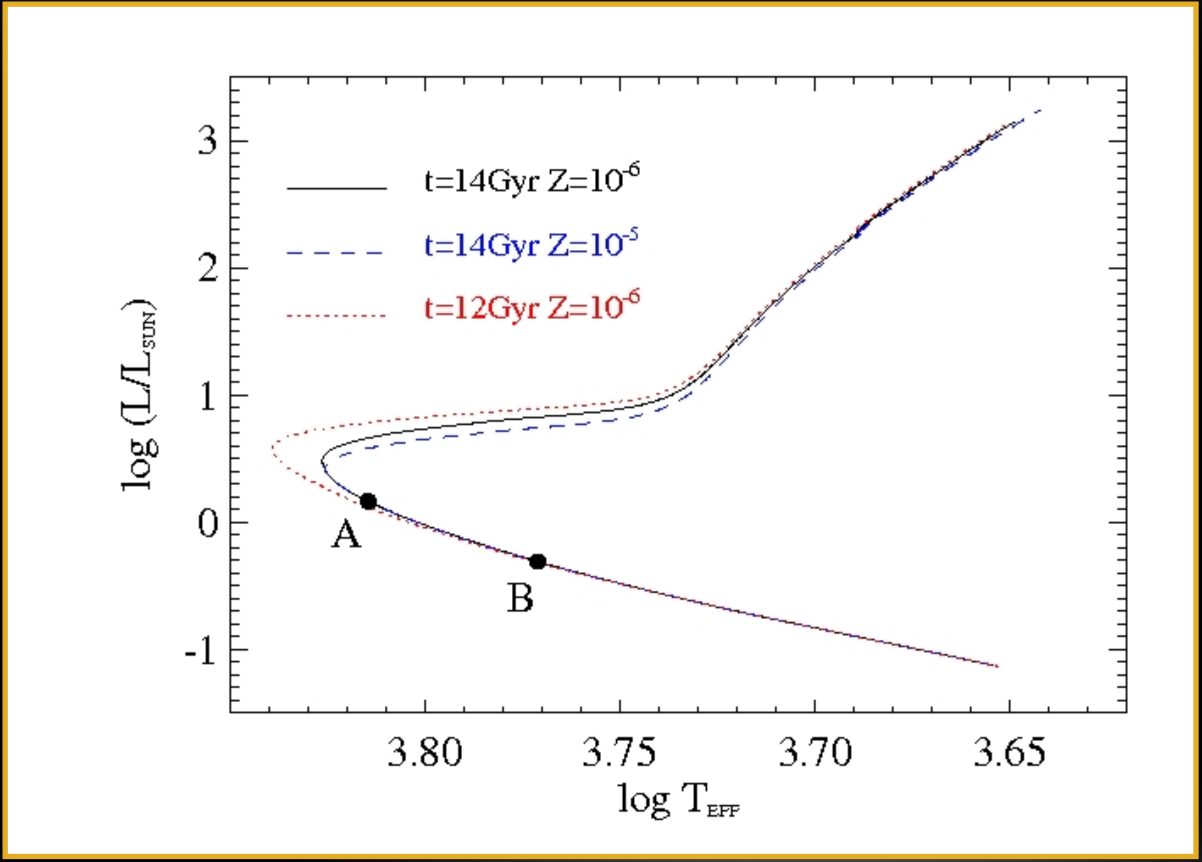




New UVES_IS#3@VLT data + González Hernández et al. (2008)

Stellar Parameters

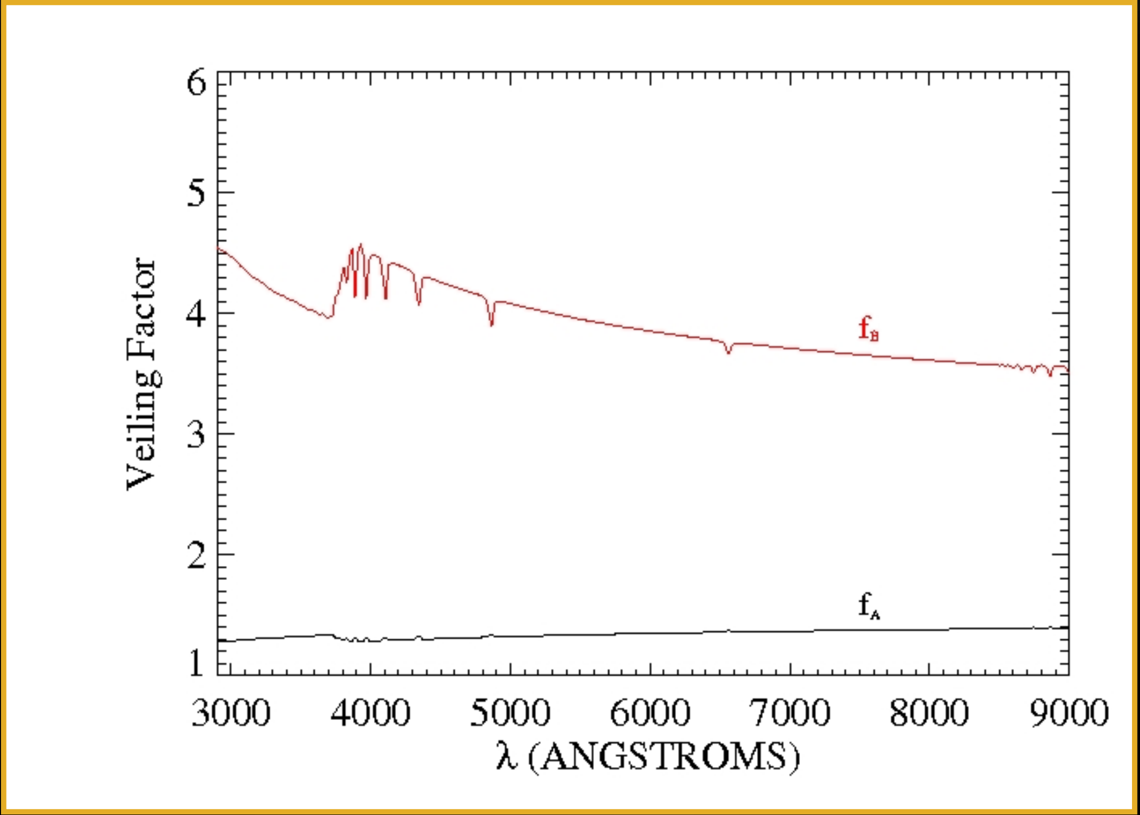
Chieffi & Limongi isochrones



Teff ~ 6500 K for the primary

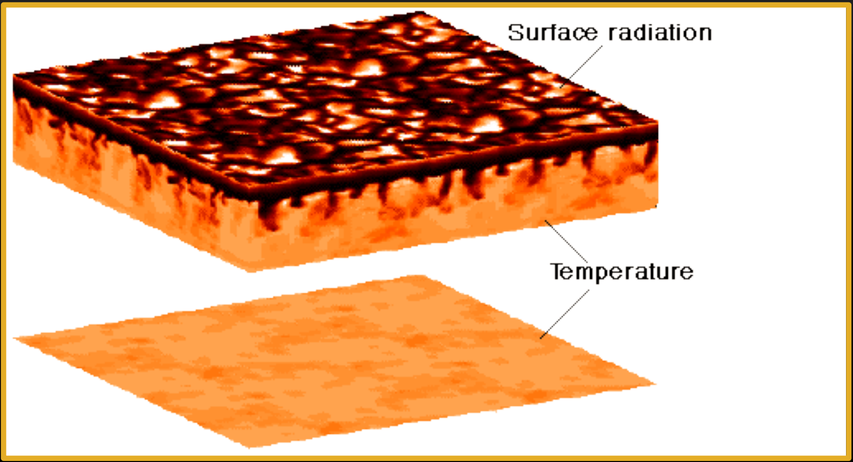
Teff ~ 5900 K for the secondary

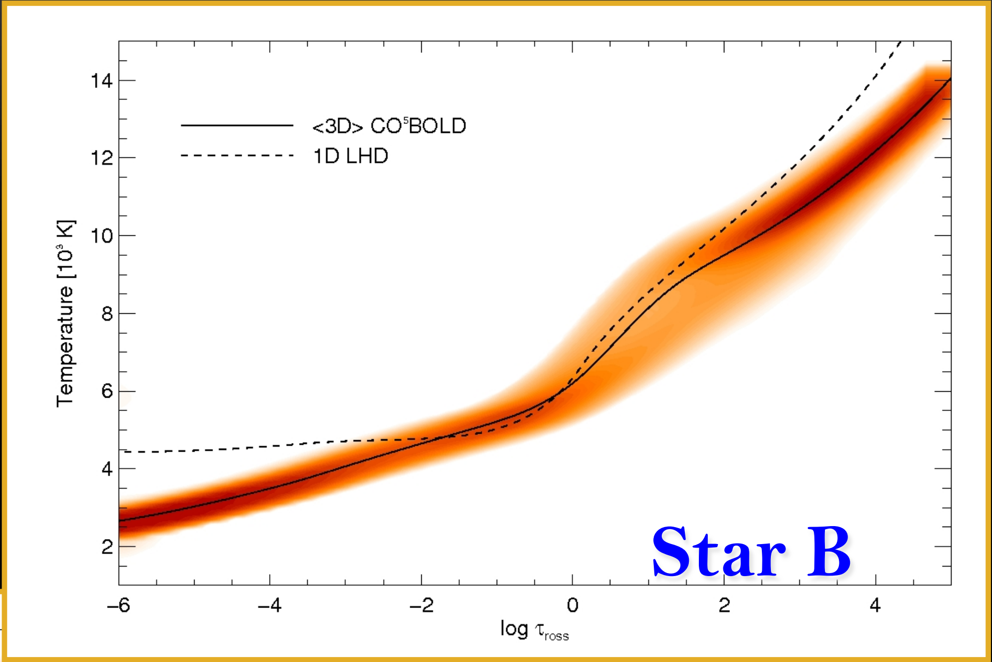
VEILING

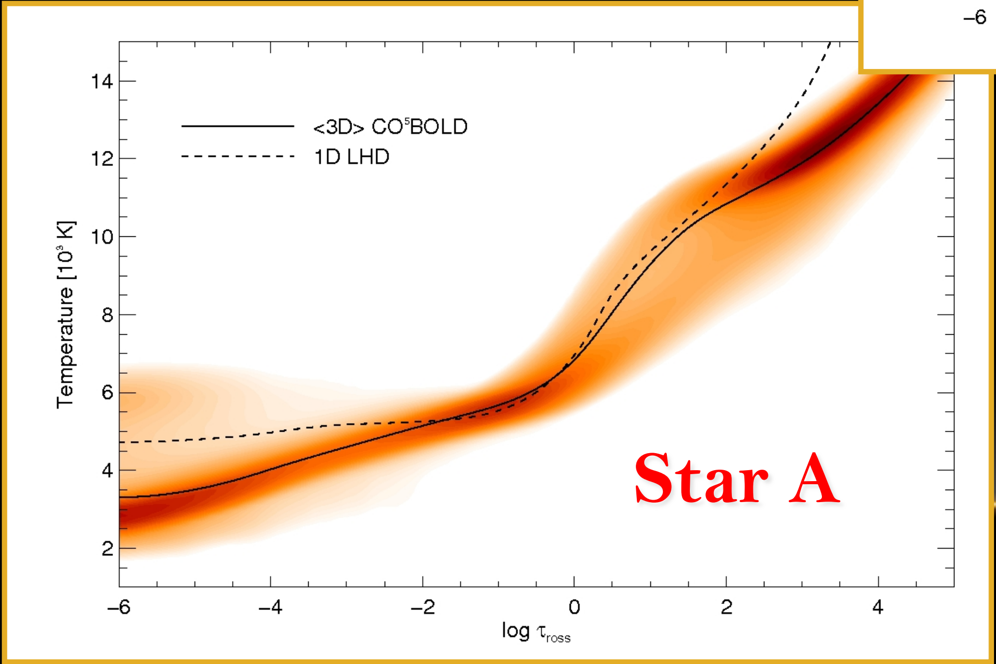


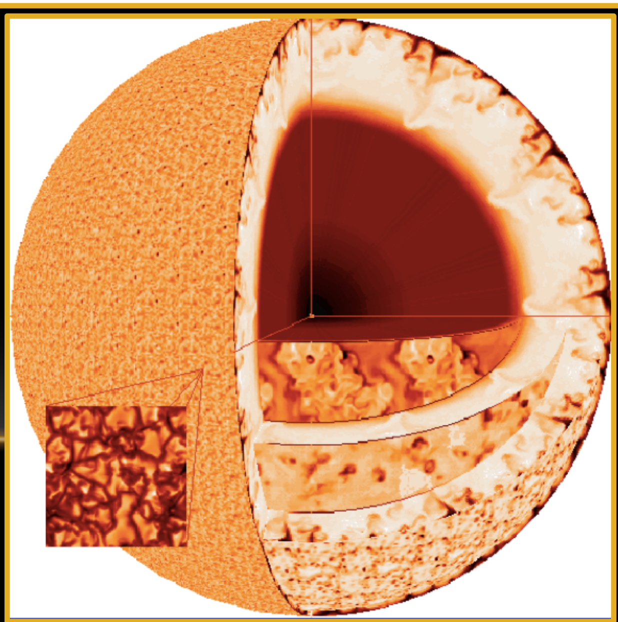
González Hernández et al. (2008)

3D Model Atmospheres



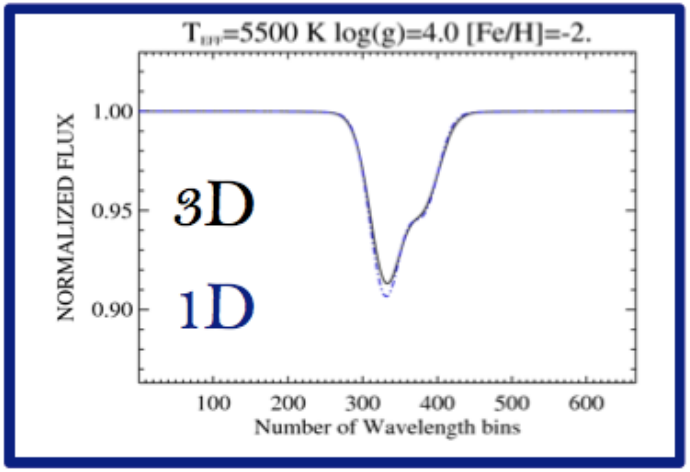




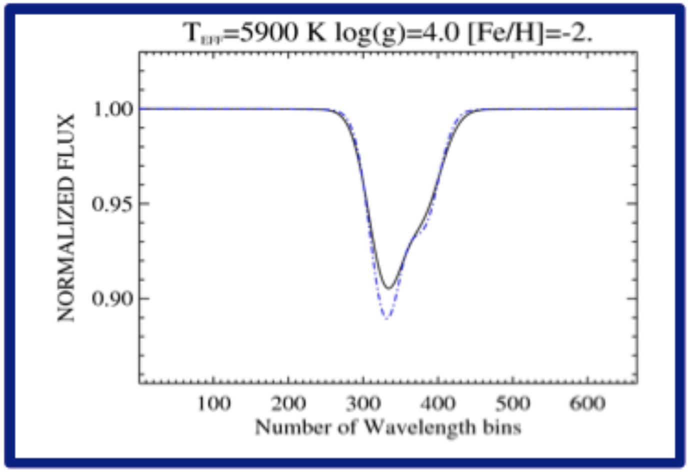


3D NLTE vs 1D NLTE Line Profiles

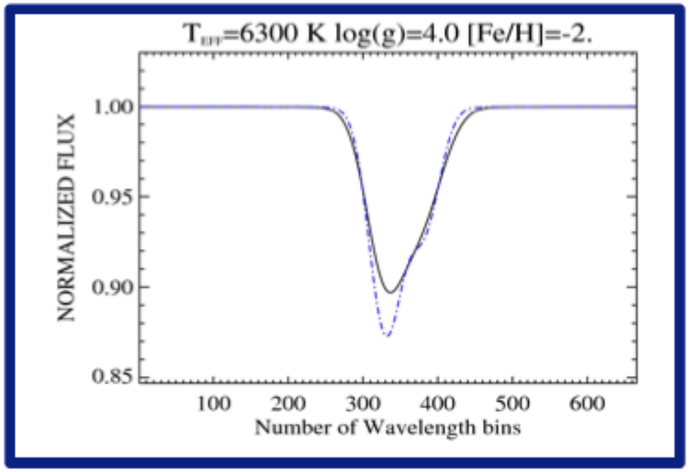
- **Teff = 5500 K**



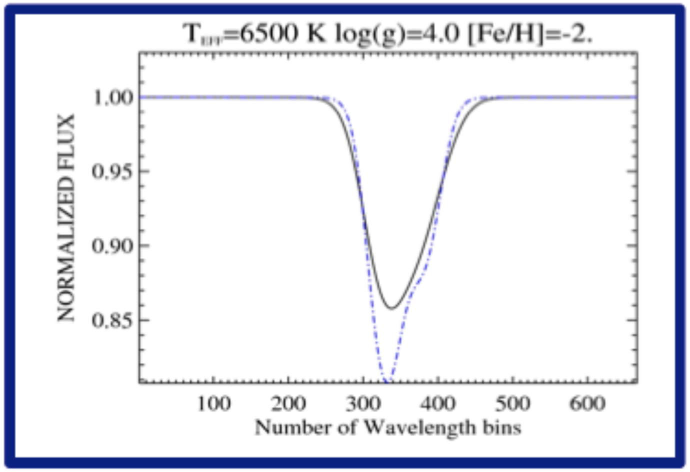
- **Teff = 5900 K**



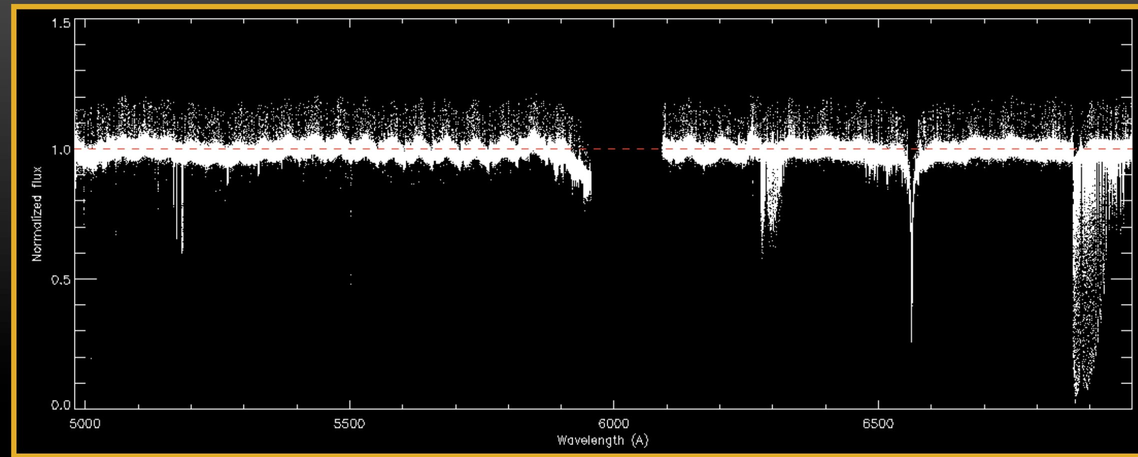
- **Teff = 6300 K**

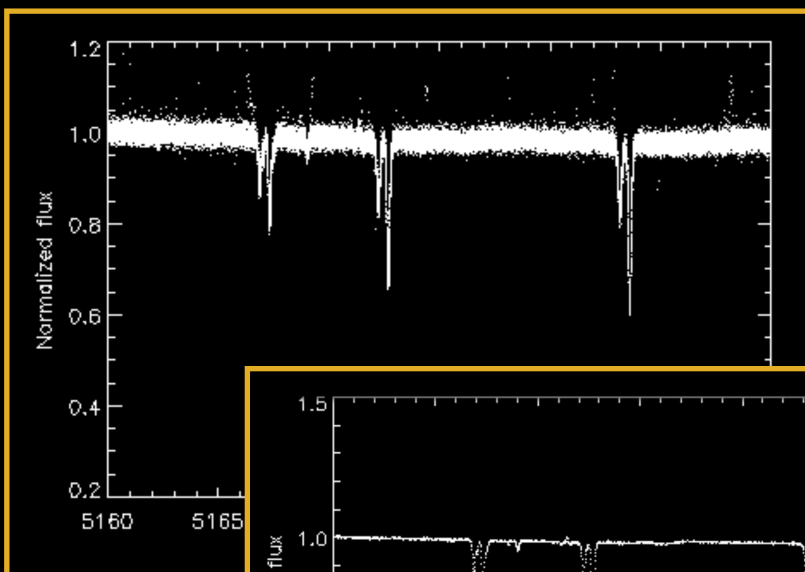


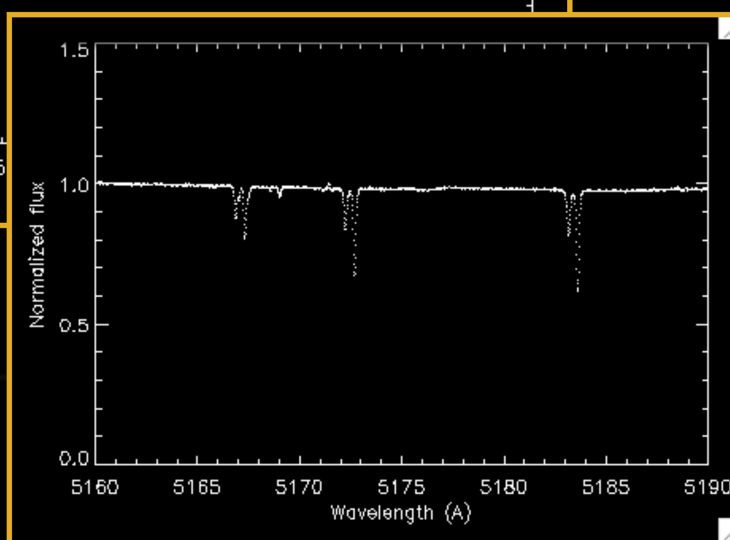
- **Teff = 6500 K**

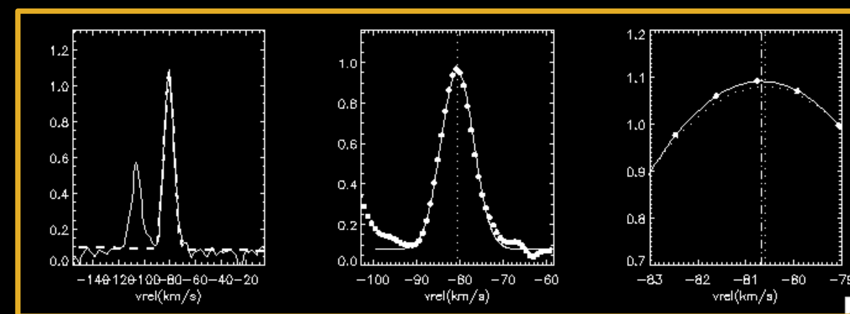


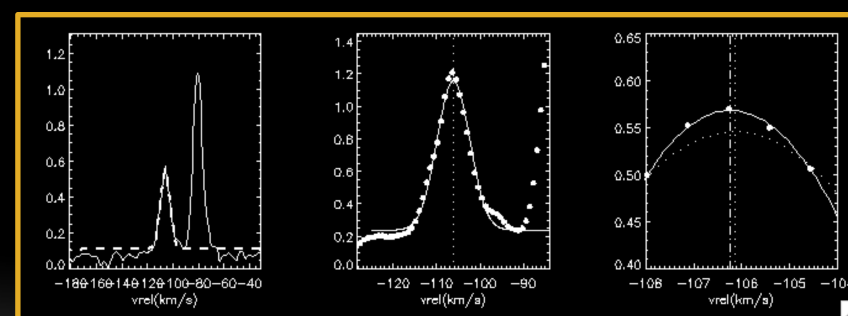
Observations:
Mg Ib Triplet



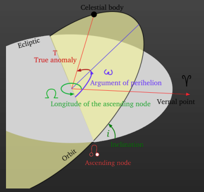


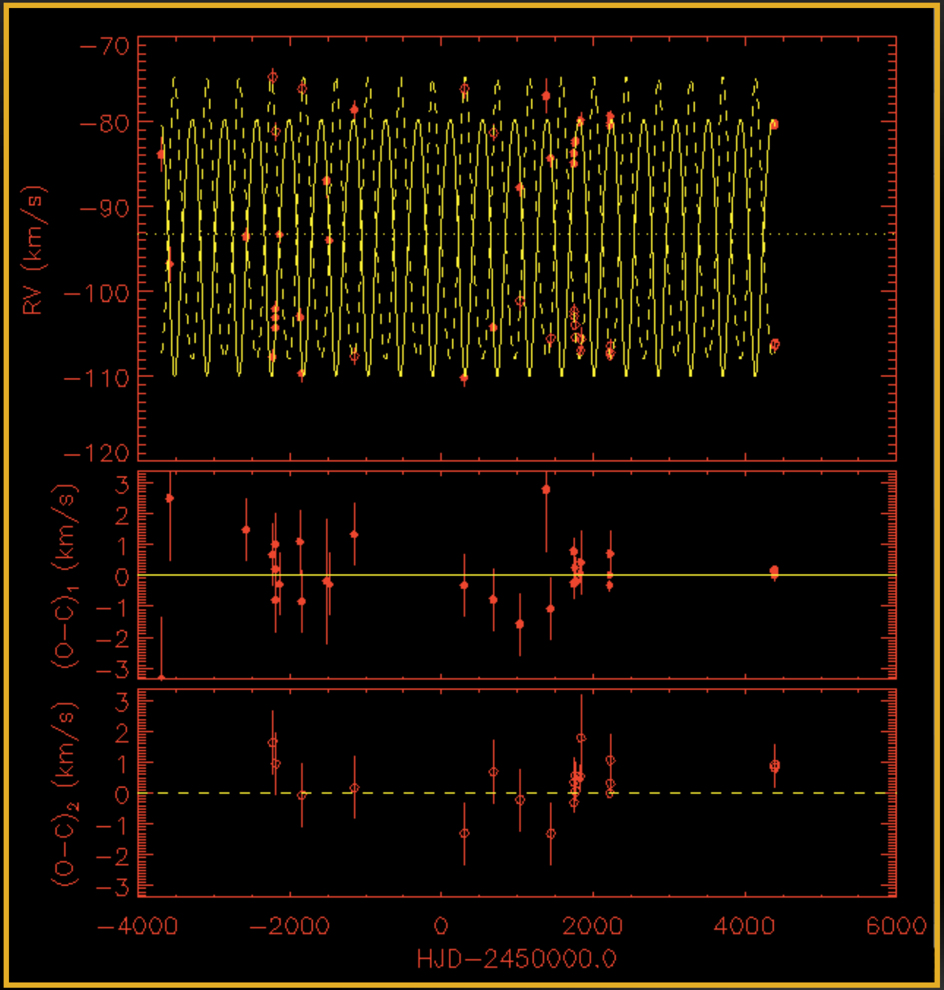


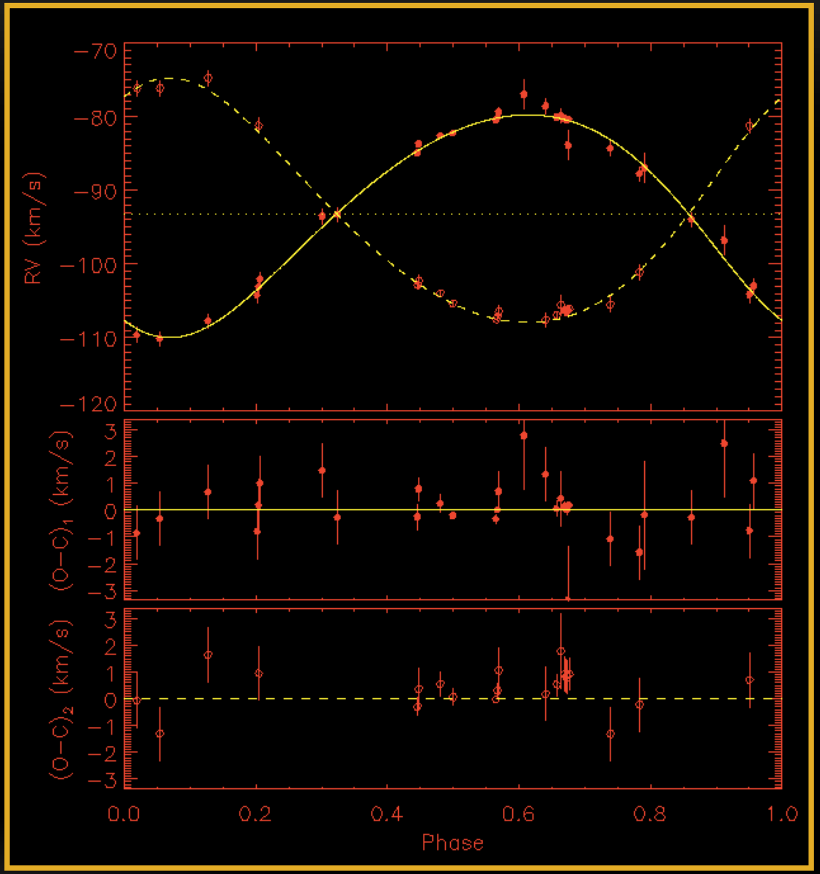




ORBITAL ELEMENTS



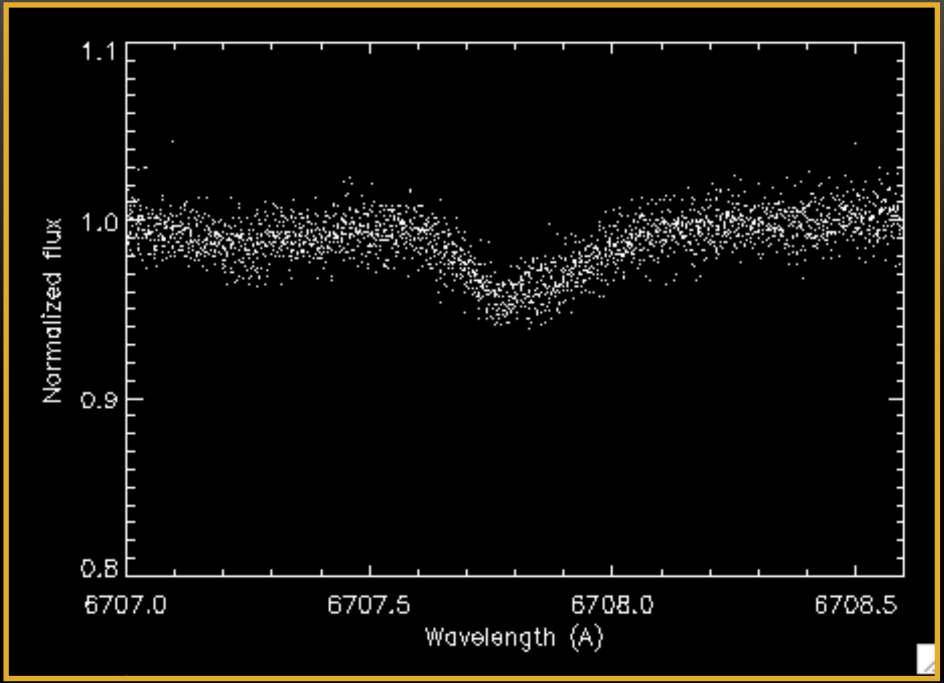


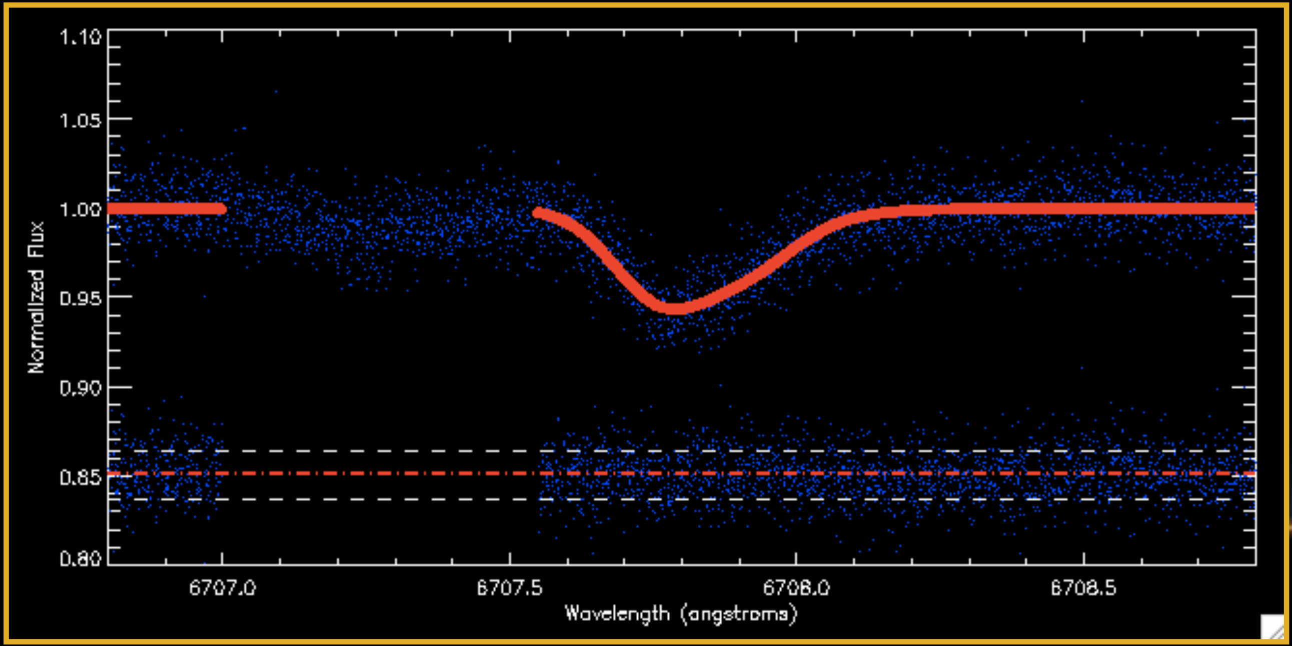


Mass Ratio ~ 0.91

New UVES_IS#3@VLT data + González Hernández et al. (2008)

Analysis: Star A
Li Doublet





$^{6}Li/^{7}Li$ = 0.07 +- 0.06

A(Li) = 2.17 +- 0.017

Vrot = 0 km/s

Vins = 2.79 km/s

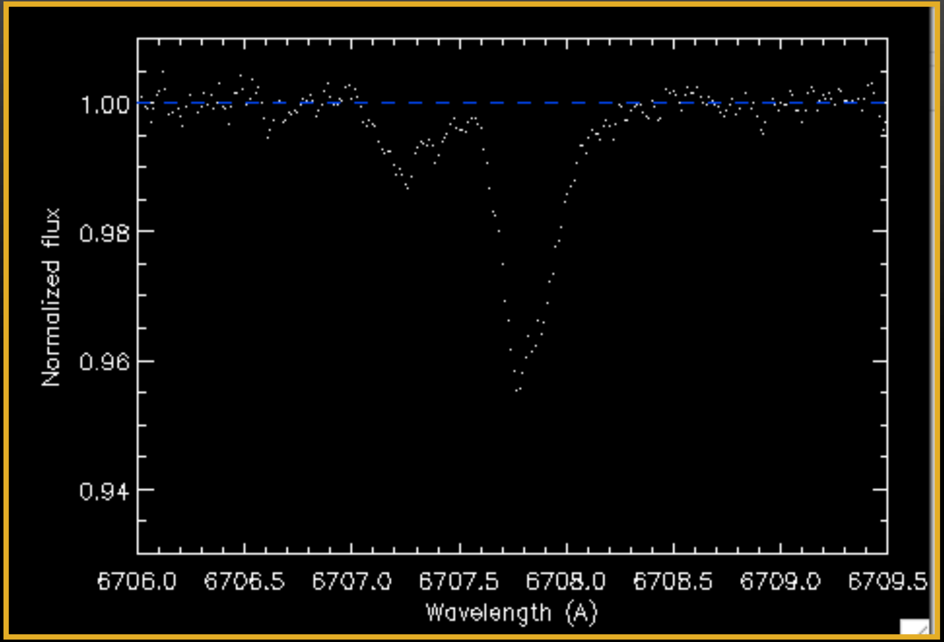
Shift = -0.28 km/s

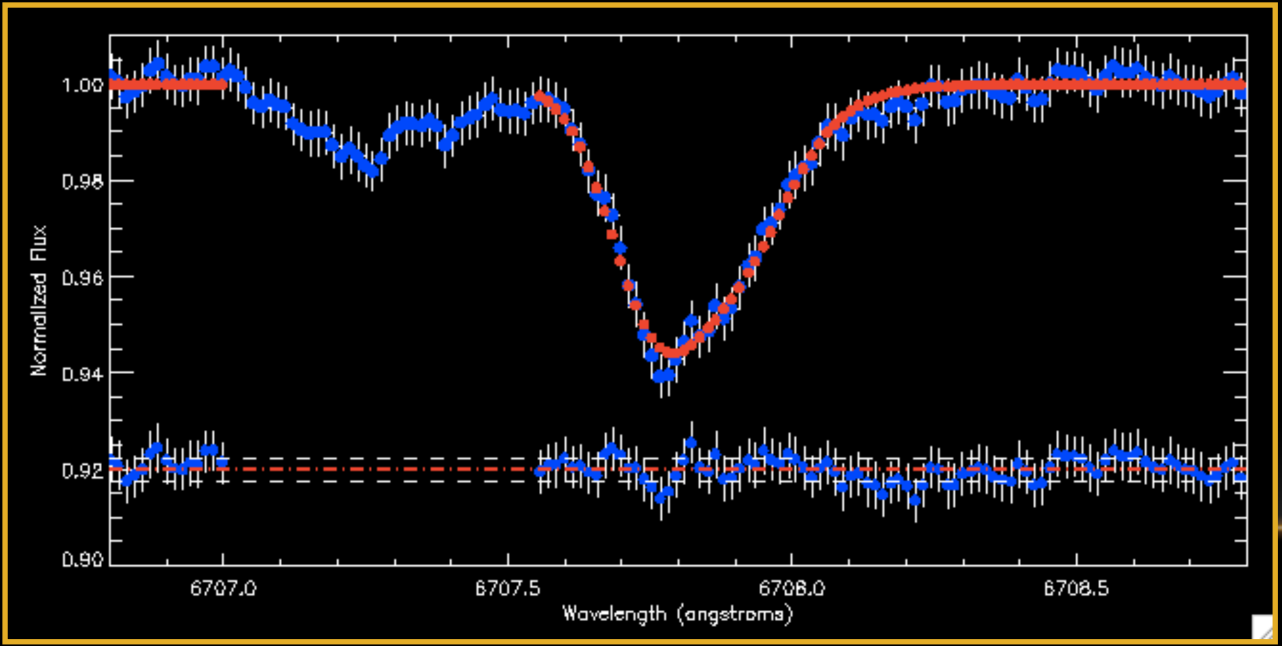
Np_line = 1103

Np_cont = 1153

S/N fit = 74

ANALYSIS: STAR A
LI DOUBLET





$^6Li/^7Li$ = 0.08 +- 0.05

A(Li) = 2.17 +- 0.013

Vrot = 0 km/s

Vins = 2.79 km/s

Shift = -0.31 km/s

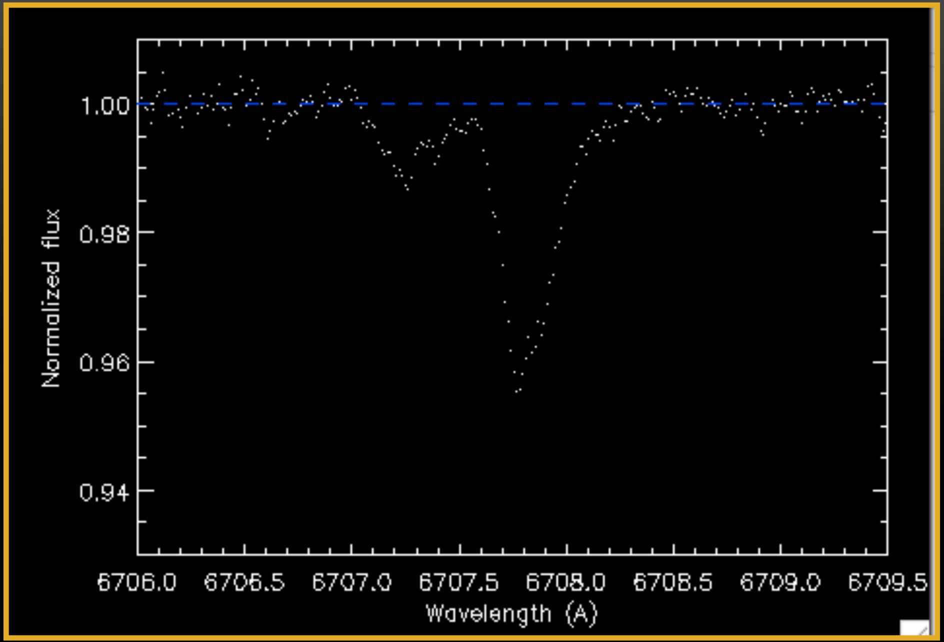
Np_line = 50

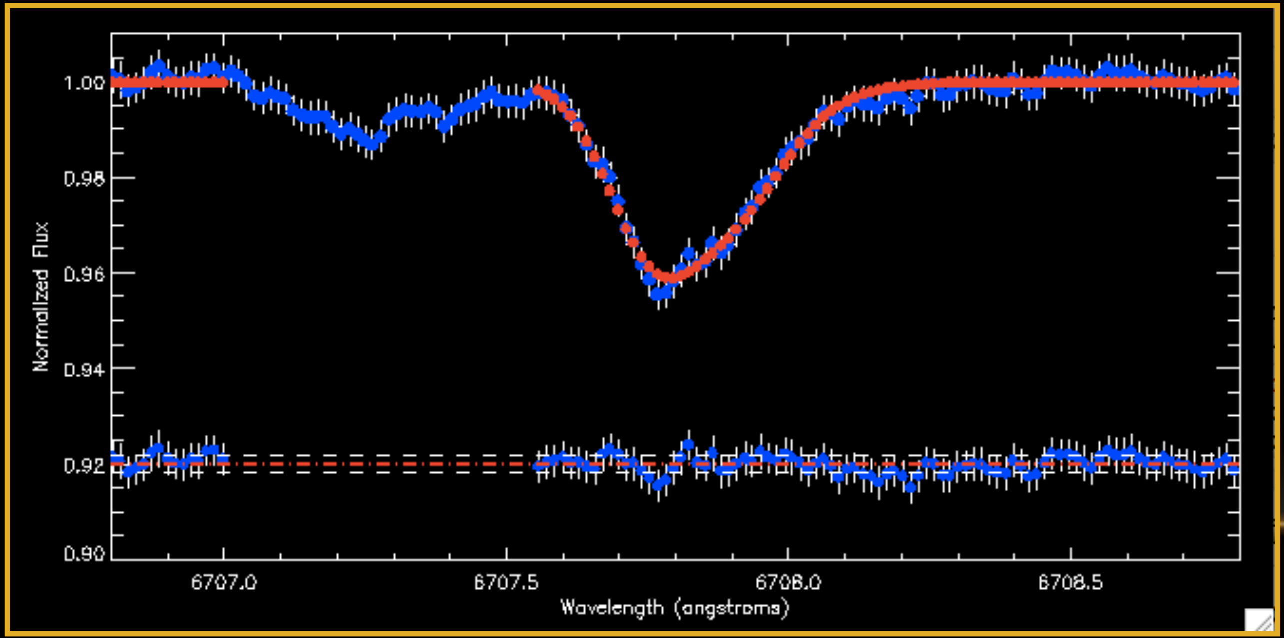
Np_cont = 54

Bin = 0.014 A/pixel

S/N fit = 416

Analysis: Star A
Li Doublet: veiled





$^6Li/^7Li$ = 0.09 +- 0.05

A(Li) = 2.04 +- 0.010

Vrot = 0 km/s

Vins = 2.79 km/s

Shift = -0.29 km/s

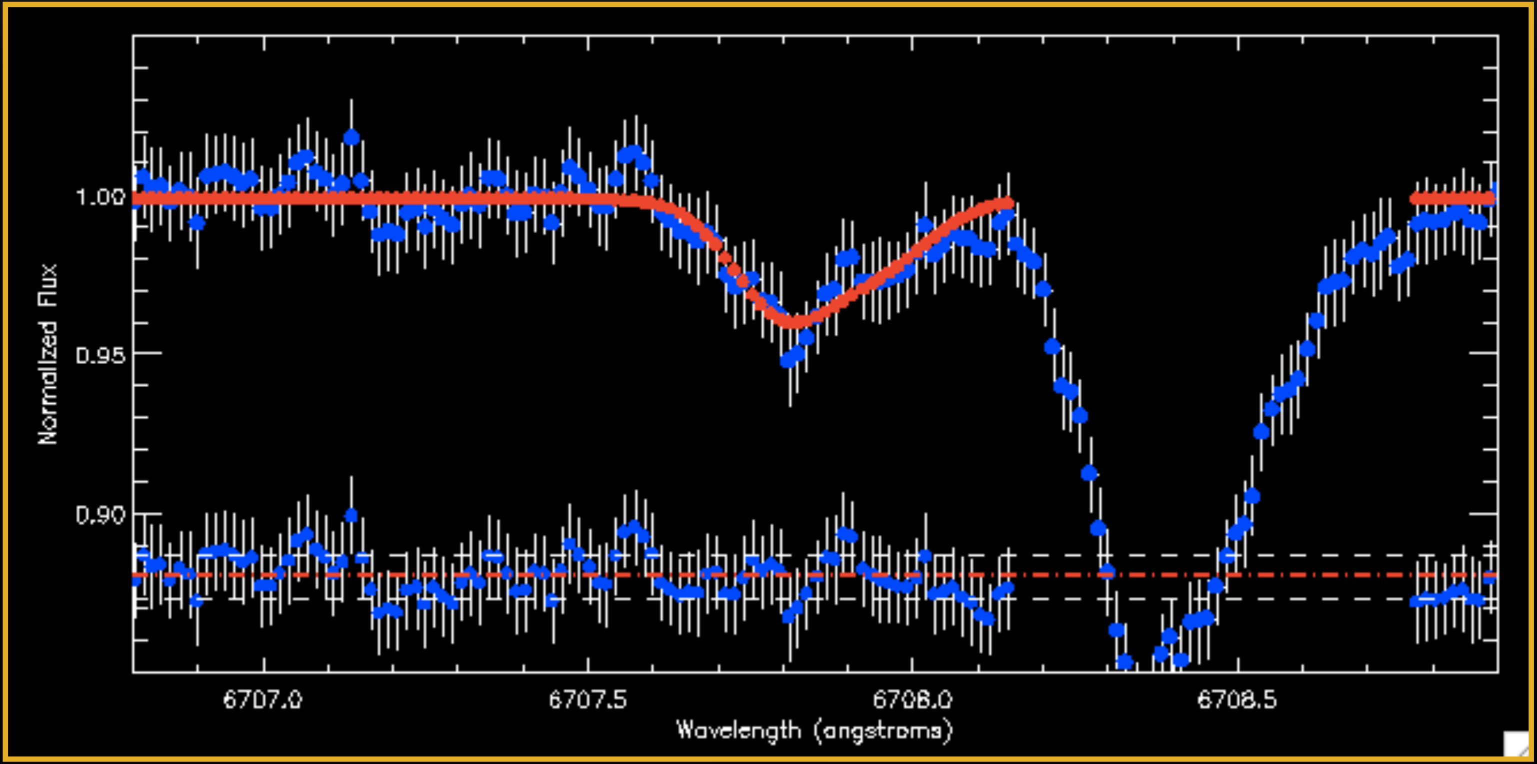
Np_line = 50

Np_cont = 54

Bin = 0.014 A/pixel

S/N fit = 574

Analysis: Star B Li Doublet



A(Li) = 1.75 +- 0.04

^{6}Li/^{7}Li = 0.0 (fixed)

Vrot = 0 km/s (fixed)

Vins = 2.79 km/s

Shift = -1.92 km/s

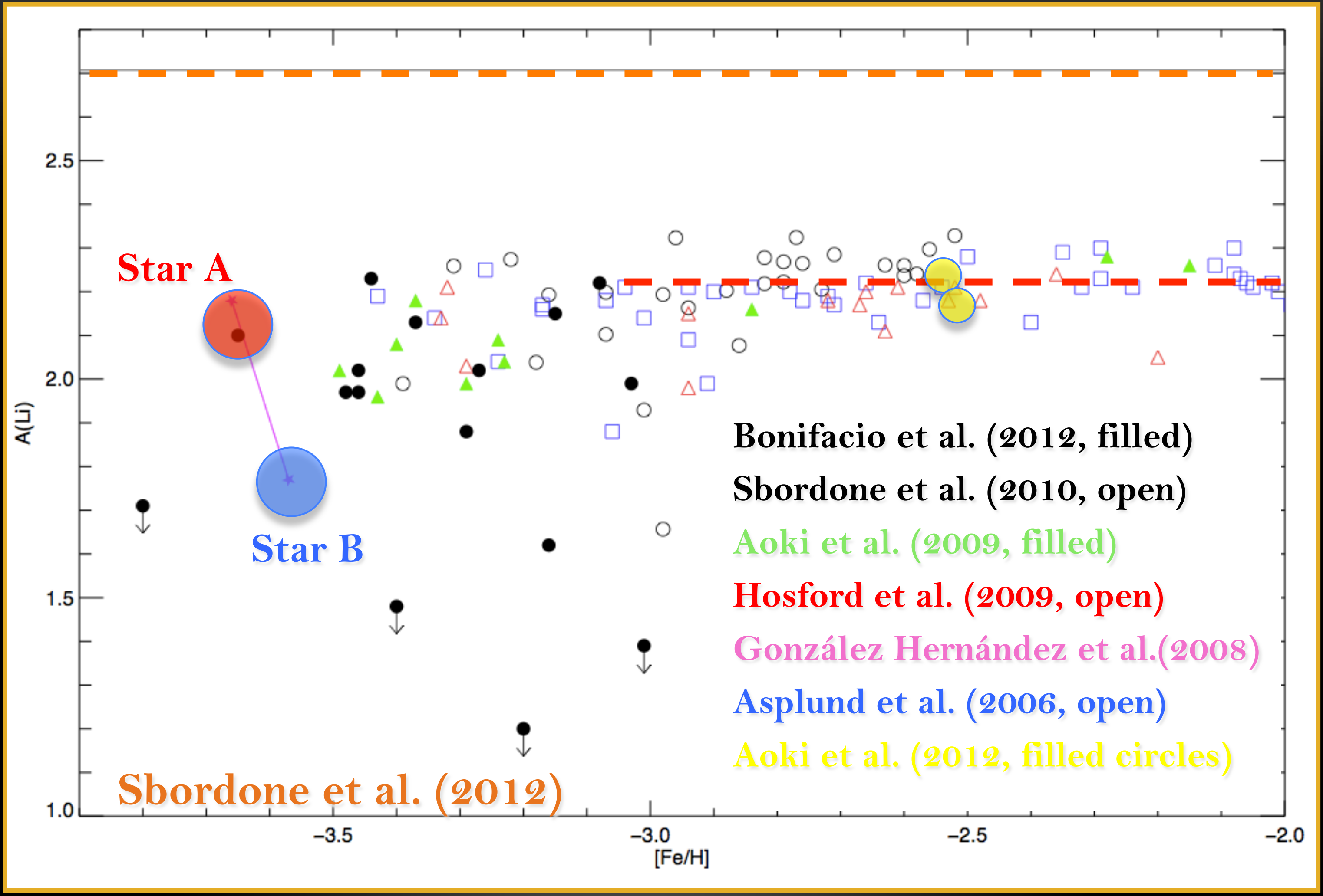
Np_line = 44

Np_cont = 62

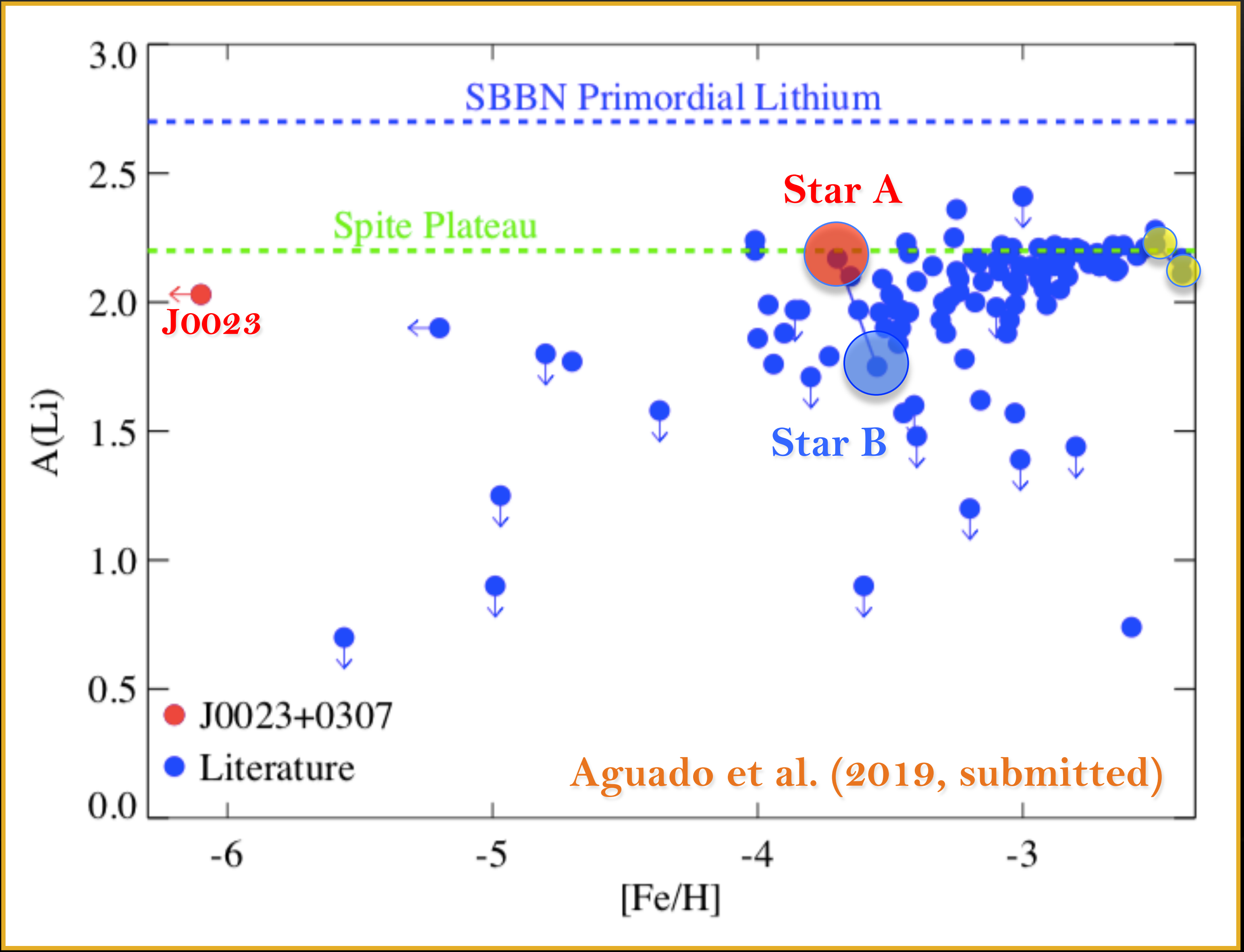
Bin = 0.014 A/pixel = 0.7 km/s

S/N fit = 148

Lithium in Metal Poor Stars

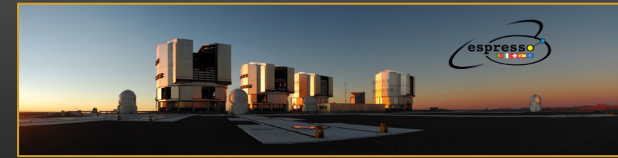


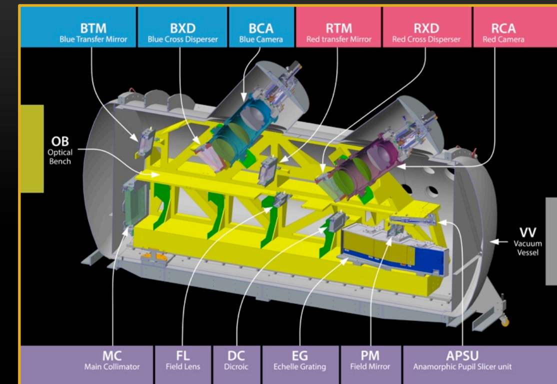
Lithium in Metal Poor Stars

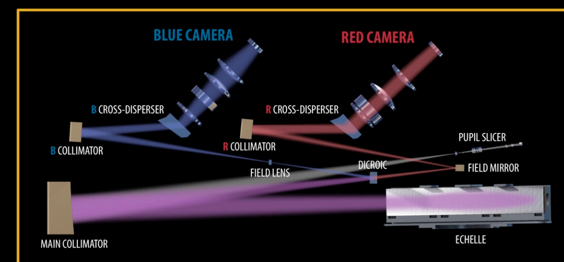


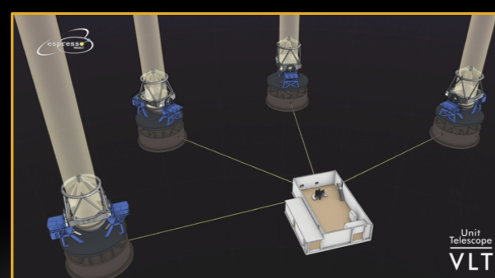
ESPRESSO

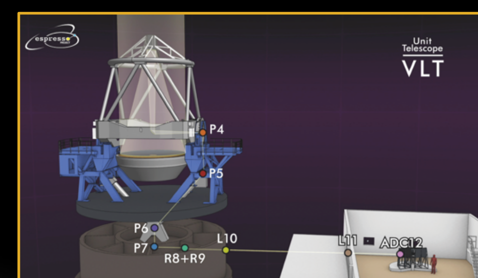
THE ECHELLE SPECTROGRAPH FOR ROCKY EXOPLANETS AND STABLE SPECTROSCOPIC OBSERVATIONS











ESPRESSO :

González Hernández et al. (2017, Handbook of Exoplanets)

More info on ESPRESSO and other high-resolution spectrographs at IAC web projects:

ARES: Alta Resolución ESpectral – High Resolution Spectroscopy